Using a µCurrent Probe as a DAQ Pre-Amplifier

There are times when monitoring current levels over an extended period of time is required. This could be while conducting a voltage/temperature range test on a product, recording the output of an energy harvesting power source over a range of conditions or other such test lasting hours, days or longer. In these situations, pairing a CMicrotek µCurrent Probe with a data acquisition system (DAQ) can be beneficial.

Do You Need a Pre-Amp?

In many cases, directly monitoring the voltage drop across a sense resistor with a DAQ may be sufficient. In other cases it may be appropriate or even necessary to amplify this voltage differential prior to taking measurements with the DAQ. These situations could be:

- Improving measurement accuracy when using a low resolution DAQ - For a DAQ with an 8-bit A/D converter (ADC) and a 5V voltage reference, the measurement resolution is roughly 19.5mV. That may be sufficient for measuring a signal of several volts but for a 100mV drop across a sense resistor that represents a measurement error of almost ±20%, this 100mV signal could be increased to 2V using a µCP100 so the 19.5mV resolution would result in a measurement error of less than ±1%.
- Improving measurement accuracy when using a low-cost USB DAQ – USB power is notoriously noisy which can impact the ADC readings if the noise isn't adequately handled. Similar to the previous situation, using a µCurrent Probe as a pre-amp will increase the signal to a level that can be measured without significant error due to the noise.
- Measuring wide-ranging current levels - It is fairly common for today's micro based products to have current level fluctuations from 10,000:1 to over 100,000:1 between their active modes and sleep modes. In this type of situation, selecting a sense resistor with a high enough value to allow measurements at the low-end of the current range will result in so much voltage drop at the high end current levels that the circuit can stop working. Selecting a sense resistor based on the high end current levels can result in very poor accuracy in the low end current level measurements. The µCurrent Probes are designed to handle these types of current ranges allowing you to measure a 10uA current as accurately as a 100mA current.
- Measuring extremely low level currents - Using very high value sense resistors can cause issues even for steady state current measurements. With a 16-bit ADC and a 2.5V voltage reference, the resolution would be roughly 38.1uV. At that resolution, to measure a 50nA current with a measurement error of less than ±1% would require a sense resistor of about 763K ohms to produce a voltage drop of 3.81mV. A resistor this large would make the signal very susceptible to noise and the capacitance on the signal between the sense resistor and the DAQ would create an RC filter that could distort important current fluctuations or even prevent them from being detected. The µCurrent Probes use much lower value sense resistors and a high-gain amplifier chain to minimize noise susceptibility and with circuit board traces instead of wires and typically banana jack connections the RC filter effect is avoided.

Considerations For Using a µCurrent Probe for a Pre-Amp

Here are several things to consider when using a µCurrent Probe with a DAQ (or selecting a DAQ for low current measurements):

- Voltage range – The µCurrent Probes have a 40V output at their maximum current level. A maximum input voltage of 5V to 20V is fairly common for DAQ systems. The µCurrent Probes have a "zoom out" mode that provides a 10:1 reduction in the output voltage. While this may be sufficient for many applications, it may be desirable to place a voltage divider on the probe output to decrease the output to place the signal within the DAQ's input voltage range without decreasing it as much as the "zoom out" mode. When using an external voltage divider, select resistor values that result in less than a 25mA load on the probe's output driver. The voltage divider must obviously be compensated for in the DAQ measurements. For the best accuracy, measure the sense resistors with a precision DMM and use these measured values to calculate the compensation factor.

- DAQ resolution – Resolution is not just based on the number of bits an ADC has. A DAQ's resolution is also determined by the voltage reference being used with the ADC. A 12-bit ADC will provide 4 times higher resolution than a 10-bit ADC given the same reference voltage (4096 "steps" across the voltage range versus 1024). However, the 12-bit ADC with a 5V voltage reference has a resolution only 2X better than a 10-bit ADC with a 2.5V reference voltage. For an 8-bit ADC with a 1.25V reference voltage the 12-bit ADC with 5V reference is only 4X better when it would be 16X better at the same reference voltage. The ADC spec sheet may not call out the reference voltage for the DAQ but it should call out the resolution so be sure to compare the resolution when selecting an DAQ and don't just assume a 12-bit DAQ will provide 4X better resolution than a 10-bit DAQ.
- Accuracy – Don't assume an accuracy spec for a DAQ applies equally to all your measurements (the same applies to using an oscilloscope). You really need to consider the resolution of the ADC relative to the voltage level being measured. A resolution of 10mV when measuring a 2V signal would give you ±0.5% accuracy while the same resolution when measuring a 100mV signal would only yield ±10% accuracy. Using the combination of measurement mode (and external sense resistor) and zoom view level on the µCurrent Probe you can increase the voltage level being measured by the DAQ to obtain more accurate measurements.
- Bandwidth – Bandwidth and sample rates generally aren't critical for most long term tests where the influence of relatively steady state conditions such as voltage or temperature on current levels are being recorded. The µCurrent Probes have a bandwidth spec of 550Khz so when paired with a DAQ with sample rates of just a few Khz should be more than adequate for these types of tests. When selecting a DAQ for these types of tests be sure to check for a minimum sample rate spec as sampling just a few times per second is usually adequate. Sampling at even a few Khz over a multi-day test will generate a LOT of data to wade through.

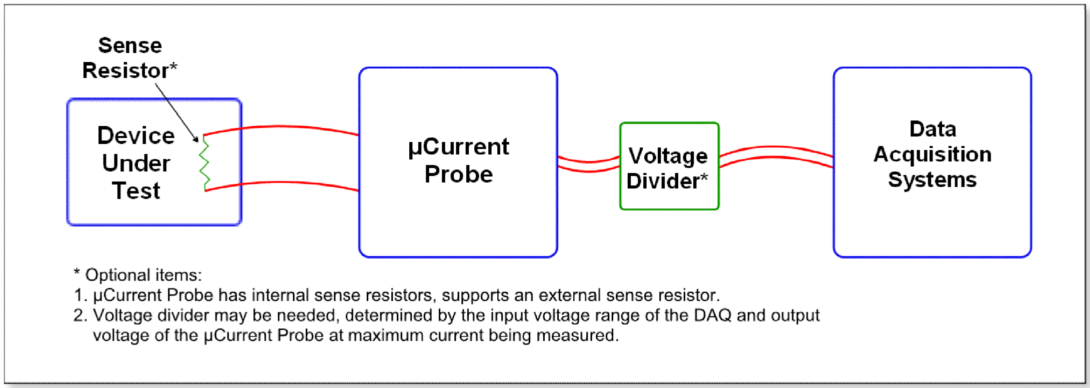
It is important to keep in mind that precision and accuracy are not the same thing but are often used almost interchangeably. The number of bits an ADC has determines its precision but the more bits it has the more difficult it is to design the circuitry around it to produce accurate measurements at that precision. For instance, the values obtained from a 12-bit ADC with a ±0.5% 2.5V reference would cover a span of 40 values over the output range of the voltage reference. For a 16-bit ADC, over this same voltage range the obtained readings would cover a span of 650 values. To achieve a span of 40 values over the voltage reference tolerance range with a 16-bit ADC the 2.5V reference would require a tolerance of ±0.03%. Very few (if any) voltage references on the market today can even come close to that tolerance level. Fortunately, voltage references tend to be very stable devices so the error in their output voltage can usually be calibrated-out. As an example of the important thing to remember here, a well calibrated 4 digit DMM may give you very accurate measurement in the millivolt range while a poorly calibrated 7 digit DMM will give you very precise measurements in the microvolts range that may be wrong by several millivolts.

Typical Test Setup

The diagram on the next page shows a typical setup when using a µCurrent Probe as a pre-amp for a DAQ. Two things to note:

1. The µCurrent Probes contain internal sense resistors for their "Precision" and "Wide Range" modes. If monitoring current levels higher than what the µCurrent Probe supports it would be necessary to use an external sense resistor. In some cases it may be desirable to use an external sense resistor with a value selected to provide a higher output voltage than the µCurrent Probe would provide using the internal sense resistors. See the "µCP100 User's Guide" for information on selecting external sense resistor values.

2. As discussed earlier, a voltage divider may be required on the output of the µCurrent Probe to ensure the maximum input voltage of the DAQ is not exceeded.



Summary

The µCurrent Probe's ability to amplify the voltage out of the millivolts range into the volts range decreases the importance of DAQ resolution in achieving accurate measurements. The table below shows the DAQ resolution influenced accuracy for several combinations of ADCs and reference voltages (from poor to excellent) at several voltage levels.

	100mV	200mV	300mV	400mV	500mV	1V	2V	3V	4V	5V
8-bit & 5V	19.5%	9.7%	6.5%	4.8%	3.9%	1.9%	0.97%	0.65%	0.48%	0.39%
10-bit & 3.3V	4.8%	2.4%	1.6%	1.2%	0.97%	0.48%	0.24%	0.16%	0.12%	0.09%
12-bit & 2.5V	1.2%	0.61%	0.40%	0.30%	0.24%	0.12%	0.06%	0.04%	0.03%	0.02%

As you can see, the level of accuracy for a 300mV signal with a 12-bit ADC and 2.5V reference is comparable (better than 1% accuracy) to an 8-bit ADC and 5V signal when amplifying the signal by a factor of 10 to 3V. While typically used as a low-current probe for an oscilloscope, a CMicrotek µCurrent Probe can be paired with a low end DAQ to achieve results comparable to much more expensive DAQs.