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Kulite TD 1015
Successfully Extending Pressure Transducer Wiring Without Compromising Signal Quality

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Locations selected for pressure transducer installations may be in or near a physical environment that is incompatible with the measurement system electronics. It then becomes necessary to provide adequate separation between the pressure transducer and measurement system components. This occurrence often results in the extension of the transducer wiring or multiconductor cable. Unless ordered with custom lengths of cable or wiring at an extra cost, a 36 inch "pigtail" is normally supplied with a catalog Kulite pressure transducer. This technical note will address the issues that arise when extension cables from a pigtail or electrical connector are necessary. Additionally, this technical note will briefly introduce the supplies and methods to be applied when cable extensions are required.

High quality pressure measurements are attainable when there may be hundreds of feet between the transducer and its power source, but the customer needs to be aware of three potential issues: excitation voltage loss and the resulting sensitivity loss, extraneous noise pickup, and bandwidth reduction.

Excitation Voltage Loss

Most unamplified Kulite pressure transducers are calibrated with 10.0 VDC applied to the 36-inch pigtail or connector. Either unipolar or balanced bipolar excitation is acceptable as an excitation source. The bridge excitation voltage level (V_B) for the ground-referenced unipolar excitation mode is 10 VDC. The voltage level of $+V_B$ for the balanced bipolar excitation mode is 5 VDC and $-V_B$ is set at -5 VDC.

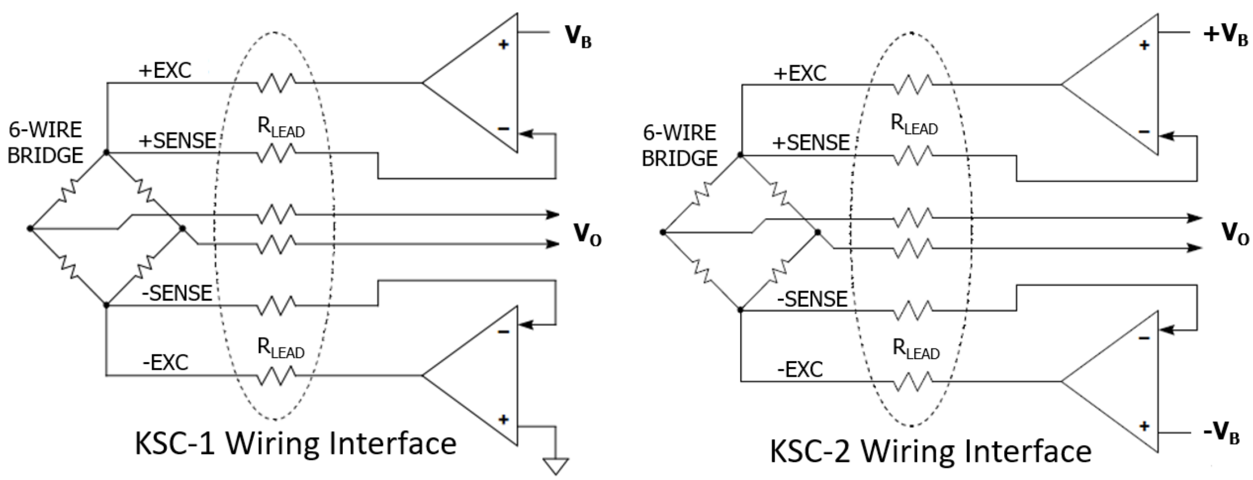

Figure 1a: Ground-Referenced Unipolar Excitation

Figure 1b: Balanced Bipolar Excitation

Without sense leads, wire resistance, R_{LEAD} shown in Figure 1a and 1b, will reduce the excitation level at the transducer. Obviously, this effect is more pronounced in smaller wire sizes and/or longer wiring runs. Also bear in mind, that the temperature coefficient of copper is 0.385%/°C.[1] Remote sensing applies 4-wire Kelvin connections near the bridge excitation terminals. This configuration allows for the continuous and automatic correction of voltage loss in the excitation leads. It is recommended that the user employ a 6-wire approach (power leads, sense leads and signal leads) for all high-accuracy bridge measurements.

Typically, a signal conditioner uses an internal power supply along with internal circuitry that form part of a feedback loop to regulate its output voltage. When the signal conditioner – acting as a power supply – is set to 10.0 VDC, the feedback loop is completed by the sense wiring either internally (Local Sense) or externally (Remote Sense). This feedback system measures the voltage across the sense terminals and adjusts the excitation boost voltage to regulate the output such that the sense lead voltage equals the 10.0 volt setting under all normal operating conditions even when the sense connection is made some distance away from the power supply. The use of twisted-pair cabling with separate pairs for each circuit function (excitation, sense, and signal) is recommended as they are designed for differential, electrically balanced applications.

There is a practical limit to the excitation boost voltage available to overcome the lead wire resistance excitation voltage loss. The KSC-1 excitation boost in each power lead is limited to 1.5V. Consequently, up to 13 VDC may be applied at the KSC-1 interface connector to achieve 10 VDC at the transducer. This is accomplished by using a pair of forward-biased, low-leakage diodes between the force leads and the sense leads when the remote sense mode is engaged. Under normal operations, current flow through the diodes is negligible and does not affect load regulation. As the maximum boost of 1.5V is approached some current will flow and will begin to affect load regulation. It is unlikely that test personnel will experience this output limitation as the wire impedance will have to reach a level of 30% of the nominal transducer input impedance, R_{IN}. This method of active overvoltage protection combined with short circuit and overcurrent protection prevents significant overvoltage occurrences in event of wiring issues.

Kulite SOI pressure transducers are ratiometric devices. That means the full-scale output voltage changes in direct proportion to the change in the excitation level. Measurement errors exceeding 2% FSO are common in larger test facilities when remote sensing is not applied due to lead wire voltage losses. However, it may be impractical to employ a six-wire approach in every installation. The 4-wire approach (power leads and signal leads) is known as local sense mode and does not correct for excitation loss. Provisions may be made for a technician to measure the excitation level three feet from the transducers using exposed terminals or temporarily insulated short wiring (Kelvin connections) when high accuracy measurements are desired, but a complete six-wire installation cannot be implemented. Some excitation level in excess of 10 VDC will be set at the signal conditioner in order to realize 10 VDC at the transducer.

The Kulite KSC-2 signal conditioner supports a high-resolution setting of balanced bipolar excitation voltages in 1.25 mV steps that enables the precise setting of 10.0 VDC at the transducer when the local sense option is requested and measured at the transducer by a technician. Bear in mind that the KSC-2 output is limited to 12.5 VDC in the local sense mode. The user must also be aware that temperature changes will impact both the lead wire resistance as well as the input impedance of the transducer necessitating frequent excitation checks and adjustments for best results.

When it is desired to maintain an excitation voltage of 10 VDC locally sensed at the signal conditioner, the customer may dedicate a second data acquisition channel to monitor the voltage at the transducer. This approach should be carefully applied as to not risk voltage saturation of the second measurement channel for instances when greater than 10 volts is erroneously delivered to the transducer. Once the installation has been completed and all of the circuits are properly functioning, data may be acquired and corrected for the actual excitation voltage using excitation ratio corrections as shown in equation 1. V_{MON} is the excitation voltage measured using the second measurement system input and $10.0/V_{MON}$ is the excitation ratio correction factor. The value should range from 1.0 to 1.05 for best results. The pressure signal is denoted by V_O and the sensitivity is available from the transducer calibration certificate.

Equation 1: $$Pressure\ (PSIA) = \frac{1000\left(\frac{mV}{volt}\right)\times\left(\frac{10.0(volts)}{V_{MON}(volts)}\right)\times\left(\frac{V_O(volts)}{Gain}\right)}{Sensitivity\left(\frac{mV}{PSIA}\right)}$$

The remaining option accounts for excitation loss in a four-wire (power/signal) transducer installation without the use of a second measurement system channel. In this final scenario, the actual voltage at the transducer is not measured. Rather, the excitation ratio correction factor ($10.0/V_{MON}$) is calculated based on the input resistance of the transducer and the estimated wire resistance (Table 1). The entries shown in the table below are nominal values that do vary among manufacturers, stranding, and wire plating.

AWG Size	20	22	24	26	28	30	32	34	36
# Strands/AWG	7/28	7/30	7/32	7/34	7/36	7/38	7/40	7/42	7/44
Ohms/1000 ft	9.8	15.6	24.5	39.7	63.6	100	170	265	423

Table 1: Stranded Wire Resistance (20° C), Courtesy Calmont Wire & Cable

The voltage delivered to the transducer may be estimated by first analyzing the loop resistance of the excitation wiring as shown in Equation 2. The scalar of 2 in the equation accounts for the combined resistance of both excitation lead wires. Thermal effects may be omitted for room temperature applications, but can significantly alter the R_{LEAD} excitation voltage loss in cryogenic or high-temperature installations due to both the thermal coefficient of the copper lead wires as well as the thermal coefficient of resistance of the pressure transducer. The ambient temperature, T_{AMB}, is entered in degrees Celsius.

Equation 2: $$R_{CABLE} = \left(2 \times Cable\ (ft) \times Resistance\,\frac{Ohms}{1000\ (ft)}\right) \times \left(1 + 0.00385 \times (T_{AMB} - 20)\right)$$

Often, several segments of wiring are required to interface a pressure transducer to its measurement system in large-scale blast test or altitude ground test facilities. Treating the cumulative cable resistance as a composite of several lumped parameters is the recommended method to estimate R_{CABLE}. Each of these cable segments may be analyzed separately then combined into a single value.

Equation 3: $$R_{CABLE(TOTAL)} = R_{CABLE(1)} + R_{CABLE(2)} + \ldots\ R_{CABLE(n)}$$

After estimating the total cable resistance, calculation of the excitation value expected at the transducer is accomplished using Equation 4. R_{IN} may be found on the calibration certificate supplied with the transducer or measured at the transducer pigtail at expected operating temperature (preferred).

Equation 4: $$V_{MON} = 10.0\ (volts) \times \frac{R_{IN}}{R_{CABLE(TOTAL)} + R_{IN}}$$

Extraneous Noise Pickup

Often, the biggest issue with lengthening the wire or cable installation is increased noise. Even with well shielded cable and twisted pair conductors, there will likely be much more noise pick up before amplification in long cable runs. The best practices for limiting the pickup of extraneous noise may be viewed in the following technical notes available at https://kulite.com/technology/reference-library/.

1. TD 1013 - Best Practices for Reducing Pressure Measurement Noise, Part 1: Electronics
2. TD 1014 - Best Practices for Reducing Pressure Measurement Noise, Part 2: Installation

Bandwidth Reduction

Extending the length of wire or cable between a pressure transducer and measurement system will have a negative impact on the frequency response of the measurement. Understanding the attenuation at various frequencies as well as the bandwidth limitations may be viewed in the following technical note available at https://kulite.com/technology/reference-library/.

1. TD 1011 Maintaining High-Frequency Signal Transmission for Pressure Systems

Installation Notes and Introduction to Wire Splicing

Various tools and techniques will be required to extend the lead length of miniature Kulite pressure transducers to interface with signal conditioning and data acquisition equipment. The following equipment listing and simplified instruction set is meant to convey an overall sense of the individual tasks involved in the operation and is by no means fully developed for any specific installation. High-temperature installations, in particular, are not fully covered in this document, but details for interfacing to nickel-plated wire used in the construction of high-temperature devices are provided.

Items Needed

Thermal wire stripper
Mechanical wire stripper
X-ACTO® knife
Teflon tape
Work bench vise
RTV, cable ties and/or tape to secure the cables
63/37 (Sn/Pb) low-temperature tin-lead solder
Lightweight, ESD safe soldering iron or station
Heat-shrinkable tubing, various diameters
Lightweight, ESD safe heat gun

Hardware Description

It is difficult to remove the insulation from small diameter transducer wires with mechanical strippers. It is recommended to purchase a thermal stripper to remove the insulator from the transducer wires before attempting splicing operations. Temperature-controllable versions are available from companies such as the TWC-1 StripAll from Teledyne Technologies. Blank blades are suggested for #28 AWG wire sizes and smaller. Mechanical stripping tools are also sized for use with the larger extension wire such as #22 or #26 AWG wires, for example. The Ideal 45-125 Wire Stripper is a common mechanical wire stripping tool.

A local AC power source for both the soldering iron and the heat gun will be required. A portable, lightweight soldering iron must be available for field installation. Multiple designs are available from Weller such as the Weller W60P-3 Soldering Iron. A selection of soldering tips would be useful. The Weller CT5D8 screwdriver tip or CT5C8 screwdriver tip may be preferred over the conical tip that comes with the catalog soldering gun as it distributes the heat over a larger area and is more forgiving. If these tips are too high of a temperature for the given splicing operations, the same size tips may be ordered in the 700° F version (CT5C7 & CT5D7). Alternately, one could order a soldering station instead of separate items if the installation location allows. The Weller WT Soldering Station may also be fitted with different tips such as the PTC8 or PTD8. One should also review the available soldering accessories. At a minimum, one should consider a holder with a sponge for cleaning the tip and flux remover to clean the completed solder joints for the prevention of corrosion, moisture absorption, and leakage between circuits.

A portable heat gun such as the Weller 6966C Lightweight Heat Gun must be available for field installation. A work bench vise such as the Panavise 396 Work Bench Vise is very useful for holding the cable in place while the transducer splicing operations take place. An X-ACTO® knife may be used to aid in separating the individual conductors of miniature flatpack transducers. The wire insulation including shield on both transducer and extension cable portions must be stripped using appropriate tools prior to splicing and each set of four wires plus shield[2] must be joined to the complementary cable (6 wires if remote sensing of the excitation is required). When a multiconductor cable is not supplied with the transducer, wrap the individual leads of the transducer together using Teflon tape of the same style used on pressure fittings to prevent the individual wires from snagging on protuberances or becoming entangled within the test article. A thin Teflon tape with a 50% overlap from the installed transducer to the splice is appropriate.

Use low-temperature, tin/lead leaded eutectic solder Sn63/Pb37 to join each wire of the transducer to the appropriate lead or pair of leads on the extension cable. Adhesive-lined 3:1 shrink tubing is recommended for strain relief and insulating purposes when splicing the individual leads. The 1/8” ID shrink tubing will typically shrink to about 0.050” diameter with a solid core of flexible hot-melt glue. This thermoplastic adhesive bonds with a wide variety of rubber, plastics and metals, forming a permanent, non-drying, flexible and water-resistant barrier. Splicing nickel-plated transducer wiring requires additional steps that are outlined in the next section.

Strain-relieve the overall cable joint by covering all splice joints with larger, adhesive-lined heat shrink tubing to prevent wire breakage at the solder joints. A section of larger (3/16”, 1/4”, or 3/8” diameter) adhesive-lined shrink tubing over the wire joints forms the completed in-line splice joint after heating. Limit the temperature of the cable splice to 110° C during operation. Higher operating temperatures will necessitate the use of fiberglass tape and/or sheathing for insulating purposes.

Splicing High-Temperature Wire

Different solder/flux formulations and additional preparation steps are required for splicing nickel-plated wiring used in the construction of high-temperature transducers.

1. Apply M-Line rosin solvent to each stripped wire to remove impurities and allow to air dry for a few seconds
2. Apply M-Flux AR-2 rosin core solder flux activator to each wire in preparation for soldering
3. Clean the tip of the 800° F soldering iron with Duratool 1471 Tinner-Cleaner
4. Apply the small-diameter, high-temperature, multicore solder with high-lead content such as Loctite MM01006 to form the wire joint
5. Apply the M-Line rosin solvent to the solder joint to remove any excessive flux that is present

Repeat steps 1 through 5 for each joint as keeping a clean tip is very important. M-Flux AR is an active, but noncorrosive rosin flux that is effective on both copper and nickel. Items 1 and 2 may be purchased as the Micro Measurements FAR-2M-Flux AR Kit. Micro Measurements solder type 570-28R may be substituted for the Loctite MM01006.

DISCLAIMER: The above information and recommendations are provided for reference purposes only. Kulite does not warrant the content, quality, accuracy, reliability, performance, or fitness for a particular purpose of any product not manufactured by Kulite, or the content of the information provided. It is the responsibility of the customer to assess the compatibility of the recommended products to the customer’s particular application.

References

[1] Walt Kester, "Practical Design Techniques for Sensor Signal Conditioning, Section 2 – Bridge Circuits," Analog Devices, 1999

[2] "Best Practices for Reducing Pressure Measurement Noise, Part 2: Installation," Kulite Semiconductor Products Technical Document TD-1014, 2022

