Lab 7: Oscilloscopes

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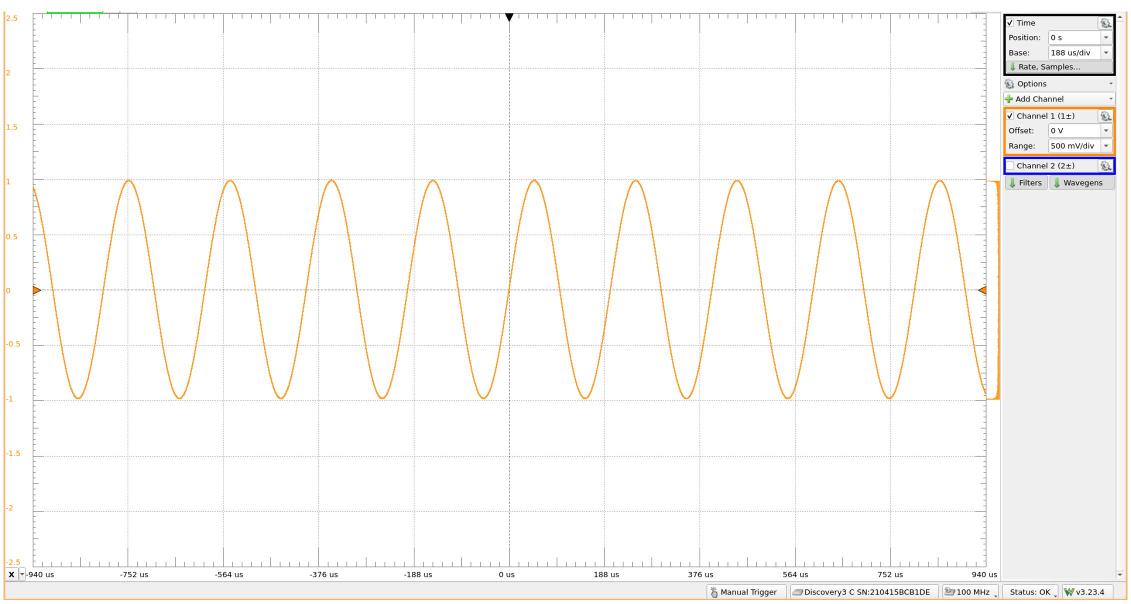
1 Introduction

Oscilloscopes are essential tools for electrical engineering. They allow complex electrical signals to be viewed in the time and frequency domains (i.e. modern Fast Fourier Transform capable devices) for analysis. In this lab, we learn how to use a digital oscilloscope's functions and work with root-mean-square AC voltage measurements.

2 Problem 1

Part 1:

The oscilloscope shows what would be expected for the input signal from the function generator. The x-axis shows a time range centered around 0 seconds which goes around 1 milisecond in both directions. The y-axis shows the voltage. The trigger level is set at 0 V (the arrows on each side of the graph).



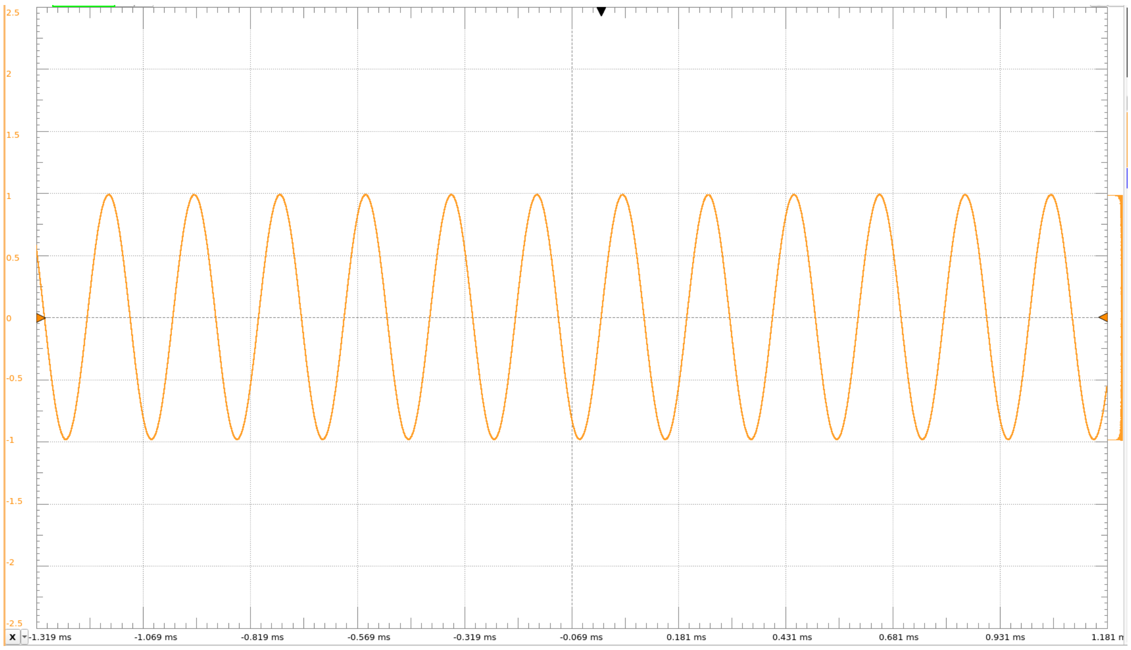
Part 2:

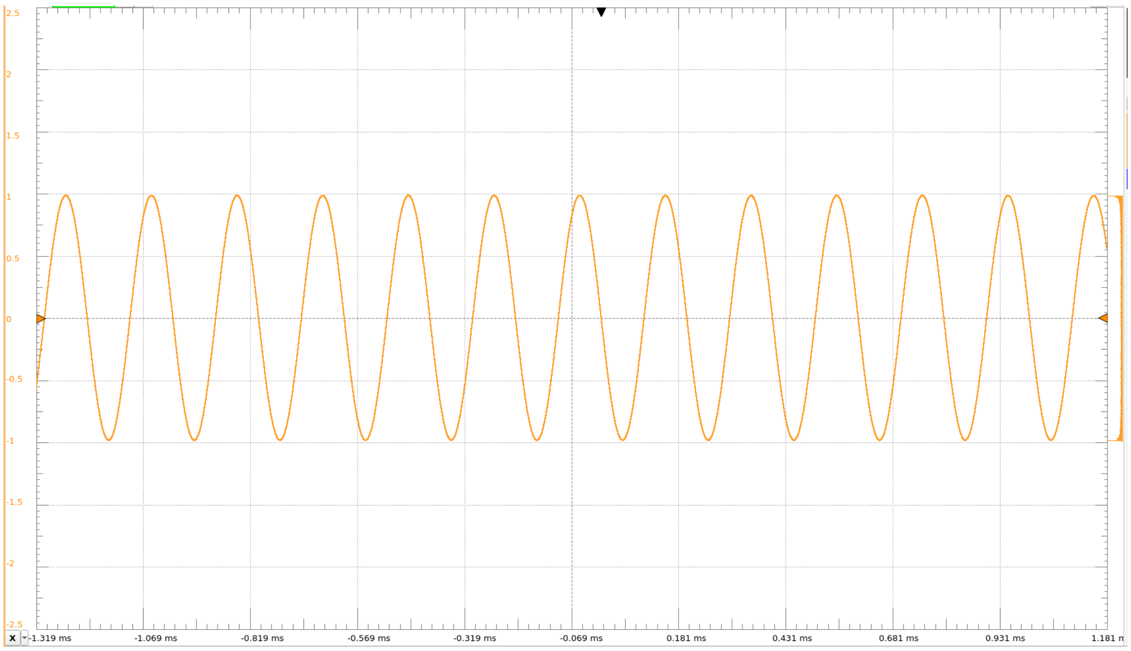
- Trigger level 200 mV: The graph shifts to the left (to adjust to the new "starting" voltage).
- Trigger level 500 mV: The graph shifts more to the left.

- Trigger level 1 V: The graph no longer stays still showing a set cycle, but instead the raw signal.
- Trigger level 2 V: The same as at 1 V, since there is no voltage to start recording a set cycle.

Part 3:

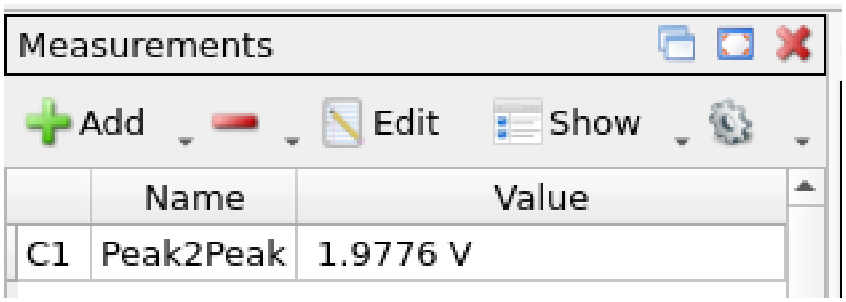
When the trigger condition is set to rising, for the oscilliscope to start recording, the voltage at the trigger level must be increasing, whereas it must be decreasing when the condition is set to falling:





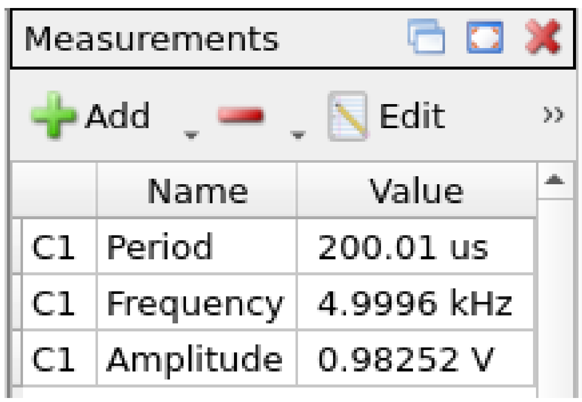
3 Problem 2

Part 1: The measured peak-to-peak value was 1.9776 V.



	Name	Value
C1	Peak2Peak	1.9776 V

Part 2: For the original sinusoidal function (for reference):



	Name	Value
C1	Period	200.01 us
C1	Frequency	4.9996 kHz
C1	Amplitude	0.98252 V

For the other three functions, the results were:

Type of Signal	Amplitude (V)	Period (us)	Frequency (kHz)
Ramp	0.74670	200.00	5.0000
Square	0.99291	200.00	5.0000
Triangular	0.25707	199.96	5.0010

One thing worth noting was that the period and frequency measurements for the non-sine waves were exact, unlike the sine wave itself. Also, the accuracy of the amplitude measurement seemed to have a lot to do with the amount of time spend by the function at the amplitude (e.g. square waves spend more time there then ramp waves). The triangular wave had a lot of trouble measuring the amplitude, and was not exact with its period and frequency.

4 Problem 3

Part 1: Since the peak-to-peak voltage is 2 V, the amplitude of the sinusoid is 1 V. Therefore, assuming $V = 0$ and $\frac{dV}{dt} = 1$ at $t = 0$:

$$V(t) = 1 \sin t$$

To find the room mean square:

$$V(t)^2 = 1\sin^2 t = \frac{1}{2}(1 - \cos 2t)$$

The average of a cosine wave across its period is 0, thus:

$$V_{\text{RMS}}^2 = \frac{1}{2} \implies V_{\text{RMS}} = \frac{1}{\sqrt{2}} = \frac{\sqrt{2}}{2} = \boxed{0.707\,\text{V}}$$

Part 2:

Waveform	V_m (V)	V_peak	V_m/V_peak
Sine	0.714	0.99930	0.7145
Triangular	0.560	0.87480	0.6401
Square	1.115	0.99935	1.1157

Part 3: *Yes.* 0.714 V is very close to the predicted value of 0.707 V.

Part 4: The integral of the *square* of each wave across their respective periods are not the same. For example, a square wave's integral works out like so, as opposed to a sine wave:

$$V_{\text{RMS}} = \sqrt{\frac{1}{T}\int_0^T V_p^2 dt} = \sqrt{\frac{1}{T}[V_p^2 t]_0^T} = \sqrt{\frac{1}{T}V_p^2 T} = \sqrt{V_p^2} = V_p$$

Part 5: The multimeter I used correctly measured the value of V_{RMS} for all the waveforms. However, the ratios from the multimeter were not dependent on the waveform, and they only nearly agreed with the oscilloscope. The multimeter is measuring the sure V_{RMS}.

Part 6:

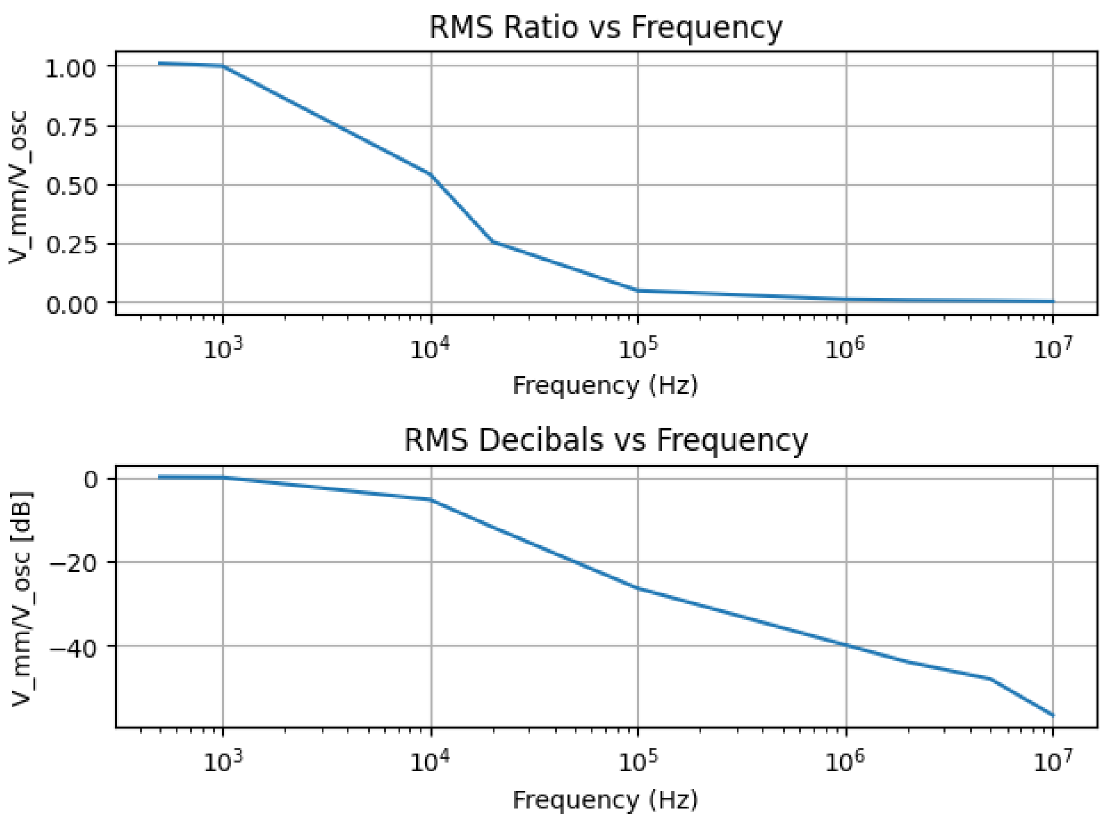
Frequency	V_osc,rms	V_mm,rms	V_mm,rms/V_fg,rms	V_mm,rms/V_fg,rms [dB]
500 Hz	0.80315	0.812	1.0110	0.0951
1 kHz	0.80593	0.805	0.9988	-0.0100
10 kHz	0.79854	0.432	0.5409	-5.3362
20 kHz	0.79609	0.203	0.2549	-11.8693
100 kHz	0.79663	0.038	0.0477	-26.4294
1 MHz	0.79065	0.008	0.0101	-39.8978
2 MHz	0.78949	0.005	0.0063	-43.9675
5 MHz	0.75453	0.003	0.0039	-48.0111
10 MHz	0.67683	0.001	0.0014	-56.6095

Part 7:

[ ]:
```
from math import *
```

```python
import matplotlib.pyplot as plt
import numpy as np

freq = np.array([500, 1e3, 10e3, 20e3, 100e3, 1e6, 2e6, 5e6, 10e6])

v_osc = np.array(
    [
        0.80315,
        0.80593,
        0.79854,
        0.79609,
        0.79663,
        0.79065,
        0.78949,
        0.75453,
        0.67683,
    ]
)

v_mm = np.array(
    [
        0.812,
        0.805,
        0.432,
        0.203,
        0.038,
        0.008,
        0.005,
        0.003,
        0.001,
    ]
)

v_div = v_mm / v_osc

v_db = 20 * np.log10(v_div)

fig, (ax1, ax2) = plt.subplots(2)

ax1.set_title("RMS Ratio vs Frequency")
ax1.semilogx(
    freq, v_div
)
ax1.set_xlabel('Frequency (Hz)')
ax1.set_ylabel('V_mm/V_osc')
ax1.grid()
```

```
ax2.set_title("RMS Decibels vs Frequency")
ax2.semilogx(
    freq, v_db
)
ax2.set_xlabel('Frequency (Hz)')
ax2.set_ylabel('V_mm/V_osc [dB]')
ax2.grid()

fig.tight_layout()
```



Part 8: The two plots are very similar, however the RMS Ratio plot looks more like a *sigmoid curve* and shows only the ratio. The decibel version is much more *linear* and shows the signals' relative power.

Part 9: The multimeter's sampling ratio, for measuring the RMS of the AC voltage, is much lower than that of the oscilloscope. So, when averaging, it slowly approaches 0, instead of staying at the true value.

5 Conclusion

This lab was a success. Many of the principles of oscilloscopes were demonstrated, and some data was gathered and analysized. The issues with measuring the RMS voltage of high frequency signals using a multimeter was also demonstrated and shown graphically. Unfortunately, it took a bit longer than the others, but hopeful the last three labs after this one won't take too long.