Today: More Electronics

- Capacitors and Capacitance
- Resistive-Capacitive Circuits
- Diodes

Administrivia

- Lab:
  - Full hours
  - Please be conscious of others needing to use the machines
  - VT 220s are also available for testing purposes
  - CTR-ALT-F1 (2,3,4,5) will give you an independent text terminal in linux (we are working on getting additional X servers up too)

Administrivia II

- RS232 connections: depending upon the machine and the cable you use, you many need to swap pins 2 and 3 on the serial connector
- There is an RS232 tester available in the lab. Look for both the TD (transmit) and RD (lights) to come on when everything is connected correctly

Administrivia III

- Lecture:
  - Make sure to read DEH Chapter 2
  - Thursday: Meet in CS 144
  - Next Tuesday: DEH Chapter 4
- Homework:
  - Homework 1 has been posted to the web site

  Due: Tuesday, October 14th in class

Sensor of the Day...

Sensor of the Day...

The Force-Sensitive Resistor (FSR)

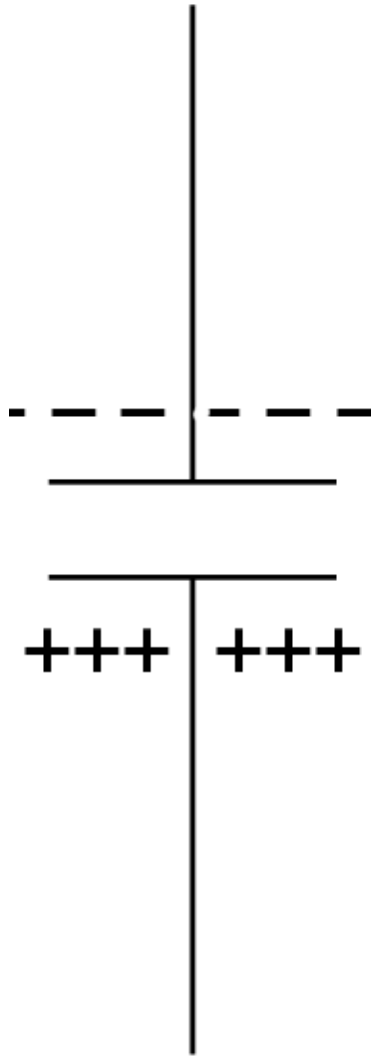
- Resistance changes as you compress the material
- Use these as you would the CDS cells
- Right now, there is only one in the lab (we will acquire more shortly)

Recall ...

- The charge (Q) that is stored in a capacitor is related to its **capacitance** (C) and the voltage across the capacitor:

$$Q = C\,V$$

- C is in units of **Farads**



What is the Current Flow Across a Capacitor?

What is the Current Flow Across a Capacitor?

- Remember that current flow is the movement of (positive) charge per unit time.

  In math this is:

$$I = \frac{dQ}{dt}$$

What does this mean for capacitors?

Current Flow Into a Capacitor

- Start with:

$$Q = C\,V$$

- And take the temporal derivative of both sides:

$$\frac{d\,Q}{d\,t} = C\,\frac{d\,V}{d\,t}$$

- So the current flow into a capacitor is related to the change of voltage:

$$I = C\,\frac{d\,V}{d\,t}$$

Current Flow

What happens when there is no change in voltage?

Current Flow

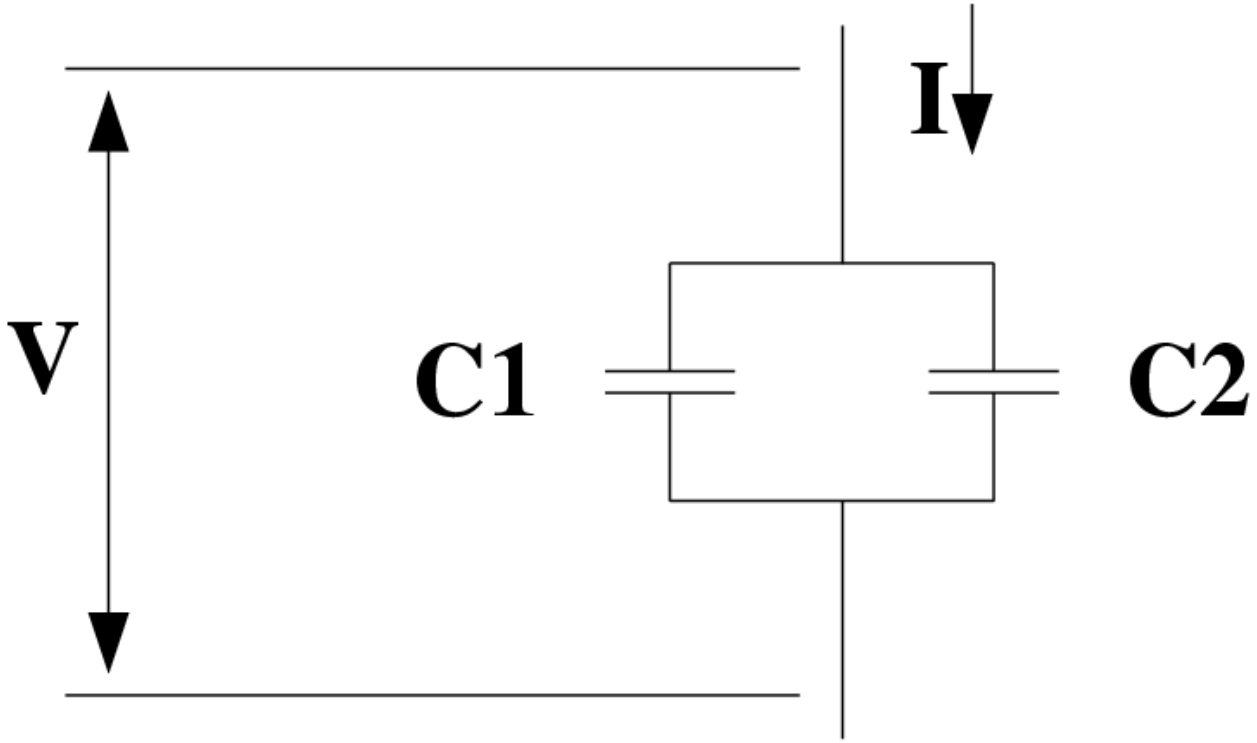
What happens when there is no change in voltage?

- There is no current flow!

Capacitors In Parallel

What is the current flow across each capacitor?

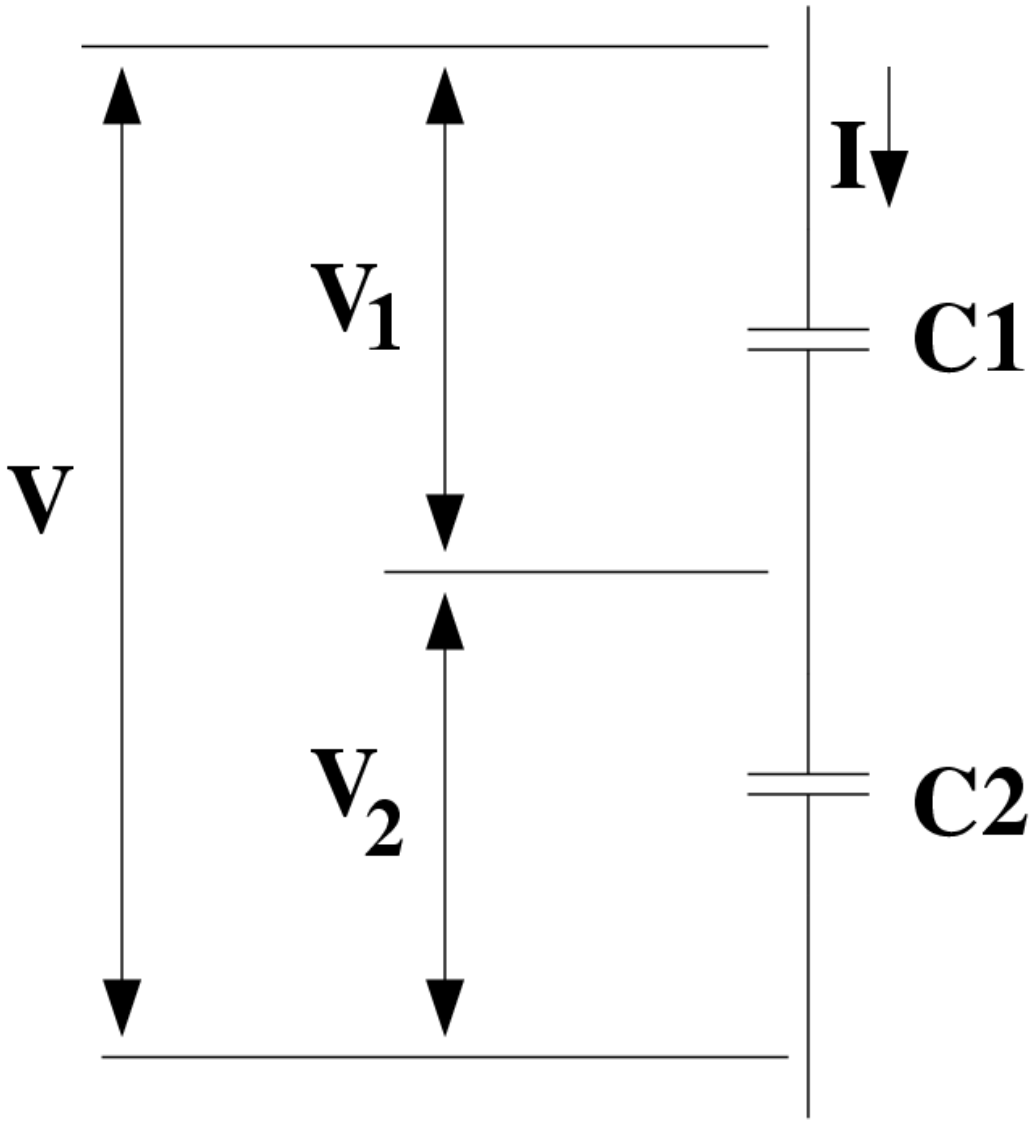
What is the effective capacitance?



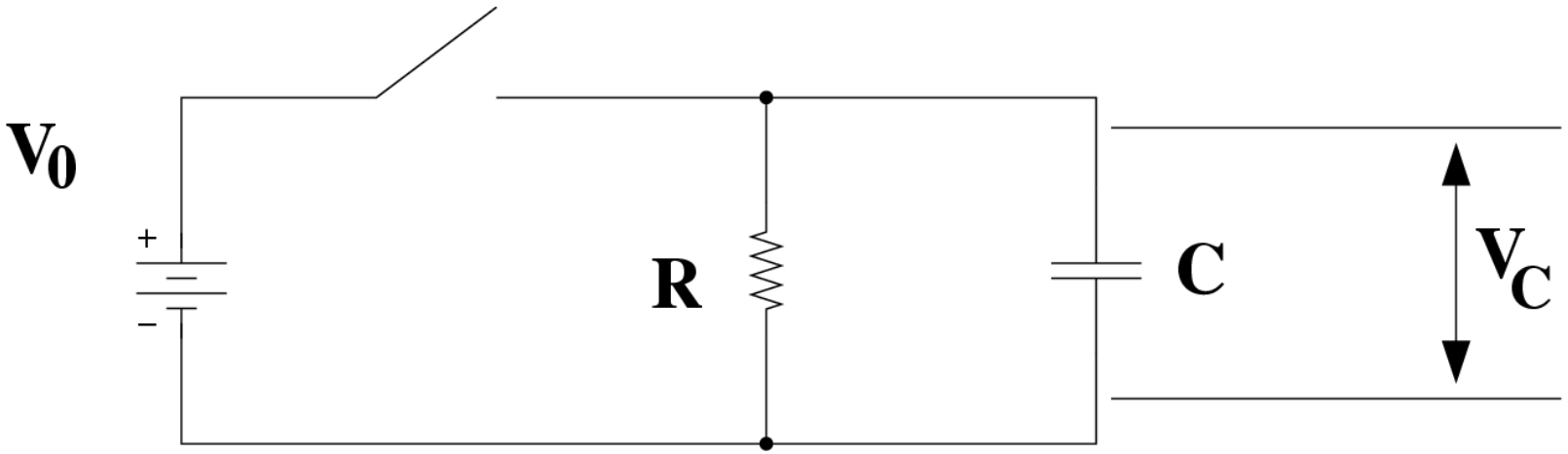
Capacitors in Series

What is the current flow across each capacitor?

What is the effective capacitance?

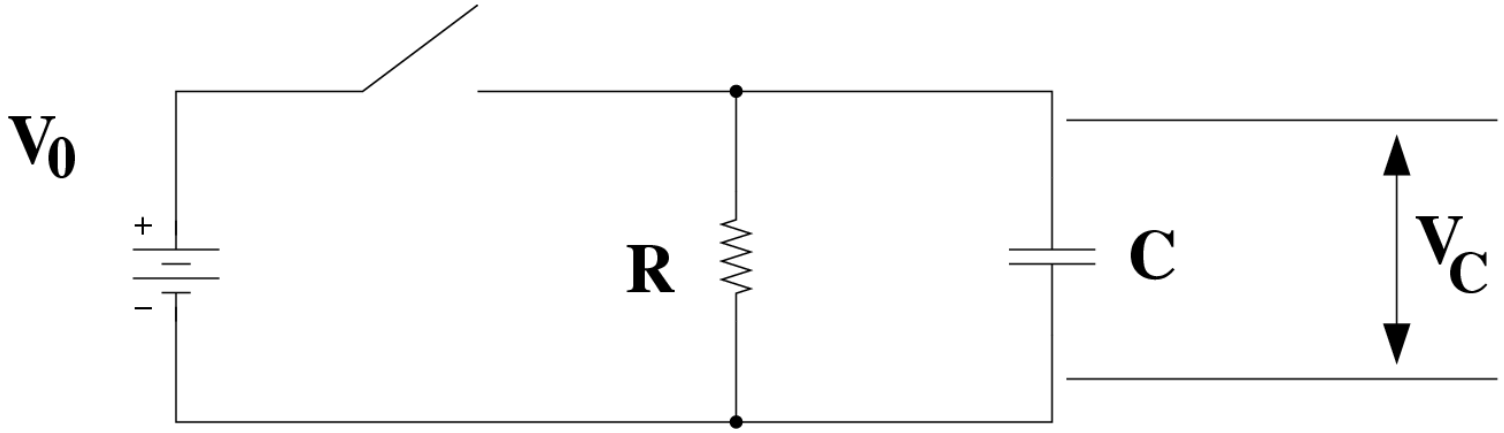


Parallel Resistive-Capacitive Circuits



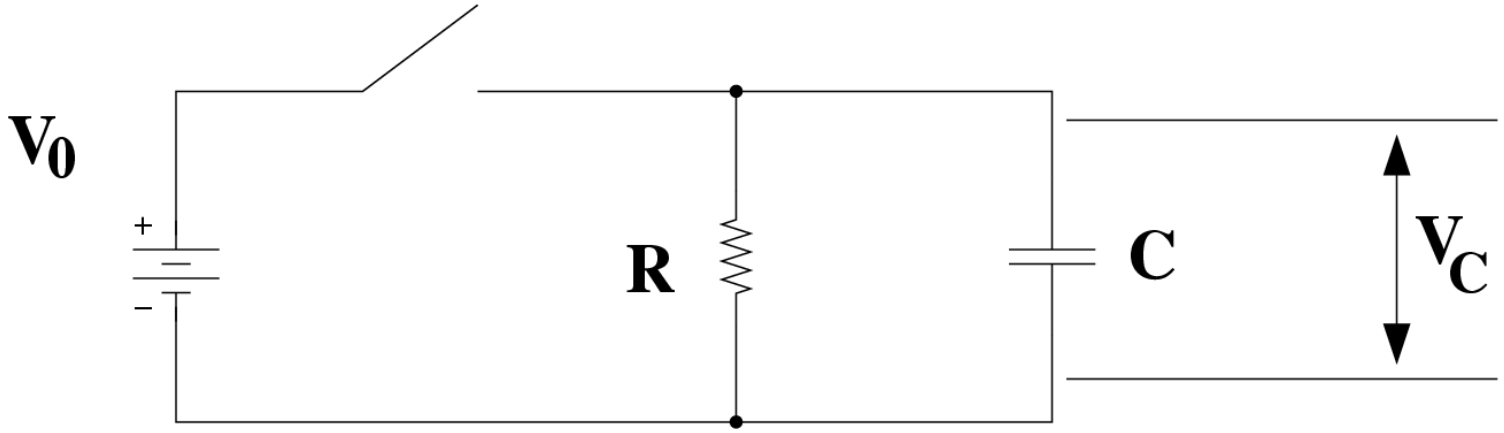
- Note the battery symbol. What does it mean?
- In general what is the voltage across the resistor?

Parallel Resistive-Capacitive Circuits



- Note the battery symbol. What does it mean?
  - The battery produces a potential difference between the positive and negative terminals
- In general what is the voltage across the resistor?
  - V_C also
- For the current state of the switch what is V_C?

Parallel Resistive-Capacitive Circuits

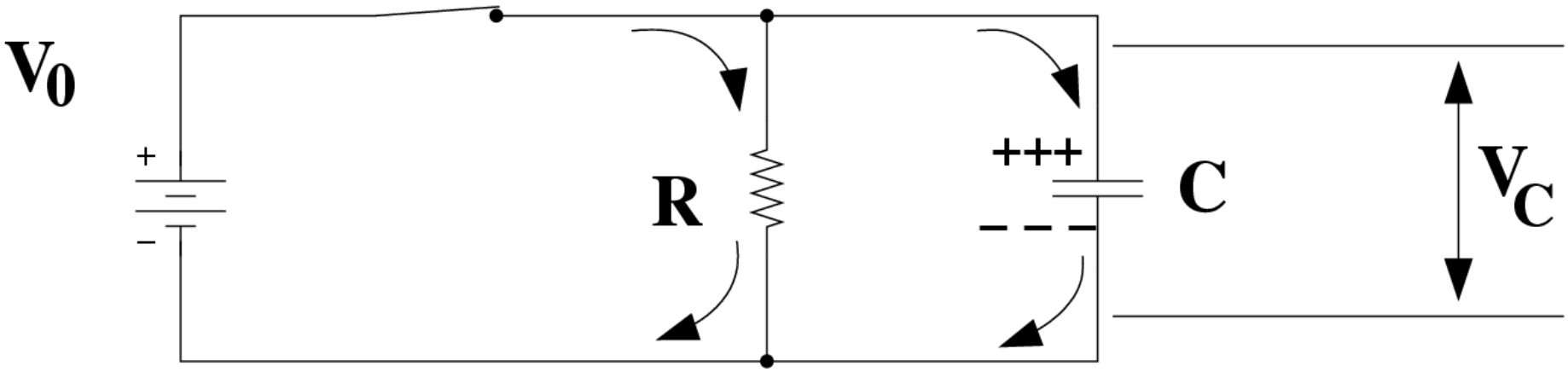


- For the current state of the switch what is V_C?
  - Assume that we have waited for a long time...
  - $V_C = 0$

Parallel R-C Circuits

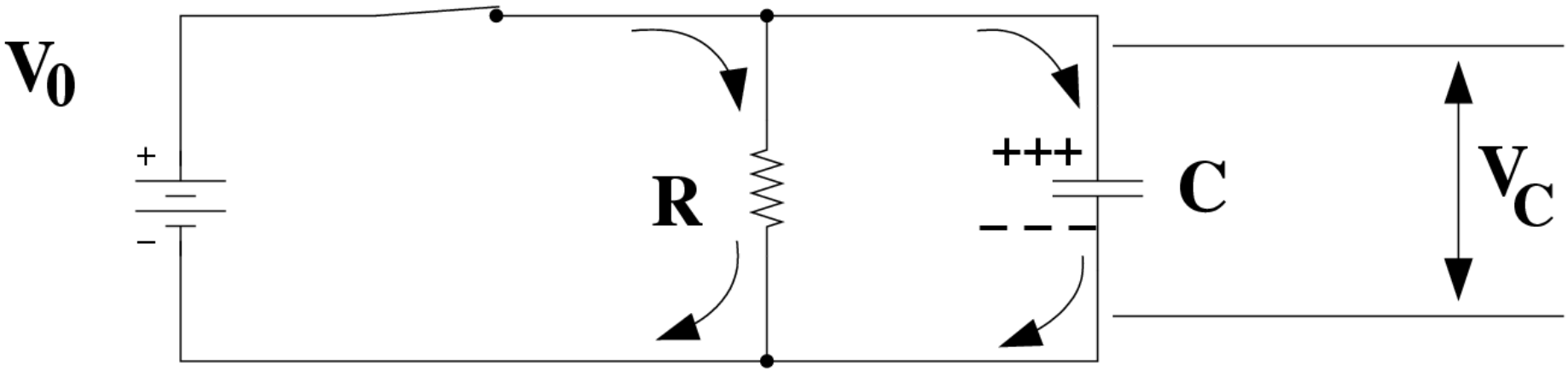
- What happens when we close the switch?

Parallel R-C Circuits



- Almost instantaneously:
  - V_C becomes V_0
  - The capacitor becomes charged
- What are I_C and I_R in the steady state?

Parallel R-C Circuits



- What are I_C and I_R?

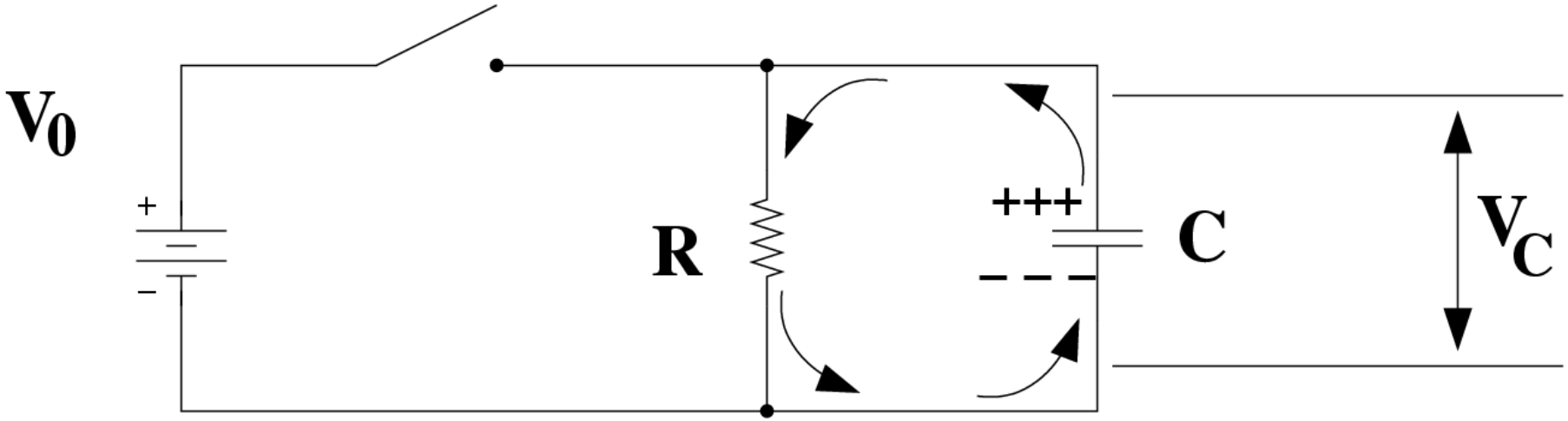
$I_C = 0$

$I_R = V_0 / R$

Parallel R-C Circuits

- What happens when the switch is opened again?

Parallel R-C Circuits



- The capacitor discharges through the resistor
  - This limits the rate of discharge. How do we compute this?

- Note that there is no current flow back to the battery. Why?

Parallel R-C Circuits

- The time evolution of the voltage across the capacitor is:

$$V_C(T) = V_0 e^{-T/RC}$$

(make sure you can derive this)

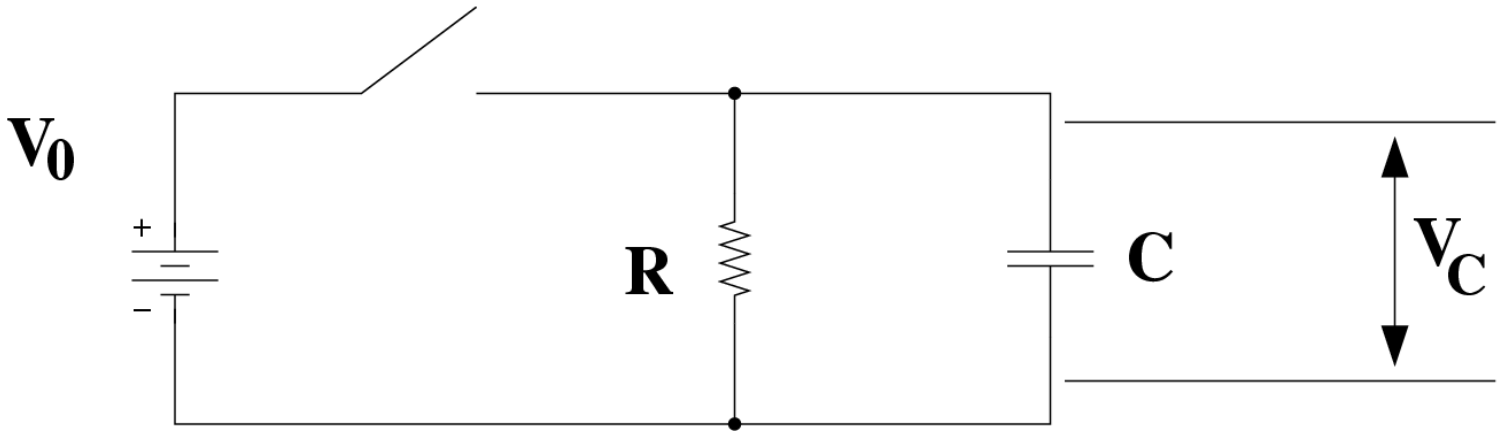
- There is no current flow back to the battery once the switch is open because there is no longer a closed circuit

Parallel R-C Circuits

Note that **RC** is the **time constant** of the circuit response

- In one time constant, the circuit will make 63% of the progress to its steady state

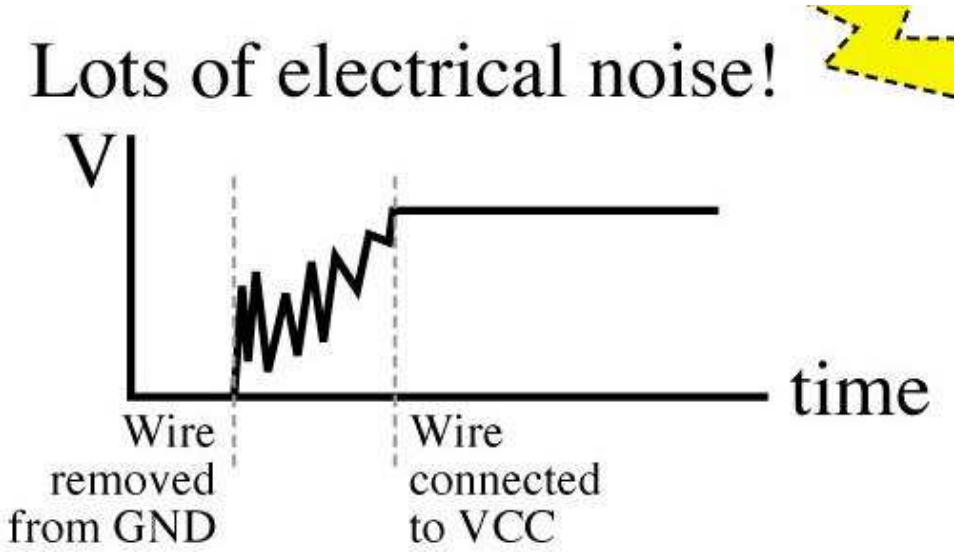
Parallel R-C Circuits



- Note that with time, V_C returns to 0
  - The capacitor is no longer storing a charge

Recall Our Noisy Switch Problem...

- We have already shown how this problem can be addressed in software...

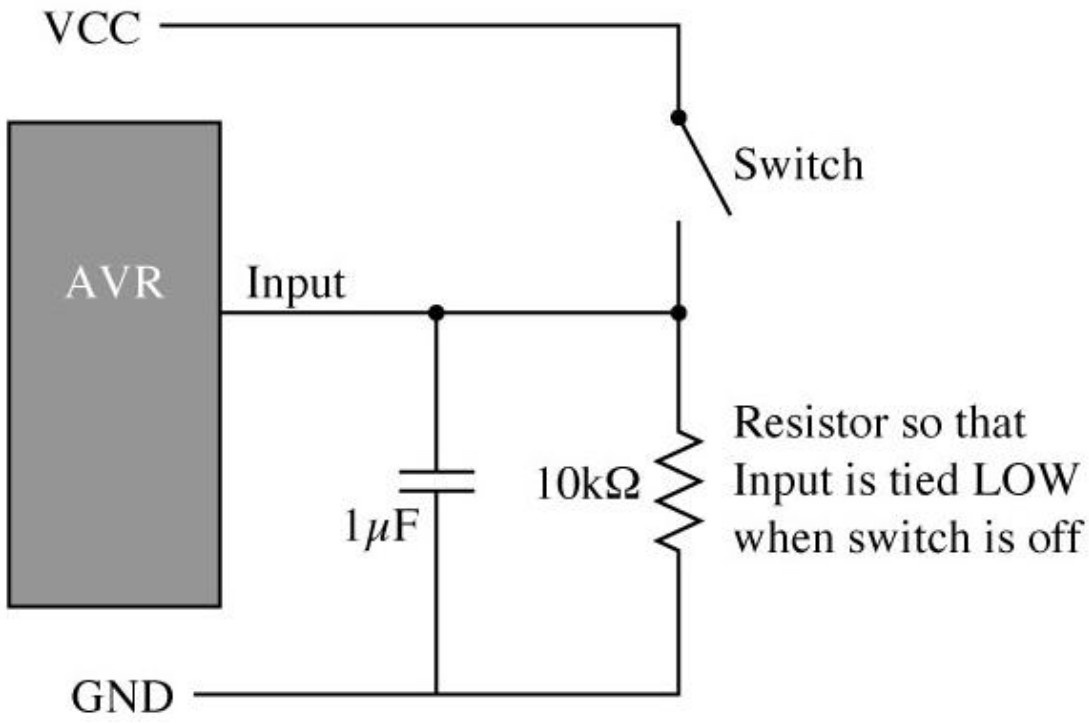


- But we can also address it in hardware. How?

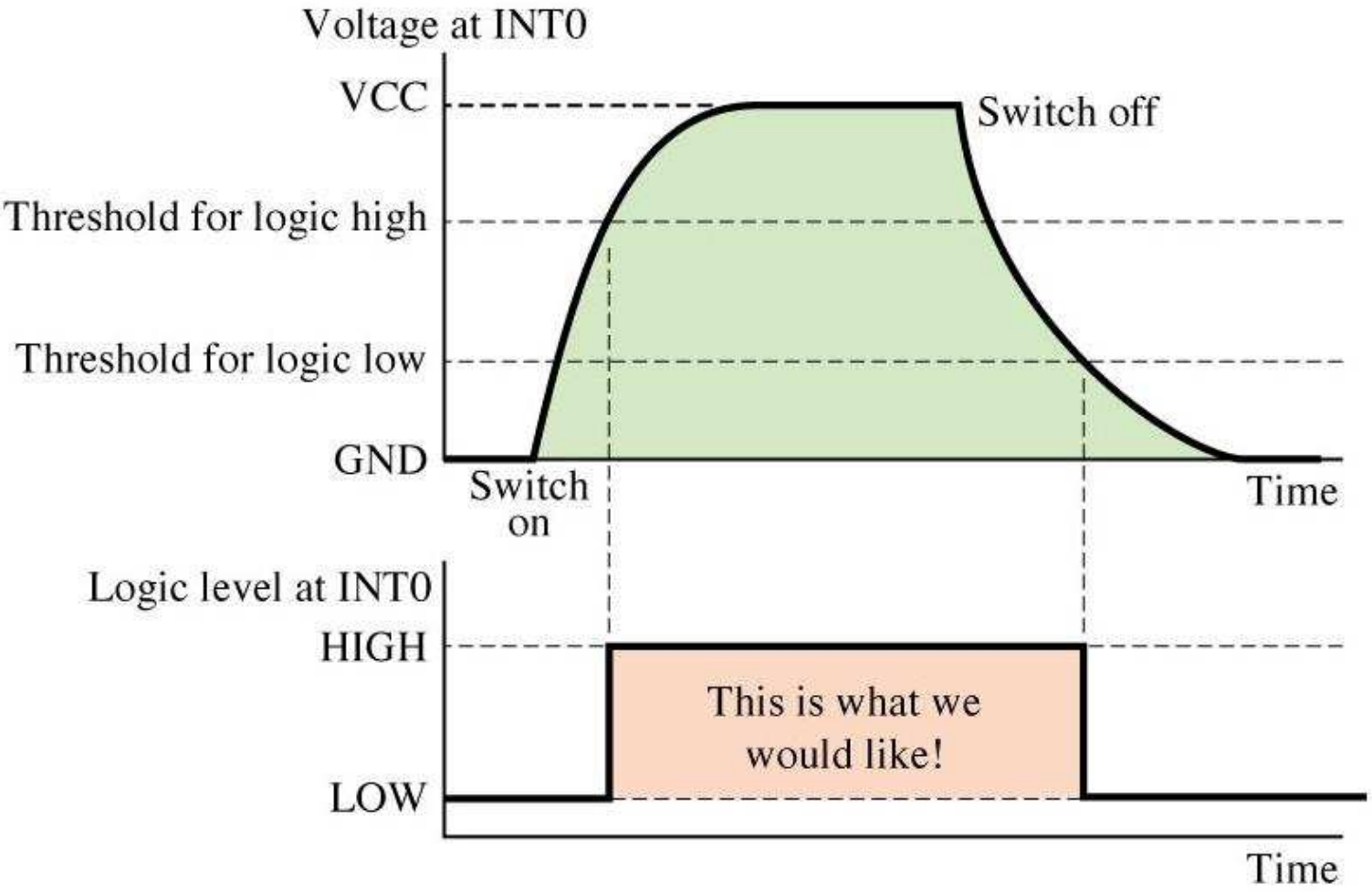
R-C Circuits as Filters

- Use a pull-down resistor with a capacitor in parallel

- When the switch is released, the input to the processor returns to **low** slowly (how slowly?)

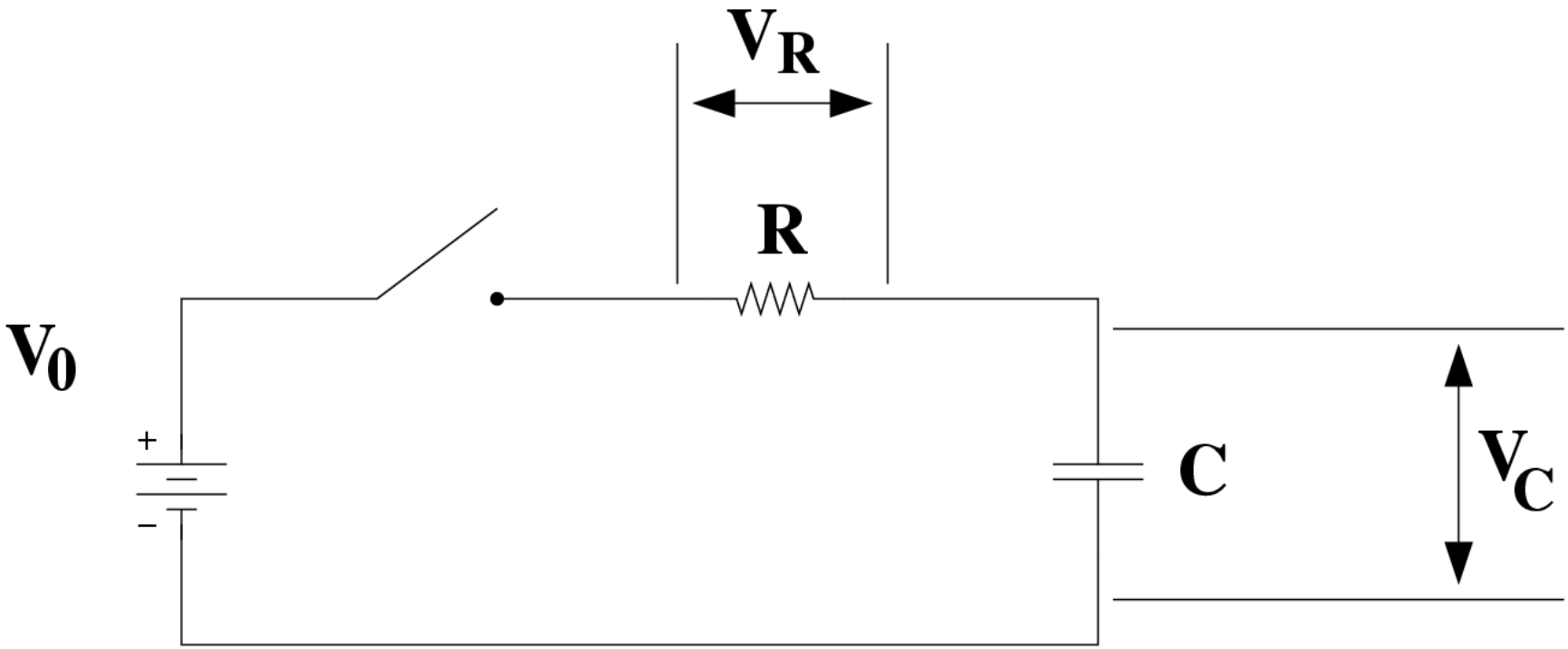


R-C Circuits as Filters



Note that for this circuit, the increase to VCC is almost instantaneous

Series R-C Circuits

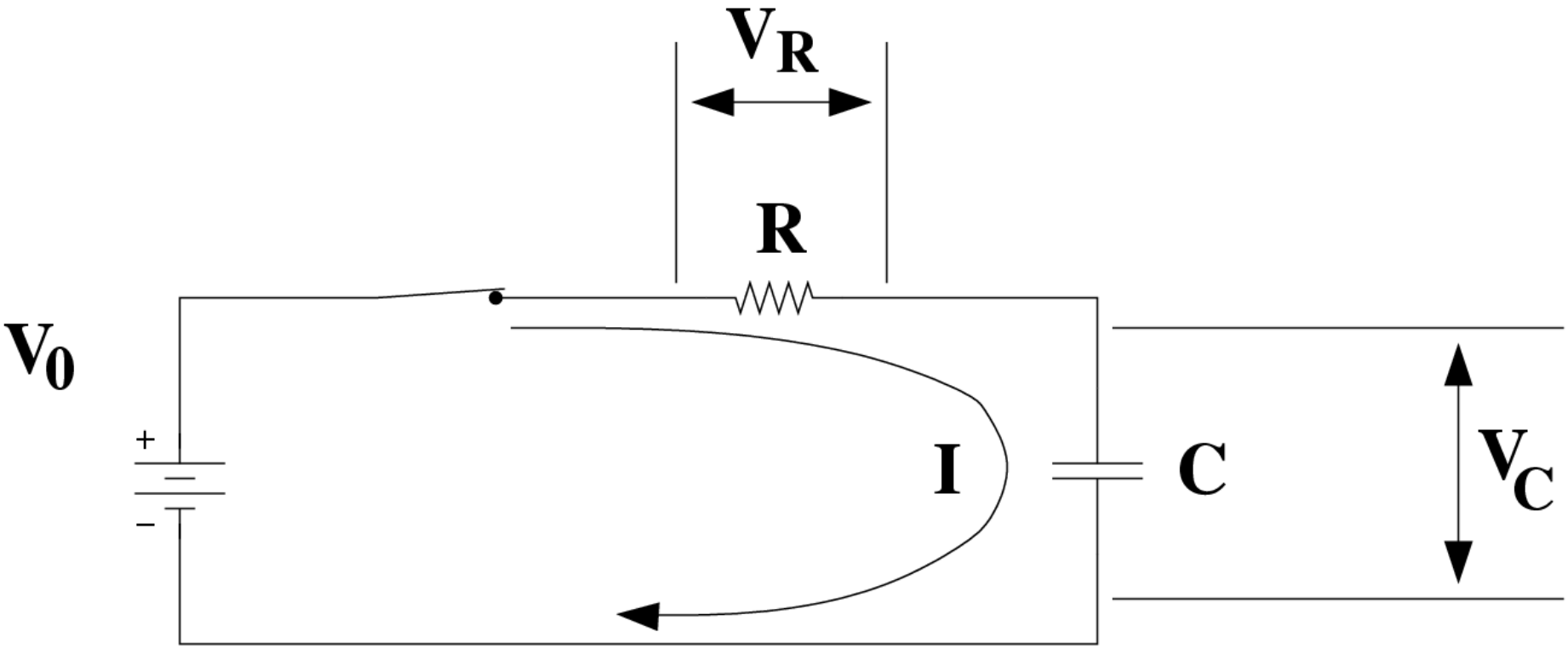


- Assume that there is no charge on the capacitor initially:

  $V_C = 0$

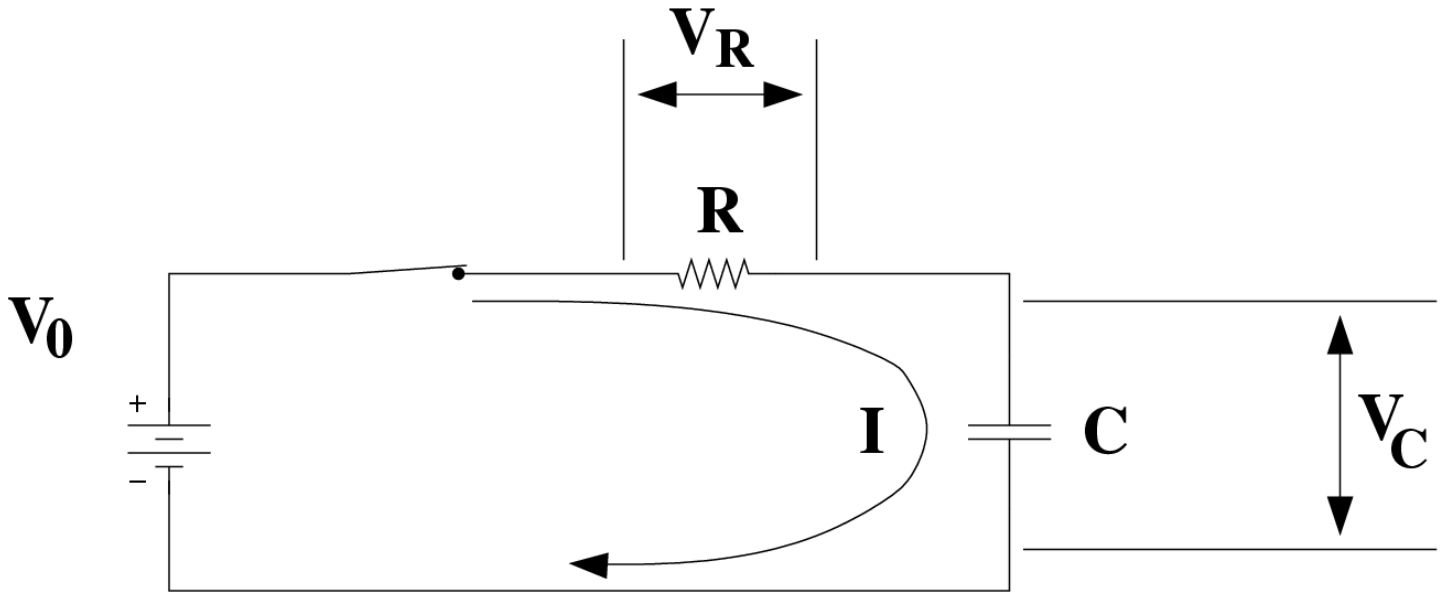
- What happens when the switch closes?

Series R-C Circuits



- There is an immediate current flow through the circuit
- At the instant that the switch is closed what are V_R and V_C?

Series R-C Circuits

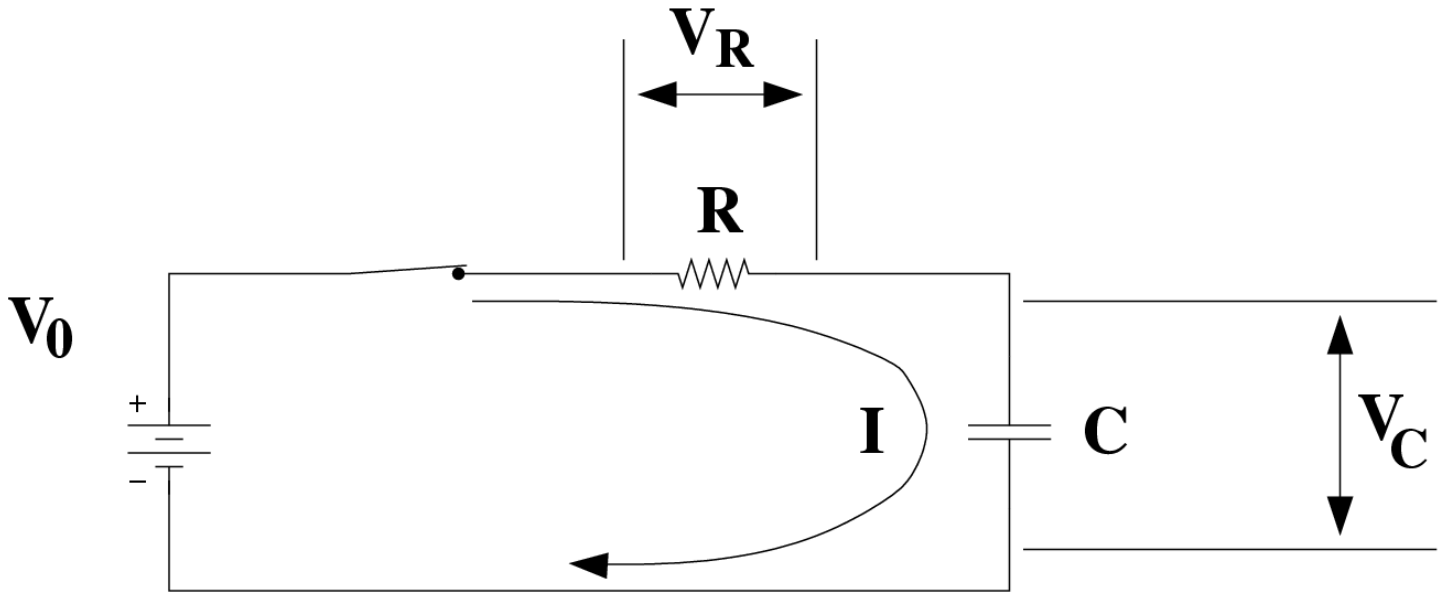


- At the instant the switch is closed:

  $V_R = V_0$ and $V_C = 0$

- What is the time evolution of V_C?

Series R-C Circuits

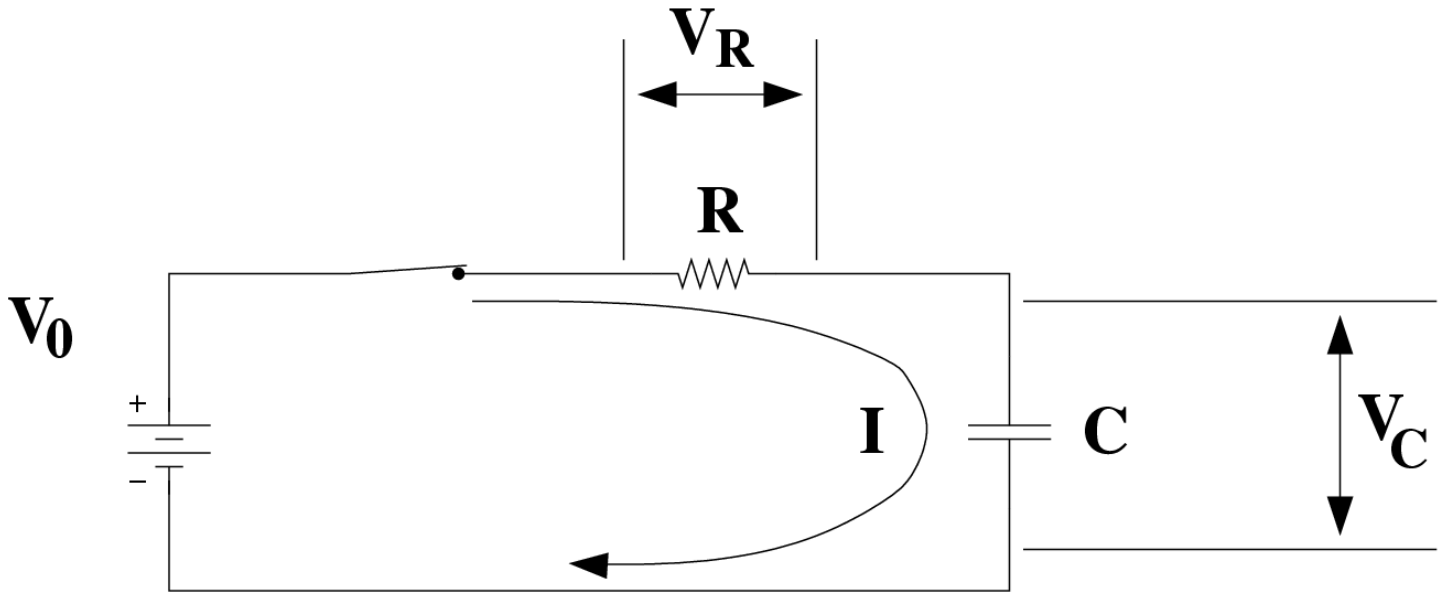


- The time evolution is:

$$V_C(T) = V_0 - V_0\, e^{-T/RC}$$

- What is the time evolution of I and V_R?

Series R-C Circuits



$$V_R(T) = V_0 - V_C = V_0\, e^{-T/RC}$$

$$I(T) = \frac{V_0}{R}\, e^{-T/RC}$$

What happens when the switch is opened after steady state has been reached?

Series R-C Circuits

When the switch opens, there no longer is a completed circuit through which current can flow. So the steady state from before remains:

$$V_C = V_0$$

$$V_R = 0$$

Types of Capacitors

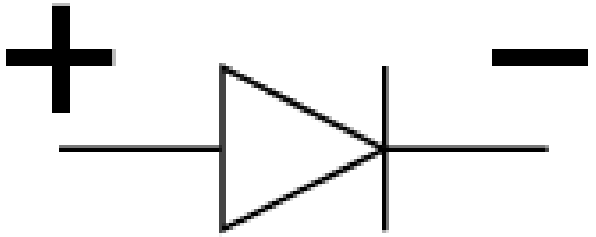
- Ceramic:
  - small packages (typically flag)
  - range from pF to μF
- Electrolytic:
  - larger packages (usually cylindrical)
  - 0.1 μF to F
  - Polarized! You can blow these up if you connect them backwards
- Tantalum (a high-quality form of electrolytic):
  - 0.1 μF to 100 μF
  - Also polarized

Any Questions about R-C Circuits?

Next Topic: Diodes

Diodes allow current to pass only in one direction:

- From the positive side (the **anode**)
- To the negative side (the **cathode**)



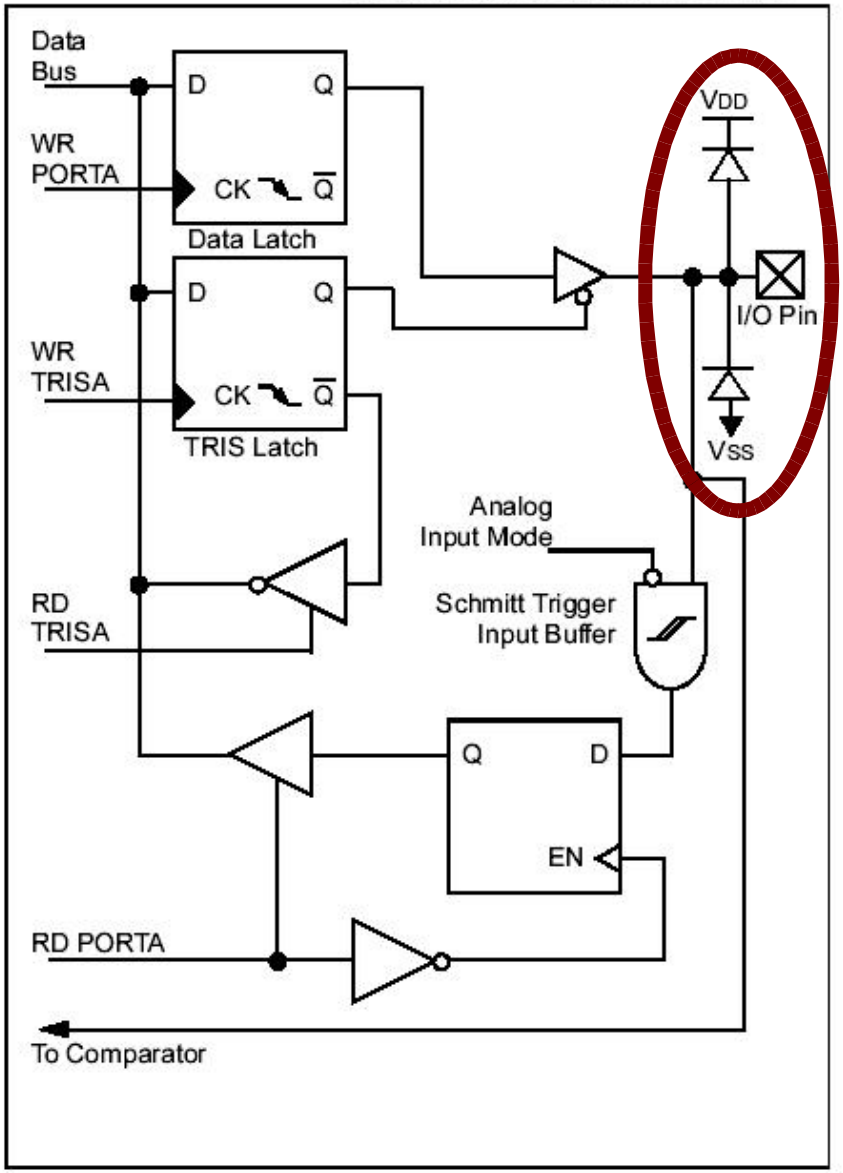
Diode Details

- There will be some voltage drop across the diode
  - This will often be called the **forward voltage**
  - The voltage drop is not necessarily constant (see the specifications for the diode that you are using)
- Limits before failure:
  - Diodes can only pass a certain magnitude of current in the forward direction
  - Diodes can only sustain a certain reverse voltage (the limit is the **peak reverse voltage**)

Diode Example

What is the function of this pair of diodes on pins RA0 and RA1?

FIGURE 5-1: BLOCK DIAGRAM OF RA0/AN0:RA1/AN1 PINS

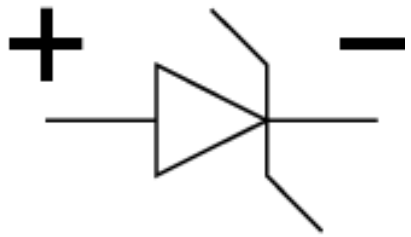


Diode Example

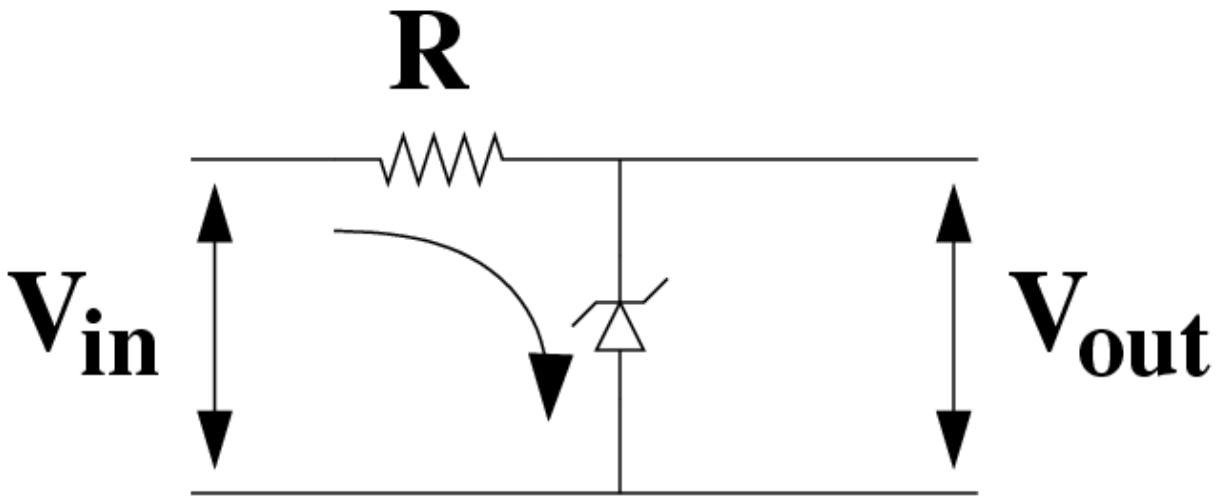
These diodes ensure that any input voltages below 0 Volts (Vss) or above 5 Volts (Vdd) will be clipped to these levels

Zener Diodes

- Allows backward current to flow
- Resistance in this backwards direction changes in order to maintain a fixed voltage drop
- See the specification for the voltage drop of a particular diode



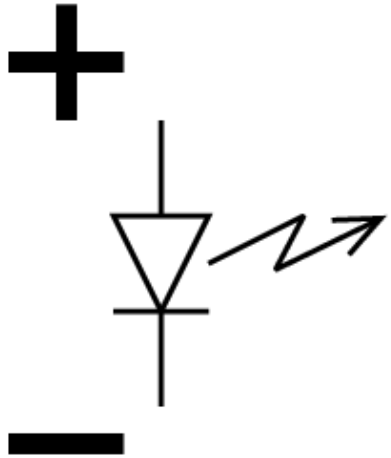
Zener Diodes as Voltage Reference Generators

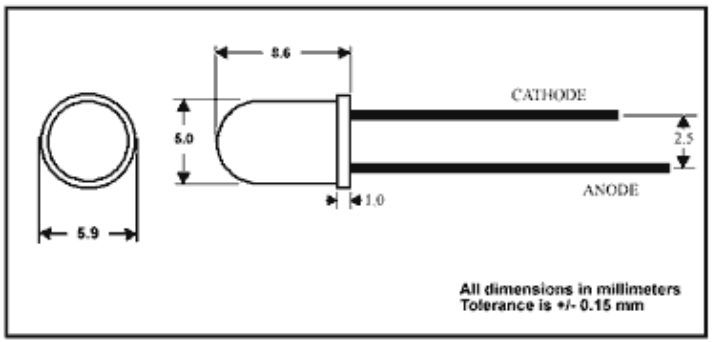


- When V_{in} exceeds the voltage drop across the diode, it sinks the additional current
- V_{out} will stay constant with different levels of V_{in}

Light Emitting Diodes (LED)

- The work done by the diode manifests itself as light
- Different types of diode will emit a different wavelength of light
  - Will also have a different voltage drop level
  - Check the specification!
- The anode is typically the longer lead

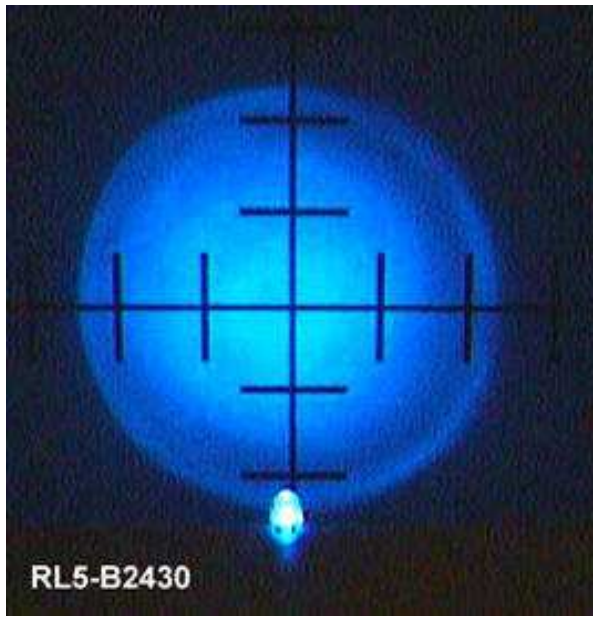




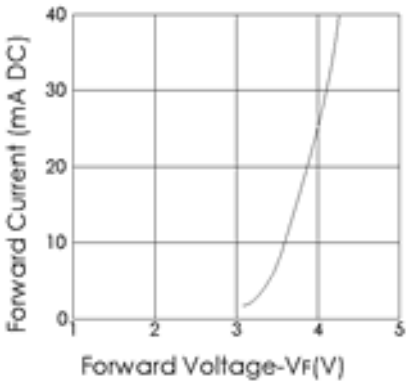
An Example LED

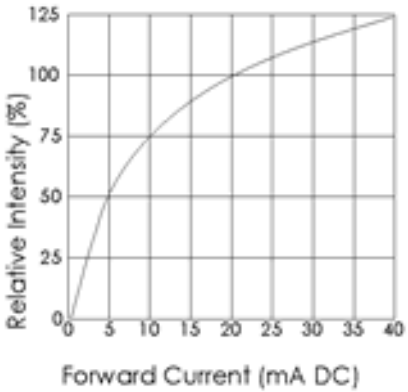
Our super-bright blue LEDs

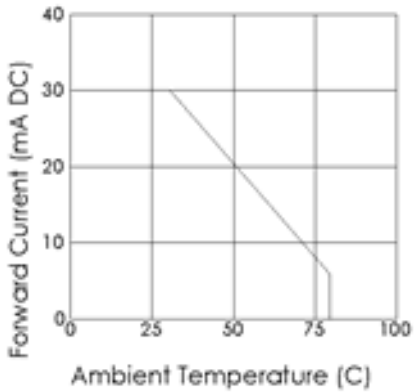
- Continuous forward current rated at 20 mA (see the specs)
  - The PICs can drive up to 25 mA
- At 20 mA, the forward voltage is about 3.8V

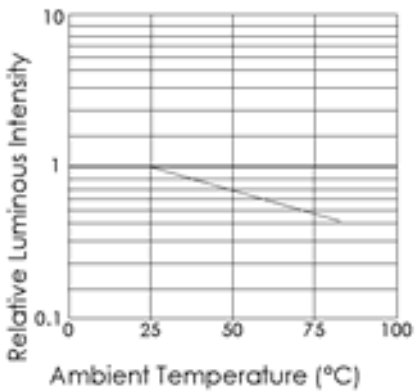


What resistor do we need?







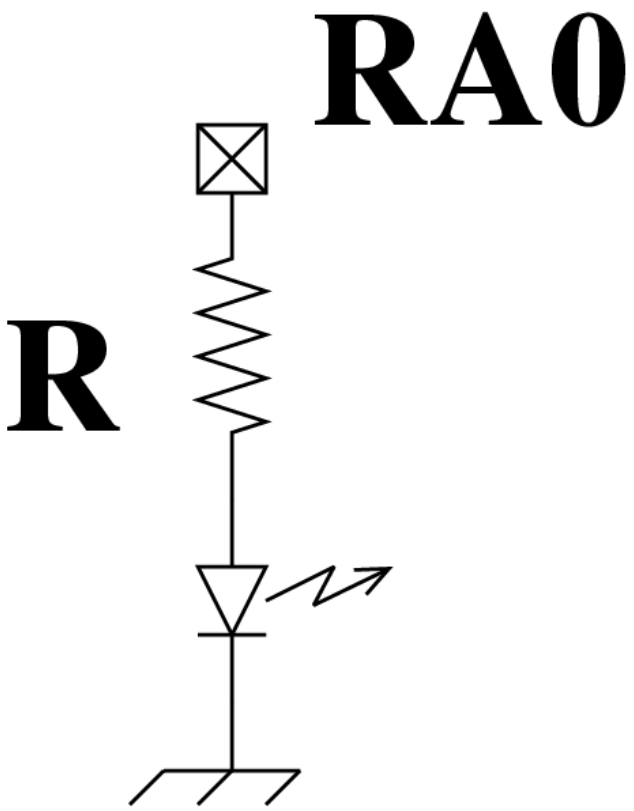


LED Example

$$R = \frac{\Delta V}{I}$$

$$= \frac{5 - 3.8}{.020}$$

$$= 60\,\Omega$$



Always be careful when you are using components near their limits!

Next Time

- Lab:
  - Milestone deadline October 6th
- Thursday lecture:
  - Robotics lab tour (CS 144)
- Tuesday lecture:
  - Circuit building wisdom. Read DEH Chapter 4