PINBALL MACHINES

How they work & Troubleshooting

Norbert Snicer

WPC SYSTEM AND SYSTEM 11

THE MOST PRACTICAL GUIDE FOR ALL PEOPLE WHO WORK WITH PINBALLS.

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I would like to thank...

• *All operators for their constant supply of questions which has encouraged me to write this book.*

• *Tony Scott and Lyn Shakespeare for the time and effort they put into the preparation and presentation of this book.*

• *Paul Toumbelekis and Ken Colgrave for their advice.*

Special Thanks to...

• *Tom Cahill, Technical Field Support Manager at WMS Games Parts and Service Inc. for his kind co-operation and contribution.*

Many thanks to all the people who supported and encouraged me to carry it through.

I would also like to thank Williams Electronics Games Inc. for their permission to use information from their literature.

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Note:
Despite the best effort to ensure this book is accurate and free from errors, some errors and inaccuracies are unavoidable due to variations in pinball circuitry.
The pinball circuitry is subject to change without notice. Use the material in this book as a guide only!
The publisher will accept no responsibility for injury, loss or damage that occurs as a result of material in this book.

Norbert Snicer
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How They Work & Troubleshooting

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CONTENTS

NOTES

Introduction

It was my close contact with pinball operators which encouraged me mostly to write this book.

It is not just a troubleshooting guide. You can find simple explanations on how various parts of a pinball machine work and what to do about problems.

Often minor faults cause unnecessary frustration, lost income and service expenses.

Just a little *know how* can avoid it.

This book is intended to provide assistance to the operators, technicians and especially new-comers to the amusement machine industry.

The troubleshooting techniques described in this book are simple and very effective.

The book is based on the *Williams* and *Bally* WPC System - the most advanced pinball system in the world. The earlier *Williams* and *Bally* System 11 is also covered.

I firmly hope this book will be of great assistance to you and will replace moments of frustration with fun and satisfaction.

I would like to express my thanks to Tony Scott and Lyn Shakespeare who contributed with their computer skills to the preparation and presentation of this book.

Norbert Snicer

NOTES

SECTION 1

INSIDE WPC

About Pinballs

Why...

The Game Does Not Start?

The Slingshot is Not Working?

A Flipper Does Not Work?

If you have asked yourself *"WHY"* you are on the right track in your troubleshooting.

The next question should be *"What can I do about it?"*

This book will try to help you to answer these questions.

It will take you step by step through the pinball machine.

You will find explanations about how different parts of a pinball machine work and what to do about problems.

The Pinball is a Computer

On Page 11 you will find the simplest view of a computer. Find the inputs and outputs of a pinball machine.

You don't need to understand how the computer works. The vast majority of problems will happen outside the control circuitry but by using correct troubleshooting techniques, you will be able to determine if the control circuitry is faulty or not.

Playfield

Find what is in the playfield on Page 12.

Each block represents a specific group of devices used in the playfield. Study it for a moment and note what they are.

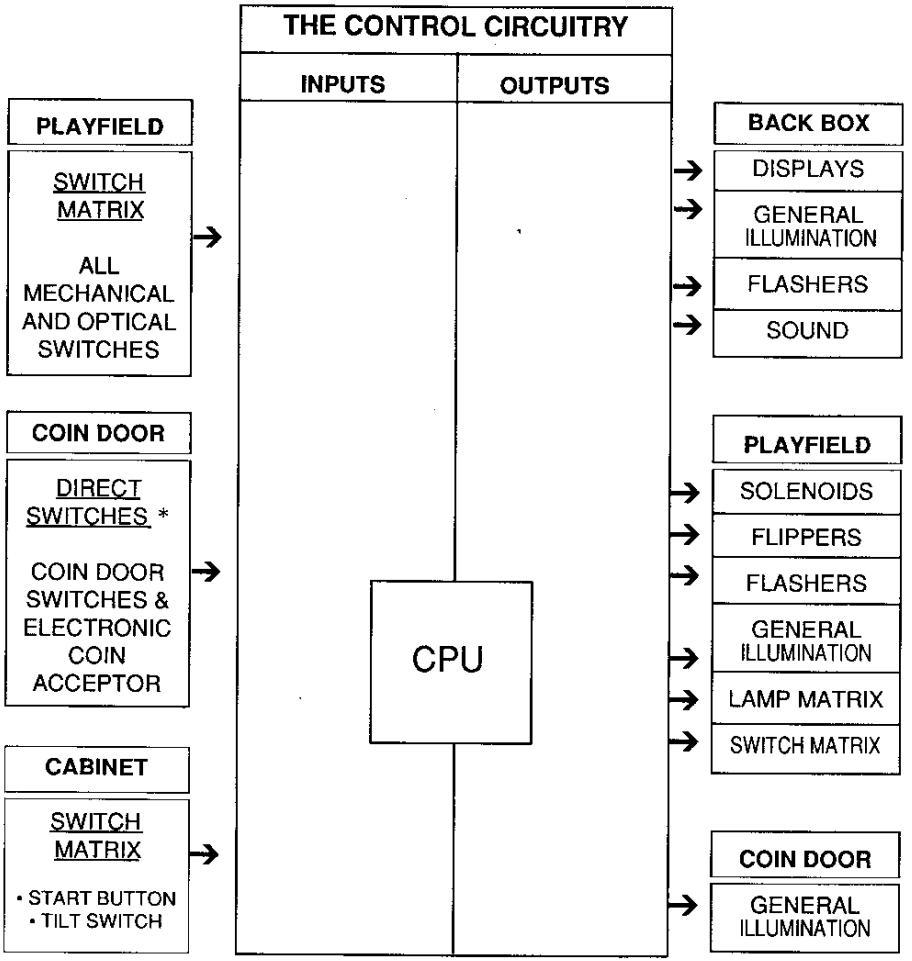
You will find the explanations on how they work further in the book.

The Inputs and Outputs of the Control Circuitry

The diagram below doesn't represent any particular Pinball System.

It illustrates that any computer system can be simplified to "Inputs" and "Outputs" with the Central Processor Unit (CPU - The Microprocessor) taking care of them.

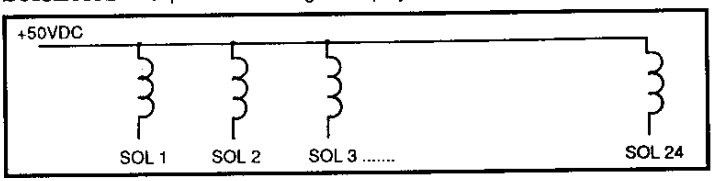
The CPU will determine what happens on the Outputs according to the Program and the information received on the Inputs.



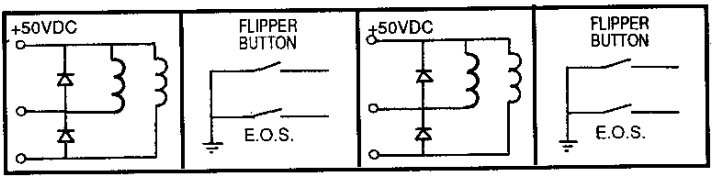
** Direct Switches in the WPC System - Switch Matrix in System 11*

What is in the Playfield

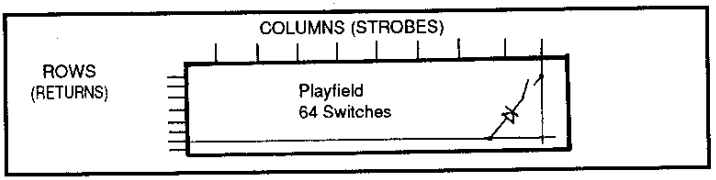
Solenoids - keep the ball moving in the playfield



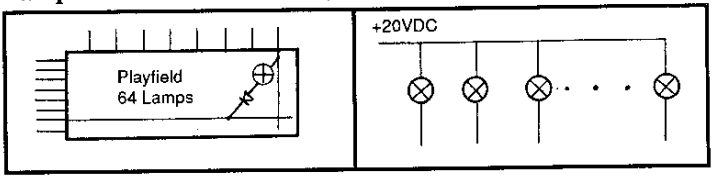
Flippers - Controlled by the Flipper Controller Board



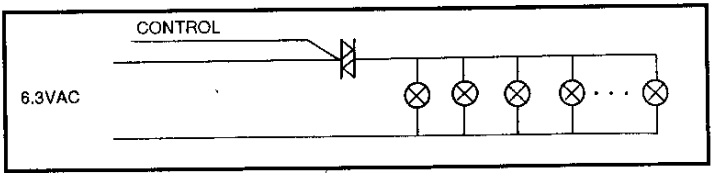
Switch Matrix - Switches inform the computer what is happening in the playfield



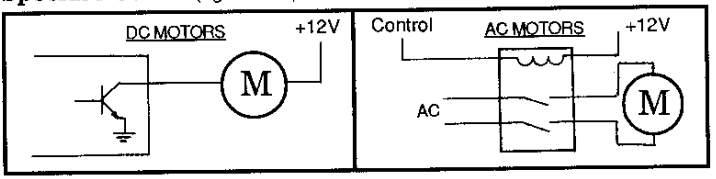
Lamp Matrix - The Feature Lamps **Flashers** - For bright light effects



General Illumination - 5 Strings



Special Devices (eg. Motors)



Inside the Backbox

The Flipper Controller

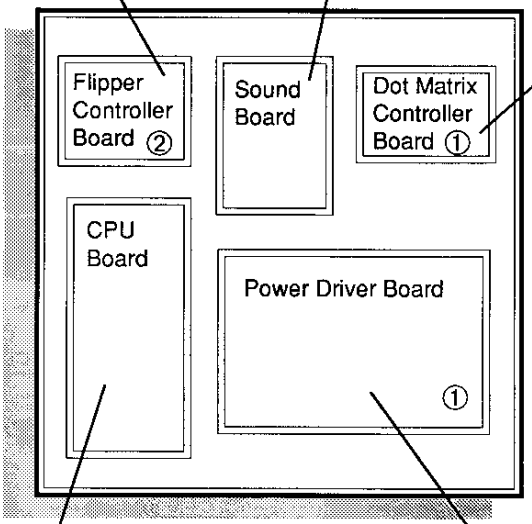
contains Power Driver circuits to drive up to 4 flippers. All switches associated with flippers connect directly to this board.

The Sound Board

is an independent microprocessor system generating all sounds. The CPU Board only instructs the Sound Board on what sounds should be outputed.

The Dot Matrix Control

controls Dot Matrix Display. The CPU Board can access the Memory on this board which can store 16 full display images. The CPU will then determine which of the 16 images will be displayed.



① *These boards are not game specific - they can be transferred between different games.*

② *This board can be transferred to different machines which use the same style of flipper controller board.*

The CPU Board...

is the brain of the pinball.
The CPU contains 68B09E Microprocessor, 4M Game ROM, 2064 CMOS RAM and ASIC Custom Chip.
All switch matrix and direct switches connect to this board.
The CPU board controls all other boards in the Backbox and thus every function in the pinball.

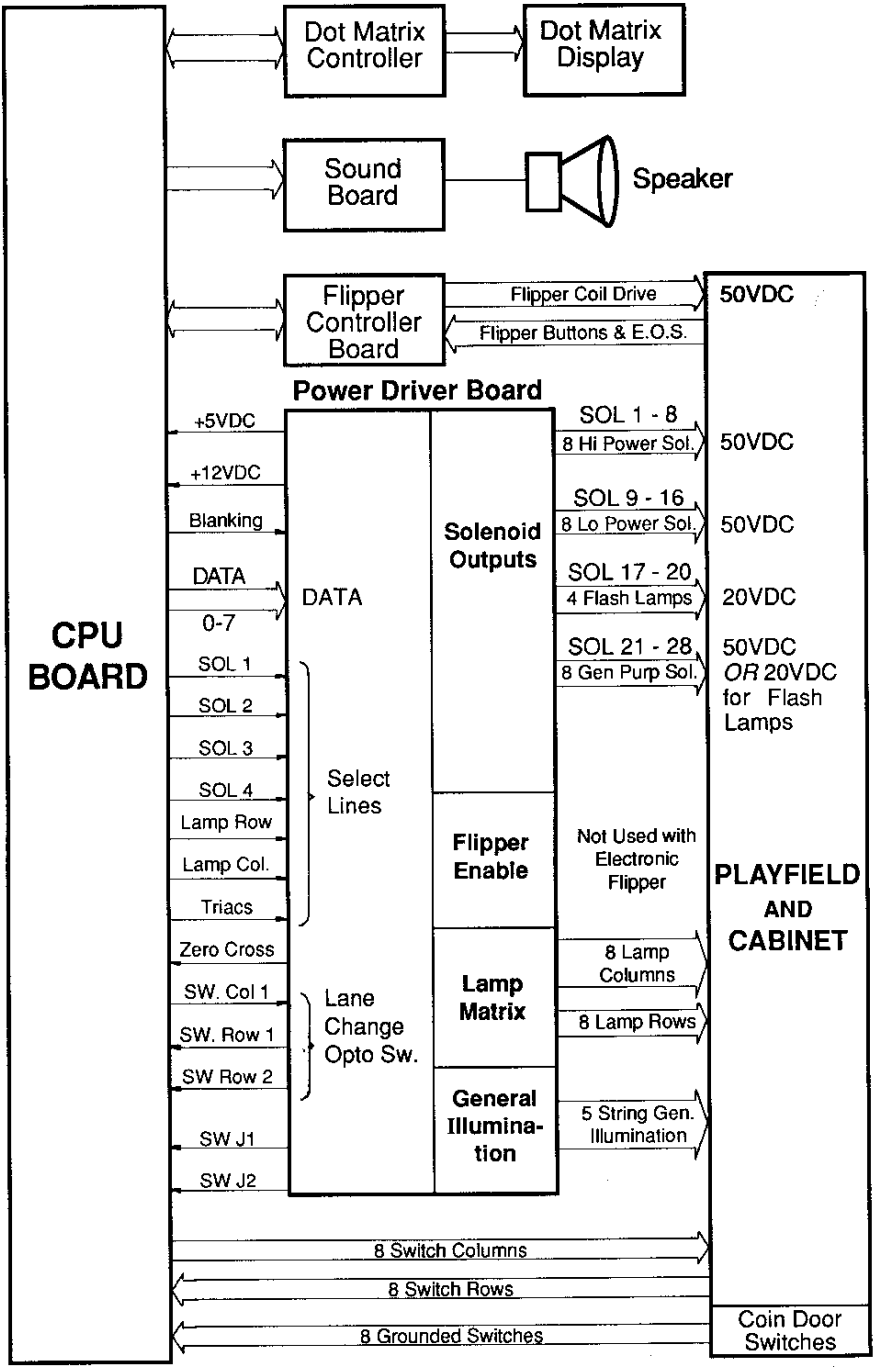
The Power Driver Board...

combines the function of the Power Supply and the Driver Board.
The Power Supply section provides...

- +5V for the Logic Circuit
- +12V for the Switch Circuit
- +12V for Motors and Relays
- +18V for the Lamp Circuit
- +50V for Solenoids
- +20V for Flashers

The Driver Board section drives all solenoids and lamps.

WPC System - Block Diagram



Get Familiar With the Power Driver Board

The more familiar you are with this board the more effective your troubleshooting will be.

The Power Driver Board drives all solenoids and lamps. It provides almost all the power for different parts of the machine. It accommodates most of the fuses in the machine.

Take a look at Page 16. This is the Power Driver Board layout.

Compare this picture with the real board in the backbox.

See if you can locate all solenoid drivers.

For Example: Can you identify **Solenoid Driver 12** in the "Low Power Solenoids" section. It is the transistor **Q52**. Can you find this transistor on the real board? This transistor drives Solenoid **Number 12** in the playfield.

Try to identify lamp rows and lamp column drivers.

Try to identify fuses -
You will be able to say what each fuse is for and what is its rating.

Have a look at the connectors. These are the connectors which the "Help Message" (which you will discover later) refers to.

Each connector is numbered and its Pin number 1 marked.

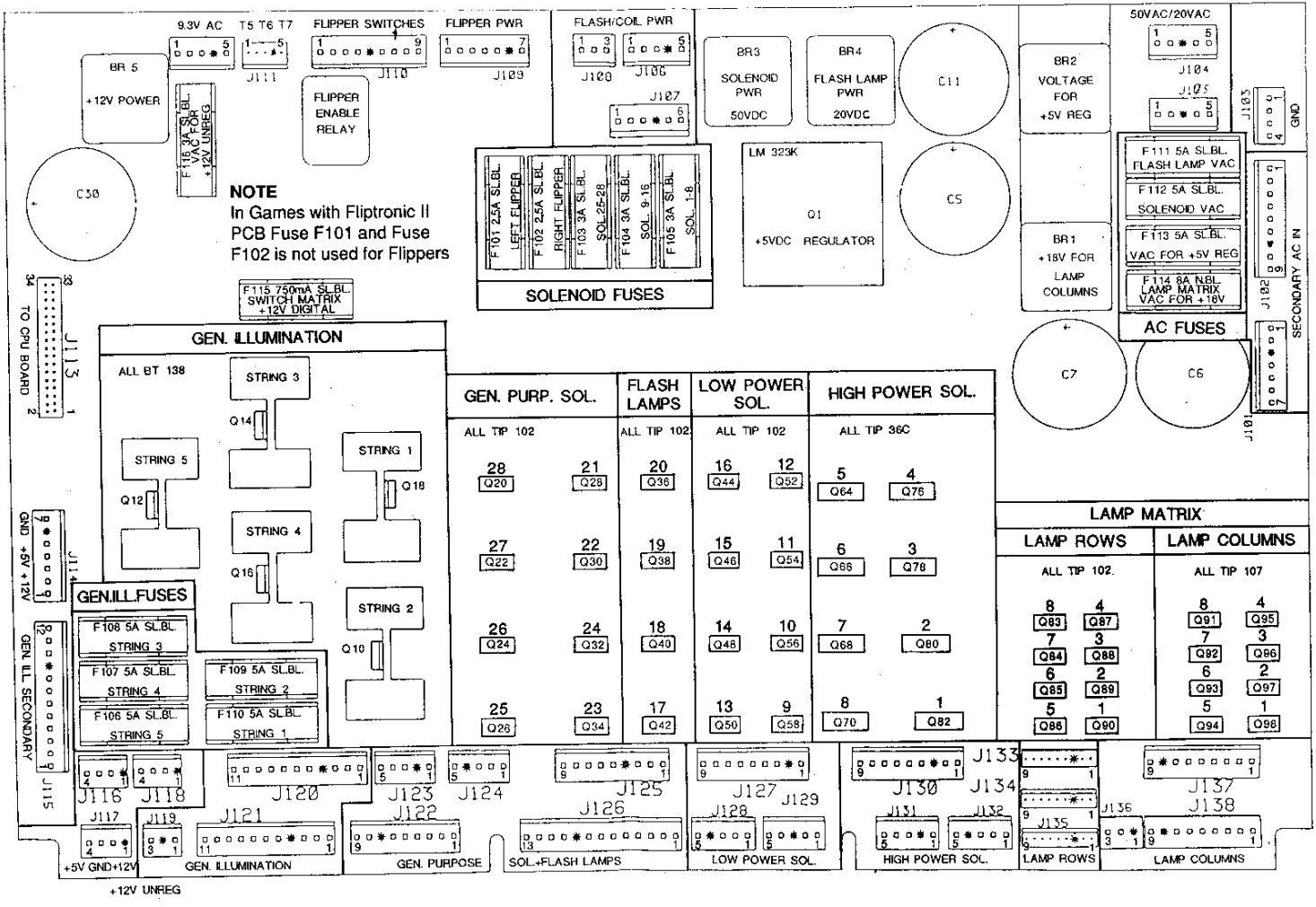
Note the description which tells what the connector is for.

For Example: Would you be able to locate Connector J127 and say what the connector is used for? Would you be able to locate Pin 8 of this connector?

As you read through this book and learn about various parts of the pinball, refer back to Page 16 and try to see the things you learned about on this board.

The Power Driver Board is used in all WPC Machines, so this exercise is well worth the effort.

WPC POWER DRIVER BOARD



Solenoids (Coils) - How They Work

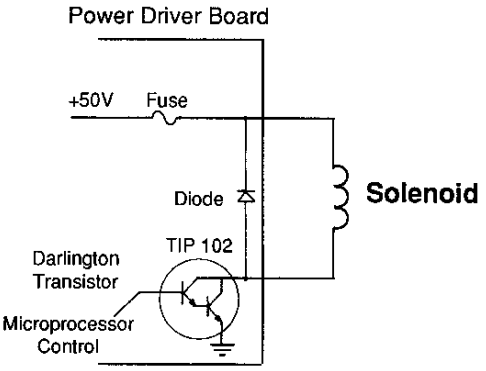


Figure A

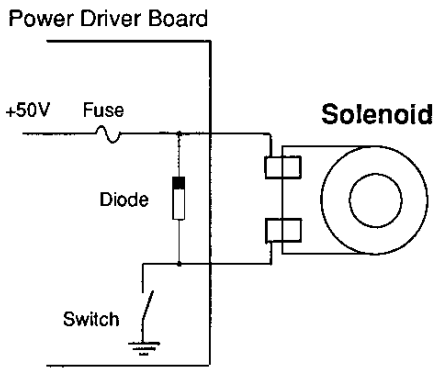


Figure B

The Solenoid Circuit is very simple. Imagine the Driver Transistor TIP 102 (Figure A) as a switch controlled by the Microprocessor (Figure B).

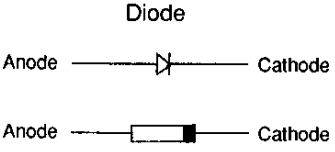
Note the Diode across the Solenoid. The Diode stops the development of high voltage when the Solenoid is turned "OFF". This high voltage could cause damage to the Driver Transistor and could also cause interference to the CPU Board.

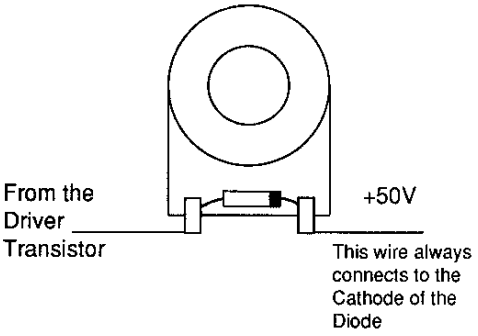
The diodes are part of the Power Driver Board and are not required to be mounted on the solenoids themselves.

The Flipper Solenoid is the only exception where diodes must be installed on the Solenoid itself.

If your replacement Solenoid has the Diode soldered across you can either remove it or connect the Solenoid correctly as shown below.

Reversed connection will cause a short circuit diode and will damage the Driver Transistor on the Power Driver Board.





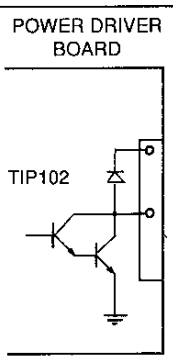
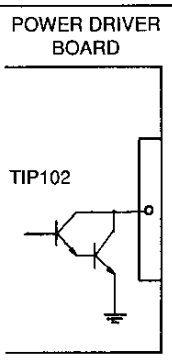
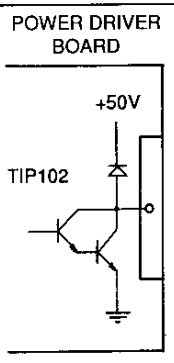
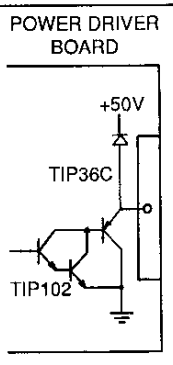
Solenoid Outputs of the WPC Power Driver Board

The WPC Power Driver Board has 28 Solenoid Outputs. These outputs are not only used for driving solenoids - they can also be used for driving Flash Lamps and sometimes motors and other devices.

All solenoids use +50VDC power and all solenoid outputs are switching to Ground.

The outputs can be divided into four groups. Groups 1 to 3 use Darlington Transistor TIP 102 and the groups are almost identical except for the diodes.

Group 4 uses PNP Transistor TIP 36C which is capable of driving more powerful coils.

	1	2	3	4
	General Purpose Solenoids	Flash Lamps	Low Power Solenoids	High Power Solenoids
DESCRIPTION	Used for driving either Solenoids or Flash Lamps. Diode can be connected externally to the operating voltage.	For Driving Flash Lamps No Diode Required Flash Lamp Voltage +20V	The Diode is connected to the +50VDC. Otherwise identical with Group 1 & 2	Transistor TIP 36C allows to drive more powerful solenoid
CIRCUIT DIAGRAM				
SOL. NUMBER	**21 - 28**	**17 - 20**	**9 - 16**	**1 - 8**
OUTPUTS	**8**	**4**	**8**	**8**

Troubleshooting Solenoids

It is absolutely essential to keep all solenoids in good working condition. A non-working solenoid will severely handicap or completely disable the game.

Troubleshooting solenoids is easy. Use the **Solenoid Test** to check them. The display will indicate the name and number of the solenoid under test.

If a particular solenoid is not working, switch the test to the *Repeat Mode* for this particular solenoid.

Press **Credit Button** to get a **Help Message** on the display.

The following information will appear on the display:

- **The colours of the wires connecting to this Solenoid**
- **Where the wires connect on the Power Driver Board (what connector and the pin number)**
- **Location of the solenoid driver transistor and the pre-driver on the Power Driver Board**
- **The related fuses**

Can you locate the solenoid in the playfield? If not see the **Solenoid Locations** chart in the Operations Manual.

Take a look at the Power Driver Board layout on Page 16 of this book. See if you can locate the transistor driver, the connectors and the fuses.

You can take the following steps in your troubleshooting:

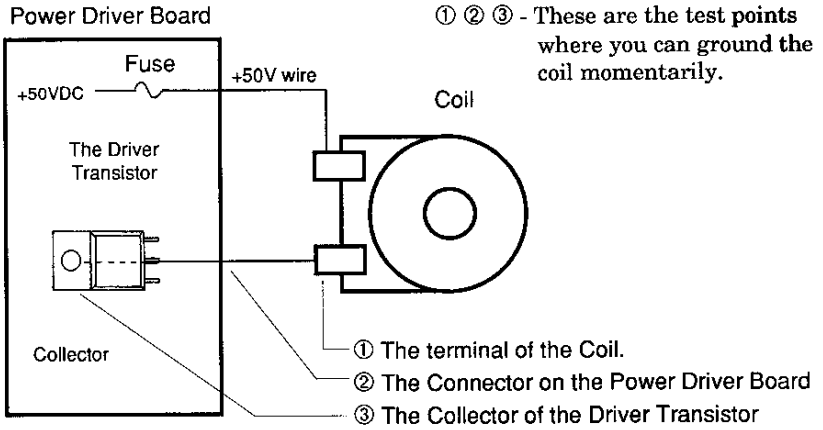
1. Look at the solenoid (coil) itself - maybe it is burnt and it is obvious it has to be replaced.
2. There are two wires soldered to the coil - check if they are well connected.
3. One of these wires is +50V DC coming from the Power Driver Board, the other one connects to the Driver Transistor on the Power Driver Board. You can momentarily ground this side of the coil with your test lead (Test Point ①).

If the coil does not work by grounding Test Point ① the likely causes are:

- No +50V DC on the coil (check fuses, check continuity of the +50V wire)
- If the +50V DC is on the coil, the coil is open circuit (repair or replace the coil - the coil wire sometimes breaks near the solder terminals and can be reconnected).

If the coil **works** when grounded by your test lead, ground the **collector (the tab)** of the Driver Transistor momentarily on the Power Driver Board **(Test Point ③)**

If the coil works, the Power Driver Board is faulty. If the coil **doesn't work**, check the continuity between the collector of the Driver Transistor and the coil.



NOTE: When troubleshooting **High Power Solenoids** grounding the Collector of the Driver Transistor will have no effect. Use the test point ② instead or the collector (the tab) of the Pre-Driver Transistor.

Q. What if a coil is energised immediately after turning the machine "ON".

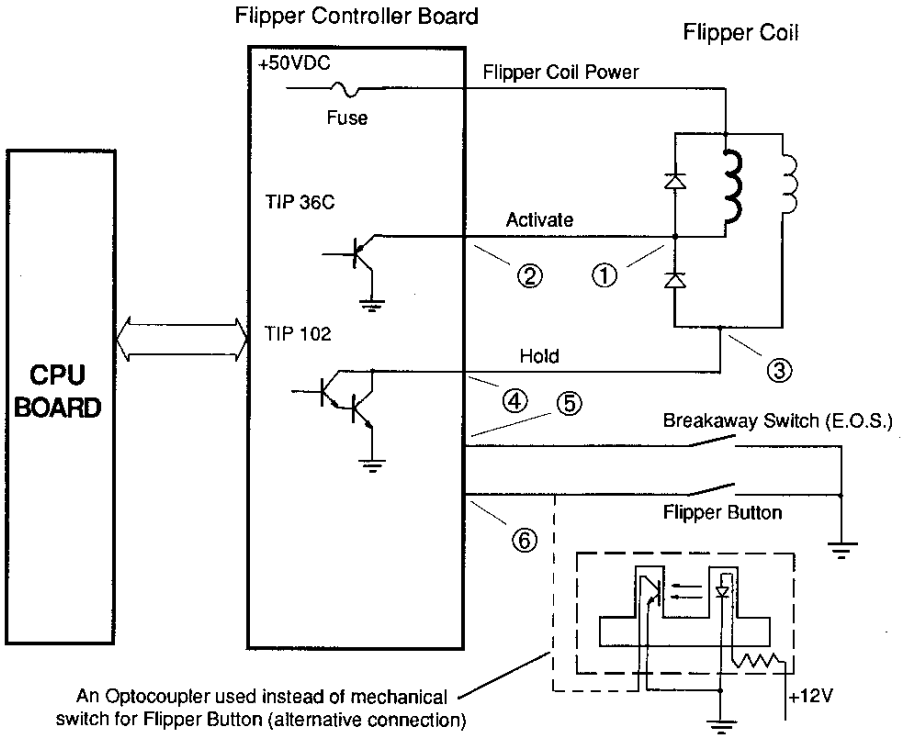
A. The Solenoid Driver Transistor on the Power Driver Board is short circuit.

Q. How can I tell which is the +50V DC wire on the coil?

A. Usually it is the thicker wire and will have one of these colours: violet/yellow; violet/green; violet/orange.

Q. What if I ground the wrong terminal of the coil? **A.** A Fuse will blow.

Flippers - How They Work



The Flipper Controller Board has the capacity to drive 4 flippers and is fully controlled by the CPU Board.

When the Flipper Button is pressed the CPU turns both the TIP36C and TIP102 transistors "ON".

The Flipper is energised and the Breakaway Switch (End Of Stroke switch) closes, signalling to the CPU that the Flipper has reached its full deflection.

The CPU then turns the TIP 36C transistor "OFF" and leaves the TIP102 transistor turned "ON" keeping the Flipper deflected as long as the Flipper Button is held closed.

Only a little current is needed to pass through the thin wire coil to keep the flipper in its active position. This ensures cool operation of the Flipper Coil.

NOTE: *Earlier WPC System pinballs didn't have electronic flippers. Their flipper circuit is compatible with System 11. See* ***Flippers*** *in SECTION 2 - SYSTEM 11 for more details.*

Flipper Coil

The Flipper Coil is a dual coil consisting of a **thin wire coil** and a **thick wire coil.**

The thick wire coil is used only momentarily when the flipper is activated and makes the flipper very powerful.

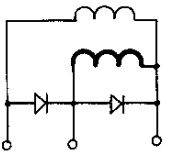
The thin wire coil then takes over and keeps the flipper in its active position.

The Flipper Coil is the only coil which must have diodes soldered across.

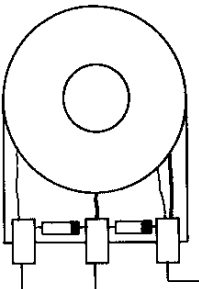
It is absolutely essential to connect the flipper coil correctly. Incorrect connection will very likely cause damage to the diodes on the coil and the Driver Transistor on the Flipper Controller Board.

Flipper Coil Connections (For Electronic Flipper Only)

NOTE: *Changes in flipper circuits can occur - always verify the connections with the operation manual for the particular pinball.*



Flipper Coil



Lower Left flipper - GREY / YELLOW
Lower Right flipper - BLUE / YELLOW
Upper Left flipper - GREY / YELLOW
Upper Right flipper - BLUE / YELLOW

+50V DC

Lower Left flipper - ORANGE / BLUE
Lower Right flipper - ORANGE / GREEN
Upper Left flipper - ORANGE / GREY
Upper Right flipper - ORANGE / PURPLE

Lower Left flipper - BLUE / GREY
Lower Right flipper - BLUE / PURPLE
Upper Left flipper - BLACK / BLUE
Upper Right flipper - BLACK / YELLOW

Troubleshooting Flippers

"Before Troubleshooting flippers start the game or initialize the test mode"

Use the diagram and the test points shown on Page 21 and the Flipper Controller Board Layout on Page 25 or 26 when you troubleshoot flippers. You can ground these test points momentarily with your test lead.

Test Points

① Middle terminal of the coil.

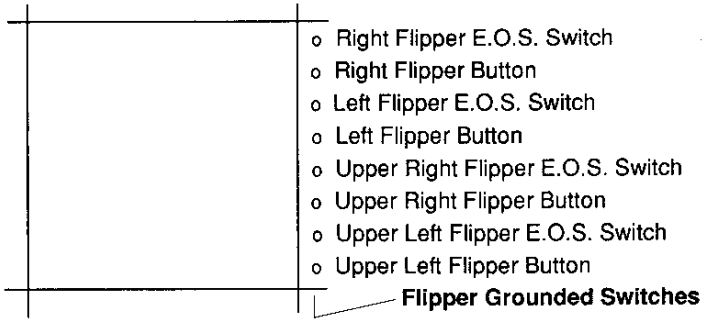
② ④ ⑤ ⑥ Connector on the Flipper Controller Board (See Page 25 or 26).

③ Edge terminal of the coil where the anode of the diode connects.

The Most Common Problems

1. Flipper Does Not Work At All - The likely causes are:

• **Flipper Button Does Not Work** - Check the flipper button in the "Switch Edges Test". The dot representing the button should turn to square when the button is pressed.



If the button does not work check, clean and adjust the contacts. You can ground the contacts with your test lead and see if you can get an indication on the display. You can test the flipper controller board by grounding test point ⑥.

If the flipper button works fine in the test, ground momentarily the middle terminal of the coil. (Test Point ①). If the coil **does not work** the likely causes are:

• **No +50V DC** - Blown fuse, replace the fuse, retest the flipper. If the fuse blows again the coil or the diode on the coil is short circuit. If the coil gets energised after replacing the fuse without pressing the flipper button the driver transistor on the flipper controller board is short circuit.

• **Open Circuit Coil** - Check the coil for continuity, check the solder connections on the terminals of the coil.

If the flipper works by grounding test point ①, ground test point ②. If the flipper still works the Flipper Controller Board is likely to be faulty.

2. The Flipper Gets Energised But Immediately Drops Back to the Home Position

Ground momentarily Test Point ③ - you can feel if the coil gets engaged - the plunger will be pulled in by little force.

If nothing happens the likely cause is:

- **The Thin Wire Coil of the Flipper Coil is Open Circuit**
  Usually one side of the coil breaks near the solder terminals of the coil. The wire can often be reconnected and the coil saved. If not, replace the coil.

- **Faulty Flipper Controller Board**
  If the thin wire coil works fine when grounded at the Test Point ③ and ④ the Flipper Controller Board is faulty.

3. Intermittent Flipper Operation

The flipper works but intermittently drops back to the home position or intermittently will not work when the flipper button is pressed.

The likely cause is:

- **The Flipper Button Does Not Make Good Contact**
  Clean the switch and make sure the switch closes properly. If the problem persists contact your Distributor.

4. The Flipper Gets Energised as Soon as the Machine is Turned "On"

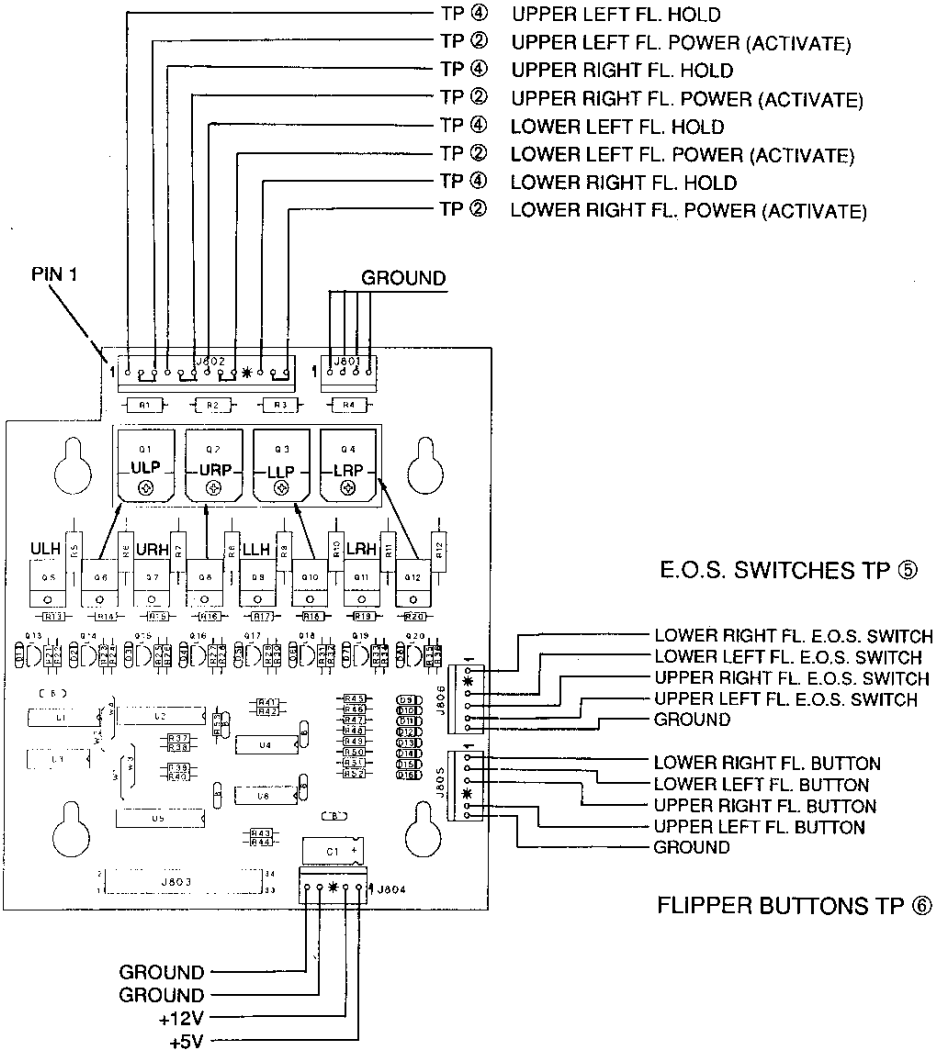
- **Faulty Flipper Controller Board**
  Short circuit Driver Transistor.

5. Weak Flipper

- **Mechanical Parts Worn Out**
  Check the plunger, sleeve, flipper link etc. Replace worn out parts, tighten up loose bolts.

- **Faulty Bridge Rectifier for Flipper Power**
  Open circuit diode in the bridge rectifier - this fault is rare and effects both flippers.

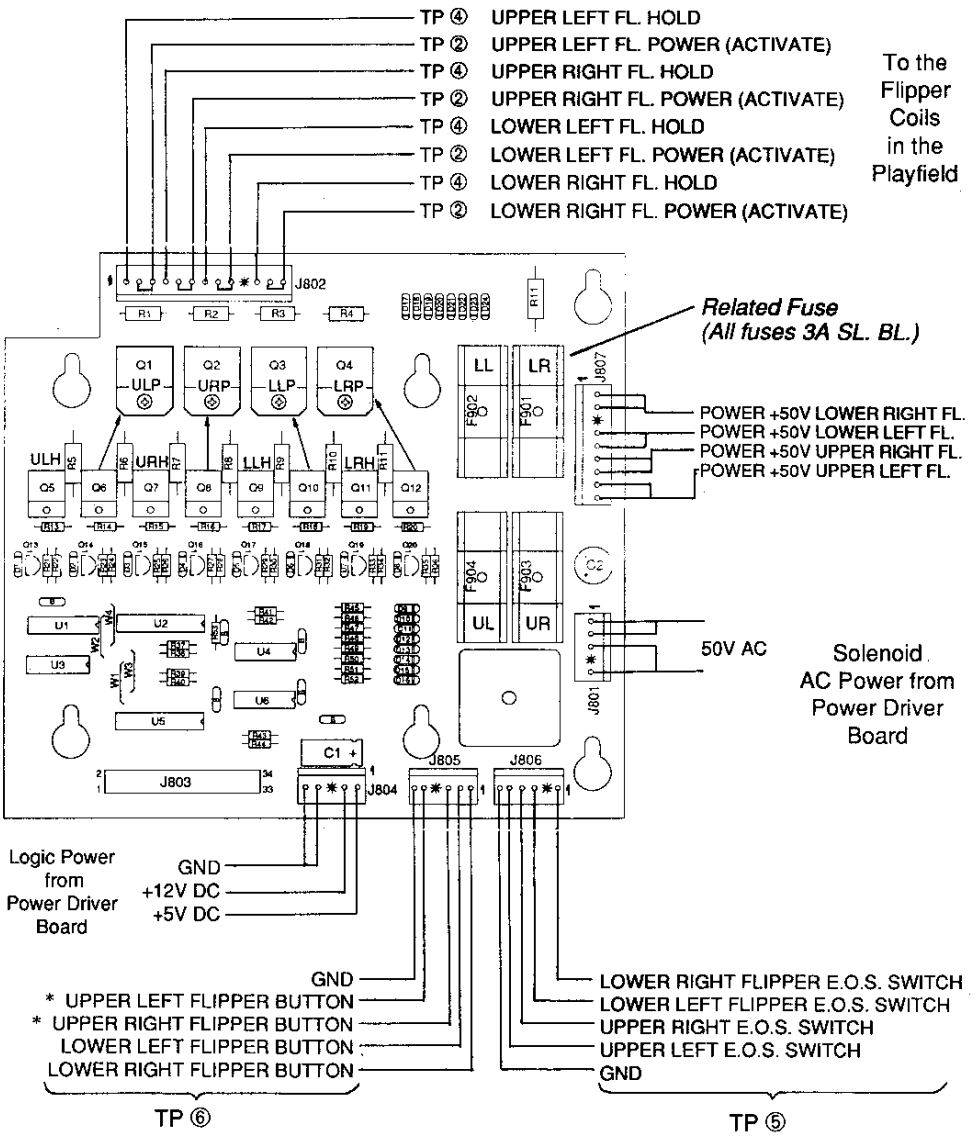
Flipper Controller Board Pinout (Earlier Version)



TP ⓟ = Test Point ⓟ - Refer to these Test Points when you troubleshoot Flippers

End Of Stroke (E.O.S.) Switch = Breakaway Switch

Fliptronic II Pinout *(Flipper Controller Board)*



* In some machines the Upper Flipper Button is connected but not used. Both Lower and Upper Flippers are controlled by the Lower Flipper Button Switch (eg: in *The Getaway*)

NOTE:

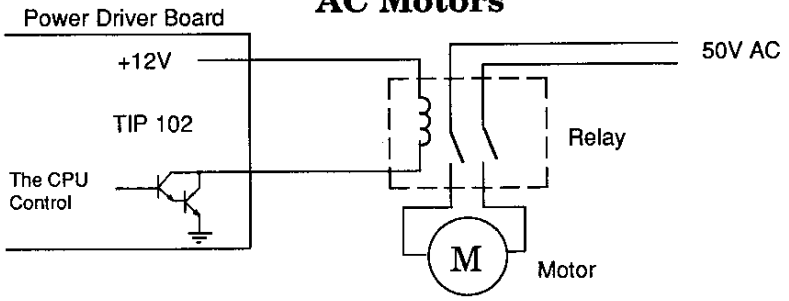
TP ⓝ = Test Point ⓝ - *Refer to these Test Points when you trouble shoot flippers.*

End of stroke (E.O.S.) Switch = Breakaway Switch

Motors in the Pinball Machine

The following are some examples of circuits involving AC and DC motors. Look in the Operation Manual for the correct circuit used in the particular pinball you are working on.

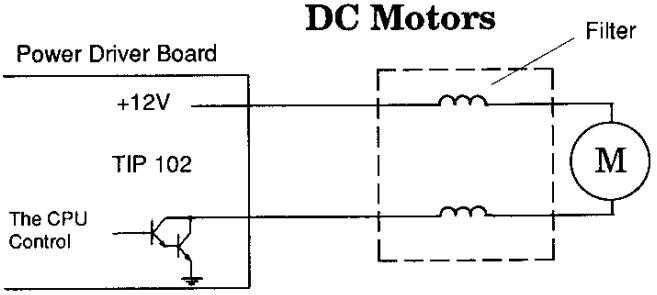
AC Motors



The AC Motors are usually driven by little relay boards in the playfield controlled by one of the Solenoid Drivers on the power driver board.

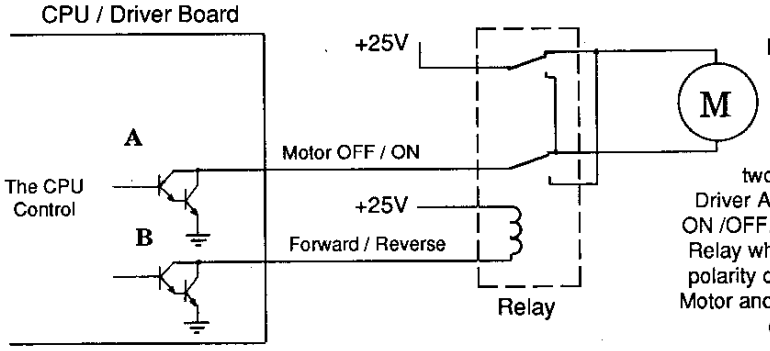
DC Motors

1)



DC Motors can be directly driven by the Solenoid Drivers on the Power Driver Board

2) Below is another example of a circuit involving a DC motor where change of direction of rotation is required. This circuit was used in "Police Force" (System 11 Pinball) for the Police Car.



This circuit requires two Driver Transistors. Driver A switches the motor ON /OFF. Driver B drives the Relay which can reverse the polarity of the voltage on the Motor and so can reverse the direction of rotation.

Introduction to the Switch Matrix

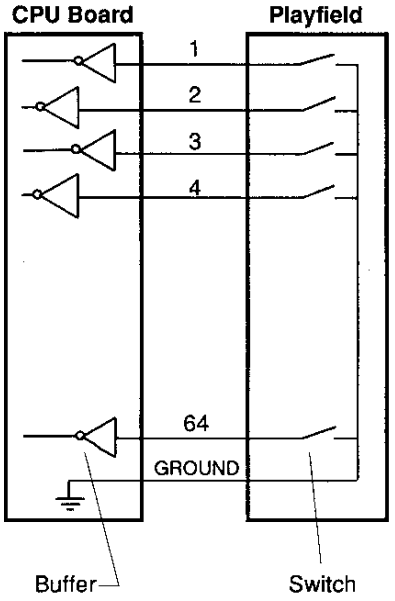


Figure A

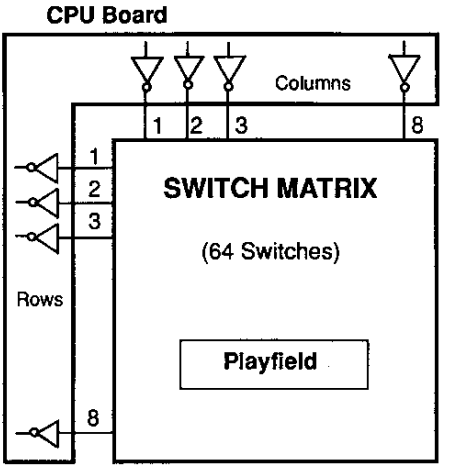


Figure B

Before we start looking at how the Switch Matrix works, let's find out the advantages of a Switch Matrix and why we use it.

Compare *Figure A* with *Figure B*.

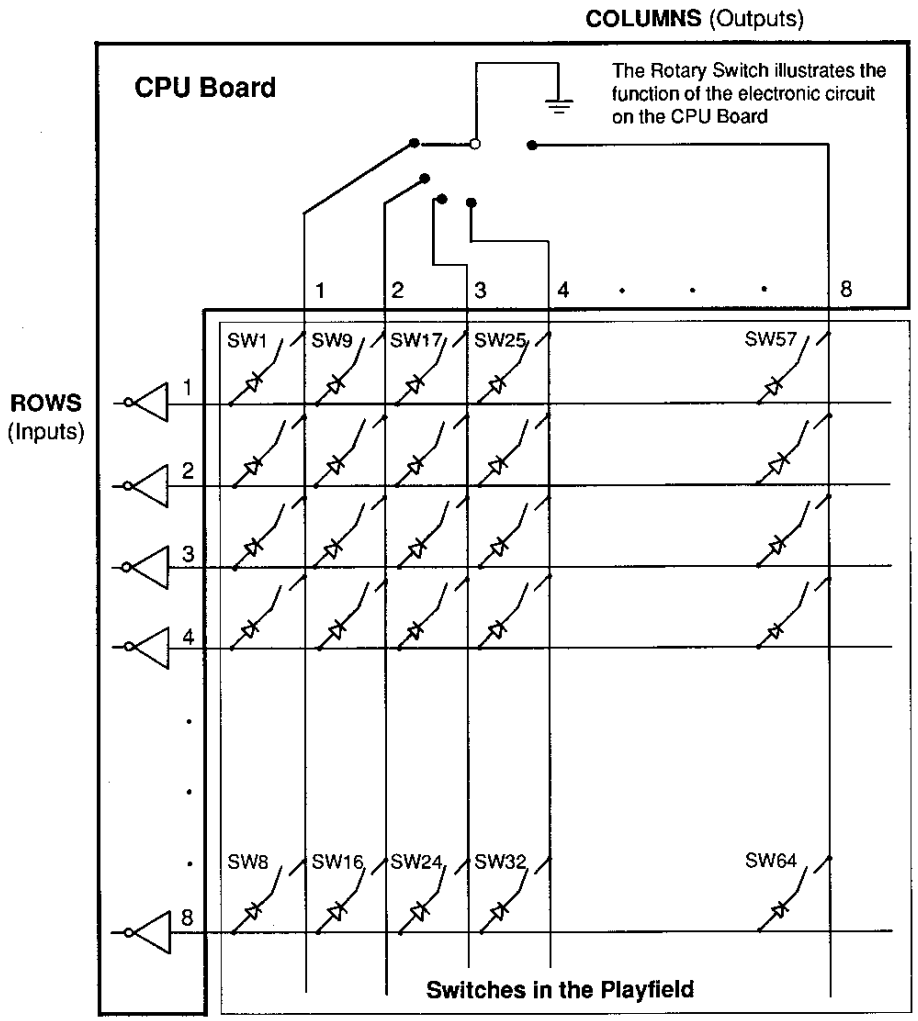
On *Figure A* we have 64 switches with one side connected to ground and the other side connected to the CPU Board.

We would need a harness between the CPU Board and the Playfield consisting of **65 wires** (64 switches & 1 ground). The CPU Board would need **64 buffers** (one buffer for each switch).

Look at *Figure B* where switches are arranged in a matrix. We need 8 wires for *columns* and 8 wires for *rows*. This totals just **16 wires** instead of 65 and only **16 buffers** instead of 64 (as is required on *Figure A*).

The circuit on *Figure B* is the one used in **Williams** and **Bally** pinballs and the following is a detailed explanation of its operation.

How does the Switch Matrix work



The CPU Board connects only **1 column at a time to the Ground.** On the diagram above, Column 1 is grounded and the state of switches 1 to 8 only can be recognised by the CPU Board.

The CPU Board then connects Column 2 to Ground and looks at the Row Inputs again. Now only the state of switches 9 to 16 can be recognised by the CPU Board. Then Column 3 is switched to Ground and so on up to Column 8 - then everything repeats.

This means the CPU Board can read only one column of switches (8 switches) at a time. This happens very quickly - every column is connected to Ground approximately 500 times in one second.

Switch Matrix Table & Switch Locations

Switch Matrix Table

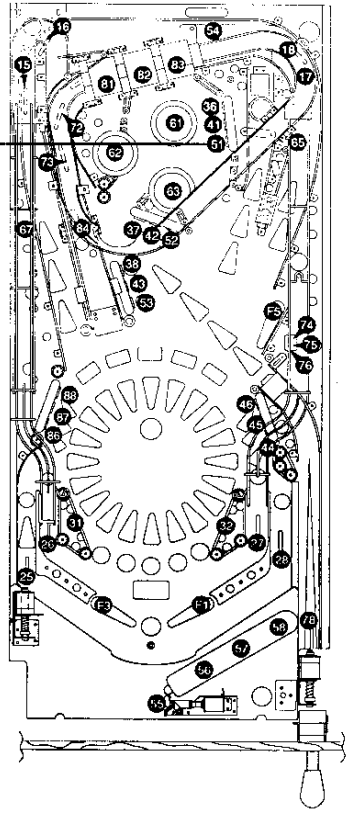
This is only an example of a Gateway Switch Matrix Table & Switch Locations. Refer to this information in the Operations Manual for the particular pinball when troubleshooting switch problems in the playfield.

Column Number
Wire Colour
Connector & Pin Number on the CPU Board
IC U20 PIN 15 on the CPU Board
Switch Number

White ——— Green

Dedicated Grounded Switches	Column / Row	1 Green-Brown J208-1 U20-18	2 Green-Red J208-2 U20-17	3 Green-Orange J208-3 U20-16	4 Green-Yellow J208-4 U20-15	5 Green-Black J208-5 U20-14	6 Green-Blue J208-6 U20-13	7 Green-Violet J208-7 U20-12	8 Green-Gray J208-8 U20-11	Flipper Grounded Switches
Orange-Brown (1) J205-1 Left Coin Chute D1	1 White-Brown J209-1 U18-11	Right Flipper 11	Slam Tilt 21	Left Sling 31	Top Yellow 41	Top Green 51	Top Jet 61	Top Loop 71	Opto 1 81	Black-Green J906-1 Right Flipper End of Stroke F1
Orange-Red (2) J205-2 Center Coin Chute D2	2 White-Red J209-2 U16-9	Left Flipper 12	Coin Door Closed 22	Right Sling 32	Middle Yellow 42	Middle Green 52	Left Jet 62	Middle Loop 72	Opto 2 82	Blue-Violet J905-1 Right Flipper Button F3
Orange-Black (3) J205-3 Right Coin Chute D3	3 White-Orange J209-3 U18-5	Start Button 13	Ticket Opto. 23	Gear Shifter Low 33	Bottom Yellow 43	Bottom Green 53	Bottom Jet 63	Bottom Loop 73	Opto 3 83	Black-Blue J906-3 Left Flipper End of Stroke F3
Orange-Yellow (4) J205-4 4th Coin Chute D4	4 White-Yellow J209-4 U18-7	Plumb Bob Tilt 14	Always Closed 24	Gear Shifter High 34	Right Bank Bottom 44	Ramp Down 54	Not Used 64	Top Lock 74	Opto Made Loop 84	Blue-Gray J905-2 Left Flipper Button F4
Orange-Green (5) J205-6 Normal Function: Service Credits / Test Function: Escape D5	5 White-Green J209-5 U19-11	Left Freeway Bottom 15	Left Outlane 25	Not Used 35	Right Bank Middle 45	Outhole 55	Made Up/Down Ramp 65	Middle Lock 75	Enter Left Ramp 85	Black-Violet J906-4 Upper Right Flipper End of Stroke F5
Orange-Blue (6) J205-7 Normal Function: Volume Down / Test Function: Down D6	6 White-Blue J209-7 U19-9	Left Freeway Top 16	Left Return Lane 26	Top Red 36	Right Bank Bottom 46	Left Trough 56	Not Used 66	Bottom Lock 76	Left Bank Bottom 86	Black-Yellow J905-3 Upper Right Flipper Button F6
Orange-Violet (7) J205-8 Normal Function: Volume Up / Test Function: Up D7	7 White-Violet J209-8 U19-5	Right Freeway Bottom 17	Right Return Lane 27	Middle Red 37	Not Used 47	Center Trough 57	Made Left Ramp 67	Eject Hole 77	Left Bank Middle 87	Black-Gray J906-5 Upper Left Flipper End of Stroke F7
Orange-Gray (8) J205-9 Normal Function: Begin Test / Test Function: Enter D8	8 White-Gray J209-9 U19-7	Right Freeway Top 18	Right Outlane 28	Bottom Red 38	Not Used 48	Right Trough 58	Not Used 68	Shooter 78	Left Bank Top 88	Black-Blue J905-5 Upper Left Flipper Button F8

Switch Locations



Switches in the Playfield

(Switch Matrix)

The correct operation of a pinball machine depends very much upon the correct operation of the switches.

The switches inform the CPU Board about what is happening in the playfield and so directly influence the subsequent action of the CPU Board.

For Example: When a ball hits a slingshot, the slingshot switch closes, instructing the CPU Board to turn the solenoid momentarily "ON". If the switch wasn't working this action would not happen simply because the CPU was not instructed to do so.

Troubleshooting switch problems in the playfield is simplified thanks to the excellent test facilities and self diagnostics of the WPC System.

If the WPC System detects a faulty switch it will try to ignore the switch and almost normal operation of the machine will be maintained. The Test Report will automatically inform the operator of the problem when the machine is next turned on.

The Test Report can be deleted only by verifying the correct operation of the troubled switch in the Switch Test.

Troubleshooting the Switch Matrix

Take a look at the **Switch Matrix Table** and **Switch Locations** on Page 30. You will find both in the Operations Manual of the particular pinball you are working on.

The Switch Locations Chart will help you to identify switches in the playfield. The Switch Matrix Table will tell you the name of the switch, the number and colour of wires used, the connector and the IC involved on the CPU Board.

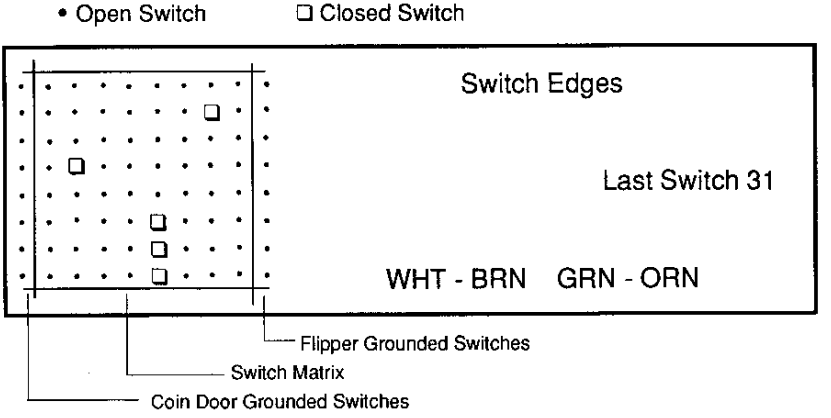
You will be able to see what switches are in a particular Row or Column.

All this information can be vital for effective troubleshooting.

Troubleshooting the Switch Matrix *(Cont.)*

How to Check Switches

1. Initialize Switch Edges Test - the left hand side of the display represents the Switch Matrix and the grounded switches. Compare this display with the Switch Matrix Table. You will be able to see which switch is closed and which one is opened.



2. Use the ball to test the switches in the playfield - Operate one switch at a time and see if the number on the display corresponds to the number shown in the Switch Locations Chart. A ***dot*** in the Switch Matrix Display will turn into a ***square***.

3. If the tested switch causes no indication on the display...

- Check if the actuator arm of the microswitch is adjusted properly.
- Check that the switch is not stuck closed.
- Check that the wires are well connected to the switch.
- Check the switch itself (short out the switch with your test lead).
- Check continuity of the wire between this switch and another working switch which uses the same Column (Row).
- Check the diode on the switch.
- If it is a blade switch, check the spacing - make sure the contacts close properly. Clean the contacts.

4. Check other switches in the same Column or Row.

You can do this test before the checks in Step 3.

Maybe the whole Row or Column of switches is not working. If so, the CPU Board can be faulty and you should check it (Refer to Page 34). **If the CPU Board is OK**, check the continuity of the Column or Row wire between the Switch and the CPU Board.

5. Check the CPU Board if...

- The whole Row or Column of switches is not working.
- An incorrect number is displayed.
- Closure of one switch shows more than one switch is closing.
- Ground short message appears on the display.

6. If the CPU Board is faulty... the fault could have been caused by short circuit between the Switch wires and Power wires in the playfield (eg: Solenoid Voltage, Lamp Matrix, General Illumination). This short has to be found and removed otherwise the repaired CPU Board could blow again.

7. If the CPU Board is OK... the problem is in the Playfield or the Cabinet.

- Disconnect the connectors from the Coin Door
- Disconnect the Opto Boards.

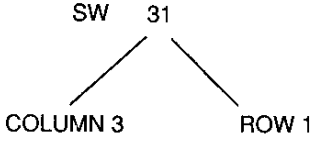
Did the problem disappear now?

8. If the problem still persists... you might need to trace wiring of the Rows and Columns involved. Two Rows or two Columns can be shorted together. Also, a Row or a Column could be shorted to ground.

Switch Numbering

The switch number itself indicates to what Column and what Row the switch is connected (only in WPC System).

For Example:



Help Facility

1. Initialize single switch test.
2. Use + and - Buttons to position the cursor on the desired switch.
3. Press **CREDIT** Button to initialize the help message.

Troubleshooting the Switch Matrix (Cont.)

How to check the CPU Board

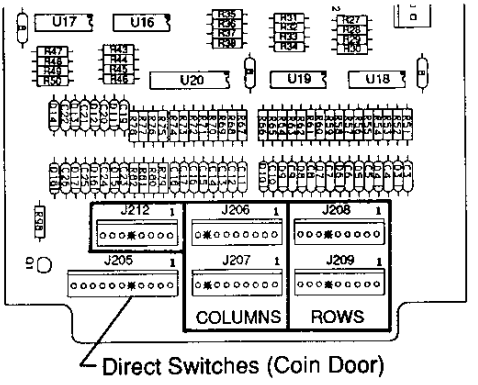
If you have doubts about the CPU board, test it. It is an easy and quick exercise. Knowing if the CPU Board is faulty or not will save you time and money.

1. Initialize switch levels test.

2. Disconnect connectors J212, J206, J207, J208, J209 from the CPU Board.

3. The Display should indicate that all switches are Open. **If not, the CPU Board is faulty.**

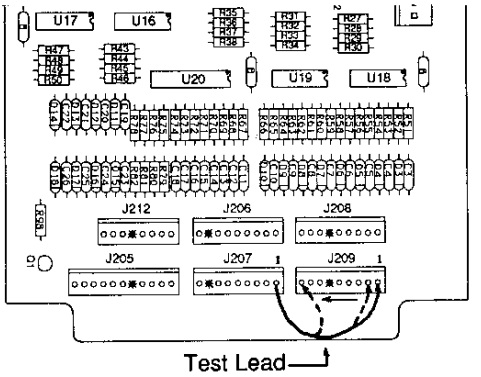
The CPU Board



Testing Rows

Connect your test lead to Pin 1 of J207, the other end of the lead to Pin 1 of J209. The display indicates switch 11 is closed. Move your test lead from pin 1 of J209, pin by pin, to pin 9 of J209.

After every connection check the display. You will see these numbers: 11, 12, 13, 14, 15, 16, 17, 18. **If any number is missing the CPU Board is faulty.**

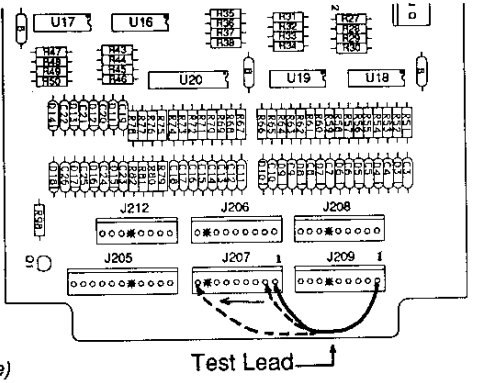


Testing Columns

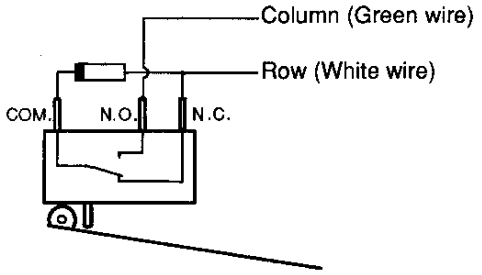
Connect your test lead to pin 1 of J209 and the other end, pin by pin, from pin 1 up to pin 9 of J207.

With every connection check the display. The numbers you expect are: 11, 21, 31, 41, 51, 61, 71, 81. **If any number is missing the CPU Board is faulty.**

NOTE: In some machines Columns 7 and 8 are not used in which case no indication for Switch 71 and Switch 81 is OK. *(Check it with the Switch Matrix Table)*



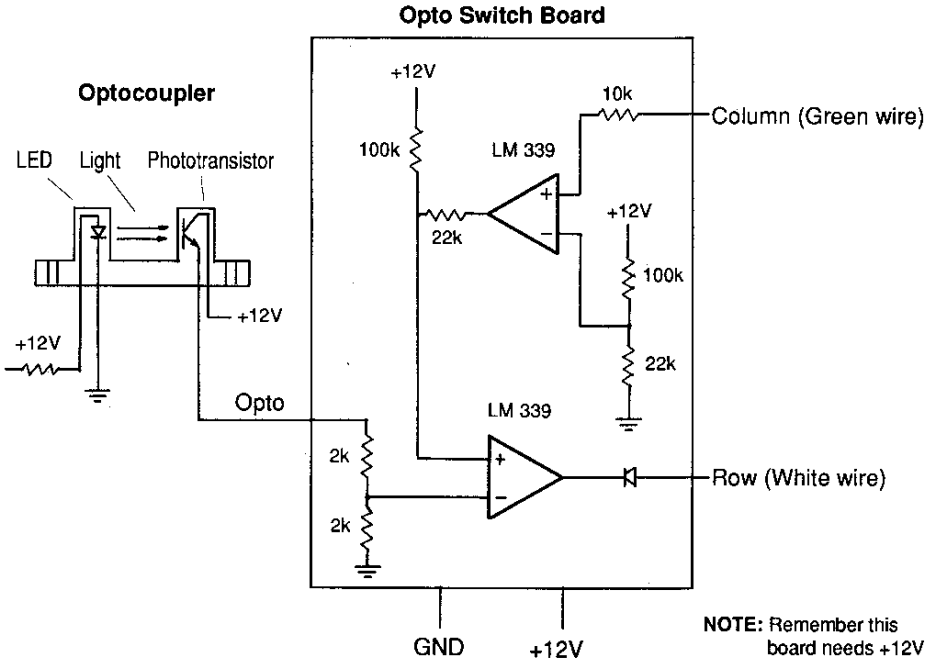
How to Connect a Microswitch in a Switch Matrix



Opto Switches (Optocouplers) in a Switch Matrix

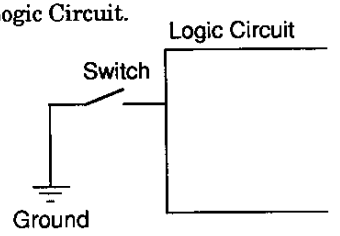
The Optocoupler is an optical switch using a LED (Light Emmitting Diode) as a source of light and phototransistor as a detector. The phototransistor works as a switch. If the light strikes the phototransistor it turns "ON" but if the light is obstructed, the phototransistor turns "OFF".

The optocouplers are usually connected to the Switch Matrix through an Opto Switch Board.



Grounded (Direct) Switches

Grounded (Direct) Switches are not a part of the Switch Matrix.
They connect Ground directly to the Logic Circuit.



There are two groups of Grounded Switches in WPC System machines.

a) Dedicated Grounded Switches

All Switches in the Coin Door except the Slam Switch *(Slam Switch belongs to the Switch Matrix).*
They are connected to the CPU Board.

b) Flipper Grounded Switches (electronic flippers only)

Flipper Buttons and all Breakaway (End Of Stroke) Switches.
They are connected to the Flipper Controller Board.

Maintaining Switches

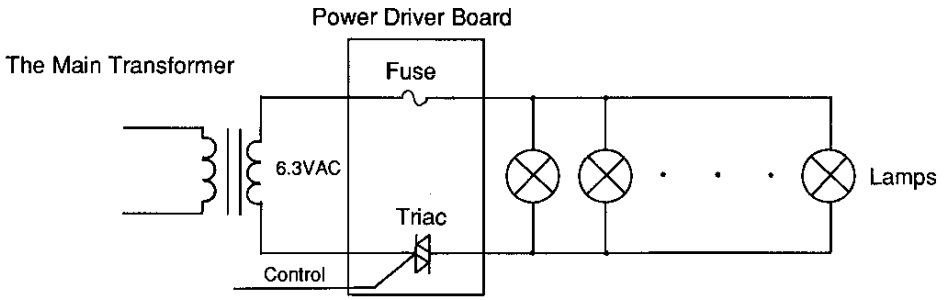
Use switch tests to verify correct operation of the switches.
Test the switches with the ball.

Type of Switch	Cleaning Procedure / Maintenance
Microswitch	Does not require any cleaning. Check and re-adjust actuator arm if necessary for reliable operation.
Blade Switch *(Recommended space between points 1/16" or 1.5mm)*	Clean with a piece of paper inserted between the contacts. Squeeze the contacts gently with your fingers and rub the contacts with the paper a few times. You can wet the paper beforehand with a contact cleaner. Do not use anything abrasive - it would destroy the gold plating on the contacts. Re-adjust the space between the contacts for correct operation if necessary.
Opto Switches	Blow off the dust and remove any dirt obstructing free passage for the light.

Lamps

The lamps are controlled by the CPU Board through the Power Driver Board. Because three different types of Driver Circuits are used, the lamps can be divided into three different groups.

1. General Illumination.



There are 5 strings of General Illumination. The diagram above illustrates one string only. The CPU can fully control the intensity of the lamps. 6.3V wedge or bayonet globes are used.

2. Flashers

Larger globes are used to create a brighter flash. The Driver Circuit is identical to the Solenoid Drivers *(refer to the table on page 18)*. 12V globes are used, powered from +20VDC.

3. Lamp Matrix

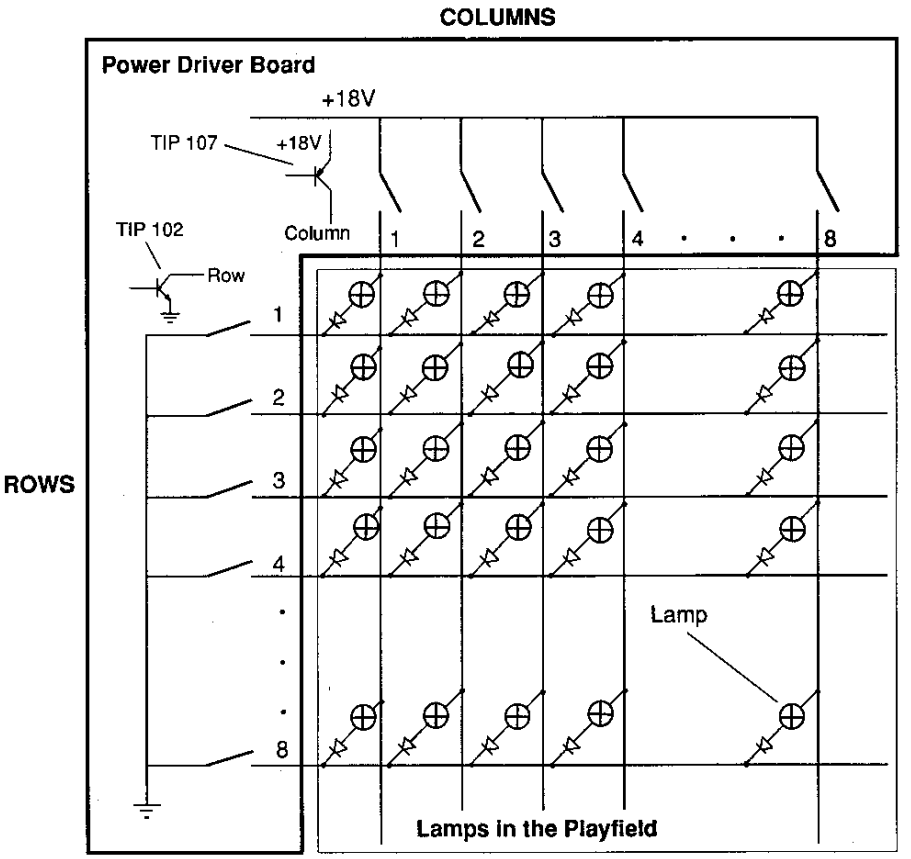
These are usually the feature lamps. The lamp Matrix Circuit can drive 64 independent lamps. The same 6.3V globes as in *General Illumination* are used.

The Driver Circuit is powered from +18VDC because the lamps are strobed.

The Driver Circuit features electronic short circuit protection which reduces to a minimum the likelihood of a failure.

Faults in the Lamp Matrix Circuit are rare - see the following page for a detailed explanation of the Lamp Matrix.

How does the Lamp Matrix work



For the same reason - to simplify the electronic circuit - the lamps are organised in the same manner as switches in the Switch Matrix. Only 8 Column Drivers and 8 Row Drivers are needed to drive 64 lamps.

The real circuit uses PNP Transistor TIP 107 for switching +18V on the Columns and NPN Transistor TIP 102 for switching ground on the rows.

The switches on the diagram above illustrate the function of the transistors.

The lamps are switched "ON" column by column, **always one column at a time**. Because each column is active 60 times per second it appears that all lamps are working simultaneously.

Troubleshooting Lamps

Lamps are often the most neglected part of a pinball machine. An operator will most certainly do something about a faulty solenoid but a non-working lamp will draw much less attention. The lamps, however, attract the players to the machine and contribute greatly to their satisfaction. Use the Lamp, General Illumination and Flasher tests to check them.

The Most Common Problems

1. Faulty Globe
Test the globe in a different place - all globes (except Flashers) are 6.3V globes (White socket - 6.3V globes, Black sockets - 12V globes - Flashers).

2. Corroded Socket
This problem is often solved by removing then re-inserting the globe in the socket. You can do it a couple of times. This usually improves the connection.

3. Blown Fuse
If a number of lamps are not working check associated fuses *(see page 16 - WPC Power Driver Board Layout or the Fuse Chart in the Backbox)*
Remember - a faulty fuse often looks OK - check it with your multimeter.

4. Burned Connector on the Power Driver Board
This sometimes happens in the General Illumination circuit. The connector has to be repaired or bypassed.

Troubleshooting the Lamp Matrix

Use the *Lamp Locations Chart* and the *Lamp Matrix Table* in the Operations Manual to identify the troubled lamps. See what particular Column or Row of lamps is effected. The *Lamp Matrix Table* will tell you the colour of the wire used, where the wire connects to the Power Driver Board and what transistor drives the particular Column or Row.

The Most Common Problems

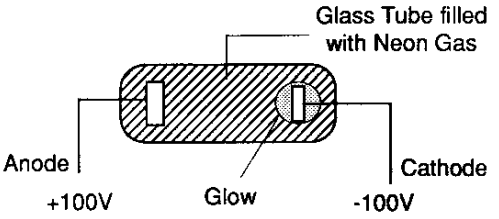
PROBLEM: Whole or part of a Column or Row of lamps always stays "OFF".
CAUSE: Most likely broken wire between lamps in the playfield or between the playfield and the Power Driver Board. Check the wire which connects the particular Column or Row for continuity.

PROBLEM: The whole Column or Row of lamps always stays "OFF".
CAUSE: If the connection between the Playfield and the Power Driver Board is OK, the Power Driver Board is likely to be faulty.

PROBLEM: The whole Column or Row of lamps remains very bright.
CAUSE: Most likely faulty Power Driver Board - probably short circuit Column or Row Driver Transistor.

PROBLEM: The globe, socket and wiring is OK, but the lamp is not working.
CAUSE: Open circuit diode - check it and if faulty, replace it.

Gas Discharge Displays



Principle of Operation

If high voltage is applied to the electrodes of the tube the gas inside becomes ionised and starts to conduct electric current. As a result the area around the negative electrode (cathode) starts to glow.

Dot Matrix Display - How Does It Work

The Dot Matrix Display is a Gas Discharge Display. It is a matrix of 32 X 128 dots. Special integrated circuits are used for switching the high voltage on the 128 Columns and 32 Rows.

It is the most compact electronic unit in the pinball machine. You should not attempt to carry out repairs on this unit.

In case of a problem check if all connectors are plugged in, check the associated fuses and check all required voltages *(see next page)*. Otherwise, contact your distributor.

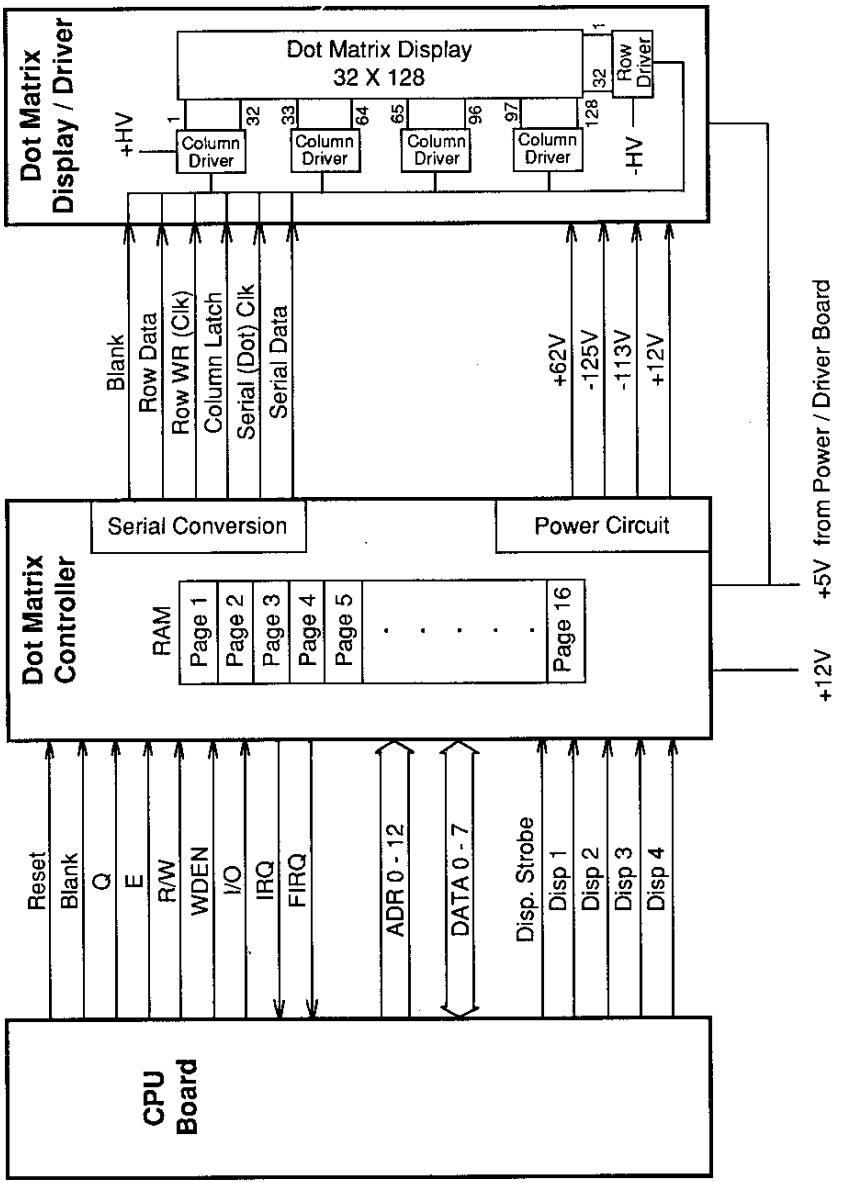
The display is controlled by the Dot Matrix Controller Board. The Dot Matrix Controller also provides all necessary power, except for the +5V and +12V which are supplied by the Power Driver Board.

The CPU Board can access the RAM (Random Access Memory) on the Dot Matrix Controller which can store 16 full display images. The CPU instructs the Dot Matrix Controller as to which of the 16 images will be displayed.

Use the Display Test to check the Display and the Dot Matrix Controller. See if all the Rows and Columns are working.

At the end of the test message "RAM OK" appears on the display indicating the result of the memory test.

Dot Matrix Display - System Diagram



Bookkeeping, Adjustments and Testing

The *Williams* and *Bally* pinballs feature very sophisticated bookkeeping, adjustments and testing - perhaps unparalleled by any other amusement machines.

The purpose of this chapter is not to provide detailed explanations - these you can find in the Operations Manual. Rather it is an introduction aimed at getting you started on taking advantage of these excellent features.

Bookkeeping

Bookkeeping - information stored by the computer for you. You will be able to check the performance of the machine and readjust it if necessary to optimize the performance.

For the convenience of the operator the WPC System provides extracts of the ten most important pieces of information called *Main Audits*.

To access the *Main Audits* keep pressing the "Enter" button in the coin door and observe the display. **B1 01** to **B1 10** are the *Main Audits*.

Bookkeeping cannot be altered by the operator - but it *can* be cleared.

For Example: "Recent Earnings" will tell you how much your pinball has earned since the last collection. Clear "Recent Earnings" by activating "Clear Coins" in *Utilities*.

Adjustments

Adjustments allow you to adjust your machine exactly to your requirements.

Each machine comes already preset with a so called **Factory Setting**. This is a setting recommended by the manufacturer and it is often the most suitable.

Minor alterations are usually necessary - For Example: pricing, number of balls, minimum volume control etc.

However, you can tailor the setting of the machine to match a particular environment.

One of the most valuable features unique to Williams and Bally pinballs is **"Auto % Replay"**

The operator does not have to keep an eye on replay levels - instead he chooses a desired percentage of replays and the computer does it for him.

This ensures consistency in good earnings because the machine constantly readjusts itself according to the skill of the players.

This feature is "Factory Set" - usually at 10% of Replays.

Testing

You will find that the most valuable tool for your troubleshooting is not in your toolbox but it is built into the WPC System.

Explore the test facilities and learn to use them.

You will not only be able to verify the correct operation of solenoids, switches, lamps etc. but by using the *Help* facility the machine will give you clues about what to check in case of a problem.

For Example: *Press the Credit Button while the solenoid test is in progress (Repeat Mode). The* ***Help*** *message will appear on the display telling you...*

- The colours of the wires connecting to this solenoid.
- Where the wires connect on the Power Driver Board (what connector and pin number).
- Location of the Solenoid Driver Transistor and the Pre-Driver Transistor on the Power Driver Board.
- The related fuses.

Not bad for just one push of the Credit Button!

Use the *Help* facilities in other tests too.

NOTES

SECTION 2

INSIDE SYSTEM 11

Section 2 - Introduction

Section 2 of this book is dedicated to the System 11 which was superseded by the WPC System.

Because most of the principles of operation and methods of troubleshooting are the same as in the WPC System, this section covers only the differences between the two systems.

There are a few versions of System 11 (11, 11A, 11B, 11C).

For the purpose of this book it is not necessary to distinguish them all and this book refers to all of them as **System 11**.

Inside the Backbox

The Sound Board

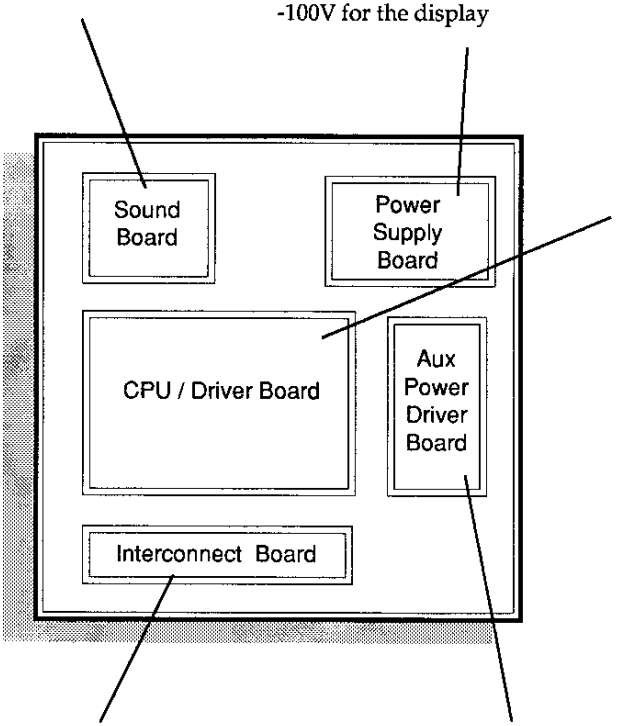
is an independent microprocessor system. The CPU Board instructs the Sound Board on what sounds should be outputed.

The Power Supply

provides:
+5V for all logic circuitry
+12V for the audio circuit
-12V for the audio circuit
+100V for the display
-100V for the display

The CPU Board

combines the function of the CPU and the Driver Board. The CPU Section is the "brain" of the pinball and controls every function in the machine. The driver board section drives all solenoids and lamps (except the General Illumination). This board also accommodates "Flipper Enable (Flipper Ground) Relay".



The Interconnect Board

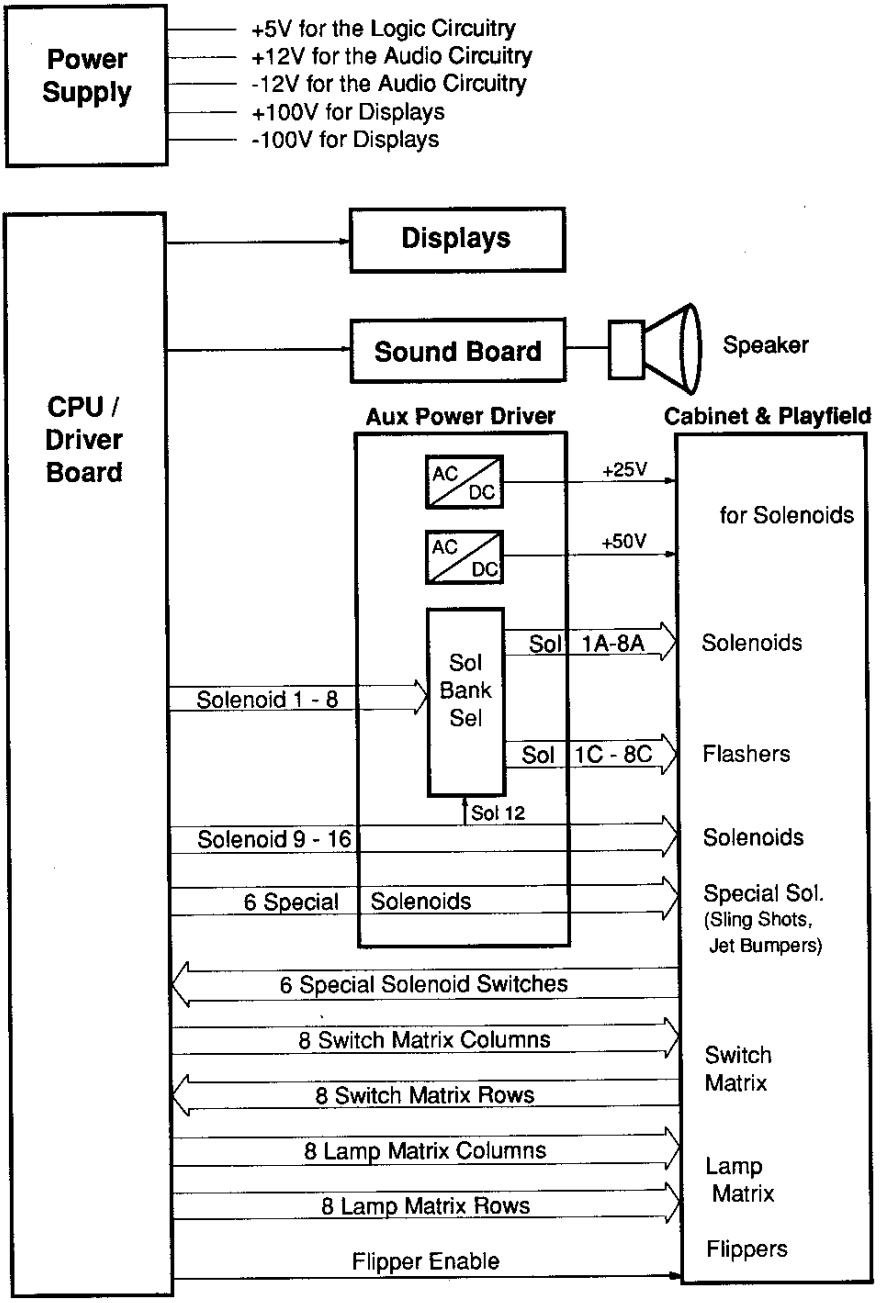
provides connections for the wiring loom between the CPU Board and the rest of the machine. This board also contains current limiting resistors for flashers and lane change optocouplers.

The Auxiliary Power Driver Board

serves several purposes...

- Provides +50V and +25V for solenoids
- Accommodates bank select circuit which increases number of solenoid outputs
- Accommodates 50V solenoid drivers
- Accommodates diodes which used to be on coils in the playfield
- Accommodates solenoid fuses.

System 11 - Block Diagram



Solenoids in System 11 Machines

The system 11 CPU / Driver Board has 16 solenoid outputs and 6 Special Solenoid outputs. All solenoid outputs use Darlington Transistor TIP 122 which switches the solenoid to ground.

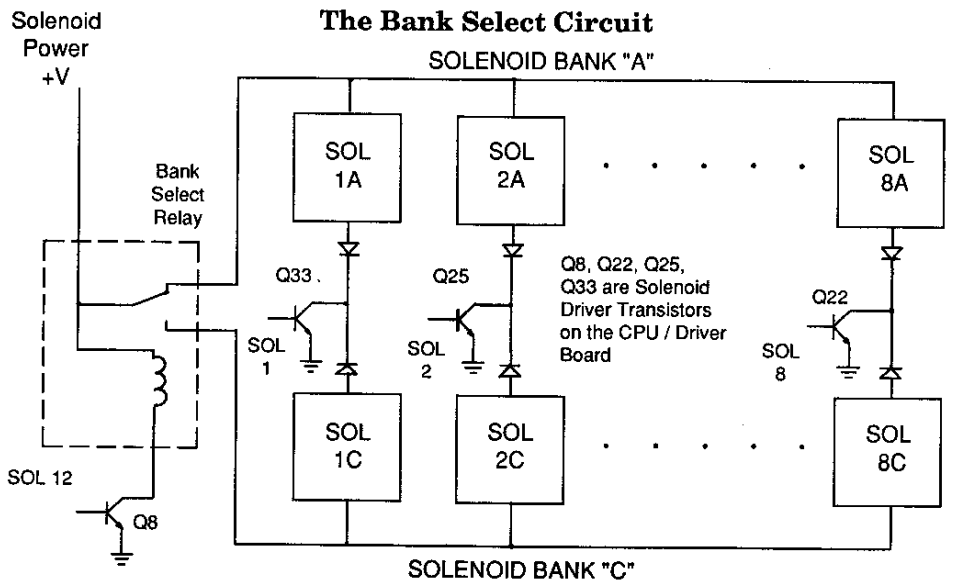
The output circuit is identical to the circuit in the WPC system shown on Page 17, except for the diode which is not on this board and solenoid power which is supplied by the Auxiliary Power / Driver Board or in earlier machines by bridge rectifier mounted on the back wall of the backbox.

Solenoid Bank Select Circuit - How Does it Work

Bank select circuit was designed to increase the capability to drive more solenoids in the machine, without increasing the number of driver transistors on the CPU/Driver Board.

The solenoids were arranged into two banks "A" and "C". This arrangement allows two solenoids or solenoid and flash lamp to be driven by one driver transistor only.

Solenoid No. 1 to Solenoid No. 8 Driver transistors on the CPU/Driver Board are used for driving 8 solenoids in the "A" bank and usually 8 flash lamps in the "C" bank. The following is an explanation on how the "Bank Select Circuit" works.



The **Bank Select Circuit** on the previous page explains how 8 driver transistors can drive 16 solenoids. The solenoids are arranged in two banks (A and C). Only one bank at a time is connected to the solenoid power (+V), depending on the state of the **Bank Select Relay**.

If the **Bank Select Relay** is de-energised the solenoid power (+V) is connected to the Bank "A" and only solenoids 1A to 8A can be driven by the driver transistors. There is no power on the solenoids in the "C" bank at this time.

If the **Bank Select Relay** is energised the relay connects the solenoid power to the "C" bank and only solenoids 1C to 8C can be driven by the driver transistors. The "C" bank is usually used for flash lamps.

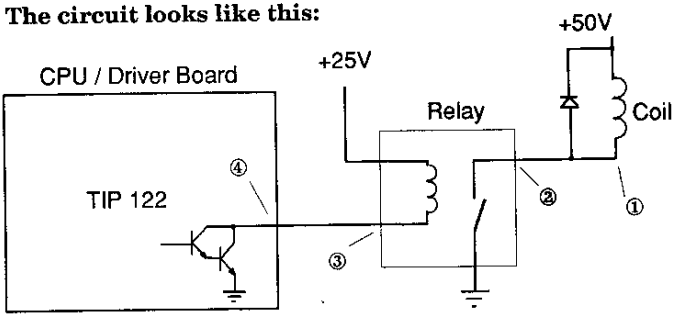
Changes in Solenoid Circuit in System 11 Machines

Early System 11 Machines... did not use Bank Select Circuit. All solenoids and flash lamps were tied directly to their power supply! The number of solenoids and flash lamps could total to a maximum 16 (Plus 6 Special Solenoids).

50V Coils in Earlier System 11 Machines

Because two different solenoid voltages were used +25V and +50V, little relay boards located under the playfield were necessary for driving 50V coils, since the driver transistors on the CPU/Driver Board were not capable of handling these coils.

The circuit looks like this:



Test Points

① Terminal of the Coil

② Relay PCB Output

③ Relay PCB Input

④ The Collector (Tab) of the Driver Transistor

Later System 11 Machines (with Auxiliary Power / Driver Board)

The first machines using Bank Select Circuit had little "Bank Select Relay P.C.B" and "Diode P.C.B." located under the playfield.

Later on the **Auxiliary Power / Driver Board** was introduced in the System 11 machines. The bank select circuit was placed on this board as well as bridge rectifiers supplying the Solenoid Power.

50V solenoid driver transistors were placed on this board eliminating the little relay boards in the playfield.

Diodes were no longer required to be installed on the coils (except the Flipper Coils). They were placed on this board. This board also accommodated all solenoid fuses. The playfield and the backbox became much neater.

Take a moment to study the simplified circuit diagram of the "Auxiliary Power/Driver Board" on Page 54. See if you can recognize the things you have just read about. (The fuses are omitted in this diagram).

Troubleshooting Solenoids

The same troubleshooting techniques are used as described on Page 19 *(Troubleshooting Solenoids in WPC System)* but you will have to take into account these differences.

1. No help facility is available in System 11 machines.
2. It is likely that the bank select circuit is used in the machine you are working on.
3. Two different solenoid voltages are used, +25V and +50V.

Check what style of machine it is:

- Does the machine have an Auxiliary Power Driver Board?
- If not, find out from the Operations Manual or by using solenoid test if a *Bank Select Circuit* is used, whether the solenoids (1 to 8) are split into two banks (e.g. 1A, 1C)
- If the Auxiliary Power/Driver Board is not used in the machine - remember that all 50V coils are driven by little relay boards located in the playfield.

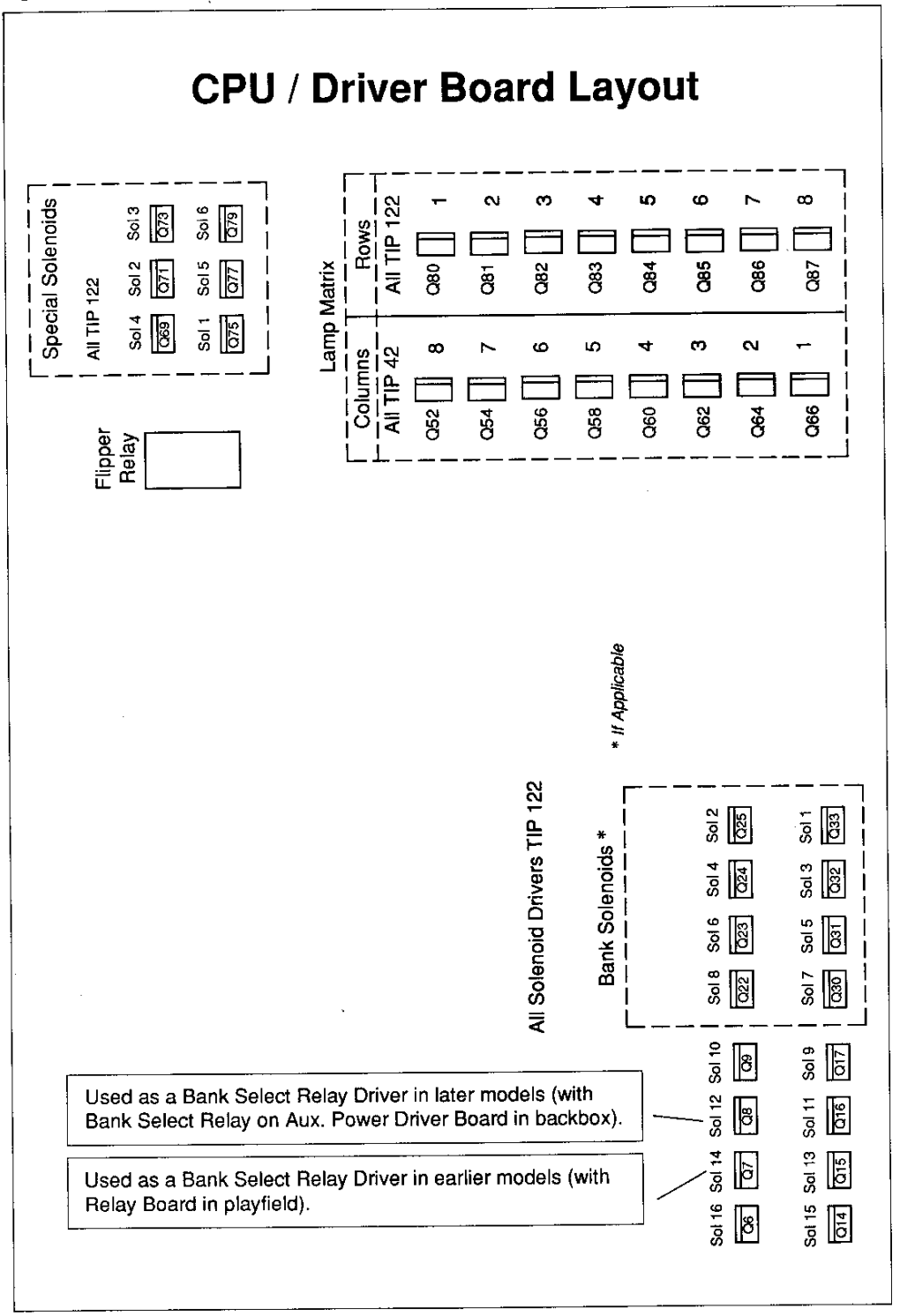
Troubleshooting 50V Solenoids in Earlier System 11 Games

See the circuit on Page 50. You can ground the test points momentarily by your test lead. By grounding test point ① and ② you can check the solenoid and the connection to it. Use test point ③ and ④ to check if the relay works.

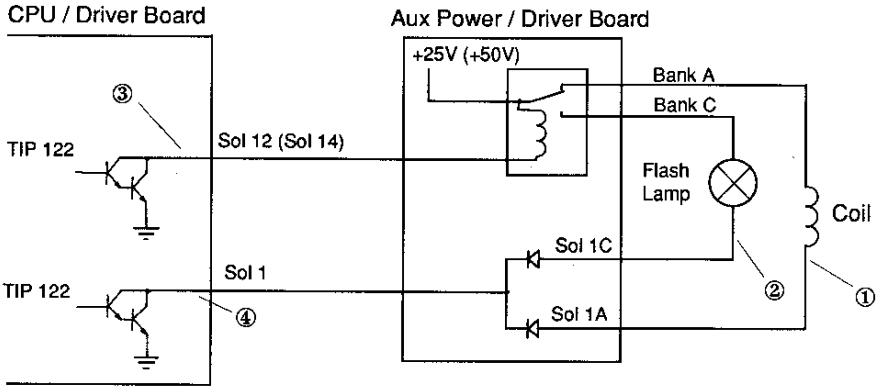
Check solder connections on this little board - they tend to crack.

If you can operate the solenoid by grounding test point ④ but the solenoid doesn't work in the solenoid test, the **CPU / Driver Board is faulty.**

CPU / Driver Board Layout



Troubleshooting Solenoids in Solenoid Banks



Test Points

① Terminal of the Coil

② Terminal of the Lamp Socket

③ ④ The Collector (The tab) of the driver transistor on the CPU/Driver Board

Use solenoid test to check solenoids and flash lamps.

Solenoid or Flash Lamp not working in the Bank "C"

Ground temporarily test point ③ and leave it grounded while you are troubleshooting the bank "C". This ensures that the solenoid power is connected to the Bank "C". You can momentarily ground test point ② and ④ to test the circuit.

Solenoid not working in the Bank "A"

To ensure that the power is connected to Bank "A", disconnect connector 1J12 on the CPU / Driver Board. Use test points ① and ④ to test the circuit.

The Whole Bank of Solenoids is Not Working

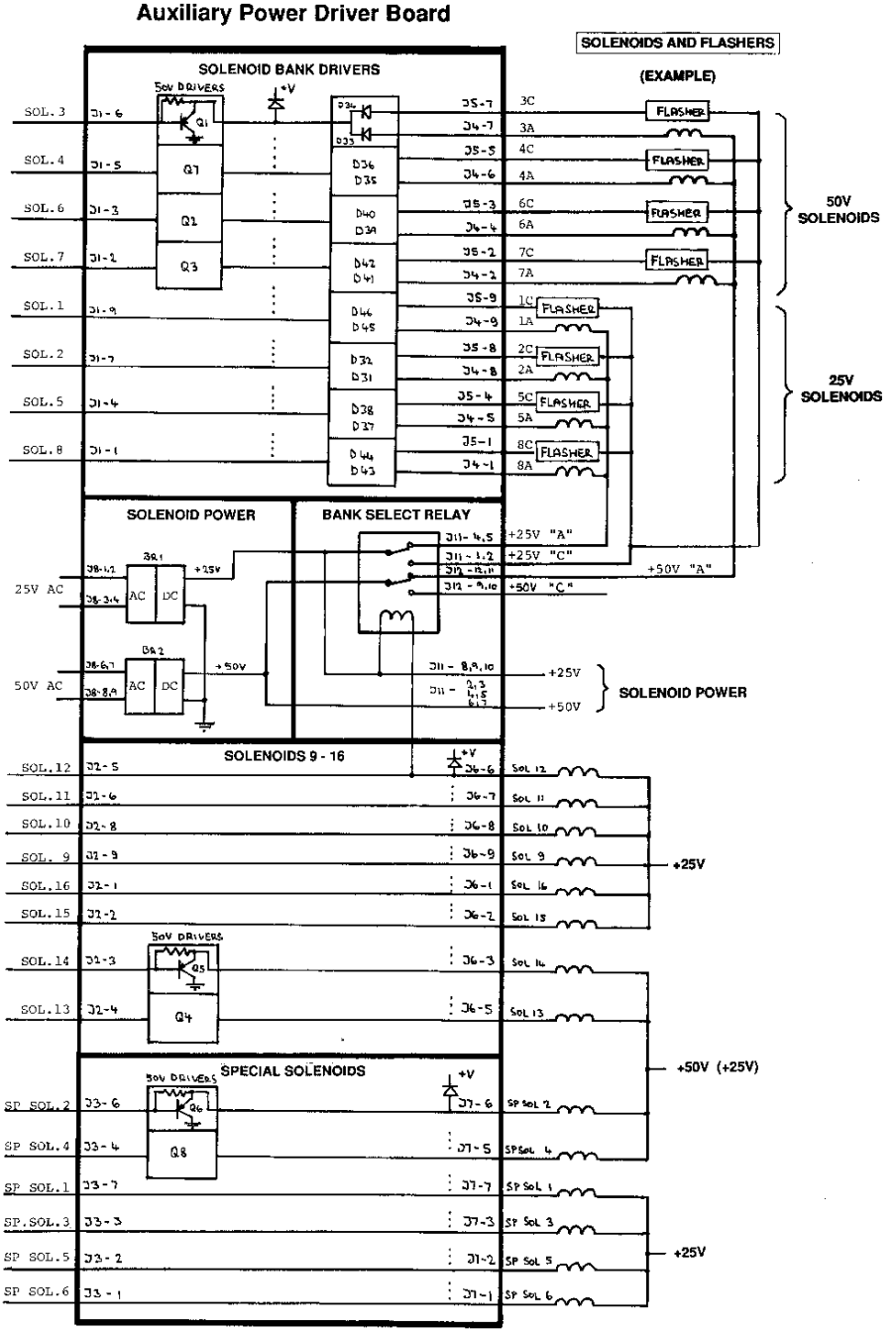
CAUSE: No solenoid power on the Solenoid Bank

- Use Test point ③ to check if the relay switches over. If it does (but does not in the Solenoid Test) the **CPU / Driver Board is faulty.**
- Check fuses.
- Check the contacts of the Bank Select Relay
- In machines where Auxiliary Power Driver Board is not used, check solder connections on the Bank Select Relay PCB in the Playfield.

Incorrect Solenoids Get Energised

Check the diodes D31 to D46 for short circuit on the Auxiliary Power Driver Board or on the Diode Board in the Playfield (in earlier Machines).

Auxiliary Power Driver Board Diagram

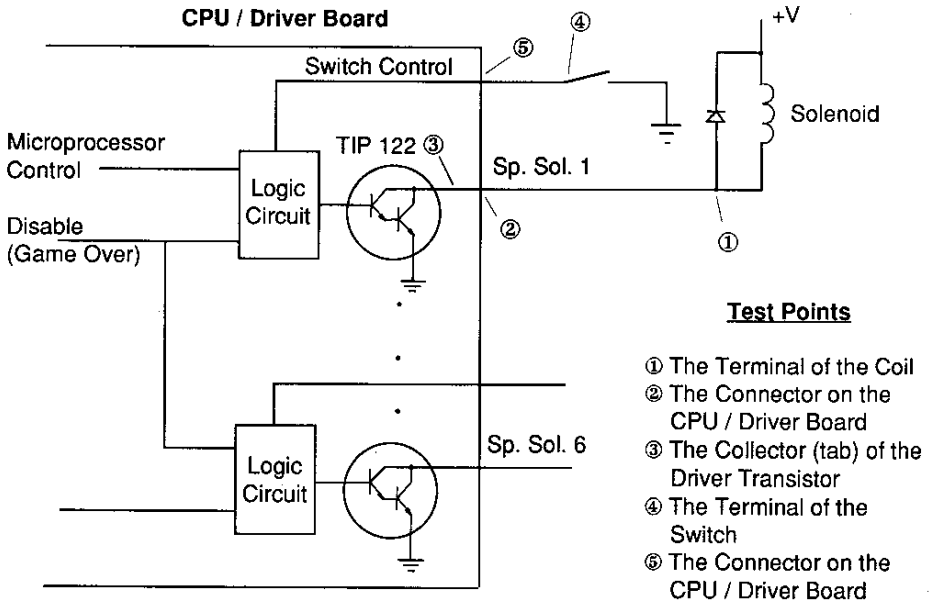


Special Solenoids

The Special Solenoids are **Slingshots** and **Jet Bumpers**. They are called *special* because they can be operated directly by switches in the playfield through the logic circuit without any involvement of the microprocessor.

The CPU/Driver Board has **6 special solenoid outputs**. In a game mode the microprocessor enables the Special Solenoids only but does not take any part in controlling them. The coil is energised as long as the switch is closed (see also *Special Solenoids* later in System 11 Machines).

The Special Solenoids are controlled by the microprocessor in the Solenoid Test only.



Special Solenoids in later System 11 Machines

Special Solenoids in later System 11 machines are not directly operated by the switches. The switches are conected to the Switch Matrix instead and the Microprocessor fully controls the Special Solenoids even in Game Mode.

The Microprocessor will pulse the coil regardless of the duration of closure of the switch. No longer will a stuck switch cause a burnt coil.

Troubleshooting Special Solenoids

Problem: A Special Solenoid Will Not Energise

Go through the following steps: For the purpose of troubleshooting we can split the special solenoid circuit into two circuits:

1. The Solenoid Circuit (The Output Circuit)

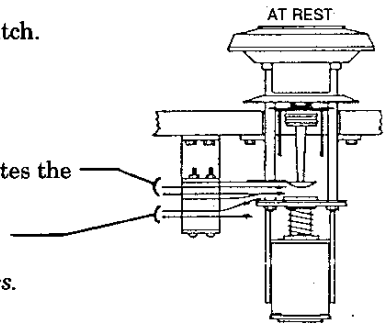
Check all special solenoids in the solenoid test. The microprocessor will pulse each special solenoid. If one is **not working** use the same troubleshooting techniques as used for other solenoids. You can ground momentarily test point ① ② ③ by your test lead to check the circuit. If the solenoid works in the solenoid test, troubleshoot the switch circuit.

2. The Switch Circuit (The Input Circuit)

Remember that special solenoids are enabled only in the game or the test mode. Initialize the test mode or start the game before you start troubleshooting. You can ground momentarily test point ④ and ⑤ by your test lead. If grounding test point ⑤ doesn't operate the solenoid the **CPU / Driver Board is faulty**. If grounding test point ④ operates the solenoid:

- Check, clean and adjust the contacts of the switch.
- Check if one side of the switch is grounded.

See Illustration of the Jet Bumper



- This is the special solenoid switch which operates the solenoid.
- This switch is used only for scoring and sound effects and connects to the switch matrix.
  It is important not to confuse these two switches.

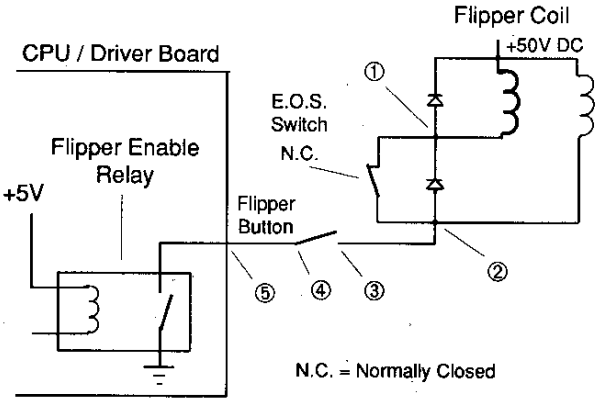
How can I tell if a Special Solenoid is controlled directly by the Switch or by the Microprocessor (in later machines)

Look at the special solenoid assembly. If only one switch is used with a diode connected to it, the special solenoid is controlled by the microprocessor. *Do not ground this switch.* It is part of the switch matrix. Use the switch test to check the switch.

Problem: A Special Solenoid is energised immediately after the machine is turned on.
Cause: Short Circuit Driver Transistor on the CPU / Driver Board.

Problem: A Special Solenoid is energised when the game starts.
Cause: Most likely the Special Solenoid switch is stuck closed. Have a look at the Switch and see why it is stuck. Readjust the space between the contacts if necessary. You can disconnect Connector 1J18 from the CPU / Driver Board. If the solenoid still stays energised the **CPU / Driver Board is faulty.**

Flippers - How They Work



Test Points

① Middle Terminal of the Coil
② Edge Terminal of the Coil where the anode of the diode connects
③ Terminal of the flipper button switch (Coil side)
④ Terminal of the flipper button switch (Relay side)
⑤ Connector on the CPU / Driver Board

The flippers are enabled only in game or test mode. **The Flipper Enable Relay** turns "ON" and connects ground to the flipper button. When the Flipper Button is pressed the circuit is completed. Large current flows through the thick wire coil, End of Stroke (E.O.S.) Switch, the Flipper Button and the contact of the Relay.

The Flipper is energised. As soon as the Flipper reaches its full deflection the End Of Stroke Switch opens. The thick wire coil is disconnected and only little current flows through the thin wire coil - just enough current to keep the Flipper deflected as long as the Flipper Button is held closed. This ensures that the Flipper coil will not be overheated when it is continuously energised.

Troubleshooting Flippers

The Most Common Problems
Before Troubleshooting flippers start the game or initialize test mode.

1. Flipper Does Not Work at All

Use test point ① to pulse ground by your test lead. If the flipper **doesn't work** the likely causes are:

- **No + 50VDC** - Blown Fuse, replace the fuse, retest the flipper. If the fuse blows again, the coil or the diode on the coil is short circuit.

- **Open Circuit Coil** - Check the coil for continuity, check the solder connections on the terminals of the coil.

If the flipper works by grounding test point ①, try to ground momentarily test point ② . If the flipper works ground test point ③ . If the flipper works test the flipper button as follows:

- **The Flipper Button Doesn't Make Good Contact** - Ground test point ④ or ⑤ and press the flipper button at the same time.

If the flipper **doesn't work** clean and adjust the contacts or replace the switch if necessary (see Note 1).

If the flipper **works** then...

- **The Flipper Enable Relay is not Grounding the Flipper Button**
  Is the machine in the game or test mode?
  If yes - check the connector 1J19, Pins 1 and 2 on the **CPU/Driver Board.**
  If O.K. - the CPU/Driver Board is faulty.

2. Weak Flipper or the Flipper Hardly Moves

- **E.O.S. Switch Doesn't Make Good Contact**
  Connect your test lead between test point ① and ②. Press and **quickly release** the Flipper Button. (Do not hold the button - the coil would **get too** hot). If the flipper is powerful the E.O.S. switch needs to be cleaned, adjusted or replaced (see Note 1).

- **Flipper Button Doesn't Make Good Contact**
  If you short out the button by your test lead **and** the flipper works O.K. the button needs to be cleaned, adjusted or replaced (see Note 1).

- **Faulty Bridge Rectifier for Flipper Power**
  Open circuit diode in the bridge rectifier. This fault is rare and effects both flippers.

- **Mechanical Parts Worn Out**
  Check the plunger, sleeve, flipper link etc.
  Replace worn out parts, tighten up loose bolts.

3. Flipper Coil Gets Hot and Burns Soon After Replacing

- **E.O.S. Switch Doesn't Open** - Broken top part of the blade of the switch or badly adjusted switch or contacts welded together.
  Clean, adjust or replace the E.O.S. switch.

- **Short Circuit Capacitor Which is Connected Across E.O.S. Switch**
  Check the capacitor for short circuit and replace it if necessary.

4. Flipper Vibrates and Makes Loud Buzzing Noise

- **The Thin Wire Coil of the Flipper Coil is Open Circuit**
  Usually one side of the coil breaks near the solder terminal of the coil. The wire can often be reconnected and the coil saved. If not, replace the coil.

NOTE 1 - *You can use a small contact file for cleaning these switches only. This is often just a temporary solution. The switch might need replacing.*

Switch Matrix

Refer to Pages 28 to 33 in Section 1 of this book.
The same principle of operation and troubleshooting techniques apply in System 11 machines.

Take into account the following differences:

Differences Between System 11 and WPC System

- No help facility is available in System 11
- Alpha-Numeric Display is used. You will not have the advantage of seeing the whole switch matrix at once.
- The switches are numbered from 1 to 64 and the numerals do not relate to any Column or Row (as it does in the WPC System). Find out from the **Switch Matrix Table** to what Column and Row a particular switch is connected.

Switch Tests

Two switch tests are available:

1. Switch Edges

Use the switch edges test to verify correct operation of switches in the playfield. Test every switch with a ball. The display will indicate the name and number of the last closed switch. No indication or incorrect number displayed means - **PROBLEM.**

See *Troubleshooting Switch Matrix* in Section 1 of this book.

2. Switch Levels

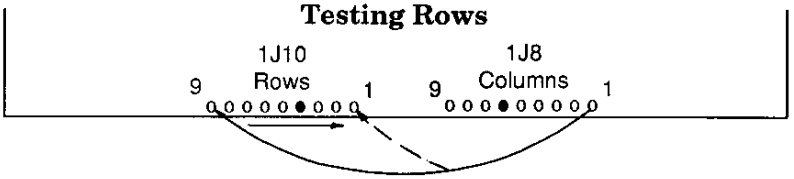
In this test the computer cycles through all switches. All closed switches are indicated on the display.
You can do more thorough testing of the switch matrix by using this test.

- Remove all balls from the playfield
- Reset all drop targets (All targets "up")
  Check the display now. No indication means that all switches are opened. If the display still indicates that some switches are closed have a look at them to see if they are supposed to be closed.

- Test one switch at a time and observe the display. If a closure of one switch gives an indication that some other switches have been closed as well, check the CPU/ Driver Board. If the CPU / Driver Board is O.K. follow the instructions in Section 1 (Page 33).

How to Check the CPU / Driver Board

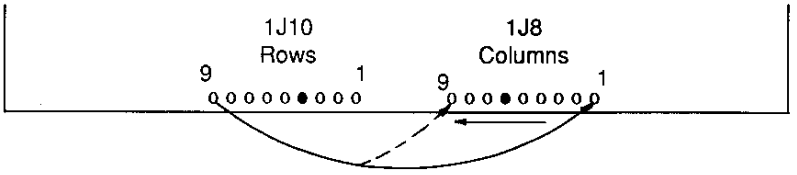
1. Initialize "Switch Levels" Test.
2. Disconnect Connectors 1J8 and 1J10 from the CPU / Driver Board.
3. The display should not indicate any closed switch now. If it does the **CPU / Driver Board is faulty.**



The CPU / Driver Board

4. Connect your test lead to Pin 1 of 1J8 and the other end of the lead to Pin 9 of 1J10. The display indicates Switch 1 closed. Move your test lead from Pin9 of 1J10 pin by pin to Pin1 of 1J10. After every connection check the display. You will see these numbers: 1, 2, 3, 4, 5, 6, 7, 8. If any number is missing the **CPU / Driver Board is faulty**.

NOTE: *Pin 4 of 1J10 is a "Key" - Expect no indication from this pin.*



The CPU / Driver Board

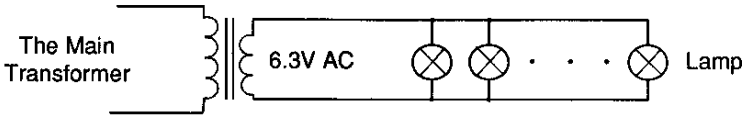
5. Connect your test lead to Pin 9 of 1J10 and the other end pin by pin, from Pin 1 to Pin 9 of 1J8. With every connection check the display. The numbers you expect are: 1, 9, 17, 25, 33, 41, 49, 57. If any number is missing the **CPU / Driver Board is faulty.**

NOTE: 1. *In some machines Column 8 is not used. If so, then no indication of 81 is O.K.(See "Switch Matrix Table if Column 8 is used).*
2. *Pin 6 of 1J8 is a "Key" - expect no indication from this pin.*

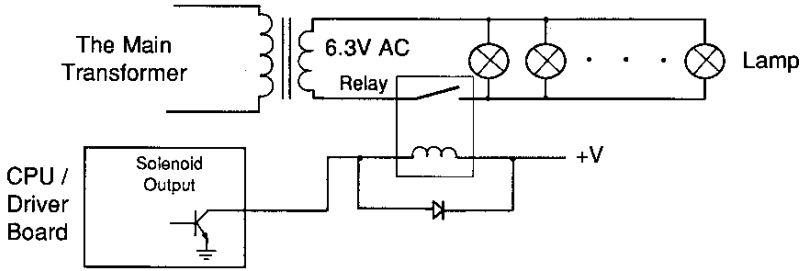
Lamps

1. General Illumination

These lamps are not controlled. They are connected directly to the 6.3V AC from the main transformer. 6.3 volts globes are used.

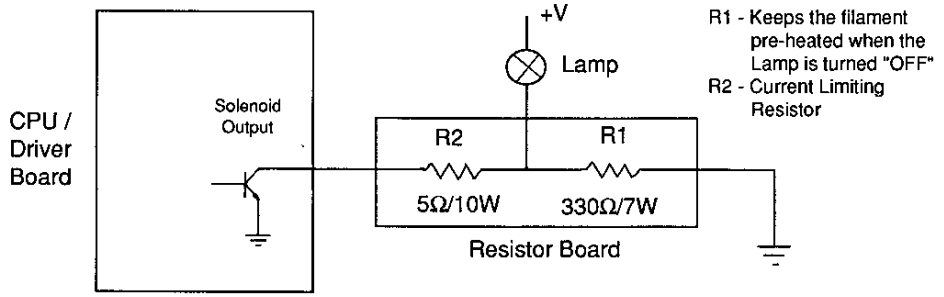


In some machines, the general illumination can be turned off/on by a relay driven by a solenoid driver transistor.



2. Flash Lamps

Flash lamps do not belong to the lamp matrix circuit. They are controlled by solenoid drivers. In earlier system 11 machines flash lamps were connected to the CPU / Driver Board through little resistor boards in the playfield. In later machines resistor R1 was left out from the circuit and resistor R2 placed on the Interconnect Board.



Use solenoid test to check the flash lamps. Troubleshoot them the same way as solenoids. Sometimes two flash lamps are in series circuit. Then one faulty globe would disable the other one. Bad connections or open circuit resistors on the resistor board were common problems in earlier machines.

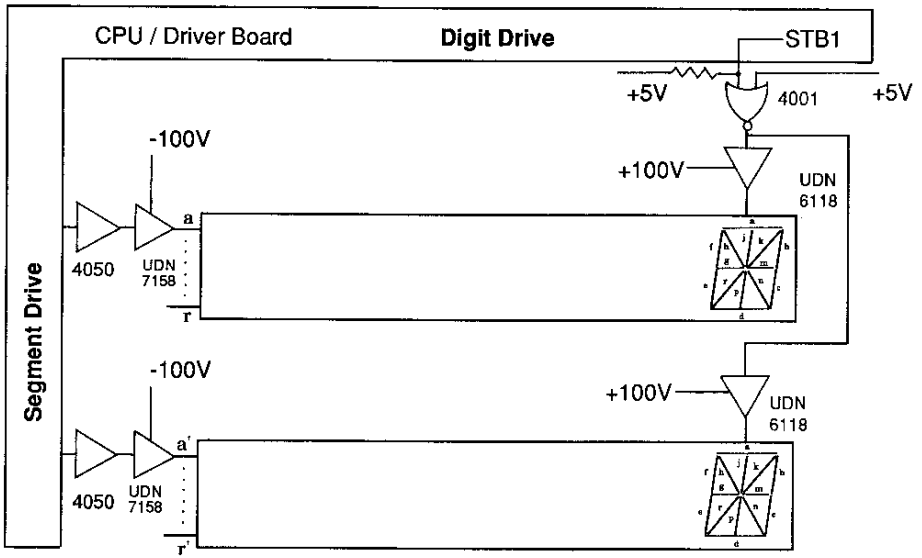
3. Lamp Matrix

Refer to Pages 37 to 39 in Section 1 of this book.
The same principle of operation and troubleshooting techniques apply in System 11 machines.
Locate the row and column drivers on the CPU/Driver Board.
See the CPU/ Driver Board layout on Page 52.

NOTES

Alpha- Numeric Displays

Two 16 digit gas-discharge displays are used. The driver circuit requires +5V, +100V and -100V generated by the power supply unit.



This is a simplified circuit diagram of the display driver circuit. Only one digit driver and segment driver is shown for each display. The rest are identical. In earlier System 11 machines the bottom display could display only numerals.

Troubleshooting Displays

Use Display Test to check if all digits and segments work properly. In case of a problem make sure that all related connectors are plugged in properly. But usually the fault is in the Display Driver Board and this should be fixed in the workshop.

Problem: No display at all but the machine works.
Cause: No high voltage (+100V, -100V). Check the voltage, check the related fuses. Replace faulty one - if it blows again the Power Supply is faulty or there is a short circuit on the Display Driver Board.

Problem: Part or whole Display is extremely bright and scrambled.
Cause: Faulty Display Driver Board - switch off the machine as soon as possible.

Problem: The displayed information is OK but the Display is very bright or flickering.
Cause: Faulty Power Supply Board.

NOTES

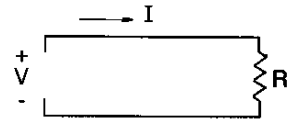
SECTION 3

ELECTRICAL PRINCIPLES AND DEVICES

Electrical Principles and Devices

Basic Electrical Circuit

I = Current *[A] Amper*
V= Voltage *[V] Volt*
R = Resistance *[Ω] Ohm*
P = Power *[W] Watt*



P = V x I

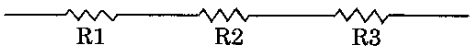
OHM LAW

$I = \frac{V}{R}$

$R = \frac{V}{I}$

$V = I \times R$

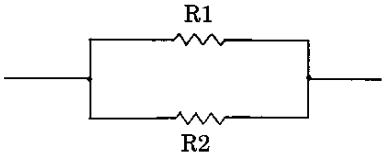
Resistors in Series Connection



R = Total Resistance

R = R1 + R2 + R3

Two Resistors in Parallel Connection

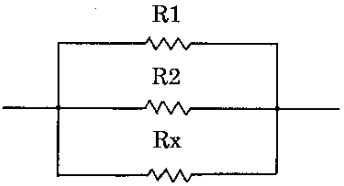


R = Total Resistance

$R = \frac{R1 \times R2}{R1 + R2}$

OR $\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2}$

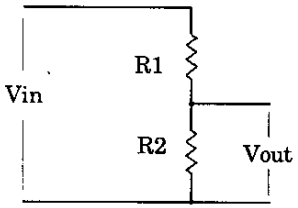
Two or More Resistors in Parallel Connection



R = Total Resistance

$\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{Rx}$

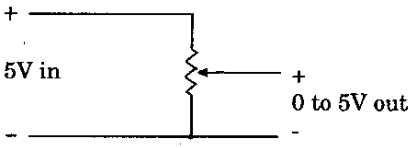
Voltage Dividers



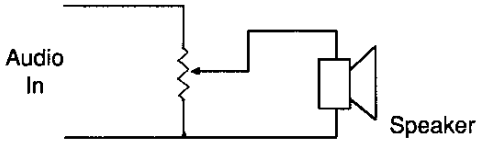
$Vout = Vin \frac{R2}{R1 + R2}$

Potentiometer as A Voltage Divider

Potentiometers are often used for accelerators and brakes in video games.

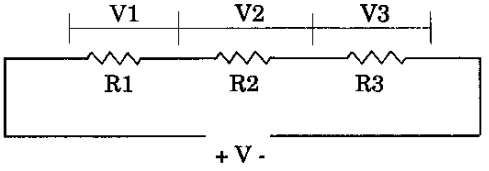


Potentiometer as a volume control



Many video game machines use this simple connection for external volume control

Distribution of voltage across resistors in series

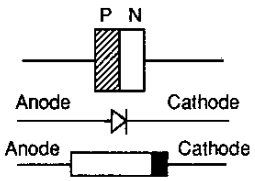


R1 - R2 - R3

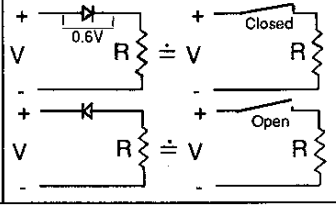
V1 - V2 - V3

The ratio of the resistance will be the same as the ratio of the voltages

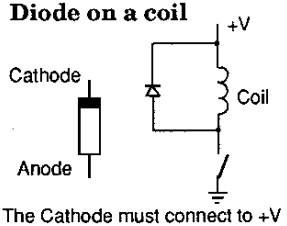
Diode



Diode in DC circuit



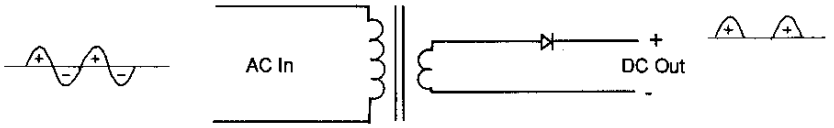
Diode on a coil



The Cathode must connect to +V

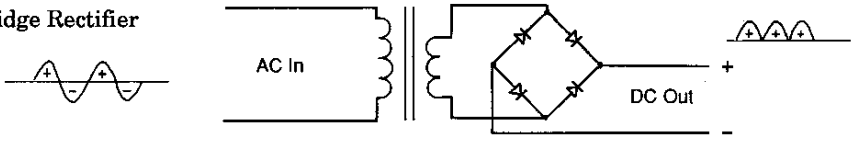
Diodes in AC circuit - Rectifiers

Half Wave Rectifier

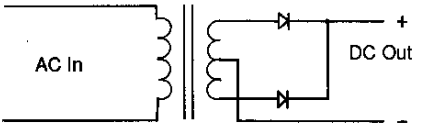


Full Wave Rectifiers

a) Bridge Rectifier



b) Rectifier using centre-tapped Transformer and two diodes

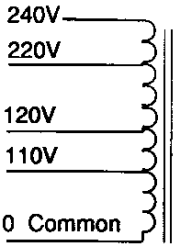


Transformers

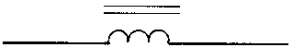
Isolating Transformer

There is no electrical connection between the Primary and the Secondary winding

Autotransformer

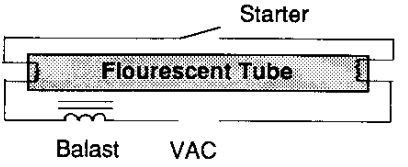


Balast



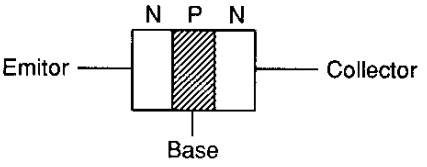
Used in AC circuits for current limiting or as a filter

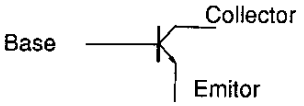
An example of using balast for current limiting in fluro circuit

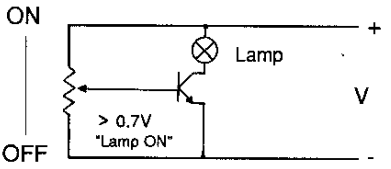


Transistors

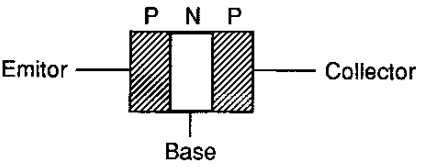
NPN

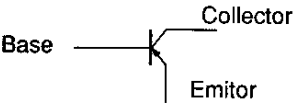


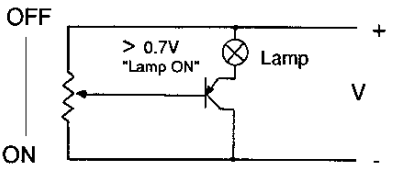




PNP

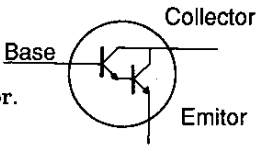




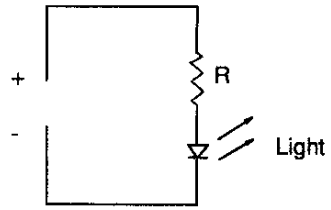


Darlington Transistor

Two Transistors in one package arranged in such a way as to achieve high current gain.
The total gain equals the product of the gain of each transistor.
Commonly used for driving solenoids in pinball machines

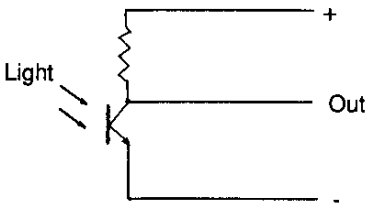


Light Emitting Diode - LED



Forward biased LED emits light

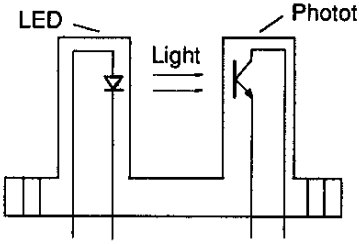
Phototransistor



The Phototransistor is switched "ON" by the light

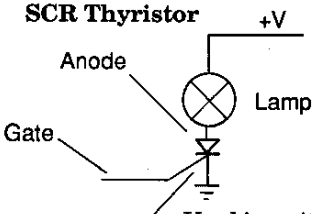
Optocouplers

Often used in pinballs and in video games (steering). They have to be kept clean so the light is not restricted.



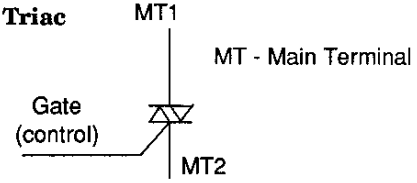
If the light strikes the phototransistor it turns "ON". If the light is obstructed the phototransistor turns "OFF"

SCR Thyristor



Used in switching circuits - unfiltered DC voltage is used.

Triac

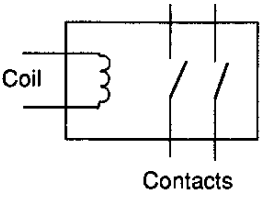


Unlike SCRs, Triacs can handle AC current. Used for switching lamps in General Illumination *(WPC System)*

Relays

A relay is an electrically operated switch. When power is applied to the coil of the relay it turns "ON" (the contacts close). There are two main reasons for using relays.

1. Only a little current is needed to control the relay. The contacts can switch high power circuits.
2. The control circuit (the coil) is completely isolated from the power circuit (the contacts).



NOTES

SECTION 4

APPENDIX

What Tools Do I Need?

The tools you'll need depends on the level to which you intend to get involved in the servicing or repairing of pinball machines.

It is difficult to work efficiently and enjoy the work without the proper tools. Even the simplest task can turn into a dreadful job.

Don't buy a whole set of tools - most of the tools you will never use. Get only the tools you need.

Below is a list of tools commonly used for servicing pinball machines.

- **Socket Drivers** - 1/4"
  - 11/32"
  - 8mm
- **Philips Head Screwdriver** - Small
  - Medium
- **Flat Screwdriver** - Small
  - Medium
- **Shifting Spanner** - 150mm
- **Allen Key** - 5/32"
- **Side Cutters**
- **Multi-Purpose Pliers**
- **Small Contact File** - (only for cleaning non-electronic flipper E.O.S. Switch and Cabinet Flipper Switch)
- **Gas Soldering Iron & Solder**
- **Multimeter** - can be an inexpensive one. Preferable digital multimeter (easier to read). Make sure it has a diode checker.
- **Test Leads** - Two extra test leads are handy. One with an aligator clip on both ends - the other with a multimeter probe on one end and an aligator clip on the other.

Try to buy good quality tools - it pays off. Cheap tools sometimes look good but are not. They are not durable and it is often difficult to work with them. You can expand your tool case according to your needs.

What Spare Parts Should I Carry?

This depends on how many machines you service.
A minimum set of spare parts would be as follows:

Description	Williams Part #	LAI Part #
• Fuses (See "Common Fuses" on Page 74)		
• Globes 6.3V Wedge Globe	24-8768(#555)	110GE555T
6.3V Bayonet Globe	24-6549 (#44)	110129
12V Wedge Globe	24-8802 (#906)	110248802
12V Bayonet Globe	24-8704 (#89)	110GE89
• Flipper Link Assembly	A-10656	014A10656
• Coil Sleeve	03-7066-5	0510370665
• E.O.S. Switch (Electronic Flipper)	SW -1A-193	039SW1A193
• E.O.S. Switch (Earlier Flipper)	03-7811	039SW10A8
• Single Cabinet Flipper Switch (Electronic Fl.)	SW-1A-191P	039SW1A191P
• Double Cabinet Flipper Switch (Electronic Fl.)	SW-1A-192P	039SW1A192P
• Single Cabinet Flipper Switch (Earlier Fl.)	SW-10A-48	039SW10A48
• Double Cabinet Flipper Switch (Earlier Fl.)	SW-1010-A13	039SW1010A13
• Small Microswitch *	5647-12073-19	0391207319
• Diode 1N4004 (Several)		
• Pinball Rubbers (Several)		
• Flipper Coil - Red	FL-11630	050FL11630

** The actuator arm can be changed over from the old microswitch.*

Flipper Coils

Listed below are the available flipper coils in ascending order from weakest to strongest. Always use the correct replacement.

Williams Part #	LAI Part #	Colour	Strength
FL - 11753	050EL11753	Yellow	Weakest
FL - 11722	050FL11722	Green	
FL - 11630	050FL11630	Red	Standard
FL - 15411	050FL15411	Orange	
FL - 11629	050FL11629	Blue	Strongest

Cleaning the Pinball Machine

Clean your Pinball Machine regularly. Every collection clean the glass thoroughly and wipe over the playfield with a clean cloth.
For more extensive playfield cleaning the manufacturer recommends **Novus Plastic Polish #1**, followed by **Novus Plastic Polish #2**.
Avoid excessive use of water and abrasive cleaners.
Do not use petroleum based cleaners.

Fuses

A fuse is the **weakest** place in an electrical circuit.

If over-current occurs the fuse blows and disconnects the circuit from the power supply.

There are two types of fuses used in pinballs.

1. Normal Blow (N.B.)

2. Slow Blow (S.B.)

The difference is in how quickly the fuse will react when the current exceeds the rating of the fuse. It is very important to always use the right type of fuse with a correct current rating.

If a fuse you have just replaced blows again then there is a problem in the machine.

Do not attempt to try a higher rated fuse - remember the fuse must remain the weakest place in the electrical circuit, otherwise damage to the equipment can occur.

How to Check a Fuse

A blown fuse often looks O.K. (Especially a Slow Blow Fuse).

- Turn off the machine. Remove the fuse from the socket and check the fuse for continuity with your multimeter.

Common Fuses in Pinball Machines

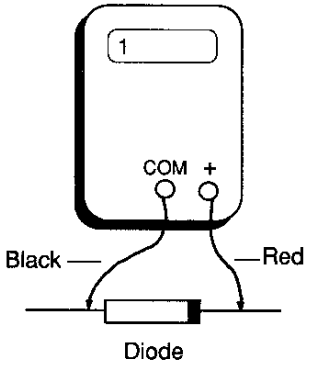
There is nothing more annoying than not having a replacement fuse when you need it. Keep spare fuses in the machine or in your toolbox.

Common Fuses:	**WPC System**	**System 11**
	750mA S.B.	100mA S.B.
	2.5A S.B.	250mA S.B.
	3A S.B.	2A S.B.
	5A S.B.	4A S.B.
	8A N.B.	5A N.B.
		7A S.B.
		8A N.B.

How To Check The Diode

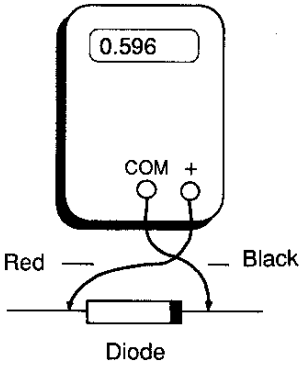
Switch your digital multimeter to the diode checker.

1.



The diode in this connection behaves like an open circuit. If you get any reading the diode is faulty.

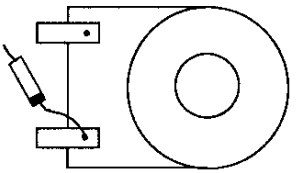
2.



You should get some reading in this connection. If you get no reading the diode is faulty. (Open Circuit)

How to Check the Diode on the Coil

Check the diode as described above.
You must disconnect one side of the diode from the coil first.
Reconnect the diode properly.
If the lead from the diode is too short it is better to replace it.



How to Check the Diode on the Microswitch

The diode is connected across the normally closed contact of the microswitch *(See Page 35)*. Hold the switch closed while you check the diode.

NOTE: *If you are checking the diode in the machine turn the machine "OFF" first.*

Pinball Rubbers

Description	Williams Part #	LAI Part #
Rubber Rings		
• Mini	23-6552	049R0032
• Bumper	23-6535	049R0041
• 3/16"		049123
• 5/16"	23-6300	049124
• 3/8"		049125
• 3/4"	23-6301	049126
• 1"	23-6302	049127
• 1 1/4"	23-6303	049128
• 1 1/2"	23-6304	049129
• 2"	23-6305	049130
• 2 1/2"	23-6306	049131
• 3"	23-6307	049132
• 3 1/2"	23-6308	049133
• 4"	23-6309	049134
• 4 1/2"	23-6530	049135
• 5"	23-6310	049136
• 5 1/2"		049137
• 6"	23-6429	049190124
Shooter Tip	23-6327	0491241
Flipper Rubbers		
• 1"	23-6553-4	0492365534
• 1 1/2" Red	23-6519-4	0491231
Playfield Rubbers		
• 3/4" Bumper	23-6551	029236551
• 3/4" Tapered Bumper	23-6579	029236579
• Bumper Sleeve - Yellow	23-6552	029236552
• Bumper Sleeve - Black	23-6556	029236556

Williams and Bally Games by System

This is a listing of games by the CPU System it uses. 11A Boards can be used for 11 and 11A Games. 11B Boards can be used for systems 11A, 11B and 11C. Systems 9, 11, 11C and WPC can only be used for their own systems respectively.

GAME	SYSTEM
Space Shuttle	9
Sorcerer	9
Comet	9
Strike Zone	9
High Speed	11
Grand Lizard	11
Road Kings	11
Alley Cats	11
Pinbot	11A
Millionaire	11A
F-14 Tomcat	11A
Fire!	11A
Tic Tac Strike	11A
Big Guns	11A/11B
Space Station	11B
Cyclone	11B
Banzai Run	11B
Swords of Fury	11B
Taxi	11B
Jokerz	11B
Gold Mine	11B
Top Dawg	11B
Earthshaker	11B
Black Knight 2000	11B
Police Force	11B
Elvira	11B
Transporter	11B
Bad Cats	11B
Shuffle Inn	11B
Mousin' Around	11B
Whirlwind	11B
Shuffle in Deluxe	11B
Game Show	11C
Pool Sharks	11C
Roller Games	11C
Radical	11C
Diner	11C

Williams and Bally Games by System (Cont)

GAME	SYSTEM	
Riverboat	11C	
Bugs Bunny	11C	
Dr. Dude	11C/WPC	
Funhouse	WPC	
Harley Davidson	WPC	
The Machine	WPC	
Slugfest	WPC	
Gilligan's Island	WPC	
Terminator 2	WPC	
Party Zone	WPC	
The Addams Family	WPC	
Strike Master	WPC	Games with
Hurricane	WPC	Electronic Flippers
The Getaway	WPC	
Black Rose	WPC	
Fish Tales	WPC	

Pinball System Error Messages

"Factory Setting" or "Adjustment Failure"

The adjustments and bookkeeping data stored in the CMOS RAM on the CPU Board have been corrupted. Check the batteries on the CPU Board. Ensure the battery holder makes a good connection. Check the Memory Protect Switch. Check diodes on coils, especially on the flipper coils. The coil can cause strong interference to the system if a diode is open circuit or poorly connected. The CPU Board can also be faulty . Restore the factory setting, readjust the pinball e.g. pricing, number of balls etc.

"Ground Short Row (Row Number and Wire Colour)"

The wire is shorted to ground in the playfield or coin door. Initialize the Switch Levels Test. Disconnect the coin door connectors. If the problem disappears check the slam switch wire (and coin switch wires in System 11 games) where they touch Ground. Disconnect the opto-boards in the playfield. If the problem persists check where the switch wires could possibly touch Ground. Disconnect the switch matrix connectors from the CPU Board. If the problem remains the **CPU Board is faulty**.

"Check Switch ##"

This switch is either stuck closed or has not been activated during 30 games. See Page 32 for how to check this switch.

"Pinball Missing"

One (or more) balls is missing. Check if you have the correct number of balls in the playfield. If yes, check Trough Switches, Outhole and the Ball Shooter Lane Switch. See Page 32 for how to check them.

"Checksum Error"

The game ROM on the CPU Board (U6 in WPC System) is faulty - replace it.

WPC CPU LED Errors

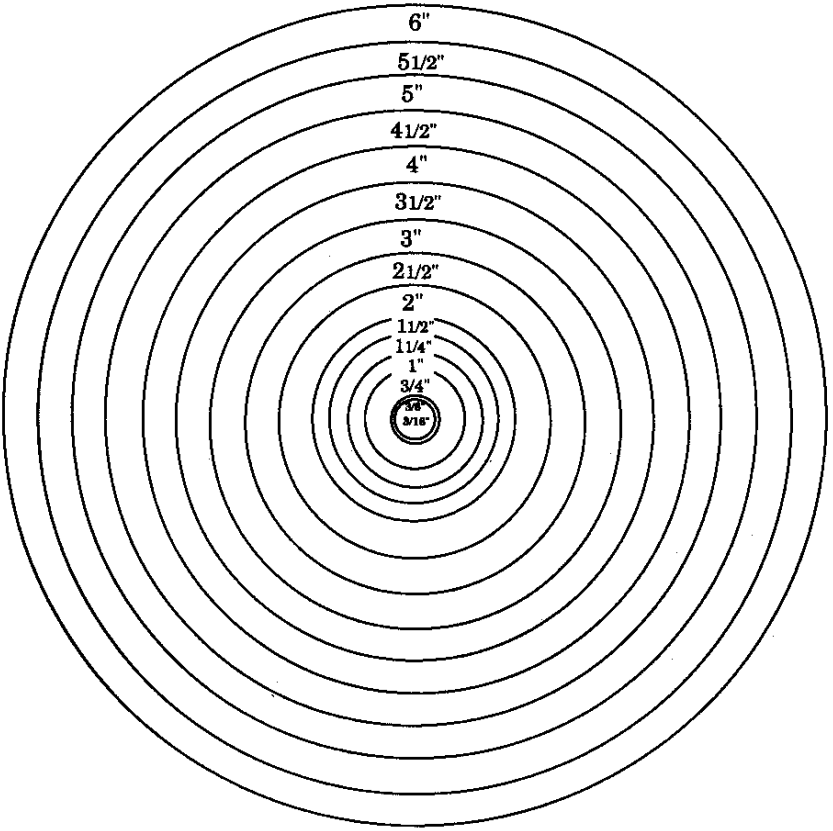
The centre LED on the CPU Board can indicate a problem with the system. Observe the LED after turning the machine "ON".

If the centre LED blinks...
- 1 time - ROM U6 is bad
- 2 times - RAM U8 is bad
- 3 times - Custom Chip U9 is bad

Normal Operation
Top LED - Blanking ("OFF")
Centre LED - Diagnostic (Flashing)
Bottom LED - +5V DC ("ON")

How To Measure Rubber Rings

Place the Rubber Ring on the Circles and Measure the Inside **Diameter**



Why...

The Game Does Not Start?
The Slingshot is Not Working?
A Flipper Does Not Work?

If you have asked yourself 'WHY' you are on the right track in your troubleshooting.

The next question should be *'What can I do about it.'*

This book will try to help you to answer these questions.

It will take you step by step through the pinball machine.

You will find explanations about how different parts of a pinball machine work and what to do about problems.