BD16 BLOCK OCCUPANCY DETECTOR

By

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1. INTRODUCTION

Your BD16 Block Occupancy Detector is the latest in train detection systems. It works with layouts using either Command Control or DC Control systems for operating trains. In addition, for DC Control systems, the BD16 can report block status in either "OCCUPIED-VACANT" form, or it can report in "VACANT-STANDING-EAST-WEST" form.

With the OCCUPIED-VACANT form of output, your BD16 is all you need for two color signaling. The VACANT-STANDING-EAST-WEST form of output is particularly helpful with hidden track. By having two LED's on your control panel, both will be on if the block is occupied and no cab is selected; when you select a cab, only one will turn on to indicate the direction the train will move.

Best of all, because of the advanced techniques used, one BD16 board will provide train detection in 16 different blocks. And will do this for about the same cost as six or seven normal block occupancy detector boards.

Because of a high level of electronic integration, the BD16 is offered complete, with built-in test functions, power supply and PC board edge connector.

The BD16 has several operating modes available. We explain what these modes are, and how you can configure your unit properly in this manual. If you need special assistance, please write, call or fax in your questions. We will do what we can to help you get the most from your investment.

If you have any suggestions or recommendations, please share them with us. We are happy to hear from you, and are committed to being **THE SUPPLIER** of the finest, most cost-effective model railroad control devices available to the railroad hobbyist.

FOR A FAST START:

This manual is divided into a number of logical sections, each intended to answer specific questions or to provide help of a specific type. So, to help you to find the information you need, here are some suggestions.

a. To see a description of the features and functions of your BD16 Block Occupancy Detector Board, read Section 2, BD16 OPERATIONAL FEATURES.
b. To learn more about general train detection methods and ways to use the output of your train detection board, read Section 8, OCCUPANCY DETECTION AND REPORTING.
c. To learn more about layout control systems and the type of system your BD16 is designed to operate with, read Section 3, TRAIN CONTROL SYSTEMS.
d. If you are routing track power through switches, you may need to install some minor changes to this wiring. Section 5, POWER ROUTING THROUGH SWITCHES will help you to understand where to make these changes and the simplest way to get it done.
e. Section 6, INSTALLING YOUR BD16 shows you exactly how to install your BD16 with the minimum effort and risk. Only read this section if you want it to work right the first time you turn it on.
f. For test as you go to instructions, or trouble shooting help at any time, read Section 6.7, TESTING YOUR BD16 DETECTOR.
g. If all else fails, for emergency relief read Section 7, CUSTOMER SUPPORT.

2. BD16 OPERATIONAL FEATURES

The BD16 Block Occupancy Detector is the latest state of the art device for sensing the presence of trains in sections of track, and providing control signals to activate signals or other devices on your layout.

a. Capacity - each BD16 will detect trains and control two color trackside signals for up to 16 separate blocks.
b. Train detection by current sensing - your BD16 will see your train no matter how long or short or how twisted your track is in the block.
c. Works with your layout control system - use DC Cab control or Digital Command Control, your BD16 will work with either.
d. Direct output of both OCCUPIED and VACANT status - you can operate two color signals with no additional hardware.
e. BUILT-IN SELF-TEST - your BD16 will help you with the installation and trouble shooting, and help you to identify specific problems.
f. Significant output capacity - operate both trackside signals and control panel indicators with no additional hardware.
g. Power supply included - depending on the type and number of your output devices, you may not need any additional power supply.
h. Output flexibility - you can operate LED's, incandescent bulbs or relays for direct control of signals and other special features. OR, use the BD16 to provide logic signals to other circuitry or a computer interface if you wish.
i. Modularity - add as many BD16 boards as you need for your layout. Each will handle 16 more blocks.
j. Furnished assembled and tested - no need to understand electronics. Just use the mounting hardware and card edge connector included with each unit, and follow the instructions, and you will have a state of the art train detection and signaling system.
k. Cost - there is NO other comparable train detection system with as low a cost per block as the BD16 - except our BD8 Block Occupancy Detector Board for 8 blocks!

The next several paragraphs describe many of these features in detail.

2.1 CURRENT SENSING

The BD16 uses a pair of 3 amp diodes to generate a small voltage whenever current is flowing to something in a block: a motor, command control receiver, light or anything else that draws current. The diodes share a common ground return connection. Hence, a common rail power distribution must be used to power the blocks connected to any given BD16. Figure 3-3 Command Control Layout Wiring shows how the BD16 is connected in a typical command control system, and Figure 3-2 shows the BD16 connected in a common rail DC control system.

The diodes are connected in series with the track feed to a block, and will result in a voltage drop of approximately ± 0.7 volts. A current of less than 1 milliamp, and up to the current limit of 3 amps can be detected. To prevent burning out the diodes, your cabs should have some means for limiting their output current to 3 amps or less if a short circuit occurs. This only makes sense, even without the BD16, since the cab, rail, wiring and electrical switches should be protected from excessively high currents.

The detected current is processed to eliminate any detection chatter due to dirty track or wheels. Special processing is also required with DCC controlled layouts to compensate for the effects of the high speed switching of the voltage applied to the track by boosters. All of this special processing is performed automatically by special circuitry included in the design of the BD16.

The BD16HC uses a pair of 6 amp diodes to handle train running current. This allows the board to be used for large-scale trains with much larger motors. In all other respects, the BD16HC is the same as the BD16.

2.2 TYPES OF OUTPUT

The BD16 Block Occupancy Detector comes equipped for three different types of outputs, and will also report occupancy in two different ways when used with DC control. These details are described below.

2.2.1 OUTPUT CAPACITY

Included with the BD16 is a five volt power supply which will not only power the board itself, but will provide up to 700 milliamps of current to operate your LED's. For typical LED's with a current of about 15 milliamps, this works out to be at least three LED's per block that can be on at the same time.

The outputs, when active, will switch to ground, sinking current from a positive supply. If configured for LED or logic output, no additional power supply is needed unless the total load current required for the LED's exceeds the limit of the BD16 power supply. If configured to activate relays, incandescent bulbs or some other type of device, you must provide the compatible supply. Any such supply must have a maximum voltage of 16 volts DC above ground to avoid damaging the BD16 output integrated circuits.

When ordering signals with LED's included, be sure the diodes are wired with their anodes in common. TOMAR and Oregon Rail Supply signals, also available from us, are fine quality signals wired in this manner. Other brands are also compatible if the diodes have individually wired cathodes. The anodes can be wired separately or in common.

Since each of the 32 outputs can handle 150 milliamps at the same time, you can use the BD16 even if your needs exceed the current capacity of the internal supply. Simply provide an external power supply of the necessary voltage, not to exceed 16 volts DC, and having sufficient current capacity. Use the external power supply to power your devices; use the internal power supply to power the BD16.

2.2.2 OCCUPIED-VACANT DETECTION

When used with a command control system, or in one of two output modes used with DC control, the BD16 will report blocks as either "OCCUPIED" or "VACANT". For each block, there are two outputs, one which is active when the block is OCCUPIED and the other when it is VACANT. The two outputs are mutually exclusive. Because of this, you can usually implement basic two-color signaling without any additional circuitry.

For a prototypical, professional installation, you will want to interlock the signal aspects to the position of switches just as the prototype does. We have developed the MSC Master Signal Controller to help you with this. The MSC has built-in 18 different track scenes such as passing tracks, junctions, crossings, etc. In addition, the MSC will control color light, position light, color position light, searchlight and semaphore signals. This allows you to create a truly prototypical three or more aspect signaling system for your layout.

2.2.3 DIRECTIONAL DETECTION

When used with DC control, the BD16 can be configured to indicate not just occupied or vacant, but which way the train is moving if it is not standing still. This is particularly helpful if you are implementing some form of automatic progressive cab control, or using the BD16 to show which way trains are moving in hidden track.

This feature is not available with command control since the motor polarity is controlled in the engine by the decoder. This means that the throttle itself always indicates the true direction of travel.

There are still two output signals for each block. In this case, one will be active if the train is moving in east bound, the second if the train is moving west bound. If the train is standing still, or "moving in both directions", both outputs will be active. If the block is empty, both outputs will be off. This is depicted simply in Table 2-1 below.

Table 2-1 Outputs for Directional Detection Mode

BLOCK STATUS	EAST OUTPUT	WEST OUTPUT
vacant	off = open circuit	off = open circuit
train standing	on = 0 volts	on = 0 volts
train moving east	on = 0 volts	off = open circuit
train moving west	off = open circuit	on = 0 volts

The BD16 has a mode jumper plug that plays a part in this. If your common rail is the south rail, install the jumper (Figure 6-7); if your common rail is the north rail (Figure 6-8), leave the jumper off.

2.2.4 LED ACTIVATION

For many applications, such as two color signaling, the BD16 Occupancy Detector needs no additional circuitry. It can operate two-color LED signal lights directly. Sufficient current capacity is available from the power supply provided with the BD16 to operate a total of 70 LED's of 10 milliamperes each, with all on at the same time.

Each LED must have a current limiting resistor connected in series with it. This is shown in detail in Figure 6-13 Driving Multiple LED's From a Single Output.

2.2.5 LOGIC SIGNAL ACTIVATION

The BD16 can be configured to output logic signals that can be used by other circuitry, such as three color signal control boards or progressive cab control circuitry. Since the BD16 provides what are known as "open collector" outputs, you simply connect a BD16 output to the desired TTL or CMOS input.

The input circuit will need, and usually comes equipped with, a pull-up resistor connecting the input to +5 volts. The resistor raises the input to a logic high when the BD16 output is off; the BD16 output pulls the input low when it is on. Typically, these resistors will have values of 1000 ohms or greater. Our TC4 uses 10,000-ohm resistors.

All of the filtering used to minimize the effects of track and wheel dirt is still operational. No additional power supplies are needed by the BD16 to function using this output mode.

2.2.6 RELAY ACTIVATION

The BD16 also has the output current capacity to switch loads of up to 150 milliamperes per output (32 total). However, the total load current could be far beyond the capacity of the power supply we include. To make use of the total output capacity, you will have to supply your own power supply. Also, if you are connecting an inductive load, such as a relay or motor coil, to the BD16, you must also use diodes which protect the BD16 outputs from the voltage spikes which are generated when current is turned off in an inductive load. How to use the diodes is illustrated in Figure 6-15.

2.3 BUILT-IN SELF TEST

The BD16 is a truly unique product in that it provides built-in test functions that will help you to test and trouble shoot the board itself and your installation. Other than our own BD8 Block Occupancy Detector Board, we know of no other train detection product that provides you with this feature. By using the mode plugs provided with the unit, you can have the BD16 sequence each of its outputs on and off in two second steps, or very rapidly if all you need is a quick check.

Everything you need to know to take advantage of the self-test functions is provided later in this manual.

2.4 ASSEMBLED AND TESTED

We realize that most model railroaders have railroading as their hobby - not electronics. To give you access to the latest electronic technology, without getting you into the electronics field, your BD16 comes to you completely assembled and tested. You don’t have to have any knowledge of electronics to use all of the board’s features. Simply follow the detailed instructions in this manual to connect the board’s 16 inputs to your blocks for train detection, and the 32 outputs to your signals or other output devices. Depending on how your layout is currently wired, it may involve no more than taping into 16 block common rail wires, and adding 2 wires per block to your signals!

3. TRAIN CONTROL SYSTEMS

Over the years, many different systems have been developed for controlling model railroad trains. Today, there are two primary ways of controlling trains: DC control and Digital Command Control (DCC). Both systems share the same goal: allow each engineer to control the speed and direction of his train. They differ in the way they achieve this goal, and the electrical complexity and operational flexibility provided.

Note that other forms of train control are still probably in use (ASTRAC, On-Board, CTC16, CTC80, etc.). But, as far as we know, these systems are no longer in production. They provide older technology versions of command control that are being replaced by DCC today.

Incidentally, the BD16 does not control trains. It simply detects the currents flowing to 16 different sections of track to determine whether or not trains are present in those separate sections, and possibly which way they are moving.

We do have some customers who have used our detector boards to activate relays when a block is occupied, and use the relays break the current to the prior block to prevent rear end collisions automatically. This is particularly helpful for modular layouts when they are operating for the public. It is sometimes difficult for the crew to converse with the spectators and keep the trains under control.

This lengthy discussion of train control methods and wiring is to help you to connect the BD16 into whatever train control system you now have, or to help you modify your present system so you can use the BD16. We will also provide some suggestions for using the BD16 to handle certain typical situations that arise on many layouts.

3.1 TERMINOLOGY

To allow us to discuss train control, we must begin by understanding certain basic terms.

ABS - Automatic Block Signaling, a system used to signal track for one direction of traffic flow. The signals will automatically protect trains from following movements.

APB - Absolute-Permissive Block Signaling, a system used to signal track for two directions of traffic flow. The signals automatically protect trains from both following and opposing movements.

BLOCK - a section of track separated electrically from other sections to allow trains to be controlled or their presence detected independently of all other blocks. Blocks on the prototype are used exclusively for detection purposes. On model railroads, we use the word to describe track sections separated for detection or for control. This latter use of the word “block” comes up in DC cab control layouts.

CAB - a mechanism of some kind responsible for the speed and direction of a single train. It accomplishes this by controlling the voltage and polarity applied to the motor(s) of a train. There are various techniques carry out this control.

CTC - Centralized Traffic Control, a system of train dispatching which allows a remotely located dispatcher to route trains through the automatic positioning of track switches and signal aspects. The actual track conditions, such as actual switch positions and the presence of trains, will over-ride the dispatcher if his actions would cause an unsafe routing or signal aspect to be displayed.

COMMAND CONTROL - a train control system in which some “full” voltage is always applied to the track, along with a special electrical control signal that carries speed and direction information to many different trains independently. With command control, there are some number of separate, independent channels of communication between a central control station and receivers located in the engines. Each engine receives its own speed and direction information over an assigned channel, and then derives the voltage and polarity applied to its motor from the “full” voltage always present on the track. Different types of command control systems implement their communications channels and form of “full” voltage in different and usually incompatible ways. There is now an NMRA Standard and related Recommended Practices for command control approved by the membership. We can all now take advantage of the NMRA Standard Digital Command Control (DCC) technology knowing that our investment in equipment to operate our trains is protected by the existence of multiple manufacturers making compatible equipment. This has been the case with the NMRA Standard for DC control for many decades.

COMMON RAIL - a method of wiring a DC controlled layout so that one rail is always considered to be at a constant, zero voltage. To control train direction of movement, the other rail would be taken to a positive or negative voltage. **Table 3-1** below shows how this works when your engines have been wired according to National Model Railroad Association (NMRA) standards. Note that train movement has nothing to do with the direction the engine is facing.

Table 3-1 Direction and Rail Usage

RR DIRECTION	COMMON RAIL	POWER RAIL	TRAIN MOVEMENT
East-West	NORTH	SOUTH & Positive	East-bound
East-West	NORTH	SOUTH & Negative	West-bound
East-West	SOUTH	NORTH & Positive	West-bound
East-West	SOUTH	NORTH & Negative	East-bound
North-South	EAST	WEST & Positive	South-bound
North-South	EAST	WEST & Negative	North-bound
North-South	WEST	EAST & Positive	North-bound
North-South	WEST	EAST & Negative	South-bound

If you have some personal dislike for "common rail wiring" at this point, simply call the rails "A" and "B", or "NORTH" and "SOUTH"; trains will physically move the same way no matter what names we pick. **<u>The only thing that matters to a motor is the voltage and polarity it sees.</u>** The rail names are chosen to enable us to communicate with each other, and identify the specific items we are talking about. We choose a system of getting the voltage to a motor based on our operational needs and desires, and our available budget.

CONTROL BLOCK - an electrically isolated section of track used for the control of a train separate from all other trains on the layout. Control blocks are generally used only with DC control.

DC CONTROL - a train control system in which the layout is divided into many electrically independent control blocks, and a means is provided to connect only one of several cabs to a given control block at a time, allowing that cab to control the speed and direction of all trains in the control block.

DCC or DIGITAL COMMAND CONTROL - A form of command control described by the NMRA Standards and Recommended Practices. Command control operates by sending speed and direction messages through the track to decoders in each engine. Each decoder accepts only messages sent to it specifically, and carries out the command. The typical commands will provide speed and direction information; additional commands can turn lights on or off, sound the bell or whistle, etc. The important thing is that these messages are sent to all trains, wherever they are on the layout. Hence, with DCC, we can operate our trains exactly like the prototype - cornfield meets and all!

DETECTION BLOCK - an electrically isolated section of track used for detection of a train separate from all other detection blocks on a layout. There is no need for control blocks and detection blocks to be identical.

EAST-BOUND - the condition of a detection block which has a train present and moving east.

HEADBLOCK SIGNAL - a signal which protects the entrance to or exit from passing tracks.

LED - Light Emitting Diode. A solid state device which emits light, visible or IR, when a small DC current flows through it. They are very efficient, operate with little temperature rise, have very long life, and are good for use in signals or on control panels to indication switch positions or block occupancy.

NORTH-BOUND - the condition of a detection block which has a train present and moving north.

OCCUPANCY DETECTION - a means for detecting the presence of a train in a block. Note that the blocks used to divide the layout for train control purposes can be different from the blocks used for detection. A normal highway grade crossing provides a good example of the difference. For prototypical control of the crossing gates or flashers, three separate occupancy detectors should be used. But there is no need or desire to provide for the control of separate trains in these three blocks. One train control block is sufficient.

OCCUPIED - the condition of a detection block that has a train present within it.

OS - On Sheet, or On Switch. The “On Sheet” usage applies to manual signaling and train control systems in which an operator will record the arrival or departure of a train “on sheet”, a form used to keep a record of train movements and presence in blocks. The “On Switch” usage applies to automatic signaling systems which detect the presence of a train on a switch and prevent throwing the switch.

POWER RAIL - the rail parallel to the common rail. Since the common rail is at 0 volts, or “ground”, the power rail is taken to positive or negative voltages with respect to the common rail to control the speed and direction of train movement.

RAILS - the parallel structures that the wheels roll on. For electrical purposes, rails need to have names. If your railroad runs east-west, you have a NORTH RAIL and a SOUTH RAIL. If your railroad runs north-south, you have an EAST RAIL and a WEST RAIL. While a particular rail is normally always NORTH or SOUTH, note that in certain special situations, such as frogs, turntables or reversing sections, a particular rail may change.

SIGNALING - the presentation of train presence or movement information to the engineers, dispatcher and other people involved in operating the railroad. For model railroads, this can be done to achieve scenic effects with trackside signals or grade crossing gates or flashers, or to display train position on control panels to show train position in areas of limited visibility to the operators, such as hidden staging yards.

SOUTH-BOUND - the condition of a detection block which has a train present and moving south.

TRAIN DIRECTION - the direction the train is moving. For prototype railroads, direction is determined by timetable direction. On east-west railroads, a train is moving either east or west. On north-south railroads, trains are moving either north or south. Sometimes the difference determined geographically; other times the choice is arbitrary. For your railroad, you decide whether your trains move east-west or north-south.

VACANT - the condition of a detection block that has no train present within it.

WEST-BOUND - the condition of a detection block which has a train present and moving west.

3.2 DC CONTROL SYSTEMS

With DC control, the layout is divided into many electrically separate blocks so that the speed and direction of trains in different blocks can be controlled independently. However, all trains within a given block receive the same voltage and polarity, and will therefore move in the same direction, and as determined by the specific motor and gearbox, at more or less the same speed.

People use countless ways for generating this voltage: batteries, variable transformers, DC supplies with rheostats, DC supplies with various forms of transistorized or integrated circuit voltage control circuits, SCR controls, and even motor-generator sets!

Such layouts usually have at least two cabs and some method for the connecting cabs, one at a time, to each block. Many different systems have been developed over the years, and you will hear names such as cab control, tower cab control, route cab control, progressive cab control, and more. All of these systems were developed to allow multi-train operation on a layout. The whole purpose is to allow different engineers to operate their trains over the layout with as little interaction and confusion as possible.

Regardless of the details involved in generating the voltage and current used to run each train, the power routing system takes only two forms: two rail switched systems, and common rail switched systems.

3.2.1 TWO RAIL SWITCHED SYSTEMS

Two rail switched systems have circuitry that routes both rails of a block to the assigned cab. In this case, all cabs are totally independent electrically, and all blocks are totally independent. While this seems like a simple, straightforward system, it does require almost twice as much wiring as is needed with common rail systems. Every switch must be a two-pole switch. Figure 3-1 provides an example of a layout wired this way.

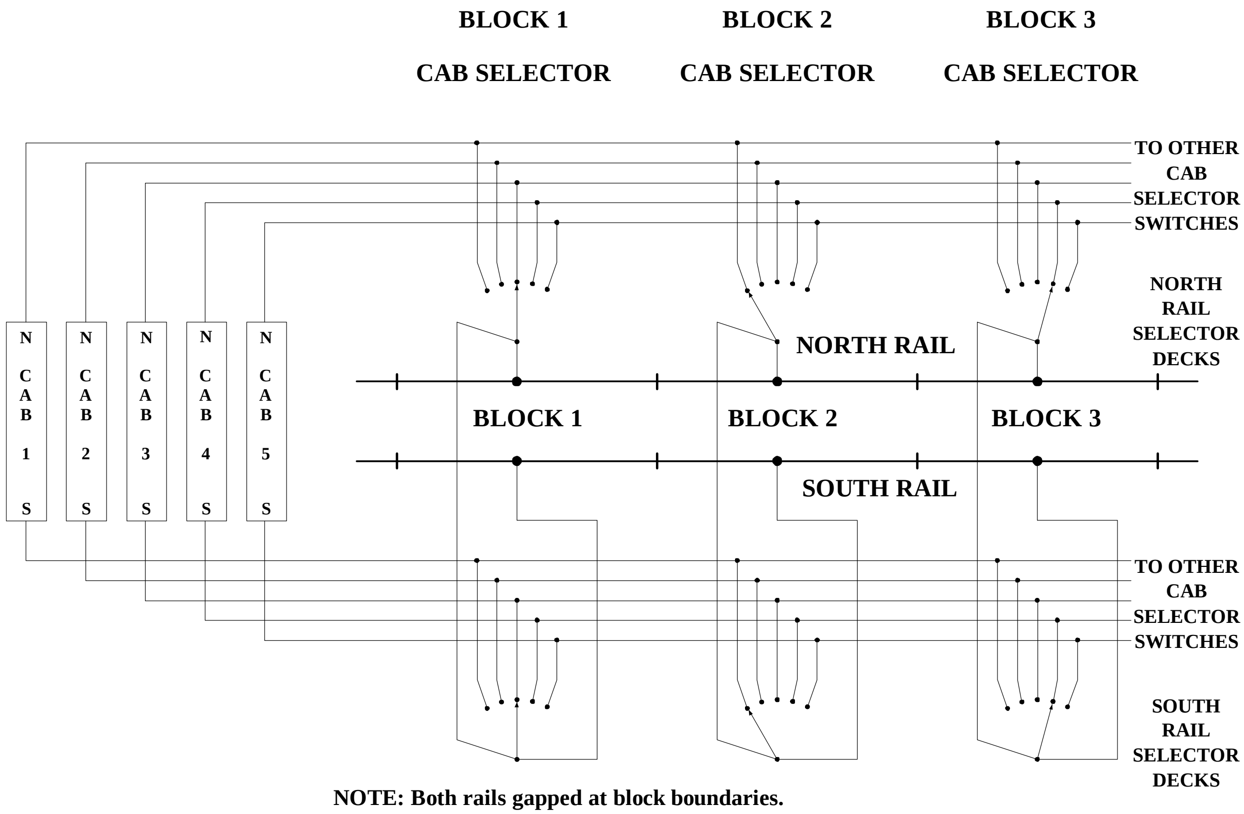


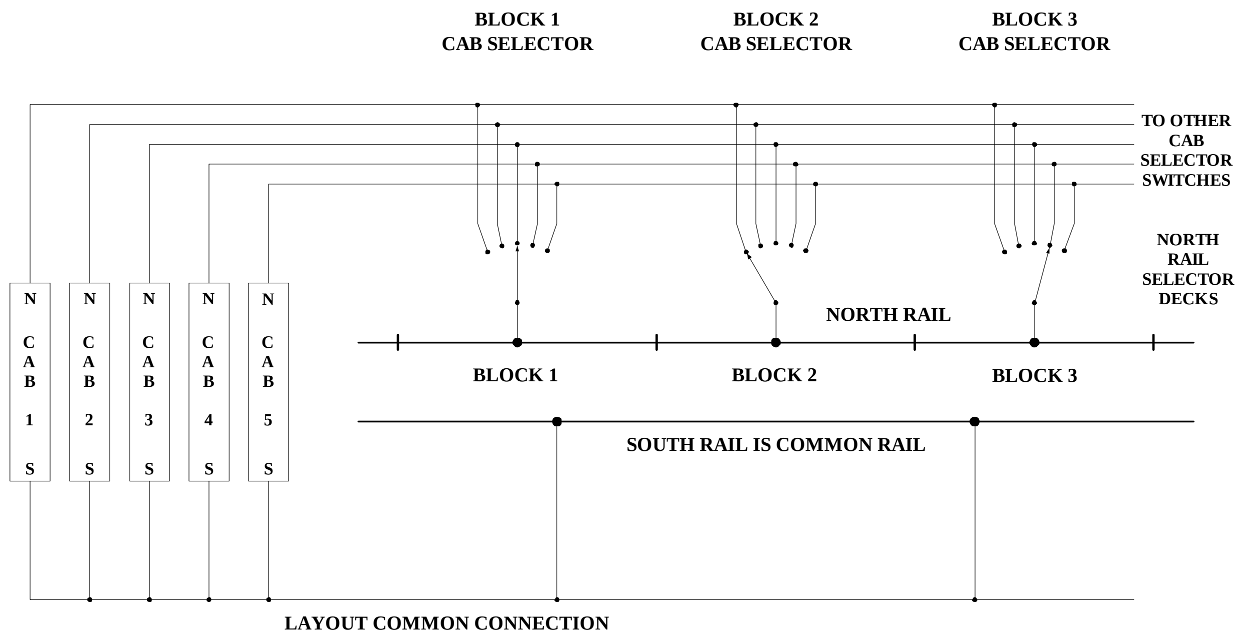
Figure 3-1 Two-Rail Switched Cab Circuits

While this system works, it does not provide any advantages for operating your trains. Because there are twice as many switched electrical contacts between a cab and an engine, reliability is lower. This method also complicates occupancy detection since the detection circuits for each block must also be electrically isolated. Such detectors exist, but are somewhat more expensive than detectors that can share an electrical ground connection.

3.2.2 COMMON RAIL SYSTEMS

Common rail electrical systems consider one of the two rails always to be at zero volts, or “ground”. Setting the polarity of the other rail relative to the common rail controls train direction: positive voltage will move the train in one direction, negative voltage in the other. Either rail may be selected as the common rail; the choice is entirely arbitrary. But a given layout must have the same rail as common throughout. Figure 3-2 below shows a layout wired using the common rail method.

Why use a common rail wiring system? There are two good reasons. First, since the common rail is always at the same voltage, namely 0 volts, you don't have to provide any switching for the common rail when connecting cabs to blocks.



NOTE: Only NORTH rail gapped at block boundaries.
SOUTH rail leads installed to provide low resistance path to cab
Cabs are internally isolated from each other electrically.

Figure 3-2 Common Rail Layout Wiring

Second, since the common rail is always at the layout common voltage, very simple circuits can be used for train detection by connecting the common rail through the detector circuit to layout common. Such detectors usually cost less than isolated detectors.

Sometimes modelers express the feeling that common rail wiring cannot be used for certain railroad track configurations. In each case, these modelers have tried to select their common rail using a rule such as "the right hand running rail is common". Please, please, do not use such rules. In a sense, they are correct: THAT RULE WILL NOT WORK.

However, if you use a rule which says "the north rail is common", you will have no problems whatsoever. Pick the north rail or the south rail if you prefer, but use the same rail as the common rail everywhere on your layout.

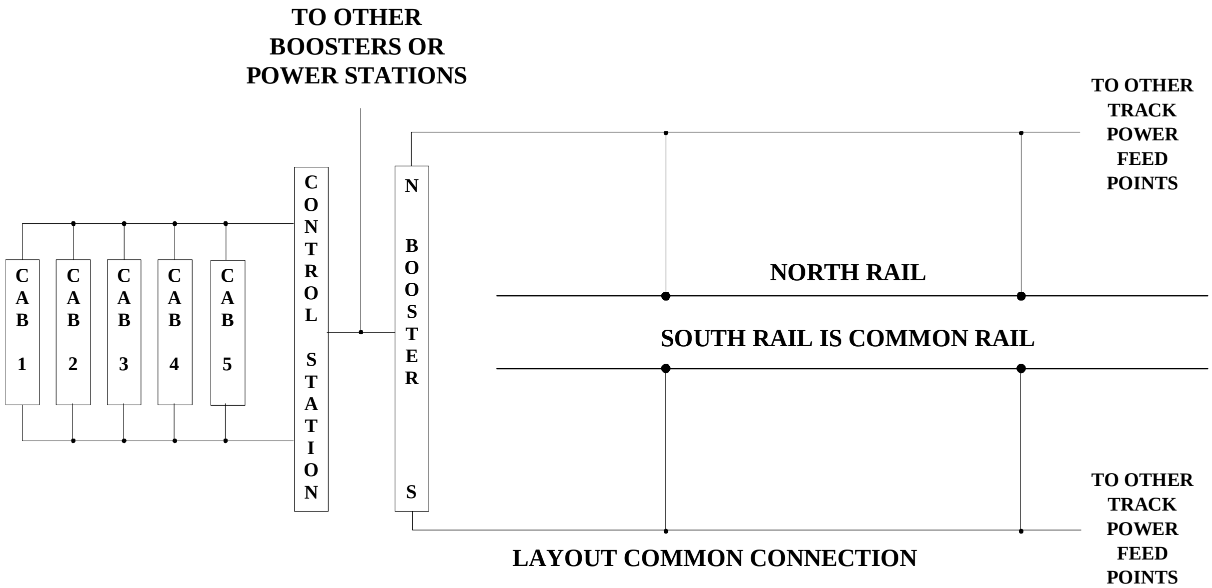
If you use DC control, the BD16 will only work if you use common rail wiring for your layout. Converting a two rail switched layout to common rail is simple - if the cabs are electrically isolated. Simply pick a rail to be used as the common rail, and then tie together all of the cab lines that connect to that rail, bypassing whatever cab select switches you may have.

Only reversing sections need to be handled with both rails isolated. This allows you to reverse the connections to these rails to match the polarity of these rails as a train enters and exits the reversing section.

Some additional modifications may be necessary if you are routing power through track switches. More on that in Section 5, POWER ROUTING THROUGH SWITCHES.

3.3 COMMAND CONTROL SYSTEMS

Command Control systems, and there are several good ones available, are gaining a share of the market. They offer the greatest flexibility currently available for operating multiple trains on a layout. As the NMRA DCC standard gains wider acceptance, we can all expect to see this form of control used more and more. Figure 3-3 below shows the typical wiring for a layout using command control. While the different systems use their own methods for implementing the control and power stations, the layouts all seem to be wired as shown.



**NOTE: Gaps are only used to isolate frogs, or to separate power stations.
Think of the entire layout as one single block.
Cab connections to control station depend on the specific command control system used.**

Figure 3-3 Command Control Layout Wiring

With Command Control, full voltage of some form is always applied to the entire track. Included in this voltage is some form of electrical signal that is picked up by a decoder within each engine, and used to determine the voltage and polarity to the motor. Note that, ultimately, the motor needs a DC voltage and polarity to rotate and move the train.

There are various systems for embedding the control signal in the high current and voltage that appears on the track. These systems allow each engineer to control his train anywhere on the layout, independent of what the other engineers are doing, and without routing power to track blocks. In this regard, these systems are extremely successful. Using a command control system lets you have a cornfield meet, if you want to or get careless!

Command control systems may, or may not, be common rail systems. Specifically, the NMRA Standard DCC System uses “boosters” to provide power to the rails for the engines and other command decoders which are attached to the rails. Each DCC manufacturer has his own recommendation concerning the connection of his booster outputs to get a layout-wide common rail. Follow the vendors’ recommendations when installing the BD16 in your system. If the DCC vendor does not recommend connecting booster outputs together, you will need to use separate detector boards for each booster. As far as the output of a single booster is concerned, its output is “common rail” wired; but there is a separate “common rail” for the power district connected to each separate booster. All BD16 boards connected to the output of a given booster will share a single “common rail” within the associated power district.

Other systems have “power stations” of some kind that provides the combined power and control signal voltage to large amounts of track. Sometimes, particularly for large layouts with many trains running, you will want to divide the layout into several sections and power each from a separate power unit. This will help in finding short circuits since only the shorted section will stop functioning. It also divides the current drawn by the engines among the power units. Most of the units have a current limit somewhere in the 4 to 8 ampere range.

To wire a layout for non-DCC command control, follow any specific instructions provided with your system. As far as we know, the BD16 Occupancy Detector Board will work with all command control systems. Should you find that it doesn’t, simply let us know within 30 days and we will provide a full refund upon return of your BD16 boards in working condition. Naturally, we are interested in getting whatever information we can about your command control system so we can design a detection system that is compatible.

4. PLANNING YOUR TRAIN DETECTION SYSTEM

Now is the time to plan your train detection system. You probably have a general idea of what you would like to accomplish. But, to help you clarify any issues that may be undefined, we would like to present some ideas that may be helpful.

The prototype railroads have only one purpose for their signal system: to help trains stop safely before reaching another train, an obstruction, or other unsafe situation. Naturally, we may want to include signaling to add realism to our layout. But there are aspects about model railroads that have no prototypical equivalent. For example, how often does a prototypical train pull into a hidden staging yard, or under a hydrocal mountain? We will also give some suggestions about using train detection to help you operate your layout, especially those portions that are hidden from view.

4.1 PROTOTYPICAL SIGNALING SYSTEMS

In the space we have available here, we cannot include complete coverage of this topic. But we will provide enough information to help you get started. There are a number of books and magazine articles available that will help you expand your knowledge of the subject. And, if you are attempting to model a specific prototype in a specific era, the final guide will be the railroad’s Employee TimeTable and Rule Book. While the figures and signal arrangements may be considered “typical” or “AAR standard”, each individual railroad is free to add to or even modify the AAR standards as it sees fit.

The purpose of a prototype signaling system is to help the engineer stop his train safely. But they also want trains to be able to move as quickly as possible when they are not stopping.

The key issue is stopping distance. Three primary factors that determine stopping distance: the weight of the train, the speed of the train, and the slope of the track. Heavier trains take longer distances to stop, faster trains take longer to stop, and trains going down hill take longer to stop.

Even if we are modeling a prototype signaling system, as modelers, our stopping distances are measured in inches no matter what our speed, and our available space is minuscule. So, we resort to selective compression. We will normally have our blocks as long as the typical train on our layout. Our passing tracks are usually the same length as well.

Before the advent of Centralized Traffic Control (CTC) systems, railroads used Automatic Block Signaling (ABS) to signal for one direction of traffic, and Absolute-Permissive Block Signaling (APB) to signal for two directions of traffic. For both of these systems, the Timetable identified where and when meets and passes were to take place, and the rules of train superiority, by class and direction, told which crew should take the siding and which to use the main. Any exceptions to the timetable, such as temporary routings, extra trains, movements opposed to the normal traffic flow, were handled using written train orders.

The train crews were responsible for setting the track switches as they came to sidings, and for leaving them in the normal position when leaving.

With CTC installations, a remotely located dispatcher controls the switches and signals at passing tracks, but usually not at industrial spurs. The timetable is still used to provide the schedule for the trains. But meets and passes are controlled directly by the dispatcher; the rules of train superiority are suspended.

One simple way to tell which type of signaling the prototype is using is to look at the signals at the entrance and exit of passing tracks. With APB systems, there are two signals, one facing each way, located near the switch points. These are called headblock signals. Trains on the frog side of the switch will stop before reaching the fouling point if the signal they see shows STOP. The signal they face as they approach from the point side indicates the condition of the main line block. The siding is normally not signaled.

The signal seen when leaving the passing track area is an absolute signal. If it displays STOP, a train is not allowed to pass. You will normally find a telephone located near absolute signals so the crew can phone for instructions if they find an unexpected STOP aspect.

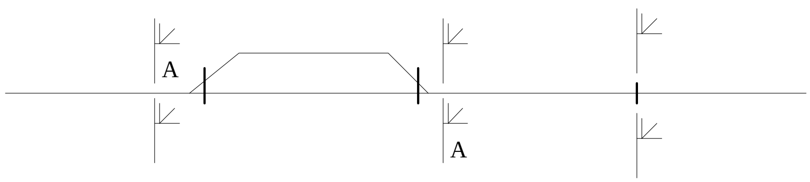


Figure 4-1 Typical APB Block Signals

With CTC installations, there are usually three signals protecting the end of a passing track. Since the timetable is no longer used to determine train superiority, the dispatcher uses the signals to issue “orders” to the crews. The signal seen when approaching the points will show CLEAR to indicate a train routing on the main, will show APPROACH to indicate a routine on the siding, and STOP to indicate STOP. Some railroads will have a two-head signal, with the upper head signaling use of the main, and the lower head signaling use of the siding. Thus, GREEN over RED routes a train onto the main; RED over GREEN or RED over YELLOW will route the train onto the siding. The yellow aspect indicates using approach speed into the siding.

On the frog side, there will be one signal for each track. These are both absolute signals, and the dispatcher will set one of these signals to display CLEAR to allow a train to depart. Signaling circuitry in the field, called ‘vital’ circuits, will over-ride the dispatchers’ command based on block occupancy, if necessary for safety.

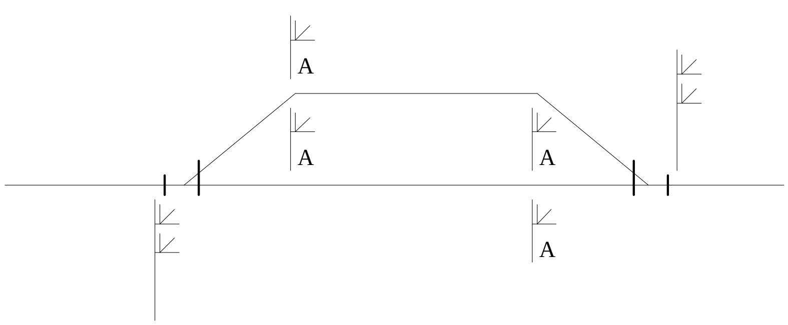


Figure 4-2 Typical CTC Signals

It should be noted that, except at passing tracks and junctions, where the dispatcher issues "orders" by signal indication, the remaining signals are normal ABS-APB signals. And even the dispatcher-controlled signals will have their aspects overridden by the ABS-APB detection circuits if trains are in the blocks ahead of the signals.

With CTC, the track circuits that detect the trains will control the aspect display at trackside; but they will also indicate occupied blocks on the dispatcher's panel so he can see where trains are. And a special track circuit detects trains which are on dispatcher controlled switches and prevents him from throwing a switch beneath a train. The short detection blocks containing the switches in Figure 4-2 indicate the 'On-Switch' or OS blocks. Usually, as soon as a train enters the switch itself, all three of the signals will automatically return to STOP. This automatically protects the rear of the train.

Also, no matter what the type of signaling, the industrial tracks along the way are interlocked into the signal system. If the switch to a spur, or the derail on the spur, is not in its safe position, the signals protecting the entrances to the block will display STOP. Normally, this will be a permissive stop, allowing the crew to stop, and then proceed at restricted speed watching for a train or obstruction.

4.2 SPECIAL MODEL RAILROAD APPLICATIONS

As modelers, we can include all of the signaling the prototype uses, especially along our visible track.

But much of our track is hidden. It really doesn't make sense to install trackside signals in places where neither the operators nor spectators can see them. But it does make sense to provide train detection and display block occupancy to help us operate trains in our hidden track.

There are two typical layout situations that would benefit from occupancy display. When installed as shown in the next several figures, train detection will allow you and your operators to function as smoothly over hidden track as you do with the visible track.

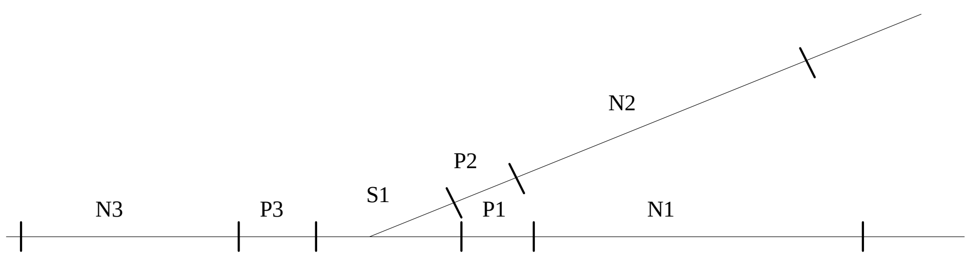


Figure 4-3 Hidden Junction Detection

In this figure, the three blocks labeled N1, N2 and N3 are "normal" length blocks, probably about a train length. The blocks P1, P2 and P3 are "positioning" blocks. Each is about the length of an engine, and they are located so that they protect the fouling points of the switch. And block S1 is the switch itself, from ahead of the points to a little beyond the fouling points on the frog side. Each of these blocks has an occupancy detector connected that controls a single "occupied" LED on a panel which is visible to everyone operating trains in the junction area. The display panel would probably depict the track in the area in schematic form.

In normal operation, an engineer might be told to "hold at the junction." He would move his train toward the junction, watching the display panel to see where his train was. As soon as the positioning block shows occupied, he stops his train. If the switch block shows occupied, he has run through the positioning block and is fouling the switch. He simply backs up until the switch shows vacant and the positioning block still shows occupied.

The next situation that we modelers have that the prototype doesn't have is a hidden holding yard. Its arrangement of detection blocks, the display of occupancy on a panel, and the method of operation are very similar.

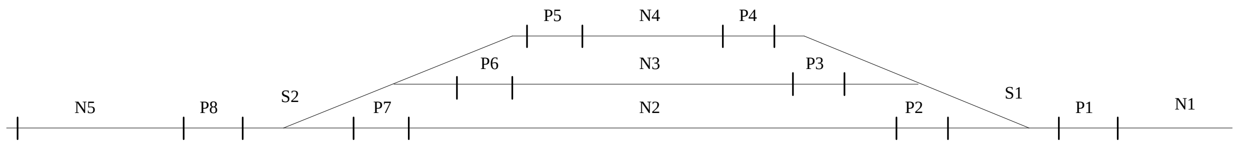


Figure 4-4 Hidden Holding or Staging Yard

Again, the blocks labeled “N” are normal blocks, those labeled “P” are positioning blocks, and the switch blocks are labeled “S.” As you pull a train into one of the holding tracks, you will move forward until the positioning block at the exit shows occupied. The exit-end switch block will show occupied if you pass the fouling point. And, if your train is too long for the track, the entrance end switch block will still show occupied.

The block arrangements shown in these two figures are detection blocks. The power routing blocks, if you are using DC control, will include the consecutive “P” and “N” blocks, based on turnout position.

5. POWER ROUTING THROUGH SWITCHES

Train detection may also have an effect on your power routing through switches. Figure 5-1 shows a normal power routing switch aligned for the main line. As you can see, both siding rails are electrically connected to the power rail “P” and any train on the siding will see no voltage and will therefore be stopped. An electrical contact is shown which operates along with the points to route power to the frog.

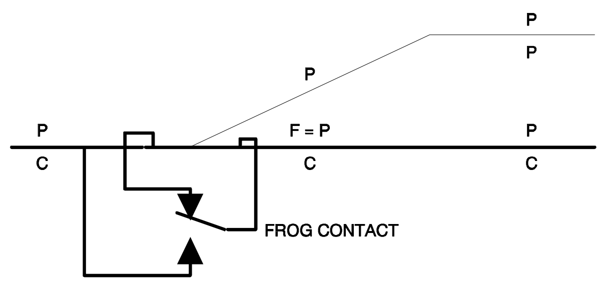


Figure 5-1 Power Routing Switch Set For Main Line

Figure 5-2 shows the same switch aligned for the siding. Now, a train on the siding sees both power and common rails and can move, while a train on the main sees two common rails and cannot move. As long as we don’t want to detect a train on the siding while the switch is set for the main, everything is just fine. But, if we want to have a separate block on the siding, with a separate detector, the standard power routing won’t work.

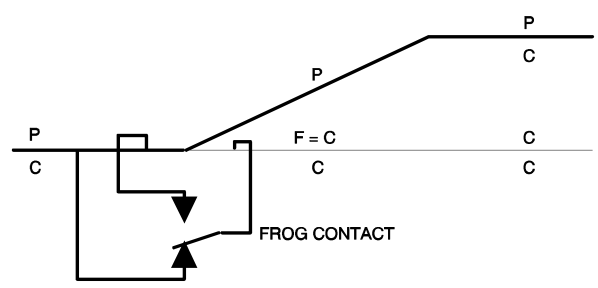


Figure 5-2 Power Routing Switch Set For Siding

Figure 5-3 shows the same track with separate train detection on the siding using detector C2, while detector C1 is looking at the main line. You can see that we need a gap in the siding common rail near the fouling point of the switch to separate the siding's common rail from the main line block.

Here is where things get interesting. The common rail for the siding is always connected to layout common through the C2 block detector, and its power rail is simply a continuous stock rail through the switch. And, even with the switch set for the main, a train on the siding will run!

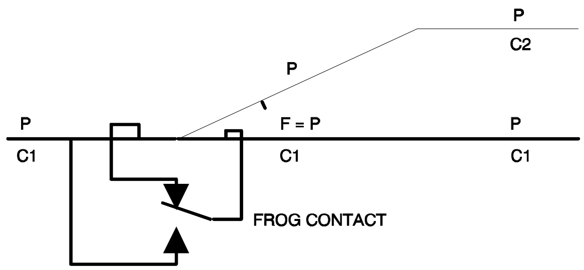


Figure 5-3 Power Routing and Separate Siding Detection

To solve this problem, we need to have an extra electrical contact that operates along with the switch to route the power rail through the switch. This means two single pole, double throw (SPDT) contacts are needed for a power routing switch with separate detection on the frog side. One contact routes power to the frog, the second routes the power rail from the point side to one of the power rails on the frog side. This is shown below in Figure 5-4. Both of these contacts move along with the points. Everything in the figure is shown with the switch aligned for the main. Note that both siding rails are gapped near the switch's fouling point, and the main line block's power rail is gapped at the fouling point.

With the switch as shown, the lower contact is connecting the main block power rail to the frog (F). The upper contact is connecting the main block power rail to the part of the main block beyond the frog (rail PM). The power rail on the siding block (PS) is not connected to anything, and a train on the siding will be stopped, *but could still be detectable by C2 if there was a source of current to detect*. We'll show you how to do that in a just a bit.

Note that this upper contact is not needed if the main and passing tracks receive their power from separate cab select switches. This would normally be done if you could run a train on the siding while other trains operate over the main.

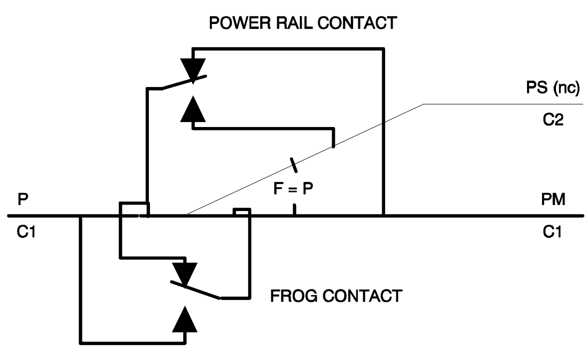


Figure 5-4 Power Rail Routing to Main Line

In Figure 5-5, the same switch is aligned for the siding. Note that the contacts move with the points, and the frog (F) is now connected to the C1 rail. The siding power rail (PS) is connected to the power rail for the main (P), and the main line power rail (PM) beyond the switch is not connected. A train will now run on the siding, but remain stopped on the main.

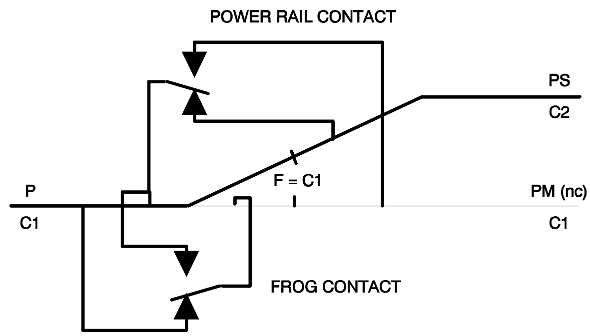


Figure 5-5 Power Rail Routine to Siding

Just for completeness, we'll show the same switch wired with the straight stock rail as the power rail, and the curved stock rail as the common rail. In Figure 5-6, the common rails are connected to two separate detectors (C1 and C2). We assume that "P" is being fed by a cab select switch, and is routed by the upper contact to the power rail (PM) in the main line block beyond the switch.

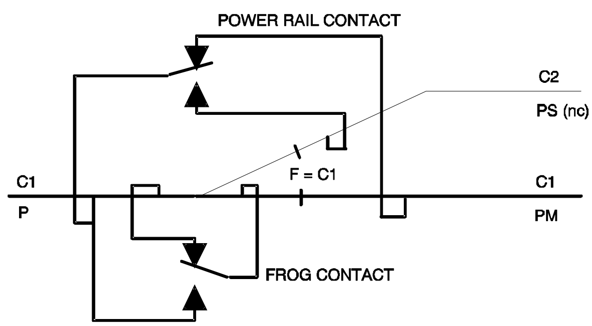


Figure 5-6 Power Routing with Straight Stock Rail Common

The power routing we have shown above is something that you will have to add to any of your switches that will have separate detection on the frog side with power being routed through the switch. One at a time, make the modifications to each of your switches that will operate this way. Again, after each is modified with the extra electrical contact, do a sanity check and run a train through all related routes. Make sure it runs when it should run, and stops when it should stop. If something doesn't work right, fix it. You have probably not wired one of the contacts properly, or have not cut the necessary gaps.

6. INSTALLING YOUR BD16

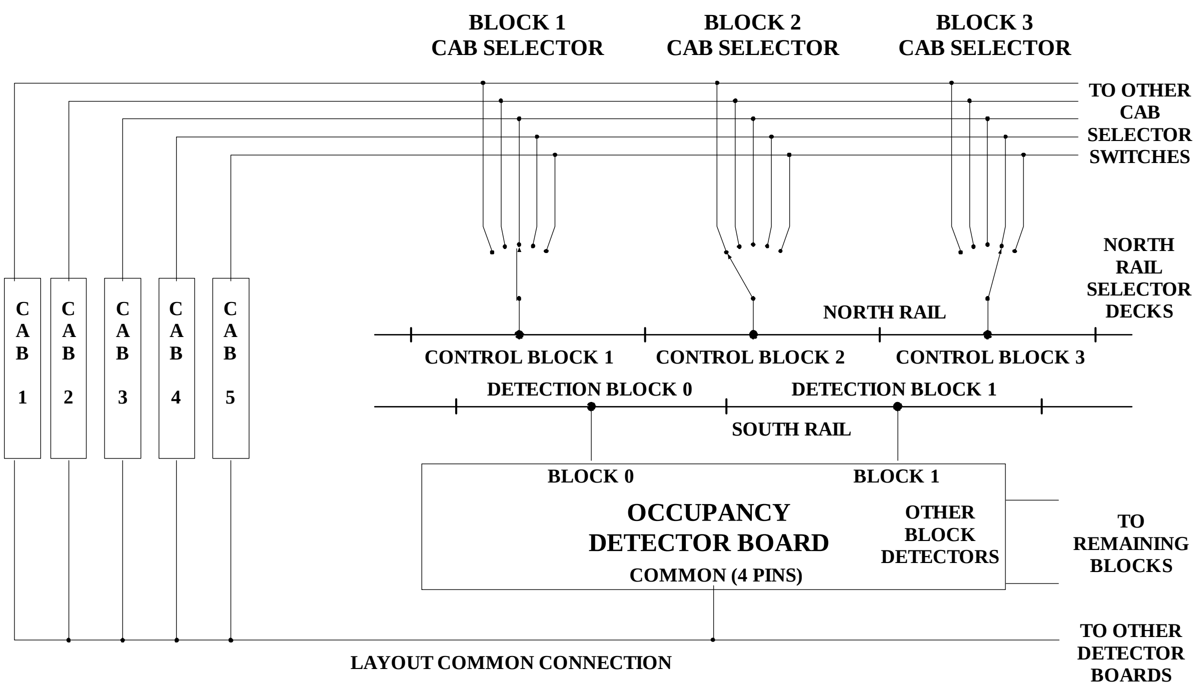
You have probably heard the adage "Prior Planning Prevents Poor Performance," and model railroading is no exception. Before doing anything on your layout, we recommend you plan your complete signaling installation, even if you have only purchased some of the detectors and signals you will eventually need.

First, make drawings of your layout showing all of the tracks: main line, sidings, spurs, hidden, visible, built, or planned but not built. Then, identify each separate detection block and give it a number from 0 to 15. If your layout needs more than one BD16, assign a letter to each BD16 (BD16-A for the first, BD16-B for the second, and so on), and label the blocks with the BD16 letter and block number. For example, if you have two BD16s, the first will have blocks labeled A0 through A15, and the second will have blocks labeled B0 through B15. Assign the labels any way you want. The purpose is simply to know how and where to connect the wires. This drawing will be the master signaling system drawing for your layout.

Before continuing here, if your layout is not already wired for common rail power distribution, follow the instructions in Section 8.

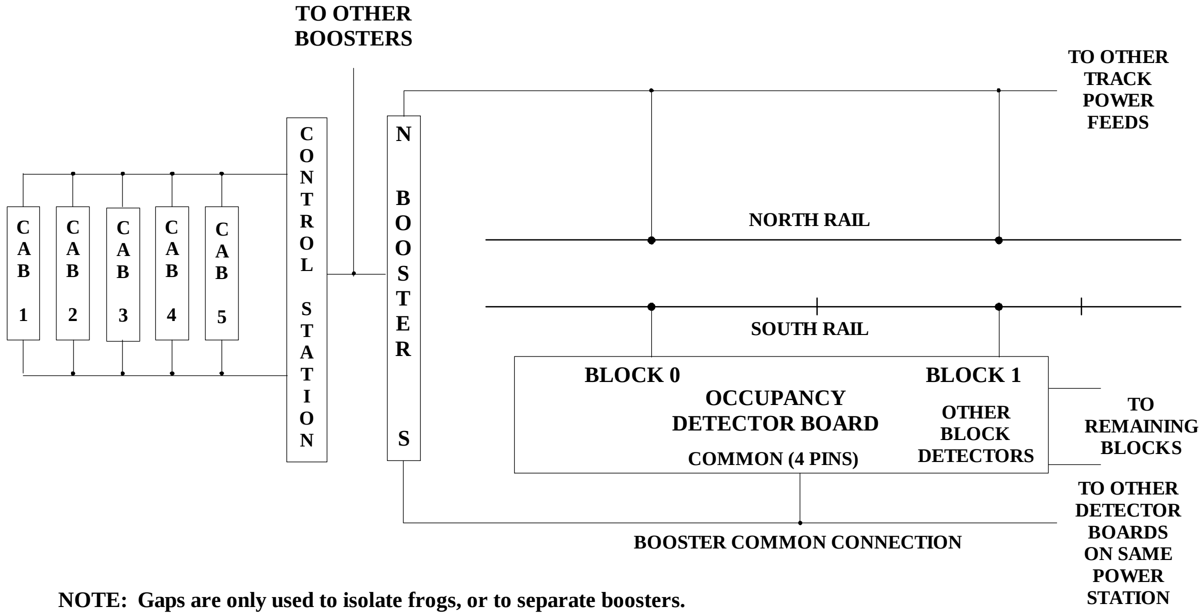
If you follow the instructions, doing everything one step at a time, you won't have any big problems. Suggestions are included with each step to help you get everything right. And, the steps have been planned out so that you can continue to operate your layout even if the conversion takes weeks or even months. There is no need to shut down your layout completely while installing signaling.

The next step is to connect your BD16 boards to your layout. There are two types of connections to make. The first group of connections will merge the BD16 into your common rail circuit so that the BD16 can detect your trains. When you have finished connecting your BD16 into the common rail feeds to your detected blocks, your wiring will look something like Figure 6-1 DC Control with BD16 Detector Board if you are using DC control. It will look like Figure 6-2 Command Control with BD16 Detector Board if you are using command control. The steps in the remainder of this section will help you to complete the installation.



NOTE: Detection blocks (SOUTH rail) and control blocks (NORTH rail) can be different.
Detection outputs from the detector board are not shown in this figure.

Figure 6-1 DC Control with BD16 Detector Board



NOTE: Gaps are only used to isolate frogs, or to separate boosters.
See your system manual for instructions concerning connections between booster outputs.

Cab connections to control station depend on the specific command control system used.

Figure 6-2 Command Control with BD16 Detector Board

The second group of wires will connect your BD16 to your signals, display LED's or any other logic circuitry you may have. Since the connections to LED's, logic and relays are all slightly different, separate paragraphs below will describe the differences. These connections are not shown in the two figures above.

<u>You only need to connect one end of one wire at a time.</u> Just repeat that one simple step for each connection to be made and you can't lose.

But, before we start wiring the BD16 into the layout, let's install your BD16 physically.

Figure 6-3 BD16 Board Assembly Diagram below shows how your BD16 and related items will look when ready for installation. For your reference, the major items are identified individually. Other than the mode plug and its jumpers (item 2), the voltage regulator and heat sink (item 12), and the DC power input jack (item 11), and the output resistor packs (items R12, R13, R16 and R17), none of the parts are of interest to you. There are no adjustable components on the board.

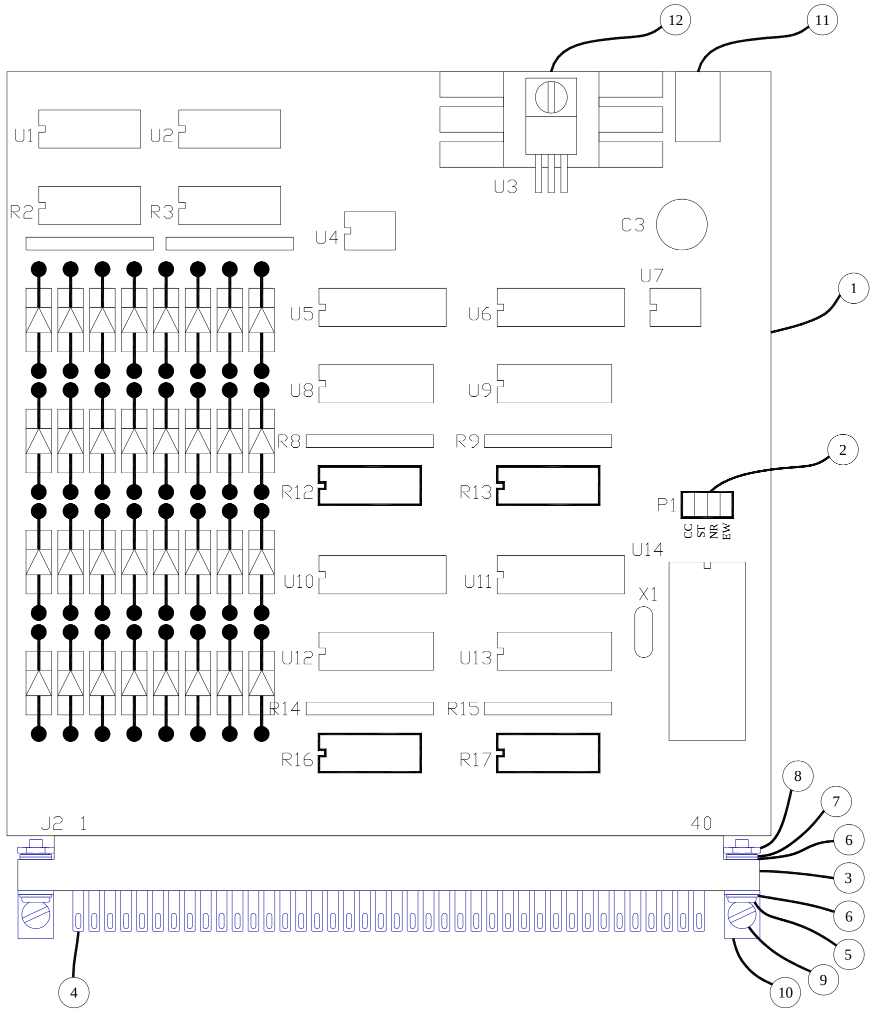


Figure 6-3 BD16 Board Assembly Diagram

The items shown are:

1. BD16 Printed Circuit board, with the top view shown.
2. Mode plug with positions for four mode jumpers (none shown).
3. Card edge connector. Your BD16 plugs into this connector.
4. Contact 1 of the 80 contact fingers on the card edge connector. Contact 1 is labeled on the connector itself, and corresponds to the top left contact on the PC board. Contact A is immediately below contact 1. The top row of contacts are numbered from 1 to 40; the bottom row is lettered A-Z, a-v. Letters “G”, “I”, “O”, “Q”, “g”, “i”, “o”, and “q” are not used.
5. Pan head #4-40 stainless steel machine screw (2 places) used to fasten the card edge connector to the right angle mounting brackets.
6. Flat #4 stainless steel washer (4 places) used to protect surfaces from the screws and lock washers.
7. Internal tooth #4 lock washer (2 places) used to secure the mounting screws and brackets.
8. Stainless steel #4-40 hex nut (2 places).
9. Round head #4 wood screw (2 places) used to attach mounting brackets to the mounting panel.
10. Right angle mounting bracket (2 places).
11. Socket for external AC power adapter.
12. Voltage regulator and heat sink. In operation, this will get warm and maybe even hot to the touch, depending on the load current from the internal power supply. The on-board circuitry draws very little current itself. Your LED’s will draw most of the current.

6.1 PHYSICAL INSTALLATION OF THE BD16 BOARD

Shown in Figure 6-4 BD16 and Panel Layout Ready below the BD16 mounted to a flat wood panel ready for installation on your layout. A piece of 1 x 8 thirteen or fourteen inches long, or a similar size piece of plywood, is just fine. Then you can attach the panel in an easily accessible location on a table leg or from the bottom of an L-girder. You will find it much easier to prepare the panel as shown at your workbench. Doing this under your layout will probably be more difficult.

Remember that you will be running wires from the board to the blocks and your signals or control panels. Plan how the wires will be routed from the board and to the layout. Use cable clamps to keep the various cables from placing any strain on the card edge connector pins and out of the way.

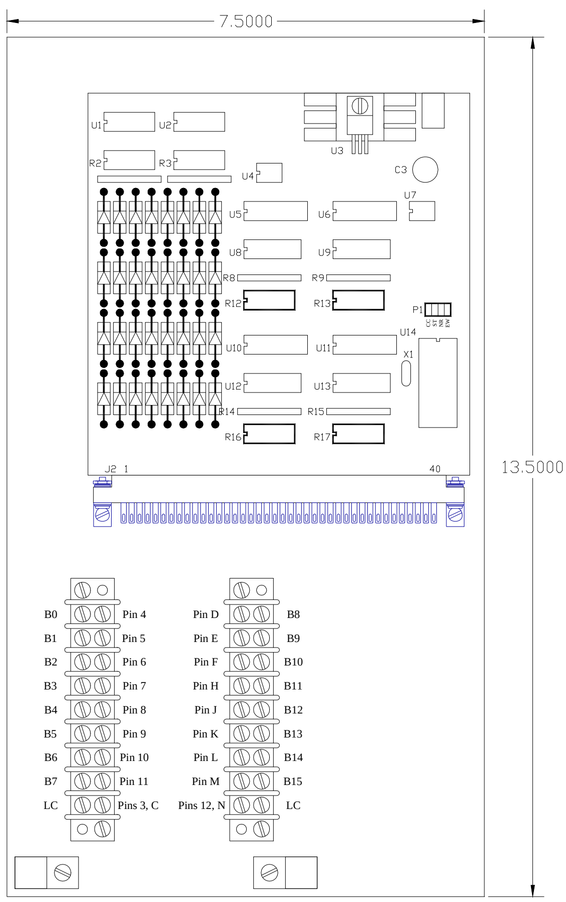


Figure 6-4 BD16 and Panel Layout Ready

To protect the contacts on the card edge connector, you should use a strain relief of some kind. For the larger gauge wires to your tracks and layout common, we suggest you use a Cinch Barrier Block part number 9-140. The current Digikey catalog (1-800-344-4539) lists this with their part number CBB109-ND. You can make the short connections from the terminal strips to the connector using 22-gauge wire. From the terminal blocks to the layout blocks, us large enough wires that the voltage drop is less that ½ volt or so. Table 6-3 Resistance Table for Wire will help you. Since each block has two wires, one to the power rail and one to the common rail, budget ¼ volt drop for each. If your trains draw a maximum of one amp, the wire should have no more than ¼ ohm.

If the distance from the BD16 and the blocks is particularly short, and your engines are equipped with low current can motors, you can probably run your common rail feed wires using 22 gauge wire. If you use stranded wire and a tight cable clamp to keep the wires from pulling on the connector contacts, you could connect directly to the card edge connector. See Section 6.2 for more detail on selecting wire sizes.

Incidentally, the screw barrier strip is a good idea for trouble shooting. It makes is easy for you to disconnect blocks, or to swap BD16 detectors to aid in fault isolation. The small cost for such strips is well worth it. In the figure above, the terminal strips are labeled to show the pins on the board connector and associated block common rail assignments. Simply run 22 or 24 gauge wires up between the terminal strips to the proper contact pins on the connector. Run the wires to the blocks and layout common outside the terminal strips. That will give you a reliable, professional looking installation.

For the smaller gauge wires to your signals, a simple cable clamp will do. A nylon cable clamp from the Richco line (also available from Digikey) will do. They come in several diameters, so pick the right size for the wire bundles going to the signals. You want the clamp to hold the wires securely and keep them from putting strain on the connector pins. Also, in most cases, you'll find that modular phone cord is a good choice for connecting to your signals. It's low in cost, available almost everywhere, and easy to work with. The four-conductor wire has a red, green and yellow wire, good choices for the signal aspects, and a black wire for the ground or +5 volt connection.

6.2 CONFIGURING YOUR BD16 DETECTOR

Your BD16 has a total of four self-test functions, and four operational functions. We call these the "modes." You can change the mode of the BD16 at any time. Unplug the power supply cord and add or remove the jumper plugs as needed. Then, reconnect the power supply. Do these steps to enter any of the self-test modes. Once in self-test, you must change the jumpers without unplugging the power supply.

In normal operations, you will simply set the mode required by your layout and leave it. From then on, whenever you turn on your BD16 it will start in your operational mode and give the type of output indications you wish.

But, in addition to that, the four self test modes are available to help you with your installation, or to help trouble shoot problems if they should arise. All of the modes are described in the paragraphs that follow. And each includes a figure showing the correct jumpers to install.

6.2.1 NORMAL OPERATIONAL MODES

There are four operational modes for your BD16. Unless you change your layout control system at some time, you will probably never have to change modes. But you always have the choice.

6.2.1.1 Command Control

Use this mode if you are using any form of command control. Your outputs will indicate the OCCUPIED or VACANT status of your blocks.

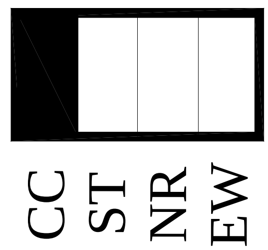


Figure 6-5 Command Control Jumper Positions

6.2.1.2 DC Control, Occupied-Vacant Output

For DC controlled layouts, this will be the most likely mode to use. The outputs are OCCUPIED and VACANT, and will operate two aspect signals at trackside. Or, you can use the OCCUPIED output to activate LED's on control or CTC panels to show train positions. This would be especially helpful where hidden track is involved. Note that no jumpers are used for this mode.

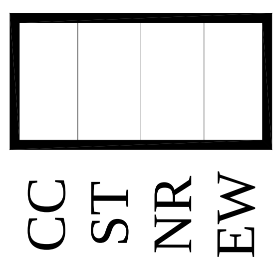


Figure 6-6 DC Control, Occupied-Vacant Output

6.2.1.3 DC Control, East-West Output, South Rail Common

The EAST-WEST outputs are used with DC controlled layouts to primarily to indicate the direction a train is moving. You may have need of this to help operate hidden track. With two adjacent LED's on a panel, both will be on if a train is present and standing. However, as soon as you connect a cab, or open its throttle a bit, one light will go out. The remaining lit LED will show which way the train will move. This is a real help, particularly with new or inexperienced operators when they are told to bring a train out of a hidden staging yard.

If, in addition to the EAST-WEST output, you would like to have a separate OCCUPIED output, or both OCCUPIED and VACANT outputs, you will need to provide some additional circuitry.

With EAST-WEST Detection, your BD16 needs to know which of your rails is the common rail. In this mode, the SOUTH rail is your common rail.

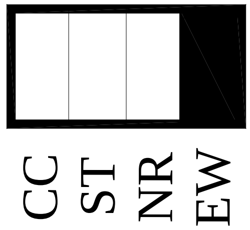


Figure 6-7 East-West Reporting, South Rail Common

6.2.1.4 DC Control, East-West Output, North Rail Common

This mode is used to obtain EAST-WEST output of block status for DC controlled layouts with the NORTH rail as the common rail. In all other respects, this mode is the same as the mode described in Section 6.2.1.3.

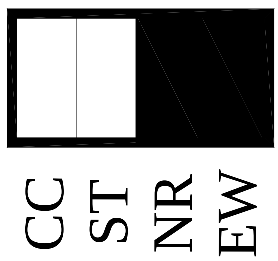


Figure 6-8 East-West Reporting, North Rail Common

6.2.1.5 Configuring the Outputs

Your BD16 has outputs that can operate in either of two ways. First, if you are only going to operate a single LED per output, you can use the built-in LED current limiting resistors. There are a total of 32 resistors, one for each output. They are packed in four resistor packs installed in the sockets labeled R12, R13, R16 and R17. You will receive the board in this configuration. The packs contain 8 220 ohm resistors, and are a 'normal' value to use with LED's.

If you will be operating two or more LED's per output, incandescent bulbs, or relays, these resistor packs will have to be replaced with 0 ohm shunt modules. These are also packed with your board, and are available for your use whenever necessary.

To make the substitution, gently lift the modules that are installed. The easiest way is to insert a small flat blade screwdriver under one end of a resistor or shunt pack, and twist it a bit to begin to raise the pack a bit. Repeat the process under the other end, going back and forth until the pack is out.

Then, carefully plug in either the resistor pack or 0 ohm shunt into the socket.

6.2.2 SELF TEST MODES

The four self-test modes are used to help you with the installation of your BD16, and to assist you in trouble shooting should any problems develop in the future. To place the BD16 board into the self-test mode of operation, you must disconnect its power. You can do this by simply unplugging the power supply from its socket on the board. Plug a jumper plug onto the two pins labeled “ST”, for self-test. These are shown as item 2 in Figure 6-3.

Finally, plug the power supply in again. The BD16 will start up, this time in its self-test mode. You can run all of the self-test operations described below, and even remove the “ST” jumper as appropriate. The board will remain in the self-test mode until power is removed and re-applied with the “ST” jumper removed.

6.2.3 Software Version Number - East

Your BD16 includes a processor with a program developed by us to perform all of the functions you have seen described in this manual. While we have tested the board under a variety of conditions, we cannot anticipate every possibility of layout control system, throttle design, or advance in various technologies.

To help you and us keep track of any changes that have taken place in the software, we have included a way for you to read out and record the version of the software programmed into your processor. If it should become necessary to help you with some problem you are having, we may need to know the specific version of the software your board is using.

To record this, put your BD16 into this mode and record which blocks are occupied and which are vacant. Simply write “ON” or “OFF” in the two columns of Table 6-1. In this mode, the BD16 is not detecting trains; it is using the 16 outputs to report its version number.

Figure 6-9 Reading the Software Version Number East

Check each output from your BD16, and mark down for each block that outputs are on. Note that it is possible for both outputs to be on, depending on the specific version number being reported.

Table 6-1 Record of Software Version Number - East

BLOCK	OCCUPIED OUTPUT	VACANT OUTPUT
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

6.2.4 Software Version Number - West

Run a very similar test to further test your BD16 outputs. Simply remove the "EW" jumper plug, without turning off the board power. Record the results in the table below.

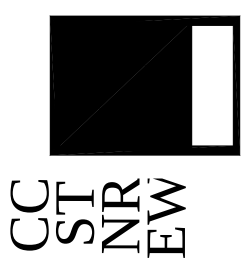


Figure 6-10 Reading the Software Version Number East

Check each output from your BD16, and mark down for each block that outputs are on. Note that it is possible for both outputs to be on, depending on the specific version number being reported.

Table 6-2 Record of Software Version Number - West

BLOCK	OCCUPIED OUTPUT	VACANT OUTPUT
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

If everything is working properly, the two output columns in this table should be flipped left right when compared to Table 6-1 Record of Software Version Number - East.

6.2.4.1 Occupied-Vacant Sequencing of Outputs

In this mode, your BD16 turns on and off each of the outputs one at a time. Each output is on for two seconds. This is enough time for bulbs and even relays to respond. You can activate this mode by placing the mode jumpers as shown and then watch your signals turn on and off in a known sequence.

Beginning with the block 0 outputs, first the vacant output will turn on. After 2 seconds, the vacant output will turn off and the occupied output will turn on. After two more seconds, it will turn off and the block 1 vacant output will turn on. This sequence repeats from block 0 to block 15, and then starts over for as long as you leave the BD16 in this mode.

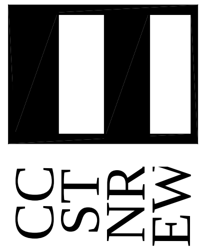


Figure 6-11 Slow Speed Occupied-Vacant Sequencing

When using this mode, watch your outputs carefully. See that each turns on and off in the proper order. If something doesn't operate properly, track down the problem beginning at the BD16 output.

When an output is on, you can measure 5 volts DC if you put your voltmeters' positive probe on the BD16 5-volt output pin (40), and the negative probe on the output pin you want to check. Measured this way, an output will show 0 volts when off, and 5 volts when on.

If you are using the BD16 with an external power supply for your output devices, such as relays or bulbs, you will need to measure in a slightly different way. Set your voltmeter for the voltage of the external power supply, and put the positive probe on the positive output of the external power supply. As before, put the negative probe on the BD16 output you want to check. You should read 0 volts when the output is off, and the voltage of the external supply when it is on.

Of course, the first thing you should do is make sure that the BD16 is turned on. If you are using an external power supply for relays or bulbs, or any other purpose, make sure that it is on.

If the output is working properly at the BD16 card edge connector, but the output device (LED, bulb, or relay) is not working, repeat the voltage measurement at the output device itself. If you don't get the correct voltage readings, check the wiring between the BD16 and the device. If you do get the correct voltage readings, check the device itself.

6.2.4.2 East-West Sequencing of Outputs

This mode is very similar to the Occupied-Vacant Sequencing of Outputs described above. Other than the positions of the mode jumpers, all of the comments above apply, except that the output sequencing is different.

For this mode, each step of the sequence again takes 2 seconds, and the pattern begins with block 0 and runs through to block 15. The outputs have the pattern: OCCUPIED-VACANT-BOTH-NEITHER.

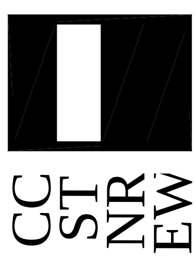


Figure 6-12 Slow Speed East-West Sequencing

Again, if you see something that isn't working, use your voltmeter to make the voltage measurements described in Section 6.2.4.1.

6.3 SELECTING THE WIRE SIZES

The contacts on the edge connector are used to connect the board to your layout. Sixteen wires will go to the common rails of the sixteen blocks, 1or 2 will go to the layout common, 32 will go to the red and green LED's, and 1 will connect the +5 volt supply to the LED anodes. We will identify these connections in detail later. What is important now is that you plan for the wiring, strain relief for the wires to protect the connector, and accessibility for maintenance, test and trouble shooting.

Because the current required to operate LED's, bulbs or relays is low, typically less than 0.1 amps, you can use wires for these circuits of 22 to 26 gauge with no problem. The wires carrying train current will probably have to be 18 to 22 gauge.

People sometimes wonder what size wire to use, and that's a good question. A general rule of thumb is to use heavy enough wire that the resistance of the wire causes no more than a 1-volt drop with the highest expected current flowing. Today, with a typical motor drawing about .3 amps under load, a three unit consist will only draw about 1 amp. Thus, a 1-ohm total resistance would satisfy this guideline. A heavier gauge wire will result in less loss.

Then, consider the round trip wire path from the power pack or booster to the most distant block and back. Select a wire size from the following table, based on the total wire path length.

Table 6-3 Resistance Table for Wire

Wire Gauge	Ohms per 100 feet of total length
26	4.08
24	2.57
22	1.61
20	1.01
18	0.64
16	0.40
14	0.25
12	0.16
10	0.10
8	0.06
6	0.04

For the layout common wire, to which all of the common rails are connected, all of the train running current will pass. This means that you need to count the entire current load from all of the trains that may be running at the same time. Also, with train detection boards installed, the voltage drop should be less than about 0.25 volts. This normally means that the layout common wire will be heavy, with 8, 10 or 12 gauge sizes being used often.

Let's say that the total length of your layout common wire is 100 feet, and that the total current of all your operating engines and cars with lights, etc., will be 5 amps. The total resistance, to give a worst case voltage drop of 0.25 volts, would have to be 0.05 ohms. From the table above, 8-gauge wire would be close enough. One good source of such heavy wire is the electrical department of a major hardware store. You can get 10 gauge stranded wire (type THHN) for about 10 cents per foot as this is being written. Use two 10 gauge wires together to get the equivalent of 7 gauge wire and a slightly lower total resistance.

Table 6-4 lists all of the block specific connections on the BD16 connector. Each of the eight blocks is listed, along with the connector pins assigned to its common rail input, occupied and vacant outputs.

Use care in connecting these wires to the PC board connector pins, especially for the larger size wires. If you haven't had experience soldering connector pins like this, ask an experienced friend to help, or read about how to do it and practice. See NMRA data sheet D1g.10, "Soldering, Electrical and Electronic", for basic information.

Table 6-4 Common Rail and Output Connections

BLOCK	COMMON RAIL PIN	OCCUPIED OR EAST PIN	VACANT OR WEST PIN
0	4	14	22
1	5	15	23
2	6	16	24
3	7	17	25
4	8	18	26
5	9	19	27
6	10	20	28
7	11	21	H
8	D	R	Z
9	E	S	a
10	F	T	b
11	H	U	c
12	J	V	d
13	K	W	e
14	L	X	f
15	M	Y	h

Table 6-5 below lists all of the general-purpose connection pins on the BD16 card connector.

Table 6-5 General Purpose BD16 Connections

FUNCTION	PIN(S)
Layout common connections	3, 12, C, N
+ 5 volt supply to LED signals	39, 40, u, v
Signal Ground Connection	13, 30, P, j

Connect your BD16 layout common connections to the layout common wire. Simply run a tap wire from at least two of the BD16 common connections to the nearest place on the layout common wire. Pins 3 and C are good choices. If you regularly run a lot of trains with high current loads, connect all 4 pins to layout common. Make sure that you are careful in attaching wires to the pins on the edge connector. Avoid using too much solder, too much pressure, and too much heat.

Carefully strip the insulation off each of the wires in the layout common group, and solder the tap wire to each of them. Since this is a bare connection, fasten it to a riser, joist or L-girder so that it can't move and come into contact with any other wires.

Connect the power supply to the BD16 by plugging the power plug into the socket at the edge of the board near the heat sink.

To see if all is well, plug in the wall module. You should measure 5-volts DC if you connect your voltmeter from any common or signal ground connection pin to a 5-volt pin.

6.4 CONNECTING TO THE TRACK BLOCKS

With the physical installation complete, we are going to connect your BD16 to each of the blocks the board is to detect. We will do this one block at a time, and test as we go, to keep from creating any big problems.

Pick a block to connect to the BD16. For your first block, pick one that is easy to get to. Let's make the learning process as easy as possible.

The block will still have your original wires from the cab select switch to the common and power rails running to the block. Our first step is to electrically isolate the common rail from the layout. Cut the common rail feed wires so that at least a few inches of useable wire remains attached to the rails. And then make sure that the common rail is separated by gaps from all adjacent blocks and frogs.

Then, test the block to make sure you have isolated the common rail. Do this by trying to run a train in the block and all connecting routes. If the train runs anywhere in the block, you still have one or more common rail feeds that need to be removed from the block.

When all common rail has been isolated, run a new common rail feed from the assigned detector in the BD16 to each of the now cut common rail feed wires dropping down from the common rail. Again, when this is done, you should be able to run your train anywhere in the block. Try it and see. If the train doesn't run in some portion of the block, you still have a common rail feed wire to connect. Keep looking till you find it and connect it to the BD16.

Table 6-4 Common Rail and Output Connections lists the connector pins used for each of the sixteen detectors.

After you have connected the block common rail to the detector, connect the outputs for the same detector. See Section 6.5, CONNECTING THE OUTPUTS for specific information on how to connect to the BD16. Choose the paragraph that describes the output device you are using.

When you have the output connections installed for a block, check them by using one of the self-test modes that sequences through the outputs. Also, remember that there are 32 steps in the occupied-vacant sequence, and each step takes two seconds. There are 64 steps in the east-west-both-neither sequence, also at two seconds each. So, it will take a while for the BD16 to cycle through all of the steps.

If the outputs for the block do not function as you expect, double check your wiring. With these self-test modes, the BD16 isn't doing train detection - it is simply operating the outputs. So any problem will be somewhere in your output wiring or the power supplies you are using for the output devices.

Finally, when you see that the outputs operate properly, then set the BD16 to the operational mode you will be using, and again run a train everywhere in the block, and through all connecting routes. Watch your output devices, signals, bulbs, panel LED's or relays, or whatever you have, and see that they activate properly as your train enters or leaves the block.

When your first block is working, pat yourself on the back, take a break, and then repeat the process for the remaining blocks.

6.5 CONNECTING THE OUTPUTS

The BD16 outputs are limited to 150 milliamps each. Naturally, you can use much smaller wire for these circuits, especially if you are only operating LED's or logic signals. For these latter cases, the current per output will be less than 20 milliamps. You could probably use flat ribbon cable if appropriate for your situation. Even though it is normally about 28 gauge wire, for such low currents it won't matter - unless your layout is as big as Yankee Stadium!

If you are using the BD16 to generate logic signals, take care to provide a good ground path between the BD16 "Layout Common Connections" (Table 6-4) pins and the ground connection for your other logic. Also, remember that the BD16 common is connected to your common rail circuit. Make sure that your other logic shares this connection. Finally, just connect the desired BD16 output on the card edge connector to the logic circuit you have.

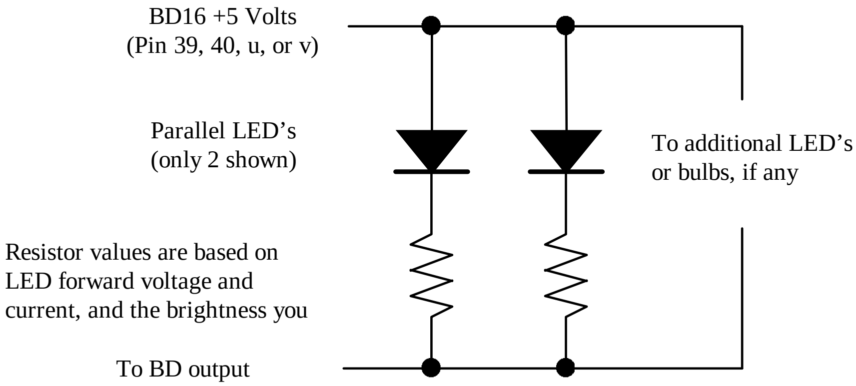


Figure 6-13 Driving Multiple LED's From a Single Output

If you are only going to operate a single LED per output, your BD16 comes with the necessary series resistors already installed on the circuit board. These are shown in Figure 6-3, and are labeled on the board as R12, R13, R16 and R17. These plug-in modules each have 8 220-ohm resistors. They are socket mounted and can be removed by gently prying up under each side until they are free of the sockets.

If you are going to operate more than 1 LED per output, or you are going to drive loads such as relays or incandescent bulbs, you will have to replace these resistor packs with the 0-ohm shunts that were provided with your BD16. After removing the resistor packs, insert one of the 0-ohm shunts in each socket. You can identify them because they are black plastic rectangular blocks with 8 gold contact wires in each. Make sure the pins are lined up in the socket properly before gently pushing them down into position.

Figure 6-13 Driving Multiple LED's From a Single Output shows how to drive two LED's from a single BD16 output. You must calculate the proper resistor values based on the LED's you use. Typically, an LED has a forward voltage drop of approximately 1.7 volts. To calculate the proper resistance value, subtract the forward voltage drop of your diodes from 5 volts (the BD16 power supply output voltage) and divide the difference by the diode forward current.

Color light signals use a single, individual color LED to display each aspect. Normally, these will be GREEN and RED LED's to represent the PROCEED and STOP aspects. Figure 6-14 LED Resistor Installation Method below shows how to connect the two LED's of a signal if you only need to display the aspect at a single location, track-side or on a panel. Since only one LED is ever on at one time, you only need one resistor to limit the current. However, since red LED's are normally much brighter than either green or yellow LED's, many people use a higher resistor value for the red LED so that its brightness matches the brightness of the other colors.

Perhaps the simplest way to connect the BD16 outputs to signals using LED's or incandescent bulbs is to use four-conductor modular phone cord. This wire is readily available everywhere (try Radio Shack), is large enough to carry the required current, and is very low in cost. We recommend that you use the black wire for the +5 volt connection, and the red and green wires for the corresponding LED's. That leaves a yellow wire as a spare, to be used if you ever convert to 3-aspect signals.

Which leads us to the question of how and where to install the current limiting resistors. One method that works well, costs little, and is very reliable is described here. A three pin terminal strip is shown, but you could use a 6 pin terminal strip if you had two signals close enough that the leads would reach. Also, if you are planning to install 3 color signals someday, considering using a four or eight pin terminal strip now. You will need the extra pins later. At the time this is being written, you can call Mouser Electronics at 1-800-346-6873 and place an order or request a catalog.

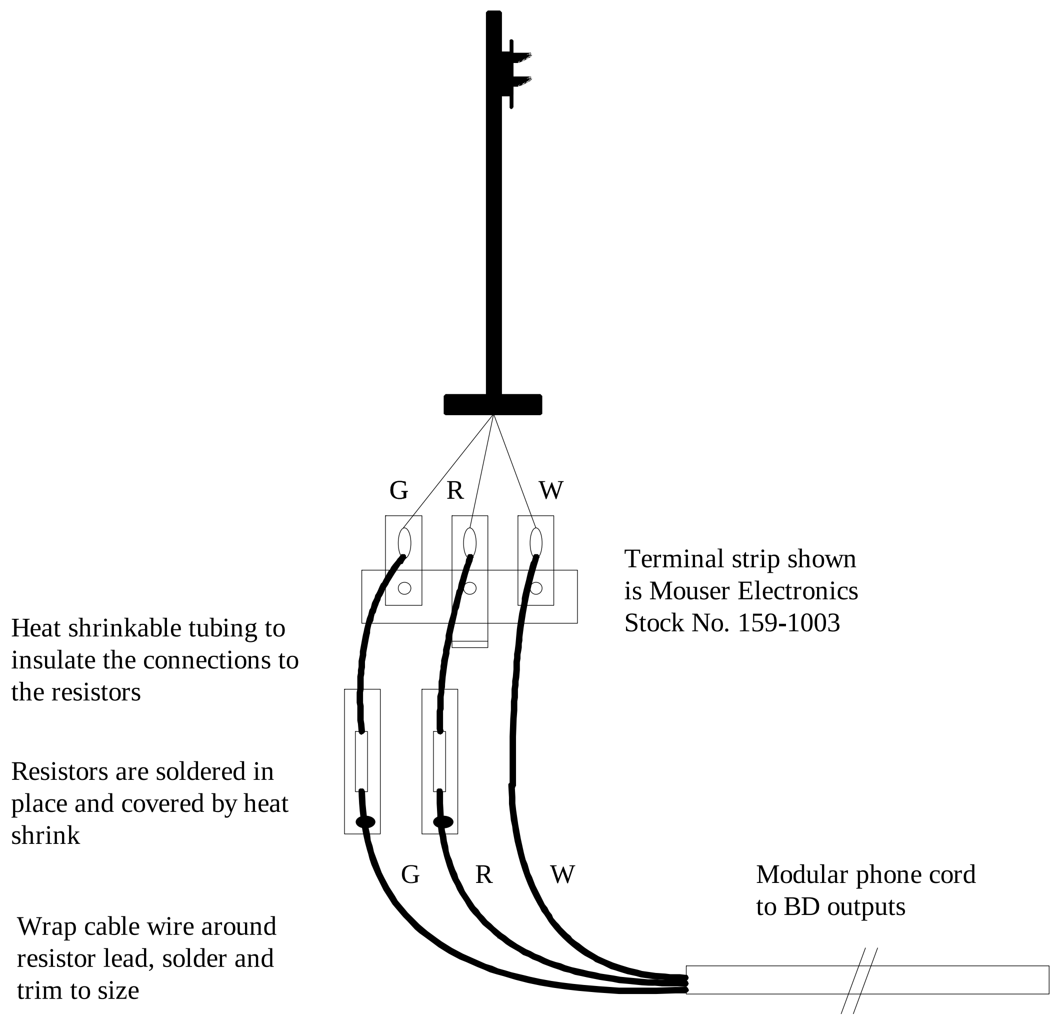


Figure 6-14 LED Resistor Installation Method

Let's work out a simple example to see how to calculate the current limiting resistors. Suppose your diode has a forward voltage drop of 1.7 volts, and gives the desired brightness with a current of 20 milliamps.

$$R = (5 - 1.7)/0.02 = 165 \text{ Ohms.}$$

In this case, pick a standard value of 160 ohms for each of the resistors. Then, calculate the power dissipation of the resistor:

$$P = R \times I^2 = 160 \times 0.02^2 = 0.064 \text{ watts.}$$

In this case, a 160-ohm, 1/4 watt, 5% tolerance resistor, costing only pennies, would be just fine. Simply substitute the forward voltage and current for the LED's you use into these equations to select the proper resistors. As long as the resistor power rating is higher than the power you calculated, you will be OK.

You can use the BD16 outputs to operate low voltage (typically 1.5 volts) incandescent bulbs in much the same way as LED's. The connections are all the same. However, you must use an external power supply with incandescent bulbs. Such bulbs draw a very high surge current when they are first turned on. This surge current can be enough to overload the BD16 power supply. The power supply won't be damaged, but, when the supply drops too low, the processor chip resets and restarts. This will cause the BD16 to operate incorrectly, or not at all.

The second difference is that your dropping resistors will almost certainly be different values because bulbs normally draw a much higher current, not including the surge current. If you are using low voltage incandescent bulbs, check their spec sheet to see what their voltage and current requirements happen to be.

Again, recall that, with DCC, your vendor may recommend that you have no connections between the outputs of separate boosters. This includes any connections between pins on BD16 boards connected to separate boosters as well. If in doubt, please contact either the manufacturer of your DCC system or us for technical assistance. We offer an 8-channel opto-isolator board. You can use this board to isolate BD16 outputs electrically from the layout common. The opto-isolator does not have sufficient current handling capacity to drive LED's, bulbs or relays; use it to isolate outputs which are connected to logic circuits such as our TC4 Three Color Signal Controller or our MSC Master Signal Controller, or to computer input logic.

When using the BD16 to operate inductive loads, such as motors or relays, be sure to use a protection diode as shown in Figure 6-15 with each such load. The protection must be wired as shown in Figure 6-15 Connecting Inductive Loads. They serve to protect the BD16 output chips from excessive voltages generated when these loads are switched off. Without them, you will almost certainly blow out some integrated circuits. Damage to the BD16 caused by inductive loads is not covered by the warranty.

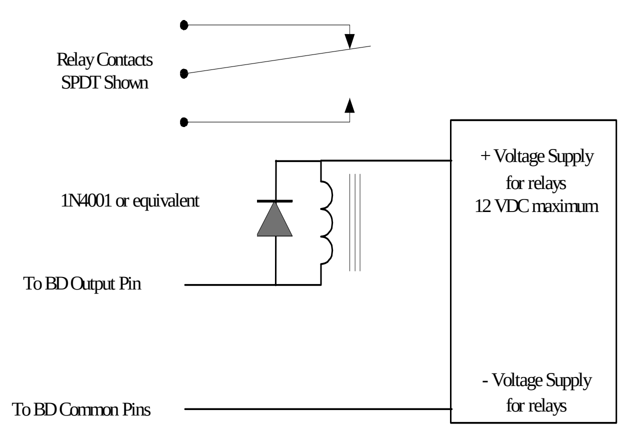


Figure 6-15 Connecting Inductive Loads

6.6 STANDING TRAIN DETECTION

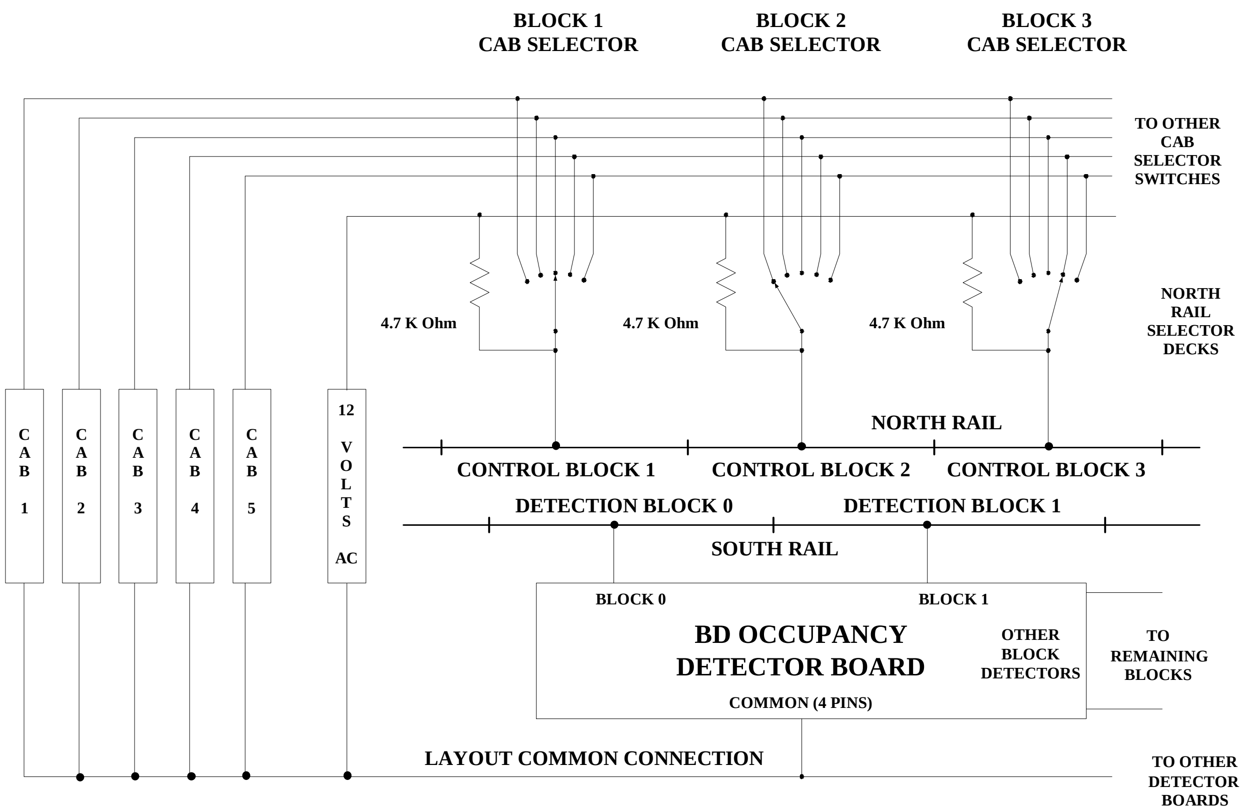
For the BD16 to detect a train, there must be some small current flow. If you are using command control, there will always be a voltage applied to the track, and the BD16 will always be able to detect the presence of equipment which draws even a small current.

Most cars, however, do not draw any current unless modified in some way. We stock non-magnetic replacement wheel sets for HO and N scale standard gauge equipment. These wheel sets are equipped with a resistor that allows a small, but detectable, current to flow. To make your cars detectable, simply replace one or two wheel sets per car with ours. On special order, we could provide wheel sets for other scales and gauges as well.

Or, you can make your own if you wish. We use a 5.1 K ¼ watt resistor bridging the insulation between the axle and the insulated wheel.

With a DC controlled layout, a special arrangement is necessary to make sure that there is always a voltage applied to each block. We recommend that you install a 12 VAC transformer as shown in Figure 6-16, and connect this voltage through a 4.7 K ohm resistor to each power rail in detectable blocks. Even when the cab select switches are in the OFF position, this very low current AC will be present.

Since this is an AC voltage, if there is a standing train present, the BD16 will detect a current that flows alternately in both directions. The change in current direction takes place 120 times per second, and we all know that a train can't really change direction that fast - it has to be standing still. If the BD16 sees current flowing in only one direction, it concludes that the train is moving in the corresponding direction.



NOTE: **Detection blocks (SOUTH rail) and control blocks (NORTH rail) can be different.**
Detection outputs from the detector board are not shown in this figure.
12 Volt AC transformer must be isolated from cab circuitry.

Figure 6-16 DC Control with Standing Train Detection

We suggest that you use 4.7 K ohm, ¼ watt axial lead resistors. They are readily available at low cost and are easy to install. A convenient method would be to install resistors for all of the blocks controlled by a control panel on an insulated mounting board behind the control panel. Then, simply run a wire from one end of each up to the power rail output pin on each cab select switch. Connect the opposite end of all of the resistors together and then to the output of the 12 VAC transformer as shown in the figure above.

One good way to mount these resistors is to use what is called a “turret terminal board.” Keystone Electronics Corp. makes several suitable ones. Their part number 15032 provides enough terminal pairs to install 25 resistors. You can get these, along with the resistors, from various distributors. Allied Electronics (1-800-433-5700) handles the terminal boards (Allied Part No. 839-2373). You can get the package of 200 resistors from Digikey (1-800-344-4539) using their part number 4.7KQBK-ND.

6.7 TESTING YOUR BD16 DETECTOR INSTALLATION

We thoroughly test each BD16 before shipping it to you. But the time may come when you want to see for yourself that the board is working properly. Also, all of our built-in test functions operate the output signals in a predictable way. Thus, you can select one of the BD16 test functions and see if your lights operate as you expect. Make sure that you have recorded exactly which outputs go to which loads.

6.7.1 TROUBLE SHOOTING SUGGESTIONS

The step by step conversion and installation procedures described throughout this manual should help you avoid most problems, and quickly identify the rest as you go. The important thing is to make just one or two changes and see if everything is still working. If not, there is some problem with what you did since the last test. The more you do between tests, the harder it will be to locate the problem.

Another benefit of the do a little and test approach to this is that it helps you to build your confidence as you go. Success breeds success, and every time you see something that you did work right, no matter how simple or seemingly inconsequential, you will see that it’s really not that difficult after all.

The next few paragraphs are a few additional suggestions for ways to prevent or at least identify problems.

6.7.1.1 WHAT IF NONE OF YOUR SIGNALS WORK

Suppose none of your signals work. If at least some of them used to work, and now they don’t, the first thing to check is the power. Measure the DC voltage from any common pin to any 5-volt pin. You should read five volts! If you don’t, make sure that the power supply is plugged into a working outlet, and into the BD16 power input socket.

Then check for a short circuit across the BD16 5-volt power supply. Unplug the power supply from the board power socket and measure the resistance between any 5-volt pin and any common pin. With your ohmmeter probes connected in one polarity, you should read about 10-ohms; in the opposite polarity, you should read about 30-ohms. These numbers may depend to some extent on the type of ohmmeter you are using. The important thing is that you not read 0-ohms.

If you do read a much lower resistance, try unplugging the board from the card edge connector and measure the resistance of just the board. Carefully touch the ohmmeter probes to the PC pad near pin 40 (on the top of the board), and the common connection near pin 3 (on the top of the board). If these measurements give acceptable results, set you meter for DC voltage readings and plug in the power supply again. With the board out of the connector, you should read 5-volts between these two pins. If you get good readings, the problem is probably a short in the wiring on the output pins of the board.

As a last resort, unplug the power supply from the board connector, but plug it into your wall outlet. You should measure about 6 volts DC on the plug that goes into the board power connector. If you get a good reading, you may have a problem on your BD16. Give us a call and we'll discuss how to fix it. If you don't get a good voltage reading, the problem is either with your wall outlet or with the BD16 power supply. See if your wall outlet will operate something else (Dremel tool, electric drill, etc.).

If you don't get any voltage out of the wall module cord, be sure that the 120 VAC power is on at the wall outlet. Plug a lamp or other line powered device into the same outlet and see if it works. If the wall outlet is working, and still you get no output voltage from the power module, contact us.

Also, make sure that, if you are using LED's, that the polarity is correct. If the power is on, you can manually activate any single LED by connecting the corresponding output pin on the edge connector to layout common with a test lead.

6.7.1.2 FIRST TEST WIRING TO SIGNALS

If your signals don't seem to be working quite right, begin by running one of the slow sequence self test modes. Watch carefully to see if the signals operate as you expect. Remember that the BD16 will activate block 0 outputs, block 1 outputs, etc. and then start over.

If the self test sequence is correct, and your problem seems to be that the wrong signals change when the train moves from block to block, then there is probably an error in the wires from the block common rails to the BD16 detectors.

If the self-test sequence is not correct, then there is probably an error in the output connections from the BD16 to the signals. Look for opens, shorts, or wires connected to the wrong pins on the edge connector.

6.7.1.3 BLOCK ALWAYS SHOWS VACANT

Normally, this would mean that the common rail lead from the block is not going to the proper detector input pin on the edge connector. Or, it might be that you still have one of your original feed wires connected to the block common rail. This will keep the BD16 from detecting the train. Go back to Section 4 and go through the step by step conversion procedure described. This will help you solve the problem.

6.7.1.4 BLOCK ALWAYS SHOWS OCCUPIED

If the vacant LED never turns on, and the occupied LED is always on, then you probably have some source of current into the BD16 common rail connection. This would appear to the BD16 that there is something in the block. See if the LED's switch when you disconnect the common rail input to the detector. If so, then look for some unexpected current source into the common rail. This could be a missing or closed gap, a wheel bridging a gap, or even an engine or piece of rolling stock being detected.

If both LED's are on when the block is vacant, and the vacant LED goes out when it is occupied, check the wiring to the occupied LED. You probably have a short to common somewhere along the wire from the BD16 output to the LED cathode.

6.7.1.5 *STANDING TRAINS ARE NOT DETECTED*

For the BD16 to detect a train, some current flow must be present if the block is occupied. With command control, power is always present on the track. However, with DC control, current flow stops when the cab stops its train, or when no cab is selected for a block. Thus, with DC control, some provision must be made to assure that a small current flows even when the cab has stopped the train. A simple technique to do this is illustrated in Figure 6-16. This circuit puts a small AC current through an occupied block when the cab is off. When the cab starts its train, the DC current over-rides the milliampere or so of AC current as the train begins to move. This AC current results in an interesting feature with the BD16: a stopped train will be reported as going both east and west! This is how we report a standing train if directional reporting is selected.

6.7.1.6 *TRAINS NOT DETECTED WHEN THROTTLE AT 0*

Be aware that some electronic throttles have a very low output impedance, and place what looks like a short circuit across the rails when the output voltage is zero to stop a train. This will shunt the current provided by the resistors shown in Figure 6-16 and keep the BD16 from detecting the train. But, when you put the reversing switch in the center off position, this electronic short circuit is removed and the BD16 will report the block as occupied with a standing train.

There is a solution for throttles that actually bring their output voltage to zero when the train is stopped. We suggest that you install a full wave bridge rectifier in series with the throttle output. This works just like a constant lighting circuit, and allows current to reach the BD16 even with the throttle off. This is shown in Figure 6-17 Zero Output Throttle Modification below. Use a full-wave bridge rectifier with a current rating at least equal to the maximum output current of your throttle. The voltage rating of the rectifier is not critical. Use the lowest available voltage unit you can find (50 volts PIV is a typical rating) for lowest cost.

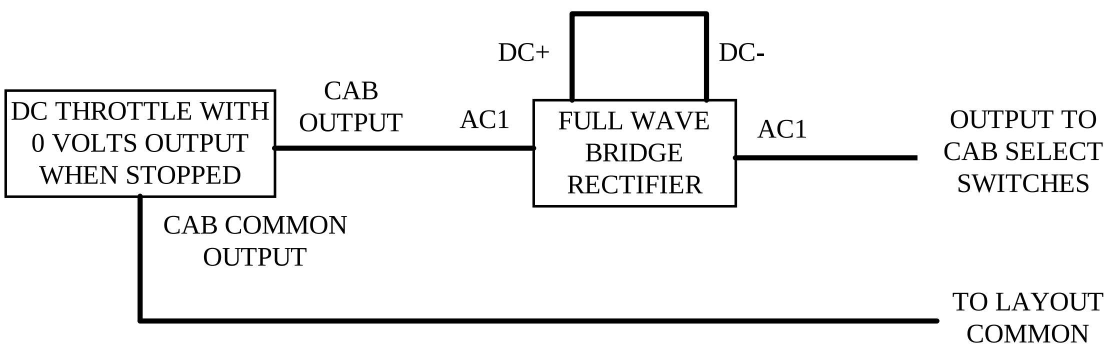


Figure 6-17 Zero Output Throttle Modification

6.7.1.7 *STRANGE OPERATION OF VACANT BLOCKS*

If the signals in one block change when the train is nowhere near the block, you may have too small a layout common wire. Double check your estimate for the current in the layout common, and the wire gauge you picked. There could be a problem with this.

If this doesn't fix it, contact us by phone, fax or letter and let us know exactly what kind of "strange operation" you have. We'll probably have some questions (easy ones!) to help us understand your layout and installation, and then make some suggestions about other things to check.

Another possible cause for this problem has to do with command control. If the wiring to a block has a very large capacitance, any block detector may show a vacant block to be occupied. The BD16 has included special processing to minimize this effect. If, however, you have used twisted pair wires to connect to your blocks, very long runs of such wire could exhibit enough capacitance to cause the problem. To confirm that this is the problem, temporarily disconnect both wires of the twisted pair at both ends, and run two separate feed wires that are not paired. If the problem goes away, then capacitance is your problem. Route the two new wires in a neat fashion and use them permanently. We have also seen this problem if the wires to the track are long and too small. Try changing to 14 or 16-gauge wires temporarily to see if this fixes the problem. If not, contact us for help.

6.7.1.8 WHEN ALL ELSE FAILS

When you have done everything you know how to do, and have followed the installation and test suggestions in this manual, and still things aren't working, please contact us. We will do all we can to help solve the problem.

While our BD16 board may not be working correctly, this has not yet been the case. But we have always been able to help our customers get everything working properly. We'll help you, too.

7. CUSTOMER SUPPORT

We understand that many model railroaders have limited experience or training in electronics, and may be somewhat apprehensive about installing train detection and signaling systems. Our goal is to make our expertise available to those in the hobby that could benefit. We are doing this by developing products, and associated manuals, which take care of as many of the details as possible, and explain clearly how you can finish your installation and enjoy the additional operational features that are now possible.

If you have questions, or recommendations, please write. We will do our best to help you get the most satisfaction available from your investment in our BD16.

7.1 TECHNICAL ASSISTANCE

We are available to provide reasonable assistance to help you get the greatest possible benefit from the BD16 Block Occupancy Detector. Feel free to write to us with any questions or comments you may have. Please enclose a large SASE if you are expecting a reply. We will do our best to clear up any issues you may raise about the use of the BD16.

We welcome any suggestions you may have for improvements to the BD16, or for any related products that you would like to see available. All such recommendations will be considered as we plan our future product offerings.

You can write to us at:

> The Signaling Solution, Inc.
> PO Box 37
> Shelburn, IN 47879
> VOICE: 812-533-1047 (9-4 est)
> FAX: 708-570-6140
> Email: bataras@wsaeng.com
> Web site: www.signalingsolution.com

7.2 LIMITED WARRANTY

Your satisfaction with the BD16 is our primary concern. The BD16 Block Occupancy Detector is warranted free of defects in materials and workmanship for a period of 90 days from date of purchase. This does not cover damage due to misuse-use, improper installation, or connection to excessive voltages or currents. We will, at our option, repair or replace any defective unit. A reasonable charge will be made for repairs not covered by the warranty.

The BD16 Block Occupancy Detector is further warranted for 30 days to perform in a satisfactory manner when connected as described in this manual. Should you feel that your BD16 is not performing as you would expect, simply write to us. Describe your specific type of installation, the type of electrical control system you are using, how you have connected the BD16, and details about what you expected of the BD16 and how it appears to fall short. If we cannot clear up any problems you have, we will refund your full purchase price upon return of your BD16 in good working order.

Naturally, we cannot be responsible for units that have been damaged by misuse-use, improper installation or connection.

8. OCCUPANCY DETECTION AND REPORTING TUTORIAL

You may have many reasons for installing a system which reports the presence or absence of trains in various sections of track: displaying train locations to operators, progressive cab control, trackside signals, grade crossing gates, sound effects, etc. There are several different techniques available for doing this. If we overlook any particular technique, it is not to give offense.

The next few sections discuss some of the options available for detecting trains, along with their strengths and weaknesses. As you will see, the BD16 successfully overcomes every limitation normally present in occupancy detector systems.

8.1 OPTICALLY BASED SYSTEMS

An optically based detector uses a light source and light detector, arranged so that the train physically prevents the light from reaching the detector when it is present. These systems have the benefit of being totally isolated from train running power. They can therefore be used on any layout, no matter how it is wired.

But they also are limited in that the light source and detector have to be positioned so that the train blocks the light. This means that they only detect at a single point. To detect trains throughout a block, many detectors, with overlapping fields of view would be required. Also, depending on the specific design, the visual systems can be sensitive to ambient light or the stability of the voltage powering the system. And empty log cars can be very difficult to detect in any case since they have little cross-sectional area available to block the light beam.

Sometimes people attempt to provide detection for long or serpentine blocks by using detectors at the beginning and end of a block, a technique called gate detection. This can work well if trains always move through the block. But what if a train enters, and then backs out? Or stops completely, say between operating sessions? Or what if the train separates? Or can leave through or enter through multiple paths? These are all factors that tend to limit the use optical detectors for signaling detection purposes.

But this doesn't mean that optical detectors have no place in train detection. Use them to take advantage of their real feature: the detection of a train at a single point. Use them to help to spot cars at difficult to see locations, to position hopper cars exactly right for the rotary car dumper to work perfectly, etc.

8.2 MAGNETICALLY BASED SYSTEMS

Magnetically operated detectors typically use a reed switch along with a permanent magnet to perform detection. The reed switch is activated by the presence of a magnetic field. Increase the magnetic field by bringing a magnet close and the contacts switch; remove the magnet and the contacts open.

Normally, the reed switch will be buried in the ballast between two ties, and magnets will be attached to the bottoms of engines and perhaps cars. As the train passes, the magnet briefly activates the reed switch. Its contacts can be wired to logic or latching relays to show that a train has passed.

But this is just another version of a gate detection system. All of the comments about optically based detection apply to magnetic detection. Except that optical detection seems to be better at detecting exact position than magnetic detection. And magnetic detection is not at all suited for detection over a "field of view" of any meaningful size.

8.3 SWITCHED ELECTRICAL CONTACTS

Several different techniques have been used over the years to detect trains using switched contacts of one kind or another. Sometimes they are activated by the weight of the train passing over the electrical switch, and sometimes by the wheels physically contacting a wire mounted next to the rails.

Most of these systems are simple and cost effective. The weight operated switches seem to present a significant installation challenge. Getting them set up to operate with a relatively heavy engine (O scale) is fairly simple; getting them adjusted to operate with a relatively light car (HO or N scale) is great way to induce a headache!

But all of these techniques operate in a gate mode, just like the optical or magnetic detectors, only detecting trains at a point. This really isn't occupancy detection, but such switching techniques can serve some useful purposes. And, like all electrical contacts, dirt and oxidation can impair switch operation. Even reed relays, which not sensitive to dirt, should have special metal alloy contacts if they are to function properly in low current logic circuits.

8.4 CURRENT DETECTION SYSTEMS

Current detection systems operate by detecting the current that passes through a motor or lights when a train is running in a block. There are many flavors of such systems, and they generally have similar advantages and disadvantages.

A major benefit of current detection systems is that they can easily detect train current, regardless of how long a block may be, or how the track is routed. And, as long as some current is present, they will respond properly to trains that stop, or enter and back out of a block. But they will generally introduce some drop in the voltage that actually reaches the motor. How significant this is depends on the specific technique used.

The next few paragraphs will describe the principle techniques of which we are aware.

8.4.1 RELAY CURRENT SENSING

Specially designed relays have been used to detect the current flowing in a track circuit. In this case, the current passes through the relay coil along with the train motor and lights. Relays have several benefits. First, they are difficult to burn out, and, since the coil is electrically isolated from the switched contacts, properly designed relays can be used with any form of DC or even AC train control. We know of no relays designed to detect current in a DCC controlled layout. And contacts can easily be designed to switch many amps, and thus control any type of load current.

The main limitation of this technique is the issue of balancing the sensitivity of the relay with the voltage dropped across the coil. As in most areas of engineering, there are conflicting factors which must be considered. With a relay, a magnetic field of a certain strength must be generated to switch the relay. To get sensitivity to low currents, many turns of wire are required in the relay coil. The more turns there are, the higher the resistance of the coil and the larger the voltage drop; using heavier wire reduces the voltage drop but increases the physical size and cost of the relay.

In years past, when motors routinely drew an amp or more of current, a workable balance in the design of the relay could be reached. But today's can motors, which draw only 20% as much current are much more difficult to detect. And when the train stops, so does the current. What is there to detect?

Relay contacts present a further limitation. They are subject to dirt and oxidation that can prevent the contacts from closing properly. Also, when used to switch the very low currents that are involved in logic circuits, typically a milliamp or less, the contacts should be gold plated to resist oxidation. Using gold increases the cost significantly; not using gold decreases the reliability significantly. Another one of those pesky engineering compromise situations!

Considering today's motor technology, relays may not work at all. In fact, we haven't seen or heard of anyone used relays for train detection and using modern can motors in the engines.

8.4.2 TRANSISTOR CURRENT SENSING

The transistor was first applied to train detection, to our knowledge, by Linn Westcott in the mid 1950's. He designed the Twin-T circuit, and later the Twin-T with booster transistor, for train detection.

His circuits were very effective, and in wide use. They had the advantage of high sensitivity, yet resulted in a low and almost constant voltage drop in the track circuit. They could easily detect milliamp-sized currents. By equipping your wheel sets with a resistor of some relatively large value, these circuits could detect a lone car parked in a block - just as the prototype does!

For practical reasons, the layout will usually be wired using common rail wiring, with the Twin-T circuit installed in the path from the common rail to the layout common return. You can avoid the need for common rail wiring by providing a separate, isolated power supply for each detector. This, of course, adds a lot to the cost.

The major limitation of the Twin-T circuit is the fact that the full train running current passes through what is normally a low current path through a transistor. Thus, relatively large and expensive power transistors had to be selected so that the base to emitter path could handle at least three to five amps. And these transistors had to be mounted on a heat sink of some fair size.

The only other limitation of which we are aware is the fact that these circuits operate very quickly, and can respond easily to momentary breaks in current due to dirty rail or wheels. This effect can be reduced somewhat by installing a capacitor in the right place.

This form of detection is still adequate, but it is no longer cost effective to use such high current transistors to carry the train running current.

8.4.3 DIODE CURRENT SENSING

The next form of current detector uses diodes in the common rail path to the block. Very low cost diodes, capable of handling 3 amps or more continuously, while giving a voltage drop of less than 1 volt, are readily available. This has the same effect as the power transistors used in the Twin-T circuit, at a much-reduced cost. Sensitivity can be just as high or even higher.

The only thing remaining is to sense the voltage drop across the diode using an operational amplifier or comparator of some kind. Today, such integrated circuits are readily available at low cost. Once the voltage has been detected, it can be conditioned to drive relays, light emitting diodes (LED) or logic circuits.

Techniques of this type result in reduced costs when compared to Twin-T and similar transistor based circuits. They also operate very quickly, and will respond to breaks in current flow due to dirty rail or wheels. As with Twin-T circuits, this can be controlled with a capacitor or other filtering in the right place.

Generally, two diodes are used, connected in parallel with opposite polarity. In this way, a positive voltage is generated when the train current is flowing in one direction, and a negative voltage is generated when the current flows in the opposite direction. This usually requires that the detector board have both positive and negative operating voltages applied, adding cost in the form of an extra power supply.

The BD16 Occupancy Detector uses an advanced form of diode detection, and a special technique that eliminates the need for dual power supplies to power the board. Special circuitry and signal processing techniques are provided which minimize the sensitivity to wheel and rail dirt.

8.4.4 ISOLATED CURRENT SENSING

There are several forms of isolated current sensing in use. An isolated detector operates much like a relay: a circuit element is wired in series with the block, and an electrically isolated signal is picked off and used to indicate train presence. One such technique uses four high current diodes in series with the track circuit, and two optical isolators. Depending on the direction of current flow, one of the two optical isolators activates.

Since the current sensing diodes are isolated from the rest of the detection circuitry by the optical isolators, this form of detector can be used even on layouts that do not use common rail wiring. The system is fairly sensitive, and appears to have, as its primary weakness, a series voltage drop of about 2 volts because there are two series diodes in the track current path. Noise filtering circuitry must be provided to minimize the effects of wheel and rail dirt. And additional signal conditioning must be provided to allow such a detector to operate LED’s, relays or bulbs.

9. CONVERTING TO COMMON RAIL WIRING

If your layout is already wired for common rail power distribution, your installation will be somewhat easier. But, even so, there may be some minor alterations in wiring, primarily involving power routing through switches under some conditions.

Begin by selecting your common rail. If your layout has already been wired using the common rail system, this step is done. All you need to do is remember which rail you picked!

The common rail can be either the north rail or the south rail, it really doesn’t matter. Incidentally, just for clarity, this manual is written assuming that your layout is an East-West railroad. If you think of your railroad as a North-South railroad, we suggest that you temporarily think of it as East-West. This will make it easier to read the manual. Otherwise, this manual would be almost twice as big. Every paragraph would have to appear twice - once written with “East-West”, and once with “North-South.”

How do you know which is the north or south rail? It’s very simple, really. Look at any section of track on your layout where a west-bound train moves from right to left. The south rail is the rail closest to you; the north rail is the other rail. If your layout is an oval of some kind, Linn Westcott suggested many years ago that you envision a north pole in the center of the oval. The rail closest to the center would then be the north rail. If he had lived in the Southern Hemisphere, his suggestion may have been different, but it doesn’t matter.

First, without common rail wiring, your layout-wiring diagram probably looks something like Figure 3-1 Two-Rail Switched Cab Circuits. As you can see, each of the two cab outputs is routed through a cab select switch to the two rails of each block. There is no single wire shared by all of the cabs - each is totally independent. Not shown are wires, or switch points, used for routing power. Perhaps you have some additional toggle switches used to connect reverse loops or crossings.

There are several steps to go through in making the conversion. We recommend that you make the conversion in simple, easy to correct steps. Doing all of the rewiring and then testing to see if it all works is very macho - but not very bright! Based on our experience with the conversion process, we are going to recommend a step-by-step approach that will minimize your aspirin consumption.

9.1 ELECTRICALLY INDEPENDENT CABS

Cab independence, of course, is essential to common rail. This lets us connect any one output terminal of each together without causing any problems. The most obvious indication that the cabs are electrically independent is simple to see. Any two cabs that have separate power cords are electrically independent.

If you have any of the dual throttle cabs on the market, you will have to do some experimentation to see if they are electrically independent. First, with the unit unplugged from the wall and the throttle outputs disconnected from the layout, use an ohmmeter to check for continuity between the two throttles. Measure from each output of one throttle to each output of the other, and reverse to ohmmeter leads as well to make sure that there are no internal diodes connected. In all of these resistance checks, look for infinite resistance or an open circuit indication. Any low resistance under 10 K ohms is a good indication that the throttles are not independent.

Then, plug the power supply into the wall outlet, leaving it disconnected from the layout, and set the output voltage of each throttle to 3 volts. With your voltmeter on the 10-volt DC or higher scale, measure the voltage between each output of one throttle and each output of the other. This will give a total of four voltage readings.

In each case, you will read 0 volts if the throttles are independent; if they are not, you will measure +6 volts for one measurement, and -6 for another.

If the two throttles in a dual power pack are not internally isolated, you can use only one of them in your new wiring. Sorry about that.

Then, reconnect only one of the throttles if they are not independent, or both if they are independent.

9.2 FINDING THE CAB COMMON OUTPUTS

Once you have selected the common rail, identify which output of each cab is connected to the common rail through your cab select switches. Turn off all of the cabs for this next step. Pick any conveniently located block, remove any engines and cars from the block, and attach one of your ohmmeter leads to its common rail. Then, one at a time, select each cab and with the cab select switch for the block and touch your other ohmmeter lead to the outputs of the cab. One of the outputs will show a very low resistance, probably less than an ohm. The other output will show a much higher resistance.

Confirm the reading by reversing the ohmmeter leads. In each case, the cab output currently connected to your common rail through the cab select switches will show a very low resistance. Mark the common rail output on each cab. Do this for all of your cabs: main line, yard or other local service cabs.

When this is done, let's do a sanity check. Make a quick and dirty temporary connection between all of the cab common rail outputs that you just identified. Then, operate a train over the layout, using each cab and taking each route, siding or spur. Everything should still work just as it always did.

If something isn't working that used to work, take the time now to identify the problem. There are only two things that could be wrong at this point. Either, cabs that you thought were isolated really aren't, or the cab output you identified as being the common rail output was incorrect. Before proceeding, correct the problem.

9.3 INSTALLING THE LAYOUT COMMON WIRE

Next, we will install the layout common wire. Review Section 6.2 to choose the correct wire size to use. If in doubt, use the next larger size. Use stranded wire, as it's much easier to pull around joists, risers and L-girders. And it will probably be easier to install multiple runs of smaller gauge wire than one run of very heavy wire. For example, use four runs of 10-gauge wire rather than one run of 4-gauge wire. Both approaches give the same effective resistance, but 10-gauge wire is probably as heavy as you would want to work with.

Of course, use copper wire, not aluminum. You will have to solder connections to the layout common, and copper is much easier to work with.

Then, run the layout common wire around your entire layout, bringing it near to all of the cabs, and close to all of the locations you have selected for BD16 installations.

When the layout common is installed, make your permanent connections between the cab common outputs and the layout common.

Wherever you need to connect a tap wire to the layout common wire, carefully skin about one inch of the insulation off each of the common wires and strip a couple of inches of insulation off the end of the tap wire. Then take the stripped end of the tap wire and wrap a tight turn around each run of the layout common. Solder each of these turns to the layout common using rosin core solder. This is shown in Figure 9-1 Tap Wire Connected to Layout Common.

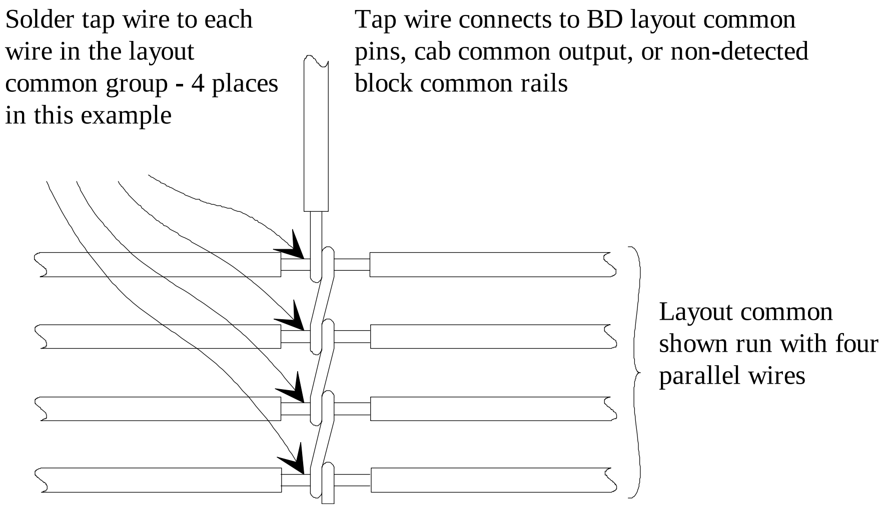


Figure 9-1 Tap Wire Connected to Layout Common

You may need a 100-watt or more iron or soldering gun to heat up 10-gauge wire enough to get a good connection. It's better to use a higher wattage, and complete the connection quickly, than to use a low wattage iron and take all day to heat the wires. This won't work well, and you'll probably have melted insulation all around the connections.

Be sure that you physically secure the bare wires so they can't move and possibly contact other circuits. Wrapping the connections with electrical tape may also be a good idea. This will save you trouble in the future.

Again, do a sanity check by running your layout to see that everything still works. At this point, the only problems were probably caused by the physical disturbance which came from running the layout common wires. Since you really haven't changed your existing wiring, it should be easy to locate and fix the problems. Make sure everything is working before you continue.

9.4 CONNECTING NON-DETECTED BLOCKS

You will probably have blocks or other sections of track that are not going to be connected to your detector boards. This will normally be yard tracks and probably industrial sidings. At this time, you will connect the common rails of these areas of track to the layout common wire. For your non-detected blocks, make sure that each such block or section of track has gaps in the common rail to separate it from any adjacent detected blocks.

Connect these sections of track to the layout common one at a time, and then test what you did. This way, you can keep any problems from growing to unmanageable proportions. Also, by doing a little at a time, you can keep your layout operational while you make this conversion.

Select a non-detected block to reconnect. After the common rail has been separated by gaps from other blocks, disconnect all of your original feed wires from your cab select switches to the common rail. We suggest you cut these wires so that at least a few inches remain connected to the rail and accessible. If you make a mistake and cut the wrong wire, you can splice the ends back together. If not, you can use the wire still attached to the rail to make the connection to the layout common wire.

At this point, the common rail for the block should be completely isolated electrically. Verify this by connecting a cab to the block, and all adjacent blocks, using the proper cab select switches. Set the cab output for a few volts, and measure the voltage in the block from its common rail to its power rail. Check throughout the block, including any switches or crossings.

The only right answer is 0 volts. This shows that the common rail has been isolated. If you get a non-zero voltage reading, it means that there is still an original wire connecting the common rail back through the cab select switches to layout common. Or, you may not have put in all the gaps needed to isolate the rail. It's time to conduct a search and destroy mission to eliminate all of the old connections to the cab select switch, or to cut all necessary gaps.

You may still have some wires attached to the common rail. These will be wires that connect stock rails and switch frogs to power routing contacts on your switch machines. Leave these wires in place.

When the common rail has been isolated from all of the original feed wires, connect it to the layout common. Attach a tap wire as described in the prior section, and connect the other end of the tap wire to the common rail using the ends of the original feed wires you left attached to the common rail. If the block is particularly long, you may want to use several tap wires from the layout common.

Note that at this time, the cab select switch is only feeding the power rail; the layout common wire is now feeding the common rail.

Finally, finish work on the block by conducting another sanity check. Run an engine in, around and through the block using each of the cabs, checking each of the routes. Fix any problems. If the engine does not run everywhere in the block, this will probably be due to missing a connection between a tap wire and one or more of the common rail wires.

Or, you may have attached a tap wire to a power rail feed. This would result in a short circuit in the block, and the engine won't run anywhere as long as the cab select switch is set for the block.

Repeat this process for each non-detected block, checking as you go. While you are doing this, you are only taking one block out of service at a time, and only long enough complete its conversion. You don't have to cancel any of your operating sessions!

When you have finished all such blocks, go on to Section 5, POWER ROUTING THROUGH SWITCHES.