Wiring the Murphy Way!

"All that Noise, Noise, Noise!" said the Grinch.

Where does it all come from? And why should I care? Any electrical signal that is present in an environment and is capable of adversely affecting another electrical signal is considered noise, even is that signal serves a useful purpose in the system. For example, if the signal from the AC power mains is coupled to the signal from a pressure transducer, and causes the pressure reading to fluctuate, then the AC power is considered to be noise to the pressure signal.

This points out three things about noise:

- There must be a noise source.
- There must be a victim.
- There must be a coupling path.

Further, this gives us three areas where noise can be reduced:

- **SOURCE** – By de-coupling, shielding, or simply making a noiseless design.
- **COUPLING PATH** – By spacing or shielding if the coupling path is radiation, or filtering if the coupling path is conduction.
- **VICTIM** – By de-coupling, isolating, shielding, or by circuit design using less susceptible circuits.

There are many noise sources to be aware of. Power line disturbances range from slow over-or-under voltage to sharp, extremely narrow transients. The sources of such disturbances are often power-switching operations, heavy loads turning on or off, power semi-conductor operation, circuit breakers or fuses blowing, lightning induced surges, etc.

Ignition systems are well known noise sources. Because of their pulsed nature, they occupy a wide frequency bandwidth, which creates a threat to a large number of circuits.

A lightning stroke creates a huge electromagnetic field and induces surge voltages in power and communication lines.

Electrostatic discharge creates an enormous number of problems (malfunctions or permanent damage) in electronic circuits. Dry atmosphere, high personnel activity, nylon or wool carpeting, etc. aggravate static discharges.

All of the above noise sources may cause permanent damage or malfunctions including nuisance shutdowns, erroneously displayed values, or valves and motors being turned on and off at the wrong time!

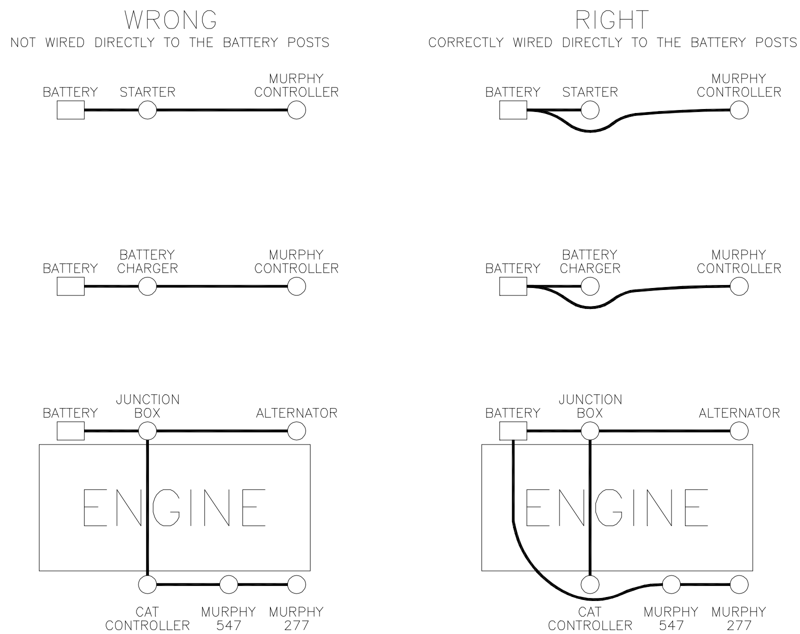
Start early to eliminate/reduce the noise and the service call!

While you may not be able to change how susceptible a design is to noise, there is plenty that you can do to reduce the effects of noise on the design. A few extra minutes and attention to details during wiring can save you a service call and make your customer much happier.

1. **SEPARATE THE WIRING** – Break the noise-coupling path. Do not route cables from one group (AC power, DC control, low voltage analog sender, etc.) parallel with cables from another group. Never run AC and DC handling wiring together. If cables from one group must cross cables from another group only cross at right angles. Route cables along frame members and metal surfaces. Avoid open space hanging. Space low voltage analog sender cables away from all other cable groups 3" for every 12" of parallel run (1 foot of separation for every 4 feet of run.) Space all other cable groups away from other cable groups 1" for every 3' of parallel run.

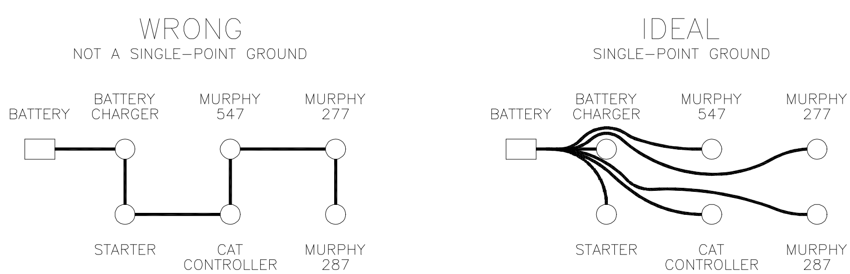
2. **USE SUPPRESSION DIODES** – Eliminate noise at its source. Place suppression diodes across all DC inductive loads. These loads include pilot relays, solenoid valves, starter solenoids, etc.

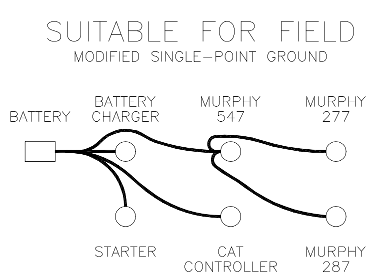
3. **WIRE DIRECTLY TO THE BATTERY** – Break the noise-coupling path. To minimize noise from battery chargers, alternators, and power droops during starting, hook the power cables from the TEST-OFF-AUTO switch or OFF-ON switch, directly to the battery posts with large gauge wire. Standby chargers should also be wired directly to the battery post using separate cables from the panel's power cables.



4. **USE SHIELDED WIRES** – Break the noise-coupling path. Shielded cable should be used for the magnetic pickup (speed signal), low level sender cables (thermocouples, etc.), and other sensitive cables. The shield should be grounded at the transducer end as close to the transducer as possible. On the panel end, the shield should be connected through a 0.01μf capacitor to ground (keep the capacitor's leads as short as possible). Do not allow any other ground connection to the shield.

5. **ELIMINATE GROUND LOOPS** – Break the noise-coupling path. Use a single point ground. The





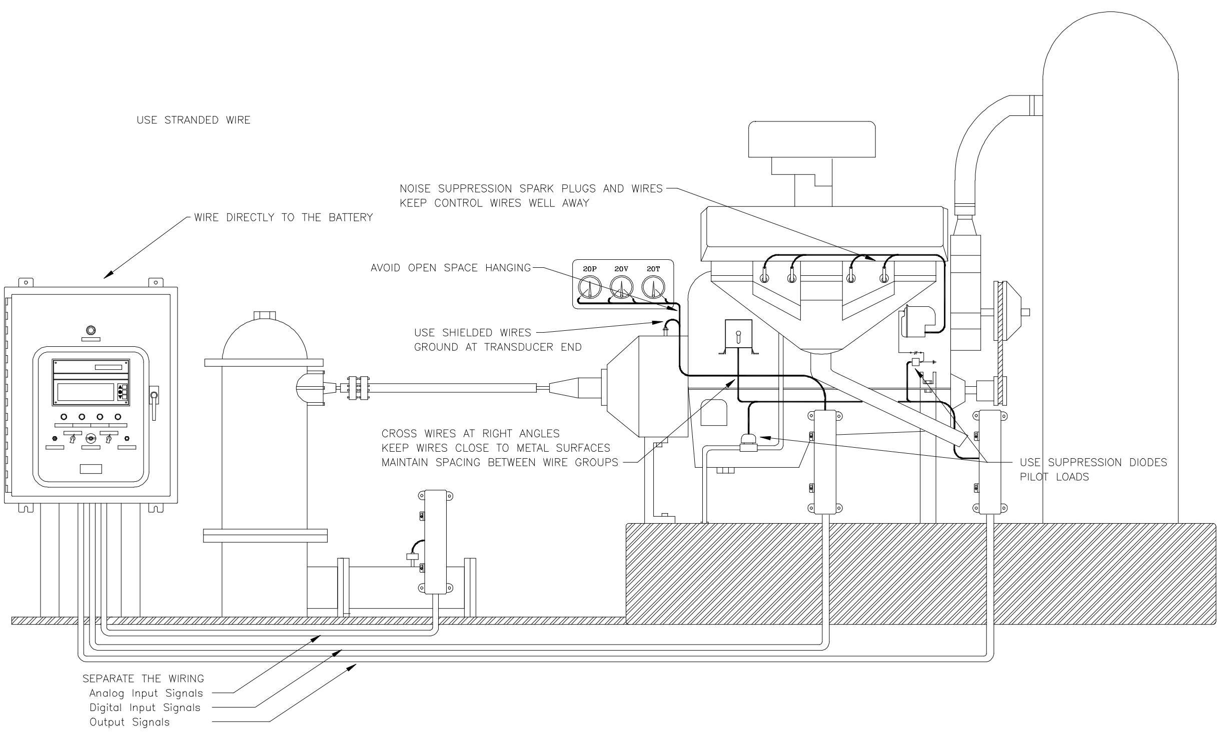
ideal single point signal ground network is one in which separate ground conductors extend from one point on the facility ground to the return side of each of the numerous circuits located throughout a facility. This type of ground network requires an extremely large number of conductors and is not generally economically feasible. In lieu of the ideal network, various degrees of approximation to single-point grounding are employed.

6. **USE EXTRA CARE WITH SPARK IGNITION ENGINES** – Eliminate noise at its source. Use noise suppression spark plugs and spark plug wires. Break the noise-coupling path. Route all wires at least 10” away from the ignition system, the further away the better! Magnetos and ignition coils produce high voltage, high frequency, high-energy noise (nasty stuff). Keep your control cables well away from the ignition system!

It’s not just good practice! It makes good cents!

It’s not just good wiring practice it also makes sense. To get the most out of any control panel, don’t overload the circuits and always use the proper wire for the signal being measured or current load required.

1. **PILOT LOADS** – Know what the controller’s outputs are rated for. If in doubt or if you need to switch more current than the controller is rated for, wire a relay to controller and use the relay to switch the heavy load. This moves the noisy heavy current away from the controller and can make your wiring easier.
2. **USE STRANDED WIRE** – Solid wire transmits vibration and is more likely to crystallize and break when subjected to movement.



It still doesn't work! Now what?

Noise troubleshooting can become very frustrating at times, particularly when you and the people observing you think that you have tried absolutely everything. If this happens, step back, mentally, step out of the bushes so that you can see the trees and answer these simple questions.

- What and where is the source?
- What is the frequency range?
- Which coupling path(s) can the noise possibly take?

Hurrying to the noise problem site to satisfy a panic call can cause you to commit two errors:

- You do not collect enough data to prepare one or more plans of attack.
- You bring either too many or not enough pieces of equipment but leave behind the one precious accessory that will not exist at the site.

Remember – forewarned is forearmed; collect detailed information in advance. Ask the user to determine a possible correlation between cause and effect.

- Is the failure intermittent or continuous?
- Does the failure correlate with a specific time of day? With the operation of local/portable transmitters? With certain loads on/off the power line?

What instrumentation is available at the site?

- An oscilloscope?
- Volt/ohm meter?

Make sure you bring whatever is needed.

If there are clues that a nearby transmitter could be the problem, get transmission data from the FCC (http://www.fcc.gov/) or other source:

- Transmitter power.
- Transmitter frequency.
- Transmitter distance and direction from the site.

In most cases, some rough prediction can be done in advance. Based on the information, make some hypothesis about what the source and coupling paths could be. Finally, plan some advance strategies for diagnosis and fix. Do not stick to one plan. Plan some "what if" actions.

- Upon arriving at the site visually inspect the victim.
- Does the victim have power line filters? Do they address both common and differential mode noise?
- Are the filters mounted correctly?
- Examine the grounding scheme. Multiple ground loops usually exist.
- Examine interconnecting control and signal cables. Are they shielded? How/where are the shields grounded? Are they near other power cables carrying large currents?
- Are there other heavy-load users on the victim's power branch circuit?
- Are there and nearby portable transmitters?
- Are there and nearby radar's? FM/TV transmitters?
- Any nearby air conditioners? Arc welders? Neon signs? Heaters, etc.?

If the failure is either always there or occurs at several times within a reasonable period, it can be probed and demonstrated over and over. A continuous problem is a blessing for a troubleshooter because it allows him to find the source faster and evaluate the fixes more easily.

Unfortunately, intermittent problems constitute a large share of field calls, and this implies a longer preliminary routine to locate the cause. A patient search is needed to find evidence of a correlation between the failure and an intermittent operation (turn-on, turn off, or changes in loading) of some equipment in the surroundings.

Ultimately, it may occur that no correlation can be found within a reasonable investigation time. This will be a case to search for the possibility of rare power line disturbances or short ESD transients.

Once the source is identified, you will search out and fix coupling paths. This may be done through:

- Shielding of case and cables.
- Physical relocation and/or reorientation.
- Filtering.
- Checking of grounding conductors.

There is obviously a more direct solution: stop noise generation at the source! This is generally not feasible because the source is out of reach or impossible to modify, or because the generation of noise is a normal product of its function.

The key things to remember are the basic, source, victim, and coupling path. There is no magic. Careful consideration and solid troubleshooting should allow you to fix any noise problem.