Ve215 Fall 2017

Lab 4 AC Lab

I. Goals

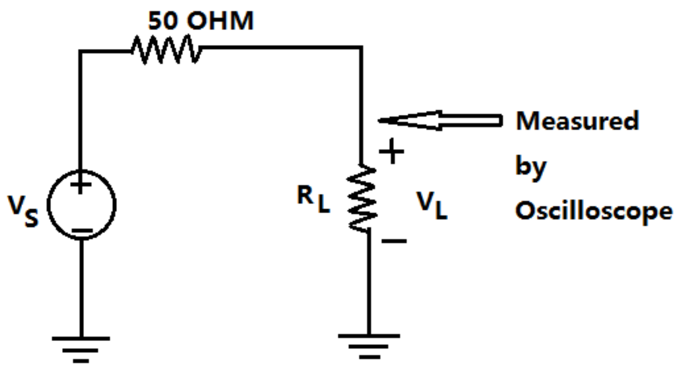
1. Learn how to define, calculate, and measure the amplitude of a sinusoidal signal
2. Learn how to define, calculate, and measure the Rise Time and Fall Time of a signal
3. Learn how to observe FFT spectra of signal and measure their parameters with cursors
4. Measure the waveforms and FFT spectra of various signals
5. Compare your theoretical results obtained in the Pre-Lab with your In-Lab data.

II. Introduction

1. High-Z mode

Here I want to introduce you what is the High-Z mode we have kept emphasizing during the previous Labs.

You have already learnt Thevenin equivalent of a circuit. You can think the function generator in terms of its Thevenin equivalent circuit, which includes the voltage source and V_S and the equivalent resistance of 50Ω as shown below.

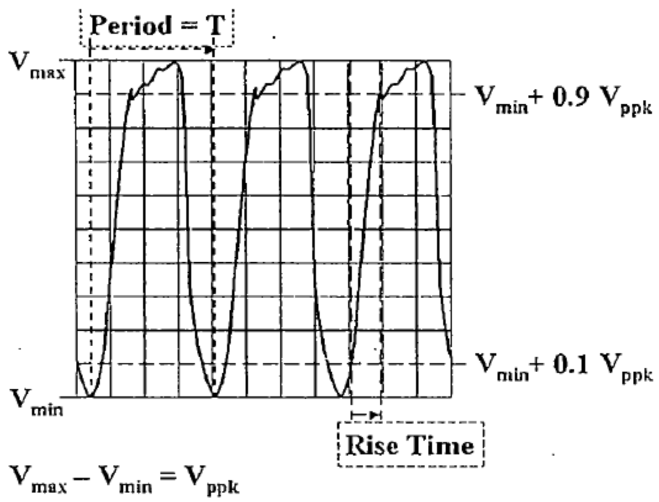


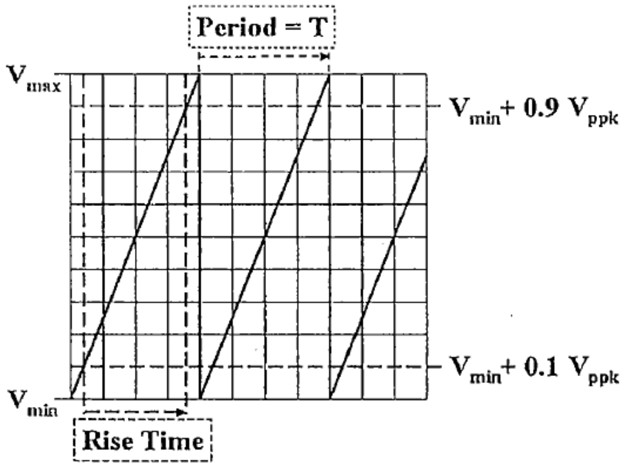
When the load R_L is 50Ω, according to voltage division, we know that the V_L measured will be $0.5V_S$. In this case, we use the 50 OHM mode, in which the function generator produces voltage V_S but displays voltage $0.5V_S$. In that way, if you set $2V_{ppk}$ for the function generator, the actual V_S will be $4V_{ppk}$ to make sure the load get a voltage of $2V_{ppk}$.

In our lab measurements, the load resistance R_L is very high—the input resistance of the oscilloscope is about $1 M\Omega$. The V_L measured across R_L practically equals V_S. So we use High Z mode, in which the function generator produce voltage V_S and displays V_S.

2. The Rise Time and Fall Time of signals

The Rise time is the interval between the moment of the time when the signal reaches its 10% level and the moment of time when the signal reaches its 90%. We have already used this concept in our Lab3.





The above two figures illustrate the rise time of a sinusoidal like wave and a saw-tooth wave. If you do not know what is V_{ppk}, you can refer to part 4 of this section.

Take the sinusoid wave as an example to calculate the rise time.

$$y = \frac{V_{ppk}}{2}\sin(2\pi ft)$$

$$V_{min} = \frac{-V_{ppk}}{2}, V_{max} = \frac{-V_{ppk}}{2}$$

$$Rise\,Time = \frac{\sin^{-1}(\frac{V_{min}+0.9V_{ppk}}{0.5V_{ppk}}) - \sin^{-1}(\frac{V_{min}+0.1V_{ppk}}{0.5V_{ppk}})}{2\pi f}$$

3. Fourier Series Representation of a Signal

Here I am going to give you a general idea of Fourier Series to help you understand some parts of this lab. You will learn Fourier Series in details in your math course this semester.

Fourier series is a way to represent a wave-like function as a combination of simply sine waves. It decomposed and period function into the sum of a (possibly infinite) set of simple oscillation functions.

Let $x(t)$ be a periodic signal with fundamental period T_0. It can be represent by the following synthesis equation,

$$x(t) = \sum_{k=-\infty}^{\infty} c_k e^{jk\omega_0 t}, \text{where } \omega_0 = \frac{2\pi}{T_0}$$

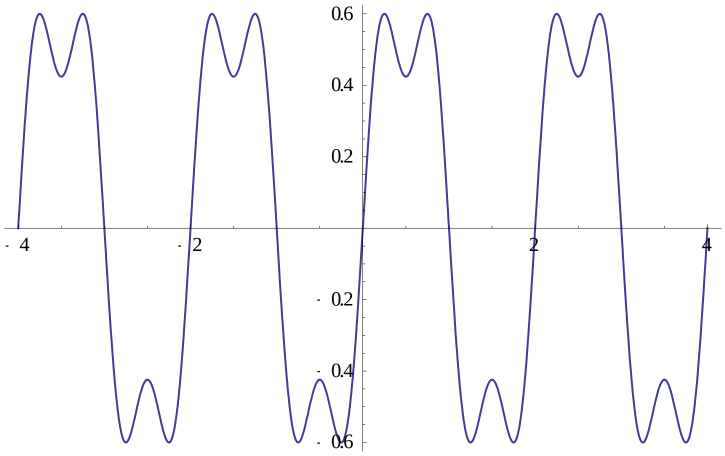
The coefficients c_k in the above equation can be calculated by the analysis equation,

$$c_k = \frac{1}{T_0}\int_0^{T_0} x(t)e^{-jk\omega_0 t}dt, k = 0, \pm 1, \ldots$$

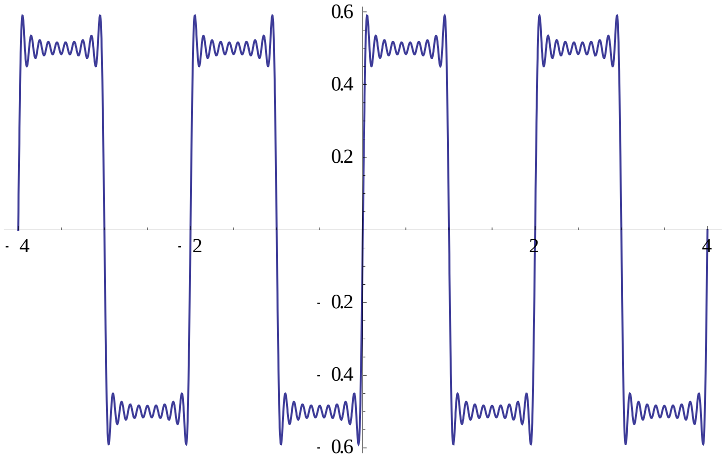
$\text{Plot}[\text{Sum}[(-1)\char`^(((k+1))\,/\,2)*2\,/\,((k*\text{Pi})\,)\ \text{Cos}[k*\text{Pi}*(t+0.5)],\{k,1,\boxed{100},2\}],\{t,-4,4\}]$

You can use the above Mathematic code to get the feeling of how a series of sinusoidal waves can form a square wave (actually, any waveform). You can change the value in the red box, and the larger the value is, the more accurate the result will be. Here we thank your Vv286 TA Gao Yuan for offering us the source code.

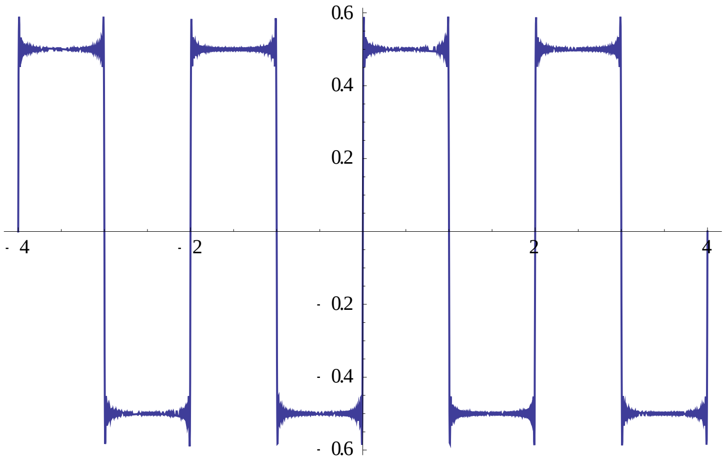
For value 3, we can get the following result.



For value 20, we can get the following result,



And for value 100, we get,

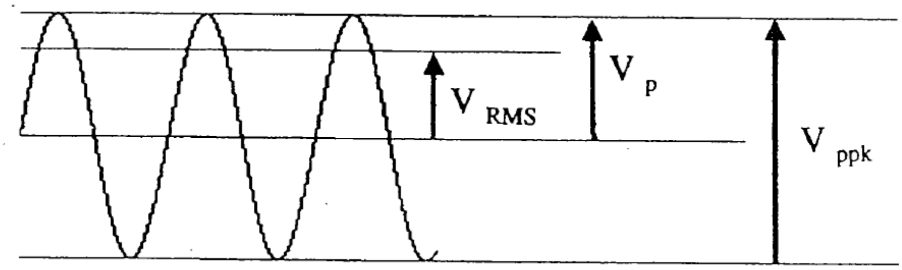


4. Four ways to measure the amplitude of a sinusoid

a) $\mathbf{V_{peak}=V_p=V_{pk}=V_0}$ is the peak amplitude of the sinusoid measured in V or mV.

b) $\mathbf{V_{peak\text{-}to\text{-}peak}=V_{ppk}=V_{max}\text{-}V_{min}=2V_0}$ is the value we often use in the lab to determine the overall size of the waveform. We have used it many times in the previous Labs.

c) V_{RMS} is the Root-Mean-Square, or RMS amplitude of the sinusoid. The sinusoidal voltage $V = V_0 \sin(\omega t + \theta)$ dissipates as much power in the load resistor as does the DC voltage equals to V_{RMS}



For any periodic function *f(t)* that has period T, the RMS amplitude is defined as

$$Amplitude, RMS = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} (f(t))^2\, dt}$$

In the case of sinusoid $f(t) = V_0 \sin(\omega t + \theta)$,

$$V_{RMS} = \frac{V_0}{\sqrt{2}} = \frac{V_{peak}}{\sqrt{2}} = \frac{V_{ppk}}{2\sqrt{2}}$$

d) The above three ways all study the signal in time domain, plotted as voltage vs. time. In this Lab, we also need to study the frequency domain, when you measure their spectra displayed as amplitude vs. frequency. In frequency domain, the oscilloscope measures the amplitude of on a logarithmic scale, using **decibels.**

$$Amplitude\ in\ decibels(\mathrm{dBV}) = 20 \cdot \log_{10}\left(\frac{Amplitude\ in\ V_{RMS}}{1V_{RMS}}\right)$$

Decibels are used to calculate ratios of **two** amplitudes on a logarithmic scale.

$$Ratio, in\ decibels\ (\mathrm{dB}) = 20 \cdot \log_{10}\left(\frac{Amplitude\, of\ signal\ \#2, RMS}{Amplitude\ of\ signal\ \#1, RMS}\right)$$

III. Pre-Lab Assignment

1. Consider a sinusoidal signal at $3V_{ppk}$ and 10 kHz. Calculate its amplitude in V_{pk}, RMS, and dBV.

2. Consider a square wave at $3V_{ppk}$ and 10 kHz. Calculate the amplitude of its frequency components—fundamental and harmonics up to the 5th –in V_{pk}, V_{RMS}, and in dBV. Fill the following table.

Column	1	2	3	4
Frequency component	Frequency, kHz	Amplitude in dBV	Amplitude in V_{RMS}	Amplitude in V_{pk}
Fundamental				
1^{nd} harmonic				
2^{nd} harmonic				
3^{nd} harmonic				
4^{nd} harmonic				
5^{nd} harmonic				

3. Consider a sinusoidal signal at $3V_{ppk}$ and 1kHz, calculate the rise time of this signal.

IV. In-Lab Procedure

Part I

1. On the function generator, set a sine wave at 1 [kHz] and keep its amplitude at 3 [Vpp]. The load must be High-Z mode.
2. Record the parameters on the datasheet. Fill the table with the data set on the function generator and displayed on the oscilloscope.
3. Repeat the Step 2 with a sine wave at 1.5 [kHz] and 5 [Vpp] on the function generator. The load should remain High-Z mode.
4. In post-report, calculate the rise time in theory and compare it with the values displayed on the oscilloscope.
5. Reminder: $RiseTime = \frac{[sin^{-1}(\frac{V_{min}+0.9V_{pp}}{0.5V_{pp}})-sin^{-1}(\frac{V_{min}+0.1V_{pp}}{0.5V_{pp}})]}{2\pi f}$

Part II

1. First, we set a sine wave and a square wave, respectively. The frequency is 1 [kHz] and the amplitude is 3 [Vpp].
2. On the oscilloscope, set 1 [V/div] and 5 [ms/div].
3. Push the “MATH” button and select “FFT” function.
4. Push the “cursor” button and select “trace” mode to trace the spectrum.
5. When the cursor reach a peak of the spectrum, record the Frequency in [kHz] and the Amplitude in [dBV].
6. Set another sine wave and a square wave. The frequency is 2 [kHz] and the amplitude is 6 [Vpp]. Repeat the steps above.
7. In post-report, you need to calculate the theoretical amplitude of sine wave in [dBV]. Besides, you need to calculate the Vpeak of each square wave measured in Part II. You should give a brief conclusion on what you learn from this lab.

8. Reminder: for sine wave. $dBV = 20log(\frac{Amplitude in V_{RMS}}{1\ V_{RMS}})$

9. Reminder: for square wave. $Vpeak = \sqrt{2} \cdot 10^{(\frac{Amplitude\ \ in\ \ [dBV]}{20})}$

V. Reference

Circuits make sense A new Lab Book for introductory Course In Electric Circuits. Fifth edition. Alexander Ganago.