UM-SJTU JI 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.

3.1

$T = 0.1s$ $\quad X_{eff} = \sqrt{10 \int_0^{0.1} 25 \cdot \sin^2(20\pi t + \pi)\,dt}$

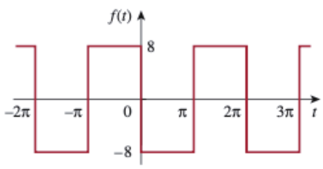
$= 5 \cdot \sqrt{10 \cdot \frac{1}{20}}$

$= \frac{5}{\sqrt{2}}$

$X_{RMS} = \frac{X_m}{\sqrt{2}}$

3.2 Question #2

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



$X_{rms} = \sqrt{\frac{8^2\pi \cdot 8^2\pi}{2\pi}} = 8$

Thus $X_{rms} = X_m$

3.3 Question #3

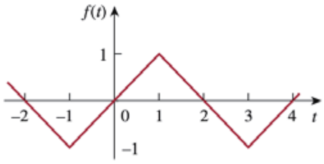
Please determine the RMS value of a triangular period signal as shown below, and summarize the RMS value equation for triangular signals.

3.3.

$X_{rms} = \sqrt{\int_0^1 t^2 dt}$

$= \frac{\sqrt{3}}{3}$

$X_{rms} = \frac{X_m}{\sqrt{3}}$



3.4 Question #4

What's the advantage of having high ratio of peak to peak voltage and effective voltage?

It can reach high voltage at a second, so as to drive something to work with more concentrated force without increasing the overall power.

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	2.13	1.97	2.29
Frequency	100	200	100
Effective Voltage	0.710	1.004	0.586

4.1.1 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?

Theoretical:

2	2	2
100	100	100
0.707	1.0	0.577

It does not vary from the experiment too much except the frequency of the square wave. That may because the oscillator regards one period as two.

4.1.2 Question #6

What is the energy consumed by the resistor in a period for these three signals? What is the average power?

#6 In a period, $T = 0.01s$

$E_1 = \frac{0.71^2}{10^4} \times 0.01 = 5.04 \times 10^{-7} J$

$E_2 = \frac{1.005^2}{10^4} \times 0.01 = 1.01 \times 10^{-6} J$

$E_3 = \frac{0.586^2}{10^4} \times 0.01 = 3.43 \times 10^{-7} J$

$\bar{P}_1 = 5.04 \times 10^{-5} W$

$\bar{P}_2 = 1.01 \times 10^{-4} W$

$\bar{P}_3 = 3.43 \times 10^{-5} W$

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	2.13	2.01	2.31
Frequency	100	200	100
Effective Voltage	0.713	1.01	0.587

4.2.1 Question #6

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?

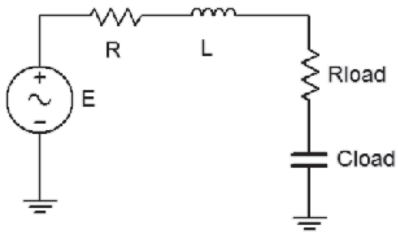
As the impedance do not change the real part of the voltage, the values are identical to that without the inductor and resistor

2	2	2
100	100	100
0.707	1.0	0.577

They are almost the same except the difference in oscillator listed in question 5

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 #7

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

$j\omega L + \frac{1}{j\omega C} = 0, \quad \omega = \frac{1}{\sqrt{LC}} = 1 \times 10^5 s^{-1}$

Then it is pure load. $R_L = R_{TH} = 1.0k\Omega$.

4.3.2 Question #8

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.

2V_PP,10kΩ

0.353V

$P_{TH} = \frac{V_m^2}{8R} = 1.250 \times 10^{-5} W$

$P_{Exp} = \frac{0.353^2}{R} = 1.246 \times 10^{-5} W$

They are very close.

Post-Lab Reflection Questions

(1) Is your experimental result the same as your analysis (Need data as proof)? If not, how do you interpret this difference? What do you think is the source of the experimental error?
(2) What do you learn from this experiment? (e.g. what experimental procedures, how to debug, etc.)

The experimental result is largely the same as the analysis. It does not vary from the experiment too much except the frequency of the square wave. The only difference may because the oscillator regards one period as two.

Follow the experimental procedures and read the lab manuel in detail, so that not leak any part of the experimental procedures.
Also, use multimeter to measure the voltage and the current of the experiment to find where there is bad contact.