Controlling 280 Turnout Servos Using Small Push-Button Fascia Panels

By Bob Judge and Al Zimmerschied

Forced to move, the Boeing Employees Model Railroad Club (BEMRRC) settled on a multi-level HO design that contains over 280 turnouts and 45 crossovers, including the switch machines and controls to operate them.

- **The club agreed that the new requirements for switch machines and controls must include:**
  - **low cost,**
  - **low profile (so the switch machines would be out of sight in the upper level),**
  - **easy to install (minimum of under layout work),**
  - **operated with push buttons (so track-selection logic could be used and to allow for the future control or monitoring from a dispatcher station),**
  - **off-the-shelf-hardware,**
  - **and easy to fabricate.**

- **The club's previous switch machines are no longer an option. They were custom made using Boeing surplus electronics and were often difficult to repair and maintain, with several parts now obsolete.**

- **The main off-the-shelf types are currently stall machines such as Tortoise and twin coil machines.**
  - **The Tortoise model is too large to readily conceal in the upper level bench-work and are more expensive than we were hoping for.**
  - **We found that the old standby twin-coil machines were no longer being made and our own viable supply was uncertain.**

Servos ----- Another Choice to Operate Turnouts

- **There are currently several articles published showing the use of RC servos as switch machines, and after experimenting some, and educating ourselves in the use of servos, we decided on using them for our turnout control. These servos can be purchased for around $3.00 apiece off the internet.**

- **The choice of servos as switch machines on our layout meant we had to develop:**

    1. an easy servo mounting system;

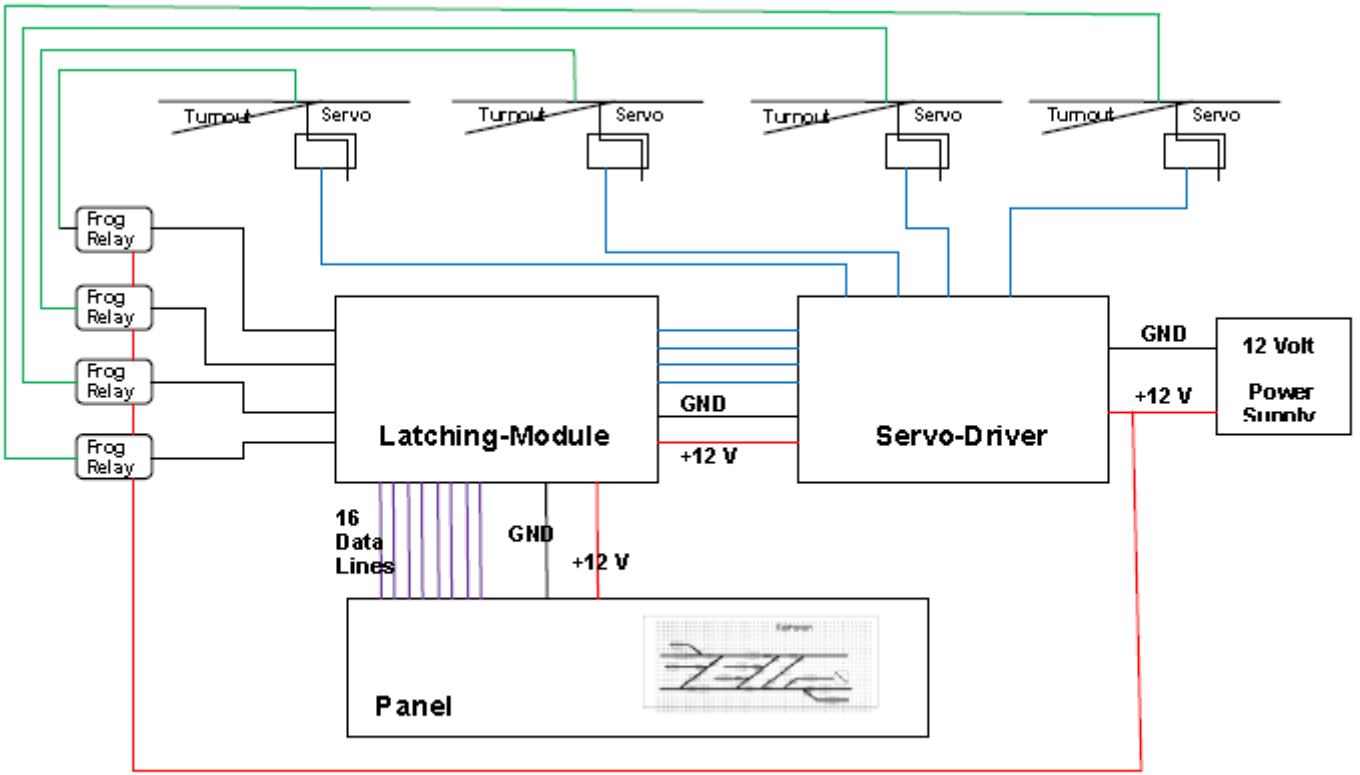
    2. a servo drive circuit;

    3. a latching circuit linking the fascia control panel and the servo drivers;

    4. a turnout control panel;

    5. a means of switching the turnout frog polarity and track signals.

Our Final Block Diagram for Controlling Turnouts



1. Easy Servo Mounting System

1. an easy servo mounting system;
2. a servo drive circuit;
3. a turnout control panel;
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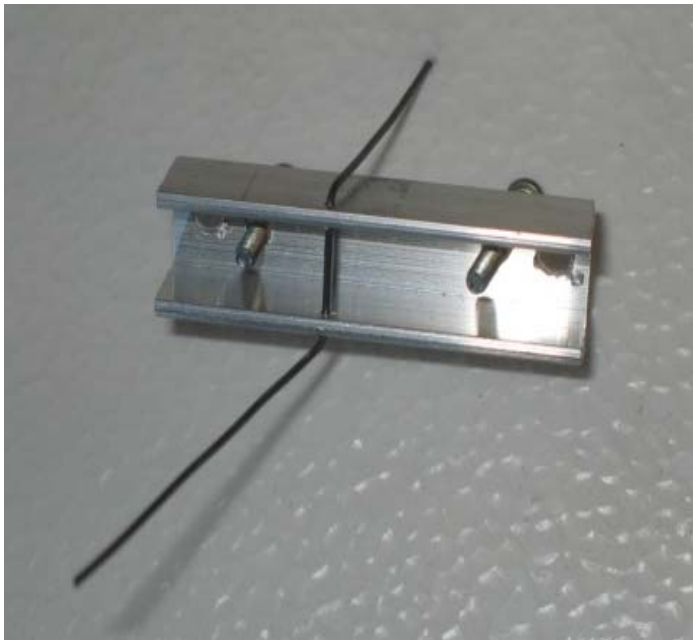
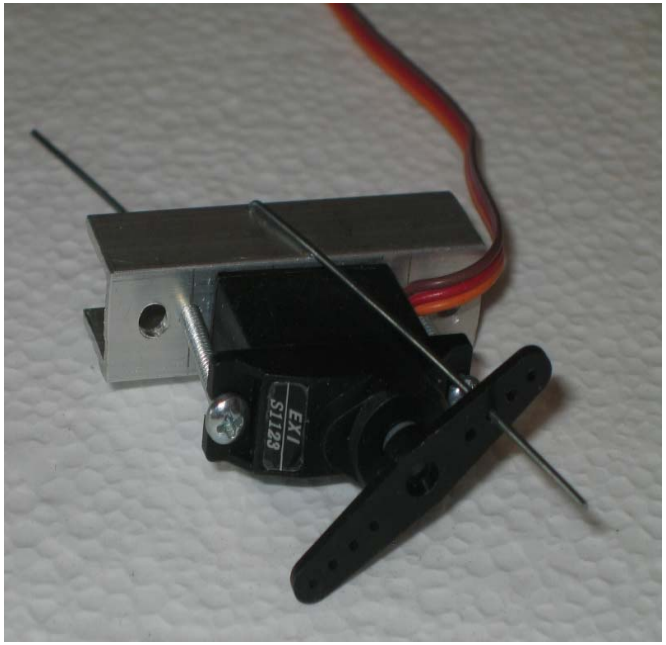
5. a means of switching the turnout frog polarity and track signals.

Al Zimmerschied developed our final servo mounting system as shown below:





Its greatest feature is that it allows removal of the servo without disturbing the linkage or having to reinsert the actuating wire into the turnout throw bar when replacing a servo.

2. Servo Drive Circuit

1. easy servo mounting system;
2. servo drive circuit;
3. latching circuit linking the fascia control panel and the servo drivers;
4. turnout control panel;
5. means of switching the turnout frog polarity and track signals.

- All RC servos have a three-wire connector.
  - One wire supplies positive DC voltage (usually 5 V).
  - The second wire is for voltage ground (0V).
  - The third wire is the signal (control) wire.

- Servos are controlled by sending a simple digital pulse of variable width, or pulse width modulation (PWM), through its control wire.

- The servo motor expects to see a pulse every 20 milliseconds (ms), (a repetition rate of about 50 pulses per second),

- The length of the pulse determines how far the motor turns.

2. Servo Drive Circuit

Continued

1. easy servo mounting system;
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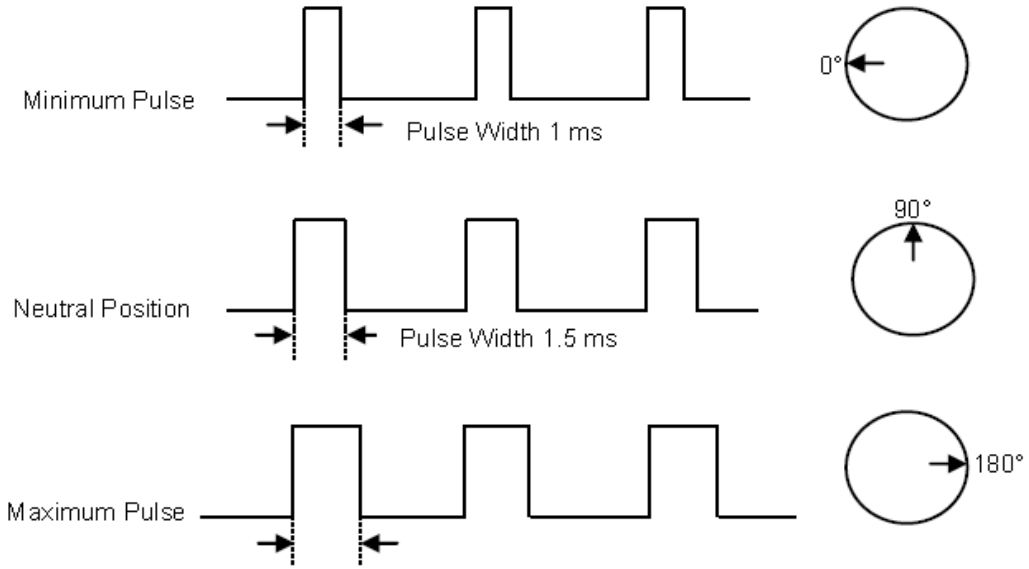
5. means of switching the turnout frog polarity and track signals.

• **For example, if a 1.5 ms pulse will make the motor turn to the 90-degree position, shorter than 1.5 ms moves it toward 0 degrees, and any longer than 1.5 ms will turn the servo toward 180 degrees.**



• **The servo will not move to its final destination with just one pulse. To move the servo, you must repeat the pulse every few milliseconds.**

2. Servo Drive Circuit

Continued

1. easy servo mounting system;
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• There are two general methods for generating the variable width pulse train. One is a combination of astable and monostable circuits usually based on the 555 IC chip and the other is a programmed microcontroller. Both methods were tried and each has its advantages.

• Al put together a circuit that he found in a Scale Rails article that used a single 555 chip to create both the train of pulses and the pulse width, but he was unable to get the circuit to work consistently. Instead, using two 555's (one 556), one to generate the pulse rate and one to generate the pulse width, gave far better results.

• Al also tried a Tam Valley Octopus, a microprocessor-based controller for eight servos that seemed to work reasonably well, although the automatic stroke adjustment apparently didn't work well with our servo mounting. With this system you also have the capability to add bicolor fascia LED controllers. Two fascia kits are needed to fully control eight servos. The cost for the servo driver and fascia controller kit, for us, was cost prohibitive.

2. Servo Drive Circuit

Continued

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- After browsing the internet, Bob Judge found that the Model Electric Railway Group (MERG) website revealed a servo driving kit, (Servo 4F Driver Kit 75), that could control four servos, and was readily available to its members.

- It was far less expensive and provided the means to set direction, stroke, and speed for each servo electronically.

- And if any conditions were changed, the parameters could be reprogrammed easily.

- Furthermore, this servo driver kit contained all the electronics, printed circuit board, and microcontroller to operate the four servos and is very easy to assemble. (However, you will need good soldering practices).

- As a general note: modern-day microcontrollers generally lend themselves to a reduction of components and wiring complexity.

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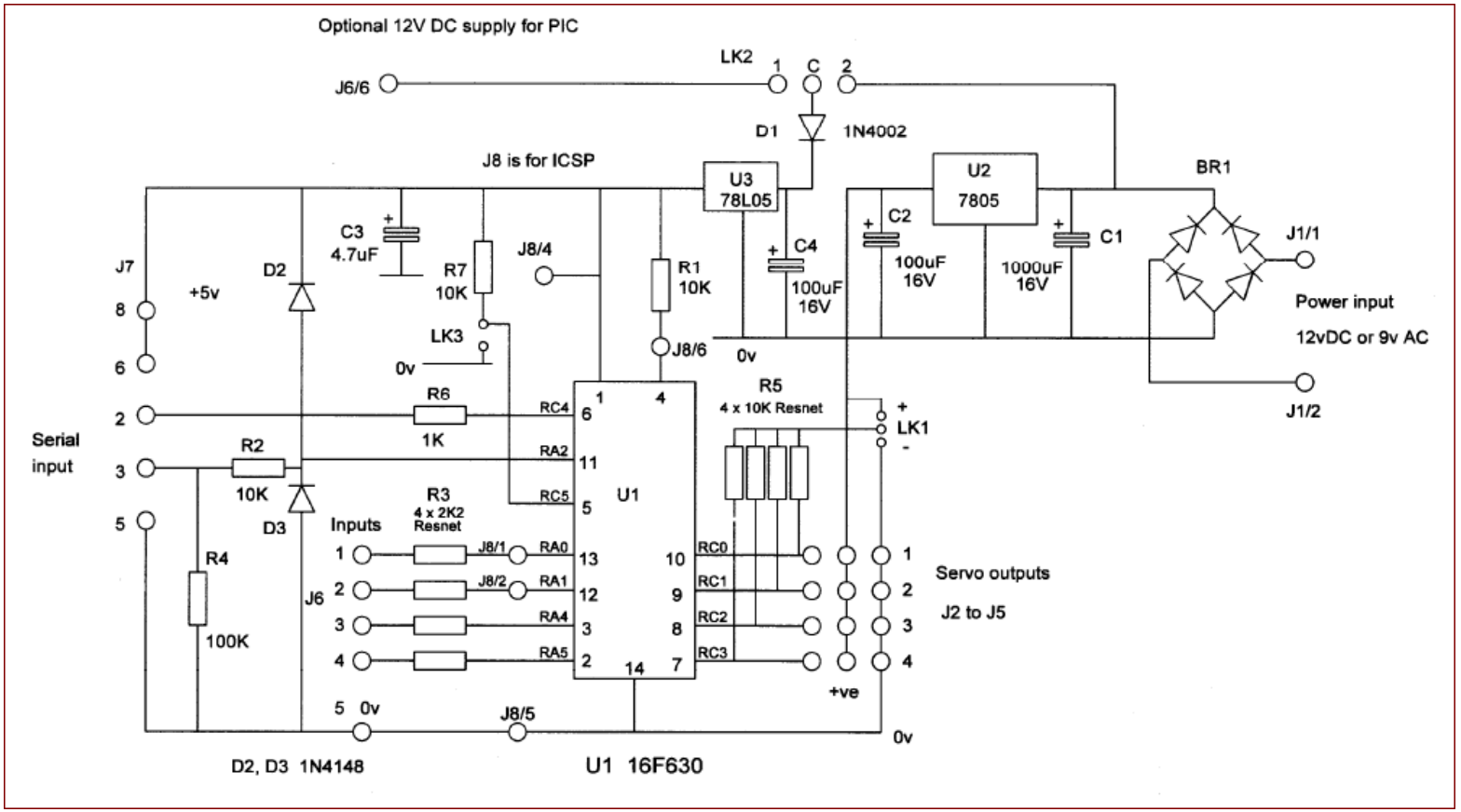
- **The schematic shows the MERG Quad Servo Driver Kit Schematic. The IC part (U1) is a 14-pin, Flash-Based 8-Bit CMOS Microcontroller (PIC 16F630) supplied by (MERG).**



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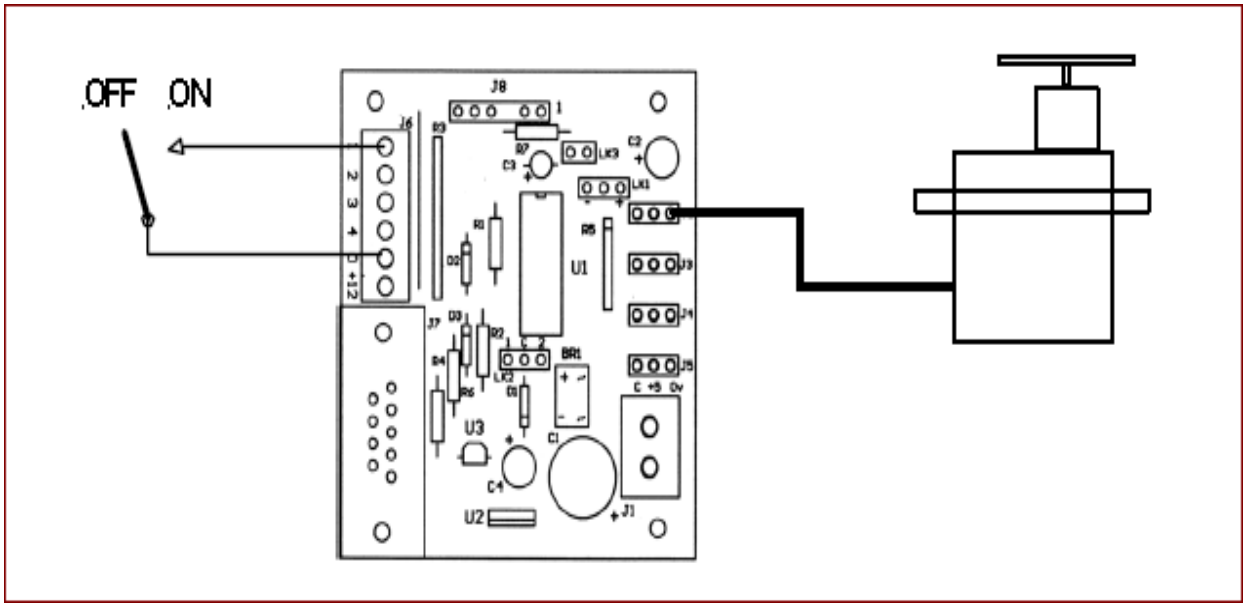
- Control is applied at the appropriate servo input on J6 pin 1, 2, 3, or 4.
- A high (OFF) input sets the servo at one end of its set range and a low (ON) input sets it at the other end.
- This operation can be done with toggle switches, or in our case by using a logic circuit that provides an on/off connection to J6 pin 5 (0v).
- On/off is illustrated in the Figure below, which shows control of the first servo.



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One outstanding feature of the Servo4 board is the way the servo adjustment is achieved. The board has a standard serial RS232 interface (9600 Baud) via a 9-way D-type connector, and the servos may be set, adjusted and tested through this serial interface using either a computer ('PC'), or the separate purpose built ServoSet box, (MERG Kit 76).

The serial interface sends information to the board without handshaking, and will operate equally well with a USB connection via a USB to serial converter. Once the required settings have been established, they are saved in the PIC's onboard memory. This gives very high reliability, as there is no possibility of accidental mis-adjustment, failure of variable controls, or interference from external sources. The settings may be altered subsequently by reconnecting the serial interface.

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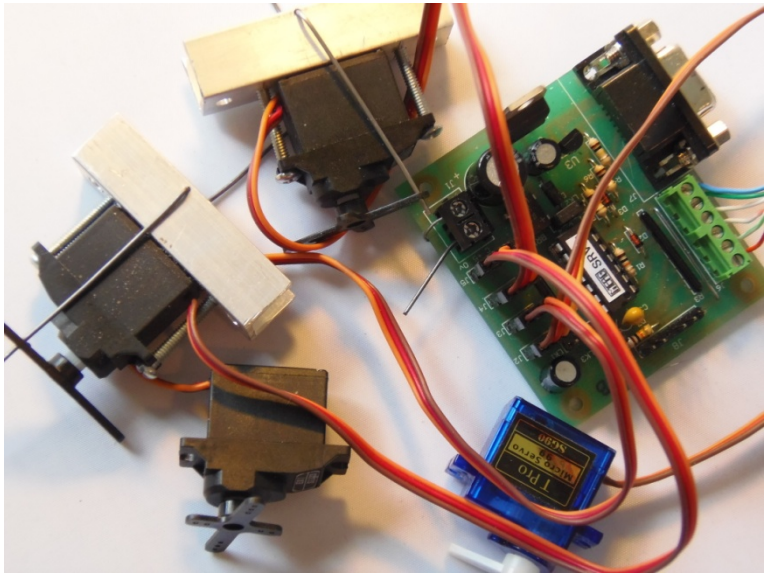
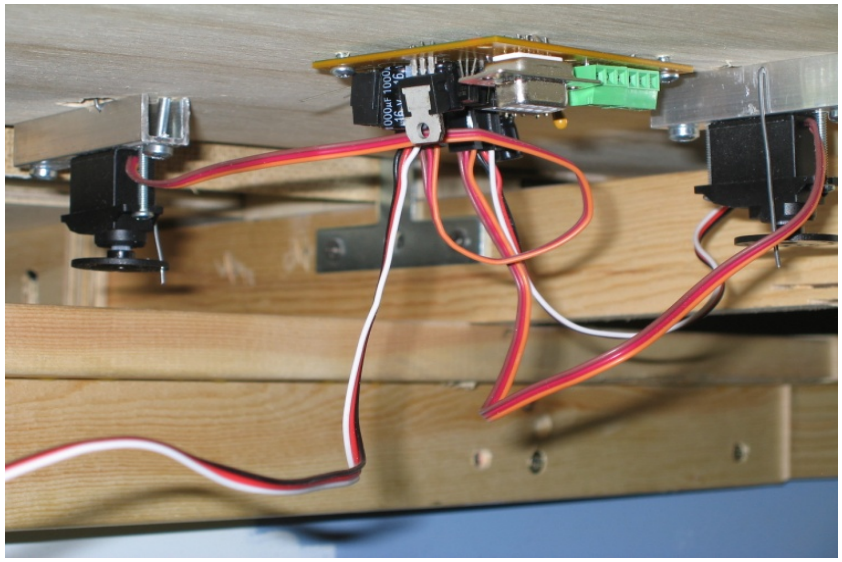
- **MERG Servo Driver and 4 Servos**



- **Mounted MERG Driver and Two Servos**



3. Latching Circuit Linking the Fascia Control Panel and the Servo Drivers

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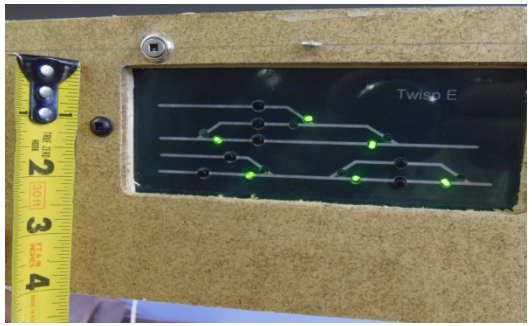
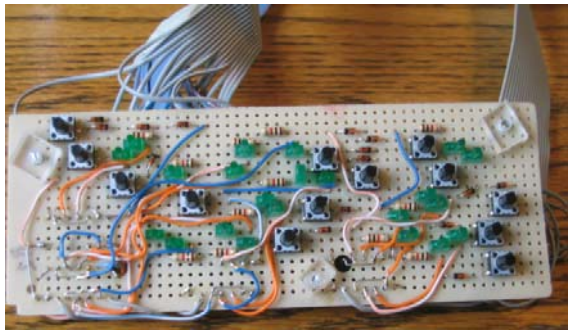
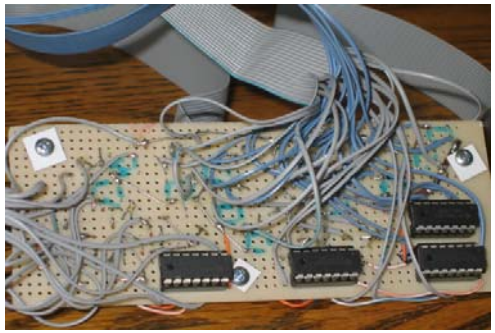
- The 'Latching Module' came about when we realized that a certain amount of repeat circuitry was needed on each panel to interface with each servo driver board assigned to that panel.
    - For example, if there were 12 turnouts mapped to a panel, three latching circuits would be required, one latching circuit for each Servo driver board. (Note that 3 Servo driver boards X 4 servos on each driver board = 12 controlled turnouts).

- Since each panel contains unique turnout position indicators, push buttons, and digital logic ICs, we decided to remove the duplicate latching circuit components and 'externally' connect them to the panel using another board.
    - Remember that the panels were designed to be small in order to fit into the fascia boards around the layout.







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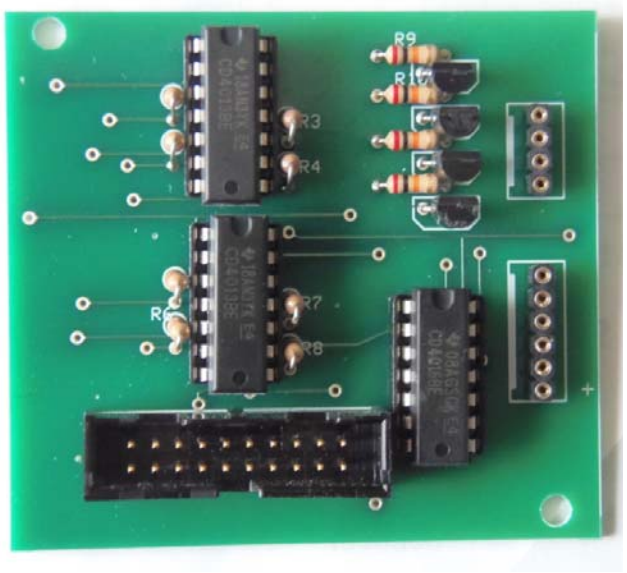
- The common circuitry that's needed to interface each Servo Driver board to the buttons, and the LEDs on the panel is straight forward .

- Since the MERG Servo Driver boards handle four turnouts per board, the Latching board was constructed accordingly.

- The parts required are:
  - four flip-flops (two Ics),
  - four electronic switches (one IC),
  - four transistors,
  - twelve resistors,
  - input connector for the servo board,
  - output connector to the relays, and
  - 20 pin connector to the panel.



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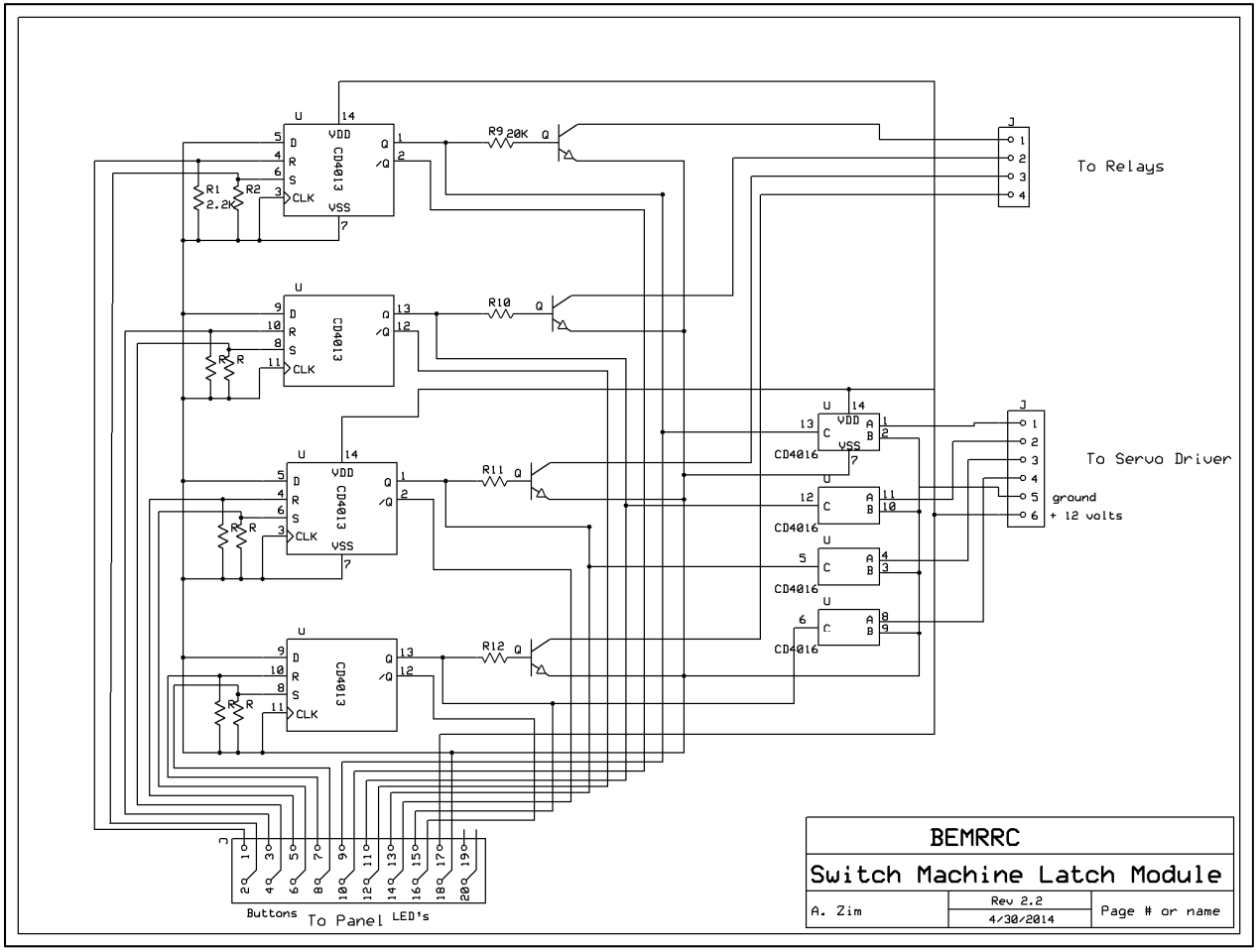
- **This is the latching circuit that's needed to interface between each Servo Driver board and the logic connectors for buttons and the LEDs on the panel.**



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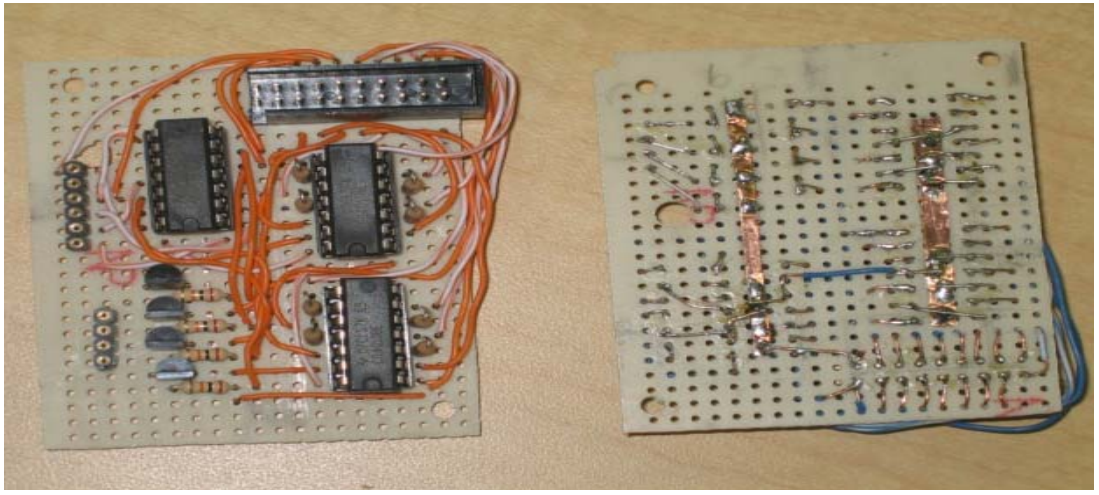
- **Our first attempt at making a Latching board was to hand-wire the components on a perf-board.**

- **You can view the two sides of one of our first boards below, and realize that hand-wiring, soldering components, and drilling holes on 70 more boards was not a logical choice.**



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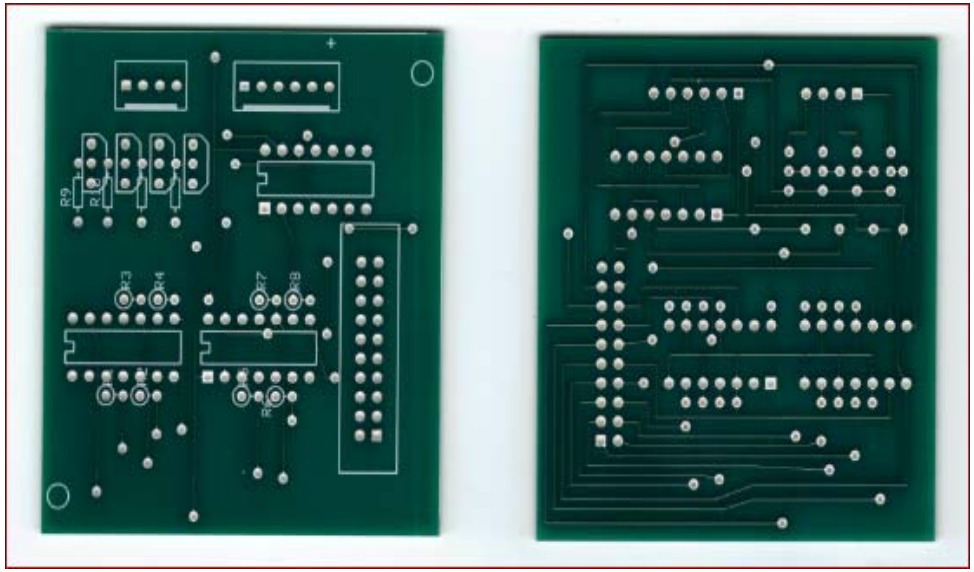
- **Since the MERG servo circuit boards assembled so well, and saved so much assembly time, we decided to try making a home version of a double- sided latching printed circuit board.**

- **However, to etch a 'double sided' board and drill all the electronic component holes turned out to be far more work than hand wiring. (Another bad choice)**

- **Our only solution was to design and obtain printed circuit boards from Express PCB. Their free software was used to draw the circuit boards, and the follow-on purchase offer was within our budget.**



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- **Latching Board Design:**

- **The MERG servo drivers require constant 'high' or 'low' to maintain the desired switch machine position, and as mentioned earlier, this can be done with toggle switches.**
    - **But in our case, this is accomplished using logic circuits.**

- **We designed the latching circuit based on the Quad Bilateral Switch (CD4016) to interface with the MERG driver board, and RS Flip-Flops (CD4013) that interface with the panel.**

- **The Latching board ICs will toggle between the desired turnout positions, turn on the matching panel indicator(s), send the appropriate MERG signals, and change the turnout frog polarity.**

- **The use of CMOS chips allow us to use unregulated 12-volt supplies, if we need to.**
    - **Later I will address the preferred 12 volt supplies that drive all our electronics. We do not use unregulated power supplies anywhere on the layout.**

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- **The bilateral switch behaves as a SPST (single pole / single throw) switch which is under electronic control. When the control signal is HIGH, the switch is closed, allowing signals to be transferred between the switch terminals. The switch is bilateral because either terminal can be used as the input. In other words, current flow can be in either direction. Note that the 4016 contains four switches, which matches the four inputs needed for the MERG servo driver board. Each switch has two input / output terminals A and B and an enable terminal C. When C is LOW, the switch is open. When C is HIGH, the switch is closed.**

- **There are two RS Flip-Flops available from each 4013, therefore two 4013 ICs are needed to interface with the 4016 bilateral switch. The RS flip-flop is constructed by feeding the outputs of two NOR gates back to the other NOR gates input. The inputs R and S are referred to as Reset and Set inputs, respectively. For our reference, Reset and Set are the two positions of a turnout. Q and /Q are the logic states of the flip-flop and these outputs are always opposite. When Set is pulsed HIGH, the outputs are Q=1, /Q=0. When Reset is pulsed HIGH, Q=0, /Q=1. Using the R and S inputs to the flip flops will also eliminate any switch bounce problems in the pushbuttons.**

- **One of the outputs from each flip-flop will also drive a High Gain transistor, which is used to drive the frog polarity relay for each turnout.**

3. Latching Circuit Linking the Fascia Control Panel and the Servo Drivers

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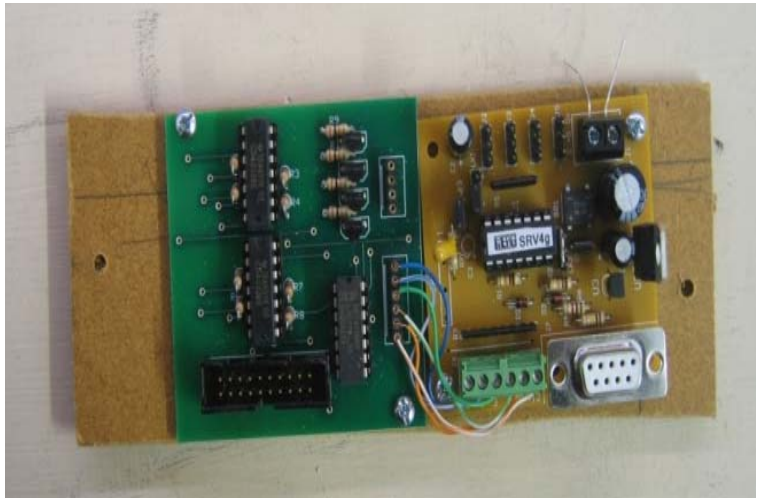
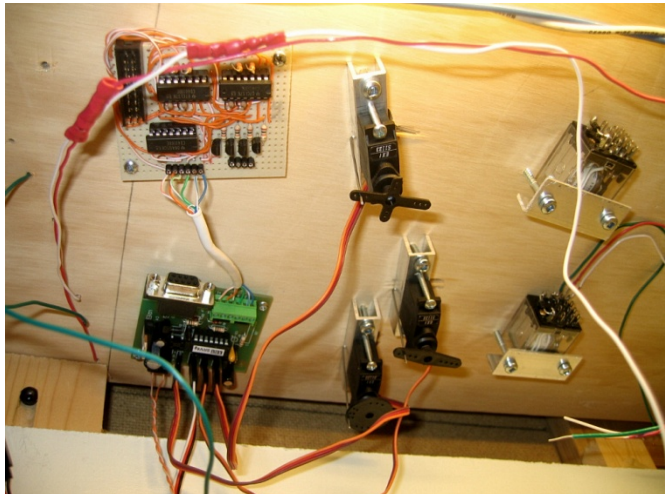
5. means of switching the turnout frog polarity and track signals.

- **The latching boards provide four circuits to match the MERG boards. Each set, one MERG and one latch board, was mounted on a small piece of hardboard for easy installation under the layout.**

  - **One figure below shows the MERG Servo Driver and Latching board set.**

  - **The other figure shows an earlier mounted MERG / Latching set, (separately mounted), and some of the bracket mounted servos and frog relays.**





4. Turnout Control Panel

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4. turnout control panel;
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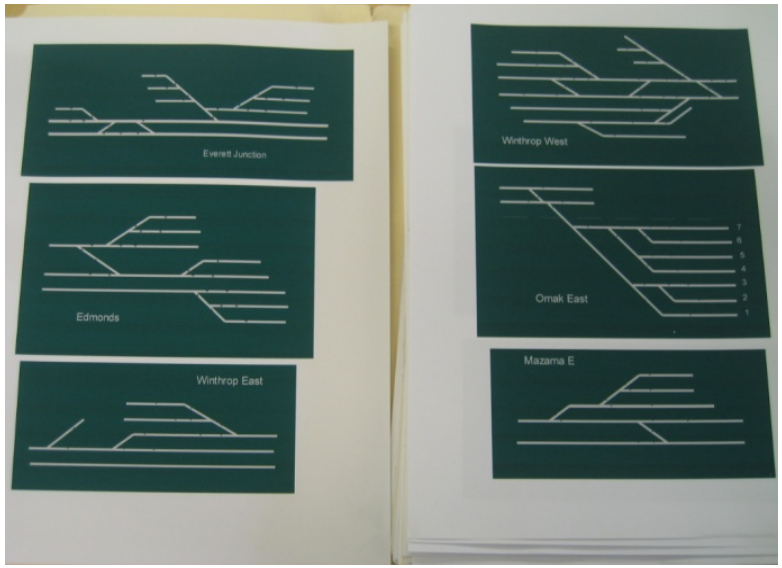
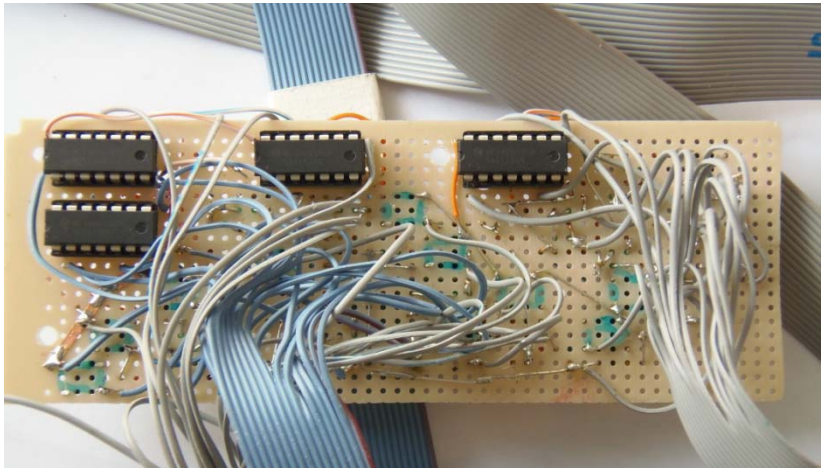
- **All of our panels were designed to be area specific, this allows for a manageable switching area for one person.**

- **It also meant that no two panels contained the same logic circuits.**



- **Since all panels contained unique logic circuits, (one-of-a-kind), hand wiring the panels was our only construction option.**



4. Turnout Control Panel

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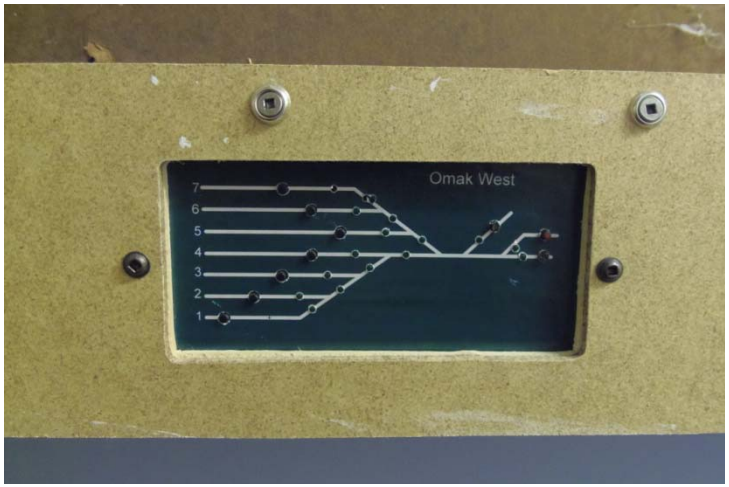
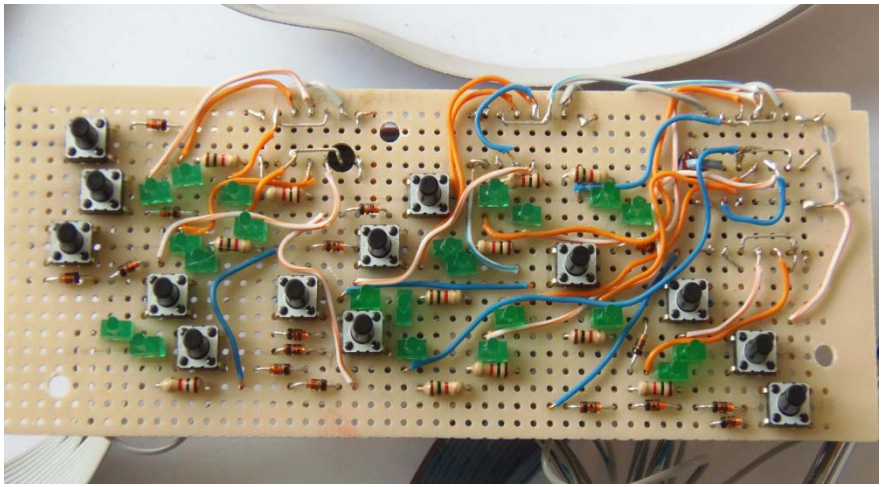
- **There was a desire to keep the control panels small, (around 2-3 inches in height by 4-6 inches), so they could be mounted in the fascia. The layout fascia is 5 inches wide.**

- **The use of pull-out drawers was not an option, since this leads to obstructing the aisles.**

- **We used small PC pushbuttons and 2mm LEDs mounted on perfboard that was soldered together on the back of the panel.**





4. Turnout Control Panel

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- **The panel face is 1/8-inch acrylic with a computer printed overlay that has the track plan on it.**

- **Track destination logic using steering diodes is used to connect the pushbuttons on the latch boards.**

- **The LEDs were either direct drive from the flip flops, buffered for those cases that the same lights appeared on two different panels, or driven by quad AND gates when the lights were cascaded with the previous turnout lights.**

- **The cascading was needed to provide a lighted active route with other routes remaining dark.**

- **As mentioned earlier, each panel is unique, since the track plan is what governs the design of the panel,.**

4. Turnout Control Panel

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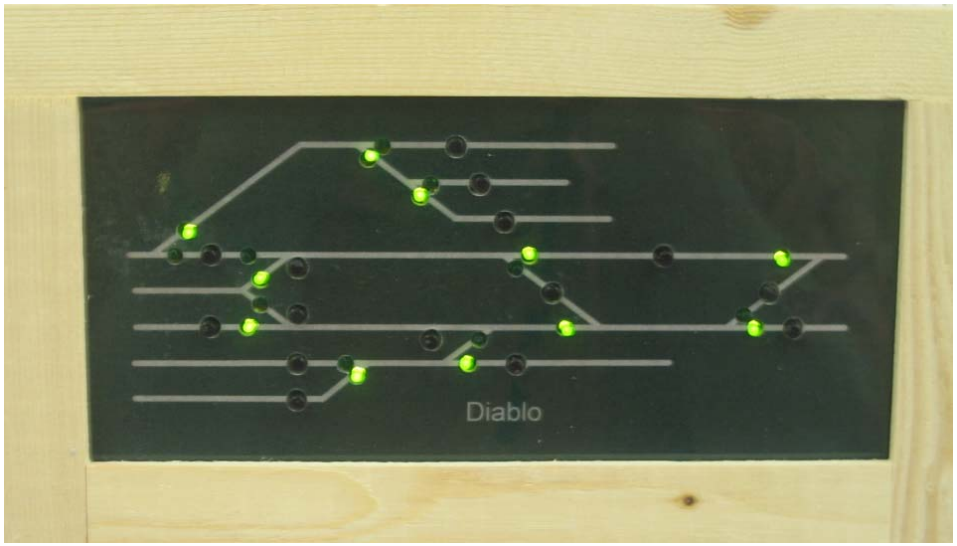
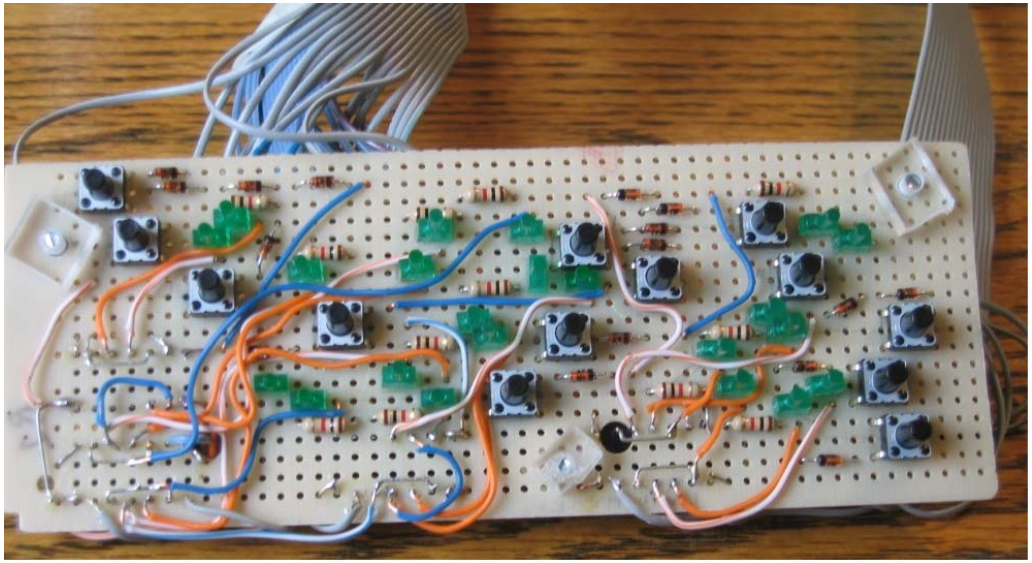


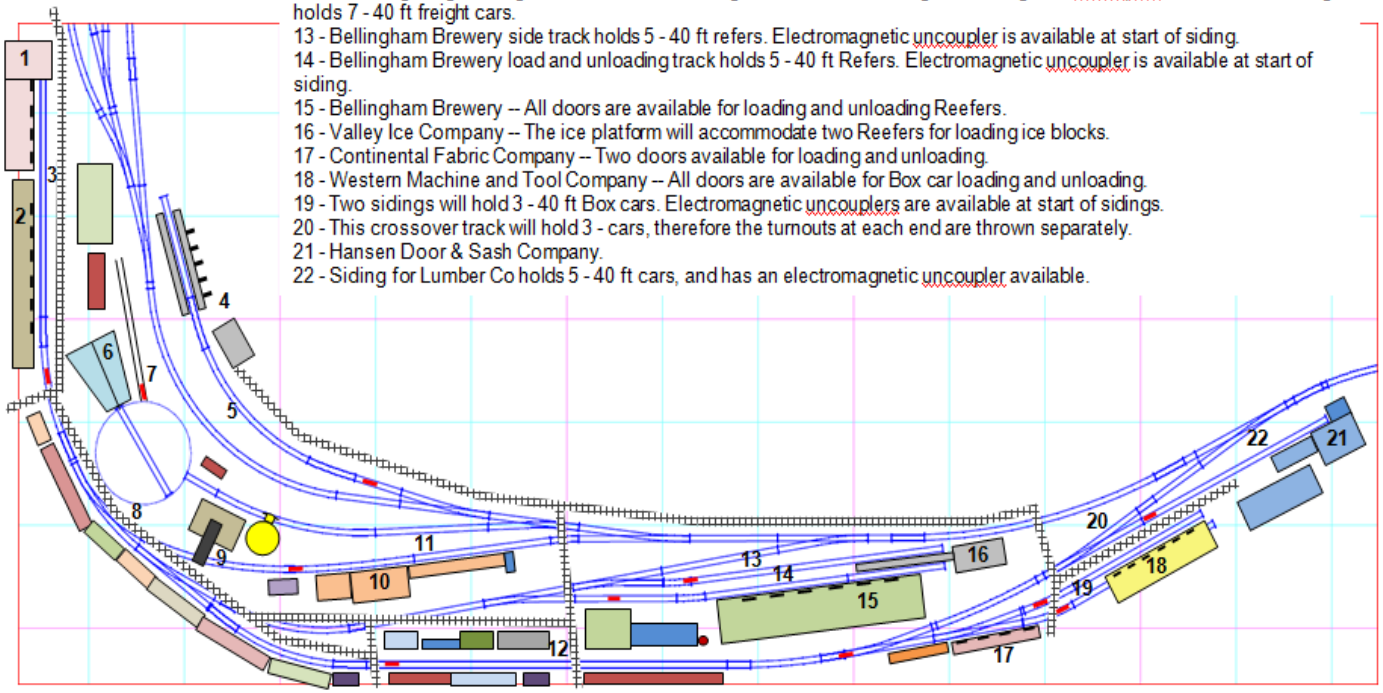


Panel Design Sample:

Step 1:
Start by determining the number of turnouts that will be controlled on an individual panel.

In this example, we are looking to control 12 turnouts in a branch line called 'Fairhaven', a small industrial town. The 12 turnouts start at building 21, and stop at building 4.

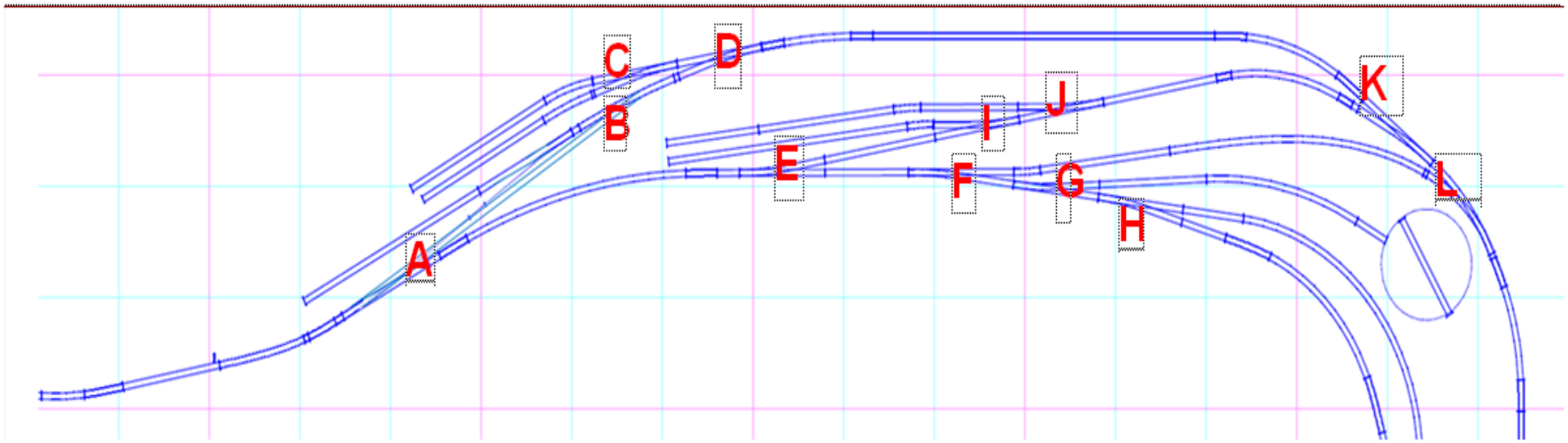
1- Nancy's Jams and Jellies -- Incoming requires Refers for fruits, Tank car for Citric Acid, Covered hoppers for raw sugar, and Box cars for glass jars. Outgoing products require Box cars, and only the first three doors used in loading and unloading.
2- Arctic Refrigeration and Storage -- Requires Refers for incoming and outgoing. The first door is used for truck access only.
3 - Siding will hold a total of 5 - 40 ft cars. An electromagnetic uncoupler is at entrance to buildings 1 & 2.
4 - Anderson Coal Company -- Elevated coal bins can hold two Hopper carloads.
5 - The siding will accommodate 5 - Hopper cars for storage. An electromagnetic uncoupler is at siding entrance.
6 - Two stall roundhouse.
7 - Caboose track with electromagnetic uncoupler at entrance. Track holds 4 - cabooses, or maintenance cars.
8 - Track is embedded into city Main St. There are no stops for loading or unloading cars, and railroad cars are not to stop except for brief switching.
9 - Coal pit used for dumping by Hopper car, coal used for loading coal tower for steam engine services.
10 - Fairhaven passenger and freight station.
11 - Passenger track holds 3-4 - 60 ft passenger or baggage cars. Electromagnetic uncoupler is available to remove engine, and/or observation car to rotate at the turntable.
12 - Incoming freight siding allows for removal of engine and caboose using electromagnetic uncouplers at each end. Siding holds 7 - 40 ft freight cars.
13 - Bellingham Brewery side track holds 5 - 40 ft refers. Electromagnetic uncoupler is available at start of siding.
14 - Bellingham Brewery load and unloading track holds 5 - 40 ft Refers. Electromagnetic uncoupler is available at start of siding.
15 - Bellingham Brewery -- All doors are available for loading and unloading Reefers.
16 - Valley Ice Company -- The ice platform will accommodate two Reefers for loading ice blocks.
17 - Continental Fabric Company -- Two doors available for loading and unloading.
18 - Western Machine and Tool Company -- All doors are available for Box car loading and unloading.
19 - Two sidings will hold 3 - 40 ft Box cars. Electromagnetic uncouplers are available at start of sidings.
20 - This crossover track will hold 3 - cars, therefore the turnouts at each end are thrown separately.
21 - Hansen Door & Sash Company.
22 - Siding for Lumber Co holds 5 - 40 ft cars, and has an electromagnetic uncoupler available.



Panel Design Sample:
Continued

Step 2:
The same Fairhaven track plan (inverted) with all buildings removed.

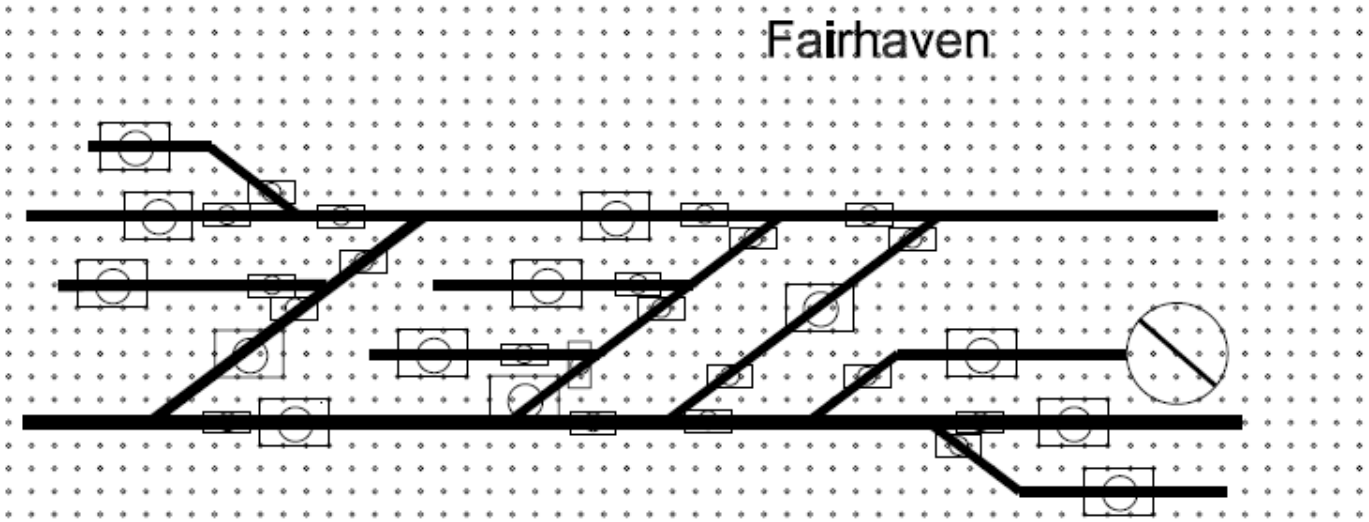
The 12 turnouts to be included in the panel are far more visible and are lettered A thru L.



Panel Design Sample:
Continued

Step 3:
Determine the panel size and draw the schematic for the front plate.

Add the turnout pushbutton locations and the LED locations on the schematic.



Panel Design Sample:
Continued

Step 4:
Number and mark all pushbutton locations on the panel schematic, then add turnout lettering to the same schematic

Determine the train travel routes and logic generated for turnout alignments.

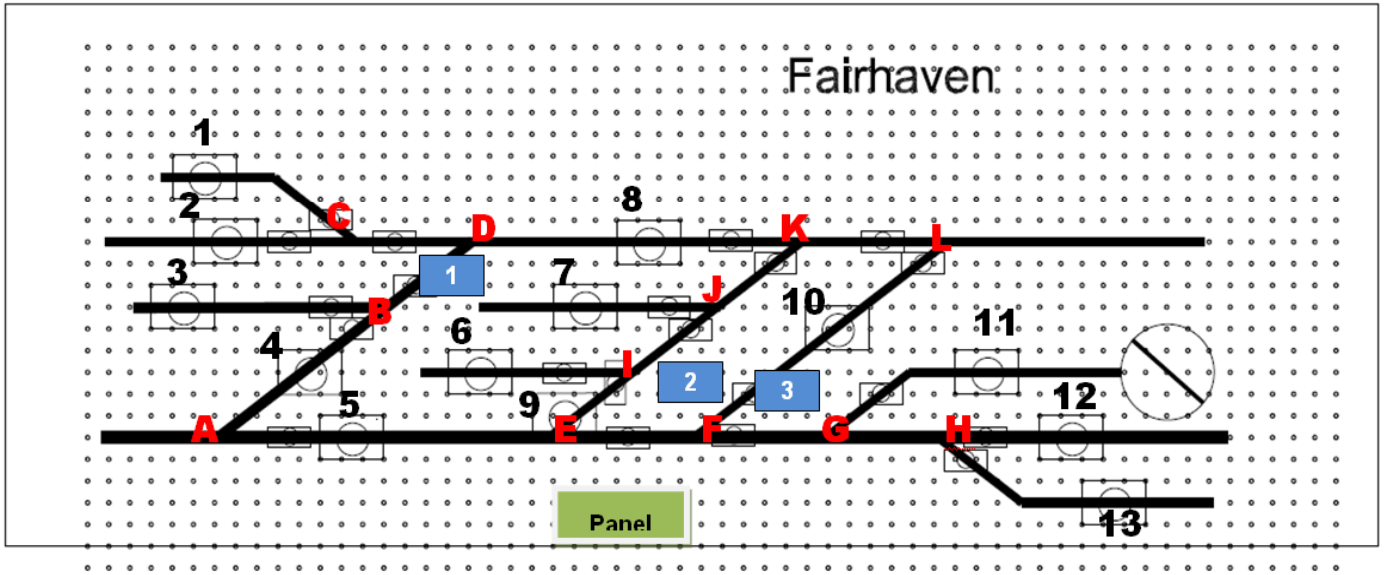
Determine appropriate LEDs that need to be ON in order to show the route.

Determine which four turnouts will be grouped and assigned to which MERG driver / latching board set.

Determine which MERG board servo position (1 thru 4) is assigned to which turnout.

- **Panel Push buttons are numbered 1 thru 13...**
- **Servos for turnouts are lettered A thru L...**
- **Servos A and D will operate independent of each other...**

Switches 1 & 2 align C & D	**Switch 3 aligns B & D**	**Switch 4 aligns A & B & D**
Switch 5 aligns A	**Switch 6 aligns I & J & K & L**	**Switch 7 aligns J & K & L**
Switch 8 aligns K & L	**Switch 9 aligns E & I & J & K & L**	**Switch 10 aligns F & L**
Switch 11 aligns E & F & G	**Switch 12 aligns E & F & G & H**	**Switch 13 aligns H**



1	**Merg Board Servo Position: (1 - D), (2 - C), (3 - B), (4 - A)**	**(3' cable Merg to Panel)**
2	**Merg Board Servo Position: (1 - E), (2 - F), (3 - G), (4 - H)**	**(2' cable)**
3	**Merg Board Servo Position: (1 - K), (2 - L), (3 - J), (4 - I)**	**(2' cable)**

Panel Design Sample:
Continued

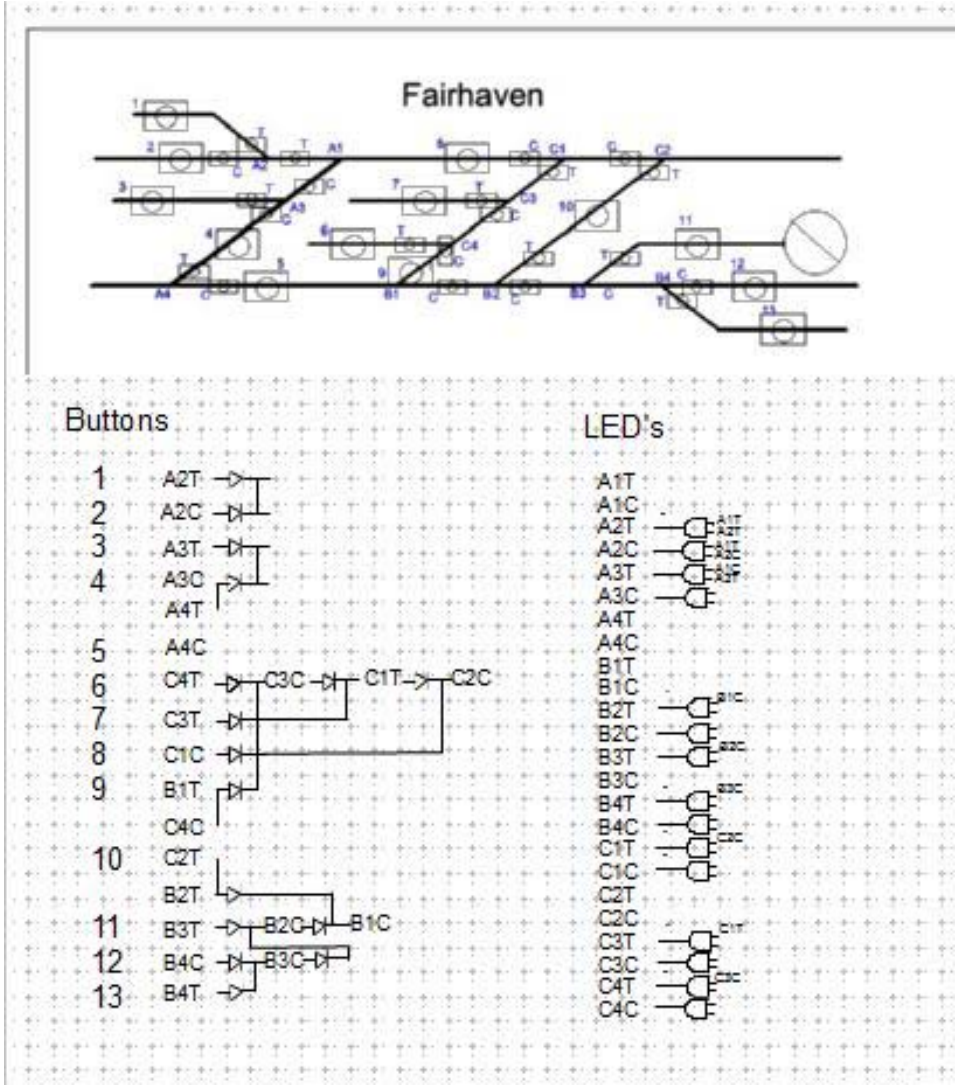
Step 5
You should develop a Boolean table, or some other schema, that allows you to match the input / output data lines from each Latching board to the panel.

In our example there are three MERG Servo Driver boards.

Each Latching board contains a 20 pin connector; eight data lines for push-button control, eight data lines for LED control, +/- 12 Volt supply lines, and two unused lines.

There will be three MERG / Latching board sets leading to the panel, with a total of 48 data lines and two power lines.

The turnout alignments, the routing, and the MERG servo assignment numbers are then mapped together in a logic table.



5. Switching Frog Polarity

1. easy servo mounting system;
2. servo drive circuit;
3. latching circuit linking the fascia control panel and the servo drivers;
4. turnout control panel;
5. means of switching the turnout frog polarity and track signals.

- **The frog polarity relays are 4pdt types so it is possible to control two frogs in a crossover with the same relay and still have plenty of contacts for signaling or other indicators.**

- **If the 4pdt relays are not readily available, a spdt relay would be adequate and are readily available for under $2.**
    - **The small PC-type relays can easily handle the electrical load because of the short length of track at the frog.**

- **Although it might be possible to add a small switch to the servo mount, instead of using relays, the adjustment could be difficult and the small micro switches are often more expensive than the relays.**

- **Another method of powering the frog is with a “Frog Juicer," a commercial reverse circuit.**

5. Switching Frog Polarity

1. easy servo mounting system;
2. servo drive circuit;
3. latching circuit linking the fascia control panel and the servo drivers;
4. turnout control panel;
5. means of switching the turnout frog polarity and track signals.

- **Our relays draw around 30 milliamps of current when they are latched 'on,' and since there are 280 turnouts, there was a conscious effort to have as many of our turnouts in the non-powered-relay 'off' position.**

- **If the relays are all powered, it would draw a bit of current.**

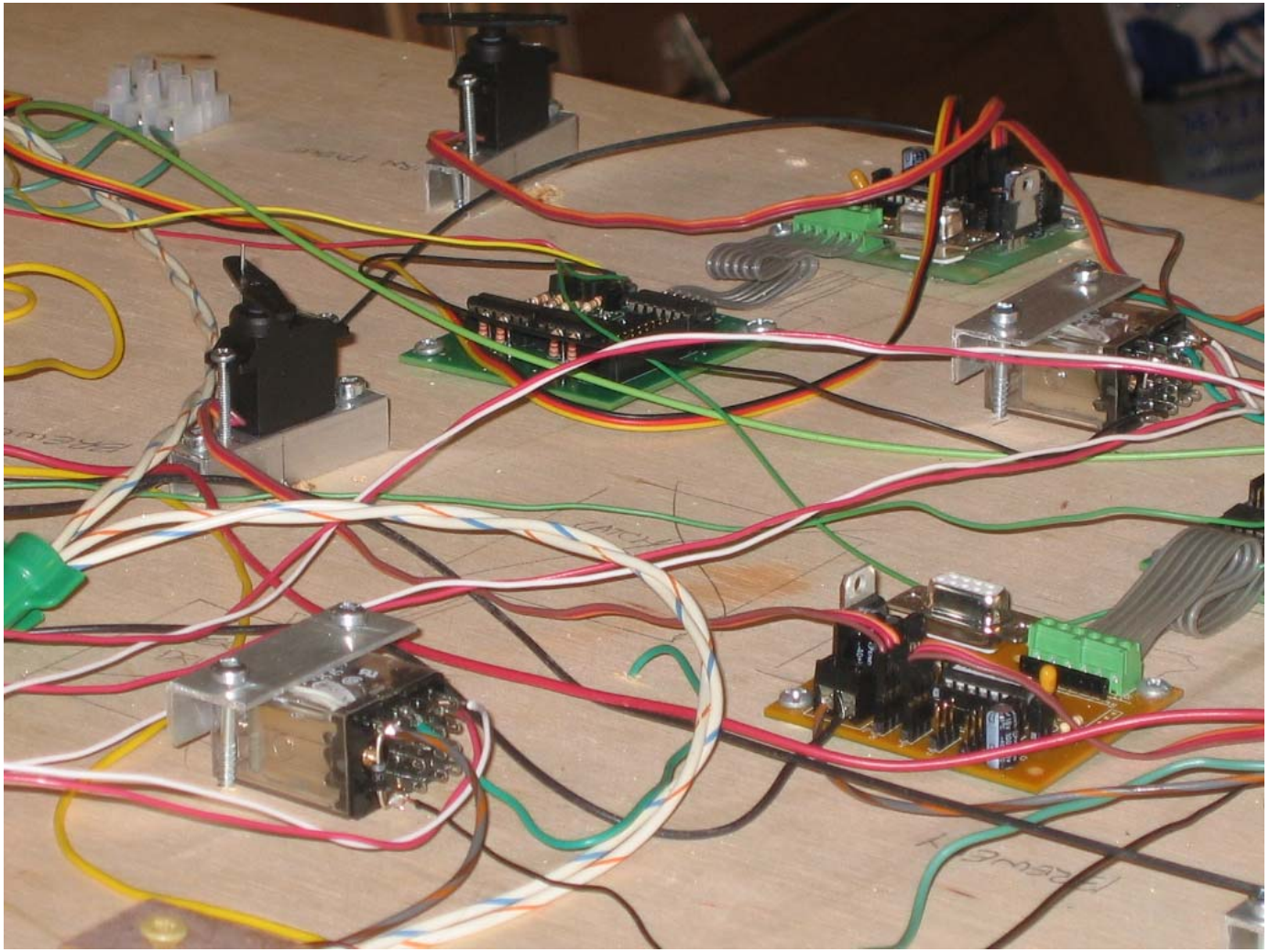
- **One example is to have all the Main-Line track turnouts in the through position, i.e., have relay power off. Then when a turnout leaves the main, the relay is latched on, (powered).**

- **The relays were mounted against the underside of the layout using an 'L' shaped aluminum bracket and a couple of mounting screws. This sort of attachment allows relay mounting to be anywhere within short range of the turnout.**

- **Removal for solder work will be fairly easy when later, we finally add the signaling and dispatch connections.**

5. Switching Frog Polarity

1. easy servo mounting system;
2. servo drive circuit;
3. latching circuit linking the fascia control panel and the servo drivers;
4. turnout control panel;
5. means of switching the turnout frog polarity and track signals.



Final Notes:

1. **We seriously recommend that if you purchase the MERG servo driver kits, that you also acquire their Servo Driver Setting Kit. This is the best way of adjusting your final turnout throw and speed.**

2. **When setting the turnout points, place the point rail's final contact with the fixed outside rail, with a light touching. The servos are quite strong with their holding power and the rails will stay put. By doing this you will eliminate servo 'chatter' when the turnout is closed. It will also eliminate higher current draw and heating from the power regulator (U2) on the MERG board.**

3. **We should also pass along the method that we established for delivering 12-volt power throughout the system. You can refer to our flow chart and see that we 'daisy-chained' the 12-volt input power through the MERG board by soldering together all three pins of LK2 which then supplies +12 volts to the output on pin 6 of connector J6. The -12 volts is already available on pin 5 of connector J6. The voltage output from the MERG then powers the latching board, and continues to the panel via the twenty pin connector, +12 volts on pin 17 and -12 volts on pin 18. Each Merg Servo Driver board / Latching board / panel set is powered that way.**

Final Notes:

Continued

4. **There is a 'Y' cable readily available for the servos that will allow you to attach two servos into any one of the MERG output connectors, J2-J5. This allows you to operate two servos simultaneously, as when throwing the two opposite points for a typical 'crossover' route.**

5. **Servo cables come in many lengths, including 4 feet long. These are great for reaching that one turnout that seems to be well away from the MERG driver.**

6. **We did not fully cover the electrical characteristics of the MERG Servo Driver, since there is already a complete five page write-up of building instructions, including a full parts list and theory of operation from MERG. There is also the computer interface instructions and S/W program for their on-board microcontroller.**

7. **All of our panels have one end of each cable attached (soldered) to a panel perfboard that eventually plugs into a twenty pin connector of an appropriate Latching board, at the opposite end. If you have the 'real estate' on your panels, consider using another twenty pin connector instead of attaching (soldering) the panel connections. This will prevent damage if someone snags a cable and detaches any of the panel wiring.**