Name: Cayce Beames
Date: October 19, 2019
Professor Steven Gillette

Abstract
In this lab, I leveraged a battery, a 120V/24V transformer, the Global Specialties Circuit Trainer, a Digital Multimeter (DMM) and an oscilloscope to learn about properly operating an oscilloscope and obtaining useful information from it.

Learning Objectives

- Understand the basic setup for oscilloscope measurements
- Measure AC & DC voltage signals with oscilloscope and DMM
- Calculate RMS voltage from peak voltage
- Calculate duty cycle from pulse and cycle durations
- Calculate frequency from waveform period

Notes:

1. Took all voltage measurements relative to ground (unless otherwise stated)
2. Recorded relevant measurements and calculation results in data tables
3. Recorded all measured values on the circuit schematics
4. Used all available precision in calculations, rounded off answers to 3 significant figures

Materials

Quantity	Description
1	Global Specialties Circuit Trainer
1	Digital multimeter (DMM)
1	Digital oscilloscope
1	120V / 24V transformer
1	AA-cell

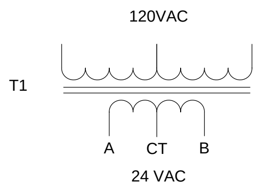
Procedure –DC Voltage Measurement

1. Set the probes to 10x attenuation, pressed the "Default Setup" button after the scope boot routine was complete.
2. Used the DMM to ***measure and record*** the DC voltage of a battery to three significant figures. **1.59 VDC**
3. Connected the scope ground clip to one end of the battery and the scope probe to the other end. ***Measured and recorded*** the DC voltage to the best available resolution (using the Volts per Division adjustment.) **1.61 VDC**
4. ***Compared and recorded*** the DMM and scope measurements using the % Error formula. Used the DMM reading as the expected value. **1.26 %**

Procedure –AC Voltage & Frequency Measurement

5. Used the oscilloscope to ***measure and record*** the peak voltage (V_p) between the transformer center tap and point A (connected the probe's ground lead to the center tap and the probe to point A.)

   V_P = 20V



6. ***Calculated and recorded*** the effective voltage value using the RMS Effective Voltage formula.

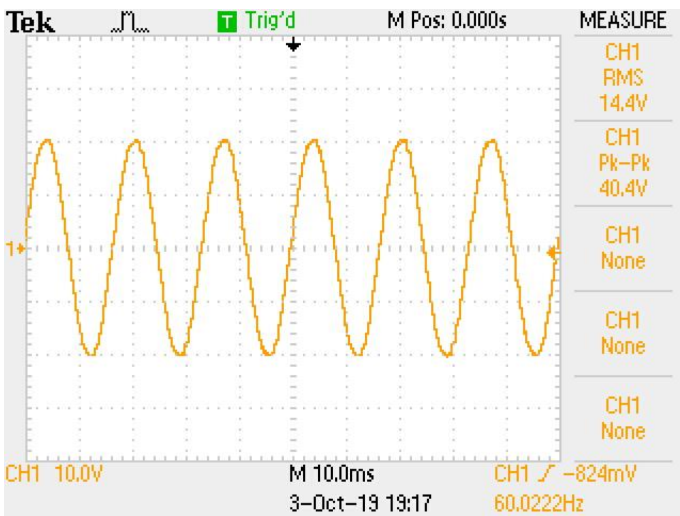
   V_{RMS} = 14.14V

7. ***Measured and recorded*** the transformer voltage using a DMM set to AC Volts. ***Compared and recorded*** the DMM measurement to the calculated RMS value using the % Error formula, using the calculated value as the expected value.

   V_{RMS} = 14.12V

   0.141%

8. Screen ***captured the waveform*** on a scatter plot with time on the x-axis (horizontal) and voltage on the y-axis (vertical.)



9. ***Measured and recorded*** the period of the wave form. Use this value to calculate the signal frequency using the Frequency formula.

   16.68 mS

   59.95 Hz

10. ***Measured and recorded*** the signal frequency using the DMM. ***Compared and recorded*** the DMM frequency measurement with the calculated frequency using the % Error formula.

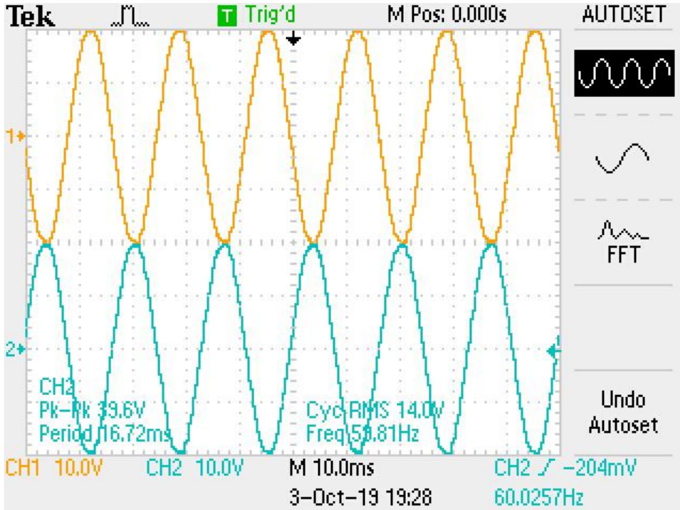
   Hz

   %

Procedure – Dual Trace Mode

11. Connected a second probe (set to 10x) to the second scope channel. Turned on the channel by pressing the blue button.
12. Connected both probe grounds to the transformer center tap. Connected a probe to each transformer output.

13. Screen ***captured the dual trace waveforms*** showing the 180° phase relationship between them.



Procedure – Alternate Wave Forms

Sine Wave

14. Set up the circuit trainer function generator to produce ≈ $8V_{P-P}$ ***sine wave*** at 100KHz. Used the oscilloscope to set the waveform amplitude and frequency.

15. Used the scope to ***measure and record*** V_P and frequency. **V_P = 4V**

101.2 kHz

16. Used the scope measured V_P value to ***calculate and record*** V_{RMS} using the RMS Effective Voltage (sine wave) formula. **V_{RMS} = 2.83V**

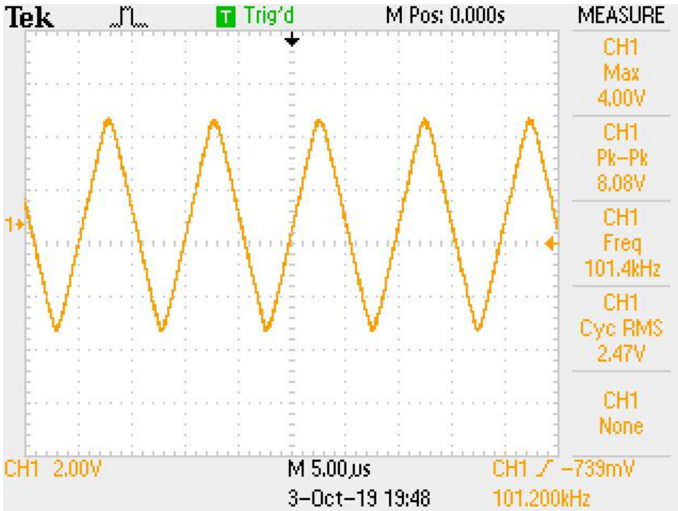
17. ***Measured and record*** the RMS effective voltage using the DMM. ***Compared and recorded*** the scope and the DMM values using the % Error formula.

V_{RMS} = 1.213V

57.11%

Triangle Wave

18. Changed the function generator and oscilloscope to produce an $8V_{P\text{-}P}$ ***triangle wave*** at 100KHz.
19. Screen ***captured the triangle waveform.***



20. Used the oscilloscope to ***measure and record*** the triangle-wave peak voltage. ***Calculated and recorded*** the RMS Effective Voltage using the RMS Voltage (triangle wave) formula.
21. ***Measured and recorded*** the voltage using the DMM. ***Compared and recorded*** the effective voltage and the DMM voltage values using the % Error formula.

V_P = 4.08V

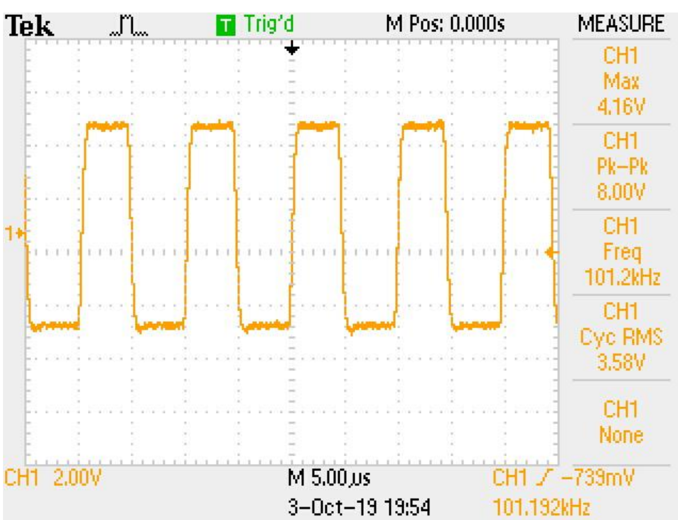
V_{RMS} = 2.884V

V_{RMS} = 0.949V

67.09%

Square Wave

22. Changed the function generator and oscilloscope to produce an $8V_{P\text{-}P}$ ***square wave*** at 100KHz.
23. Screen ***captured the waveform.***



24. Used the oscilloscope to ***measure and record*** the square wave peak voltage, the pulse duration and the cycle duration. ***Calculated and recorded*** the Duty Cycle using the Duty Cycle formula.

V_P = 4.24V

Pulse Duration = 4.603µS

Cycle Duration = 9.867µS

Duty Cycle = 46.65%

25. ***Calculated and recorded*** the average voltage of this signal using the Average Voltage (square wave) formula.

V_{AVG} = 1.98V

26. ***Measure and record*** the voltage using the DMM.

1.795V

27. ***Compare and record*** the average voltage and the DMM voltage values using the % Error formula.

9.34%

Formulas

Frequency

$$f = \frac{1}{p}$$

Where;
f = frequency (Hertz)
p = period (seconds)

RMS Effective Voltage (sine wave)

$$V_{RMS} = \frac{V_P}{\sqrt{2}}$$
$$V_{RMS} = V_P \times 0.707$$

Where;
V_{RMS} = effective voltage
V_P = peak voltage

Duty Cycle (square wave)

$$Duty\_Cycle = \frac{t_w}{T} \times 100\%$$

Where;
t_w = pulse duration (seconds)
T = cycle duration (seconds

Average Voltage (square wave)

$$V_{AVG} = V_P \times D$$

Where;
V_{AVG} = average voltage
V_P = peak voltage
D = duty cycle (pulse duration / cycle duration)

RMS Effective Voltage (triangle wave)

$$V_{RMS} = \frac{V_P}{\sqrt{3}}$$
$$V_{RMS} = V_P \times 0.577$$

Where;
V_{RMS} = effective voltage
V_P = peak voltage

RMS Effective Voltage (sawtooth wave)

$$V_{RMS} = \frac{V_P}{\sqrt{3}}$$
$$V_{RMS} = V_P \times 0.577$$

Where;
V_{RMS} = effective voltage
V_P = peak voltage

% Error/Change

$$\%Error = \frac{measured - \exp ected}{\exp ected} x100\%$$

Where;
%Error = % change between measured and expected values
measured = a value taken from direct measurement
expected = a value calculated from component or

process specifications

Critical Thinking

1. **DC Voltage Measurement** – Does the DMM and oscilloscope provide similar measurements when measuring DC voltages? Why?

The digital multimeter and oscilloscope used in this lab provide similar measurements when used for measuring direct current (DC) voltages. This is primarily due to the constant voltage nature of direct current voltages.

2. **AC Voltage & Frequency Measurement** – Does the DMM and oscilloscope provide similar measurements when measuring 60 Hz sine wave voltages? Why?

The digital multimeter and oscilloscope used in this lab *do not* provide similar measurements when used for measuring alternating current (AC) voltages. This is primarily due to the varying voltage nature of alternating current voltages, noise and sampling rates of the meter. Digital multimeters will measure an average voltage over time, will assume a clean sine wave, and may have a slower sampling rate than a multimeter. The Oscilloscope will take into account the actual characteristics of the line signal. The RMS voltage in both instruments is then calculated.

3. **Alternate Wave Forms** – Does the DMM and oscilloscope provide similar measurements when measuring increased frequency sine waves, triangle waves and square wave voltages? Why?

The digital multimeter and oscilloscope used in this lab *do not* provide similar measurements when used for measuring alternating current (AC) voltages of increased frequency sine waves, triangle waves and square wave voltages. As mentioned in the previous response, this is primarily due to the varying voltage nature of the AC current signal. The digital multimeter is calibrated to only accept a sine wave when calculating the average voltage. Oscilloscopes take into account the characteristics of the line signal whether triangle, square, etc. at varying frequencies. The accuracy of the oscilloscope is dependent on the sample rate of the meter and it's calibration to a known reference.

Conclusions

This lab was an introduction to the proper use of the oscilloscope, a number of methods to obtain measurements using the oscilloscope and a comparison to measurements that can be achieved through the digital multimeter and its limitations. Further, this lab introduced the calculation methods to aid in understanding A.C. currents and voltages.

WORKSHEET

AC VALUES

Solve the following conversion problems. Always include the unit of measurement, and the AC value, in your answer. For example: 10V p-p

unit of measurement — AC value

1.

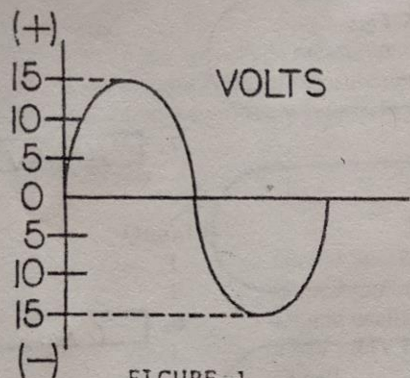


FIGURE 1

A. What is the peak to peak value of the sine wave in figure 1? — 1A. 30V p-p

B. What is the peak value of sine wave 1? — 1B. 15V pk

C. ~~Determine the average value of the sine wave.~~ — 1C.

D. Compute the effective value of the sine wave. — 1D. 10.61V RMS

....

2.

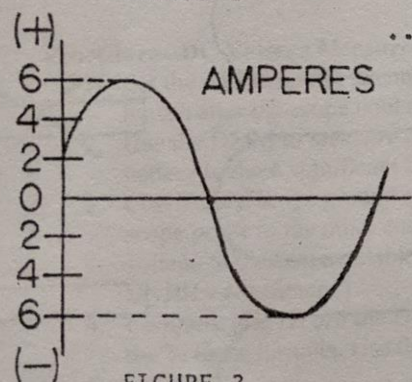


FIGURE 2

A. Determine the peak value of the sine wave in figure 2. — 2A. 6V pk

B. ~~What is the average value of the sine wave?~~ — 2B.

C. Find the peak to peak value of sine wave 2. — 2C. 12V p-p

D. Compute the RMS value of the wave. — 2D. 4.24V RMS

3. $V = 30V_{p-p}$--Convert to peak value. — 3. 15V pk

Show work $30V/2 = 15V$

4. $V = 40V_{PK}$--Find the peak to peak value. — 4. 80V p-p

Show work $40V \times 2 = 80V$ p-p

5. $I = 5A_{PK}$--Find the average value.

Show work

5.

6. $I = 33mA_{PK}$--Convert to effective value.

Show work 33mA x .707 = 23.3 mArms

6. 23.3mArms

7. $V = 117V_{RMS}$--Solve for peak value.

Show work $\frac{117V}{.707} = 165.5V$

7. 165.5V

8. $I = 6A_{EFF}$--Find the RMS value.

Show work 6AEFF = 6Arms

8. 6Arms

9. $V = 40mV_{p-p}$--Find the average value.

Show work

9.

10. $I = 10A_{p-p}$--Find the effective value.

Show work

10Ap-p = 5Ap =

10.

11. $V = 20V_{EFF}$--Convert to peak to peak value.

Show work $\frac{20V}{.707} = 28.3V_{PK} \times 2 = 56.6V_{p-p}$

11. 56.6Vp-p

12. $I = 7A_{EFF}$--Convert to average value.

Show work

12.

Appendix A – Lab Notes

SIERRA COLLEGE	MECH 10 - Lab 11 Oscilloscope	Mechatronics Real Skills Real Jobs
Name Cayce Beames		10/3/19

Learning Objectives

- Understand the basic setup for oscilloscope measurements
- Measure AC & DC voltage signals with oscilloscope and DMM
- Calculate RMS voltage from peak voltage
- Calculate duty cycle from pulse and cycle durations
- Calculate frequency from waveform period

Notes:

1. Take all voltage measurements relative to ground (unless otherwise directed)
2. Record relevant measurements and calculations results in data tables
3. Use 4 significant figures in your calculations

Materials

Quantity	Description
1	Global Specialties Circuit Trainer
1	Digital multimeter (DMM)
1	Digital oscilloscope
1	120V / 24V transformer
1	D-cell

Procedure –DC Voltage Measurement

1. Set the probes to 10x attenuation, press the "Default Setup" button after the scope boot routine is complete.
2. Use the DMM to ***measure and record*** the DC voltage of a battery to three significant figures. $\boxed{1.59V}$
3. Connect the scope ground clip to one end of the battery and the scope probe to the other end. ***Measure and record*** the DC voltage to the best available resolution (using the Volts per Division adjustment.) $\boxed{1.61V}$
4. ***Compare and record*** the DMM and scope measurements using the % Error formula. Use the DMM reading as the expected value.

$$\frac{1.61 - 1.59}{1.59} \times 100\% = \boxed{1.26\%}$$

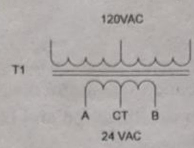
SDG 09/12

Page 1 of 4

Procedure –AC Voltage & Frequency Measurement

5. Use the oscilloscope to ***measure and record*** the peak voltage (V_p) between the transformer center tap and point A (connect the probe's ground lead to the center tap and the probe to point A.)

$V_p = \boxed{20V}$



$V_{RMS\ osc} = 14.2V$

6. ***Calculate and record*** the effective voltage value using the RMS Effective Voltage formula.
7. ***Measure and record*** the transformer voltage using a DMM set to AC Volts. ***Compare and record*** the DMM measurement to the calculated RMS value using the % Error formula, using the calculated value as the expected value.
8. Draw or screen ***capture the waveform*** on a scatter plot with time on the x-axis (horizontal) and voltage on the y-axis (vertical.) For screen capture use a 2GB max flash drive in the scope port and use the PRINT button to capture the screen to your drive.
9. ***Measure and record*** the period of the wave form. Use this value to calculate the signal frequency using the Frequency formula.
10. ***Measure and record*** the signal frequency using the DMM. ***Compare and record*** the DMM frequency measurement with the calculated frequency using the % Error formula.

Tek0001.jpg

$V_{RMS\ calc} = V_p \times .707$
$= 20 \times .707$
$= 14.14V$ ✓

$V_{RMS\ DMM} = 14.12V$

$Error = \frac{14.12 - 14.14}{14.14}$

$= 0.141\%$

Period $= 16.68ms$

$f = \frac{1}{16.68ms} = 59.95Hz$

Procedure – Dual Trace Mode

~~11.~~ Connect a second probe (set to 10x) to the second scope channel. Turn on the channel by pressing the blue button.

~~12.~~ Connect both probe grounds to the transformer center tap. Connect a probe to each transformer output.

~~13.~~ Draw or screen ***capture the dual trace waveforms*** showing the 180° phase relationship between them.

Tek0002.jpg

Procedure – Alternate Wave Forms

Sine Wave

14. Set up the circuit trainer function generator to produce ≈ $8V_{P-P}$ ***sine wave*** at 100KHz. Use the oscilloscope to set the waveform amplitude and frequency.
15. Use the scope to ***measure and record*** V_P and frequency.
16. Use the scope measured V_P value to ***calculate and record*** V_{RMS} using the RMS Effective Voltage (sine wave) formula.
17. ***Measure and record*** the RMS effective voltage using the DMM. ***Compare and record*** the scope and the DMM values using the % Error formula.

Function generator - use the second pin out from the right.

$V_p = V_{max} = 4.00V$

$f = 101.2kHz$

$V_{RMS} = V_p \times .707$

$V_{RMS} = 4 \times .707$

$V_{RMS} = 2.828$ ✓

$V_{RMS\ DMM} = 1.213V$

$Error = \frac{1.213 - 2.828}{2.828} \times 100$

~~Tek0003.jpg~~

Triangle Wave

18. Change the function generator and oscilloscope to produce an $8V_{P-P}$ ***triangle wave*** at 100KHz.
19. Draw or screen ***capture the triangle waveform.***

Tek0007.jpg

SDG 09/12

Page 2 of 4

$Error = 57.11\%$

20. Use the oscilloscope to ***measure and record*** the triangle-wave peak voltage. ***Calculate and record*** the RMS Effective Voltage using the RMS Voltage (triangle wave) formula.
21. ***Measure and record*** the voltage using the DMM. ***Compare and record*** the average voltage and the DMM voltage values using the % Error formula.

$V_p = 4.08v$
$V_{RMS} = 4.08 \times .707$
$= 2.884V$

$V_{DMM} = .949$
$Error = \frac{.949 - 2.884}{2.884}$
$= 67.09\%$

Square Wave

22. Change the function generator and oscilloscope to produce an $8V_{P\text{-}P}$ ***square wave*** at 100KHz.
23. Draw or screen ***capture the waveform.*** Tek0000.jpg
24. Use the oscilloscope to ***measure and record*** the square wave peak voltage, the pulse duration and the cycle duration. ***Calculate and record*** the Duty Cycle using the Duty Cycle formula.
25. ***Calculate and record*** the average voltage of this signal using the Average Voltage (square wave) formula.
26. ***Measure and record*** the voltage using the DMM. ***Compare and record*** the average voltage and the DMM voltage values using the % Error formula.

$V_p = 4.24V$
Pulse Duration $= 4.603\mu s$
Cycle Duration $= 9.867\mu s$
Duty Cycle $= \frac{4.603\mu}{9.867\mu} \times 100$
$= 46.65\%$

$V_{AVG} = 4.24 \times 46.65\%$
$= 4.24 \times .4665$
$= 1.98V$

$V_{DMM} = 1.795V$
$Error = \frac{1.795 - 1.98}{1.98} \times 100$
$E = 9.34\%$

Formulas

Frequency

$$f = \frac{1}{p}$$

Where;
f = frequency (Hertz)
p = period (seconds)

RMS Effective Voltage (sine wave)

$$V_{RMS} = \frac{V_P}{\sqrt{2}}$$
$$V_{RMS} = V_P \times 0.707$$

Where;
V_{RMS} = effective voltage
V_P = peak voltage

Duty Cycle (square wave)

$$Duty\_Cycle = \frac{t_w}{T} \times 100\%$$

Where;
t_w = pulse duration (seconds)
T = cycle duration (seconds

Average Voltage (square wave)

$$V_{AVG} = V_P \times D$$

Where;
V_{AVG} = average voltage
V_P = peak voltage
D = duty cycle (pulse duration / cycle duration)

RMS Effective Voltage (square wave)

$$V_{RMS} = V_P$$

Where;
V_{RMS} = effective voltage
V_P = peak voltage

RMS Effective Voltage (triangle wave)

$$V_{RMS} = \frac{V_P}{\sqrt{3}}$$
$$V_{RMS} = V_P \times 0.577$$

Where;
V_{RMS} = effective voltage
V_P = peak voltage

Grading Criteria

		Points Possible	Points Earned
Documentation	Abstract, introduction, experiment, data results, conclusions, attachments, clarity, spelling, grammar	**10**	
DC Voltage	DMM & Scope readings recorded, values compared	**5**	
AC Voltage & Frequency	DMM & Scope readings recorded, values compared,	**5**	
	Waveform scatter plot drawn (or captured) & accurate	**5**	
Dual Trace	Waveform scatter plot drawn (or captured) & accurate with phase shift labeled	**5**	
Alternate Waveforms	DMM & Scope readings recorded, values compared, waveforms drawn or captured	**5**	
Critical Thinking	Questions answered completely & accurately. State conclusions drawn and lessons learned from the lab	**10**	
On-time submittal	Lab report is submitted in accordance with the assignment due date as posted on Canvas	**5**	
	Total	**50**	

Lab Report Format

Abstract - a summary and high-level overview of the lab and its results
Introduction - State the objectives of the laboratory and list the equipment required
Experiment - Describe the procedure used to carry out the lab
Results Data - list data taken in table or graphical format where appropriate
Critical Thinking - State the conclusions drawn and lessons learned from the laboratory activities. Answer any questions found within the lab procedure.
Attachments – grading criteria, verification signatures, circuit diagrams, lab procedures & notes