

Musings of a Lifelong Hacker: How Pinball Electronics Work

By Hugh Spahr



Introduction

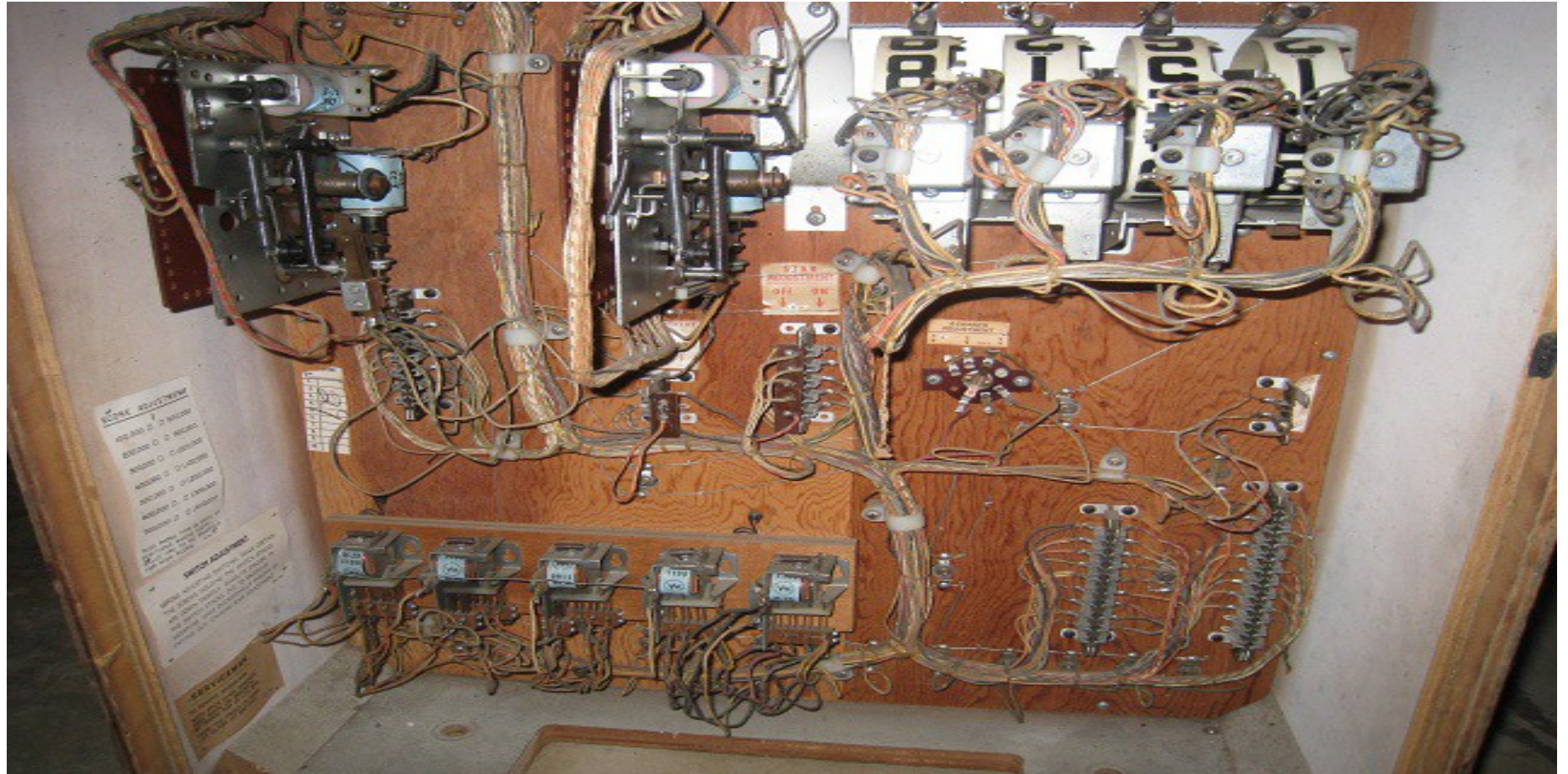
- Started fixing pinball machines about 10 years ago
 - Fixed EM machines and early SS machines
- Created Open Pinball Project as low cost pinball driver alternative
- Fixed numerous machines for an operator in Vermont
- Built Sharpe Shooter 3 for Pintastic 2015
- Kickstarter for Gen 2 Open Pinball Project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



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

EM Back box:

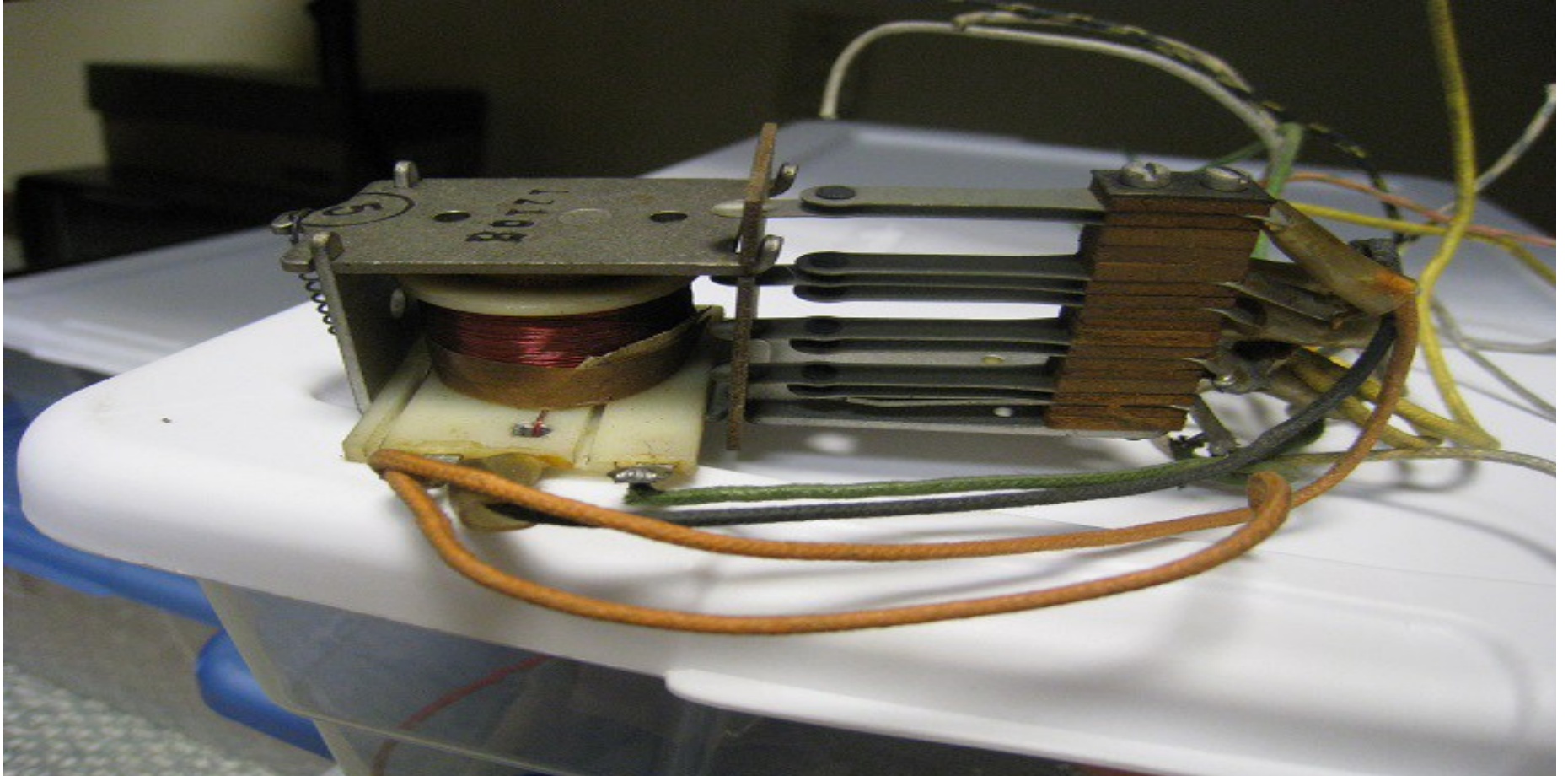


Normal solenoid and switch stacks:

- 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



Solenoid and switch stack:



Set/reset relays:

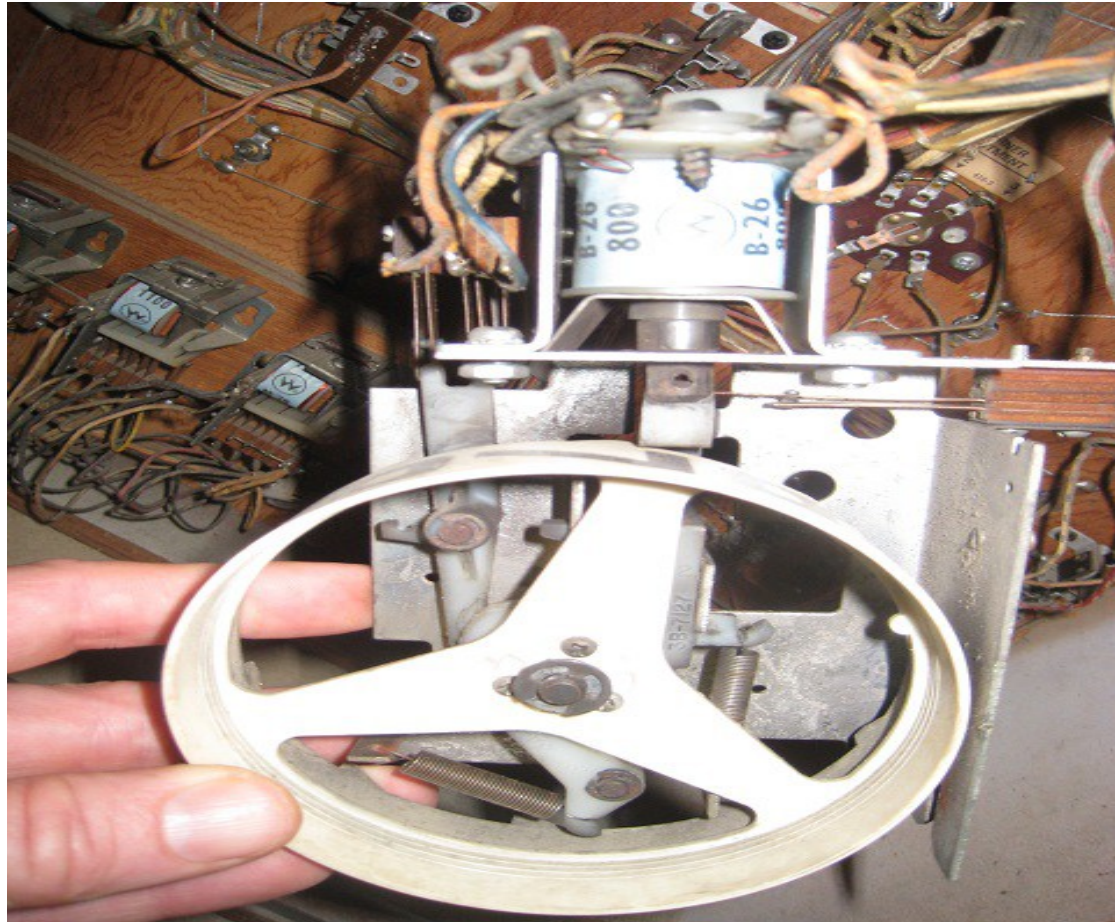
- Solenoid is pulsed to move stack to set position
 - Latches into the position
- Different solenoid is pulsed to reset the switch stack
 - Goes back to reset position
- Many fewer than normal solenoids, but these are crucial
 - Typically used to enable power to the rest of the machine
- Use same techniques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



Score motor:

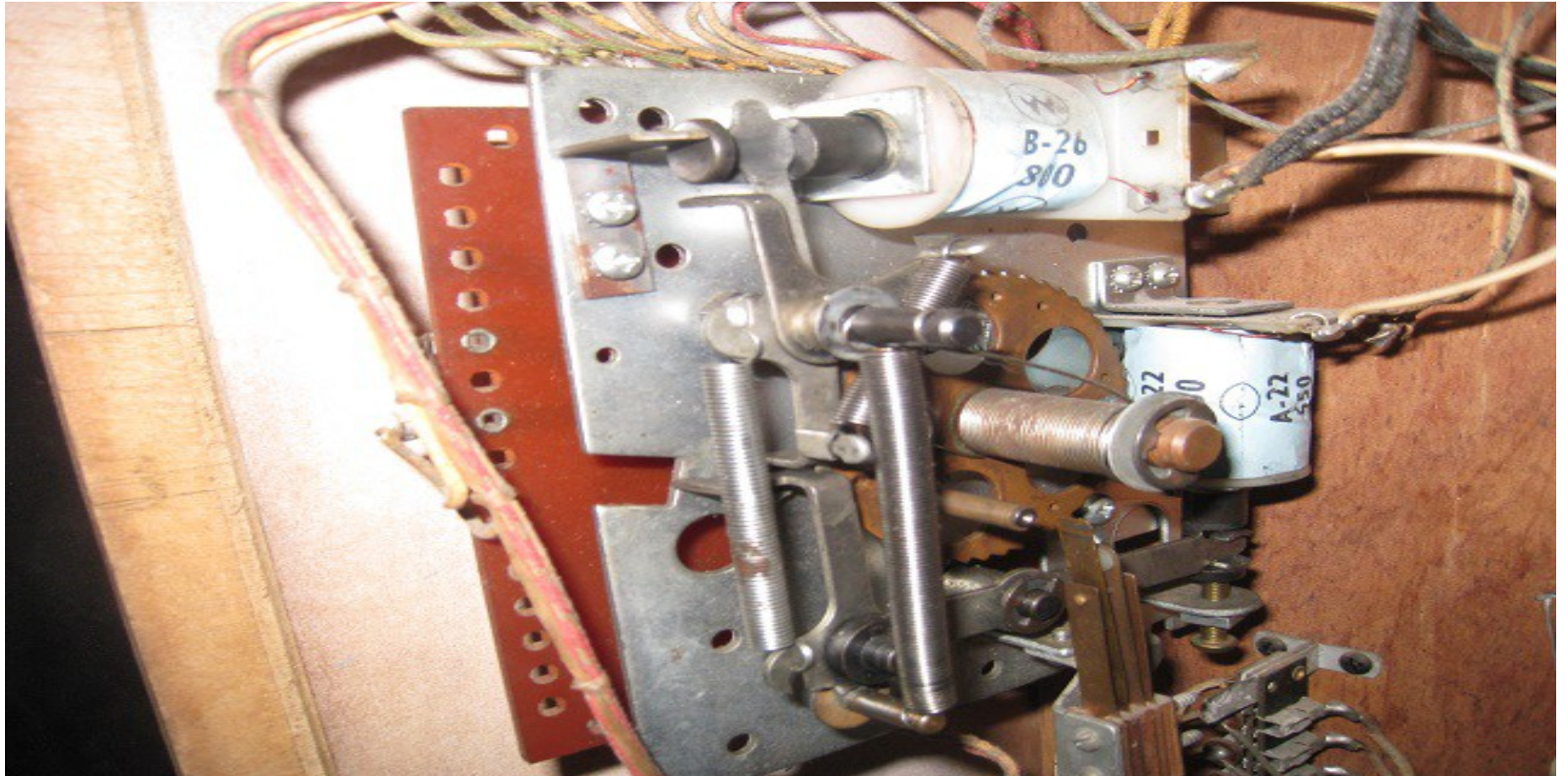
- Allows multiple values to be added at once
- Uses multiple disks with notches to create pulses
- Disks with multiple notches used to add values
- Used heavily when counting up bonuses/initializing game
 - If running continuously, look towards score reels

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 disassembled 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



Up/down count units:



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



Solid State machines (Gen 2):

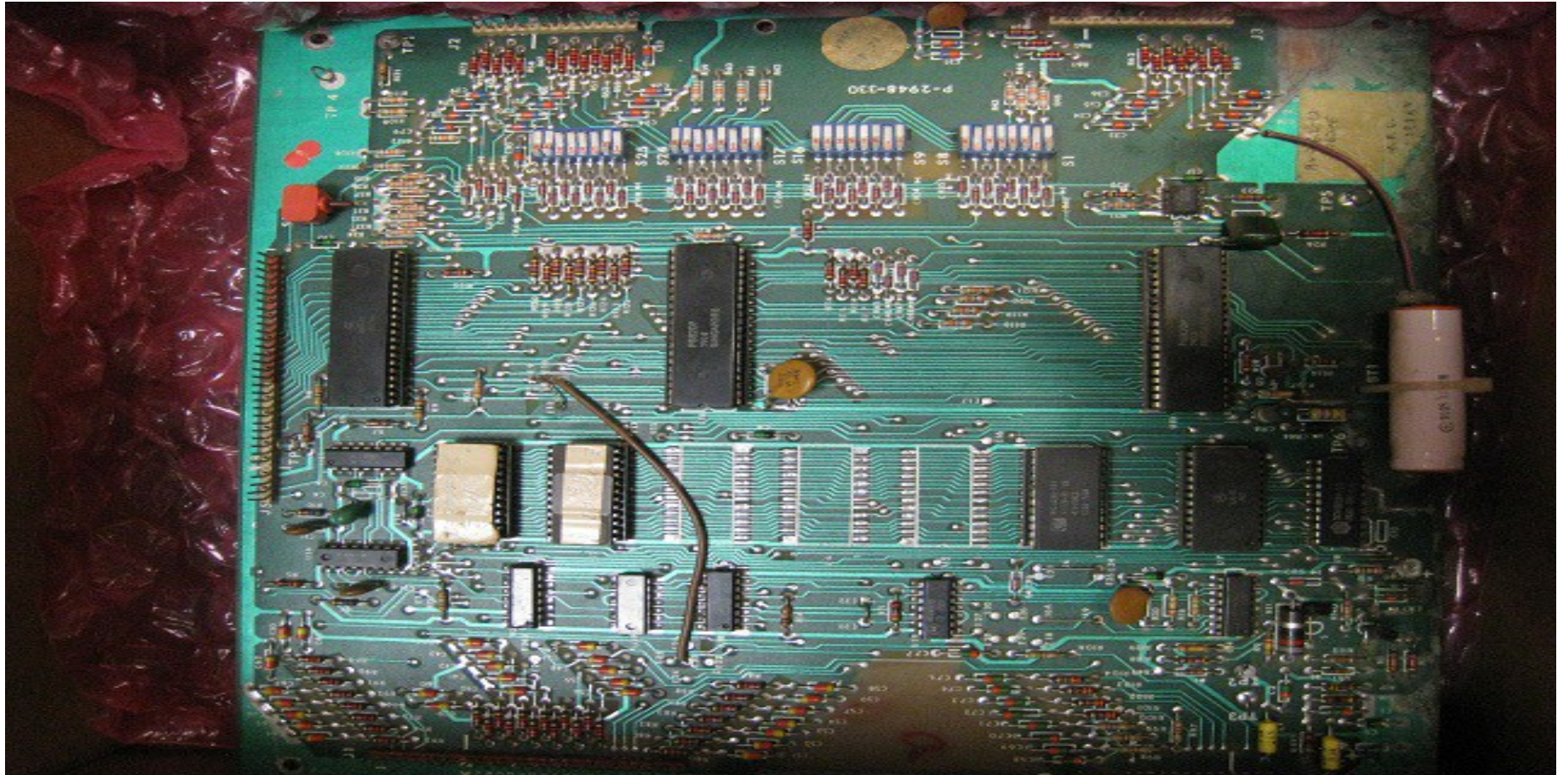
- Reduce cost and amount of wiring (less/simpler wiring)
- No switch stacks which means less solenoids
- Mechanical parts (flippers, kickers, saucers are unchanged)
- Move from AC to DC to add more power

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



Bally MPU:



Simple input:

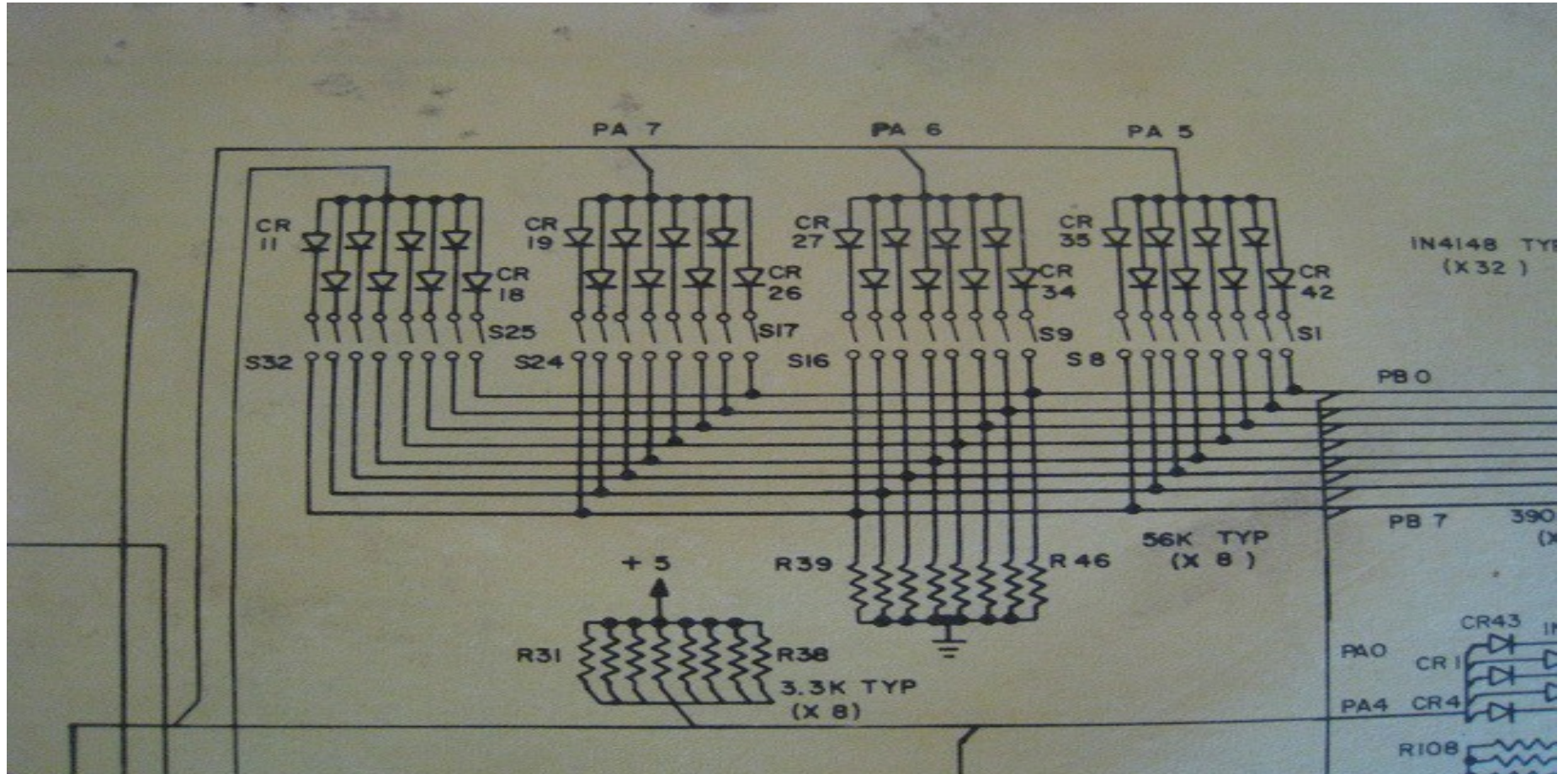
- 1 wire per input
- Requires pullup to always be in known good state
- Closing contact typically grounds input
- Life is simple

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



Dreaded switch matrix:

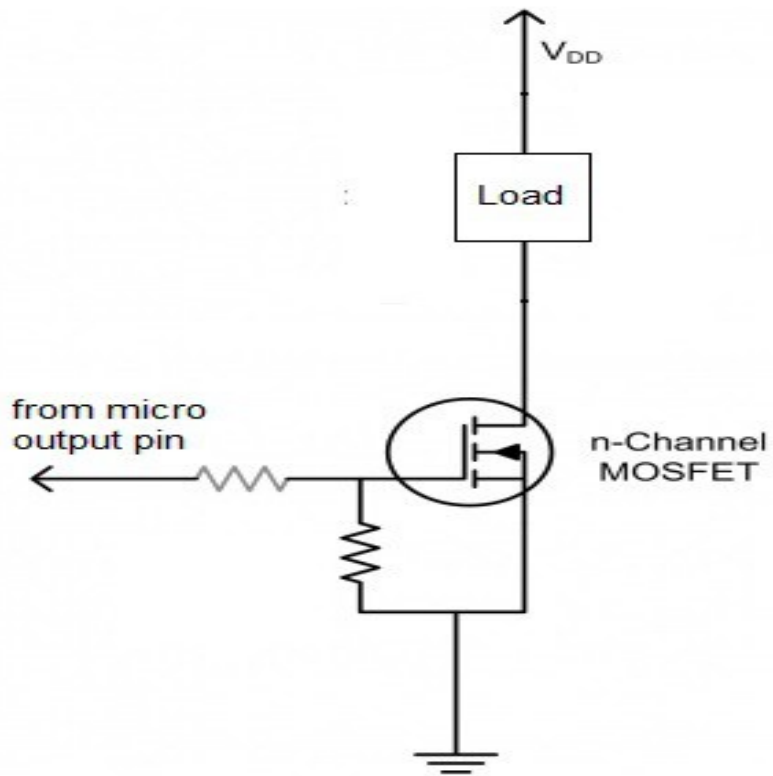


Simple lamp output:

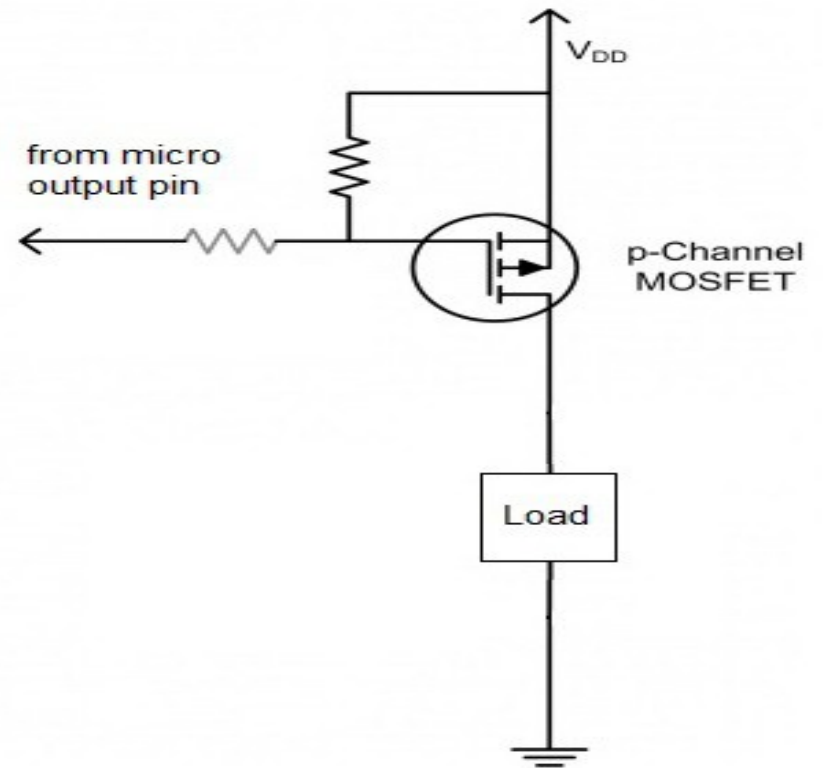
- Processor output can't source enough current
 - Requires transistor or FET to turn on/off
 - FET is typically used as a low side switch
 - Connects/disconnects the ground

Low/High side switches:

Low-side Switch



High-Side Switch



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

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!



Flipper:



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



Gen 3 (cont):

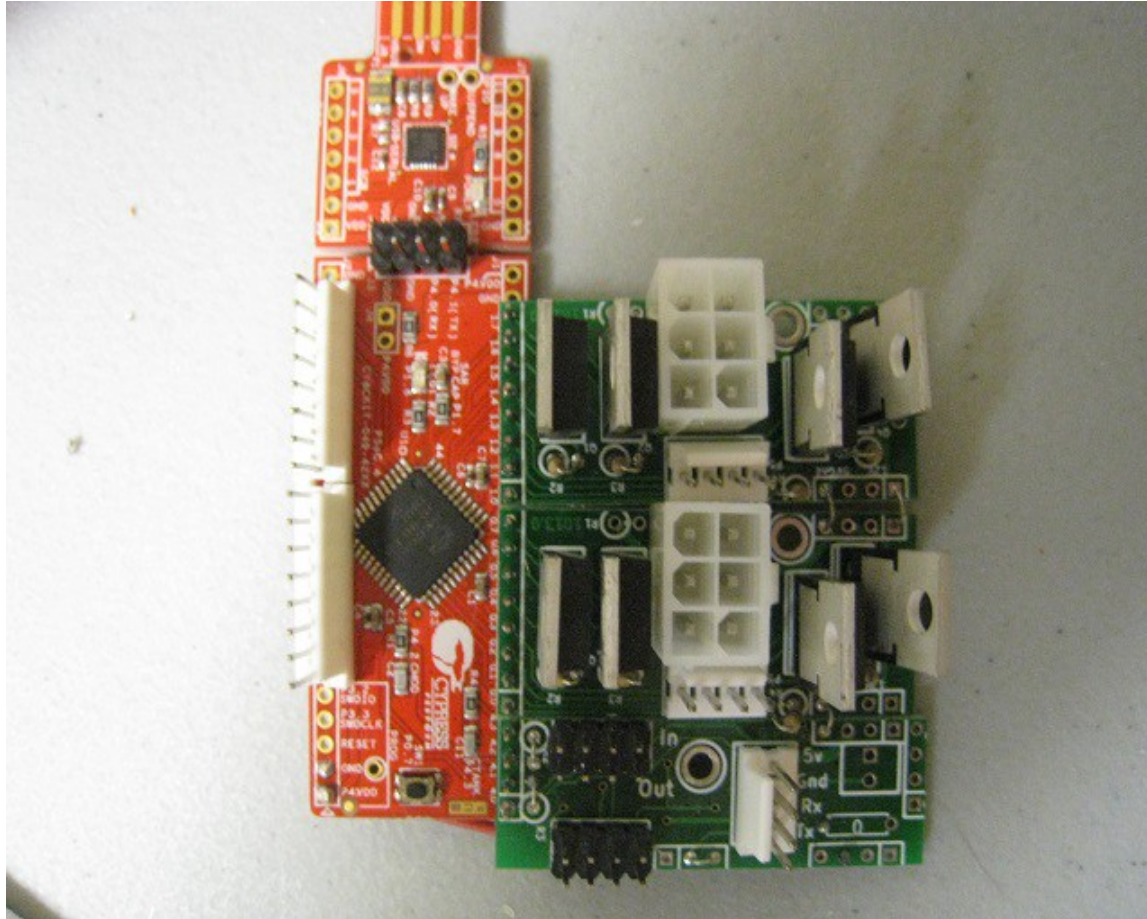
- Transformer power supply replaced with SMPS
 - Less expensive to manufacture
 - Less weight
- Manufacturing will probably move in next couple of years

OPP Update:

- Approximately 700 wing boards sold at this point
 - About 20 wing boards are needed for a full pinball machine
 - Boards have been sent to about 8 different countries
- OPP firmware updates include:
 - Support for switch matrices
 - Support for delayed solenoid kicking
- Van Halen machine has demonstrated OPP cards can be used to drive a pinball machine without rewiring
- Original target cost to drive a machine was \$100
 - Current cost is about \$65



OPP board, 8 solenoids, 72 inputs (cost \$15):



What are you waiting for?

- MezelMods has been selling OPP cards for nearly a year
 - Wing cards only \$1
 - LerMods has coupons for free shipping from Mezel Mods

Quit your procrastinating, and
go build some pinball!



Questions?

