RTI vs. RTO

HOW TO COMPUTE THE DRIFT OF INSTRUMENTATION AMPLIFIERS

THE PROBLEM

An instrumentation amplifier's offset drift is typically specified at two values of gain, for example, 150μV/°C at unity gain and 0.5μV/°C at gain of 1000, referred to the input. How does a user determine the drift at a gain of 100? What is the difference between "referred to the input" and referred to the output?

THE BACKGROUND

Operational-amplifier offsets and drifts are always "referred to the input" (RTI), as though they were produced by voltage sources in series with one of the input terminals, and would have to be balanced, in feedback circuits, by output self-adjustment. The predicted magnitudes of offset and drift at the output are computed by multiplying the RTI specifications by the closed-loop gain of the feedback circuit. On the other hand, offset or drift of a given device is deduced from a measurement of the output offset or drift at a known value of closed-loop gain (with impedances low enough for current effects to be negligible).

The reason offset and drift in op amps are always specified as RTI is that, while the amplifiers' high open-loop gain allows them to be used in a wide variety of connections yielding a wide range of closed-loop gains, the feedback circuit also maintains the input voltage at the RTI value, allowing the output drift (RTO) to be readily calculated as a function of gain.

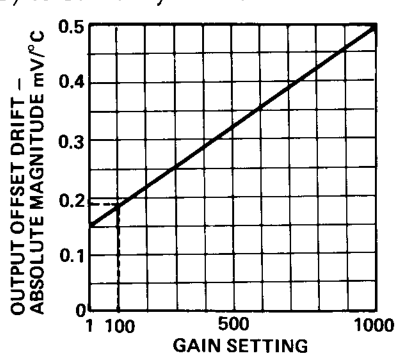

Figure 1. Output Offset Drift vs. Gain for Model 605L.

Fixed-gain instrumentation amplifier users don't care whether the specification is RTI or RTO, since the one can be computed from the other by simply multiplying or dividing by the gain.

With *adjustable-gain instrumentation amplifiers*, it might be thought useful to consider offset and drift in the same way it is done for op amps, i.e., RTI, then to simply multiply by the gain.

But... there is a catch. Many types of instrumentation amplifiers have more than one significant source of offset, with differing influence for each at different values of gain. Usually, there is a term that is constant, added to one that is proportional to gain. For this reason, manufacturers of these devices usually specify the offset (or drift) at a minimum of two values of gain. However, there is little agreement among manufacturers as to whether to specify the drift referred to the input or at the output, and there has been precious little analysis published as to how to predict the maximum drift at *intermediate* values of gain, depending on whether the spec is RTI or RTO.

THE SOLUTION

The simplest favor a vendor could do his customers would be to provide a specification in the form of a plot of maximum output drift as a function of gain (Figure 1). Next best, or in addition, would be an equation specifying the drift as a function of gain. Finally, if you have neither plot nor equation, you can develop both quite easily from the available specs, if the drift vs. gain can be considered a linear function.

Plot

The plot of output drift vs. gain in Figure 1, based on the given example, is a straight line between the end points established at gains of 1 and 1000. At unity gain, RTO and RTI drift are the same. At gain of 1000, use either the RTO specification or the RTI spec multiplied by the gain (1000). Hence, the end points in the example are 0.15mV/°C at unity gain and 0.5mV/°C (i.e., 1000 x 0.5μV/°C) at gain of 1000. The straight line is the locus of the magnitude of offset drift vs. gain. Thus, at a gain setting of 100, the maximum drift would be about 0.18mV/°C at the output, or 1.8μV/°C, referred to the input.

Equation

An equation of the form $y = mx + b$, where m is the slope and b is the intercept, can be easily derived. The slope is the drift change divided by the gain change (0.5 - 0.15)/(1000 - 1)mV/°C, or about 0.35μV/°C, and the intercept is, to a very good approximation, 0.15mV/°C. Thus, at gain 100, the output drift is (100 x 0.35μV/°C) + 150μV/°C, or 185μV/°C (or 1.85μV/°C, referred to the input).

The approximate equation for output drift is

$$\text{Drift}\Big|_{G}^{\text{RTO}} = \left[\text{Drift}\Big|_{1000}^{\text{RTO}} - \text{Drift}\Big|_{1}\right] \bullet \frac{G}{1000} + \text{Drift}\Big|_{1}$$

To refer drift to the input, either divide the above equation by the gain, or use the approximation

$$\text{Drift}\Big|_{G}^{\text{RTI}} = \text{Drift}\Big|_{1000}^{\text{RTI}} + \text{Drift}\Big|_{1} \bullet \left[\frac{1}{G} - 0.001\right]$$

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