

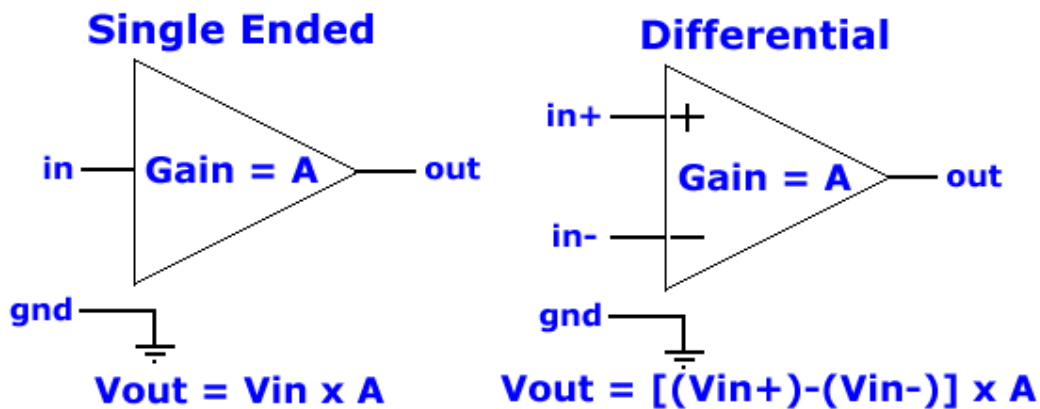
# Transducer Interfacing Guidelines

## Overview

UFI transducers can be interfaced to a wide variety of signal conditioners besides those sold by UFI. Understanding the few basic concepts discussed in this paper will make this process much simpler. If you find this discussion helpful, let us know. And please send us your suggestions for improvements!

## Signal conditioner configurations

There are basically two signal conditioner input configurations: *single-ended* and *differential* (Figure 1). The appropriate configuration depends on the type of transducer you will be using.



**Figure 1 Single Ended and Differential inputs**

A *single-ended configuration* provides two input terminals, a signal terminal and a return/reference terminal (usually the system ground). This configuration accepts only one input signal, which may generally go positive, negative or both with respect to the reference. The signal conditioner output is simply the single input signal, but amplified with respect to the reference by a multiplier, or *gain* factor.

A *differential configuration* has three input terminals, a *non-inverting* signal input, a reference input, and an *inverting* signal input. As for the single-ended configuration, the signals supplied to the non-inverting and Inverting terminals can generally go both positive and negative with respect to the reference terminal. As its name suggests, the signal at the differential configuration output is the arithmetic *difference* between the two input signals (each expressed with respect to ground), but amplified by the gain factor.

The differential configuration can be very useful when both input signals consist of small, varying signal voltages superimposed on (added algebraically to) substantial and matching DC *offset voltages*. (The bridge type of transducer often supplies two input signals of this sort -- see below.)

With the differential configuration, the DC offset voltages effectively cancel each other out in a process termed *common-mode rejection (CMR)*. This leaves the *difference* between the original small and varying signal voltages to be amplified (and perhaps filtered) by the signal conditioner.

The CMR property of the differential configuration is also put to good use when there is external electrical interference (“noise”) present in the experiment area. (50/60 Hz electro-magnetic radiation from AC power mains is an especially common and serious source of such interference.) If the source of interference is reasonably distant, chances are good that it will show up equally at both differential input terminals, and thus be canceled just as DC offset voltages are canceled.

### Interfacing the transducer to the signal conditioner

Connecting a single-ended transducer – one with just one active output terminal plus a reference terminal – to a single-ended signal conditioner is very easy (Figure 1a). Just tie the active transducer output to the active signal conditioner input, and then tie the reference terminals for each of the two circuit blocks together. The main prerequisite for a good interface is that the signal conditioner input range should be large enough to accommodate the expected variation in the transducer output signal.

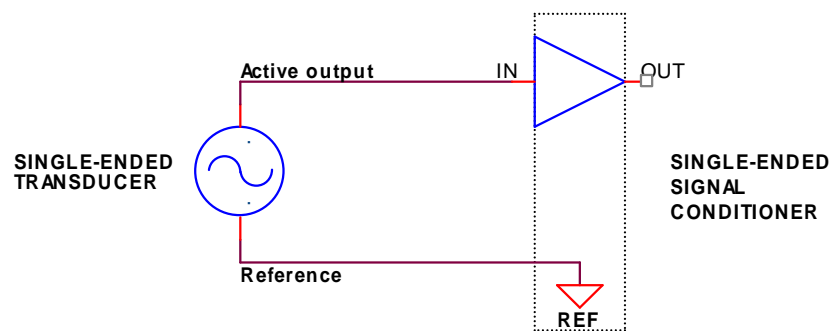
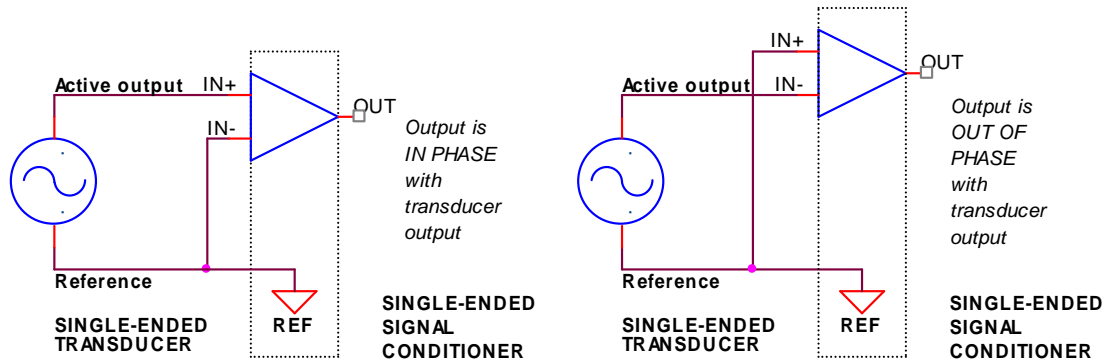


Figure 1a

While there are more terminals to deal with, interfacing a differential-output transducer – two active output terminals and probably a reference terminal – is also straightforward. (See Figure 4a and the discussion of bridge transducers, below, for details.)

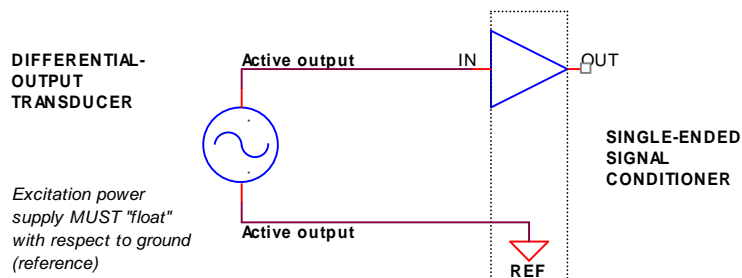
A single-ended transducer can also be connected to a differential-input signal conditioner (Figure 1b). One of the transducer outputs is connected the reference input terminal and the other is connected to *one* of the two active inputs. (The unused differential input should be connected to the reference terminal to minimize noise.)



**Figure 1b**

If the inverting input is the one tied to the common reference, then the output from the differential signal conditioner will be *in phase with* (moving the same direction as) the input signal. Conversely, if the non-inverting input is the one tied to the reference, then the output from the differential configuration will be 180 degrees out of phase with the active-input signal. For some transducers, this inverting arrangement may be helpful.

Connecting a differential-output transducer to a single-ended signal conditioner is much more difficult, and generally not recommended. For this combination, one output of the transducer must be tied to the single active input of the signal conditioner; the other transducer output must be tied to the signal conditioner reference terminal/ ground (Figure 1c).



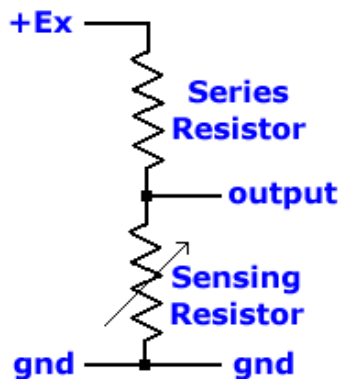
**Figure 1c**

For this to work, the excitation power supply will need to "float" with respect to ground. That is, the supply will need to be isolated from system ground to avoid shorting out the transducer. This involves additional circuitry, but may be required in some instances when you only have a "round peg" transducer to mate with a "square hole" signal conditioner.

## Voltage divider transducers

Some transducers can generate their output signals without the aid of any external power source. The UFI Model 1010 Piezo-electric Pulse Transducer and the UFI Model 1132 Pneumotrace II™ respiration transducer are examples.

However, most transducers require an *excitation current* in order to supply an output signal to the signal conditioner. Such transducers generally take the form of resistor *voltage dividers*. In the transducer shown in Figure 2, the active element, the *sensing resistor*, changes resistance in reaction to changes in the property that is to be measured. For example, a temperature change modifies the resistance of a thermistor, mechanical strain induces a resistance change in a strain gauge, and so on.



**Figure 2**  
**Simplified Transducer Circuit**

A second, *series resistor* forms the “upper arm” of the voltage divider. The excitation current flows through the series resistor, then through the sensing resistor and finally to ground. (The ground is simply the return path the current takes to reach the excitation power source.) By Ohm’s Law, the voltages across each of the two resistors are proportional to their resistances -- as long as the current flow through each is the same. Therefore, the transducer output voltage, which is developed across the sensing resistor, will vary in proportion to the changes in its resistance. These changes are in turn induced by the property to be measured – temperature, strain, whatever. (And sometimes by environmental properties that are *not* of interest – see the discussion below on temperature compensation.)

If a simple voltage divider transducer is to give reasonably accurate measurements, two considerations are especially important. First, the series resistor usually must have a high resistance in comparison to the sensing resistor’s range. Otherwise (and given a constant excitation voltage), the excitation current will vary and throw off the voltage proportionality of the divider.

Second, the transducer output must be tied to a signal conditioner input that has a high input *impedance*. (Impedance is simply resistance generalized to include the “push-back” to alternating currents as well as direct currents.) Otherwise, most of the excitation current will flow through the signal conditioner input circuit and not the sensing resistor, again throwing off the divider’s proportionality.

Practically speaking, one the first consideration really limits the accuracy and applications for simple voltage divider transducers. This is because practically all modern signal conditioners present very high input impedances to any signal source that might be connected. These signal conditioners are built with operational amplifiers that have been designed with high input impedance as a principal selling point.

### Temperature compensation and bridge transducers

Unfortunately, not just thermistors are temperature-sensitive to varying degrees: many resistive transducer sensing elements have this characteristic. Two common solutions to this problem of *temperature compensation* discussed here.

The *half-bridge* transducer (Figure 3) uses material for the series resistor that has the same temperature characteristics as the sensing resistor. Thermally induced resistance variation will be similar for both resistors IF they have similar values. (The current through the combined resistance may change, of course, but the voltages across each of the resistors maintain their relationship.) The half-bridge transducer can be used with the single-ended signal conditioner to keep the interface simple, but other circuit components may be required to remove DC offset from the signal.

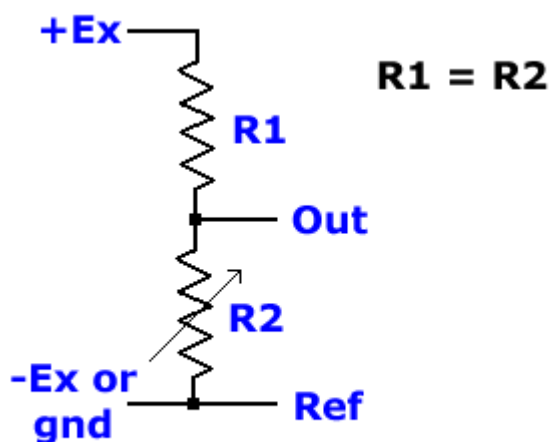
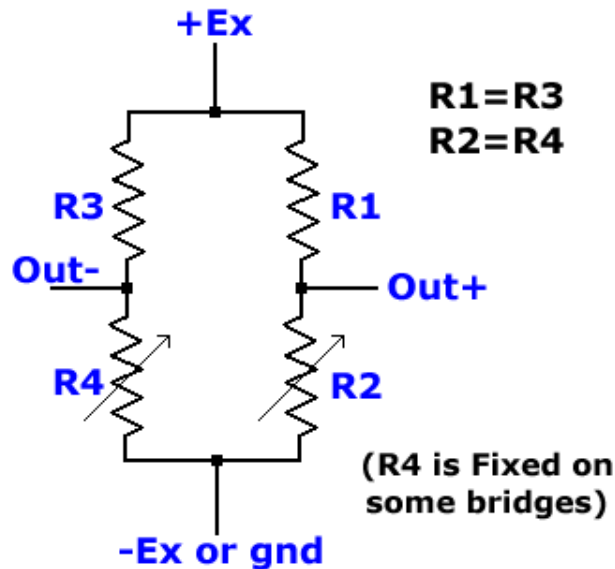


Figure 3 Half Bridge

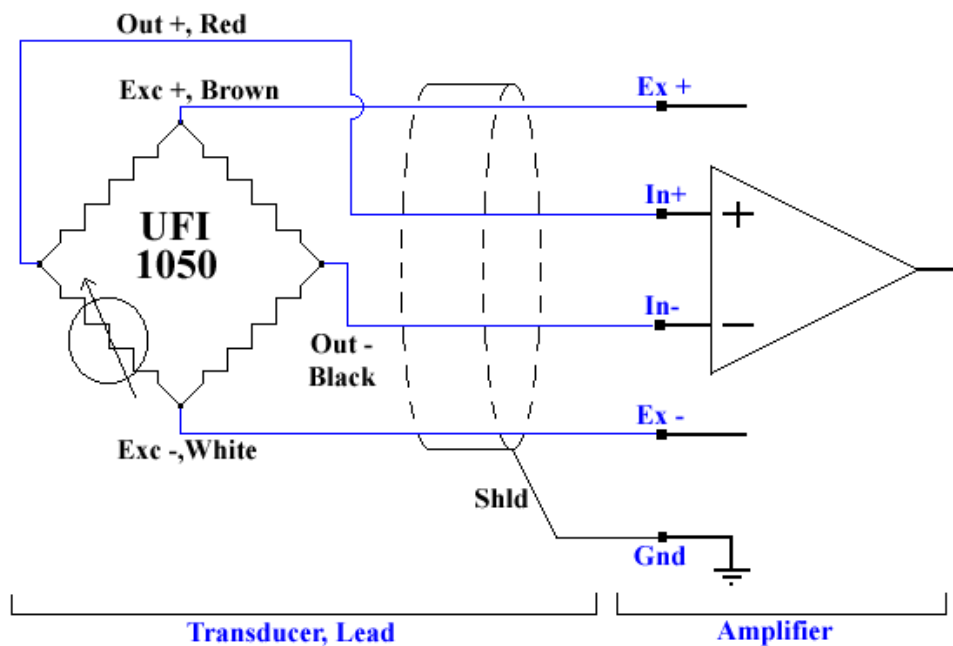
The *full-bridge* transducer (Figure 4) is constructed from two half-bridge elements with their “top” (excitation) and “bottom” (usually ground) terminals tied together. Full-bridge transducers must be connected to differential- input signal conditioners. One differential input is tied to the R1-R2 resistor junction (Out+); the other is connected to the R3-R4 junction (Out-). (One of the two “sensing” resistors, usually R4, may in fact have a fixed resistance in some full-bridge transducers.)



**Figure 4 Full Bridge**

There are a number of advantages to the combination of full-bridge transducer and differential signal conditioner. First, the series resistances can be much larger than the sensing resistances, and of different materials (though they must match each other), and yet still maintain good temperature stability. Second, since the difference signal between the Out+ and the Out- terminals is amplified, noise contributions from the environment are minimized. Finally, both bridge transducer outputs may be “contaminated” by substantial DC offset components. However, such offsets will be removed by the differential signal conditioner, permitting amplification of just the desired signal.

Figure 4a shows a "real world" full-bridge transducer -- here the UFI Model 1050 Blood Pressure Transducer -- interfaced with a differential-input signal conditioner. The top and bottom bridge points supply the excitation current. The junctions in the two side branches provide the output signal, which rides on matching offset voltages. The differential amplifier removes the offset and any noise common to both inputs (In+ and In-), and amplifies just the remaining difference voltage. (Interfacing the UFI Model 1030 Force Transducer and the Model 1040 Displacement Transducer is much the same: only the transducer wire colors differ.)



**Figure 4a Bridge Transducer Interfacing Example**

Some transducer/signal conditioner combinations do not include negative excitation. In such cases, the "bottom" of the bridge can be connected to ground if two conditions are met. First, the amplifier input terminals must be able to handle the positive offset voltage on the two transducer outputs. Second, the return for the (positive) excitation supply must be connected to the same ground as the bottom of the bridge. That is, both the transducer Exc - wire (and the shield, if any) must be connected to signal conditioner ground.