UM-SJTU JOINT INSTITUTE
Intro to Circuits
(VE215)

LABORATORY REPORT

EXERCISE 4
AC Lab

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1 Introduction and Theoretical Background

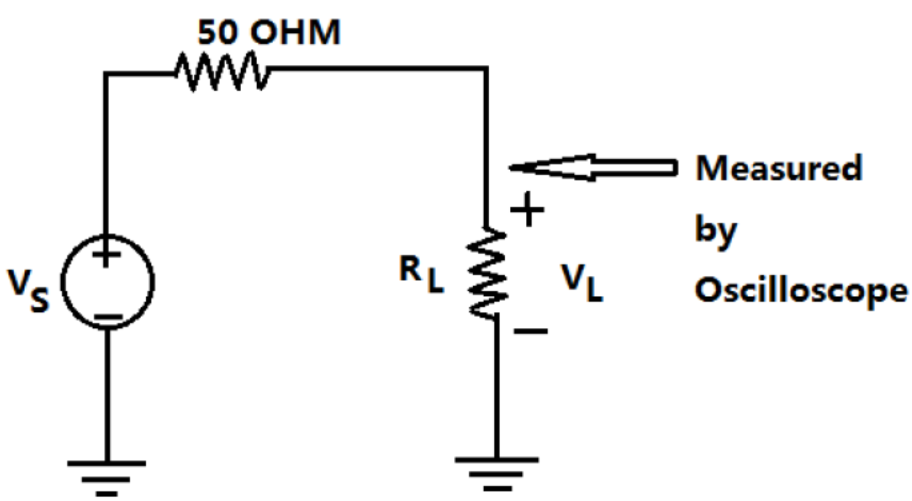
1.1 Objectives

1. Define, calculate and measure the amplitude of a sinusoidal signal.
2. Define, calculate and measure the rise time and fall time of a signal.
3. Observe FFT spectra of signal and measure their parameters with cursors.
4. Measure the waveform and FFT spectra of various signal
5. Compare the theoretical results and the results obtained in the lab word.

1.2 Introduction

1.2.1 High-Z Mode

The function generator is like a Thevenin circuit including a voltage source V_S and a equivalent resistance of 50Ω.

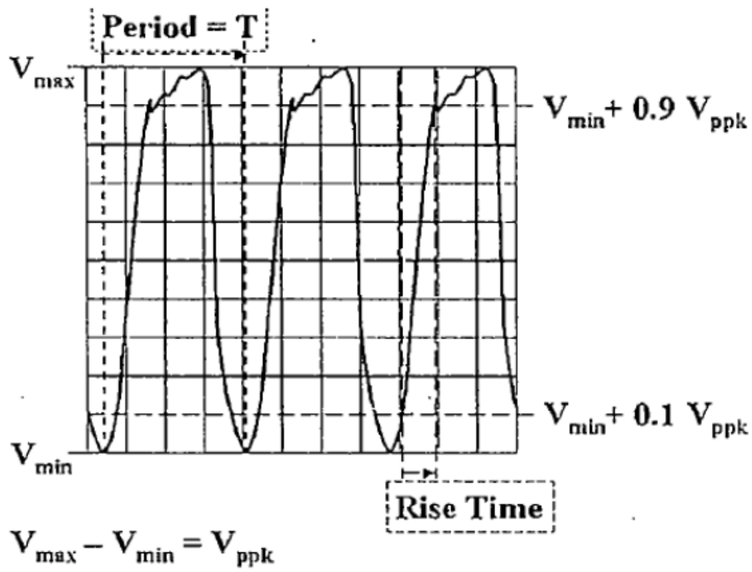


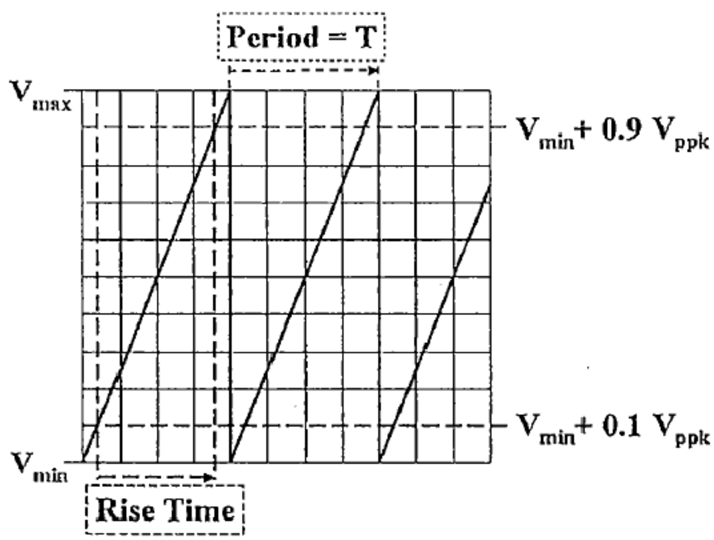
When $R_L = 50\Omega$, according to voltage division, V_L is 0.5 V_S. If $2V_{ppk}$ is set for the function generator, the actual V_S will be $4V_{ppk}$ to make sure the load get a voltage of $2V_{ppk}$.

In the lab work, the load resistance R_L is about $1M\Omega$, so the V_L measured across R_L practically equals V_S. In the High-Z mode.the function generator will produce voltage V_S and display it.

1.3 The Rise Time and Fall Time of Signals

The Rise time is the interval between the moment of the time when the signal reaches the 10% level and the moment of time when it reaches 90% level.





The above two figures illustrate the rise time of a sinusoidal like wave and a saw-tooth wave.Take the sinusoidal wave as an example to calculate the rise time:

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

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

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

1.4 Fourier Series Representation of a Signal

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 set of simple oscillation functions.

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

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

The coefficient c_k in the above equation can be calculated by the analysis equation

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

for Mathematic code:

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Plot[Sum[(−1)^(((k + 1)) / 2) ∗ 2 / ((k ∗ Pi) ) Cos[k ∗ Pi ∗ (t +
0.5)],{k, 1,100,2}],{t,−4,4}]
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The larger the value in red box is, the more accurate the figure will be.

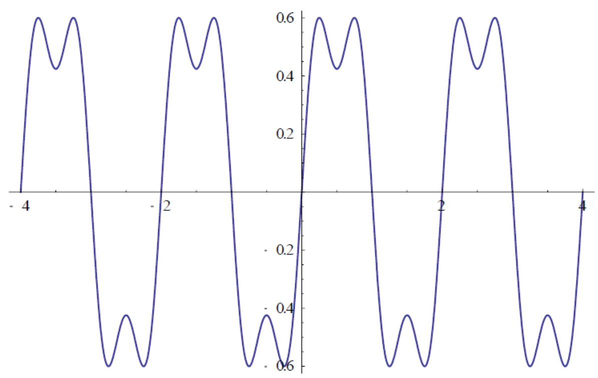


Figure 1: For value 3

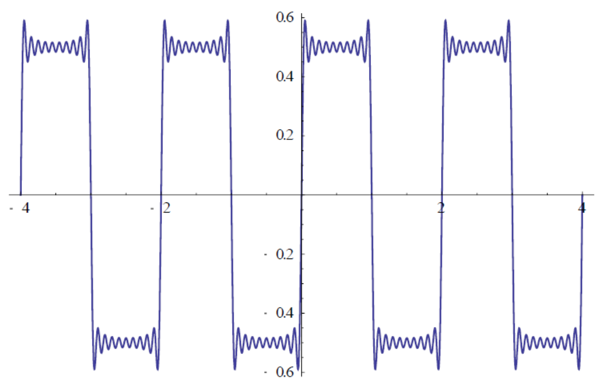


Figure 2: For value 20

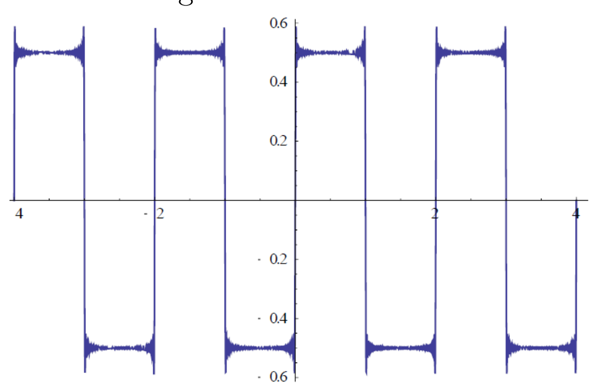


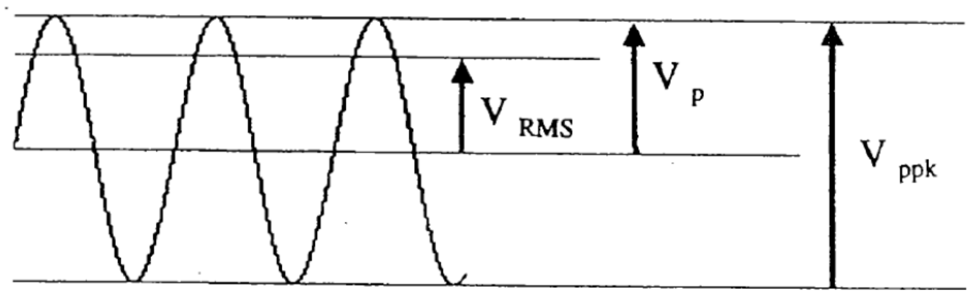
Figure 3: For value 100

1.5 Four ways to measure the amplitude of a sinusoid

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

2. $V_{ppk} = V_{max} - V_{min} = 2V_0$ is the value we often use in the lab to determine the overall size of the waveform, We've used it many times in the previous labs.

3. V_{RMS} is the Root-Mean-Square, or RMS amplitude of the sinusoid. The sinusoid 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 $f(t) = V_0 sin(\omega t + \theta)$

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

4. The above three ways all study the signal in time domain, plotted as voltage vs. time. We also study the frequency domain by measuring their spectra displayed as amplitude vs. frequency. In frequency domain, the oscilloscope measures the amplitude of on a logarithmic scale, using decibels.

$$AmplitudeInDecibels(dBV) = 20 \cdot log_{10}(\frac{AmplitudeInV_{RMS}}{1V_{RMS}})$$

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

$$RatioInDecibels(dB) = 20 \cdot log_{10}(\frac{Signal\#2'sAmplitude, RMS}{Signal\#1'sAmplitude, RMS})$$

2 Procedure

2.1 Part 1

1. I set a sine wave at 1 [kHz] and keep its amplitude at 3 [Vpp] on the function generator. The load must be High-Z mode.

2. I record the parameters and fill the table with the data set on the function generator and displayed on the oscilloscope.

3. I 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. I calculate the rise time in theory and compare it with the values displayed.

2.2 Part 2

1. I set a sine wave and a square wave, respectively. The frequency is 1 [kHz] and the amplitude is 3 [Vpp].

2. I set 1 [V/div] and 5 [ms/div] on the oscilloscope.

3. I push the MATH button and select FFT function. Push the cursor button and select trace mode to trace the spectrum.

4. When the cursor reach a peak of the spectrum, I record the Frequency in [kHz] and the Amplitude in [dBV].

5. I Set another sine wave and a square wave with the frequency is 2 [kHz] and the amplitude is 6 [Vpp], then I repeat the steps above.

6. I calculate theoretical amplitude of sine wave in [dBV] and the V_{peak} of each square wave measured in Part II

3 Results

3.1 Part 1

	Set on Function Generator	Measured with Oscilloscope
Amplitude in V_{pp} [V]	3.000	3.100
Frequency [kHz]	1.000	1.005
Rise Time [μs]	295.17	276.58
Amplitude in V_{pp} [V]	5.000	5.01
Frequency [kHz]	1.500	1.4996
Rise Time [μs]	196.78	184.95

Table 1: Rise Time Measurement

3.2 Part 2

1. Set the wave at 3[V_{pp}] 1[kHz]

Peak	Frequency (measured) [kHz]	Amplitude (measured) [dBV]
f_0	1.999	5.494

Table 4: FFT spectrum for Sine Wave

Peak	Frequency (measured) [kHz]	Amplitude (measured) [dBV]
f_0	1.000	-0.261

Table 2: FFT spectrum for Sine Wave

Peak	Frequency (measured) [kHz]	Amplitude (measured) [dBV]
f_0	1.000	-1.878
$3f_0$	3.000	-7.790
$5f_0$	5.001	-12.519
$7f_0$	7.003	-15.520
$9f_0$	9.001	-17.516

Table 3: FFT spectrum for Square Wave

2. Set the wave at 6[V_{pp}] 2[kHz]

Peak	Frequency (measured) [kHz]	Amplitude (measured) [dBV]
f_0	2.000	7.658
$3f_0$	6.001	-2.006
$5f_0$	10.000	-6.527
$7f_0$	14.000	-9.169
$9f_0$	18.000	-11.650

Table 5: FFT spectrum for Square Wave

4 Conclusion

4.1 Part 1

In first part of the lab, I set a sine wave on the function generator and record its amplitude, frequency, and rise time. When the amplitude is $3V_{pp}$ and frequency is 1kHz, the rise time measured on the function generator and oscilloscope are $295.17\mu s$ and $276.58\mu s$, which is very close to my theoretical data $295\mu s$.

$$RiseTime = \frac{sin^{-1}(\frac{V_{min}+0.9V_{ppk}}{0.5\cdot 3}) - sin^{-1}(\frac{V_{min}+0.1V_{ppk}}{0.5\cdot 3})}{2000\pi} = 295[\mu s]$$

Then I change the amplitude to $5V_{pp}$ and frequency to 1.5, the rise time is measured as $196.78\mu s$ and $184.95\mu s$,while my calculated data is $196.7\mu s$.

$$RiseTime = \frac{sin^{-1}(\frac{V_{min}+0.9V_{ppk}}{0.5\cdot 6}) - sin^{-1}(\frac{V_{min}+0.1V_{ppk}}{0.5\cdot 6})}{2000\pi} = 196.7[\mu s]$$

My calculated data is the same as it on the function generator but the data on the oscilloscope is a bit smaller than it.

4.2 Part 2

In the second par of the lab, I measured the frequency and amplitude in dBV of since and square wave of different amplitude in V_{pp} and frequency.

When the amplitude of the sine wave is $3V_{pp}$, my calculated amplitude in dBV is 0.512, which is bigger than my measured value -0.261.

When the amplitude of the sine wave is $6V_{pp}$, my calculated amplitude in dBV is 6.532, which is also bigger than my measured value 5.494.

For the square wave, my calculated value is always bigger than the measured data.

$$v = 20log\frac{3\sqrt{2}}{\pi \cdot (2n-1)}$$

$$v_1 = 20log\frac{3\sqrt{2}}{\pi} = 2.610$$

Peak	Measured Amplitude in dBV	Calculated Amplitude in dBV
f_0	1.878	2.610
$3f_0$	-7.970	-6.932
$5f_0$	-12.519	-11.370
$7f_0$	-15.520	-14.292
$9f_0$	-17.516	-16.475

Table 6: Amplitude when the square wave is set at $3[V_{pp}]$ 1 kHz

Peak	Measured Amplitude in dBV	Calculated Amplitude in dBV
f_0	7.658	8.630
$3f_0$	-2.006	-0.912
$5f_0$	-6.527	-5.349
$7f_0$	-9.169	-8.271
$9f_0$	-11.650	-10.455

Table 7: Amplitude when the square wave is set at $6[V_{pp}]$ 2 kHz

In this lab, I learned about the principle of High-Z mode of the function generator and reviewed the concept of rise time and fall time of signals. Also, I had a general idea about the Fourier Series and how to use it to represent a square wave signal. In addition, I learned four ways to calculate amplitude of a sinusoid in $V_{peak}, V_{ppk}, V_{RMS}$, and in dBV. I calculate the amplitude in dBV of square and sinusoid wave at different amplitude and frequency and compared it with the data measured in the lab work.

5 Reference

- *VE215FA2017 AC LabManual*

- *Circuits Make Sense*, Alexander Ganago, Department of Electrical Engineering and Computer Science, University of Michigan, Ann Arbor.