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Electronic circuits testing and applications

Vehicle electronics

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1 Task 3

1.1 Scope Time Division Calculations (6)

For each measurement, the oscilloscope time base was set so that one complete waveform occupied the full screen width. The time per division was calculated using the equation $\text{Time/Div} = 40/10 = 4$.

1.2 Function Generator output square wave (6)

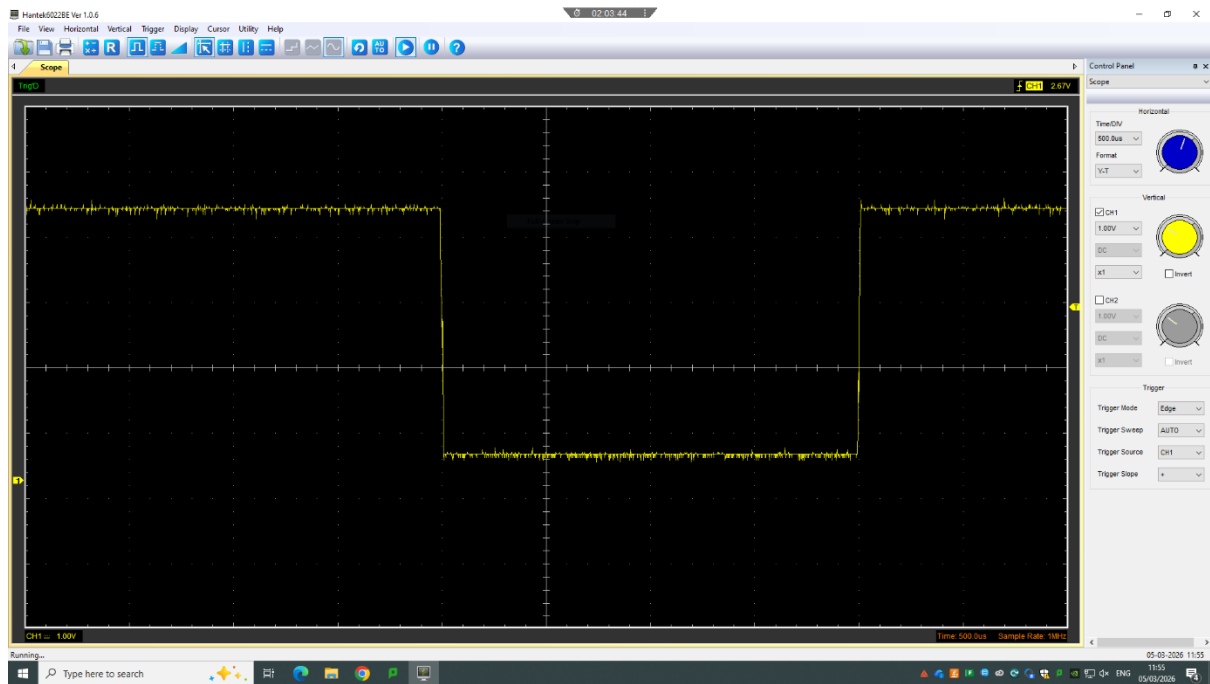


Figure 1, This figure shows a square wave output.

1.3 Capacitor charge and discharge wave marked at correct points. (6)

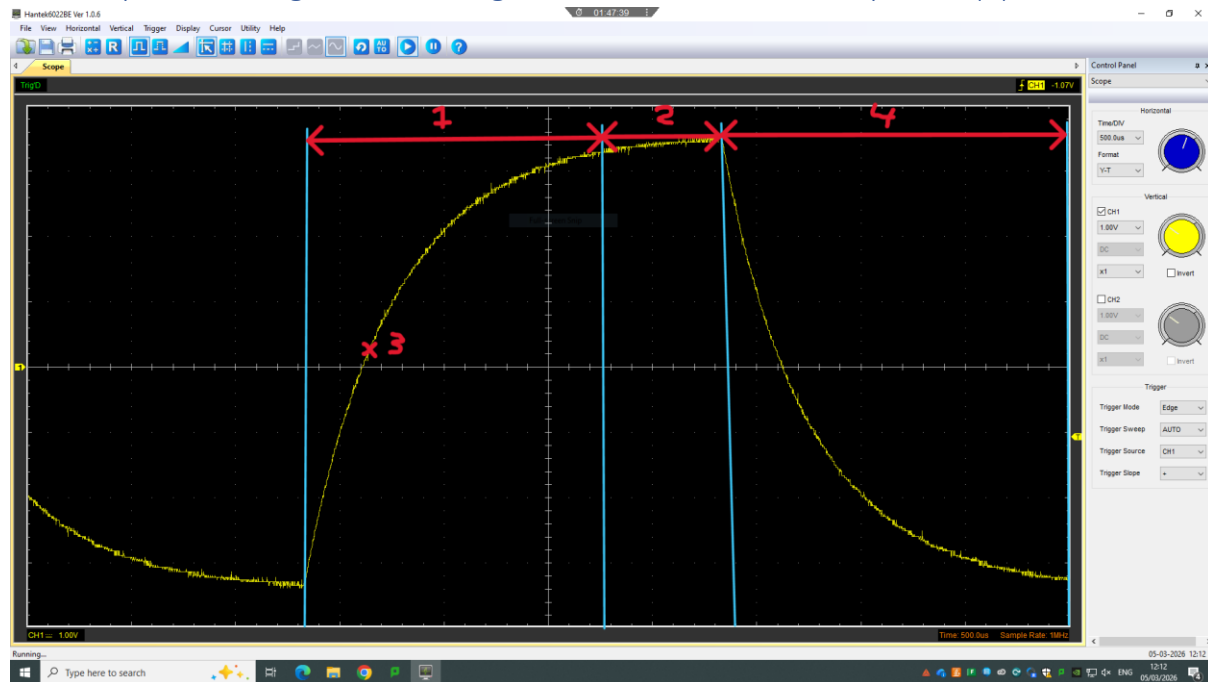


Figure 2, This is an annotated screenshot of a Capacitors waves.

Annotation 1 Marks the Transient Period where the capacitor begins to charge and continues to until annotation 2 where the capacitor reaches the steady state period. In this period it will become fully charged. Annotation 3 is the 63% rise in voltage. Annotation 4 is the period of the capacitor discharging voltage and will end with the capacitor being fully discharged.

1.4 Basic Capacitor Calculations (6)

To calculate the Capacitance the equation used is $\tau = R \cdot C$, when rearranged it creates the equation $C = \tau / R$. When using the relevant units it becomes $(4 \cdot 10^{-3}) / 40 = (1 \cdot 10^{-4})$. This means that Capacitance = 100 μF

1.5 Capacitor discharge table (5)

Time (s)	Voltage (V)	ln(V)	dy	dx	dy/dx
0	1.00	0.000	x	x	x
0.0005	0.78	-0.248	-0.248	0.0005	-496
0.0010	0.62	-0.478	-0.230	0.0005	-460
0.0015	0.50	-0.693	-0.215	0.0005	-430
0.0020	0.40	-0.916	-0.223	0.0005	-446
0.0025	0.32	-1.139	-0.223	0.0005	-446
0.0030	0.26	-1.347	-0.208	0.0005	-416
0.0035	0.21	-1.560	-0.213	0.0005	-426
0.0040	0.17	-1.772	-0.212	0.0005	-424
0.0045	0.14	-1.966	-0.194	0.0005	-388

Ten points were taken from the discharge curve and used to calculate $\ln(V)$, dy , dx , and dy/dx . The gradient remained approximately constant, confirming the expected behaviour.

1.6 Plot log(V) Gradient (5)

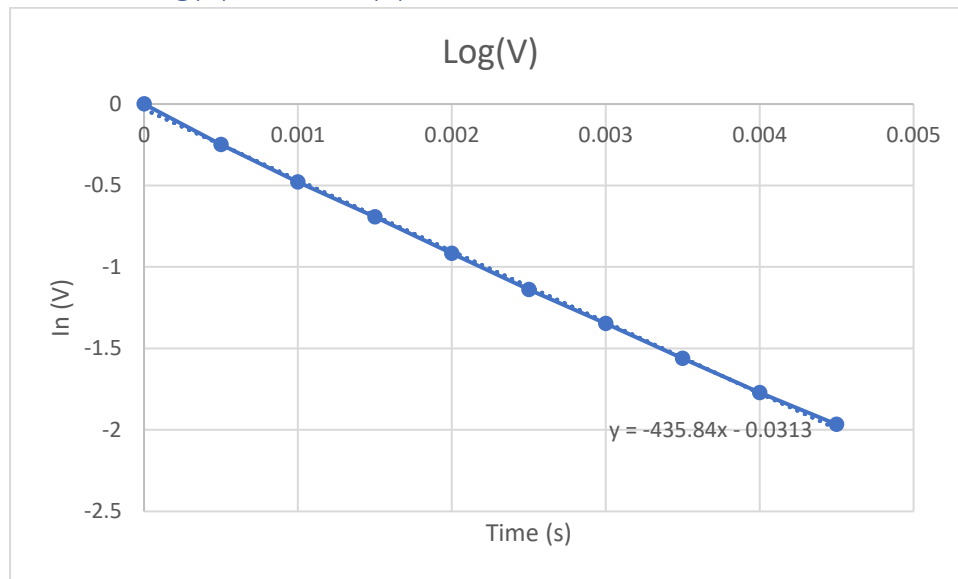


Figure 3, This Graph shows $\ln(V)$ against Time (s)

1.7 Gradient Calculations and Compare(8)

1.7.1 Gradient Calculations

The discharge of the capacitor was analysed by taking the natural logarithm of the voltage, which turns the exponential decay into a straight-line relationship given by $\ln(V) = \ln(V_0) - t/(RC)$. From this, the gradient of the graph is $m = -1/(RC)$. The gradient was measured as -435.84 s^{-1} , and using the known resistance of 40Ω , the capacitance was calculated using $C = -1/(Rm)$. Substituting the values gives $C = 1/(40 \times 435.84) = 5.736 \times 10^{-5} \text{ F}$, which is $57.35 \mu\text{F}$. This was compared to the expected value of $100 \mu\text{F}$, giving a difference of $-42.65 \mu\text{F}$ and a percentage error of 42.65% . This means the measured value is lower than expected because the graph had a steeper gradient.

1.7.2 Comparison table

	Capacitance	Delta	Percentage difference
Actual	1 μF	x	X
Marker Calculation	100 μF	+99	9900%
Gradient Calculation	57.35 μF	+57.35	5735%

1.8 Capacitor Uses (5)

In automotive engineering capacitors are widely used as they can store and release electricity. They can also smooth signals and help maintain stable voltage levels. Often they are used in power supplies to smooth out voltages and reduce ripple. They are also important in filtering circuits, where they can remove unwanted electrical noise in both analogue and digital systems. Also capacitors are used in timing circuits, where their charging and discharging creates controlled delays. In power systems, capacitors are used for power factor correction, which improves efficiency in electrical distribution networks, including those studied by organisations like IEEE. In automotive systems, they are used in ignition circuits to generate sparks, such as in systems developed by Bosch.

To ensure reliable function of ECU's they can help stabilise voltage. Capacitors can support energy storage and regenerative braking systems in electric and hybrid vehicles. Other common uses include reducing electrical noise in audio systems, providing short-term backup power for memory circuits, and helping motors start and run in devices like fans and fuel pumps.

1.9 Inaccuracies Question (4)

There were some mistakes in the measurement that caused the measured capacitance to be different from the specified value. Tolerance in components is a big reason for inaccuracy. For example, capacitors often have tolerances of $\pm 10\text{--}20\%$, which means that the real value may be different from the value on the label. The capacitor's internal resistance (also known as equivalent series resistance or ESR) and leakage current can also change the discharge rate, which can cause the voltage to drop faster than expected. Measurement tools can also cause mistakes. For example, voltmeters may not be able to read accurately at low voltages because they have limited resolution and response time. Capacitance and resistance values can be affected by things like temperature and other environmental factors. Also, noise in the circuit can make the data deviate from the ideal exponential model. This is especially true if the data points aren't evenly spaced or if a full linear regression isn't used. When you put all of these things together, you can get a steeper measured gradient and a lower calculated capacitance than thought.

1.10 Risk Question (10)

Vehicle CAN bus enable ECUs to talk to one another; however, they offer extremely little built-in protection against potential cyberattacks such as spoofed message attacks, replay attacks, and message flooding attacks. ISO/SAE International offers some information on how to lower these cybersecurity threats through its ISO/SAE 21434:2021 publication. Threat analysis and risk assessment (TARA) can help automotive engineers spot potential risks. For example, TARA would show wireless communications and diagnostic interfaces as possible targets. The other important measure involves segmenting the network into two parts, so that an attack would not affect critical components such as the braking system. The other systems would include the infotainment system. ECUs can be equipped with message authentication capabilities to help prevent spoofing attacks. Intrusion detection systems (IDS) can help identify malicious activities within CAN networks. It should be noted that ENISA encourages the deployment of monitoring systems. It is also necessary to pay attention to software protection. Secure Boot technology guarantees that only authorized software operates on ECUs, while secure OTA updates ensure that no unauthorized software can be installed by attackers. Periodic software testing and secure software development contribute to the minimization of potential risks. ISO/SAE 21434 pays particular attention to the combination of technical approaches and the implementation of effective organizational processes, including employee training and the development of incident response plans.

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