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| [*Support this Pinball Repair Website & PHoF. Please purchase the pinrepair.com/top*](http://www.pinrepair.com/top)  **Repairing Williams/Bally WPC Pinball Games from 1990 to 1999, Part Three.** by [*cfh@provide.net*](mailto:cfh@provide.net?subject=from%20the%20WPC%20Repair%20Document), 11/05/10. *Copyright 1998-2010 all rights reserved.*  **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://pinrepair.com/fix.htm](http://www.pinrepair.com/fix.htm) if you have Internet access. **This document is part three of three** (part one is [here](http://www.pinrepair.com/wpc/index1.htm), and part two is [here](http://www.pinrepair.com/wpc/index2.htm)).  **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://pinrepair.com/begin](http://www.pinrepair.com/begin/index.htm), 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](http://www.pinrepair.com/parts.htm).  **Table of Contents**  **1.** [**Getting Started:**](http://www.pinrepair.com/wpc/index1.htm#top)   * 1. [Experience, what is WPC?, Schematics](http://www.pinrepair.com/wpc/index1.htm#intro1)   2. [Necessary Tools](http://www.pinrepair.com/wpc/index1.htm#tools)   3. [Parts to have On-Hand](http://www.pinrepair.com/wpc/index1.htm#parts)   4. [Different WPC Generations](http://www.pinrepair.com/wpc/index1.htm#gen)   5. [Game List](http://www.pinrepair.com/wpc/index1.htm#list)   6. [Lubrication Notes](http://www.pinrepair.com/wpc/index1.htm#lub)   7. [The Circuit Boards (Board Differences)](http://www.pinrepair.com/wpc/index1.htm#intro)   8. [Introduction to Operation](http://www.pinrepair.com/wpc/index1.htm#intro2)   9. [Troubleshooting (quick guide)](http://www.pinrepair.com/wpc/index1.htm#trouble)   **2.** [**Before Turning the Game On:**](http://www.pinrepair.com/wpc/index1.htm#mid)   * 1. [Check the Fuses and Power LEDs](http://www.pinrepair.com/wpc/index1.htm#fuses) - Blown Fuses and What Causes them. How to diagnose the "Check Fuses F114/F115" or "F106/F101" error messages. And, "Why at power-on does my game repeatedly fire a coil".   2. [Burnt GI Connectors (and WPC-95 GI Diodes)](http://www.pinrepair.com/wpc/index1.htm#connect)   3. [Quick and Dirty Transistor Testing](http://www.pinrepair.com/wpc/index1.htm#testran0)   4. [Should I leave my Game Powered On?](http://www.pinrepair.com/wpc/index1.htm#turnon)   **3.** [**When Things Don't Work:**](http://www.pinrepair.com/wpc/index2.htm#top)   * 1. [Removing the Driver board](http://www.pinrepair.com/wpc/index2.htm#remove)   2. [Replacing Components](http://www.pinrepair.com/wpc/index2.htm#replace)   3. [Checking Transistors and Coils (stuck on coils and flashlamps)](http://www.pinrepair.com/wpc/index2.htm#trans)   4. [Game Resets (Bridge Rectifiers, Diodes and Caps)](http://www.pinrepair.com/wpc/index2.htm#reset)   5. [Problems with Flippers](http://www.pinrepair.com/wpc/index2.htm#flip0)   6. [The Lamp Matrix](http://www.pinrepair.com/wpc/index2.htm#lamp)   7. [The Switch Matrix](http://www.pinrepair.com/wpc/index2.htm#switch)   8. [Infrared Optic Switches](http://www.pinrepair.com/wpc/index3.htm#opto)   9. [Electronic Ball Sensors (Eddy Sensors & Magnetic Reed Switches)](http://www.pinrepair.com/wpc/index3.htm#eddy)   10. [Ball Trough Problems (random multi-ball and bad trough LEDs)](http://www.pinrepair.com/wpc/index3.htm#trough)   11. [Dot Matrix/AlphaNumeric Score Displays](http://www.pinrepair.com/wpc/index3.htm#dots)   12. [Power-On LEDs and Sound Beeps](http://www.pinrepair.com/wpc/index3.htm#poweron)   13. ["Factory Settings Restored" error (Battery Problems)](http://www.pinrepair.com/wpc/index3.htm#factory)   14. [Lightning Strikes](http://www.pinrepair.com/wpc/index3.htm#light)   15. [Sound Problems](http://www.pinrepair.com/wpc/index3.htm#sound)   16. [More General Illumination (GI) Problems](http://www.pinrepair.com/wpc/index3.htm#gi)   17. [Test Report & The Diagnostic Dot, Strange Game Behavior](http://www.pinrepair.com/wpc/index3.htm#dot)   18. [Fixing a Dead or Non-Booting CPU board](http://www.pinrepair.com/wpc/index3.htm#cpu)   19. [Game Specific & Miscellaneous Repair Tips](http://www.pinrepair.com/wpc/index3.htm#odd)   **4.** [**Finishing Up:**](http://www.pinrepair.com/wpc/index3.htm#mid)   * 1. [Rebuilding Flippers](http://www.pinrepair.com/wpc/index3.htm#flip)   2. [New Coil Sleeves](http://www.pinrepair.com/wpc/index3.htm#sleeve)   3. [Protecting Slingshot Plastics](http://www.pinrepair.com/wpc/index3.htm#sling)   4. [Cleaning and Waxing the Playfield](http://www.pinrepair.com/wpc/index3.htm#cleanPF)   5. [Playfield Rubber](http://www.pinrepair.com/wpc/index3.htm#rubber) |

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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 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.* ***Right:*** *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.* ***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*](mailto:Phil@pinballheaven.co.uk?subject=from_WPC_repair_guide) *and* [*pbliz.com*](http://www.pbliz.com/id33.htm)*.* | |  |   **Flipper Opto Board Type List.** If a WPC game is not listed below then the game did not use optic switches for the flippers. Note the type1 and type2 interuptors (either plastic or metal) are not interchangable between type1 and type2 flipper optic boards.  Type 1 (interuptor slot runs vertical). Originally used in:   |  | | --- | | * + Addams Family Gold (and some regular Addams Family)   + Creature From the Black Lagoon   + Doctor Who   + Dracula   + Fish Tales   + Twilight Zone   + Whitewater |   Type 2 (interuptor slots runs horizontal). Originally used in:   |  |  | | --- | --- | | * + Attack From Mars   + Cactus Canyon   + Champion Pub   + Cirqus Voltaire   + Congo   + Corvette   + Demolition Man   + Dirty Harry   + Flintstones   + Indiana Jones   + Indianapolis 500   + Jack\*Bot   + Johnny Mnemonic   + Judge Dredd   + Junkyard | * + Medieval Madness   + Monster Bash   + NBA Fastbreak   + No Fear   + No Good Gophers   + Popeye   + Roadshow   + Safecracker   + Scared Stiff   + Shadow   + Star Trek Next Generation   + Tales of the Arabian Nights   + Theatre of Magic   + Who?Dunnit   + World Cup Soccer 1994 |   **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 transmitter LED is mounted in a WHITE plastic case with a small GREEN printed circuit board. The receiver 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 dipped 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](http://www.pinrepair.com/wpc/index2.htm#reset) 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](http://www.pinrepair.com/wpc/index2.htm#reset) 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). (Remember the transmitter opto is usually the one with the gray and black wires going to it.) 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 less-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.  **Testing the Opto Receiver with a DMM.** Put the DMM leads on each of the two legs of the opto receiver to measure its voltage. When an opto receiver is seeing light from its transmitter, it should show 1 volt DC or less. Now block the light going to the receiver, and the voltage across the opto receiver should jump to 12 or 13 volts DC. (Remember the opto receiver is usually the one with the orange and gray wires going to it.) This test can be done anytime, the game does not need to be in a particular test, it can just be in attract mode.  What happens is the LM339 voltage comparitor chip on the opto board read these opto receiver voltage differences, and triggers the switch matrix accordingly. If the above voltage changes are not happening on the opto receiver, it could be a bad opto transmitter. Use a flashlight (NOT an LED flashlight, a "regular" Maglight style) and shine in in the opto receiver. If it works now, the opto transmitter is bad. If this doesn't effect the receiver opto's voltages, the opto receiver is probably bad.  One thing I have noticed is that opto receivers don't just "die", but they progressively die. That is, when an opto receiver "sees" light it should have 1 volt DC on it's two leads. When there's no light, that voltage goes up to 12 or 13 volts DC. Again this is interpretted by the LM339 chips and sent to the switch matrix as a zero or a one (open or closed switch.) But what I have been seeing is when there's light on an older opto receiver, it shows 2 or 4 or even 6 volts DC (instead of 1 volt or less). This confuses the LM339 voltage comparitor chips, which trigger the switch matrix. And this can cause huge problems.  For example I was recently working on a Getaway where a supercharger magnet's TIP36 driving transistor kept burning and locking on (this happened three times in about three months.) The reason was because the magnet's receiving opto was not registering zero voltage when the opto receiver was seeing light (it was reading like 6 volts.) In turn this meant the LM339 was "confused", and would pulse the associated magnet on and off quickly, eventually frying the driving TIP36 transistor. Replacing the opto receiver fixed this problem, as when light shined on the opto receiver, it showed less than 1 volt DC.  With this in mind, should you pro-actively measure all the opto receiver voltages in a game, making sure there's low voltage when the receiver sees light, and 12 or 13 volts when the receiver's light is blocked? Well it's not a bad idea, and it may save some problems down the road. This really only a worry on optos that directly control coils. So optos that just score or give the game some other information are not as critical on one that is used for a magnet or an upkicker.  **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, or a TV remote control (which is basically an infrared flashlight). 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 properly but the switch does not work, often the opto transmitter has burned out.  Another way to test the opto receiver is using a DMM. (We talked about that a few paragraphs above.) First block the opto transmitter with a piece of black electrical tape or some other object. The game can be in attract mode or in switch test, it does not matter. Now 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 to 13 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). Note as discussed above opto receivers do wear out, and instead of showing zero volts, may show 2 or 4 volts. If they get above 2 volts, than it's time to replace 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. This card is available from Radio Shack #276-1099 or MCM Electronics #72-6771, about $7.* | |  |   **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 properly. 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.  **Opto Board (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 opto board. Usually before messing with the opto board I make darn sure that the optos themselves are not the problem.  I typically do this (for non U-shaped optos) by taking a new opto (receiver or transmitter), and holding its legs to the back of the opto board. For the transmitter I can check it with a digital camera or an opto sensor card. For a receiver I can test it with a penlight (or the other tests given above). Unfortunately if the opto board has a problem, these tests may not work...  Most of the newer WPC games have a seperate board mounted under the playfield called an "opto board". These have some LM339 voltage comparitor chips and diodes and resistors. If this board fails it can really confuse the game. Also games Indiana Jones to Demo Man usually have an opto board under the playfield AND the trough board is essentially a second opto board. Both these board have LM339 chips, which can be problematic. (After Demo Man starting with WCS94, the trough opto boards no longer have LM339 chips, as these were all moved to the under-playfield mounted opto board. So the trough opto board becomes less of an issue.)  There are many different 'flavors' of these opto boards, so it's hard to give an exact test for the opto board. But there are some general things that should be looked at:   * + - Make sure the CPU board is not the problem. I always put the game in switch test T1, remove all the connectors from the bottom of the CPU board, and cross each switch column/row (this test is described in the switch matrix section). This rules out the CPU board as the problem. I always start there.     - After eliminating the CPU board as a problem (and reinstalling the CPU board connectors), I remove all the connectors from the opto board and make sure the switch matrix test T1 operates cleanly with no errors (other than the missing optic switches). If problem free, then the optic board(s) is starting to look like the problem.     - Don't forget Indiana Jones to Demo Man games essentially have two problematic opto boards: the under PF mounted board and the trough opto board. Games after this WCS94 and later trough boards do not have any LM339 chips on their trough opto boards, so these trough boards don't implode like the Indiana Jones to Demo man trough boards. Also the trough opto boards on this series of games daisy chain 12 volts to all the other opto boards under the playfield! So if you have a bad .100" connector on the trough opto transmitter board, it can interrupt 12 volts to the other under playfield opto boards. This is particularily a problem on Star Trek Next Gen.     - Opto board LED - there's a red LED showing the opto board has power. It should be on.     - Opto board has many IDC connectors. It is not uncommon for these connectors to get a wire broken/pulled, causing an opto (or set of optos) to not work. To test this (game off), pull one female connector just slightly off its male header. Then use a DMM and check for continuity from one male header pin to where the wire goes. Repeat for all pins. No continuity, and you have an IDC connector problem (very common).     - Check the back of the opto board and make sure all the male header pins do not have cracks in the solder where they attach to the circuit board.     - Using a DMM set to diode function, make sure all the 1N4004 diodes on the opto board test correctly. They should read .4 to .6 in one direction, null in the other.     - Check all the resistors with a DMM.     - Check the traces from the header pins to the resistor/diodes. It is not uncommon for a trace to be broken or burned on an opto board. Actually this is a very common problem.   If everything checks out, that only really leaves one thing left: the LM339 chips on the opto board. I generally 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](http://www.mouser.com) 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](http://www.mouser.com) sells the Fairchild QSD124 photo transistor. [Digikey](http://www.digikey.com) 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.  **How Can I tell a Transmitter from a Receiver?** In case you have optos laying around and you don't know if they are transmitters or receivers, a simple diode test with a DMM across the leads will reveal which LED type it is. A transmitter will check about 1.5 across the leads one way, open (no reading) the other way. A receiver will check open (no reading) either direction unless you shine a flashlight on it, then it will check open one way and shorted (0) when the leads are reversed.  **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.** The Williams part number for 5-leg optics is 5490-14575-00 (or QTE734, QT724, QT850, or QT902 has been seen), and is called "IC Opto Integ Schmitt 10mA". Replacement five legged optos are available from [Mouser #512-H22LOI](http://www.mouser.com/search/refine.aspx?Ntt=H22LOI), which is a Fairchild Semiconductor part #H22Loi.  **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](http://www.mouser.com), part number 512-QVE11233, $0.90) and Digikey ([www.digikey.com](http://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](mailto:dragster_73@hotmail.com?subject=U_optos_from_WPC_fixit_doc), Prestige Industries (800-456-7277 [www.pinball4u.com](http://www.pinball4u.com)) or Competitive Products (800-562-7283 [www.competitiveproducts.com](http://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). Slot optos use a dot for the collector, and a "S" for the sensor, "E" for the emitter, and unmarked is the cathode.  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 [www.ClassicCoinOps.com/wmsoptos.htm](http://www.ClassicCoinOps.com/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 (STNG), Road Show (RS), Theatre of Magic (ToM) uses these eddy sensors. These electronic switches are used in playfield areas where a regular mechanical switch is not practical or visually pleasing. Twilight Zone also uses an eddy sensor in the ball trough, but it's a different design than the STNG/ToM/RS eddy.   |  | | --- | | *An under the playfield eddy sensor control board as used on Roadshow, STNG, 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.* | |  |   **Adjusting Eddy Sensor Boards.** 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 the STNG/ToM/RS 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. Also from the bottom of the playfield, the eddy board LED should go ON as a ball passes in front of the eddy board's senssor (this can be seen anytime, the game does not need to be in switch test.)  **Different R1/C1 Eddy Sensor Values (Fine Tuning).** Because the ball sensors are different on some games, the value for R1 on the Eddy sensor boards can be different. For example, on Star Trek Next Generation and (two of the eddys on) Theatre of Magic), R1 is 4.7k ohms (these games uses the small ball sensor). But on Roadshow and the ToM trunk, which uses a much larger ball sensor, R1 is 2k ohms. So if you switch an Eddy board between these games, the Eddy R1 resistor may need to be changed to the correct value.  The purpose of the R1 resistor is to make the adjustment pot "centered" for the particular ball sensor. For example, if you use a 2k ohm R1 eddy board in STNG, the adjustment pot will be turned almost all the way up (with very little adjustment range). It still works most of the time, just the adjustment range is not centered.  With this in mind, I once had a Roadshow where I could not get the eddy board's LED to turn off, no matter where the adjustment pot was moved. Normally Roadshow uses 2k ohm R1 resistors for all three eddy boards - but in this case I had to replace the R1 resistor with a jumper wire (0 ohms). This put the adjustment pot about dead center, and the eddy boards worked great (with the 2k ohm R1 resistor, the eddy boards would not adjust, and hence would not work.) Another trick is to change the C1 cap to 3300pF, which widens the field of the eddy sensor a bit.   |  | | --- | | ***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 (Auto Adjust) Eddy Sensors.** Games made in 1996-1998 (like Sacred Stiff, Cirqus Voltaire, Monster Bash) 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. You can buy replacements for these boards at [PinBits](http://pinbits.com/index.php?main_page=product_info&cPath=13_4&products_id=175). The new auto-adjust boards are plug compatible with the older manual adjust eddy boards (generally speaking), but some resistor values may need to be changed (again R1).  **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](http://www.actionpinball.com/tech/tz_prox.htm#info)). 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 temporarily remedy the problem, but the issue will return. The .100" molex connector pins need to be replaced inside the plastic connector housing. Or the wires can be soldered directly to the .100 male pins. This obviously is not ideal, but it does solve the problem, as the pins in the connector cable lose their grip over time. Also this small board often needs to have its male .100" molex header pins resoldered. The solder joints on the board's header pins can crack. 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 from Marco.  **Modifying your Twilight Zone Eddy Sensor.** Ray Johnson (<http://www.actionpinball.com/tech/tz_prox.htm#info>) 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](http://www.aros.net/~rayj/action/tech/tz_prox3.jpg) 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](http://www.aros.net/~rayj/action/tech/tz_prox5.jpg) 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](http://www.aros.net/~rayj/action/tech/tz_prox6.jpg) 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](http://www.aros.net/~rayj/action/tech/tz_prox7.jpg) 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):   * 1. Turn the potentiometer until the LED just turns on.   2. 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 SafeCracker and NBA Fastbreak, Williams started using a different ball sensor switch instead of Eddy 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 Safecracker and NBA Fastbreak. This style of switch is contained in a black epoxy package, about 2" long, and 1/2" wide. Like an Eddy sensor, it can sense when a pinball is near the switch. Games which used this reed switch include NBA Fastbreak, Safecracker No Good Goofers, Cirqus Voltaire, Cactus Canyon and Star Wars Episode I. I believe these are the only games that used the reed 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 1/2" 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.  Also another tip concerning Indiana Jones: Check the front right switch on the bottom side of the mini playfield. Balls hit it underneath and mash the wires/diode/switch lugs together creating a short. Since this mini-PF switch is in the same row as the ball trough jam opto in the switch matrix. This can cause the game to continually kick out balls because the machine thinks the ball jam opto has a ball in front of it, and kicks out another.   |  | | --- | | *The front right mini-playfield switch on Indy Jones. This switch's leads often get crushed by flying pinballs, shorting them together. This can cause all kinds of switch matrix problems including continual multi-ball and switch matrix confusion (multiple  switch closures by a single switch closure).* | |  |   **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.  **Check the Shooter Lane switch.** Though usually not the problem with random multiball (a closed shooter lane switch does not get the ball to the shooter lane), it's a good idea on most WPC games to make sure this switch is in good condition and working. Use a ball to test the switch (in switch test T.1).  **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 1/4" to 7/16" outside, Williams part# 23-6626, $1.02 each.   + (6) Trough board mounting screws (same #6 size/thread as the originals, just 3/4" 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 1/4" 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 3/4" #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 1/4" (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](http://www.digikey.com), 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 [www.ClassicCoinOps.com/wmsoptos.htm](http://www.ClassicCoinOps.com/wmsoptos.htm), for a really nice price. 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 or TV remote control 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).   |  | | --- | | *Here a ball trough transmitter opto board is being tested outside of the game using an external 12 volt DC power supply. There are seven  infrared LEDs here, but the one with the red arrow is not lighting. Check for a bad blue power resistor, broken traces, or even a bad opto itself. Note the digital camera this picture was taken with shows the infrared light quite well. Pic by Tx.* | |  |   **Testing the Ball Trough Transmitter Board outside of the Game.** The ball trough transmitter board needs +12 volts DC to operate, and nothing more. Because of this, the ball trough transmitter board can be tested outside of the game using an external 12 volt DC power supply. Also needed is some way to "see" the infrared light coming from the transmitter LEDs. A digital camera with a viewing screen works well, or a Radio Shack/MCM Electronics infrared card.    **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://pinrepair.com/sys11/index3.htm](http://www.pinrepair.com/sys11/index3.htm#display) 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 and "Outgassing".** 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 won'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.  When a DMD starts to get blurry or displays gaps, the rumor is the power requirements for the display increases. It turns out this rumor is actually incorrect, at least as far as the High Voltage (-120 and +65 volts) is concerned. The HV (high voltage) power used by a display is directly proportional to the number of dots lit on the display. If a display is entirely outgassed and not lighting (even though the CPU is asking the display to lit), it will consume no more HV (high voltage) than a working display that is not lit. Kirb did some test of various displays and metered the results, proving this.  But what about the 5 volt consumption? Unfortunately we did not do enough testing of the 5 volts to draw any conclusions. But based on reports of outgassed displays causing game resets (stressing the 5 volt supply), it is reasonable to think that an outgassed DMD does consume more 5 volt power. Another interesting fact is that certain DMD makes consume more 5 volt power than others. The biggest 5 volt power hog is Dale/Visay, consuming nearly twice what other DMD displays use.  Regardless, I still encourage people to buy a new display if theirs is outgassed. The 5 volt power stress, particularly on games like Twilight Zone, can cause potential game reset problems.  **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 money 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. I have seen problems where a DMD requiring 12 volts won't operate in a game, but one that does not require 12 volts will work.  **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, RAM errors).** 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](http://pinrepair.com/connect) 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). To avoid this, I usually use remove the ribbon cable about 1/8 of a inch, and then push it back in place. This way I don't fully remove the cable, but it gets "off and on" on header pins enough for a "reseat". Hence no issues with putting the cable on wrong (because the cable was never really 100% "off" its male 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.  Is there still strange behavior on the display? Maybe happens just sometimes, but not all the time? Do a diagnostic RAM test on the display. Enter the WPC diagnostics through the coin door switch, and go to Tests "Display" (often test T.11). This will do a RAM test. If any "Page Errors" or "Data Errors" are seen, the RAM chip on the Dot Matrix Control board will need to be replaced. This diagnostic test should come up with absolutely no errors. Alternatively the whole Dot Matrix Controller board can be replaced (these are available for less than $100 brand new.)  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 (or -103, -115). 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**](http://www.pinrepair.com/wpc/wpchvs.gif) 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 -103 and -115), 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); Williams lowered this voltage to -115.   + Pin 2: -113 volts (-98 to -118 volts); Williams lowered this voltage to -103.   + 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, -125 volts (or -103, -115), 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 (or -115, -103) 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).  **Lowering the -125 and -113 voltages to -115 and -103 volts.** At some point Williams lowered the -125 and -113 voltages to -115 and -103. This was done to increase the life of the score display. Just keep this in mind when measuring these voltages. The important part is these two voltage must be 12 volts apart.  **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 (or -115 and -103) 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). Also check resistor R8 (4.7k ohms 5 watts), if this is bad the two negative voltages will be the same. 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 (or -115) 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 R6 or R26 on WPC95 (47K ohms) and it was open. Also checked resistor R4 or R30 on WPC95 (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**](http://www.pinrepair.com/wpc/dmdhv.htm)). Note all these parts are also available in kit form from [Great Plains Electronics](http://www.pinrepair.com/parts.htm) 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 (or -115) 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 (or -115) volt section.   + D6 (D3 on WPC-95, 1N4742 or NTE142, 12 volts): Part of the -113 (or -103) 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 1/2 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 1/2 watt resistors at R4, R5 WPC-S and prior (R30, R31 on WPC-95).   + 47k ohms 1/2 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](http://www.pinrepair.com/parts.htm) 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](http://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, bounce, or Horizontal Roll on the Dot Matrix Display.** The "wavy hum-bar", graphic "bounce, 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 or a display "bounce", 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. As the game warms up the wave, roll or bounce may change (get better or worse).  **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)   **CPU Board EPROM Size Jumpers (W1/W2).** On pre WPC-S CPU board A-12742, there are two jumpers that relate to the size of the U6 EPROM. In most cases, these jumpers will not need to be changed. This is mentioned here though if a CPU board is not booting, it could be because of the ROM jumpers. Only on very early WPC games using smaller 1meg EPROMs (Funhouse, Harley Davidson, Bride of Pinbot) this can be a problem. For example, if a Funhouse game is running the original first version of software (using a 1meg 27010 EPROM), and then is upgraded to the latest vesion (using a 2meg 27020 EPROM), the jumpers will need to be changed. Or if an original Funhouse CPU board is used in a later game using a 4meg 27040 EPROM, the jumpers will also need to be changed.  Both of these jumpers are located to the right of the U6 game ROM chip, when looking at the board as mounted in the backbox (see below). A jumper is basically a wire that connects two points on the board. The CPU board jumper labels are located in between two points, with dotted lines outlining the two points to jumper. The jumper may be just a simple bare wire, or a wire with white ceramic insulator around the middle of it, or may look like a (zero ohm) resistor. A connection between either set of two points is considered "In". A set of two points that doesn't have a connection between them is considered "Out". A soldering iron is required to change these jumpers. Here is the jumper chart:   |  |  |  | | --- | --- | --- | | **Pre WPC-S CPU Board EPROM Jumpers** | | | | **EPROM Size** | **Jumper W1** | **Jumper W2** | | 1meg (27010) | OUT | IN | | 2meg (27020) | IN | OUT | | 4meb (27040) | IN | OUT |   **Other WPC-89 CPU Board Jumpers.** Some WPC-89 CPU boards were originally fitted with a 2064 RAM and jumper W4 installed, and no resistor at R93. The older 2064 RAM at U8 is not readily available today. For the most part a 6264 RAM is the generic RAM replacement for WPC-89 CPU boards at U8. When running a 6264 RAM chip, be sure jumpers W1, W4, W7 and resistor R93 are installed.  **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](http://www.pinrepair.com/wpc/index2.htm#switch) 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](http://www.pinrepair.com/wpc/index2.htm#switch) 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.   **G10 Security Chip.** To prevent distributors from selling games outside their sales district in Europe, Williams implemented a security PIC chip into the CPU board on WPC-S and WPC95 boards. The chip is implemented into the switch matrix, so it's part the architecture of the CPU board. There is a particular PIC chip for each game, and they are NOT exchangable between games, and they are available for sale from Williams. So you can't take a PIC chip from say Attack from Mars and run it in Medieval Madness. You have to have the correct PIC chip for your exact game.  This was a major hassle for quite some time until a couple of different guys reverse engineered the PIC chip. So it is available for sale from Dave at [astillentertainment@rogers.com](mailto:astillentertainment@rogers.com?subject=from_WPCrepair_document) for a reasonable cost.  The game can report a G10 error for other reasons though too. For example if the game's serial number at boot-up comes up as "000 00000 000", often the data communications handling chip at U24 (74HC574) is bad.  If the G10 Pic chip is really bad, there was a "hack" written by someone that modifies the game EPROM code to run with \*any\* PIC chip. This would allow someone to run say a Cirqus Voltaire PIC chip in a Corvette. This small DOS program modified the game ROM code to ignore the Pic chip's serial number and game type.  **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 properly. 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 next test for voltage on the WPC CPU board's RAM chip. The last pin of the RAM should show at least 4 volts DC. Test this with the game off and the black DMM lead on ground, red DMM lead on U8 pin 28. If battery power is not getting to the RAM, then either the battery holder is bad or the blocking diodes are bad. The blocking diode D2 (1n914 or 1n4148) can be tested with a DMM set to diode test (game off). Black DMM lead on the banded side should show .4 to .6 volts.  **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.  **Remote Battery Holder.** Another excellent solution to potential battery corrosion problems is to install a remote battery holder. This way if the batteries do fail and leak, the damage is limited to a $1 battery holder. The cost of replacing an entire CPU board because batteries have leaked and corroded the board is too big of a risk for me personally. Though it doesn't happen a lot, if you have ever had to fix battery corrosion, it's a lesson you will not soon forget. Because of this I have installed remote battery holders in all my WPC games. They cost less than an original style WPC battery holder, and it's good insurance.  I personally use a four "AA" battery holder, using the fourth battery cell area for a back-up blocking diode and as the screw area (to do this I put a 1N4004 or 1N5817 diode with the band towards the red wire, where the fourth battery would be located). The four AA battery packs seem to be easier and cheaper to find, but of course only use three batteries! Install three "AA" batteries, and then solder the red positive wire of the remote holder to the CPU board's main positive battery holder trace, and the black lead of the remote holder to the CPU board's opposite main negative battery holder trace (see pictures below for installation in WPC-89, WPC-S, and WPC-95). On WPC-89 and WPC-95, the main positive battery terminal is at the upper right of the original battery holder, and the main negative terminal is at the lower left. On WPC-S the main positive battery terminal is at the lower right, and the main negative at the upper left.  Some people ask why I put the "blocking diode" in my 4 "AA" battery holder? Well it is not required, but I put the blocking diode in as a backup diode (which prevents the CPU board from trying to charge the AA batteries when the game is on). The other advantage to this is the added blocking diode slightly decreases the voltage from the batteries. This is like an advance alarm clock for me, where the game will tell me when the batteries are getting low (opposed to them totally dying and leaking, and then I find out I need to replace them!) Using a common 1N4004 diode will give the most voltage drop (about .4 volt). This decreases the battery voltage just enough that the game will give me a "factory settings restored" error just before the batteries are totally dead - which is exactly what I want!   |  | | --- | | *Using an inexpensive four AA battery holder, a IN4004 or 1N5817 blocking diode, & three AA batteries as a remote battery holder for the CPU board. On WPC  games the diode is not required, and a wire can be used instead. A 1N5817 diode is used instead of a 1N914 or 1N4001 because of the forward voltage drop is less with the 1N5817 diode. But I actually prefer a 1N4004 as an "auto alarm" when the batteries are getting low.* |  |  | | --- | | *Remote battery holder installed in WPC-89 game.* |  |  | | --- | | *Remote battery holder installed in WPC-S game.* |  |  | | --- | | *Remote battery holder installed in WPC-95 game.* |   **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 (1n4148, all WPC revisions); this is a small glass diode, right next to diode D1 (1n5817). To find 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. 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 1/2 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 D2 is bad. Diode D2 is a 1N4148 or 1N914 diode. The D2 can be replaced with a 1n4001 in a pinch (the 1n4148 or 1n914 is a 'faster' diode, but in this situation a 1n4001 will work fine.) Note that diode D1 is a 1n5817, which has a low .2 volt forward voltage drop. In a pinch a 1n4001 can be substituted here too (with a .4 volt forward voltage drop, not quite as much power gets to the ASIC/RAM when the game is turned on). But using a 1n5817 gives the game better power management to the RAM/ASIC when the game is turned on.  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.  **Missing/Wrong Sounds (A-12738)** This is a common problem on the pre-DCS sound board A-12738. What happens is the CPU calls the sound board for a particular sound. This is done using a encoded sound byte call. This data goes over the ribbon cable from the CPU board to the sound board, where the encoded data is decoded, and the sound board plays the appropriate sound. The problem is, if a single bit of this encoded sound call gets corrupted or lost, the wrong sound call number is interpretted by the sound board. Hence the wrong sound (or no sound) is played.  This problem can usually be seen in the Sound diagnostics, where most of the sound calls are played. Make sure the sound routine played matches the sound description on the score display.  To fix missing or wrong sound calls, usually either or both of the 74LS374 chips at U29,U30 are bad. These chips sit right next to the ribbon cable connector on the A-12738 sound 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! Sound volumes change up and down during game play? Other weird sound behavior? Again just do a "reseat" of the ribbon cables and see if anything changes. Note to do a "reseat", do NOT pull the ribbon cables completely off their connector. Just pull it back 1/8", and push it back on. This way you don't bend any pins or get the ribbon cable on incorrectly.   + Check the EPROM chips for bent pins and incorrect insertion! This is very common if someone just upgraded a sound chip. 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 and Loud Whistle.** 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 (WPC DCS and 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. Aldo check for cracked solder joints on these large filter caps (solder jumper wires, as done to the bridge rectifiers explained earlier).  Another problem I saw on a WPC DCS sound board was a really high pitch whistle as soon as the game was powered on (in this case Jackbot). The volume control did not the whitle volume, and the game play sound could be heard behind the whistle. The whistle was so loud and obnoxious it was difficult to have the game powered on for more than a few seconds.  First thing done was to isolate the CPU from the amplifier section. This was done by removing the ribbon cable from the sound board, and by removing the sound EPROM. This way the sound board could not execute any code, and the CPU was basically detached from the amplifier. The whistle contined, indicating the problem was not in the processing of the sound, but in the sound amplification.  Looking at the schematics showed that the only things really not involved in computer processing of sound is the pair of TL084 Op-Amp chips and the TDA2030A ampifiers. In this case it was a bad TL084 causing the problem.  **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.  **Intermittent Sound Cuts and Shrieks.** After playing a WPC game for a while (5 minutes or longer), the game sound starts to cut out or in some cases it will emit an extremely loud tone that can get louder and louder until the speaker (or your eardrum) blows. If you turn off the game and re-start, the problem will appear again very shortly. Sometimes you can play a while and it never happens. Often the heat sink attachment to the TDA amps can be very poor and cause the amp(s) to overheat. You can feel the amp(s) get red hot. Solution is to simply un-bolt the sinks, re-grease them and re-attach, making sure to use a locking washer or kep nut to stop it from coming loose.  **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](http://www.decoratorsupply.com/pinball/speakers.htm) 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, you can try this on DCS sound games: Turn the game off and remove ALL the sound ROMs from the sound board except for the "low number" sound ROM (for example, U2 or S2.) Turn the game on, and instead of the one power-on "bong", you should hear three "bongs". Turn the game off, and replace the next sound ROM (U3 or S3 depending on the WPC generation). Turn the game back on, and four "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.  **Blown Sound Board Fuse.** User states, "On my T2 machine the sound board A-12738-(50013 in this case) kept blowing fuse F501 on power up. I traced this down to a shorted diode D2. I suspect that any of the diodes D1-D4 would cause these fuses to blow on any of the A-12738 sound boards."  **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  R21 27k 15k  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.  John Wart added some info to the A-12738 Sound board resistors. The schematics indicates R22/R25 should be 150k, and R23/R24 should be 120k. However, I never found a sound board with those values installed. I went through piles of boards from various games. And after looking at manuals and parts lists I'm convinced that those values weren't used in those locations! My research indicates that the following combination was used from Funhouse through Party Zone (FH, HD, BOP, Slugfest, GI, T2, Hurricane, Party Zone):  R22/R25 = 120k  R23/R24 = 150k  And the rest of the games (Hot Shots basketball through TAFG) used the following:  R22/R25 = 120k  R23/R24 = 56k  So, it would appear that R22/R25 never changed, and R23/R24 are the values that WMS changed, depending on the game.  In addition there are some capacitors on the pre-DCS sound board that effect sound balance. If the resistors check out OK for your game, try replacing caps C15, C36, and C38, as these are filter caps and will help balance the sound of certain frequencies. If one of these caps is bad, certain frequencies won't sounds as loud or clear as other frequencies, giving a seemingly unbalanced sound (c.hibler.)    **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)](http://www.pinrepair.com/wpc/index1.htm#connect) for that information.  **The Single Biggest Problem with WPC General Illumination.** Beside burnt connectors (see [Burnt GI Connectors](http://www.pinrepair.com/wpc/index1.htm#connect) 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.  **Triacs.** The Triacs allow the game software to control the intensity of the GI circuits. This involves driver board chip U1 (74LS374), which turns on the Triacs, the Triacs themselves, and the PNP drivers transistors. The Triacs take 6.5 volts AC from J115, and when the Triac gate is high (in the GI Ilumination test mode with all GI strings at "8" brightness level), the 74LS374 has a low on the corresponding pins.  With the game turned on using a voltmeter on AC, connect the ground side of the meter to the ground. Now touch the red lead to the "tab" screw on each of the Triac heatsinks. There should be around 1 volt AC (or a little less) on each of the tabs if all the G.I. lights are on. This is an indicator the Triac is working correctly. Also feel each heat sink and see if it's warm or not. If one feels somewhat cold, it's probably not "turned on" and is the culprit you will want to investigate further (but in my experience the traiac itself is never the problem - it's usually the input connector J115, the fuse, or a broken board trace).  A Triac is like a switch. It has one input pin, one output pin, and a "gate" that causes the input to be routed to the output when the gate goes high. When the lights are to be turned on, U1 (74LS374) supplies a low that turns on the PNP Triac driver transistor, which causes the PNP Collector to approach 5 volts. This 5 volts is connected to the Triac "gate", which turns on the Triac. When this gate goes high, the J115 AC voltage (the low side of the secondary AC) of the Triac is routed to the other pin of the Triac, which completes the circuit for the light bulbs to turn on. The game can turn the Triacs on and off many many times per second, giving them a "duty cycle". This is how a G.I. string can be dimmed (more "off" time between "on" cycles, and the G.I. string looks dimmer).   |  | | --- | | *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.  **Shorts in the General Illumination (Blown GI Fuses).** If the fuse is blown and blows again when replaced, there is a short somewhere. First isolate the problem to the Power Driver board or the affected GI string. Disconnect the GI connector for the string fed by the blown fuse (J119,J120,J121 or J105,J106 on WPC95), replace the fuse and power on the machine. Using a DMM, check for about 6.3 volts AC (WPC-S and prior):   * + GI String 1: J120 pin 1 and J120 pin 7 (fuse F110).   + GI String 2: J120 pin 2 and J120 pin 8 (fuse F109).   + GI String 3: J120 pin 3 and J120 pin 9 (fuse F108).   + GI String 4: J120 pin 5 and J120 pin 10 (fuse F107).   + GI String 5: J120 pin 6 and J120 pin 11 (fuse F106).   + GI String 5: J119 pin 1 and J119 pin 3 (fuse F106).   If voltage is seen then the driver board is OK, and there is a short on the playfield or backbox wiring. Common causes of shorted strings include solder drips on or in a lamp sockets, metal objects in a lamp socket, chaffed wires touching ground, socket terminals touching another wire or metal, a shorted socket, or even a shorted bulb (this is why I like to replace GI bulbs one at a time with the power on).  With the game off, use a DMM and test either of the two GI power wires for continuity to ground (it doesn't matter which wire is tested as there is continuity between the two GI wires if even one light bulb is installed in the GI string). If the wire is grounded, examine the wire run for chaffing or a socket terminal touching metal ground. If neither wire is grounded, remove all the bulbs from the string and check continuity to ground across each of the two GI wires, and check for continity between the two GI wires. If there is continuity between the two GI feed wires, there is either still a bulb installed in the string or there is a short (probably in one of the lamp sockets). If no continuity, then reconnect the connector and begin testing bulbs. A shorted bulb will not blow the fuse or cause all the GI bulbs to dim noticeably. If the string was indicating a short with all bulbs removed, then inspect each socket carefully -- inside and out. Another trick is to incrementally disconnect one of the feed wires along the chain to isolate sections and localize the short to a smaller area. This process will be tedious but sometimes it's the only means to find the problem.  Another neat trick is to take a blown fuses and solder wires from the ends of the blown fuse to a light socket. Then put a good #44 or #47 bulb in the socket. Be sure to solder the wires so that they will still allow the fuse to go back in the fuse holder. Now plug the blown fuse/socket into the fuse holder which controls the GI string in question. If all the GI bulbs are removed from this GI string, the lamp attached to the blown fuse should be off. If the lamp is on (and all the GI bulbs are removed), you have a short in the GI string somewhere. You can leave the game on and wiggle wires and exam the blown fuse/socket to see if the lamp goes off. This will help locate the short without going through lots of fuses in the process.    **3q. When things don't work: Test Report & The Diagnostic Dot, Strange Game Behavior.**  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 attact 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.   |  | | --- | | *A Getaway with vertical bars on the DMD every  8 bits of data - a ribbon cable wire is broken.* | |  |   **Strange Game Behavior.** WPC games uses ribbon cables extensively for moving address and data between the CPU, driver board, fliptronics, sound and dot matrix display controller boards. The ribbon cables are rather fragile devices and can be damaged easily. They also have gold plating which will require a re-seating now and then (unlike the .100" and .156" Molex connectors which should not be reseated).  Sometimes strange game behaviors can be seen that results from ribbon cable problems. For example, a series of veritcal lines in the dot matrix display. Or a coil or lights that do not work. Or at power-on more than one beep is heard from the sound board (signaling a sound board problem). Often just a simple re-seating of the ribbon cables will fix this.  WARNING: be careful when reseating ribbon cables. They can be easily damaged where they connect to the plastic connectors. The ribbon cable damaged the most if the cable with the four connectors that attaches to the CPU, fliptronics, sound and dot matrix display controller. An open wire in the ribbon cable can cause a lost data bit, resulting in wacky sound and dot matrix display data. This can cause vertical lines in the dot matrix display or game sounds are wrong. Often the problem is the ribbon cable that links the sound and display controller together fail because they get old and brittle in the hot backbox.    **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](http://www.pinrepair.com/wpc/index1.htm#intro) 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 (or black) 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, and this chip is very expensive and hard to get. Don't plug the ASIC chip in wrong either, as this will likely damage the chip (and of course the CPU board will never work). There is an angled notch in the chip that matches the angled notch in the socket. When you press the chip into place it should "snap" firmly. But be careful everything is lined up correctly or you may damage the chip and/or the socket.   |  | | --- | | *Using the correct tool to remove the ASIC chip from the CPU borad. pic by Tx.* | |  |   **Boot-Up LED Sequence.** As power is applied to the CPU board on the bench, a working CPU board will behave the same as in the game: All three LEDs briefly flash on, then the top LED turns off (while the bottom LED stays lit this whole time), and then the middle LED starting pulsing rapidly on and off. If that's what happens, then the board is "booting" and running. Booting and running means the top LED is off, the middle is pulsing quickly, and the bottom LED is on. Anything else and there's a problem.  **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 properly. 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 15th 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. Another trick is to link the two opto outputs together at the flipper opto board connector. Just add some solder at the connector between opto board connector pins 1 and 2, joining together the pins for S1 and S2. This will "fix" a failing opto as the good opto takes care of both opto switch outputs.  ***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/green 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 and/or Q7) 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/green 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 check D7 and D15 on the aux board with a DMM's diode test (and while you're at it test TIP102 trans Q7 and Q15). With the coil power fuse removed, you can also test U1 pin 13 and pin 8 with a logic probe or DMM - if high (and the diverter is not supposed to be energized), then that U1 is bad (74LS576). That is, the U1 pins that connect to the driver transistors are normally high (when an output U1 pin goes low, the driver transistor completes the ground path for its associated coil). So a logic probe or DMM is useful to look at the U1 output pins (anything low and the associated coil will be energized). Another test of this is to use an aligator jumper wire connected to ground, and touch each U1 output pin - the associated coil should energize. The Aux8 U1 chip is driven through the ribbon cable from the CPU board's U7 chip. A damaged cpu-to-aux8 ribbon cable can also cause some wacky behavior.  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.  Finally, these 8-driver Auxiliary boards are not necessarily exchangable between game titles. The boards are the same, but there are a set of four jumpers on the Aux board, and the jumpers vary depending on the game title. So if a Aux8 board is transplanted from say Demo Man to STNG, make sure the Aux8 board jumpers are changed accordingly.   |  | | --- | | *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](mailto:Phil@pinballheaven.co.uk?subject=from_WPC_repair_guide). 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. Even if the optos are cleaned and appear to be working normally in the switch test, an opto transmitter or receiver may be staerting to go bad and cause intermittent problems. This is especially common in STNG and diagnosing it can be a headache. On a STNG (user reported), every time the game initialized with six balls in the trougn, it would load the first ball into the right gun, then immediately kick it out, but then then next 3 balls loaded normally one into each popper. Then during game play, an extra ball would randomly be kicked out from the upper left popper. All of the optos tested normally in the T.1 switch test and the connectors and were all well seated. Finally diagnosed this by leaving the game on for a while in the switch test mode T.1 and eventually the bad opto showed up in the test (in this case it was #33, the right gun #2 opto), showing as the last switch activated. During game play, the opto occasionally must have blanked out and the game sensed an extra ball at that gun and kicked a ball out. Replacing the bad opto pair solved the problem.  ***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](mailto:Phil@pinballheaven.co.uk?subject=from_WPC_repair_guide).  ***Problem:* Corvette LT-5 Engine is not functioning. The "Linear hall Effect Sensor" is malfunctioning.**  Answer: Much of this info came from Cliffy and Martin. The manual does not mention anything about the Hall Effector board part number A-19158. This small board sits inside the engine next to another board (with the pot for adjusting the engine left-middle-right). On early games there was no provision to manually adjust the engine positioning when the engine initializes at power up. If there's a problem the game compensates by disabling the LT5. In later production Wms added a small PC board placed beneath the ramp with a potentiometer, that could be adjusted to allow the engine to be centered. The slave board was also slightly changed to accommodate the remote adjustment board. A hole was drilled in the ramp allowing access with a jewelers screwdriver to the adjustment pot. This is the easiest way to tell if a game is early or late production (if the ramp has no access hole then there's usually no adjustment pot, unless the ramp was replaced.)  The engine centers itself by first tilting over to one side all the way till it stops. The opto is tripped by a metal blade and tells the system the engine is tilted left. Then the Hall effect sensor reads the horseshoe magnet's left pole at that position and remembers the position as a digital number, for example, 128. Then the coils are pulsed to bring the assembly back to the right where it again trips the opto, and the sensor remembers the right side number which may be say 255. Now the system divides that number in half and that's the center. The engine finally pulsed back to halfway and the motor should be level and centered.  The CPU controlls the small slave board in the backbox, which then controls another board under the playfield. This in turn controls another board inside the engine (the one with the adjustable pot), and that one is connected to the Linear Hall Sensor board. That's a lot of connectors to go bad, so always check those. Also, there is an opto board inside the engine too, simiar to path of adventure design, a metal blade breaking the opto beam at left and right (as discussed above). This is hard to diagnose since there's so many parts linked to each other. Note there are 4 coils (ae-25-1000) controlling the movement, two for each side.  The linear hall sensor board is in essence a magnet mounted on the top of a C shaped horseshoe (the whole horseshoe is a magnet) and the hall board with only a sensor (looks like a small transistor with 3 legs on it) is magnetic sensitive.  Martin explains: the Hall effect sensor is not read by the WPC processor. It is part of a servo loop, much like you would find on a model aircraft. Its normal position should be centered, and that is what the adjustment pot does. The WPC system sends a digital signal to the slave board, which converts it into a servo position voltage. That voltage causes the engine to move to its new position. By doing it this way, Williams could get the engine to move very quickly (hence two solenoids per side, to keep the power up and spread the heat) and move (somewhat) like the real thing. The adjustment board added later is a bit of a hack, duplicating circuitry on the slave board, but it makes it easy to adjust without having to mess about on both sides of the playfield.  If the right and left engine optos are dirty or broken, the test will fail. Make sure they are working in either switch test or ZR1/LT5 test. Move the engine by hand to test both sides. Remember, the computer needs to know where left and right are, and the optos are paramount for this.  After checking the optos, go to the LT5 test. Both right and left numbers should be displayed. These numbers show up on the display when the sensor is working correctly. Without both sets of numbers the computer doesn't know how to find center. If a number is missing, the engine will have to be disassembled. Sometimes the magnet poles get loose. There is a bracket under the magnet with the poles clamped to the assembly frame. There are two nut inserts for the screws that hold that magnet clamp. Make sure these are snug. In early production Corvettes with no center adjustment pot, you can try gently try bending the poles just a bit, to increase the movement range. This gives the sensor a good side range to work within, and can help center the motor.  If the LT5 Engine is completely dead and does not move, check the four coils. Sometimes these burn or the TIP102 transistor that controls the coil is open or shorted. If the engine doesn't know which is left, right or middle, check the two optos inside the engine (as described above).  If the engine wouldn't shake left or right and the optos were okay, there may not be any errors at game startup or in LT5 test. The engine may go left and stay left. Then try to go to the middle or right, but just staying left. When manually trying to move to the engine to the right, the coils may "resist", and when released would slam to LT5 to the left and stay there. This problem could be the two ULN2803A chips on the backbox auxiliary board. These are often the problem as the chips can internally short. Also the schematics for the backbox auxiliary board is wrong. There are two ULN2803 chips on the board, one 74LS374 chip, and one 74LS174 chip (the manual states two 74LS374 chips).  ***Problem:* How do I prevent playfield wear around upkickers?**  Answer: Cliffy (www.passionforpinball.com) and 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](mailto:Phil@pinballheaven.co.uk?subject=from_WPC_repair_guide).  ***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 or the POA's "U" optics are dirty/failing, this can cause the PoA to "stutter" as it moves in either or both directions. This happens because as the 4 legged "U" optos fail, they are interpretted by the CPU board as a quickly "fluttering" switch (many many times a second, going quickly on-off-on-off), instead of a solid "on" or "off". The game uses two "U" optos on the POA switch board too (mounted against the back inside panel of the playfield), and these too could be failing, giving the same studdering POA. Use a Q-tip and some Windex, and clean the flipper board optics and the POA switch board optos.  To figure out if the problem is the flipper opto board(s) or the POA optics, 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, as the flipper button optic switches are not used in the POA diagnostic test. That is, in the diagnostic mode, the coin door buttons are used instead of the flipper optos to move the PoA. This is why a flipper opto problem does not show any problems in diagnostic mode, but only in game 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.  ***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 properly. 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](http://www.happcontrols.com) 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).  Go to the solenoid test and make sure the hand magnet works. Often because of the movement of the hand, the wires going to the hand magnet fatique and break inside the wire's insulation (so a wire break is not obvious). If the driver board fuse is good (I believe it's F103), there should be 70 volts at both leads of the magnet wire. If there's only voltage at one magnet lead, there's a break in the wiring. I found these magnet leads often need to be replaced with new stranded wire.  The same also applies to the ball-in-hand switch. Again movement of the hand fatiques the wires going to this switch. Test the switch in T.1 diagnostic test. It's just a leaf style switch with two wires going to the ball-in-hand switch blades. 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).  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](http://www.pinrepair.com/wpc/index3.htm#opto) 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. Also check the header pins for cracked solder joints on these two opto boards.  Also check the glove direction motor board mounted under the playfield. Often there are cracked solder joints around the header pins on this board. Resolder the header pins to fix this.  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](http://www.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**](http://www.pinrepair.com/wpc/neonspec.gif). But basically these are the specs:   * + Model VT 1510-12   + Input Voltage: 12 VDC (+/-10%)   + Output Voltage: 1500V   + Input Current: 650 mA (Max)   + Driving Distance: Neon 1-5 ft in length, based on a 12mm tube   + Output Current: 10 mA   + Operating Temp: 0° to 104°F   + Length: 1.5 in.   + Width: 1.0 in.   + Height: 2.25 in.   + Mounting: 1.15 in.   + Weight: 3.0 oz.   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](http://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](http://www.sunsupply.com/transformers/winind.html).  After getting the new transformer test it using some aligator test leads, and hook it up to the game's 12 volts and to the neon tube. Make sure everything is safe and insulated and turn the game on (remember 1500 volts output!) After you're sure the new transformer is working properly, reassembly the ramp. You can use small screws instead of rivets if you don't have the proper rivets and rivet tools.  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 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: Though replacement strobe lights can be gotten at local discount stores and Pep Boys, they are really not the correct replacement for your AFM game. The proper strobe rate for AFM is 6.25 lights per second. The inexpensive replacements will only allow maybe 2 or 3 lights per second. What is needed is a "low-pressure" horseshoe type of strobe light. The low-pressure is key, because it allows the strobe capacitor enough time to charge and discharge, lighting the strobe 6.25 times per second. The proper strobe light is available from <http://www.pinbits.com> (go to the AFM parts section). 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:* On Medieval Madness the ball hits the trolls, but doesn't always register a hit.**  Answer: There are two main reasons why the troll would only register hits intermittently, or not at all. The first is that a one of the soldered wire connections on the switch attached to the troll head has broken. The second is that the contact rivets have become loose on the switch blades on the troll head switch, allowing only an intermittent connection at best. To fix the problem of loose contact rivets remove the switch assembly from the troll head assembly and then peen (flatten with a small hammer) the switch stack rivets so this removes any play in the switch stack, allowing for good contact with the switch blade.  ***Problem:* Monster Bash sometimes slam tilts when the ball goes down the right outlane.**  Answer: Check the switch behind Frank, airballs will short the switch causing the problem (only when the frank targets are raised).  ***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). Linked game play works like this: the first player presses Start, and their display shows "Waiting for 2nd player." You can play a stand-alone game by pressing both flipper buttons, or press Start on the second machine for a linked game. Linked games are broken down into four quarters, with a halftime. The quarter length can be modified in the menus. The gameplay is constant, there is not limit to the number of balls (because it's a timed game). If a player drains the ball, a new ball is served with no penalty (other than the time this takes). The head-to-head players select their teams and play begins. The players work together to complete modes. For example, player 1 might complete the two left "in the paint" shots, and player 2 may complete the two right "in the paint" shots, which allows that mode's multiball to start. If both players complete all modes and reach the final (wizard) mode, they compete for the championship ring(s). If there is a tie the game goes into an extra overtime period.  ***Problem:* On Fishtales, the reel doesn't always release the ball. It's like the reel doesn't align with the metal opening on the catipult.**  Answer: First try a new belt. The original is made of polyurethane, and often gets "memory" if the game has sat a long time. The memorized oblong shape won't allow the reel to spin freely. New belts are available, but I often find it's better to use a pinball rubber. It has more "grip" and generally seems to work at least as well as the original, if not better. second i've had to modify many fishtales using a dremel to widen the opening in the metal catapult where the ball is released from the reel. this allows for less accuracy in reel alignment. The problem here is the motor, as it does not "stop on a dime". With time it "over coasts" past where the game thinks it should stop. Then the ball can't be released because it coasts past the alignment in the catpult metal. So I widen the catapult metal ball release hole, and this solves the problem.  ***Problem:* What motor is used in my WPC game?**  Answer: See the web page [**gearbox.htm**](http://www.pinrepair.com/wpc/gearbox.htm) for details.  ***Problem:* The auto adjust Eddy Sensor board in my Monster Bash or Circus Voltaire has the LED continually flashing (instead of coming on when a ball approaches the PF sensor, and off with no ball near the sensor).**  Answer: The auto adjust Eddy LED will flash if 1) You don't have the coil plugged into the auto eddy sensor board, 2) You have the wrong (resistance) coil plugged into the eddy board, 3) You have the wrong value capacitors for C1 and C2 installed in the eddy board. How can the caps be the wrong value? If the eddy board was transplanted from Circus Voltaire to Monster Bash (or vice versa), this can happen. Check yor game manual for the correct cap values.  ***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 1/2 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.  [Rottendog Amusements](http://mywebpages.comcast.net/rottendog/products.htm) and [Pin Lizard](http://www.pbliz.com/id31.htm) sells replacement TZ clock boards with bright LEDs already installed. 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) 1/2 watt resistor, and install them in locations D1-D4. Bend the LED leads as shown in this photo [**here**](http://www.pinrepair.com/wpc/tzclock3.jpg). This spreads light more evenly over the clock face (click [**here**](http://www.pinrepair.com/wpc/tzclock4.jpg) and [**here**](http://www.pinrepair.com/wpc/tzclock5.jpg)). 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 1/4" 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).  ***Problem:* How do I prevent my Addams Family magnets from burning my playfield?**  Answer: The three under-the-playfield mounted magnets are energized by a small board with three TIP36 transistors (mounted under the playfield). If one of these TIP36 transistors shorts on, the magnet will stay on, and could get hot enough to burn the playfield.  To prevent this, it's a good idea to install three 2amp slow-blow fuses (one for each magnet) under the playfield. This way if a magnet locks on, the fuse for that magnet will blow before the magnet gets hot enough to burn the playfield.   |  | | --- | | *Installing three fuses under the playfield for the Addams Family magnets.* | |  | |

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| **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).  **Get the Correct Flipper Parts When Possible.** When Williams stopped making pinball machines in 1999, the number of companies making flipper parts has dwindled to about ONE. That means that if you order WPC flipper pawls/plungers/coil stops from any of the pinball parts suppliers, you pretty much get the same part (regardless of the exact part number you specified). The reason I mention this is simple - parts are not parts when it comes to WPC flippers. Coil plungers changed length with Pinball 2000 (coil stops are the same), and the one company making these parts changed their WPC flipper specs to Pinball 2000 flipper parts. The problem with this is when these Pinball 2000 spec'ed flipper parts are installed in a WPC game, the flipper travel is reduced. This means the game doesn't play quite the same as it did when it was new; the flipper travel is decreased and the game will be much harder to play.  [Pinball Life](http://www.pinballlife.com/index.php?p=catalog&parent=172&pg=1) (and to a lesser extent [Pinball Resource](http://www.pbresource.com)) have taken this into account and have started to have custom flipper plungers and coil stops manufactured to the correct specs. For this reason I suggest buying your parts from these people. But I understand this is not always possible, and I have shown in this document how to use the 'generic WPC' (Pinball 2000 spec'ed) flipper parts in a WPC game, and to get proper flipper travel.  In the case of Pinball Life, they break flipper rebuild kits into three WPC categories:   * + Williams/Bally Flipper Rebuild Kit - 02/1988 to 08/1991 (#pbl\_0288-0891). This kit is good for WPC games Funhouse, Harley Davidson, Bride of Pin-bot, Gilliagan's Island, Termainator2, Party Zone, Hurrincane (Williams #A-13524-1). Notes these are all non-fliptronic games.   + Williams/Bally Flipper Rebuild Kit - 02/1992 to 04/1993 (#pbl\_0292-0493). This kit is good for WPC games Getaway, Addams Family, Black Rose, Docter Who, Fish Tales, Creature from the Black Lagoon, Whitewater, BS Dracula, Twilight Zone (Williams #A-13524-7). Note these are all Fliptronic games, with long flipper travel.   + Williams/Bally Flipper Rebuild Kit - 08/1993 to 10/1998 (#pbl\_0893-1098). This kit is good for WPC games Indiana Jones to Cactus Canyon (Williams #A-13524-8). Note these are all Fliptronic games, but the flipper travel was slightly decreased in these games compared to Twilight Zone and earlier pins.  |  | | --- | | ***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.* | |  |   **Step1: Remove 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 could 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).  New coil stops are cheap, so I suggest just replacing them. For WPC-DCS and WPC-95 games, use coil stop #A-12390. For pre-WPC-DCS (Addams Gold being the last WPC-DCS game) and WPC games (and system 11 games), use coil stop #A-12111. If the newer #A-12390 coil stop is used on an older WPC game, the flipper bat will have less travel. Two allen head tempered black 10-32 x 3/8" bolts are used to hold the coil stop. If the used coil stop is worn, there can be 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.* | |  |   **Step 2: 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 3/8" wrench (needed for most pawls, though newer style pawls may not need the 3/8" 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.  **Step 3: Check for Worn Coil Bracket.** If the game was played so much that the coil sleeve wore out (thanks in part to a worn plunger link) and the coil stop mushroomed, 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.  **Step 4: 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 properly when fully extended. If in doubt, replace this trivial part.   |  | | --- | | *Shown is "flipper drag" playfield wear (see the wear in the word "Twlight"). This can be caused by worn or broken nylon  flipper bushings. This allows the bottom of the flipper bat to drag on the playfield, causing this wear. Actually in this case the wear is not from flipper bat drag, but is just from excessive play, but you get the point.* | |  |   **Step 5: Replace the Nylon Playfield Bushing.** The nylong playfield 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.* | |  |   **Step 6: Replace or Rebuild 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 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).  Before proceeding, check the hole in the pawl which bolts the plunger/link to the pawl. This hole can enlongate (egg-shape), making the pawl useless. Even if a new plunger/link is installed, the eggshaped hole will create "play" in the pawl assembly. If the pawl holes are enlarged or eggshape, the pawl must be replaced (or just buy a completely new pawl/plunger/link assembly). Also check the bolt that goes through the pawl and link (and link bushing). Often its center section wears again causing play. The only solution to this is a new bolt.   |  | | --- | | ***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 cheap (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.* | |  |   **Step 7: Check or Replace the Pawl Heat Shrink Tubing.** Skip this if a new pawl was installed. One of the flipper pawl's job is to activate the EOS switch at the flipper's 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 1/2" length of new 1/4" 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.* | |  |   **Step 8: Check the Flipper Coil Type.** 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.  **Step 9: Re-install the Flipper Pawl Assembly and Flipper Coil/Coil Sleeve.** 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.  **Step 9b: 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).  **Step 10: Check for Flipper bat up and down movement.** 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. It is designed to provide a bit of up and down movement of the flipper bat inside the nylon playfield bushing so the bat doesn't bind (and the flipper doesn't "stick"). I personally don't use this tool - just make sure there's a bit of up and down movement (as you pull the flipper bat from the top of the playfield) so the bat does not bind.   |  | | --- | | *Using a toothpick as a flipper alignment tool.* | |  |   **Step 11: Aligning the Flipper Bat.** 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. Some people put a toothpick into the roll pin, and move the flipper against it (with the rubber installed or not installed, it varies from game to game). This will give you a general idea of where the bat should be aligned. 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 the playfield.  Unfortunately the toothpick alignment is really not the proper way to align a flipper. Instead take a straight edge and use the lane guides to give the flipper bats a final position adjustment. The ball should roll off the guides and to the flipper bat in a straight line, which should be easy to see with the straight edge.   |  | | --- | | *Both flippers in the "up" position. Notice how they look symmetrical.* | |  |   **Step 12: Check 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.  **Step 13: Check/Adjust Flipper Travel.** From the flipper's rest to full extension should be 2 3/8" of flipper travel, measured at the center tip of the flipper bat. If there is less than this, the game will not play right. This is often due from using the wrong plunger/link or wrong coil stop (if there is too much travel, that is usually caused by worn flipper parts). But fear not, too little flipper travel can be easily adjusted.   |  | | --- | | *Measuring flipper travel from rest to full extension should be 2 3/8 inches.* | |  |   To fix too little flipper travel, use a set of channel-locks and bend the \*rest\* flipper link bracket. Just bend it a bit, then re-check the flipper for 2 3/8" of flipper travel. Note the resting flipper position will need to be adjusted after bending the rest flipper stop. You will have to re-position the flipper pawl on the flipper bat, so repeat above step#11 and step#12.   |  | | --- | | *Bending the rest link stop for added flipper bat travel (2 3/8 inches).* | |  |   **Step 14: Tighten the Flipper Pawl.** Now you are ready to tighten the flipper pawl assembly to the flipper shaft. With the flipper positioned correctly, lift the playfield and tighten down (very tight) the flipper pawl assembly's allen bolt. Use an allen wrench and a 3/8" open wrench (if needed). If the flipper spacing tool is still in place remove it and the toothpick.  **Step 15: 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 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, clean the EOS switch contacts with a rag and some alcohol. Or 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. Adjust the EOS switch to close at near the end of the flipper bat travel  Make sure the EOS switch doesn't hang on the flipper pawl when the flipper is fully extended.  Last, turn the game on and put it into diagnostic test mode. Close the coin door (to turn power on to the flippers). Now press the cabinet flipper buttons and AGAIN check the EOS switch spacing and adjusted as needed.  **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 old style with a less meaty link and a tapered link shape and a shorter plunger, giving the entire plunger/link assembly slightly less length. The newer A-15847 which has a more robust link with a boxier shape, but the overall length of the plunger/link is longer (the newer style A-15847 plunger/link may not allow as much flipper travel if installed on pre-fliptronics games). Because these two plunger/link assemblies have different lengths, they must be used with the correct coil stop. Otherwise the flipper may have less travel than the game intended (making it play strange).   + Nylon Flipper Link only: #03-8050 (or 03-8753 which is the meatier link).   + Coil Stop: for WPC-95 games, use coil stop #A-12390. For WPC-S and WPC games (and system 11 games), use coil stop #A-12111. If the newer coil stop #A-12390 is used on an older WPC game, the flipper bat will have less travel. Two allen head tempered black 10-32 x 3/8" bolts are used to hold the coil stop.   + EOS Switch: non-Fliptronics version #03-7811. Fliptronics version #SW-1A-193.   + 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](http://www.pinrepair.com/parts.htm) 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](http://www.pinrepair.com/wpc/servbull/92wmsTIP0.gif) 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](http://www.pinrepair.com/wpc/servbull/89mylar.gif).   |  | | --- | | *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.*  \* Go to WPC Repair document [Part One](http://www.pinrepair.com/wpc/index1.htm) \* Go to WPC Repair document [Part Two](http://www.pinrepair.com/wpc/index2.htm) \* Go to the [Pin Fix-It Index](http://www.pinrepair.com/) at http://pinrepair.com |