

Noise Reduction and Filtering Techniques

Purpose:

This Application Guide discusses the use of filtering to improve null measurements when noise on the signal source makes measurements difficult or introduces error. This note also helps the experienced user compare a null meter with variable filtering with one that has fixed filtering.

Background:

Frequently circuits generating very low-level voltages (such as those measured by null meters) often also allow the signals (voltages) of interest to be accompanied by unwanted AC signals. The unwanted signal may be random noise or of a fixed frequency such as line frequency related signals. Signals that are either random or a fixed frequency can easily interfere with low-level DC measurements as they add to or subtract from the voltage of interest—and may add at times and subtract at other times making either absolute measurements or null indications very difficult.

Random noise can be generated by the circuits generating the signal of interest, by the connections between the signal source and the instrument as well as by the instrument itself. A contributor of truly random noise is Johnson Noise (also called thermal noise), caused by the random activity of electrons moving in a resistance. The amount of thermal noise increases with temperature. Truly random noise has equal intensity at all frequencies (often called white noise), however, noise often has varying amplitude with frequency and may be referred to as pink noise or by other similar terms.

Noise (that is, unwanted voltages interfering with the null meter measurements) may also be generated by many external sources and while appearing to be random is actually synchronized to an external event such as fluorescent or dimmed lighting circuits, heating systems, other instruments (especially those with microprocessors or other fast digital circuits), motorized equipment, radio systems and many other sources. Unfortunately, many times it is impossible to eliminate these sources (the best approach) so measurements must be made with this noise combined with the voltage of interest.

One of the measurement difficulties encountered in reducing the impact of noise on the measurements of interest is determining at what frequency to cut off unwanted measurements. All measurements normally involve some change in amplitude—if there is no change usually there is no measurement to be made. So, the user must decide what frequency of change is of interest (for example, with a null meter, the user may wish to see changes that happen over a period of one-second as the setup approaches null, and therefore signals of 1 Hz are of interest.)

Random noise and unwanted higher frequency signals can be substantially reduced by adding filtering to the measurement; however, filtering also “colors” the measurement—that is, it adds its own characteristics to the final measurement.

Filters used in instruments such as null meters typically reduce the amplitude of voltages above a particular frequency while not changing the amplitude of lower frequency signals. These are called low-pass filters and are used with null meters as the signals of interest are usually very low frequency. A filter reduces the effects of both random noise and of unwanted signals of a particular frequency such as line related signals.

Filtering techniques are simply forms of averaging. Given enough time, the average value of a random signal is zero as is the value of a pure sine wave; however, infinite time is impractical (and many interfering signals are not pure sine waves). For practical amounts of time, increasing the filtering time (or reducing the filter corner frequency) reduces the noise by the square root of the change in time. For example, changing the AVM-2000 filter time from 1 second to 100 seconds (a 100 fold increase in time) reduces the effects of noise by 10 fold while increasing the filter to 10 seconds (10 fold) reduces the noise by a factor of three.

The Technique:

The first step in noise reduction in any measurement situation is to eliminate the source of the noise wherever possible. Some steps to aid in noise elimination are:

- Turn off noise making devices (unused instruments, computers, motorized equipment, lighting, etc.). NOTE: Switching power supplies as often used in modern electronic products (especially computers) tend to generate sufficient noise over a wide range of frequencies.
- Make all interconnections between the signal sources and the null meter with twisted pair, copper wires with a shield. The shield connections are normally connected to the instrument GUARD terminal
- Keep all connections as short as possible and where possible keep similar connections (for example the connections from a source to the HI and LO instrument terminals) of equal length
- Position (and reposition) all interconnections to minimize inductive (transformer like) and capacitive coupling of external unwanted signals into the measurement interconnections. NOTE: Not infrequently signals a local AM, FM or Television station may couple into the measurement wiring. Although the frequency of such signals is well beyond the frequency response of a null meter, it is possible that these signals may be rectified (detected) by some of the measurement circuits and thus be turned into either DC or low frequency AC interfering signals
- Connect the EARTH/CASE terminal (Yellow binding post on the rear of the AVM-2000) on signal sources and the null meter to a common high-quality earth ground
- Eliminate any un-needed resistances in the signal path (to reduce Johnson Noise)
- Use battery operation (vs. line operation) for the null meter and as many other active electronic devices connected to the system as possible
- Move the measurement setup into a location with shielding against noise such as a Faraday enclosure (Screen Room)

Reducing the noise through filtering is the second step and should be done after all measures have been taken to eliminate unwanted noise signals from the measurement. Steps to reduce noise via filtering include:

- Start with 2 or 5 second filtering if the instrument provides adjustable filtering. Increase the filtering if the measurement will allow a slower response. Remember most fixed filtering null meters have 2-second filtering for ranges of 30 μ V and above and 5-second filtering for ranges below 30 μ V.
- If strong interfering signals may be present and the signal source is a high-impedance device such as a bridge (Reference Divider, Kelvin Varley Divider, etc.) placing a low leakage (Polypropylene or Polystyrene) 2 – 5 μ F capacitor across the null meter input terminals

Summary:

The first step in reducing unwanted noise from measurements is to eliminate the source of unwanted signals.

- Turn off or otherwise eliminate noise sources
- Configure wiring and the measurement layout to reduce coupling noise into the circuits
- Use the maximum level of filtering (by the instrument) possible that still allows the measurement
- Add external capacitance to the null meter input