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Electronic Circuits Testing and Applications

Electrical control system (ACHA4010)

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1 Task 2

1.1 Scope Time Division Calculations (4)

$$f = \frac{1}{\text{period}}$$

Equation 1 - Frequency equation

Frequency = 10Hz

$$\text{Period} = \frac{1}{f}$$

$$\text{Period} = \frac{1}{10} = 0.1 \text{ seconds}$$

Equation 2 - Period equation

Time = 0.1 seconds

1.2 Function Generator output sine wave (3)

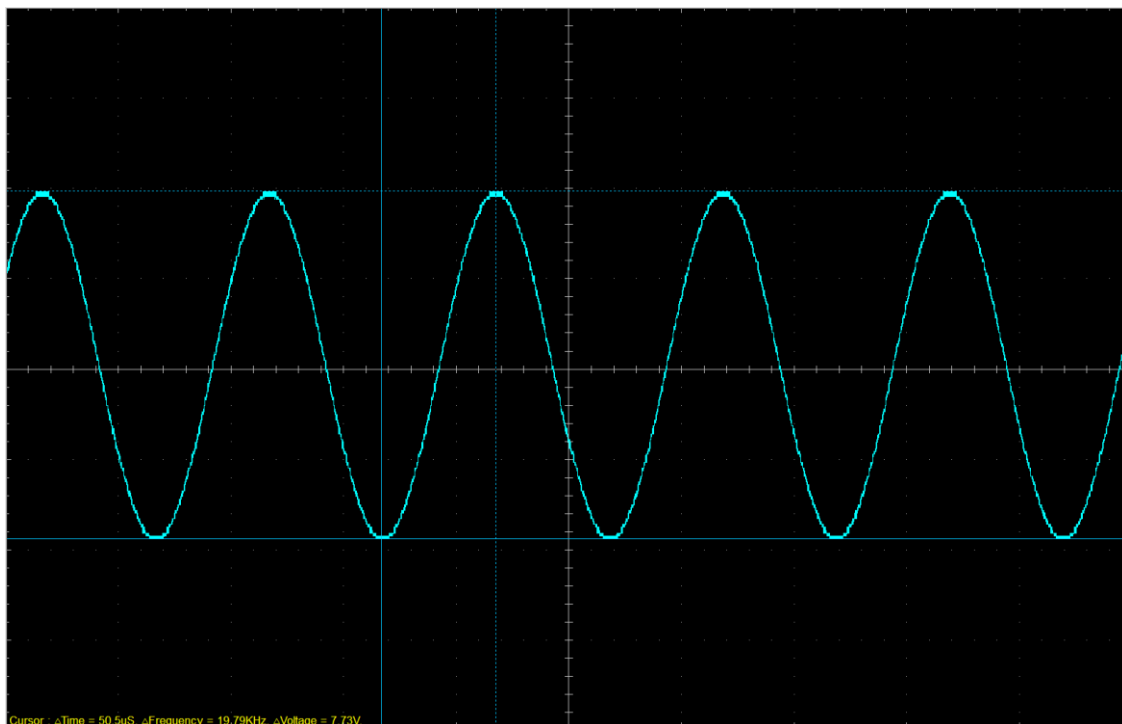


Figure 1 - Function generator output sign wave

Cursor : ΔTime = 50.5uS. ΔFrequency = 19.79KHz. ΔVoltage = 7.73V.

1.3 Unsmoothed Rectifier Wave (3)

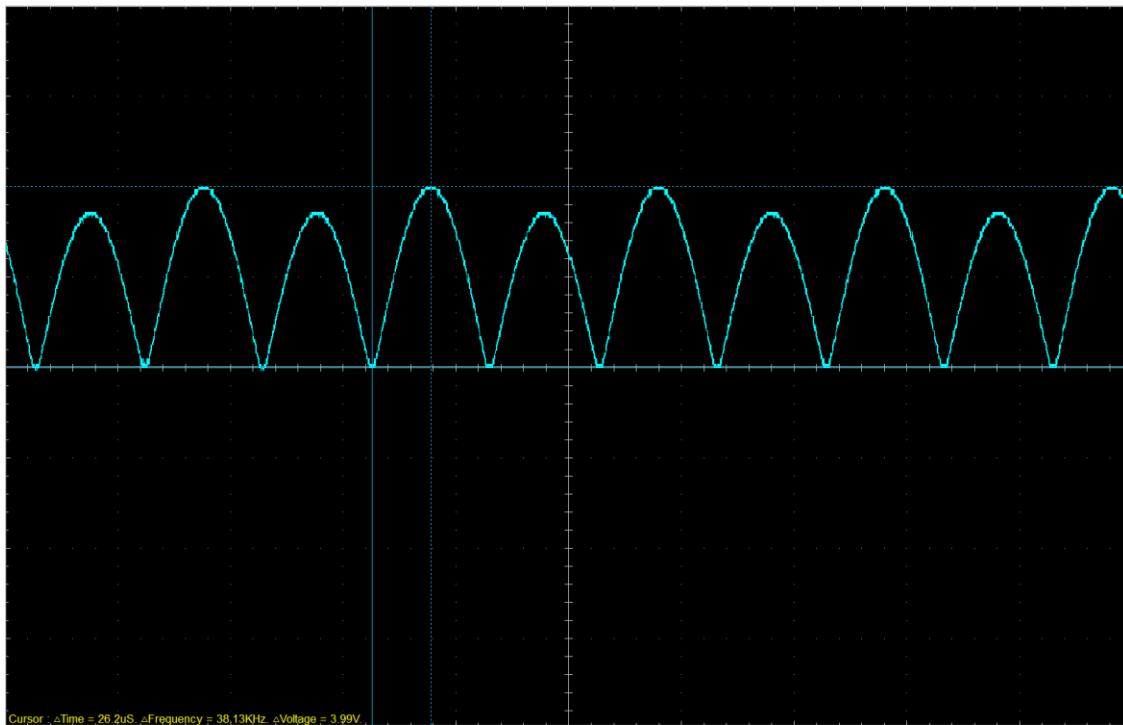


Figure 2 - Unsmoothed rectifier wave

Cursor : ΔTime = 26.2uS, ΔFrequency = 38.13KHz, ΔVoltage = 3.99V

1.4 Smoothed Rectifier Wave with capacitor (3)

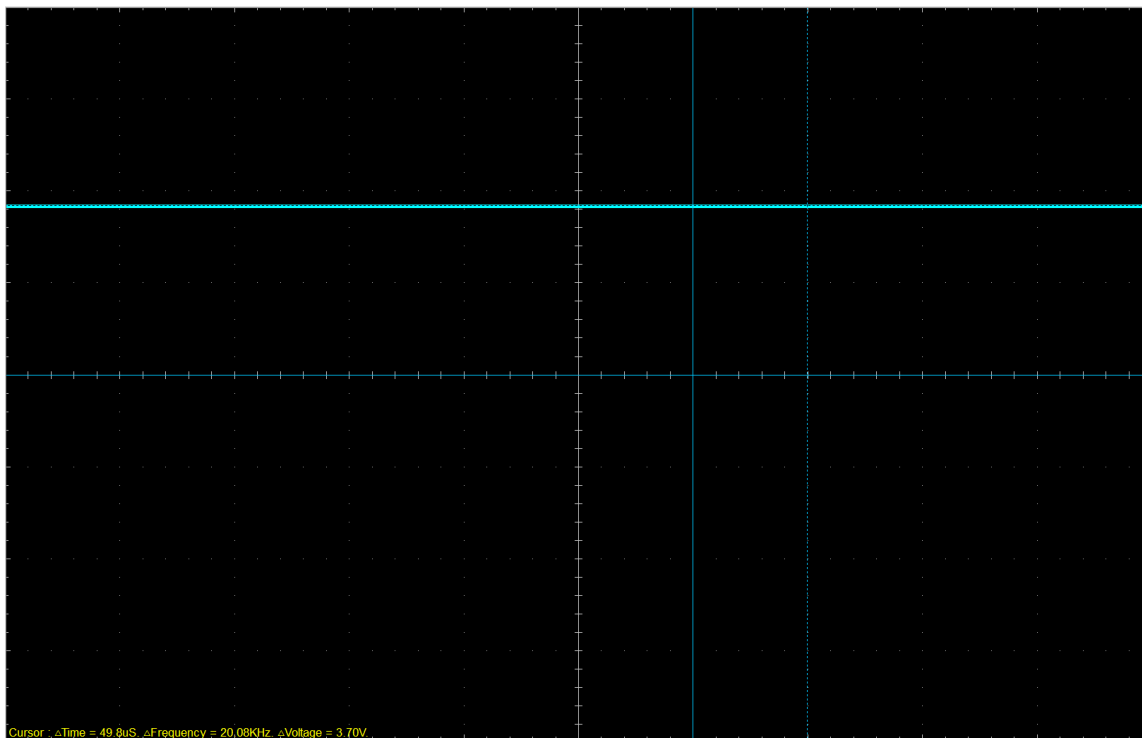


Figure 3 - Smooth rectifier wave

Cursor : ΔTime = 49.8uS, ΔFrequency = 20.08KHz, ΔVoltage = 3.70V

1.5 Drop in Voltage Question (4)

The drop in voltage of the DC rectifier output compared to the peak of the sin wave input is in part due to the voltage lost across the resistor and the forward voltage drop of the diodes. This voltage drop is around 0.7 volts per silicon diode. With 4 being in series in this circuit this amounts to a total voltage drop of 2.8 volts. Other factors should be considered such as the precision of the function generator and oscilloscope.

1.6 Different Voltage Readings Question (5)

Table 1 - Different voltages and the RMS

Peak positive input voltage (V_{pk})	Peak to peak voltage (V_{pp})	RMS (V_{RMS})
3.87V	7.73V	2.74V

$$V_{RMS} = \frac{1}{\sqrt{2}} \times V_{pk}$$

$$V_{RMS} = \frac{1}{\sqrt{2}} \times 3.87$$

$$V_{RMS} = 2.74V$$

Equation 3 - Root mean square calculations

Voltage Root Mean Square is the measure of an AC voltage waveform. It represents the equivalent DC voltage that would produce the same amount of power dissipation in a resistive load as the AC voltage. V_{RMS} is calculated by taking the square root of the mean of the squares of the instantaneous voltage values over one period of the waveform. For a sinusoidal waveform, the V_{RMS} value is related to the peak voltage (V_{pk}).

(William et al., 2011)

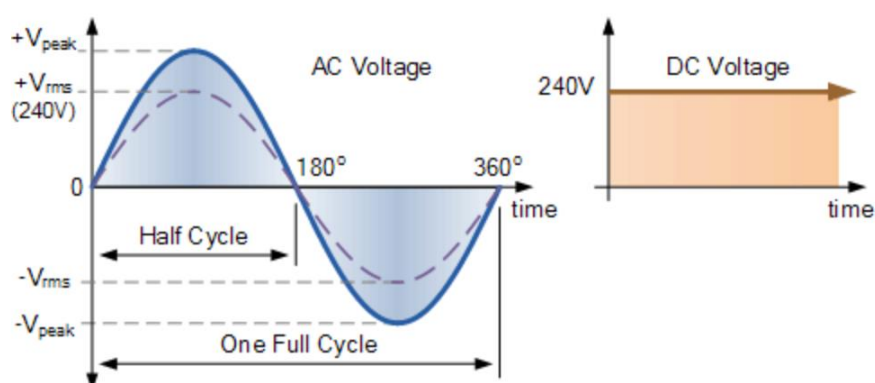


Figure 4 - Sin wave and DC voltage output demonstrating RMS

(Electronic Tutorials, 2024)

1.7 Rectifiers use in Automotive applications Question. (4)

Rectifiers play an important role in vehicle electrical systems by converting alternating current (AC) generated by the alternator into direct current (DC) necessary for powering various vehicle components and charging the battery. This conversion ensures the efficient operation of critical systems such as lights, sensors, ignition, and entertainment systems, all of which require DC power. Moreover, rectifiers facilitate voltage regulation, maintaining stable voltage output from the alternator to prevent damage to electrical components such as LED lighting systems. Effective battery charging is also ensured by rectifiers, contributing to the longevity and reliability of the battery and ensuring reliable vehicle starting. In summary, rectifiers serve as indispensable components in vehicle electrical systems, supporting efficient power conversion, voltage regulation, battery charging, and optimal operation of electronic components, all crucial for the reliable performance of modern vehicles.

(Kassakian, 2002)

1.8 Probing Question (4)

The inability to simultaneously probe the input of a function generator and the output of a rectifier using separate channels on a scope can be due to various issues such as grounding. Each channel of the oscilloscope shares a common ground, meaning if both channels were to be used at the same time on the circuit this could cause ground looping, affecting measurement accuracies and introducing interference. To allow for simultaneous probing the use of a signal combiner would allow for the output signal from the function generator and the rectifier to be combined into a single signal. This signal can then be connected to one channel on the oscilloscope, showing both signals simultaneously.

(Hrobat & Papič, 2011)

2 Task 3

2.1 Scope Time Division Calculations (4)

Resistor = 10k Ω

Capacitor = 104x10⁻⁶ farads

$$\text{Time period} = 10\,000 \times 104 \times 10^{-6} \times 20$$

$$\text{Time period} = 20.8 \text{ seconds}$$

Equation 4 - Time period calculation

$$\text{Time deviation} = \frac{20.8}{10}$$

$$\text{Time deviation} = 2.08 \text{ seconds}$$

Equation 5 - Time division calculation

$$\text{Frequency} = \frac{1}{2.08}$$

$$\text{Frequency} = 0.48 \text{ Hz}$$

$$\text{Frequency} = 480 \text{ mHz}$$

Equation 6 - Frequency calculation

2.2 Function Generator output square wave (3)

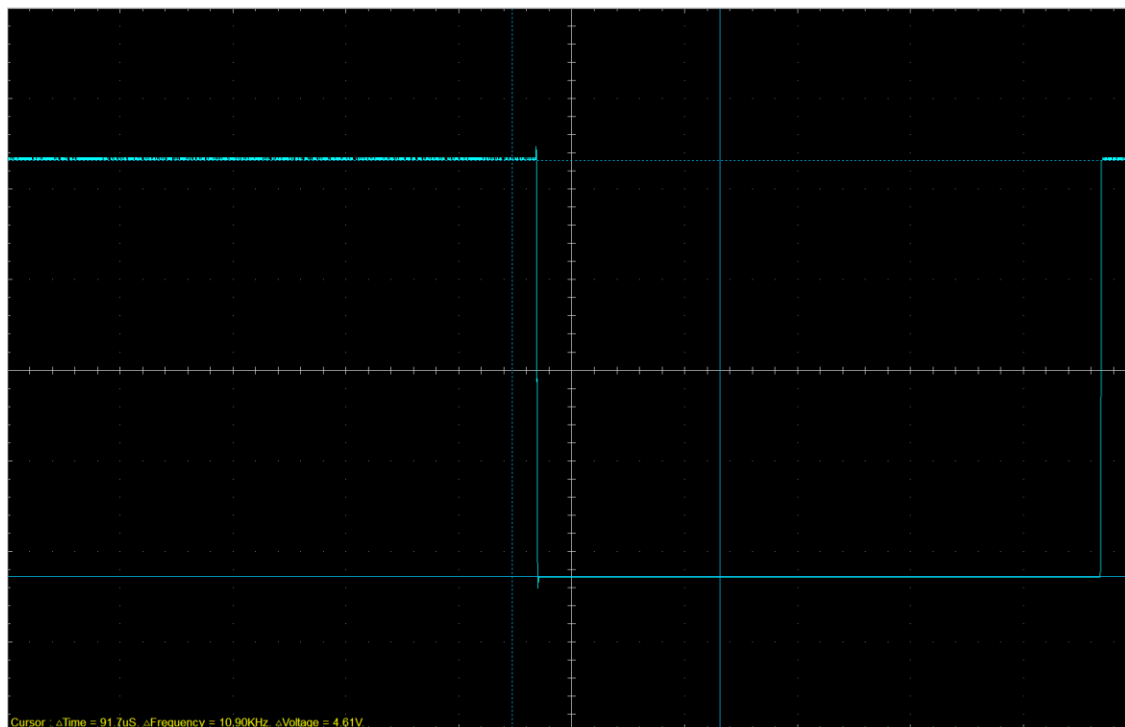


Figure 5 - Function generator output square wave

Cursor : ΔTime = 91.7uS, ΔFrequency = 10.90KHz, ΔVoltage = 4.61V.

2.3 Capacitor charge and discharge wave marked at correct points. (3)

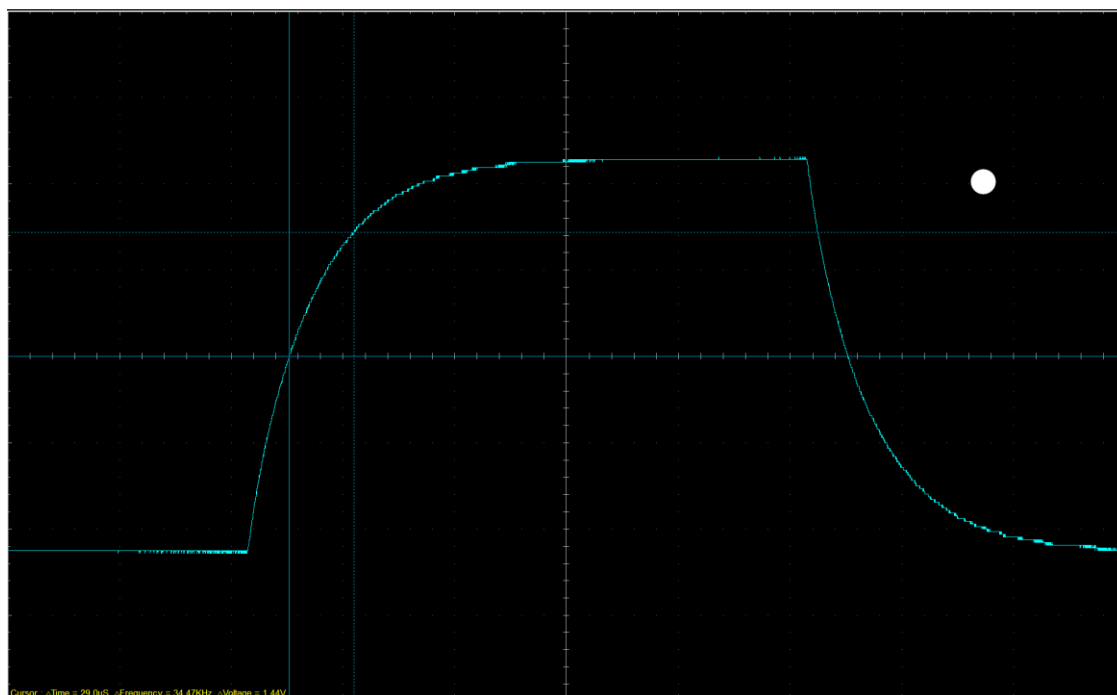


Figure 6 - Discharge and charge wave

Cursor : ΔTime = 29.0uS, ΔFrequency = 34.47KHz, ΔVoltage = 1.44V.

(Peak (V) – start (V) x 63.2%+start (V)) = V top cursor

$$2.28 - 0 \times 0.632 + 0 = 1.44 \text{ V}$$

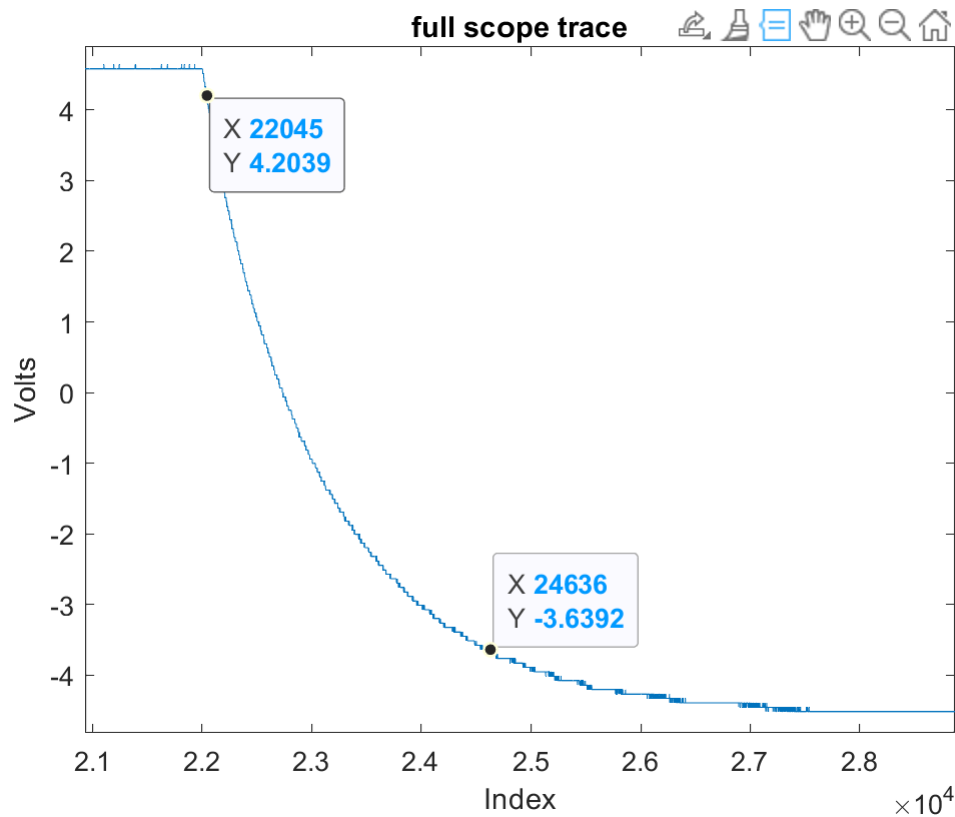


Figure 7 - MATLAB discharge wave

2.4 Basic Capacitor Calculations (3)

$$\tau = RC$$

Equation 7 - Time constant equation

$$C = \frac{\tau}{R}$$

$$C = \frac{29 \times 10^{-6}}{10\,000}$$

$$C = 2.9 \times 10^{-9} \text{ farads}$$

$$C = 0.0029 \mu\text{F}$$

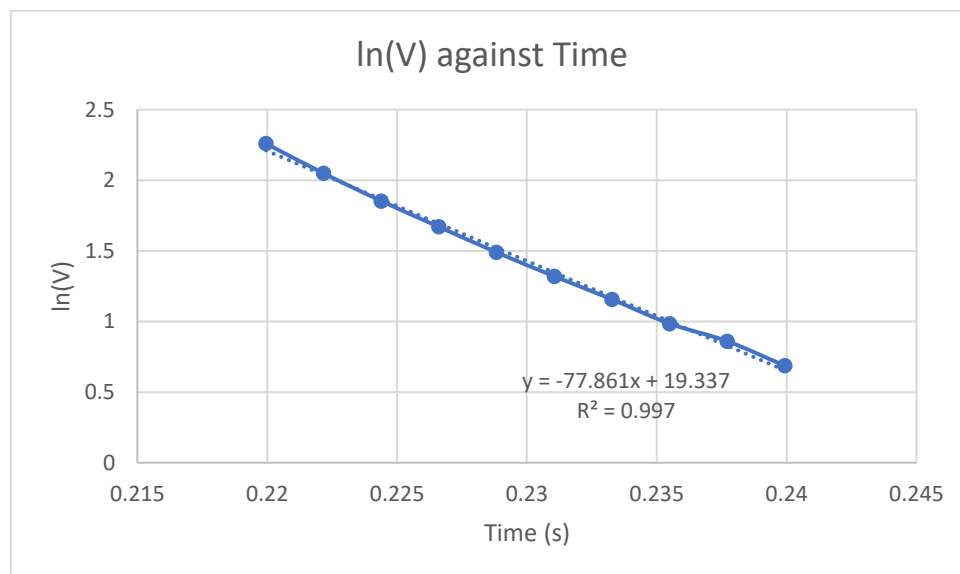
Equation 8 – Measured capacitance calculation

2.5 Capacitor discharge table (4)

Table 2 - Table containing different calculations for $\ln(V)$ along with data for time and voltage

	Time (s)	Voltage (V)	V+	$\ln(V)$	$dy = y_2 - y_1$ $dy = \ln(V)_2 - \ln(V)_1$	$dx = x_2 - x_1$ $dx = \text{Time}_2 - \text{Time}_1$	dy/dx
1	0.21995	4.5804	9.5804	2.259719345	x	x	x
2	0.22217	2.7608	7.7608	2.049085422	-0.210633923	0.00222	-94.88014554
3	0.22439	1.3804	6.3804	1.853230791	-0.19585463	0.00222	-88.22280646
4	0.22661	0.3137	5.3137	1.670288391	-0.1829424	0.00222	-82.40648659
5	0.22883	-0.5647	4.4353	1.489595257	-0.180693134	0.00222	-81.39330355
6	0.23105	-1.2549	3.7451	1.320448319	-0.169146938	0.00222	-76.19231457
7	0.23327	-1.8196	3.1804	1.157006975	-0.163441344	0.00222	-73.62222695
8	0.23549	-2.3216	2.6784	0.985219601	-0.171787374	0.00222	-77.38169988
9	0.23771	-2.6353	2.3647	0.860651164	-0.124568437	0.00222	-56.1119087
10	0.23993	-3.0118	1.9882	0.687229707	-0.173421457	0.00222	-78.11777352

2.6 Gradient Plot and calculations (4)



Graph 1 - Excel graph plotting $\ln(V)$ against time

$$\tau = -\frac{1}{\text{Gradient}}$$

$$\tau = -\frac{1}{-77.861}$$

$$\tau = 0.013$$

Equation 9 - Time constant equation utilising the gradient

$$C = \frac{\tau}{R}$$

$$C = \frac{0.013}{10\,000}$$

$$C = 1.3 \times 10^{-6} \text{ farads}$$

$$C = 1.3\mu F$$

Equation 10 - Calculated capacitance equation

$$\Delta\% = \left[\frac{(0.0029 - 1.3)}{\frac{(0.0029 + 1.3)}{2}} \right] \times 100$$

$$\Delta\% = 199.11\%$$

Equation 11 - Percentage difference

$$\Delta C = 0.0029 - 1.3$$

$$\Delta C = -1.296 \mu F$$

Equation 12 - Delta difference of the capacitance

2.7 Capacitor Uses (5)

Ten possible uses for capacitors in the automotive industry are the following:

1. Power supply, capacitors are used to smooth fluctuations in voltage providing stable DC power.
2. Energy storage in ignition systems, capacitors store electrical energy releasing it in bursts to aid engine startup.
3. Electrical motors, capacitors provide a high voltage boost for the initial startup and then ensure a consistent voltage throughout the run time.
4. Audio systems, capacitors are used to filter out low-frequency noises improving sound quality.
5. Lighting systems, capacitors are used to stabilize voltage and prevent flickering.
6. Safety systems such as airbags and ABS, capacitors store energy and provide rapid deployment when needed.
7. Onboard diagnostic systems (OBD), capacitors used to maintain power during engine startup and operation, facilitating diagnostics.
8. Engine management systems, capacitors provide stable voltage to sensors and electronic components.
9. Electronic control units (ECU), capacitors are used to stabilise voltage and provide backup power during voltage fluctuations.
10. Climate control, capacitors are incorporated into the air conditioning and heating system of vehicles to stabilise voltage and ensure correct function of each system.

(Denton, 2017; Hughes & Drury, 2013; Kaye, 2020)

2.8 Inaccuracies Question (4)

The measured capacitance of the capacitor may differ to that of its specified value due to multiple factors including measurement errors, such as inaccuracies in the equipment and poor connections. Along with the time constant of the circuit which can affect the rate at which the capacitor charges and discharges. Allowing the time constant is comparable to the measurement time or the sampling rate of the measurement equipment this can affect the behaviour of the capacitor and lead to errors in the measured capacitance.

The frequency may also have implications on measurement errors. In a circuit with resistors, the frequency of the applied voltage signal can affect the impedance of the capacitor-resistor combination leading to differences in the measured capacitance.

It is important to consider these factors and use the correct measuring techniques ensuring all connections are secure and the equipment is functioning correctly. Furthermore, by comparing the capacitor behaviour with the theoretical behaviour can show what is affecting the measured capacitance.

(Horowitz & Hill, 2015; Malvino & Bates, 2007)

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