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

by *cfh@provide.net*, 02/01/10.

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 if you have Internet access. **This document is part two of three** (part one is here, and part three is here).

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

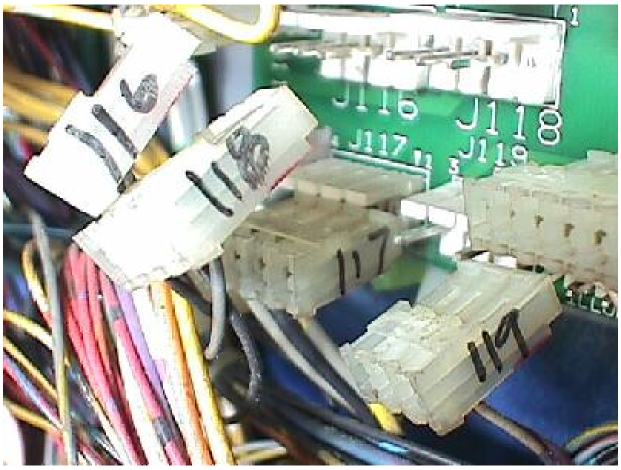
If you aren't up to repairing pinball circuit boards yourself or need pinball parts or just want to buy a restored game, I recommend seeing the suggested parts & repair sources web page.

Table of Contents

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

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

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



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

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

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

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

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

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

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

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

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

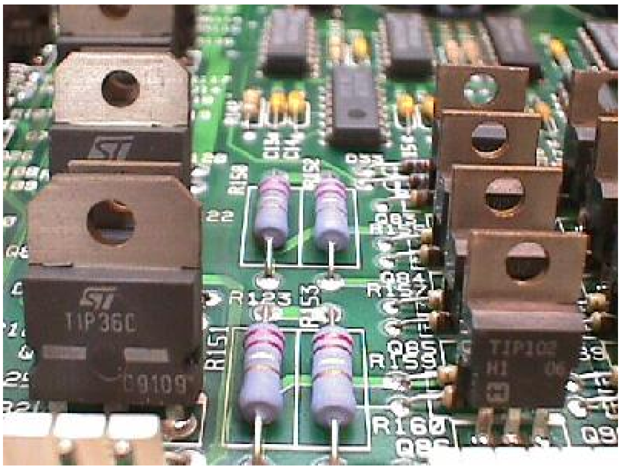
If a coil is "stuck on" when the game is turned on, a shorted driver transistor is often the cause. If a coil does not work (and the fuses are good!), an open driver transistor could be the cause. This section will help diagnose this, and other related faults.

What do the Driver Transistors Do?
Basically, a driver transistors completes each coil's path to ground. There is power

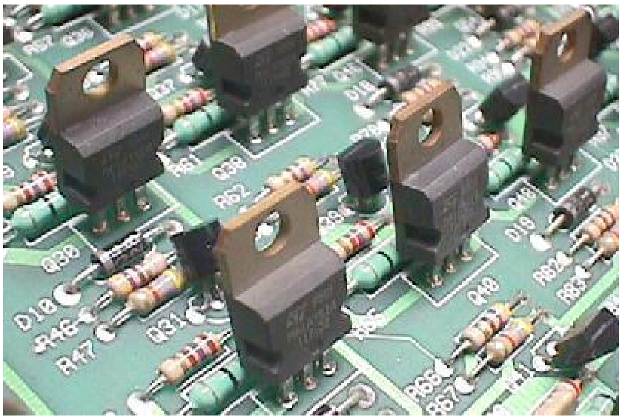
at each coil, all the time. The driving transitor is "turned on" by the game's software, through a TTL (Transistor to Transistor Logic) chip. When the transistor is turned on, this completes the coil's power path to ground, energizing the coil. Driver transistors also work the CPU controlled lamps and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

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

TIP36 and TIP102 transistors on the driver board.



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



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

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

Games with Solenoid Numbers Above 28 (Auxiliary Driver Board).
Even though the WPC driver board only supports solenoids 1 to 28, there can be solenoids numbered up to 44. Most often seen are numbers 29 to 36, which use transistors in the fliptronics section of the board. If the game only has two flippers, the fliptronics section will have two flipper power (TIP36) and two flipper hold (TIP102) transistors that may be used by the game for things other than flippers. Also several games (Indiana Jones, Twilight Zone, Demo Man, Roadshow and Star Trek Next Gen) used an 8-driver auxiliary driver board, which contained eight more TIP102 transistors for even more flash lamps or coils. Note this board also contains circuitry for an extra ninth switch matrix column (used on STNG, Twilight, Indy Jones

only).

This auxiliary driver board could be problematic, especially on Star Trek Next Gen. On Star Trek, this board needs +50 volts for a "tieback diode" voltage for the circuit (because it controls solenoids, and not just flashlamps; all the other games that use this Auxiliary driver board only control flashlamps). The 50 volt tieback power is connected by a thin violet/yellow wire which connects to the playfield's single drop target coil (at the back of the playfield), and goes to the Auxilary Driver Board. If this wire breaks, or if some other power wire in this coil power daisy chain breaks, it can cause the two under-playfield diverter coils to lock on (after they're first activated in game play!) If the problem is not found quickly, the diverter coils and their driving transistors can fail. Transistors on the auxiliary driver board will short out in a couple of activations on Star Trek if the tieback voltage is not present on the board. If the two Star Trek diverter coils lock on after a game is started, check the violet/yellow wire which connects to the playfield's single drop target coil. Additionally, add 1N4004 diodes to the two diverter coils (banded side of the diode to the coil's power lug), and test the TIP102 transistors on the Auxiliary driver board.

If a transistor shorts on the Auxiliary driver board, this will cause the driving coil to lock-on as soon as the game is turned on. Again on STNG this is very common for the under-playfield diverter coils. With the game off, check the diverter coils first - they should have 7 to 9 ohms of resistance (tested in-circuit, any less and replace the coil). Then go to the manual and figure out which Auxiliary driver board transistor drives the coil in question. Don't bother testing the transistor(s) on the Auxiliary driver board. They will *not* test correctly in-circuit. Just replace the TIP102 and it's companion 2N4403. Replace *both* transistors at the same time! Do not skimp here, or you will have to replace both transistors again after the game is turned on! Also test all the resistors related to these two transistors, and the 1N4004 diode (the diode and resistors can be tested in-circuit). Buzz out all traces related to the two transistors also, especially the 50 volt tie-back trace.

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

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

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

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

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

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

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

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

If after replacing the driver transistors the coil/flashlamp is still locked on, then replace the TTL 74LS374 logic chip. The TTL 74LS374 can also go bad (though it is not real common). This can be tested with the diode function of a DMM (red lead on ground, black lead on each leg of the chip) A value of .4 to .6 should be seen for all pins except ground and power.

Also if the new TIP102 transistor is not soldered in correctly, this can cause the TIP102 to short again. This happens becasuse the old TIP is hastly removed, destroying the plated-through holes in the circuit board. After soldering the new transistor, make sure all three transistor legs are connected to their traces. Use the continuity feature of a DMM to test this. Particularly if the center leg does not connect to the 1n4004 diode (trace on the component side of the board), the TIP102 will work for one "fire" and then lock-on during game play and destroy itself.

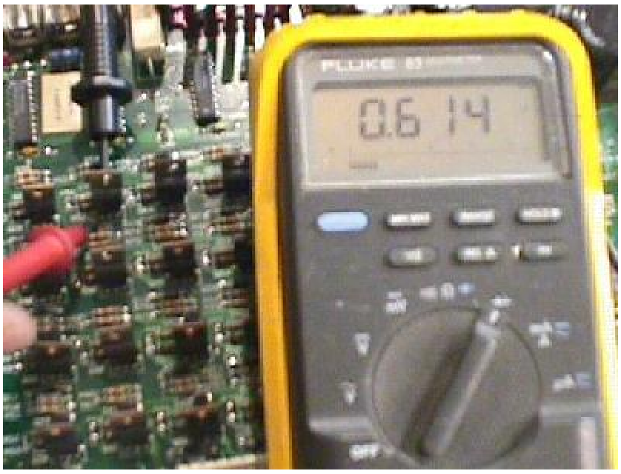
Also remember to test the resistance of a coil after replacing the driver transistors. If a coil gets hot, it can burn the painted enamel insulation off the coil windings. This lowers the overall resistance of the coil because adjacent windings short together. If resistance gets much below 3 ohms, the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

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

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

Do the Transistor Test Procedures work 100%?
In short, no. But they do work about 98% of the time, and are an excellent starting point. But yes, a transistor can test as "good", but still be bad. The DMM test procedures test the transistors with no load. Under load, a transistor could not work.

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



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

If you're testing transistors in the board, with the board installed in the game, leave all the connectors in place and do the tests below. If a transistor tests as "bad", *then* remove the associated connectors from the bottom edge of the driver board, and re-test. If the transistor now tests as "good", chances are excellent the associated coil is shorted. But you knew this already right? (because you did a coil resistance check already.) Another quick note in this regard for flashlamps - if one flasher TIP102 is bad, all the flasher transistors generally test as "bad". Removing the connectors across the bottom of the driver board will resolve this test issue.

Testing Transistors INSTALLED in the WPC driver board.

- **TIP36c**: Put the **red** lead of the DMM on the metal tab of the transistor. Put the black lead of the DMM on each of the two outside legs of the transistor one at a time. A reading of .4 to .6 volts should be seen. Put the black lead on the center transistor leg (collector) and the red lead on the metal tab, and a zero reading should be seen. Put the **black** lead of the DMM on the left/top (base) leg of the transistor. The red lead on the center transistor leg should show .4 to .6 volts. The red lead on the right/bottom leg should be .2 volts. Any other value, and the transistor is bad and will need to be replaced.
- **TIP102**: Put the **black** lead of the DMM on the metal tab of the transistor. Put the red lead of the DMM on each of the two outside legs of the transistor one at a time. A reading of .4 to .6 volts should be seen. Put the red lead on the center transistor leg (collector), and a zero reading should be seen. Any other

value, and the transistor is bad and will need to be replaced.
- **TIP107**: Put the **red** lead of the DMM on the center leg or on the metal tab of the transistor. Put the black lead of the DMM on each of the two outside legs of the transistor one at a time. A reading of .4 to .6 volts should be seen. Put the black lead on the center transistor leg (collector) and the red lead on the metal tab, and a zero reading should be seen. Any other value, and the transistor is bad and will need to be replaced.
- **2N5401, MPSD52, 2N4403** (pre-drivers): Put the **black** lead of the DMM on the center leg of the transistor (note this transistor doesn't have a metal tab). Put the red lead of the DMM on each of the two outside legs of the transistor one at a time. A reading of .4 to .6 volts should be seen. Any other value, and the transistor is bad and will need to be replaced.

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

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

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

Testing Coils and Transistors; a Systematic Approach.

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

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

Testing Transistors/Coils, Driver board installed in a (near) WORKING game, using the Diagnostics Test.
If the game powers on, the WPC diagnostics can be used to test most devices.
- Press the "Begin Test" button inside the coin door.
- Select "MAIN MENU: TESTS".
- Select "TEST MENU: SOLENOID TEST".
- Use the "+" and "-" buttons to move the test from coil to coil. Each coil should fire. (Note the coin door interlock switch must be held in on 1993 and later games. Otherwise the coil 50 volts will be turned off, and the coils won't fire. Also make sure the "REPEAT" portion of the test is used. This can be changed using the "Begin Test" button.)
- Press the "help" button. The game's start button during the coil test wil give more coil information including coil wire colors, Driver board connector and pin numbers; related fuse number; Driver board transistor and pre-driver transistor numbers.

Solenoid Doesn't Work during WPC Diagnostic Tests.
If a solenoid doesn't work from the diagnostic tests, here's what to check. Turn the game off before doing this.
- Check all the fuses on the driver board. A non-working solenoid could be as easy to fix as just replacing a fuse.
- Find the solenoid in question under the playfield. Make sure the wire hasn't fallen off or become cut from the coil (a very common problem).
- If the above is correct, make sure the winding of the coil haven't broken off

from the solder lugs. If one has broken, it can be re-soldered. Make sure the painted enamel insulation is sanded from the wound coil wire before re-soldering, otherwise there will be no connectivity.
- Make sure there is power at the coil. Using a DMM, there should be 20 to 75 volts DC on either lug of a coil. If there is power only on one lug, the coil winding is broken, and the coil should be replaced.
- Check the coil diode (for any other pinball game, this would be the next step). The coil diode for all games (except WPC) are attached right to the coil, with the banded side of the diode connecting to the power side of the coil. On WPC games however, Williams moved this diode to the power driver board for all coils but the flipper coils. This increases reliability as the diode is not subject to the jarring and heat a coil can produce. It also eliminates the need for the operator to know which coil wire goes to the banded side of the diode when replacing a coil! On a WPC game, these coil diodes are mounted on the driver board next to the transistor that drives each particular coil.

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

- Make sure the game is off.
- Put the DMM (digital multi meter) on ohms (buzz tone).
- Put one lead on the ground strap in the backbox.
- Touch the other lead to the metal tab on the TIP102 transistors.
- If zero ohms (buzz) is indicated, the transistor is bad! (shorted on)
- If you're do this test obviously with the board installed in the game, leave all the connectors in place and do the test above. If a transistor tests as "bad", *then* remove the associated connectors from the bottom edge of the driver board, and re-test. If the transistor now tests as "good", chances are excellent the associated coil is shorted. But you knew this already right? (because you did a coil resistance check already.) Another quick note in this regard for flashlamps - if one flasher TIP102 is bad, all the flasher transistors generally test as "bad" using the above test. Removing the connectors across the bottom of the driver board will resolve this test issue.

The Coin Door Interlock switch.
In the middle of Twilight Zone's production in 1993, Williams added a coin door interlock switch. This turned off the power to all the coils when the coil door was opened (for safety reasons). On 1993 and later games with this interlock switch, make sure the coin door is closed when testing coils!

Failed Coin Door Interlock switch.
Yes it does happen. The coin door interlock switch can fail, or does not get pushed in enough when the coin door is closed. This will prevent voltage from getting to the solenoids. If none of the solenoids work, and the fuses are good, check the coin door interlock switch for problems. A sure sign of this is the Driver board solenoid power LED's will NOT be lit if the coin door interlock switch is not closed! The interlock switch opens the coil power coming from the transformer, which is way before the power gets to the Driver board's fuses and power circuits.

Testing for Power at the Coil.
Most pinball games (including WPC) have power at each and every coil at all times. To activate a coil, GROUND is turned on momentarily by the driving transistor to complete the power path. Since only ground (and not power) is turned on and off, the driving transistors have less stress on them. With this in mind, if we artificially attach a coil to ground, it will fire (assuming the game is turned on).

- Turn the game on and leave it in "attract" mode.
- Lift the playfield.
- Put the DMM on DC voltage (100 volts).
- Attach the black lead of the DMM to the metal side rail.
- Touch the red lead of the DMM on either lug of the coil in question.
- A reading of 20 to 80 volts DC should be indicated. Switch the red test lead to the other lug of the coil, and the same voltage should be seen again. On flipper coils, test the two outside lugs of the coil. If no voltage reading is shown, no power is getting to the coil. On a two lug coil, if there is only voltage at one lug, the coil winding is broken. On 1993 and newer WPC games, make sure the coin door is closed!
- If no power is getting to the coil, a wire is probably broken somewhere. Trace the power wire.

No Coil Power, Fuse is Good and No Broken Wires.
I recently had a problem on a Safe Cracker (WPC-95) where none of the low power (20 volt) coils worked. It was very frustrating; the fuse was good, and power was getting to the Driver board, but not out of the driver board and to the coils.

It turned out that the capacitor that filters the DC voltage after the bridge rectifier on the Driver board had a cracked solder pad. This prevented the voltage from getting any further than it's associated bridge rectifier (I should have known; the +20 volt LED on the Driver board was not lit!). To fix this, I soldered jumper wires from the bridge to the capacitor, as outlined in the below Game Resets (Bridge Rectifiers and Diodes) section.

Testing the Coil and the Power Together.
This test will show if the power and the coil are indeed working together:

- Game is on and in "attract" mode, and the playfield lifted. On 1993 and newer

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

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

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

The Above Tests Worked, but the Coil Still doesn't Work.
If all the above tests worked, there is probably a driver board problem. Everything has been tested from the TIP102 back to the coil itself. That only leaves the TIP102 itself, its pre-driver transistor, and the logic chip that controls the transistors. It has to be one (or more!) of these devices that are causing the problem.

Installing a New Transistor.
If it has been determined a coil's driver board transistor is bad, there are a few things to keep in mind. Most TIP102 transistors also have a "pre-driver" transistor (2N5401 for WPC-S and prior, or MPSD52 for WPC-95). Both 2N5401 and MPSD52 transistors are basically the same (use either). They both cross to NTE288.

If a coil's TIP102 transistor is replaced, it's a good idea to also replace its corresponding pre-driver. It will be located near the TIP102 transistor. See the schematics or the internal solenoid test "help" to determine the specific pre-driver transistor(s).

Heavier duty coils use a bigger TIP36c driver transistor. These transistors have TWO pre-drivers: a TIP102 and a 2N5401 (or MPSD52) transistor. Again, if the TIP36c has failed, it's a good idea to replace both corresponding pre-driver transistors.

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

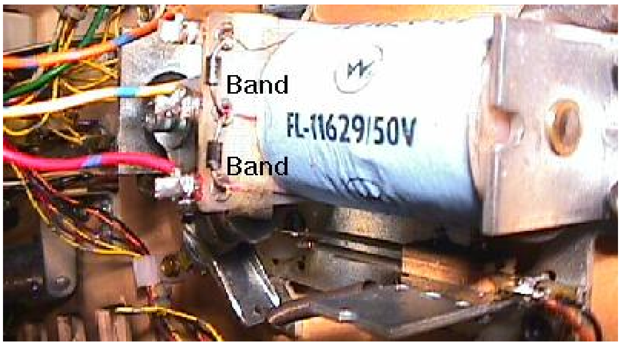
Don't Forget the 74LS374 TTL Chip!
If a coil locked on really hard and for a period of time (and without blowing the coil fuse, over fused?), the controlling 74LS374 chip may have also died. If after replacing the TIP driver transistor(s) and the smaller pre-driver transistor, the coil is still locked on, now is the time to replace the 74LS374 TTL chip. Use the schematics and trace the transistors in question back to the 74LS374 chip. This will be chip U2, U3, U4, or U5 on WPC-S and prior driver boards, or chip U4, U5, U6, or U7 on WPC-95 driver boards.

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

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

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

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



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

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

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

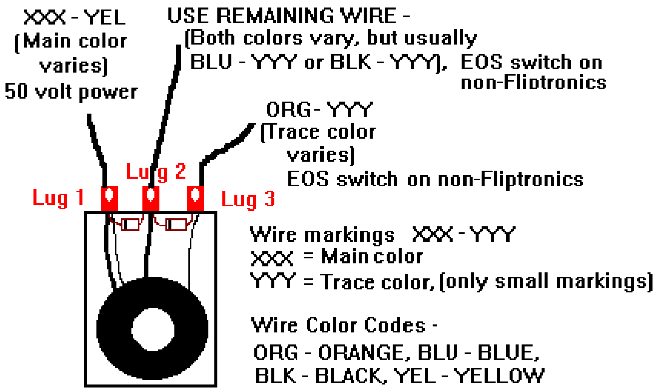
Lug 3 (outside non-banded diode lug, one winding wire):

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

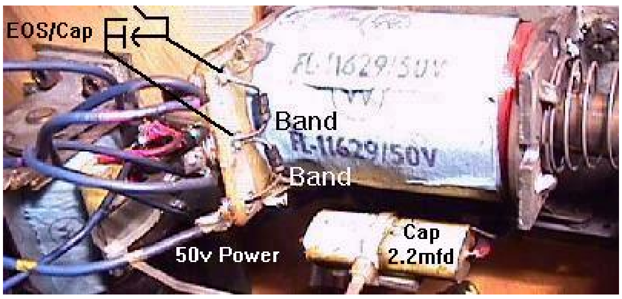
Lug 2 (middle lug):

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

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



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



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

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

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

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

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

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

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

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

- Have the power wires fallen off the coil's solder lugs?
- Is the coil damaged? Has the internal winding broken off the coil's solder lug?
- Is there power at the coil? See Testing for Power at the Coil for more details.
- If there is no power at the coil, check its fuse. Use the internal diagnostics and the "help" button to determine which fuse controls the coil. See Testing Transistors/Coils using the Diagnostics for details.
- Check the other coils that share one of the same wire colors. Are they working too? If not, suspect the fuse that handles these coils.
- Power to coils are often ganged together. If the power wire for this coil has fallen off a previous coil in the link, power may not get to this coil.
- Using the DMM and its continuity test, make sure the coil connects to the correct connector/pins on the driver board. This information can be seen from the Diagnostics solenoid test.
- Check the driving transistor. Usually this transistor will short on when it fails, but not always.
- Reset the driver board and CPU board ribbon cables. I have seen situations where a coil hasn't worked because the gold plated ribbon cable connectors were dirty.

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

What is a Reset?
Game resets are probably the biggest problem with 1990 to 1995 WPC to WPC-S games (and to a much lesser extent, WPC-95 games). The pinball will seemingly shut off, then power back on (like the game was turned off and back on quickly). Typically, this will happen during game play, when the flippers are used. If the +5 volts (which powers all the logic circuits) dips momentarily below 4.7 volts (from heavy voltage draw when the 50 volt flippers are used), the "watchdog" circuit chip on the CPU board resets the CPU, momentarily shutting the game down. The high current draw flippers stresses the 5 volt power components in the system. If these 5 volt power components are starting to fail, the +5 volts dips, and the watchdog circuit resets the game. When the game shuts down, the power components under stress are relieved. Then the voltage returns to +5 volts, and the game powers back up. This reset process can happen anytime, but usually happens during game play. (When things are really bad, sometimes the game won't even power-up, as it gets into a loop of turning itself off and on.)

Why are Resets so Common on WPC and WPC-S games?
I get this question a lot. "Why don't I have this reset problem on my Williams System11 games?" When WPC was designed they decided to use a voltage watchdog device, which was not implemented on earlier board designs. This 3-legged transistor-looking MC34064 device is on the CPU board at U10. (With pin1=output reset voltage, pin2=input supply voltage, pin3=gnd, and could be replaced with a TO-92 case Dallas DS1811-10 with a 4.35 volt reset, but not suggested.) Williams did this to "micro-manage" the voltage to the CPU board. The new parts implemented on WPC (ASIC chip, which replaced the six PIA chips on system11), requires a consistent 5 volt power source. Their fear was without a solid 5 volt power source, sparatic behavior could result, causing game and coil lock ups. Of course the downside to this is, as WPC games get older, reset problems become much more common.

Check the Easy Stuff First.

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

This problem happens mostly in the summer, when household power consumption is at a high, or if the game is plugged into the same circuit as another high power device (air conditioner, refrigerator, etc). WPC pinball games draw a maximum of 8 amps of power. Most home circuits are 15 amps, so two pinballs on one circuit should be the maximum. Also don't have the game plugged into the same circuit as another power sucking device (like a dehumidifier, sump pump, air conditioner, refrigerator, etc.) If the problem is persistent, the game can be re-jumpered for low-line voltage, or the driver board modified to bump up the 5 volt power to 5.1 volts (this is described at the end of this section, and really are 'last resort' things).

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

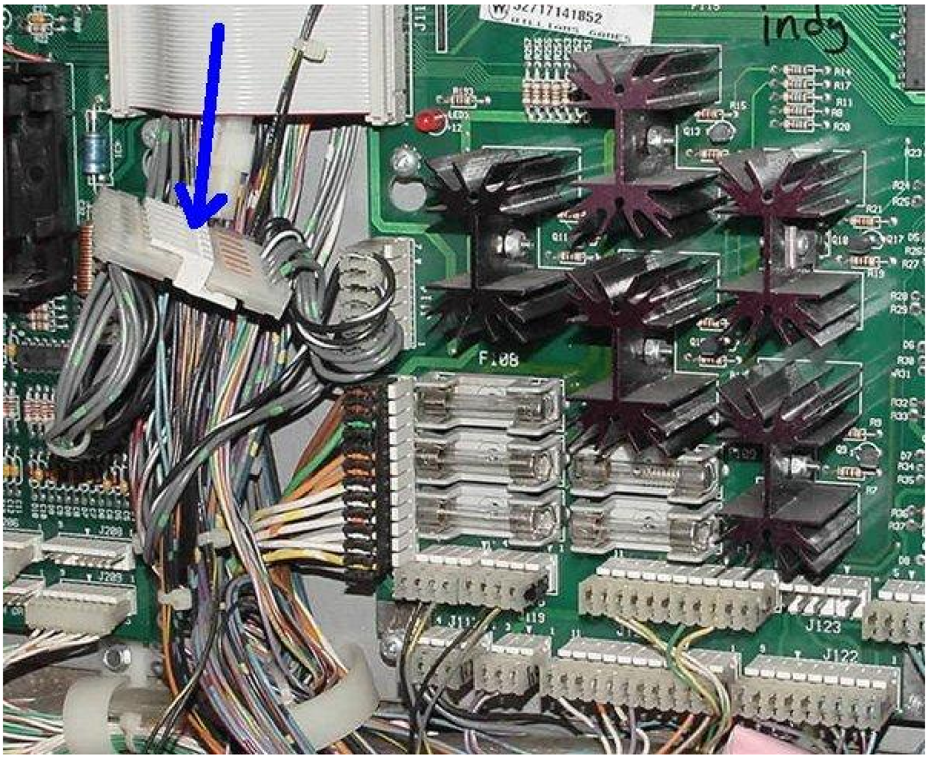
- +5 volts DC: TP2 (TP101 on WPC95). Should be 4.92 to 5.1 volts DC. If this is below 4.92 volts, the game will most certainly reset easily, as this is the voltage the "reset watchdog" examines. Often the problem is bridge rectifier BR2 (diodes D7-D10 on WPC95) and the related filter capacitor C5 (C9 on WPC95). Sometimes it could also be the +5 volt voltage regulator is failing (Q1 LM323K or LM317 on WPC95). Or it's very common for the input connector (J101 or J129 wpc95) or 5 volt to CPU board output connector (J114 or J101 wpc95) on the driver board. **At this point do NOT remove/reseat the connectors!**
  This is very important. Removing or reseating the connectors will make finding the actual problem nearly impossible. So don't touch them yet!
- Check for +5 volts on the CPU board. Yes I know, you checked the +5 on the driver board TP test point. But there are *two* connectors (or sometimes a third/fourth "Z" conector too) that go from the driver board to the CPU board. If these connector(s) are having problems, the +5 volts will be lower on the CPU board than it is on the driver board. The best place to test for +5 on the CPU board is right at the CPU board game EPROM pin 32 (the last pin). If the CPU board's +5 volts is even just a bit lower than the Driver board's Test Point +5 volts, that means the connector(s) between these two boards need to be re-pin'ed with new Trifurcon connector pins. This is very common and just re-pin'ing these two connectors can fix a lot of reset problems (without having to change any driver board parts).
- Z-connector games: this includes Twilight Zone, Indiana Jones, Demo Man, Star Trek Next Generation (STNG) only. The "Z" connector allows +5 volts to be routed to the Auxiliary 8-driver board A-16100, which only the above games use. It's another "link-in-the-connector-chain", and can be problematic. If reseating the Z-connector changes the 5 volt measurement at the CPU board, this connector needs to be either eliminated or re-pinned. The Z connector was used to allow the existing stock Wms wiring harness a tap-in point for +5 volts to the Auxiliary 8-driver board. So eliminating this connector (soldering the wires directly together and insulating with heat-shrink tubing) does not cause any issues, and is probably a good idea.
- Next reseat the right side driver board connectors J101. Power up and re-test the +5 volts on the driver board Test Point. If the voltage has gone up, then the input connector J101 is bad. Repin this connector with new Trifurcon connector pins. If it's the original connector (IDC), you will have to replace the connector housing too.
- Recheck the voltage on the CPU board at the game ROM pin 32. Now reseat driver board connector J114 (J101 on wpc95) at the lower left. Recheck the CPU board +5 volts at game ROM pin 32. If the voltage has gone up, connector J114 needs to be replaced. Repeat this procedure for CPU board connector J210, and then repeat with the "Z" connector (if the game has one). Again if voltage changes after a connector reseat, the connector MUST be repinned with new Trifurcon connector pins. (And wire brush the male

connector pins or replace them too.)

- If the CPU and Driver board +5 volts are very close to each other and are 4.92 volts DC or higher, try this. Remove driver board +5/12 volt connectors J114 (power to CPU board), J116 (cabinet), J117 (backbox), J118 (playfield), and measure the 5 volts at TP2 on the driver board (on WPC95 connectors J101, J139, J138, J140/J141 respectively). If you still below 4.92 volts, BR2/C5/C4/LM323K regulator are the likely culprits. If the +5 volts goes up with these four connectors removed, one of the other boards/devices is dragging the +5 volts down. Replace the connectors one at a time to try and find the culprit.

- +18 volts DC (lamp matrix): TP8 (TP102 on WPC95). This is an unregulated voltage, so it can vary from 16 to 20 volts. If this is low, check bridge BR1 and capacitor C6/C7 (diodes D11-D14 and caps C11/C12 on WPC95).
- +12 volts DC regulated: TP3 (TP100 on WPC95). Should be 11 to 13 volts DC. This voltage comes from the +18 volts lamp matrix (discussed above), and goes through a 12 volt regulator (7812) and some 1N4004 diodes and an LM339 chip. If the +18 volts is correct at TP8 (TP102 on WPC95), but this voltage is low, it is usually the 7812 voltage regulator at Q2 has failed.

The Z-connector on an Indiana Jones. This connector set routes power to the Auxiliary 8-driver board. It can also cause reset problems because it's one more connectors in the +5 volt power chain.



If any of the above voltages are low, resets can occur. But really the voltage that matters the most is the +5 volts. Again it must be 4.92 volts or higher for a game to not reset. Remember just because the above voltages are Ok, does *not* mean the game won't reset. Remember, the above voltages are being tested in attract mode, and not under stress.

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

- Check TP2 (+5 volts DC) on the power board. Try and get the game to reset and see if the +5 volts dips during the reset. There should be no change in the +5 volts, even during a reset.
- Check TP4 on the power driver board, which is the zero cross signal. Again it should look steady with no changes even during a reset.
- On the CPU board check U10 pin 1 (the reset pin on the MC34064). This pin may dip low during reset, forcing a game reset when the flipper buttons are pressed. The U10 is the watchdog circuit, and when it's reset pin 1 goes below 4.7 volts, the MC34064 forces the CPU to reset and reboot. You can follow the voltage trail back from the MC34064 and try and figure out the exact component causing the problem. Remember if during the process a reset connector fixes the problem, this connector must be replaced (both header pins and terminal pins) to fully fix the problem.

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

Check the Connectors (J101/J129, J102/J128, J114/J101, CPU J210, and Transformer).
First connector to check is input power J101 (J129 on WPC995) on the power driver board. This provide AC power from the transformer to the power driver board, which ultimately ends up as +5 volts DC, 18 volts DC unregulated, and +12 volts DC regulated (via bridge

rectifier BR1 & BR2, some filter caps, and some voltage regulator circuits). If this connector is damaged in any way, this can cause the voltages discussed above to be low, and resets to occur. Try a simple reset. If a "dark" game now boots or resets go away, replace the connector pins with Trifurcon style .156" pins, and replace the driver board pins with new .156" header pins.

Also check the connector that takes power out of the driver board and to the CPU board. This is connector J114 on WPC/WPC-S, or connector J101 on WPC-95.

Check the input power connector on the CPU board at J210. Also if there is a "Z" connector inline to connector J210, check that too.

Now try re-seating the connectors on the large transformer in the bottom of the cabinet. If there is any resistance in the transformer plugs, that can reduce the voltages going to the rest of the game. This only takes a moment to do, so it's not a bad thing to try.

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

If the reset problem changes after reseating a connector, you have a TEMPORARY fix! Yes I did say temporary, as chances are excellent the reset problem will come back. The connector pins really need to be replaced to permanently fix this problem The only way to fix this properly is to replace (at minimum) the connector housing terminal pins (with Trifurcon pins), and the circuit board header pins (but at dead minimum replace the terminal pins with Trifurcons). It is very common for these connectors to have bad pins or cracked solder joints, especially on Twilight Zone. Due to vibration and age, these connectors can just plain fail, and have some internal resistance. Again use Trifurcon style pins, which grab the male connector pin on three sides (thus giving better contact and vibration resistance.)

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

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

Aside from Connectors, Biggest Game Reset Culprits: Bridge Rectifier (or WPC-95 Diodes), Filter Cap, Cracked Solder Pads, and bad J101/J129 connector.

Bridge rectifiers or diodes (and their corresponding filter capacitor) convert AC voltage to smooth DC voltage. This is very important, as all the circuit boards run on DC voltage. If a game plays fine, but randomly resets, often the bridge rectifier (or diodes) and its filter capacitor and J101/J129 connector are over stressed and need replacement.

On WPC-S and prior games, a bad BR2 bridge rectifier, its associated C5/C4 filter capacitor, and marginal terminal pins on connector J101 are probably the most commonly failed components relating to game resets. As a general rule, if the wall voltage is good (above 116 volts) these three things are what I replace first when there is a reset problem. I replace ALL FOUR ITEMS (BR2 bridge, C5 cap, C4 cap, J101 terminal pins) at the same time. Again this is my first line of attack when repairing reset problems, and 95% of the time it works. On WPC-95 resets are less common but the diodes D7,D8,D9,D10 and filter cap C9/C1 and connector J129 are what I replace.

Also very common on WPC-S and prior games are cracked solder pads on the bridge rectifier and/or associated filter capacitor, which also causes game resets. Always run jumper wires between the BR2 bridge rectifier and the C5 filter cap when I replace them (solder side of board, top right BR2 "+" lead to top C5 "+" lead, and diagonal BR2 "-" lead to bottom C5 "-" lead). And I always check the continuity between the new BR2 bridge rectifier's AC leads and the zero cross diodes (component side lower left AC BR2 board pad to the right side of D3 and the upper right BR2 AC lead to the right side of D38).

Warning: when replacing a bridge rectifier it is VERY easy to damage the circuit board. The bridge has four rather thick legs soldered through the board. If they are incorrectly heated as they are removed, it can pull the "plated-thru holes" out of the circuit board. This will compromise the connectivity between the bridge and the board, causing further reset problems. To avoid this, CUT the old bridge out first, leaving the legs as long as possible. Now heat each leg individually, and pull them out of the board with needlenose pliers, one at a time. Removing a bridge this way should minimize damage to the board.

Testing Bridges.

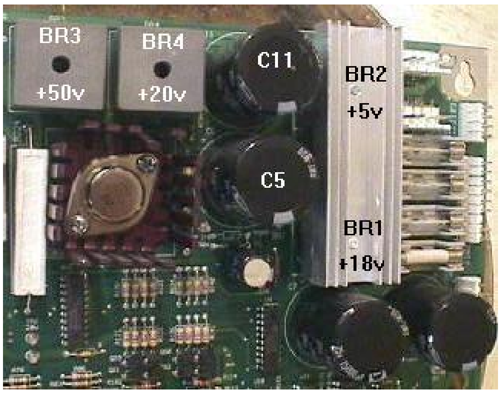
Also keep in mind that just because a bridge rectifier tests as "good", does *not* mean it is good. After all, a bridge can not be easily tested when the game is in multi-ball, with the flippers flipping, and the pop bumpers popping. A bad bridge rectifier (or diodes on WPC-95), or cracked solder pads around a bridge can also give game boot-up error messages saying fuse F114/F115 (or F106/F101 on WPC-95) have failed, when the fuses are actually good. See the Check the Fuses section (and below) for a list of fuses and what bridges they connect to.

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

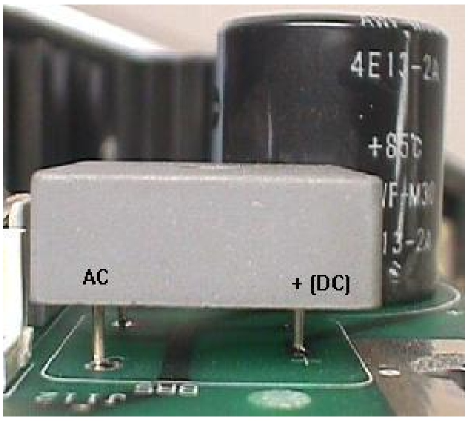
Failed bridges/diodes can often short or "go open". BOTH of these problems are quite common! A shorted bridge/diode will immediately blow a fuse when powered on. An open bridge/diode will cause lower or no voltage to get past the bridge. If the fuses are good, but power driver board LEDs are not lit,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

When replacing bridge rectifier BR2, be careful not to tear or break the circuit board traces at the bridge. Board damage here is very common because BR2 is often replaced, and often in a hurry. Since a bridge rectifier is a large part, vibration can crack the circuit board traces. In particular notice the small trace on the component side of the driver board under one of the bottom left AC leads of BR2. This goes to the non-banded side of diode D3 (under connector J109) for the zero cross circuit. If this trace is torn or cracked, resets will likely still occur (more details/pics on that below). After soldering in a new BR2, be sure check continuity on the board component side from the lower left AC BR2 board pad to the right side of D3. Likewise check the continuity from the upper right BR2 AC lead to the right side of D38 (or the solder side of the driver board from the upper left BR2 board pad to the solder pad about 1" to the right). Also it's a good idea to run jumpers from BR2 to its filter capacitor C5, as described below, because the plated thru holes for the BR2 are damaged.

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



The BR5 bridge used on WPC-S and earlier generation driver boards. Note the "+" lead of the bridge is offset slightly, from an otherwise perfect square shape. Notice the bridge is installed about 1/4" above the board. This aids air flow and keeps the bridge cool.

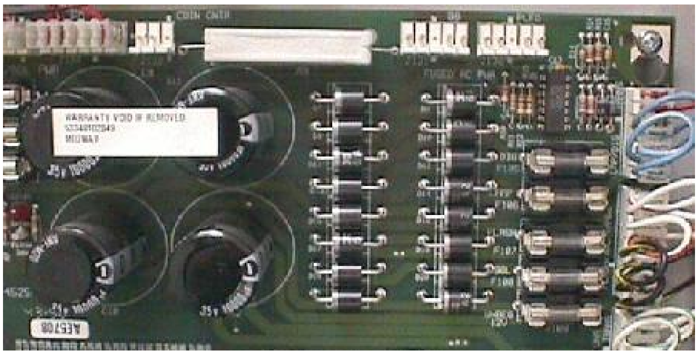


WPC-95 "Bridges".
When WPC-95 was released, Williams decided to stop using bridge rectifiers. Instead they just installed four diodes right on the driver board for each replaced bridge. By using four discrete diodes instead of a single bridge, the heat generated by the components is spread out and reliability is greatly improved. Bridge rectifier failure is very common in WPC-S and prior systems. Replacement of even a single diode in the

WPC-95 system games is very rare (but these games are not as old as WPC-S and prior systems). Certainly all the problems associated with the bridge rectifiers can still be exhibited in a WPC-95 system too.

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

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



The Electrolytic Capacitors: the Bridge Rectifier and Diode's Partner.
Each bridge rectifier or diode set must also have an associated electrolytic capacitor. These are needed to polish the converted rough DC voltage to smooth DC voltage.

Electrolytic caps are largely mechanical devices. With time, they can fail. Expect about 10 years maximum life from an electrolytic filter capacitor. It is fairly common for these caps to fail. A failing electrolytic capacitor can cause the game to reset, as the DC voltage won't be "smooth". Because of this, when replacing the BR2 bridge on pre-WPC95 games, it is a good idea to also replace the associated filter capacitor C5 (15,000 mfd 25 volts). A good replacement cap is available from Digikey, Panasonic 15,000 mfd 25 volts, part number P6891-ND. Also replace cap C4 (100 mfd 25 volts) with a 470mfd or 1000mfd cap.

Another potential electrolytic cap problem is at C4 on the driver board (C1 on WPC-95). This 100mfd cap is a "keep alive" cap for the +5 volts, that helps prevent the +5 from dropping when other parts of the power supply are stressed, and helps stablizes the +5 a bit behind the LM323K. Just like C5, the cap C4 also dries out and should be replaced too. This 100mfd cap can be bumped up to 470mfd or even 1000mfd to help prevent reset (but don't go any higher than 1000mfd, as this puts undo stress on the LM323k voltage regulator).

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

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

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

WPC-S and Earlier Driver Board:

- **BR1** to C6 & C7 (15,000 mfd @ 25v) to F114: +18 volts used for lamp driver columns. Then the 18 volts goes through voltage regulator Q2 (LM7812) and F115, and is converted to 12 volts (regulated) for the switch matrix.
- **BR2** to C5 (15,000 mfd @ 25v) to F113: +5 volts. **The bridge and capacitor that fail the most, and cause the most reset problems.** Also replace driver board cap C4 with a 470mfd or 1000mfd cap.
- **BR3** to C8 (100 mfd @ 100v) to F112: +50 volts, used for solenoids.
- **BR4** to C11 (15,000 mfd @ 25v) to F111: +20 volts, used for flash lamps.
- **BR5** to C30 (15,000 mfd @ 25v) to F116: +12 volts unregulated for playfield devices, opto power, dot matrix display, and the coin door.
- **BR1** (on Fliptronics II board) to C2 (100 mfd @ 100v) to F901-F904: +50 volts used for the flippers. Located on the Fliptronics II board. Note early versions

of the Fliptronics II board had C2 installed, but later versions did *not* use this capacitor, and it is missing from the board. In any case, this capacitor is not needed, as the flipper coil 50 volts does not really need to be filtered.

WPC-95 Driver Board:

- **D3, D4, D5, D6** to C8 (10,000 mfd @ 35v) to F109: +12 volts unregulated for playfield devices, opto power, dot matrix display, and the coin door.
- **D7, D8, D9, D10** to C9 (10,000 mfd @ 35v) to F105: +5 volts for all board logic circuits. **The diodes and capacitor that fail the most, and cause the most reset problems.** Also replace C1 (100mfd 25 volts) with a 470mfd or 1000mfd version.
- **D11, D12, D13, D14** to C12 (10,000 mfd @ 35v) to F106/F101: +18 volts used for lamp driver columns. Then the 18 volts goes through voltage regulator Q2 (LM7812) and F101, and is converted to 12 volts (regulated) for the switch matrix.
- **D15, D16, D17, D18** to C10 (10,000 mfd @ 35v) to F107: +20 volts for flash lamps.
- **D19, D20, D21, D22** to C22 (100 mfd @ 100v) F108/F102/F103/F104: +50 volts for solenoids.
- **D25 to D32**: +6.3 volts for general illumination. These were replaced with jumpers starting with Scared Stiff. See the Burnt Connector section (WPC-95 GI diodes D25-D32 remove and jumper) for a description of this.

Testing a Bridge (WPC-S and prior), Board Removed.
Note testing a bridge with the game off is NOT conclusive to whether the bridge is bad! The bridge is being tested under NO load. Only a bridge which is shorted (and hence is blowing fuses) or open will test as "bad". A bridge could test as "good", and still cause the game to reset. Also testing a bridge "in circuit" (while still soldered in the board) can often not give proper results.

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

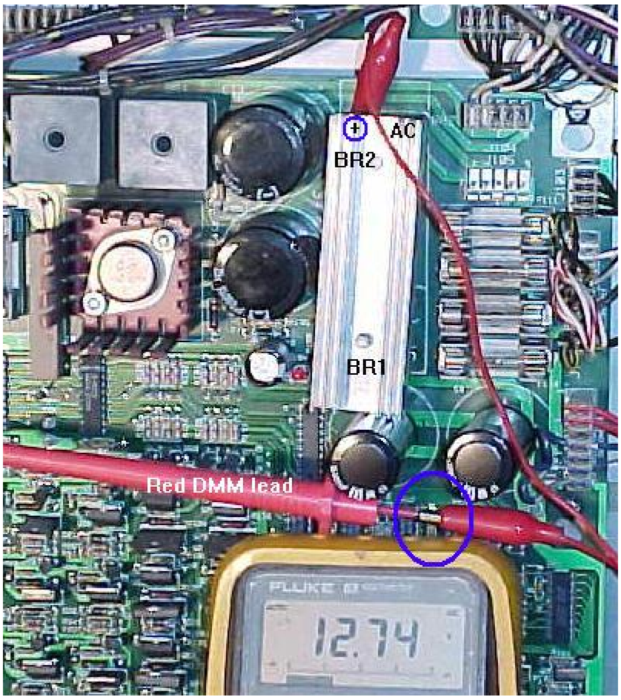
1. Put the DMM on diode setting.
2. Put the black lead of the DMM on the "+" (positive) terminal of the bridge.
3. Put the red lead of the DMM on either AC bridge terminal. Between .4 and .6 volts should be seen. Switch the red DMM lead to the other AC bridge terminal, and again .4 to .6 volts should be seen.
4. Put the red lead of the DMM on the "-" (negative) terminal of the bridge.
5. Put the black lead of the DMM on either AC bridge terminal. Between .4 and .6 volts should be seen. Switch the black DMM lead to the other AC bridge terminal, and again .4 to .6 volts should be seen.

If values outside of .4 to .6 volts are shown for any of the above tests, the bridge is bad. Typically you will get a zero value (a short) for at least one of the above tests in a bad bridge.

Testing a Bridge (WPC-S and prior), Under Minor Load, In the Game.
This tip is from John Robertson. This test is a more conclusive way to test a bridge (though a bridge that tests good here can still cause game resets!) This procedure requires a DMM, two alligator jumper wires, and a 6 amp rectifying diode (6A50 or 6A2 or 6A4, or whatever is available; Radio Shack sells 6A50 diodes, part number 276-1661). Here is the procedure:

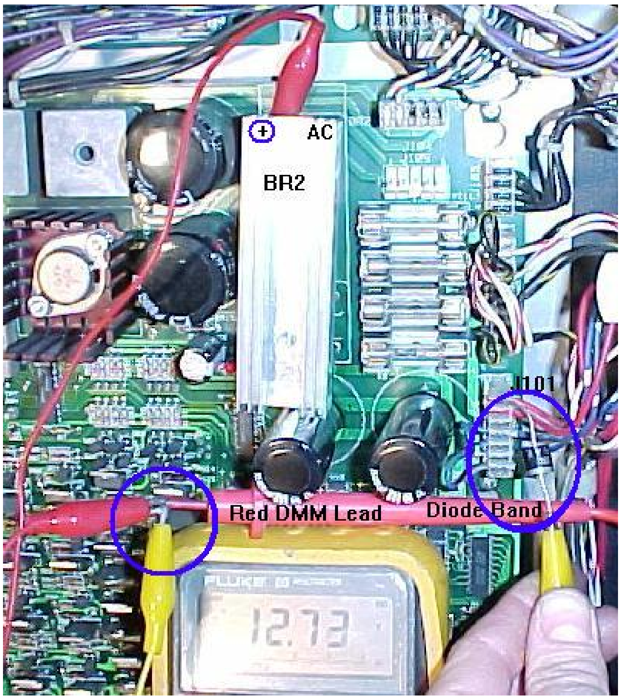
1. With the game off, clip one end of an alligator test wire on the "+" lead of bridge BR2 (top most bridge) on the driver board. The "+" lead is the top left most lead (see picture below). Often the side of the bridge is labeled too. One lead is "AC", and the other is "+" (connect the alligator clip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

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



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

A second alligator clip is connected to where the first alligator clip connects to the red lead of the DMM. Now touch the second alligator clip with a 6 amp diode, NON-BANDED end, to connector J101 pins 1 or 2. The voltage on the DMM should NOT drop when the diode is touched to connector J101 pins 1 or 2.

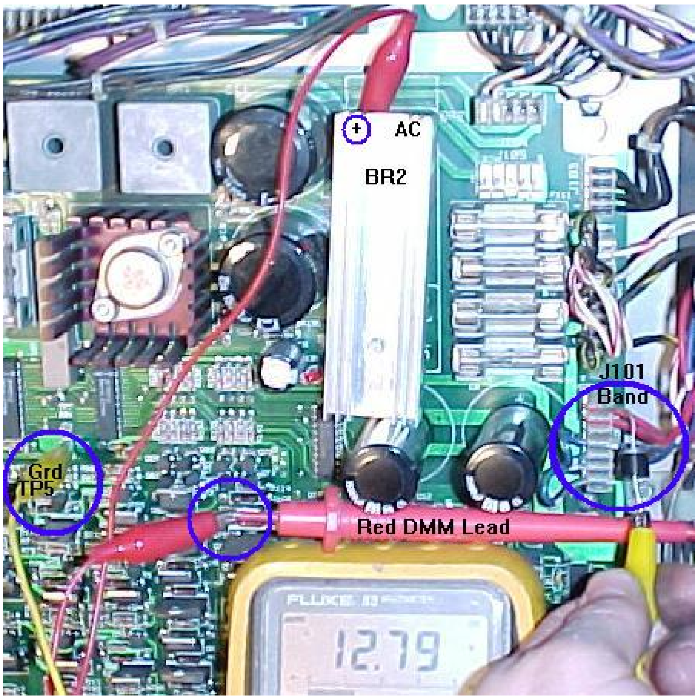


12. Turn the game off. Reverse the diode in the alligator clip so the NON-BANDED end of the 6 amp diode is connected to the alligator clip.
13. Connect the other end of the alligator clip to TP5 (ground).
14. Turn the game on.
15. Touch the banded end of the diode to connector J101 in either pin 1 or 2 (two top most pins). Note the IDC connector will have some exposed metal at the

top of the connector to touch, and the plug should not be removed.
16. While doing the above step, examine the DMM voltage reading. If the voltage rises when the diode lead is touched to Connector J101 pin 1 or 2, the bridge BR2 is bad.

If the above tests all work as described (no voltage drops or readings below 12 volts), the problem is mostly likely a bad C5 (15,000 mfd 25 volt) filter cap (or a cracked solder joint to the bridge and/or capacitor, which can be solved by installing the jumper wires described below), or C4 cap (100 mfd 25 volt). But remember, a bridge that tests good here can still cause game resets!

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



Testing a Diode (WPC-95)
The diodes that replaced the bridge rectifiers in WPC-95 are even easier to test. Again, testing diodes in curcuit may not give the following results.

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

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

The Above Bridge/Diode Tests Don't Always Work!
Yes, you heard right. The above outlined bridge and diode tests above don't always find a faulty component. These devices can just start to fail, and this will cause the game to reset. But a bridge or diode can become "leaky", which will cause the game to reset, and may not show as bad in the above tests (though the bridge test "under load" as explained above is the most accurate of the tests).

So what do you do now? How can you be sure the resetting game has a bad bridge or diode? Well you really can't! First make sure the wall voltage is at the proper level. Then re-solder the bridge/diodes and their associated capacitor's solder pads. Then just go ahead and replace the suspected bad bridge/diode (BR2 or D7, D8, D9, D10 on WPC-95). Also, if the game is 10 years old or more, I suggest replacing filter capacitor C5/C4 (C9/C1 on WPC95). If the game is still resetting (and the filter cap was not replaced), definately go ahead and replace the associated filter capacitors (C5/C4, or C9/C1 on WPC-95). If the game is still resetting, replace the LM339 voltage comparitor at U6 (U1 on WPC-95) as a last resort.

Replacing a Bridge or Diode.
Replacement is as simple as cutting out the old component and soldering in a new one. When installing the new bridge, mount it 1/4" or even 1/2" above the board. This allows for air to flow underneath the bridge for better cooling.

Replacing BR2 and/or BR1 on WPC-S and Prior:
Splitting the Large Heatsink.
When replacing either (or both) bridges BR1 and BR2 on WPC-S and prior, both bridges will have to be dealt with. These two bridges share a single large silver heat sink. Since they both share the same heat sink (and one failed due to heat), the

other may need replacement shortly. If either BR1 or BR2 is bad, generally not a bad idea to replace both. To remove them, both will need to be unsoldered from the Driver board, and the heat sink un-screwed from the bottom of each bridge. The new bridges are then screwed to the heat sink, and both bridges re-installed (it is much easier to install the bridges if they are both already screwed to the heat sink).

Also a lot of people cut the heat sink in half when replacing BR2/BR1. This makes replacing one bridge a lot easier. The theory is, the driver board's plated through holes for these bridges take enough abuse, so doing any unnecessary desoldering is a bad thing in my opinion. Hence the heat sink is cut in half.

Note I do NOT recommend cutting the heat sink in half. The reason has to do with physics. When the heat sink is cut in half, it acts like a cantilever. This puts A LOT of stress on the bridge's four solder points, and the circuit board's plated-thru holes. Since pinball is a high vibration environment, the cantilever effect can actually pull the bridge out of the circuit board. But if the heat sink is a single unit with eight solder points, the cantilever effect is far reduced. This is why I do not recommend cutting the BR1/BR2 heat sink in half.

Also there should be a thin layer of white heat sink compound on the top of the bridges too. Make sure to add some heat sink compound when replacing the bridges. Heat sink compound can be purchased at Radio Shack. A good brand of heat sink compound is "Arctic Alumina".

Replacement Bridges and Diodes.
The stock bridge installed in WPC games is 35 amps at 200 volts. The original part number will be something like "MB3502W" or "MB352W". The "MB" signifies a metal cased bridge. The "35" signifies 35 amps. The "02" or "2" signifies 200 volts peak. The "W" at the end means the bridge has wire leads. Higher amps or voltage ratings work fine. I generally use 35 amps at 400 volts for example.

Replacement wire lead bridges are available from Competive Products Corp (800-562-7283), or from Williams, part number 5100-09690. Mouser also sells them, part number 625-GBPC3502W ($3.48). And so does Digikey, part number MB352WMS-ND. Radio Shack even sells 35 amp bridges at 50 volts (which isn't enough voltage). But look at the bridge inside the Radio Shack package, as often they are labeled 3502W or 352W (35 amps 200 volts), and not 50 volts. Always buy only the labeled bridges from Radio Shack. Sometimes these "35 amp" bridges are labeled 1001W (10 amp 100 volts!). Obviously put that one back and grab another!

Replacement diodes for WPC-95 boards are P600D (6A4 or 6A400), or NTE5814. A lower voltage version can be used too, 6A2 or 6A200 (200 volts). Radio Shack sells a 6 amp 50 volt (6A50) version which can be used in a pinch, part number 276-1661.

Testing the Filter Caps.
Testing the filter capacitors on the driver board is fairly easy. With the game on, set the DMM to AC volts. Then put the leads of the DMM across the two leads of each filter capacitor (doesn't matter which DMM lead to which capacitor lead, as AC voltage is being measured). If more than 0.20 volts AC is seen, the capacitor is bad (actually many people would say if more than 0.10 volts AC is seen the cap is bad).

The problem with this test is the leads for the filter caps are nearly impossible to access when the driver board is installed in the game. In the case of C5 (+5 volts with bridge BR2), use an alligator jumper lead connected to the red DDM lead to side of the "+" BR2 bridge rectifier, and the black DMM lead to ground. Switch the DMM to low AC volts to measure the C5 capacitor ripple. Note if the BR2 bridge is bad, excessive ripple will be seen. For this reason, I usually just replace the filter caps in question (C5/C4 or C9/C1 on WPC95) when replacing the BR2 bridge or WPC95 +5 volts rectifiers.

Replacement Filter Caps.
If replacing a filter capacitor, use a 15,000 mfd 25 volt "snap" cap (on any WPC generation, even WPC-95). Higher voltage caps can be used (but are more expensive). Do not use a capacitor greater than 15,000 mfd, because the in-rush current puts more stress on the rectifying bridge/diodes. A lower value of 10,000 or 12,000 mfd could also be used (but no lower than 10,000 mfd). These are available from many sources, such as Digikey (www.digikey.com or 800-344-4539) or Mouser (www.mouser.com or 800-346-6873). Don't get a cap that is too "tall", as it will stick out horizontally from the driver board and increase stress on the cap's solder points.

- 15,000 mfd 25 volt, Digikey part# P6891-ND, Panasonic snap cap. An excellent replacement in both quality and size.
- 15,000 mfd 25 volt, Mouser part# 5985-25V15000 or Digikey part# P6577-ND.
- 12,000 mfd 25 volt, Mouser part# 5985-25V12000 or Digikey part# P6575-ND.
- 10,000 mfd 25 volt, Mouser part# 5985-25V10000 or Digikey part# P6573-ND.

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

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

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

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

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

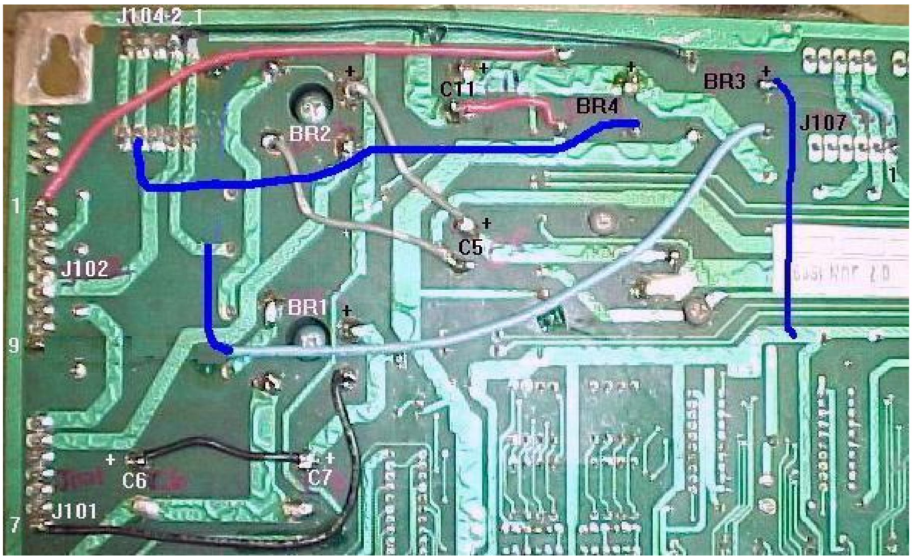
The most important bridge/capacitor to jumper is BR2 and C5. Jumper two 18 guage wires on the solder side of the driver board from BR2 to C5 (positive lead of BR2 to positive lead of C5, and negative lead of BR2 to negatvie lead of C5). This will help prevent random game resets. All the other bridges/capacitors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

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

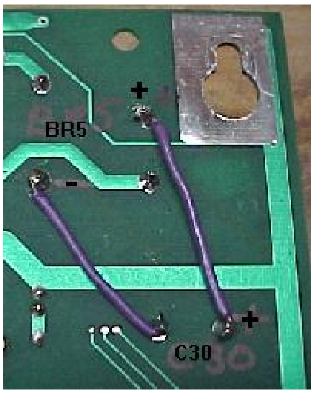
WPC and WPC-S Driver Board Jumpers:
For reference, the driver board is positioned with the solder side showing, and connector J104 at the "top". All jumpers added to the solder side of the driver board.

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

All the above jumpers have been installed. The most important jumper is the one from BR2 to C5 (the gray wires). Note the "+" (offset leg) of the bridge goes to the "+" lead of the associated capacitor. The "-" lead of the bridge is diagonal to the offset "+" lead. Shown is a WPC and WPC-S style driver board.



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



Are Jumper Wires Good Insurance for WPC-95 Games Too?
Yes! Even though WPC-95 games stopped using bridges in favor of diodes (which have far less heat/vibration solder pad cracking problems), jumper wires are still a good idea. On WPC-95 games, all the large electrolytic capacitors on the driver board have the potential for cracked solder pads.

To give an example of solder pad cracking, I recently had a problem on a Safe Cracker (WPC-95) where none of the low power (20 volt) coils worked. It was very frustrating; the fuse was good, and power was getting to the Driver board, but not out of the driver board and to the coils.

It turned out that the capacitor that filters the DC voltage after the rectifying diodes on the driver board had a cracked solder pad. This prevented the voltage from getting any further than it's associated rectifying diodes (I should have known; the +20 volt LED at TP104 on the Driver board was not lit!) Adding the jumper wires from the diodes to the capacitor fixed the problem.

Remember, the purpose of the jumpers on a WPC95 driver board is for added insurance on the *filter cap*. The diodes do *not* need the jumpers (other than the filter cap connects to the diodes). Its the weight of the filter cap is what causes the solder pads to crack (from vibration). The diode's solder pads just don't crack.

WPC-95 Driver Board Jumpers.
At minimum, add jumper wires for the +5 volt filter capacitor and rectifying diodes. The other diodes and filter cap can be jumpered too, as desired:

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

- 20 volt coils: Jumper from the non-banded side of D16/D18 to the negative lead of cap C10, and from the banded side of D15/D17 to the positive lead of cap C10.

Replace the +5 Volt Filter Capacitor at C5/C4 (or C9/C1 on WPC-95).
If the game is still resetting, there's probably a good chance that the +5 volt filter capacitor at C5 (15,000 mfd @ 25v) or C9 (WPC-95, 10,000 mfd @ 25v) needs to be replaced. The C5/C9 capacitor filters and smooths the +5 volts. If this cap is worn out, unsmooth +5 volts will result. This will cause random game resets. On WPC-S and prior games, when replacing bridge BR2, it is a good idea to just go ahead and replace the filter cap C5 with a new 15,000 mfd 25 volt capacitor. Any game that is 10 years old or more should have the +5 volt filter cap replaced. Also replace driver board cap C4 (100 mfd 25 volts) or C1 (WPC-95) with a 470mfd or 1000mfd version.

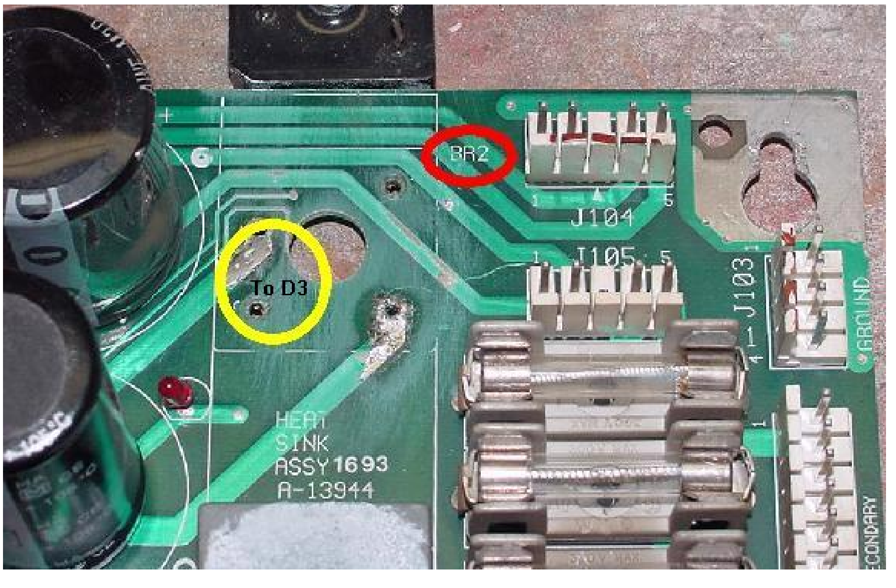
Again Check the Power Driver Voltage Plugs (Transformer, J101/J129).
The molex plug that provides the input voltage to the driver board can also have problems. On WPC-95, J129 supplies the voltage that gets rectified to +5 volts. On WPC-S and prior, J101 handles this. Also check the main power plugs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

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

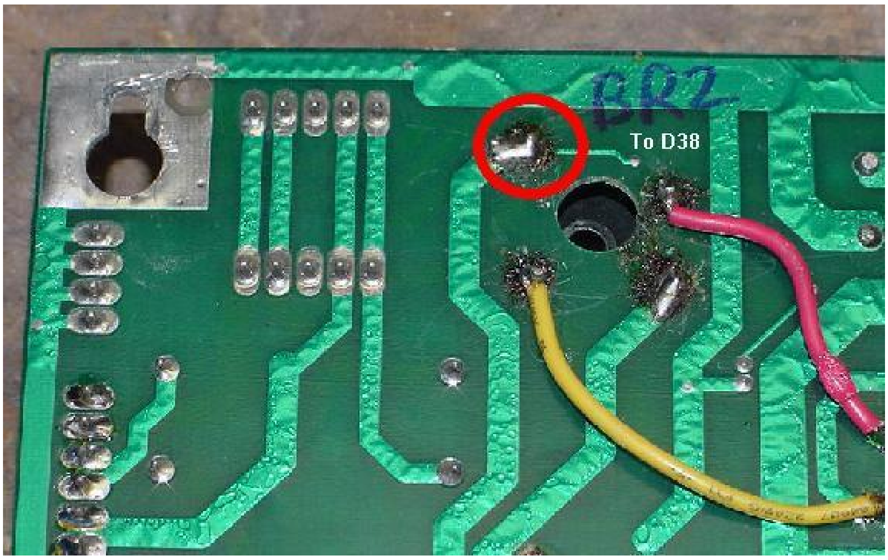
The Zero Cross Circuit and Resets on WPC-S and Prior.
The zero cross circuit serves a couple purposes, one of which has to do with game resets. Part of the driver board's zero cross circuit are diodes D3 and D38 (located just below connector J109), which are both powered from driver board AC power traces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

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

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



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



Game is Still Resetting.

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

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

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

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

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

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

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

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

The Power Box and Game Resets.

The Thermistor and Resets.
the Thermistor's job is to act like a low value resistor when cold. After warming up for a moment, it essentially becomes a zero ohm resistor. When the game is first

turned on, it provides a slightly lower input voltage to the game's transformer (and hence bridge rectifiers/caps), limiting the in-rush current (and lengthening the life of the bridges) by acting as a low value resistor. With time sometimes the thermistor does not function correctly after warm up, therefore acting like a full time resistor. This keeps the input voltages lower, and makes game resets more prevalent, especially when the game is "cold". The Thermistor is located in the "power box" just inside the coin door. This power box also housing the game's power switch.

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

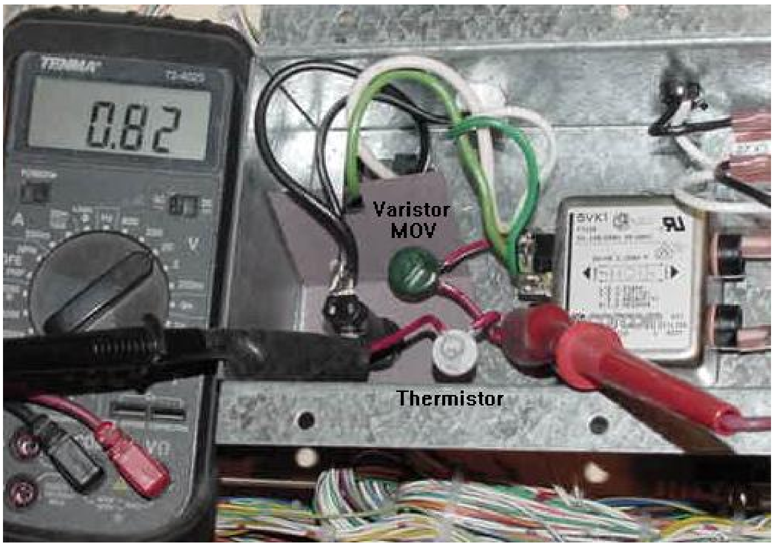
Also measure the thermistor with the game power off and "cold" using a DMM set to ohms. No more than a 2 or 3 ohms should be seen. If any more than that, replace it.

But the easiest way to determine if the thermistor is a problem with game resets, is to jumper around it temporarily. Using an aligator test lead, just jumper around the thermistor, and power the game on and test for resets when the game is "cold". No more resets means the thermistor is bad.

Note the thermistor was removed for many (but not all) WPC-95 games. It was no longer needed as the bridge rectifiers were replaced with discrete diodes, and the filter caps were changed from 15,000 mfd to 10,000 mfd. So WPC-95 games may or may not have a thermistor installed.

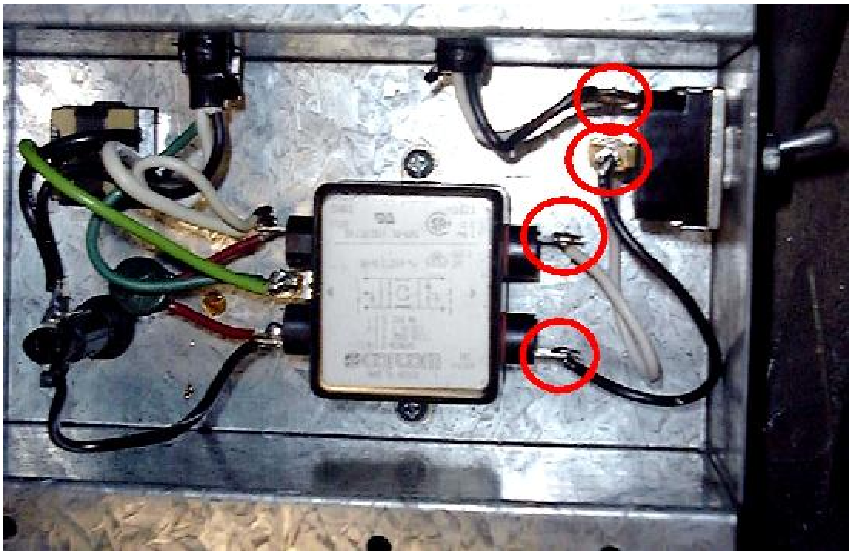
The "power box" just inside the coin door.
Picture by John Robertson.

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



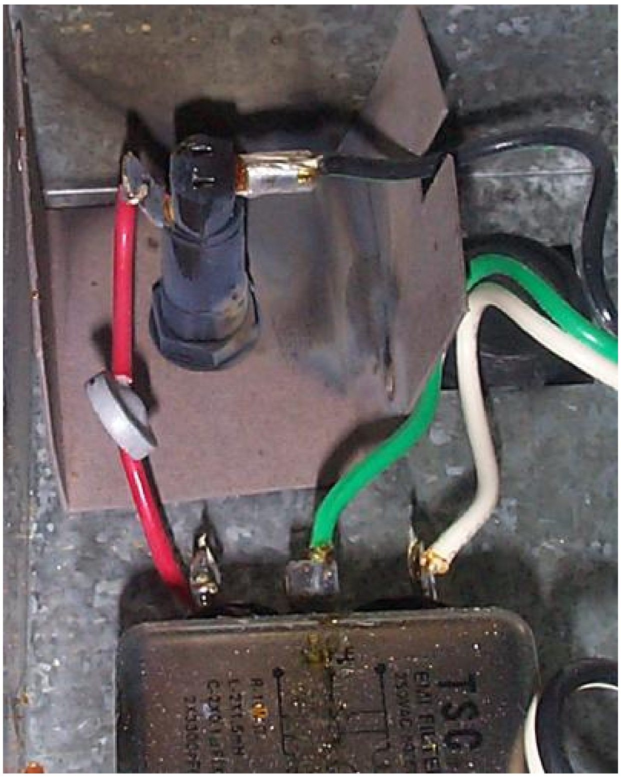
Connectors inside the Power Box.
While checking the thermistor and varistor, also check the single spade lug connectors used on the power switch and the RF (Radio Frequency) Filter. Sometimes these connectors can get loose and burn, causing low power to the driver board, and game resets. Instead of installing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

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



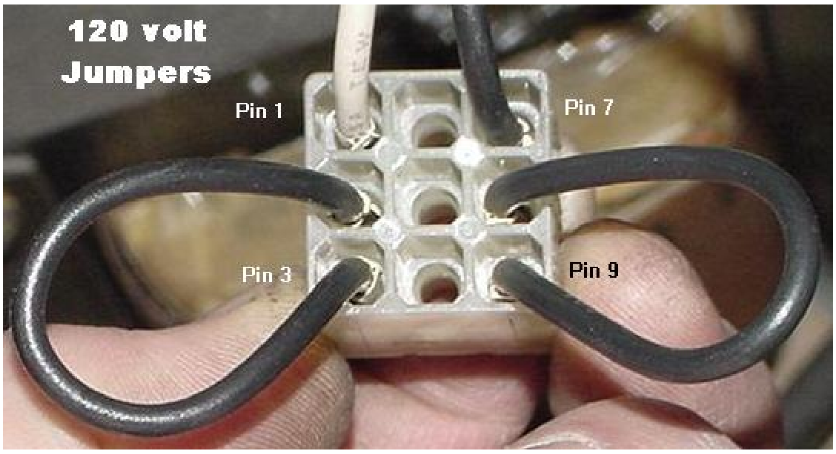
Bad Line Fuse Holder.
Another not so common failure point is the main line fuse for the game in the power box. This style of fuse holder is not great quality, and can become "loose" and cause resets. Though not common it can happen. Also the line fuse itself can have resistance and lower the line voltage.

Power box where the power switch and RF filter reside, and the line fuse holder is obviously having some problems (see the arcing burn marks on the right side of the fuse holder). In this Twilight Zone replacing the line fuse holder fixed the reset problems. The gray disc connected to the line fuse is the Thermistor.

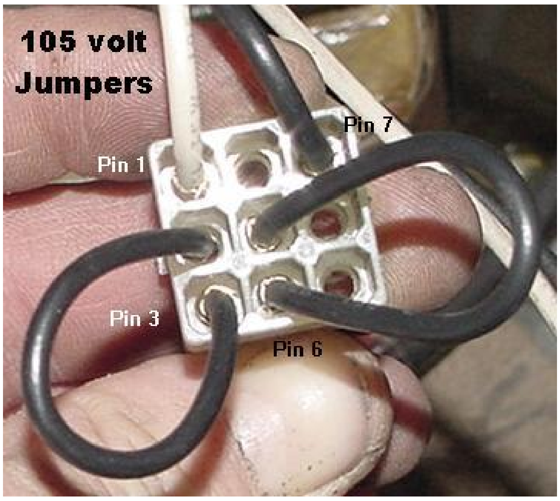


Low Line Voltage Jumpers (105 Volts).
If the game is at a 120 volt location but has 112 volts or less at the wall outlet and is resetting, the game can be jumpered for "low line voltage". This is also known as the 105 volt Japanese voltage setting. I don't recommend this if the voltage is above 112 volts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

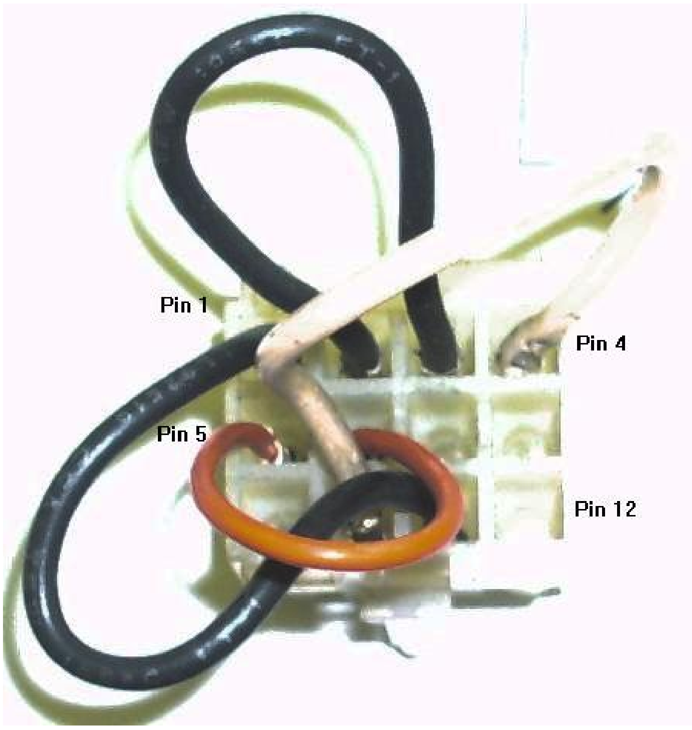
The normal 120 volt transformer jumpers on an Addams Family.



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



The low line 105 volt transformer jumpers for WPC-S and later:
Pin 1 to 11, Pin 2 to 3, Pin 4 to 10, Pin 5 to 6.

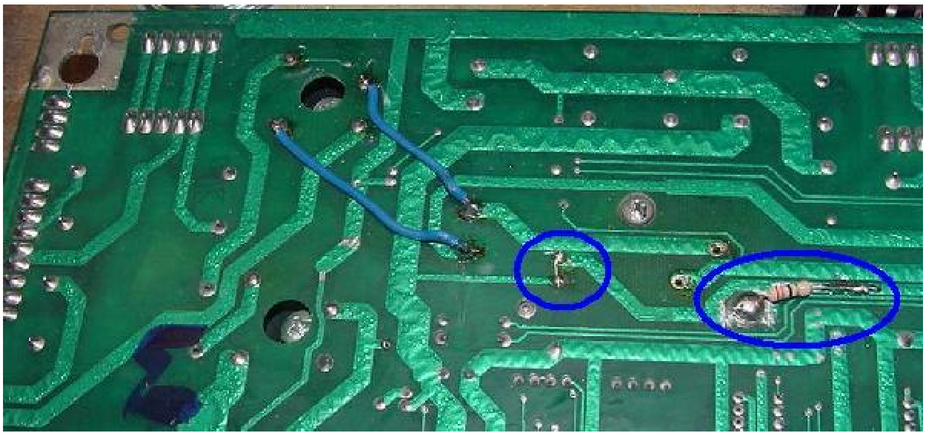


Still Reseting? Another Last Resort.
This bit of information is unique to this repair guide. You probably won't hear about this stuff elsewhere. And there may be a good reason for that. As this is the last reset thing I can recommend. This is not a bad thing to do, but I just think it's the absolute last thing you should try.

On WPC and WPC-S games, the 5 volt regulator is a LM323K. These regulators have a working voltage range of 4.7 to 5.3 volts. That's a big range, but unfortunately, that's how they work. The problem is for a WPC game, anything below 4.9 volts and you will have reset problems. Yes you can replace the LM323K, but really, if you have 4.8 volts, the LM323k is working within spec. And these LM323k regulators are becoming more expensive.

Though normally thought as a fixed voltage regulator, the LM323k does have the ability to vary the output voltage. The metal case of the LM323k goes directly to ground on the WPC and WPC-S driver board. But if the LM323's metal case is isolated from ground, and then connected to a 22 ohm 1/2 watt resistor (with the other end of the resistor going to ground), this will increase the output of the LM323k slightly. I found using a 22 ohm 1/2 watt resistor will raise the output voltage to about 5.15 volts. This should fix any persistant reset problems. (Note as the resistance is increased to say 33 ohms, 5.25 volts will result.) This option works GREAT in situations where resets are a problem, and all the other options have been tried.

Modification to a WPC/WPC-S driver board to bump the 5 volts to 5.15 volts. Here the BR2/C5 jumper wires are installed (red wires), and the blue circles show the modifications to implement a 22 ohm resistor to the LM323 rectifier. Note the ground trace is cut around the LM323k bolt, and ground is directed to the bolt thru a 22 ohm 1/2 watt resistor. Also on some revisions of the WPC driver board, the LM323 has a ground trace on the component side of the board that will also need to be cut. Always buzz out the ground to the metal case of The LM323 to ensure you have it isolated from ground when doing this mod.



Component side of the driver board with the LM323k voltage regulator removed. The blue line shows where the ground trace was cut to isolate the metal case of the LM323k from ground. This mod is only needed on some revisions of the driver board.

A similar modification can also be performed on a WPC-95 driver board. In this case the 5 volt regulator is a LM317, which is an adjustable output voltage regulator. Williams has the voltage set to 5 volts using a 750 ohm 1/2 watt resistor at R1. If you change this R1 resistor to 780 ohms, this will raise the LM317 output voltage to 5.2 volts. Again this should cure any persistant reset problems.

The question may arise why any of this is needed. It turns out the LM323 and LM317 do not have very tight manufacturer specs. So the output voltage can vary greatly from regulator to regulator. Also as components age in a game, they can consume more power. Because of this you may find it necessary to do the above modification to fix a persistant reset problem. I have found this modification to work well on stubborn WPC games with four flippers, and in conditions where the wall voltage is in the 110 to 115 range.

End of Reset Problems.

Other Misc. Bridge/Power Problems.

Fuse F116 Keeps Blowing on WPC-S and Prior Games.

When fuse F116 keeps blowing on WPC-S and earlier games, it's almost always a bad bridge rectifier at BR5. Replace and make sure there is good solder contacts leading to the "+" lead of C30.

"Check Fuse F114/F115" (or F106/F101) Message.
This indicates the voltage is out for the lamp/switch matrix. Sometimes this message is gotten even when the fuses are good!

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

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

- Test for AC voltage at J101 pins 4 and 7 (or J129 pins 4 and 7 on WPC-95). A reading of 13 to 18 volts AC should be seen. This is the AC voltage coming from the transformer. If no voltage here, check the Molex connectors around the transformer and at the power driver board.
- Test for DC voltage at TP8 (or TP102 on WPC-95) and ground. A reading of 16 to 18 volts DC should be seen. If no voltage here, replace BR1 (or D11 to D14 on WPC-95). Also no voltage here can occur because the solder pads are cracked around bridge BR1 (or D11 to D14 on WPC-95). Using jumper wires for BR1 (as described in the Game Resets section) helps prevent this.
- Test for DC voltage at TP3 (or TP100 on WPC-95) and ground. A reading of 12 volts DC should be seen. If no voltage here, check or replace diodes D1 and D2 (1N4004, all WPC version).
- If diodes D1/D2 are OK, replace Q2 (all WPC versions), a LM7812 voltage regulator.
- If the above still does not fix the problem, replace U20 (all WPC versions) on the CPU board (ULN2803). If U20 died "hard", it could also blow the U14 (74LS374) on the CPU board. On WPC-95 and WPC-S it's U23 (74HC237 or 74HC4514 respectively).
- If the above still does not fix the problem, and the game has an under-the-playfield optic board, replace the LM339 chips on this board. Replace them all, and use sockets.
- If voltage is still not right, or BR1 (or diodes D11 to D14 on WPC-95) are REALLY hot, check all the TIP107 transistors on the power driver board. If these test good, check/replace the power driver board's ULN2803 at U19 (or U11 on WPC-95), or maybe the power driver board's 74LS374 at U18 (or U10 on WPC-95).

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

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

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

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

Exploding +20 volt C11 Capacitor (or C10 on WPC95).
There are cases when the +20 volt capacitor (Driver board C11 on WPC-S and prior, C10 on WPC-95) can just explode. This happens when a shorted flipper coil diode or shorted transistor on the Fliptronics board causes the 70 volt coil power to feedback into the 20 volt flashlamp circuitry. Because of reverse voltage, this blows the 20 volt capacitor. Also installing one of the ribbon cable connectors in the backbox on the header pins (top row of header pins to bottom row of housing) can do the same thing. And lastly, if connector J124 is mistakenly plugged into the driver board connector J128 (they are keyed alike!), this can cause capacitor C11 to explode.

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

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

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

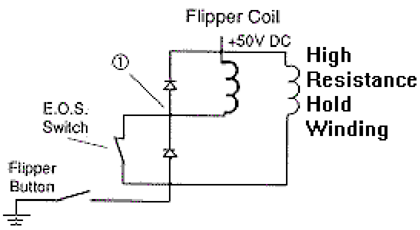
Flippers connect the player to the pinball game. Having perfectly working flippers is extremely important. Here are some common flipper problems and answers.

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

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

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

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



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

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

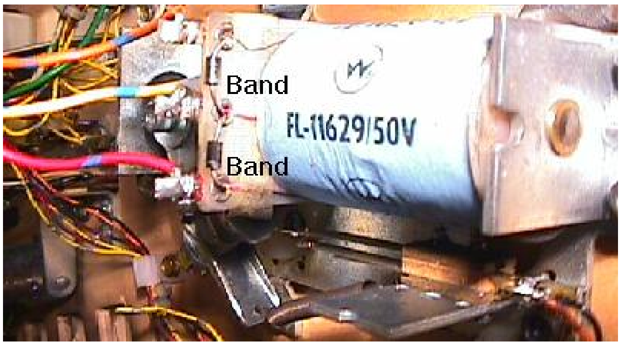
Flipper Coil Numbers and Strength.
If there are problems with fliptronics fuses and fliptronics TIP36 and/or TIP102 transistors blowing, check the flipper coil resistance. Resistance is shown below so a questionable flipper coil may be tested. The upper measured ohms should be within 10% of the values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

- FL-11753: used for small flippers, like the "Thing" flipper on Addam's Family. 9.8 ohms/165 ohms. Usually a yellow coil wrapper.
- FL-11722: used for weak flippers, like Twilight Zone's upper right flipper. 6.2 ohms/160 ohms. Usually a green coil wrapper.
- FL-11630: "standard" flipper strength, as used on older games like Earthshaker, Whirlwind, etc. 4.7 ohms/160 ohms. Usually a red coil wrapper.

- FL-15411 : strong flipper, as used for main flippers on Addam's Family, Twilight Zone, etc. 4.2 ohms/145 ohms. Usually an orange coil wrapper.
- FL-11629: strongest Williams flipper. Used on most of the newest WPC games. 4.0 ohms/132 ohms. Usually a blue coil wrapper.

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

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



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

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

- Lower Left flipper: Grey/Yellow
- Lower Right flipper: Blue/Yellow
- Upper Left flipper: Grey/Yellow
- Uppper Right flipper: Blue/Yellow
- Note on fliptronics games, this lug's base wire color often changed to Red.

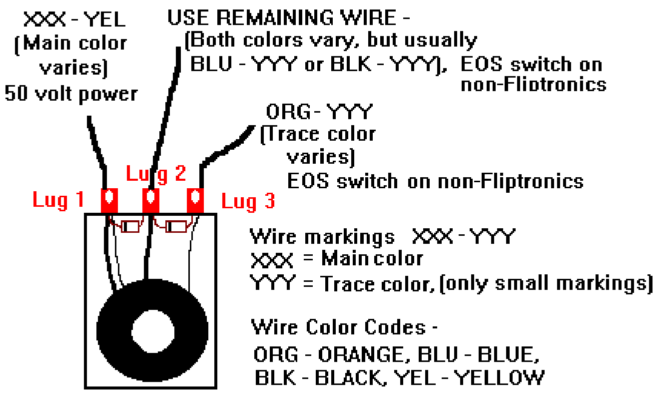
Lug 3 (outside non-banded diode lug, one winding wire):

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

Lug 2 (middle lug):

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

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



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

Fliptronics versus "Classic Old Style" Flippers.
Starting with Addams Family in 1991, Williams changed from a conventional "classic" flipper system (which had change very little from its invention in 1947), to an electronic CPU controlled flipper system called "Fliptronics". The Fliptronics flippers were now controlled by a circuit board mounted in the upper left corner of the backbox (above the CPU board).

When the player pressed the cabinet flipper button, the Fliptronics board would send 70 volts to the high-powered side of the flipper coil (Fliptronics and non-Fliptronics parallel-wound flipper coils are the same). Then the Fliptronics board looks for the low voltage flipper EOS (End of Stroke) switch to *close* (where classic old-style flippers had the EOS switch *open* when the flipper coil was energized). As soon it sees this switch close, it diverts the 70 volts to the low-power side of the flipper coil. This allows the player to hold the flipper cabinet switches in for extended periods without burning the flipper coils. If the Fliptronics board sees no EOS switch closure in a short period of time (the EOS switch is mis-adjusted or broken), it still diverts power to the low-power side of the flipper coil, preventing coil burn.

The advantage to this electronic system is the EOS switch can be broken, missing or mis-adjusted and the flipper will work normally. That is, the flipper coil will have normal power and won't burn if the player holds the cabinet flipper buttons in. Essentially the EOS switches are redundant and not absolutely needed. In older "classic" style flipper systems, a broken or mis-adjusted EOS switch meant weak flippers, burnt flipper coils, or blow fuses. The fliptronics system avoided this. It also allows the CPU board to control the flippers too, allowing the game to flip for the player. This was used in games like Addams Family's "thing flip" and Monster Bash's "phantom flip".

Another advantage to the Fliptronics system is it gave the game designers more transistors for driving other coils. For example if the game only had two flippers (Fliptronics boards could drive up to four flipper pairs), the Fliptronics board's unused driver transistors could be used for other chores. This was done on Theatre of Magic and Tales of the Arabian Nights (both two flipper games). The game designers ran out of Driver board transistors, and used the extra Fliptronics board drivers to control non-flipper coils.

Fliptronics I versus Fliptronics II.
The first Fliptronics system was used in Addams Family and is known as "Fliptronics_I". This was the *only* game that used this sytle Fliptronics circuit board. All games after Addams Family (including Addams Family Gold) use the "Fliptronics_II" circuit board. The differences between these two boards is minor. The main difference is the Fliptronics_II circuit board has an on-board 70 volt DC power supply for powering the flipper coils. The Fliptronics_I system uses a separate circuit board (mounted on the right middle side of the backbox) for supplying the 70 volt DC flipper power.

Since the Fliptronics_I system was only used in Addams Family, many people look for a spare Fliptronics_I circuit board (why I am not sure as this board is easy to repair). The thinking being the Fliptronics_I board was only used in Addams and is fairly rare and hard to find as a spare. The good news is that a Fliptronics_II board *will* fit and work without any modifications in an Addams Family (so there is no need to look for the rare Fliptronics_I board as a spare, as any Fliptronics_II board will work in Addams Family). Here is the connector mapping for the conversion from Fliptronics-I to Fliptronics_II for the Addams Family (thanks to M.McAndrew for this info). Note using a Fliptronic_II board in an Addams Family makes the game play *no* different than the original Fliptronic_I board.

Using a Fliptronics_II board in an Addams Family:

- Fliptronics_II J902 = Fliptronics_I J802
- Fliptronics_II J905 = Fliptronics_I J805
- Fliptronics_II J906 = Fliptronics_I J806
- Fliptronics_II J904 = Fliptronics_I J804
- Fliptronics_II J903 = Fliptronics_I J803 (ribbon cable)
- Fliptronics_II connectors not used: J901, J907

Using a Fliptronics_II board in an Addams Family.
Power Driver board (only pertaining to flipper power section):

- J111 - Remove connector (disconnect) and do no use
- J112 - Leave connector
- J110 - Leave connector
- J109 - Leave connector

Using a Fliptronics_II board in an Addams Family.
Flipper Power Board board (small board, backbox middle right side):

- J901 - Leave connector
- J902 - Leave connector
- J903 - Leave connector

What If I Hook up a Flipper Coil Wrong in a Fliptronics Game?
If the wires are reversed or incorrectly attached to a flipper coil on a fliptronics WPC game, damage will occur to the flipper coil and the fliptronics board.

The first thing that happens is the flipper fuse will blow on the Fliptroncs board. Turn the game off, and wire up the flipper coil correctly (see the above information and pictures). Next replace BOTH 1n4004 diodes on the flipper coil, and replace the blown fuse. You can try powering up the game, but I would suspect the driving TIP36 transistor on the fliptronics board will also be shorted. (This is easy to tell, as the flipper coil will stay energize as soon as the game is powered up or a game is started.) Also check all the 1n4004 diodes in that flipper circuit on the Fliptronics board with a DMM. There is a good chance the 'hold' TIP102 and 2n4403 transistors may be bad too, which you can test with a DMM. Lastly, check the traces on the back of the fliptronics board coming from the top J902 connector. Often the hold traces will be burned right off the board. (This happens because when the flipper coil is wired in reverse, the hold circuit is now wired thru the high-current portion of the coil, and the traces just burn like a fuse.)

Flipper Problem Troubleshooting.
If the flipper(s) don't work at all...

Non-Fliptronics Games:

- Check the flipper fuses on the driver board, fuses F101 and F102.
- Check for 50 to 75 volts at the flipper coil. Put a DMM on DC volts, and the black lead on ground (metal side rail of game). Put the red lead on any of the three lugs of the coil. It should be between 50 and 75 volts. No voltage means a fuse is blown, or a wire has broken going to the coil. If voltage is missing from one of the coil lugs, then the coil has a broken winding and should be replaced.
- Another way to test the flipper coil itself. To do this, turn your game on and leave it in attract mode. Attach an alligator test lead to ground (metal side rail of game), and momentarily touch the other end of the test lead to the middle lug of the flipper coil. The coil should activate.
- Also check the flipper coil with a DMM set to ohms. With the game turned off, try this:
    - Notice the three solder lugs for the flipper coil. The outside lug with the banded side of the diode connected has both the thick and thin wires connecting to it. This is the "common" lead.
    - Put one lead of the DMM on the outside common flipper lug.
    - Put the other lead of the DMM on the thick wire lug. Around 3 ohms should be seen. This is the high powered side of the coil.
    - Put the leads of the DMM on the thin wire lug of the coil. About 3 ohms should be seen until the flipper is manually moved to the full extended position, opening the EOS switch. Now about 125 ohms should be seen. Note if more than about 5 ohms is seen when the flipper is at rest in this test, the EOS switch is pitted and causing some resistance. Clean it for stronger flippers.
    - If the above readings are not seen, the flipper coil is bad. Typically the hold side of the coil goes bad more often that the power side.
    - Now put the leads of the DMM on each outside lug of the flipper coil. Around 3 ohms should be seen. This is the high powered winding of the coil. About 3 ohms should be seen until the flipper is manually moved to the full extended position, opening the EOS switch. Now about 125 ohms should be seen. Note if more than about 5 ohms is seen when the flipper is at rest in this test, the EOS switch is pitted and causing some resistance. Clean it for stronger flippers. If when the flipper bat is moved to the full energized position 125 ohms is not seen, the EOS switch is not opening, and the flipper coil will get hot and burn. If when the flipper bat is in the energized position there is no resistance, the hold side of the coil is bad (this happens more often that the power side going bad).
- On non-fliptronics games, clean the flipper cabinet switch contacts and the EOS switch contacts with a small metal file. Make sure this **normally closed** EOS switch is adjusted properly. The switch should open about 1/8" at the flipper's end of stroke. If this switch is dirty or not closed, the flippers may not work at all.
- Test the flipper diode(s). To do this you'll have to cut one lead of each diode off the coil lug. Then set the DMM to the diode setting. Put the black lead of the DMM on the banded side of the diode. About .4 to .6 volts should be seen. Reverse the leads and no reading should be seen. When done, re-attach each diode lead (or just put a new diode on!)
- Check the DPDT flipper engage relay on the driver board. When this relay is energized, it completes the ground path for all the flippers. Transistor Q99 (2N5401) controls this relay (if this transistor is shorted, the flippers will always work even when the game is over). There are also two jumpers W4 and W5 on the driver board which should NOT be installed (if these jumpers are installed, the flippers will always be activated, even when the game is over).

Fliptronics and WPC-95 Games:

- Check the flipper fuses on the Fliptronics board. On WPC-95, the flipper fuses are on the driver board.

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

  If the EOS switches aren't working on a Fliptronics or later game, check the continuity with a DMM from the switch to the CPU board (on WPC-95), or the Fliptronics board (on earlier games). On pre WPC-95 games, these direct EOS switches go to the Fliptronics board connector J906 and the flipper opto switches go to J905. On WPC-95 games, the direct EOS switches go to the CPU board connector J208 and the flipper switches go to CPU board connector J212. Non-fliptronics games have the flipper switches and EOS switches wired directly to the flippers, and don't connect to any board.
- On fliptronics games, if the flipper button doesn't register in the above test, check the flipper opto boards. Flipper opto boards were implemented on Addams Family, mid-production (some Addams have them, some don't). Also if the game uses plastic flipper opto activators, often these can warp. This will cause the activator to not clear the "U" shapped opto on the flipper opto board, causing a flipper to never energize!
- On fliptronics (before WPC-95) games, there can be a very rare and unusual problem with the fliptronics board. There is +50 volts power at the flipper coils (and the coils & diodes are good), but flipper switches just don't seem to work. This can be caused by a failed flipper switch input chip at location U5 (74HCT244) and U2 (74HCT374) on the fliptronics board.
- Re-seat the ribbon cables going from the CPU board to the Fliptronics board (be careful to not mis-install the ribbon cable). Some flipper confusion can be caused by these ribbon cable going from the CPU board to the Fliptronics board, and reseating the ribbon cable often clears this problem.
- Flipper flutter (flipper bat goes up and down repeatedly or just a couple times as the player holds the flipper cabinet button in). This is almost always a bad flipper coil where the "hold" portion of the coil (the thin wires) have broken away from the coil lug. Also could be a bad Fliptronics board TIP102 and/or 2N4403 and/or 1N4004. See below for more info on this.

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

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

<u>All WPC Games:</u>

- Check for +50 volts at the flipper coil. Put the DMM on DC voltage. Put the black lead on ground (metal side rail of game). Put the red lead on either of the outside lugs of the coil. A reading of 50 to 80 volts on either lug should be indicated. No voltage means (the coin door is open on 1993 or later games or) a fuse is blown, or a wire has broken.
- Test the coil itself. To do this, turn the game on and leave it in attract mode.

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

If the flipper works, but...

Non-Fliptronics Games:

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

Fliptronics and WPC-95 Games:

- When activated, doesn't hold up (the flipper "flutters"). This means the Fliptronics board hold TIP102 transistor and/or pre-driver 2N4403 and/or 1N4004 diode for that flipper is bad. Or the hold winding on the coil itself is broken. The hold winding on the coil is the thin wire. If it is broken, usually the wire has broken away from one of the solder lugs (one outside lug should have both the thick and thin wire attached to it). Test the coil first (see above) before replacing the transistor. Check the Fliptronics hold circuit fuse. If flipper is still fluttering, swap the right and left flipper opto boards and see if the problem changes (indicating a bad cabinet switch flipper opto). See below for more info.
- Flipper coil gets really hot after playing the game for a while. This is often a dirty flipper optic on the flipper board next to the flipper buttons. It could also be a bad LM339 chip at U4 and/or U6 on the Fliptronics board (or U25/U26 on a WPC-95 CPU board). An easy way to see if it's the LM339 chip or the optics is to swap the two flipper optic boards, and see if the problem changes to the other flipper. A dirty flipper switch "U" optic can essentially cause the flipper button to automatically turn on and off quickly (even when the player is not pressing the button), making the flipper coil warm.
- Flipper seems to work fine, but gets very hot and eventually starts to burn and smell. Often the flipper will get stuck in the "up" position. On Fliptronics/WPC-95 games, the hold TIP102 transistor for that flipper is shorted on, and needs to be replaced.
- When a game is started, all the flippers activate for a moment, then go dead. This can be caused by having the flipper switch board connectors removed from the Fliptronics (or CPU board on WPC-95). With the connector removed, the game thinks all the flipper buttons are pressed. The flippers go dead

because the secondary 50 volt power fuse blows.
- The flipper stays up for a moment after the flipper button is released. This happens on fliptronic and later games that have plastic activators which activate the flipper board optos. Sometimes the plastic's elasticity is lost, causing it not to spring back quickly when the button is released. Replace this plastic flipper activator. A temporary solution is to stretch a rubber band across the back of the plastic activator for additional tension. Flipper opto boards were implemented on Addams Family, mid-production (some Addams have them, some don't).
- Flippers work fine, but the flipper buttons do not work in video mode or high score entry mode. On games with flipper optic switch boards, there are two "U" shaped optic on each board. Games with 2 or 3 flippers often use one of the two "U" optics for the flippers, and the other for video mode and high score entry. This problem could be caused by this second "U" optic being bad, dirty, or there is a problem with the plastic activator not clearing the second "U" optic.

If one or both flippers are weak...

Non-Fliptronics Games:

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

Fliptronics and WPC-95 Games:

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

- Check the flipper power connections. On WPC fliptronics to WPC-S games, this is connector J907 and J902 on the fliptronics board. On WPC-95 this is connectors J119 and J120 on the power driver board. Make sure the solder joints on these board header pins are not cracked, and that the connector and header pins are in good shape.
- On WPC fliptronics to WPC-S games, check the fliptronics board bridge rectifier (BR1). On non-fliptronics games, check the bridge and capacitor that supplies voltage for all coils (BR3 and C8). An open diode in the bridge rectifier that supplies power to the flippers can cause weak flippers. A fatigued or cracked solder joint on this bridge (or its associated capacitor) can do that too. Soldering jumper wires from the bridge to its associated capacitor is a good idea. This is rare, but does happen. This problem will effect BOTH flippers equally. See the section, Testing Bridge Rectifiers for more information.

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

Fliptronics and WPC-95 Games:

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

Flipper coil gets very hot...

Non-Fliptronics Games:

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

Fliptronics and WPC-95 Games:

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

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

Mechanical "Stuck Up" Problem:

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

Electrical "Stuck Up" Problem:

Non-Fliptronics Games:

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

Fliptronics and WPC-95 Games:

- On games that use opto boards for the flipper buttons, in particular the "type2" opto boards with plastic opto actuators - check the actuator. On the plastic actuators, they can get "bent" so they don't interrupt the optical light beam in the "U" slot opto. If this happens, the flipper will immediately energize when a game is started. The metal actuators are easy to fix - just bend them. But on the plastic "type2" actuators, a heat gun will be needed to re-form (bend) the plastic actuator so it interrupts the "U" slot optos. Also if the game has a really light touch to energize the flippers, often the plastic actuators again need to be rebent.
- Re-seat the ribbon cables going from the CPU board to the Fliptronics board (be careful to not mis-install the ribbon cable). Some flipper confusion can be caused by these ribbon cable going from the CPU board to the Fliptronics

board, and reseating the ribbon cable often clears this problem.
- Flipper cabinet switch is bad. On games with opto flipper cabinet switches, check the two opto boards. A bad or dirty opto can cause this problem. Flipper opto boards were implemented on Addams Family, mid-production (some Addams have them, some don't). On pre-opto flipper switch WPC games, check/clean the mechanical cabinet flipper switch.
- Flipper gets very hot and eventually starts to burn and smell. This means the hold TIP102 transistor for that flipper is shorted on, and needs to be replaced.
- Flipper immediately energizes and stays up when a game is started or when the game is tured on (assuming the coin door is closed). The flipper's TIP36 transistor that controls the high voltage side of the coil is shorted on, and needs to be replaced. And/or the flipper's TIP102 transistor that controls the "hold" side of the coil is shorted on, and needs to be replaced. (Usually it's usually pretty easy to tell if the TIP36 or TIP102 is shorted. If the TIP36 is shorted, the flipper comes up very hard when powered on. If the TIP102 is shorted, the flipper usually, but not always, comes up slower, and sometimes not at all. But test both transistor, as *both* or *either* could be bad.) Also sometimes a bad Fliptronics board U2 chip (74LS374) can cause a flipper to energize as soon as the game is powered on.
- <u>Addams Family ONLY:</u> The Addams Family pinball was the first Williams solidstate "fliptronics" game. It was the only game to use a "Fliptronics I" board (all later games used a "Fliptronics II" board). The Fliptronics I board has a unique personality. If both diodes on the right flipper coil (upper or lower) are missing or broken, as soon as the right flipper cabinet button is pressed in a game, both right flippers will stick in the "up" position. The right flippers will not release until the left flipper cabinet button is pressed! Note this MAY also happen if one diode on each right flipper coil is bad too. This problem can also happen to the left flipper, and is still related to coil diode failure. To fix this, check both right flipper coils and make sure the diodes are not broken or missing. Also make sure the left flipper coil's diodes are present and not damaged. Finally, sometimes a bad flipper diode will cause the Fliptronics I board's TIP102 hold transistor to fail. If the problem still exists after replacing the diodes on all the flipper coils, check the TIP102 hold transistor on the Fliptronics board.

Fliptronics II Board Repair Info.

The Fliptronics board is a pretty robust board. That is, it will be rare that you will need to change any chips on this board. Usually all problems are related to the TIP36 and TIP102 driver transistors, 2N4403 pre-driver transistors, or 1N4004 diodes, or the resistors.

There are four large TIP36 transistors on this board. These are the driver transistors for the high-powered side of the flipper coil. There are four because this board can support up to four flippers (one TIP36 for each flipper). Above each TIP36 is a 220 ohm 1/2 watt resistor.

There are eight TIP102 transistors. Four are used to pre-drive the larger TIP36 transistors, and the other four are used as the "hold" transistors for the low-power side of the flipper coil. There is a 2.6k ohm 1 watt blue resistor next to each TIP102, and a 56 ohm 1/4 watt resistor below each TIP102.

There are eight 2N4403 small transistors used to pre-drive the eight TIP102 transistors. In addition, right next to each 2N4403 transistor is a 1N4004 diode and two resistors (1k and 470 ohm 1/4 watt).

When there is a flipper problem, before replacing anything, make sure there is power (70 volts DC) at all three lugs of the flipper coil in question. If there's only power at one or two lugs, check the fuses on the fliptronics board (remove and test with DMM). If fuses are good, then the flipper coil is bad.

Next check the flipper cabinet opto boards. swap the right and left boards and see if the problem changes. If it does change, you have a flipper opto board problem.

Reseat all the ribbon cables.

With the game on and coin door closed, use an alligator clip and attach one end to ground. Now momentarily touch each metal tab of the Fliptronics' TIP102 transistors (*not* the TIP36). You should see a flipper react (if only a 2 flipper game, four of the TIP102 transistors will do nothing). Remember each TIP102 is controlling either the power or hold part of a flipper coil. So the right most TIP102 (Q12) should be power for the lower right flipper. The TIP102 right next to it (Q11) should be the hold power for the lower right flipper. Moving to the left, TIP102 Q10 should be the power for the lower left flipper, and TIP102 Q9 should be the lower left flipper hold power. This exercise is not testing the transistors. But it is testing the wiring from the Fliptronics board to the flipper, and testing the flipper coil and coil power (fuses). It is also a good way to identify which TIP transistors are controlling which flippers.

If the flipper problem(s) are still there, next check the easy things on the Fliptronics board. That is the resistors:

- Check the four 220 ohm resistors above the TIP36 transistors.
- Check the large blue 2.6k ohm resistors next to each TIP102. Note these will test as 2.1k ohms in circuit. If you get anything less than 2.1k ohms, remove one leg of the resistor from the board and retest it.
- Check the 56 ohm 1/4 watt resistor below each TIP102.
- Check the 1k and 470 ohm 1/4 watt resistors next to each 2N4403.

If any resistors are open (no reading) or questionable, replace them.

Now check the 1N4004 diodes next to the 2N4403 using a DMM set to diode test. Black DMM lead on the banded side should show .4 to .6 volts. Replace if any questionable values are seen

Now check all the 2N4403, TIP102, TIP36 transistors. The transistor checking part of this document tells you how to do that with a DMM. Remember a transistor that tests as "good" is only really good about 90% of the time. If in doubt replace it.

Note the above tested parts are the ones that fail most often on a Fliptronics board. The chips rarely fail! So don't go changing any chips until all the above parts are tested and/or replaced.

If the power side of a coil is not working or the flipper is electrically "on" at all times, replace the associated TIP36, TIP102, 2N4403 and 1N4004 diode. Do not skimp! Replace the entire component power train.

If the hold side of the coil is not working or the flipper is electrically "on" at all times (and you're sure it's not the flipper coil itself), replace the associated TIP102, 2N4403 and 1N4004 diode. Do not skimp! Replace the entire component power train.

Note I have seen a problem with a Fliptronics board where the flipper "fluttered". Normally this would be a hold flipper coil problem, or a Fliptronics TIP102 problem. But in this case it was the Fliptronics TIP102's 1N4004 diode that has failed, which caused the flipper flipper (or "double flip") and not hold in the up position. I found this problem because the 2.6k ohm 1 watt resistor tested low (1.8k ohms). After removing one end of the resistor from the board, I found the resistor tested correctly (2.6k ohms). I then tested the 1N4004 diode again and found it read 1.2 volts (not .4 to .6). Replacing the diode fixed the flipper flutter problem. Note I had previously replaced the TIP102/2N4403 transistors (and not the 1N4004 diode!) and the flipper still fluttered.

In regards to weak flippers and the Fliptronics board. The culpruit of weak flippers is usually mechanical or in the coils. But aside from that, the cabinet flipper opto boards can also be a problem (the optos get old, and turn on and off very quickly and un-noticably, causing the flippers to be weak). If all these areas have been addressed, there are the two LM339 chips on the Fliptronics board. These chips are voltage comparitors, and read the cabinet flipper board optos. The LM339 chips can go bad (rare though), causing the flippers to be weak.

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

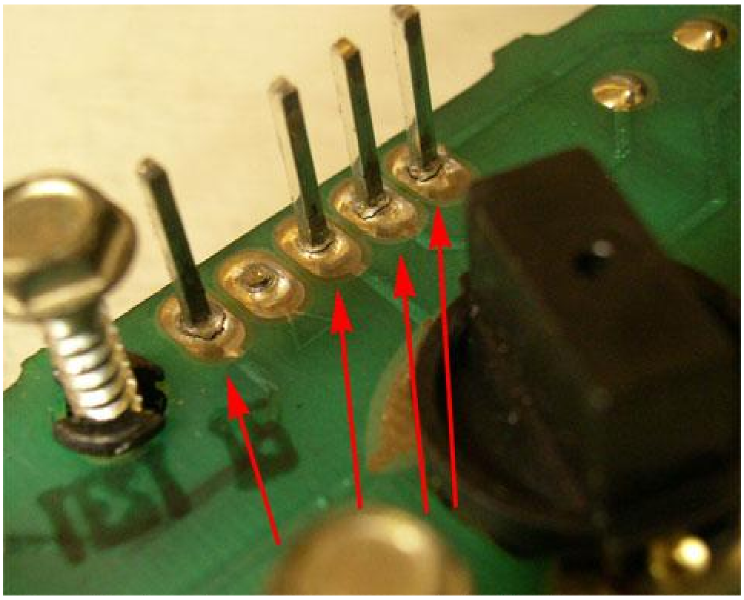
Lights controlled by the CPU (not the General Illumination lights), are controlled in a similar fashion as a switch matrix. That is, there are eight lamp rows, and eight lamp columns. This gives a total of 64 CPU controllable lamps. These lamps are powered by +18 volts DC. This voltage is strobed (turned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

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

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

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

The header pins on an under-the-playfield lamp board. Cracks at these header pins will prevent CPU controlled lamps from working. Resolder these to fix them. Pic by Tx.



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

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

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

No Lamp Matrix Lights Work, or are Confused.
If none of the lamp matrix lights are working, the obvious thing to check is the fuse. If the +18 volts is missing, none of the lamp matrix lights will work and the 18 volt LED will not be lit. This is powered through bridge BR1, fuse F114, LED6, and test point TP8 (on WPC-95 games diodes D11-D14, fuse F106, LED102, and TP102).

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

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

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

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

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

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

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

Lamp Diodes (Lamps that don't work or work "twice").
Each CPU controlled lamp will have a diode associated with it. If this diode is bad (shorted on), it will cause other lamps in that row or column (or even another row or column) to turn on. This can usually be seen in the "All Lamps Test". The faulty row or column will light *twice* in a single lamp matrix sweep (once when it should be on, and a second time due to the short on *another* row or column re-lighting it). The lamp(s) in question are on twice as long as all the other CPU controlled lamps.

Another way to test this is to use the "Single Lamp" test. If two different lamps are on for a single lamp test, there may be a short, a bad diode, or a bad transistor.

If a lamp diode has broken (become open), or is disconnected from the lamp socket, its lamp will not light. Broken diodes can happen on circuit board mounted lamps (555 style bulbs). If the diode was inserted and soldered into the circuit board "tightly", the diode can crack due to mechanical stress and vibration. During the soldering process, the diode body can elongate slightly. When it cools, the diode shrinks back, adding more stress. If there's no other place for that stress to be dissipated, the diode body is the weakest link, and it can crack.

Two Lamps On Instead of One.
If a lamp diode is shorted on (or installed incorrectly), a bad TIP107/TIP102 transistor, or just a short on the playfield lamp matrix, can cause two lamps to act as one. This can be seen in the "Single Lamp Test". Each individual lamp in the lamp matrix (as displayed on the screen) should flash. The "+" and "-" buttons will move the test from one lamp to another. If TWO lamps flash in this test instead of just one, suspect this lamp has having a bad or mis-installed lamp diode, or it's associated TIP107/TIP102 transistors as bad, or just a short between two row or column wires.

It is pretty easy to tell which problem it is. First reference the game manual, and figure out which rows/columns are the problem. To do this, note all the lamps that "double light", and see what row/column they occupy. A pattern should be seen, with the double lights being all in the same row or column. As shown in the previously mentioned Transistor Testing section, test the related TIP107 and TIP102 transistors (as indicated in the manual for the related rows/columns) for a problem.

If that checks out OK, next look for a short and/ or bad lamp diode on the playfield. This is easy to test; just remove the lamp matrix plugs from the power driver board (these connections are shown a few paragraphs below). Using the DMM set to ohms, see if the associated row/column wires are shorted to each other on the disconnected lamp matrix plugs (not on the driver board!). If two lines buzz out with zero ohms, there is a short or bad diode on the playfield somewhere. Shorts happen often from solder drips when someone resolders a coil under the playfield. These solder drips often land on the lamp boards under the playfield, on the header pins, shorting two together.

Testing a Lamp Diode.
In order to test a lamp diode, use the DMM set to diode test. Put the black test lead on the banded side of the diode. A reading of .4 to .6 volts should be indicated. Reverse the leads and put the red lead on the banded side of the diode. A null reading should be shown. Any other reading and this lamp's 1N4004 diode should be replaced. The light bulb doesn't need to be removed, nor does the diode need to be desoldered to perform this test. Also test the diode soldered to the circuit boards that hold the 555 lamps in the same manner (but remove the connector and the 555 lamp before testing).

Common Connectors.
There are several lamp matrix connectors which are common on the power driver board. Here are the breakdowns:

WPC and WPC-S

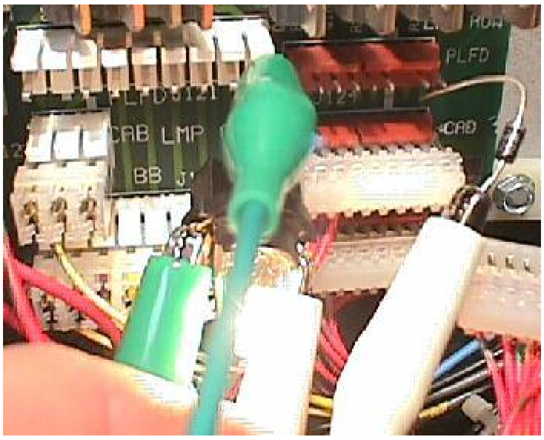
- J133, J134, J135 = Lamp Rows (all wired identical)
- J137, J138 (large plug), J136 (small 3 pin plug) = Lamp Columns (J137, J138 wired identical)

WPC-95

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

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

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



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

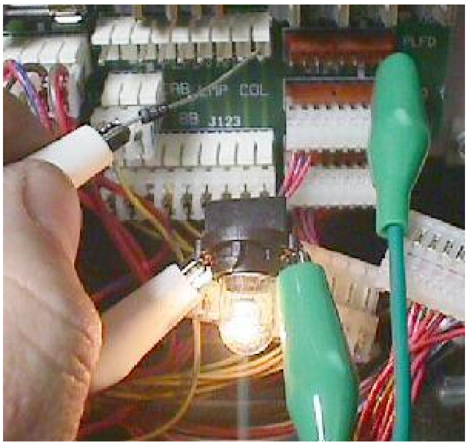
1. Remove the backglass and fold down the display to gain access to the Driver board.
2. Turn the game on.
3. After the game boots, press the "Begin Test" button in the front door. Go to the Test menu's "All Lamp Test" test.
4. Unplug the row connectors at J133 (or J124 on WPC-95) and column connector at J137 (or J121 on WPC-95). These are on the lower right portion of the Driver board.
5. Connect an alligator test lead to column connector pin 1 of J137 (or J124 on WPC-95). Pin 1 is the right most pin, as facing the board.
6. Connect the other end of this test lead to one lead of a 555 light socket. One can be temporarily borrowed from a playfield lamp (make sure it's a working

lamp first!).

7. Connect another test lead to the second lead of the 555 light socket.
8. On the other end of the test lead, clip on a 1N4004 diode, with the non-banded end away from the alligator lead.
9. Touch the non-banded end of the diode to row connector J133 (or J124 on WPC-95) pin 1. Again, pin 1 is the right most pin, as facing the board.
10. The lamp should flash.
11. Move the diode/alligator lead on row connector J133 (or J124 on WPC-95) to the next pin. Again, the lamp should flash.
12. Repeat the previous step, until the last pin of row connector J133 (or J124 on WPC-95) is reached.

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

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



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

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

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

Most Common Problems with Lamps.

- Bad bulb. Any light bulb can burn out. Often it can visually be seen the bulb is burnt, but sometimes it can't. Test the bulb with the DMM, set to continuity. Put the test leads on the bulb. No continuity, and the bulb is bad.
- Wire broken away from the socket. This happens quite often and requires re-soldering the wire back to the socket lug. On lamp sockets, wires are "daisy

chained" from other sockets. Did a wire break "up stream" in the chain?

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

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

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

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

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

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

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

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

All switches on a WPC game (except for the direct dedicated switches, which includes flipper, EOS, and test button switches, which are in columns outside the 8x8 playfield matrix) are in the "switch matrix". The switch matrix on a WPC game is controlled by eight switch columns (or nine columns for Twilight Zone, Star Trek Next Gen, and Indy Jones - more on that later), and eight switch rows. The cross-section of any row and column designates any one of the potential 64 different switches (or 72 switches for Twilight Zone, Star Trek Next Gen, and Indy Jones).

Diagnosing the Switch Matrix: Where's the Problem?

Before you try and diagnose a switch matrix problem, you need to figure out if the problem lies in the CPU board, or on the playfield. You will need to get the game into the T.1 Switch Test diagnostic mode. And from there do some simple testing. The information below describes how to do this. There's a lot of info below, and at first it will seem confusing. But the key is this: break the system down into pieces (the CPU board, the descrete playfield switches/wiring, or the playfield mounted opto boards).

Figure out where the problem lies, and fix it.

The first thing I would do is again relative to the game's internal T.1 switch test diagnostics. And from there, determine if the problem is just one switch, a whole row or column of switches, or opto switches. Then branch off into more analysis. I highly suggest having the game manual when diagnosing switch problems. The inside front cover of the game manual shows the switch matrix rows/columns. This is important information when trying to figure out if the problem is a single switch, an entire row or column, an opto switch, a switch connector, wire colors, etc.

Remember the switch matrix is based on 8 rows and 8 columns (except Star Trek Next Gen, Indiana Jones, Twilight Zone which have 9 columns). If there's just a single switch not working, that's usually pretty easy to fix using this micro switch info. If a couple switches in a row or column don't work, often it's a broken row or column wire under the playfield which daisy chains the row and eight column wires between switches for that particular row and column. This can cause other switches in that row or column "down stream" from working.

In the case of a whole row and/or column of switches, or if the game is reporting a "ground row/column short" error, get the game into T.1 switch test and remove the playfield switch connectors from the bottom of the CPU board. Then do these tests: Switch Columns and Switch Rows. This will tell if the problem is on the CPU board (like a shorted CPU board ULN2803 chip). Or if the problem is just a bent and shorted diode on a playfield switch. Or an opto switch board(s) mounted under the playfield (if the game uses them, which most WPC games do).

If the switch involved is an Opto switch, that will require other repair ideas. Not all games use opto switches, but most do. And some era of games use more optos than others. For example, starting with Indiana Jones, all WPC games use opto switches for the ball trough. And games from Indiana Jones to Demo Man use trough opto boards different than later games (with problematic LM339 chips installed right on the trough opto board). To further complicate things, the problem could be the opto transmitter/receiver itself, or the under-the-playfield mounted board that controls the optos. Often disconnecting the under-playfield opto board (and the trough opto board on games Indiana Jones to Demo Man) will determine if the problem is playfield related, or opto board related. It's a good idea to disconnect the opto board(s) and see if the switch test T.1 reacts differently. (Tip: if it's Indy Jones to Demo Man, then reconnect the opto and trough boards one at a time to see if the problem changes, to help isolate which board is the problem.) Check here for more opto repair information.

Once the problem location is known to be on the CPU board, the playfield, or the playfield mounted opto board(s), that makes things a lot more managable to fix. What you're trying to do is break the problem down into smaller parts (as smaller parts are easier to test, diagnose, and ultimately fix).

If you hadn't noticed, diagnosing switch problems can range from pretty easy to very complicated! Sometimes it best to bring a professional in for these issues. But if you can keep your head straight and follow a systematic approach (as outlined above), often an "average joe" can fix a pretty complicated switch matrix problem. The remainder of this section will deal with individual parts of the switch matrix, how it works, and common problems & solutions to switch issues.

Dedicated Switches (Direct Switches).
The direct switches (or dedicated switches) are not part of the WPC switch matrix and are outside of the 8x8 switch rows and columns. Direct switches include the diagnostic coin door switches and flipper EOS switches. Since these switches do not go thru the CPU board's ULN2803 chip, if there is damage to the switch matrix, 99% of the time the direct switches will still work. This is handy if someone shorted 50 volts to the switch matrix, killing the switch matrix. In this situation, the direct switches will still allow the diagnostics to be run. Because the dedicated switches do not use the ULN2803, they are a bit more simple in operation. There is a row number associatd with the direct switches, but no column. Instead the row wire (orange) is connected directly to ground (black), which triggers the needed dedicated switch. Often if a dedicated switch does not work, the reason is a broken ground wire. The dedicated switches only use CPU chips U16,U17 (LM339) and U15 (74LS240), through CPU connector J205. An easy way to test the dedicated switches is to ground each pin of J205 while the game is in switch test mode. This will tell if the problem is in the CPU board or in the wiring.

The Chips that Control the Switch Matrix.
The switch columns are controlled by a single 18 pin ULN2803 chip on the CPU board at position U20. The switch rows are controlled by two LM339 chips on the CPU board at positions U18 and U19. The direct switch rows are controlled by two LM339 chips on the CPU board at positiion U16 and U17. These chip designations apply to all WPC generations.

On WPC-S and WPC-95 games, the ULN2803 that controls the switch columns on the CPU board is socketed. On all other WPC games up to 1994 this chip is not socketed. When a series of switches goes out, it tends to be the ULN2803 at U20 (all WPC revisions) that fails. Williams recognized this, and started socketing this chip with WPC-S. On WPC-S CPU boards, the ULN2803 chip is underneath the battery sub-board. ULN2803 is equivalent to NTE2018. If U20 dies "hard", it could also blow the 74LS374 at U14 (on WPC-95/WPC-S it's U23, a 74HC237/74HC4514 respectively) on the CPU board.

The LM339 chips that control the switch rows at U18 and U19 (all WPC revisions) tend to fail less often. LM339 is equivalent to NTE834. There are also two more LM339 CPU board chips at U16 and U17 (all WPC revisions). These two chips control the direct switches (coin door, diagnostics, etc). These do not fail often either.

There are also LM339 chips used on the under-the-playfield optic board (if the game has one) or in the ball trough boards on Indy Jones, Judge Dredd, Star Trek, Popeye and Demo Man. If any one of these LM339 chips fail (common on under playfield opto boards), the switch matrix will be confused. When there is a switch problem that can not be diagnosed, disconnect the opto boards and see if problems change. If they do, it's a good idea to replace all the LM339 chips on the under-the-playfield optic board(s), and use sockets for these chips. Remember that games Indy Jones, Judge Dredd, Star Trek, Popeye and Demo Man use trough optic boards with LM339 chips (WCS94 and later games don't have LM339 chips on the trough optic board). So these Indy Jones to Demo Man games have a second opto board with more potential chip problems.

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

> **Check TP3 (TP100 on WPC95) on the Driver board for +12 volts.**
> Again, if the regulated 12 volts is not getting to the CPU board, the switch matrix will not work (*none* of the switch matrix will work). Using the DMM multi-meter set to DC volts, check for +12 volts at TP3 (test point 3, TP100 on WPC95) on the driver board (while the game is on and in attract mode). If +12 volts isn't there, the switch matrix will never work. Also if this 12 volt test point fluctuates to under 11 volts, the switch matrix could exhibit some wacky behavior.
>
> If 12 volts is not at the test point, back up to TP8 (TP102 on WPC95) and check for +18 volts DC. This comes right from BR1 (D7-D10) where the AC transformer voltage is rectified to DC. Also check for +18 volts at the "+" lead of bridge rectifier BR1 (the "indented" lead of the bridge) on the driver board (WPC-S and before). Occassionally the solder joints on this bridge will fail, therefore not providing +12 volts to the switch matrix (see the "Game Resets" section of this document, and solder jumper wires under the board as shown in that section). If 18 volts is there, but there is no +12 volts at TP3/TP100, the next part to suspect is the 12 volt regulator at Q2 (LM7812), or a bad circuit board trace leading to the voltage regulator Q2.
>
> **Wacky Switch Matrix due to Low 12 volts.**
> On some WPC games, in particular Theatre of Magic, a weak BR1 or weak 7812 voltage regulator on the power driver board can cause some wacky switch matrix problems. For example, if the game is doing a "slam tilt" or randomly firing the slingshots or flippers or other coils, the power to the switch matrix may be weak. The 12 volt fluctuation for the switch matrix can often be seen when many of the feature lamps are on. Try removing connector J133 (disabling the playfield controlled lamps) and see if the problem goes away. If it does, rebuild the 12/18 volt power secition (BR1, C6, C7, the Q2 7812 voltage regulator), and install jumper wires from BR1 to its associated filter caps (as described in the reset section). This bridge rectifier and voltage regulator supply the power for the switch matrix.
>
> For example, wacky game behavior on Theatre of Magic (ToM) can be caused by low or intermittent 12 volt power (usually due to a bad or cracked traces around bridge BR1). Maybe most all coils fire like slingshots, magnets, pop bumpers, and the low (hold) voltage on flippers, or even a slam tilt.

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

How does the Game know the Switch Matrix doesn't work?
There is ONE switch in all WPC games called "always closed" (usually switch 24 on WPC games). This switch is monitored by the CPU board. If it sees this switch as open, the game knows there is a switch matrix problem (perhaps no +12 volts!). Also if the connectors are not attached on the CPU board at J206, J207 (colums) and J208, J209 (rows), the CPU board can be confused about switch 24 (because the switch is actually wired "closed" at the coin door interface board via J212). For example, if fuse F115 (or F101 on WPC-95) was blown, removing these connector J206-J209,J212 for testing purposes, the game will probably give an error until the fuse is replaced AND the connectors put back on. These connectors may have to be removed to determine if the switch problem was on the CPU board or in the playfield wiring.

One way to determine this is to disconnect all four switch matrix playfield plugs from the bottom right of the CPU board {connectors J206-J209}. If the error goes away, that usually means there's a playfield short (but there still could be a CPU problem). If the error stays, the problem is definately on the CPU board. (Be sure to keep CPU connector J212 attached as it keeps switch 24 "always closed".) At this point best to test the switch row/columns with a diode and jumper wire in the T.1 diag test to totally rule out the CPU board.

Switch Connectors (all WPC revisions).

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

U20 Chip Failure (or Keeps Failing).

Shorting the Switch Matrix to +50 volts Coil Power.
When in a hurry, the repair person may make an under playfield adjustment with the game turned on. If the coin door is closed, or the game doesn't have a coin door interlock switch, it is easy to short a coil lead (+50 volts) to a switch lead with a screwdriver. This will immediately blow the switch matrix power fuse (F115 on WPC-S or earlier, or F101 on WPC-95), and fry the ULN2803 at U20 on the CPU board. There is a good chance the 74LS374 at U14 (on WPC-95/WPC-S it's U23, a 74HC237/74HC4514 respectively) will fail too on the CPU board. On WPC-S or later games, the U20 chip is socketed (but not the feed chip U14/U23).

Shorting the Switch Matrix to 6.3 volts General Illumination.
Though 6.3 volts is not much voltage compared to the switch matrix's 12 volts, damage can definately occur. For example, on Indiana Jones the left slighshot has a G.I. lamp socket very close to the rivits of the slingshot switch. If these touch, the U20 (ULN2803) CPU board chip can fail, killing the switch matrix column three (green/brown wire which the left slignshot connects). Also a G.I. short to the switch matrix can cause all kinds of strange problems without frying the U20 CPU chip, as seen in the switch edge test. An entire switch row can turn on and off repeatedly. Or nearly all the switch rows can flash on and off. The voltage of the general illumination circuit can definately cause some strange behavior to the switch matrix.

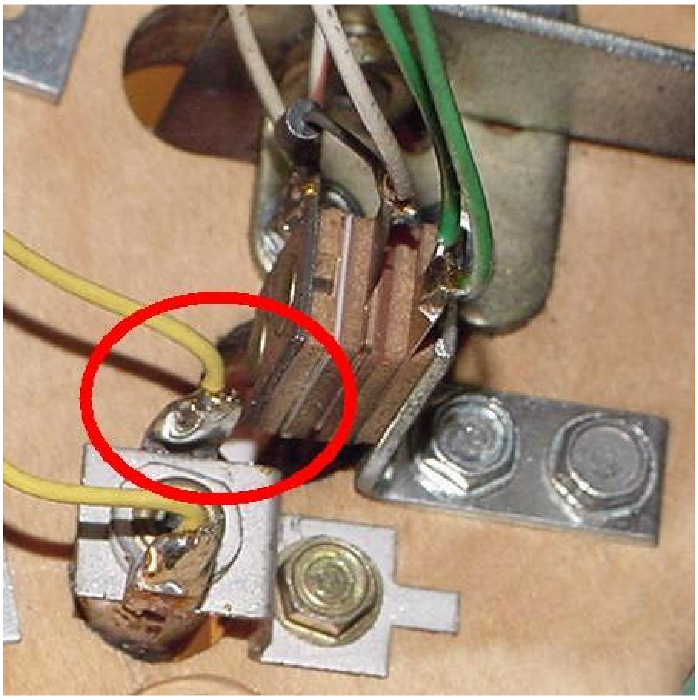
Other U20 Failure Analysis.
Another way to determine if there is a short to power on the switch matrix is to remove U20 and power the game on. With all the switch connectors installed on the CPU board, use a DMM and check U20 socket pins 18 to 11 (switch columns 1 to 8 respectively) for any voltage greater than 12 volts DC. In a working game, with U20 removed, socket pins 11 to 18 should show 12 volts DC. If higher voltage is seen, there is a short on that switch column on the playfield, or some other wiring problem. The flashlamp circuit could be shorted to the switch matrix, or the solenoid power, or even the 6.3 volt AC general illumination.

Also with U20 removed, U20 socket pins 1 to 8 (all the switch rows) should be at +12 vdc. If the u20 socket rows measure +12 vdc but there's switch closures in switch test T.1, there's something wrong in the LM339 section of the CPU board. It's usually the LM339 chips but it can sometimes be other parts, usually due to battery corrosion in that section. If a couple of the 339 chips are socketed you can swap them and see if the problem moves.

Other things can cause U20 to fail too. If the game works for a few minutes and then U20 fails, this could be caused by a bad U14/U23 chip on the CPU board. Or a bad LM339 chip on one of the under playfield opto board(s). A simply way to tell is to unplug all the CPU board's switch plugs and see if U20 fails after 15 minutes or so. If it does not, the problem is on the playfield. If it does fail, suspect U14 (WPC) or U23 (WPC-S/WPC-95) as the problem.

Mark Clayton describes a way to help figure out a U20 problem using the "dead" u20 chip. You can use an Ohmmeter to see which column(s) are dead, and track the problem back to the playfield looking at all switches in the dead column(s). The ULN2803 is little more than eight Darlington transistors in one chip. Just take the dead u20 and measure Ohms (or diode test) straight across the part. Start at pin 1 (that is, pin 1 to pin 18, pin 2 to pin 17, etc.) Put the red DMM lead on pins 1 to 8 and the black DMM lead on pins 18 to 11. The value that you get on the meter will vary depending upon how the meter deals with Darlingtons (most meters will show .4 to .6), but what you're looking for is one or more measurements that are way different than the others. Remember u20 pins 1/18 is column one, pin 2/17 column two, and so on. It's a quick test and it can help narrow down the area with the problem.

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



Row or Column "Ground Shorts" and the U20 Chip.
The CPU board's U20 chip ULN2803 is a common failure point for the switch matrix. If the game is reporting rows or columns as shorted to ground (especially multiple shorted rows or columns), often this U20 chip and downstream the 74LS374 chip at U14 (on WPC-95/WPC-S it's U23, a 74HC237/74HC4514 respectively) on the CPU board are usually the problem. Rarely the CPU board's LM339 chips fail too, where U18 controls rows 1,2,3,4, and U19 controls rows 5,6,7,8 (but replace U20 first followed by U14/U23, and then look at U18/U19 last). Another thing to remember is there's LM339 chips on the under-playfield mounted opto board(s). If there was a 50 volt coil power to switch short, often the LM339 chips on these opto board(s) can fail. Disconnect the opto board(s) and see if the problem changes. This will isolate the problem to a particular board. Remember Indy Jones to Demo Man uses a different trough opto board that has its own LM339 chips, and these can fail too (in addition to the *other* under-PF mounted opto board on these games).

After Replacing CPU Chip U20, the Fuse does not Blow, but Many Switches show in the Test Report.
This is very common. The CPU is confused from the blown U20 switch matrix chip, and will report many switches as "bad" in the test report. To "unconfuse" the game, go into diagnostic, and select the first switch test (T.1, switch edges). Using a pinball, manually activate the switches that came up in the test report (see the game manual for their location, if they can't be found). The switches should report correctly on the display in this test mode. After activating each switch once, exit the diagnostics, and the game should work normally. Alternatively, if the game will allow it, just play a game! This is often all that is needed to clear the test report.

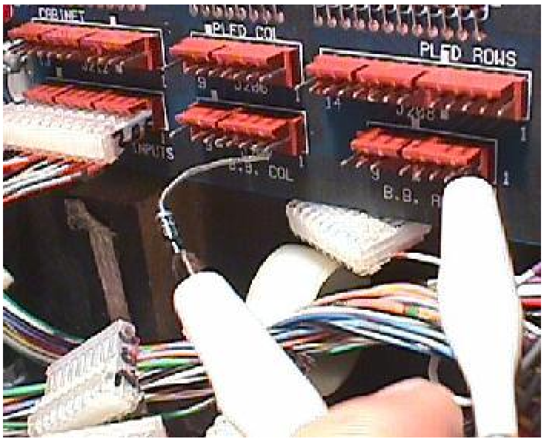
More on Ground Row Shorts and Other Strange Switch Problems.
Switch ground short errors are often the most confusing problem to find. One may think that if the game is reporting a switch ground short, that a playfield row switch wire has somehow been shorted to ground. Unfortunately this is rarely the case! More often it is some other problem (usually a bad U20 CPU chip, or a bad LM339 chip on an under the playfield opto board, especially if the U20 and U14/U23 CPU chips has already been replaced).

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

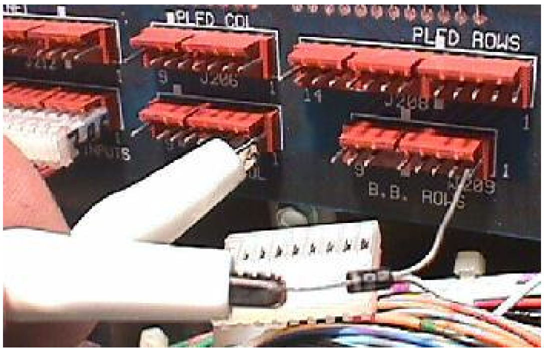
Now that we know there really is not a playfield switch grounding problem, we can do some further testing. Disconnect all four switch input plugs from the bottom of the CPU board. Put the game into switch diagnostic test T.1, and none of the switches should be activated (except for switch 24, which is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

To isolate the switch problem from the playfield, it is a good idea to use a jumper wire to test the switch matrix, right at the CPU board row and column plugs. The diode is optional and not needed if all the playfield switch connectors are removed from the CPU board. This is procedure is described later in this section, but here's a couple pictures below. Also don't forget a ground short or other wacky switch behavior could be caused by a bad LM339 chip on the under-PF mounted opto board(s).

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



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



If a particular row or column of switches does not work using the above jumper wire/diode test, chances are good the CPU board U20 chip (or possibly U14/U23) have failed. Battery corrosion on the CPU board can also cause these problems, so keep that in mind too (any green parts on the CPU board is a bad sign).

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

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

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

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

The Ninth Switch Column On Indy Jones, Twilight Zone, Star Trek Next Gen.
On these three games Williams needed more than 64 switches, so an additional ninth column of switches was added. This was done using a small Auxiliary Eight Driver PC Board, mounted in the backbox on the top far right side. Note two other games also used this Auxiliary board (Roadshow, Demo Man), but do not use the ninth switch column.

IMPORTANT NOTE: This ninth column of switches does NOT show up in the standard Switch Matrix test! Activating the switches below will show nothing in the switch tests. But Williams does provide a special test menu item for the ninth column switches (for example, "Clock Test" for TZ and "Rt Gun Test" for STNG). Also if the ribbon cable from the CPU board to this Auxiliary Switch board is bad or missing, the ninth column of switches will not work.

On Twilight Zone, as Mark Clayton describes, the TZ clock optos are driven by a ninth column driver that's on the Auxilary driver board. By design, the CPU can only activate one of the first eight switch columns - that's imposed by the digital logic on the CPU board. However, the ninth switch column is controlled by software and a separate circuit off the CPU board and on the Aux driver board. So if there are any problems with that 9th column driver, it can interfere with testing. On Twilight Zone while troubleshooting the switch matrix, it's best to disconnect the clock. The game doesn't drive the clock opto column during switch test anyway, so if this "fixes" any problems, there's something wrong with the ninth column driver, or more likely with the wiring to the Aux driver board.

	TZ Col 9 Gray-Wht Q? J5-1	IJ Col 9 Vio-Wht Q11 J5-4	STNG Col 9 Vio-Wht Q11 J5-1
Row 1 Wht-Brn	Clock 15 Min	Wheel Pos 1	N/A
Row 2 Wht-Red	Clock 0 Min	Wheel Pos 2	Left Gun Mark
Row 3 Wht-Org	Clock 45 Min	Wheel Pos 3	N/A
Row 4 Wht-Yel	Clock 30 Min	Mini PF Left Lim	N/A
Row 5 Wht-Grn	Clock Hour 1	Mini PF Rght Lim	Rght Gun Home
Row 6 Wht-Blue	Clock Hour 2	N/A	Rght Gun Mark
Row 7 Wht-Vio	Clock Hour 3	N/A	Left Gun Home
Row 8 Wht-Gray	Clock Hour 4	N/A	N/A

There are some things to check on the Auxiliary8 board if you are missing the ninth switch matrix column:

1. Are both the LEDs on the 8-driver board ON? (They should be on.)
2. Check resistor R37. Make sure there is +12V on one side of this resistor.
3. Check the other side of R37 using a logic probe. There should be a strobing signal. No strobe means a bad Q12 (a very common problem.)
4. Check resistor R3 with a logic probe, again should see strobing. No strobe means bad U1.
5. Check resistor R18. Should be strobing. No strobe means a bad Q1 or D1.
6. Check U1 pin 2. Should see strobing since it's part of the extended switch matrix ninth column. No strobe means a bad/mis-seated ribbon cable.

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

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

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

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

If the problem is still present, Check for solder splashes and maybe a nut/bolt that has fallen somewhere and has caused a playfield short. Shorts on the playfield are quite common. Somewhere, the 20 volt lamp matrix or flashlamp circuit is getting shorted to the switch matrix. Or the 50 volt solenoid voltage is getting shorted to the switch matrix. Look under the playfield for lamp and solenoid wire lugs that are close to switch lugs. The problem could also be on the top of the playfield. Perhaps a errant pinball knocked a lamp socket into a switch lug, causing a permanent or intermittent short.

If nothing can be found, here is a techinque to help find which switch is shorted:

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

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

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

Using the Internal Switch Tests.
To test switches, use the WPC internal test software. Press the "Begin Test" button, look at the test reports and make note of any problems (if the game shows a test report), and go to the Test menu. Select the first T.1 "switch edge" test. Activate any switch on the playfield **using a pinball** (this simulates real game play), and it should show on the game's display. The display will indicate the wire colors going to this switch, too.

On ocassion some games won't let you into the diagnostic mode. Pressing the "Enter" coin door button does nothing! This can be caused by the switch being broken (that happens more than one would think). The coin door switches are cheap, and they do corrode internally, making them not work. I will use a small screwdriver and short the two wires going to the switch to see if that gets the game into test mode. If so, the switch is bad and will need to be replaced. Also there is one black ground wire common to all four coin door switches. If this wire breaks, none of the switches will work. Also make sure the connector on the CPU board for the coin door switches is attached (as facing the CPU board, it's the lower of the pair of far bottom left connectors J205).

Check for Broken Switch Wires "Up Stream" (Switches are "Daisy Chained").
Since the switch matrix is a series of eight columns and eight rows, the playfield switch wiring is "daisy chained". For example, check out a switch matrix row in the manual. For row one, the playfield switch in column three row one (switch 31) is wired before the playfield switch in column four row one (switch 41). So if the row one wire breaks off switch 31, all the switches "down stream" (41, 51, 61, 71, 81) will not work! This is one of the simpliest, and easily overlooked, switch matrix problems.

Another hint that the there is a switch matrix wire broken; If for any particular column and row other switches work, this indicates there probably is not a problem on the CPU board! If there was a column/row problem on the CPU board, it would most likely affect all the switches in that column or row.

Broken switch wires can also occur at the CPU connector too. Make sure to look at the connectors. The wires can fatique and break at the connector, inside the insulation!

If a Bad Switch is Found.
If a switch does not work, check these things:

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

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

Quick & Easy Switch Matrix Diagnosis.
This is a simple case where one or more switches are not working. The first thing to do is check the game manual and find the switch matrix chart. There is also a drawing of the playfield with all the switch numbers shown in their respective positions. You will need to know the switch numbers which don't work. To do this, use the game's switch test diagnostics and the game manual, and write down the switch numbers that don't work.

In most simple cases, the non-working switches will all be in the same Row or Column. For our example, say that half of the switches in column 4 are not working (if your situation has non-working switches in multiple rows/columns, you will have to repeat the following steps once for each row and/or column).

Referring to the switch matrix chart in the manual, at the top of the chart it will give the column's wire color (column 4, Green/Yellow) and the pin on the CPU board where the column 4 originates (J206/J207 pin 4). With this information, follow these steps:

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

playfield pinches the wire and cuts the internal strands without breaking the insulation, while the playfield is lifted and lowered. The only way to find this problem is to use a DMM's continuity feature and "buzz out" the Green/Yellow wire from switch to switch (start with one lead of the DMM connected at the CPU board's connector pin J206 pin 4 in this example, and the other DMM lead on each switch, looking for continuity).

5. If all switches check out and the wire/continuity is good, the problem is on the CPU board itself. Go back to J206 pin 4 and trace that pin back to the chip it connects (in this case U20 pin 15 as shown on the top of the switch matrix chart for column 4). Use the DMM's continuity feature to check this. The best way to check continuity is to put one lead of the DMM on the first switch in the daisy chain, and the other lead on U20 pin 15 (for this example of column 4). This will test the wiring from the playfield all the way to the CPU board's logic point. If the continuity checks out good, then I would suspect the chip which connects to J206 pin 4 (in this case ULN2803 chip at U20, a common switch matrix failure point).

Here's the switch column connections to U20 chip:

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

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

Slam Tilt Stuck Closed Error.
Upon turning the game on, a "slam tilt stuck closed" error is shown, and the game just won't do anything past that. This can be as simple as the slam switch inside the coin door is bent closed. Also there is a slam switch in the bottom of the cabinet to the left of the coin box (be sure to check that switch too). Or it could be some sort of CPU switch problem.

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

Upper Flipper Switch Bad, but my game doesn't have an Upper Flipper!
On Williams games that use flipper opto switch boards (Addams Family and later), the flipper opto boards have TWO switch optics. One optic controls the lower flipper, and the other controls the upper flipper. The same opto board is used on all games, even if the game has no upper flippers.

Unfortunately, on some games, the software can create a switch error "test report", if the game thinks the upper flipper board optic switch is bad (even if the game has no upper flippers, and is not using the switch). If the problem is really bothersome, the opto can be replaced. But often, the problem is mearly the metal or plastic flipper opto interuptor (the passes between the "U" of the opto switch) is never moving outside the "U". By bending the activator to clear the optic's "U", often this error message can be cleared.

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

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

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

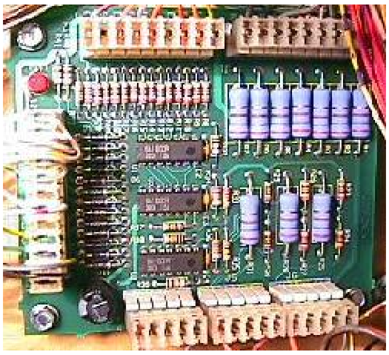
For example, if a row wire is attached to the wrong end of the switch's diode, the following can happen: If the mistake-wired switch (#1) is triggered and another switch (#2) on the same column is triggered at the same time, then another switch

(#3) on the same row as the mistake-wired switch #1 is triggered, the switch (#4) on the same column as switch #3 and on the same row as switch #2 will also shows as triggered, even though switch #4 wasn't actually triggered. (Wow, that was confusing!) For example, row 3 column 3 (r3c3) is mistake-wired as described above. If r3c3 and r2c3 are triggered simultaneously as well as r3c6, then r2c6 will also show as triggered (falsely).

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

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

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



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

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

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

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

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

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

Fail-Safe Diode Test.

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

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

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

- Disconnect the middle green (ground) wire from the switch. It should have a quick connector. If the middle green ground wire is soldered to the switch, ignore this test and do the above "fail-safe" diode test.
- Put the DMM on diode setting.
- Connect the black lead of the DMM to the diode's banded side, and the red lead to the non-banded side.
- Activate the switch.
- A reading of .4 to .6 should be shown on the meter.
- Reverse the DMM's leads (red lead to the diode's banded side), and keep the switch activated. A null meter reading should be indicated.

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

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

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

Installing a New Switch Diode.
The diode can be replaced with a new 1N4004 (or 1N4002 or 1N4001) diode. Make sure the new diode is installed with its band in the same orientation as the old diode (assuming it's correct!). If unsure, compare the diode's band orientation to a working

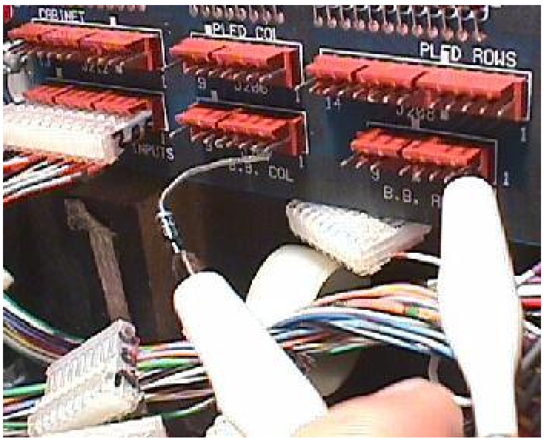
switch and diode. Most (but not all!) switches have the green (column) leads connected to the center (normally open) lead of the switch. Then the white (row) wire is connected to the switch lead closest to the center lead (the normally closed lead). The banded end of the diode is connected solo to the far (common) switch leg, and the non-banded end is connected to the same leg as the white (row) wire. **There are some exceptions to this mounting.** The game manual should specify any non-standard switch installations (Bride of Pinbot's zero position head switch is one such exception).

*Notice the orientation of the diode's band on these switches. On a micro-switch, the column (green) wire usually goes to the center lug, the row (white) wire and the non-banded side of the diode to the lug **closest** to the center. The band on the diode goes to the solo, far third switch lug. The leaf switch uses the same connection method (green to center, banded end of diode solo). Note there are some exceptions to this mounting.*


Accidental Reversal of a MicroSwitch's Row and Column Leads (mis-wired switch causes switch matrix havok!)
If someone has installed a new microswitch, the row and column leads could be accidentally reversed to the switch. Say for example switch 48 is a microswitch in the game, and has the row and column wires accidentally reversed. The switch matrix will still reconized this switch (the switch will seemingly work), but is registered as switch number 68, not 48! This can be a hard problem to find, as the switch still seems to work. Unless there is access to the game manual, and know that this switch should be number 48 (and not number 68), the problem may not be found!

If a switch is mis-wired, it can cause other problems too. Using the internal wwitch test, often a single switch can show as multiple switch closures (one switch shows two or more switches activated during the switch test). Normally looking for crossed wires, bad diodes, bad LM339 and ULN2803 chips on CPU or under-the-playfield optic board would be the thing to do. But there can be another (simple) cause too: a switch wired completely backward. This happens often when someone changes a switch, and accidentally wires it "backwards". Keep this in mind when diagnosing switch matrix problems.

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



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

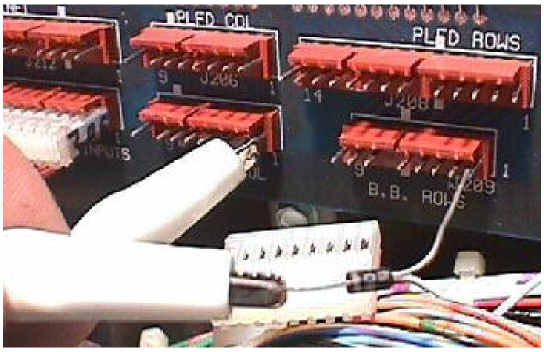
1. Remove the backglass and fold down the display to gain access to the CPU board.
2. Turn the game on.
3. After the game boots, press the "Begin Test" button in the front door. Go to the Test menu's "Switch Levels" test.

4. Unplug the connectors at J212, J206, J207, J208 and J209 (lower portion of the CPU board).
5. Connect an alligator test lead to pin 1 of J209. Pin 1 is the right most pin, as facing the board.
6. Optional*: On the other end of the alligator test lead, clip on a 1N4004 diode, with the banded end away from the alligator lead.
7. Touch the banded end of the diode (if using a diode) or the other end of the aligator clip to pin 1 of J207. Again, pin 1 is the right most pin, as facing the board.
8. The display should show switch 11 is closed.
9. Move the diode/alligator lead on J207 to the next pin. The display should show switch 21 is closed.
10. Repeat the previous step, until pin 9 of J207. Switches 11, 21, 31, 41, 51, 61, 71, 81 should be closed on the display as moving forward, pin by pin, on connector J207.

    Note: on some WPC games, columns 8 and/or 7 are not used. In these cases, there may be no indicator for switches 81 and/or 71.
    * Diode not needed if all playfield switch connectors are removed.

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

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



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

1. Remove the backglass and fold down the display to gain access to the CPU board.
2. Turn the game on.
3. After the game boots, press the "Begin Test" button in the front door. Go to the Test menu's "Switch Levels" test.
4. Unplug the connectors at J212, J206, J207, J208 and J209 (lower portion of the CPU board).
5. Connect an alligator test lead to pin 1 of J207. Pin 1 is the right most pin, as facing the board.
6. Optional*: On the other end of the alligator test lead, clip on a 1N4004 diode, with the non-banded end away from the alligator lead.
7. Touch the non-banded end of the diode (or alligator clip if not using a diode) to pin 1 of J209. Again, pin 1 is the right most pin, as facing the board.
8. The display should show switch 11 is closed.
9. Move the diode/alligator lead on J209 to the next pin. The display should show switch 12 is closed.
10. Repeat the previous step, until pin 9 of J209. Switches 11 through 18 should be closed on the display as moving forward, pin by pin, on connector J209.

    * Diode not needed if all playfield switch connectors are removed.

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

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

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

1. Remove the backglass and fold down the display to gain access to the CPU board.
2. Turn the game on.
3. After the game boots, press the "Begin Test" button in the front door. Go to the Test menu's "Switch Levels" test.
4. Unplug the connectors at J212, J206, J207, J208 and J209 (lower portion of the CPU board).
5. With the logic probe connected to power and ground, probe each pin 1 to pin 9 of J207 (pin 1 is the right most pin, as facing the board). These are the switch columns. All pins should show PULSE on the logic probe. If no pulsing

activity is shown, the ULN2803 at U20 is bad.
6. With the logic probe connected to power and ground, probe each pin 1 to pin 9 of J209 (pin 1 is the right most pin, as facing the board). These are the switch rows. All pins should show HIGH on the logic probe. If a pin is not high, its corresponding LM339 on the CPU board is bad (rows 1,2,3,4 is U18, rows 5,6,7,8 is U19)

Switch matrix short: is it the CPU board or the playfield?
One of the diagnostic errors gotten from WPC games often is "switch matrix row shorted". This can happen for a variety of reasons (see below), but the big question is this: is the short on the CPU board (a failed component like the LM339 at U18-U19 or the ULN2803 at U20), or on the playfield (where a switch may be physically touching ground)? The easiest way to determine this is to disconnect all four switch matrix playfield plugs from the bottom right of the CPU board (connectors J206-J209). If the error goes away, there is a playfield short. If the error stays, there is a problem on the CPU board.

Further Diagnosing of the Switch Matrix.
If there is a switch matrix problem, the first plan of attack is to do the above column and row switch matrix tests. If these tests pass, the problem most likely is in the wiring. Note most switch failures show as Row failures (even though it could be a column problem). Here are eight different ways the switch matrix can fail. All require use of the internal "switch level" or "switch edge" tests of the game.

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

The Optic Switches are Going Crazy!
The optic switches are a bit more complicated than standard micro switches. All the optics require +12 volts to operate. If this 12 volt unregulated supply gets interrupted (usually fuse F116 on WPC-S and prior, or F109 on WPC-95) or has become intermittent or drops to a lower voltage, the switch matrix can go crazy. Sometimes this can be seen in the diagnostic switch tests as optic switches that very quickly open and close.

This can be caused by cold or cracked solder joints on the connectors going to optic boards (or a bad fuse). While the game is in the switch test mode, wiggle the wires and connectors on the opto driver boards under the playfield. Also check the connectors at the power driver board too.

Another problem can be cracked power solder joints on the power driver board at capacitor C30 and bridge BR5 (WPC-S and prior), or capacitor C8 and diodes D3, D4, D5, D6 (WPC-95). This happens much more often on WPC-S and prior games though. Soldering jumper wires to capacitor C30 (or C8 for WPC-95) can fix this problem.

If a large number of optics seem to be affected, it could also be a CPU board problem. The U20 chip (ULN2803) on the CPU board may have failed (this chip is socketed on WPC-S and later games). Or possibly the +12 volt bridge and/or its associated capacitor on the power driver board has a cracked solder pad, or the +12 volt bridge itself could be bad.

Fliptronics Flipper Switches, EOS switches, and Test Button Switches.
On WPC-95 games, the flipper switches are wired directly to the CPU board (on WPC-S and prior Fliptronics games, the flippers are wired directly to the Fliptronics board). The test button switches (inside the coin door) are also wired directly to the CPU board on all WPC revision. These switches **do not** go through the switch matrix on any WPC revision. The flippers and EOS switches (on WPC-95), and test button switches (all WPC revisions) are part of set of 8 direct switches to the CPU board, which go through two LM339 chips, at position U16 and U17.

On WPC-95, the EOS switches go to connector J208 on the CPU board, and the flipper opto switches go to CPU connector J212. On pre WPC-95 games, the EOS switches go to the Fliptronics II board connector J906, and the flipper opto switches go to Fliptronics II board connector J905. The test switches on all WPC game revisions go to CPU board connector J205.

On pre-Fliptronics games, the EOS switches and flipper switches are NOT wired through any circuit board. They are wired directly to the flippers themselves. The cabinet flipper switches and EOS switches just complete the flipper power circuit to ground.

Switch Maintainence.
Here are the procedures for maintaining WPC switches:

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

Micro Switch Notes.
Yes race fans, micro switches do wear out! Generally this happens when the plastic "nib" that the switch activating arm activates wears out. But more common is internal wear. Microswitches are only designed to last 100,000 closures. After this, the mechanical parts inside the switch just plain wear out (or become intermittent or "sticky"). At this point, there is nothing that can be done except replace the switch.

With this in mind, nearly all the micro switches in any given "used" pinball machine are near the end of their life! Most WPC games on location got at least 10,000 commercial plays (in some cases like Addams Family upwards of 50,000 plays). So take something as simple as the switch in the shooter lane. This sees at minimum three closures per game (three balls), and probably a lot more if the game goes into multiball. So say a given game has 25,000 plays and is set to three balls. That means the shooter lane switch has seen at minimum 75,000 closures! And realistically, that number is probably much higher. So nearly every microswitch in the game is at the end of its life. And that's just the shooter lane (I would expect ramp and lane micro switches to have many more closures per game).

But most micro switch problems are related to the metal activator. If this metal activator gets bent down too far (from contact ball contact), a switch may not work. This fix is just a matter of re-bending the activator (please do this with the game off).

Another thing to remember about micro switches is excessive soldering heat will easily damage them. These switches are almost entirely plastic. If too much heat is applies when soldering a diode or wire to them, it can easily melt the internal parts or even the switch's plastic body. This often makes the switch "sticky" and intermittent. So be careful when soldering to these switches.

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

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

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

End of WPC Repair document Part Two.

---

* Go to WPC Repair document Part One
* Go to WPC Repair document Part Three
* Go to the Pin Fix-It Index at http://pinrepair.com

Not Found

The requested document was not found on this server.
