Williams System 3 - 7

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1 Introduction

Williams entered the SS (http://www.pinwiki.com/index.php?title=Glossary#Solid_State_.28SS.29) or Solid State era with a conversion of a 1976 Williams EM (http://www.pinwiki.com/index.php?title=Glossary#Electro_Mechanical_.28EM.29) or Electro Mechanical pinball game called Grand Prix (http://www.ipdb.org/machine.cgi?id=4828) .

System 1 is considered to be the Solid State version of *Grand Prix*. It is thought that about 5 Grand Prix EM games were converted to SS prototypes using the new System 1 MPU Board and digital displays. The computer was only used for accumulating and displaying the player scores.

IPDB links: Grand Prix SS version (http://www.ipdb.org/machine.cgi?id=5647) Grand Prix EM version (http://www.ipdb.org/machine.cgi?id=1072)

System 2 was next, with a 10 unit run of another 1976 EM game called *Aztec*. A working SS version is very rare. Both System 1 & 2 occurred quickly after each other at the end of 1976. Aztec SS was still a hybrid machine retaining the EM chime unit in the cabinet and a credit window with an EM numbered reel behind the backglass). Player scoring was still the only digital function at that time.

IPDB links: Aztec SS version (http://www.ipdb.org/machine.cgi?id=4828) Aztec EM version (http://www.ipdb.org/machine.cgi?id=119)

System 3 games were the first Williams SS production games, starting with *Hot Tip* in Nov. '77 and ending with *Disco Fever* in Aug '78. There were based on the Motorola 6800 8-bit CPU and using a Motorola 6820 PIA (Peripheral Interface Adapter) to handle the Display I/O from the MPU board. They also had three other 6820 PIAs on the Driver Board reading targets and other switches as inputs and controlling the insert Lamps and solenoids as outputs. Solenoid drives were mainly used for ball handling by firing coils, with a few triggering sound calls or a 'start of game' tune. This was the start of Williams using computers for game rules and settings. At this point they designed an 8x8 Switch Matrix, an 8x8 Lamp Matrix and solenoids driven by Darlington transistors. This design remained virtually unchanged to the end of Williams System 7.

During System 3 (*Phoenix* and *Disco Fever*) a memory protect circuit modification was added as to help protect CMOS RAM data during power up and power down of the game. DIP switches were used to program game settings (such as # of balls per game, high score replays).

System 4 games ran from *Pokerino* in Nov '78 through to *Stellar Wars* in Mar '79, according to IPDB.com. A notable game which outsold all of the other System 4 games combined with a production run of 19,505 was *Flash* (Steve Ritchie's first designed game for Williams). During System 4, Williams moved from using DIP switches to change game settings to having the game settings changed from the coin door switches. The settings were still stored in battery protected CMOS RAM. [ed Note: Citation needed] A coin door interlock switch enforced that CMOS memory could not be modified unless the coin door had been opened by the operator. Some of the game audits (coins accepted, total number of games played, etc.) still could not be changed without access to the MPU board behind the backglass.

System 6 games ran from *Tri Zone* in Jul '79 to *Scorpion* in Jul '80. Two notable games from this era were from the end of '79 and the beginning of '80 *Gorgar* and *Firepower*. Gorgar (14,000 produced) was the first talking pinball, and Firepower (17,410 produced) both talked and introduced the 'Lane Change' and 'Multiball (tm)' features to SS games. Note that there had been Multiball play available in EM games, it just wasn't called Multiball (tm) until Firepower. and this is a common misunderstanding. The features these games introduced became standards for almost all pinball games produced right up until today.

System 6a deserves to be mentioned here as it marked a transition to System 7. The game *Alien Poker* from Oct '80 used the Syatem 6a MPU board (which was not very different from System 6). But it supported 7 digit scoring displays and a redesigned Master Display Driver board, located behind the backglass on the back of the 'Lamp

Board'. It also used a special 4 digit "credit/match" display in the approximate position where the System 6 Master Display Driver had been showing the same information (on a 6 digit display, with 2 of the digits unused). This new 7 digit scoring displays with a 4 digit credit/match display were then used in all the System 7 games (and System 9).

System 7 games ran from *Black Knight* in Nov '80 through to *Star Light* in Jun '84.

IPDB link: Complete System 7 Game list (http://www.ipdb.org/search.pl?mpu=4&qh=checked&ng=checked&sortby=date&searchtype=advanced)

Black Knight (13,075 produced) introduced a two level playing field and Magna-Save (tm) where the ball could be stopped from draining down the sides by pressing a cabinet button that activated an electromagnet. *Star Light* (100 produced) was a 'boutique' game by Williams' production standards as the focus was on ramping up production for the first System 9 game Space Shuttle (7,000 units). At least one Star Light game was made as the Prototype for System 9.

System 8 was used on a single game *Pennant Fever* in May '84. This was a 2 player 'Pitch and Bat' game with men running round bases. It was the first solid state 'Pitch and Bat' that Williams produced. System 8 was never used for pinball games.

Further discussion of changes and good pictures of the backbox boards for System 3-7 games can be found here: Tukkan.fliput.net (http://tuukan.fliput.net/wms_en.html)

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2 Games

2.1 System 3

Title	Date of Release	Model #	Sound	Other Boards	Notes
Hot Tip	11-1977	477	Chimes		
Lucky Seven	03-1978	480	Chimes		
World Cup	05-1978	481	Type 1 Sound		
Contact	05-1978	482	Type 1 Sound		Widebody
Disco Fever	08-1978	483	Type 1 Sound		Used banana flippers

2.2 System 4

Title	Date of Release	Model #	Sound	Other Boards	Notes
Pokerino	10-1978	488	Type 1 Sound		Widebody
Phoenix	11-1978	485	Type 1 Sound		
Flash	01-1979	486	Type 1 Sound		First game with continuous Background sound/Later games produced on System 6 platform
Stellar Wars	03-1979	490	Type 1 Sound		Widebody

2.3 System 6

Title	Date of Release	Model #	Sound	Other Boards	Notes
Tri Zone	07-1979	487	Type 1 Sound		
Time Warp	09-1979	489	Type 1 Sound		Used banana flippers for most of run.
Gorgar	12-1979	496	Type 2 Sound w/ Speech		First game with speech
Laser Ball	12-1979	493	Type 1 Sound		Widebody
Firepower	02-1980	497	Type 2 Sound w/ Speech		First SS Multiball (3 balls). First lane change.
Blackout	06-1980	495	Type 2 Sound w/ Speech		
Scorpion	07-1980	494	Type 1 Sound		Widebody

2.4 System 6A

Title	Date of Release	Model #	Sound	Other Boards	Notes
Algar	09-1980	499	Type 1 Sound	7 digit display board	Widebody
Alien Poker	10-1980	501	Type 2 Sound w/ Speech	7 digit display board	

2.5 System 7

Title	Date of Release	Model #	Sound	Other Boards	Notes
Black Knight	11-1980	500	Type 2 Sound w/ Speech		First game with magnasave
Jungle Lord	02-1981	503	Type 2 Sound w/ Speech		
Pharaoh	05-1981	504	Type 2 Sound w/ Speech		
Solar Fire	07-1981	507	Type 2 Sound		
Barracora	09-1981	510	Type 2 Sound		
Hyperball	12-1981	509	Type 2 Sound	Uses different driver board than pinball games	Not a pinball - a flipperless game firing tiny pinballs
Cosmic Gunfight	06-1982	502	Type 2 Sound		
Varkon	09-1982	512	Type 2 Sound		Pinball in stand-up Video cabinet
Warlok	10-1982	516	Type 2 Sound		
Defender	12-1982	517	Type 2 Sound		
Time Fantasy	03-1983	515	Type 2 Sound		
Joust	04-1983	519	Type 2 Sound		Two player head-to-head pinball
Firepower II	08-1983	521	Type 2 Sound		
Laser Cue	02-1984	520	Type 2 Sound		
Star Light	06-1984	530	Type 2 Sound		

Game date of release and model numbers provided by the Internet Pinball Database - http://www.ipdb.org

3 Technical Info

3.1 Backbox Overview

++++++Need backbox overview pics of System 3, 4, 6, 6A, and 7 games++++++
The Williams backbox is similar for most of the games in the System 3-7 games. System 7 was the biggest step change, System 3-6 are very similar in their Backbox layouts.

- During the beginning of System 7 the transformer moved to the bottom cabinet,
- The System 7 PSU was redesigned and changed to incorporate a G.I. relay,
- An upgraded System 7 MPU (or CPU) Board was used.

Some games do not use the optional speech board, early games had no sound boards in the backbox at all! Other than that many of the components and connections were standard and so we will use the System 6 backbox boards as a baseline. Here is a document that shows the System 6 backbox and components in detail, and will help you become familiar with them: System 6 Backbox Wiring Diagram

3.2 Fuses

Power Supply Fuse Table

Williams System 3 - 7 Fuse Ratings							
System	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**
3	1/4amp SB	2 1/2amp SB	8amp FB	15amp FB	4amp SB	NA	NA
4	1/4amp SB	2 1/2amp SB	8amp FB	not used	4amp FB	NA	NA
6	1/4amp SB	2 1/2amp SB	8amp FB	10amp FB	4amp FB	NA	NA
7	1/4amp SB	2 1/2amp SB	8amp FB	not used	7amp SB	7amp SB	NA

Other fuses

3.3 MPU Boards

3.3.1 System 3

Williams System 3 MPU Board

System 3 was a major step by Williams to digital pinball games. It ushered in the Solid State machines, but to begin with there were problems with acceptance of the new machines.

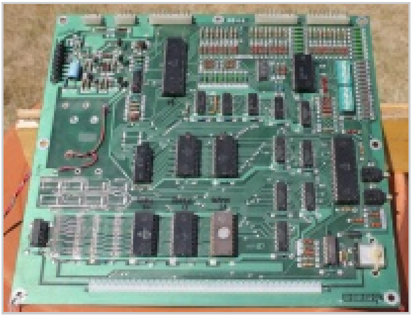
Williams had the Driver board firing the solenoids on Chime units on the first two System 3 games, and even had a device called a 'noisemaker' (an EM score reel mounted in the body of the game) to provide the sounds of the score reels clicking over! This gave the player the familiar sounds of EM machines which were still around, The player's scoring, their credits remaining and the ball-in-play were all digital and being displayed on the seven-segment gas plasma displays.

Even once they dropped the chimes and 'noisemaker' (for World Cup in May 1978) and added a digital sound board, the operator could still select the more familiar 'bings & bongs'. A switch was provided on the sound board which allowed selection of simple digital chimes. This option persisted right through on System 3 to System 7 sound boards, but for the most part was not used. Digital sound became more popular as time went on.

The design of System 3 was based on the Motorola 6800 CPU and what has become a standard arcade peripheral I/O device, the 6821 PIA (originally the 6820). The PIA (or Peripheral Interface Adapter) on the MPU boards was used to drive the display I/O. All other peripherals, switches, lamps, solenoids, and sound, are driven by the 3 PIAs on the driver board.

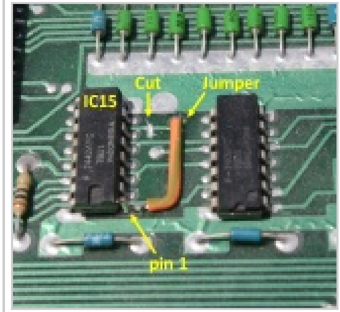
3.3.1.1 Upgrading a System 3 board to System 4

A system 3 MPU can be upgraded to use a single 2716 EPROM at what will be IC14 (System 3 schematics do not give this IC position a designation number). This essentially converts the board to a System 4 board. This upgrade is useful to reduce the number of sockets (and failure points). Install a 24 pin socket at the unpopulated area, just to the right of the IC17 socket. Combine the original game ROM code into a single 2716, and install it into the socket of what is now being called IC14. The flipper ROMs are installed in the same locations, ROM 1 into IC20, ROM 2 into IC17.


Overview of a board converted from System 3 to System 4

Procedure:

1. Locate IC15 on the MPU (see picture at left)
2. Locate the trace that runs from between pins 6 and 7 of IC15 to a via just to the right of the chip
3. Sever that trace carefully
4. Using jumper wire, connect the through hole via to pin 1 of IC15.

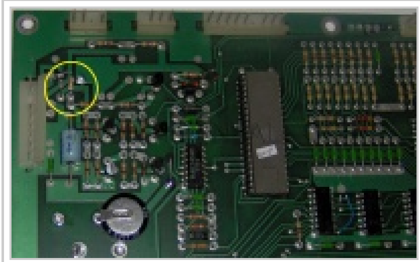


IC15 (on left), showing necessary cut and jumper

Doublecheck the work once the jumper is installed. Perform a continuity test between pin 1 and pin 9 of IC15. There should not be continuity. Conversely, there should now be continuity between pin 1 of IC15, and pin 20 of IC14.


Components which must be removed from a stock System 3 MPU board

Another modification which has to be performed on a System 3 MPU board is to replace some of the components in the reset circuit. This upgrade was recommended by Williams in manual amendment 16P-482-110, and is done to improve protection to the CMOS RAM memory content during turn-on / turn-off.

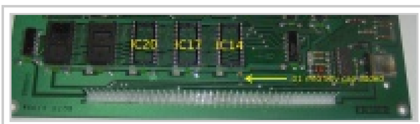

10 Kohm 1/4 w resistor added to circuit

Procedure:

1. Locate capacitor C27 and resistors R30 and R40 in the upper left corner of the board
2. Remove C27, R30, and R40
3. Install a 10 Kohm 1/4 watt resistor. One leg of the resistor will be soldered to the cathode of ZR1 (banded side - top). The other leg of the resistor will be soldered to the left through hole where R30 formerly was. The newly installed 10 Kohm resistor is referred to as R96 in System 4 MPU schematics.

Addition of the D19 1N4148 diode installed

It is recommended to install a 1N4148 diode, if it is not already installed. The location is in the upper left quadrant of the cicuit board. The anode (non-banded side) of the diode should be installed in a via, which is just to the right of resistor R23. This via is routed to pin 17 of IC19. The cathode (banded side) of the diode



Addition of the C68 .01mfd 50v capacitor installed should be tack soldered to the solder pad where the right leg of resistor R23 is installed. Once installed, this 1N4148 diode is referred to as D19 on System 4 MPU schematics.

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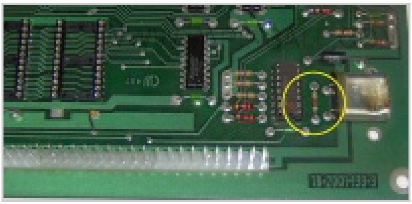
Another recommendation is to install a .01mfd 50v capacitor just below the newly installed IC14 socket. One leg of the capacitor goes to +5v, while the other leg is inserted in a via which is routed to the /RESET line.



Addition a capacitor and inductor to the R1 resistor

Although it is not shown, it is recommended to add a 120pF capacitor (C66) and a 15uH inductor (L1) in parallel with the R1 resistor located just to the left of the crystal. This modification also applies to System 4 boards which do not have these components already installed.

Finally, if an incorrect capacitor is installed at position C22, (located just below IC19 - 5101 RAM), it is recommended to replace it. This replacement is only necessary, if a 0.1mfd cap is installed. If so, replace the 0.1mfd capacitor with a .01mfd 50v capacitor. This applies to System 4 MPU boards too.

Once the above modifications are performed, a System 3 MPU board will be one-to-one compatible with a System 4 board.

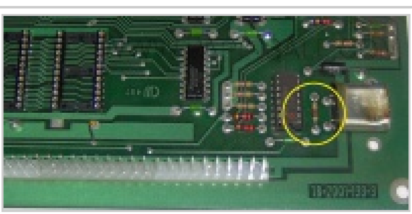
3.3.2 System 4

Williams System 4 MPU Board

The System 4 architecture is little changed from the previous System 3 generation. The only functional changes from System 3 to System 4 was a minor alteration to the reset circuit as well as minor changes to the data and address bus in order to more easily facilitate the use of larger EPROMS for the game specific programming.

System 4 machines began with Pokerino in 1978 and ended with Flash in 1979. Late production Flash machines also utilized the then-new System 6 boardest in place of System 4.

3.3.2.1 Upgrading a System 4 MPU Board

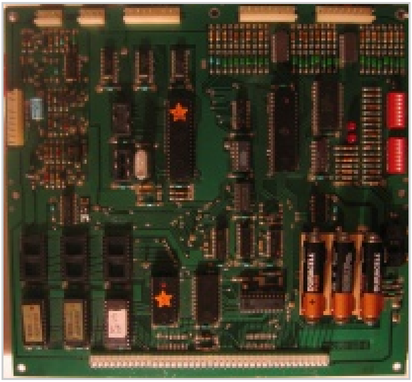


Addition a capacitor and inductor to the R1 resistor

Although not shown, it is recommended to add a 120pF capacitor (C66) and a 15uH inductor (L1) in parallel with the R1 resistor located just to the left of the crystal. This modification also applies to System 3 boards which do not have these components already installed.

If an incorrect capacitor is installed at position C22, (located just below IC19 - 5101 RAM), it is recommended to replace it. This replacement is only necessary, if a 0.1mfd cap is installed. If so, replace the 0.1mfd capacitor with a .01mfd 50v capacitor. This applies to System 3 MPU boards too.

3.3.3 System 6


Williams System 6 MPU Board

System 6 was an upgrade to the System 4 design, replacing the 6800 processor with a 6808. They took advantage of the internal clock in the 6808 CPU, removing the need for the 6875 clock generator (a companion chip to the 6800 and now obsolete and impossible to find).

This also changed the way the 'watchdog' circuit functioned. The watchdog monitors the CPU (IRQ signal), and will blank the displays and lamps as well as stopping the solenoids from firing. When something goes wrong (perhaps the MPU board has locked up), 'blanking' should prevent further damage to the game by 'locked on' coils and other output components driven from PIAs on the MPU/Driver boards.

More ROM memory could be addressed, and this was used to hold more sophisticated game code. As an example, Firepower used a 2716 2K Game ROM (which was standard for IC14) plus 3 x Harris bipolar proms (512 bytes each) giving a total game code size of 3,584 bytes. Having just 3K of code space is nothing by today's standards. Programmers had to work hard to get good game code in such a small space.

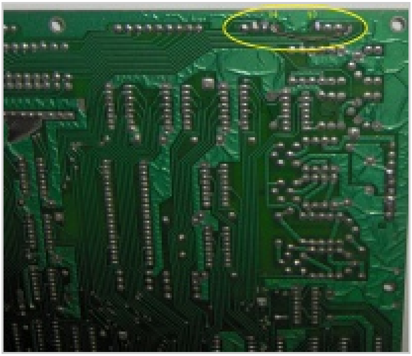
During early System 6 revisions the transceiver chips 8T28 ICs at IC9 and IC10 were found to not be needed. They were eliminated from the design as they didn't need to amplify signals to and from the data bus with modern ROMs. If the ICs are working, leave them alone. But if not, these buffers are obsolete and can be removed and bypassed, in effect by jumpering the data bus pins of the CPU directly to the data bus. On Firepower alone you must do the 'Combo ROM' modification, to allow the use of a 2732 Eprom as the Game ROM at IC14. This replaces the Firepower game code found in 4 ROMs as described above, and is an excellent idea. Less chips to worry about, less sockets to replace. All other System 3-6 games will use one 2716 2K Game ROM (or Eprom) in IC14.

Williams also moved to using the updated 6821 PIAs and the 6802 CPU during System 6. [ed note: A citation is needed for exactly when this happened, perhaps with verification from an original owner's game board? - all system 6 boards are 6802-sc]

The 6802 processor was the same architecture and 'backwards compatible' with the 6808, but had internal RAM, instead of the 128 x 8 bit MC6810 at IC13 which must be used with the 6808 CPU. Pin 36 is usually grounded on the 6808, and you can therefore use a 6802 on older boards and it will work, provided the external 6810 RAM is good. If you set Pin 36 of the 6802 "high" (usually through a 4.7K "pull up" resistor to the +5v logic rail) then the internal RAM is enabled. The 6810 (if not socketed) can usually be left in place. On System 6(a) boards, this is accomplished easily by removing jumper J1 and adding a 4.7K resistor at R4.

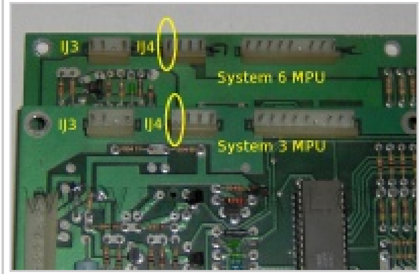
3.3.3.1 Factory Jumper on System 6 MPU Board

Some System 6 MPU boards have a jumper installed between IJ3 pin 1 and IJ4 pin 1. This is a factory jumper, and should not be removed. Its purpose is due to the addition of the memory protect circuit, which was incorporated with the System 6 MPU. System 3 and 4 MPU boards did not have a memory protect circuit. The method in which this was added is the addition of pin 1 of IJ4. This pin was formerly the keying pin on System 3 and 4 MPU boards. However, Williams failed to run a trace to this pin for the memory protect circuit. Hence, a jumper was installed.



Williams System 6 MPU board with factory jumper

If using a System 6 MPU board in a System 3 or 4 game, it is recommended to remove the keying plug from the IJ4 connector in the game, as opposed to cutting / removing pin 1 or IJ4. This will allow the MPU to be used in any System 6 games in the future.



Williams System 6 and System 3 MPU board comparison

3.3.4 System 6A

Williams System 6A MPU Board

3.3.5 System 7

Williams System 7 MPU Board

System 7 was considered a major step change. It had a redesigned MPU board, now supporting a single 7-segment LED display for indicating improved diagnostic information instead of the original 2 LEDs that System 3-6a MPU boards had used. It also added commas to the player scoring displays and moved the sound select support to the MPU board. An extra 6821 PIA supported both the sound/speech selects and the display of commas. An extra 12-pin header at 1J8 was added to provide connections for the new Sound and Commas support. This freed up five solenoid drives at positions #9-13 on the Driver board, which had been sound/speech selects. They were then available to drive extra game Coils or Flash Lamps.

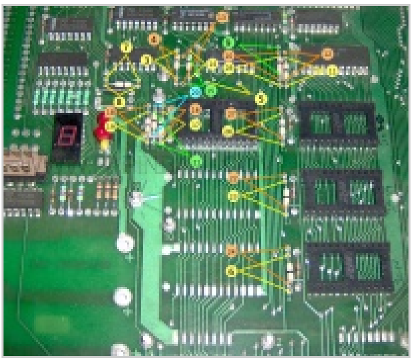
The MPU used two 2114 Static RAMs; these 1024 x 4 bit RAMs replaced the use of 6810 RAMs mentioned above. There was extended memory addressing, support for multiple 2732 ROMs (or EPROMS) as standard and a huge number of jumper selections available. The jumpers support various memory addressing schemes and ROM sizes, making the System 7 board MPU "backwards compatible" and able to emulate any of the previous System 4-6a games. (Provided, of course, that the correct Jumper Settings and EPROMS are installed.)

The Sound and Speech boards were unchanged for System 7; both sound and speech boards remained compatible from their introduction for Gorgar. In some cases the System 7 game had no 0.100" 40-way IDC header for the speech board connection. This was a cost saving measure made by Williams for games produced without speech.

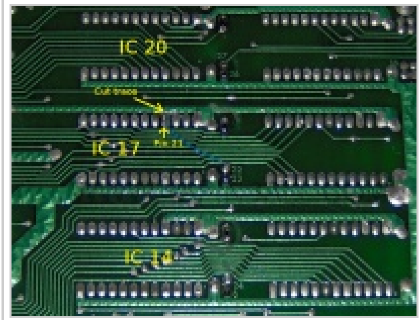
This connector is cheap and available today as it is still used for PC IDE hard drives and modern PCB connections. Adding this connector back to the sound board allows it to support a speech 'daughter board' by removing the Jumper at W1.

The Driver Board mates with the MPU board using 40 x 0.156" header pins on the MPU and female sockets on the Driver Board. This is a continual source of repair problems for this era of Williams machines. To solve this, when designing System 9 Williams combined the MPU and Driver Boards (and the Sound Board) onto a single PCB (Printed Circuit Board), and removed the problems associated with the now infamous Williams "40-way" connector. Only the speech board remained separate, as digital speech was considered an optional feature.

3.3.5.1 System 7 MPU Jumper Info



Positions of the jumpers on a System 7 MPU board



Solder side of a System 7 MPU board with modifications for a 2732 at position IC17

3.3.6 MPU Compatibility

Williams 3-7 MPU are pretty flexible. With some modifications, boards can be upward compatible, while others are downward compatible.

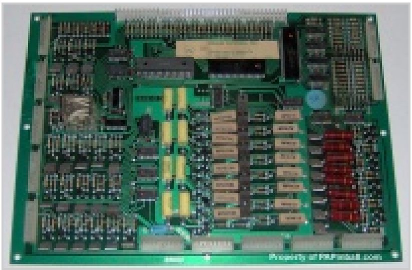
Here are the details:

- A System 3 MPU can be upward compatible to a System 4 MPU, if the upgrades are performed as laid out above (http://www.pinwiki.com/wiki/index.php?title=Williams_System_3_-_7#Upgrading_a_System_3_board_to_System_4) . And if a System 3 MPU is upgraded to a System 4 MPU, it is then upward compatible with a System 6 MPU board. There will not be a memory protect circuit though.
- System 4 and 4A MPUs are upward compatible to a System 6 MPU, when a socket is installed and used at position IC14. However, there will not be a memory protection circuit. A System 4 MPU is backward compatible with a System 3 MPU with no modifications performed.
- System 6 and 6A MPUs are backward with System 3, 4, and 4A MPU boards with no modifications performed.
- A System 7 MPU is backward compatible with System 3, 4, 4A, 6, and 6A MPU boards. However, board jumpers will have to be removed / installed. It not recommended to use a System 7 MPU board in any previous systems, but it can be done.
- System 3, 4, 4A, 6, and 6A MPU boards are **not** upward compatible with System 7 MPU boards.

In any instance where a non-native MPU board is used in place of the original MPU board, the correct flipper ROMs and game ROM must be installed. An example would be if an upgraded System 3 MPU were to be used in Gorgar. The GREEN flipper ROms and Gorgar game ROM would have to be installed in postions IC20, IC17, and IC14.

3.4 Driver Boards

3.4.1 System 3-6



Williams System 3-6 Driver Board

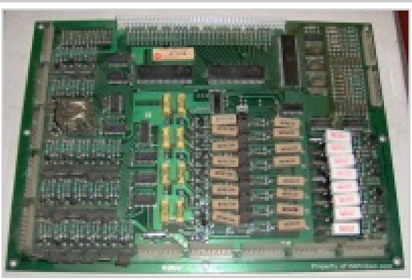
The driver board used three PIA chips to drive:

- an 8x8 Matrix for the Lamps
- an 8x8 Matrix for the Switches
- the last PIA drove the Solenoids and sound signals

More properly the PIAs were used to drive transistors that then accomplished the output tasks. In the case of the solenoids, darlington transistors were used as an electronic 'relay' to ground coils and fire them. Usually this was used for ball movement, but as mentioned before solenoids could also be used to sound chimes and for other tasks as needed.

The electronic design choices Williams made became the basis for all the digital Bally / Williams pinball games and even games being made today. The CPU chips and PIAs may change, more memory and ROM space is available to the programmers, mosfets are used as the switching relays instead of transistors... yet the basic designs for the lamp matrix, switch matrix and firing of the solenoids remain unchanged.

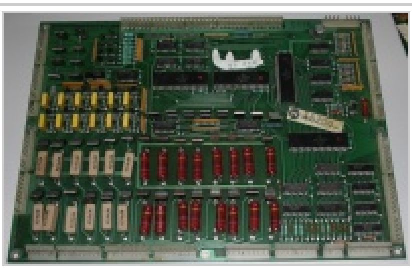
3.4.2 System 7



Williams System 7 Driver Board

The driver board remained almost completely unchanged from System 3 right through to System 7. One small change was made to the Driver Board during System 7. Eight resistors were changed to zero-ohm jumpers in the switch matrix inputs to increase sensitivity and responsiveness. These zero ohm resistors are located in the upper right corner of the driver board.

3.4.3 System 7 Hyperball Specific Driver Board



Williams System 7 Driver Board

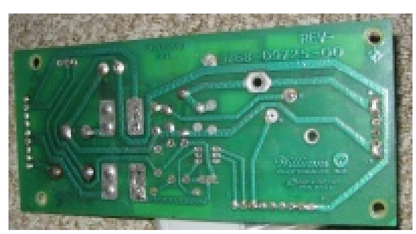
3.5 Power Supplies

Williams System 6 Power Supply


Williams System 7 Power Supply (GI input connector modified from stock)

3.6 C-9939 50V Flipper Power Supply

Williams System 7 50V Flipper Power Supply Board

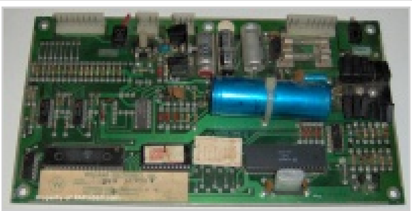
	
Front	**Back**

This Board was first used in Hyperball for controlling the spindle motor. As you an see there it orginally had many more components stuffed. In Firepower II, Laser Cue and Star Light the trimmed down version shown here is only used to supply the flipper coils with 50V DC. The AC voltage for it is supplied by a second smaller transformer mounted at the wodden plank in the back of the cabinet.

Because with it the coil voltage is exactly the same as in later System 11 pins the far superior blue FL-11630 coils can be used in these games. With these coils you can also install the antispark 2.2μF capacitor at each EOS switch. The board suffers from cold solder joints at the connectors. Here someone did a (bad) job at resoldering them. The exact same board is also used in all System 9 and early System 11 games up to F-14. Data East copied the design and you can also put it in Laser War to Time machine if it's missing there.

3.7 Sound Boards

Williams System 3-4 Type 1 Sound Board (Version 1)

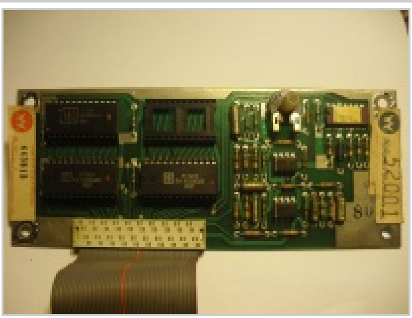


Williams System 3-4 Type 1 Sound Board (Version 2)

Williams System 6-7 Type 2 Sound Board

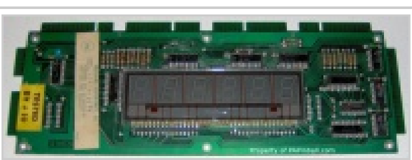
Type 2 sound boards rely on an off board volume pot, located in the cabinet along the left wall. The POT is a 5K POT.

Williams System 6-7 Type 2 Sound Board with Speech Board Connection

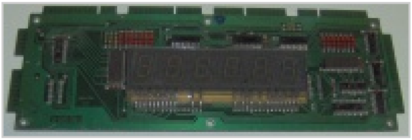


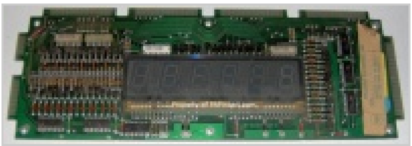
Williams System 6/7 Speech Board - Pic taken from Alien Poker

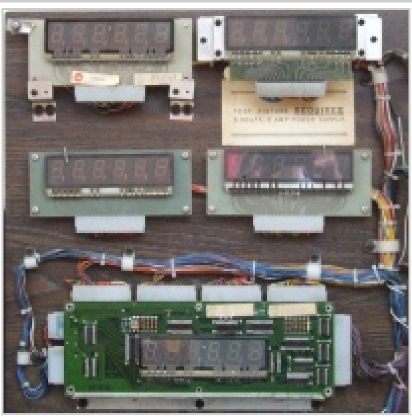
3.8 Displays



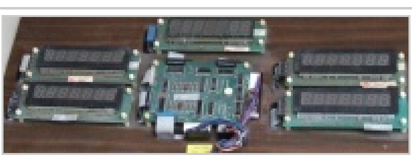
Williams System 3-6 Master Display Board (Using UDN7180A - Common)


Williams System 3-6 Master Display Board (Using NE584 - Less Common)


Williams System 3-6 Master Display Board w/ Discrete Components


Williams 6-Digit Slave Displays


Williams System 6A-7 Display Driver Board

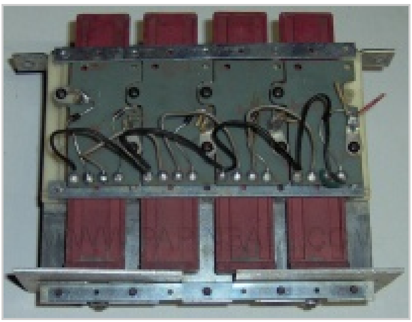

Williams 7-Digit Slave Displays

3.9 Other Boards

3.10 Flippers

3.11 Drop Target Banks

3.11.1 First Generation Drop Target Bank



Typical first generation Williams solid state drop target bank (Time Warp)

Starting with the first Williams solid state game, Hot Tip, Williams introduced their version of the solid state drop target bank. Drop target banks were a rather new design for Williams. They were the last major pinball manufacturer to introduce the drop target bank earlier in 1977 with the electromechanical game, Big Deal. And, only 3 games prior to the solid state version of Hot Tip, including the electromechanical version of Hot Tip, were manufactured with drop target banks.

The reason for mentioning the background regarding Williams drop target banks is because of the actual design implemented. There is one distinct difference between Williams drop target banks and any other manufacturer's drop target bank. In addition to using a scoring switch for each drop target in a bank, Williams used a secondary set of switches paired in series to detect when all of the drop targets were physically dropped. The drop target bank frame, reset coil or coils, appearance of the drop target faces on the playfield, and operation of the bank was virtually the same between Williams electromechanical games and solid state games. Therefore, it is believed that Williams designed their banks this way, because they had not been designing drop target banks that long, and decided upon a legacy approach. In other words, the Williams solid state drop target banks used hardware instead of software to detect when all the drop targets were down.

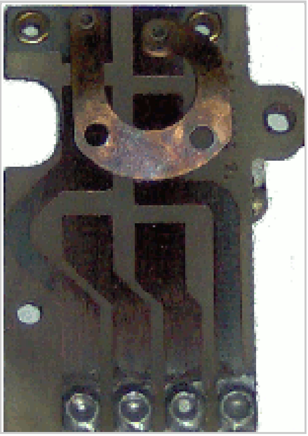
Backside of Williams first generation drop targets

The design of the drop targets are very different from any other manufacturer's design. Unlike Bally, Stern, or Gottlieb, the Williams drop target is a meaty, reinforced plastic which is fairly consistent in thickness and width throughout the target. Williams does not use a face with a long neck stemmed down in size. The benefit to this design is that breakage is minimized. The downside to this design is extra added weight. There are several other design differences too, such as the compression spring used to pull the target down. It is physically screwed to the front of the drop target plastic, as opposed to being attached via a molded "hook" like other manufacturers. This too is a plus, because the molded hooks on other drop target systems are prone to breakage. However, probably the most recognizable difference is the drop target switch design. On the back side of a Williams drop target, a switch triggering mechanism in the form of a copper horseshoe with two contacts is physically screwed to the plastic. The combination of the horseshoe contacts and discrete circuit boards for each target mounted to the bank of the bank are what is used to detect the three states of the drop target position.

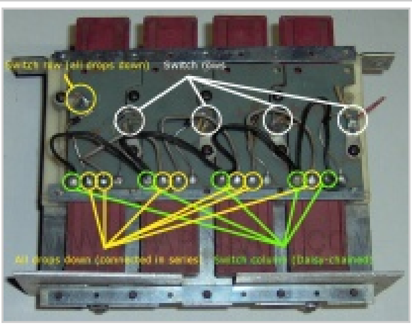
A simulation of the operation of a Williams drop target switch can be viewed at the animation located to the left. As mentioned before, the horseshoe contact is attached to the backside of the drop target plastic. The horseshoe contact makes physical contact with the thick copper or tinned traces of the circuit board, which is secured to the backside of the drop target bank.

An explanation of the three different states of the drop target are:

1. When the horseshoe contact is located at the uppermost set of traces, the first frame in the animation, the drop target is in the upright position (fully reset).
2. Once the drop target face is struck by the ball, the drop target plastic is pushed from the metal ledge of the metal drop target frame. As the drop target falls, the horseshoe contacts slide over a second set of traces on the circuit board, as seen in the second frame of the animation. These contacts are tied to the switch matrix via a switch strobe and return line respectively. The switch strobe line is common to all drop targets in the bank, while each drop target in a bank will have its own switch return line. Each switch pair is used for scoring purposes.
3. Finally, the drop target will fully drop, and the contacts come to rest on a third set of traces on the circuit board. This set of traces is tied in series from one drop target circuit board to the other. Because the pairs of traces for each target are tied together in series, a switch, secondary to the individual scoring switches is used. Once all of the targets in the bank are dropped, the series switch circuit is complete. The switch matrix detects this as a single switch closure. In turn, the drop target bank is reset.



Simulation of the three different states of a Williams drop target

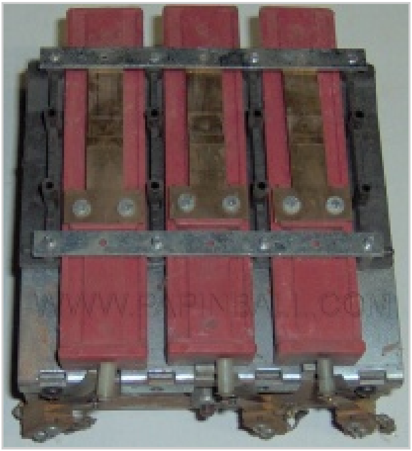


Switch solder points identified on a drop target bank

With the maze of similar-colored wires on the back of a Williams first generation drop target bank, it can be somewhat intimidating as to what wire goes where. The switch return lines (white wires with colored traces) attach to the solder tabs of the eyelets. Likewise, the non-banded side of the diode attaches to the same solder tab of the eyelet. The switch strobe line (green wire with a colored trace) can be attached to any of the points circled in green. On the bank in the adjacent pic, the switch strobe wire was attached to the green circled area on the far right. The black and gray wires are sometimes substituted with different colors like yellow.

3.11.2 Second Generation Drop Target Bank

Starting with Black Knight, Williams slightly changed the design of the drop target bank. Instead of using horseshoe contacts and circuit boards for switch detection on each drop target, the horseshoe contacts were replaced with a copper leaf spring and the discrete circuit boards were replaced with leaf switch stacks. Detecting when all the drop targets down was now handled via software. There are subtle physical differences in the drop target plastic. The most obvious difference is the thickness of the bottom of the drop target. The thickness was increased to compensate for the use of bottom mounted leaf switches.



Typical second generation Williams drop target bank

3.11.3 Third Generation Drop Target Bank

+++ Need pic of drop target bank with microswitches +++

The third and final generation of System 3-7 drop target banks are essentially the same as the second generation. The main difference is that microswitches were used to detect when a drop target drops versus leaf switches.

3.12 Built In Diagnostics

Diagnostic switch location on a WMS System 3 MPU

The built in diagnostics of the Williams System 3 - 7 board set are extremely limited. The board set either powers up or it doesn't.

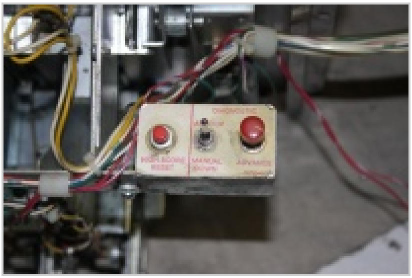
There are two diagnostic LEDs on the MPU (system 7 MPUs feature a 7 segment display). However, the usefulness of these LEDs is at best limited and generally just confusing. A properly booting System 3-6 game will flash both LEDs once, and then the LEDs will remain off. This flash is a bit longer than a flicker, staying on for about 1/2 second. A properly booting System 7 game will flash a zero on the 7 segment display. The 7 segment display will then go blank.

Pressing the Diagnostic button on a properly functioning System 3 - 6 MPU will cause both LEDs to flash twice in unison and then go off. If the bottom LED remains on, the game software is indicating a ROM failure. If the top LED remains on, the game software is indicating a RAM failure (6810). And if both LEDs remain on, the game software is indicating a CMOS RAM failure (5101). However, the accuracy of this test is questionable since the game software must be functioning properly for the test report to be valid and the game software requires ROM and RAM to function in the first place. The short advice is: don't rely on this diagnostic test result.

Pressing the Diagnostic button on a properly functioning System 7 MPU will cause the 7 segment display to flash a zero and then go blank. System 7 diagnostics are a bit more useful than prior Williams game systems but are still not 100% trustworthy. If the MPU built-in-test software detects a problem with the game hardware, the 7 segment display will remain on with an error code displayed. Possible error codes are:

- 0 - and then goes out...all tests passed

- 1 - IC13 RAM or IC20 ROM failed
- 2 - IC16 RAM failure
- 3 - IC17 ROM failure
- 4 - IC17 ROM failure (duplicated test...yes)
- 5 - IC20 ROM failure or the coin door was closed or memory protect fault
- 6 - IC14 Game ROM failure
- 7 - IC26 Game ROM failure
- 8 - IC19 (5101) RAM failure or the coin door was closed or memory protect fault
- 9 - IC19 (5101 again) RAM failure or the coin door was closed or memory protect fault


Williams System 3 - 7 Coin Door Switches

Entering the familiar diagnostic mode of later game systems is a bit less intuitive with a System 3 game. To enter diagnostics, press the diagnostic button on the MPU once. Both LEDs should flash and all displays will go blank. At this point, the game is ready to accept new game settings like "balls per play" via the obtuse and ridiculous to use dip switches on the MPU. Skipping over the process that essentially amounts to "memory pokes" (who remembers that), the diagnostics can now be controlled from the front door switches. If the AUTO/MANUAL switch is in the MANUAL position, pressing the ADVANCE button will cause each score display to show all zeros. The next press will show all ones, etc. If the AUTO/MANUAL switch is in the AUTO position, pressing the ADVANCE button will cause the score displays to begin cycling, starting with all zeros, then all ones, etc.

Placing the AUTO/MANUAL switch in the AUTO position, allows you to proceed to the next test by pressing the ADVANCE button. The match portion of the credit/match display will show "01" and all playfield lamps will begin to cyclone on/off. Pressing ADVANCE again will display "02" in the match window, and the game will begin an ordered activation of each coil in sequence (including buzzers, flashers, etc). Pressing ADVANCE again will display "03" in the match window. This is "switch test" mode. If no switches are closed, the credit half of the credit/match window will be blank. Closing a switch will result in the switch number being displayed in the credit window. If more than one switch is closed when switch test begins, the number of each switch will be displayed once in the credit window. After that point, only closing a switch will cause it's number to be displayed. i.e. switch test does not cycle through all closed switches (at least in System 3 games).

Pressing the ADVANCE button one more time displays "04" in the match window, and game status information is displayed in sequence.

3.13 Flipper ROMs

The OS (Operating System) for a Williams pinball game is called the Flipper ROM. Flipper ROMs with the same color label can be considered generic, although there is at least one exception where a 'custom' White Flipper ROM was used World Cup Soccer.

The Game ROM can be considered the 'personality' ROM, it provides the rules and objectives that are specific to that game's playfield layout. It also maps the Lamps, Solenoid and Switch Matrix to their specific purpose for that game and controls how they are sequenced and timed. Examples would be the 'attract mode' lamp sequence or when sound / speech select calls are made.

Because of large game production runs, Williams bought batches of Masked ROMs (fixed and not erasable) for the games. This was cheaper at the time than using Eproms (UV erasable, with a small window) as Eproms were still fairly expensive in the 80's. They used the same method for producing most of their Flipper, Game and Sound ROMs.

You may want to replace Masked ROMs with Eproms of the correct type as the original ROMs are 30+ years old. As the legs blacken and tarnish they will weaken and fall off. For a similar reason, many of the ROM sockets on the MPU boards will need to be replaced, especially any sockets bearing the words 'Scanbe', which are poor quality. Masked ROMs are very stable as they start life as all 1's and then the information is programmed by "burning" each selected bit open, like blowing a tiny fuse. They will rarely lose their programming over time. If you ever wonder about why we 'burn' our CDs and Eproms, that may be the source of the term.

3.13.1 Flipper ROM Colors

Williams used standard ROM files for System 3-7. These two Flipper ROMs are located at IC17 and IC20. Systems 3-6 use two 2716 or 2316 Eproms, while system 7 used a 2716 in IC20 and a 2532 in IC17.

3.13.1.1 White Flipper ROMs

Mainly for System 3 games.

3.13.1.2 Exceptions

Pokerino (Nov '78) and Phoenix (Jan '79): Both System 4 games, but use standard White Flipper ROMS. World Cup Soccer: Uses White Flipper ROMs, but the ROM in IC17 is unique - the MPU will not boot and run with the standard White ROM. (you CAN use the world cup white rom in the other white flipper rom games)

3.13.1.3 Issues

When downloading ROM software for Lucky 7, Hot Tip and World Cup, be aware the code available directly from Planetary Pinball has known faults and will not work properly. Code available from IPDB generally is correct and functional. The issues with these games is as follows...

World Cup: Provided with the standard IC17 Flipper Rom, not the unique one required for World Cup.

Lucky 7: When the original 512 byte files were combined into a 2k file for IC14 Game Rom, blank areas were entered incorrectly. This causes the machine to register a failed checksum test when attempting to enter settings via the dip switches.

Hot Tip: When the original 512 byte files were combined into a 2k file for IC14, they were done out of order.

3.13.2 Yellow Flipper ROMs

Used in System 4 games.

3.13.2.1 Exceptions

Flash (Jan '79): Earlier version used Yellow, a later version used Green Flipper ROMs (Green is preferred). As always, the Game ROM used **must match the Flipper ROM color** that it was written for.

3.13.3 Green Flipper ROMs

Used in System 6 / 6a games. Tri Zone (Jul '79) to Alien Poker (Oct '80)

3.13.3.1 Exceptions

There is an upgraded rom 2 written by Ted Estes that allows /10 scoring in all 6 digit Green rom games except for Algar and Alien Poker. These 2 games utilize an extension to the operating system rom contained wholly in the game rom that is incompatible with the Ted Estes hack (when enabled - with it disabled, the game works fine). It is not recommended to install the hacked rom in these games in case there are other unforeseen consequences. (Basically, both extensions to the roms shift the scoring over before and after the normal routines, internally, Alien Poker and Algar are 6 digit games.)

3.13.4 Blue Flipper ROMs

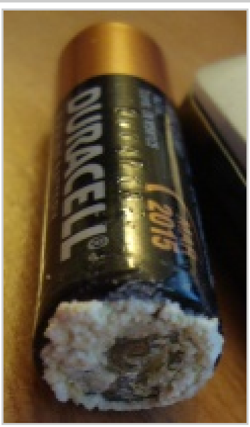
Used in System 7 games. Black Knight (Dec '80) and later.

3.13.4.1 Exceptions

Star Light (June '84, 100 produced) which was the last System 7, appears to have non-standard Blue Flipper ROMs. For very small production runs, games were supplied from the factory with Eproms. Both my Flipper ROMs 1 & 2 are not standard Blue ROMs (checksums differ).

4 Problems and Fixes

4.1 Relocating the batteries away from the MPU board



Leaking Battery

Relocating the 3xAA batteries from the MPU board is always a good idea. Leaky alkaline batteries are the #1 killer of pinball boards. Sometimes the battery terminals don't look corroded, but the metal rivet which contacts the battery are actually missing.

If you see "04 00" in the credit/match display, rather than your game going into attract mode then you are in audits:

- The batteries have failed and need replacing
- The battery voltage is not reaching the 5101 CMOS RAM (check Test Point TP7, which should measure 4.3v with the power on and 3.9v (or so) with the power off.
- Blocking Diode D18 (1N5817) has shorted, and the batteries are trying to run the MPU board when the game is off.
- You have another problem holding settings, such as a faulty 5101 CMOS RAM.

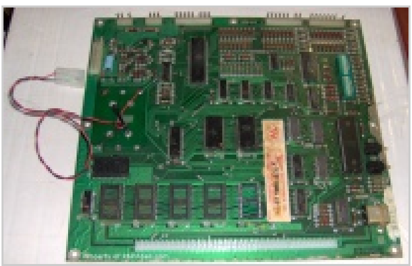
Simply removing the batteries is not really an option as the game will not boot directly into "attract mode" when switched on. It also will not retain the settings such as the number of balls per game, the free play setting (usually obtained by setting maximum credits to 0) or high scores. If you don't mind always getting default settings, then it's possible on System 3-7 games to switch them off, and then quickly back on to go from the '04 00 audit mode' to attract mode. You would still need to add credits from the coin door, and change settings as needed before starting a game. Too much trouble in my opinion.

Your best option is to remotely locate the battery holder somewhere below all the other boards. This ensures that even if the remotely located batteries leak, they won't leak onto (or even drip onto) any circuit board (see driver board pic below). Use good quality alkaline batteries, mark the date of replacement with a Sharpie, and replace the batteries annually.

Adding a connector between the battery pack and the MPU board is a good idea. You can easily remove the battery pack from the board. Plus, it the batteries are forgotten, and do leak, the MPU board will not have to be removed to add another battery pack. Another solution is to buy a battery holder with the 'transistor radio' type connector which can be snapped on and off. Just be very careful if using this style of connector. Adding a tag noting that a **9 volt battery should never be connected** is a very good idea. A 3 x AA battery holder is the typical recommended replacement. If you can only find a 4 x AA battery holder, you can solder a jumper in the first position. Likewise, a diode can be placed in this position instead. This will prevent the batteries from being charged and 'cooked' by the game if blocking diode D17 on the MPU board fails. Keep in mind that an added secondary diode to this circuit will decrease the voltage passing to the 5101, if D17 is still good. Locate a 1n4001 or 1N4004 diode in the position closest to the last + terminal (where the Red Wire exits). You must have the banded side of the diode pointing in the direction of current flow, which is towards the Red wire and towards the (+) terminal marking on the MPU board.

The game takes 3 x AA Batteries, so it uses at least 4.5v total. However, it will still store settings down to about 3v or so. After that an AA battery's life will taper off very quickly. A fresh set of batteries should last for at least a year, or the is some other issue. If the 5101 CMOS RAM is socketed, it's possible that it isn't the low power version. Or, possibly the D17 diode has shorted.

You can see the pictures on the left for how to install the wiring for battery packs to the MPU Boards, if you right-click on the image you can open it in a new tab and enlarge the view.



Williams System 4 MPU Board

On the System 4 MPU, solder the battery cables: Ground (Black Wire) to the Bottom Left pad and Positive (Red Wire) to the Top Right.

Williams System 6 MPU Board

On the System 6(a) MPU, solder the battery cables: Ground (Black Wire) to the Top Right pad and Positive (Red Wire) to the Bottom Left.

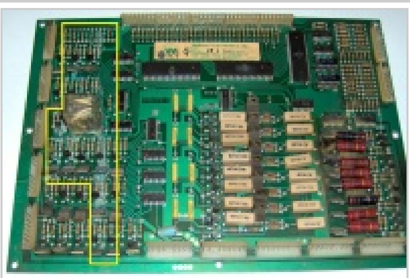
Williams System 7 MPU Board

On the System 7 MPU, solder the battery cables: Ground (Black Wire) to the Bottom Left pad and Positive (Red Wire) to the Top Right.

After adding a remote battery pack, and while the board is still out of the game, it is a good practice to measure the battery pack's voltage at the (+) and (-) pads of the MPU board. All battery packs are pretty cheaply made, and failures "out of the box" are somewhat common. Checking to make certain the battery pack is functioning before reinstalling the MPU board in the game will save you some headaches.

Another good practice, while the MPU board is already out, is to check the D17 blocking diode. An open blocking diode will not allow the battery pack voltage to pass through to the 5101 non-volatile memory, and the newly installed battery pack will be ineffective. Conversely, a shorted blocking diode will allow the board's +5vdc logic power bus to pass through to the battery pack. This in turn, will charge the batteries, while the game is turned on. If you're unaware, alkaline batteries do not like being charged. They will heat up, and fail prematurely, (rather quickly). In worse cases, the new batteries can even leak or explode if charged. Testing the D17 diode is quick and easy, and worth the trouble checking it out. When in doubt, replace the D17 diode with a 1N4148, or add a secondary 1N4004 to the battery pack. Once again, if a secondary diode is added, it will decrease the voltage passing to the 5101, if D17 is still good.

An alternate solution to a battery pack is to use a single CR2032 battery mounted on the MPU board in a holder. Lithium button batteries do leak, although it is not nearly as common or severe as alkaline batteres. If using a lithium battery, it should still be changed annually for piece of mind. Although it is a 3v battery, it does work well. The holder and the replacement batteries are low cost. See this Robotron-2084 link by Dave Langley (http://www.robotron-2084.co.uk/techwilliamscpubattery.html) for details. His method can be adapted to work with any of this era of MPU boards.


Battery Damaged Williams Driver Board

It is important to remotely relocate the batteries from the MPU board, unless using a lithium replacement. The potential is there for not only the MPU to become damaged, but other associated boards in the backbox. The pic to the left is a prime example of extended damage. The damage occurred in this instance, because the shuffle bowler this board came from was stored with the batteries still on the MPU board for an extended period of time (roughly 5-8 years). It's a costly shame, because this was an otherwise decent, clean, working driver board. The amount of repairs which have to be performed now are going to be extensive.

4.2 Installing a Memory Capacitor Instead of Batteries

Another alternative is to install a memory capacitor. In essence, a memory capacitor is similar to a rechargeable battery, although, the likelihood of a memory capacitor leaking is greatly reduced compared to a rechargeable battery. When the game is turned on, it is charging the capacitor. When the game is turned off, and this is where the memory cap slightly differs than a rechargeable battery, the memory capacitor slowly loses its charge over time. Therefore, it is imperative that the game periodically be turned on to allow the capacitor to charge up to its full capacity again. If a game will not be turned on for long lengths of time, a memory capacitor may not be the best solution.

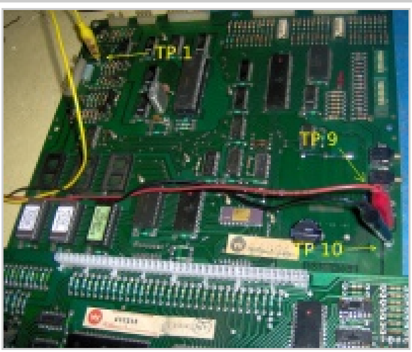
When installing a memory cap, two things will have to be done. It will be necessary to add a jumper to tie the negative lead of the cap to ground or positive lead to the non-banded side of the blocking diode. The picture to the left shows a jumper added to tie the negative lead of the cap to ground on a System 6 MPU board. Installation on System 3, 4, and 7 boards is similarily performed. Secondly, the 1N5817 blocking diode (D18) will have to be

Memory Capacitor Added to a System 6 MPU Board. The circled areas show an added jumper for the cap's negative terminal to ground and a jumper added in place of the blocking diode.

removed, and a zero ohm jumper must be installed. A scrap piece from the leg of a new resistor or diode will do the trick. By adding a jumper where the blocking diode once was, this will enable the game to charge the capacitor. Once the capacitor is installed, and the board installed back in the game, it is a good idea to leave the game on for 15-20 minutes to allow the game to initially charge the capacitor to full capacity. After that, turning the game on monthly for about 10 minutes to allow the cap to recharge is a good idea.

4.3 Using a PC Power Supply For Bench Testing

Sometimes it is more beneficial to do testing / troubleshooting while the MPU and / or driver boards are outside of the game. It's unfortunate, but the System 3-7 boards were designed in such a way that both the MPU and driver board have to be attached to one another for the MPU to effectively boot and function. Since the driver board has no intelligence located on it, it needs to be connected to the MPU to be of any use.



WMS System 6 MPU and Driver Board Powered by a PC Power Supply. Power connections are attached to the readily available test points on the MPU board.

The voltages needed to power a System 3-7 board pair on the bench are +5v, +12v, and ground. Connections can be made to the appropriate pins on 1J2 (only header connection on left side of MPU board). The connections are as follows:

- Pins 1-3 (ground)
- Pins 4- 6 (+5 volts)
- Pin 9 (+12 volts)

If connecting a **System 6 or 7 board pair**, it is easier to connect to the test points. The connections are as follows:

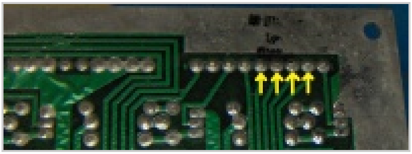
- Test point 1 (+12 volts)
- Test point 9 (+5 volts)
- Test point 10 (ground)

Placeholder for WMS System 7 MPU and Driver Board Powered by a PC Power Supply. Power connections are attached to the readily available test points on the MPU board.

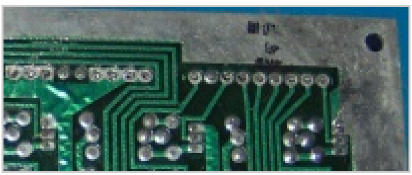
Note that test points 9 and 10 have different locations between a System 6 and 7 MPU board.

4.4 Connectors, connectors, connectors

With this era of game, most of them 30+ years old now, you will have problems with connectors. One of the most common issues is cracked solder joints on header pin connections to the PCBs. Some cracks are more obvious than others, while some can only be seen clearly under proper magnification.



Cracked solder joints on the header pins of a Williams driver board



Solder removed from the header pins of a Williams driver board

Although it can be somewhat time consuming and a tedious chore, it is best to remove the old solder from a header pin joint, and then add new, fresh solder. Performing this procedure is a necessity on these games to ensure reliability. The other option is removing the header pin connection completely, and replace with a new one.

If your game starts to reset for no reason during play, or when you flip both flippers, it may be worth first re-pinning the connectors at 1J2 on the MPU Board and at the outputs from the PSU. This is always a good step even if it does not fix the immediate issue, as it avoids power problems later on.

This will involves replacing the header pins on the PSU board and the female connectors on the cables. The pins are .156" and square pins are preferred, although round are still available. Use phosphor bronze. On the female side, crimp pins of the trifuricon type are best.

Second prize goes to reflowing solder to the back of the header pins, and just replacing the female IDC connectors with new ones. In that case rather than a crimper, you ***must*** buy a .156" 'punch-down' tool, ***which is a specific part*** for this replacement to work correctly. If you don't buy the tool you will damage the IDC housing and pins using a screwdriver or some other makeshift tool. After that the wires just don't seat correctly. Always cut back to clean wire and punch down correctly to a new IDC connector, reusing an old one rarely works.

Again, the connector is a .156" 9-way connector at 1J2. There is also a 'key' pin where the hole is blanked off on the connectors and the pin cut off flush with the board. This prevents plugging the power in to say the switch matrix or swapping two connectors over. It's easiest to just buy a bag of these for blanking off the 'key' positions, rather than try to re-use old ones.

4.4.1 List of Common Molex Connectors for Pinball Games

Here is a list of Molex Connectors used on this era of games and pinball in general:

System 3-7 Molex Connectors

You can search the PDF with <CTRL-F>. You can also use the 'select cursor' to cut and paste part numbers from the document. The information is correct to the best of my abilities but you should always match up with the existing parts before replacing them.

4.5 Wiring Connector Issues

Williams made a poor wiring harness decision with this series of games that will allow you to incorrectly connect the cabinet harness to the head harness (the inline connectors). **Always be sure to double check not just connector pin counts and colors, but most importantly, wire colors. Not mating these connectors correctly will allow the 28V solenoid circuit to fry the 5V logic circuit and can cause extensive damage.**

4.6 System 6 MPU Board Issues

4.7 System 6 MPU Board Diagrams

Here are PDFs of the MPU Board for System 6 games. These documents contain information that should be helpful when fault finding or identifying components and their locations

System 6 MPU Assembly Drawing

> Because IC9 and IC10 can be bypassed directly, these diagrams are accurate for System 6a.

System 6 MPU Logic Diagram

> The Schematic is a logical rather than physical layout of the MPU Board. Meaning that while it shows the circuit connections correctly, it does not match the actual layout of traces on the board.

4.8 System 7 MPU Board Issues

Diagnostics, and 'my System 7 MPU Board won't boot'.

Forget about getting anything at all on the Player Displays without having working ROMs in place and a good MPU board. Blanking has to go 'high' before the displays will work. So coin door game diagnostics are useless until the MPU board runs correctly.

But help is at hand on the System 7 MPU, Williams added a single 7 segment LED display to the board. To get anything at all on the 7 segment display LED on the MPU you need: The 74LS47 Display Driver IC34 to be working. The 6821 PIA (at IC18) on the MPU responsible for driving the score displays to be working. The logic +5v to be good.

Normally when a properly functioning board boots, the 7 segment LED display will flash "0" briefly and then the display is turned off, and remains off. If within a game, the game would then be in attract mode if everything was perfect. Pressing diagnostics should show a "0" and then return to attract mode with the LED display blank. [ed Note: Correct me if that is wrong]

Once you have that the above chips installed and working and sockets replaced or tested good: With no ROMs installed, a board with a fault or a ROM fault if they are installed, the "top two" LEDs (if there) would be lit and the LED display would show "0". The MPU board is 'locked up', in that condition. Display Driver PIA IC PA4 - PA7 will be high. Pressing the Diagnostic switch will not change things.

Then you need an OS, which is the 'Flipper Roms' in pinball. When they 'Boot' (provide a set of instructions to the CPU)- even with the Game ROM removed, the fist thing they do is to "turn off" the LEDs 1+2 and so the onboard LED display (7447) would then go blank.

In fact, you should see "0" flash once and go blank. That means the board is not locked and at least booted the OS.

Anding in a good Game ROM after that may get you to the point of running diagnostics. Pressing the diagnostic switch would then provide a (hopefully) valid indication of what component is stopping the (pinball or whatever) from running. Here are the key indications (for System 7, SYs 8&9 may be similar):

You can get these results with error conditions by using your Flipper and Game ROMs, or the 2532 WMS Test ROM in IC17 (on Sys 7 boards): If all the support chips are good, and you can get one "0" flash and then it goes blank, then you can trust the on-board display,

Press the diagnostic button, the numbers are:

System 7 LED Diagnostics	
Number	**Meaning**
0	Test Passed (only if display goes blank)
1	IC13 RAM Faulty
2	IC16 RAM Faulty
3	IC17 ROM 2 Faulty
4	IC17 ROM 2 Faulty
5	IC20 ROM I Faulty
6	IC14 Game ROM 1 Faulty
7	IC26 Game ROM 0 Faulty
8	IC19 CMOS RAM or memory protect circuit faulty
9	Coin-door closed, memory protect circuit faulty, or IC19 CMOS RAM Faulty.

Getting a 0 and remaining on could potentially be that the CPU / board has not successfully reset. In other words, no instructions have been passed to and from the CPU chip. This problem could be due to a faulty reset circuit. The lack of +12v on the MPU board can cause this too.

Getting an 8 or 9 is *good* indication - it means you're almost there! Here are some further tips about those conditions:

8 - MPU board may be good. Is it looking for the Driver Board? (Like the missing 7th flash on a Bally MPU).

Make sure the Driver Board is connected and the "40-way" interconnect has continuity on all pins. From System 8 on there is no interconnect... so by System 9 MPU and Driverboard (and Sound!) are all one PCB.

Then suspect that IC19 RAM is faulty or finally a memory protect fault.

9 - First check for coin door closed (or pin 1J4-1 or 1J3-1 is being grounded), then is IC7 faulty? Finally is IC19 RAM faulty?

If you get a "9" - I'm always tempted to install in a game open the coin door and try and boot up. But this is wrong, as you still have something not right. Your IC19 5101 CMOS Ram is faulty, or another memory protect component is faulty.

Remember to do the "switch on, off and back on again quick" trick to see if you can get attract mode when reinstalling in a game after taking an MPU out. That's a classic Fonzarelli move, a "golden oldie" of the pinball world. Because lots of times that does the trick. Also if removing the Driver Board and reinserting it on the MPU board 'fixes' your problems and the boards will then boot correctly, then it points to the "40-way" connector needing to be replaced. Both header pins on the MPU and sockets on the Driver Board.

Parts:

The 7-Segment display can be replaced with a KINGBRIGHT SA03-12HDB LED 0.3" RED DISPLAY.
5101 CMOS RAM. 5101-1 The low power version is needed, as it needs battery backup to hold RAM contents when the game is powered off.
A 6821 PIA is a standard part. MC6821 MC68B21 are common. The 6820 designation is much earlier but also works. Other designations:

xx6821, xx68A21, xx68B21, where xx can be MC (Motorola) or HD (Hitachi Data) will all work. The 'A' in 68A21 means the PIA will run at up to a 1.5Mhz Clock , the 'B' in 68B21 means up to a 2Mhz clock, without any letter is up to 1MHz. Any final letter is Package type (P,S or L) P=Plastic S=Cerdip and L=Ceramic. Any of the above speeds or package types will work for this era of pinball, so you can ignore the letters and use any 6820 or 6821.

4.9 Chip Sockets

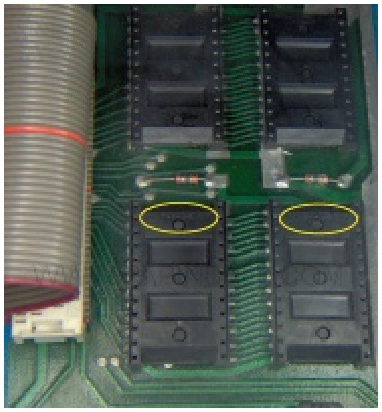
Reliable socket connections are a requirement for any printed circuit board to work as designed. Old sockets, as discussed below, should be replaced. Use extreme care in desoldering the old sockets, the traces and pads on circuit boards are easily lifted, especially if any battery corrosion is in the area.

The chip sockets on old Williams boards (also most any board of this era) are long past their reliable lifetimes. They may work, but they may also cause intermittent connections that will have you chasing your tail tracking down odd problems with your game. Like the 40-pin interconnect used in Williams System 3-7 games, these sockets should always be replaced.

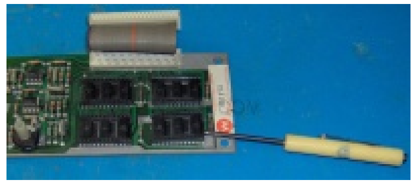
Perhaps the most maligned socket brand, and rightfully so, is the Scanbe brand. In the picture below, you can see why. These 30+ year old sockets passed the point of reliability many years ago. Included in the Scanbe socket picture below are two pins pulled from a Scanbe socket. The pins were designed to grip the SIDES of the IC legs, unlike the design of modern sockets that grip the front and back faces of the IC leg. Get rid of them now.

Later WMS switched to sockets made by Augat or Raychem (all Tyco now). They occasionally go bad but you can usually leave them alone. But there is another type made by Molex which should also be replaced if you find it in a pcb. When you look at the picture below you see why. Curvy isn't it? And the contacts break easily too. Not as bad as the Scanbe but not much better either.

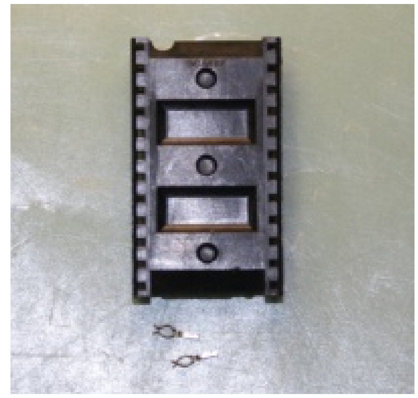
Poor quality and old sockets found on many early pinball machine circuit boards



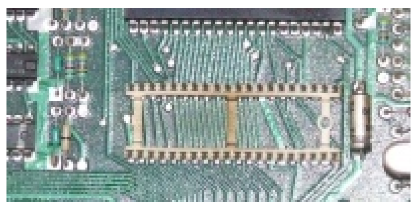
It's hard to believe that these sockets ever worked.



A Scanbe socket being removed from circuit board by gently prying it up.



Closeup of the infamous "Scanbe" brand socket. "Scanbe" is molded into the top of the socket face.



Another bad socket type usually found in system 7 pcbs. This one was made by Molex.

4.10 Reset Issues

4.11 Voltages

The MPU board needs two voltages to boot: +12v which only the MPU uses for the reset circuit, and +5v (logic power) for the MPU and Driverboard IC chips.

If the game goes dead, but the sound board continues to work then you may have a fault with the PSU, power connections to the MPU, blanking or the reset circuit.

You check for sounds by pressing the sound board diagnostic test. You need to switch off & back on to cancel the looping sound test. The sound board has its own PSU. It takes 18v AC directly from the transformer and makes +12v (reset) +5v (logic) and also -12v (Speech and mixers). It's probably OK to assume the +5v and +12v going to the MPU (and Driver Board) are OK from the PSU if the sound board boots and runs. it's like a mini MPU, with the same CPU and one PIA chip.

The main PSU board only needs to make the first two, +12v and +5v (no -12v) for the MPU and Driver board. But it also generates DC power for the flippers and the solenoids (+28v DC or so).

4.12 The MPU Reset Circuit

The +12v for reset goes into a circuit that waits (for about a 1 sec. delay) for the +5v to stabilize before it lets the CPU boot. If the +12v (or output from the reset circuit) drops, the reset halts the CPU, PIA(s) and the 5101 CMOS RAM chips before the +5v to them dies. A shutdown of the CPU will also pull blanking low and halt solenoids, lamps and displays to protect them from further damage (coils firing, memory glitching) during the power down. So spikes or drops to the +12v line may halt the CPU at the wrong time.

An MPU unable to boot may mean that its reset circuit is faulty. A +12v line comes in from the PSU board to the MPU on pin 9 of 1J2. That's the top pin on the top left (and only connector on the left) of the MPU board. +12v can also be measured at TP1 on a System 6, 6a, or 7 MPU. Don't get hung up on it being exactly +12v, as it's not regulated. However, it can't drop too much lower than +11.5v, or the reset circuit **may** have a problem generating enough voltage to keep reset "up" to the CPU. But +11.5v to +14v is not unusual and will still work. A fluctuating reset can cause the game to reboot during a game.

The state of the reset (high or low) can be observed at pin 40 of the 6808 or 6802 CPU chip. Likewise, the reset can be observed at TP8 on System 6, 6a, and 7 MPU boards. TP8 is located just to the right of IC19 (5101 memory) on a System 6 or 6a board, and the far right test point on the bottom of the MPU just above the 40-way connector on a System 7 MPU board. It will be marked as TP8 on the PCB mask. For System 3, 4, 4a MPU boards, the reset will have to be measured at pin 40 of the 6800 CPU board. When booting the game and watching reset, it stays low for a heartbeat after power on and then rises to +5v. +4.75v or around that is fine. Don't get hung up too much on the voltages being exact for the reset circuit either.

If the +12v appears OK when measured, and the sound board is always booting and working, it's safe to assume that +12v at the PSU is stable.

A good trick to 'inject' a reset, is to try connecting +5v for a second or two to the reset test point at TP8 or the leg of the CPU chip (pin 40). If the CPU boots (reset must be a logic high now on pin 40 of IC1), then the reset section will need to be rebuilt..

So that involves running a jumper lead from TP8 and **briefly** touching TP9 (+5v). TP9 is located just to the bottom right of the battery holder on a System 6 or 6a MPU board, while it is at the top right the battery holder on a System 7 board. The battery holder should have been removed, so the test point is located in the vicinity of where the original holder **used to be**.

4.12.1 Repairing the Reset Circuit 'Divide and Conquer'

Let's assume the game boots and works if the CPU reset pin is held high. How do we figure out what is wrong? One solution is a shotgun method - just start changing transistors and components until it is fixed. A better way is to narrow down the fault location using the 'injection' trick.

The reset circuit is easily seen as two halves. For a System 7 MPU board, you can apply +5v directly to the top of resistor R12. If the board boots and stays stable, you know that the problem is on the 'right hand' side of the circuit. (On System 6, you do the same thing but using R32. In this way you have 1/2 the components to worry about.

Assuming that you know the +12v getting to MPU board is good, if the above injection of 5v doesn't work you measure where the voltage disappears on the left hand side of the reset circuit. Then replace parts on that side, checking for reset becoming good when the board boots each time, if you want to replace the minimum number of components. Remember that for System 6 and 7, there are just 12 active components that make up the reset circuit, and 8 of those are transistors. They are usually the source of the problem.

4.12.2 Step One

The Right Hand Side. Start by replacing transistors Q6 – Q9 (all 2n4401 NPN) get 10 or more of them, they're cheap to buy and you will need them lots of times. They are used as pre-drivers for the solenoid power transistors on the Driverboards for System 3-7). Test the board for your booting problem. If still there, replace the two zener diodes: ZR1 is a 6.8v Zener (1n5996) and ZR2 is a 3.9v Zener (1n5990) - you can't replace these components with anything else to my knowledge. These are critical values. And put the orientation of the band of the diode the same way as the ones you remove. Taking a digital picture of how the circuit in the top left of the board looked before you started is a good ides. Or replace components one at a time. You could of course test for boot on the bench each time you replace something, that may slow things down but you won't replace too many components you didn't have to. It should be booting now, if not attack the other half.

4.12.3 Step Two

The Left Hand Side. Start by replacing transistor Q2. Q2 is a 2n4403 PNP transistor, cheap as well but you won't need as many for pinball repairs. then replace Q3-Q5 with the 2n4401 's like before. I would replace D19 (a 1n4148 fast switching diode) you could test it with the diode setting of your DMM, but I don't trust testing diodes in circuit, and if I'm soldering in that section, I just cut it out and replace it. Cost will be pennies, and most pinball people should have new ones on hand. Again, be sure and notice the direction of the band on the old diode, and put the new one back the same way. Same thing goes for the orientation of the flat side of the transistors. Don't get them wrong when replacing. The last component to replace would be the capacitor at C27 (10 uF @10v is the original part –look on the side of the cap). Replace it with a tantalum 10 uF @ 16v, if you can find it. You can go up in voltage even to 20v or more, but don't change the value of the capacitance. Note that some caps have markings showing a (-) side, usually running down the side of the capacitor. If it shows a polarity, the (-) side of C27 points down on the PCB, towards the 40-way interconnect.

4.12.4 Step Three, Hopefully Reset is Back Up

That's it. Usually fixed at step one, and down to one (or more) of those transistors. I have seen a zener or the 1n4148 diode at D19 be the problem before. But for me, the cap C27 has always been good. If all else fails, test the capacitor for a dead short with the power off and replace it with a 10uF electrolytic if it is shorted to ground or you aren't sure it's working.

4.12.5 An Alternative to Rebuilding the Reset Circuit (System 6 and 6a only at this time)

There is an alternative to the stock reset circuit on System 6 and 6a MPU boards. A reset generator can be installed. To do so, some components will need to be removed, and two jumpers installed. The following work will have to be done.

1. Remove the following transistors - Q4 and Q6
2. Remove the following resistors - (from left to right as installed on the board) R43, R38, R39, R41, and R42
3. Add reset generator MCP120-460GI/TO where Q4 was (green highlighted area in image). Orient the reset generator in the same manner Q4 was oriented (pin 1 of reset generator will install where the "E" emitter was for Q4). In other words, the "flat" side of the reset generator will face to the left.
4. Add a jumper where resistor R39 was installed (yellow highlighted area in image).
5. Add a jumper connecting the "B" base and "C" collector pads where Q6 was installed (orange highlighted

Williams System 6a MPU board reset circuit with a reset generator installed

area in image).

This a very simple, and in some cases, cheaper alternative to repairing the existing reset circuit. After this modification is performed, the MPU board will no longer need the +12v to successfully boot. Likewise, any of the other components in the reset circuit can be removed if desired. Please consult the System 6 MPU board BOM and schematics to determine exactly what components can be removed. The MCP120-460GI/TO reset generator can be purchased from Great Plains Electronics (http://www.greatplainselectronics.com/proddetail.asp?prod=MCP120-460GI%2FTO) .

4.12.6 Reset Circuit Summary

Connectors were mentioned above for completeness. While I agree a good 40-way connector is essential for correct operation of this era of games, changing the Bridge Rectifiers in the backbox or rebuilding connectors probably won't help fix the reset circuit .

That because the **BR's are only for the Lamps and Solenoids** and won't fix a problem with the MPU power (or reset) as that is sourced directly from the PSU. The +5v logic power comes from a regulator on the PSU board, and the +5v for the reset pins of the MPU ICs is created on the MPU from the +12v unregulated supply.

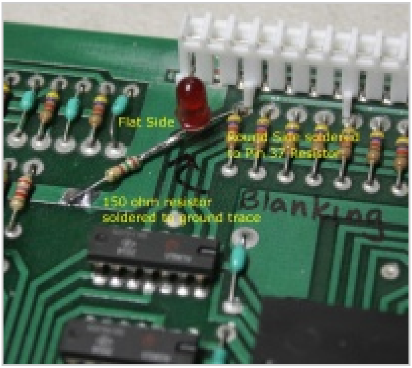
If you are looking here because game resets (reboots to attract mode or locks up) when flipping the flippers, it makes sense to check and rebuild the solenoid power circuit as well. That is the flipper power on games prior to System 7 when 50v flippers and a Flipper Power Board was introduced. You should also read the WPC section (http://www.pinwiki.com/wiki/index.php?title=Williams_WPC#WPC_5VDC_Power_Derivation_Path) , while the games only similar- the approach for resets caused by power fluctuations is sound. It takes you from the 'AC mains' wall plug right through to the power needed on the boards.

Topics such as electrolytic capacitors aging and drying out, testing the Bridge Rectifiers and checking and tweaking the LM323K 5V regulator on the Power Baord will all be the same or very similar.

4.13 The Blanking Circuit

The blanking circuit is used by the MPU to prevent damage to the game when the MPU can not determine that the game is in a valid state. A low blanking signal means that the MPU has detected a problem and is "blanking" (turning off) the coils and displays. A high blanking signal means that the MPU thinks all is well and coils and the displays are allowed to function normally.

The blanking signal is logically ANDed, by a 7408, with the enable signal for each coil and the displays.



A "blanking" LED added to a Williams System 3-7 Driver Board.

4.13.1 Blanking Circuit Stuck Low

The blanking signal is generated from either a 555 (System 7) or a 556 (System 3-6) timer chip. The blanking signal originates on the MPU board, and is passed onto the driver board. Upon a successful boot of the MPU board, the blanking will go from a low signal to a high signal, and remain high as long as there are no issues. If the blanking signal does not go high, the MPU will not boot.

One of the most common issues for a blanking signal to remain low is discontinuity between the MPU board and the driver board. the blanking signal passes through the 40-pin interconnect at pin 38 (3rd pin in from the left side). Poor connections due to fatigue or seeping battery damage can cause a break in this connection. It is best to replace both the male and female sides of the 40-pin interconnect to ensure that all is well.

A System 6 MPU board with the upper right battery holder through-hole highlighted.

A special note about System 6 & 6A MPU boards. The upper right through-hole for the battery holder passes the ground from the solder side of the board to the IC5 (74LS02) chip. This through-hole can become compromised from battery corrosion or the careless removal of the battery holder. If there is a break between both sides of the board, ground will be lost going to IC5, and the chip will not function. If this occurs, the blanking signal will never go high, and the board will not boot.

A special note about System 7 MPU boards. The trace for the blanking signal is very fragile. If the batteries have leaked on the board, or leached under the 40-pin header pins, make certain that the trace which carries the blanking signal has not been broken. The break most commonly occurs at the junction of the trace and the component side of the through-hole pad for the header pin on the MPU board. The header pin connector will have to be removed to inspect this junction, should there be a break.

Placeholder for a System 7 MPU board with the blacnking signal trace notated.

4.14 Driver Board Issues

4.14.1 The Dreaded 40-way Connector

The driver board mates with the MPU board using 40 x 0.156" extra long header pins on the MPU and female 'bottom entry' Molex sockets on the driver board. Common belief is that these connectors are good for about 25 reliable connects and removals. You may disagree with this number, but the fact remains that the connector is good for a limited number of uses, and must be replaced over time.

This is a continual source of repair problems for this era of Williams machines. However, it was eliminated by System 8, (and the more common System 9 platform), when the MPU board and driver board were no longer modular, and became merged together as one board.

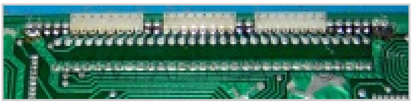
If the header pins on the MPU board look good, you can get away with re-flowing the solder them on the back of the pins:

- Heat up the pad, add a little new solder
- Remove all the solder you can (the old and new) with a solder sucker
- Add fresh solder back to get a nice flow around each pin

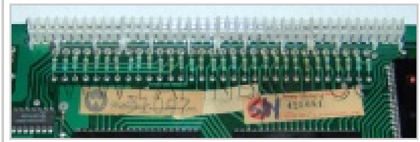
Then, replace all the female connectors on the driver board. Even if the driver board side pins look good, replace them. Simple cleaning the pins with a contact cleaner or burnishing them are not viable solutions. The bottom feed pins loose tensile strength over time, which make connections between the MPU and driver board less reliable with age. The picture to the left illustrates the 40 pin female bottom feed connectors on the driver board. It should be

The 40 pin female connector on the driver board

noted that the connector in the picture is an extreme example of poor condition connections. Missing and alkaline damaged pins, connectors from position 17-40 on the left, are not the norm. Connections from position 1-16 on the far right are more commonly seen.

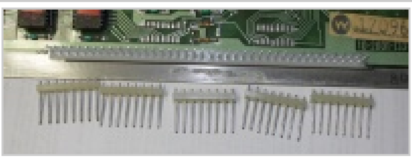


Installing a new 40 pin female connector on the driver board



A new 40 pin female connector installed on the driver board

If using four 10 pin female connectors, (the originals on the driver board were five 8 pin), here's a little trick to keep them lined up nicely when soldering them. Take the old 8 pin male header pin connectors, which were installed on the MPU board. Install three of the 8 pin headers on the back side of the driver board and into the new female connectors (see picture to the left). If any of the older header pin sections have battery corrosion on them, do not use use them for this. Allow enough space between the connectors so some of the female connector leads can be soldered. Solder all of the exposed leads on the female connector. Once they are soldered in place, remove the male headers, and solder the remaining leads on the female connectors.



Fresh male headers installed on this System 6 MPU. Nice. Note the new headers are 10 pins long while the original headers were each 8 pins long.

Parts for the connector are: MPU board Pins are: Round (or Square) .156" header pins. '10-way 0.156 headers' with extra long pins (0.629" or 16mm length). Driver Board Sockets are: '10-way 0.156" Bottom Entry' Female Molex Part Number: 09-52-3102 (4 needed per board) Original 5A-9066 8-way .156" Female Molex Part Number: 09-52-3082 (5 needed per board) Alternate for Molex 09-62-6104 and 09-52-3102 which are hard to obtain.

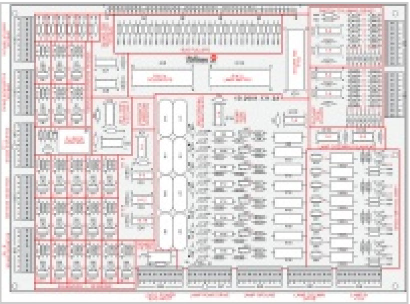
Check with: Ed at GPE (http://www.greatplainselectronics.com/Category-82.asp) or your favorite supplier for these.

There is no substitute for doing this correctly, other than buying repro replacement boards. A somewhat recent solution is a board made by Rottendog Amusements, where the MPU and driver board are combined into one board (http://www.rottendog.us/mpu327.htm) . At the time of this writing, cost is around $280 with good reports about this board. Another option is purchasing both the MPU (http://www.pinballpcb.com/System3-7MainBoard.html) and driver board (http://www.pinballpcb.com/System3-7DriverBoard.html) from Kohout Enterprises for around $400. When both boards are purchased, they can be tied together via an auxiliary ribbon cable. Of course they can be connected via the 40-pin interconnect too.

Repairs on the MPU and driver board connectors can cost up to $20 or less in parts (header pins, sockets and solder), along with several hours to replace the connectors and pins correctly. This of course depends on your level of soldering skills and the value you put on your time. It's a fairly long job but it's likely that it only needs to be done once.

4.14.2 Driver Board Diagrams

Here are PDFs of the Driver Board for System 3-7 games. They contain information that should be helpful when fault finding or identifying components and their locations

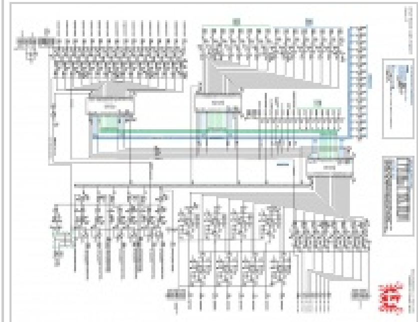


Driver Board Assembly Drawing. Click the HyperLink on the right for the full PDF

Driver Board Assembly Drawing

The Tables for Solenoids, Switch Matrix and Lamp Matrix are examples for Firepower. However the wiring colors and locations do not change from game to game. System 7 does not use Driver Solenoids to trigger sounds, and that is covered in the Sound Board section.

Driver Board Logic Diagram



Driver Board Schematic Drawing. Click the HyperLink on the right for the full PDF

The Schematic is a logical rather than physical layout of the Driver Board. This means that while it shows the circuit connections correctly, it is not drawn to match the actual layout of traces on the board.

4.15 Power Supply Issues

The key thing to remember is that the PSU board is made up of separate output circuits combined on one board. They don't interact, and are in order:

- +18v for Lamps,
- +28v Solenoids (and Flippers),
- Regulated +5v for logic B+ and an unregulated +12v for CPU reset,
- +/- 100v HV supply for the Displays.

We're not counting the G.I. (General Illumination) circuit as it is AC only and is fused on the fuse card below the PSU. It only passes through the PSU board to be fused and controlled with a relay starting from System 7 games.

Input AC power gets to the PSU board directly from the transformer for the +5v/+12v and the display voltages. However, in the case of the Lamp and Solenoid voltages AC is 'full wave' rectified (to DC) *before reaching the PSU board*. This is done using two Bridge Rectifiers BR1 for Lamps (to the Right of the backbox) and BR2 for Solenoids and Flippers (to the Left of the backbox).

Lamp Voltage Supplies:

- The +18v DC Lamp voltage passes through a very large 'blue can' filter capacitor between the BR and the PSU board. This 'smooths out the 'bumps' (called AC ripple) in the DC waveform.
    - Because the MPU Controlled Lamps (for the inserts) are strobed by the Lamp Matrix, the resultant voltage to the bulbs is "averaged down" to about 6v DC.
        - Lamps are rated at 6.3v and 250mA for #44 Bulbs (so 1/4 Amp) or 150mA for #47 Bulbs (about 1/7 of an Amp).
        - Because they use less power, #47 bulbs will generate less heat.
        - Replace any shiny 'silvered' bulbs and any that say 0.3A as they burn way too hot and will ruin inserts and cause paint to flake on your backglass!
    - **Note:** This has nothing to do with the G.I. (General Illumination circuit) which is fused on a fuse card and reaches to G.I. bulbs as about 6.3v AC.
        - As they (almost) always stay lit, the G.I. bulbs tend to last longer running on an AC voltage.
        - The AC is 'Tee-d' off to the cabinet, playfield and the insert board (for the backglass lighting).

        - Wire colors for G.I. (and must be measured as AC) are Yellow and Yellow/White.

Flipper and Solenoid Voltage Supplies:

- The +28v DC Solenoid voltage passes straight through to the PSU where it is fused before leaving on the way to the playfield.
    - There are some additional components (a varistor and some filter capacitors) on the PSU board for the Solenoid/Flipper power.

Connectors on the PSU Board

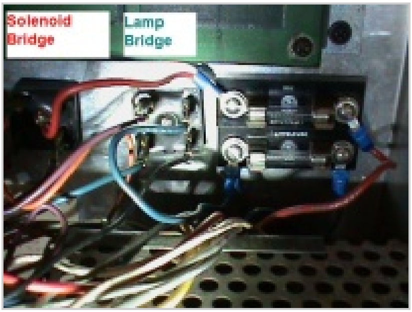
- All AC voltages come into the PSU board in the large 12-way connector 3J1, while the black ground wires are on the 6-way 3J2.
    - The fused ***AC and DC*** voltages exit on the larger of the 'D' shaped connectors, while the black Lamp and solenoid ground wires exit on the smaller of the 'D' connectors.

+5v Logic and +12v Unregulated Supplies:

- In the case of the +12v (and +5v a logic power), the AC comes into the PSU board at 3J1-10 11&12 directly from the transformer windings.
    - You can measure about 10v AC in at the bottom of the diodes D7 and D8 with respect to the board's ground.
        - The total AC input is 18.6v, so each diode 'sees' 9.3v because the transformer winding 'center tap' at 3J1-12 is grounded.
        - D7 connects to 3J1-10, and D8 to 3J1-11 and you would trace connections from there back to the transformer.
        - If you measure AC across the bottom of these two diodes you should see the full 18.6v AC.
        - Do not worry if this AC value is higher without a load, it can (and will) vary with changes in line voltages.
        - Values over 20v AC are considered normal without a load. *It's a 'schoolboy error' to chase the voltages of unregulated supplies trying to get them to be exact*. This includes the AC input and +12v DC unregulated supply.
    - The two large diodes at D7/D8 rectify the voltage to around +12v DC, again this is unregulated.
        - It is filtered by a large capacitor (12,000 uF or higher) to smooth out the AC ripple.
        - It is fused at 4A Slo-Blow, before exiting at 3J6-6 as the +12v DC for the reset circuit on the MPU Board.
- To generate the regulated +5v logic supply
    - The +12v input is filtered more by capacitor C16 and then passed through X3 which is a +5v voltage regulator.
    - This exits at 3J5-6 as exactly +5v for the Master Display Board ICs and at 3J6-7 to 3J6-10 for the other +5v supplies (MPU and Driver Boards).

Please note that the Sound Board generates its own +12v and regulated +5v supplies for both Sound and Speech Boards. This is discussed in the Sound & Speech Board Repair Section.

Williams missed a couple of tricks in an otherwise good design. They are:



Lamp and solenoid bridge fuses added

- No fuses on the 'AC side' of the Bridge Rectifiers. This can be fixed fairly easily.
- Basically you add an 8A fuse and fuse holder to one side of the AC input. Do this for both the BR's. As it's AC voltage, it doesn't matter which wire of the two you fuse, find two the same color and fuse one of them. So for example, put a fuse in-line to one Red and one Blue wire. ***Easy to do and it may prevent a fire***.
- They are both marked with a 'tilde' on the BR which looks like an 'S' on it's side: **~**. AC inputs will be the Top and Bottom spade terminals of the BR squares, on a standard unmodified game. They should be Red (or Green) wires for Solenoids, and Blue wires for Lamps. That's the standard on most Williams games of this era.

- They didn't make the connectors to the G.I. wiring handle enough current, so they get hot and burn the nylon housings brown. As they tarnish and melt further resistance builds up and they get hotter.
  - This can be worse to the backbox insert lamps and you can feel the connector is hot to the touch where the yellow and yellow/white AC wires run. In some cases the connector will have been bypassed by an operator or a previous owner as the hinged insert board isn't normally removed.
  - Sadly this also happens for the G.I. connectors out to the playfield and got even worse on System 7, where they ran the G.I. through the Sys 7 PSU board so it could be flashed on/off with a relay (Black Knight and later games).
  - The only sensible option is to buy the correct Molex housing and pins and replace the connectors.
  - The next step is to replace the G.I. bulbs with 150mA #47 Bulbs (which is what I do) or warm white LEDs (which are even cooler and draw less current. Be sure you buy LEDs made specifically for use on '6.3v AC' G.I.

4.15.1 +/-100v Display HV Section of PSU

Here is a document for troubleshooting and repair of the Williams System 3-6 PSU Board Display Power.

An attempt was made to create step by step tests so that reading a schematic is not required. Includes replacement parts for the HV section repairs.

If the 1/4A (0.25A) fuse at F1 always blows on power up, you may have a shorted UDN IC chip on the Master Display Driver board. See this section on Sys 3-6 Master Display Drivers for testing all the UDN chips on the display board. You can use these tests for both UDN7180 and UDN6118 (or UDN6184) IC's.

Try removing the master display power connectors. If that stops the F1 fuse from blowing, suspect the Master Display Driver needs repairs before you rebuild the HV section of the PSU. Test the HV outputs of the PSU without any displays connected and see if the proper voltages are being generated from the PSU without a load. You need +5v logic, +100v and -100v supplies to run the Master Display board correctly. This will let you figure out if you need to rebuild the Master Display, the HV section on the PSU Board or both.

From experience, if components on the PSU Board HV section are stressed, it is best to go ahead and rebuild the entire HV section replacing all components with new parts from a $10 kit. It will save you time!

4.15.2 PSU Parts Suppliers

Check with:
Ed at GPE (http://www.greatplainselectronics.com/Category-29.asp) has HV rebuild kits and most parts.
Rob Anthony's LockWhenLit (http://lockwhenlit.com/Products.aspx) (Borygard from RGP) may also have some PSU parts.
Bob's PSU parts list (http://www.bobramstad.com/pinball/sys6ps.html) shows the Mouser part numbers which is useful if you live in the USA, or just want to order a few items for your PSU repair.

Also check with your favorite electronics supplier. Please be aware that NTE replacement parts may have wide tolerances so they will be compatible with a greater number of original parts. So get the correct replacement parts wherever possible.

4.15.3 PSU Diagrams and Resources

Please refer to these files while using this section to diagnose and repair your PSU Board:

- Williams System 3-6 Power Wiring Diagram showing the wiring from your AC mains plug right through to the connection to the PSU board, Sound Board and the G.I.

- Williams 3-6 PSU Logic Diagram. A PSU Board Schematic for System 3-6 games, containing test points with approximate voltages and help with fault finding your game's power.

- Troubleshooting and repair of the Williams System 3-6 PSU Board HV Display Section

- External link to a PDF of WMS HV parts and instructions (http://www.greatplainselectronics.com/Downloads/W3-11_HV_Kit.pdf) from Ed at GPE, a great place to get your HV repair kits.

Other Resources to visit
Except for the possible use of different transistors for Q1 and Q3 the later System 9-11 HV section is very similar in design. So it will be worth reading through the Sys 9-11 Master Display Driver Problems, for more detail before starting your repair.

Missing PSU Upgrade Sections to add

- Testing the AC in and DC out for all sections, including the Solenoid and Lamp BRs. Simple to do, but should it be spelled out?
- How to fit the replacement transistors with the 'twisted legs' as the SDS-201 and SDS-202 are obsolete. Although a diagram is on the GPE PDF for Ed's HV kit, some shrink wrap tubing could be added to the 'lowest leg' to reduce failures.
- How to fit the 2 x 1n4763a 91v zenerDiodes, at locations Z2 & Z4 to reduce the Display out put to about+/-90v under load and extend display life.
- Repin of Headers at 3J1 and the used pins at 3J2, theory for using crimped trifuricon connectors and new housings which replace the existing female IDC connectors.

...etc.

4.16 Display Driver Board Issues

4.16.1 Repairing the Master Display Driver

Note that the detail here is for System 3 - 6a with 6-digit displays only. So it does not include Alien Poker or Algar, which both used the System 7 type display setup. System 7-9 used a smaller Master Display Board located on the back of the lamp board, and it had IDC type ribbon cables that ran to the 4 player 7-digit displays. They added a 4-digit Credit/Match display which also used a ribbon cable. The harness connecting the backbox (PSU and MPU) signals to the Master board used the same 'edge-connector' as System 3-6).

4.16.2 Firstly, a High Voltage ***Warning***

With the game on you are dealing with +100 and -100v HV DC (High Voltage) going to the displays. That's a potential 200v difference and you only need to feel that once to know it. Wear tennis shoes (trainers or any rubber soled shoe) when working on displays with the backbox open. This is a shock hazard! If you are not capable or happy with measuring these voltages with a steady hand, then get someone else to help you and be there to 'spot' you. Always a good idea and more fun than working on your own.

Another useful tip is to remove Fuse F1 from the PSU (Power Supply Board). This is the HV fuse and is 1/4A Slo-Blow (250mA 'T' fuse in Europe). This will let you troubleshoot the logic (BCD binary decoders and Buffer ICs) with your DMM or Logic Probe without the danger of shocks or shorting them out when measuring TTL (logic) voltages. It may also save your logic probe from a crispy fate.

4.16.3 Master Display Wiring Harness

Sometimes displays just go blank and it is a fault in the wiring harness from backbox to the Master Display Driver. If you can swap a working Master Display Driver board from a System 3-6a game with stable displays, then do that as a first step. This way you quickly determine if the fault is in the backbox **OR** the Master Display Driver PCB or displays on the front of the light board. If it's the towards the backbox then suspect display harness cabing Driver to MPU, or the display PIA or decoding on the MPU. If you don't have the ability to swap in a spare Master Display board, then turn off the game and test the harness for continuity between the backbox (MPU board) and the cables at the left and right side of the Master using this *Master Display board harness wiring diagram*.

4.16.4 Segment failures

Segment failures on a single display could be that display failing. Same issue if just one display is blank. Swap that display with another (power off first) and see if the problem moves with that display. If it moves, it's that display glass or its board. If it doesn't move and stays at the same player location, see below for the possible suspects.

Segment failures on multiple displays and probable cause:

Players 1 & 2 Segments and master display Segments are out:

- BCD inputs are A1 B1 C1 D1 from the MPU board
- MC14543 BCD to 7-Seg. Decoder IC5
- UDN7180 Display Driver IC9
- Resistors R1-R7

Players 3 & 4 Segments

- BCD inputs are A2 B2 C2 D2 from the MPU board
- MC14543 BCD to 7-Seg. Decoder IC8
- UDN7180 Display Driver IC10

- Resistors R8-R14

Start out by measuring all the resistors on the master display board with the power off. R1-R14 should be around 10K ohms. Any that are not within about 10% (say a range between 9.6K to 10.4K ohms) need to be replaced. Also look and see if any look "toasted".

Those resistors get cooked on the Master display boards and usually will then cause single segments to fail on both the player 1&2 or 3&4 displays together, as they are linked. Te resistors need to be replaced with the same value: 10K but at 1/2 Watt. Some of the modern 'metal film' resistors are rated at 0.6W which is perfect and they fit nicely in that location. Older 0.5W (1/2W) resistors are larger, but are fine. Mount them slightly off the PCB so they get good airflow all around the resistor body.

Do the above steps anyway, no matter what the display problem is although it's probably not going to be the whole story. Replacement resistors are cheap and will prolong the life of your displays. Reducing the voltage going to the displays when rebuilding the HV section of the PSU is a good step to take and will help as well. You only need to replace two Zener diodes to achieve this.

4.16.5 Digit Failures

Strobe inputs for the display digits come in to three 14069 hex inverters on the driver board. IC1, IC2 and IC3.

- IC1 is dedicated to the Master Display 'Credit/Match'. Strobes are: 15,16,7,8 left to right, for the 4 digits it uses.
- IC2 and IC3 strobe inputs are more complicated, to strobe distribution between these IC chips is shown in the display diagram below.

Strobe (or strobe input) failures are likely to show up in the player display pairings 1&3 or 2&4 because:

- Strobes 1-6 are shared for players 1 & 3
- Strobes 9-14 are shared for players 2 & 4

4.16.6 All Displays are Blank

This could be that the +100v or the -100v HV are missing from the PSU board. Both have to be there, so check that the output from the PSU and that the voltages (HV) are good first, and getting to the Master display driver to be relayed to the player displays.

There are also 5 x 3 Mega ohm resistors, at R15-R19, These are for the cathode "keep alives" and again should be near that value. If the 3 Meg resistors don't look cooked and are within spec, check that you can see an "orange glow" in the displays when the lights in the room are dim or off. If you see a faint glow (some describe it as an 'orange neon dot'), then look elsewhere for the fault.

If you don't see the display glow, check the wiring to the connectors carefully looking for a burnt wire at pins 4J7-1 -2 and -6 on the master display. Do this with the power off, as you are dealing with 100v and -100v DC. If you find a cooked wire, sometimes just cutting the wire back a bit to expose clean metal and then reinserting it firmly in the IDC connector will repair the problem with a bad connection for one of the HV lines. Remove and reseat all the edge connectors on the master display board and especially examine the ones that go to the backbox. You can clean the copper contacts on the edge connectors gently with an eraser to shine up the copper if it's dull or has "dead spots" worn on it. Check any inline connectors as well.

I also recommend disconnecting all the player displays 1-4 at the Master display. Get it working with the just the credit/match and then with one other display attached, like player 1. Then add back the player 2-4 displays one at a time (you need to power off each time you add or swap a display), tesing for correct function each time. You can also swap the player displays as a diagnostic step and carefully observe if the fault(s) stay with the Display in question or move to the new location. Use the "display test" on the diagnostics for this. After the above is checked, perhaps you do have to suspect the IC chips (or for the discrete version the transistors). Depending on whether the Segments or Digits are out, it will point you at a specific IC (or transistor array). Knowing which displays are out helps reduce the fault domain down to one chip. You need be like a detective, following the clues. Having a Master Display Assembly drawing and a schematic on hand will help with this process.

Here's hoping that it isn't one of the UDN6118A-1 (aka UDN6184-5) IC chips that's faulty. Hard to remove from another board in one piece, without a de-soldering station and becoming obsolete.

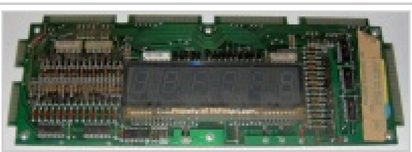
4.16.7 Displays only showing even number

This is caused by a display signal connector issue. This shows up in pairs; player and and two or player three and four. Likely to be header pins on MPU board connector J5, J6, J7

4.16.8 Master Display Drivers for System 3 to 6

Master Display Driver Boards came in two versions, discrete and IC based. Williams designed the discrete version when the UDN7180 / UDN6184 Gas Plasma Display Driver ICs became scarce (and they were expensive even then). There are some logic chips that decode the BCD data for the 7 display segments (MC15453 or MC15458) and to buffer and invert the display strobe lines for the digits (MC14069). These buffers and decoders are common to both the D8000 and D8168 versions.

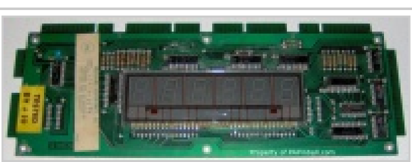
4.16.8.1 Discrete version Display Driver



Williams System 3-6 Master Display Board (Discrete Components)

The D8168 board uses MPSA92 (PNP in a TO-92 package) and MPSA42 (NPN also TO-92) transistors to drive the Master (Credit/ Match) and player scoring displays. These gas plasma display driver transistors are available today and still very cheap to buy. Unfortunately, this style of board is less common to find in the wild, but actually easier to maintain. At least no one can try to charge you $20+ for an obsolete driver IC.

4.16.8.2 IC version Display Driver



Williams System 3-6 Master Display Board

The D8000 IC version board is composed of ICs that implement the transistor arrays. Usual factory chips are the UDN-7180 for the Segment Driver and the UDN6118a-1 for the Digit Driver. You may find the Digit Driver IC is a UDN6184-5 as well from Williams.

4.16.9 System 3-6 Display Board Diagrams

Here are Display Driver Board diagrams for System 3 through 6 games. They contain information that should be helpful when fault finding or identifying components and their locations:

Display Diver Board Assembly Drawing

> This is a Layout Diagram showing component locations and wiring. Please refer to it during your repairs and while following the section below.

Display Driver Board Logic Diagram

> The Schematic is a logical rather than physical layout of the Driver Board. This means that while it shows the circuit connections correctly, it is not drawn to match the actual layout of traces on the board.

The UDN-7180 IC chips are still fairly easy to find. Cost should be reasonable, if you shop / ask around. (Sprague) or uPA6118c may still be available for $3-5 but have a lower breakdown voltage (~85v DC) than original part. The displays run at +/-100v DC as standard and need the higher rated original part which is the the UDN6118A-1 (note we have -1 at the end). The UDN6118a-1 is rare and also becoming very expensive, as much as $20+ for an IC chip.

If you do find the **lower rated UDN6118a (or uPA6118c)**, then you will need to replace two zener diodes on the PSU to lower the display voltage down from 100v. It's a good idea anyway on a working System 3-7 game. Not overdriving display glass and less stress on the expensive display driver chips will lengthen the life of your game. Arcades sometimes had bright lights or windows, while in your home you won't notice any difference running at a lower voltage.

I usually drop the voltage down leaving the Power Supply to about +/- 90v with 2 x 1n4763a 91v zeners, at locations Z2 & Z4. This seems to work well, but you are still probably driving near the limits of the replacement UDN6118a. Unlike the Bally games of the same era, there is no fine adjustment on the voltage output of the HV section of the PSU.

See the Power Supply repair section for more information about parts to use and other upgrades.

Remember to compare the costs and trouble of repairs with buying a replacement Master Display Driver board:

- If all that is wrong with the Master is that the Credit/Match display is out, but it drives all player displays correctly, in my experience the repair is easier than on the player display parts of the driver board:

- **Carefully placing a new 6-digit glass against the pins of the non-working display will confirm if it is the display glass or an IC chip that has failed.** Be Careful of the HV (High Voltages) when doing this, and only hold it by the display glass as it is a natural insulator! It takes a steady hand and some practice, but this test will work on other player displays as well. This usually proves the old display has a digit/segment missing, is 'out gassed' or is just prone to flickering. This isn't foolproof, it works works provided the existing display doesn't have a short. If both displays exhibit the fault, cutting the correct 'leg' or legs in the middle on the old display may help reveal this, and you can bend it back and solder back together if it's not shorted.
  - You replace the Master display glass with a standard 6-digit gas plasma display, you can even use an old (but working) player display.
  - You can also replace the Master display with a player display that has a digit fault and would otherwise be unusable! It's possible because the '100,000s' and '100s' digits are not used on the Master [x00x00]. So you can take two faulty components (a non-working Master and non-working player score display) and make a working Master Display Driver Board. Pinball repair nirvana.

Once you feel the display glass is good, you can look to the ICs which are dedicated to driving the Master (or Credit/Match) Display:

- Start by testing IC1, a 14069 Hex Buffer/Inverter with your logic probe. Run the display digits diagnostic test, with the Auto/Manual switch in the Auto/Up position. The digits on all displays should be counting 0-9. Test the strobe lines are being inverted. The strobe lines and associated pins are in the diagram given below.

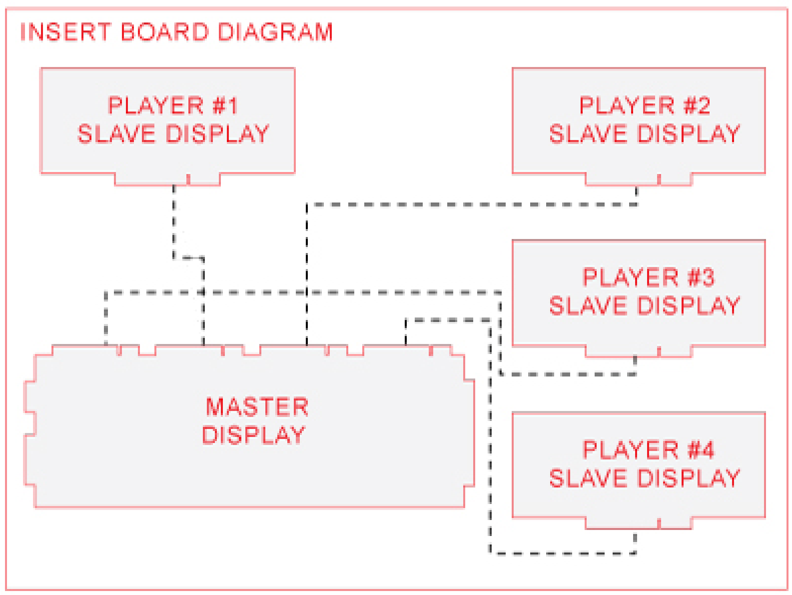
When reading this diagram remember that Player 1&3 Score Displays share Strobes 1-6, while Player 2&4 Score Displays share Strobes 9-14. One strobe for each digit.

The Master Display has 4 digits only: Strobes 7,8,15,16. So if the output pin is not the inverse of the input pin or a signal is missing, then replace IC1. It's available as a 4049U or MC14049UB. Cost is maybe 50 cents, certainly < $1 even in low numbers. Useful chips to buy and have around, as the 4049 is also used on the System 3-7 Driver Board for the switch matrix and on other later games.

DIGIT CROSS REFERENCE CHART

DIGIT	(UDN)6184 DIGIT DRIVER	STROBE	(MC)14069 INVERTER
Master 1 (Left)	IC4 pin 1 / 18	15	IC1 p. 11/10
Master 2	IC4 pin 3 / 16	16	IC1 pin 1/ 2
Master 3	IC4 pin 5 / 14	7	IC1 pin 3/ 4
Master 4 (Right)	IC4 pin 7 / 12	8	IC1 pin 5/ 6
#1 100,000	IC11 pin 1 / 18	1	IC2 pin 5 / 6
#1 10,000	IC11 pin 2 / 17	2	IC2 pin 3 / 4
#1 1,000	IC11 pin 3 / 16	3	IC2 pin 1 / 2
#1 100	IC11 pin 4 / 15	4	IC2 pin 9 / 8
#1 10	IC11 pin 5 / 14	5	IC2 p. 11/10
#1 Units	IC11 pin 6 / 13	6	IC2 p. 13/12
#2 100,000	IC11 pin 7 / 12	9	IC3 pin 9 / 8
#2 10,000	IC11 pin 8 / 11	10	IC3 pin 5 / 6
#2 1,000	IC12 pin 5 / 14	11	IC3 pin 3 / 4
#2 100	IC12 pin 6 / 13	12	IC3 p. 13/12
#2 10	IC12 pin 7 / 12	13	IC3 p. 11/10
#2 Units	IC12 pin 8 / 11	14	IC3 pin 1 / 2
#3 100,000	IC12 pin 1 / 18	1	IC2 pin 5/ 6
#3 10,000	IC12 pin 2 / 17	2	IC2 pin 3/ 4
#3 1,000	IC12 pin 3 / 16	3	IC2 pin 1/ 2
#3 100	IC12 pin 4 / 15	4	IC2 pin 9/ 8
#3 10	IC13 pin 1 / 18	5	IC2 p. 11/10
#3 Units	IC13 pin 2 / 17	6	IC2 p. 13/12
#4 100,000	IC13 pin 3 / 16	9	IC3 pin 9 / 8
#4 10,000	IC13 pin 4 / 15	10	IC3 pin 5 / 6
#4 1,000	IC13 pin 5 / 14	11	IC3 pin 3 / 4
#4 100	IC13 pin 6 / 13	12	IC3 p. 13/12
#4 10	IC13 pin 7 / 12	13	IC3 p. 11/10
#4 Units	IC13 pin 8 / 11	14	IC3 pin 1 / 2

System 3-7 Master Display Driver



Digit failures will show up in these pairings if they are related to the strobes (so digit drivers):

- Strobes 1-6: shared for players 1 & 3
- Strobes 9-14: shared for players 2 & 4
- The Diagram below is the same for all games, as are the Master Displays which makes them interchangable:
- The Table / Diagram is listed in the most obvious order: Master, Player 1,2,3,4 displays.

This is a clearer Table from the above diagram:

MASTER DISPLAY			
DIGIT	**(UDN)6184 DIGIT DRIVER**	**STROBE**	**4049 INVERTER BUFFER**
(Left) 10,000	IC4 pin 1 / 18	15	IC1 pin 11 /10
1,000	IC4 pin 3 / 16	16	IC1 pin 1 / 2
10	IC4 pin 5 / 14	7	IC1 pin 3 / 4
(Right) Units	IC4 pin 7 / 12	8	IC1 pin 5 / 6

PLAYER 1 DISPLAY				PLAYER 2 DISPLAY			
DIGIT	(UDN)6184 DIGIT	STROBE	4049 INVERTER	DIGIT	(UDN)6184 DIGIT	STROBE	4049 INVERTER
100,000	IC11 pin 1 / 18	1	IC2 pin 5 / 6	100,000	IC11 pin 7 / 12	9	IC3 pin 9 / 8
10,000	IC11 pin 2 / 17	2	IC2 pin 3 / 4	10,000	IC11 pin 8 / 11	10	IC3 pin 5 / 6
1,000	IC11 pin 3 / 16	3	IC2 pin 1 / 2	1,000	IC12 pin 5 / 14	11	IC3 pin 3 / 4
100	IC11 pin 4 / 15	4	IC2 pin 9 / 8	100	IC12 pin 6 / 13	12	IC3 pin 13 /12
10	IC11 pin 5 / 14	5	IC2 pin 11 /10	10	IC12 pin 7 / 12	13	IC3 pin 11 /10
Units	IC11 pin 6 / 13	6	IC2 pin 13 /12	Units	IC12 pin 8 / 11	14	IC3 pin 1 / 2

PLAYER 3 DISPLAY				PLAYER 4 DISPLAY			
DIGIT	(UDN)6184 DIGIT	STROBE	4049 INVERTER	DIGIT	(UDN)6184 DIGIT	STROBE	4049 INVERTER
100,000	IC12 pin 1 / 18	1	IC2 pin 5 / 6	100,000	IC13 pin 3 / 16	9	IC3 pin 9 / 8
10,000	IC12 pin 2 / 17	2	IC3 pin 3 / 4	10,000	IC13 pin 4 / 15	10	IC3 pin 5 / 6
1,000	IC12 pin 3 / 16	3	IC3 pin 1 / 2	1,000	IC13 pin 5 / 14	11	IC3 pin 3 / 4
100	IC12 pin 4 / 15	4	IC3 pin 9 / 8	100	IC13 pin 6 / 13	12	IC3 pin 13 /12
10	IC13 pin 1 / 18	5	IC3 pin 11 /10	10	IC13 pin 7 / 12	13	IC3 pin 11 /10
Units	IC13 pin 2 / 17	6	IC3 pin 13 /12	Units	IC13 pin 8 / 11	14	IC3 pin 1 / 2

If that doesn't fix it, next move on to the Segment Drivers:

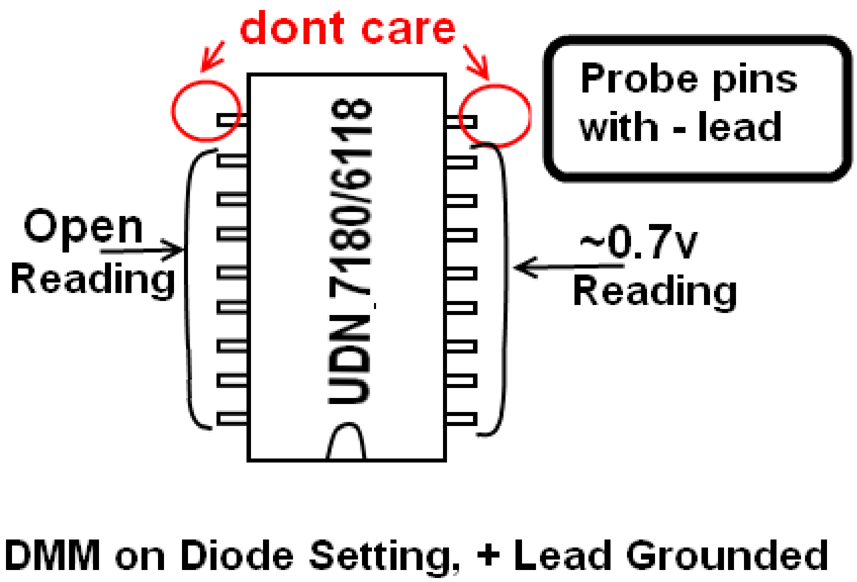
- Look at IC4, the UDN6118A, follow the steps to do a DMM test of the UDN chip. A trick here can be that all the pins are not used (because of the missing digits, so it is possible to make use of the original UDN6118-A-1 (or UDN6184-5) that has a previous fault and one I/O pair is faulty.

This works for the Master Display, so I would keeep a faulty UDN chips (or a faulty board) for spares. You never know (e.g. there is an *extra unused pair* on every UDN7180 type chip pins 1+18 when we get to Segment driver tricks!!! This does not work when you get to for System 7-9 Masters, as all the pins are used.

Pairs that **are needed** for IC4 are: (1,18) (3,16) (5,14) (7,12). So you can get away without pairs: (2,17) (4,15) (6,13) (8,11) so you can have up to 1/2 the chip faulty, but it needs to be the right positions without using wire jumpers.

There is a way to test the UDN6118's with the power off and your DMM (multimeter).

- **With the game OFF**:
  - Remove the power in to the Master Display board, connector 4J7.
  - DMM goes on the Diode test setting, usually a symbol like this: ->|
  - Red lead clipped to ground, I use the ground braid in the backbox, or on the display board connected by a jump lead (alligator clips each end)
  - Touch black lead to the UDNxxxx pins 2 through 8
  - You should get .5 to .7 for each pin
  - Then touch Black lead on each UDNxxxx pins 17 through 11.
  - An open reading (no reading) is the correct result.
  - A shorted display glass can show up during the UDNxxxx 11 through 17 test.



Shorts Are Found in UDN Chip Test
If a short reading is found in the tested pins (don't test the pairs 1,18 and 9,10), the UDN chip should carefully be desoldered and removed from the board. Take care to preserve this chip, as they are nearly impossible to find and expensive to replace. Now install an IC socket in its place. Repeat the test with no chip installed. If the short is gone, then the UDN chip needs to be replaced. If the short remains, then the display glass needs to be replaced.

Notes on different board revisions: Williams also used the DI-0512 (Dionics-512) for the Digit Driver IC. I have owned the discrete transistor version, but the Dionics-512 version is even harder to find, and I've not seen one in 7 years of collecting. That's not to say they are not out there. All the troubleshooting instructions above are intended for the UDN type boards, but the Dionics boards work in a similar way, so consult the schematics. You will also need to make sense of the warnings below.

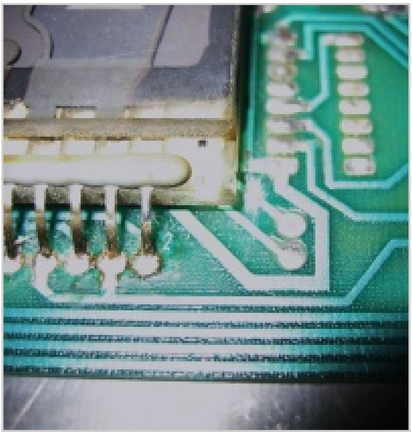
Warnings: These are factory changes, but if you replace or swap chips, you should be aware of the following

- The Display board must run similar chips, so for example all UDN-6118 / UDN-6184 types for the Digit Drivers OR all DI-0512 Digit Drivers (which are longer, meaning they have more pins). They have different power requirements! The two Segment Driver ICs need to match, too. So two MC14548 ICs at IC6 & 7, OR two MC14543 ICs at IC5 & 8. Mix & Match or having all four installed is mental (crazy)! You should have empty pads on the board for the optional IC chips.

- With the DI-0512 at ICs on these boards, the '10K' resistors R1-R14 are all 15K. Adjust the repair instructions below accordingly.
- If IC4 and IC11-14 are UDN-6118 chips, then a +100v trace is cut connecting pin 2 of connector J7 and ZR1 (1N4740A Zener diode) is added.
- With the DI-0512's this trace is left, and there is no Z1 used.

Sometimes a HV arc can occur between two pads on the Master Display board, and if this happens it will blow out the HV section of the PSU (power Supply Unit). If you have the UD7180 version of the System 3-6 Master Display board, it may be worthwhile taking this **easy step** to prevent a problem:

There is an unused track on the front of the board near to the bottom right corner of the Master display glass. The top round pad in this picture is unused on the UDN7180 version but goes to the +100v supply at Pin 2 of 4J7. Click to expand the picture at left for a better view.



Williams System 3-6 Master Display Board

It appears that the pad shorted out to the ground track that goes around both of the round pads. Cutting the track to the top round pad as shown in the picture (with the board removed from the game) will cause no problems for the displays on your game. And it could prevent disaster. A short could damage the HV section of the PSU, even the Master Display board itself. I have seen it happen, so better safe than sorry. BTW- This track **should not be cut** if the Dionics Digit Driver ICs are installed. The writer has owned many games and has never seen a board with the Dionics ICs.

4.17 Sound / Speech Board Issues

Sounds and speech are one of the most important parts of a pinball game for me. Few things are more depressing for me than the sound of a pinball rolling around the wood with no background noises and without sounds of points being scored.

This section deals with the square sound board Type 2 (System 6 & 7, with or without the speech "daughter card"). The Williams part number is 1C-2001-146-x, although much of the information applies to the Type 1 boards (System 3 & 4).

A description of the sound board Type 2:

- The sound board is actually a "mini-MPU" board running a 6808 CPU and a single 6821 PIA. So read the MPU board sections about the replacing sockets and the reset circuit as it will work in a very similar way.
- It has an external 6810 RAM for the CPU registers / 'stack'. This can be replaced by internal RAM in the 6802 CPU if that is used.
- It has it's own PSU (Power Supply Unit) and takes ~18v AC voltage directly from the games mains transformer and rectifies it to DC voltages that provide the +5v logic to the ICs and +12v for the CPU reset circuit.

- It provides -12v DC only used on the speech card for IC2 & IC3 the two 1458 OP Amps. They act as mixers for the analogue sounds and digital speech.
- A single 2K 2716 Eprom (ROM) which contains program instructions that 'boot' the CPU and code to create the sounds. Different ROM versions are containing specific sounds are numbered: Williams' Sound ROM 1, Sound ROM 2, Sound ROM 3...

The last item deserves some explanation. The Sound ROM does not store sounds as samples, but as mathematical 'strings' which describe parameters such as attack, frequency, decay and echo. So the board functions as a synthesizer, rather than playing a WAV file or compressed sound like an MP3 player today. In fact a 2K sample at 22K Hz sample rate could last about 1/10 of a second.

The 4K 2532 Eproms on the Speech Board can hold sampled sound but at very low quality. Black Knight used 4 Speech ROMs for a total of 16K and could speak about 20 words along with the famous laughter. Earlier games having 3 Speech ROMs Like Gorgar or Firepower could speak only about 11 words using 3 x 2532 ROMs.

Why did they provide a different PSU for the Sound card? This early Williams game design could be for ground isolation, perhaps to provide a cleaner sound by avoiding interference from the other components which created RFI. Notice that I used "early Williams game design" and "cleaner sound" were just used together in the same sentence. I have also seen Sound Boards where the BR1 was missing and replaced by 4 x diodes, which also works. Two were mounted on the front and two on the back, with the bands on the diodes all pointing in the direction of TP1 (+12v). Start at 1N5401, rated 100v @ 3A.

Understanding this background should help you pinpoint the source of problems with Sounds and Speech on games of the early 80's.

4.17.1 Useful Sound Board Repair Links

Leon Borre's site flipper-pinball-fan.be (http://www.flipper-pinball-fan.be) has a good starting guide for William board repair, he was a clever guy in Belgium, who developed special test ROMs for lots of pinball systems, including Williams System 3 through 7. **I can't thank him enough here!** He wrote a test chip you can download and burn to a 2716 Sound EPROM which will start the CPU, "pulse" the PIA and also test the memory. It's harder to do any advanced fault repairs without this test ROM. So it's a good place to start if your sound board doesn't boot at all. Leon's technical article pertaining to Williams System 3 through 7 sound can now be found here (http://www.pinwiki.com/wiki/index.php?title=Leon_Borre_Williams_Early_Sound_Repair) .

Dave Langley's site robotron-2084.co.uk (http://www.robotron-2084.co.uk/techwilliamshardwareidsound.html) has a clear diagram of jumper settings for most games on Williams Type 2 boards. Check jumpers first, W1 must be present if no speech board is attached.

4.17.2 Do you have a Sound Board fault?

Before you start to repair your Williams sound card, determine that you actually have a sound board problem! Do the sounds work correctly from the sound board 'self test' by pressing the diagnostic button? Have you followed the diagnostic procedures in the game manual and checked the 'Solid State Flipper Maintenance Manual' or equivalent for your game? You probably will have a fault on the sound board if the diagnostic test on the sound board produces nothing (or the wrong sounds) **and** grounding the input pins won't work. See the 'sound selects' section for your game below. Check out the Basic Sound Troubleshooting section (http://www.pinwiki.com/wiki/index.php?title=General#Basic_Sound_Troubleshooting) first. After reviewing it, here are are some specific things to eliminate first:

- Bypass the volume control in the cabinet by removing the connector at IOJ4 and jumpering pins 1 & 2. It will be really loud (full volume in fact) so a couple K ohm resistor (3K?) looped around those two pins will

substitute for the volume pot and save your ears.
- Take the sound board out, leave all the connectors still plugged in and the game running.
  - The speaker and volume control can be set as above.
  - Touch the back of the sound amp at IC1 with your finger - it's just under the Volume control connector J2 which you jumpered and has 5 legs. Not hearing this hum could be a missing +12v or a bad amp IC.
  - You should hear a loud hum from the speakers, this proves the TDA2002 sound amp is working and also that the speakers are capable of producing sound.

Treat the sound board as a mini-MPU board (but with an on-board PSU) and all the usual fixes apply:

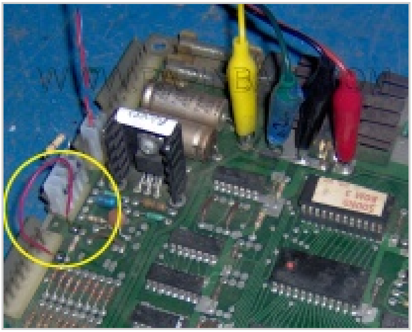
- Test that you have around 18v AC coming in to the sound card. It's directly from the transformer to connector 10J1 and then fused with 2 x 8A fuses.
  - Are both fuses good? Take them out and test them.
  - Is the voltage getting further than the fuse clips? Are the fuses hot to the touch when you switch off the power and remove them? This may indicate high resistance at the fuse clips.
  - Pin 5 of 10J1 is the 'center tap' or reference for the AC. You should see about 9.6 V AC between pins 1 and 5, and the same voltage between pins 9 and 5.
- Use the test points to measure DC +5v +12v and -12v. A short-cut (and much easier) is to touch the Red test lead to the left side leads of the 3 big capacitors, with the black lead on Ground which is the metal trace on the edge of the board.
  - Remember -12v is only needed for the speech board, and even around -10v will normally be fine.
  - Don't worry if the voltages aren't perfect (especially the +/-12v DC which is unregulated). Only the +5v needs to be in a narrower range (4.8-5.2v).
  - No +5v with +12v present suggests the 1 amp '7805 5v regulator' at IC8 is faulty. It looks like the TIP-xxx transistor as it is in a TO-220 case, with a heatsink. Measuring +12v input on the top pin and no +5v output on the bottom pin will confirm this diagnosis. Obviously the CPU (and other ICs) can't run without the +5v logic voltage.
- If there are Scanbe sockets, replace them first, including the ROM socket. You can leave the PIA for now if it's not socketed.

Read the MPU board repair and troubleshooting if the board still won't 'boot' (the CPU, working RAM and reset circuit are very similar).

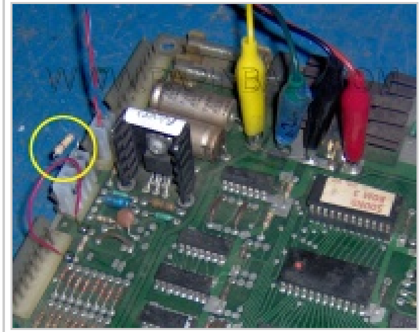
-
  - Because there are no LEDs to show the board is 'locked up', you will need to look at pins 9 - 20 & 22-33 on the CPU for any activity with a logic probe. If the CPU has started, there should be some activity on these address and data bus lines. If they are 'dead', then the CPU has not started.
  - If you look at the CPU bus lines with Leon's sound board test ROM (instead of the sound ROM) you can see which lines are missing, and also will see the PIA lines 'dance' as he calls it. The PIA I/O lines strobe Hi/Lo/Hi/Lo if they are working as they should. You will need to burn the Test code on a 2716 Eprom, get one supplied to you.
  - Review Leon Borré's Williams sound board article (http://www.pinwiki.com/wiki/index.php?title=Leon_Borre_Williams_Early_Sound_Repair) for advanced troubleshooting. You can fix boards more easily with his free test ROMs.
  - Note: The the test chip will not start on a Type 2 board with jumper W1 missing, unless the speech card is also connected. Mine didn't start "pulsing" without the speech card. Because of this, here's a *key tip*: **Jumper W1, and set DS1: SW1 and SW2 to OFF and run without a speech board** until the sound is working 100%. Do this now if you haven't removed the speech board already, it may not be obvious at first, but you have to get back to a basic setup and work forward from there.

See also Advanced Sound/Speech Board Repair on the Bench

4.17.3 Back to Basics



Temporary W1 jumper installed



Bypassing the volume control

The next step, once you have verified voltages is to remove the speech board (if one is fitted) and jumper W1. Verify W1 is present for any board you are working on, as no sound gets to the audio amp without a speech board or jumper W1 present.

To bypass the volume control, a xxx ohm resistor can be installed across pins 1 & 2 of connector 10J4. Alligator clips can be used, but if you intend on testing sound boards in the future, a resistor can be crimped and installed in a .156" housing. Although xxx ohms resistor is used in this example, other values can be used to obtain the volume you desire. xxx ohms sets the volume to medium loudness.

The .156" set up can be used on all Williams sound boards from System 3-7 games and 9-11 gmaes too.

4.17.4 Modification for Noisy Type 1 Sound Boards

On the Type 1 sound boards, Williams did not use a small value bypass capacitor on the input to the 7805 +5V regulator as recommended by the manufacturer. This bypass capacitor is used to keep noise off of the +12V voltage rail, which is used by the power amplifier IC. Installing a .22uF capacitor across the input pin (pin 1 - left pin from front) and ground (pin 3 - center pin) of the 7805 regulator can significantly reduce the amount of noise and hum on these sound cards.

4.17.5 System 4-6 Sound Selects

Press the diagnostic switch on the Sound Board. When sounds do work on the sound board self test, but you get missing or incorrect sounds during a game, then a simple test for all models of sound card is to ground the input pins. This gives you an indication that the sound board is working, as each pin should produce a distinct sound. For Type 2 boards (square ones) that's 10J3 pins 2-4 and 7, pin 1 is on the right, It may also be the same pin locations on the Type 1 boards (Flash, and other System 3 & 4 games).

Grounding those sound select pins is exactly what the Driver Board does during a game solenoid diagnostic test. It fires solenoids 9-13 to ground the select pins and this triggers 'sound calls' on System 3-6 games. If grounding the sound board pins works, then suspect cabling between the Sound Board and Driver Board or faulty transistors (or pre-drivers) on the Driver Board for the System 3-6a games. You can ground the transistor's metal tabs from the chart below, if this does not produce sounds then the cabling between Driver and Sound Boards is then suspected.

Please note that **grounding the center tab of a transistor** *does not test the transistor(s)*, it only proves that the cabling from that tab out to the sound board select pins has continuity. It does not prove the transistor(s) work as a switch under the CPU's control.

This is true for ***any testing of solenoids (or flashers) by grounding transistor tabs***. It only proves that the cabling from the Driver Board out to the device is intact, and that the device has power and can function when grounded.

So the Solenoid part of diagnostic test will help you figure it out for a System 3-6 game. It can perhaps help for System 7 game too, although remember that sound calls are triggered from the MPU board instead.

On System 6 (and earlier) you will have a fault on the Driver Board, and specifically the solenoids in the range 9-13 if the following are true:

- The self test on the sound board works as expected,
- Grounding tabs on the Driver Board produces the same sounds,
- But the game's diagnostic tests do not trigger sounds when testing solenoids number 9-13.

If it fires the device, your problem is the transistors or the logic on the driverboard and then the PIA upstream from them. You should first replace both the associated TIP 120/102 and the matching 2n4401 pre-driver transistors on the Driver Board (a fairly easy fix) and re-test. Then follow Driver Board testing and repairs.

If a transistor gets shorted 'on' (or a 7408 IC is faulty) and one of the sound selects is constantly grounded from the Driver Board, you will certainly get fewer and usually wrong (or no) sounds played. You can chase this kind of problem around for hours, if you don't work logically through the problem.

Driver Board Positions

2J9	10	9	6	7	8
2J9	11	12	13	14	15

Blue shows the 5 Sound Selecr Transistors on the bottom two rows of a System 3-6(a) Driver Board.

If diagnostics don't work as you expect, as explained, ground the metal tabs of the TIP120 transistors (briefly - they may be real coils or flash lamps!) on the bottom 2 rows of the driver board. and you should hear 5 different sounds. The first 3 are at the bottom left of driver board, and then the first two the next row up are the sounds from solenoids 9-13 as shown on the chart above.

You can of course also **turn off the game** and measure between the center tab and the input pins on the sound card with an DMM (meter set on continuity or Ohms). If you get high resistance readings, check for cold solder joints on the input pins of the sound board at 10J3. Then check the output pins on the Driver board at 2J9. Reflow the solder on all these pins. Do the other pins on the sound board at the same time.

Another tip is that you should see the center tab of the Blue "sound transistors" running at about +5v DC on the driver board with the game running. If a tab is at zero volts, and others are at +5v then that grounded select points to the problem. Other TIP120 transistors could be at the coil potential, so have your DMM set to voltage and +50v or above for this test if it does not 'auto-range'.

If you get this far and can get 5 distinct sounds, then the problem is not the sound board, nor the connection to the driver board. With System 3-6, this could still be on the driver board and specifically:

- a power transistor TIP120,
- a matching 2n4401 pre-driver transistor ,
- a 7408 logic IC

  and finally

- a 6821 PIA for Solenoids at IC5. As this is a 40 pin IC, it should be replaced as a last step.

At this point just follow the driver board testing and repair guide to get further.

Complete list of Driverboard 2J9 pins and the associated transistors (for Sys3-6) are:

System 6 Driver Board 2J9 Sound Outputs

Pin	Sol.	Function	Transistors	Wire Colour
2J9 P9	# 9	Sound Select 0	Q31 / Q30	Brown / Black

2J9 P8	(*)	Key		N/C
2J9 P7	#10	Sound Select 1	Q33 / Q32	Brown / Red
2J9 P6	#16	Coin Lockout*	Q45 / Q44	Brown / Grey
2J9 P5	#15	Depends on game*	Q43 / Q42	Brown / Violet
2J9 P4	#14	Credit Knocker*	Q41 / Q40	Brown / Blue
2J9 P3	#13	Sound Select 4	Q39 / Q38	Brown / Green
2J9 P2	#12	Sound Select 3	Q37 / Q36	Brown / Yellow
2J9 P1	#11	Sound Select 2	Q35 / Q34	Brown / Orange

- Typical functions, but depends on the game.

List of J3 sound select pins on the System 6 or 7 sound board are:

System 6/7 Sound Board Inputs

10J3 Pin	Sol.	Function	Wire Colour
J3 P3	# 9	Sound Select 0	Brown / Black
J3 P2	#10	Sound Select 1	Brown / Red
J3 P5	#11	Sound Select 2	Brown / Orange
J3 P4	#12	Sound Select 3	Brown / Yellow
J3 P7	#13	Sound Select 4	Brown / Green
J3 P1	(*)	Key	N/C

On System 6, using only 5 solenoids for sound limits the number sound and speech calls. Makes $2^5 = 32$ so only 31 usable combinations, a call of all 0's being null. But (using Firepower as an example) you then can have all the combinations of maybe 20 sounds plus the 11 speech phrases it "knows". So it's enough given the small amount of sound and speech memory they had to work with at the time. In fact it's amazing! For more background, see: An interview with " Eugene Jarvis (http://www.firepowerpinball.com/downloads/Eugene_Jarvis_Interview.pdf) , the sound engineer and programmer for Williams at the time.

Changing the sound board won't cure the problem of a missing solenoid signal, and a major clue is that the sound board tests good, and is also good when grounding the 5 input pins at (Board #10) J3 input connector on the sound board. While the "in game" sounds or game diagnostics will play incorrectly or have missing sounds. For example, an email from someone said that their Firepower game could say "Power" but not "Fire"! A fairly easy diagnosis if you know the game, it pointed to transistor Q35 (a TIP120, a better replacement is the TIP102) which was completely missing from the Driver board. Transistors on the bottom row often get bent back and forth and snap clean off - hard to spot if you aren't familiar with inspecting the Driver Board.

That transistor's center tab connects to 2J9 pin1 and solenoid 11 then fires sound select #2, according to the table above. Without that sound select being triggered, only half the game sounds could be produced (2^4-1> = 15). "Fire" was one of the missing sounds, there were others but they may have not been so obvious to the owner. They would not be listed in the manual as a sound triggered by an achievement (making to rollovers F-I-R-E in this case). The point is to use all the information available to help determine the root cause of your fault.

4.17.6 System 7 Sound Selects

By System 7, Williams had stopped using solenoids to fire sounds and had added a dedicated Sound/Comma PIA on the CPU board to trigger sound/speech. This meant more playfield coils and even flash lamps were now possible, as the Driver Board wasn't used to trigger the Sound Board.

On a Black Knight and later games, the fault could still be on the MPU board. Perhaps PIA 5 (IC36 a 6821 PIA) is suspect as this drives the sound board (and display commas) only. Again you can trigger sound selects by grounding pins on the sound board, and then move back to the header pins of the MPU at 1J8. The pins are12,11,10,9,8 in that order for the 5 sound selects 0-4

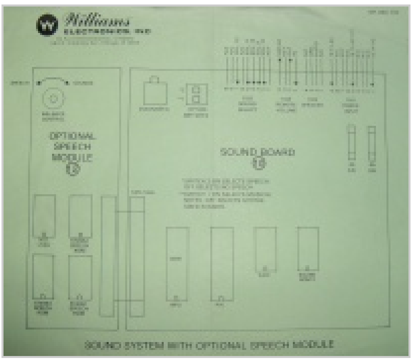
The outputs of the IC36 PIA at PA0-PA6 connects to 1J8 starting at pin 12 (1J8 P12) and run backwards numbered as the Sound Selects in the table below:

SYS 7 1J8 Sound & Comma Outputs		
Pin	**Function**	**Wire Colour**
1J8 P1	Comma 3 & 4	Brown / White
1J8 P2	Comma 1 & 2	Violet
1J8 P3	Key (*)	N/C
1J8 P4-7	No Connection	White
1J8 P8	Sound Select 4	Yellow
1J8 P9	Sound Select 3	Green
1J8 P10	Sound Select 2	Blue
1J8 P11	Sound Select 1	Red
1J8 P12	Sound Select 0	Red / Yellow

In theory Williams had the ability to trigger Sound Selects 0-6 from the System 7 MPU board, and could have programmed 127 sound / speech calls. But the sound boards at the time never used that many, to my knowledge. So you only need to worry about the same 5 sound selects 0-4. Be sure to first ***check the output pins at 1J8 on the MPU Board for cold solder joints***, before replacing the 40 pin PIA.

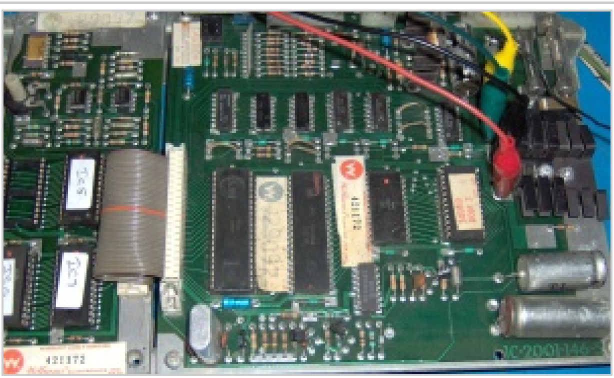
4.17.7 Put the Sound/Speech Board on the Bench

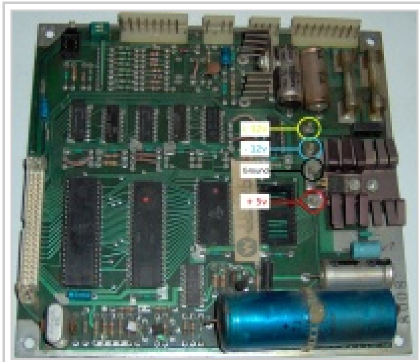
OK, so by now you probably do have a sound board fault. If you don't feel comfortable troubleshooting or don't want to get involved with low level board repairs, you are encouraged to search the PinWiki for a board repair service. You can also buy excellent reproduction sound and speech boards 'ready to go', if you are planning to keep the game. ***This guide can't tell you the best choice for you!***



WMS System 6/7 Sound Board Pinouts

If none of this helped so far, read the rest of the section below. you will probably need to get the boards on the workbench to test any further. You don't need to use an AC supply, though. Any PC power supply has the +12v and -12v DC you need on the mother board connectors will work. The older the PC PSU the better as they will have a power switch, but you can jumper two pins or add a switch on the later type to enable the voltage outputs.


WMS System 6/7 Sound Board Connected to an AT Power Supply


WMS System 6/7 Sound Board Connections for an AT Power Supply (Four Sound Board Test Points)

Search for an "AT Power supply" on the web for the connector locations or measure them with the DMM. The wires on one example were colored Yellow (+12v) and Blue (-12v). Ground was black as usual. Sliding the existing pins from the motherboard connector housing, and they will potentially fit right in a .156" socket to connect to the sound board. The +12 and -12 goes to the outsides of a 9 pin connector (pins 1 & 9) and the ground to the center pin (pin 5). It doesn't matter which way around you install the connector, if the Bridge Rectifier (BR) is working it will sort it out by conducting through the correct diodes.

Another method is to connect the AT power supply connections with alligator test leads directly to the four test points on the sound board. However, this method will not ensure that the bridge rectifer on the sound board is working or not.

At this point refer to Leon Borre's sound board test link (http://www.pinwiki.com/wiki/index.php?title=Leon_Borre_Williams_Early_Sound_Repair) . He has an excellent approach to a sound board that is dead. You will also need to burn a copy of his sound test ROM or find someone you can supply one for you. You also need a logic probe (under $20), or Leon shows you how to make an LED test probe with some wire, an LED and a resistor which costs a few cents. The logic probe tells you more without swapping leads around, and is just easier to handle around IC pins. As mentioned before, the Test ROM can check the CPU, memory and also exercises the PIA inputs/outputs. An added bonus is that the test ROM will allow the board to boot, even though there are faults on the board.

4.17.8 Checking for Sounds Prior to the Sound Amplifier

An unamplified speaker used to probe for sounds before the sound amplifier

A method to test for sounds prior to the amplifier is to check the output of the D/A converter. This can be accomplished by building a speaker set up. It starts with a low wattage speaker, which does not need amplification to produce sounds. A speaker from an old computer case is great source. After acquiring a speaker, solder two wire leads to it. Then, solder an alligator test clip to one of the leads, and a small piece of solid, copper, house wire (14 or 12 gauge romex works well) or a small finishing nail to the other lead. The second lead will be used to probe the sound output before amplification. This speaker test set up can be used on any other brand sound board too.

After the speaker test set up is constructed, clip the alligator test lead to ground. Then, place the probe lead on the "C" collector leg / solder pad of the Q2 transistor, as shown in the picture. Once the probe is in place, press the sound board test button. The speaker will have to be placed close to one's ear to hear the sounds, if any sounds are being output. If the sounds are being heard, either the amp (IC1 - TDA2002) has failed, has lost connection (cold solder joints), or is not being powered properly.

Normally the probe would be used to check the sound output right on the leg of the D/A converter (IC13 - 1408). However, pin 4 of IC13 (the output) is adjacent to pin 3, which inputs the -12vdc power to the D/A converter. It is much safer to use the collector leg of Q2 as a probing point to avoid shorting pins 3 and 4 together.

4.17.9 Getting Sound and Speech Working Together

The very first thing is to make sure you have the correct jumper settings and ROM types. You can NOT "mix and match" sound and speech ROMs as you like.

My experience is on Williams System 4-7 pinball where the Sound ROMs are 2716 Eproms and the Speech are always 2532 Eproms. The exceptions are video games (and a few pinballs), such as Defender, Sinistar, Robotron and Joust which use a 2532 on the sound board ROM and each has special jumper settings.

You need the correct Sound ROM type for your game's Speech ROMs.

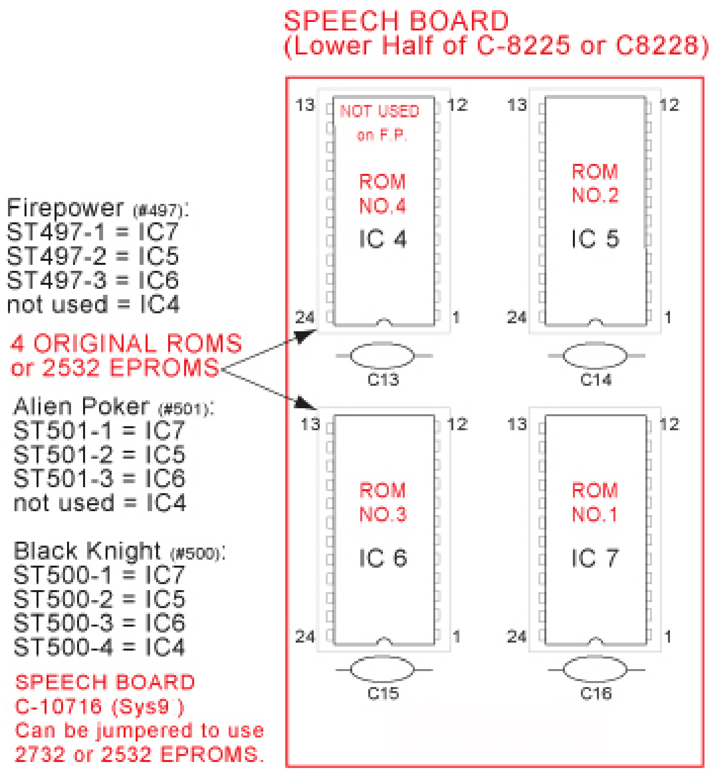
Firepower **and** Alien Poker both use "WMS Sound ROM 3" no matter **what** the Alien Poker manuals (or ROM download archives) say. It's the only way I ever got speech to work on my Alien Poker. If you have Blackout, you will need a 2716 Sound ROM 2 to go with Blackout's 2532 Speech ROMs.

This is mainly a warning if you will be plugging together different boards on a workbench or when troubleshooting a problem, don't trust that all Sound ROMs work with all speech boards !

Here is a diagram on placement of the Speech ICs, as the layout of the ROMs aren't very logical. Check they are correct. This diagram works for any of this type of Speech Daughter board. Replace your game number nnn in ST-nnn-ROM# format. See examples for Firepower (497), Alien Poker (501) and Black Knight (500), which are among my favourites. The information is provided for clarity, it is recommended that you replace Original Speech Mask Roms with newer 2532 Eproms.

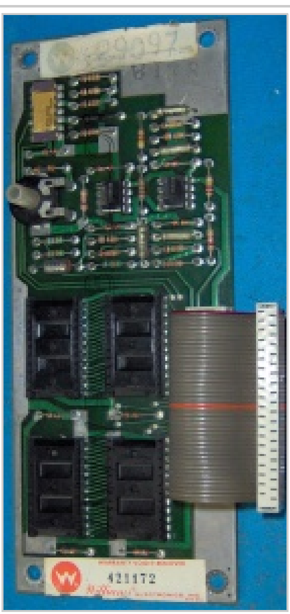
Note: unless a System 9 speech board is available with jumpers, 2732 Eproms cannot be used for the speech board, unless the board is modified (http://www.pinwiki.com/wiki/index.php?title=Williams_System_3_-_7#Modifying_the_System_6.2F7_Speech_Board_to_Use_2732_EPROMs) .

Speech ROM IC socket locations:



Also distrust the switch settings and be aware that you could have a faulty DIP switch on the Type 2 board. It can happen! Test by removing the 2-way switch, or jumpering across the back of the switch. If DS1-2 is not connecting, you will hear sounds- but no speech.

The clue here is that if you press the sound board diagnostic switch, you hear BOTH sounds and speech.



System 6/7 Speech Board with Scanbe Sockets

Identifying Scanbe Sockets

Speech ROMs and Speech Board sockets should eliminated, you can measure continuity on all pins from the Speech ROM to the bottom of the socket or back of board before replacing Sockets. If they say **SCANBE** then replace them as they will be faulty.
Gaps in speech usually point to a faulty Speech ROM, look in the manuals for which ROMs hold the missing words.
Suspect the logic selects on the sound board or the 40-way IDC connection between the speech board to the sound board. Watching for 'chip select' pins 20 on each Speech ROM with a logic probe will help you see the chips being selected by the sound board. Again knowing which ROMs hold the missing phrases will help. No speech selects can point to the interboard cables, or missing outputs from IC2 (a 7442 decoder) **on the Sound Board**.
Bear in mind that the Speech card is an 'expansion board' to hold ROM space for the speech and the digital/analogue mixer. The address and data buses extend across the '40-

way' IDC connector in a similar way to the connector between the MPU and Driver Board. Except the connector solution is more robust and IDC was still used until recently to connect IDE PC hard drives.

Other problems that could cause sounds but missing speech include:

- W1 is jumpered,
- W9 is NOT jumpered (W4 is probably in place),
- IC7 (inverter) faulty,
- IC10 (6821 PIA) is faulty (use Leon's Sound Board test chip)
- Faulty speech board (no speech) or speech ROMs are installed incorrectly

Switch 2 MUST be ON for speech. OFF for no speech.

Switch 1 selects between Tones and Synth Sounds. ON for musical tones (more like bings and bongs), OFF for Synthesized Sounds.

SW 2	ON
SW 1	OFF

DS1 Set correctly for Sounds and Speech.

SW 2	OFF
SW 1	OFF

DS1: Set for Sounds only.

You will also have to **jumper W1** if this is not in place.

4.18 Speech Board Issues

4.18.1 Common failure parts

Before bench testing a speech board it is advised to replace the following parts first:

- Scanbe sockets for the sound eproms IC4 to IC7.
- MC1458 operational amplifiers at location IC2 and IC3. Use machine pin sockets for them.

Also check the ribbon cable to the sound card. It breaks frequently at pin 1 which carries the 5V Analog voltage. If you replace the cable make sure that you do not damage the J1 connector. The part is either NLA or so obscure no one stocks it. Fortunately you can gently pull off the cover and reuse it with a new cable. The counterpart is a standard ribbon connector and must be replaced.

If your speech is garbled and you replaced the MC1458 chips your HC-55516 CVSD at location IC1 might be bad. This is very rare. The part is NLA and hard to get. It can be replaced with a HC-55532, HC-55536 or HC-55564. Only the HC-55564, which was used up to the Williams WPC era, seems to be somewhat available. Check your favorite pinball shop for it.

As with all electronics other parts can fail but the above parts are responsible for around 95% of all speech card failures.

4.18.2 Using the Sound Board Test ROM

Leon's test ROM and instructions will be very useful. The ROM and instructions are available here (http://www.pinwiki.com/wiki/index.php?title=Leon_Borre_Williams_Early_Sound_Repair) .

Note: The the test chip will not start on a Type 2 board with jumper W1 missing, unless the speech card is also connected. Mine didn't start "pulsing" without the speech card. You also need to put the Test code on a 2716 Eprom.

Here's a key tip: Jumper W1, and set DS1: SW1 and SW2 to OFF and **run without a speech board** until the sound is working 100%. Do this now if you haven't removed the speech board already.

This may not be obvious at first, but you have to get back to a basic setup and work forward from there.

The following is an attempt to list notable Williams games that used these boards.

There are conflicting lists, Hyperball could be a 2532 ROM #8. as the file hypsnd12.532 has a checksum of 0x25A8 - which doesn't match other sound ROM images. So the list is not perfect. Some corrections have been as of Feb 2011 after more research. If you have updates or can confirm Williams sound ROM numbers (and compared checksums) then please go ahead and edit this table.

The games with speech in the first table are right, I'm less happy with the Video games and Hyperball.

Williams Pinball Games which use a Type 2 Sound Board and a Speech Board:

NAME	SYS	GAME	WMS SOUND ROM
Blackout	6	495	Sound ROM 2
Gorgar	6	496	Sound ROM 2
Firepower (r)	6	497	Sound ROM 3
Black Knight(r)	7	500	Sound ROM 5
Alien Poker	6a	501	Sound ROM 3 confirmed
Jungle Lord	7	503	Sound ROM 3
Pharoah	7	504	Sound ROM 6

(r) Steve Ritchie Game Design

Video Games with Sound and Speech Board: Sinistar (cockpit front) & Upright, Type 2,VIDEO ROM 9

Pinball Games with Sound Boards Only:

NAME	SYS	GAME	WMS BOARD, SOUND ROM
Flash (r)	4	486	Type 1 Board, ROM 1*
Time Warp	6	489	Type 1 Board, ROM 1
Stellar Wars (r)	4	490	Type 1 Board, ROM 1
Laser Ball	6	493	Type 1 Board, ROM 2
Scorpion	6	494	Type 1 Board, ROM 1
Algar	6a	499	Type 1 Board, ROM 4
Cosmic Gunfight	7	502	Type 2 Board, ROM 12
Solar Fire	7	507	Type 2 Board, ROM 7
Hyperball (n)	7	509	Type 2 Board, SPECIAL ROM 8 ?
Barracora	7	510	Type 2 Board, ROM 4
Time Fantasy	7	515	Type 2 Board, ROM 13
Warlock (pin)	7	516	Type 2 Board, ROM 14
Defender (pin)	7	517	Type 2 Board, ROM 15
Joust (2 player pin)	7	519	Type 2 Board, SPECIAL Snd_IC12.532 ROM
Laser Que	7	520	Type 2 Board, ROM 3
Firepower II (m)	7	521	Type 2 Board, ROM 13
Star Light **	7	530	Type 2 Board, ROM 3 ROM 4 is on my game!

(r) Steve Ritchie Game Design

(m) Mark Ritchie Game Design

(n) Not a Pinball, a gun game that shoots tiny pinballs.

* Sound ROM 1 was used from World Cup #481 to Scorpion #494, but not Laser Ball from my notes.

** Quite a rare and beautiful pinball. Only 100 were produced, the last Williams System 7.

Here is some useful pinball sound file checksum (http://pin-logic.com/early_williams_pinball_game.htm) information. At Tom Callahan's pinlogic.com (http://pin-logic.com)

NAME	WMS BOARD VIDEO ROM
Bubbles	Type 2 Board, VIDEO ROM 5
Defender (Video)	Type 2 Board, VIDEO ROM 1
Joust (Video)	Type 2 Board, "VIDEO" ROM 4 (Checksum matches ROM 4 from Algar and Barracora)
Robotron 2048	Type 2 Board, VIDEO ROM 3
Sinistar (cockpit rear)	Type 2 Board, VIDEO ROM 10

Please Note: VIDEO ROMS and those for Joust (a 2 player head to head pin) and Hyperball are 2532 Eproms

An annoying fact is that from around System 7, most of the WMS sound ROM files are all named something like **SND_IC12.716** , which makes them harder to identify.

4.18.3 Running a Type 2 Sound Board with a 6802 CPU

You might not have an 6808 CPU, or you might upgrade to a 6802 because then there is one less IC (the 6810 RAM) to go wrong. You can leave the 6810 (as it's not socketed) if the card functions with it in place.

You can get the Type 2 board to run on a 6802 CPU, without a working 6810 RAM in IC11. To do this you cut a track called W14. It isn't a 0 ohm resistor (or a real jumper), it's a track located under R30, the 3rd resistor in from Left on the Bottom Left of the board. W14 grounds pin 36 of the processor for a 6808 CPU.

If you want to use a 6802, you cut the track W14. Pin 36 will go high through the 4.7K "pull up" resistor at R30. You could then remove the 6810 RAM as the 6802 has internal RAM. My advice is again to just ***leave it in place*** if the card functions with it there. I had to rework tracks damaged by removing a 6810 on one sound board being repaired. Avoid making extra work for yourself, and ***spend more time playing pinball***. That way it can be reverted back to 6808 operation in future. Good instructions are currently at www.robotron-2084.co.uk (http://www.robotron-2084.co.uk/techwilliamshardwareidsound.html) . A useful site for arcade video and pinball and Dave has a nice Defender pinball to look at while you're there.

4.18.4 Modifying the System 6/7 Speech Board to Use 2732 EPROMs

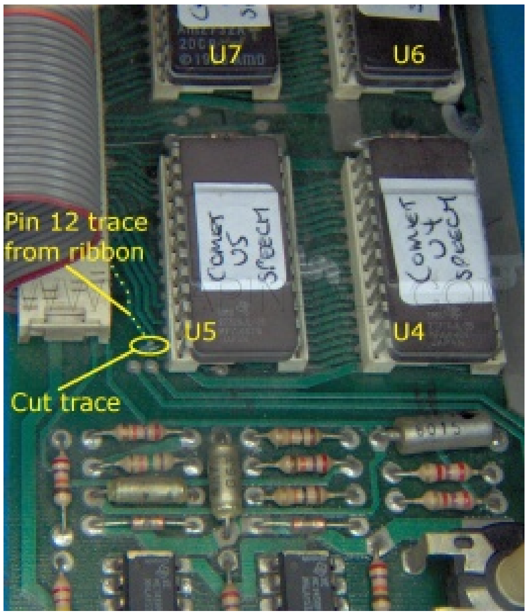
The original System 6/7 speech board is setup to only use 2532 EPROMs. With the following simple modifications, a speech board can use 2732 EPROMs instead, if the need arises. Please be aware that although these modifications are reversible, it is not nearly as easy to change a modified board using 2732 EPROMs back to a board which uses 2532 EPROMs.

Procedure:

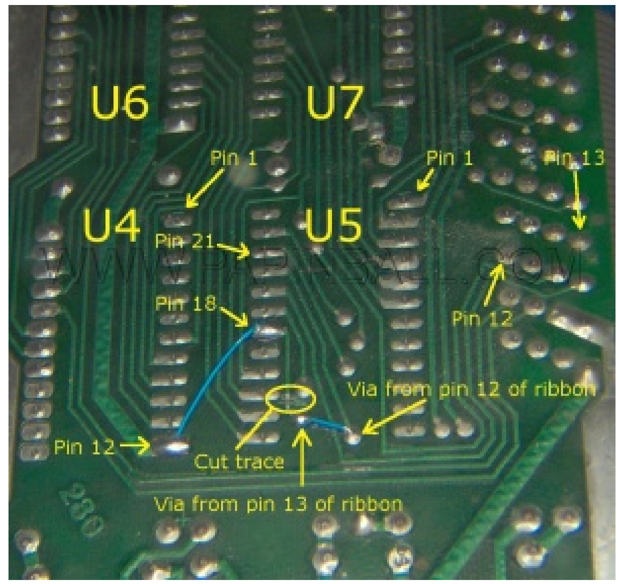
1. On the component side of the board, there is a trace which runs beneath the ribbon cable connection and between pins 11 and 12 of U5 (the lowest two pins on the left). Cut this trace.
2. Turn the board over to the solder side. The orientation of the board in the pic below is with the ribbon cable connection on the right.

3. Locate pin 18 of U5. There is a trace between pin 18 of U5 and a via down and to the right of it. To verify the correct via, check continuity between pin 13 of the ribbon cable (fourth pin up on far right of the ribbon connections) and the via. Cut the trace between this via and pin 18 of U5
4. There is another via slightly down and to the right of the previously discussed via. This second via will have continuity between it and pin 12 on the ribbon cable (third pin up on far left of the ribbon connections). The via will also have continuity between pin 21 of U5. Using wire wrap or a thin gauge wire, tie these two vias together.
5. Locate pin 18 of U5 and pin 12 of U4 (down and to the left of U5 pin 18). Again using wire wrap or a thin gauge wire, tie pin 18 of U5 to pin 12 of U4.

System 6/7 Speech Board 2732 EPROM Modification

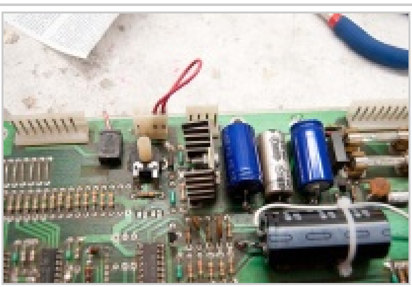


Trace cut on component side



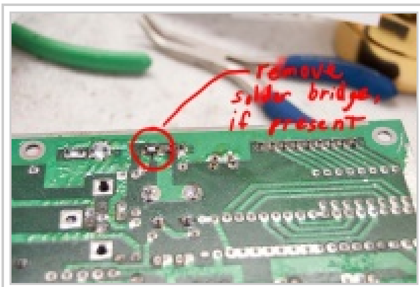
Trace cut and two jumpers added on solder side

4.18.5 Replacing the on-board volume control with a remote volume pot (System 4)



System 4 original volume pot

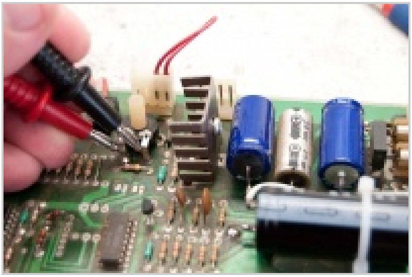
If the volume pot on your system 4 or later sound board fails or otherwise needs replacement, it's often difficult (or impossible) to find a direct matching part. In such cases adding a remote volume pot may be the only solution.



Connector 10J4, with pins 1 & 2 bridged with solder.

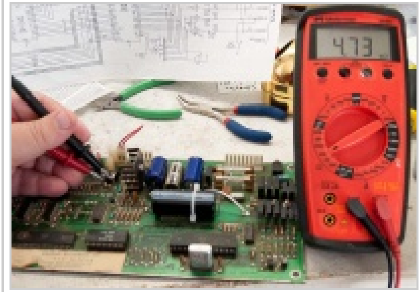
The first thing to do is flip the board over and make sure that somebody hasn't bridged pins 1 and 2 of connector 10J4, as shown here. If it has been bridged, remove the solder bridge and solder the pins independently to the board.

Take a resistance reading across the existing volume potentiometer's legs. If you get a reading above 4K ohms, the potentiometer is not mostly shorted and will not require its leg to be cut as detailed below. (i.e. you may skip that step below.)



Taking a reading across volume pot legs.

This potentiometer is not mostly shorted and could be left un-cut.

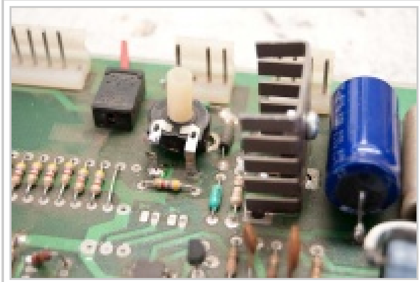


Taking a reading across volume pot legs.

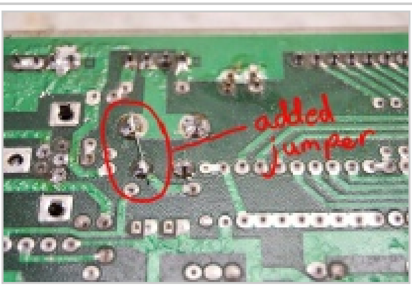
Cutting the volume pot's left leg.

If the previous resistance reading reads less than 4K ohms, then one leg of the potentiometer **must** be cut. (This one was cut for the sake of demonstration.)

After the cut, the potentiometer should look similar to this.



After cutting volume pot's left leg.

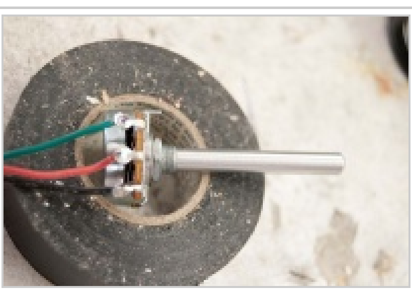


Jumper added across volume pot legs.

In all cases, a jumper must be added to the back side of the board to bypass what is left of the old potentiometer.

A new 5k-ohm, audio (logarithmic) taper potentiometer must be sourced.

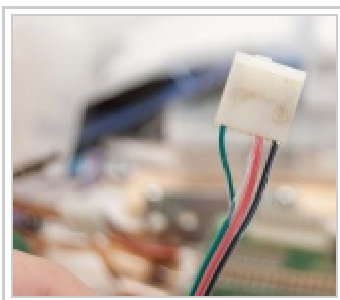
Replacement potentiometer.



Wiring of new potentiometer.

Here a radio shack 271-1720 potentiometer was used.

Three wires must be run between the potentiometer and 10P4, the plug that connects to 10J4. The wires must then be connected to 10P4, as shown.



Wiring of 10P4.

Plug the new 10P4 into 10J4, and the on-board volume pot will be bypassed with the new external pot.

4.18.6 If All Else Fails

You can source a replacement sound/speech board. It may be more cost effective than sending out your sound boards to be fixed, especially as you may be able to sell the original boards to get back some of the initial outlay. These are good quality products, the price isn't bad and they should last for many years to come. James Kohout's pinballpcb.com (http://www.pinballpcb.com)

4.19 Solenoid Problems

4.19.1 Controlled Solenoids

4.19.2 Special Solenoids

4.20 Switch Problems

A word of warning: ***Do not ever file or sandpaper gold switches. Also, do not adjust switches with the power on! It is too easy to potentially short the switch to adjacent power (lamps or solenoids) with a conductive (metal) switch adjustment tool.***

The only switches you can file look like the 'points' in a car distributor (tungsten) if you are old enough to remember them. They can arc and will get blackened (or whitened!) and pitted. Once this happens they offer resistance to current and your flippers will seem weaker. You can file two switches, located on the flipper EOS (end-of-stroke) on early games (EM and SS) and the cabinet flipper switches. Later switches on the EOS are low power switches and have gold contacts. If you file switches that are part of the switch matrix, you will ruin them and they will need to be replaced.

Switches vary from game to game, most are standard for WMS System 3-7.

A few of the common switches are listed here:

System 3-7 Switches	
Part Number	**Common use**
SW-1A-118	Spinner Blade switch
SW-1A-124	Rollover Lanes (inlanes/outlanes as well)
SW-1A-130-1	Switch Rightmost on Ball Runway (Ball Locks, with round white nylon piece on leaf end)
SW-1A-136	2nd Ball Runway Switch (typical, depending on game)
SW-1A-137	3rd Ball Runway Switch (typical, depending on game)
SW-1A-138	Shooter Lane Switch
SW-1A-139	Lane Change Switch (can use SW-1A-150, usually stacked to right flipper or right EOS)

These were used throughout the Williams games: Examples are for the above include System 3, System 4 (Flash), System 6(a) (Firepower and Alien Poker), System 7 (Black Knight). Some appear on F-14 Tomcat ('87) and further, even after most Ball Ramp switches had changed over to micro switches. Black knight also used micro switch kits, which Williams provided as a field replacement kit for operators. Drop Targets also had factory micro-switch adapters fitted later to make them more reliable.

Switch Assembly Note: The Williams factory (or more accurately their suppliers) assembled many switches so one of the blades was facing the wrong way. It should have to gold contacts facing each other, where in fact one blade faces so that the rough-sided rivet is making contact. If you have an intermittent switch, it can be worth the time to de-solder it and remove from the game and then carefully pry the switch stack apart and reassemble the switch so the gold contacts face toward each other. Keep the exact order of spacers and just reverse the one blade. While there, carefully clean the switch contacts with naptha and a clean cloth. Again, please don't use emery (or files) on these switch points! Once the gold has worn, they form "dead spots" and won't work reliably.

4.20.1 How the Switch Matrix Works

First of all a switch is usually an electro-mechanical device with moving parts. This includes leaf blade switches, tilt switches (where the ring is fixed and the plumb bob is the moving part of the switch) and micro-switches. When a mechanical switch closes the contacts tend to oscillate before coming to rest. It literally 'bounces' several times before remaining closed.

The CPU could see the rapid open/close events as multiple switch closures, so there is usually some 'debounce logic' built into switch matrix reading programs. The CPU sees a switch closure and then 'checks back' to see if it remained closed as few milliseconds later. If it is closed, the CPU processes the event once, scoring the correct value or in some cases triggering a solenoid to fire. In the case of Williams 3-7 games, the switch debouncing for normal switches is done at the software level; unlike other contemporary manufacturers' method, Williams' software is more sophisticated in that the definition of switches include the ability to treat a switch as fast-response (example: spinner switch), normal response (lane rollovers - longer 'ignore time' to prevent duplicate reads on a slow traveling ball), and the longest time (trough switches - where the ball would travel over the first 2 switches on a multiball machine, you would not want those to react unless a ball were truly in the trough).

As an aside, an optical switch (or opto) has no moving parts and so doesn't suffer from mechanical switch 'bounce'. (An optical switch can suffer from electronic switch bounce - many rapid activations per second - which is why they usually utilize circuitry known as a Schmidt Trigger to lower the probability of debounce errors). It also shouldn't need adjustment or in theory wear out as quickly as say a micro-switch. However, an opto needs additional circuits and is not as simple to work on or replace as other switch types. Although you can not see an infrared transmitter with you naked eye, you can look at it with a digital camera. Optos were never used in System 3-7 games, although they were engineered and prototyped just at the end of System 7.

Wiring up every switch separately with multiple wires running to the backbox would be expensive in the amount of wiring and in the number of inputs required to the game's logic. Rather than do that, the engineers designed a switch matrix with 8 column wires and 8 row wires, creating a 'matrix' of 8x8 giving a total of 64 possible switches. Not all of these switch positions are used.

The first column of the switch matrix (COL 1) is dedicated to the same switches on the System 3-7 games. You can check in a manual, but these will be the cabinet tilts, the coin switches which sense coin drops, the credit button (to start a game) and the high score reset which is also in the cabinet (on the coin door). In order from row 1 through row 8, they are the plumb bob tilt, ball roll tilt, credit button, right coin chute, center coin chute, left coin chute, slam tilt, and high score reset button.

For the most part other switches will be on the playfield (exceptions could be a lane change or magnasave button/switch).

So how is the switch matrix read by the MPU? It uses the most useful Peripheral I/O device in this pinball era, the Motorola 6821 PIA (earlier this was the MC6820 PIA).

The 6821 is made up of two 8 bit ports, one port is known as 'Port A' and the other 'Port B'. Any of the 16 pins can be configured as inputs or outputs. That's exactly what's needed to drive our Switch Matrix! An 8-way output port B to 'send' (or strobe) down the Columns to the switches, and an 8-way input port A to 'read' the Rows from the switches. The Columns are known commonly as 'Drives' or 'Strobes' and the Rows are known as 'Returns' for this reason. In a similar way (an 8x8 matrix) another PIA is used for the Lamp Matrix.

The switch matrix PIA is at IC11 on the Driver Board (also called PIA II). This PIA doesn't drive the switch matrix directly from it's TTL output pins. There are +5v powered 'pull-up' resistors and 4 IC's which act as drivers/buffers helping to protect the PIA from damage if the switch matrix is shorted.

Two 7406 (Hex Inverter / Buffer with open collector HV outputs) is used to 'drive' the Columns.
    A 7406 or 74LS06 will work and are common parts.
Two 4049 (or 14049 "CMOS Hex Inverter / Buffer) is used to 'read' the Rows.
    The MC14049 or CD4049UBCN are common examples, although any 14049 or 4049 14-leg DIP will work.
    (Hex in this context refers to six inverters contained in the one IC package. It's nothing to do with the computer (or math) Hex meaning of 'base 16'.

The CPU writes to the output port of the PIA driving column 1, then the return input port is saved, holding the status of all 8 rows in one byte. The program then 'looks' at each of the rows 1-8 in quick succession. It checks to see if the signal is getting through on the row that's currently being read. Think of it as an 8 bit answer for that column showing which switches in that column are closed. Say 00010001 returned would mean switches at C1,R4 and C1,R8 are closed.

So for every 'drive' down a column, the machine does 8 'reads' of the rows. Then the CPU moves on and drives column 2, looking again at each of the rows 1-8. It continues through all of the remaining columns in this way. This is done very rapidly by the CPU, strobing the whole matrix looping over and over many times a second. Because it's so fast, even multiple switch closures are rarely missed, in fact as mentioned above it has to debounce the results to obtain an accurate result. Williams' operating system software on machines from at least system 6 up through system 11 have differing debounce values depending on the type of switch, allowing greater sensitivity on certain types of switches, and desensitizing others (such as lock or trough switches).

The diodes on every switch help to steer the drives only to the row that's being read and not back into other parts of the matrix. That's why good diodes on switches are so important, as they must only allow current to flow in one direction: ***from*** column ***to*** row. Essentially that's how the switch matrix reads switch closures.

This article (http://www.flippers.be/basics/101-switch_matrix.html) by Aeneas describing a later game's switch matrix may be useful as a different explanation with a diagram. Transistors can be used on the drives (as with modern games like DE or Stern), different buffer chips can be used, but the basic switch matrix design hasn't changed over the years.

Finally a warning about protecting the switch matrix. Please note that ***nothing*** will protect the switch matrix IC's and PIA if (for example) the +50v solenoid voltage is shorted into the matrix. This happens if the 'lane change' switch is attached in a stack on the flipper mech and shorted to the EOS switch. In later designs the 'lane change' was moved to be stacked with the flipper buttons (nearly as bad) or to a separate button which was a better design. Be very careful if working under the playfield **not to short the solenoid or lamp power into a switch**. It can be a lot of work to repair the damage done to the driver board, so be careful with you screwdriver and loose solenoid power wiring. Most people who have been repairing games long enough learned the hard way, and won't work under the playfield with the power on.

4.20.2 Special Switches

There are a few switches that are dedicated, and not part of the switch matrix. The coin door Advance and Auto/Up Manual/Down switches, which let you start diagnostic tests when the switch matrix is faulty.

Also, there are a maximum of 6 special solenoid switches, which directly connect to the solenoid logic on the driver board. When Williams first designed these games, they were worried that the CPU couldn't always 'keep up' with the ball hits to the pop bumpers or slingshots. So during game play the switches on the playfield fire the special solenoids directly from the playfield. These usually include the spoon switches on the pop bumpers and slingshot stand-up switches. There is a 22uF capacitor and a 100 ohm resistor mounted across these switches. The use of the capacitor and resistor creates what is called an RC circuit (http://en.wikipedia.org/wiki/RC_circuit) . The RC circuit is used to filter noise from the switch signal as well as to ensure a minimum pulse length for the solenoid activation. If using a polarized capacitor the positive terminal goes to the tie point with one end of the resistor attached.

All pop bumpers and slingshots have a secondary switch which is part of the switch matrix. It closes when the coil is fired and tells the CPU to increment scoring and in some cases to trigger sounds for these devices. The scoring switch is mechanically closed, by the 'elbow' of the slingshot arm or by the armature connected to the pop bumper ring.

Confusingly, the CPU can also fire the 6 special switches from PIA lines for the diagnostic tests, but these PIA signals are never used during game play. If all these solenoids work during diagnostic tests, but not in game play it points to the switch inputs or the 7408s at IC6/7. It won't be the 7402s at IC8/9.

I have seen a game that worked in play perfectly, but the diagnostics could not fire two of the pop bumper solenoids during tests. This was a Switch Matrix PIA with faulty output at pins 19 (CB2) and 39 (CA2), other than that the PIA was working correctly and so it could still be used to drive the Switch Matrix. If a switch row or column went out, the PIA would then have to be replaced.

Here is a list of the PIAs and where the pins are that fire the 'special solenoids' during diagnostics:

Special Solenoid Diag. PIAs				
ST#	**PIA**	**CHIP**	**Pin #**	**Location / Board**
1	III	IC10 Lamps	19	Mid PIA on Driver Board
2	III	IC10 Lamps	39	Mid PIA on Driver Board
3	II	IC11 SW Matrix	19	Left PIA on Driver Board
4	II	IC11 SW Matrix	39	Left PIA on Driver Board
5	IV	IC 5 Solenoids	39	Right PIA on Driver Board
6	I	IC18 Displays	19	Via 1J1-26 on CPU Board

4.20.3 Testing the Switch Matrix

To test the switch matrix in the game, first remove both Switch Matrix connectors on the top right of the driver board. J2 is Column (green wires) and J3 is Row (white wires). Then run a switch test from diagnostics, you should get no switches being sensed.

Use an alligator test lead as follows:

- Connect one end of the test lead's alligator clip to the column pin, starting at column 1. That's the bottom pin of J2.
- Then use the other end of the test lead to touch the appropriate row pins.
- Start at the bottom pin of J3, which is row 1. You should see switch #1 indicated (R1C1).
- Move the probe to the next pin up on J3, which is row #2. You should see switch #2 indicated (R2C1).

- When you got to the top of the row pins, move the clip end to COL #2 (up one pin) and start again with row #1.
- Activate each switch in turn by connecting the appropriate 2 male pins on the CPU board with your test lead.

Using your switch matrix chart from the manual as a guide, you may find the faults as your game "sees" on the same switches.

If you get an error in sequence, more than one switch registers at a time or you are missing a row or column - then you **know the problem must be on the MPU board**. You can either try to fix it or send the board out for repair.

If the above test works correctly, meaning all switches register correctly then your problem must be the wiring or on the playfield.

4.20.4 Testing the Switch Matrix PIA

No section on the switch matrix is complete without mentioning the switch PIA. That IC and 4 buffer IC's are the only logic in the switch matrix. The complete instructions for testing all the PIAs are beyond the scope of this section.

The only sure-fire way to test the PIA is with the 'Leon Borre test ROM' in the MPU board. You do this by taking the MPU and Driver boards out of the game and putting them on the bench. This will also let you trace back through the circuit to find a fault more easily, and it's not as hard as you may think. It will also exercise the CPU memory and test all the PIAs on the Driver Board, not just the switch matrix PIA. Here are his excellent instructions:

Leon's Repair Pages for WMS System 3-6 games including a free test ROM.

Leon's Repair Pages for WMS System 7 games including a free test ROM.

These Belgium guys are knowledgeable about pinball.

Should any of the chips in the switch matrix prove to be faulty, be particularly cautious in replacing them. They have a greater than usual tendency for lifted traces and pads when desoldering. Heat rising from the lamp matrix resistors has a tendency to not only cause these chips to fail, but also to loosen the bond between the circuit board and the solder pads and traces on this area of the driver board.

4.20.5 Switch Matrix Components

Final thoughts about components which make up the switch matrix.

The passive components: On the driver board there is an RC network, made up of 16 x 4.7K pull-up resistors that you can measure with a DMM. Tolerance is not critical, but should measure between 4.5K to 5K which is about a +/- 5% range. There are also 16 x capacitors (470pF at 50v, ceramic) these should not measure as a short, if in doubt just replace them. And 8 x 1K ohm resistors at the switch inputs (rows) at R196-R203 these can not be open or shorted and must be around 1K each.

You can see the above chips inverting signals with the game running and a logic probe. Check if signals look weak or suspect. If you see a signal on the input side and then nothing inverted on the output side, then that's your problem.

Beyond that IC15-18, which are the Switch Matrix inverting buffer / drivers:			
IC Location	**Inverting Pairs. Leg a to b listed as a,b**	**Switch Row/Col Numbers**	**IC Part Number /Eqivalent**
IC15	3,2 7,6 14,15 9,10 in that order	Rows 1-4	(MC)14049U / 4049U
IC16	3,2 7,6 14,15 9,10 in that order	Rows 5-8	(MC)14049U / 4049U
IC17	2,1 6,5 12,13 8,9 in that order	Columns 1-4	7406(S) / 74LS06
IC18	2,1 6,5 12,13 8,9 in that order	Columns 5-8	7406(S) / 74LS06

J2 (Column) and J3 (Row) connector pins:				
Connector	**Male connector Pins**	**Switch Row/Col Numbers**	**IC Location**	**IC Part Number /Eqivalent**
2J2	pins 1-3 and pin 5	Columns 5-8	IC18	7406(S) / 74LS06
2J2	pins 9-6	Columns 1-4	IC17	(MC)14049U / 4049U
2J3	pin 1 and pins 3-5	Rows 5-8	IC16	(MC)14049U / 4049U
2J3	pins 9-6	Rows 1-4	IC15	(MC)14049U / 4049U

Except for the 6821 PIA which is getting harder to find, all the switch matrix components are readily available. However there are acceptable substitutes on the market. Any of the following part numbers are drop-in replacements for the 6821. 68A21, 68B21, 6521, W65C21N.

4.20.6 Wire Jumpers on System 7 Driver Boards

Williams removed some resistors from the switch matrix inputs and used wire jumpers instead. This happened from the start of System 7. The first thing to do with a driver board (which may not be from that game) is to measure these resistors and make sure you have the the driver board set up for the correct game. ***While you may be able to use a board with wire jumpers in System 4-6 games, using a board with resistors in a System 7 game will cause problems.*** Having the wire jumpers helps with switch sensitivity and helps with sensing more than one switch closed at the same time.

On driver boards from Black Knight and later System 7 games, there should be 8 wire jumpers (or zero ohm resistors) used on the switch matrix at positions W9-W16. These are located on the upper right hand corner of the Driver Board just to the left of J2, the top left connector which is the switch matrix column input. To the left are two columns of 7 resistors, the second column should be the wire jumpers, and also the top position of the next column (column with 2 resistors only).

On System 4-6 Driver boards, (games like Alien Poker, Firepower and earlier SS games) there are usually 330 ohm resistors (orange, orange, brown) in the same 8 locations. For Black Knight and later (System 7 games) they are called R204-R211, and are zero ohm resistors (usually a tan body with one black stripe). You can replace or jumper over them with wire leaving the resistors in place. In all other aspects the driver boards are identical, so it's easy to convert between the two. This is why they are usually known as *System 3-7 driver boards*.

Before you start to replace parts on the driver board, be sure your playfield switches are working and the diodes are good. You need to unsolder one end of the diode from the switch to be able to test it correctly with a DMM on the diode setting. While you are there, clean the switch with a business card soaked in naptha or contact cleaner sprayed on the business card (with the game off, contact cleaner is flammable!) See if any blackness comes off on the card. You can also gently wipe the contacts until shiny with a Q-tip or the corner of a clean rag dipped in isopropyl alcohol. A pencil eraser also works well to clean switch contacts.

4.21 Lamp Problems

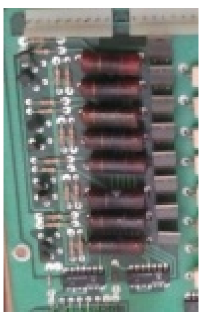
4.21.1 General Illumination Lamps

- Discuss problems with GI passing through power supply and poor connectors used

4.21.2 Controlled Lamps (Lamp Matrix)

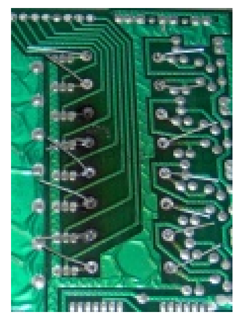
One source of problems with the lamp matrix can be the 27 ohm 3 watt resistors used for the lamp columns. These resistors put out a **ton** of heat! In some extreme instances, they can get so hot that they will literally melt the solder which holds them to the driver board, and fail off the board. It is best to replace these resistors with 27 ohm 5 watt resistors. The 5 watt variants can dissipate the heat a little better. When replacing these resistors, make certain to allow enough space under them to allow for air cooling. Even though it is best to use higher wattage resistors, they still put out a fair amount of heat.

Williams System 3-7 Driver Board Lamp Matrix Resistors

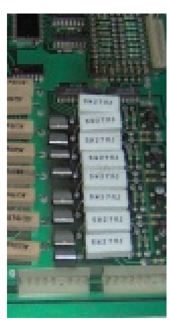


Old resistors in questionable condition due to overheating. Note these are 3 watt resistors as shipped by WMS. Later boards used 5 watt versions.

Using a pencil to allow proper spacing of the resistors from the driver board. One by one, place the legs of the resistors through the circuit board, and bend the legs over.



Flip the board over, and allow the resistors to "hang" off the board.



New resistors soldered on the board with ample air flow beneath them.

4.21.3 Testing the Lamp Matrix

This is a generic Lamp Matrix Diagram which you can refer to for testing the lamp matrix.

5 Improving the Early System 3 Flipper Response

For the early solid state games, Williams re-used the flipper mechanism from their electromechanical games. This design, composed of multiple pieces screwed to the bottom of the playfield, is functional but somewhat clunky in operation. There are those that advocate scrapping the mechanism and replacing it with modern Williams baseplate design flippers. While this certainly works, and provides a much nicer flipper response, it also costs money for new parts when the old parts can be made to work reasonably well.

First, rebuild the flipper assembly with fresh parts. This includes the coil stops, plunger and links, coil sleeves, EOS switches, cabinet switches, and pawls (if needed). Pinball Resource has all these parts.

This leaves a functional, reasonably strong, but 'clunky' flipper. It will work, but it will not seem as 'snappy' and 'fast' as a modern game. While the modern (WPC) baseplate style flipper mechanism is nice, the most important change is actually not the baseplate, it is the modern flipper bat itself.

There is a slight difference in mass between the original bat at 1.5 oz and the new bat at a little under 1 oz, but what accounts for the difference is the way the mass is distributed. On the old flipper design, a heavy metal base is welded to the shaft, and the plastic bat is screwed to the base. On the new design, the plastic bat is simply molded to the shaft, eliminating the base entirely.

Williams Flipper Bat Comparison

Williams System 3 flipper bat assembly (two-piece)

Williams molded flipper bat assembly

When the flipper coil is energized, it begins accelerating the plunger, pulling it in to the centre of the coil. This acceleration is transmitted to the shaft via the crank, accelerating the flipper bat. In this rotational acceleration of the bat, the further the mass is from the centre of the shaft, the more work required to accelerate it, and the slower the rate of acceleration. (Incidentally, this is why magnesium wheels first became popular in drag racing; they are lighter than steel wheels and increase the car's rate of acceleration. It does not change the car's top speed, but it does reduce the time it takes the car to reach top speed, making it quicker.)

At the end of the coil's power stroke, the plunger slams in to the coil stop, rapidly decelerating. In turn, then, the link, crank, and flipper bat also slam in to the previous part and rapidly decelerate. In this part of the action, the higher mass of the old flipper bat has more momentum, and due to the location of that mass, has more leverage to apply the force of the momentum. This leads to a hard clunk as all of that mass slams to a stop, and often results in a flipper bat that 'bounces' at the end of stroke.

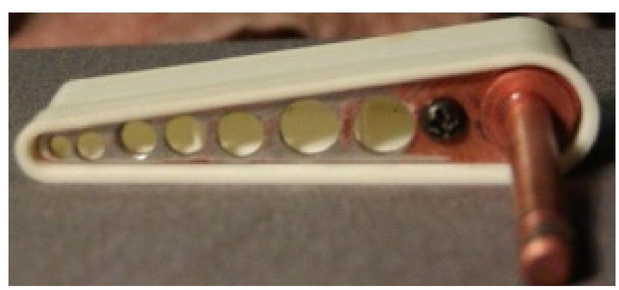
The solution to both of these is to reduce the mass of the flipper bat, especially reducing it as far from the centre line of the flipper shaft as possible. Looking at the options, there are only three pieces to the flipper bat. The plastic bat is not really easily modified to reduce any serious mass. The screw that holds the plastic bat to the base is not easy to reduce in mass, and being located close to the centre line of the flipper shaft, it has very little effect on the operation. That leaves the flipper shaft and its welded on base.

The shaft itself has significant mass, but the mass of the shaft is located very close to the centre line, so it can be ignored as well. That, then, leaves the base. Here there is quite a lot of mass, and much of it is located a good distance from the centre line of the flipper shaft.

First remove the plastic shoe from the bat (there is a single screw underneath the bat). Then screw the metal bat to a piece of scrap wood, and drill the metal bat baseplate to remove metal. This is easiest to do neatly with a drill press. Drill two 5/16" hole near the shaft, and progressively smaller holes toward the tip. A total of seven holes can be drilled: 5/16", 5/16", 1/4", 7/32", 3/16", 5/32", 1/8". These holes remove about 1/2 oz from the flipper bat assembly without significantly affecting its strength or durability.

System 3 Flipper Bat Modification

Drilling the flipper bat shoe



Flipper bat shoe after being drilled

Reassemble the flipper bat, install, and enjoy. Your flippers should feel snappier.

6 Game Specific Problems and Fixes

See the "games" section (http://pinwiki.com/wiki/index.php?title=Williams_System_3_-_7#Games) of this guide, and click on the particular game that you need info.

7 Repair Logs

Did you do a repair? Log it here as a possible solution for others.

7.1 Unreliable +5V

A Firepower won't boot consistently. It was reliable before it was moved in a box truck. +5V supply measures low. For some reason, I decided the problem had to be the diodes in the power supply and replaced them, which didn't help. I replaced the +5V cap in the power supply, C16, and all was well. (Thirty year old filter caps are all absolutely suspect.)

Once I had the cap loose, I discovered I could shake it and hear it rattling inside. Presumably, the jelly roll of electrolytic was dried out. Shaking it might have the internal components in the right place, but probably not. A few miles in the back of the truck was enough to wreck it, more permanently before. The game has been very well-behaved since replacing the cap with a new one. ts4z (talk) 18:12, 21 May 2014 (CDT)

7.2 Firepower won't start a game

Firepower and other multi-ball games are infamous for being stubborn if there aren't three balls in the trough, or if one of the trough switches isn't closed. Additionally, multiball games usually have a shooter lane switch. If MORE than 3 switches are closed, the game will also not start.

My Firepower, in particular, is frequently upset if the right-most switch isn't closed, and that switch has an unusual actuator on it that doesn't work as well as a common rollover actuator. That switch is a little mangled, so it's the one that is most problematic. ts4z (talk) 18:12, 21 May 2014 (CDT)

7.3 Time Warp loses background sound occasionally

There is a software bug in Time Warp where the background sound (if enabled) will go mute at ball launch. This happens whenever the ball launches twice without scoring any points. There is a fix for this identified as Time Warp L-3 however it is not officially sanctioned by Williams and so is not readily available.

7.4 Black Knight

There are 2 under playfield relays used to shunt high voltage to the magna saves. These are high voltage contacts and should be filed for maximum conductivity and power for the magnets.

Fast moving ball flies through upper lock: If you take a shooter lane bracket, you can mount it underneath the plastic of the upper ball lock trough. If you bend it creatively, all ball motion will stop on entering the trough and drop down ensuring that you get credit for the lock.

There is a software bug in version L-3 and possibly L-4 where instead of getting 5000 points with other balls in the lock you get 10,000, scored in increments of 5000. There is no current fix for this; it may have been intentional for the additional score (usually picked up by another player) but probably an oversight by the original programmer.