# Experiment 16

Sunday, January 29, 2023 3:32 PM

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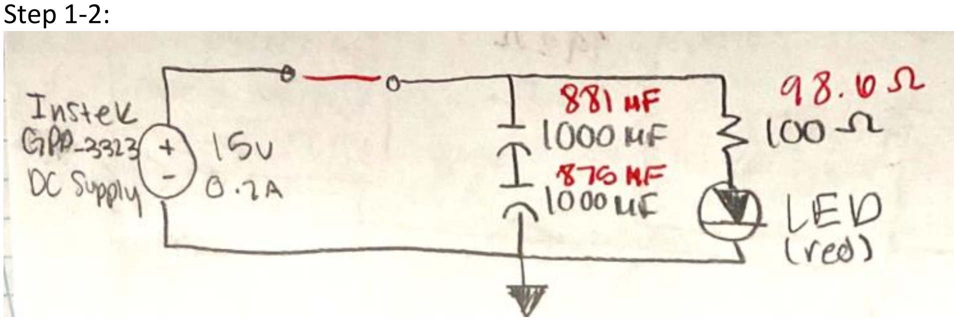
**Objectives:**
1. Demonstrate the storage capability of a capacitor.
2. Calculate and measure time constants in capacitor charge/discharge circuits.
3. Demonstrate the characteristics of a supercapacitor.

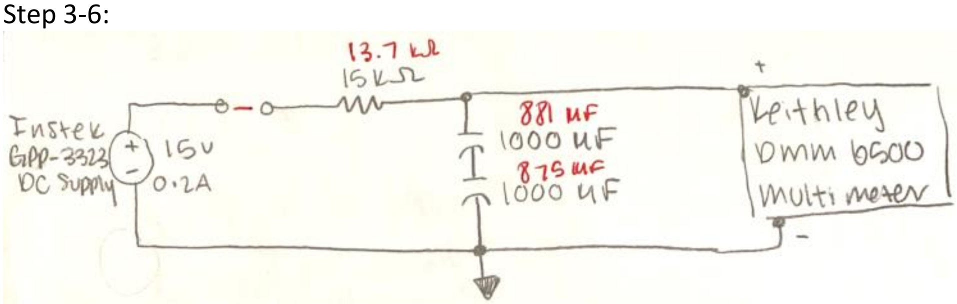
**Pre-Lab Information:**
- CAPACITOR POLARITY MATTERS
- Steady State = 5$\tau$ (time constant)
- $\tau$ = RC
- Charging Equation for voltage drop over C:
  $v(t) = V_{ss}(1 - e^{-\frac{t}{\tau}})$ where τ = RC and Vss = steady state
- Discharging Equation for voltage drop over C:
  $v(t) = V_0(e^{-\frac{t}{\tau}})$ where τ = RC and V0 = initial voltage

**Procedure:**
- Step 1-2:




When the hookup wire is only connected to the capacitor, nothing happens. When the hookup wire is connected to both the capacitor and the LED/resistor, it lights to yellow for a fraction of a second then quickly turns on to a constant orange light. When the supply is turned off, the light fades to yellow (noticeably slower than when turned on) and then turns off

- Step 3-6:

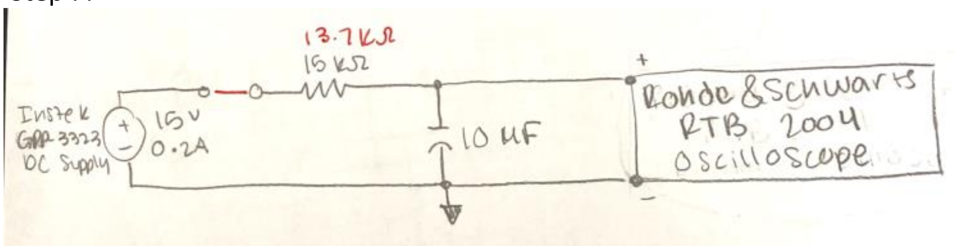



Charging Capacitor:

$$v(t) = V_{ss}\left(1 - e^{-\frac{t}{\tau}}\right)$$
$$v(\tau) = V_{ss}\left(1 - e^{-\frac{\tau}{\tau}}\right)$$
$$v(\tau) = 15\left(1 - e^{-1}\right)$$
$$v(\tau) = 9.48\ V$$

| $\tau$ [s] (theoretical) | $\tau$ [s] (real) | $5\tau$ [s] (real) |
|---|---|---|
| 7.5 (ideal) | 7.60 | 48.98 |
| 6.01 (actual) | 7.55 | 44.33 |
| | 7.49 | 44.65 |

- Step 7:

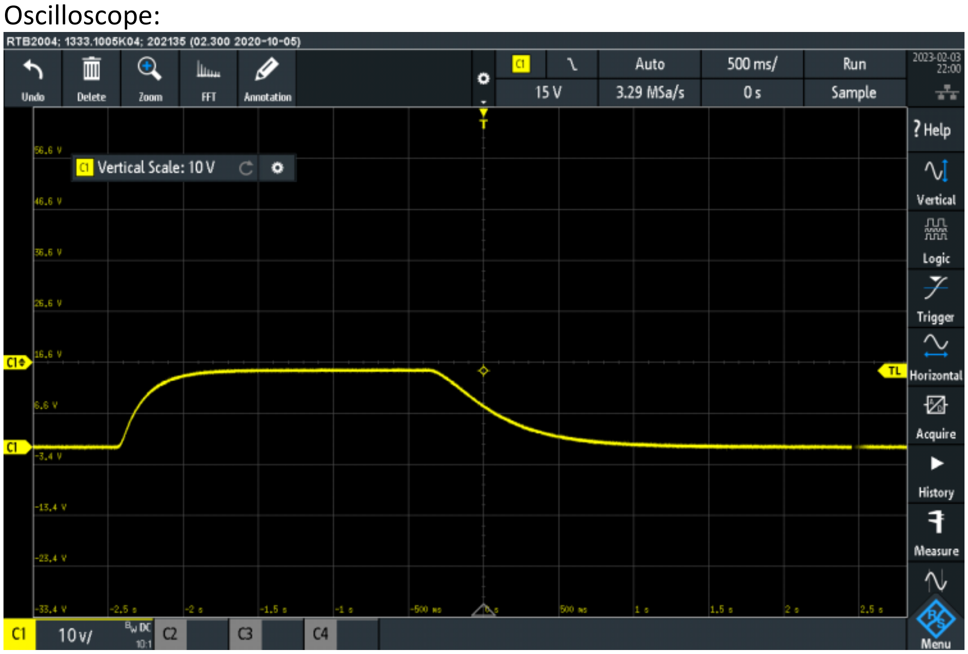



<u>Charging Capacitor:</u>

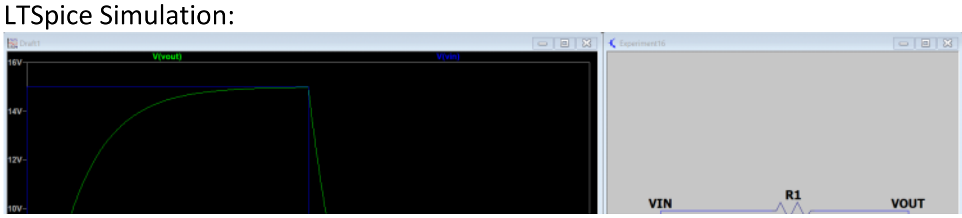
$v(t) = V_{ss}\left(1 - e^{-\frac{t}{\tau}}\right)$
$v(\tau) = V_{ss}\left(1 - e^{-1}\right)$
$v(\tau) = 15\left(1 - e^{-1}\right)$
$v(\tau) = 9.48\ V$

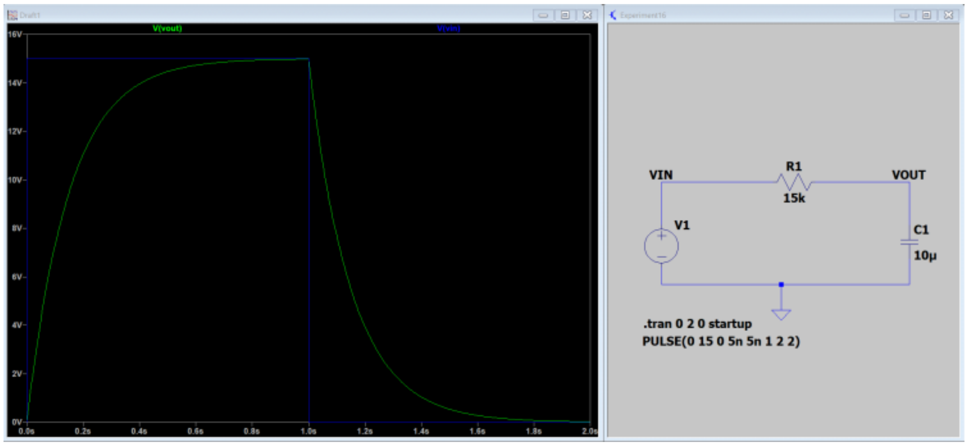
| $\tau$ [ms] (theoretical) | $\tau$ [ms] (real) | $5\tau$ [ms] (real) |
|---|---|---|
| 150 (ideal) | 115 (LTSpice) | 929 (LTSpice) |
| 137 (actual) | 210 (measured) | 850 (measured) |

Oscilloscope:



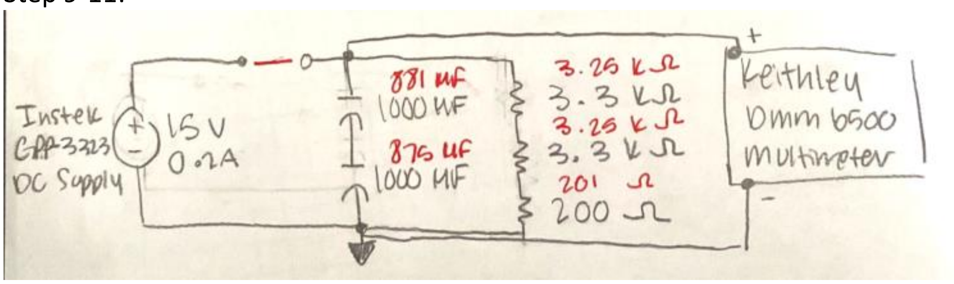

LTSpice Simulation:






- Step 8: A decrease in resistance would result in a smaller time constant, which means a shorter amount of time for the capacitor to charge and discharge.

- Step 9-11:



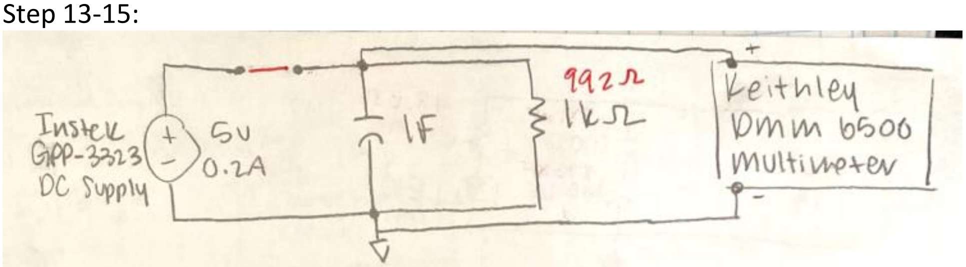

<u>Discharging Capacitor:</u>

$v(t) = V_0\left(e^{-\frac{t}{\tau}}\right)$
$v(\tau) = 15(e^{-1})$
$v(\tau) = 5.18\ V$

| $\tau$ [s] (theoretical) | $\tau$ [s] (real) | $5\tau$ [s] (real) |
|---|---|---|
| 3.4 (ideal) | 4.08 | 25.87 |
| 2.94 (actual) | 4.24 | 24.84 |
| | 4.15 | 24.71 |

- Step 12:
  An increase in capacitance would result in a larger time constant, which means a longer amount of time for the capacitor to charge and discharge.

- Step 13-15:



Charging Capacitor:

$v(t) = V_{ss}\left(1 - e^{-\frac{t}{\tau}}\right)$
$v(\tau) = V_{ss}\left(1 - e^{-1}\right)$
$v(\tau) = 5\left(1 - e^{-1}\right)$
$v(\tau) = 3.16\ V$

| $\tau$ [s]<br>(theoretical) | $\tau$ [s]<br>(real) | $5\tau$ [s]<br>(theoretical) |
|---|---|---|
| 1000 (ideal) | 1060.61 | 5303.05 (actual) |
| 992 (actual) | | 5599.75 (measured) |

Discharging Capacitor:

$v(t) = V_0\left(e^{-\frac{t}{\tau}}\right)$
$v(\tau) = 5\left(e^{-1}\right)$
$v(\tau) = 1.16\ V$

| $\tau$ [s]<br>(theoretical) | $\tau$ [s]<br>(real) | $5\tau$ [s]<br>(theoretical) |
|---|---|---|
| 1000 (ideal) | 1119.95 | 5303.05 (actual) |
| 992 (actual) | | 5599.75 (measured) |

**Questions:**

1. A supercapacitor makes a good replacement for a(n) _______________ for some high-resistance, low-current circuits.
 - Battery

2. What would be the capacitance and voltage rating of two 1-F, 5.5-V supercapacitors in series?

$$C_{eq} = \frac{C_1 * C_2}{C_1 + C_2} = \frac{1 * 1}{1 + 1}$$
$$C_{eq} = 0.5\ F$$

$$V_{eq} = V_1 + V_2 = 5.5 + 5.5$$
$$V_{eq} = 11\ V$$

3. Write the formulas for the charge and discharge curves of an RC circuit.

$Charge{:}\ v(t) = V_{ss}(1 - e^{-\frac{t}{\tau}})$ where τ = RC and Vss = steady state

$Discharge{:}\ v(t) = V_0(e^{-\frac{t}{\tau}})$ where τ = RC and V0 = initial voltage