Low-power measurement techniques

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One of the most important differentiators in smartphones these days isn't bells and whistles; it's something far more fundamental: How long does the battery last? Unfortunately, battery technology hasn't kept pace with engineers' ability to create palm-sized computers with power-hungry multicore processors and multiple radios. On the server side, the massive operation centers powering the cloud (as the Internet is known these days) benefit from even minute reductions in energy consumption.

Everywhere you look, reducing power consumption is almost always an important design goal. This means that engineers and technicians need to be adept at making low-power measurements. While these measurements are not overly difficult, obtaining consistent results requires a solid understanding of your measurement tools—in this case, oscilloscopes and voltage and current probes.

Below are a couple of screen shots showing the use of an oscilloscope to evaluate power consumption. The upper image shows the power consumption of an LCD monitor in standby power mode; the lower image shows the power consumption of a cell-phone charger while the phone is charging. By using good measurement technique coupled with a scope-based power-analysis application, measurements such as this are easily accomplished. In this post, I’ll run through some of the most important techniques.

Power quality of an LCD monitor in standby-power mode.
Power quality of a cell-phone charger while the phone is charging.

Voltage-probing tips

Good measurements all start at the source—the probe. Since voltage measurements are differential, the preferred probe for millivolt-level measurements is an active differential probe. This will deliver the best measurement quality and ease of use. For microvolt-level differential voltage measurements, a differential preamplifier may be necessary, as well. While a pair of passive probes can be used as shown illustrated by the top image in the figure below, this method provides good measurement results only when the probes and oscilloscope channels are very well matched (gain, offset, delay, and frequency response). For most low-power measurements, an active differential probe, shown in the lower image, is the way to go.

\[\text{Differential signals can be measured (top) using two passive probes and math in an oscilloscope (bottom), preferably by using a differential probe.}\]

While on the topic of probe selection, you should consider the effects that the probe’s impedance or loading will have on the circuit under test. For good measurement accuracy, the probe’s input impedance should be much greater than the circuit’s impedance at the highest frequency of interest.

For small signals, another important consideration is probe attenuation. Your goal should be to use no more than what’s needed to precisely match the signal amplitude to the dynamic range of the oscilloscope input. The typical “10X” passive probe has an attenuation factor of 10, which means that only 1/10th of the input signal amplitude is applied to the oscilloscope. Although probe attenuation extends the maximum voltage range of the measurement system, it has the side effect of
reducing the signal-to-noise ratio.

**Current-probing tips**

Current measurements can be done most accurately and easily with an AC/DC current probe, and these probes are recommended for low-power applications. AC/DC current probes use a transformer to measure AC currents and a Hall Effect device to measure DC current.

The first step in using a current probe is to connect the head around the current-carrying conductor, either by adding a wire loop or adding current probe access to the product’s design-for-test requirements.

Most likely you will experience parasitic capacitances between the conductor and the current probe body and between the current probe body and ground. Fast slew-rate voltage signals can be capacitively coupled into the probe body. This means that you should probe on the lowest-impedance nodes to minimize the loading effects of capacitive coupling to ground. Also, probing on the grounded side of the circuit will minimize the signal’s slew rate (dV/dt), driving the parasitic capacitance.

As with voltage probes, don’t use more attenuation in the current probe than is necessary to match the signal amplitude to the dynamic range of the oscilloscope input.

You can improve measurement sensitivity by wrapping multiple turns of the conductor around the current probe, as shown below. This is because current probes respond to the total current flowing through them, but this has limits. Winding more turns around the probe increases insertion impedance and reduces upper bandwidth.

You can increase current sensitivity by wrapping N turns of the conductor around the current probe.

Lastly, to reduce the susceptibility of the probe to radiated noise, try connecting a probe ground lead from the ground connection on the current probe to the circuit ground. This may increase the parasitic capacitance from the probe head to ground, but it should make the probe’s internal shielding more effective.

**Oscilloscope-setup tips**
Accurate measurements always begin with a calibrated oscilloscope. Allow the oscilloscope to warm up for at least 20 minutes to reach a stable internal temperature. The majority of short-term errors are caused by amplifier drift over time and temperature.

As with the voltage and current probing, optimize the dynamic range of all of the signals. Adjust the vertical-scale controls so that the signals fill most of the display vertically, but make sure that the peaks do not extend beyond the top or bottom of the display. This adjustment uses the lowest necessary attenuation settings and optimizes the SNR.

Deskew the probes. Each probe has a different propagation delay, and the differences can be dramatic, especially when comparing voltage and current probes. Because the instantaneous power calculation is the sample-by-sample product of the voltage and current waveforms, precise time (phase) matching of the waveforms is required. The deskew process time-aligns the signals at the oscilloscope inputs to help ensure that the calculated power waveform represents the circuit’s true instantaneous power.

With power consumption taking center stage in many device and system designs, the ability to ensure that designs are meeting or exceeding design goals is a critical capability. Good measurement techniques such as those described here will help you to easily and accurately make low-power measurements. Are low-power measurements on your agenda? Let us know what’s working for you.

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