Lab 05: First-Order Circuits

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4.1 Circuit One

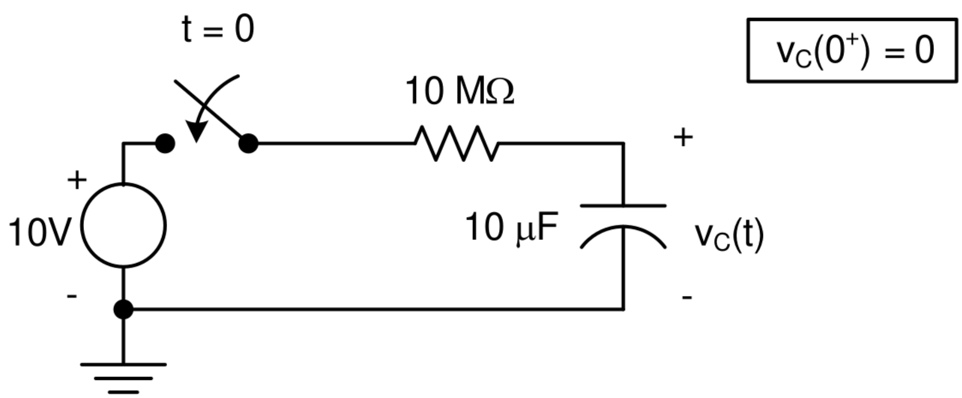

Figure 1: An Virgin Resistive Capacitive Circuit

Initial voltage $V_0 = 0V$, Resistance $R = 10M\Omega$, Capacitance $C = 10\mu F$, Final voltage $V_f = 10V$.

The time constant $\tau = RC = 10M\Omega \times 10\mu F = 100s$.

Transient response:

$$v_C(t) = V_f(1 - e^{-\frac{t}{\tau}})$$

$$v_C(t) = 10V(1 - e^{-\frac{t}{100s}})$$

4.2 Circuit Two

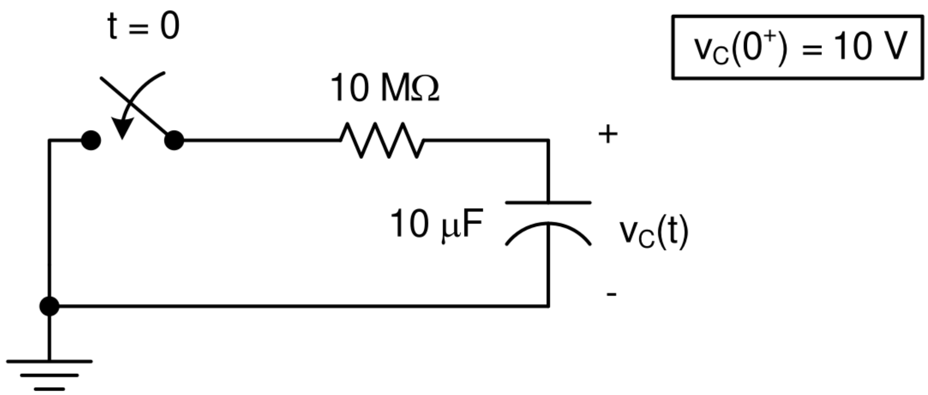

Figure 2: An Excited Resistive Capacitive Circuit

Initial voltage $V_0 = 10V$, Resistance $R = 10M\Omega$, Capacitance $C = 10\mu F$, Final voltage $V_f = 0V$.

The time constant $\tau = RC = 10M\Omega \times 10\mu F = 100s$.

Transient response:

$$v_C(t) = V_0 e^{-\frac{t}{\tau}}$$

$$v_C(t) = 10V e^{-\frac{t}{100s}}$$

4.3 Circuit Three

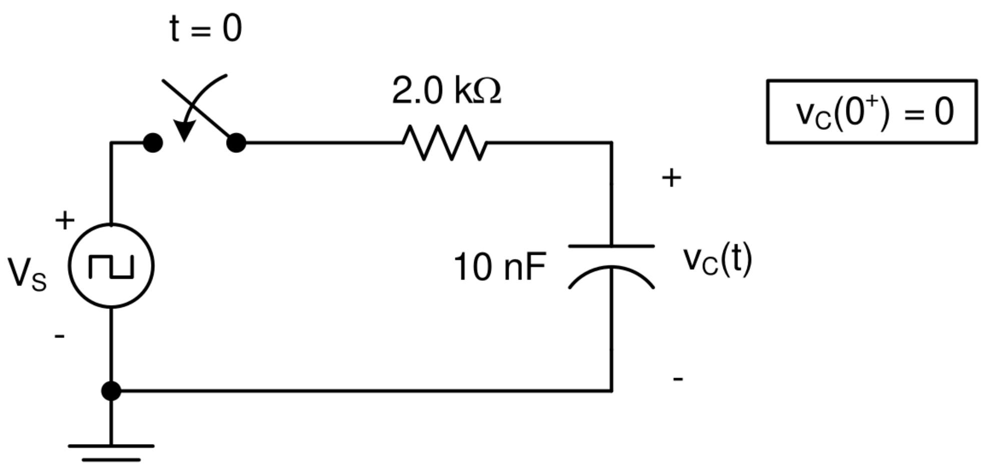

Figure 3: A Square Wave Input RC Circuit

Resistance $R = 2.0k\Omega$, Capacitance $C = 10nF$, Time Constant $\tau = 20\mu s$.

Transient response for a square wave input with $5V$ amplitude and $T = 200\mu s$:

$$v_C(t) = 5V(1 - e^{-\frac{t}{20\mu s}}) \quad \text{during charging}$$

$$v_C(t) = 5Ve^{-\frac{t}{20\mu s}} \quad \text{during discharging}$$

$V_c(0^+) = 0V$ The Time Constant, τ is calculated for this circuit.

$$\tau = RC = 10nF * 2.0k\Omega$$
$$\tau = 20\mu s$$

The time constant is then multiplied by a factor of ten to obtain the period for the input sine wave.

$$\tau \cdot 10 = T$$
$$20\mu s * 10 = 200\mu s$$

4.4 Circuit Four

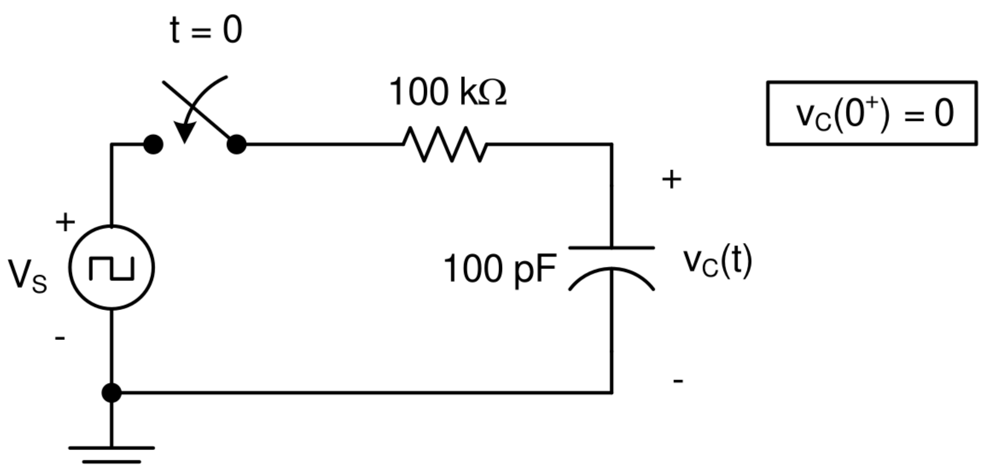

Figure 4: Circuit Three with Adjusted Components

Resistance $R = 100k\Omega$, Capacitance $C = 100pF$, Time Constant $\tau = 10\mu s$.

Transient response for a square wave input with $5V$ amplitude and $T = 100\mu s$:

$$v_C(t) = 5V(1 - e^{-\frac{t}{10\mu s}}) \quad \text{during charging}$$

$$v_C(t) = 5Ve^{-\frac{t}{10\mu s}} \quad \text{during discharging}$$

$V_c(0^+) = 0V$ The Time Constant, τ is calculated for this circuit.

$$\tau = RC = 100pF * 100.0k\Omega$$
$$\tau = 10\mu s$$

The time constant is then multiplied by a factor of ten to obtain the period for the input sine wave.

$$\tau \cdot 10 = T$$
$$10\mu s * 10 = 100\mu s$$

4.5 Circuit Five

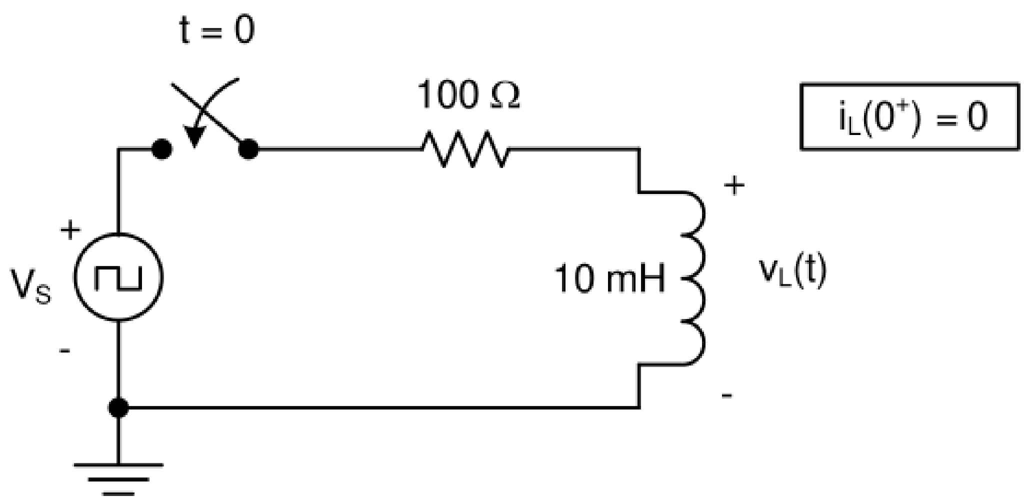

Figure 5: A Resistive-Inductive Circuit with Square Wave

Inductance $L = 10mH$, Resistance $R = 100\Omega$, Time Constant $\tau = 100\mu s$.

Transient response for a square wave input with $1V$ amplitude and $T = 1.0ms$:

$$i_L(t) = \frac{V}{R}(1 - e^{-\frac{t}{\tau}}) \quad \text{during the positive half-cycle}$$

$$i_L(t) = \frac{V}{R}e^{-\frac{t}{\tau}} \quad \text{during the negative half-cycle}$$

$I_L(0^+) = 0A$ The Time Constant, τ is calculated for this circuit.

$$\tau = \frac{L}{R} = \frac{10mH}{100\Omega}$$
$$\tau = 100\mu s$$

The time constant is then multiplied by a factor of ten to obtain the period for the input sine wave.

$$\tau \cdot 10 = T$$
$$100\mu s * 10 = 1.0ms$$

5 Results and Discussion

5.1 Circuit One: Charging Transient

Measure the transient response for the RC circuit (Figure 5-1) as described.

5.1.1 Data Table for Circuit One

Time (s)	Voltage (V)	Notes
0	0	Capacitor initially discharged
20	.751	none
30	1.05	none
60	1.595	none
90	1.937	none
120	2.12	none
150	2.20	none
180	2.26	none
210	2.29	none
240	2.31	none
270	2.32	none
300	2.33	none
330	2.33	none

5.1.2 Analysis

Question: Are the final voltage and the time constant within the expected variations due to tolerances?

Answer:

5.2 Circuit Two: Discharging Transient

Measure the discharge transient for the RC circuit (Figure 5-2).

5.2.1 Data Table for Circuit Two

Time (s)	Voltage (V)
0	2.44
30	1.83
60	1.39
90	1.05
120	0.815
150	0.636
180	0.400
210	0.387
240	0.304
270	0.239
300	0.186
330	0.148

5.2.2 Analysis

Question: Estimate the time constant from your data. Is this result expected?
Answer:

5.3 Circuit Three: Response to a Square Wave

Measure the transient response using a square wave input (Figure 5-3).

5.3.1 Oscilloscope Image

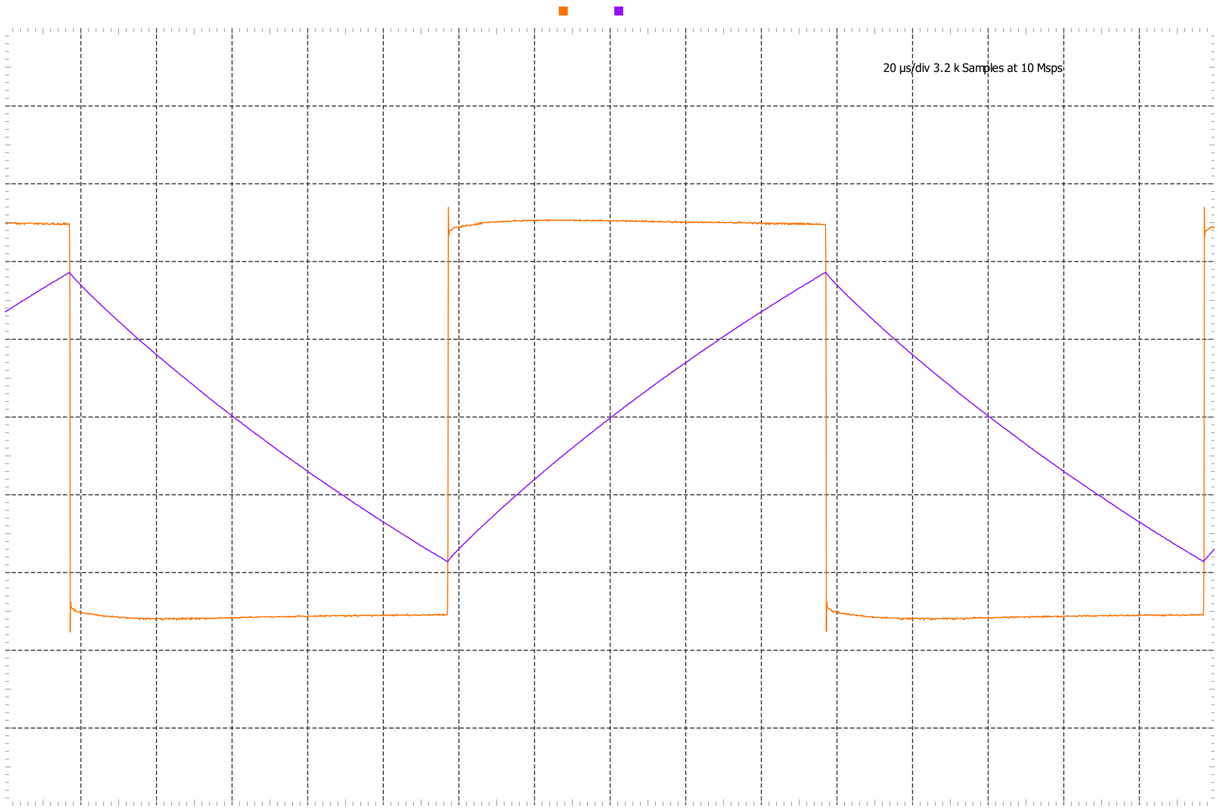

Figure 6: Oscilloscope display for Circuit Three

5.3.2 Analysis

Question: Does the experimental time constant agree with your calculations and PSpice analysis?

Answer:

5.4 Circuit Four: Square Wave Response

Repeat the measurement for Circuit Four with adjusted component values.

5.4.1 Oscilloscope Image

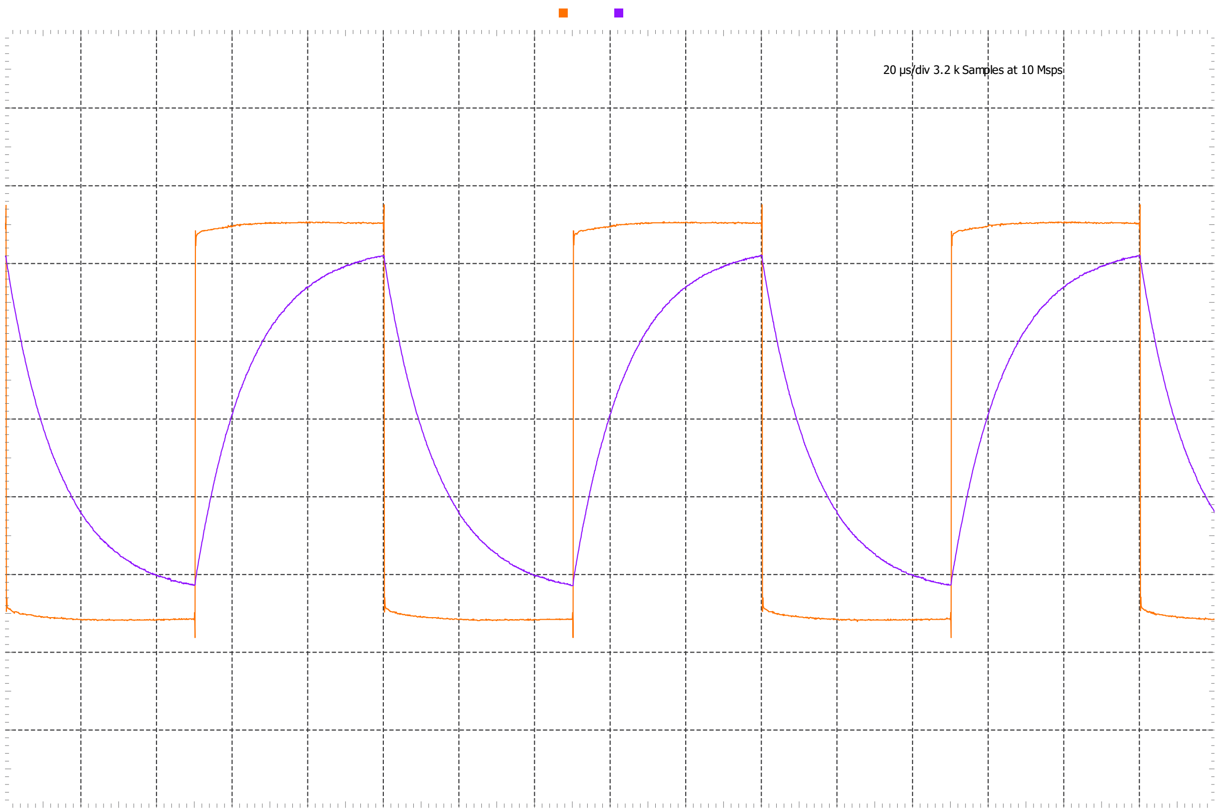

Figure 7: Oscilloscope display for Circuit Four

5.4.2 Analysis

Question: Does the experimental time constant match the calculated value?
Answer:

5.5 Circuit Five: RL Circuit Response

Measure the transient response for the RL circuit (Figure 5-5) using a square wave.

5.5.1 Oscilloscope Image

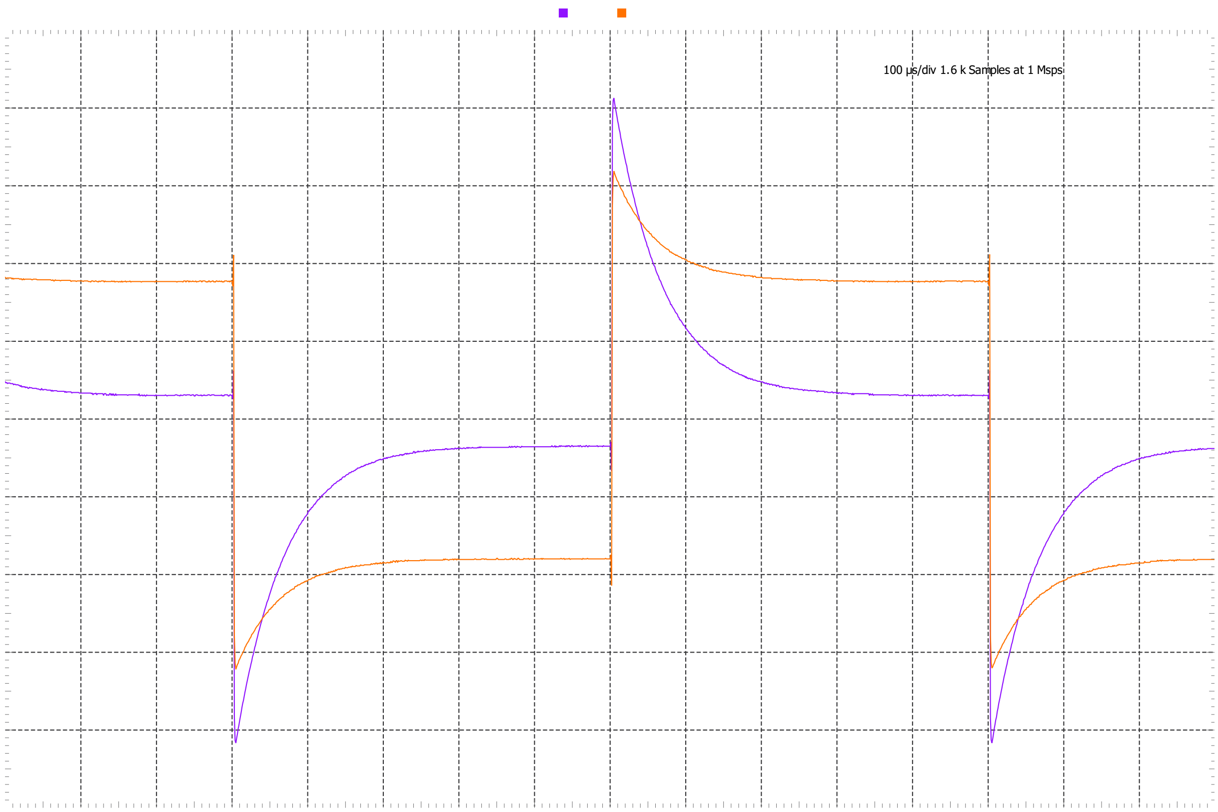

Figure 8: Oscilloscope display for Circuit Five

5.5.2 Analysis

Question: Is the transient response as expected? How does the experimental setup affect the results?

Answer:

6 Conclusion