Williams WPC

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3 Technical Info

At the heart of the WPC MPU is the Motorola 68B09EP microprocessor, running at 2Mhz. Note that the "E" suffix indicates externally clocked and is necessary to work in a WPC MPU. The "P" suffix merely indicates a "plastic" chip case. 6809 processors lacking the "E" suffix will **not** work in a WPC MPU.

The 68B09EP is a 2Mhz, 8-bit/16-bit CPU, with a 64KB address space. Bank switching is required to address more than 64KB. Bank switching is accomplished by the ASIC in WPC systems. The game ROM size varies from 128KB to 8MB, depending on the game. 8KB of battery backed RAM is available to the processor.

For more information, see The FreeWPC Manual (http://www.oddchange.com/freewpc/manual/The-WPC-Hardware.html#The-WPC-Hardware)

3.1 WPC Parts List Lookup

A really nice utility has been put together by Øyvind Møll, enabling lookup of WPC parts. The utility can be used to see which games used particular parts. The utility can be found here (http://www.moll.no/pinball/parts/) .

3.2 WPC System Generations

3.2.1 WPC CPU

The WPC CPU was the cornerstone of the new WPC pinball system, introduced by Williams in 1990.

The board has the following features:

- Motorola 68B09E processor
- Switch matrix inputs
- 8k of CMOS battery-backed memory
- A single EPROM, sized from 128K (1 megabit, 27C128) to 1M (8 megabits, 27C080 / 27C801)
- Watchdog circuit and master reset
- Three digital I/O ports - general-purpose; display; auxiliary (labeled "display")
- WPC ASIC - a 108-pin PLCC that has decoding, watchdog, and real-time clock circuitry.

What Goes Wrong

Loose Chips - resets and strange behavior

The natural heating and cooling cycle, and vibration, in a pinball machines causes the socketed chips to slowly walk out of their sockets. This loosening can cause mysterious behavior and resets. Firmly pressing each socketed device - including the ASIC - and listening for a small click can solve many odd problems.

Battery Corrosion - rows of switches failing

When batteries reach old age, they always leak electrolyte. In WPC boards, this electrolyte drips onto the switch matrix circuits. There, it causes extensive corrosion. The corrosion will eat up traces under the green solder mask, creating a lumpy appearance. This corrosion is extremely destructive. It must be caught early, and gently washed with vinegar. Damaged components must be replaced, and damaged traces cleaned with a fiberglass brush and carefully tinned with a soldering iron. Battery corrosion can render a board unrepairable, or undesirable.

The Switch Matrix - assorted switch problems

The WPC system, like many pinball machines, uses a switch matrix to read the switches. The matrix is 8 rows by 8 columns, and can read 64 switches with just 16 wires. Under the playfield, the wires snake between the lights, creating strings of rows and strings of columns. The lights are isolated with diodes.

The root cause of switch matrix problems on the WPC CPU is often a voltage short to the switch matrix. This can happen with residual charge from the solenoid or flasher supply, so the machine does not have to be on for damage to occur. One easy way to do this is to touch a coil lug while adjusting slingshot switches. The row detectors - the LM339s - are quite safe from everything but the 70V solenoid voltage, and will often survive that. The column drivers, however, are directly exposed to the wiring. So many shorts - from the GI; lamp matrix; flashers; or solenoid wiring can destroy the driver. A solenoid wiring short will often destroy the 74LS374 at location U14 ahead of the driver as well.

The symptom of a bad driver is a column short that does not go away when the playfield is disconnected. A bad driver may also be confused by neighboring columns, so switches may register twice.

WPC-089 CPU, this one from Twilight Zone, with battery holder removed.

3.2.2 WPC-S CPU

The WPC-S CPU is the second generation of WPC CPU board. The designer switched to a remote battery holder, located on a daughter board that clips to posts on the lower half of the board. This approach mostly eliminated the PCB damage caused by battery leakage. The next version of the board, the WPC-95 CPU board, switched to a plastic battery holder that also protects the board. The board also has different switch matrix connectors to WPC and WPC-95.

The digital I/O connectors remain unchanged from the WPC CPU.

The most significant difference was the introduction of the security PIC. This devices contains a serial number and a handshake mechanism. The serial number is displayed at startup, and allowed the manufacturer to identify the dealer who sold a machine into a particular region. This approach was necessary when substantial price differences were common across Europe, to prevent grey imports.

To prevent simple removal of the PIC, the device also controlled the switch matrix, and would not operate without a correct machine code from the WPC CPU. Therefore, there is one PIC for each machine. An incorrect or defective chip will result in a "G13 error" or "U22 error" at startup.

When buying a used WPC-S MPU, the battery holder is often missing. If connecting a battery pack, a Molex housing and 2 crimp contacts is needed. The part number for the 5 pin housing is 50-57-9405 (Digikey WM2903-ND). The crimp contacts are part number 16-02-1125 (WM2554-ND).

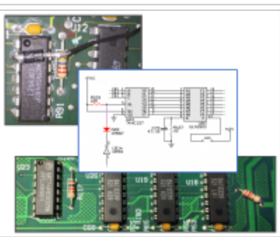

WPC-S CPU

3.2.3 WPC-95 CPU

The WPC-95 CPU is the third generation of the WPC CPU design. It includes the security PIC added in the WPC-S system, and returns to an on-board battery holder. The new battery holder has a large plastic shell, designed to shield the PCB from any battery leakage. The pinout of the switch matrix connectors changed again from WPC-S.

WPC-95 CPU Board

3.2.3.1 WPC-95 CPU Factory Modification



WPC-95 CPU Board factory mod. Drawing by Sascha Voskuil.

CPUs manufactured for Jack*Bot and Congo sample games before 12-15-95 have a factory modification that includes one cut, an additional diode, and an additional resistor. Williams Service Bulletin 86 (http://www.planetarypinball.com/mm5/Williams/tech/sb86.html) details the reason for the mod, premature loss of backup battery voltage.

3.3 WPC Power/Driver Board Generations

3.3.1 WPC-089 Power/Driver Board

The WPC power-driver board converts AC power from the transformer; drives the solenoids; drives the lamp matrix; drives the GI lamps; and detects flipper switch operation in non-FlipTronics machines.

The power-driver board has the following functions:

- AC rectification and smoothing for 70VDC solenoid voltage
- AC rectification and smoothing for 20VDC flasher voltage
- AC rectification and smoothing for 18VDC lamp matrix voltage
- AC rectification and smoothing for unregulated 12V supply
- AC rectification and smoothing for 5VDC flasher voltage
- Regulated 12V supply

- Regulated 5V supply
- 6.3VAC supply for GI circuits

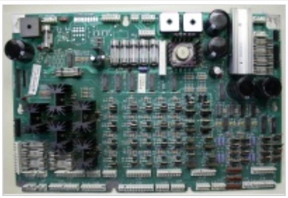
- Power control for high power solenoids
- Power control for low power solenoids
- Power control for flashers

WPC Power-Driver board with Flipper Relay, or the -1 version.

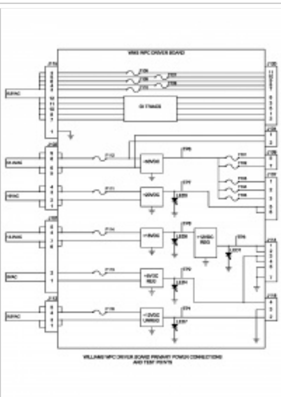
- Power control for lamp matrix
- Power control for pre-FlipTronics flippers (not on all boards)
- Sense optos for pre-FlipTronics flippers (not on all boards)

- Power control for 5 6.3VAC GI channels using four-sector triacs
- Zero crossing sense for AC line in

- Logic interface to WPC CPU



WPC Power-Driver board without Flipper Relay, or the -3 version.



Summary schematic of WPC Power Driver board showing test LED's and test points. A PDF of this image can be viewed here

3.3.1.1 WPC Power/Driver Board Layout Errors

3.3.1.1.1 C9 Connection Error

WPC Power/Driver board with C9 connection corrected.

At the time that this PCB was laid out and manufactured, a small tantalum capacitor, located at C9, was connected to the wrong side of the LM323K 5VDC regulator. While it should have been connected to Vin, it was in fact connected to Vout. The picture at left shows a method to correct the board so that it matches the schematics, also shown at left. In this picture, an additional "tab" was added to the top bolt of the regulator and soldered to ground, creating a redundant path to ground for the regulator.

Note that while the schematics show this capacitor as .33μF, it is listed as 2.2μF in each game's parts listing, matching the capacitor that is actually installed.

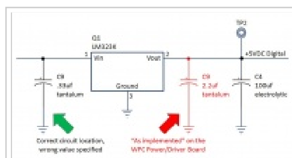
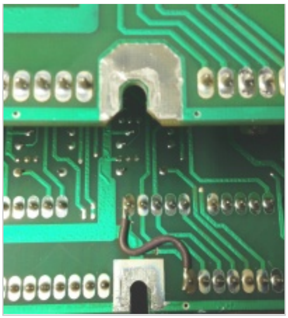


Image of WPC Power/Driver board schematic, showing LM323K 5VDC regulator and C9.

This change isn't generally considered necessary and not thought to be a significant contributor to game resets. The original purpose of the cap was to filter high frequency noise. According to the LM323K datasheet, a 1 to 2μF tantalum capacitor should be added to the input of the LM323K if the regulator is more than 4" away from the main filter capacitor. The regulator is just inside of 4" from the 15,000μF filter capacitor at C5. As it sits on Vout, it causes no harm, but does no good either.

3.3.1.1.2 J122/J124, pin 1 Connected to Board Ground

Some revisions of the WPC power/driver board, were manufactured with J122 and J124, pin 1, connected to board ground. This would cause whatever is connected to those connector positions, to be turned on constantly. For the game Twilight Zone, this would result in the left mini-playfield magnet being powered constantly. The picture at left shows a factory modification to the power/driver board to rectify the problem.



Two power/driver boards showing the factory corrected trace routing (bottom) and a later version of the board with the correction incorporated into the PCB mask (top).

3.3.2 WPC-95 Power/Driver Board

WPC-95 Power/Driver board. This is the later model, with zero ohm jumpers installed in the GI circuit, lower left.

The WPC-95 Power/Driver board performs all of the same functions as it's WPC predecessor, and also integrates flipper power circuits into the design, eliminating the need for the FlipTronics board present in WPC FlipTronics I & II games as well as WPC-S games. The bridge rectifiers are replaced by ganged 6A2 diodes and the filter capacitors were spec'd down from 15,000μF to 10,000μF. While the WPC P/D board supported brightness control of 5 general illumination circuits, the WPC-95 P/D board can control brightness of only 3 general illumination circuits. The two remaining GI circuits are used for backbox illumination.

3.4 WPC Dot Matrix Controller board

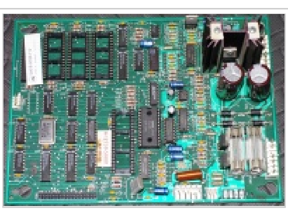
WPC DMD Controller board

The WPC DMD display and DMD controllers are common features in Williams 1990's era pinball machines. The display is a high-voltage plasma system that has scanning electronics built in. The WPC dot matrix controller board, or WPC-95 AV (Audio/Video) board in later machines, provides the power for operation, and maintains the display dot images in its memory. The CPU loads these pages ahead of time, then instructs the display controller to "flip" the images onto the screen.

Clive at the Coin-Op Cauldron has an excellent article detailing some of the nitty gritty of the DMD controller here (http://webpages.charter.net/coinopcauldron/dotarticle.html) .

3.5 WPC Sound Boards

3.5.1 WPC pre-DCS Sound Board



WPC pre-DCS Sound Board, sound ROMs removed

The pre-DCS sound board uses a single LM1875 amp and can accommodate up to 3 sound ROMs. With a single "sound lane" and amp, stereo sound is not possible. The three speakers are connected in series, each of them attempting to accentuate different bands of the audio spectrum. A broken wire to any of the three speakers will result in no sound at all.

3.5.2 WPC DCS Sound Board

With Indiana Jones: The Pinball Adventure, Williams introduced the DCS sound system. Its DSP architecture was a significant improvement on earlier systems, and it allowed Williams to use recorded music from EPROM rather than synthesizer music. The board also introduced dual amplifiers and an electronic crossover. DCS allowed Williams to use compressed sound samples, significantly improving the sound quality of the games.

The board dropped the microprocessor controlled synthesizer chip and sound bite system of earlier WPC machines, and replaced them with the still in production Analog Devices ADSP-2105 DSP. For its time, this was an extremely fast device (40MHz), and is capable of providing all of the sound processing needed in a WPC pinball machine. The ADSP-2115 can also be used as a replacement for the 2105. It adds a second serial port which is not used in WMS pinballs. Williams also upgraded the chip amp. The new chip amp operates at a lower voltage, and forced a corresponding change in the transformer voltage (12VAC + 12VAC). Therefore, DCS machines have different transformer winding to previous WPC machines. The system has an electronic crossover, separating high frequencies to the backbox and low frequencies to the cabinet.


The WPC DCS Sound Board

The card connects to the WPC CPU through the I/O port. It shares the port with the Fliptronics board and the display board.

What's on the Board?

The DCS sound board has the following subsystems:

- Rectifier and fused power supply for +/-16VDC amplifier power [check - WPC was 35V?]
- Dual-channel power amplifier with electronic crossover
- DSP-based sound synthesizer
- One EPROM for DSP code storage
- Other EPROMS for sound storage
- High-speed program memory for the DSP
- Mailbox interface for WPC-CPU

On power-up, the board runs a diagnostic and sounds a bong. It does this without any help from the WPC CPU. If there is no bong, the board has a problem.

What Goes Wrong

The smoothing capacitors C20 and C21 are often at the end of their useful lives. The chip amp, like the Honey Badger, really doesn't care, and will accomodate capacitor variance. However, replacing them will make even the pre-DCS sound much richer.

The coupling capacitors at C32 and C41 can fail.

3.5.3 WPC-95 AV Board


WPC-95 AV Board

The WPC-95 AV board integrated the sound and video system into a single board, siginifcantly reducing power and space.

The board has the following major subsystems

ASIC The ASIC is a 208-pin flatpack device. It incorporates the following functions:

- Interface registers to CPU
- Memory control and display output logic for the diaplay subsystem
- Memory interface for the AD2105 DSP

The ASIC has a tendency to fail in such a way that the sound disappears. New ASICs are available, but replacing them requires skill with surface mount devices.

Audio DSP The audio susbsystem uses the same part as the DCS sound board the Analog Devices DSP part ADSP-2105 and an AD1851 DAC. For its time, this was an extremely fast device (40MHz), and is capable of providing all of the sound processing needed in a WPC pinball machine. The AD1851N in DIP package was discontinued 2010 but the DSP is still available at Digikey and many other stores (ADSP-2105BPZ-80).

Location: lower center of board

Serial Port The serial port is rarely populated. Its uses include: machine debugging; machine linking (NBA Fastbreak); ticket printers

Location: lower left of board

Audio Amplifier The audio amplifier is a dual-channel TDA 2030A operating at X volts. The system has an electronic crossover, separating high frequencies to the backboox and low frequencies to the cabinet.

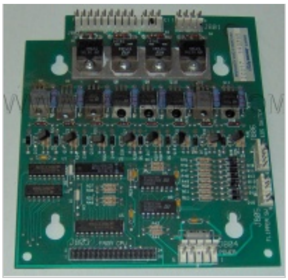
Location: lower right of board

DMD Power The DMD requires 62, 95? and 107V to operate. The board uses a temperature-compensated design to supply these voltages. The 107V line is built as a 12V offset from the 95V line.

Location: upper right of board.

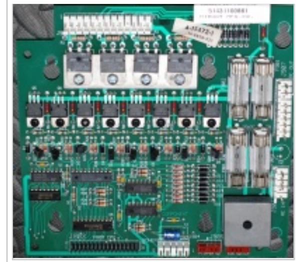
3.6 WPC FlipTronics I & II Boards

Beginning with The Addams Family, Williams implemented the FlipTronics flipper power and switch sensing system. The Addams Family and The Addams Family Gold were the only two games which used the FlipTronics I board. Subsequent games until the WPC-95 board set debuted used the FlipTronics II board. FlipTronics II boards are backward compatible with the FlipTronics I board. The WPC-95 board set integrated the flipper electronics into the driver board.



WPC Fliptronics I Board

Prior to the FlipTronics system, flipper circuit design had essentially been the same simple circuit. This circuit consisted of power to two flipper coil windings (the "power stroke" and "hold" windings). When the flipper cabinet switch was closed, the power winding and hold winding were both energized. As the flipper plunger was pulled in, the flipper EOS switch opened, interrupting power to the "power stroke" winding, leaving only the "hold winding" energized to hold the flipper in the up position. Flipper coil systems were designed this way so a flipper could be energized indefinitely (in theory). A failed EOS switch could result in weak flipper performance (poor EOS switch conduction) or result in burned flipper coils (EOS switch that never opens).



WPC Fliptronics II Board

The FlipTronics system ended reliance on properly operating EOS switches. While FlipTronics systems still have EOS switches, they generally are not used to control power to the coil windings. The EOS switch provides feedback to the MPU that the flipper has completed a stroke. A failed EOS switch will not cause damage to either the coil or to the switch circuitry. If the MPU doesn't receive feedback that the flipper has completed a full stroke within a specific time (milliseconds), the "power stroke" winding power will still be interrupted.

There is a special case where a properly operating EOS switch comes into play. The EOS switch on FlipTronics games helps to keep the flipper bat in the up position when a fast moving pinball strikes the flipper. When the ball strikes the flipper, moving it toward the "at rest" position, a properly operating EOS switch will open. The FlipTronics board will then provide a path to ground for the "power stroke" winding until the flipper completes the upward stroke, closing the EOS switch again. Games with broken or malfunctioning EOS switch(es) may allow the flipper bat to drop all the way to the "at rest" position when struck by a rapidly moving ball, with possible loss of ball, and a great deal of "what the @#$% just happened".

FlipTronics game flipper operation:

1. Flipper power is always present at the flipper coil lugs. For the flipper to actuate, that coil power needs to find a path to ground.
2. The FlipTronics board switch sensing circuitry recognizes closure of a flipper cabinet switch.
3. The FlipTronics board communicates closure of the flipper cabinet switch to the MPU.
4. The MPU commands the FlipTronics board to provide ground for the "power stroke" winding of the flipper coil (via a circuit passing through a 2N5401, TIP-102, and TIP-36C). This process is similar to how high powered coils are controlled by the power driver board.
5. A few milli-seconds later (thousandths of a second), the MPU commands the FlipTronics board to interrupt the ground path for the power stroke winding and to provide ground for the hold winding portion of the coil (via a circuit passing through a 2N5401 and a TIP-102).
6. The FlipTronics board switch sensing circuitry recognizes close of the flipper EOS switch, and communicates that switch closure to the MPU. Again, this switch closure isn't used to control power to the flipper coil windings. It's merely information.
7. When the player releases the cabinet flipper switch, the FlipTronics board again senses that open switch, communicates the change in state to the MPU which then commands the FlipTronics board to interrupt ground to the hold winding also, and the flipper returns to it's at rest position.

WPC-95 games use the exact same methods. However, the WPC-95 board set integrates the capabilities of the FlipTronics board into the power driver board.

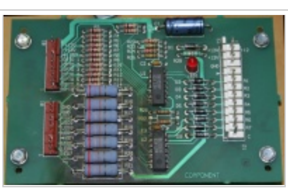
The FlipTronics II board also rectifies AC voltage sourced from the game transformer, and relayed to it from the Power/Driver board to create the 70VDC flipper power (the FlipTronics I board relies an an "extra flipper power supply" to rectify the flipper voltage). A FlipTronics board can sense 8 switches, and control up to four flipper power and hold windings. In some games, spare flipper cabinet switches, EOS switches, and coil drive circuits are used for other game features.

Note that sometimes C2 is installed on this board and sometimes it is not. The board pictured does not have C2 installed. Since C2 is a 100μF/100V capacitor, it can't be doing too much AC smoothing of the full wave rectified flipper power. Some RGP discussions indicate that C2 may have been designed in originally to reduce EMI (electro-magnetic interference) from the board. Installing C2 will have a negligible affect on flipper power. Some report that installing C2 fixes a "jittery gate" symptom on BSD's "mist" assembly.

More information about bench testing FlipTronics board is available here.

3.7 Miscellaneous WPC Boards

3.7.1 WPC 7 Opto Board (A-14977, A-15576, A-15595)



Example WPC 7 Opto Board, as found in AFM and many other WPC games.

This board is a typical example of a WPC opto board.

The connector on the lower left (as pictured) provides the power for seven IR emitters. The emitters are powered from the 12V supply through a 260 ohm resistor (the large blue resistors adjacent to the connector). Williams runs the opto emitters at about 40mA, which results in the resistors becoming hot. The opto boards are often darkened by the heat, as this one is.

The connector on the upper left carries the signals for the photo-transistors. The photo-transistor collector connects to 12V, and its emitter connects to ground through two 2KOhm resistors connected in series. When the transistor is illuminated by the emitter, it passes more current through the resistors, raising the input voltage on the LM339. The other pin on the LM339 is set to about 2.8V buy a 100K/22K voltage divider. Therefore, when the voltage at the junction of the two 2K resistors and the LM339 input is above 2.8V, the switch will read as closed. This happens at 1.4mA.

The two left side connectors can be used for optical trough switches. The connector on the right hand side provides the the row/column switch matrix interface to the MPU.

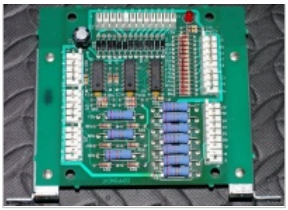
What Goes Wrong?

The resistor discoloration is cosmetic, and rarely causes problems. The biggest problem for these boards is switch matrix shorts. If any of the power lines hits the switch matrix, it can easily destroy the LM339 and possibly its output diode. This issue will manifest as a ground short on one or more rows. It can be tested by removing the switch matrix connector. If the problem goes away, the associated LM339 and possibly its diode need to be replaced.

If the short was from the 70V supply, multiple LM339s may be damaged.

Replacing LM339s on these boards needs to be done carefully, as it is easy to lift traces and pull the through-hole plating. Always socket replaced ICs.

3.7.2 WPC 10 Opto Board (A-15430, A-18159, A-20246)



Example WPC 10 Opto Board.

The 10 opto board was used in Bram Stoker's Dracula, Dr. Who, Indiana Jones, Pinball Circus, Popeye, Cactus Canyon, Corvette, Monster Bash, Medieval Madness, Revenge From Mars, SafeCracker, SWE1, Shadow, Congo, Indianapolis 500, and World Cup Soccer.

The connector on the upper left carries the power for seven of the IR emitters. The emitters are powered from the +12V supply through a 260 ohm resistor (the large blue resistors adjacent to the connector). Williams runs the opto emitters at about 40mA, which results in the resistors becoming hot. The opto boards are often darkened by the heat, as can be viewed in the adjacent picture.

The connector on the lower left carries the signals for the photo-transistors. The photo-transistor collector connects to +12V, and its emitter connects to ground through two 2KOhm resistors connected in series. When the transistor is illuminated by the emitter, it passes more current through the resistors, raising the input voltage on the LM339. The other pin on the LM339 is set to about 2.8V by a 100K/22K voltage divider. Therefore, when the voltage at the junction of the two 2K resistors and the LM339 input is above 2.8V, the switch will read as closed. This happens at 1.4mA.

These two connectors can be used for optical switch troughs. The three connectors on the right hand side each carry signals for one transmitter/receiver pair. These connections are often used for ramp entrances, and sometimes the pair is mounted on a single bracket.

The connector on the bottom provides the the row/column switch matrix interface to the MPU.

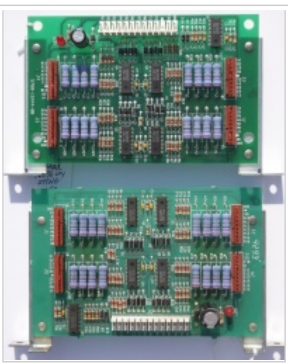
What Goes Wrong?

The resistor discoloration is cosmetic, and rarely causes problems. The biggest problem for these boards is switch matrix shorts. If any of the power lines hits the switch matrix, it can easily destroy the LM339 and possibly its output diode. This issue will manifest as a ground short on one or more rows. It can be tested by removing the switch matrix connector. If the problem goes away, the associated LM339 and possibly its diode need to be replaced.

If the short was from the 70V supply, multiple LM339s may be damaged.

Replacing LM339s on these boards needs to be done carefully, as it is easy to lift traces and pull the through-hole plating. Always socket replaced ICs.

3.7.3 WPC 16 Opto Board (A-16998, A-17223)



WPC 16 opto boards, both versions

This board is used in at least Star Trek: The Next Generation and Champions Pub. Note the two different "versions". The bracket on one side is believed to be part number 5768-13739-00 while the bracket on the other side is believed to be part number 5768-13739-01. The boards are identical in layout and components. The only difference is bracket mounting, some silk screening, and one version has holes in the PCB which are not used.

3.7.4 Auxiliary 8-Driver Board (A-16100)

An example 8-Driver board

The auxiliary 8-driver board sits in the top right of the backbox in a handful of WPC machines. The connector labeling is tricky as the 8-Driver board is controlled by a ribbon cable that is connected to the "Display" connector on the WPC CPU board (J204). The "Display" label is a historical artifact and refers to the alphanumeric display used in Funhouse.

The board has 8 outputs, driven by TIP-102 transistors with a 2N4403 pre-driver, similar to the WPC power/driver board (which uses a 2N5401 as a pre-driver). It is used in the following games:

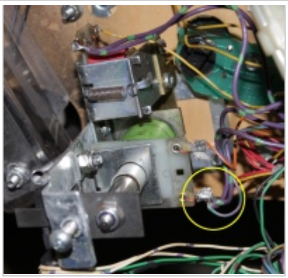
- Demolition Man
- Indiana Jones
- Road Show
- Star Trek: The Next Generation
- Twilight Zone

The board circuitry can also be used for added switch columns to the switch matrix (e.g. Indiana Jones, Star Trek: The Next Generation).

The board is designed to run flashers, low-power solenoids, and perhaps motors. The two lowest transistors can be repurposed to add columns to the switch matrix or lamp matrix circuit. This is accomplished via jumpers on the board. This makes the boards more flexible but also may require different jumpers to use the board in different games (i.e. the boards are not completely interchangeable between machines "as is").

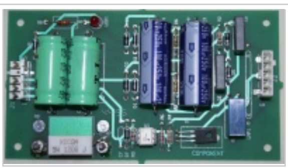
What Goes Wrong?
This is a pretty simple board. Generally, the problem is going to be a blown transistor, or possibly a failed 74ALS576 latch.

One thing to watch for is that the board ground connection may be hidden under the ribbon cable between the CPU and the power-driver board. The board may partially work if this connection is open, which can be a big time sink. So, check the ground wire if this board seems to be giving trouble.


Diode tie-back at the single drop target assembly. Note the small purple/green wire soldered to the target reset coil's power side (two larger gauge purple/green wires).

Another thing to watch for is a "diode tieback" connection to the board for games like Star Trek: The Next Generation. Without this "diode tieback", transistors on the 8-Driver board WILL be damaged. The diode tie-back wire is purple/green and connects from the coil power side of one of the drop target assembly coil lugs to J4 pin 1 on the 8-Driver board. If the solder connection at the coil lug is solid, suspect the wire connection at the IDC connector. Repinning this connection with good a quality crimp-on TriFurcon pin is advised.

3.7.5 Attack from Mars "Strobe" Board (A-20669)


A-20669 Attack From Mars Strobe Board

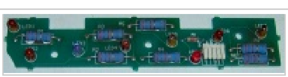
The strobe board at left is unique to Attack from Mars. Williams used underrated 100μF/100V non-polarized caps on the board that often fail with the telltale "bulge" at one end. The "transformer" on the board (blue rectangular box, lower/right in the picture) has very fine legs which can break due to vibration at the back of the playfield.

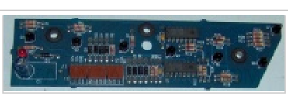
Excellent repair information for this board can be found here (http://www.iobium.com/fixing_the_afm_strobe_board.htm)

3.7.6 Trough opto boards

When WIlliams moved to the gravity trough, they also switched to optical switches to detect the ball. The trough is covered by a Williams patent.

There are two generations.


WMS A-17982 Trough Transmitter Board - First Generation


WMS A-17981 Trough Receiver Board - First Generation

The first generation (Judge Dredd - Indiana Jones ???) used a receiver board with all of the switch logic on the board. The vibration in the trough makes extra components subject to failure. The second generation (xxx -) uses a regular opto board, and the trough receiver just has phototransistors.

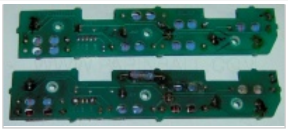
As with all Williams opto circuits, the transmitters are driven to the very limit, and the series resistors overheat. This overheating destroys the solder joints.

Also, the continued vibration makes the resistor legs crack, and weakens the pins in the IDC connectors.

Later versions used rubber grommets to isolate the boards from the trough.

What Goes Wrong?

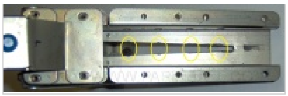
Broken Parts Leads



Typical Trough Opto Transmitter Boards after resistors have been replaced or soldered multiple times

The resistors on the emitter board are subject to cracked legs. Wiggle them to see if they are good. replace the resistor if there are any signs of trouble. On earlier receiver boards, inspect all components.

Trough Divots



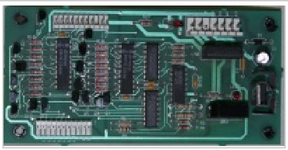
Typical Trough Divots Caused by Balls

Balls make great hammers and, over time, they will beat divots into the trough floor. Then, they will then rest in the divots and cause all kinds of ball count problems. The problem is exacerbated with slightly magnetized balls.

The fix is to file them out, and then sand the metal smooth. A dremel tool with grinding stone works great for this. PinBits.com sells a nice "fix" for this problem called a "Ball Trough Magnetic Jam Protector" (http://www.pinbits.com/index.php?main_page=product_info&products_id=449) that slides in over the divots. This product eliminates the ability of balls to rest in the divots as well as breaking any magnetic connection, because it is made from PETG plastic.

Mad Amusements offers a stainless steel version of a trough sleeve insert (http://mad-amusements.com/product.php?id_product=459) . Although it is more costly, this is a high quality product.

3.7.7 WH2O Chaser Lamp Board (A-15761)

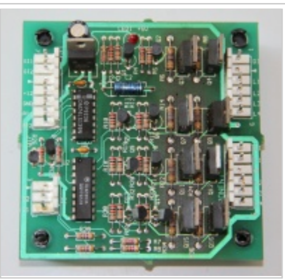


A-15761 Chase Light Board

This board is used for the chaser lamps on Whitewater. It is a simple lamp sequencing board that causes the lamps to "chase".

The board rectifies 16VAC via BR1 and BR2 to create approximately 12VDC to power the chase lamps. The board also receives 12VDC from the power/driver board and regulates it down to 5VDC via an LM7805. This 5VDC is used for the logic level ICs on the board.

3.7.8 CFTBL Chase Light II Board (A-15541)



A-15541 Chase Light II Board

This board is used for the chaser lamps located around the ramps and whirlpool bowl in Creature From the Black Lagoon.

Eight BT138 triacs, which are predriven by 2N4403 transistors, control eight discrete lamp strings. In addition to the lamps chasing, the lamp strings can be dimmed for effect.

3.7.9 High Current Driver Board (C-13963)

C-13963 High Current Driver board as used in NBAFB and Funhouse.

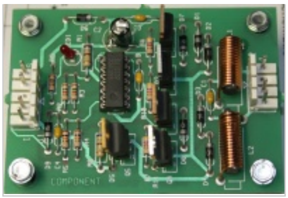
This board drives the jaw motor for the playfield heckler Rudy in the game Funhouse.

3.7.10 Bi-Directional Motor Board (A-15680)

This board is used in Cirqus Voltaire, Dr Who, Party Zone and White Water.

One problematic aspect of the board's design is that the 100μF electrolytic cap is mounted over the trace that carries 12VDC power to the drive transistors. If the electrolytic cap fails and leaks it's corrosive contents, it will eat through the trace and the board won't work correctly. If this happens in WH2O, Big Foot will not turn his head during game test at boot up. Note: the board pictured at left exhibited this problem and was repaired.

Another seemingly prevalent issue with this board is failure of the diodes. If either D8 or D9 fail, the associated motor will turn ONLY counter-clockwise.


A-15680 Bi-directional Motor Board

The board is controlled by two transistors on the driver board. One transistor "enables" movement of the associated motor. The other determines whether the motor moves clockwise or counter-clockwise.

3.7.11 Double Flipper Opto Switch Board (A-15894)

A-15894 Flipper Opto Board Mounted on the Cabinet Wall

This board is used in early WPC games which used the Fliptronics II board starting with Doctor Who (please confirm first game).

Please note when testing these boards, the right flipper board has to be plugged in for the left board to function. This is due to the +12v and ground connections being daisy-chained through the right board PCB to the left board.

3.7.12 HSII & CFTBL Triac board (A-13088-2)


A-13088-2 Triac Board

This board is used in High Speed 2: The Getaway, CFTBL, and Hot Shot (basketball redemption game).

Since the board is single sided, fractured solder joints are frequently a problem with this board, especially at C1 for some reason. The other failure point on this board is the MOC 3031 otpoisolator.

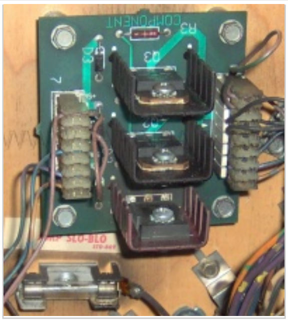
3.7.13 24 Inch Opto Board (A-15646)


WPC 24 Inch Opto Board as used on BSD and Shadow

Note: This board is sometimes referred to as the "24 Switch Opto PC Board".

This board is used on Bram Stoker's Dracula to sense the "Mist Ball" and on Shadow to sense when the ball is at the bottom of the mini playfield. The board is also used in Star Wars: Episode 1, NBA Fastbreak, Judge Dredd, and Hot Shot (basketball redemption game). The usual problem with this board is that the large inductor (marked "106C" in the picture) vibrates off the board. The circuitry on this board is similar to a television remote control circuit. It senses a particular signal frequency.

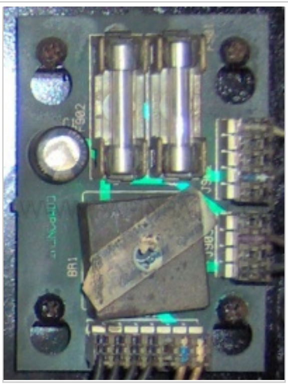
3.7.14 TAF & TAFG High Power Board (A-15139)



A-15139 High Power board as used in TAF and TAFG

This board (aka magnet board) drives the three under playfield magnets used on The Addams Family and The Addams Family Gold. It is located under the bottom left of the playfield.

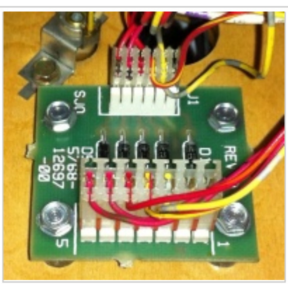
3.7.15 TAF & TAFG Extra Flipper Power Supply (A-15416)



A-15416 Extra Flipper Power Supply board as used in TAF and TAFG

This board powers the flippers for The Addams Family and The Addams Family Gold. It is located just to the right and just above the driver board in the backbox.

3.7.16 The Shadow Five Switch and Diode P.C.B. (A-13940)



This board was used only on "The Shadow" to provide lamp matrix diode isolation for the 4 "Ring Grain of Wheat" lamps, in-situ.

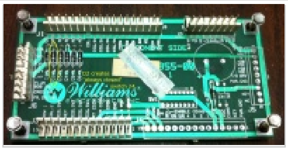
This board was used only on "The Shadow" to provide lamp matrix diode isolation for the 4 "Ring Grain of Wheat" lamps. Yes, that's really it's name.

The bare board.

3.7.17 Coin Door Interface Board

The coin door interface board provides electrical connection between the coin door switches and the WPC switch matrix and dedicated switches like the "diagnostic" and volume control buttons. The coin door interface board also creates the "always closed" switch 24 by bridging column 2 and row 4 with a diode. WPC games use this "always closed" switch to test game functions.

If the coin door interface board gets dusty from flipper parts wearing, clean it. That dust conducts electricity and may cause some interesting coinage issues. There really isn't much that can go wrong with this board.

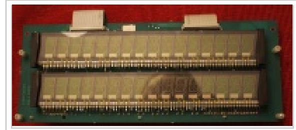


WPC/WPC-95 Coin Door Interface Board

3.7.18 WPC Alphanumeric Plasma Display Board

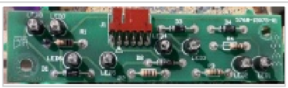
The component side of the Funhouse / Bride of Pinbot WPC alphanumeric display.

Funhouse and The Machine: Bride of Pin*Bot used dual 16-Alphanumeric displays, and a special (specific) high voltage power supply/logic board. The high voltage circuit is similar, if not identical, to late System 11 high voltage power circuits.



The display glass side of the Funhouse / Bride of Pinbot WPC alphanumeric display.

3.7.19 Scared Stiff Crate Board



The "Scared Stiff" Crate Board

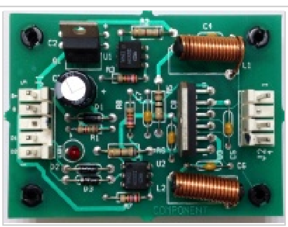
This simple board mounts to the top of the Scared Stiff crate. It creates the "eyes" that look out the top of the crate. It contains 8 LEDs, 4 current limiting resistors, and 4 diodes, which isolate the LED "lamps" in the lamp matrix. Very little can go wrong with this board other than fractured solder joints, since it lives in a high vibration area of the game.

3.7.20 DC Motor Control Board (A-16120)

A-16120 DC Motor Control Board

This board is used in Cactus Canyon, Demo Man, Monster Bash, No Good Gophers, The Shadow, Twilight Zone, Theater of Magic, World Cup Soccer.

3.7.21 Bridge Driver PCB Assembly (A-15946)



A-15946 Bridge Driver PCB Assembly

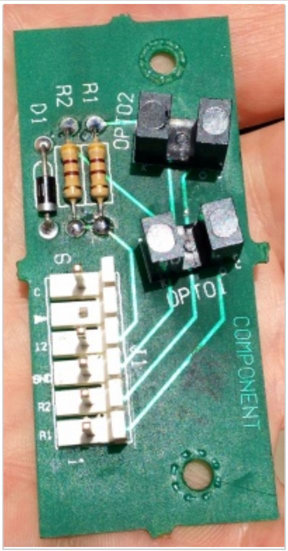
This board is used in Indiana Jones and Hot Shots Basketball. The board is close in design to the A-16120 DC Motor Control Board (above). For Indiana Jones, it controls the Path of Adventure motor, which must turn both clockwise and counter-clockwise.

This simple assembly receives 12VDC power and ground, along with two solenoid connections to the driver board. Grounding one pin of the connection causes +12VDC to be output at the motor power pins. Grounding the other pin will cause -12VDC to be output at the motor power pins.

Indiana Jones uses solenoid 22 to move the POA left and solenoid 23 to move the POA right.

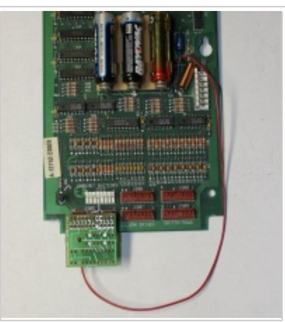
3.7.22 Indiana Jones Path of Adventure (POA) Opto Board

This simple board is used in Indiana Jones to provide "travel limit" feedback to the MPU for the POA. Typical problems include fractured solder joints, since the board experiences a lot of vibration from the POA motor, as well as simple opto failures.



The Indiana Jones POA opto board. The optos are identical to those used on cabinet flipper switch opto boards.

3.7.23 Coin Doubler Board


An Aftermarket "Coin Doubler" Board, shown attached to a WPC MPU.

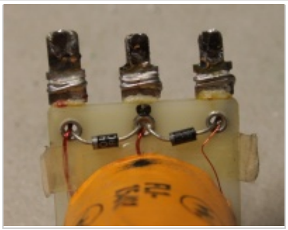
This aftermarket add-on board connects atop the direct switches connector on the WPC MPU. It intercepts the coin switches and, for each switch closure it sees, sends the computer two closures. This "hack" effectively halves game pricing. This was done because Williams removed the one-coin-per-play pricing for some games to try and force a price increase.

These are still for sale from Two Bit Score (http://www.twobits.com/coindblr.html) .

3.8 Flipper Coils

WPC games use different flipper coils dependent on flipper placement and application. Below is a chart of the flipper coils used, their wrapper color, and strength.

WPC Flipper Coils			
Part #	**Color**	**Strength**	**Notes**
FL-11753	Yellow	Weakest	
FL-11722	Green	Weaker	
FL-11630	Red	Standard	
FL-15411	Orange	Stronger	
FL-11629	Blue	Strongest	



Note the windings of this typical WPC coil. The larger wire is the high power winding, the smaller wire is the hold winding. Both wires are soldered to the lug on the left.

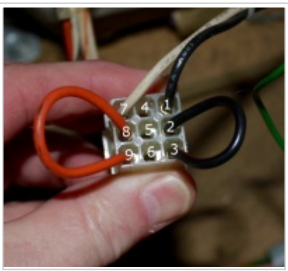
3.9 Primary Voltage Selection Jumpers at the Transformer

On all WPC games, there are either a 9 pin or 12 pin Molex connector used to change the primary voltage setting fed to the transformer. 9 pin connectors were connected to a pigtail off the transformer itself. Later units used a 12 pin connector on the power source metal box located inside the cabinet floor on the right just inside the coin door. Depending on the placement of the jumpers, common configurations are 115v (typical domestic setting), 230v (European setting), and 100v (Japanese setting).

It is common to change the voltage setting (220 to 120 volt conversion) if a game is re-imported back into the US. Although probably more common at the moment is to convert a domestic game to 220 volts (more games are currently being exported from the US than imported).

3.9.1 Early WPC Transformers (9 pin connection)

The 9 pin connectors used are Molex 19-09-2099 (butterfly connection w/jumpers) and Molex 19-09-1099 (connection on transformer pigtail).



9 Pin WPC Transformer Power Configuration, configured for US 115V systems.

Jumper settings for 115V should be as follows:

- Pin 1 - black - 115v "hot" input
- Pin 7 - white - 115v "neutral" input
- Pins 2 and 3 jumped together
- Pins 8 and 9 jumped together

9 Pin WPC Transformer Power Configuration, configured for 230V systems.

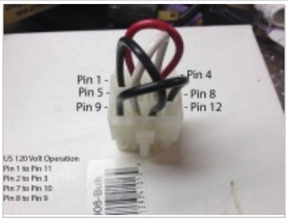
Jumper settings for 230V should be as follows:

- Pin 1 - black - 115v "hot" input
- Pin 7 - white - 115v "neutral" input
- Pins 3 and 9 jumped together

3.9.2 Later WPC Transformers (12 pin connection)

Jumper settings for 120v should be as follows:

- Pins 1 and 11 jumped together
- Pins 2 and 3 jumped together
- Pins 7 and 10 jumped together
- Pins 8 and 9 jumped together



12 Pin WPC Transformer Power Configuration, configured for US 120V systems

The 12 pin connector used is Molex 19-09-1129.


12 Pin Connector as Found inside later games

4 Problems and Solutions

4.1 Jumpers, RAM and ROM size

Closeup of WPC-089 MPU that uses a 6264 RAM and a 4M game ROM. Note jumpers W1, and W2 to set ROM size as well as W3 (out) and R93 (in) to set RAM size.

RAM Size
The WPC-089 MPU can be configured for two different RAM sizes. This is done with jumper W3 and resistor R93 as shown below.

- 6264 RAM - W3 out, R93 in (a 1.5K 1/4W resistor)
- 62256 RAM - W3 in, R93 out

Both RAM sizes work fine in all games. Williams probably provided this flexibility to allow use of whichever RAM was cheaper or more available.

The WPC-95 MPU can be configured for two different RAM sizes. This is done with jumper W3 (only) as shown below. R93 is always installed.

- 6264 RAM - W3 out
- 62256 RAM - W3 in

Again, both RAM sizes work fine in all games.

Closeup of WPC-089 MPU that uses a 62256 RAM and a 4M game ROM. Note jumpers W1, and W2 to set ROM size as well as W3 (in) and R93 (out) to set RAM size.

Closeup of WPC-95 MPU that uses a 62256 RAM. Note jumper W3 is installed to set the RAM size for a 62256 RAM.

ROM Size
The MPU can also (and needs to be) jumpered for different ROM sizes. This becomes important when upgrading ROMs or swapping a CPU (and ROM) into a different game. Games like Funhouse shipped with a 1M ROM, jumper W2 in, and jumper W1 out. Updating the Funhouse ROM to a larger size ROM requires W1 in and W2 out.

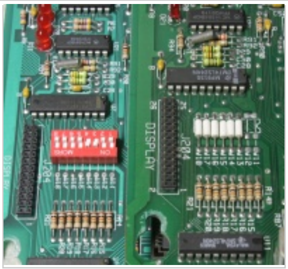
The official Williams ROM size/jumper settings are shown below.

- 512K/1M - W1 out, W2 in
- 1M/2M/4M - W1 in, W2 out

4.2 Country DIP Switch (or jumper) Settings

Country Code Jumper message.

The message shown at left occurs sometimes when the game software seems to want the "country code" jumpers to be configured in a certain way. The simple solution (for English speaking users) is to remove the jumpers noted in the message by cutting them off. This sets the board to "AMERICA2". Twilight Zone, and perhaps game ROM version 9.4H, seem to prefer the "AMERICA2" country code. Other country code jumper configurations are shown below.


Two WPC-089 MPUs, one configured with DIP switches, the other with "zero ohm resistors" (jumpers).

Two WPC-089 MPUs are shown at left. Early versions of the MPU used "zero ohm resistors" or jumpers to figure the country code. Later versions of the MPU (as well as WPC-S and WPC-95 MPUs, used DIP switches.

Note: If a dip switch is installed, **always leave W11 and W12 in the OFF position**. If both are set on ON, the undervoltage detection circuit on the WPC Power/Driver will not work and both LED2 and LED3 will always remain on.

Country Code	W13	W14	W15	W16	W17	W18
America	Always IN	Always IN	IN	IN	IN	IN
America 2	Always IN	Always IN	OUT	OUT	OUT	OUT
Spanish	Always IN	Always IN	OUT	IN	IN	IN
Europe	Always IN	Always IN	IN	OUT	IN	IN
French	Always IN	Always IN	IN	IN	OUT	OUT
German	Always IN	Always IN	IN	IN	IN	OUT

WPC-089 Country Code Jumper Table

The complete WPC-089 (vice WPC-S and WPC-95) country code jumper table is shown at left.

Country Code	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8
America	OFF	OFF	ON	ON	ON	ON	ON	ON
Spanish	OFF	OFF	ON	ON	OFF	ON	ON	ON
Europe	OFF	OFF	ON	ON	ON	OFF	ON	ON
French	OFF	OFF	ON	ON	ON	ON	OFF	OFF
German	OFF	OFF	ON	ON	ON	ON	ON	OFF

WPC-S/WPC-95 Country Code Jumper Table

The complete WPC-S/WPC-95 country code jumper table is shown at left. WPC-S/WPC-95 MPUs do not have an "AMERICA2" configuration.

4.3 Power-On LEDs and Sound Tones (Bongs)

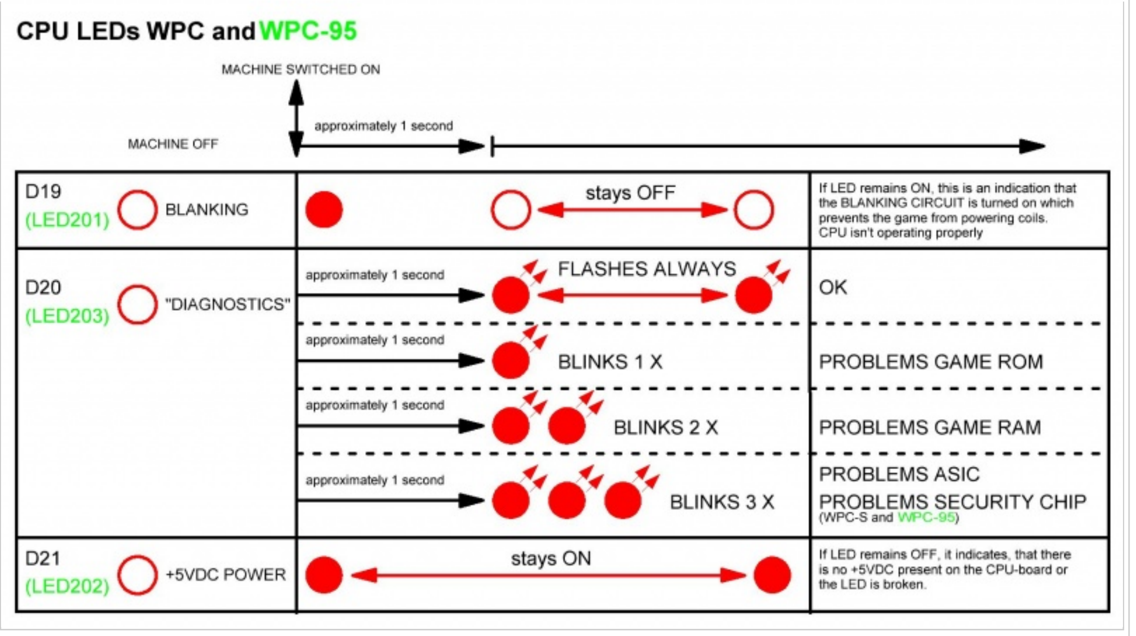
When the game is booted, several LEDs in the backbox will light, and the game may provide sound "bongs" to indicate diagnostic status.

A properly booting WPC game will show a "progress bar" on the DMD along with a "ticking" sound which results from a series of reset signals being sent to the sound board. After a successful boot, the sound board will create a single "bong" tone.

4.3.1 LEDs on the MPU

Note: WPC and WPC-S games label the MPU and Power/Driver board LEDs as "Dxx". WPC-95 games label these same LEDs "LEDxxx".

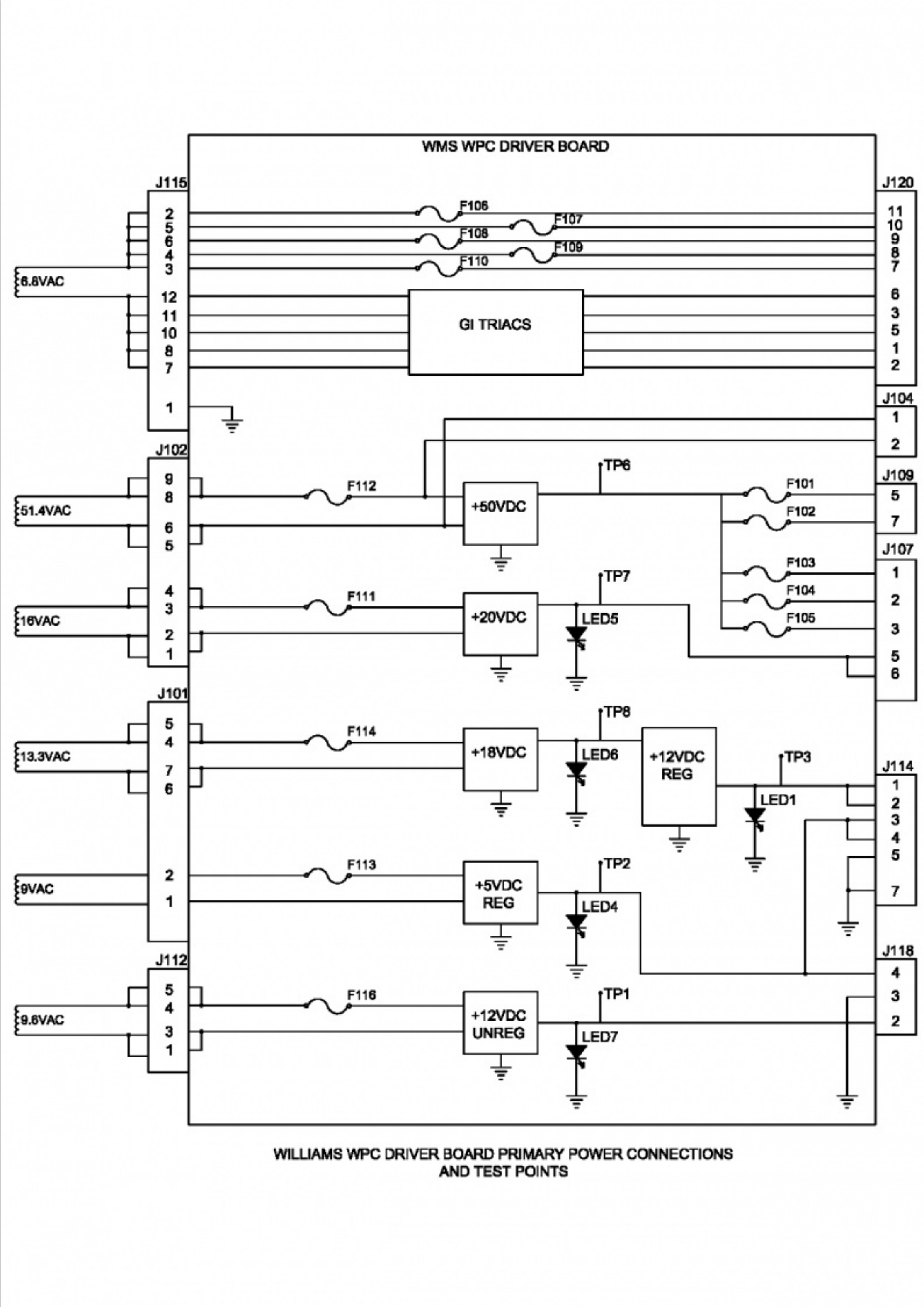
- D19 (LED201) - "Blanking". This LED should light when power is applied, then after about 1 second, go off and stay off. If D19 remains on, this is an indication that the blanking circuit is turned on which prevents the game from powering coils. The blanking circuit was implemented to eliminate the possibility of damaging the game due to locked on coils when the CPU isn't operating properly.
- D20 (LED203) - "Diagnostics". Once the blanking LED turns off, this LED should begin blinking and remain blinking as long as the game is turned on. This LED is a simple "I'm working" indication from the MPU. This LED is toggled from pin 35 of the ASIC (DLED signal). D20 will also indicate basic issues with the MPU by blinking as such...
  - One blink - problem with the game ROM.
  - Two blinks - problem with the game RAM (or accessing the RAM, i.e. open traces).
  - Three blinks - problem with the ASIC (WPC) or a problem with the security chip (WPC-S and WPC-95).
- D21 (LED202) - "5VDC present". This LED provides a simple indication of the presence of 5VDC. This LED isn't CPU controlled. It's illuminated by a simple 5VDC connection.



Graphic provided by Ingo Kramer. Used with permission.

4.3.2 LEDs and test points on WPC-089 Power/Driver Boards

LED/Test Point	Explanation
LED1-TP3	Normally lit. Indicates presence of regulated 12VDC (12VR). AC voltage is rectified to about 18VDC by BR1 and smoothed by C6 and C7 (this power is tapped for the lamp matrix). D1 and D2 are used to drop the voltage by 1.0 to 1.4V and then the voltage is further regulated down by the LM7812 at Q2. This 12VDC power is shown as "+12V Digital" on the schematics. **This power is fused by F114.** If LED6 isn't lit, LED1 won't be lit either.
LED2-no TP	If installed, provides an indication of high/low line voltage. This LED isn't very useful as it will flicker as power consumption by the game fluctuates.
LED3-no TP	If installed, provides an indication of high/low line voltage. This LED isn't very useful as it will flicker as power consumption by the game fluctuates.
LED4-TP2	Normally lit. Indicates presence of regulated 5VDC. AC voltage is rectified by BR2 and smoothed by C5. The voltage is regulated down by the LM323K at Q1. This 5VDC power is shown as "+5V Digital" on the schematics. **This power is fused by F113.**
LED5-TP7	Normally lit. Indicates presence of unregulated 20VDC. AC voltage is rectified by BR4 and smoothed by C11. The voltage is used to power the flash lamps. Note that beginning sometime during production of Twilight Zone in 1993, a "coin door interlock" switch was added. This switch interrupts power to both the 20VDC and 50VDC circuits when the coin door is opened, providing a measure of safety against higher voltage shocks. If the coin door is opened with power applied, this LED will fade to off. It will not light with the coin door open. **This power is fused by F111.**
LED6-TP8	Normally lit. Indicates presence of unregulated 18VDC. AC voltage is rectified to about 18VDC by BR1 and smoothed by C6 and C7. This 18VDC power is used to power the lamp matrix lamps. **This power is fused by F114.**
LED7-TP1	Normally lit. AC voltage is rectified to about 12VDC by BR5 and smoothed by C30 to provide unregulated 12VDC power. This 12VDC power is shown as "+12V Power" on the schematics. It is used to power motors, optos, and other game features that do not require a precise 12VDC. **This power is fused by F116.**
TP4	Zero Cross. By using an oscilloscope, this test point allows testing of the "zero cross" circuitry. "Zero cross" is when the AC sine wave crosses through the zero voltage point relative to ground. Zero cross is important for the proper operation of the general illumination lamp circuit.
TP5	**Ground**. This test point stud may be used to measure all DC voltages against.
TP6	50VDC power. This test point will actually measure 70 - 75VDC. This power is used for all coils in the game. **This power is fused by F112. Individual coil power circuits are fused by F101 thru F105**



Summary schematic of WPC Power Driver board showing test LED's and test points

4.3.3 LEDs and test points on WPC-95 Power/Driver Boards

LED/Test Point	Explanation
LED100-TP100	Normally lit. Indicates presence of regulated 12VDC. AC voltage is rectified to about 18VDC by D11-D14 and smoothed by C11 and C12. D1 and D2 are used to drop the voltage by 1.0 to 1.4V and then the voltage is further regulated down by the LM7812 at Q2. This 12VDC power is shown as "+12V Digital" on the schematics.
LED101-TP101	Normally lit. Indicates presence of regulated 5VDC. AC voltage is rectified by D7-D10 and smoothed by C9. The voltage is regulated down by the LM317K at Q1. This 5VDC power is shown as "+5V Digital" on the schematics.
LED102-TP102	Normally lit. Indicates presence of unregulated 18VDC. AC voltage is rectified to about 18VDC by D11-D14 and smoothed by C11 and C12. This 18VDC power is used to power the lamp matrix lamps, and is subsequently regulated to 12V for use in the switch matrix.
LED103-TP103	Normally lit. AC voltage is rectified to about 12VDC by D3-D6 and smoothed by C8 to provide unregulated 12VDC power. This 12VDC power is shown as "+12V unreg" on the schematics. It is used to power motors and other game features that do not require a precise 12VDC.
LED104-TP104	Normally lit. Indicates presence of unregulated 20VDC. AC voltage is rectified by D15-D18 and smoothed by C10. The voltage is used to power the flash lamps. Note that a "coin door interlock" switch is present on all WPC-95 games. This switch interrupts power to both the 20VDC and 50VDC circuits when the coin door is opened, providing a measure of safety against higher voltage shocks. If the coin door is opened with power applied, this LED will fade to off. It will not light with the coin door open.
LED105-TP105	Normally lit. Indicates presence of unregulated 50VDC. This test point will actually measure 70 - 75VDC. This power is used for all coils in the game. AC voltage is rectified to about 75VDC by D19-D22 and smoothed somewhat by C22.
TP106	Zero Cross. By using an oscilloscope, this test point allows testing of the "zero cross" circuitry. "Zero cross" is when the AC sine wave crosses through the zero voltage point relative to ground. Zero cross is important for the proper operation of the general illumination lamp circuit.
TP107	**Ground**. This test point stud may be used to measure all DC voltages against.

4.3.4 Power on Sound Tones (Bongs)

After a successful boot, the game should make a single "bong" sound. The game provides a sound board problem indication with the following number of bongs.

Pre-DCS Sound Board Games.

- 1 - No issues...enjoy a game.
- 2 - U9 RAM failure.
- 3 - U18 ROM failure.
- 4 - U15 ROM failure.
- 5 - U14 ROM failure.

DCS Sound Board Games.

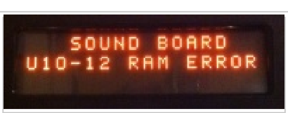
- 1 - No issues...enjoy a game.
- 2 - U2 ROM failure.
- 3 - U3 ROM failure.
- 4 - U4 ROM failure.
- 5 - U5 ROM failure.
- 6 - U6 ROM failure.
- 7 - U7 ROM failure.
- 8 - U8 ROM failure.
- 9 - U9 ROM failure.
- Note - DCS sound board RAM failures are indicated by a message on the display, "U10-U12 RAM error".

Audio/Video Board Games (WPC-95).

- 1 - No issues...enjoy a game.
- 2 - S2 ROM failure.
- 3 - S3 ROM failure.
- 4 - S4 ROM failure.
- 5 - S5 ROM failure.
- 6 - S6 ROM failure.
- 7 - S7 ROM failure.
- 10 - U9, U10, or U11 RAM failure (see below)

WPC-95 boot time RAM error message, accompanied by 10 very annoying bongs.

A/V sound board RAM failures are indicated by a message on the display, either "U9-U11 RAM error" or "U10-U12 RAM error". This is apparently game software dependent. A/V RAM are, in fact, U9-U11. Apparently, this message wasn't updated in some of the software with the introduction of the A/V board.

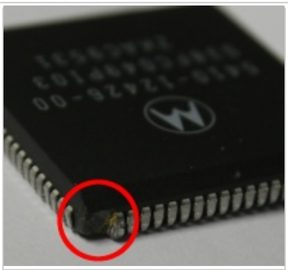


WPC-95 boot time RAM error message, accompanied by 10 very annoying bongs.

4.4 Removing the ASIC

Using a PLCC puller to properly remove the ASIC. Grip firmly, and "rock" the chip out gently.

Should ASIC need to be removed from a WPC MPU, it is strongly advised that tthe proper tool is used, as shown at left. The tool is called a PLCC puller.

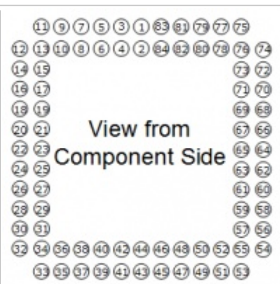


This ASIC was damaged by not using the proper removal tool.

Using a jewelers screwdriver or other such tool can fracture the ASIC chip carrier socket as shown at right. Since these are 84 pins sockets, replacement is non-trivial. Using the incorrect tool may also irreparably damage the ASIC itself by permanently fracturing leg joints, as shown at left.

This cracked ASIC socket caused intermittent operation of the game.

4.5 WPC ASIC Pinout



WPC ASIC pinout and board connections

Clicking on the thumbnail at left will open a .pdf file containing pin connections for the WPC (in work) and WPC-S MPUs.

4.6 Game blows power line circuit breaker immediately

Underside of power box showing varistor and thermistor

Had a thunderstorm roll through or a power surge from the electric company recently? The varistor in the power box may have done it's job protecting the rest of the game's circuitry from the possibly tremendous power surge.

Signs of a failed varistor are typically black, charred discoloration throughout the "button" portion (green in the case of the adjacent picture) of the varistor. Likewise, varistors can blow rather violently, and there may be charred or burnt remains in the area surrounding the varistor.

Over time, the rating of a varistor will lower, causing "occasional" blowing of the mains fuse. The varistor will visually appear to be OK. A good hint is how violently the fuse blows. Likely varistor problems will cause the fuse to totally obliterate.

Varistors can be purchased from Great Plains Electronics (https://www.greatplainselectronics.com/products.asp?cat=76) . Order the 130V variant for 120VAC (typically games in the US), and the 275V variant for 240VAC (typcailly games in Europe).

4.7 Credit Dot

The credit dot is a decimal point (a single, lit pixel on the display), that appears after the number of credits or after the words free play on the DMD display on WPC games. It is a quick indicator used to tell the operator or owner that there may be an issue with the game. Most commonly, there is a switch or multiple switch problems with the game. However, a credit dot will appear for other reasons, such as when the date and time are not set.

Example credit dot on Star Trek The Next Generation

If, after 30 balls or 10 games, a particular switch hasn't registered, the credit dot is posted to alert the user to check the diagnostics. Some high usage switches will trigger the alert earlier. The credit dot may or may not indicate a real problem. For the example shown in the pic, it's simply reporting a switch that is hard to hit in the game. So, the credit dot is actually saying "Play Better". :-)

4.8 Battery Issues

4.8.1 Relocating the battery from the MPU board

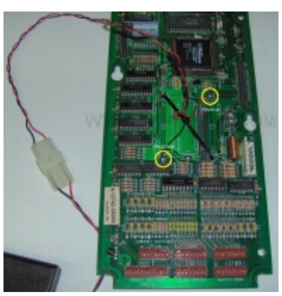
An example of worse than usual battery damage

Relocating the 3xAA battery pack from the MPU board is always a good idea. Leaky alkaline batteries are the #1 killer of MPU boards. Simply removing the batteries is not an option with WPC games as a message stating "Factory Settings Restored" will be received when the game boots.

There are several options other than allowing the battery pack to remain on the MPU board. Below are the two most common methods.

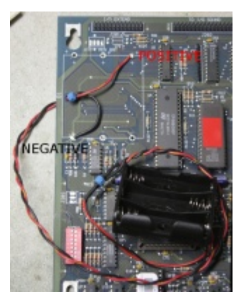
The first, most common, and most economical option is to remotely locate the battery holder off the MPU board and somewhere below all other boards. This ensures that even if the remotely located batteries leak, they won't leak onto (or even drip onto) any circuit board. Replace the batteries annually, dating them with a Sharpie. Connections are as follows. With the CPU oriented as it would be in the game, solder the red (positive) wire to the upper right battery pack position. Solder the black (negative) wire to the lower left battery pack position. Note: most battery packs do not come with wire leads long enough to allow the battery pack to rest in the backbox bottom. Lengthen the wires as necessary. As can be viewed in the adjacent picture, a male / female .093" Molex connector was added to easily remove the battery pack from the MPU board should the need arise.

WPC, WPC-S, and WPC-95 Remote Battery Holder Connections.



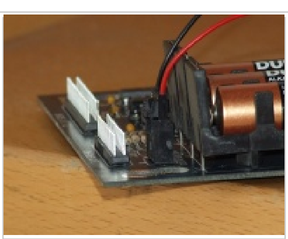
WPC-089

WPC-S



WPC-95

4.8.2 Installing an external battery on a WPC-95 CPU using the Auxiliary Battery header (J213)

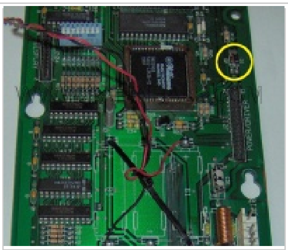


Installed Remote Battery Connector

The WPC-95 CPU board has an unused external battery connector just above the battery holder. The connector is labeled J213 AUX BAT. The 4 pads can be seen in the above picture of the CPU with the old holder removed. Installing this 4-pin connector is a good and clean way to get the batteries off the board and prevent alkaline damage. The Molex part number for the C-Grid® SL™ 70543 4 pin connector is 70543-003 (Digikey WM4802-ND). Crimp pins for the female side are 16-02-1125 (WM2573-ND) and the housing is 50-57-9404 (WM2902-ND). The WPC-S CPU uses a 5 pin version of this connector.
Warning: Do not use both the internal and external connector at the same time. Doing so will likely damage the batteries.

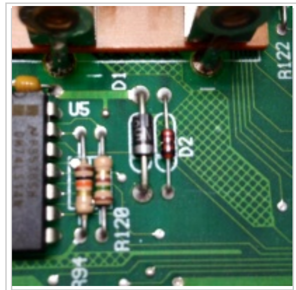
An alternate, but equivalent method. Positive and Negative are clearly labeled.

4.8.3 Settings Not Held or Battery Depletes Rapidly

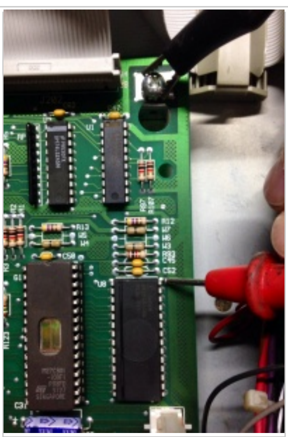

A WPC MPU board with D1 and D2 circled

During the process of installing a remote battery holder, it is a good practice to check the diodes utilized in conjunction with the battery power. Diode D2, a 1N4148, is used to keep the MPU board's logic power from charging the batteries in the battery pack. Diode D1, a 1N5817, is used to keep the battery pack from powering the entire MPU board when the games's power is turned off.

- If D2 fails shorted, 5VDC power will be applied to the batteries while the game is turned on. The end result is batteries which die prematurely, possibly leak, and/or possibly explode (alkaline batteries do not like to be charged).
- If D2 fails open, the batteries will not power the static RAM, and the "FACTORY SETTINGS RESTORED" message will be displayed when the game boots.
- Should D1 fail, the batteries would more than likely just deplete prematurely.



A WPC-95 MPU board with D1 and D2 shown in the middle of the picture, just below the battery holder

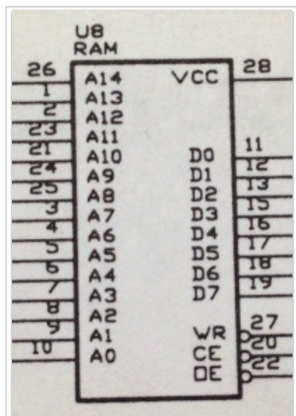

Probing pin 28 of the WPC-95 MPU RAM IC for Vbb (battery backup power)

Testing to see if battery backup power is reaching the RAM with sufficient voltage is easy.

- Set your DMM to DC Voltage
- Connect the black probe to game ground (in the picture at left, a clip lead is attached to the ground screw)
- Use the red lead to probe pin 28 of the RAM

Measuring in this way should yield over 3.5 VDC. If measuring shows 0 VDC, either the batteries are dead, or D2 has failed (see above).

Ideally, this measurement should yield 1.5 VDC * 3 - .6 VDC = 3.9 VDC. This calculation represents the nominal voltage delivered by a single AA battery, times 3 (batteries), less a typical .6 VDC drop across diode D2. Remember that nominal voltage drop across a typical diode is .5 to .7 VDC.



Pinout of the 6264 RAM. Note Vcc, upper right, pin 28

4.9 Replacing the CPU RAM with non-volatile RAM

A second option is to replace the 6264 static RAM with a SIMTEK non-volatile RAM (STK12C68). These SIMTEK RAM chips are increasingly hard to find but offer a nice alternative to changing batteries annually. This method requires desoldering/soldering on the MPU and also has the down-side of not maintaining the Real Time Clock (meaningless in some games...nice in games like Twilight Zone that moves the playfield "toy" clock to the current time during attract mode, and Who?Dunnit which has a "Midnight Madness" feature). Note, the WPC MPU is designed to accept either 6264 or 62256 static RAM. W3 needs to be installed (62256) or removed (6264) depending on the RAM size. Installing the SIMTEK part requires W3 to be removed, and R93 (1.5K ohms, 1/4 watt) to be present.

A WPC-089 MPU board with 6264 RAM, jumper W3 removed, and R93 in place.

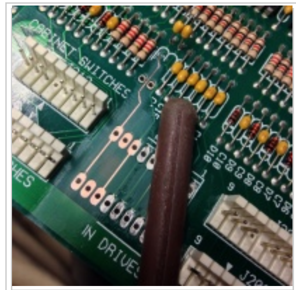
4.10 Repairing Alkaline Corrosion

A WPC-089 MPU board, after a couple hours of alkaline corrosion abatement.

Alkaline damage abatement on WPC MPUs is generally more difficult than Bally -17/-35 or Stern MPU-100/200 or Gottlieb System 80 MPUs. The traces on WPC MPUs are finer, and more abundant than on any of those boards. And, the "banks" of resistors and ceramic capacitors below the ULN-2803 and LM339s provide numerous hiding places for alkaline damage. The small traces under these components implement the switch matrix on the game.

Should alkaline abatement be attempted, if the ULN-2803 or LM339s are damaged, using any technique **other than** cutting them off the board, heating the alkaline damaged pads, and pulling the leftover legs out, WILL damage the board further. The alkaline adheres to the component legs and through-holes very strongly, making it almost impossible to remove the component using typical desoldering tools, no matter how skilled the individual is.

As is normally done during this process, sand with fine grit sandpaper (or use an abrasive stick as shown on the right for precision work) until bare copper can be seen, treat the board with 50/50 white vinegar/water to neutralize the alkaline, then rinse thoroughly with isopropyl alcohol or other favorite cleaner. Re-tin the exposed traces.



Using a "lamp socket cleaning stick" for precision removal of alkaline corrosion. These can be acquired at The Pinball Resource.

4.11 Slam Tilt

A WPC game (STTNG) that has been "slam tilted".

WPC games incorporate a slam tilt switch on the back side of the coin door. When closed, the game immediately stops, and the display fills with diagonal lines, as pictured at left. Note that this is not a power problem like a "game reset", below.

4.12 Game resets

One of the more annoying faults exhibited by WPC machines is the chronic reset problem. The game will restart, often when both flippers are used at the same time. Note that game resets are a power issue. "Slam Tilts" are something completely different (see above).

There are several possible reasons for game resets. Before doing ***any*** work on the circuit boards, it is recommended that a number of much easier to fix, and just as probable root causes, be examined.

Possible causes are listed below, in the recommended order of examination. This order is a derived from a combination of "ease of examination" crossed with "probability of root cause". The standard advice dispensed on RGP to change BR2 and C5 is often wrong and unnecessary. If BR2/C5 are changed out and the game no longer resets, some will conclude that, sure enough, BR2/C5 was the problem. What is being missed is that along with replacing those components, at the very least, the connectors on the board are being reseated, the solder on the cap and bridge is being reflowed, and the board ground to the backplane is perhaps better due to torquing the screws better. Any of these changes can improve voltage/current enough to reduce the frequency or eliminate resets.

4.12.1 The "Replace BR2 and C5 Mantra"

And now, a word on the classic "BR2/C5 mantra".

A long time ago…in a pinball galaxy far, far away…a kindly fellow was playing a nice game of pinball, hitting all the shots, and earning multiball after multiball. Just as he was about to beat the game’s high score to date, the WPC game MPU reset. "Not-A-Finga" he yelled in some ancient, dead, language.

A visitor from the neighboring planetary system noted that, "I once fixed that by replacing BR2 and C5". And lo, the mantra was born.

Fortunately, through advances in both our knowledge of these game systems, and the application of clearer thinking, we’ve come to realize that leaping to the “solution” of replacing components before doing real testing is not advisable. Most pinball owners do not possess the skill, experience, and tools that would allow them to work on circuit boards without damaging an expensive, and sometimes irreplaceable board.

Still, with regular frequency, a post will be read on RGP or PinSide that goes something like this…"My game was resetting so I replaced BR2 and C5 and the resets vanished." This logical construct is known as "Post hoc, ergo propter hoc" (after this, therefore because of this), an insidious logical fallacy that states "Since that event followed this one, then that event must have been caused by this one". Clearly, this is an invalid assumption. The fallacy lies in coming to a conclusion based solely on the order of events, rather than taking into account other factors that might rule out the connection.

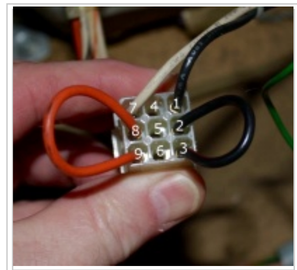
In reality of course, when components are removed and replaced on a circuit board, the attendant "changes" to the state of the game system include…

1. reseating connectors and possibly improving electrical conductivity
2. possibly changing the connectivity through fractured solder joints which may be flexed differently
3. reseating the entire board in the backbox and possibly improving ground for the board
4. reflowing solder joints on both components possibly improving electrical conductivity
5. possibly improving heat dissipation from the bridge to the heat sink by replacing thermal grease
6. perhaps an air conditioner, refrigerator, or heater has shut off thereby increasing available electrical current

So please, hold off on heating up the soldering iron until methodically working through the disciplined process in the following section.

4.12.2 WPC 5VDC Power Derivation Path

Following is the nominal path from the wall plug to eventual consumers of the clean 5VDC power supplied by the Power/Driver board.



WPC Transformer Power Configuration Plug, configured for US 120V systems.

1. 120VAC/60Hz power is nominally provided at the wall plug. Different voltages are accommodated also (see below)
2. An RFI (radio frequency interference) filter, which is seldom a contributor to game problems.
3. Line power is connected to a service outlet sometimes incorporated into the metal "power box" and made available to the tech via a short, uniquely plugged, extension cord. Line power is wired in parallel and does not require the power switch to be in the ON position.
4. Both sides of the AC power pass through the double pole/double throw (DPDT) game power switch
5. The "black" side of the AC power passes through an 8A FB fuse housed in a bayonet style (screw in) fuse enclosure.
6. The "black" side of the AC power then passes through the thermistor, which limits current inrush into the system.
7. "Butterfly" voltage select connector used to accommodate typical voltage systems used around the world (120VAC in US, 230VAC abroad, low line voltage, etc). When configured for 120VAC in the US, the connector and wiring resemble a butterfly.
8. Transformer Primary windings
9. Transformer Secondary windings
10. Yet another Molex connector, mating with the harness that will eventually lead to the Power/Driver board.
11. Some games incorporate a "coin door interlock switch" which interrupts coil and flasher power when the coin door is open. If the game is equipped with this switch, there will be an extra Molex connector necessary to implement this switch.
12. J101 on the Power/Driver board (WPC-95: J129)
13. Full Wave AC rectification and smoothing via BR2 and C5 (WPC-95: D7 through D10 and C9)
14. Regulation to 5VDC via the LM323K at Q1 (WPC-95: LM317 at Q1))
15. Lighting LED4... (WPC-95: LED101)
16. And finally, delivery to 5VDC power consumers via J114, J116, J117, and J118 (WPC-95: 105, J139 through J141)

WPC-95 Voltage Adjust resistors R1 and R1

Note that the LM317 is an adjustable voltage regulator where the LM323K is a 5V specific regulator. The LM317 is "programmed" to 5.108V using precision resistors R1 (750 ohms) and R2 (243 ohms), located just to the right of the LM317 heat sink. It is possible, although not advised, to adjust the output of the LM317 regulator to something other than the nominal 5.108 volts.

4.12.3 Possibly Skip Steps

If the game is resetting **only** within the first minute or two, and plays fine after that, skip to Step 8, Failed Thermistor (http://www.pinwiki.com/wiki/index.php?title=Williams_WPC#Failed_Thermistor) . If the thermistor turns out to not be the cause, return to step 1.

4.12.4 Low Line Voltage

Step 1: measure line voltage

Low line voltage can occur for several different reasons...

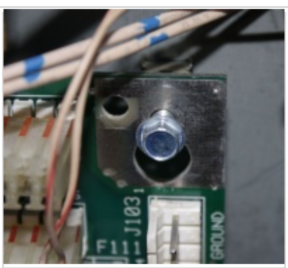
- Peak summer usage may cause a drop in line voltage (at the wall). Nominal voltage should be 115VAC minimum.
- Too many games or "power hungry" devices on the same circuit. This is common when numerous devices are plugged into a power strip.
- Game(s) plugged into an extension cord or power strip with too small of wire gauge. If the game is plugged into an extension cord, make sure that it carries all three conductors and is constructed of **at least** 16 gauge wire, or specified as 16/3. Using a beefier 14/3 extension cord is better, and advised if more than one game is plugged into the cord.

Measure line power at the wall plug that the game is plugged into (not on the bench, as shown here). Almost 118VAC...Nice...

If the machine is resetting, open the coin door and measure the AC voltage at the auxiliary socket with the machine turned off, and then with the machine turned on. If the voltage at the auxiliary socket is over 105VAC, the problem is most likely inside the game. If the voltage is below 105VAC, there is a line voltage problem and the local electricity company's help will be needed to correct the problem.

4.12.5 Poor Ground Connection for Power/Driver Board

Step 2: Make sure the power/driver board is screwed down tightly

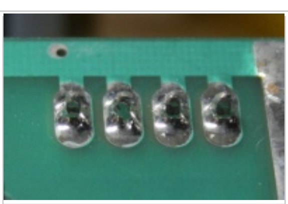


As my friends in Texas might say, "that dog won't hunt". All backbox boards must be securely screwed down.

A poor ground connection from the power/driver board to the backbox ground plane can reduce 5VDC by as much as .3 volts. Ensure that the screws that hold the power/driver board down, secure it tightly.

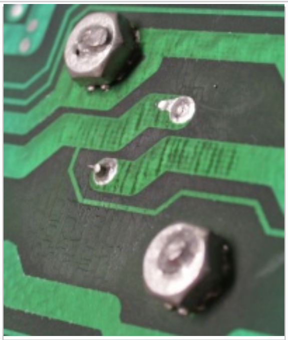
4.12.6 Cracked Power or Ground Header Pins and Cracked Solder Joints at the 5V Fuse

Step 3: Examine the header pins at J101, J102, and J103 as well as at the LM323K regulator (WPC-95: J136 and J137)

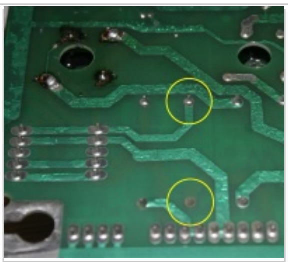

Cracked header pin solder joints at J103 in a Twilight Zone, causing game resets.

Similar to step 2 above, cracked header pins where the power enters the board or at the ground connections on the board can cause game resets. In the picture at left, cracked header pins at J103 (ground) in a Twilight Zone caused game resets. Either reflow the solder, or better yet, replace the headers with new pins.

Another place to examine for fractured solder joints is on the solder side of the board, where the LM323K (WPC-95: LM317) 5VDC regulator is placed. This area is subjected to very high temperatures that sometimes causes the solder to crystallize. If the solder joint is in any way suspect, remove the old solder and reflow new solder on the joint. Ensure that a nice solder "meniscus" is created (a volcano shaped solder joint) vice a "doughnut" around the wire lead.



Fractured solder joints at the LM323K 5V regulator (WPC-95: LM317), causing game resets.

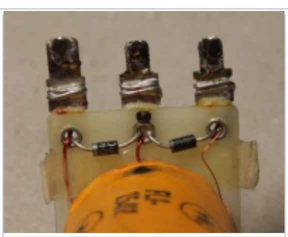


Fractured solder joints at fuse F113.

Fuse F113 (WPC-95: F105) fuses the 5V power for the game. Fractured solder joints here may cause the DMM to read near 5V, yet the joint doesn't allow enough current to pass. This can cause game resets and even cause the game to not boot. Reflowing the solder at these joints is prudent.

4.12.7 Missing diodes, open diodes, or cold solder joints at the Flipper coils

Step 4: Examine flipper coil diodes



Example flipper coil diodes shown on a FL-15411 flipper coil.

WPC flippers are, in general, the only coils in the game that should have diodes across the coil lugs. While diodes seldom fail, sometimes the pounding environment that flipper diodes must live within causes solder joints to fail. Ensure that each flipper coil has the required two diodes, that the diodes are good, and that they are soldered to the coil lugs with a quality solder joint.

4.12.8 Poor Connections between the Transformer Secondary and the Power/Driver Board

Step 5: Examine the "cube shaped" molex connector in the cabinet

The connections from the transformer secondary to the Power/Driver board can degrade over time, a natural result of hours and hours of "power on" time. Try re-seating each connector. If the reset frequency is reduced or disappears, then the root cause has probably discovered. These connectors should be repinned at a minimum with at least new pins (the connector housings may be salvageable) for a long term solution. It is especially important to re-pin the red 9VAC wires that carry power to the Power/Driver board as this is converted to the 5VDC logic voltage.

Note: the molex pin extractor for these "round" pins is relatively expensive but there is no other good way to remove the pins.

The 15-pin Molex "cube" connector. The red wires carrying 9VAC to the Power/Driver board can be seen here.

4.12.9 Poor Connection at J101 on the Power/Driver Board

"Step 5.5: Examine both male and female connectors at J101 (WPC-95: J129)"

Connector J101 In-Situ (bottom of picture)

J101 (WPC-95: J129) connects the transformer secondary supply of both 9VAC (solid colored red wires, ultimately used to create 5VDC power) and 13VAC to the power/driver board. This connector often becomes tarnished, increasing resistance and reducing the effectiveness of the circuit. Reseating the connector may temporarily reduce reset frequency. This is an indication that this connector should be repinned. As always, it's best to repin both the male and female connectors.

4.12.10 Poor Connections between the Power/Driver board, the CPU, and other PCBs

Step 6: Examine other wiring harnesses and the connectors

A convenient location to find ground in a WPC backbox.

Measure DC voltage at TP2 (WPC-95: TP101) on the Power/Driver board.

1. DMM set to DC volts (if not an auto-ranging meter, expect to measure 5VDC)
2. Black lead secured to game ground (the ground braid in the head is a good place to pick up ground)
3. Red lead on TP2 (WPC-95: TP101). Remember the reading.

Measuring DC voltage at the 5VDC test point, TP2.

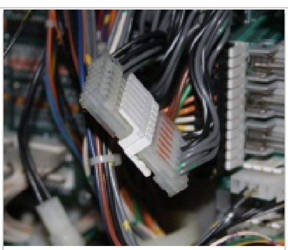
Measure DC voltage at the CPU board.

1. Again, DMM set to DC volts
2. Black lead in the same place
3. Red lead on pin 32 of the game ROM, or on pin 2 (center pin) of the MC34064 under voltage watchdog at U10
4. Record this reading

Compare the two readings. ANY difference indicates voltage loss across the connectors. Some voltage loss is expected/natural since no circuit path can provide zero resistance. A difference of .1VDC is enough to warrant examination of the connectors between J114 (WPC-95: J105)on the Power/Driver board and J210 on the CPU board.

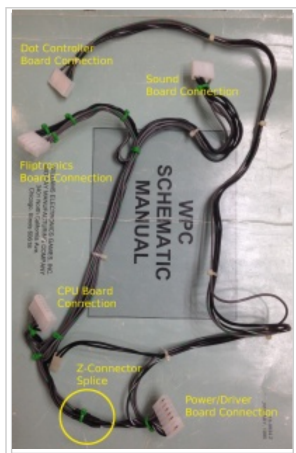
Reseating the wire harness that connects the power-driver board to the CPU board may identify the root cause (but reseating is not a long term solution).

Measuring DC voltage at pin 32 of the game ROM


The "Z" connector, as used in Twilight Zone, etc.

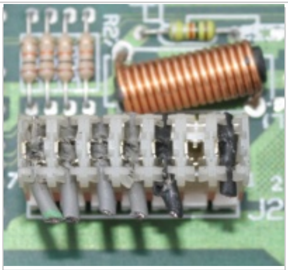
Some games use an interceptor harness to power extra boards (IJ, TZ, WH20, STTNG, FT, etc). There is a inline splice connector (commonly called a Z-connector) between the driver board and the CPU board. The Z-connector can be replaced, or more robustly, eliminate it by splicing the wires together, soldering and heat-shrinking. This removes the Z-connector as a contributor to game resets entirely.

At least on Twilight Zone, the wire harness that contains the "Z" connector can be removed from the game entirely, as shown at right. This harness has been repinned and the "Z" connector eliminated.

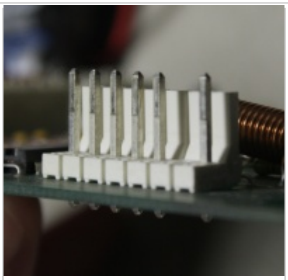


The entire harness containing the "Z" connector in Twilight Zone can be removed from the game for easier repinning.

Some field techs will "repunch" IDC connectors in an attempt to make a better connection. Without the correct punch tool, sometimes and even worse connection is created, as pictured at left. If the decision is to use IDC connectors, at least use the correct tool to punch the wires.



A poorly "repunched" IDC connector. This connection was probably "punched" with a small flat-blade screwdriver. Note the bare wires where the insulation has been damaged. Yikes!



MPU connector J210. This connector has had the plating worn off right where the female connector mates with it. When mated with a worn female connector, increased resistance results in reduced voltage, causing resets and possibly failure to boot.

Tarnished, heat damaged, or damage to header pin plating creates resistance and can sometimes be a contributor to game resets. If the male header pins are tarnished, their female mates are probably tarnished also. If tarnished pins are found, now might be a good time to remove that aspect as a contributor to game resets.

If following this step-by-step process, now is the first time that a soldering/desoldering station will be needed.

Replace the male header pins, remembering to clip the correct "key" pin before reinstalling the board into the game.

Replace the female connector and pins with good quality Trifurcon crimp-on pins. IDC (Insulation Displacement Connectors) connectors as found originally on the game were used by the OEM to speed the manufacturing process and do not provide the level of robustness that can be achieved using Trifurcon crimp-on pins and good technique.

Another possible contributor to poor power connections is cracked header pin solder joints. Although, with WPC double-sided PCBs and the relatively large header pin through-holes, this is rarely seen. Should you identify cracked header pin solder joints, it's best to remove as much of the old solder as possible before reflowing new solder at the joint.

4.12.11 Using a Multimeter to Test the Bridge Rectifier and Capacitors

Step 7: Bridges and Caps in circuit

There's one last test we can do before disassembling parts of the machine. This test can clearly identify a bad bridge rectifier or capacitor. You will need a clip lead.

1. With the machine off, clip the lead onto the top left lead (positive) of BR2. You will have to do this by feel, as you cannot see the lead. This clip point is the output of the bridge rectifier, and is connected to the smoothing (filter) capacitor and LM323K regulator input. It should be at 9V DC.
2. Next, place the other clip on the red (+) lead of your meter.
3. Connect the black lead to ground by tucking it under the braid. Check your installation to make sure that nothing is shorting.
4. Set your meter to DC volts.
5. Turn on the game.

The meter should read about 9V. This will be true whether C4/C5 are working or not. If the bridge rectifier is bad, it will read about 7V.

For the capacitor, turn your meter to AC volts. Note that inexpensive meters may give false readings here. Ideally, your meter should be a true RMS meter. Good capacitors will read about 300mV AC. Bad capacitors will read up to 2VAC. Anything over 1VAC indicates a failed/failing filter capacitor at C5 which should be replaced.

Measuring "un-smoothed" DC voltage output from BR2. The voltage is smoothed later by C5. This bridge is functioning properly.

4.12.12 Failed Thermistor

Step 8: Examine the Thermistor

A look inside a typical WPC power box. This particular box was from a Fish Tales. The Thermistor is grey, the varistor is green.

The thermistor is (generally) a black or grey disk, about the size of a dime. It is located inside the power box which is found just inside the coin door and to the right. If your game has one (and not all WPC games do), it will be connected in series between the power box fuse and the black side of AC power. Note that the power box may also contain a "varistor", or MOV, which is essentially a surge protector. The varistor will be wired in parallel with (across) the AC power. The varistor is not a factor in game resets.

The thermistor's job is to limit current inrush into the capacitors when the game is first powered on. This reduces stress on the bridge rectifiers or diodes in the game's power circuits (which is the primary cause of bridge rectifier failures). After a few seconds, the thermistor heats up and drops to a very low resistance. Failing thermistors pass less current and have to get hotter to work. This heating takes time, so the game will often reset in the first 30 minutes of operation, and then be fine afterwards. Obviously, a cold environment will make the symptoms worse, and a warm room may appear to cure the problem.

Resetting while the game warms up is therefore a key indicator of a failing thermistor. Note also that DCS and WPC-95 A/V boards may reset independent of the MPU. If this is the case, you'll hear the characteristic same "bong" as when the game boots.

*****Safety Warning***** Unplug the game **AND** turn the game off before conducting the following test.

Sometimes, the thermistor may be visibly damaged. However, it may look good and still be bad. An easy test of the thermistor is to jumper across the legs of the thermistor with a heavy gauge wire. If the game resets no longer occur, replace the thermistor with the correctly rated part. The original Williams part number is 5016-12978-00. A replacement is available from Great Plains Electronics (http://www.greatplainselectronics.com/search.asp?pg=1&stext=5016-12978-00) .

While you have the box open try wiggling the connectors (the game ***IS*** unplugged!) you probably will find at least one that is loose - this can contribute to reset issues. The fix is to solder all the crimp quick connect (examples on coil (http://www.pinwiki.com/wiki/index.php?title=File:DSCF0810.JPG)) wires to the pins they were connected to in the box: cut the quick connects off, one at a time, and then solder the wires directly. Insulate the connections with Heat-Shrink or a good grade of electrical tape.

4.12.13 Questionable Prior Rework

Step 9: Examine prior rework

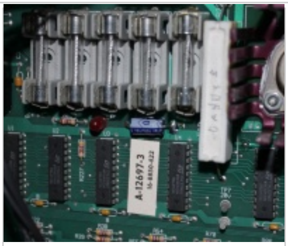
The printed circuit boards used in pinball machines sometimes have traces on both sides of the board. Most WPC boards are manufactured in this way. The traces are joined through the board by a thin layer of copper, plated to the inside of the hole. This plating is delicate. Without great care, the plating can pull out or crack when components are removed, especially alkaline damaged components as found on MPU boards (after batteries have leaked) and "snap caps" as found on OEM WPC Power/Driver boards (at C5 for instance).

Extreme care as well as good technique must be exercised when removing these components as it is very easy to lift traces or damage through-holes on the board. If the component is known to be bad, it is sometimes easier to snip the component from the board with a flush cutter and remove each leg of the component individually.

An excellent way to repair a lifted trace or cracked through-hole is to create a 'solder stitch (http://pinwiki.com/wiki/index.php?title=How_to..._(solder,_desolder,_%22stitch%22,_test_transistors,_test_ICs,_etc)#Repairing_traces_or_creating_a_.22solder_stitch.22) ' between the traces on each side of a two sided board. Some PCB repairmen will install jumpers as a "repair" for cracked through-holes or to "guarantee" connectivity between components. Some PCB repairmen will avoid the use of jumpers in favor of better looking rework.

4.12.14 Failed Capacitors

Step 10: Power smoothing capacitors at end of life



C4, shown "in-situ" on a typical WPC Power/Driver Board. A new C4 cap has been installed on this board (100μF/10V). Nice job by the installer orienting the cap so that its value is in easy view!

Electrolytic capacitors do not last forever. They are designed to operate for about 1,000 hours at their full rating. Capacitor life is a function of temperature: the cooler the capacitor operates, the longer the life. The system designer must select higher voltage and capacitance ratings to achieve the design life, which can be as short as 5 years in a pinball machine operated continuously in a warm environment.

The WPC Power/Driver board uses a 15,000μF, 25V capacitor at C5 to smooth the full wave rectified AC from BR2. When this capacitor is no longer smoothing the rectified AC well enough to produce a clean 5VDC, the voltage may drop below the threshold enforced by the watchdog circuit on the MPU (an MC34064 at U10). When this happens, resets sometimes result.

Note that commonly available replacement capacitors are rated to 35V, and will work fine for this application. In general, you may use a capacitor rated for higher operating voltages but the capacitance specification (μF, or micro-farads) should not be changed.

C4 (spec'd at 100μF, 10V, axial) can sometimes fail and cause the game to reset also. If you've gotten this far and are replacing C5, you might as well replace C4 too.

A good view of a 15,000uf cap, with a pulled through hole still on the left lead (the brown donut looking object)

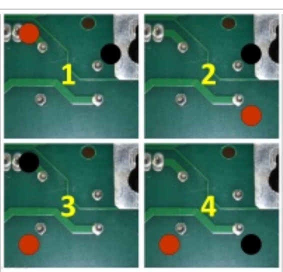
Removing the big 15,000uf capacitors on a WPC-089 power/driver board is a bit tricky. More often than not, an amateur will damaged the through hole that connects one side of the board to the other, either severing the connection completely, or badly enough to cause intermittent reset issues. Should the through hole be pulled, a solder stitch (http://www.pinwiki.com/wiki/index.php?title=General#Repairing_traces_or_creating_a_.22solder_stitch.22) needs to be installed, or "jumpers" need to be installed connecting the associated bridge rectifier to the capacitor. **Advice:** Without the experience, tools, and technique to accomplish this task, most hobbyists would be well advised to send the board to a pro for rehab.

4.12.15 Failed Bridge Rectifier

Step 11: Test Bridge Rectifier #2 (BR2)

The thermistor protects the bridge rectifiers from inrush current. Still, bridge rectifiers will occasionally fail.

Testing a bridge rectifier is simple.



Four Connections to Test a Bridge Rectifier. Black/Red dots represent test lead positions.

The picture at left illustrates the 4 readings to be taken when testing a bridge rectifier.

Procedure:

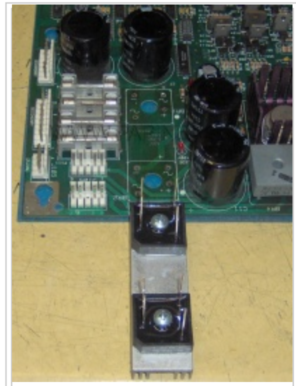
1. Place your DMM into "diode test".
2. Put the black lead of your DMM on the "oddball" lead of the bridge rectifier. This will be the lead that isn't oriented the same as the others (as with the "spade" type of bridge) or the lead that prevents the four legs from forming a square (as with the "wire lead" type of bridge). This will also be the DC positive lead of the bridge.
3. Place the red lead of the DMM on each of the adjacent legs, one at a time.
4. A reading nominally between .5 and .7 should be seen (this represents the voltage drop across the bridge's internal diodes).
5. Swap locations of the red and black leads. A reading of "null" should be seen.
6. Now place the red lead of the DMM on the lead opposite of the "oddball" lead, or the DC negative lead of the bridge
7. Place the black lead of the DMM on each of the adjacent legs, one at a time.
8. Again, a nominal reading between .5 and .7 should be seen.
9. Swap locations of the red and black leads. A reading of "null" should be seen.

Readings outside of these ranges indicate a failed or failing bridge. Note that these readings are not "hard and fast". For instance, a reading of .462 is probably acceptable. We are looking for an "open" or a "short". Note also that this test is not conducted "under load" and it is possible for the bridge to test "good" when it will in fact fail under load (this is also true when testing diodes, transistors, etc).

Testing a Bridge Rectifier in circuit. This part of the bridge is good.

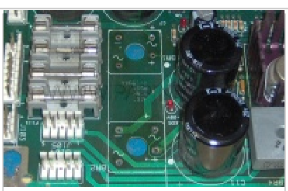

Applying heat transfer grease (heat sink compound) to the new bridge rectifiers.

Should you decide to replace the bridge, it is best to screw the heat sink to the bridge before soldering it in place as the heat sink is shared between BR1 and BR2. A small amount of heat sink compound between the bridge and the heat sink is necessary. This compound improves conduction of the heat away from the bridge and into the sink.


New bridge rectifiers screwed to heat sink before placing on driver board.

Some repair tips suggested cutting the heat sink in half, separating it into two parts, one part for each bridge. This technique is no longer considered to be a best practice.

Solder both the top and bottom solder pads of the bridge. Should the through-hole of the bridge leads be cracked or otherwise damaged, use the "solder stitch" technique noted above or install jumper wires between the DC outputs of the bridge and the terminals of C5. When clipping the leads of the wire bridge, do not cut into the solder "meniscus" (the "volcano" of solder around the wire lead). Cutting into the solder meniscus can cause cracked solder joints later.


Bridge rectifiers 1 and 2 removed elegantly with a desoldering iron.

With proper desoldering tools, like the Hakko 808 or Hakko 470D, removal of bridge rectifiers and other components is greatly simplified. After replacement of bridge rectifiers is made, it's not a bad idea to mark the replacement date. In doing this, you or anyone else will know when these were replaced, and more importantly that they were replaced.


New bridge rectifiers installed, and replacement date noted.

4.12.16 Failed Voltage Regulator

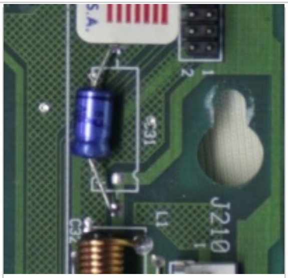
Step 11: When all else fails...

The LM323K 5V regulator is a robust device, but it can drift over time to below the design requirement of 4.8VDC. If your 5VDC reads less than 4.8VDC at the test point, or less than 4.75V on the CPU board, you have to replace the regulator. Note that these voltages are compliant to the LM323K's spec. However, at the lower end of this spec, this lower voltage may be the cause of resets.

4.12.17 Failed Electrolytic Capacitor on the MPU

Step 12: Failed C31 on the MPU

There is one more possibility. C31 acts as a filter on the WPC-089 MPU. It is a 100μF, 10V capacitor, connected between incoming 5VDC and ground. Failure of this part has the same low probability as a failed C4 on the power/driver board. Swapping the suspect CPU with a known working CPU is a good diagnostic step.



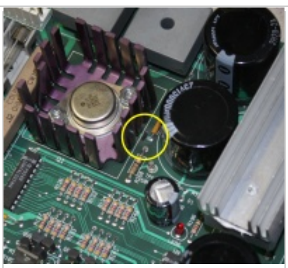
C31 on the MPU rarely fails.

4.12.18 The Absolute Last Resort

Step 42: We really didn't want to get to this point!

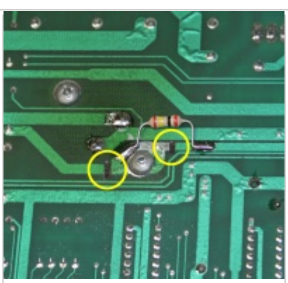
There is a method of absolute last resort. This is absolutely, positively a hack. And yes, it can push some extra margin into the design, covering up other problems, which is why it is a hack.

The LM323K draws a small current to operate, which it passes to ground. We can use that current to raise the voltage of the whole LM323K, pushing the output closer to 5V.


Ground Trace severed leading to C9.

Procedure:

1. Isolate the LM323K's metal case from board ground by cutting the ground traces that run left and right from the nut on the back of the board that bolts the LM323K to the board. The neater you make these cuts, the easier it to reverse this hack.
2. Some versions of the Power/Driver board include a ground trace on the component side of the board that provides a ground to the tantalum capacitor at C9. This trace must be cut on the component side of the board.
3. Add a 1/2W resistor in series, from the LM323K ground to the board's ground trace.


LM323K case isolated from ground, and a 25ohm resistor added. This raised the nominal voltage by .2VDC.

A 12 ohm resistor will nominally raise the LM323K voltage output by .1 VDC.
A 24 ohm resistor will nominally raise the LM323K voltage output by .2 VDC.
Note: The LM323K is designed to operate this way.

4.12.19 The Conductive Grease Hack

What is a "Hack"? Some techs will recommend the use of conductive grease to improve conductivity at a connector. While some techs will "swear **by** the stuff", other techs will "swear **at** the stuff", and as such, this is not considered a best practice. The grease can extend the life of new header pins, and protect against hostile environments that would cause corrosion. However, when used on header pins that are already damaged, grease can only slow further deterioration. Worse, the heat in the connector will turn the grease to gunk. If you find a flaky connector with gunk in it, you've been "greased" and you will want to re-pin it.

Damaged/burnt connectors should always be replaced (http://www.pinwiki.com/wiki/index.php?title=General#Electrical_Tools) . Dow Corning #4 (http://http://www.dowcorning.com/applications/search/products/details.aspx?prod=01903128&type=prod) grease can't help them.

On the other hand DC#4 (http://http://www.dowcorning.com/applications/search/products/details.aspx?prod=01903128&type=prod) Electrical Insulating Compound Grease does a superior job reducing friction and corrosion on contacts and that would be considered a net benefit to any game. JRR's shop and others have also found a decrease in the temperature of power contacts using DC#4 (http://http://www.dowcorning.com/applications/search/products/details.aspx?prod=01903128&type=prod) along with reduced resistance which should increase the life of the connector. This product is also good to use on EM pins for the interconnect plugs/sockets as it reduces friction and improves conductivity.

Note that DC#4 (http://http://www.dowcorning.com/applications/search/products/details.aspx?prod=01903128&type=prod) is stable from -57C to 204C (-70F to 399F). If your game has contacts at the high end of those temperatures then certainly, the smoke (http://en.wikipedia.org/wiki/Magic_smoke) would be getting out...

If other products are used, investigate carefully to ensure they are a proper dielectric grease suitable for high temperature applications. There is a time and place to use this type of product, mostly as a preventative measure on newly replaced contact surfaces. Applying it after the plating has burned off is a questionable practice and no substitute for proper connector replacement.

4.13 Check fuses F114 and F115 message

Check Fuses F114 and F115 Message

This message is sometimes displayed when the game boots and a game cannot be started. Most of the time, F114/F115 will be found to be just fine.

The game issues this message because it cannot read the switch matrix normally. The crafty designers at Williams inserted an “always closed“ switch into the matrix as switch 24. Switch 24 isn’t a switch at all, but instead provides the game software with a “known closed” switch matrix return. Switch 24 is actually a diode across column 2, row 4 of the switch matrix and is located on the coin door interface board.

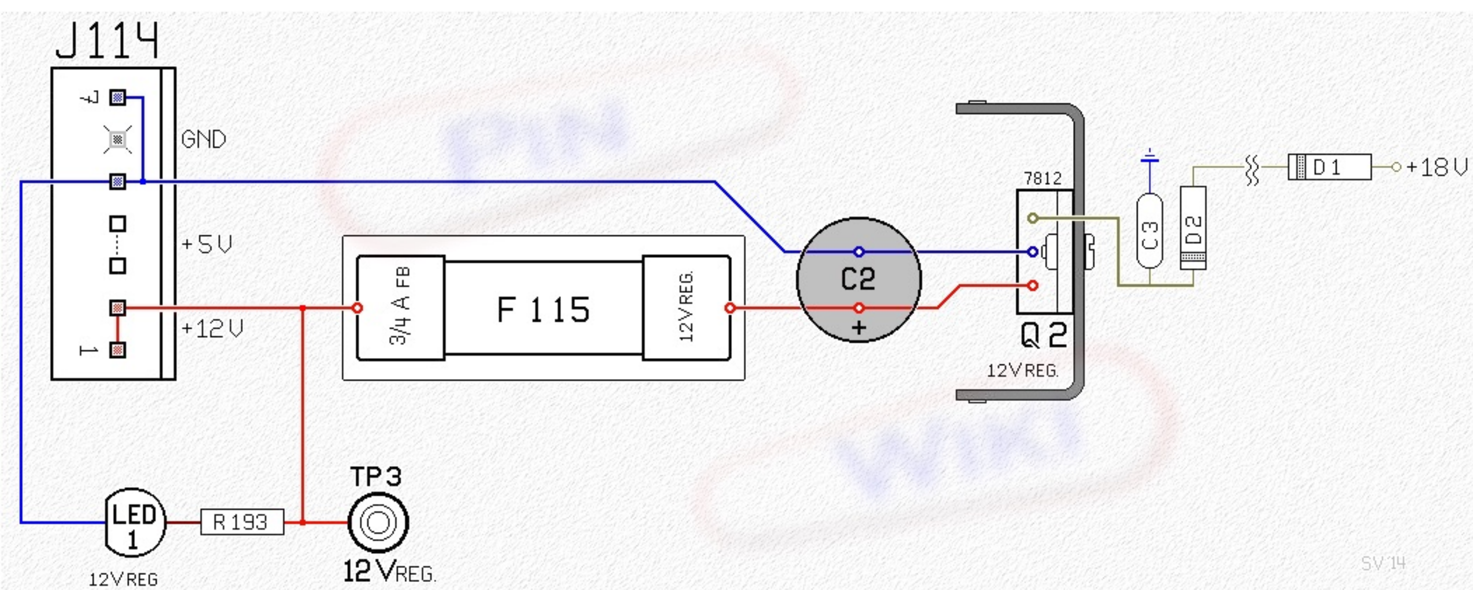
Since the WPC switch matrix circuitry on the MPU uses 12V to determine switch state, the game assumes that the 12VDC power has been interrupted. F114/F115 fuse the 12V generation circuit; F114 on the AC side of BR1; F115 on the DC side of BR1. Hence, the game assumes that one of these fuses is blown and the message is displayed.

Diagnosing the problem

Start by checking DC voltage at TP3. You should see about 12VDC. If not, follow these steps.

1. Actually check fuses F114 and F115 using the procedure **here**. If a blown fuse is found, replace it. If F114 immediately blows again, then BR1 is probably shorted. Skip to the paragraph below to test the bridge.
2. Check LED6. If not lit (indicating the absence of 18V at TP8), then suspect BR1 or the filter caps for BR1, C6 and C7. If BR1 had failed shorted or if C6 or C7 where shorted (rare) then you would expect to see F114 blown. BR1 can be tested using the procedure below.
3. Check LED1. If not lit (indicating the absence of “digital” 12V at TP3, then test D1 and D2 (both 1N4004 diodes that can be tested with the game off or board removed using the standard "diode check" on your DMM).
4. If D1/D2 test good, then check continuity from pin 2 of the 7812 voltage regulator at Q2 to J114, pin 1. This verifies the path through F115.
5. If this all checks out, yet 12VDC is still not at TP3, then suspect the 7812 voltage regulator at Q2. Q2 is in a TO-220 package (like a TIP-102) and has a small heat sink attached.

Alternate Problem Determination Method: Test Power Across the Driver Board



The diagram above shows the simple path for the 12VDC power regulation circuit. Power may be tested across the circuit, as follows.

1. Turn the game on.
2. Set your meter to DC volts. If your meter isn't an auto-ranging meter, expect to see less than 20VDC.
3. Clip the black lead of your DMM to game ground, or tuck it under the backbox ground braid.
4. Probe TP8 with the red lead of your DMM. It should measure about 18VDC. If not, suspect F114.
5. Probe the banded side of D1. It should measure about 18 minus .5 to .7 volts, (the typical voltage drop across this kind of diode), or about 17.4VDC. If not, suspect D1.
6. Probe the banded side of D2. It should measure about 17.4 minus .5 to .7 volts (again), or about 16.8VDC. If not, suspect D2.

7. Probe the top leg of the 7812. It should measure about 16.8V. If not, suspect the trace between D2 and the 7812 or a fractured solder joint at the 7812.
8. Probe the bottom leg of the 7812. It should measure about 12VDC since the job of this regulator is to produce 12VDC. If not, suspect the 7812 regulator.
9. Probe the right side of fuse F115. It should measure about 12VDC. If not, suspect the trace between the lower leg of the 7812 and fuse F115. In particular, suspect that C2 has leaked and corroded the trace carrying the 12VDC. See: "Leaky Capacitor C2 corrodes trace", below.
10. Probe the left side of fuse F115. Again it should measure about 12VDC. If not, suspect F115 is blown or the fuse block has a poor mechanical connection to the fuse or to the PCB.
11. Finally, probe pin 2 of J114. It should read about 12VDC. If not, suspect the trace from fuse F115, the connection of the F115 fuse block to the PCB, or a fractured pin at J114.

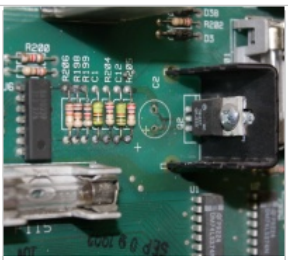
The only circuit path remaining to test is the path to the ground pin of J114 (pins 5 and 7) from the 7812. This is easily accomplished with power off.

1. Set your DMM to continuity and "buzz" between the tab of the 7812 to J114, pin 5 and 7. If no continuity, suspect a fractured solder joint at the center pin of the 7812, or corrosion under C2 that has compromised the trace.

Short on the MPU causing F115 to blow

There is one more way for the 12VDC power to be lost and for F115 to blow. A shorted IC on the MPU that uses 12VDC can cause F115 to blow. To help isolate the problem to the MPU, replace F115, disconnect power going to the MPU at J210, and turn power to the game on. If the fuse does not blow, the problem is almost definitely on the MPU board. Any of the LM339s (theoretically) or the ULN2803 (definitely) can fail and short 12V to ground, causing F115 to blow.

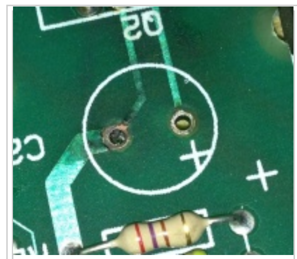
Leaky Capacitor C2 corrodes trace



Filter capacitor C2 (removed), leaking it's corrosive electrolytic contents, eating through traces

Yet one more way for the 12VDC regulated power to be lost is shown in the picture at left. In the picture, the electrolytic cap at C2 has failed and leaked corrosive electrolytic contents onto the board. The lower trace from Q2 (7812 voltage regulator) to C2 (+ side), that goes on to connect to F115 on the solder side of the board, has been eaten away, no longer providing a path for the regulated 12VDC power. Corrective action here is the same as alkaline damage abatement.

Shown on the right is another shot of the damage caused by a leaky cap at C2. This one resulted in reducing the 12V power to about half of spec.

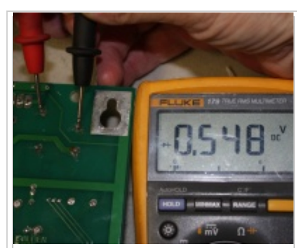


Filter capacitor C2 (removed), showing damage caused by a leaky cap.

If TP3 does, in fact, have 12VDC present, then we need to dig deeper.

1. First check for 12VDC on the CPU board to ensure that the 12V is getting to the board via the 2 (and possibly 4 if your game has a “Z-Connector”) connectors that carry the 12VDC. An easy place to measure 12VDC on the CPU is at pin 10 of the ULN2803 (U20). Pin 10 is on the bottom row of pins, furthest left. Note that this connection (and also the 12VDC connection to pin 3 of the LM339s) is not shown on the schematic.
2. If the CPU is receiving 12VDC, and you still have the “Check fuses F114 and F115” message, then the problem lies within the CPUs switch matrix logic circuitry.
3. Prime candidates for CPU switch matrix failure are U20 (a ULN2803), the two LM339s at U18 and U19, the 74LS374 at U14, and the 74LS240 at U13. All of these ICs are in the “corrosion zone” caused by leaky alkaline batteries. If your CPU exhibits the “blue/green fuzzies”, address the alkaline damage first.
4. Testing the 74LSXXX ICs is simple using the procedure **here**.
5. If coil power, flasher power, or even lamp power was somehow shorted to the switch matrix, there is a near 100% probability that the ULN2803 at U20 has been damaged. There is no good way to test the ULN2803 other than using a logic probe with the game powered on. Both the input side and the output side of the ULN2803 should be toggling between logic 0 and logic 1. If not, socket and replace the ULN2803.

Testing a bridge rectifier is simple.



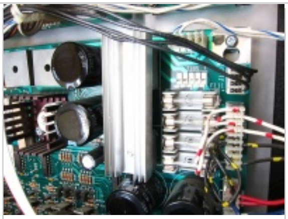
Testing a Bridge Rectifier in circuit

1. Place your DMM into "diode test".
2. Put the black lead of your DMM on the "oddball" lead of the bridge rectifier. This will be the lead that isn't oriented the same as the others (as with the "spade" type of bridge) or the lead that prevents the four legs from forming a square (as with the "wire lead" type of bridge). This will also be the DC positive lead of the bridge.
3. Place the red lead of the DMM on each of the adjacent legs, one at a time.
4. A reading nominally between .5 and .7 should be seen (this represents the voltage drop across the bridge's internal diodes).
5. Now place the red lead of the DMM on the lead opposite of the "oddball" lead, or the DC negative lead of the bridge.
6. Place the black lead of the DMM on each of the adjacent legs, one at a time.
7. Again, a nominal reading between .5 and .7 should be seen.

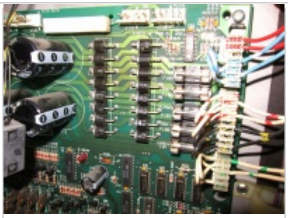
Readings outside of these ranges indicate a failed or failing bridge. Note that these readings are not "hard and fast". For instance, a reading of .462 is probably acceptable. We are looking for an "open" or a "short". Note also that this test is not conducted "under load" and it is possible for the bridge to test "good" when it will in fact fail under load (this is also true when testing diodes, transistors, etc).

Take special care when replacing a bridge rectifier. It is easy to lift the traces of the plated through holes when removing these. After removing the heat sink, cut the old bridge rectifier off of the board close to the top leaving as much of the lug as possible. Then add a small amount of solder to the connection on the solder side to improve heat transfer. Finally apply the iron to the solder side to heat the joint and remove the remaining lug with small pliers.

When replacing the new bridge rectifier you should remove the old thermal compound and apply a new thin layer. The old compound can be removed with a little rubbing alcohol. Apply the thermal compound to the top of the bridge rectifiers and reattach the heat sink with the screws (see above). It is much easier to replace the heat sink before resoldering the new bridge rectifier. Make sure that the heatsink is sitting flush with the tops of the bridge rectifiers and that you leave about a 5/8" gap between the bridge rectifier and the board to improve air flow.


The heat sink covering BR1 and BR2 on a WPC-board

Splitting the heat sink between BR1 and BR2 was at one time thought to improve reliability. This is no longer considered a best practice and is **not** recommended.


Diodes replaced BR1 and BR2 on WPC-95 boards

In WPC-95 games, BR1 and BR2 were replaced by a series of diodes. D11-D14 replaced BR1. D7-D10 replaced BR2. These are much less prone to failure. Still, they do fail on occasion. If one or more fail, it's best to replace all four in the "gang". These diodes were originally 6A2 diodes. Replace them with 6A4 diodes (6 amp 200V vs 6 amp 400V). See the "Check Fuses F106 and F101" section below for the equivalent WPC-95 message.

4.14 Check Fuses F115 and F116 Message

Check Fuses F115 and F116 Message

Similar to the "Check Fuses F114 and F115" above, games like Demolition Man will display this message at power up if switch 24 isn't seen as closed and none of the optos are seen as closed (remember, the opto switch open/closed logic is inverted). Debug this issue in the same way as the Check Fuses F114 and F115 problem, above.

4.15 WPC-95 Check Fuses F106 and F101 Message

Check Fuses F106 and F101 Message

If a WPC-95 game detects loss of 12VDC power by not seeing switch 24 as closed, "Check Fuses F106 and F101" will be displayed at power up. This could obviously mean that F101 and/or F106 are blown. It might also indicate failure of the LM7812 12VDC regulator at Q2 in which case LED102 will be on and LED100 will be off or, failure of one or more of the 6A2 diodes that rectify the AC power (D11-D14). In the latter case, both LED102 and LED100 will be off. Use these LED indicators, as well as testing for 18VDC at TP102 and 12VDC at TP100 to guide your repairs.

4.16 Line Voltage Detection - LED2 & LED3

LED2 and LED3 on the Power Driver Board are indicators for the line voltage detection circuit. On on-board comparator circuit uses +5V and +18V to check the line voltage. The comparator consists of a resistor voltage divider and an LM339 comparator.

The following table shows how to interpret the LED states. Note that other problems with the +18V or +5V supply could cause a high or low line voltage indication.

Line Voltage Indicator Chart

LED2	LED3	Voltage
On	Off	OK
Off	Off	High
On	On	Low

4.17 Solenoid, Flasher, and Motor problems

Flashers, solenoids, and motors in WPC games are turned on via transistors on the driver board and in some games, transistors on the Auxiliary 8 Driver Board.

Before proceeding to diagnose solenoid or flasher problems, see this section: How Coils, Flashers, and Motors are Turned On.

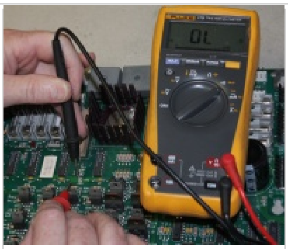
The general logic for providing a path to ground for a coil, solenoid, flasher or motor (subsequently, we'll refer to coils only, but this is true for coils, flashers, and motors), is as follows.

1. The MPU places the appropriate bit pattern on the data bus to control a "bank" of 8 transistor circuits. The data bus is extended to the power/driver board via the interboard ribbon cable.
2. The MPU/ASIC "clocks" the appropriate 74LS374 (http://www.datasheetcatalog.org/datasheets/90/375622_DS.pdf) , an "octal latch" on the power/driver board, to latch data on the data bus into the 74LS374.
3. The outputs of the 74LS374 turn on a 2N5401 transistor.
4. The output of the 2N5401 turns on a TIP-102 transistor.
5. The TIP-102 transistor either provides the path to ground for the waiting coil power or, for higher powered coils, turns on a TIP-36c transistor which provides the path to ground.

The reason that (up to) 3 transistors are used in the circuit is to "amplify" the power. A 2N5401 transistor can handle a comparatively small amount of current. A TIP-102 transistor can handle a much greater current load. The TIP-36c in 8 of the WPC power/driver board circuits can handle an even greater current load.

Note: With the exception of flipper coils, diodes used to snub (http://en.wikipedia.org/wiki/Snubber) the reverse current caused by the collapse of the coil's electromagnetic field, are located on the driver board. Playfield and backbox coils should not have a diode on them. This convention eases the tech's job in that he/she doesn't need to be careful with diode orientation on the coil.

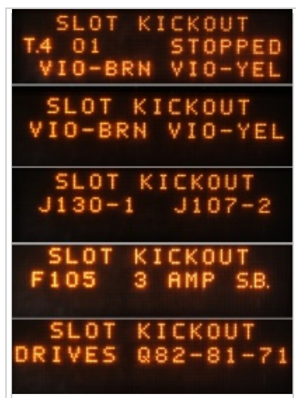
4.17.1 Transistor "Quick Check"



Testing TIP-102s quickly on a WPC power/driver board.

A quick check of the TIP-102s on the driver board can save time. Set your DMM to "continuity check". Place the black lead of your DMM on board ground. Touch the tab of each TIP-102. If the meter indicates continuity, then that TIP-102 is shorted. This quick test works only with TIP-102s and not with TIP-107 or TIP-36c transistors.

4.17.2 "Help" Info Provided by WPC Games



WPC games provide help during coil test.

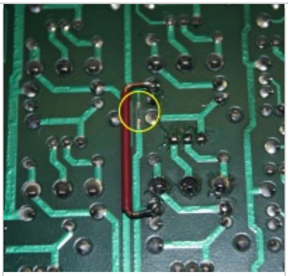
During coil test, pressing the credit button provides a bit of information helpful in debugging your game.

With coil test "stopped", pressing the credit button sequences through the following information.

- Solenoid power and ground (drive) wire colors
- Solenoid power and ground (drive) connections
- The fuse that protects the circuit
- The sequence of cascading transistors that provide a path to ground for the solenoid. In the picture at left, Q82 (TIP-36), Q81 (TIP-102), and Q71 (2N5401) provide the path to ground.

4.17.3 Failed TIP-36c

When replacing shorted transistors, examine the traces connected to the transistor for further damage. In the picture at left, a shorted TIP-36c was replaced. During test, the first time the TIP-36c was called upon to provide a path to ground for the associated coil, the TIP-36c failed shorted again. This was caused by the blown trace.



A blown trace (inside the yellow circle) caused by a shorted TIP-36c transistor. The damage has been nicely repaired with a solid core jumper, soldered to through hole components vice "tack soldered" to the trace, making a stronger solder joint. Note: solder flux visible on replaced TIP-102 and TIP-36c later removed with isotropy alcohol.

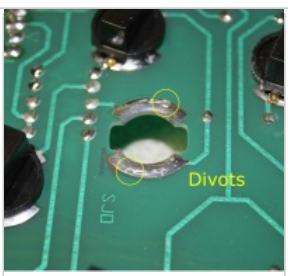
4.18 Lamp problems

Lamps (or globes for those of you in the UK) fall into two categories. "General Illumination" and "Controlled Lamps". Your game probably has other lamps which are actually "flashers" that require an 89 or 906 bulb. Flashers are covered elsewhere in this Wiki.

General illumination lamps (GI) provide the ambient lighting for the playfield, backbox, and coin door. These lamps are lit most of the time. The only "controllable" aspect of these lamps is their brightness, which of course, includes off.

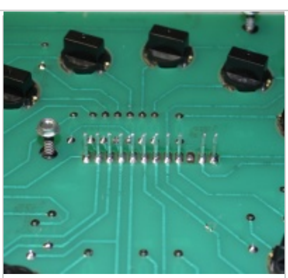
Controlled lamps (sometimes called "feature lamps") are under complete CPU control via the 8-by-8 lamp matrix. These lamps illuminate the various "features" of the game such as mode inserts, pop bumper lamps, inlane/outlane insert lamps, etc.

4.18.1 General Lamp Problems



"Divots" in the connection pad of a "twist in" lamp.

WPC and WPC-95 systems employed "lamp boards" to ease the manufacturing process. These lamp board PCBs used "twist in" sockets, each with a 555 lamp. Over time, the pads on these sockets develop "divots" which sometimes results in a poor connection to the twist in socket. This can be easily corrected by removing the lamp board from the game and reflowing the solder on the pads.

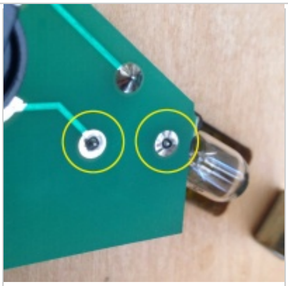


The solder on these header pins has been reflowed nicely.

Another problem with lamp boards is the header connections. The solder joints at the connection pins often fracture due to connector insertion pressure, heat, fatigue, etc, and due to being a single sided PCB. The fix for this is again to reflow the solder around the header pins.

One of the less reliable designs Williams used was to "cantilever" lamp sockets over the end of lamp boards. This was done on a great many games such as Twilight Zone, Judge Dredd, etc. The repeated pressure needed to insert a new lamp into the socket causes the solder to fracture. This can be corrected easily by simply reflowing the solder at the joint.

However in some instances, the socket has become damaged beyond the simple repair of just soldering the legs to the lamp board. Replacement sockets are available from most pinball parts vendors.

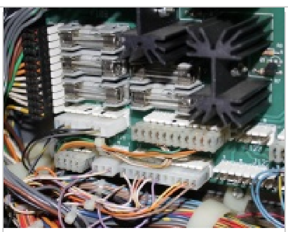


Fractured solder joints on this lamp socket caused intermittent operation.

If after repairing the lamp board divots, reflowing the header connectors, the lamp socket is still completely intact, (the contacts do break off of the socket sometimes), and the bulb is good, suspect that the diode associated with the particular lamp may be bad.

4.18.2 General Illumination Problems

Background



WPC/WPC-S General Illumination Connectors J119 (cabinet), J120 and J121 (repinned)

The WPC power/driver board provides 5 GI circuits under CPU "brightness control". The WPC-95 power/driver board provides 3 GI circuits under CPU "brightness" control and 2 circuits that are always powered. Those two circuits are always connected to the backbox lamps.

GI power is provided by the transformer in the form of 6.3VAC at power/driver board connector J115. Although there are five pairs of wires, they are all connected together at the transformer. One side of the AC GI circuit on the power/driver board is fused by F106 through F110 which are all 5ASB fuses. This side runs to the GI lamps, and carries 6.3VAC to the backbox, playfield, and coin door via power driver board connectors J120, J121, and J119 respectively. J119 is a 3-pin header that is always connected to the coin door lamps. J120 and J121 are electrically and physically identical (keyed at pin 4) and therefore can be connected to either the female playfield GI connector or the female backbox GI connector without care. The other side of the GI AC feed is connected to ground.

The GI power is controlled by a triac in the return line from the playfield. When these triacs are off, no current passes and the lamps are off. When the triac is turned on, the GI lamps glow. The triac is a slightly special part - it must be a "four sector" triac. This means that it can switch both positive and negative sides of the AC cycle with only a positive signal.

Each triac is switched on/off by a 2N5401 transistor which is controlled by U1, a 74LS374, an octal D-Type Flip-Flop with three state outputs (a fancy way of saying that the device is an 8-bit data buffer).

U1 is "clocked" by the ASIC via the /TRIAC signal. If you have AC power present at J115, and no GI at all, it's possible that the /TRIAC signal is not getting through to U1. A logic probe applied to pin 11 of U1 will prove that the signal is getting through. If the signal is not present, try (after turning the power OFF)...

- Pressing firmly on the MPU ASIC to "reseat" it.
- "Reseating" the ribbon cable between the MPU and the Power/Driver board.
- Use your logic probe to track the signal from pin 66 of the ASIC, across the MPU to the MPU connector, across the ribbon cable, then across the Power/Driver board to U1 pin 11.

The CPU can dim the GI by switching on the GI for only parts of the AC waveform. To do this, it uses a zero crossing signal generated from the 6.5VAC that feeds the 5V circuit.

Wire colors to J115 during the early WPC games were always yellow (AC) and yellow-white (AC return) as pictured at left. Pin 1 of J115 provides the "ground reference". Later WPC games used different wire colors at J115 and instead of "looping" power through the connector at J115, connected two wires to the same pin at the 9-pin connector between the transformer secondary and J115.

The colored wire connections for this era of WPC game are yel-wht connected to pin 1, yellow connected to pins 2-6, yel-wht connected to pins 7,8, 10, 11, & 12. Pin 9 is the key.

WPC General Illumination Connector J115 (AC power in). Note wire colors, beginning on the bottom with a yellow/white, then three (looped) yellow, then three (looped) yellow/white.

J119 is always keyed at pin 2, with a **white-Violet** wire at pin 1 and a **Violet** wire at pin 3

J120 and J121 are 11 pin connectors. Wire color/positions (when used) are identical for all WPC games and are shown in the table.

Pin	Wire color at J120/J121
1	**Brown**
2	**Orange**
3	**Yellow** (yellow)
4	**Key**
5	**Green**
6	**Violet**
7	**White-Brown**
8	**White-Orange**
9	**White-Yellow** (yellow)
10	**White-Green**
11	**White-Violet**

Common GI Problem Causes (listed by probability/ease of testing and correction)

GI Bulbs Not Lighting

Let's start by determining if the problem is "off board", i.e. not on your power/driver board, or "on board".

1. Take note of the wire color of the GI string that is not working.
2. Set your DMM to AC voltage. If your DMM is not an "auto-ranging" model, expect to measure about 7 volts AC.
3. Turn the game on.
4. Insert one probe of your DMM (either one) into the rear of the female connector position with the same wire color as noted earlier. Make sure you make contact with the conductor.
5. Insert the other probe into the rear of the female connector with the white wire that has the same color "tracer" as the color noted earlier.
6. You should be measuring 6 to 7 VAC.
7. If there is voltage at the connector, then the problem is "off board".
8. If there is no voltage at the connector, then the problem is "on board".

Off board GI problems

1. **All lamps blown.** Don't laugh. Just for giggles, put a known working lamp into one of the lamp sockets of the suspected GI string. I've seen it more than once. Usually the result of operators never changing a bulb, or somehow connecting higher voltage to the circuit.
2. **"Open" in GI wiring.** The GI wires leading from J120/J121 may be cut/broken between the connector and the GI lamp sockets. Remove both of the female connectors at J120/J121. Use your DMM to check continuity between the lamp socket and the appropriate wire/pin at J120/J121.

On board GI problems

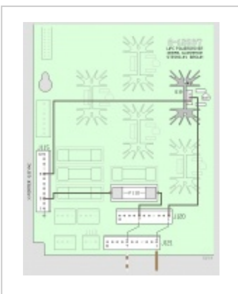
1. **Blown fuses.** This is also the easiest problem to fix. Check each GI fuse following this **procedure**. Don't trust your eyes.

2. **Loss of "Cross Board" Connectivity.** This problem is generally caused by burned header pins, traces, or in some cases, poor prior repairs. Use the following table to check cross board connectivity with J120/J121 as your target. Buzz between the pins/parts shown in the table or use the diagrams below.

GI Connector/pin	Connects to	...and to fuse	associated circuit wire color
J120-1	Triac Q18 tab		**Brown**
J120-2	Triac Q10 tab		**Orange**
J120-3	Triac Q14 tab		**Yellow** (yellow)
J120-4	Key pin		
J120-5	Triac Q16 tab		**Green**
J120-6	Triac Q12 tab		**Violet**
J120-7	J115-3	F110	**White-Brown**
J120-8	J115-4	F109	**White-Orange**
J120-9	J115-6	F108	**White-Yellow** (yellow)
J120-10	J115-5	F107	**White-Green**
J120-11	J115-2	F106	**White-Violet**

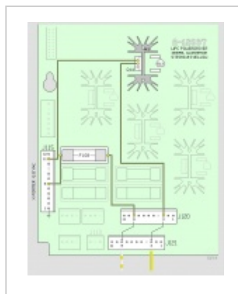
GI Connector/pin	Connects to	associated circuit wire color
J115-7	Triac Q10 pin 1	**Orange**
J115-8	Triac Q18 pin 1	**Brown**
J115-9	Key pin	
J115-10	Triac Q16 pin 1	**Green**
J115-11	Triac Q14 pin 1	**White-Yellow** (yellow)
J115-12	Triac Q12 pin 1	**Violet**

WPC-089 Power/Driver Board GI Buzz Diagrams provided by Sascha Voskuil

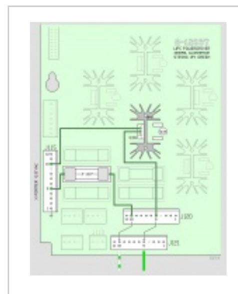


Brown GI String

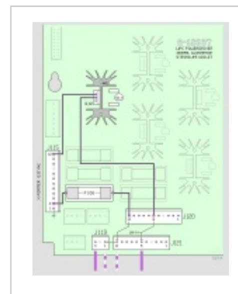
Orange GI String



Yellow GI String



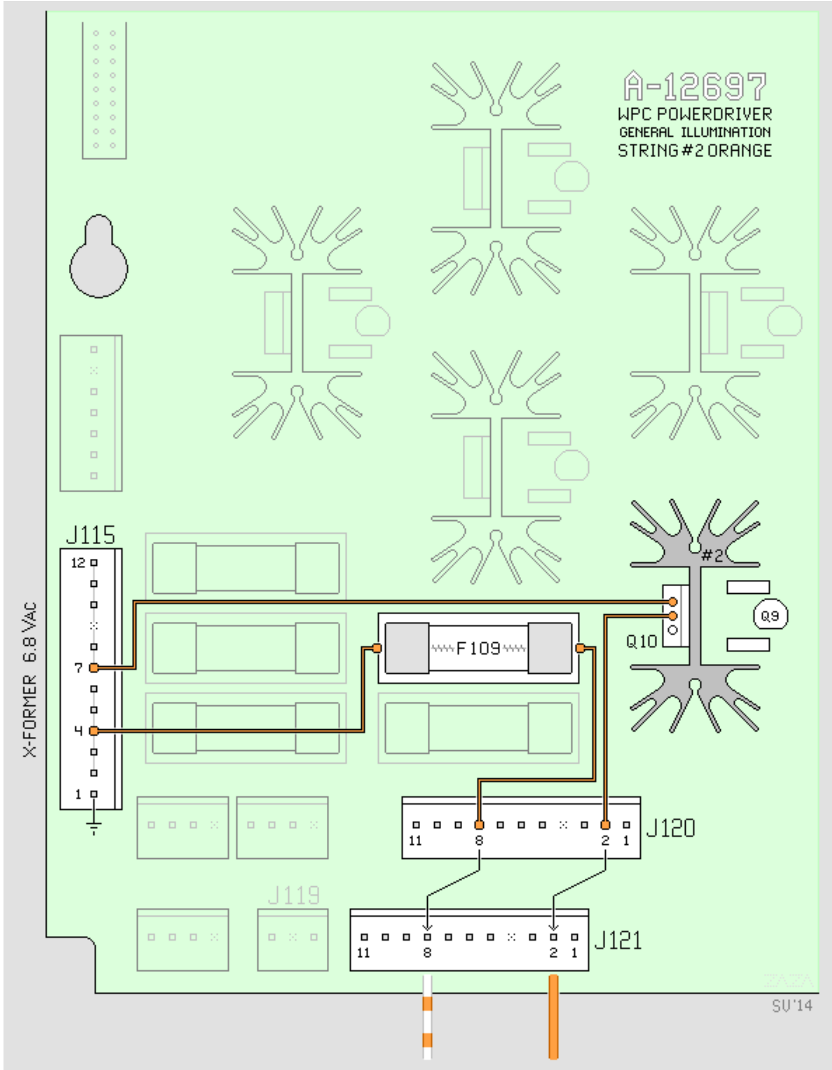
Green GI String



Violet GI String

Click on the thumbnails above for the full sized GI buzz image

The clickable images above, in an animated gif...

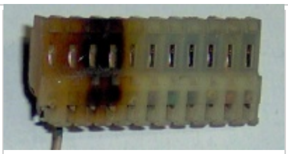


Critical PCB traces for the brown and orange GI circuits that are often compromised with amateurish attempts to replace J120.

Regarding poor prior rework, sometimes when J120 is replaced, the through holes at pins 7 and/or 8, are pulled causing a loss of connectivity from the board front to the board rear. This will prevent the brown and/or orange color GI circuit from working properly. Additionally, the through hole at J121, pin 6, that routes power to the 3-pin connector at J119, if pulled, will cause the cabinet GI (violet) to not light (coin door lights).

3. **Burned connectors.**
Over long periods of time, both the male and female GI connectors at J115, J120, and J121 often burn.
This was especially prevalent in early WPC games like Terminator 2.

Numerous "hacks" have been employed over the years by well meaning repairmen but the only real way to fix burned connectors is to replace both the male header pins and the female housings/pins. "Trifurcon" phosphor-bronze crimp-on pins are recommended to provide a better connection at the female connector. Note that these must be phosphor-bronze (7A rating, as original). Don't buy them unless the supplier calls that out as the brass version looks the same but is only rated at 5A. If you replace burned female connectors, the male connectors are probably burned too and should be replaced. The damaged surface of the male pins will generate heat, and cause early failure of the replacement connector. Plus, the GI will be dimmer than it should be. J115 is a special case. The black Panduit connector that Williams used on many machines is far superior to any crimp pin, with a 12A rating (compared to 7A for


Typical burned connector on the output (female) side of the playfield GI on the driver board

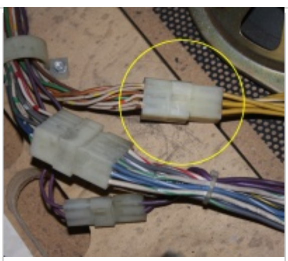
phosphor-bronze Trifurcon pins). These, however, can be hard to find. Fortunately, they rarely burn and therefore rarely require service. Another alternative for high current connections is to use Molex MarKK series contacts (Molex part number 45570-3050) along with Molex 41695 series plugs. Although they cost more than the Trifurcon style contacts, these contacts are rated for a current load up to 13 amps.

WPC-089 Power/Driver Board J120/J121 connector repair parts list...

Qty	Part	Product ID
2	11 pin .156 male header (cut to size)	26-48-1245
2	Connector, .156 Plug, 11 pin (Molex 41695 series)	09-50-8111
10	.156 Trifurcon crimp contacts for the larger gauge wires	08-52-0113
10	.156 Trifurcon crimp contacts for the smaller gauge wires	08-52-0125
2	"Keying Pins" for Molex 41695 series plugs	15-04-0297
1	Crimp tool	1028-CT (or equivalent)

Note: Product IDs shown above can be found at http://www.greatplainselectronics.com/Category-80.asp. Other vendors may carry these same parts.

4. **Burned AC power input connector.** There is also a 9-pin (3x3) connector between the transformer secondary and J115. This connector/pins sometimes burn and may require replacement. Check to ensure that AC power is being delivered to the power/driver board at J115.


WPC General Illumination power connection between the transformer secondary and J115 (AC power in). This picture is from a Twilight Zone, which used the newer, multicolored wires between this connector and J115 on the power/driver board.

- Set your DMM to AC voltage. If your DMM is not an "auto-ranging" model, expect to measure about 7 volts AC.
- Turn the game on.
- Insert one probe of your DMM (either one) into the rear of the female connector at J115, pin 3.
- Insert the other probe into the rear of the female connector at J115, pin 11.
- You should be measuring 6 to 7 VAC.
- If no voltage is present, examine the 9-pin connector between the transformer secondary and J115, pictured at left.

5. **Burned traces.** Usually, this is a secondary problem created after the connectors burn. Visual inspection of the traces might uncover the problem, but "buzzing" them for continuity is the best practice.
6. **Failed 2N5401.** These don't fail very often, but are easy to test following this **procedure**.
7. **Failed resistors.** Again, these don't fail very often but are easy to test with your DMM. Keep in mind that "in-circuit" measurements may not be reliable.
8. **Failed 74LS374.** This is rare too but easy to test following this **procedure**. You can also test the outputs of the LS374 by probing pins 2, 5, 6, 16 and 19 with your logic probe. At full GI brightness, these pins should test as "high".
9. **Failed Triac.** These rarely fail. But, if you've gotten to this step in the procedure, it's time to replace the Triac. Remember, you need a 4-sector triac.

As these boards age it is easy to pull out the little copper hole liners that connect traces from one side of the board to the other. If you install new connector pins, be sure to check continuity from the new pins onto the board somewhere. This only takes a couple minutes and can save you a lot of time.

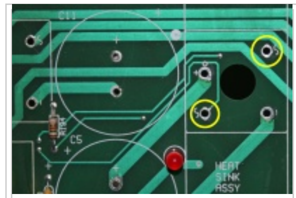
<u>**GI Lamps Not Dimming**</u>

The primary cause of GI lamps failing to dim is broken traces at BR2, usually caused when BR2 was replaced. These traces lead to D3 and D38. Both of these traces must be intact for dimming to work as they supply the power to generate the signal to the Zero Cross circuit (ZC) which is key to dimming.

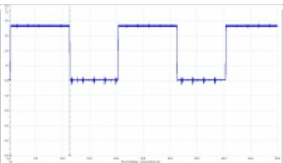
Before you go too far diagnosing the hardware, if your WPC game will not dim the general illumination, make sure that **Standard Adjustment #25, "Allow Dim Illum.",** is set to "YES". If set to "NO", then the GI will never dim, even during General Illumination test.

General dimming "theory of operation"...

- The driver board generates the ZC signal with the BR2, D3/D38 and U6 circuitry (different resistors).
- The ZC signal is connected to the ASIC (across the driver board, the ribbon, and then across the MPU).
- The ASIC uses the ZC signal to determine when to send the /TRIAC signal to U1 pin 11 (an 74LS374 buffer IC) as it simultaneously presents GI string enable data on the data bus.
- U1 latches GI string enable data from the MPU's data bus.
- The output of U1 forms signals T0 thru T4, which enable the TRIAC circuitry.



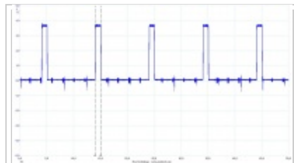
Small traces leading from the through holes of BR2's AC solder pads (pads circled) can be easily damaged, causing GI lamps to not dim. On this board revision, the upper/right through-hole has a small trace on the solder side of the board that connects to the "via" visible to the left of the through-hole. These traces lead to vias which can be seen just SouthWest of R194.


This is the ZC signal from a Doctor Who with a broken trace between the two 270 ohm resistors after D3. Dimming did not work in this example.

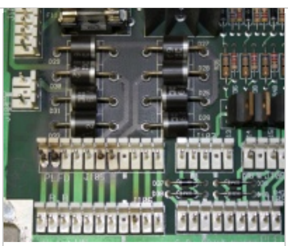
It is possible that D3, D38 (1N4004 diodes) or the LM339 at U6 have failed. If the ZC test point on the power/driver board is not strobing (which can be seen with a logic probe), something upstream of the test point has failed.

U6 is an LM339 comparator. The resistors around it (R16 and R17, both 230 ohm 1/4 watt) help generate the correct ZC signal. If a resistor is burned or out of spec, or if a trace is broken in the circuit (there are several "vias"), then ZC may still strobe but in an incorrect way which the ASIC doesn't recognize as the zero cross signal.

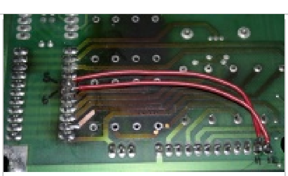
The ZC may be strobing, yet the GI still won't dim. Use a logic probe to test both sides of diodes D3 and D38 as it is necessary for both the positive going and the negative going portions of the AC sine wave to be detected. If the traces buzz out back to BR2, then suspect one side of BR2 being open. Incredibly, it is possible for the game to work correctly in all regards other than GI dimming with half of the bridge open. Odd...but it happens.


This is the ZC signal from a properly working Twilight Zone with General Illumination dimming working correctly.

4.18.3 WPC-95 General Illumination Problems


The GI section of a WPC-95 driver board with 6A2 diodes installed. Note the significant burn around the diodes as well as the melted connectors and burned pins.

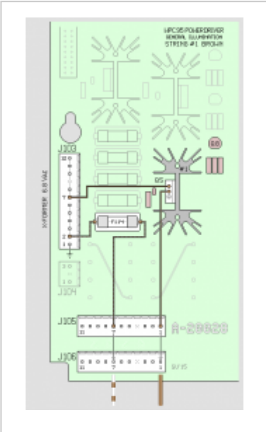
The General Illumination circuit for WPC-95 games is very similar to WPC games. When the WPC-95 system was implemented, Williams reduced the number of "dimmable" GI circuits from 5 to 3, with 2 of the circuits being lit at all times. Within the two "always on" GI circuits, Williams placed 8 large 6A2 diodes, to create a voltage drop in the circuit which would dim the lamps slightly and presumably lengthen lamp life. However, these big 6A2 diodes create a great deal of heat. Without a heat-sink like those used on the TRIACs, the high heat they produce causes the printed circuit board and traces to burn. Later versions of the WPC-95 driver board replaced these 6A2 diodes with zero ohm jumpers.


The back side of a WPC-95 driver board with jumpers installed across the GI circuit.

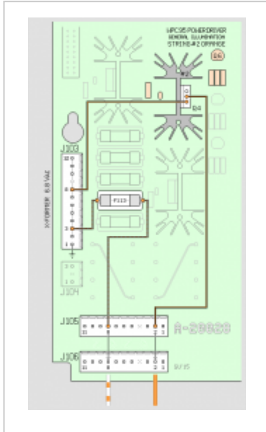
You can (and probably should) remove the 6A2 diodes, and either replace them with zero ohm jumpers, or, more easily, implement the solution pictured at left. This solution bypasses the diodes completely, by installing the following jumpers.

- J103 pin 11 jumped to J105 pin 5
- J103 pin 12 jumped to J105 pin 6

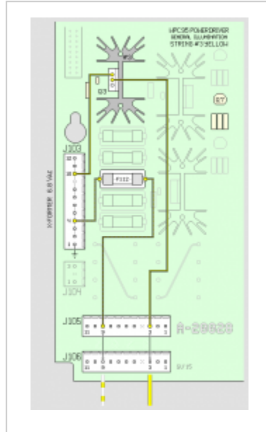
WPC-95 Power/Driver Board GI Buzz Diagrams provided by Sascha Voskuil



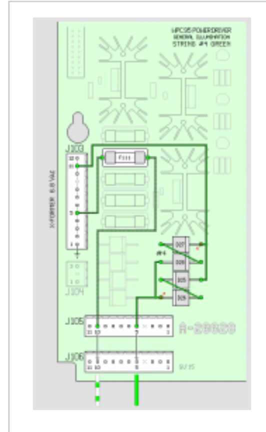
Brown GI String



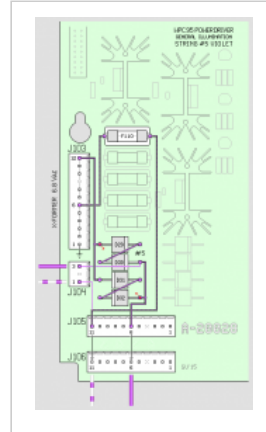
Orange GI String



Yellow GI String



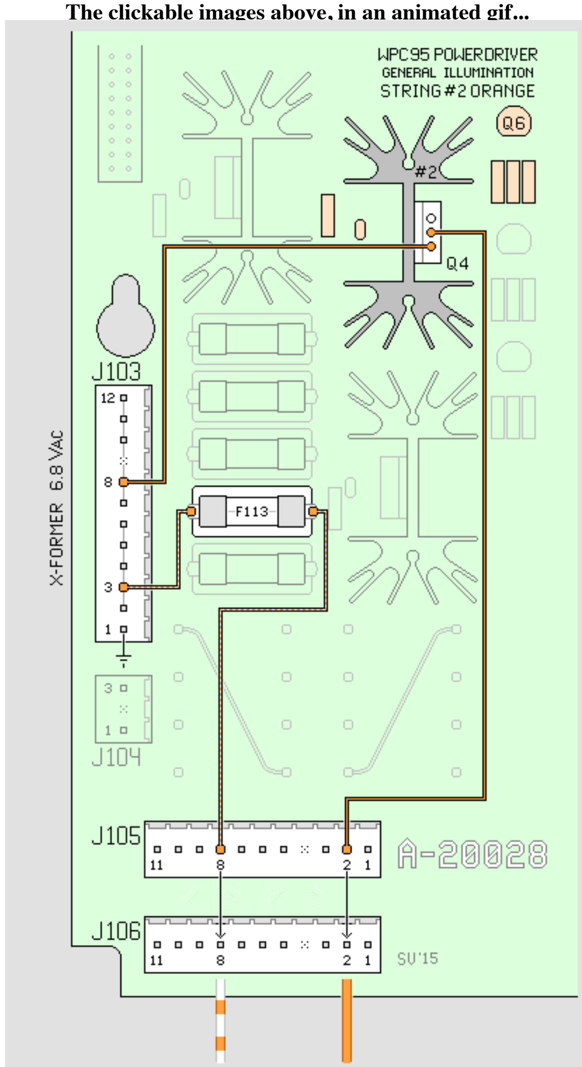
Green GI String



Violet GI String

Click on the thumbnails above for the full sized GI buzz image

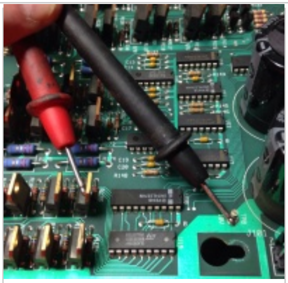
The clickable images above, in an animated gif...



4.18.4 Controlled Lamp Problems

Quick Test of Lamp Column Transistors

If the game has an entire column of lamps locked on, there is a good chance that a lamp column transistor has shorted. Testing for this condition is very simple. Set your DMM to continuity. Touch one probe to the 18V lamp matrix test point as pictured at left. Touch the other probe to the tab of each of the TIP-107 transistors. Any that "buzz" are shorted and will need to be replaced.



"Quick Test" for a shorted lamp column transistor.

General Lamp Matrix Testing

The control logic for the WPC lamp matrix can be tested by connecting a spare lamp using two jumper wires. The following sections show the separate procedures for testing the lamp matrix columns and rows. The example applies to WPC-089 power/drive boards. The procedure is the same for WPC-95 power/driver boards, but the connector designations and transistor numbers differ.

We provide this section for completeness knowing that WPC games offer independent lamp row and column tests as part of the diagnostics.

Testing the lamp matrix columns:

Use the following procedure to test the TIP-107 transistors that drive the lamp matrix columns. Note that a diode is not needed for these tests since it's function is to block current flow and prevent interaction between the lamps in the matrix. In this test we are connecting a single lamp at a time.

Jumper connection for testing lamp matrix columns.

1. Remove the backglass and open the insert to get access to power/drive board connectors J133/134/135 (row) and J136/137/138 (column).
2. Unplug all connectors with red or yellow wires leading to them. These are the lamp matrix connections (lower right corner of power/driver board)
3. Turn the game on and start "All Lamps" test in the Test/Diagnostic Menu.
4. Clip one end of the test jumper to J137 pin 1, the rightmost pin on the connector
5. Touch the other end of the jumper to J133 pin 1, the rightmost pin on the connector
6. The test lamp should flash to indicate that the column driver is working.
7. Repeat the test for the pins 2 through 9 on J137. There is no pin 8 as it is the key.

If a column doesn't light or is stuck on, reference the lamp matrix table in the manual to identify the transistor to test.

The following table shows the lamp number and driving transistor for each of the column pins.

Pin	Wire Colors	Lamp number	Transistor number
J137-1	Yel-Brn	1	Q98
J137-2	Yel-Red	9	Q97
J137-3	Yel-Orn	17	Q96
J137-4	Yel-Blk	25	Q95
J137-5	Yel-Brn	33	Q94
J137-6	Yel-Blu	41	Q93
J137-7	Yel-Vio	49	Q92
J137-8	Key Pin		
J137-9	Yel-Gry	57	Q91

Testing the lamp matrix rows:

Use the following procedure to test the TIP-102 transistors that drive the lamp matrix rows.

1. Remove the backglass and open the insert to get access to power/drive board connectors J133/134/135 (row) and J136/137/138 (column).
2. Unplug all connectors with red or yellow wires leading to them. These are the lamp matrix connections (lower right corner of power/driver board)
3. Turn the game on and start "All Lamps" test in the Test/Diagnostic Menu.
4. Clip one end of the test jumper to J133 pin 1, the rightmost pin on the connector
5. Touch the other end of the jumper to J137 pin 1, the rightmost pin on the connector
6. The test lamp should flash to indicate that the column driver is working.
7. Repeat the test for the pins 2 through 9 on J133. There is no pin 3 as it is the key.

If a row doesn't light or is stuck on, reference the lamp matrix table in the manual to identify the transistor to test. The following table shows the lamp number and driving transistor for each of the row pins.

Pin	Wire Colors	Lamp number	Transistor number
J133-1	Red-Brn	1	Q90
J133-2	Red-Blk	2	Q89
J133-3	Key Pin		
J133-4	Red-Orn	3	Q88
J133-5	Red-Yel	4	Q87
J133-6	Red-Grn	5	Q86
J133-7	Red-Blu	6	Q85
J133-8	Red-Vio	7	Q84
J133-9	Red-Gry	8	Q83

Jumper connection for testing lamp matrix rows.

4.19 Switch Problems

Switches in WPC games fall into two categories, those within the switch matrix, and "direct" switches.

4.19.1 Built-in Switch Testing

WPC games monitor switch closures as the game is played. If a switch is not activated after a certain number of balls (usually 30, but will vary depending on the switch in question), the game will show the "credit dot", an indication to the operator that a switch may be faulty. Some switches are not often closed (like switch 55 located in the White Water pop bumper garden) and some switches simply aren't hit by rookie players (like the upper exit to the Twilight Zone mini playfield). Some switches will be marked non-operational immediately after a certain event where the switch is known to have been activated (switches related to The Shadow's brick wall drop target are one example; any error in the lock sequence causes the credit dot to light immediately).

There is a table held in NVRam that contains counters for all monitored switches. Each ball served decrements the counter for each switch; as soon as that switch is hit on the playfield, the counter is reset to the initial value. The credit dot gets lit when any counter for any monitored switch goes to zero. Switches such as flipper optos are set to very low initial values, as flippers are hit on every ball. It would have been possible to have higher values set for switches that would occasionally be activated but not often by novice players as noted above, however this aspect of the programming was rarely if ever used.

When a credit dot is lit, often the game will offer "switch compensation", which was a Williams' patented feature, that allowed a nearby or alternate switch to achieve the same result as hitting the original, marked non-operational, switch. This enabled a game with faulty switches to still be played close to the original gameplay. Sometimes the faulty switch will auto-clear itself when activated, but more often than not, the fault would have to be cleared manually. To clear a switch manually, enter the "Switch Edges" test (as described below), and manually activate the switch. If the switch in question is functioning properly, activating the switch will remove the credit dot.

The first action to be taken is to enter diagnostics. The game will indicate the reason(s) for the credit dot on the display, upon pressing the enter button on the coin door to receive a test report.

Since the normal switch matrix is 8 by 8, games like Twilight Zone, Star Trek: The Next Generation, and Indiana Jones employ a 9th column of switches. These switches are tested via a dedicated switch test tied to the playfield feature. An example is the Star Trek: The Next Generation cannon switches.

4.19.1.1 T.1 Switch Edges Test

An example switch matrix display, this one from Twilight Zone. Note the opto switches in column 7 (for example) are shown as boxed dots.

Switches can be tested by entering Test T.1, Switch Edges. Switch Edges Test presents an 8 by 8 switch matrix grid with one or two switch columns outside of the matrix. The additionally columns are for dedicated switches. The left column is for switches located on the coin door (all WPC games), and the right column is for flipper cabinet and flipper EOS switches (WPC games which use a Fliptronics board - Addams Family and newer). Open switches show as a simple dot on the DMD. Closed switches show as a boxed dot on the DMD. Microswitches and leaf switches will show as a dot when open. Optos will show as a boxed dot when the opto beam is not being broken. The last closed switch name and number will be shown on the display along with the two wire colors that are connected to that particular switch. While in switch edges test, manually closing properly operating switches will be shown on the display.

4.19.1.2 T.2 Switch Levels Test

4.19.2 Direct Switch Problems

Direct switch operation

Direct switches include:

- Left coin chute
- Center coin chute
- Right coin chute
- 4th coin chute
- Service Credits/Escape (referred to as "escape" here)
- Volume down/Down
- Volume up/Up
- Begin Test/Enter

Direct switches are not part of the WPC switch matrix. All of the direct switches are located on the coin door, and connect to the MPU at J205. The MPU senses these switches individually, and apart from the switch matrix. Therefore, isolation diodes are not used with direct switches.

Normally, with the switch open, the LM339s at U16 and U17 compare 12V (supplied on the MPU to both the switch and to the LM339) with 5V (as a comparison level) and signals the 74LS240 at U15 that the switch is open. When the switch closes, it shorts the 12V to ground and the comparison at the LM339 then indicates to U15 that the switch is closed. U15 is "clocked" by pin 48 of the ASIC (SW DIR), causing U15 to present its data to the data bus. The 6809/ASIC "debounces" the switch. Debouncing is not a factor to be considered here and doesn't factor in switch testing at all.

Direct Switch Pinout at J205 for both WPC and WPC-S MPUs
Notes:

J205, pin 5 is the "key" pin.
J205, pin 10 provides ground (black wire)
J205, pin 11 is unused
J205, pin 12 is an "enable" back to the coin door interface board

Signal	Wire color at J205	MPU pin	Diode	LM339 & input pin	U15 input pin
Left chute	orange/**brown**	J205-1	D15	U17-5	11
Center chute	orange/**red**	J205-2	D16	U17-7	13
Right chute	orange/**black**	J205-3	D17	U17-11	15
4th chute	orange/**yellow**	J205-4	D18	U17-9	17
Escape	orange/**green**	J205-6	D11	U16-9	2
Down	orange/**blue**	J205-7	D12	U16-11	4
Up	orange/**violet**	J205-8	D13	U16-7	6
Enter	orange/**gray**	J205-9	D14	U16-5	8

Debugging direct switch problems

To discover the problem as quickly as possible, we'll divide the problem into smaller pieces. We must first determine if the problem is on the MPU board or the problem lies with the wiring to the coin door and/or the specific switch. If your MPU has obvious alkaline damage at U15, U16, or U17, address the alkaline damage first.

Begin testing with the game OFF.

Isolate the problem to the MPU or to the game wiring/switch

1. Remove connector J205 from the MPU.
2. Build a jumper wire with alligator clips on both ends.
3. Clip one end of the jumper wire to the game's ground braid in the game head.
4. Turn the game on
5. Carefully touch the other end of your jumper wire to the appropriate pin on J205 as shown in the table.
6. If the MPU carries out the function of the switch, the problem is not on the MPU.
7. If the MPU does nothing, the problem is on the MPU.
8. Skip to the appropriate section below.

Identifying problems NOT on the MPU

Test the direct switch's path to ground

1. Your game should still be turned off.
2. DMM set to continuity.
3. Clip the black lead of your DMM to any game ground, like the lockdown bar or ground braid.
4. Red lead on the solder joint between the switch and the black wire that provides ground.
5. You should hear "tone". If not, further diagnose the break in the black wire between the solder joint and game ground.

Test the direct switch itself

1. Black lead of your DMM still clipped to game ground.
2. Red lead on the solder joint opposite the black wire (or bare wire jumper) of the switch under test.
3. Depress the switch. You should hear "tone". If not, the switch is defective and not "making". See the section below that describes cleaning these switches.

Test the signal path to the MPU

1. Clip the black lead of your DMM on the solder joint opposite the black wire (or bare wire jumper) for the switch under test.
2. Remove the connector plug at J205 from the MPU.
3. Red lead on the appropriate pin of J205 for the switch under test. See the table above. It's easiest to access the pin through the rectangular hole in the back of the connector where the pin's "tang" snaps in.
4. You should hear "tone". If not, there is a discontinuity in the wire between the direct switch and J205. Note that the coin door interface board is between these two points. The coin door interface board is a "pass-through" for these signals and rarely causes a problem. Still, reseating connectors J1, J3, and J4 on the coin door interface board might uncover the problem. More likely, the wire between J1 on the coin door interface board and J205 has a break in it.

Identifying problems on the MPU

Test the signal path through J205 and onto the MPU
J205 is right below the battery holder and as such, sometimes receives the unwanted gift of dripping alkaline from depleted batteries. Carefully examine both the male and female connections of J205 for alkaline "greenies". Assuming no alkaline damage...

1. Begin with your game turned off.
2. Connect J205 to the MPU.
3. Clip the black lead of your DMM to the solder joint opposite the black wire (or bare wire jumper) for the switch under test.
4. Red lead on the banded end of the appropriate diode shown in the table above.
5. You should hear "tone". If not, there is either a problem with the physical connection at J205 or the alkaline "greenies" are sneakier than you gave them credit for. Re-examine J205 and the surrounding area of the board for alkaline damage. The traces from the switch connectors are very small and it takes very little alkaline damage to compromise them. You may also re-pin the female side of J205.

At this point, a logic probe would be the best tool to use. You can pick up 5V power for your probe across the electrolytic cap at C31 which is immediately to the right of the battery holder. Black lead on the negative side (top of the cap). Red lead on positive side (bottom). The board is silkscreened with polarity markings. Set the logic probe to "CMOS" test mode, as you will be measuring 12VDC.

If you don't already have a logic probe, you should. Although for this test, you can still get by with your trusty DMM. Clip the black lead of your DMM to game ground. The ground braid in the head is a good place to pickup ground at this point. Set your DMM to DC volts.

Test the LM339 inputs

1. Start with the game turned off.
2. Again, set your logic probe to "CMOS"
3. Clip one end of your jumper wire to the appopriate pin of J205. Leave the other end of your jumper wire unconnected, but handy as you'll touch it to ground later.
4. You now need to turn the game ON.
5. Measure the signal at the appropriate LM339's appropriate pin shown in the table above. Either place your logic probe on the pin or place the Red lead of your DMM on the pin. The signal should measure high (or about 12VDC with your DMM).
6. Now, with your other hand, touch the free end of your jumper wire to the ground braid in the backbox as you observe the results.
7. You should see the signal transition to low. If you still measure high, then the pin isn't being grounded correctly. Candidates are a failed diode/resistor in the circuit, the board trace between the diode and the LM339 is compromised, or a badly failed LM339.

Test the LM339 outputs/74LS240 (U15) inputs

1. Set your logic probe back to TTL as you will be measuring 0 - 5V signals
2. Measure the signal at the appropriate pin (see table) of U15. The signal should measure high (or about 5VDC with your DMM).
3. Touch the free end of your jumper wire to the ground braid in the backbox as you observe the results.
4. You should see the signal transition to low. If you still measure high with the jumper wire grounded, then either the LM339 outputs have failed, the board trace between the LM339 and U15 is compromised, or the 74LS240 has failed and is corrupting the signal. You can test U15 using the procedure in the "How to..." section of PinWiki, here.

The output side of U15 can't be tested effectively since that is the processor/ASIC data bus and should be constantly and irregularly changing states.

If you've followed this process step-by-step, you should have identified the problem with the signal and will be able to effectively perform the appropriate repair.

Cleaning direct switches

Coming soon...will describe disassembly and cleaning... Sometimes, several rigorous open/close cycles will "clean" corrosion from the switch.

4.19.3 Switch Matrix Problems

Isolate the problem to the MPU or to the game wiring/diodes/switches

Follow these steps to determine if the switch matrix problem is on the CPU or somewhere in the game wiring.

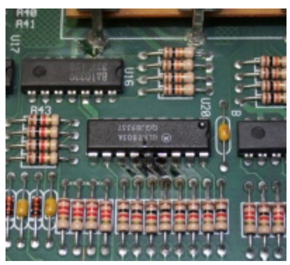
1. Remove connectors J206/J207, J208/209 and J212 from the bottom of the CPU (J206 and J207 are electronically the same and J208 and J209 are electronically the same).
2. Clip one lead of a test jumper to pin one of J207 making sure you don't touch any of the nearby pins on J207.
3. Power the game on, and enter Switch Edge test (you've left J205 on the CPU so the diagnostics switches still work).
4. Touch the other end of the jumper to pin one on J209, then pin two and so on. You should see (and hear) the CPU indicate that switches #11, #12, #13, etc. are being "made" as you touch the pins of J209. You should *never* see multiple switches being made.
5. Move the jumper from J207 pin 1 to pin 2. Re-test to every pin on J209, listening for the machine to read every switch as closed. Continue in a similar manner testing each pin of J207 to every pin in J209.

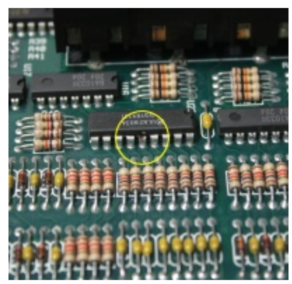
Example jumper connection for testing the switch matrix.

If only one switch shows on the Switch Edge test for each pin combination, then the CPU's switch matrix is working properly and you can confidently assume that any switch problems lie elsewhere. Possibilities include a shorted wire, bad/broken/shorted diode, bad under playfield opto board, bad coin door interface board, etc. If the problem is observed with row 2 of the switch matrix, and you're game has a "-1 Power/Driver" board installed (the one with the flipper power relay), it is possible that one/both of the 4N25 opto-isolators on the power/driver board have failed. These opto-isolators communicate flipper switch closures for pre-FlipTronics games.

If multiple switch closures are reported when you touch one pin of the connector, or if the CPU reports a row or column short, then there is a fault with the switch matrix circuitry on the CPU board itself. Be aware that an additional fault may still be present on the playfield; switch matrix chips do not simply blow for no reason!

Blown ULN2803 (U20) Examples


An obviously blown ULN2803 (U20) caused by shorting 50V coil power to the switch matrix. Ouch!


Another obviously blown ULN2803...happens all the time...Don't work on your game with power on.

4.19.3.1 MPU Circuitry Switch Matrix Problem Diagnosis

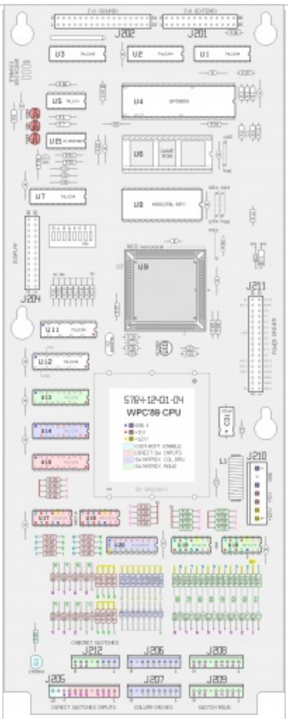
4.19.3.1.1 Quick Switch Column Strobe Testing


Testing the switch column strobes quickly with a logic probe. The picture also shows a convenient place to connect logic probe power leads.

A quick way to test that switch column strobes are working properly, is to use a logic probe as shown in the picture at left. Each pin of J206/J207 (all WPC MPU versions) should be pulsing high.

4.19.3.1.2 Further MPU Circuitry Diagnosis

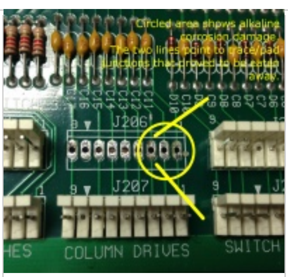
The following two images (authored by Sascha Voskuil, used with permission) will help diagnose particular ICs at fault on the MPU.



Color Coded Switch Matrix Circuitry.click image to enlarge

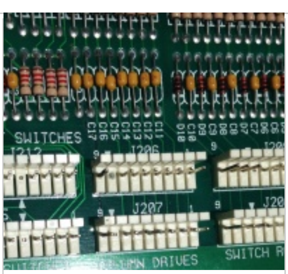
Let's use the diagram above to walk through a simple "on board" switch matrix issue.

A board presented with very slight alkaline damage to U20, the ULN2803. After socketing, and replacing the ULN2803, column 3 still failed to strobe. We used out logic probe to determine that pin 16 of U20 was strobing. Therefore, there MUST have been an on board fracture of the trace. Setting our DMM to continuity, and buzzing between J206 pin 3 (marked with a gray "3" in the diagram) and U20 pin 16 failed. Moving our probe from J206 pin 3 to the junction of R69 and C13 (also marked with a gray "3" in the diagram) succeeded. However, buzzing between the junction of R69/C13 and U20 pin 16 succeeded. Using this information, we must conclude that the discontinuity in the trace was between J206 pin 3 and the junction of R69/C13.



A look under connector J206 showing alkaline corrosion damage. This caused column 3 of the switch matrix to malfunction.

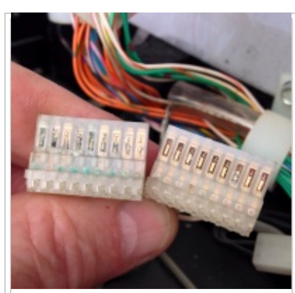
The picture at left shows the problem. Once the J206 header was removed, we could see that alkaline had dripped onto the connector and leached down to the solder joint. The corrosion etched enough of the trace away to prevent connectivity.

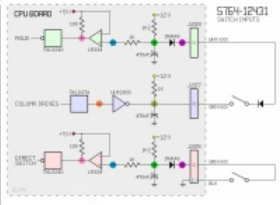


A different board, with a similar problem at the header pins...

The picture at left shows another WPC-089 MPU board with a similar problem, but much worse. This board was the victim of dripping alkaline which invaded the trace which runs under the "C17" label to J206-9 and J207-9.

The picture at right shows the female connector housings that were the victim, and transportation medium, for the alkaline corrosion. The connector on the left required repinning. The connector on the right showed only light damage which was cleaned up with a vinegar swab.


...and the matching female housings.



Switch Matrix Circuit Operation. Note: Colors are coordinated with the prior diagram (authored by Sascha Voskuil, used with permission). Click image to enlarge.

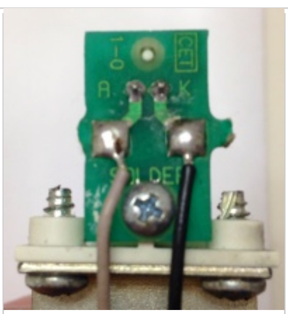
4.19.4 Opto Switches

4.19.4.1 Basic Operation

Williams opto switches are comprised of a "transmitter" and a "receiver" opto, which are each unique parts. This is different from later Sega and some Stern game systems where the optos that serve as transmitter and receiver are identical.

The transmitter opto is housed in a white plastic frame. It is powered by unregulated 12VDC. If the opto is good, measuring either solder joint of the opto should read about 12VDC as long as the game is turned on.

Note that the ball trough uses these opto transmitters also. Orient the ball trough transmitter flat side as is silkscreened on the board.

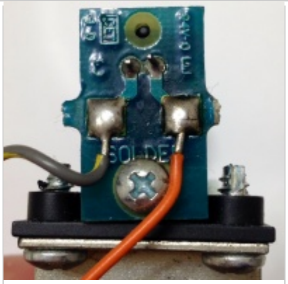


The solder side of a typical Williams opto transmitter.

The component side of a typical Williams opto transmitter. When replacing the opto, orient the flat side toward the "K" (equivalently, orient the "short" leg of the opto toward the "K")

The receiver opto is housed in a black plastic frame. This "IR detector" opto conducts the 12VDC supplied to it, as long as the transmitter's "light" is cast upon it. Once the transmitter light is removed, the opto no longer conducts the 12VDC. Typically, circuitry on an "opto switch board" interprets the lack of 12VDC using an LM339 comparator, and indicates that the switch is open. Remember that the "sense" of opto switches is reversed from regular "hard" switches such as leaf switches and micro-switches.

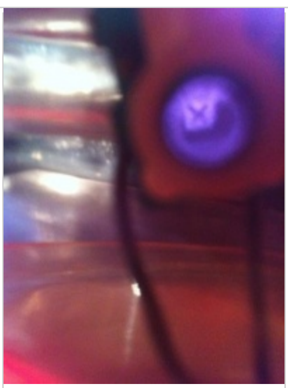
Note that the ball trough uses these opto receivers also. Orient the ball trough receivers flat side so that the leg on the flat side is furthest away from the "ear" that is silkscreened on the board.



The solder side of a typical Williams opto receiver.

The component side of a typical Williams opto receiver with an aftermarket receiver LED. When replacing the opto, orient the flat side toward the "C" (equivalently, orient the "short" leg of the opto toward the "C"). OEM LEDs have an "ear" that matches the silkscreen on the board

4.19.4.2 Opto Testing



Testing an opto "sending" unit with a digital camera. This opto pair senses "Rudy Hits" in Funhouse. The white opto housing can be seen (upside down)

The "sending side" or transmitter side of an opto pair, which should be housed in a white plastic frame, can be tested with just about any digital camera. In the picture at left, an iPhone camera was used to clearly see the purplish glow of a working opto sender.

The "receiving side" of an opto pair, which should be housed in a black plastic frame, can be tested with just about any strong incandescent flashlight. Note that an LED flashlight does not typically work too well for this test. Place the game in switch test. Block the sending opto that would normally illuminate the receiver under test. Shine your bright incandescent flashlight on the reciever opto. The switch state as shown on the display should change.

4.19.5 "Jittery" Opto Switches

It is possible for all opto switches in the game to act erratically. This can be difficult to diagnose because the problem can manifest itself in various ways during game play. For instance, the bulldozer blade in "Roadshow" may occasionally be unable to find it's home position. Or, the auto launcher in "Twilight Zone" may seem to want to launch a ball when none is present. Since the cabinet flipper switches are sometimes optos as well, the game's flippers may also behave strangely.

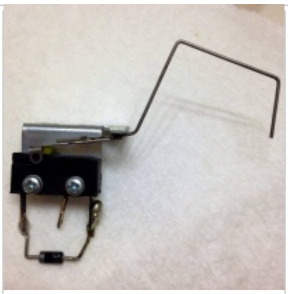
The first step is to check the optos in switch edge test. If the optos appear to blink on and then off, when the actual physical state of the opto is open, suspect an issue with the unregulated 12VDC voltage.

Measure for about 12VDC at TP1 on the power/driver board. If the voltage is significantly below 12VDC (i.e. around 10VDC) then there may be a problem with the bridge rectifier at BR5 or the 15,000uf filter capacitor at C30. Examine the solder joints at C30, especially if that capacitor has been replaced in the past. A damaged through hole may effectively remove the filter cap from the circuit, AC voltage will remain in the power circuit, and the optos will be flakey.

Use your DMM to test the bridge rectifier (http://www.pinwiki.com/wiki/index.php?title=General#Testing_a_Bridge_Rectifier) and to "buzz" between the solder joints at the cap and the appropriate legs of BR5. If this connection is flakey, repair it using a solder stitch (http://www.pinwiki.com/wiki/index.php?title=General#Repairing_traces_or_creating_a_.22solder_stitch.22) or connect jumpers from the C30 to BR5.

4.19.6 Sub-microswitch Issues

Some WPC games have an issue with micro-switches that are heat damaged during game assembly. When soldering the wire lead(s) onto the switch, flux leaches into the switch body and, over time, causes the switches to become "sticky".



A typical micro-switch and wireform.

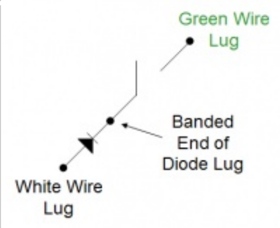
Game switches from smoky environments often become intermittent or fail. You may be able to repeatedly actuate the switch with your finger and get it to work for a game session, but when you return to the game later, the switch will have failed again.

Tightening the screws too tightly on the switch can damage the switch internals making the switch intermittent.

The switches in games that were played on location for many years simply wear out.

When micro-switches are damaged or past their useful lifetime, there is nothing to repair, adjust, or clean inside them. Simply replace them for reliable operation. You can purchase generic switch bodies and transfer the wireform carefully to the new body.

4.19.7 Switch Wiring

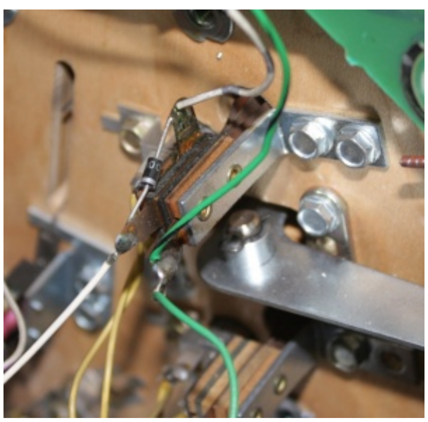


Williams Individual Switch Connection Schematic. The green wire is the switch column. The white wire is the switch row.

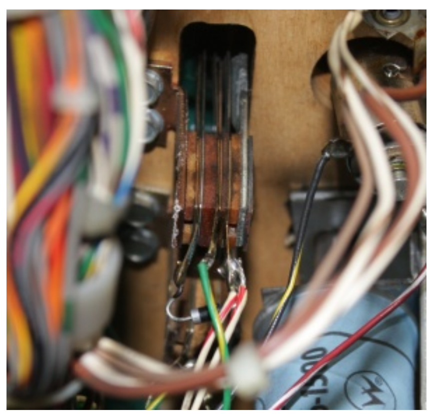
Williams switches are always wired the same. The white (plus tracer) colored wire (row) always attaches to the same solder lug as the NON-banded end of the diode. The green (plus tracer) colored wire (column) always attaches to a lug by itself. The banded end of the diode always attaches to a lug by itself. This creates the following circuit, shown schematically at left.

The picture gallery below provides an example of correct wiring for different types of switches.

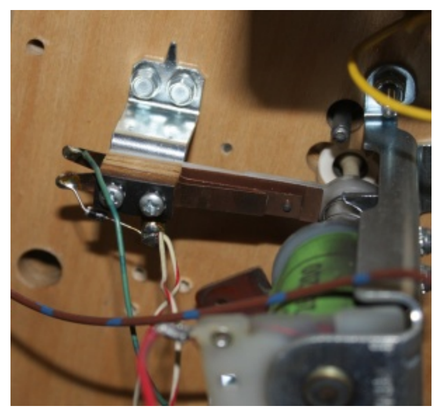
Connections for Various Types of Williams Switches



Slingshot Switch. The Green and White wires go off-frame to the other slingshot switch in the pair.

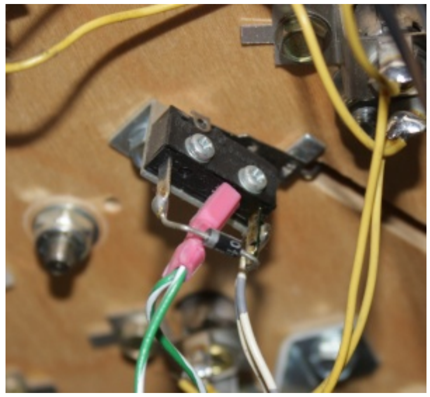


Standup Target

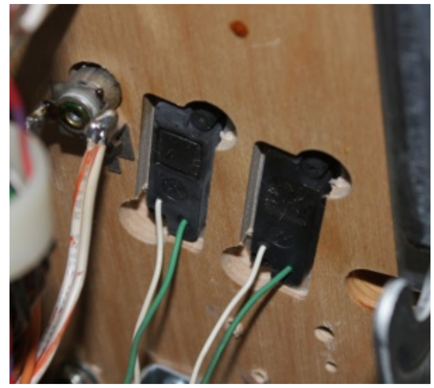


Typical Pop Bumper Switch

Older Style Micro Switch



The Pervasive Sub-MicroSwitch



Reed Switches, as found in Cactus Canyon and NBA Fastbreak. The diodes are located elsewhere.

4.20 Display problems

Display problems are usually the result of failing dot matrix displays themselves, flakey ribbon cables or connectors, ribbon cables installed "one row off" (or even one column off), failing high voltage sections of the dot matrix controller board, and rarely logic IC problems on the dot matrix controller board.

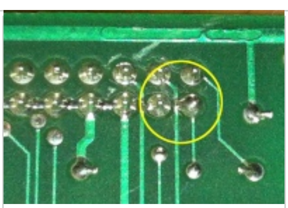
Start by checking the easy things first...

1. Reseat the narrow ribbon cable between the DMD controller board and the DMD.
2. Reseat the wide ribbon cables from the MPU to the DMD controller.
3. Ensure each ribbon cable is correctly mated, and not "one row off" or even "one column off".

4.20.1 Display Panel Problems

The display panel itself may have problems. The glass component has a limited life. The continued electrical discharge releases gases inside the display, which eventually stop the pixels from glowing, and the dots will slowly fade over time. If the voltages are too high, the panel will show sparkles, clouds or ghosting.

4.20.2 Slow Animations



A solder bridge formed on a pre-DCS sound card, affecting speed of display animations.

Slow animations along with sound synced to the animation is a very unusual problem. It is caused by a manufacturing defect in pre-DCS sound boards. As shown at left, an imperfect solder mask led to a solder bridge connecting pins 31 (R/W, read/write) and 34 (FIRQ) on the solder side of the sound board. By connecting the FIRQ signal and the R/W signal, the whole system slows down due to extraneous FIRQ interrupts to the MPU ASIC. The correction for this is straightforward, remove the solder bridge.

A screen shot from the YouTube video showing slow animations on a Twilight Zone.

A YouTube video of this problem can be found here (http://www.youtube.com/embed/gThgBHVuwio?autoplay=1&rel=0) .

A PinSide thread leading to this solution can be found here (http://pinside.com/pinball/forum/topic/tz-slow-dmd-animations-and-parts-suggestions) .

4.20.3 "SuperScript or SubScript" Characters

One of the more interesting display failures is the appearance of characters on some display formats that appear to be shifted up/down 1/2 character or SuperScripted/SubScripted. The cause of this failure is not the display or the dot controller. This failure is caused by a poor connection between the ASIC on the MPU board and it's socket. Reseating the ASIC generally solves this problem. You can "retension" the ASIC leads using this method (http://www.greatplainselectronics.com/tech_wms_asics.asp) provided by Ed at GPE.

Super/Subscripted Characters

Superscripted characters...

Subscripted characters...

4.20.4 "Rolling" Horizontal Line on WPC-95 Display

This problem resembles an old CRT with a vertical hold problem. A wide horizontal line "rolls" through the display from top to bottom.

This problem is easily rectified by replacing C28 and C42 on the Audio/Video board. The original value of these radial capacitors was 150μF/160V. If the original valued capacitors can't be located, the more common 220μF/160V cap is a good replacement.

4.20.5 Outgassing Displays

An "outgassed" display on a Williams FishTales during display test (all pixels should be on except the single vertical line). This display took several minutes to "warm up". The plasma seemed to "float" with various portions at the top of the display appearing dark.

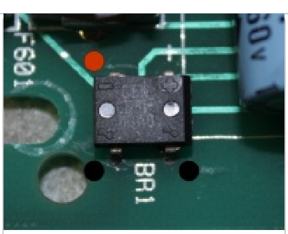
DMDs will eventually fail. It is important to replace an outgassing display as they place extra strain on the power supply, and will eventually damage the power supply. One sign of an outgassing display is that areas of the display need to 'warm up' before becoming fully bright or that the display will remain completely blank for a few seconds and then appear normal.

Outgassing displays look very much like a display that is being overdriven by too much voltage. The acid test is to measure the high voltage using the technique described later in this section.

4.20.6 Display is "delayed" after turn on

There are cases of import machines incorporating an aftermarket circuit that delays the DMD display from appearing for a fixed amount of time after the game is booted. This was done by some operators so that serial number and location information could not be ween when the machine is powered on, thereby preventing identification of a game and potential sales/operation outside a given geographic area. This circuit will not damage anything but is not standard. More information about this can be found in a rec.games.pinball discussion. (https://groups.google.com/d/topic/rec.games.pinball/Q7_FezXgJ7Y/discussion)

4.20.7 Fuse F601 or F602 blows



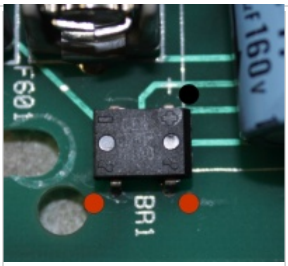
Testing the bridge, step 1, red lead on negative.

The WPC DMD controller rectifies AC voltage via two small 1 amp bridge rectifiers. If a bridge shorts, generally the associated fuse will blow. Sometimes the current draw on the other side of the bridge is so great that the fuse blows too. Whatever the reason, the bridge can be easily tested using the same general bridge testing technique.

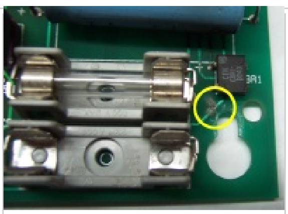
The pin layout for these small bridges is different from the larger 35A bridges on the power/driver board.

Begin with your DMM set to diode check, and the red probe on the leg marked with a negative sign as shown in the picture at left. Placing the black lead on each of the AC legs in turn should yield a reading between .5 and .7 volts. If your measurements fall outside of this range, replace the bridge.

Next, move the black probe to the leg marked with a positive sign as shown in the picture at left. Placing the red lead on each of the AC legs in turn should yield a reading between .5 and .7 volts. If your measurements fall outside of this range, replace the bridge.



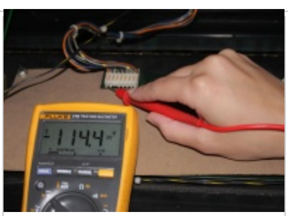
Testing the bridge, step 2, black lead on positive.



The circled area clearly shows where this trace arced to ground.

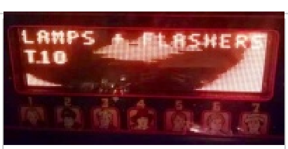
Another reason for F601 to blow is shown at left. Some revisions of the DMD Controller routed the trace from one side of BR1's AC power to F601 too close to the lower right screw that secures the board to the backbox ground. If the star washer for this screw bites through the solder mask, this creates a direct path to ground, blowing F601, as it should. This can be corrected by either leaving the screw out, using a nylon washer, or using a nylon screw. Any of these three methods will work fine.

4.20.8 Testing DMD Controller Power



Testing DMD Controller voltages at the display

After you've checked the easy things, measure the voltages supplied by the DMD controller to the DMD display panel. To test the DMD controller voltages, first open the backbox, and rest the DMD panel face down on the glass. The simplest place to test the voltages provided by the DMD controller is at the display end of the power wire bundle as shown in the picture. **SAFETY WARNING: Your left hand should be in your pocket, to avoid a potentially serious shock. We are working with high voltages, so be VERY CAREFUL. Keeping one hand in your pocket is a good practice to follow as it eliminates the easy electric current pathway across your heart. A DMD controller provides enough electric current to kill you!**



A manifestation of overdriving a DMD with too much voltage.

Most high voltage problems are lack of the proper voltage levels. This results in no display at all. It is possible however, for the high voltage circuitry to fail in such a way that too much voltage is supplied. This manifests as a "plasma" look on the display, as shown on the left. Note that this looks very much like an outgassed display.

The dot matrix display needs three voltages to operate. Williams designed the DMD controller to drive the the DMD display panel just a bit below its specified voltages, presumably to extend the life of the panel. You can find the specification of a panel here (http://www.vishay.com/docs/37006/apd128g.pdf) .

Place the black lead of the DMM under the ground braid in the game's head or use clip leads to secure the black lead to ground. Remember, you are working one-handed, so this becomes a necessity. Place the red lead of your DMM on each of the pins supplying power as shown in the picture. At some point in the production of DMD controllers, Williams changed the Anode and offset voltages from about -124VDC and -112VDC to about -112VDC and -100VDC. As long as there is a 12VDC difference between the Anode and 12VDC offset voltages, your DMD controller is providing correct voltage levels.

Function	Pin	Spec	nominal WPC voltage	Notes
Anode	1	-110V	**-112V**	-124V in early DMD machines
12VDC Offset	2	-98V	**-100V**	Must be 12V less than anode voltage. Will be about 20V less than anode voltage if display not connected
Key	3			
Ground	4			
Ground	5			
5VDC	6	5V	**5V**	
12VDC	7	12V	**12V**	
Cathode	8	75V	**62V**	Williams runs this voltage low

If the high voltages are off by more than a few volts, turn the game off, disconnect the power connector at the DMD controller, and test the voltages at the DMD controller male header pins. If the voltages return to nominal WPC voltages, the zener diodes on the DMD controller are probably OK but the resistors and transistors around them are suspect. As shown in the table above, if DMD controller power is not connected to the display, the nominal 12VDC offset will be about 20VDC.

Note that a failing or failed DMD display glass can drag these voltages down. Before you begin any work on the DMD controller board, perform the above test with the DMD display power disconnected. If the voltages return to nominal WPC voltages, it's possible that your display is the culprit. Test the DMD controller with a known good display to isolate the fault to either the DMD controller or the display panel.

Measuring for 62VDC, and finding only 19.95VDC. The result of this low component of the high voltage trio can be seen in the picture. The manifestation is similar to an outgassed display. The display is showing "FREE PLAY".

For the 62V and -112V circuits Williams used a relatively sophisticated regulator circuit. The problem is, the resistors and diodes dissipate quite a lot of heat. In a warm operating environment, this leads to burned components and circuit boards. The board traces are often weakened. Repair in the area is tricky.

Here's a description of the function of the parts in the -112V circuit.

Q1 is an output buffer. It just follows the voltage set at the top of zener diode D2. Q2 and Q3 form a constant current 5mA driver for the diode. Q2 is a current control for D2. By pulling on the base of Q2, the zener current can be reduced to compensate for the diode leaking as it warms. Q3 is a current sensor for D2. Note the very low 120 ohm resistor. If D2 passes more than 5mA, Q3 will start to turn on, and reduce the current through the diode by pulling on the base of Q3. So the zener diode always operates at 5mA.

The transistors can be tested in circuit, just watch out for the 120 ohm resistors across the base and emitter of Q3.

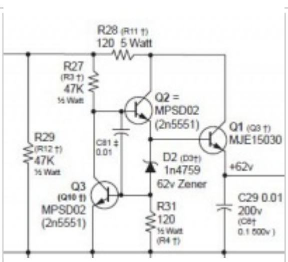
The board is subject to transistor shorts, which can also blow out the resistors. Open resistors are a common problem if Q2 and Q3 are bad.

4.20.9 Schematic Diagram for WPC and WPC-95 DMD Controller Board

This link explains my experience repairing a Twilight Zone ('93 WPC) DMD Controller Board. Also repaired the actual display PCB, which was damaged from a from a faulty +62v circuit:

TZ DMD Controller Board Repair (http://www.firepower.2ya.com/4-TZ-dmd-repair.html)

Here’s a schematic with a list of the parts needed for both WPC and WPC-95 high voltage section repairs. the two boards are similar in the high voltage regulation sections.



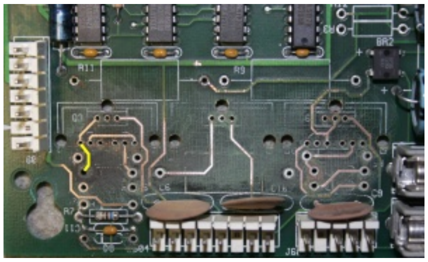
Click on the hyperlink at right for the .pdf of this circuit.

http://www.pinwiki.com/wiki/images/e/e6/Wpc-dmd-hv-all.pdf

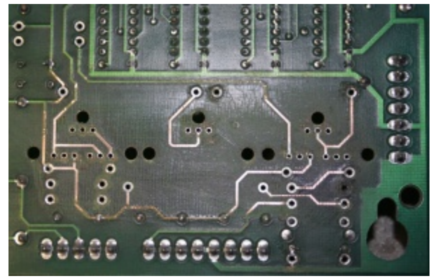
Another area which will help with troubleshooting the DMD Controller Board can be found in the DE section of the PinWiki (DE copied the Williams board designs), Data East High Voltage Repair (http://www.pinwiki.com/wiki/index.php?title=Data_East/Sega#PS_520-5047-01_-_High_Voltage_Missing_at_the_DMD_display) .

The following images of a fairly crispy WPC-089 DMD controller will assist you in ensuring that all traces are repaired.

DMD Controller, High Voltage Section Parts removed

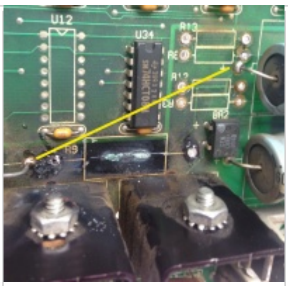


Front side traces. The yellow line shows where a trace had burned off of this board.



Rear side traces.

4.20.10 Heat Damaged Trace Under R9



The burn spot in the center of this picture obliterated the trace that runs from R3/C4 to R11, indicated by the yellow line.

Resistor R9 eats a lot of current and becomes very hot, especially as the associated circuit components age. This damages the trace and PCB beneath it, sometimes to the extent that the trace is severed. "Buzzing" the connection between C4 and R11 is a simple test to ensure continuity of this trace.

4.20.11 DMD Repair Warnings

Be careful when repairing the DMD Controller Boards, you are dealing with High Voltages when the boards are running. A good safety measure is to put one hand in a back pocket (or behind your back) when testing voltages.

It's also fairly easy to lift traces on the PCB or ruin the 'through holes' when removing components. If this happens, you may have to check continuity and 'stitch' the component hole with a thin wire strand. It's a good idea to practice on some useless PCB boards first, before taking on the DMD Controller Boards. For details on a stitch see the "How to Stitch" section of the Wiki.

If you do not have decent soldering and de-soldering skills, DMD HV work should be left to a professional.

HV Repair Kits and advice are available from: Ed at Great Plains Electronics (http://www.greatplainselectronics.com)

- WPC-95 HV REPAIR KIT $5.00 (http://www.greatplainselectronics.com/proddetail.asp?prod=WPC95-HVP-KIT)
- WPC HV REPAIR KIT $5.50 (http://www.greatplainselectronics.com/proddetail.asp?prod=WPC-HVP-KIT)
- *GPE kits do not contain capacitors, which can be ordered separately as needed.*

HV Repair Kits and advice are also available from: Rob Anthony at Pinball Classics (http://LockWhenLit.com)

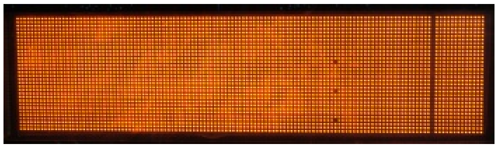
- WPC-95 or WPC HV REPAIR KIT $10 (http://LockWhenLit.com/Products.aspx)
- *Indicate in the notes section of the order if you need the WPC or the WPC-95 HV kit, Pinball Classics kits do contain the 150µF 160V capacitors.*

Bally/Williams and Data East have similarities with the 128x32 display and the display itself is interchangeable between manufacturers. DMDs have a limited lifetime and will eventually outgas. Please see the information about outgassing displays in the Data East section.

4.20.12 Failed RAM

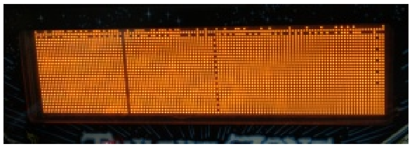
Most failures of the DMD controller that are not attributed to the high voltage section are caused by failed 6264 static RAM at U24. Since the RAM is very susceptible to electrostatic discharge, they are often damaged by improper handling. Sometimes, they just fail. Failure of this RAM manifests in many ways, including some shown below.

Various display issues resulting from failed 6264 RAM on the WPC-089 DMD Controller board.



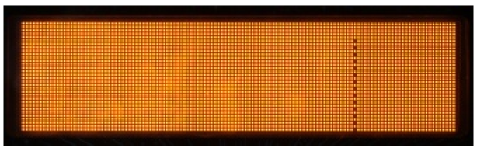
Example 1

Example 2

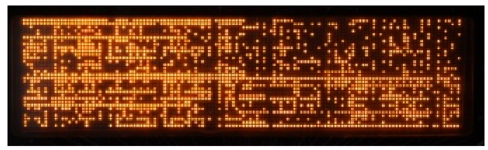


Example 3

Example 4



Example 5



This random pattern caused by a blown 6264 RAM. It was blown by sending Flipper Coil power (nominally 70VDC) down the data lines (D0-D7).

4.21 Sound problems

Before going any further, check all of the basics in the Basic Sound Troubleshooting (http://www.pinwiki.com/wiki/index.php?title=General#Basic_Sound_Troubleshooting) section.

4.21.1 Sound Board Interface Error

A "Sound Board Interface" error occurs when the MPU board can not communicate properly with the sound board at boot up. There could be several reasons for this problem.

1. Ribbon connector not properly seated. The ribbon to the sound board(s) originates at J202 on the MPU board, goes to the FlipTronics board, then to the sound board (whether pre-DCS or DCS), then on to the DMD controller board.
2. Failed ribbon cable. Due to over-flexing, the ribbon may have failed.
3. Mismatched ROMs between the MPU and sound board. This isn't as big of an issue as with Data East games, but updating the game ROM to a newer version while leaving the sound ROMs at an older, even prototype version, could cause this problem.
4. Solder bridges, or corrosion under the ribbon connector.
5. Failed I/O buffer ICs on either the sound board or on the MPU board

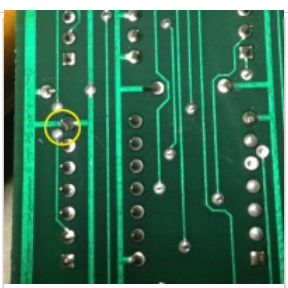
On **DCS sound boards**, U18 buffers data **from** the MPU. U19 buffers data **to** the MPU. Testing these ICs using the this method (http://www.pinwiki.com/wiki/index.php?title=General#Testing_an_integrated_circuit) should yield similar results to the values listed below. Note that this test method can't identify either a good or a bad integrated circuit with 100% certainty but using this test is preferable to removing chips unnecessarily. These readings were taken using a Fluke 179 DMM. Different meters, different manufacturers chips, and even individual variation in manufacture will probably cause your readings to be slightly different, yet consistently different. i.e. If the table shows .657 and your meter yields .630, then every pin listed at .657 should read close to .630 with your meter.

Probe pin 10 with the DMM red lead. Probe each of the other pins with the black lead.

Pin	Diode Test Value U18	Diode Test Value U19
1	.583	.580
2	.519	.659
3	.657	.510
4	.657	.516
5	.511	.656
6	.511	.656
7	.657	.510
8	.657	.510
9	.511	.656
10	Red Lead	Red Lead
11	.580	.580
12	.510	.657
13	.657	.518
14	.657	.516
15	.519	.656
16	.517	.578
17	.657	.517
18	.578	.509
19	.517	.657
20	.398	.398

Corrosion in the area of a critical signal caused a "Sound Board Interface Error".

The root cause of a "Sound Board Interface Error" on a Star Trek:The Next Generation game is shown at left. The corrosion on the trace leading to pin 28, created a conductive bridge to pin 29, which is a critical signal to the sound board (WDEN).


A solder bridge at the circled location (U16), connecting pin 7 of the IC (ground) to the via and hence connecting pin 2 to ground, manifested as a "Sound Board Interface Error".

Another physical PCB problem pictured at left (but repaired), caused a "Sound Board Interface Error". The sounds on this board operated fine since the error was in the hardware that talks back to the MPU.

4.21.2 Lowering the Minimum Volume

By default the game volume can be set no lower than '8' to prevent an operator from setting the volume too low. This can be overridden by entering the adjustments menu and setting Adjustment 1.28 (Minimum Volume Override) to yes. You can now set the volume as low as you like.

4.21.3 High Frequency Sound Only

This applies to pre-DCS and DCS sound boards. Uncertain if AV boards apply or not.

There is a situation where only the tweeter / high frequency sound can only be heard. This will result in the game sounding much quieter than usual. Most speaker systems are parallel circuits. However, the woofer on a pre-DCS sound system is in series with the midrange speaker. The high frequency speaker is in a parallel circuit to the mid and low range speakers. If there is no sound from the woofer in the bottom of the cabinet, there will be no midrange from the speaker panel.

First, make certain that the speaker output wiring from the sound board is connected correctly. Also, there is a bullet connection located inline which must be connected. This bullet connections ties the low and midrange speakers in series. Finally, check the connections at the woofer in the bottom of the cabinet to make certain the female spade connectors are secured to the speaker terminals. If all connections are secure, there is a chance that the woofer speaker is blown.

4.21.4 Pre-DCS Sound Board Issues

4.21.4.1 Power on Sound Tones (Bongs)

After a successful boot, the game should make a single "bong" sound. The game provides a sound board problem indication with the following number of bongs.

Pre-DCS Sound Board Games.

- 1 - No issues...enjoy a game.
- 2 - U9 RAM failure.
- 3 - U18 ROM failure.
- 4 - U15 ROM failure.
- 5 - U14 ROM failure.

4.21.4.2 No Sound at all

The highest probability reason for the complete lack of sound is connections to the speakers. The IDC connectors at J504 and J505 carry the sound to all speakers in the game. Since the speakers are connected in series on a pre-DCS game, any break in the speaker signal loop will cause loss of all sound. First check the small gauge wires at connectors J504 and J505. Since they are IDC connectors, they are prone to breaking free from the connector. Next ensure that all speaker connections are solid.

It is possible for a speaker to fail, commonly called "blown". You can test a speaker by applying anything from an AA battery to a 9V battery to the speaker terminals. You should see the speaker cone react when the battery is touched to the terminals.

4.21.4.3 Unbalanced Sound

Pre-DCS sound boards are not 100% interchangeable across games. Games from Funhouse to Party Zone (including Funhouse, Harley Davidson, Bride of Pinbot, Slugfest, Gilligan's Island, Terminator 2, Hurricane, and Party Zone) use different resistor values at R23/R24 than the remaining games that used the pre-DCS sound board (games from Hot Shots basketball through The Addams Family Gold). If you find the sound "unbalanced" between background sounds and voices, for instance, check the following resistor values.

R23/R24 values for...

> Funhouse through Party Zone - 150K ohms
> Hot Shots through TAFG - 56K ohms

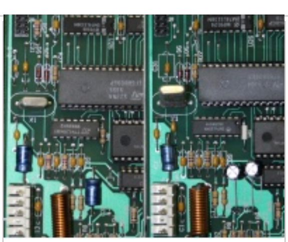
Note that the resistor value indicated in the schematics for pre-DCS sound boards at R22 and R25 are wrong. The schematics indicate 150K ohms. The correct value is 120K ohms.

4.21.4.4 Distorted or slightly "off" sounds

C38 is not stuffed on some pre-DCS sound boards.

The pre-DCS sound board uses 47μF capacitors as filters in the sound circuit; C15, C36, and C38. If one or more of these caps fail, certain sounds may not be as loud or as clear as intended. The game will just sound "off" with perhaps slightly unbalanced sounds. An amazingly high percentage of these caps fail. It is recommended that if your sounds are a bit "off" that you replace all of these caps.

Note: as shown at left, C38 is sometimes not stuffed at the factory. It appears that audio channel 1 and channel 2 (in C38s path) from the Yamaha YM3012 are redundant, making the this cap unnecessary.



C49, implemented in two different ways on the pre-DCS sound board.

Also, some pre-DCS sound boards looked to have been "hacked" to add a ceramic capacitor just below the clock crystal X1. This is not in fact a hack. It appears to "fix" the omission of C49 on some versions of the PCB. C49 is located at the edge of the board, just above the crystal.

4.21.4.5 Popping, Scratchy Sound, Very Hot LM1875 Heat Sink, or Shorted Speakers

Sometimes, the tantalum/ceramic caps in the amp circuit fail too. This can result in too much AC "ripple" feeding the amp as well as DC output to the speakers, which they do not like. The following components are all suspect...

- C20 (10μF, 20V tantalum)
- C46 and C47 (both 1μF, 35V tantalum), and
- C23 (.22μF, 10V, ceramic)

Normally, the positive side of the tantalum cap at C26 will measure about 50mv of AC referenced to game ground. Anything more indicates a problem with these tantalum caps. You will also be able to measure DC voltage across the speaker outputs. There should normally be no DC voltage across the speaker outputs.

The LM1875 may also run very hot. Normally, you can grasp the heat sink without burning your hand. It will be hot, but not so hot that you can not squeeze it or grasp it very long. If the heat sink is so hot that you can not grip it, failing tantalum caps should be suspected. If after replacing the tantalum caps the popping and scratchiness persist, the LM1875 amp may have been damaged.

4.21.4.6 Volume Not Adjustable and Stuck at Low Volume

This problem manifests as a very low volume from the speakers, equivalent to the lowest sound level setting. The volume setting may be adjusted from the coin door, and the DMD volume "thermometer" will move normally, but the speaker volume will not change. While the cause of this issue could be a failed digital POT as discussed here (http://www.pinwiki.com/wiki/index.php?title=Williams_WPC#Volume_Suddenly_at_Maximum) , a failed MC3340 electronic attenuator may also be the cause. You may be able to identify the MC3340 as the problem by comparing "diode test" results with a known good MC3340.

In one such case, pins 7 and 8 of the device where shorted together, causing the symptoms described. The failed MC3340 may also have caused the amp to become very hot, but this has not been conclusively proven.

Take care to ensure the MC3340 is actually at fault as this obsolete part is pricey and hard to find.

4.21.4.7 Wrong sounds being played

Generally, this problem boils down to a communication problem between the MPU and the sound board. Possible failure points are:

- Ribbon cables
- Male header pins on both MPU and sound board
- 74LS374 data buffer ICs on the sound board used to communicate between the MPU and the sound board.
- Rarely, a failed 6264 RAM can cause this. The RAM is "tested" by the MPU. Sometimes it will pass the test, yet fail in game play. Odd...I know.

4.21.4.8 Volume Suddenly at Maximum

If while playing a game, the volume suddenly jumps to full volume and control of the volume via the coin door buttons does not work, there is a good chance that the digital POT (volume control) on the sound board has failed. The part is located at U5 and is an X9503. The X9503 is obsolete but it's successor the X9C503 works fine here.

4.21.5 DCS Sound Board Issues

4.21.5.1 Power on Sound Tones (Bongs)

After a successful boot, the game should make a single "bong" sound. The game provides a sound board problem indication with the following number of bongs.

DCS Sound Board Games.

- 1 - No issues...enjoy a game.
- 2 - U2 ROM failure.
- 3 - U3 ROM failure.
- 4 - U4 ROM failure.
- 5 - U5 ROM failure.
- 6 - U6 ROM failure.
- 7 - U7 ROM failure.
- 8 - U8 ROM failure.
- 9 - U9 ROM failure.
- Note - DCS sound board RAM failures are indicated by a message on the display, "U10-U12 RAM error".

4.21.5.2 Loud Humming

The DCS board uses 2 10,000μF caps at location C20 and C21. The negative side of C21 and the positive side of C20 are connected to the analog ground at header J4 pin 6 and 7. This connection is fragile. If you hear loud humming when turning the game on check for continuity between these points. Often this is diagnosed as a failing cap when it's just a broken trace.

4.21.5.3 Ram Error

Replacement RAM ICs for the DCS sound board are becoming harder to find. The board uses three 2K skinny dip 6116 cache rams with an access time of 35nS or better. These are long obsolete and gone. The good news is that the board has jumpers for 6264 type 8K cache rams. Jumper W4 is installed for 2K rams. Jumper W4 should be removed and jumper W5 installed to use 8K rams. All RAM ICs need to be replaced at the same time for this configuration to work. A relatively inexpensive, and still in production replacement, is the CY7C185-20PXC (Digikey 428-2157-5-ND).

4.21.5.4 Muffled Sound and Speech


C32 and C41, both electrolytic caps, are in series in the sound amplification circuit of the DCS sound board.

Muffled audio can be caused by two 1uf/63V electrolytic capacitors that are in series with the audio path for both amplifiers. Simply replacing them may clean up the audio. A typical 1uf/50V axial electrolytic capacitor will work fine.

4.21.5.5 Scratchy Audio or mumbled speech

For WPC-95 WMS removed two small ceramic caps (C47 and C51) in later revisions of the A/V board to clean up the sound. This fix can also be applied to the DCS sound board. On the DCS board C37 und C45 need to be removed. Just clip both sides of the cap. You do not need to desolder them. This cleans up the sound and speech on some games like Demo Man quite well.

4.21.6 WPC-95 A/V Board Sound Issues

Always check the speaker connections to the A/V board (J504 and J505) and the wiring at the speakers before assuming there is a problem with the board. The speakers themselves can go bad; you can do a quick "click test" with a D-cell battery and a set of jumper leads to rule out dead speakers. Disconnect the speaker connections at the A/V board and connect your battery jumper leads to the pairs of wires in the J504 and J505 connectors; you should hear a click from the speaker if it is good. If you don't hear the click try the connection at the speaker itself to rule out wiring issues.

The analog output of the A/V board feeds into a TLO84 op-amp (U1) that is configured as a pair of low-pass and high-pass filters; these are used to separate the low-frequency sounds (destined for the cabinet speaker) and the high-frequency sounds (destined for the back box speakers). These two channels - signfied on the schematic as AUDIO_R (cabinet) and AUDIO_L (back box) feed into a pair of TDA2030AV amplifiers; U5 drives the back box speakers and U6 drives the cabinet speaker.

The outputs of U1B and U1C (pins 7 & 8) can be briefly connected with a jumper lead to help narrow down issues when one of the two channels is not working or has weak/distorted output. When the two pins are jumpered you should be able to hear approximately the same level of sound from the cabinet and back box speakers. (Use the T.7 diagnostic test to play sound clips for the game during your testing.)

4.21.6.1 Power on Sound Tones (Bongs)

After a successful boot, the game should make a single "bong" sound. The game provides a sound board problem indication with the following number of bongs.

Audio/Video Board Games (WPC-95).

- 1 - No issues...enjoy a game.
- 2 - S2 ROM failure.
- 3 - S3 ROM failure.
- 4 - S4 ROM failure.
- 5 - S5 ROM failure.
- 6 - S6 ROM failure.
- 7 - S7 ROM failure.
- 10 - U9, U10, or U11 RAM failure (see below)

WPC-95 boot time RAM error message, accompanied by 10 very annoying bongs.

A/V sound board RAM failures are indicated by a message on the display, either "U9-U11 RAM error" or "U10-U12 RAM error". This is apparently game software dependent. A/V RAM are, in fact, U9-U11. Apparently, this message wasn't updated in some of the software with the introduction of the A/V board.

WPC-95 boot time RAM error message, accompanied by 10 very annoying bongs.

4.21.6.2 Loss of One Channel

If one channel is out or weak/distorted try the jumper at U1 pins 7 & 8 noted above. If no change is detected in the sound output it is likely the associated TDA2030AV amplifier (U5 or U6) has failed. Before replacing the amplifier jumper a 1 MFD 63 volt capacitor across C38 and C39 in turn (observe polarity!) to rule out a defective coupling capacitor. If jumpering pins 7 & 8 of U1 significantly improves the sound levels it is likely that U1 itself has failed.

4.21.6.3 Scratchy Audio

A later production Williams WPC-95 AV Board, with C47 and C51 intentionally unstuffed at the factory

Williams removed two small ceramic caps (C47, C51, pictured at left) later in the production run of AV boards. If your game's audio is just a bit scratchy, and these caps have not been removed, you may be able to improve audio quality by removing them. Simply clip both sides of the cap. There is no real need to desolder them.

4.21.6.4 Really Loud buzzing sound for a second or two

If your game sometimes produces a really loud buzzing sound at random, check the version of your S2 sound rom. This problem was fixed with the latest S2 sound ROM for Attack from Mars, Congo, Safe Cracker and Tales of the Arabian Nights. Scared Stiff might also be affected but no version history for sound 1.1 exists for this game. Later games are not affected.

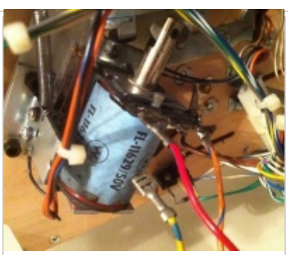
4.22 Flipper Problems

In most instances, an inexperienced tech will immediately blame the flipper coil itself for weak or non-functioning flippers. It is logical to blame the coil for the source of the problem. The flipper coil is, after all, the end reason why a flipper becomes engaged. However, its failure is the least probable reason that a flipper is not working.

4.22.1 Flipper does not work

In this case, you've started a game, you press the flipper cabinet switch, and nothing happens.

The first thing to do is inspect the wire connections to the flipper coil lugs. The most common reason a WPC flipper does not function is that either one of the wires broke from the game to the lug, or one of the coil winding wires, has broken away from the coil lug and is no longer connected to the coil. This is a pretty simple fix. Make a clean cut to the wire, strip or sand 1/4" to 3/8" of insulation back, and make a nice solder joint on the coil.



A good reason to nip spade connectors off and solder directly to the coil lug. This spade connector simply **fell off** the coil lug. Luckily, it didn't come to rest on an adjacent lug.

Some WPC-95 titles used "spade connectors" (also known as FASTON connectors) to attach wires to the coil lugs. This was done for ease of manufacture and for that reason only. Similar to a wire breaking free, these spade connectors sometimes do not provide a solid connection and sometimes simply fall off. In that case, cut the spade connector off and solder the wire directly to the coil lug. This makes a much better connection that is also much more reliable. Should a spade connector fall onto an adjacent coil lug, it's very possible that a short circuit will be created, possibly damaging the FlipTronics board.

4.22.1.1 Mechanical Reasons

There are a couple of mechanical reasons a flipper may not be working, including:

- Broken flipper link
- Flipper crank not "biting" flipper shaft (this would most likely manifest as a flipper that continues to move backwards, out of adjustment)

Simple inspection of the flipper mechanism should guide your corrective actions.

4.22.1.2 Pre-FlipTronics Games Electrical Reasons

- Failed flipper power supply - make sure that DC flipper power is present at the coil using your DMM. Place the red lead on a coil lug, the black lead on game ground (siderail or ground braid anywhere in the game). You should read about 70VDC.
- Flipper cabinet switch not "making" or fouled so badly that it doesn't conduct flipper power
- Fouled or missing flipper end-of-stroke switch. Pre-FlipTronics games relied on EOS switches in the same way that older games do. That is, power is routed to the power stroke winding of the coil via the EOS switch. If the EOS switch is fouled, only the hold winding will receive power; perhaps inadequate to move the flipper at all.

4.22.1.3 FlipTronics Games Electrical Reasons

- Failed flipper power supply. Flipper power originates at the transformer. It is routed through the power/driver board (which does nothing to it) and then to the FlipTronics board. The FlipTronics board rectifies the AC power via an onboard bridge rectifier. Power may be interrupted anywhere along this path, including a failed bridge rectifier or blown fuse.
- Failed flipper coil "power stroke" winding
- Flipper cabinet switch not "making" or flipper opto board not working
- Damaged connection between flipper cabinet switch and FlipTronics board
- FlipTronics board not recognizing flipper cabinet button switch closure

A missing pin in the **FlipTonics-to-MPU interface**. The missing pin prevented transmission of the F8 signal (D7), which is the upper left flipper switch closed signal.

An unusual reason for the flipper switch closure signal not being sent to the MPU is shown at left.

- Failed logic path on the FlipTronics board including the transistors. See: WPC FlipTronics I and II Boards for a description of the signal path.
- Improperly seated or failed ribbon connectors between MPU and FlipTronics board

4.22.2 Flipper is weak

In this case, the flipper makes a stroke, but it's a weak stroke, not striking the ball with normal force.

4.22.2.1 Mechanical Reasons

- Not enough vertical movement in flipper bat (crank tightened too close to bushing)
- Cracked, broken or egged flipper bushing
- Mushroomed coil stop and plunger (replace coil sleeve too)
- Missing link bushing or oval link "eyelet"
- Tired flipper crank (will not tighten on bat shaft)

An Example of an Egged Flipper Link and Mushroomed Flipper Plunger - Lower Link and Plunger Shown in Picture is new

4.22.2.2 Pre-FlipTronics Games Electrical Reasons

- Flipper cabinet switch not "making" or fouled so badly that it does not conduct
- Failed flipper end-of-stroke switch

4.22.2.3 FlipTronics Games Electrical Reasons

- Dirty flipper cabinet switch optos
- Power stroke winding of coil failed

4.22.3 Flipper locks on or fails to fall to resting position

In this case, the flipper locks in the up position, either at game power on or when the flipper cabinet switch is pressed.

4.22.3.1 Mechanical Reasons

4.22.3.2 Pre-FlipTronics Games Electrical Reasons

4.22.3.3 FlipTronics Games Electrical Reasons

- Flipper cabinet switch opto interupter not returning to proper at rest position
- Sticky flipper buttons, which can lead to opto interupter not returning to at rest position.

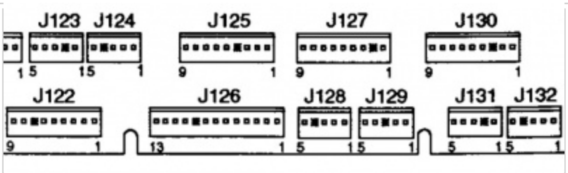
4.22.3.4 Fodder (may be useful to complete this section)

- Fouled or broken "normally closed" EOS switch
- Fouled or broken flipper cabinet switch
- Flipper relay not enabled
- Fouled / dirty or non-functioning flipper opto switches
- Upper flipper switch closures in switch test, when there aren't any upper flippers on game

5 Repair Logs and Game Specific Problems and Fixes

Since WPC games are overwhelmingly the most popular pinball titles at the moment, and there are a vast amount of titles with so many game specific issues, please refer to the Game List (http://pinwiki.com/wiki/index.php?title=Williams_WPC#Game_List) section of this guide. Click on the specific game, and a new page will open regarding repair logs and game specific problems and fixes for that particular game title.

5.1 World Cup Soccer locks on Right Sling and both Left and Right Kickout Holes at Power On



Board layout diagram showing identical connector and keying at J124, J128, and J132)

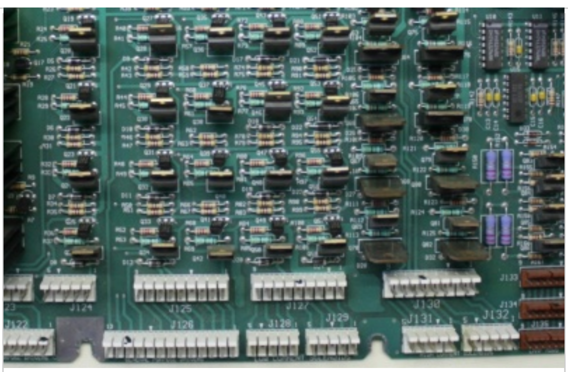


Image showing identical connector and keying at J124, J128, and J132)

Problem

Upon power on, and with the coin door closed (defeating the high voltage interlock switch), the right slingshot as well as the left and right saucer kickout hole coils lock on.

Cause

The flash lamp drive connector that should be connected to J124 is instead connected to J128.

Discussion

Connecting the female plug to the wrong header pins is entirely possible since the connectors are the same width and are keyed identically. In World Cup Soccer (at least), the wire bundle is long enough to be connected (properly) to J124 or (improperly) to J128 or J132.