EMI GROUNDING

Using Grounding to Control EMI

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Electromagnetic compatibility is an important consideration in the design and operation of today's sophisticated electronic measurement equipment, particularly as portable systems proliferate. Electronic devices can both emit and be damaged by electromagnetic interference (EMI) and must be protected from its harmful effects. Issues of human safety must also be addressed. Other means of achieving EMI control include filtering, cable shields, and enclosure shielding. This article focuses on grounding.

Perhaps no topic in electronics is as misunderstood as grounding, which usually evokes an image of a long braid snaking off to a ground post set into a concrete floor. As the following discussion makes clear, an earth ground is not essential to EMI control and is almost never needed. In the overwhelming majority of measurement electronic applications, good grounding involves achieving a sufficiently low-impedance return path for the highest interference frequency of interest. If it were possible to achieve zero impedance, all other grounding issues would become meaningless. Since it isn't, device designers need to seek ways of maximizing the effectiveness of the grounds that can be implemented.

WHAT IS A GROUND?

Succinctly put, a ground is a return path for current. Its purpose is to close the current loop, not to lead it into the earth. If interference current is diverted successfully into earth ground, it will simply come out elsewhere in order to return to its source. The only time earth ground is necessary is for lightning.

Confusion arises because the term "ground" is used for a variety of applications and means different things to different people. Facility engineers, for example, look at a ground as a return for lightning strikes. In this application, the ground needs to be able to handle currents up to 100,000 A for a few milliseconds. Because the approximately 1-microsecond rise time produces significant Fourier frequency components up to about 300 kHz, inductance can become an important concern. In contrast, electricians look at a ground as being a return path for fault currents, which may involve tens or hundreds of amperes at 50 or 60 Hz. At this frequency level, inductance is not important, so a length of 4/0 wire connected to the nearest building steel works just fine--an earth ground may be present, but is not needed for electrical safety.

These two cases are the most commonly known uses of grounding. Importantly, the grounding requirements for EMI control in measuring device applications are vastly different. EMI can cover a very wide range: currents from microamperes to amperes and frequencies from direct current to daylight. The duration of an event can range from nanoseconds, in the case of a transient, to years, in the case of a continuous wave. For the specific case of electrostatic discharge (ESD), transients are measured in nanoseconds (giving Fourier frequency components up to 300 MHz), and currents range to 10 A or even higher. The edge rates and current magnitudes are such that significant voltage bounce will occur across even the smallest length of wire or circuit-board trace. Whatever the condition, however, device designers must provide a way for the interfering current to return to its source, and that rarely involves earth ground.

GROUND LOOPS AND SINGLE-POINT GROUNDS

Whenever grounding is an issue, design engineers inevitably turn to ground loops and single-point grounds. What do these terms mean and when are the techniques appropriate?

A ground loop exists whenever there is more than one conductive path between two points. This condition allows interference currents to mix with signal currents, which may lead to ground interference. This problem can be eliminated by having a zero-impedance ground. Lacking such a ground, separate ground paths can be provided. By breaking the ground loop, the device designer can create a single-point ground. The need for a single-point ground originated in telephony, where it was almost impossible to get impedances low enough to prevent power line frequencies from intruding as a hum, and the technique is still useful in a number of low-level, low-frequency analog applications, such as strain gage load cells.

The fundamental assumption behind the principle of single-point grounding is that the velocity of light is infinite. Any time designers need to consider the velocity of light, notably at computer speeds, the single-point ground technique doesn’t work. A useful rule of thumb is that a single-point ground is appropriate if the longest dimension of interest is less than a 1/20 wavelength of the highest-frequency threat. Thus, single-point grounds are appropriate for handling EMI with audio (low) frequencies in most cases but inappropriate and unachievable for radio frequencies used in digital electronics.

ACHIEVING GOOD GROUNDS

A lightning strike, for example, might result in 10,000 A flowing in an I-beam with 10-V transients across even short lengths. Two interconnected devices grounded to that I-beam at different points may easily experience upset.

Because ordinary wire is not a satisfactory ground in many circumstances, the common wisdom is to use a flat strap instead. This approach is indeed appropriate, but the rationale behind it is widely misunderstood. To achieve low inductance, the key factor is not the strap’s flatness but its length-to-width ratio. To ensure that the inductance of a ground strap is sufficiently low, its width must be at least one-fifth or, better yet, one-third of its length. If a designer cannot achieve this ratio, there will not be a satisfactory high-frequency current return path.

Probably nowhere in electronics do designers face such a difficult challenge as that posed by sensitive analog input circuits. The circuits can be fairly well protected on an isolated ground plane; the problem involves interconnections to an un-isolated ground or to the wires and cables that connect the sensor to other equipment. For an isolated ground, it is important to minimize the amount of external EMI currents that reach the ground plane.

Interconnect Grounding. EMI problems are frequently the result of high-impedance interconnects. Again, designers need to keep the ground impedance low, either by connecting to a common ground plane or by providing a very-low-impedance ground interconnect via the cable. For typical low speed measurement signals one ground line is generally sufficient.

External Grounding. Finally, if a low impedance ground plane can be implemented between enclosures, problems should be minimal. However, with cables running long distances and/or if sensitive low-frequency analog signals are being transmitted; audio-frequency interference may be a concern. In such cases a single-point ground will be needed. A hybrid ground with a capacitor termination at one end, typically 0.010.1 µF, and a hard termination at the other end can provide an open circuit at audio (low) frequencies and a short circuit at radio (high) frequencies, thus combining the best of both worlds.