Bruce Trump Apr 25, 2012

Other Parts Discussed in Post: INA133

In the design of monolithic ICs we routinely exploit the ability to accurately match internal components. Input transistors of op amps, for example, are accurately matched to provide low offset voltage. If we had to make our own op amps with discrete transistors we would have offset voltages of 30mV or more. This ability to accurately match components includes on-chip resistors.

Integrated difference amplifiers make use of precise on-chip resistor matching and laser trimming. The excellent common-mode rejection of these integrated devices relies on the accurate matching and temperature tracking of a carefully designed integrated circuit. Figure 1 shows a common use of a difference amplifier such as the INA133, measuring the voltage across a low resistance shunt to monitor current in a load. To reject the 10V common-mode voltage, Vs, the two input terminal gains must be precisely equal but opposite polarity.

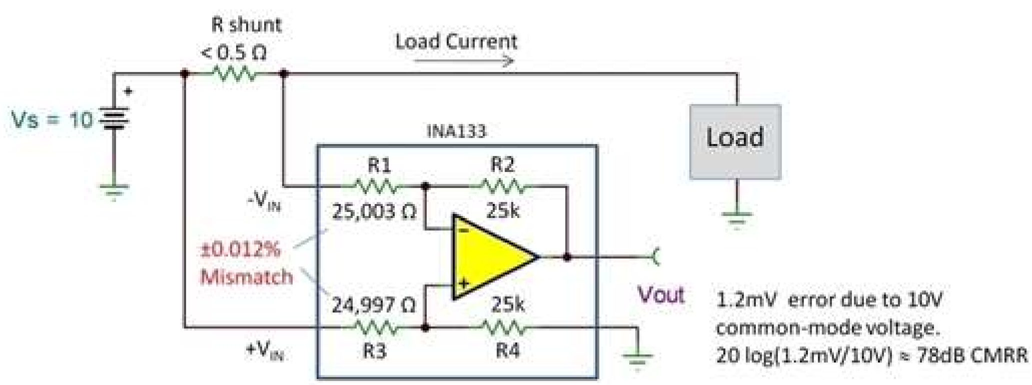

Figure 1.

In figure 1, I've assumed a perfect op amp but the input resistors are skewed by ±3Ω each, a ±0.012% mismatch in their nominal 25kΩ value. This very small error in resistors creates a 1.2mV error for the 10V common-mode voltage. With zero voltage across the shunt resistor the offset due to the 10V common-mode voltage is 1.2mV. This would be acceptable in most applications, a 2.4% offset error for a commonly used 50mV full-scale shunt voltage. But check out the error if you made your own difference amp with common 1% or even 0.1% resistors:

Resistor Mismatch[1]	Error for Vs = 10V	Error on 50mV full scale	CMRR	Comments
±1%	99mV	198%	40dB	Too much C-M voltage error!
±0.1%	9.9mV	19.8%	60dB	Possibly usable with lower C-M voltage.
±0.012%	1.2mV	2.4%	78dB	Acceptable C-M error.

(1) Assumes two resistors are mismatched to extremes.

Figure 2.

As with figure 1, this table assumes that two of the four resistors are skewed in opposite directions to their maximum tolerance, a reasonable estimate of the possible error. If all four resistors were skewed to worst case, these errors would double but that is an unlikely case.

This example also points out the importance of keeping source impedance low and matched with these difference amps. An additional ±3Ω due to mismatched source impedance might produce unacceptable error.

It's worth noting that the internal resistors in the INA133 are not accurate to an absolute value. The 25kΩ values are only ±15% accurate, or so. It's the ratios, R1/R2 and R3/R4, that are crucial in creating the same (but opposite polarity) gain at the resistor inputs. These ratios are accurately matched, temperature tracking and laser trimmed. The same issues apply to the internal difference amplifier that serves as the output stage of most instrumentation amplifiers.

Now, after pointing out the value of these integrated matched internal resistors, I'll reverse the message. Next week, I'll suggest a situation where common 1% resistors and good op amp make a perfectly adequate difference amp. Can you guess where I'm going?

Thanks for reading and comments welcome,

Bruce

p.s. Good geek fun… http://www.evilmadscientist.com/article.php/bristlebot. Yes, I made one.

2 comments 0 members are here

白萝卜 *over 10 years ago*

Hi Bruce Trump I am a student from China and it's my honor to read your blog in my spare time ,I don't know how to calculate a 1.2mV error for the 10V common-mode voltage in this example.

James Kim *over 3 years ago*

I just accessed the files Time Sobering placed in his profile, I had no problems at all downloading them. The fence installation Harris Ap Note looks quite good. Thanks Bruce.