TRAIN DETECTION

A SHORT HISTORY AND HOW TO BUILD
AN INEXPENSIVE AND RELIABLE DETECTOR

Presented by BOB VAN CLEEF
of the North River Railway
A FIRST TRAIN SET

• Take a walk into any toy store and you will probably find a wooden train set something like this.

• Kids like this sort of thing but if this was all they have they will usually lose interest rather quickly.

• BUT...
A SLIGHTLY LARGER “LAYOUT”

- Add a few pieces of ‘scenery’, a grade crossing, maybe some switches and a few other accessories and just watch how it becomes more interesting.

- Even kids can associate the various accessories with their counterparts and what you would find around a railroad, abstract though they are.
• Even a four-year-old for instance knows that a green ‘GO’ sign means go and a red ‘STOP’ sign means stop.

• Grade crossings are also used for holding back cars as a train goes by.

• This is exactly how model railroading started over 140 years ago.
This 1906 crossing featured a mechanical trip between the rails that would lower the gates as a train went by.

- Model railroading can trace its origins back even before the first Ives first clockwork O scale ‘trains for boys’ in 1901.
- Working semaphores and crossing gates were popular accessories even back then.
- Cohan’s Lionel soon began to compete but while more rugged, it would be several years before he was able to claim better detail and realism.
FIRST ELECTRIC TRAINS

• Ives targeted the rural population thinking that not every household had electricity.
• Eventually Ives started making electrified accessories and was the first to make an “auto-reversing” engine.
EARLY PRESSURE PLATE DETECTION

- This 1940 Lionel device was essentially a SPDT pressure Switch placed under the track.
- The weight of a passing train operated a central contact (right) between two other contacts (on left).
- This was used to operate turnouts, animated figures, signals and other accessories.
AUTOMATIC GUARD SHANTY

This is an accessory commonly sold with the pressure plate. The figure would “pop out” to wave at a train as it went by.
POST WAR CONTACT DETECTION

• This versatile device also worked with Lionel’s 3-rail system to detect trains but in several different ways.
• The underside of the clip could be insulated.
• Power was conducted through the axels between wheels and between rail and clip to provide a signal current.

Post war 154C-1 Contact
THE SEEDS OF PROTOTYPE OPERATION WERE SEWN

- Later switches were thrown and a primitive block systems developed to automatically stop one train to allow another to pass.
- Automatic couplers and ramps allowed the first realistic switching movements.

1957 Lionel Layout Plan
FADING OF THE TOY TRAINS

This 1916 layout cost about $60, of a lot of money when an average worker earned $5 a week.

- Both Ives and Lionel advertised their products as a “Father and Son” hobby.
- They were still however considered as very expensive toys mostly used during Christmas time around the tree.
- Ives slowly faded into bankruptcy after 1945 and Lionel branched out into other products starting in the 1950s.
THE FIRST MODELERS

• Meanwhile, the 1930s saw the introduction of less wealthy modelers who liked to experiment and build some of their own crude boats, planes and trains for a lot less than the expensive “toys” of the time.
• These were extensive year-round layouts paying more attention to prototype detail and operation.
• Several ‘do-it-yourself’ craft magazines the led to the Model Railroader in 1934.
DETECTING RESISTENCE BETWEEN RAILS

- MODEL railroaders had developed a more sophisticated block system.
- An early article in the June, 37 MR shows how the resistance of the train’s motor could be used to operate relays for an automatic block system.
- Note that among the many problems was that the power supplies required had to be in phase for the system to work.

Dozens of detections Schemes were designed over the next fifteen years using different methods of detecting changing resistances between the rails.
• This March 1950 circuit for block occupancy used frequencies and vacuum tube technology to detect trains. It used (3) voltages, tubes and relays but it worked better than many other circuits once the tubes warmed up.
Lower prices and simpler solid state components made it possible for a wider range of armatures to join the experimentation.

- It had high sensitivity, a low component count and it required only a single power supply.
- Current was measured in *series* of the motor instead of *parallel*.
- It was also much simpler and was easy to understand which made for a much wider audience.
FIRST PHOTO TRANSISTORS

- Photo-sensitive transistors was already been invented around 1950.
- They were more compatible with the growing number of solid state technology devices used to miniaturize other circuitry.
- This typical schematic shows a photo-transistor train detector.
- Note that because ambient lighting is used this would not be suitable for nocturnal operations.
• **Any** optoelectronic device, such as this simple 1960s LED, can by definition both source *and detect* light.

• Some LEDs are designed to be a much better source (emitter) of light (visible or otherwise) than one made as a detector.

• They are made to produce or detect a specific wavelength which can be anywhere in the full spectrum of light from infrared to x-rays and beyond.
LED EMITTER vs. DETECTOR

• It is important to understand that LEDs are most sensitive as a detector to a different wavelength than the wavelength it emits and vice versa.
• LEDs Emitter/detector are paired to operate best at a common frequency.
• These are usually designed to also have a very narrow viewing angle.

Response wavelength vs. Emission wavelength.
SIMPLE DIRECT DETECTION

A transistor and some sort of sensitivity control is usually added to improve performance.

- A very primitive system can be built with a simple emitter/detector pair.
- Adding hoods or shades the size of a soda straw greatly improves reliability.
- This works with a single track but distance can be limited.
- Using infra red further improves reliability for nocturnal operations.
- Changes in ambient light or shadows from train crew movements (especially around derailments) can cause false triggers.
REFLECTIVE DETECTION

• This diagram shows two “light guns” (the emitter and detector) mounted between the rails and pointing upwards toward the bottom of a passing train.
• Fortunately Reflective Detection is less sensitive to movements in the room than simple direct detection.
• Unfortunately the underside of a car or train may have a wide range of reflective properties.
• This disadvantage can be overcome by pulsing the light source at between 1 and 10 kHz and filtering the signal from the detector. (more on this later)
Heathcote IRDOT Optical Detector

- The IRDOT uses a reflective beam to detect movement almost three feet away under ideal conditions.
- The $33 cost for a single detector however is relatively high.
- Several versions exist such as holding the circuit on for \((x)\) seconds or wires to connect to other devices. This prevents signals from blinking between cars.
A 1990 DETECODER

• This represents a simpler dual detector used a ‘555 timer and two ‘567 tone decoder chips.
• It cost about $20 per detector and did work but the range was limited to about three inches.
• The adjustment was also fairly critical.
This version contains two detectors and cost less then $10 to build. Each has a dependable range of 9” and are easy to adjust.

While the circuit is designed to be interfaced with a computer and other solid state devices it can be easily modified to power signals, relays or other type of devices.
POWER SUPPLY

The (4) resistors limit the current to the emitters and detectors to a safe level.

- IC-1 is a common LM7805 voltage regulator.
- Any supply voltage between 8 and 18 volts DC can be used to power this circuit.
- The two capacitors are used to prevent any transient spikes in the supply voltage from causing variations in the output.
REFERENCE VOLTAGES

• Two separate voltages are generated here.
• The first is generated by the 33K Ω and the 3.3k Ω resistors.
• Op Amp 4-D strengthens this voltage for use in holding the input signal to a usable level.
• The 2nd voltage is generated by the 12K Ω resistor and the 10k Ω potentiometer.
• Op Amp 3-D uses this voltage to determine the threshold of the input signal used to turn the output device on.
PULSE GENERATOR

- 3-B is one section of a voltage Comparator used as an oscillator.
- The .001 mfd capacitor and the 330K Ω resistor set the frequency to about 10kHz.
- The two 330K Ω resistors shape the oscillator output to a square wave.
- 2-A and 2-C are two gates of a hex inverter and drive the emitters such that one, but only one emitter is powered at any given time.
INPUT CIRCUIT

• This section is a high-pass filter.

• The .001 capacitor (103) blocks any DC component of a signal but will pass a 10 kHz signal from the blinking emitter between gates (A-4) and (4B).

• A 10KΩ resist er prevents a bias voltage from overpowering the signal.
This section is a low-pass filter.

The .001 mfd capacitor (103) blocks any AC component of a signal but will pass a low frequency signal between gates (A-B) and (4-C).

This frequency is determined by the values of the 68KΩ resister and the .001 mfd capacitor.

The 10kΩ resister and diode stabilize the output to be either on or off and not half way between.
OUTPUT TO SIGNALS

- IC-6 is a dual optoisolator that electrically separates the outputs from gates 2-E and 2-F.
- It contains its own emitter / detector encapsulated within the chip.
- This makes it perfectly safe to use for computer connections, signals and a variety of output devices.
- All four resistors limit currents to safe levels.
DETECTOR CONNECTIONS

- The right hand connector is for the (2) emitters and (2) detectors plus the main power.
- This drawing shows the left hand connector wired to a LED signal. These can be connected to a computer the same way.
INSTALLING LEDs

• This tool makes drilling the 3/16 (press fit) holes for the LEDs a bit easier.
• Drill one hole, insert the pin, then drill the other.
THE EMITTERS AND DETECTORS

- (from right to left)
- Cut a length of 3/16 brass tubing to ½” or thickness of roadbed.
- The body will be shaped from 1/8” square basswood.
- Cut or file a deep groove on opposite sides of body.
- The plug is formed from cut down header strip.
- Solder #26 magnet wire between the LEDs and plugs.
- Glue tube to body.

Use nail polish to mark cathode and anode of LEDs.
Add another dot of color to mark the emitter and detector.
TEST BENCH FOR DETECTORS

This simple test bench is used to test the various components of the train detection system including the Emitters, Detectors and the Detector circuits.
This test track was built to test all the components of the train detection system. Both the main detector board to the left and the photocells to the right are easily replaceable. The center panel has LEDs to indicate when a car is rolled over the photocells. Not shown is a 12v wall transformer that supplies the power.
POWER DISTRIBUTION

• This card accepts power from two different style plugs and converts it to 5 and 16v DC.
• It connects to the detector board.
• It emulates to trackside signals to show when a car has been detected over a photo cell.
TESTING THE DETECTORS

• This block is used with the test bench.
• The white, reflective copper and dark foam replicates the underside of the cars and engines.
• All three surfaces should trigger the circuit at a distance from $\frac{1}{4}''$ to 12”
INSTALLING PHOTO CELLS

• Tracing wires under the table can be difficult.
• This is a little tool to make the installation of photo cells a bit easier.
• A half-disk rotates slowly over the cells.
• An ohm meter at the other end of the wires will help trace the signals and insure the cells are correctly connected.

This TAMIA 6-speed gearbox motor runs on a single 1.5v battery
LAYOUT OF PARTS ON BOARD
<table>
<thead>
<tr>
<th>PARTS LIST</th>
<th>R1, R3</th>
<th>100 Ω - 1/6w</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC-1 LM7805 - volt regulator</td>
<td>R31, R32</td>
<td>330 Ω - 1/6w</td>
</tr>
<tr>
<td>IC-2 SN7404 hex inverter</td>
<td>R15, R23</td>
<td>1K Ω - 1/6w</td>
</tr>
<tr>
<td>IC-3 LM339 quad volt comparator</td>
<td>R10, R11</td>
<td>1.5 K Ω - 1/6w</td>
</tr>
<tr>
<td>IC-4, IC5 LM324 quad op-amplifier</td>
<td>R19, R26</td>
<td>3.3 K Ω - 1/6w</td>
</tr>
<tr>
<td>IC-6 LTV826 dual optoisolator</td>
<td>R4, R14, R22</td>
<td>10 K Ω - 1/6w</td>
</tr>
<tr>
<td>C3 .001 mfd (102)</td>
<td>R20, R27</td>
<td>33K Ω - 1/6w</td>
</tr>
<tr>
<td>C4, C5, C7, C8 .01 mfd (103)</td>
<td>R2, R9</td>
<td>47K Ω - 1/6w</td>
</tr>
<tr>
<td>C8, C9 .022 mfd (223)</td>
<td>R17, R25</td>
<td>110K Ω - 1/6w</td>
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<tr>
<td>C2 4.7 mfd @ 25v</td>
<td>R12, R13</td>
<td>270 Ω - 1/6w</td>
</tr>
<tr>
<td>C1 47 mfd @ 25v</td>
<td>R5, R6, R7, R8</td>
<td>330 Ω - 1/6w</td>
</tr>
<tr>
<td>D1, D2 1N4148FS-ND - TO35 Diode</td>
<td>R29, R30</td>
<td>680 K Ω - 1/6w</td>
</tr>
<tr>
<td>R18, R33 10K trim potentiometer</td>
<td></td>
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</tbody>
</table>
For More Information...

Digi-Key Corporation Home Page - http://www.digikey.com/
Large inventory of electrical components, datasheets and tools. Almost all parts for this project were purchased through Digi-key

Jameco Electronics - http://jameco.com/
Supplier of electronic related parts and kits at bargain prices.

Collection of circuits useful to model railroads

first 75 years of Model Railroader Magazine on a CD
(can be loaded and run on computer without CD once loaded)