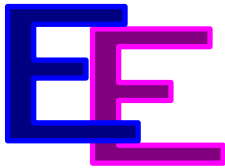


Eckert Engineering's Booklet on the
**Electrical Aspects of a
Märklin HO Layout**



Eckert Engineering

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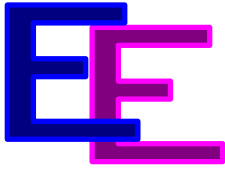
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Eckert Engineering's Booklet on the Electrical Aspects of a Märklin HO Layout

I wrote this booklet in the hope of answering many of the electrical questions related to building a Märklin HO layout. Although geared towards building a conventional layout, many of the topics are applicable to building a digital layout as well. *Tim Eckert*

Table of Contents

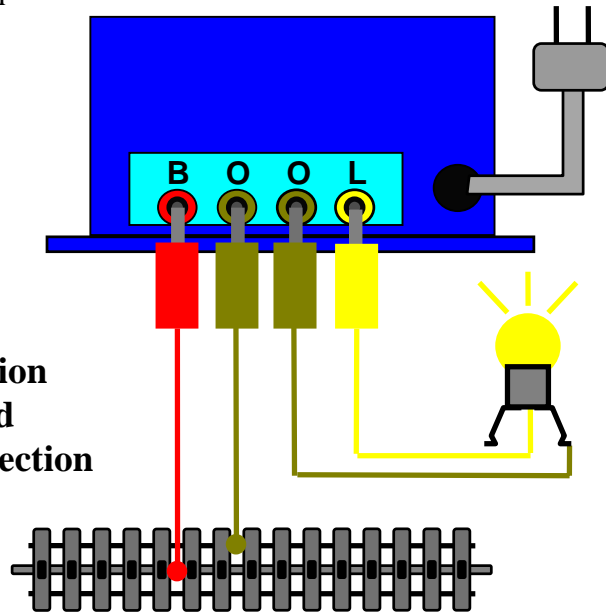
Sect.	Topic	Page #
1.0	Connections on a Typical Märklin Transformer	3
2.0	The 280A Transformer with 6 Sockets	3
3.0	Using Multiple Feeder Tracks With 7209 Distribution Strips	4
4.0	An Alternate Wiring Bus and Loom Arrangement	5
4.1	Bus	5
4.2	Looms	6
5.0	Using 7072 Control Box to Operate Solenoid Devices	7
6.0	The Signal and Its Block	8
6.1	Home Signal Basics	8
6.2	Distant Signal Basics	9
6.3	Märklin Signal Model Numbers	9
6.4	Signal Control of a Catenary Block	10
7.0	Using Circuit Tracks to Operate Signals	10
7.1	Introduction to Circuit Tracks	10
7.2	Circuit Track Basics	11
7.3	Automatic Train Control	11
8.0	Multiple Transformers on Layouts	12
8.1	The Phenomena of Polarity	12
8.2	Why Be Concerned about Correct Polarity?	13
8.3	Polarity Test Procedure	14
8.4	Transformer Assignments on Medium & Larger Layouts	15

Please feel free to call with any questions that you might have, and don't hesitate to offer suggestions, corrections, (?? appreciation ??) at the address or phone numbers below:

	<h2 style="margin: 0;"><i>Eckert Engineering</i></h2> <p style="margin: 0;">c/o Timothy Eckert 8721 High Ridge Lane Concord NC 28027 days 704 547-6058 fax 704 547-6035 evenings and weekends 704 784-4387 email EckertT@epri.com</p>
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1.0 Connections on a Typical Märklin Transformer

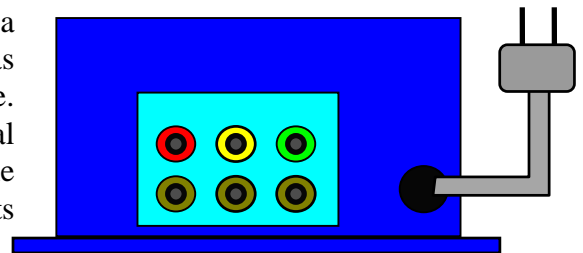
Shown is a typical Märklin transformer. Depending on model, there are 3 or 4 colored sockets on the back for connection to the layout. The brown socket(s) goes to the layout ground (i.e., the two rails of the track), the red socket (variable train power) goes to the middle rail (3rd rail) of the track, and the yellow socket goes to various devices that need power, either continuously or on demand. The figure below shows a schematic view of these transformer sockets hooked up to a simple Märklin HO train layout. The transformer has 4 sockets, the 2 brown sockets are connected internally.



- B = Bahn** = Train Connection
- 0 = (Zero Potential)** = Layout Ground
- L = Licht** = Lighting Connection

2.0 The Model 280A Transformer with 6 Sockets

The 280A transformer has 30 VAs (watts) of power and a very nice metal casing. Some 280As have 3 sockets as described above, but others have 6 sockets as shown here. These are **highly desirable** as they have an additional voltage, and a very attractive plate with function Icons. The outputs are described in the table below. The brown sockets are connected internally.



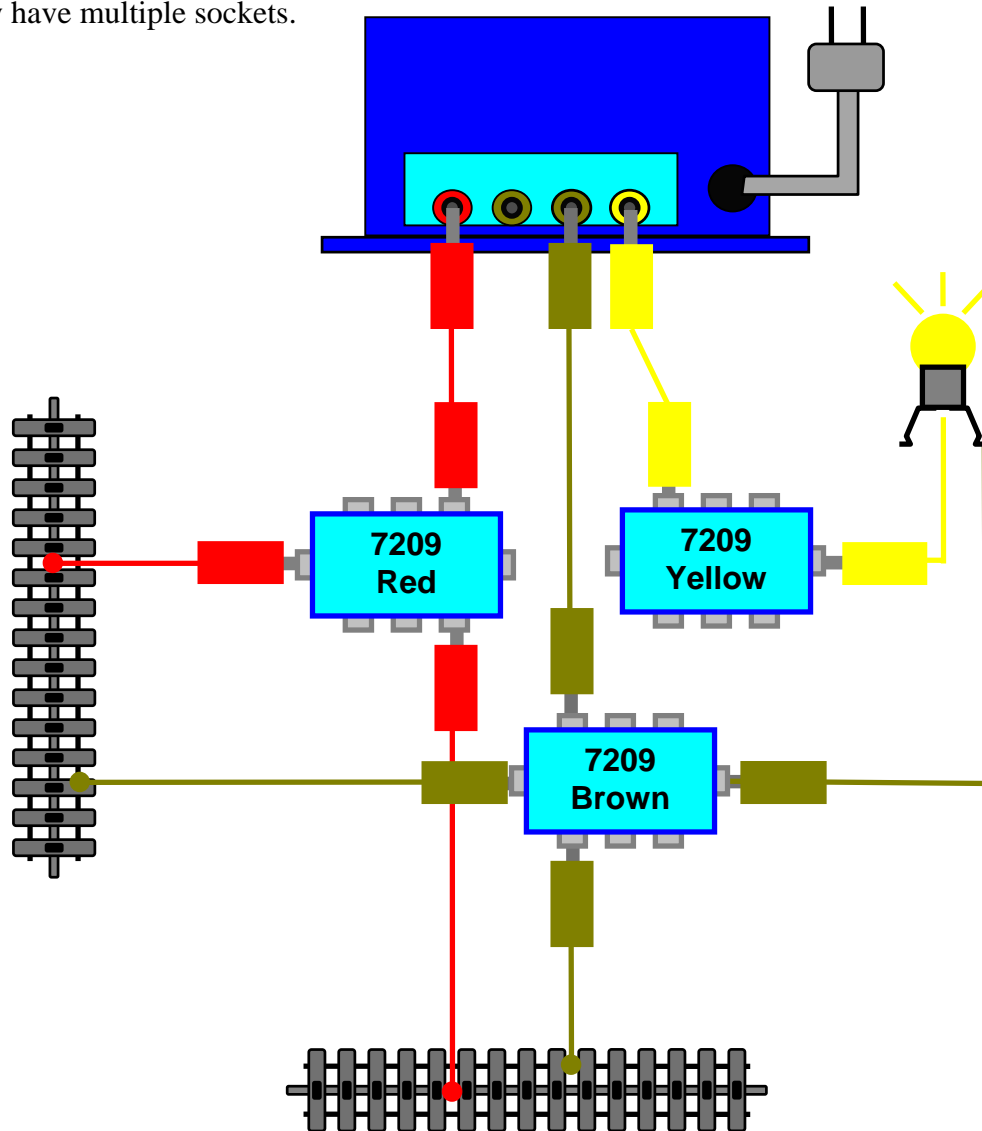
Socket Color	Function	Voltage (Relative to Brown Socket)
Red	Train Power, Variable Speed	0, 4-16 VAC, 24 VAC pulse
Yellow	Constant Power for Lighting	16 VAC
Green	Constant Power for Older Solenoid Devices (that need more voltage to change.)	24 VAC
Brown	Ground for all 3 above circuits.	Ground

3.0 Using Multiple Feeder Tracks With 7209 Distribution Strips

To avoid a series of voltage drops in the track (the cause for a train going slower as it gets farther from the transformer connection), close attention must be paid to good track connections at both the rail joiners and third rail connectors. In addition, multiple track feeders are recommended to minimize track voltage drop. Layouts built by *Eckert Engineering* typically feature a feeder every 7 pieces of track.

Feeder tracks are also installed before and after each block section. Of course, the block section must have a feeder, which gets its power from the signal. (Refer to Section 6.0.)

The 7209 distribution strips (7069 are similar) can be used to help distribute the current to many locations. They have multiple sockets.



In a well-designed layout, there will be a network of wires (referred to as “buses”) for each of the circuits. In the above example, there is a red track power bus, a yellow lighting / solenoid power bus, and a brown ground bus.

4.0 An Alternate Wiring Bus and Loom Arrangement

In Section 3.0, it was shown how 7209 Distribution Strips can be used to help distribute the current to multiple locations. That arrangement has the advantage of being easy for the beginner layout builder, as no soldering is necessary. All connections are mechanical; i.e., wires are attached to plugs with a screw, and plugs stick into sockets with a tight press fit. However, these same advantages (to the beginner) become disadvantages on a large permanent layout:

- Plugs can often come off the wires.
- Plugs can work loose from sockets.
- The ‘mechanical’ connections can have electrical resistance, and can corrode.

4.1 Bus In building many Märklin HO layouts for myself and for customers, I have developed an Alternate Wiring Bus Arrangement. The term “bus” is used to refer to an easily accessible electrical conductor, or place to connect wires. The bus is routed all over, under the layout, usually underneath the path used for the main lines of the train tracks, to yards, to the control panel area of the layout, and any other area that will have features that need to make connections (i.e., a city with lots of lighted buildings.) This bus is constructed of heavy gauge wire so that voltage drops are negligible. There is a separate wire for each of the circuits, and a ground wire. EE always uses and recommends a common ground for all circuits. Below are specifications for a bus for a conventional layout, and for a digital layout.

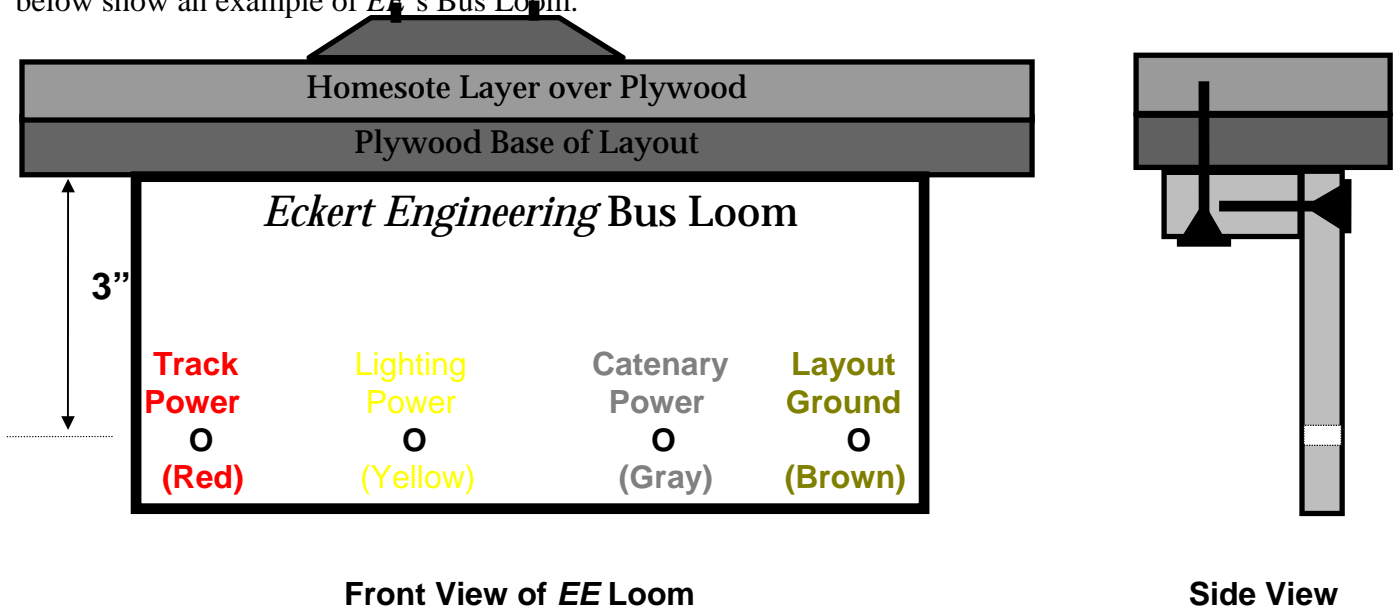
Table 4.1, Wiring Bus for Conventional Layout		
Circuit	Wire Type / Size	Color Coding
Track Power	Bare Multi-Strand Copper / 16 AWG	Red
Catenary Power	Bare Multi-Strand Copper / 16 AWG	Gray
Lighting Power	Bare Multi-Strand Copper / 16 AWG	Yellow
Ground	Bare Multi-Strand Copper / 14 AWG	Brown
<i>On a layout featuring older Märklin accessories and the Model 280A transformer with 6 sockets (see Section 2.0), an additional circuit for the Accessories, with 24 VAC and Green color coding would be appropriate.</i>		

Bare wire is specifically chosen; it avoids having to strip off the insulation at the many places required when wiring a large layout. Not only is the stripping process tedious, it allows the opportunity to make undesirable nicks in the conductor.

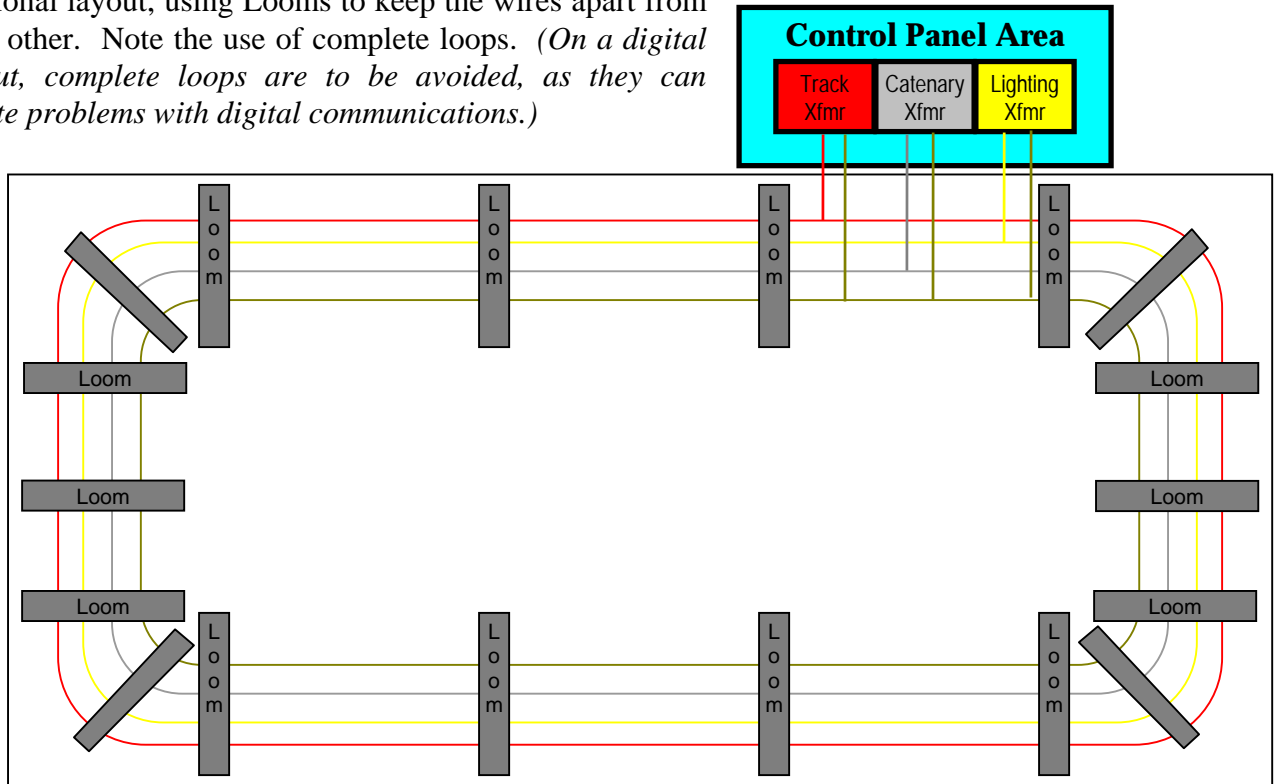
Table 4.2, Wiring Bus for Digital Layout		
Circuit	Wire Type / Size	Color Coding
Digital Track Power	Bare Multi-Strand Copper / 16 AWG	Red
Digital Catenary Power	Bare Multi-Strand Copper / 16 AWG	Gray
Digital Control Power	Bare Multi-Strand Copper / 16 AWG	White
Non-Digital Lighting Pwr	Bare Multi-Strand Copper / 16 AWG	Yellow
Ground	Bare Multi-Strand Copper / 14 AWG	Brown

The Ground circuit uses bigger wire due to it being the common return for all other circuits.

4.2 Looms The multiple wires of the bus are run in parallel paths with each other, via “looms”, and are clearly marked for which circuit they are (their order is not critical). A loom is simply a piece of hardwood with a hole drilled for each wire. These looms are placed at corners and at about every 3 feet on straight runs. Looms are attached firmly to the bottom side of the layout with screws, in a position to keep the bus wires about 3 inches away from the bottom side of the layout. This 3-inch clearance protects the bus wires from damage when drilling holes through the layout. The figures below show an example of *EE’s* Bus Loom.

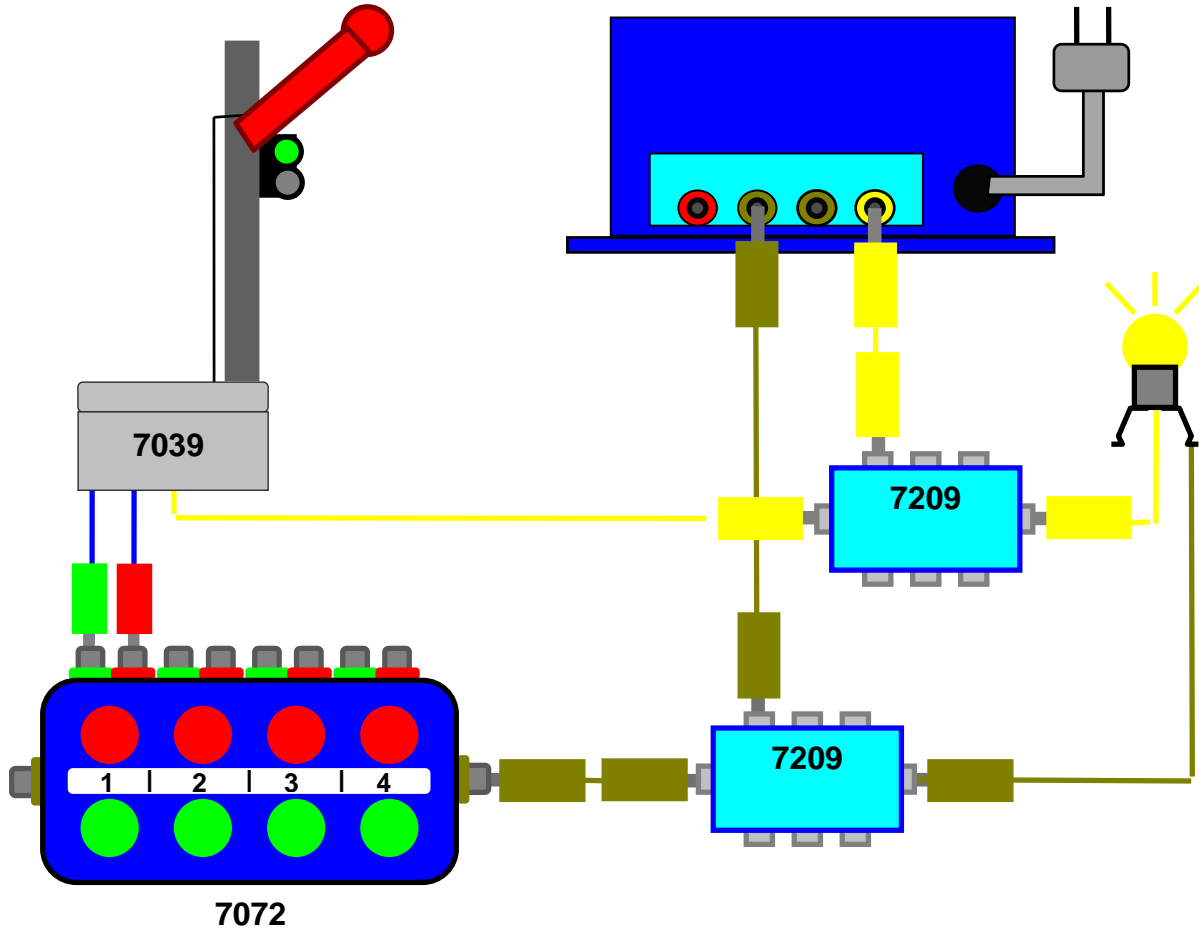


Below is a schematic view of a wiring bus on a conventional layout, using Looms to keep the wires apart from each other. Note the use of complete loops. *(On a digital layout, complete loops are to be avoided, as they can create problems with digital communications.)*



5.0 Using 7072 Control Box to Operate Solenoid Devices

Using a 7072 Control Box is the easiest way to operate a Märklin Double Solenoid device. Track turnouts and signals are the most common of these devices, and this manual operation should be thoroughly understood before more elaborate operational schemes are considered.



Study the figure above, and consider the following points:

- The Märklin 7072 control box has positions for four (4) double solenoid devices. Each double solenoid device has two blue wires, one with a red plug and one with a green plug. Therefore, the 7072 has eight (8) sockets on the rear. In addition, it has a brown socket and brown plug on its sides for connection to ground, or to another 7072.
- Both the lamp and the signal (i.e., all solenoid devices) are always connected to the lighting power supply (yellow bus).
- The lamp is on, because there is a ground connected (brown bus), which provides a complete circuit.
- The double solenoids of the signal are NOT on, unless either the red or green button is being pushed. Pushing the button completes the circuit.
- If the signal was wired as shown in the figure, it would work (change states). However, the light in the mast will not glow. That is because the base of the signal needs to be connected to ground to make the light glow; such a ground connection has not been shown.

6.0 The Signal and its Block

The Märklin signals are very handsome. As a youngster, I spent hours studying a 1959 Märklin Catalog in great detail, especially the colorful pictures of a professionally built layout (see front cover of this Booklet.) Wonderful semaphore signals, both the “distant” signals with the big orange round disk, and the “home” signal with their semaphore arms, were always present.

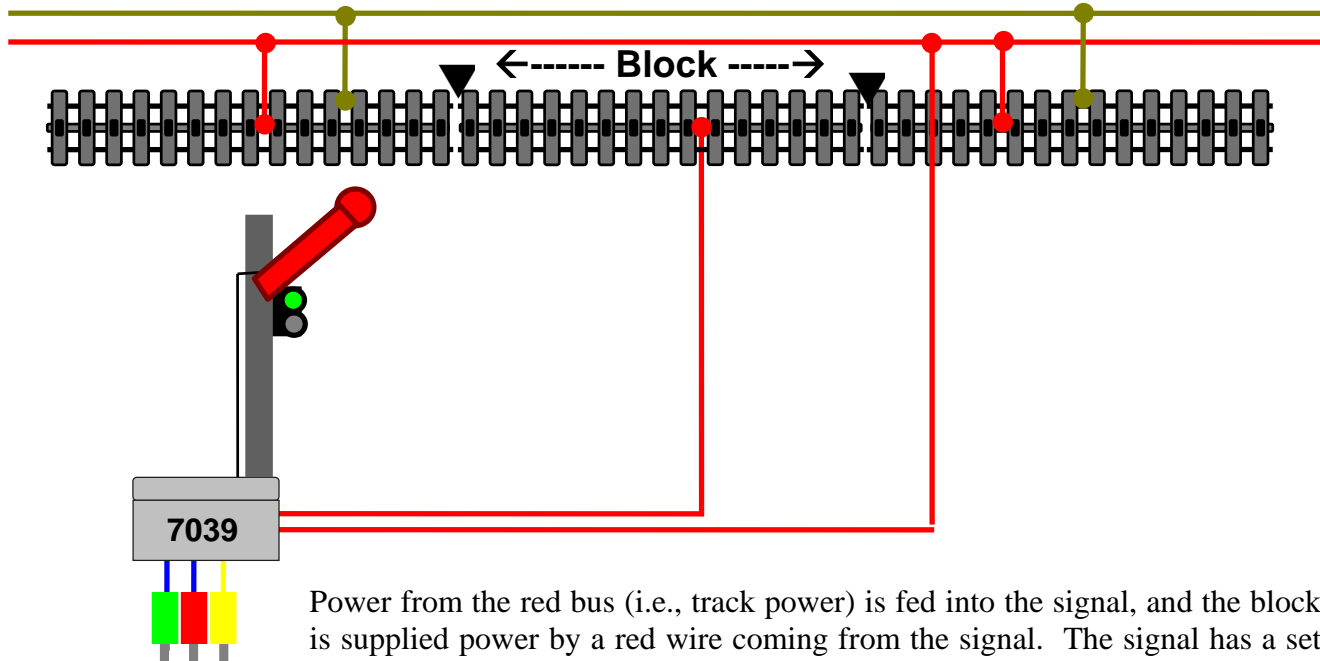
Even though I thought these were a very beautiful part of the layout, it wasn't until I was over 30 years old before I actually bought my first signal, and learned how to use it. I now understand that I had been held back by two reasons:

- The signal would cost money, and it was not necessary to have one to play trains.
- Even if I had one, I was not sure what it was for, nor know how to install it.

Once I finally bought my first signal, a whole new aspect of Märklin model railroading opened up to me! Not only does the signal look really neat, it can actually stop and start trains!

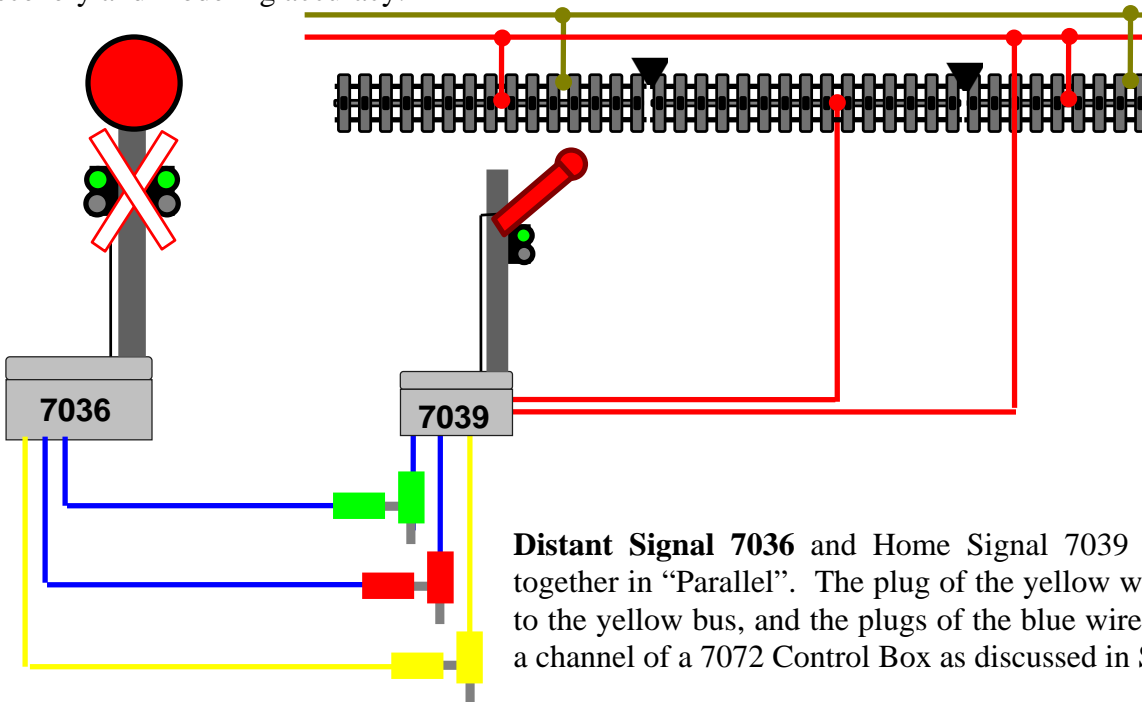
(Note: My fascination with signals has only increased. *Eckert Engineering's* main item of manufacture is the Signal Controller; we also refurbish used Märklin signals and sell them at affordable prices.)

6.1 Home Signal Basics - The home signal is that signal located where the train is supposed to stop if it is not safe to continue. Of the home and distant signals, only the home signal can actually stop and start a train. The figure below shows a “block” which is usually 2 full sections of track long, or 14”. This block section has its middle rail (or 3rd rail) isolated at both ends (isolation is shown by a ▼), so that power cannot come in from the “main” track.



Power from the red bus (i.e., track power) is fed into the signal, and the block is supplied power by a red wire coming from the signal. The signal has a set of contacts inside it that open or close this circuit. When the signal is on green (GO), the circuit is complete and there is power at the block. When the signal is on red (STOP) the circuit is open and the block is dead (no power.)

6.2 Distant Signal Basics - The distant signal is that signal located ahead of the home signals, to let the engineer know what is ahead. The distant signal does NOT perform any train control. It is only for scenery and modeling accuracy.

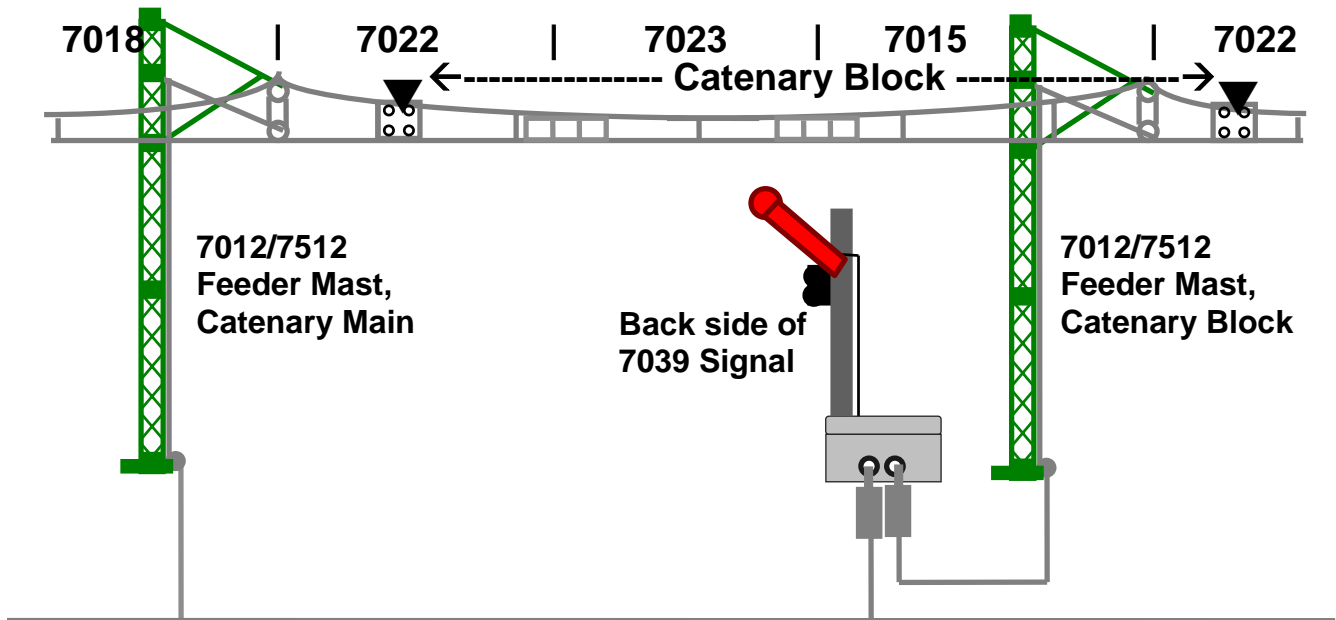


Distant Signal 7036 and Home Signal 7039 connected together in “Parallel”. The plug of the yellow wires attach to the yellow bus, and the plugs of the blue wires attach to a channel of a 7072 Control Box as discussed in Section 5.

6.3 Märklin Signal Model Numbers - The Märklin signals that are usually available for HO are listed below. The distant signal used with a home signal is listed on the same line.

HOME SIGNAL		DISTANT SIGNAL	
MODEL	DESCRIPTION	MODEL	DESCRIPTION
7039	M TRK SEMAPHORE, Single Arm	7036	M TRK, W/DISC
7040	M TRK SEMAPHORE, Double Arm	7037 (nla)	M TRK, W/DISC
7041	M TRK SEMAPHORE, Double Arm (3 blue wires)	7038	M TRK, W/DISC (3 blue wires)
7042	M TRK SEMAPHORE, YARD	N/A	
7043	M TRK SEMAPHORE HUMP YARD (nla) (3 blue wires)	N/A	
7044	M TRK COLOR LIGHT (OLDER)	N/A	
7188	M TRK COLOR LIGHT	7187	M TRK COLOR LIGHT
7239	K/M COLOR LIGHT	7236	K/M COLOR LIGHT
7240	K/M COLOR LIGHT	7237	K/M COLOR LIGHT
7241	K/M COLOR LIGHT (3 blue wires)	7238	K/M COLOR LIGHT (3 blue wires)
7242	K/M COLOR LIGHT YARD	N/A	

6.4 Signal Control of a Catenary Block - In addition to being able to control the power going to a Block in the track, the home signal can also control an independent source of catenary power from the main catenary to a Block section of catenary. In the figure below is a “block” in the catenary (overhead wire), which usually corresponds to the block in the track below. This catenary block section has been isolated at both ends by a plastic piece in cat wire part 7022, (isolation is shown by a ▼), so that power cannot come in from the “main” catenary.



Power from the gray bus (i.e., catenary power) is fed into the signal, and the catenary block is supplied power by a gray wire coming from the signal. The signal has a set of contacts inside it that open or close this circuit. When the signal is on green (GO) the circuit is complete and there is power at the block. When the signal is on red (STOP) the circuit is open and the block is dead (no power.) On Märklin signals, this set of contacts for the catenary is found on the backside of the signal, without wire, but with sockets to accept the Märklin plug.

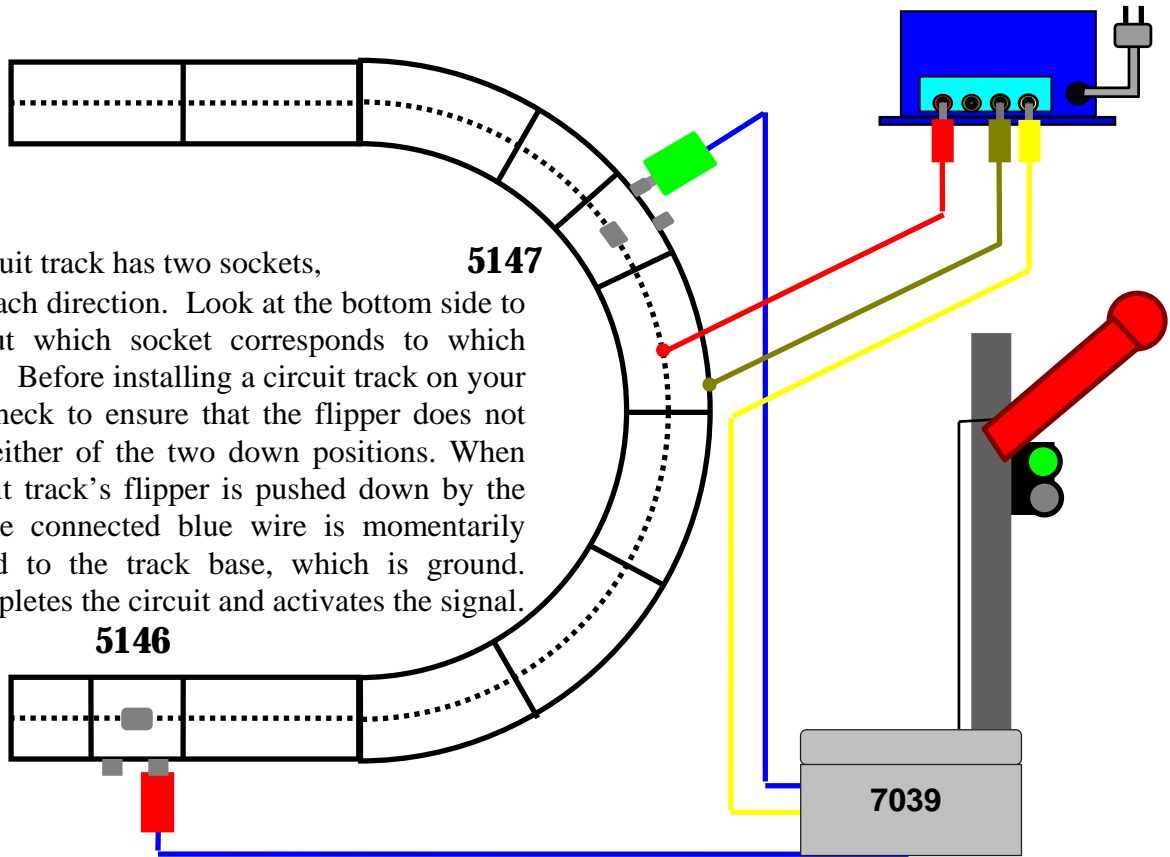
7.0 Using Circuit Tracks to Operate Signals

7.1 Introduction to Circuit Tracks In Section 5.0, it was shown how the Märklin signal could be manually controlled using the 7072 control box. This section introduces a further step of complexity known as Automatic Train Control (ATC). Instead of using your fingers to push buttons, trains will turn the signals to green (Go) and red (Stop) by means of Circuit Tracks. These circuit tracks are half pieces of track with a plastic “flipper” in the middle that is pushed by the locomotive’s slider as it travels on the track. The table below lists the “M” and “K” circuit tracks available.

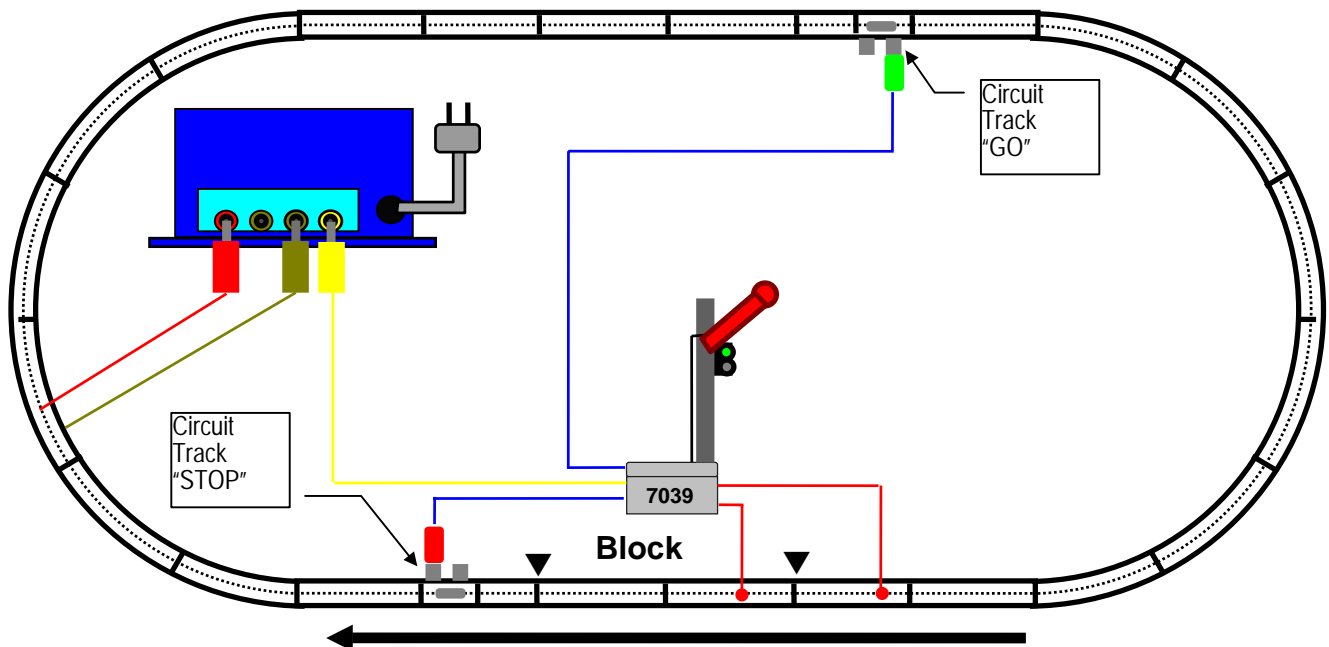
Part #	Description	Part #	Description
5146	M Track, Straight	2299	K Track, Straight
5147	M Track, Curve	2229	K Track, Curve
5213	M Track, Big Curve	2239	K Track, Big Curve

7.2 Circuit Track Basics The figure below shows a 7039 semaphore home signal installed with its two blue wires connected to circuit tracks, instead of to a 7072 control box.

Each circuit track has two sockets, one for each direction. Look at the bottom side to figure out which socket corresponds to which direction. Before installing a circuit track on your layout, check to ensure that the flipper does not stick in either of the two down positions. When the circuit track's flipper is pushed down by the slider, the connected blue wire is momentarily connected to the track base, which is ground. This completes the circuit and activates the signal.



7.3 Automatic Train Control - The figure below shows a very basic installation of Automatic Train Control (ATC). A 7039 semaphore home signal is installed with its two blue wires connected to circuit tracks. The two red wires of the 7039 signal are controlling power to a block of track, as presented earlier in Section 6.0.



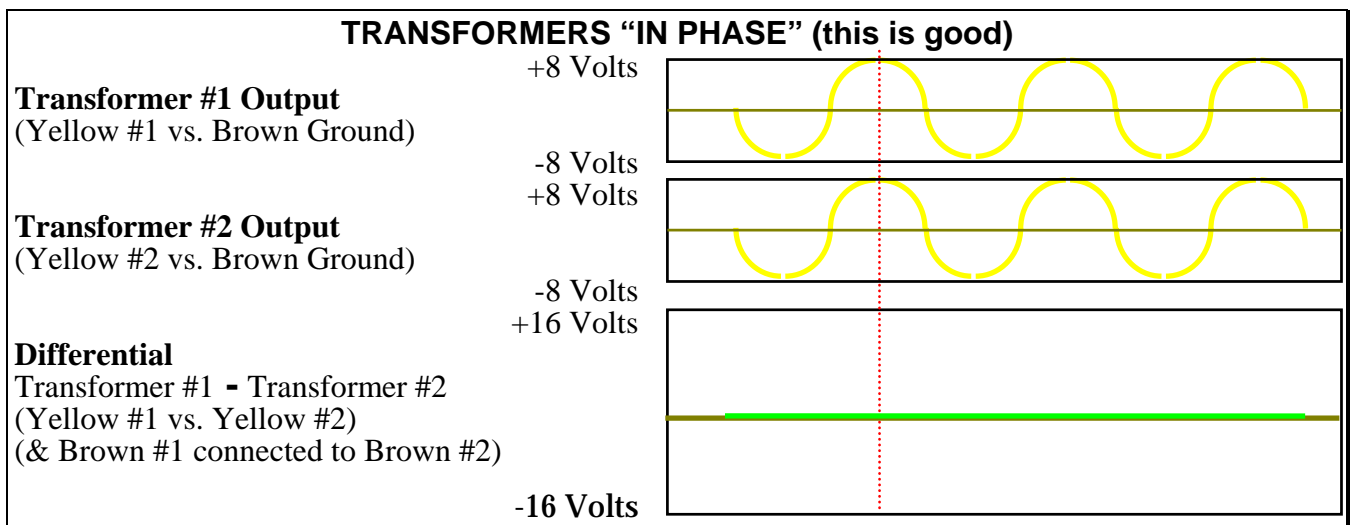
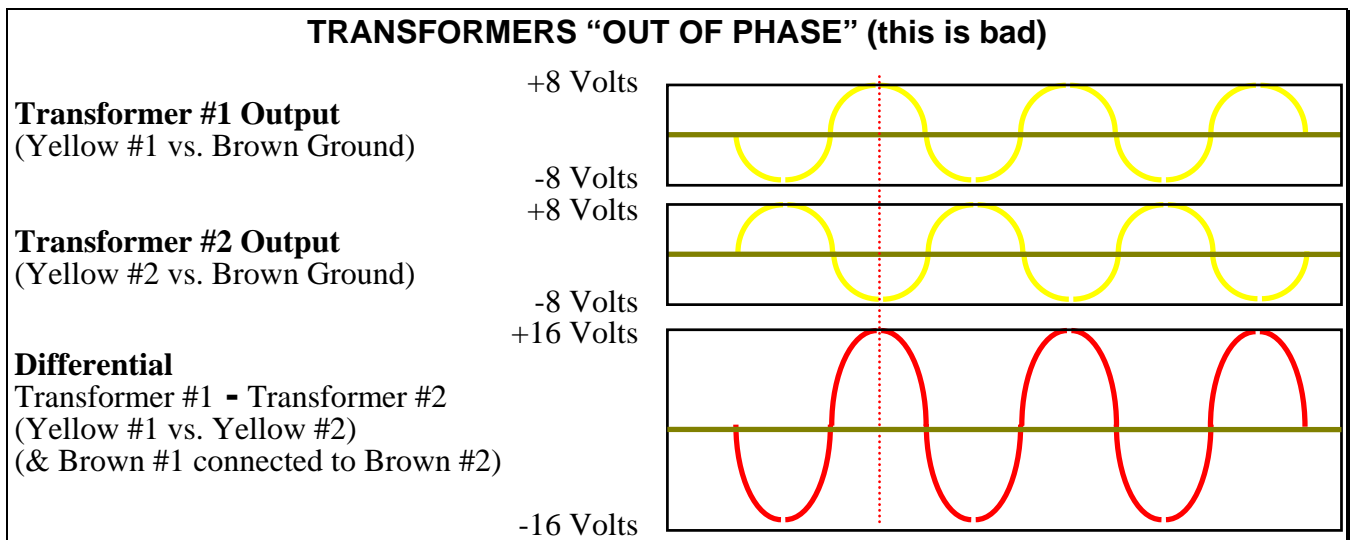
Picture two trains, Train A and Train B (not shown) traveling clockwise. They can control each other on the above layout with the following logic:

1. Train A is stopped at the block, because the 7039 signal is red.
2. Train B passes over the circuit track “GO”; 7039 signal turns green; block has power.
3. Train A starts because of green signal; leaves block; passes over the circuit track “STOP”; 7039 signal turns red; block has no power. Both trains moving now.
4. Train B arrives at block; stops because the 7039 signal is red.
5. Train A passes over the circuit track “GO”..... this becomes an endless loop.

8.0 Multiple Transformers on Layouts

Medium size and larger layouts need multiple transformers to supply enough power. When two or more transformers are used in a layout, it is important that they be connected with “Correct Polarity”. This section will explain the phenomena involved, and how to test for correct polarity.

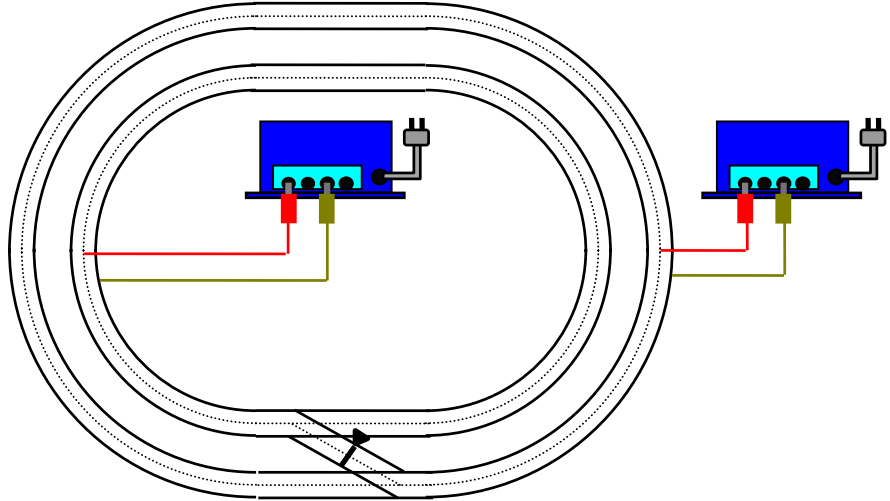
8.1 The Phenomena of Polarity Correct polarity is the same as “In Phase”; which means that the voltage peaks and valleys of two or more transformers’ AC outputs are in sync with each other. The output of a transformer (secondary) is in the same phase as its input (110 volt primary). Thus, if a transformer’s output is found to be “out of phase” with the others, simply rotating the input 110-volt plug will bring it “in phase”.



8.2 Why Be Concerned about Correct Polarity? Many layouts have been built without a concern for correct polarity, without any obvious problems, so why is there such a concern here? One answer is presented below:

In the figure below are two ovals of track with their third rails isolated (▼) from each other at the pair of turnouts. The outer rails (i.e., grounds) remain connected. Each oval is powered by its own transformer. This is a common layout design as it allows for independent train operation between the two loops.

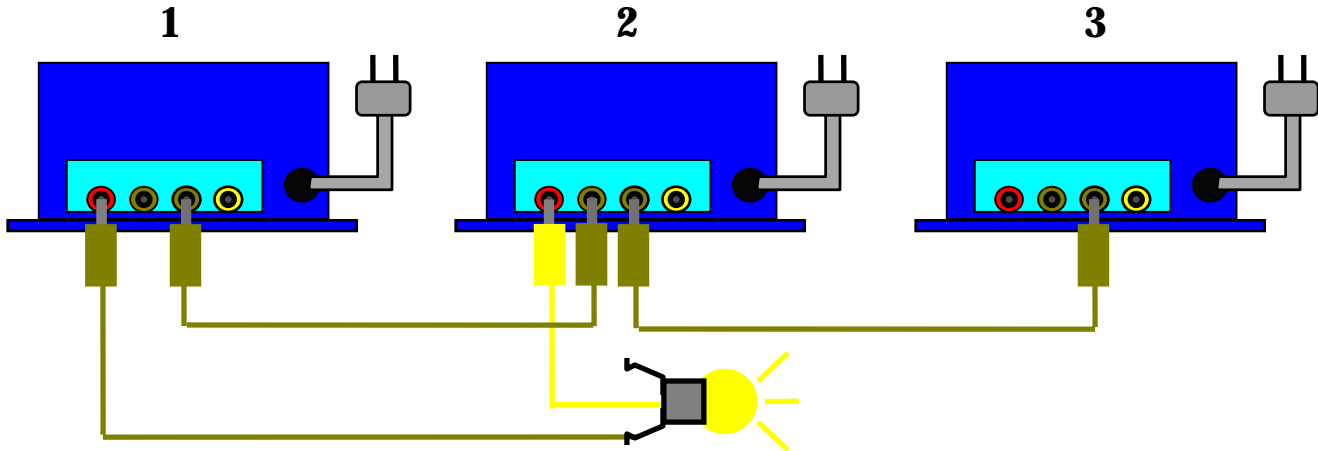
Let both transformers be set at full power (~16 VAC) and let a train be at the turnouts, moving from one oval to the other. The train's slider is at the isolation point, touching the third rail studs of both ovals. There are two possible scenarios:



- 1. Transformers are correctly polarized:** When the slider passes over the isolation point, it will be shorting together the two transformers. But since they are both at 16 VAC and “In Phase”, there is no differential potential, and there really is no short, $16 - 16 = 0$ VAC. If one of the transformers is slightly different (i.e., 13 VAC), there would be $16 - 13 = 3$ VAC differential potential. This is a small short, but very acceptable.
- 2. Transformers are NOT correctly polarized:** When the slider passes over the isolation point, it will be shorting together the two transformers. Since they are both at 16 VAC and “Out of Phase”, there is a differential potential of $16 - (-16) = 32$ VAC, and is a PROBLEM. Because the train is going fast, the time of the short is small, and the circuit breakers of the transformers probably won't trip, but they might. If one of the transformers is slightly different (i.e., 13 VAC), there would be $16 - (-13) = 29$ VAC differential potential. This is still a large short. If the transformers are set to slow speed (i.e., 8 VAC) then the short is $8 - (-8) = 16$ VAC. Because the slider is spending a longer time shorting across the studs, the transformers might trip. Even if the transformers don't trip, these shorts are making sparks at the slider, which is damaging both the slider and the track studs, and is not healthy for the transformers.

If you are interested in performing an experiment, create the above scenario and operate the train as described with the house lights off. You will see sparks at the slider in condition #2, but not in condition #1.

8.3 Polarity Test Procedure The Märklin transformers do not have polarized plugs (a plug with one prong wider than the other); this procedure will rotate the plugs to ensure that all of the transformers are in “phase” with each other.



1. Remove all existing layout plugs from transformer sockets.
2. Plug all transformers into a multiple outlet plug strip that has an On/Off switch.
3. Connect all grounds together with brown wires and plugs at the ground (0) sockets as shown.
4. Turn the knob of each transformer to a mid position such as “100”.
5. Connect a 16 volt lamp (i.e., 7073, used for lighting a building) across the red track power sockets of Transformers #1 and #2. Note that such a light usually has 1 yellow wire and 1 brown wire; it does not matter which wire plugs into which transformer.
6. The 110 Volt wall plug for Transformer #1 is correct by default. Turn the outlet plug strip ON. If the bulb lights medium to bright, rotate the 110 Volt wall plug of Transformer #2 180 degrees. The bulb should now be dark, or with just a faint glow. Now the wall plug for Transformer #2 is correct.
7. Connect the 16 volt lamp across the red track power sockets of Transformers #1 and #3. If the bulb lights medium to bright, rotate the 110 Volt wall plug of Transformer #3 180 degrees. The bulb should now be dark, or with just a faint glow. Now the wall plug for Transformer #3 is correct.
8. Continue the above step for each remaining Transformer.
9. Paint a dab of white paint or “whiteout” to the top of all plugs for future reference.
10. When you want to turn off the layout, use the On/Off switch of the multiple outlet plug strip. Do NOT unplug each transformer (doing so opens up the chance to have the transformers with incorrect polarity when they are plugged back in). However, if a single transformer must be removed from the layout and then reinstalled, matching the dabs of white paint will help to reinstall it correctly. If a new transformer is to be added to the layout, repeat Steps 2-7 of this procedure.

(An alternate test procedure uses the yellow sockets of the transformers instead of the red sockets; this has the advantage of not needing to position the control knobs in Step 4. However, if the polarity is wrong the voltage applied to the bulb will be about 32 volts, which possibly could burn out the bulb. A voltage meter can be used instead of a bulb. In such cases, using the yellow sockets is preferred.)

8.4 Transformer Assignments on Medium and Larger Layouts Here are some ideas on how to divide up the power requirements of larger layouts between several transformers.

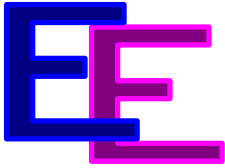
Layout Ideas with 2 Transformers	
Use of Transformer #1	Use of Transformer #2
All track (locomotives)	All accessories (lighting and solenoids)
- or -	
All tracks	All catenary
- or -	
All main tracks	Siding tracks (yard)
- or -	
Outer loop tracks	Inner loop tracks

Layout Ideas with 3 Transformers		
Use of Transformer #1	Use of Transformer #2	Use of Transformer #3
All tracks	All catenary	All accessories
- or -		
Outer loop tracks	Inner loop tracks	All accessories
- or -		
Outer loop tracks	Inner loop tracks	Siding tracks
- or -		
Outer loop tracks	Inner loop tracks	All catenary
- or -		
All main tracks	All main catenary	Siding tracks and catenary

Remember, there needs to be isolation between where two transformer outputs meet. For example, review the figure shown in Section 8.2. One transformer feeds the inner loop, a second transformer feeds the outer loop. Where the two loops meet at the pair of turnouts, the third rail of the inner loop is isolated from the third rail of the outer loop. This isolation can be achieved by any of the following methods:

1. Isolation paper (part number 5022) for M track.
2. Isolation plastic piece (part number 7522) for K track.
3. Physical removal of third rail connector from both pieces of track.

Note that the outer rails (ground) are NOT isolated from each other. All parts of the layout should share a common ground.



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- ***EE's Layout Building Catalog.*** We stock a huge collection of new and used Märklin track, turnouts, bridges, catenary, signals, and electrical components. We have many items such as 3 rail track, "model track" and "older style catenary", items no longer available as new product.
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- ***EE's Booklet on the Electrical Aspects of a Märklin HO Layout.*** This 15-page booklet answers many of the questions related to building a Märklin HO layout. Although geared towards building a conventional layout, many of the topics are applicable to building a digital layout as well. Available free of charge with your next order, or for a \$5 color printing charge.
- ***Power Supply Catalog.*** Another of our specialty products is our line of Power Supplies. Large digital layouts requiring multiple power circuits can benefit from having all of the transformers correctly phased with each other, outfitted with over current protection and cooling fans.
- ***Layout Building / Technical Discussions.*** Finally, we build layouts for customers, in either conventional or digital format. We can build in our facility and deliver, or we can build in place at your location. Either way we charge \$20 per hour. Should you want to build a layout for yourself, we are available free of charge by mail, phone, or e-mail for any technical questions you may have.

Sincerely Yours,

Timothy Eckert, PE

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