# Lecture 02

## Using LEDs and the Teensy

# Agenda for Today's Lecture

01 Passsive Component Recap

02 LED's  Intro for Lab 1.1 (1st out of 4 parts)

03 Binary and Hex

04 Teensy Intro for Lab 1.2 (2nd out of 4 parts)

05 Pulse Width Modulation (PWM)

# Announcements

- COVID-19 pre-cautions
- Lab 1 will go out soon for those who want to start early.
- Recitation Friday will cover basics of C programming.
- Quick online tutorials (do this before Friday)

A. http://www.tutorialspoint.com/cprogramming/
B. http://www.learn-c.org/

# Class participation (graded)

QUESTIONS IN GREEN

Either live annotate or *private* chat to me.

We will check CHAT logs to verify class participation

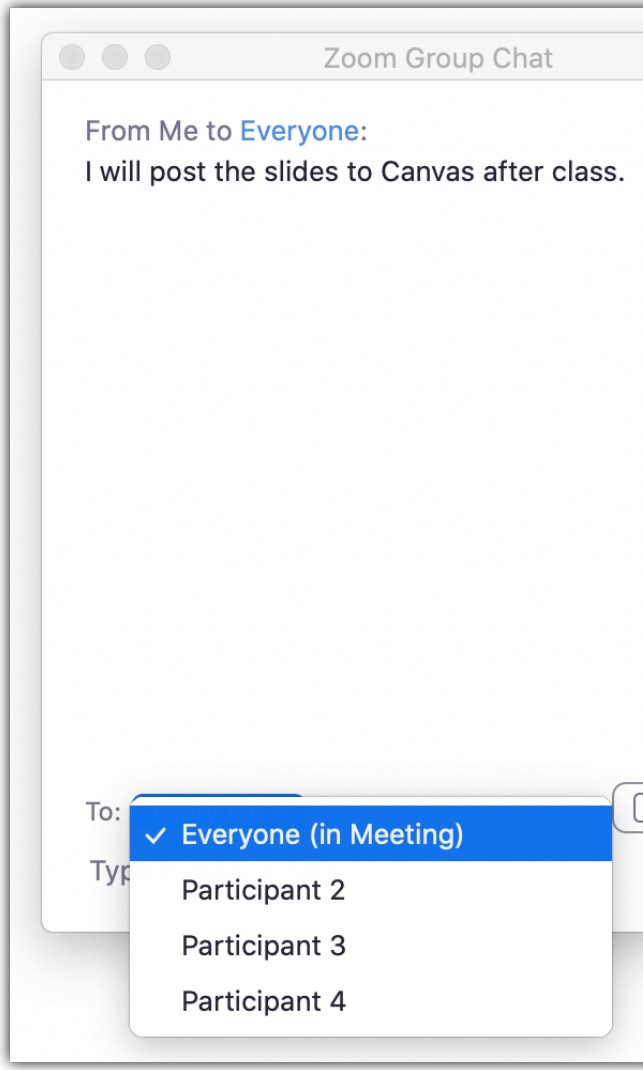
We are looking for any answer, not necessarily the right one.
Possible extra pts for corrections to early wrong ones.

For asynchronous video watchers:

Get link to the "Activity Sheet" on Canvas Assignments
Follow along and (re)submit finished sheet to Canvas

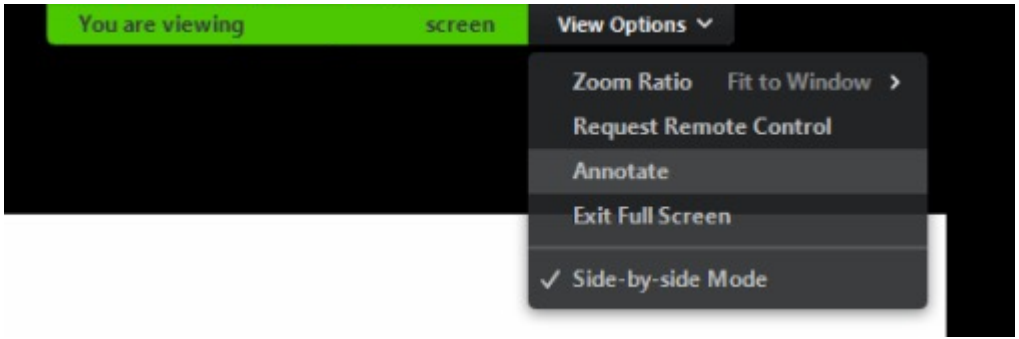
# In Private Chat to me:

- What times of day will you prefer to do 510 Lab work?
  - Ex: Evenings
  - Ex: Weekend afternoons
  - Ex: 2PM to 5PM




Click on To: "Everyone"
select "Mark Yim" <privately>

# Zoom Annotate Practice





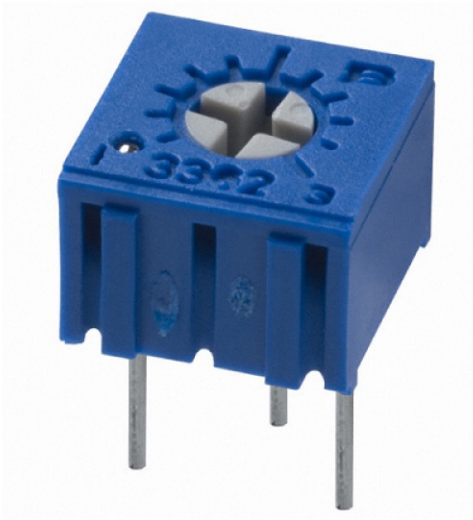
Draw circle here. The circle will appear to others when you release.

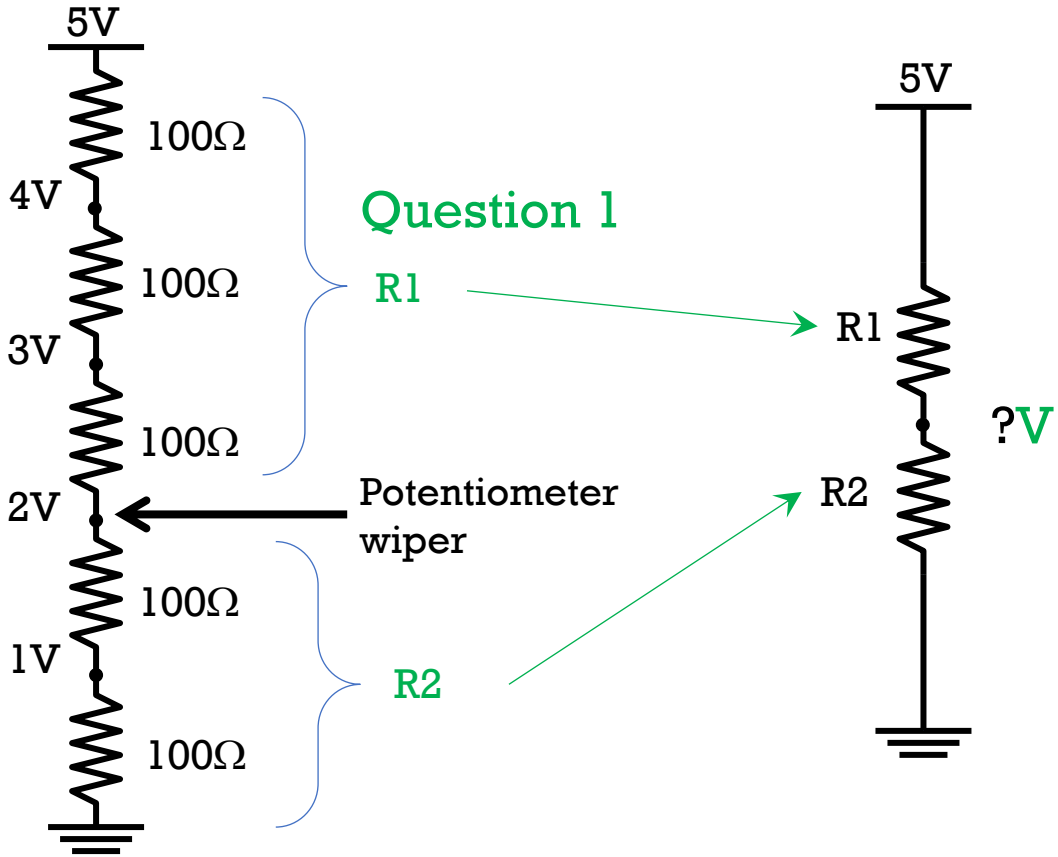
Draw circle here, but hold down the button. Don't release until I say so

# 01

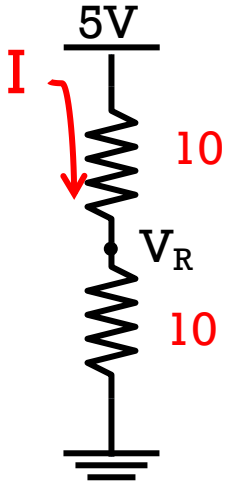
# Passive Component Recap

# Voltage dividers/potentiometers





# Voltage divider




1/4W Resistor

$$V_R = 5\,\frac{R_1}{R_1 + R_2} = 2.5\,V$$

$$I = \frac{5}{R_1 + R_2}$$

Power in Watts = Volts * Amps

$$\text{Power} = VI = 2.5V\,\frac{5}{R_1 + R_2} \qquad R_1 = 10,\ R_2 = 10$$

Power = 12.5/20 = 0.625W

For 1/4W Resistors, W < 0.25 ->

W = 12.5/50

For nominal 5V cases
Use 1/4W resistors
~**25Ω << 1MΩ**

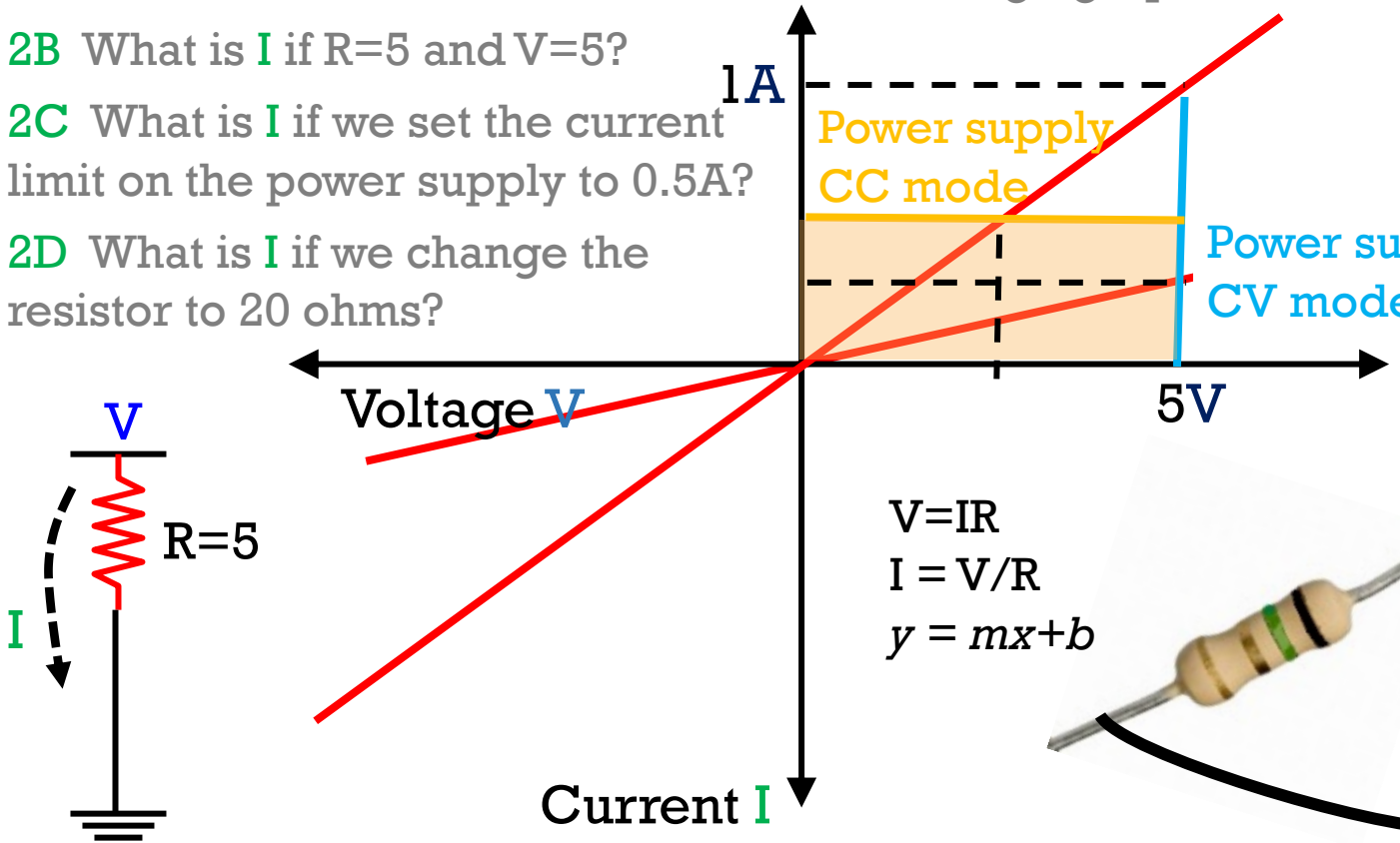
# Resistance on Voltage/Current graph

**Question 2A** Draw and hold the current/voltage graph for a resistor

**2B** What is I if R=5 and V=5?

**2C** What is I if we set the current limit on the power supply to 0.5A?

**2D** What is I if we change the resistor to 20 ohms?



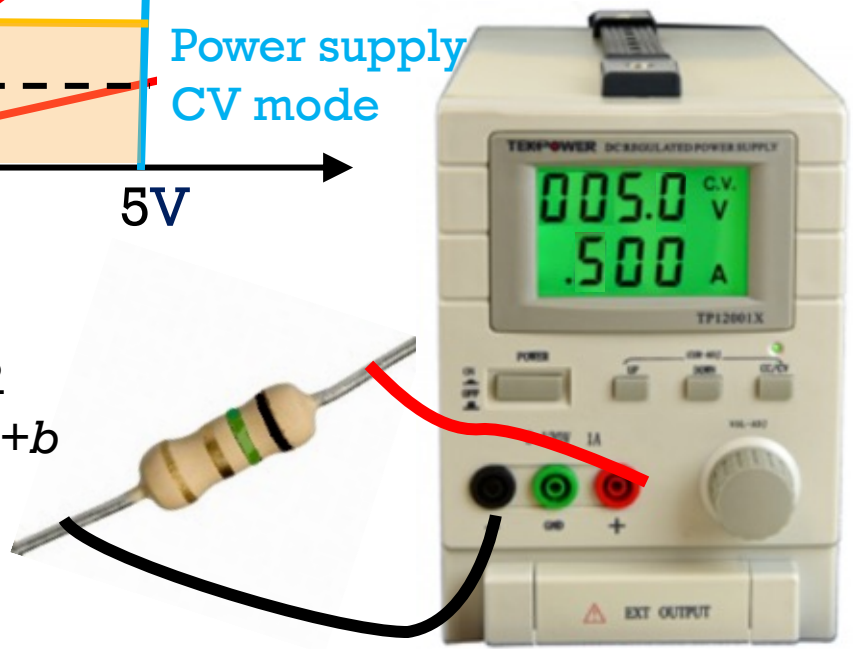




V=IR

I = V/R

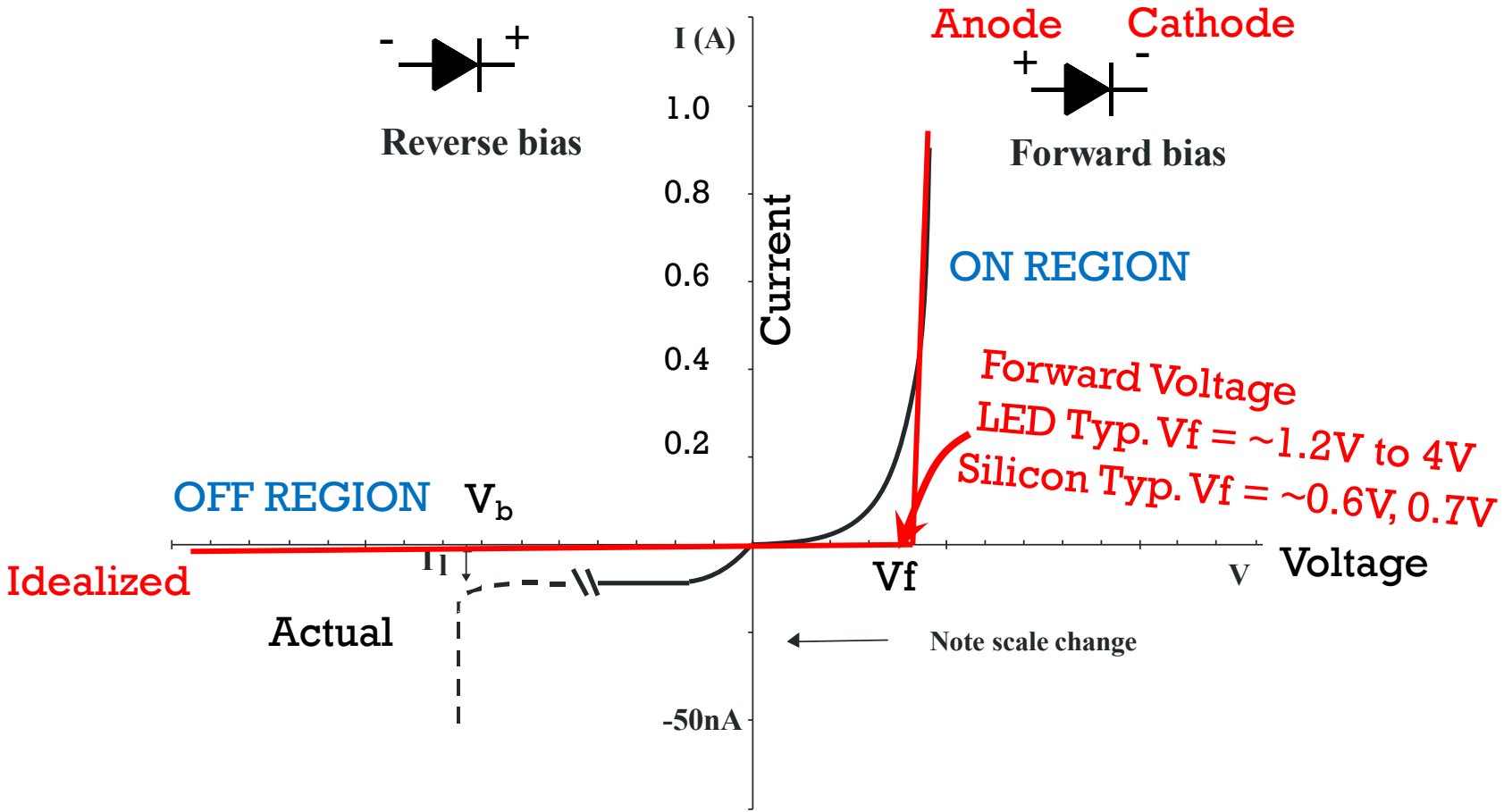
$y = mx+b$



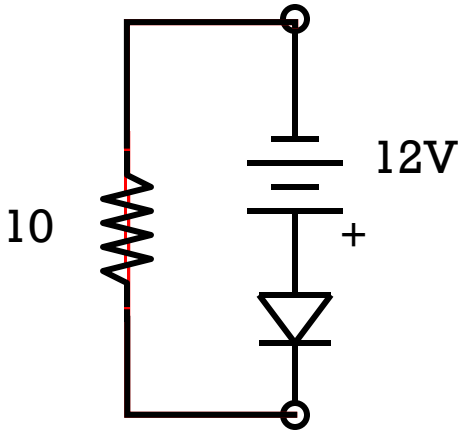
02

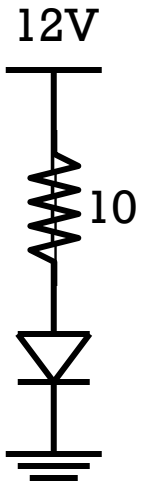
# Intro for Lab 1.1 LED's

# Standard Diode Behavior



# Question 3: C

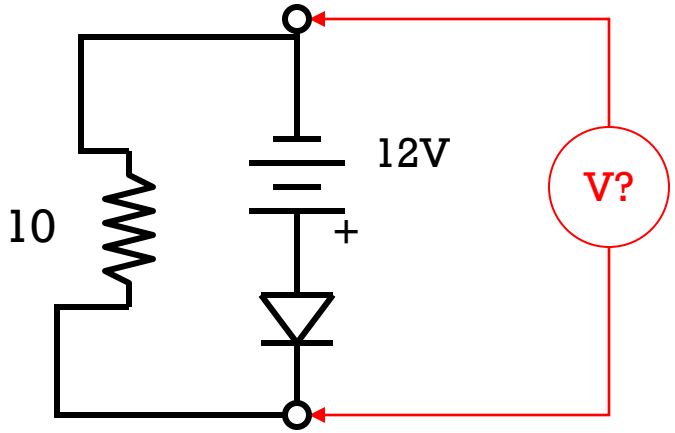



Why do we need a resistor?

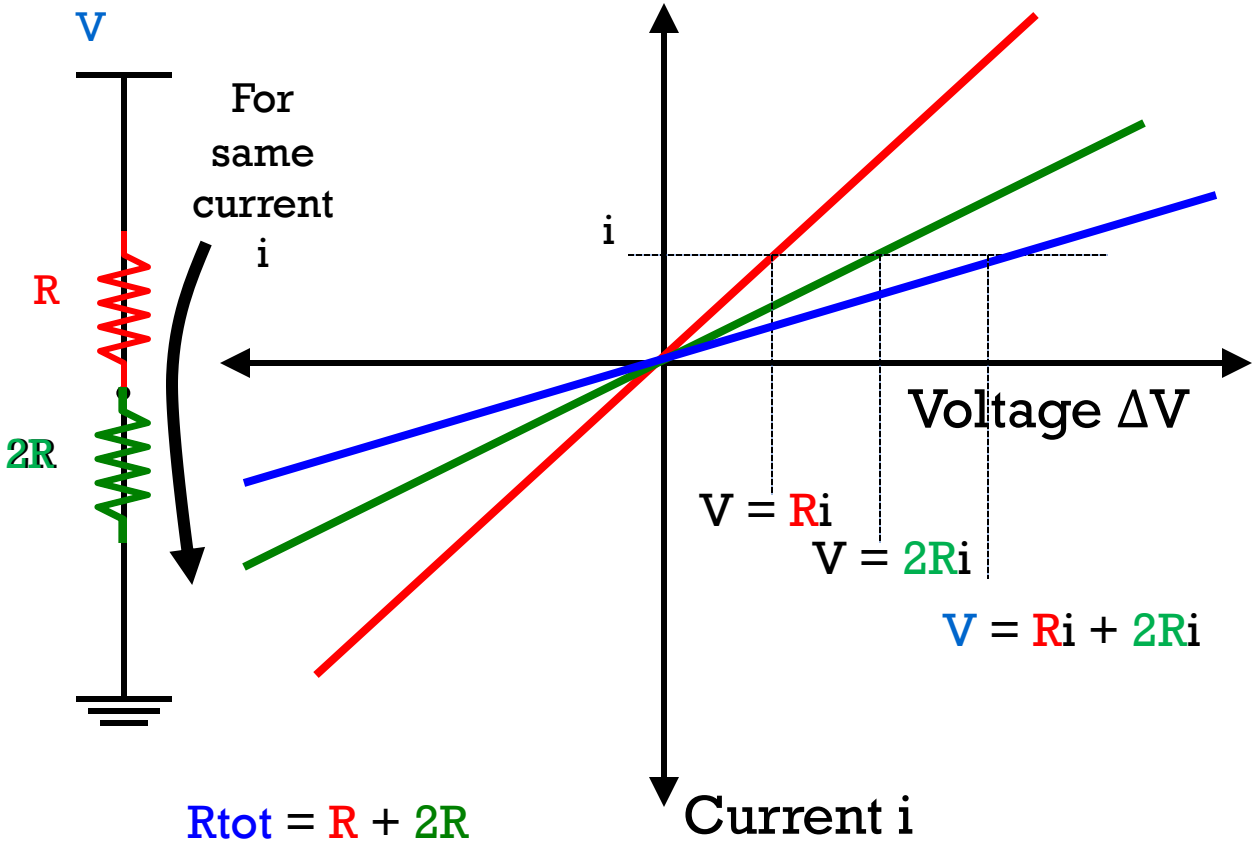
Is the LED on or off?

# Question 4: C



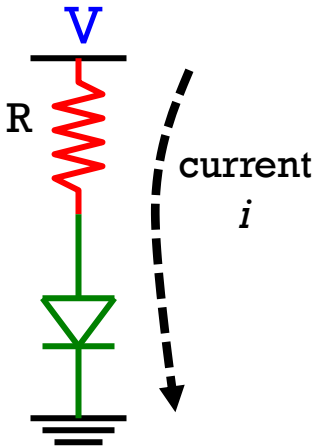

What is the measured voltage V?

# Devices in series

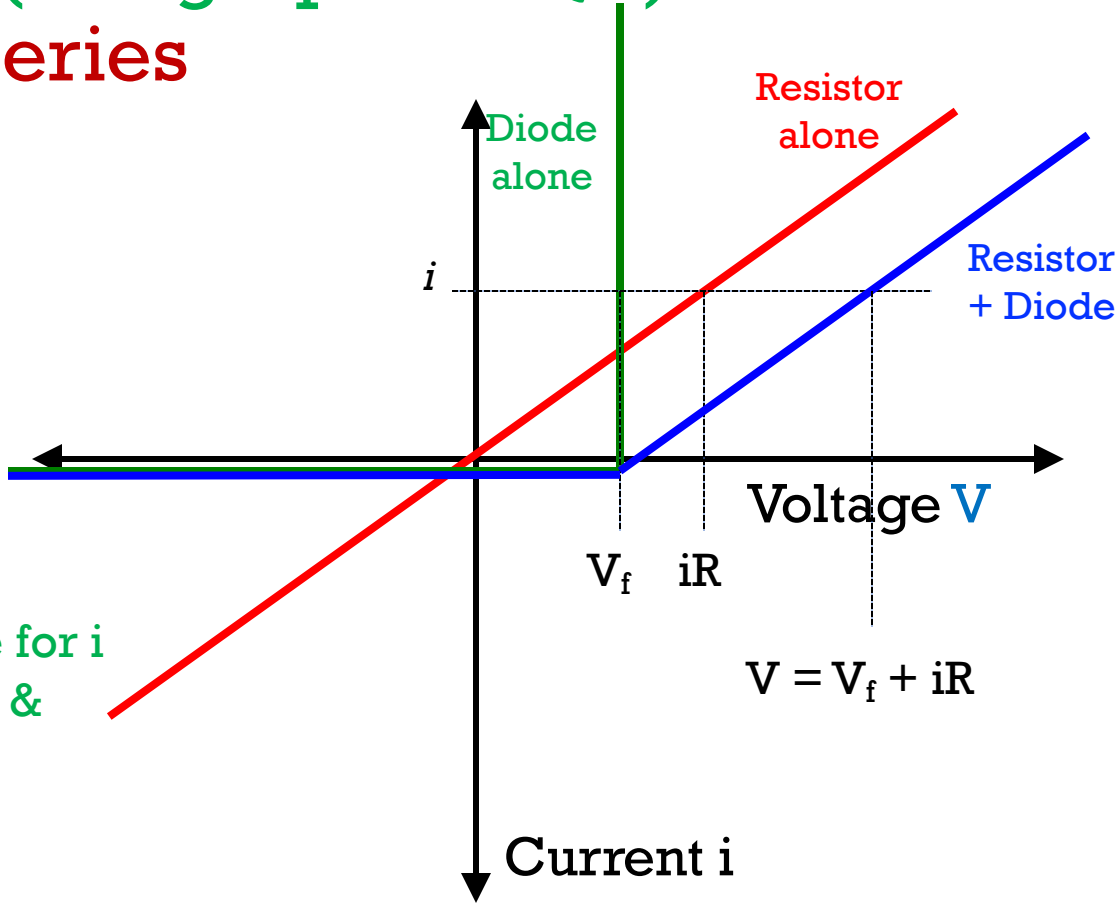


# Question 5: (use graph for Q2)

## Devices in series




Draw and hold the curve for i as V varies for the diode & resistor in series.



# Diodes in series

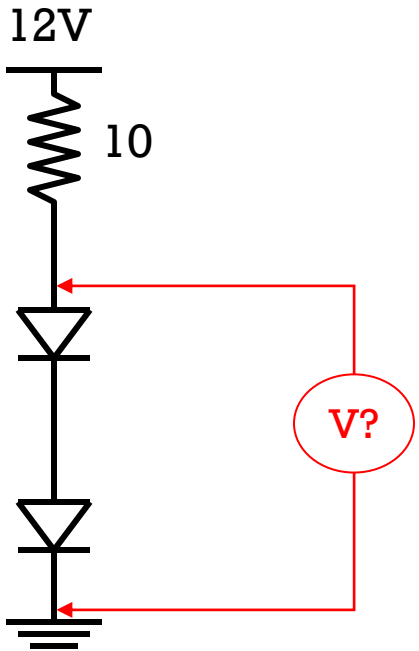
The amount of light from an LED generally increases with current.

Q6: What happens to total amount of light emitted if we put 2 in series?

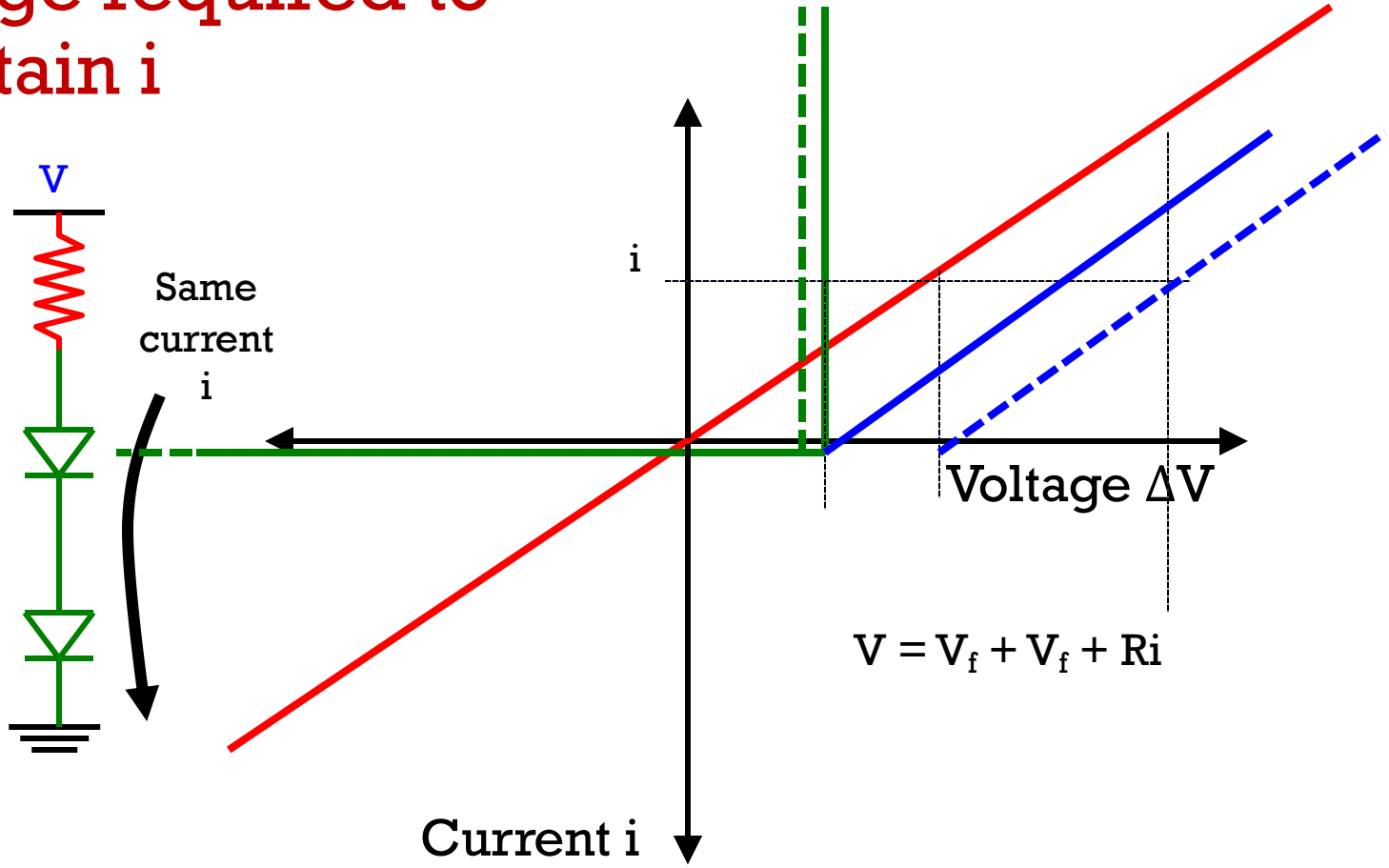
A) Double the light as one LED with res?

B) Same light as one LED (1/2 from each)?

C) More than one, but less than two?



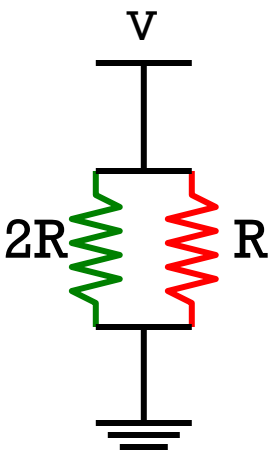
# Voltage required to maintain i

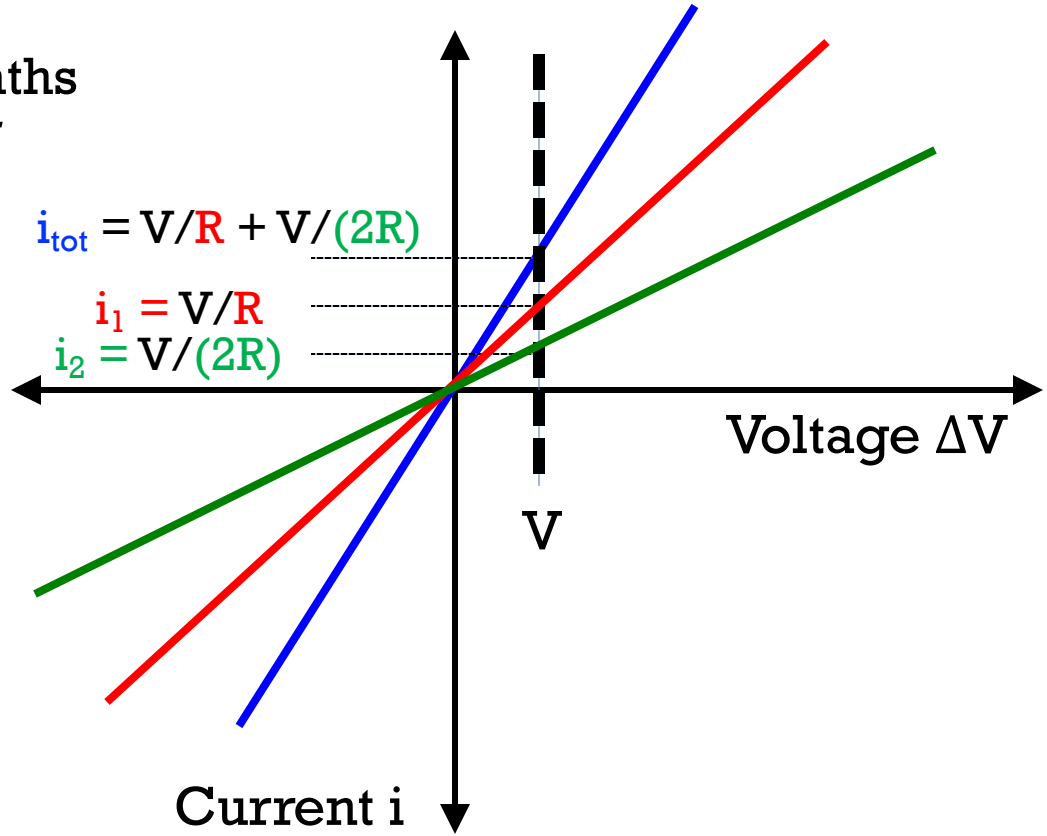


# Parallel case?

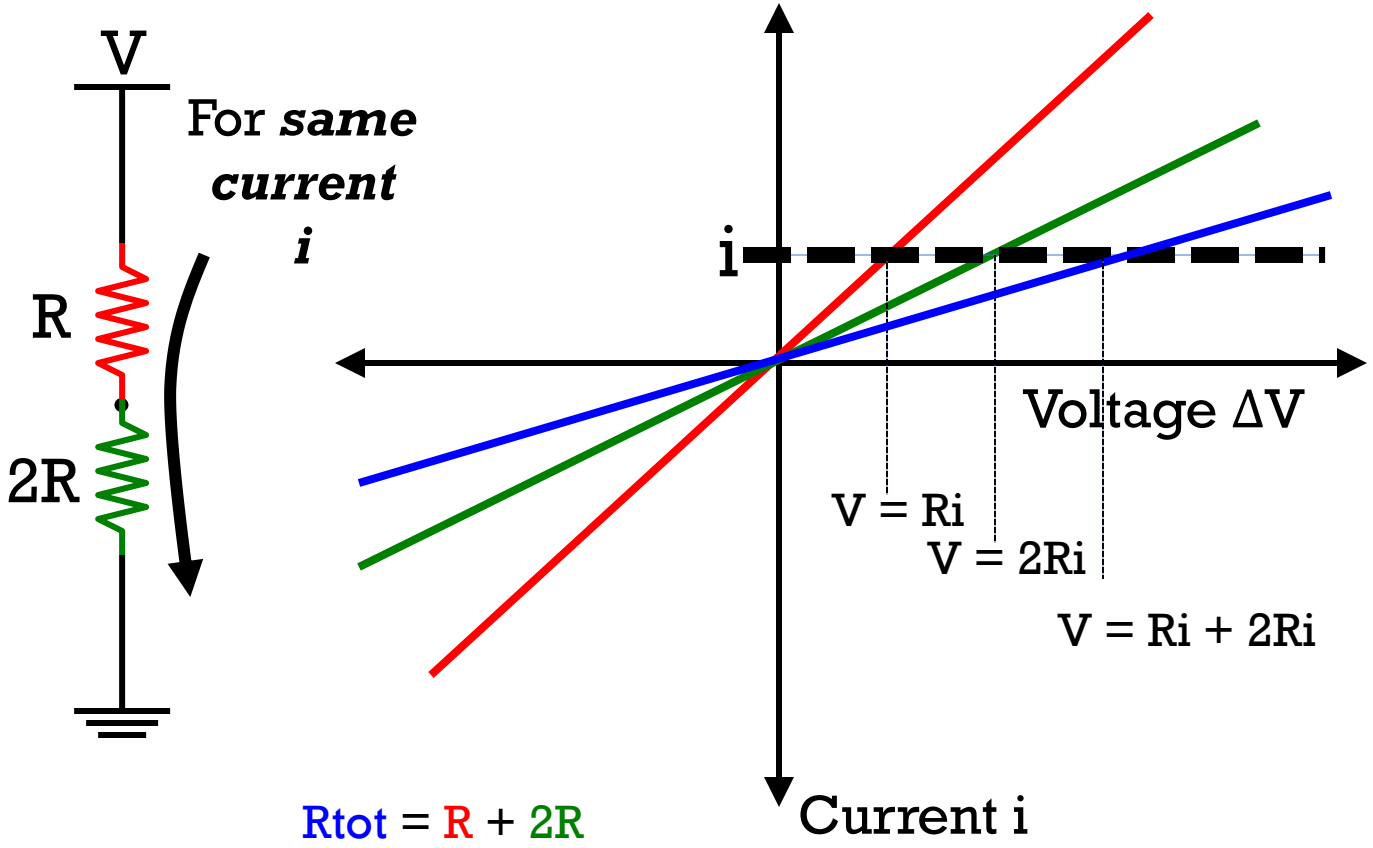
Two current paths
but ***same V***

$i_1$ , $i_2$



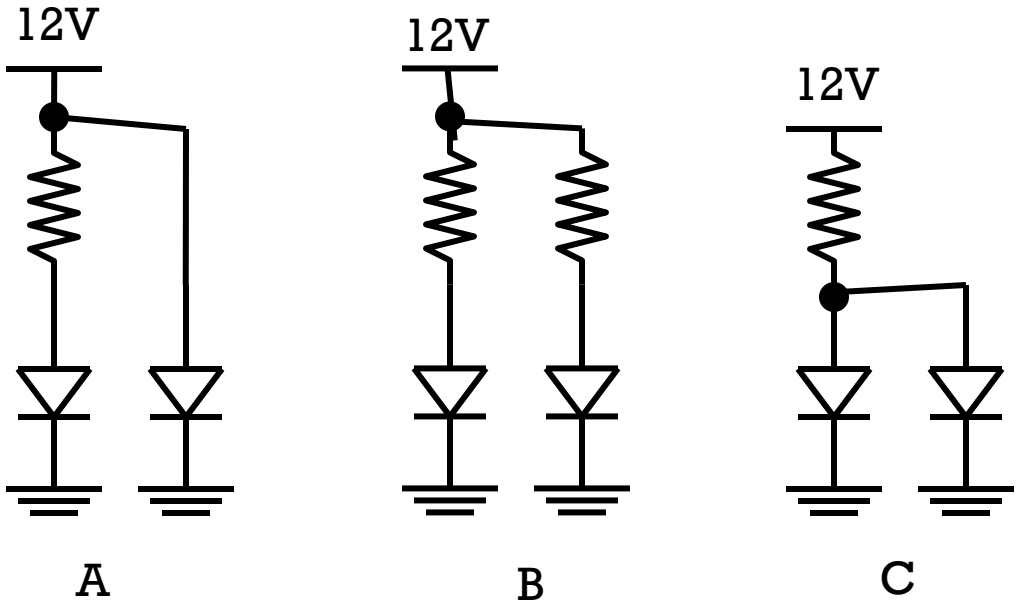



# Devices in series




Rtot = R + 2R

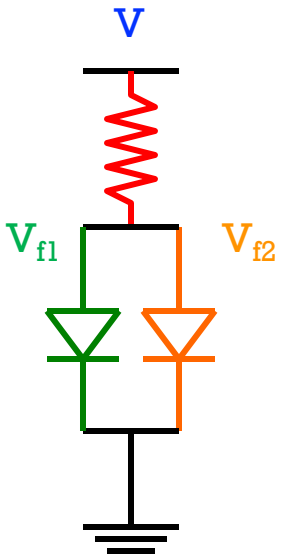
# Diodes in Parallel

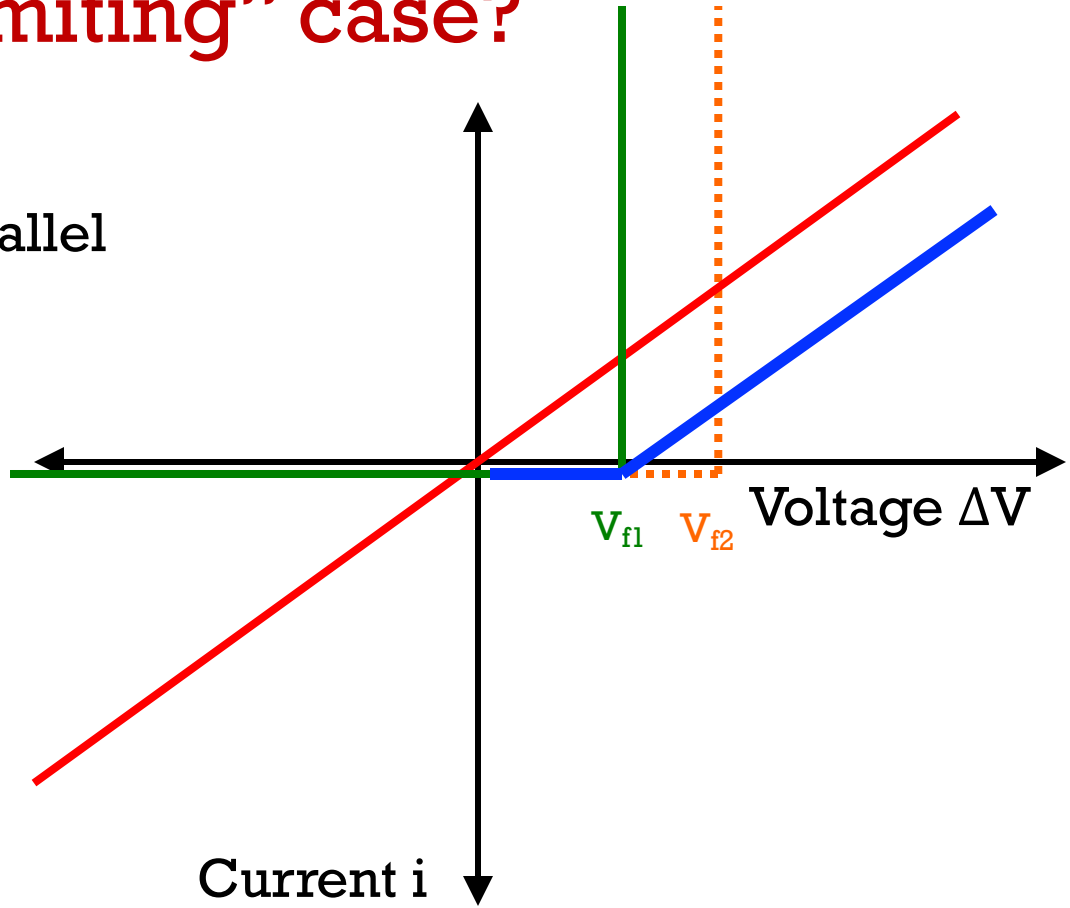



If we have 2 diodes with different Vf which circuit will light both diodes? Circle and hold the best answer.

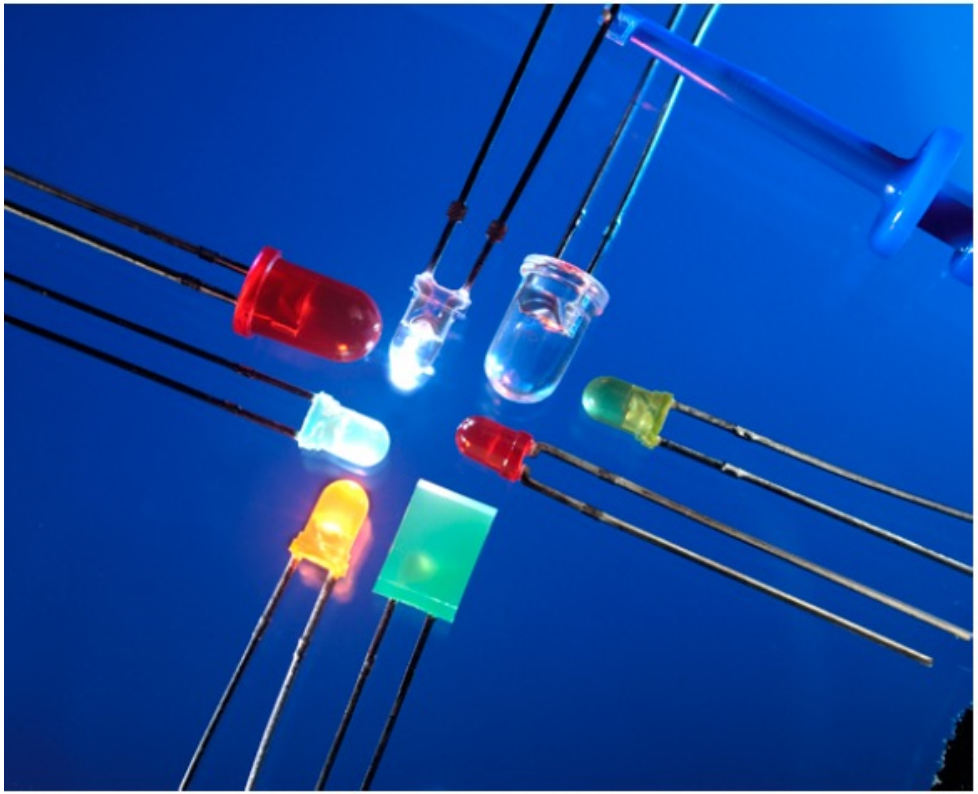
# What is “limiting” case?

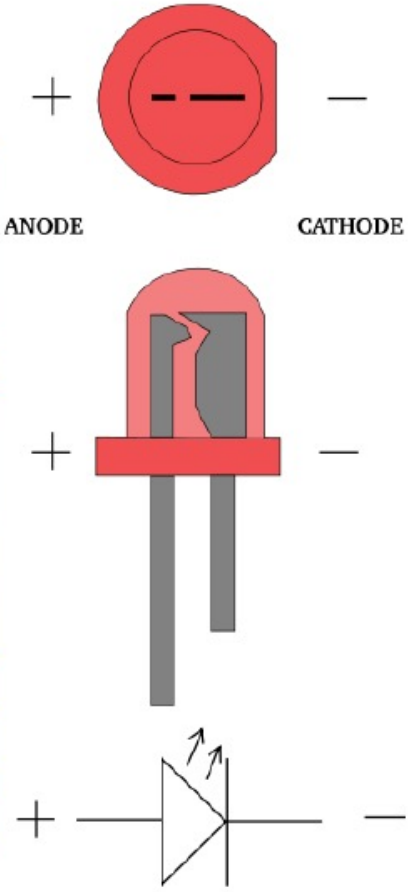
- Circuits in parallel



# LED Packages





# DataSheet

## LN77L

GaAlAs Infrared Light Emitting Diode

For optical control systems

### ■ Features

- High-power output, high-efficiency: $P_O$ = 18 mW (typ.)
- Fast response and high-speed modulation capability: $f_C$ = 20 MHz (typ.)
- Wide directivity: θ = 20° (typ.)
- Transparent epoxy resin package

### ■ Absolute Maximum Ratings $T_a$ = 25°C

| Parameter | Symbol | Rating | Unit |
|---|---|---|---|
| Reverse voltage | $V_R$ | 3 | V |
| Forward current | $I_F$ | 100 | mA |
| Pulse forward current * | $I_{FP}$ | 1 | A |
| Power dissipation | $P_D$ | 190 | mW |
| Operating ambient temperature | $T_{opr}$ | −25 to +85 | °C |
| Storage temperature | $T_{stg}$ | −30 to +100 | °C |

Note) ∗: f = 100 Hz, Duty Cycle = 0.1%

Exceed "absolute maximum", device may be damaged

Don't design to these numbers.

DataSheet

# LN77L

## GaAlAs Infrared Light Emitting Diode

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- Wide directivity: θ = 20° (typ.)
- Transparent epoxy resin package

### ■ Electrical-Optical Characteristics $T_a$ = 25°C ± 3°C

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Forward voltage | $V_F$ | $I_F$ = 100 mA | | 1.6 | 1.9 | V |
| Reverse current | $I_R$ | $V_R$ = 3 V | | | 10 | μA |
| Radiant power * | $P_O$ | $I_F$ = 50 mA | 10 | 18 | | mW |
| Peak emission wavelength | $\lambda_P$ | $I_F$ = 50 mA | | 860 | | nm |
| Spectral half band width | Δλ | $I_F$ = 50 mA | | 40 | | nm |
| Half-power angle | θ | The angle when the radiant power is halved | | 20 | | ° |

# DataSheet

## ■ Electrical-Optical Characteristics $T_a = 25°C \pm 3°C$

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Forward voltage | $V_F$ | $I_F = 100$ mA | | 1.6 | 1.9 | V |
| Reverse current | $I_R$ | $V_R = 3$ V | | | 10 | μA |
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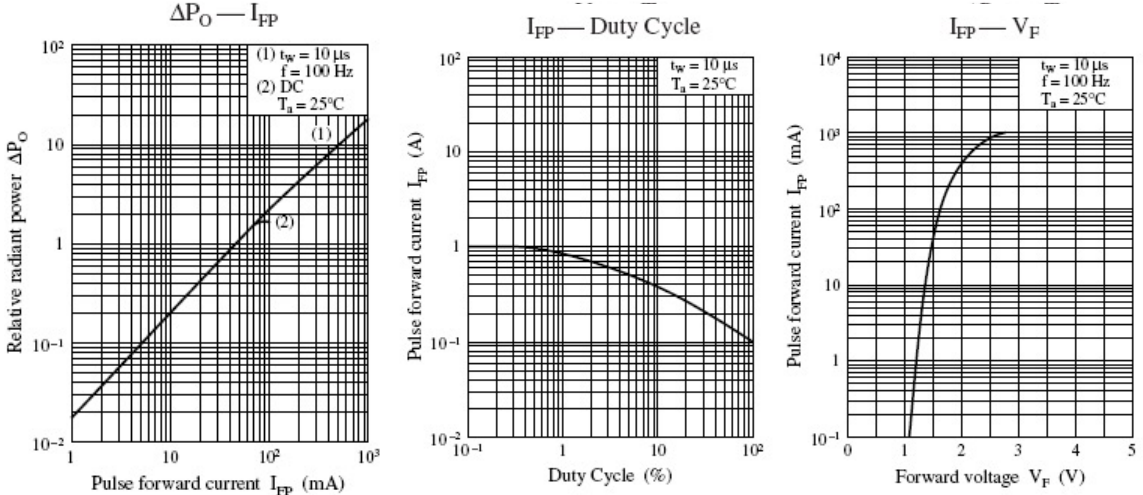
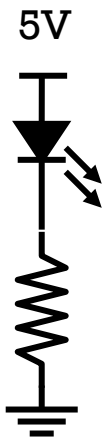
| Half-power angle | θ | The angle when the radiant power is halved | | 20 | | ° |



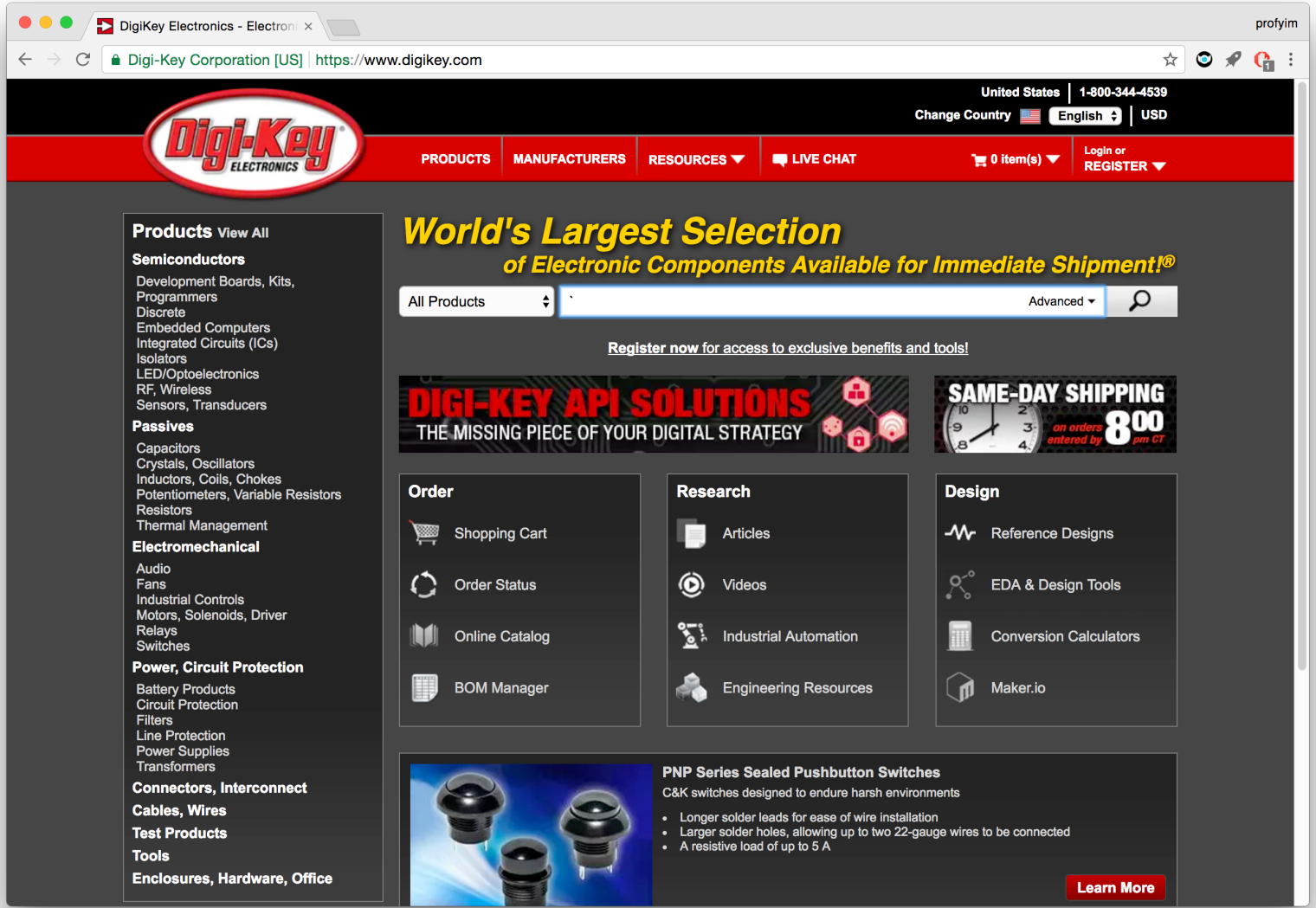
# Q7: LED resistor problem




- You have an LED part number WP7113PBC. You want it is as bright as safely possible from a 5V supply. What resistor will work best? What specifications are important from the spec sheet?
- Hint: the more current through the diode, the brighter it will be, but if you have more sustained current than the tested forward current ($I_F$), the diode may burn out. Don't forget the diode drop. Always be conservative.

Spec sheet:
http://www.us.kingbright.com/images/catalog/SPEC/WP7113PBC-A.pdf

# Digikey.com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Inductors, Coils, Chokes
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Design
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EDA & Design Tools
Conversion Calculators
Maker.io
PNP Series Sealed Pushbutton Switches
C&K switches designed to endure harsh environments
Longer solder leads for ease of wire installation
Larger solder holes, allowing up to two 22-gauge wires to be connected
A resistive load of up to 5 A
Learn More

# 03

# Binary, Hex

# Binary numbers (base 2)

00=0

**01=1**

**10=2**

11=3

In this example:
2-bit number
2 digits, each binary
total of 4 possible.

MSB LSB

0000=0

**0001=1**

**0010=2**

0011=3

**0100=4**

0101=5

0110=6

0111=7

**1000=8**

**... up to 15**

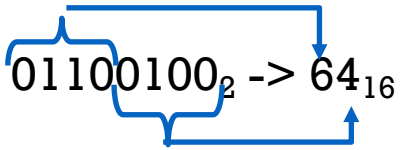
MSB = Most significant bit
LSB = Least significant bit

In this example:
4-bit number
4 digits, each binary

# Hexadecimal numbers (base 16)

- "Digits" represent 0-15. Use 0123456789ABCDEF
- Compact way to represent binary numbers
- Represents exactly 4 bits:
- Chunk 8 bit "bytes" into two 4 bit hex "nibbles"

$100_{10}$ -> $01100100_2$ -> $64_{16}$



'C' notation

asm notation

- Hex notation represented by 0x_ _ or $_ _

  0x64 or $64

# Binary - Hexadecimal

- 0000=0
- 0001=1
- 0010=2
- 0011=3
- 0100=4
- 0101=5
- 0110=6
- 0111=7
- 1000=8
- 1001=9
- 1010=A
- 1011=B
- 1100=C
- 1101=D
- 1110=E
- 1111=F

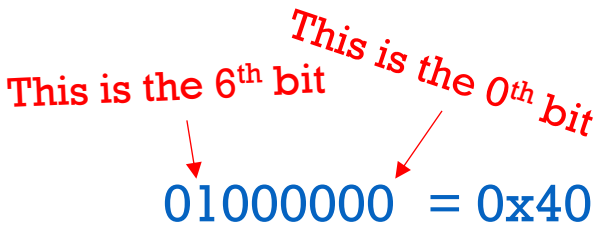
11111111 = 0xFF

11000011 = 0xC3

11011110 10101101 = ?

10111110 11101111 = ?

Question 8: Translate binary to hex



# 04

# Intro Lab 1.2 and Teensy

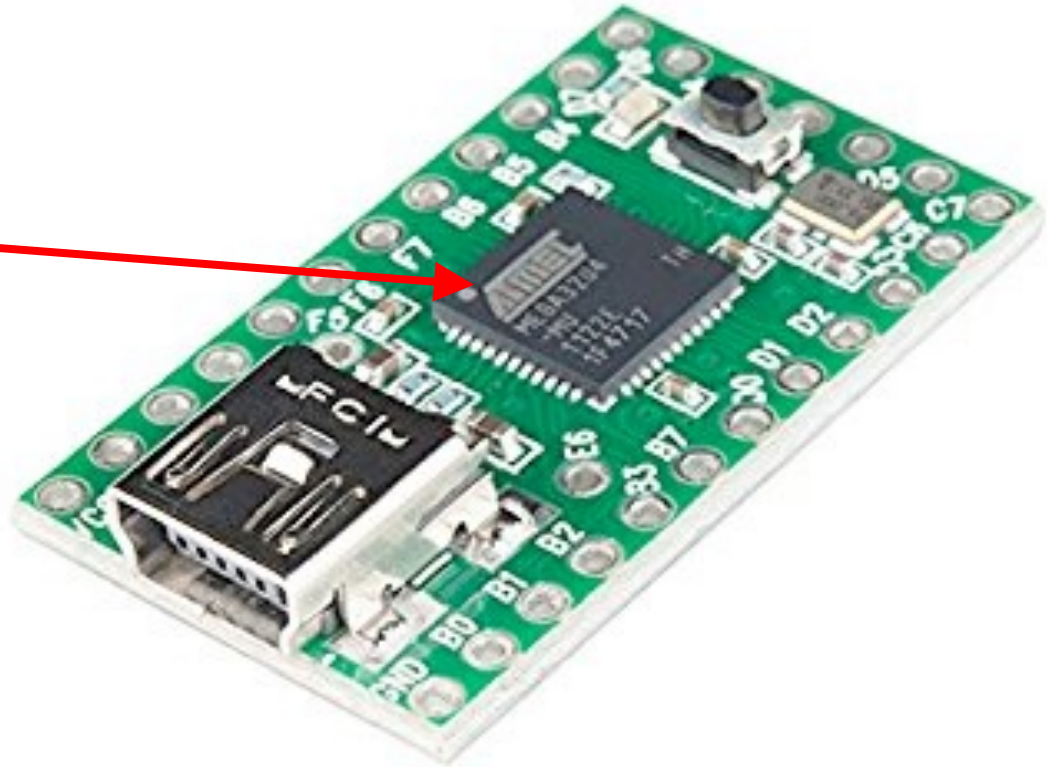
# Microcomputers/Microcontrollers

- Are very common and can be found many places like:
  - Cell phones
  - Automobiles
  - Home appliances
- They interface with sensors and/or actuators
- They need to be programmed to function


# The Teensy 2.0

(ATmega 32 U4)

From PJRC.com



# ATmega32 U4 8-bit Microcontroller

- Can operate @ 5 V
- 32K of program space, 2.5K RAM
- 16 MHz clock speed,
- Peripherals:
  - USB 2.0 interface
  - USART / SPI
  - 16-Bit Timer
  - 12-channel 10-bit ADC
  - 26 GPIO (24 available on Teensy)

Easy development
Note USB Mini

Communication with other devices

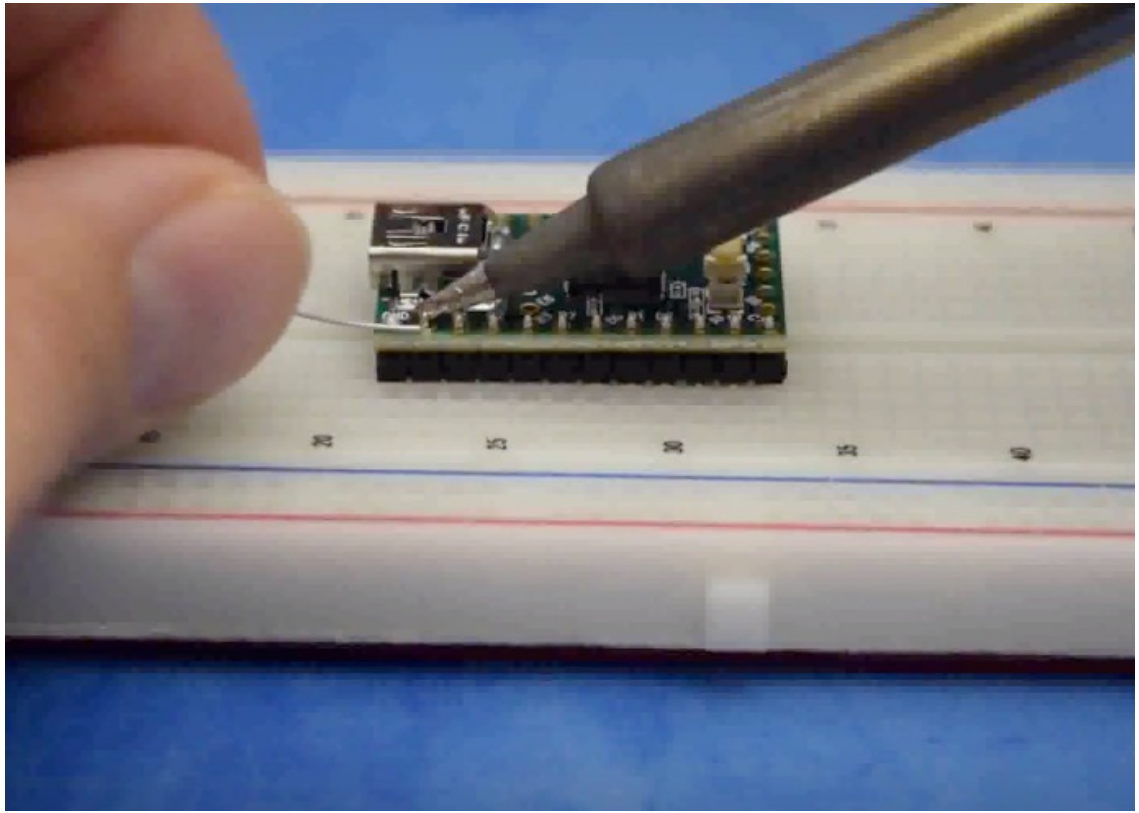
Timer + PWM

Analog input

Digital input/output

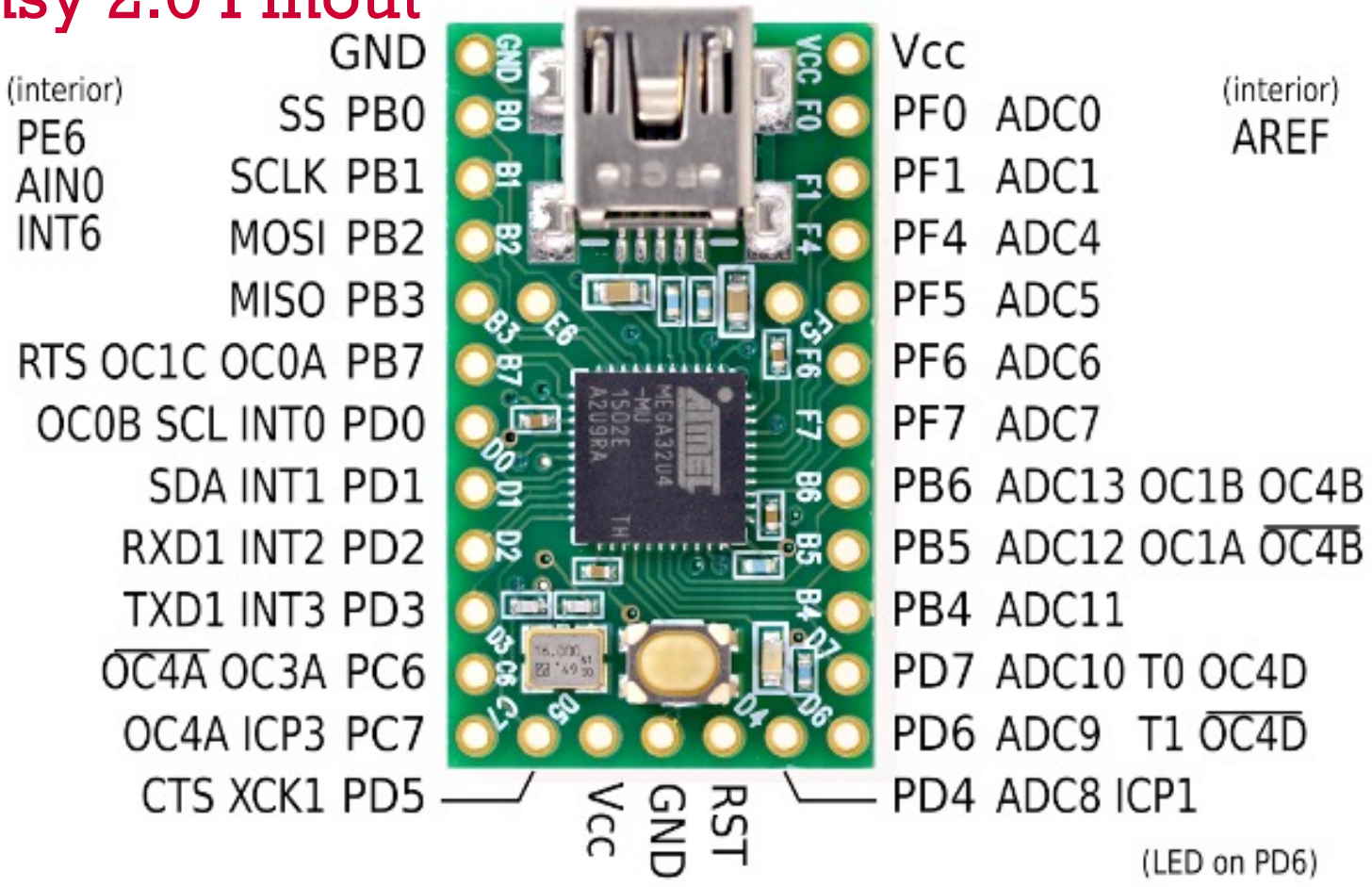
# Soldering the Teensy 2.0

3 min video
on good soldering
tips, how to solder
your teensy



https://www.youtube.com/watch?v=XYIqK4uzNYQ&t=78s

# Teensy 2.0 Pinout



# Example Program

Starting comment, explain what program is

```
/* Blink.c - Blinks internal LED  */
#include <avr/io.h>

int main(void)
{
    DDRD = 0x40;
        /* insert your hardware initialization here */
    for(;;){
      int i;
      PORTD ^= 0x40;
      for (i=0;i<30000; i++) ;
    }
    return 0;          /* never reached */
}
```

Includes another file into program

Initial setup

Puts a 1 in the 6th bit of DDRD register

Loop forever

XORs the value in the 6th bit of PORTD register
Causing pin D6 to alternate 5V or 0V

Runs ";" no-op, 30,000 times

# Example Program from Lab 1.2 (Blinky.c)

```
#include "teensy_general.h"

int main(void)
{
    teensy_clockdivide(0); //set the clock speed
    teensy_led(ON);        // turn on the on board LED
    teensy_wait(1000);     // wait 1000 ms when at 16 MHz

    for(;;){     /* insert your main loop code here */
        teensy_led(TOGGLE);// switch the led state
        teensy_wait(1000);
    }
    return 0;    /* never reached */
}
```

Includes another file into program

Initial setup

Loop forever

Calls no-ops, but calibrated to take 1ms per input value.

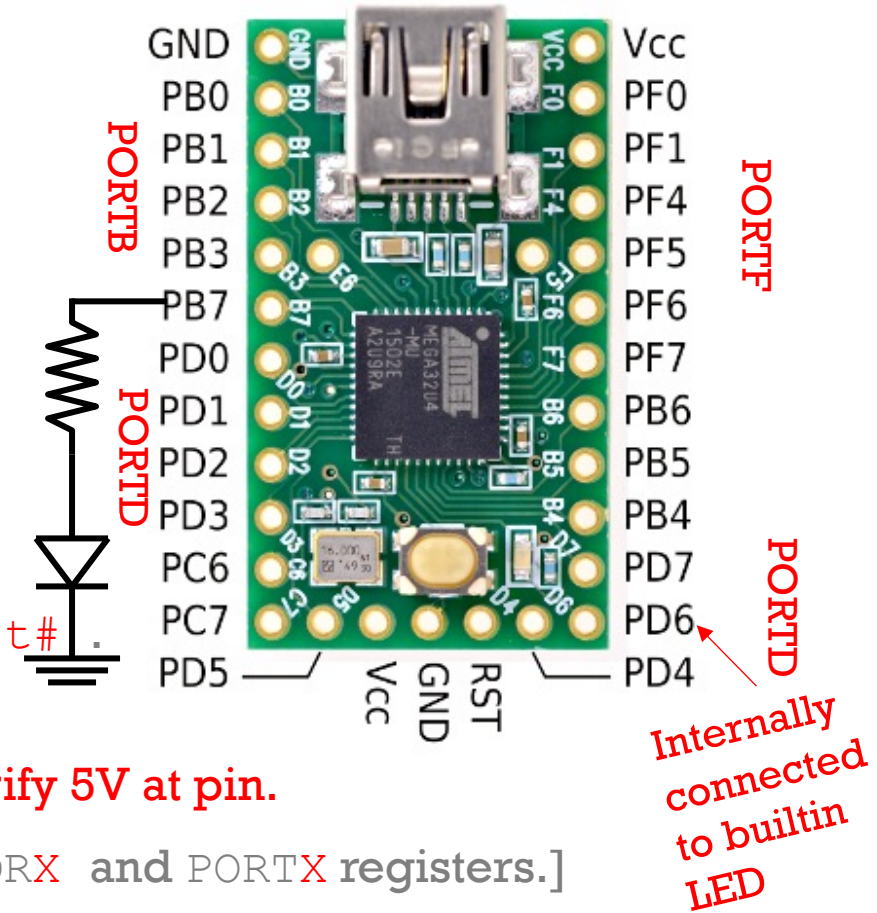
# "teensy_general.h" Header File

```
[…]
#define teensy_led(val)     set(DDRD,6);\
        if(val==OFF){set(PORTD,6);}\
        else if(val==ON){clear(PORTD,6);}\
        else if(val==TOGGLE){toggle(PORTD,6);}

[…]
#define OFF         0
#define ON          1
#define TOGGLE      2

[…]
#define set(reg,bit)          reg |= (1<<(bit))
#define clear(reg,bit)        reg &= ~(1<<(bit))
#define toggle(reg,bit)       reg ^= (1<<(bit))
```

Allows macro to continue past the end

# Blinking external LED

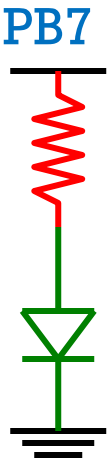
1. Choose any pin PX#
   - Example: PB7
2. Hookup LED to pin
   - current limited so port is not blown
3. In code, set `DDRX bit#` to be 1.
   - Example `DDRB = 0x80;`
4. Alternate writing 0 and 1 at `PORTX bit#`.
   - Example `PORTB ^= 0x80;`

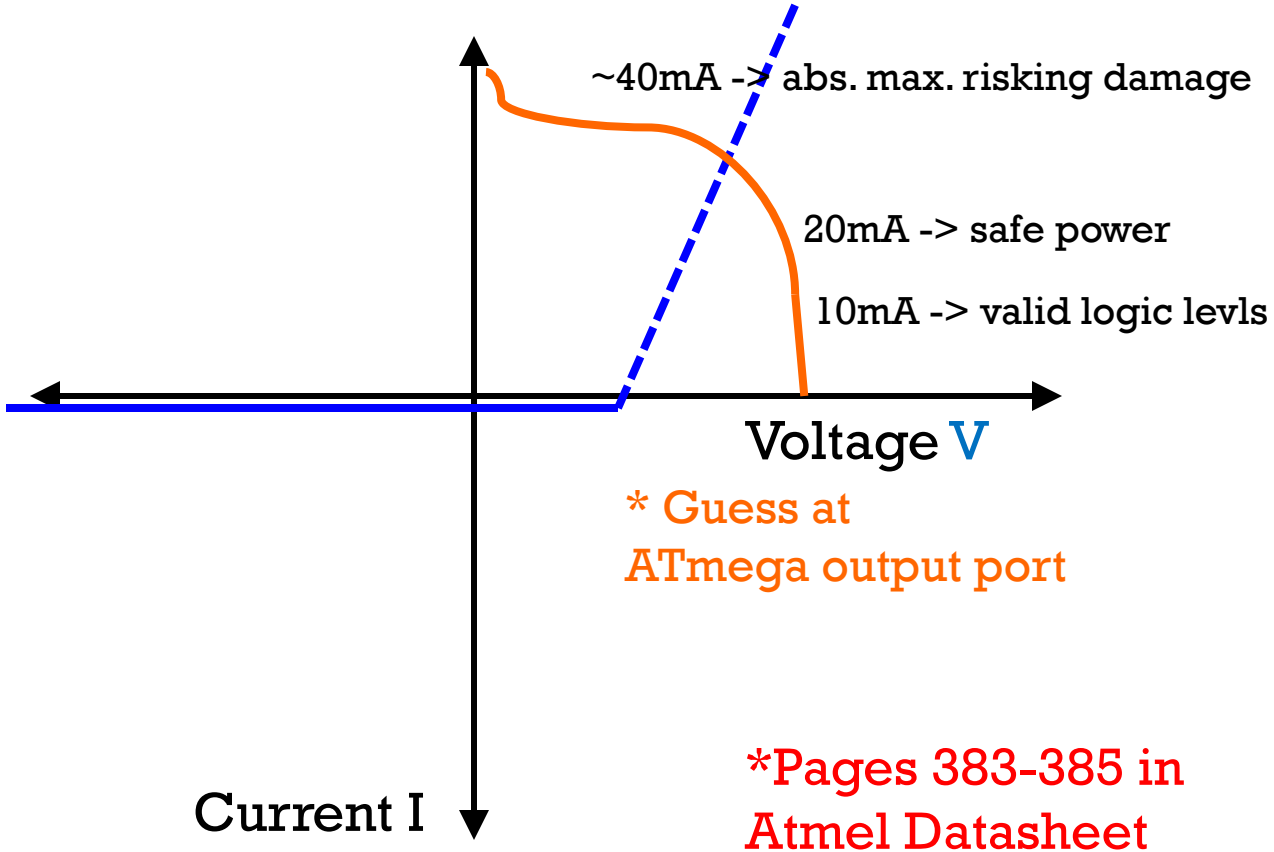



**To debug: write 1 to port, use DMM to verify 5V at pin.**

[Next lecture we'll talk more about the `DDRX` and `PORTX` registers.]

# What is “limiting” case for Atmega ?




* Guess at
ATmega output port

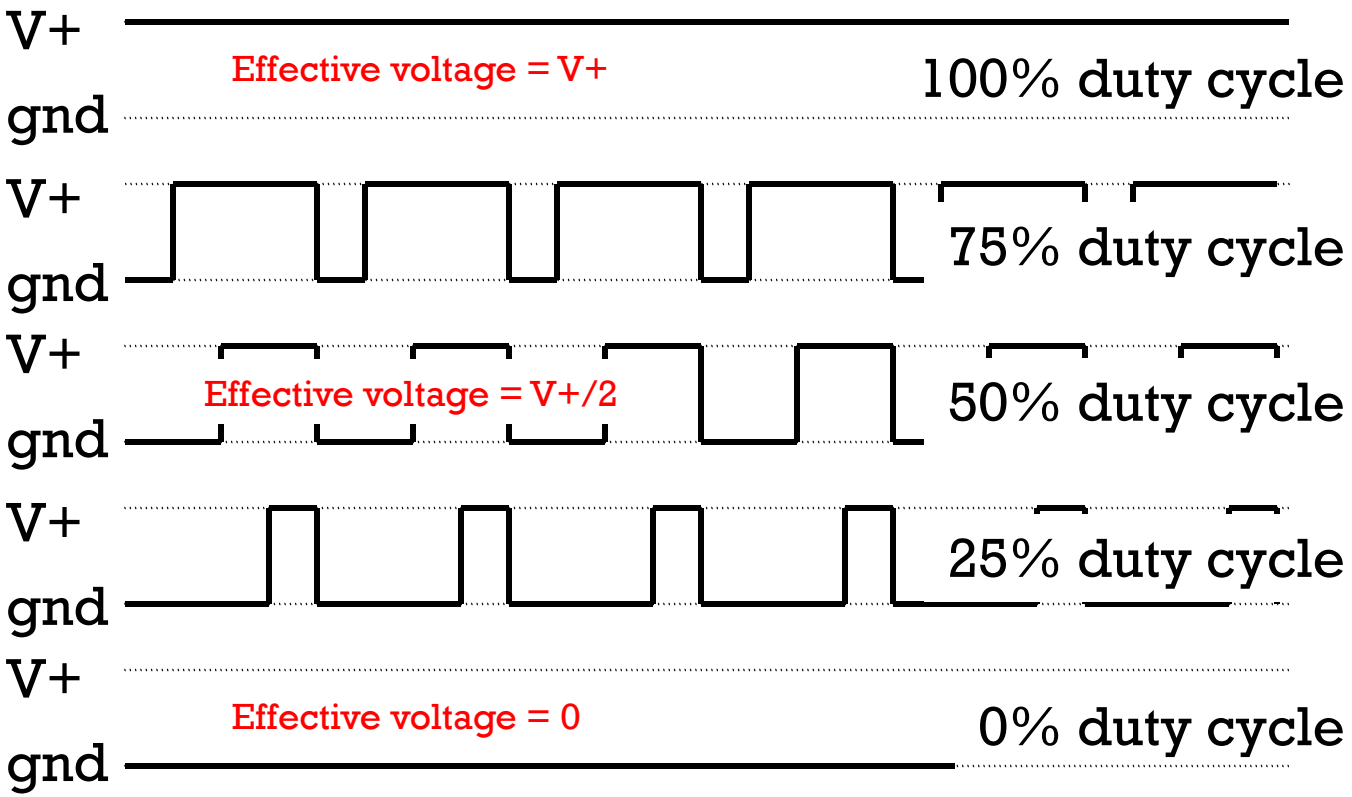
*Pages 383-385 in
Atmel Datasheet

# 05

# PWM
# Pulse Width Modulation

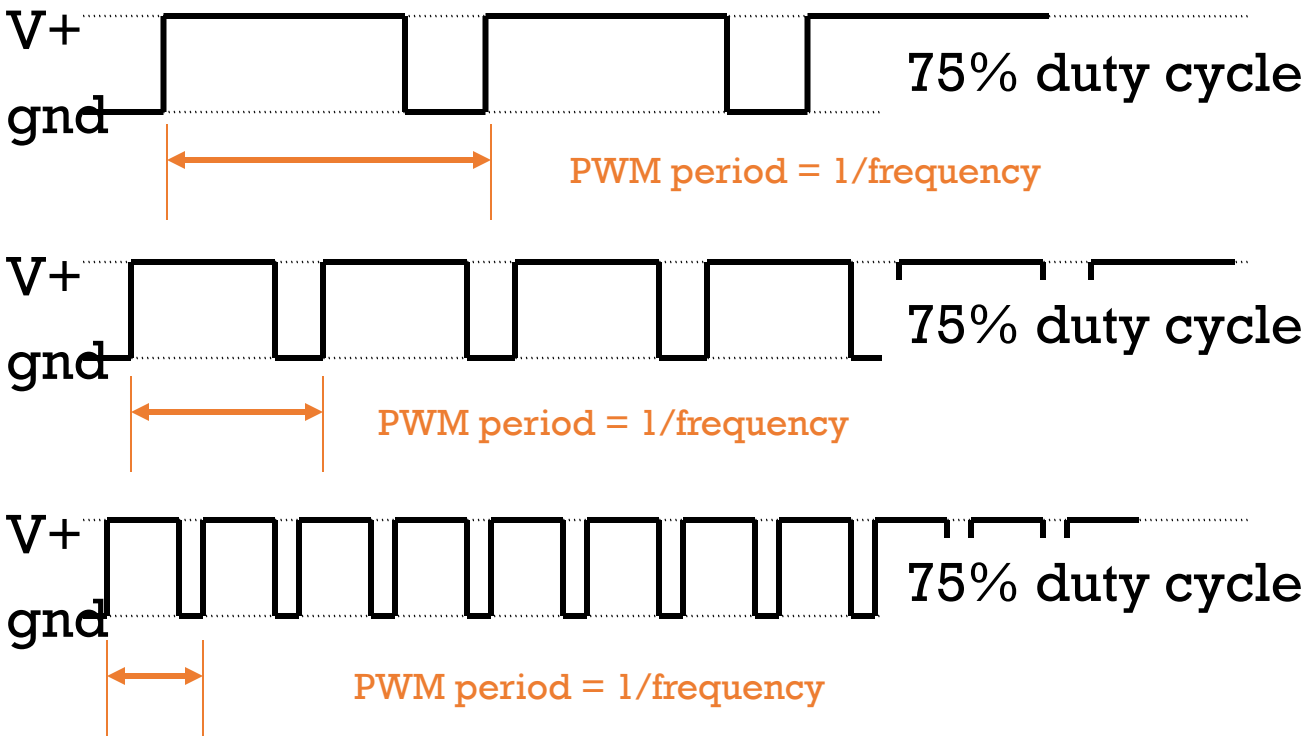
# What is pulse width modulation? (PWM)

## Duty Cycle



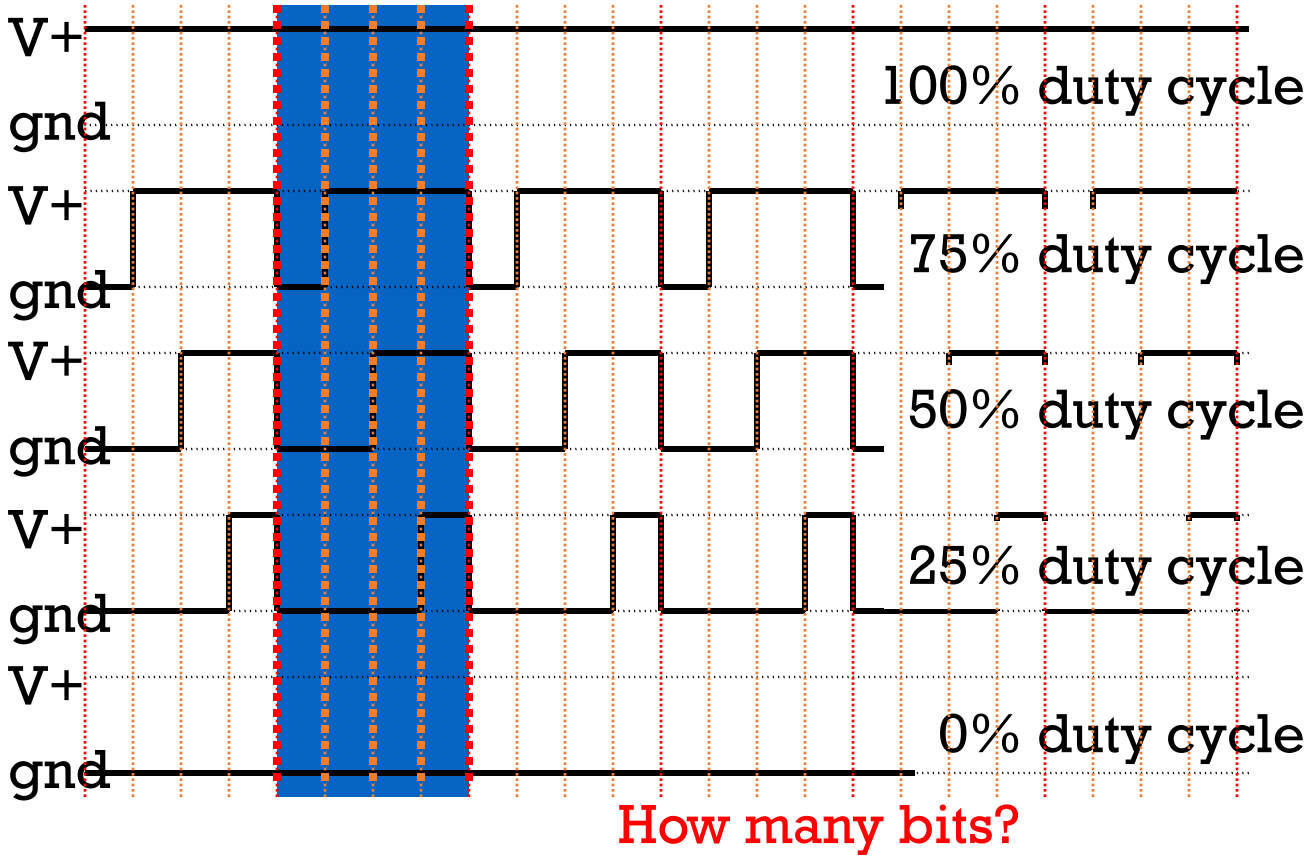
# What is pulse width modulation? (PWM)

## PWM frequency



# What is pulse width modulation? (PWM)

## Resolution




How many bits?

# Summary for Lab 1.1 and part of 1.2:

- Use function calls to make code easier to build on.
- Don't use "Absolute Maximum" for design purposes.
- Resistors in series with diode limits current
- Our Teensy boards sink/source up to 20mA at a pin
- Prep for next lecture: watch this 5 min video
  https://www.youtube.com/watch?v=p3q5zWCw8J4

# Answer in CHAT

Answer how you feel about each topic below with:

1. I don't understand this topic at all
2. I don't know now, but know what to do to get by
3. I understand some, but expect to get the rest later
4. I understand completely already

A. Passive components

B. LED's

C. Teensy programming