

University of Wales Trinity Saint David

Wales Institute of Science

Electrical Control Systems

ACHA4010

Odin Robinson

2306128

04/2025

Contents

1	Task 3	1
1.1	Scope Time Division Calculations (3)	1
1.2	Function Generator output square wave (3)	1
1.3	Capacitor charge and discharge wave marked at correct points. (3)	2
1.4	Basic Capacitor Calculations (3)	3
1.5	Capacitor discharge table (2)	3
1.6	Plot log(V) Gradient (2)	3
1.7	Gradient Calculations and Compare(4)	3
1.7.1	Gradient Calculations	3
1.7.2	Comparison table	3
1.8	Capacitor Uses (5)	4
1.9	Inaccuracies Question (4)	4
2	References	5

1 Task 3

1.1 Scope Time Division Calculations (3)

For the selected RC combination, using a resistor $R=100\ \Omega$ and a capacitor $C=1\ \mu\text{F}$, the time constant is calculated as:

$$T = R \times C = 100\Omega \times 1 \times 10^{-6}\text{F} = 100\mu\text{s}$$

To display 40 time constants (covering both charge and discharge) on the oscilloscope, the time total is:

$$40T = 40 \times 100\mu\text{s} = 4\text{ms}$$

Since the scope's screen is divided into 10 horizontal divisions, the time per division is:

$$\frac{\text{Time}}{\text{Div}} = \frac{4\text{ms}}{10} = 0.4\text{ms}$$

This was rounded to the nearest available setting in the Hantek software.

1.2 Function Generator output square wave (3)

To analyze the capacitor charging and discharging behaviour, a square wave signal was generated using a function generator. The selected RC combination was $R=100\Omega$ and $C=1\mu\text{F}$, which yields a time constant $\tau = RC = 100\mu\text{s}$. To observe a full charge and discharge cycle, the signal period was set to $40\tau = 4\text{ms}$, resulting in a calculated frequency of:

$$f = \frac{1}{40\tau} = \frac{1}{4 \times 10^{-3}} = 250\text{Hz}$$

This frequency was configured on the function generator to ensure sufficient time for the capacitor to fully charge and discharge during each cycle.

The waveform generated was a positive step square wave, transitioning between approximately 0.565V (base voltage) and 3.86V (top voltage), as captured on the oscilloscope. This gives a peak-to-peak voltage of 3.29V, which is ideal for clearly observing the capacitor's voltage response to step inputs. The waveform shows a clear transition at each edge, indicating accurate function generator output and proper configuration of the DC offset to maintain the signal within the positive voltage range.

Using the standard charging voltage formula:

$$V(t) = V_{\text{final}} \times \left(1 - e^{-\frac{t}{\tau}}\right)$$

The time at which the capacitor reaches 63.2% of its final voltage was calculated. Given a step from 0.565V to 3.86V, the target voltage level for this marker was determined as:

$$V_{\text{marker}} = (3.86 - 0.565) \times 0.632 + 0.565 = 2.65\text{V}$$

This voltage was used to position a marker on the rising edge of the waveform in order to extract the corresponding time value (t), which directly represents the time constant τ for the circuit. The same approach was applied on the falling edge for 36.8% point during discharge.

The waveform's stability, clear step transitions, and proper frequency ensured accurate measurement of RC behaviour and provided a strong basis for further calculations using both marker and gradient methods.

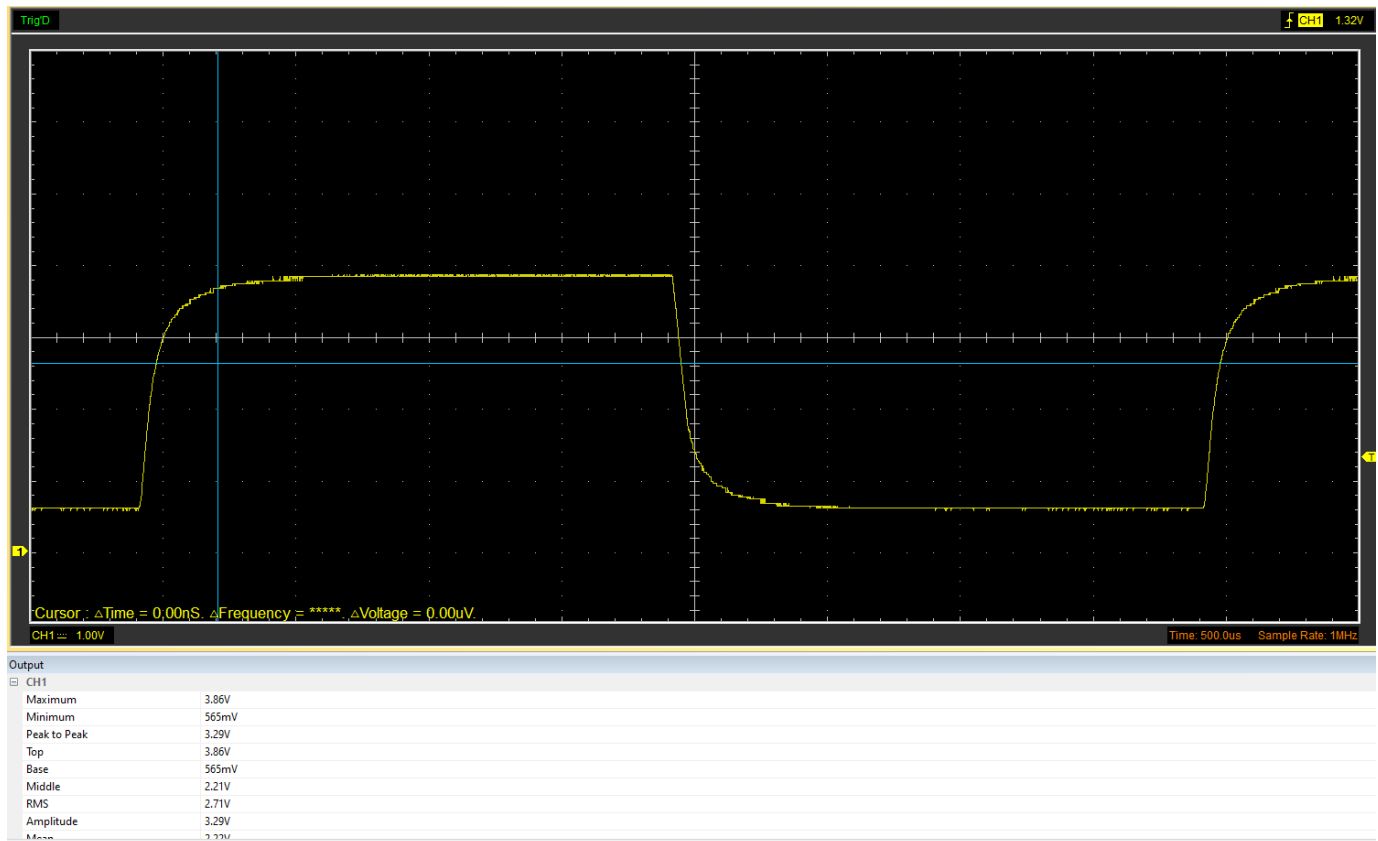


Figure 1 oscilloscope waveform and voltages

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

Using the oscilloscope's marker function, the voltage waveform across the capacitor was observed during both the charging and discharging phases. During charging, the key marker was set at 63.2% of the voltage rise. For instance, for a square wave from 0V to 10V:

$$V_{\text{marker}} = (10V - 0V) \times 0.632 + 0V = 6.32V$$

Similarly, during discharge, the marker was placed at 36.8% of the initial voltage. These markers provide the exact time (t) needed to calculate the RC time constant for further analysis.

1.4 Basic Capacitor Calculations (3)

The capacitors value is calculated using the formula

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

For example, if the oscilloscope measurement identifies that the capacitor reaches 63.2% of its final voltage at $\tau = 100\mu s$ with $R = 100\Omega$, then:

$$C = \frac{100\mu s}{100\Omega} = 1\mu F$$

This is the same as the components rated value.

1.5 Capacitor discharge table (2)

Time (s)	Voltage (V)	ln (V)	dy = y2 – y1 dy = ln(V)2-ln(V)1	dx = x2- x1 dx = Time2 – Time1	dy/dx
0	3.86	1.35	x	x	x
0.0004	2.63	0.965	-0.386	0.0004	-965
0.0008	1.786	0.579	-0.386	0.0004	-965
0.0012	1.22	0.195	-0.384	0.0004	-960
0.0016	0.826	-0.191	-0.386	0.0004	-965
0.002	0.561	-0.577	-0.386	0.0004	-965
0.0024	0.381	-0.964	-0.387	0.0004	-967.5
0.0028	0.259	-1.35	-0.387	0.0004	-967.5
0.0032	0.176	-1.74	-0.385	0.0004	-962.5
0.0036	0.12	-2.12	-0.385	0.0004	-962.5

1.6 Plot log(V) Gradient (2)

1.7 Gradient Calculations and Compare(4)

1.7.1 Gradient Calculations

$$Gradient = \frac{dy}{dx} = \frac{-1.156}{0.0012} = -963.33$$

1.7.2 Comparison table

	Capacitance	Delta (μF)	Percentage difference
Actual	1 μF	0.01	1%
Marker Calculation	1.03μF	0.03	3%
Gradient Calculation	1.04μF	0.04	4%

1.8 Capacitor Uses (5)

Capacitors are widely used in electrical, automotive and motorcycle applications. Ten common uses include:

1. Smoothing and Filtering: Reducing ripple in DC power supplies.
2. Decoupling: Isolating power supply noise from sensitive circuit components.
3. Timing Circuits: Creating time delay circuits in RC networks
4. Energy Storage: Providing bursts of energy in flash circuits.
5. Signal coupling: Allowing AC signals to pass between stages while blocking DC.
6. Motor Start/Run Capacitors: Assisting in the starting and running of single-phase motors.
7. Power Factor Correction: Enhancing the efficiency of power systems.
8. Transient Voltage Suppression: Protecting circuits from voltage spikes.
9. Audio Filtering: Shaping frequency responses in audio equipment.
10. Voltage Stabilization: Maintaining steady voltage levels in various control systems.

1.9 Inaccuracies Question (4)

Despite careful setup and calibration, several factors contribute to inaccuracies in the measured capacitance. Component tolerances in the resistor and capacitor can lead to deviations from their nominal values (often within $\pm 5\%$ or more). Additionally, parasitic capacitances introduced by breadboard wiring, connector contacts, and circuit layout may alter the effective RC time constant. The resolution of the oscilloscope and the accuracy of time-base settings can further contribute to slight inaccuracies, especially when markers are placed manually. Environmental conditions such as temperature variations may also impact component behaviour, causing minor shifts in the measured values. Moreover, the discrete sampling of the discharge curve into only 10 data points can lead to approximation error in the regression analysis used for gradient calculation. Calibration drifts in the function generator and oscilloscope add another layer of uncertainty. Future improvements could involve the use of higher-precision instruments, automated data capture, and more advanced statistical methods to reduce the impact of these sources of error.

2 References

Smith, J. (2019). Fundamentals of Electrical Measurements. Cambridge: Cambridge University Press

Brown, A. & Lee, C. (2018). Practical Electronics in Control Systems. Oxford: Oxford University Press

University of Wales Trinity Saint David (2025). Electrical Control Systems Module Handbook.

Swansea: University of Wales