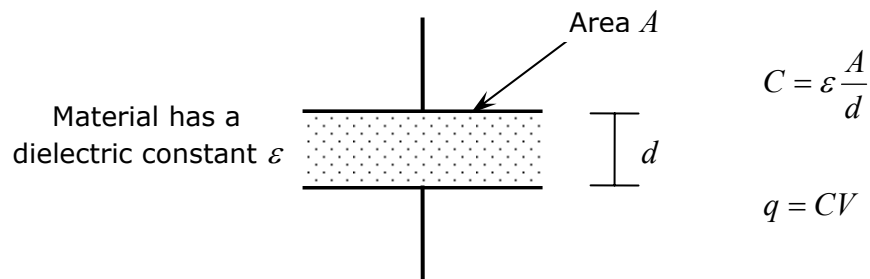


SP.764, Practical Electronics  
Dr. James A. Bales  
**Lecture 4: RC Circuits**

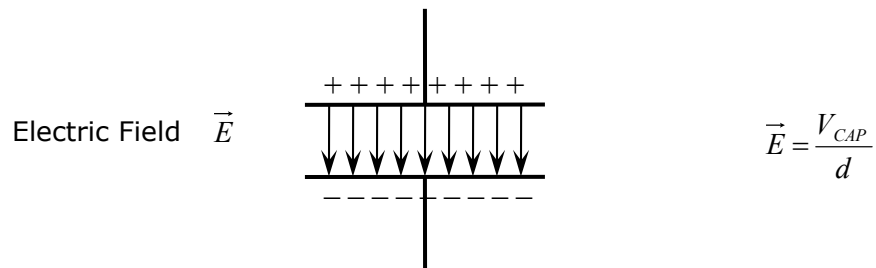
**Topics:**

- 1) RC circuit review
- 2) Equations for RC
- 3) Time Response of RC circuits
- 4) RC Filters

Question: What factors contribute to the capacitance of a capacitor?



If  $d$  becomes smaller, the capacitance goes up. Therefore, the capacitor can store more charge.



For a given voltage, if one makes the separation  $d$  smaller, the electric field  $E$  increases. Why is this a problem? If the electric field gets too large, the insulator breaks down. A small spark will jump between plates and short the capacitor, which will not work anymore.

In summary, if  $V$  gets too large or  $d$  gets too small, the dielectric material will “breakdown” and destroy the capacitor. In some cases the capacitor “pops”, or may not act properly anymore.

A capacitor is specified by:

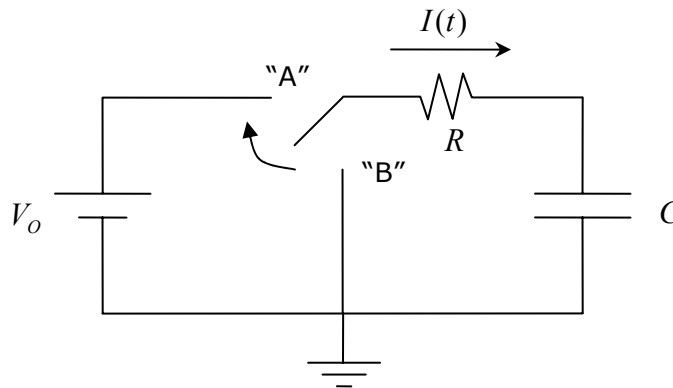
- Capacitance value
- Maximum voltage across capacitor
- Polarized or non-polarized.

What is polarized?

- Polarized capacitors are marked with “+” lead and “-” lead.
- If the positive and negative leads are connected the wrong way, the capacitor can blow up.

If one is working with high voltages, then one would want to keep electric field small by putting plates apart, but one would lose some capacitance.

**RC circuit review:**



Move switch from “A” to “B” at time  $t = 0$ .

$$V_{CAP}(t) = V_0 \left( 1 - e^{-\frac{t}{RC}} \right) , \quad I(t) = \frac{V_0}{R} e^{-\frac{t}{RC}}$$

RC = time constant

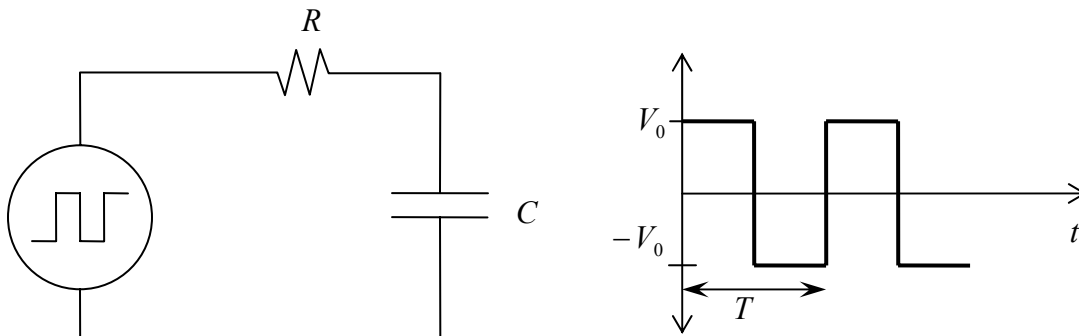
$$[\text{OHM}][\text{FARAD}] = [\text{SEC}]$$

The current  $I(t)$  starts at peak value  $V_0/R$ , and then drops off and dies out exponentially. The voltage across the capacitor  $V_{CAP}(t)$  starts at 0, goes up rapidly, and asymptotically approaches  $V_0$ .

### Time Response of RC circuits:

RC circuits can do interesting things. Consider the following example:

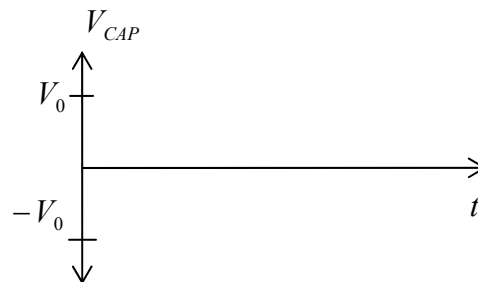
Problem: A square wave that goes between  $\pm V_0$  with period  $T$  is applied to the following RC circuit.



Question: Complete the following graphs.

Plot  $V_{CAP}(t)$  for:

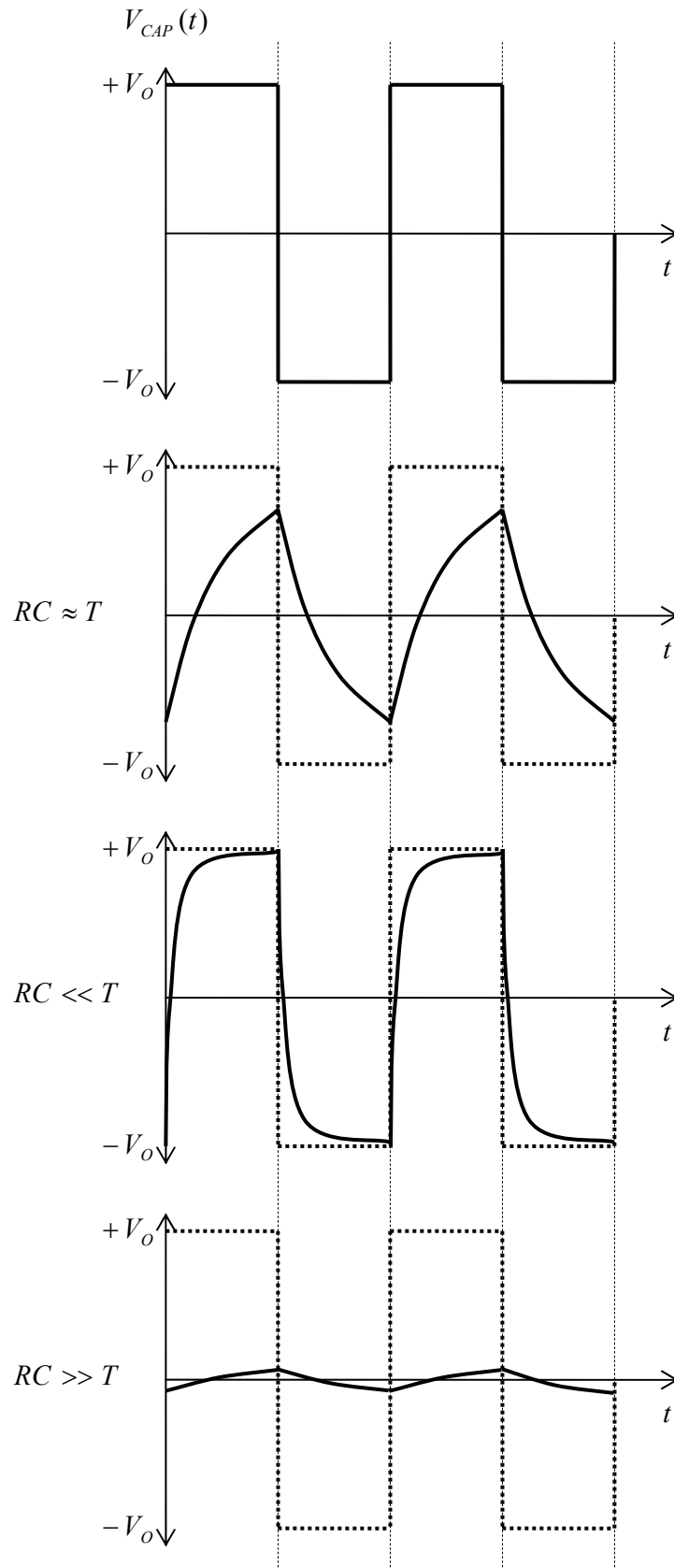
1.  $RC \approx T$
2.  $RC \ll T$
3.  $RC \gg T$



Hint:  $e^{-1} = 1/3$

Solution:

Assume that the square wave signal has been "ON" for a long period of time. At least one knows  $V_{CAP}(t)$  will range between  $+V_0$  and  $-V_0$  (but will never reach those voltages).



## RC Filters:

### Swing analogy

If one pushes a person sitting in a swing slowly, the person swings smoothly, so the swing works fine. However, if one starts pushing too many times per second, the swing barely moves at all.

The performance of the swinging motion depends on the frequency at which the person is pushing the swing. Frequency is just the inverse of the period  $T$ ,

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

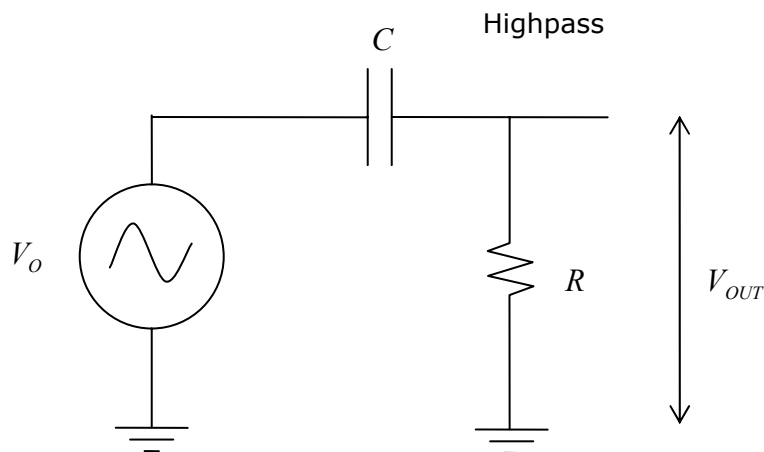
When  $RC \ll T \rightarrow f$  is "small" or "LOW"  
(Signal gets through)

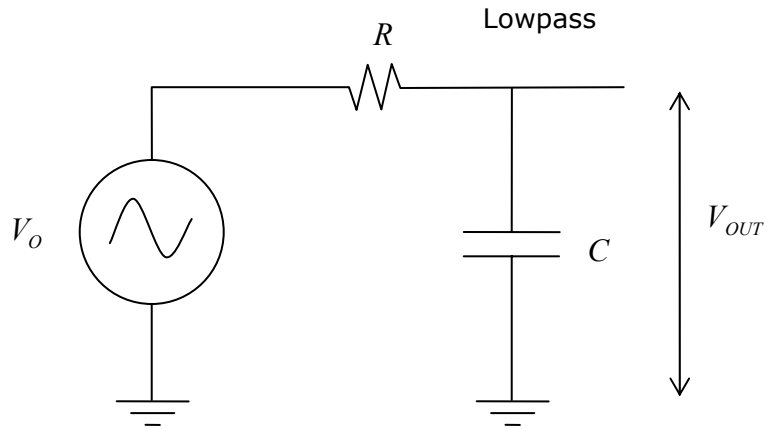
When  $RC \gg T \rightarrow f$  is "HIGH"  
(Signal is blocked)

IF  $RC \ll T$ , SIGNAL PASSES

→ LOWPASS FILTER

On the upcoming Lab 5, groups will build one either a highpass or lowpass filter circuit with one of the RC values listed below, and measure plot the voltage gain at each of the frequencies listed below.





Plot  $\frac{V_{OUT}}{V_o}$  vs. Frequency

$3Hz$	$300Hz$	$30kHz$
$10Hz$	$1kHz$	$100kHz$
$30Hz$	$3kHz$	$300kHz$
$100Hz$	$10kHz$	

$RC = 10ms \quad 1ms \quad \text{or} \quad 0.1ms$

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