

Applications Note

Noise Reduction Techniques for Reliable Computer-Controlled Model Railroad Operation

Overview:

The noisy electrical environment of a model railroad, with its many motors, solenoids, and relays presents a challenge to the sensitive electronics of a computer control system.

Noise-induced performance problems such as sensor false-alarms, corrupted data transfers, and module crashes are usually intermittent, seemingly random, and are a nuisance to track down.

The CTI system incorporates numerous features specifically designed to deal with the harsh electrical environment of a model railroad. Nevertheless, there are a variety of steps the user can take to help ensure reliable network performance. This Applications Note describes these noise abatement techniques.

Techniques for Noise Tolerance:

The key to ensuring robust operation in any digital system begins with a good, clean power supply. Digital electronics is highly reliable, but it can only do its job if provided with sparkling clean power. By adhering to a few simple **Do's** and **Don'ts** you'll be sure to get consistent, reliable service from your CTI network.

Do start with a good quality *filtered* (and preferably *regulated*) DC power supply. Very reasonably priced regulated 12V supplies are widely available, and can be found in any electronics store or mail order catalog. **Don't** try to cut corners by using the DC output of a train transformer to power your CTI network. These seldom do more than rectify the raw AC input, and are ill suited to powering digital logic. [However, for a few dollars in parts, you can indeed turn the output of an old train transformer into a computer grade supply perfectly suited to powering your CTI boards. See our separate App Note on that subject if you're interested.]

Do dedicate a “*clean*” power supply solely to powering your CTI modules. **Don't** share the CTI power supply with other “*dirty*” electrical circuits such as switches, relays, motors, lights, etc.

Don't share “*common ground*” bus wiring between the CTI power bus and other power circuits. **Do** provide independent ground return paths back to each supply, and when necessary, connect the various power supplies to a common ground at a single point near the power supplies.

Do physically isolate CTI network and power wiring from other layout wiring. **Don't** bury CTI power and network wiring into tightly packed cable bundles along with other noisy, high current electrical wires (switch control leads, track power busses, etc.) Avoid long parallel wire runs between CTI network wiring and other layout wiring. To the extent practical, run the two types of wiring at right angles to one another.

Techniques for Noise Abatement:

The techniques we've discussed so far all serve to make the CTI network more immune to the existing noise sources found around your layout. But as the old adage so correctly states, "*an ounce of prevention is worth a pound of cure*". In the following paragraphs we'll look at ways to actually eliminate many of these sources of noise before they ever start.

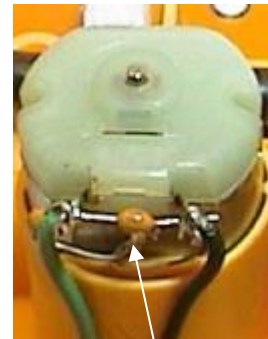
The numerous electro-mechanical devices found around every model railroad are the usual suspects when it comes to tracking down noise sources causing intermittent network problems. These include motors (found in every engine of course, but also in any motorized accessories and stall motor switch machines), solenoids (found in snap-action switch machines), and relays.

Motors are natural arc generators. Arcing is caused by the inherent make/break connection between the motor's brushes and commutator plates. Arcing produces high voltage, high frequency electrical spikes that can travel easily (either by direct electrical connection, or via electromagnetic emission through the air) onto other nearby electrical circuits. Simply turn on a radio in your train room, and you'll almost certainly hear the effects of motor arcing.

Fortunately, the effects of this *commutator noise* are easy to virtually eliminate. It's unfortunate that for the few cents it costs to do so, few engine manufacturers bother to incorporate this noise-mitigation into their designs.

The solution is simply to install a small capacitor (between 0.01 and 0.1 uF is a good rule of thumb) across the motor leads. The capacitor should be placed as close to the motor as possible, preferably right at the motor itself. This capacitor will serve to filter out the high frequency electrical arc before it can propagate out of the engine, and onto adjacent wiring.

In addition, keep your motors clean and well maintained. Dust, grime, and carbon deposits left from earlier arcing cause spurious loss of contact between the brushes and the commutator that leads to unnecessary arcing.



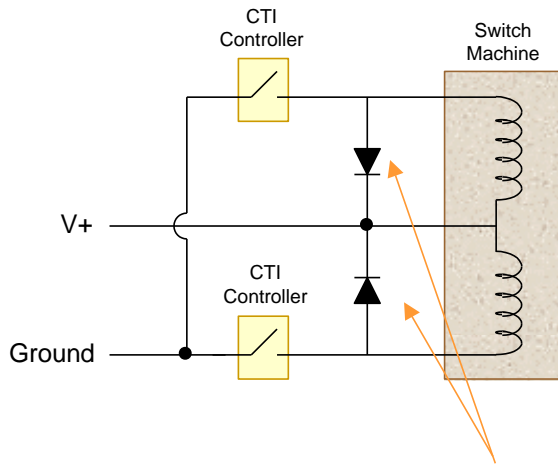
Commutator Noise Suppression Capacitor

The solenoids found in snap-action switch machines are another notorious source of noise in model railroads. When the solenoid is deactivated following a switch throw, the magnetic field built up in the solenoid begins to collapse. As the coil tries to maintain the magnetic field, a large transient voltage spike ensues. These can easily reach 100 Volts or more. This spike can readily couple into adjacent wiring, or can cause momentary *ground bounce* if the CTI network's power wiring and that of the solenoid are not adequately isolated.

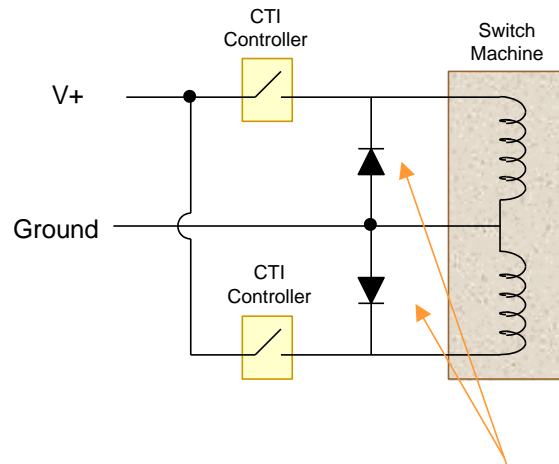
Fortunately again, this scenario is easy to avoid. We simply need to install a "*snubber*" diode across the coil of each solenoid. (Most snap-action switch machines actually have two solenoids, so a separate diode is required for each. This diode "*clamps*" the voltage spike to the diode drop voltage (a mere 0.7V), so it's much less likely to affect neighboring circuits.

The direction in which to install the diode depends on whether your switch's solenoids are wired as common-anode or common-cathode. Both cases are illustrated below. A 1N4002 diode will normally work fine for most model railroad applications. These diodes cost just a few cents each and can work miracles in eliminating hard-to-find noise problems.

[Note: This circuit only works if your switch machines are powered by a DC voltage. It cannot be used with an AC power source.]

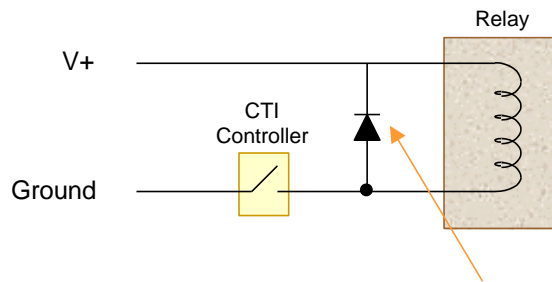


Snubber Diodes
Common-Anode Switch Machine
Noise Reduction Diode Circuit



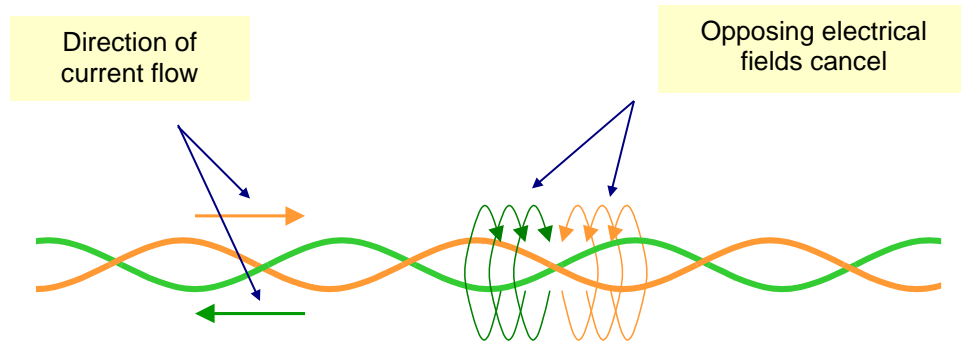
Snubber Diodes
Common-Cathode Switch Machine
Noise Reduction Diode Circuit

If you use any relays on your layout, they have a coil just like the solenoids in your switch machines. The same snubber-diode circuit described above works here, too. (See the circuit diagram below.) [Note: All CTI modules that employ relays have noise suppression diodes already built-into their design. You won't need to provide any external diodes in those cases.]



Snubber Diode
Relay Noise Reduction Diode Circuit

Another simple but effective technique is to twist the two leads of the wires driving noisy high-current loads such as motors and solenoids. Since the currents in each wire are traveling in opposite directions, twisting the two leads closely together causes their respective magnetic fields to overlap and cancel one another, minimizing emissions into the surrounding environment. About six twists per foot are generally adequate. If you have a lot of such wiring, you can save time by purchasing two-conductor cable with the appropriate twists already present.



Twisted-Pair Wiring for Noise Reduction in High Current Loads

Summary:

Noise is an unavoidable aspect of any electrical system. The nature of the typical model railroad makes it particularly prone to being “electrically noisy”. The CTI system has numerous features designed-in to deal with this harsh electrical environment. In addition, by adopting a few simple common-sense design practices when installing your layout wiring, your CTI system will provide years of reliable service.