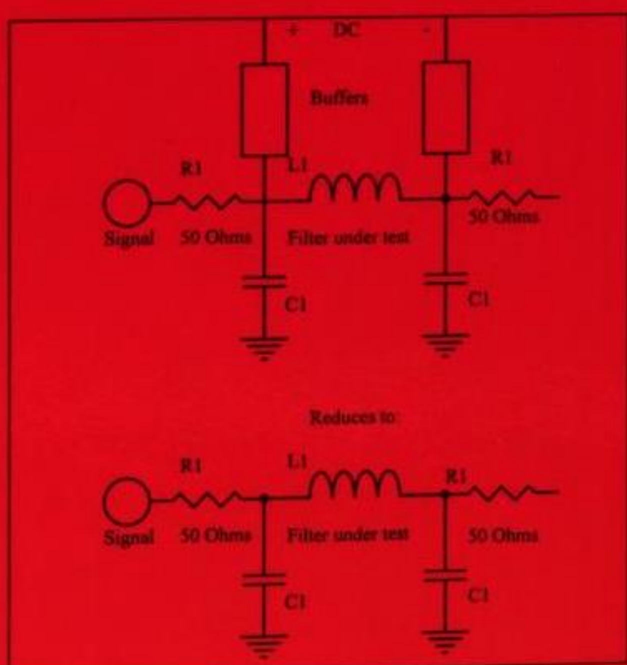
EMI Filter Design

Second Edition
Revised and Expanded



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Common Mode and Differential Mode—Definition, Cause, and Elimination

There is a wide range of opinion about the definition, cause, and elimination of common mode noise and differential noise. This should cover most of these ideas.

2.1. COMMON AND DIFFERENTIAL MODE DEFINITIONS

A basic definition of common mode and differential mode is required. Differential mode means the normal transfer of energy down the line. In fact, this is also called normal mode. A voltage across the line with a current flowing in one direction in one wire and the opposite direction in the other wire is normal mode. In this case, the subject is differential mode noise. In other words, it flows just like normal power in the line energy.

Common mode means a voltage impressed across both, or all, lines. This voltage is between all these lines and ground. If there is only one line, then the pulse is still between this line and ground. In this unbalanced case, differential mode and common mode act the same—between line and ground.

A current flows in the same direction in all the lines and the return is ground. Again, the subject is common mode noise. I have found that opinions vary from EMI guru to guru with little agreement. I hope this section will, at least, achieve some agreement among the various groups. Many claim that if the common mode noise voltage impressed on these lines is not exactly equal, then it is not common mode.

Two signals cannot be equal on both lines because of differences between the lines, the different spacing between the lines and ground, different capacitance to ground between the lines, and so forth. Even the EMI filter input feed-through capacitors, MOVs, transzorbs, and the like upset the common mode according to some groups. Therefore, using that definition, common mode does not exist. But common mode does exist, so this definition must be lacking or faulty.

To sum up, differential mode noise voltage is impressed between the lines whereas the common mode noise is across the lines—typically two—and ground (Fig. 2.1).

2.2. WHAT CREATES COMMON MODE NOISE ON THE LINE SIDE?

The simple definition of common mode noise is a pulse of voltage on both power lines of equal value (Fig. 2.1). This pulse is between the power line wires and ground. The EMI filter should be designed to handle this energy. A lightning strike on the power line side will create a magnetic field that will cut the two, or more, power line wires. This voltage is impressed between the lines and ground. This strike will be several quick high-voltage pulses typically around 50 kHz. The spacing between the lines may be 3 or 4 feet, depending on the voltage and location, creating a slightly different voltage in the two power lines. This voltage will be added algebraically to the AC power line voltage on all the lines. All of this section assumes that the lines do not fuse and that transformers will take this pulse without failing. If any failure occurs on the line, this reduces the high-pulse problem at the filter and equipment following, but the power will be down. It will be the difference in the two line voltages feeding the transformer that is transformed to the secondary. This difference between the lines is now transferred to differential mode noise. This difference voltage will be transformed (stepped down) to the user side. There will be extra transformer losses due to the high-frequency core losses. These noise pulses are at higher frequencies, accentuating core losses. The skin effect within the transformer and on the lines where this high-frequency pulse is being conducted adds to the pulse losses. The primary

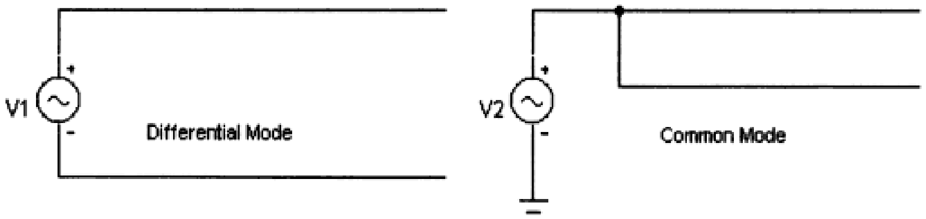

FIG 2.1 V1, differential mode, and V2, common mode.