So, what's in a name?

I am “Signal Aspect Engineering”, a purveyor of electronics as it relates to Model Railroading signalling. The “aspect” of a “signal” is referring to the information relayed to a train crew by the display of the signal. That display may be one (or more) clear or coloured lamps or a moving arm that positions itself for a given aspect or a number of combinations of both. There are other signalling methods but I will consider them novel or unusual and they are not covered here.

As an electrical engineer, I used my background to develop the circuits for the purpose. I have been told, often, that I write like one. This is a technical subject and as such makes for dry reading. There are many drawings; such is the language of electricity.

To a great extent, my background is heavy industrial control, measurement and instrumentation. That design philosophy will be reflected in my circuits. They tend toward being "brute force simple", one basic concept with suitable modifications appropriate to the task at hand. Not a lot of "bells and whistles", that one person in ten will want. More a basic system for basic needs. Yet open enough to allow inter-connecting different functions and expanding the capabilities into full blown automation when and if it is ever desired. No need to start from scratch when you upgrade. Merely add another circuit and tie them together where appropriate.

As a Model Railroader, I model a late 19th century industrial road. Very little signalling there. But the subject does interest me and as fellow railroaders ask for a gizmo for some purpose or another, I will develop a circuit specific to that need. Over time, I realized that many of these circuits had near identical features and similar functions.

The printed wiring board for the SLC, a Signal Logic Controller, was developed for clubs where the large quantity of required modules precluded hand building the circuits. My design philosophy includes use of readily replaced or modified components. As an aid to the novice when hand building a circuit, I-Cs (integrated circuits) were avoided. As were specialty devices; most of the components in my designs are readily obtained "standard" parts. This approach is carried over into the LBO design, a Latch-Bridge-Oscillator. One basic form compatible to any number of fundamental designs.
There are many producers of excellent signal models. Having my own preferences in style, type, and format, I have no intent to infringe on their experience and product lines. What I provide is the ability to control any signal models that I have encountered or read of; even when supposedly incompatable models are mixed together on a layout. My circuits are designed to allow the modeler to use their own judgement and preference in appearance and make it all work together.

These circuits are powerful in that they are so readily adapted to multiple applications. To permit these many options, the circuit must have flexibility where it leaves the circuit board and connects to the real world. That flexibility precludes "Plug and Play" installation.

I had the option; a dozen or more different boards that did one thing and are easy to use; or a flexible system that could ease the overall burden on modelers. I chose the latter route; I do hope you approve.

Because of this flexibility, I must assume a modicum of knowledge and skill on the part of the modeler. A basic knowledge of power supplies, the fundamental skill of soldering, and the wisdom of maintaining a neat and orderly wiring system, with copious notes of what was used where. There is no need for an aero-space quality installation, but wiring run point to point, willi-nilli, by the shortest route, will eventually cause problems.

Circuit board assembly is not difficult for the experienced, nor for the patient. The novice needs a little help. I designed the mounting pads oversized and widely spaced to assist in that "learning curve". The boards are produced by a supplier to industrial control systems. They can withstand a considerable amount of abuse, but are not bullet-proof.

There are subject specific "essays" toward the back of the manual that cover some of the finer points of several technical subjects. If you are new to soldering, read up on the basics of the subject. If you are new to electricity, I don't attempt to teach the subject but do give a little insight into some of the pitfalls found by railroaders.

Tooling requirements are not expansive, or expensive. Radio Shops often carry a beginner's tool kit. It should be sufficient for assembly of most any of my modules.

Just remember, electrical equipment works on magic smoke. If that smoke gets out, the device won't work any more. And it's a whole lot harder to put the smoke back in than it was to let it out.

And so; the magic of electricity
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Signals over the Week-End
Quick start directions

In these directions, I cover the installation of a basic "2 Aspect" signaling system. The signal will display **GREEN** until a train is in the block, at which point it will display **RED**. This can be expanded into a **three aspect** system with a few connections detailed on the last page. The project can usually be accomplished in an afternoon, a weekend at most, by using assembled boards and the optional edge connectors.

This installation will assume a small layout, perhaps a couple of "train sets" combined on a plywood platform on a frame. Track from the set boxes, a few switches and the ability to run two trains independently.

Scale is unimportant; it may be G, O, H-O, or N. The circuits given here will work with any scale, provided the trains run on D-C power. Other power sources are more complex and are covered elsewhere.

**Requirements**

- A starter package of **three SLC boards**
- **Electrical tools** suitable for making up soldered connections. Needle-nose pliers, cutters, soldering iron, solder, screwdriver(possibly)
- **Small wire**. Telephone or Networking(CAT3 or 4) is a suitable wire, AWG-24 in multiple colours. Length depends on the size of the layout.
- **Power supply**. A 9 volt *battery eliminator* is the *ideal* supply; anything from 8-12 volts will work. The load is negligible, less than 1 watt per board. The only stipulation is that it be separate from the train packs.
- **Signal models** with either "Grain of Wheat" lamps or Common Anode LEDs. Two for each board will permit signaling both directions.

Any other *known* signal models can be accommodated but you get out of the "Quick Start" region and into more complex wiring. The matter is covered in depth in the complete manual.

**Highly recommended extras**

- Pre-assembled circuit boards
- Circuit board "Edge Connectors", one for each card
- Insulated Rail Joiners for the "Set" track if you aren't comfortable cutting the rails.
- Rail joiners with wiring pre-attached, or extra terminal track sections if you aren't comfortable with soldering wires to the rail.
Getting Started

Detection

The first order of business is to determine if there is a train in the block. Assuming there are two power packs, normally one track lead from each is connected together and then wired to one rail of the track. Often called "Common", it is the rail we will use as a "Signal Rail".

Isolate a section of that rail with insulated rail joints that is a suitable length for the signal block. If the track is already gapped in both rails with no common, so much the better. Just pick a rail to call the "Signal Rail" and follow it around the layout marking it occasionally. Should you end up where you started, but on the opposite rail, you have a "reverse loop". Reverse loops require a special technique and are not covered here.

A very good book for the novice on the subject of wiring a layout is provided by Atlas, the track folks. Atlas also has electrical controls for running two trains together, the "Controller" and the "Selector". These are proven products that have stood the test of time. They should be stock items at your local Hobby Shop.

The illustration below is what you are going to build at the track. All wiring is done below the layout, with wires coming up through the roadbed to the rails. The blocks are shown short. Make them as long as you want. Instructions for each step are given as they apply.
The SLC package contains a number of loose electronic components. The part you need first will be the power diodes. The part number may vary; usually 1N4006 or JE125, similar in appearance to D-1 on the circuit board. They are black with a silver band on one end. Make up four of them, as shown here, for each signal block. Just be sure you don't use the small glass diodes.

From the rail you just isolated, run a wire to the diodes. From the other side of the diodes, run a wire back to the "common" point of the power packs. There will be other wires attached here shortly. If you want to see the detector in action right away, connect a 2-3 volt GoW lamp across the diodes and run a train. When the locomotive is in the isolated block, the lamp will light. Should you have a volt-meter, it will read on the order of 1.5 to 2.0 volts. This is the phenomenon we will use to operate the detection circuit.

If the lamp doesn't light or you don't see the voltage, the "signal rail" isn't fully isolated and the detector won't.

**The Circuit Board**

![The Circuit Board Diagram]

This is the appearance of the SLC from the component side. The "edge connector" fingers are on the foil side and show here as a shadow. Pin (1) is to the Right and Pin (22) is to the left. The two short pins, 5-6, are the positive power input. They are the last connections to make contact should the card be inserted in a connector with power already on.

The preferred power supply is a "9 Volt Battery Eliminator". Other supplies may be used as well, but a 9-12 volt supply is preferred. Connect the (--)Negative lead to Pin 12 of the SLC. Connect the (++)Positive lead to Pin 5 or 6 of the SLC cards. The board is protected, if you hook it up backward, the board won't be damaged but nothing will function.

The average "Wall Wart" battery eliminator has sufficient power to operate up to eight(8) of the SLC boards when you are using LED signals. Power connections may be "daisy chained" between boards.
The Signal Models

The signal models are installed at each end of every block, facing along the track, visible from the right side (usually) of the locomotive cab. It is suggested the signals be temporarily connected near the controllers, so you can see them while you work. They may be moved to their final location later when the wiring is completed and tested.

Take one lead from each lamp and connect them together for the common lead. For LEDs, use the long leads (common anode). Connect these common wires to the SLC at Pins 1 and 2. For Common Cathode models, see the complete manual. The word "common" is used to indicate that several wires are connected together. It does not refer to a track or power supply return.

Connect the other wire from the top lamp of each signal head to pins 8 or 11 (Green). Connect the bottom lamps to pins 20 and 21 (Red). If you have three lamp signals, connect the middle lamps to pins 7 and 10 (Yellow). In the case of LEDs, a series resistor is required for each LED. They should be included with the LEDs. The resistor keeps the magic smoke inside the LEDs.

For single LED "Search Light" signals, connect the red leads to pins 20 and 21. Connect the green leads to pins 8 and 11. Again, remember the resistors. To use the "approach aspect" (yellow) with these models, special wiring is required. Refer to the complete manual.

Power up the signal system to test your work. The Green lamps should light, the others stay dark. Temporarily connect a wire from pin 13 to pin 19. It needn’t be soldered, just touch the two pins. The Green lamps should go dark and the Red lamps light.

If these two tests don’t work properly, check your wiring or soldering work. There may be a loose strand across two pins of the connector. If nothing lights, check the power supply and wiring to the signal models.

Wiring for Detection

With the signal models operating correctly, you are ready to connect to the detection circuits. There are three wires for each block. It is suggested the connections be kept within a few inches of each other.

Connect a wire from Pin 14 to the "Low Reference" side of the detection diodes. Connect a wire from Pin 16 to the "High Reference" side of the detection diodes. Connect the excitation wire from Pin 17 to the "Control" rail, across the track from the detection diode connection.

The signal system is ready for use. Run a train and as it enters an isolated block, that block will display a Red Aspect at each end of the block. Install the signal models at their final location and:

you have ..... Signals!
Beyond "STOP & GO"

"Approach Aspect" is an integral part of the SLC. If you have used three colour position signal models connected as described above, the function may be used by connecting in the following manner:

Start with the middle block SLC board. Connect two wires at Pins 9 and 15. Make them long enough to reach the other boards. It is suggested different colour wires be used, for your convenience. Route one of these wires to each SLC board on either side. Connect to Pin 18 or 19. Doesn't matter, they are connected internally.

When a train enters the first block, the middle block will shift from Green to Yellow. Should the wrong end of the block go Yellow, reverse the connections at Pins 9 and 15 of the middle SLC connector.

This is a crude but effective method for determining direction. By using this method, several pages of detailed instructions are avoided on the subject of traffic direction and feed forward signal levels.

Connect two wires to Pins 18 and 19 of the middle SLC. Connect one of these wires to the SLC in either direction. Start with Pin 9 at each board.

Run a train. In one block, "Approach" won't work correctly. On that SLC move the wire from Pin 9 to Pin 15. As before, this is a crude method but it's simple and works every time.

As you expand the system beyond the original three blocks, continue this method block by block. The last block in each direction will be unable to display outbound "Approach" because it has no input indicating the next block.

Technical Note

The wire at Pin 17 of the SLC is used to detect a standing train when power is not applied to the track. A lighted passenger car (or lighted caboose) or a freight car with a resistor across the wheels is all that is required. 1000 ohms is sufficient. Wheel sets are available with 5100 ohms between the rails specifically for this method of detection. If idle detection is not needed or desired, the wire may be left out at installation or eliminated after the fact.
Signal Logic Controller

Signal Aspect Engineering

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Signal Logic Controller (SLC) from Signal Aspect Engineering is a self-contained module for model railroads providing three color signal indications in both directions for a protected block of track. That is the source of the name, the 32 being 3 color and 2 directions.

An "Occupied Block Detector" is built into the signal controller. It uses current sensing from the track and is capable of detecting a standing train with no locomotive coupled up and no power applied. There are jumpers that may be configured for other detection methods. See the chapter on detection (page) and the associated drawings.

This feature makes the aspect controller compatible with any control system. Power requirements are readily met. Power output of the module is sufficient for lamp loads ranging from LEDs to automotive marker lamps. Remote repeaters for panel indications and/or relays for automatic train control may be connected to the system without additional buffering.

By using external components, single tri-color LEDs may be used for "Searchlight" signals. Complex signaling at track switches is accomplished through the use of external contacts from the switch machines. Modules may be hardwired or socket mounted.

No one is going to convince me that adding functional signals to a layout is easy. The aspects of the signals themselves is a complicated enough subject. Adding in electrical theory only makes the matter more incomprehensible. This circuit is my solution to that complexity. Merely connecting the wires as directed will provide a basic Automatic Block Signal (ABS) that will satisfy the most particular "Rivet Counter".

With the advent of interfacing between DCC systems and "Personal" computers, Model Railroad control has entered the computer age. Anyone with the "savvy", the time, and the funds can have computer controlled signals that do everything but feed the cat. Yes, the computer can even brew a pot of coffee.

The SIGNAL ASPECT controller is for the rest of us that just want to run our own trains, with all the foibles that make Model Railroading...

FUN
At one time, I was a Field Engineer for a computer company that was big enough to give even Big Blue headaches. I have put computer systems on my personal machine shop equipment. And then taken them off. It took the fun out of making stuff. (And making mistakes)

**Getting Started**

Please read this section twice, even if you are a master electrician. I, like many of my friends, well remember the transition from vacuum tubes to transistors. (Just a passing fad, some said) And, I have seen some technical people try to resolve “Integrated Circuits” into transistor equivalents. An exercise in futility. So; I'm the engineer . . . that you won't need to be.

Accept the forest, the trees will take care of themselves. Treat this module the same as an Integrated Circuit. Don't think of it as discrete components; look at the function of each pin on the edge connector. Think of it as a little black box with inputs and outputs. There are twenty wires per module to be dealt with. A little insight into complex electrical systems will help ease the complexity.

There is a Power Supply, of course. 8-18 volts, AC or DC(±) doesn't matter. Although **8-12 volts D-C** is the preferred supply.

Interconnect wires between modules; east and west in, east and west out. The "look ahead" circuits for the adjacent blocks.

Outputs to the signal heads themselves; one lamp, one wire.

And the detection inputs. You normally will be working with only one of these, so leave the wires off the other two and forget about them. Take the matter one function at a time.

A wire only has two ends. It comes from somewhere and it goes somewhere. Taken one wire at a time, there are only two points to deal with:

**“From” and “To”**
Before grabbing up the soldering iron, please take the time to read these instructions through, including the enclosures, so that you may get a grasp of how the system interacts. I am prone toward the verbose, and this is a technical manual, so the reading may be somewhat dry, but please, stay with it. A little preparatory work will ease the installation and could well make the difference between a solid system and a kludge. Your satisfaction is the best advertisement I can get.

When I first made up these instructions, I attempted to keep the page count low by putting as much information on each drawing as the page would hold. There were far too many data on the page to pick out which were important and which did not apply to any given system.

I have since revised the drawings in an attempt to provide only the pertinent information for each option on a page. There are many drawings. Such is the language of electricity. Just use the portions you need and set the rest aside or use them to impress your friends with just how complex the system was to implement.

STEP 1:
Populate the circuit boards. If you purchased assembled boards, this can be ignored and you may proceed with Step 2. Construction of the circuit boards is covered in their own chapter at page 43. Start there, then come back here.

I recommend you read up on the assembly options anyway. At least once. There are many options in the configuration process; you may be asked to modify the boards to accommodate a particular detection circuit. You'll know where to look for the information if you need it.

STEP 2:
Planning the system. It is amazing how something as basic as a compass point will simplify operations. So . . ., which way is North? All of my drawings assume North to be the top of the page with logic flowing from West (left) to East (right). When you have decided where North is, place yourself about the layout such that while you sit and plan, West will be to your left hand and East to your right. While you do, you may decide that operation will flow better if North is somewhere else. If only 12" to the foot scale were that simple. . . I realize that on a small layout, such a position may be in the middle of the bench work. If so, you will need to visualize as you work. But we are Model Railroaders. Such visualization is part and parcel of the hobby.
Make a simple sketch of the sections that you will be protecting. Show switches, sidings, crossings; any interference with the smooth running of a train. For setup and testing, a train can consist of a locomotive and a caboose. Normally, a spur would not be signaled although there is provision in the module to set the signal RED if a switch is set wrong. More on that later, but it needs to be noted in the planning.

Determine where the block boundaries are to be. Of course, if there is a crossover, that is a logical place. Perhaps you have a “Show” track, where you like to impress visitors. That track might be signaled every couple feet. Hidden track is a must, at least to the panel. Or repeat them all to the panel. Again, more later. The signal system **MUST** exist as an outline before the first wire is run.

Decide which method(s) of detection you want to use. The module comes with a current detector built in. If you prefer to use photocells, there is provision on the board to move a jumper permitting use of a photo resistor. Perhaps you already have a detection system. Use the “OCC” input to the circuit board. Possibly a combination of several methods. **Section 3** deals with detection and may be consulted prior to implementing your final decision.

The core system will consist of a minimum of three (3) modules. The reasoning behind the “Starter Kit”. That, and the instruction book has grown to such a size that enclosing a copy with every controller is not practical. A "Quick Start" guide is included with the starter kit. With the information in this manual, you can expand the basic system into multiple aspects over the basic three aspect ABS installation.

I recommend the signal system be mounted at some "central" location, keeping the boards grouped together. Primarily to simplify the interconnect wiring. Six inch jumpers are much easier to deal with than six foot long bundles.

Entry of the cabling into this central location must be considered. There will be many, many wires coming in from around the layout. Give thought to routing of that cabling. Should you turn your back for a week and lose your place, tracing wires will be much easier if the bundle contains only the signal cabling. Interference from power cabling is not that much of an issue, but I do control and measurement professionally and I like to take pride in a neat and **organized** installation. Remember, **any** technology more advanced than a round rock will require service or modification eventually.
STEP 3:
Mount the boards

Mounting the circuit boards flat to a surface is recommended against. In many installations, the detection circuit can "see" a dry finger across the rails. Moisture content of wood framing or the condensation on metal framing can cause random detection. I have heard tales of high humidity causing moisture to build up on the board and showing occupancy. Sounded like a poor place for a layout to me; I have never been able to reproduce the phenomenon.

If you really must mount flat to a surface, use small pieces of plastic tubing as stand-offs. Drilling holes in the circuit board will, of course, void any warranty. Some users have tried hanging the boards by the wires. As a professional electronicist, I naturally take exception to that method. But, it is an option. And will make for long interconnects.

A "card rack" arrangement is most suitable for an installation of this nature. Each card will have upwards of twenty(20) wires attached, many of them jumpers between adjacent boards.

A suitable rack can be fabricated using a plastic shape sold at lumber yards as trim moulding. In appearance, it resembles a piece of 1 inch "angle iron" made of "blow moulded" styrene. Slots cut with a hacksaw hold the cards. The other "leg" of the angle is then attached to the mounting surface. Or use PVC pipe with saw slots.

Such a "rack" may be fabricated from "dimensional" lumber as well. A "standard" 1x2 is actually 3/4 by 1-1/2 inch. Make a saw cut (kerf) across the wide dimension, every 1-1/2 inch, to a depth of 1/4 inch. Two pieces mounted opposite each other form a slotted rack.

Either material will hold screws. I usually recommend #4 by 3/4" sheet metal screws. Metric would be 2.5-3 mm by 15-20 mm. Sheet metal screws are preferred over wood screws for the lack of taper and more aggressive thread form. Please, do make a pilot hole for the screws.

Using "edge connectors" is the preferred method. However, they are a costly addition, and in an effort to keep the cost of the SLC within the budget of a novice are not included. Each circuit connection of the SLC has a solder pad for attaching wire; the connectors are not mandatory.
To fabricate a rack for the edge connectors, mount two pieces of dimensional lumber, or the plastic angle, at a distance of approximately 3-3/4", inside to inside surface. Use the connector as a pattern to get the exact dimension. They will vary some. The structure should resemble a double legged (H) or a section of a ladder. The connectors mount to these edges, leaving a "well" for the cards and exposing the electrical connections. Using this method, a metal frame is acceptable, as well. The "angle" shape used for suspended ceiling will work, provided it has a heavier backing material, such as a 1x2, as a stiffener on the sides.

So, why did I not include a mounting bracket? These are "standard size boards... Cheap rascal....

Every installation will be different. In a retro-fit situation, the boards will be imbedded in the existing wiring system. For modular layouts, out of necessity, the boards will be widely spaced. One layout will be framed with 1x2s, the next with 2x4s. Yet another will use structural shapes laid up from smaller parts. Such as an "I" beam laid up from 1/4 plywood. Or even a "box" beam.

I didn't want to burden the modeler with making structural modifications on their layout to accommodate the electronics package. Keep in mind, the space required is not only the cards themselves, but the wiring access as well. For a small system, less than a dozen cards, we are looking at a minimum of two cubic feet. That's a goodly sized space to a model railroad.

The boards should be mounted with a minimum spacing of 1-1/2 inch, 35mm. 2" is better, if you can spare the space. It looks wide right now, but with the wiring added, the space fills up fast. It isn't so much keeping the wires separated. You need room for your hands to work around the connections.

Be sure to provide routing space for cabling, as well. I mention elsewhere modelers that bring the track returns into a bus near the controller cards. It keeps the sense leads short and protected. You should also consider future expansion. Convert to double track along the front and suddenly you need to add four more cards.

Another thought is to route power supply leads down each side of the card rack. Positive or A-C on the Pin 1 side and Return or Common on the Pin 22 side. A few inches removed, of course.

Suddenly, that two cubic feet doesn't look so empty....
Electrical Requirements

With all that foofarah out of the way, let’s run some wires. As is always the case, we need to attend to power supply first. As I have stated earlier, the power requirements are very forgiving. There are a couple of MUST’s however. The power supply **MUST** be transformer isolated from all other electrical devices on the layout. Do not attempt to use the “accessory” terminals on a power pack that is connected to anything else.

A further concern here is that the signal system could become power hungry as it grows. The electrical load will be dependant on the type of lamps used on your layout.

Most signal models today use LEDs as lamps. With LEDs, the electrical footprint of a single SLC module, with the signal, is less than 50mA (0.05 Amp). What that means is that twenty SLC modules will load about an Amp. Or, to compare to rolling stock, the average "off the shelf" H-O model locomotive uses about as much power as ten blocks worth of signals. If you use large lamps and repeaters, you will need more power. That lamp current must be considered when planning a power supply.

In addition to lamp current, the resistors in the logic circuits use some power. It is normal for them to be warm to the touch. If the circuit board starts to discolour, the supply voltage is too high. Socket vertical and 8-12 volts D-C supply is **preferred.** GOW lamps last much longer, as well, at this reduced voltage.

The other point is that the supply **MUST** return to a track common (and ground if your system is so configured). In the instructions that follow and in most of the drawings I refer to this rail as the "SIGNAL RAIL". For a "CAB" control system, it will be the COMMON rail. This detection system is also in use on numerous layouts with NMRA standard DCC. They are known to work together. One leg of the DCC supply will become the "Signal" rail. Just be sure to use the same rail through-out.

There are exceptions, though; even to this rule. If you have a two wire system, the internal detection may not be the best option. Don’t worry, there are several alternatives. Same with A-C; see Section 3.
STEP 4

With the controller modules physically mounted the way you want them, determine a location for a power bus. Normally, when I design a layout there is a heavy (AWG 10) bare wire that sort of wanders around the entire layout. It is grounded to the building electrical supply and serves as a common point for everything. Such a bus is somewhat heavy handed if all it's for is signals. AWG 16 is more than sufficient.

A convenient source of reasonably sized wire is a piece of AWG 14 solid NM, (Romex) such as that used for residential wiring. A little large perhaps, but readily available and much less costly than "hook up" wire. Most any electrician can spring for a few of feet of scrap. And, the solid wire will hold its' shape when you dress it.

The power leads for each controller will normally be carrying lamp current. This could be as low as 10 mA per signal head to as heavy as nearly an amp. I recommend you treat it as worst case. In any case, each controller should have separate power leads to the bus, they should not be "daisy chained" between boards. AWG 24 is sufficient for this short run, or use a piece of the signal head cable.

For a small system of less than a dozen boards, a 9 volt battery eliminator is a good source of power. Such "wall warts" are so universal they are almost invisible. You probably have a few in your junk box. 12 volts is even better. The preferred supply is 8-12 volts D-C; but the board will work with 8-18 volts A-C or D-C.

Connect the power supply (−)Negative to pins 13 or 14 from each controller to the common bus. Remember to leave slack in the wires to permit dressing into a cable later. Connect the power supply (+) Positive to pins 5 or 6. For an A-C wall wart, just pick a wire, it won't matter.

Should you install a control transformer with direct line connections, be sure to install the high voltage side per the local Electrical Code, noting that the common lead of the low voltage side must also be grounded. You might find it easier to install an external rectifier at the transformer. Doing this permits using other accessory circuits on the same power supply. Connect negative(−) to common (ground) and positive(+) to power.

A good source of power is an old "Home Computer" supply. Details on converting them for utility use are covered in the section of the manual called "Random Thoughts".
STEP 5
Signal Lights

There are numerous signal models available, many of them of exquisite construction with brass castings and etchings. There are also nearly as many electrical standards for connections. Lamps vs. LEDs.... "Colour Position" vs. "Search-Light" vs. "Semaphores".... The SLC-32 can accommodate most any signal model I have yet to encounter. It is merely a matter how to connect the wiring.

These instructions are based on the use of incandescent lamps. That is the simplest way to present the concepts. A three colour position signal with LEDs would be connected similarly. Connect the LEDs as "Common Anode" and insert a current limiting resistor in each lead as it exits the signal model and runs to the SLC. For any other signals, please refer to "Advanced Techniques".

With power in place, now is the time to wire the signal heads. Each signal head requires four(4) conductors. I usually use four conductor telephone "station wire". It is correctly colour coded, cheap and easy to acquire in large quantities. It also binds together all the conductors for a given signal, making for a tight installation.

Using "CAT-2" or "CAT-3" cable will work. I recommend against using the extra conductors merely over the confusion factor. If the cable is carrying multiple circuits, you could lose your place in a hurry. Abandon the extra conductors or better still, burst the cable out and use the individual wires.

Because many applications of the SLC use incandescent lamps or relays, current limiting resistors are not installed on the circuit board. For Signal Aspect LEDs, appropriate resistors are included with the LEDs. For others, a dropping resistor will be required for each LED. (Minimum recommended value: 680 ohms)

Assuming the use of station wire, BLACK connects to the “LMP” pins (1 or 2), providing power to the signal head. RED, YELLOW, and GREEN, of course, connect to each individual lamp, observing east and west. Although normally one considers BLACK as a ground wire, in this case it is hot to the signal power supply level. There is no current limiting for this wire; if a metal signal head goes to ground, the current could lift traces on the circuit board or the power diode on the controller board may open. I said the board was almost bulletproof. The diode is rated at one (1) Amp; in theory to provide circuit protection. These diodes are notoriously unreliable as fuses, however, and may not fail.
SLC Connections

Note that "Control" and "Signal" gaps needn't align.

See text for Detection Options

LED Connection Options

Single Signal Head

Searchlight

Semaphore

Signal Logic Controller
STEP 6
Smoke Test

Now is a good time to test the installation. Make one last pass checking all the wiring. Power on the system, look for smoke and listen for any unusual sound, then power it off again, quickly. If nothing untoward happens, pat yourself on the back and power it up again. An electrolytic capacitor connected with reverse polarity will usually make itself known with smoke, a loud report, or scattering pieces of foil for several feet. The pasty substance inside a capacitor is not poison but does have a "decidedly unpleasant" odor.

Check each signal head; the green lamp should be lit. If not, find out why. Is the controller getting power? Is the signal head wiring connected correctly? Heaven forbid the controller is not assembled correctly. Just in case, use substitution and see if the problem follows the board or stays with the wiring. Make this part work correctly before you have all the other wires in the way.

With all signals GREEN, use a jumper to ground the “OCC” pin (22) on each controller in turn. Both signals on that controller should drop to RED. If not, use the same pointers as in the previous paragraph to troubleshoot the system.

When you are satisfied that the RED and GREEN circuits are correct, ground the “PREVIOUS” block leads (9, 15) one at a time and check the function of YELLOW signals operate when grounding the appropriate input. When the YELLOW lights, the corresponding GREEN should blank.

STEP 7
Handshaking (or “look ahead”)

With each controller operating correctly, connect the handshaking lines. “NEXT EAST” of one controller connects to “PREVIOUS WEST” of the next controller to the east. Do the same with “NEXT WEST” to the “PREVIOUS EAST” in the other direction. Test each block as you connect it. Ground the “OCC” pin (22). The block will turn RED as before and the approaches from each direction should turn YELLOW. Should you get a Yellow light at the wrong end of the block, the PREVIOUS lines are rolled.
STEP 8
Tickler Supply

The tickler supply is used ONLY with the onboard current sensing detection and analogue control. If you are using any other detection method, including current sensing with DCC, you may safely disregard this connection. The intent of the circuit is to provide detection of a "standing" train. With no power to the track, a locomotive draws no current, hence the detection circuit cannot "see" it. The tickler provides sufficient current flow to overcome this situation.

The modules require a connection to each rail power feed, each control block, that is part of the protected track. The recommended practice is to connect a wire to the control rail in the general vicinity of the sense lead to the detection diodes. Connect this lead to Pin 17 of the SLC module. There may be some redundancy, this is a fairly forgiving circuit. So long as every control rail in signaled territory has such a lead, the function will work.

STEP 9
Detection

Install the detection circuits. This will be the standard current sensing circuit built into the circuit board. If you purchase pre-assembled boards, they will be delivered with this circuit enabled.

I recommend that each block be tested as it is completed. Should there be a problem, all that you must troubleshoot will be the work done since the last test. To test the detector, place a locomotive or a lighted car on the rails within a given signal block. That block should drop to RED and the approaches go YELLOW from both directions.

Built in current detection

(Alternative Detection methods are dealt with in "Advanced Techniques")

The detection module is nothing more than silicon diodes in inverse parallel. When train current passes through these diodes, there is a predictable voltage drop across them that is measured by the controller and acted upon. There are four, two conducting in each polarity. Your locomotives may start a little further up the scale than before. In most cases, this is irrelevant. If you have adjustable starting voltage, it may need to be increased.
The load is passive, it will not interfere with DCC systems that meet the NMRA standard for signal level. The DCC, however, may interfere with the signals. Should this be the case, an explanation of why and several solutions are covered following, in Advanced Techniques.

Most DCC systems will measure a little over 16 Volts AC with a standard meter, Analogue or Digital. With the detection module installed, you will see this voltage fall off to around 15 volts.

What will be needed is a gap cut in the signal rail at each signal boundary, and one (and ONLY one) path for electricity from that isolated section back to common. Many layouts will have wires from the rail to a heavy copper wire below the track at regular intervals to reduce resistance. I personally consider it good practice to use relatively heavy copper, AWG 18 minimum, for this main wire. Be careful that two such leads do not fall in the same signal block.

Another pitfall is from the jumpers used to get around frogs at a switch. Watch out for rail spikes touching the scenery screen. All current that flows in the rails for that block must somewhere return on one conductor.

This rule applies to DCC and A-C power systems, as well. There are optional techniques to provide magnetic isolation for DCC and to sense current on Lionel and Flyer systems. But, all methods must have insulated sections for each signal block. See Advanced Techniques.

Somewhere in that one wire, between the rail and common, place the detection diodes. Run a wire from the rail side back to the controller. This wire should terminate as near as possible to the diodes themselves, but again, mostly so you can find it later. It is strictly a sense wire and carries a very small current, AWG 24 being plenty large enough.

Connection to the circuit board will be through the “TTL” (16) pin. An assembled board is delivered with straps (jumpers) soldered across the “TTL” position. (JU0 & 2)

When you have connected and tested each controller, the system is ready to run a train. Make up a locomotive and caboose and run it around. Turning off the room lights makes it fun to watch the lights changing aspect.

Play trains; have fun; admire your hard work.
Advanced Techniques

Why all the lights come on with DCC

DCC power applies an "asymmetric" A-C waveform to the rails, usually to the entire layout. Or at least a “Power District”. While this does provide the excitation voltage for a standing train, in some cases it can interfere with the signaling. With the SLC, this will manifest itself with all signals indicating Red and Green at the same time. Possibly Yellow, as well. What is actually happening is coupling between the detection and logic circuits, changing from Green to Red at a high frequency. The high efficiency LEDs sold by Signal Aspect tend to exacerbate the problem because it takes so little current to light them.

There is also a communications protocol known as “Loco Net” that is a form of “Ether-Net” used to connect the various components of a DCC control system. The interconnect cabling is not shielded, causing magnetic coupling from the network cabling into the signals. Loco-Net was a fascinating challenge, I thoroughly enjoyed beating that problem. In the best case, the Loco-Net wiring would have been made with shielded cable. As an Industrial Roboticist, I would have considered that to have been the correct practice. As a vendor however, I must devise “work-arounds” so that my circuits are not affected by that signal.

For any detection other than current sensing, cable routing will usually suffice. The SLC cabling must be kept separated from the DCC wiring. Empirical observations have determined that two(2) feet is sufficient. Some 600 mM. Avoid dressing SLC wiring parallel to DCC wiring. Any close routing of the two should be at as near right angles as is practical.

The DCC power output has a wave shape that is almost a square wave. Almost. There is a steep slope where it changes polarity. In the early days of HiFi Audio, this problem was the cause of noise called "crossover distortion". During this short period, known as the "Zero Crossing Interval", the voltage, and hence the current, fall below the threshold of the detection circuit, approximately one(1) volt. When that happens, the signal logic "sees" a clear block and reverts to GREEN. The clear aspect immediately returns to OCCUPIED as the waveform increases in the other polarity. It all happens in a few millionths of a second. (micro-seconds)
With lamps, and older, low efficiency LEDs this transition is not visible. With most newer, high efficiency LEDs, including Signal Aspect devices, it will cause a dim glow. Look closely at the signal head. The RED will be strong and the GREEN faint, or vice versa. In some circumstances, you may see faint YELLOW as well. This is the effect of your eye interpreting a high frequency flicker as a faint light. Many times, I can't even see it. The customer tries to point it out, and all I can do is agree and try to figure out what is taking place.

The technical explanation isn’t important, that the signals won’t work right is all that really matters.

In the directions for assembly of the SLC board are numerous circuits for the detection portion of the board. They run the gamut from simplest to most complex. Similar to “Advanced Techniques” directed specifically toward getting a clean detection signal into the logic.

If the Twin-T doesn’t work correctly, look there for the various fixes. Often strategic placement of cables will solve the problem.

**Detection Methods**

**On Detection**

There is a saying to the effect that; “*In theory, theory and practice are the same. In practice that isn’t always the case.*” In theory, signaling is easy. Simply tell the signal system where the train is, and watch the blinkey lights.

? A little too light hearted for you ?

Sometimes, you just have to laugh at problems to bring them down to size. Signaling, including detection, is a deep subject. As Model Railroad control systems grow in complexity, it becomes more and more difficult to get circuits from different manufacturers to work together.

A fully integrated system from one source is a solution. If one truly exists... However, in such a case, I could not market my (better) system. In my product line, attempts are made to simplify circuits where ever possible. Not only for ease of assembly, but for reliability as well.

The SLC32 is somewhat “over-engineered” for the function it provides. However, that seemingly excessive circuit is compatible with all of my other circuits. The SLC-32, for example, can drive a positioning servo through an LBO-4 to operate semaphores to three positions. Merely with three wires between the two boards to indicate the signal aspect.
These circuits can also interact with many devices from other vendors without interference. I am a strong advocate of theoretical standardization but at the same time prefer to keep as many options open as possible. Thus my belief in stand-alone systems.

The signal system I produce is designed to be as stand-alone as possible. And to be as compatible as possible with a wide range of control systems. That's why this instruction manual has grown to such proportions; explaining as many different options as possible. I am attempting to do what the major software house isn't. I want to be everything to everyone, yes ... **BUT**. I want you to have the option to do it *your* way. And with those options comes some complexity.

So; a few detection methods...

Of the many methods, my personal preference is **Current Detection**. Why? Because it is simple. And absolute. If there is current flow, there is something on the track. It may be a finger, a lamp, or a nail; or a standing train. Doesn't matter, something is there. The down side is that it is active, it affects the train power and train power affects it. False signals are not unknown. And, plastic wheels on rolling stock don't help, either.

**Optical Detection** is as good, provided there is sufficient ambient light to turn the signal off after a train has passed. A photo-cel between the rails is unobtrusive enough. Several may be required on a long block or with short trains. Infra-red eliminates the need for ambient light but does require optical shielding.

Another method is to use a contained beam, such as a laser diode, with a photo-cel. Placed so that the light beam crosses the track at a shallow angle, this method can cover a long stretch of track. Scenery and train length permitting, it can even operate around curves.

**Magnetic; Reed Switches** in the smaller scales are a little iffy. A magnet, fairly strong, is required on board the train. And mechanical alignment is crucial. With H-O, it can be made to work. With N scale, the magnet may be too large to be practical. Such a system is more common in the larger scales, O-1/4 and above. Usually, this method is applied as a “Check in - Check out” latching system. The train sets the signal on entering a block and releases it on leaving.
Magnetic; **Sensitive Relays** are actually an implementation of current sensing and have largely been supplanted by the solid state current detection circuits. The last reference I have heard about them was in the early 70's, on the Sunset Valley. The entire system was configured around relay logic. Even with small wire, the wiring bundles were as big as a man’s arm in places. It was(is) in use on many layouts, but I am out of touch with them.

Using reed switches in place of sensitive relays can work with the larger scales, but H-O, and smaller, motors are so efficient that there is not enough current to set the signal reliably.

Magnetic; **DCC Current Transducers** are actually miniaturized current transformers similar to those used for instrumentation. In small electronics, they are used to generate a pulse train from the passage of an A-C current through the primary. The primary being the wire that passes through the hole of the “do-nut”.

The amplitude of the pulses is directly proportional to the amount of current through the primary wire. The theory gets into some pretty heavy duty math so I won’t cover it here. But for **DCC** applications, they are an excellent solution to isolating the DCC from the rest of the electrics on a layout.

**Track-side Contacts** are reliable enough, with a Check in-Check out circuit, but again, require a protrusion from the rolling stock to trigger the signal. And the problems with small, light rolling stock would be obvious. This is probably one of the oldest detection methods devised, dating back at least to the 1930’s.

**Trigor-Track®** works, sort of, kinda, sometimes, when you hold your mouth right and squint one eye. Subject to the same restrictions as a track side contact, it cannot detect light rolling stock in the smaller scales. But, it did provide inspiration for a circuit I devised some years back. This little trick is original thought on my part, but has been original thought for countless other modelers over the years. It is by no means a new idea.

Though drawn in two rail, it will work just as well with three rail systems. On a two rail track, a short section of one rail is isolated. It need only be half an inch, 12mm, or there-about. Shorter than the wheelbase of a small locomotive. Just long enough to be mechanically stable. A short span of epoxy and a piece of copper wire would also work. The working rail is jumpered around the insulated section.
This small piece of rail is connected to one coil lead of a relay with the other coil lead hot from a power supply. The low side of the power supply connects to the working rail on either side of the short piece. So long as the supply is transformer isolated, the circuit will be transparent to the rest of the layout electrics.

When a metal wheel crosses the gap, it shorts to the low side of the relay coil, picking it up. The relay output may be used to set the signal or to latch itself in. With some consideration, this approach will work with most any control system.

In either case, an un-latch circuit, just as with “Check out”, is required. I have used this circuit many times, not only for signals but to operate a first-in lockout into an interlocking and as a reversing circuit for display tracks. In those days, of course, relays were far less costly than power transistors.
The layout I use as a “beta test” site is electrically a worst case scenario, with switch selectable “Common Rail” analogue and DCC running concurrently. The DCC is fed through the existing common rail wiring. An electrical nightmare perhaps, but the transition is lengthy because of the size of the man’s locomotive stud. There are still analogue locomotives yet to be converted and many visitors with analogue equipment. Myself included.....

My circuit is not proprietary, merely a carefully selected combination of components that provide the desired electrical characteristics. Although original thought on my part, I’m sure many others have devised the same or a similar circuit.

It was inspired by the Twin-T circuit, developed by Linn Westcott some fifty years ago, when those new-fangled contraptions called transistors first became available. His circuit uses the base of a fairly high power transistor to carry locomotive current. My circuit uses the drop across a silicon diode to bias a smaller signal transistor. Same end result, without the size and expense of the heavy transistors.

And Photo-cels

Optical detection is available on-board the SLC, with jumper selection. The circuit is limited to a single photo-cel and the limitations of a single cell come into play. A long block, or a short train. A better option would be to use an LBO-4 circuit with the capability of using more than one photo-cel.

An LBO-4 can handle up to four photo-cels each, in four circuit iterations. Output of the circuit(s) is “open collector”, a low signal equates to occupancy. Four circuits to a board, known to work with two photo-cels each, in tandem; more if they are hand picked. The same technique as that used for detecting for crossing flashers. Simply route the output to an SLC board rather than an auxiliary circuit.

The SLC has a circuit in place on the board for using photocells. Mount the light emitter and the photocell in soda straws that have been painted flat black inside. When they are aligned, anything breaking the light beam will indicate occupation. The flat black makes a “black body” surrounding the devices, reducing the effects of ambient light.
The original design pre-dates LEDs, especially "lasers". The circuit was developed and is balanced for using a "pen-light" lamp number 222. That lamp has a fairly concentrated light beam from a lens cast into the front of the lamp. Actual usable distance varies, depending primarily on ambient lighting and absolute sensitivity of the photo-cel. The range, in typical use, was four(4) to six(6) feet. (just under 2 meters)

CAUTION

Lasers produce an intense beam of "coherent" light at considerable distance. You should NEVER look into the laser at the beam.

It will blind you... Painfully... Forever...

- Use of this page is at your own risk –

Professionally, I work with Fiber Optic Communications systems. Lasers are a known hazard in the field. Or read the directions and labels on a Laser Printer or copier. Lasers are dangerous.

The optical detection circuit has been tested using a laser pointer as a source. The circuit function is rock solid at over 30 feet. That’s a long passing siding.... Of the laser diodes tested, all performed well, lasing reliably at 14mA at around three(3) volts.

Laser pointers are available at discount outlets and office supply houses at low to moderate cost. Dismantling the assembly will reveal a brass bound optical device with two leads. Often with no resistor....

To use as a source for signaling, install the laser as you would the source lamp in the drawings. Use 1000 ohms (1K0) resistance as a starting point. At 12 Volts (D-C of course) the diode should "lase". That means it creates a visible beam that can be seen as a spot of light on a piece of paper. Use the highest resistance possible that allows consistent lasing. Be aware of what is behind the photo-cel.
Cutting a chord across the arc and using mirrors will allow detection around a curve or in a tunnel. There are other, non-railroad possibilities for this application. But I didn’t tell you about them.

You may want to use an “Infra-Red” photo-diode pair. Although the circuit has not been tested with these, the base pull-up resistor will serve as a current limiter for the diode connected to common. If you opt for a phototransistor, it will require its own collector (load) resistor.

In Section 3, Signaling with the LBO-4, there is a circuit that is imminently suitable for optical-detection. Containing four independent photocell amplifiers, each sensing up to four(4) photo-cells, it can provide detection for multiple blocks, hidden tracks, staging tracks, or as an input to the 3 Aspect SLC systems.

Alternate Detection

Check-In / Check-Out

There is a very old signaling system referred to as "CheckIn - CheckOut". It uses trackside contacts to set up a latch circuit when the locomotive enters the block. As the locomotive leaves the block, the latch is released and the signal returns to "Clear". The concept, and its many circuits, date back at least as far as the NMRA. Into the ‘30s. Or even further.....

Personally, I have not seen this method used in over thirty years. However, just because I haven't seen it doesn't mean it isn't a viable control method. It is certainly suitable for directional track; where a train only operates in one direction through a given block. Such as would be seen for a high traffic density double track main line.

I am told that Check In - Check Out is still used on many large layouts. The Signal Aspect SLC will indicate such a system using an external latching circuit. It is the perfect drop in replacement for an existing system that is upgrading.

Signal Aspect produces another circuit board, called the "Latch Bridge Oscillator", or LBO-4, for use in general purpose applications on Model Railroads. The -4 is to indicate there are four iterations of the essential circuit on one board.

One of the options for this board is a latch circuit, known in the Electronics field as an "R-S Flip-Flop". There are numerous methods of triggering this circuit suitable for Model Railroading. Specific details are given in the section Signaling with the LBO-4.
For the larger scales, where motors will draw at or above an amp, current sensing is possible through the use of reed switches. This technique is well suited for the older, A-C powered motors, as it is isolated from all rail power. It can be used on H-O locomotives, but requires some finagling and isn’t really reliable at the low currents common to this scale. Re-motored Flyer may have the same problem. If the motor pulls an amp or more, it’s pretty solid.

If you hit a brick wall

go get some coffee, read some Heinlein, or take a nap. No system is worth getting frustrated over. Remember:

**Model Railroading is supposed to be Fun!**

These directions have been tested on real life layouts. The circuits and directions both serve their function well. As the designer, however, I may be too close to the circuit to see all the possible problems. I can be contacted at the following eMail address:

signals@HudsonTelcom.com
Advanced Techniques
Signal Models, Alternative Connections

In the basic installation directions, I used incandescent lamps to illustrate the electrical connections. At the time of the original design, that was the primary method for lighting signals. With the advances of solid state technology, many types of LEDs have become available and the options for signal models have expanded exponentially.

In the instance of a three colour position signal, many suppliers provide the LEDs pre-wired in a "Common Anode" configuration. This is the simplest form to implement. The LEDs simply replace the lamps in a circuit. Positive to the "top" (common) and the negative colour leads to the SLC outputs, with suitable limiting resistors.

"But," you say, "my signal model has 'Common Cathode' connections. The three colour wires connect to a positive supply and the common cathode to ground."

At first thought, the inclination is to try to invert the logic of the SLC. A complicated process involving re-design of the board in the long run. The end result is a mixed lot of controllers that are not interchangeable. The very situation I designed to avoid.

The matter is much more straightforward when one inverts the "logic" of the signal model itself. The solution then becomes a hand-full of small diodes and the time to grasp the concept and make the connections. The diodes required will be same as used on the SLC board itself. 1N914 or an equivalent. Some extras are packaged with the SLC. If you need more they are readily available at negligible cost.

What we are going to do is light all the LEDs from signal power and then blank the ones we don't want for a given aspect with the SLC. Since they are LEDs and require a current limiting resistor; and with common cathode this resistor must be on the positive side of each LED, the resistor is between signal power and the LED. When you use a jumper to "ground" the connection between the resistor and the LED, the LED goes dark. The resistor prevents a "short circuit".

We then control this "blanking" with the SLC outputs, through the small diodes. For a GREEN aspect, we blank RED and YELLOW. For a RED, we blank GREEN and YELLOW.

The drawing below illustrates this much more clearly than can be expressed with text. The small diodes permit connecting the multiple circuits together without them interfering with each other.
The circuits of interest are to the top left. They illustrate both Common Anode and Common Cathode connections for a three colour position signal head.

In most cases, the power supply labeled as "Vsig" is Pin 1 and 2 of the SLC card, feeding out to the signal itself. I call for using a four wire cable to each signal so the circuit can be readily dressed and traced. If an external signal supply is used, be sure to reference the return line to the SLC common.

I also highly recommend connections such as these be made as close to the signal as practical.

**SO WHY?**
If the resistors or other components were placed near the SLC, touching a field wire to ground by mistake could let the smoke out of an LED and it wouldn't work anymore.

The outputs of the SLC are either floating or at ground. Grounding anything connected to it will have no effect beyond possibly setting the signal until the ground clears. With the components near the signal, all wiring is pulled to ground in the normal course of operation. Only the signal power lead has any risk.

Advanced Techniques

Signal Models, search-light connections

As with colour position signals, search-light signals have improved dramatically with the introduction of LEDs. In the "old days", the usual method in small scales was to use a "light pipe", a plastic rod, to transmit light from lamps below the layout to the target face. Electrically, these were identical to colour position signals. Thankfully, we have advanced far beyond that arrangement.

There are LEDs produced that contain multiple "junctions" in a single package. One has two LEDs in "inverse parallel", the other type contains two junctions with one end connected together. In both cases, the practice is to use one RED and one GREEN. When both are lit, the resultant colour is a "sort of" orange-ish or amber-ish colour.

The quality of this mixed colour is a function of the quality of the LED and is, for the most part, beyond the control of the SLC electronics. There are methods that can adjust within a narrow band, but these methods vary as widely as the LEDs themselves. I can't cover the subject readily without teaching you the finer points of electronics. There is no universal fix.

The first type of LED, the inverse parallel, will be identifiable by having only two leads. Colour is changed by reversing the current flow through the LED package. The third colour is achieved by switching the polarity faster than the eye can resolve the individual colours. This device will require an external control. Refer to the section Signaling with the LBO-4 for a deeper explanation of the methods for dealing with these devices.

The latter type of LED is identified by having three(3) leads. They are then further separated into "Common Anode" and "Common Cathode". The difference lies in whether they must be driven directly or with inverted logic. Either method is accomplished with diodes, just as we saw in the colour position example previously.
In both cases, the illustration above conveys far more information than several pages of text. If the instructions (if you have them) for the model identify the device as Common Anode or Common Cathode, merely match their diagram to the circuits to find the appropriate method.

Starting with the "Common Cathode" arrangement, such as used by TOMAR®, connect the common wire, the white, to signal common or ground. Using two resistors, connect the two colour leads to positive signal supply. Pin 1 or 2 of the SLC. This will produce the YELLOW or "Approach" aspect and will be the default condition.

Next, use a jumper to ground the connection between the resistor and the RED lead from the signal. The RED will blank, leaving a GREEN aspect. Conversely, ground the GREEN lead and the LED will blank, leaving a RED aspect. It can be readily expressed in Boolean, but I’m not going to burden you with it. No diodes are required for this application, though I do recommend you use them. The extra 1N914 diodes in the SLC package were provided specifically for this type application.

Connect the diode with its' painted band toward the SLC output connection. Should there be a fault, the diode will normally fail before the SLC output transistor. Connect the RED lead to the GREEN output and the GREEN lead to the RED output. Be sure the resistors are between the outputs and power! Leave the YELLOW output of the SLC open. (disconnected)

Should your signal model have Common Anode connections, the issue is a little more complex. Here, we must light each LED, RED and GREEN as appropriate. For YELLOW, **both** must be lit. This is also readily achieved through steering or isolation diodes.

The LED will be connected as though it were a three colour position signal, with the LED common to signal positive and a resistor in each of the colour leads. Connect the appropriate colour leads for RED and GREEN, through a diode, to their corresponding SLC outputs. As before, the painted band is toward the SLC connection.

The YELLOW output from the SLC will have two diodes, band to the SLC. These two diodes will then connect to the leads from the resistors, alongside the other diodes. The result should physically resemble the letter "M", with two connections to the signal and three to the SLC. Again, all four bands will be toward the SLC output connections.

Such a primitive "Diode Matrix" has been used in the hobby for many applications for as long as diodes have been available.
Approach Lighting

To quote Mr. Richard Schumacher, of Gateway NMRA, St Louis;

Battery power is conserved by real railroads with the use of approach lighting, where the signal is off until a train approaches it. For model railroads, approach lighting usually reduces the impact and effectiveness of the signals.

His clinic on signals may be found on the internet at: http://www.gatewaynmra.org/detection3.htm

Well worth the visit, although I like to think my circuits are better.... What he implies is that, as a general rule, approach lighting is seldom used on Model Railroads, except in cases where accuracy is paramount. (Or the modeler prefers it, the true bottom line for accuracy)

With approach lighting, there must be provision for blanking the signals selectively. In theory, a relatively straight-forward process. But, as with many theories, it is complicated by the plethora of connection methods used by signal models.

On first thought, the most direct method would blank the outputs of the SLC. However, some signal models are 100% lit and the SLC is used to mask individual lamps, as shown on page 32. And too, this could easily lead to “non-standard” controllers, something I avoid whenever possible.

My method is to blank the actual signal, powering it on as needed. That way, the logical outputs from the controller are still available for other control purposes such as panel repeaters. As noted, it also keeps the signal board version consistent across the layout.

I will concede, such a method can get complicated from the many different connections available for signal models. This is one of those issues where personal preference has a broad impact. My design is as near universal as I can make it; independent of any control system (AC, DC analogue, or DCC) so the SLC will accommodate as wide a range of personal preferences as possible.

There will be two separate functions in the control circuit. Methods of blanking the signal itself will be dependant on the model used and how it is connected. Determining proximity will be essentially the same for all methods.
Since this is my railroad and I like pre-USRA steam, the 4-6-0s have slide valve engines. (Though if you can see that, your eyes are much better than mine)

In the illustration above, there are two trains, one following the other. Let us assume Train 1 in Block (5), upper right, has stopped for a passenger whistle stop. Train 2 in Block (2) is a freight and is moving fairly slowly.

The East-bound signal for Block (4) is dark. As Train 2 advances into Block (3), both signals will light Red; the block is now occupied.

Both signals for Block (4) will light Yellow. The “Next” block in both directions is occupied.

The Westbound signal for Block (2) will light Green and the East-bound will blank. Both signals for Block (1) will blank.
Decoding Detection

The SLC provides inputs for detection from adjacent blocks so the Yellow (approach aspect) can be displayed. This provides a convenient point to tap into the detection circuits. Each end of the block will be lit separately until the train is actually in the block. At that point, both signals come up and the next block is in lighted approach mode.

Lighted approach will not be available in the first block out of “Dark Territory” unless you have a detection circuit to provide “approach aspect” already in place in the first (or last) dark block.

Because the SLC uses the common practice of grounding an input to operate a circuit, the circuits are so configured. Pin 20 and 21 of the SLC are the detection amplifier. They “ground” through an “open collector” NPN transistor, providing “NEXT” outputs to fan out occupancy in either direction to the “PREVIOUS” inputs of adjacent controllers. It will be necessary to measure occupancy in the home block twice, a separate diode for each directional circuit. Along with the “Previous” inputs, this will total four diodes, 1N914s being sufficient.

Observe the banded end of the diode(Cathode) Make up each diode with a short (3 or 4”) piece of small wire attached to the Cathode end. Connect the Anode ends together, also using a piece of wire, somewhat longer this time, perhaps a foot. This assembly may be covered with “heat shrink” tubing if you use it. Or left open for diagnostic purposes if you prefer and there is space.

They will be attached as follows:

[ ] Attach the cathode leads of one pair to SLC Pins 21 and 15.
[ ] Attach the cathode leads of the other pair to SLC Pins 20 and 9.

If the SLC has an edge connector, these leads may be “double lugged” to the connector, soldered alongside the existing wires.

The two single leads from the anode end of the diodes are now the directional detection lines to the signal, either to ground or to a power control module, depending on signal wiring.

For Common Cathode connected LEDs, no further circuits are required. Where the LEDs are tied to ground, route them instead through the two leads in hand. If you get them backward, the wrong signal head will light up in use. Swap the two leads ...
The right hand illustration is the “Power Circuit” required with Common Anode signals. This is the suggested method if using lamps.

In the smaller scales, the transistor will accommodate current up to 100mA per lamp. For the larger scales and specialty applications, a relay may be substituted. The equivalent relay circuit is shown.

Use of automotive power relays is recommended against. They often have high coil inrush and require substantial snubbers to keep fly-back out of the transistor circuits. P.C. Board mount relays are available at moderate cost from many sources. (including Signal Aspect)

A power control circuit is available on the LBO-4. There are four iterations per board, for controlling four (4) blocks. For operating in directional mode, the board can be split to provide control for up to eight (8) blocks. The LBO connection diagram and circuit board layout:

Power supply can be external or tapped into a conveniently located SLC. When the Common Anode lead to the signal is routed through the control switch, Pins 1 - 4 of the corresponding SLC become available.
Advanced Techniques
Signal Models, Semaphores

Countless semaphore actuators have been devised over the years, probably since there have been railroad modelers. This is by no stretch a recent issue. I have seen the extremes from a dual solenoid with a rocker bar and cams, to a fluid controlled "dash-pot" device to a motor driven actuator with limit switches and a box full of relays.

A simple method of my own devising involves a centering spring to force an APPROACH aspect until operated off center by the mechanical control. In almost every case, however, it involved a (momentary) pulse to position the signal. A maintained output was too power hungry.

As with "Solid State Lamps" (LEDs), advances in technology have brought many low cost solutions to our door-steps. R-C Servos are now readily available at moderate to low cost. What I have developed is a packaged control that contains two independent servo drivers and two servos to operate the semaphore arms. The end result is a circuit that permits use of these Model Aviation servos in Model Railroad applications.

As with many new devices, once the original is developed, many other uses come to mind. Refer to Section 5, Servos with the LBO-4 for further uses of this very useful circuit.

The primary advantage of the servo operation of a semaphore is the ability to position the arm with a constant signal, in this case, the open collector output of the SLC. In addition, the servo will maintain its position against force sufficient to deform the model, so is quite stable.

The greatest advantage (to my thinking anyway) is the ability to adjust the actual position of the signal arm within a degree of arc with an electrical adjustment. Within reasonable limits, of course. Although each position can be made adjustable, I made the default (HOME) position fixed. The linkage is "zero-ed" to HOME position and the other positions are then adjustable, within their band.

In normal operation, the servo would be HOMEd for the HALT aspect. Should there be an unknown condition or loss of power to the signal system, the arm would then set itself at HALT. Not really necessary with a model, to be sure, but it is impressive.

Again, refer to the section on LBO circuits for specific details. This introduction is because semaphores are an integral part of signaling.
I must concede, I have not investigated the semaphore model produced by TOMAR®. What I have seen of their product line is impressive. For my development on the bench, I used a product from NJ International®. That particular model has a solenoid actuator built in. The solution I have devised involves disabling that actuator and using an external operator.

And, just to keep the record straight, the Tortoise® switch machine has an available controller to operate three aspect semaphores. The product is merely an output device, it contains no detection or signaling logic. However, keep in mind the original design of the LBO-4 was specifically for use with the Tortoise machine.

There is a brief period in the motion of the Tortoise arm when two contacts are shorted. This represents the approximate center of travel. That point may be used to indicate APPROACH and cease motion. I have yet to develop a circuit for this because I like to think I have the better solution with servos. For several reasons, actually.

First, and most important, I can provide the LBO-4 with two(2) servos at the price of one Tortoise with the servo option. That covers both ends of the block, two signals, with one module.

Secondly, a linear actuator is subject to displacement or drift when it is powered down. The LBO servo resists displacement with surprisingly high torque. Often enough torque distort the signal or bend the linkage if you try to force it.

Lastly, and certainly the most "user friendly" reason. A linear actuator must operate the signal mechanism through a linkage. That mechanical linkage must be adjusted for all three positions. And requires maintenance of that adjustment.

With the servo, a linkage is adjusted only to its "home" position and approximately to the opposite end of travel. Fine adjustments are then made electrically, with trimmers. Future adjustments are merely a matter of setting the desired aspect and "tweaking" the arm back into place with the internal trimmers.

Another, albeit esoteric, solution involves the use of a "Muscle Wire" from the Robotics hobby. When current is applied to the wire, it contracts a measurable amount, proportional to the current applied. In my experiences with this remarkable material, the motion is consistent and repeatable. However, using it for signaling involves considerable mechanical tinkering.
Advanced Techniques
Moving Beyond 3 Lamps
Alternative Signal Displays

There are probably as many methods of providing guidance to a train "head end" crew as there have been railroads since the advent of trackside signals. I am not going to attempt to cover the subject in depth. Signaling will be as individual as the modeler. I will suggest you read up on the subject, starting with the NMRA data sheets at D9g.

From there, you should look up any books you can find on the subject. The "Inter-Net" is an excellent source for information, as well. The subject can easily fill a library shelf. A long one. Take some field trips to watch your favorite road, especially at a junction or interchange, if you can get to one. Watch how they signal, and try to comprehend what the different aspects actually represent. Then develop your own signaling standards for your road.

Perhaps you are fascinated, as I am, by the round signal heads common to the B&O or N&W. But want to use a different definition for the aspects. For many modelers, signaling has become a lifelong obsession and the primary reason for running trains on a layout.

In my case, a small industrial and mining road of the late 19th century has little need for signals. But, I am interested in the subject, so have signals where none logically are needed. So what, it's my railroad. And, who needs to "Drop Pans" (pantographs) on a Steam road, anyway.

I bring this up as an introduction to a portion of the directions that will require some thought and decision making on your part. When you are ready to move beyond a basic, three aspect signal system, you need to understand where you're going. I can't build a ready made module that does what you want because you often don't know what you want yet. And why should you be limited to what I have designed? Nor can I build a module specific to some esoteric railroad that only lasted 30 years and disappeared into the mists of anonymity.

What I do provide is a core electronics package that has enough access to the logic functions that you can add, remove, modify, or duplicate most any function through the use of a few external components. Such as you would do in the directions for Common Anode Search Light signals. A hand full of diodes, applied "just so" and you have a signal system that does what you want it to do.
As a first step in this direction, I present a method of displaying three aspects with multiple signal heads. This illustration is a subset of the previous drawing. These signals are in common use over much of the country. Each signal head has two lamps, rather than three. With two targets, there are now four lamps. Each lamp has only one colour, just as the 3 lamp colour position uses. In the illustration, we are going to restrict things to manageable proportions. Merely a novel or different method of displaying the basic three ABS aspects.

On the left is the essential colour position method from the basic installation. Next to it is the same display using two dual lamp signals. And to the right, the same again, using two dual colour search light signals. In each case, the display is only the basic ABS three aspect display. What I want you to study is how the different lamps are lit to provide the desired result. The information is similar to that dealing with signal model variations. The use of a "diode matrix" to light (or mask) an LED to get the desired display for an aspect.

Using this method, you can make up any combination that suits your taste. Use one search-light over one dual lamp. Or the other way around. Make it the way you want it. And it’s still three aspects....

Now, let’s make things interesting.
Yes, the SLC is capable of generating these aspects. With suitable interconnections and diodes and contacts on switch machines, and other external controls. **Without** investment in specialty controllers.....

And no, I am not going to include the wiring diagrams for doing it. First off, I don’t want to fill up this manual with information that maybe one user in a hundred would want. And too I haven’t the time to adapt to every possible track arrangement that would justify such signaling. But I **will** tell you that with planning, it is possible.
Module Assembly:
Assembling and testing the component kits

Assembly of the circuit board will require minimal soldering skills. If you already solder the wiring on your layout without melting insulation or cross-tie strips, you should have sufficient skill. But anything over a 40 watt iron is out. Sorry . . .

For any hobbyist that solders on a casual basis, may I recommend an essay on basic soldering that is included in the "Random Thoughts" section of this manual. Building my circuit boards doesn't require "Aerospace" grade work, but there are limits to what the small components can take. Comments and recommendations on technique by an old hand in the electronics business may help you to improve your skills. Please understand, I cannot warrant boards where the foil traces have been burned off from overheating.

Recommended bench space is the typical two square feet. Equipment needed is: Soldering iron on the order of 20-30 watts. (my bench iron is 20W, the field iron is 32W) Also, long nose pliers, small wire cutters, flush cut if available. A clip on heat sink is nice, the pliers may be used if you must. A jig to hold the board is optional but not necessary. I don't normally use one unless troubleshooting. Use Rosin Core solder, do not use an acid based flux. An old toothbrush and denatured alcohol make for good flux removal.

For bench testing after assembly, you will want a power supply 8-12V, a test lamp and a couple of jumpers with small alligator clips. I use a 9 Volt "Wall Wart" for a testing supply. A 9 volt battery will suffice. A 16 volt "Grain of Wheat" lamp can serve as a test light.

Package Contents:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>4700 ohm</th>
<th>Yel-Vio-Red</th>
<th>(4K7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Resistor</td>
<td>2200 ohm</td>
<td>Red-Red-Red</td>
<td>(2K2)</td>
</tr>
<tr>
<td>2</td>
<td>Resistor</td>
<td>2N4401</td>
<td>(NPN)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Transistor</td>
<td>2N4403</td>
<td>Yellow face</td>
<td>(PNP)</td>
</tr>
<tr>
<td>1</td>
<td>Transistor</td>
<td>1N400x</td>
<td>Reverse power protection</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Diode</td>
<td>1N914</td>
<td>Small signal detectors</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Diode</td>
<td>33-100uF</td>
<td>Value varies</td>
<td>(Filter)</td>
</tr>
</tbody>
</table>
There will be three jumpers soldered on the board. They are made of trimmings from the diode leads. It is suggested that components be "layered", smaller components installed first. It allows the board to be pressed flat holding the components in place as they are soldered. These instructions will proceed in that fashion.

Start with the bare board; place it so the white patch is to the upper right. Pin 1 is in the near right corner. The edge connector fingers are on the foil side of the board. They appear as shadows in the illustration.

There are two white lines to the left of center, about an inch from the edge. The lines locate jumpers and help to separate the detection logic(left) from the signal logic(right). All components of the signal logic portion are of the same value, excepting the power diode at D-1.

You will build only to the white lines in this step. The detection circuits are covered later. You must have determined the method of detection before working beyond this step.

[ ] Install a 1N4006 Diode on the right side of the board below the white patch, identified as D-1. This is a large, black plastic rectifier diode. It may have another part number, but will be black with a silver band and larger than the resistors. Be sure the band is up. Solder and trim.

[ ] Install 4 pieces 1N914 Diode in the top row as indicated by [D]. These are glass diodes, all with the band toward the top of the board. Solder and trim.
[ ] Install 5 pieces 4K7 (Yel-Vio-Red) Resistor in the top row as indicated by [R]. All colour bands aligned is a sign of good workmanship but has no bearing on operation of the circuit. Solder and trim.

[ ] Install 8 pieces 1N914 Diode in the middle row as indicated by [D]. Be sure the band is toward the bottom. Solder and trim.

[ ] Install 4 pieces 2N4401 Transistor along the lower edge of the board, as outlined, from the right side inward. Solder and trim.

At this point, the method of detection must have been decided; for on-board CURRENT DETECTION, continue with the assembly below. An option follows for using a relay to isolate the signals from track power.

For any other method of detection, please refer to the instructions that are given in the "Advanced Techniques" and "Detection" instructions that follow.

This illustration is oriented with the edge connector fingers to the right. It allows a closer view of the components involved.

[ ] Install 2 jumpers as marked in the middle of the board. JU-0 and JU-2.

[ ] Install 1 piece 4K7 (Yel-Vio-Red) Resistor in the last resistor(R-7) location to the bottom left. Solder and trim.

[ ] Install a jumper at the diode location along the left edge of the board. Solder and trim.

[ ] Install 2 pieces 2N4401 Transistors at locations Q-11, 12. Of the transistor outlines in the detection circuit, they will be the lower and middle.
Install 1 piece 47uF Capacitor thusly: Between the upper jumper and the 4K7 resistor will be two pads. The left one is marked for a resistor, the other is unmarked.

Install the capacitor with the positive lead into the lower (resistor location) pad. Electrolytic capacitors are usually marked with a broad stripe on the (-)Negative side. Connect this in the right (unmarked) pad.

For a low profile (close) installation, it is suggested the capacitor leads be left long enough to fold the capacitor back over the top edge of the board. If a high profile and shallow depth are preferred, leave it upright. Solder and trim.

Relay Isolation

Users may prefer using a relay to isolate the signal system from track power. A relay also permits use of Twin-T current sensing with DCC. Should you prefer the use of a relay, proceed with detection assembly as shown below.

Install 1 jumper as marked in the middle of the board, at JU-0.

Install 2 pieces 2N4401 Transistors at locations Q-11, 12. Of the transistor outlines in the detection circuit, they will be the lower and middle.

Install 1 piece 47uF Capacitor thusly: Between the upper jumper and the 2K2 resistor will be two pads. The left one is marked for a resistor, the other is unmarked.

Install the capacitor with the positive lead into the left (resistor location) pad. Electrolytic capacitors are usually marked with a broad stripe on the (-)Negative side. Connect this in the right (unmarked) pad.
[] Attach the relay AZ-943 to the circuit board in the location shown. This will be a close fit, the component solder pads must be left accessible. “Super Glue” or a silicone sealant may be used to attach the relay. Most common plastic cements will not hold to the circuit board.

[] Install a wire lead from the exposed solder pad of R-7 to the left coil lead.

[] Install a wire lead from the right solder pad of JU-2 to the right coil lead.

[] Install a wire lead from the lower solder pad of Q-21 to the top contact pin.

[] Install a wire lead from the left solder pad at D-10 to the lower right contact pin. Either solder pad may be used.

[] Install a wire lead from the right solder pad of D-10 to the lower left contact pin. This normally closed contact provides a “Clear” output at Pin 22. If a clear output is not required, this lead may be omitted.

Use of this option will be transparent to both the external connections and for signal connections. The only effect will be a clicking as the locomotive crosses into the protected block.

Testing

Apply AC or DC to pin 5. Connect the return to pin 13.

Connect a test light on pin 1. Check to pin 8, then pin 11. Both should light the lamp. (Green circuit)

Jumper pin 13 to pin 22. Pin 8 and 11 should not light, but pin 19 should (Red circuit).

Jumper pin 13 to pin 9. The lamp should light on pin 7, not light on pin 8. Jumper pin 13 to pin 15. The lamp should light on pin 10, not light on pin 11 (Yellow circuits).

If an output stays on, look for a solder bridge or a shorted transistor. If a function doesn’t light, look for a cold solder joint or reversed diode.

If any component other than a transistor is installed reversed, the board will not be damaged, but will not operate correctly.
Clean and Inspect

Clean the solder side of the board with denatured alcohol and an old toothbrush. Examine the foils very closely for solder bridges and cold joints. The design of the board accommodates the novice by providing wide spacing of the component pads and is such that solder bridges should not be a problem. However, I have been in this business many years and experience dictates that as soon as you get over-confident, you will get a bad solder joint or bridge. When I preassemble the boards, I get a cold joint about every fourth or fifth board. And I am the expert (supposedly). It pays to take your time.....

Let’s play trains!

Construction of the board is complete. Continue with the installation procedures in Part 2 when you have enough completed boards. If you are “normal”, you’ll want to see the system “do something”. It takes a minimum of three (3) modules to get all three aspects.

*******************************************************************************

Other Detection Methods

Many installations will use external detection sources. There are numerous formats. For most of these, special component positioning will be required. The board was designed to accommodate such applications by having extra solder pads in strategic locations.

These instructions cover the more common possibilities. For any method not covered here, feel free to ask. My eMail address is:

Signals@HudsonTelCom.com

Existing relay logic, trackside contacts, and any other “dry” contact closure will be connected to Pin 22. The only assembly requirement is the installation of a jumper wire at location D-10. Should isolation be desired for logical purposes, such as setting all signals red with a switch, use a 1N914 diode at this location. There is no latching circuitry on board the SLC. Any momentary contact must provide its’ own latch such as would be found on the LBO board from Signal Aspect.

Signal level will be “Grounded” for occupancy, open for clear.
**Positive True Logic**

In this protocol, the “Occupied” signal will be a positive voltage of some nominal value to indicate occupied. This output is common with DCC manufacturer’s detection circuits. It may be +5 volts for 7400 TTL or +12 for 4000 series CMOS. It may well also be a contact that closes when the track is occupied. In any case, the ground reference must be connected to the SLC ground reference at Pin 12.

The illustrated circuit is a “logic inverter”. It converts a voltage to ground and a ground to a voltage. The circuit has been tested, and is reliable, from 3.5 volts to 18 volts DC at the input Pin 16. There are two 2K2(Red-Red-Red) resistors packaged with the kit. They are for these options.

[ ] Install 1 jumper as illustrated in the middle of the board, at JU-1.

[ ] Install 1 jumper as marked at the bottom edge of the board, at D-10.

[] Install 1 piece 2N4401 Transistor at location Q-21. Of the transistor outlines in the detection circuit, it will be the furthest left.

[ ] Install 1 resistor as marked at the left side of the board, at R-6.

[ ] Install 1 resistor as illustrated, spanning from the inside of R-7 to the lowest pad of Q-12.

Input will be at Pin 16, referenced to ground on Pin 12.
Buffered Input

In normal operation of the SLC, any lamps on the Red circuit are powered by the detection circuit. This was done to reduce the number of elements in the circuit. Should the desired detection device have insufficient power for the load, a buffer can be assembled on board the SLC, isolating the lamps from the input. There are two 2K2(Red-Red-Red) resistors packaged with the kit. There is also a solitary transistor with a painted yellow face. They are for these options.

[ ] Install 1 jumper as illustrated in the middle of the board, at JU-1.

[ ] Install 1 jumper as marked at the bottom edge of the board, at D-10.

[ ] Install 1 piece 2N4403(yellow)Transistor at location Q-21. Of the transistor outlines in the detection circuit, it will be the furthest left. Take note the transistor is installed opposite the screened outline on the board.

[ ] Install 2 resistors as marked on the left of the board, at R-6 and R-7.

Input will be at Pin 17, referenced to ground on Pin 12. Protocol will be a “Low” signal indicates Occupied, a “High” indicates Clear. The circuit is known to indicate “Clear” at 3.5 volts DC on the input.
Internet Circuits

There is a plethora of Model Railroad circuits available on the InterNet. Some of them work well, some work only with the authors’ other designs. Should one of the latter be encountered, and be the perfect solution for your application, another buffer circuit is illustrated here. It has a higher element count but is an order of magnitude more sensitive. Because of that sensitivity, it is not as resilient as the buffer above. For that reason, I cannot guarantee the long term reliability of the circuit. Care must be exercised in its’ use that the input levels do not cause excessive base current. Do not drive this circuit with a high level signal.

- Install 2 jumpers as illustrated in the middle of the board, at JU-1, 2.
- Install 1 jumper as marked at the bottom edge of the board, at D-10.
- Install 2 pieces 2N4401 Transistor at location Q-11, 21, the left and right detection transistors.
- Install 1 resistor as marked on the left of the board, at R-6.
- Install Electrolytic capacitor as illustrated at location R-7
- Route a jumper as illustrated from the right pad of JU-1 to the lower pad of Q-12, the center of three detection transistors.

Input will be at Pin 17, referenced to ground on Pin 12. Protocol will be a “Low” signal indicates Occupied, a “High” indicates Clear. The circuit is known to indicate “Clear” with 3.5 volts DC on the input.
Magnetic DCC Transducer

While the Twin-T circuit will work perfectly well with DCC, using a relay, it does require active connections to the rails and electrical interfacing with the DCC power supply. There are valid reasons for not using the Twin-T, not the least of which is personal preference.

For whatever reason, a “Current Transducer” may be installed in the power leads to isolated sections of rail that provides magnetic coupling of the DCC signal into the SLC.

The LBO board is normally used with a CT option for this purpose. There are two iterations of the amplifier on the LBO, permitting detection for two signal blocks. Should it be desired, it is possible to install a two transistor amplifier on the SLC board, permitting a single board signal installation. This modification is not available as a kit, only as a prewired product. I do guarantee the board if I made the changes.

Disclaimer

The circuit requires physical modifications to the circuit board. Considerable skill is required. It is not recommended to the novice as a learning experience.

I include the information primarily for those that wish to retrofit an existing system. Please understand, if this mod is attempted, I cannot guarantee the SLC board. Nor will I accept a board for repair if the modification is botched. You must assume all responsibility for using this modification.
The preferred tool is a motor tool with a dental burr or small router tip. An alternate method is to use a utility knife to cut the foil in two places with an eighth inch gap. Using a soldering iron if necessary, delaminate the foil from the board. There must be no possibility of a connection across the gap.

Working on the foil side of the board, with the edge pins nearest you, identify the solder pads for Q-21 and Q-12 toward the right side of the board. Between the right pin of Q-21 and the center pin of Q-12 is a foil running at a slope. Tracing out this foil will eventually lead to ground at Pin 12. Cut the foil between Q-12 and Q-21, at the solder pads on each end, completely removing it.

At the solder pad on Pin 16, cut the trace above the pad, disabling the pin. Be sure to leave the “Y” junction intact between Q-11 and Q-12. This is strictly a precautionary measure, should the board be plugged into another socket where the pin is active with Twin-T detection.

The rest of the modifications will be made on the component side of the board. All references to component position will refer to that side.

[ ] Install one piece 4K7 resistor (Yel-Vio-Red) vertically at location Q-12. Mount with the resistor vertically in the center pad and the wire lead led down into the left pad. Leaving the lead bowed out a little will assist when making other connections to this point. Solder and trim.

[ ] Install one piece jumper at location R-6.

[ ] Install 1 piece 2N4401 Transistor at location Q-11.

[ ] Install 1 piece 2N4401 at location Q-21 thusly: Holding the transistor with the label facing you (the flat surface), fold the left leg out at a 90 degree angle. Insert the transistor otherwise normally, with the center and right legs as indicated by the outline.

[ ] Install Electrolytic Capacitor, as illustrated, at location R-7. The positive lead will solder through the pad. The negative lead will be folded out toward the transistor at Q-21. **Do not** use the lower pad of R-7 to stabilize the capacitor.

[ ] Connect the negative capacitor lead to the wire lead in the left pad of Q-12 from the vertical resistor at that location.

[ ] Connect the left lead of the transistor at location Q-21 to the negative capacitor lead spanning to the resistor at Q-12.
Remove the current transducer (CT) from its' package. Attach a 1N914 across the pins on the CT. If it is a three pin CT, use the two outboard pins.

Attach a twisted pair wire to the same pins of the CT. It is recommended the twist be on the order of 4-8 twists per foot. Identify the wire to the banded end of the diode as the active lead.

Connect to Pins 17 and 12 of the SLC. Route this wiring separate from any other electrical wiring to the SLC board. This is to keep DCC pulses from radiating into the detection circuit. It should not be necessary to use shielded cable. Polarity of the diode is the Cathode (banded end) to Pin 17.

In use, a section of track is isolated and a separate wire lead is routed to a feeder below the layout. Route this power wire such that it passes through the CT center. Make a second pass, creating one loop on the outside of the CT.

This constitutes two passes inside the CT. It is the normal starting count when initializing a detection circuit. Restrain the wire with a small wire tie, a piece of tape, or a piece of shrink sleeving over both ends of the feeder wire, binding them together.
In a “retro-fit” application, the same track feeder wire used for Twin-T detection may be used, abandoning the Twin-T in place or running it concurrently with another signal controller. In the illustration, it can be seen that the wiring is almost identical for either method.

The circuit was developed using a low sensitivity CT. Part number is Murata 56100C, with an inductance of 37mH and 100 turns. This low value was to simulate a worst case situation. The circuit is known to work with this particular CT.

Most CTs used in the hobby are on the order of 150-300 turns, 50-200mH. Such a CT is the Vitec 57P1820G, 180 mH at 300 turns. The Vitec part number is for illustration, not necessarily a recommendation; it is also known to work with this circuit.

Sensitivity may be increased by making another turn through the CT. There is little likelihood of a DCC supply overdriving the detection circuit in a short circuit condition. The Murata CT works well with two loops, the Vitec sometimes requires three, as tested on actual layouts.

Too much sensitivity may cause the CT to measure leakage or stray coupling from the DCC power supply. Removing a turn should eliminate any such problem.
The following essays are on topics I have been asked to explain or comment on over time. I don't like to give "advice" because the question is often a matter of perspective and what's right for me may be the worst possible course of action for the asker. The topics are somewhat esoteric in that they don't justify a separate chapter in a book.

There are some matters where I have many years experience and I am willing to give an opinion on a subject where I'm sure of my ground. Although, I can get wound up on a favorite topic and then you can't shut me up. It is my earnest hope that some of the information presented here may help modelers become better at what they do.

Soldering, especially electronics soldering, is a topic close to my heart. Well, of course it is. I sell circuit boards in kit form, where the user has to do the soldering.

It troubles me immensely when I have to refuse a warranty replacement because someone used a 120 watt iron to install a diode and managed to delaminate a couple of square inches of foils in the process. I build good stuff, and I know it's good. I design in features that help the novice develop their skills. The oversize pads and wide spacing are there for your benefit, not mine. I solder consistently on 0.062" (1.5mm) centers. For my own use, most circuits could be half their size.

The following is by no means an exhaustive look at the subject. Merely an overview to get you started. Like most manual skills, regular and frequent practice is the primary part of developing that skill. And the better you are, the better I feel about replacing boards.

**General Soldering Techniques:**

Soldering is not some great hidden mystery to be concealed from the eyes of the unworthy heathen. It is merely a method of attaching one piece of metal to another using a low melting point metal. Usually associated with electrical assemblies, soldering is also used to construct metal models.

It is a skill well worth acquiring, especially in model building. The solder itself is often colloquially referred to as "wire glue". It serves the same purpose. There is actually a product available with that name that is literally an electrically conductive glue. I won't recommend it for electronic assembly mostly because I am old fashioned and haven't yet tried the stuff.
Soldering requires some minimum tooling; obviously a good soldering “iron” is a must. I won’t recommend by brand name, but do suggest looking into a number of brands to gain some understanding of what makes a quality iron. They are available, and I have, from 13 watts to 350 watts, so it is not unusual to have several. Each has a specific use; I have been in the electrical and electronics business for over 40 years and have accumulated quite a number.

The tip should be sized to the work and the heat (wattage) sized to the tip. For general electronics work, such as one will find around Model Railroads, I would suggest a “pencil” iron on the order of 20-35 watts. With proper preparation and good technique, code 100 rail can be soldered with a 30 watt iron, so this is a good general purpose range for the smaller scales.

Tip shape will make a difference. I suggest a pointed tip for small electronics work and a “chisel” tip for rail. Iron tip plating is available on some better quality tools, so you should consider this a feature to look for. Also, tips should be readily replacable. A screw in tip will usually corrode from the heat and is virtually useless after about twenty or thirty hours heat time. The type with setscrews on the side of the heating body are not much better.

A soldering “stand” is a nice accessory, I have several. But; I have worked for years with no more than an ash tray to lay the iron on. And still often do, in the field away from my bench. Anything to keep the iron away from flammables and away from your hand.

A “sal ammoniac” block at one time was a necessary item. Today, most tips are plated and soldering stands come with a sponge. Dampened, it serves to clean the tip. I personally use a cotton rag, such as a TEE shirt, folded several layers thick. Don’t use synthetics. And, in the field, I have used my jeans, in a pinch. That is not a recommended technique, however. I mention it merely to illustrate the simplicity of what is actually required as opposed to what is nice to have.

On "tinning"

The tip of the iron should be kept wet with solder whenever it is hot. Iron plated tips are dull silvery in colour. Copper will be a dull brown or black from scale. Properly tinned tips are bright silver; almost looks like mercury....
I most often use a “rubberized abrasive” to clean my tips. Often called “rust erasers”, they are sold to modelers as track cleaners. (read as Bright-Boy®) They are also available at electrical maintenance supply houses as “commutator polishing” bars. “Ideal” brand... Maybe I should add them to my product line. They are quite suitable for cleaning up that old "perf-board" that’s been floating around the shop for 10 years, getting darker and darker.

Wipe the tip clean of the dust and apply a little solder, wetting the tip. There will be spots where it doesn’t want to take. Buff it up a little with the “rust eraser” and try again. This is crucial for proper heat transfer. At least a half inch of the tip should be tinned.

**On fluxes**

Flux serves two distinct purposes. First of all, it serves to keep oxygen away from the surface of the metal being worked. Heat greatly accelerates the corrosion factor, especially with soft metals such as copper. Flux forms a liquid, insulating barrier to the air.

Flux also will help clean the surface of the metal. But, you shouldn’t depend on the flux to do all the work. If there is any corrosion visible, use a rust eraser, scrape with a knife, or use fine sand paper. You want a bright, clean surface to start with. The flux will get the stuff you can’t see. Many component leads come tinned or plated but should be wiped clean before use.

Most electronic solders will be flux “cored”. The hollow center is filled with a rosin flux that applies itself as the solder is melted. Some plumber’s solder has an acid core. This must be avoided at all costs. The acid will come back to haunt you a year or two down the road.

There are fluxes available separate from the solder. A good rosin based Radio-TV liquid flux is available from suppliers of G-C® products. Brush on just enough to wet the work and apply a little heat. Let it work a second or so then apply the solder.

Zinc Chloride is a mild acid based flux that is usable on electrical work. It is sold in small tins about the size of a snuff can. Very handy for a badly corroded tip... And virtually indispensable for building brass models.

**But,** if you need it for small electrical work, you probably don’t have the work clean enough. And it certainly should be cleaned off the board when you’re finished.
On solders

Soldering, “silver soldering”, and brazing are identical practices; indeed, brazing was, and still often is, called spelter soldering, as opposed to “soft” soldering. The difference is in temperature. Brazing (copper, tin, zinc) spelter flows around 2200F. “Silver solders” flow in the region of 1800. And common(soft) Tin/Lead alloys on the order of 500-700 degrees F.

“Tinner’s” solder is what would be seen for roof gutters and tin-plate work, rarely seen today. The solder is “50/50”, meaning 50% tin and 50% lead. Usually available as one pound bars. Plumber’s solder will usually be 50/50 or 60/40. Heavy, wire-like, 1/8” diameter or more, with or without a flux core. Avoid it like the plague.

“Normal” electrical solder will be that or smaller, also 60/40 or thereabouts. Usually with a flux core. Electronics solder may be a more esoteric alloy, such as 63/37. There may also be trace amounts of other metals to alter the eutectic temperature. 3 to 5% silver is common.

As technology moves away from lead, “lead free” solders are becoming more common. One type, specifically for circuit board work, is 97% tin and 3% silver. The silver is to improve electrical conductivity, which is marginal for tin. It is readily available, but somewhat more costly.

The different alloys provide different “eutectic” temperatures, the point at which the solder goes from a soft plastic state to a flowable liquid. I won’t go into details but if you are interested, investigate large scale modeling and the old Master Modelers that scratched from brass. Proper use of different eutectic alloys permits adding a piece next to an existing piece without softening the existing solder. Here, all we want to do is stick transistors to circuit boards.

I use 1/16” solder, 0.062”. A convenient size. Many people are more comfortable with smaller diameter, such as 0.025. Most modelers are not working SMD circuit boards so it is largely a matter of taste. Of course, DCC decoders do fall into that catagory.

And by the way; regular tin/lead solder will not stick to aluminum. I often use a sliver of flashing metal as a guard for small work. And aluminum fixtures for soldering switch frogs.
On technique

There are many schools of thought on what makes good soldering technique. With my many years experience, I have found a few basic rules that are universal to them all.

1) **Clean, tinned tips.** Just barely damp with solder.
2) Practice
3) **Clean**, bright copper (or brass)
4) Lots of practice
5) A good electronics alloy solder.
   I use 63/37 multicore; but it is lead bearing.
6) Still more practice.

   My technique is self taught, doing circuit board repairs in “on site” situations. With a clean, hot iron, address the work. If the two pieces are of radically different mass, heat the heavier piece more. Apply just a dab of solder to the iron next to the work so that it flows onto the work. This is to get good heat transfer. As the work heats up and solder flows freely, apply more until the joint is covered. Back the iron out and let the work cool.

   The components packaged with my kits are time rated for heat. It’s safe to use an 850 degF iron on a transistor, *for about 5 seconds*. Sorry, I don’t mean to scream, but contact time is the issue with electronics soldering. Get in, make it up and get out! In my opinion, needing a heat sink with circuit boards means the technique is bad.

   This applies to rail, as well. The larger the tip, the more residual heat it can transfer before it starts to cool. The principle is to heat the metal so that it melts the solder. Not the iron. The little dab on the tip is to improve heat transfer. The base metal must be hot enough to melt the solder. That is the key to soldering: get the work hot enough to melt the solder and then get out.

   Once you have done it a few times, you will learn the appearance of the freezing solder. You can see it change surface texture as it chills. It will go from shiney to dull silvery colour. If the surface has a grainy texture, you got a “cold joint”. Probably the work moved just as the solder froze. Heat it just enough to get liquidus and let it cool again. This is called “reflow” and is a common practice in industrial applications where age and heat have caused premature failure.
Another problem to watch for is the solder beading up. This will often give a fair mechanical bond but is not a good conductor. I have seen it where an ohm-meter shows an open circuit. The solder should flow like thin, light oil. It will wick up a wire lead making a small cone. When it beads up, usually the surface of the work or the iron is dirty. When it sticks, it's usually too cold.

"Reflow"

"Old" solder is difficult to describe. As is my technique for dealing with it. When it has been reheated repeatedly the alloying seems to change. Commercially produced circuit boards are often "wave" soldered. An automated process I won't go into. But, the solder alloy is different for that process. When you attempt to de-solder such a component, the solder won't flow "properly" and may not even melt at a reasonable temperature.

I can't recommend my technique to the novice, it uses "excessive force".... A very hot iron and extended application of heat. I use a vacuum desoldering tool and resolder the part in question, as though a new install. Then desolder it again and remove it. I'm not sure why it works, but have found over the years that it does work in most cases. The point to consider is that the board may be damaged in the process.

The boards themselves

I designed my boards with wider than standard lead spacing and oversized pads. Most model railroaders are pretty good with a soldering iron. The novice needs a little help. The board is designed to assist them in learning good technique.

Component leads will require spreading a little, especially on transistors. Use needle nose pliers to bend an offset. Approximately 1/8" spacing (3mm), center to center. Resistors usually may be bent right at the component to get the proper spacing. For mounting components in "non-standard" configuration, guage the gap by eye before bending.

Apply heat to the lead, right at the pad, add a dab of solder for transfer, then more as it flows. The solder should just fill the hole. Avoid letting it "blob" up. A piece of stranded wire can be used as a wick to remove excess. Just watch that you don't keep the iron on too long.
ON MODELING ALLOYS:
If you’re interested... (WAY too much information for electronics)

Should you pursue soldering on large surfaces, such as adding details to models, the situation is a little different. You will want a larger iron, on the order of 50 watts, or more. With a chisel tip, correspondingly larger. Of mine, one is a 50, another 85, watts. There is also a 120, but that one is reserved for serious soldering on very large electrical work. Also, your fluxes will be different. As may be your solder alloys. This is as much art as science. Much to learn......

Of greater import here is the alloys used for casting model parts. Brass, of course, is readily solderable. As is bronze, and “Nickle Silver”. Zamak, on the other hand, will not solder. Period. Well, it actually can be, but requires considerable prep work. OK, so why?

-- Aluminum --

Brass is primarily copper, 65 to 85%, or more. Zinc makes up most of the rest. Zinc doesn’t solder very well but the copper does. Bronze is similar, with Tin making up most of the rest. That’s why it solders so much better than brass. In both cases, there usually are other trace elements to provide ductility (workability) or special electrical characteristics. As an aside; standard brazing rod is a bronze alloy containing both tin and zinc. In the 1/8” size, very useful for modeling.

Nickle Silver, also known as “German Silver”, contains little or no silver. It is composed of copper and nickle, again with other trace elements. U.S. coins have been made of this alloy since 1974, or thereabouts. Whenever it was that inflation got bad. It is hard enough to use as coinage, but soft enough to be “drawn” through a die, such as is used to make rail.

Today, most Model Railroads are constructed with nickle-silver rail. There are many advantages; it doesn’t readily corrode, certainly not like brass, it solders well, from the copper content. The scale, or corrosion, is moderately conductive. Again, unlike brass. But, there ain’t no free lunch, as Goodman Long likes to say. Electrical conductivity is about half that of copper. That’s why you should use copper power drops every few feet from the track rails to the power cabling.
**Pot Metal** is often used for casting model parts, especially detail parts. It is composed of Aluminum and Zinc. Approximately two parts Al to one part Zn. The eutectic or plasticus temp is on the order of 900 degF. For this reason alone, it should not be soldered. As with other alloys, there are trace elements to acquire specific characteristics, but none of sufficient quantity to permit soldering.

Pot Metal does have some useful properties beyond low production costs. It is almost as strong as “gray” iron, low carbon cast iron. Good surface finish. Many modern conveniences have pot metal parts. Small motor frames, gears, decorative castings.... It takes paint quite well.

I have a lathe, a UniMat, from the ’60's, that is still usable. Most of my work is with normal, full sized machines, but the UniMat does get used. But, it is of an aluminum alloy and will not take Tin/Lead solder.

**Zamac** is an alloy quite often seen in Model Railroading. It has the weight lacking in plastic models. Details can be added so they needn’t be cast on. It can be machined and threaded. For many years, before miniature CNC machining, dies or molds were less costly than those for plastic. The material is harder than plastic. And on, and on, and on...

So, what is so special about Zamac? It’s a pot metal. Big deal... I spoke earlier of trace elements in the various alloys, especially the castable alloys. One of the problems associated with casting metal is shrinkage; another is distortion as the metal freezes.

Zamac was developed as a pot metal to provide some measure of control of these problems. It is composed of Zinc, Aluminum, Magnesium, and Copper. Proper spelling, way back when, was Zamak, from the German word for copper, Kupfer.

Although it contains a significant percentage of copper, it still will not take solder. The specific alloy creates a higher temperature plasticus, above 1000 degF. (aluminum alone is on the order of 1450) This higher temperature makes it safer around a soldering iron. Not fully safe, but safer. Many soldering irons actually reach a tip temperature well above the 500-800 degree liquidus of solder. Often as high as 1000 degreesF.

The trick to soldering Zamac is to plate the surface, usually with copper or tin. I use Tin, because I already have it in the shop for electrical purposes. The liquid is considered a hazardous material, so I recommend against it for modeling.
There is a mail order house that markets to many modelers, not just railroaders. Micro-Mark® They carry a wide line of tooling and supplies. One of their products is a kit for electro-plating with copper. Copper is used as the base coat when doing chrome plating, as well, so copper plating may well be available through an independant motorcycle shop that does custom work.

The copper plating is solderable, but you should watch your temperature closely. Keep in mind, too, that the part in question may not be Zamac, but merely Pot Metal. With a correspondingly lower plasticus.

The old Mantua® line, also sold for a while by Tyco®, used Zamac castings for many of their models. I have a very old Mantua kit of the General, (4-4-0) with a number of Zamac castings and a brass wrapped boiler.

The greatest problem associated with Zamac seems to be that as the casting ages, it becomes powdery. The General kit noted above is facing this problem. I also have an early Japanese “brass” 4-6-0, center cab, with a Zamac frame and boiler. Details are of brass castings, only the major parts are of Zamac. Both models date from the mid 50's and are starting to de-compose. The 4-6-0 is beyond repair, the spoked drivers are Zamac. The General I think can be recovered as I intend to use brass shim stock to replicate a number of pieces.

On the other hand, I have a couple of Varney steam, and some Penn Line (later Bowser, now Walther's®) stuff that are reasonably intact. I suppose it is a matter of slight differences in the alloying elements.

Tin-plate I will mention briefly, mostly to fill up the page... Steel is solderable, but not readily. You have to use a serious acid flux. Tin plating provides the solderable surface. I can’t count the number of models I have built from Campbell’s soup cans, when I was a kid. Before they went to the environmentally friendly enamel or plastic lining.

Did I just tell my age?! Humph... Well, having been NMRA since 1971, I guess it already shows.
I often hear comments about the difficulty of finding power supplies for layout circuits. Or the cost of power packs for auxiliary circuits such as mine. Or the worst, a "supposedly" 16 volt supply that lights up Grain of Wheat lamps like aircraft landing lights, burning them out within a very few hours.

Well, in many cases, that "off the shelf" transformer isn't exactly what the package says it is. Low voltage power supplies are everywhere, by the truckload, at very low cost. Ya just got to know where to look.

**SOME THOUGHTS ON TRANSFORMERS**
*(and power supplies)*

At some risk of belabouring the obvious and waxing far too deeply technical, there are some considerations for dealing with low voltage power supplies that warrant discussion. That sure sounds uppity, maybe too much coffee too early in the day...... I've been in the electrical business for many, many years, devising novel solutions to unusual applications. A recent experience while developing a new circuit design brought to the forefront a problem that has arisen in recent years. The situation is thus:

Electrical supplies in much of the world are of 100/200 volts at 50 cycles. The United States, Canada and a few other locations use 120/240 volts at 60 cycles. There are valid reasons for both systems. Now, A-C power has a number of curious characteristics, the most important being the fact that coils and capacitors cause distortion of, and are affected by, the essential wave form. The 50 to 60 cycle differential and different voltage levels are at the root of the problem.

A good example of this would be a simple relay. Many industrial control systems use 24 VAC.(for safety) A relay rated at 24 VAC will overheat and often destroy itself on 24 VDC. On the other hand, it will operate quite well on DC at 12 VDC. The reason has to do with the magnetic properties of the coil. I won't go into details but that information is available from many sources.

Some years back, I wrote an article (at 50 pages it might be considered a small book) on the subject of fractional horsepower motors. It is written for hobby machinists that want to get the most out of small, home shop machines. And adapting used industrial machines to home shop operation. The article may be found at "www.hudson telecom.com" as a PDF download. There is sufficient information there in lay terms (no heavy math) that one may grasp the fundamental concepts of electromagnetism.
Now, the "meat and potatoes" of the matter.... In recent years, many of the electrical devices sold in the US at the consumer level are manufactured in Asia. Both Mainland China and Indonesia use 100 V at 50 Cycles.

Using a common doorbell as an example, the required voltage is 16 VAC. The transformers are wound to provide this 16 volts from a 100 volt supply. (In techno-speak, this would involve a "turns ratio" of 6.25:1)

When the transformer is sold in the States, it is connected to a 120 volt supply. The output of this 6:1 transformer now outputs 19.2 volts. The average doorbell can handle it, but...

Then we, as Model Railroaders, rectify this to obtain DC, and the voltage goes higher still, to upwards of 27 volts. Why DC has a higher voltage than AC involves some pretty heavy duty math so I won’t go into it here. Just trust me and accept it as a postulate.

There is some loss involved from the 60-50 Cycle business, but even with a wild stab at 10% loss, we’re still talking more than 24 Volts. (27.15-2.7) On what we thought was 16. That’s over 50% too high. Could well be the reason 16 volt Grain-of-Wheat lamps burn out so quickly....

The solution?! There are many, with no single answer. The most obvious would be to use a lower voltage transformer. The problem here is cost. 16 Volt doorbell transformers are available most anywhere. Inexpensive, but too high voltage.....

"Power" transformers may be obtained from an electronic supply house. The trouble there is that you get a transformer.... period. At a premium price. No case, no line cord, no fuse. You will need to work with the line side, 120 volts, and anything less than excellent work will yield a dangerous device.

12 Volts DC can be had from a common automotive battery charger. Here again, the label will be misleading. An automotive battery is actually higher than 13 volts, with charging voltage (usually) closer to 15 volts. None the less, a good source of (relatively) high current 16 volt power, already rectified to DC.
Another good source is scrap “Wall Warts”, battery chargers and “eliminators” for portable electronic devices. Many are rated too low to be of practical use; many cell phones and cordless phones have 3.5 volt batteries. (I do use them for bench tinkering) Other types of equipment run the gamut from 6 volts to 18 volts (cordless drills). They are safe. And readily available. But usually of lower current capacity.

The output voltage on the label will only give you a range. These supplies are rated to operate at a specific load. Without that load, the output voltage goes **up**. I use a 9 volt (at 350 mA) wall wart for one of my displays. Actual output is closer to 13 volts.

The boards I sell are very low current devices, far less than 50 mA. An SLC signal board, in normal operation driving LEDs, sinks around 35 mA. An LBO-4, with crossing flashers and a gate actuator, about the same. The regulator circuit in a wall wart doesn’t regulate well at that level. Measure the output voltage at “open circuit” to determine the low current voltage range.

For the more technically minded, an excellent source of regulated DC is a computer power supply. They do require some tinkering to get them to work. But the result is well worth the effort. Pure, clean DC, regulated to (usually) better than 1%. The 5 volt supply will often work for devices rated at 6 volts. Usually.... The 12 volt output may have a capacity of 1000 mA to upwards of 5000 mA (1-5 Amps)

A “thrift store” is often a good source for these. Being in the right place at the right time may well yield a pickup truck load of computers for $25.00. As technology advances, older computers cannot handle the data load. PCs, XT’s, 286s, 386s, and early 486s too slow to run “WinDoze”... They end up in thrift stores and flea markets for a few cents on the dollar. The staff at thrift stores aren’t usually well versed in technology; with household goods, they know how to set prices. With technical stuff and machinery; well ..... So computers often go dirt cheap. You will end up with a lot of scrap, but some good power supplies.

If you are uncomfortable working with line voltage power, you may prefer to have someone with a technical bent handle the conversion. So long as the metal enclosure is intact, a computer power supply is intrinsically safe. Not waterproof, but otherwise safe. Opened, there are voltages well above the line supply in the high voltage side.
There will be a bundle of wires coming out of the case for the mother board and various storage devices. The board connectors may be cut off and connected inside the case if you're comfortable with opening it up. There are two single row flat connectors. The drive connectors have three or four wires and will be the outputs used:

<table>
<thead>
<tr>
<th>Color</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>Ground</td>
</tr>
<tr>
<td>Red</td>
<td>+5 volts</td>
</tr>
<tr>
<td>Yellow</td>
<td>+12 volts</td>
</tr>
</tbody>
</table>

The supply will not “come ready” until the motherboard signals “power good”. To generate this signal, connect the orange wire on the motherboard plug to a red wire from the same connector. There must also be a slight load to initialize the regulator; use a #67 automotive lamp between a yellow wire and a black wire on that same plug.

Some newer, higher wattage supplies may need more load; use a #1156 back-up lamp, if necessary. When the load is correct, the lamp will light on power up. The supplies I use on the bench are from early "AT’s", '286 and '386 machines. For them, the ideal lamp is an 8 watt reading lamp for use in RVs. They are readily available at RV dealers. However, the cost will usually be higher.

Often, there will be a connection from the negative side of the low voltage supply to frame ground. If the supply is stand alone, just ignore it. If you plan to use two of the 5 volt supplies in series to get 10 volts, it will be necessary to lift this strap. This is perfectly safe, the metal case has a separate ground strap to the power cord. Just be sure to get the correct **low voltage** ground, and leave the line ground in place.

Televisions and radios haven’t used linear transformer power supplies for many years, but older “tube type” transformers are an excellent source of both 8 and 16 volt power. I don’t remember the colour code for the 12 volt windings but the 6 volt filament leads will be green to green/yellow to green. Just as in your house panel, connecting across the solid colours will usually double the voltage. When the 6.3 volt winding is rectified and filtered, the result will be around 8 volts. And be sure to tape off the red lead, the “anode” supply is at or above 180 volts. The 8 Volts is perfect for powering a 7805 or LM340 regulator.

Another useful source, although thought sacrilegious by some, is toy train transformers. Older Lionel and American Flyer transformers are true variable transformers, usually 8-16 volts. Rectify the output, adjusting the voltage until it reads what you want.
Many transformers are rated in “watts.” The toy train transformers, being variable, are a bit confusing. A 20 watt rating is for full voltage. At 16 volts, it will source over an amp.(1.25) What is important is that when used at 8 volts, calculation will indicate 2.5 amps, which is incorrect. The calculation **must** be made for full voltage rating. So the capacity is 1.25 amp, at any setting.

Another example of this would be a control transformer from an HVAC system. 24 volts control from a 240 volt line, at 50 watts. Connecting the line side to 120 volts will give an output around 12 volts. Rectified and filtered, it would be around 16 volts DC. However, the current limit is the same; 50 watts at 24 volts is a fuzz over 2 amps. This is an absolute limit; at 12 volts, the usable power would be 25 watts.(still 2+ amps at 12 volts)

With such control transformers, we are getting back into the original problem with “doorbell” supplies. For commercial machines, the rating is flexible. For railroading, not so much so.

If you want some **really serious** power, there is a device called a “Buck/Boost” transformer. They are relatively costly, and large, and heavy. But can deliver 50 amps or more, continuously. I have used them for modeling, more for the stability than for the power.

Some years back, I got wound up trying to build in large scale. 1/5 scale... 7-1/2" gauge.... The design called for using a third rail for power. It never really got off the ground, so to speak; I lost the pasture..... But I did run a locomotive back and forth for a while. With a "buzz-box" welder to hot the third rail. Now there's a sea story.....

Probably better to use a battery charger with a starting booster.
Ever tried to re-motor an older AHM locomotive? Especially the "pancake" motors that have brushes on the back. "Can" motors just won't fit without half a tube of silicone caulk. Get new brushes in that old switcher and chances are it'll run like new. Well, pretty good enough to use, anyway....

**SERVICING VINTAGE RIVAROSSI MOTORS**

In response to a conversation regarding very old AHM steam I went digging through my parts boxes looking for “traction tire” inserts.... My stuff is so old there weren’t any, but I did find several of the “pancake” motors that had been set by for worn or missing brushes. The type with brushes on the back, opposite the shaft coupling. Seemed like a good time to service them and see if they were salvagable. I “borrowed” brushes from two motors to make a set. That’s when I noticed several of the brushes were made of rolled copper mesh....

During a “buying spree” of potential modeling materials, I had found a package of copper screen, on the order of a 40 mesh; I no longer have the package to verify the size. From a chain craft store, Michael’s and Hobby Lobby are the two big ones in my area.

For small electrical work, I keep a scissors, high quality sewing tools. A Fiber Splicer’s Kevlar snips would work better, but it is a specialized tool for an esoteric craft. I wouldn’t even think of “borrowing” my wife’s good sewing scissors, too fond of my scalp...

Key stock is made of “cold rolled” steel and has sharp, fairly square corners. Usually available in one foot long pieces, I found a bundle of mixed sizes, with one piece as big as ½ x 5/8 inch. This stuff has numerous uses cut up into short pieces. I have a number for gluing blocks that double as weights and “squares.” (For most models, instrument tolerances aren’t really necessary)

To make the brushes I cut a strip of the copper screen an inch and a quarter long by some 3/8” (8-10mm) wide. The width is the length of the brush. Use about double what you think you may need. It will run to the side a little and you need room on the ends to trim it smooth.

It is a characteristic of metal to curl when rolled with a round rod. Laying the strip on a wood work surface, I rolled it with a piece of coat-hanger wire until it was tight. Use short pieces of the keystock to apply pressure at the ends of the wire, right up to the edges of the mesh...
Then followed up with a piece of 1mm (0.040) welding rod. Twist drills would also work here, but may warp. Once it was below 1/4 inch or so diameter, I used pressure on the roll itself to take it down to a very tight roll.

This technique is common in metal working shops for straightening "wire size" drills.(numbered drills) It also can be used to straighten brass rod and coat hanger wire on the modeling bench. The smaller the material, the stiffer the surface needed. "Masonite" hard board does well for small stuff used in railroading. A small metal plate even better.

The brush holders are a little under an eighth inch (1/8), the finished copper brush will be oversized. Unlay a layer or so and trim with scissors, rolling it with your finger to reform the end. Check the size and trim it again, repeating until it makes a smooth, sliding fit. If you botch it, start a new one. It isn’t worth trying to recover a too small piece.

When the diameter is good, trim the ends with scissors to make a smooth, blunt surface. Use tweezers to pick out any short, loose “whiskers” and smooth it again. It may take two or three passes. The finished length will be slightly longer than the brush holder so the brush spring has something to press against. Work the top the same way as the commutator end. While a smooth surface isn’t as important, be sure to get all the loose whiskers out.

The brush spring has a hook on the end. It goes into the hole in the end of the brush. Try to keep the spring from riding too high, the excessive brush tension would cause more wear on the commutator. For the same reason, be sure to use copper mesh, brass is harder than the commutator segments. Although I didn’t have any other style motors to try it on, I would think the same technique would work for any motor with round, replaceable brushes.

Long ago, it would have been the mid ’70s I guess, my favorite uncle sent me some of his original text books. Well into his 90’s then, he was the operating engineer that commissioned the Pentagon building in 1943; the books dated from before 1910, when he was studying engineering.

Now, I don't mean to imply that "older is better" as a rule. But we would do well to learn from history and look at the development of technology. In many cases there are valid reasons for doing things the way they were done. In our modern society, much of technology has become "disposable". In older times, machinery was not readily replaceable and was designed to be serviced quickly.
In those books, generators are referred to as “dynamos” and had copper brushes. Solid brushes were a later development. On larger machines, the brushes were fabricated from a copper mesh the same as described here. The point being that the copper mesh brushes are a valid premise, actually a sign of quality, not of “cheap” construction.

Carbon brushes are a later development. Much less efficient and of higher resistance than the copper. Many high current applications today still have rich copper content in the brushes. Look at a set of replacement brushes for an automotive starter motor. There is just enough carbon in the brushes to act as a lubricant. They’re almost solid copper.

Since the original project, I have experimented successfully with making brushes for other brands of motors. It appears most any motor with round brushes can be restored with this method. Provided, of course, the commutator isn’t cut up.
From a Clinic

This might be thought of as an editorial. It comes off more like a sermon. My apologies, up front. I tend to be overly verbose when I wax technical or philosophical; the more so when I feel I am on solid ground. And there is a high incidence of the perpendicular pronoun herein. It’s not so much that I want to talk about myself as to illustrate points supporting my position on the subject matter.

**The essence of a “Master Modeler”**
(or why I don’t believe in kits)

First off, let me acknowledge that I am not a “Master Model Railroader”, even after 35 years a member.

"Who having tried and failed, is a far better man than he who has never tried."

I have never tried; actually it is more a matter of I haven’t bothered. I am a master if my peers consider me as such, and I have no particular desire for the recognition from anyone else. I tinker in that part of model railroading that pleases me to pursue at the time. I receive recognition from my peers when my opinion is asked on how to deal with a specific matter and my opinions and advice are followed.

Recently I was discussing scratch building with some friends, and was asked some rather pointed questions regarding my position on that subject. The answers were given without any serious consideration of the matter; something I don’t like to do. This little sermon is to clarify my position, define the semantics involved, and explain why I hold the positions I do.

I have been NMRA since 1971 as a life member. I had joined in the mid 60’s, but for fiscal priorities could not renew. (A teenager, need I elaborate?) I cannot describe the transition from “playing trains” to “model railroading” because I really don’t remember when I lost interest in running in circles and started trying to emulate the C&O. I’m from that area. My first attempt at a chasing girls was the daughter of a C&O locomotive engineer.
Shortly after, I drifted away from railroading; taking an interest in “Steam”; as described by Rudyard Kipling. The triple expansion “Liberty Ship” engine of the First World War is quite a contraption. But consider a 6000 HP steam plant and engine that can move itself around at eighty feet per second. Now there is Horse-power with a capital POWER. Which brought me back around to trains. (UP 4000s)

That is not particularly indicative of my activities in the hobby though. I actually spend a goodly portion of my time playing at and with contraptions of all sorts. Some are railroad specific, some are just interesting ideas that I want to try.

When I have an idea for an interesting model, I will pursue it for a while, until I determine that the concept will or will not work, or a better way is discovered. Maybe it gets finished, maybe it doesn’t. I also spend considerable time working with friends on their layouts either in the design / problem solving stages, or just doing little piddling detailing.

With this background and attitude in mind, let us explore scratch building and bashing. I scratch build to scratch an itch. On occasion, I will decide that this, or that, or the other thing is of interest to me and there is no commercial version available. Or maybe I’m too cheap to buy one. So I build it. There may be no more information than a picture, or sometimes just a memory of something I saw.

The model will be sufficiently representative that it is recognisable for what it is. And most importantly, it will be functional railroad equipment. Or I may find a key piece of junk that transforms an idea into a viable project.

Some years back, I acquired in a horse trade some USRA era 0-4-0 switchers. I have no real interest in USRA locomotives, but I’m not the sort to arbitrarily scrap them. Two or three years later, I find a plastic boiler assembly from an earlier era, but twice as long. Now in my model world, there is a place for a 2-4-4-0. That project hasn’t started yet, but I got all the stuff in one box. That makes it a project in my shop.

Scratch building and bashing are the conversion of a concept into a tangible object. In many cases, the plans exist only in my head. There may or may not be a “prototype”. The specific question that got me started studying on this subject was thus:
If one buys a “craftsman” kit and assembles it, it is a kit, albeit a difficult one. If one then purchases the raw materials, and following the same plans, assembles another model from these plans, is he scratch building?

My answer at the time was yes, that is scratch building. After reflecting on the subject for a while, I would change my answer to no.

**O K, so why?**

For a long time, I viewed the “Achievement Program” process as a test of sorts. This person has achieved this level, give him another tic in the register. As I grow older and more cynical (and curmudgeonly), I have come to realize that the AP system in reality is an attempt to quantify the intangibles of knowledge and manual skills. Those qualities that cannot be readily measured.

To return to the kit in the previous question, the assembly of that kit is a test only of one’s ability to follow directions. If that’s all there was to it, I would stick with picture puzzles or “origami”. There is no knowledge imparted of the subject beyond modeling technique. To me, the whole point of the AP system, of modeling in general for that matter, is the knowledge and skills gained through research and construction of the subject.

Scratch building is not just the laying out of measurements, and cutting out the pieces, and gluing them together. It is the process of learning enough about the subject that you become a master of that craft. Whether it be constructing a wooden building, or fabricating a locomotive, whatever skills are necessary to build one in full size, the same skills must be developed and learned in miniature.

This is the reason that serious model railroaders have always been held in such high esteem by the technical community. The modeler could not only build a locomotive engine, anyone can learn that; he builds it in miniature.

The skills are honed to a razor’s edge to accomplish in minute detail what the machinist and the steam fitter and many other crafts fabricate in full scale. Just to run the pipes around the outside of the boiler in duplicate of a photograph is not the point. What is each of those pipes, and why are they routed the way they are?
Some years ago, I won’t admit to how many, I was associated with a hobby shop “over the mountain”. There was a “regular” who was scratching a steam locomotive. Live steam. In H-O scale. I had to go “out of town” before it was anywhere near complete; at the time I saw it the engine was functional, the boiler would hold air pressure and one set of drivers would rotate.

There was no boiler detail, no cab, no plumbing, trailing trucks, tender, any of the stuff we consider to be locomotive details. No super detailing, not even stuff normally associated with steam locomotives; stack, cab, domes, &c. **BUT** the engine ran! It test ran on compressed air, but the steam chests were airtight. The slide valves functioned, as did the valve timing mechanism. And it wasn’t Stevenson either, it was by gosh Young, with a crosshead link and reversing linkages!

And it ran, and was reversible.

I don’t know if the model was ever completed, or entered in any contest, or if the fellow is even still railroading; but in my eyes that man was a “Master Mechanic, Power” whether the NMRA ever condescended to call him such or no.

According to the rules, as he only built the one piece, it was not sufficient. But he had researched the operation of a steam engine, learned how they worked in locomotive applications, and **then** he learned the skills of a machinist and fabricated the contraption. And it ran.

The construction project that this was written for is a wooden structure. It was conceived, planned, and constructed without any instructions. What was used was an intimate knowledge of the building trades. I did not need specific instructions on building the house because I know from my research (experience working on them) how such houses are built. And I have the skills to do pretty good jack leg carpentry work.

To me, that is the essence of the AP system. To become a Master Modeler, one must reach that level of proficiency in each of the AP categories. A Master Modeler is one who has acquired the skills and knowledge to sit down and build anything he wants in the railroading field. And it needn’t be in miniature. My (limited) skill in a machine shop making model railroading stuff has developed the skills to use machine tools to make the stuff that I need to keep my household running. And my tractor, and my dump truck, and so on.
Professionally, I am an electrical engineer specializing in machine automation. I have worked in the field almost as long as I have been modeling. Only had a degree for half that time. I got into the field literally as a child to learn how to make my trains run better.

By early schooling and childhood training (Pop was a hard man) I should have been in construction or a structurial discipline. But as a youngster, I wanted to make my trains run better.

Lacking the resources to buy them, I figured out how electrical switches work, and having busted a few in the process, proceeded to build them out of old hacksaw blades and machine screws. Suprisingly, having learned that I had juice for the asking at a wall plug, I am still alive. And not very good at following directions, either.

End of sermon, you may pass the plate

Footnote: Personally, I would acknowledge a mediocre job of kit-bashing over a masterful job of assembling a craftsman kit. The bash job involves more innate creativity than a kit. Provided it isn't a "paint by numbers" project that someone else developed.

A quote worth remembering:

Always listen to the Experts.
They will tell you what can't be done; and why.
Once you have heard them; go on out and do it.

Lazurus Long
(With respects to Robt A Heinlein)