

Detecting and Displaying the MEAN (Average) Voltage of any Wave Form Using a Common DC Voltmeter

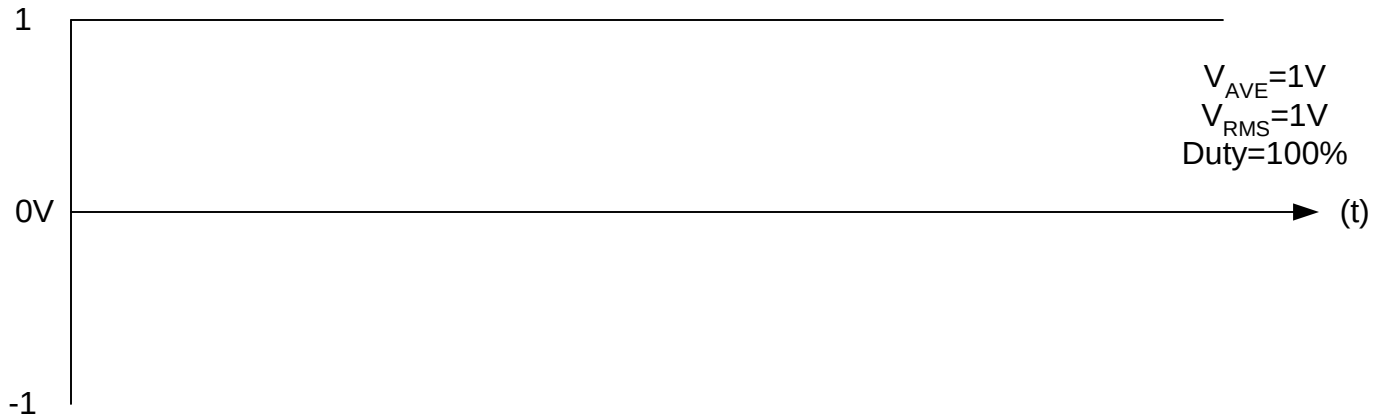


Figure 1

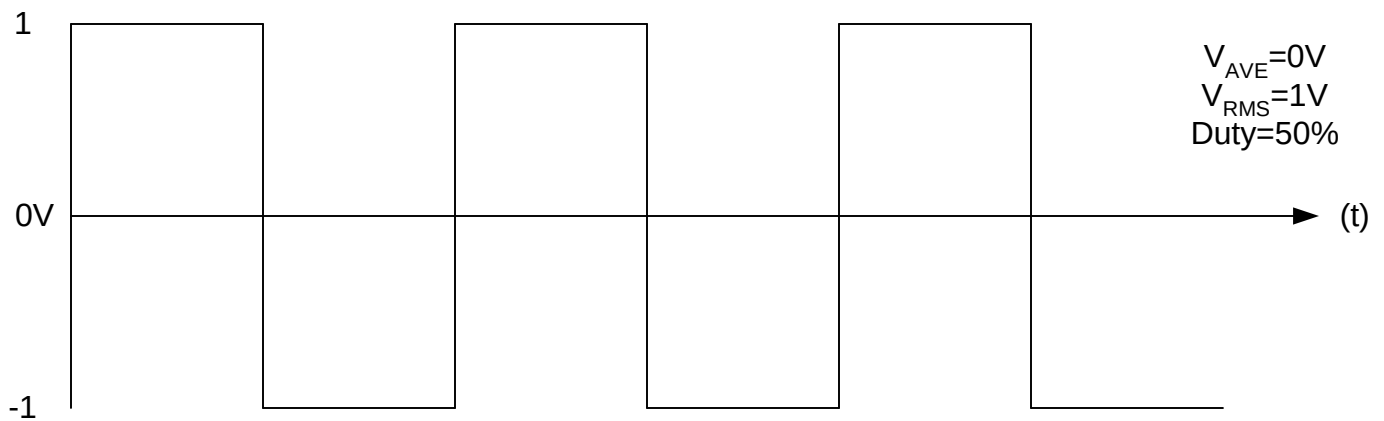


Figure 2

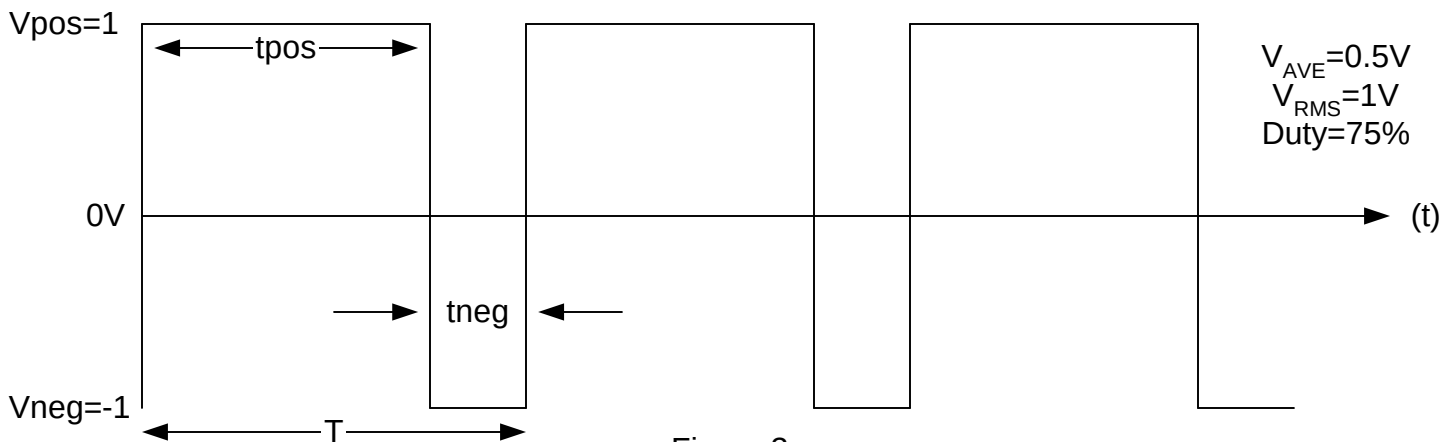


Figure 3

In **Figure 1** we see the type of signal that is normally measured with our DC voltmeters--strictly a flat or slow varying DC voltage. This can be equated to a square wave with 100% duty cycle. **Figure 2** depicts a 50% duty cycle square wave. Note that V_{AVE} is 0V because the positive and negative portions or areas of the wave form are equal. In **Figure 3** the duty cycle has been altered but the peak voltages kept the same. As $V_{AVE}=[V_{pos}*(t_{pos}/T)]+[V_{neg}*(t_{neg}/T)]$ a 75% duty results in 0.5V. Note that a 25% duty would result in $V_{AVE}= -0.5V$. "Vneg" can be 0V for pulsed-DC situations. Notice also that V_{RMS} (the equivalent DC value) in all cases shown is 1V, no matter what the duty cycle setting is.

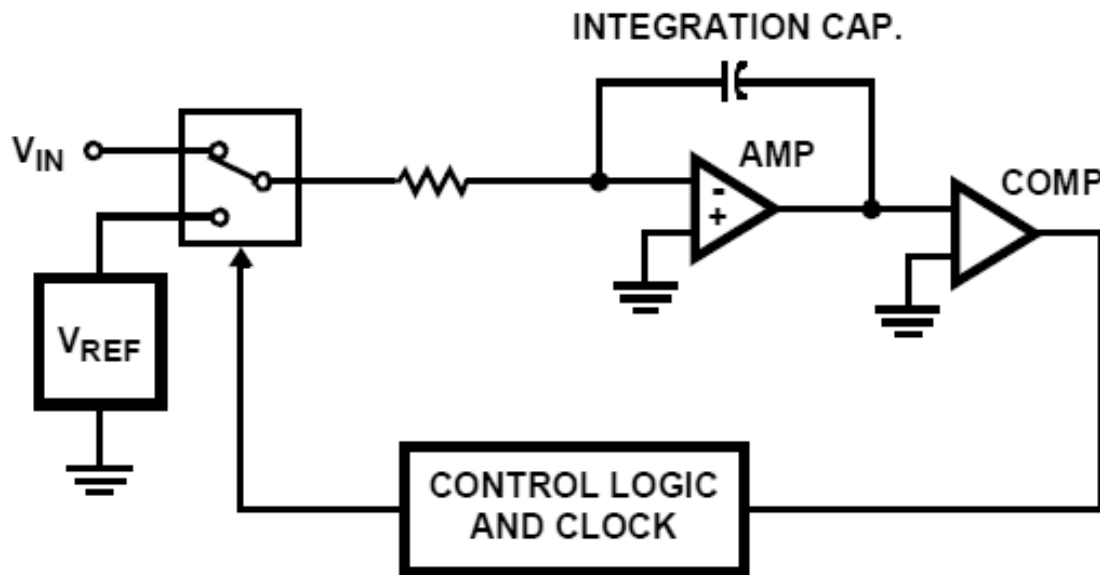


Figure 4

At least as far back as the early eighties (and since that time), 95% or more of the digital DC voltage meters in production were designed using a "dual-slope integrating A/D converter". A simplified block diagram courtesy of Intersil is shown in **Figure 4**. This type of analog to digital converter is particularly well-suited to accurately measuring slow-changing and steady DC voltages. It is also cheap to produce.

As the name implies, a key ingredient involved is an integrator, and it's formed by the R, C and op-amp shown in the diagram. When driven by any wave form on its input, it will by its very nature, perform a type of **averaging function** on it.

A digital DC voltmeter is not capable of measuring the peak-to-peak or RMS voltage of any varying wave form above a few Hertz, but it excels at detecting and displaying the average or mean value of a signal presented to its input. In theory, it accomplishes this regardless of frequency, wave form, wave shape, pulsed-DC, alternating current, or amplitude. In practice, lower frequencies will be limited to less than 1Hz and higher than 100Hz or so, and the upper frequency limit on most meters will be in excess of 1MHz. To a certain degree, the higher the frequency, the more accurate and stable the measurement. Voltage amplitudes should be kept to within reason, and not exceed the input maximum recommended by the manufacturer.

Tests have been performed on 5 different digital voltage meters ranging in price and "quality" from about \$20 to \$300 using a $\pm 100\text{mV}$ peak input level at a frequency of 1MHz. The test results show remarkable accuracy and correlation with a high quality oscilloscope. See the video demonstration.

For further insight into how and why this works, the reader is encouraged to look up "Class D Amplifiers". The concept is the same (PWM), and the application nearly identical. In our case, one just has to imagine the input as periodic and not changing in pulse width from one cycle to the next. Basically, the low pass filter function (to extract the MEAN voltage) is facilitated by the integrator in the converter.

An excerpt from the excellent page at: <http://sound.westhost.com/articles/pwm.htm>

"But how can our beloved audio signal be represented by an awful square wave with only two possible levels? Well, in fact it modulates some characteristics of this square wave so the information is there. Now we "only" have to understand the way the modulation is done and how to restore the amplified audio signal from it. The most common modulation technique used in Class-D is called PWM (Pulse Width Modulation) - a square wave is produced that has a fixed frequency, but the time it is in the "high" and "low" states is not always 50%, but it varies following the incoming signal. This way, when the input signal increases, the "high" state will be present for longer than the "low" state, and the opposite when the signal is "low". If we do some maths, the mean value of the signal in a single cycle is simply ...

$$V_{\text{mean}} = V_{\text{high}} * D + V_{\text{low}} * (1-D), \text{ where } D = T_{\text{on}} / T, \text{ (duty cycle)}$$

T being the period of the signal, that is, 1/F_{sw} (switching frequency).

For example, the mean value of a 50% duty cycle (both states are present for exactly the same amount of time) signal going from +50V to -50V is: $50 * 0.5 + (-50) * 0.5 = 0V$. In fact, the idle (no signal) output of a Class-D amplifier is a 50% duty cycle square signal switching from the positive to the negative rail.

If we modulate the input up to the maximum, we will have a near-100% duty-cycle. Lets put 99%: $V_{\text{mean}} = 50 * 0.99 + (-50) * 0.01 = 49V$. Conversely, if the signal is lowest, we need near 0% (lets use 1%), so $V_{\text{mean}} = -49V$."

Best Regards,

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