Repairing Williams/Bally Pinball 2000

by *cfh@provide.net*, 08/09/03.

Scope.
This is a WORKING document! It is not complete. This doucment has also borrowed info from other source (check the bibliography below). There is still much info to document on Pinball 2000. I will add info as time permits. This document covers both Williams and Bally Pinball 2000 games (Revenge from Mars and Star Wars Episode 1).

Internet Availability of this Document.
Updates of this document are available for no cost at http://arcarc.xmission.com/Pinball/Web%20Archives/www.Marvin3m.com%20(Sep-08-2003)/fix.htm if you have Internet access. **This document is part one of one.**

IMPORTANT: Before Starting!
IF YOU HAVE NO EXPERIENCE IN CIRCUIT BOARD REPAIR, YOU SHOULD NOT TRY TO FIX YOUR OWN PINBALL GAME! Before you start any pinball circuit board repair, review the document at http://arcarc.xmission.com/Pinball/Web%20Archives/www.Marvin3m.com%20(Sep-08-2003)/begin/index.htm, which goes over the basics of circuit board repair. Since these pinball repair documents have been available, repair facilities are reporting a dramatic increase in the number of ruined ("hacked") circuit boards sent in for repair. **Most repair facilities will NOT repair your circuit board after it has been unsuccessfully repaired by you.**

Table of Contents

Bibliography.

- Pinball 2000 Collectors page.
- Jack Robinson (Ratherplaypinball).
- WMS P2000 Tech Notes.
- WMS P2000 Tech Notes2.
- Ray Johnson.
- Randy Fromm's Pinball 2000 article at www.randyfromm.com/shopping.

1a. Getting Started: What is Pinball 2000?

Pinball 2000 has a 19 inch video game monitor which has been integrated with a traditional pinball playfield. Virtual images are projected onto the playfield, allowing the ball to interact with video targets as well as traditional "hardwired" targets. Images on the video monitor can be moved and animated in respect to the playfield architecture, creating 3-D video targets. With a hardwire target behind the animated 3-D video target, the computer knows when the ball "hits" the animated 3-D video target. It can then project a 3-D explosion of the target, or any other computer generated affect, seemingly right on the playfield!

Unfortunately there were only *two* pinball 2000 game titles manufactured: Revenge from Mars (aka RFM), and Star Wars Episode 1 (aka SWE1). Game number three, titled Wizard Blocks (designer Pat Lawlor) was never produced. Likewise for game number four, Playboy (designer George Gomez). The existing two Pinball 2000 games (RFM and SWE1) were rushed to market while the pinball 2000 system itself was being developed. Because of this, the first two games aren't as "deep" as they could have been. Games three and later addressed many of the criticisms of Pinball 2000 ("too reliant on the video", "shoot up the middle only" and "I can't see the ball at the top of the playfield"). But unfortunately we will never see the full potential of this new and unique pinball system.

The big advantage to this style of pinball is playfield "toys" no longer need to be physical. They can be projected onto the playfield. This means no maintainance of broken mechanical "toys", more flexibility in the design of video "toys", and lower manufacturing costs. Also pinball design is now expanded to another level. Before, limits were in place as to what a pinball designer could do. With Pinball 2000, these limits are largely gone. Mechanical toys can still be used, but the designer now has a choice and can use video "toys" (instead of, or in addition). And video toys can interact with the ball easily.

Pinball 2000 is also modular. Game play is controlled by a ROM-based personal computer (not unlike the one you are using to view this document) housed in the backbox. By simply upgrading the software and replacing the lightweight, easily removable playfield, an entirely new Pinball 2000 game can be installed in minutes.

Features of Pinball 2000 include:

- Video images appear under the glass providing virtual targets and helpful gameplay information in the player's direct view. For example, a dancing Alien can be projected onto the playfield. Behind the Alien is a "hardwired" target. When the ball hits the vitual Alien (and hence hits the hardwired target, which is not seen by the player), the computer senses this and then does an alien explosion animation!
- Virtual mechanisms provide greater variation in game play. At the same time virtual mechanisms also increase overall reliability of the game. After all, a virtual spinner never wears out, never tears it's decal, and never breaks.
- The cabinet, backbox, monitor and electronics provide the base for a convertible system. With its unique skid-rail and connector panel configuration it takes only 60 seconds to replace a Pinball 2000 Playfield.
- Special "Location Key" provides the location with access to the playfield while keeping the cashbox and electronics secure.
- New Stereo Sound System places speakers closer to the player for maximum enjoyment at any volume level.
- Powerful built-in troubleshooting with full screen video menus and displays include the detection and reporting of blown fuses and burnt out lamps.

Convertability is another main selling point. The game may be converted to a new model through the purchase of a kit containing a new playfield, software and cabinet graphics. Generic Pinball 2000 side graphics may be applied to the game allowing operators to rotate playfields instead of entire machines on a route. This process may include rotating the playfield into the shop for general maintenance. A route collector is able to swap a playfield requiring service with a working playfield, allowing the defective playfield to be serviced by the trained technician in the shop, at his leisure.

Logic Box in backbox slides out for easy access, replacement or conversion. Power-Driver board is located in the bottom cabinet for easy access, and provides the following enhancements:

- Unique power-driver board mounting system requires only 2 screws and has 22 fewer connectors than the previous WPC system.
- All fuses are in easy reach at the front of the machine. Each fuse is mounted next to a status LED for easy troubleshooting.
- Standard PC parallel port interface allows for easy isolation of problems using any Personal Computer as a portable test fixture (unfortunately, this aspect of Pinball 2000 was never developed).

Software updates are available via several methods:

- Using a laptop or other personal computer, a serial port transfer via a null modem cable can update the software on the Pinball 2000 game (no EPROM programming required).
- Direct update from Williams' web site when connected via phone line to an optional modem (unfortunately this option was never developed).
- ROM updates from your distributor using a "PUB" card. This card can be borrowed from a local distributor, and installed into one of the empty slots in the Pinball 2000's personal computer.

Many of the above statements came directly from Williams' own Pinball 2000 literature.

Many people have noticed that the Pinball 2000 cabinet is a bit shorter than the older WPC pinball games. Below is a comparison of playfield sizes from System11, Pinball 2000, and WPC games. Note the Pinball 2000 playfield is only slighly shorter than a WPC game, and is longer than a system11 playfield. The Pinball 2000 cabinet/playfield was made shorter than WPC to minimize waste of raw materials, and to maximize units shipped per container, in an effort to save money.

High Speed (1985)
42" Playfield

Revenge From Mars (1999)
43" Playfield

Terminator 2 (1991)
46" Playfield

Comparison of playfields from three different production eras.

Personal Thoughts about Pinball 2000.
By Randy Fromm. This information used with permission from Randy's CDROM on pinball and video game repair. See www.randyfromm.com/shopping for more details.

The integrated monitor may be the most obvious change, but there were many other surprises in Pinball 2000. While pinball machine have always been modular (the power/driver module, the CPU module, the sound module and so on), Williams has carried the concept one step further by making the playfield an easy to replace module as well. Instead of using long harnesses leading from the playfield that are snaked up through the backbox area and into the connectors on the boards, the connectors (there are six) come off the playfield itself. This makes it possible to remove the entire playfield in a matter of seconds. Heavy-duty tubular rails on the bottom protect the playfield components from damage and allow the playfield to slide out easily. The playfield can be swapped out in about a minute. This can be done for maintenance purposes (where a damaged, dirty or faulty playfield can be

swapped out for a clean, working unit), or to change to a different game altogether. With a change of the backglass translite (now illuminated by a single florescent tube instead of dozens of miniature lamps) and new software, a new game is installed.

Another Pinball 2000 surprise was a new locking concept called the "location key." The location key is used with a standard lock, located in the front of the game near the start button. The location key unlocks the handrail, allowing the glass to be removed for access to the top of the playfield. However, it leaves the playfield itself locked down preventing access to the cashbox and the electronics beneath the playfield. This makes it possible for the location to provide simple maintenance such as removing a stuck ball or, in some cases, cleaning the playfield or replacing broken rubbers.

Opening the coin door with a separate key reveals another couple of surprises. The coin door is now spring-loaded and forcefully pops open as soon as the key is turned to unlock it. This keeps the coin door out of the way so you won't strike it with the playfield glass as you remove it. It also releases the passive locking system that holds the playfield down.

The power/driver board is now located in the bottom of the cabinet. A hinged, plastic cover protects the board from possible damage due to hardware falling off the playfield. Lifting the cover reveals another design change that is geared toward making it easier to service the machine. No longer is a meter needed to locate a blown fuse. There is now a row of LEDs adjacent to the fuse bank; one LED for each fuse. If the LED is on, the fuse is good (assuming the coin door interlock switch is closed). Dark LEDs indicate a problem. This same data is simultaneously and graphically displayed on the monitor when the game is put into test mode. Additionally, the value of the fuse is displayed on the monitor for those that have trouble reading the value that is etched into the end cap of the fuse.

The power/driver board is now removed with just two screws instead of nine. There are also twenty-two fewer connectors than their previous WPC-95 system. Communications between the power/driver board and the computer is now accomplished through a standard, personal computer parallel port. This gives the capability of additional troubleshooting using a computer (thought this software was never developed because Williams closed pinball before its completion).

The computer in Pinball 2000 is just that: a standard personal computer (PC) motherboard with a plug-in PCI card that holds the software. It's a "baby AT" form factor with a Cyrix 233 Mhz processor. There is no floppy disk or hard disk and Williams uses their own Operating System (OS). This is not a windows based "Arcade PC."

The computer is housed in an easily removable, steel box located within the backbox of the game. The box pulls out and down for servicing or can be removed completely without any tools at all. The box also houses a digital audio amplifier and a standard, switching regulator power supply such as you would find in any computer.

The images and sound data are on masked ROMs plugged into the PCI card, called the Prism card. All of the program software for both sound and game are in re-programmable, flash memory. This means the game can be updated without ever burning an EPROM or opening the backbox. On the inside of the coin door, there is another standard 9 pin serial PC connector. This RS232 port that allows the use of a

laptop computer to load the new software. Software updates are available on floppy disk through distributors, or by downloading off the Williams website.

The redesigned cabinet also allowed Williams engineers to relocate the speakers. They are now much closer to the player's ears, allowing the volume to be set lower. Additionally, the DCS2 sound system sports a third channel that is used to drive a bass speaker in the cabinet. This is more than a sub-woofer. This is a discrete, third channel of audio.

Pinball 2000 is a really neat combination of all the repair disciplines most techs have acquired over the years. On a system level, the machine has a monitor, an audio amplifier, a PC motherboard, a switching power supply, and a linear power supply (for the logic on the power/driver board). The switch matrix, lamp matrix, and solenoid driver circuits that account for the rest of the power driver board circuits are very straight forward and similar (if not identical) to Williams' WPC system. A professional coin-op technician will know how to work on all of these things. Williams' attention to serviceability makes Pinball 2000 a joy to work on.

Upon closer inspection, Pinball 2000 isn't really revolutionary at all. In fact, it is most "evolutionary" as game techs will already be familiar with the vast majority of the circuits. Oh sure, Pinball 2000 looks really different with its monitor enhanced backbox. Sure, it has an off-the-shelf PC motherboard instead of a custom made CPU board. But deep down inside, where it really matters, in the control circuits and the I/O, it's just a slightly refined and enhanced version of the Williams' pinball circuits with which we're already familiar.

1b. Getting Started: Why WMS Stopped Making Pinball 2000 (Or How Slot Machines Killed Pinball)

Coming soon.

1c. Getting Started: Repair Experience, Schematics

What Repair Experience Is Expected?

Little experience in fixing pinballs is assumed. Basic electrical knowledge is helpful, but not necessary. I do assume you can solder and use the basic features of a Digital Multi-Meter (DMM) such as measuring voltage and resistance. Please see http://arcarc.xmission.com/Pinball/Web%20Archives/www.Marvin3m.com%20(Sep-08-2003)/begin/default.htm for details on the basic electronics skills and tools needed. This document should help if you just bought your first (or second, or third) Williams pinball "as-is", and hope to fix it.

Got Schematics?

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

1d. Getting Started: Necessary Tools

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

Non-Specialized Tools Required:

- Work Light: clamp style lamp

- Screwdrivers: small and medium size, phillips and flat head
- Nut Drivers: 1/4", 5/16", and 11/32"
- Wrenches: 3/8", 9/16", 5/8" required, other sizes suggested
- Allen Wrenches: get an assortment of American sizes
- Needle Nose Pliers
- Hemostat. Handy for holding parts and springs. Best to have both the curved and straight versions if possible.
- Right Angled Screwdriver: both phillips and flat head.
- A hand mirror.
- Hex Keys for Backbox Mounting (there are three sizes): 7/32" outside cabinet to attach backhead and 1/4" inside to hold metal insert in place while. Also 5/32" holds the plastic rest knob.

Specialized Tools Required:
These specialized electronics tools are needed. Please see http://arcarc.xmission.com/Pinball/Web%20Archives/www.Marvin3m.com%20(Sep-08-2003)/begin/default.htm for details on the basic electronics tools needed.

- Alligator clips and wire. Buy these at Radio Shack, part number 278-001, $3.69.
- Soldering Iron.
- Rosin Core 60/40 Solder.
- De-soldering tool.
- Digital Multi-Meter (DMM).
- Logic Probe.
- Infrared Sensor. Used for determining good infrared optic LED's. Radio Shack sells these for $5.99, part number 276-1099

Cleaning "Tools" Required:

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

Novus is available at many places (my local grocery store sells it), or from any good pinball vendor. I don't recommend MillWax, but others like it (mostly because they have been around for a LONG time and are used to it). Trewax or Meguires Carnauba Wax is available at Kmart or a local hardware store.

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

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

Parts to have:

- #555 light bulbs: have 20 or so around. Fifty is plenty to do most games.
- #906 or 912 flash bulbs: have 10 or so around.
- #89 flash bulbs: have 10 or so around.
- Fuses: I would have five of any needed value on hand at all times. Pinball 2000 uses the new smaller **"T" fuses**, all 250 volts. Note these are **not** GMA fuses. GMA are similar to American fast-blo fuses. "T" fuses are more like American slow-blo fuses. Pinball 2000 uses nothing but "T" fuses. These

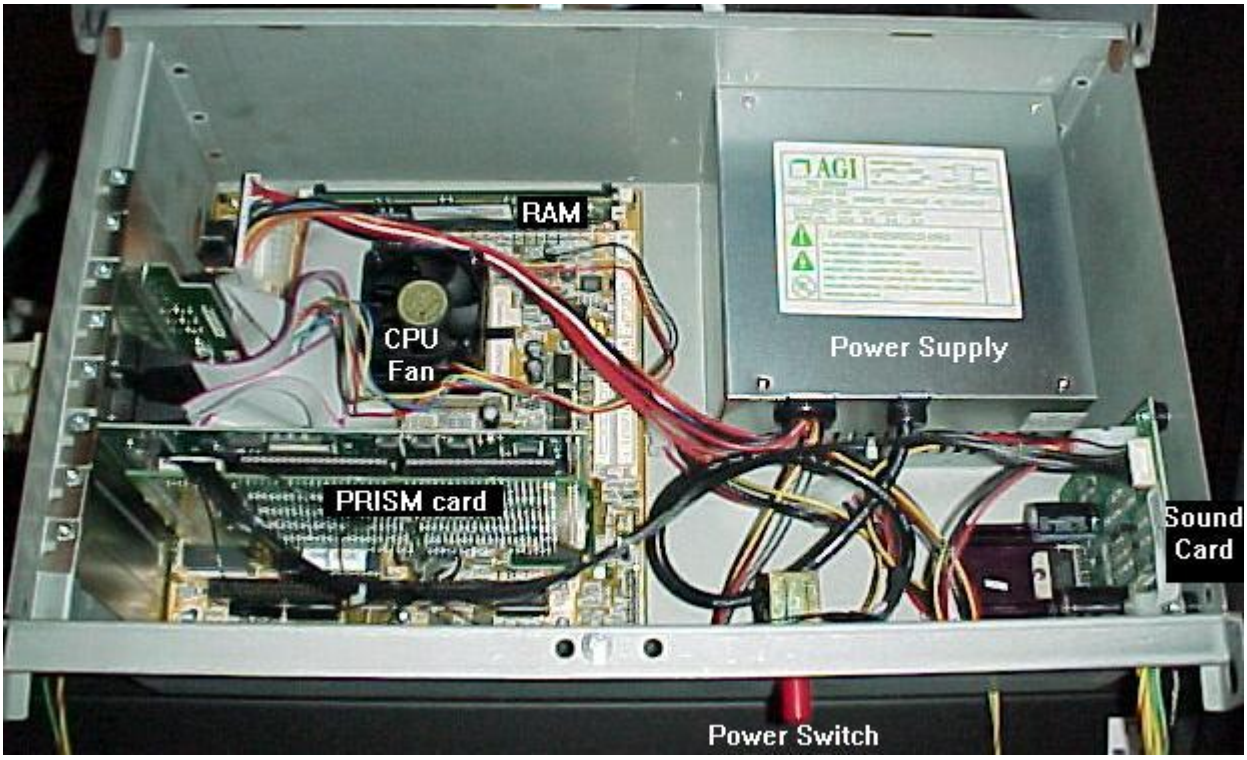
fuses are smaller, about .75" long (but technically known as 5x20mm). Have available:
    - T4.0 amp
    - T5.0 amp
    - T6.3 amp
- Nylon Coil Sleeves: the longer 2 3/16" length (part number 03-7066-5) are used when rebuilding flippers (same part number used for WPC). The 1.75" length (part number 03-7066) are used for pop bumpers, etc. Sleeves with a lip (part number 03-7067-5) and tubing on each side (known as an "inline" sleeve) are used on the knocker, etc.
- Flipper Crank Link Assembly: this includes the pawl and the plunger/link. A different assembly than the WPC unit, the same part is used for *both* right and left flippers. Part number A-23000.
- Flipper Pawl Assembly: same as the above, but without the plunger/link. Again, same part used for both the right and left flippers. Part number 01-11764-R.
- Flipper Plunger/Link: used when rebuilding flippers (part number A-15847, same as WPC).
- Flipper Link Spacer Bushings: these small bushings go inside the flipper links (part number 02-4676, same as WPC).
- Flipper Coil Stops: used when rebuilding flippers (part number A-12390, same as WPC).
- Flipper EOS Switch: part number SW-1A-194.
- Flipper EOS Switch Shock Deflector (fish paper): part number 03-9878. A new part for Pinball 2000.
- 1/4" Heat Shrink Tubing: this is used on the flipper pawl when rebuilding flippers.
- Blue Spring Steel: used for rebuilding the entrance of clear plastic ramps. Available from Pinball resource or http://www.mcmaster.com/. Buy the thinner .006" thickness.
- Shooter Spring: the short chrome spring on the outside of the shooter mechanism (part number 10-149). These rust and look like crap in short order.
- 1 1/16" Pinballs: a new pinball will make a playfield last longer.
- Leg Levelers: replace those old crummy looking leg levelers with brand new ones. 3" are used on solid state games.
- Rubber Rings: order game-specific ring kits with exactly the rings needed (from Pinball Resource). Don't forget to get flipper rubbers and a shooter tip.
- Transistors: keep a few TIP102, TIP107, FET 20N10L (IRL540) transistors around.
- Diodes: keep a few 1N4004 diodes around. Also keep a few P600D or 6A4 diodes around (used for converting AC voltage to DC).
- 74HCT574 chip: have several for the driver board.
- ULN2803 chip: have several for the driver board.
- LM339 chip: have several for the driver and flipper opto boards.
- CR2032 battery for the CPU board.
- Optics. LED transmitter optics and "U" shaped optics are good to have on hand. Radio Shack sells the infrared LED (transmitter), part number 276-143C, $1.69 (replaces Williams A-14231). The "U" shaped optos (as used on flipper boards) are available from mailto:dragster_73@hotmail.com?subject=from_the_p2000_repair_guide, Competitive Products or Pinball Lizard (remember there are several types of U shaped optos).

Transistors and diodes are available from many sources. Check out the part sources web page for help.

1f. Getting Started: Pinball 2000 Guts

Behind the backglass is a metal case which houses the Personal Computer for Pinball 2000. Inside this computer case there are several items, which are described below.

The brain to Pinball 2000, with the top cover removed.



PRISM Card.
This is a custom card made just for Pinball 2000. Essentially, this is the "hard drive" for Pinball 2000. The PRISM card interupts the PC's boot process when the PC is powered on, and loads code directly from the ROMs on the PRISM card. There are two parts to the "sandwich" Prism card. One part is a ROM card which includes the ten game specific Williams ROMs. These contain the images and other fixed parts like a first code boot version. The main part of the PRISM card contains flash PROMs for the update sound and game code, and several ASIC chips for the PCI-control, the DCS-2 sound hardware, and some glue logic.

The PRISM card was used instead of a CD-ROM or hard drive because it is shock and tilt proof. It is also less prone to environmental factors, is easy to transport and easy to install. Also the data transfer rate is extremely fast. It also added the DCS (Digitially Compressed Sound) and flash memory (for field software updates).

The two halves of a separated PRISM card.

The PRISM card also houses a Li-battery for buffered RAM, storing the big amount of statistic data, adjustment data, bookkeeping, and date/time. To prevent a total data loss when this battery becomes empty some of the data is also stored within the flash PROMs (for example, the total earnings). Williams part number A-22994-50070 for the Prism Card Sandwich assembly. The programmed PRISM card is A-23171-50070 and the daughter card with ROMs is A-22995-50070.

PC Mother Board.
Pinball 2000 uses a "baby AT" personal computer mother board with a Cyrix Media GX 233 or 266 mHz processor (though some early production was also made with a 200 mHz processor). This Cyrix processor and the Cyrix bridge are required for Pinball 2000 and are not replaceable by any other PC mother board or processor! There were at least three different mother board brands/types used in Pinball 2000 production, but all shared this common Cyrix Media GX architecture and support chips (for example, the GXM/GCT/7520 by Semi). At one time you could order a complete motherboard from a Williams distributor, part #04-12604, for around $300. Now often these motherboards can be found on Ebay (not in the pinball section!) and through other distributors like DMS computer (www.dmspinballs.com/p2k.html) and Emtel Electronics (http://www.emtel.com/search/product_detail.asp?product_id=379). Other sources for finding these is at local computer shows, computer recyclers, or online auctions.

Louis Koziaz describes the decision to use to the Cyrix MediaGx chipset/motherboard: "The Cyrix chipset is merely a x86 chipset with built-in VGA video. Williams was told by National Semiconductor at the time that the MediaGX chipset would be around a long time, since it was being positioned for set-top boxes and other multimedia uses. Also it was possible to add other chipsets to the Pin2000 system if MediaGx was discontinued. But MediaGx equipped motherboards were inexpensive at that time, hence that is why Williams decided to use them in Pin2000."

Monitor.
Pinball 2000 uses a 19" CGA color monitor from Duckscan (CGM-1901CW) or Wells Gardner (19K7302), model number WGZ1973-U3GS35J. The CGA (lo-res 640x240) digital RGB monitor used is a standard video game monitor. But note, "Pacman" or other older video game monitors (which are analog RGB) can work, but the pinout will need to be changed. Also the Pinball 2000 monitor is lower resolution than standard computer VGA (640x480) monitor or even med-res video game monitor. Other than that, almost any standard cheap low-res video game monitor can

usually be used. The mounting brackets for the Pinball 2000 monitor are custom (but can be transfered to another monitor).

Powerdriver Board.
The powerdriver board has a parallel port which interfaces it to the computer. The powerdriver looks similar to the 'old' WPC driver boards, but has many innovations:

- Coils/Flash lamps are controlled with MOS-FET 20N10L (logic level) transistors, using less board components.
- No General Illumintion lights. Instead there are 128 CPU controlled lamps divided into two 64 lamp "A" and "B" banks.
- Lamp matrix is similar in design to the early WPC lamp matrix, using TIP107 and TIP102 transistors.
- Burnt lamp detection has been implemented in lamp matrix (Capcom had a similar system).
- Power loss detection for several voltages (coil voltage, etc).
- Fuse LEDs showing which fuse has failed.

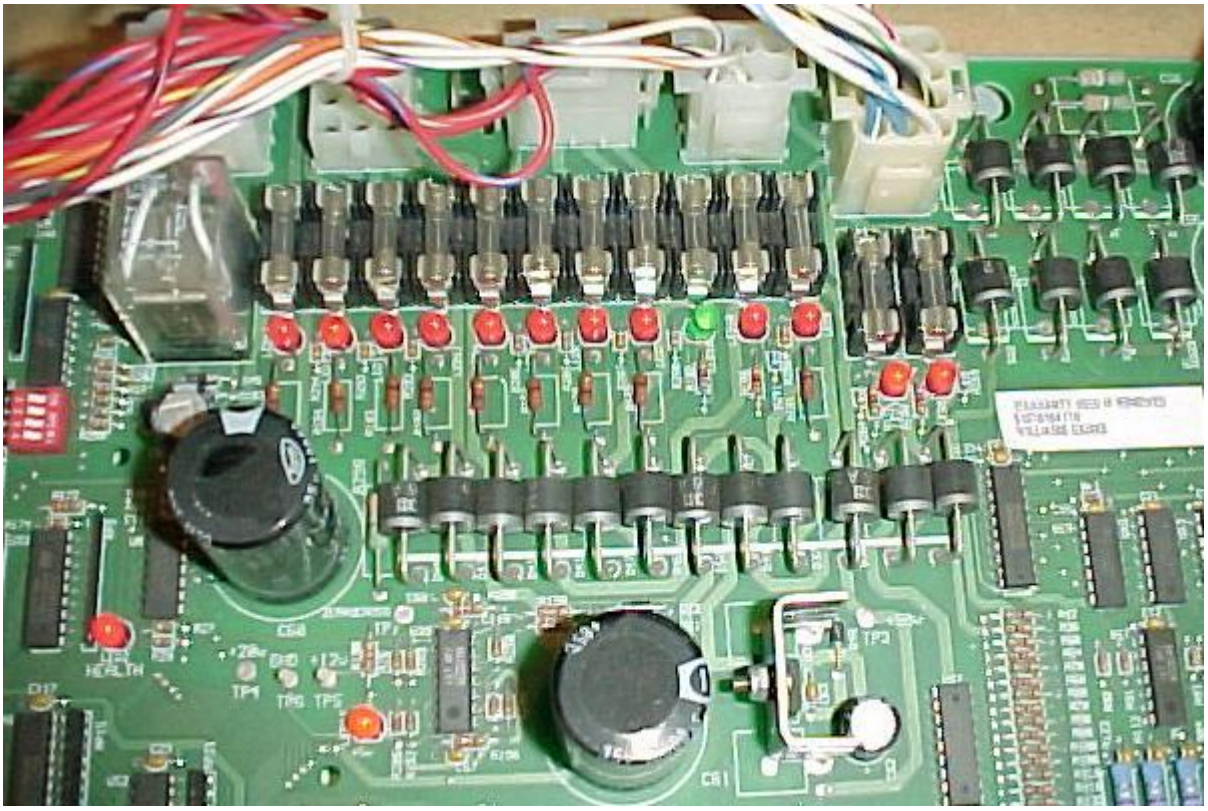
2a. Before Turning the Game On: Check the Fuses/LEDs.

(The subtitle "Before Turning the Game On", may be a bit of a misnomer.) Pinball 2000 has adopted an extremely easy way to check for failed fuses. All fuses are located on the power driver board, and there is an LED for each fuse. If the LED is not lit (and the coin door is closed!), then the fuse has failed. Also look for over-fused circuits. For example, is there an 8 amp fuse where there should be a 5 amp? Also all fuses in Pinball 2000 are slow blow "T" style 5mm x 20mm fuses. So checking for any fast blow fuses is a good idea too.

A Particular Fuse Keeps Blowing in my Game when I Power-on.
Often a shorted coil or rectifying diode will cause a fuse to instantly fail when the game is turned on. See below for which fuse connects to which rectifying diode. If a solenoid fuse keeps blowing after a game is started, usually that means a related driver transistor had shorted. See the Checking Transistors and Coils section for help with that.

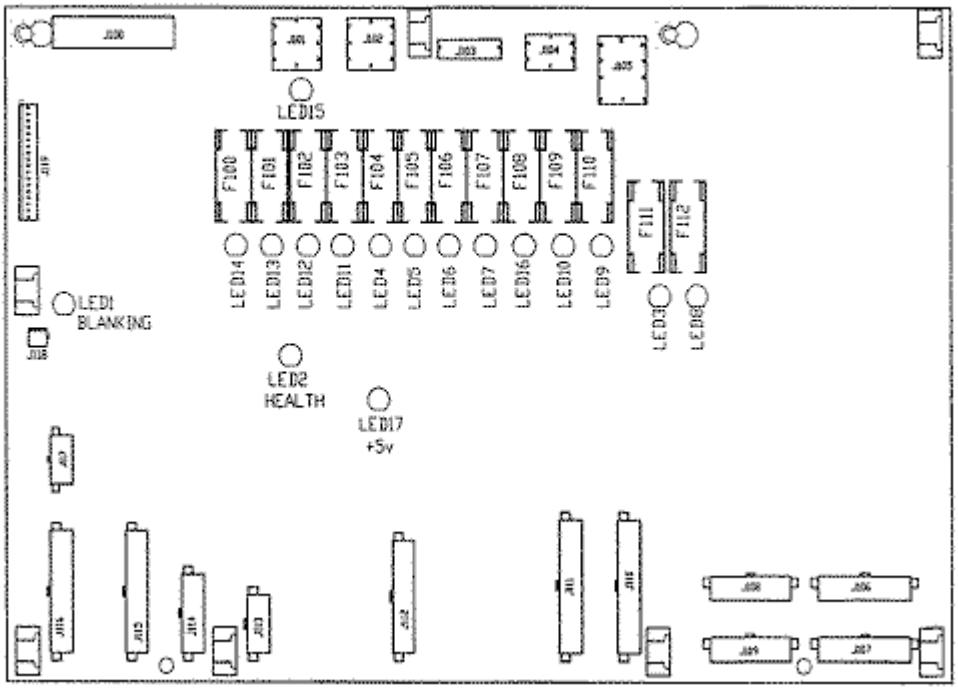
Smaller Fuses in Pinball 2000.
As in WPC-95, Williams changed to the smaller international ISO size (.75" or 5mm x 20mm) "T" fuses. Since Williams exported about 50% of their production outside of North America, it made sense to use the smaller international fuses. The "T" fuses take up less board space too.

Driver board LEDs. Note the single green 12 volt LED. If this LED is not on, +5 volts will also be missing.



LED AND FUSE LIST

POWER DRIVER BOARD



P2000 Power Driver Board LEDs.
All LEDs should be "on" when the game is powered on and has fully booted, and the coin door is closed.

- LED1: Blanking (watchdog). Far left LED.

- LED2: Health. Off upon power up, starts to blink after game boots. Left of cap C60.
- LED3: +18 vdc Lamp Matrix A.
- LED4*: +50 vdc Lower Right flipper. Off when coin door open.
- LED5*: +50 vdc Lower Left flipper. Off when coin door open.
- LED6*: +50 vdc Upper Right flipper. Off when coin door open.
- LED7*: +50 vdc Upper Left flipper. Off when coin door open.
- LED8: +18 vdc Lamp Matrix B.
- LED9: +50 vdc Solenoids.
- LED10: +20 vdc flash lamps.
- LED11*: +50 vdc Solenoids Power 1. Off when coin door open.
- LED12*: +50 vdc Solenoids Power 2. Off when coin door open.
- LED13*: +50 vdc Solenoids Power 3. Off when coin door open.
- LED14*: +50 vdc Solenoids Power 4. Off when coin door open.
- LED15: +20 vdc. Above relay.
- **LED16:** +12 vdc (+5 is derived from this). GREEN LED.
- LED17: +5 vdc. Left of cap C61, and below cap C60.

* designates LED as off when coin door is open.

P2000 Power Driver Board Fuses.

- F100: Solenoid Power 4 (T4.0 amp).
- F101: Solenoid Power 1 (T4.0 amp).
- F102: Solenoid Power 2 (T4.0 amp).
- F103: Solenoid Power 3 (T4.0 amp).
- F104: Lower Right Flipper Power (T4.0 amp).
- F105: Lower Left Flipper Power (T4.0 amp).
- F106: Upper Right Flipper Power (T4.0 amp).
- F107: Upper Left Flipper Power (T4.0 amp).
- F108: 12 vac unregulated (T4.0 amp).
- F109: 20 vac flashlamps (T4.0 amp).
- F110: 50 vac solenoid (T6.3 amp).
- F111: 18 vac lamp matrix A (T5.0 amp).
- F112: 18 vac lamp matrix B (T5.0 amp).
- Line Fuse: T5.0 amp (domestic, 4 amp for foreign games).

LED Boot Up Sequence.
At initial power on, LEDs 15-17, LEDs 8-10, and LED 3 are on. After about 15 seconds, the monitor screen will turn from white to black (and the text "TESTING" will appear), and all remaining LEDs (LEDs 4-7, LEDs 11-14) will come on (assuming the coin door is closed), and the Health LED2 will start to blink. Note if LED16 (+12 volts, the green LED) is out, +5 volts will be missing too. Without LED16, the whole game is pretty much dead.

The "Health" LED.
Originally the health LED was going to give indications of hardware problems in the game. There was supposed to be logic on the driver board to turn on the Health LED, or to give flashes indicating a problem (and where the problem lies, much like the 1977-1985 Bally seven flash LED system). But Williams ran out of time to develop the hardware side of the Health LED.

So what does the Health LED tell us? Really nothing! At power up the Health LED is off. But once the software code loads and starts running on the PC, the software starting blinking the Health LED, and keeps it blinking.

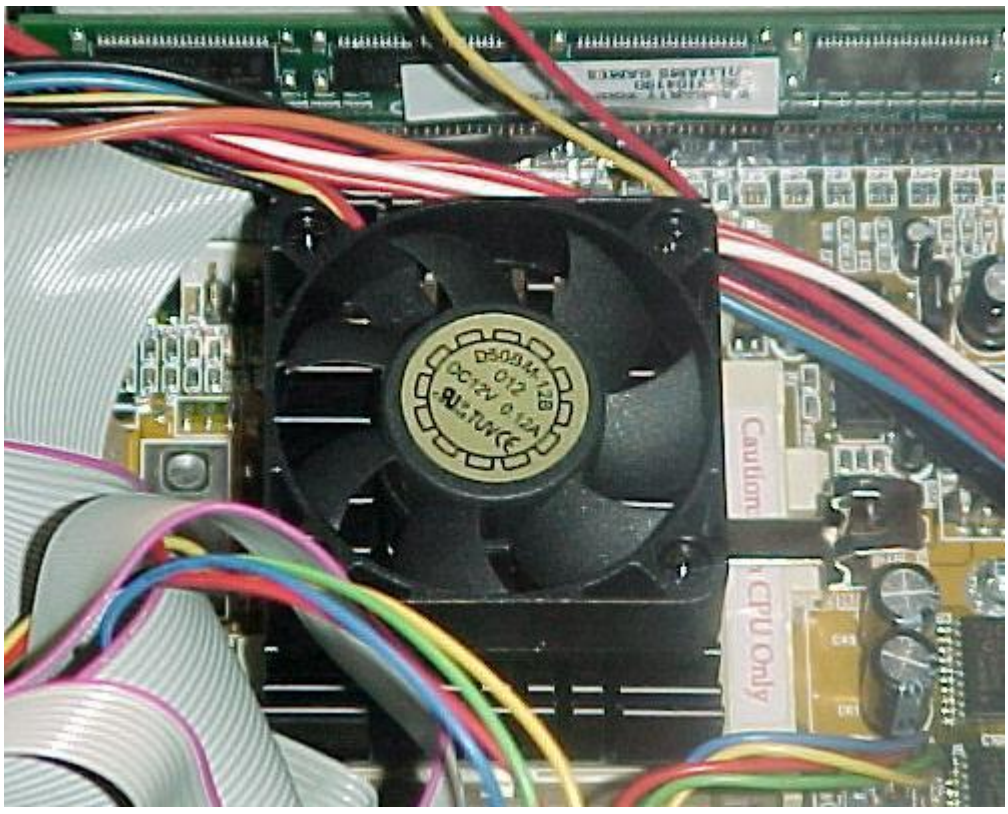
That's it, end of story! So if the health LED is blinking, that means the game is powered on and running its software. But hey, we already knew that, because we can see the game is working. So in reality, the Health LED tells us nothing. Williams may have eventually developed the Health LED into something useful, but given the development time frame, nothing ever came of it.

2b. Before Turning the Game On: Check/Replace the CPU Processor Chip Fan

Like all Pentium personal computers, the Pinball 2000 CPU processor has a fan strapped to the top of the CPU chip. This fan also acts like a metal heat sink. This fan is very important, as the CPU chip itself can overheat and "seize".

Although Williams used a ball bearing fan, the fan can fail very quickly. Often after some weeks of operation they need to be replaced. When replacing them remove the foil between the fan and the processor chip. Instead use 'Thermoleitpaste thermal conducting paste'. This white paste is available at Radio Shack in a small tube. Non-working fans can get so hot the metal block had turned light green instead of the original dark green color that came from Williams.

The CPU fan, which can easily fail.



Replace the CPU Fan.
Replacement CPU chip fans can be bought easily in the $5 to $20 range. It's just plain smart to replace this fan when buying a pinball 2000 game, because these fans do wear out, and there is no way to tell "how many miles" an old fan has. So just replace it! For a really nice, high-end model,

check out PCPowercooling.com (the suggested model is their CPU-Cool Z1 Skt 7), or from Indek.com (the suggested model is their HDF5010L-12HB).

2c. Before Turning the Game On: Check/Replace the Power Supply & Fan

The power supply is a approximately 4" by 4" metal box in the computer box. It is an "AT" style power supply with a "hard" power switch (compared to the newer "ATX" style power supplies used today with a "soft" power switch). If the power supply and its fan in your Pinball 2000 is still working, consider yourself lucky! The fan in particular likes to seize. This of course increases the heat in the power supply, which in turn causes power supply failure quickly.

Replace the Power Supply and it's Fan.
Power supplies are cheap. And when buying a pinball 2000, there is really no good way to tell "how many miles" are on the old power supply & fan. Since it is not practical to replace just the power supply fan (and not the power supply too), just replace both. It's cheap insurance.

Replacement AT power supplies can be bought easily in the $10 to $30 range. For a really nice, high-end model, check out PCPowercooling.com (the suggested model is their Turbo-Cool 300 Slim power supply).

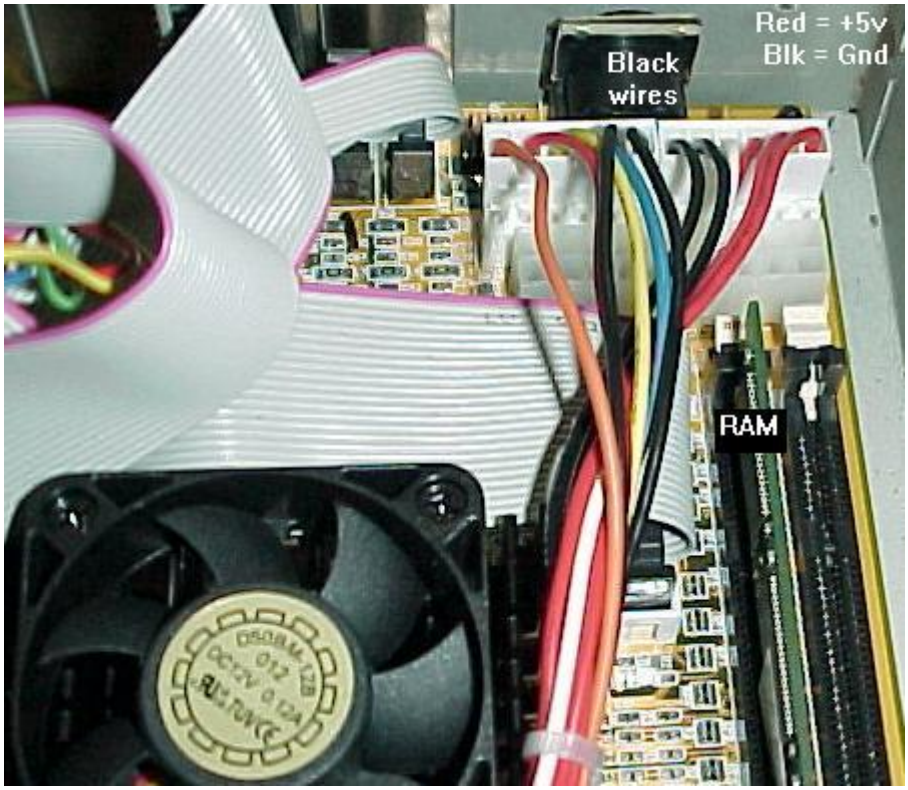
Can Just a Replacement Fan be Installed?
I imagine someone could just replace the power supply's fan, and not the entire power supply. But I don't recommend it. If the power supply's fan needs to be replaced, chances are good the power supply has been running hot. So it's just a good idea to replace both. And given the low cost of a new power supply/fan, it just doesn't seem worth it to replace just the fan.

Power Supply Input Voltage (115 volts).
All pinball 2000 game computers run at 115 volts. It does NOT matter what the wall voltage is, the computer runs at 110 to 120 volts! If the game is in Europe and running on the 220 volt wall voltage, the main game transformer is jumpered to take that 220 volts and convert it to 115 volts for the computer's power supply. Because of this, the Pinball 2000 computer power supply should be set to 115 volts.

Installing a New Power Supply/Fan.
Once a new AT power supply and fan has been bought, installing it is pretty straight forward. Just bolt it in, and re-attach the connectors. WARNING: make sure the connector going to the motherboard is installed correctly! The motherboard connectors are actually two connectors, and can easily be installed "backwards". If this is done, the mother board can be damaged.

Be sure to install the new plug with the black wires of each of the two connectors "together" (in the center), as shown in the picture below.

The power plug from the power supply to the motherboard.



ATX Power Supplies.
Newer ATX power supplies can also be used, but these do not have a physical power switch. Instead they get a signal from the computer's motherboard connector to turn the power supply off. But these power supplies can be fooled to turn on when their power cord is plugged in. Just tie the green /PS-ON wire (power supply on, active low, normally pin 14 on the motherboard connector) to the black COM ground wire. (a diagram of the 20-pin ATX connector can be found at wired.hard.ru/data/atxpower.shtml). The only problem with this approach is the physically size of an ATX power supply is different than an AT power supply. So if a standard AT power supply can be found, that should be used over an ATX power supply.

3a. Motherboard Repair/Replacement Info.

Pinball 2000 uses a "baby AT" personal computer mother board with a Cyrix Media GX 200, 233 or 266 mHz processor (most Pinball 2000 games were shipped with 233 mHz processors, but some early games had 200 mHz and some later games had 266 mHz processors). This Cyrix processor and the Cyrix bridge are required for Pinball 2000 and are not replacable by any other PC mother board or processor! There were at least three different mother board brands/types used in Pinball 2000 production, but all shared this common Cyrix Media GX architecture (for example, the GXM/GCT/7520 by Semi). At one time you could order a complete motherboard from a Williams distributor, part #04-12604, for around $300. Now often these motherboards can be found on Ebay (not in the pinball section!) and through other distributors like DMS computer (www.dmspinballs.com/p2k.html) and Emtel Electronics (http://www.emtel.com/search/product_detail.asp?product_id=379). Other sources for finding these is at local computer shows, computer recyclers, or online auctions.

A 200, 233 mHz or 266 mHz Cyrix processor used in Pinball 2000 motherboards.

The Cyrix 5520 companion chip used in the Pinball 2000 motherboard.

In order for a PC motherboard to be a replacement candidate, it has to have the Cyrix MediaGX 200, 233 or 266 mHz processor. And it must also have the 5520 companion chip, and one of the following types of super I/O chips: SMCFDC37C932, SMCFDC37C931, NSPC9731. Note Williams used several different style of PC motherboards in their Pinball 2000 games. These vary in color and layout. But they all have the above chips in common.

The Cyrix Media GX board system was choosen by Williams because it was an "all in one" CPU board, and it was inexpensive. Unfortunately Cyrix went out of business, and it's assets were purchased by National Semiconductor. Via then turned around and bought all the Cyrix assets from National, except for the Media GX line (Via had no interest in this system). Since National did not have the right to use the "Media GX" name, they renamed the line "Geode". National still makes the Geode line of chips and boards, which are using the 5530A chipset (an update to the 5520; Williams was porting Pinball 2000 to the newer 5530 chipset when they closed the pinball division). But unfortunately the new National Geode boardsets usually lack PCI slots (and some other required

features), and the newer 5530A chipset is not Pinball 2000 compatible. So the new National Geode boards are not usable for Pinball 2000.

The original boardsets used for development of Pinball 2000 were 150MHz with the Media GX 5510 chip. Sometimes these old 5510 chip boards with 150 MHz or 200 MHz CPUs can be found on Ebay or at computer "junk" sales. Though somewhat risky, all of the code for the 5510 chip is still in the RFM and SWE1 code, and it autodetects on startup which one to use (the 5510 or 5520 chipset). However, the older 5510 code was obviously not as extensively field-tested as the 5520 code, and RFM at least was running into speed limits even at 233MHz (SW:EI was not as bad in that regard). So if buying one of these older 5510 CPU boardsets, be aware it may not work properely. In theory it should work, but it could "bog" down on some display routines, or the display could be out of sync with sound.

A companion NSPC9731 Super I/O chip used in some Pinball 2000 motherboards.

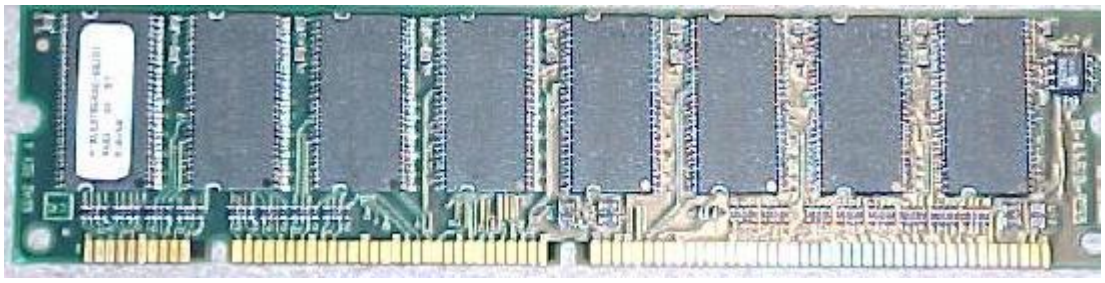
Motherboard Chips NOT Needed.

The motherboard choosen by Williams was clearly an "all in one" type board. That is, the motherboard had an on-board video, sound, and other support circuits/chip. The audio stuff is however not needed. Williams had a off-board sound card, making the on-board sound chip(s) unnecessary. Some boards will have these sound chips installed, and some will not. So an empty socket or two on an otherwise fully populated motherboard can be OK.

An unneeded audio chip often found on Pinball 2000 motherboards.

Motherboard Memory.
The memory used in pin2000 motherboards is SDRAM PC100 memory in a DIMM package (commonly known as "168 pin PC100 SDRAM 3.3v DIMM"). Any amount 8 meg or higher can be used (typically 8 meg is seen in most games). PC133 memory can probably also be used (the only difference between PC100 and PC133 is that PC133 can run at a higher bus clock speed).

P2000 motherboard memory.



3b. Game does not Boot or Re-boots.

Here is a list of things to try when the game will not turn on.

Pinball 2000 power switch behind the backglass on the computer case.

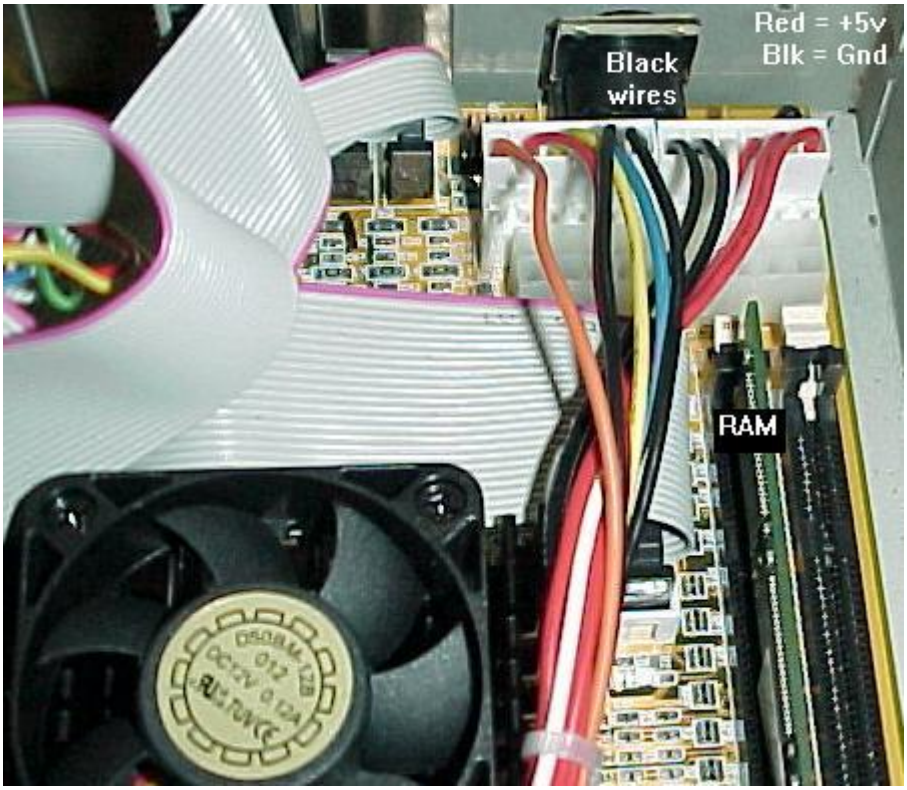
Power On.

1. Switch on the machine.
2. If backglass does not light up go to next section (Main Power)
3. If backglass lights up but after 30 seconds or so there is no bong, no monitor pic, and no attract mode flashing continue...
4. If bong can be heard and/or attract mode lamp flashing arises, but no monitor pic, go to monitor diagnostics.

Main Power.

5. Check the power line to the game.
6. Check the main fuse.
7. Measure the 110V which come out of the transformer (all games, regardless of the wall voltage). Measure the 110V that goes into computer case's power supply.
8. If no power there, check main fuse again and wall plug.
9. If power there, go to next secton (Check Computer Case).

The power plug from the power supply to the motherboard.



Check Backbox Computer.

1. Verify the red button in front front of the computer case is pressed down (on).
2. Check the power cabling on the rear left side of computer case.
3. Are the fans (CPU and power supply) running? If not, go to the next section.
4. Check the parallel port cable and monitor cable on left side of computer case (as facing the game from the front).
5. With the game off, open computer case and check whether PRISM seats firmly within it's PCI slot (it can come loose).
6. If game still does not boot, check the power supply voltages with a DMM, where the power supply plugs into the mother board (red=+5 volts, yellow=+12 volts, black=ground). The +12 volts should be in the 10 to 14 volt range. The +5 volts should be 4.9 to 5.2 volts. If either the +5 or +12 volts is not within these ranges, replace the power supply, as the game will not reliably boot with voltages that are outside these ranges.
7. If everything looks OK but still nothing works, go to next section.

Backbox Computer Problem.

8. Remove all cables from the computer case's left side (as facing the game from the front).
9. Slide the computer case out of the game.
10. Open the computer case.
11. Remove the PRISM card from its internal slot inside the computer.
12. Connect any PC VGA Monitor to the Monitor output on the outside of the computer case (also connect a PC keyboard if available).
13. Connect the PC box power supply directly to a 110 volts line (if in US) or switch the power suply to 220V and connect it to 220 volts (don't forget to switch back later to 110 volts). Use a standard PC power cable for connection to power.
14. Switch the computer on via the red switch on the front panel.
15. The pin 2000 computer should now boot like a standard PC. Video should be seen on the computer monitor. Note a BIOS Message will be seen ("No boot

device found"). This message is Ok and should be seen (after all, there is no hard drive or floppy to boot from). If this is OK, then go to the next section. If not, go to the "power supply or mother board error" section). Note if a CMOS (BIOS) checksum error appears on the screen, the motherboard battery can be removed (this will reset stored BIOS settings/memory). A new battery should be installed.

Pinball 2000 Specific Boot Problems.

16. Switch off the computer case power switch.
17. Re-install the PRISM card.
18. Switch the computer on again.
19. Pin2000 should boot up now. Although the image on the monitor looks ugly, it should display something (the monitor will not "sync"). If nothing happens, PRISM must be faulty. Try to reseat the PRISM card in another PCI slot. If a picture comes up, then the pin2000 monitor may be back, or the problem is solved.

Power Supply or Mother Board Error.

20. Check whether Fans are running (power supply and/or CPU fan).
21. If not, power supply seems to be bad. Replace with another AT style computer power supply.
22. If power supply OK, probably one of the mother board components is bad. Check the CPU processor (MEDIA GX 233 or 266 mHz), RAM (minimum 8 Meg, 168 pin PC100 SDRAM 3.3v DIMM or better), mother board (Media GX board), or power supply.
23. Measure the -5, +5, +12 volt output from the power supply with mother board attached. If erronious it still might be the mainboard, but don't measure power supply output without mainboard attached (the lack "load" may kill the power supply).
24. Try to exchange the easiest available thing (RAM, power supply), and reboot.
25. Replace the mother board with a working spare board.

When Entering Diagnostics/Bookkeeping, the Game Re-boots.
The game boots and plays fine, until the ENTER button is pressed on the coin door. This causes the machine to reset and reboot.

To diagnose this problem, a laptop computer running a terminal emulator (Windows Hyperterminal, using settings "9600 8N1") was connected to the serial terminal port of the pinball 2000. With the computer on, the pinball 2000 game is booted. When the game's Enter button is pressed (to enter diagnostics), a Fatal error was being generated and the game reboots. But the fatal error can be seen on the laptop computer's terminal emulator program, "*** Fatal: Got invalid time stamp!"

This can be further diagnosed with the pinball 2000 game on and the laptop connected and running a terminal emulation program. The XINA command "enter" can be issued on the laptop to enter the pinball 2000 diagnostics. This Xina command may cause the game to reboot (just as if the "enter" button was pressed on the coin door). Again, during the transaction, the laptop terminal received the error message. The error contained this key information:

```
% BAD: 4, 12, 29, 128 (22)(00)(45)
*** Fatal: Got invalid time stamp!
```

The numbers after the "BAD" are the time stamp's: weekday, month, day, year, hour, minutes, seconds. In this case, the year seems to be out of the acceptable range of 1999 to 9999. Since pushing the ENTER button causes a time stamp to be generated and checked, the checking code (for reasons unknown) does not just report and fix the problem, but instead generates a Fatal error, which then resets the machine. When "time" command was entered on the laptop, the pinball 2000 echoed back, "Sorry, clock is bad".

Fortunately, there is a fairly simple cure to this problem. With a laptop computer running a terminal emulator (Windows Hyperterminal) attached to the serial port (9600, 8N1), the following command can be entered to set the date and time, after the pinball 2000 game is booted:

```
time set <year> <month> <day> <hour> <minutes> <seconds>
```

(for example):

```
time set 2002 12 31 08 53 00
```

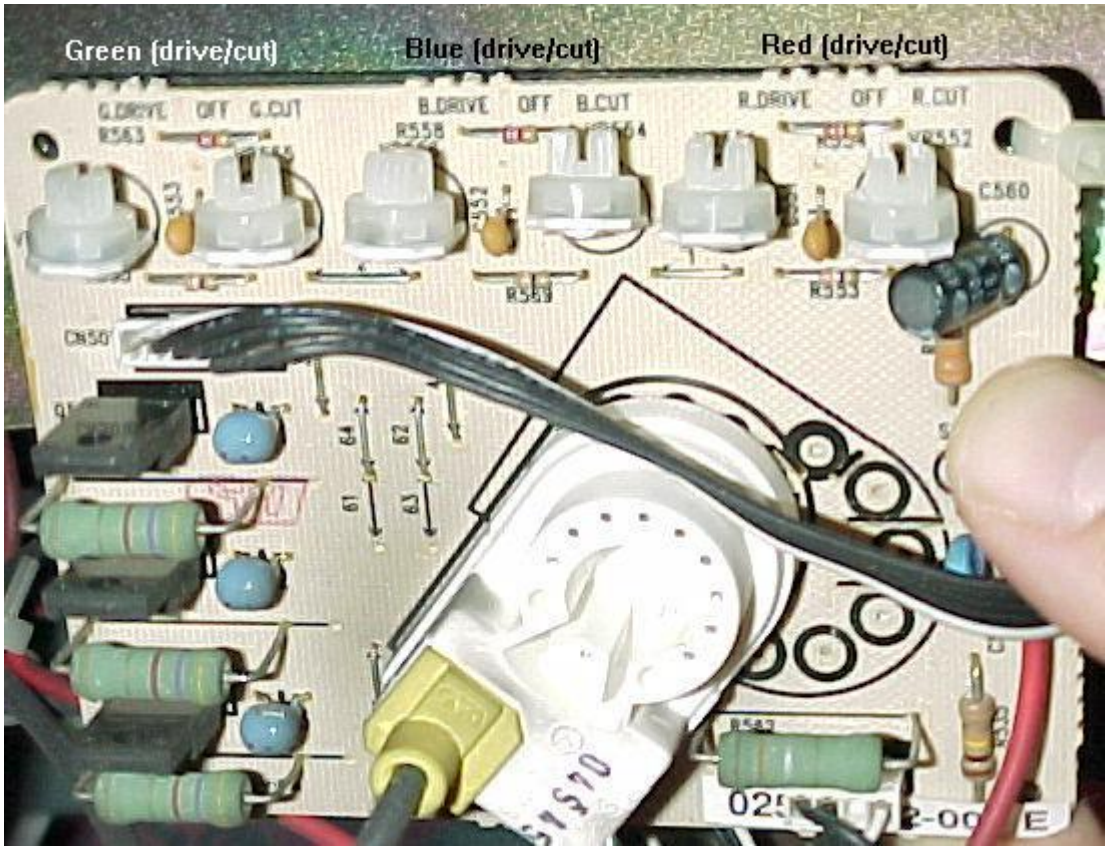
(which sets the game to Dec 31, 2002 8:53am)

The battery on the motherboard and the PRISM cards should probably both be checked and probably replaced prior to performing this fix, since the battery is what keeps the time when the game is off.

3c. Video Monitor Information.

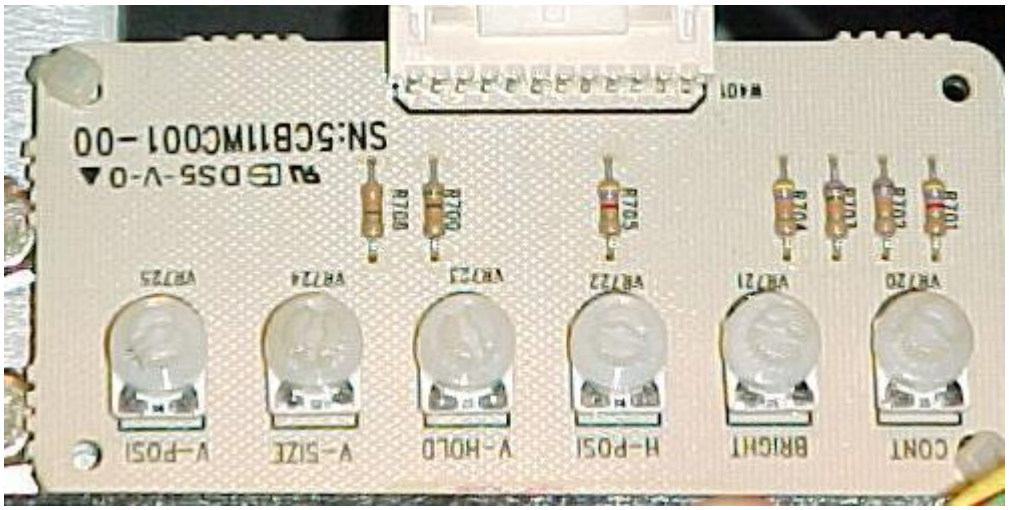
Pinball 2000 uses a 19" CGA color video monitor from Duckscan (CGM-1901CW) or Wells Gardner (19K7302), model number WGZ1973-U3GS35J. The CGA (lo-res 640x240) RGB monitor used is a standard video game monitor. The Pinball 2000 monitor is lower resolution than standard computer VGA (640x480) monitor or even med-res video game monitor. Other than that, any standard RGB low-res video game monitor, with inputs for positive horizontal and vertical sync, can be used. Also there is no need for a separate isolation transformer for the monitor, since the monitor power already comes from the P2000 transformer in the bottom cabinet. The mounting brackets for the Pinball 2000 monitor are custom though (but can be transfered to another monitor).

WG7300 color neck board monitor adjustments (board removed from monitor neck).



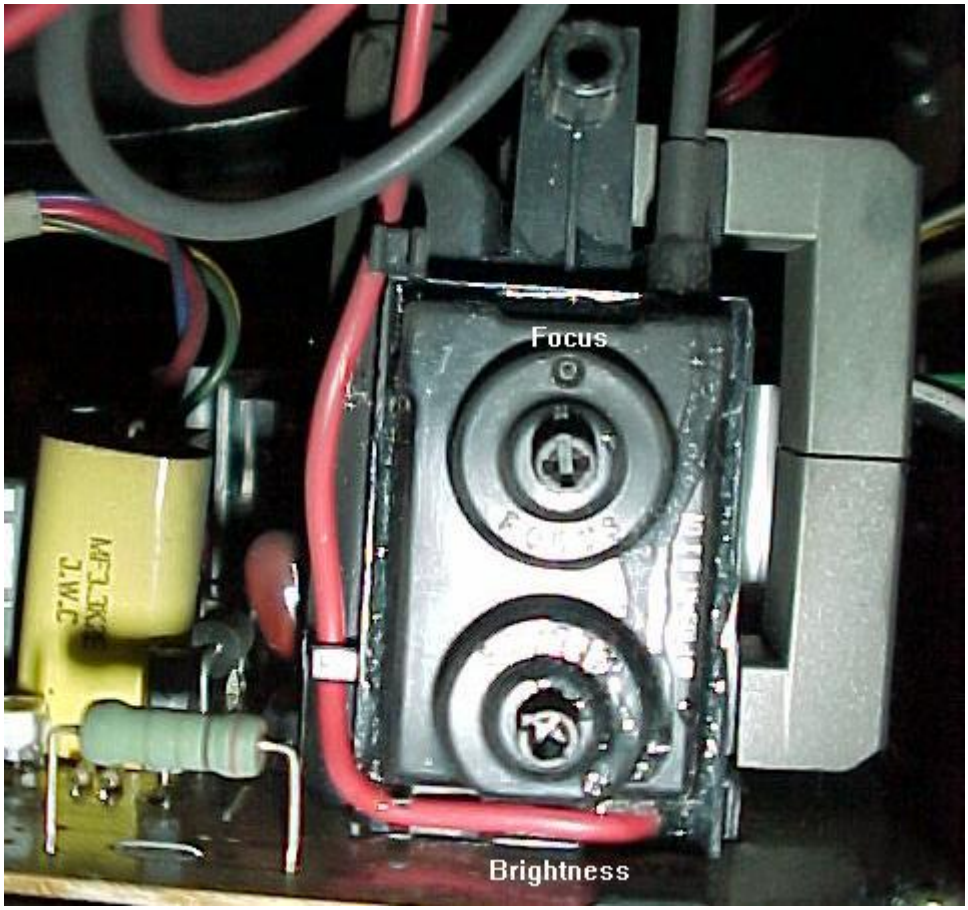
Monitor Color Adjustments.
Pinball 2000 color monitor adjustments are on the neck board. There are six adjustments, two for each color (RGB).

Monitor controls behind the backglass, to the bottom right of the monitor (as playing the game). Yes, this board is mounted upside down!



Brightness Adjust.
Remove the backglass and you'll see six small knobs (pots) mounted to the bottom right of the monitor. Four of the knobs adjust the picture position, horizontally and vertically. The two knobs on the right are the brightness and contrast. Also on the back side of the monitor on the flyback transformer there are two knobs. The knob closest to the circuit board controls the brightness (the other knob controls the focus).

Monitor adjustments (brightness, focus) on the flyback (as playing the game).



Monitor Cabling.
Unfortunately, the cabling (the cable from the monitor to the computer) used for the Duckscan and Wells Gardner 7300 are different. Different connectors are used because the cabling goes directly to the monitor chassis header, rather through a standardized connector. So plugging a Wells Gardner 7300 into the Duckscan monitor cable will not work.

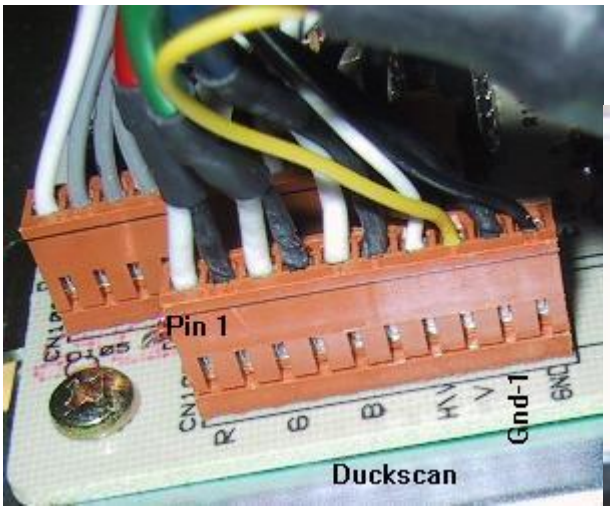
15 Pin PC Connector Pinout	
Pin #	**Description**
1	Red Video
2	Green Video
3	Blue Video
4	Sense 2 (Monitor ID bit 2)
5	Self Test (TTL Ground)
6	Red Ground
7	Green Ground
8	Blue Ground
9	Key - reserved, no pin
10	Logic Ground (Sync Ground)
11	Sense 0 (Monitor ID bit 0)

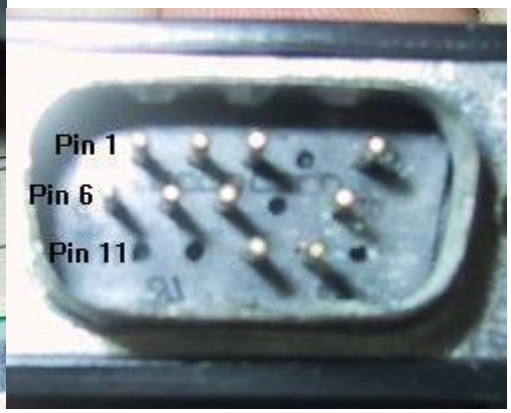
12	Sense 1 (Monitor ID bit 1)
13	Horizontal Sync (HS)
14	Vertical Sync (VS)
15	Sense 3 - often not used

Duckscan Monitor Cable Wiring		
15 pin PC Connector	**Signal**	**Monitor Board Connector**
1	R	pins 1/2
2	G	pins 3/4
3	B	pins 5/6
5	GND	pin 10
10	GND-1	pin 9
13	H/V	pin 7
14	V	pin 8

Note: GND-1 is not labeled on the monitor board,
but this pin is located between the GND and V pins.

Duckscan 1900 monitor cabling.



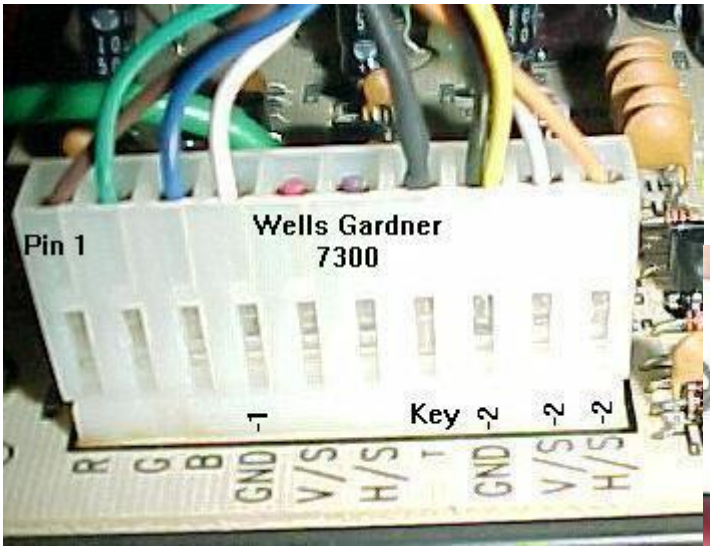


Wells 7300 Monitor Cable Wiring			
15 pin PC Connector	**Signal**	**Monitor Board Connector Negative Sync**	**Monitor Board Connector Positive Sync****
1	R	pin 1	pin 1
2	G	pin 2	pin 2
3	B	pin 3	pin 3
6	GND-1	pin 4	pin 4
6,10,11	Key*	pin 7	pin 7
10,11	GND-2	pin 8	pin 8

13	HS	pin 9	pin 6
14	VS	pin 10	pin 5

* Yes there are wires connected to the .156" monitor board header "key" position. I have no idea why, and they don't need to be connected.
** Positive sync can be used instead of negative sync if the monitor will not adjust properely horizonitally. There is a switch on the monitor that can swap between negative and positive sync.

Wells Gardner 7300 monitor cabling.



Converting a Duckscan Monitor Wiring to Wells WG7300.
The Duckscan monitor is the worst of the two different monitors that were sold with Pinball 2000. Because of this, there may be some need to convert a Duckscan monitor cable so it can be used with a Wells Gardner 7300 monitor. Below is that conversion.

Converting Duckscan to Wells 7300 Monitor Cable Wiring				
Duckscan Monitor Connector	**Wire Color**	**Signal**	**WG7300 Monitor Connector Negative Sync**	**WG7300 Monitor Connector Positive Sync***
1	Red/Wht	R	pin 1	pin 1
2	Red/Blk	Gnd	pin 4	pin 4
3	Grn/Wht	G	pin 2	pin 2
5	Blue/Wht	B	pin 3	pin 3
7	Wht	HS	pin 9	pin 6
8	Yel	VS	pin 10	pin 5
9	Blk	GND	pin 8	pin 8

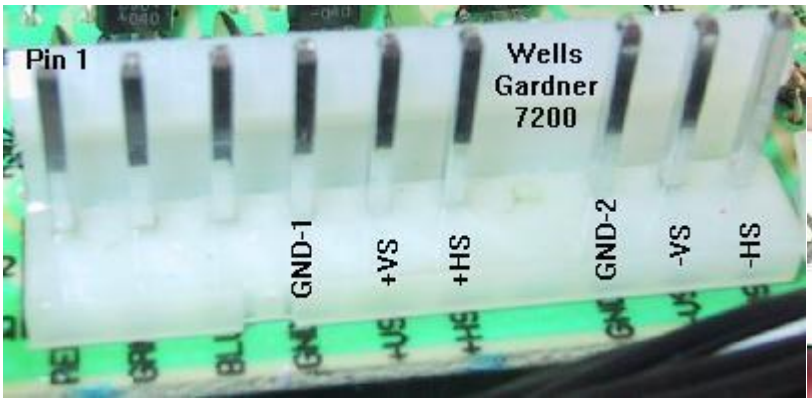
Connector pins 4,6,10 are not used.
* Positive sync can be used instead of negative sync if the monitor will not adjust properely horizonitally. There is a switch on the monitor that can swap between negative and positive sync.

Wells Gardner 7200 Monitor.
To use a Wells Gardner 7200 monitor (currently available from Wells), the cable from the Wells Gardner 7300 (or from the Duckscan) will *not* work. If the 7300 cable is used, it will cause the 7200 monitor to scroll horizontally. No amount of adjusting will correct this either.

The solution is that the 7200 has different pins for negative versus positive sync. On the 7300 there is a switch setting on the chassis board that is set to either negative (the most common, and how it is set for Pinball 2000), or positive (there for backward compatability for older video games). Because of this, the 7300's H/S-2 wire need to be moved to +HS on the 7200 monitor. Likewise, the 7300's V/S-2 wire must be moved to the 7200's +VS. Also the 7200 should be set to negative sync. The corrected cabling for the 7200 Wells Gardner monitor (set to negative sync) is shown below.

Wells 7200 Monitor Cable Wiring		
15 pin PC Connector	**Signal**	**Monitor Board Connector**
1	R	pin 1
2	G	pin 2
3	B	pin 3
6	GND-1	pin 4
13	+HS	pin 6
14	+VS	pin 5
10,11	GND-2	pin 8

Wells Gardner 7200 monitor cabling.



Wells Gardner 4600 Monitor.
The WG4600 was a very popular video game monitor from the early 1980s, and was standard equipment in many Williams video games such as Stargate and Robotron. It is a good example of how an early video game monitor with inputs for positive and horizontal sync can work in p2000. This info thanks to Russel Willoughby.

Wells 4600 Monitor Cable Wiring		
15 pin PC Connector	**Signal**	**Monitor Board Connector**
1	R	pin 1

2	G	pin 2
3	B	pin 3
6	GND	pin 4
13	HS	pin 6
14	VS	pin 5

Wells Gardner 4600 monitor running P2000 SWE1.

Upside Down or Reversed (Left/Right) Video.
When installing a new video monitor, sometimes the video can appear upside down or reversed (left to right), while playing the game.

Probably the easiest way to fix this is to issue a **fb flip** command to the Xina operating system. This will require a keyboard to be plugged into the Pinball 2000 computer (I am not sure if this command will need to be issued everytime the game is rebooted). The **fb** command will only fix an upside down picture (it does not change left to right picture reversals).

A better (more permanent) way to fix the problem involves reversing the yoke header wires (on some monitors there is a switch for this). Check for a switch near the yoke, or on the edge of the neck tube circuit board.

If there is no switch, find the yoke wires. The Yoke is the coil of wires on the neck of the picture tube. There should be four wires coming off of the yoke. Swap the blue/red wires if the picture is reversed left to right. Swap the

green/yellow wires if the picture is upside down. Be careful to get the right two voke wires though, as the monitor chassis can burn up if this is done wrong!

Degaussing.
The monitor in a P2K degausses automatically everytime it does a "cold start". You can hear this as a short buzzing sound (only a fraction of a second) at the moment the machine is turned on.

Sometimes when moving the game, a light colored "spot" (varying in size, usually about 1" to 3" diameter) on the monitor may appear. If this is the case, there is probably an external magnetic interference from speakers or nearby lighting transformers (anything with a magnet or electro-magnet). Check for anything like this near the machine.

If there is no hum at game start up, there is usually a varistor that burns out. If the monitor gets a reasonable magnetic field, it may take several power cycles to clean up (look out for vacuum cleaners and speakers, these often have strong magnetic fields). Check for what is causing the magnetic field before just powering on and off to degauss. Five or so power cycles should be all that is needed. If the purity doesn't come back, refer to a shop manual for the monitor that describes purity adjustments for the monitor. Even the earth's magnetic field is strong enough to effect purity of many color monitors. If the spot remains the degauss mechanism is malfuntioning. Often the monitor can be degaussed by taking a powered-on soldering gun, and moving it in front of the monitor glass. The magnetic field from the soldering gun can often degauss the monitor.

3d. When things don't work: Checking Transistors and Coils (stuck on coils and flashlamps)

A transistor is a small electronic device that can cause changes in a large electrical device (a solenoid), by small changes in a small input signal (the driver board logic circuit). That is, a weak input signal can be amplified (made stronger) by a transistor. Essentially, this allows a small +5 volt logic signal to control a large 50 volt solenoid coil.

Occasionally driver transistors fail. If a coil is "stuck on" (energized) when the game is turned on, a shorted driver transistor is usually thecause. This section will help diagnose this.

When the game's top glass is removed, the Pinball 2000 backglass can be used as a temporary reflective mirror to read the monitor during diagnostics. The backglass conveniently fits under the monitor, and the backbox head tabs stop the backglass from sliding forward.

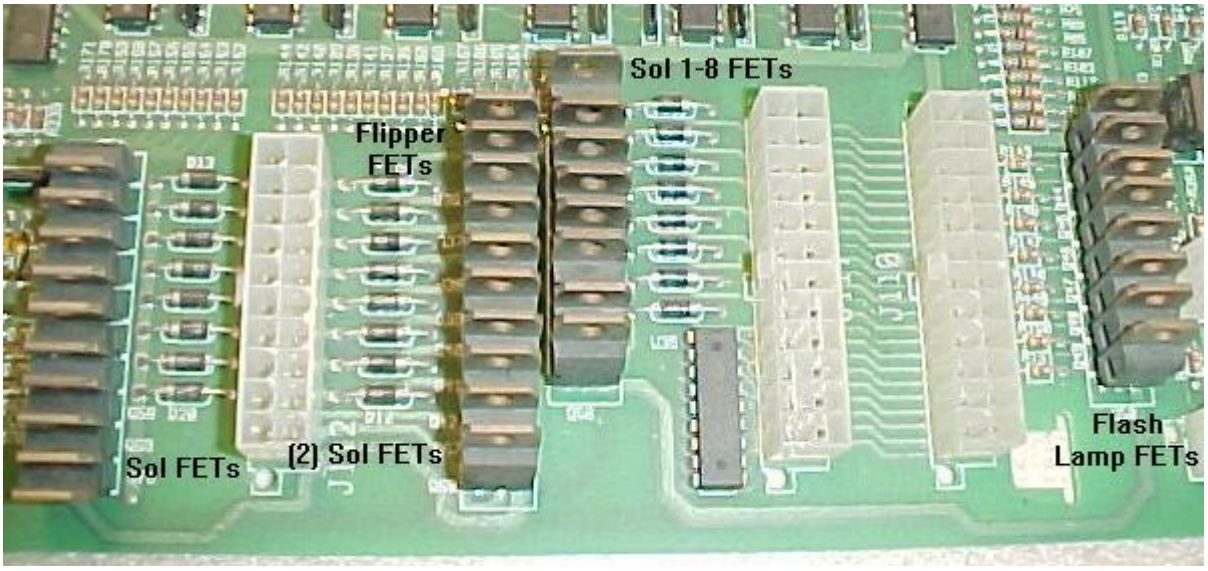
What do the Driver Transistors Do?
Basically, a driver transistors completes each coil's path to ground. There is power at each coil, all the time. The driving transitor is "turned on" by the game's software, through a TTL (Transistor to Transistor Logic) chip. When the transistor is turned on, this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

Sometimes these driver transistors short "on" internally. This completes a coil or flash lamp's power path to ground permanently, making it "stuck on", as soon as the game is turned on.

Transistors Used in Pin 2000.
There are basically three types of transistors used on a pin2000 driver board:

- **FET STP20N10L** (N-Channel logic level, NTE2987): used as the driver transistor for all solenoids and flash lamps.
- **TIP102** (NPN, NTE2343): used for the lamp matrix rows, to switch ground on for any particular lamp row.
- **TIP107** (PNP, NTE2344): used to drive the CPU controlled lamp (columns) on the playfield. The TIP107 switches the +18 volts on for any particular lamp column.

FET Transistors on the P2000 driver board.



FET Transistors (New for Pin 2000).
One area that really has been really changed for the better in Pinball 2000 is in the solenoid driver circuits. Williams has switched from using conventional "bipolar" transistors to MOSFETs in the solenoid and flash lamp driver circuits. A MOSFET (Metal Oxide Semiconductor, Field Effect Transistor) looks exactly the same as a regular coil driver transistor. It comes in the same TO-220 package as the TIP102 that is familiar to just about everyone that works on pinball machines. But this is where the similarity ends. In fact, even the names of the three component leads are different. In the transistor, the three component leads are called the emitter, collector and base. In the FET they are the source, drain and gate.

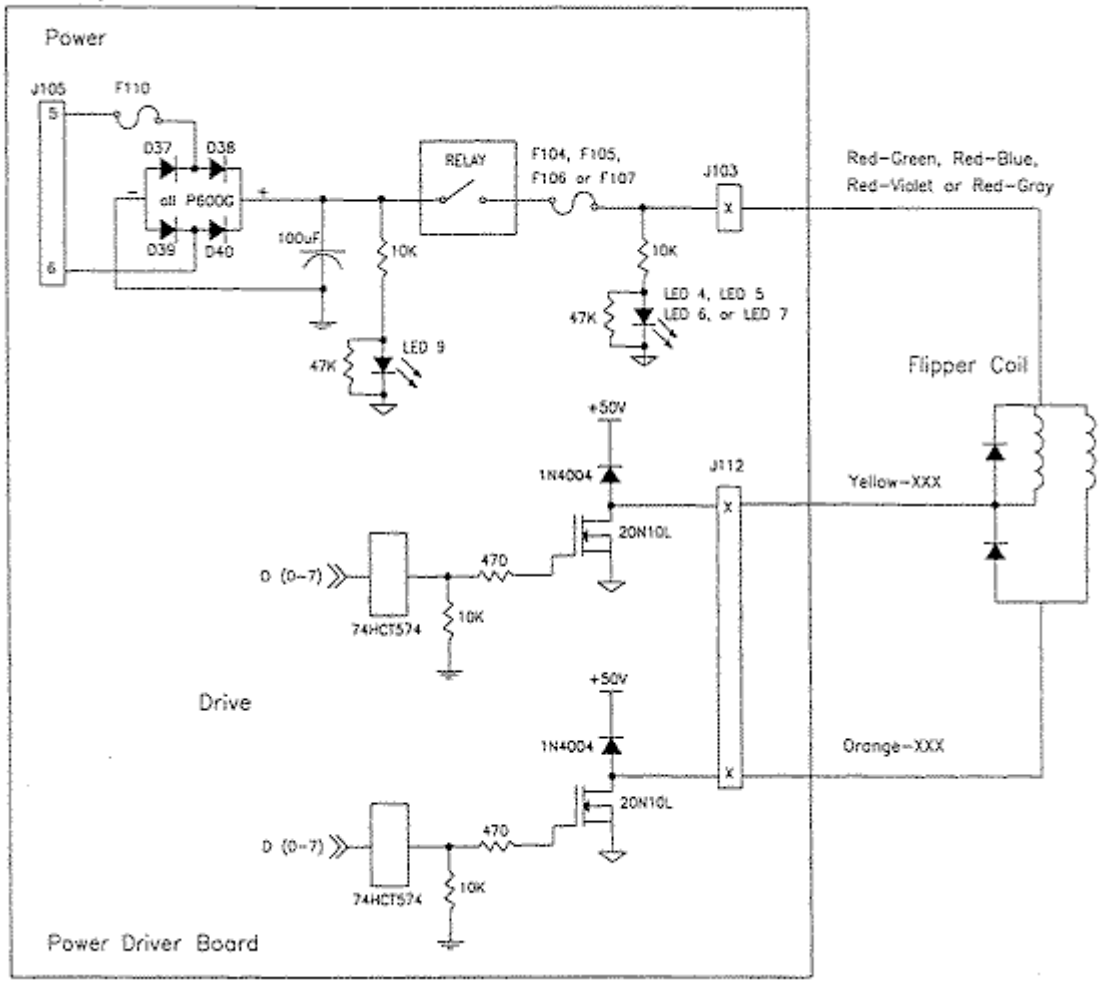
Although the component lead names are different, their functions are much the same. For example, the major current flow through a transistor is between the emitter and the collector. It's called the "collector current". The emitter/collector connection is used to control the current through the solenoids. In the MOSFET, the same job is handled by the source and the drain. To energize a coil, the FET closes the source/drain connection, completing the circuit. The main current flow in a FET is called the "drain current.

The remaining component lead is the controlling element of the device. In the transistor, the "base" lead controls the flow of current between the emitter and collector. A small voltage on the base will turn the transistor on. In the MOSFET, the controlling element is called the "gate". Pinball 2000 uses MOSFETs that are controlled by standard logic levels (about 5 volts) on the gate. Instead of using a system of integrated circuit latches, pre-driver transistors and driver transistors, the MOSFETs are driven directly by data latches (a 74HCT574 chip). This reduces the number of components on the circuit board, simplifying troubleshooting and reducing cost. For example, when Williams was using a TIP36 to drive a flipper coil, it required (in addition to the TIP36), TIP102 and 2N4403 pre-driver transistors, which were driven by the octal latches (a 74LS374 chip).

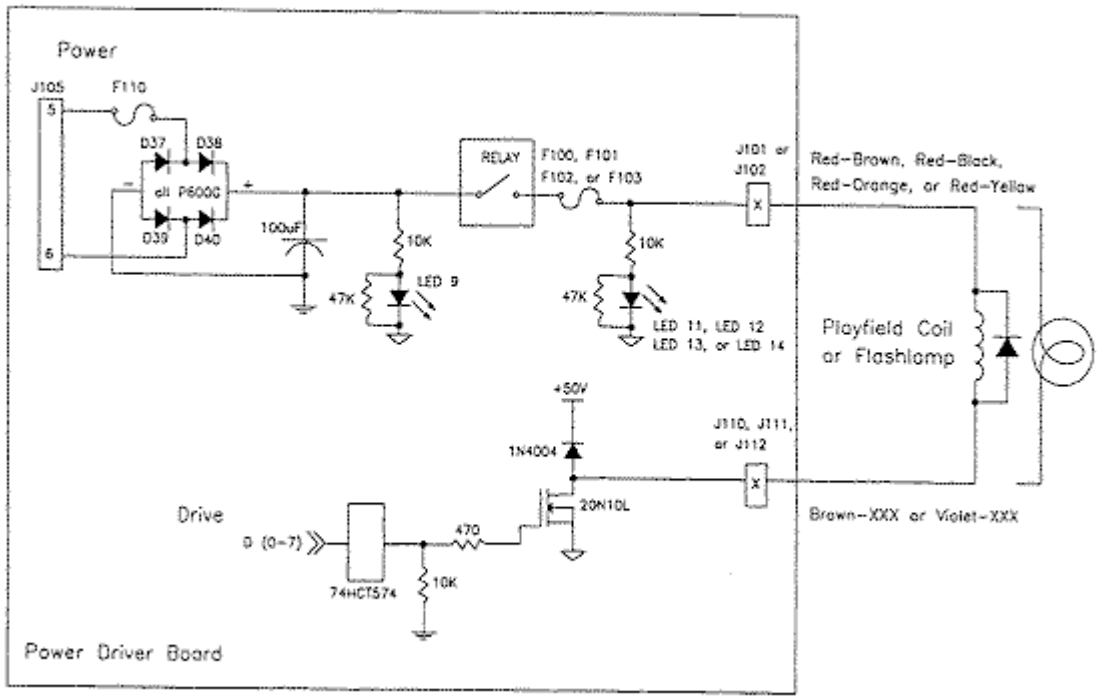
The MOSFETs used in the solenoid driver circuits are type 20N10L (regardless if the FET controls the flippers, an upkicker, or a flash lamp). The first pair of numbers refers to the current rating. In this case, it's rated at a maximum drain current of 20 amps. This is more than enough for any coil with plenty of headroom. The "N" indicates an N-channel FET (some FETs are of opposite polarity, known as P-channel FETs). The final 2 digits indicate the voltage rating.

The 20N10L is a 100 volt MOSFET. And last (but not least!), the "L" suffix indicates that a "logic" level is used on the gate to turn the FET on (this is very important, as some FETs do not have the "L", and hence will not work in Pinball 2000).

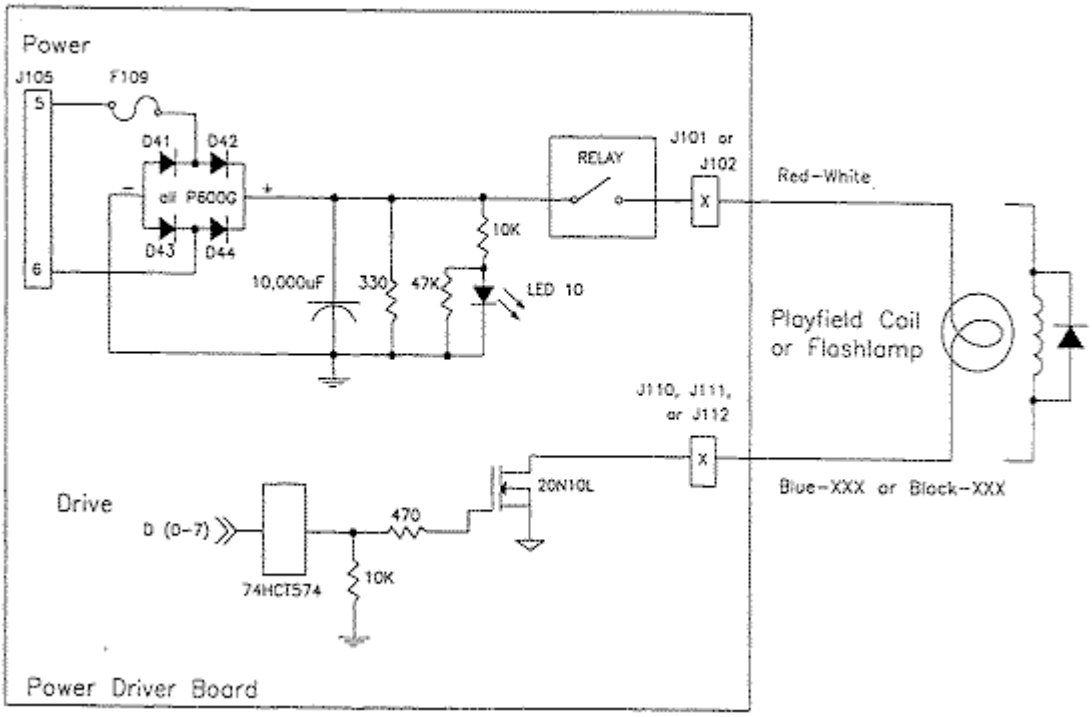
FLIPPER COIL CIRCUIT



CIRCUIT for SOLENOIDS 1 to 16



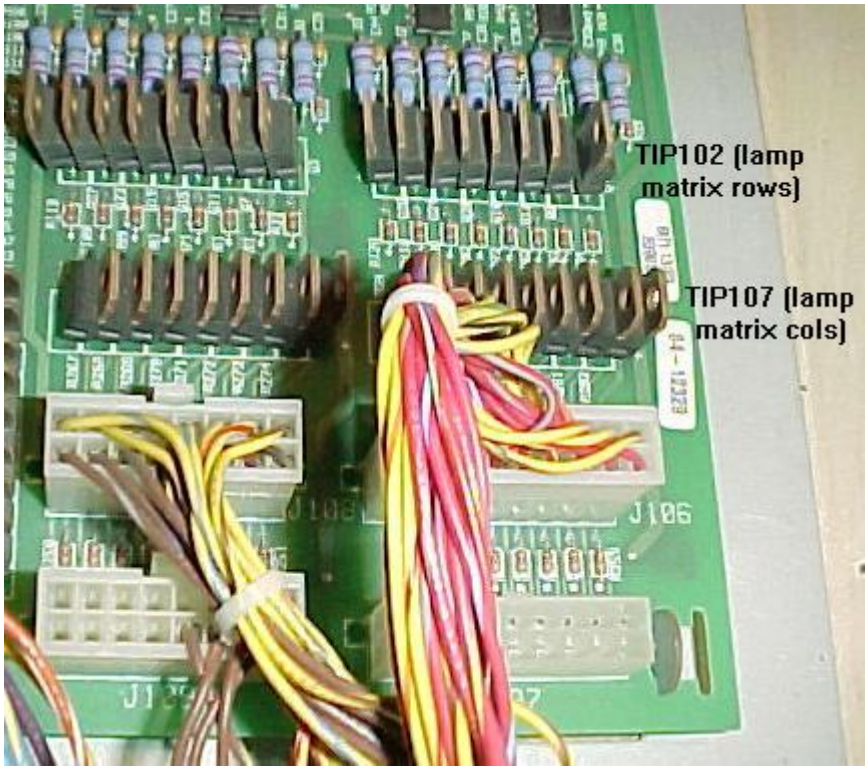
CIRCUIT for SOLENOIDS 17 to 28



TIP Transistors used in Pin 2000.

The only TIP style transistors used in Pinball 2000 are for the lamp matrix. This includes TIP107 and TIP102 transistors. The lamp matrix circuit is nearly identical to the previous WPC circuit. That is, TIP107 transistors are used to provide power to the lamp matrix columns. TIP102 transistors are used to complete the ground for the lamp matrix rows.

P2000 lamp matrix TIP transistors on the Driver board.



I have a Stuck-on Coil (or Flashlamp), What should I Replace?
The following procedures will test the driver transistors in question. If bad, it will need to be replaced.

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

If after replacing the driver transistors the coil/flashlamp is still stuck on, then replace the TTL 74HCT574 logic chip.

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

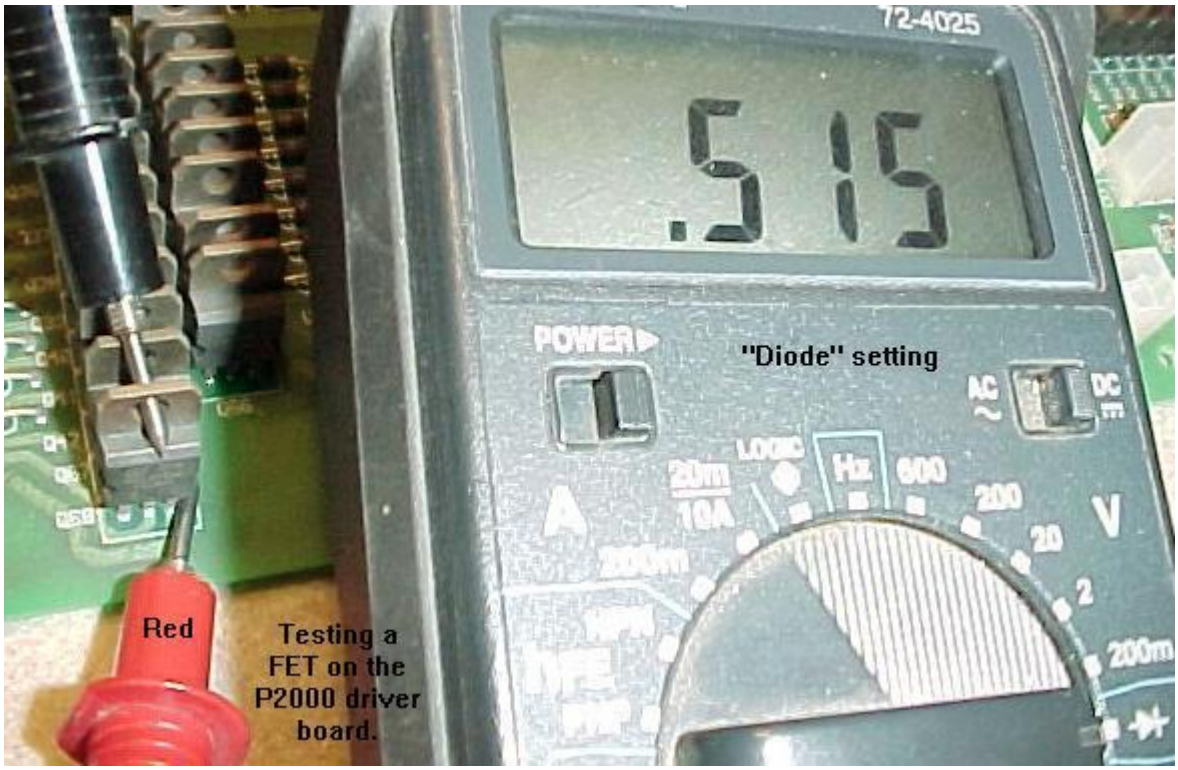
Do the Transistor Test Procedures work 100%?
In short, no. But they do work about 98% of the time, and are an excellent starting point. But yes, a transistor can test as "good", but still be bad. The DMM test procedures test the transistors with no load. Under load, a transistor could not work.

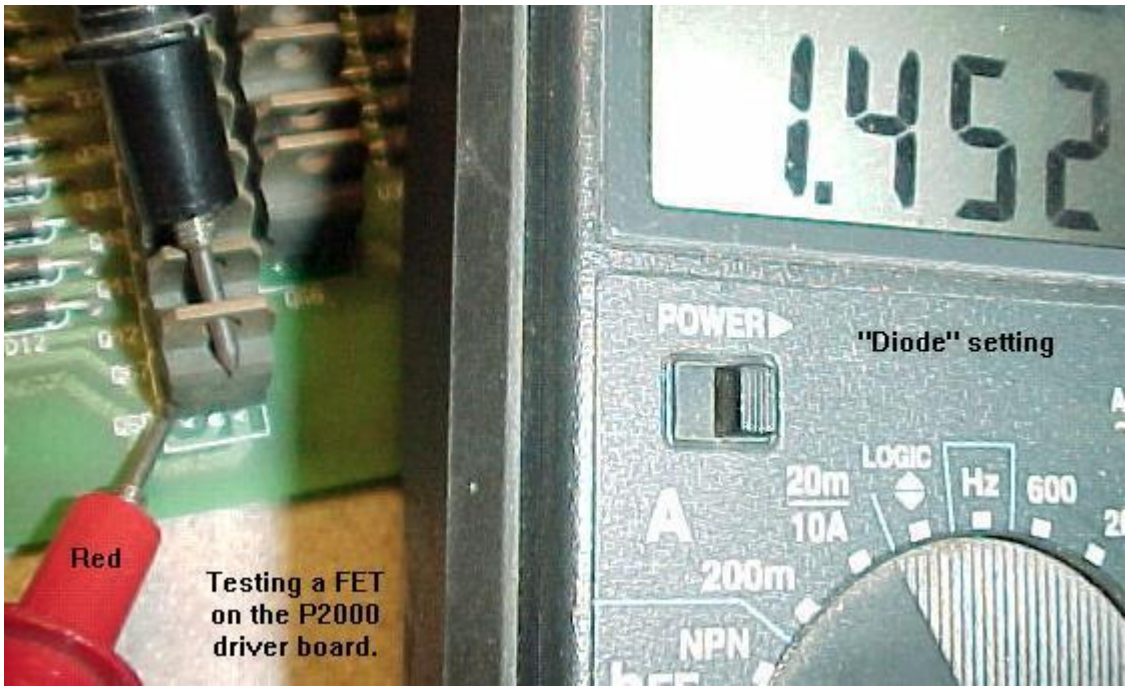
Transistor Testing procedures using a DMM.
If the driver board is out of the game for some reason, test all the transistors. It only takes a moment, and will ultimately save time. To test a transistor, a digital multi-meter (DMM) is needed, set to the "diode" position. NOTE: testing transistors with a DMM is not 100% fool-proof. A transistor can test as "good" and still be bad (rare, but it does happen!).

Testing Transistors INSTALLED in the Pin2000 driver board.

- **FET 20N10L**: Put the **black** lead of the DMM on the metal tab of the transistor. Put the red lead of the DMM on the right outside leg of the FET (as facing the transistor). A reading of .4 to .6 volts should be seen. Then move the red lead of the DMM to the left leg of the FET. A reading of 1.2 to 1.4 volts should be seen. Put the red lead on the center FET leg, and a zero reading should be seen. Any other value, and the FET is bad and will need to be replaced.

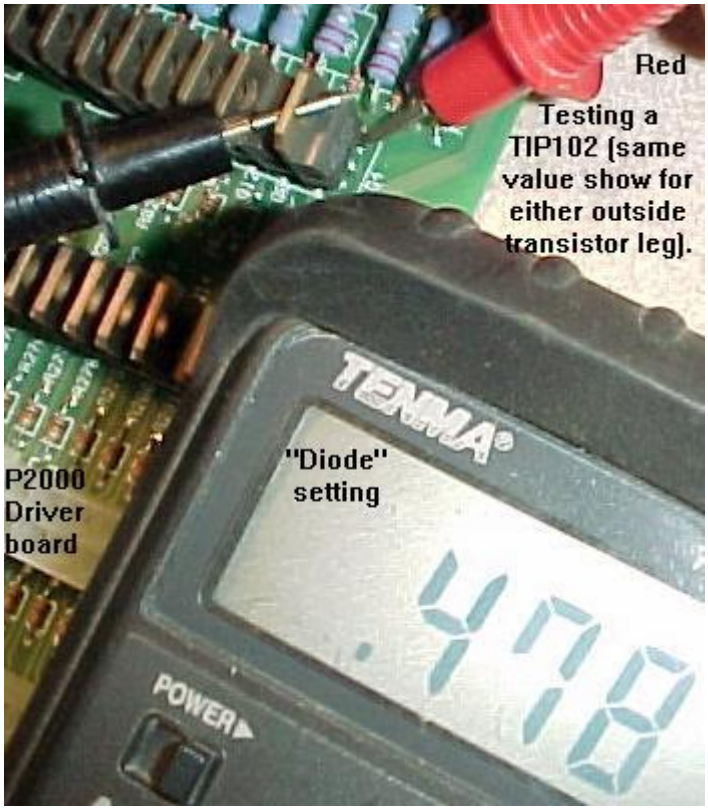
Testing a FET on the P2000 driver board.





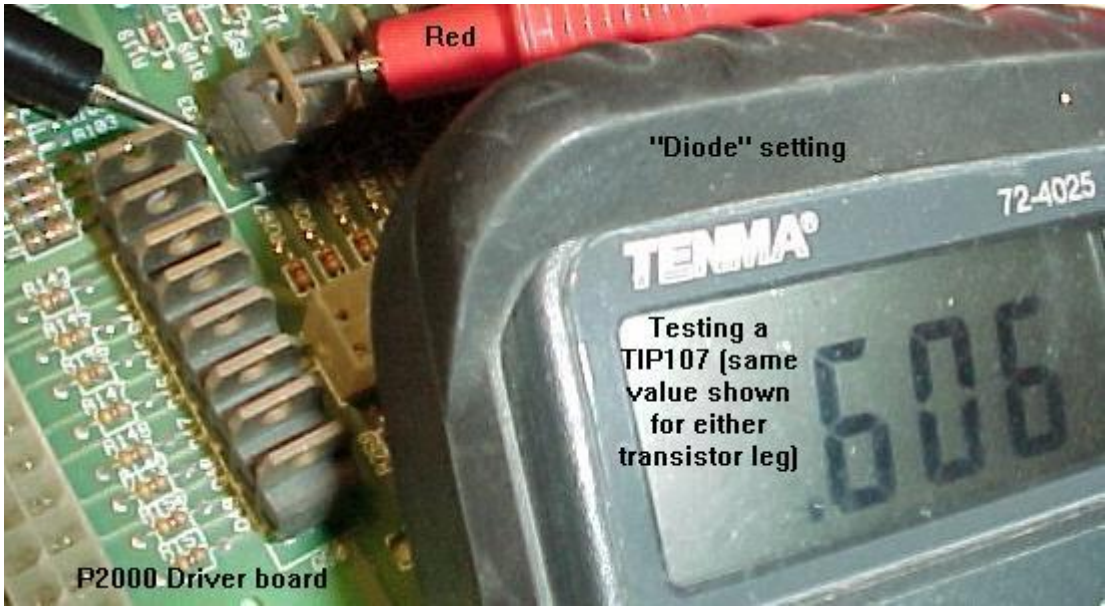
- **TIP102**: Put the **black** lead of the DMM on the metal tab of the transistor. Put the red lead of the DMM on each of the two outside legs of the transistor. A reading of .4 to .6 volts should be seen. Put the red lead on the center transistor leg (collector), and a zero reading should be seen. Any other value, and the transistor is bad and will need to be replaced.

Testing a TIP102 on the P2000 driver board.



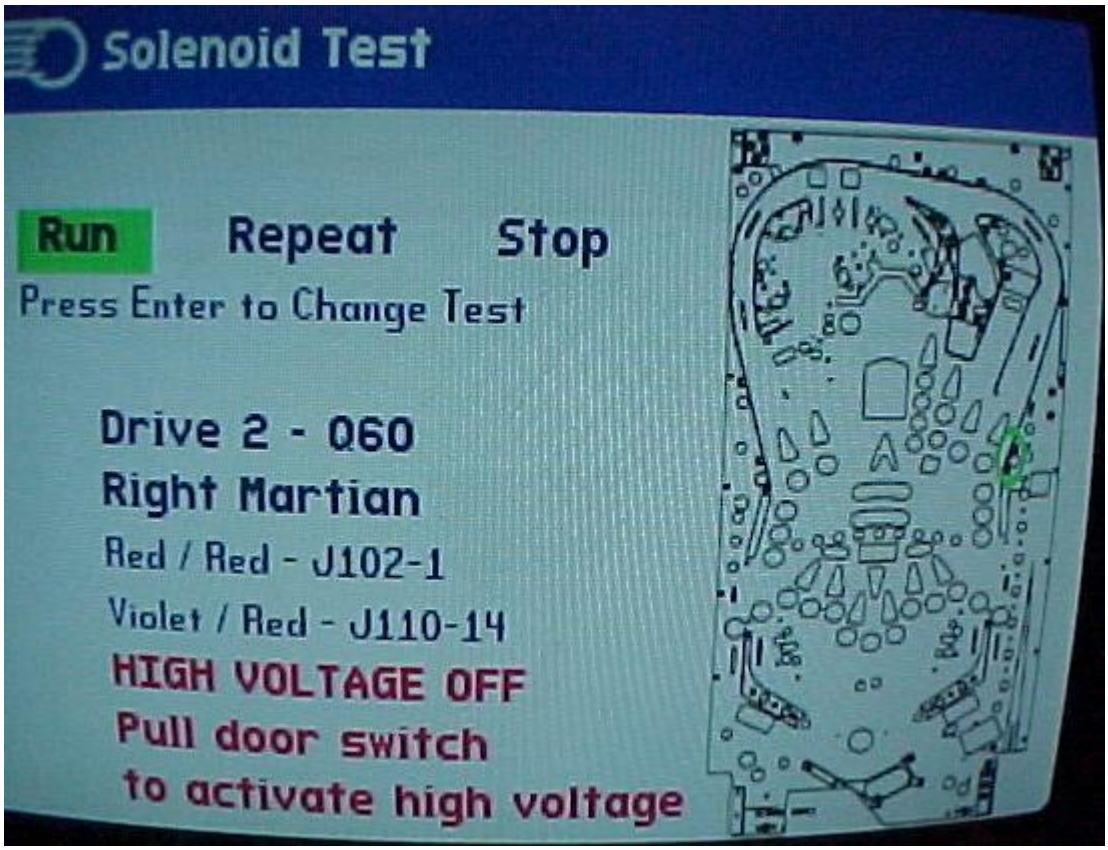
- **TIP107**: Put the **red** lead of the DMM on the center leg or on the metal tab of the transistor. Put the black lead of the DMM on each of the two outside legs of the transistor. A reading of .4 to .6 volts should be seen. Put the black lead on the center transistor leg (collector), and a zero reading should be seen. Any other value, and the transistor is bad and will need to be replaced.

Testing a TIP107 on the P2000 driver board.



If a coil is not working, the following approach is a good one to take. It starts with the easiest test first; using the internal pin2000 diagnostics. Then the tests moves to the coil itself, and goes back towards the driver board. This makes the chain smaller, and gives a very systematic approach to finding the problem.

Information shown in the solenoid test diagnostics. The top row of information (J102) is the power to the coil. The bottom row is the drive (J110), completion to ground back at the driver board transistor.



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

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

- Press the "Begin Test" button inside the coin door.
- Select "MAIN MENU: TESTS".
- Select "TEST MENU: SOLENOID TEST".
- Use the "+" and "-" buttons to move the test from coil to coil. Each coil should fire.
- Remember the coin door interlock switch must be held in. Otherwise the coil 50 volts will be turned off, and the coils won't fire. Also make sure the "REPEAT" portion of the test is used. This can be changed using the "Begin Test" button.

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

- Check all the fuses on the driver board. A non-working solenoid could be as easy to fix as just replacing a fuse.
- Find the solenoid in question under the playfield. Make sure the wire hasn't fallen off or become cut from the coil (a very common problem). Remember, the power wire is "daisy chained" from coil to coil. If one breaks "upstream", all coils "downstream" will not work.
- If the above is correct, make sure the winding of the coil haven't broken off from the solder lugs. If one has broken, it can be re-soldered. Make sure the painted enamel insulation is sanded from the wire before re-soldering. This is easy to check using a DMM set to DC volts. There should be voltage on *both* lugs of the coil (with the coil door closed). Voltage on only one lug means a coil wire has broken.
- Check the coil diode (for any other pinball game, this would be the next step). The coil diode for all games (except Pin2000 and WPC) are attached right to the coil, with the banded side of the diode connecting to the power side of the coil. On Pin2000 and WPC games however, Williams moved this diode to the power driver board for all coils but the flipper coils. This increases reliability as the diode is not subject to the jarring and heat a coil can produce. It also eliminates the need for the operator to know which coil wire goes to the banded side of the diode when replacing a coil! These coil diodes are mounted on the driver board near the transistor that drives each particular coil.

The Coin Door Interlock switch.
All pin2000 games have a coin door interlock switch. This turned off the power to all the coils when the coil door was opened (for safety reasons). On games with this interlock switch, make sure the coin door is closed when testing coils!

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

A Systematic Approach.

1. Test for Power at the Coil.
Most pinball games (including pin2000) have power at each and every coil at all times. To activate a coil, GROUND is turned on momentarily by the driving transistor to complete the power path. Since only ground (and not power) is turned on and off, the driving transistors have less stress on them. With this in mind, if we artificially attach a coil to ground, it will fire (assuming the game is turned on).

- Turn the game on and leave it in "attract" mode.
- Lift the playfield.
- Close the coin door interlock switch.
- Put the DMM on DC voltage (100 volt range or higher).
- Attach the black lead of the DMM to the metal side rail.
- Touch the red lead of the DMM on either lug of the coil in question.
- A reading of 50 to 80 volts DC should be indicated. Switch the red test lead to the other lug of the coil, and the same voltage should be seen again. On flipper coils, test the two outside lugs of the coil. If no voltage reading is shown, no power is getting to the coil. On a two lug coil, if there is only voltage at one lug, the coil winding is broken.
- If no power is getting to the coil, a wire is probably broken "upstream" or there is a bad fuse.

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

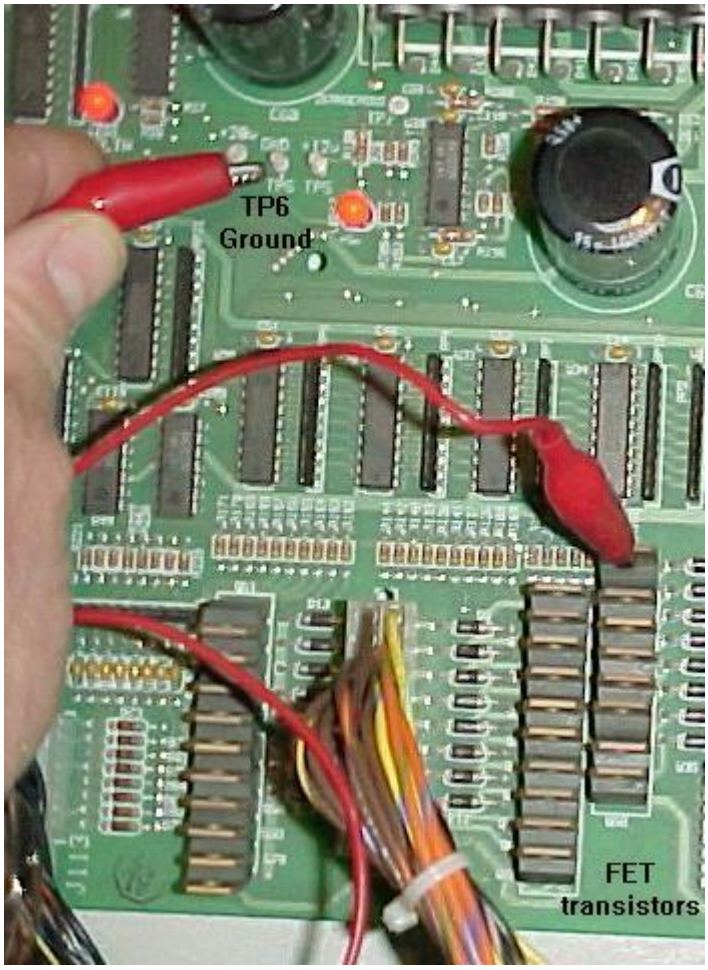
- Game is on and in "attract" mode, and the playfield lifted.
- Close the coin door interlock switch.
- Connect an alligator clip to the metal side rail of the game.
- Momentarily touch the other end of the alligator clip to the GROUND lead of the coil in question. This will be the coil lug with the thinner single wire attached. On flipper coils, this is the middle lug (the power wire on most coils is usually the thicker violet or red wire).
- The coil should fire (if the alligator clip is accidentally touched to the power side of the coil, the game will reset and/or blow a fuse, as the solenoid high voltage is being shorted directly to ground).
- If the coil does not fire, either the coil itself is bad, or a fuse is blown, or the "daisy chained" power wire has broken "upstream".

3. Testing from the FET or TIP102 Transistor to the Coil.
If the coil fires in the above test, this test will check from the FET's or TIP102's output, the wiring to the playfield, and the coil itself.

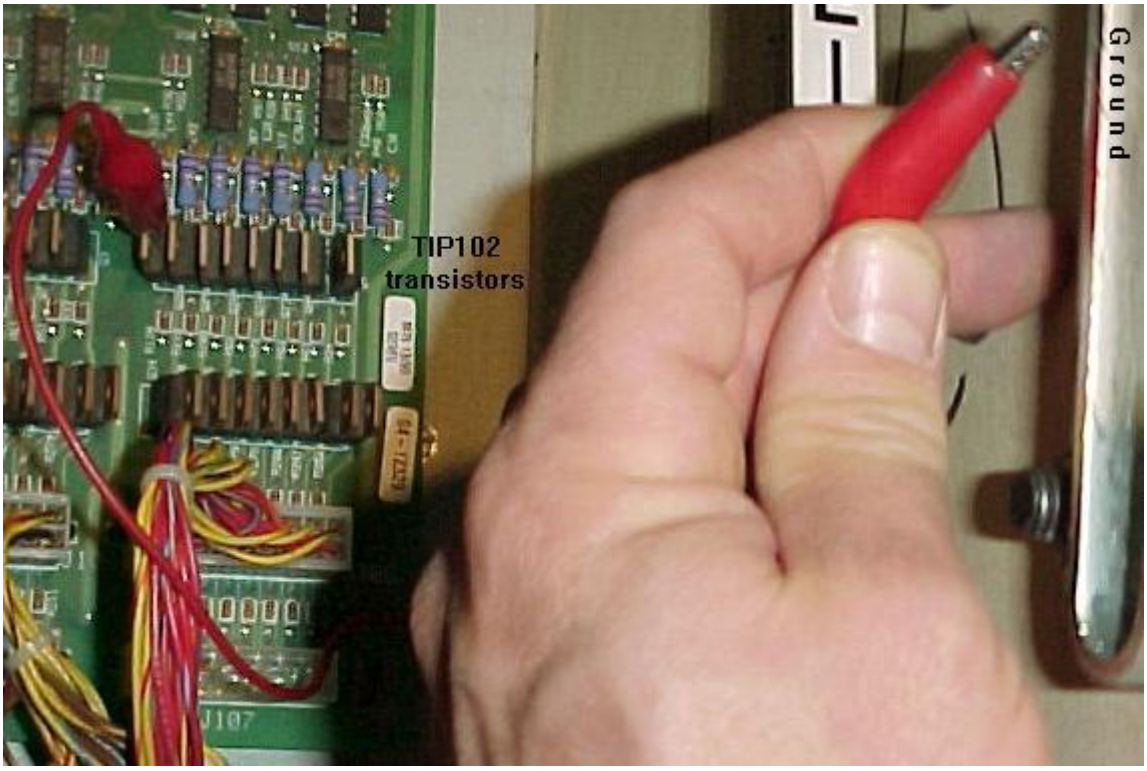
- Game is on, and the "test mode" button is pressed once to enter diagnostics.
- Close the coin door interlock switch.
- Find the transistor that controls the coil in question (refer to the manual, inside the front cover).
- Attach an alligator clip to the game's metal side rail or some other ground point.
- Momentarily touch the other lead of the alligator clip to the metal tab on the FET or TIP102 transistor in question.
- Its associated coil, flash lamp or lamp matrix row should energize.
- If the coil/flashlamp/lamp row does not energize, and it did in the previous tests, there probably is a wiring problem. A broken wire or bad connection at the connector would be most common. It is also possible there is a bad transistor. Continue to the next step, or use the DMM

meter and test the transistor on the board (see Transistors Testing Procedures for details).

Testing the coil by touching the metal tab of the FET to TP6 (ground) with a jumper wire.



Testing a lamp matrix row by touching the metal tab of the TIP102 to ground with with a jumper wire. The entire lamp matrix row associated with this transistor should light.



What if the above tests worked, but the coil still does not work during game play? If all the above tests worked, there is probably a driver board problem. Everything has been tested from the FET back to the coil itself. That only leaves the FET itself, a resistor, and the 74HCT574 logic chip that controls the FET transistor. It has to be one of these devices that are causing the problem.

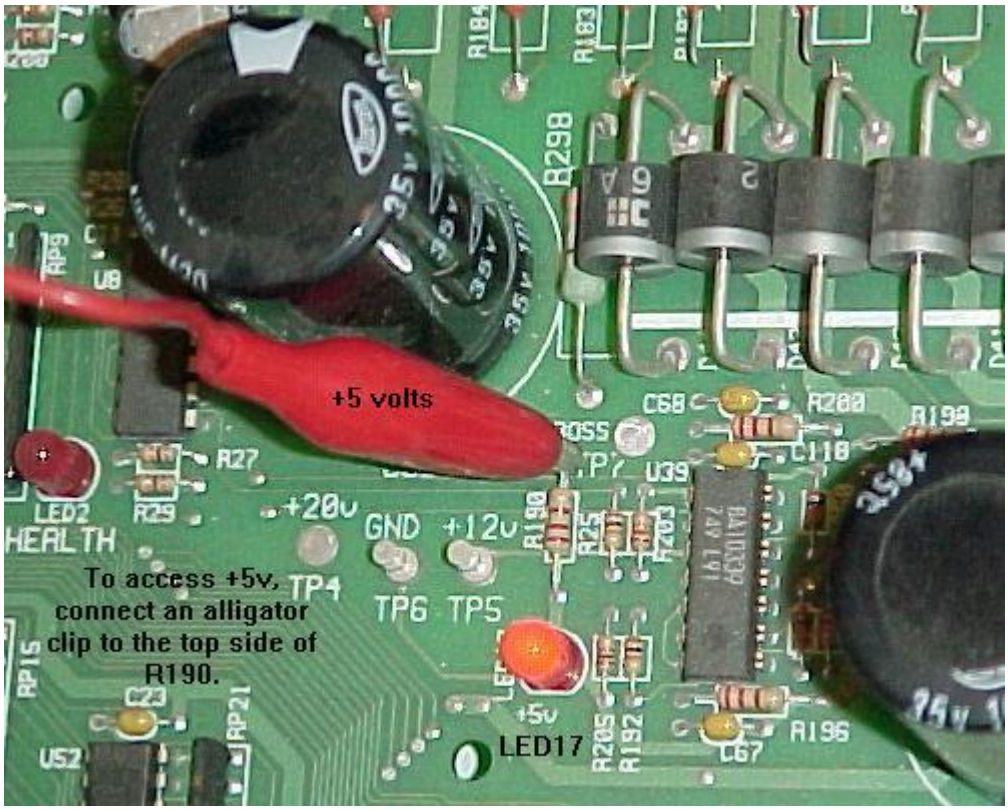
4. Testing the FET (simulating the Logic Chip's Output to test the Coil).
The next thing to check is one step further "upstream". This is done by simulating what the 74HCT574 logic TTL chip does to turn on a coil. The TTL chip turns +5 volts on, which goes to the resistor, which then turns on the FET, completing the ground path for the coil (hence the coil fires). By simulating the output of the logic chip, everything in the chain is tested except for the logic chip itself. If this test works, it is nearly certain the 74HCT574 has failed. If the test does not work (and the previous tests did work), there is probably a bad FET (most common), an open resistor, or a broken board trace.

First find the resistor that connects to the FET to be tested. Refer to the chart below to determine this resistor.

FET #	Resistor #	74HCT574 #		FET #	Resistor #	74HCT574 #
Drive Bank A				**Drive Bank C**		
Q59	R160	U31		Q43	R143	U29
Q60	R161	U31		Q44	R145	U29
Q61	R162	U31		Q45	R146	U29
Q62	R163	U31		Q46	R147	U29
Q63	R164	U31		Q47	R148	U29
Q64	R165	U31		Q48	R149	U29
Q65	R166	U31		Q49	R150	U29

Q66	R167	U31	Q50	R151	U29
Drive Bank B			**Drive Bank D**		
Q51	R152	U30	Q67	R168	U32
Q52	R153	U30	Q68	R169	U32
Q53	R154	U30	Q69	R170	U32
Q54	R155	U30	Q70	R171	U32
Q55	R156	U30	**Flipper Drivers**		
Q56	R157	U30	Q35	R136	U28
Q57	R158	U30	Q36	R137	U28
Q58	R159	U30	Q37	R138	U28
			Q38	R139	U28
			Q39	R140	U28
			Q40	R141	U28
			Q41	R142	U28
			Q42	R144	U28

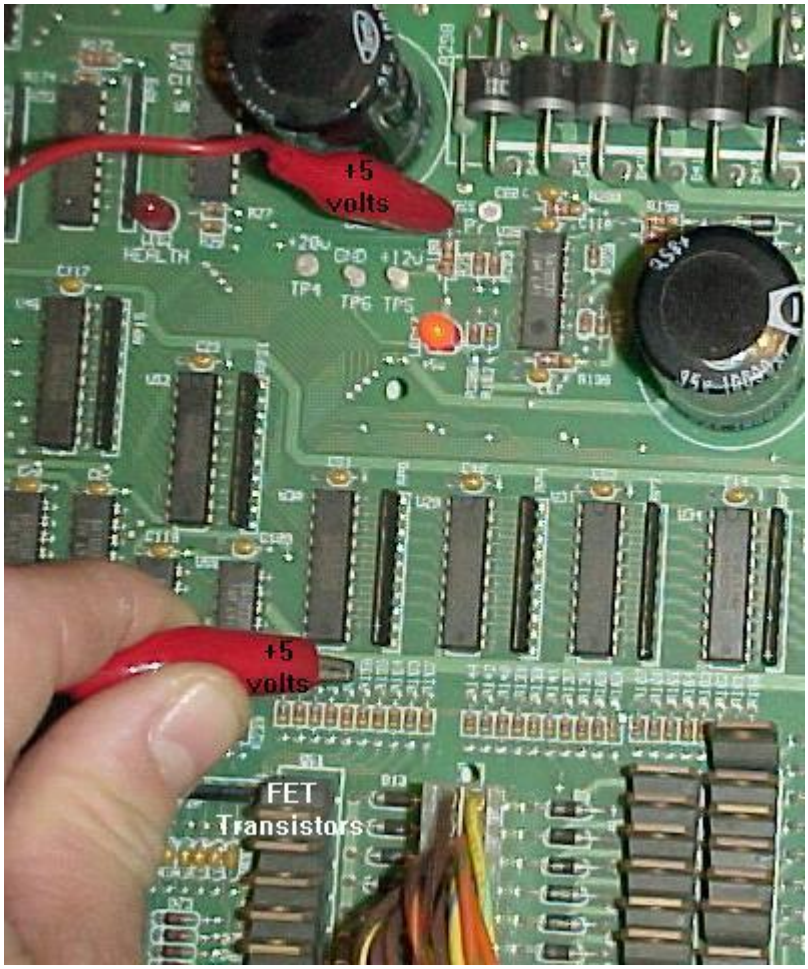
Access +5 volts on the driver board by connecting an alligator clip to the top side of resistor R190.



1. Connect an alligator clip to +5 volts. This can be found on the top side of resistor R190. This resistor lives just above the +5 volt LED #17 (see picture). The alligator clip *must* be clipped only to the top side of this resistor (the side closest to the fuses).
2. Turn the game on.

3. Close the coin door interlock switch.
4. Momentarily touch the other end of the alligator clip to the above noted resistor on the *top* side (the side closest to the fuses).
5. The coil should fire.

*Momentarily touching +5 volts to the *top side* of the resistor which connects to the FET to be tested. This should fire the coil.*



What if the above tests worked, but the coil still does not work during game play? If all the above tests worked, the 74HCT574 chip has probably failed. Everything has been tested from the FET back to the coil itself. That only leaves the 74HCT574 logic chip that controls the FET transistor.

End of Systematic Approach.

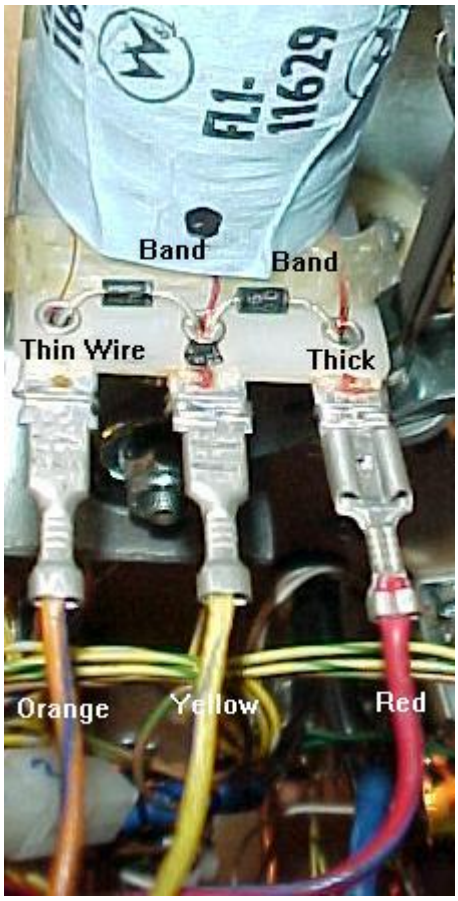
Coil Diodes.

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

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

On older games (pre-1990 Williams games), sometimes a diode lead breaks on the coil from vibration. Also, when replacing a coil, the operator can install the coil wires incorrectly (the power wire should always be attached to the coil's lug with the banded side of the diode). To prevent this, **Williams moved the coil diode to the Driver board**. This isolates the coil diode from vibration and eliminates the possibility of installing the coil's wires in reverse. This was done on all coils **except** the flipper coils.

The coil diodes on a Pin2000 flipper coil.
The red (right) wire is the "hot" wire.
The yellow (middle) wire handles the initial hi-power "flip", and the orange (left) wire handles the flipper's "hold".



Installing a New Coil.
Many replacement coils will come with a diode soldered across its solder lugs. On Pin2000 and WPC games, all coils except the flipper coils have the diode mounted on the Driver board. For all coils except flipper coils, cut the diode off the coil before installing. Then put the coil wires to either coil lug. *The diode can also be left in place, but the coil wires must be installed correctly. The ground wire MUST go to the lug of the coil with the non-banded side of the diode. The power wire attaches to the lug with the banded side of the diode.* If the wires are reversed, this essentially causes a shorted diode. Though the Driver board mounted diode is still present as protection, damage can occur to the coil's driver board transistor.

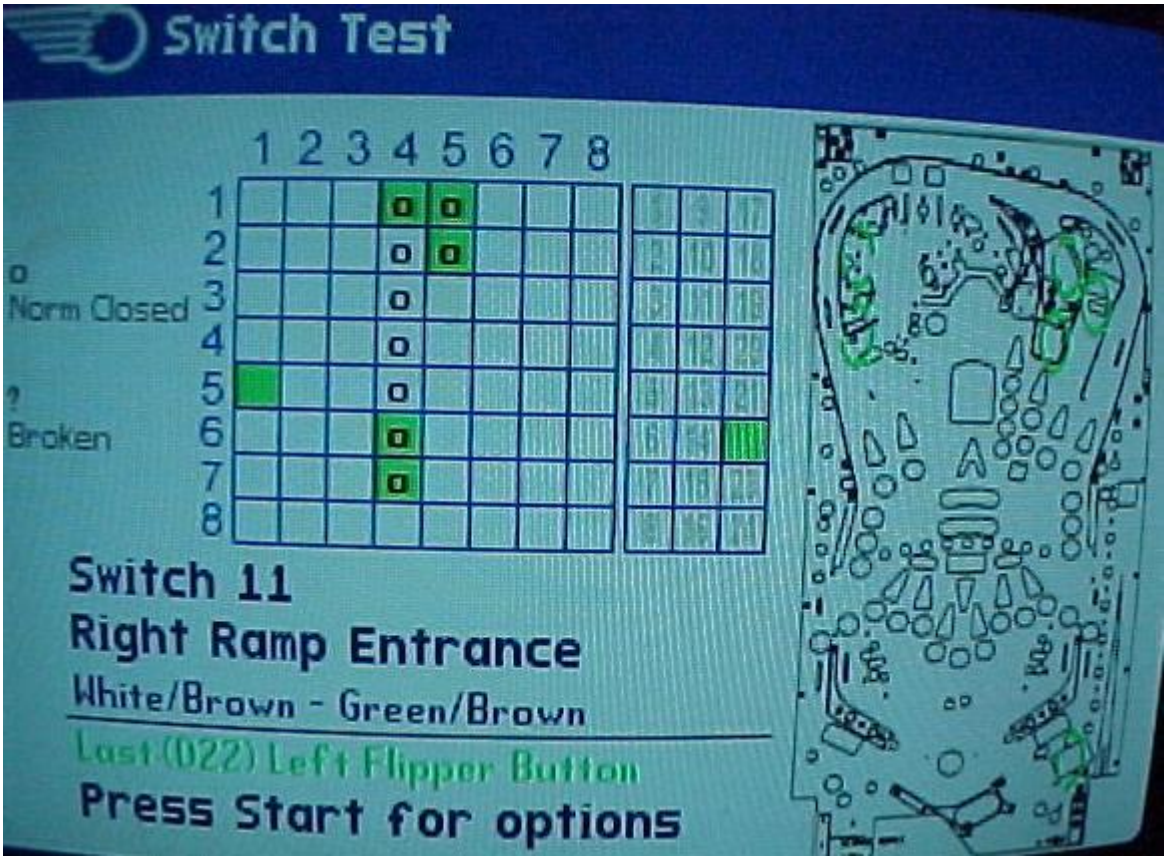
Coil Doesn't Work Check List.
If a coil doesn't work in a game, here's a check list to help determine the problem.

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

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

- Have the power wires fallen off the coil's solder lugs?
- Is the coil damaged? Has the internal winding broken off the coil's solder lug?
- Is there power at the coil? See Testing for Power at the Coil for more details.
- If there is no power at the coil, check its fuse. Use the internal diagnostics and the "help" button to determine which fuse controls the coil. See Testing Transistors/Coils using the Diagnostics for details.
- Check the other coils that share one of the same wire colors. Are they working too? If not, suspect the fuse that handles these coils.
- Power to coils are often ganged together. If the power wire for this coil has fallen off a previous coil in the link, power may not get to this coil.
- Using the DMM and its continuity test, make sure the coil connects to the correct connector/pins on the driver board. This information can be seen from the Diagnostics solenoid test.
- Check the driving FET transistor. Usually this transistor will short on when it fails, but not always. Also check the 74HCT574 chip that drives the FET transistor.

3e. Switch Matrix.



3f. Lamp Matrix.

Lamp Matrix Introduction. by Randy Fromm.
The circuit and operation of the lamp matrix is the same in both Williams' WPC-95 system and the new Pinball 2000 machines. The lamp matrix consists eight columns and eight rows, with a lamp connected between each column and each row. There is also a diode in series with each lamp. In a matrix, this is known as a "steering" diode. It is needed to keep the current flowing along the proper pathways.

Each of the columns is a separate source path, individually controlled by each of eight TIP107 PNP darlington transistors. These transistors are turned on and off in rapid succession, one after another. This is known as "strobing".

It's easy to understand how the strobe circuit works. The emitter connections of all eight TIP107 transistors are connected directly to the +18 volt DC power supply. The collector connection of each transistor becomes the strobe output that drives each of the lamp columns. On the schematic diagram and in the lamp matrix table (conveniently located on the inside of the back cover of every Williams operations manual) they are labeled column 1 through 8.

In order to control the column outputs, the base of each TIP107 is connected to the output of driver IC U11, a ULN2803. Actually, this device only looks like an integrated circuit. It's really an NPN darlington transistor array of eight individual transistors that take TTL level inputs. Driving the ULN2083 is an "octal latch" (74LS374) at U10. This chip grabs data off the rapidly changing data bus and holds on to it for as long as the strobe lines need to be active.

One at a time, each output of U10 (74LS374) is activated for a period of approximately 1 millisecond (1/1000 second). As one would expect, it takes 8 milliseconds to complete the cycle which then repeats and runs continuously.

When the output of chip U10 (74LS374) activates, the associated TIP107 transistor is switched on. This allows the +18 volt power supply to pass through the transistor, sending a +18 volt DC pulse down the column.

The columns are only half of the lamp matrix circuit. Each strobe line is used to send a pulse to a group of eight lamps but all eight lamps don't light up at once. How do we light just one lamp? Individual lamps are selected by energizing a separate "lamp return" transistor that is connected to each lamp in the group. Each lamp return is a "row." In fact, the lamp return transistors are really our old friend the ground switch!

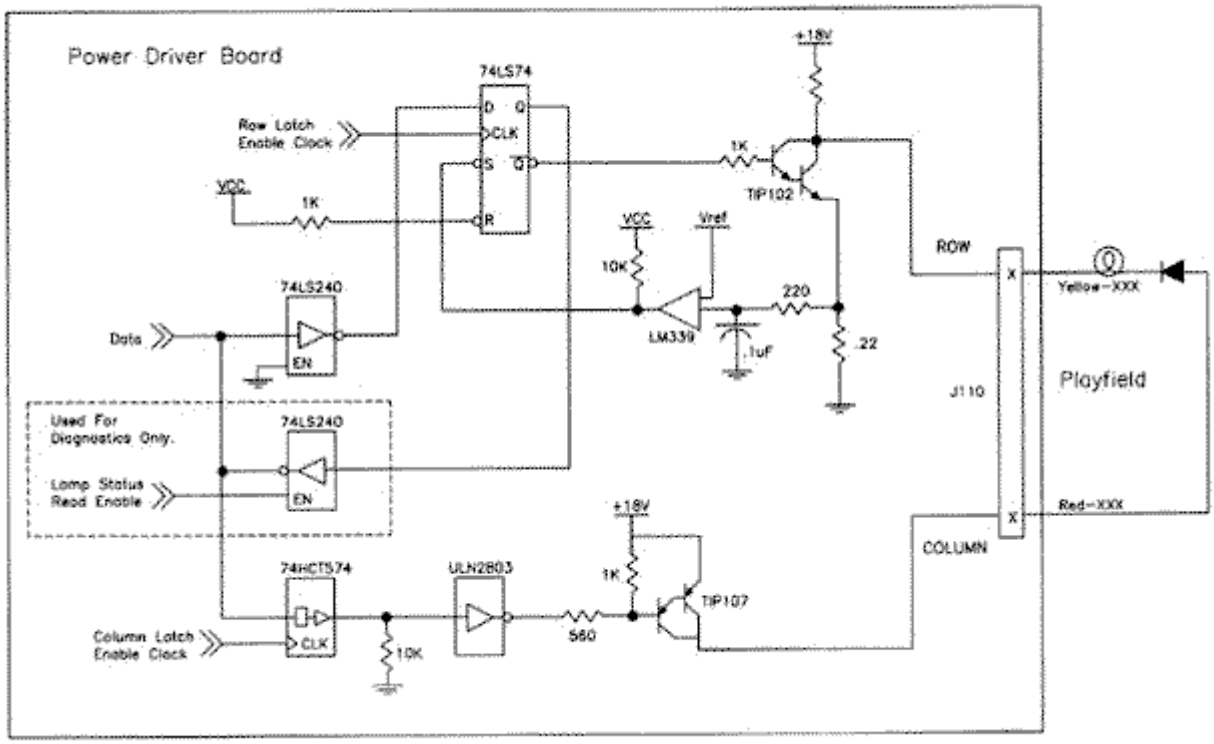
The lamp return transistors are the same type as those used to drive the solenoids, type TIP102. The lamp return transistor completes the ground circuit for each lamp. To light a single lamp, the lamp return circuit for that lamp is energized at the exact moment the column is sending out its pulse. The column provides the source path to the lamp while the row provides the return path and Viola! We have a complete circuit and the lamp lights up. The computer then moves on to the next column, energizing it while simultaneously activating the appropriate row in order to light the lamps it wants to illuminate. The process repeats for all eight columns.

With the strobe circuit to drive them, the lamps are "refreshed" every 8 milliseconds. During each refresh time, the selected lamps are given another pulse of current at +18 volts DC. Although the lamps are standard 6 volt lamps, the +18 volt pulse does not blow them out or cause them to glow too brightly. Remember, each pulse lasts just 1 millisecond. This short "duty cycle" prevents the filament in the lamp from getting too hot.

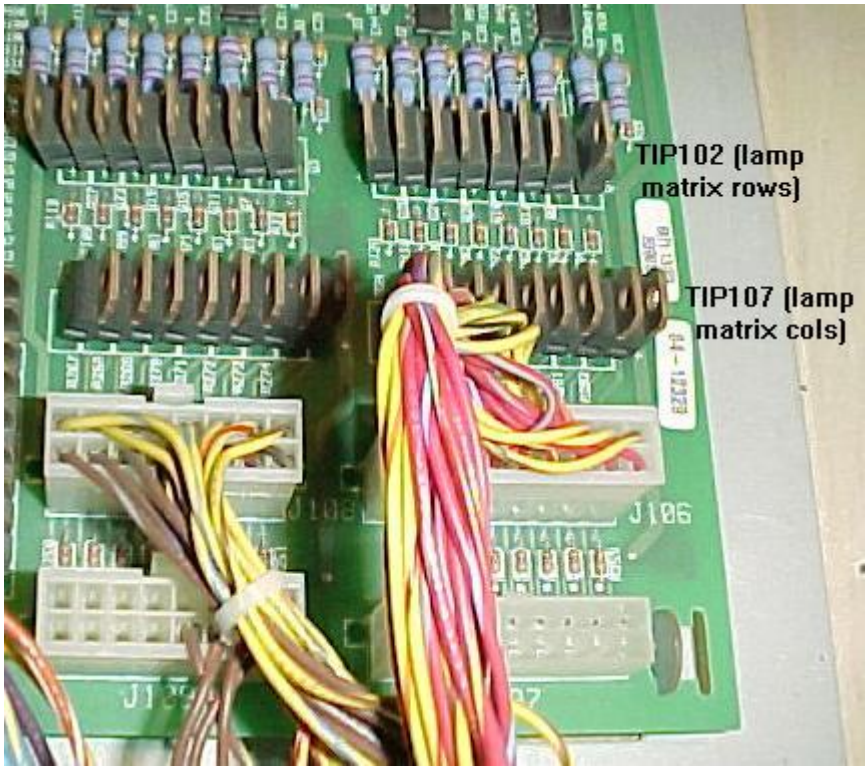
Also, despite the brief pulses they receive, the lamps do not appear to flicker. With a refresh rate of approximately 120 cycles per second (120 Hertz) the filament in the lamp will not cool enough to dim between pulses. Additionally, the human eye cannot perceive any flicker faster than about 50 hertz. Even if the bulbs flickered a bit, we wouldn't be able to see it.

The advantage of the lamp matrix over the "one ground switch for each lamp" method is obvious. The lamp matrix allows us to control 64 lamps using just 16 transistors and 16 wires connected to the lamp driver circuitry on the printed circuit board.

LAMP MATRIX CIRCUIT



P2000 lamp matrix TIP transistors on the Driver board.



Lamp Short Circuit Protection.
Shorted lamps and lamp sockets aren't uncommon. Without some type of protection circuitry, a short circuit in a single lamp could take out an entire column or row. To prevent that from happening (or at least reduce the likelyhood), Williams has included a simple but effective over-current protection (OCP) circuit in the return path circuit.

The emitters of the TIP102 transistors in the row circuit aren't connected to ground directly. Instead they are connected through a low value resistor of just a fraction of an ohm (.22 ohms). That's not very much resistance. What could that possibly do? Well, normally nothing. It's practically the same as grounding the emitter directly.

But if a lamp or lamp socket short circuits, there will be a dramatic rise in the amount of current flowing through the emitter of the TIP102 and through the .22 ohm resistor to ground. This will create a voltage across the resistor due to increased IR drop (V=IR). This voltage is applied to the inverted (-) input of the voltage comparitor U16 or U17, a LM339 chip.

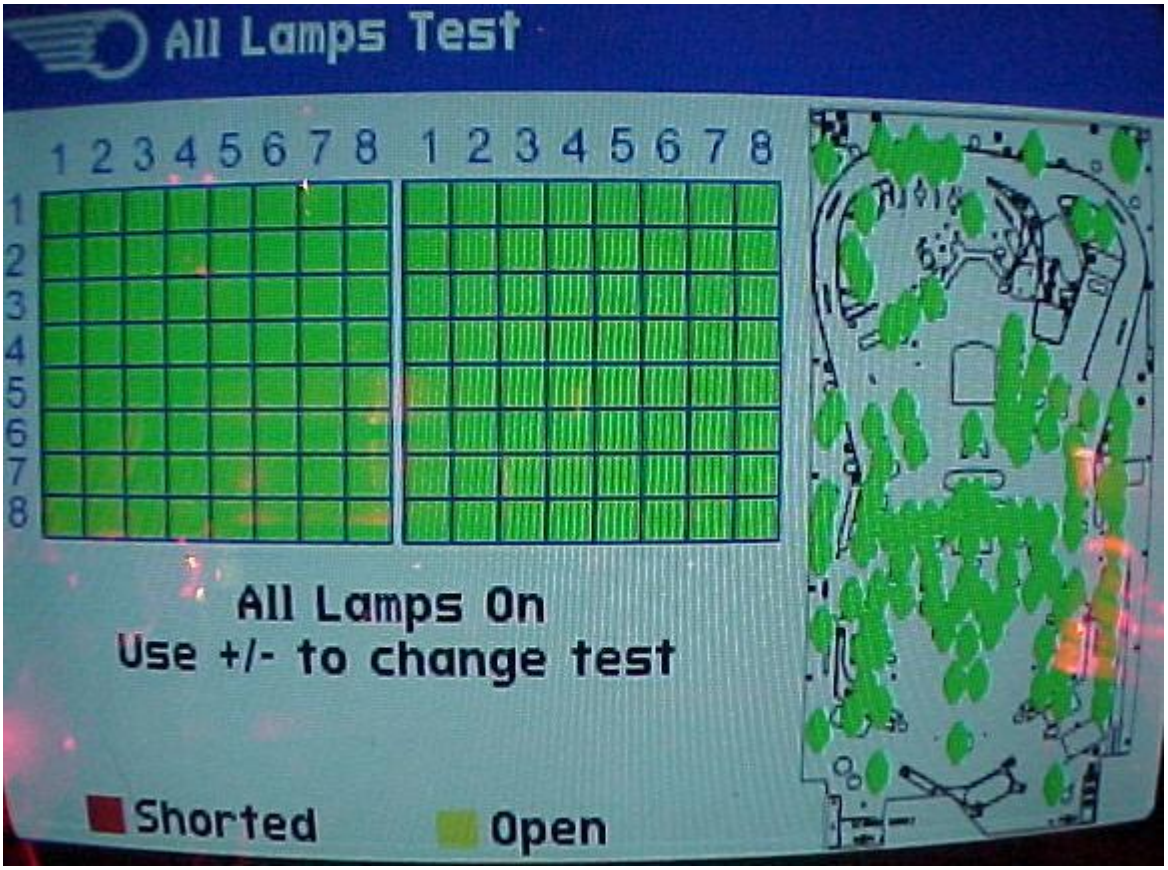
The non-inverted (+) input of all the comparitors (LM339) is connected to a +1.4 volt reference source. When an LM339 is connected this way it has a very simple operation. The device compares the two inputs to see which one has the highest voltage. If the non-inverted input has the highest voltage, the output of the LM339 is +5 volts DC. If the voltage at the inverted in the higher of the two, the output goes to ground.

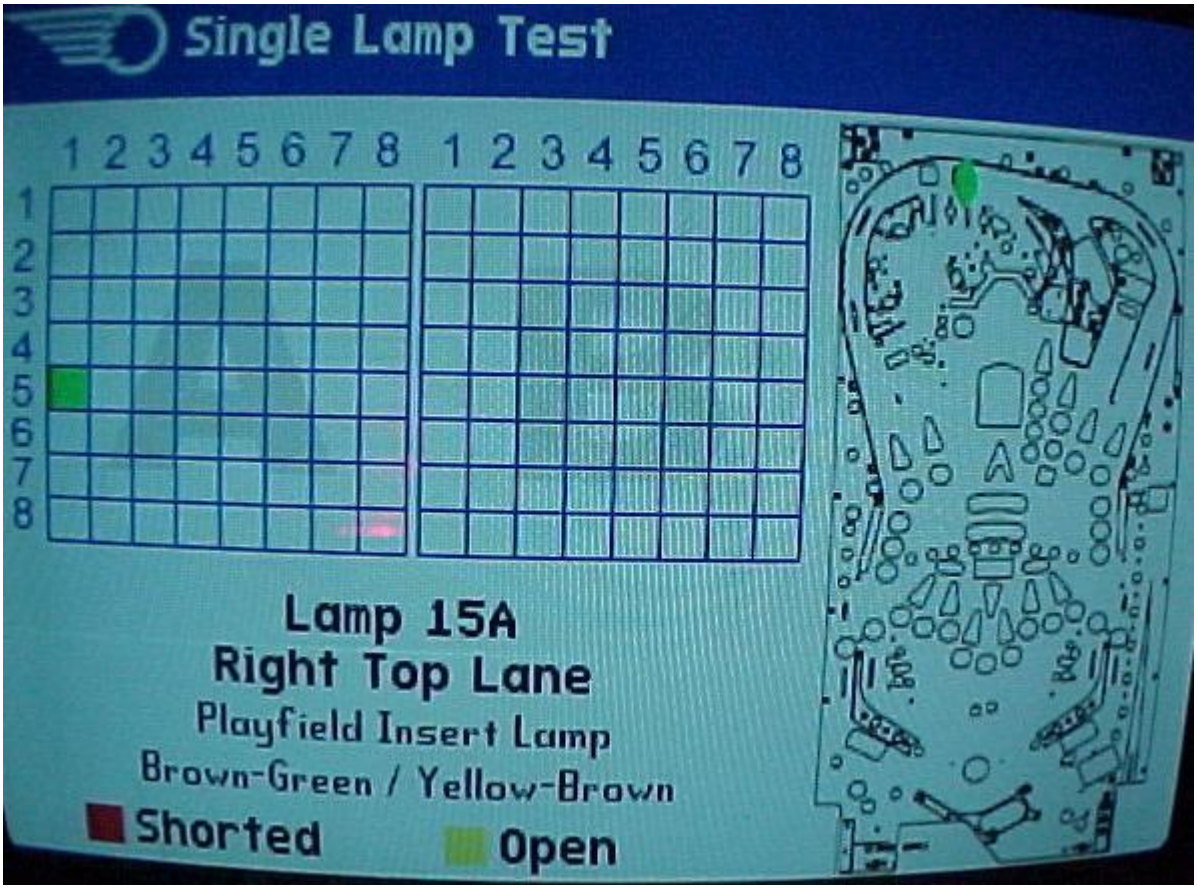
So when a lamp or lamp socket shorts, the extra current causes the comparator's output to go to ground. This is, of course, a logical "0" or "low." This signal is then used to "set" a flip-flop (chips U12-U15). Since the base of the lamp return transistor is connected to the inverted output of the flip-flop, "setting" the flip-flop causes the transistor to turn off. This breaks the return path, opening the circuit and preventing damage to either the column driver transistor or the row transistor. Pretty neat eh?

All of the other lamps will continue to function as normal. It is only when the shorted lamp or lamp socket is energized that the OCP kicks in.

Testing the Lamp Matrix Rows.
This test will check from the TIP102's output, the wiring to the playfield, and any lamp matrix row.

- Game is on, and the "test mode" button is pressed once to enter diagnostics.
- Close the coin door interlock switch.
- Find the transistor that controls the lamp matrix row in question (refer to the manual).
- Attach an alligator clip to the game's metal side rail or some other ground point.
- Momentarily touch the other lead of the alligator clip to the metal tab on the TIP102 transistor in question.
- Its associated lamp matrix row should energize (all the bulbs in this row).
- If the lamp row does not energize, there probably is a wiring problem. A broken wire or bad connection at the connector would be most common. It is also possible there is a bad TIP102 transistor. Use the DMM meter and test the transistor on the board (see Transistors Testing Procedures for details).


All Lamps Test
1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8
1
2
3
4
5
6
7
8
All Lamps On
Use +/- to change test
Shorted
Open


Single Lamp Test
1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8
1
2
3
4
5
6
7
8
Lamp 15A
Right Top Lane
Playfield Insert Lamp
Brown-Green / Yellow-Brown
Shorted
Open

3g. Sound Problems.

Problem: *Sound was static noise, and then nothing.*
Answer: Changed prism cards from my other one and it works fine.

Check to see if the game passes the POST for the sound section (it'll flag it in the error report if not). If it does pass, the DSP chip is probably Ok and look onwards from there for other faults. It's likely a very simple fix - either a simple little opamp or a bad connection. If no error report, then the DSP chip is likely okay, so suspect something in the output. Unfortunately, there also isn't anything *between* the DSP and the output connector, so it may be the DSP chip after all. (Jonathan Deitch)

When swapping RFM to SWE1 the sound might no longer work and you might see the message U109 error! This is no hardware defect but a Star Wars problem. You need the latest SWE1 sound software to be loaded and the the sound works fine again.

Problem: *Static comes on all three speakers during attract mode, particularly when there was no background sound and white text was displayed.*
Answer: There is "crosstalk" on the cable group between the PRISM board and the amplifier board. This cable group is several cables, which are tied together with nylon tie wraps. Cut and discard the nylon tie wraps (separating the cables), and the static problem should go away.

If the static is still present, changed the 04-12621 audio amplifier board. The audio amp is a small board inside the backbox's computer box, which connects to the PRISM card. Sometimes the old amp, when failing, can cranking out way too much volume even at the lowest settings.

3h. Software Updates.

There are 3 ways to update the Pinball2000 game software.

- Change the complete PRISM card to a one with newer Software on it
- Update the game via Laptop, serial cable and Pinball2000 upgrade manager
- Program a PUB (prism update) Card in your PC and plug it into the Pinball2000 game

Updating a Pinball 2000 Game using a Computer.
A new system has been designed to update the game and sound software in your Pinball 2000 System. Software updates are now stored on the PRISM card in your CPU box, no erasing and programming of EPROM chips is necessary.

The following is required to update your Pinball 2000 machine:

- A PC running Windows 95 or Windows 98 with approximately 10 megabytes of disk space.
- A serial "null-modem" cable to connect the PC to the pinball machine. A "Null Modem" connector defines a connector that crosses the wires between pins 2 and 3 (that is, pin 2 of the first connector is connected to pin 3 of the other connector).
- Update software, available from Williams (Pinball.com).

Step 1: Download the Update Manager from the website.
The Update Manager handles the transfer of the game program from your PC to the Pinball 2000 system. You only need one copy of the Update Manager for all Pinball 2000 machines. If you do not have the Pinball 2000 Update Manager, go to Pinball.com to download this to the PC. If you have downloaded the Revenge From Mars update software, this is not the same program. Download the Update Manager as well.

Step 2: Download the software update file from the website.
Again, go to Pinball.com and download to your local PC. Save the file into a temporary area on your PC. **Do not change the filename when saving this to your PC!** Also you do *not* need the "Pub" version of this software (this is for use with a "Pub Card", which we are not using here). Download both the Program and Sound updates.

Step 3: Install the Update Manager, if not already done.
From the Windows Explorer, locate the Pin2000_UpMgr_120.exe file on your PC and double-click to start the Setup program. Follow the instructions and prompts to install the program on your PC.

Step 4: Connect the PC to the Pinball 2000 Machine/
With your Pinball 2000 system turned off, connect the serial port "null-modem" cable from your PC to the serial port inside the coin door. If your cable has thumbscrews, tighten them to make sure the cable does not become disconnected during the update process. Once the two machines are connected, power up the Pinball 2000 system.

Step 5: Run the Pinball 2000 Update Manager on the PC.
Once the Pinball 2000 Update Manager is installed, double-click the Pinball 2000 Update Manager icon on your desktop. Under the 'Connection Port' box on the Update Manager window, select the serial port on the PC that you will be using (COM1 or COM2. On most PCs, the external serial port is COM1).

Once the proper serial port is selected, confirm that the Pinball 2000 game is powered up. Click on the 'Connect to Game' button on the upper right of the Update Manager window. The program will connect to the pinball machine and report back the model number and software revision found (example: 50070 = Revenge From Mars, 0.82 = Software Revision 0.82).

In the middle box on the upper right, select the drive letter that is holding the software update file that you downloaded from the website. Click on 'Scan Drive for Updates' to locate all the software updates related to this model number. This will scan your entire C: hard drive for the Pinball 2000 software (this is why the filenames of the update software can *not* be changed!)

Click and highlight the update version to upload to your Pinball 2000 system, then click the Update button to begin the upload process.

Step 6: Do not disturb!
The update process may take up to 10 minutes to complete. A bar graph will be shown on the pinball screen and in the Update Manager window to show approximate progress, but do NOT disconnect once the bar has reached the end. The system needs to reset itself before the update is considered complete.

Once the machine is rebooted and running in attract mode, the Update Manager will reconnect to verify that the update is successful.

Step 7: Disconnect Cables
Congratulations, all done with the software update!

3i. Misc Problems.

Problem: **The game automatically recycles the balls,** on power up or whenever the coin door is opened and closed. The game works perfectly but recycles upon each new powerup.

Answer: a bad trough eject optic (number 41). Replacing this optic fixed the problem.

Problem:**My RFM machine has on three occasions failed to boot.** When turning on the power, the screen is completely blank on no lights appear on the playfield (only the backglass powers up). I've looked over everything in the PC case and nothing seems loose. The only "fix" to this problem was a good whack on the outside of the PC case. Not a comforting solution, especially since this game is new.

Answer: The couple of times I have seen this it has been the same thing: the Prism card is not seated properly in its slot. It looks like it's in, the screw holding the one side to the bulkhead is in, you press on the card and it feels like it's in, but it's not. With the power off, open the lid to the PC box and with the heel of your hand press VERY FIRMLY on the free end of the Prism card (the end away from the bulkhead. I'm betting you will feel it THUNK down in another millimeter or two. Also try removing the screw, pulling the card out and putting it back in square to begin with (since if it's cockeyed like that, the high corner of the card may be catching on the housing of the PCI slot connector.) Also trying another slot in the mother board is a good idea.

Problem: **During gameplay sometimes the pictures on screen looked like they were recorded during an earthquake.**

Answer: Reaseating the connectors to the computer-case (at least the 15 pin VGA/CGA conector) resolved the problem.

Problem: **Pin 2000 Software Update program will not connect to the game.**

Answer: Make sure that the filenames are EXACTLY as indicated by the source files on the web site. If the update manager still can't find them, move them to the "Pinball 2000 Update Manager" subdirectory under "Program Files\Pin2000" (assuming that is the install directory). Remember after connecting to the game, the update manager will scan all the drives/directories for those exact filenames.

Now check the serial port cable on the Pinball 2000 game, which runs from the coin door to the computer in the backbox. Remember on Star Wars E1, this serial cable "splits" (so the backbox can be easily removed), and the splits much be connected at the back of the game. Lastly check the small ribbon cables inside the computer box. These connect the box's outside serial plugs to the motherboard. Sometimes these are connected *backwards* from the factory!

Try connecting to the back of the computer directly, instead of through the coin door serial connection.

Also make sure the communication is over the COM1 port, and doesn't have any other program active that tries to grab the COM1 port on the connecting computer.

If "fupdate" still continues to fail, check the null modem cable and power off/on the game after the game is connected to the connecting computer, and try again. Try not to have other DOS sessions open (I've had fupdate fail with other DOS sessions open)

If all else fails, run FUPDATE directly:

```
fupdate -b115200 -debug COM1
```

Also check to see if things like Dial up Networking or modem drivers are "claiming" a serial port and locking it out on the connecting computer.

Problem: **Light from the florescent tube is "bleeding" out around the monitor.**

Answer: Add another layer of weather stripping around the corners and monitor edge nearest the front of the backbox. The original weather stripping's glue had come loose, allowing light to bleed past the monitor. This light reflects off the top glass, decreasing the 3-D affect of the computer animation.

What happens is that the strip got stretched around the monitor when originally installed. Eventually the glue lets go and the ends shrink back away from each other to release the tension. Putting it on with less tension, or even (for goodness' sake!) putting it on with the gap on the other side of the monitor (so when it comes apart you don't have light in the worst possible place) would have been great solutions.

You can buy similar stuff at any hardware store. Strips of sticky-backed foam, used for weatherstripping, usually comes in a roll in a plastic bag. I believe some pinheads already have some around as a replacement for the foam on older EM lockdown bars. Just cut a few lengths of it and stick them in the gap. You might need to stick some pieces on top of other pieces to block all the light, but you shouldn't need more than a couple of inches total.

Problem: **The translight's florescent light is not working.**

Answer: The florescent light in pinball 2000 uses a standard 120 volt .35amp "ballast" (a small florescent transformer), a 120 volt FS2 starter, and a F15WT8/35 18" (15w=15 watts, "T8" is the diameter where T8=8/8=1", 35 is the color degree [also seen is "CW"=cool white or "D"=daytime], 18" long) florescent tube. Regardless of where the game is operated, the florescent light runs at 120 volts (just like the PC computer). So even if the game is jumpered and running in a 240 volt country, the florescent lamp is still running at 120 volts.

When a florescent tube immediately blows on powerup, it is usually caused by a shorted ballast. Since there is no ballast resistance and hence no way of limiting the initial current flow to the elements in either end of the tube, bang the tube

is blown. A ballast should always be warm when in operation, in confined spaces with no air flow it will get very warm. But the construction of the ballast should have a large enough surface area to allow heat dissipation.

Replacement 120 volt ballasts can be purchased at any hardware (Home Depot) or a lighting store. But note, if a game is operated overseas in a 220/240 volt 50 Hz environment, the replacement ballast should be capable of running at 50 or 60 Hz. If a 60 Hz ballast is used in a 50 Hz environment, the ballast will run hot and die quickly. So for European users a good replacement is available from Robertson (1-800-922-9226) who makes a 50/60 Hz ballast, number SP1556. Fortunately the cost of this ballast is low, but the shipping and tax cost to the U.K. is quite high (perhaps as much as twice the cost of the actual ballast). Thanks to C.King for this information.

Problem: **None of my keys will open the backbox - either the front or back.** I have both sets of keys, the coin door and the playfield security lock, and they work fine, but neither of them fit in the backbox locks.

Answer: The key that unlocks the back of the backbox will indeed open the backglass lock. The problem is the locking arm gets jammed over the CPU box and the lock won't turn. Try sticking your arm back there (through the back) and freeing it manually. Since my game was already in place against the wall, I gave the lock an extra twist with a pair of pliers before resorting to moving it and the lock turned finally. Of course, this approach risks a key broken off in the lock, so watch it!

Problem: **My SWE1's neon lamp is not working.**

Answer: First check that 12 volts is present going *into* the neon lamp's transformer (is fuse 108 blown?) The neon transformer is mounted inside the black handle of the light saber. The easiest way is to check for 12 volts at the Molex connector going to the transformer (under the playfield), or at the power driver board connector J111 pin 9. If 12 volts is getting to the transformer, next make sure the return path to ground is being completed (this is handled by a MosFET transistor on power driver board). Ground the black wire on the Molex connector going to the neon transformer. Does the neon tube turn on? If not (is the neon tube itself damaged? very unlikely), the neon transformer itself is probably bad. If the neon does light when the black wire is grounded, then the MosFET transistor and/or the ULN2803 chip at U35 on the power driver board have most likely failed (or the wire going to the power driver board has broken.

If the 12 volts is present at the neon transformer, and grounding the black wire does not light the neon tube, then the neon transformer is probably at fault. The neon transformer takes 12 volts DC and converts it to a very high voltage (about 1500 volts, at low current). Because of this, to get the UL rating, Williams was required to rivit close a plastic case around the transformer! To access the transformer, the rivits will need to be drilled out with a 1/8" drill bit (or grind off the heads of the rivets). On SWE1, do not try and remove the decorative plastic "light saber handle" from half of the plastic transformer case! (they uses silicon to attach it, and it does not come off without destroying the decorative plastic!)

Once the rivits are removed, the transformer can be removed and checked. Is there any high voltage (1500 volts DC) being output? If your DMM does not go this high, just replace the transformer. The cheapest way is to buy a car neon

license plate transformer. If needed, wire the automobile neon transformer under the PF (if it doesn't fit in the ramp housing), and run the high voltage wire up to the ramp and bulb. Note if you do this to be sure to use wire rated for at least 2000 Volts (it'll have thick insulation; look at the wire already on the bulb if you need some reference).

Specs for the original neon transformer are **here**. The original Williams SWE1 transformer (part number 04-10947) may also still be available. The original transformer for SWE1 (and Cirqus Voltaire) was a Ventex model VT12D5, but they seem to have changed their model numbers so now it's VT1510-12. A replacement is Ventex model NPS-12D5 and it fits and works fine. Key specs are input 12 volts DC at 0.6A, and output 1500V 5mA. You can find it at www.ventextech.com/lowv.htm. Note the output connector will need to be changed to a Molex connector. Another transformer source is www.sunsupply.com/transformers/winind.html.

Testing the neon tube itself, without using the high voltage transformer, and not that easy. There is no to test a neon tube with a DMM - basically the gas inside the tube conducts electricity. So basically a DMM can't generate a big enough voltage to test it. They make little inductive testers - the tube will glow when this thing is held near the neon tube, if the gas is still in there. Also try taking the neon under some high voltage power lines at night to see if it glows (and to scare yourself about how much energy is leaking out of them!)

Problem: **Tell me about Pinball 2000 serial numbers.**

Answer: Because Pinball 2000 shipped in two separate containers (body and head) and the heads were universal (not country-specific), they decided to give them each their own serial number, in the normal random fashion, but all out of the same pool of numbers. So twice as many serial numbers got used up as there were games. This created all sorts of problems, but they hadn't come up with a solution by the time of the SW:EI MEL (Mechanical Engineering Lab) games. So my game, at 000051, is the 26th MEL game (my head has serial number 000050). But for production they came up with some other scheme - I believe they gave the heads numbers in a different range (the beginning digits were somehow different). I'm not sure what number they started on, could have been 000052, or it could have been 000100. No attempt was made to make the body and head serial numbers always be the same way odd/even, or to be sequential, so your head could have just about any number!

Problem: **Tell me about country specific differences in Pinball 2000 games.**

Answer: The Pinball2000 tops are 100% identical all over the world - no country specific packages. The Pinball2000 bodys have been packed country specific with following differences:

- the coin door (e.g. german Pin2000 have an electronic Mars coin acceptor).
- the transformer jumper, which for worldmarket can be easily jumpered for different voltages.
- the country DIP switch settings on the powerdriver (mainly only for default language and coin setting).
- the different power cord and main fuse (e.g. half value for 220V compared to 110V countries).

- the manual package, which might cointain translated parts.

Problem: **Tell me about the differences between RFM and SWE1.**

Answer: There seem to be several little technical and mechanical differences between Star Wars and Revenge.

- There is a Backbox connector for the serial cable on SW:E1, which makes the game assembly much easier. On RFM, the serial cable must be fished from the back of the game to the coin door.
- There is a clamp at the end of the SW:E1 playfield, which fixes the playfield when raised, so it does not lean against the backbox.

Problem: **I got a SWE1 playfield, and put the SWE1 PROMS in my current PRISM card, and swapped the playfield into my RFM. During the boot sequence it had the following message: [UPDATE MISMATCH].** When the game started there was no sound except when the ball would hit bumpers and slingshots. I went to the test and read the test report it had the following entries:

- DCS Checksum test failed (U109)
- Check Lamp Column 6B
- Check Lamp 73B left sling GI Lower.

I reseated PROM U109 and rebooted, but had the same problem. What am I doing wrong?

Answer: Since the PRISM card had a RFM update image in the flash ROMs with RFM PROMs installed. It says [UPDATE MISMATCH] because the update (RFM) doesn't match the PROMs (SWE1). All the other errors listed are probably also caused by this.

To fix this, boot the game with the PRISM board and RFM PROMs installed in it. Once it's up and running, go to the Utilities Menu and disable the update. This will force the machine to boot from the PROMs. Now put the SWE1 PROMs back in. Once the system boots, install the latest flash SWE1 update.

It's supposed to effectively do that for you: when you fire up the game with ROMs from one game, but the latest update of the other game is still in Flash, it should say "update mismatch", disable the updates, and then the Flash updater can be run without problems. What it is doing is getting confused and sort of running the mismatched update anyway. But unfortunately this PREVENTS the Flash updater from running!! So you have to manually go into the menu and disable updates first... If you update with a PUB card it doesn't happen, because of the way the PUB card takes over the machine.

4a. Networking Pinball 2000.

Pin2000 uses PC-Xinu as the basis of its core OS, although WMS added a lot of functionality to it. This was the decision of Tom Uban who was the chief software engineer on the project and all-round hardcore superstar programmer in general. PC-Xinu already includes a TCP/IP stack, and he had already written a packet driver for one kind of Ethernet card because all the code and image downloads for development were done via ethernet. A really simple web server

wasn't too hard to write on top of that - all the statistics it reports are already collected by the game and displayed on-screen in the administration menus.

Louis Koziarz described the decision to use the PC-Xina operating system: "XINA (the Williams written Pin2000 operating system) is an application layer on top of PC-Xinu, which is a multithreaded operating system. Originally created by Douglas Comer, he documented it in a very well known two volume set of books (see public.ise.canberra.edu.au/~chrisc/xinu.html for more details).

PC-Xinu won over other operating systems for a few reasons. For example, making Linux into a real-time system with thread support would involve modifying the kernel. This would then obligate Williams into releasing the kernel modifications to the plubic, under the GPL. Williams legal didn't like that. Comer's Xinu license was much more friendly for the lawyers; WMS could do anything they wanted to it with no obligations.

Xinu also turned out to be quite easy to turn into a real-time system. And in the end, proved to be as easy as Linux or BSD to work with in an embedded application."

Pinball Expo 1999.
The TCP/IP stack was demo'ed at Pinball Expo in 1999, where there was a tournament automatically running. Barcode badges were made for entrants. This allowed them to walk up to a game, swiped the badge in a barcode reader, play, and their score was recorded. Their picture was also taken with a webcam and printed on the badge, and the games showed the current high score list including their digitized pictures on all the tournament games during their attract mode (while they weren't being played).

Why add an Ethernet card to your pinball 2000 game?
Good question! Maybe because you saw the SW:E1 machines network-linked together at Pinball Expo '99. Maybe because with an Ethernet card installed you can access your RFM's internal commands via the Internet (to check earnings, diagnostics, etc). Or perhaps you own more than one PB2K machine and you're going to have your own tournament.

Ethernet Card Specifications
Pinball 2000 only supports one brand of Ethernet Card, an **SMC (brand) ETHEREZ 16BIT ISA 10MBPS RJ-45** network card (mfg part# SMC8416T, typically goes for $31 USD at places like http://www.buy.com/ or Ebay, but this card is becoming increasing difficult to find). This network card needs to be installed into the extra ISA slot in the RFM (v1.4 or higher) or SWE1 (v1.4 only) pinball machine motherboard. After the settings are configured for the network adjustments, you can connect to the XINA command shell via telnet or alternately you can connect to the machine using a web browser (a simple httpd server is built in!).

To all trying to add networking to a Pinball 2000 game: The networking capabilities of P2000 were added and activated about a week or two before Pinball Expo 1999. And one day after the Expo, Williams pinball was shut down! Tom Uban rushed to get the networking added for the Pinball Expo 1999, so he standardized on a network card that he had access to, and that was easy to write into the system. There were no plans to "lock" into a certain brand of

network card. But because Williams closed down pinball, that's essentially what happened.

Ethernet Configuration Instructions.
Note that depending on the motherboard in the RFM machine, you may have to adjust the BIOS setup setting prior to getting the network card working in order to avoid an IRQ conflict. This can be determined if there is a problem by configuring the network adjustments, setting an IP address/mask, and then using the keyboard (or serial port) to access a command prompt and run 'ping'. If the 'ping' works (the lights on the card blink or device on the network responds to the ping, etc.), then you don't need to change the BIOS. If you get some kind of "ez" error message, then you will have to do the following:

> Remove the PRISM board, plug in a keyboard and power up the box. If you are lucky and the monitor "syncs up" to the BIOS screen, then you can see what you are doing. If not, you may want to temporarily plug in a PC monitor instead of the Pin2000 monitor.
>
> Disable the 'Built in OnBoard Audio' in the 'Integrated Peripherals' menu. On some RFM motherboards, the onboard audio uses the IRQ that the default setting of the EtherEZ network card uses.
>
> Here are the key strokes that should effect the change:
>
> 1. Remove the PRISM board/plug in PC monitor and keyboard
> 2. Power up (you will see the normal PC BIOS startup because the PRISM card is out).
> 3. Press DEL to enter setup (the BIOS setup should appear).
> 4. Press the RIGHT ARROW key (move to the INTEGRATED PERIPHERALS menu).
> 5. Press the ENTER key (enter the INTEGRATED PERIPHERALS menu).
> 6. Press the RIGHT ARROW key (move to the right hand column of menu items).
> 7. Press the DOWN ARROW key (move to the BUILT IN ONBOARD AUDIO menu).
> 8. Press the PAGE UP key (change the adjustment from ENABLE to DISABLE).
> 9. Press the ESC key (leave the INTEGRATED PERIPHERALS menu).
> 10. Press the DOWN ARROW key (move to the SAVE AND EXIT menu).
> 11. Press the DOWN ARROW key.
> 12. Press the DOWN ARROW key.
> 13. Press the ENTER key (SAVE AND EXIT).
> 14. Press the Y key (confirm).
> 15. Press the ENTER key (do it).
> 16. Replace the PRISM board.

The default username / password are set to "PIN2000" and "MANAGER" (respectively), which you may want to change since all RFM machines are initially set to the same values (but who would want to hack into a pinball machine?)

XINA commands.
The Xina operator system has its own commands, which are available at marvin3m.com/pin2000/xina.htm.

Below are some notes from other users and their own networking experiences.

This weekend, I got my RFM up and running on our LAN using the information at http://members.home.net/ratherplaypinball/rfmnotes.htm (dead site). We're now attempting to write a frontend for the shell commands, with the ultimate goal being a frontend that can start a game, launch balls and use the flippers. This would be combined with a good webcam and MS Media Server stream to facilitate someone playing my RFM over the Internet.

Regardless of the outcome of this project, the ability to telnet into the game while it's being played is great, if only for the world of opportunities one has to mess with their (unsuspecting) friends while they're playing . The game tilt, scenemgr and flip commands alone can wreak havok on an unsuspecting player :) "Hey! These flippers are possessed!! Tilt?!?! I never touched it! And why is it starting Attack Mars already??" Muhahahaa :)

Another user: Installed a SMC 8416 Ethernet Card in my RFM. After disabling the onboard sound, the ethernet card should work fine. Afterwards I took a PC with WIN98 and plugged in an ethernet card, installed Internet Explorer and started setup. A static IP adress has to be setup in the PC (normally ISPs need dynamic IP adresses). I selected 168.0.0.2 for the PC. In the communication options of RFM the own IP adress has to be set and I selected 168.0.0.1. After that the RFM was rebooted. Then TELNET could connect to the RFM and also Internet Explorer could display the PIN2000 Webpage on RFM.

The communication options of RFM offer lots of settings. I detected this when entering the PC's IP address as 'Tourney Address' and activate tournament mode, the game hangs up at game over (and seem to try a webserver update). An IP observer tool finds 'attacks' on my PC Port 2069 when the RFM boots or ends game. The Port 5001 of Pin2000 wants to establish a UDP connection to Port 2069 of my PC. The tournament functions already seem to be implemented on RFM 1.4!

I also find in the game info display, that there is a card_no display for the current player, also some info about tournament functions.

End of Pinball 2000 document

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* Go to the Pin Fix-It Index at http://marvin3m.com/fix.htm
* Go to Marvin's Marvelous Mechanical Museum at http://marvin3m.com