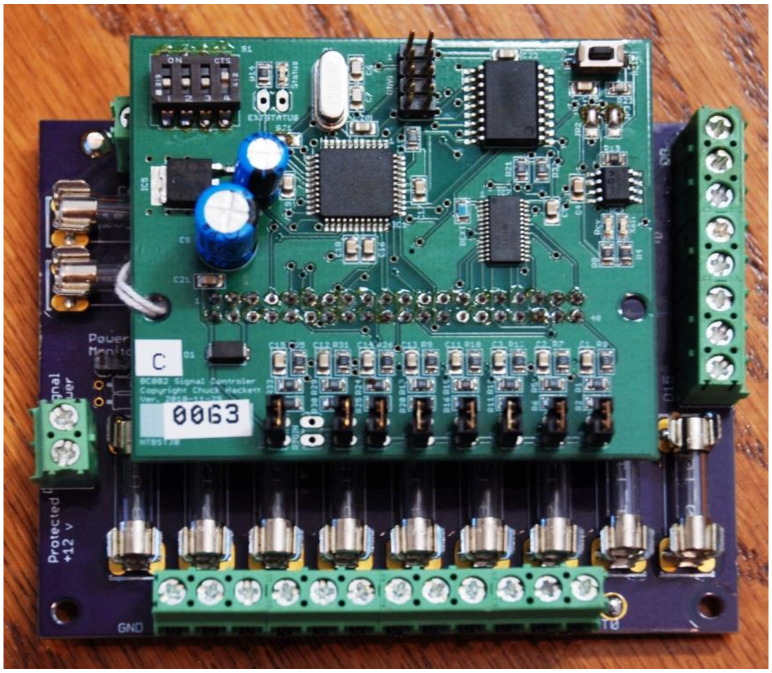

# MiniRail Solutions

# BC002 Signal Controller

# User Manual


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*If you have comments or suggestions about this manual please send them to the email address above.*

This document has been released to you for your use in evaluating or using the BC002 signal system. Please do not distribute this document. If you know of others that might be interested in it please let me know and I will send them the latest version.

# Table of Revisions

| | |
|---|---|
| 2017-02-27 | Initial creation of Table of Revisions |
| 2017-02-27 | Alteration of Approach Track handling to better handle when a train exits the block at a point that is also as entrance to the block. |
| 2017-03-30 | Added the section: “Installation Suggestions” |
| 2017-05-06 | Added sections describing support for Full-Size Searchlight signals |
| 2017-07-10 | Updated section 18 entitled [“Test” Devices] to reflect change from numbers to symbols for the test configuration. |
| 2017-08-10 | Added section 39 “TWI Expansion Card I/O Addresses” which documents how to calculate the addresses for the expansion cards. |
| 2017-12-04 | Miscellaneous changes to the “Ladder Track” object |
| 2017-12-07 | Added support for “MultiSelect Button One Of Many” |
| 2017-12-21 | Minor edits and removed the index (difficult to maintain a good one and Adobe Reader allows you to search which somewhat replaces the index function), reorganized the description and parameter info for signal heads. |
| 2018-08-28 | Fixed a cross-reference error in section 5.2 (Terminology/Blocks) |
| 2019-05-15 | Major revision.<br>• Updated contents to more accurately reflect the current firmware version.<br>• All configuration information moved to separate BC002 Configuration Manual.<br>• All installation information moved to separate BC002 Installation Manual. |
| 2019-06-08 | Correcting cross-references and minor revisions prior to release of new manual on website. |
| 2019-06-10 | Added “Stand-Alone” mode, minor corrections, and deleted “Summary” Table of Contents. |

# Table of Contents

# 1 Train Crew Responsibility

***Train crews are always and SOLELY responsible for the safe operation of their trains.***

***This means that the train crew will always ensure the protection of people and property on and around the train as well as taking all measures necessary to protect other trains. This includes the use of appropriate following distances, speeds, flagmen, etc.***

***No signal system is perfect.***

***Train crews will not assume that other trains will obey the signals.***

***Train crews will not assume that, because a signal indicates that it is clear to proceed, that it is, in fact, safe to do so. False "Clear" indications are possible.***

***The signal system is designed to add a level of prototypical feel and facilitate traffic flow. Specifically: This signal system is NOT designed as a Safety Device.***

***Again: Train crews are always and SOLELY responsible for the safe operation of their trains.***

# 2 Overview

There is a lot to digest in this document. If this is your first exposure to the MiniRail Solutions signal system, please do not be intimidated by the amount of information here. Some railroads will use all the features, some will only need a few.

The MiniRail Solutions signal system is designed to automatically control signals in response to trains detected on sections of track.

The system is specifically designed to fulfill the demands of automatic signaling required by "Large Full-Time Bi-Directional" railroads where engineers are able to go "anywhere at any time" as opposed to the less demanding signaling required by unidirectional tracks for train separation only.

The system can be easily configured for small railroads only wanting ABS/APB-like signals and not wanting centralized monitoring, etc. - in which case you can install the controllers in "Stand Alone" mode which is greatly simplified. See "Stand-Alone Mode" on page 48 for more information.

I try to replicate full-size practice when possible, but I make changes where I feel the design better suits ride-on practice and engineers.

While providing train separation, the system also enhances traffic flow by attempting to minimize deadlocks, etc.

Although designed for bi-directional running, the system easily handles unidirectional track where only train separation or multi-entry features are required. The more advanced features are available as you add more complexity to the railroad (more choice of routes, etc.).

When someone implements automatic signals, they will typically use a set of relays to control the signals.  Wires are run from each track segment to relays that control each signal.  Additional wires are run between signals to allow the relays to “know” about the occupancy status of tracks ahead for a signal to display, for example, an “Approach” aspect (it must know the status of the block and the following block).  These relays must be carefully selected and installed to ensure that they will reliably detect trains in any weather conditions which is sometimes not an easy task.

For a dispatcher to be able to see the status of tracks and signals in a relay system additional wires must be run from each track to the dispatch location.  To allow the dispatcher to control switch motors, etc. more wires must be run from the dispatch tower to each individual device in the field.

The MiniRail Solutions signal system is different in that the signals are controlled by small, single chip, microprocessors (“a computer on a chip”) distributed around the railroad.  No programming is required. The user merely configures the system by setting parameters.

The track signals are processed by an adaptive conditioning algorithm that removes the effects of weather, wheel noise (leaves, etc.).  I have yet to encounter a track condition that it cannot deal with.

Using microprocessors provides a level of flexibility that is not achievable with traditional signal systems. The system provides the ability to control any signal, switch motor, etc. from multiple points on the railroad (typically, the dispatch tower).  The system can display the real-time status of all tracks (which tracks are occupied, switch positions, etc.).  These displays can be at any point on the railroad (dispatch, passenger station, etc.).  The system allows adding new tracks, signals, etc. or changing the way the signals operate simply by changing configuration parameters (See BC002 Configuration Manual).  No additional wire is needed except that needed to connect your device to the nearest controller.

Because the features of the system are implemented via configuration parameters (downloaded by the user into the controller), system changes or new features are much easier to implement.  No hardware changes are required except those needed to add or remove physical items such as tracks, signals, switch motors, etc.

The microprocessors are located on small printed circuit cards.  These cards are referred to as Signal Controllers.  The number of controllers required, and their physical location depends on the needs of the railroad.  Locations are selected to minimize the amount of wire needed.  Tracks and signals are connected to the closest controller regardless of the block they are associated with.  This minimizes wire cost as well as lightning/surge exposure.

To coordinate traffic through Blocks, Interlocks and Routes, the controllers communicate with each other via a single twisted-pair of wires within a CAT-5/6 cable buried along the right-of-way.

There is no “central computer” involved in controlling the signals.  The control logic is distributed around the railroad within the controllers, thus there is no central PC to fail causing the entire signal system to go out of service.

The system supports one or more PC's connected to the system to display real-time track status and issue commands to the system (throw switches using switch motors, etc., See "SComm Monitor and Control Program" on page 71).

The controllers get their power from an additional pair of wires buried with the data cable. Since the controllers draw very little power (less than 60 ma), small installations can simply use one or more pairs within the CAT-5/6 data cable to deliver power.

The biggest challenge with solid state signal systems is their vulnerability to nearby lightning strikes. Careful layout of the printed circuit boards along with the on-board protection devices minimizes the possibility of damage to the controllers.

The controllers detect trains by using "track circuit" technology (i.e.: train is sensed by the fact that it's axles "shunt" or "short circuit" the rails together). As an alternative, "Axle Counting" and/or "entry/exit" methods can be added to the system firmware where track circuit detection is impossible or impractical (e.g.: steel rail with welded steel ties but these alternatives have issues that must be accounted for using additional operating rules, etc. (See "Train Detection Alternatives" on page 78)

Throughout this manual, it is assumed that "track circuit" detection is in use.

If a controller is unable to communicate with other controllers (another controller is not working, the cable has been cut, etc.) it may not have all the information it needs to properly control the signals. In this case, the signals will operate in a 'degraded' mode. The controller attempts to display the least restrictive signal aspect while still providing block protection and train separation. If a controller does not have access to the minimum information needed to provide such protection it will set the affected signals to an "Error" aspect to warn engineers that protection no longer exists.

# 3 System Feature Summary

- Signal Features
  - Designed from the outset for Full-Time bi-directional, "Go Anywhere at Any Time" running and easily handles unidirectional blocks as a subset of bi-directional control.
  - Blocks are protected from two trains entering simultaneously. This cannot be accomplished with simple occupied/unoccupied systems. See "Why ABS or APB Signals Are Not Sufficient" on the MiniRailSolutions.com website.
  - Block entry points can be assigned a priority. This allows you to prioritize one or more entry points over other entry points (e.g.: give eastbound traffic priority over westbound traffic, etc.).
  - The system attempts to detect and avoid deadlocks by controlling traffic flow.
  - Signal aspects are 'soft' and can be customized by the user (see "Signal Aspects" on page 39).
  - Signals can be dimed at night (if you are using the "dimmable" LED driver built into the controller).
  - Signals can be configured as "approach lit" (dark when no train present) as in some prototype practice to save power.
  - Blocks can have an arbitrary number of entry/exit points.

- Facing point (route) signals can be configured to display the status of the alternate route in addition to the currently selected route.
- System can show route status (e.g.: double signal heads at track switches) using feedback from motorized track switches or via the MiniRailSolutions Point Detector or microswitches attached to track switches (manual or powered).
- If desired, you can provide engineers with additional information via "blink/wink" codes in the signal aspects. For example, the engineer can tell if the signal is at "Stop" aspect due to occupied block, dispatch hold, etc.
- System can have multiple configurations such as one for Run Days, another for Public Days or Card Order, and yet another for Large Meets where there are a lot of visiting engineers who may be unfamiliar with the railroad and signals.
- Only 4 wires are required in the right-of-way to support all functionality (typically one CAT-5 cable and a pair of #16 for power).
- No new right-of-way wires are required to add signals or trackside devices other than that required to connect them to the nearest controller. If a new controller is needed you just tap into the existing data and power cables.
- All wires from tracks and trackside devices are "home run" to the nearest controller. No need for long wire runs to a relay frame. Easier to layout and maintain and minimizes lightning damage.
- No relays to corrode, stick or adjust.
- Train Detection automatically adapts to wet/dry conditions, rejects noise caused by dirty wheels/tracks.
- Functionality can be altered by changing system configuration parameters, no re-wiring or re-programming is required. There is only one version of the controller firmware to support all functionality. Controllers only differ in the parameters set for them.
- Can accommodate wireless connections between controllers in cases where it is difficult to run cable connections.
- Supports real-time display of track occupancy, etc. of the entire railroad on a computer monitor with the capability to display on a club web site, etc.
- Can accommodate pre-existing signal heads, semaphores, etc.
- Drivers are available to control other track-side devices like crossing gates, trigger sound cards, etc. In general, any device that accepts a digital or analog input. This includes drivers for electric switch motors and full-size searchlight signals. If you have a need that is not covered by a current driver I can design and build additional hardware and firmware in a fairly short timeframe.
- The controller can accept digital or analog inputs from any device, including serial data (axle weigh scale, etc.). This includes accepting information from switch motors (or micro-switches) to sense which way the points are set.

- Dispatch Features
  - System can run in ABS-like (auto) or CTC mode (dispatcher controls switch motors and can place holds on signals).

- A free PC program provides a real-time track display showing the status of all tracks, switch positions, signal aspects, etc. It also supports multiple displays, sub-regions (yard, East Subdivision, etc.).
- All train movements, switch positions, signal aspects can be displayed at any point on the railroad (typical: Dispatcher position, station track display, laptop for maintenance activities).
- Any device on the railroad (switch motor, etc.) can be controlled from any point on the railroad (typical: Engineer-operated Route Selection buttons, Dispatcher, Yard Master, etc.).

- Diagnostic Features
  - A free PC program provided for monitoring and control. (Note: the program is NOT required for the signals to operate in automatic mode).
  - Diagnostic program can display track voltages (including strip-chart) in real time.
  - Provides diagnostic information to aid in troubleshooting broken wires, rail joints, etc. including the ability to identify the location of a bad joint/bond wire.
  - Signals blink an error code to aid in locating faults.
  - Fail-safe track detection is supported (detection of "broken rails")
- The Future
  - Ability to "Replay" track occupancy to determine routing problems, etc.
  - Internet display of real-time track occupancy (club website, etc.)
  - Smartphone App to allow use of smartphone as a diagnostic terminal.
  - Smartphone App to allow anyone to see the current track status to decide where they want to go, etc.
  - Voice annunciation of:
    - Trains approaching the yard/station
    - Trains needing clearance by a dispatcher
    - Trains violating a red signal
    - Etc.
  - See also: "Thinking "Outside The Box"", on page 76

# 4 Why not a simpler approach?

One might ask: "Is a microprocessor really needed?" There are many railroads using simpler approaches. My goal was to create a system that provided more functionality than that achievable without getting into very complex relay setups and the more complex the relay setup is, the more difficult it is to maintain.

Simpler systems cannot easily:

a) Accommodate more complex interchanges
b) Protect against cornfield meets without additional relays and additional train detection (i.e.: implement approach tracks or claiming blocks)
c) Deal with Wet/Dry track conditions (especially long blocks, or blocks using new wood preservatives) in a general way, each situation must be addressed individually by adjusting relays, voltage sensing levels, etc.

d) Deal with excessive wheel-rail contact noise (i.e.: signals “flicker” or blink randomly)
e) Adaptable to “wheel counting” or “entry – exit” train detection when required by welded steel rail/ties, etc.
f) Use wireless connections.
g) Accommodate additional signal aspects such as “Approach Distant” plus others that give more information to the engineer (dispatch hold, route blocked by point position, etc.) without additional wires.
h) Accommodate multiple-entry blocks with priority handling of trains.
i) Support CTC mode of operation.
j) Change signal operation depending on the use of the railroad (Public Run Day, Card Order, Large Meet, etc.).
k) Support multiple real-time Track Occupancy Displays and remote control of switches.
l) Display Track Occupancy in real-time on the Internet.
m) Support “anywhere – anytime” traffic movement.
n) Provide more advanced traffic flow functions such as priority routings, congestion/deadlock prevention, etc.
o) Provide diagnostics to help locate broken joints, etc.

# 5 Terminology

## 5.1 Sidings

The diagrams in this document assume “right-hand-running” on all passing sidings. Left-hand-running, or a mixture means that the signal positioning is slightly different, but the same concepts apply.

It is also assumed that, in general, sidings are made with spring switches and they are single-direction tracks between two bi-directional blocks. One could construct passing sidings where each siding is bi-directional, and the system can be setup to handle it, but this is not the normal practice.

This document refers to both tracks at a passing siding as “sidings” because they are defined and act the same. The only difference is that they are going opposite directions. Some railroads would refer to one of these tracks as a “siding” and the other as the “main”.

## 5.2 Blocks

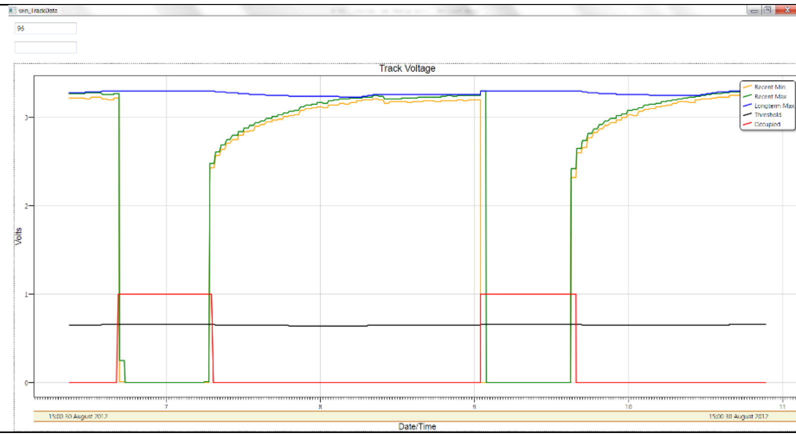
This document uses the term “Block” somewhat differently than is common in full-size practice. See "Blocks" on page 23 for more information.

# 6 Tracks

## 6.1 Detected Tracks

This document uses the term “Detected Track” to refer to a section of track that the controller can use to detect the presence of a train.

It detects trains by the short-circuit (shunt) created by the wheel sets of locomotives and rolling stock. A voltage (Track Bias) is applied to the track through a ballast resistor. The controller detects the presence of the train by the fact that the voltage on the rails drops to (near) zero when there is a train on the track.




Typical track voltage as two trains pass through a detected track section.

Reliable train detection on long track segments in ride-on scale track is not a straight-forward proposition. Detection is hampered by the changing electrical characteristics of the track (wet/dry ballast, loose joints, etc.) as well as light cars with dirty wheels, etc.

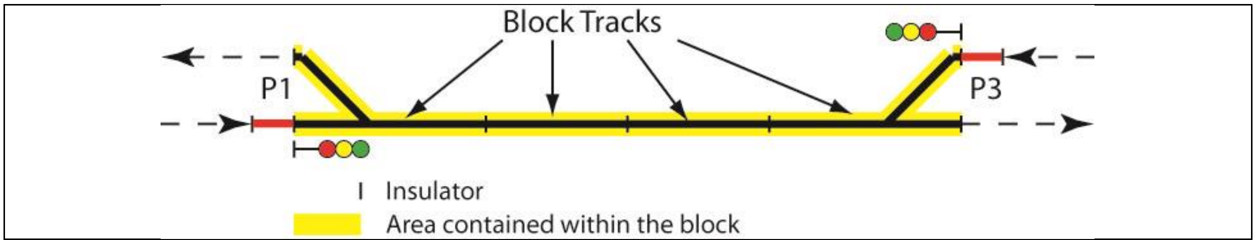
The task has been made more difficult by the fact that, in the effort to remove arsenic from wood preservatives (CCA), suppliers have moved to formulations that contain much higher levels of copper. This means that ties have become more conductive and produce more corrosion on aluminum rails, particularly in wet weather. The controller can deal with this situation by being able to detect small differences in track voltage as well as through the adaptive signal processing algorithm it uses on the raw track voltage data.

Extensive effort has been put into the development of the hardware and software used by the controllers to detect trains reliably without the use of excess current through the track which can accelerate corrosion of the rail and track screws.

## 6.2 Block Track

This is a section of track between head-end signals. In other words, a section of track totally within a block. A block can contain one or more “Block Tracks”.

A block may be split into multiple tracks for many reasons, one is that it gives more precise knowledge of train location to a dispatcher viewing the track display.

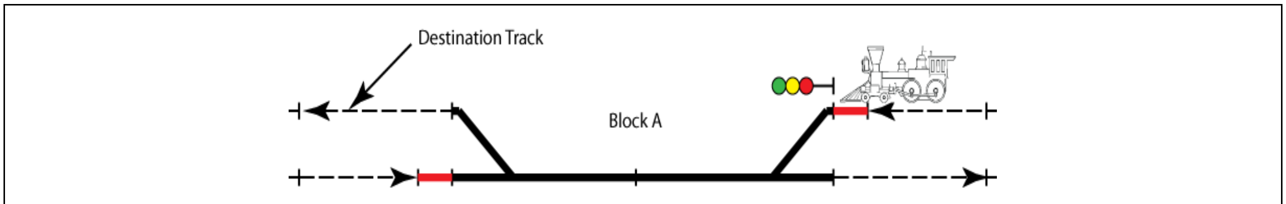



Example of a block containing four detected tracks

Note: In all the track diagrams the short vertical lines that go across the tracks represent insulators that isolate two sections of track into separately detected segments.

## 6.3 Destination Track

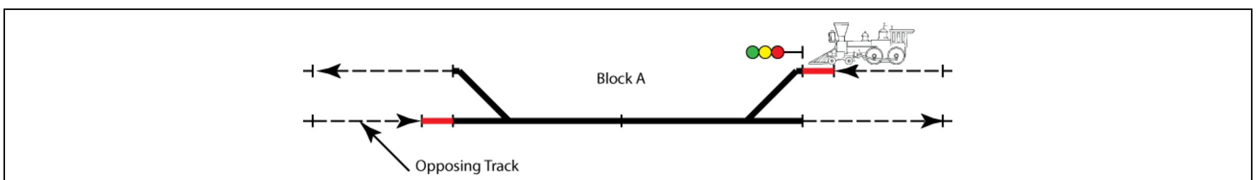
This is the track that the train will be on when it exits a block after entering at the signal which references this track as its "Destination Track".




Example of a Destination Track

## 6.4 Opposing Track

This is a track that, if it contained a train, and the train were allowed to proceed, the train would be traveling toward the train waiting at the signal containing the reference, i.e.: The train on the "Opposing Track" is opposing this train/signal.




Example of an Opposing Track

## 6.5 Approach Tracks

"Approach Tracks" are perhaps the most important and most miss-understood part of the system.

An Approach Track replaces the engineer-operated push-button used on many scale railroads to allow the engineer to request permission to enter a block.

An Approach Track is a detected track segment that lies immediately in front of a signal that guards an entry point into a block. Some railroads call this section of track a "Claiming Block".

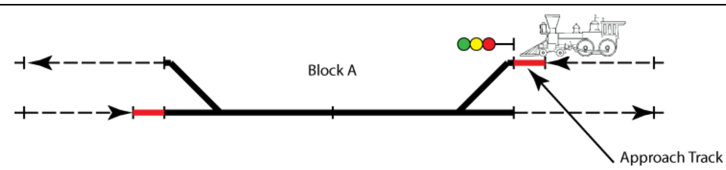
Prototype railroads do not use "approach tracks" because prototype ABS/APB signals are designed to provide "train separation" but not traffic flow control. The approach track basically takes the place of a train calling the dispatcher on the radio and requesting permission to enter a block, thus preventing two trains from entering at the exact same time.

Prototype ABS/APB signals ***do not prevent two trains from entering a given block at the same time***. They ***will*** prevent a "head-on" because all bi-directional prototype sections between Head-End signals are defined with ***at least one intermediate signal***. If two trains happen to enter a block at the same time (and each engineer thus observes that his signal drops to Red when his front axle passes the signal) the two trains will eventually meet with at least one red intermediate signal between them – thus satisfying the "Train Separation" requirement. This prevents a head-on but does not prevent one of the trains from having to back up (possibly a long way!). In prototype practice this situation is eliminated by Track Warrants, timetables (schedules), and ***rules*** … and by firing you if you violate the rules – we can't very well "fire" someone attending a ride-on scale railroad meet. In ride-on scale railroad practice this results in frustrated engineers and everyone loses trust in the signal system (I've seen this …).

This system prevents two trains entering the block at the same time by ***guaranteeing*** that only one train is given a clear signal at any given time.

### 6.5.1 Bi-Directional, or Multi-Entry Blocks

One end of the approach track is directly opposite the signal and extends away from the signal in the direction the signal is pointed (i.e.: the direction a train would be approaching from). Immediately on the other side of the signal is track contained in the block being guarded by the signal.




Approach Track setup

A common practice is to break passing sidings in the center (illustrated below). One half of each side is the "Destination" track of the signal at the other end of the block. The other half on that side is the approach track for the signal to enter the next block. This way a train is (usually) cleared through the next signal when he passes the half-way point (assuming the next block is available).


Suggested passing track setup

Note that, even if the train is on the approach track he does not ***have*** to move, other trains will be allowed access to the block each "Entry Timeout" period (See "Rule 3 – Entry Timeout" on page 27).

> ***Warning***
>
> If a head-end signal (i.e.: an entry point to a block) does not have an approach track the entire block will not have protection from multiple trains entering the block at the same time.
>
> ***ALL entry points of a bi-directional or multi-entry block must have approach tracks for this protection to function correctly. The approach track is critical to protecting from multiple trains entering simultaneously***.
>
> If you choose not to use an Approach Track at a block entry, the protection degrades to that provided by simple "Occupied/Unoccupied" ABS/APB systems – i.e.: no protection from multiple trains entering the block at the same time.

See "Block Rules" on page 26 for information on how Approach Tracks are used.

### 6.5.2 Unidirectional (Single-Entry) Blocks

Even though not strictly required, you should define an Approach Track even for a signal that protects a unidirectional block – one with only one entry point and traffic always goes one way. This way the signal will change from "Idle" aspects to "Permitted" when the train approaches the block to give the engineer visual confirmation and make these signals behave the same as other signals on the railroad. It can also be used to implement "Approach-Lit" signals.

### 6.5.3 Laying Out Approach Tracks

When deciding on the length of an approach track, keep in mind that, due to a train entering the block at a different entry point, the signal may change to "Stop" at any time up to the moment a train hits the approach track and has been cleared to enter (See ""Permitted" Signal Aspects" on page 41). This means that a train going at the max speed allowed for a given location must be able to stop within the length of the approach track. If an approach track is too short a train may be unable to stop in time to not pass a "Stop" signal, in which case he would have to back up.

Once a train has hit an approach track and been given a signal to proceed the signal is guaranteed not to drop to Stop unless:

1) Another train enters the block without permission ("busts" a red, backs into a block, etc.). *Whenever a track within a block is occupied all signals drop to "Stop" (*See "Rule 1 – All Block Entry Signals Set to Stop If Block Is Occupied" on page 26*).*
2) This train did not enter the block ("Take the signal") within the "Entry Timeout" period (see "Rule 3 – Entry Timeout" on page 27) and there was another train waiting on another approach track to the same block. In this case the first train's signal drops to red and the second train is cleared to enter the block.

Note that, when a train is on an approach track the signal system assumes that he wants to enter the block. If you have a siding commonly used for parking a train you might want to use a short approach track so that all trains can fit in the siding without being on the approach track and thus requesting the block (perhaps 4-5 feet). When a train wants to leave the siding, all he must do is pull up onto the approach track and wait for a clear signal.

In addition to short approach tracks, there are other ways to handle "Parking Sidings" such as an engineer-operated pushbutton used to request departure from a parking track. This is basically a "request to depart" that lasts for one "Entry Timeout" interval.

## 6.6 Detection of Train Movement Direction

Detection and display of train movement may seem simple, but it is complex where only partial information is available.

One place where this becomes important is on Approach Tracks. If a train is *departing* a block at a signal that also serves as an entry to the block and no direction information is available, the following will occur:

- Train is in the block; signal is at Stop because the block is occupied
- The last car of the train exits the block – but is still on the approach track
- The signal sees a train requesting permission to enter the block and is selected
- The signal goes from Stop to Proceed, granting permission to enter … thus possibly causing other trains wanting to enter the block to be delayed
- The train proceeds, clearing the approach track
- The signal reverts to Idle (no other trains present) or Stop (another train was granted access to the block)

Thus, other trains following some distance behind this train might be needlessly delayed.

This can be resolved if the system 'knows' the direction of the train on the approach track. In the case above, the system would know that the train was departing the block because the block was occupied, then the approach was occupied, then the block was not occupied. In this case the system can ignore the occupancy of the Approach Track for one "Entry Timeout" interval on the assumption that the train will keep going. If the train does, in fact, want to back into the block at the same signal, he just needs to wait one "Entry Timeout" interval and he will then be given permission to enter the block in turn.

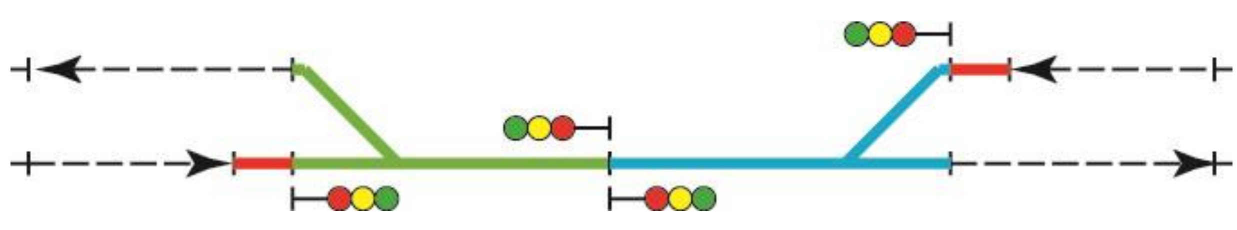
This situation (exiting a block on an approach track) is unusual in that most exits are on unidirectional passing sidings going in the direction of the train.

The direction information can also be used by the track display (SComm) to show (assumed) train movement direction for monitoring or dispatch activities.

Implementing “Direction Information” is currently in development. Currently this particular case is handled by the controller granting entry to other trains first if they hit their approach track before the train exited the block on an approach track.

To enhance the ability of the system to detect direction it is suggested that all block mainlines (i.e.: bi-directional track between block entry points) be split into (at least) two segments.

This break can also serve as a location for “Intermediate Signals” to enhance train separation or for added realism (see “Intermediate Signals" on page 36).



Split block to allow detection of train movement direction. The intermediate signals shown in the center of the block are optional.

## 6.7 “Unknown” Track Condition

When the controller powers on it does not have any historical information about track conditions.

The controller analyzes track conditions over time to compensate for weather and track conditions (wet/dry, etc.). It does this, in part, by recording the high (no train) and low (train present) voltages on each section of track.

If the controller powers up and does not see any voltage from the track it does not know if there is a train on the track since the ‘low’ voltage might also be due to a broken wire, etc.

At power-on the controller places each track in “unknown” status. When the controller sees some voltage from each track it clears the “unknown” track status to “unoccupied”.

This means that if the system is powered up while there are trains on the track there will be a period of time when the signals are indicating “Unknown Status” aspect (see “Error Signal Aspects” on page 43). During this time, trains must proceed slowly or get clearance by radio. Each of the “Unknown Status” conditions will automatically clear as trains move to other tracks.

If the controller performs an auto restart to recover from an error condition it will not set tracks to unknown because it has historical data available in memory. This cannot be done at power on because the controller has no idea how long it was powered down and it may have been moved to a different location with different track conditions.

## 6.8 Track Parameters

The following parameters are available to define a track input:

| *Parameter* | *Description* |
|---|---|
| Object ID | Every track has a unique ID. |
| Input Channel | This identifies which controller input the track is connected to. |
| VRI | Voltage Reporting Interval: Seconds between track voltage reports. |
| Option | Generate random occupied/unoccupied status (for firmware testing) |
| Option | Invert status "Occupied" and "Unoccupied". This is typically used for binary inputs to reverse the "sense" of a switch or button. |
| Option | Do not generate a status of "Unknown". Typically used for binary inputs. |
| Option | "Occupancy Release Delay" – Seconds before a track will be considered unoccupied after the last shunt detection on a track |

The occupancy release delay is typically used to compensate for very dirty rails (leaves, oil, etc.). If a value of 0 is used the signals might "flicker" – i.e.: as a short 'box cab' locomotive traverses the block the signal might rise briefly from "Stop" (typically red) to "Clear" to proceed (typically green) for a train on an approach track because the train is undetected for a brief time due to debris on the track. I typically use 2 seconds.

Remember to take this into account when testing tracks i.e.: a signal will not clear until "Occupancy Delay" seconds after the last axle departs a block.

Up to eight track inputs (tracks, buttons, etc.) can be defined on a single controller.

*(There are plans to develop an input expansion module to expand the number of tracks per controller)*

# 7 Blocks

The controller logic supports an arbitrary number of blocks. The block may contain one or more detected track segments.

A "block" is an area of track signaled such that all entry points are controlled in a manner that ensures that only one train is in a block at a given time.

A block consists of:

1) One or more sections of detected track containing no "dead spots" (i.e.: such that a train cannot be detected, or might "disappear" within the block).
2) The block may contain switches (branches)
3) The track contained in the block may have one entry (a unidirectional block from point A to point B) or multiple entries (bi-directional or multi-entry blocks)
4) Each entry is guarded by a Head-End signal. "Exit Only" points do not require a signal.

*Note: In full-size practice, the term "Block" is usually a section of track between any two signals (Head-End signals, or Intermediate signals). I use the term to refer to one or more segments of track between "Head-End" signals.*

A block can be a simple unidirectional detected track segment with one head-end signal at the beginning. In this case, all trains are traveling in one direction therefore the signal is serving to enforce train separation (i.e.: still only one train in the block at a time).

To eliminate "cornfield meets" the block logic ensures that ***only one train is ever given permission to enter a block at any given time even if multiple trains approach the block at the same time from different directions.*** It does this, in part, using Approach Tracks prior to each head-end signal to detect the presence of a train wanting to enter the block (see "Approach Tracks" on page 18).

A block may be a detected section of bi-directional track between sidings, a complex multi-diamond intersection, or a bi-directional block with multiple entries in both directions. If you can envision it and describe the rules controlling it, the controller can probably do it.

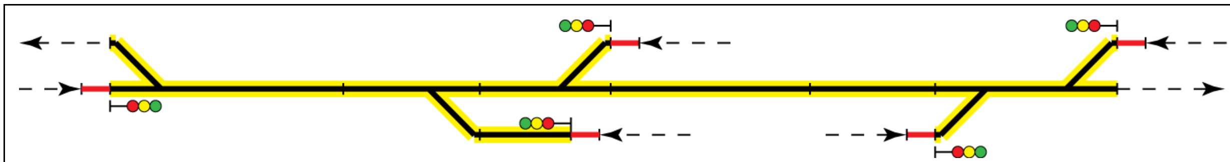
## 7.1 Block Examples

### 7.1.1 Simple Block Between Two Sidings


Simple block between two sidings

This is probably the simplest block in common use. There are two entries to this block (P1 & P3). Each entry is protected by a signal and each signal has an Approach Track in front of it (in red).

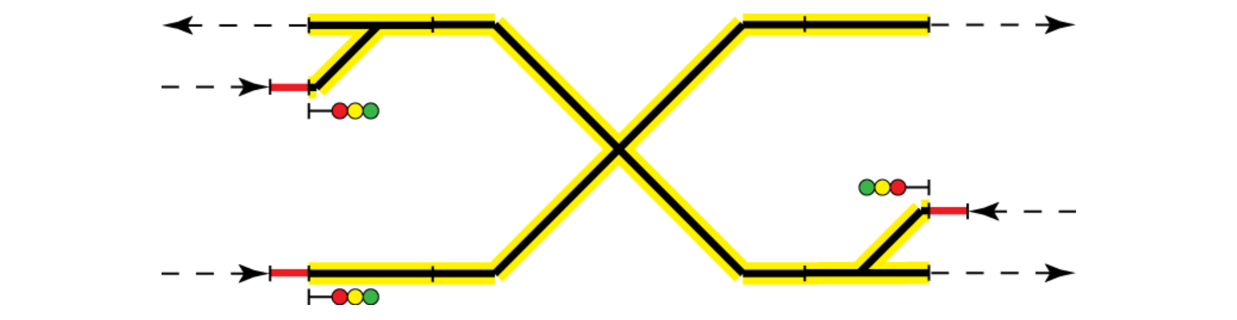
### 7.1.2 Simple Block With Multiple Entry Points



Simple block with five entry points

This is an expansion of the previous example in that one more east-bound entry was added and two west-bound entries were added. Each added entry has a signal protecting it and an Approach Track to detect trains wanting to enter.

### 7.1.3 Handling a Diamond

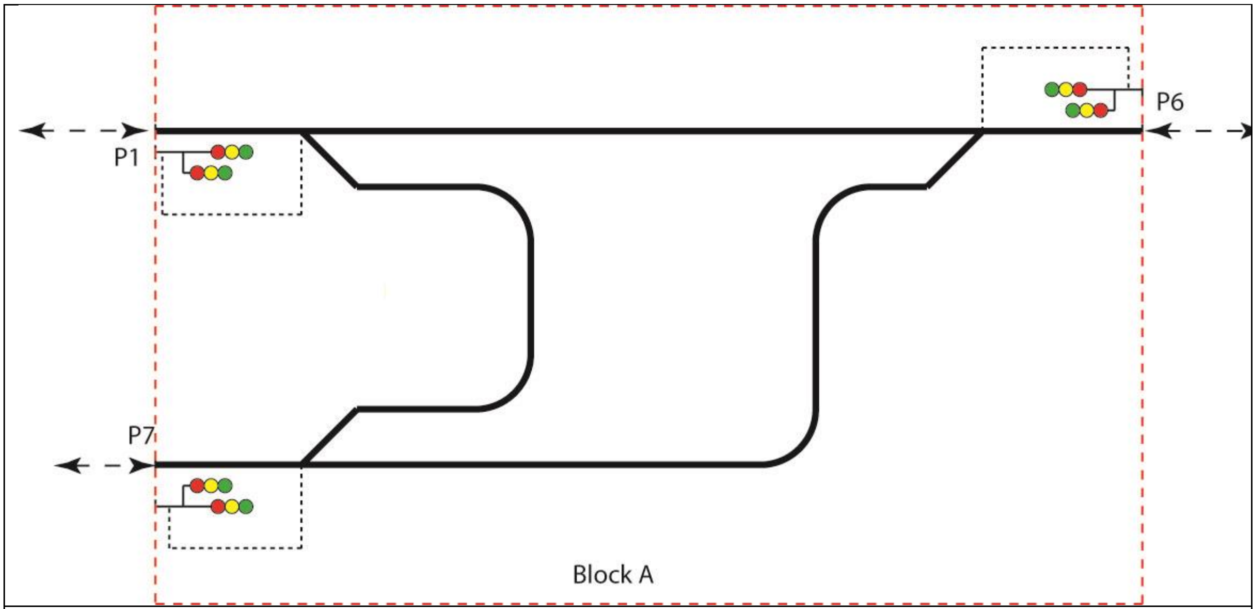


Diamond as a single block with three entry points

This is a simple diamond where the distances are short enough that the entire area is implemented as one block. There are three entries protected by signals and Approach Tracks and three exits.

### 7.1.4 Handling a Wye

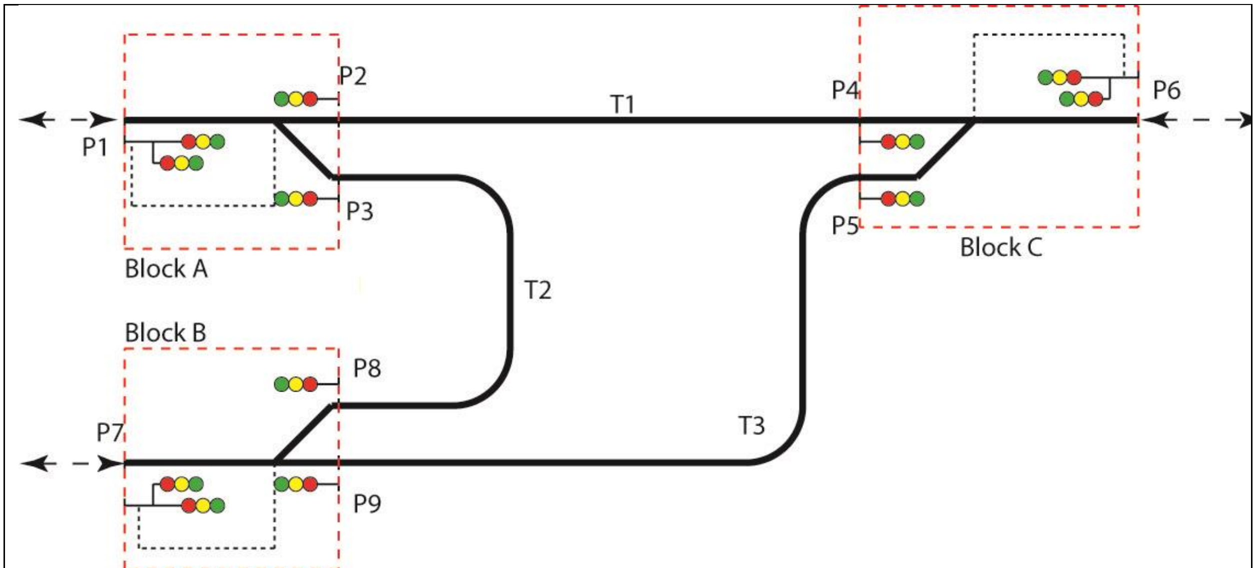
Here are two examples of how to handle a wye (approach tracks are not shown in these examples):




Simple wye as one block

In this example the entire wye is treated as a single block. This approach uses only six signal heads and is simple to configure. The disadvantage is that only one train can be in the wye at any given time, other trains must wait.

This configuration is appropriate for a compact wye where trains take only a short time to transit the wye (i.e.: it is not 'occupied' for an extended period and the trains can see each other).




Wye configured as multiple blocks

In this example the wye is configured as three blocks, each of these blocks is connected to two others by bi-directional single-track. The advantage is that multiple trains are allowed into the block at a given time, but it requires twelve signal heads.

The challenge is that the system must prevent a train at P1 from attempting to go to P6 at the same time as a train is traveling from P6 towards P1 (conflicting routes). This can be accomplished by defining T1 as a Virtual Block that must be "reserved" (see "Rule 6 – Block Reservations" on page 28) by the left (upper) signal at P1 and the right (upper) signal at P6. Since only one signal can reserve a block at a given time only one train will be cleared into T1. The other train must wait.

With this configuration, there can be three non-conflicting trains in the wye at one time – one on each leg of the wye.

This configuration is appropriate for large wyes where it takes a significant amount of time for trains to transit the wye or where trains cannot see each other.

## 7.2 Block Rules

### 7.2.1 Rule 1 – All Block Entry Signals Set to Stop If Block Is Occupied

***If any track within the block is occupied, all entry signals will display the "Stop" aspect.***

This rule protects the block even if a train backs in on an unauthorized entry, a car is set down on the track, a train parts – leaving a car within the block, etc.

This rule also protects the block if the tracks were setup for fail-safe operation and a wire should break or a rail joint would open.

### 7.2.2 Rule 2 – Single Train Entry

***At no time will two trains be given permission to enter a block at the same time.***

Whenever a train is given permission to enter a block, all other block entry points are set to the "Stop" aspect. This rule alone separates this system from 90% of the signal systems in use on ride-on railroads today.

Note: Simple "Occupied/Unoccupied" ABS/APB systems cannot satisfy this rule.

Trains are guaranteed to be notified to stop prior to hitting the Approach Track in front of a signal so that, assuming the length of the Approach Track is consistent with the speeds allowed at the location, the train has time to stop prior to passing the signal.

### 7.2.3 Rule 3 – Entry Timeout

***If a train has been given permission to proceed (Permitted, Approach, etc.) but does not enter the block within a specified time (default 20 seconds) and there is another train waiting to enter the block at a different entry point, the first train's signal will drop to the "Stop" aspect and another train will be permitted to enter the block.***

This rule prevents a derailed train, bad injector, talking engineer, etc. from stopping traffic flow.

### 7.2.4 Rule 4 – Entry Service Order

***Each signal is assigned a Service Priority. If multiple trains are waiting to enter a block at a given time, the approaches will be served in priority order. Within a given priority the approaches will be serviced in a round-robin manner.***

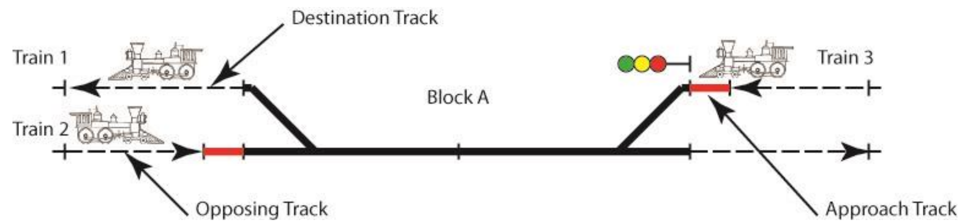
### 7.2.5 Rule 5 – Destination and Opposing

***If a signal's Destination and Opposing tracks are both occupied, the system will not give a clear signal to the train at the signal, because:***

- ***The train at this signal has no place to go when he gets to the end of the block (the Destination Track is occupied), and***

- ***There is a train on the "Opposing" track defined for this signal that might be able to proceed towards him thus clearing congestion, a deadlock, etc. Whether the opposing train will, in fact, be able to proceed or not will depend on the definition of his signal and the occupancy of his Destination and Opposing tracks, dispatch hold, etc.***

This rule attempts to prevent deadlocks. The effects will cascade from block-to-block. For example, it will attempt to keep traffic flowing through multiple blocks/sidings in one direction around a train that is disabled on a siding with an available passing siding.




Example: Destination and Opposing are occupied

In the above example train 3 will not be cleared to proceed because train 1 has not departed the destination track yet (therefore train 3 has no place to go) and train 2 is on the opposing track and can (and will) be cleared to proceed.

### 7.2.6 Rule 6 – Block Reservations

***If a signal has a "Block Reservation" defined for it, the signal will not allow a train to proceed until the signal has reserved the track in question. A given block can only be "Reserved" by one signal at a time and the block cannot be reserved if it is occupied.***

This rule is designed to address the case where multiple signals in different blocks have the same track as their Destination Track or where there are one or more sections of "bi-directional" track between two controlled blocks.

It prevents two trains from arriving at the same track and being unable to proceed because a track they both need is, or will be, occupied, thus preventing the trains from clearing their respective blocks and allowing other traffic to proceed. In effect, it turns the tracks in question into a "temporary extension" of the block controlled by the signal that holds the reservation.

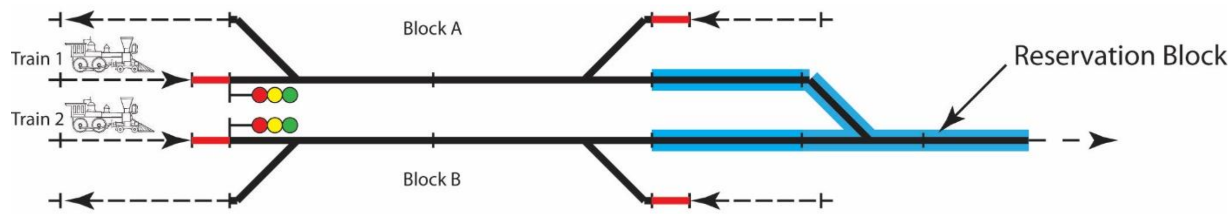
The reservation is automatically canceled if the train does not, in fact, enter his block within the "Entry Timeout" (see "Rule 3 – Entry Timeout" on page 27) or his block goes from Occupied to Unoccupied (i.e.: The train exited onto the reserved block, exited at some other point, backed out of the block, etc.).

This rule can also be used to resolve other complex interlock challenges. You could also define a "Virtual Block"** to prevent multiple trains from entering a multi-track station when passenger loading is underway.

**A "Virtual Block" is a block consisting of track segments but does not have any signals controlling entry to it.

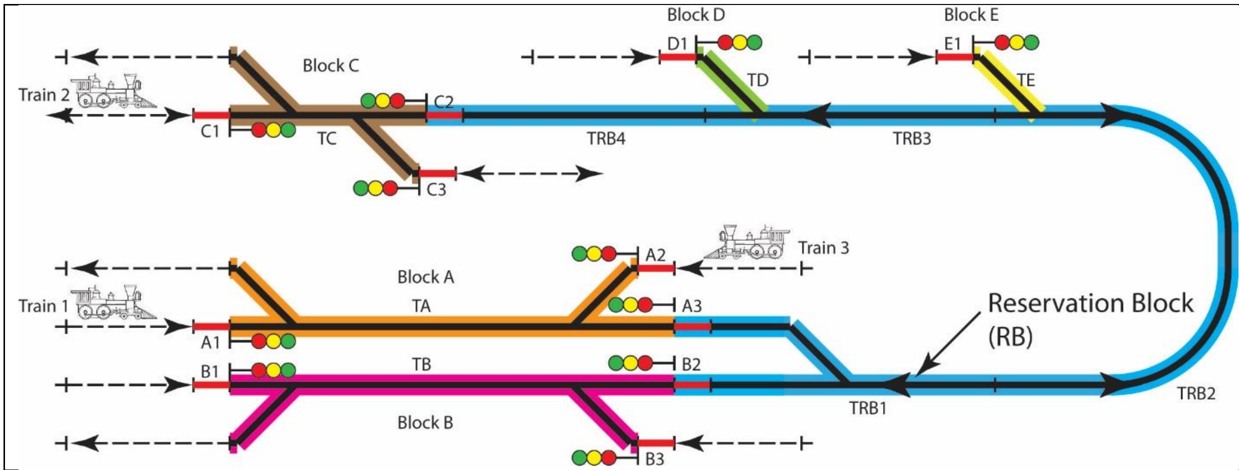
The "Reserved Block" could also be a toggle switch used by the station master to indicate that passenger loading is in progress, thus preventing any train from entering the station. After the station master clears the toggle switch the next train in que will be cleared into the station.

When multiple signals are requesting a block, the block will keep track of the reservations and grant higher priority signals first and round-robin within a given priority.




Example: Block Reservation

The Reservation Block can only be accessed by one signal at a given time. The Reservation Block is defined for both signals on the left therefore only train 1 or train 2 will be permitted to proceed.




More Complex Example of Using Reservation Blocks

In this example we have:

- Main blocks A (track TA), B (track TB), and C (track TC).
- Blocks D (track TD) and E (track TE) that connect the mainline to two small yards.
- Reservation Block (RB) consisting of tracks TRB1, TRB2, TRB3, and TRB4.
- All blocks are bi-directional.

Train 1 and Train 3 are protected from each other by the normal block logic.

***The problem:*** Without reservation blocks (and in the absence of Train 3) Train 1 would be given permission to head towards block C because there are no conflicting trains requesting block A. At the same time, Train 2 could be given permission to travel towards block B because there are no other trains requesting block C. … Result … Train s 1 & 2 meet head-on somewhere inside block RB … not good …

***Traditional Solution:***

With a traditional signal system, you would have to resolve this by defining the entire area (blocks A, B, C, D & E) as a single block.  This would work, but, if this covers a substantial area it would needlessly delay trains going from C3, A2 & B3 because those areas would be "occupied" the entire time that it takes a train to go from (for example) A1 to block C.

***MiniRail Solution:***

We define "Reservation Block" (RB) as a block consisting of tracks TRB1, TRB2, TRB3, and TRB4.  We do not define any signals for this block because they are not needed in this case (although you could if you wanted to be more prototypical).

*When a block is defined without signals is referred to as a "Virtual Block".*

We define block RB as needing to be reserved by:

- Signal A1 – a train here will need to traverse RB to get to block C
- Signal B1 – a train here will need to traverse RB to get to block C
- Signal C1 – a train here will need to traverse RB to get to block A or B.  Note: since the entry at C3 is shown as bi-directional (both entering and exiting trains) the signal at C1 would probably be a double head.  In this case, the head for the route towards C3 would not have RB as a reservation block but the signal for the route towards blocks A & B would have RB as a reservation block.
- Signals D1 and E1 because they also need it to traverse to block A or B

By doing this, only ***one*** of signals A1, B1, C1, D1, or E1 will be permitted at any given time.

If a train at A1 receives a green to travel to block C:

- Trains will not be permitted from C1, D1, E1 or B1
- ***However,*** while the train at A1 is traveling to block C, trains ***will*** be permitted to:
    - Travel from B3 (he will pass B1 on the left)
    - Travel from C3 (he will pass C1 on the right)
    - (after train A1 exits block A) Travel from A2 (he will pass A1 on the right)

This is all accomplished by simply defining an area between blocks that needs to be "reserved" by a signal before a train at that signal can be permitted.

This is a simple case – Reservation Blocks can be used to accomplish much more complex track configurations.  Contact me if you need assistance in addressing a challenging configuration.

***Note:*** There is nothing to prevent blocks from containing tracks that are also part of other blocks.  A block can overlay some or all of other blocks.  All block logic still holds – i.e.: If any track defined in a block is occupied, the block is occupied, and signals defined for that block will be at "Stop" (default solid Red).

### 7.2.7 Rule 7 – Follow Behind

***(Future) This rule will allow a train to follow a previous train into a block (on an "Approach" or "Approach Distant" signal) once the previous train has cleared the next Intermediate Signal within the block.***

This functionality is being implemented. When implemented, just as on prototype railroads, you will need to add at least one set of intermediate signals between the "head end" signals (the signals at the ends of the block).

For now, club rules can address this by saying something like "You may follow a train ahead through a "Stop" signal (as a second section) as long as you can ***see*** the train ahead and maintain safe following distance". The signal system will handle this correctly (i.e.: the block will remain 'occupied' until all trains have left the block. Keep in mind that, if this is allowed, engineers are responsible for train separation because there are no intermediate signals which means that the signal system cannot enforce separation.

### 7.2.8 Rules Governing the Selection of a Train to Enter a Block

A train may be permitted into a block if ALL the following are true:

1) The block is not occupied
2) Any "Reservation Track" defined is available
3) No other signal has been selected and permitted (set to Clear, Approach, etc.).
4) This signal is not "suspended" (see Note 1)
5) This is the highest priority signal meeting the above restrictions (see Note 2).
6) This signal is next in terms of (round-robin servicing of entry points).

*Note 1:* A signal is "suspended" if a train was cleared into the block (Clear, Approach, etc.) but the train did not proceed into the block within the required timeout period (see "Rule 3 – Entry Timeout" on page 27). This means that other occupied approach tracks (other block entry signals) will get a chance to proceed if there is a train that does not proceed into the block for some reason (derailment, balky injector, engineer talking to someone or otherwise distracted, etc.). The "suspended" status is removed when another signal is selected to allow a train to enter another entry point or the approach track for this signal goes to the un-occupied state (i.e.: the train backs up).

*Note 2:* The ability to define individual priorities for signals means that the certain routes can be given higher priority over other routes. For example, eastbound traffic can be given priority over westbound traffic. In the case where there are multiple signals with the same priority they are given permission to proceed in a "round-robin" sequence.

## 7.3 Degraded Mode

If (due to cable break, controller failure, etc.) a logic module (Block Control, Signal Control, etc.) residing within a controller does not have the information it needs to properly control the signals it will enter

"Degraded Mode" and attempt to provide as much control as possible while still maintaining train separation.

When operating in degraded mode the signal system (each controller independently) will attempt to display the least restrictive signal aspect possible with the information available to it.

For example, if a Block Control module has all the information it needs to control the block except that it cannot obtain the status of a "Destination Track" it will perform all functions except the ability to display the Approach and Approach Distant aspects of the effected signals. In this case, it will revert to Clear which is still valid because the controller knows that the block itself is clear.

## 7.4 Normal Signal Aspect Sequence

Using the default aspect definitions, the normal sequence seen by an engineer as he approaches an idle block would be (Note: this is the default aspects, the user is free to redefine them):

1) "Idle" (winking dim red)
2) The signal will change to "Permitted" (bright green), "Approach", etc. as his first axle hits the approach track (some distance prior to the signal). At the same time the signals for all other entries to the block are set to "Stop" (bright red)
3) As his first axle passes the signal and hits the "Block Track" the signal will change to "Stop" (bright red). This confirms to the engineer that he has claimed the block.

## 7.5 Block Parameters

Multiple signals can be defined for a given block. A signal is required for each entry point into the block.

There is a special case of a "Block" referred to as a "Virtual Block" which is a block that does not have any signals of its own (see "Rule 6 – Block Reservations" page 28).

For each signal in the block the following parameters can be defined (all except the Object ID are optional):

| *Parameter* | *Description* |
|---|---|
| Object ID | Unique ID associated with the signal head. |
| Approach Enable | The ID of the track that enables the Approach Track. The original purpose of this has been replaced by the "Switch Hardover" below. |
| Approach Track | The track that serves as the Approach Track for this signal (see "Approach Tracks" on page 18) |
| Priority | Higher priority means that this entry is favored above other entries of lower priority. Signals with equal priority are treated in a round-robin sequence. |
| Destination Track | The track that the train will exit the block on. This is used for traffic flow control and setting the "Approach" and "Approach Distant" aspects (see "Destination Track" on page 18). |
| Opposing Track | The track that is "opposing" this signal. This is used for traffic flow control (see "Opposing Track" on page 18). |
| Switch Hardover Expression | Expression used to determine if the switch points are set for this route making the signal available for selection (see "Runtime Expression Evaluator" on page 50). |
| Reservation Block | The block that must be "reserved" before clearing a train to enter the block at this signal (see "Rule 6 – Block Reservations" on page 28). |
| Entry Delay | Seconds delay between entries at this signal. This is used to provide more time between trains even after the block has been cleared. This effectively prevents this signal from being selected even if this is the only signal with a train on the approach track. Other signals may be permitted as normal during this delay. |

# 8 Button Blocks

The controller supports an additional type of block referred to as a "Button Block". A Button Block does not use "Detected" Tracks to control the signals.

This type of block uses "Capture" buttons at each block entry point and "Release" buttons at each exit from the block. The buttons are pressed by the engineer to request entry into a block and release the block upon exiting the block. The Capture buttons are usually located just prior to the signal used to control that entry to the block.

This form of block access control has many fewer options than those available using detected tracks because there are only "Entry" and "Exit" events (points in time). It is possible for an engineer to fail to press a Release Button which leaves the block in the 'occupied' state. This condition will remain until someone realizes what is going on and presses one of the Release buttons.

***Warning:*** Because these blocks are controlled by 'events' (button presses) as opposed to 'states' (track occupied, etc.), at power-on or controller restart the block is assumed to be unoccupied because it has no history information available – i.e.: "Idle" is displayed at all signals.

*Button Blocks are supported in a limited fashion. They are usually used when a railroad wants to transition from "buttons" to automatic signals by being able to install all the hardware for the automatic* *signals but keep the buttons active until the system is cut over to fully automatic signals. Contact MiniRail Solutions if you have a need for Button Blocks.*

# 9 Dispatcher and Routes

To minimize deadlocks (situations where trains are sitting at STOP signals and no-one can move) all blocks should be connected by passing sidings (i.e.: places where trains can meet and pass).

“Blocks” provide train separation, but they do not, in themselves, guarantee deadlock prevention and free traffic flow.

To enhance traffic flow across blocks automatically, a higher level of control is needed to coordinate traffic flow across multiple blocks.

When a train is granted a Route, blocks along the Route will be reserved for his use. As the train passes blocks along the way the reservation on those blocks will be released for use by other trains.

This higher level of control is referred to as “Routes”. When a train is granted a “Route” from point “A” to point “B” he is guaranteed that he will be able to travel from point A to point B without conflict. He may be delayed by merging traffic (trains in the same direction) but will not be deadlocked by opposing traffic.

At a level above Routes is another function referred to as the “Dispatcher” function. This function replaces a human dispatcher who decides who can proceed from point to point by reserving certain non-conflicting routes.

The system will have two modes of operation:

1) Automatic Dispatcher, and
2) Human Dispatcher.

When in Human Dispatcher mode it will be a human, using SComm (see “SComm Monitor and Control Program” on page 71), who grants trains access to routes rather than the automated Dispatcher function.

The “Dispatcher” and “Routes” functionality are currently in development.

In the meantime, many of these situations can be handled by the following Track Circuit signal rules (note: these rules are not available to “Button Blocks”):

- “Reservations” (see “Rule 6 – Block Reservations” on page 28)
- “Destination and Opposing” (see “Rule 5 – Destination and Opposing” on page 27)

# 10 Signal Heads

Signal heads accept commands to display different "aspects" (see "Signal Aspects" on page 39). These commands originate from several sources such as Blocks, Ladder Tracks, Independent Signals, etc.

## 10.1 Types of Signal Heads Supported

When this document uses the term "signal head" it assumes a 3-light (Green, Yellow, Red) signal head, however, a signal head containing two or even one light could be used. The only ramification of fewer lights is that your choice of available aspect displays will be more limited. It is conceivable (but not desirable) to use a single green light with "on" meaning "Go" and "off" meaning "Stop". One could also use a searchlight signal, semaphore, position light, etc. The signal indication for a given aspect is defined by you when the system is configured (see "Signal Aspects" on page 39).

### 10.1.1 Head End Signals

"Head End" signals control entry into a given block as opposed to "Intermediate" signals that control movement within a block or a special section of track that only needs control of train separation – i.e.: Is there a train ahead?

#### *10.1.1.1 Single Head-End Signal*

This signal is used at a block entry point where there is no choice of routes. The signal must be immediately preceded by an ***Approach Track*** and must be immediately followed by a ***Block Track*** within the block being protected – in other words, the signal is at the junction of an ***Approach Track*** and a ***Block Track***.

#### *10.1.1.2 Multiple Head-End Route Signal*

This is the same as the "Single Head-End Signal" above except that there are two or more signal heads mounted together. The signal system treats these as separate signals and does not know/care that they may be mounted on the same mast.

These signals are typically used at "route selection" points on the railroad. Each signal head has a "Switch Hardover" expression parameter the signal uses to determine if its route is aligned.

Each individual signal will indicate the status of the route it is associated with (see ""Stop due to switch point" Signal Aspects" on page 42). As with all signals for a block, only one signal will ever have a Permitted aspect at any given time. The turnout(s) controlling the routes typically have a switch motor with an engineer-operated toggle switch or remote manual throw that the engineer uses to select his desired route.

The signal system can use voltages provided by many switch motors to determine turnout direction. In addition, MiniRail Point Detectors (see "BC028 Switchpoint Sensor Interface" on page 70) can be used on manual or motorized turnouts. The advantage of these detectors is that they detect ***actual*** point closure as opposed to commanded point position. Thus, they can detect rocks in a point, point rail binding, etc. that would cause a derailment.

Depending on the railroad design, the turnout(s) that select the route may be just past the signal, the far end of the block, or anywhere in between.

There are cases where a route selection is a choice between three or more routes such as at the throat of a yard or station. These cases are just an extension of the, more common, double-head route signal.

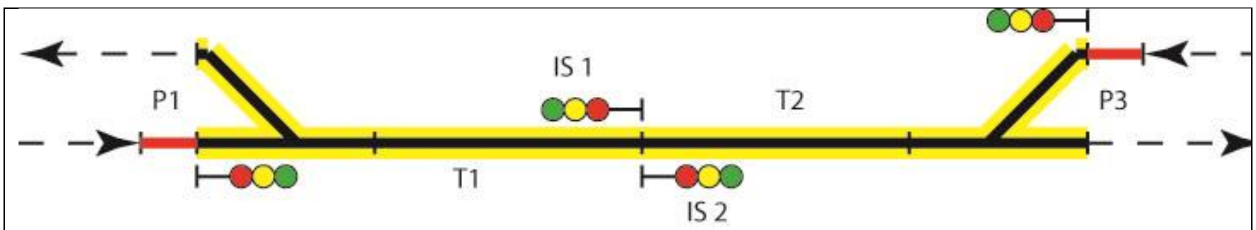
### 10.1.2 Intermediate Signals

This is a signal within a block used for train separation. It controls access to a track segment but not the block itself. This signal is immediately preceded by a detected track segment within the block and immediately followed by a detected track segment within the same block.

If a train does violate a Stop signal at a block entry point, adding Intermediate Signals enhances train separation because the trains will encounter a Stop Aspect Intermediate Signal before encountering the opposing train, thus preventing a head-on collision (this is how Full-Size ABS/APB blocks prevent a head-on when two trains enter from opposite ends at the same time[1]).

Full support for Intermediate Signals (including "Tumble Down") is on the development list but no-one has requested it. The prototype "Tumble Down" functionality is not really required since, unlike prototype ABS/APB signals, only one train is ever cleared into a block at a given time.

At this time, Intermediate Signals can be partially implemented using "Independent Signals" (see "Independent Signals" on page 38).




Independent signals used to implement Intermediate Signals

Using Independent Signals: In the example above the occupancy status of T2 could be used to drive IS2 ("Stop" if occupied, "Proceed" if unoccupied) and the status of T1 could be used to drive IS1.

Another way to implement Intermediate Signals is to define the signal as the only entry into a dummy "block" that has only one entry point. In the example above, you could define IS1 as a signal entry into a block consisting of block tracks T1 and the switch track P1 (note that a given track can be a Block Track in multiple blocks). In addition, you could define T2 as the approach track to IS1 and the west-bound track on P1 as the "Destination Track" for IS1.

### 10.1.3 Switch Position Dwarf

This is typically a two-lamp signal mounted close to the ground at a turnout to indicate which way the turnout is currently set.

[1] See "Why ABS or APB Signals Are Not Sufficient" at http://www.minirailsolutions.com/why-abs-or-apb-signals-are-not-sufficient/

These signals are usually connected directly to the switch motor or microswitches. They can also be connected to a MiniRail Switch Point Detector and/or a signal controller to allow blinking the signal when the points are in transition (moving, rock in points), etc.

## 10.2 Configuring Standard 1, 2 and 3 Lamp Signals

The following parameters are available when defining a signal head:

| *Parameter* | *Description* |
|---|---|
| Object ID | Unique ID used to identify this signal head. |
| Green-DevID<br>Yellow-DevID<br>Red-DevID | Controller driver the lamp is connected to. This is omitted on a given lamp if that lamp is not used. |
| Green-Chan<br>Yellow-Chan<br>Red-Chan | The channel on the driver listed above. |
| Green-Dim<br>Yellow-Dim<br>Red-Dim | Brightness level of the “Dim” setting for this lamp. |
| Green-Bright<br>Yellow-Bright<br>Red-Bright | Brightness level of the “Bright” setting for this lamp. |

## 10.3 Searchlight Signals (Full-Size and Scale)

The system supports full-size Searchlight signals as well as scale signals that have the same mechanisms as their full-size counterparts.

These signals contain a lamp and a set of lenses driven by a magnet within a coil. For Red the coil is deactivated, for Yellow the coil is driven in one direction, for Green the coil is driven in the opposite direction.

Since the (full-size) coil needs a significant amount of current and the current needs to be reversed, a BC017 Relay Board is used to connect the controller to the coil (see “BC017 Relay Driver” on page 66). If you have your own ‘driver’ to deliver the current and the reversal, you can use two output channels of the normal on-board LED driver, BC009 Low Side Driver, etc. instead of the Relay Board.

Searchlight signals can be setup with or without control of the lamp. At a minimum, two output channels are used to drive one pair of wires to the signal as described above. The signal lamp can be left on constantly or, optionally, a third channel can be configured to control the lamp to provide “Approach Lit” capabilities as well as dimming (when using an output channel capable of dimming). Using Approach Lit signals will reduce overall system power consumption and increase the life of the lamps.

*Note: If dimming is desired, the on-board LED driver (with dimming) is typically not capable of delivering the current required by the incandescent lamps used in these signals but its output can be passed through a transistor or MOSFET to provide this capability. Contact MiniRail Solutions for details.*

The controller also supports blinking of the signal lamp (as in the standard three-lamp LED signals) but this is discouraged if you are using incandescent lamps (as opposed to LEDs) because it can significantly shorten the life of the bulbs. There is a parameter to disable blinking for a signal head even if the aspect defined calls for it. In this way, you can define aspects that use blinking for your LED-based signal heads and disable the blinking on the signals that use incandescent lamps. (Note: SComm will still indicate the "commanded" signal aspect)

The on/off cycles due to "Approach Lit" configurations are not a problem because the cycles are much less frequent, i.e.: only when the block is in use.

You should not define aspects that the Searchlight signals cannot display – e.g.: An aspect with both Red and Yellow on at the same time. To address this, the Searchlight signal driver will display the 'most restrictive' aspect and uses the following rules. If the aspect definition has:

1) The Red lamp on it will display Red (Yellow and Green are ignored)
2) The Red lamp off and the Yellow lamp on it will display Yellow (the Green lamp is ignored)
3) The Red and Yellow lamps are off, and the Green lamp is on it will display Green
4) If no lamps are on it will display Red (or dark, if the third lamp control channel is defined)
5) Any blinking/winking will be honored unless the third lamp control channel is defined and "Suppress Blink" is not specified.

### 10.3.1 Searchlight Signal Parameters

The following parameters are available for searchlight signal heads:

| *Parameter* | *Description* |
|---|---|
| Object ID | Unique ID used to identify this signal head. |
| MotorON-DevID<br>MotorON-Chan | Controller driver and channel used to control the 'slug motor' in the signal. |
| MotorReversal-DevID<br>MotorReversal-Chan | (optional) Controller driver and channel controlling the signal lamp. |
| Lamp-Dim | Brightness level of the "Dim" setting of the lamp (if dimming is used) |
| Lamp-Bright | Brightness level of the "Bright" setting of the lamp (if dimming is used) |
| Suppress Blink | (optional) Specifies that this signal is to ignore any Blinking/Winking defined for the commanded aspect. |
| Approach Lit | (optional) Specifies that the signal will be off if the commanded aspect is "Idle" (i.e.: the block is not in use). |

## 10.4 Position Light, and Semaphore signals (Full-Size and Scale)

Support for full-size (or scale) Position Light and Semaphore signals will be implemented as soon as a customer requests it.

## 10.5 Independent Signals

These are "stand-alone" signals that are not associated with a specific block. Their aspects are governed by the condition of various inputs (track occupancy, switch point settings, etc.).

For each aspect you want to use at the signal you define a logical expression (see "Runtime Expression Evaluator" on page 50). If the expression is "true" at any time, that aspect will be displayed.

These signals can be used to implement “Intermediate” signals by just indicating the status of the track segment immediately past the signal head.

### 10.5.1 Independent Signal Parameters

The Independent Signal is given a set of aspects to be displayed and what condition triggers the presentation of that aspect. If the expression for a given aspect evaluates to True, that aspect is displayed. If the expression is “false” the next aspect entry is evaluated and so on to the end of the aspects listed. Since the aspects are processed in order and the first aspect definition whose expression evaluates to “true” is selected, the aspects listed first take priority over those that follow.

For example, you can define:

> “T(23)”, SA_Stop
> “T(45)”, SA_Approach
> “1”, SA_Permitted

This says: “If track 23 is occupied, display Stop, if track 45 is occupied, display Approach, otherwise, display Permitted”. Other examples are given in the configuration manual.

# 11 Signal Aspects

The controller defines many different “aspects”. These aspects are very specific to the conditions detected. The user defines what the signals will display for each of these aspects (i.e.: which lamps are on). It is common to define several aspects as the same lamp display, such as defining all “you have to stop” aspects as solid Red, but the exact condition is always available in the SComm track display.

Your approach can be a very simple one or one that provides engineers and maintenance people added information while still maintaining simplicity for visiting engineers – e.g.: “Green or Yellow means clear to proceed, anything else means stop”.

These settings are “System Wide” meaning that all signals in all blocks have the same aspect definitions

A “Signal Aspect” refers to a signal display state but does not define what lights are displayed, semaphore arm positions are used, etc. When you configure the system, you can specify what outputs are activated for each “aspect” defined by the system. Thus, you have control of what the signals display in each situation.

For example, if you have single-lamp signal heads containing a single red LED, you can define all “Stop/do not proceed” type aspects as solid red and blinking red, or off for any “Permitted/Ok to proceed” aspect. In this case the built-in LED driver on the controller can control 16 signal heads (only one output needed per signal) as opposed to the normal 5 (three outputs needed for each signal).

To determine which aspect is displayed in response to a given set of track conditions, traffic flow, and configured options the firmware must perform a complex sequence of calculations. Below are tables listing all possible aspects and the conditions under which that aspect will be displayed.

Not all systems will make use of all possible aspects, for example, if your installation does not use detected switch points the “Switch Point Against” aspects will not be used.

A given system designer might choose not to use certain aspects. For example, you could define “Approach” (typically defined as a bright yellow signal) and “Approach Distant” (typically defined as a flashing bright yellow signal) such that the signal lights are the same as “Permitted” (typically defined as bright green).

The default aspect definitions use “winking” to provide maintenance people and engineers additional information (if they desire, but not required). For example, if a switch point is set against a movement, the standard aspect will be red (stop) winking twice (“switch point against”). As an alternative, you can define all “stop” aspects to be solid bright red.

SComm can always be used to examine why a given signal is displaying a given aspect (see “SComm Monitor and Control Program” on page 71).

You can switch between multiple configurations such as a more complex configuration for your normal run days, card order runs, etc. and a simpler configuration to be used at a large meet, etc. where you may have many visiting engineers who are not familiar with the railroad or signal aspects.

For example: at a large meet I saw someone waiting at a signal displaying “Approach” (Bright Yellow), when I asked him why he was waiting he said, “Can I go on Yellow?” even though there was a sign at the exit of the yard saying “If a signal is RED, Stop, anything else, Go”.

*Note: All aspects except “Permitted” aspects (Permitted, Approach, Approach Distant) are absolute, i.e.: the train MUST stop. If a stop indication persists for an unusual period the engineer should use radio or other methods to determine if it is safe to proceed.*

## 11.1 Aspect Parameters

The following parameters are available for each aspect:

| ***Parameter*** | ***Description*** |
|---|---|
| Blinking | Possible Values:<br>• “None” – Lamps are on solid if brightness is not defined as ***off*** below.<br>• “Wink” – Lamps are on most of the time but wink a code (below) with 1 second delay between cycles. This is normally used for ‘normal’ aspects where you want to give the engineer or signal maintainer additional information such as “this red is because the points are against this route”.<br>• “Blink” – Lamps are off most of the time but blink a code (below) with 1 second delay between cycles. This is normally used for ‘error’ aspects where the signal maintainer needs to be notified such as “Comm Loss”. |
| Blink Number | This is the code to be Winked/Blinked (see above). You should avoid numbers that have a 0 in them (10, 101, etc.) because the 0 Wink/Blink is very short and hard to see. |
| Green Lamp Brightness** | Possible values:<br>• Off – Lamp is at 0 brightness |

| | |
|---|---|
| | • Dim – Lamp is at the "Dim" setting defined for the individual signal.<br>• Bright – Lamp is at the "Bright" setting defined for the individual signal. |
| Yellow Lamp Brightness** | (see: Green Lamp Brightness above) |
| Red Lamp Brightness** | (see: Green Lamp Brightness above) |

** If a signal does not have all three lamps defined, the unused colors are ignored.

## 11.2 "Idle" Aspects

These aspects indicate that the block is unoccupied and there are no trains requesting entry to the block (i.e.: no trains on any of the block's approach tracks). They also indicate that the train has NOT been granted permission to enter the block. These aspects should use red indications (or "dark" if using the "Approach Lit" option).

These aspects are typically defined using "Dim" LED settings to reduce power consumption.

To emulate "Approach Lit" signals (i.e.: signals are dark until a train is present) you could define these aspects to have all LEDs off.

| *Aspect* | *Description* |
|---|---|
| Idle | Idle, no special conditions. |
| Idle Approach | Idle, see "Approach" for other conditions. |
| Idle Approach Distant | Idle, see "Approach Distant" for other conditions. |
| Idle With Switch Point Stop | Idle, see "With Switch Point Stop" for other conditions. |
| Idle Approach With Switch Point Stop | Idle, see "Approach With Switch Point Stop" for other conditions. |
| Idle Approach Distant With Switch Point Stop | Idle, see "Approach Distant With Switch Point Stop" for other conditions. |
| Idle Blocked By Reservation | Idle, see "Blocked By Reservation" for other conditions. |

## 11.3 "Permitted" Signal Aspects

These aspects indicate that there is a train on the signal's approach track and it is being cleared into the block. Note: All other head-end signals associated with this block were changed to "Stop" aspect at the same time. Thus, only one train is ever cleared into a block at any given time.

Since these aspects indicate that the train can proceed, they should use green or yellow indications.

| *Aspect* | *Description* |
|---|---|
| Permitted | Train is permitted to enter the block. No other special conditions. |
| Approach | Block is clear but "Destination Track" is occupied. |
| Approach Distant | Not yet used. Anticipated to be similar to "Approach" but the other train is further ahead (i.e.: two blocks away as opposed to one). |

## 11.4 "Stop" Signal Aspects

These aspects indicate that the train is ***NOT*** allowed to proceed. These aspects should use red indications.

| *Aspect Name* | *Description* |
|---|---|
| Stop | Block is occupied or another entry is being given permission to enter the block. |
| Blocked By Reservation | Another signal is holding a conflicting reservation. This condition will clear when the Reservation Block becomes available. |

| | |
|---|---|
| Reservation In Progress | This aspect is displayed when the signal was selected as the signal to be "Permitted" but there is a Block reservation required for this route and that reservation has not yet been granted.<br><br>All other head-end signals were changed to "Stop" aspect at the same time to prevent another train from entering while the reservation request is being processed.<br><br>Since the reservation process is usually very fast, this aspect will rarely, if ever, be seen. It will only occur:<br>• Immediately after a train hits the approach track of an idle block,<br>• there is a reservation block defined for the signal, and<br>• there is a delay in communicating with the controller that is handling the Reservation Block. |
| Blocked By Destination And Opposing | The train is not permitted to proceed because the Destination and Opposing tracks are occupied (see "Rule 5 – Destination and Opposing" on page 27). This aspect is used to allow traffic to flow in the other direction. |
| Entry Delay | Train is not permitted to enter the block until the "Entry Delay" time defined for this signal expires. See "Block Parameters" on page 32. |
| Dispatch Hold | (Future) This indicates that the train is not permitted to proceed because the dispatcher is holding the train to manage traffic flow, derailment ahead, etc.<br><br>The signal remains in this state regardless of track conditions until the dispatcher manually removes the hold or the system is returned to fully automatic mode. |

## 11.5 "Stop due to switch point" Signal Aspects

These aspects indicate that the train is ***NOT*** allowed to proceed and should defined with red indications.

These aspects are typically used in multiple-headed "route selection" signals just prior to switches where a route decision is to be made.

To use these aspects, some form of point position input must be in place. There are several ways to do this:

- Inputs provided by a switch motor indicating where the switch points should be.
- User-provided microswitch, etc. that indicates where the switch points are/should be.
- MiniRail Switch Point Detector that senses the ***actual*** point position. This method protects against giving "false clear" signal indications when the points are not, in fact, closed because of a rock in the points, binding switch points, etc.

If the signal has a switch point input defined for it and the switch point is currently set "against" the route, the aspects below are used. This allows you to define aspects that indicate the status of a route even though the switch is thrown against it. By default, these aspects are defined the same as their "Idle" namesakes except that the lamps are configured to be 'bright' rather than 'dim' as is the default for Idle aspects.

Using these aspects is not "prototypical" but I encourage their use because, unlike prototype practice where route decisions are typically made by dispatch, in ride-on scale railroading the engineer is making route choices.

By using these aspects, the engineer can see, for example, that the currently selected route is unavailable ("Stop" aspect) but that the alternate route has a status of "Idle With Switch Point Stop" which means that if he changes his route selection he can immediately proceed because that route is clear.

If you want to disable this feature (the ability to see the status of the alternate route) you can configure these aspects the same as your definition you used for the “Stop” aspect. In this case the alternate route (the direction not selected) will show “Stop” as it would in prototype practice.

| *Aspect* | *Description* |
|---|---|
| Permitted With Switch Point Stop | (No longer used) |
| Approach With Switch Point Stop | Same as “Approach” except that the switch point is not set for this route. |
| Approach Distant With Switch Point Stop | Same as “Approach Distant” except that the switch point is not set for this route. |
| Blocked By Destination And Opposing With Switch Point Stop | Same as “Blocked By Destination And Opposing” except that the switch point is not set for this route. |

## 11.6 Error Signal Aspects

These aspects indicate that the controller cannot determine the status of the block. The train is ***NOT*** permitted to enter the block and these aspects should be defined with red indications. If the condition persists, trains should notify the signal maintainer and use radio or other means to determine if it is ok to proceed.

It is suggested that these aspects be defined with “blinking” LED codes (i.e.: the LED(s) are OFF most of the time) all other aspects use solid on or “winking” LED codes (i.e.: the LED(s) are ON most of the time). Thus, these aspects will be easily recognized as unusual condition.

| *Aspect* | *Description* |
|---|---|
| Signalhead Power On | Signals are initialized with this indication at power-on. The indication should only appear for a short time because it will be quickly replaced with another aspect command received from the block commanding this signal.<br><br>If this aspect persists it indicates a parameter error (this signal is not configured in a block, etc.), a communications error (broken bus wire, fuse, etc.), or a controller has failed. |
| Sender Power On | Modules use this aspect at power-on to initialize the signals that they are commanding. This aspect should quickly be replaced by another aspect. |
| Unknown Status | This indicates that a track critical to determining the signal status (block track or approach track) is in an “unknown” state or the controller handling the block is not receiving status updates from the controller handling the track in question (see ““Unknown” Track Condition” on page 22).<br><br>SComm can be used to identify the specific unknown track. |
| Comm Loss | The controller driving the signal head is not receiving aspect commands from the block. Block occupancy is unknown. |
| Permitted Not Selected | This indicates that this signal met the conditions required to be selected but another signal was selected instead. This usually indicates that the “Hardover” input of two different signal heads was “true” (only one should be true).<br><br>This probably indicates:<br>• A wiring problem<br>• A problem in the switch motor or point detector such that it is indicating that the points are set for both directions at the same time.<br>• A configuration issue such as an incorrect “Switch Hardover” expression in a signal definition. |

| | |
|---|---|
| Sender Restart | This indicates that the controller containing the commanding entity for this signal head restarted. This aspect should quickly be replaced after the controller restarts (seconds). |

## 11.7 Signal Aspect Parameters

See BC002 Configuration Manual.

## 11.8 Aspect Default Settings

The default signal aspect definitions are as follows:

| Aspect | Blink | Blink Number | Green Brightness | Yellow Brightness | Red Brightness |
|---|---|---|---|---|---|
| SA_Permitted, | SBl_None, | SAB_None, | SBr_Bright, | SBr_Off, | SBr_Off |
| SA_Approach, | SBl_None, | SAB_None, | SBr_Off, | SBr_Bright, | SBr_Off |
| SA_BlockedByDestinationAndOpposingWithSwitchPointStop, | SBl_None, | SAB_None, | SBr_Off, | SBr_Off, | SBr_Bright |
| SA_SenderPowerOn, | SBl_None, | SAB_None, | SBr_Bright, | SBr_Bright, | SBr_Bright |
| SA_ApproachDistant, | SBl_Blink, | SAB_50Percent, | SBr_Off, | SBr_Bright, | SBr_Off |
| SA_Stop, | SBl_None, | SAB_None, | SBr_Off, | SBr_Off, | SBr_Bright |
| SA_ReservationInProgress, | SBl_None, | SAB_None, | SBr_Off, | SBr_Off, | SBr_Bright |
| SA_PermittedWithSwitchPointStop, | SBl_Wink, | 2, | SBr_Off, | SBr_Off, | SBr_Bright |
| SA_ApproachWithSwitchPointStop, | SBl_Wink, | 2, | SBr_Off, | SBr_Off, | SBr_Bright |
| SA_ApproachDistantWithSwitchPointStop, | SBl_Wink, | 2, | SBr_Off, | SBr_Off, | SBr_Bright |
| SA_BlockedByDestinationAndOpposing, | SBl_Wink, | 3, | SBr_Off, | SBr_Off, | SBr_Bright |
| SA_BlockedByReservation, | SBl_Wink, | 4, | SBr_Off, | SBr_Off, | SBr_Bright |
| SA_EntryDelay, | SBl_Wink, | 5, | SBr_Off, | SBr_Off, | SBr_Bright |
| "Idle" aspects (no trains in the block, no trains requesting entry) | | | | | |
| SA_IdleApproachDistant, | SBl_Blink, | SAB_50Percent, | SBr_Off, | SBr_Dim, | SBr_Off |
| SA_Idle, | SBl_Wink, | 1, | SBr_Off, | SBr_Off, | SBr_Dim |
| SA_IdleApproach, | SBl_Wink, | 1, | SBr_Off, | SBr_Off, | SBr_Dim |
| SA_IdleWithSwitchPointStop, | SBl_Wink, | 2, | SBr_Off, | SBr_Off, | SBr_Dim |
| SA_IdleApproachWithSwitchPointStop, | SBl_Wink, | 2, | SBr_Off, | SBr_Off, | SBr_Dim |
| SA_IdleApproachDistantWithSwitchPointStop, | SBl_Wink, | 2, | SBr_Off, | SBr_Off, | SBr_Dim |
| SA_IdleBlockedByReservation, | SBl_Wink, | 4, | SBr_Off, | SBr_Off, | SBr_Dim |
| Error Aspects | | | | | |
| SA_SignalheadPowerOn, | SBl_None, | SAB_None, | SBr_Bright, | SBr_Bright, | SBr_Bright |
| SA_UnknownStatus, | SBl_Blink, | 12, | SBr_Off, | SBr_Off, | SBr_Bright |
| SA_CommLoss, | SBl_Blink, | 13, | SBr_Off, | SBr_Off, | SBr_Bright |
| SA_Permitted_NotSelected, | SBl_Blink, | 14, | SBr_Off, | SBr_Off, | SBr_Bright |
| SA_SenderRestart, | SBl_Blink, | 15, | SBr_Off, | SBr_Off, | SBr_Bright |

# 12 Binary Inputs

A Binary Input is a variation of the "TrackIn" item and is designed for button, toggle switch, or other on/off input. See BC002 Configuration Manual for more information.

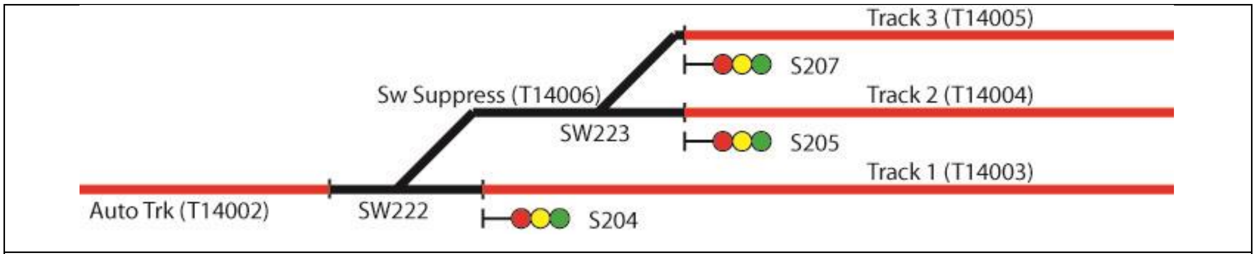
# 13 Ladder Tracks

A "Ladder" is a series of tracks connected to a single "Lead" track through a cascading set of track switches with attached switch motors.

It can be used to align a series of switches to a particular route in response to engineer-operated trackside buttons or toggle switches.

The Ladder Track supports automatic or manual selection of a "ladder" of tracks. This can be used to auto route trains to an unoccupied yard or station track.

There is also a “None” option to allow a Station Master/Yard Master to override the selection and prevent anyone from entering the station/yard.




Ladder track example

The determination of which track is selected is via a “Multi-Select”. A Multi-Select outputs a multi-level status (see “Multi-Select” on page 45).

A track can be selected by the Multi-Select or the track can be automatically selected based on track occupancy.

The Multi-Select can be a multi-position rotary switch controlled by a station master or a set of track selection buttons or toggle switches at the entry of a station/yard, etc.

When the ladder is in “auto” mode it will select the first track that is available.

To prevent switch motors from throwing switches under trains the movement of the switch motor is suppressed if there is a train on the switch.

The Ladder Track supports signals that are associated with each track. These signals should be located at the start of the track or above each track (such as in a station).

Note that these signals are independent signals that simply indicate the state of track availability. They are independent of normal “Block” signals discussed elsewhere. These signals only indicate the occupied/unoccupied and switch aligned status of the single track they are attached to. If the “Ladder Track” is used within a controlled block such as routes out on the railroad, the normal Block signals should be used and the “Ladder Track” signals should be omitted.

## 14 Multi-Select

A Multi-Select accepts an analog input and decodes it to a selection code based on the incoming voltage level. Examples:

- A multi-position rotary switch that selects a tap into a resistor ladder for each position. Example: rotary switch used by a station master to select “auto”, “none”, Track 1, Track 2, etc. of a Ladder Track (see “Ladder Tracks” on page 44).
- A series of momentary pushbuttons that select a tap into a resistor ladder thus producing a different voltage based of which button is pressed. Example: A set of buttons at the entry to a station to allow the engineer to select “auto”, Track 1, Track 2, etc. station track.

The Multi-Select device has several forms:

| *Type* | *Description* |
|---|---|
| One Of Many | This configures the Multi-Select to be used with an input that produces a ***constant*** voltage of several different levels (such as a multi-position rotary switch).<br><br>The status of this Multi-Select always reflects the value of the voltage seen at the input. When the input voltage changes, the status of the Multi-Select changes accordingly. |
| Button One Of Many | This configures the Multi-Select to be used with an input that produces a ***momentary*** voltage of several different levels (such as a set of pushbuttons).<br><br>The status of the Multi-Select reflects the last button pressed and is retained until another button is pressed or the controller is reset. |
| R2R Buttons | This configures the Multi-Select to be used with an input from an R2R resistor network (see Internet references).<br><br>An R2R network produces the 'sum' of the inputs and can be used with a series of buttons or toggle switches where more than one button/switch may be closed at any given moment.<br><br>The status of the Multi-Select reflects the last selection and is retained until another selection is made.<br><br>This type of Multi-Select device is defined but not yet implemented. Contact me if you have need for this type of Multi-Select device. |

# 15 Relay Board

This is used to configure access to several different types of expansion cards such as:

- BC009 Low Side Driver
- BC010 Relay Board (obsolete, replaced by the BC017)
- BC015 Opto Driver
- BC017 & BC018 Relay Driver

These allow the controller to control external devices such as switch motors, etc. Switch motors are now usually accessed via the "Switch" entity - See "Track Switches" on page 47.

# 16 Track Switches

Track switch entities will accept commands to direct switch motors and coordinate the movement of the points including suppressing movement if the switch is occupied.

This device accepts command messages to select a switch position such as from a Ladder Track (see "Ladder Tracks" on page 44). It also suppresses switch motor movement if there is currently a train on the switch.

> *Note: Once a switch motor has started movement the movement cannot be suppressed because the system does not know if the points have started moving therefore it continues the movement to ensure that the points are not left in an undefined position.*

# 17 "Test" Devices

Several different test devices can be configured to test signal heads, track inputs, etc. The following 'test devices' can currently be selected:

- Cycle All Aspects - Cycle all defined signals through all defined aspects
- Cycle Brightness - Cycle all defined signal heads through brightness levels
- Alternating Pattern - Cycle all defined signal heads through an alternating light pattern

# 18 XBee Radios

XBee radios are small digital radios that come in two general flavors: 400-foot line-of-sight range, and two-mile line-of-sight range. One source is Spark Fun (http://SparkFun.com).

The controller supports the XBee radios in two general forms:

1) "Transparent" or "Pass-through" Mode – In this mode a pair of radios can be configured to act like a serial cable. All data passed to the radio as "transmit data" is passed unaltered to the other radio which outputs it as "receive data".
2) API Mode – In this mode multiple radios can form a "mesh network" connecting multiple points. In this mode, messages must be sent directly to another radio or sent as a "broadcast" message.

The radios in the mesh network can forward messages across the network to any other radio to traverse larger distances.

## 18.1 XBee SComm Connection

The radios can be used in simple Transparent Mode to support a remote link to SComm to monitor and control the railroad.

It could be used as a portable connection for a laptop to facilitate signal system maintenance activities.

## 18.2 XBee Bridge

In Transparent Mode, the radios can be used to link (or "bridge") two controllers together.  All CAN bus traffic will be passed to the other controller.  This happens in both directions.  In this way two CAN busses can be connected over a distance.

One use of this is a simple way to form a network connection to a section of the railroad that is somewhat removed from the rest.

The railroad network can have multiple XBee bridges in use but each requires two XBee radios and only one XBee radio can be connected to a given controller.

## 18.3 XBee as a substitute for the CAN data bus

It is possible to setup a system that does not use the normal CAN bus to connect the controllers.  XBee radios could be used at each controller.

One way to do this would be to use the "broadcast" mode of the XBee radios.  This has been tested but, at this time, it is unknown if the radios can support the required data volume in a medium to large railroad.  Contact me for more guidance on this.

# 19 Differences from Prototype Practice

## 19.1 Relaxation of Rules

Where applicable, every attempt has been made to follow prototype North American Railroad practice. However, modifications have been made to accommodate ride-on scale railroad practices and conditions.  For example, the prototype practice of waiting 5 minutes after requesting permission to exit a siding (i.e.: claim the mainline) has been eliminated because:

1) We can see/hear a train at a reasonable distance,
2) The signal system will not indicate clear to proceed unless you have requested the block (your train is on an approach track) and the block is unoccupied.

## 19.2 Additional Signal Aspects

There are additional signal aspects defined such as the "Switch Point Aspects" that allow an engineer to see the status of an alternate route to decide if he wants to select an alternate route by activating a switch motor control.

## 19.3 Approach Tracks

See "Approach Tracks" on page 18.

# 20 Stand-Alone Mode

In Stand-Alone Mode the controller is connected directly to the signals and tracks involved in the block(s) it is controlling without the need to communicate with other controllers.

You do not need to install a data bus.  Each location can be individually powered with batteries, solar, etc.

In this mode the controller simply replaces the functionality other track detectors (relays, etc.) and signal controllers but you retain the advantages of the BC002 such as reliable train detection in all weather conditions, handling of complex interchanges, diagnostics, etc. as well as all of the enhanced block logic described in “Block Rules” on page 26.

This can be used to replace traditional relay logic in a cabinet to control one or more blocks, isolated interlocks, yards, etc.

It can be combined with other signal systems to provide enhanced capabilities at certain locations by exchanging inputs and outputs with other systems allowing you to “mix and match” to achieve the exact capabilities you want.

Another option is the ability to use the BC002 to control a complex interlock or wye allowing for better traffic flow than can be easily implemented with traditional relays (see “Handling a Wye” on page 25).  If the interlock is large, multiple controllers can be installed in a single cabinet to handle any size configuration.

If you want to run in strict ABS/APB mode, you can eliminate the “Approach Track” connections and simply detect the “Block Tracks” (trackage between Head-End signals).

Any number of Stand-Alone controllers can be easily configured for small railroads only wanting ABS/APB-like signals without centralized monitoring, etc.  For simple block configurations you only need to connect the signal heads and tracks to the controller and you’re done.

# 21 Firmware

The hardware provides the physical connection between the controller and its environment (tracks, signal heads, switch motors, etc.).  The firmware provides the controller with the rules and logic by which outputs are driven in response to input changes, passage of time, etc.

I use the term “Firmware” as opposed to “Software” to indicate that the rules, etc. are “burned into” the controller and are retained across power failures, system off/on, etc.

Firmware updates (bug fixes, new features, etc.) are sent via email and are available for download from my web site.

The user can easily load new firmware releases via a USB-to-serial cable and adapter sold separately.  This cable connects to the Diagnostic Port on the controller and the firmware is loaded via simple program running on a PC/Laptop.  In the future, SComm, the monitoring software provided with the controller will be able to download the firmware to the controller via the serial cable or remotely via the data bus.

The same procedure is used to load the user's specific configuration into the controller (see "Configuring the Controller" on page 71).

***Bus Master:*** *The firmware was recently updated to support a "Bus Master" (no special hardware required). The Bus Master now monitors the firmware and system configuration data version loaded in all the controllers connected to the system. If any controllers are out of date the Bus Master will automatically update the controllers. A new controller can be plugged in and it will automatically be updated – no user action required.*

## 21.1 Runtime Expression Evaluator

The firmware supports building of expressions that are evaluated at runtime. These expressions are used in various parameter entries to combine track occupancy and switch position statuses into a single result.

Currently supported "functions" (functions return values and perform actions at runtime) are:

| | |
|---|---|
| T(x) | This returns the occupancy status of track "x" or any other entity that supports an Occupied/Unoccupied status. Returns "True" if occupied, otherwise "False". |
| S(x,y) | 'x' = requested state (1 = Straight, 2 = Turnout), 'y' = switch ID. This checks to see that the track switch is in the requested state. If the switch is not in the requested state this causes a command to be sent to the switch motor requesting the specified state. The function returns True if the state of the switch points matches the requested state. |
| SS(x,y) | This is the same as "S(x,y)" except this is "Sense Only". It will not issue commands to the switch to change position. It is typically used in the "Points Hardover" expression in block signal parameters. |

Currently supported operators are:

| | | |
|---|---|---|
| () | => | Open and close parenthesis |
| \| | => | "logical or" |
| & | => | "logical and" |
| ! | => | "logical not" |

*Other functions and operators can be provided upon request.*

*Note: Spaces are not currently allowed within the expression.*

Examples:

| | |
|---|---|
| "T(14006)" | => Evaluates to true if track 14006 is occupied |
| "!T(14005)" | => Evaluates to true if track 14005 is not occupied |

"S(1,222)&S(2,223)" => Requests that track switch 222 go to position 1 and track switch 223 go to position 2. Evaluates to true if both switches are in the requested positions.

"!T(1)&S(1,0)" => Requests that track switch 0 go to position 1 and evaluates to true if switch 0 is in position 1 and track 1 is not occupied.

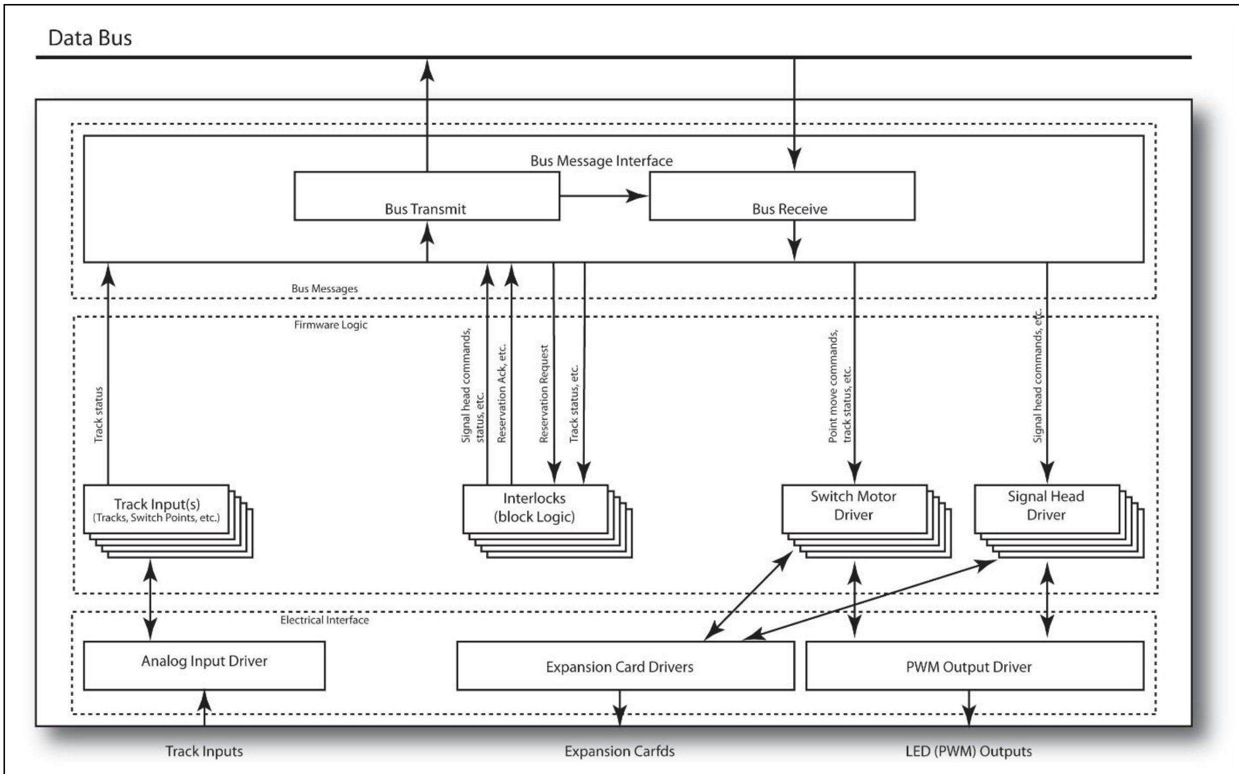
## 21.2 Technical Details

I am providing some technical details that may be too much for some to digest but the information in this section may allow you to make more effective use of the system by knowing something about how it works "under the hood". For example, knowing a bit of how a "Track Input" works as well as how "Block Logic" works you might think of an application where you would substitute a toggle switch controlled by a station master for a track input and allow the station master to control signals that stage trains into the station, etc.

## 21.3 Firmware Internal Structure

In addition to the usual functions required by "embedded" firmware that is performing complex control functions (timers, task dispatching, configuration, diagnostic support, memory management, etc.) the controller supports modules that are designed specifically for railroad signal management.

Below is a simplified depiction of the functions specific to the management of the track signals.




Simplified Firmware Module Structure

Notice that all modules communicate with each other by exchanging messages on the Data Bus. All transmitted messages are passed to the bus. All transmitted messages as well as messages received over the bus from other controllers are passed to the modules within the controller that are registered (by message ID) to receive them.

Even a block module that needs status information from a track input connected to the same controller gets that status information from the Bus Message Interface as though it came from the data bus. The block can't tell, and doesn't care, that the track module is within the same controller.

Because of this:

a) It does not matter which controller contains a given input, output, or interlock. All controllers (and hence all modules) within the system can communicate with each other.
b) All inter-module communication is available for all copies of SComm to monitor (i.e.: station track display, dispatcher, web, etc.).
c) Any controller (and any copy of SComm) can issue commands to any module/controller.

## 21.4 Data Bus Messages

The system is designed as a distributed, message-based system. All information is exchanged over the CAN Bus that is connected to each controller.

One characteristic of this distributed system is that there is no central entity like a Dispatcher's PC that is controlling train movements. Therefore, there is no single-point-of-failure.

All information concerning the status of every entity on the railroad (Tracks, switches, signals, etc.) is transmitted over the data bus. Entities that need this information, such as a block that needs to know the status of a track segment, just monitor the bus for the required information.

Because the system is message-based, in most cases, it does not matter what controller node the entities are defined on. Tracks can be sensed on one node and the information can be used on any node in the system.

Below is a list of some of the messages passed on the bus. The format of each message is included with each firmware release to aid those who want to build their own monitoring programs, etc.

| *Message* | *Description* |
|---|---|
| Track Status | Current occupancy status of a track |
| Track Voltage | Track voltages (recent min, max, threshold, etc.) |
| Signal Head Command | Aspect command to a signal head |
| Controller Statistics | Controller statistics to SComm (# restarts, last restart reason, firmware version, etc.) |
| Test Message | Link test message |
| Block Reservation Request | A request to reserve a block |
| Relay Command | Command to a relay on a relay board |
| MultiSelect Status | Status of a Multi-Select device |
| Switch Status | Switch position status |
| Switch Command | Switch command (switch motor request) |

| | |
|---|---|
| Brightness Command | Adjust all signal head brightness (% of defined brightness) |
| Link Report | Controller report to SComm about the status of node-to-node communication. |
| CAN Statistics | CAN Bus statistics to SComm |
| XBee Statistics | XBee radio link statistics to SComm |
| IO Pin Command | Command to an IO pin of an IO expansion driver |

# 22 Physical Relationship Between Controllers and Blocks, Signals, etc.

The firmware is implemented such that there is no relationship between tracks, blocks, signals and controllers other than the wiring connections you choose to make.

The only things that must be configured in particular controllers are those things that are connected by wire. The following shows each supported entity and its allowed physical location:

| *Firmware Entity* | *What it does* | *Physical location requirement* |
|---|---|---|
| Track Input | Samples a single-track input and performs digital signal conditioning, filtering, etc. It reports the current occupied/unoccupied status of the track segment to the data bus. | Must reside within the controller that the track is physically connected to. |
| Block,<br>Ladder,<br>Multi-Select,<br>Etc. | Receives status of inputs from the data bus (tracks, switch points, etc.) and sends appropriate commands over the data bus to signal heads to coordinate access to a single block. | May reside in any controller. |
| Signal Head | Receives commands from the data bus and activates the appropriate signal head outputs for a single signal head. | Must reside within the controller that the signal head is physically connected to. In addition, all outputs to the signal head (from one to three) must be connected to the same controller. |
| Contact Input | Uses a Track Input to resolve the On/Off status of an input (typically a microswitch input, etc.) and reports the status to the data bus. | Must reside within the controller that the input is physically connected to. |
| Switch Point Input | Uses a single-Track Input to resolve the “Left/Right/Transitioning” status of a set of switch points and reports the status to the data bus. | Must reside within the controller that the input is physically connected to. |
| Track Switch | Receives commands and track status messages from the data bus and activates the appropriate outputs to control a single switch motor. It also can prevent a switch motor from throwing a switch under a train. | Must reside within the controller that the switch machine is physically connected to. |

Note that everything above receives messages from and/or reports status to the data bus.  This means that you are free to locate controllers around the railroad to minimize wire runs, etc. without regard to track blocks, etc.

See the BC002 Configuration Manual for more information.

# 23 Hardware

## 23.1 BC002 Controller

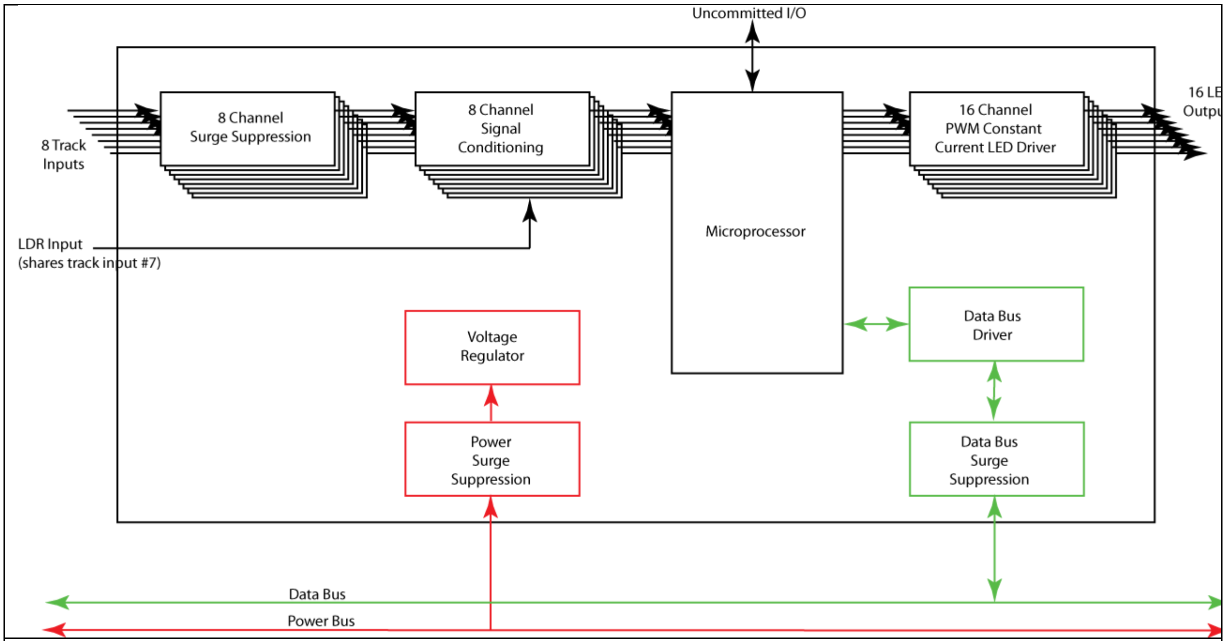



Figure 1 : Simplified Block Diagram

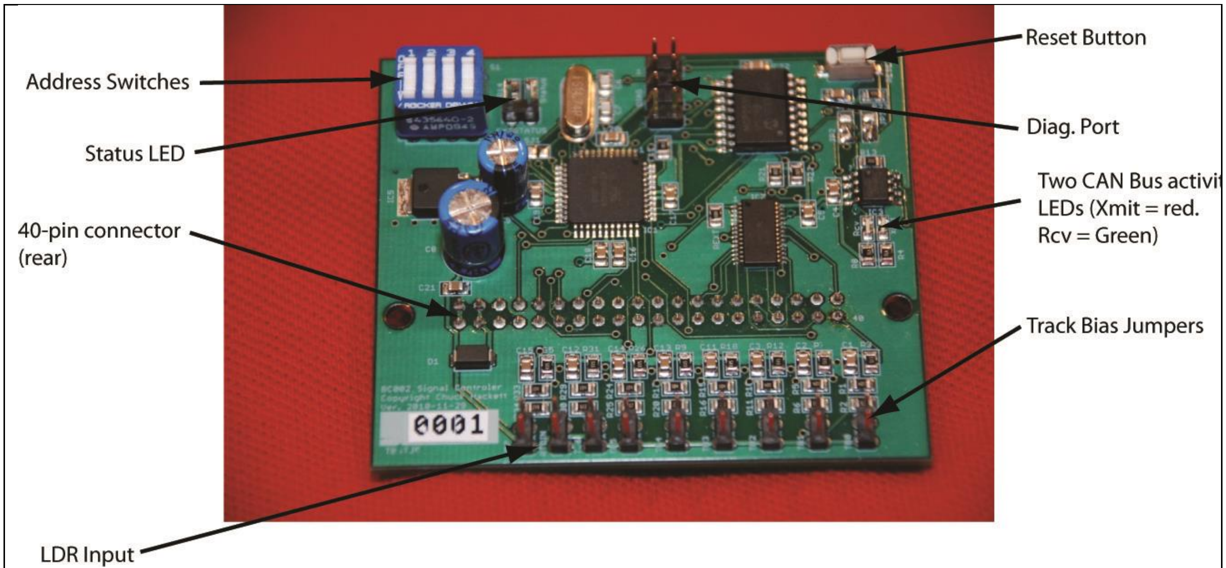



Photo 1: Production Controller

### 23.1.1 40-Pin Field Wiring Connector

All field wiring connections are brought out to a single 40-pin connector on the rear of the controller board. This allows the board to be quickly swapped out if the controller should develop a hardware fault. This connector mates with a plug on the Base Board that provides convenient screw terminals to accept field wiring (see “BC002-02 Base Board” on page 61).

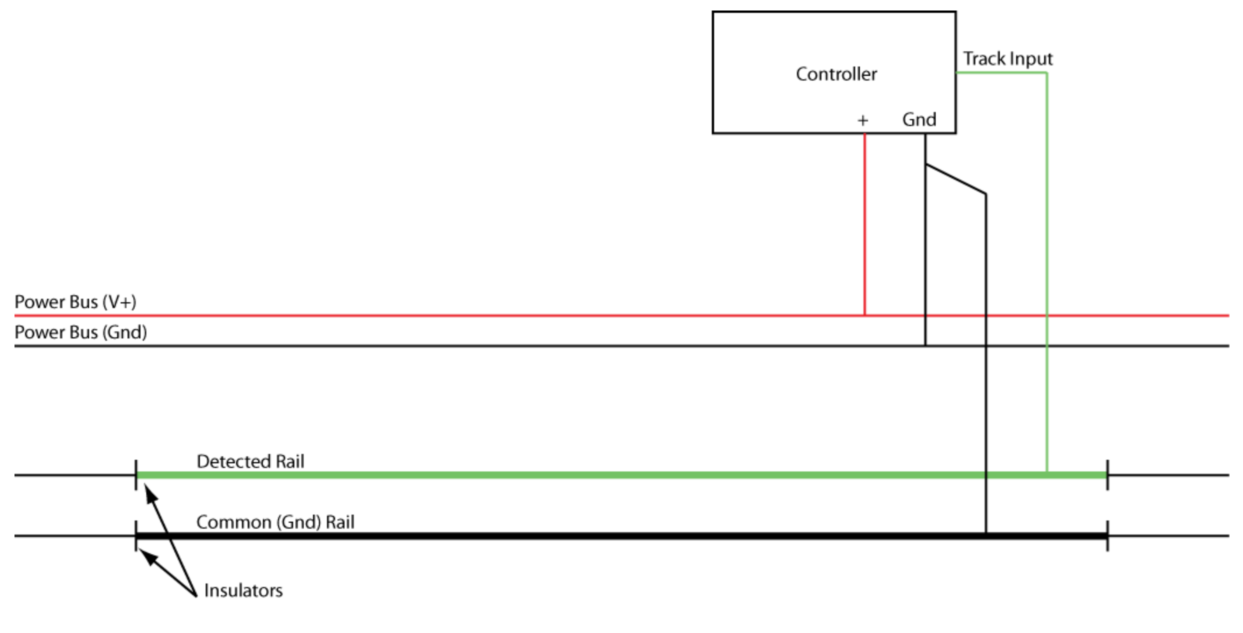
### 23.1.2 Rail Inputs

There are 8 analog inputs that are typically used for rail inputs but can also be used for other purposes. Each of these inputs has the option of supplying the track bias voltage by placing a jumper on the appropriate 2-pin header. On the Base Board these inputs pass through surge protection and then to terminals for field wire connections.

In conjunction with the Base Board, the track inputs are designed to withstand nearby lightning discharges. They have been tested with over 6,000 volts and an arc of over 3/16”.

The T0-T7 signals are intended to be connected to the track for train detection but they can be used for just about any analog or digital input.

The “detected” rail of a section of track is connected to one of these inputs. The other rail (ground, or common rail) is connected to system ground (GND at the controller or the power bus negative line).




Track Connections

These inputs go through a signal conditioning circuit which damps transients and provides some protection from noise/over-voltage conditions. The signal is then passed directly to one of the Analog-To-Digital Converter (ADC) inputs of the microprocessor. The data is then processed by an adaptive software algorithm to eliminate the effects of:

1) Wheel/rail contact noise, debris on the track, etc.
2) Long sections of track in a single block or track segment (rail & joint resistance, etc.)
3) Wet/Dry conditions (leakage through ties, ballast, etc.)

These inputs can also be used for other items such as:

1) Switch point position detection (points left, right, or in transition)
2) Axle weight detectors (scales) to read-out axle weights as a train passes possibly activating “overweight” signals
3) Wheel-gauge detectors, possibly not allowing a train to exit a yard area
4) Other digital/analog inputs

Call for support of these or other analog input applications.

### 23.1.3 LED Drive Outputs

Signal outputs D0 through D15 are designed to drive large “Super Bright” 10mm LEDs. On the Base Board these outputs pass through surge protection and then to terminals for field wire connections.

These are constant-current, Pulse Width Modulated (PWM) outputs. Each channel supplies a regulated 20-ma to the LED. No “current limit” resistors are required on the LEDs if they can handle 20-ma but you can use them if desired.  It is recommended that you use current-limiting resistors in the LED signal heads.  This provides several benefits:

a) The signal can be tested by just grounding the appropriate output terminal on the controller base card,
b) The signal head will not be damaged if someone applies power directly to it to test the lamps,
c) The signal heads will not be damaged if connected to the IO Expansion driver cards that do not have the "constant current" capability of the built-in LED driver.

The controller can set the brightness of each channel individually (256 levels of brightness) from off to full on.  This allows different levels of brightness for day/night running as well as the ability to match the "perceived brightness" of different color LEDs used in the signal heads.

The outputs are protected from a short circuit to ground condition.

These outputs can also be used to drive switch motors, crossing gates, or just about anything that can be handled by electronics or a relay.  They can also be used to generate an analog (varying voltage) output.  Call for more information on these applications.

***These outputs are not designed to absorb large surges.*** *It is recommended that these not be used to drive signals at a great distance from the controller due to lightning induced inductive pickup and ground differentials.  It is better to locate another controller near the distant signal heads or drive long signal head connections using the BC016 Base Board Opto Adapter, BC015 TWI Opto Driver, or BC017 Relay Driver to connect to long signal runs.*

#### 23.1.4 Controller Power

The controller is connected to the trackside power bus through the VIN and GND connections.  The power may be supplied by a regulated, or unregulated, DC source supplying a voltage of 8 to 16 volts (the higher voltages might be needed to accommodate the voltage loss over long power cable runs).  It is desirable to keep the voltage around 9-12 volts to maximize efficiency and minimize the generation of excess losses (as heat) within the controller's regulator.

For planning purposes, you can assume that each controller and associated signals will consume approximately 150-ma (0.15 amps).  Thus, a system with 10 controllers might consume approximately 1.5 amps on the power bus.

As an example:  The track in Florida where I do my testing currently draws 1.9A at 15 VDC to support:

- 19 Controllers
- 60 signal heads
- Over 100 track and other inputs

This averages out to a real-life measurement of 100-ma per controller where each controller has an average of three signal heads and five sampled tracks.

The controller's power bus connection is protected against accidental reversed connections within the controller.  In this case the controller will not come on until the power is connected correctly.

The controller Base Board and Cable Interface Card use surge protection that requires the supply voltage to be below approximately 16 volts.  The protection devices on the LED terminals require the voltage to be below approximately 14 volts (above 14 volts you will start to get "blead through" and the LEDs may start to glow dimly).

***Warning: Because of how they function, you will damage the protection devices and/or blow fuses on the Cable Interface Card and the Base Card if the power is connected backwards.  The BC002 Controller itself has protection against reversed power so it will not be damaged.***

*Note: The new BC020 Cable Interface Card contains a regulator that allows using a power bus of up to 30 volts.  This allows for very long cable runs that do not require large gauge wire.  The BC020 provides 12 volt power for devices at the controller location.  It can be used at non-controller locations to power other trackside devices.*

### 23.1.5 Network Interface

*Note: No data bus connection is required to a controller if that controller is running in "Stand Alone" mode and you do not want to monitor the controller remotely.  All of the diagnostic and monitoring capabilities of SComm are still available via the controller's "Diag" connector (see "*SComm Monitor and Control Program*" on page 71).*

The CANH and CANL controller terminals are connected to the data bus.  This bus allows the controllers to communicate with each other to exchange information on track status, signal aspects, drive dispatch displays, etc.

On the Cable Interface Card and the Base Board this CAN bus connection passes through surge protection and then to terminals for field wire connections.

There are two on-board LEDs that indicate Transmit (red) and Receive (green) activity.

The data bus must be a "twisted pair" within a standard CAT-5 or CAT-6 LAN cable.

The data bus uses "CAN Bus" data transmission (same as that used in modern automobiles and Industrial Automation) but uses a proprietary data format.

Messages on the data bus can be monitored by SComm, the free PC application provided (see "SComm Monitor and Control Program" on page 71).  These messages include:

1) The status of all detected track segments (currant and historic voltages, occupied/not occupied, etc.)
2) The status of all signal heads (aspect currently displayed)
3) The status of all blocks (occupied/not occupied/reserved)
4) The status of all detected switch points
5) Controller status

6) Commands to hold a signal at Stop aspect (red). This is typically for CTC applications.
7) Commands to throw switch motors, etc.
8) Etc.

### 23.1.6 Uncommitted I/O

This I/O signal is connected directly to the microprocessor. It can be used to provide an additional input or output to/from the controller.

Caution must be used when using this terminal as there is no surge protection; it is connected directly to the microprocessor on the controller. Misuse will damage the controller.

Call for additional information on connecting to this terminal.

On the current Base Board this terminal is connected to a jumper used to increase the number of controller node addresses (see "Address Switches" on page 59).

Let me know if you need to use this as an input or output.

### 23.1.7 LDR Input

This 2-pin header is intended that a Light-Dependent-Resistor (LDR) that can be used to provide automatic control of day/night dimming of the signal head LEDs.

This input shares the Track #7 controller input.

### 23.1.8 Address Switches

This 4-position switch bank is used to set the node address of the controller (0-31) and thus the system configuration it will run. There is a jumper on the Base Card that can be used to extend this address range to 0-63.

### 23.1.9 Status LED

This LED indicates the current state of the controller. After power-up this LED will normally indicate how busy the microprocessor is sampling tracks, processing bus messages, etc. and will flash rapidly at various levels of brightness, the brighter it is, the busier the processor is.

If a fault condition is detected the controller will automatically restart itself and flash a status code indicating the cause of the last restart. If the controller repeatedly restarts itself contact me and I will help you resolve the issue.

The most common code you will see is "1 - 3" which indicates that the input power level went below the minimum required for the processor to function and it shut itself down (commonly referred to as a "Brownout" condition) and restarted when the power was restored.

When power is turned off and on again (or the controller reset button is pressed) the code will be cleared, and the LED will resume the normal "processor busy" indication.

There is a 2-pin terminal block that allows connection of an additional, user-supplied, LED (w/current-limiting resistor). This can be mounted in the wall of an enclosure as an external status indication.

### 23.1.10 Diagnostic Port

This 8-pin header accepts a local hand-held diagnostic terminal (in development) or connection to a laptop/PC via a serial-to-USB cable. This allows checking of track voltages, signal indications, fault conditions, etc. to facilitate troubleshooting. Any system command (such as switch point commands, signal hold, etc.) can also be issued using this port (see “SComm Monitor and Control Program” on page 71).

This port also provides access to the on-board TWI bus to support additional add-on functionality available as future options such as additional track inputs, outputs, etc. This TWI bus is also brought out to terminals on the Base Board.

### 23.1.11 Local Reset

The controller may be reset to its power-up condition by pressing this button.

This should only be required in rare circumstances such as restarting the controller to reload the system configuration after changing the Node Address switches.

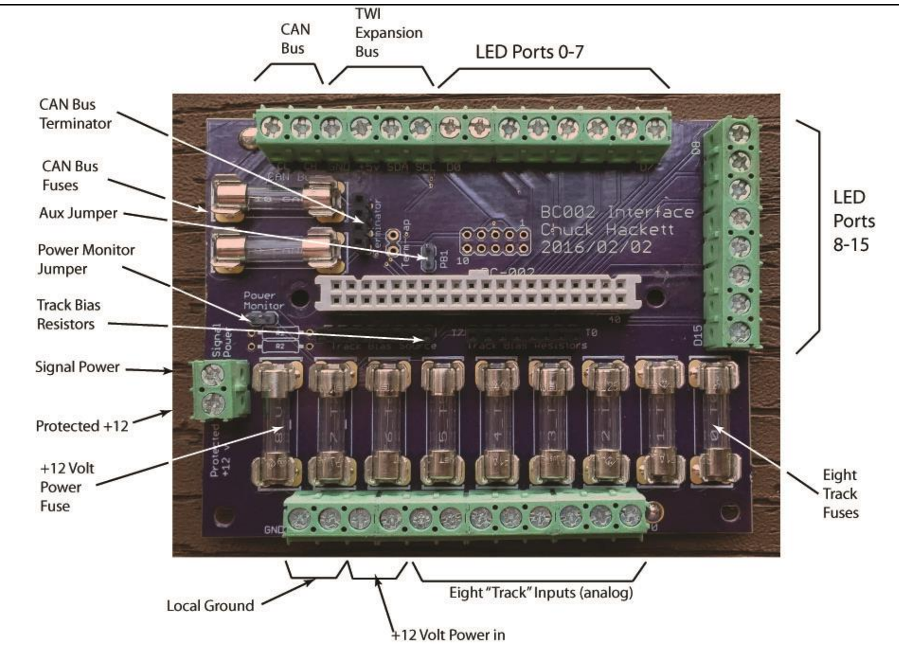
### 23.1.12 Surge Protection

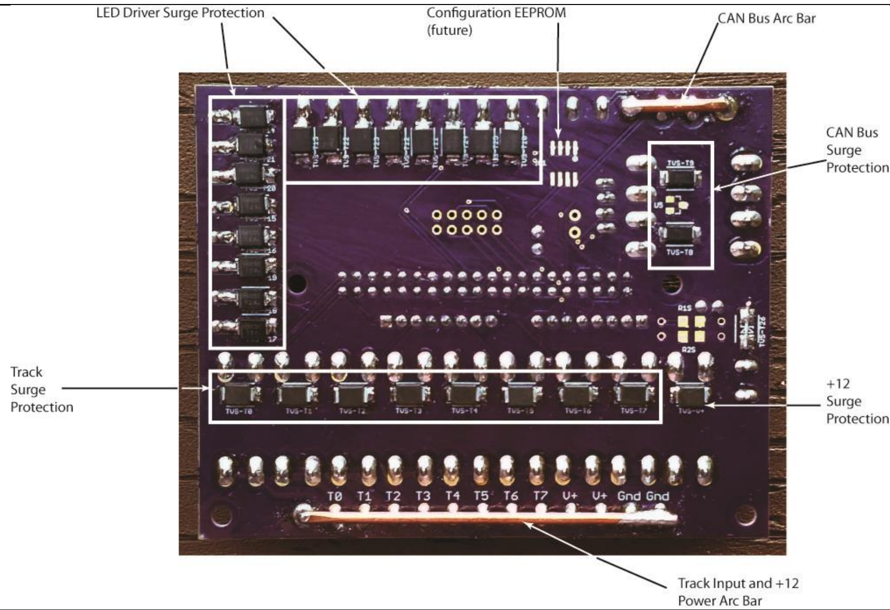
The surge protection shields the controller and other devices from nearby lightning strikes and other power surges. Keep in mind that this will only protect the controller from lightning strikes in the area. It is NOT capable of protecting the unit from a direct/close lightning strike.

The surge protection protects the controller from surges coming from the Power Input, Track Inputs, LED outputs, and Data Bus.

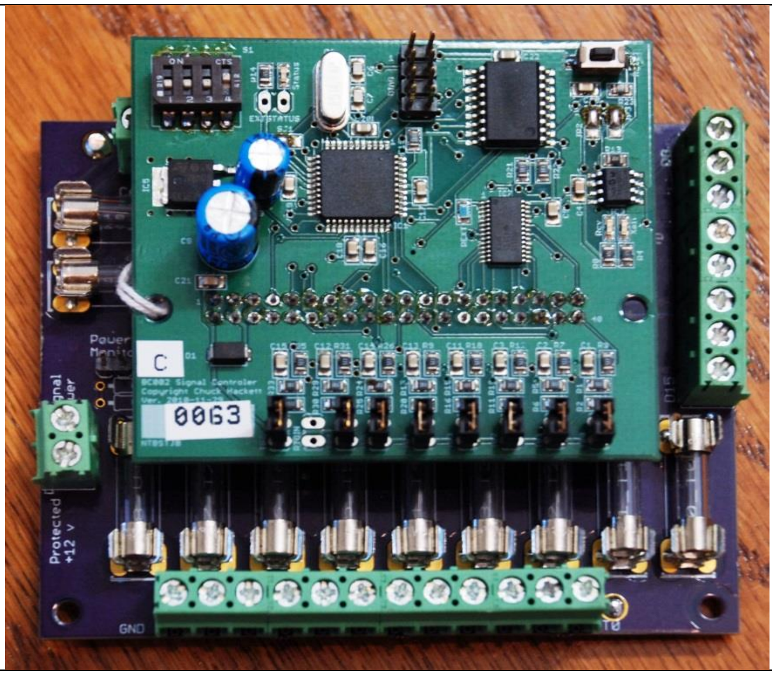
The surge protection is implemented on the various cards used by the system (Base Board, Cable Interface Card, IO Expansion Boards, etc.)

## 23.2 BC002-02 Base Board




Base Board to connect controller to field wiring



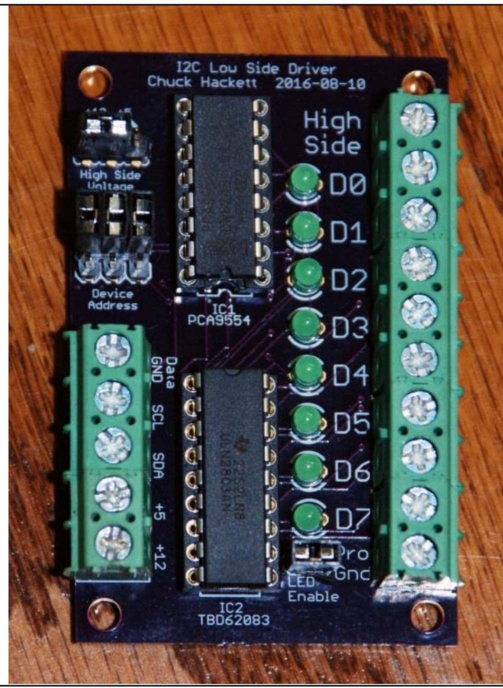
Base Board with controller installed

The Base Board supports a memory chip which will be used by future versions of the controller to hold the system configuration information for this location (it is currently stored in the controller itself).

This memory will also be used to record historical information on track voltages, etc.  This information will be used to enhance the track voltage signal conditioning algorithm.

This board contains the surge suppression along with fuses to protect the surge suppression devices from extreme surges.

## 23.3 BC009 Low-Side Driver




Low-Side Driver

The outputs are "Low Side" meaning that, when active, they connect the output terminal to ground. One side of the load is connected to the output terminal, the other side of the load can be connected to any positive supply up to 15 volts. Maximum current is 500ma per channel.

In addition to several expansion cards described below I can add support for temperature sensors, force (weight) sensors, etc. Contact me for details.

This driver can be used to add additional signal heads, external relays, etc. to the controller. It provides:

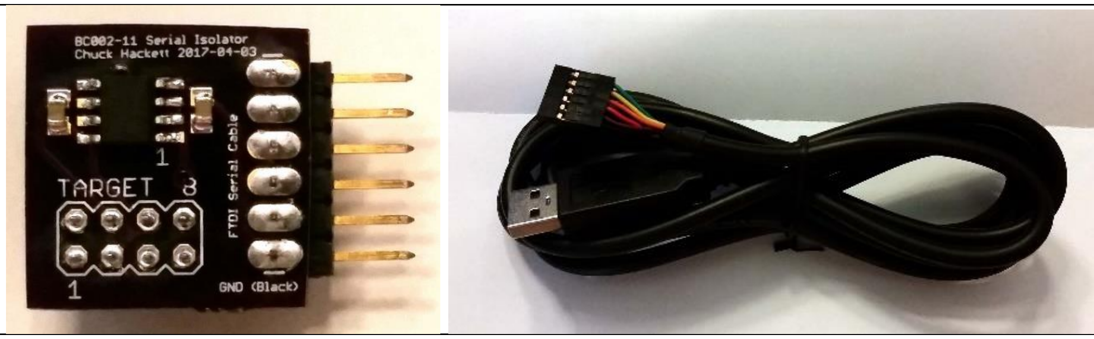
- Eight independent outputs
- Eight LEDs to show the status of each pin
- Jumper to enable the LEDs (remove to reduce power consumption when not using the LEDs)
- Jumper to select the “high side” power source for the outputs (+12 or +5)
- Three address jumpers to support up to eight of these cards on a single controller
- “fly-back” diodes so that inductive loads can be driven (relays, solenoids, etc.)
- Eight TVS diodes to protect against surges from long lines connected to output terminals (signal heads, switch motors, etc.)

Note: This device does not have the dimming capability of the on-board LED driver. If this driver is used for signal heads the signals will be on at full brightness (determined by their current-limiting resistor) whenever the “brightness” setting defined in the aspect is greater than 0.

## 23.4 BC010 Relay Board

This card is very similar to the Low-Side Driver card except that it also contains four relays that can be used for things like switch motors, etc. (Obsolete, replaced by the BC017 Relay Driver)

## 23.5 BC011 Serial Isolator And USB-to-Serial Cable



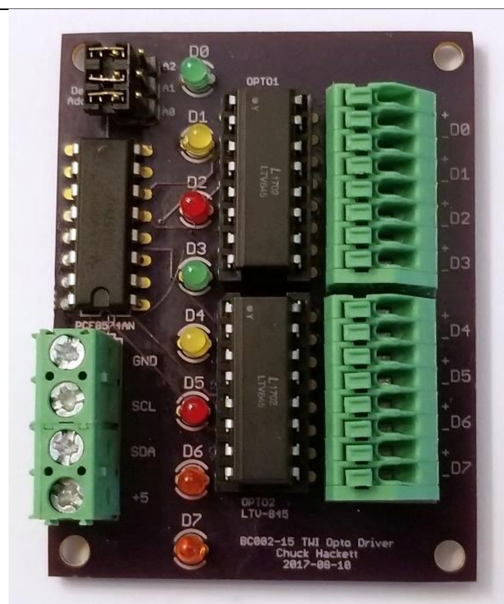

Serial Isolator and USB-to-Serial Cable

The Serial Isolator is used with the FTDI USB-To-Serial cable (available from me or other suppliers).

The cable and isolator are used to connect a PC/laptop (running SComm) to a controller for diagnostics, setup a dispatcher terminal, or load new firmware or system configuration information.

The Serial Isolator provides complete isolation between the PC/laptop and the controller. This eliminates any chance of ground potentials, etc. from damaging the controller's diagnostic port.

## 23.6 BC015 Opto Driver




BC015 Opto Driver

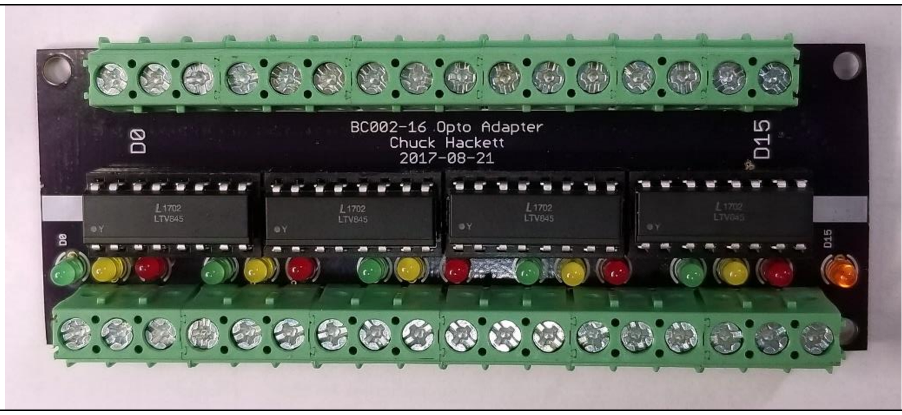
This expansion card is very similar to the Low-Side Driver card except that the 8 outputs are opto-isolators that isolate the BC002 controller from external devices or surges that might damage the controller.

Each channel has a + and - terminal to connect to the load. The load is fully isolated from the controller up to 5,000 volts. The output is limited to 15 volts at a maximum current of 50 ma. Each output has an associated LED indicator and surge protection device.

Each output can be used as a "High Side Driver" (load on the ground side) or as a "Low Side Driver" (load on the + supply side).

It can be used to provide additional signal head outputs where the cable run is long, requiring additional lightning protection.

## 23.7 BC016 Base Board Opto Adapter




BC016 Base Board Opto Adapter

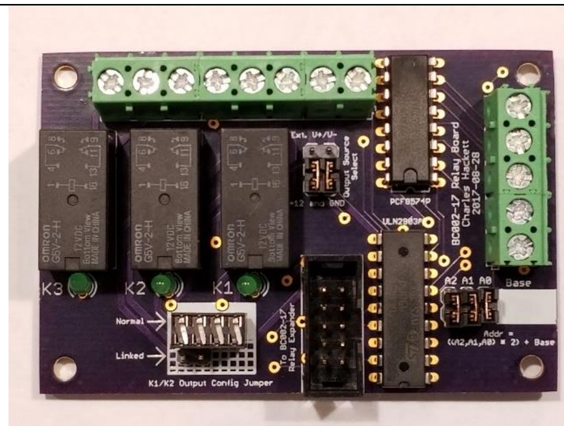
This board is designed to provide additional lightning and surge protection to the 16 signal outputs on the BC002 controller as well as a local display of the signal indications.

The load is fully isolated from the controller up to 5,000 volts. The output is limited to 15 volts at a maximum current of 50 ma. Each output has an associated LED indicator and surge protection device.

If you are in a very lightning prone area (such as Florida) and/or you want to connect signal heads that are a significant distance from the controller (more than 100 feet) I recommend using this adapter.

This adapter can also be used to isolate other TTL active-low signals you might have developed yourself.

## 23.8 BC017 Relay Driver




BC017 Relay Driver

The BC017 Relay Driver adds three relay outputs (8 with the expander) to the BC002 controller.

In "Normal" mode the relays provide outputs that are always on. The output from K1, K2 and K3 terminals is "reversing" upon command (each channel is independent). Normal Mode is designed for operating switch motors that move the points to one direction with "forward" polarity and the other direction with "reverse" polarity.

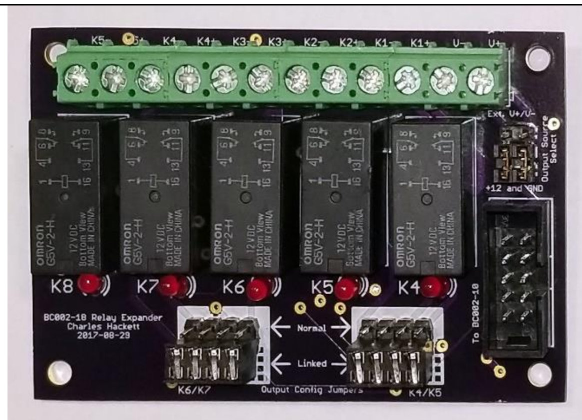
In "Linked" mode the load is connected to K2 and K1 provides the On/Off function. K2 output is either “Off”, On with normal polarity or On with reversed polarity.

Linked mode is designed for driving full-size searchlight signal heads (or scale signals that operate the same as the full-size) that use a magnetic "Slug" motor. These display Green for forward current, Yellow for reverse current, and Red for no current.

K3 is always in "Normal" mode.

There are jumpers on the board to set Normal or Linked mode, relay output power source (on-board or external), and the card's expansion address.

## 23.9 BC018 Relay Expander




BC018 Relay Driver Expander

The BC018 Relay Expansion Card can be added to the BC017 relay Card via a ribbon cable (provided with the BC018) enabling it to drive an additional 5 "Normal" outputs or 2 additional "Linked" outputs and one "Normal" output. See “BC017 Relay Driver” on page 66 for more information on Linked/Normal, etc.

## 23.10 BC020 Cable Interface Card

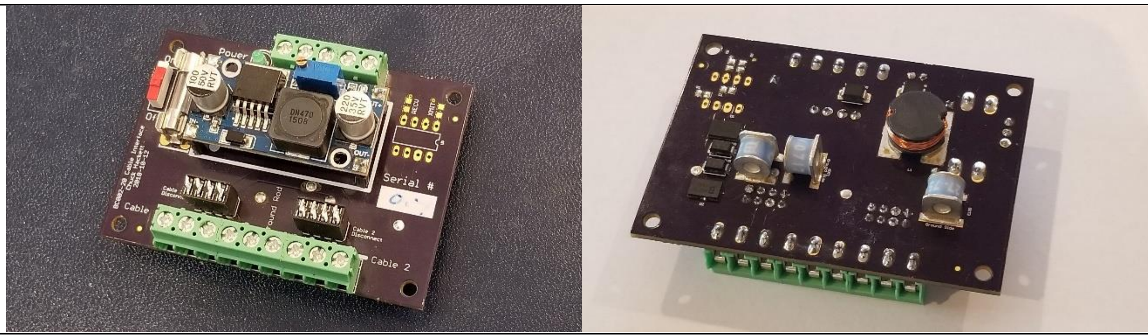
Controller installations usually consist of a Power/Data cable coming in one side from a previous controller and out the other side towards the next controller. This cable usually consists of one twisted-pair of a CAT-5/6 cable and a pair of #14 or #16 conductors for positive power and ground (larger installations). For smaller installations the other six conductors of the CAT-56 cable can be used for power and ground.

In cases where there are multiple controllers in a given equipment cabinet, only one Cable Interface Card is required.

I recommend that a Cable Interface Card be used to connect a power supply to the power bus at a tower, etc. This will help protect against surges coming in from the commercial power grid.

The Cable Interface Card provides a clean termination of two cables and a connection for the local controller(s). It also provides:

- Power switch
- Power indicator
- Optional regulator to support a “Power Bus” voltage of 16 to 30 volts DC.
- Additional protection devices and fuses for lightning/surge protection for both the power and Data Bus signals
- Ability to easily isolate the cable runs for testing by removing the 4-channel jumper blocks.




Cable Interface Card (also available as a kit)

## 23.11 BC022 Dual-Port Adapter

This is a ‘Daughter Board’ that mounts onto the BC002 Controller to add a second CAN Data Bus Port.

This allows this Dual-Port controller to provide a “Bridge” function from one CAN bus to another.

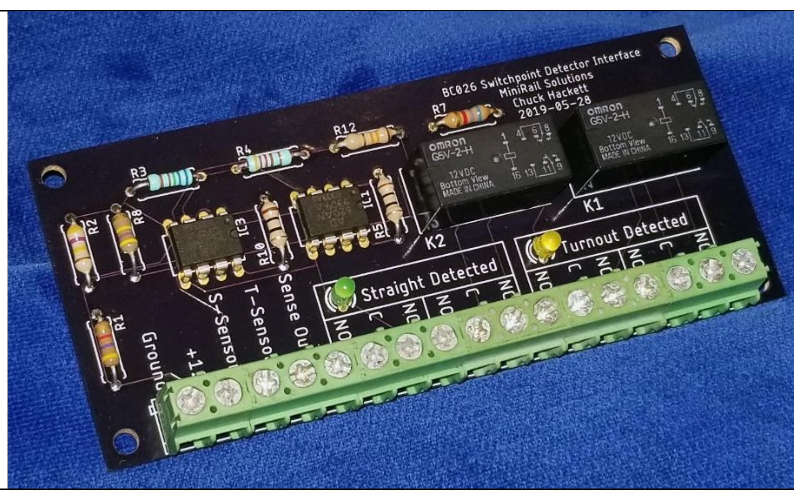
This allows the user to:

- Extend the data bus to any distance you would require.  Currently there are two railroads with data busses almost a mile long.
- Provide “Branches” to the bus topology (see BC002 Installation Manual).

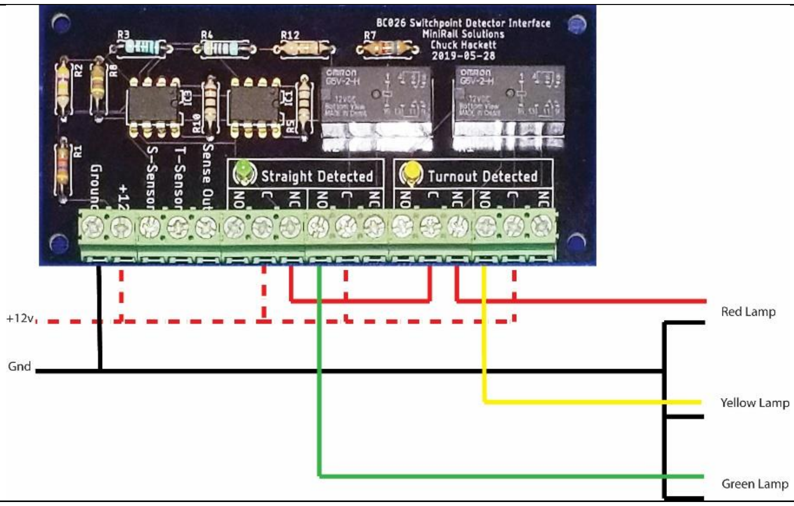
## 23.12 BC026 Switchpoint Sensor Interface With Relay Output

Two BC027 Switchpoint Sensors are connected to this module.  This module supplies a single multi-level analog output used by the BC002 Controller to detect the position of the switch points.

In addition, the module contains two DPDT relays, one for each switch position.  These relays can be used to drive a switch dwarf signal directly in response to point position and/or used to drive a traditional relay-based signal system.




BC026 Switchpoint Sensor Interface with Relay Output




One way of connecting a two or three lamp switch dwarf signal.

The example above could be used to operate a three-lamp switch dwarf with Green for “Locked Straight”, Yellow for “Locked Turnout”, and Red for “Points not Locked”.

For a two-lamp dwarf you could just eliminate the wiring for the red lamp.

See “BC027 Switchpoint Sensor” on page 69 for more information.

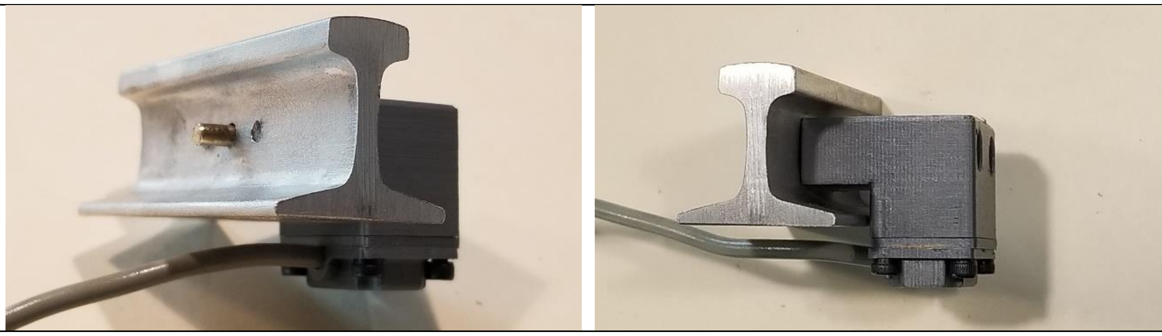
## 23.13 BC027 Switchpoint Sensor

In locations where there is a choice of routes (either tower selected, or engineer selected) there will usually be a signal mast with multiple heads on it – one signal head for each possible route (see “Multiple Head-End Route Signal” on page 35). One or more turnouts are usually located just beyond the signal mast (although, in some cases, the turnouts may be some distance beyond the signal).

The signal system needs to know the position of the points at each turnout associated with the signals on this multi-head signal mast to determine if a train can be cleared.

You can use inputs from a switch motor, microswitches, etc. attached to the turnout to tell the signal system that “the points are hard-over to the straight/turnout position”. The signal system will then provide a Clear/Approach signal aspect on the signal for the appropriate route (provided that route is clear).

The recommended method of detecting the switch point position is with the MiniRail Solutions “Point Detector”. This detector consists of two sensors designed to detect the position of a switch point itself along with a small printed circuit board that interfaces the detectors to the signal system. Unlike switch motors or most microswitch setups where there are springs between the device and the points, these detectors sense the ***actual*** point position as opposed to the ***assumed*** point position. They can detect point closure down to approximately 0.010”. With these detectors the system ***will not*** indicate that the route is clear unless the point is ***actually*** closed. A rock, binding point, broken spring, etc. that prevents the points from closing ***will*** be detected and, in that case, the signal system will not clear a train through that turnout.

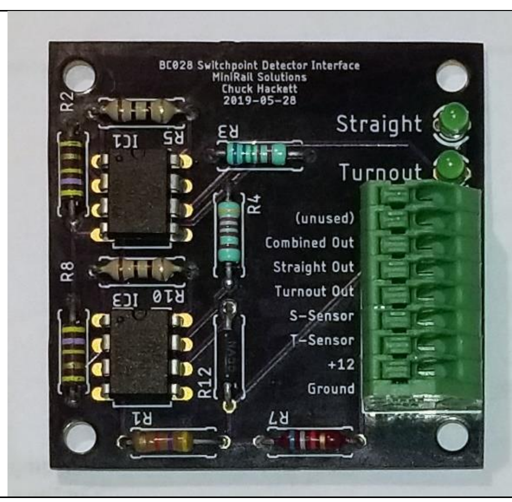


Production Point Detector

Prototype Point Detector installed for testing (prototype shown)

## 23.14 BC028 Switchpoint Sensor Interface

This is the same as the BC026 except that it has a smaller footprint and does not have relay output.  It is used to connect the BC027 Switchpoint Sensor to the BC002 Controller when the controller is driving the dwarf signal, or a dwarf signal is not used.




BC028 Switchpoint Interface

## 23.15 Additional Input Options

(Future) This card will provide an additional eight or sixteen analog inputs that can be used to connect additional tracks, buttons, etc.  Contact me if you have a requirement for additional analog input channels.

# 24 Configuring the Controller

As a free service I will completely pre-configure the system for you and provide complete installation instructions.

I will need a map showing the railroad layout and where you are planning to install signals, track insulators, where your control cabinets will be located, etc.  I will work with you to devise this map – it is usually an iterative process.

The controllers will be shipped to you pre-configured.

I can provide pre-configured subsystem boards where all the cards involved in each cabinet are pre-mounted ready to be installed in a cabinet as a unit.  Just mount the subsystem in the cabinet and connect your field wiring as shown in the installation instructions.

If your configuration changes, I can make the required configuration changes and email the new configuration to you.

If you want to do your own initial configuration or make changes, see the BC002 Configuration Manual for more information.

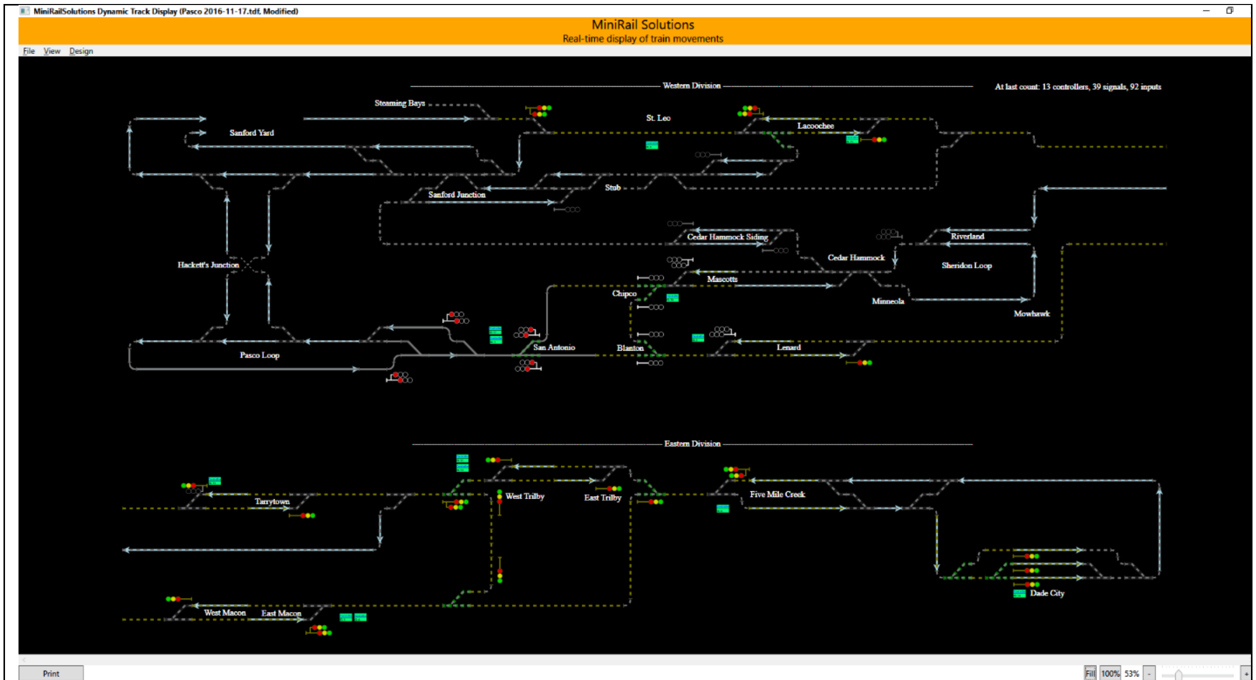
# 25 SComm Monitor and Control Program

SComm is a Windows-based program supplied free of charge.

SComm connects to the Diagnostics Port on any controller to monitor the entire system (see “Diagnostic Port” on page 60).  It can be connected to a controller in the field to monitor/diagnose signal problems (typically broken wires from a track, broken bond wires, etc.) or it can be connected to a dedicated controller for use by a dispatcher or to display traffic to people waiting in the loading area, etc.

Because all controllers are connected to the same data bus, SComm has access to all of the data available on the bus, track status, switch positions, signal head aspects, etc.

A future version will allow the track status to be made available on your web site so people can see a real-time display of train movements.  Because the display is then web-based, engineers will be able to access the display real-time track status on any wirelessly connected Smart Phone, Tablet, IPad, etc.

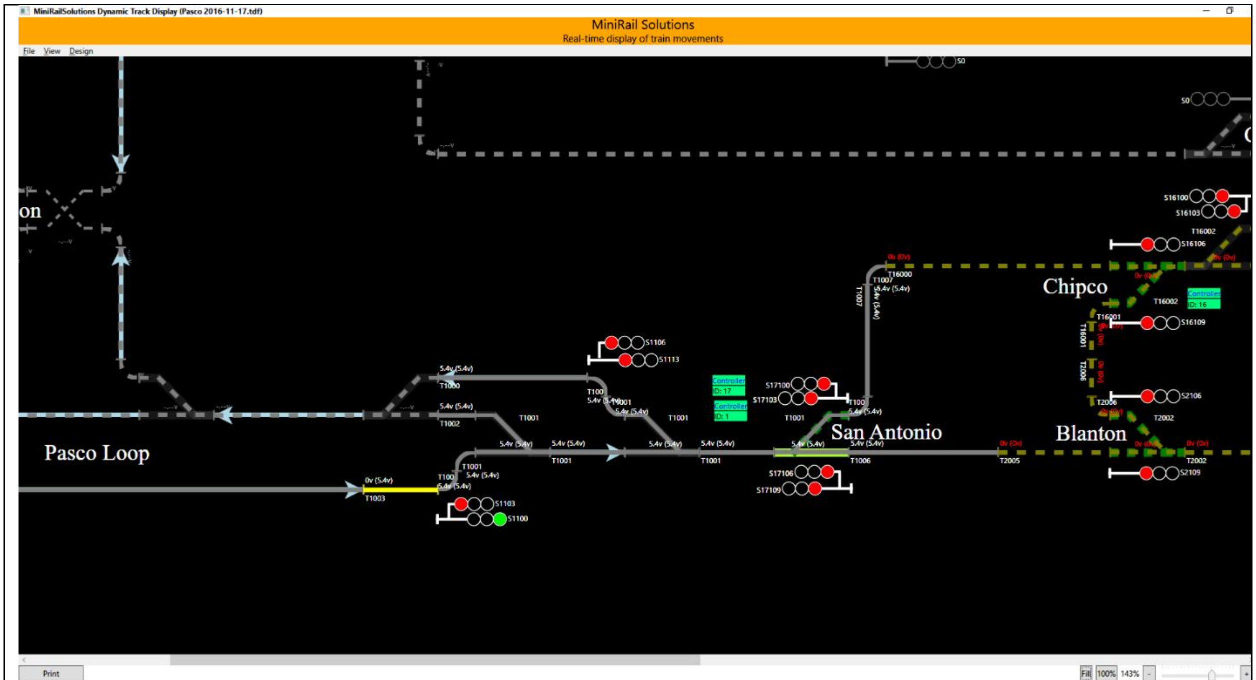


SComm Track Display

This display shows the layout of the track I use for system testing.  This image was captured on my home system with a single controller (node #1) connected.

The signals with no color are signals that are planned but not yet installed and the dotted gray tracks are tracks that are not yet sensed (i.e.: "dark" territory).

The dotted yellow tracks are tracks that are connected but no data is being received for them because only one node is connected.  Note "San Antonio" just left of center-screen.  The image below shows the display after zooming in on this area:



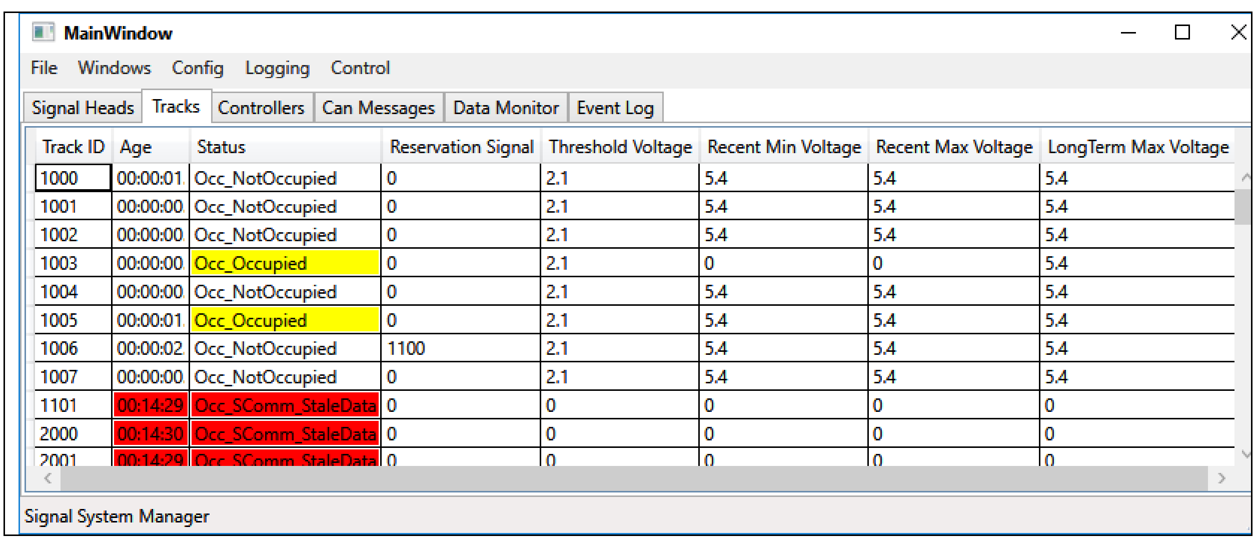

SComm display of area with active controller

In this display I have turned on the display of IDs and Track Voltages.

A train is shown on the approach track for the signal exiting “Pasco Loop” (track segment is yellow indicating “occupied”). Note that he has a Clear (Green) signal to proceed towards “Blanton”. Note also that the signal towards “Chipco” is Red because the turnout** at San Antonio is set for the straight-through route as indicated by the green bar on the turnout.

**These turnouts have electric switch motors controlled by a post-mounted toggle switch far enough from the signal that the engineer can activate them without being in the block.

The “Tracks” tab shows the real-time status of each detected track in the system along with other details such as the voltage levels used to determine the Occupied/Unoccupied status of a track section.




| Track ID | Age | Status | Reservation Signal | Threshold Voltage | Recent Min Voltage | Recent Max Voltage | LongTerm Max Voltage |
|---|---|---|---|---|---|---|---|
| 1000 | 00:00:01 | Occ_NotOccupied | 0 | 2.1 | 5.4 | 5.4 | 5.4 |
| 1001 | 00:00:00 | Occ_NotOccupied | 0 | 2.1 | 5.4 | 5.4 | 5.4 |
| 1002 | 00:00:00 | Occ_NotOccupied | 0 | 2.1 | 5.4 | 5.4 | 5.4 |
| 1003 | 00:00:00 | Occ_Occupied | 0 | 2.1 | 0 | 0 | 5.4 |
| 1004 | 00:00:00 | Occ_NotOccupied | 0 | 2.1 | 5.4 | 5.4 | 5.4 |
| 1005 | 00:00:01 | Occ_Occupied | 0 | 2.1 | 5.4 | 5.4 | 5.4 |
| 1006 | 00:00:02 | Occ_NotOccupied | 1100 | 2.1 | 5.4 | 5.4 | 5.4 |
| 1007 | 00:00:00 | Occ_NotOccupied | 0 | 2.1 | 5.4 | 5.4 | 5.4 |
| 1101 | 00:14:29 | Occ_SComm_StaleData | 0 | 0 | 0 | 0 | 0 |
| 2000 | 00:14:30 | Occ_SComm_StaleData | 0 | 0 | 0 | 0 | 0 |
| 2001 | 00:14:29 | Occ_SComm_StaleData | 0 | 0 | 0 | 0 | 0 |

Track #1003 is the approach track that is occupied in the previous picture. "Track" #1005 is a "binary input" defined as inverted. It is one of the "Point Sensing" inputs from the track switch at San Antonio and is telling the system that the turnout is set to the right.

Note that Track #1006 is "Reserved" by signal S1100 (the one that is currently Green). This reservation would prevent an opposing train at the siding east of Blanton from being allowed to proceed to the west (conflicting with the first train).

*Note: This image was taken when "tracks" were reserved. This has been changed to "blocks" being reserved.*

The voltage display is "C.Cv (L.Lv)". This shows the "Current Voltage" (C.Cv) and "Long-Term Voltage" (L.Lv) voltage on the track. If there is a train on the track the "current" voltage should be near 0.0. The Long-Term voltage shows the nominal voltage when a train is not present. This will typically be 5.4v (max detectable). A smaller track bias resistor should be used if this voltage falls below about 1 volt when the track is very wet just to ensure the highest reliability. Note: train detection will still work at below 1 volt but, as the Long-Term voltage approaches 0 the reliability of train detection will decrease.

Many other signal systems would misinterpret this low voltage as a train occupying the block which would cause "False Red" signals resulting in unnecessary traffic delays.

The "Signal Heads" tab shows the aspect currently displayed at each signal head.

The "CAN Messages" tab shows each bus messages (in decoded format) as it is transmitted by any controller on the bus.

The "Controllers" tab shows the status of each controller on the bus (current firmware version, time since last restart, last restart code, etc.).

The "Event Log" tab shows diagnostic information such as faults detected, controller restarts (reset button, power-up, firmware fault detected, etc.).

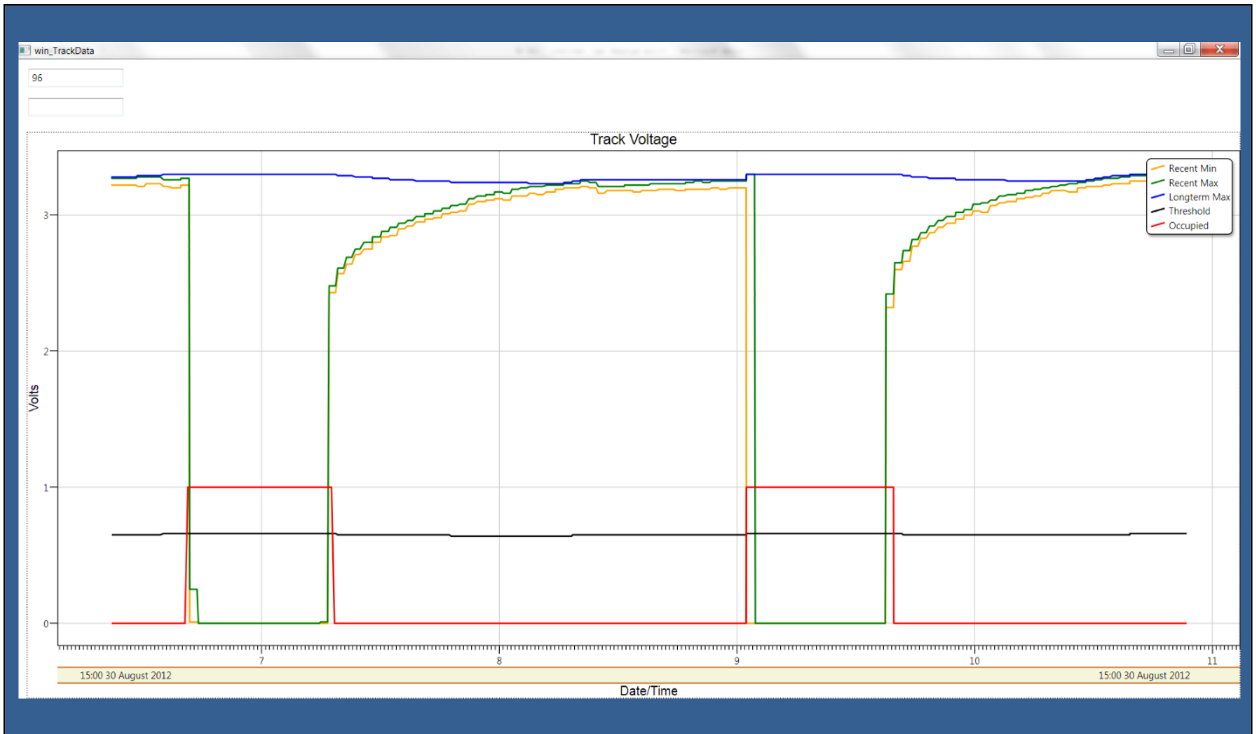
All columns in the tabbed display are sortable by clicking on a column heading.

## 25.1 Track Display Format

Currently SComm uses an "Atlas Track" form of display. If desired, it would be fairly straight-forward to add the capability to display it in "CTC" format similar to an old "CTC Panel".

## 25.2 Monitoring Track Voltage

It is often helpful to get a "Strip Chart" display of the voltage on a given section of track for diagnostic purposes. Below is such a display produced by SComm:




"Strip Chart" of an actual track with two trains traversing it

This display shows two trains passing through a section of track (about 500 feet long with mostly plastic ties).

Note that, as the train entered (left side of chart) the track voltage (orange line) went to (very near) zero and the "Occupied" status (red line) immediately went to 1 (occupied). As the train left the track section the voltage rose to about 2.5 volts but the track did not go "unoccupied" for several seconds. This delay (value configured by the user) is to ensure the train is, in fact, out of the block and not on a dirty section, etc.

Also note that, as the train left the track section, the voltage did not immediately return to just above 3 volts. This effect is due to the R-C effects of the rail contact with the ties, etc.

If, as the train was traversing the track, you noticed a slight rise in the track voltage it would probably indicate that a bond wire has been cut/dislodged causing a "high resistance joint". This allows you to see problems before they actually cause signal problems.

You can have multiple Track Voltage charts open at once.

## 25.3 Control Functions

A future version of SComm will support commands to the system as a whole (dim the signals, transition to CTC mode, "Lamp Test" commands, etc.) as well as commands to individual controllers (change a parameter, etc.), signal heads (dispatch hold, etc.), switch motors, etc.

### 25.3.1 CTC functions

(future) Clicking on a signal to place it in "Dispatch Hold", clicking on a switch to change the position of switch points, etc.

### 25.3.2 Configuration

The user configures his Track Display by using "Drag and Drop" style object placement and changing component parameters by right-clicking any object.

SComm will soon be able to download the configuration data to the controllers directly rather than using the current text-mode configuration file. SComm will be able to load the configuration to the controller either by direct serial connection (via the Diagnostics Port) or over the network.

# 26 Installation

See the BC002 Installation Manual.

# 27 Switch Motor Control

(Future, when requested) This feature will allow both remote (dispatcher) control of switch motors as well as the currently supported control via engineer-operated toggle switches, etc. The advantages of controlling switch motors through the controller rather than directly wiring the motor to a toggle switch, etc. are:

a) The controller can prevent a switch from being thrown under a train while "remembering" that a request was made to throw the switch (i.e.: delay throwing the switch until the switch is unoccupied).
b) Switches can have a "Normal Route" designated for them such that, after a train passes, the switch will return to the "Normal Route". This is useful for switches used as the entry point to a siding so that the engineer does not have to remember to go back and throw the switch to protect the rear of his train.

# 28 Thinking "Outside The Box"

After you work with the controller for a while you will realize that what you really have is a device that accepts an analog or digital input and sends that input to any location on the railroad, possibly combining it with other inputs, and activate a digital or analog (add a capacitor to the PWM LED output and you have a 0-5v analog signal) device at a remote location, all without extra wire. I'll bet you can think of many uses …

At a track in Florida the signal power is on a resettable timer that runs for about six hours after the last press of the "On" button. Sometimes during meets the signal power goes off because people forget to push the button periodically. A solution being installed is to have the controller in the tower (the same controller that provides the dispatcher display connection) turn off the signal power 60 minutes after the last train movement. To do this the controller simply monitors the bus for track status changes and activates an output relay via the Low-Side-Driver that releases the latched power relay.

If desired, a user can use other third-party software to monitor and control the system. One alternative is the JMRI system used by the "tabletop" railroad community. The software could be interfaced using either a controller containing firmware designed for the purpose (see me for details) or you could use the Windows DLL available from me that will process the CAN bus messages into a set of "Observable Objects" that your software can use. An example program is shipped with the DLL.

The above program could be used for operator monitoring and control (similar to SComm) or you could just configure the field controllers to sample tracks and drive signal heads and your PC software could provide all block/interlock functionality. Warning: Doing this is a LOT of work and would create a single-point-of-failure. If the central PC is down or can't connect to the network, all signals will be inoperative.

# 29 Future Enhancements

The implementation timeframes for the future enhancements listed below as well as suggestions from users will be driven by demand.

These items are planned in the system design but have not been implemented because no one has yet requested them.

If you have a need for one of these items or something that is not currently addressed by the system, please contact me so I can explain how to accomplish what you want or see how quickly I can address your needs.

- Auto-Dimming of signals at night.
- Switch Motor Control from SComm.
- Track Detector: This is a stripped-down version of the controller that just does track detection. This is intended as a retrofit for railroads currently using relays, etc. but wants enhanced track detection (wet/dry conditions, wheel noise, etc.).
- "Follow Behind" (see "Rule 7 – Follow Behind" on page 31)
- "Wheel Counting" train detection (see "Wheel-Count Detected Track" on page 78)
- "Entry-Exit" train detection (see "Entry-Exit Detected Track" on page 78)
- SComm command to switch between multiple configurations (such as "Run Day", Card Order", etc.)
- Storage of Controller ID and configuration information in the Base Board as opposed to within the controller itself.
- SComm Track status display available as a web page.
- SComm commands to switch the system between ABS and CTC mode, place Dispatch Holds, activate switch motors, lamp tests, etc.
- Input expansion plug-in module (so more track inputs can be added to a controller)
- Stripped-down "Signal Driver" for use in locations that only contain one or two signal heads (such as Intermediate Signals).

# 30 Train Detection Alternatives

## 30.1 Wheel-Count Detected Track

Some outdoor ride-on scale railroads use track construction methods that do not allow using shunt detection to detect trains. These cases include clubs that use welded steel bar stock rails and welded steel ties.

This may seem straight-forward, but precautions are required to approach the reliability of shunt detection which are not obvious at first glance.

One of the biggest issues that any "wheel counting" system must account for is the case where an axle miss-count occurs due to:

1) Leaves/debris/metal interfering with the axle detector
2) A defective car being removed while the train is in the block
3) A car was shunted onto a siding
4) Etc.

Many people handle miscounts by having a timer that clears the block after being 'occupied' for a given time. There are many cases where this can cause a "false clear" indication, not the least of which is a derailment that causes the timer to expire before the (derailed) train has exited the block.

"False Clear" conditions can cause danger of trains colliding, traffic snarls, deadlocks, etc. causing, at best, frustration, at worst, injury.

"Wheel Counting" train detection is used in some of today's full-size railroads but they use complex rules and procedures to recover from "miss-count" situations. In one case, if a miss-count occurs the block is taken out of service and a train must, while continuously communicating with dispatch, proceed from one end of the block to the other at dead-slow speed to verify that the track is clear.

Wheel-Count track detection is not currently supported but could be added if there is interest in supporting it.

## 30.2 Entry-Exit Detected Track

This is another method of dealing with track that cannot use shunt detection. This method typically uses short (6-12") sections of track at the entry and exit of a section of track to detect trains. In the simplest form it consists of one section and the direction of travel is "assumed" (always dangerous). In more complex forms there are multiple short sections in sequence to allow determining the direction of the train ("quadrature detection") as well as backing up part way through, etc.

This method has the same drawbacks as the "Wheel Counting" method in that it needs to recover (timer again) from things like one train following another into the block and then one of the trains backing out or becoming disabled in the block.

Entry-Exit track detection is not currently supported but could be added if there is interest in supporting it.

## 31 Suggested "Rules" For Visiting Engineers

This is a suggested set of rules to be given to visiting engineers at meets. It tries to be as brief as possible. It assumes that "Track Circuit Blocks" are used (i.e.: not "Button Blocks") and that the default signal aspects are used.

# Signal Guide

The signals are ***fully automatic***. There are no buttons to press, etc. Trains activate the signals by "Track Circuit" detection. The signals are provided to add to realistic operation and provide a level of traffic control. ***The signals are NOT a safety device, the engineer is solely responsible for the safe operation of his train, no exceptions.***

### *The Rules (The Short Version)*

1) **You must never pass a Red signal.** There is one exception noted below.
2) You may proceed on ***Clear*** (Green) or ***Approach*** (Yellow).
3) Always pull up to within a couple of feet of the signal head to request the block – but never **past** a Red signal.

Note the three signal heads shown in the photo to the right.

The single-headed signal in the center is located where you do not have a choice of route (typically proceeding from a siding into a section of bi-directional track).

You will encounter a double-headed signal at locations where you have a route choice. Just prior to the signal will be a post containing a switch you can use to activate the track switch motor controlling the route you will take.

In a double-head signal the upper head indicates the status of the route straight through the switch and the lower head indicates the status of the "turnout" route. The side that the lower head is on indicates the direction of the turnout (i.e.: "left-hand" or "right-hand" switch).

In a double-headed signal, one head will always be Red to indicating that the points are set against this route. The other head will indicate the status of the other route (which may also be Red if that block is occupied, etc.). Note that, after you activate the switch motor, both signals will be Red until the switch points have finished moving to their new position (up to 10 seconds) and that the signal indicates that the points "should" be closed, not that they "are" closed – as always, be sure to visually check all switch points.

If this is your first time at the railroad it is recommended that you take a trip around the railroad with a club member or someone who has been here before.

## More Detailed Info

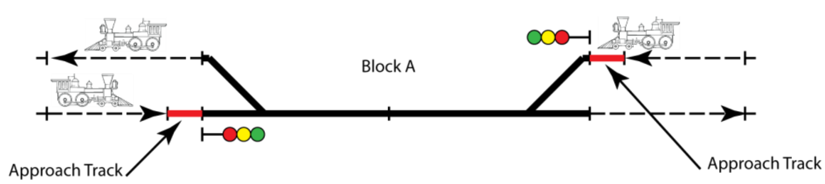
- The track between signal heads is bi-directional.
- The signals will **never** present a **Clear (Green)** or **Approach (Yellow)** aspect to more than one train at a time. Therefore, unless a train passes a **Stop (Red)** signal a "cornfield meet" will never occur.

## Terminology

- **Approach Track:** Immediately in front of each signal head is a section of track called the Approach Track. This section of track is used by the signal system to detect a train that wants to enter a block. Some people refer to this section as the "Claiming Block" because it allows the train to "Claim" (i.e.: obtain sole access to) the block. The beginning of the Approach Track is indicated by an orange tie some distance in front of the signal head. **You must pull up to the signal head, onto the Approach Track, for the signal system to clear you into the block.** If you do not pull up to the signal head trains at the far end of the block will be allowed to proceed because you have not requested the block by placing your train on the approach track.
- **Block Boundaries:** The boundaries of the block are indicated by orange ties at the signal head and at the clearance point on the mainline (nearly) opposite the signal head.

## More Info About Signal Aspects (Indications)

- **Idle Block** — Dim Red that "winks" off once per second. Approach at reduced speed, be prepared to stop.
- **Clear** — Steady bright Green, you may




pass the signal head and enter the block. The signal should turn Red as the locomotive passes the signal (if it does not, please notify a club member).
- **Approach** — Steady Yellow, you may pass the signal head and enter block. The block itself is clear but the track beyond the block is occupied. Be prepared to stop at the end of the block.
- **Stop** — Steady Red, stop is **mandatory**, do **NOT** pass this signal. *Exception: You may follow another train through a **Stop** signal **if, and only if**, you can see the train in front of you. Be aware however that there may not be room for you on the siding at the far end of the block which may require some "sorting out" when you get there.*

- **Abnormal** Blinking Red or other indication not described above. Please notify a club member as soon as possible.
- **Switch Points Against** This is a Red signal that "winks" off twice per second. This is used at a double-headed signal to indicate that the points are set against this route but that the route is currently clear in case you would like to select that direction.

There are many more infrequently seen signal aspects that provide additional information. These are mostly Red signals with different "winking" or "Blinking" sequences that provide more information about why the signal is red. See the signal maintainer for more information.

## Normal Signal Operating Sequence

The following assumes that you are approaching a signal for an unoccupied block:

- Be aware that the signal may change to **Stop** (Solid, bright Red) at any time before you hit the approach track due to another train hitting his approach track first.
- When you are on the approach track, and the block is clear, you will receive a **Clear** (Green) or **Approach** (Yellow) signal. B*e aware that the signal may change to* ***Stop*** *just prior to you hitting the approach track. The signal will also change to* ***Stop*** *if your 20 seconds has expired (see below) or if someone else enters the block without permission (backing into the block at the far end to manage a deadlock, etc.).*
- At the same time you are given the **Clear/Approach** signal, all other signals for the block are changed to **Stop**. Thus, only one train at a time ever has permission to enter the block.
- Upon receiving the **Clear** or **Approach** signal you may proceed. You have 20 seconds to enter the block. If you do not enter the block within 20 seconds, ***and*** there is a train on another approach track, your signal will change to **Stop** and the other train will be given permission to enter the block.
- As you pass the signal head, it will change to **Stop** to confirm that the signal system knows that you have entered the block (all signals for the block now display **Stop** indications). If the signal does not change to **Stop** as you pass the signal head it means that the signal system does not know that you have entered the block. Please notify a club member as soon as possible.
- *Reminder: You must never pass a* ***Stop*** *signal unless you are following another train* ***that you can see*** *ahead of you*.