EE315 - Electronics Laboratory

Experiment - 1 Simulation

AC Signal Measurement and Half-Wave Rectifiers

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Preliminary Work:

1. Show that the RMS value $\mathbf{V_{rms}}$ of a sinusoidal voltage waveform $\boldsymbol{v}\mathbf{(t) = V_p}\ \boldsymbol{sin}\mathbf{(\omega t)}$ is given by

$$\mathbf{V_{rms} = \frac{V_p}{\sqrt{2}}}$$

where, $\mathbf{V_p}$ is the peak value of the voltage waveform.

$$v(t) = V_p \sin(\omega t)$$

$$V_{rms} = \sqrt{\frac{2}{T}\int_0^{T/2} V_p^2 \sin^2(\omega t)\,dt} = \sqrt{\frac{2V_p^2}{T}\int_0^{T/2}\frac{1-\cos(2\omega t)}{2}.\,dt}$$

$$= \sqrt{\frac{V_p^2}{T}\left[\frac{T}{2}+0\right]} = \sqrt{\frac{V_p^2}{2}} = \frac{V_p}{\sqrt{2}}$$

2. Show that the total RMS value $\mathbf{V_{\Sigma rms}}$ of a voltage waveform $\boldsymbol{v}\mathbf{(t) = V_{DC}} + \boldsymbol{v}_{\mathbf{AC}}\mathbf{(t)}$ is given by

$$\mathbf{V_{\Sigma rms} = \sqrt{V_{DC}^2 + V_{ACrms}^2}}$$

where, $\mathbf{V_{ACrms}}$ is the RMS value of the pure AC component $\boldsymbol{v}_{\mathbf{AC}}\mathbf{(t)}$.

$$v(t) = V_{DC} + v_{AC}(t)$$

$$V_{\Sigma rms} = \sqrt{\frac{1}{T}\int_0^T (V_{DC}+v_{AC})^2.\,dt} = \sqrt{\frac{1}{T}\int_0^T (V_{DC}^2 + 2V_{DC}v_{AC} + v_{AC}^2)\,dt}$$

$$= \sqrt{\underbrace{\frac{V_{DC}^2}{T}\int_0^T 1.\,dt}_{V_{DC}^2} + \underbrace{\frac{V_{DC}}{T}\int_0^T v_{AC}.\,dt}_{0} + \underbrace{\frac{1}{T}\int_0^T v_{AC}^2.\,dt}_{V_{ACrms}^2}} = \sqrt{V_{DC}^2 + V_{ACrms}^2}$$

Results:

Part 1. Voltage Measurements

1a - Run the simulation and record the following for the sine wave:

Peak voltage: 998.90956mV Peak to-peak voltage: 1.9979272V

DC voltage: -5.2598µV RMS voltage: 707.19mV

1b - Change the voltage source value to "**`PULSE(-1 1 0 500u 500u 0 1m)`**" to obtain a triangle wave and measure the following:

Peak voltage: 998.89686mV Peak to-peak voltage: 1.9900717V

DC voltage: -398.84pV RMS voltage: 577.32mV

1c - Change the voltage source value to "**`PULSE(-1 1 0 1u 1u 499u 1m)`**" to obtain a square wave and measure the following:

Peak voltage: 1V Peak to-peak voltage: 2V

DC voltage: -54.115nV RMS voltage 999.33mV

1d - Change the voltage source parameters to obtain a square wave with **4 Vp-p** AC amplitude and **1 V** DC offset. Measure the following voltages:

Peak voltage: 3V Peak to-peak voltage: 4V

DC voltage: 1V RMS voltage 2.2349V

Part 2. Diode Circuit

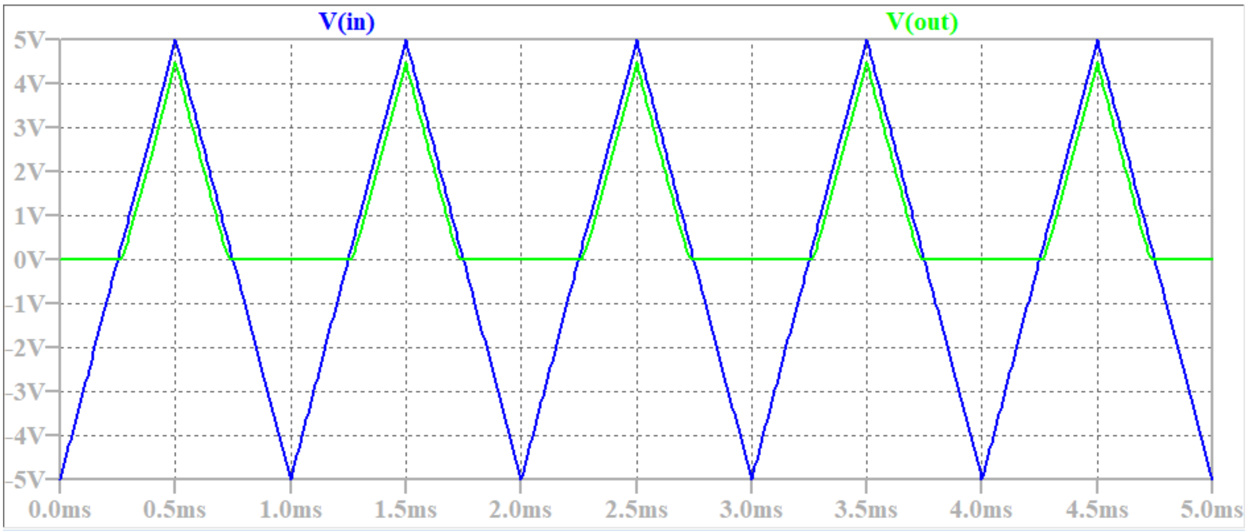
2a - Describe a method to measure the current in this circuit based on voltage measurements only.

To measure the current, firstly V(in) and V(out) are measured. After that, V(out) is subtracted from V(in). And finally, previous answer is divided by 1k ohm and the result gives us the current in this circuit from in to out.
Simply, I = (V(in) – V(out))/1k. In LTspice we can measure the potential difference with one measurement and we show the graph of I by typing that equation.

2b - Measure the circuit current using the current probe of LTspice and compare with the results you obtained based on voltage measurements.

The results are identical, because LTspice is using the same method to measure the current in simulation. However, if we were doing this experiment in real life, We would encounter with some error because of inaccuracy of measuring tools, inaccurate component values, loading affects and etc.

3a - Sketch the $\boldsymbol{v}_{\text{in}}$ and $\boldsymbol{v}_{\text{out}}$ waveforms.

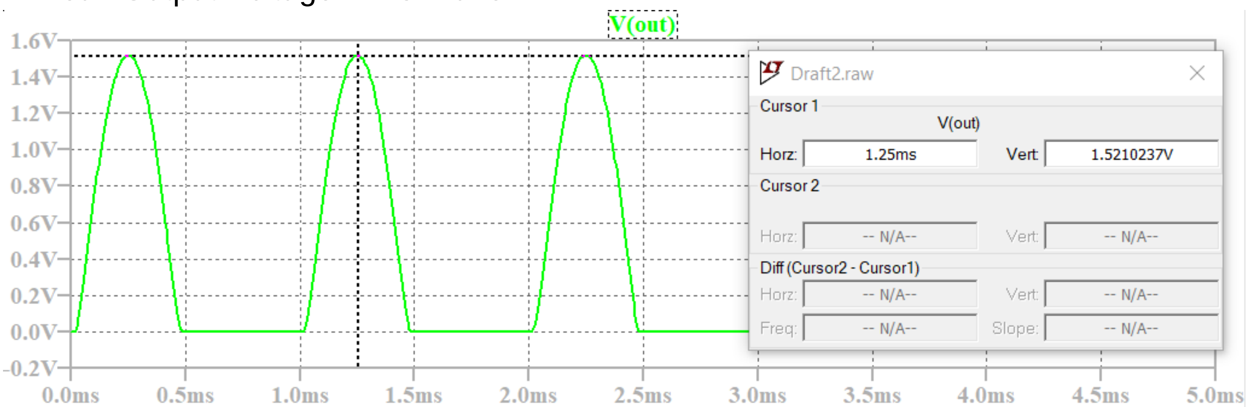


3b - Estimate turn on voltage of the diode on the $\boldsymbol{v}_{\text{in}}$ and $\boldsymbol{v}_{\text{out}}$ waveforms.

Estimated V(turn on) = 476.10618mV

4a - Sketch $\boldsymbol{v}_{\text{out}}$ waveform. What is the peak output voltage measured?

Peak Output Voltage = 1.5210237V



4b - Verify that the measured peak output voltage is correct with calculations.

We found V_f as 476.11mV and according V-I characteristic of example 1 the slope is 27.7803. Slope is equal to $1/R_f$.

R_f = 1/slope = 0.036

<u>KVL Around the Circuit</u>

$-V_{IN} + 476.11mV + I{*}R_f + V_{OUT} = 0$ (R_f is neglectable, when we compare R_1 and R_f.)

$V_{OUT} = 1.52389$

The measured and simulated voltages are quite close. There is just ‰1.81 error.

4c - Measure the frequency and period of $\boldsymbol{v}_{\text{in}}$ and $\boldsymbol{v}_{\text{out}}$.

Measured frequency of $\boldsymbol{v}_{\text{in}}$ and $\boldsymbol{v}_{\text{out}}$ is 1kHz and the period is 1ms. They are identical.

5a - Measure the peak voltage and DC component of v_{out}.

Measured Peak Voltage = 1.5237763V

DC component = 761.02mV

5b - Calculate the expected average value of v_{out} based on the measurements on v_{in} signal and compare with the DC value measured before.

Expected average value of v_{out} = 761.95mV

They are pretty close. There is just ‰1.22 error.

5c - Measure the frequency and period of v_{in} and v_{out}.

Measured frequency of v_{in} and v_{out} is 1kHz and the period is 1ms. They are identical.

Conclusion

In this experiment we learned how to use LTspice tools such as cursor and waveform, also we learned how to calculate rms value and average value of a signal and then we used them.

In experiment 1, we learned how to set a voltage source and change its settings for our purposes. Also, we learned how to use voltage measurement tools of LTspice.

In experiment 2, we set a circuit wit a diode, resistor and voltage source and then we figured out how to measure a current value based on voltage measurements. In the second part we measured the current with ammeter tool of LTspice, however the results were the same. Because LTspice also uses this method to measure the current. If we were doing this experiment in the lab we would get slightly different results due to imperfect conditions and some other affects.

In experiment 3, we set the similar circuit before with triangular wave and in different order. We learned how to obtain graphical results from LTspice and from that graph we figured out how to estimate turn on voltage of the diode.

In experiment 4, cursor usage and finding average value of the signal were learned.

In the final experiment, we calculated average voltage and compared it with measured DC value. However, there were pretty small difference.

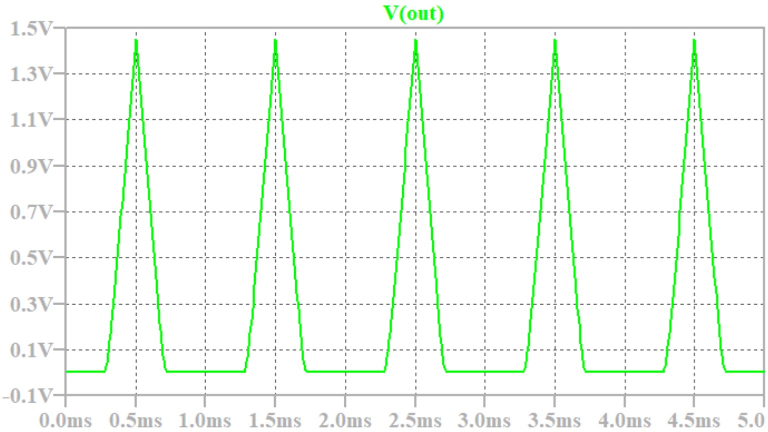
Answers

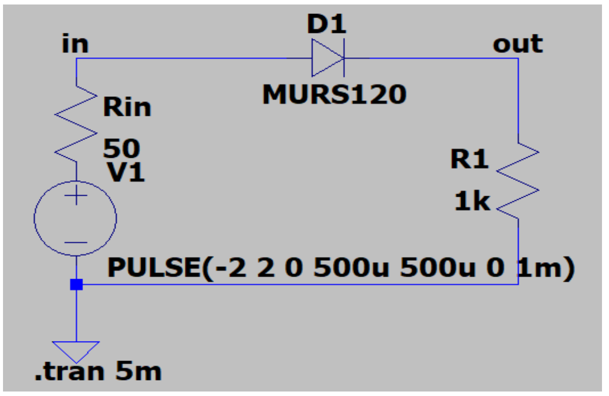
Q1. What is the minimum possible value of the ratio **V_{peak}/V_{rms}** for a waveform? Describe a waveform that has the minimum **V_{peak}/V_{rms}** ratio.

If we observe the waveforms and obtain the rms value of them by the formula that we used in 1st question of preliminary work, and if we divide peak voltage to that value, we get these rates;
Ratio of sine wave is $\sqrt{2}$
Ratio of triangular wave is $\sqrt{3}$
Ratio of square wave is 1.

Also, according to formula that we proved in preliminary work 2nd question, if we have a DC voltage source, the equation $V_{RMS} = \sqrt{V_{DC}^2 + 0} = V_{DC}$ gives us the rate of **V_{peak}/V_{rms}** = 1
Consequently, according to our calculations the minimum value of the **V_{peak}/V_{rms}** ratio is 1 and only square waveform and DC wave has that ratio. This ratio is named as crest factor.

Q2. A function generator has **50 Ω** output source resistance. Draw a modified schematic for the circuit used in step-**3** of the procedure that gives a closer simulation of the actual experiment with a function generator.





Loading affect of function generator does affect our simulation results slightly. If we had smaller resistor, the affect would be increased.