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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)

Equation 1 - Frequency & Time Period

$$f = \frac{1}{T} \therefore T = \frac{1}{f}$$

Where f = Frequency & T= Time period

The Hantek software displays 10 time divisions, to fit one whole wave cycle within the oscilloscope the time period needs to be divided by 10 and the function generator frequency used was 250 Hz

$$T = \frac{1}{250} = 0.004 \text{ s or } 4 \text{ ms}$$

Equation 3- Scope Time Division

$$\text{Scope Time Division} = \frac{\text{Time period}}{\text{Scope Divisions}} = \frac{0.004}{10} = 400 \mu \text{ seconds Round up to } 500 \mu \text{ seconds}$$

The scope time divisions do not calculate to be an exact matching scale; the solution is to round up to the next nearest division to 500 μ Seconds as rounding down will not show the full wave cycle.

1.2 Function Generator output square wave (6)

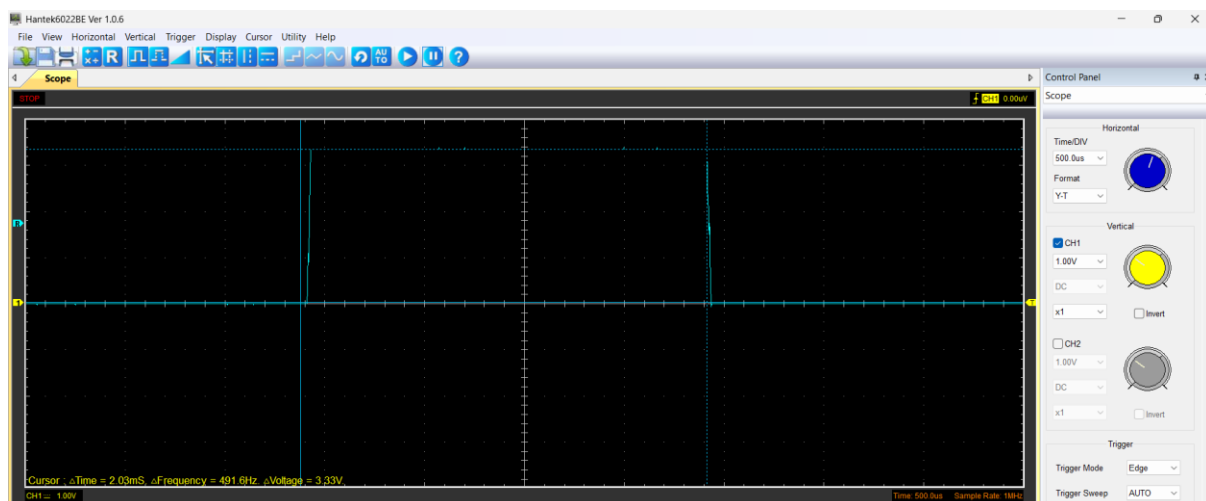


Figure 1 - Square Wave Full Cycle

Figure 1 shows a capture, of the Hantek oscilloscope software displaying 1 complete cycle of a square wave being produced by the function generator peaking at 3.33 Volts, the view of the square wave is partially obscured by the cursor function of the software.(Hantek, no date)

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

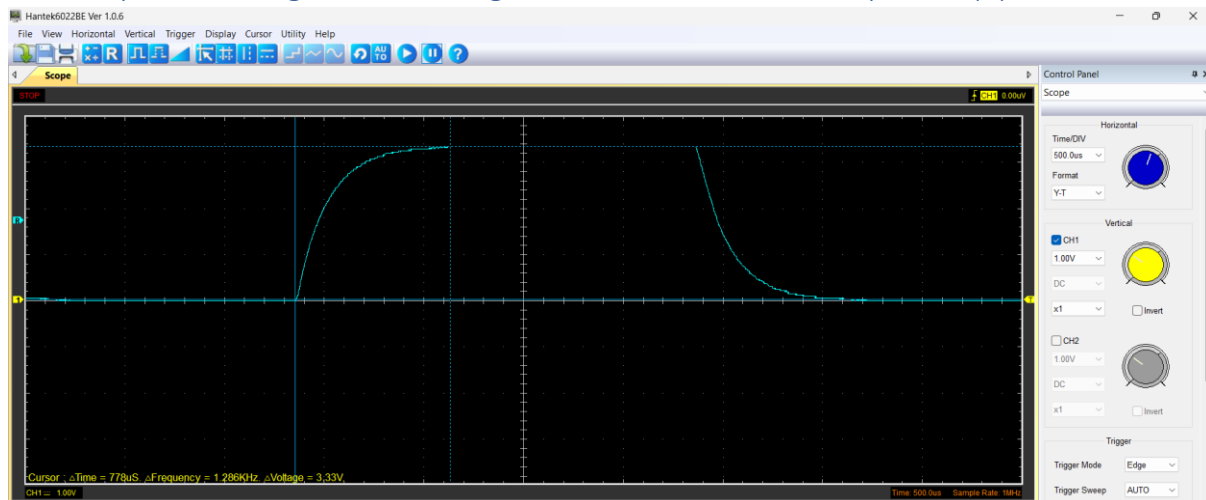


Figure 2- Capacitor wave Charge Section

Figure 2 shows a marked capture of the resistor capacitor circuit using the Hantek Oscilloscope showing that is charging to 3.33 volts in approximately 778 μ Seconds.

The slight variation in peak voltage is negligible, this could be caused by inaccuracies on the oscilloscope and or function generator, as well as high impedances within the circuit and loading from the probes. (MINESHIGE *et al.*, 2022)

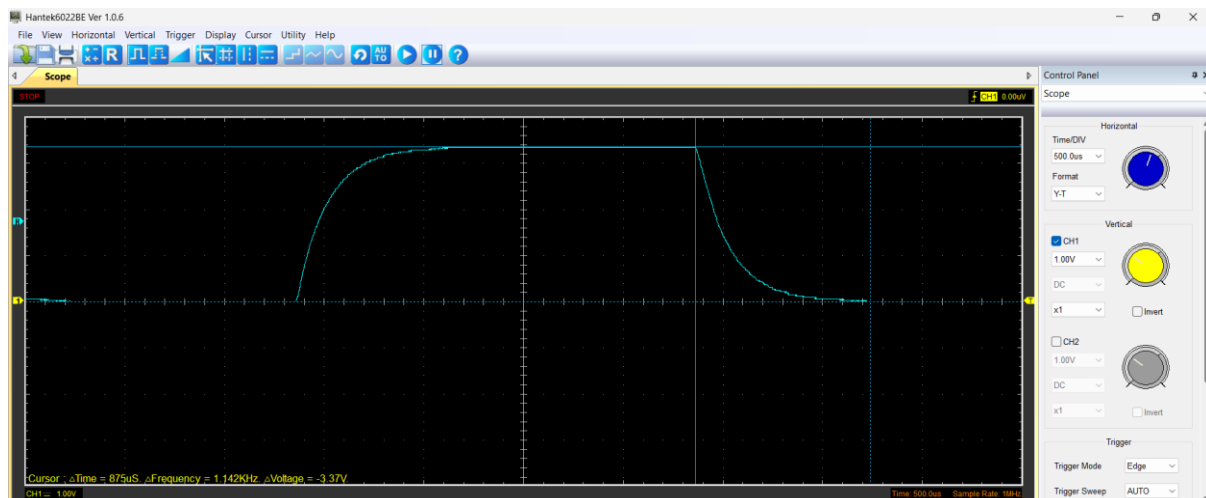


Figure 3- Capacitor Wave Discharge Section

Figure 3 shows the capacitor discharge section of the circuit showing that the capacitor discharges 3.37 Volts in approximately 875 μ Seconds, the discrepancy in voltage is likely from where the cursors have been selected on the wave possibly from noise in the oscilloscope signal.

1.4 Basic Capacitor Calculations (6)

Equation 2 - Capacitance Equation

$$T = R * C \quad \therefore \quad C = \frac{T}{R}$$

Size of resistor used = 100Ω

Equation 3 - Charging Constant equation

$$(Peak\ Voltage - Start\ Voltage \times 63.2\% + Start(V)) = V\ top\ cursor$$

$$((3.33 - 2) * 0.623) + 2 = 2.828\ V$$

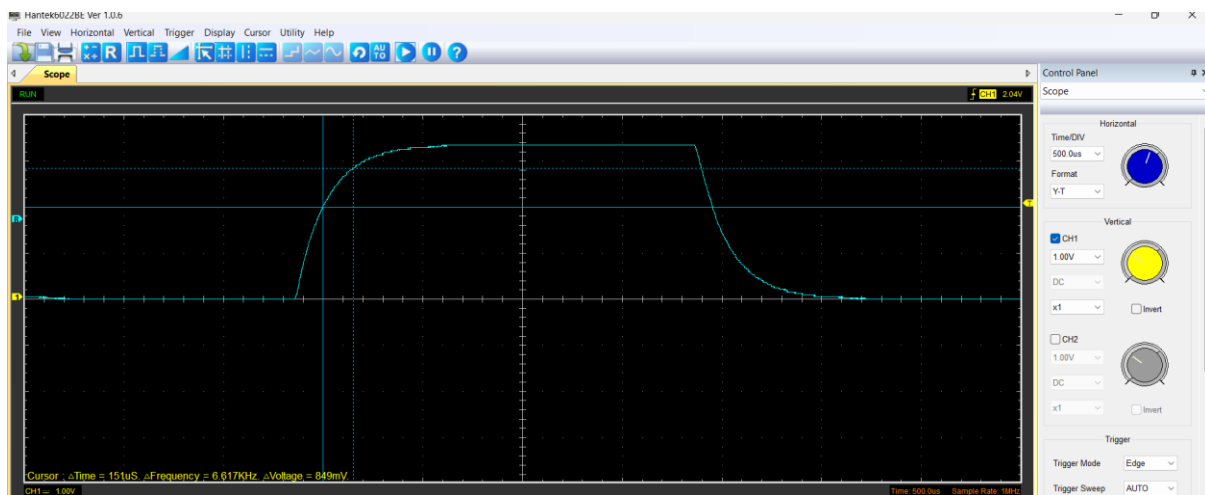


Figure 4 - Time period between 2 & 2.282-Volts Capacitor wave

Time Period shown for Charging 151 Microseconds

Equation 4 - Capacitance using Time period of charging

$$C = \frac{151 * 10^{-6}}{100} = 1.51 * 10^{-6}\ Farads$$

1.5 Capacitor discharge table (5)

Table 1 - Capacitor discharge data

Time (s)	Voltage (V)	ln (V)	$dy = y_2 - y_1$	$dx = x_2 - x_1$	dy/dx
			$dy = \ln(V)_2 - \ln(V)_1$	$dx = \text{Time}_2 - \text{Time}_1$	
0.00129	5.3079	1.66919628	x	x	x
0.00132	4.4294	1.48826413	-0.180932142	0.000028	-6461.86222
0.00135	3.551	1.26722925	-0.221034881	0.000028	-7894.10288
0.00138	2.7353	1.00624112	-0.260988135	0.000028	-9321.00482
0.00141	2.0451	0.71544669	-0.290794431	0.000028	-10385.5154
0.00143	1.4804	0.39231232	-0.323134367	0.000028	-11540.5131
0.00146	1.0412	0.04037389	-0.351938427	0.000028	-12569.2295
0.00149	0.6647	-0.40841947	-0.448793362	0.000028	-16028.3344
0.00152	0.4137	-0.88261421	-0.474194738	0.000028	-16935.5263
0.00155	0.1	-2.30258509	-1.419970887	0.000028	-50713.246

1.6 Plot $\log(V)$ Gradient (5)

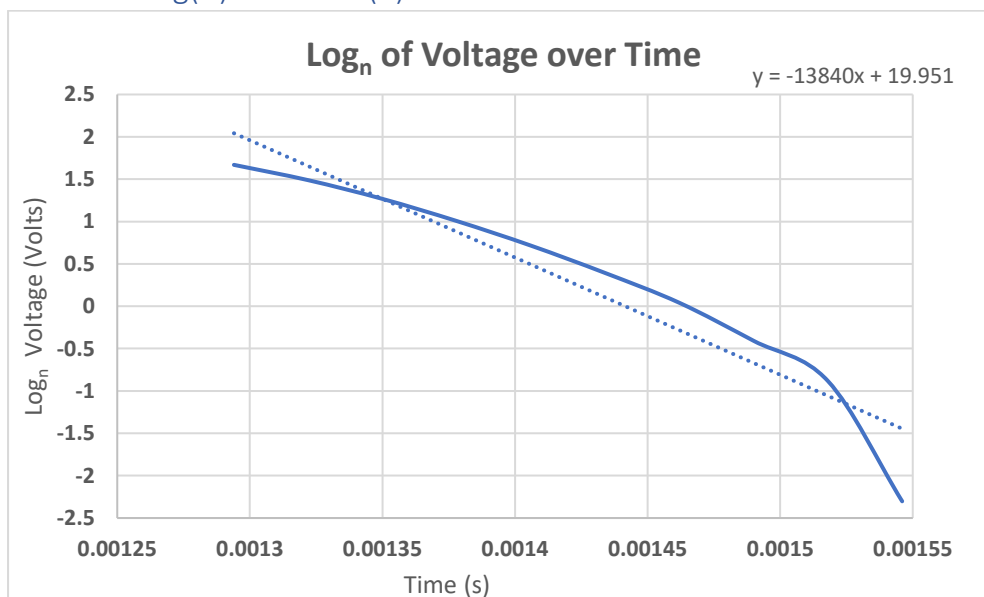


Figure 5 - A plot of Log n against time

1.7 Gradient Calculations and Compare (8)

1.7.1 Gradient Calculations

Gradient = average of dy/dx = -15761.03718

Equation 5 - Gradient Tau

$$\text{Gradient } \tau = \frac{1}{\text{Gradient}} = \frac{1}{-15761.03718} = -6.34476 * 10^{-5}$$

Equation 6 - Capacitance from average gradient

$$\text{Capacitance} = \frac{6.34476 * 10^{-5}}{100} = 6.34476 * 10^{-7} = 63.4 \mu \text{ Farads}$$

1.7.2 Comparison table

Table 2- Capacitance Comparison Table

	Capacitance	Delta	Percentage difference
Actual	1 μF	x	X
Marker Calculation	1.51 μF	0.51 μF	51 %
Gradient Calculation	63.4	62.4	6340 %

1.8 Capacitor Uses (5)

Capacitor discharge ignitions – suitable for high revving engines

RC Timing Circuits – controlling time delay

Regenerative breaking

Backup power for safety systems – Airbags

Flash rate control for indicators

Signal Filtering

Voltage Stabilisation

Surge protection – semiconductors

Starting motors – Supply strong torque

HID lighting – compensating for reactive power

(ASC Capacitors, no date; Microchip USA, 2023)

1.9 Inaccuracies Question (4)

There is a plethora of reasons as to why there is such large inaccuracies within the results of this experiment, an increased circuit resistance could be caused by the breadboard as this was not assembled with precision this could cause an unknown variation of resistance within the circuit skewing results, the scoping equipment and function generators also have an amount of accuracy variance they are built to, these parameters can all compound into a large variation of results, to reduce these issues the test could be repeated with much higher accuracy tooling in a much more controlled environment.

The largest possible source of inaccuracy could be a mismatch in impedance between components, if the impedance between the circuit being measured and the scope are different the voltage measured by the scope is not the true voltage in the circuit regardless of how negligible it is the probing also add parallel resistance to the circuit changing values, these all contribute to the calculated and measured values being different to the true values. (Roberts, no date; Wang *et al.*, 2025)

1.10 Risk Question (10)

Originally implemented in Europe in 1986 Controller Area Network Bus (CANBUS) , was an innovative new way to communicate and exchange parameters and information from in vehicle networks (IVN's) to external systems allowing for more efficient diagnosis and increased control over systems via the exchange of information through a variety Vehicle control modules embedded within components. (Perston, no date; Kha, Mubashir and Iqbal, 2025)

Once CANBUS had become common practice within electronic vehicle control systems, it was quickly discovered that these systems are vulnerable to cybersecurity attacks similar to most computer networks, it took some time to realise the scale of the health and safety issues this could cause and that mitigation for these risks needed to be enforced and regulated (Nasser, 2024)

There are two main attack types passive and active, a passive attack is usually when a party gathers and stores information without being discovered or traced it will skim CAN networks and messages and store them one the data has been stored this can be replayed in the IVN's to cause an unwanted or unexpected parameter change such as setting the throttle to 100% providing the information has been skimmed before or bypassing certain safety systems, passive attacks are usually implemented by interfering with a network such as Bluetooth.

Active attacks are where a device physically interacting with the vehicle and targeting a specific CAN module such as ABS or other parts, this attack allows parts to be recalibrated and modified permanently and does not rely on replaying old data, an active attack usually spoofs and BCM or ECM by using a known handshake protocol. (Nasser, 2023)

These security Risks have been recognised by the International Organisation for Standardisation (ISO) and have been given a standard for engineering requirements for cybersecurity risk management such as ISO / SAE 21434 this gives vehicle manufacturers a structure to help manage these risks within electronic systems, it pushed for the industry to all work to the same standard and help each other develop new defence mechanisms , part of the structure mandates manufactures to do a threat analysis and risk assessment for the full life of the vehicle not just the manufactures design lifecycle.

Another mitigation for these attacks is to implement computer style firewall security within connection ports of a CANBUS system, as well as start to use much more complex handshake protocols like those found within modern Wi-Fi networks to reduce the ability of spoof attacks.

(ISO/SAE 21434:2021 - Road vehicles — Cybersecurity engineering, no date; Linus Tech Tips, 2024)

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