What is this third signal wire and what do I do with it?

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Introduction

Some sensor manufacturers and some instrument (measuring device) manufacturers' products have a third signal terminal. This terminal is variously labeled as shield, common, ground, etc. Usually, the signal wires are shielded and this is another third wire in typical installations. The following discussion is offered in an attempt to give a better understanding of the various factors driving the design of the products and the proper use of the third terminal. Most important is the information contained in the discussion of the possible result of the misuse of the terminal. If your data system isn't a possible victim of the common mode induced effects described in the following discussion, you are a sure winner in tomorrow's lottery!

Sensor

The third wire is the shield (guard) for the signal and it must represent the common mode potential of the signal. If this is not true, the third wire potential will likely cause an erroneous normal mode signal to be generated. The "center" of the signal will not likely have identical impedance to each of the two signal wires. Thus, if a potential exists between the shield and the signal "center", an unequal voltage will appear in series with each signal lead caused by the current flowing from the shield through the unequal impedances of the signal source device (sensor). In this way, the voltage that exists between the sensor case or lead wire shield and the true sensor common mode voltage has generated a false normal mode voltage (signal error). If the sensor is of a design that uses an internal high frequency voltage to enhance the signal generating ability of the sensor, this effect will be greatly exaggerated with the additional likelihood of cross modulation products of the shield voltage frequency and the sensor carrier frequency appearing in the output signal. If the shield is used with a floating thermocouple or strain gage, the sensor case as well as the shield must be forced in some way to represent the signal common mode so the afore described problem will not exist. The thermocouple bead may be tied to the shield or an R-C network may be used to couple the signal leads and the shield. A strain gage power lead will often provide an acceptable common mode potential. In most cases, the sensor case mounting determines the common mode potential of the sensor. Insulating the case has little effect as the capacitive reactance at higher frequencies significantly affects the (lack of) isolation of the case.

Signal Receiver

The third wire is used to present the common mode (CM) voltage existing at the sensor to the receiving device. The difference between the average signal voltage and input circuit reference voltage **(common mode voltage) will generate an error in <u>all</u> receiving devices**. Whether or not this error is significant depends upon the amplitude and frequency of the common mode voltage and the immunity of particular receiving device. It is not unusual for two "identical" receiving devices to exhibit entirely different apparent zero offset values as the signal wires are moved from one device to the other because of differing and insufficient CM immunity. In general, the very best devices will have common mode rejection ratios

(CMRR) of about 1,000,000 / 1 at low frequencies (<100 Hz). As the CM frequency increases, both the CMRR **and** the maximum allowable CM voltage decrease at about 6 dB/octave. At higher CM frequencies (>100 kHz), the error is caused by slew limiting in the input amplifier and appears as a DC error. It is therefore not coherent with the CM voltage and the term CMRR is meaningless. The onset of slew error is sudden and serious. All accurate receiving devices have input filters to help to limit the CM voltage presented to the input circuit and a method of driving the device input circuit common at CM. If the input amplifier is non-linear (samples the signal), the filter must also remove any signal components that might alias with the sampling signal.

System considerations

The overall data acquisition system design must not allow the receiving device to be presented with normal or CM signals that have voltage levels or slewing rates that are incompatible with the device's input circuit limitations. The system design must also provide for a method to connect floating signals ohmically to the receiving device circuit common. This is necessary to provide a pump-out current source and to limit the CM signal voltage at the device input. Many systems, containing devices that exhibit good test bench accuracy fail when long signal leads, typical of many test laboratories, are used. Before an installed system may be certified and used with certainty, checks must be made to assure that the total system is not being exposed to and responding to unknown and undesired signal sources.

Ground (earth)

This term is purposely avoided in the above discussion as almost never is an instrument or sensor is ever tied directly, within millimeters, to ground. In this world of computers, cellphones, and FM and TV broadcast stations, it is well to remember that a quarter wavelength at 200 MHz is only 3/8 meter, or slightly more than a foot. "Unipoint Grounds" are good for low level, low frequency signals that are compatible with D'Arsonval meters. All instruments containing "electronics" are sensitive to higher frequencies, usually the higher the frequency, the more effect. The signal presented to an instrument is recognized by the instrument as relative to its circuit reference (its "ground"), not the system designer's designated ground. It is therefore incumbent upon the system designer to consider all signals, both wanted and unwanted, and their effect upon the individual instrument as well as the total system accuracy.

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Suggested reading: Gelbach, H.R., The Contaminator of Signals: High-Frequency Common-Mode-Generated Errors.