University of Utah
Electrical & Computer Engineering Department
ECE 2210
AC Meters & Transformer

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rev, 11/7/06

Objectives
1.) Compare peak and RMS voltages of a sine wave.
2.) Learn about the characteristics of AC voltmeters.
3.) Investigate transformer voltage and turns ratios.

Equipment and materials to be checked out from stockroom:
- ECE 2210 kit
- Transformer
- Digital multimeter (APPA 95 if possible)

Experiment 1, Meter Responses
Sinusoid: Set the Agilent or HP 33120A function generator 60 Hz and 5 Vpp (will actually output 10 Vpp). Observe this sine wave on the oscilloscope and measure it's peak-to-peak voltage (if you don't get 10 V, check your scope calibration and/or get help). Divide this value by 2 to get the peak voltage (V_p) and divide V_p by $\sqrt{2}$ to get the RMS voltage of this sine wave. This should be 3.54 V RMS

Set your two voltmeters (the Agilent or HP 34401A and the other meter you checked out) to AC volts (sometimes meters show a small sine-wave symbol instead of "AC"). Now measure the function generator voltage with both voltmeters. Do the both meters show the RMS value?

Almost all AC voltmeters are designed to show the RMS voltage if the input is a sine wave. However, most meters do not actually read the true RMS value of an AC waveform. Instead, they read the *rectified average* (V_{RA}) of the AC waveform and then multiply that by 1.111 to display an estimate of the RMS (V_{RMS}) value. The multiplication factor works out exactly for a sinusoidal waveform but not for other waveforms. That's because the the factor would be different for different waveforms and the meter cannot tell one waveform from another. Meters that measure the "true RMS" of any waveform are more complicated and more expensive.

Sinusoid: $$V_{RMS} = \frac{V_p}{\sqrt{2}} = 0.707\,V_p \qquad V_{RA} = \frac{2}{\pi} V_p = 0.6366\,V_p \qquad V_{RMS} = 1.111\,V_{RA}$$

Square: Lets try the same measurements with a square wave. Observe the scope and change the function generator output to a square wave. Measure this voltage with each of the voltmeters again. Do the meters show the RMS of this wave correctly?

Square: $$V_{RMS} = V_p = V_{RA}$$

Again, the majority of inexpensive meters actually measure the rectified average (V_{RA}) of the waveform. The rectified average is the average of the absolute value of the voltage (take all the negative parts and make them positive). They measure this V_{RA} and multiply it by 1.111 to display a V_{RMS}. This works fine for a sine wave, but not for any other waveform. In this case, if a meter measured the V_{RA} of your square wave and multiplied it by 1.111, what would it display? Does this correspond to what you see on either of the meters? Do either of the meters read the "true RMS" of the square wave.

Does the 34401A meter actually measure, V_{RMS}, or V_{RA}? Does the other meter actually measure, V_{RMS}, or V_{RA}?

DC Offset Effects

Now let's see what the meters do if we add some DC into the mix. Set the function generator back to sine wave and adjust the DC offset to 2.5 V (will actually offset the output by 5 V). Now you have a sine wave that swings between 0 V and 10 V.

Sinusoid + DC: $$V_{RMS}=\sqrt{V_{RMS(AC)}^2+V_{DC}^2}$$

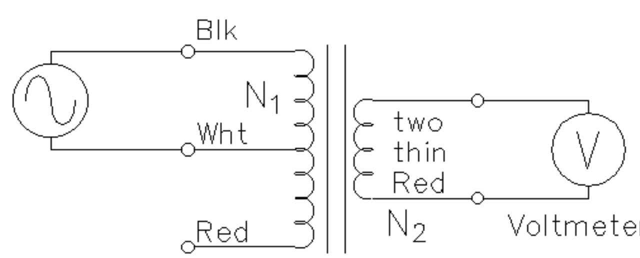
Do any of the meters read correctly now? Do any of them even respond to the added DC? Actually, most meters filter out the DC before measuring the AC. Do these meters do that?

Frequency response

The final meter characteristic we will look at in this lab has nothing to do with RMS. I want you to find the frequency response of each meter. So far we have only measured waveforms at about 60 Hz. All AC meters should measure sine waves correctly at t 60 Hz because that's the power frequency. Most will also work well up to 400 Hz because 400 Hz is common in aircraft. Meters vary greatly in how well they work above 400 Hz, some work well but many do not.

Remove the DC offset from your sine wave and turn up the frequency until the 34401A starts to read a little off (say 5% high or 5% low). Write down the frequency as the upper limit of that meter. Now turn the frequency back down and repeat this for the other meter. Also look for weird effects (especially the APPA 95) and note them. Some AC meters do strange things, like read way too high at higher frequencies.

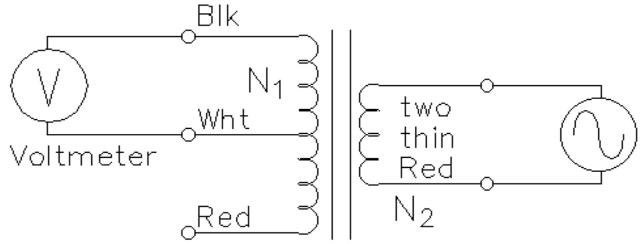
Experiment 2, Transformer



Readjust the function generator to 60 Hz and 5 Vpp (will actually output 10 Vpp) with no DC offset. Connect it to the primary winding as shown and make sure that no other wires of the transformer touch one another. Connect a voltmeter to the secondary winding (two thin red wires) and measure V_2. Move the voltmeter to the primary winding and measure V_1. Calculate N_2/N_1 for this transformer. What do you think the secondary voltage would be if the primary was hooked to the 110 V AC line voltage (plugged into a wall socket) instead of the function generator?

Measure the voltage between the White and the Red (thick) wires. Can any winding serve as a secondary, even if it shares a connection with the primary? What do you think this voltage would be if the primary was hooked to the 110 V AC line voltage instead of the function generator?

Measure the voltage between the Black and the Red (thick) wires. This connection is similar to an "auto-transformer" where the windings are not separate from one another. What do you think this voltage would be if the primary was hooked to the 110 V AC line voltage instead of the function generator?



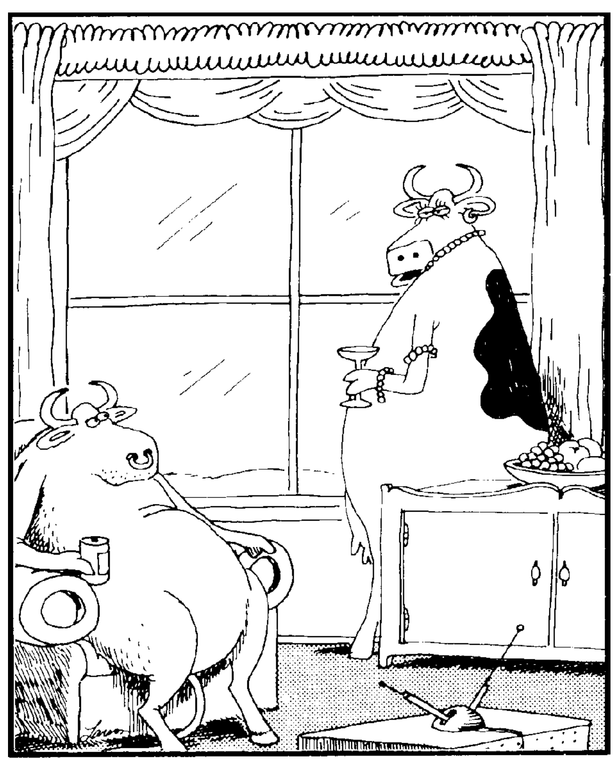
Swap the voltmeter and the function generator connections as shown. Measure the voltages V_1 and V_2 again. Calculate N_2/N_1 again. Note that this ratio does not come out the same as before. This transformer is not ideal. Not all of the flux created by the winding connected to the input voltage actually goes though the output winding. It seems that only about 95% does. To see what I mean, go back to the first calculation of N_2/N_1 and calculate it as $V_2/0.95V_1$ instead. You are reducing the input voltage by 5% to account for the flux lost in the transformer. Now recalculate the second N_2/N_1 as $0.95V_2/V_1$. Do they agree better now? If they don't, maybe the loss in your transformer is different than the 5% that I found in mine. Try to find the approximate flux loss in your transformer.

Note that we haven't used very high voltages or made any significant currents flow in the transformer. If we did, we'd find many other non-ideal characteristics.

Predict the voltage you think you'll find between the Black and the Red (thick) wires. Measure this voltage and compare it to your prediction.

Conclude

As always, check off and write a conclusion. In particular, draw some conclusions about how the AC meters work and about transformer characteristics.



"Wendell . . . I'm not content."