Musings of a Lifelong Hacker: How Pinball Electronics Work

By Hugh Spahr

Open Pinball Project

Introduction

- Started fixing pinball machines about 10 years ago
  - Fixed EM machines and early SS machines
- Created Open Pinball Project as low cost pinball driver alternative
- Fixed numerous machines for an operator in Vermont
- Built Sharpe Shooter 3 for Pintastic 2015
- Kickstarter for Gen 2 Open Pinball Project boards in 2016
- Rethemed Dolly Parton as Van Halen for Pintastic 2017

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EM machines (Gen 1):

- Often bought by first time pinball buyers because of price
- Most use only AC voltage
  - End of era showed conversion to DC voltage for flippers
- Most contain the following mechanical units:
  - Normal solenoid and switch stacks
  - Set/reset relays
  - Score reels
  - Score motor
  - Up/down count units

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Normal solenoid and switch stacks:

- Solenoid de-energized certain connections are made
- Solenoid energized, different connections are made
- Things to check:
  - Make sure all switch stack screws are tight
    - Do before any attempt at adjusting switches
  - Move to rest/energized positions and visually inspect
    - Verify all connections change
    - Make sure gaps are correct (about 1/8” between them)
    - Adjusting a stack leaf should be a last resort
    - Your eyes are the best debugger in EM machines

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Set/reset relays:

- Solenoid is pulsed to move stack to set position
  - Latches into the position
- Different solenoid is pulsed to reset the switch stack
  - Goes back to reset position
- Many fewer than normal solenoids, but these are crucial
  - Typically used to enable power to the rest of the machine
- Use same techniques as normal solenoids to inspect

Score reels:

- A pulse increments a digit
- When a digit is 9, a connection is made to increment the next digit
- A separate connection is made when a digit is 0
  - Allows machine to detect when score has been reset
  - Important for starting/initialization of a game
- Inspect each individual digit verifying that the 3 positions work properly
- If score motor runs continuously, most likely candidate

Score motor:

- Allows multiple values to be added at once
- Uses multiple disks with notches to create pulses
- Disks with multiple notches used to add values
- Used heavily when counting up bonuses/initializing game
  - If running continuously, look towards score reels

Up/down count units:

- Uses wipers to make different connections
- Can have single solenoid to only count up
- Can have two solenoids, count up/count down
- Can have two solenoids, count up/reset
- These seem to always need to be dissassembled and cleaned
  - Use isopropyl alcohol to clean
  - Thinking a spring isn't strong enough indicates it needs cleaning
  - Don't add oil/WD40, it is never the answer

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General tips:

- Dirt and grime on switch contacts can be cleaned by exercising contacts
  - Non-destructive in lieu of filing or harsh solvents
  - Arc can clean oil off contacts
  - Filing is almost never the answer
- www.pinrepair.com is the definitive resource
  - Clay Harrell's site is an encyclopedia of pinball repair knowledge

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Solid State machines (Gen 2):

- Reduce cost and amount of wiring (less/simpler wiring)
- No switch stacks which means less solenoids
- Mechanical parts (flippers, kickers, saucers are unchanged)
- Move from AC to DC to add more power

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Microprocessors

- MPU/CPU/etc now running rules
- Started as 4 bit but quickly moved to 8 bit processors
- Early SS machines use parallel IO expanders to increase pins
  - Called PIAs or peripheral interface adapters
  - MC6820 or MC6821 are examples
- RAM, used for variables such as player's score
- ROM, used to store program or rules
- PIA, used to expand I/O
  - Used addr lines, data lines and chip select to talk to chip

Simple input:

- 1 wire per input
- Requires pullup to always be in known good state
- Closing contact typically grounds input
- Life is simple

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Switch matrix inputs:

- Processor enables columns, one at a time
- Diode is used so other columns don't affect input
- Reduces wire for 64 inputs down to 16 wires
- To debug, use input screen on DMD if available
  - Helps find failed diodes
  - Many resources describing how to debug issues
    - www.pinballrehab.com has good tutorial, video at end is great
    - https://www.youtube.com/watch?v=ZgSyTmyZAxM
  - Good luck if a DMD can't continuously display inputs

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Simple lamp output:

- Processor output can't source enough current
  - Requires transistor or FET to turn on/off
  - FET is typically used as a low side switch
    - Connects/disconnects the ground

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Lamp matrix outputs:

- Requires high side and low side switches
- High side power is enabled for column while low side is enabled for lamps that are lit
- Persistence of vision makes lamp look like it is always on
  - Typically 2 ms strobe time
- Reduces wiring from 64 outputs and FETs to 16 outputs and FETs
- Essentially how a DMD works

Solenoids:

- Requires diode with DC voltage
- Current is like water flowing through a pipe
  - Stop current too quickly and get pressure hammer
  - Diode gives current path to dissipate

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Flippers:

- Can have 1 or 2 coils
- 2 coil flippers:
  - Primary high power coil gives strong initial kick
  - Secondary coil provides “hold” to keep flipper up without burning out the primary coil
  - Comes in many flavors
- 1 coil flippers:
  - Initial kick uses full power
  - After time, PWMs output to hold coil with lower power
  - Love that PWM hum!

Distributed Computing Machines (Gen 3):

- Distribute multiple cards beneath playfield to reduce complexity
  - Wiring harness becomes much simpler
  - Issues become easier to isolate
- Stern is doing this, and JJP has moved in this direction
- SAM, P-ROC, Fast and OPP support this style architecture
- Real time programming happens locally at distributed points
- Main controller
  - Collects inputs
  - Runs rules
  - Shows videos

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Gen 3 (cont):

- Transformer power supply replaced with SMPS
  - Less expensive to manufacture
  - Less weight
- Manufacturing will probably move in next couple of years

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Questions?

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