AN-25: Understanding Auto-calibration and WinSystems' PCM-ADIO Advanced Analog I/O

February 27, 2004 David Fitzgerald

"Auto-calibration" circuitry has been included in high-end analog-to-digital converter products and digital multi meters for many years. The design goal of any auto-calibration circuit is to correct for drift errors that occur over time and temperature. WinSystems' PC/104 based PCM-ADIO advanced analog I/O card approaches calibration and drift from the ground up through thoughtful design and careful component selection to minimize the effects of drift error.

The single most important component in any analog converter design is the analog voltage reference. Reference voltage drift directly affects analog conversion accuracy, expressed as full-scale (gain) error. Drift contributions from any other source, whether from the converter itself or signal conditioning circuitry, can affect either zero (offset) or full scale trim (gain). Drift errors are predominantly functions of component drift over time and how changes in temperature affect components in the system.

At the highest level of instrumentation design and cost, the extremely low linearity error performance of analog to digital converters and resolutions upwards of 27 bits enable system auto-calibration using direct ratio transfers to calibrate all input ranges against a very high performance system voltage reference. Most high performance analog to digital converters used in industrial systems have neither the resolution or linearity performance to use ratio transfers to auto-calibrate. This dictates that highly stable discrete voltages from which each range is to be calibrated must be generated on board.

A typical auto-calibration circuit alternately switches the converter input to zero scale to correct offset drift, and to near full scale to correct gain drift. Hardware or software methods are used to trim the converter accordingly. Multiple input voltage ranges require unique full-scale voltages for each range. Precision resistive dividers are often used to generate the representative full-scale voltages for each range, or at least voltages reasonably close to full scale. Keep in mind that each divider requires a separate multiplexer channel, switch, or relay to apply its output to the converters input, increasing system complexity and cost. If an input voltage range is greater than the onboard reference voltage, more complex circuitry is required to accurately generate the higher calibration voltage.

Resistor choice and reference drifts pose the greatest challenge to this type of auto-calibration circuit. The ratio of the divider must be extremely stable over time and temperature. In order to ensure very low ratio drift, the divider chosen must be fabricated on a single substrate using processes and materials specifically engineered for this purpose. Dividers whose ratio is trimmed to an appropriately tight tolerance increase expense and component lead times significantly as well. Resistive dividers that fulfill these specifications are very costly and usually must be custom manufactured for each ratio value.

This method of generating calibration voltages also assumes that the on-board voltage reference is very stable over time and that its temperature coefficient is very low. **All of the auto-calibration voltages are derived from the on board reference.** If the reference voltage drifts considerably over temperature, not only will it affect the analog accuracy directly, it will also affect the accuracy of the auto-calibration circuit and compound the effect of reference drift on the converter accuracy after auto-calibration. Many products are specified to be accurate only in a very limited temperature range because of the effects of temperature on the reference.

Some poorly implemented designs use inexpensive 1% discrete resistors for the divider networks and have voltage references with large temperature coefficients. Standard thick film resistors can have temperature coefficients of 100ppm or greater per degree C, and long term drift characteristics into the hundreds of ppm per year. Resistors built of different materials (or different value ranges within one family of resistors) will also have dissimilar temperature coefficient characteristics and can not maintain the ratio match necessary for this application. The auto-calibration circuit in this case will drift more appreciably over time and temperature than the analog converter and associated circuitry it is intended to calibrate.

At their best, auto-calibration circuits effectively compensate for drift error between calibration intervals over a limited temperature range on products with highly stable references. The worst auto-calibration circuit does little more than add marketing weight to the datasheet, and will likely reduce the functional accuracy of the board in the field.

The WinSystems' PCM-ADIO Advanced Analog I/O product has been designed with the highest attention in component selection and system design to minimize drift error effects. From the +/- 2ppm per degree C drift precision reference to the ultra low drift custom resistor networks and active components in the signal conditioning paths, WinSystems' PCM-ADIO maximizes converter accuracy over time and temperature while avoiding the pitfalls of conventional auto-calibration techniques when applied to precision industrial analog conversion designs.

More information is available at www.winsystems.com, or, contact the WinSystems Application Engineering department at (817) 274-7553