Comparitors and Schmitt Triggers

ECE 211 Circuits I

Lecture #18

Please visit Bison Academy for corresponding lecture notes, homework sets, and solutions

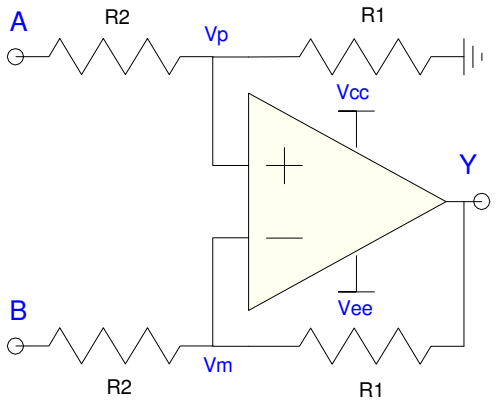
Vp = Vm does not *always* hold

Previous lectures assumed Vp = Vm

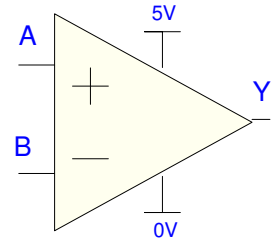
- Usually the case when there's negative feedback

Sometimes, this is *not* the case

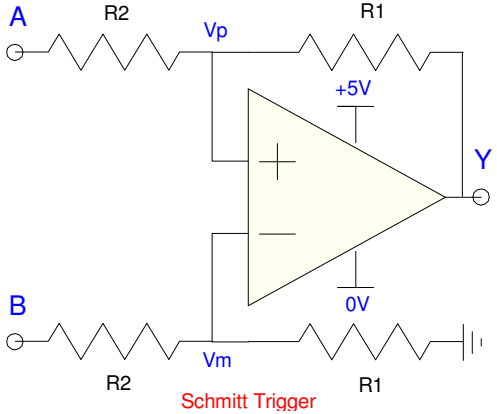
- Amplifiers with clipping
  - *Output cannot go above Vcc*
  - *Output cannot go below Vee*
- Comparitors
  - *No feedback*
  - *Y rails at either +5V or 0V*
- Schmitt triggers
  - *Positive feedback*
  - *Y rails at either +5V or 0V*



Clipping: Vcc < Y < Vee



Comparitor

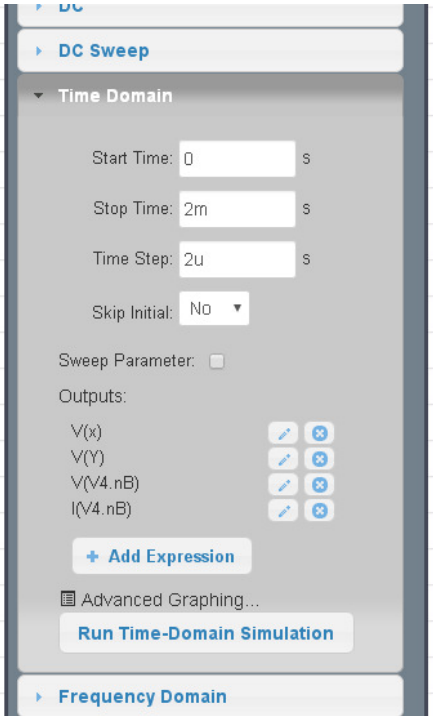


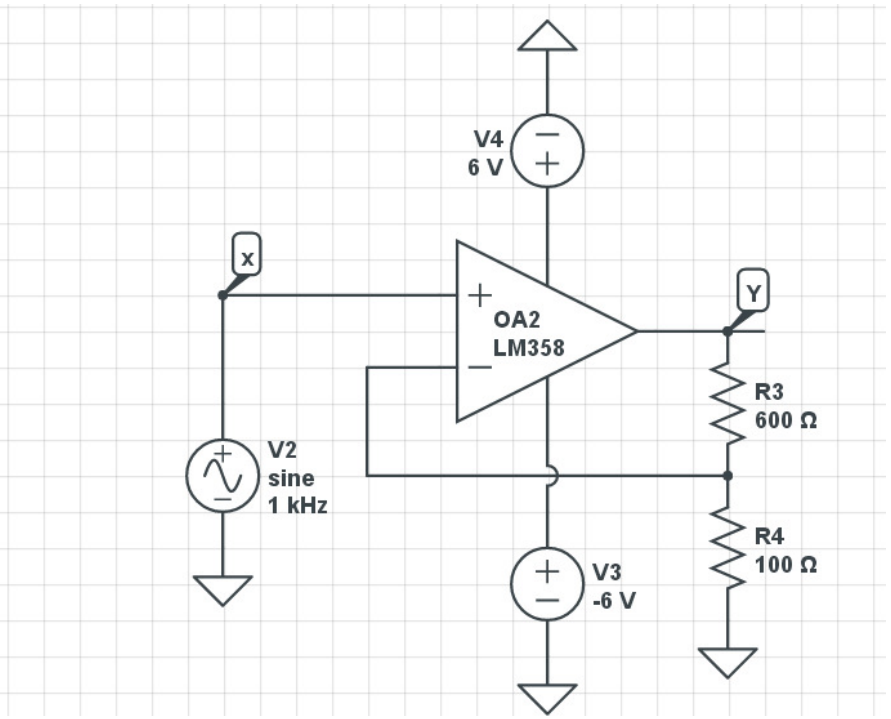
Schmitt Trigger

Clipping

- If you are using negative feedback Vp = Vm
- *Unless* you try to output a voltage that exceeds your power supplies

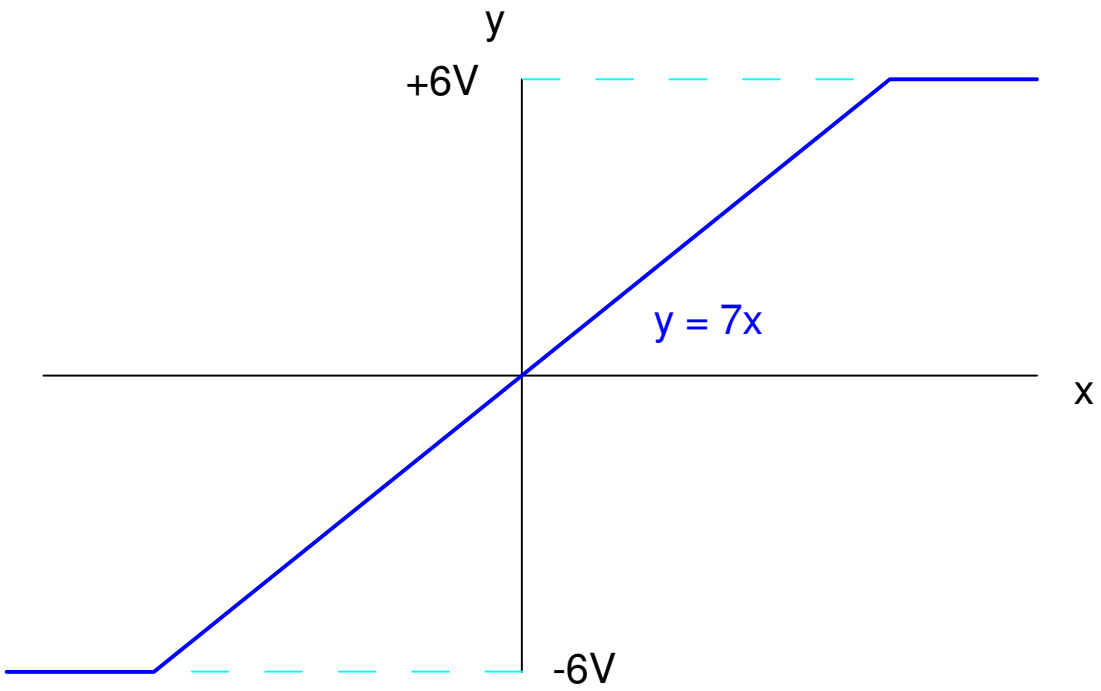
Example: $y = 7.00x$





With a +6V and -6V power supply

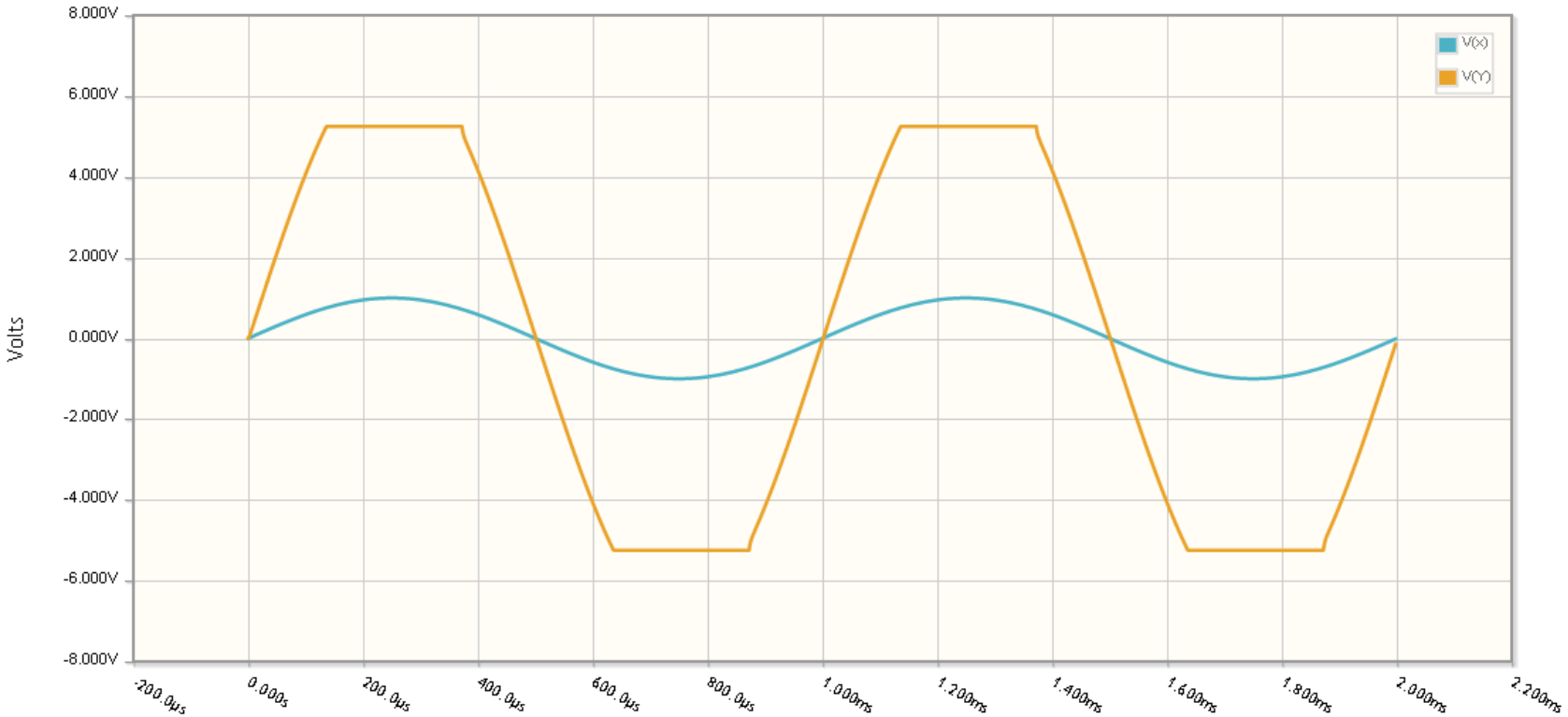
- Y = 7X
- Limited to -6V < Y < +6V



With +/- 6V power supplies, the output (y) is limited to +6V and -6V

Example:

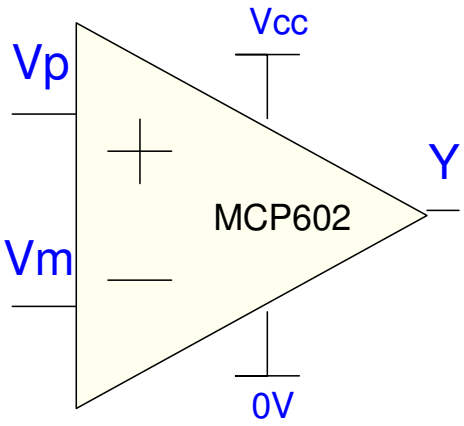
- V1 = 1Vp, 1kHz sine wave
- V2 = 7Vp, 1kHz sine wave
- Clipped at +/- 6V



Comparitors:

Outputs a binary signal

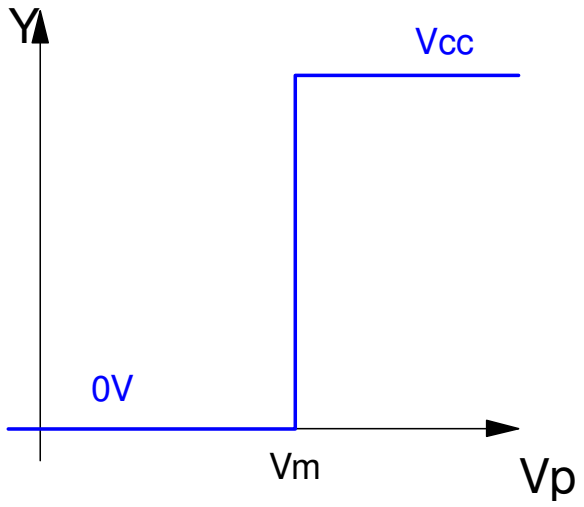
- Y = Vp > Vm
  - *0V = Logic 0*
  - *Vcc = Logic 1*



Comparitor

Usually use an MCP602 Op-Amp

- Single-Sided Power Supply
  - *2.7V < Vcc < 6.0V*
- Rail-to-Rail output
  - *Can go all the way down to 0V*
  - *Can go all the way up to +Vcc*



Comparitor: Y = (X > 4.00)

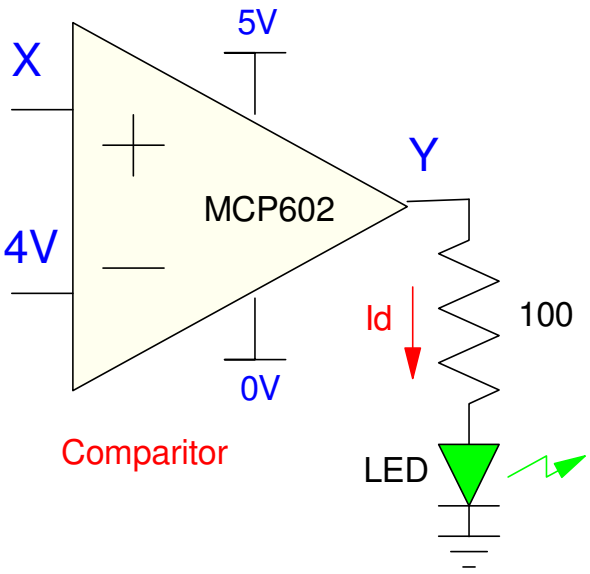
- Turn on an LED when X > 4.00V

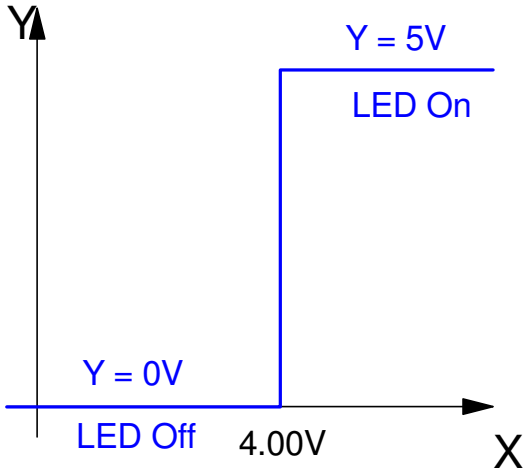
Logic Output

- Y = +5V when X > 4.0V
  - *LED On*
- Y = 0V otherwise
  - *LED Off*

LED

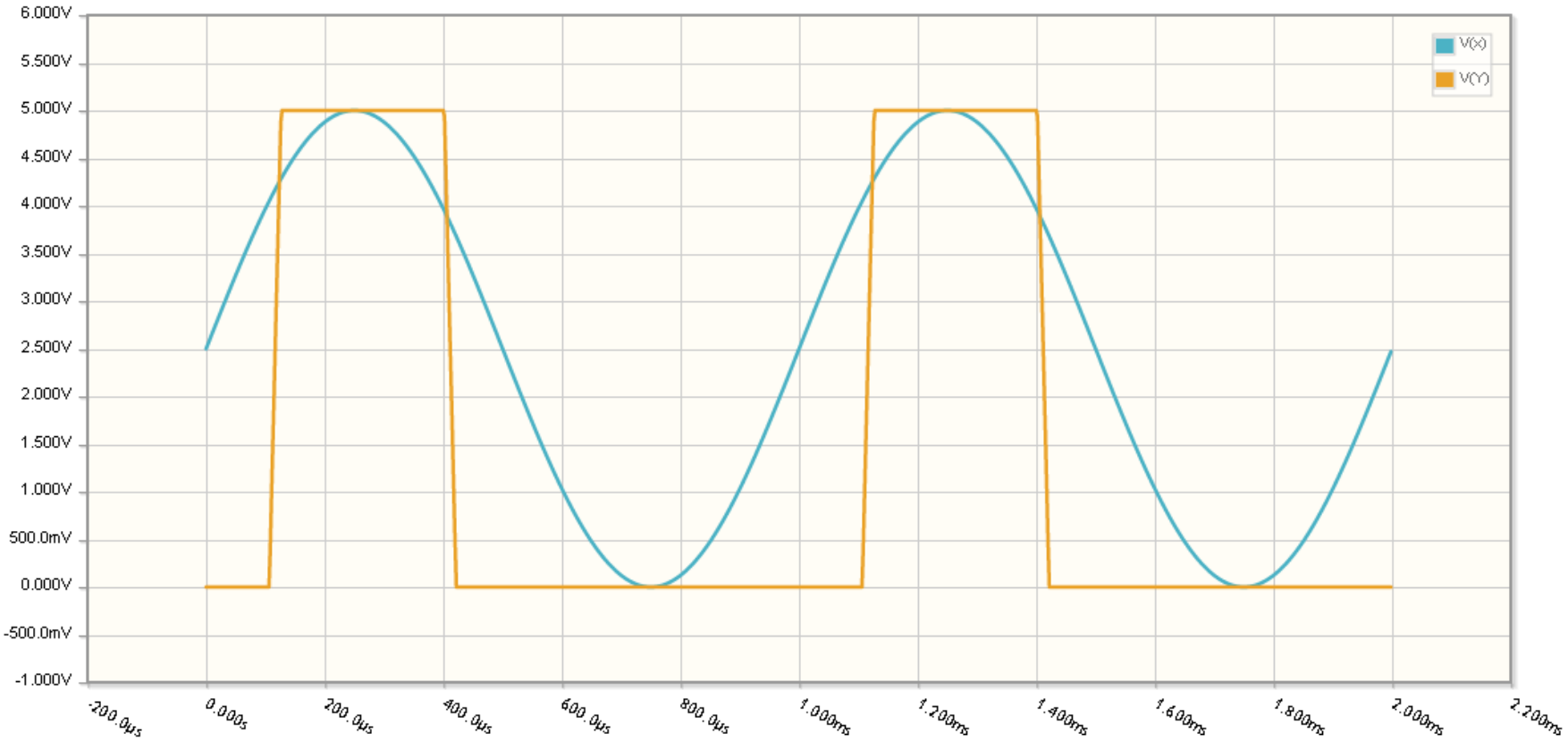
- Y = 5V in turns on the LED
- Id = 20mA @ Y = 5.0V
- Within limits of MCP602





CircultLab Example:

- X = 5Vpp 1kHz sine wave with a 2.5V offset
- $y(t) = \begin{cases} 5V & x > 4.0V \\ 0V & otherwise \end{cases}$



Y = (T > 20C)

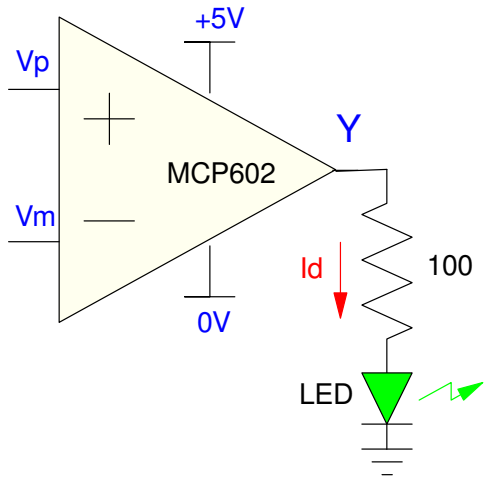
- Turn on an LED when T > 20C
- Y = 5V makes Id = 20mA

Assume a thermistor

$$R = 1000 \cdot \exp\left(\frac{3950}{T+273} - \frac{3950}{298}\right)\Omega$$

At 20C

$$R = 1250\Omega$$



Y = (T > 20C)

- Turn on an LED when T > 20C

Use a thermistor & voltage divider

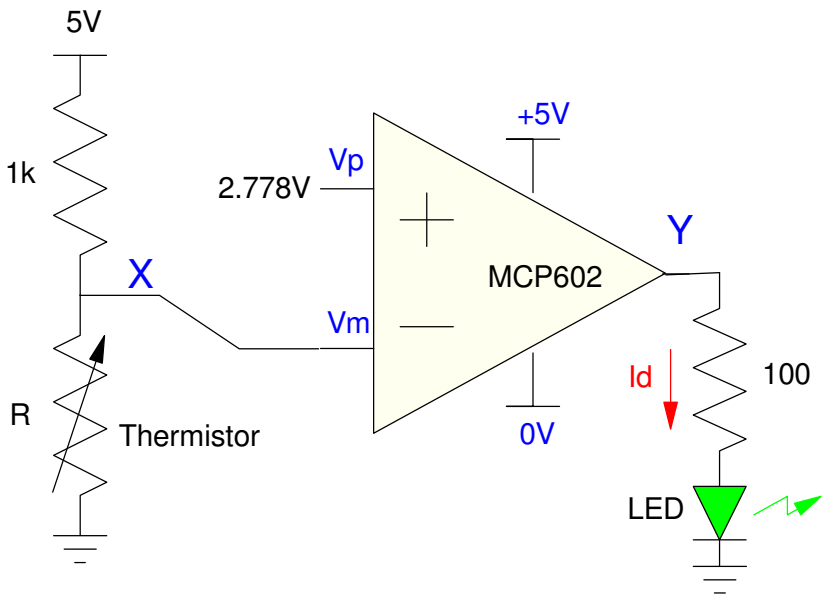
$$R = 1000\ \exp\left(\frac{3905}{T+273} - \frac{3905}{298}\right)\ \Omega$$

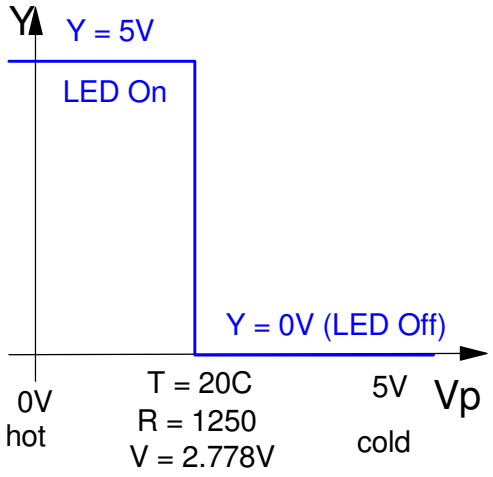
At 20C:

- R = 1250.59 Ohms
- X = 2.7784V
- Offset = 2.7784V

Connect to Vm

- When T = 1000C
- R = 0 (ish)
- X = 0 (ish)
- Y = 5V
  - *LED On*

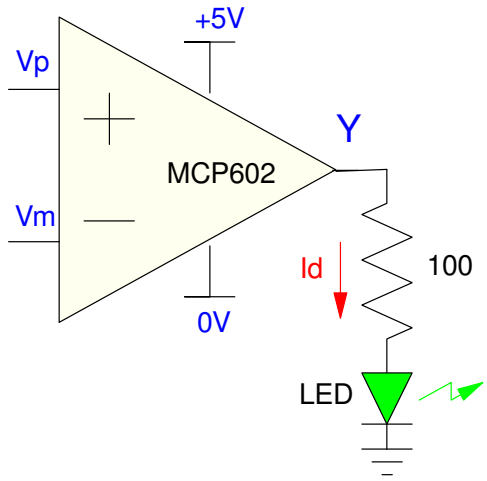




Night Light

Turn an LED on when it's dark

- CdS Photo-Resistor
- Light: R = 3.8k
  - *Turn LED off*
- Dark: R = 55.8k
  - *Turn LED off*



Night Light

Add a voltage divider

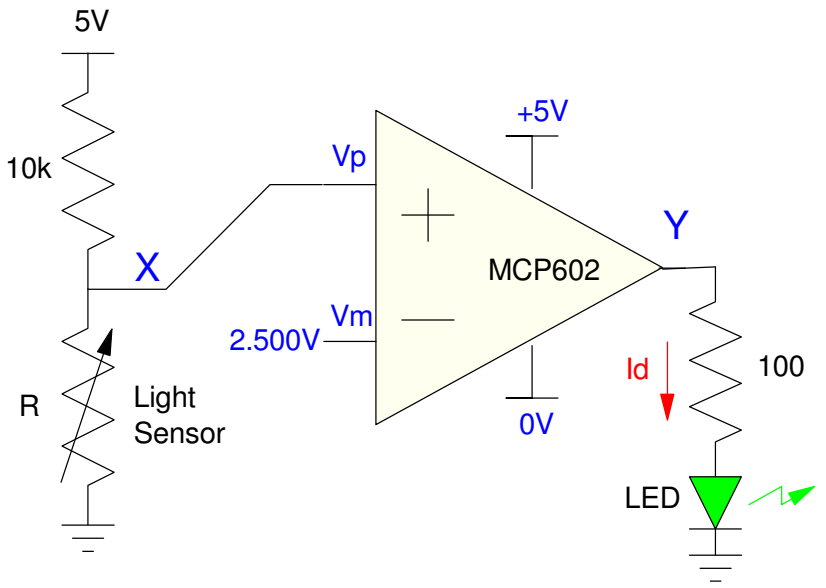
- Light: X = 1.377V
  - *LED off*
- Dark: X = 4.240V
  - *LED on*

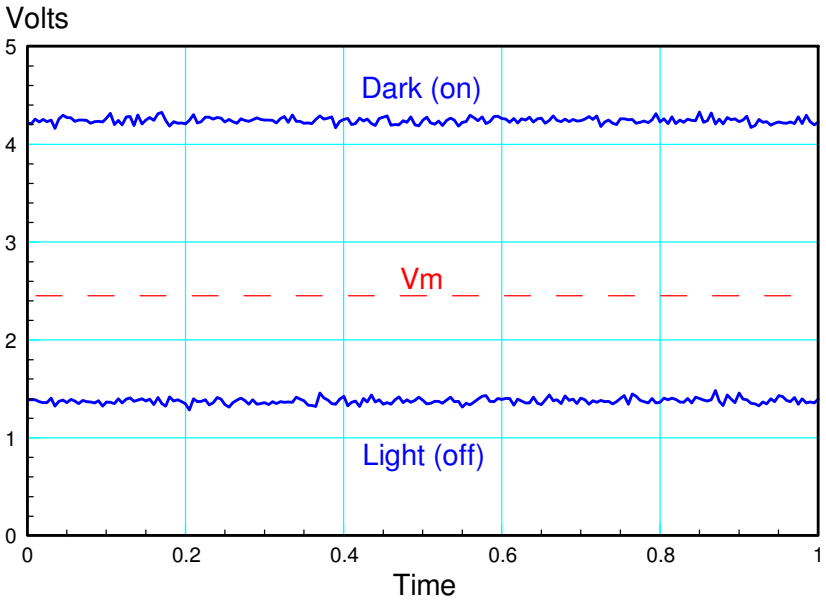
Connect to Vp

- Y goes high when X goes high

Let Vm = 2.5V

- Anything between X(light) and X(dark)
- 1.377V < Vm < 4.240V





Schmitt Trigger

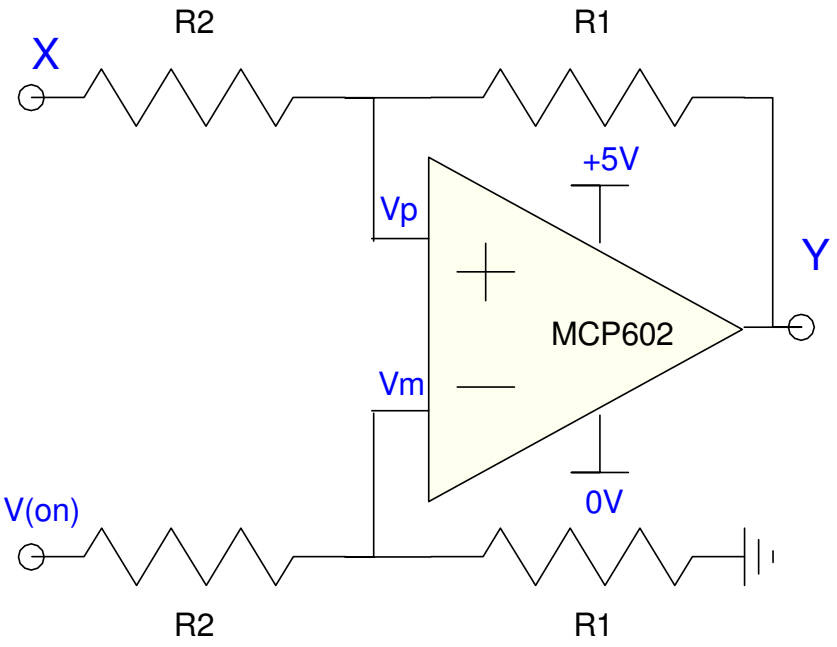
- Comparitors chatter when Vp = Vm
- To avoid this chatter, add hysteresis

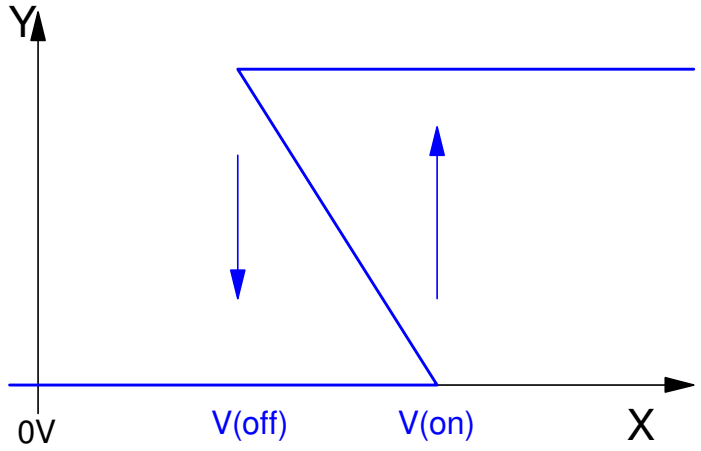
There are two variations:

- V(on) > V(off)
- Connect to the plus input

$$Y = \begin{cases} 5V & X > V_{on} \\ 0V & X < V_{off} \\ \text{no change} & V_{off} < X < V_{on} \end{cases}$$

$$gain = \left(\frac{5V - 0V}{V_{on} - V_{off}}\right) = \left(\frac{R_1}{R_2}\right)$$





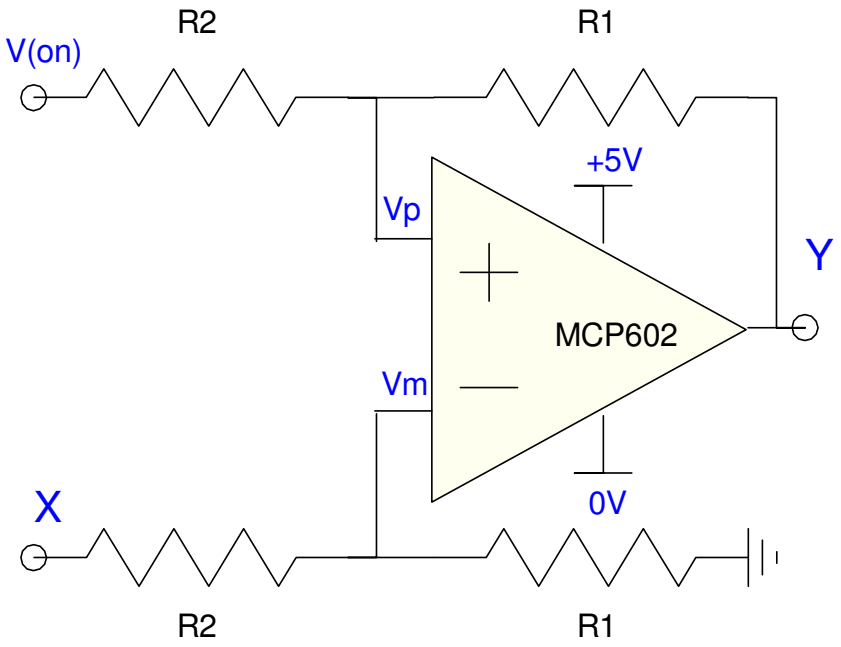
Schmitt Trigger

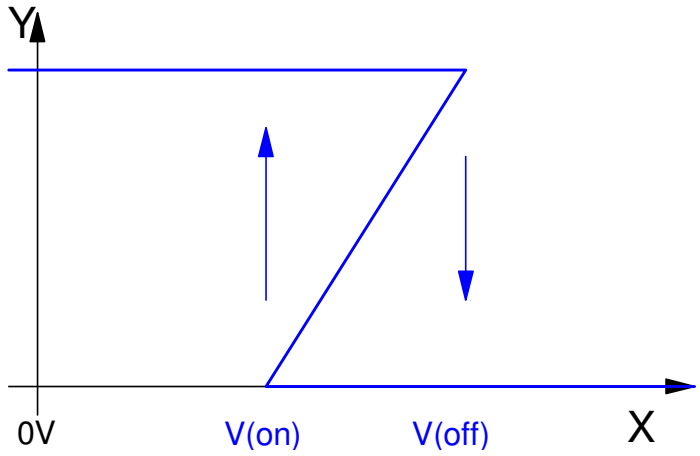
Second variation

- V(on) < V(off)
- Connect to the minus input

$$Y = \begin{cases} 5V & X < V_{on} \\ 0V & X > V_{off} \\ \text{no change} & V_{off} < X < V_{on} \end{cases}$$

$$gain = \left(\frac{5V-0V}{V_{off}-V_{on}}\right) = \left(\frac{R_1}{R_2}\right)$$





Schmitt Trigger Example

Design a circuit which outputs

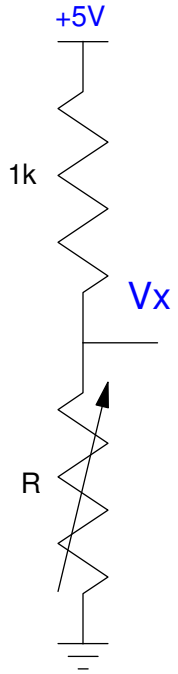
- 5V for temperatures more than 20C
- 0V for temperatures below 15C, and
- No change of 15C < T < 20C

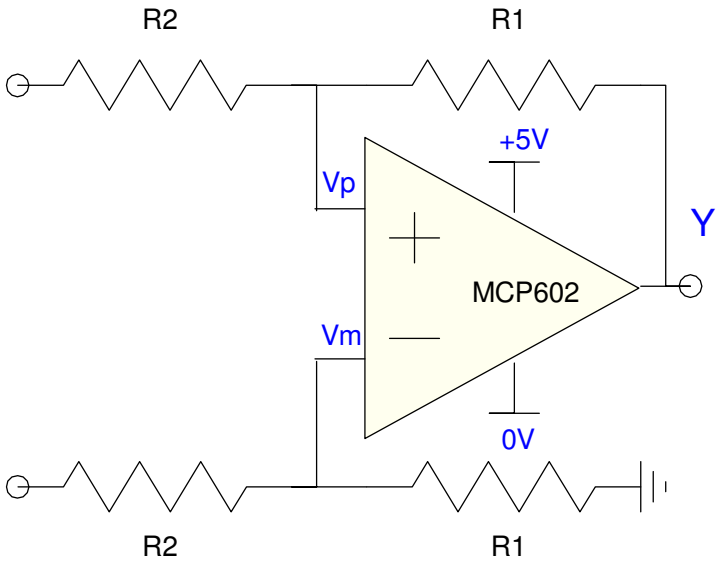
Assume a thermistor

$$R = 1000\ \exp\left(\frac{3905}{T+273} - \frac{3905}{298}\right)\ \Omega$$

Assume a voltage divider

- 1k resistor





Design

At 20C (on)

- R = 1250.59 Ohms
- Vx = 2.7784V

At 15C (off)

- R = 1576.17 Ohms
- Vx = 3.0591 V

V(on) < V(off)

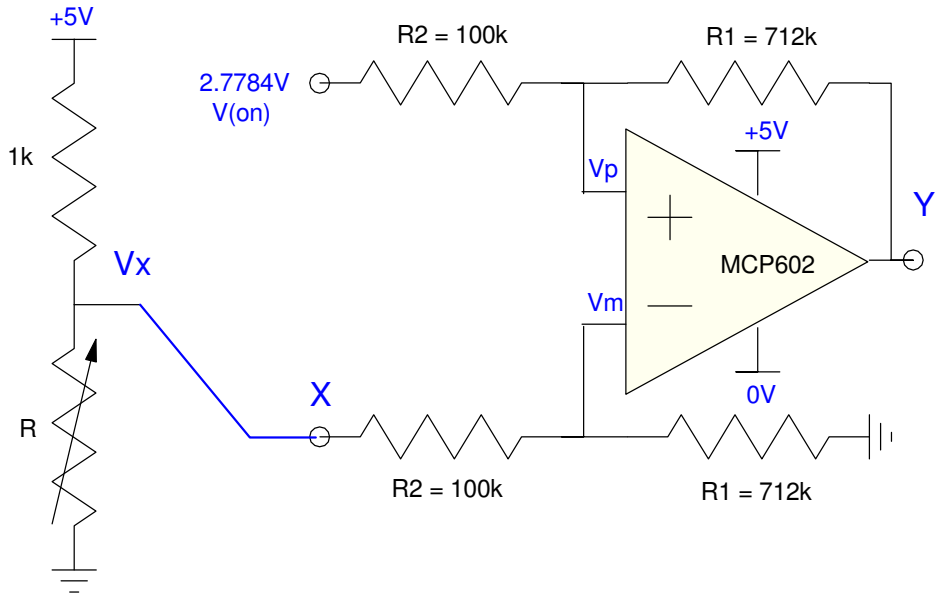
- Connect to the minus input.

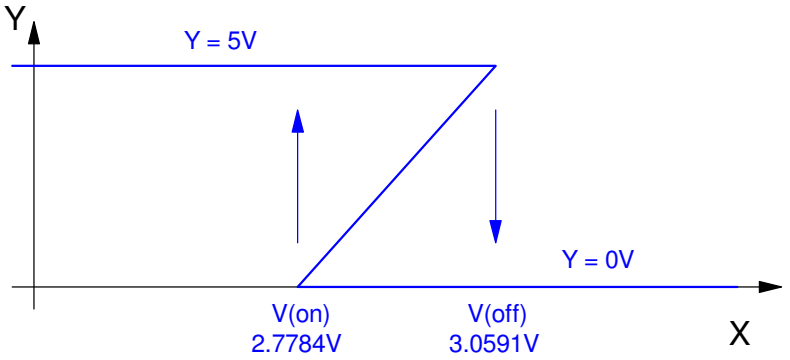
V(on) = 2.7784V

- Make the offset 2.7784V.

The gain required is

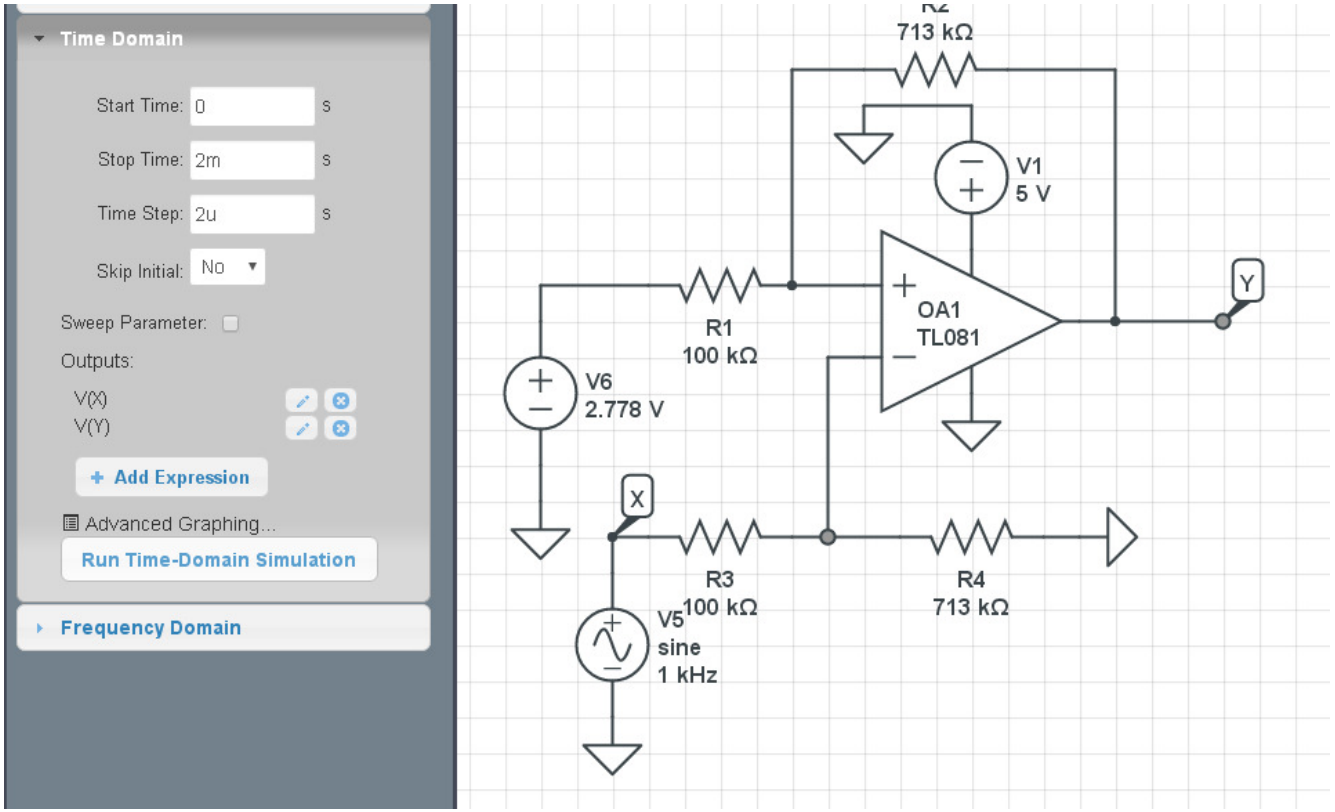
$$gain = \left(\frac{5V-0V}{3.4797V-2.7784V}\right) = 7.1296$$





Validation in CircuitLab

- Sweep temperature and verify that Y switches at 20C and 15C, or
- Sweep R and verify that Y switches at 1250 Ohms and 1576 Ohms, or
- Sweep the voltage at X and verify that Y switches at 2.778V and 3.4797V

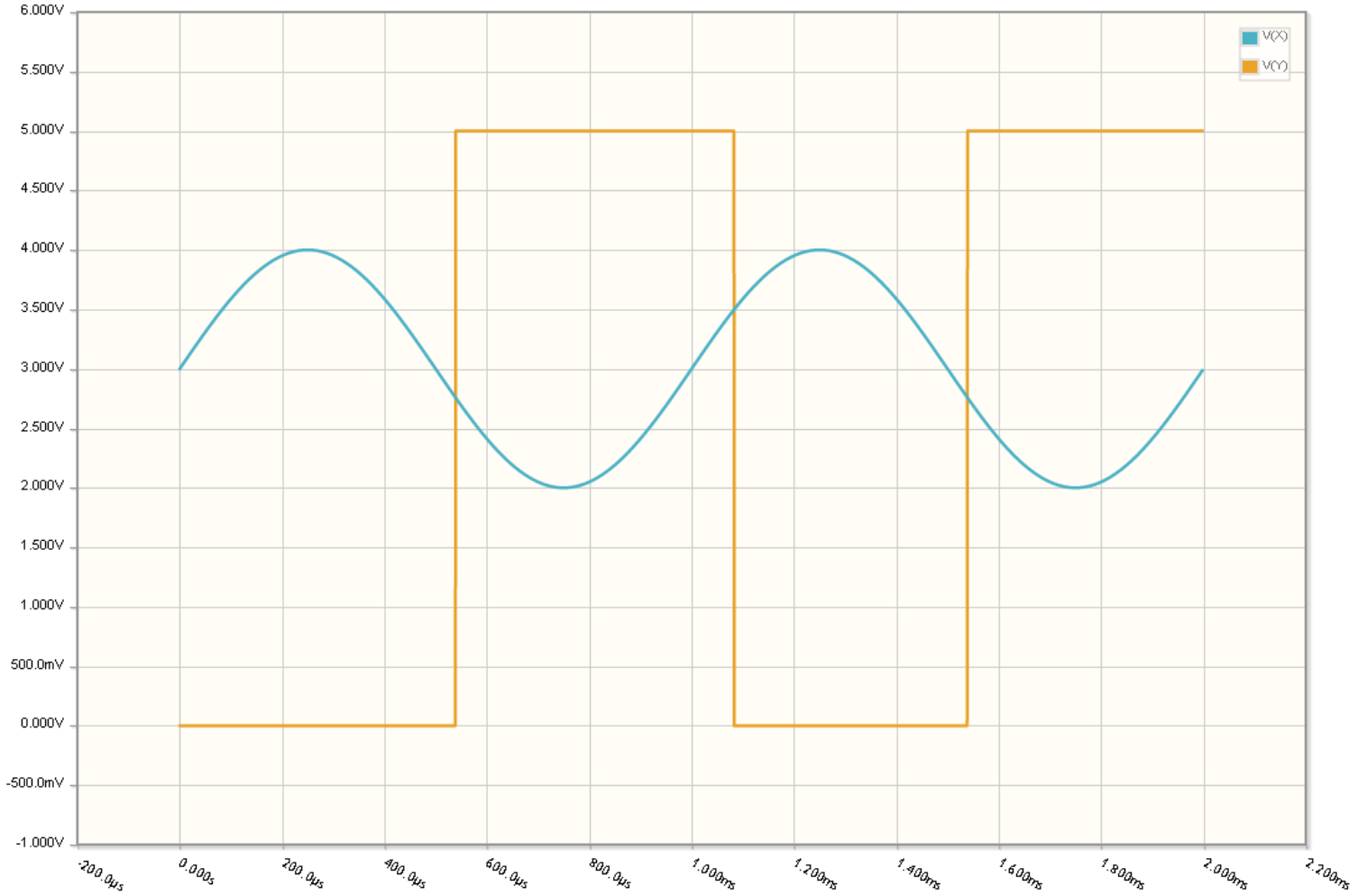


Circuitlab Results

X = blue

Y = orange

- Von = 2.760V
- Voff = 3.514V



Night Light

Turn on an LED when

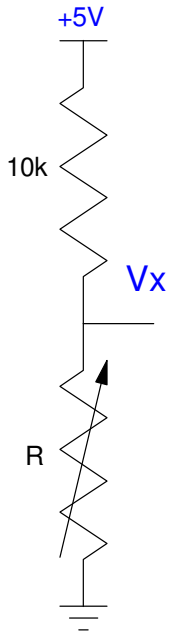
- Room is dark
- R = 55.8k
- Vx = 4.240V

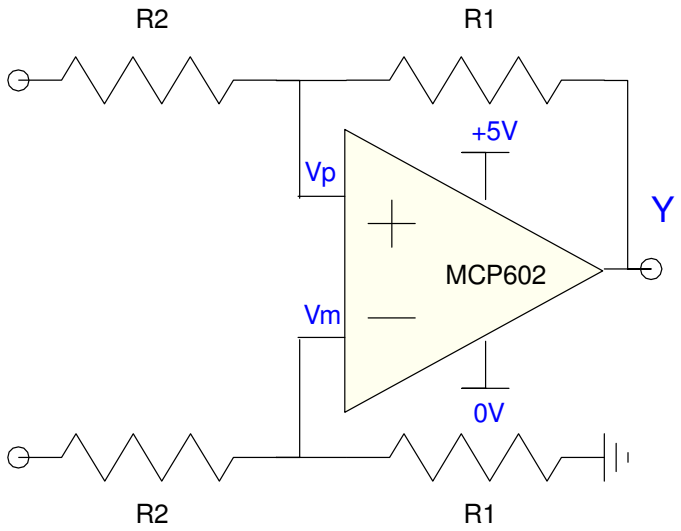
Turn off an LED when

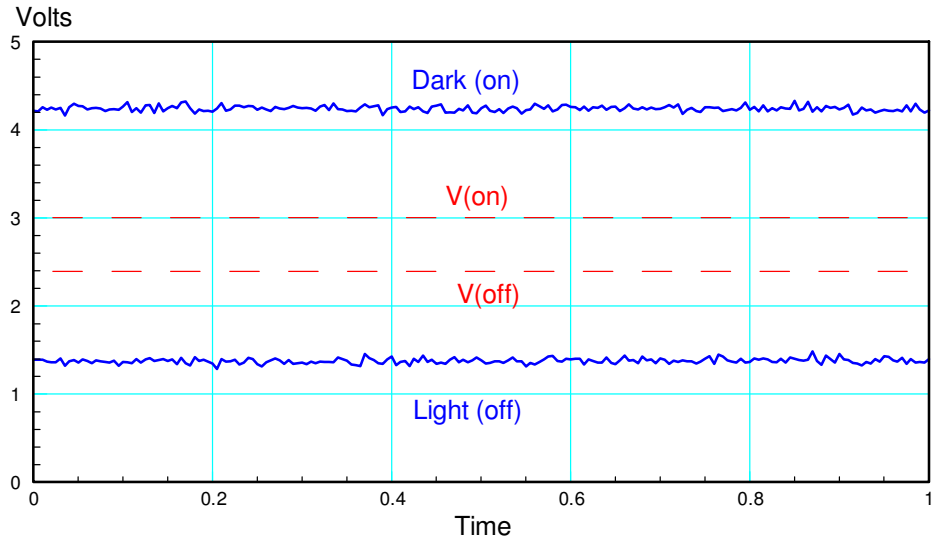
- Room is light
- R = 3.8k
- Vx = 1.377V

Let

- V(on) = 3.00V
- V(off) = 2.40V







Night Light (cont'd)

V(on) > V(off)

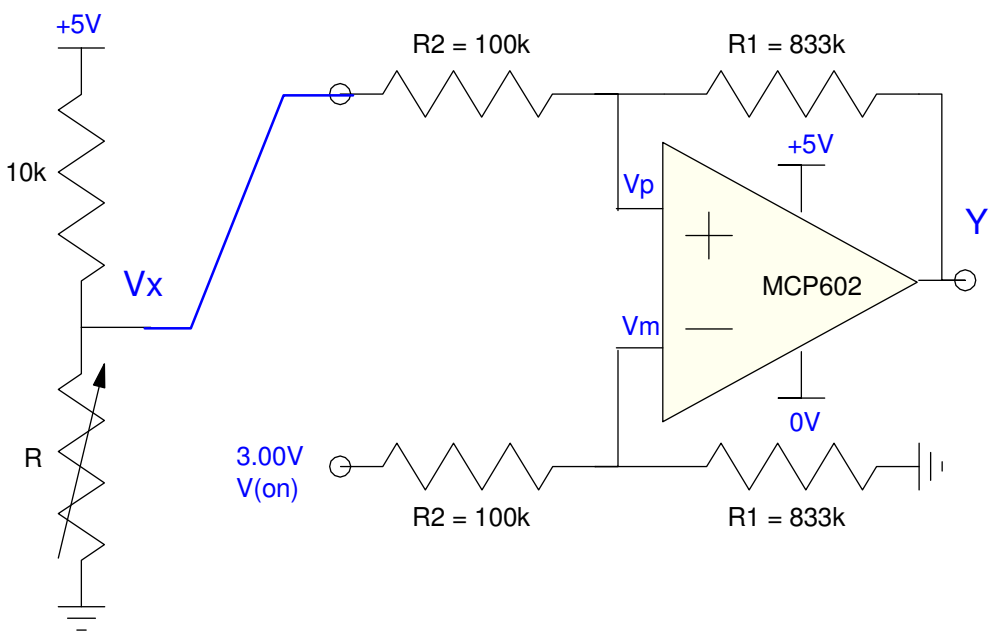
- Connect to the plus input

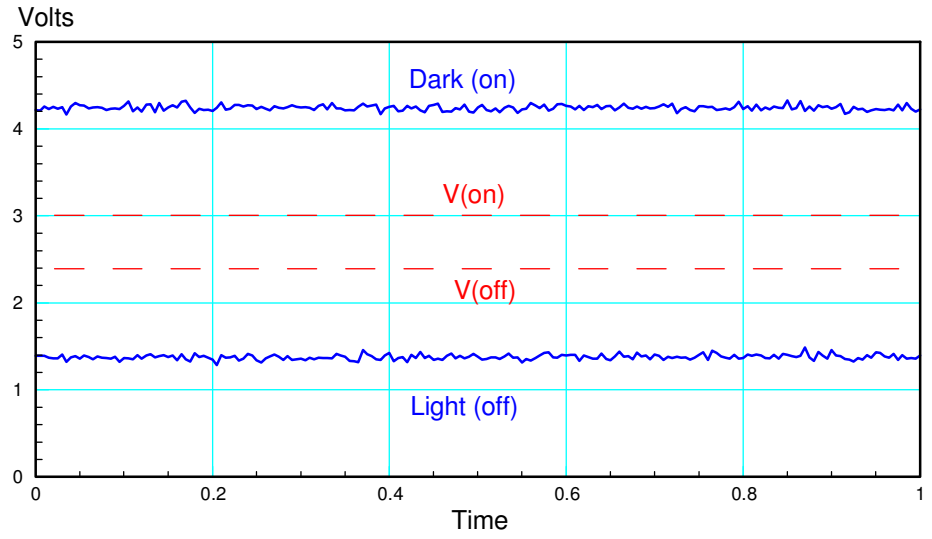
Set the offset to V(on)

Find the gain

$$gain = \left(\frac{5V - 0V}{3.0V - 2.4V}\right)$$

$$gain = 8.33$$

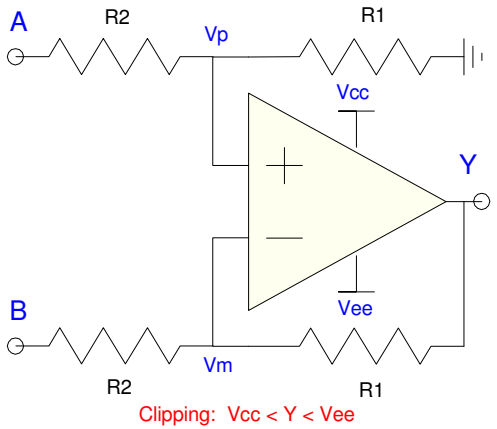




Summary

Vp is not always equal to Vm

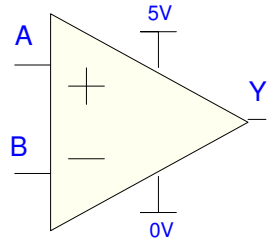
- Amplifiers when there's clipping
- Comparitor circuits
- Schmitt triggers



Clipping: Vcc < Y < Vee

Comparitors output a binary output

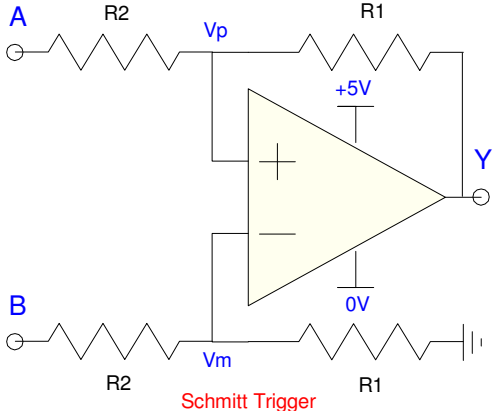
- 5V when Vp > Vm
- 0V when Vp < Vm



Comparitor

Schmitt Triggers also output a binary signal

- With hysteressis
- 5V when Va > V(on)
- 0V when Va < V(off)



Schmitt Trigger