LINEAR TECHNOLOGY

DESIGN NOTES

RMS-to-DC Conversion Just Got Easy – Design Note 288

Glen Brisebois and Joseph Petrofsky

Introduction

The LTC®1966 is a precision, micropower, true RMS-to-DC converter that utilizes an innovative patented ΔΣ computational technique.* The internal delta-sigma circuitry of the LTC1966 makes it simpler to use, more accurate, lower power and dramatically more flexible than conventional log-antilog RMS-to-DC converters. Unlike previously available RMS-to-DC converters, the superior linearity of the LTC1966 allows hassle-free system calibration with any input voltage, even DC.

Ease of Use

The flexibility of the LTC1966 is illustrated in the typical applications shown in Figures 1a, 1b and 1c. The LTC1966 accepts single ended or differential input signals (for EMI/RFI rejection) and supports crest factors up to 4. Common mode input range is rail-to-rail while the differential input range is $1V_{PEAK}$. The LTC1966 also has a rail-to-rail output with a separate output reference pin providing for flexible level shifting. The LTC1966 operates on a single power supply from 2.7V to 5.5V or dual supplies up to ±5.5V while drawing only 155µA. When the LTC1966 is shut down, supply current is reduced to just 0.1µA.

The Trouble with Log-Antilog

Older RMS-to-DC converters used log/antilog techniques. The log/antilog function was derived from the logarithmic relationship between the base emitter voltage and collector current of bipolar junction transistors. This method suffers from a variety of problems. BJT transistors match and track well over temperature while operating at the same collector current, for example in op amp differential pair input stages intended to run closed loop. However, their log conformance is NOT very good over wide current variations and they do NOT match and track well when operating at different collector currents in open-loop configurations. This gives rise to the poor linearity and poor temperature rejection characteristic of log-antilog converters and also makes them uncorrectable using simple calibration techniques. In contrast, the LTC1966 gives exceptional accuracy over broad varieties of signal type and temperature, with even better results obtainable via a simple DC calibration. Figure 2 compares the linearity of the LTC1966 with that of the now inferior log/antilog methods.

Another drawback to log-antilog techniques arises due to the fact that the bandwidth of a BJT depends on how much current flows through it. Thus, log-antilog converters have a bandwidth that varies with signal amplitude. In the extreme, the bandwidth drops to near zero as the signal amplitude drops. To see this effect, take a true RMS meter that employs one of these devices and give it an input signal. Then remove the signal and short the

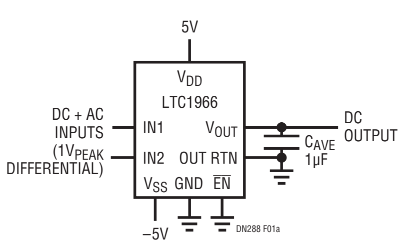

Figure 1a. ±5V Supplies, Differential, DC-Coupled RMS-to-DC Converter

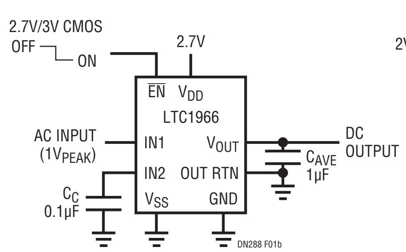

Figure 1b. 2.7V Single Supply, Single Ended, AC-Coupled RMS-to-DC Converter with Shutdown

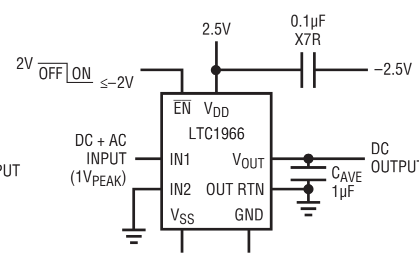

Figure 1c. ±2.5V Supplies, Single Ended, DC-Coupled RMS-to-DC Converter with Shutdown

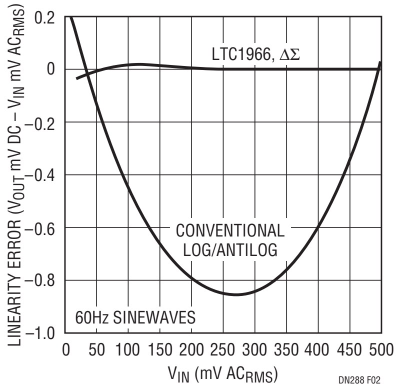

Figure 2. Quantum Leap in Linearity Performance

meter inputs. The meter reading will fall fairly quickly at first, but will slow down and keep slowing down and can take as long as a few minutes to get back down to an effective zero. In contrast, the same situation using an LTC1966 gives a true zero reading within seconds.

Still another problem with the log/antilog approach is the need for an absolute value circuit at its front end. Because the input current takes a different path depending on the input polarity, there is a polarity dependant gain error. To see this effect, put an asymmetric signal waveform with 10% to 30% duty cycle into your RMS meter. Now swap the inputs around. You will typically see about a 0.5% difference in the readings. If you don't see that much difference, change the signal amplitude and try again. (Note that this effect will be apparent on DC signals as well, but that most RMS meters are internally AC coupled precluding a DC test.) Because of its symmetric ΔΣ inputs, the LTC1966 does not have an absolute value circuit, and this error is eliminated.

How the LTC1966 RMS-to-DC Converter Works

The LTC1966 uses a completely new implementation (Figure 3). A ΔΣ modulator acts as the divider and a simple polarity switch is used as the multiplier. Applying V_{OUT} to the ΔΣ reference voltage results in the V_{IN}^2/V_{OUT} function before the lowpass filter and causes the RMS-to-DC conversion.

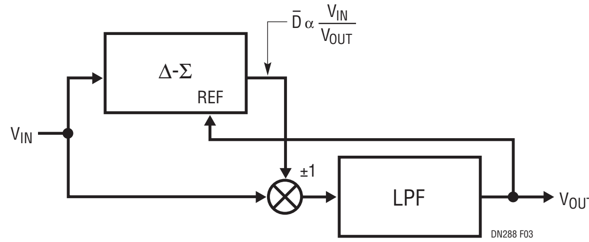

Figure 3. LTC1966 Block Diagram

The ΔΣ is a 2nd order modulator with excellent linearity. It has a single-bit output whose average duty cycle is proportional to the ratio of the input signal divided by the output. The single-bit output is used to selectively buffer or invert the input signal. Again, this is a circuit with excellent linearity because it operates at only two gains: –1 and +1. The average effective multiplication over time will be on the straight line between these two points.

The lowpass filter performs the averaging of the RMS function and must have a lower corner frequency than the lowest frequency of interest. The LTC1966 needs only one capacitor on the output to implement the lowpass filter. The user selects this capacitor depending on frequency range and settling time requirements, given the 85kΩ output impedance.

This topology is inherently more stable and linear than log-antilog implementations primarily because all of the signal processing occurs in circuits with high gain op amps operating closed loop. Note that the internal scalings are such that the ΔΣ output duty cycle is limited to 0% or 100% only when V_{IN} exceeds ±4 • V_{OUT}.

Summary

The LTC1966 is a breakthrough in RMS-to-DC conversion bringing a new level of accuracy to RMS measurements. It is extremely simple to connect and provides excellent accuracy over temperature and time without requiring trims. These features, along with its small size and micropower operation, make the LTC1966 suitable for a wide range of RMS-to-DC applications, including handheld measurement devices.

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Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7417
(408) 432-1900 • FAX: (408) 434-0507 • www.linear.com