UM-SJTU JI 2024FA VE215 Lab#8

1 Goals

In this lab you will learn about RMS (root mean square) values.

- Please hand in your post-lab assignment before the due date. Please do your post-lab assignment following the requirements in each problem. Both hand-written and printed are accepted.
- You are encouraged to print this lab manual and then finish the post-lab questions on it. For pictures or diagrams, you may print it in a paper, cut it down and paste on this worksheet.
- Always attach the pictures or screenshots of your waveform if using the oscilloscope.

2 Instruments

- function generator
- two $10k\Omega$ resistor
- a $0.1\mu F$ capacitor
- a $1mH$ inductor
- an oscilloscope
- a multi-meter

3 Background

Effective current refers to the dc current that delivers the same average power to a resistor as the periodic current. For a circuit containing only resistor and power source, the average power can be calculated by:

$$P = \frac{1}{T}\int i^2 R dt = \frac{R}{T}\int i^2 dt$$

According to the DC current calculation, the formula should be:

$$P = I_{eff}^2 R$$

By equating these two equation, it can be found that:

$$I_{eff} = \sqrt{\frac{1}{T}\int i^2 dt}$$

The effective value for voltage can be derived in the same way. From this, the effective value can be calculated using the equation:

$$X_{rms} = X_{eff} = \sqrt{\frac{1}{T}\int x^2 dt}$$

Due to the form of equation, it is also known as root mean square(RMS) value.

3.1 Question #1

Please determine the RMS value of a sinusoidal period signal $y = 5 * sin(2\pi * 10t + \pi)$, and summarize the RMS value equation for sinusoidal signals.

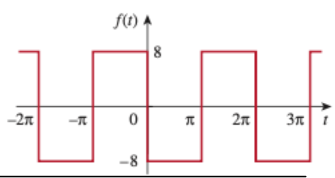
$T = \frac{2\pi}{\omega} = \frac{1}{10}$

$V_{rms} = \frac{V_m}{\sqrt{2}}$,

$V_{rms} = \sqrt{10 \int_0^{\frac{1}{10}} 25 \sin^2(20\pi t + \pi)\, dt}$.

3.2 Question #2 $= 3.5\,V$.

Please determine the RMS value of a square period signal as shown below, and summarize the RMS value equation for square signals.



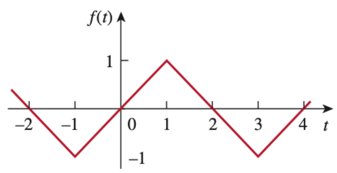
$V_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} 8^2\, dt}$

$= 8$.

$V_{rms} = V_m$.

3.3 Question #3

Please determine the RMS value of a triangular period signal as shown below, and summarize the RMS value equation for triangular signals.



$$V_{rms} = \sqrt{\frac{1}{4}\left(\int_0^1 x^2 dx + \int_1^3 (2-x)^2 dx + \int_3^4 (x-4)^2 dx\right)}$$

$$= 0.5.$$

$$V_{rms} = \frac{V_m}{2}.$$

4 Experiment

1. Connect the load to function generator and turn on the generator.
2. Set the function generator to:
   (a) Sine wave, 100Hz, 2Vpp, HighZ
   (b) Square wave, 100Hz, 2Vpp, HighZ
   (c) Triangle wave, 100Hz, 2Vpp, HighZ
3. Connect oscilloscope to load, record peak to peak voltage value, frequency.
4. Connect multi-meter to load, set the multi-meter to AC mode and measure the effective current and effective voltage across the load.

4.1 R

Use a $10k\Omega$ resistor as load, conduct the experiment on the resistor.

Resistor	Sine	Square	Triangle
Peak to Peak Voltage	2.15 V	2.41 V.	2.13 V
Frequency	99.97 Hz	100.00 Hz	100.02 Hz
Effective Voltage	0.701 V.	1.094 V.	0.551 V.

4.1.1 Question #4

What are the theoretical effective voltage values for the three signals input according to your calculation in previous part? Do they vary from the experiment result?

Sine, $V_T = \frac{1}{\sqrt{2}} = 0.707\,V$

Square $V_T = 1\,V$

Triangle, $V_T = \frac{1}{2} = 0.5\,V$.

The experiment values are all closed to the theoretical value, verifying that our experiments are correct.

4.2 RLC

Use a $10K\Omega$ resistor, a $1mH$ inductor, and a $0.1\mu F$ capacitor, connect them in series as load, and conduct the experiment on the capacitor.

RLC series	Sine	Square	Triangle
Peak to Peak Voltage	1.77V	2.03V.	1.51V.
Frequency	100.08Hz	100.02Hz	100.00Hz
Effective Voltage	0.593,	0.799	0.474V.

4.2.1 Question #5

What are the theoretical effective voltage values for the three signals input according to your calculation in previous part? Do they vary from the experiment result?

Sine, $V_T = \frac{1}{\sqrt{2}} = 0.707\,V$

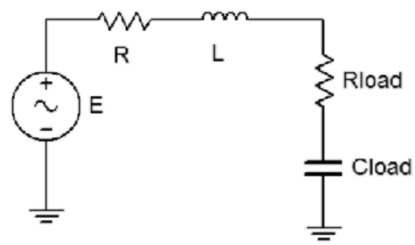
Square $V_T = 1\,V$

Triangle, $V_T = \frac{1}{2} = 0.5V.\,V$.

They are still close to the experimental result.

4.3 Maximum Power

Use a $10K\Omega$ resistor, a $1mH$ inductor to build the circuit below:



Here, the C load is $0.1\mu F$ capacitor, and power supply $2Vpp$. Design R load and altering current frequency so that the maximum power is achieved.

Use the value calculated to build the circuit, and design an experiment to measure the power delivered to the load.

4.3.1 Question #6

If we want to achieve the maximum power for the load part, what value should the power supply frequncy and resistor be?

$Z_L = j\omega L = 10^{-3} j\omega$.

$Z_C = \frac{1}{j\omega C} = -10^{7} j \frac{1}{\omega}$ $\Rightarrow$ $Z_L = -Z_C$, $\omega = 10^{5}$.

$R = R_c = 10 K\Omega$.

4.3.2 Question #7

How do you measure the power delivered to the load? What is the result you obtain? Calculate the theoretical power and compare it to the measured one.

$$P = \frac{V^2}{8R} = \frac{1}{8\times10^4} = 1.25\times10^{-5} W.$$

which is closed to the measured value.