Name: Cayce Beames
Date: November 17, 2019
Professor Steven Gillette

Abstract
In this lab, I leveraged an Alternating Current (AC) source, 1N4002 diode, a capacitor, and two different resistors to experiment with and create half and full wave AC rectification circuits to approximate a clean Direct Current (DC) signal. Further, I researched

Learning Objectives

- Build and test a half-wave rectifier
- Build and test a full-wave rectifier
- Visualize and analyze rectifier waveforms
- Test a filter capacitor's impact on rectifier waveform and RMS voltage

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
5. ***Measured and captured peak-to-peak voltages using scope channel 1 configured for AC coupling.***
6. ***Measured mean and RMS voltages using scope channel 2 configured for DC coupling.***

Materials

Quantity	**Description**
1	120/24V center tapped transformer
2	1N4002 diode, D_1 Measured: V_F = 646mV, C = 9pF D_2 Measured: V_F = 667mV, C = 22pF
1	1.5K resistor, measured 1.507kΩ
1	5K resistor, measured 5.060kΩ
1	1000µF capacitor, measured 946.7µF
1	DMM
1	DO Scope
1	Proto-board

Setup

1. Checked the capacitor label to verify that the voltage rating is 25 V or more. Identified the polarity of the capacitor leads. Entered the capacitor label value into the spreadsheet cell labeled ***Filter Capacitor Value***.

   C_1 measured 946.7µF

2. Verified diode function; used the DMM diode check feature and ***measured and recorded*** the forward bias voltages for each diode.

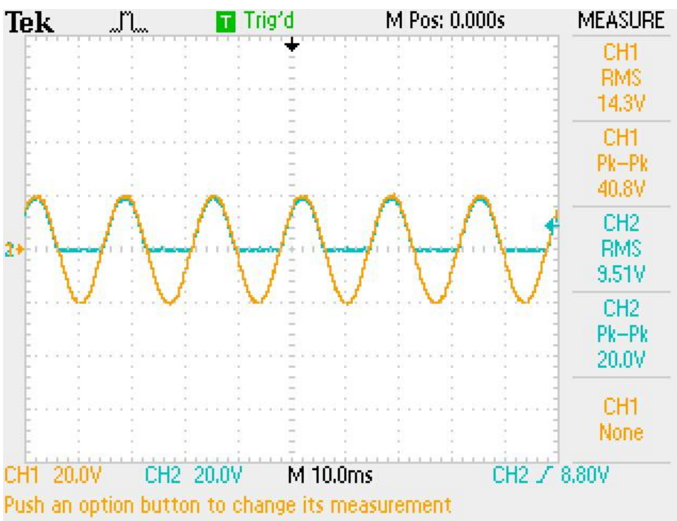
D_1 Measured: V_F = 551mV
D_2 Measured: V_F = 591mV

3. ***Measured and recorded*** the load resistor values. Entered these values into the lab spreadsheet cells labeled ***Load Resistance***.

R_1 - 1.5K resistor, measured 1.507kΩ
R_2 - 5K resistor, measured 5.060kΩ

Procedure – Circuit 1, Half-Wave Unfiltered Rectifier

4. ***Built Circuit 1***, a half-wave rectifier.
5. ***Captured and recorded*** the waveform taken at ***test point A and B*** on the circuit diagram. ***Measured and recorded*** voltage data including;
   a. Channel 1 - RMS voltage (V_{RMS}), Peak-to-Peak voltage (V_{P-P})
   b. Channel 2 – RMS voltage (V_{RMS}), Peak-to-Peak voltage (V_{P-P})

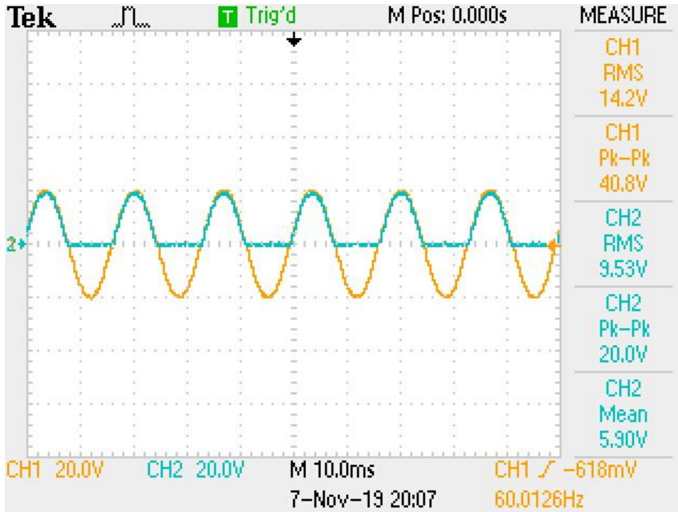


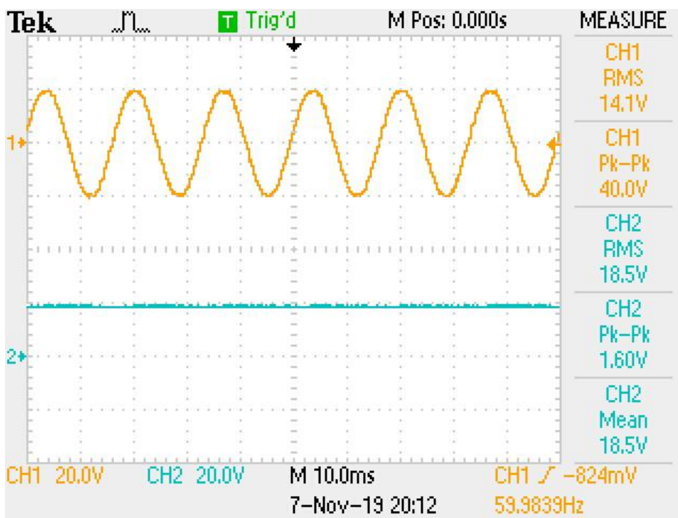
6. ***Entered the voltage data into the lab spreadsheet for Circuit 1.***

Circuit 1 - Half Wave Unfiltered		
Load Resistance	1.51E+03 Ω	
	Vrms	Vp-p
Test Point A	14.2	40.0
Test Point B	9.5	20.8
Total Current (Amps)	6.3E-03	
Total Power (Watts)	60.0E-03	

Procedure – Circuit 2, Half-Wave Filtered Rectifier

7. Added a 1000µF filter capacitor to Circuit 1 to create ***Circuit 2***.
8. ***Captured and recorded*** the waveform taken at ***test point B*** on the circuit diagram. ***Measured and recorded*** voltage data including;
    a. Channel 2 – Mean voltage (V_{MEAN} 18.5 DC Coupled), Peak-to-Peak voltage (V_{P-P} 352mV AC Coupled)





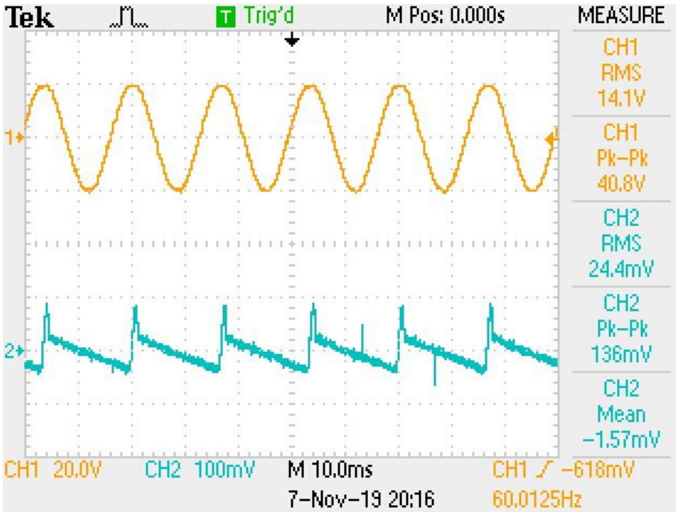
9. ***Entered the voltage data into the lab spreadsheet for Circuit 2.***

Circuit 2 - Half Wave Filtered				
Load Resistance	1.51E+03 Ω			
	Vmean	Vp-p(meas)	Vp-p(exp)	Vp-p(error)
Test Point B	18.5	352.0E-03	216.1E-03	62.9%
Total Current (Amps)	12.3E-03			
Total Power (Watts)	227.1E-03			

10. Changed the load resistor to 5k Ω.

11. ***Captured and recorded*** the waveform taken at ***test point B*** on the circuit diagram. ***Measured and recorded*** voltage data including;

    a. Channel 2 – Mean voltage (V_{MEAN} 19.1V DC Coupled), Peak-to-Peak voltage (V_{P-P} 136mV AC Coupled)



12. ***Entered the voltage data into the lab spreadsheet for Circuit 2.***

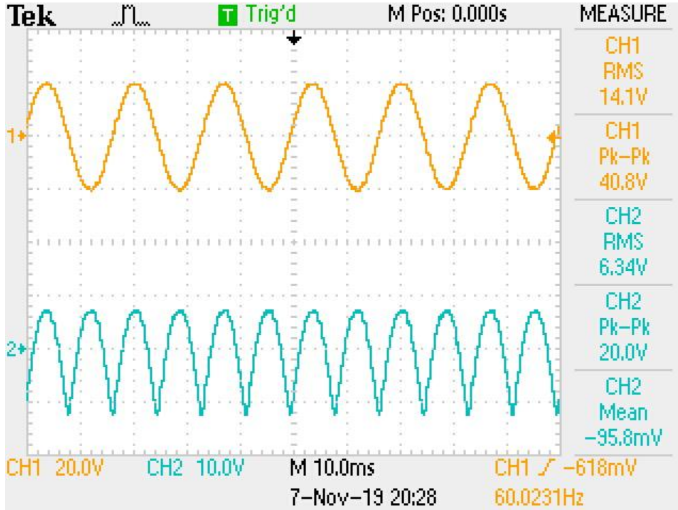
Circuit 2 - Half Wave Filtered					
	5.06E+03 Ω				Filtered v Unfiltered V_{RMS} Increase
	Vmean	Vp-p(meas)	Vp-p(exp)	Vp-p(error)	
	19.1	136.0E-03	66.5E-03	104.7%	94.5%
Total Current (Amps)	3.8E-03				
Total Power (Watts)	72.1E-03				

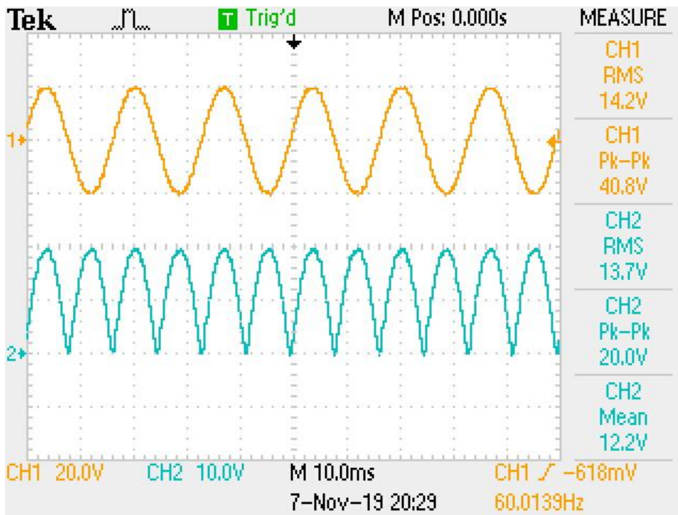
Procedure – Circuit 3, Full Wave Unfiltered Rectifier

13. Built ***Circuit 3***, a full-wave rectifier. Used the 1.5KΩ resistor.

14. ***Captured and recorded*** the waveform taken at ***test point B*** on the circuit diagram. ***Measure and record*** voltage data including;

    a. Channel 2 – RMS voltage ($V_{RMS\ 13.7V}$ DC Coupled), Peak-to-Peak voltage (V_{P-P} 20V AC Coupled)





15. ***Entered the voltage data into the lab spreadsheet for Circuit 3.*** Noted the increase in full wave RMS voltage as compared to half-wave RMS voltage.

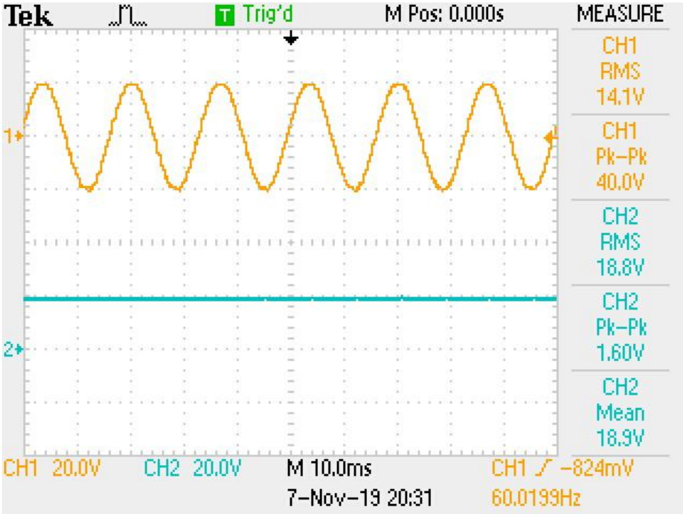
Circuit 3 - Full Wave Unfiltered				
Load Resistance	1.51E+03 Ω			
	Vmean	Vp-p(meas)	Vp-p(exp)	Vp-p(error)
Test Point B	18.9	208.0E-03	110.4E-03	88.4%
Total Current (Amps)	12.5E-03			
Total Power (Watts)	237.0E-03			

Procedure – Circuit 4, Full Wave Filtered Rectifier

16. Added a 1000µF filter capacitor to Circuit 3 to create ***Circuit 4***.

17. ***Captured and recorded*** the waveform taken at ***test point B*** on the circuit diagram. ***Measured and recorded*** voltage data including;

a. Channel 2 – Mean voltage (V_{MEAN} 18.9V DC Coupled), Peak-to-Peak voltage ($V_{P\text{-}P}$ 208mV AC Coupled)



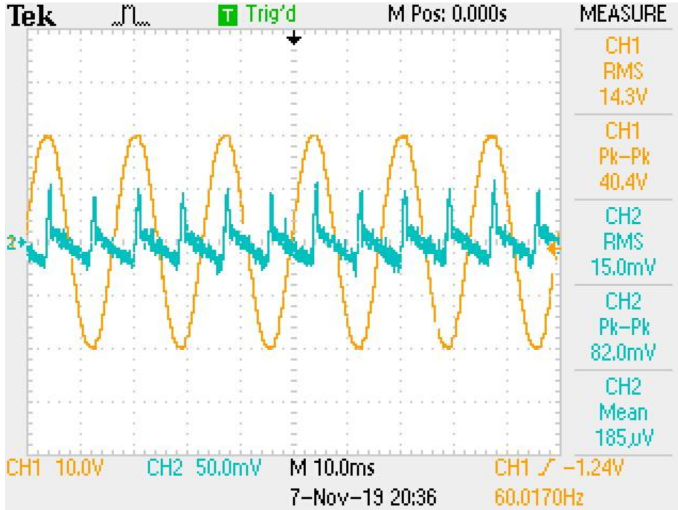
18. ***Entered the voltage data into the lab spreadsheet for Circuit 4.***

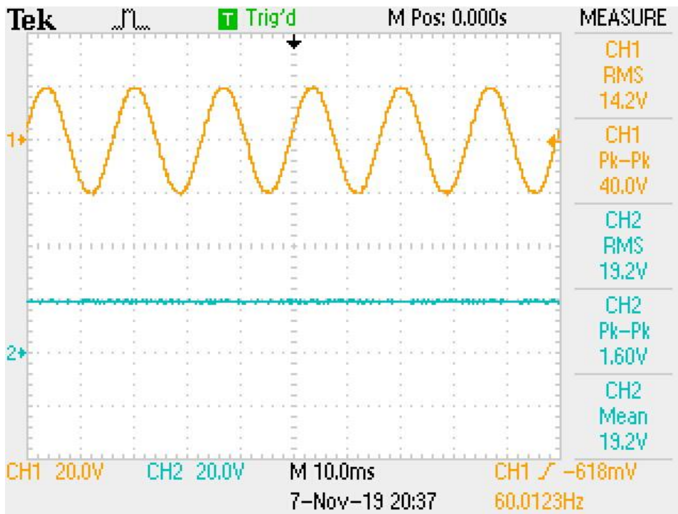
Circuit 4 - Full Wave Filtered					
	5.06E+03 Ω				Filtered v Unfiltered
	Vmean	Vp-p(meas)	Vp-p(exp)	Vp-p(error)	V_{RMS} Increase
	19.2	82.0E-03	33.4E-03	145.5%	38.0%
Total Current (Amps)	3.8E-03				
Total Power (Watts)	72.9E-03				

19. Changed the load resistor to 5k Ω.

20. ***Captured and recorded*** the waveform taken at ***test point B*** on the circuit diagram. ***Measured and recorded*** voltage data including;

a. Channel 2 – Mean voltage (V_{MEAN} 19.2V DC Coupled), Peak-to-Peak voltage ($V_{P\text{-}P}$ 82mV AC Coupled)





21. ***Enter the voltage data into the lab spreadsheet for Circuit 4.***
22. Calculate expected ripple voltage for Circuit 2 using data already collected. Compare expected with measured (from scope readings) using the error formula.

Vp-p(meas)	Vp-p(exp)	Vp-p(error)
136.0E-03	66.5E-03	104.7%

23. Calculate expected ripple voltage for Circuit 4 using data already collected. Compare expected with measured (from scope readings) using the error formula.

Vp-p(meas)	Vp-p(exp)	Vp-p(error)
82.0E-03	33.4E-03	145.5%

Results Data

Inserted spreadsheet data

Circuit 1 - Half Wave Unfiltered		
Load Resistance	1.51E+03 Ω	
	Vrms	Vp-p
Test Point A	14.3	40.8
Test Point B	9.5	20.0
Total Current (Amps)	6.3E-03	
Total Power (Watts)	60.0E-03	

Circuit 3 - Full Wave Unfiltered		
Load Resistance	1.51E+03 Ω	
	Vrms	Vp-p
Test Point B	13.7	20.000
Total Current (Amps)	9.1E-03	
Total Power (Watts)	124.5E-03	
Full v Half Wave V_{RMS}	44.1%	

Circuit 2 - Half Wave Filtered				
Load Resistance	1.51E+03 Ω			
	Vmean	Vp-p(meas)	Vp-p(exp)	Vp-p(error)
Test Point B	18.5	352.0E-03	216.1E-03	62.9%
Total Current (Amps)	12.3E-03			
Total Power (Watts)	227.1E-03			

Circuit 2 - Half Wave Filtered					
Load Resistance	5.06E+03 Ω				Filtered v Unfiltered V_{RMS}
	Vmean	Vp-p(meas)	Vp-p(exp)	Vp-p(error)	
Test Point B	19.1	136.0E-03	66.5E-03	104.7%	94.5%
Total Current (Amps)	3.8E-03				
Total Power (Watts)	72.1E-03				

Circuit 3 - Full Wave Unfiltered				
Load Resistance	1.51E+03 Ω			
	Vmean	Vp-p(meas)	Vp-p(exp)	Vp-p(error)
Test Point B	18.9	208.0E-03	110.4E-03	88.4%
Total Current (Amps)	12.5E-03			
Total Power (Watts)	237.0E-03			
Full v Half Wave Ripple		-40.9%		
Filter Capacitor Value	946.70E-06 F			

Circuit 4 - Full Wave Filtered					
Load Resistance	5.06E+03 Ω				Filtered v Unfiltered V_{RMS}
	Vmean	Vp-p(meas)	Vp-p(exp)	Vp-p(error)	
Test Point B	19.2	82.0E-03	33.4E-03	145.5%	38.0%
Total Current (Amps)	3.8E-03				
Total Power (Watts)	72.9E-03				
Full v Half Wave Ripple		-39.7%			

Formulas

Frequency

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

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

Half-wave Ripple Voltage (expected)

$$V_{p-p} = \frac{I}{f \times C}$$

Where;
$V_{p\text{-}p}$ = Ripple peak to peak voltage
I = current (Amperes)
C = capacitance (Farads)
f = AC supply frequency

Full-wave Ripple Voltage (expected)

$$V_{p-p} = \frac{I}{2f \times C}$$

Where;
Vp-p = Ripple peak to peak voltage
I = current (Amperes)
C = capacitance (Farads)
f = AC supply frequency

RMS Voltage

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

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

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

Where;
%Error = the percent difference between measured and expected values
measured = a value taken from direct measurement
expected = a value taken from component or process specifications

Critical Thinking

1. Which rectifier circuit produces the lowest effective output voltage? Why?

Circuit 1 produces the lowest effective voltage. This is because, the half wave unfiltered wave has a significant area of non-peak voltage and significant areas of no voltage. It approximates slightly less than (due to the rounded rising and falling edge) a 50% duty cycle pulse width modulation signal.

2. How does the filter capacitor affect RMS voltage in full-wave and half-wave rectifier circuits?

The filter capacitor helps to retain the voltage during the falling (voltage decreasing) portion of the AC circuit period thereby keeping the average (RMS) voltage higher than it would be without the filtering capacitor.

3. When comparing unfiltered and filtered rectifiers, by what percentage did effective voltage increase for the filtered rectifiers?

In Circuit 2, the effective voltage of the filtered circuit increased by 94.5% versus the unfiltered circuit. In Circuit 4, the effective voltage of the filtered circuit increased by 38% versus the unfiltered circuit.

4. Which rectifier circuit provided the best overall performance when judged by low ripple voltage and high power output?

The full-wave and filtered circuit 4 provided best performance in terms of lower ripple voltage and lower current draw which results in less power consumption.

5. What did you learn from this lab?

In this lab, I learned about the behavior, effect, and benefit of using diodes and capacitors on alternating current signals to inexpensively create a DC voltage. This also helps to understand which components might be at fault when troubleshooting power supplies if an analyzed signal shows unexpected output.

Appendix A – Lab Notes

SIERRA COLLEGE	MECH 10 - Lab 18 Rectifiers	Mechatronics *Real Skills Real Jobs*

Name

Learning Objectives

- Build and test a half-wave rectifier
- Build and test a full-wave rectifier
- Visualize and analyze rectifier waveforms
- Test a filter capacitor's impact on rectifier waveform and RMS voltage

Notes:

1. Take all voltage measurements relative to ground (unless otherwise stated)
2. Record relevant measurements and calculation results in data tables
3. Record all measured values on the circuit schematics
4. Use all available precision in calculations, round off answers to 3 significant figures
5. ***Measure and capture peak-to-peak voltages using scope channel AC coupling.***
6. ***Measure mean and RMS voltages using scope channel DC coupling.***

Materials

Quantity	Description	
1	120/24V center tapped transformer	
2	1N4002 diode	$V_F = 646mV$ $V_F = .551V$ $C = 9pF$, $V_F = 667mV$ $V_F = .592V$, $C = 22pF$
1	1.5K resistor	1507Ω
1	5K resistor	5060Ω
1	1000μF capacitor	946.7μF
1	DMM	
1	DO Scope	
1	Proto-board	

Setup

1. Check the capacitor label to verify that the voltage rating is 25 V or more. Identify the polarity of the capacitor leads. Enter the capacitor label value into the spreadsheet cell labeled ***Filter Capacitor Value***.
2. Verify diode function; use the DMM diode check feature to ***measure and record*** the forward bias voltages for each diode. $V_F = .551V$ $V_F = .591V$
3. ***Measure and record*** the load resistor values. Enter these values into the lab spreadsheet cells labeled ***Load Resistance***.

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Procedure – Circuit 1, Half-Wave Unfiltered Rectifier

4. ***Build Circuit 1***, a half-wave rectifier.
5. ***Capture and record*** the waveform taken at ***test point A and B*** on the circuit diagram. ***Measure and record*** voltage data including;
   a. Channel 1 - RMS voltage (V_{RMS}) 14.2v, Peak-to-Peak voltage (V_{P-P}) 40v
   b. Channel 2 – RMS voltage (V_{RMS}) 9.51v, Peak-to-Peak voltage (V_{P-P}) 20.8v
6. ***Enter the voltage data into the lab spreadsheet for Circuit 1.***

Procedure – Circuit 2, Half-Wave Filtered Rectifier

14+
7. Add a 1000µF filter capacitor to Circuit 1 to create ***Circuit 2.***

15
8. ***Capture and record*** the waveform taken at ***test point B*** on the circuit diagram. ***Measure and record*** voltage data including;
   a. Channel 2 – Mean voltage (V_{MEAN}) 18.5v Dc couple, Peak-to-Peak voltage (V_{P-P}) 352mV Ac coupling
9. ***Enter the voltage data into the lab spreadsheet for Circuit 2.***
10. Change the load resistor to 5k Ω.
11. ***Capture and record*** the waveform taken at ***test point B*** on the circuit diagram. ***Measure and record*** voltage data including;
    a. Channel 2 – Mean voltage (V_{MEAN}) 19.1V Dc couple, Peak-to-Peak voltage (V_{P-P}) 136mV
12. ***Enter the voltage data into the lab spreadsheet for Circuit 2.***

Procedure – Circuit 3, Full Wave Unfiltered Rectifier

13. Build ***Circuit 3***, a full-wave rectifier. Be sure to use the 1.5KΩ resistor.
14. ***Capture and record*** the waveform taken at ***test point B*** on the circuit diagram. ***Measure and record*** voltage data including;
    a. Channel 2 – RMS voltage (V_{RMS}) 13.7v Pic 20, Peak-to-Peak voltage (V_{P-P}) 20v Pic 19
15. ***Enter the voltage data into the lab spreadsheet for Circuit 3.*** Note the increase in full wave RMS voltage as compared to half-wave RMS voltage.

Procedure – Circuit 4, Full Wave Filtered Rectifier

16. Add a 1000μF filter capacitor to Circuit 3 to create ***Circuit 4***.
17. ***Capture and record*** the waveform taken at ***test point B*** on the circuit diagram. ***Measure and record*** voltage data including;
    18.9V Pic 21 208mV
    a. Channel 2 – Mean voltage (V_{MEAN}), Peak-to-Peak voltage (V_{P-P})
18. ***Enter the voltage data into the lab spreadsheet for Circuit 4.***
19. Change the load resistor to 5k Ω.
20. ***Capture and record*** the waveform taken at ***test point B*** on the circuit diagram. ***Measure and record*** voltage data including;
    19.2V Pic 25 82mV Pic 24
    a. Channel 2 – Mean voltage (V_{MEAN}), Peak-to-Peak voltage (V_{P-P})
21. ***Enter the voltage data into the lab spreadsheet for Circuit 4.***
22. Calculate expected ripple voltage for Circuit 2 using data already collected. Compare expected with measured (from scope readings) using the error formula. See H+I row 4
23. Calculate expected ripple voltage for Circuit 4 using data already collected. Compare expected with measured (from scope readings) using the error formula. See H+F Row 12

Results Data

Insert spreadsheet data

Formulas

Frequency

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

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

Half-wave Ripple Voltage (expected)

$$V_{p-p} = \frac{I}{f \times C}$$

Where;
V_{p-p} = Ripple peak to peak voltage
I = current (Amperes)
C = capacitance (Farads)
f = AC supply frequency

Full-wave Ripple Voltage (expected)

$$V_{p-p} = \frac{I}{2f \times C}$$

Where;
Vp-p = Ripple peak to peak voltage
I = current (Amperes)
C = capacitance (Farads)
f = AC supply frequency

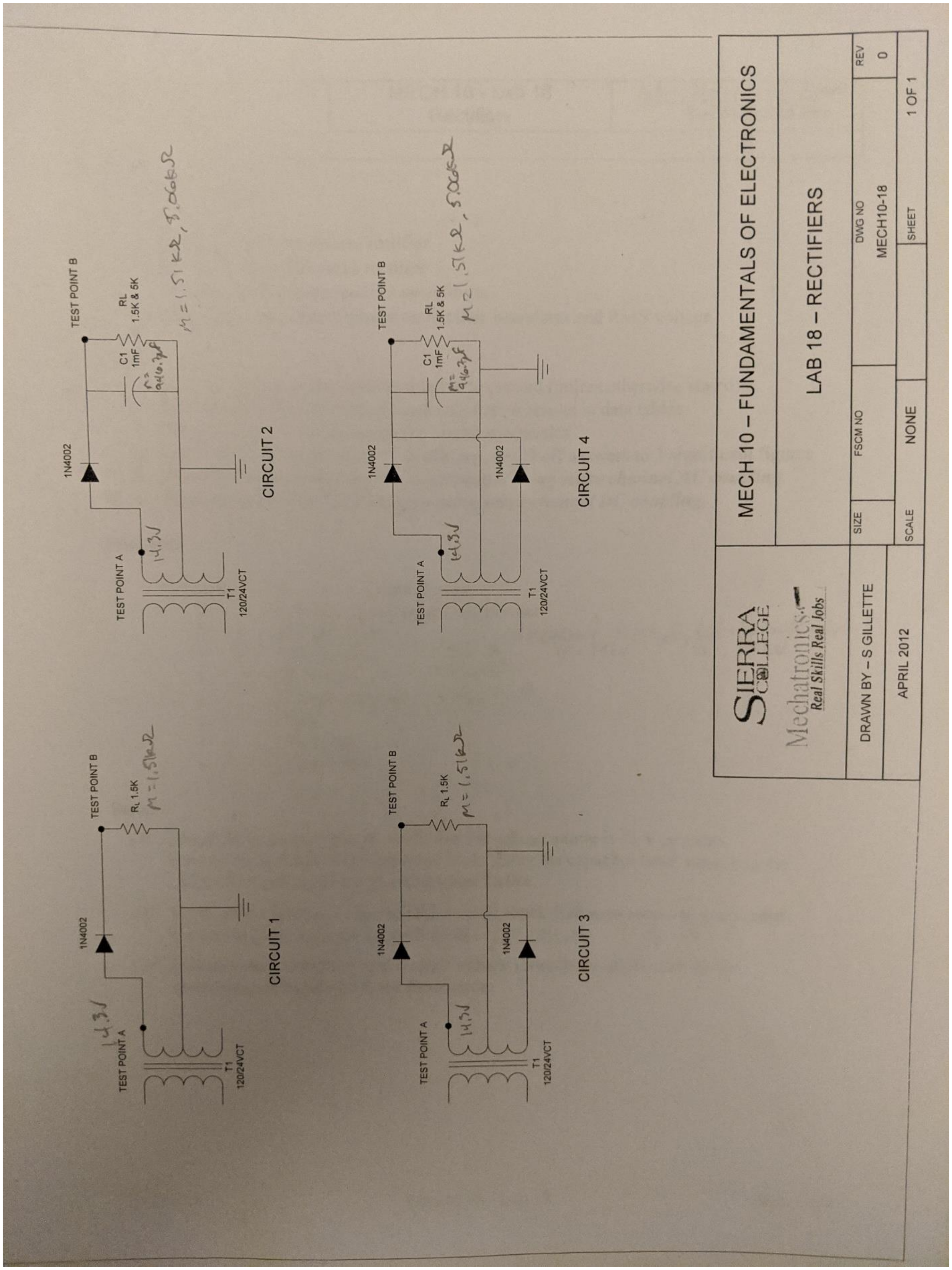
RMS Voltage

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

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

$$\%Error = \frac{measured - expected}{expected} x100\%$$

Where;
%Error = the percent difference between measured and expected values
measured = a value taken from direct measurement
expected = a value taken from component or process specifications


MECH 10 – FUNDAMENTALS OF ELECTRONICS
LAB 18 – RECTIFIERS
SIERRA COLLEGE
Mechatronics
Real Skills Real Jobs
DRAWN BY – S GILLETTE
APRIL 2012
SIZE
FSCM NO
DWG NO
MECH10-18
REV
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SCALE
NONE
SHEET
1 OF 1
CIRCUIT 1
CIRCUIT 2
CIRCUIT 3
CIRCUIT 4
TEST POINT A
TEST POINT B
1N4002
T1
120/24VCT
RL 1.5K
RL 1.5K & 5K
C1 1mF
14.3V

Grading Criteria

		Points Possible	Points Earned
Documentation	Abstract, introduction, experiment, data results, conclusions, attachments, clarity, spelling, grammar	**10**	
Setup	Diode and capacitor test results recorded	**5**	
Half-wave Rectifier	Test point A & B waveforms captured with V_{RMS} & V_P annotations, values recorded	**5**	
Half-wave Rectifier, Filtered	Test point B values recorded for 1.5k & 5k Ω resistors, ripple waveforms captured	**5**	
Full-wave Rectifier	Test point B waveforms captured with V_{RMS} & V_P annotations, values recorded	**5**	
Full-wave Rectifier, Filtered	Test point B values recorded for 1.5k & 5k Ω resistors, ripple waveforms captured	**5**	
Ripple Voltage Calc	Circuit current & ripple voltage measured and compared to expected	**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	**55**	

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
Data Results - 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, ***spreadsheet data***, lab procedures & notes