APPLICATION NOTE 50532

WOODWARD

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EMI CONTROL
IN ELECTRONIC GOVERNING SYSTEMS

INTERFERENCE CONTROL IN ELECTRONIC GOVERNING SYSTEMS

INTRODUCTION

Electronic governing systems are required to operate in close proximity to other electrical and electronic devices. Many of these devices emit electromagnetic energy. The emissions may be incidental to the operation of the.device, such as from rectifiers (SCR's), motors, generators, relays, and switching power supplies. The emissions may be deliberate, such as from communication transmitters, radar and navigation aids. When these emissons adversely affect another device, it is called electromagnetic interference (EMI).

This application note covers some of the ways EMI occurs and some ways in which interference can be prevented. Only the practical aspects of EMI in the typical prime mover wiring installation are covered.

INTERFERENCE PATHS

These are two basic ways an interfering signal (noise) can be introduced into an electronic device:

1. When two or more devices share a common ground, current drawn by one device creates a ground voltage seen by the other devices.
2. Wires running through a noisy environment can pick up noise and conduct it into the electronic circuits.

METHODS OF NOISE REDUCTION

There are two primary ways of reducing interference:

1. Grounding.
2. Shielding.

The application of these techniques will prevent EMI in almost all systems employing electronic governors.

GROUNDING

There are two important reasons for grounding:

1. To prevent a high voltage shock hazard from lightning or component failure.
2. To provide a common reference to the system.

The ground system can also provide effective protection against EMI if properly designed.

GROUND

Ground is defined as an equipotential point or plane used for the system reference. Ground can be at earth potential, as required for safety grounds, or floating with respect to earth. The important point of this definition is equipotential. In the real world, all conductors have some impedance. When carrying current, no two points on the conductor are at the same potential. A good ground, then, is one in which the ground potentials and their effects are minimized.

GROUND SYSTEMS

The objectives of a good ground system are:

1. To prevent ground potential noise coupling caused by currents from two or more circuits flowing through a common ground impedance.
2. To avoid ground loops which are affected by magnetic fields and differences in ground potentials.

The first step in proper grounding is to establish a separate signal ground for the system electronics. A typical system will have a minimum of three separate grounds:

1. Hardware ground. This is for connecting enclosures, chassis, equipment racks, etc. In ac power systems, this is where the green safety wires are connected.
2. Power ground. This is the return for noisy equipment such as motors, relays, and SCR's.
3. Signal ground. This serves as the reference for the electronic devices in the system. Signal ground may be connected to the other grounds at a single point near the primary ground point.

Figure 1 illustrates why a separate signal ground is important.

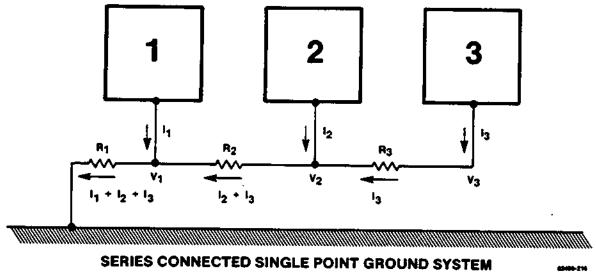

Figure 1. Series Connected Single Point Ground System

The resistors shown represent the impedances of the ground conductors. Currents from circuits 2 and 3 combine with the current from circuit 1 to develop the ground potential

$$V_1 = R_1 (I_1 + I_2 + I_3)$$

The potential at 2 is

$$V_2 = R_1 (I_1 + I_2 + I_3) + R_2 (I_2 + I_3)$$

and likewise

$$V_3 = R_1 (I_1 + I_2 + I_3) + R_2 (I_2 + I_3) R_3 I_3$$

This is a commonly used ground system due to simplicity and low cost. It is also the least desirable system from a noise standpoint. If this system must be used, locate the electronics nearest to the primary ground point as the ground potential will be lowest there.

Figure 2 illustrates a properly designed ground system for low frequency noise. Separate returns are provided for hardware, power and signal grounds. Each circuit sees only the ground potential generated by its own ground impedance and current.

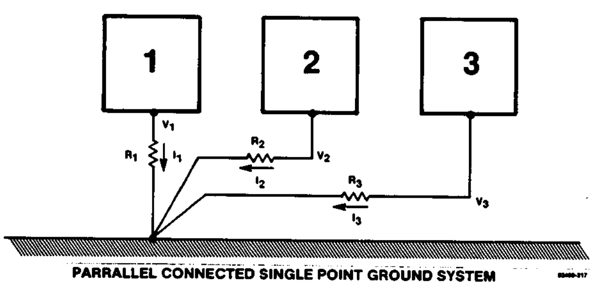

Figure 2. Parallel Connected Single Point Ground System

HIGH FREQUENCY GROUNDING

The above ground system is useful at frequencies below about 10 MHz. Occasionally, prime mover systems may be located near high frequency transmitters. In this case, a single point ground may not be appropriate due to the excessive length of the ground conductors. For instance, 1 meter of #10 AWG wire has an impedance of .0033 Ohms at 60 Hz and 225 Ohms at 27 MHz (CB band).

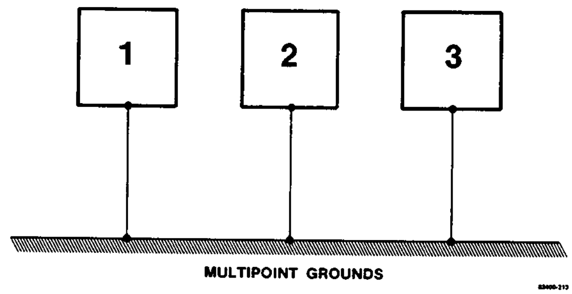

Figure 3. Multipoint Ground System for High Frequency Grounding

For high frequency noise rejection, a multipoint ground system may be better. Connect all common terminals to the chassis grounds directly. All chassis then should be bonded together with heavy copper strapping. Enclosures should then be strapped to a ground rod located as close as possible. It is still a good idea to separate signal and power grounds by providing a non chassis return for power distribution.

GROUND LOOPS

Ground loops can occur from two sources of noise:

1. Ground potentials.

2. Electromagnetic fields.

The previous section covered how ground potentials occur. Figure 4 illustrates how a ground potential can cause interference to an electronic control system.

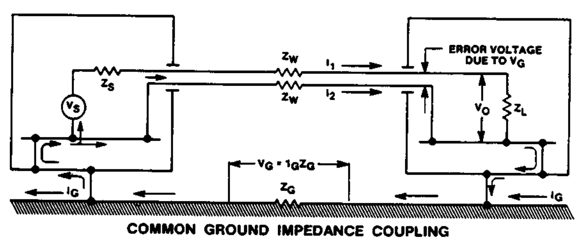

Figure 4. Common Ground Impedance Coupling

Ground current, I_G, creates the ground potential, V_G, through the common ground impedance, Z_G. This potential drives current through the loop formed by the source and load wiring. This current creates an error voltage across the load impedance.

In a load sharing system, load imbalance is a result of dc ground potentials. Load sharing instability or slow system response are a result of ac ground potentials. Provide separate ground returns for electronic devices.

Electromagnetic fields also can induce current into a loop. Figure 5 shows a ground loop formed by signal leads and circuit common. The field flux cuts through the loop and induces current flow. (This is the same principle that applies to generators.) The resulting voltage across the load causes an error in the measurement.

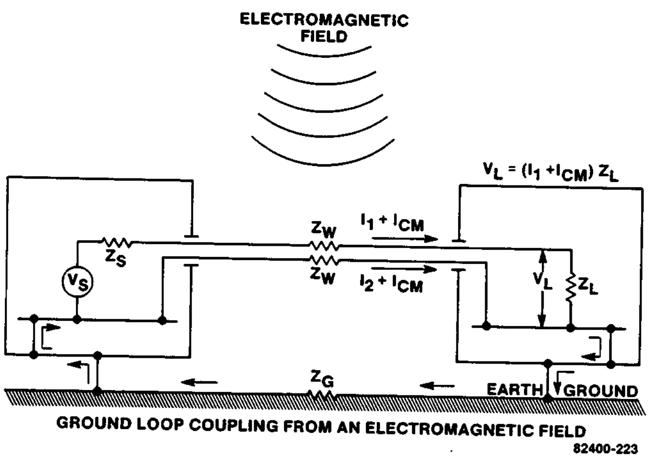

Figure 5. Ground Loop Coupling from an Electromagnetic Field

The current induced into a loop is proportional to the field strength and area of the loop. Reducing field strength and loop area are both effective reduction methods. Loop area can be reduced by locating the electronics closer together and routing interconnecting wires near signal ground. Field strength can be reduced by routing wires as far from field sources as possible and orienting wiring at right angles to field sources. Shielding can be placed between the field source and wires to reduce the flux reaching the loop. This will be covered in the shielding section.

The most effective (and most expensive) solution to interference from ground loops is to open them. Figure 6 shows the source floating with respect to ground and no loop is formed as in figures 4 and 5.

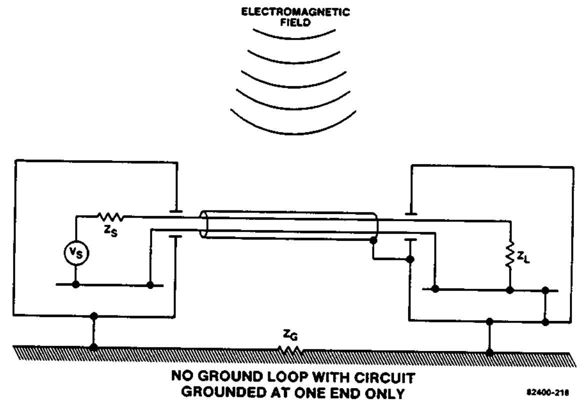

Figure 6. No Ground Loop with Circuit Grounded at One End Only

Ground loops may be broken with isolated power supplies on the source or receiving circuits. For process signals such as 4-20 mA or 1-5V, loop isolators are available. Care should be taken in the wiring to prevent grounding of isolated circuits, usually via shields, and defeating the ground loop isolation.

Though not related to grounding, electromagnetic fields can also induce current into loops formed by signal lines as in figure 7.

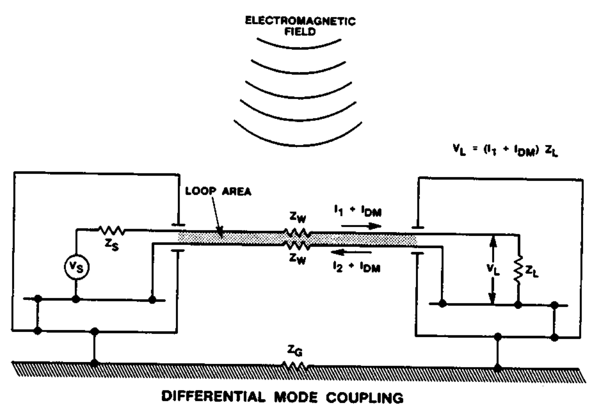

Figure 7. Differential Mode Coupling into Loop Formed by Signal Lead Pair

Loop area and field strength reduction are again effective methods of reducing interference. Loop area is reduced by using twisted pairs and minimizing the area at terminations. Twisted pairs also offer cancellation effect on low frequency noise.

SUMMARY

A properly designed ground system is the most effective EMI control method at low frequencies. The design should consider using:

1. Signal ground for electronics separate from power and safety ground to prevent ground potentials.

2. Minimum loop areas to reduce electromagnetic field coupling.

3. Electronic wiring located as far as possible from sources of fields.

4. Elimination of ground loops by single point grounds and isolation from ground.

SHIELDING

Shielding is the second primary method of reducing noise. Shielding techniques depend on the frequency of the noise and if the field component is magnetic or electric. The major field component is usually electric if the noise source is separated from the susceptable circuits. Magnetic fields decrease proportional to the cube of the distance, where the electric field decreases directly proportional to the distance. High current alternating signals are good magnetic field sources and high voltage, low current circuits are electric field sources.

ELECTRIC FIELD SHIELDING

Electric fields are relatively easy to protect against. Two basic rules apply.

1. Minimize the exposed wire beyond the shield.

2. Provide a good ground for the shield.

Wire extending beyond the shield should be limited to two inches or less. Avoid unneccesary breakouts. A terminal block in a cable run exposes a considerable length of wire.

For low frequency electric fields, a single point ground connection is preferred to prevent ground loops. Where this single ground connection is made is important. In most cases, the shield must be grounded at the receiver end of the wires. *Ground is the one the circuits are referenced to.* In a properly designed ground system, this is signal ground, not chassis or safety ground. Figure 8 shows a shield terminated to chassis ground when a separate signal ground is provided. Due to impedances aroung the loop, noise currents cause a common mode voltage between the shield and wires. This noise voltage can couple capacitively into the circuits. The results can be worse than no shield at all.

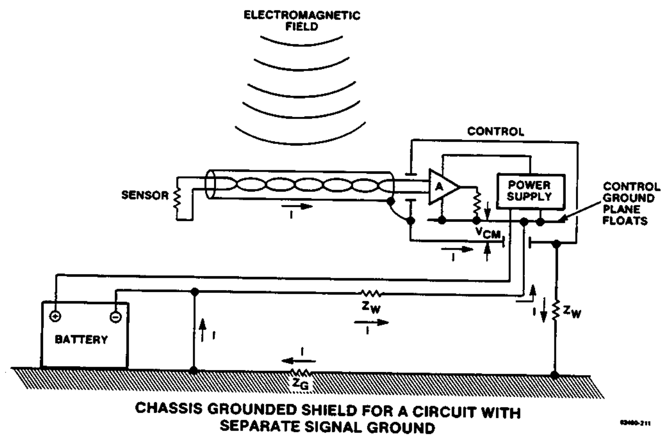

Figure 8. Chassis Grounded Shield for a Circuit with Separate Signal Ground

In a circuit that is floating, the shields must be connected to circuit common. If the shield is connected to chassis ground, it has no meaning.

Occasionally there are exceptions to grounding shields at the receiving end of the circuit. When grounded thermocouples with a floating amplifier are used, the shield should be grounded at the thermocouple end. Loadsharing lines are another exception. Both ends of the lines are transmitters and receivers of signals. For controls with non-isolated circuits, the shields should be broken near the middle of the circuit. For controls with isolated power supplies, the shields may be connected at both ends to circuit common — providing there are no other connections between the controls to create a ground loop.

Shielding for high frequencies is different than for the low frequencies. When the shield length exceeds approximately one-twentieth of a wave length of the noise, the shield on twisted pair wires is no longer effective. At 60 Hz, the wave length is over 3000 miles. At the 27 MHz CB band, the wave length is 37 feet. A shield over two feet is electrically long at 27 MHz. Single point grounding of shielded twisted pair wires is effective at low frequencies only. Grounding the shields every two feet can be cumbersome and also create ground loops. To effectively shield at high frequencies solid conduit, continuously grounded, should be used. Fortunately, high frequency noise in great enough amplitude to cause interference is not common. Equipment cabinets typically shield the electronics sufficiently to prevent problems.

MAGNETIC FIELD SHIELDING

Shielding against magnetic fields is more difficult than for electric fields. Magnetic fields induce current into loops. To shield a loop effectively, the entire loop must be shielded. Figure 9 shows a ground loop area and induced current. Note that the shielded cable does not affect the ground loop. Electric field shielding is not effective for magnetic fields.

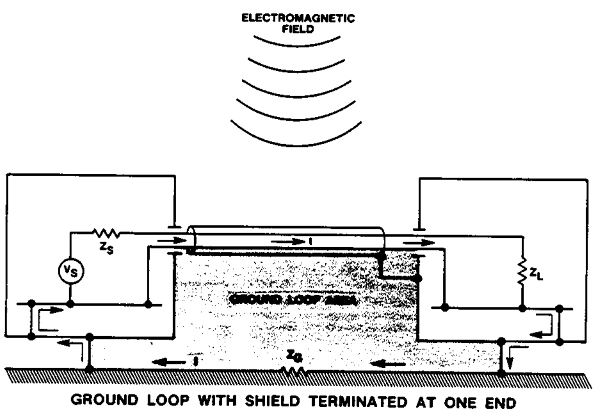

Figure 9. Ground Loop with Shield Terminated at One End. No Shielding of Magnetic Field Occurs

Grounding the shield at both ends as in figure 10 will remove the ground loop from the signal wires. However, the large ground loop current in the shield circuit will induce noise into the wires anyway.

The most effective ways of shielding against magnetic fields is to decrease the loop area, reduce field strength, and isolate power supplies to eliminate the loops.

Since grounding shields at both ends does reduce magnetic field strength, place the shield around the field source. Use a magnetic material such as steel to enclose magnetic field sources completely. The induced ground currents can be quite high, so cabinets and doors should be well grounded to prevent arcing. Sensitive electronics and wiring should not be placed in these cabinets.

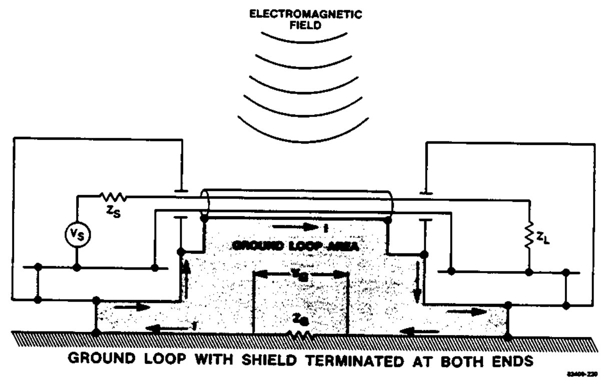

Figure 10. Ground Loop with Shield Terminated at Both Ends

SUMMARY

Electric fields are easy to guard against:

1. Single point grounds for low frequencies.
2. Minimum exposed wires at shield ends.

Magnetic field shielding involves:

1. Reducing or eliminating loop areas.
2. Shield magnetic fields at their source.

ECONOMICS OF EMI CONTROL

Noise suppression should be considered at the system design stage. Proper attention to grounding and shielding will prevent almost all EMI problems. When EMI occurs during system test, the problems can be very difficult and expensive to solve. For example, by separating sensitive wiring from noisy wiring, many problems can be prevented at practically no cost. Rewiring a system to fix it can entail considerable expense and production delays.

The elimination of noise at the source should always be given priority. An unsuppressed relay coil can generate noise that can interfere with several other devices in the system.

Effective design requires minimizing noise generation and preventing the remainder from reaching sensitive electronics.

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