# Basics of Auto Referencing

Auto-referencing is a family of powerful techniques used to compensate time and temperature errors by periodic correction of the output signal with respect to one or more reference pressure levels. The error correction circuits are usually simple and low in cost, and at least one pressure level suitable for referencing is usually accessible or can be easily produced. So, it's natural to want to use auto-referencing, since the alternative (an expensive precision pressure trans-ducer) is usually more trouble than it's worth and definitely more expensive than an auto-referenced pressure transducer with comparable accuracy. While it's never wise to declare that a technique is "univer-sal", some techniques are so powerful that it becomes easier to cite instances where the technique should not be used than where it should. Auto-referencing is just such an "almost universal" technique. Why then is this technique not more widely used with transducers? Traditionally, transducer users and producers are "linear/ analog" oriented people, to whom "digital" people are those other guys in the soft world. Factu-ally, analog approaches to auto-referencing are less cost effective. So, there's a natural reluctance for analog people to employ digital circuitry for an analog function. Yet, all mensuration theorists and educators highly recommend the technique. Therefore, the message is...get on board, fellow analogers, digital auto-referencing is good for you.

Which pressure transducer users should not use a common-mode auto-referencing circuit? In applications involving a short measurement cycle, where the zero point is either read or manually adjusted at the start of the cycle, an auto-referencing circuit is of no value. In acoustic measurements where the transducer is AC coupled such that DC or steady state response is of little value, common-mode auto-referencing won't help. In all other applications, common-mode auto-referencng yields the optimum accuracy for the lowest cost.

## COMMON-MODE AUTO-REFERENCING — EASY AND EFFECTIVE

Common-mode errors are generally the largest (especially at lower pressures, where it really counts in some applications) and therefore give way to the greatest accuracy improvement when auto-referenced. They are also the easiest to auto-reference as shown in Figure 2, since all that's required is to sample the signal at reference pressure and subtract the error from the signal at any "measure" pressure. This is expressed by the formula

$$V_{SCM} = V - \Delta V_O$$

Where V is any measure pressure signal, $\Delta V_O$ is the error pressure signal and $V_{SCM}$ is the output signal corrected for common-mode error by subtracting the error from the measure signal. As seen in Figure 2, no slope correction is involved.

The basic auto-reference functions required to implement this formula are shown in Figure 3. They include a switch, a sample-and-hold, and interconnecting logic for synchronizing with the measure-reference cycle.
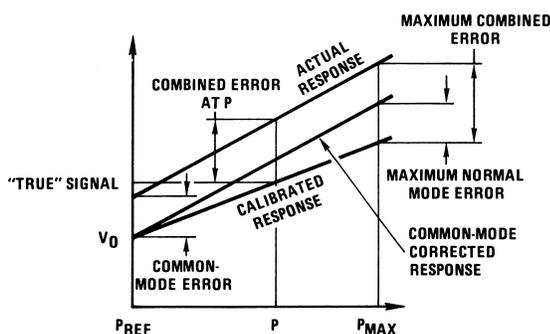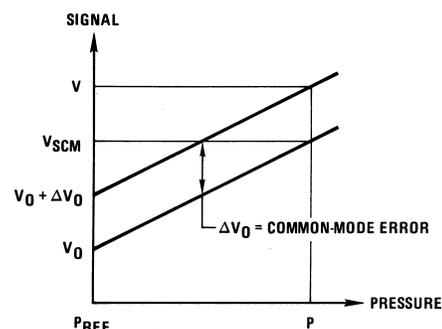
**FIGURE 1**
**Transducer Errors**

**FIGURE 2**
**Common-Mode Error Correction**

What's the best way to use auto-referencing? The correct, but imprecise, answer is... as often as you can. The object is to have those measurements of greatest interest closest in time to an auto-reference command. The kind of duty cycle naturally best suited to auto-referencing is "short repeated cycles", each containing a reference point. Another well suited kind of duty cycle is a short interest period immediately preceded by a referencing point, but followed by a long no-interest period. In either case, a measurement point of interest is within several hours of the preceding reference point. Most applications have duty cycles that are in one of the two aforementioned "naturally well suited for auto-referencing" categories. Equally important, many applications that have duty cycles not naturally well suited can be converted to the short repeated cycle situation with relative ease if the value of doing so is recognized by the designer early enough. The simplest of the best suited applications involve things that go up, then go down, and then rest awhile. Ideally, the pressure increases rapidly to the range of interest, hovers at the measurement condition, decreases quickly, and hovers at the reference condition.

Some applications very closely resemble the ideal description. For example, a weighing scale is ideal. Also ideal are filling washing machines, beer bottles, and toilet tanks. Another ideal category is pressure sumps such as tire pressure, oil pressure, and block pressure.

In these cases, the measurement apparatus is usually turned-on at a reference condition before experiencing the measurement condition of interest. Less ideal, but certainly improved by auto-referencing, are flow measurement and control applications. Examples are fuel pumps, pulmonometers, and even machines that smoke cigarettes. In these cases, the flow rate is zero at some point in a relatively short cycle...usually at turn-on.

The trick is to cause the command signal at the right time. The best time is after the transducer is warmed up and when the application is hovering at a reference condition. All the previous examples were of a type wherein the reference condition exists at and shortly after turn-on. This makes life easy. If the warm-up error is of little concern, then the turn-on signal can be used

**FIGURE 3**
**Basic Common-Mode Auto-Reference Functions**
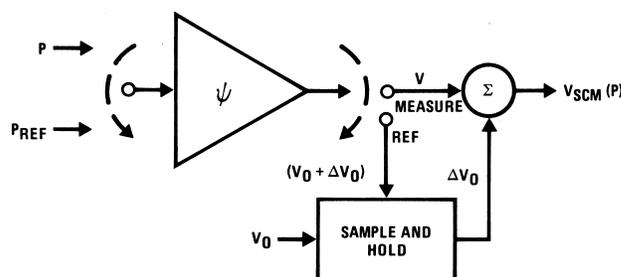
**FIGURE 4**
**Auto-Reference Commanded by Turn-on**
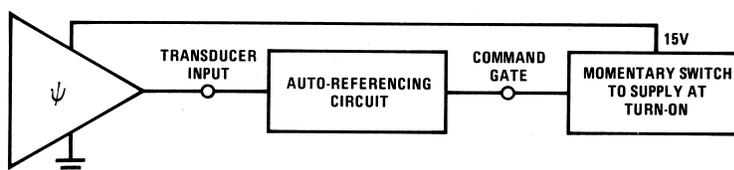
directly as the command signal, as shown in Figure 4. Other ways of getting the required momentary command signals often present themselves as appropriate to the application. For example, in weighing systems, some displacement is inherent just as the load is applied to the scale pan barely before pressure build-up, an invitation to use a mechanical switch.

## SIMPLE CIRCUIT FOR SIMPLEST CASE

The momentary switch referred to for the simplest case, forms an enable signal for input to the command gate, Figure 5.
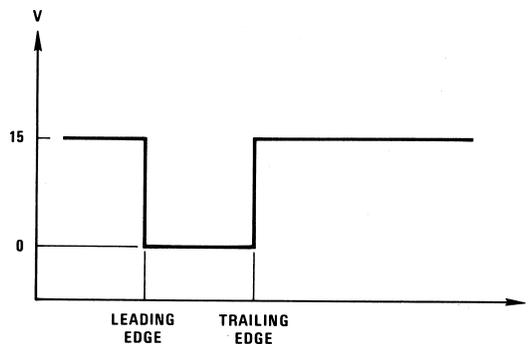
The basic functions of an auto-reference circuit are shown in Figure 6.

The leading edge, negative transition of the enable signal resets the control latch and resets the counter to zero. While in the low state, the enable signal inhibits the counter from accepting input pulses to

allow time for stabilization of pressure. The referencing sequence is initiated on the trailing edge, positive transition of the enable signal. The D to A converter is used as an infinite sample-and-hold as well as a programmable voltage source, supplying and maintaining the desired correction voltage. The output of the transducer is summed with the auto-reference correction voltage at the summing junction of the first amplifier. The circuit is shown in Figure 7.

The "bit" rating of the (D/A) determines the resolution of the output signal. The quality of regulation of the reference voltage applied to the (D/A) determines the system stability. Thus, these easily attained circuit parameters take control of the transducer system's key accuracies. The control logic resets the (D/A), steers clock pulses into the (D/A) until the system output is at reference voltage and sends a busy signal to the sequence logic, as shown in Figure 7.

**FIGURE 5**
**Typical Auto-Reference Enable Signal**



**FIGURE 6**
**Basic Functions of Digital Auto-Reference Circuit**