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Electrical Circuits Testing and Application

Electrical Control Systems ACHA4010

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1 Task 1

1.1 A

$$\frac{12}{4} = 3V$$

$$\frac{3}{0.5} = 6\Omega$$

1.2 B

$$0.5 - 0.3 = 0.2$$

$$\frac{0.2}{2} = 0.1 \text{ A}$$

1.3 c (i)

$$V = I \times R, \quad V = \frac{P}{I}$$

$$I \times R = \frac{P}{I}, \quad R = \frac{P}{I^2}$$

$$R(A) = \frac{0.9}{0.3^2} = 10\Omega$$

1.4 c (ii)

$$R(A) = 3R(B) = 3R(C)$$

$$\frac{10}{3} = 3.33\Omega$$

1.5 c (iii)

$$\left(\frac{1}{3.33} + \frac{1}{3.33} + \frac{1}{10} \right)^{-1} = R_T = 1.427 \dots \Omega$$

$$1.427 \dots \times 0.5 = 0.714 \text{ V (3sf)}$$

1.6 c (iv)

$$5 - (0.714 + 3) = 1.286 \text{ V}$$

$$\frac{1.286}{0.5} = 2.572\Omega$$

1.7 d

$$R = \frac{V}{I}, \quad r = \frac{2}{0.5} = 4\Omega$$

$$R_t = \frac{1}{\left(\frac{1}{4} + \frac{1}{4} + \frac{1}{4} \right)} = 1.333\Omega$$

1.8 e

$$V = IR, V = 0.5 \times 6 = 3V$$

1.9 f

$$1.427 + 2.572 + 6 + 6 + 1.333 = 17.332\Omega$$

1.10 g

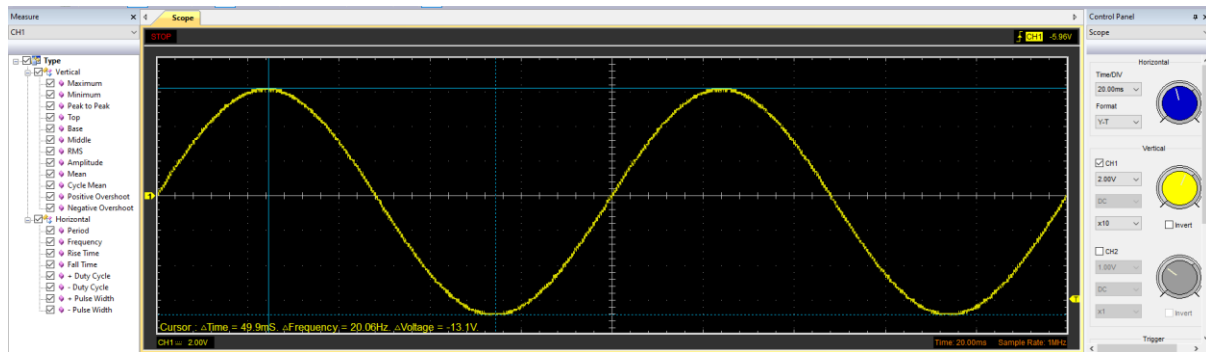
$$\text{emf} = 17.332 \times 0.5 = \mathbf{8.666 \text{ V}}$$

2 Task 2

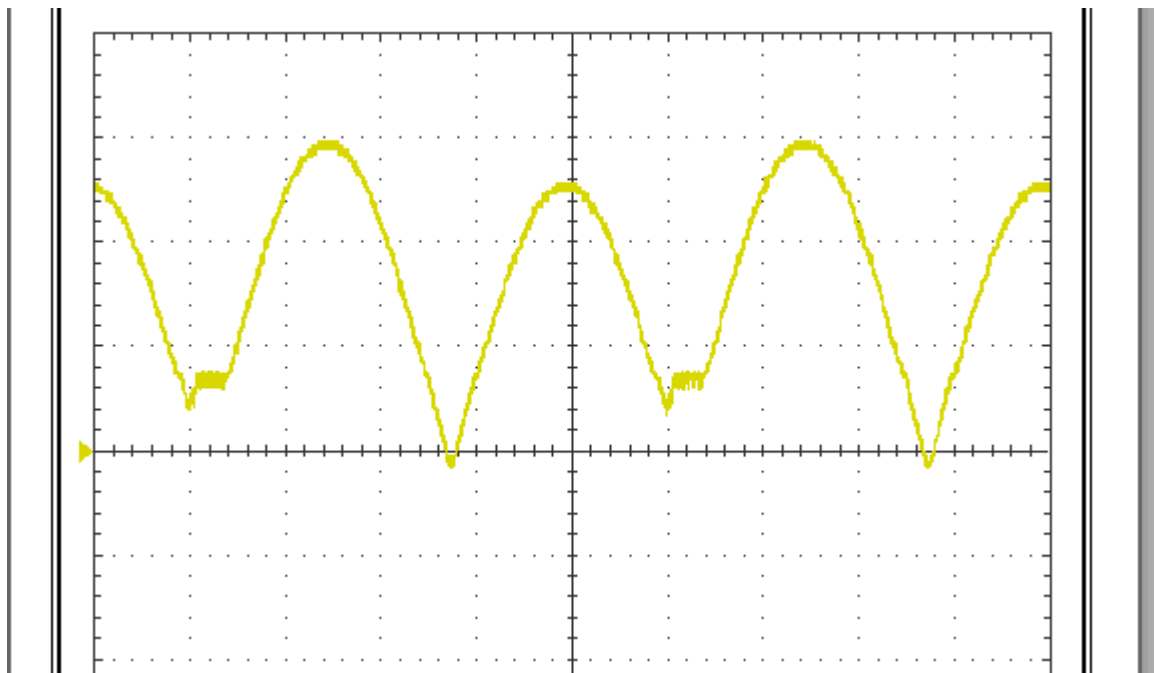
2.1 Scope Time Division Calculations

$$period = \frac{1}{f} = \frac{1}{10} = 0.1s$$

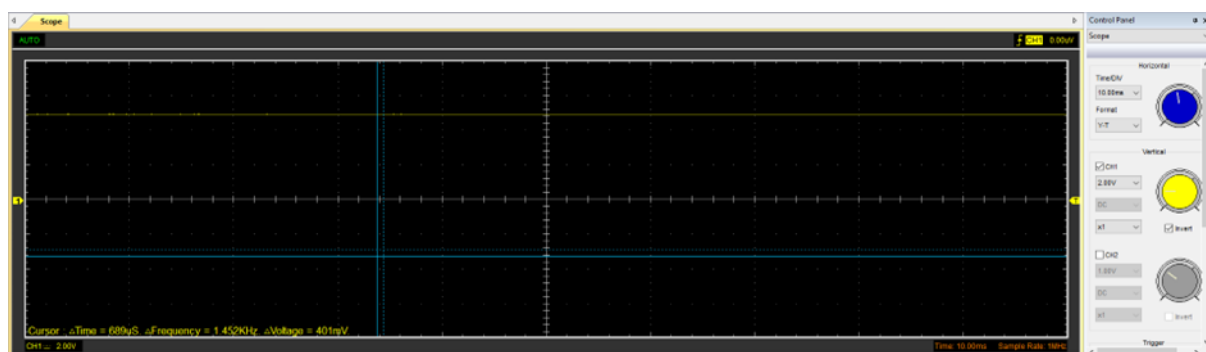
2.2 Function Generator output sine wave



2.3 Unsmoothed Rectifier Wave



2.4 Smoothed Rectifier Wave



2.5 Drop in Voltage Question

There is a difference in peaks of the rectifier DC output, and the sine wave input. The sine wave has a higher peak voltage than the rectifier output. This is because some of the voltage is lost as it passes through the circuit. This is because of resistance within the circuit. There is a resistor within the circuit that is partially responsible for this loss in voltage. The other components and the circuit itself will have a resistance lowering the input voltage. Making the rectifier circuit have a lower peak value.

2.6 Rectifiers use in Automotive applications Question.

“...alternator connected to a rectifier...” (1990, F. Piriou, A. Razek). Rectifier circuits convert alternating current into direct current, this is for systems where opposing flowing current would damage the system. An alternator system requires a rectifier circuit as the current generated is used to charge the battery. The circuit requires a rectifier as the battery would supply a current in the opposing direction creating AC and draining the battery. The rectifier redirects this current back to the battery. If this current found its way to the alternator, then a resistant force would be applied to the alternator. This would lower the current flowing to the battery, lowering the charge held by the battery.

2.7 Probing Question

When the signal from the function generator is introduced to the circuit the current travels through the circuit and returns to the generator. This alters the wave shape and amplitude. This is when the rectifier can be probed to check the wave form. The function generator is checked before it is introduced to the circuit so the changes between waves can be analysed. When the function generator is introduced to the circuit the current passes through the circuit itself, the circuit and generator cannot be probed both at once. This is because the wave has been altered and therefore only the signal from the circuit would be shown.

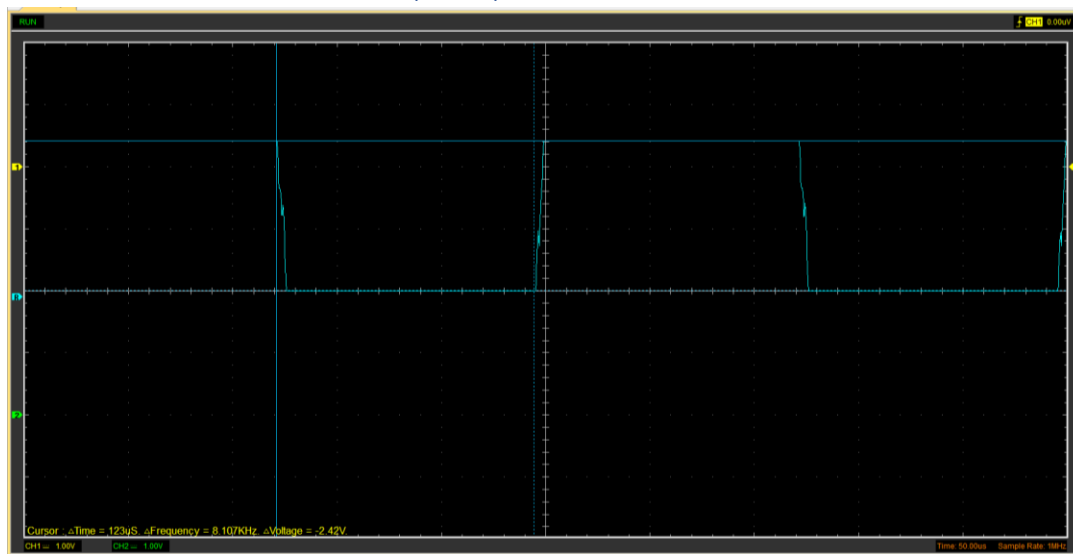
3 Task 3

3.1 Scope Time Division Calculations

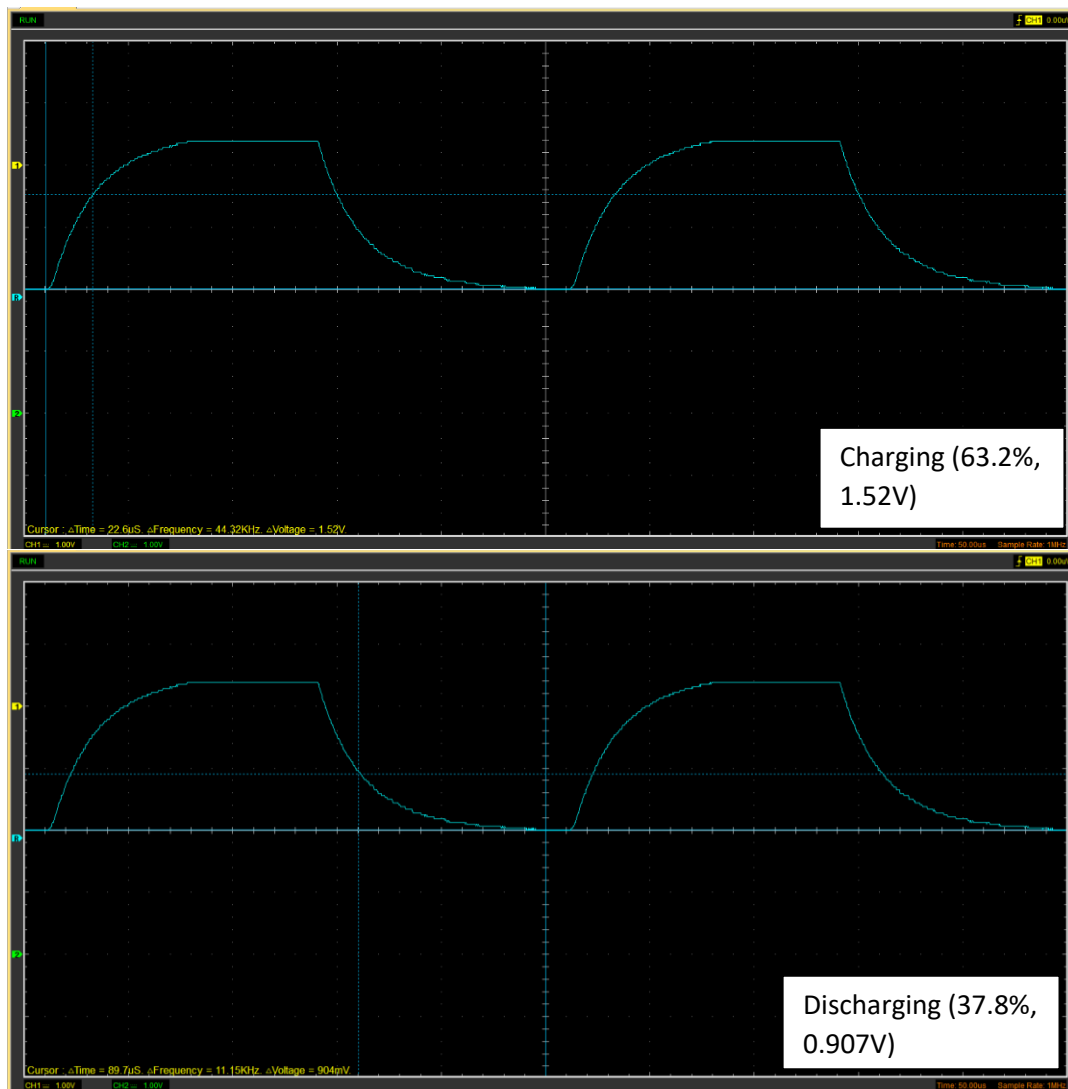
$$Period = \frac{1}{Frequency}, Period = \frac{1}{1.002 \times 10^3} = 9.98 \times 10^{-4} s = \mathbf{998\mu s}$$

$$0.22\mu F = 0.22 \times 10^{-6} F, T = R \times C, R = \frac{T}{C}, R = \frac{9.98 \times 10^{-4}}{0.22 \times 10^{-6}} = \mathbf{4536\Omega}$$

3.2 Function Generator output square wave



3.3 Capacitor charge and discharge wave marked at correct points.



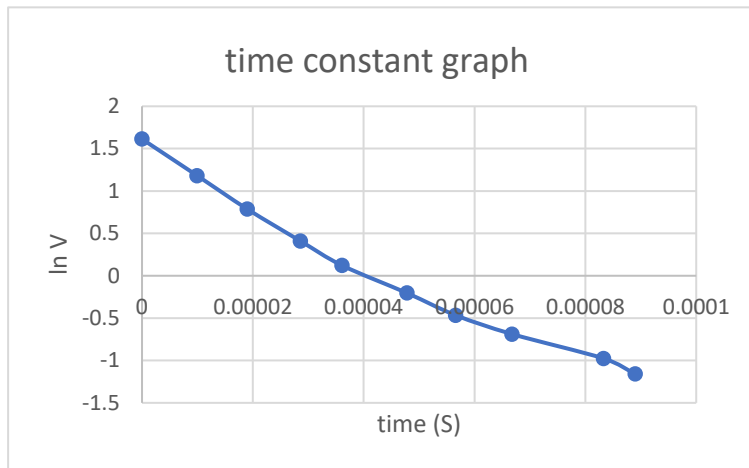
3.4 Basic Capacitor Calculations

$$\tau = R \times C, C = \frac{\tau}{R} = \frac{9.98 \times 10^{-4}}{4536} = 2.20 \times 10^{-7} F$$

3.5 Capacitor discharge table

Voltage (V)	ln V	Time (S)
5.0196	1.61335	0
3.2627	1.182555	9.93×10^{-6}
2.1961	0.786683	19×10^{-6}
1.5059	0.409391	28.6×10^{-6}
1.1294	0.121687	36.1×10^{-6}
0.8157	-0.20371	47.8×10^{-6}
0.6275	-0.46601	56.6×10^{-6}
0.502	-0.68916	66.8×10^{-6}
0.3765	-0.97684	83.3×10^{-6}
0.3137	-1.15932	89×10^{-6}

3.6 Gradient Plot and calculations



value (V)	ln V	time (S)
5.0196	1.61335	0
3.2627	1.182555	9.93E-06
2.1961	0.786683	0.000019
1.5059	0.409391	2.86E-05
1.1294	0.121687	3.61E-05
0.8157	-0.20371	4.78E-05
0.6275	-0.46601	5.66E-05
0.502	-0.68916	6.68E-05
0.3765	-0.97684	8.33E-05
0.3137	-1.15932	0.000089

$$\ln V = \ln V_0 - \frac{t}{RC}, RC = \frac{t}{(\ln V_0 - \ln V)}$$

$$\ln V_0 = 1.61335$$

$$\frac{dy}{dx} = -\frac{1}{RC}$$

RC	C
2.31E-05	2.31E-07
2.30E-05	2.30E-07
2.38E-05	2.38E-07
2.42E-05	2.42E-07
2.63E-05	2.63E-07
2.72E-05	2.72E-07
2.90E-05	2.90E-07
3.22E-05	3.22E-07
3.21E-05	3.21E-07

$$\text{Average Capacitance} = 2.67541 \times 10^{-7} \text{ F}$$

$$\% \text{ difference in capacitance} = 17.7630 \%$$

$$\Delta \text{ capacitance} = 4.7523 \times 10^{-8} \text{ F}$$

3.7 Inaccuracies Question

The capacitor used was indicated to be 0.22μF, the calculated value is 0.22μF, but the value from the graph suggests a capacitance of around 0.2675μF. As can be seen in the above section the capacitance indicated by the lnV by time graph is significantly higher than the calculated capacitance. “maximum percentage error of 7.8%.” (V. Stornelli, L. Safari, G. Barile, G. Ferri, 2021). This extract shows has maximum capacitance error of 7.8% and the value calculated for the experiment in this paper is more than double that, implying that the value in this experiment is unusually high. “Increase of dielectric loss in the second, third, and upper half of the first capacitor will cause a negative phase error and positive magnitude error” (Bin Chen, Lin Du, Kun Liu, Xianshun Chen, Fuzhou Zhang, Feng Yang, 2017). Some of the energy is transferred into the thermal store of the dielectric material within the capacitor, which increases the capacitance error as shown by the extract. As energy is proportional to voltage and capacitance is inversely proportional to voltage, as the energy is lost from the useful store the voltage lowers which in turn increases the value for capacitance that is found from the data.

4 References

- *Numerical simulation of a nonconventional alternator connected to a rectifier*. (1990, F. Piriou, A. Razeq). IEEE Journals & Magazine | IEEE Xplore.
<https://ieeexplore.ieee.org/abstract/document/105275>
- International Journal of Electronics and Communications, A new VCII based grounded positive/negative capacitance multiplier, (V. Stornelli, L. Safari, G. Barile, G. Ferri, 2021).
- Measurement Error Estimation for Capacitive Voltage Transformer by Insulation Parameters, Simulation of Measurement Error with Various Insulation Parameters, (Bin Chen, Lin Du, Kun Liu, Xianshun Chen, Fuzhou Zhang, Feng Yang, 2017).