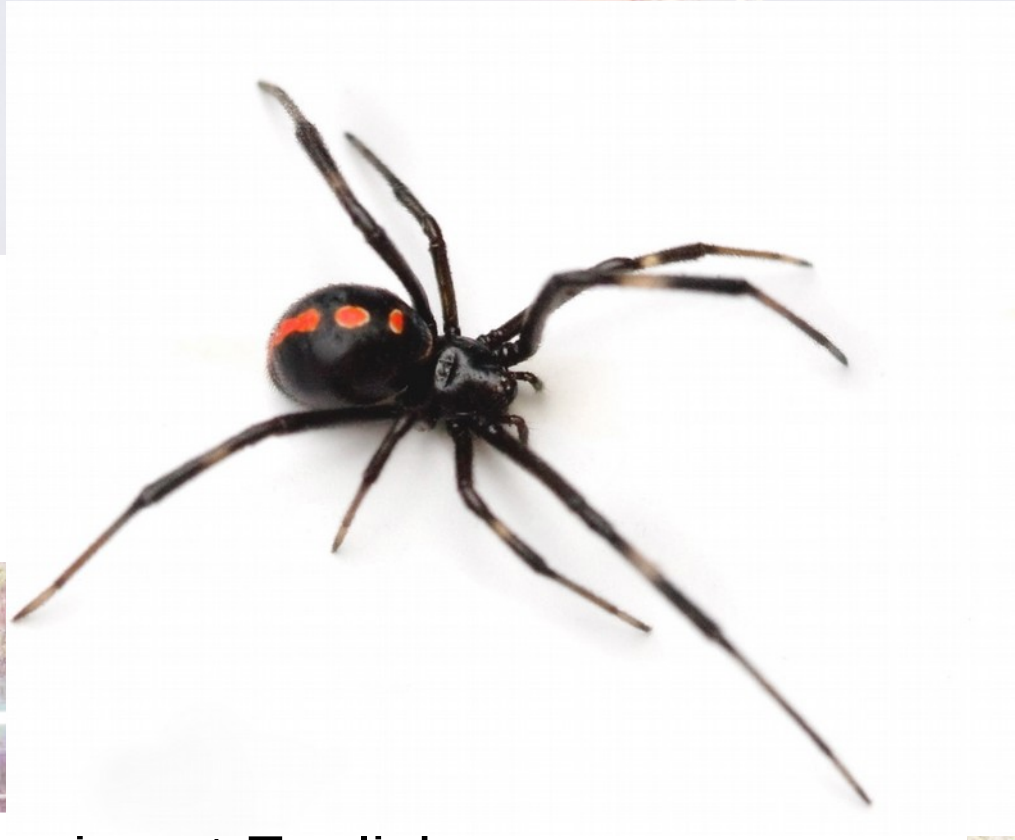
Orange Empire Signal Garden

Lessons Learned

OR

Remove spider* before servicing main board.



* For those of you who's first language is not English “spider” is a bug+ not a computer term..

+ “Bug” denotes an animal – again not a computer term.

About me

- I am a software engineer who knows a little about hardware.
- I wanted a project which would give me a opportunity to learn.
- If I wasn't such an idiot when it came to hardware I would have learned a whole lot less.

Orange Empire

Historic Transportation Museum In Perris CA.

Interactive Signal Garden

Railroad Signal Design

- Created at a time when electricity was a new and unproven technology.
- Designed to last.
- Built to work with little or no maintenance

Conventional Relay

12v, Low Amp relay

- Small
- Cheap
- Plastic
- Thin wires
- Protected Environment

Railroad Relay

12v, low amps

- Big and heavy
- Glass, steel, and ceramic
- Gravity driven, no springs.
- Thick wire
- Harsh environment

OERM's Signals

- Some of our signals were build over 100 years ago.
- … and some of them are really old.
- The OERM wants to preserve not only the artifacts but the skills of the time.
- Almost all artifacts are scheduled to be restored and used.
- “Real soon now”.

Signal Garden

- Has over 16 signals.
- Most are working
- Push a button, the signal operates

Nice things about working on the signal garden as opposed to regular signals.

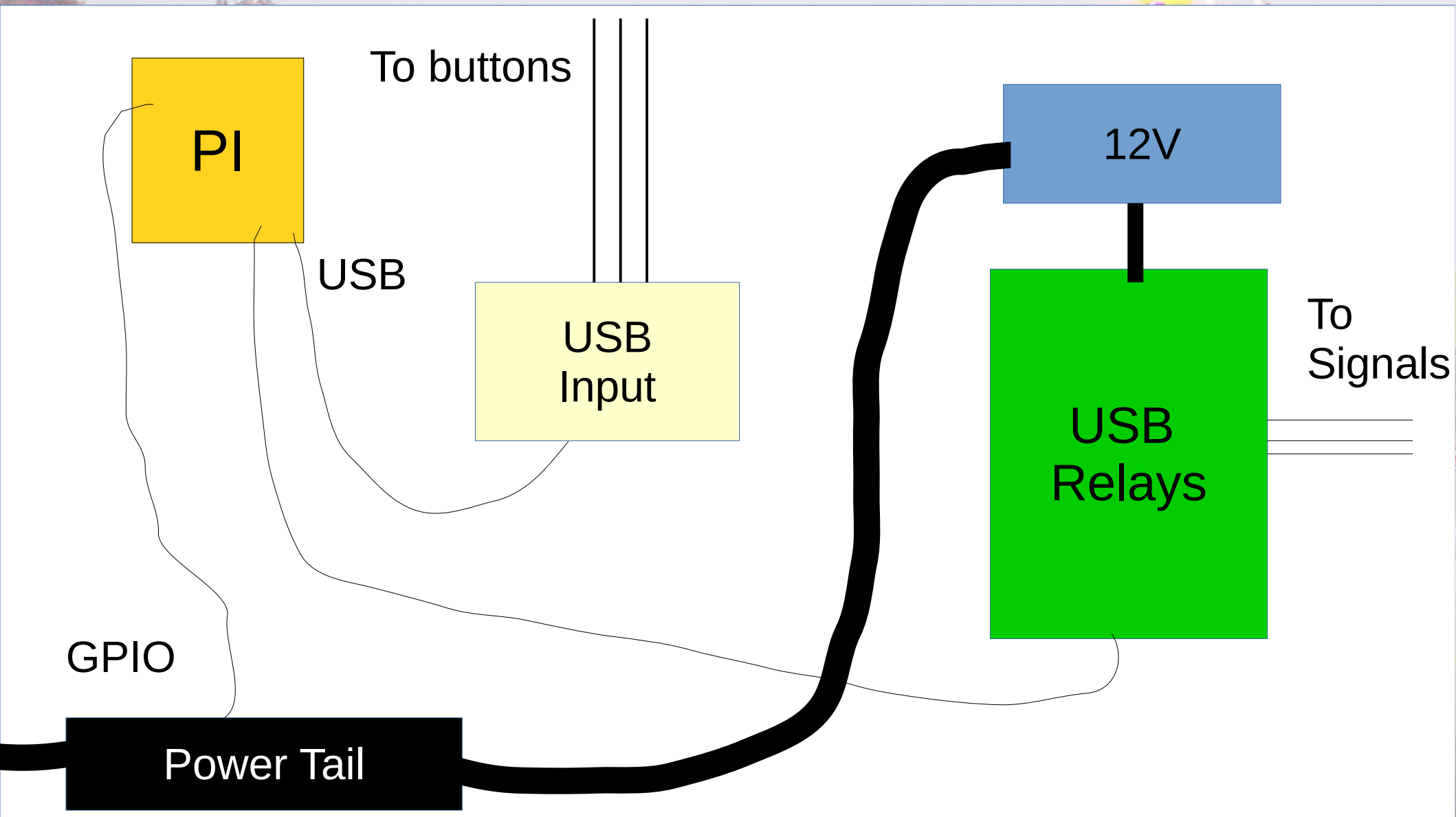
- You don't have to go a mile down the track to reach the next signal.
- When the signals don't work, operations isn't made at you because trains can't run.

Why Linux and the Raspberry PI

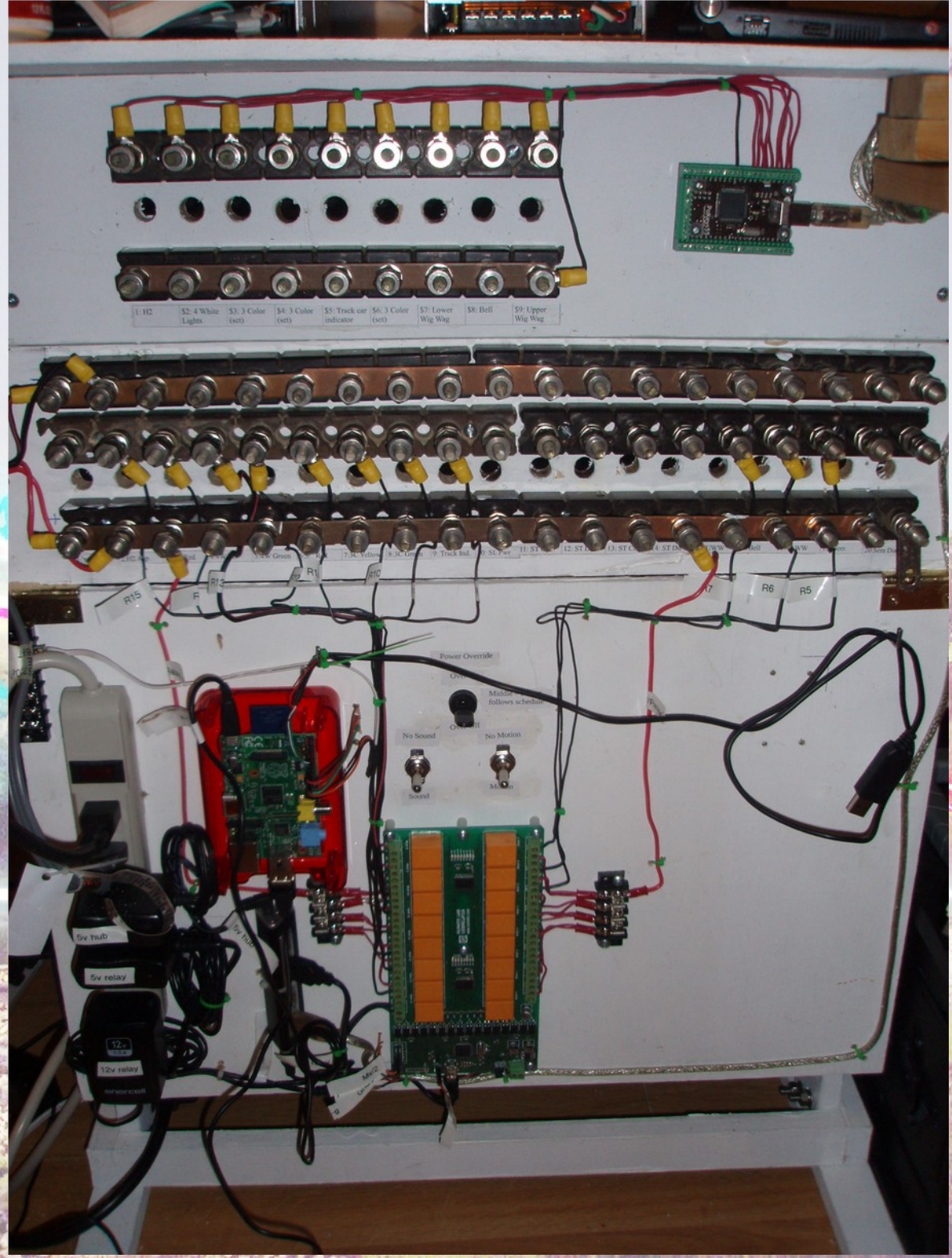
- Commercial off the shelf parts as much as possible.
- Development system = production system.
- Very easy to program.
- Relatively low cost ($150) for the total system.

  (I work for a company that could make a custom system using a PIC for $5.98 in quantities of 1,000, but there is only one OERM)

Basic Design



Garden Controller



Major Components

- Raspberry PI Model A
  - Replaced with Model B+

USB relay board

USB relay board

- Programming is extremely simple
- Device considered a serial interface (RS232)
- Open the device, send commands.

udev issue.

- udev assign device names based on it's rules.
- `/dev/ttyACM0, /dev/ttyACM1, /etc/ttyACM2`
- You can't be guaranteed the right device each time.

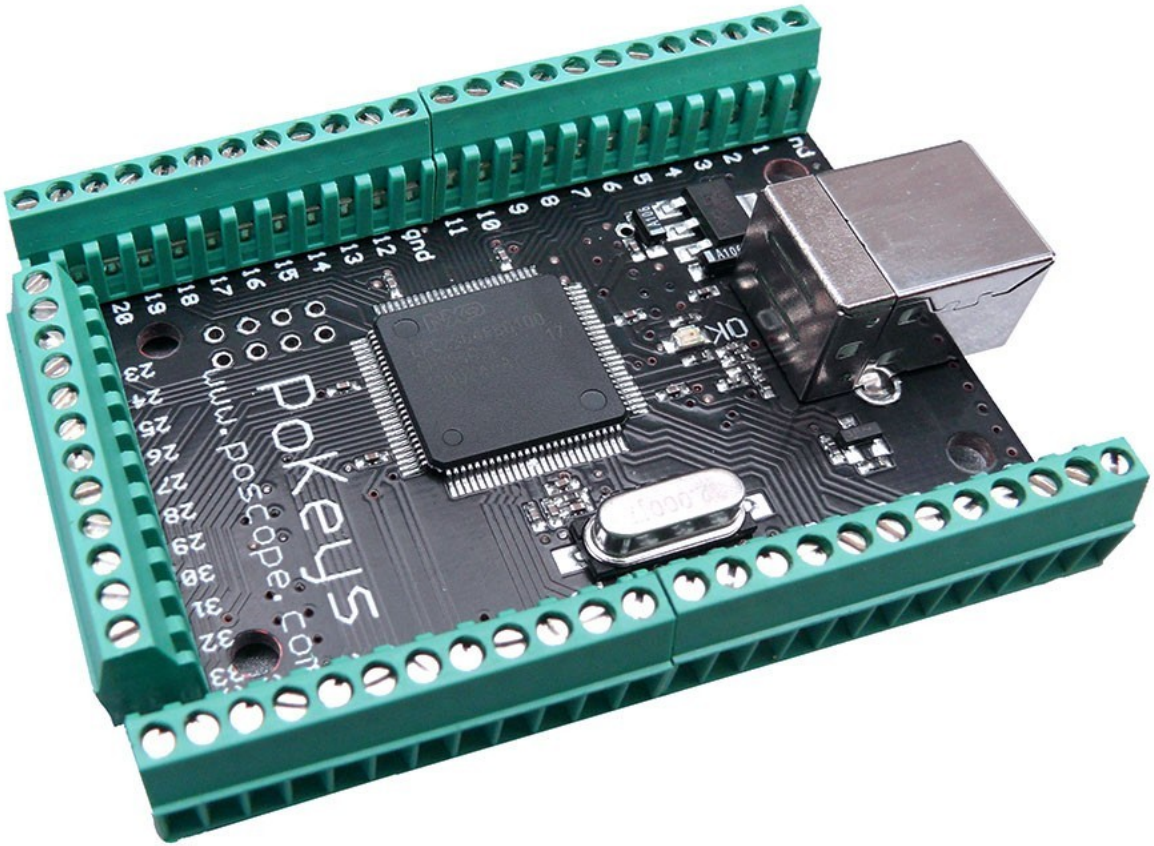
Solution

- Use the “device by-id” name
- `#define RELAY_DEVICE "/dev/serial/by-id/usb-Microchip_Technology_Inc._CDC_RS-232_Emulation_Demo-if00"`

Relay Programming

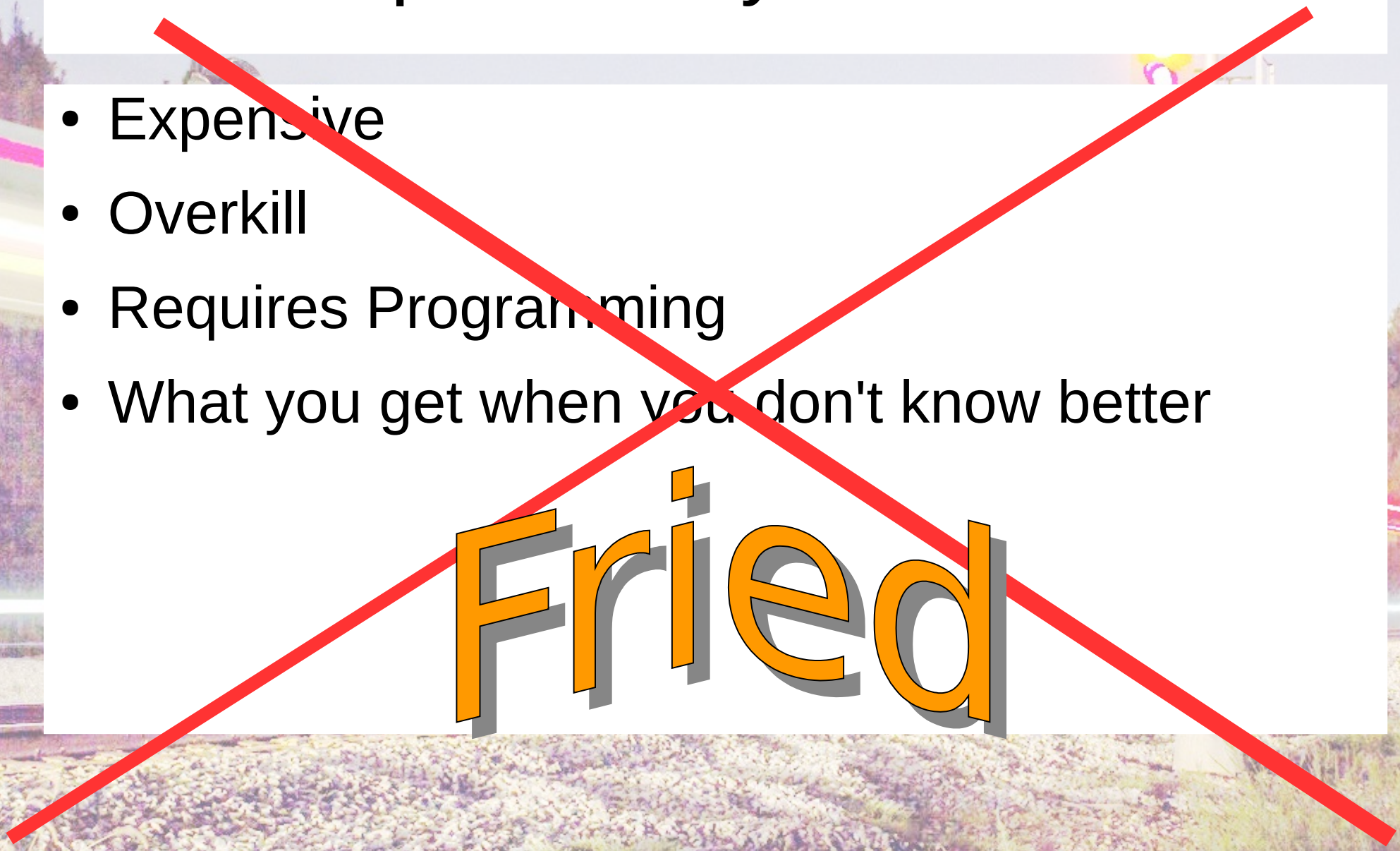
```
relay_fd = open(RELAY_DEVICE, O_RDWR);
if (relay_fd < 0)
     throw(relay_error(...));
// … set raw mode
write(relay_fd,
   “relay on 5\r”, sizeof(msg));
```

Input: Pokey55 board



Input: Pokey55 board

- Expensive
- Overkill
- Requires Programming
- What you get when you don't know better



Pokey55 board programming

- Pokey55 is a keyboard emulator.
- Press a button, a key is typed on the keyboard.
- Linux routes all keys through a common interface.

Pokey55: Programming

- The low level HID interface allows you to intercept events from specific input devices
- Poorly documented though.

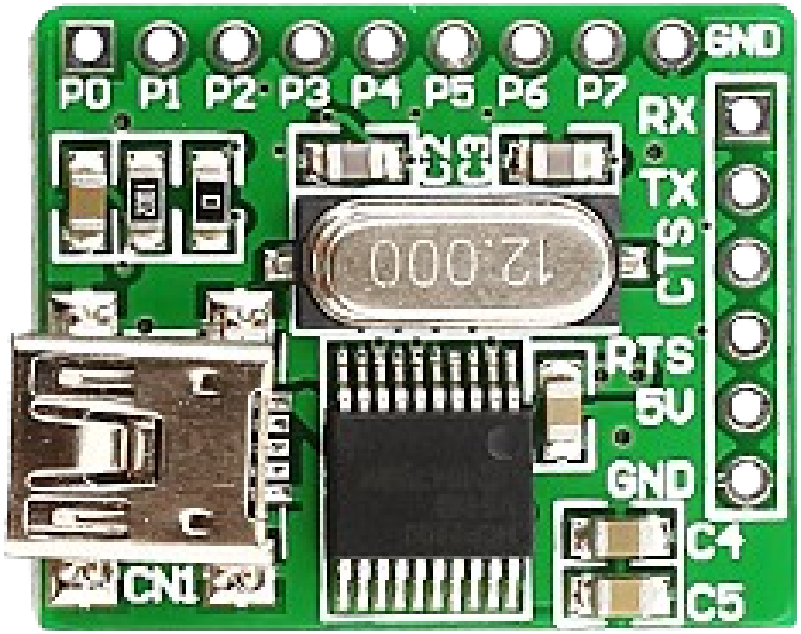
Pokeys programming

```
int fd = open(device, O_RDONLY);
if (ioctl(fd,
        EVIOCGRAB, (void *)1) != 0)
      die("GRAB failed");


struct input_event event;
int read_size = \
    read(fd, &event, sizeof(event));
```

Input #2: USB/Serial with GPIO

- MIKROE-549 (USB serial breakout board)



Input #2: USB/Serial with GPIO

- Cheap ($9)
- Requires external pull-up resistor.
- GPIO requires polling.
- Works well.

Input #2: USB/Serial with GPIO

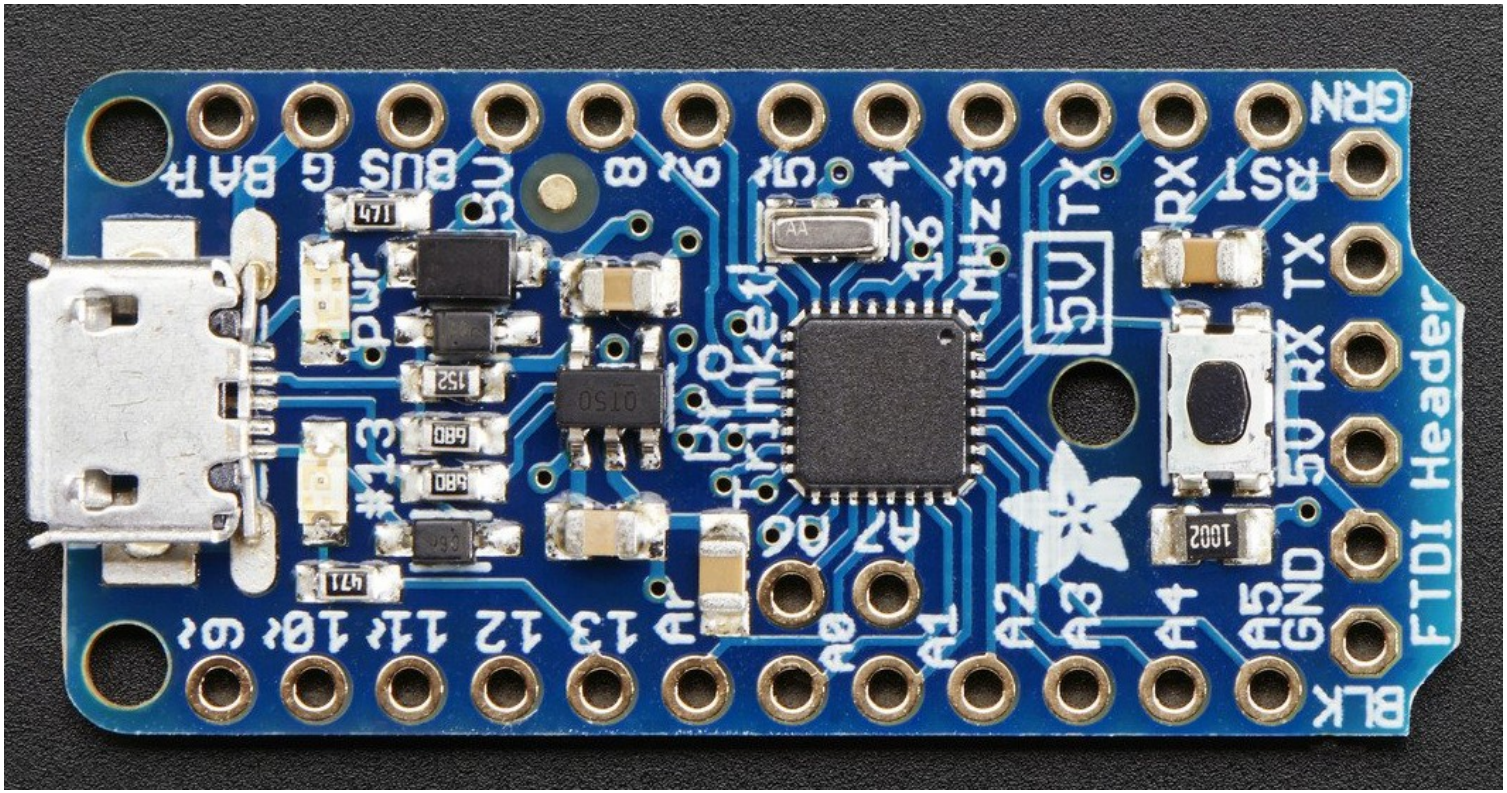
- Programming is a nightmare
- Low level programming must be done through libusb.
- Must have good knowledge of libusb and the UART chip.
- Code to read 8 GPIO pins periodically: 861 lines long!

UART Code

```
int result = libusb_claim_interface(handle, MCP2200_HID_INTERFACE);
if (result != 0) {
    syslog(LOG_ERR, "CONFIGURE claim interface result %d", result);
    throw(mcp2200_error_t(__FILE__, __LINE__, result,
          "Claim of interface failure"));
}
// Send the configuration command.   Get the result of the transfer
result = libusb_interrupt_transfer(
handle,
MCP2200_HID_ENDPOINT_OUT,
const_cast<unsigned char*>(config_data.get_data()),
config_data.get_data_size(),
&write_size,
MCP2200_HID_TRANSFER_TIMEOUT);

libusb_release_interface(handle, MCP2200_HID_INTERFACE);
```

Input #3 (Backup): AVR Trinket



Input #3 (Backup): AVR Trinket

- Cheap ($10)
- Easy to program
- Self contained (no extra resistors required)
- After programming acts like a keyboard sending a character when a button is pressed.
- Took example program and stripped out the fancy stuff, so easy to program.

AVR Trinket Programming

- Pretty much the same as the Pokey programming.
  - Grab the HID device
  - Read raw events

Powerswitch Tail

Powerswitch Tail

- Inherited big power battle between
  - Programmer (keep it on all the time)
  - Management (Turn it off at night)
- Absolute requirement: Garden turns itself off at night.
- Practice: Docent's put the system in power override mode and keep it on 24/7.

Power Programming

- Wired to Raspberry PI GPIO
- Programmed using the Wiring PI library
- Simple to use and program
- However, no interrupts

Power Programming

```
    switch (new_state) {
        case POWER_ON:
            digitalWrite(POWER_CONTROL, 1);
            break;
         case POWER_OFF:
    kill_garden();
    digitalWrite(POWER_CONTROL, 0);
    log_msg += "off";
    break;
default:
    std::cout << "Internal error " << std::endl;
    exit(8);
    }
```

Programming

1) Every I/O board had a test program.

2) Signal program was connected to the button input program by a pipe.
   - Allowed for input to be tested with button simulator
   - Allowed for multiple button handling programs for multiple input boards

WIFI

- Does a industrially controller really need wifi?
- YES!
  - If you want to debug it in the air conditioned office instead of the 100° garden.

Design vs. Reality
A few hard lessons

Tools

Expected to use:

- Soldering Iron
- Wire Strippers
- Volt ohm meter

Tools (Actual)

Vacuum Cleaner

- Mouse poop removal – high priority item.

Tools (Actual)

Clearing supplies.

- Lots and lots of dirt.
- Spider webs.
- Wasps nests.

Tools (Actual)

Label Maker

Ran through three cartridges before I got everything labeled.

Tools (Actual)

Caulk

Me to head signalman:

Me: Why do you have dirt floors at the bottom of each signal box.

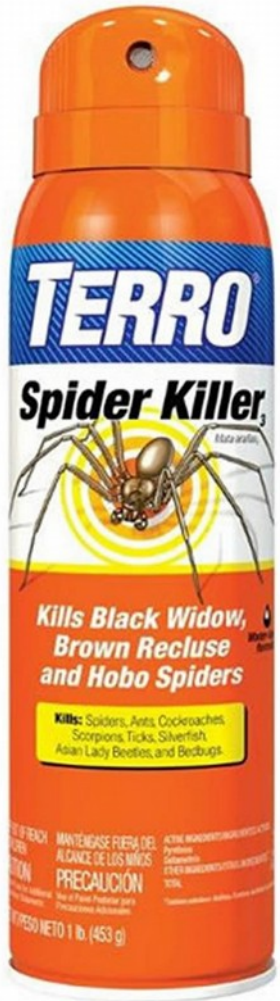
Head: We don't. They are concrete.

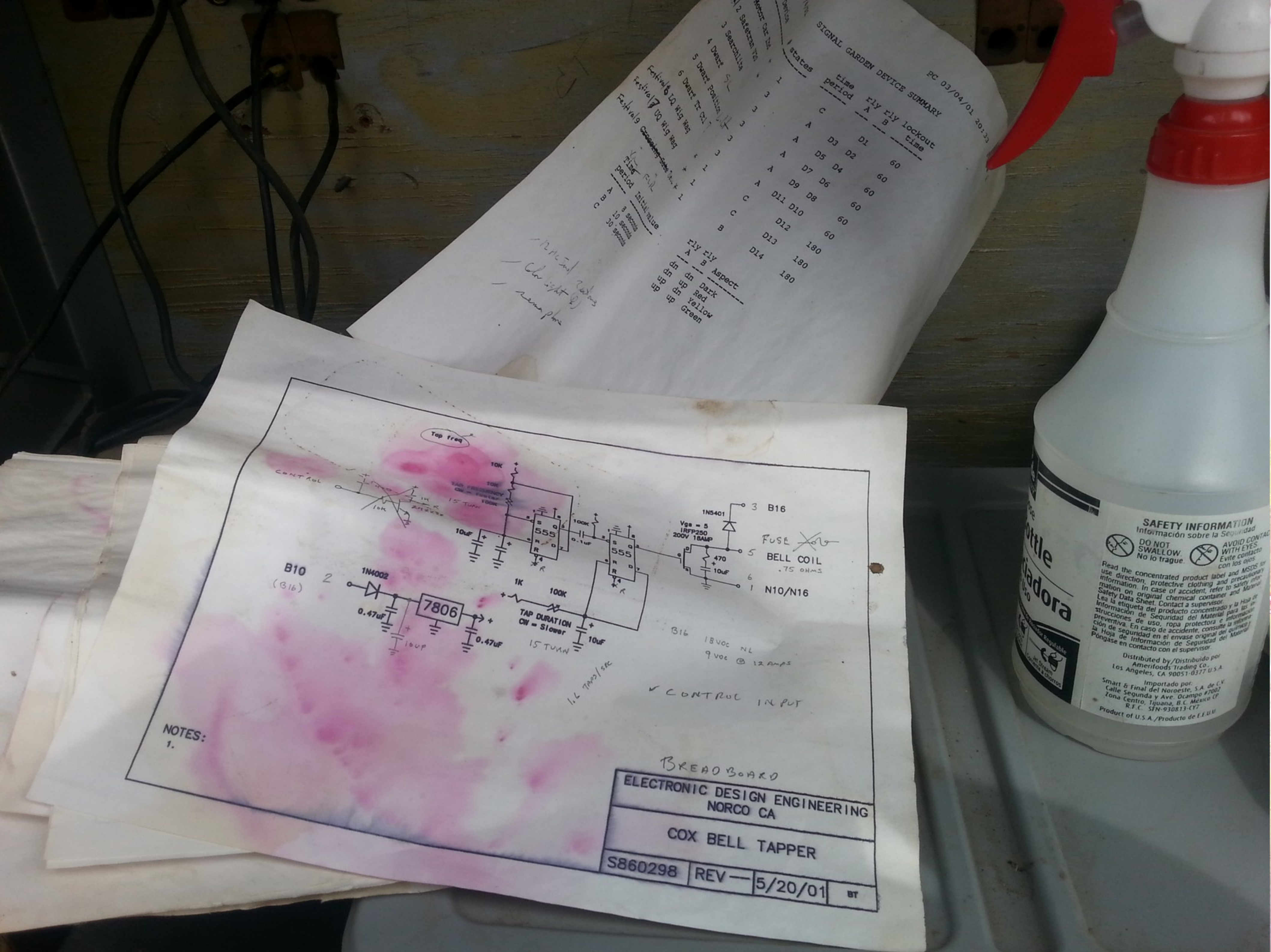
After cleaning found out what he said was true.

Tools (Actual)

- Heavy Gloves
- Spider Killer

(More on this later)





PC 03/04/01
SIGNAL GARDEN DEVICE SUMMARY
states
time period
rly A
rly B
lockout time
C
D1
A
D3
D2
60
A
D5
D4
60
A
D7
D6
60
A
D9
D8
60
A
D11
D10
60
C
D12
60
C
D13
180
B
D14
180
180
time period
initial value
A
8 seconds
B
10 seconds
C
30 seconds
rly A
rly B
Aspect
dn
dn
Dark
dn
up
Red
up
dn
Yellow
up
up
Green
Tap freq
CONTROL
10K
TAP FREQUENCY
CW = Faster
100K
15 TURN
10uF
555
100K
0.1uF
555
1N5401
3
B16
Vgs = 5
IRFP250
200V 18AMP
FUSE
5
BELL COIL
.75 OHMS
470
10uF
6
1
N10/N16
B10
(B16)
2
1N4002
0.47uF
7806
10uF
0.47uF
1K
100K
TAP DURATION
CW = Slower
15 TURN
10uF
B16
18VDC NL
9VDC @ 12 AMPS
1.6 TAPS/SEC
CONTROL INPUT
NOTES:
1.
BREADBOARD
ELECTRONIC DESIGN ENGINEERING
NORCO CA
COX BELL TAPPER
S860298
REV —
5/20/01
BT
SAFETY INFORMATION
Información sobre la Seguridad
DO NOT SWALLOW
No lo trague.
AVOID CONTACT WITH EYES
Evite contacto con los ojos
Distributed by/Distribuido por
Amerifoods Trading Co.
Los Angeles, CA 90051-0377 U.S.A.
Product of U.S.A./Producto de E.E.U.U.

Button Labeling
East Side

Legacy Labeling / North

Other Wiring Issues

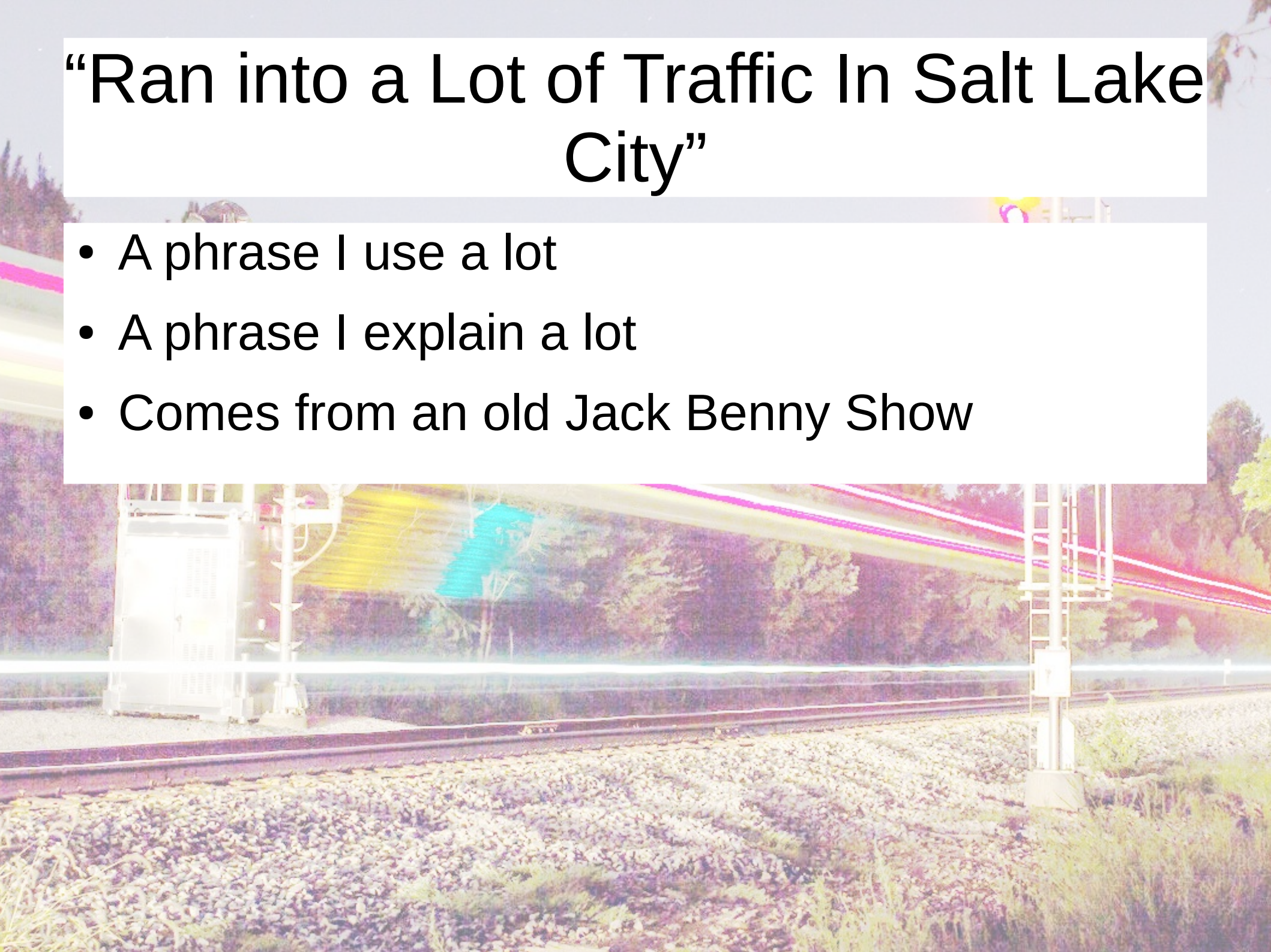
- WWA (Wig Wag Signal A)
  - Connected to relay WWB
  - Relay connect to terminal WWA
  - Terminal connected to port labeled “Upper Wig Wag” on the computer
- Button 2
  - Yellow / Blue wires at the switch
  - Purple / Black at the signal box

Big Problems

- Hidden underground junctions
- Buttons and signals had ground wires connected together (more on this later)

“Ran into a Lot of Traffic In Salt Lake City”

- A phrase I use a lot
- A phrase I explain a lot
- Comes from an old Jack Benny Show



The Characters

- Jack Benny, comedian
- Dennis Day
  - Only man I know of who successfully played a dumb blond

The Show

From a show done in San Diego during the war.

Dennis rushes on stage out of breath.

Dennis: I'm sure glad I got hear Mr. Benny. I barely made it.

Jack: Dennis, there something I don't understand. You left Los Angeles Tuesday for a show that we are doing in San Diego on Sunday and you just got here.

Jack: How come?

The Show

Dennis: I ran into a lot of traffic in Salt Lake City.

Jack: Dennis… Dennis… Why did you go from Los Angeles to San Diego by way of Salt Lake City.

Dennis: I wanted to avoid the stoplight in Oceanside.

Typical Wiring Path

Button #1 has a yellow wire goes down a pipe which goes to...

Typical Wiring Path

… the track indicator where it is tied to a red wire with a wire nut (hidden junction) which goes to:


Signal
Block Indicator

Typical Wiring Path

… tri-color light's base where a terminal block ties it to a purple wire which goes to:


Signal
Block Indicator

Typical Wiring Path

… secondary signal box (I think) where it turns around and goes to:


Signal
Block Indicator

Typical Wiring Path

… controller box where it goes to a terminal block and becomes a black wire where it is connected to:

Typical Wiring Path

.. the input relay (it's final destination):


RAIL ROAD CROSSING
2 TRACKS
STOP ON RED SIGNAL

Mysteries

Why is the signal box full of grass?

(This isn't a nest of any sort, just a bunch of grass)

Much later – tried to drop a wire down a 4” pipe and failed.

Birds nests (2 of them)

ACME Traffic Signal Head #1

Birds nest #3.

Nest constructed during restoration.

Found while I was on top of the ladder when the bird flew out on full afterburner.

ACME Traffic Signal Head #2

Arms removed temporarily for maintenance (For 10+ years)

Leaving small round holes at the top.

ACME Traffic Signal Head #2

Arms removed for maintenance (For 10+ years)

Leaving small round holes at the top.

Bird's nests #4, #5, #6, #7.

Removed

Next task: Figure out what I've got

- Entire layout was probed.
- Every wire was labeled (or so I thought)

New Linux controller designed, and extensively tested before deployment.

Deployment

The plan:

1) Open cabinet
2) Remove old controller
3) Install new controller

Four hour job – maximum

Deployment Actuality

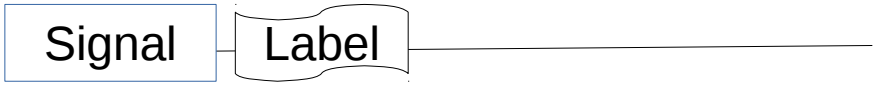
1. Open cabinet
2. Quickly close cabinet
3. Go to Home Depot, get work gloves and spider spray.
4. Open cabinet
5. Kill black widow
6. Remove web and dead spider.
7. Carefully proceed with installation

Mistake #1

I assumed that the wires went like this:

Instead they went like this

After removal I had a bunch of this:



Rework

- All wires had to be re-identified.
- 4 hours of work took about 3 months of weekends.

Alpha testing

Button was designed to start signal when pressed.

Stop on second press or timeout.

Alpha testers had different ideas.

Problem #1:
Input controller going offline

- Input controller was disappearing from the USB bus.
- Happened every time a wig wag stopped sounding.
- Ran through a bunch of USB hubs trying to figure out the problem.

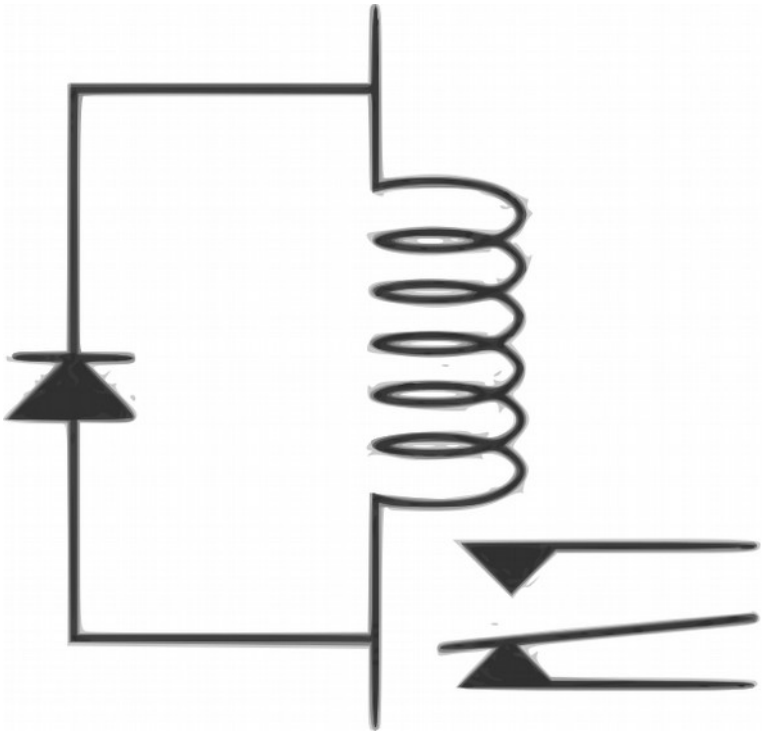
Cause

- Wig wags have huge magnets. (Two of them.)
- Turning off a big magnet generates a big energy pulse
- … which then goes down the common ground wire and
- … causes the input controller to reset.
- – – – and later fry.

Fix #1

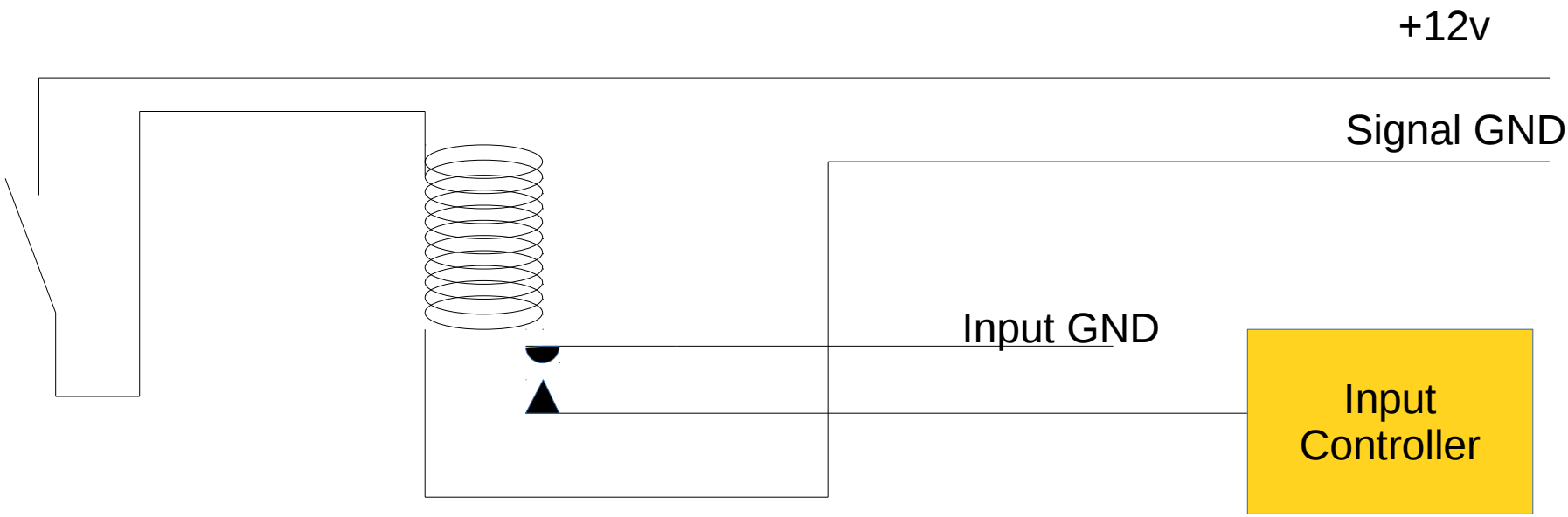
- Huge capacitor
- Result fried input board.

Fix #2: Flyback Diode



Result: Fewer problems – but still problems.

Fix #3: Relay isolation and flyback diodes



- Result: The system mostly works. Now it's all USB problems.

Alpha testing: Operators

- Wrote a page of instructions for the docents concerning:

1) Turning the system on
2) Turning the system off
3) Recovering from hangs

Docent's Reality

1) If the garden's down, turn the whole thing off and back on.

2) If it's still down, call Steve.

RTC

- Raspberry PI has no RTC.
- Resetting power causes it to loose track of time.
- USB problems prevent the system from getting time from the network.

RTC

- Raspberry PI's solution, “fake hardware clock”
- When shutting down, record the time
- When starting up, use this time to set the time of day.
- Good for keeping time marching forward
- Lousy for turning on the garden in the morning.

Solution: DS3231 RTC

- Small I2C board that sits on the Raspberry PI GPIO connector.

RTC Programming

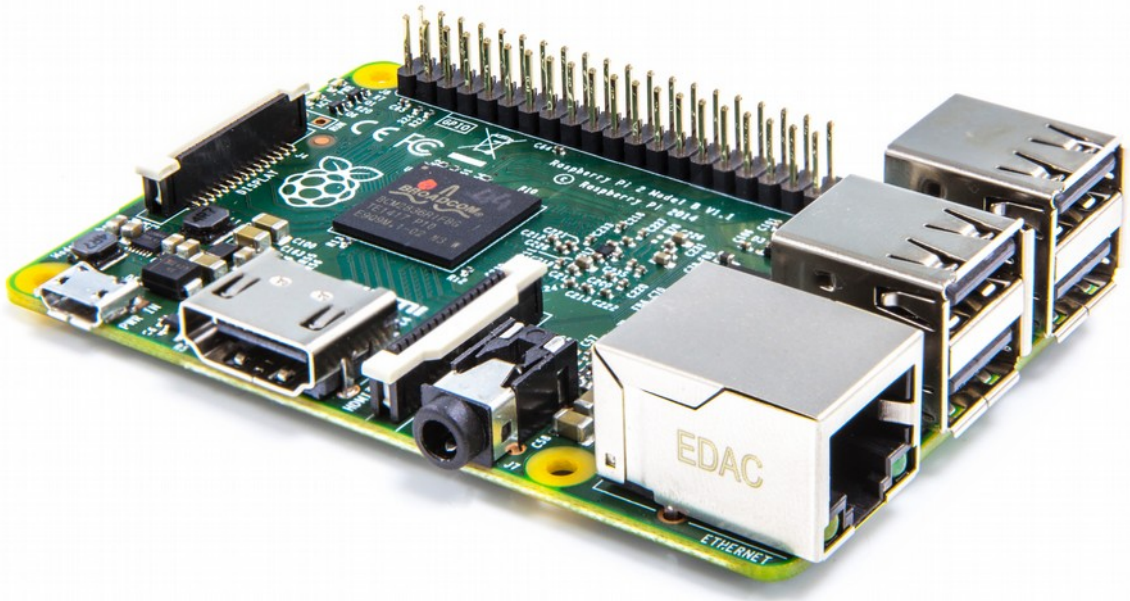
- Must enable I2C bus in /boot/config.txt
- Need new packages: i2c-tools
- Requires a bit of configuration:
  - Tell the I2C system you have a RTC
  - Tell udev to create devices for it
  - Tell systemd to start and stop it

Lesson #2: USB and USB Hubs

- Raspberry PI did not have enough USB power to power the devices (relay board, input board, wifi).
- Almost all powered hubs will backpower the Raspberry pi.
  - With an inadequate amount of power.
- Two power supplies fight each other and the Raspberry Pi looses.

Solution: Model B

- 4 USB ports.
- Enough power to make everything work.



Next Project: The Semaphore

Semaphore Guts

Semaphore Restoration

- Picture is not what I got originally – I cleaned it up before taking the picture.
- Found service manual on the Internet.
- Got a second mechanism off the Internet, but
  - One part arrived damaged
  - The only part, the only vital part
  - That I happened to have a spare for

New Feature **Demand!**

It's nice that you got the crossing bells to work.

Now make its stop.

Request made a board of directors member who was trying to hold a meeting next door.

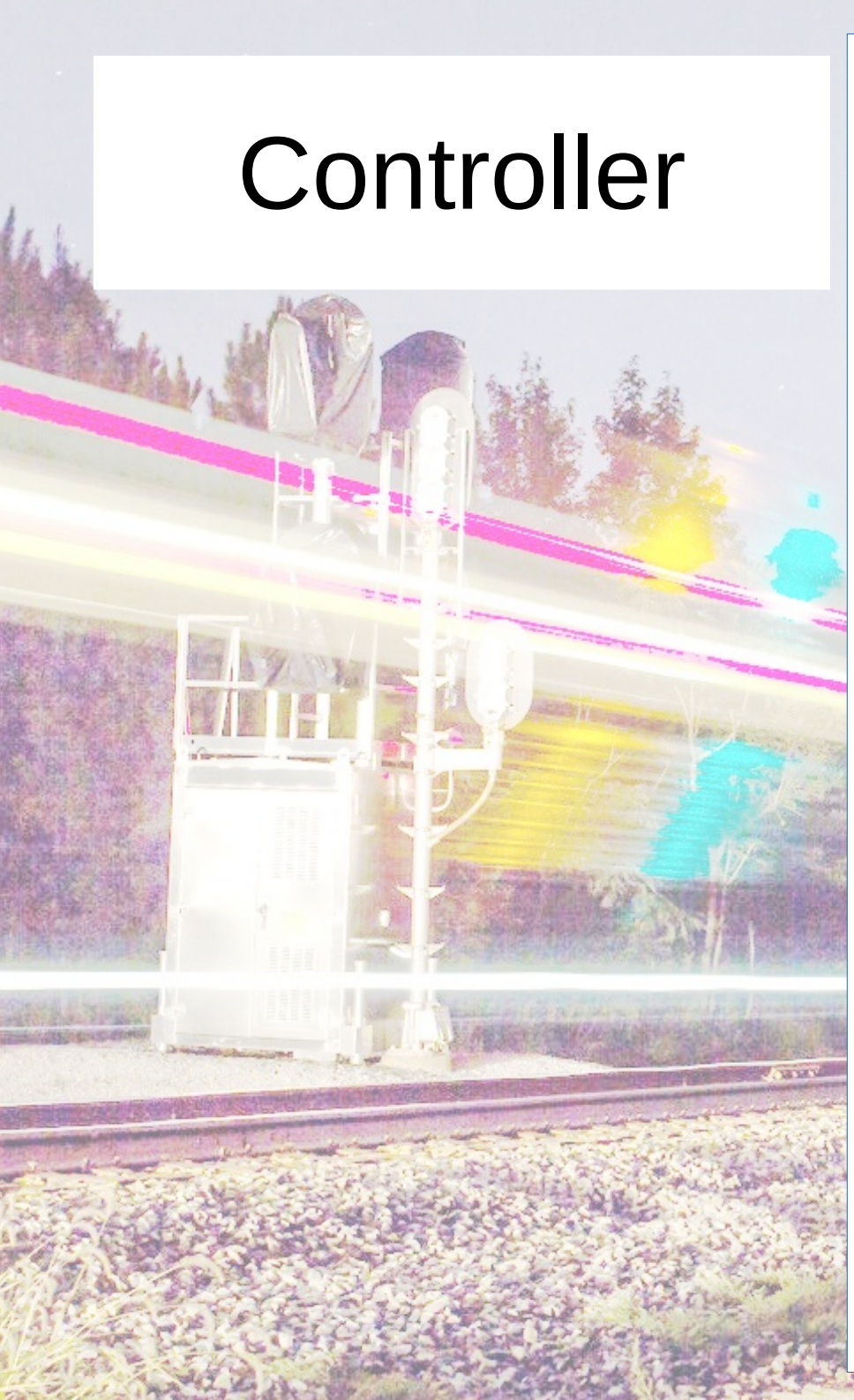
Easily programmed in Linux.

Future Work

- Acme Traffic Signal Improvements

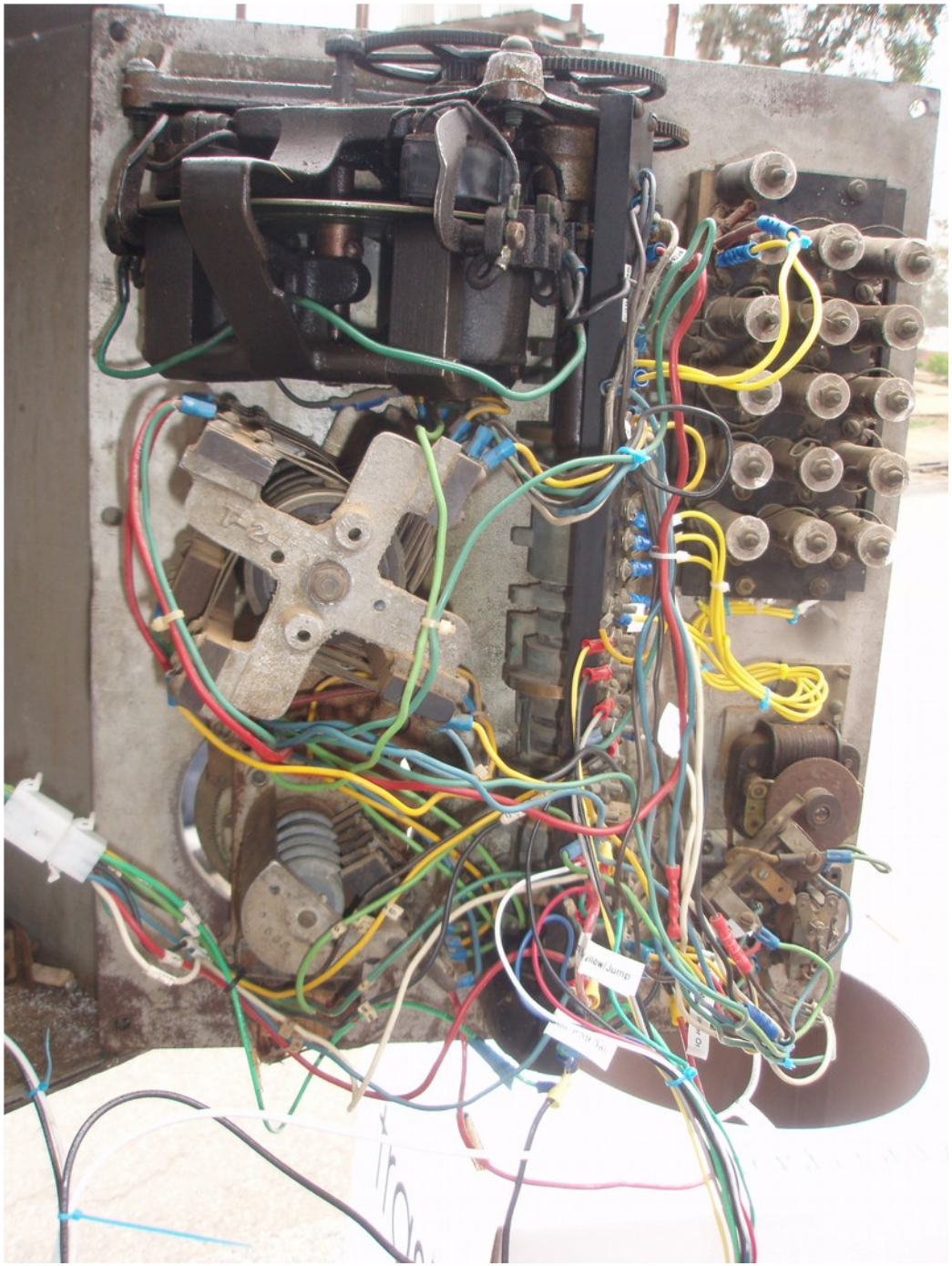
  Planned: New controller
- First a look at the old (1930) controller

Controller




TIME CONTROL
ACME TRAFFIC SIGNAL CO
TIMER No
TYPE
AMPS
VOLTS
CYCLES
FOLD
MANUAL
CONTROL
GO
STOP
OFF
COOL
HEAT
105
EMERGENCY
ARMS
LIGHTS
TIMER

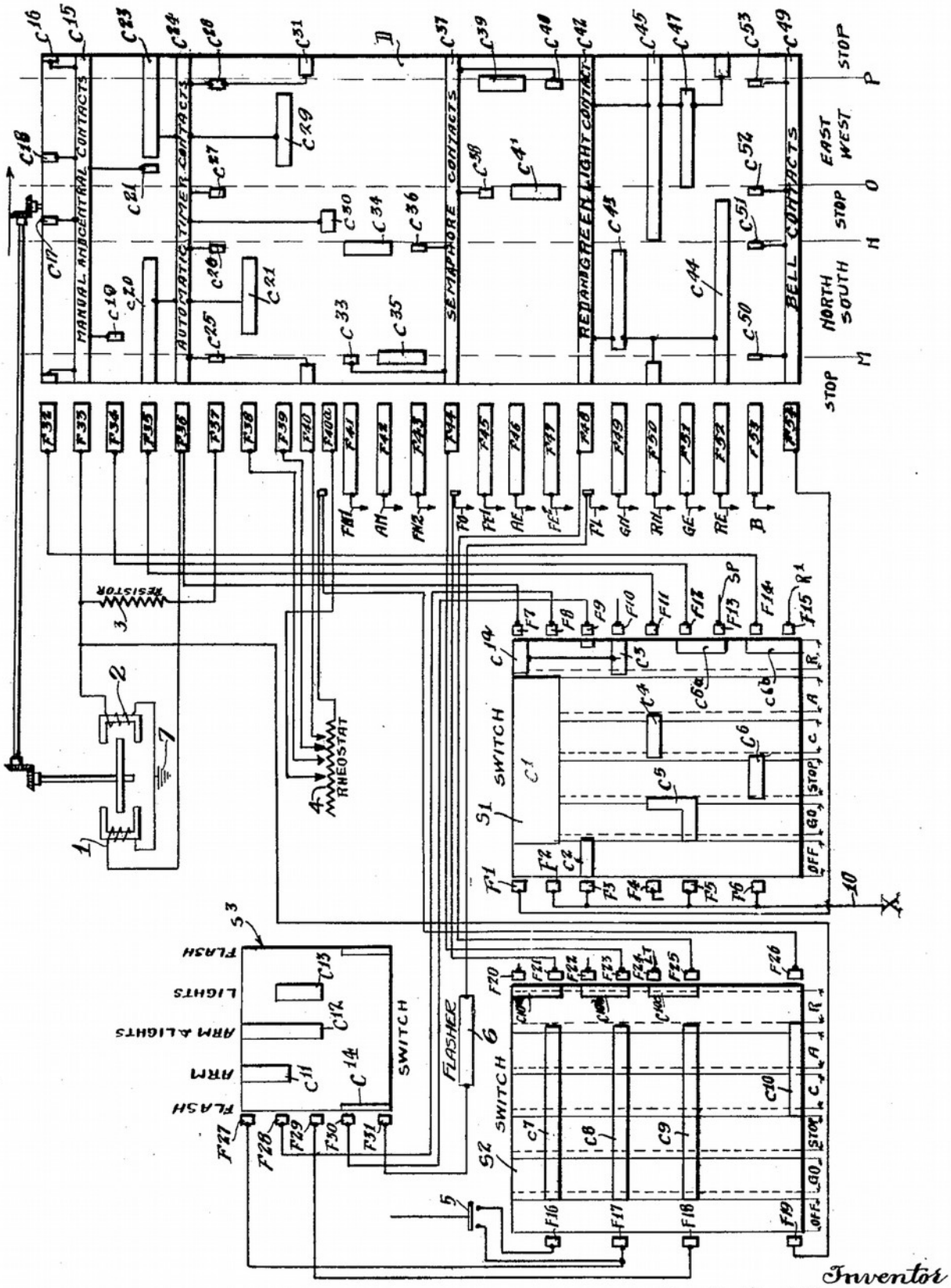
Controller



March 27, 1934. C. A. GLOCK 1,952,371

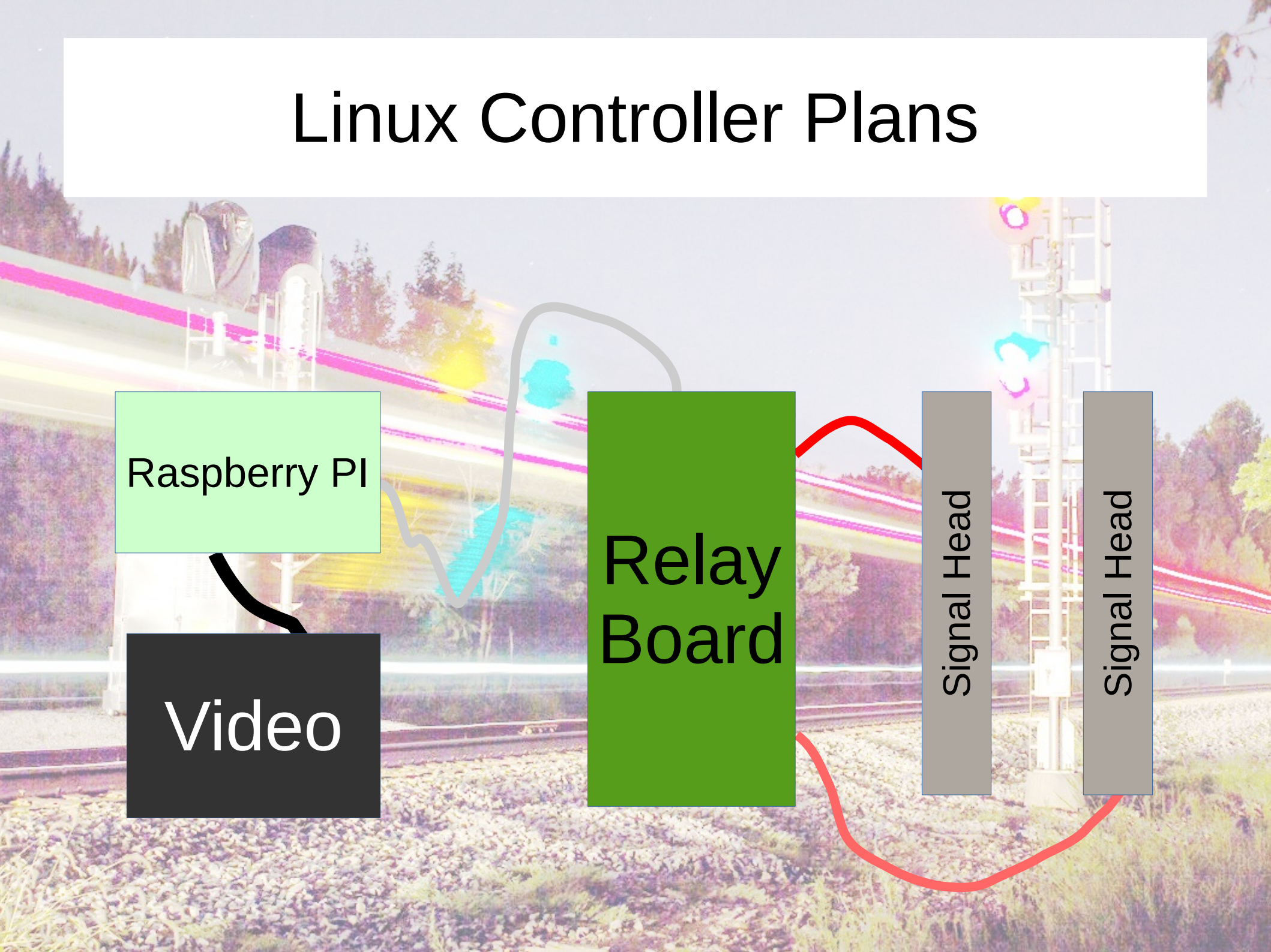
TIMER FOR TRAFFIC SYSTEMS

Filed April 24, 1929



Inventor
Carl A. Glock
By Lyon & Lyon
Attorneys

Linux Controller Plans



Lessons Learned (General)

- You can accomplish a lot with a vacuum cleaner and cleaning rag.
- Perris, CA is an ideal climate for the black widow spider.
- Never assume that previous engineers who deigned your system were sane.
- Document well (and correctly) for those that come after you.

Lessons Learned (Electrical)

- Very large inductors create a very large energy pulse when turned off.
- ***Flyback didoes***
- ***Isolation***
- Cross talk
- Common grounds suck.
- Circuit isolation (computer and signal use different wires totally)

Lessons Learned (Restoration / Design)

- Talk to people who know more than you do
  - Preferably before you ruin equipment.
- Patent searches are useful for finding historical documents.
- You can find lots of old manuals on the Internet.

Lesson Learned Linux

- Lots of hooks into low level drivers
  - USB
  - Keyboard
  - GPIO
  - I2C/RTC
- USB Hubs – most are badly built
  - Avoid them

Contact Information

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Contact Information

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TODO

- ## how to interface to relay board.
- ### how to interface to keyboard simulator
- ### GPIO / serial simulator
-
- ### programing the input (how)
- ### programming the gpio
- ### programming