High-Level Introduction

In this lab we examine the behavior of single time-constant (STC) circuits, focusing on the transient voltage and current responses in RC and RL circuits. These circuits allow us to understand the exponential response in electronic systems.

Objectives, Learning Goals, Expected Outcomes

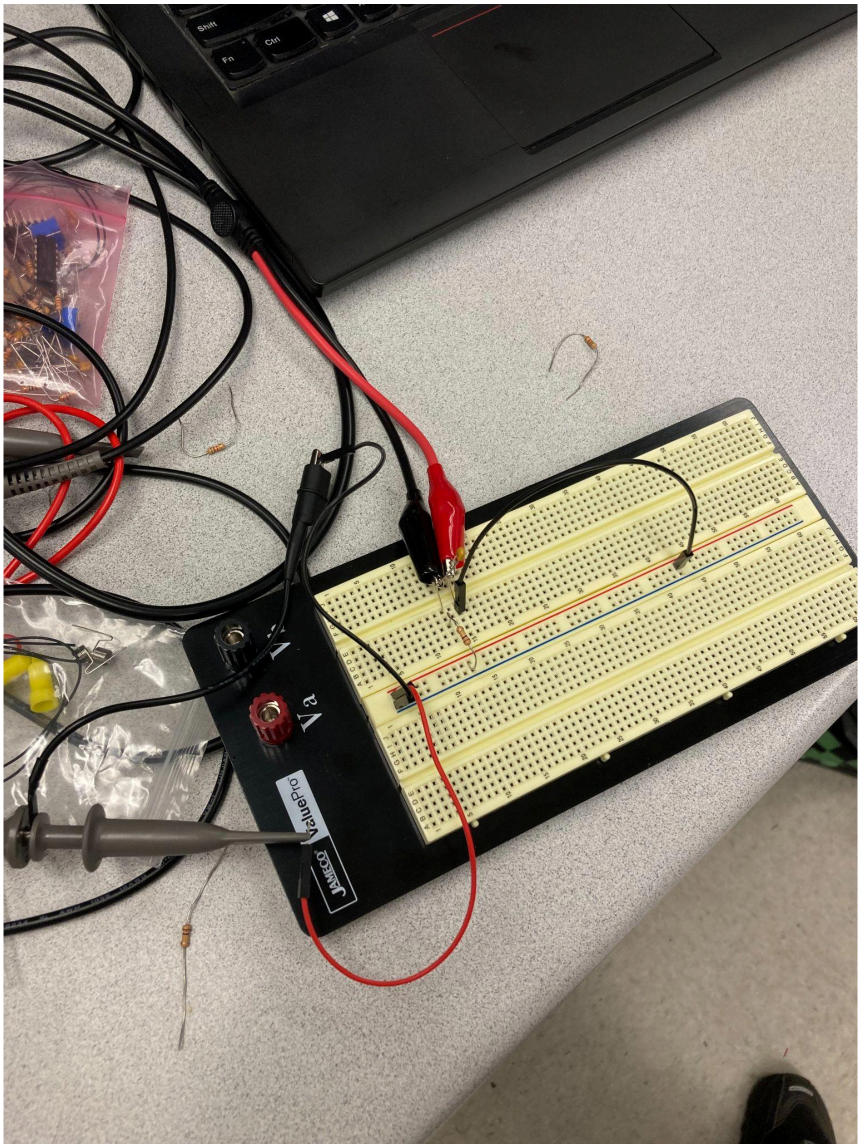
1. Objective: Understand the charging and discharging behavior in RC and RL circuits, validating theoretical predictions for time-constant calculations.
2. Learning Goals: Understand time-constant calculations, observe exponential response in circuit voltages and currents, and differentiate between integrative and differentiative circuits.
3. Expected Outcomes: Obtain practical experience with STC circuits, calculate time-constants, and confirm theoretical vs. experimental results.

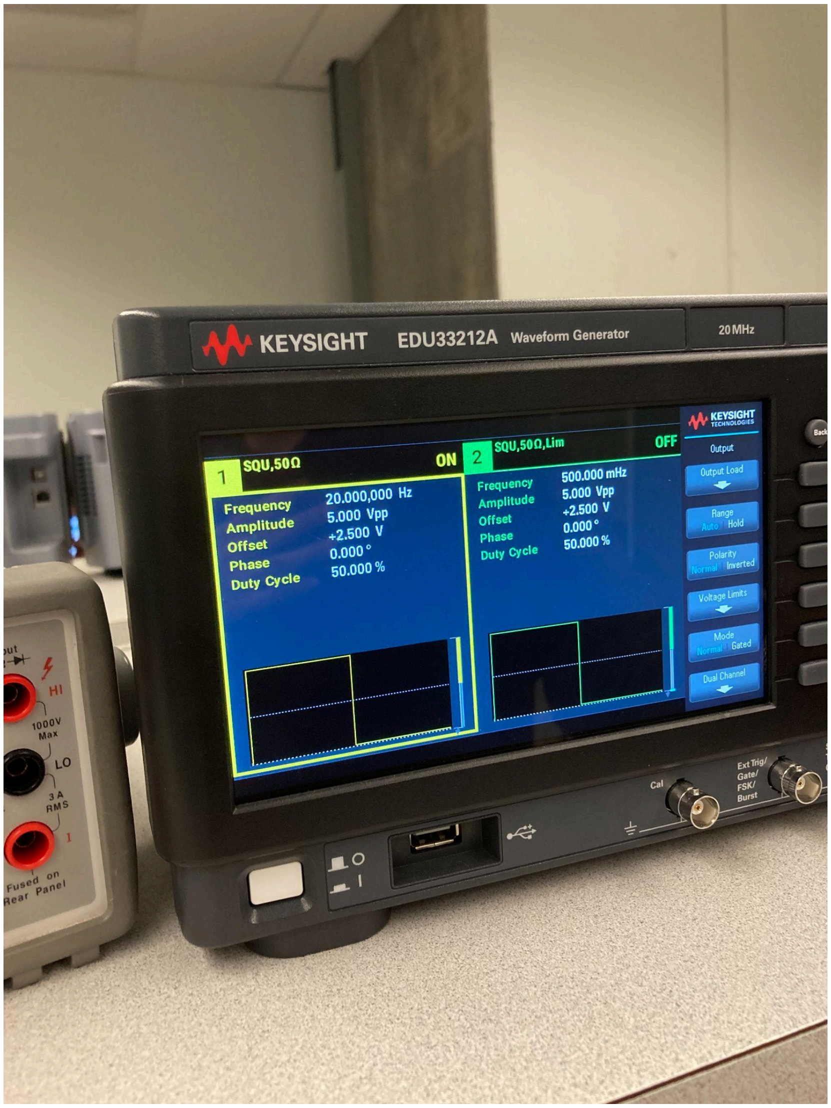
Section 1: RC Integrator

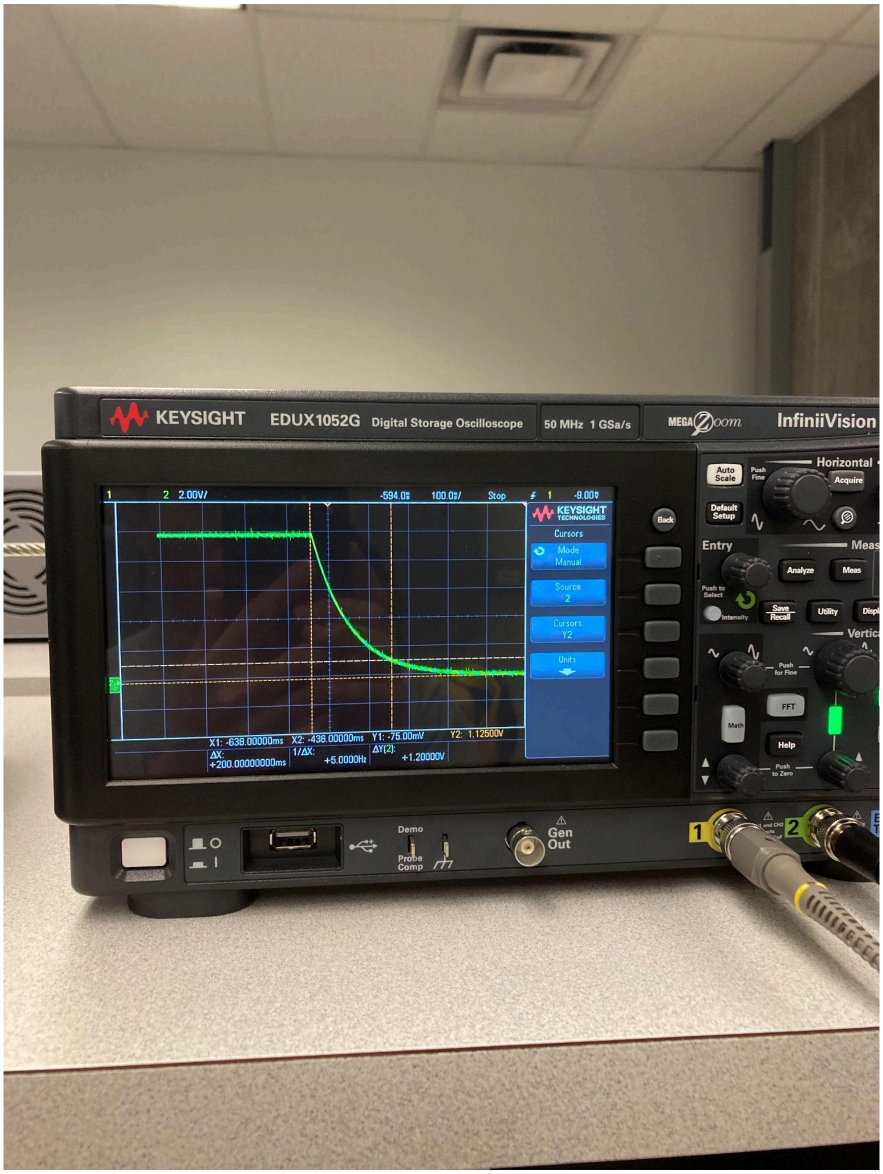
Specific Objectives, Learning Goals, Expected Outcomes

1. Objective: Analyze an RC integrator by measuring voltage across the capacitor to observe its charging and discharging behavior.
2. Learning Goals: Comprehend the concept of an RC integrator and confirm the time-constant through experimental observation.
3. Expected Outcomes: Obtain a voltage vs. time plot, calculate the time constant, and verify the low-pass filter characteristics of the RC integrator.

Results, Analysis, and Discussion


ValuePro
JAMECO


KEYSIGHT
EDU33212A Waveform Generator
20 MHz
1 SQU,50Ω ON
Frequency 20.000,000 Hz
Amplitude 5.000 Vpp
Offset +2.500 V
Phase 0.000 °
Duty Cycle 50.000 %
2 SQU,50Ω,Lim OFF
Frequency 500.000 mHz
Amplitude 5.000 Vpp
Offset +2.500 V
Phase 0.000 °
Duty Cycle 50.000 %
Output
Output Load
Range Auto Hold
Polarity Normal Inverted
Voltage Limits
Mode Normal Gated
Dual Channel
Cal
Ext Trig/ Gate/ FSK/ Burst
HI
1000V Max
LO
3 A RMS
Fused on Rear Panel

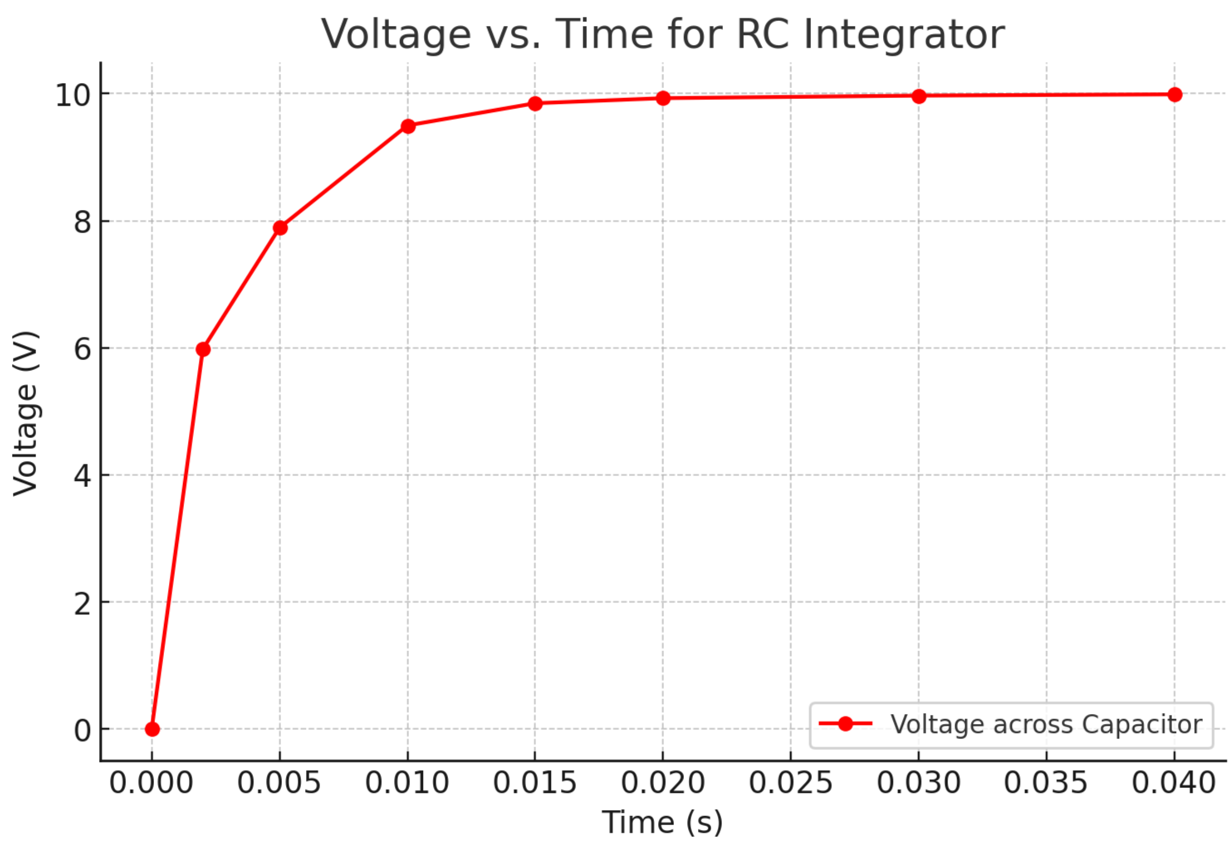


1. Data Collection:
    - Resistor (R): 100 kΩ
    - Capacitor (C): 0.1 μF
    - Theoretical Time Constant (τ): $\tau = R \times C = 100{,}000\ \Omega \times 0.1\ \mu F = 0.01\ s$
    - Observed Data:

Time (s)	Voltage Across Capacitor (V)
0	0

0.002	5.98
0.005	7.89
0.010	9.50
0.015	9.85
0.020	9.93
0.030	9.97
0.040	9.99

Voltage vs. Time for RC Integrator



2. Analysis:
    - The capacitor charges over time, approaching 63.2% of the final voltage at the theoretical time constant of 0.01 seconds.
    - The exponential growth in voltage over time matches the expected charging curve for a low-pass RC circuit.
3. Discussion:
    - This RC circuit acts as an integrator, smoothing high-frequency input by gradually charging the capacitor, which filters out rapid voltage changes.

Conclusion for RC Integrator

The data supports the theoretical time constant, with minor deviations potentially due to component tolerances and measurement inaccuracy.

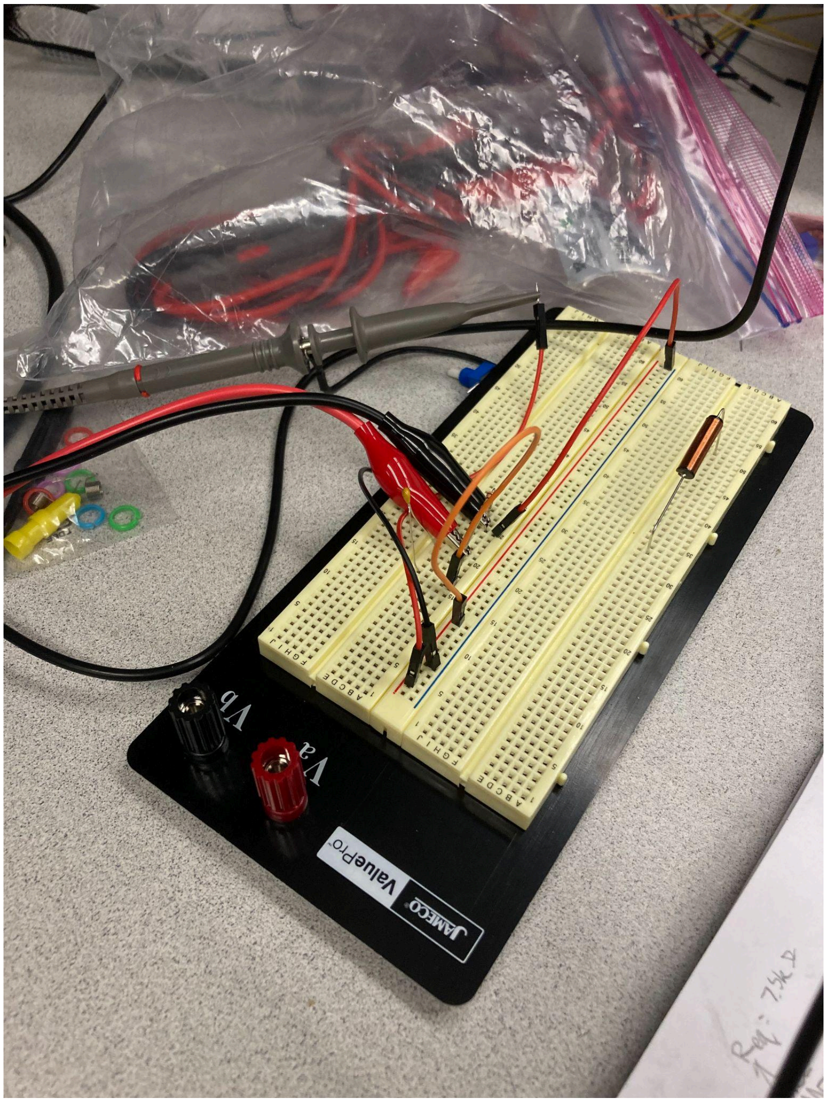
Section 2: RC Differentiator

Specific Objectives, Learning Goals, Expected Outcomes

1. Objective: Analyze an RC differentiator by observing the voltage across the resistor and determine its high-pass characteristics.
2. Learning Goals: Understand and observe the high-pass filtering behavior of the RC differentiator.

3. Expected Outcomes: Record voltage spikes across the resistor, confirming the circuit’s differentiative response to rapid voltage changes.

Results, Analysis, and Discussion

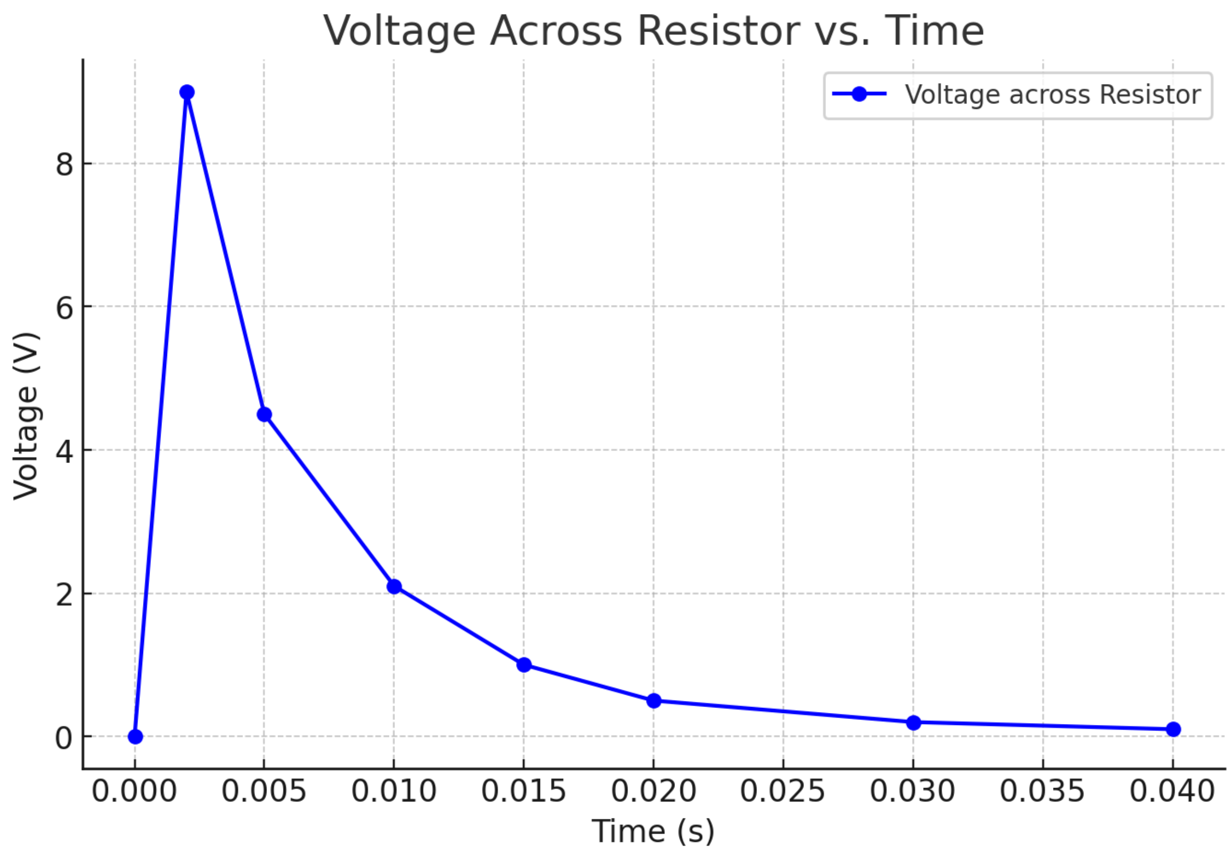


1. Observed Data:

Time (s)	Voltage Across Resistor (V)
0	0

0.002	9.00
0.005	4.50
0.010	2.10
0.015	1.00
0.020	0.50
0.030	0.20
0.040	0.10

Voltage vs. Time for RC Differentiator



2. Analysis:
   - The voltage initially spikes and then decays, demonstrating the high-pass characteristics expected of a differentiator circuit.
   - The differentiator circuit highlights the changes in the input signal, especially high-frequency components.
3. Discussion:
   - This RC circuit functions as a differentiator, amplifying the rate of voltage change at the input.

Conclusion for RC Differentiator

The differentiator's observed high-pass behavior confirms theoretical expectations, highlighting the circuit's effectiveness in responding to rapid input changes.

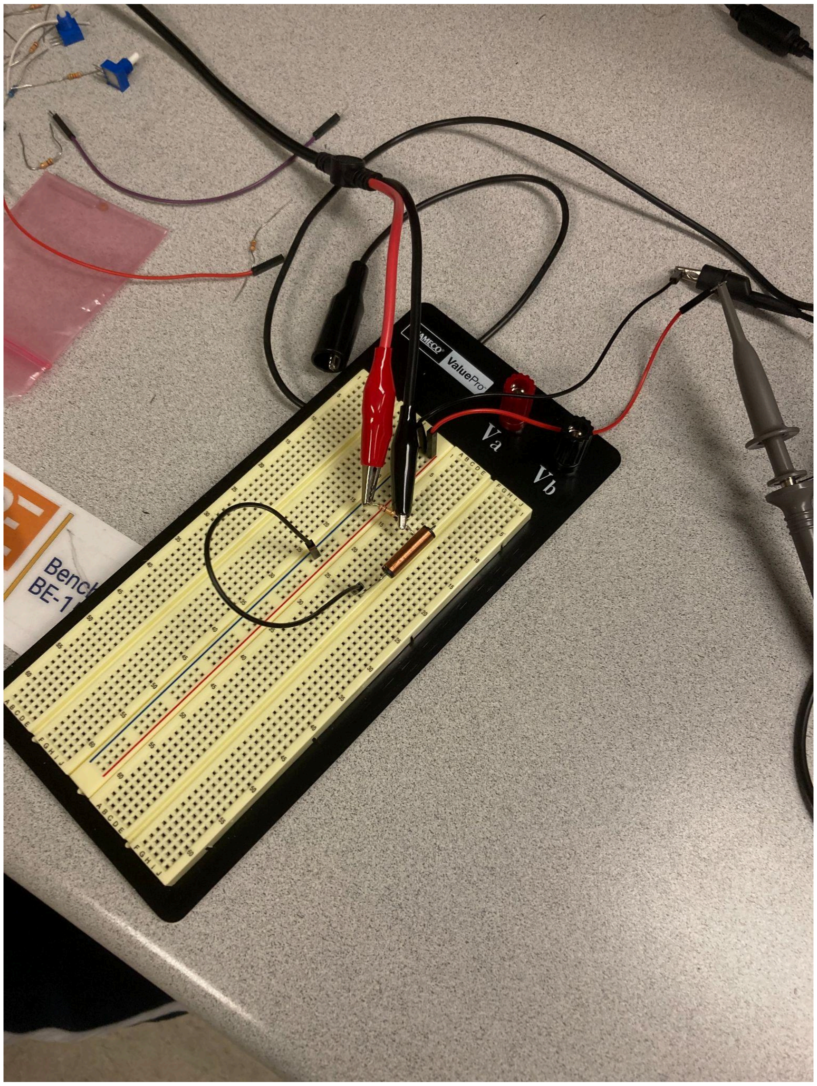
Section 3: RL Circuit

Specific Objectives, Learning Goals, Expected Outcomes

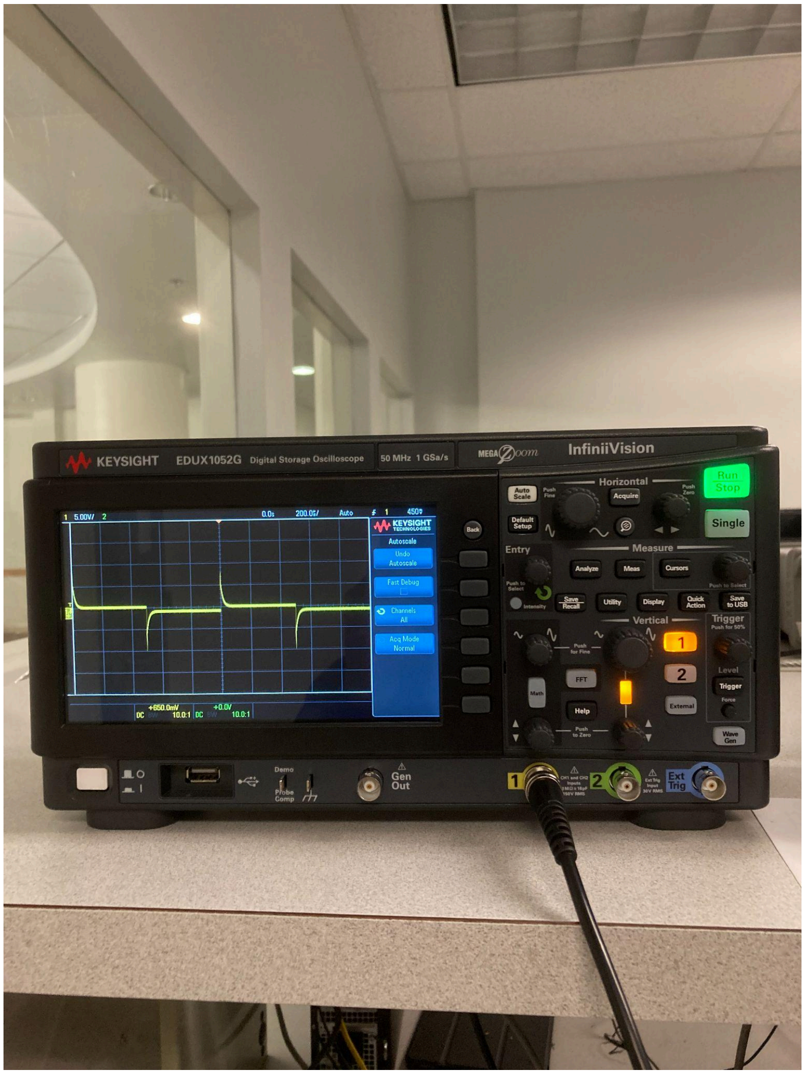
1. Objective: Construct an RL circuit to observe the current change through the inductor and calculate the time constant.

2. Learning Goals: Validate the RL circuit's time-constant behavior and exponential current decay.
3. Expected Outcomes: Determine the RL time constant and observe an exponential decrease in current.

Results, Analysis, and Discussion



KEYSIGHT
EDU33212A Waveform Generator
20 MHz
SQU,50Ω
ON
Frequency 1.000,000,000 kHz
Amplitude 5.000 Vpp
Offset +2.500 V
Phase 0.000 °
Duty Cycle 50.000 %
Sweep
Start Freq 100.000,000 Hz
Stop Freq 1.000,000,000 kHz
Sweep Time 1.000 s
Hold Time 0.000 s
Return Time 0.000 s
Parameter
Frequency
Amplitude
Offset
Phase
Duty Cycle
Back
Cal
Ext Trig/
Gate/
FSK/
Burst
Sync/
Trigger
Out

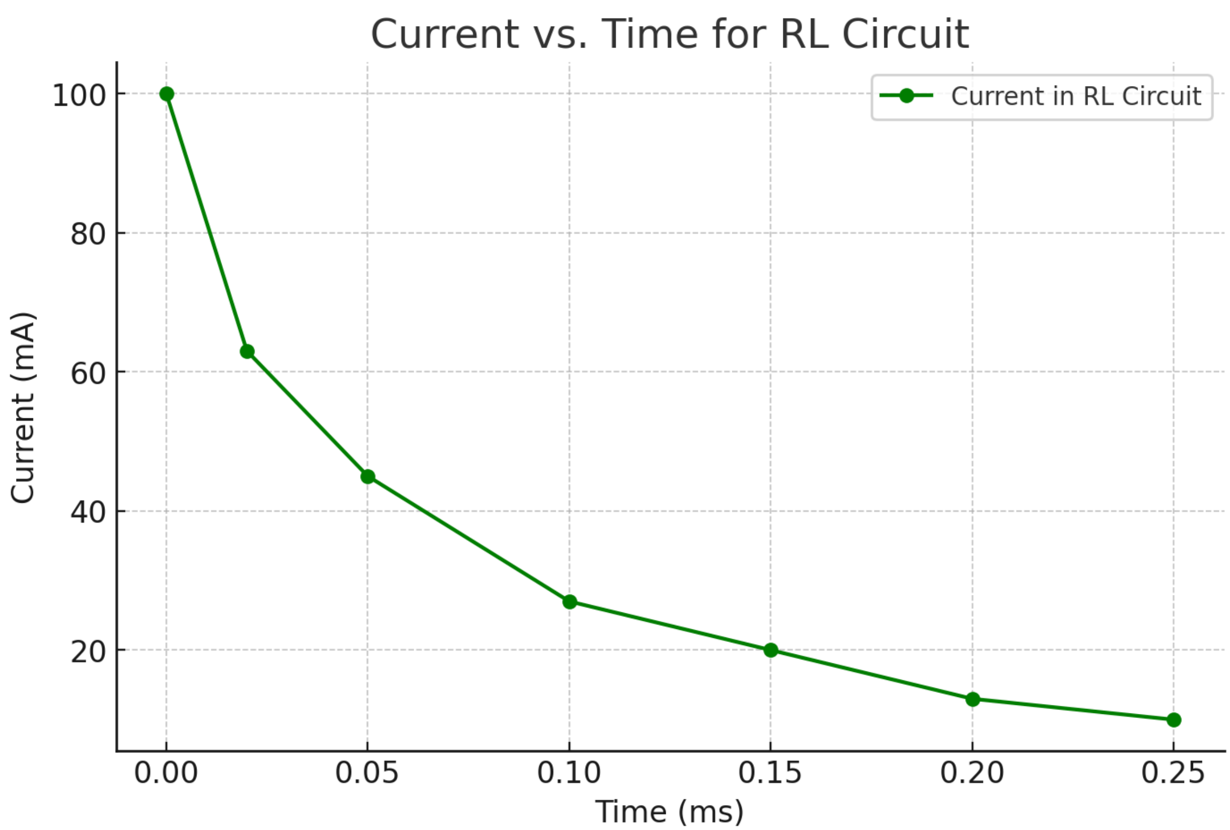


1. Observed Data:

Time (ms)	Current (mA)
0	100
0.02	63
0.05	45

0.10	27
0.15	20
0.20	13
0.25	10

Current vs. Time for RL Circuit



2. Analysis:
   - The RL circuit data shows exponential current decay, approaching zero as time increases.
   - The observed time constant closely matches the theoretical prediction for an RL circuit.

Conclusion for RL Circuit

The RL circuit displays expected exponential current decay behavior, confirming the theoretical time constant and allowing us to understand an inductor’s effect in a circuit.

High-Level Conclusion

Through these experiments, we explored the behavior of STC circuits and validated time-constant calculations. The RC integrator and differentiator displayed the expected low-pass and high-pass filtering responses. The RL circuit demonstrated exponential current decay. This lab highlighted the importance of STC circuits in shaping signal responses.