Modular Signal System

Design Standard Version 2.0.2 (MSS-2)

1. Introduction

The Modular Signal System, or MSS, provides a way to interconnect model train detectors and track-side signals in a modular fashion, for the purpose of animating model railroad signals in response to model train movements. The modular nature of MSS allows for straightforward implementation in any model railroad format or scale, though it is especially applicable to modular model railroads.

1.1. Document Scope

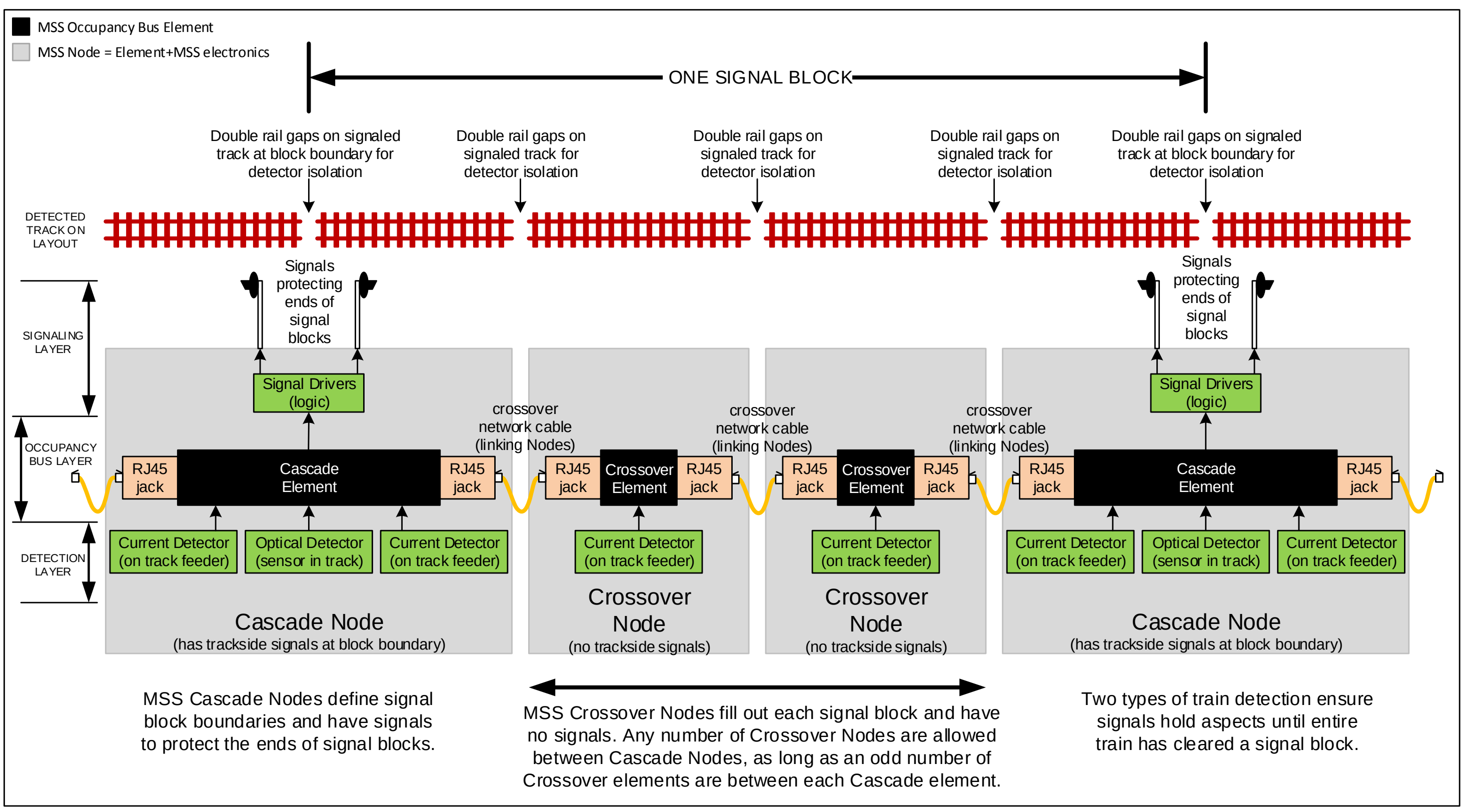
This document defines the Modular Signal System (MSS) Standard Version 2.0. The MSS v2.0 Standards are designed to be compatible with legacy MSS v1.0 implementations, as introduced by Gregg Fuhriman in the February 2005 Rail Model Journal Magazine. Some features of MSS v2.0 might be rendered inoperable if used with MSS v1.0, but no unsafe signal indications will arise.

1.2. Document Conventions

Statements using phrases such as “shall”, “must”, or “required” are requirements of the standard.

Statements using phrases such as “should” or “recommended” are not requirements, but are considered best practices for a functional system.

Statements using phrases such as “may”, “can”, or “acceptable” are not requirements, but are optional practices.



2. Definitions and General Information

2.1. MSS Layers and Elements

The MSS is organized as functional “layers”, each having specific types of elements, as follows:

2.1.1. MSS Occupancy Bus Layer

The MSS Occupancy Bus connects together the MSS Nodes. It has the following eight wires:

- five cascading occupancy wires that carry signal block occupancy status through a model railroad,
- one Approach Diverging wire for junction status,
- two wires for a common ground reference.

The MSS requires the following MSS Occupancy Bus wiring elements:

2.1.1.1. MSS Crossover Element

An MSS Crossover is an MSS Occupancy Bus wiring element in which two pairs of cascading occupancy wires swap connector pin locations, and the Approach Diverging wire passes straight through. This element allows the MSS to function properly regardless of MSS Node orientation in a layout (for example, this allows model railroad modules to be rotated 180 degrees for placement in either orientation in a modular layout). This wiring element occurs within the length of a signal block (between signal block boundaries).

> Note: The term “MSS Crossover” is not to be confused with a railroad track crossover, an arrangement of track and switches for connecting two parallel railroad tracks. The MSS Crossover term defines a wiring pattern only, and has nothing to do with the model railroad track arrangement.

2.1.1.2. MSS Cascade Element

An MSS Cascade is an MSS Occupancy Bus wiring element in which the cascading occupancy wires transfer from one connector pin location to another, and the Approach Diverging wire begins or terminates. This element allows detection information for a given signal block to propagate in a "cascading" fashion through a layout in both directions. This wiring element occurs at the boundary delimiting two signal blocks.

2.1.1.3. MSS Ground

Two wires in the MSS Occupancy Bus are used as a common electrical ground that runs the entire length of the Bus. All MSS electronics are required to connect to this ground to ensure reliable electrical operation.

2.1.1.4. NC

Abbreviation for "not connected".

2.1.1.5. RJ45 Jacks and Plugs

The MSS utilizes robust, low-cost, 8-position, 8-contact (8p8c) modular RJ45 jacks and plugs commonly used for interconnection of Ethernet communication networks.

2.1.2. MSS Detection Layer

The MSS Detection Layer consists of sensors and supporting electronics that detect the presence of trains or other track status (for example, track switch positions). The MSS Detection Layer sends information into the MSS Occupancy Bus Layer. The MSS requires two types of train detectors:

2.1.2.1. Current Detector Element

Current Detectors sense electrical current flowing in track power feeder wires. Their activation relies on train equipment drawing current from the track. Examples of such equipment are powered locomotives and cars with lights powered from the track.

2.1.2.2. Optical Detector Element

Optical Detectors sense when train equipment occupies specific points along the track. Their activation relies on train equipment affecting a light sensor, typically mounted within the track or next to the track.

> Note: The term "Optical Detector" is generalized to mean any type of sensor that uses light to detect an object. For model railroad applications, the type of light is typically either visible light or infrared light, though other wavelengths are possible.

2.1.3. MSS Signaling Layer

The MSS Signaling Layer consists of the model signals located alongside the track and their supporting electronics. The MSS Signaling Layer receives information from the MSS Occupancy Bus Layer.

2.2. MSS Nodes

The term "MSS Node", or just "Node", refers to the collection of MSS Occupancy Bus Layer wiring elements, MSS Detection Layer sensors and electronics, and MSS Signaling Layer model signals and electronics implemented at a specific point in the model railroad layout.

2.2.1. MSS Crossover Node

An MSS Crossover Node always includes at least one MSS Occupancy Bus Crossover wiring element, always includes MSS Detection Layer elements, and never includes MSS Signaling Layer elements.

2.2.2. MSS Cascade Node

An MSS Cascade Node always includes at least one MSS Occupancy Bus Cascade wiring element, always includes MSS Detection Layer elements, and typically includes MSS Signaling Layer elements.

2.2.3. MSS Complex Cascade Node

An MSS Complex Cascade Node is located where the detected track has two or more possible routes determined by the position of track switches. Examples include junctions, double track crossovers, single-to-double detected track transitions, or ends of detected sidings.

An MSS Complex Cascade Node always includes at least one MSS Occupancy Bus Cascade wiring element, always includes MSS Detection Layer elements (including track switch position detection), and typically includes MSS Signaling Layer elements.

2.2.4. MSS Node End Naming Conventions

MSS Nodes always have a minimum of two ends. For reference, these two ends of an MSS Node are designated the “A” end and “B” end.

> Note: This usage is intentionally analogous to the “A” and “B” ends of a railroad car that are functionally identical and interchangeable (except for placement of the brake wheel), but must be differentiated for purposes of construction, maintenance, and repair.

For MSS Nodes having more than two ends (e.g. a junction in the MSS Occupancy Bus), the additional ends are designated “C”, “D”, and so on.

It is recommended that the MSS Node ends be labeled with their letter designation for ease of troubleshooting the MSS. This labeling may be discrete or hidden from general view, but should be readily identifiable to a person working on the MSS Node.

When installed in a layout or module, an MSS Node is generally oriented so that its MSS Occupancy Bus RJ45 jack connectors correspond to the associated detected track at each end of the MSS Node. Likewise, one set of its MSS Detection and MSS Signaling Layer circuits will generally correspond to each detected track at each end of the MSS Node.

3. MSS Layer Requirements

This section details the requirements for each MSS layer to ensure proper operation and interoperability of devices designed for the MSS.

3.1. MSS Occupancy Bus Layer

The MSS Occupancy Bus uses industry standard EIA/TIA 568A/B 8-conductor network cabling for interconnection between MSS Nodes. Both straight-through connected “patch” cables and cross-wired “crossover” cables are used for different purposes in the MSS Occupancy Bus. For crossover cables, all four wire pairs must be present and only the wiring pattern specified in section *3.1.5 MSS Crossover Node Wiring* is allowed. Any other crossover configuration is not allowed.

> Note: Specific information about Ethernet network cable types is provided in *Appendix A: Relevant Ethernet Network Cable Standards*.

3.1.1. MSS Node End Connectors

Each MSS Node shall provide one female RJ45 jack connector per detected track at each Node end for connecting the MSS Occupancy Bus, such that every MSS Node has a minimum of two RJ45 jacks.

> Example 1: An MSS Node supporting one detected track running from one end of the Node to the other end will have a total of two RJ45 jacks – one at the A end and one at the B end.

> Example 2: An MSS Node supporting two parallel detected tracks running from one end of the Node to the other end will have a total of four RJ45 jacks – two at the A end (one for each of the two tracks) and two at the B end (one for each of the two tracks).

> Example 3: An MSS Node supporting a single track wye junction where both branches are detected, or a single-to-double track transition where all tracks are detected, will have a total of three RJ45 jacks – one at each branch of the junction.

> Note: When implemented in a modular model railroad format, for durability it is recommended to use female/female, straight-through-wired RJ45 couplers mounted to each module's endplates and cable-connected to the actual MSS Node RJ45 jacks. Using the RJ45 jacks mounted on an MSS Node circuit board for direct Node-to-Node connection is not recommended, since the MSS Occupancy Bus cable hanging between modules could be accidentally snagged and pulled taught, resulting in damage to the MSS Node hardware. Coupling and uncoupling of an interconnect cable could also be difficult or cause damage to the MSS Node circuit board.

3.1.2. Multiple Detected Tracks

Each detected track shall have its own dedicated and independent MSS Occupancy Bus. Multiple MSS Occupancy Busses may interact with each other at MSS Complex Cascade Nodes (section *4.3. MSS Complex Cascade Nodes*).

> Example: An MSS Node supporting a single track wye junction where both branches are detected, or a single-to-double track transition where all tracks are detected, must "split" a single MSS Occupancy Bus into two MSS Occupancy Busses, requiring appropriate routing of the MSS Occupancy Bus based on the selected route.

3.1.3. MSS Occupancy Bus Element Connection

MSS Cascade elements (including MSS Complex Cascade elements) must connect to each other by an odd number of MSS Crossover elements, with the minimum number of MSS Crossover elements being one.

> Note: When implemented in a modular model railroad format, a module is constructed as either an MSS Crossover Node, or as an MSS Cascade Node, or as a multi-element module having some combination of MSS Crossover and MSS Cascade Nodes.
>
> Modules incorporating MSS Cascade elements must avoid extraneous MSS Crossover elements that, when incorporated into a larger layout, result in violation of the requirement for an odd number of MSS Crossover elements between MSS Cascade elements.
>
> Modules constructed as MSS Crossover Nodes must have an odd number of MSS Crossover elements built in.
>
> All MSS Occupancy Bus inter-module connections must be made using MSS Crossover elements (typically Category 5 crossover network cables, for modularity and ease of layout setup). This arrangement guarantees the required odd number of MSS Crossover elements between MSS Cascade elements, regardless how the modules are arranged.

3.1.4. MSS Occupancy Bus Connector Pin Assignments

The RJ45 jack connector pins shall have the following assignments:

Pin	568A Wire Color	568B Wire Color	Assignment
1	Green/White	Orange/White	Advance Approach In
2	Green	Orange	Approach In
3	Orange/White	Green/White	Advance Approach Out
4	Blue	Blue	Local Block In/Out
5	Blue/White	Blue/White	MSS Ground
6	Orange	Green	Approach Out
7	Brown/White	Brown/White	MSS Ground (default), or alternate functions (see text)
8	Brown	Brown	Approach Diverging In/Out (see text)

Table 1: MSS RJ45 connector pin assignments

Pin 5 shall always be connected to the MSS Ground, without exception.

Pin 7 shall be connected to the MSS Ground by default, when not used for an alternate function. Pin 7 may be used for an alternate function other than MSS Ground as long as the purpose, behavior, and electrical characteristics of the alternate function are disclosed in publicly-available literature.

> Note: Such disclosure could be made in the printed or electronically published Use Instructions of a commercial product, for example.

Pin 8 shall be used for the Approach Diverging feature by default. However, this standard recognizes that some legacy MSS v1.0 implementations connected pin 8 to MSS Ground. There is no requirement to retrofit such implementations for compliance to MSS v2.0, though the optional Approach Diverging feature might not function properly in some situations.

3.1.5. MSS Crossover Node Wiring

Within an MSS Crossover Node, the two RJ45 jack connectors shall be connected as follows:

“A” End Pin	**“B” End Pin**
1	3
2	6
3	1
4	4
5	5
6	2
7	7
8	8

Table 2: MSS Crossover Node RJ45 connector wiring pattern

The pin-outs are symmetrical; therefore, the assignment of “A” vs. “B” end is arbitrary.

> Note: The MSS Crossover wiring pattern is identical to that of a standard EIA/TIA 568A/568B Category 5 or 5e network crossover cable that has all four wire pairs. Therefore such a cable meets the MSS Occupancy Bus wiring requirements of an MSS Crossover Node.

> Note: See Appendix A: Relevant Ethernet Network Cable Standards. Some variants of crossover cables, including EIA/TIA 568A/568B Category 6 cables, do not meet this requirement. Category 5 or 5e cables that have only two wire pairs do not meet this requirement.

3.1.6. MSS Cascade Node Wiring

Within a MSS Cascade Node, when the detected track is configured for train movement through the main or normal route, the wires of the two RJ45 jack connectors shall have the logical relationships as shown in Table 3.

"A" End Pin	"B" End Pin	Notes
(NC)	1	The Advance Approach cascading occupancy wires from both directions terminate at MSS Cascade Nodes
1	(NC)	
2	3	
3	2	
4	6	
5	5	
6	4	
7	7	
(NC)	8	The Approach Diverging wires from both directions terminate at MSS Cascade Display Nodes, and originate at MSS Complex Cascade Source Nodes
8	(NC)	

Table 3: MSS Cascade Node RJ45 jack connector pin logical relationships

> Note: The pin-outs are symmetrical; therefore, the assignment of "A" vs. "B" end is arbitrary.

When the detected track is configured for train movement through other than the main or normal route, the MSS Cascade Node wire relationships may be altered to accommodate prototypical occupancy status routing and signal behavior.

This MSS Standard does not limit or specify the nature of the implementation of MSS Cascade Node circuitry. The implementer is free to use any circuit, provided it meets the requirements of this section, and section *3.2.2. MSS Detection Layer Element Outputs*, and section *3.3.2. MSS Signaling Layer Element Inputs*.

> Example: The status of a track switch position can logically alter the standard MSS Cascade Node RJ45 connector pin relationships at a junction, such as a wye, when the normal route is not selected by the track switch.

MSS Cascade Nodes shall not connect pin 8 from one end to the other and shall not connect the "A" end pin 8 to the "B" end pin 8. Rather, both pin 8 lines shall terminate at the MSS Cascade element for potential use by signals to display Approach Diverging status (section *4.4. Diverging Route Signals*).

Note: This standard recognizes that some legacy MSS v1.0 implementations connected pin 8 to MSS Ground. There is no requirement to retrofit such implementations for compliance to MSS v2.0; however, the optional Approach Diverging feature might not function properly in some situations.

3.2. MSS Detection Layer

MSS Detection Layer elements monitor the state of the detected track and send this status onto the MSS Occupancy Bus. Examples of detected state include:

a) Train presence or absence
b) Track switch position (thrown vs. closed)
c) Dispatcher or Interlocking override

Each signal block of each detected track shall have at least one Current Detector element that creates an active Block Occupied when a train draws current from the track in that block.

Each signal block boundary shall have an Optical Detector element that creates active Block Occupied for both blocks on either side of the boundary when a train is present at the boundary.

When reversed (thrown against the normal route), all track switches on the detected track(s) shall create an active Block Occupied for the block in which they are located.

Note: This may be implemented with a contact on the track switch that connects the pin 4 and pin 5 wires of the local MSS Occupancy Bus connectors, or by placing a current load on the detected track sufficient to activate the Current Detector element for that block.

This MSS Standard does not limit or specify the nature of the detection circuitry. The implementer is free to use any circuit, provided its connection to the MSS Occupancy Bus meets the requirements in section *3.2.1. MSS Detection Layer Element Wiring* and section *3.2.2. MSS Detection Layer Element Outputs*.

3.2.1. MSS Detection Layer Element Wiring

MSS Detection Layer elements shall be grounded to the MSS Ground (MSS Occupancy Bus connector pin 5, and pin 7 when not used for alternate functions).

MSS Detection Layer element outputs shall connect to the MSS Occupancy Bus “Local Block In/Out” wire (pin 4 of the MSS Occupancy Bus connectors at the MSS Node ends).

MSS Detection Layer elements shall not drive any other wire in the MSS Occupancy Bus.

Note: Acceptable methods for implementing detector element outputs include open-collector transistors, electro-mechanical relays, or mechanical switches.

3.2.2. MSS Detection Layer Element Outputs

MSS Detection Layer element outputs shall have the following states:

Function	Output State	Description	Notes
Local In/Out cascading occupancy wire	Low	Active (i.e. Block Occupied – the detected block is occupied by a train, a track switch on the detected track is open/thrown, etc.)	
	Floating	Inactive (i.e. Block Clear – the detected block is not occupied, track switches on the detected track are closed, etc.)	logic high established by pull-up resistor to +12V in MSS Signaling Layer
Approach Diverging wire	High	The Junction at a Complex Cascade Node ("Source Node") is aligned to Diverging route and the first block of the Diverging route is not occupied	logic high established by "Source Node" connecting +12V through 2.2KΩ current-limiting resistor
	Floating	The Junction at a Complex Cascade Node ("Source Node") is aligned to Main route, or the first block of the Diverging route is occupied while the Junction is aligned to Diverging route	logic low established by pull-down resistor to MSS Ground in MSS Signaling Layer of the "Display Node"

Table 4: MSS Detection Layer element output states

MSS Detection Layer element outputs shall have the following electrical characteristics:

Function	Parameter	Unit	Min Value	Nom Value	Max Value	Notes
Driving the Local In/Out cascading occupancy wire	Output voltage, low Vo(l)	V	0	0	0.8	
	Output voltage, high Vo(h)	V	8.0	12.0	12.0	logic high established by pull-up resistor to +12V in MSS Signaling Layer
	Current sink capacity Io(l)	mA	36			Minimum current sink and power dissipation capacity calculated as equivalent to 30 Signaling Layer inputs with 10KΩ pull-up resistors to +12V.
	Power Dissipation	mW	30			Vo = Vo(l)
Driving the Approach Diverging wire	Output voltage, low Vo(l)	V	0	0	2.0	logic low established by pull-down resistors to MSS Ground in MSS Signaling Layer
	Output voltage, high Vo(h)	V	8.0	12.0	12.0	logic high established by connecting +12V through 2.2KΩ current-limiting resistor

Table 5: MSS Detection Layer element output electrical specifications

3.3. MSS Signaling Layer

MSS Signaling Layer elements interpret track status information received from the MSS Occupancy Bus and control track-side signals to display the appropriate indications.

The minimum required signal indications for the MSS are:

- Clear
- Approach
- Stop

The MSS also supports these optional signal indications:

- Clear with Approach Light
- Advance Approach
- Approach Diverging

Additional indications are allowed, as long as they do not conflict or interfere with the display of those listed above.

This MSS Standard does not limit or specify the nature of the MSS Signaling Layer element logic or drive circuitry, the model track-side signals, or the aspects used to display the indications. The implementer is free to use any circuit, provided its connection to the MSS Occupancy Bus meets the requirements of section *3.3.1. MSS Signaling Layer Element Wiring* and section *3.3.2. MSS Signaling Layer Element Inputs*.

3.3.1. MSS Signaling Layer Element Wiring

MSS Signaling Layer elements shall be grounded to the MSS Ground (MSS Occupancy Bus connector pin 5, and pin 7 when not used for alternate functions).

Each MSS Signaling Layer element has the following inputs available from the MSS Occupancy Bus:

MSS Occupancy Bus RJ45 Jack Pin	MSS Signaling Layer Input Function
1	Occupancy status for two blocks ahead (i.e. Advance Approach)
2	Occupancy status for one block ahead (i.e. Approach)
4	Occupancy status of the Local block (i.e. Stop)
8	Diverging route status of MSS Complex Cascade Node one block ahead (i.e. Approach Diverging)

Table 6: MSS Signaling Layer input functions

> Example: An MSS Cascade Node has an "A" end RJ45 connector on one side and a "B" end RJ45 connector on the other side. The pins of the "A" end connector provide the status listed in Table 6 to a signal element facing away from the "A" end connector. And, the pins of the "B" end connector provide the status listed in Table 6 to a signal element facing away from the "B" end connector.
>
> Note: Because signals are located at MSS Cascade Nodes in the MSS Occupancy Bus, there are additional wires available that may be used for optional features such as approach lighting.

3.3.2. MSS Signaling Layer Element Inputs

MSS Signaling Layer element inputs shall conform to these electrical requirements:

a) Meet logic level definitions and voltage specifications per section *3.2.2. MSS Detection Layer Element Outputs*;
b) Have one pull-up resistor of 10KΩ minimum, 100KΩ maximum to +12V on each cascading occupancy wire input that is used to determine signal indications (i.e. Local In/Out, Approach, and Advance Approach);
c) Have one pull-down resistor of 10KΩ minimum, 100KΩ maximum to MSS Ground on each Approach Diverging wire input when used to determine signal indications;
d) Draw no more than 2 mA current per input.

Note: signal drivers are required to have pull-up and/or pull-down resistors only on occupancy bus wires that they actually use to determine signal indications.
Example 1: if the Advance Approach occupancy wire is not used by a signal driver, that driver is not required to have a pull-up resistor on the Advance Approach occupancy wire.
Example 2: if the Approach Diverging wire is not used by a signal driver, that driver is not required to have a pull-down resistor on the Approach Diverging wire.

MSS Signaling layer element inputs shall have the following electrical characteristics:

Function	Parameter	Unit	Min Value	Nom Value	Max Value
Receiving the five cascading occupancy wires	Input voltage, low Vi(l)	V	0	0	0.8
	Input voltage, high Vi(h)	V	8	12	12
Receiving the Approach Diverging wire	Input voltage, low Vi(l)	V	0	0	2.0
	Input voltage, high Vi(h)	V	8	12	12
Receiving any Occupancy Bus wire	Current input, Iin	mA			2
	Resistance input, Rin	Ω	10K		100K

Table 7: MSS Signaling Layer element input electrical characteristics

4. MSS Node Requirements

This section details the requirements for each type of MSS Node to ensure proper operation and interoperability.

4.1. MSS Crossover Node

4.1.1. MSS Occupancy Bus Layer

Every MSS Crossover Node must have:

a) One, and only one, MSS Crossover wiring element per section *3.1.5. MSS Crossover Node Wiring*.
b) RJ45 jack connectors per section *3.1.1. MSS Node End Connectors*.

Directly shorting together occupancy wires of the MSS Occupancy Bus within an MSS Crossover Node is forbidden. The wiring implementation must maintain electrical isolation among the occupancy wires.

4.1.2. MSS Detection Layer

Tracks other than the detected track (e.g. sidings and spurs) shall not be detected.

Each detected track requires a minimum of one Current Detector. The Current Detector output shall connect to the MSS Occupancy Bus “Local Block In/Out” (pin 4 of the RJ45 jacks).

> Note: additional Current Detectors are allowed to accommodate more complex detected track configurations.
>
> Note: Optical Detectors in MSS Crossover Nodes are allowed (e.g. in situations where non-powered train equipment must be sensed on the detected track). The detector output shall connect to the MSS Occupancy Bus “Local Block In/Out” (pin 4 of the RJ45 jacks).

4.1.3. MSS Signaling Layer

MSS Crossover Nodes shall not implement the MSS Signaling Layer.

4.2. MSS Cascade Node

MSS Cascade Nodes are placed at signal block boundaries, i.e. the locations in a model railroad layout where one signal block ends and the next begins. This implies that the detected track on either side of the block boundary (and MSS Cascade wiring element) must have independent train detection (i.e. via two separate Current Detectors). This in turn means that both track rails must be gapped at the block boundary to prevent current flow through the rails from one block to the other. And, the entire length of a train must be detected at the block boundary (i.e. via an Optical Detector) to ensure the track-side signals hold their indications until the entire train clears the block boundary.

4.2.1. MSS Occupancy Bus Layer

Every MSS Cascade Node must have:

a) One, and only one, MSS Cascade wiring element per section *3.1.6. MSS Cascade Node Wiring*.
b) RJ45 jack connectors per section *3.1.1. MSS Node End Connectors*.

Directly shorting together occupancy wires of the MSS Occupancy Bus within an MSS Cascade Node is forbidden, except as specified in section *3.1.6. MSS Cascade Node Wiring*. The wiring implementation must maintain electrical isolation among the occupancy wires.

4.2.2. MSS Detection Layer

Tracks other than the detected track (e.g. sidings and spurs) shall not be detected.

4.2.2.1. MSS Cascade Node Current Detection

Each detected track requires a minimum of two Current Detectors – one to monitor track current on the “A” end side of the signal block boundary rail gaps, and the second to monitor track current on the “B” end side of the block boundary rail gaps.

The “A” end Current Detector output shall connect to the MSS Occupancy Bus “Local Block In/Out” on the “A” end (pin 4 of the “A” end RJ45 jack).

The “B” end Current Detector output shall connect to the MSS Occupancy Bus “Local Block In/Out” on the “B” end (pin 4 of the “B” end RJ45 jack).

> Note: additional Current Detectors are allowed to accommodate more complex detected track configurations.

All tracks at the signal block boundary must have gaps in both rails, thereby isolating the Current Detectors located to either side of the block boundary by preventing track power current from flowing through the rails across the block boundary.

4.2.2.2. MSS Cascade Node Optical Detection

A minimum of one Optical Detector sensor is required per detected track, and shall be located on the detected track at or near the signal block boundary rail gaps. This ensures the associated track-side signals hold their indications until the entire train clears the block boundary.

Each Optical Detector shall drive a Block Occupied status for both the "A" end and "B" end blocks, but maintain electrical isolation between the two MSS Occupancy Bus “Local Block In/Out” wires.

One method is to use a pair of diodes (1N4001 or similar) such that:

- the cathodes (“-“ pin) of both diodes connect to the Optical Detector output;
- the anode (“+” pin) of one diode connects to the MSS Occupancy Bus “Local Block In/Out” on the “A” end (pin 4 of the “A” end RJ45 jack);
- the anode (“+” pin) of the second diode connects to the MSS Occupancy Bus “Local Block In/Out” on the “B” end (pin 4 of the “B” end RJ45 jack).

Logic circuits or processor control may also be used as long as both blocks are set to occupied and isolation between the two MSS Occupancy Bus “Local Block In/Out” wires is maintained.

> Note: additional Optical Detectors are allowed to accommodate more complex detected track configurations.

4.2.3. MSS Signaling Layer

An MSS Cascade Node may include any number of MSS Signaling Layer elements. Signaling Layer element input circuitry shall incorporate pull-up and/or pull-down resistors per section *3.3.2 MSS Signaling Layer Element Inputs.*

For MSS Cascade Nodes that support the optional Approach Diverging indications, refer to section *4.4.2. MSS Signaling Layer at Display Nodes* for additional requirements.

4.3. MSS Complex Cascade Nodes

MSS Complex Cascade Nodes are located at signal block boundaries where the detected track has two or more possible routes determined by the position of track switches. Examples include junctions, double track crossovers, single-to-double track transitions, or ends of detected sidings.

When the track switches associated with an MSS Complex Cascade Node are aligned for a route between two endpoints, that route is designated as “active”. When any track switch is aligned to not allow movement on a route, that route is designated as “inactive”.

4.3.1. MSS Occupancy Bus Layer

Eeach MSS Complex Cascade Node active route shall have:

a) One MSS Cascade per section *3.1.6. MSS Cascade Node Wiring*, with pin 8 left open on both ends except as provided in section *4.4. Diverging Route Signals*;
b) One RJ45 jack connector for each route entering the Node, per section *3.1.1. MSS Node End Connectors*.

Directly shorting together MSS Occupancy Bus occupancy wires within an MSS Complex Cascade Node is forbidden, except as specified in section *3.1.6. MSS Cascade Node Wiring*. The wiring implementation must maintain electrical isolation among the occupancy wires.

4.3.2. MSS Detection Layer

Tracks other than the detected track (e.g. sidings and spurs) shall not be detected.

Each detected route into an MSS Complex Cascade Node must have independent train detection. And the entire length of a train must be detected at each signal block boundary to ensure the track-side signals hold their indications until the entire train clears the block boundary.

An inactive route shall drive pin 6 “Approach Out” of both RJ45 jacks to logic low (Block Occupied), except for RJ45 jacks associated with another active route.

If Interlocking or Dispatcher control has set the entrance signal for a route to Stop, that entrance point shall be considered inactive, and pin 6 “Approach Out” of the associated RJ45 jack shall be driven to logic low (Block Occupied).

> Note: Pin 6 must be driven logic low to provide a safe Approach indication on distant signals that do not support the optional Approach Diverging indication.

4.3.2.1. MSS Complex Cascade Node Current Detection

A minimum of three Current Detectors are required:

a) one to monitor detected track current on the "A" end side of the block boundary rail gaps;
b) a second to monitor detected track current on the "B" end side of the block boundary rail gaps;
c) additional detectors to monitor detected track current on each additional end point.

The "A" end Current Detector output shall connect to the MSS Occupancy Bus "Local Block In/Out" on the "A" end (pin 4 of the "A" end RJ45 jack).

The "B" end Current Detector output shall connect to the MSS Occupancy Bus "Local Block In/Out" on the "B" end (pin 4 of the "B" end RJ45 jack).

Each additional Current Detector shall connect to its associated MSS Occupancy Bus "Local Block In/Out" (pin 4 of that end's RJ45 jack).

> Note: additional Current Detectors are allowed to accommodate more complex detected track configurations.

All tracks at the signal block boundary must have gaps in both rails, thereby isolating the Current Detectors located to either side of the block boundary by preventing track power current from flowing through the rails across the block boundary.

4.3.2.2. MSS Complex Cascade Node Optical Detection

A minimum of one Optical Detector sensor is required for each possible route through the MSS Complex Cascade Node, and shall be located on the detected track at or near the signal block boundary rail gaps. This ensures the associated track-side signals hold their indications until the entire train clears the block boundary.

It is permissible for an Optical Detector to serve more than one route as long as it affects only the presently active route ends.

Each Optical Detector shall drive a Block Occupied status for both ends of the route it serves, but maintain electrical isolation between the two MSS Occupancy Bus "Local Block In/Out" wires.

One method is to use a pair of diodes (1N4001 or similar) such that:

- the cathodes ("-" pin) of both diodes connect to the Optical Detector output;
- the anode ("+" pin) of one diode connects to the MSS Occupancy Bus "Local Block In/Out" on the "A" end (pin 4 of the "A" end RJ45 jack);
- the anode ("+" pin) of the second diode connects to the MSS Occupancy Bus "Local Block In/Out" on the "B" end (pin 4 of the "B" end RJ45 jack).

Logic circuits or processor control may also be used as long as both blocks are set to occupied and isolation between the two MSS Occupancy Bus "Local Block In/Out" wires is maintained.

> Note: additional Optical Detectors are allowed to accommodate more complex detected track configurations.

4.3.3. MSS Signaling Layer

An MSS Complex Cascade Node may include any number of MSS Signaling Layer elements. Signaling Layer element input circuitry shall incorporate pull-up and/or pull-down resistors per section *3.3.2 MSS Signaling Layer Element Inputs.*

4.4. Diverging Route Signals

Diverging indications are optional for the MSS. However, when implemented, the requirements of this section must be met.

For the purposes of the MSS:

- "Diverging indication" means any signal displaying Diverging Clear or Diverging Approach, or (if speed signaling is used) any signal displaying Medium Clear, Medium Approach, Limited Clear, or Limited Approach.
- "Approach Diverging" means Approach Medium.
- Indications for Slow Clear, Slow Approach, and Restricting are treated as Stop indications.

> Note: Aspects, names, and indications vary greatly among prototype railroads. If the railroad modeled uses other names, it is up to the end user to determine which should be considered "Diverging" and "Approach Diverging" for their MSS implementation.

4.4.1. MSS Detection Layer at Source Nodes

When any route into an MSS Complex Cascade Node (the "Source Node") is displaying a Diverging indication, and no other indication, the MSS Complex Cascade Node shall drive pin 8 (the Approach Diverging output) of the associated RJ45 jack connector to +12 volts through a resistance of 2200 ± 10% ohms.

> Note: Some legacy MSS v1.0 implementations connected pin 8 to MSS Ground. Therefore, MSS Complex Cascade Node circuitry connected to pin 8 must withstand a direct short to ground in case it is connected to an MSS v1.0 Node. In such a case, the Approach Diverging feature will not be available for use by distant signals.

When the MSS Complex Cascade Node (the "Source Node") is displaying a Diverging indication, the MSS Complex Cascade Node shall drive pin 6 (Approach Out) of the associated RJ45 jack connector to logic low.

> Note: Pin 6 must be driven to logic low to provide a safe Approach indication on distant signals that do not support the optional Approach Diverging indication.

4.4.2. MSS Signaling Layer at Display Nodes

MSS Cascade or Complex Cascade Nodes optionally can display Approach Diverging indication on any or all signals (the "Display Node"). When Approach Diverging indication is desired, pin 8 of the associated RJ45 jack connector must have a pull-down resistance to MSS Ground of between 10K ohms and 100K ohms (and must not have a pull-up resistance to +12 volts).

When supported by the Display Node, signaling logic must be arranged so that Approach Diverging indication supersedes Approach indication, and Stop indication supersedes all other indications.

> Note: The logic must be as above since the Source Node, when displaying a Diverging indication, will output active low on its Approach Out wire simultaneously with logic high on its Approach Diverging output wire. This is necessary so that a safe Approach

indication is displayed on Display Nodes that do not support the optional Approach Diverging indication.

Example: When the "Source Node" Junction is set to the Diverging route and no trains occupy the Diverging route, it pulls its Approach Diverging output high to +12 volts (diverging) and drives its Approach Out to logic low (active). However, if a train does occupy the diverging route, the "Source Node" leaves its Approach Diverging output floating (not pulled up to +12 volts); the distant "Display Node" that monitors the Approach Diverging wire pulls it to logic low through the required pull-down resistor in its Signaling Layer per section *3.3.2 MSS Signaling Layer Element Inputs*.

5. System Requirements

This section defines requirements and best practices for track, track power wiring, and detection.

5.1. MSS Detection Layer

There shall be at least one Current Detector for each signal block of detected track on the signaled portion of the layout.

There shall be an Optical Detector at each signal block boundary.

5.2. Track and Track Power

Each detected block of track shall be electrically isolated from adjacent detected blocks by gapping both rails to prevent current from flowing across block boundaries through the rails.

All track power feeder wires for a block of detected track shall be current detected.

Note: A detected track with multiple parallel power feeders must be wired such that all current paths to the track are detected. It is recommended that the parallel feeders be brought to a common sub-bus wire and the Current Detector installed on the sub-bus wire.

Appendix A: Relevant Ethernet Network Cable Standards

The MSS uses standard Category 5 or 5e network cables as defined by the TIA/EIA 568 Standard, commonly used for Ethernet networks. These are the familiar cables used to connect most computers with most common networking hardware, and are readily available from a number of retail outlets.

The wires in a TIA/EIA 568 Category 5 or 5e cable are arranged as four twisted pairs. Each pair has one wire with a solid color (green, blue, orange or brown) and a matching color/white striped wire (green/white, blue/white, orange/white or brown/white).

> Note: Cables with only two wire pairs are available on the market – such cables cannot be used in the MSS.

TIA/EIA 568 defines two types of connector pin arrangements, designated 568A and 568B:

Pin	568A Wire Color	568B Wire Color
1	Green/White	Orange/White
2	Solid Green	Solid Orange
3	Orange/White	Green/White
4	Solid Blue	Solid Blue
5	Blue/White	Blue/White
6	Solid Orange	Solid Green
7	Brown/White	Brown/White
8	Solid Brown	Solid Brown

Table A-1: EIA/TIA 568A and 568B wire colors

With these two connector pin arrangements, two types of cables with three different wire color patterns are defined.

TIA/EIA 568A/568A or 568B/568B "Straight-through" or "Patch" cables

A cable with matching pin-outs at both ends, either 568A/568A or 568B/568B, is called a "straight-through", "patch", or "standard" cable. Each wire is connected to the same pin on both ends of the cable.

Straight-through cables are the most commonly available network cables, and are the kind most often used to connect computers to computer networks. While the end-connector wire color arrangements are different between 568A/568A and 568B/568B cables, they are electrically identical and thus interchangeable in practical use.

For the MSS implemented in modular model railroads, straight-through (patch) network cables are sometimes used to extend an MSS Node to the module's end plates, where female/female RJ45 couplers are mounted for connection to the adjacent modules using crossover cables.

TIA/EIA 568A/568B “Crossover” cables

A network cable with 568A pin-out on one end and 568B pin-out on the other end is called a “crossover” cable. Crossover cables are used to directly connect one computer to another using Ethernet networking. They are less common than straight-through (patch) cables, but are readily available.

Category 5 or 5e crossover cables used in the MSS connect pins 4, 5, 7, and 8 straight through, but swap pins 1 and 3 and pins 2 and 6 from one end to the other.

> Note: Crossover cables with other wiring variations are available on the market and might be labeled as Category 5, 5e, 6, or 7 – such cables cannot be used in the MSS because the MSS Occupancy Bus relies on pins 4, 5, 7, and 8 being wired straight through all cables.

For the MSS, the cable connections between MSS Nodes must be crossover cables having all four wire pairs connected as described above. Cables with only two wire pairs cannot be used, and straight-through (patch) cables cannot be used.

For the MSS implemented in modular model railroads, two crossover cables (instead of two straight-through cables) can be used to extend an MSS Crossover Node in both directions to the module’s end plates, where female/female RJ45 couplers are mounted for connection to the adjacent modules using crossover cables. This results in an odd number of MSS Crossover elements within the module, which meets MSS requirements.

Note that crossover cables cannot be used to extend MSS Cascade Nodes to a module’s endplates - this could result in an even number of MSS Crossover elements between MSS Cascade elements, which violates the MSS requirement for an odd number of MSS Crossover elements between MSS Cascade elements.

Network cables are available in many different jacket colors. The jacket color of a network cable does not indicate whether it is a crossover or straight-through cable. The best way to determine the type of a given cable is to visually compare the wire patterns of its two RJ45 end connectors, or use a cable testing device.

Appendix B: Automatic Block Signaling

Automatic Block Signaling, or ABS, is a relatively simple train control signal system that gives the train engineer information about the occupancy of the track ahead, and therefore about how he should proceed with his train. Implementation varied over time and across railroads, but a simple, generic example implementation is described here for reference and to help make the MSS specifications more understandable.

The following description does not conform to any particular railroad signaling system, and has been simplified to bring out the key points of a speed-based ABS signaling system for understanding of how the MSS works.

In an ABS system, the mainline track is divided into sections called “blocks”. Each block is usually, but not necessarily, long enough to hold a single train and the control system works to ensure that (with certain exceptions) only one train occupies a given block at any time.

Electrical circuits are installed on each block to detect the presence of a train within that block. At each block boundary a signal is installed which is capable of showing one of several signal indications that convey needed information to the train engineer. In a typical simple ABS system, four basic indications are presented based on occupancy of the track ahead:

Indication	**Meaning**
Stop	Next track block is occupied. Stop and do not pass the signal.
Approach	The next signal displays STOP. Proceed prepared to stop at the next signal.
Advance Approach	Slow to “Medium” speed. Expect an “Approach” indication at the next signal.
Clear	Track ahead is clear for at least 3 blocks. Proceed at up to maximum allowed speed.

Table B-1: Example ABS signal indications and associated rules

The precise meanings (and names) of “Slow”, “Medium”, and “maximum allowed” (or “track”) speed are usually spelled out in the railroad’s Employee Timetable. Generally speaking, “Slow” speed is no faster than the engineer can go and still be able to stop for any obstruction on the track, usually not more than 10-15MPH depending on the track conditions and geometry, and the type of train. “Medium” speed is often around 25-35MPH, and “track speed” can be anywhere from 40MPH or higher, depending on track conditions and type of train.

The actual color(s) and arrangement of lights or flags on the signal itself is known as the signal “aspect”. Signal aspects vary widely across eras and railroads. This simplified example ABS system uses four aspects as follows:

Indication	**Aspect**
Stop	Red
Approach	Yellow
Advance Approach	Flashing Yellow
Clear	Green

Table B-2: Example signal indications and aspects

Aspects may take the form of a set of three separate lights (red, yellow, green) or a single multi-color "searchlight" capable of showing all three colors. The most common arrangement is a vertical set of three lights usually in the order red, yellow, green from bottom to top, resembling an upside-down automobile stoplight and known as a "color light signal".

There is a large variety of other signal aspect systems, including color position lights, position lights, semaphores, and so on.

In some cases, trains may be permitted to pass a Stop signal at no more than "restricted speed" after coming to a full stop. This rule (and any exceptions) is usually spelled out in the Employee Timetable.

In some areas, the "Advance Approach" indication (and rule) is not used. Advance Approach gives fast freights and passenger trains more time to slow when catching up to a slower train ahead, and in some cases allows them to keep moving without having to come to a complete stop and wait for the track ahead to clear. If Advance Approach is not used, then Clear only indicates that two blocks ahead (vs. three) are clear.

The specific indication that a signal shows depends upon the occupancy of the block immediately beyond the signal, the next block beyond that one, and in places where Advance Approach is used, two blocks ahead. Table B-3 shows the relationship between the block occupancy and the signal indication shown. The MSS is designed to provide the information needed for a signal and its associated electronics to display these aspects and indications with a minimal amount of logic, and to allow for adding logic to show more complex aspects and indications.

Track Occupation			**Signal State**	
Next Block	**1 Block Ahead**	**2 Blocks Ahead**	**Indication**	**Aspect**
Occupied	(don't care)	(don't care)	Stop	Red
Clear	Occupied	(don't care)	Approach	Yellow
Clear	Clear	Occupied	Advance Approach	Flashing Yellow
Clear	Clear	Clear	Clear	Green

Table B-3: Track occupancy and signal state

Document Revision History

Document Rev	Changes
v2.0.2 09/30/16	Clarifications of pull-up and pull-down resistors required in the Signaling Layer on inputs used by signal drivers to determine signal indications (sections 2.1.1, 3.2.2, 3.3.2, 4.2.3, 4.3.3); enhanced and consolidated voltage specifications in sections 3.2.2 and 3.3.2; Notes column added in section 3.1.6 for clarification; example added to section 4.4.2; minor spelling, syntax, and formatting cleanups.
v2.0.1 12/09/15	Updates to sections 3.1, 3.1.5, and Appendix A to clarify that only the most commonly available CAT 5/5e crossover cable wiring pattern can be used in the MSS; other crossover wiring variants cannot be used with MSS. Updates to sections 4.4.1 and 4.4.2 to clarify Approach Diverging behavior and requirements.
v2.0.0 10/23/15	Initial release