Practical Instrument Electronics

Application Notes

Can You Calibrate your RTD Devices Correctly with your RTD Calibrator?

The basic concept behind RTDs (Resistive Temperature Detectors) is a very simple one. A current is passed through a material that has a stable and defined change in resistance versus a change in absolute temperature. The most common example of this is the Platinum (Pt) 100 curve equal to 0.00385Ω/Ω/°C. This Pt 100 curve has a base resistance of 100Ω at 0°C and is described typically according to the Callendar-Van Dusen equation with the associated coefficients. At 100°C the resistance is equal to 138.50Ω (ITS-68) or 138.51Ω (ITS-90). The name of the curve is typically the ratio of resitance at 100°C divided by the resistance at 0°C. The curves are very reliable and can be improved depending on the purity of the materials used. RTDs are typically used for the most demanding and accurate industrial measurements as well as many laboratory measurements. While there are many methods of measuring temperature the RTD remains the most practical for the high accuracy, mid range process temperatures ranging from about -100°C to 800°C. Outside these ranges thermocouples and other devices should be considered more appropriate.

Going back to the basic property that makes RTDs useful is the ease of measuring the inherent change in resistance proportional to a change in temperature. Obviously this is where they get the name RTD. The basic principle required to read an RTD is based on the simple Ohm's Law equation. $I = V/R$, where I is electrical current, V is voltage and R is resistance. Conveniently rearranging the Ohm’s Law equation to solve for R (an RTD in our case) results in R = V/I. From this it should be apparent that if a KNOWN current is driven through an unknown resistance BUT the resulting voltage is monitored the unknown resistance can be easily calculated. This is the basic principle for all devices that measure resistance including multi-meters, RTD thermometers, temperature transmitters etc. While the basic theory of measuring the output of an RTD is relatively simple, there are countless subtle variations on the theory in application. In our experience these methods are as varied as the engineers’ imagination and the applications they are designing to. A partial list of these applications include low measurement currents, high measurement currents, pulsed and intermittent currents, switched PLC input currents, split and equal lead currents (typically used for compensating 2, 3 and 4 wire connections), voltage excitation (not current). Sometimes all these methods may be combined with polarity switching (for offset voltage cancellation). Some combination of these may be present depending on the particular (or in many cases peculiar) applications for monitoring RTDs. The applications range from well thought out and critical to the just plain cheap and dirty implementations. As a user looking at a device who would know all this is going on. Unfortunately the myriad of implementations pose a serious challenge to the users and designers of calibration equipment. Making matters worse many calibrator designers themselves are unaware of the techniques used in various equipment. We have learned these through years of experience. The variety of techniques unless they are properly addressed can often cause very serious problems. This is especially true when considering that these are typically high accuracy and high repeatability requirements to justify the use of RTDs. Probably the most common results are poor accuracy or repeatability resulting in replacing transmitters, receivers, etc. as the inconsistencies are discovered and troubleshooting the problem begins. There are many calibrators today that are not designed for operation with all these devices and expect the technicians or engineers to know when and where to use their calibrators based on the application. This is very difficult to do since how the transmitter accomplishes its specification is rarely disclosed. That manufacturer is interested in relaying information on its specifications not HOW it meets its specifications.

Signal Polarity

Many calibrators are mistakenly designed for currents flowing in only one direction through the device. They are not bipolar or bidirectional with respect to current. RTDs and resistors are. In this case the calibrator won’t act like a true resistor. This design approach would theoretically be fine in an ideal world if the user or the calibrator knew this and could always guarantee which direction current would flow through the calibrator. The reality is unless you know and account for this during hookup this may be a significant problem. Typical problems that might be experienced range from catastrophic errors, which are generally easier to find to the more insidious linearity errors in the calibrator due to internal circuit saturation or leakage currents affect the calibrator. This often leads to the technician or engineer to incorrectly assume and blame the transmitters or receivers. Replacing those repeatedly in a hope to fix the problem can be costly especially as it relates to down to process.

Even if the calibrator is designed for bidirectional currents it is important that any internal offset voltages need to be very low. If they are not this may lead to inconsistent results depending on which polarity the calibrator is connected from one calibration cycle to the next. This is very important on transmitters or receivers in applications that may use switched polarity readings used to cancel thermocouple effects imposed on RTD probes with low current excitation. This technique is most commonly found only for the most accurate devices and as a result makes it that much more critical that the offsets are accounted for.

Pulsed Currents

Pulsed currents are a relatively new feature in field devices' ranging back to about 1990's and have become increasingly more popular. Pulsed currents have been implemented for various reasons. Some of the reasons behind pulsed currents range from reducing self heating in the RTD probe due to the required excitation current, low power applications in remote battery powered devices such as stand alone gauges, PLCs that scan several inputs and may only look at the RTD for brief period and switch to another input. While these are clearly all valid applications they require special attention to assure proper operation and calibration. Making things even more confusing is the field devices requiring calibration often don't indicate that they use pulsed or intermittent currents. As a result this probably accounts for more misunderstandings, time lost and field problems than any other all by itself. This is because the calibrator may often appear to work and may manifest itself in noisy readings, inconsistent reading or even as a temperature offset. The reasons for these manifestations are beyond the scope of this paper and could be the subject of a whole paper on its own. However because of this confusion the most likely thing done in the field is to replace the installed field devices such as transmitters, controllers or receivers only to find that the problem persists.

Many RTD calibrators don't specify operation with pulsed currents. Other calibrator manufacturers specify compatibility with pulsed or intermittent currents but state a duty cycle such as 10mS/Second. This can be very misleading. Be sure to check that they respond to repetitive pulses less than 10mS to the full rated accuracy of the device.

Current Ranges

Another area often overlooked that leads to many field problems is current ranges allowed. Many of the RTD calibrators available specify very narrow bands of excitation current from the transmitter or receiving device. Many RTD calibrators on the market will specify current ranges as narrow as 0.5mA to 3mA. This is insufficient for compatibility with many new devices. Many of the newer devices use currents from 0.1mA and lower. Devices that measure lower temperatures or other low resistance curves like Cu10 use 10mA or higher currents. Practical Instruments manufactures RTD calibrators that go from low micro-amps to 20.00mA. This is the widest in the industry without question and this has been done for a reason.

Banana Plugs

Be careful with banana jacks. Many calibrators are equipped with just two double insulated banana jacks for simulating RTDs with 2, 3 or 4 wire connections. Fluke is a champion of this method. These are convenient for two wire connections but for the more accurate 3 and 4 wire connections may introduce significant errors. So care must be used when using these. The contacts or plugs will be stacked by its nature to achieve 3 and 4 wire connections. This will introduce unbalanced paths in 3 and 4 Wire connections. Another concern with this approach is if there is any corrosion or contamination this can also introduce both resistive mismatch errors as well as thermocouple errors. The thermocouple error for copper corrosion is quite high. Depending on the amount of excitation current, this may approach the total accuracy of the calibrator itself if it is not accounted for. Obviously these connections are convenient but be careful. Our suggestion is to find a calibrator with four rather than two banana connections for simulating RTDs. The reason is with four protected banana it reduces the possibility *of mismatched* corrosion, signal path length and thermocouple effects for high accuracy measurements at lower currents.

RTD Decade Boxes

While a decade box may seem like a good compromise there are many things to consider when using a decade box as a calibrator.

The first issue is they are scaled in ohms. They are very expensive to approach the equivalent accuracies. Unless you have all the necessary tables, they are not useful since they still need to be converted to temperature. The conversion from resistance to temperature is very error prone especially in the process environment. Any one that has done calibrations this way has experienced making table conversion errors or transposed numbers, etc.

This method can potentially be catastrophic if not highly suspect for minor errors. For any errors that are caught there will be equally many that are not.

Another insidious error with a decade box is subtle damage due to resistor heating and overload. The same decade box that is used for precision RTD calibration may at times be used in a 4-20mA loop as a current limiter or voltage divider or some other unintended use. This often damages the precision resistors within a decade box. This will cause internal resistance values of one or many of the resistors to shift and will likely not be discovered until the decade box goes out for recertification. A decade box typically cannot be recalibrated. They have many fixed resistors that are switched in by mechanical switches. Once one of the resistors is damaged they are damaged forever or the parts need to be replaced and may never be returned to original specifications. Most often an offset at different error values will accompany the certification. These error values are intended as a correction that needs to be remembered during calibrations. This will further complicate the calibration process since these will hopefully be remembered and added or subtracted ***correctly*** during the conversion to temperature. Most electronic calibrators are protected from over current and over voltage conditions. Typically even if an electronic calibrator is damaged they are easily repaired to original specifications. Practical Instrument Electronics calibrators are protected against misconnection to ±60VDC.

Why Practical Instrument's RTD Calibrators are Preferred

Practical Instrument's RTD calibrators are engineered specifically to address all of the "technology concerns" discussed above and many more. Our engineering designs minimize the potential for misdiagnosed field devices and the costly downtime that is often associated with troubleshooting or replacing transmitters, receivers, controllers etc. Our calibrators are intended to be simple in operation and use, while providing the highest level of engineering integrity available. We believe if you take the time to actually compare our calibrators with any in the industry and understand the subtle details associated with making precision RTD calibrations, you will find our accuracies and field compatibility second to none.