

# Sub- $\mu\text{A}$ RMS Current Measurement for Quartz Crystals

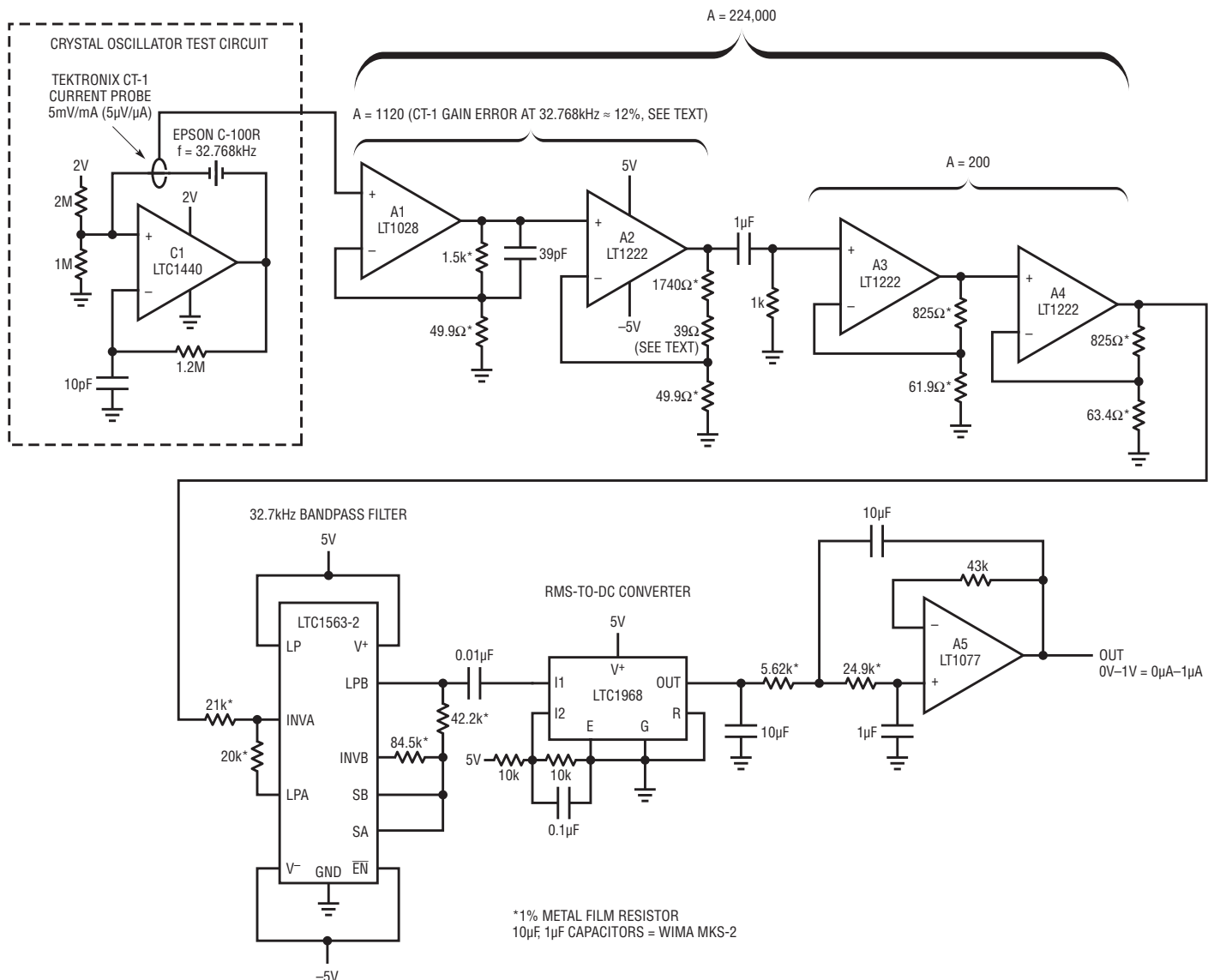
by Jim Williams

Quartz crystal RMS operating current is critical to long-term stability, temperature coefficient and reliability. Accurate determination of RMS crystal current, especially in micropower types, is complicated by the necessity to minimize introduced parasitics, particularly capacitance, which corrupt crystal operation.

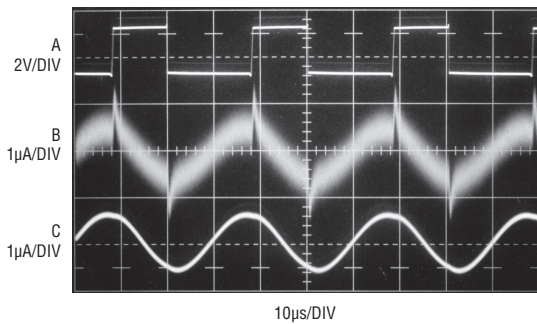
Figure 1's high gain, low noise amplifier combines with a commercially available closed core current

probe to permit the measurement. An RMS-to-DC converter supplies the RMS value. The quartz crystal test circuit shown in dashed lines exemplifies a typical measurement situation. The Tektronix CT-1 current probe monitors crystal current while introducing minimal parasitic loading. The probe's  $50\Omega$  terminated output is fed to A1. A1 and A2 take a closed loop gain of 1120; excess gain over a nominal gain of 1000 corrects for the

CT-1's 12% low frequency gain error at 32.768kHz.<sup>1</sup> A3 and A4 contribute a gain of 200, resulting in total amplifier gain of 224,000. This figure results in a  $1\text{V}/\mu\text{A}$  scale factor at A4 referred to the gain corrected CT-1's output. A4's LTC1563-2 bandpass filtered output feeds an LTC1968-based RMS-to-DC converter (A5), which provides the circuit's output. The signal processing path constitutes an extremely narrow band amplifier tuned to the crystal's



**Figure 1.** Op amps A1-A4 furnish gain of > 200,000, permitting sub- $\mu\text{A}$  crystal current measurement. The LTC1563-2 bandpass filter smooths residual noise while providing unity gain at 32.768kHz. The LTC1968 RMS-to-DC converter supplies RMS calibrated output.



**Figure 2. The 32.768kHz output of the crystal oscillator (Trace A) and crystal current monitored at A4 output (Trace B) and the RMS-to-DC converter input (Trace C). Peaks in Trace B's unfiltered waveform derive from inherent and parasitic paths shunting the crystal.**

frequency. Figure 2 shows typical circuit waveforms. Crystal drive, taken at CI's output (trace A), causes a 530nA RMS crystal current, which is represented at A4's output (Trace B) and the RMS-to-DC converter input (Trace C). Peaking visible in Trace B's unfiltered

presentation derive from inherent and parasitic paths shunting crystal.

Typical circuit accuracy is 5%. Uncertainty terms include the transformer's tolerances, its approximately 1.5pF loading and resistor/RMS-to-DC converter error. Calibrating the

circuit reduces error to less than 1%. Calibration involves driving the transformer with 1µA at 32.7kHz. This is facilitated by biasing a 100k, 0.1% resistor with an oscillator set at 0.1V output. The output voltage should be verified with an RMS voltmeter having appropriate accuracy. Figure 1 is calibrated by padding A2's gain with a small resistive correction, typically 39Ω. **LT**

**Notes**

1 The validity of this gain error correction at one sinusoidal frequency—32.768kHz—was investigated with a 7-sample group of Tektronix CT-1s. Device outputs were collectively within 0.5% of 12% down for a 1.00µA, 32.768kHz sinusoidal input current. Although this tends to support the measurement scheme, it is worth noting that these results are as measured. Tektronix does not guarantee performance below the specified -3dB, 25kHz low frequency roll-off.

# New Device Cameos

## High Voltage Dual Input Li-Ion Battery Charger

The LTC4075HVX is a standalone linear charger that is capable of charging a single-cell Li-Ion/Polymer battery from both wall adapter and USB inputs. The charger can detect power at the inputs and automatically select the appropriate power source for charging.

No external sense resistor or blocking diode is required for charging due to the internal MOSFET architecture. The LTC4075HVX features a maximum 22V rating for both wall adapter and USB inputs although charging stops if the selected power source exceeds the overvoltage limit (typical 6V). Internal thermal feedback regulates the battery charge current to maintain a constant die temperature during high power operation or high ambient temperature conditions. The float voltage is fixed at 4.2V and the charge current is programmed with an external resistor. The LTC4075HVX terminates the charge cycle when the charge current drops below the programmed termination threshold after the final float voltage is reached.

Other features include automatic recharge, undervoltage lockout,

charge status outputs, and "power present" status outputs to indicate the presence of wall adapter or USB power. No trickle charge allows full current from the charger when a load is connected directly to the battery.

## Small 1.8A Step-Down Regulator Switches at 4MHz for Space-Sensitive Applications

The LTC3568 is a 10-lead DFN, synchronous, step-down, current mode, DC/DC converter, intended for medium power applications. It operates within a 2.5V to 5.5V input voltage range and switches at up to 4MHz, making it possible to use tiny capacitors and inductors that are under 1mm in height. The output of the LTC3568 is adjustable from 0.8V to 5V, and its 0.11Ω switches allows up to 1.8A of output current at high efficiency. By using the LTC3568 in a small 3mm x 3mm, 10-lead DFN package, a complete DC/DC converter can consume less than 0.3 square inches of board real estate.

Efficiency is extremely important in battery-powered applications, and the LTC3568 keeps efficiency high with an automatic, power saving Burst Mode

operation, which reduces gate charge losses at low load currents. With no load, the part only draws 60µA, and in shutdown, the device draws less than 1µA, making it ideal for low current applications.

The LTC3568 uses a current-mode, constant frequency architecture that benefits noise sensitive applications. Burst Mode operation is an efficient solution for low current applications, but sometimes noise suppression is a priority. To reduce noise problems, a pulse-skipping mode and a forced continuous mode are available, which decreases the ripple noise at low currents. Although not as efficient as Burst Mode operation at low currents, pulse-skipping mode and forced continuous mode still provide high efficiency for moderate loads. In dropout, the internal P-channel MOSFET switch is turned on continuously, thereby maximizing the usable battery life.

A Power Good output is available for power supply monitoring or for Power On Reset use. Internal overvoltage and undervoltage comparators pull the open-drain PGOOD output low if the output voltages are not within about ±7.5%.

The LTC3568's small size, high efficiency, low component count and flexibility make it an ideal DC/DC converter for portable devices. **LT**