True RMS Converter Utilising TRAC

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With a combination of programmable silicon and design software, TRAC brings a truly Integrated Route to signal processing problem solving, providing designers with benefits formerly associated only with programmable digital devices, and offering a path to Custom Silicon for higher volume users.

Introduction

True RMS conversion is normally performed by an expensive dedicated chip. This application note demonstrates the adaptability of TRAC in performing this function adapting a computational approach.

The RMS value of a waveform is the **R**oot of the **M**ean of the **S**quared value and is sometimes needed to calculate the power dissipated in a component. For example if a pulsed waveform has peak of 10 Amps and a duty cycle of 10:1 then clearly the average current would be 1 Amp. The RMS current, on the other hand, would be the true RMS value

$$\sqrt{\frac{10^2}{10}} = 3.16 \text{ Amps}$$

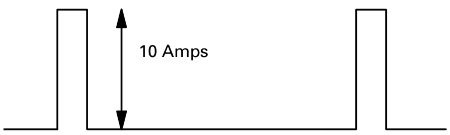

Figure 1
Typical Peak Rectifier Transformer Current Waveform

This could be the typical current waveform in a mains transformer when followed by a rectifier and smoothing capacitor. The diode only conducts on the voltage peaks and large capacitor values result in narrow conduction angles.

In this example the average current of 1 Amp would result in power dissipation in the transformer winding (I^2R) ten times higher than might be expected at first sight.

Theory of Application

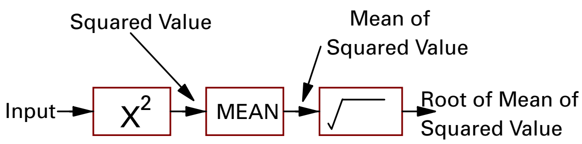

Figure 2
RMS Conversion Block Diagram

The RMS value is achieved by squaring the input signal, taking the mean value and finally the square root. This is shown diagramatically in Figure 2.

The basic TRAC implementation of the RMS converter is shown in Figure 3. First the waveform is transformed into the log domain and then doubled. This effectively squares the input since doubling in the log domain is the equivalent of squaring in the linear domain.

An antilog function transforms the waveform back into the linear domain and the mean value is derived using a single pole filter.

Finally the waveform is transferred to the log domain and halved which is the equivalent of taking the square root in the linear domain. The final antilog function transforms the waveform to the linear domain resulting in the square root of the mean of the squared input.

Software

The TRAC implementation is shown in Figure 4 and uses two TRAC ICs. Additions to the block diagram given in Figure 3 include a scaling voltage which is added/subtracted at the inputs to the log/antilog functions as appropriate to keep the cells within their operating range. This is achieved by adding a fixed DC voltage of one volt to I/O pin 26. A nominal one volt is also applied to I/O 36 but in the practical version this is adjusted to give the correct RMS DC output voltage. It performs both the function of scaling voltage and practical tolerance adjustment.

All TRAC functions, with the exception of the NIP (Non Inverting Pass) and the OFF function, invert the waveform applied with respect to the input which explains various NEG functions used to re-invert waveforms in the design.

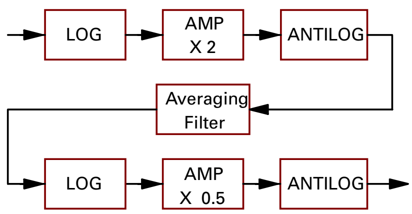

Figure 3
Block Diagram of TRAC Configuration

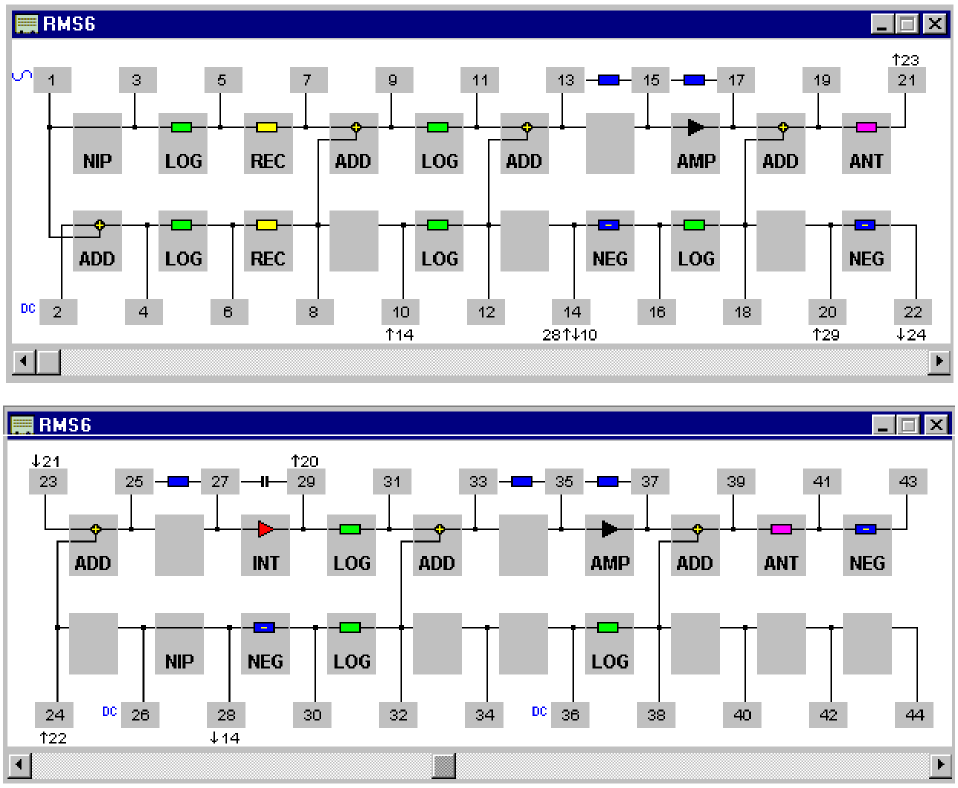

Figure 4
TRAC True RMS to DC Design

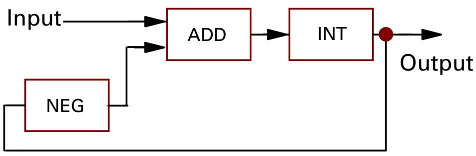

Figure 5
TRAC Software Implementation of Low Pass Filter

The input section comprises a full wave rectifier function which includes a suitable dc input I/O 2 used to adjust the two halves of the rectified input waveform for equal amplitude. This is needed to ensure that practical tolerances in the LOG-REC function do not result in errors in the final RMS value. Inputs not greater than ± 100 mV should be used.

A filter function is required to achieve the mean value of the waveform and this is shown in Figure 5.

Figure 6 shows the input waveform and the output from I/O 43. The output can be seen to ramp up to the correct DC RMS value of the input waveform and a slight ripple will be observed. The latter can be removed by judicious choice of resistor and capacitor in the filter. This in turn will increase the time taken to reach the final value which would usually be of no consequence in a practical circuit since this takes place in the first few hundred cycles required to average the waveform.

Hardware

In addition to applying an input waveform and the trim and scaling voltages, it is necessary to define the gain of the two amplifier functions and the integrator using external components.

Suitable values for the first amplifier (gain = 2) are Rinput = 1.5kΩ and Rfeedback = 3.0kΩ

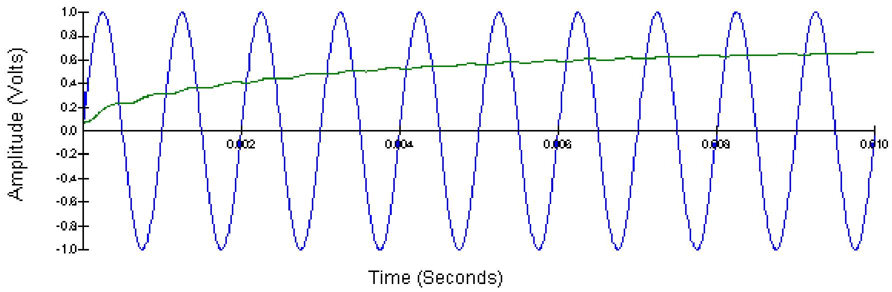

Figure 6:
Input and Output Waveforms

Suitable values for the second amplifier (gain = 0.5) are Rinput = 3.0kΩ and Rfeedback = 1.5kΩ

Suitable values for the filter are R = 3.0kΩ and C = 680nF

These are only suggested values in this application. In practice values in the range 1k - 100 kΩ would be suitable.

The filter values are dependant on the frequency of the input waveform and the values given are suitable for frequencies above 1 kHz. For lower frequencies it will be necessary to increase the capacitor value to reduce the ripple content of the output DC RMS level.

To set up the converter in practice, it is recommended that a sine wave of 1 volt peak is applied to I/O 1 and the full wave rectified waveform, viewed on I/O 9, adjusted for equal heights on alternate peaks.

Finally the nominally 1 volt DC on I/O 36 is adjusted to give the correct DC RMS of 707 mV on I/O 43.

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