
Comparitors and Schmitt Triggers

ECE 211 Circuits I Lecture #17

Please visit [Bison Academy](#) for corresponding
lecture notes, homework sets, and solutions

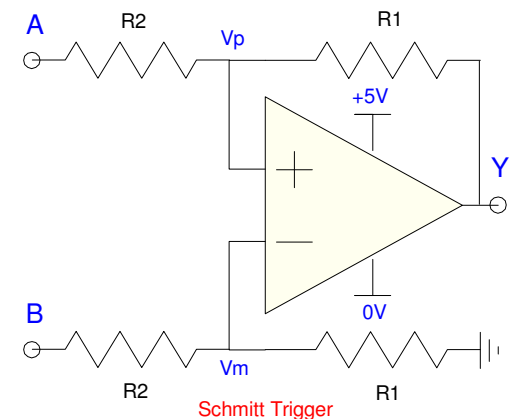
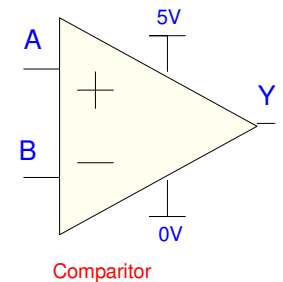
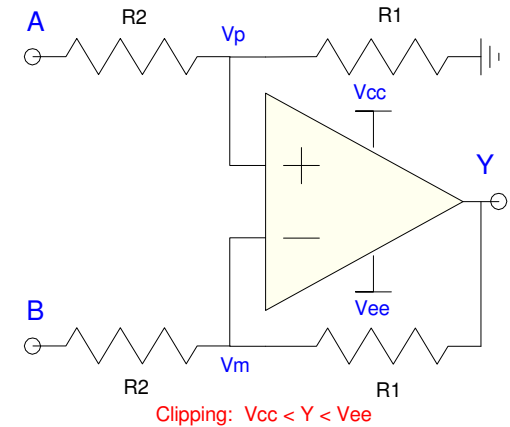
$V_p = V_m$ does not *always* hold

Previous lectures assumed $V_p = V_m$

- Usually the case when there's negative feedback

Sometimes, this is *not* the case

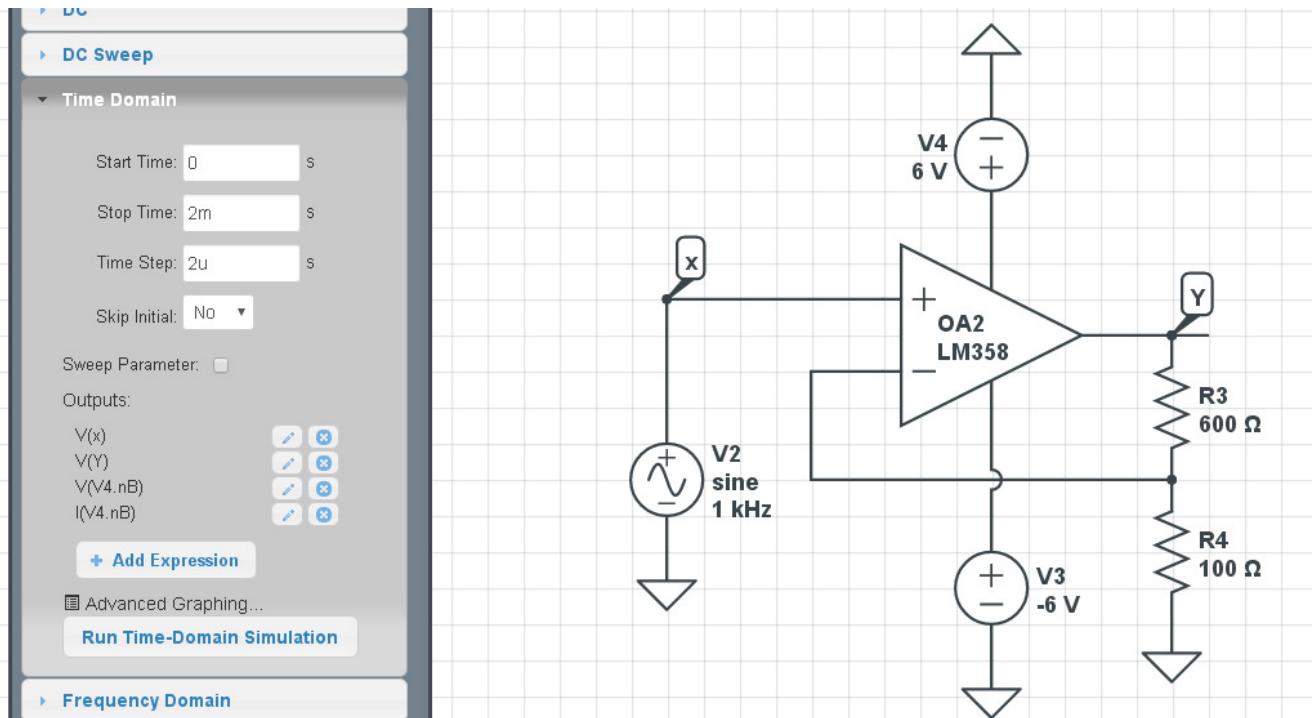
- Amplifiers with clipping
 - *Output cannot go above V_{cc}*
 - *Output cannot go below V_{ee}*
- Comparitors
 - *No feedback*
 - *Y rails at either $+5V$ or $0V$*
- Schmitt triggers
 - *Positive feedback*
 - *Y rails at either $+5V$ or $0V$*



Clipping

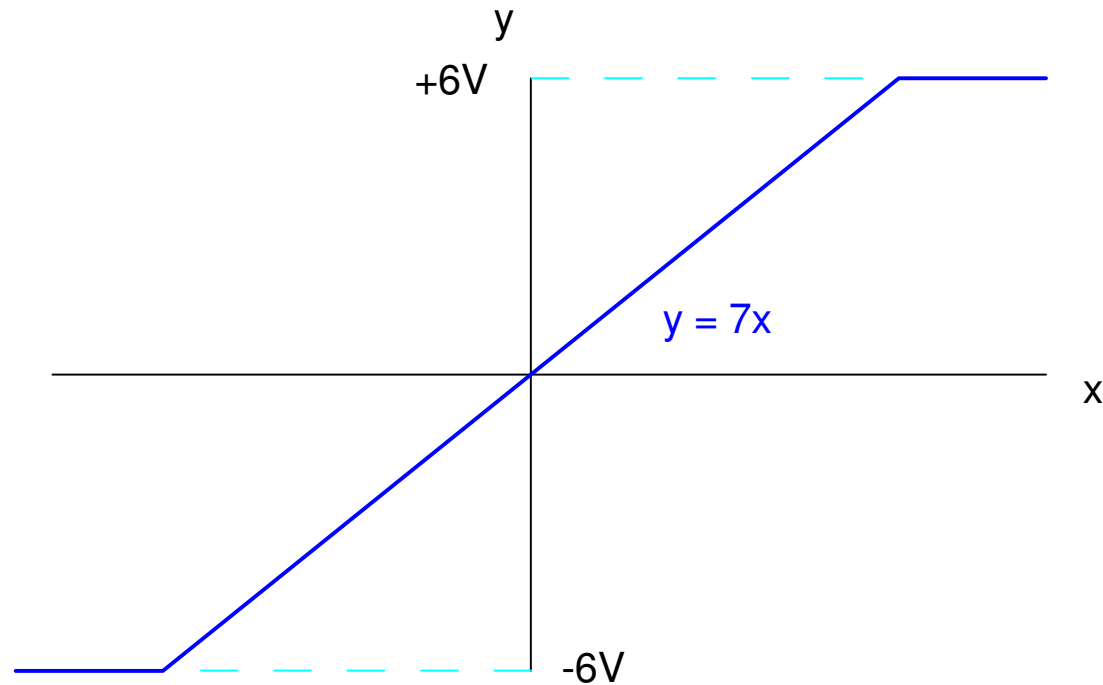
- If you are using negative feedback $V_p = V_m$
- *Unless* you try to output a voltage that exceeds your power supplies

Example: $y = 7.00x$



With a +6V and -6V power supply

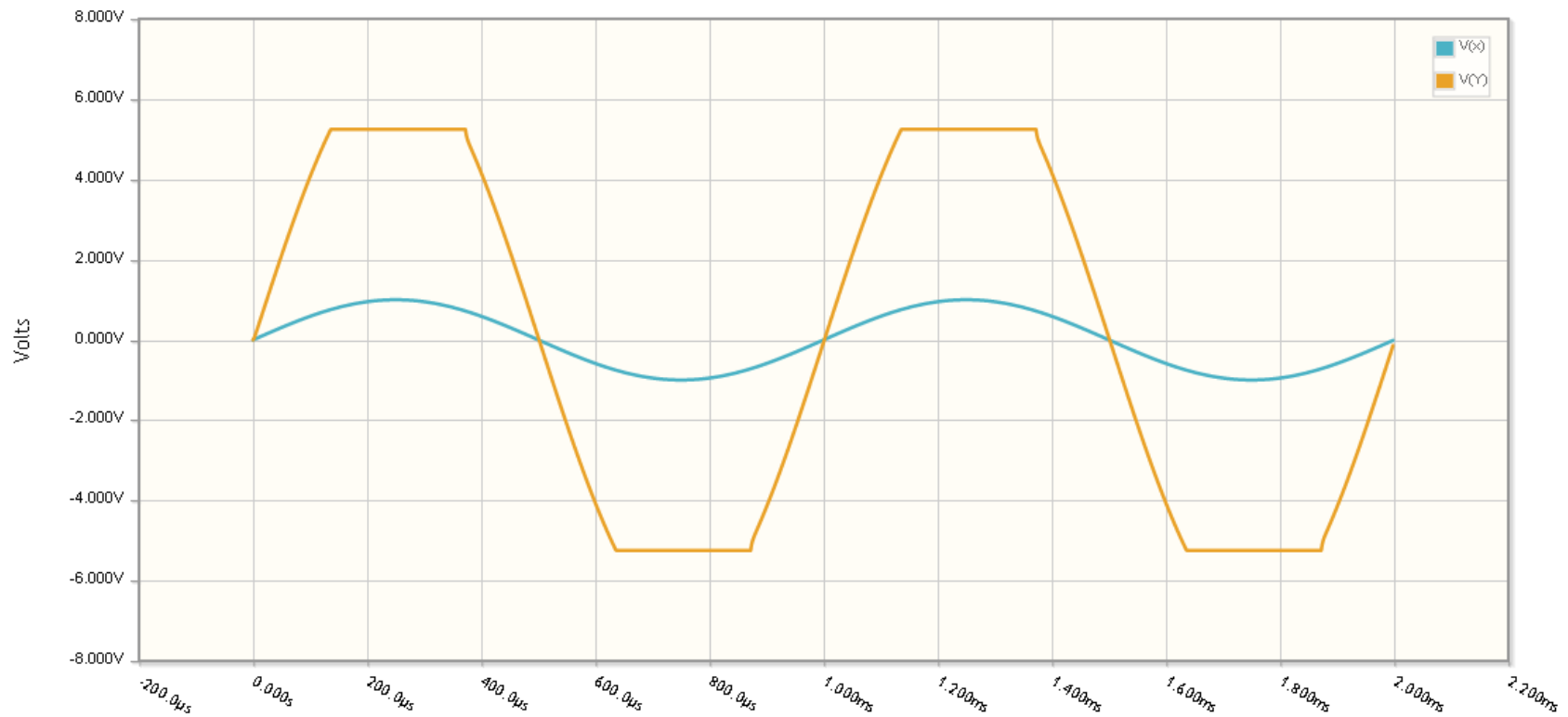
- $Y = 7X$
- Limited to $-6V < Y < +6V$



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

Example:

- $V1 = 1V_p$, 1kHz sine wave
- $V2 = 7V_p$, 1kHz sine wave
- Clipped at $\pm 6V$



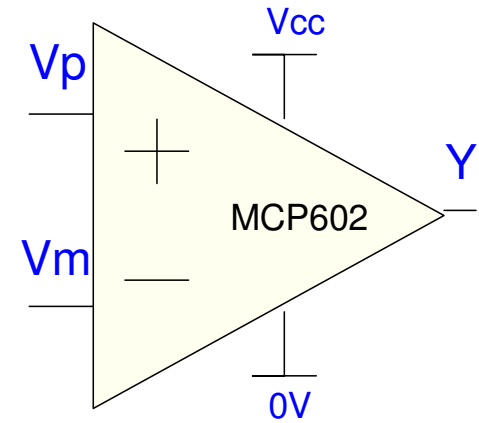
Comparitors:

Outputs a binary signal

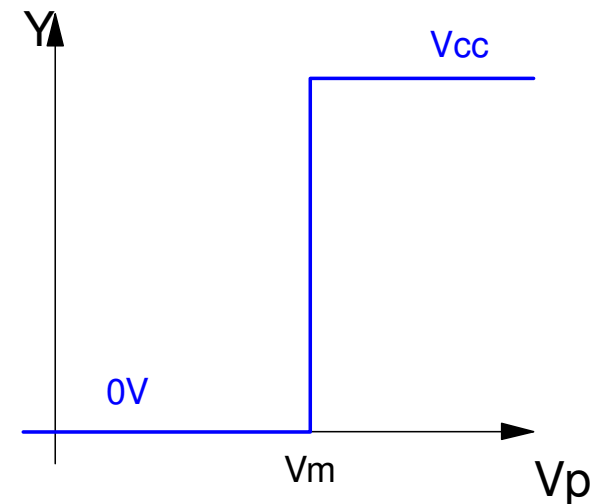
- $Y = V_p > V_m$
 - $0V = \text{Logic } 0$
 - $V_{cc} = \text{Logic } 1$

Usually use an MCP602 Op-Amp

- Single-Sided Power Supply
 - $2.7V < V_{cc} < 6.0V$
- Rail-to-Rail output
 - *Can go all the way down to $0V$*
 - *Can go all the way up to $+V_{cc}$*



Comparator



Comparator: $Y = (X > 4.00)$

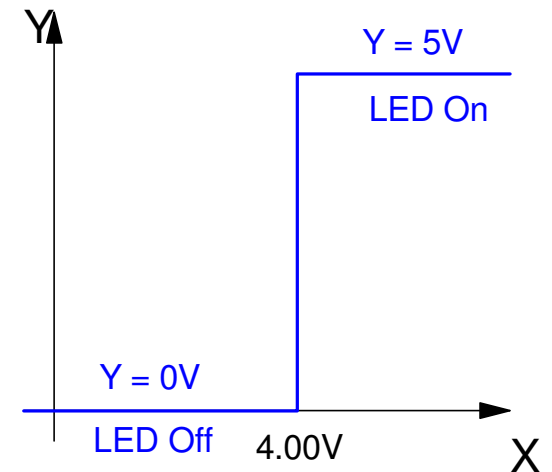
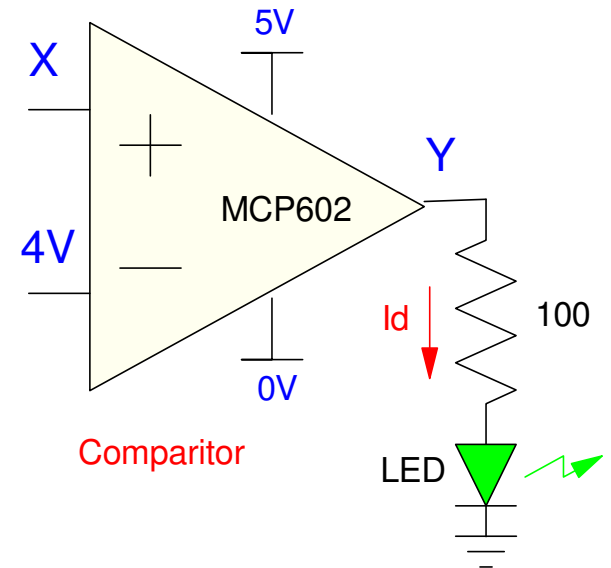
- Turn on an LED when $X > 4.00V$

Logic Output

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

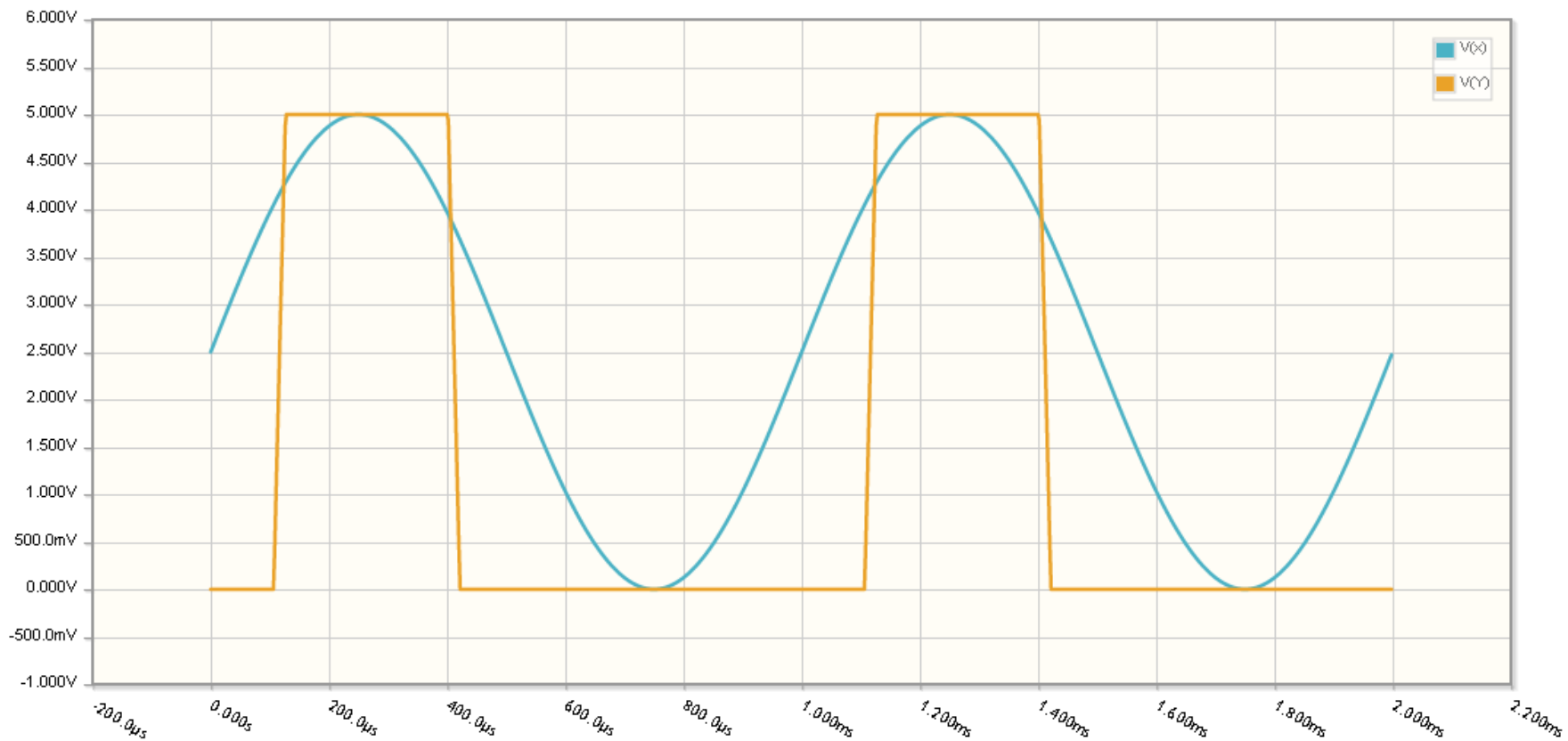
LED

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



CircuitLab Example:

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



$Y = (T > 20C)$

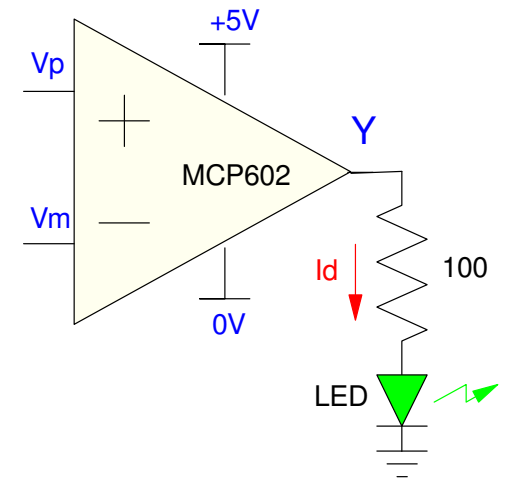
- Turn on an LED when $T > 20C$
- $Y = 5V$ makes $I_d = 20mA$

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

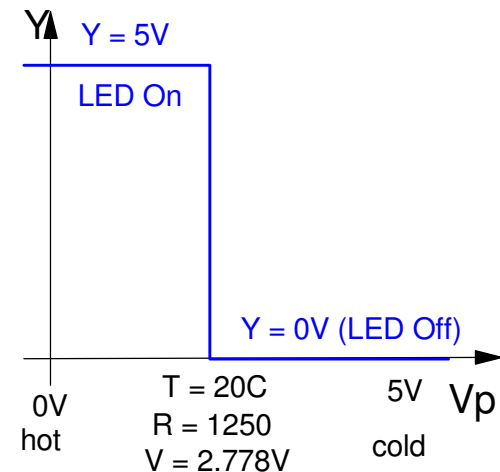
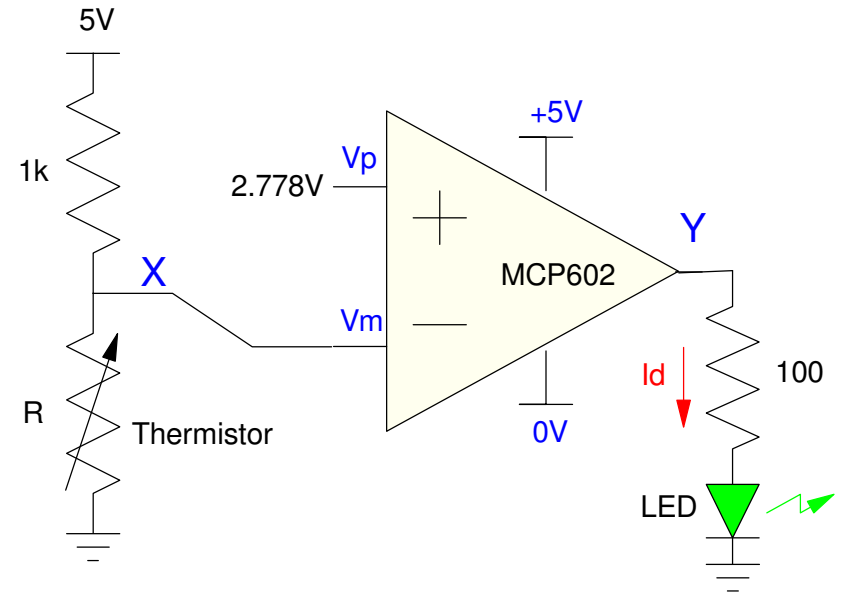
$$R = 1000 \exp\left(\frac{3905}{T+273} - \frac{3905}{298}\right) \Omega$$

At 20C:

- $R = 1250.59 \text{ Ohms}$
- $X = 2.7784V$
- Offset = $2.7784V$

Connect to V_m

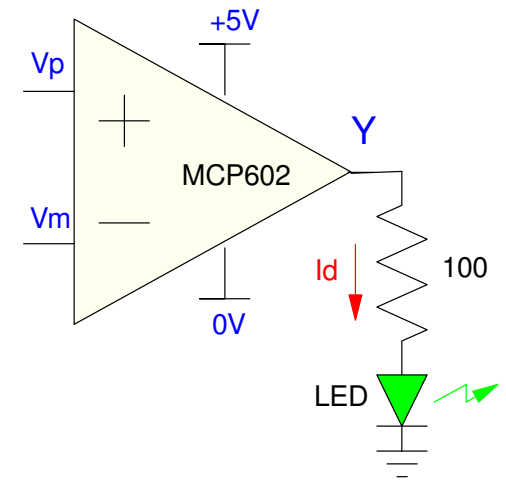
- When $T = 1000C$
- $R = 0$ (ish)
- $X = 0$ (ish)
- $Y = 5V$
 - *LED On*



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 on*



Night Light

Add a voltage divider

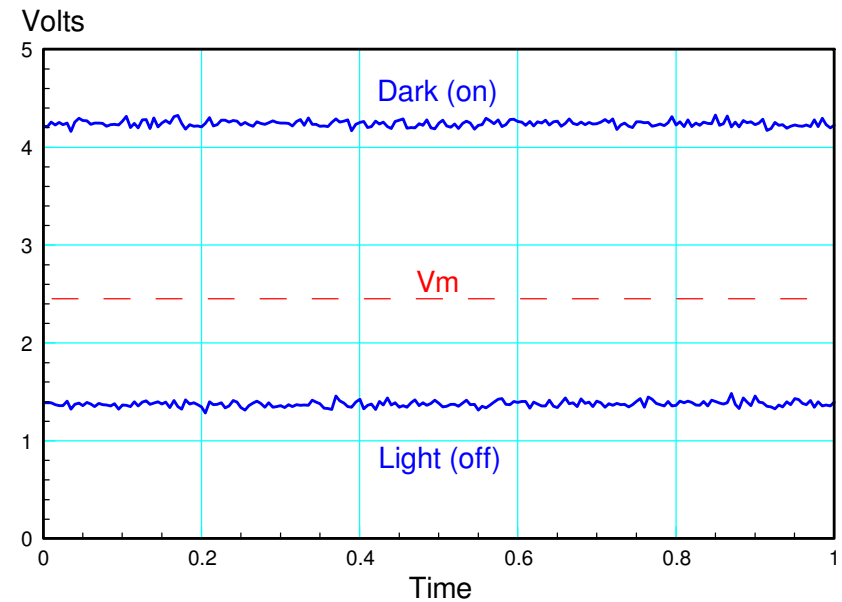
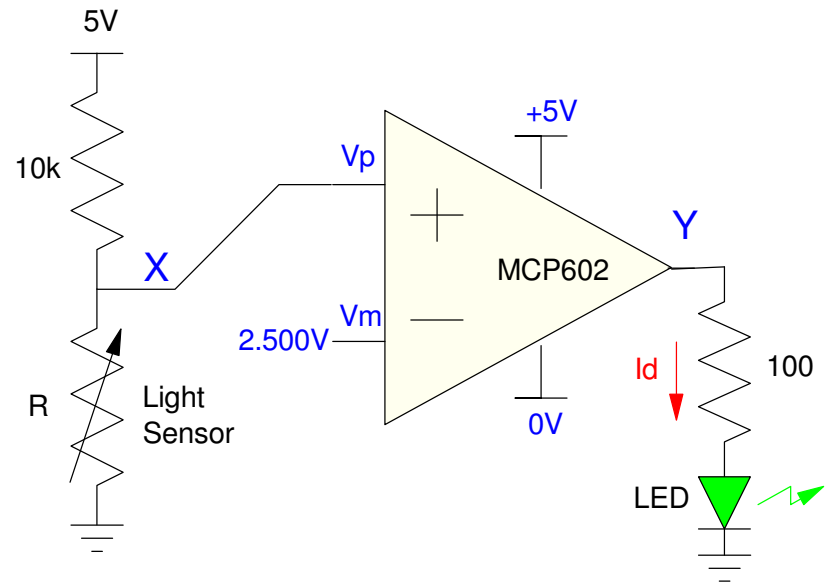
- Light: $X = 1.377V$
 - *LED off*
- Dark: $X = 4.240V$
 - *LED on*

Connect to V_p

- Y goes high when X goes high

Let $V_m = 2.5V$

- Anything between $X(\text{light})$ and $X(\text{dark})$
- $1.377V < V_m < 4.240V$



Schmitt Trigger

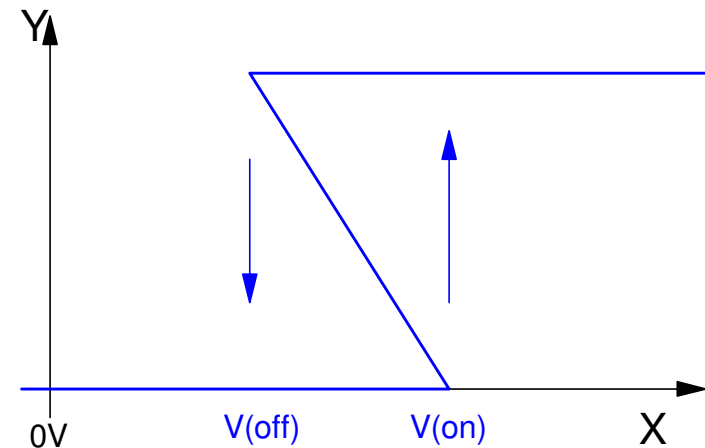
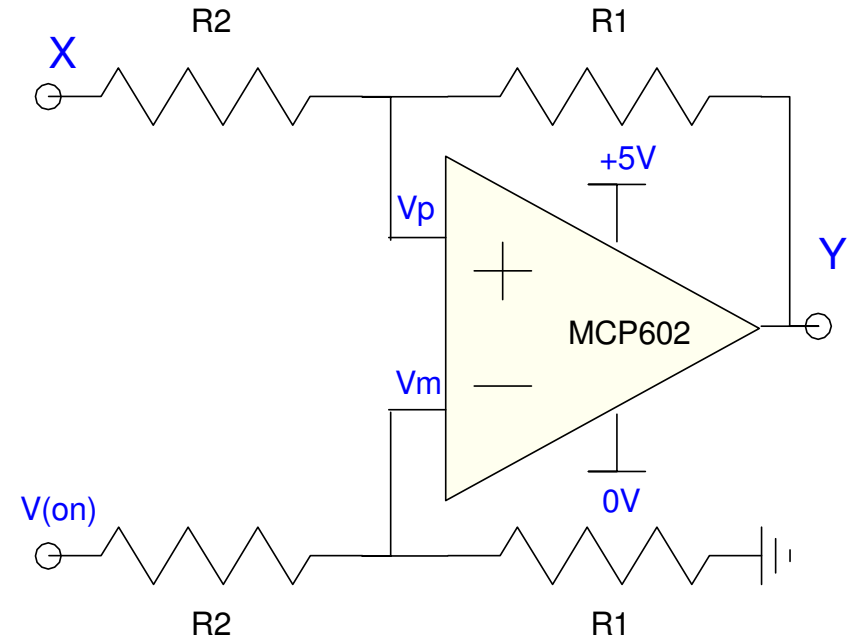
- Comparitors chatter when $V_p = V_m$
- To avoid this chatter, add hysteresis

There are two variations:

- $V_{(on)} > V_{(off)}$
- Connect to the plus input

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

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



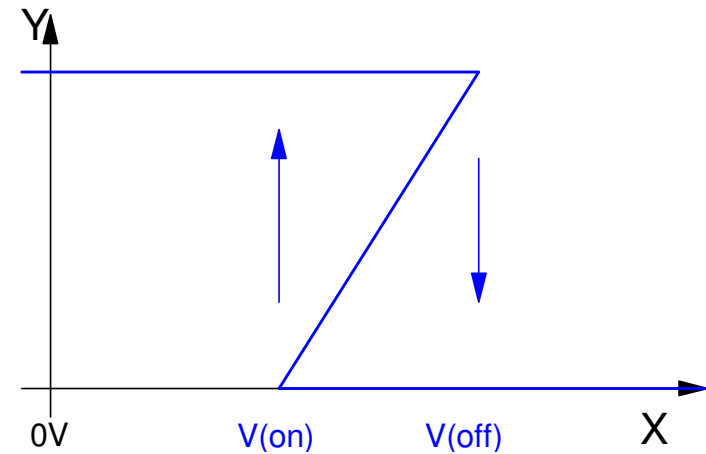
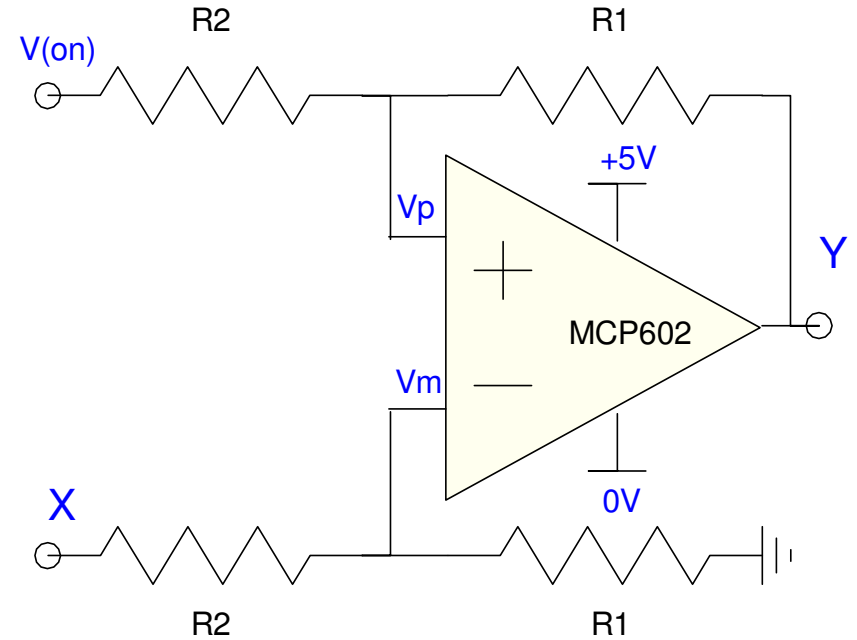
Schmitt Trigger

Second variation

- $V_{on} < V_{off}$
- Connect to the minus input

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

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



Schmitt Trigger Example

Design a circuit which outputs

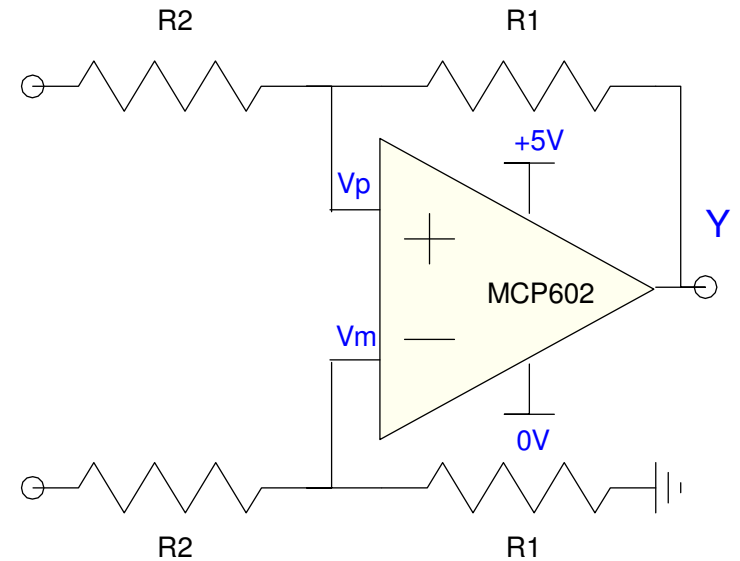
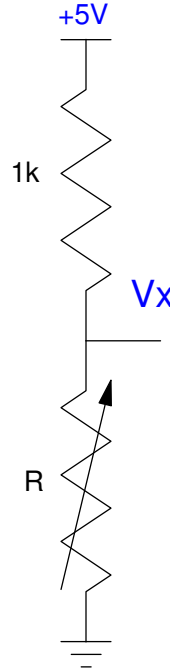
- 5V for temperatures more than 20C
- 0V for temperatures below 15C, and
- No change of $15C < T < 20C$

Assume a thermistor

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

Assume a voltage divider

- 1k resistor



Schmitt Trigger Design

At 20C (on)

- $R = 1250.59 \text{ Ohms}$
- $X = 2.7784\text{V}$
- $Y = 5.00\text{V}$

At 15C (off)

- $R = 1576.17 \text{ Ohms}$
- $X = 3.0591 \text{ V}$
- $Y = 0.00\text{V}$

$V(\text{on}) < V(\text{off})$

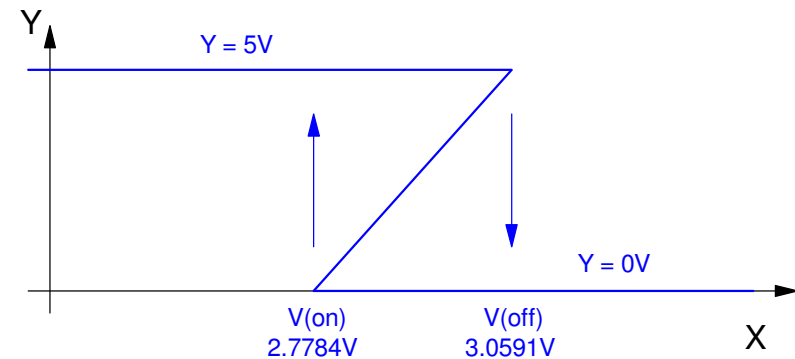
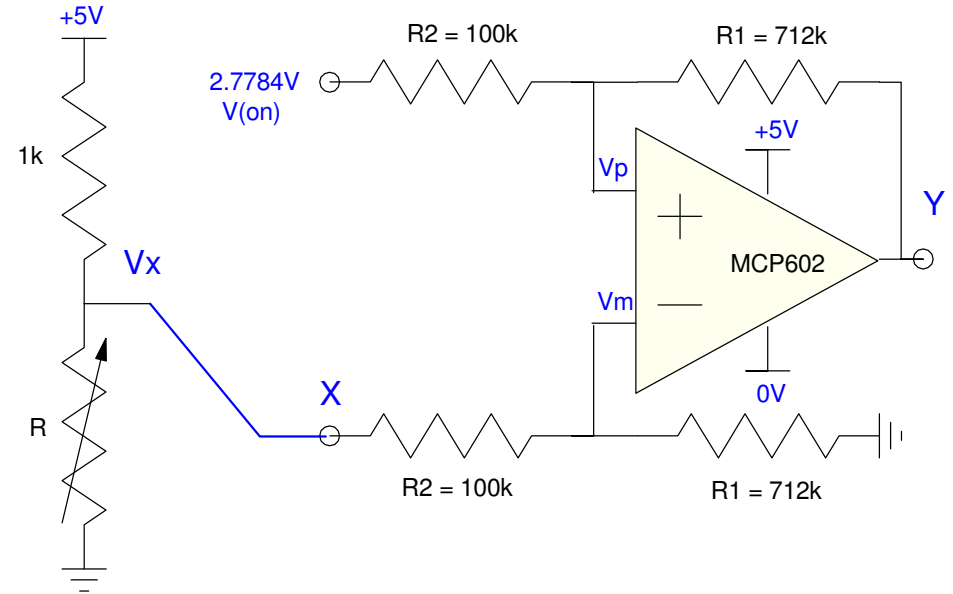
- Connect to the minus input.

$V(\text{on}) = 2.7784\text{V}$

- Make the offset 2.7784V.

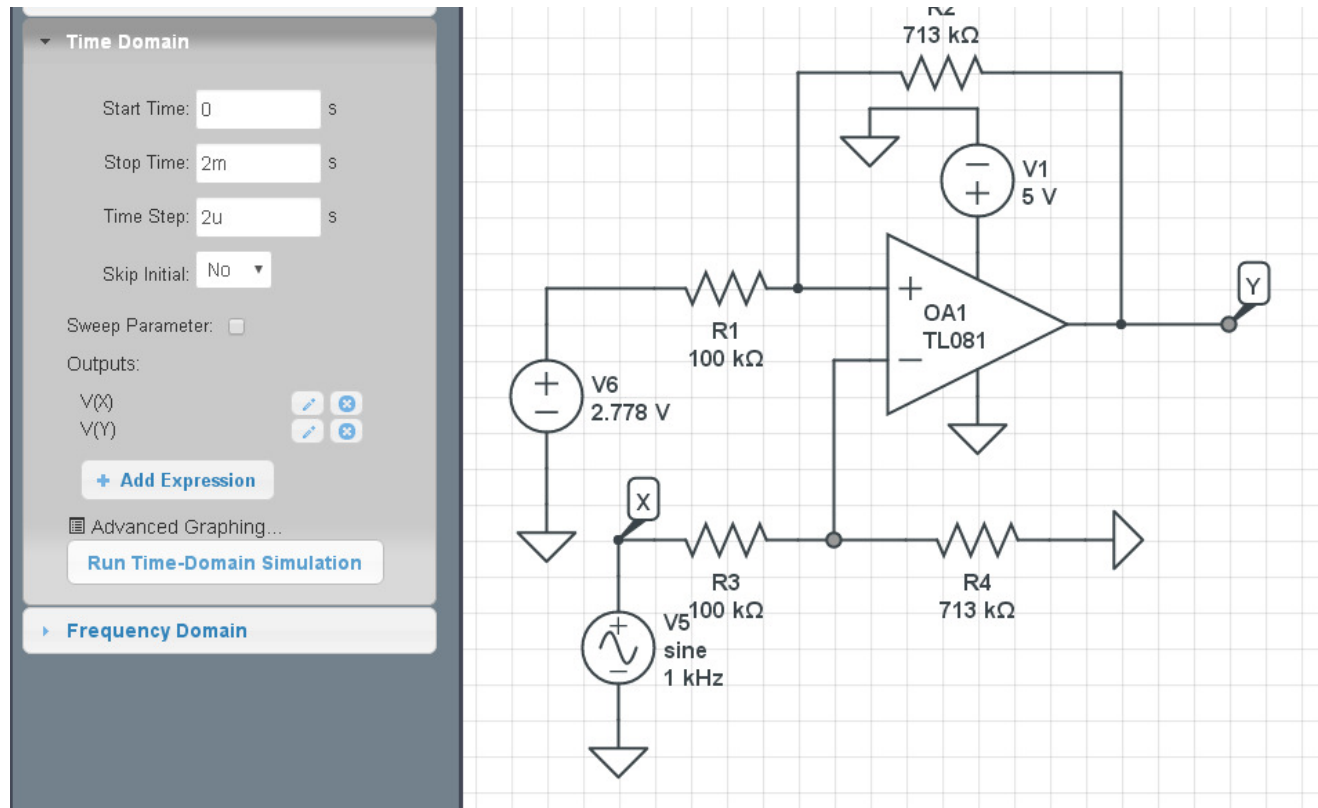
The gain required is

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



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

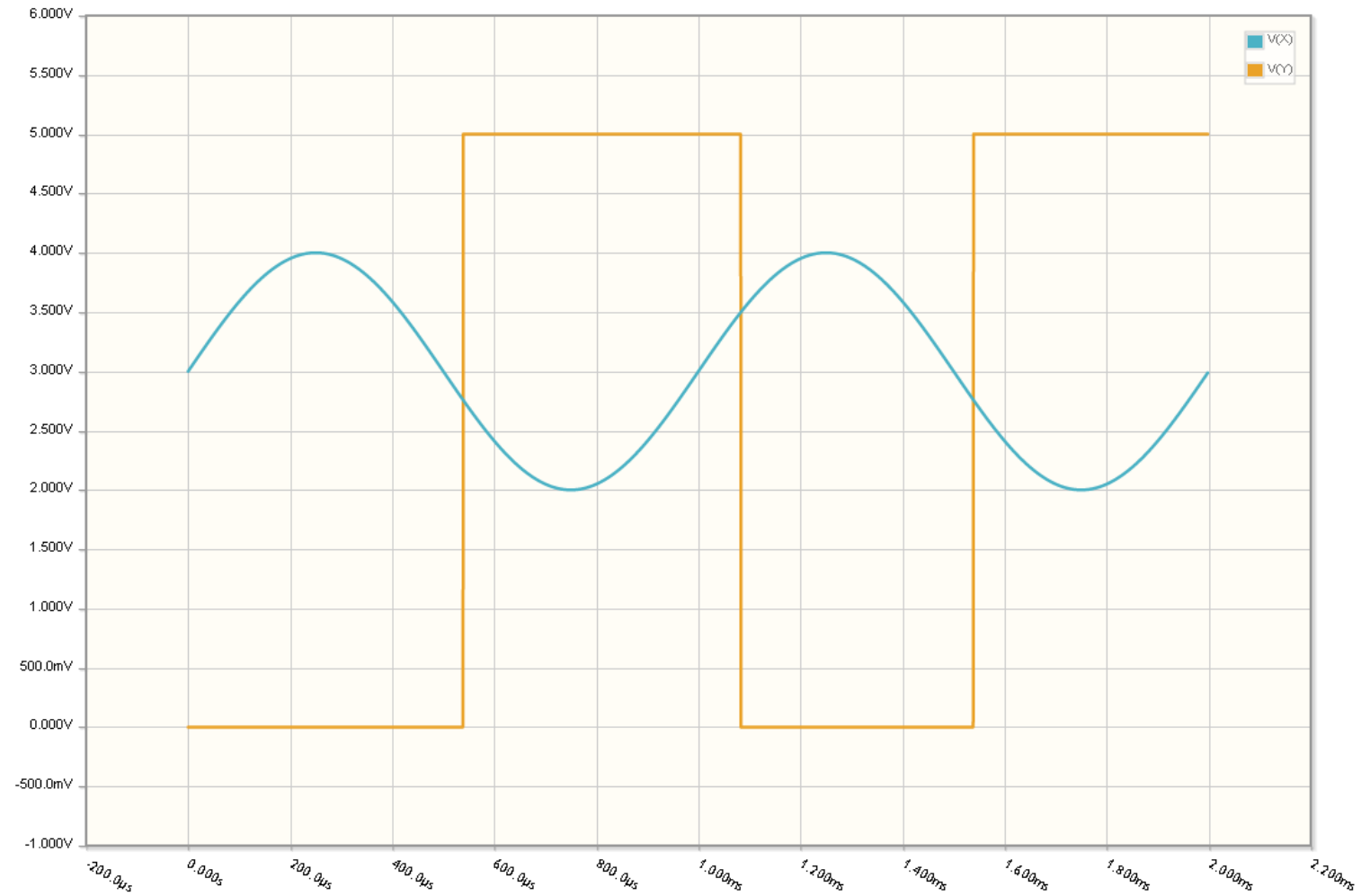


Circuitlab Results

X = blue

Y = orange

- $V_{on} = 2.760V$
- $V_{off} = 3.514V$



Example 2: Night Light

Turn on an LED when

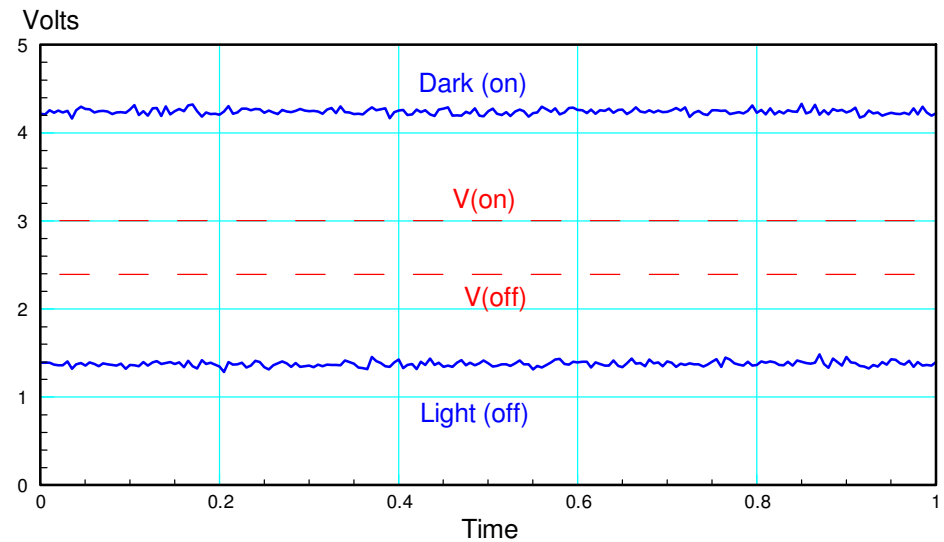
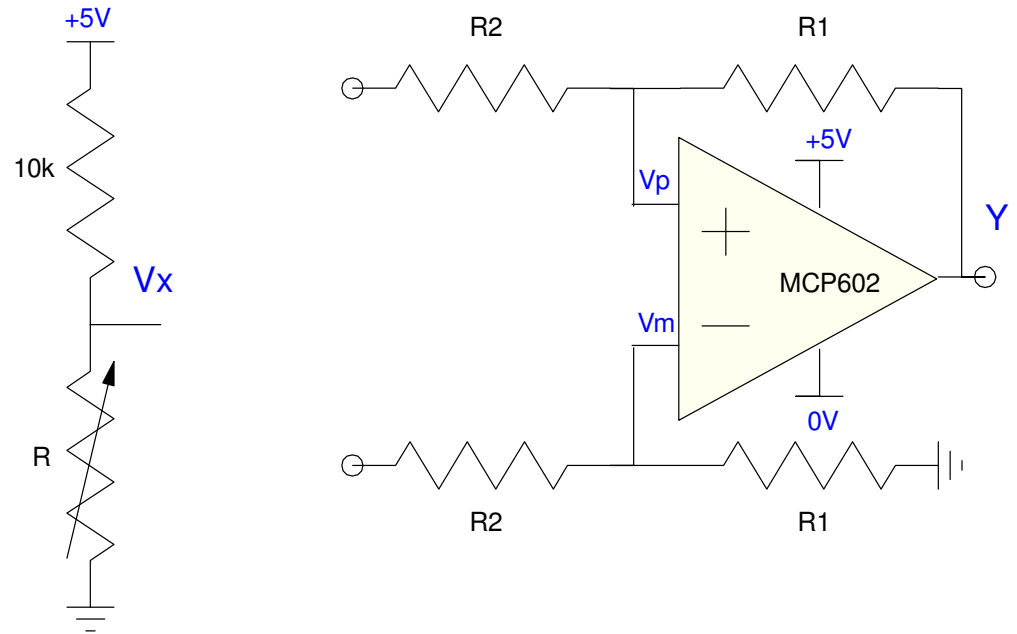
- Room is dark
- $R = 55.8k$
- $V_X = 4.240V$

Turn off an LED when

- Room is light
- $R = 3.8k$
- $V_X = 1.377V$

Let

- $V(\text{on}) = 3.00V$
- $V(\text{off}) = 2.40V$



Night Light (cont'd)

$V(\text{on}) > V(\text{off})$

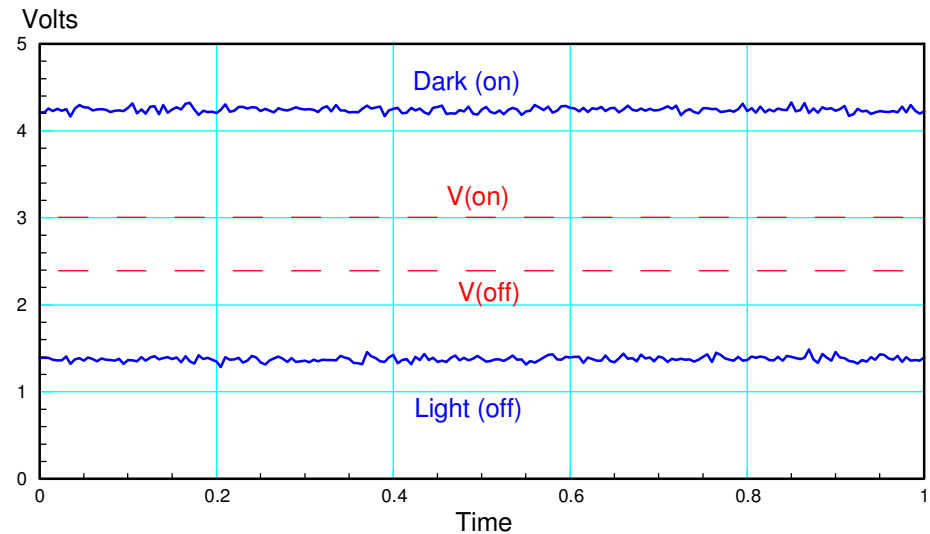
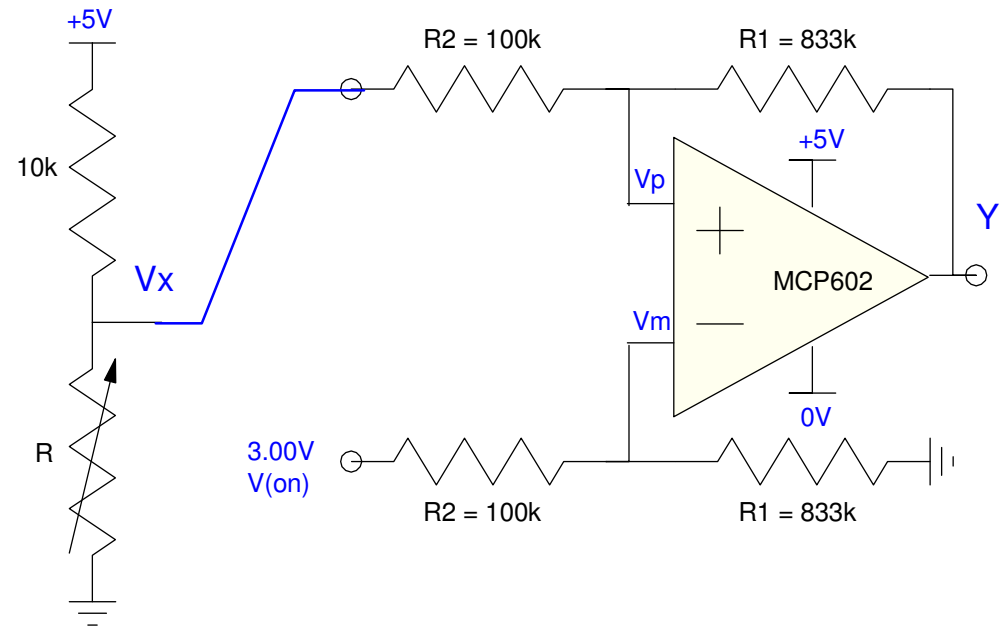
- Connect to the plus input

Set the offset to $V(\text{on})$

Find the gain

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

$$\text{gain} = 8.33$$



Summary

V_p is not always equal to V_m

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

Comparitors output a binary output

- 5V when $V_p > V_m$
- 0V when $V_p < V_m$

Schmitt Triggers also output a binary signal

- With hysteresis
- 5V when $V_a > V(\text{on})$
- 0V when $V_a < V(\text{off})$

