Repairing Williams/Bally WPC Pinball Games from 1990 to 1999, Part One

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Scope.
This document is a repair guide for Williams and Bally WPC pinball games made from 1990 (Funhouse) to 1999 (Cactus Canyon).

Internet Availability of this Document.
Updates of this document are available for no cost at http://marvin3m.com/fix.htm if you have Internet access. **This document is part one of three** (part two is here, and part three is here).

IMPORTANT: Before Starting!
IF YOU HAVE NO EXPERIENCE IN CIRCUIT BOARD REPAIR, YOU SHOULD NOT TRY TO FIX YOUR OWN PINBALL GAME! Before you start any pinball circuit board repair, review the document at http://marvin3m.com/begin, which goes over the basics of circuit board repair. Since these pinball repair documents have been available, repair facilities are reporting a dramatic increase in the number of ruined ("hacked") circuit boards sent in for repair. **Most repair facilities will NOT repair your circuit board after it has been unsuccessfully repaired ("hacked").**

If you aren't up to repairing pinball circuit boards yourself or need pinball parts or just want to buy a restored game, I recommend seeing the suggested parts & repair sources web page.

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Bibliography and Credit Where Credit is Due.
Many of the ideas in this repair guide are not original. Lots of people contributed to this document, and I just want to say, "thanks!" Below are a list of the resources used in the development of this guide. Some resources/people may have been innocently left out. If this is the case, and an idea is here that was originally yours, please notify me and I will make sure to give you credit!

- "WPC theory of operation" (#16-9289), 1991, Williams Electronic Games. This is a great book, and is partially reprinted in part one of this document. Unfortunately it does not include WPC-S and WPC-95.
- "Pinball Machines: How They Work & Troubleshooting", 2nd edition, 1993, Norbert Snicer, ISBN 0 646 11126 4. Another great resource, but unfortunately it also does not include WPC-S and WPC-95.
- Jerry Clause, who provided tons of tips and tricks.
- Mr. Johnson and his web site at www.aros.net/~rayj/action/tech. Ray's postings and tips were most helpful.
- Jonathan Deitch's advice, tips and tricks.
- Duncan Brown. Duncan provided lots of tips and tricks.
- Rob Hayes, who's advice and proof reading were very appreciated.
- David Gersic, who also did proof reading and provided some tips.
- Bill Ung for his excellent knowledge of this system.
- Pin Lizard and their very informational web page at pbliz.com.

- John Sladek for some great tips and tricks.
- John Robertson and his posts & tips helped mucho grande.

Some people question whether I wrote all this material myself. I did, but of course like everyone, my repair techniques and ideas are gathered not only from my own experience, but from work that others in this hobby do and share at shows, on the internet, etc. So if you're the originator of some cool trick or tip in this document, and I'm not giving due credit, just let me know and I'll add you to the list of contributors above.

1a. Getting Started: Experience, What is WPC, Schematics

What Repair Experience Is Expected?

Little experience in fixing pinballs is assumed. Basic electrical knowledge is helpful, but not necessary. I do assume you can solder and use the basic features of a Digital Multi-Meter (DMM) such as measuring voltage and resistance. Please see http://marvin3m.com/begin for details on the basic electronics skills and tools needed. This document should help if you just bought your first (or second, or third) Williams WPC pinball "as-is", and hope to fix it.

What is WPC?

WPC stands for "Williams Pinball Controller". It is the internal pinball computer designed by Williams and used from from late 1990 to 1999. Technically, the WPC chip is functioning as an address decoder. It handles the I/O addressing (done previously with TTL logic and 6821 PIA's on System 11), as well as system clocks, watchdog reset, blanking, and real time clock. There are several generations of WPC (see Different WPC Generations).

Got Schematics?

Having a schematic for the game would be ideal, but sometimes it can be fixed without it. If a schematic is not available, order one from one of the suppliers on the parts and repair sources web page.

WPC Schematic Manuals.

Some 1991 and prior WPC games (Gilligan's Island and before) have the backbox circuit board schematics inside the game manual. For all other WPC games, the backbox circuit board schematics (CPU, driver, sound and fliptronics) are in a separate manual:

- Pre-DCS (Funhouse to Twilight Zone): part number 16-9473
- WPC DCS/WPC-S (Indiana Jones to Jackbot): part number 16-9834.2
- WPC-95 (Congo to Monster Bash): part number 16-10159.2

1b. Getting Started: Necessary Tools

Fixing electronic pinball games will require a few tools. Luckily, most are not that specialized and are easy to get.

Non-Specialized Tools Required:

- Work Light: clamp style lamp
- Screwdrivers: small and medium size, phillips and flat head
- Nut Drivers: ¼", 5/16", and 11/32"
- Wrenches: 3/8", 9/16", 5/8" required, other sizes suggested
- Allen Wrenches: get an assortment of American sizes
- Needle Nose Pliers
- Hemostat. Handy for holding parts and springs. Best to have both the curved and straight versions if possible.
- Right Angled Screwdriver: both phillips and flat head.

Specialized Tools Required:

These specialized electronics tools are needed. Please see http://marvin3m.com/begin for details on the basic electronics tools needed.

- Alligator clips and wire. Buy these at Radio Shack, part number 278-001, $3.69.
- Soldering Iron.
- Rosin Core 60/40 Solder.
- De-soldering tool.
- Digital Multi-Meter (DMM).
- Logic Probe.
- Hand Crimping Tool: Molex WHT-1921 (part# 11-01-0015), Molex part# 63811-1000, Amp 725, or Radio Shack #64-410.
- Infrared Sensor. Used for determining good infrared optic LED's. Radio Shack sells these for $5.99, part number 276-1099

Cleaning "Tools" Required:

- Novus #2 or MillWax (for cleaning playfields and rubber)
- Novus #3 (for polishing metal parts)
- A hard paste wax (like Trewax) or hard automotive Carnauba Wax (for waxing playfields and cleaning rubber)

Novus is available at many places (my local grocery store sells it), or from any good pinball vendor. I don't recommend MillWax, but others like it (mostly because they have been around for a LONG time and are used to it). Do not use any Wildcat products! They react with acyrlic plastics, which the playfield and ramps are coated. Trewax or Meguires Carnauba Wax is available at Kmart or a local hardware store.

1c. Getting Started: Parts to Have On-Hand

When fixing electronic pinballs, I would highly recommend having some parts on-hand to make things easier and cheaper. All these parts are available from a pinball retailer as listed on the parts and repair sources web page.

Parts to have:

- #44 light bulbs: have 20 or so around. Fifty is plenty to do most games. Many people suggest using #47 bulbs instead, as they consume less power and produce less heat, but are also less bright. As a compromise, I personally like #44 bulbs for the computer controlled lights, and #47 bulbs for the general illumination lights. Note "import" 44/47 bulbs are fine and are less expensive (I don't personally see the need to spend more money for the General Electric bulbs).
- #555 light bulbs: have 20 or so around. Fifty is plenty to do most games.
- #906 or 912 flash bulbs: have 10 or so around.
- #89 flash bulbs: have 10 or so around.
- #86 bulbs: used in Twilight Zone and Creature from the Black Lagoon only.
- #455 or #545 bulbs: blinking style bulbs. The #545 have a (#555 style) wedge base. Used only in Twilight Zone, Addams Family and No Good Gofers.
- Fuses: I would have five of any needed value on hand at all times. The voltage rating really does not matter for fuses, as long as they are at least 125 volts. Coils run at 50 volts, only the line voltage fuse in European games could be higher than 125 volts. The fuse voltage only determines **how** the fuse blows (it's the current rating that determines **when** a fuse blows). Do not buy 32 volt fuses.
  WPC-S and Earlier Games:
  For WPC/WPC-S games, these use 1.25" long, 3AG fuses. Radio Shack sells fuses for a decent price. Slow-blo fuses are known as MDL fuses. Fast-blo fuses are known as AGC fuses. At minimum have:
    - 3/8 amp fast-blo (for dot matrix display)
    - ¾ amp fast-blo (used for 12 volts)
    - 2 ½ amp slo-blo (used for flippers on non-Fliptronic games)
    - 3 amp slo-blo (used for solenoids, 12 volts, flippers)
    - 5 amp slo-blo (used for general illumination, flash lamps, solenoids, +5 volts)
    - 7 amp slo-blo (for solenoid voltages)

- 8 amp fast-blo (used for playfield lamps and line filter)

WPC-95 Games
Uses the new European standard, smaller **GMC “T” fuses**, all 250 volts (but 125 volt fuses work fine too). Note these are not GMA “F” (F means “fast blow”) fuses, but are GMC “T” (the T means “time delay”) slow-blo fuses. As for the “T” and “GMC” terminology, Buss uses the “GMC” and Littlefuse uses the “T” terminology (“T” and “GMC” are the same thing). WPC-95 uses only “T” (GMC) slow-blow 5x20mm fuses. These fuses are smaller, about .75” long. Note these fuses are small and difficult to tell if they are fast or slow blow. So look for the “T” impression on the metal fuse ends to confirm they are slow blow fuses (Radio Shack often mistakenly calls the 5x20mm slow-blow style fuses “GMA” F instead of “GMC” T). Have available (all “T” or “GMC” slow-blo):

- T0.315 amp (audio/video board)
- T0.63 amp (driver board)
- T2.5 amp (audio/video board)
- T4.0 amp (driver board)
- T5.0 amp (driver board, line fuse)
- T6.3 amp (driver board)

- Nylon Coil Sleeves: the longer 2 3/16” length (part number 03-7066-5) are used when rebuilding flippers. The 1.75” length (part number 03-7066) are used for pop bumpers, etc. Sleeves with a lip (part number 03-7067-5) and tubing on each side (known as an “inline” sleeve) are used on the knocker, etc.
- Flipper Plunger/Link: used when rebuilding flippers (part number A-15847 or A-10656).
- Flipper Link Spacer Bushings: these small bushings go inside the flipper links (part number 02-4676).
- Flipper Coil Stops: used when rebuilding flippers (part number A-12390).
- Flipper EOS Switch: part number 03-7811 (non-Fliptronics) and SW1A-193 (1992 and later Fliptronics games).
- ¼” Heat Shrink Tubing: this is used on the flipper pawl when rebuilding flippers.
- Blue Spring Steel: used for rebuilding the entrance of clear plastic ramps. Available at http://www.mcmaster.com, order the .006” thickness.
- Shooter Spring: the short chrome spring on the outside of the shooter mechanism (part number 10-149). These rust and look like crap in short order.
- 1 1/16” Pinballs: a new pinball will make a playfield last longer.
- Leg Levelers: replace those old crummy looking leg levelers with brand new ones. 3” are used on solid state games.
- Rubber Rings: order game-specific ring kits with exactly the rings needed (from Pinball Resource). Don’t forget to get flipper rubbers and a shooter tip.
- Transistors: keep a few TIP102, TIP107, 2N5401, 2N4403, and TIP36c around.
- Diodes: keep a few 1N4004 diodes around. For WPC-95 games, keep a few P600D or 6A4 diodes around (used on the WPC-95 driver board for converting AC voltage to DC).
- Bridge Rectifiers: for WPC-S or earlier game, keep a few 35 amp, 200 volt (or higher) bridge rectifiers around, with wire leads. The industry part number is MB3502W (Williams part number 5100-09690, Mouser part number 625-GBPC3502W, Digikey part number MB352WMS-ND).
- ULN2803 chip: have several for the driver board.
- LM339 chip: have several for the driver and flipper opto boards.
- Triacs: used for the general illumination circuit (not needed very often). The specs for a WPC triac to use are pretty lose. For example all these work: BT138-600E, BTA12-600, NTE5671 (800v 16amp), NTE56010 (800v 15amp), or NTE56008 (600v 15amp).
- Connector pins and housings: used to repair burnt connectors. Buy the plastic connector housing (11 pins or greater), the board header pins, and crimp-on Trifurcon pins (Molex part# 08-52-0113, Digikey part# WM2313-ND), all in .156” size.
- Optics. LED transmitter optics and “U” shaped optics are good to have on hand. Radio Shack sells the infrared LED (transmitter), part number 276-143C, $1.69 (replaces Williams A-14231). The “U” shaped optos (as used on flipper boards) are available from Competitive Products (remember there are several types of U shaped optos).
- 15,000 mfd 25 volt “snap caps”. These capacitors are used for rectifying +5 and +12 volts. Digikey part# P6577-ND, $5.52 each.

Transistors and diodes are also available from www.mouser.com and www.digikey.com. Common game parts are available from www.competitiveproducts.com (800-562-7283). They have great prices on fuses, plunger & links, coil stops, EOS switches, flipper link spacer bushings, barrel springs, pinballs, optos, bridge rectifiers, connector pins, etc. All other parts (especially game specific parts) should be ordered from one of the suppliers on the parts and repair sources web page.

1d. Getting Started: Different WPC Generations

There are essentially six different generations of WPC systems. Components and circuit boards change with each generation. Therefore it is essential to know the game generation before starting repair.

- **WPC Alpha-Numeric**: used from Funhouse (10/90) to The Machine BOP (4/91). This generation of WPC used 16 digit alpha-numeric displays. These also used "normal" flippers, without a Fliptronics board. Identified by no Fliptronics board in the upper left corner of the backbox, and no dot matrix control board in the upper right side of the backbox (some Dr.Dude games were also this WPC generation although most were System11). All Dr.Dude WPC and early Funhouse games used System11 sound boards.
- **WPC Dot Matrix**: used from Terminator2 (6/91) to Party Zone (10/91). This generation of WPC used "normal" flippers, without a Fliptronics board. Identified by no Fliptronics board in the upper left corner of the backbox. Most Party Zone games don't have Fliptronics boards, and fall into this category.
- **WPC Fliptronics**: Used from Addams Family (2/92) to Twilight Zone (5/93). Some late Party Zone games also used this generation of WPC. The Fliptronics (I) board used in Addams Family and Party Zone are slightly different than all later Fliptronics II boards. The difference being the addition of a bridge rectifier to the Fliptronics II board for the flipper voltage.
- **WPC DCS**: Starting with Indiana Jones (10/93), Williams upgraded the sound card to use "digitally compressed sound" (DCS) as a different sound compression system. This gave much better sound and more sound storage space.

A WPC-Security CPU board. The chip with the white bar code label is the security PIC. This chip is game specific. Replacements are now available from www.shiftedbit.com. Note the different battery placement configuration on WPC-S CPU boards.

- **WPC-Security (WPC-S)**: Starting with World Cup Soccer (3/94), a security PIC chip was added to the CPU board in all WPC-S games. This PIC (Programable Integrated Circuit) chip was game specific. CPU boards can not be swapped between different models of game without changing the security PIC chip (i.e. Corvette CPU board put into a Shadow game must have the Corvette PIC changed to a Shadow PIC chip). Each security PIC chip had a special serial number encoded into the chip. This number displays on the dot matrix screen for a few seconds as the game is turned on.

  The number displayed shows what distributor the game was shipped to from the factory. This was done by Williams because of problems in Europe with distributors selling games outside of their sales territory. Anyone could turn a game on, write down the displayed serial number, and determine if the game was "bootlegged" from another distributor. However, this was defeated by adding a dot matrix power delay board. This small board didn't power the dot matrix display until the game was turned on for about 10 seconds. This meant the game was in attract mode (and the PIC number no longer displayed), before the dot matrix display was even turned on. This was embarrassing to Williams, as they spent much time and money to develop the security PIC chip system as a distributor territory protection device, yet the system was disabled by a simple modification. As a backup, there is probably a set of "secret" flipper button codes that will display the PIC number when the game is in attract mode (hence getting around the DMD power delay).

  Unfortunately for us, the PIC chip makes CPU repair more difficult, as CPU boards can't be swapped between games without changing the PIC chip. To make things worse, new PIC chips were available from Williams for about $180 (retail) each. They were priced at this amount to deter distributors who are bootlegging from purchasing additional PIC chips. Now that Williams is out of the pinball business (as of Oct 25, 1999), another company called **www.shiftedbit.com** is selling new PIC chips (called "Ewe-22") for a very reasonable price. These new chips are a complete re-write of the original PIC code, so there are no copyright or legal issues. They work with any version of the game's CPU ROM code too. These new PIC chips are still game specific, but for the price, they are a bargain!

- **WPC-95**: Starting with Congo (3/96) (and some Jackbot games), Williams introduced a new WPC-95 CPU, driver board, and audio/visual system. The Fliptronics board is now incorporated into the driver board. The sound and dot matrix controller board are combined into one board. WPC-95 also used a security PIC chip. Most of the WPC-95 circuits are the same as WPC-S and earlier. Exceptions include putting all the dot matrix display and DCS sound driver logic into a single logic array chip (similar to the WPC chip on the CPU board).
- Williams manufactured and distributed a few redemption games during the "FunHouse Games" label era (around 1992), including Screamin' Slopes, Wheel of Fortune, and Real Monsters. They were designed and programmed out-of-house, and have no WPC circuitry inside. The only redemption pieces that used WPC hardware are Ticket-Tac-Toe and Addams Family Values (Curiously, neither of those were marketed under the "FunHouse Games" label).

1e. Getting Started: Game List

Here are the list of WPC games and which generation they are. The date indicated is the initial release date of the game (determined from William's ROM code release dates, where available). Note that pre WPC-S games are also known as "WPC-89" games (so the three main WPC generations are WPC-89, WPC-S, and WPC-95).

WPC Alpha-Numeric

- Dr.Dude, 10/90 *
- Funhouse, 10/90 *
- Harley Davidson, 3/91
- The Machine BOP, 4/91

WPC Dot Matrix

- Slugfest Baseball, 6/91
- Gilligan's Island, 7/91
- Terminator2, 7/91
- Hurricane, 2/92
- Party Zone, 10/91 *

WPC-Security

- World Cup Soccer, 7/94
- Flintstones, 7/94
- Corvette, 9/94
- RoadShow, 10/94 #
- The Shadow, 12/94
- Dirty Harry, 1/95
- Theatre of Magic, 3/95
- No Fear, 4/95
- Indianapolis 500, 8/95
- Johnny Mnemonic, 9/95
- Jackbot, 8/95*

- Hot Shots (Basketball game)
- Addams Family Values (redemption)

WPC Fliptronics

- Party Zone, 10/91 *
- Addams Family, 3/92
- The Getaway, 4/92
- Black Rose, 8/92
- Fish Tales, 10/92
- Dr.Who, 10/92
- WhiteWater, 12/92
- Creature Black Lagoon, 1/93
- Dracula, 2/93
- Twilight Zone, 4/93 #
- Addams Family Gold, 7/94

WPC DCS

- Indiana Jones, 7/93 #
- Judge Dredd, 8/93 #
- Star Trek Next Generation, 11/93 #
- Popeye, 1/94 #
- Demolition Man, 4/94 #

- Who Dunnit, 11/95

WPC-95

- Congo, 12/95
- Attack from Mars, 2/96
- Safe Cracker, 4/96
- Ticket Tac Toe (redemption), 3/96
- Tales of Arabian Nights, 5/96
- Scared Stiff, 9/96
- Junkyard, 1/97
- NBA Fast Break, 3/97
- Medieval Madness, 7/97
- Circus Voltaire, 11/97
- No Good Gofers, 12/97
- Champion Pub, 3/98
- Monster Bash, 8/98
- Cactus Canyon, 2/99

* These games share two different systems. Only about 100 Dr.Dudes are WPC (most are System11). Early production Funhouse and all WPC Dr.Dude games use System11 sound boards. Most Party Zone games are not WPC Fliptronics (also a few Jackbot games were WPC-95).

Other Interesting Historical Tidbits.

The first dot matrix Williams/Bally game released for sale was actually Slugfest in the summer of 1991. Terminator2 was the first game designed with a dot matrix display, but Slugfest and Gilligan's Island (which both had shorter development cycles) beat T2 to market.

All games Gilligan's Island and later use "diamondplate" for the playfield coating (though not all later games say "diamondplate" right on the playfield). Diamondplate is a automotive style urethane coating, which replaced Lacquer. Bride of Pinbot and early games used Lacquer playfields, except for a few in each game title (mostly Pat Lawlor games, since Pat was the one pushing Diamondplate) that were made with Diamondplate. These early pre-Gilligan Island diamondplate playfields are always labeled with a "Diamondplate" logo usually on the lower right side of the playfield near the game credits. Banzai Run (system11) was the first game (by Pat Lawlor) where diamondplate was tried.

Most WPC games use a "translight" (a plastic film) for the backglass artwork. The only exceptions to this is No Good Gofers and Champion Pub, which used a "real" backglass with artwork screened directly onto the tempered glass.

Playfield Glass Size.

All pinball playfield glass is "tempered" glass. Do NOT use "plate" glass in a pinball game!

- All the above games (except where noted below) use the standard glass size of 21" x 43" x 3/16". This size was used on most pinball games from the 1950's through WPC.
- # - These games are "super-pins" with wide playfield bodies. These use 23.75" x 43" x 3/16" tempered playfield glass.
- Safe Cracker and Ticket Tac Toe used 18.5" x 36.5" x 3/16" tempered playfield glass.
- Slug Fest, a WPC pitch and bat game, uses 23" x 35 ¼" x 3/16" tempered playfield glass.

The size of the glass covering the translight on nearly all WPC games is 18 7/8” x 27” (Safe Cracker uses 18 7/8” x 19 ½). The glass thickness is what most hardware stores call “double thick” glass, which is about 1/8” thick. Tempered glass can be used for the translight, but really it is not needed there (unlike playfield glass which must be tempered!) Note backglass assemblies changed with WPC-95, when Williams changed to the “light tub” to hold the backbox lighting. The translight channels are wider than previously used. WPC-95 translight lift channel part numbers are WLL-03-9420 for the bottom lift channel, WLL-03-9421-1 for the top channel, and WLL-03-9421-2 for the (2) side channels.

Leg Color.

Most WPC Bally/Williams games use chrome legs, but there are some exceptions. Corvette, Creature from the Black Lagoon, Dr.Who, Harley Davidson, Black Rose, Star Trek Next Generation and Party Zone (and also all Pinball 2000 games) used black legs. Corvette even used black metal side rails and lockdown bar, and was the only Bally/Williams WPC game to have that. Roadshow used blue legs (and early “sample” games used a blue lockdown bar too). A few games used gold anodized legs, including Indiana Jones, Flintstones, Addams Family Gold, World Cup Soccer and Judge Dredd. All other games not mentioned above used chrome legs.

1f. Getting Started: Lubrication Notes

Pinball machines, for the most part, **do not** require any lubrication. Most parts run “dry”. Far more damage can be done to a pinball machine by over-lubricating, than by under-lubricating. As a rule, if in doubt as to lubrication, don’t do it! Throw that WD-40 away, it won’t be used here.

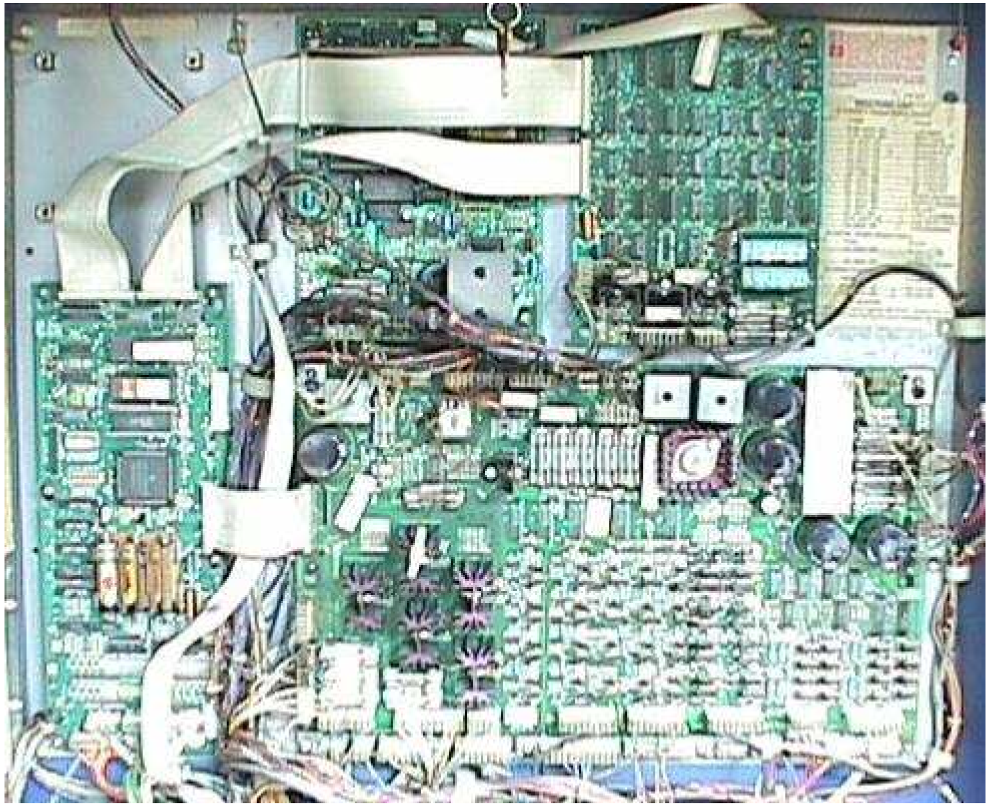
The only parts that will require any lubrication are metal-to-metal moving parts. There aren’t very many in a game. Only ball eject and slingshot hinges. Use 3-in-1 oil on these if you must. But try and keep that lubrication in the tool box and away from the game.

If some prior person did lubricate the game, the lubrication has probably now congealed with the infamous “black pinball dust” to form a thick, black mess. This is unrepairable on coil sleeves, and new parts will need to be installed.

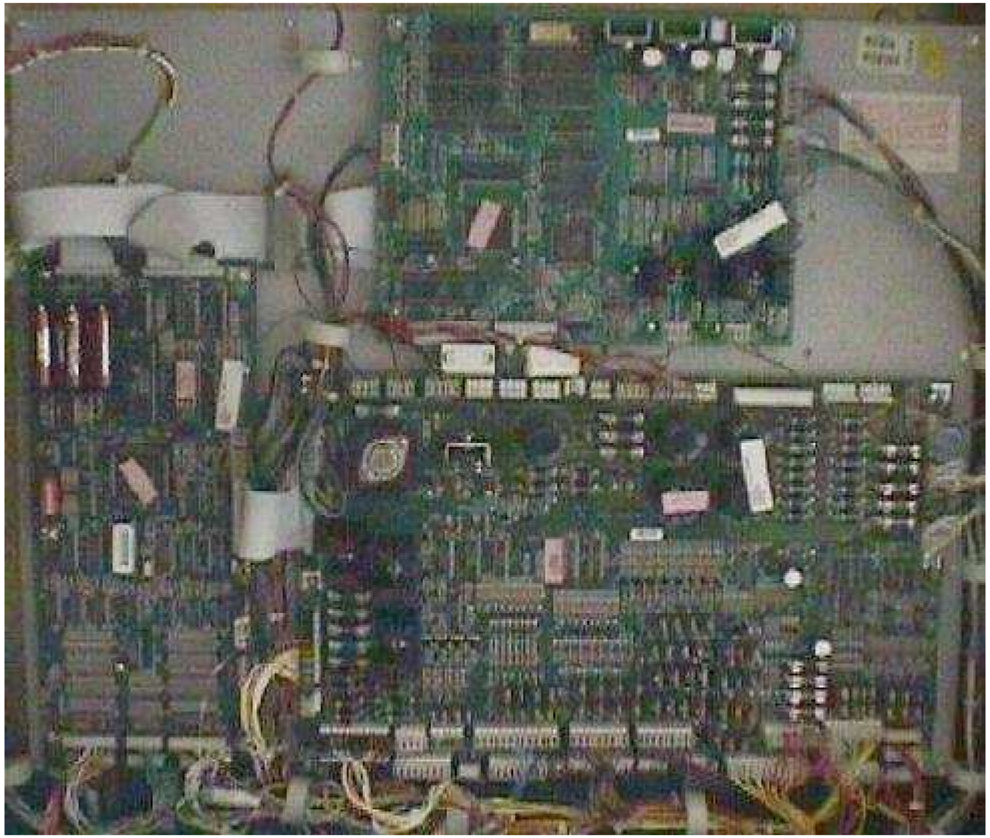
1g. Getting Started: The Circuit Boards (Generations)

There are basically three main WPC generations: WPC-89, WPC-S, and WPC-95, with WPC-89 have several sub-generations. Some boards are interchangable between games and systems, some are not.

The back box in a 1991 Bally Gilligan’s Island (second generation WPC-89). The CPU board is on the far left. The driver board is the largest board, and occupies the lower right area. The sound board is at the upper middle. The dot matrix controller board is at the upper right. The “missing” board (upper left) is where the Fliptronics board will be located on 1992 and later games. Note the four mounting posts for this missing Fliptronics board. Newer Fliptronics II boards use six mounting posts.



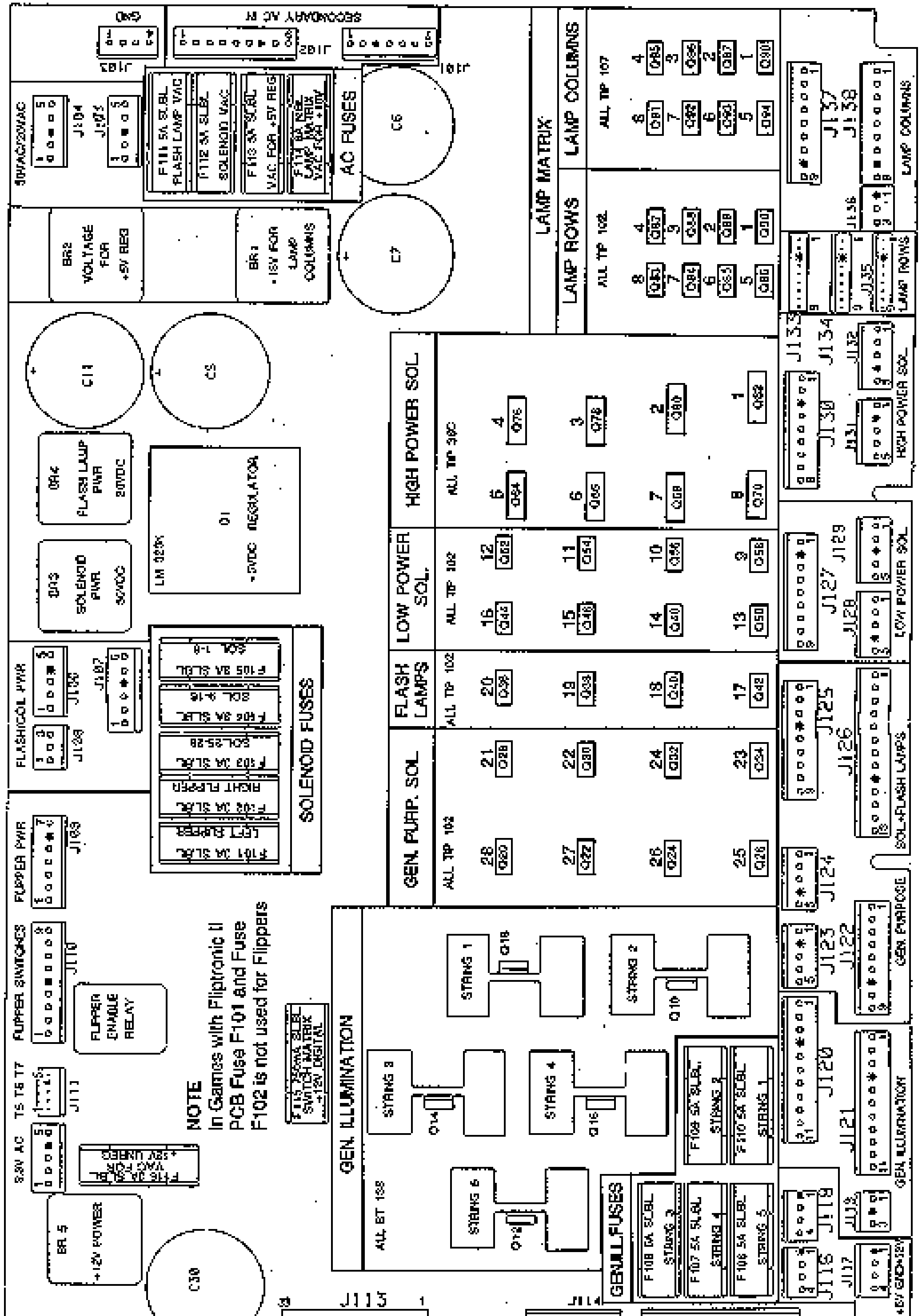
WPC-95 boards. Note fewer number of boards in WPC-95. The Fliptronics board is now incorporated into the Driver board. The dot matrix controller board and the sound board are combined into one board called the “A/V board”.



WPC Power Driver Board.

Most of the repair work will probably relate to this board. The more familiar one is with the Driver board, the better they will be able to fix WPC games. The driver board drives all solenoids and lamps. It provides the power for almost all the parts of a WPC pinball game. It houses most of the fuses too.

A drawing showing the usage of the connectors, fuses and transistors on a WPC-S and prior Driver board.



LAMP MATRIX
LAMP ROWS
LAMP COLUMNS
AC FUSES
HIGH POWER SOL
LOW POWER SOL.
FLASH LAMPS
GEN. PURP. SOL
SOLENOID FUSES
GEN. ILLUMINATION
GEN.ILL.FUSES
SECONDARY AC IN
NOTE
In Games with Fliptronic II
PCB Fuse F101 and Fuse
F102 is not used for Flippers

2a. Before Turning the Game On: Check the Fuses/LEDs - Blown Fuses and What Causes them

Click here for detailed information on the “Check Fuse F114/F115” or “Check Fuse F106/F101” (WPC-95) error messages.

Check every fuse, and remove it and check it with a meter! Do NOT try and check fuses visually. Remove the fuse from the game, as often the fuse’s infrastructure (glass to metal ends) has failed (though the fuse may still be intermittently working). If the fuse falls apart as it is removed, that’s a good indication there’s a problem.

Seems like such a simple thing, yet many of us forget to do it. Before turning the game on, check the fuses. Not only look for blown fuses, but especially over-fused circuits. For example, is there an 8 amp fuse where there should be a 5 amp? Is there a slow blow fuse where there should be a fast blow?

Most of the fuses for a WPC game are located in the backbox. The majority of which are on the driver board. There are a few fuses on the other boards too, and a line fuse at the front of the game.

A Particular Fuse Keeps Blowing in my Game when I Power-on.
First determine if a failing fuse is caused by a circuit board. The easiest way to do this is to disconnect the playfield from the board(s). This can be done by unplugging the appropriate circuit board connectors, and see if the fuse still blows.

For example, say fuse F105 keeps blowing on a WPC game. Looking at the schematics shows this is the high power solenoid fuse, and provides power to connectors J105 (cabinet), J106 (backbox), and J107 (playfield). Remove these connectors, replace fuse 105, and turn the game on. If the fuse does not blow, the problem is not on the circuit boards. If the fuse still blows, the problem is on the driver board.

If the fuse does not blow with the connectors removed, this procedure can be taken a step further. Replace connectors J105,J106,J107 one at a time, and turn the game on. Notice which connector causes the fuse to blow, and trace this connector to the device(s) in question.

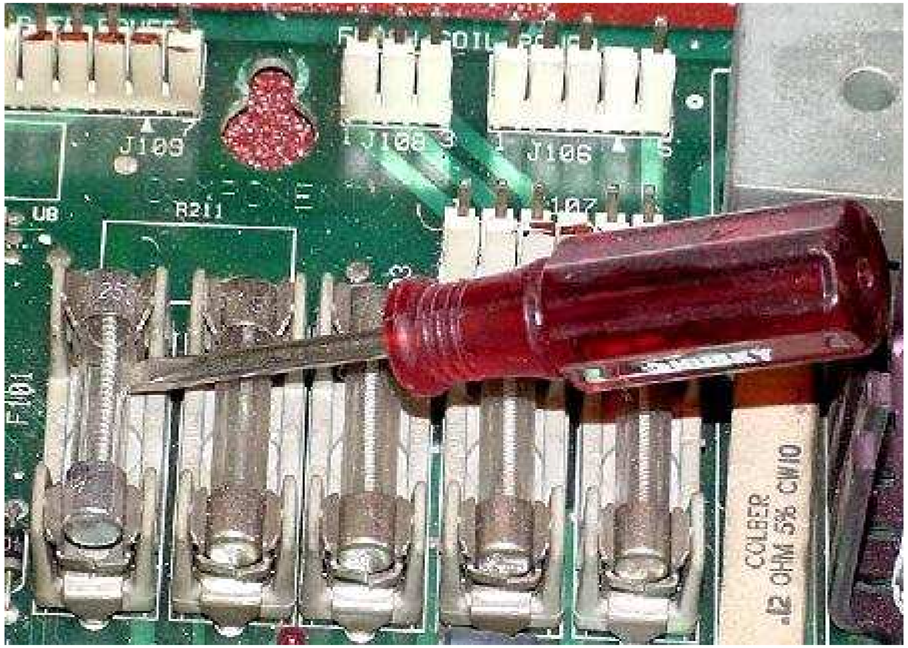
If the circuit board(s) are causing a failed fuse, often a shorted bridge rectifier will cause a fuse to instantly fail when the game is turned on. See below for which fuse connects to which bridge. See the Game Resets (Bridge Rectifiers and Diodes) section for help with testing bridges. If a solenoid fuse keeps blowing after a game is started, usually that means a related driver transistor had shorted. See the Checking Transistors and Coils section for help with that.

“I turn my Game On, and a Coil Keeps Firing On and Off - Why?”
This is a fuse related problem too. Chances are good the fuse for the 12 volts that feeds the switch optos has blown. Since there is no light source for the optos, this makes the CPU think the opto switches are closed (like there is a ball stuck in an upkicker). The machine is trying to eject the phantom ball as part of the power-on process. Check all the backbox fuses (on WPC-S and prior, usually this is fuse F116, which is the unregulated 12 volt fuse via BR5, or F109 on WPC-95).

Testing Fuses: the Right Way.
Don’t depend on your eyes or sense of smell to check fuses. A perfectly good looking fuse could be blown, it happens all the time. Use a Digital Multi-Meter (DMM). With the game off, first remove the fuse from its holder, (or at minimum remove just one end of the fuse from the holder). Don’t try and test the fuse installed as it can give false readings, depending on the circuit. Set the DMM to “continuity”, put a lead on each end of the fuse, and buzz out those fuses. No buzz means fuse is bad.

(Side Note: a “buzz” on the DMM meter means zero resistance. If there is no “buzz”, either the circuit is OPEN, or the resistance is 100 ohms or greater. If the meter doesn’t have a continuity function, just use the lowest resistance setting. A good fuse will measure zero ohms.)

Removing a fuse with a small screwdriver. Note the screwdriver is at the end of the fuse, and is pulled away from the board to release the fuse. Do not pry the fuse out at the metal fuse clip, as this will bend the fuse clip and basically ruin the fuse holder.



Yes a fuse can be tested in the game with the power on, and without removing it. But don't do it! Remove all the fuses, inspect them for the correct value and good condition, and test them with a DMM set to resistance. All fuses should be check before the game is even powered on for the first time. And working on a game with the power on is just not a good idea for most people, as it can lead to other problems.

Another Reason to Pull a Fuse from its Holder to test it.
Always remove a fuse from its holder to test it. Do this because a particularily fatigued fuse will often fall apart as taken out of its holder. This may never be seen if the fuse is tested in its holder. This is especially true if the fuse tests 'good' then the fuse wire pulls away from an end-cap as it heats up. For this reason, regardless of the convenience, all fuses should always be pulled from its holder for testing. Also removing the fuse forces the user to examine the fuse holder and its condition too.

Smaller Fuses in WPC-95 Games.
With WPC-95 Williams changed to the smaller international ISO size (.75" or 5x20mm) GMC "T" fuses 250 volts (but 125 volt fuses work fine too). The "T" designation means "timed delay", or in other words, it's a slow-blow style fuse. Note there are also GMA "F" (F means "fast blow") fuses, but part WPC-95 games only use slow-blow GMC "T" fuses. As for the "T" and "GMC" terminology, Buss uses the "GMC" and Littlefuse uses the "T" terminology ("T" and "GMC" are the same thing). WPC-S and earlier games used the older American 3AG or AGC 1.25" size fuses. Since Williams exports over 50% of their production outside of North America, it made sense to change. The 5x20mm fuses take up less space on the circuit boards too.

WPC-S and Prior Driver Board LEDs, Test Points (TP), and Fuses.
For reference, TP5 is ground.

- **LED1/TP3:** +12 volts DC regulated circuit. Should be always ON. If off, check fuse F115. This is often caused by a bad CPU board chip U20 (see the switch matrix section for more details). The AC Power originates at connector J101 pins 4,5 and 6,7. It then goes through fuse F114, bridge BR1, capacitors C6 and C7, LED6/TP8 (18 volts DC), diodes D1 and D2, voltage rectifier Q2, fuse F115, LED1/TP3 (12 volts DC), then to connector J114 pins 1,2. Also, just before diodes D1 and D2, the circuit splits to the LM339 chip U6, and LED2/LED3.
- **LED4/TP2:** +5 volts DC digital circuit. Should be always ON. If off, game will not boot. Check fuse F113 (or bridge BR2 and capacitor C5). Though not likely to fail, there is also a voltage regulator LM323 at Q1, a LM339 chip at U6 ("zero cross"), and two 1N4004 diodes at D3 and D38. The AC Power originates at connector

J101 pins 1 and 2. It then goes through fuse F113, bridge BR2, capacitor C5, voltage rectifier Q1, LED4/TP2 (5 volts DC), then to connector J114 pins 3,4. Note after fuse F113, the AC power also continues to diodes D3 and D38, and to LM339 chip U6. Then this “zero cross” power merges back into the +5 volt line before hitting connector J114.

- **LED5/TP7:** +20 volts DC flashlamp circuit. Normally ON. Twilight Zone and later, this LED fades off when the coin door is opened. If off, check coin door and fuse F111 (or bridge BR4 and capacitor C11). The AC Power originates at connector J102 pins 1,2 and 3,4. It then goes through fuse F111, bridge BR4, capacitor C11, LED5/TP7 (20 volts DC), then to connector J107 pins 5,6 (and J106 and J108).
- **LED6/TP8:** +18 volts DC lamp matrix circuit. Normally ON. If off, check fuse F114 (or bridge BR1 and capacitors C6, C7). Though not likely to fail, there is also a voltage regulator LM7812 at Q2, a LM339 chip at U6, and two 1N4004 diodes at D1 and D2. The AC Power originates at connector J101 pins 4,5 and 6,7. It then goes through fuse F114, bridge BR1, capacitors C6 and C7, LED6/TP8 (18 volts DC), diodes D1 and D2, voltage rectifier Q2, fuse F115, LED1/TP3 (12 volts DC), then to connector J114 pins 1,2. Also, just before diodes D1 and D2, the circuit splits to the LM339 chip U6, and LED2/LED3.
- **LED7/TP1:** +12 volts DC unregulated power circuit (opto light, motors, relays, etc). Should always be ON. If off, check fuse F116 (or bridge BR5 and capacitor C30). The AC Power originates at connector J112 pins 1,2 and 3,5. It then goes through fuse F116, bridge BR5, capacitor C30, LED7/TP1 (12 volts DC), then to connector J118/J117/J116 pin 2.
- **TP6 (no LED):** +50 volts for the coil. The AC Power originates at connector J102 pins 5,6 and 8,9. It then goes through fuse F112, bridge BR3, capacitor C8, TP6 (50-70 volts DC), then fuses F103/F104/F105 (and F102/F102), then to connector J107, J106 J108, and J109.
- **LED2 (no TP):** This LED is not always installed. High/low line voltage sensor. Normally ON, but flickers with the playfield lamps.
- **LED3 (no TP):** This LED is not always installed. High/low line voltage sensor. Normally OFF, but flickers with the playfield lamps.

WPC-95 Driver Board LEDs, Test Points (TP), and Fuses.
For reference, TP107 is ground.

- **LED100/TP100:** +12 volts DC regulated. Should be always ON. If off, check fuses F101 and F106 (or diodes D11-D14 and capacitors C11, C12). If fuse F101 has failed, this is often caused by a bad CPU board chip U20 (see the switch matrix section for more details). Though not likely to fail, there is also a voltage regulator LM7812 at Q2, and two 1N4004 diodes at D1 and D2. If fuse F101 has failed, suspect the voltage regulator Q2. The AC Power originates at connector J129 pins 6,7 and 4,5. It then goes through fuse F106, diodes D11-D14, capacitors C12,C11, LED102/TP102 (18 volts DC), diodes D1-D2, voltage rectifier Q2, fuse F101, LED100/TP100 (12 volts DC), then to connector J101 pins 1,2.
- **LED101/TP101:** +5 volts DC digital. Should be always ON. If off, game will not boot. Check fuse F105 (or diodes D7-D10 and capacitor C9). Though not likely to fail, there is also a voltage regulator LM317 at Q1, a LM339 chip at U1, and two 1N4004 diodes at D23 and D24. The AC Power originates at connector J129 pins 1 and 2. It then goes through fuse F105, diodes D7-D10, capacitor C9, voltage rectifier Q1, LED101/TP101 (5 volts DC), then to connectors J101 pins 3 and 4, J138 pin 4, J139 pin 4, J140 pin4, J141 pin 4.
- **LED102/TP102:** +18 volts DC lamps. Normally ON (can flicker with playfield lamps). If off, check fuse F106 (or diodes D11-D14 and capacitors C11, C12). The AC Power originates at connector J129 pins 6,7 and 4,5. It then goes through fuse F106, diodes D11-D14, capacitors C12,C11, LED102/TP102 (18 volts DC), diodes D1-D2, voltage rectifier Q2, fuse F101, LED100/TP100 (12 volts DC), then to connector J101 pins 1,2.
- **LED103/TP103:** +12 volts DC un-regulated for opto lights, motors, etc. Should be always ON. If off, check fuse F109 (or diodes D3-D6 and capacitor C8). The AC Power originates at connector J127 pins 1,2 and 3,5. It then goes through fuse F109, diodes D3-D6, capacitors C8, LED103/TP103 (12 volts DC), then to connectors J138 pin 2, J139 pin 2, J140 pin 2, J141 pin 2.
- **LED104/TP104:** +20 volts DC flashlamps. Normally ON. This LED fades off when the coin door is opened. If off, check coin door and fuse F107 (or diodes D15-D18 and capacitor C10). The AC Power originates at connector J128 pins 1,2 and 3,4. It then goes through fuse F107, diodes D15-D18, capacitors C10, LED104/TP104 (20 volts DC), then to connectors J133 pin 5 and 6, J134 pin 5.
- **LED105/TP105:** +50 volts DC coils. Normally ON. This LED fades off when the coin door is opened. If off, check coin door and fuse F108 (or diodes D19-D22 and capacitor C22). The AC Power originates at connector J128 pins 8,9 and 5,6. It then goes through fuse F108, diodes D19-D22, capacitors C22, LED105/TP105 (50-70 volts DC), fuses F102, F103, F104, then to connectors J134 pins 1,2,3, J135 pins 1,2,3.

Summary of Typical Fuses that Blow, and What Causes it.
WPC-S and prior games:

- Line Fuse (main power fuse): Located in the metal power box just inside the coin door, if bridge rectifier BR3 is blown, this fuse can fail immediately at power up. Also if the varistor inside the metal power box is shorted, this fuse will blow. And finally, if a bridge rectifier on the fliptronics board is blown, this can also cause the line fuse to blow on some games (but only when the coin door is closed!)

- F101-F102: Bad flipper EOS switch or shorted/mis-wired flipper coil (pre-Fliptronics), or shorted coil or driving transistor.
- F103-F105: Shorted coil or driving transistor.
- F106-F110: Shorted general illumination socket.
- F111: Shorted bridge BR4 or shorted flashlamp socket.
- F112: Shorted bridge BR3. Can also make the game main line fuse to blow.
- F113: Shorted bridge BR2 or +5 vdc shorted to ground.
- F114: Shorted bridge BR1, shorted cap C6 or C7, or shorted controlled lamp socket.
- F115: Defective CPU board chip U20 and maybe CPU chip U14.
- F116: Shorted bridge BR5 or shorted motor or shorted opto light or other 12 volt device on playfield or backbox.

WPC-95 games:

- Line Fuse: Located in the metal power box just inside the coin door, if one of the driver board diodes D19-22 is blown, this fuse can fail immediately at power up. Also if the varistor inside the metal power box is shorted, this fuse will blow. And finally, if a bridge rectifier on the AV board is blown, this can also cause the line fuse to blow on some games (but only when the coin door is closed!)
- F101: Defective CPU board chip U20 and maybe CPU chip U23.
- F102-F104: Shorted coil or driving transistor.
- F105: Shorted diode D7-D10 or +5 vdc shorted to ground.
- F106: Shorted diode D11-D14 or shorted controlled lamp socket.
- F107: Shorted diode D15-D18 or shorted flashlamp socket.
- F108: Shorted diode D19-D22.
- F109: Shorted diode D3-D6 or shorted motor or shorted opto light or other 12 volt device on playfield or backbox.
- F110-F114: Shorted general illumination socket.
- F115-F118: Shorted or mis-wired flipper coil.

In-Depth Fuse/Voltage/Bridge Explainations.
<u>WPC-S and Earlier:</u>
Line Fuse: Value/type depends on the game's main voltage. If there is a problem as the line cord or power box, this fuse blows. Also if bridge rectifier BR3 is bad, it can blow this fuse. If a bridge rectifier on the fliptronics board is blown, this can also cause the line fuse to blow on some games (but only when the coin door is closed!) This happens because some games use power from the Fliptronics board to power the flipper and other coils too. For domestic games, usually 8 amp fast blo 1.25" fuses (check game manual).
Driver Board for WPC-S and Earlier
These games use standard American 1.25" fuses.

- F101: usually 2.5 amp slo-blo (non-Fliptronic) or 3 amp slo-blo (Fliptronic). 50 volts. Used for left flipper on non-Fliptronic games (bad EOS switch can cause this fuse to blow). Used for other solenoids on Fliptronic games. A shorted or locked-on coil can cause this fuse to blow.
- F102: usually 2.5 amp slo-blo (non-Fliptronic) or 3 amp slo-blo (Fliptronic). 50 volts. Used for right flipper on non-Fliptronic games (bad EOS switch can cause this fuse to blow). Used for other solenoids on Fliptronic games. A shorted or locked-on coil can cause this fuse to blow.
- F103: usually 3 amp slo-blo. After bridge BR3. Used for 50 volt continuous duty solenoids 25 to 28. A shorted or locked-on coil can cause this fuse to blow.
- F104: usually 3 amp slo-blo. After bridge BR3. Used for 50 volt lower power solenoids 9 to 16. A shorted or locked-on coil can cause this fuse to blow.
- F105: usually 3 amp slo-blo. After bridge BR3. Used for 50 volt high power solenoids 1 to 8. A shorted or locked-on coil can cause this fuse to blow.
- F106, F107, F108, F109, F110: All 5 amp slo-blo. Used for the 6.3 volt General Illumination (GI). A shorted GI lamp socket can cause any of these fuses to blow.
- F111: 5 amp slo-blo. Before bridge BR4. Used 20 volts flash lamps AC input voltage. A shorted flashlamp socket or bad bridge BR4 can cause this fuse to blow.
- F112: 7 amp slo-blo. Before bridge BR3. Used for solenoid AC input voltage. A failed BR3 bridge will cause this fuse to blow and perhaps the main power fuse.
- F113: 5 amp slo-blo. Before bridge BR2. Used for AC input voltage that is converted to regulated +5 volts DC.

- F114: 8 amp fast-blo. Before bridge BR1. Used for AC input voltage that is converted to +18 volts for the lamp matrix. A shorted controlled lamp socket or bad BR1 bridge rectifier can cause this fuse to blow, or shorted cap C6 or C7.
- F115: ¾ amp fast blo. This voltage comes after a voltage regulator (which gets power from BR1). Used for the switch matrix regulated +12 volts. A defective U20 chip (all WPC revisions) on the CPU board can cause this fuse to blow. Also sometimes the U14 chip (on WPC-95, U23) on the CPU board fails in addition to the U20.
- F116: 3 amp slo-blo. Before bridge BR5. +12 volt unregulated power for opto light, motors, etc.

Fliptronics Board for WPC-S and Earlier
These games use standard 1.25" fuses.

- F901: 3 amp slow-blo. Used for lower right flipper.
- F902: 3 amp slow-blo. Used for lower left flipper.
- F903: 3 amp slow-blo. Used for upper right flipper.
- F904: 3 amp slow-blo. Used for upper left flipper.

  NOTE: **Sometimes fuses F903 and F904 on the fliptronics board are used for powering other coils, instead of flippers!** For example, on Theatre of Magic (which has no upper flippers), F903 and F904 are used for playfield magnet power. This can be really frustrating, and not very obvious.

Sound Board for WPC-S and Earlier
These games use standard 1.25" fuses.

- F501: 3 amp slow-blo. Used for -25 volts.
- F502: 3 amp slow-blo. Used for +25 volts.

Dot Matrix Controller Boards for WPC-S and Earlier
These games use standard 1.25" fuses.

- F601: 3/8 amp fast-blo. Used for +62 volts.
- F602: 3/8 amp fast-blo. Used for -113, -125 volts.

<u>WPC-95:</u>
Line Fuse: Value/type depends on the game's main voltage. If there is a problem as the line cord or power box, this fuse blows. Also if driver board diodes D19-D22 are bad, it can blow this fuse. WPC-95 (domestic): T5.0 amp, "T" small size. WPC-95 (foreign): T4.0 amp, "T" small size.
WPC-95 Driver Board
Uses smaller "T" (.75" or 5x20mm) 250 volt fuses.

- F101: T0.63 amp. Regulated +12 volts, after a voltage regulator.
- F102: usually T4.0 amp. 50 volt solenoids #9 to #16 to diodes D19-D22.
- F103: usually T4.0 amp. 50 volt solenoids #1 to #8 to diodes D19-D22.
- F104: usually T4.0 amp. 50 volt solenoids #25 to #28 to diodes D19-D22.
- F105: T4.0 amp. +5 volts logic to diodes D7-D10.
- F106: T5.0 amp. +18 volts lamp matrix poewr to diodes D11-D14.
- F107: T4.0 amp. Flash lamp power secondary, after diodes D15-D18.
- F108: T6.3 amp. 50 volt solenoid power secondary, after diodes D19-D22.

* F109: T4.0 amp. Unregulated +12 volts to diodes D3-D6, for opto light, motors, etc.
* F110: T4.0 amp. GI#5 white/violet.
* F111: T4.0 amp. GI#4 white/green.
* F112: T4.0 amp. GI#3 white/yellow.
* F113: T4.0 amp. GI#2 white/orange.
* F114: T4.0 amp. GI#1 white/brown.
* F115: T4.0 amp. Flippers +50 volts.
* F116: T4.0 amp. Flippers +50 volts.
* F117: T4.0 amp. Flippers +50 volts.
* F118: T4.0 amp. Flippers +50 volts.

WPC-95 Audio/Video Board
Uses smaller "T" 250 volt fuses.

* F501: T2.5 amp. -15 volts.
* F502: T2.5 amp. +15 volts.
* F601: T0.315 amp. +62 volts.
* F602: T0.315 amp. -113 and -125 volts.

Check Fuses F114/F115 (or F106/F101 on WPC-95) Error Message.
This error message on the score display is a very common problem on WPC games. Not so much because these fuses are blown, but because often these fuses are **not** blown, yet the error message persists.
If fuse F114 (or F106 on WPC-95) is indeed blown, this usually indicates a shorted BR1 bridge (D11-D14 on WPC-95) or cap C6 or C7. If this fuse is OK, check fuse F115 (or F101 on WPC-95). If this is blown, typically it is caused by a shorted U20 chip (and possibly U14, or U23 on WPC-95) on the CPU board.
The way the game determines if fuse F114/F115 is blown is through the game's switch matrix. Looking at the switch matrix chart, it can be seen that switch 24 on every WPC game is named "always closed". This switch 24 is monitored by the CPU's software. If the software see this switch is not closed, it assumes the power to the switch matrix is gone, and hence the F114/F115 (or F106/F101 on WPC-95) fuse error is displayed. The problem with this assumption is that the switch matrix fuse can be fine, but the switch matrix can be otherwise blown, thus giving a false fuse error.
So the first thing to check are the fuses themselves. If this pair of fuses (F114/F115 or F106/101 on WPC-95) are bad, replace them and power on the game. If they blow immediately, chances are good bridge rectifier BR1 (or diodes D11-D14 on WPC-95) have shorted. This is a fairly common problem. Less common is capacitor C6 or C7 have shorted.
Another thing to try is this:

* Power off.
* Remove the fuse F115 from the powerdriver board.
* Insert a new fuse at F114.
* Switch the game on and wait for the fuse to blow.

If nothing happens the powerdriver is okay and the problem is located elsewhere (playfield or CPU board). If the fuse F114 does blow, chances are good either bridge rectifier BR1, or caps C6 or C7 are shorted. Using a DMM and measure the voltage at TP8. This should read about 18 volts - if lower (but more than 2 volts), the caps at C6 and/or C7 are suspect.
If the F114/F115 (or F106/101 on WPC-95) fuses are good yet the error message still persists, there is a switch matrix problem. As mentioned above, the CPU monitors switch 24 for its "always closed" status. Switch 24 is actually physically closed by having a loop of wiring going from the CPU board connector J212 down to the coin door interface board connector J3. Here the switch matrix column 2 and row 4 are joined together through a 1N4004 diode, band connected to switch column 2 on the interface board. If one of these connectors are disconnected, or the wiring broken to the coin door interface board, the blown fuse error will be displayed (note this is rarely the problem).
Assuming all is good so far (no blown fuses and CPU board connector J212 and coin door interface connector J3 are attached), the next thing to check is CPU board chip U20 (ULN2803). Often this chip is blown, usually because the solenoid voltage somehow touched a playfield switch. On WPC-S and later games, Williams socketed CPU board

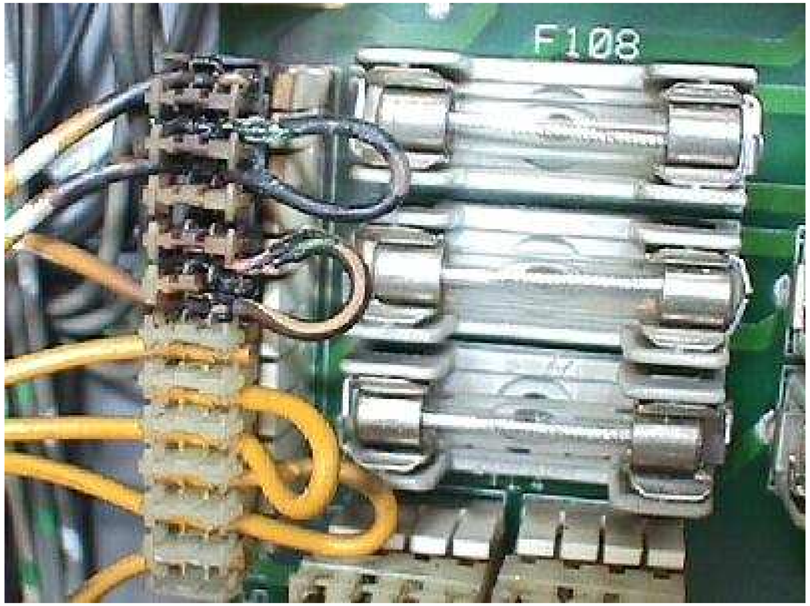
U20 because this problem was so common. If U20 has failed, the game will display the F114/F115 (or F106/F101) fuse error (even though these fuses are good). Replace U20 with a new ULN2803 chip (use a socket if one is not there). If the error still persists, replace CPU board chip U14 (74LS374, or on WPC-95 U23, a 74HC237).
Regarding U14 (74LS374 on WPC/WPC-S) and U23 (74HC237 on WPC-95). For some reason, this chip can die **without** the U20 (ULN2803) failing. This is very strange, as the chip in question is between the ULN2803 and the cpu logic. But it does happen! Just keep this in mind. It doesn't happen a lot, but it does happen.
Here is a further indepth, step-by-step approach to see exactly what is causing the F114/F115 (or F106/F101) error message, assuming the fuses themselves are **not** blown. With the game on and the coin door closed:

- Test for AC voltage at J101 pins 4 and 7 (or J129 pins 4 and 7 on WPC-95). A reading of 13 to 18 volts AC should be seen. This is the AC voltage coming from the transformer. If no voltage here, check the Molex connectors around the transformer and at the power driver board.
- Test for DC voltage at TP8 (or TP102 on WPC-95) and ground. A reading of 16 to 18 volts DC should be seen. If no voltage here, replace BR1 (or D11 to D14 on WPC-95). Also no voltage here can occur because the solder pads are cracked around bridge BR1 (or D11 to D14 on WPC-95). Using jumper wires for BR1 (as described in the Game Resets section) helps prevent this.
- Test for DC voltage at TP3 (or TP100 on WPC-95) and ground. A reading of 12 volts DC should be seen. If no voltage here, check or replace diodes D1 and D2 (1N4004, all WPC version).
- If still no voltage at TP3 (or TP100 on WPC-95) and diodes D1/D2 are OK, replace Q2 (all WPC versions), a LM7812 voltage regulator.
- If the above still does not fix the problem, replace U20 (all WPC versions) on the CPU board (ULN2803). If U20 died "hard", it could also blow the 74LS374 at U14 (on WPC-95 it's U23, a 74HC237) on the CPU board.
- If voltage is still not right, or BR1 (or diodes D11-D14 on WPC-95) are REALLY hot, check all the TIP107 transistors on the power driver board. If these test good, check/replace the ULN2803 at U19 (or U11 on WPC-95) on the power driver board, or maybe the 74LS374 at U18 (or U10 on WPC-95) on the power driver board.

2b. Before Turning the Game On: Burnt GI Connectors (and WPC-95 GI Diodes)

Often when getting a WPC game, after turning it on, the general illumination (GI) lights don't work. This can be caused because the connectors going to the board burned.

The J115 GI connector used up to 1993. The J115 connector is located on the driver board in the lower left hand corner, next to the five fuses. Resistance is the result of cold or fatigued solder joints and smallish connectors with not enough surface area to handle the GI power requirements. Note the use of a white connector housing on this early WPC game.



The transformer converts 120 volts AC to 6 volts. The 6 volts AC goes to connector J115 (or J103 on WPC-95) on the driver board. This incoming voltage goes through fuses (F106 to F110 on WPC-S and prior, F110 to F114 on WPC-95), then the triacs (a type of transistor). The triacs allow the CPU to control the intensity of the GI lights. After the triacs, the AC power goes to connectors J120 and J121 (J105 and J106 on WPC-95), and finally to the playfield lights. As a WPC game is powered on, the GI lamps do not come on until the CPU board has fully booted and initialized the game (except on WPC-95 games, where two of the five GI lamp strings are not triac controlled; they come on immediately as the game is powered on, and their light intensity is not CPU controlled).

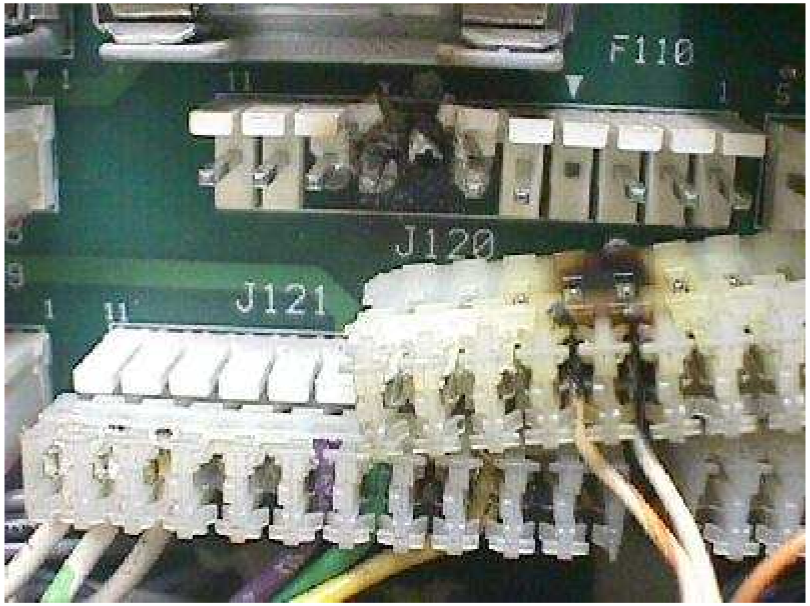
On WPC games (prior to Twilight Zone) with a white J115 connector, this connector will get warm and can actually burn. This happens because the molex connector pins don't have enough surface area to handle the GI power requirements. The heat from the connector pins will cause the solder joints to fatique which causes resistance (and heat) to increase. The connector pins get so warm they soften the solder. All this causes more resistance, which causes more heat. It doesn't end till the board burns, the fuse heat fatiques and fails, or the connectors pins fall out (or burn!) and open the circuit.

The driver board as seen from the back. Note the cold solder joints on the right, and the two missing pins that got so hot the solder melted away.

On original WPC games (1990 to 1993), the J115 GI connector pin housings are made of milky white plastic (like all the other connectors). These are "normal" molex connector housings. Starting with Twilight Zone in 1993, Williams changed to a black "hi-temp" molex connector housing for J115. The only difference between the white and black connector housings is the temperature that they will start on fire. They do NOT dictate better connectivity in the GI circuit. Williams used the black connectors in a "CYA" (cover your a*s) mode, since GI connectors were burning up, and Williams didn't want any issues with their games starting on fire.

Unfortunately, Williams didn't upgrade the GI connectors pins. Trifurcon pins, which have three sides of surface area surrounding the header pins, are not capable of machine automation. Hence Williams used the old style single-side connector pins, which allowed machines to make the connectors. Starting with WPC-95, Williams changed to black hi-temp connector housings all around, thicker GI wires, and upgraded pins and larger wires for the playfield GI circuits (unfortunately the backbox GI wires were still too small).

A burnt J120 connector on a WPC-S game. Notice the gauge of wire used on connector J120. It's very small compared to the wire used on connector J121. This also contributes to the burnt connector problem.



Fixing a Burnt Connector.

Fixing a burnt connector requires more than just replacing the connector! The driver board will need to be removed, and the male header pins **replaced**. If only the connector housing and connector pins are replaced, the board pins' resistance will still be there (from the cold or fatigued solder joints and tarnished pins). The newly installed connector will burn in short order.

When replacing the Male Header pins...

When replacing male header pins on the driver board at connector J115, J120, J121 (or J103, J105, J106 on WPC-95), it's a good idea to check for continuity with a DMM on BOTH SIDES of the driver board. Often the plated through holes on the these GI traces will break. This is not a problem for traces on the solder side of the driver board (since the board is solder there). But it is a problem for traces on the component side of the board. Check for continuity between the front and back solder pads on each GI board hole with a DMM. If there is no continuity, a "solder stitch" will be needed. The stitch is just some stranded wire put through the board hole, and bent over on each side of the board on the solder pad. This connects the component and solder pad traces, as they originally were with the (now broken) plated through hole. After the wire is inserted in the hole, solder it down on the component side of the board. Then installed the new male header pins through the holes (including the one with the solder stitch), and solder all the pins on the solder side of the board.

The solder pad at J115 that is circled does not have continuity between the component and solder sides of the driver board (the plated through hole has broken). To fix this, some stranded wires (a "solder stitch") is inserted through the hole, and soldered on the component side of the board. Then the new header pins are insert through the holes, and solder on the solder side of the board.

Above all the pins are soldered except for the “stitched” pin (which is circled). This pin was soldered right after this picture was taken!

G.I. Continuity Checks.

After new male header pins are installed on the driver board, do these DMM continuity checks to make sure there are no broken traces. I stress this must be done, otherwise you’ll be wondering why one or more strings of G.I. do not work. As a note, I have never had a problem with a G.I. triac, but I have had plenty of problems with broken G.I. circuit board traces. All continuity checks are done on the component side of the driver board, with the game off, and with connectors J115, J120, J121 and J119 removed. This info only applies to WPC-S and prior driver boards:

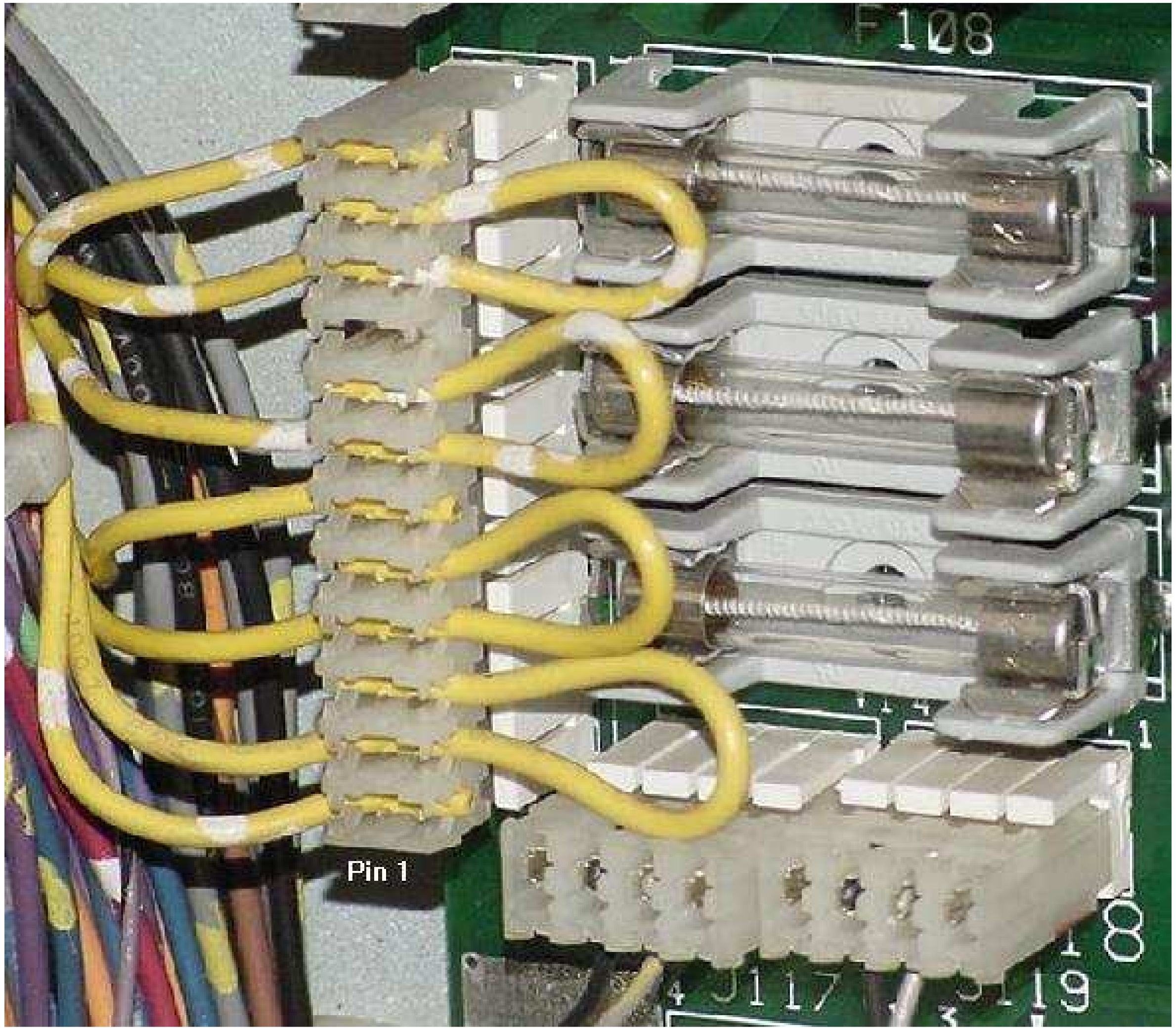
- J115 pin 2 to fuse F106 (lower left) to J120/J121 pin 11, to J119 pin 1.

- J115 pin 3 to fuse F110 (lower right) to J120/J121 pin 7.
- J115 pin 4 to fuse F109 (upper right) to J120/J121 pin 8.
- J115 pin 5 to fuse F107 (middle left) to J120/J121 pin 10.
- J115 pin 6 to fuse F108 (upper left) to J120/J121 pin 9.
- J115 pin 7 to Q10 top leg (triac lower rt). Q10 middle leg to J120/J121 pin2.
- J115 pin 8 to Q18 bottom leg (triac upper rt). Q18 middle leg to J120/J121 pin1.
- J115 pin 10 to Q16 top leg (triac lower mid). Q16 middle leg to J120/J121 pin5.
- J115 pin 11 to Q14 top leg (triac upper mid). Q14 middle leg to J120/J121 pin3.
- J115 pin 12 to Q12 top leg (triac left). Q12 middle leg to J120/J121 pin6, to J119 pin3.

J115 G.I. Connector Wiring.
On games before the black J115 connector plug was used (before Twilight Zone), there were just two input GI wire colors to connector J155: three yellow wires (the GI supply) and four yellow w/white (the GI return). All the yellow wires connect directly to the transformer and are the GI supply. All the yellow w/white wires connect directly to the transformer and are the GI return. Here's the pinout for that:

- J115 pin 1,7,8,10,11,12 = Yellow w/white (GI return)
- J115 pin 9 = key
- J115 pin 2,3,4,5,6 = Yellow solid (GI supply)

Earlier WPC games used just too input GI wire colors to connector J115 (yellow and yellow/white band). Here's a pictures an unburnt J115 connector.

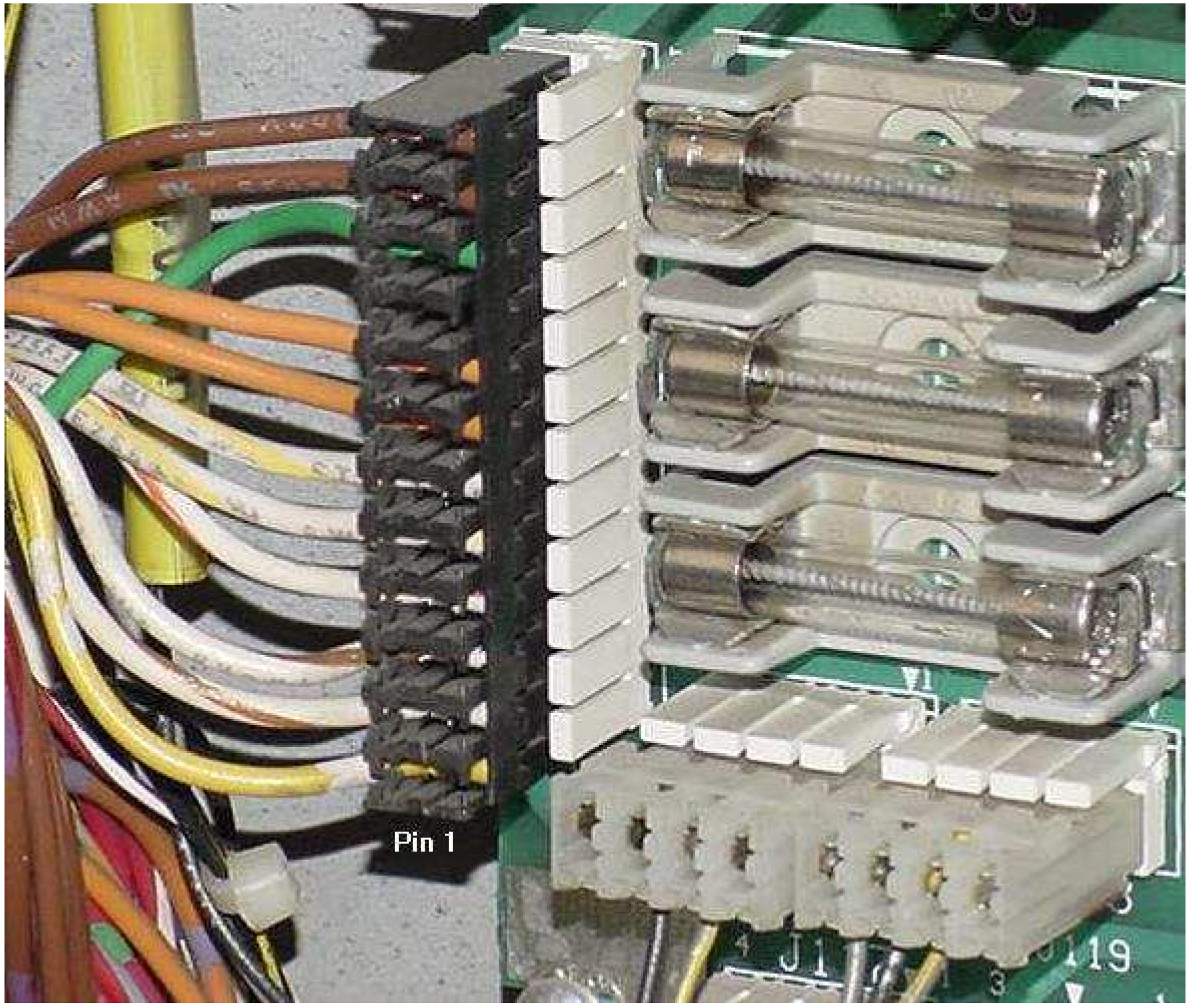


Games with black J115 connector plugs (Twilight Zone to Jackbot) used different wire colors at J115. Here's the typical wiring (taken from a Corvette):

- J115 pin 11,12 = brown
- J115 pin 10 = green
- J115 pin 9 = key
- J115 pin 7,8 = orange
- J115 pin 5,6 = white w/yellow
- J115 pin 4 = white w/orange
- J115 pin 2,3 = white w/brown

- J115 pin 1 = yellow w/white

Later WPC games (about Twilight zone to Jackbot) with the black J115 connector plug used different wire colors. Here's a Corvette's J115 wiring, which is typical of these games.



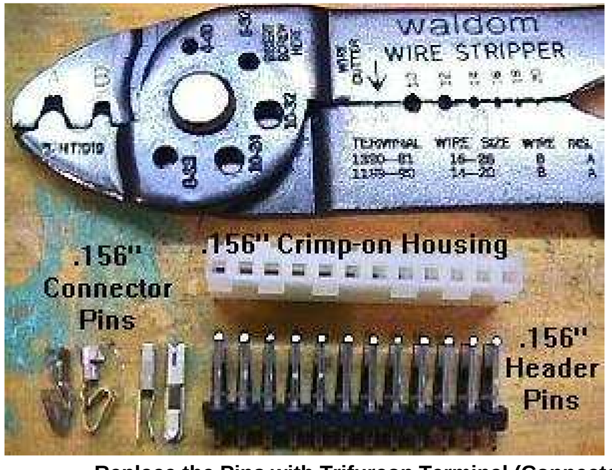
G.I. Power Test.
Now that the driver board header pins have proper continuity, the driver board can be test with the power on. With G.I. connector plugs J120, J121 and J119 removed, use a DMM set to AC volts and check the following for 6.3 to 7.3 volts AC. This info only applies to WPC-S and prior driver boards:

- GI String 1: J120 pin 1 and J120 pin 7 (triac Q18, fuse F110).
- GI String 2: J120 pin 2 and J120 pin 8 (triac Q10, fuse F109).

- GI String 3: J120 pin 3 and J120 pin 9 (triac Q14, fuse F108).
- GI String 4: J120 pin 5 and J120 pin 10 (triac Q16, fuse F107).
- GI String 5: J120 pin 6 and J120 pin 11 (triac Q12, fuse F106).
- GI String 5: J119 pin 1 and J119 pin 3 (triac Q12, fuse F106).

Crimp-On Pin Connectors vs. Insulation Displacement Connectors (IDC) Plugs.
Insulation displacement connector (IDC) plugs are very convenient for an assembly line or automated procedure to install. No wire stripping is needed, the wire is just pushed onto the "V" in the pin, which cuts (displaces) the insulation to make contact with the wire. But they aren't very good in the long run. Many problems of older games are attributed to these IDC plugs. A far better connector uses the crimp-on style of pin. A special tool will be needed to crimp them, but the reliability will be much higher. Only use crimp-on pin connectors when replacing burnt ones. Inexpensive hand crimping tools include Molex WHT-1921 (part# 11-01-0015), Molex part# 63811-1000, Amp 725, or Radio Shack #64-410.
More Connector Information and How to Crimp.
For more info on how to crimp connectors, and the hows and whys of connectors, check out this page at **marvin3m.com/connect** for details.

A crimping tool (top), two different types of pins (left), and a new connector housing and male pins. Note the connector pins; the far left two pins are the crimp-on, single wiper type. The two pins on the right are insulation displacement pins, but with multiple wipers. It's ideal to use the crimp-on style pin, but with the multiple wipers (not shown). These are known as Trifurcon pins.



Replace the Pins with Trifurcon Terminal (Connector) Pins.
Molex makes a crimp-on .156" size female terminal pin called a "trifurcon" pin (not available in the .100" pin size). This style .156" pin differs from the "normal" pin; it has three wiper contacts instead of just one. The more contact points means the female pin "hugs" the male header pin with greater surface area and are more resistive to vibration. These are highly recommended. The specs for these pins can be viewed at http://www.molex.com/product/pcb/6838.html. Compares these to the "normal" connector pin specs at http://www.molex.com/product/pcb/2478.html.
Note Molex sells these pins in "strips" or on a "reel". Do NOT buy connector pins this way! Always buy them in "bags" (separated). It's just too difficult to cut them when they are in strips (sharp scissors do work pretty good for cutting them though). If a good job cutting them is not done, the pins will not insert into their plastic housing correctly. Also always get the tin plated version (perferably over phosphor bronze). NEVER get gold plated pins.

- .156" Trifurcon terminal pins (three wipers), part# 08-52-0113 (tin plated phosphor bronze) for 18 to 20 guage wire. Tin plated phosphor bronze is the best pin material, as it has better spring, fatigue resistance and current capacity. But if this part number is not available, part# 08-50-0189 (tin plated brass) can be used instead. Great Plains Electronics, Mouser and Competitive Products (#06-2186) sells these.

Replace the Board-Mounted Header Pins.
These are available in several styles. Get the most number of pins available, and cut the header to the size needed. They also come with a “lock” and without a lock. The lock variety is what will be used the most. Get the 12 pin variety, because the input GI connector is 12 pins. (the ouput connector is 11 pins or less). Then cut the header to the size needed. Great Plains Electronics, DigiKey and Mouser sell these.

- .156” header pins with lock (12 pins), part# 26-48-1**12**5. This is the prefered variety. The 11 pin version part# is 26-48-1115.
- .156” header pins with no lock (12 pins), part# 26-48-1**12**1. The 11 pin version part# is 26-48-1111.

* bold text denotes the number of pins, in this case, 12.

Replace the Plastic Connector Housing.
Sometimes the plastic connector housing will need to be replaced too if it is burnt, in addition to the pins within the housing. Get the most number of pins available, and cut the connector to the size needed. Remember though, the connector housing does not influnce how well the connectors actually work (so don’t bother with the black hi-temp versions). Get the 12 pin variety, because the input GI connector is 12 pins. (the ouput connector is 11 pins or less). Then cut the plastic connector on a bandsaw to the size needed. Available from Great Plains Electronics, Digikey and Mouser.

- .156” white housings (12 pins), part# 09-50-3**12**1. The 11 pin version is part# 09-50-3111.
- .156” white housings (12 pins), part# 26-03-4**12**1: Mouser. This particular housing is less expensive, and specially designed for Trifurcon terminal pins. The 11 pin version part# is 26-03-4111.

* bold text denotes the number of pins, in this case, 12.

Polarized Pegs.
A polarized peg is a small nylon plug that go into the connector housing so the housing is “keyed” (plugging it into the wrong board header pin connector is impossible). It is highly recommended to use these when replacing a connector housing. Again Great Plains Electronics, Digikey and Mouser sells these.

- .156” polarized peg, part# 15-04-0219.

G.I. Connectors to Replace.
Here are the driver board connectors associated with the General Illumination. Any of these connectors can burn, replace as needed, all are .156” molex style terminal pin connectors.
WPC and WPC-S games:

- J115 (12 pins): Input G.I. connector bring power from the transformer.
- J120 (11 pins): Output G.I. connector, often going to the backglass*.
- J121 (11 pins): Output G.I. connector, often going to the playfield*.
- J119 (3 pins): Output G.I. connector going to the coin door.

* Game dependant.

WPC-95 games:

- J103 (12 pins): Input G.I. connector bring power from the transformer.
- J105 (11 pins): Output G.I. connector, often going to the backglass*.
- J106 (11 pins): Output G.I. connector, often going to the playfield*.
- J104 (3 pins): Output G.I. connector going to the coin door.

* Game dependant.

Looped IDC Connector Wires.

Because of the nature of IDC connectors, sometimes a wire will loop around a single connector pin, going to the next adjacent connector pin (this is seen on the input connector plug J115 or J103 on WPC-95). Since we are replacing these problemsome IDC connectors with crimped connectors, how do we attach **two** wires to a single G.I. connector pin? The easiest way to do this is described here. Be sure to use heat shrink tubing over the wire pig tail for a nice clean professional look.

While you are checking the G.I. Connectors Also Check...

The other power inputs to the power driver board which supply the AC voltages (which ultimately gets turned into +5/+12 volts DC). This could potentially save you some trouble and random game resets. Here are the connectors to check/replace, all .156" Molex connectors. Same rules apply (replace both the header pins and connector terminal pins, use Trifurcon terminal pins, and look for breaks in the plated-through holes in the circuit board):

- J101 (J129 on WPC-95): 7 pins, main 9/13 volt AC power connector (which ultimately end up creating the +5 and +12 volt DC power).
- J102 (J128 on WPC-95): 9 pins, 16 volts AC. Typically not a problem.
- J112 (J127 on WPC-95): 5 pins, 9.8 volts AC. Typically not a problem.

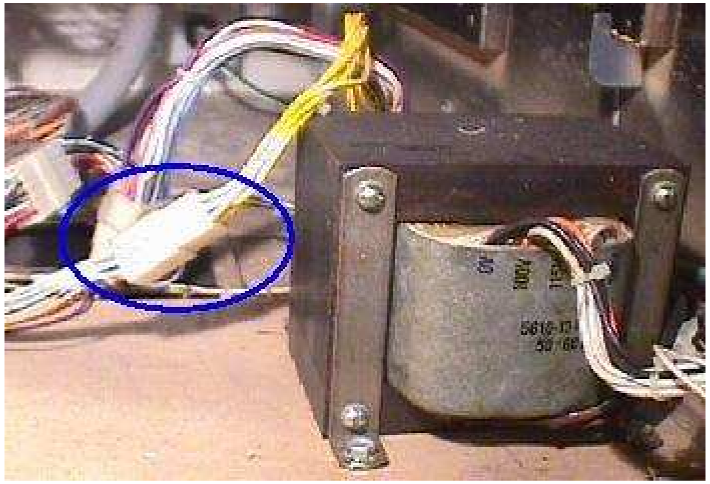
.100" Connectors.

The CPU board uses .100" connectors for the switch matrix. For completeness, here are those part numbers.

- .100 » pins: Molex part# 08-50-0114
- .100" white housings (12 pins), part# 22-01-3**12**7
- .100" polarized peg, part# 15-04-9210.
- .100" header pins with lock (12 pins), part# 22-23-2**12**1. This is the prefered version.
- .100" header pins with no lock (12 pins), part# 22-03-2**12**1.

* bold text denotes the number of pins, in this case, 12.

A transformer in Indiana Jones. Note the yellow wires leading from the transformer to a plug. These are the GI wires, and sometimes this plug will burn.

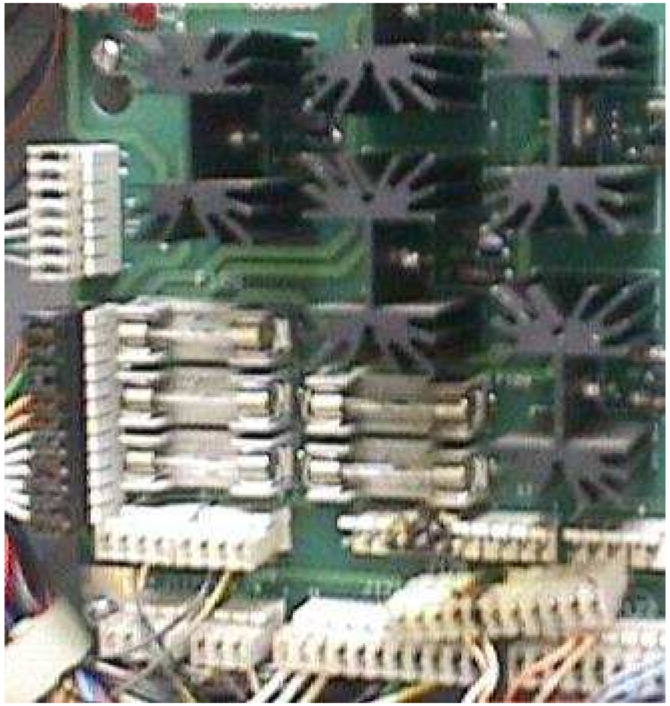


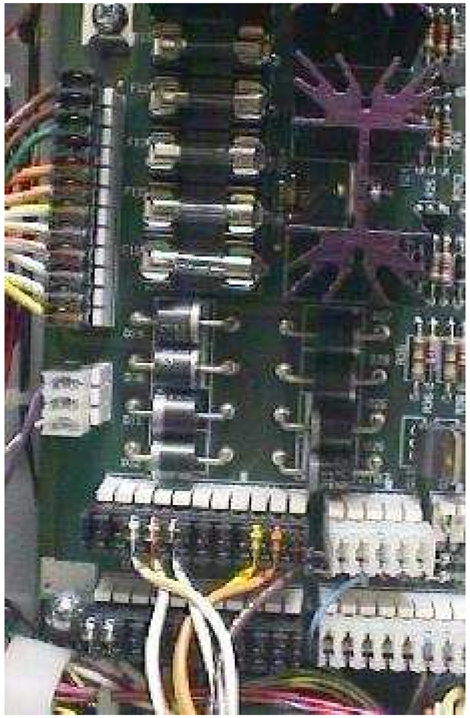
The GI Transformer Plug.

If having general illumination problems, and none of the connectors are burnt on the driver board, there is one more plug that needs to be checked. This is the plug that connects the transformer to the GI circuit, in the bottom of the cabinet, before the power gets to the driver board. It uses a different type of Molex plug, with round pins. This plug doesn't burn nearly as often as the square pin plugs on the driver board, but it does happen. Look for the plug that connects the yellow/white wires to the transformer. This plug uses Molex .093" round pins. Again Great Plains Electronics, Digikey and Mouser sells these.

- Female pins Molex part# 02-09-1119 (http://www.molex.com/product/power/236ftmt.gif).
- Male pins Molex part# 02-09-2118.

Left: *A WPC-S driver board. Note the burnt connector at J120.*
Right: *A WPC-95 driver board. Notice the diodes used in this GI circuit (D25 to D32). Starting with Scared Stiff, these diodes were removed and replaced with jumpers because they were getting too hot. On earlier WPC-95 boards like this one, remove and/or jumper these diodes with 18 gauge wire.*





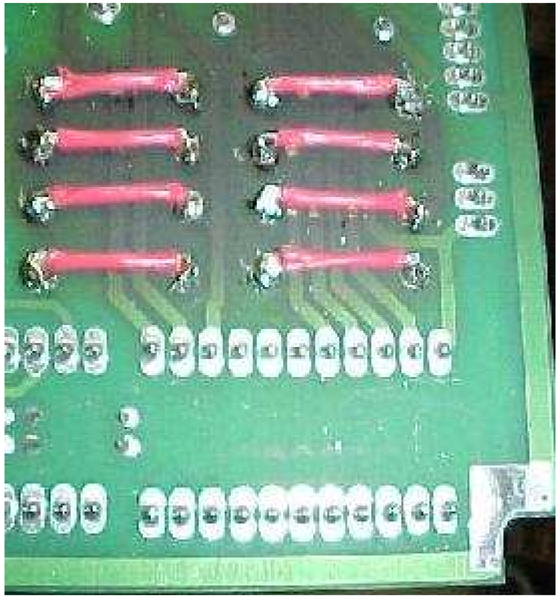
Helping to Prevent Further GI Damage.

After replacing the GI board and connector pins, there is one more thing that can be done to help eliminate future GI connector damage. The software of all WPC games allows the user to set the intensity of the GI lamps when the game is in attract mode. In the "Adjustments - Standard" (A.1) menu, set the GI Power Saver time to 2 minutes (the lowest time allowed). Also set the GI Power Saver level to "4" (the lowest value allowed). This simple modification will automatically dim the GI lamps when the game is in attract mode, after two minutes. This will dramatically help save the GI connectors. The game's GI will automatically return to normal intensity when a game is started.

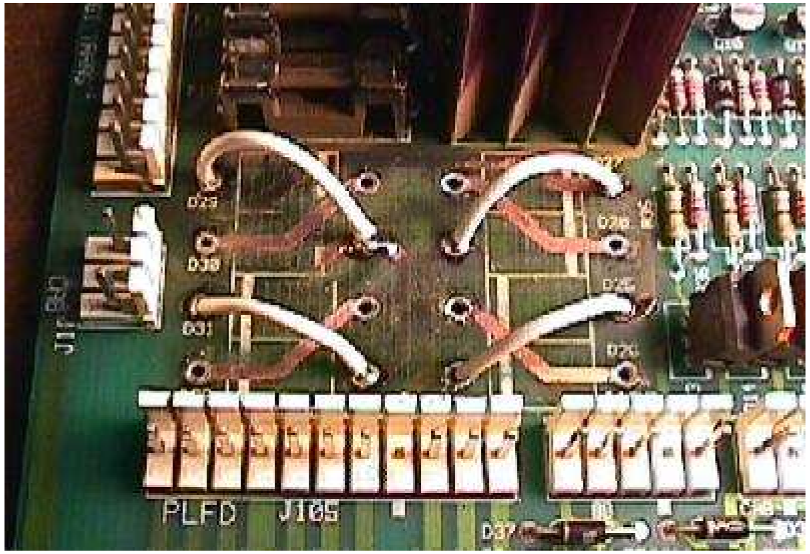
WPC-95 GI Diodes D25 to D32: Remove and Jumper.

Williams used diodes D25 to D32 in the general illumination circuit to convert the 6.3 volts AC to DC. This caused problems as the diodes got too hot and often burned and damaged the driver board. Williams recommended (starting with Scared Stiff) removing these diodes and replacing with zero ohm resistors. If zero ohm resistors are not available, 18 guage wire can be used instead. If removing the diodes is a concern, they can instead just be jumped over with 18 guage wire, leaving the original diodes in place. Alternatively, just four jumper wires can be used and the diodes removed (as shown below). Any of these methods works fine.

The back of a WPC-95 driver board. The black area is the GI diodes D25 to D32. Instead of removing the original diodes, they were just *jumpered over with 18 gauge wire. This could have been done from the component side of the board instead.*



Alternative (Better) Method:
Jumpering the component side of the driver board. Note the GI diodes D25 to D32 have been removed, and only these four jumper wires need to be installed, instead of eight (as shown in the method above).



2c. Before Turning the Game On: Quick and Dirty Transistor Testing

Whenever I get a new game, before I ever turn it on, I test all the TIP102 solenoid transistors. I do this because I'm already in the backbox (examining the fuses and the GI connectors), and a blown transistor can really confuse a game. This is the procedure I use, and it takes about 20 seconds to test all the TIP102 transistors:

- Make sure the game is off.
- Put the DMM (digital multi meter) on ohms (buzz tone).
- Put one lead on the ground strap in the backbox.
- Touch the other lead to the metal tab on the TIP102 transistors.
- If getting zero ohms (buzz), the transistor is bad! (shorted on)

I replace any bad TIP102 transistor(s) immediately before I turn the game on. I also usually replace the associated pre-driver transistor too (see the testing transistors and coils section for more details on this).

2d. Before Turning the Game On: Should I leave my Game Powered On?

This is a very common question. After all, arcades leave their games on almost continually with minimal damage (that is known!). So why not do it with games at home? Although commercial pinball machines can handle being powered on continually, I would recommend not leaving games turned on when not in use. Here are some reasons:

- Electronic score displays (dot matrix displays and others) have a limited life, which is proportional to how much time they have been turned on.
- General illumination circuits will be stressed. Burnt pins and connectors are very common on games that are on for extended periods of time.
- Light bulbs don't last forever, and aren't all that easy to change on a playfield.
- The bulbs, displays, fans, and transformers only attract dirt when they are on. Leaving a game on means sucking dirt out of the air and depositing it into the machine.
- Heat generated by the general illumination lamps can warp playfield plastics or help delaminate backglass paint. Not much of an issue on WPC games, but this is a major issue on older games.
- Electricity is a precious resource. Conserve it! An electronic game from this era consumes about 4 amps in attract mode. So leaving a game on is like running a 240 watt light bulb. By comparison, an entire stereo system plus a television use about the same amount of power.

Leaving a pin on all the time can cost much more than any potential damage that could be done turning it off and on as needed.
End of WPC Repair document Part One.

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* Go to WPC Repair document Part Two at http://marvin3m.com/~cfh/wpc/index2.htm
* Go to WPC Repair document Part Three at http://marvin3m.com/~cfh/wpc/index3.htm
* Go to the Pin Fix-It Index at http://marvin3m.com/fix.htm
* Go to Marvin's Marvelous Mechanical Museum at http://marvin3m.com

Repairing Williams/Bally WPC Pinball Games from 1990 to 1999, Part Two

by *cfh@provide.net*, 09/17/04.

Scope.
This document is a repair guide for Williams and Bally WPC pinball games made from 1990 (Funhouse) to 1999 (Cactus Canyon).

Internet Availability of this Document.
Updates of this document are available for no cost at http://marvin3m.com/fix.htm if you have Internet access. **This document is part two of three** (part one is here, and part three is here).

IMPORTANT: Before Starting!
IF YOU HAVE NO EXPERIENCE IN CIRCUIT BOARD REPAIR, YOU SHOULD NOT TRY TO FIX YOUR OWN PINBALL GAME! Before you start any pinball circuit board repair, review the document at http://marvin3m.com/begin, which goes over the basics of circuit board repair. Since these pinball repair documents have been available, repair facilities are reporting a dramatic increase in the number of ruined ("hacked") circuit boards sent in for repair. **Most repair facilities will NOT repair your circuit board after it has been unsuccessfully repaired ("hacked").**

If you aren't up to repairing pinball circuit boards yourself or need pinball parts or just want to buy a restored game, I recommend seeing the suggested parts & repair sources web page.

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i. Troubleshooting (quick guide)

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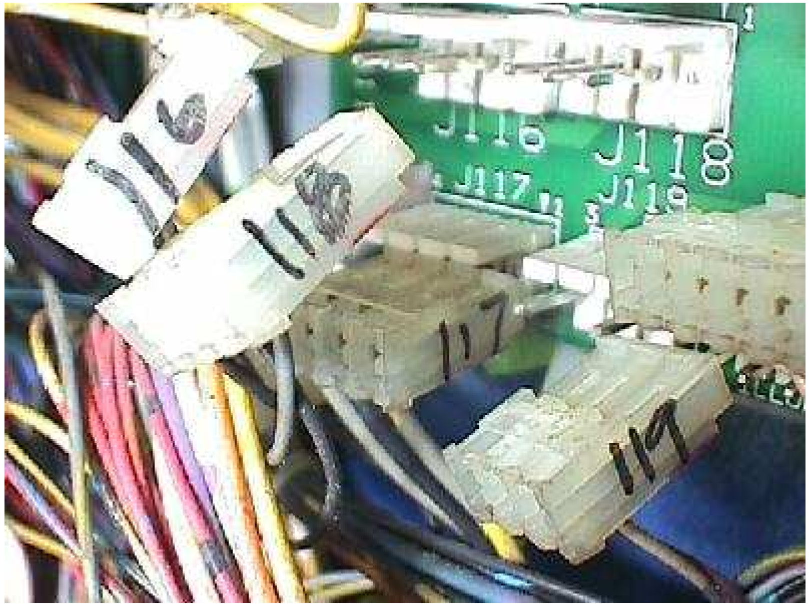
3a. When things don't work: Removing the Driver Board

The majority of electronic repairs will be on the WPC Power Driver board. To do any repairs to the driver board, it must be removed from the game. Yes, there are seemingly an endless array of connectors that will have to be dealt with. Fear not, all are keyed so they can't be plugged into the wrong place (in most cases!). For confidence and simplification, always label the connectors as they are removed. Sure, this is probably unnecessary. But if there are any problems, the idea that I might have incorrectly plugged the connectors can be eliminated. It only takes a minute, and there is never any doubt about what goes where.

Using a mark-all "Sharpie" pen, label the sides of all the connectors as they are removed.



Use a mark-all "Sharpie" pen to label the connectors. The side of each connector has room for writing. After the connectors are all marked and removed, loosen the phillips head screws that hold the driver board in place. The screws don't have to removed all the way! Only loosen them. The board has slots for all the screws, so the board will lift up and out of the backbox.

Note: some connectors are "parallel". That is, they have the same keyed pin configuration so as many as three plugs, can be switched around. To minimize this confusion, again just mark the plugs with a Sharpie as they are removed.

3b. When things don't work: Replacing Components

If a bad component has been found, now comes the hard part; replacing it! Transistors, bridge rectifiers, and most chips are not socketed. They are soldered directly into the driver board. Care must be taken when replacing a bad component.

Please see http://marvin3m.com/begin for details on the basic electronics skills and tools needed when replacing circuit board components.

When replacing components, the object is to subject the board to the least amount of heat as possible. Too much heat can lift or crack the board's traces. Too little heat and the plated-through holes can be ripped out when removing the part. New circuit boards are too expensive to replace. So be careful when doing this.

To remove a bad component, just CUT it off of the board, leaving as much of its original lead(s) as possible. Then using needle nose pliers, grab the lead in the board while heating it with the soldering iron, and pull it out. Clean up the solder left behind with a desoldering tool.

When replacing chips, alway install a socket. Buy good quality sockets. Avoid "Scanbe" sockets at all costs! A good machine pin socket is desirable.

3c. When things don't work: Stuck On Coils and Flashlamps (Checking Transistors and Coils)

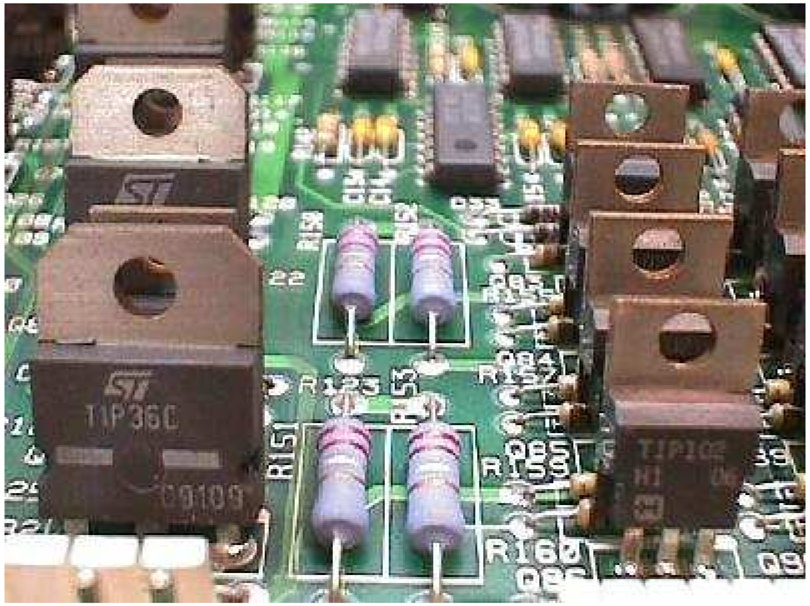
If a coil is "stuck on" when the game is turned on, a shorted driver transistor is often the cause. If a coil does not work (and the fuses are good!), an open driver transistor could be the cause. This section will help diagnose this, and other related faults.

What do the Driver Transistors Do?

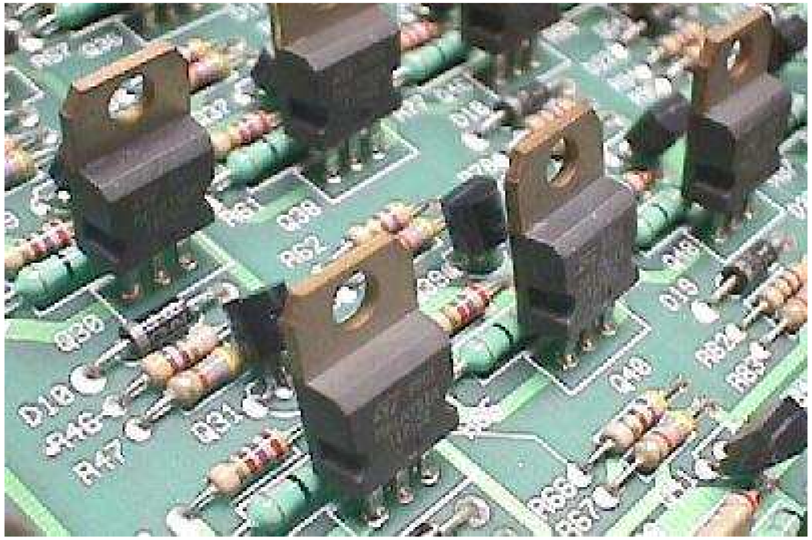
Basically, a driver transistors completes each coil's path to ground. There is power at each coil, all the time. The driving transitor is "turned on" by the game's software, through a TTL (Transistor to Transistor Logic) chip. When the transistor is turned on, this completes the coil's power path to ground, energizing the coil. Driver transistors also work the CPU controlled lamps and flash lamps, causing a lamp to "lock on".

Sometimes these driver transistors short "on" internally. This completes a coil or flash lamp's power path to ground permanently, making it "stuck on", as soon as the game is turned on. Also a shorted pre-driver transistor, or shorted TTL chip (which controls the transistors) could be the problem (though a shorted driver transistor is the most common cause). To fix this, the defective component (and perhaps some other not defective, but over stressed componets) will need to be replaced.

TIP36 and TIP102 transistors on the driver board.



TIP102 transistors, the small 2N5401 pre-driver transistors, and the coil diodes on the driver board.



There are basically four types of driver and pre-driver transistors used on a WPC driver board:

- **TIP36c** (PNP, NTE393): used for solenoid numbers 1 to 8 (and solenoids 29,31,33,35 on some games). High power transistors used for more powerful solenoids (and the flipper, on their initial "flip" on the Fliptronics board).
- **TIP102** (NPN, NTE2343): used for solenoid numbers 9 to 28 (and solenoids 30,32,34,36 on some games, and solenoids/flash lamps 37 to 44 on Indiana Jones, Star Trek Next Gen, Demo Man, Roadshow and Twilight Zone). Low power solenoid and flash lamp drivers, used for most devices (and for the flippers on their "hold" circuit on the Fliptronics board). Numbers 9 to 16 are used for low power solenoids, number 17-20 for flash lamps, and number 21 to 28 for general purpose solenoids or flash lamps. TIP102's are also used to switch GND on for any particular lamp row.
- **TIP107** (PNP, NTE2344): used to drive the CPU controlled lamp (columns) on the playfield. The TIP107 switches the +18 volts on for any particular lamp column.
- **2N5401 & MPSD52** (PNP): used as a pre-driver for the TIP102 transistors. 2N5401, MPSD52 and NTE288 are all equivalent transistors.
- **2N4403** (PNP, NTE159): used as a pre-driver for the Fliptronics board.

Games with Solenoid Numbers Above 28.
Even though the WPC driver board only supports solenoids 1 to 28, there can be solenoids numbered up to 44. Most often seen are numbers 29 to 36, which use transistors in the fliptronics section of the board. If the game only has two flippers, the fliptronics section will have two flipper power (TIP36) and two flipper hold (TIP102) transistors that may be used by the game for things other than flippers. Also several games (Indiana Jones, Twilight Zone, Demo Man, Roadshow and Star Trek Next Gen) used an 8-driver auxiliary driver board, which contained eight more TIP102 transistors for even more flash lamps or coils.
This auxiliary driver board could be problematic, especially on Star Trek. On Star Trek, this board needs +50 volts for a "tieback diode" voltage for the circuit (because it controls solenoids, and not just flashlamps; all the other games that use this Auxiliary driver board only control flashlamps). The 50 volt tieback power is connected by a thin violet/yellow wire which connects to the playfield's single drop target coil (at the back of the playfield). If this wire breaks, or if some other power wire in this coil power daisy chain breaks, it can cause the two diverter coils to lock on (after they're first activated in game play!) If the problem is not found quickly, the diverter coils and their driving transistors can fail. Transistors on the auxiliary driver board will short out in a couple of activations on Star Trek if the tieback voltage is not present on the board. If the two Star Trek diverter coils lock on after a game is started, check the violet/yellow wire which connects to the playfield's single drop target coil. Additionally, add 1N4004 diodes to the two diverter coils

(banded side of the diode to the coil's power lug), and test the TIP102 transistors on the Auxiliary driver board.

Driver Transistor Operation.

As described above, the main driver transistor (a TIP102 or TIP36) completes the coil or flash lamp's power path the ground, energizing it. But there are other components involved too!

Each driver transistor has a "pre-driver" transistor. In the case of a TIP102 (the most common WPC driver transistor), this is a smaller 2N5401/MPSD52 or 2N4403 transistor.

If the main driver transistor is a TIP36c, this is pre-driven by both a TIP102 and a smaller 2N5401/MPSD52 or 2N4403 transistor. The bigger TIP36c transistor is an even more robust than the TIP102, and controls very high powered, high use coils (like the flippers).

Then before even the smaller 2N5401/MPSD52 or 2N4403 pre-driver transistor, there is a TTL (Transistor to Transistor Logic) 74LS374 chip. This is really the first link in the chain. This is what in affect turns on the smaller 2N5401/MPSD52 or 2N4403 pre-driver transistor, which then turns on the TIP102 (which then turns on the TIP36c, if used for the coil/flash lamp in question), and energized the device.

This series of smaller to bigger transistors is done to isolate the hi-powered coil voltage (50 volts), from the low-power logic (5 volts) on the driver board. Also the 74LS374 chip (operating at +5 volts), which really controls the transistors, can not directly drive a high power TIP102 or TIP36c transistor (which is controlling 50 volts).

If ANY of these components in the chain have failed, a coil/flashlamp can be stuck on, and will energize as soon as the game is powered on!

I have a Stuck-on Coil (or Flashlamp), What should I Replace?

A short summary (before reading all the info below). The following procedures will test the driver and pre-driver transistors in question. If either is bad, it will need to be replaced. When replacing either a driver or pre-driver transistor, replace them both (or in the case of a TIP36, replace the TIP102 and smaller 2N5401/MPSD52 or 2N4403 transistor)! A shorted transistor will cause the other transistors in the link to be stressed, and they should all be replaced.

Inside the front cover of the game manual is a list of each coil used in the game. Also listed are the driving transistor(s) for each coil. Use this chart to determine which transistors could potentially be bad. Also use the schematics.

If after replacing the driver transistors the coil/flashlamp is still stuck on, then replace the TTL 74LS374 logic chip. The TTL 74LS374 can also go bad (though it is not real common).

Also remember to test the resistance of a coil after replacing the driver transistors. If a coil gets hot, it can burn the painted enamel insulation off the coil windings. This lowers the overall resistance of the coil because adjacent windings short together. If resistance gets much below 3 ohms, the coil becomes a "short", and will fry its associated driver transistors very quickly!

A Coil just Does Not Work - What is Wrong?

Driver transistors can go "open" too. This means all the logic prior to the open transistor could be working fine, but the coil will not energize. If there is power at the coil, this is something to consider (but first see the test procedures below to make sure the coil itself is actually OK).

Checking for power at the coil first. Use a DMD set to DC volts, one DMD lead on either coil lug, the other DMD lead to ground (the metal side side rail on the game is a good ground). Around 20 to 75 volts DC should be seen. Now switch to the other lug of the coil, and the same voltage should be seen. If there is no power at either coil lug, check the game's fuses. Also remember power is "daisy chained" from other coil(s). Perhaps the power chain is broken "upstream" from a broken wire (it is easy to manually trace the power wire from coil to coil). If power is only seen at one lug of the coil, the coil itself is bad, usually from a broken winding. Often it is the winding that attaches to the coil's solder lug. Sometimes the broken wire can be unwound one winding, sanded (to remove the painted-on enamel insulation), and resoldered to the coil lug. Note intermittent coils can have a broken coil winding that makes the coil sometimes work (or not work!)

Do the Transistor Test Procedures work 100%?

In short, no. But they do work about 98% of the time, and are an excellent starting point. But yes, a transistor can test as "good", but still be bad. The DMM test procedures test the transistors with no load. Under load, a transistor could not work.

Testing a transistor on the driver board. Note the DMM is set to the diode position, and one lead is connected to the metal tab on the TIP transistor. The two outside leads are then tested.

Transistor Testing procedures using a DMM.
If the driver board is out of the game for some reason (like to fix the burnt GI connector pins), test all the transistors. It only takes a moment, and will ultimately save time. To test a transistor, a digital multi-meter (DMM) is needed, set to the “diode” position. <u>NOTE: testing transistors with a DMM is not 100% fool-proof. A transistor can test as “good” and still be bad (rare, but it does happen!).</u>
Testing Transistors INSTALLED in the WPC driver board.

- **TIP36c**: Put the **red** lead of the DMM on the metal tab of the transistor. Put the black lead of the DMM on each of the two outside legs of the transistor. A reading of .4 to .6 volts should be seen. Put the black lead on the center transistor leg (collector) and the red lead on the metal tab, and a zero reading should be seen. Put the **black** lead of the DMM on the left/top (base) leg of the transistor. The red lead on the center transistor leg should show .4 to .6 volts. The red lead on the right/bottom leg should be .2 volts. Any other value, and the transistor is bad and will need to be replaced.
- **TIP102**: Put the **black** lead of the DMM on the metal tab of the transistor. Put the red lead of the DMM on each of the two outside legs of the transistor. A reading of .4 to .6 volts should be seen. Put the red lead on the center transistor leg (collector), and a zero reading should be seen. Any other value, and the transistor is bad and will need to be replaced.
- **TIP107**: Put the **red** lead of the DMM on the center leg or on the metal tab of the transistor. Put the black lead of the DMM on each of the two outside legs of the transistor. A reading of .4 to .6 volts should be seen. Put the black lead on the center transistor leg (collector) and the red lead on the metal tab, and a zero reading should be seen. Any other value, and the transistor is bad and will need to be replaced.
- **2N5401, MPSD52, 2N4403** (pre-drivers): Put the **black** lead of the DMM on the center leg of the transistor (note this transistor doesn’t have a metal tab). Put the red lead of the DMM on each of the two outside legs of the transistor. A reading of .4 to .6 volts should be seen. Any other value, and the transistor is bad and will need to be replaced.

Testing Transistors NOT INSTALLED.
Only the TIP36c will test slightly different out of circuit. The other transistors will test the same as described above. All transistors are laying on the workbench with their “face” (side with the markings) up, and metal tab away from you. Orientation is BCE (base collector emitter), from left to right for the TIP transistors. Orientation for the small plastic transistors is EBC (emitter base collector) with the flat side up.

* **TIP36c**: Put the **black** lead of the DMM on the **left** (base) leg of the transistor. Put the red lead of the DMM on each of the two other legs (center and right legs) of the transistor. A reading of .4 to .6 volts should be seen. Put the DMM leads on the metal tab and the center transistor leg (collector), and a zero reading should be seen. Any other value, and the transistor is bad.

Most often transistors short when they go bad. This will usually give a reading of zero or near zero, instead of .4 or .6 volts.

Testing Coils and Transistors; a Systematic Approach.

If a coil is not working, the following approach is a good one to take. It starts with the easiest test first; using the internal WPC diagnostics. Then the tests moves to the coil itself, and goes back towards the driver board. This makes the chain smaller, and gives a very systematic approach to finding the problem.

Pressing the "start game" button on the outside of the cabinet during the Solenoid Test gives important information. In this example (the Auto Plunger coil), it shows the coil's wire colors, the board connectors/pins used, the fuse rating and position, and the transistors that drive this coil. Note Q72 is a TIP36 transistor with Q60 (a TIP102) as a pre-driver, and Q56 (a MPSD52) as a pre-driver to the TIP102.

Testing Transistors/Coils, Driver board installed in a (near) WORKING game, using the Diagnostics Test.

If the game powers on, the WPC diagnostics can be used to test most devices.

* Press the "Begin Test" button inside the coin door.
* Select "MAIN MENU: TESTS".
* Select "TEST MENU: SOLENOID TEST".
* Use the "+" and "-" buttons to move the test from coil to coil. Each coil should fire. (Note the coin door interlock switch must be held in on 1993 and later games. Otherwise the coil 50 volts will be turned off, and the coils won't fire. Also make sure the "REPEAT" portion of the test is used. This can be changed using the "Begin Test" button.)
* Press the "help" button. The game's start button during the coil test wil give more coil information including coil wire colors, Driver board

connector and pin numbers; related fuse number; Driver board transistor and pre-driver transistor numbers.

Solenoid Doesn't Work during WPC Diagnostic Tests.
If a solenoid doesn't work from the diagnostic tests, here's what to check. Turn the game off before doing this.

- Check all the fuses on the driver board. A non-working solenoid could be as easy to fix as just replacing a fuse.
- Find the solenoid in question under the playfield. Make sure the wire hasn't fallen off or become cut from the coil (a very common problem).
- If the above is correct, make sure the winding of the coil haven't broken off from the solder lugs. If one has broken, it can be re-soldered. Make sure the painted enamel insulation is sanded from the wound coil wire before re-soldering, otherwise there will be no connectivity.
- Make sure there is power at the coil. Using a DMM, there should be 20 to 75 volts DC on either lug of a coil. If there is power only on one lug, the coil winding is broken, and the coil should be replaced.
- Check the coil diode (for any other pinball game, this would be the next step). The coil diode for all games (except WPC) are attached right to the coil, with the banded side of the diode connecting to the power side of the coil. On WPC games however, Williams moved this diode to the power driver board for all coils <u>but the flipper coils</u>. This increases reliability as the diode is not subject to the jarring and heat a coil can produce. It also eliminates the need for the operator to know which coil wire goes to the banded side of the diode when replacing a coil! On a WPC game, these coil diodes are mounted on the driver board next to the transistor that drives each particular coil.

Quick and Dirty TIP102 Transistor Testing.
There is an easy way to test TIP102 (only) transistors. This procedure takes about 20 seconds to test all the TIP102 transistors:

- Make sure the game is off.
- Put the DMM (digital multi meter) on ohms (buzz tone).
- Put one lead on the ground strap in the backbox.
- Touch the other lead to the metal tab on the TIP102 transistors.
- If zero ohms (buzz) is indicated, the transistor is bad! (shorted on)

The Coin Door Interlock switch.
In the middle of Twilight Zone's production in 1993, Williams added a coin door interlock switch. This turned off the power to all the coils when the coil door was opened (for safety reasons). On 1993 and later games with this interlock switch, make sure the coin door is closed when testing coils!
Failed Coin Door Interlock switch.
Yes it does happen. The coin door interlock switch can fail, or does not get pushed in enough when the coin door is closed. This will prevent voltage from getting to the solenoids. If none of the solenoids work, and the fuses are good, check the coin door interlock switch for problems. A sure sign of this is the Driver board solenoid power LED's will NOT be lit if the coin door interlock switch is not closed! The interlock switch opens the coil power coming from the transformer, which is way before the power gets to the Driver board's fuses and power circuits.
Testing for Power at the Coil.
Most pinball games (including WPC) have power at each and every coil at all times. To activate a coil, GROUND is turned on momentarily by the driving transistor to complete the power path. Since only ground (and not power) is turned on and off, the driving transistors have less stress on them. With this in mind, if we artificially attach a coil to ground, it will fire (assuming the game is turned on).

- Turn the game on and leave it in "attract" mode.
- Lift the playfield.
- Put the DMM on DC voltage (100 volts).
- Attach the black lead of the DMM to the metal side rail.
- Touch the red lead of the DMM on either lug of the coil in question.
- A reading of 20 to 80 volts DC should be indicated. Switch the red test lead to the other lug of the coil, and the same voltage should be seen again. On flipper coils, test the two outside lugs of the coil. If no voltage reading is shown, no power is getting to the coil. On a two lug coil, if

there is only voltage at one lug, the coil winding is broken. On 1993 and newer WPC games, make sure the coin door is closed!

- If no power is getting to the coil, a wire is probably broken somewhere. Trace the power wire.

No Coil Power, Fuse is Good and No Broken Wires.
I recently had a problem on a Safe Cracker (WPC-95) where none of the low power (20 volt) coils worked. It was very frustrating; the fuse was good, and power was getting to the Driver board, but not out of the driver board and to the coils.
It turned out that the capacitor that filters the DC voltage after the bridge rectifier on the Driver board had a cracked solder pad. This prevented the voltage from getting any further than it's associated bridge rectifier (I should have known; the +20 volt LED on the Driver board was not lit!). To fix this, I soldered jumper wires from the bridge to the capacitor, as outlined in the below Game Resets (Bridge Rectifiers and Diodes) section.
Testing the Coil and the Power Together.
This test will show if the power and the coil are indeed working together:

- Game is on and in "attract" mode, and the playfield lifted. On 1993 and newer WPC games, coin door is closed.
- Connect an alligator clip to the metal side rail of the game.
- Momentarily touch the other end of the alligator clip to the GROUND lead of the coil in question. This will be the coil lug with the single wire attached (usually brown). On flipper coils, this is the middle lug (the power wire on most coils is usually the thicker violet or red wire). This works on both Fliptronics and non-Fliptronics WPC games.
- The coil should fire (if the alligator clip is accidentally touched to the power side of the coil, the game will reset and/or blow a fuse, as the solenoid high voltage is being shorted directly to ground).
- If the coil does not fire, either the coil itself is bad, or the coil's fuse is blown and power to the coil is not present.

Testing the TIP102 Transistor and Wiring to the Coil.
If the coil fires in the above test, there may be a transistor problem. The TIP102 transistors can be tested this way. **Only do this for the TIP102 transistors! Damage can occur if this test is done on other transistors (like TIP107 or TIP36).**

- Game is on, and the "test mode" button is pressed once. On 1993 and newer WPC games, coin door is closed.
- Remove the backglass.
- Find the transistor that controls the coil in question (refer to the manual).
- Attach an alligator clip to the grounding strap in the bottom of the backbox.
- Momentarily touch the other lead of the alligator clip to the metal tab on any TIP102 transistor (only works on these).
- The coil should fire.
- If the coil does not fire, and the coil did fire in the previous test, there probably is a wiring problem. A broken wire or bad connection at the connector would be most common. It is also possible there is a bad transistor. Use the DMM meter and test the transistor on the board (see Transistors Testing Procedures for details).

The Above Tests Worked, but the Coil Still doesn't Work.
If all the above tests worked, there is probably a driver board problem. Everything has been tested from the TIP102 back to the coil itself. That only leaves the TIP102 itself, its pre-driver transistor, and the logic chip that controls the transistors. It has to be one (or more!) of these devices that are causing the problem.
Installing a New Transistor.
If it has been determined a coil's driver board transistor is bad, there are a few things to keep in mind. Most TIP102 transistors also have a "pre-driver" transistor (2N5401 for WPC-S and prior, or MPSD52 for WPC-95). Both 2N5401 and MPSD52 transistors are basically the same (use either). They both cross to NTE288.
If a coil's TIP102 transistor is replaced, it's a good idea to also replace its corresponding pre-driver. It will be located near the TIP102 transistor. See the schematics or the internal solenoid test "help" to determine the specific pre-driver transistor(s).
Heavier duty coils use a bigger TIP36c driver transistor. These transistors have TWO pre-drivers: a TIP102 and a 2N5401 (or MPSD52) transistor. Again, if the TIP36c has failed, it's a good idea to replace both corresponding pre-driver transistors.

Replacing the pre-driver transistors is optional (if they test Ok). Test these pre-drivers instead of just replacing them. But if the driver transistor has failed, the pre-driver was probably over-stressed too. It is a good idea to replace the pre-driver transistor(s) too.

Don't Forget the 74LS374 TTL Chip!

If a coil locked on really hard and for a period of time (and without blowing the coil fuse, over fused?), the controlling 74LS374 chip may have also died. If after replacing the TIP driver transistor(s) and the smaller pre-driver transistor, the coil is still locked on, now is the time to replace the 74LS374 TTL chip. Use the schematics and trace the transistors in question back to the 74LS374 chip. This will be chip U2, U3, U4, or U5 on WPC-S and prior driver boards, or chip U4, U5, U6, or U7 on WPC-95 driver boards.

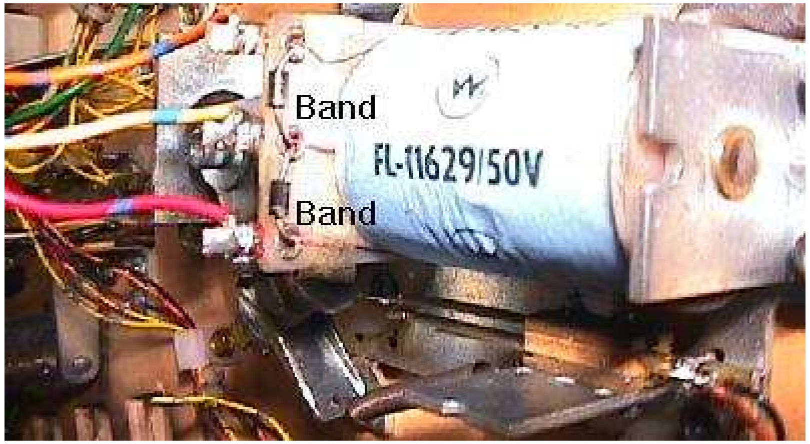
WPC Coil Diodes.

On all electronic pinball games, each and every CPU controlled coil must have a coil diode. This diode is VERY important. When a coil is energized, it produces a magnetic field. As the coil's magnetic field collapses (when the power shuts off to the coil), a surge of power as much as twice the energizing voltage spikes backwards through the coil. The coil diode prevents this surge from going back to the driver board and damaging components.

If the coil diode is bad or missing, it can cause several problems. If the diode is shorted on, coil fuse(s) will blow. If the diode is open or missing, strange game play will result (because the driver board is trying to absorb the return voltage from the coil's magnetic field collapsing). At worse a missing or open diode can cause the driver transistor or other components to fail.

On **non-WPC games**, sometimes a diode lead breaks on the coil from vibration. Also, when replacing a coil, the operator can install the coil wires incorrectly (the power wire should always be attached to the coil's lug with the banded side of the diode). To prevent this, **Williams moved the coil diode to the Driver board**. This isolates the coil diode from vibration and eliminates the possibility of installing the coil's wires in reverse. This was done on all coils **except** the flipper coils.

*The coil diodes on a **Fliptronics** flipper coil. The red (bottom) wire is the "hot" wire. The yellow (middle) wire handles the initial hi-power "flip", and the orange (top) wire handles the flipper's "hold".*



Flipper Wire Colors.

From game to game, Williams often used a consistent set of wire colors for flipper wiring (unfortunately, this is not always the case, as seen in the picture above). In the picture below, the flipper coil lugs are labeled "lug1" to "lug3". Here are the wire color break down for most games:

Lug 1 (outside banded diode lug, two winding wires, 50 volts):

- Lower Left flipper: Grey/Yellow
- Lower Right flipper: Blue/Yellow
- Upper Left flipper: Grey/Yellow
- Uppper Right flipper: Blue/Yellow

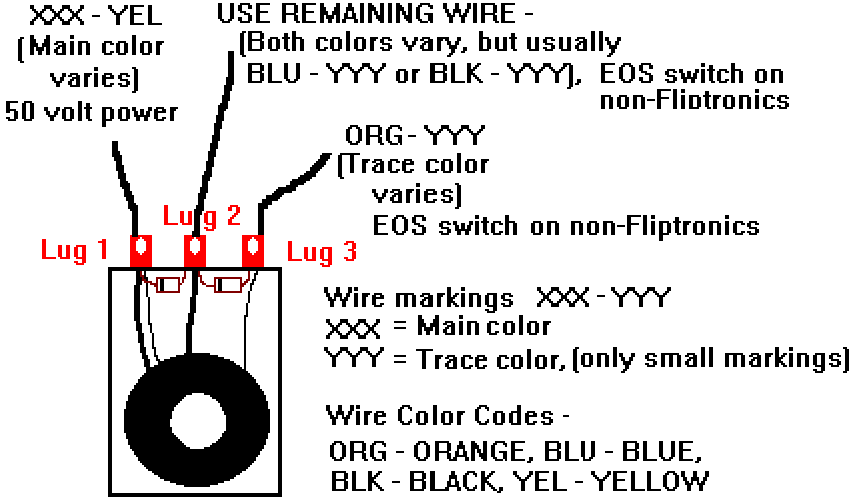
Lug 3 (outside non-banded diode lug, one winding wire):

- Lower Left flipper: Orange/Blue
- Lower Right flipper: Orange/Green
- Upper Left flipper: Orange/Grey
- Uppper Right flipper: Orange/Purple

Lug 2 (middle lug):

- Lower Left flipper: Blue/Grey
- Lower Right flipper: Blue/Purple
- Upper Left flipper: Black/Blue
- Uppper Right flipper: Black/Yellow

Flipper coil wiring. Note the wire color rules specified below are the "usual" wire colors (but can't be 100% guarenteed).



*The coil diodes on a **Non-fliptronics** flipper coil. Note the solo center wire and the all blue wire on the top lug goes to the EOS switch and the 2.2 mfd 250 volt spark arresting capacitor (the EOS switch and capacitor are wired in parallel). The blue/yellow (lower) wire (or gray/yellow) is the "hot" wire. The blue/violet (upper) wire continues to the cabinet switch, the driver board relay, and ultimately ground.*

Even on WPC games, the coil diode can fail. The coil diode can be tested. It is mounted on the driver board, near it's corresponding driver transistor (refer to the schematics; it's the diode that is tied to one of the legs of the driver transistor).

Use a DMM set to "diode" setting, and test the board mounted coil diode. With the black lead on the banded side of the diode and the red lead on the non-banded side, a reading of .4 and .6 volts should be seen. Reverse the leads (red lead to banded side of diode), and a null reading should be seen. If this reading is not indicated, cut one lead of the diode from the driver board, and repeat the test. If these results are still not seen, replace the diode with a new 1N4004 diode.

Test the Coil Resistance with a DMM.

After replacing the driver transistor, ALWAYS measure the resistance of the associated coil. This is important. If a coil gets hot (becuase its driver transistor was shorted), it can burn the painted enamel insulation off the coil windings. This lowers the overall resistance of the coil because adjacent windings short together. If resistance gets much below 3 ohms, the coil becomes a "short", and will fry its associated driver transistors very quickly!

To test the coil's resistance, it is best to remove the attached wire from one (either one) of the coil's lugs. Then set the DMM to low resistance, and put the DMM leads on the lugs of the coil. Most coils should be in the 5 to 15 ohm range, but could go as high as 150 ohms, or as low as 3 ohms. If the coil is much below 3 ohms, it should be replaced with a new coil of the same type. Coils with resistance much below 3 ohms are basically a dead short, and this will fry its associated driver transistor.

Installing a New Coil.

Many replacement coils will come with a diode soldered across its solder lugs. On WPC games, all coils except the flipper coils have the diode mounted on the Driver board. For all coils except flipper coils, cut the diode off the coil before installing. Then solder the coil wires to either coil lug. The diode can also be left in place, but the coil wires must be installed correctly. The green (ground) wire MUST go to the lug of the coil with the non-banded side of the diode. The power wire solders to the lug with the banded side of the diode. If the wires are reversed, this essentially causes a shorted diode. Though the Driver board mounted diode is still present as protection, damage can occur to the coil's driver board transistor.

Coil Doesn't Work Check List.

If a coil doesn't work in a game, here's a check list to help determine the problem.

Before starting, is the coil stuck on? (Hint: is there heat, smoke and a bad smell?). If so, the coil's driving transistor has probably failed. Turn the game off and check the driving transistor, and replace if needed. See Transistors Testing Procedures for more info.

If the coil just doesn't work, here's a list of things to check:

- Have the power wires fallen off the coil's solder lugs?
- Is the coil damaged? Has the internal winding broken off the coil's solder lug?
- Is there power at the coil? See Testing for Power at the Coil for more details.
- If there is no power at the coil, check its fuse. Use the internal diagnostics and the "help" button to determine which fuse controls the coil. See Testing Transistors/Coils using the Diagnostics for details.
- Check the other coils that share one of the same wire colors. Are they working too? If not, suspect the fuse that handles these coils.
- Power to coils are often ganged together. If the power wire for this coil has fallen off a previous coil in the link, power may not get to this coil.
- Using the DMM and its continuity test, make sure the coil connects to the correct connector/pins on the driver board. This information can be seen from the Diagnostics solenoid test.

* Check the driving transistor. Usually this transistor will short on when it fails, but not always.
* Reset the driver board and CPU board ribbon cables. I have seen situations where a coil hasn't worked because the gold plated ribbon cable connectors were dirty.

3d. When things don't work: Game Resets (Bridge Rectifiers and Diodes)

Game resets are probably the biggest problem with WPC to WPC-S games (and to a lesser extent, WPC-95 games). The pinball will seemingly shut off, then power back on (like the game was turned off and back on quickly). Typically, this will happen during game play, when the flippers are used. If the +5 volts (which powers all the logic circuits) dips momentarily below 5 volts (from heavy voltage draw when the 50 volt flippers are used), the "watchdog" circuit shuts the game down. The high current draw flippers stresses the other power components in the system. If these power components are starting to fail, the +5 volts dips, and the watchdog circuit resets the game. When the game shuts down, the power components under stress are relieved. Then the voltage returns to +5 volts, and the game powers back up. This reset process can happen anytime, but usually happens during game play.

Check the Easy Stuff First.

Proper AC Wall Voltage?

Important: Before starting to dig in and try to diagnose the bridge rectifiers, set the DMM to AC Voltage and **test the wall socket voltage**. Make sure there is 115 to 120 volts AC present! If there is only 112 volts, this can cause the game to reset. Some games, like Twilight Zone, will often reset if the wall voltage is below 117 volts.

This problem happens mostly in the summer, when household power consumption is at a high, or if the game is plugged into the same circuit as another high power device (air conditioner, refrigerator, etc). WPC pinball games draw a maximum of 8 amps of power. Most home circuits are 15 amps, so two pinballs on one circuit should be the maximum. Also don't have the game plugged into the same circuit as another power sucking device (like a dehumidifier, sump pump, air conditioner, refrigerator, etc.) If the problem is persistent, the game can be re-jumpered for low-line voltage.

Check the Driver Board Voltages.

Next make sure the voltages at the driver board are Ok. Of course this assumes the wall voltage is Ok (if the wall voltage is low, any unregulated voltage will certainly be low, and often regulated voltages will be low too). Here's what to check ("TP" means Test Point, which are test points on the driver board). Check these voltages with the game on, and in "attract" mode. Remember there is more information on voltages in **part one** of this document.

* +5 volts DC: TP2 (TP101 on WPC95). Should be 4.9 to 5.1 volts DC. If this is below 4.9 volts, the game will most certainly reset easily, as this is the voltage the "reset watchdog" looks at. Often the problem is bridge rectifier BR2 (diodes D7-D10 on WPC95) and the related filter capacitor C5 (C9 on WPC95). Sometimes it could also be the +5 volt voltage regulator is failing, LM323 at Q1 (LM317 at Q1 on WPC95), though this is rare.
* +18 volts DC (lamp matrix): TP8 (TP102 on WPC95). This is an unregulated voltage, so it can vary from 16 to 20 volts. If this is low, check bridge BR1 and capacitor C6/C7 (diodes D11-D14 and caps C11/C12 on WPC95).
* +12 volts DC regulated: TP3 (TP100 on WPC95). Should be 11 to 13 volts DC. This voltage comes from the +18 volts lamp matrix (discussed above), and goes through a 12 volt regulator (7812) and some 1N4004 diodes and an LM339 chip. If the +18 volts is correct at TP8 (TP102 on WPC95), but this voltage is low, it is usually the 7812 voltage regulator at Q2 has failed.

If any of the above voltages are low, resets will usually occur. But just because the above voltages are Ok, does **not** mean the game won't reset. Remember, the above voltages are being tested in attract mode, and not under stress.

Now it's time to check some more voltages, but under stress. This is a bit more difficult to do, but here is the procedure. Use a non-autoranging DMM (or set your auto ranging DMM to non-autorange). Or use a scope.

* Check TP2 (+5 volts DC) on the power board. Try and get the game to reset and see if the +5 volts dips during the reset. There should be no change in the +5 volts, even during a reset.
* Check TP4 on the power driver board, which is the zero cross signal. Again it should look steady with no changes even during a reset.
* On the CPU board check U10 pin 1 (the reset pin on the MC34064). This pin may dip low during reset, forcing a game reset when the flipper buttons are pressed. The U10 is the watchdog circuit, and when it's reset pin 1 goes below 4.7 volts, the MC34064 forces the CPU to reset and

reboot. You can follow the voltage trail back from the MC34064 and try and figure out the exact component causing the problem. Remember if during the process a reset connector fixes the problem, this connector must be replaced (both header pins and terminal pins) to fully fix the problem.

But why is the voltage on U10 pin 1 dipping below 4.7 volts? There are a number of things that can cause this, as discussed here.

Check the Connectors (Transformer, J101/J129 and J102/J128).

Though this doesn't tend to be a big problem, try re-seating the connectors on the large transformer in the bottom of the cabinet. Unplugging then plugging these connectors temporarily cleans them and makes sure they are snuggly attached. If there is any resistance in the transformer plugs, that can reduce the voltages going to the rest of the game. This only takes a moment to do, so it's not a bad thing to try. After reseating the transformer connector, test the game. If the reset problem went away, you have a TEMPORARY fix! Yes I did say temporary, as chances are excellent the reset problem will come back. The connector pins really need to be replaced to permanently fix this problem

Next connector to check is J101 (J129 on WPC995) on the power driver board. These provide AC power from the transformer to the power driver board, which ultimately ends up as +5 volts DC, 18 volts DC unregulated, and +12 volts DC regulated (via bridge rectifier BR1 & BR2, some filter caps, and some voltage regulator circuits). If these connectors are damaged in any way, this can cause the voltages discussed above to be low, and resets to occur! Replace the connector pins with Trifurcon style .156" pins, and replace the driver board pins with new .156" header pins.

Another bad connector could be J102 (J128 on WPC95) on the power driver board, 16 volts AC. Though less likely to be a problem, check it. Also check J112 (J127 on WPC-95), as this provides power from the transformer too (9.8 volts AC).

Again, if reseting any connector fixes the reset problem, it is only temporary. The only way to fix this properely is to replace BOTH the circuit board header pins and the connector housing terminal pins (with Trifurcon pins). It is very common for these connectors to have bad pins or cracked solder joints, especially on Twilight Zone. Also these connectors can just plain BURN, causing resets.

Disconnect the Dot Matrix Display.

A failing dot matrix display consumes more power, and can drive down the other voltages in the game, causing resets. To make sure the display is not causing resets, disconnect the power connector from the dot matrix display glass (*not* the ribbon cable!) Then turn the game on and play (blind, no display), and see if the game still resets. If it no longer resets, the dot matrix display and/or the high voltage power section on the DMD controller board will need to be replaced.

Flipper Coil Diodes.

Though not a big problem on WPC games, if the flipper coil diodes (there are two per coil) are damaged or missing, this too can cause game resets. This is a lot more common on games prior to WPC, but it can happen here too, and the diodes are needed. If missing or broken, resets can happen on and WPC or WPC-95 game. The flipper problems section of this manual shows how the flipper diodes should be installed. Check for broken/cracked diodes, and replace them with new 1N4004 diodes if in doubt.

Biggest Game Reset Culprits: Failing Bridge Rectifiers, WPC-95 Diodes, Filter Caps, and Cracked Solder Pads.

Bridge rectifiers or diodes (and their corresponding filter capacitor) convert AC voltage to smooth DC voltage. This is very important, as all the circuit boards run on DC voltage. If a game plays fine, but randomly resets, often the bridge rectifiers (or diodes) and their capacitor are over stressed and need replacement.

On WPC-S and prior games, a bad BR2 bridge rectifier and its associated C5 filter capacitor (C9 on WPC95) are probably the single most commonly failed components relating to game resets. Also very common are cracked solder pads on the bridge rectifier and/or associated filter capacitor, which also causes game resets. And remember, just because a bridge rectifier tests as "good", does **not** mean it is good! After all, a bridge can not be easily tested when the game is in multi-ball, with the flippers flipping, and the pop bumpers popping.

A bad bridge rectifier (or diodes on WPC-95), or cracked solder pads around a bridge can also give game boot-up error messages saying fuse F114/F115 (or F106/F101 on WPC-95) have failed, when the fuses are actually good. See the Check the Fuses section (and below) for a list of fuses and what bridges they connect to.

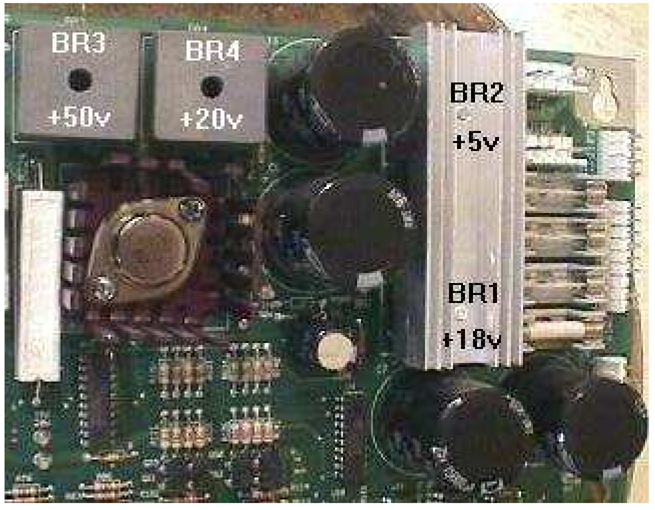
WPC bridge rectifiers and diodes reside on the driver board (although there is also a bridge on the Fliptronics board prior to WPC-95). A bridge rectifier is mearly four diodes strung together in a square. There are two AC input voltages, and two DC (positive and negative) output voltages. These diodes are encased in epoxy, and covered with a square metal casing.

Failed bridges/diodes can often short or "go open". BOTH of these problems are quite common! A shorted bridge/diode will immediately blow a fuse when powered on. An open bridge/diode will cause lower or no voltage to get past the bridge. If the fuses are good, but power driver board LEDs are not lit, this could be an indicator of a bridge/diode that has "gone open".

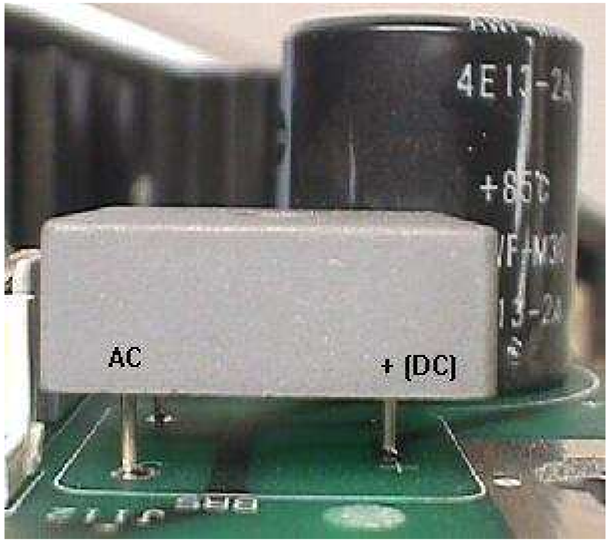
When replacing bridge rectifier BR2, be careful not to tear or break the circuit board traces at the bridge. Board damage here is very common because BR2 is often replaced, and often in a hurry. Since a bridge rectifier is a large part, vibration can crack the circuit board traces. In particular notice the small trace on the component side of the driver board under one of the bottom left AC leads of BR2. This goes to the non-banded side of diode D3 (under connector J109) for the zero cross circuit. If this trace is torn or cracked, resets will likely still occur (more details/pics on that below).

After soldering in a new BR2, be sure check continuity on the board component side from the lower left AC BR2 board pad to the right side of D3. Likewise check the continuity from the upper right BR2 AC lead to the right side of D38 (or the solder side of the driver board from the upper left BR2 board pad to the solder pad about 1" to the right). Also it's a good idea to run jumpers from BR2 to its filter capacitor C5, as described below, because the plated thru holes for the BR2 are damaged.

Bridge rectifiers on a WPC-S and earlier generation driver boards. From the left to right: BR3, BR4, BR2 (top), BR1 (bottom). BR2 and BR1 have a large silver heat sink over them.



*The BR5 bridge used on WPC-S and earlier generation driver boards. Note the "+" lead of the bridge is offset slightly, from an otherwise perfect square shape. Notice the bridge is installed about ¼" above the board.
This aids air flow and keeps the bridge cool.*

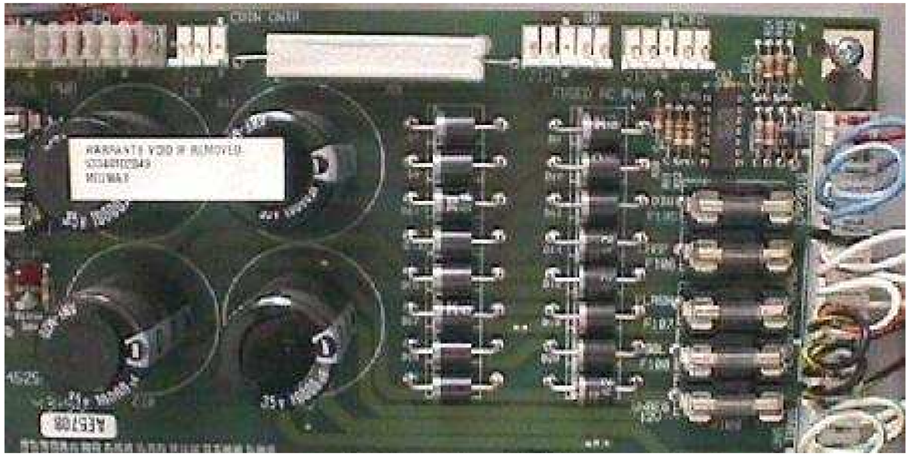


WPC-95 “Bridges”.

When WPC-95 was released, Williams decided to stop using bridge rectifiers. Instead they just installed four diodes right on the driver board for each replaced bridge. By using four discrete diodes instead of a single bridge, the heat generated by the components is spread out and reliability is greatly improved. Bridge rectifier failure is very common in WPC-S and prior systems. Replacement of even a single diode in the WPC-95 system games is very rare (but these games are not as old as WPC-S and prior systems). Certainly all the problems associated with the bridge rectifiers can still be exhibited in a WPC-95 system too.

The diodes used in WPC-95 are called P600D (or 6A4 or 6A400). These are 6 amp at 400 volt rectifiers. A substitute device is NTE5814.

WPC-95 P600D diodes D7 to D22 which replaced MB3502W/MB352W bridge rectifiers. Also note the smaller “T” fuses (on the right) used in WPC-95.



The Electrolytic Capacitor: the Bridge Rectifier and Diode’s Partner.

Each bridge rectifier or diode set must also have an associated electrolytic capacitor. These are needed to polish the converted rough DC voltage to smooth DC voltage.

Electrolytic caps are largely mechanical devices. With time, they can fail. Expect about 10 years maximum life from an electrolytic filter capacitor. It is fairly common for these caps to fail. A failing electrolytic capacitor can cause the game to reset, as the DC voltage won't be "smooth". Because of this, when replacing the BR2 bridge on pre-WPC95 games, it is a good idea to also replace the associated filter capacitor C5 (15,000 mfd 25 volts).

Smaller Filter Caps Used with WPC-95. Why?

Interestingly, Williams changed from 15,000 mfd (at C5) on WPC-S and prior, to a lower value of 10,000 mfd on WPC-95 (at C9). With time, WPC-95 games may be more sensitive to bad filter caps, because of this lower value. Right now, since these games are fairly new (1996 and later), this isn't a huge problem.

Higher filter cap values are generally good; they provide a better level of AC filtering as the capacitor gets older. As electrolytic capacitors wear (they really are a mechanical device), they are less efficient at AC filtering, and their MFD value drops. However, the higher the MFD value of a capacitor, the more strain it puts on the rectifying bridge or diodes. When a game is turned on, the filter cap draws significant current during the first half AC cycle (since this power is used to "charge" the capacitor). This can subject the bridge rectifier (or diodes) to an excessive in-rush of current. This in-rush current can be up to ten times the current needed after the filtering capacitor has charged. This can cause a connection inside a bridge to instantly go open (this is not the same as over-current, which can cause the bridge to short). In-rush current is a factor of both voltage and the capacitor. A larger cap will force more in-rush current to the bridge, potentially causing damage. Also capacitors with higher MFD values cost more (the change from 15,000 to 10,000 mfd could have been in fact a cost/availability issue; the 10,000 mfd capacitors may have had a shorter lead time, and were cheaper for Williams to buy).

Bridge Rectifier, Diode, and Filter Capacitor Device List.

Here's a list of what bridge rectifiers and diodes control which functions, and their associated capacitors. All are located on the driver board, unless otherwise stated.

WPC-S and Earlier Driver Board:

- **BR1** to C6 & C7 (15,000 mfd @ 25v) to F114: +18 volts used for lamp driver columns. Then the 18 volts goes through voltage regulator Q2 (LM7812) and F115, and is converted to 12 volts (regulated) for the switch matrix.
- **BR2** to C5 (15,000 mfd @ 25v) to F113: +5 volts. **The bridge and capacitor that fail the most, and cause the most reset problems.**
- **BR3** to C8 (100 mfd @ 100v) to F112: +50 volts, used for solenoids.
- **BR4** to C11 (15,000 mfd @ 25v) to F111: +20 volts, used for flash lamps.
- **BR5** to C30 (15,000 mfd @ 25v) to F116: +12 volts unregulated for playfield devices, opto power, dot matrix display, and the coin door.
- **BR1** (on Fliptronics II board) to C2 (100 mfd @ 100v) to F901-F904: +50 volts used for the flippers. Located on the Fliptronics II board. Note early versions of the Fliptronics II board had C2 installed, but later versions did **not** use this capacitor, and it is missing from the board. In any case, this capacitor is not needed, as the flipper coil 50 volts does not really need to be filtered.

WPC-95 Driver Board:

- **D3, D4, D5, D6** to C8 (10,000 mfd @ 35v) to F109: +12 volts unregulated for playfield devices, opto power, dot matrix display, and the coin door.
- **D7, D8, D9, D10** to C9 (10,000 mfd @ 35v) to F105: +5 volts for all board logic circuits. **The diodes and capacitor that fail the most, and cause the most reset problems.**
- **D11, D12, D13, D14** to C12 (10,000 mfd @ 35v) to F106/F101: +18 volts used for lamp driver columns. Then the 18 volts goes through voltage regulator Q2 (LM7812) and F101, and is converted to 12 volts (regulated) for the switch matrix.
- **D15, D16, D17, D18** to C10 (10,000 mfd @ 35v) to F107: +20 volts for flash lamps.
- **D19, D20, D21, D22** to C22 (100 mfd @ 100v) F108/F102/F103/F104: +50 volts for solenoids.
- **D25 to D32**: +6.3 volts for general illumination. These were replaced with jumpers starting with Scared Stiff. See the Burnt Connector section (WPC-95 GI diodes D25-D32 remove and jumper) for a description of this.

Testing a Bridge (WPC-S and prior), Board Removed.

Note testing a bridge with the game off is NOT conclusive to whether the bridge is bad! The bridge is being tested under NO load. Only a bridge which is shorted (and hence is blowing fuses) or open will test as "bad". A bridge could test as "good", and still cause the game to reset. Also testing a bridge "in

circuit” (while still soldered in the board) can often not give proper results.
A bridge has four terminals: two AC terminals, and two DC terminals (postive and negative). On the side of each bridge, printed on the metal casing, there will be two labels: “AC” and “+”. From the solder side of the driver board, mark with a Sharpie pen these two terminals. Figuring out the other two terminals is easy: the other AC terminal is diagonal to the labeled AC lead. The negative DC lead is diagonal to the labeled positive DC lead. Mark these right on the board with the Sharpie pen. To double check, the two DC leads (positive and negative) connect to that bridge’s respective electrolytic capacitor, and it’s positive and negative leads. Testing a bridge while soldered in the board (in curcuit) may not give the following results. For example, testing BR2 in curcuit will not give these results (but most of the other bridges will). To test the bridge:

13. Put the DMM on diode setting.
14. Put the black lead of the DMM on the “+” (positive) terminal of the bridge.
15. Put the red lead of the DMM on either AC bridge terminal. Between .4 and .6 volts should be seen. Switch the red DMM lead to the other AC bridge terminal, and again .4 to .6 volts should be seen.
16. Put the red lead of the DMM on the “-“ (negative) terminal of the bridge.
17. Put the black lead of the DMM on either AC bridge terminal. Between .4 and .6 volts should be seen. Switch the black DMM lead to the other AC bridge terminal, and again .4 to .6 volts should be seen.

If values outside of .4 to .6 volts are shown for any of the above tests, the bridge is bad. Typically you will get a zero value (a short) for at least one of the above tests in a bad bridge.
Testing a Bridge (WPC-S and prior), Under Minor Load, In the Game.
This tip is from John Robertson. This test is a more conclusive way to test a bridge (though a bridge that tests good here can still cause game resets!) This procedure requires a DMM, two alligator jumper wires, and a 6 amp rectifying diode (6A50 or 6A2 or 6A4, or whatever is available; Radio Shack sells 6A50 diodes, part number 276-1661). Here is the procedure:

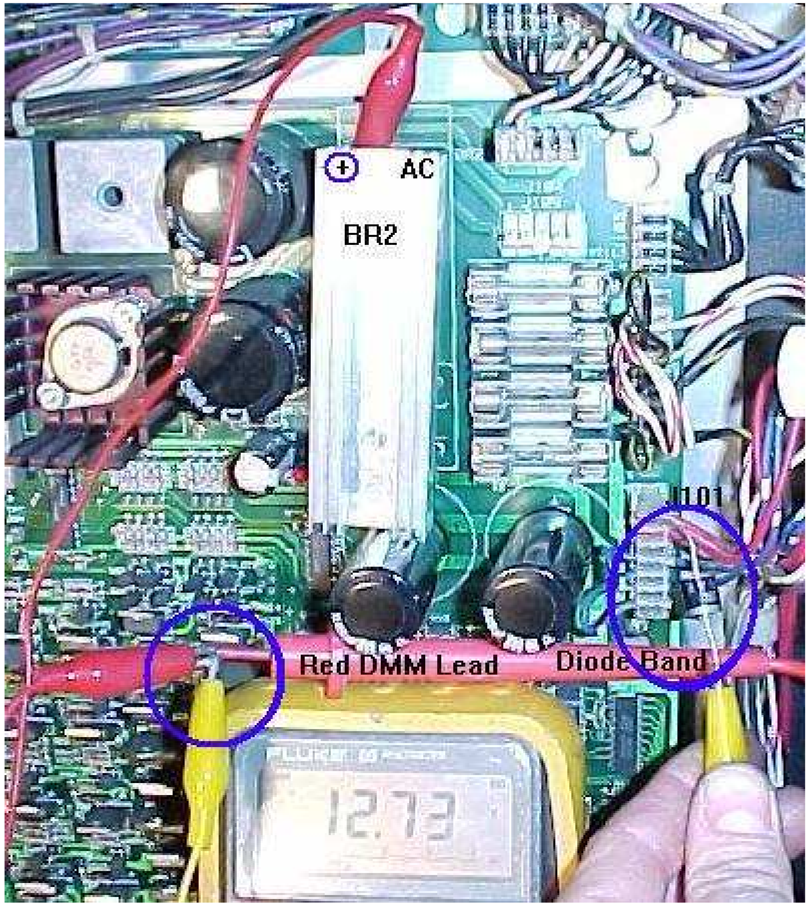
18. With the game off, clip one end of an alligator test wire on the “+” lead of bridge BR2 (top most bridge) on the driver board. The “+” lead is the top left most lead (see picture below). Often the side of the bridge is labeled too. One lead is “AC”, and the other is “+” (connect the alligator clip to the “+” lead, which is the left lead as facing the board).
19. Connect the other end of the alligator test wire on the RED lead of the DMM.
20. Put the BLACK lead of the DMM on the braided metal grounding strap at the bottom of the backbox.
21. Turn the DMM on, and set it to DC Volts (20 volt range).
22. Turn the game on. A value of 12 to 13 volts should be shown. Any less than 12 volts, and the bridge (or the connection to the bridge) is bad.

Attaching the red alligator test lead to the “+” leg of bridge BR2. The other end of the alligator lead is attached to the DMM’s red probe.

6. Turn the game off. Take the second alligator jumper wire, and connect the clip to the BANDED end of the 6 amp diode.
7. Connect the other loose end of the alligator jumper wire to where the first alligator clip connects to the red lead of the DMM (see picture below). This is essentially the same as connecting the second alligator clip to the "+" lead of bridge BR2 (but there is not enough room at the bridge to do this, since the first alligator clip is in the way).
8. Turn the game on.
9. Touch the non-banded end of the diode to connector J101 in either pin 1 or 2 (two top most pins). Note the IDC connector will have some exposed metal at the top of the connector to touch, and plug should not be removed.
10. While doing the above step, examine the DMM voltage reading. If the voltage rises when the diode lead is touched to Connector J101 pin 1 or 2, the bridge BR2 is bad (bad internal positive diode).

A second alligator clip is connected to where the first alligator clip connects to the red lead of the DMM. Now touch the second alligator clip with a 6 amp diode, NON-BANDED end, to connector J101 pins 1 or 2. The voltage on the DMM should

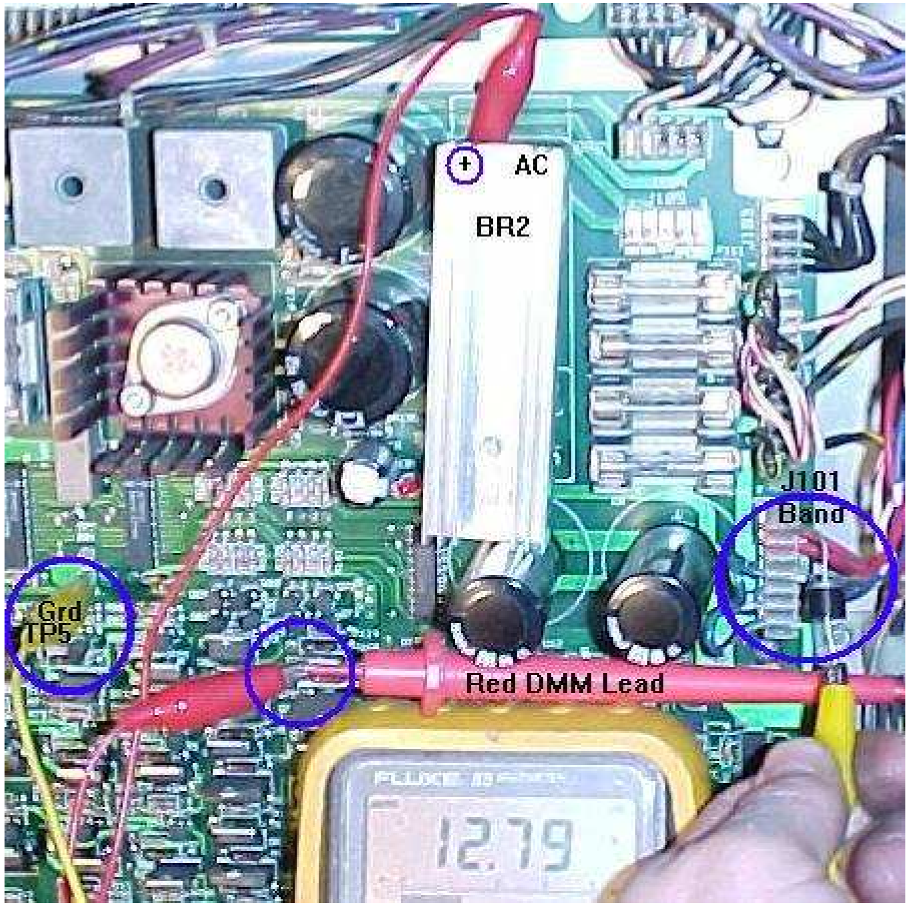
NOT drop when the diode is touched to connector J101 pins 1 or 2.



12. Turn the game off. Reverse the diode in the alligator clip so the NON-BANDED end of the 6 amp diode is connected to the alligator clip.
13. Connect the other end of the alligator clip to TP5 (ground).
14. Turn the game on.
15. Touch the banded end of the diode to connector J101 in either pin 1 or 2 (two top most pins). Note the IDC connector will have some exposed metal at the top of the connector to touch, and the plug should not be removed.
16. While doing the above step, examine the DMM voltage reading. If the voltage rises when the diode lead is touched to Connector J101 pin 1 or 2, the bridge BR2 is bad.

If the above tests all work as described (no voltage drops or readings below 12 volts), the problem is mostly likely a bad C5 (15,000 mfd 25 volt) filter cap (or a cracked solder joint to the bridge and/or capacitor, which can be solved by installing the jumper wires described below). But remember, a bridge that tests good here can still cause game resets!

The second alligator clip is now connected to TP5 (ground), and the diode is reversed in the alligator clip. Touch the other end *of the second alligator clip with the 6 amp diode, BANDED end, to connector J101 pins 1 or 2. The voltage should not drop when the diode is touched to connector J101 pins 1 or 2.*



Testing a Diode (WPC-95)

The diodes that replaced the bridge rectifiers in WPC-95 are even easier to test. Again, testing diodes in curcuit may not give the following results. Also, testing a diode is NOT conclusive to whether the dioide is bad! The diode is being tested under NO load. Only a diode which is shorted (and hence is blowing fuses) will test as "bad". A diode could test as "good", and still cause the game to reset.

1. Put the DMM on diode setting.
2. Put the black lead of the DMM on the banded lead of the diode.
3. Put the red lead of the DMM on the non-banded lead of the diode.
4. A reading between .4 and .6 volts should be indicated.

The Above Bridge/Diode Tests Don't Always Work!

Yes, you heard right. The above outlined bridge and diode tests above don't always find a faulty component. These devices can just start to fail, and this

will cause the game to reset. But a bridge or diode can become "leaky", which will cause the game to reset, and may not show as bad in the above tests (though the bridge test "under load" as explained above is the most accurate of the tests).
So what do you do now? How can you be sure the resetting game has a bad bridge or diode? Well you really can't! First make sure the wall voltage is at the proper level. Then re-solder the bridge/diodes and their associated capacitor's solder pads. Then just go ahead and replace the suspected bad bridge/diode (BR2 or D7, D8, D9, D10 on WPC-95). Also, if the game is 10 years old or more, I suggest replacing filter capacitor C5 (C9 on WPC95). If the game is still resetting (and the filter cap was not replaced), definately go ahead and replace the associated filter capacitor (C5 or C9 on WPC-95). If the game is still resetting, replace the LM339 voltage comparitor at U6 (U1 on WPC-95) as a last resort.

Replacing a Bridge or Diode.

Replacement is as simple as cutting out the old component and soldering in a new one. When installing the new bridge, mount it ¼" or even ½" above the board. This allows for air to flow underneath the bridge for better cooling.

Replacing BR2 and/or BR1 on WPC-S and Prior.

When replacing either (or both) bridges BR1 and BR2 on WPC-S and prior, both bridges will have to be dealt with. These two bridges share a single large silver heat sink. Since they both share the same heat sink (and one failed due to heat), the other probably will need replacement shortly. If either BR1 or BR2 is bad, replace them both. To remove them, both will need to be unsoldered from the Driver board, and the heat sink un-screwed from the bottom of each bridge. The new bridges are then screwed to the heat sink, and both bridges re-installed (it is much easier to install the bridges if they are both already screwed to the heat sink).
Also I am personally cutting the heat sink in half when I do BR2/BR1 bridge replacement. This just makes replacing one bridge a lot easier. If BR2 is bad but BR1 is fine, I don't want to unsolder BR1 in the process. The driver board's plated through holes for these bridges take enough abuse, so doing any unnecessary desoldering is a bad thing in my opinion. Hence the heat sink is cut in half. This is optional, but it is something I do now.
Also there should be some white heat sink compound on the top of the bridges too. Make sure to add some heat sink compound when replacing the bridges. Heat sink compound can be purchased at Radio Shack. A good brand of heat sink compound is "Arctic Alumina".

Replacement Bridges and Diodes.

The stock bridge installed in WPC games is 35 amps at 200 volts. The original part number will be something like "MB3502W" or "MB352W". The "MB" signifies a metal cased bridge. The "35" signifies 35 amps. The "02" or "2" signifies 200 volts peak. The "W" at the end means the bridge has wire leads. Higher amps or voltage ratings work fine. I generally use 35 amps at 400 volts for example.
Replacement wire lead bridges are available from Competive Products Corp (800-562-7283), or from Williams, part number 5100-09690. Mouser also sells them, part number 625-GBPC3502W ($3.48). And so does Digikey, part number MB352WMS-ND. Radio Shack even sells 35 amp bridges at 50 volts (which isn't enough voltage). But look at the bridge inside the Radio Shack package, as often they are labeled 3502W or 352W (35 amps 200 volts), and not 50 volts. Always buy only the labeled bridges from Radio Shack. Sometimes these "35 amp" bridges are labeled 1001W (10 amp 100 volts!). Obviously put that one back and grab another!
Replacement diodes for WPC-95 boards are P600D (6A4 or 6A400), or NTE5814. A lower voltage version can be used too, 6A2 or 6A200 (200 volts). Radio Shack sells a 6 amp 50 volt (6A50) version which can be used in a pinch, part number 276-1661.

Testing the Filter Caps.

Testing the filter capacitors on the driver board is fairly easy. With the game on, set the DMM to AC volts. Then put the leads of the DMM across the two leads of each filter capacitor (doesn't matter which DMM lead to which capacitor lead, as AC voltage is being measured). If more than 0.30 volts AC is seen, the capacitor is bad.
The problem with this test is the leads for the filter caps are nearly impossible to access, when the board is installed in the game! For this reason, I usually just replace the filter cap in question (C5 or C9 on WPC95) when in doubt.

Replacement Filter Caps.

If replacing a filter capacitor, use a 15,000 mfd 25 volt "snap" cap (on any WPC generation, even WPC-95). Higher voltage caps can be used (but are more expensive). Do not use a capacitor greater than 15,000 mfd, because the in-rush current puts more stress on the rectifying bridge/diodes. A lower value of 10,000 or 12,000 mfd could also be used (but no lower than 10,000 mfd). These are available from many sources, such as Digikey (www.digikey.com or 800-344-4539) or Mouser (www.mouser.com or 800-346-6873):

- 15,000 mfd 25 volt, Mouser part# 5985-25V15000 $4.63 each, or Digikey part# P6577-ND $5.52 each.
- 15,000 mfd 25 volt, Digikey part# P6891-ND, Panasonic snap cap.
- 12,000 mfd 25 volt, Mouser part# 5985-25V12000 $4.95 each, or Digikey part# P6575-ND $4.74 each.
- 10,000 mfd 25 volt, Mouser part# 5985-25V10000 $3.65 each, or Digikey part# P6573-ND $4.17 each.

Reflowing Bridge or Diode Solder Joints.

Often a bridge or diode will test Ok, but the game still resets. This can be caused by cold, fatigued, or cracked solder joints on a bridge. Since bridges (especially BR2) and diodes can get hot, they will mildly heat up a solder joint, and make it go "cold" or fatigued. Reflowing these solder joints with new solder often fixes this problem. Also reflow the solder joints on the bridge or diode's associated filter capacitor. Often these solder joints and plated through circuit board holes crack.

The problem with reflowing the solder joints on the bridges and capacitors is this; often the traces on the top side of the board (which can not be accessed because of the components), do not get as good solder contact. This can cause an intermittent connection, which can lead to game resets. The best solution to this problem is adding some jumper wires (see below).

Insurance: Installing Bridge/Capacitor Jumpers.

Another problem with the bridge rectifiers/diodes and the filter capacitors are their solder pads and plated-through circuit board holes. The WPC driver board is a double sided board (that is, it has "traces" running on both sides of the board, both leading to different components). Soldering of both top and bottom traces is done on the bottom (solder side) of the board. The plated-through circuit board holes allow continuity from the solder side traces to the component side traces. Since the components themselves are in the way on the top side of the board, it is hard to even see the component side solder pads.

The problem is this; these components (bridges/capacitors) are large, and they can get hot (softening the solder). Vibration, heat, or both, can cause the solder points to crack. It's the size and weight of the bridge rectifiers and filter capacitors that causes this problem, and heat just makes the problem worse. This can cause an intermittent connection, or a higher resistance connection (cold solder joint). This can cause game resets, or whole banks of coils or lamps to not work.

Reflowing the solder on the back of the driver board is one solution. But it really isn't the ultimate solution. Since the driver board is a double sided board, and the components on the top side of the board are large, the traces can only be soldered on the bottom side of the board. This does not guarentee a good connection to the traces on the top (component) side of the board, especially if the circuit board's plated-through hole traces are cracked (very common). To fix this problem, it is recommended to add jumper wires on the solder side of the driver board. This is done to back up the bridge/capacitors' component side board traces.

The most important bridge/capacitor to jumper is BR2 and C5. Jumper two 18 guage wires on the solder side of the driver board from BR2 to C5 (positive lead of BR2 to positive lead of C5, and negative lead of BR2 to negatvie lead of C5). This will help prevent random game resets. All the other bridges/capacitors can be jumpered too.

Installing the Jumpers.

When installing the jumpers, first label the back of the driver board. Use a "sharpie" pen and label the bridge, and its "+" and "-" leads, on the back side of the driver board. <u>The positive lead of the bridge is the one offset lead in the square. The negative lead is diagonal the postive lead. The other two diagonal legs are the AC leads.</u> Also label the capacitor and it's positive lead with a sharpie pen (the positive lead on most of the filter caps is the "top" lead). Double check all potential connections with a DMM, and buzz out the jumper paths BEFORE you install them (installing a jumper incorrectly can cause SERIOUS problems!). This will make installing the jumpers much easier and error-free.

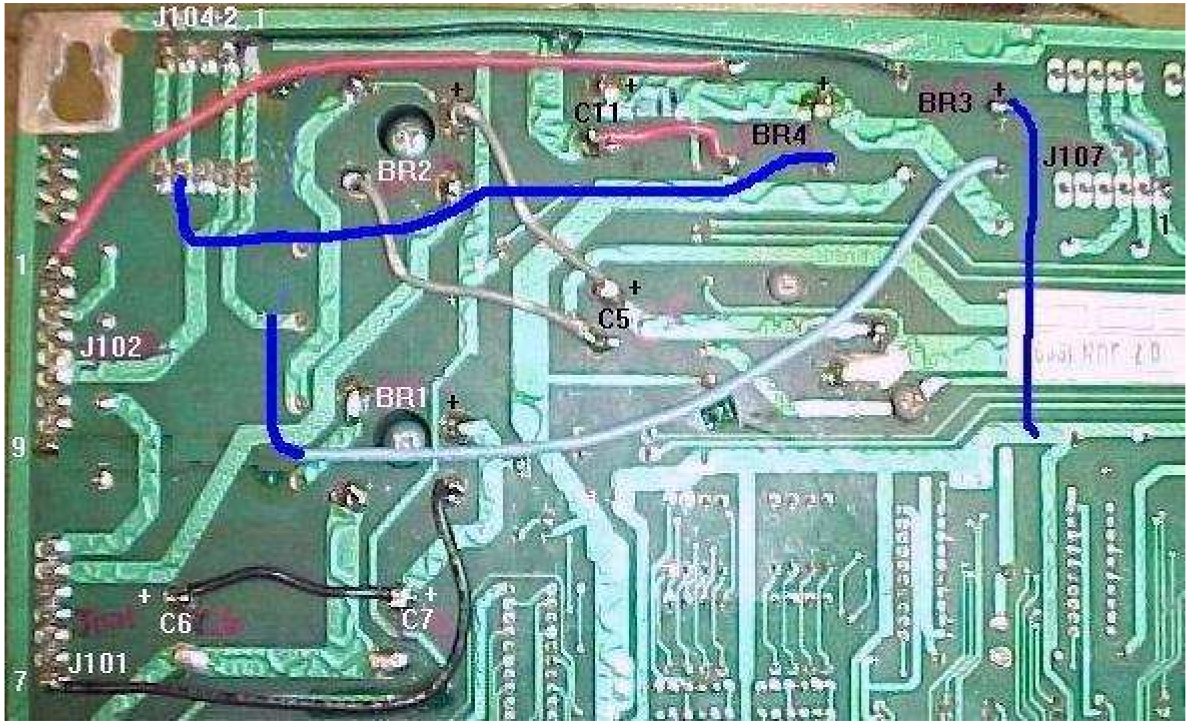
WPC and WPC-S Driver Board Jumpers:

For reference, the driver board is positioned with the solder side showing, and connector J104 at the "top". All jumpers added to the solder side of the driver board.

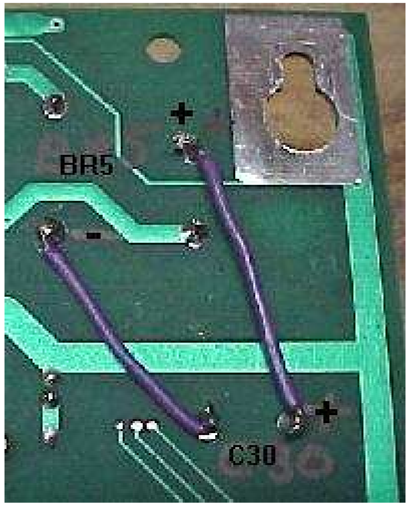
- BR2 to C5: two jumpers. Jumper the positive lead of bridge BR2 to the positive lead of C5. Repeat for the negative leads also.
- BR1: ONE jumper. Jumper the AC lead of BR1 (just below the positive lead) to connector J101 pin 7.
- C6/C7: jumper the two positive leads of capacitors C6 and C7 together (this also jumpers also helps BR1).
- C6: Add another jumper from the positive lead of C6 to TP8 (Test Point 8, 18 volt DC). Note this jumper is not shown in the picture below.
- BR3: three jumpers. Jumper the lower AC lead of BR3 (just below the positive lead) to connector J104 pin 1. Jumper the other upper AC lead (to the left of the positive lead) to connector J104 pin 2. Jumper the positive lead of BR3 to the large solenoid fuse trace about 2" below the bridge (see picture below).
- BR4: three jumpers: Jumper the negative lead of BR4 to the negative lead of C11. Jumper the AC lead of BR4 (just above the negative lead) to connector J102 pin 1. Jumper the other lower AC lead of BR4 (just below the positive lead) to connector J104 pin 4.
- BR5 to C30: two jumpers: Jumper the positive lead of BR5 to the positive lead of C30. Repeat for the negative leads also.

All the above jumpers have been installed. The most important jumper is the one from BR2 to C5 (the gray wires). Note the "+" (offset leg) of the bridge goes to the "+" lead of the associated capacitor. The

"-" lead of the bridge is diagonal to the offset "+" lead. Shown is a WPC and WPC-S style driver board.



Probably the second most important jumpers to install are those from BR5 to C30. Note the "+" (offset leg) of the bridge goes to the "+" lead of the associated capacitor. The "-" lead of the bridge is diagonal to the offset "+" lead. Shown is a WPC and WPC-S style driver board.



Are Jumper Wires Good Insurance for WPC-95 Games Too?
Yes! Even though WPC-95 games stopped using bridges in favor of diodes (which have far less heat/vibration solder pad cracking problems), jumper wires are still a good idea. On WPC-95 games, all the large electrolytic capacitors on the driver board have the potential for cracked solder pads.
To give an example of solder pad cracking, I recently had a problem on a Safe Cracker (WPC-95) where none of the low power (20 volt) coils worked. It was very frustrating; the fuse was good, and power was getting to the Driver board, but not out of the driver board and to the coils.
It turned out that the capacitor that filters the DC voltage after the rectifying diodes on the driver board had a cracked solder pad. This prevented the voltage from getting any further than it's associated rectifying diodes (I should have known; the +20 volt LED at TP104 on the Driver board was not lit!) Adding the jumper wires from the diodes to the capacitor fixed the problem.
Remember, the purpose of the jumpers on a WPC95 driver board is for added insurance on the **filter cap**. The diodes do **not** need the jumpers (other than the filter cap connects to the diodes). Its the weight of the filter cap is what causes the solder pads to crack (from vibration). The diode's solder pads just don't crack.
WPC-95 Driver Board Jumpers.
At minimum, add jumper wires for the +5 volt filter capacitor and rectifying diodes. The other diodes and filter cap can be jumpered too, as desired:

- +5 volts: Jumper from the non-banded side of D7/D8 to the negative lead of cap C9, and from the banded side of D9/D10 to the positive lead of cap C9.
- 12 volts unregulated: Jumper from the non-banded side of D5/D3 to the negative lead of cap C8, and from the banded side of D4/D6 to the positive lead of cap C8.
- 12 volt regulated & 18 volt Lamp Matrix: Jumper from the non-banded side of D11/D12 to the negative lead of caps C11/C12, and from the banded side of D13/D14 to the positive lead of caps C11/C12.
- 50 volt coils: Jumper from the non-banded side of D19/D22 to the negative lead of cap C22, and from the banded side of D20/D21 to the positive lead of cap C22.
- 20 volt coils: Jumper from the non-banded side of D16/D18 to the negative lead of cap C10, and from the banded side of D15/D17 to the positive lead of cap C10.

Replace the +5 Volt Filter Capacitor at C5 (or C9 on WPC-95).
If the game is still resetting, there's probably a good chance that the +5 volt filter capacitor at C5 (15,000 mfd @ 25v) or C9 (WPC-95, 10,000 mfd @ 25v) needs to be replaced. The C5/C9 capacitor filters and smooths the +5 volts. If this cap is worn out, unsmooth +5 volts will result. This will cause random game resets. On WPC-S and prior games, when replacing bridge BR2, it is a good idea to just go ahead and replace the filter cap C5 with a new 15,000 mfd 25 volt capacitor. Any game that is 10 years old or more should have the +5 volt filter cap replaced.

Again Check the Power Driver Voltage Plugs (Transformer, J101/J129).

The molex plug that provides the input voltage to the driver board can also have problems. On WPC-95, J129 supplies the voltage that gets rectified to +5 volts. On WPC-S and prior, J101 handles this. Also check the main power plugs that supply +5 and +12 volts to the power driver boards. On WPC-S and prior, this is J114. On WPC-95, this is J101.

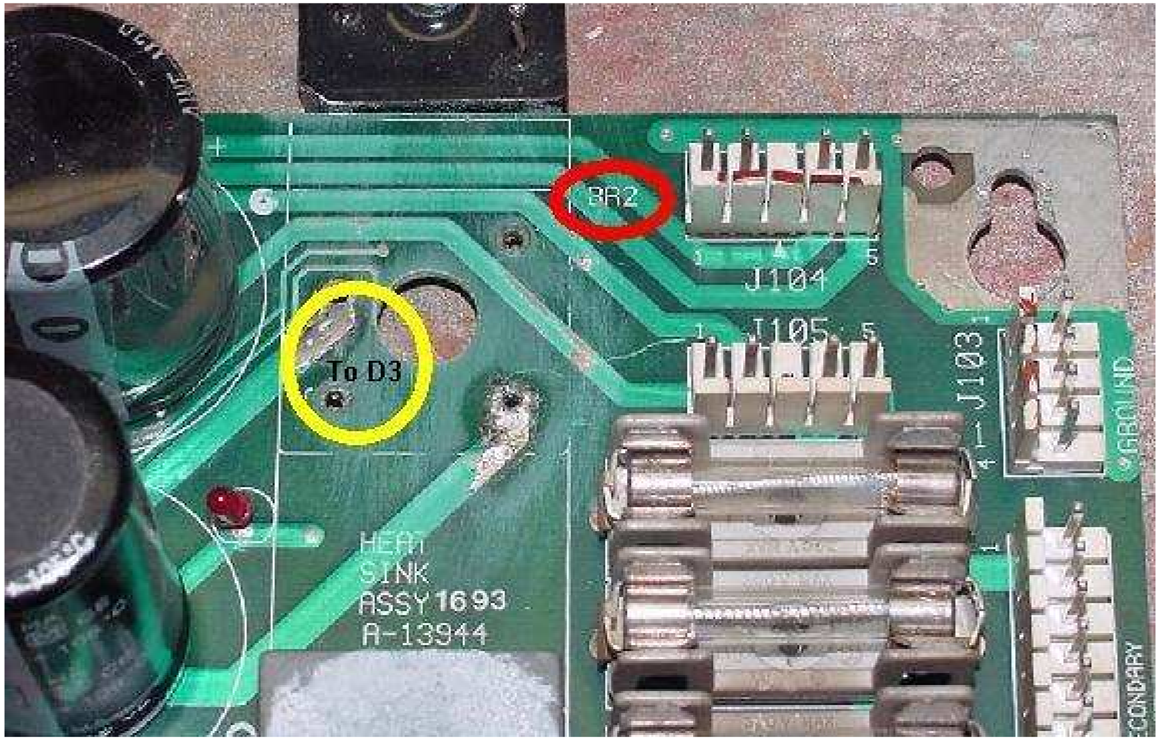
Make sure the above connectors are in good condition. Check the pins on the driver board for burnt pins, cold/fatiqued or cracked solder joints (also see the Burnt Connector and connectors sections). Any problems with the above mentioned connectors can cause random game resets.

The Zero Cross Circuit and Resets on WPC-S and Prior.

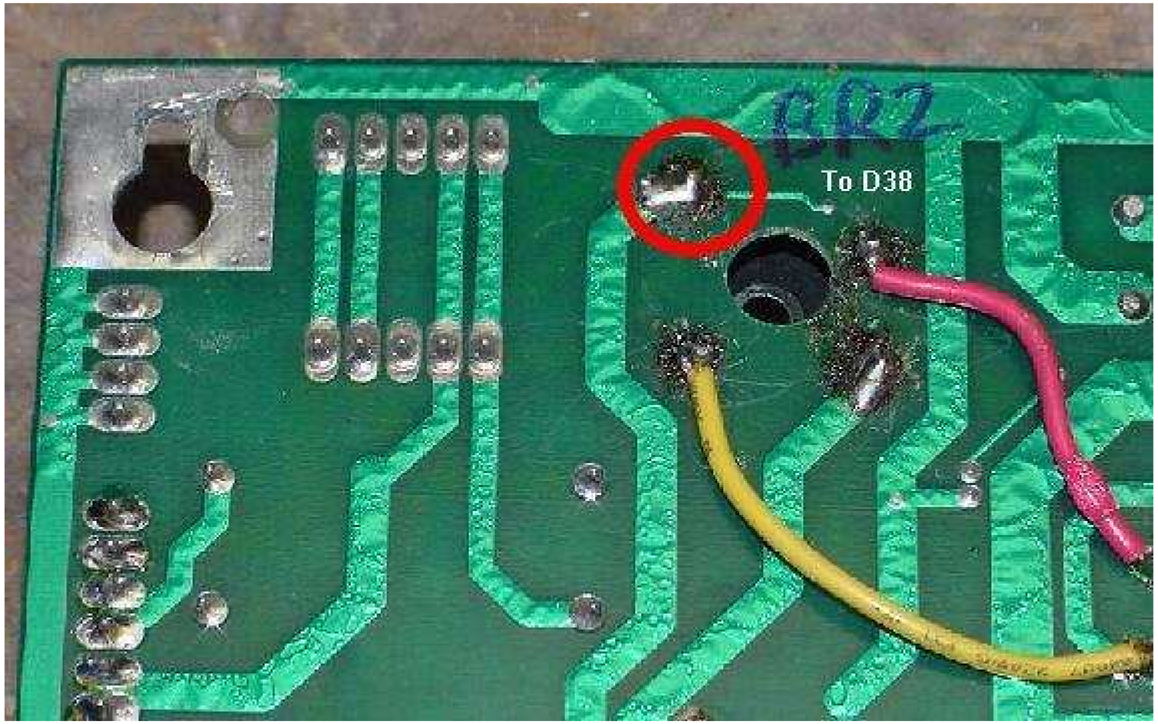
The zero cross circuit serves a couple purposes, one of which has to do with game resets. Part of the driver board's zero cross circuit are diodes D3 and D38 (located just below connector J109), which are both powered from driver board AC power traces going to bridge rectifier BR2. Since BR2 is often a replaced part, sometimes the traces going to D3/D38 get broken. This can cause random game resets (it can also cause the General Illumination lights to not dim!) So whenever replacing the bridge Rectifier BR2, be sure to use a DMM and "buzz out" the two AC leads of the BR2 bridge, making sure they go to non-banded side of diodes D3 and D38 (component side upper right BR2 lead to the right side of D38, component side bottom left BR2 lead to right side of D3).

There is also a very easy way to make sure that the zero cross traces from the AC leads of BR2 are not broken. Just power the game on and go to the G.I. test menu. If the G.I. lamps do not dim (they are full on regardless of the brightness level), then a circuit board trace going to D3 and/or D38 is broken.

Component side of a WPC-S and prior driver board. Note the broken trace (yellow circle) from BR2 to diode D3, which can be easily seen with BR2 removed. If this trace is broken, the game will still ramdomly reset and the GI will not dim.



Solder side of a WPC-S and prior driver board. Note the trace (red circle) which goes to diode D38, and is easily broken at BR2. If this trace is broken, the game *will not allow the GI lights to dim (GI only full on, or off, no in-between).*



Game is Still Resetting.

As last things to check, the +5 volt regulator at U1 (LM323 on WPC-S and prior) on the power driver board could be weak or bad. This is a cheap and available part (Radio Shack even sells them), so go ahead and replace it (on WPC-95, the +5 volt regulator is again Q1, but it is a LM317k). This +5 volt regulator does fail, and it's a smallish part, so it would be the first thing to replace if everything else has been checked or replaced.

Also the LM339 voltage comparator chip at U6 (U1 on WPC-95) on the power driver board could be bad. This chip is in the zero crossing circuit. If bad or leaky, this will cause game resets too. Replace the LM339, and make sure to install a socket for this chip.

Yet another reset problem can be caused by the CPU board chips at U1, U2, U3 (all WPC revisions). These chips connect directly to the CPU, and can have heat problems that cause a game to reset.

Also I have seen problems with the CPU board's U8 (6264) RAM chip causing reset problems. This is a static sensitive chip, so it is easily damaged.

Last Reset Resorts - Failing Dot Matrix Controller/Display.

The game in question was Star Trek Next Generation, and the symptoms included occasional game resets, weak flippers, and dim lights. The usual stuff was tried: replaced all the bridge rectifers and filter caps, rebuilt the flippers, etc, and nothing worked. A bad transformer was suspected, so it was re-taped for 100 volts, as an experiment. After powering the game back on, immediate smoke was seen off the dot matrix display controller board. On closer inspection, a number of the diodes and large resistors on the dot matrix display board showed signs of severe heating (the experiment with the lower voltage tap wasn't nearly long enough to cause the damage observed - this had built up over considerable time). After rejumpering the game back to 115 volts, a spare dot matrix display board was installed in the game, and everything worked: bright lights, strong flippers, and no game resets.

In this case the high-voltage supply circuits on the dot matrix display controller board were marginal. A considerable amount of current was being drawn by the dot matrix display board. This problem caused enough load on the transformer to bring all the voltages down for the whole game (there was a clue: with the game turned on, the AC inputs into the bridge rectifers all read at the low end of the acceptable range).

Even having an "out-gassed" dot matrix display with a good dot matrix controller board can cause game resets (see Dot Matrix/AlphaNumeric Score Displays for more details on out-gassing displays). The problem of weak, old, out-gassed dot matrix displays causing game resets is becoming more common. The moral of this story is to not use a dot matrix display that is out-gassed and at the end of its life.

Lesson: not all game resets and low voltage problems are caused by the notorious bridge rectifers. Bad CPU chips or bad voltage supply circuits on the dot matrix display board can also mimic these problems. Check the large resistors and diodes near the heat-sunk transistors on the dot matrix controller board. Look for clear signs of overheating (blackened PC board), even though the board is functional. To fix this, rebuild the high voltage section of the dot matrix display board, as described later in this document in the Dot Matrix/AlphaNumeric Score Displays section. Also be sure to replace a marginal dot matrix display. A bad display can consume much more power, stressing the dot matrix controller board, and potentially lowering other voltages, and causing game resets.

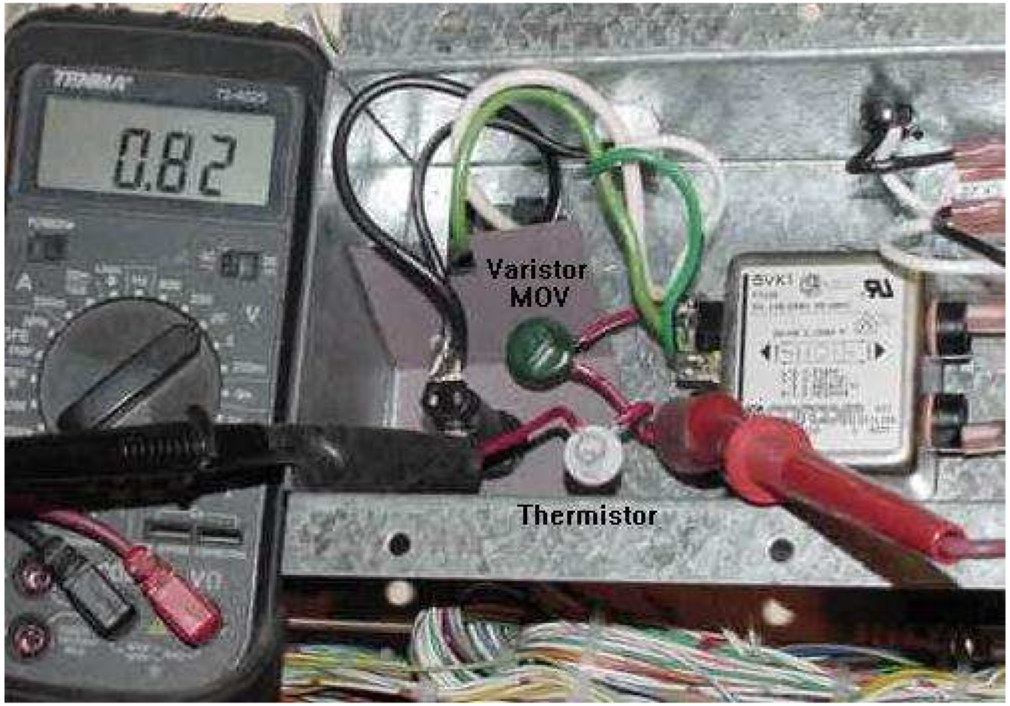
The Thermistor and Resets.

The Thermistor's job is to act like a low value resistor when cold. After warming up for a minute, it essentially becomes a low ohm resistor. When the game is first turned on, it provides a slightly lower input voltage to the game's transformer (and hence bridge rectifiers), limiting the in-rush current (and lengthening the life of the bridges). But with time, sometimes the thermistor does not function correctly after warm up, therefore acting like a full time resistor. This keeps the input voltages lower, and makes game resets more prevalent. The Thermistor is located in the "power box" just inside the coin door. This power box also housing the game's power switch.

With the game turned on and warmed up (five minutes), no more than 1.00 volts AC should be measured with a DMM across the Thermistor, with the game in the attract mode (not playing). Note when the game is first turned on, as much as 5 volts AC can be seen across the Thermistor. But this voltage should slowly drop down to under 1 volt AC as the game warms up in the next five minutes. The thermistor is the gray disc device wired from the line filter to the fuse. The thermistor is an 8 amp, 2.5 ohm current limiter, and can be purchased from Mouser Electronics (part number 527-CL30). Do not confuse the thermistor with the Varistor (MOV), which is the green disc wired across the two AC lugs of the line filter. Also be careful monkeying around inside the power box, on do this with the game unplugged, as there is 115VAC (or 220VAC for Europe) present.

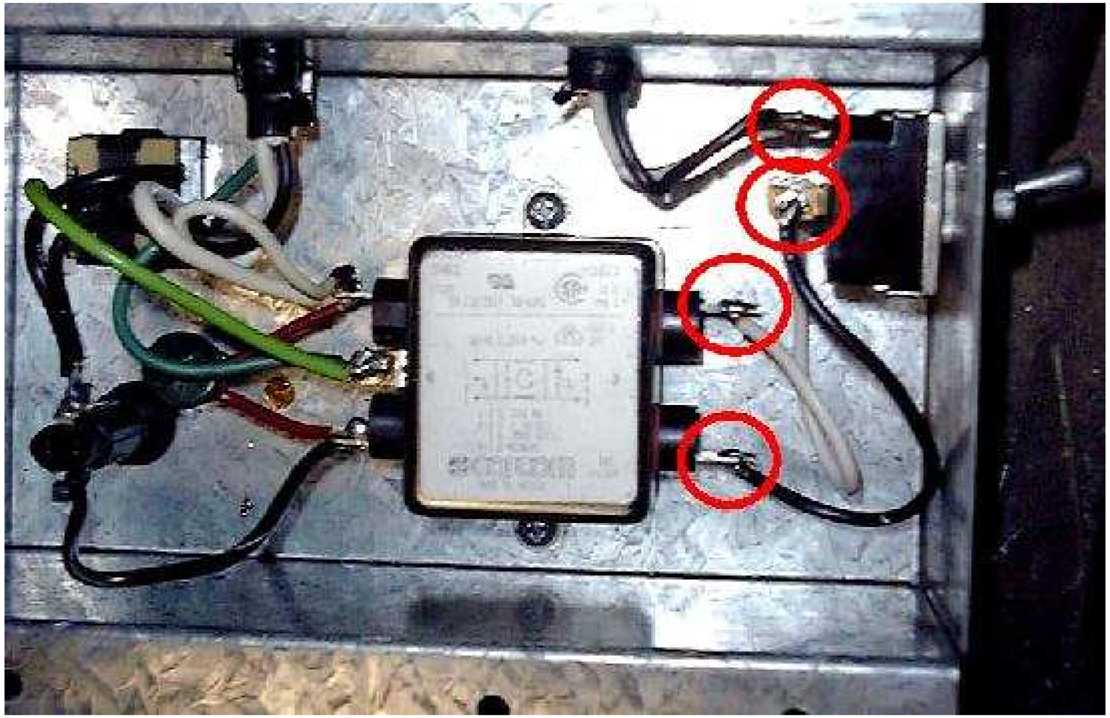
The "power box" just inside the coin door.
Picture by John Robertson.

Measuring the AC voltage across the Thermistor, with the game in attract mode. No more than 1.00 volts AC should be seen.



Connectors inside the Power Box.
While checking the thermistor and varistor, also check the single spade lug connectors used on the power switch and the RF (Radio Frequency) Filter. Sometimes these connectors can get loose and burn, causing low power to the driver board, and game resets. Instead of installing new connectors, just solder the wires directly to the power switch and RF Filter, as shown below.

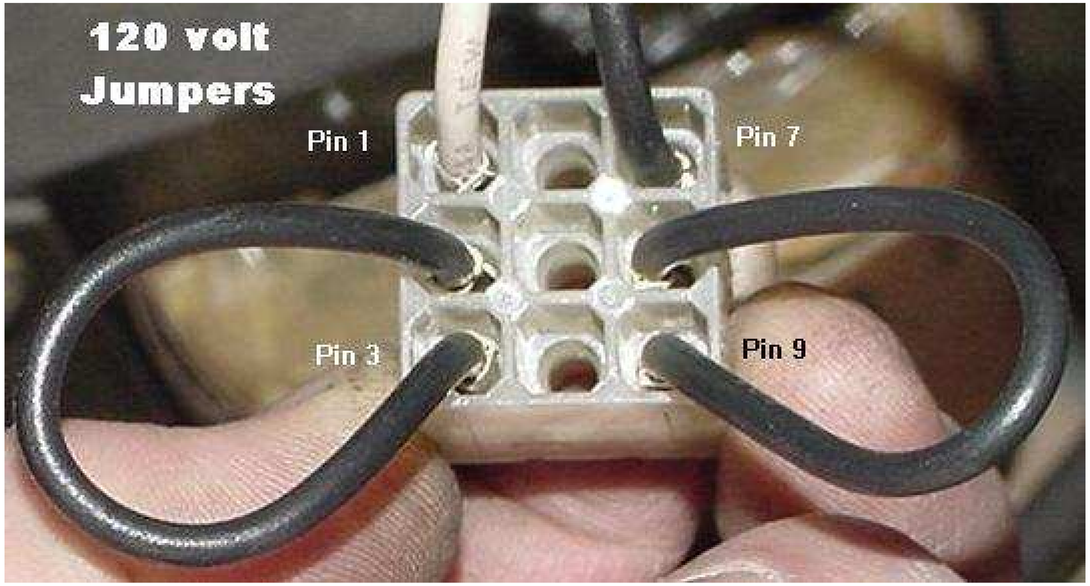
A power box where the power switch and RF filter connectors have been removed, and the wires soldered directly (red circles). This was done because the original spade lug connectors had burnt. Pic by J.Robertson.



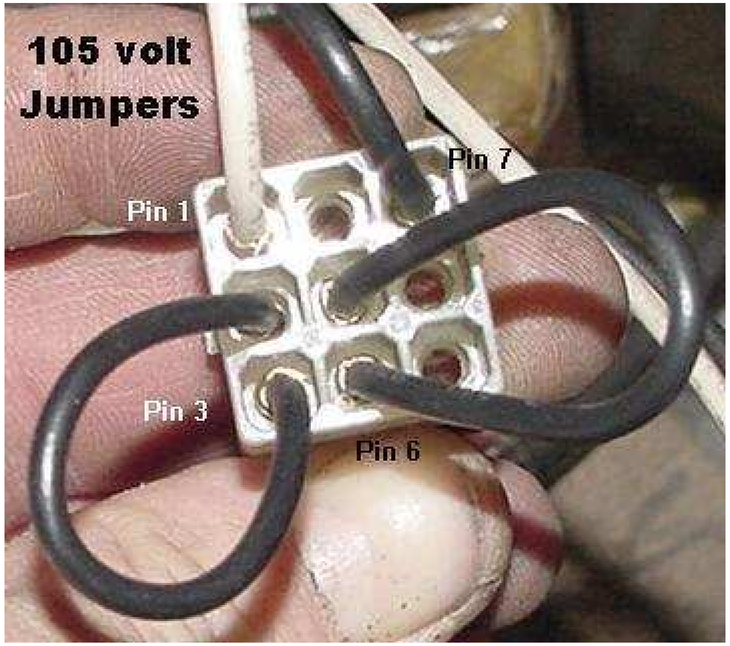
Low Line Voltage Jumpers (105 Volts).

If the game is at a 120 volt location but has 112 volts or less at the wall outlet and is resetting, the game can be jumpered for "low line voltage". This is also known as the 105 volt Japanese voltage setting. I don't recommend this if the voltage is above 112 volts as it does put stress on the regulated voltage components on the driver board and possibly the transformer. Please let me say that again: DAMAGE can occur to your game if it is transformer jumpered incorrectly! But it can be used in those rare situations where power is below 112 volts. It involves rejumpering the .093" round Molex connector plugs at the transformer (a .093" round Molex connector remover is required, available from Waldom Electronics part# W-HT-2038 or Radio Shack part# 274-223 ($4.99). Instead of the jumper going between pins 8 & 9 of this connector, they are moved to pin 5 & 6. Below are pictures of this modification on pre-DCS WPC games.

The normal 120 volt transformer jumpers on an Addams Family.



The low line 105 volt transformer jumpers on an Addams Family.



Fuse F116 Keeps Blowing on WPC-S and Prior Games.
When fuse F116 keeps blowing on WPC-S and earlier games, it's almost always a bad bridge rectifier at BR5. Replace and make sure there is good

solder contacts leading to the "+" lead of C30.

"Check Fuse F114/F115" (or F106/F101) Message.

This indicates the voltage is out for the lamp/switch matrix. Sometimes this message is gotten even when the fuses are good!

A failing bridge (or diodes) can cause the game to think their respective fuses are bad. If the fuse F114 (or F106 on WPC-95) is actually blown, usually this is an indication that BR1 (or diodes D11-D14 on WPC-95) usually failed. But it could be as simple as a cracked solder pad on power driver board's BR1 (or diodes D11-D14 on WPC-95). See the above about jumper wires, and install those for good reliability. The shotgun method can also be used, replacing BR1 (and BR2, both for WPC-S and prior, while you are at it!) on the power driver board, in addition to the jumper wires.

Here is a step-by-step test to see exactly what is causing the F114/F115 (or F106/F101) error message. With the game on and the coin door closed:

- Test for AC voltage at J101 pins 4 and 7 (or J129 pins 4 and 7 on WPC-95). A reading of 13 to 18 volts AC should be seen. This is the AC voltage coming from the transformer. If no voltage here, check the Molex connectors around the transformer and at the power driver board.
- Test for DC voltage at TP8 (or TP102 on WPC-95) and ground. A reading of 16 to 18 volts DC should be seen. If no voltage here, replace BR1 (or D11 to D14 on WPC-95). Also no voltage here can occur because the solder pads are cracked around bridge BR1 (or D11 to D14 on WPC-95). Using jumper wires for BR1 (as described in the Game Resets section) helps prevent this.
- Test for DC voltage at TP3 (or TP100 on WPC-95) and ground. A reading of 12 volts DC should be seen. If no voltage here, check or replace diodes D1 and D2 (1N4004, all WPC version).
- If diodes D1/D2 are OK, replace Q2 (all WPC versions), a LM7812 voltage regulator.
- If the above still does not fix the problem, replace U20 (all WPC versions) on the CPU board (ULN2803). If U20 died "hard", it could also blow the 74LS374 at U14 (on WPC-95 it's U23, a 74HC237) on the CPU board.
- If the above still does not fix the problem, and the game has an under-the-playfield optic board, replace the LM339 chips on this board. Replace them all, and use sockets.
- If voltage is still not right, or BR1 (or diodes D11 to D14 on WPC-95) are REALLY hot, check all the TIP107 transistors on the power driver board. If these test good, check/replace the power driver board's ULN2803 at U19 (or U11 on WPC-95), or maybe the power driver board's 74LS374 at U18 (or U10 on WPC-95).

Also on WPC-S and prior games, connectors J114, J116, J117, J118 can be removed. Replace the fuse and power on the game. If the fuse blows, its corresponding bridge rectifier is most likely shorted and should be replaced. If the fuse doesn't blow, the problem is not in the circuit boards. Most likely a shorted wire, which can only be manually hunted down.

Burnt +18 Volt BR1 Bridge or WPC-95 Diodes D11-D14.

This problem is strange, but a lot more common than one might think. The +18 volt (lamp columns) bridge or WPC-95 diodes get excessively hot and burns. I've seen this where the driver board is black from the heat. This happens because the lamp matrix is demanding more power than the circuit is designed to handle. Eventually the associated fuse F114 or F106 (WPC-95) will blow. Note the BR1 bridge or WPC-95 diodes D11-D14 are probably OK. If these were bad, the fuse F114 or F106 (WPC-95) would blow immediately.

The reason for the burned bridge or diodes is simple; for some reason, one (or more!) of the lamp columns is stuck "on". Remember, the lamp matrix uses 12 volts, but this is derived by strobing (turning on and off very quickly) 18 volts. If a column locks on, instead of getting 12 volts, the full 18 volts is delivered. This added voltage puts stress on the lamp column circuit, and causes the +18 volt BR1 bridge or WPC-95 diodes D11 to D14 to get really hot (and their associated fuse to eventually blow).

To fix this, first check all the TIP107 column driver transistors (see the Checking Transistors section). If none of these transistors are shorted on, then next suspect the ULN2803 at U19 (or U11 on WPC-95), or maybe the 74LS374 at U18 (or U10 on WPC-95). If the TIP107 transistors are OK, the ULN2803 is probably the culprit. An easy way to tell if the lamp matrix has a problem is to notice the controlled lamps right when the game is turned on. If any playfield lamps flash on right at power-on, there may be a problem with the ULN2803 driver chip.

Exploding +20 volt C11 Capacitor (or C10 on WPC95).

There are cases when the +20 volt capacitor (Driver board C11 on WPC-S and prior, C10 on WPC-95) can just explode. This happens when a shorted flipper coil diode or shorted transistor on the Fliptronics board causes the 70 volt coil power to feedback into the 20 volt flashlamp circuitry. Because of reverse voltage, this blows the 20 volt capacitor. Also installing one of the ribbon cable connectors in the backbox on the header pins (top row of header pins to bottom row of housing) can do the same thing. And lastly, if connector J124 is mistakenly plugged into the driver board connector J128 (they are keyed alike!), this can cause capacitor C11 to explode.

First check the ribbon cable header pins to make sure they are attached correctly. Then check the flippers. If when the flippers are activated, one of the flashlamps dimly lights, there may be a bad flipper transistor on the Fliptronics board.

There is a preventive measure which can be taken for this. Install a blocking diode on the driver board ceramic 10 watt resistor R224 (or R9 on WPC-95). To do this on a WPC-S or earlier driver board, first remove the lower leg of resistor resistor R224 (the leg just above TP7). Connect the anode (non-banded end) of a 1N4004 (or 1N4007) diode to the resistor's leg. Then solder the cathode (banded side) of the diode back into the driver board (where one leg of R224 was removed). This will prevent the problem.

3e. When things don't work: Problems with Flippers

Flippers connect the player to the pinball game. Having perfectly working flippers is extremely important. Here are some common flipper problems and answers.

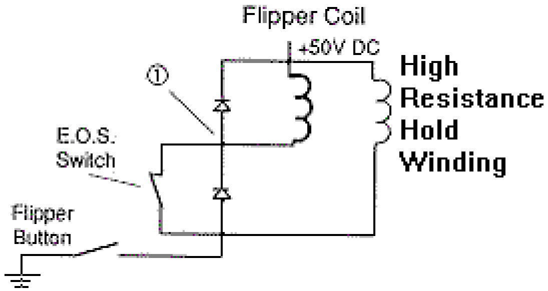
Remember, all flippers (regardless of the game) will have EOS (end of stroke) switches. This tells the CPU a flipper is at full extension. If this switch is broken, it could cause problems (depending on the WPC generation). Bad EOS switches should always be fixed.

How Flippers Work.

Flipper coils are actually two coils in one package. The "high power" side is a few turns of thick gauge wire. This provides low resistance, and therefore high power. The "low power", high resistance side is many turns of much thinner wire. This side of the coil is important if the player holds the cabinet switch in, keeping the flipper coil energized. The high power low resistance side of the coil is only active when the flipper is at rest.

To simplify how the two sides of a flipper coil work, it's best to examine the non-fliptronics version. In this case, when the flipper is energized and at full extension, the normally closed EOS switch opens. This removes the high powered side of the coil from the circuit. The low powered side of the flipper coil is always in the circuit, but is essentially ignored when the high powered side is in the circuit. This happens because the current takes the easiest path to ground (the low resistance, high power side of the coil). The low power high resistance side of the flipper coil won't get hot if the player holds the flipper button in.

A simplified drawing of the flipper circuit in non-fliptronic games.



EOS Switches: Normally Closed or Normally Open?

Pre-fliptronics games have a high voltage, normally closed end-of-stroke (EOS) switch. But Fliptronics flippers are basically an electronic (instead of mechanical) version of the above explained non-fliptronics flippers. The main difference is fliptronics flippers have EOS switches that are low voltage, **normally open** switches (instead of high voltage, normally closed as used on non-fliptronics flippers).

Is the problem Mechanical or Electrical?

Before diving into any flipper problem, identify if the problem is mechanical or electrical. For example, if a flipper gets stuck in the "up" position during a game, is it a mechanical binding problem, or an electrical problem? In this case it's simple to tell; just turn the game off! If the stuck flipper falls back to rest, the problem is electrical. If the flipper stays in the up position, it's a mechanical problem. Knowing this will help fix flipper problems.

Flipper Coil Numbers and Strength.

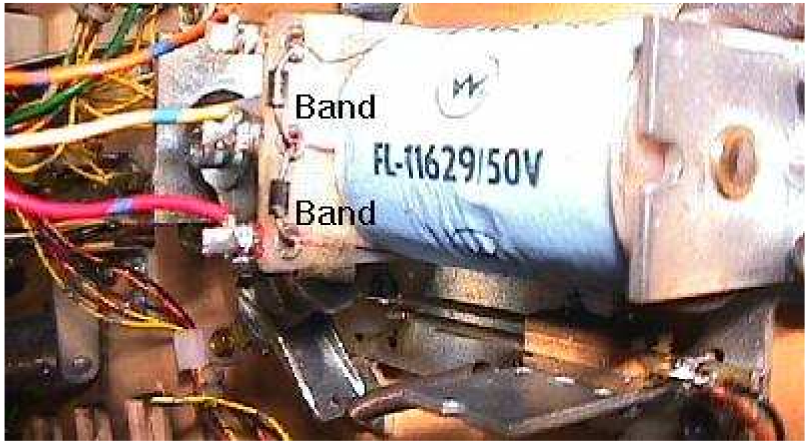
If there are problems with fliptronics fuses and fliptronics TIP36 and/or TIP102 transistors blowing, check the flipper coil resistance. Resistance is shown below so a questionable flipper coil may be tested. The upper measured ohms should be within 10% of the values below, and the smaller measured ohms should be within 3%. To measure flipper coil resistance, used a DMM with one lead on the center coil lug, and the other DMM lead on either outside coil lug. The high powered side of the coil is the low resistance. Note no WPC flipper coil should ever be lower than 3.8 ohms! If it is, it will blow flipper fuses and could ruin fliptronics driver transistor(s). Likewise the hold side of the flipper coil should never be below 120 ohms, or again fuses can blow and transistors may fail. The flipper coils are listed below from weakest to strongest.

- FL-11753: used for small flippers, like the "Thing" flipper on Addam's Family. 9.8 ohms/165 ohms. Usually a yellow coil wrapper.
- FL-11722: used for weak flippers, like Twilight Zone's upper right flipper. 6.2 ohms/160 ohms. Usually a green coil wrapper.

- FL-11630: “standard” flipper strength, as used on older games like Earthshaker, Whirlwind, etc. 4.7 ohms/160 ohms. Usually a red coil wrapper.
- FL-15411 : strong flipper, as used for main flippers on Addam’s Family, Twilight Zone, etc. 4.2 ohms/145 ohms. Usually an orange coil wrapper.
- FL-11629: strongest Williams flipper. Used on most of the newest WPC games. 4.0 ohms/132 ohms. Usually a blue coil wrapper.

Flipper Diodes.
All WPC games will have diodes attached at the flipper coil. Make sure these diodes are oriented like the ones pictured below.

*The coil diodes on a **Fliptronics** flipper coil. The red (bottom) wire is the “hot” wire. The yellow (middle) wire handles the initial hi-power ”flip”, and the orange (top) wire handles the flipper’s “hold”.*



Flipper Wire Colors.
From game to game, Williams often used a consistent set of wire colors for flipper wiring (unfortunately, this is not always the case, as seen in the picture above). In the picture below, the flipper coil lugs are labeled “lug1” to “lug3”. Here are the wire color break down for most games:

Lug 1 (outside banded diode lug, two winding wires, 50 volts):

- Lower Left flipper: Grey/Yellow
- Lower Right flipper: Blue/Yellow
- Upper Left flipper: Grey/Yellow
- Uppper Right flipper: Blue/Yellow

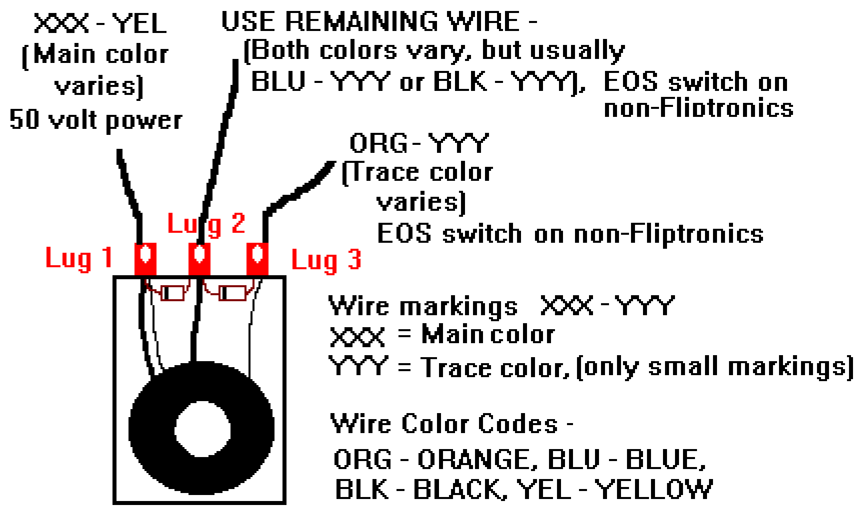
Lug 3 (outside non-banded diode lug, one winding wire):

- Lower Left flipper: Orange/Blue
- Lower Right flipper: Orange/Green
- Upper Left flipper: Orange/Grey
- Uppper Right flipper: Orange/Purple

Lug 2 (middle lug):

- Lower Left flipper: Blue/Grey
- Lower Right flipper: Blue/Purple
- Upper Left flipper: Black/Blue
- Uppper Right flipper: Black/Yellow

Fliptronics *flipper coil wiring. Note the wire color rules specified below are the "usual" wire colors (but can't be 100% guarenteed).*



The coil diodes on a ***Non-fliptronics*** *flipper coil. Note the solo center wire and the all blue wire on the top lug goes to the EOS switch and the 2.2 mfd 250 volt spark arresting capacitor (the EOS switch and capacitor are wired in parallel). The blue/yellow (lower) wire (or gray/yellow) is the "hot" wire. The blue/violet (upper) wire continues to the cabinet switch, the driver board relay, and ultimately ground.*

If the flipper(s) don’t work at all...
Non-Fliptronics Games:

- Check the flipper fuses on the driver board, fuses F101 and F102.
- Check for 50 to 75 volts at the flipper coil. Put a DMM on DC volts, and the black lead on ground (metal side rail of game). Put the red lead on any of the three lugs of the coil. It should be between 50 and 75 volts. No voltage means a fuse is blown, or a wire has broken going to the coil. If voltage is missing from one of the coil lugs, then the coil has a broken winding and should be replaced.
- Another way to test the flipper coil itself. To do this, turn your game on and leave it in attract mode. Attach an alligator test lead to ground (metal side rail of game), and momentarily touch the other end of the test lead to the middle lug of the flipper coil. The coil should activate.
- Also check the flipper coil with a DMM set to ohms. With the game turned off, try this:
    - Notice the three solder lugs for the flipper coil. The outside lug with the banded side of the diode connected has both the thick and thin wires connecting to it. This is the “common” lead.
    - Put one lead of the DMM on the outside common flipper lug.
    - Put the other lead of the DMM on the thick wire lug. Around 3 ohms should be seen. This is the high powered side of the coil.
    - Put the leads of the DMM on the thin wire lug of the coil. About 3 ohms should be seen until the flipper is manually moved to the full extended position, opening the EOS switch. Now about 125 ohms should be seen. Note if more than about 5 ohms is seen when the flipper is at rest in this test, the EOS switch is pitted and causing some resistance. Clean it for stronger flippers.
    - If the above readings are not seen, the flipper coil is bad. Typically the hold side of the coil goes bad more often that the power side.
    - Now put the leads of the DMM on each outside lug of the flipper coil. Around 3 ohms should be seen. This is the high powered winding of the coil. About 3 ohms should be seen until the flipper is manually moved to the full extended position, opening the EOS switch. Now about 125 ohms should be seen. Note if more than about 5 ohms is seen when the flipper is at rest in this test, the EOS switch is pitted and causing some resistance. Clean it for stronger flippers. If when the flipper bat is moved to the full energized position 125 ohms is not seen, the EOS switch is not opening, and the flipper coil will get hot and burn. If when the flipper bat is in the energized position there is no resistance, the hold side of the coil is bad (this happens more often that the power side going bad).
- On non-fliptronics games, clean the flipper cabinet switch contacts and the EOS switch contacts with a small metal file. Make sure this **normally closed** EOS switch is adjusted properly. The switch should open about 1/8” at the flipper’s end of stroke. If this switch is dirty or not closed, the flippers may not work at all.
- Test the flipper diode(s). To do this you’ll have to cut one lead of each diode off the coil lug. Then set the DMM to the diode setting. Put the black lead of the DMM on the banded side of the diode. About .4 to .6 volts should be seen. Reverse the leads and no reading should be seen. When done, re-attach each diode lead (or just put a new diode on!)

- Check the DPDT flipper engage relay on the driver board. When this relay is energized, it completes the ground path for all the flippers. Transistor Q99 (2N5401) controls this relay (if this transistor is shorted, the flippers will always work even when the game is over). There are also two jumpers W4 and W5 on the driver board which should NOT be installed (if these jumpers are installed, the flippers will always be activated, even when the game is over).

Fliptronics and WPC-95 Games:

- Check the flipper fuses on the Fliptronics board. On WPC-95, the flipper fuses are on the driver board.
- Use the internal WPC test software to test the flipper switches. Press the "test button", and go to "Test Switch Edges". A matrix chart will appear. The flipper switches are connected directly to the CPU board (on WPC-95) or the Fliptronics board (on earlier games) through direct switches, and not through the switch matrix (non-fliptronics games have the flipper switches and EOS switches wired directly to the flippers, and don't connect to any board). This means if the flipper button is pressed on any Fliptronics and later game, the circles on the right most column (outside the box) of the matrix should change to a square. Here is the order for that matrix column, from top to bottom:
    - Lower Right Flipper EOS switch
    - Lower Right Flipper button
    - Lower Left Flipper EOS switch
    - Lower Left Flipper button
    - Upper Right Flipper EOS switch
    - Upper Right Flipper button
    - Upper Left Flipper EOS switch
    - Upper Left Flipper button

  If the EOS switches aren't working on a Fliptronics or later game, check the continuity with a DMM from the switch to the CPU board (on WPC-95), or the Fliptronics board (on earlier games). On pre WPC-95 games, these direct EOS switches go to the Fliptronics board connector J906 and the flipper opto switches go to J905. On WPC-95 games, the direct EOS switches go to the CPU board connector J208 and the flipper switches go to CPU board connector J212. Non-fliptronics games have the flipper switches and EOS switches wired directly to the flippers, and don't connect to any board.

- On fliptronics games, if the flipper button doesn't register in the above test, check the flipper opto boards. Flipper opto boards were implemented on Addams Family, mid-production (some Addams have them, some don't). Also if the game uses plastic flipper opto activators, often these can warp. This will cause the activator to not clear the "U" shaped opto on the flipper opto board, causing a flipper to never energize!
- On fliptronics (before WPC-95) games, there can be a very rare and unusual problem with the fliptronics board. There is +50 volts power at the flipper coils (and the coils & diodes are good), but flipper switches just don't seem to work. This can be caused by a failed flipper switch input chip at location U5 (74HCT244) on the fliptronics board.

Optos are used on fliptronics flipper switches. Note the plastic activator arm that moves between the "U" shaped optos. Originally Williams made these from metal, but switched to plastic to save money. The plastic version can often warp so they don't clear the opto, causing a flipper not to work.

If the flipper button works fine in diagnostics, but the flipper doesn't work...

<u>All WPC Games:</u>

- Check for +50 volts at the flipper coil. Put the DMM on DC voltage. Put the black lead on ground (metal side rail of game). Put the red lead on either of the outside lugs of the coil. A reading of 50 to 80 volts on either lug should be indicated. No voltage means (the coin door is open on 1993 or later games or) a fuse is blown, or a wire has broken.
- Test the coil itself. To do this, turn the game on and leave it in attract mode. Then attach an alligator test lead to ground (metal side rail of game), and momentarily touch the other end of the test lead to the middle lead of the flipper coil. The coil should activate. This works on both Fliptronics and non-Fliptronic WPC games.
- Check the flipper coil with a DMM set to ohms. With the game turned off, try this:
  - Notice the three solder lugs for the flipper coil. One of the outside lugs has both a thick and thin coil winding attached to it. This is the "common" lead.
  - Put one lead of the DMM on the outside common flipper lug (the one with the thin and thick coil windings attached to it).
  - Put the other lead of the DMM on the middle lug. A reading of about 4 ohms should be indicated. This is the high powered side of the coil.
  - Put the leads of the DMM on the two outside lugs of the coil. For fliptronics games, a reading of about 125 ohms should be seen. For non-fliptronics games, a litle more than 4 ohms should be seen until the the flipper is moved manually to the full extended position, opening the EOS switch. Now about 125 ohms should be indicated.
  - If approximately these readings are not seen, the flipper coil is bad. Typically the hold side of the coil goes bad more often that the power side.
- Test the flipper diodes. To do this cut one lead of each diode off the coil lug. Then set the DMM to the diode setting. Put the black lead of the DMM on the banded side of the diode. A reading of .5 volts should be seen. Reverse the leads and no (null) reading should be shown. When done, re-attach each diode lead.

If the flipper works, but...

<u>Non-Fliptronics Games:</u>

- Any one of the flippers flutters (goes up, comes down, goes up, comes down), when the cabinet flipper button is held in (the flipper flutters slowly). On a non-fliptronics games, this is a problem with the EOS switch. The EOS switch for the offending flipper, which should be closed when the flipper is de-energized, is not making good contact. Either the switch contacts are misadjusted or burned, or an EOS switch wire is broken. Or it could mean the hold winding on the coil itself is broken. The hold winding on the coil is the thin wire. If it is broken, you can usually see the wire has broken away from one of the solder lug. Test the coil (see above) with a DMM. Sometimes the break can provide an intermittent connection too.
- Flipper flutter could also be the EOS switch is not adjusted properely. If the moving EOS switch blade does not have enough tension against the other switch blade, flipper flutter can occur. Sometimes adjusting the EOS switch with the game on and the flipper button held in is the best way (but be careful not to short the high voltage EOS to another switch!), because wear in the flipper linkages can give wrong EOS switch measurements when moving a flipper bat by hand. Also check the cabinet switches for proper tension and that they are clean. Lastly, try replacing the coil stop. A very worn coil stop can cause flipper flutter.
- Flipper seems to work fine, but gets very hot and eventually starts to burn and smell. Often the flipper will get stuck in the "up" position. On non-fliptronic games, the EOS switch contacts are not opening when the flipper is fully extended. Or the EOS switch capacitor has shorted on.
- Pre-Fliptronics WPC game's lane change doesn't work. This is almost always driver board chips U7 (left flipper) or U8 (right flipper) which are the 4n25 opto isolators. Note on later Fliptronics games these chips were no longer used and were removed from the driver board, along with the flipper relay.

<u>Fliptronics and WPC-95 Games:</u>

- When activated, doesn't hold up (the flipper "flutters"). This means the hold TIP102 transistor for that flipper is bad, or the hold winding on the coil itself is broken. The hold winding on the coil is the thin wire. If it is broken, usually the wire has broken away from one of the solder lugs (the middle lug should have both the thick and thin wire attached to it). Test the coil first (see above) before replacing the transistor.
- Flipper coil gets really hot after playing the game for a while. This is often a dirty flipper optic on the flipper board next to the flipper buttons. It could also be a bad LM339 chip at U4 and/or U6 on the Fliptronics board (or U25/U26 on a WPC-95 CPU board). An easy way to see if it's the LM339 chip or the optics is to swap the two flipper optic boards, and see if the problem changes to the other flipper. A dirty flipper switch "U" optic can essentially cause the flipper button to automatically turn on and off quickly (even when the player is not pressing the button), making the flipper coil warm.
- Flipper seems to work fine, but gets very hot and eventually starts to burn and smell. Often the flipper will get stuck in the "up" position. On Fliptronics/WPC-95 games, the hold TIP102 transistor for that flipper is shorted on, and needs to be replaced.
- When a game is started, all the flippers activate for a moment, then go dead. This can be caused by having the flipper switch board connectors removed from the Fliptronics (or CPU board on WPC-95). With the connector removed, the game thinks all the flipper buttons are pressed. The flippers go dead because the secondary 50 volt power fuse blows.
- The flipper stays up for a moment after the flipper button is released. This happens on fliptronic and later games that have plastic activators which activate the flipper board optos. Sometimes the plastic's elasticity is lost, causing it not to spring back quickly when the button is released. Replace this plastic flipper activator. A temporary solution is to stretch a rubber band across the back of the plastic activator for additional tension. Flipper opto boards were implemented on Addams Family, mid-production (some Addams have them, some don't).
- Flippers work fine, but the flipper buttons do not work in video mode or high score entry mode. On games with flipper optic switch boards, there are two "U" shaped optic on each board. Games with 2 or 3 flippers often use one of the two "U" optics for the flippers, and the other for video mode and high score entry. This problem could be caused by this second "U" optic being bad, dirty, or there is a problem with the plastic activator not clearing the second "U" optic.

If one or both flippers are weak...

<u>Non-Fliptronics Games:</u>

- Rebuild the flippers. Play and wear in the flipper parts is the primary reason for weak flippers. A mushroomed flipper plunger dragging against the coil sleeve is a classic cause of weak flippers.
- Make sure there is about 1/16” up and down play on the flipper. To test this, from the top of the playfield, grab the plastic flipper and pull up. There should be some play. If not, the flipper could be binding on the nylon playfield insert. This gap is adjustable from under the playfield by changing the flipper pawl’s grip on the flipper shaft.
- Make sure the EOS (end of stroke) switch is properly adjusted. On non-fliptronics games, the EOS switch should open no more than 1/16” to 1/8” at the end of the flipper stroke. If the EOS switch is misadjusted, this can cause a slightly weaker flipper on old and new WPC games.
- On non-fliptronics games, file clean the EOS switch contacts and the cabinet flipper switches. These are high-voltage tungsten switch contacts, and a metal file will be needed to clean them. These switch contacts often become pitted and tarnished, and resistance develops, weakening flippers.
- Check the flipper power connections. On non-fliptronics games, this is connectors J109 and J110 on the power driver board. Make sure the solder joints on these board header pins are not cracked, and that the connector and header pins are in good shape.
- Check the bridge and capacitor that supplies voltage for all coils (BR3 and C8). An open diode in the bridge rectifier that supplies power to the flippers can cause weak flippers. A fatigued or cracked solder joint on this bridge (or its associated capacitor) can do that too. Soldering jumper wires from the bridge to its associated capacitor is a good idea. This is rare, but does happen. This problem will effect BOTH flippers equally. See the section, Testing Bridge Rectifiers for more information.

Fliptronics and WPC-95 Games:

- Rebuild the flippers. Play and wear in the flipper parts is the primary reason for weak flippers. A mushroomed flipper plunger dragging against the coil sleeve is a classic cause of weak flippers.
- Make sure there is about 1/16” up and down play on the flipper. To test this, from the top of the playfield, grab the plastic flipper and pull up. There should be some play. If not, the flipper could be binding on the nylon playfield insert. This gap is adjustable from under the playfield by changing the flipper pawl’s grip on the flipper shaft.
- Make sure the EOS (end of stroke) switch is properly adjusted. On games with electronic flippers (fliptronics), the EOS switch should close right at the end of stroke, and not prematurely. If the EOS switch is misadjusted, this can cause a slightly weaker flipper on old and new WPC games.
- On WPC fliptronics and later games, try cleaning the “U” shaped optics on the cabinet flipper opto boards. Use a Q-tip and some Windex to clean them. Also make sure the opto activator bars fully clear the optos when the cabinet switch is pressed. If one weak flipper still exists, try swapping the cabinet flipper opto boards (remember, both flipper boards must be plugged in for this to work!). If the weak flipper problem moves to the other flipper, the opto board’s optic has become faulty, and it will need to be replaced with a new “U” shaped optic. A marginal cabinet flipper board optic, even if clean, can cause a weak flipper. Replace if in doubt. Also check the opto switch with your multimeter. With the game on and your meter set to DC volts, on the flipper opto board measure the connector pin marked SW1 and SW2 against ground. A measure of below 0.7 volts (below 1V is OK) should be shown, with the button pressed. A higher reading means a dirty or defective opto switch. If cleaning does not remedy the problem, replace the opto switch. NOTE Later WPC-95 pinballs use a Schmitt Trigger opto switch (3 legs on the receiver, 2 on the transmitter) which eliminates this problem. The Schmitt trigger optos will not oscillate (turn on and off quickly, making the flipper weak) when the optics gets dirty. They usually either work, or don’t work.
- On WPC fliptronics to WPC-S, replace the U4 and/or U6 LM339 chips on the Fliptronics board. On WPC-95 games, replace U25 and/or U26 on the CPU board (since these games don’t have fliptronics boards). Although these don’t fail often, then can cause weak flippers. See “WPC Fliptronics Flipper Optos” in the switch matrix section for more details.
- Check the flipper power connections. On WPC fliptronics to WPC-S games, this is connector J907 and J902 on the fliptronics board. On WPC-95 this is connectors J119 and J120 on the power driver board. Make sure the solder joints on these board header pins are not cracked, and that the connector and header pins are in good shape.
- On WPC fliptronics to WPC-S games, check the fliptronics board bridge rectifier (BR1). On non-fliptronics games, check the bridge and capacitor that supplies voltage for all coils (BR3 and C8). An open diode in the bridge rectifier that supplies power to the flippers can cause weak flippers. A fatigued or cracked solder joint on this bridge (or its associated capacitor) can do that too. Soldering jumper

wires from the bridge to its associated capacitor is a good idea. This is rare, but does happen. This problem will effect BOTH flippers equally. See the section, Testing Bridge Rectifiers for more information.

While playing a game, a flipper gets weaker and weaker. The longer the machine is left on, whether playing or not, the flipper will still get weaker until it won't work at all...

Fliptronics and WPC-95 Games:

- Dirty optic switches on the flipper board can cause this. Try cleaning them with Windex and a Q-tip.
- Failing optic switches on the flipper optic board can cause this too. Try swapping the left and right flipper boards. See if the problem switches to the other flipper. Remember, both flipper boards must be plugged in for this to work!
- On WPC fliptronics to WPC-S games, failing LM339 voltage comparators at U4 and/or U6 on the fliptronics board. On WPC-95 games, replace U25 and/or U26 on the CPU board (since these games don't have fliptronics boards). Although these don't fail often, they can cause weak flippers. Do this as a last resort. See "WPC Fliptronics Flipper Optos" in the switch matrix section for more details.

Flipper coil gets very hot...

Non-Fliptronics Games:

- Check the EOS switch to make sure it is adjusted properly, and that the contacts are clean and filed. The EOS switch should open 1/16" to 1/8" when the flipper is fully extended (on non-fliptronics games).

Fliptronics and WPC-95 Games:

- On WPC fliptronics and later games, if there is a marginal flipper switch reading, this causes the high powered side of the flipper to rapidly oscillate between on and off. The holding side of the flipper coil never engages. This problem will cause the flipper coil to get very hot in a short time. First try cleaning the flipper board optics. If this doesn't work, the LM339's on the Fliptronics board at U4 and/or U6 (or CPU board on WPC-95 at U25 and/or U26) will need to be replaced.
- Bad regulation of the 12 volt power to the optos can cause the flipper coils to get hot too. Though rare, the 7812 voltage regulator on the power driver board could be failing, or the electrolytic filter capacitor for the 12 volts.

Flipper gets stuck in the up position...

If the flipper is stuck in the up position, turn the game off. If the flipper falls back, the problem is electrical. If the flipper stays up, the problem is mechanical.

Mechanical "Stuck Up" Problem:

- Check the EOS switches and the flipper pawl. Often the rubber coating on the flipper pawl that contacts the EOS switch will wear. This causes the flipper pawl to hang up on the end of the EOS switch. The end of the EOS switch can even get torn and fray from this. See "Rebuilding Flippers" for information on fixing this. Also if the flipper coil stop get mushroomed, this will increase the flipper plunger travel. This will make it easier for the flipper pawl to stick on the EOS switch.
- Flipper too tight inside the playfield flipper bushing. This causes binding between the playfield bushing and the flipper crank assembly. There should be about a 1/32" gap. If the flipper paddle doesn't have any vertical movement, it's too tight. Use the flipper adjustment tool included with the game to fit this (see rebuilding flippers for more info).
- Check the flipper return spring. Is it broken or missing?

Electrical "Stuck Up" Problem:

Non-Fliptronics Games:

- Make sure the cabinet flipper switch is adjusted properly, and not stuck closed.

Fliptronics and WPC-95 Games:

- Flipper cabinet switch is bad. On games with opto flipper cabinet switches, check the two opto boards. A bad or dirty opto can cause this problem. Flipper opto boards were implemented on Addams Family, mid-production (some Addams have them, some don't). On pre-opto flipper switch WPC games, check/clean the mechanical cabinet flipper switch.
- Flipper gets very hot and eventually starts to burn and smell. This means the hold TIP102 transistor for that flipper is shorted on, and needs to be replaced.
- Flipper immediately energizes and stays up when a game is started or when the game is tured on (assuming the coin door is closed). The flipper's TIP36 transistor that controls the high voltage side of the coil is shorted on, and needs to be replaced. And/or the flipper's TIP102 transistor that controls the "hold" side of the coil is shorted on, and needs to be replaced. (Usually it's usually pretty easy to tell if the TIP36 or TIP102 is shorted. If the TIP36 is shorted, the flipper comes up very hard when powered on. If the TIP102 is shorted, the flipper usually, but not always, comes up slower, and sometimes not at all. But test both transistor, as **both** or **either** could be bad.)
- Addams Family ONLY: The Addams Family pinball was the first Williams solidstate "fliptronics" game. It was the only game to use a "Fliptronics I" board (all later games used a "Fliptronics II" board). The Fliptronics I board has a unique personality. If both diodes on the right flipper coil (upper or lower) are missing or broken, as soon as the right flipper cabinet button is pressed in a game, both right flippers will stick in the "up" position. The right flippers will not release until the left flipper cabinet button is pressed! Note this MAY also happen if one diode on each right flipper coil is bad too. This problem can also happen to the left flipper, and is still related to coil diode failure. To fix this, check both right flipper coils and make sure the diodes are not broken or missing. Also make sure the left flipper coil's diodes are present and not damaged. Finally, sometimes a bad flipper diode will cause the Fliptronics I board's TIP102 hold transistor to fail. If the problem still exists after replacing the diodes on all the flipper coils, check the TIP102 hold transistor on the Fliptronics board.

Flipper problems should be addressed by at least one of the above.

3f. When things don't work: the Lamp Matrix

Lights controlled by the CPU (not the General Illumination lights), are controlled in a similar fashion as a switch matrix. That is, there are eight lamp rows, and eight lamp columns. This gives a total of 64 CPU controllable lamps. These lamps are powered by +18 volts DC. This voltage is strobed (turned on and off very quickly), and hence the final power to the lamps is about 6 volts.

The lamp columns are controlled by TIP107 transistors that switch the +18 volts on and off many times within a second. The lamp rows are controlled by TIP102 transistors that switch the ground on and off. Because the TIP107's source the current (instead of sinking the ground like a TIP102), lamp column TIP107 transistors go bad more often than TIP102 lamp row transistors.

Non-Working Lamps.

If certain individual lamps do not work (but others do, indicating the lamp matrix is functioning), there are several things to check. If the lamp is mounted in a standard socket, these sockets can become "loose" and go bad. A "loose" socket allows air (and moisture) to get between the parts, causing corrosion. Also the wires going to lamp socket are "daisy chained" from other sockets. Did a lamp wire break "up stream"?

Circuit board mounted lamps have different problems. The most common is cracked header pins on lamp circuit board. The connector header pins soldered to the lamp's circuit board can crack right at the board. Resoldering the header pins can fix this. Also the diodes can break on the circuit board. For circuit board mounted 555 lamps, this can happen due to vibration. This will make the lamp not function. Finally, check the IDC (Insulation Displacement Connector) on the lamp circuit board. These can have problems too.

Overly Bright Lamps.

When a transistor or diode goes bad, generally it shorts on. If a transistor shorts on in the lamp matrix, it can make all the lamps in that row or column appear permanently on, and be very bright. It can also make lamps that flash on and off appear brighter too. This happens because the lamp matrix is actually +18 volts that is continually turned on and off, a row or column at a time. This nets a lower +6 volts that the lamps require. The lamps are never allowed to get full brightness at +18 volts before being switched off. If a transistor has shorted on, a row or column of lamps will be turned on for a longer time, and hence be brighter.

All the computer controlled lamps in the lamp matrix should flash in attract mode, or in the "All Lamps Test" diagnostic test. If a number of lamps are just on (and they aren't general illumination lamps), there may be a lamp matrix transistor problem.

If a number of lamps are out, check the bulbs and fuses first. If a number of lamps are stuck on, check the game manual and see if they are in the same row or column. If so, test the individual transistor (see the Testing Transistors and Coils section) before replacing it.

No Lamp Matrix Lights Work, or are Confused.

If none of the lamp matrix lights are working, the obvious thing to check is the fuse. If the +18 volts is missing, none of the lamp matrix lights will work and the 18 volt LED will not be lit. This is powered through bridge BR1, fuse F114, LED6, and test point TP8 (on WPC-95 games diodes D11-D14, fuse F106, LED102, and TP102).

What if the fuse is good (which would indicate the bridge/diodes are good), the LED is lit, and the test point shows 18 volts DC? Yet the lamp matrix lights don't work, or are "confused"? With the power off, reseat the short ribbon cable that goes between the CPU and driver board (this will clean the connectors on this ribbon cable). Often this simple approach will solve the problem.

Lamp Matrix Fuse Keeps Failing (F114 or F106 on WPC-95).

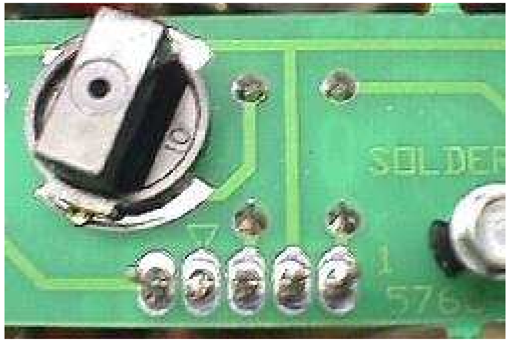
If the lamp matrix 18 volt fuse keeps blowing (F114 or F106 on WPC-95), isolate the lamp matrix power from the rest of the game. This will determine if there is just a simple short or bad diode on the playfield, or if there is a bad rectifying bridge or diode on the power driver board.

On WPC-S and earlier, remove connectors J133-J138. On WPC-95, remove connectors J121-J126. Replace the blown fuse, and power the game on. If the fuse blows, the problem is probably a bad bridge BR-1 (WPC-S and prior) or bad diode D11-D14 (WPC-95). See the Game Resets (Bridge Rectifiers, Diodes and Caps) section of this document for testing or replacement.

If the fuse does not blow with the game powered on, replace the removed connectors one at a time. When the fuse blows, you have isolated the problem to the connector just installed. Most likely there is a playfield lamp socket shorted. Or if new bulbs were just installed, there may be a new bulb that is shorted (yes this does happen). Either way, the wires from the connector just installed can be traced, and the short located.

Left: *#44/47 lamp, socket and the orientation of the diode. Note the banded end of the diode goes to the "middle" lamp lug. The non-banded end goes to the lamp's tip lug.*
Right: *The playfield socket used for 555 lamps. The small metal tabs on the outside of the socket often get bent. This prevents a good connection to the board on which they plug. Bend them back for better contact.*

Left: *the component (lamp) side of a lamp board. Note the 1N4004 diodes mounted to the board, and the use of 555 bulbs. The diodes can crack if soldered too tightly to the board, causing the bulb to not work.*
Right: *the solder (socket) side of a lamp board. Note the Molex header pins soldered here. Often these Molex pin solder joints crack or become fatiqued, preventing the lamp(s) from working.*



Testing a diode on a lamp socket circuit board. The black lead is on the banded side of the diode.

Lamp Diodes (Lamps that don't work or work "twice").
Each CPU controlled lamp will have a diode associated with it. If this diode is bad (shorted on), it will cause other lamps in that row or column (or even another row or column) to turn on. This can usually be seen in the "All Lamps Test". The faulty row or column will light **twice** in a single lamp matrix sweep (once when it should be on, and a second time due to the short on **another** row or column re-lighting it). The lamp(s) in question are on twice as long as all the other CPU controlled lamps.
Another way to test this is to use the "Single Lamp" test. If two different lamps are on for a single lamp test, there may be a short, a bad diode, or a bad transistor.
If a lamp diode has broken (become open), or is disconnected from the lamp socket, its lamp will not light. Broken diodes can happen on circuit board mounted lamps (555 style bulbs). If the diode was inserted and soldered into the circuit board "tightly", the diode can crack due to mechanical stress and vibration. During the soldering process, the diode body can elongate slightly. When it cools, the diode shrinks back, adding more stress. If there's no other place for that stress to be dissipated, the diode body is the weakest link, and it can crack.

Two Lamps On Instead of One.
If a lamp diode is shorted on (or installed incorrectly), a bad TIP107/TIP102 transistor, or just a short on the playfield lamp matrix, can cause two lamps to act as one. This can be seen in the "Single Lamp Test". Each individual lamp in the lamp matrix (as displayed on the screen) should flash. The "+" and "-" buttons will move the test from one lamp to another. If TWO lamps flash in this test instead of just one, suspect this lamp has having a bad or mis-installed lamp diode, or it's associated TIP107/TIP102 transistors as bad, or just a short between two row or column wires.
It is pretty easy to tell which problem it is. First reference the game manual, and figure out which rows/columns are the problem. To do this, note all the lamps that "double light", and see what row/column they occupy. A pattern should be seen, with the double lights being all in the same row or column. As shown in the previously mentioned Transistor Testing section, test the related TIP107 and TIP102 transistors (as indicated in the manual for the related rows/columns) for a problem.
If that checks out OK, next look for a short and/ or bad lamp diode on the playfield. This is easy to test; just remove the lamp matrix plugs from the power driver board (these connections are shown a few paragraphs below). Using the DMM set to ohms, see if the associated row/column wires are shorted to each other on the disconnected lamp matrix plugs (not on the driver board!). If two lines buzz out with zero ohms, there is a short or bad diode on the playfield somewhere. Shorts happen often from solder drips when someone resolders a coil under the playfield. These solder drips often land on the lamp boards under the playfield, on the header pins, shorting two together.
Testing a Lamp Diode.
In order to test a lamp diode, use the DMM set to diode test. Put the black test lead on the banded side of the diode. A reading of .4 to .6 volts should be indicated. Reverse the leads and put the red lead on the banded side of the diode. A null reading should be shown. Any other reading and this lamp's 1N4004 diode should be replaced. The light bulb doesn't need to be removed, nor does the diode need to be desoldered to perform this test. Also test the diode soldered to the circuit boards that hold the 555 lamps in the same manner (but remove the connector and the 555 lamp before testing).
Common Connectors.
There are several lamp matrix connectors which are common on the power driver board. Here are the breakdowns:
WPC and WPC-S

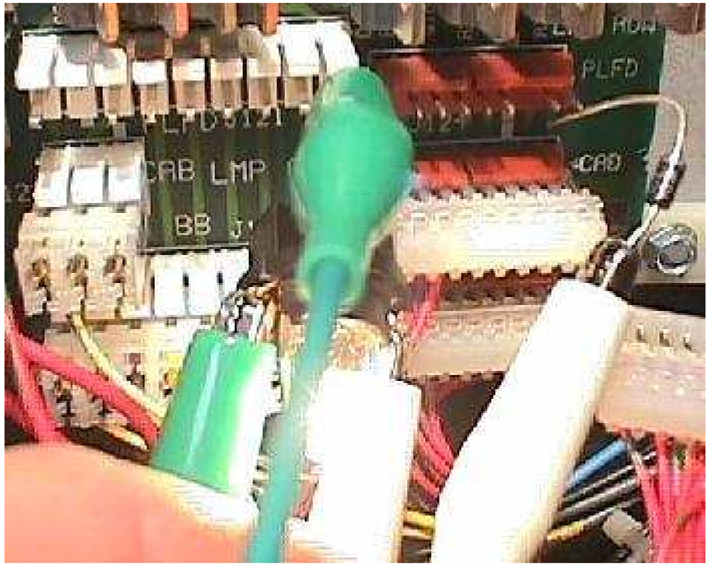
- J133, J134, J135 = Lamp Rows (all wired identical)
- J137, J138 (large plug), J136 (small 3 pin plug) = Lamp Columns (J137, J138 wired identical)

WPC-95

- J124, J125, J126 = Lamp Rows (all wired identical)
- J121, J123 (large plug), J122 (small 3 pin plug) = Lamp Columns (J121, J123 wired identical)

With this in mind, on a WPC-95 game for example, connectors at J124 and J125 and J126 can be mixed up, because they are plug compatiable.

*Testing the lamp matrix **rows** using two test leads, a 555 socket (pulled temporarily from the playfield), and a 1N4004 diode on a WPC-95 game. One test lead is attached to column connector J121 pin 1 (J137 on WPC-S and prior) on the driver board, and is stationary. The other end is attached to the light socket. Another test lead is connected to the second lead of the lamp socket. A diode is clamped into the other end of the test lead. Then the **banded** side of the diode is touched to each pin of row connector J124 (J133 on WPC-S and prior). The "all lamps" test should flash the lamp for each pin.*



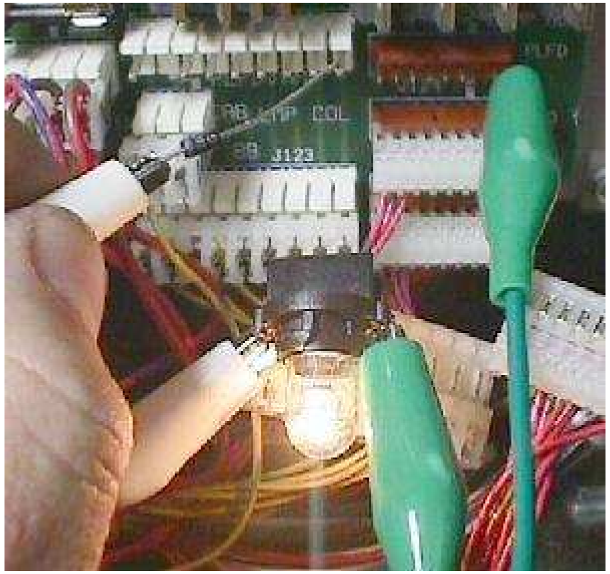
Testing the Lamp Rows.
If a TIP102 transistor that drives a lamp row is suspected as bad, test it:

1. Remove the backglass and fold down the display to gain access to the Driver board.
2. Turn the game on.
3. After the game boots, press the "Begin Test" button in the front door. Go to the Test menu's "All Lamp Test" test.
4. Unplug the row connectors at J133 (or J124 on WPC-95) and column connector at J137 (or J121 on WPC-95). These are on the lower right portion of the Driver board.
5. Connect an alligator test lead to column connector pin 1 of J137 (or J124 on WPC-95). Pin 1 is the right most pin, as facing the board.
6. Connect the other end of this test lead to one lead of a 555 light socket. One can be temporarily borrowed from a playfield lamp (make sure it's a working lamp first!).
7. Connect another test lead to the second lead of the 555 light socket.
8. On the other end of the test lead, clip on a 1N4004 diode, with the non-banded end away from the alligator lead.
9. Touch the non-banded end of the diode to row connector J133 (or J124 on WPC-95) pin 1. Again, pin 1 is the right most pin, as facing the board.
10. The lamp should flash.
11. Move the diode/alligator lead on row connector J133 (or J124 on WPC-95) to the next pin. Again, the lamp should flash.
12. Repeat the previous step, until the last pin of row connector J133 (or J124 on WPC-95) is reached.

If a lamp row tested doesn't give a flashing test lamp, that row is bad (or the test diode is reversed!). No light or a non-flashing, bright lamp are signs that the respective TIP102 row transistor is bad. Test the transistor as described in Testing Transistors and Coils.

*Testing the lamp matrix **columns** using two test leads, a 555 socket (pulled temporarily from the playfield), and a 1N4004 diode on a WPC-95 game. One test lead is attached to row connector J124 pin 1 (J133 on WPC-S and prior) on the driver board, and is stationary.*
The other end is attached to the light socket. Another test lead is connected to the second lead of the lamp socket. A

*diode is clamped into the other end of the test lead. Then the **non-banded** side of the diode is touched to each pin of column connector J121 (J137 on WPC-S and prior). The "all lamps" test should flash the lamp for each pin.*



Testing the Lamp Columns.
If a TIP107 transistor that drives a lamp column is suspected as bad, test it:

1. Remove the backglass and fold down the display, to gain access to the Driver board.
2. Turn the game on.
3. After the game boots, press the "Begin Test" button in the front door. Go to the Test menu's "All Lamp Test" test.
4. Unplug the row connectors at J133 (or J124 on WPC-95) and column connector at J137 (or J121 on WPC-95). These are on the lower right portion of the Driver board.
5. Connect an alligator test lead to row connector pin 1 of J133 (or J121 on WPC-95). Pin 1 is the right most pin, as facing the board.
6. Connect the other end of this test lead to one lead of a 555 light socket. One can be temporarily borrowed from a playfield lamp (make sure the lamp works first!).
7. Connect another test lead to the second lead of the 555 light socket.
8. On the other end of the test lead, clip on a 1N4004 diode, with the banded end away from the alligator lead.
9. Touch the banded end of the diode to column connector J137 (or J121 on WPC-95) pin 1. Again, pin 1 is the right most pin, as facing the board.
10. The lamp should flash.
11. Move the diode/alligator lead on column connector J137 (or J121 on WPC-95) to the next pin. Again, the lamp should flash.
12. Repeat the previous step, until the last pin of column connector J137 (or J121 on WPC-95) is reached.

If a lamp column tested doesn't give a flashing test lamp, that column is bad (or the test diode is reversed!). No light or a non-flashing, bright lamp are signs that the respective column TIP107 transistor is bad. Test the transistor as described in Testing Transistors and Coils.
Most Common Problems with Lamps.

- Bad bulb. Any light bulb can burn out. Often it can visually be seen the bulb is burnt, but sometimes it can't. Test the bulb with the DMM, set to continuity. Put the test leads on the bulb. No continuity, and the bulb is bad.

- Wire broken away from the socket. This happens quite often and requires re-soldering the wire back to the socket lug. On lamp sockets, wires are "daisy chained" from other sockets. Did a wire break "up stream" in the chain?
- Cracked header pins on circuit board mounted lamps. The connector header pins soldered to the lamp's circuit board can crack. Resoldering the header pins can fix this.
- Diode broken away from the socket. If the lamp diode becomes disconnected from its socket, the lamp will not light.
- Diode broken on the circuit board. For circuit board mounted 555 lamps, the diode can fail due to vibration. This will make the lamp not function.
- Corroded or Bad Socket. Re-seating the bulb in its socket can sometimes fix this problem, but often replacing the socket is the only choice. On 555 plug-in sockets, bend the contact tabs slightly for better contact.
- Blown Fuse. If several lights don't work, check the fuse associated with them.
- Burned Connector on the Driver board. This happens most often with GI (general illumination) lamps. See Burnt GI Connectors for more info.
- Bad Column Transistor. The TIP107 transistors that control the lamp matrix columns often fail. If this is the case, all the lamps in a particular column will be brightly locked on, or can turn on and off much brighter than other lamps.
- Two Lamps act as One. If a lamp diode has a shorted on, this can cause two different lamps to act as one. A bad TIP107 transistor can cause this too.

Burnt +18 Volt BR1 Bridge or WPC-95 Diodes D11-D14.

This problem is strange, but a lot more common than one might think. The +18 volt (lamp columns) bridge or WPC-95 diodes get excessively hot and burns. I've seen this where the driver board is black from the heat. This happens because the lamp matrix is demanding more power than the circuit is designed to handle. Eventually the associated fuse F114 or F106 (WPC-95) will blow. Note the BR1 bridge or WPC-95 diodes D11-D14 are probably OK. If these were bad, the fuse F114 or F106 (WPC-95) would blow immediately.

The reason for the burned bridge or diodes is simple; for some reason, one (or more!) of the lamp columns is stuck "on". Remember, the lamp matrix uses 12 volts, but this is derived by strobing (turning on and off very quickly) 18 volts. If a column locks on, instead of getting 12 volts, the full 18 volts is delivered. This added voltage puts stress on the lamp column circuit, and causes the +18 volt BR1 bridge or WPC-95 diodes D11 to D14 to get really hot (and their associated fuse to eventually blow). To fix this, first check all the TIP107 column driver transistors (see the Checking Transistors section). Also see the next section too, on problems other than the transistors.

All the Lamp Transistors are Good, so What's Next?

If none of the lamp matrix transistors have failed, then next suspect the ULN2803 (U19 or U11 on WPC-95), or maybe the 74LS374 (U18 or U10 on WPC-95). If the TIP107 transistors are OK, the ULN2803 is probably the culprit. An easy way to tell if the lamp matrix has a problem is to notice the controlled lamps right when the game is turned on. If any playfield lamps flash on right at power-on (and the lamp matrix transistors are good), there may be a problem with the ULN2803 driver chip.

If the lamp matrix still does not work, the next thing to check are the LM339 chips at U15/U16 (or U16/U17 on WPC-95). If one of these LM339 chips are bad, part of the lamp matrix will not work. If the entire lamp matrix is not working, also check resistors R150-R153/R172-R173 (or R225, R228, R231, R234, R237, R240 on WPC-95) for proper ground, as one side of all these resistors are tied to ground. Likewise, capacitors C13-C20 (or C32-C39 on WPC-95) are also tied to ground.

3g. When things don't work: the Switch Matrix

When a switch closes, it informs the CPU to score points, award a feature, and/or to activate a solenoid. If a switch is stuck closed for a coil (such as a pop bumper switch), the CPU will ignore this switch. Therefore the pop bumper will not work.

If a switch is not activated in some number of games, or is permanently closed (when it should be open), the switch is assumed to be bad. This will create a test report, which is shown when the game is turned on (that obnoxious "beep beep" at power-on), or when the coin door test "enter" button is pushed, going to diagnostics. If a particular feature of a game is difficult to score, it's associated switch may be (falsely) assumed bad (if not activated in a number of games). To correct the test report, remove the playfield glass, and activate the switch by hand within a game, or within the diagnostics switch edge test.

All switches on a WPC game (except for the direct switches, which includes flipper, EOS, and test button switches, which are in columns out side the 8x8 playfield matrix) are in the "switch matrix". The switch matrix on a WPC game is controlled by eight switch columns, and eight switch rows. the cross-section of any row and column designates any one of the potential 64 different switches.

The Chips that Control the Switch Matrix.

The switch columns are controlled by a single 18 pin ULN2803 chip on the CPU board at position U20. The switch rows are controlled by two LM339 chips on the CPU board at positions U18 and U19. The direct switch rows are controlled by two LM339 chips on the CPU board at positiion U16 and U17. These chip designations apply to all WPC generations.
On WPC-S and WPC-95 games, the ULN2803 that controls the switch columns on the CPU board is socketed. On all other WPC games up to 1994 this chip is not socketed. When a series of switches goes out, it tends to be the ULN2803 at U20 (all WPC revisions) that fails. Williams recognized this, and started socketing this chip with WPC-S. On WPC-S CPU boards, the ULN2803 chip is underneath the battery sub-board. ULN2803 is equivalent to NTE2018. If U20 dies “hard”, it could also blow the 74LS374 at U14 (on WPC-95 it’s U23, a 74HC237) on the CPU board.
The LM339 chips that control the switch rows at U18 and U19 (all WPC revisions) tend to fail less often. LM339 is equivalent to NTE834. There are also two more LM339 CPU board chips at U16 and U17 (all WPC revisions). These two chips control the direct switches (coin door, diagnostics, etc). These do not fail often either.
There are also often LM339 chips used on the under-the-playfield optic board (if the game has one). If any one of these LM339 chips fail (common), the switch matrix will be confused. When there is a switch problem that can not be diagnosed, replace all the LM339 chips on the under-the-playfield optic board, and use sockets.

The Switch Matrix Power and its Fuse.

If fuse F115 (WPC-S or earlier) or fuse F101 (WPC-95) opens (blows), the switch matrix will not work (and hence none of the playfield switches will work). This fuse supplies the (regulated!) +12 volts needed to operate the switch matrix.

Check TP3 (TP100 on WPC95) on the Driver board for +12 volts.

Again, if the regulated 12 volts is not getting to the CPU board, the switch matrix will not work (*none* of the switch matrix will work). Using the DMM multi-meter set to DC volts, check for +12 volts at TP3 (test point 3, TP100 on WPC95) on the driver board (while the game is on and in attract mode). If +12 volts isn’t there, the switch matrix will never work. Also if this 12 volt test point fluctuates to under 11 volts, the switch matrix could exhibit some wacky behavior.
If 12 volts is not at the test point, back up to TP8 (TP102 on WPC95) and check for +18 volts DC. This comes right from BR1 (D7-D10) where the AC transformer voltage is rectified to DC. Also check for +18 volts at the “+” lead of bridge rectifier BR1 (the “indented” lead of the bridge) on the driver board (WPC-S and before). Occassionally the solder joints on this bridge will fail, therefore not providing +12 volts to the switch matrix (see the “Game Resets” section of this document, and solder jumper wires under the board as shown in that section). If 18 volts is there, but there is no +12 volts at TP3/TP100, the next part to suspect is the 12 volt regulator at Q2 (LM7812), or a bad circuit board trace leading to the voltage regulator Q2.

Wacky Switch Matrix due to Low 12 volts.

On some WPC games, in particular Theatre of Magic, a weak BR1 or weak 7812 voltage regulator on the power driver board can cause some wacky switch matrix problems. For example, if the game is doing a “slam tilt” or randomly firing the slingshots or flippers or other coils, the power to the switch matrix may be weak. The 12 volt fluctuation for the switch matrix can often be seen when many of the feature lamps are on. Try removing connector J133 (disabling the playfield controlled lamps) and see if the problem goes away. If it does, rebuild the 12/18 volt power secition (BR1, C6, C7, the Q2 7812 voltage regulator), and install jumper wires from BR1 to its associated filter caps (as described in the reset section). This bridge rectifier and voltage regulator supply the power for the switch matrix.

Wacky Switch Matrix due to Ribbon Cables.

The ribbon cables that connect the CPU board to the driver board, fliptronics board, sound board and DMD display board can cause some wacky game behavor. often goofy things are due to the ribbon cables, particularly on games like Terminator2, Star Trek Next Gen and Indy Jones, where coils don’t work or balls are cycling through the game or there is random coil energizing. Before doing any more difficult work, try reseating the ribbon cables on their gold circuit board header pins. It’s easy, cheap, and just takes a second to reseat all the ribbon cable connectors, and it removes one possible problem from the mix.

How does the Game know the Switch Matrix doesn’t work?

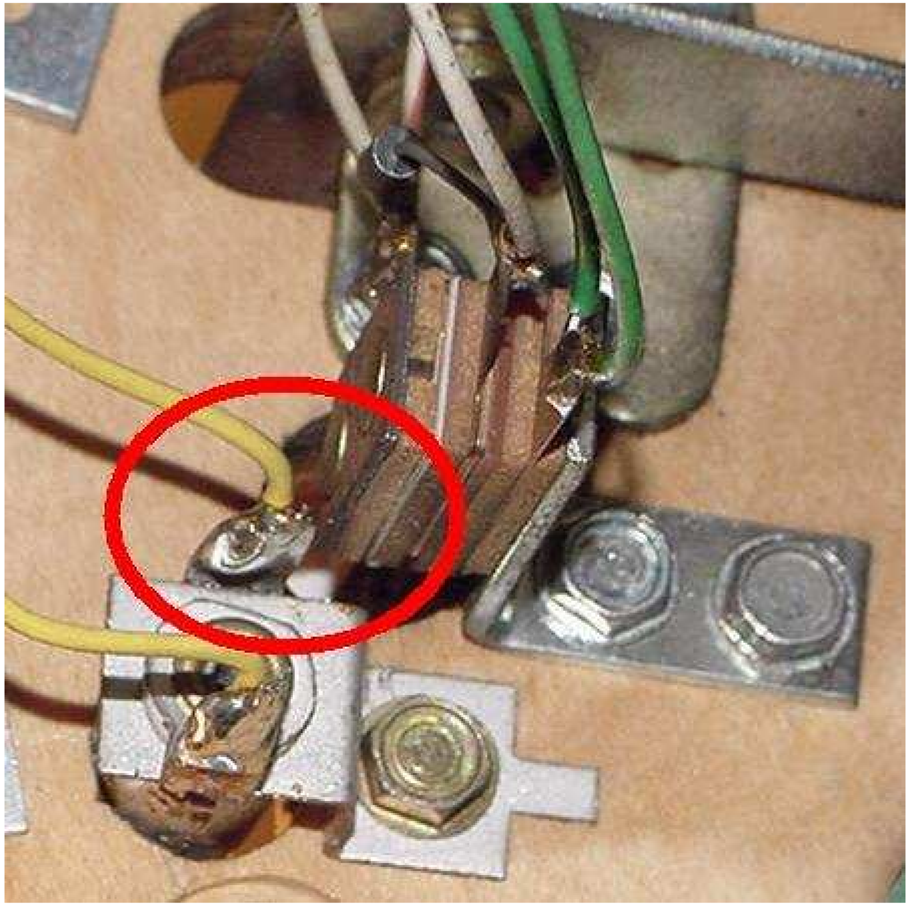
There is ONE switch in all WPC games called “always closed” (usually switch 24 on WPC games). This switch is monitored by the CPU board. If it sees this switch as open, the game knows there is a switch matrix problem (perhaps no +12 volts!). Also if the connectors are not attached on the CPU board at J206, J207 (colums) and J208, J209 (rows), the CPU board can be confused about switch 24 (because the switch is actually wired “closed” at the coin door interface board via J212). For example, if fuse F115 (or F101 on WPC-95) was blown, removing these connector J206-J209,J212 for testing purposes, the game will probably give an error until the fuse is replaced AND the connectors put back on. These connectors may have to be removed to determine if the switch problem was on the CPU board or in the playfield wiring. (The easiest way to determine this is to disconnect all four switch matrix playfield plugs from the bottom right of the CPU board {connectors J206-J209}. If the error goes away, there is a playfield short. If the error stays, there is a problem on the CPU board. Be sure to keep connector J212 attached as it keeps switch 24 “always closed”.)

Switch Connectors (all WPC revisions).

- J206,J207: Switch Columns (pin1=column1)
- J208,J209: Switch Rows (pin1=row1)
- J212: Rows and Columns (pins 1-3 are switch columns 1-3, pins 4,6-8 are switch rows 1-4) for the coin door interface board. Also used for the "always closed" switch 24 (column 2, row 4). Keep this connector attached during testing so switch 24 stays closed.
- J205: Direct connect switches (diagnostic coin door switches, slam tilt), which goes to the coin door interface board. Does **not** use the ULN2803 chip (uses U16,U17 which are LM339 chips, and U15 a 74LS240 chip). Keep this connector attached during testing so the diagnostic switches will work.

Shorting the Switch Matrix to +50 volts Coil Power.
When in a hurry, the repair person may make an under playfield adjustment with the game turned on. If the coin door is closed, or the game doesn't have a coin door interlock switch, it is easy to short a coil lead (+50 volts) to a switch lead with a screwdriver. This will immediately blow the switch matrix power fuse (F115 on WPC-S or earlier, or F101 on WPC-95), and fry the ULN2803 at U20 on the CPU board. There is a good chance the 74LS374 at U14 (on WPC-95 it's U23, a 74HC237) will fail too on the CPU board. On WPC-S or later games, the U20 chip is socketed (but not the U14, or U23 on WPC-95).
Shorting the Switch Matrix to 6.3 volts General Illumination.
Though 6.3 volts is not much voltage compared to the switch matrix's 12 volts, damage can definately occur. For example, on Indiana Jones the left slighshot has a G.I. lamp socket very close to the rivits of the slingshot switch. If these touch, the U20 (ULN2803) CPU board chip can fail, killing the switch matrix column three (green/brown wire which the left slignshot connects). Also a G.I. short to the switch matrix can cause all kinds of strange problems without frying the U20 CPU chip, as seen in the switch edge test. An entire switch row can turn on and off repeatedly. Or nearly all the switch rows can flash on and off. The voltage of the general illumination circuit can definately cause some strange behavior to the switch matrix.

Indiana Jone's left slingshot switch and a very close General Illumination lamp socket. If these two touch, the U20 CPU chip can fry. Or at minimum, the switch matrix can exhibit some really strange behavior!



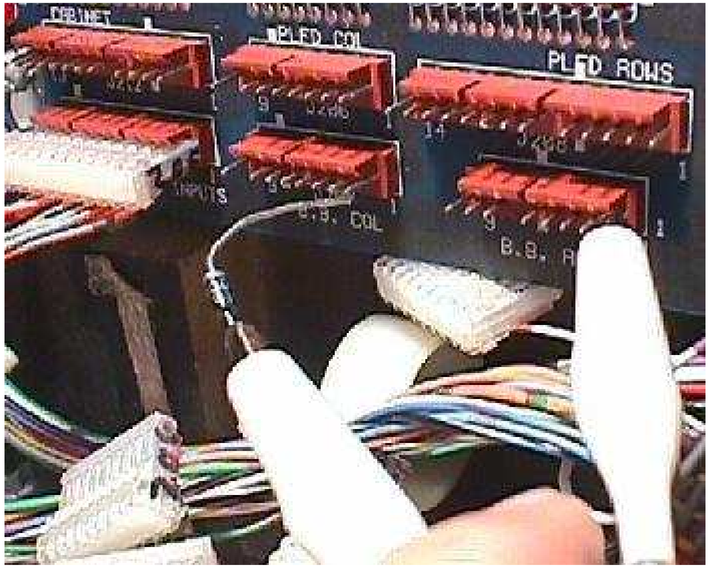
Row or Column "Ground Shorts" and the U20 Chip.
The CPU board's U20 chip ULN2803 is a common failure point for the switch matrix. If the game is reporting rows or columns as shorted to ground (especially multiple shorted rows or columns), often this U20 chip and downstream the 74LS374 chip at U14 (on WPC-95 it's U23, a 74HC237) on the CPU board are usually the problem. Rarely the CPU board's LM339 chips fail too, where U18 controls rows 1,2,3,4, and U19 controls rows 5,6,7,8 (but replace U20 first followed by the 374 chip, and then look at U18/U19 last).
After Replacing CPU Chip U20, the Fuse does not Blow, but Many Switches show in the Test Report.
This is very common. The CPU is confused from the blown U20 switch matrix chip, and will report many switches as "bad" in the test report. To "unconfuse" the game, go into diagnostic, and select the first switch test (T.1, switch edges). Using a pinball, manually activate the switches that came up in the test report (see the game manual for their location, if they can't be found). The switches should report correctly on the display in this test mode. After activating each switch once, exit the diagnostics, and the game should work normally. Alternatively, if the game will allow it, just play a game! This is often all that is needed to clear the test report.
More on Ground Row Shorts and Other Strange Switch Problems.
Switch ground short errors are often the most confusing problem to find. One may think that if the game is reporting a switch ground short, that a playfield row switch wire has somehow been shorted to ground. Unfortunately this is rarely the case! More often it is some other problem (usually a bad U20 CPU chip, or a bad LM339 chip on an under the playfield opto board, especially if the U20/U14 CPU chips has already been replaced).
If you are a skeptic and want to believe the switch "ground short" message, there is an easy test for this. Power the game off and remove the row and

column connector plugs from the CPU board at J205, J212, J206/207 and J208/J209. Then using a DMM, check for continuity between any switch row or column wire to ground. Chances are really good you will find there is no ground short. If you do find a short, then the wire will have to be traced from the CPU board connector to the last switch in the daisy chain.

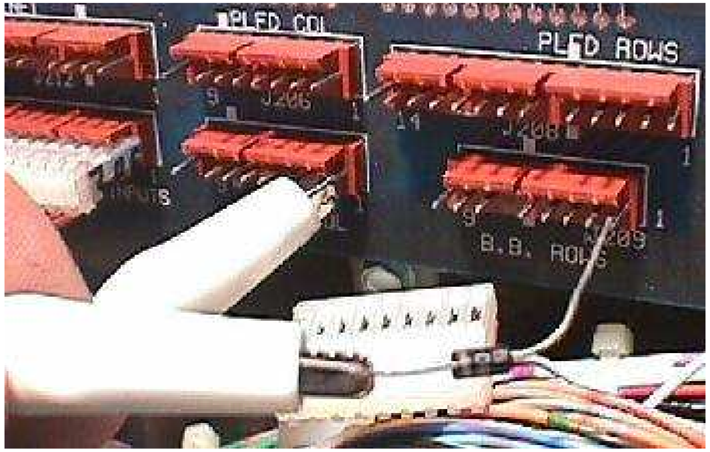
Now that we know there really is not a playfield switch grounding problem, we can do some further testing. Disconnect all four switch input plugs from the bottom of the CPU board. Put the game into switch diagnostic test T.1, and none of the switches should be activated (except for switch 24, which is “permanently closed”, as discussed above). If a whole row of switches is activated, that would mean that row’s LM339 is bad. If a column of switches are activated, this means a bad U20 chip. If just one or two switches are activated, plug the four bottom connectors back in and disconnect the ribbon cable that goes between the CPU and the power driver board. If the switch matrix confusion clears up, the problem in on the power driver board! This could be U7 and/or U8 (WPC-S and prior) on the driver board, which are 4N25 opto issolators used for some of the direct switches.

To isolate the switch problem from the playfield, it is a good idea to use a jumper wire and a diode to test the switch matrix, right at the CPU board row and column plugs. This is described later in this section, but here’s a couple pictures of the procedure.

Switch Column Testing*: Using a diode and a test lead, the test lead is attached to pin 1 of J209, and is stationary. The other clip holds the non-banded side of the diode. Then the* ***banded*** *side of the diode is touched to each pin of connector J207. The ”switch levels” test should indicate switches 11 to 81 (by ten) when activated.*



Switch Row Testing*: Using a diode and a test lead, the test lead is attached to pin 1 of J207, and is stationary. The other clip holds the banded side of the diode. Then the* ***non-banded*** *side of the diode is touched to each pin of connector J209. The ”switch levels” test should indicate switches 11 to 18 when activated.*



If a particular row or column of switches does not work using the above jumper wire/diode test, chances are good the CPU board U20 chip (or possibly U14) have failed. Battery corrosion on the CPU board can also cause these problems, so keep that in mind too (any green parts on the CPU board is a bad sign).

If the above jumper wire/diode tests show all switch rows/columns as working, then the problem is located on the playfield. This usually has to do with the under-the-playfield opto board(s), as used in games Twilight Zone and later. There are LM339 chips used on the under-the-playfield optic board (if the game has one, and most games Twilight Zone and later do use at least one). If any one of the LM339 chips fails on the under-the-playfield opto board (very common), the switch matrix will be confused. This is often reported as a "ground row short", or other weird and sparatic switch matrix errors.

In this situation, put the game in switch test mode, then remove the power plug on the opto driver board under the playfield. Usually there is one large plug that houses 12 volts and all the switch row and column wires. Remove this plug. Remember opto switches are normally closed until the opto light source is blocked, and is shown as a "box" on-screen in the dot matrix switch display. So removing power to the opto board should make all the opto switch "boxes" change to "dots" (and the switch test report may quickly go "bonk" for each opto switch that now triggered from closed to open, when the opto board's power was removed). If a ground row short clears up after doing this, then there is a LM339 problem on the opto board.

Since the optos themselves and the opto board runs on 12 volts, at this point make sure you have 12 volts at the opto board! If it is 11 volts or less, this can cause sparatic problems and weird switch reports. Low 12 volts is usually a BR1 bridge or LM7812 voltage regulator problem, as discussed above. Get this fixed before proceeding.

If 12 volts is good and present on the opto board, I generally replace all the LM339 chips on the under-the-playfield optic board, and use sockets. These are cheap chips, and they are not easy to test with a DMM, so I generally just socket and replace them. These chips can be diagnosed with a logic problem, but often I just replace them wholesale.

I replaced F115 (or F101 on WPC-95), and the Fuse keeps Blowing.

If the switch matrix +12 volt fuse (F115 or F101 on WPC-95) keeps blowing immediately when replaced, check these things out.

With the game off, replace fuse F115 (or F101), and remove connector J114 (or J101 on WPC-95) from the power driver board. Turn the game on (the game will complain when powered on, but don't worry about that).

If the switch matrix fuse F115 (or F101) **does** blow with connector J114 (or J101 on WPC-95) removed, then there is a problem on the CPU board. This usually means the CPU board chip U20 (ULN2803A) is probably blown. Replace U20 (use a socket!), and reconnect J114 (or J101), and the problem should be solved. Sometimes U14 on the CPU board (U23 on WPC-95) will also need to be replaced. See the section on fuses for more information on what other problems can cause this fuse to blow.

If the switch matrix fuse F115 (or F101) does **not** blow (and the +12 volt LED is lit on the power driver board), then there probably is a short somewhere in the playfield wiring or on an opto board under the playfield. The opto boards under the playfield have large blue resistors, and one to four LM339 chips. By disconnecting the power to this opto board (there is a red LED on these boards showing power) and turning the game on with connector J114/J101 connected, the opto board can eliminated or be the culprit (if fuse F115/F101 blows).

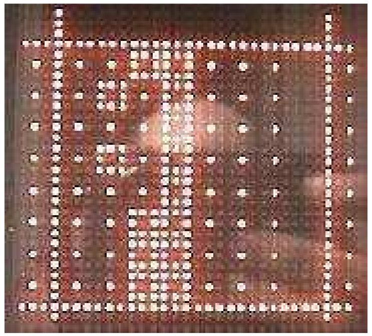
If the problem is still present, Check for solder splashes and maybe a nut/bolt that has fallen somewhere and has caused a playfield short. Shorts on the playfield are quite common. Somewhere, the 20 volt lamp matrix or flashlamp circuit is getting shorted to the switch matrix. Or the 50 volt solenoid voltage is getting shorted to the switch matrix. Look under the playfield for lamp and solenoid wire lugs that are close to switch lugs. The problem could

also be on the top of the playfield. Perhaps a errant pinball knocked a lamp socket into a switch lug, causing a permanent or intermittent short.
If nothing can be found, here is a techinque to help find which switch is shorted:

1. After replacing the U20 on the CPU board with a socket, remove the ULN2803 chip.
2. Turn the game on. With the CPU chip U20 removed, the game will complain with test reports, but ignore it.
3. Using a DMM, set the meter to DC volts.
4. Put the black lead of the DMM on ground (the side rail of the game works well for this).
5. Put the red lead of the DMM on pin 1 of the empty U20 socket.
6. If the DMM reads anything over ~13 volts (for example 18 or even 70 volts), there is a permanent short for that switch matrix column. Check all eight playfield switches in that switch column for a short.
7. Repeat steps 5 and 6 for all pins on the U20 socket.
8. If no voltage over 13 volts is found, put the red lead of the DMM back on CPU socket U20 pin 1.
9. Press each playfield the switches on the playfield. If the DMM reads anything over ~13 volts (for example 18 or even 70 volts), check that target for a physical short to another voltage (flash lamp power, solenoid power, etc.)
10. Repeat steps 8 and 9 for all the pins of socket U20 on the CPU board, by depressing each playfield switch.

Switch Numbering.
Each switch has a number associated with it. This number is referenced in the game manual, and is shown in the diagnostics in the switch edge test. The switch number is always two digits: the first digit is the switch matrix column number, and the second digit is the switch matrix row number. For example, switch number "42" is the cross section of column 4, row 2. This is handy when trying to figure out if bad switches are all in the same row or column.

Both internal switch tests use this matrix to show which switches are activated. The two outside columns of dots are the direct ground switches; the left most dot column being the coin door switches, and the right most dot column being the flipper switches. The dots inside the square box are the 8 by 8 switch matrix. A square represents an activated switch, a dot means a non-activated switch. Notice the right most column inside the box is missing; this game doesn't use a switch matrix column 8, as it was not needed. Also the display shows the wire colors (WHT-BRN and GRN-BRN) going to the last activated switch. The "T.2" means this is test menu option #2.



Using the Internal Switch Tests.
To test switches, use the WPC internal test software. Press the "Begin Test" button, and go to the Test menu. Select the "switch edge" test. Activate any switch on the playfield **using a pinball** (this simulates real game play), and it should show on the game's display. The display will indicate the wire colors going to this switch, too.
Check for Broken Switch Wires "Up Stream" (Switches are "Daisy Chained").
Since the switch matrix is a series of eight columns and eight rows, the playfield switch wiring is "daisy chained". For example, check out a switch matrix row in the manual. For row one, the playfield switch in column three row one (switch 31) is wired before the playfield switch in column four row one

(switch 41). So if the row one wire breaks off switch 31, all the switches "down stream" (41, 51, 61, 71, 81) will not work! This is one of the simpliest, and easily overlooked, switch matrix problems.
Another hint that the there is a switch matrix wire broken; If for any particular column and row other switches work, this indicates there probably is not a problem on the CPU board! If there was a column/row problem on the CPU board, it would most likely affect all the switches in that column or row.
Broken switch wires can also occur at the CPU connector too. Make sure to look at the connectors. The wires can fatique and break at the connector, inside the insulation!

If a Bad Switch is Found.

If a switch does not work, check these things:

- Check the switch wiring "up stream". Switches are wired in a "daisy chain". If a switch row or column wire breaks "up stream", ALL the switches daisy chained after the wire break in that row or column will not work!
- If it's a micro-switch, check the actuator arm. Make sure it's adjusted properly. Listen for the micro-switch's "click" when activating. No click usually means the switch is mis-adjusted or broken.
- Check that the wires going to the switch are soldered well, and haven't fallen off.
- Check the continuity (using the DMM's continuity setting) of the wire between this switch and another working switch in the same column (white wire) or row (green wire).
- If it's a blade or leaf style switch, check the contacts for proper closure. Clean the switch contacts with a business card (do NOT use a file as the contacts are gold plated). Put the card between the contacts, close the contacts, and pull the card through the contacts. This is all that is needed to clean gold plated switch contacts.
- Check the switch to make sure it works. Use the DMM's continuity setting, and put one lead on the "common" lug (the lug to which the banded end of the diode connects) of the switch. Put the other lead on the green (normally open) switch lug. The meter should only beep when the switch is activated, and not beep when the switch is de-activated. Move the DMM's lead from the green to the white wire (normally closed) switch lug. The meter should beep when the switch is de-activiated, and NOT beep when activated.
- Check the diode on the switch. Make sure the diode is connected properly, and is working (see below).
- Check other switches in that switch's row or column. A ULN2803 controls columns and a LM339 controls rows, and often a gate within these chip can fail. This will affect all the switches in that particular row or column.

If the switch is bad, replace it. If all the switches are bad in a particular switch column, replace the ULN2803 on the CPU board at U20. If all the switches in a row are bad, replace the LM339 at U18 or U19.

Quick & Easy Switch Matrix Diagnosis.

This is a simple case where one or more switches are not working. The first thing to do is check the game manual and find the switch matrix chart. There is also a drawing of the playfield with all the switch numbers shown in their respective positions. You will need to know the switch numbers which don't work. To do this, use the game's switch test diagnostics and the game manual, and write down the switch numbers that don't work.
In most simple cases, the non-working switches will all be in the same Row or Column. For our example, say that half of the switches in column 4 are not working (if your situation has non-working switches in multiple rows/columns, you will have to repeat the following steps once for each row and/or column).
Referring to the switch matrix chart in the manual, at the top of the chart it will give the column's wire color (column 4, Green/Yellow) and the pin on the CPU board where the column 4 originates (J206/J207 pin 4). With this information, follow these steps:

9. For columns check connector J206/J207 on the CPU board and make sure all pins are making a good connection (rows are J208/J209). Pin one of these connectors is row or column one. They are .100" Molex connectors, and occassionally the wires get fatiqued or ripped out of the connector. It is not uncommon for this connector to be replaced or repaired. Originally it was an IDC (Insulation Displacement) connector. If it is damaged, be sure to replace it with a crimp-on .100" Molex connector.
10. Lift up the playfield and locate the first switch at the top (area closest to the player) of the playfield with the appropriate wire color (in this example, Green/Yellow). This switch is usually the furthest down the "daisy chain". If you have found the first switch in the daisy chain, it will only have one Green/Yellow wire connected at the switch instead of two wires. All other switches for that column will have two column wires (hence the term, "daisy chained"). Check the wire(s) for obvious flaws and breaks. Check the switch's diode. And check how the switch is wired relative to the diode (there are pictures further down in this document showing switch/diode wiring).
11. Now follow the daisy chain back. That is, follow the Green/Yellow wire to the next switch or switches. Most often a break will be found in this

wire daisy chain. If this happens, all the switches "upstream" will not work. A broken wire is probably the most common dead-switch problem.

12. If all eight switches are found and the Green/Yellow column wire is not broken, then there is a more serious problem. Sometimes the column wire breaks internally, which can't be seen with the eye. This happens because the playfield pinches the wire and cuts the internal strands without breaking the insulation, while the playfield is lifted and lowered. The only way to find this problem is to use a DMM's continuity feature and "buzz out" the Green/Yellow wire from switch to switch (start with one lead of the DMM connected at the CPU board's connector pin J206 pin 4 in this example, and the other DMM lead on each switch, looking for continuity).
13. If all switches check out and the wire/continuity is good, the problem is on the CPU board itself. Go back to J206 pin 4 and trace that pin back to the chip it connects (in this case U20 pin 15 as shown on the top of the switch matrix chart for column 4). Use the DMM's continuity feature to check this. The best way to check continuity is to put one lead of the DMM on the first switch in the daisy chain, and the other lead on U20 pin 15 (for this example of column 4). This will test the wiring from the playfield all the way to the CPU board's logic point. If the continuity checks out good, then I would suspect the chip which connects to J206 pin 4 (in this case ULN2803 chip at U20, a common switch matrix failure point).

Here's what rows connect to which U20 chip pins:

- Sw.Column 1 (J206/207 pin 1): U20 pin 18
- Sw.Column 2 (J206/207 pin 2): U20 pin 17
- Sw.Column 3 (J206/207 pin 3): U20 pin 16
- Sw.Column 4 (J206/207 pin 4): U20 pin 15
- Sw.Column 5 (J206/207 pin 5): U20 pin 14
- Sw.Column 6 (J206/207 pin 6): U20 pin 13
- Sw.Column 7 (J206/207 pin 7): U20 pin 12
- Sw.Column 8 (J206/207 pin 9): U20 pin 11

All switch (and lamp matrix) problems can be diagnosed this way, or at least this is a good starting point.

Slam Tilt Stuck Open Error.

Upon turning the game on, a "slam tilt stuck open" error is shown, and the game just won't do anything past that. This can be as simple as the slam switch inside the coin door is bent closed. Or it could be some sort of CPU switch problem.

To issolate the problem, turn the game off and disconnect all the connectors from the bottom of the CPU board. Then turn the game back on. If the error is no longer shown, the problem is in the playfield or cabinet wiring/switches. If the error is still shown, the problem is in the CPU board itself. If the problem is on the CPU board, usually it's a problem with a ULN2803 or LM339 chip.

Upper Flipper Switch Bad, but my game doesn't have an Upper Flipper!

On Williams games that use flipper opto switch boards (Addams Family and later), the flipper opto boards have TWO switch optics. One optic controls the lower flipper, and the other controls the upper flipper. The same opto board is used on all games, even if the game has no upper flippers. Unfortunately, on some games, the software can create a switch error "test report", if the game thinks the upper flipper board optic switch is bad (even if the game has no upper flippers, and is not using the switch). If the problem is really bothersome, the opto can be replaced. But often, the problem is mearly the metal or plastic flipper opto interuptor (the passes between the "U" of the opto switch) is never moving outside the "U". By bending the activator to clear the optic's "U", often this error message can be cleared.

Phantom Switch Closures: a Shorted or Mis-Wired Switch.

It's a strange problem. While playing a game, the ball goes down the right inlane, and the left slingshot fires! Or when making a ramp shot, the game slam tilts. One switch closes, but a completely unrelated event than occurs.

This is a classic problem of a shorted or mis-wired switch. It confuses the switch matrix into thinking something else has occurred. This can happen from an "air" pinball, that bashes an above playfield switch's contacts together, causing a short. This is very commonly seen on say Indiana Jones, un the front right side of the Path of Adventure, where the switche contacts are exposed and easily bent together by an air pinball. This problem can also occur from an improper repair where the row/column wire is wrongly attached to the switch and/or switch diode. Also a bad switch diode can do this too. In any case, the problem switch needs to be found. Unfortunately, it won't be obvious. The switch matrix is confused, so any diagnostics the game provides will be of limited help.

First, try and find the "phantom" switch (the switch that causes something unrelated to happen). Take the playfield glass off, and start a game. Activate the switches with your hand, and find the phantom switch. Once the switch is found, go to the game manual and find the switch's number, row number, and column number. Say for example, switch 53 (column 5, row 3) is causing the phantom closure. Now get the other three switches that make up the "square" of this row and column. First get the reverse switch number, switch 35 (column 3, row 5). Then get the other two switches: switch 33 (column 3, row 3), and switch 55 (column 5, row 5). The switch short will probably be one of these four switches.

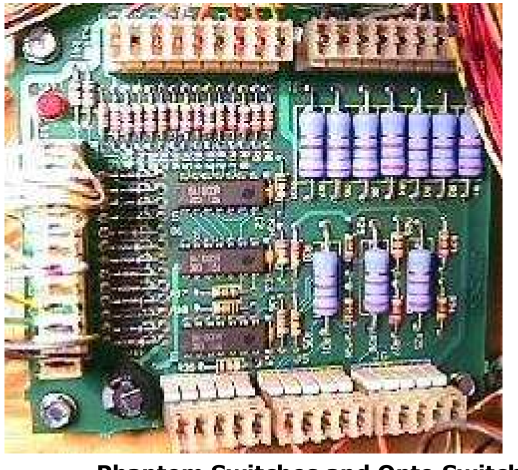
For example, if a row wire is attached to the wrong end of the switch's diode, the following can happen: If the mistake-wired switch (#1) is triggered and another switch (#2) on the same column is triggered at the same time, then another switch (#3) on the same row as the mistake-wired switch #1 is triggered, the switch (#4) on the same column as switch #3 and on the same row as switch #2 will also shows as triggered, even though switch #4 wasn't actually triggered. (Wow, that was confusing!) For example, row 3 column 3 (r3c3) is mistake-wired as described above. If r3c3 and r2c3 are triggered simultaneously as well as r3c6, then r2c6 will also show as triggered (falsely).

The above example came to light with a reader (Bill Johnson), who has a Terminator2 machine. This problem was discovered because when the 'right ramp entry' switch was triggered, it would also trigger 'left ramp made' (even though no balls were falling in the left ramp). This was because most of the time the gun is in the home position. In this configuration, both the 'gun home' and 'gun mark' switches are triggered. This happened because the row wire was soldered to the wrong end of the switch diode on the 'gun home' switch.

Check the Switch Wiring on NEW Replacement Parts.

I have seen many times brand new parts offered by Williams/Bally where the switches are mis-wired right from the factory! If these are installed, phantom switch closures will occur. Always check replacment ramps and upkickers for proper switch wiring before installing them.

The 10 opto switch driver board as used in Indiana Jones and many other games. The three IC's are LM339 chips. The power plug for this board is on the left, next to the row of diodes. This board is mounted under the playfield.



Phantom Switches and Opto Switches.

If one of the phantom switches is an optic switch, there may be a problem with the under-the-playfield optic board. Williams also used optic light emitting diodes (LED's) for switches. These are controlled by sub-boards (opto driver boards), mounted under the playfield, which interpret the light signals and converts them to digital signals. This is done using LM339 chips on the opto driver board. If a LM339 goes bad, it will give the CPU board bad switch signals. This is interpretted as a bad switch column or row, when in fact, it's really a bad opto driver board. This can make an optic or non-optic switch row or column act wacky.

If there are phantom switches, the first and easiest thing to try is to disconnect the power to the under-the-playfield optic board. When the power plug is disconnected (usually the plug nearest the row of diodes) from the optic board (you can do this with the game on), the LED soldered to the optic board will turn off. Now re-test the switches. If the problem has changed, there is a bad optic board! If the problem has not changed, plug the optic board back in and move on.

If the optic board is at fault, replace ALL the LM339 chips on this board (there are usually two or three of them). These chips can not be tested easily. It is just easier to replace them all (use sockets!).

Some games (Shadow) with lots of optics can use a "opto24" board. This board can control up to 24 optics! Again, this is done using LM339 chips. In addition to this, there is also a 555 timer chip on the opto24 board. This too can fail, causing intermittent opto switch problems.

No Opto Power and the Switch Matrix.

If the 12 volt unregulated power fuse is blown (usually fuse F116 on WPC-S and prior, or F109 on WPC-95), there will be no power to the emitter portion of the LED switches. This means the opto switches will think they are 'closed' (the receiver portion of the Opto switch will still work even if the tranmitter has no power). This can cause some weird problems when the game is first turned on. For example, an upkicker that continually fires on and off (because the upkicker has an opto switch, and the game thinks there's a ball in the upkicker because the opto switch is closed due to no opto emitter power and no light shining in the opto receiver). See the "Opto switches are going crazy" below for more info.

Bad Switch Diode.

Each micro-switch on the playfield also has an 1N4004 diode soldered to it. This diode can short closed. It doesn't happen often though. **Important:** If a switch diode does short closed, all switches in that particular column or row will exhibit strange behavior. If a switch diode goes permanently open, the switch will never register. Keep this in mind when diagnosing switch matrix problems.

Fail-Safe Diode Test.

A fail-safe way to test a switch diode is to disconnect one lead of the diode from the switch, to remove it from the circuit. Then use a DMM set to diode position. With the black lead on the banded side of the diode, a reading of .4 to .6 volt should be shown. Reverse the leads, and get a null reading. Reconnect the diode after testing, or replace if bad.

Testing a switch diode on a microswitch without removing the diode. Not the screw driver keeps the switch activated, and the middle green wire (ground) has been disconnected.

Testing a Microswitch's Diode, without removal.

The diode on a microswitch can be tested without unsoldering a diode lead from the switch. This technique assumes the switch is wired in the standard configuration: green (ground) wire to the center lug, the banded end of the diode to the far switch lug, and the non-banded diode lead and the switch wire(s) to the close switch lug (as shown in the pictures below).

- Disconnect the middle green (ground) wire from the switch. It should have a quick connector. If the middle green ground wire is soldered to the switch, ignore this test and do the above "fail-safe" diode test.
- Put the DMM on diode setting.
- Connect the black lead of the DMM to the diode's banded side, and the red lead to the non-banded side.
- Activate the switch.

- A reading of .4 to .6 should be shown on the meter.
- Reverse the DMM's leads (red lead to the diode's banded side), and keep the switch activated. A null meter reading should be indicated.

Testing a Blade/Leaf Switch's Diode.
Testing the diode on a leaf switch is far easier. No wires need to be disconnected, and the switch should not be activated. This technique assumes the switch is wired in the standard configuration: green (ground) wire to the center lug, the banded end of the diode solo, and the non-banded diode lead and the switch wire(s) to the other switch lug (as shown in the pictures below).

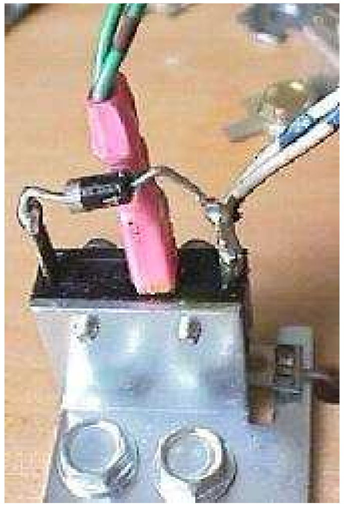
- Leave the leaf switch's diode and all wires connected.
- Make sure the switch isn't activated.
- Put the DMM on diode setting.
- Connect the black lead of the DMM to the diode's banded side, and the red lead to the non-banded side.
- A reading of .4 to .6 on the meter should be seen.
- Reverse the DMM's leads (red lead to the diode's banded side). A null meter reading should be indicated.

Testing a switch diode on a blade/leaf switch, without removing the diode. The switch doesn't need to be activated, and no wires need to be disconnected.

Installing a New Switch Diode.
The diode can be replaced with a new 1N4004 (or 1N4002 or 1N4001) diode. Make sure the new diode is installed with its band in the same orientation as the old diode (assuming it's correct!). If unsure, compare the diode's band orientation to a working switch and diode. Most (but not all!) switches have the green (column) leads connected to the center (normally open) lead of the switch. Then the white (row) wire is connected to the switch lead closest to the center lead (the normally closed lead). The banded end of the diode is connected solo to the far (common) switch leg, and the non-banded end is connected to the same leg as the white (row) wire. **There are some exceptions to this mounting.** The game manual should specify any non-standard switch installations (Bride of Pinbot's zero position head switch is one such exception).

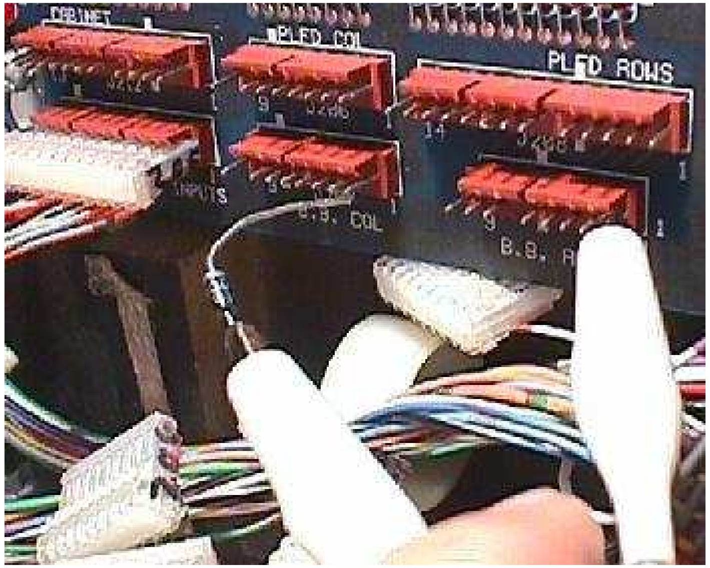
Notice the orientation of the diode's band on these switches.
On a micro-switch, the column (green) wire usually goes to

*the center lug, the row (white) wire and the non-banded side of the diode to the lug **closest** to the center. The band on the diode goes to the solo, far third switch lug. The leaf switch uses the same connection method (green to center, banded end of diode solo). Note there are some exceptions to this mounting.*



Accidental Reversal of a MicroSwitch's Row and Column Leads (mis-wired switch causes switch matrix havok!)
If someone has installed a new microswitch, the row and column leads could be accidentally reversed to the switch. Say for example switch 48 is a microswitch in the game, and has the row and column wires accidentally reversed. The switch matrix will still reconized this switch (the switch will seemingly work), but is registered as switch number 68, not 48! This can be a hard problem to find, as the switch still seems to work. Unless there is access to the game manual, and know that this switch should be number 48 (and not number 68), the problem may not be found!
If a switch is mis-wired, it can cause other problems too. Using the internal wwitch test, often a single switch can show as multiple switch closures (one switch shows two or more switches activated during the switch test). Normally looking for crossed wires, bad diodes, bad LM339 and ULN2803 chips on CPU or under-the-playfield optic board would be the thing to do. But there can be another (simple) cause too: a switch wired completely backward. This happens often when someone changes a switch, and accidentally wires it "backwards". Keep this in mind when diagnosing switch matrix problems.

*Testing the switch matrix **columns**: Using a diode and a test lead, the test lead is attached to pin 1 of J209, and is stationary. The other clip holds the non-banded side of the diode. Then the **banded** side of the diode is touched to each pin of connector J207. The "switch levels" test should indicate switches 11 to 81 (by ten) when activated.*



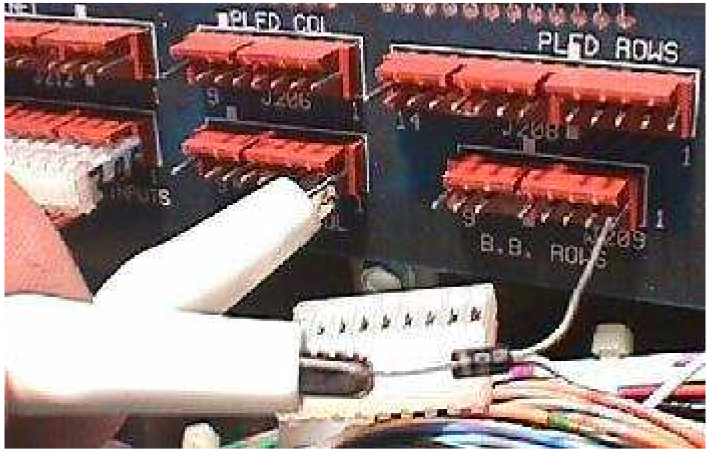
Testing the Switch Columns (all WPC revisions).
To test the switch columns, do the following:

1. Remove the backglass and fold down the display to gain access to the CPU board.
2. Turn the game on.
3. After the game boots, press the “Begin Test” button in the front door. Go to the Test menu’s “Switch Levels” test.
4. Unplug the connectors at J212, J206, J207, J208 and J209 (lower portion of the CPU board).
5. Connect an alligator test lead to pin 1 of J209. Pin 1 is the right most pin, as facing the board.
6. On the other end of the alligator test lead, clip on a 1N4004 diode, with the banded end away from the alligator lead. Touch the banded end of the diode to pin 1 of J207. Again, pin 1 is the right most pin, as facing the board.
7. The display should show switch 11 is closed.
8. Move the diode/alligator lead on J207 to the next pin. The display should show switch 21 is closed.
9. Repeat the previous step, until pin 9 of J207. Switches 11, 21, 31, 41, 51, 61, 71, 81 should be closed on the display as moving forward, pin by pin, on connector J207.

   Note: on some WPC games, columns 8 and/or 7 are not used. In these cases, there may be no indicator for switches 81 and/or 71.

If a particular column does not display as closed, or is closed without any test lead connection, replace the ULN2803 at U20 on the CPU board.

*Testing the switch matrix **rows**: Using a diode and a test lead, the test lead is attached to pin 1 of J207, and is stationary. The other clip holds the banded side of the diode. Then the **non-banded** side of the diode is touched to each pin of connector J209. The ”switch levels” test should indicate switches 11 to 18 when activated.*



Testing the Switch Rows (all WPC revisions).
To test the switch rows, do the following:

1. Remove the backglass and fold down the display to gain access to the CPU board.
2. Turn the game on.
3. After the game boots, press the “Begin Test” button in the front door. Go to the Test menu’s “Switch Levels” test.
4. Unplug the connectors at J212, J206, J207, J208 and J209 (lower portion of the CPU board).
5. Connect an alligator test lead to pin 1 of J207. Pin 1 is the right most pin, as facing the board.
6. On the other end of the alligator test lead, clip on a 1N4004 diode, with the non-banded end away from the alligator lead. Touch the non-banded end of the diode to pin 1 of J209. Again, pin 1 is the right most pin, as facing the board.
7. The display should show switch 11 is closed.
8. Move the diode/alligator lead on J209 to the next pin. The display should show switch 12 is closed.
9. Repeat the previous step, until pin 9 of J209. Switches 11 through 18 should be closed on the display as moving forward, pin by pin, on connector J209.

If a particular row does not display as closed, or is closed without any test lead connection, replace its corresponding LM339 chip on the CPU board. Here are the switch rows and which LM339 controls them:

- Rows 1,2,3,4 = U18
- Rows 5,6,7,8 = U19

Testing the Switch Matrix Columns and Rows with a Logic Probe.
If a logic probe is available, the switch matrix can be easily tested:

12. Remove the backglass and fold down the display to gain access to the CPU board.
13. Turn the game on.
14. After the game boots, press the “Begin Test” button in the front door. Go to the Test menu’s “Switch Levels” test.
15. Unplug the connectors at J212, J206, J207, J208 and J209 (lower portion of the CPU board).
16. With the logic probe connected to power and ground, probe each pin 1 to pin 9 of J207 (pin 1 is the right most pin, as facing the board). These are the switch columns. All pins should show PULSE on the logic probe. If no pulsing activity is shown, the ULN2803 at U20 is bad.
17. With the logic probe connected to power and ground, probe each pin 1 to pin 9 of J209 (pin 1 is the right most pin, as facing the board). These

are the switch rows. All pins should show HIGH on the logic probe. If a pin is not high, its corresponding LM339 on the CPU board is bad (rows 1,2,3,4 is U18, rows 5,6,7,8 is U19)

Switch matrix short: is it the CPU board or the playfield?
One of the diagnostic errors gotten from WPC games often is "switch matrix row shorted". This can happen for a variety of reasons (see below), but the big question is this: is the short on the CPU board (a failed component like the LM339 at U18-U19 or the ULN2803 at U20), or on the playfield (where a switch may be physically touching ground)? The easiest way to determine this is to disconnect all four switch matrix playfield plugs from the bottom right of the CPU board (connectors J206-J209). If the error goes away, there is a playfield short. If the error stays, there is a problem on the CPU board.
Further Diagnosing of the Switch Matrix.
If there is a switch matrix problem, the first plan of attack is to do the above column and row switch matrix tests. If these tests pass, the problem most likely is in the wiring. Note most switch failures show as Row failures (even though it could be a column problem). Here are eight different ways the switch matrix can fail. All require use of the internal "switch level" or "switch edge" tests of the game.

18. **Switch column shorted to ground.**
    When a column wire is shorted to ground, and any switch in that column is closed, the switch test will show ALL switches in the ROW of the closed switch as being closed. If no switches are closed, the switch test will show no switches closed. To find the location of the short, go to the end of the switch column wire on the playfield (the switches are "daisy chained" together for an entire column or row). Then break the daisy chain one switch at a time until the short no longer shows in the switch test.
19. **Row shorted to ground (diode anode).**
    When the anode (non-banded end of the switch diode) is shorted to ground, the switch test will show the entire row as activated (whether any switches are closed or not). To find the location of the short, go to the end of the switch row wire on the playfield (the switches are "daisy chained" together for an entire column or row). Then break the daisy chain one switch at a time until the short no longer shows in the switch test.
20. **Row shorted to ground (diode cathode).**
    When the cathode (banded end of the switch diode) is shorted to ground, that switch's entire row will show as closed in the switch test (whether the switch is open or closed). To find the location of the short, go to the end of the switch row wire on the playfield (the switches are "daisy chained" together for an entire column or row). Then break the daisy chain one switch at a time until the short no longer shows in the switch test.
21. **Column wires shorted together.**
    When two column wires are shorted together, and none of the switches in those columns are closed, the switch test will show no problems. But pressing any switch in either column will show that switch, along with a switch in the column that is shorted on the row of the switch being closed. For example, if column 2 and column 4 are shorted together, closing switch column 2 row 3 will also show a closed switch in column 4 row 3.
22. **Row wires shorted together.**
    When two row wires are shorted together, and no switches are closed, the switch test will show no closed switches. When any switch in either row is closed, another switch on the same column as the closed switch will also show as closed. For example, if rows 1 and 4 are shorted, closing a switch in row 1 column 3 will also show a closed switch on row 4 column 3.
23. **Column and row wires shorted together.**
    When a column and row wire are shorted together, the switch test will show the switch that is at the intersection of the row and column as being closed, even though it is not closed. All other switches on all other rows and columns will work correctly. For example, column 1 and row 3 are shorted together. The intersection of this column and row will show that switch as closed (even though it's not). And remember, this switch is not the cause of the problem!
24. **Open diode on a switch.**
    An open diode on a switch will cause only that switch to not work.
25. **Shorted diode on a switch.**
    A shorted switch diode will show no problems when only that switch is opened or closed. However if additional switches in that row or other columns are closed, false switch readings can be shown.

The Optic Switches are Going Crazy!
The optic switches are a bit more complicated than standard micro switches. All the optics require +12 volts to operate. If this 12 volt unregulated

supply gets interrupted (usually fuse F116 on WPC-S and prior, or F109 on WPC-95) or has become intermittent or drops to a lower voltage, the switch matrix can go crazy. Sometimes this can be seen in the diagnostic switch tests as optic switches that very quickly open and close.
This can be caused by cold or cracked solder joints on the connectors going to optic boards (or a bad fuse). While the game is in the switch test mode, wiggle the wires and connectors on the opto driver boards under the playfield. Also check the connectors at the power driver board too.
Another problem can be cracked power solder joints on the power driver board at capacitor C30 and bridge BR5 (WPC-S and prior), or capacitor C8 and diodes D3, D4, D5, D6 (WPC-95). This happens much more often on WPC-S and prior games though. Soldering jumper wires to capacitor C30 (or C8 for WPC-95) can fix this problem.
If a large number of optics seem to be affected, it could also be a CPU board problem. The U20 chip (ULN2803) on the CPU board may have failed (this chip is socketed on WPC-S and later games). Or possibly the +12 volt bridge and/or its associated capacitor on the power driver board has a cracked solder pad, or the +12 volt bridge itself could be bad.

Fliptronics Flipper Switches, EOS switches, and Test Button Switches.

On WPC-95 games, the flipper switches are wired directly to the CPU board (on WPC-S and prior Fliptronics games, the flippers are wired directly to the Fliptronics board). The test button switches (inside the coin door) are also wired directly to the CPU board on all WPC revision. These switches **do not** go through the switch matrix on any WPC revision. The flippers and EOS switches (on WPC-95), and test button switches (all WPC revisions) are part of set of 8 direct switches to the CPU board, which go through two LM339 chips, at position U16 and U17.
On WPC-95, the EOS switches go to connector J208 on the CPU board, and the flipper opto switches go to CPU connector J212. On pre WPC-95 games, the EOS switches go to the Fliptronics II board connector J906, and the flipper opto switches go to Fliptronics II board connector J905. The test switches on all WPC game revisions go to CPU board connector J205.
On pre-Fliptronics games, the EOS switches and flipper switches are NOT wired through any circuit board. They are wired directly to the flippers themselves. The cabinet flipper switches and EOS switches just complete the flipper power circuit to ground.

Switch Maintainence.

Here are the procedures for maintaining WPC switches:

- Micro-switch: no maintainence required. Can adjust the actuator arm only by rotating the switch in its bracket. Do not BEND the activator arm! Loosen the two screws holding the switch, and rotate the switch to adjust the activator arm. Re-tighten the screws, but not too tight as it will bind the switch mechanism.
- Blade or Leaf switch: clean with a business card inserted between the contacts. Squeeze the contacts closed, and remove the business card. Do not use a file on these gold plated contacts! Re-adjust the contact spacing for correct operation.
- Opto switches: use a Q-Tip and some Windex. Dip the Q-tip in the Windex, and clean the opto’s two LED’s (receiver and transmitter) with the Q-tip.

Micro Switch Notes.

Yes race fans, micro switches do wear out! Generally this happens when the plastic “nib” that the switch activating arm activates wears out. But more common is internal wear. Microswitches are only designed to last 100,000 closures. After this, the mechanical parts inside the switch just plain wear out (or become intermittent or “sticky”). At this point, there is nothing that can be done except replace the switch.
With this in mind, nearly all the micro switches in any given “used” pinball machine are near the end of their life! Most WPC games on location got at least 10,000 commercial plays (in some cases like Addams Family upwards of 50,000 plays). So take something as simple as the switch in the shooter lane. This sees at minimum three closures per game (three balls), and probably a lot more if the game goes into multiball. So say a given game has 25,000 plays and is set to three balls. That means the shooter lane switch has seen at minimum 75,000 closures! And realistically, that number is probably much higher. So nearly every microswitch in the game is at the end of its life. And that’s just the shooter lane (I would expect ramp and lane micro switches to have many more closures per game).
Another thing to remember about micro switches is excessive soldering heat will easily damage them. These switches are almost entirely plastic. If too much heat is applies when soldering a diode or wire to them, it can easily melt the internal parts or even the switch’s plastic body. This often makes the switch “sticky” and intermittent. So be careful when soldering to these switches.

WPC Switch Connectors.

The connectors that attach to the bottom edge CPU board are the switch matrix connectors. These originally are .100” IDC (Insulation Displacement Connector) style. If a wire pulls out of the connector, it is often a good idea to replace the whole connector with a crimp-style .100” Molex connector. Here are the part numbers:

- .100” terminal pin: Molex part# 08-50-0114. Digikey part# WM2200-N, and Mouser sells these.
- .100” polarized peg, part# 15-04-9210.
- .100” header pins with no lock (12 pins), part# 22-03-2**12**1.
- .100” white connector housing (12 pins), part# 22-01-3**12**7: Mouser.

* bold text denotes the number of pins, in this case, 12.
End of WPC Repair document Part Two.

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* Go to WPC Repair document Part One
* Go to WPC Repair document Part Three
* Go to the Pin Fix-It Index at http://marvin3m.com/fix.htm
* Go to Marvin’s Marvelous Mechanical Museum at http://marvin3m.com

Repairing Williams/Bally WPC Pinball Games from 1990 to 1999, Part Three.

by *cfh@provide.net*, 09/15/04.

Scope.
This document is a repair guide for Williams and Bally WPC pinball games made from 1990 (Funhouse) to 1999 (Cactus Canyon).

Internet Availability of this Document.
Updates of this document are available for no cost at http://marvin3m.com/fix.htm if you have Internet access. **This document is part three of three** (part one is here, and part two is here).

IMPORTANT: Before Starting!
IF YOU HAVE NO EXPERIENCE IN CIRCUIT BOARD REPAIR, YOU SHOULD NOT TRY TO FIX YOUR OWN PINBALL GAME! Before you start any pinball circuit board repair, review the document at http://marvin3m.com/begin, which goes over the basics of circuit board repair. Since these pinball repair documents have been available, repair facilities are reporting a dramatic increase in the number of ruined (“hacked”) circuit boards sent in for repair. **Most repair facilities will NOT repair your circuit board after it has been unsuccessfully repaired (“hacked”).**

If you aren’t up to repairing pinball circuit boards yourself or need pinball parts or just want to buy a restored game, I recommend seeing the suggested parts & repair sources web page.

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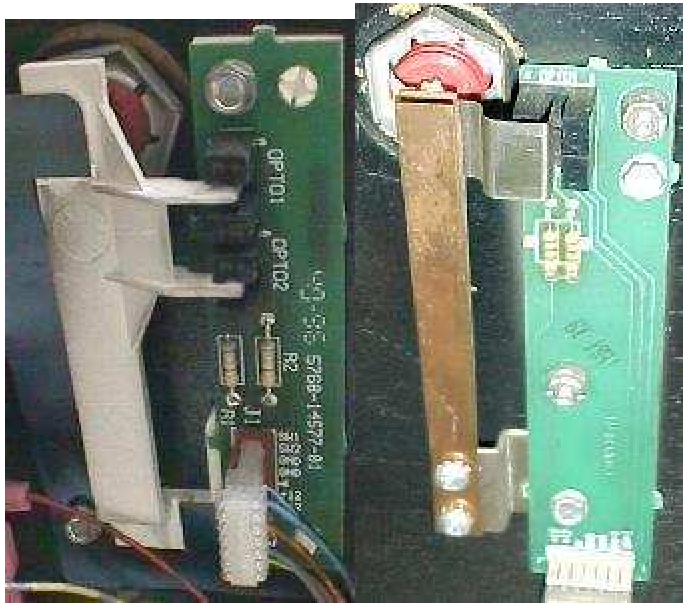
3h. When things don't work: Infrared Optic Switches

As early as 1982, Williams started using infrared optic light emitting diodes (LED's) for switches. This is similar technology to what is used in TV remote controls today. These optics have two advantages over conventional mechanical switches: no moving parts, and they can fit in tighter spaces. They also have some disadvantages. They consist of two parts (instead of one part like a micro-switch): a transmitter (the LED that emits the light), and the receiver (the LED that receives and interprets the light). They can also get dirty (from that infamous black pinball dust) and not work. Pin LEDs are always on too. That is, the light emitting half of an opto switch is always powered on, as long as the game is powered on (even when not in play mode). LED's aren't much different than light bulbs; they eventually burn out too.

Several different optos used in Williams games. The "U" shaped slot optos are used for Fliptronics flippers, Twilight Zone clocks, etc. These consist of a transmitter and receiver in one package. The stand-up optos are two parts: the green board opto stand-up is the transmitter, and the blue board opto stand-up is the receiver. The transmitter LED is larger and protrudes further from its case. The single LED shown below is a replacement LED transmitter for the stand-up optos, and for opto boards used in ball troughs, etc. The specs for this infrared LED replacement are also shown in the picture.

Left: *Type 2 Flipper Optic board. Note the orientation of the optics, and the horizontal plastic optic interuptor. This style of flipper optic board was used on WPC games Indy Jones to Cactus Canyon (with only a minor revision around WPC95, using the 5 pin "U" slot Schmitt trigger optic). The plastic activators can be troublesome, as they often warp and don't clear the opto, causing a flipper not to work.*
Right: *Type 1 Flipper Optic board. Again note the orientation of the optics, and how this is different than the Type 2 board, and the vertical metal optic interuptor. This style was seen on games from Addams Family to Twilight Zone.*

Note: *When purchasing a replacement flipper optic board, be sure to get the correct style! Many times the newer Type 2 flipper optic board is fitted in older games (all versions of the WPC flipper optic boards are plug compatible)! Replacement flipper opto boards are available from pinballheaven.co.uk.*



Where Optos are Used.
Williams uses optos for lots of applications. WPC Fliptronics flipper buttons are opto activated. These flipper opto boards were implemented on Addams Family, mid-production (many Addams have them, but early models don't). Often clear ramps have opto ball switches. Many pre-1990 Williams drop targets use optos (they stopped using them there because the LED's leads would break from vibration, and the optos would fall off). All WPC-DCS (1993) and later games use optos to sense balls in the ball trough.

Two parts to a opto switch.
Each opto switch has two parts; a transmitter, and a receiver. The transmitter is a infrared LED (light emitting diode). The receiver is a light sensitive photo transistor. The transmitter (LED) is always on when a game is powered on. If the light beam from the transmitter is interrupted, then this registers the switch as "open". Because the transmitter is always on and producing light (and hence heat), the transmitter is the part that fails 98% of the time in a opto switch. The receiver part rarely fails in comparison.

On non-U shaped optos, usually the <u>transmitter</u> LED is mounted in a WHITE plastic case with a small GREEN printed circuit board. The <u>receiver</u> is usually mounted in a BLACK plastic case with a small BLUE printed circuit board.

Cleaning Optos.
Optos can get dusty from the "black dust" inside a game. To clean an opto, use a Q-tip dipped in glass cleaner. Wipe the opto with the Windex-wet Q-tip, then dry the opto with a clean, dry Q-tip. Do NOT use canned air to blow optos clean! The air in these cans is too cold and can damage an opto.

Testing Opto Switches.
Testing infrared optos switches is no different than testing mechanical switches (to a point). Just use the WPC internal test software. Press the "Begin

Test" button inside the coin door, and go to the Test menu. Select the "switch edge" test. Activate an opto switch by passing something in front of it to block the light from its corresponding transmitter. The display will indicate if the switch works. Opto switches that are not activated will be displayed as solid "blocks" in the switch test on the dot matrix display (which is basically reverse what you would expect, compared to a micro switch).

12 Volts to the Optos.
If an opto switch doesn't work, first check that the +12 volts is working. If you have blown the +12 volt fuse (either the unregulated 12 volts which provides power directly to the optos, or the regulated 18/12 volts which provides power to the entire switch matrix), the optos won't work. Check fuses F115 and F116 (F101 and F109 on WPC-95) on the power driver board. Also if the unregulated +12 volts is below about 11 volts, the optic switches can work intermittently! If this is the case, usually it indicates a bad BR5 bridge rectifier on the driver board (or bad 12 volt D3-D6 rectifying diode on WPC-95; see the Reset Section of this document for more information on this). BR5/D3-D6 is the unregulated 12 volts (where BR1/D11-D14 is the regulated 12 volts, which could also be the problem since this powers the entire switch matrix, which ultimately reads the opto switches). Remember there is also a large 10,000 or 15,000 mfd filtering capacitor C30 (C8 on WPC95) associated with the power driver board's unregulated 12 volt rectifiers. Check that too for cracked solder joints around the capacitor's leads from vibration (often I will run jumpers to the capacitors and bridges, as shown in the Reset section of this document).

Testing the Opto Transmitter.
On the transmitter LED (the one emitting light), you usually can not check for 12 volts DC right on the opto with a DMM. Unfortunately in most cases the opto voltage will show only about 1 volt (putting the red DMM lead on each leg of the transmitting LED, and the black DMM lead on ground). A better way is to remove the connector going to the opto, and measuring the voltage at the source connector (usually black and gray wires, where the orange and gray pair go to the receiver). If there is no 12 volts present (and other optos in the game work), there is either a break in the ground or 12 volt connection going to the transmitting LED. Also sometimes the optos get cold solder joints (from vibration) on their associated circuit board. Resoldering the opto leads can fix this (assuming the opto lead going to the LED itself hasn't broken). Heck vibration often breaks the wire off the opto board too.

If there is +12 volts going to the transmitter opto but the switch does not work, there is a good chance the transmitter LED has failed. Radio Shack sells a $5 credit card sized "infrared sensor". MCM Electronics also sells one, #72-6771, for about $7 (800-543-4330 or www.mcmelectronics.com). If you put this card right in front of an opto transmitter, the opto's emitting light can be seen; the light will show on the colored band of the sensor card. Also, a digital camera or a camcorder will usually show infrared light from the transmitting opto, if the digital camera has a small LCD screen used to show images "live" (but personally I like using the opto cards better).

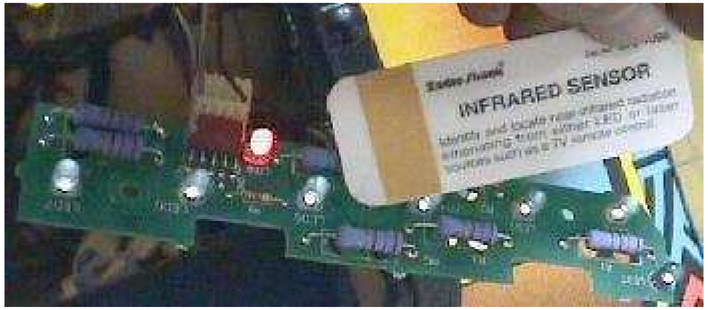
If there is +12 volts (hint: do other optos work?), and the opto switch doesn't register in the diagnostic test, your opto transmitter is probably burnt. The receiver side of an opto switch rarely dies. That's because it only senses light, and doesn't produce light. The transmitter will be the offending unit 98% of the time. Remember the opto transmitter is powered-on all the time the game is turned on, and it can burn out just like a light bulb can burn out.

Reversed Leads on the Transmitter.
Another common fault of the LED opto transmitters is having the wires reversed. Yes it does matter which wire goes where. And don't think you are the only one that can make this mistake. I have seen NOS parts right from Williams where they have soldered the leads reversed on the opto transmitter! Note usually having the leads reversed does not blow the transmitter. There is a flat spot on many LED transmitters too, signifying which side to connect ground or 12 volts. But I have also seen some manufacturers have the flat side reversed! So if in doubt, try reversing the black and gray leads on a non-working opto transmitter.

Testing the Opto Receiver.
The simplest way to test the opto receiver is to first put the game into the "switch edge" test. Then block the opto transmitter with a piece of black electrical tape. Now shine a penlight flash light into the opto receiver. The switch should "close" (go from a solid block to a small dot on the DMD screen). When you remove the light, the switch should "open". If the LED receiver is working properely but the switch does not work, often the opto transmitter has burned out.

Another way to test the opto receiver is using a DMM. First block the opto transmitter with a piece of black electrical tape. Put the black DMM lead on ground (the metal side rail of the game works well). Put the red DMM lead on one leg of the opto receiver (gray wire). One opto receiver leg should show 12 volts DC, and the other opto leg should show close to zero volts (orange wire). Keep the red DMM lead connected to the "low" (zero volt) opto leg. Now shine a flashlight into the opto receiver. The DMM should now go to 12 volts DC, and when the light is removed, go back to near zero volts. If this does not happen, the opto receiver is bad. Or if 12 volts is seen on both opto receiver legs, the receiver is bad (or there is direct light shining into the opto receiver).

Testing the infrared opto transmitters on a 7 LED ball trough assembly. The LED's can be seen lit in this photo, but you won't be so lucky with the naked eye. That's why this Infrared Sensor card or a digital camera/camcorder is so handy. Note in the digital picture below, the red and blue infrared LEDs are lit. With the naked eye, the LEDs do not look lit.



Opto Transmitters on Newer WPC games.
Older WPC games use optos with straight resistive photocells. Some newer WPC95 games use a transistor gate photocell. This means the internal transistor can die, even if the photocell part of the opto is OK. Keep this in mind; if an opto transmitter tests good (with your Radio Shack or MCM test card), the opto could still not function properely. Replacing the opto is the only thing that will fix it. This is rare and hard to diagnose, but if everything checks out this could be the problem.

The Opto Receiver and Transmitter Tests Good, now what?
If the receiver tests good with the penlight flashlight, and the transmitter tests good with the infrared sensor card, there is one more thing that could be wrong. This would be the LM339 voltage comparitor on the opto board. If everything else checks out, replace ALL the LM339 chips (and use sockets!) on the opto board (there are usually two to four of these chips on the opto board). Unfortunately the LM339 chips are not that easy to test, since they're dealing with voltage levels. But as long as the voltage levels on the outputs of the LM339 are stable (not pulsing and not fluctuating), the truth table for the individual comparators can be tested with a DMM (inputs) and a logic probe (output).

Other Problems.
Often the source of ground for the 12 volts going to the opto switches can be tricky to find. And if this ground connection fails, several or all optos will not work. For example on Indiana Jones, the drop target board and flipper opto boards get their ground from the Fliptronics II board's J905 connector. If this connector is bad or removed or off by one pin, there would be no ground optos ground, and none of the optos would work.

WPC Fliptronics Flipper Optos.
Flipper opto boards were implemented on Addams Family, mid-production. If a WPC Fliptronics flipper doesn't work, and it's not a coil, transistor or wiring related problem, you should suspect the flipper opto board. This board has two "U" shaped optos that detects the flipper button. These boards are all made with two optos, even if the game only has two flippers instead of four.

Use the infrared sensor card to determine if the opto is working on the flipper board. If you suspect a problem with this opto (and don't have a infrared sensor card), swap the left and right flipper opto boards, and see if the problem moves to the opposite flipper. Note: **both** flipper opto boards must be plugged in for this test to work! Flipper opto power is run from the backbox, through the left flipper opto board, to the right flipper opto board. Flipper opto ground is run from the backbox, through the right opto board, then to the left flipper opto board. Hence both opto boards must be plugged in for them to work!

If indeed one of the flipper optos is bad, and the game only has two flippers, reverse the two optos on the bad flipper opto board. One of the optos will be unused since the game only has two flippers, instead of four. Mark the bad opto, and its position on the opto board. As a general rule, the "top" opto on the flipper board (the opto farthest away from the two resistors) is the LOWER flipper opto. Unsolder both optos and move the good opto into the marked (upper) position on the flipper opto board.

The only problem with doing this is a potential switch error with the bad opto. Even though the second flipper board opto is not used, many Williams games check for this switch, and will report it as "bad" in the game's power-on test report (even though the game may not use it). Also some games use the "unused" flipper opto for scrolling through the high-score initials. So ideally it is best to just replace a bad opto instead of swapping.

Weak Flippers and Bad LM339's on the Fliptronics Board.
On WPC fliptronics to WPC-S board, chips U4 and U6 (LM339) on Fliptronics II board can fail. On WPC-95, these LM339 chips are on the CPU board at locations U25 and U26. This will make the flipper opto boards seem like they are not work. Swap the two flipper boards to test this. If the problem doesn't change, suspect the LM339 chip(s). These LM339 chips can also become "leaky". This will make flippers seem very weak. A bad LM339 can also give the indication that the EOS switch is bad.

If there is a marginal flipper switch reading, this causes the high powered side of the flipper to rapidly oscillate between on and off. The holding side of the flipper coil never engages. This problem will cause the flipper coil to get very hot in a short time.

Opto Wavelength.
Optos come in basically two different wavelengths: 880 nM and 940 nM. The 880 nM optos came first, but the opto industry has largely moved to the newer 940 nM wavelength in the last few years. Williams used 880 nM in nearly all applications, but this older wavelength is harder to purchase today. The newer 940 nM standard minimizes false triggering from sunlight and incandescent light, and can operate at longer distances from the opto receiver. Also the newer 940 nM wavelength works better in foul air (high humidity and polution). The only down side to the new standard is if the application has a newer 940 nM transmitter, and an older 880 nM receiver, this can cause problems.

Replacement Infrared LED Optos.
The infrared LED transmitters have the industry part number QED123 (Fairchild, MOT and QT brands). These are 5mm sized LEDs. The color of the LED will range from pink to yellow to blue. They also have one flat size, which denotes the "K" (cathode) lead, which is the shorter lead. The flat side of the LED is usually marked on the circuit board too. The other non-flat side lead should be longer, and is the "A" (anode) lead. Typically in a WPC game, the black switch matrix wire goes to the "K" (flat side) of the infrared LED. The gray wire goes to the "A" lead. Radio Shack sells the infrared LED (transmitter), part number 276-143 (or 276-143c), $1.69 (replaces Williams A-14231). Also Mouser sells Fairchild QED123 LEDs.

Replacement Photo Transistors.
The photo transistor (receiver) have the industry part number QSD124 (Fairchild, MOT and QT brands). These are 5mm sized LEDs. The color of these are usually black. They also have one flat size, which denotes the "E" (emitter) lead, which is the shorter lead. The other non-flat side lead should be longer, and is the "C" (collector) lead. Typically in a WPC game, the orange switch matrix wire goes to the "E" (flat side) of the infrared LED. The gray wire goes to the "C" lead. Radio Shack also sells an infrared transistor (receiver), part number 276-145a (or 276-145), $0.99 (replaces Williams A-14232). When mounting these, the flat edge goes in the hole furthest away from the hole that has the notch drawn on the circuit board. Mouser sells the Fairchild QSD124 photo transistor. Digikey also sells a receiver, part number PN104-ND. When installing this photo transistor remove the center pin before installing. Just wiggled the center lead back and forth until it breaks off at the base. Install this part so the notch at the base lines up with the notch drawn on the circuit board.

Radio Shack also sells a combo package with both the receiver and transmitter, part# 276-142, $1.99. This is essentially the #276-143 and #276-145 parts combined into one package, at a discounted price. The word from Radio Shack is part number 276-142 will change. The the old stock LED style transmitter/receiver is discontinued, and replaced by a "U" shape style opto (though the part number is still the same). This "U" style opto will work on some unique WPC optos (see the "Radio Shack 'U' Opto" section below), but nothing else. But lately the U optos have again been replaced with separate LED style optics.

Lastly, it has been reported that the Radio Shack #276-145a photo transistor is not as sensitive as the stock Williams part. Apparently if the distance is greater than two inches between the two optos, often the photo transistor will not register the infrared LED. In conclusion the #276-145a photo transmitter is not sensitive enough, since using a Radio Shack #276-143 LED and a Williams photo transmitter does seem to work at greater distances. Your mileage may vary, as Radio Shack parts can often be inconsistent.

WPC-95's Five Leg "U" Shaped Slot Optos.
Starting with WPC-95, Williams changed to a "U" shaped Schmitt Trigger opto (five legs in total, three legs on the receiver, two on the transmitter). The Schmitt trigger optos will not oscillate (turn on and off quickly) when the optics gets dirty/old (they either work, or don't work).

The problem with the older 4 legged flipper optos when dirty/failing was the oscillation. This would cause the flipper coils to get low amounts of power continuously during game play (like the player was pressing the flipper button on and off continuously, and very fast). This would cause the flipper coils to get hot. It would also make the flippers weak (because when the player really did press the button, the oscillation would try and turn the flippers off very quickly too!).

The older 4 legged "U" optos also caused other problems on games that used the flippers to control playfield toys. For example on Indiana Jones, a dirty/failing flipper optic could cause the mini-playfield Path of Adventure (POA) to "stutter" when the player tried to move it right or left with the flipper buttons. This was a confusing error because in test mode, the POA would act normally (because the flipper buttons were not involved in the test - if the POA stutters in both game and test mode, the two 4 legged optos on the POA board could also be bad).

Because of the oscillation problem, Williams changed to a five leg Schmitt trigger "U" shaped opto with WPC-95. This solved the dirty/failing optic flipper problem, and made diagnosing flipper related optic problems easier. The new five leg optos usually either work, or don't work.

Replacement 5-Leg "U" Shaped Slot Optos.
Unfortunately the five legged "U" optics are much harder to find than their four legged cousin. The Williams part number for these optic is 5490-14575-00 (or QTE734, QT724, QT850, or QT902 has been seen), and is called "IC Opto Integ Schmitt 10mA". The only source I know of for this optics is www.infineon.com, part number SFH9340 ("active low"). The alignment of the fifth leg is not quite right on this part, but this optic should still work. Replacement five legged optos are available from http://www.pbliz.com/id43.htm.

Replacement 4-Leg "U" Shaped Slot Optos.
Unfortunately, "U" optos are fairly expensive (compared to micro-switches). For example, if you are repairing your Twilight Zone clock (which means replacing all eight of the "U" shaped optos), this can get costly.

The industry part number for the pre-WPC95 four leg "U" shaped optos is QVE11233, with a standard sensitivity of .0110. Unfortunately, Williams requires a higher sensitivity opto for their applications. This means the cheap $1 optos from most electronic supply houses may not work, as their sensitivity rating isn't high enough. If you are shopping for these "U" optos, keep this in mind. You should be looking for part number QVE11233.0086, where .0086 is the increased sensitivity rating. This is the exact part used in Twilight Zone clocks, one of Williams most sensitive opto applications. This means a QVE11233.0086 "U" opto should work every where else just fine!

As a side note, the original Williams optos were made by Motorola. But around about 1996, they split their opto electronics division into a new company called QT Optoelectronics. Then in early 2001, Fairchild bought QT. What does this all mean? Well it means the "original" Motorola brand "U" optics are all gone, but there is a fairly good stock of QT brand "U" optics around (which are identical to the original Motorola brand, differing in name only). Fairchild unfortunately has discontinued the older optic line, and no longer makes an exact duplicate of the original Motorola/QT "U" slot optos. They do make some similar optos, but the leg spacing and specs are slightly different (but they may work!)

Generic "U" shaped slot optos (QT brand) with the lower .0086 sensitivity are available from Mouser (www.mouser.com, part number 512-QVE11233, $0.90) and Digikey (www.digikey.com, part number QVE11233QT-ND, $0.90). Unfortunately, these most often do not work in Williams pinball applications.

A replacement "U" shaped slot opto that works 100% of the time for sure (and mounts dot on the opto to the dot on the PCB) is available from dragster_73@hotmail.com, Prestige Industries (800-456-7277 www.pinball4u.com) or Competitive Products (800-562-7283 www.competitiveproducts.com). At about $5 each (QT brand, long leads too, for the Twilight Zone clock), these are a very good replacement for nearly every Williams pinball application.

The Radio Shack "U" Shaped Slot Opto.
Radio Shack used to sells a "U" shaped four leg opto, part# 276-142, $1.99. The "new stock" of this part number is NOT a "U" shaped opto, but is essentially the LED style #276-143 and #276-145 receiver/transmitter combined into one package. The word from Radio Shack is the "U" style was discontinued, and replaced by the LED shape style opto (though the part number is still the same). The old R.S. U opto does work in the Twilight Zone clock and in the flipper opto boards (four leg variety, prior to WPC-95), with some minor mounting modifications. The spacing on the bottom part of the "U" of the opto is slightly different, and some mounting adjustments are needed to offset this (especially on the Twilight Zone clock). The old Radio Shack "U" optics is also a perfect replacement for the Indianapolis 500's lighted target. The style of optic used on this target is exactly like the Radio Shack part.

Installing the old Radio Shack "U" Optic.
Installing the Radio Shack optic is "backwards". This opto has a "dot" silkscreened or impressed on its side. Normally, this opto dot should line up with the dot silkscreened on the printed circuit board. But in the case of the Radio Shack #276-142, this dot goes OPPOSITE of the circuit board dot. On the Indy500 targets, the board does not have a dot. Instead the dot on the Radio Shack Opto goes to the "A" terminal (instead of the "C" terminal of the original Williams Opto). If there is any question you can confirm the orientation using your DDM. Testing with the red DMM lead on "A" and the black DMM lead on "K". This will show a reading of about "1". All other combinations get a reading of "0".

On the Radio Shack optos can not be found for an Indy500 fix, drill out the rivets and remove the "R" opto case from the target board. Then take a 4-legged Twilight Zone opto and pry off the case. This will expose the "guts", which can be transplanted to the Indy 500 opto board. Note the cover does NOT need to be put back on the opto.

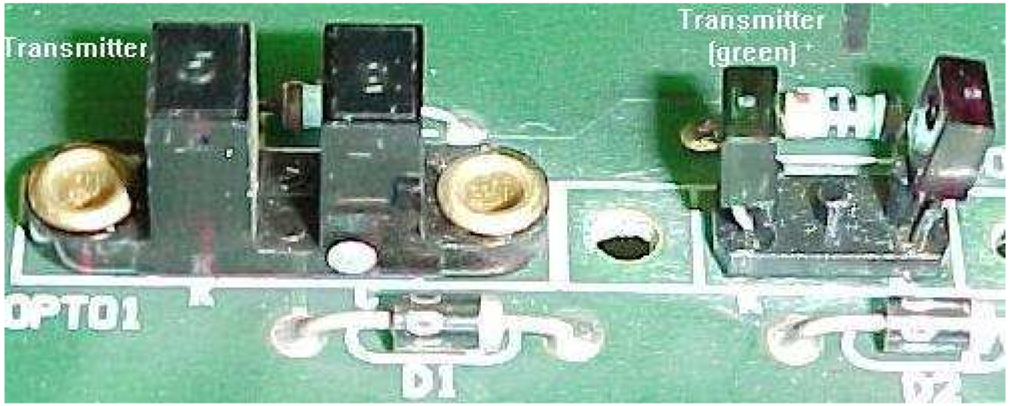
A Williams flipper switch opto board. The "top" (lower flipper) opto has been replaced. Note the "dot" markings on the flipper opto board. Many replacement optos will have a corresponding "dot" or "notch" in the opto, which aligns with the board's dot. If the new opto does not have a dot/notch, align the "S" and "+" leg of the opto closest to the circuit board's dot.

Installing "U" Shaped Optics (Other than Radio Shack's "U" Optic).
There are two positions that a "U" shaped optic can be installed. Putting the optic in "backwards" usually does not ruin the optic, but it will prevent the optic switch from working! Many replacement optics have a "dot" or "notch" on one side of the optic. This dot/notch should align with the dot silkscreened on the circuit board (there are exceptions to this, such as the Radio Shack #276-142 "U" optic, where the optic's dot goes OPPOSITE of the board's dot, but this is a rare exception, see above).

If the new opto does not have a dot/notch, there should be "S", "E" and "+" markings on the top of the two legs of the optic. In this case, align the "S/+" leg of the opto closest to the circuit board's dot.

After the new optic is installed and in the game with the power on, use the Radio Shack infrared card to find the transmitter leg of the optic. The newly installed optic should have its transmitter leg in the same relative position as the other original adjacent optic(s).

The "U" optic on the left is an original base mounted Williams optic (this one from No Good Gofers). This style of "U" optic case is sometimes hard to find. But the case can be pried apart, reused, and new optic guts placed inside. The optics on the right are the replacement "guts" for the "U" shaped optic (taken from a regular "U" shaped optic). The original case is then set over top and snapped into place. Alternatively, the plastic case can be discarded, as shown here!



"U" Optic Replacment Alternative: Reusing the "U" Optic Case.

The U shaped optic's black plastic case can be reused, and just loaded with new optics "guts". Guts can be taken from other new "U" optics (that use a different style case), or the optic guts can be purchased separately. The "U" case pries apart from the bottom, using a small screw driver. The new guts are then placed inside. When doing this be careful to identify which is the transmitter **before** taking the original optic apart. This way the new transmitter and receiver can be inserted in the same positions, and the case cover installed with the "dot" in the correct location. In some applications, the black plastic case may not even need to be replaced (if there is no risk of a pinball hitting the optics, and no risk of stray ambient light). Gregg Woodcock sells these individual optic guts at users.sisna.com/woodcock/wmsoptos.htm. The transmitter (Gregg's are red) goes into the spots marked "A" and "K". The receiver (Gregg's are clear) goes into the spots marked "C" and "E".

3i. When things don't work: Electronic Ball Sensors (Eddy Sensors and Magnetic Reed Switches)

Starting in 1993, Williams starting using "eddy sensors" to determine when a pinball rolled under a portion of the playfield. A eddy sensor is a electronic switch; it has NO moving parts. It can sense when a steel pinball passes over it, and acts like regular mechanical switch. Star Trek Next Generation and Theatre of Magic uses these eddy sensors. These electronic switches are used in playfield areas where a regular mechanical switch is not practical or visually pleasing.

An under the playfield eddy sensor control board as used on Theatre of Magic. Note the potentiometer and LED. The connector on the left goes to the actual under-the-playfiled mounted "sensor" (see pictures below) that tell this board there is a ball above it.

Often eddy sensors can go out of adjustment and become less sensitive. This can cause the eddy sensor to not activate when a ball passes above it on the playfield. To adjust an eddy sensor do this:

- On the under the playfield eddy sensor control board, turn the potentiometer counter-clockwise until the LED just turns on.
- Now turn the potentiometer back clockwise until the LED just turns off.

That is all that is required to adjust an eddy sensor. To test the sensor, put the game into WPC diagnostic's first switch test. Then move a pinball over the playfield area where the eddy sensor is located. The switch should activate on display.

***Left:** the actual sensor that senses the ball. This is a smaller sensor as used on the outlanes of many games.*
***Right:** another type of eddy sensor that senses the ball. This sensor is used in Theatre of Magic and covers a wider area.*


Second Generation Eddy Sensors.

Some games made in 1996 and 1997 (like Cirqus Voltaire) use a second generation Eddy sensor. Instead of having a potentiometer under the playfield to adjust sensitivity, these are "auto-adjust" Eddy sensors. This style of Eddy sensor is better, as they do not go out of adjustment. But they also use more logic parts, meaning more electronic parts to potentially fail.

Twilight Zone Eddy Sensors.

The eddy sensor that causes the most trouble in Twilight Zone is the sensor by the ball trough (switch# 26). Note eddy sensors were used as early as Twlight Zone. The eddy sensors in TZ are different than the later sensors, and do NOT have an adjustment pot and they are not auto-adusting (they also are called a different name, like the "Trough Proximity" board). On the ball trough sensor, it is actually two boards: the sensor board, and the driver board (the driver board is the one with the two molex connectors; a picture of the two boards is here). The only adjustment you have on the TZ eddy is moving the sensor board closer to the ball. This can sometimes fix many problems.

Another common TZ problem are the molex connectors on the driver board. Just taking the two pin molex connector off and putting it back on its header pins will usually the problem. If not, this small board often needs to have its molex header pins resoldered. The solder joints on the board's header pins can crack. Also, it is possible for the TDA0161 (Williams part number 5370-13452-00) chip to die on this board. If you don't want to replace just this chip, the whole proximity driver board is available for under $15.

Modifying your Twilight Zone Eddy Sensor.

Ray Johnson (http://www.aros.net/~rayj/action/tech/tz_prox.htm) came up with this cool modification. It adds a small PC-board trimmer pot to the sensor PC board. This allows you to always be able to adjust the sensitivity of the sensor. Here are the steps:

1. Buy a small PC-mount trimmer pot. Get the lowest resistance rating you can find (something around 100 ohms would be ideal, but the most common "low rated" pots are about 1k ohms). Some of these small pots can be very, very touchy, so it's best to get one that has a low resistance rating (like 100 ohms), which allows you a good accurate adjustment. The average amount of resistance you'll want from the pot is around 20 to 30 ohms, so check your pot with your meter first to make sure it will let you adjust it easily to this value.
2. With the power off, remove the sensor board from the game. Two hex-head screws hold it to the underside of the playfield.
3. On the component side of the board, cut the trace between the connector pin and the sensor. This is the only trace on this side of the board, so you can't miss it. Use a sharp knife, or X-Acto blade, to slice through the trace. Use multimeter to make sure there is no continuity after you've made the cut.
4. Scrape some of the insulation off the trace that leads to the sensor (see image above). Remove enough to adequately solder a jumper wire onto the bare metal of the trace. Click here for a picture of this step and the prior step.
5. On the solder side of the board, use a small marker to mark the position of the three legs of the trimmer pot onto the PC board. Drill three holes in the board through which you will mount the pot. Use a very small drill bit (1/16" or smaller). Click here for a picture.
6. Install legs of pot through the holes you drilled in the PC board. Bend the legs on the other side of the board to hold the pot on the board. Click here for a picture.
7. On the component side of the board, connect two small jumper wires to the pot. The first jumper wire will come from the back side of the pin on the connector (the one with the trace going away from it). The other jumper wire will come from the other side of the trace that you cut, where the insulation was scraped away. Connect the other ends of the jumper wires to the pot. One goes to the middle leg, and the other goes to either side leg (doesn't matter which side leg). Click here for a picture.

The modification is now done. Install the sensor board and the cable that goes between it and the driver board. With the sensor board installed, the pot should be easily accessible with a small screwdriver. Now power on the game. With NO balls in the ball trough, adjust the installed pot just as described above (for the newer Eddy sensors):

- Turn the potentiometer until the LED just turns on.
- Now turn the potentiometer back until the LED just turns off.

Test your work by putting a single steel ball in the ball trough. The LED on the Proximity driver board should come on. Move the ball away from the sensor and the LED on the driver board should turn off.

Magnetic Reed Switches (beyond Eddy sensors).

Starting with NBA Fastbreak, Williams largely stopped using Eddy ball sensors. This change came about because the Eddy sensor had reliability problems. Even the later self-adjusting Eddy sensors were not as reliable as needed.

Instead, Williams changed to a Magnetic Reed Switch (MRS) with NBA Fastbreak. This style of switch is contained in a black epoxy package, about 2" long, and ½” wide. Like an Eddy sensor, it can sense when a pinball is near the switch.

MRS switches uninstalled, Williams part number 20-10293
(the “9937” is a manufacturer date code).

The advantage to the MRS is great; there is NO additional circuitry needed for the switch (unlike Eddy sensors). And MRS switches generally do not break, fail or wear out. This makes a MRS more reliable and cheaper. A MRS plugs directly into the switch matrix, just like a micro switch. It doesn’t use an additional circuit board, or even a diode! Williams used the MRS under plastic ramps and under playfields.

a MRS switch under a Cactus Canyon ramp.

There are some drawbacks to a MRS though. First, it does not read a really fast moving pinball as predictably as an Eddy switch. For this reason, often Williams puts two MRS switches in parallel to compensate for this. Also the ball must roll directly over the MRS switch. Because the switch is only ½" wide, again two switches are often used in parallel to make sure the pinball is "seen" by the MRS. Finally, a MRS must be very close to the ball. If mounted under the playfield, they can only sense the ball through the thickness of a playfield insert or a plastic ramp, and not through wood (which apparently is too dense). The mounting for the MRS under the playfield is often two rubber grommets. If a grommet falls off, this will not allow the MRS to be snug against the playfield, making ball detection difficult.

3j. When things don't work: Ball Trough Problems (random multi-ball and bad trough LEDs)

The ball trough is the area where the balls drain and collect when a game is over. Up to 1993, Williams used a conventional ball trough design. This old style ball trough used mechanical switches to sense the ball's presence. It also used two coils to move the balls; one to kick the ball from the outhole to the trough, and another coil to kick the ball from the trough to the shooter lane.

Starting in 1993 with Indiana Jones, a new ball trough design was used that instead relied on gravity to feed the balls into the trough. This saved one coil (the outhole coil was no longer needed). The new design also used opto switches instead of mechanical switches. This allowed one ball trough design to be used in all Williams games, regardless of the number of balls used in the game. The ball trough could now comfortably hold from one to six balls (depending on the game; most used four to six balls).

The two opto boards used on either side of the ball trough to sense the balls. Note the large blue resistors used on the top board. Often these resistors can vibrate and break. This will give the opto board false ball senses or no ball senses.

Ball Trough problems (Random Multi-Ball, Drained Ball not Sensed, Game won't Start).

When the opto ball trough was first used on Indiana Jones, Star Trek Next Generation, Judge Dredd, Popeye, and Demoman, William bolted the opto boards right to the side of the trough. The vibrations from the trough often caused the leads on the large blue two watt resistors and the infra-red LED's on the opto transmitter board to break. This would cause the game to start random multi-ball at just about anytime during the game. Often the game would never end (because the trough would not reconize when all the balls had drained).

To fix this problem, Williams redesigned the attachment points for the two opto boards. Instead of being bolted directly to the trough, the mounting holes on the opto boards were enlarged (and one hole moved). Then rubber gromets where inserted into the holes, and short metal tube bushings where inserted through the rubber gromets. When the opto board bolts where tightened down, they tightened on the metal tubes. This allowed the opto boards to "float" on the rubber gromet, reducing vibration considerably.

Also be aware that on Star Trek Next Generation if fuse 103 on the Power Driver Board is blown (3A slow blow), the game will not start and will constantly throw out balls. Fuse 103 powers the solenoid which controls the upper diverter on the under-the-playfield diverter. Without a working diverter, the game can't load the balls where it wants, and the game will attempt to load and reload balls continually.

Later Opto Board Design.

To make the opto boards more resistant to vibration, starting with World Cup Soccer 94, Williams moved all the electronics off the opto boards and onto a separate board. This meant that only the optics were on the trough opto boards, and no other components. No longer could the large blue two watt resistors crack from trough vibrations. Unfortunately, Indy Jones, Star Trek Next Generation, Judge Dredd, Popeye and Demoman all use the older ball trough opto boards with the easy-to-break blue resistors and bad mounting design.

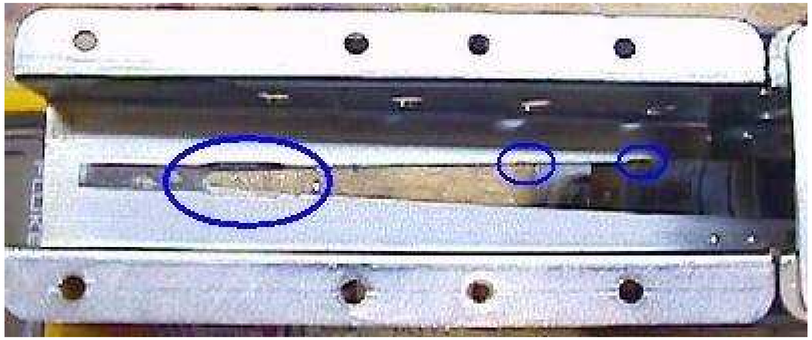
Ball Trough Divots (Indy Jones to Cactus Canyon).

Another problem with the new ball trough design is "divots". As the pinballs fall into the ball trough from the playfield, they eventually make divots into the metal. This can cause the balls to hang and not roll the length of the ball trough and down to the shooter lane upkicker coil. All sorts of weird game problems can occur from this. The most common is trying to start a game by pressing the start button, and the game responds with "pinballs missing", or a game that doesn't end when the ball drains. Random multi balls can be caused by this problem too.

At first look, where the balls fall from the playfield into the trough would seem to be the problem. But that really is not the big problem; where the balls rest in the trough "V" slot can develop very small divots or nicks in the metal. All these newer game use four to six balls, and often a pair of nicks in the metal can exist where each ball rests in the trough!

To fix this, a Dremel tool or a hand file can be used to grind the divots out of the metal. After the nicks are ground out smoothly, sand the sides of the "V" in the trough smooth with 220 or 320 sandpaper. If this doesn't work, order a new ball trough, part number A-16809-2. This newer design of the ball trough should last longer and divot less.

On the left blue circle is where the balls slam down into the trough. But the big problem is the two smaller blue circles, center and right. These very small nicks will stop the balls from rolling down the trough as a single ball is fed to the shooter lane. These causes all the balls to hang and not roll the length of the ball trough.



Buying a Ball Trough Mounting Upgrade Kit.
If you want to upgrade your Indiana Jones to Demo Man ball trough to the current board mounting design (which can help solve random multi-ball problems), order an upgrade kit, part# A-18244. This includes two new opto boards, and all the mounting hardware needed (the mounting hardware is absolutely necessary). At $50, this is an expensive kit!
Modifying the Existing Trough Boards Mounting Instead.
Modify the existing trough boards can be done for much less money. The parts can be ordered from Williams:

- (6) Metal bushings, 3/16” outside diameter and 3/16” long, Williams part# 02-4975, $0.28 each.
- (6) Rubber grommets 3/16” inside diameter and ¼” to 7/16” outside, Williams part# 23-6626, $1.02 each.
- (6) Trough board mounting screws (same #6 size/thread as the originals, just ¾” long).

These parts can be bought locally. Rubber grommets can be bought at any decent hardware store in the electrical department. The inside diameter grommet hole (the important part) is 3/16”. The outside diameter can vary from ¼” to 7/16”. The metal 3/16” bushings can be bought at hobby shop that sells 3/16” brass or aluminum tubing (usally in 12” lengths), used for hobby applications. This tubing cuts easily with a Dremel cut-off tool, or for $5, most hobby shops also sell small tubing cutters (easier to use than the Dremel). Buy metal tubing which fits easily but snuggly inside the 3/16” rubber grommet (3/16” or even 5/32” outside diameter tubing). The longer ¾” #6 trough board mounting screws are also required, and are a standard hardware store item.

The rubber grommets and metal tubing which goes inside the grommets. Three grommets/tubes are needed for each of the two optic boards.

After buying the above parts (either from Williams or elsewhere), drill or use a hand remer and make the trough optic board holes bigger, about ¼" (or up to 7/16", depending on the outside size of your rubber grommets). Be careful you don't drill through any board traces (this should not be a problem). Also, drilling the center hole is optional; mounting with just two (outside) of the three holes per board works fine too. Insert the rubber grommets in the enlarged holes, and put the metal tubing inside the grommet. The metal bushing should be just very slightly shorter than the width of the rubber grommet, no longer. This allows the board bolt to tighten down on the bushing, but leaving a bit of "play" in the board (which the rubber grommet gives).

More Random Multiball: the Ball Trough Optic Resistors.

On Indy Jones, Star Trek Next Generation, Judge Dredd, Demo Man, and Popeye, the ball trough optic boards have several large blue resistors mounted to them. Since these boards get a fair amount of shock and vibration from balls, often these resistors can crack or break. If this happens, random (and continual) multiball can result. Check these large blue power resistors for breaks or cracks. Usually the resistor leads break right where they connect to the circuit board.

Do not try and repair the resistors; just replace them. They are 270 ohm 2 watt resistors (do not replace with a version less than 2 watts). These are available from Digikey, part number ALSR3J-270-ND, $1.37 each. NTE/ECG sell these too at many local electronic part houses for about 99 cents a pair.

Ball Trough Optos.

The ball trough optos also commonly break from ball vibration and wear. Every optic is a pair; a transmitter (which gives off infra-red light), and a receiver (or photo transistor, which sees the infra-red light). The receiver rarely goes bad. The transmitter optics are on the trough board closest to the coin door (lucky for us, as this board is easiest to access). The transmitter optic is available from Radio Shack, part number 276-143c, $1.69. This replacement optic transmitter is blue in color, and works fine as a replacement. Gregg Woodcock also sells yellow trough LED infrared transmitters at users.sisna.com/woodcock/wmsoptos.htm, for $1 each. In either case, this part should only be installed one way. Printed on the circuit board is a round circle with a flat side. The optic also has a flat side, which should match the circuit board.

The receiver optic is also available from Radio Shack, part number 276-145a, $0.99. This receiver is clear, unlike the Williams receiver. The flat edge of the receiver needs to be mounted closest to the top edge of the circuit board. That is, the flat edge goes in the hole furthest away from the hole that has the notch drawn on the circuit board. Digikey also sells a receiver, part number PN104-ND. When installing this photo transistor remove the center pin before installing. Just wiggled the center lead back and forth until it breaks off at the base. Install this part so the notch at the base lines up with the notch drawn on the circuit board.

The New Williams Ball Trough and the Blue Resistors.

If using the newer metal trough #A-16809-2, and using all three mounting holes, it will also be necessary to move one of the large blue resistors to the back of the board, and drill a new center position mounting hole in the opto board. Another option (and spending $50 is not an issue), order the upgrade kit from Williams, part# A-18244, and get the two new trough opto boards and the mounting hardware. Or use the existing trough boards with just the two outside mounting holes. If drilling the current trough boards is not an option, they can always be mounted with two of the three holes instead. This works fine too.

Bad Ball Trough Connectors.

Another ball trough problem can be related to the connectors used on the ball troughs. Again, due to vibration, the solder joints for the circuit board header pins can crack, causing intermittent connections. To fix this, reflow the solder on the connector pins on both trough boards.

Testing the Ball Trough Optos.

After modifying the trough boards and grinding the divots out of the trough, I connect the transmitter and receiver boards to their connectors. Now I dim the lights to the room, turn the game on, and go to the first switch test T.1. Using a Radio Shack or MCM infrared detector card (or a digital video or digital still camera), check all the transmitter LED infrared optos to see if they are working.

After that is done, shine a small pocket flashlight into each of the receiver board detector optos. They should register in the T.1 switch test (room needs to be somewhat dim for this; ambient room light can also activate these). Turn the game off and assembly and install the trough board on the trough, and install the trough back in the game.

Now it's time for another test, one that is especially good to verify your work, or to test the trough if you have not modified it. With all the balls removed from the game, turn the game on and go to the first switch edge test T.1. Most switches should show with a dot, indicating the switch as open (a sqaure indicates a switch is closed). But on optic switches, a blocked opto is a dot, and an unblocked opto is a square (opposite of what one would expect).

There should be a number of squared switches, indicating the opto trough switches (check your game manual for exact switch numbers). If your switch matrix has no squares (all dots), your playfield has lost the +12 volts powering the optic switches. Check fuses F115 and F116 (F101 and F109 on WPC-95) on the power driver board.

Now slowly roll a ball down the trough and watch it cause a square in the switch matrix to turn into a dot, as the ball rolls past each ball trough optic.

When the ball is resting at ball trough optic one, physically push up on the ball lane shooter solenoid (that would kick that ball onto the playfield). This will cause that "trough jam" opto to turn to a dot. This opto only sees the ball as it gets kicked out, or if there are two balls jammed so they are sitting on top of each other at the right end of the trough.

Fill up the trough completely with balls, then remove the balls manually, one by one. Try this a few times to see if you can isolate any of the ball trough squares which are not turning to dots consistently.

Lastly, remove ALL balls from the trough and close the coin door. Press the flipper buttons to activate the flippers while still in switch edges test. Look for flickering square-to-dots on the ball trough column on the display. This tests flipper vibrations which can cause intermittent flickering on the opto switches. Now continue checking for bad optos by hitting the playfield with the meat of your fist near the flippers (it's not as bad as it sounds!) If any of the squares flicker to a dot, there is some vibration related problem (broken/cracked blue resistor or opto lead, or cracked header pin solder joints). If nothing has appears, leave the game in this test mode for 20 minutes (note some games will exit test mode automatically after 15 minutes) with no balls in the game. Be close by, within listening distance. If you hear the game "bong" that means a switch has opened/closed in the switch test. Go to the game and check the score display, as the last switch closed will be reported. See if this is a trough opto switch number. If so, it is a flakey opto or bad opto board resistor or bad connector. This "time test" allows the game to 'warm up' too, which often the other tests don't account for.

If all the trough switches change from squares to dots when the optos are blocked with a ball, and there is no flickering when the playfield is vibrated, and the game doesn't report any random switches in test mode for 20 minutes, the opto boards have test good. If there are still random multi ball problems, there is most likely a divot problem in the ball trough (see above).

3k. When things don't work: Dot Matrix/AlphaNumeric Score Displays

Dot matrix displays are one of the coolest features on a WPC game. They provide the score and graphic animations, and even video games within the pinball game. Note that the first three WPC games (Funhouse, Harley Davidson, the Machine) used the older style AlphaNumeric displays.

WPC Alpha Numeric Score Display Problems.

The first three WPC games that used AlphaNumeric displays have a common problem. The resistors R48 and R49 (39k ohm) on the AlphaNumeric Display board often fail and go open, or go out of spec. This can cause all the score displays in the game to work very weak, or not work at all. Before replacing a score display, replace BOTH of these 39k resistors with "flame proof" 1 or 2 watt versions. See the Williams System 11 repair guide at http://marvin3m.com/sys11/index3.htm for more information on repairing AlphaNumeric score displays. All the information there applies to these three WPC games (though the component label numbers will be different).

A dot matrix display on the way out. Notice the absence of some characters in the display (on the right side).

Dot Matrix Displays.

The unfortunate part about dot matrix displays (DMD) is they wear out. Time will eventually kill these, and the display will "outgas" and fail. Because of the high voltage involved with score displays, the anode and/or cathode inside the diplay glass breaks down. This results in the “outgassing” of impurities that eventually change the internal gas properties, so the display can’t glow (the gas must be very pure for the display to work). Often the gaps that don’t light up at power-on will gradually come on as the display warms up. This happens because as the existing gas warms up, it expands. A new display will solve this problem, and is easy to get and replace (a 5 minute job). These do cost a bit of money though at about $115 each (complete). There is no way to fix an old “outgassed” display.

But the really bad news about DMD’s that are failing is how they die. When a DMD starts to get blurry or displays gaps, the power requirements for the display dramatically increases. This stresses the dot matrix controller board (and can lead to the machine resetting in the middle of a game!) If the display is not replaced, the controller board can fail too. Sometimes the controller board burns beyond repair.

The moral to this story is to replace a marginally bad “outgassing” DMD with a new display as soon as possible. Don’t postpone the inevitable. You can get a new DMD from one of the suppliers on the parts and repair sources web page. The whole assembly is about $115 or so.

Buy an entire DMD display glass and board, or just a new Glass?

A new dot matrix glass only can be purchased, which will also solve the “outgassed” problem. These are available for about $65, which is almost half the price of buying both the display and its attached circuit board. But trust me on this, don’t be cheap; just spend the extra $50 and get both the display and its attached circuit board. Installing a new glass into the surrounding board is A LOT of work. And games produced in 1993 and later don’t have “pin” style glasses, so these display glasses alone are NOT replacable. Even if a display has the “pin” style glass, it’s just not worth the trouble to unsolder 132+32 pins, install the new glass, and resolder all those pins again. It’s a solid two hours worth of eye straining work, and it’s very easy to make a mistake. It’s just not worth the trouble.

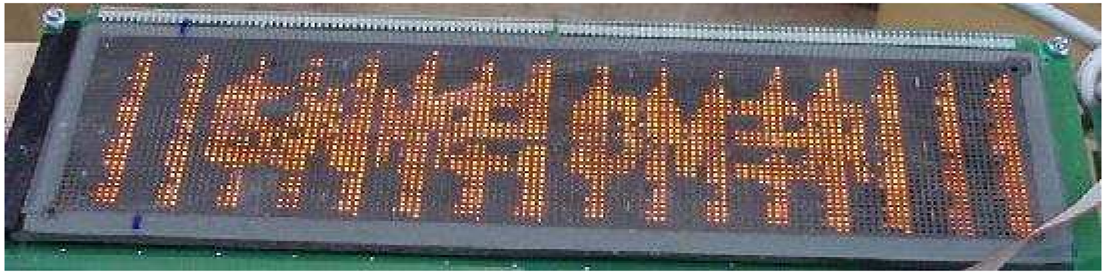
Are All Dot Matrix Displays the Same?

The short answer is “yes”. But be aware DMDs come in different sizes. Williams always used the 128x32 column/row variety (DataEast for example used a 128x16 and a 192x64 display, in addition to 128x32). And yes a 128x32 dot matrix display from a Gottlieb, Sega, DataEast or Stern game will work in any DMD WPC/WPC-S/WPC-95 game or vice-versa (but note that DataEast/Sega/Stern have an additional controller board bolted to the back of their 128x32 DMD, which is not used on a Williams WPC game). Also it should be stated that some brands of dot matrix displays (like Babcock) require 12 volts to operate, and most others don’t.

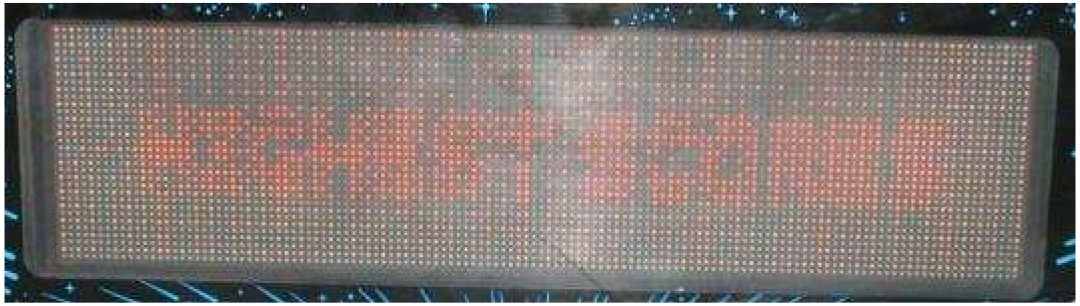
Can the Dot Matrix Display Itself be Fixed?

This is a tricky question. Sometimes the display itself fails due to problems other than an “outgassed” score glass. The controller chips on the display glass’ circuit board can die (they are static sensitive). This usually causes “garbage” to be displayed. Other problems I have seen includes delamination of the surface mounted parts on the score display glass’ circuit board (often this is fixable). And the power .156” header pins on the display itself can have cracked solder joints, causing the display to not work (though sometimes these are nearly impossible to resolder, because the display glass is in the way!)

Example a ribbon cable problem on a WPC game (Demo Man). Can you tell it says, “Game Over”? Reseating the ribbon cables often fixes this. Click on the picture below for a larger version, and note the dark spots in the corners of this display - this is an indication the display is starting to outgas. Note it’s not just the display ribbon cables, but also the other ribbon cables like the one between the CPU and driver boards.



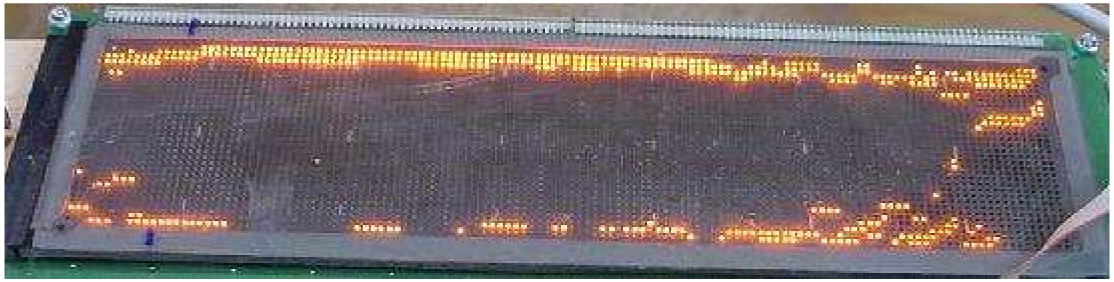
Another example of DMD garbage that was fixed by reseating the ribbon cable between the driver and CPU boards. Picture by Wil.



Blank, Strange Garbage, or Diagonal Lines on the Dot Matrix Display (Re-seating Ribbon Cable connectors).

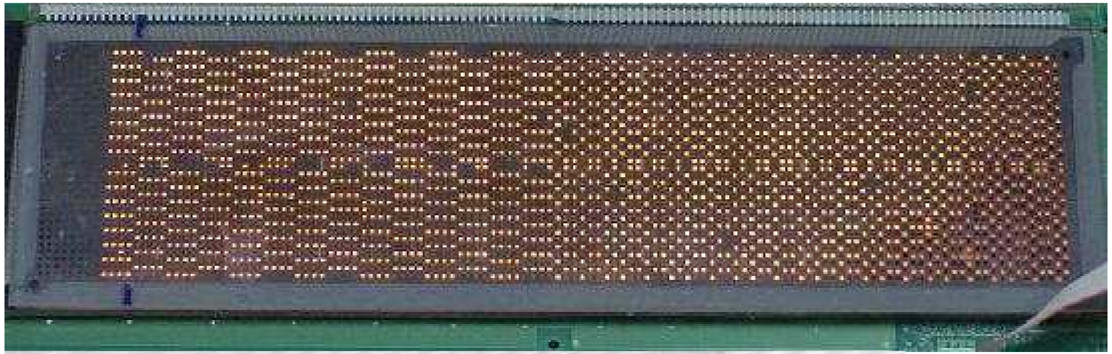
This problem can be caused by a bad dot matrix ribbon cable. A blank display (assuming all the fuses are good and voltages are present) is usually a backwards installed ribbon cable from the dot matrix controller to the DMD itself. Garbage or diagonal lines is typically a problem with the large cable running from the CPU board to the fliptronics board to the sound board to the dot matrix controller board. The ribbon cable connectors are gold plated, and sometimes require a "reseating" (remove and re-install) of their connectors to "clean" them. Since these are gold plated connectors, reseating is an acceptable means of cleaning a gold plated connector. (All the non-ribbon cable connectors in the game are **not** gold, and if reseating "fixes" a problem, that means the connector board pins and housing pins need to be replaced! See Pinball Connector web page for more info on that.)

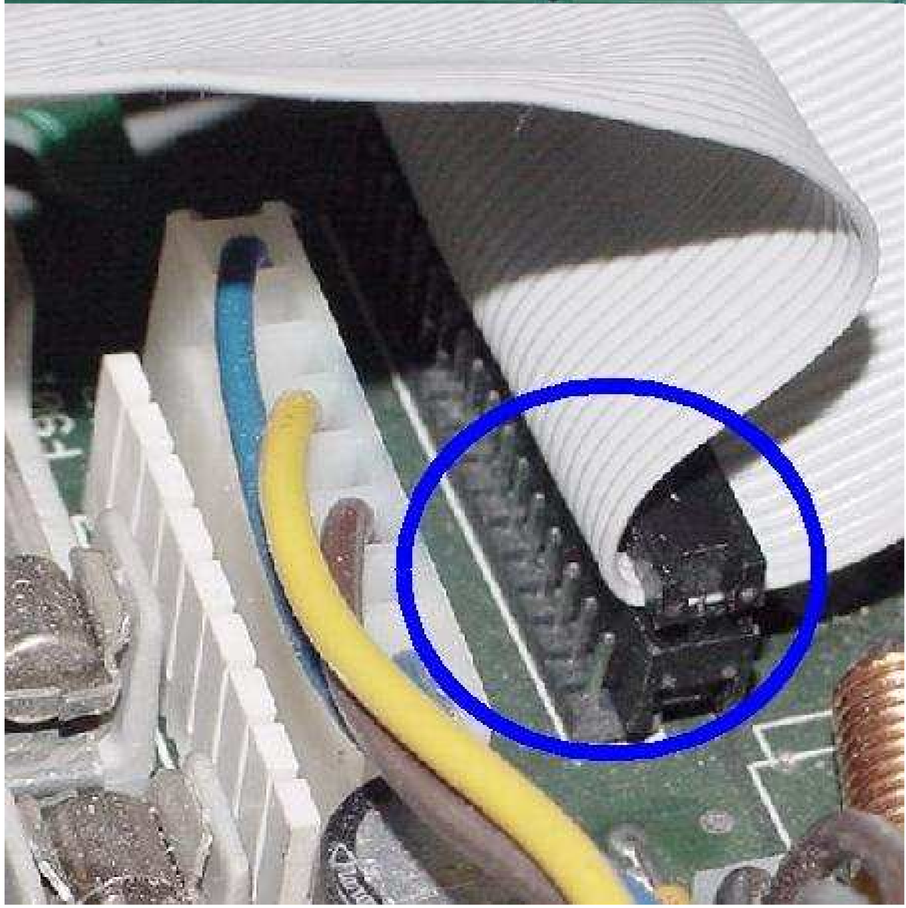
Example a dirty or removed ribbon cable from the dot matrix controller board to the dot matrix display itself. Reseating the ribbon cables often fixes this.



When reseating the ribbon cables, be careful not to re-insert the ribbon cable one pin off. This is very easy to do, making pins 1,2 hang off the side of the mail connector (or cable pins 1,2 connected to board pins 3,4). This will cause additional problems like garbage display (but luckly all are fixed with the proper reseating of the ribbon cable connector). Also note the red line on the ribbon cable - this indicates pin 1 of the cable, and it should align with the white arrow or "1 2" silkscreened on the circuit board. Luckily the only ribbon cable connector that can be easily installed "backwards" is the ribbon going from the dot matrix controller board to the display. If this cable is installed "backwards", usually the display is blank, showing nothing (like the display does not work).

Here's what happens if the sound board ribbon cable is connected one row of pins off-center.





Also be aware that an over-zealous previous owner may have runined a ribbon cable connector when it was reseated. It is very easy to rip the ribbon cable away from the connector, making the game do some very strange things (usually the diagonal lines are a symptom of this). So be careful when reseating ribbon cable connectors.

Finally, random vertical or diagnal lines could be caused by 12 volts not getting to the dot matrix display. This voltage comes directly from the driver board (see "Testing DMD voltages" below for diagnosing this problem further). Also some dot matrix displays (Babcock in particular) require 12 volts to operate, where other brands do not need 12 volts.

Missing Vertical or Horizontal Display Lines are Missing.

Another common problem is missing display lines in the DMD score display. This is very common with the "pin" style DMD display glass. This type of DMD glass has pins, bent at a right angle, that solder into the attached DMD circuit board. Often these pins break, due to vibration, right where they attach to the display glass' edge. Because of this problem, all the DMD manufacturers have changed to a very flat ribbon cable style of connection between the display glass and the attached circuit board. This largely solved the problem.

If missing some lines, and the score display glass is a "pin" style, often the pins can be reattached to the display glass using a conductive silver epoxy. This often works well, but is a difficult repair. It usually does not work if more than two horizontal and/or two vertical pins are broken.

Diagnosing Other Dot Matrix Problems.

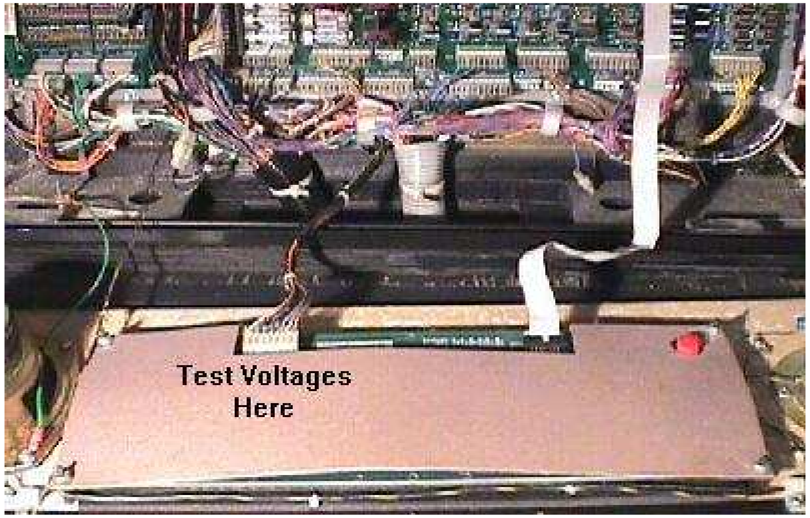
If you are sure the display itself is working, there are some other things to check when a DMD doesn't work.

Make sure to check fuses F601 and F602 (all WPC games). F601 is used for +62 volts, and F602 is used for -113, -125 volts. On WPC-S and before, these are 3/8 amp fast-blo 1.25" fuses (originally Williams used slow-blo fuses here, but about 1994 they changed to fast-blo, so either fast or slow-blo can be used). On WPC-95, these are T0.315 amp 5x20mm fuses.

The Dot Matrix Display circuit is the same in all WPC generations!

Even though there are three different WPC dot matrix controller boards, the DMD voltage circuit is nearly identical. Click **here** for the high voltage dot matrix display controller board schematics (showing part references for all generations of WPC dot matrix display controller boards).

It's easier to test voltages at the dot matrix display itself than at the controller board. Use the "key" pin for reference to figure out which is pin 1 and pin 8.



Testing DMD Voltages.

If the fuses are good on the dot matrix controller board (or audio/visual board for WPC-95), you should next check the power at the DMD itself. Voltages used are +62, +12, +5, -113 and -125 (or within +/- 10% of these values). Check these voltages at the dot matrix display with the display connected, or at connector J604 on the controller board. The pin out at the DMD is:

- Pin 1: -125 volts (-110 to -130 volts)
- Pin 2: -113 volts (-98 to -118 volts)
- Pin 3: Key
- Pin 4: Ground

- Pin 5: Ground
- Pin 6: +5 volts (4.9 to 5.2 volts)
- Pin 7: +12 volts (10 to 14 volts)
- Pin 8: +62 volts (58 to 68 volts)

All voltages should be pretty much right at the above specs, or within +/- 10%. In regards to the -113 and -125 volts, these two voltages need to be 12 volts apart - that's the important part. That is, if -98 and -110 volts are measured, those two voltages are fine. If -118 volts is measured, the other voltage should be -106 volts. If they are not within 12 volts of each other, the dot matrix controller's high voltage section probably needs to be rebuilt. If the -125 volts is missing, -113 volts will be missing too. If the +62 volts is above 70 volts, chances are good someone jacked up this voltage by changing the DMD controller 1N4759 zener diode to compensate for an outgassed dot matrix display (very common on games imported back to North America from other countries).

If any voltage is low, try disconnecting the power connector to the DMD, and re-measure the voltages. If they return to the correct voltages, the display is bad or the high voltage section on the dot matrix controller board is failing and can't handle the power draw of the display.

Remember the voltages created by the DMD controller card are -125, -113 and +62. The +5 and +12 volts come from the driver board. If the 5 volts is missing yet the game boots, there's a connector problem. If 12 volts is missing there's either a connector problem, or the dot matrix display itself is "sinking" the 12 volts (disconnect the DMD power connector and see if the 12 volts comes back up, if so the display is bad or maybe the driver board 12 volt section is failing). Or the 12 volt driver board section is failing. (Measure the 12 volts at the driver board, and then at the installed DMD, if the voltage is different there is a connector problem. If they are both the same voltage and are below 10 volts, there is a driver board 12 volt problem).

Both the -125 and the -113 volts are the same voltage.

The dot matrix display will not work if both the -125 volts and -113 volts measure as the same voltage. These two negative high voltages should be 12 volts apart. The difference in voltage occurs because of diode D6 (D3 on WPC-95), a 12 volt 1N4742 diode. The failure of this diode also kills transistor Q7 (known as Q7 in all WPC generations, a MJE15030). The -125 volts and -113 volts must be 12 volts apart, or the dot matrix display will not work!

The +62 volts drops to +12 volts under load.

When this happens, check transistor Q3 (all WPC generations). This transistor has probably shorted. Also check diode D3.

The +62 volts is not +62 volts.

On WPC-S and earlier games, the positive DC voltage trace that comes from a very small bridge rectifier BR1 is physically routed underneath resistor R9 (1.8k 5 watt resistor). Because of the heat generated by this 5 watt resistor, and the current drawn from the bridge rectifier, this circuit board trace can become burnt and break underneath resistor R9. Because the trace physically runs under this resistor, the broken trace can be hard to see. If the +62 volts is not +62 volts, check this trace. If the +62 volts is above 70 volts, chances are good someone jacked up this voltage by changing a DMD controller 1N4759 zener diode to compensate for an outgassed dot matrix display (very common on games imported back to North America from other countries).

The -125 volts is too High.

Another problem is the -125 volts is too high, reading instead -140 volts. The usual cause of this problem is a broken trace on the circuit board. These traces are fragile, and the high voltage section of the dot matrix controller can get very hot, and burn them. Use your DMM set to continuity and check all traces.

Negative High Voltage Low, DMD barely lights.

Negative high voltage reads -102 and -93 volts, and the display barely lights. DMD high voltage controller section was just rebuilt, so that was ruled out. Checked resistor R26 (47K ohms) and it was open. Also checked resistor R30 (120 ohms) and it read 1k ohms (had to unsolder and lift one leg to test them). After resistors replaced, high voltage went up to -112 and -100 volts, and the DMD was nice and bright.

Rebuilding the Dot Matrix High Voltage (HV) Section.

If the fuses are good, and the display itself is good (tested in another game), it is time to rebuild the high voltage section of the Dot matrix controller board. But before doing that, raise the playfield and inspect all the connections from the transformer in the bottom of the cabinet. Though a rare problem, one of the connectors may have come apart or became oxidized.

After all else is checked, the best idea is to just replace everything in the high voltage section (parts also listed at **dmdhv.htm**). Note all these parts are also available in kit form from Great Plains Electronics for around $6 per kit. This is a **very** economical way to rebuild the dot matrix high voltage section. The parts to replace includes:

- Q6 (MJE15031 or NTE55): Controls the -125 volts (and supplies voltage to the -113 volts).
- Q7 (MJE15030 or NTE54/BUV27/BUV28): Controls the -113 volts.

- Q3 (Q1 on WPC-95, MJE15030 or NTE54/BUV27/BUV28): Part of the +62 volt section.
- Q4,Q5 (MPSD52 or 2N5401/NTE288): Part of the -125 volt section.
- Q2,Q10 (Q2,Q3 on WPC-95, MPSD02 or 2N5551/NTE194): Part of the +62 volt section.
- D4,D5 (D1,D18 on WPC-95, 1N4758 or NTE5090, 56 volts): Part of the -125 volt section.
- D6 (D3 on WPC-95, 1N4742 or NTE142, 12 volts): Part of the -113 volt section.
- D3 (D2 on WPC-95, 1N4759 or NTE149, 62 volts): Part of the +62 volt section.
- Q1 (2N3904, WPC-S and prior only).
- R4,R5 (120 ohm ½ watt). Usually Ok, but replace if they look burned.

Check/Replace the Resistors too.
Also check the resistor values. Resistors either work or do not work, and are easily tested (unlike the above transistors). All resistors should be within 10% of spec. Replace any resistors that are out of tolerence or that appear burnt. The 5 watt resistors take the most abuse; if these are working yet cracked, replace them! Always mount resistors slightly above the board to allow air flow below them. On all these resistor, replace if they look at all damaged, even if they measure OK.

- 1.8k ohms, 5 watts: R9 on WPC-S and prior (R44 on WPC-95).
- 4.7k ohms, 5 watts: R8 on WPC-S and prior (R43 on WPC-95).
- 120 ohm, 5 watts: R11 on WPC-S and prior (R28 on WPC-95).
- 120 ohm ½ watt resistors at R4, R5 WPC-S and prior (R30, R31 on WPC-95).
- 47k ohms ½ watt at R3, R6, R12, R13 on WPC-S and prior (R25, R26 R27, R29).

An Alternative to Rebuilding the HV Section.
If the inexpensive HV rebuild kit from Ed at www.greatplainselectronics.com is beyond one's technical skills, there is an alternative to rebuilding the high voltage section. That is to purchase a pre-fabricated board which essentially does the same thing. The DMD-HVP (dot matrix display-high voltage power) board is available from www.pinball-parts.com for about $60. This plugs into and overlays the existing DMD controller board, replacing the original high voltage section on the original DMD controller board. Installs in about five minutes with no soldering. If the original high voltage section is blown on the original DMD controller board, it does not matter (as this completely replaces it). A good alternative for those that have more money than time, or limited soldering skills. Only works on pre-WPC95 games though.
I have some minor critisms with the DMD HV board though. For example, they use the smaller WPC-95 style fuses. Now this would be Ok if the board worked on WPC-95 games. But since it does not, it puts a mix of fuse sizes into a WPC game that otherwise don't use this smaller fuse size. This is bad for the end consumer that may have a supply of stock WPC HV fuses, which now won't work in their game! Also, I feel there should be LEDs for each of the high voltages to show at a glace that -125 volts, -113 volts, +62 volts (and perhaps the +12 volts and +5 volts) were working on the board.
DMD Components by Voltage.
Here are the same list of components, organized by voltage. If only a particular voltage is missing from your DMD, only these selective components can be replaced (not recommended):

- -125 volts: MJE15031 transistor Q6 (all WPC versions). MPSD52 transistors Q4, Q5 (all WPC versions). 1N4758 diodes D4, D5 (D1 and D18 on WPC-95). All these components supply voltage to the -113 volt section too. Hence, replace the -113 volt components too.
- -113 volts: MJE15030 transistor Q7 (all WPC versions). 1N4742 diode D6 (D3 on WPC-95), which drops the -125 volts down to -113 volts.
- +62 volts: MJE15030 transistor Q3 (Q1 on WPC-95). MPSD02 transistors Q2, Q10 (Q2, Q3 on WPC-95). 1N4759 diode D3 (D2 on WPC-95).

The BIGGEST Tip when Fixing the High Voltage.
The single biggest tip when fixing the high voltage section on the DMD controller is this: REPLACE EVERYTHING. This is a high voltage section. This means if all parts were replaced except for ONE bad part, this bad part can cause all the others just replaced to immediately fail! It's just not worth the trouble. Rebuild the whole high voltage section, and replace everything. In the long run money and time will be saved.

Example of a "cloudy" dot matrix display.

Cloudy Dot Matrix Display.
Cloudy display problems are strange. The display can test perfectly in the internal "line" dot matrix test. But when large areas or inverted graphics are shown, the display is "cloudy". This is usually caused by heat related problems. Fixing this could be as simple as adding new white heat sink compound to the three heat sinked MJE transistors. Also make sure they are tight to their heat sink. Check the three large 5 watt resistors too. If they are more than 5% out of spec, replace them (see above). Lastly, cold solder joints in the high voltage section can also cause cloudiness. Try reflowing the solder joints on the 5 watt resistors, the high voltage diodes, and the high voltage MJE transistors. If none of this works, rebuilding the high voltage section should solve this problem (see above).

Wavy Hum-bar and Horizontal Roll on the Dot Matrix Display.
The "wavy hum-bar" or horizontal roll seen on the dot matrix display's images can be bad DMD power filter capacitors. On WPC-95, these are caps C28, C42 on the audio visual board. On WPC-S and earlier, these are caps C4, C7 on the dot matrix controller board. These original capacitors were 150 mfd 160 volts. This value is somewhat hard to find, but can be replaced with the more common 220 mfd 160 volt electrolytic caps (remember going up in value on electrolytic capacitor's voltage and/or capacitance is Ok, but never go down). If 220 mfd caps are used instead of the 150 mfd, don't get ones that are too large (due to their weight, vibration can crack the capicator's solder pads, essentially removing those new capacitors from the circuit!) Additionally, if there is still a "wavy hum-bar" or horizontal roll, try replacing the smaller high voltage filter capacitors. On WPC-S and earlier, these are capacitors C6, C9 and C10 (.1 mfd 500 volts) on the dot matrix controller board. On WPC-95, these are caps C29-C31 (.01 mfd 200 volts). If these caps fail, hum bars or roll can occur.

Crystallized Solder Joints.
If a DMD display is not displaying correctly, and the voltages seem Ok, also check this. It's common for the solder joints on the zener diodes in the power section to crystallize, causing heat damage, excessive resistance, and finally a lost of voltage regulation. This can then lead to a failed DMD and damaged power circuits. These diodes are D3, D4, D5, D6 (D1, D2, D3, D18 on WPC-95) on the dot matrix controller board.

A bad 6264 RAM chip on the DMD controller board can cause this problem
(verify it's not the Dot matrix display itself first though!)

DMD Columns Stuck "On".
If there is a column or two stuck on (as seen in the picture above), chances are good the 6264 dot matrix controller card RAM at U24 (WPC-S and prior) has failed. Of course this assumes that the dot matrix display itself is not the problem (try the display in another game to verify). If not the display itself, replace U24 (WPC-S and prior) with a new 6264 RAM chip, and this should fix the problem.

Missing Lines on a DMD Display.
The first generation of dot matrix displays used pins to connect the DMD glass to the DMD circuit board. Due to vibration, often these pins would break right where they meet the display glass. This would give the display a "missing" vertical or horizontal line (depending on which pin broke). And often more than one pin would break, making an otherwise good display nearly useless. This problem was solved with newer DMD score displays that used a short thin flexible ribbon cable instead of the pins.

On displays with broken pins, there isn't enough material to solder the pins back to the display glass. But another technique can be used instead. This involves "conductive epoxy", and essentially gluing the broken pin to the score glass. The conductive epoxy has silver powder in it, so it conducts well. And it's the only way to get a broken pin attached back to the score glass. Usually one or two broken pins can be repaired in this manner (trying to do much more than three seems to not work well!) Just be careful not to short two pins together with the epoxy. Success rate is certainly not 100%, but it usually works. The epoxy is expensive though, because of the silver powder in the glue.
I have also used conductive epoxy to fix the thin ribbon cable variety of DMD displays with missing lines, where the ribbon cable has ripped away from the display glass. The success rate is not as high, but it can work.

using conductive silver epoxy to fix a missing line on a dot matrix display, where the metal pin broke away from the edge of the display glass. Note this display uses both the ribbon cable (at the circuit board) and the metal pins (at the display glass). But the conductive epoxy can be used to repair either style (pins or ribbon), but the success ratio is higher on metal pins.

Problem: **Dot Matrix Display Got Blurry.** When I was playing my Twilight Zone, the dot matrix display started to become very blurry. Within 5 minutes the display became almost unreadable. The dots to the left and right of the active ones started to flicker.
Answer: the ASIC chip on the CPU board was not making good contact to its socket. The ASIC chip is the large square chip on the CPU board. After removing the chip and cleaning all of its pins, and reseating the chip in the socket, the problem went away. Another thing to try is reseating the board ribbon cables in their sockets.
Problem: **Funhouse alphanumeric display, character 16 was mimicking every segment being displayed in the other 15 characters.**
Answer: If this is happening in display one, replace chip U8 (6184 Anode Drive) on the WPC display driver board. If happening to display two, replace chip U5 (6184).
Problem: **My Twilight Zone's dot matrix display shows random vertical lines. At first it was just occassionally during game play, but now they appear from the moment I power on the game. The problem has gotten worse, and now every time I turn on the machine, all four**

flippers energize.
Answer: the problem was a bad ribbon cable. There is a single ribbon cable that goes from the CPU board to the fliptronics board to the sound board to the dot matrix controller. If the ribbon cable was mis-installed by one pin, or the cable has torn at its connector, this problem can happen. The ribbon cable houses the address and data lines to the fliptronics, sound and dot matrix controller. Often the ribbon cable's connectors can just be dirty, so reseating the connectors sometimes fixes this problem. If the ribbon cable is damaged, mis-installed or the connectors are dirty, strange things like this can happen. Another potential cause could be the lack of 12 volts getting to the dot matrix display controller board.

3L. When things don't work: Power-On LEDs and Sound Beeps

CPU Board LED Flashes.
A simple diagnostic LED (Light Emitting Diode) flash pattern exists on all generations of WPC CPU boards. These flashes can signify a problem and what might be causing the trouble. They can be seen immediately when powering on the game. LED's exist on both the CPU and Driver boards, but only the CPU board's LED have a diagnostic flash pattern. On WPC-S and earlier CPU boards, the LED's are labeled D19 to D21. On the driver board and all WPC-95 boards, they are labeled "LEDx" (with "x" being the LED number).
CPU Board LED Flash Codes, all revisions.
WPC-S and prior uses a "Dx" designation for its CPU LEDs. WPC-95 uses a "LED20x" designation.

- D19/LED201 (blanking): at power-on should be ON for about 3 seconds (1 second on WPC-95), and then turn off and stay off. When D19/LED201 is on, the blanking circuit is disabled (and will not allow any coils to be energized).
- D20/LED203 (diagnostic): After D19/LED201 turns off, D20/LED203 should stay flashing permanently while the game is turned on. This indicates the CPU is "running".
- D21/LED202 (+5vdc): this LED should ALWAYS be on. It indicates the CPU has +5 volts DC power.
  Problem Power-On CPU D20/LED203 (diagnostic) Flash Codes. If D20 does not flash continually, here are the flash codes diagnostics:
  - blinks ONE time: U6/G11 CPU game ROM bad
  - blinks TWO times: U8 CMOS RAM chip bad
  - blinks THREE times: U9 WPC custom chip bad (pre WPC-S), or G10 Security PIC chip bad (WPC-S and later)

WPC-S and Prior Driver Board LEDs, Test Points (TP), and Fuses.
For reference, TP5 is ground.

- **LED1/TP3:** +12 volts DC switch matrix circuit. Should be always ON. If off, check fuse F115. This is often caused by a bad CPU board chip U20 (see the switch matrix section for more details). The AC Power originates at connector J101 pins 4,5 and 6,7. It then goes through fuse F114, bridge BR1, capacitors C6 and C7, LED6/TP8 (18 volts DC), diodes D1 and D2, voltage rectifier Q2, fuse F115, LED1/TP3 (12 volts DC), then to connector J114 pins 1,2. Also, just before diodes D1 and D2, the circuit splits to the LM339 chip U6, and LED2/LED3.
- **LED4/TP2:** +5 volts DC digital circuit. Should be always ON. If off, game will not boot. Check fuse F113 (or bridge BR2 and capacitor C5). Though not likely to fail, there is also a voltage regulator LM323 at Q1, a LM339 chip at U6 ("zero cross"), and two 1N4004 diodes at D3 and D38. The AC Power originates at connector J101 pins 1 and 2. It then goes through fuse F113, bridge BR2, capacitor C5, voltage rectifier Q1, LED4/TP2 (5 volts DC), then to connector J114 pins 3,4. Note after fuse F113, the AC power also continues to diodes D3 and D38, and to LM339 chip U6. Then this "zero cross" power merges back into the +5 volt line before hitting connector J114.
- **LED5/TP7:** +20 volts DC flashlamp circuit. Normally ON. Twilight Zone and later, this LED fades off when the coin door is opened. If off, check coin door and fuse F111 (or bridge BR4 and capacitor C11). The AC Power originates at connector J102 pins 1,2 and 3,4. It then goes through fuse F111, bridge BR4, capacitor C11, LED5/TP7 (20 volts DC), then to connector J107 pins 5,6 (and J106 and J108).
- **LED6/TP8:** +18 volts DC lamp matrix circuit. Normally ON. If off, check fuse F114 (or bridge BR1 and capacitors C6, C7). Though not likely to fail, there is also a voltage regulator LM7812 at Q2, a LM339 chip at U6, and two 1N4004 diodes at D1 and D2. The AC Power originates at connector J101 pins 4,5 and 6,7. It then goes through fuse F114, bridge BR1, capacitors C6 and C7, LED6/TP8 (18 volts DC), diodes D1 and D2, voltage rectifier Q2, fuse F115, LED1/TP3 (12 volts DC), then to connector J114 pins 1,2. Also, just before diodes D1 and D2, the circuit splits to the LM339 chip U6, and LED2/LED3.
- **LED7/TP1:** +12 volts DC power circuit (motors, relays, etc). Should always be ON. If off, check fuse F116 (or bridge BR5 and capacitor C30). The AC Power originates at connector J112 pins 1,2 and 3,5. It then goes through fuse F116, bridge BR5, capacitor C30, LED7/TP1 (12 volts

DC), then to connector J118/J117/J116 pin 2.

- **TP6 (no LED):** +50 volts for the coil. The AC Power originates at connector J102 pins 5,6 and 8,9. It then goes through fuse F112, bridge BR3, capacitor C8, TP6 (50-70 volts DC), then fuses F103/F104/F105 (and F102/F102), then to connector J107, J106 J108, and J109.
- **LED2 (no TP):** This LED is not always installed. High/low line voltage sensor. Normally ON, but flickers with the playfield lamps.
- **LED3 (no TP):** This LED is not always installed. High/low line voltage sensor. Normally OFF, but flickers with the playfield lamps.

WPC-95 Driver Board LEDs, Test Points (TP), and Fuses.
For reference, TP107 is ground.

- **LED100/TP100:** +12 volts DC regulated. Should be always ON. If off, check fuses F101 and F106 (or diodes D11-D14 and capacitors C11, C12). If fuse F101 has failed, this is often caused by a bad CPU board chip U20 (see the switch matrix section for more details). Though not likely to fail, there is also a voltage regulator LM7812 at Q2, and two 1N4004 diodes at D1 and D2. If fuse F101 has failed, suspect the voltage regulator Q2. The AC Power originates at connector J129 pins 6,7 and 4,5. It then goes through fuse F106, diodes D11-D14, capacitors C12,C11, LED102/TP102 (18 volts DC), diodes D1-D2, voltage rectifier Q2, fuse F101, LED100/TP100 (12 volts DC), then to connector J101 pins 1,2.
- **LED101/TP101:** +5 volts DC digital. Should be always ON. If off, game will not boot. Check fuse F105 (or diodes D7-D10 and capacitor C9). Though not likely to fail, there is also a voltage regulator LM317 at Q1, a LM339 chip at U1, and two 1N4004 diodes at D23 and D24. The AC Power originates at connector J129 pins 1 and 2. It then goes through fuse F105, diodes D7-D10, capacitor C9, voltage rectifier Q1, LED101/TP101 (5 volts DC), then to connectors J101 pins 3 and 4, J138 pin 4, J139 pin 4, J140 pin4, J141 pin 4.
- **LED102/TP102:** +18 volts DC lamps. Normally ON (can flicker with playfield lamps). If off, check fuse F106 (or diodes D11-D14 and capacitors C11, C12). The AC Power originates at connector J129 pins 6,7 and 4,5. It then goes through fuse F106, diodes D11-D14, capacitors C12,C11, LED102/TP102 (18 volts DC), diodes D1-D2, voltage rectifier Q2, fuse F101, LED100/TP100 (12 volts DC), then to connector J101 pins 1,2.
- **LED103/TP103:** +12 volts DC un-regulated. Should be always ON. If off, check fuse F109 (or diodes D3-D6 and capacitor C8). The AC Power originates at connector J127 pins 1,2 and 3,5. It then goes through fuse F109, diodes D3-D6, capacitors C8, LED103/TP103 (12 volts DC), then to connectors J138 pin 2, J139 pin 2, J140 pin 2, J141 pin 2.
- **LED104/TP104:** +20 volts DC flashlamps. Normally ON. This LED fades off when the coin door is opened. If off, check coin door and fuse F107 (or diodes D15-D18 and capacitor C10). The AC Power originates at connector J128 pins 1,2 and 3,4. It then goes through fuse F107, diodes D15-D18, capacitors C10, LED104/TP104 (20 volts DC), then to connectors J133 pin 5 and 6, J134 pin 5.
- **LED105/TP105:** +50 volts DC coils. Normally ON. This LED fades off when the coin door is opened. If off, check coin door and fuse F108 (or diodes D19-D22 and capacitor C22). The AC Power originates at connector J128 pins 8,9 and 5,6. It then goes through fuse F108, diodes D19-D22, capacitors C22, LED105/TP105 (50-70 volts DC), fuses F102, F103, F104, then to connectors J134 pins 1,2,3, J135 pins 1,2,3.

Sound Board Error Beeps pre WPC-DCS (WPC alpha-numeric, WPC dot-matrix and WPC fliptronics.

- 1 Beep: Sound board OK
- 2 Beeps: U9 sound ROM failure
- 3 Beeps: U18 sound ROM failure
- 4 Beeps: U15 sound ROM failure
- 5 Beeps: U14 sound ROM failure

Sound Board Error Beeps WPC-DCS and WPC-S.

- 1 Beep: Sound board OK
- 2 Beeps: U2 sound ROM failure

- 3 Beeps: U3 sound ROM failure
- 4 Beeps: U4 sound ROM failure
- 5 Beeps: U5 sound ROM failure
- 6 Beeps: U6 sound ROM failure
- 7 Beeps: U7 sound ROM failure
- 8 Beeps: U8 sound ROM failure
- 9 Beeps: U9 sound ROM failure

WPC-95 Audio/Video LED.

- LED501: +5 volts DC, normally FLASHING (but at a slower rate than CPU LED203).
  Problem Power-On Audio/Visual Board Beep Error Codes:
  - 1 Beep: Audio/Visual board OK
  - 2 Beeps: S2 sound ROM failure
  - 3 Beeps: S3 sound ROM failure
  - 4 Beeps: S4 sound ROM failure
  - 5 Beeps: S5 sound ROM failure
  - 6 Beeps: S6 sound ROM failure
  - 7 Beeps: S7 sound ROM failure
  - 10 Beeps: Audio/Visual board's Static RAM bad

3m. When things don't work: "Factory Settings Restored" Error (Battery Problems)

Often when you buy a used WPC game, upon power up, you'll get an error message stating, "Factory Settings Restored". This message indicates that the CPU RAM chip at location U8 on the CPU board has forgotten the game's bookkeeping and options settings.

Most often, this error occurs because the three "AA" batteries on the CPU board have died. These batteries should be replaced every year with good quality alkaline batteries (batteries are cheap, battery damage is expensive). The three batteries must keep at least +4 volts of power to the U8 RAM chip for it to remember. When power goes below +4 volts, memory reset can occur (and you get the "Factory Settings Restored" error message).

A bad battery holder. At first glace, this holder looks fine. But the two battery contact points on the left have corroded and fallen off. The contact on the right is the only one intact. These contact points are actually rivets, but corrosion will cause the face of the rivet to break as it goes through the fiber insulator, and the face of the rivet that contacts the battery falls off.

Changing Batteries.
If your game is working, and it's time to replace the batteries, follow this procedure:

- Remove the backglass and gain access to the CPU board.
- Turn the game ON.
- Note the orientation of the installed batteries (All positive terminals up, or to the right on WPC-S).
- Remove the old batteries and discard.
- Check the battery holder's terminals for any corrosion (they can be clean with 220 grit sandpaper if any corrosion). If damaged, turn game off and replace battery holder.
- Using a Sharpie pen, write today's date on the new batteries.
- Install the new batteries.
- Turn the game off.

If you install new batteries with the game turned on, the machine will **not** forget the old option settings or bookkeeping totals.
More on Installing Batteries and Measuring their Voltage.
On all flavors of WPC (except WPC-S), the batteries install with the positive terminal (the terminal with the "tit") UP. On WPC-S, batteries install with the positive terminals to the right. To not lose the game's memory and firmware settings, new batteries can be installed with the game powered ON (assuming the old batteries are removed with the game on too). After the new batteries are installed, turn the game off. Now measure the voltage with a DMM to make sure then are connecting to the battery holder properely. Put the black lead of the DMM on the lower left battery holder solder point (or on WPC-S the upper left), and the red lead on the upper right battery holder solder point (or on WPC-S the lower right). About 4.5 to 4.8 volts DC should be seen.
The Battery Holder: a Weak Link.
If after replacing the batteries, you still get a "Factory Setting Restored" error when turning the game on, suspect the battery holder. Use your DMM and check the battery voltage at the CPU board. With the game off, put your DMM on DC volts and put the black lead on ground (the grounding strap or on one of the screws holding the CPU board in place, or the bottom left battery terminal). Put the red lead on each of the CPU board's POSITIVE battery terminal solder points (positive is the "up" side of each battery). Test each of the three batteries' positive leads individually, starting at the left. You should get about 1.5, 3.0, 4.5 volts at each battery (note the batteries are additive and the first battery in the chain will give you 1.5 volts, and the last battery will give you 4.5 volts). If you don't these positive voltages, suspect damaged battery holder terminals. These corrode quite often if new batteries aren't installed religiously. Replace the battery holder and re-test to ensure proper repair.

A battery gone bad on a WPC game. Note the white "fur" on the bottom of the battery, and how it has corroded the chip and socket below it. The battery holder, chip and socket must all be replaced. Also the board must be washed with a *mixture of 50/50 water and white vinegar (a mild acid) to neutralize the alkaline battery, and then rised with water. After drying, the corroded areas are sanded clean to the bare copper traces, and the components replaced. If the board isn't washed with this vinegar solution, the corrosion will return.*

The best battery holder to buy for any WPC game is the new black plastic battery holder used in WPC-S and later games. This is Williams part# A-15814. This design of battery holder is much better than the pre WPC-S design.

Is Power getting Past the Battery Holder? (bad diode D2 or RAM U8)

If the battery holder is OK, next check to see if power it getting past the battery holder. Find CPU board diode D2 (all WPC revisions); this is a small glass diode, right next to diode D1. On WPC-S and prior, look to the right of the big square chip U9. On WPC-95, look just below the battery holder. With your game off and new batteries installed, put your DDM on DC volts and put the black lead on the backbox ground strap. Then put the red lead on diode D2 on the CPU board. The banded side of the diode should show about .5 volts less than the non-banded side (which should be about 4.3 volts). If only one side of the diode shows voltage, or both sides show the same voltage, this diode is bad. Diode D2 is a 1N4148 or 1N914 diode.

Next test for voltage at the CPU U8 RAM chip (all WPC revisions). With the game off, you should get about 4.3 volts DC at pins 26, 27 or 28 of chip U8.

If you don’t, the battery voltage is not getting to the U8 RAM chip, and the game will boot up with the “Factory Settings Restored” error. Note pin 28 of the 28 pin U8 chip is in the same position as pin 1 of the chip, but on the opposite row of pins. Pin 1 is designated with an impressed “dot” right on the top of the chip.

There can still be problems even if a new batteries are installed and all the voltages check out. If the game is still giving “Factory Setting Restored” or “Set Time and Date” errors, there may be a bad CPU U8 RAM chip. This does happen where a bad U8 RAM will suck the life out of new batteries, causing them to go dead in one to four weeks. But make sure to double check that battery holder. Even minor corrosion can cause this problem. The voltages may all check out, but the corrosion may be enough to limit CURRENT, and cause this problem. The U8 RAM chip is a 6264-L or 2064 RAM chip.

Batteries Die Too Quick.

Batteries in a WPC game usually last for years. If the batteries in a game die quickly (a few days or a few weeks), the D1 diode is probably bad. If the D1 diode has failed, the batteries are trying to power up the entire CPU board (instead of just the U8 RAM). This will drain the batteries quickly. Find diode D1 (all WPC revisions); this is a small glass diode, right next to diode D2. On WPC-S and prior, look to the right of the big square chip U9. On WPC-95, look just below the battery holder.

Also check and test diode D2. With your game off and new batteries installed, put your DDM on DC volts and put the black lead on the backbox ground strap. Then put the red lead on diode D2 on the CPU board. The banded side of the diode should show about .5 volts less than the non-banded side (which should be about 4.3 volts). If only one side of the diode shows voltage, or both sides show the same voltage, this diode is bad. Diode D2 is a 1N4148 or 1N914 diode.

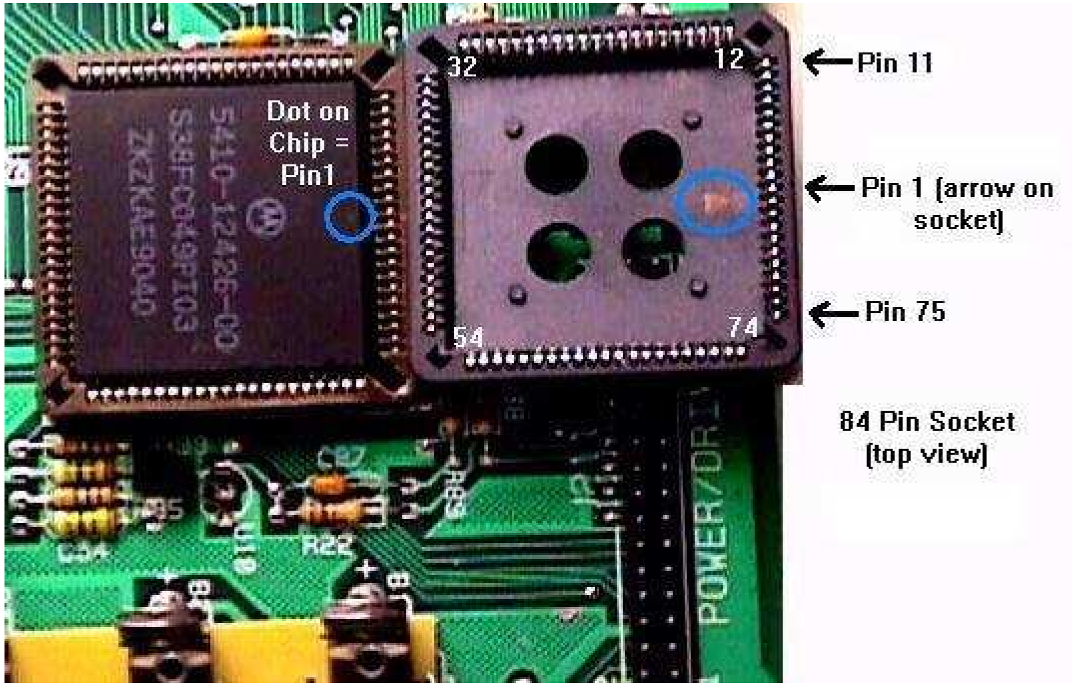
Batteries are HOT!

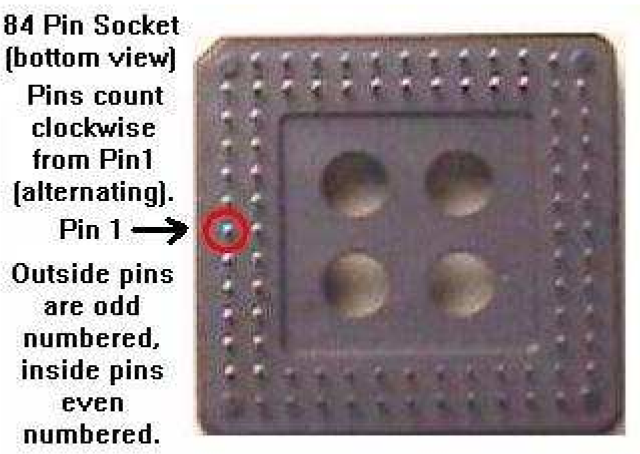
Another problem can occur where the batteries get hot. So hot, they can melt the covering off of them! If this is not fixed, the batteries will surely leak, or even explode. This happens when the game tries to charge the batteries, while the power is on. The problem is usually diode D2 (1N4148).

Does the Battery Power Anything Else?

Actually yes it does! Besides the RAM chip at U8, the battery also supplies voltage to the large square ASIC (Application Specific Integrated Circuit) 84 pin chip at U9 in the PLCC (Plastic Leaded Chip Carrier) socket. Because the 8-bit 6809 microprocessor (the brain behind WPC, on the CPU board) is such a bad time keeper, the time information for the WPC clock is generated in the U9 ASIC chip. A DMM can be used to measure the battery voltage on the ASIC chip at pins 1,22,43, and 64. If 4 volts DC is not seen at these pins, suspect the PLCC socket for the square U9 ASIC chip. These delicate sockets can corrode easily from leaking batteries.

The WPC ASIC chip Pinout.





My Game's Time Clock is Slow!

There is an internal time clock that keeps the time and date for the WPC system. Within the game's adjustments, you can turn the clock display on, so it shows the time and date on the dot matrix display. On Twilight Zone, this internal time clock is used during attack mode to set the playfield clock. If you notice the WPC time clock running slow (losing time), or the game just won't remember the time (boot up error of "Set Time and Date"), the batteries are getting weak and need replaced. If you still have this problem with new batteries, suspect the battery holder's terminals. They may be corroded enough to cause resistance, and lower the voltage at CPU chip U8.

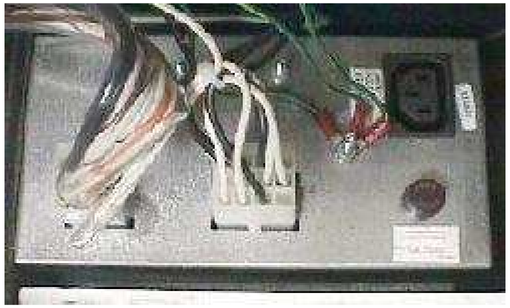
3n. When things don't work: Lightning Strikes

All William's WPC pinball games are very durable commercial devices. They are well protected against voltage surges from lightning storms. There are several lines of defense against voltage surges:

- Excellent grounding
- MOV (metal oxide varistor)
- Line fuse
- Power transformer (all voltage goes through a transformer)
- Bridge Rectifiers

If the power line to your WPC game is struck by lightning, usually this will take out the line fuse and the MOV. Damage beyond this is extremely rare. To repair your game, you will have to replace both the line fuse and the MOV.

The MOV lives inside the "power box".



The MOV is the green disc soldered across the lugs of the radio frequency interference filter.

The MOV (metal oxide varistor) is designed to have high resistance. But when its rated voltage is exceeded, it internally shorts. This immediately blows the line fuse and halts the power to the game, saving everything but the line fuse and the MOV itself. Smaller voltage surges are absorbed by the MOV without total destruction (though lots of small surges can eventually destroy a MOV and make it short).
The MOV is located inside the cabinet's metal power box, next to the coin box. If you need to replace it, here are the values needed:

- North America (115 volt power): 150 volt or 130 volt MOV.
- Europe (220/240 volt power): 275 volt MOV.

The rating is the voltage at which the MOV will short. Lower voltage ratings will provide more protection. But remember the power supply circuits have other protections from high input voltages too. So don't select a voltage too low, or you'll be replacing the MOV often from small voltage surges. Radio Shack sell MOV's that work well in WPC games.

3o. When things don't work: Sound Problems.

The Pre-DCS A-12738 Sound Board.

Williams' pre-DCS (pre-Indian Jones, Funhouse to Twilight Zone) sound board is part number A-12738. This is sound board has a 68B09E CPU chip, YM2151/YM3012 8-voice FM sound synthesizer (8-bit sound hardware) a AD-7524 DAC for processing 8-bit digital samples, and a 55536 CVSD chip for speech. The WPC A-12738 sound board has similar features to the System11 D-11581 sound board, but with much greater ROM memory space (allowing more speech and sound). The I/O circuitry is improved as well, allowing more control of the sound board by the CPU board.

Line-Out.

The pre-DCS A-12738 has "line out", through connector J509. This is a tap into the mixed analog signal (from all three sound generating devices) before it going to the volume control and final output amplifier circuits. Connector J509 pin 1 is the Analog ground, and J509 pin 3 is the Analog sound out. Unfortunately a bit more needs to be done then just tapping into connector J509 to get a usable "line out". On pre-DCS games on the component side of

the sound board, lift resistor R102 on the side which connects to pin 3 of J509. On the back of the sound board, connect a jumper wire between the negative side of capacitor C21 and the plated-thru hole left of resistor R102 (which connects to pin 1 of J509). This will give a functional line-out at J509 with the pins indicated above. The line-out you get from this modification is a fixed level and does not get changed by the volume control.
To get a line-out on a WPC DCS game (pre-WPC95), add a two pin .156" molex header to the sound board connector J6 (the left pin is audio and right pin is ground). On WPC-95, just add a two pin header to sound board connector J509 (left pin is ground and right pin is audio). Note the line-out on DCS and WPC95 sound boards is directly controlled by the volume control buttons inside the coin door.

Volume Control.

The pre-DCS A-12738 sound board also features a volume control chip (U5, an electronic Z-pot) which allows software commands for controlling volume. On the sound board an option exists so the operator can install a conventional resistor-pot volume control. To do this, remove A-12738 sound board jumper W9 to disconnect the software controlled volume circuit. Then connect a potentiometer (any value 5k to 200k ohms should work) to connector J507:

- J507 pin 2: To center pot leg
- J507 pin 4: To outside pot leg (Analog ground)

General Sound Repair Tips.

The sound on WPC games is very robust; it just doesn't fail too often. But here are some things that do fail related to sound:

- No sound or intermittent sound? Check the speaker in the bottom panel of the cabinet. If one of the leads is off the speaker, or the speaker is broken, sound won't get to the other speakers (hence silence)! Sometimes the bottom speaker wire connectors are intermittent too. So when a solenoid fires, the sound can cut off and on.
- Re-seat all the sound board ribbon cables. Surprisingly, this fixes a large number of WPC sound problems!
- Check the EPROM chips for bent pins and incorrect insertion! This is very common. The EPROMs are about the only socketed chips on the sound board, and often people will remove/replace/update the chips. And sometimes in their haste, when the chips are plugged back into the sockets, a pin or two may bend over (underneath the chip), or bend outside of the socket. If this happens, just unplug the chip, straighten the bent leg, and reinsert carefully. A worse problem is if the EPROM chips is plugged into the socket "backwards" (notch on the EPROM not matching the notch on the socket). This will ruin the EPROM chip. In either case, bent pin(s) or backwards EPROM chip(s) can cause the sound board to not work at all (no sound), or to work intermittently.
- Speakers blown: yes this happens more often than you might think. If the game was in a noisey arcade, the volume could be up so loud it blows the speakers. You can test the speakers (with the game off) using a 9 volt battery. Momentarily hook the battery up to the leads of the speaker. You will hear the speaker cone pull in if the speaker is good, when you attach the battery to the speaker. Make sure you check the speaker in the bottom of the cabinet too. Often if one speaker is blown, the others will not work.
- Main amplifier is bad: On pre WPC-DCS games, the sound board uses a LM1875 as the main amplifier. This device has a large heat sink attached to it. Often, this component has heat failure. The sound works fine until the game warms up for five minutes or so. Then the sound starts cutting in and out. You can use a logic probe on the leads of the LM1875. If the probe's beeps correspond to the cut in sound on one of the leads, the LM1875 is probably bad. The LM1875 is at U1 on the WPC audio board (not used on WPC-DCS or WPC-95).
- Main amplifiers are bad: On WPC-DCS and WPC-95 games, the TDA2030A amps are pretty fragile too. On WPC-DCS this is at U27 & U28, on WPC-95 at U5 & U6 (not used on pre WPC-DCS games).
- Check both of the TL084 op-amps too. Depending on the revision of the sound board, these audio amps can effect a certain type of sound they amplify. On WPC these are at U7 & U8, on WPC-DCS at U21 & U29, and on WPC-95 at U1 & U2.
- Bad rectifier diodes on the sound board. Often these become leaky and can cause intermittent problems before they total short.

Volume up FULL and Can't turn it Down.

The volume control on all WPC games is electronic. On pre WPC-DCS games, this is controlled by an electronic prom pot. This E-pot is a X9503, at location U5 on the sound board. If turning the volume up or down has no effect, and the volume is stuck on full blast, this is the first component that should be checked. Also the capacitor C18 (47 mfd, 25 volts) that connects to the E-pot can fail too, and should be checked. As described above, the electronic volume control can be disabled by removing A-12738 sound board jumper W9 to disconnect the software controlled volume circuit. Then connect a potentiometer (any value 5k to 200k ohms should work) to connector J507:

* J507 pin 2: To center pot leg
* J507 pin 4: To outside pot leg (Analog ground)

Static Noise.
Problem sound boards can produce a large amount of static. The TL084 quad Op-Amp (U7 & U8 on WPC, U21 & U29 on WPC-DCS, U1 & U2 on WPC-95) can be the cause of this. Also the TDA2030A (U5 & U6 on WPC-95) amp can also cause this. Finally the large filtering 4700 mfd or (or 10,000 mfd on WPC-95/WPC-DCS) 35 volt capacitors can also be the problem. Finally check for cracked solder joints on these large filter caps (solder jumper wires, as done to the bridge rectifiers explained earlier).
Static/Minor Hum and the Sound Board Filter Caps.
These are often the cause of minor sounds problems such as hum and static. Cracked solder joints at these capacitors is common. Soldering jumper wires from the PCB traces directly to these capacitors' legs often solves many problems (as described previously on the power driver board's bridges and capacitors).

* WPC-95: C36 and C37, which are 10,000 mfd at 35 volts.
* WPC-DCS: C20 and C21, which are 10,000 mfd at 35 volts.
* WPC: C24 and C25, which are 4700 mfd at 35 volts.

Static & Scratchy/Tinny Sound on Early WPC-95 Games.
Early WPC-95 games (Sacred Stiff for example) have two capacitors installed at locations C47 and C51 on the A/V board. These two capacitors are located between chips U5/U6, and near connectors J505/J504. With later WPC-95 games, these two capacitors were **removed**. If an early WPC-95 game has some static noise or just thin tinny scratchy sound, a good first step is to completely removed these two capacitors. It doesn't cost anything to remove them, and often provides a solution to the static.
TDA2030A Amp Chip.
This is a fragile chip used on WPC-DCS and WPC-95 games. It comes in two flavors; the TDA2030 and the TDA2030A. You want the TDA2030A version, as the TDA2030 does not have a high enough power rating, and can distort under higher volumes.
Loud Hum from the Speakers.
Problem: a loud hum from the speaker which does not change in loudness as you change increase the game's volume. This is often caused by the large filter caps on the Audio board (as discussed above). For early WPC games, this is capacitors C24 & C25. On WPC-DCS games, this is capacitors C20 & C21. And on WPC-95, this is capacitors C36 & C37. To fix this problem, check for cracked solder joints on the leads to these capacitors. It is a good idea to solder jumper wires to the two capacitor's leads to ensure good continuity (like you did on the Driver board's large capacitors).
"Popping" Sound, Hot LM1875, and Speakers Shorting.
Problem: pre-DCS sound board works, but eventually shorts the speakers. First the speakers start to "pop" (not very loud), every second or so. Eventually the speakers short and are ruined. Also the sound board's LM1875 heat sink gets very hot. DC voltage was measured at the speakers, and found to be 40mV (there should be no DC voltage).
Solution: At first the LM1875 was thought to be bad. But the real problem was the capacitors feeding the LM1875. Caps C46-C47 (1 mfd Tant), C20 (10 mfd), C22 (22 mfd), C23 (.22 mfd) were replaced, and the problem was solved. Also the LM1875's heat sink now ran cool. The giveaway here was the DC voltage at the speakers, pointing to the capacitors. There should be zero DC volts at the speakers. As little as 5mV DC at the speakers can cause the LM1875's heat sink to run hot.
Replacement Speakers.
All speakers in a WPC game are 4 ohms. No other speaker value should be used in these games.
The most common speaker to die on a WPC game is the backbox tweeter (right speaker, as playing the game). This is a small 3.5" speaker with a capacitor attached to the negative speaker terminal (the capacitor is the "cross-over", which filters out all but high frequency sounds). A quick and dirty replacement tweeter is available from Radio Shack, part #40-1233, $9.95. Though this is a 3.75" tweeter, the holes can be enlongated slightly to fit the 3.5" bolt pattern.
The 6" speaker in the bottom of the cabinet can be replaced with a PinballPro subwoofer. See www.pinballpro.com for details. They also sell replacement speakers for the backbox.
Sound Board Interface Error and Sound ROM Checksum Problems.
This is a fairly rare problem. When the game is powered on, a "sound board interface error" or sound ROM checksum message is shown on the display.

Often the game will seemingly work otherwise.
First thing to try is reseating all the ribbon cable connectors. Past this, usually the problem is a bad sound ROM. If the error is still present, turn the game off and remove ALL the sound ROMs from the sound board. Turn the game on, and instead of the one power-on “bong”, you should hear two “bongs”. Turn the game off, and replace the first sound ROM (U9, U2, or S2, depending on the WPC generation). Turn the game back on, and three “bongs” should be heard. Keep adding ROMs one at a time. If there is a problem with one of the sound ROMs, a checksum or soundboard interface error message will be displayed when the problem ROM has just been installed. If this happens, replace the ROM in question.

I Accidentally Shorted -125 volts on the AV board, and now my WPC-95 game will not Turn on.

This immediately blew fuse F602 (WPC-95, -125/-113 volts), and burned resistor R30 (WPC-95), which I replaced. If the Audio board is plugged into the game, the game will not start! After checking the +5 volts at the Audio board, I noticed it measured 3.5 volts. If the Audio board is disconnected, the +5 volts measures 5.02 volts, and the game will boot fine (except for the lack of sound).
In this case, do the easy things first. With the game off, remove all the EPROMs from the sound board. Then try your game again. The game will complain with a “bong bong”, signifying a sound board ROM problem. But if the game turns on fine otherwise, you know one of the sound EPROMs is bad.

Unbalanced Speech and Music.

Here’s a story from Phil Brown: I decided to swap the sound boards between my Addams Family and Funhouse to see if the problem would follow the board or stay with the machine. After I’d done it, I started a game on Addams and noticed that the speech and drum effects were much louder than the music, as if the balance betwwen them had been changed. I then started a game on Funhouse and found the opposite - it was much harder to hear Rudy’s speech over the music. This got me curious and I had a look at the schematics in the Funhouse manual for the sound board. It seemed that there are four sound outputs, CVSD, CH1, CH2 and DAC. Just before the point where they are mixed, they travel through four resistors, R22-R25. In the schematics, R25/R22 are 150k, and R23/R24 are 120k ohms. R23/R24 are on the outputs of CH1 and CH2, which I presume is the music. The other two are on the outputs of CVSD and DAC, which I presume are the speech and sound effect outputs. I also checked the schematic in the WPC Theory of Operation book and found the same thing. Then I had a look at the parts list in the Funhouse manual and the TAF manual - that’s when my theory was confirmed. This is what I found:

R#	Schem.	Funhouse	Addams
R25	150k	120k	120k
R24	120k	150k	56k
R23	120k	150k	56k
R22	150k	120k	120k

So, at least for these two machines, Williams has changed the resistor value to change the balance between speech/sound effects and music. On Funhouse they have biased the sound toward speech, and on Addams towards music. This means that WPC audio boards are not quite as interchangable between machines as thought, although they work, both Addams and Funhouse sound very different.

3p. When things don’t work: General Illumination (GI) Problems.

Note this section does not cover general illumination burnt connectors. See Burnt GI Connectors (and WPC-95 GI Diodes) for that information.

The Single Biggest Problem with WPC General Illumination.

Beside burnt connectors (see Burnt GI Connectors for that information), the single biggest problem with WPC GI is broken driver board TRACES! Yea sure, the GI connector pins got replaced on the driver board, but were the freshly soldered pins checked, one by one, for continuity to the fuse holders and to the triacs? I see this problem constantly where the connectors were replaced, but the plated through holes for the replace connector pins have cracked. New connectors pins are great, but if they don’t have continuity to the triacs or fuse holders, the GI will not work. In all the driver boards I have fixed, I have never seen a failed triac. But I constantly see broken traces at the header pins, preventing the GI from working.
It is really simple to check. Just use a DMM set to “buzz” (low ohms), and check the continuity from the header pins, to the fuse holder, and to the triacs. You will need the schematics to verify the pin numbers, fuse numbers and triacs. But if the GI is not working, it’s pretty much a for sure the problem is a broken circuit board trace (specifically it’s usually a broken plated-thru hole on one of the .156” GI header pins).

CPU Control of WPC General Illumination.

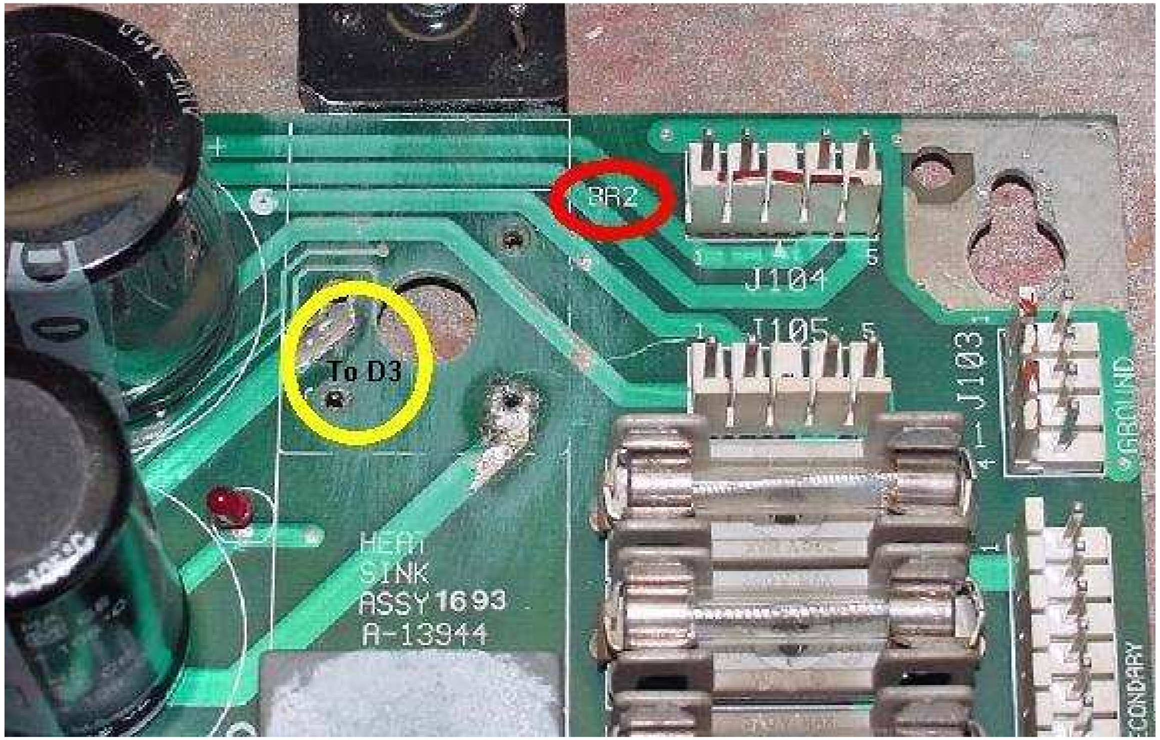
As a WPC game is powered on, the GI lamps do not come on immediately (unlike most other solidstate pinball machines). Only when the CPU board has fully booted and initialized the game, does the playfield and backbox GI lamps turn on. This happens because the general illumination is CPU controlled through the driver board triacs. The only exception to this is on WPC-95 games. The GI lamps in the backbox of WPC-95 games are not triac controlled; they come on immediately as the game is powered on (yet the playfield GI lamps are CPU controlled through the triacs, and their power is delayed until the game has fully booted). Therefore the backbox GI lamp intensity in WPC-95 games is not CPU controlled, and is alway “full power”.

Triacs are used for the general illumination circuit (not needed very often). The specs for a WPC triac are pretty lose. For example all these work: BT138-600E, BTA12-600, NTE5671 (800v 16amp), NTE56010 (800v 15amp), or NTE56008 (600v 15amp).

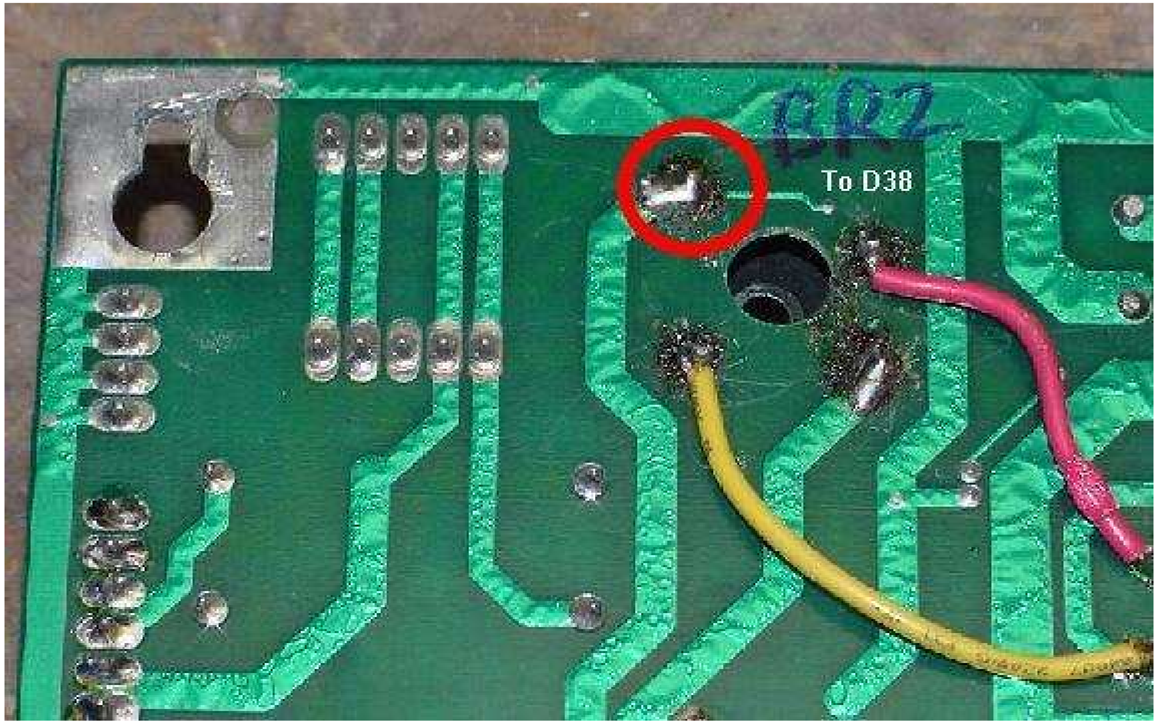
GI String(s) do not Dim.

Using the WPC general illumination (GI) diagnostic test, the test can dim the GI strings from very dim to very bright (1=dim, 8=bright). If this option is not working (that is, the GI lights stay the same brightness regardless if they are set to 1 or 8), you may have a problem with the zero-cross detection circuit. The zero cross circuit serves a couple purposes, one of which has to do with game resets and dimming the GI lights. Part of the driver board’s zero cross circuit are diodes D3 and D38 (located just below connector J109), which are both powered from driver board traces going to bridge rectifier BR2. Since BR2 is often a replaced part, sometimes the traces going to D3/D38 get broken. This can cause the General Illumination lights to not dim (or the game to randomly reset). So whenever replacing the bridge Rectifier BR2, be sure to use a DMM and “buzz out” the two AC leads of the BR2 bridge, making sure they go to non-banded side of diodes D3 and D38 (solder side top left BR2 lead to D38, component side bottom left BR2 lead to D3). This information is thanks to Jerry Clause.

Component side of a WPC-S and prior driver board. Note the broken trace (yellow circle) from BR2 to diode D3, which can be easily seen with BR2 removed.



Solder side of a WPC-S and prior driver board. Note the trace (red circle) which goes to diode D38, and is easily broken at BR2.

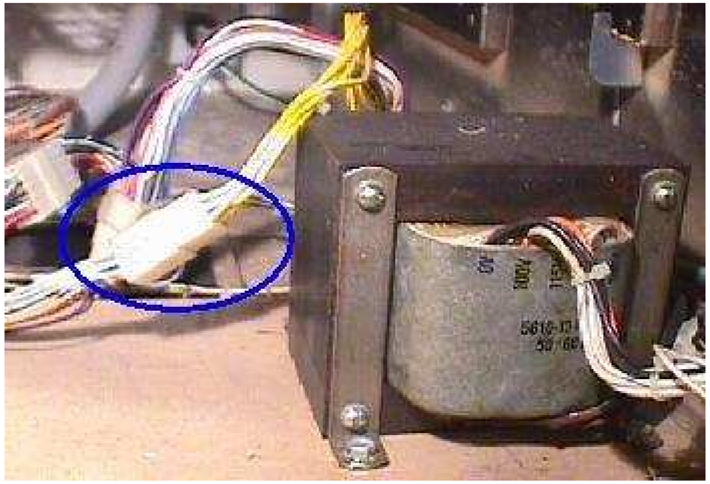


If the GI light still do not dim, replace the Driver board's zero cross circuit LM339 chip at U6 (or U1 on WPC-95). This will usually fix the problem (assuming there are no broken driver board traces, as shown above). It could also be the 74LS374 at U1 (or U2 on WPC-95). Note if only one GI string does not dim, the LM339 is probably not the problem (start with the Triac).

GI String Refuses to Work (and it's not the Driver board connector).

If the Driver board GI plug is not burnt, and the GI fuses are good, next check the GI connector coming off the transformer in the bottom of the cabinet. Often just unplugging and plugging this connector several times will clean it for good contact. Also check the traces on the Driver board leading to it's GI connector pins. Often these are not making a good connection.

The plug with the yellow wires is the GI connector coming off the transformer.



Testing a GI Triac.

The driver board Triacs are the devices that allow the GI strings to be dimmed. I've never had to replace one, but here's how to test a Traic.
First a Triac is basically a bipolar (meaning it can be used for AC voltage) SCR (Silicon Controlled Rectifier). A SCR has a Cathode (often labeled "K"), Anode, and Gate (instead of a Base, Collector and Emitter like a transistor). A Triac also has three connections, but are labeled Gate, "Main Terminal 1" (MT1), "Main Terminal 2" (MT2). In this case, the "Main Terminal 1" is the Cathode. "Main Terminal 2" is the Anode, and the Gate is the Gate.
The normal "diode test" on your DMM just won't work for testing a Triac (or a SCR), because of the device's need to be triggered first. All you can tell from the DMM's diode test is if the Triac is shorted, but nothing else.
Because of this, to test a Traic, you will need some sort of power. The best way to do this is using a 9 volt battery. Here's how you hook up your battery, and a test 555 or #44 light bulb (note this will probably have to be done with the triac removed from the board).

- Triac's MT1 (Cathode): to battery negative lead.
- Triac's MT2 (Anode): to one lead of the test lamp.
- Triac's Gate: Connect to MT1 (Cathode) using a 50 ohm resistor.
- Lamp's last lead: to battery positive lead.

Now briefly move the resistor from the Gate to MT2 (Anode). The lamp should turn on. Move the resistor back to MT1 (Cathode), and the lamp should stay on.
Since a Triac is bipolor (used for AC applications), reverse the battery's polarity and repeat the above test. It should work the same.

3q. When things don't work: Test Report & The Diagnostic Dot.

WPC's built-in diagnostics are very good. It can determine problems with your game long before you have even noticed them. When you power a WPC game on, if diagnostics detects a problem, you'll get a "test report" notification message. Pressing the "begin test" button inside the coin door will display the full test report. Each problem will be shown on the display for a few seconds. If there's no test report at power-on, the diagnostics thinks the game is working 100% correct.
Most test reports refer to switches that are tagged as defective. Often this is not the case. If a switch hasn't be used in 30 games, it will be listed as bad. But it could be the switch is working, yet positioned in a place that it just doesn't get activated much during game play.
If you do get a test report about a possibly defective switch, go to the "switch edge" test and manually activate the switch. This will indicate if the switch is working. If it does work, this will reset the 30 game counter for this switch and the switch will not be reported in the test report.

Prototype ROM Software and Bad Switches.

If your game has early prototype U6 CPU EPROM software, sometimes non-existant switches can show up in the test report. This happened in early versions of Twilight Zone and Judge Dredd games. There is no way to correct this but to upgrade to the lastest U6 CPU EPROM software. A new EPROM will need to be "burned" (using an EPROM programmer). The software for this is available at Williams' home page at the http://www.pinball.wms.com/tech/roms.html website.

The Diagnostic Credit Dot.

If you are checking out a game that is being operated, look for a period after the number of credits shown on the display during attract mode. If there is a period (dot) after the number of credits, this means there is a test report for the game. If there is no period after the credits, there's no diagnostic test report and the game is probably functioning correctly.

3r. When things don't work: Fixing a Dead or Non-Booting CPU board.

It doesn't happen often on WPC games. You have power (+5 and +12 volts) getting to the CPU board. The +5 LED (lower of the three) is on, as it should be. But the middle diagnostic LED is not flashing constantly (indicating the CPU is dead). And the blanking LED (the top one) is doing nothing (no flashes when the game is turned on). You have a dead CPU.

CPU Flash Codes, all revisions.

WPC-S and prior uses a "Dx" designation for its CPU LEDs. WPC-95 uses a "LED20x" designation.

- D19/LED201 (blanking): at power-on should be ON for about 3 seconds (1 second on WPC-95), and then turn off and stay off. When D19/LED201 is on, the blanking circuit is disabled (and will not allow any coils to be energized).
- D20/LED203 (diagnostic): After D19/LED201 turns off, D20/LED203 should stay flashing permanently while the game is turned on. This indicates the CPU is "running".
- D21/LED202 (+5vdc): this LED should ALWAYS be on. It indicates the CPU has +5 volts DC power.

D21/LED202 should **always** be on, as this indicated there is +5 volts at the CPU board. The board will never run without +5 volts!

Problem Power-On CPU D20/LED203 (diagnostic) Flash Codes.

If D20/LED203 does not flash continually, here are the flash codes diagnostics:

- D20/LED203 blinks ONE time: U6/G11 CPU game ROM bad.
- D20/LED203 blinks TWO times: U8 CMOS RAM chip bad.
- D20/LED203 blinks THREE times: U9 WPC custom chip bad (pre WPC-S), or G10 Security PIC chip bad (WPC-S and later).
- D20/LED 203 Never Blinks.
  If D20/LED203 (diagnostics) never blinks (not even once) and is just off, check D19/LED201 (blanking). Is it on and staying on? If so, the first thing to suspect is a bad game ROM at U6 (or G11 on WPC-95). If the game ROM (the Read Only Memory chip that stores the game's program, which the CPU runs) is bad, the CPU will never boot (even if everything else is Ok on the CPU board.

  Was this game ROM recently upgraded to a new version? Was the ROM installed correctly? (No bent pins.) Note the ROM chip has a "notch", which should be installed so it matches the "notch" on its socket. Is the ROM the correct size? (If the game's program expects a 4 meg (27040) EPROM yet it was programmed into a 2 or 8 meg EPROM, it won't work!) Is the ROM chip verified as good? (An EPROM programmer is often needed to verify the chip's checksum, or install the suspect ROM chip into another working game). EPROM chips can lose their memory and go bad (especially if there is no label over the clear quartz window on the chip). The EPROM can also be programmed incorrectly making it bad.

Some Basic Info on the WPC CPU Board.

The WPC CPU board is a pretty tight board. There is a custom ASIC chip, which controls most of the board's Input/Output functions (the ASIC is that big square custom chip). Frankly it rarely fails (actually its socket is more of a problem than the chip itself, as the socket is easily ruined by battery corrosion or somebody trying to remove the square chip without the proper tool). The next section of the board is the switch matrix, which comprises most of the components on the lower 1/3 of the CPU board (and hence generally does not stop a CPU board from booting). The only other things on a WPC CPU board are the game EPROM itself (fails rarely), and the U8 (all WPC revisions) 6264 RAM chip (which is very static sensitive, and thus can fail easily). A bad 6264 RAM chip can cause all sorts of strange CPU behavior, and due to it's static sentitive nature, it should be suspected. Also the TTL chips across the top of the CPU board (U1,U2,U3, all WPC revisions) can also fail. Beyond this, there is not much else on the WPC CPU board! Even the U10 reset chip (34064) and U5 (74LS14) clock chip does not fail often. Broken traces on the CPU board from previous repairs are very common though.

Dead CPU Step Zero: Check the ROM jumper setting.
This does not apply to WPC-95 or WPC-S CPU boards. If the CPU board came from a Funhouse, Bride of Pinbot, or Harley Davidson, the game ROM jumper W1 may be set for a 1 meg EPROM. All other games use a larger 2, 4 or 8 meg EPROM at U6. If a larger U6 EPROM is installed but the CPU board is jumpered for the smaller 1 meg U6 EPROM, the CPU board will never work. Before doing any repair work to the board, check this W1 jumper! See WPC Circuit Boards section for more details.

Dead CPU Step One: Remove the Ribbon Cables.
Before you do anything, turn the game off and remove all the ribbon cables from the CPU. This will issolate the CPU from the driver board, the dot matrix display board, the sound board, the fliptronic board (if your game has one), and any other connecting boards. The ribbon cables are at connectors J201, J202, J211, and J204 (on some games). While you're at it, you might as well remove the switch connectors at J205 to J209, and J212. The only connector still attached is J210 (the power connector).

After everything is removed but connector J210, turn the game on. If the CPU board boots correctly, the lower LED (+5 volts) should be on, the middle LED (diagnostics) should be blinking continually, and the top LED (blanking) should be off. If this is the case, turn the game off and replace the ribbon cables, one at a time, and turn the game back on.

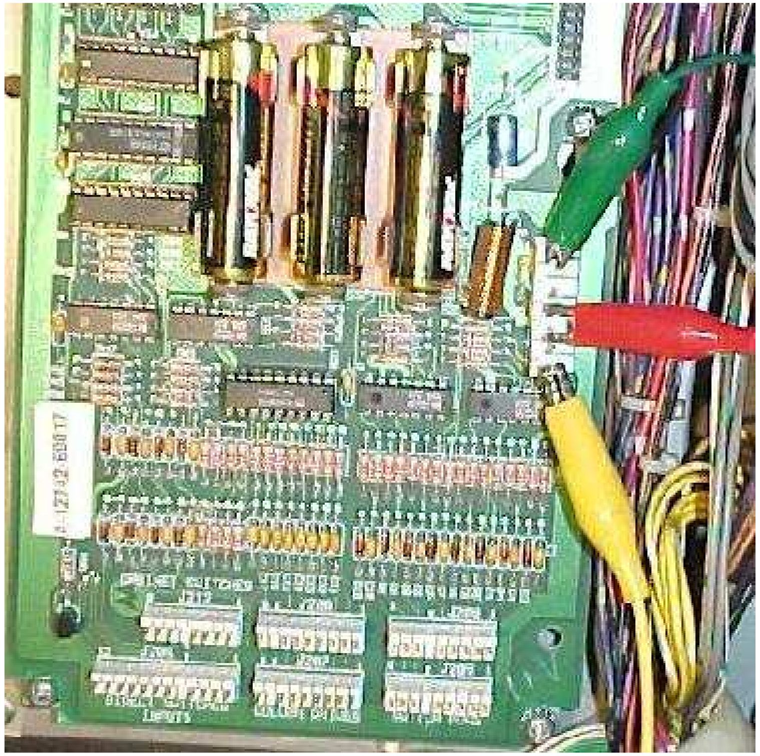
Start with replacing the the driver board to CPU board ribbon cable first. Chances are good the CPU board will still boot with this cable connected. Next try the other ribbon cables. If connecting the other ribbon cables stops the CPU board from booting, chances are good the TTL chips across the top of the CPU board are the problem (U1,U2,U3 on all WPC revisions).

Move to the Work Bench.
If the above "step one" didn't get you anywhere, don't worry. Now it's time to remove the CPU from the game. Don't try and fix a dead CPU while it's still in the game. You are much better off fixing it on your workbench. Fixing it on the workbench means you have issolated the bad CPU from the rest of the game (including it's power supply!).

Left: *a video game switching power supply. All voltages and ground are clearly marked on these.*
Right: *a computer power supply. You'll have to check the power supply lines to get the right voltages on these. But 99% of the time, red = +5 volts, yellow = +12 volts, and black = ground. Double check them with your DMM.*

The best power supply for your CPU is one of those switching video game power supplies, or an old computer power supply. You need to get +5 and +12 volts, and ground from the power supply. On computer power supplies most of time red = +5 volts, yellow = +12 volts, and black = ground.

The CPU board with an external power supply connected. On connector J210, the green aligator clip goes to ground, the red to +5 volts, and the yellow to +12 volts.



Now hook up the power supply to the CPU board using aligator clips. Here's the pinout for the power connector J210 on the CPU board. Note pin 1 starts at the top of connector J210. This applies to all versions of WPC and WPC-95 CPU boards:

- Pins 1,3 = ground
- Pins 2 = KEY
- Pins 4,5 = +5 volts DC
- Pins 6,7 = +12 volts DC

With the CPU on the workbench and issolated from the game, you can test the board much easier.

Re-seat the U9 ASIC WPC chip.

You would be amazed at how often this works. A dead CPU can suddenly come to life after removing and reinserting this large U9 chip. You will need a special tool to remove this big, square ASIC chip. You can buy this tool at Radio Shack, part number 276-2101, $9.99. Do NOT try to remove this chip without this tool! Note one corner of this chip is "notched", so you can only re-insert the chip one way. Be careful! Damage to the ASIC chip or socket is very easy.

Bad socket at U9.

The large U9 WPC square chip can have a bad socket. It's not much fun to replace this 84 pin socket! Radio Shack sells replacement sockets, part number RSU 11354453, $1.99, but they may not stock it. Use your DMM and check for continuity with the chip installed before you replace this socket.

Good CPU Reset and IRQ.

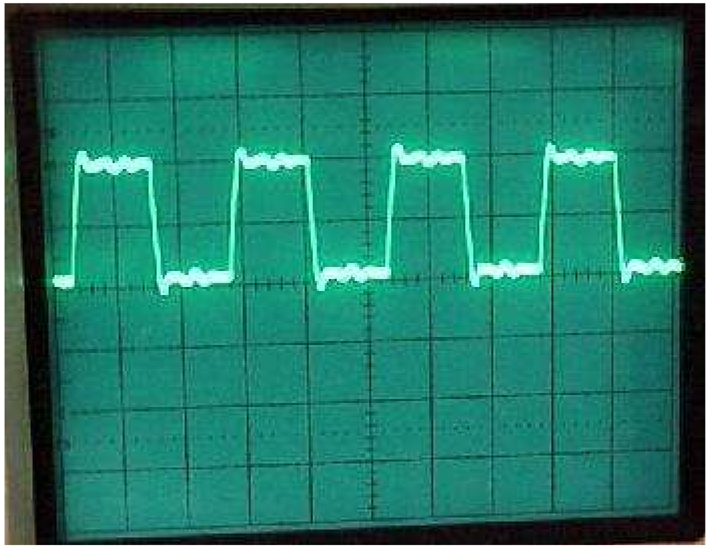
Make sure that the reset pin 37 of the CPU chip U4 (all WPC revisions) works properely. When the CPU board is first powered on, this pin should be low (zero volts), and then go high (4.5 volts). The reset line is held low for an instant so the +5 volts can stablize, and then goes high, letting the CPU boot.

This can be checked with a DMM. If pin 37 never goes high, the CPU board will never boot! Suspect the U10 (34064) reset chip if this is a problem. Also check the CPU IRQ signal at U4 pin 3. This should also start low and then go high.

Good Clock Signal.

Using a logic probe, also check for a good clock signal on pins 34 and 35 of the U4 CPU (6809). If the clock signal is missing, the CPU board will never boot. The clock signal comes from the large square U9 chip (pins 81,82), and from U5 (74LS14). Below is a picture of what the clock signal looks like on an o'scope.

The WPC clock signal on an o'scope.



Shotgun Approach.

The chips at U1, U2 (74LS244) and U3 (74LS245) and (sometimes U5, 74LS14) are the ones that affect on a dead CPU the most. The U1 and U2 chips connect to the address lines. The U3 chip connects to the data lines. If you are using a shotgun approach, replace these three chips first.

If replacing these chips yeilds nothing, next try replacing U5 (74LS14), which is part of the clock signal circuit (if the clock signal is good, this chip is probably not the problem!)

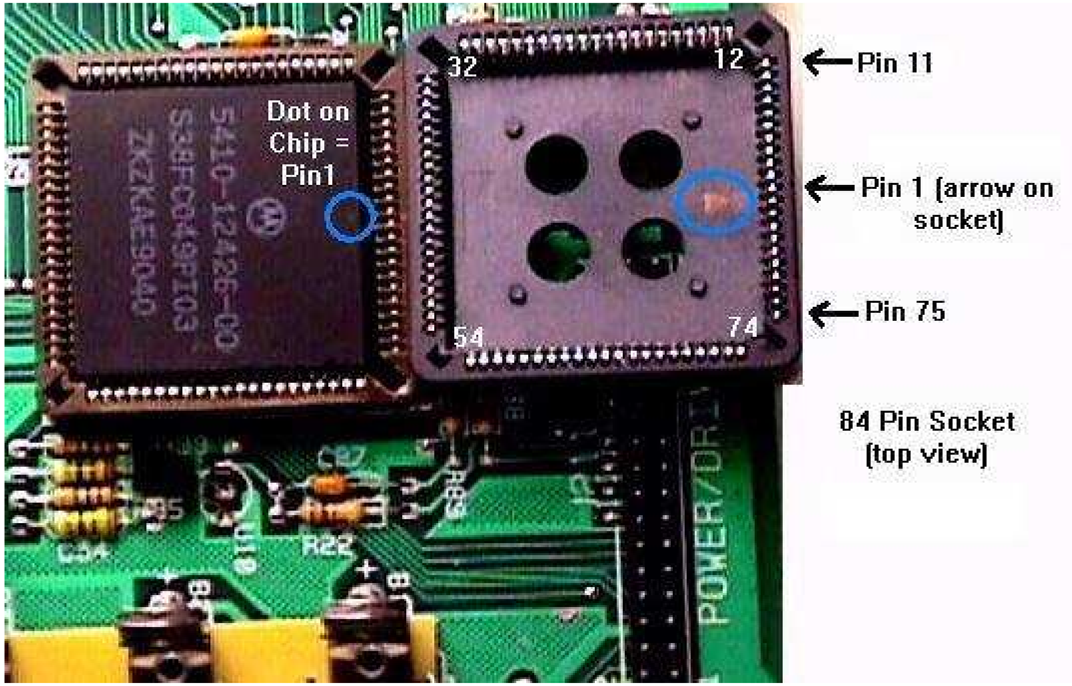
You can also replace U7 (74LS244) and U12 (74lS240) which connect to the data lines. Also check resistors R95 and R99 (1 meg ohms) to make sure these are the correct value. Finally U10 (a MC34064 transistor that is part of the reset startup circuit) can be replaced.

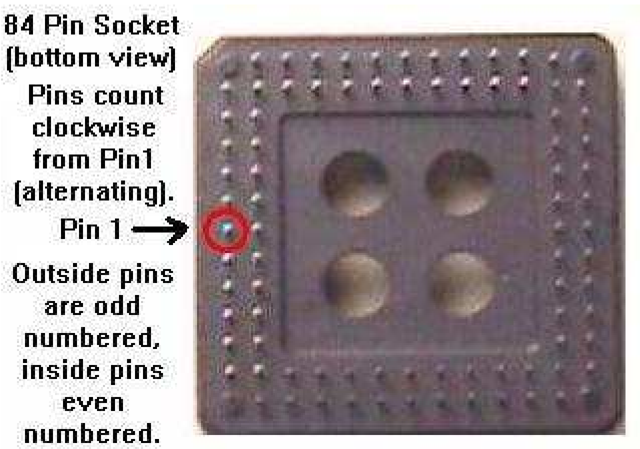
Address and Data Lines.

It is not uncommon for an address and data line to become broken on the CPU board. This can happen from flexing the CPU board, or scratching (breaking) the traces, or prior "hack" repair work.

Using your DMM set to continuity, check for continuity of the A0-A12 address lines between the U4 CPU 6809, the G11 ROM, and the U8 RAM chips. Also check for continuity betwen the D0-D7 data lines between these three chips. There should also be continuity between the A13 line on the G11 ROM chip and the U4 CPU 6809. After you have done that, check for continuity of the A0-A15 address lines and D0-D7 data lines between the U4 CPU 6809 and the U9 WPC chip. If you are missing continuity between any of these, the CPU will not function! You may have to use wire wrap to fix any breaks.

The WPC ASIC chip Pinout.





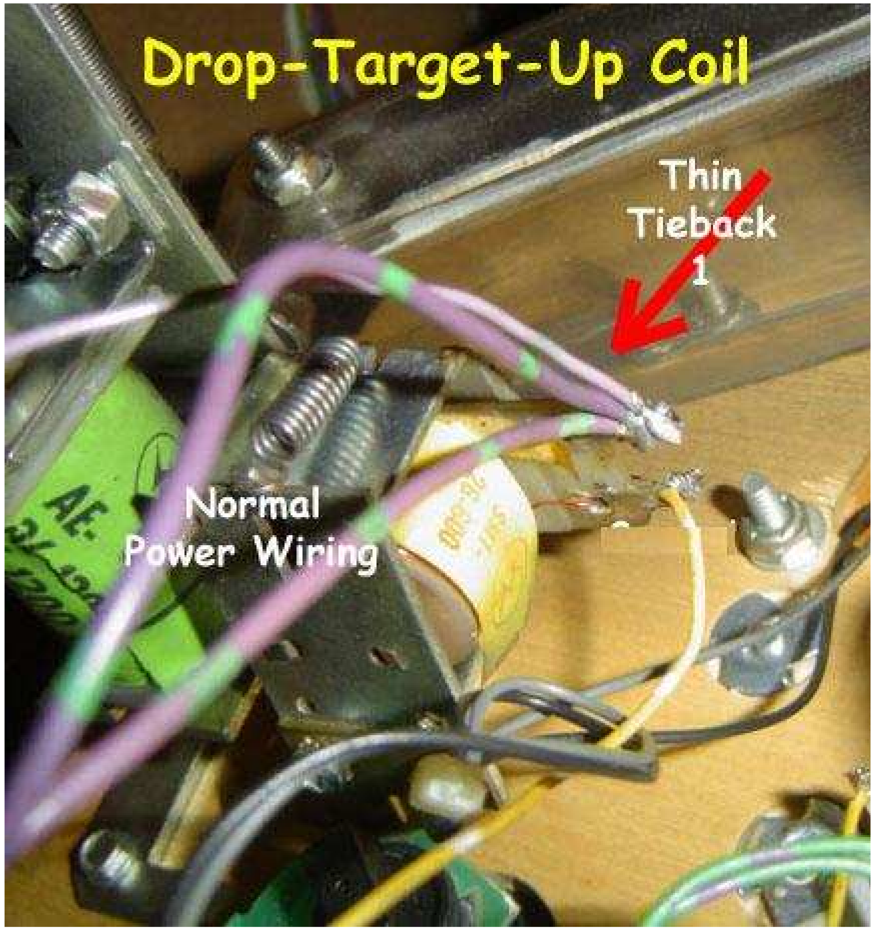
3s. When things don't work: Game Specific & Miscellaneous Repair Tips.

Problem: **The game clock won't keep time.** The internal time clock appears to be running very slow, only about 25% of real time speed. Numerous spot checks show that it advances about 6 hours per day. The batteries, which when weak can cause the clock to lose time, but these are brand new. Answer: First check the batteries again! Make sure they are installed correctly. If the middle battery is installed the wrong way, this will cause a low memory protect voltage. Although game statistics will be saved, the clock will stop every time the game is switched off. All batteries should be pointing

the same direction.
The clock function is handled by U9 (the ASIC chip) and U21 (a CMOS 4584), and the 32.768KHz crystal. I have seen where both legs of crystal X1 were soldered to the same trace, and looks like it came from the factory that way. After removing the crystal and putting both legs in the correct locations, the time tracks correctly.
The 32.768 KHz crystal is very common and used in everything from wrist watches to computers to anything that keeps time. The reason for that particular frequency is 2 to the 15^{th} power equals 32,768. The frequency is very easy to divide by two, fifteen times, using flip-flops or some other form of divider network. This nets a one second time increment. Since the crystal was shorted, the oscillator was free running at a RC-determined frequency that undoubtedly drifted with temperature and miniscule voltage changes, hence the accumulated errors.
Problem: **I can't enter my high score initials on Funhouse.** The game works fine, but won't let player advance through the initials by pressing the flipper buttons when a high score is achieved. The start button works correctly as "enter", and the flippers work fine in game play.
Answer: there are two optocouplers on the power driver board at U7 and U8 that are numbered 4N25. If these go bad, they will prevent the flippers from moving through the high score initials. Since this game does not have fliptronic flippers, these optocouplers don't effect the flippers themselves. When the advent of the Fliptronics board, these (no longer used) optocouplers were eventually removed from the driver board.
Problem: **My Twilight Zone's dot matrix display shows random vertical lines. At first it was just occassionally during game play, but now they appear from the moment I power on the game. The problem has gotten worse, and now every time I turn on the machine, all four flippers energize.**
Answer: the problem was a bad ribbon cable. There is a single ribbon cable that goes from the CPU board to the fliptronics board to the sound board to the dot matrix controller. If the ribbon cable was mis-installed by one pin, or the cable has torn at its connector, this problem can happen. The ribbon cable houses the address and data lines to the fliptronics, sound and dot matrix controller. Often the ribbon cable's connectors can just be dirty, so reseating the connectors sometimes fixes this problem. If the ribbon cable is damaged, mis-installed or the connectors are dirty, strange things like this can happen. Another potential cause could be the lack of 12 volts getting to the dot matrix display controller board.
Problem: **The flippers and dot matrix display died while playing a game.** The flippers on my Indy Jones died. The dot matrix display only has one vertical line which is always lit. The GI lamps are fine, as are the controlled lamps. I turned the game off and back on, the game continually launched balls from the ball trough.
Answer: the +12 volts has died, probably from a bad fuse at F116, or maybe a bad BR5 bridge. Some dot matrix power is derived from the +12 volts, and the +12 volts also powers the optos (hence the auto ball launching problem and no flippers). If the +12 volts is good, unplug the fliptronics and sound board ribbon cable, leaving just the dot matrix display plugged in to the ribbon cable. Now see if the display clears up and you can see the error report.
Problem: **Strange Error Message when I turn my Creature from the Black Lagoon on.** I get the error message "check switch #F6 U.R. Flipper". But this game doesn't have an upper right flipper.
Answer: Every flipper opto board has two optos. One is wired to the lower and the other to the upper flipper switch inputs. This is true even on games with just lower flippers. If the flipper opto board has a dirty opto, you can get this error, even if your game doesn't have the flipper reported in the error message. Clean your flipper opto board optos with a Qtip. Replace the opto if the problem doesn't resolve.
Problem: **The backbox beacon light on my Getaway is constantly running after I put it in test mode.** Capacitor C11 (15,000 mfd 25 volts) on the driver board gets really hot and starts smoking.
Answer: Install a 1N4004 diode on the bottom end of the large ceramic resistor right above the test point for +20 volts DC on the driver board. Install the diode with the banded end going towards the driver board. The non-banded side goes to the bottom side of the ceramic resistor. This diode prevents feedback voltage from going back to the driver board, and damaging the C11 capacitor.
Problem: **Star Trek Next Generation diverter coil stuck on!**
Star Trek Next Generation (STNG) uses more coils than there are transistors on the Power Driver board. Williams solution was to add a small auxiliary driver board, mounted above and to the right of the main driver board in the backbox. This small auxiliary driver board holds more TIP102 driver transistors for the additional coils needed in STNG. This board needs +50 volts for a "tieback diode" voltage for the circuit. The power is connected by a thin violet/yellow wire which connects to the playfield's single drop target coil (at the back of the playfield). If this wire breaks, or if some other power wire in this coil power daisy chain breaks, it can cause the two diverter coils to lock on (after they are first activated in game play!) If the problem is not found quickly, the diverter coils and their driving TIP102 transistors (usually Q15) can fail. Transistors on the auxiliary driver board will fail in one or even a couple of activations if the tieback voltage is not present on the board.
Answer: If the two diverter coils lock on after a game is started, check the violet/yellow tie-back wire which connects to the playfield's single drop target coil. This wire than daisy chains to the other coils controlled by the auxiliary driver board. It's not a bad idea to add a second back-up wire from the single drop target coil (or another adjacent coil) to the circuit board, just in case one wire breaks. Additionally, add two 1N4004 diodes to each of the under-the-playfield diverter coils (banded side of the diode to the power lug with the thick wire). Also make sure the diverter coils are the correct type and resistance. The correct coil type is very important (AE-25-1000, but always confirm with the manual). Remove one wire going to each coil, and

measure the resistance with a DMM. It should be around 12 ohms and no less. Another common problem is when moving the game and the backbox is laid down, the ribbon cables get pulled, and it wasn't plugged in fully on the board. So if a wire in the ribbon cable is faulty, a diverter coil can lock on and burn and ruin its associated driver transistor on the auxiliary board in the process.

The STNG tie back wire on the drop target coil. Picture by Jelle Nelemans.



Problem: **Star Trek Next Generation cannons work intermittently, or upon power on, the cannon(s) continue to rotate and won't stop** (this applies to many other games with similar cannons, such as Terminator2, or other similar moving devices like the Trolls on Medieval Madness). Answer: The constant back and forth movement of the wires leading to the moving device cause an intermittant break in the wires. Usually this break can not be seen, since it is inside the insulation covering the wire strands. Usually the break is at a wire tie or some major angle. Checking the wires using the a DMM continuity setting is helpful, but does not alway work. On Star Trek Next Gen, just replace the cannon wiring loom! (Believe me, they need replaced, it is a high wear part.) They are available from pinballheaven.com/cannon.htm. After replacing the Star Trek cannon wiring loom, check the optics for each cannon in the switch test (the optics tell the game when a ball is loaded in a cannon). If an optic is dead, this can can confuse the game too. Finally, sometimes the cannon plunger becomes magnetic, and will stick in the fired position (and this in turn will block the cannon opto, confusing the game). Replace the plunger to fix this.

Problem: **My STNG (Star Trek Next Generation) has random multiball problems, and I have done all the ball trough upgrades, as described earlier in this document.**

Answer: This was a combination of problems including dirty optos below the playfield in the diverter tunnels, and a not properly working drop target below the borg ship.

Problem: **On STNG (Star Trek Next Generation), when I turn the game on, it constantly tries to load balls in the under ball runways.** It starts with all 6 balls in the ball through. Now it starts the initialization and shoots one ball via the catapult into the left side tunnels below the playfield. It ends in the upper tunnel, then it kicks out a second ball via the catapult which is again going into the upper tunnel. Now the strange thing happens. It ejects one of the balls from the upper tunnel and lets it drain. As soon as the ball drains, a new ball gets kicked out via the catapult (and going into the upper tunnel again). This is an endless loop as the ball drain and re-catapulting steps are repeated. Why?

Answer: the game is trying to load the two guns endlessly (the machine loads a ball under each gun at initialization). It should put one ball in the upper tunnel and one ball under the left gun, and one under the right gun. Then three balls should stay in the trough. Be aware if fuse 103 on the Power Driver Board is blown (3A slow blow), the game will not start and will constantly throw out balls. Fuse 103 powers the solenoid which controls the upper diverter on the under-the-playfield diverter. Without a working diverter, the game can't load the balls where it wants, and the game will attempt to load and reload balls continually.

As a test, try this: go into the feature adjustments and set both guns to "Broken=Yes". This will disable the guns. If the machine then starts up OK, you have a problem with a gun assembly optos, or the under-playfield diverters. Enable each gun individually to see which one causes the failure. Also a dirty/broken opto in the upper tunnel can cause this problem.

Problem: **The Frogs are missing on my Scared Stiff. Where can I get replacements?**

Answer: The frogs used in Scared Stiff are standard toys, with a slight modification. The bottom of the frog is drilled and tapped for a threaded rod. Often the frogs and their associated rods are missing. Replacements can be purchased from pinballheaven.co.uk.

Problem: **How do I prevent playfield wear around upkickers?**

Answer: Mantis Amusements (mantisamusements.com) sells metal protectors that can be attached to the bottom of the playfield, preventing this wear. They are also available in Europe from pinballheaven.co.uk.

Problem: **Shadow Battlefield Optical Sensors work intermittently.** The battlefield would sense a ball on the sides of the battlefield, but not when the ball was in the center of the battlefield! Interestingly, the problem went away when the playfield glass was removed.

Answer: The ball is "seen" by optics on the battlefield. The beam of light provided by the optic transmitter is too wide/conical. So wide, the light was reflecting off the playfield glass and back to the optic receiver (that's why removing the playfield glass solved the problem). The solution to this is to put a piece of 3/8" long black heat-shrink tubing (without shrinking it) over the optic transmitter (and maybe the receiver too, if needed) to sheild the light beam into a tighter pattern.

Problem: **None of my Whitewater's coin door buttons do not work!**

The volume buttons do not work, nor do the diagnostic menu buttons.

There is a shared ground wire that "daisy chains" (goes between) all four coin door buttons. Check that this wire hasn't broken. Also all the coin door buttons are electronic buttons. If the game is missing its +12 volts digital power, these buttons will not work. Check fuses F114 and F115. The red 12 volts LED on the power driver board should be lit also.

Problem: **On my Indiana Jones, the Path of Adventure mini-playfield "stutters",** when it moves in one direction during game play (but not in diagnostic mode). Why?

Answer: The PoA (Path of Adventure) uses the flipper buttons during game play to move left or right. If the flipper opto board's "U" optics are dirty/failing, this can cause the PoA to "stutter", as it moves. Also the game uses two "U" optos on the POA switch board (mounted against the back inside panel of the playfield), and these too could be failing. Use a Q-tip and some Windex, and clean the flipper board optics and the POA switch board optos. Now go to the POA test in the diagnostics. Does the POA stutter in diagnostic mode? If so, the POA switch board optics are failing and need to be replaced. Now retest in diagnostic mode. If the POA works fine in diagnostic mode, but the POA still stutters in game mode, replace the flipper "U" optos (if the POA stutters to the left, it's the left flipper opto board). Another way to test if the flipper optos are the problem is to swap the right and left flipper opto boards, and see if the problem moves to the other side. Note in the diagnostic mode, the coin door buttons are used instead to move the PoA. This is why a flipper opto problem does not show in diagnostic mode, but only in game mode!

Problem: **On Bride of Pinbot, the game does not show the correct "face" during game play.**

Answer: Under the playfield, there is a small circuit board with a relay on it. This relay controls the direction of the motor, which controls which face is shown. Usually the solder joints on this relay crack, causing the relay to not always engage, and showing the wrong face during game play. Resolder the relay's solder joints to fix this.

Problem: **On Tales of the Arabian Nights (ToTAN), after six "Tiger loops" are made for the extra ball, the game shuts down!**

Answer: This seems to be a software problem in all versions of the CPU ROM code. The problem is caused by switch 45 (inner right loop) not working. After the extra ball light comes on, the software compensates for the non-working switch 45 by resetting the game! To fix the problem, make sure switch 45 is working correctly.

Problem: **On Roadshow, the bulldozer blade refuses to go up.**

The eddy switches in front of the dozer blade and in front of Ted's head work perfect. Also the dozer blade works fine in test mode.
Answer: Check the two "U" shaped optos on the dozer opto board, which determine the position of the dozer blade. If either one of these "U" optos has failed or are dirty, the dozer blade will not work properely. Sometimes these optos will seem to work correctly while in the diagnostic switch test. But if they are starting to fail, instead of giving a solid 0 volt or 5 volt signal, they give something in between (like 0.4 volts). To fix this, first try and clean the optos with a Q-tip and some Windex. If still a problem, replace the "U" optos.

***Problem:* On Getaway, the rotating beacon on the top of the backbox is missing.**

Answer: HAPP Controls makes a great replacement for this 12 volt beacon and lamp. Call HAPP at 888-289-4277 (BUY-HAPP) and order part number 95-0115-10UC. Price is right around $40. This is a red beacon light assembly with a chrome ring and outer mounting plate. The HAPP motor is DC, and the game's driver board supplies AC voltage. To convert the voltage to DC, use a 35 amp 200 volt bridge rectifier (as used on the driver board). Connect the two wires coming off the small beacon board to the AC leads of the bridge. Connect the two wires coming off the beacon to the "+" and "-" leads of the bridge.

***Problem:* On Indy500, the lighted targets have broken off the plastic opto activators (the part that passes between the "U" opto.**

Answer: Use some Duct tape or electrical tape and tape both sides of the plastic stub that is left on the target, so the tape is sticking to the stub and itself. Then trim the tape with a razor blade. Note the reason the plastic tab breaks is because the two foam pads on either side of the clear target that prevent the plastic flag from hitting the back of the opto are missing. These can be easily replaced with new 3/16" weatherfoam on the sides of the target to prevent non-broken target tabs from breaking in the future.

***Problem:* On Johnny Mnenomic, the glove does not work.**

Answer: First, remember the glove motor works off the 20 volt flash lamp circuit. So if the coin door is open, the glove motor will not work. Therefore if the coin door is open when the game is turned on, the power-on glove test will fail, making the glove not work (until the game is reset). On the last Johnny I owned, I wired the coin door interlock switch so the 20 volt flash lamp circuit didn't turn off when the coin door was open (the 50 volt solenoid circuit was still disabled with the coin door open). I found this to be much less confusing and more convenient when I was working on the game (I typically leave the coin door open to turn off the 50 volt solenoid power).
The glove on JM uses four "U" shaped optos (for X/Y direction), two microswitches to locate the center and left most position of the glove, and a switch inside the hand's magnet. Test these switches by going into the WPC diagnostic switch test T.1.
One microswitch finds the "mid" position of the hand (forward and back). The other microswitch finds the left most position of the hand. Make sure both of these micro switches are working in the switch test T.1 by activating them manually. Then make sure when the glove moves these switches actually close.
Next check the four "U" shaped opto switches for the glove. These four optos tell the computer the X and Y position of the glove. They are mounted on two small PC boards, positioned behind the back panel of the playfield (pull the playfield all the way forward to see these). The glove moves much like a Genie garage door, on threaded rods (one rod for X movement, one for Y movement). Each rod has a metal interuptor, which rotates between two "U" shaped optos. The threaded rods can be spun by hand. In switch test T.1, make sure both optos ("A" and "B") work for each rod (these "U" optos are the five leg variety). If just **one** of these four optos does not work, the entire glove assembly will not work, and an error report will be generated when the game is turned on (or when entering diagnostics). The error relating to these optos is "No X Movement Detected" or "No Y Movement Detected". This signifies a problem with any one of these four "U" optos. If one of these "U" optos does not work, or works intermittently, just replace it (see here for info on replacements).
Another problem can be the small .100" molex connectors on the glove's two opto boards. Often just reseating these connectors will fix a glove opto problem. If reseating does fix the problem, it is suggested the connectors be replaced.
Finally check the "ball in hand" switch. This switch is located inside the magnet, under the moving glove. Use a **pinball** to check if this switch (labeled "F5" in the switch matrix, right most column) is working. It is important to test this switch with an actual pinball (opposed to just using a finger).
After all switches are confirmed as working, go into the solenoid test and make sure the glove's magnet is working.
Last, make sure the latest CPU ROM software is installed in the game. The latest is version 1.2. A new U6 CPU ROM would need to be "burned" if a game has a revision other than this (the CPU revision number is shown upon game boot up, and when entering diagnostics).

***Problem:* My Scared Stiff crate LEDs are broken. Where can I get replacements?**

Answer: The crate LEDs are standard red T-1 sized LEDs. Any T1 LED should work, but here are some that mimic the originals, from mouser.com, part# 604-L934SRCD, KingBright super bright LED lamps T-1 red water clear, $0.34. Or part# 351-3230, LED lamps T-1 red water clear, $0.25 as a second choice.

***Problem:* My Cirqus Voltaire neon lamp is not working.**

Answer: First check that 12 volts is present going **into** the neon lamp's transformer (is the fuse blown?) The easiest way is to check for 12 volts at the Molex connector going to the transformer (under the playfield), or at the power driver board. Past that, if the neon tube itself is not damaged, the transformer itself is probably bad.
The neon transformer takes 12 volts DC and converts it to a very high voltage (about 1500 volts, at low current). Because of this, to get the UL rating,

Williams was required to rivit close a plastic case around the transformer! To access the transformer, the rivits will need to be drilled out with a 1/8" drill bit or grind off the heads of the rivets (on SWE1, do not try and remove the decorative plastic "light saber handle" from half of the plastic transformer case; they uses silicon to attach it, and it does not come off without destroying the decorative plastic!)
Once the rivits are removed, the transformer can be removed and checked. Is there any high voltage (1500 volts DC) being output? If your DMM does not go this high, just replace the transformer. The cheapest way is to buy a car neon license plate transformer. If needed, wire the automobile neon transformer under the PF (if it doesn't fit in the ramp housing), and run the high voltage wire up to the ramp and bulb. Note if you do this to be sure to use wire rated for at least 2000 Volts (it'll have thick insulation; look at the wire already on the bulb if you need some reference).
Specs for the original neon transformer are **here**. The original Williams Star War Episode 1 transformer (part number 04-10947) may also still be available. The original transformer for Cirqus Voltaire (and SWE1) was a Ventex model VT12D5, but they seem to have changed their model numbers so now it's VT1510-12. A replacement is Ventex model NPS-12D5 and it fits and works fine. Key specs are input 12 volts DC at 0.6A, and output 1500V 5mA. You can find it at www.ventextech.com/lowv.htm. Note the output connector will need to be changed to a Molex connector. Another transformer source is www.sunsupply.com/transformers/winind.html.
Testing the neon tube itself, without using the high voltage transformer, and not that easy. There is no to test a neon tube with a DMM - basically the gas inside the tube conducts electricity. So basically a DMM can't generate a big enough voltage to test it. They make little inductive testers - the tube will glow when this thing is held near the neon tube, if the gas is still in there. Also try taking the neon under some high voltage power lines at night to see if it glows (and to scare yourself about how much energy is leaking out of them!)
Problem: **In my Getaway High Speed2 the The ball does not accelerate well around the super charger, and was blowing fuse F103 after a few revolutions. Also all three magnets seemed to pulse no matter which supercharger opto was activated.**
Answer: Clive suggested the problem may be one or both of the CMOS chips on the Accelerator board, or the LM339's on that board. By checking the accelerator optos in switch test mode, verified the optos all work fine and there were no multiple openings for each opto. If this tests good, the LM339 chips are probably fine. This leaves the CMOS chips U2 (4011) and U3 (4071) as suspect, so replace those.
Problem: **Where can I get a replacement strobe light tube for my Attack from Mars?**
Answer: At your local Target store for $5! It's made by Liteglow (Lite Glow) part# OS470 or Target# 092 03 0215. As of the fall of 2003, they were on a clearance endcap near the automotive section. Also the same style of strobe light bulb was available from Pep Boys, known as the "Fast and Furious" strobe lights for $15. Coincidentally enough the bulb inside looked just like the recently broken one in my AFM. I took the slight apart and installed in my AFM and so far it works. There are several manufactures of these lights so you can probably find them cheaper. When installing don't touch the bulb. And before assuming the bulb is bad check the power supply board mounted under the metal box in the back. Make sure the game is unplugged before taking it off. You need to take it off anyway to take the strobe assembly off. I had two leads broken off on the small blue box on the board on a recent repair job.
Problem: **How do I link two NBA Fastbreak games together?**
Answer: (from Louis Koziarz) the NBA Fastbreak link option is done through the A/V board's serial port. Installing a serial port on WPC-95 games is easy, and you can save the money by doing it yourself instead of buying the kit. The WPC-95 A/V board comes with those two serial port chips missing by default, so these chips will need to be purchased and insert them into positions U22 and U24 on the WPC-95 A/V board. U22 is a MAX239 RS-232 driver chip, and U24 is a 16C450 UART. Digi-Key (www.digikey.com) is currently selling the MAX239 for $7.55 and the 16C450 for $5.60 (using a buffered 16C550 as an equivalent part).
The pinouts for the A/V board are on page 9 of the schematics, but here's a summary:

- J607-1 - Ground
- J607-2 - TX output
- J607-3 - RX input
- J607-4 - CTS
- J607-5 - RTS
- J607-6 - DTR
- J607-7 - DSR
- J607-8 - Key (no connection)
- J607-9 - RI
- J607-10 - DCD

For basic RS-232 operation, all that is needed are the first three signal lines, and you should be able to talk to the board. If not familiar with RS-232

interfacing, obtain a copy of the WPC-95 Schematics, as these go a long way in helping understand how the system works.
If the chips are installed properly the operating system should detect the board automatically and start sending audits out the port. It may need to enable printouts in the Adjustments menu, I don't remember if that option trips automatically.
That's all there is to it. NBA Fastbreak also used this port in a null-modem configuration for the head-to-head gameplay (swap TX and RX lines between games).

Problem: **What motor is used in my WPC game?**
Answer: See the web page **gearbox.htm** for details.

Problem: **On my Twilight Zone, I get the error, "clock is broken". How do I fix this?**
Answer: On my TZ clocks, this problem occurs because of high heat inside the clock from the #86 General Illumination lamps. To fix the problem, all the "U" slot optos should probably be replaced (along with the feeding 470 ohm ½ watt resistors R1-R8, and the .100 interboard connector), and the heat some how decreased inside the Twilight Zone clock.
There are two trends on decreasing the heat inside a TZ clock: Using diodes on the clock's #86 GI lamps, or installing bright LEDs instead of the #86 lamps. If the clock's heat issue is not address, the internal heat will cook the "U" slot optos and other parts, giving a "clock is broken" error message.
Pin Lizard sells replacement TZ clock boards with bright LEDs already installed at pbliz.com/id31.htm. Using their boardset, the internal heat can be reduced from about 160 degrees in an unmodified clock, to about 100 degrees. But if using the original boards, they can be modified for LEDs to reduce the internal clock heat to about 125 degress. This will decrease the power consumed by the clock from about 8 watts to 1 watt (as documented by PBliz), thus reducing heat.
The existing TZ clock boards can also be modified for LEDs. To do this, first get four T1-3/4 size (5mm diameter) water clear white LEDs (PBliz suggests Digi-Key, part# CMD333UWC-ND). The brighter the LED, the better for this application. Also get four 100 ohm (or 133 ohm) ½ watt resistor, and install them in locations D1-D4. Bend the LED leads as shown in this photo **here**. This spreads light more evenly over the clock face (click **here** and **here**). Note that the LEDs can be installed in either direction; there is no need to pay attention to how the LED's "flat spot" is installed (since the supply current is AC volts). But since the supply voltage is AC, it is ideal if the LEDs can be mounted so two are "on" and two are "off" during any half of the AC cycle (see the picture above for this mounting configuration).
Please remember, just putting in LEDs does not fix previously damaged boards. Often original clock boards will have burnt traces, bad "U" optos, bad opto resistors R1-R8, a damaged .100" inter-board connector going between the two clock boards, or cold solder joints on the interboard connectors. Also the look of clock LEDs is quite different than the #86 bulbs; it is a more blue colored light. Some people don't like this look, as it is not "stock".
There is another clock modification which retains the original look of the clock (some people do not like the look of LEDs). Four 1N4004 diodes can be installed at locations D1-D4 on the clock board (Williams actually has zero ohm resistors installed there), and the original #86 bulbs can still be used (the diodes will decrease the current to the #86 bulbs, lowering the internal temperature). Also install the D2,D3 diode bands in the reverse of the silkscreening on the original clock board. This will cause lamps one and four to light on one half of the AC cycle and lamps two and three to light on the opposite half of the AC cycle. This mod will decrease the consumed clock power from 8 watts to about 6 watts, lowering the heat yet still retaining the original look of the clock. With this modification it is recommended the plastic clock housing be drilled on the top with two ¼" holes to vent the heat, directly above the top two #86 lamps (no bottom holes are needed since there are already bottom holes for the connectors).

4a. Finishing Up: Rebuilding Flippers

Regardless of your playing skill, the one thing everyone notices about a pinball game is the flippers. Novices and pros alike can tell you if your game has good, powerful flippers, or whimpy, limp, dead ones. Flippers are the interface between the game and the person playing. If you don't maintain anything else on your game, at least maintain the flippers. Games with good flippers are fun. Games with bad flippers aren't fun (regardless of what the game title is).

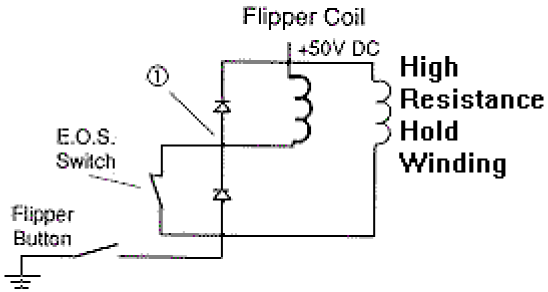
Flippers get weak because they have moving parts that get substantial use. When they wear, the mechanisms get play (slop) in these moving parts. Instead of the flipper coil transmitting all its energy in propelling the ball, some energy is absorbed by the sloppy mechanisms. Rebuilding the flippers removes this slop, and will dramatically increase the strength and feel of your flippers.

How Flippers Work.

Flipper coils are actually two coils in one package. The "high power" side is a few turns of thick gauge wire. This provides low resistance, and therefore high power. The "low power", high resistance side is many turns of much thinner wire. This side of the coil is important if the player holds the cabinet switch in, keeping the flipper coil energized. The high power low resistance side of the coil is only active when the flipper is at rest.

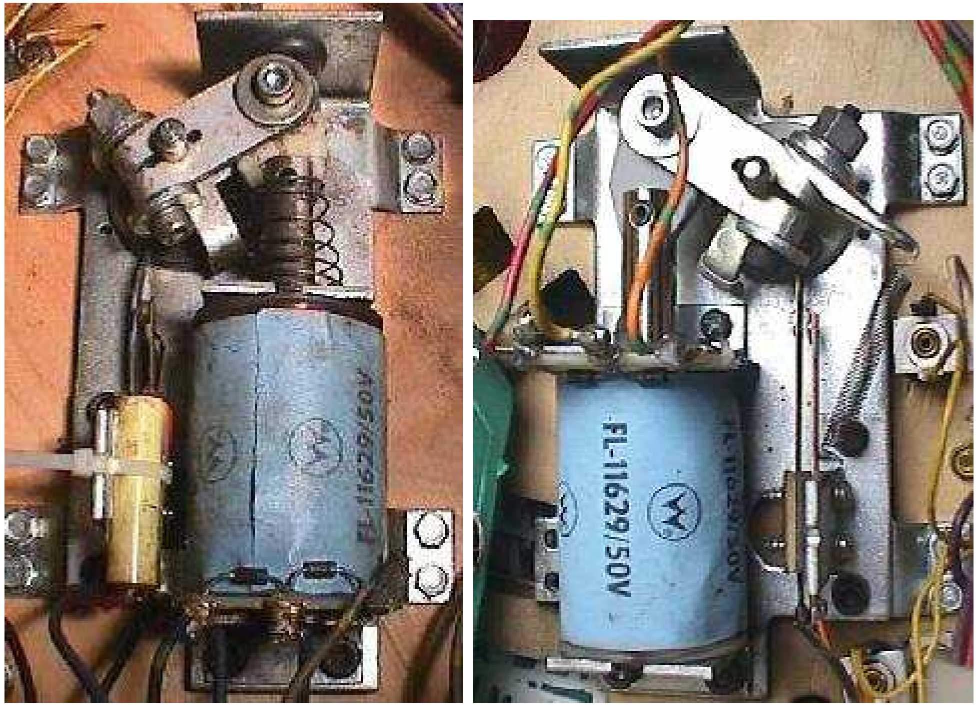
To simplify how the two sides of a flipper coil work, it's best to examine the non-fliptronics version. In this case, when the flipper is energized and at full extension, the normally closed EOS switch opens. This removes the high powered side of the coil from the circuit. The low powered side of the flipper coil is always in the circuit, but is essentially ignored when the high powered side is in the circuit. This happens because the current takes the easiest path to ground (the low resistance, high power side of the coil). The low power high resistance side of the flipper coil won't get hot if the player holds the flipper button in.

A simplified drawing of the flipper circuit in non-fliptronic games.



EOS Switches: Normally Closed or Normally Open?
Pre-fliptronics games have a high voltage, normally closed end-of-stroke (EOS) switch. But Fliptronics flippers are basically an electronic (instead of mechanical) version of the above explained non-fliptronics flippers. The main difference is fliptronics flippers have EOS switches that are low voltage, **normally open** switches (instead of high voltage, normally closed as used on non-fliptronics flippers).

Left: *Non-Fliptronics WPC flipper. Note the capacitor to minimize EOS switch arc, and the style of return spring used. The EOS switch is a high voltage, Tungsten contact,* ***normally closed*** *switch. This flipper coil is installed incorrectly; can you see why?*
Right: *A freshly rebuilt Fliptronics WPC flipper. There is no capacitor, and a different return spring. The EOS switch is a low voltage, gold contact,* ***normally open*** *switch. This flipper coil is installed correctly.*



Answer to the above trivia question *("what's wrong with the left picture's flipper coil?"): The problem shown on the left is the flipper coil is installed* ***upside down!****. The wire terminals that the flipper coil wires connect should be as far away from the coil stop as possible. The coil stop is where most flipper vibration originates. The coil plunger slams into the coil stop, causing vibration. This vibration will eventually break the coil wires off of the coil wire lugs. To minimize this, the coil is mounted so the wire lugs are further away from the coil stop. The coil picture on the right is mounted correctly. Note many pre-Fliptronics WPC games had the flipper coils mounted incorrectly from the factory!*

Non-Fliptronics WPC Flippers.

When the player presses the flipper button, the high-powered side of the flipper coil is activated and fully extends the flipper. Then the end-of-stroke (EOS) switch is opened, and removes the high-powered side of the coil from the circuit. As the flipper reaches it's end-of-stoke, the flipper pawl opens the high voltage, normally CLOSED switch. The electricity now only passes through the low powered side of the flipper coil. The use of the low powered, high resistance side of the flipper coil consumes less power. This allows the player to hold in the flipper button without burning the flipper coil. If the high-powered side of the coil was activated alone for more than a few seconds by itself, the coil would get hot, smoke, smell, and burn.

Non-Fliptronic EOS switches use a 2.2 mfd 250 volt capacitor (part number 5045-12095-00). This minimizes the high voltage electrical arc between the contacts of the EOS switch. The EOS switches on these games do need periodic maintainence. Since they are high voltage switches, there is some electrical arcing. This will cause the switch contacts to pit and burn, and cause some resistance. As the resistance increases, more arcing occurs (which causes even more resistance). Eventually, bad EOS switches will make the flippers very weak. They must be filed clean with a small point file periodically. The switch contacts are made of Tungsten.

Fliptronics WPC Game Flippers.
The Fliptronics board allows computer control of the flippers. When the EOS switch is damaged or broken, the Fliptronics board can turn off the high powered side of the flipper coil. This provides a better level of reliability.

The EOS switch is now a low voltage, normally OPEN switch. As the flipper pawl reaches its end of stroke, it now closes the EOS switch.

When the player presses the flipper button, the CPU turns on the high powered side of the flipper coil. When the EOS switch is sensed closed, the high powered hold side of the coil is turned off. If for some reason the EOS never closes, the CPU turns off the high powered side of the coil after a short period of time (a few milliseconds). The low-powered hold side of the coil is powered for as long as the player holds the flipper button.

Computer control of the flipper coil via the Fliptronics board provides an extra level of reliability to the game. The computer now controls this. The EOS switch is monitored, and if the computer sees a problem, the operator is notified via a diagnostic message. But if the operator chooses to ignore this, the game will still function as designed. Also, since the EOS switch is now a low-voltage, gold plated contact device, it requires no big maintanence schedule.

Flipper Coil Numbers and Strength.
When you get a new game and are rebuilding the flippers, check the game manual and make sure the proper flipper coils are installed. Often operators will replace flipper coils with the wrong coil. Use what the manual suggests for proper game play. Resistance is included below so a questionable flipper coil may be tested. The upper measured ohms should be within 10% of the values below, and the smaller measured ohms should be within 3%. To measure flipper coil resistance, used a DMM with one lead on the center coil lug, and the other DMM lead on either outside coil lug. The flipper coils are listed below from weakest to strongest.

- FL-11753: used for small flippers, like the “Thing” flipper on Addam’s Family. 9.8 ohms/165 ohms. Usually a yellow coil wrapper.
- FL-11722: used for weak flippers, like Twilight Zone’s upper right flipper. 6.2 ohms/160 ohms. Usually a green coil wrapper.
- FL-11630: “standard” flipper strength, as used on older games like Earthshaker, Whirlwind, etc. 4.7 ohms/160 ohms. Usually a red coil wrapper.
- FL-15411 : strong flipper, as used for main flippers on Addam’s Family, Twilight Zone, etc. 4.2 ohms/145 ohms. Usually an orange coil wrapper.
- FL-11629: strongest Williams flipper. Used on most of the newest WPC games. 4.0 ohms/132 ohms. Usually a blue coil wrapper.

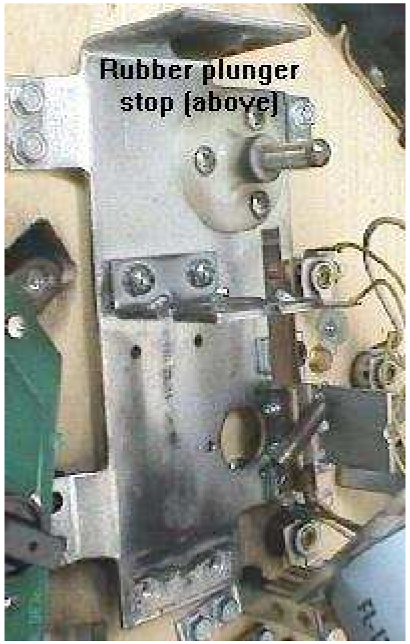
Flipper Rebuild Kits.
Williams sells a flipper rebuild kit that contain all the parts you would need to rebuild two flippers. It includes parts like the entire right and left flipper pawl and plunger/link assemblies, coil sleeves, coil stops, EOS switches, EOS switch capacitors (for the non-fliptronics kits), and other parts. At $20 a kit (to repair two flippers), it’s a pretty decent deal because it’s all the parts you’ll need in one kit. But you can save some money if you just replace the parts that are worn (the plunger/link, link bushing, coil sleeves and usually the coil stops). For fliptronics flippers, the kit’s part number is A-13524-8. For non-fliptronics flippers, it’s part number A-13524-1. The genuine Williams kits come in a cute plastic claimshell container.
Rebuilding Fliptronics and Non-Fliptronics Flippers.
Regardless whether you have Fliptronic or non-Fliptronic flipper, the rebuilding process is the same (except for the cleaning and adjustment of the EOS switch). These two styles of flipper assemblies even share the same parts (except for different EOS switches and return springs).
Left: *Flipper assembly with the coil stop (and coil) removed.*
Right: *The coil stop. Notice the mushroomed head on the top example. Below that is a re-worked coil stop (using a file). It is recommended replacing the coil stop rather than re-working it.*

Measuring the coil stop with a dial caliper.
The thickness of a new coil stop is .440 inches.
After re-working, if yours is .425 inches or less, replace it.

Removing the Coil Stop.

First, use your allen wrench and remove the two 10-32 x 3/8" bolts that hold the coil stop in place. This will release the coil from the assembly. Move the coil to the side for now.
Examine the coil stop. Often, the coil stop will have a "mushroomed" head. This happens from the coil plunger slamming into the coil stop. If this is the case, replace the coil stop. In a pinch, you can re-work the coil stop and file the mushroomed head flat and bevel the edge. The problem with this is plunger travel length increases. If excessive, the plunger link will now slam into the top coil bracket, destroying it. Also the increase in plunger travel can cause the flipper pawl to hang on the EOS switch (leaving the flipper in the up position). A new coil stop is .440 inches thick. If your coil stop, after filing, is less than .425 inches thick, you should replace it. Less than .425, and you'll have problems with the flipper pawl hanging on the EOS switch, especially on fliptronics flippers.

The flipper assembly with the pawl assembly removed. The flipper shaft can be seen extending thru the playfield, and thru the nylon flipper bushing.



Removing the Flipper Pawl Assembly.
On Fliptronics flippers, remove the one side of the return spring from the flipper pawl. Then using your allen wrench and an open wrench, loosen (but don't remove) the bolt that clamps the pawl assembly to the flipper shaft. From the playfield side, turn and pull the flipper while holding the pawl assembly until the flipper can be pulled from the playfield. The pawl assembly can then be removed from under the playfield.

Worn Coil Bracket?
If the game was played so much that the coil sleeve wore out (thanks in part to a worn plunger link), the plunger could then come in contact with the coil bracket. This would elongate the bracket's hole. Also, if the coil stop was filed (to removed a mushroomed head) and plunger travel increased, this could ruin the coil bracket too. In either case, the coil bracket will need to be replaced.

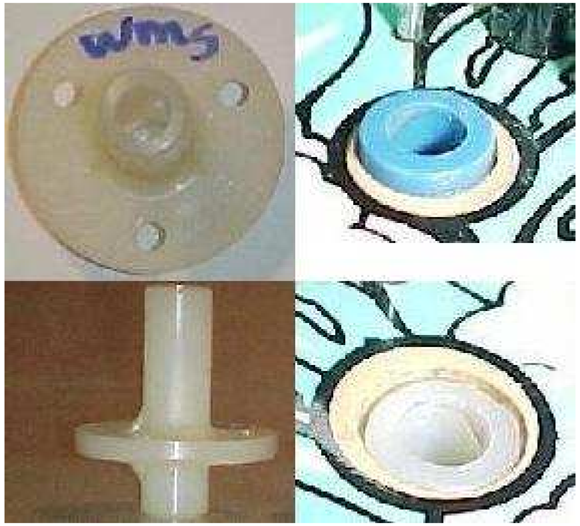
Check the Rubber Flipper Plunger Stop.
A trivial flipper part that is often overlooked is the black rubber plunger link stop. This little black piece of rubber softens the flipper's return to home. If the rubber piece get chewed up, it can cause problems. First, the flipper plunger will have too much travel. Next the plunger and link will wear quicker (due to the increase shock to the plunger's link). And last, the flippers will not align properely when fully extended. If in doubt, replace this trivial part.

Shown is "flipper drag" playfield wear (see the wear in the word "Twlight"?). This is caused by worn or broken nylon *flipper bushings. This allows the bottom of the flipper bat to drag on the playfield, causing this wear.*

Replace the Nylon Flipper Bushing.

The flipper bushing is a nylon part that the flipper shaft passes through. It is very common for this part to crack, or wear excessively. This can cause the flipper bat to drag on the playfield finish. If this happens, ugly playfield wear marks can result (see picture above). It's pretty easy to tell if the bushings need to be replaced. With the flipper pawl removed from the flipper shaft, wiggle the flipper on the playfields, side to side. There should be some play, but not excessive play. The bushing should also stick up ABOVE the playfield about 1/8". If the bushing is too low to the top of the playfield, this will allow the flipper bat to drag on the top of the playfield. To play it safe, always replace both nylon flipper bushings. Flipper drag marks on the playfield are not worth the risk!

Left: *Williams nylon flipper bushing, top and side view.*
Right: *The top right picture shows how the flipper bushing should protrude above the playfield 1/8". The bottom right picture shows a playfield bushing that is much too low, allowing the flipper bat to drag on the playfield.*



When replacing the flipper bushing, remove the entire flipper bracket from under the playfield. This allows access to the three 6-32 x 3/8” bolts and nuts that hold the bushing to the bracket. These bolts have nuts on the bottom side of the flipper bracket, which can’t be accessed with the bracket in place.

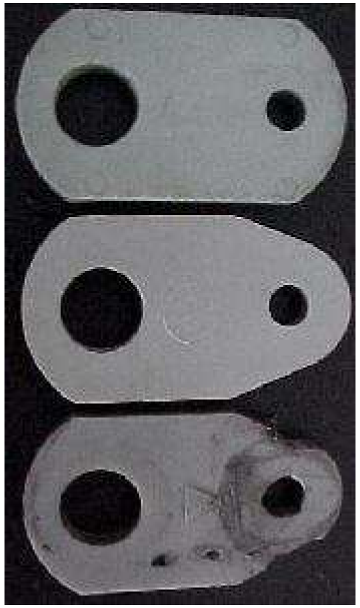
Left: *Note the flipper link’s hole has enlongated. Also, the black heat shrink tubing on the pawl is very worn from activating the EOS switch. Although it doesn’t look it, the flipper link spacer bushing (lower left) is also worn.*
Right: *Note the plunger tip has mushroomed, and there is considerable plunger pitting.*


Rebuilding the Pawl.

The flipper pawl assembly can now be rebuilt (if you buy a whole new flipper pawl assembly with a new plunger/link for about $10, skip this section). Remove the allen bolt that holds the flipper plunger/link to the pawl. The plunger/link can now be removed (you may need to use a screwdriver to spread the pawl assembly slightly to release the plunger/link).

Top: *New style, fatter and more substantial flipper link.*

Middle: *Old style, thinner flipper link; the preferred version for the newer style return spring set up. Since it’s not as thick, it doesn’t hang up inside the flipper pawl assembly as easily. It’s also a more versatile link, and can be used in most Williams (and DataEast!) games from the mid-1980’s and forward.*
Bottom: *Old style, chewed up link from a flipper plunger return spring. This is why Williams went to the newer style (top) plunger link. The plunger return spring just hacks away at the link.*



Inspect the **flipper link spacer bushing**, which should be inside the flipper link’s hole. Brand new bushings have an outside diameter of .310 inches, and an inside diameter of .090 inches. If you have a dial caliper, measure yours. If even .003” less than these values, replace this bushing. If in doubt, just replace it.

Replace the flipper plunger and link. A new plunger/link can be bought for $1.50. (rebuilding the plunger is hardly worth it. Spend the $1.50 and get a new plunger/link. If rebuilding the plunger/link is your only option, here’s what to do: grind and bevel the plunger tip to remove the mushroom. Using a 1/8” metal punch, remove the roll pin that holds the link in place. Install a new link, and hammer the roll pin back in place. Make sure the new link moves freely.)

Install the plunger/link and a flipper link spacer bushing. Remember the allen bolt that holds this is place goes through the pawl assembly with the nut on the same side as the pawl (see pictures).

A new plunger/link and new spacer bushing. Note the freshly installed (white) pawl heat shrink tubing and allen bolt.

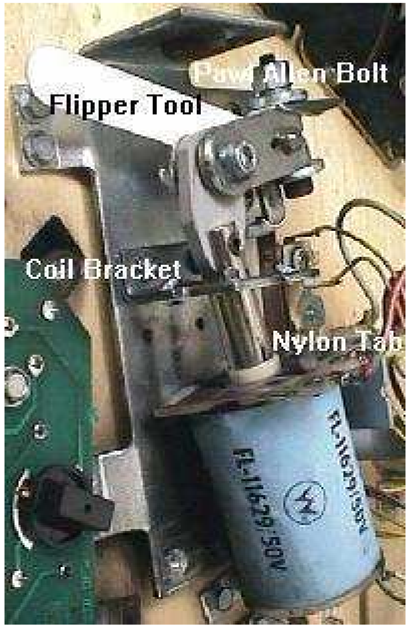
Replacing the Pawl Heat Shrink Tubing.

The flipper pawl's job is to activate the EOS switch at the flippers' end of stroke. This metal pawl tab is factory coated with heat shrink tubing to prevent wear to the EOS switch. When the coating is worn, metal-to-metal contact (pawl to EOS switch) occurs. This will shred the EOS switch blade. When the EOS switch blade frays, it will hang-up on the flipper pawl. This will cause the flipper to stick in the up position (regardless of the condition of the return spring).

The heat shrink tubing also provides insulation between the metal flipper pawl and the EOS switch. This is especially important on non-Fliptronics games (as the EOS switch is a high voltage switch). Worn or missing heat shrink tubing on these games can cause all sorts of strange game behavior.

New pawl heat shrink tubing should always be installed when rebuilding the flippers. Cut the old tubing off using a razor blade. Cut a ½" length of new ¼" heat shrink tubing. Push it over the pawl, and use a heat gun or hair drier to shrink the tubing in place. Trim with a razor blade as needed.

Installing the flipper pawl and flipper coil. Note the use of the white plastic flipper "tool" to get the spacing correct.

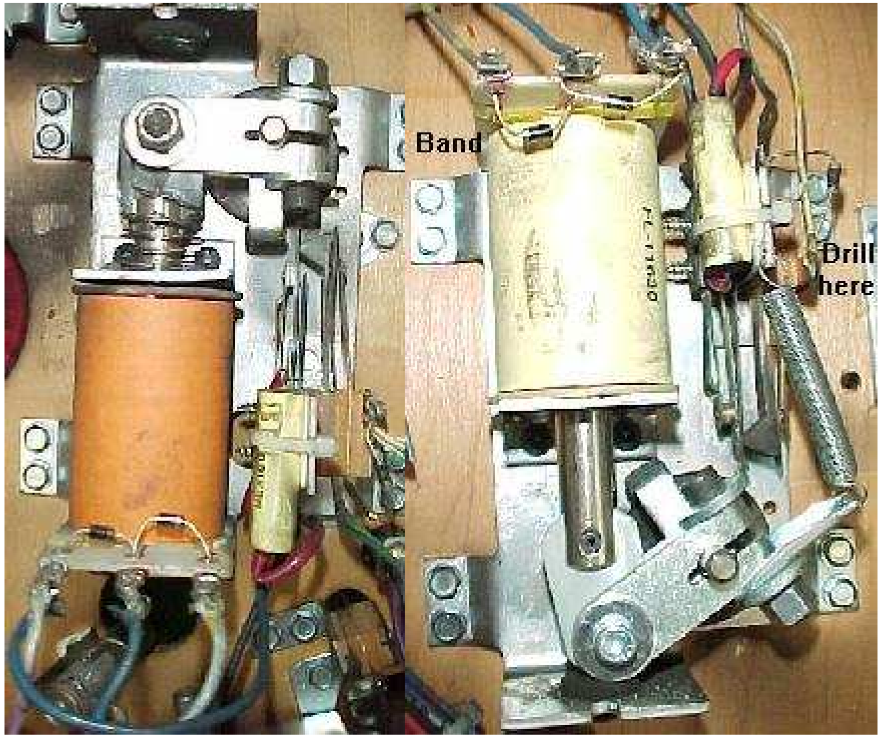


Flipper Coil Types.
Often, operators will replace a flipper coil with the wrong type. This happens quite often. You should verify in the manual that your particular game has the correct flipper coil installed.

Re-installing the Flipper Pawl Assembly and Flipper Coil.
After the flipper pawl assembly is rebuilt (or replaced), reinstall it. Put the plunger through the coil bracket. Make sure the pawl is down (toward the playfield). Push the flipper shaft through the flipper bushing and into the pawl assembly. Do not tighten yet.
Put a new coil sleeve in the flipper coil. If you can't get the old coil sleeve out of the coil, replace the entire coil (it has been heat damaged otherwise the coil sleeve would easliy slide out). The coil sleeve should be installed from the non-terminal end of the coil, and extend through the coil at the terminal end about 1/8".
Put the flipper coil in place, the coil end with the wire terminals goes closest to the flipper pawl. Note the nylon "tab" that is molded into the the nylon terminal portion of the coil. This tab will fit into a notch in the coil bracket. The extended part of the coil sleeve will go through this coil bracket too. Install the coil stop and its two allen bolts.

Changing to the New Style Flipper Return Spring on Older Flippers.
Williams changed flipper return spring styles in 1992. Before, there was a cone-shaped flipper return spring that went over the flipper plunger. The problem with this set up was it chewed up the flipper link, and often the spring just got weak and broke from the constant contact with the flipper link. To combat this problem, Williams made two changes when they went to Fliptronics flippers. First they changed the style of flipper link to be thicker, and have a more rounded contact point. Second they stopped using a plunger style return spring. The return spring was moved outside of the plunger, where it takes less abuse and doesn't chew up the flipper link.

Left: *Here the flipper plunger spring has gone soft, and won't return the flipper back. Note how the spring is biting into the flipper link (new style flipper links help prevent this).*
Right: *A conversion to the new style return spring. This involved using Fliptronic flipper pawl parts, and drilling a 1/16" hole in the metal bracket holding the flipper capacitor.*



To change to the new style return spring on older flippers, just order the fliptronics style flipper pawl. Then drill a 1/16” hole in the bracket that holds the flipper capacitor. This hole will anchor the new style return spring. Entire flipper pawl, with plunger and link is part number #A-15848-L (left), or -R (for right). The flipper pawl only is part number #A-17050-L (left), or -R (for right).

Tightening the Flipper Pawl Assembly.

Now you are ready to tighten the flipper pawl assembly to the flipper shaft. Williams provides a white plastic spacing “tool” (that comes with every game) which fits between the flipper bushing and the flipper pawl (see above picture). This spacer is .030” thick (1/32”), or about the thickness of three business cards.

Using a toothpick as a flipper alignment tool.

On the top of the playfield, note the roll pin inserted through the playfield, just behind the flippers. This pin is used for alignment purposes at the factory when the playfield was first assembled. Put a toothpick into the roll pin, and move the flipper against it (with the rubber installed on the flipper). With the flipper positioned correctly, lift the playfield and tighten down (very tight!) the flipper pawl assembly's allen bolt. Remove the flipper spacing tool and the toothpick. I wouldn't suggest trying to push the roll pins back through the playfield for flipper alignment; just use toothpicks. No need to possibly damage your playfield!

Both flippers in the "up" position. Notice how they look symmetrical.

Flipper Alignment in the Up Position.

When you are finished, extend both flippers to the up position. They should look "equal", both extending the same amount. If not, you will need to re-align one or both of the flippers. If you didn't replace the flipper coil stops (and instead filed them down to remove a mushroomed head), the flippers may not line up when extended. This happens because the plunger travel has increased from filing the coil stop. Also worn rubber flipper plunger stops can cause the flippers to not align with fully extended.

Cleaning and Adjusting the EOS Switch.

Cleaning and adjusting the EOS (end of stroke) switch is the last step in rebuilding flippers. This is VERY important, especially on non-fliptronics games. On non-fliptronics games, the EOS switch is what diverts power away from the high-powered side of the flipper coil. If not adjusted correctly and the EOS switch stays closed, the flipper coil can burn. If the EOS switch is dirty and doesn't make good contact, the flipper will be extremely weak. Therefore it's critical that the EOS switch be adjusted and cleaned on non-fliptronics flippers. On fliptronics games the EOS switch is less critical, but should still be inspected.

On non-fliptronics games, clean the EOS switch contacts with a small file. There should be no pitting in the contacts when done. The EOS switch is a normally closed switch. So adjust the non-fliptronics EOS switch so it opens about 1/8" at the end of the flipper's stroke.

On fliptronics games, make sure the EOS switch doesn't hang on the flipper pawl when the flipper is fully extended. Clean the EOS switch by running a business card through the closed contacts once or twice. The EOS switch is a normally open switch. So adjust the fliptronics EOS switch so the contacts close when the flipper is at its end of stroke.

Parts Reference.

- Flipper Rebuild Kits (for two flippers). Includes all the following parts, plus some others. Part number A-13524-8 for fliptronic flippers, #A-13524-1 for non-fliptronic flippers.
- Entire Flipper Pawl, with Plunger/Link: #A-15848-L (left), or -R (right).
- Flipper Pawl only: #A-17050-L (left), or -R (right).
- Plunger/Link: #A-10656 (or A-15847 which has a slightly meatier link). Use this plunger/link for the older spring set up where the cone-shaped flipper return spring is over the plunger.
- Nylon Flipper Link only: #03-8050 (or 03-8753 which is the meatier link).
- EOS Switch: non-Fliptronics version #03-7811. Fliptronics version #SW-1A-193.
- Coil Stop: #A-12390 (uses two allen head 10-32 x 3/8" bolts)
- Coil Sleeve: #03-7066-5, 2 3/16" long.
- Flipper Link Spacing Bushing: #02-4676
- Flipper Bushing: #03-7568 (uses three 6-32 x 3/8" bolts and nuts)

All of these parts are available from your local Williams distributor or one of the suppliers on the parts and repair sources web page.

4b. Finishing Up: New Coil Sleeves

Replacing the coil sleeves on all major coils has a big impact on snappy game play. If you didn’t rebuild your flippers, definately replace the flipper sleeves at a minimum. It makes an amazing difference in flipper power. Replace the coil sleeves on the pop bumpers and slingshots. Your game will have much more snap. Just replace the flipper, pop bumper and slingshot coil sleeves (and any other ball action coil sleeves).

4c. Finishing Up: Protecting Slingshot Plastics

Corners of slingshot (kicking rubber) plastics often break. This happens because the ball comes off the flippers with so much force, it breaks the overhanging plastic. To protect this plastic from breakage, put a 3/16” by 1” round Fender washer underneath the plastic. You can get these washers at any decent hardware store. This way the ball will hit the metal washer instead of the plastic when coming off the flipper.

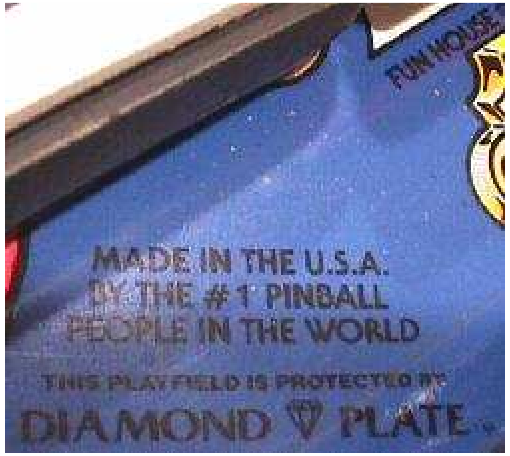
A fender washer underneath the slingshot plastic.

Note you install the washer between the metal post and the plastic post. That is, you remove the slingshot plastic. Then you remove the lower metal post that holds the plastic star post in place. Then put the metal post through the washer, and through the plastic star post. Re-installed the metal post/washer/plastic star post to the playfield, and re-install the slingshot plastic.

4d. Finishing Up: Cleaning and Waxing the Playfield

Keeping the playfield clean is of major importance in game performance. Dirt on the playfield slows the ball down, and increases playfield wear. Williams recommends using Novus 2 plastic polish for cleaning playfields. It works great, and leaves a great shine. It’s very gentle, yet cleans fast and well. It can be used on both the playfield and on plastic ramps. I buy it at my local grocery store, but you can also get it through most pinball retailers. There are a number of products available for cleaning the playfield that should not be used. Millwax and Wildcat 125 come to mind. Avoid these products. Millwax and Wildcat aren’t even really waxes. They are cleaners with extremly small amounts of wax and lots of solvents to keep the cleaner/wax in an easy-to-apply liquid form. Also Millwax and Wildcat contains high levels of petroleum distillates. Williams recommends not using these products on their games. Please see this service bulletin dated October 1989.

A Diamondplated Funhouse playfield.



If your playfield is Diamondplated, using a wax after cleaning is optional. All Williams playfields were Diamondplated starting with Terminator2. Prior to that, the playfield will say "protected by Diamondplate" in one of the outlanes if it is indeed Diamondplated. Diamondplate is basically a polyurathane top coating originally used to protect hardwood floors.

A good HARD wax such as **Treewax** or **Meguires Carnauba Wax** works great, even on Diamondplated playfields. Ball speed will improve, and playfield wear will decrease. Both of these waxes are just that; wax! They have little or no detergents or cleaners in them. Notice how difficult they are to remove and polish after they haze (as applied per the instructions)? This is good! It means your pinball will have a hard time getting them off too. I like to quickly re-wax my playfield every 100 games with these waxes.

Also a scratched ball can slow and damage the playfield. Replace the ball if it's not shiney like a mirror. They are only about $1.25 each. Throw the old balls away.

4e. Finishing Up: Playfield Rubber

Clean WHITE playfield rubber will keep your game in tip-top shape. Many suppliers sell rubber ring kits; just specify the name of your game, and they'll send you the exact rings for it. Don't forget to get flipper rubber and a new shooter tip, if not included in the rubber kit.

I would recommend not using black rubber on your games. It looks bad, is much harder, and hence has different (less!) bounce. Black rubber is now pretty much standard equipment on most Williams games after about 1995. For an operator, black rubber gives a distinct advantage: it doesn't show dirt! This creates an illusion. For the hobbiest, I would recommend using white rubber instead. It gives a brighter look to your game. And on newer games that don't have much rubber, white rubber can give more ball bounce.

Some games were designed, and looked better, with black rubber. Scared Stiff is one such games. Later new games (like Circus Voiltaire, 1997) were going to be designated for white rubber by the designer, but got black rubber installed at the factory.

Clean rubber has amazing bounce properties. Dirty rubber has seriously reduced bounce. The more bounce, the more fun your game will be. If you want to try and clean your old (only slightly dirty) rubber, you can use WAX. Meguires Carnauba Wax, TreWax or even Novus#2 plastic cleaner works great on lightly soiled rubber. Just remove the rubber and wax it with a CLEAN rag, and wipe off the excess. Wax will keep your rubber supple and UV protected. You don't even have to remove the rubber if it's not too dirty. For dirtier rubber, try alcohol, Westley's Bleche White tire cleaner, or Goof-off (but be careful with Goof-off, as it damages plastic). Use a clean rag and wipe the rubber down. If flipper rubbers are wearing out quickly, reverse it (turn it inside out), and re-use it.

End of WPC Repair document Part Three.

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* Go to WPC Repair document Part One at http://marvin3m.com/~cfh/wpc/index1.htm
* Go to WPC Repair document Part Two at http://marvin3m.com/~cfh/wpc/index2.htm
* Go to the Pin Fix-It Index at http://marvin3m.com/fix.htm
* Go to Marvin's Marvelous Mechanical Museum at http://marvin3m.com