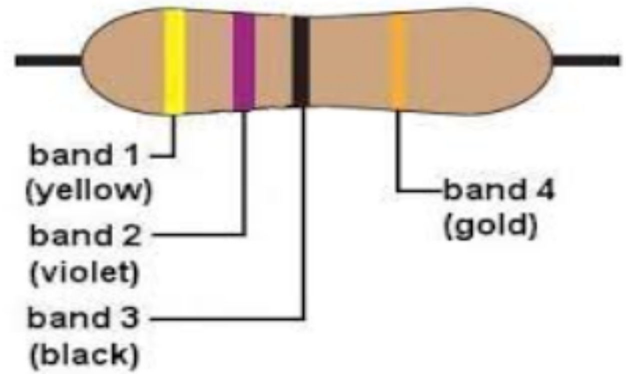
CST8227 INTERFACING

Lab 1 Help Slides

Resistors

- By far the most common type of device.
- Resistors have two purposes in a circuit:
    1. To reduce that amount of current flow.
    2. To create different voltage levels.
- Resistors convert the energy passing through them into heat.
    - This can be an advantage because, in addition to being sensors, they can sometimes be actuators.
    - This can also be a disadvantage, for example heat can affect the accuracy of sensing measurements.
- Many sensors are manufactured such that its resistance changes in response to a change in environment (ex. temperature, humidity, strain/stress/pressure, light, wind, etc.)



Resistor Color Code

COLOUR	NUMERICAL VALUE (1st and 2nd BANDS)	MULTIPLYING VALUE OF 3rd BAND	PERCENT TOLERANCE OF 4TH BAND
BLACK	0	1 (= 10^0)	
BROWN	1	10 (= 10^1)	1%
RED	2	100 (= 10^2)	
ORANGE	3	1,000 (= 10^3)	
YELLOW	4	10,000 (= 10^4)	
GREEN	5	100,000 (= 10^5)	
BLUE	6	1,000,000 (= 10^6)	
VIOLET	7	10,000,000 (= 10^7)	
GRAY	8	100,000,000 (= 10^8)	
WHITE	9	1,000,000,000 (= 10^9)	
GOLD		0.1	5%
SILVER		0.01	10%
IF TOLERANCE	IS NOT INDICATED	BY COLOUR	20%

What do the bands mean?

- **Bands 1 and 2** refer to the size of the resistor.
- **Band 3:** Multiplier 10 raised to the power, 10^{+0} to 10^{+9}

  Note:

  Gold = 10^{-1} (i.e. **x 0.1** ohms), Silver 10^{-2} (i.e. **x 0.01**ohms)
- **Band 4:** Tolerance: Gold = 5%, Silver = 10%, Blank = 20%

<u>Example:</u>

Band 1 = red (2)

Band 2 = blue (6)

Band 3 = red (2)

Band 4 = gold (5%)

$26 * 10^2 = 26 * 100 = 2600\ \Omega$ $= 2.6\ k\ \Omega$, 5% tolerance

Series and Parallel Circuits

- There are only two ways of arranging resistors (or any other circuit element):
  1. Series
  2. Parallel.

- Resistors in *series*, can be replaced by a single equivalent resistance, according the following formulae:

  $R_T = R_1 + R_2 + \ldots\ldots + R_N$ where R_T = R total

- Resistors in *parallel*, can be replaced by a single equivalent resistance, according the following formulae:

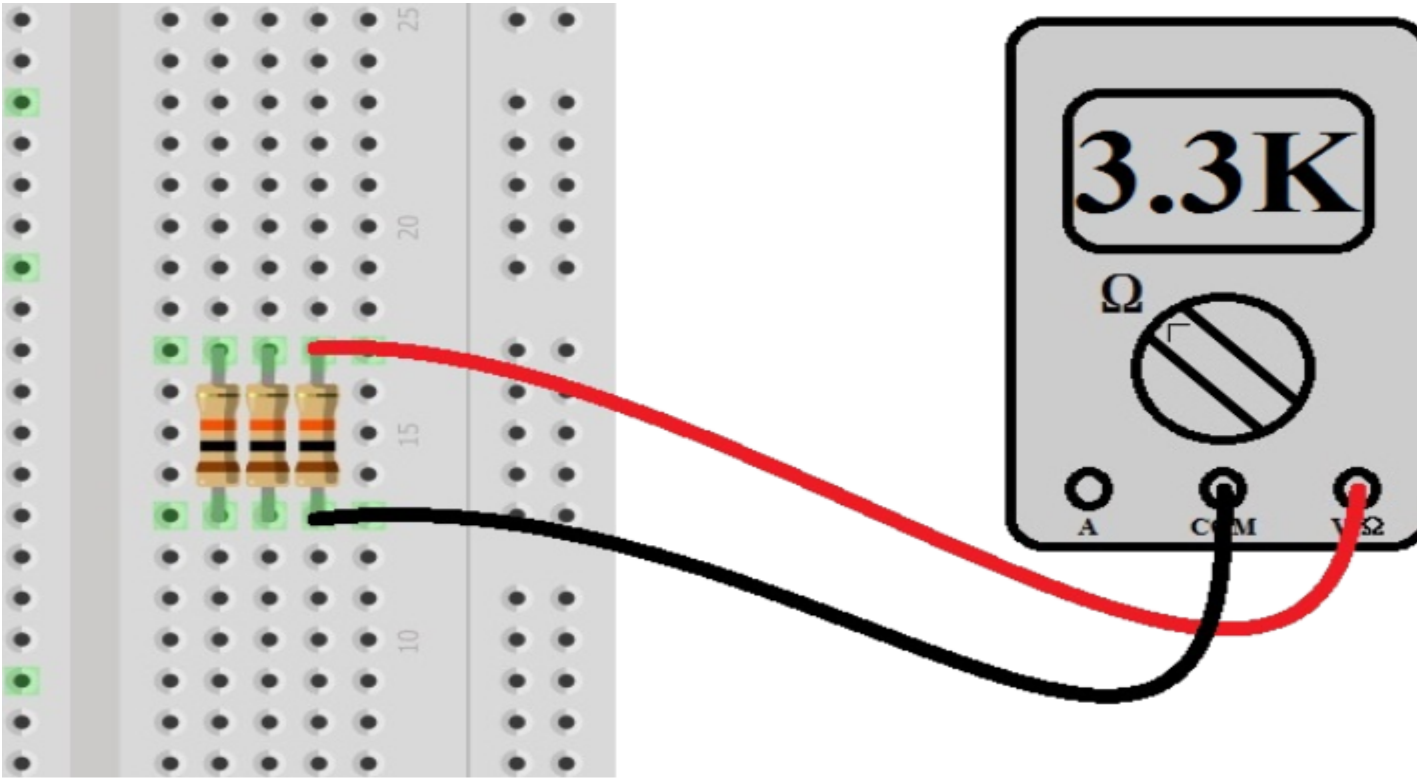
  $\frac{1}{R_T} = \frac{1}{\frac{1}{R1}+\frac{1}{R2}+\ldots\frac{1}{RN}}$ *in the case of only two resistors in parallel,* $R_T = \frac{R_1 * R_2}{R_1 + R_2}$

- *Now some "pencil and paper" calculation*

Series Components in a Protoboard

Graphic courtesy of https://learn.sparkfun.com/tutorials/series-and-parallel-circuits

Parallel Components in a Protoboard



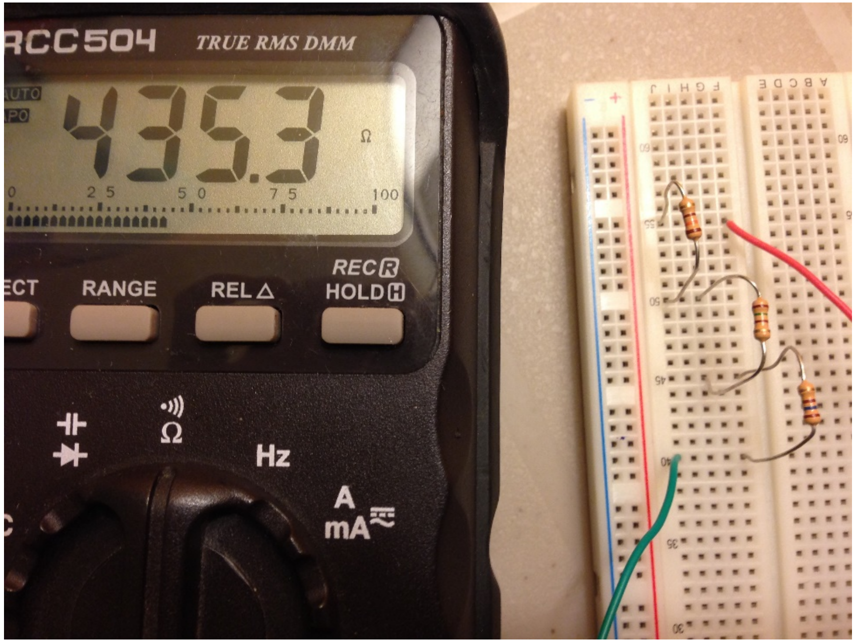
Lab 1

<u>Circuit 1:</u>

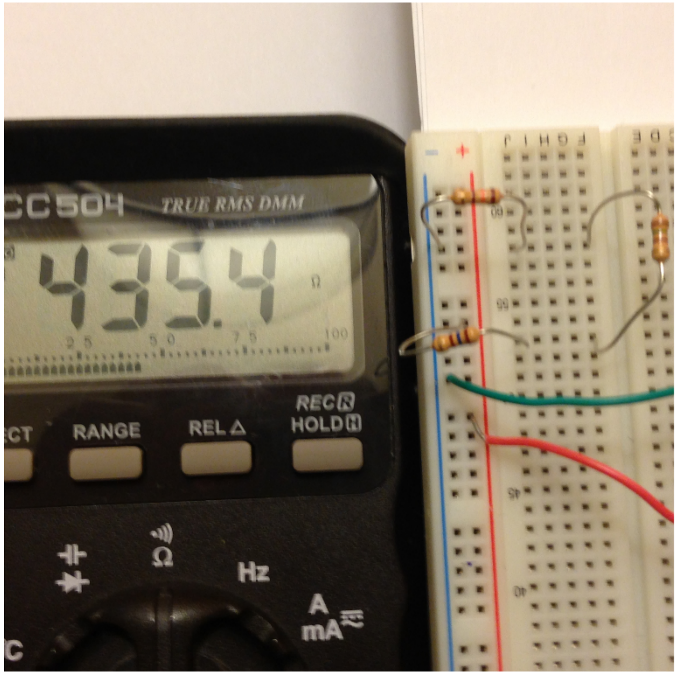
$R_T = R_1 + R_2 + R_3$

$= 130\ \Omega + 150\ \Omega + 160\ \Omega$

$= 440\ \Omega$



Circuit 1 Connected to power rails



Lab 1

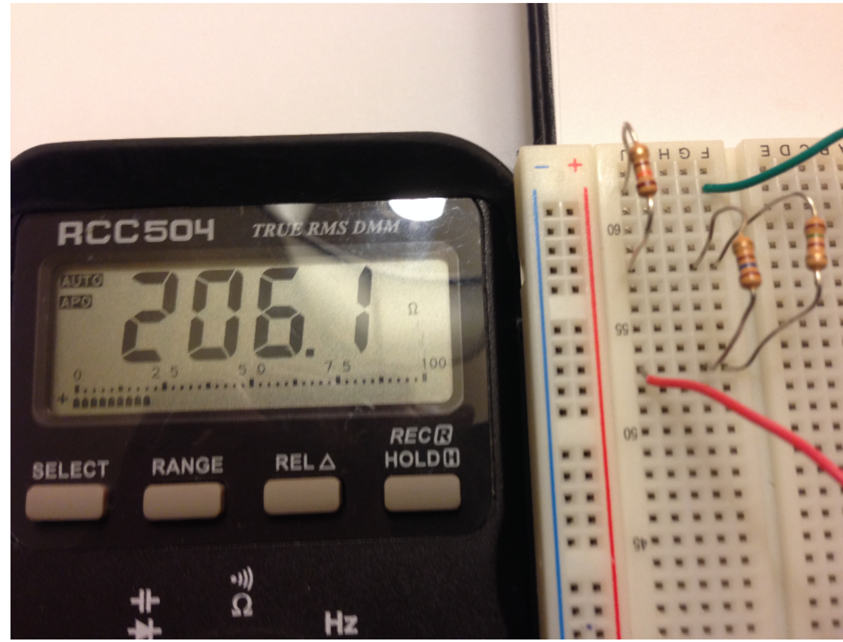
<u>Circuit 2:</u>

$$R_T = R_1 + R_2 \parallel R_3$$

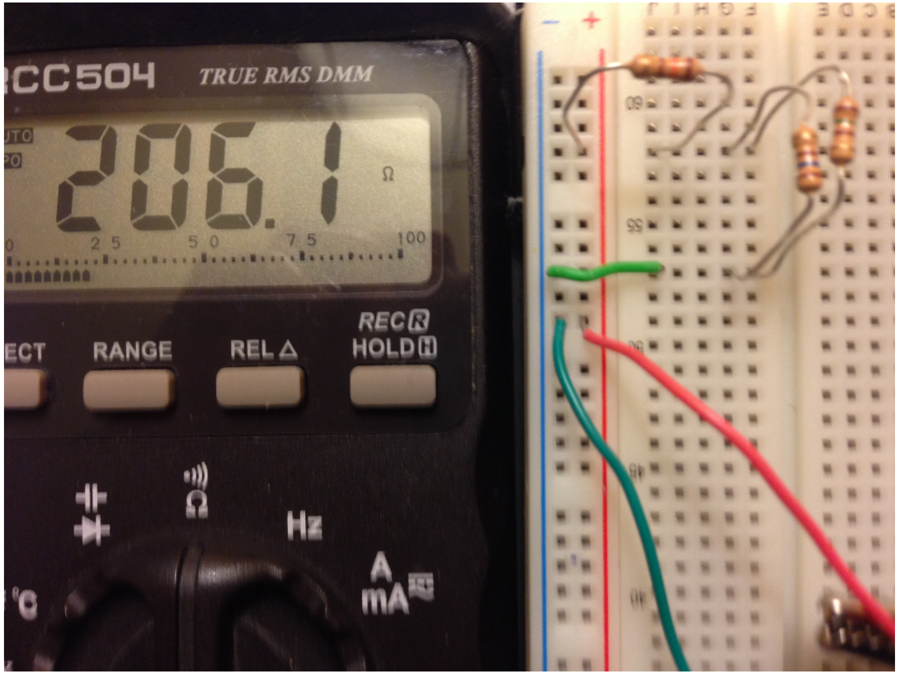
$$= 130\ \Omega + 150\ \Omega \parallel 160\ \Omega$$

$$= 130\ \Omega + 77.4\ \Omega$$

$$\approx 207.4\ \Omega$$



Circuit 2 Connected to power rails



Lab 1

<u>Circuit 3:</u>

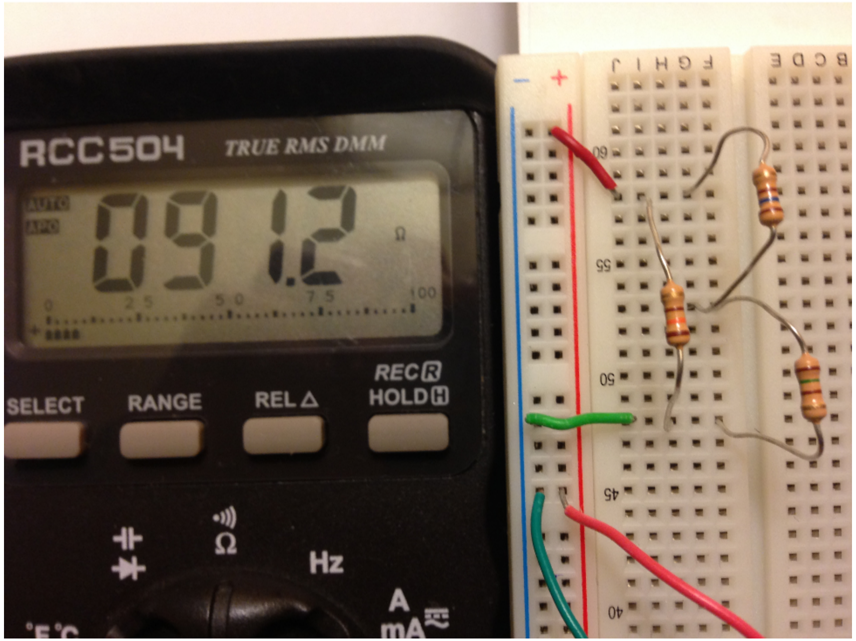
$R_T = R_1 \parallel (R_2 + R_3)$

$= 130\ \Omega \parallel (150\ \Omega + 160\ \Omega)$

$= 130\ \Omega \parallel 310\ \Omega$

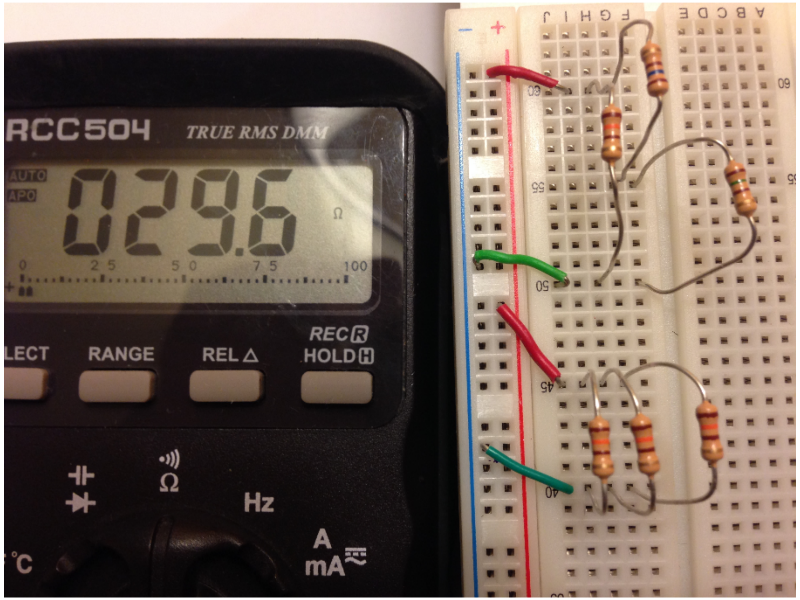
$\approx 89.6\ \Omega$

[91.2 Ω measured]



Lab 1

When several circuits are connected to the power supply rails, they become a parallel circuit. This resistance "load" will dictate the total current drawn by the circuit according to Ohm's Law: V = I*R

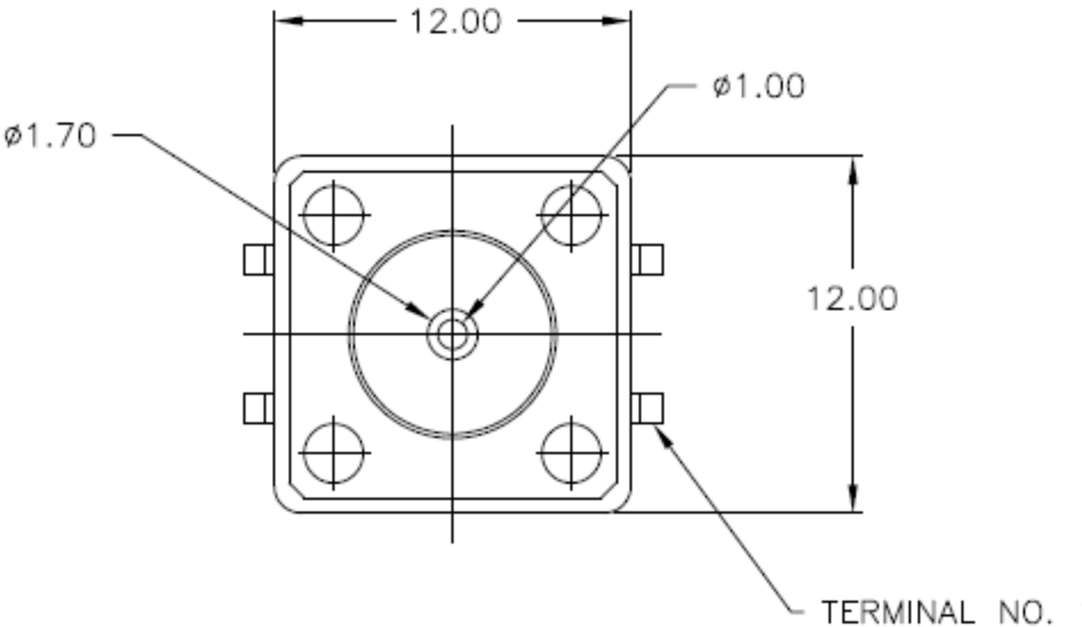


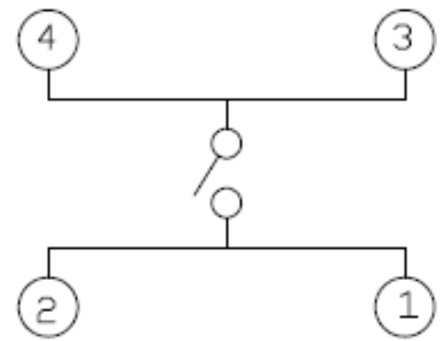
Circuit 1 $R_T \approx$ 89.6 Ω
Circuit 2 $R_T \approx$ 43.3
Circuit 1 || Circuit 2 = 89.6 Ω || 43.3 ≈ **29.2 Ω**

Circuit 1 I_T = 36.8 mA
Circuit 2 I_T = 76.2 mA
Circuit 1 || Circuit 2 I_T = 113 mA

Using Vcc = 3.3 volts

Switch pinout and Schematic

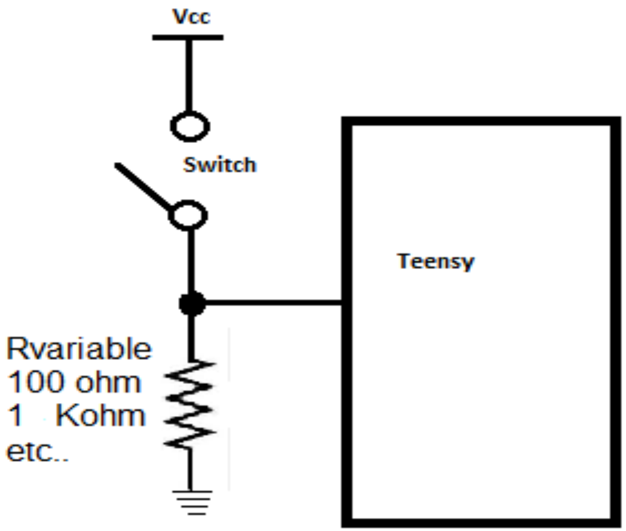




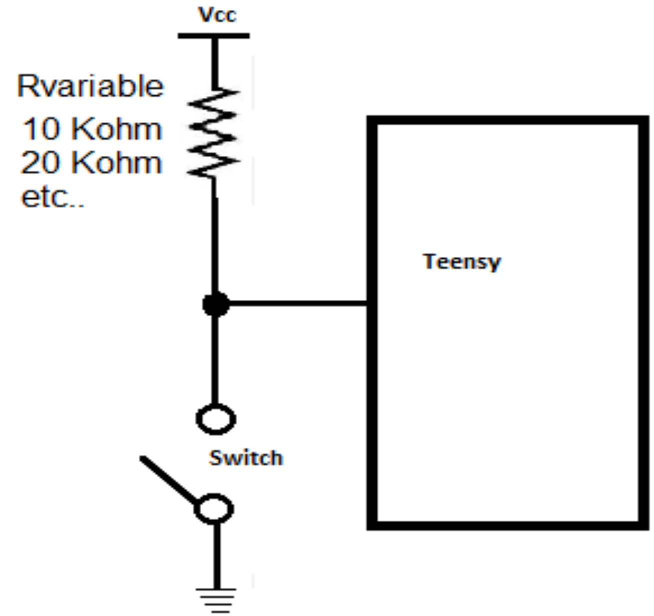
CIRCUIT DIAGRAM

“Pull-Down” and “Pull-Up” Resistors

Pull-down configuration

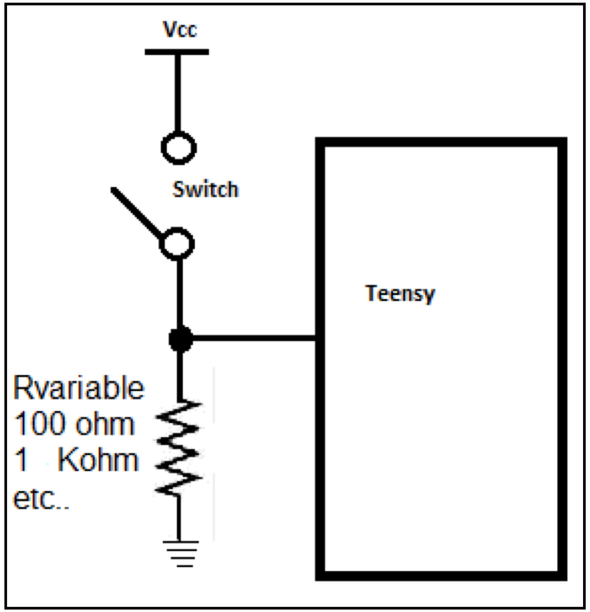


Pull-Up configuration



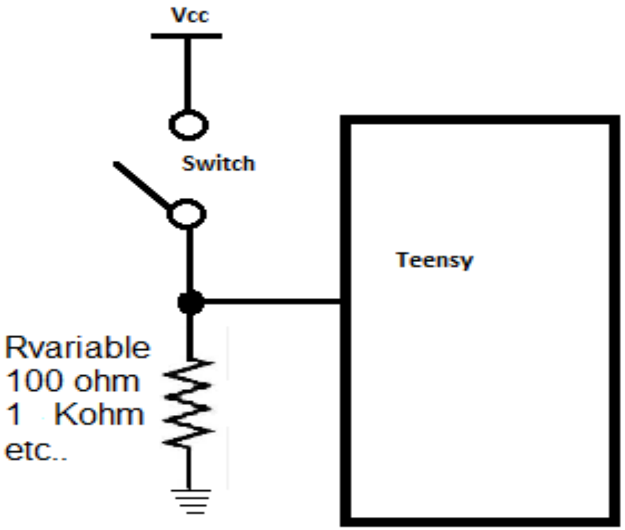
Pull-down Resistor

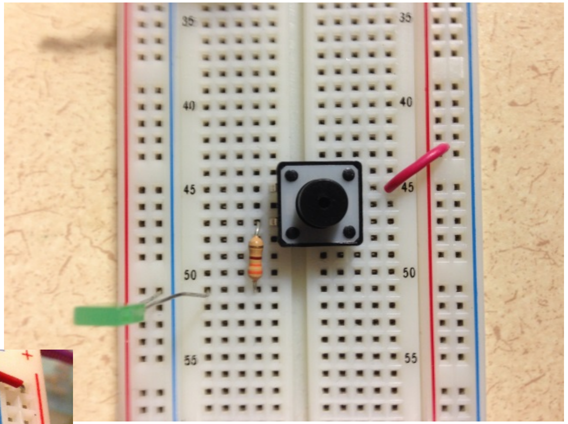
- The pull-down resistor must have a small resistance.
- I/O pins on the ARM chip (and therefore the Teensy), have a small leakage current.
- This leakage current is in the 10^{-6} range (see ARM data sheet).
- When the switch is open, the leakage current will flow from the Teensy, through the pull-down resistor, to GND.
- When the switch is open and is supposed to be reading a binary “0” or LOW, the pull-down resistor must be sufficiently small, such that the leakage current would not cause a large enough voltage to be developed, and accidently trigger a “false” HIGH reading

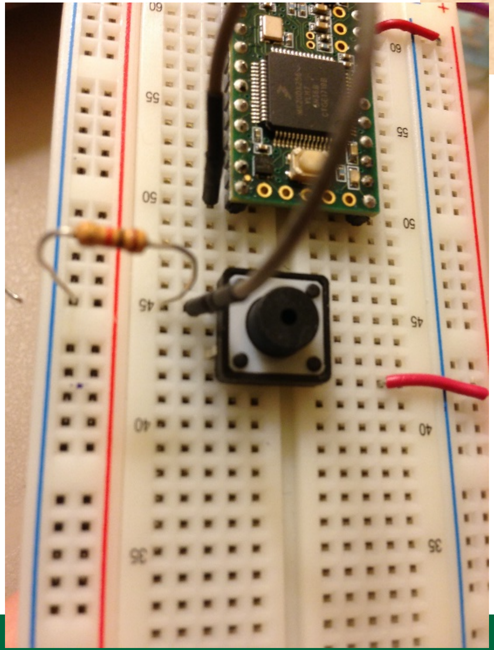


Pull-down Configuration

Pull-down configuration

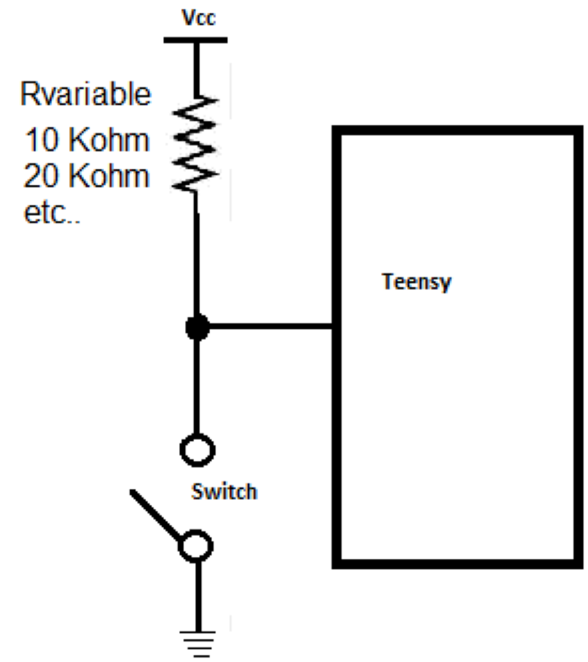




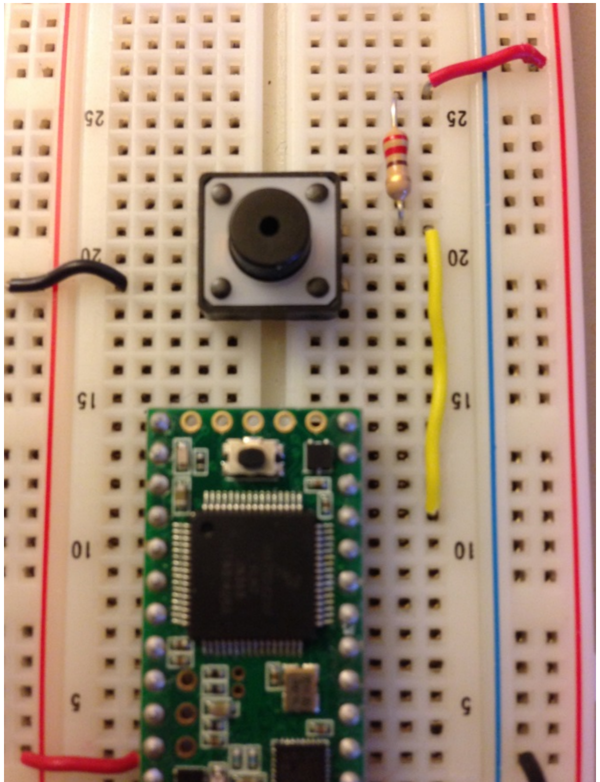


Pull-up Resistor

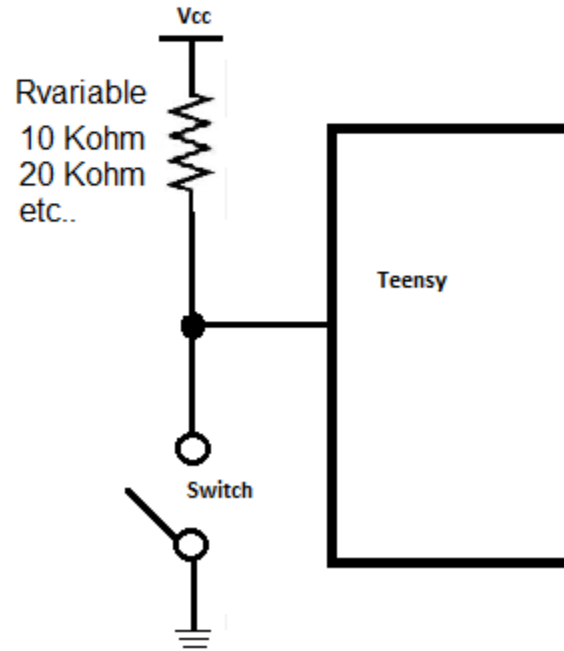
- The pull-up resistor must have a larger resistance than the *impedance* of the logic circuit, or else it might be able to pull the voltage down by too much and the input voltage at the pin would remain at a constant logical low value – regardless of the switch position.



Pull-Up Configuration



- Pull-Up configuration

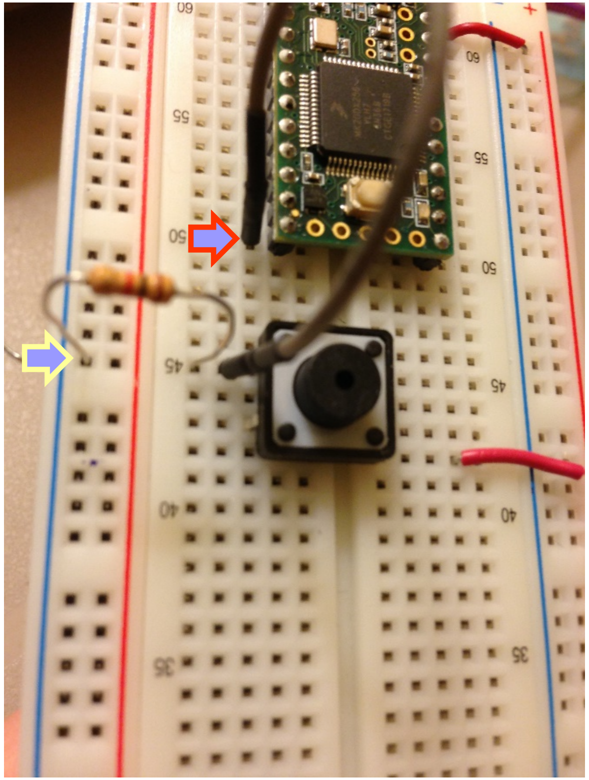


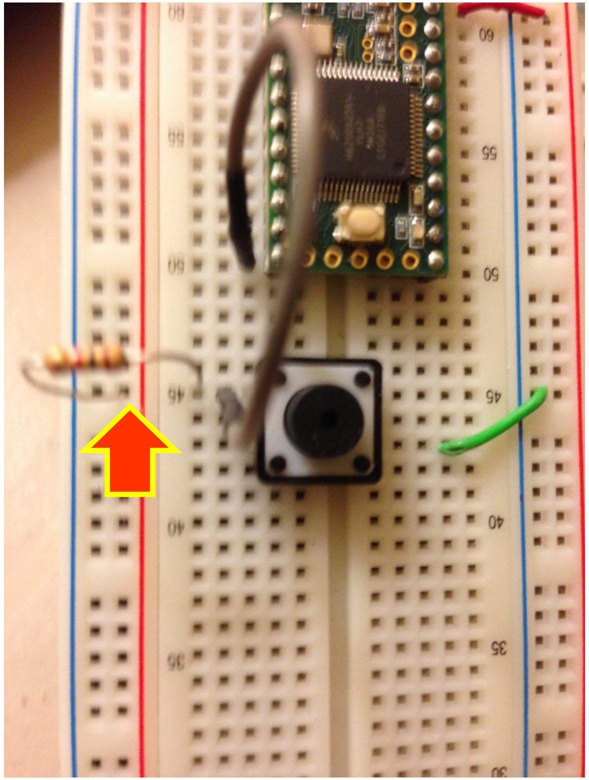
Pull-down versus Pull-up

Resistor connected to GND rail.

Output to microcontroller measured at resistor to GND side of switch

Other side of switch connected to Vcc rail





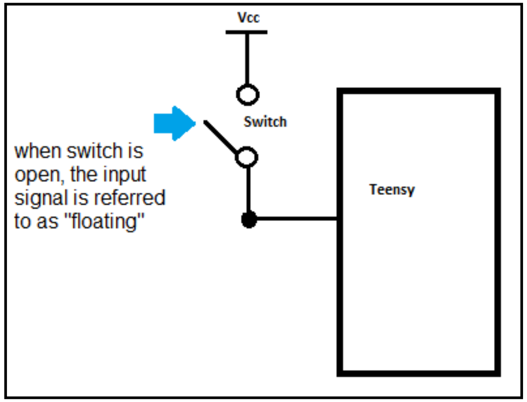
Resistor connected to Vcc rail.

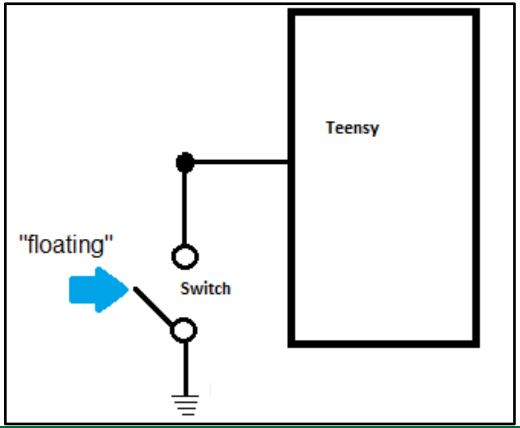
Output to microcontroller measured at resistor to Vcc side of switch

Other side of switch connected to GND rail

Why use these two configurations?

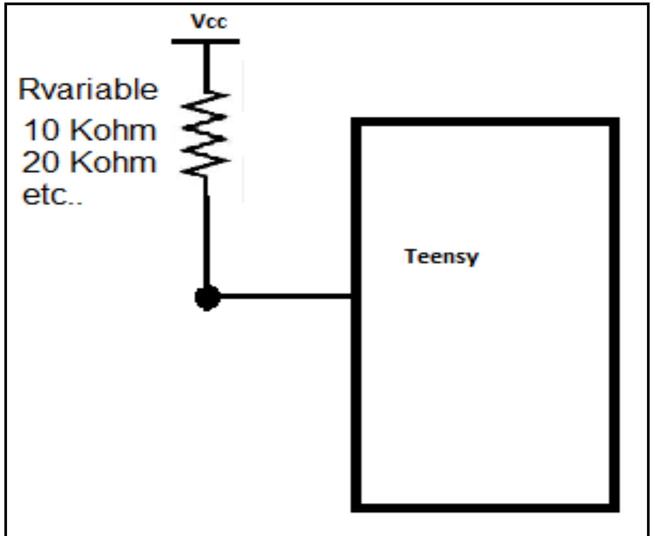
- To avoid a condition known as “floating inputs”.
- A floating input is an input that is not connected to a GND or VCC – it is left open-circuited.
- Anything nearby may accidently trigger a false positive and the circuit may “think” that a relevant input has been specified.
- Things that could accidently trigger a false positive could be static electricity in the room (especially in dry Canadian winters), electrical noise (perhaps due to fluorescent lights), etc…





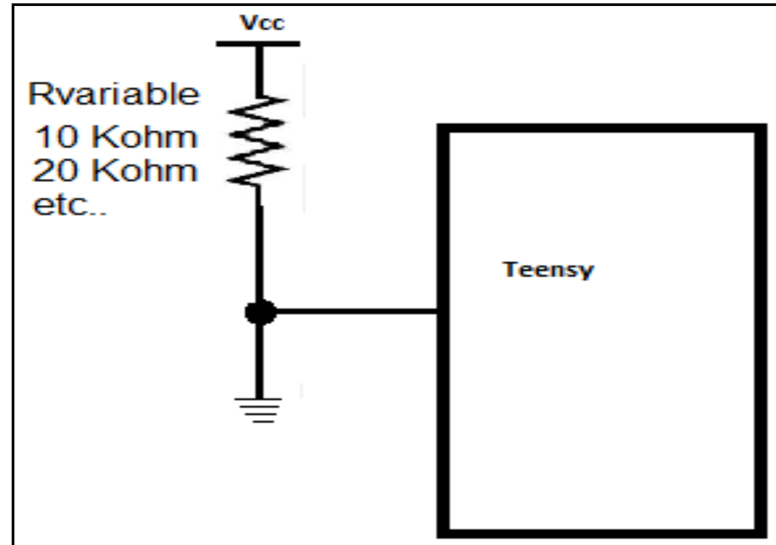
Open or Closed Switch Makes Two Different Circuits

Switch Open



When the button is not pressed, the input pin is pulled high. The value of the pull-up resistor controls the voltage on the input pin. General rule: use a resistor that is at least 10 times smaller than the value of the input pin impedance.

Switch closed



When the button is pressed, the input pin is pulled low. The value of resistor R controls how much current you want to flow from VCC, through the button, and then to ground.

Pull-Up Resistor Tips

- The actual value of the pull-up's resistance depends on the impedance of the input pin, which is closely related to the pin's leakage current.
- The appropriate value for the pull-up resistor is limited by two factors:

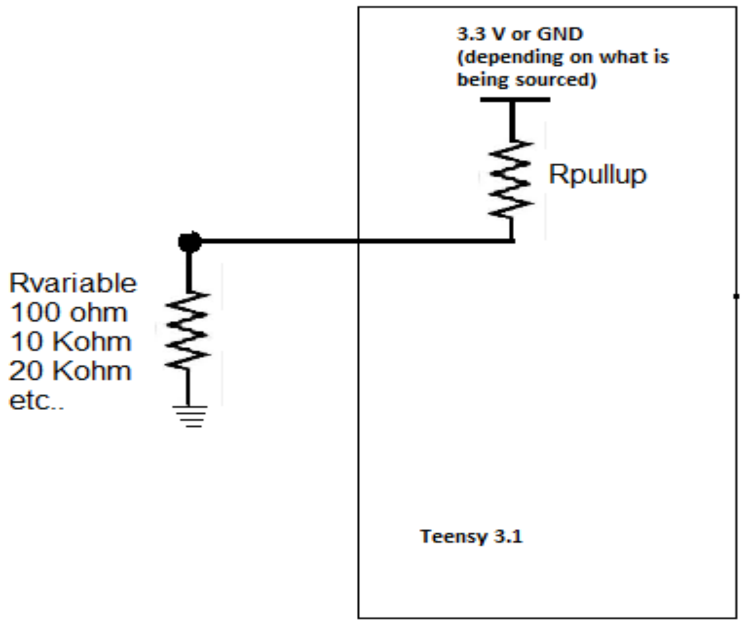
1. If the resistance value is too low, a high current will flow through the pull-up resistor (P=VI pin gets hot)
2. If the resistance value is too high, combined with a large leakage current of the input pin, the input voltage can become insufficient when the switch is open

Teensy 3.2 and Internal Pullup

- All of the pins have a pullup resistor (by virtue of the microcontroller) which may be activated when the pin is an input.

ex. pinMode(PIN_D7, INPUT_PULLUP);

- Check microcontroller data sheet document K20P64M72SF1.pdf page 13:
  - R_{PU} and RPD have internal resistors whose values are between 20 kΩ and 50 kΩ
- Pullup resistors are useful when connecting pushbuttons that can connect the pin to ground (low), but when the button is not pressed there is no connection at all.
- The pullup resistor causes the voltage to be high when nothing is connected.



Document K20P64M74SF1.pdf (the 67 page document)

Data Sheet for the MK20DX256 32 bit ARM Cortex-M4 72 MHz

Symbol/Description	What is it?
V_{DD} – Digital Supply voltage	An output from pins 3, 30 and 48
I_{DD} – Digital Supply current	The max. current permissible in the chip at any one time. The "global" current.
I_D	Maximum current single pin limit (applies to all digital pins)
V_{IH}	Input high voltage
V_{IL}	Input low voltage
R_{PU}	Internal pullup resistors
R_{PD}	Internal pulldown resistors
I_{IN}	Input leakage current (per pin) for full temperature range

Some noteworthy definitions

Closed circuit:

- In order for current to flow, a circuit must have a *closed* path (i.e. all components are connected in either a series or parallel configuration).

Open circuit:

- A circuit that has a component that is not interconnected

Continuity Test and short circuits:

- A test that determines if a circuit is open, closed or a short circuit.
- Use a multimeter set on resistance [Ω]
- If the meter reads ~0 Ω, then the circuit is a short circuit
- If the meter reads something like O.L. (overload) then the amount of resistance is [theoretically] infinite, and is called an open circuit.