ZWORLD

WHITE paper

Solving Noise Problems

This white paper describes common causes of noise and suggests ways to reduce or eliminate noise problems.

Environmental Noise Problems

Noise problems can range from the mild to the catastrophic, from the loss of a small amount of data to the destruction of expensive equipment. The cause might be a electrically harsh environment—a 150-horsepower motor, for example—or a completely external source like a nearby lightning strike. While electrical noise can be difficult to trace, it usually results from one of four sources:

- Power line disturbances
- Externally conducted noise
- Transmitted noise
- Ground loops

In particular, coil-driven devices, SCR-fired heaters, motors and motor drives, and electric welders generate one or more types of noise.

Power Line Disturbances

The wide availability of line filtering equipment makes most power line disturbances easy to solve. When other devices connected to the local power line are switching large amounts of current, line filtering equipment will dampen the resulting noise. In severe cases, an isolation transformer may be needed.

Externally Conducted Noise

Externally conducted noise creates disturbances on signal and ground wires connected to the controller. When a noisy device such as a relay or solenoid shares a DC ground with other devices, disturbances within the controller may result. If this type of noise gets onto logic circuit ground or into the processor power supply, it may scramble the program.

To solve this problem in DC mechanical relays and solenoids, connect a diode backwards across the coil; this clamps the induced voltage “kick” produced by the coil. Select a diode rated at four times the coil voltage and ten times the coil current. To eliminate this effect altogether, use solid-state relays.

If multiple devices are on one circuit, ground them together at a single point.

When power supplies and programmable controllers have DC common tied to Earth (AC power ground), it is preferable to have controller signal ground or DC common floating with respect to Earth. This configuration prevents the equipment that is grounded to Earth from sending noise into the controller.

In many cases, it may be necessary to optically isolate the controller to completely eliminate contact between it and a noisy environment. Solid-state relays provide this total isolation.

Transmitted Noise

External connections can transmit noise to the controller; in severe cases, noise can be transmitted to controllers with no external connections. The index enclosure is designed to shield the controller from this kind of transmitted noise. However, the enclosure must have openings to accommodate connections and front panel controls, and noise may “leak” through these openings. Connecting the controller chassis to Earth minimizes this problem.

High current levels can contribute to noise problems in two ways. First, high current and high voltage wires are surrounded by an electrical field, which may transmit noise to signal wiring. Second, high-current contacts draw an arc when they open; this arc generates a burst of broad-spectrum radio frequency noise that may transmit to a controller limit switch or other wiring.

Shielding signal cables or isolating the signals reduces this type of noise. A proper shield surrounds the signal wires to intercept electrical fields, but this shield will not drain the induced voltages unless it is tied to Earth. At a minimum, run wires in twisted pairs to limit straight-line antenna effects.

Ground Loops

Noise caused by ground loops is often difficult to track. Ground loops occur in systems with multiple Earth ground connections, especially when these connections are widely spaced. Systems using RS-232C communication seem to be most vulnerable to this type of noise. Typical symptoms are intermittent operation symptoms and garbled transmission.

Reducing Noise Problems

Noise problems are best handled in the design process, before they occur. The following checklist is taken from Henry Ott's *Noise Reduction Techniques in Electronic Systems*, second edition (New York: John Wiley & Sons, 1988). The items indicated with "❑" can be implemented at little or no cost, and should be used whenever appropriate; the remaining items can be used when additional noise reduction is needed.

A. Suppressing Noise at the Source

- Enclose noise sources in a shielded enclosure.
- Filter all leads leaving a noisy environment.
- Limit pulse rise times.
- Provide relay coils with some form of surge dampening.
- ❑ Twist noisy leads together.
- Shield and twist noisy leads.
- ❑ Ground both ends of shields used to suppress radiated interference (the shield does not need to be insulated).

B. Eliminating Noise Coupling

- ❑ Twist low-level signal leads.
- Place low-level leads near chassis (especially if the circuit impedance is high).
- ❑ Ground shielded cables used to protect low-frequency, low-level signal leads at one end only. (Coaxial cable may be used at high frequencies with shield grounded at both ends.)
- Insulate shield on signal leads.
- When low-level signal leads and noisy leads are in the same connector, separate them and place the ground leads between them.
- Carry shield on signal leads through connectors on a separate pin.
- ❑ Avoid common ground leads between high- and low-level equipment.
- ❑ Keep hardware grounds separate from circuit grounds.
- ❑ Keep ground leads as short as possible.
- ❑ Use conductive coatings in place of nonconductive coatings for protection of metallic surfaces.
- ❑ Separate noisy and quiet leads.
- ❑ Ground low-frequency, low-level circuits at one point only. (High frequencies and digital logic are exceptions.)
- Avoid questionable or accidental grounds.
- For very sensitive applications, operate source and load balanced to ground.
- Place sensitive equipment in shielded enclosures.
- Filter or decouple any leads entering enclosures containing sensitive equipment.
- ❑ Keep the length of sensitive grounds as short as possible.
- Use low-impedance power distribution lines.
- ❑ Avoid ground loops in low-frequency, low-level circuits.
- Consider using the following devices for breaking ground loops:

  — Isolation transformers
  — Common-mode chokes
  — Optical couplers
  — Differential amplifiers
  — Guarded amplifiers
  — Balanced circuits
  — Hybrid ground

C. Reducing Noise at the Receiver

- Use only the necessary bandwidth.
- Use frequency-selective filters when applicable.
- Provide proper power-supply decoupling.
- Bypass electrolytic capacitors with small high-frequency capacitors.
- Separate signal, noisy, and hardware grounds.
- Use shielded enclosures.
- With tubular capacitors, connect outside foil end to ground.

D. Guidelines for Controlling Emissions in Digital Systems

- Minimize ground inductance by using a ground plane or ground grid.
- Locate decoupling capacitors next to each integrated circuit (IC) in the system.
- Use the smallest value capacitor that will do the job.
- Use a bulk decoupling capacitor to recharge the individual IC decoupling capacitors.
- Keep clock signal loop areas as close to zero as possible.
- Treat all cables to minimize their common-mode current.
- Connect all unused inputs on logic gates to either power or ground.
- Locate I/O drivers near where the cables leave the system.
- Use the lowest-frequency clock and the slowest rise time that will do the job.
- Keep the clock circuits and leads away from the I/O cables.

The first step in solving a noise problem is identifying it. When faced with a problem situation, eliminate potential sources of noise until the problem disappears. If this is not practical, use the guidelines above to troubleshoot the system.

Proper use of a watchdog timer and careful programming can facilitate system recovery if a transient does crash the system.

Additional Information

General Semiconductor Industries in Tempe, Arizona publishes a catalog that contains a great deal of information about protection against lightning and other transient disturbances. General Semiconductor makes devices called TransZorbs, similar to Zener diodes, which can absorb transients.

Harris Semiconductor also publishes an excellent catalog of transient voltage suppression devices with considerable general information.

Circuit Designs

The circuit in Figure 1 was devised by a Z-World customer who observed board failure when switching on a 24-volt, 5-ampere DC motor. The diode has a PIV of 250 volts.

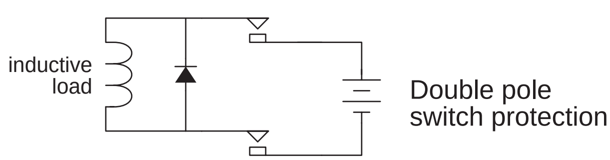

Figure 1. Sample Circuit

Figure 2 shows several circuits for protecting relay contacts taken from the *Electromechanical Design Handbook* by Ronald Walsh (McGraw Hill). These circuits should also reduce transient disturbance associated with unprotected contacts.

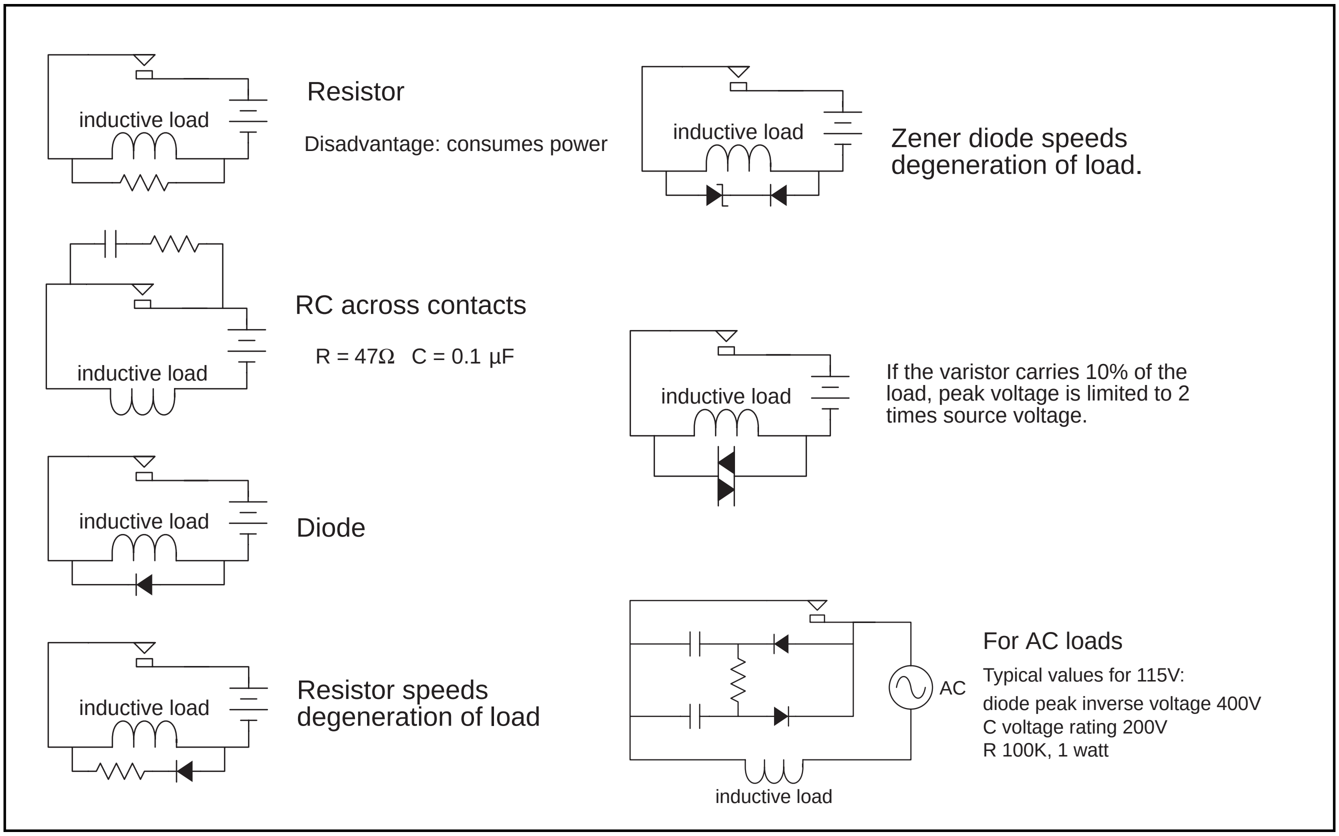

Figure 2. Sample Circuits

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