
Comparitors and Schmitt Triggers

ECE 211 Circuits I

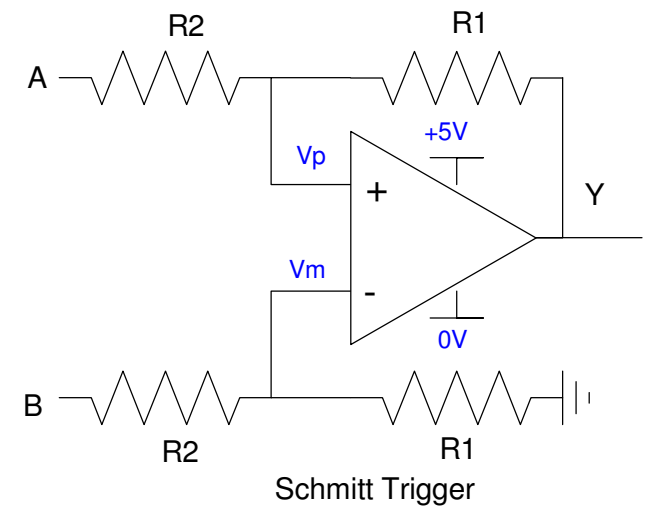
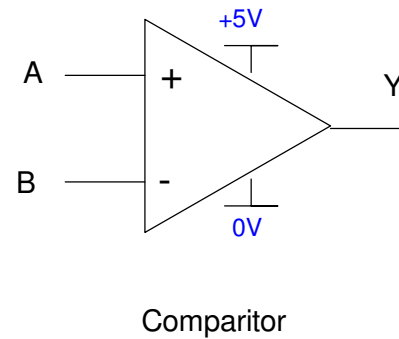
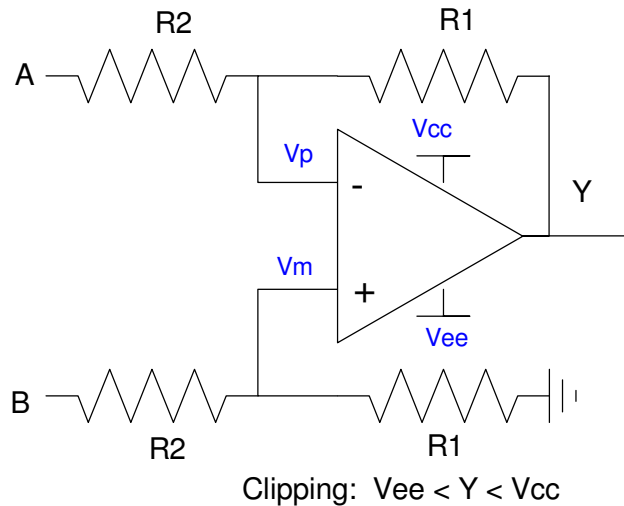
Lecture #16

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

Comparitors and Schmitt Triggers

$V_p = V_m$ does not *always* hold

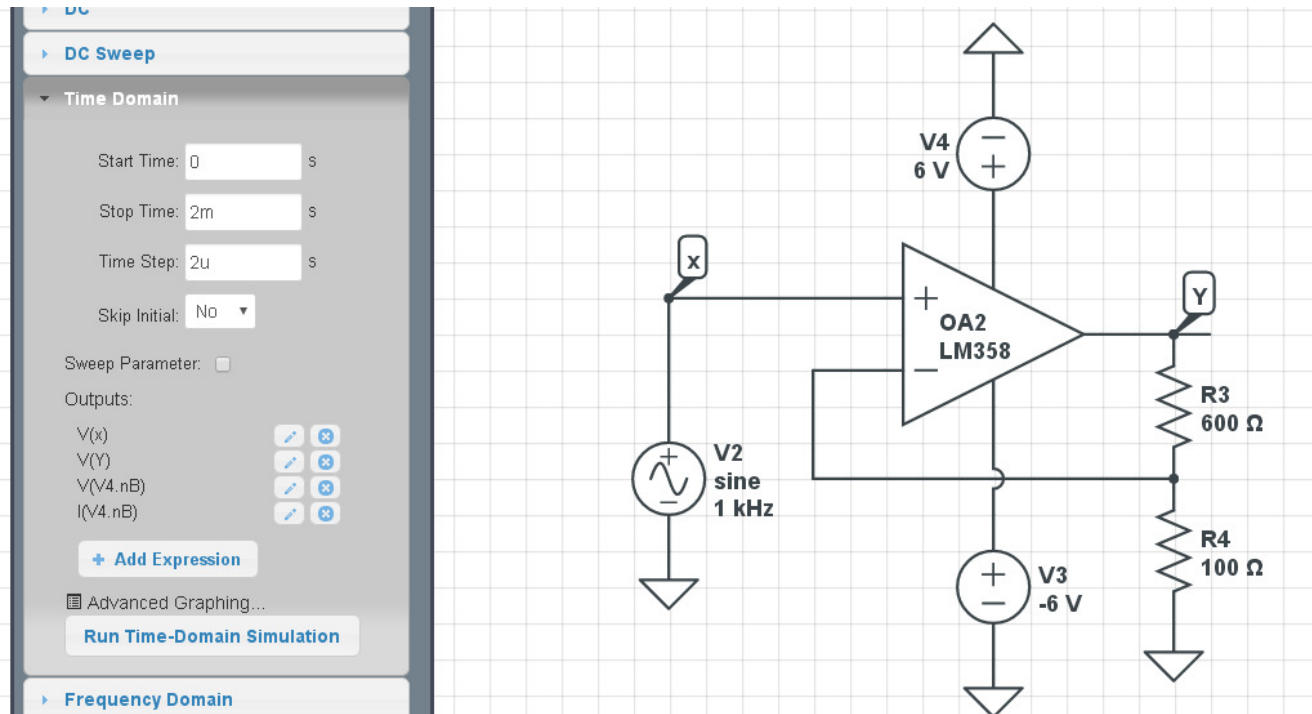
- Clipping (if you try to output $Y > V_{cc}$, Y clips at V_{cc})
- A comparitor circuit (no feedback), or
- A Schmitt trigger (positive feedback).



Clipping

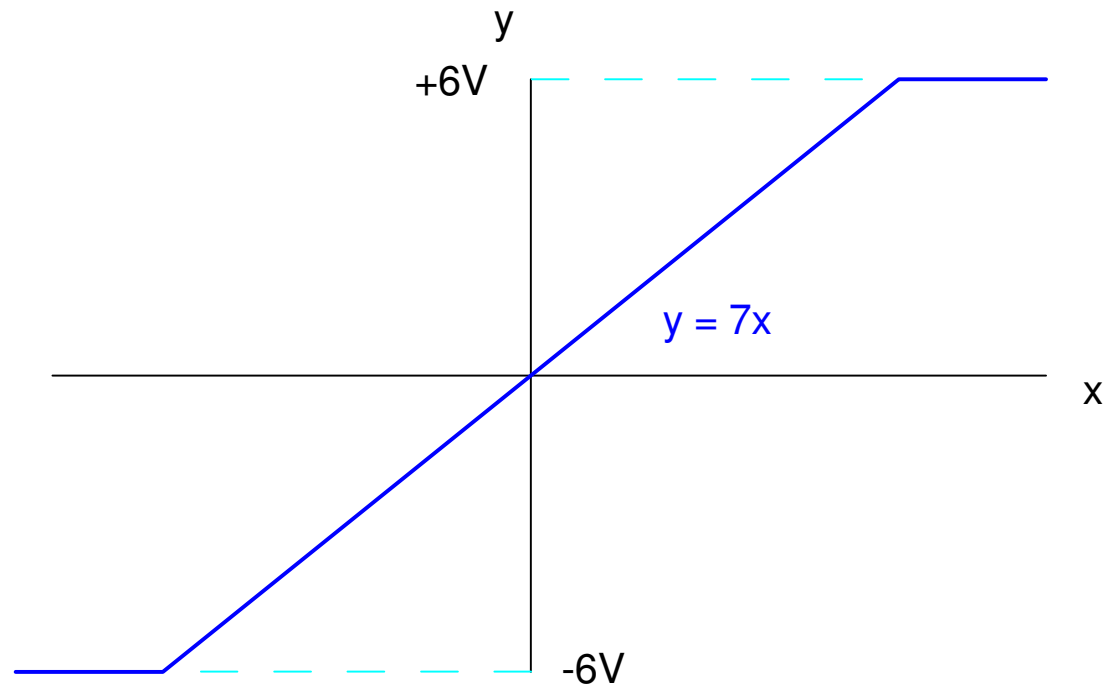
- If you are using negative feedback $V_p = V_m$
- Unless you try to output a voltage that exceeds your power supplies

Example: $y = 7.00x$



With a +6V and -6V power supply

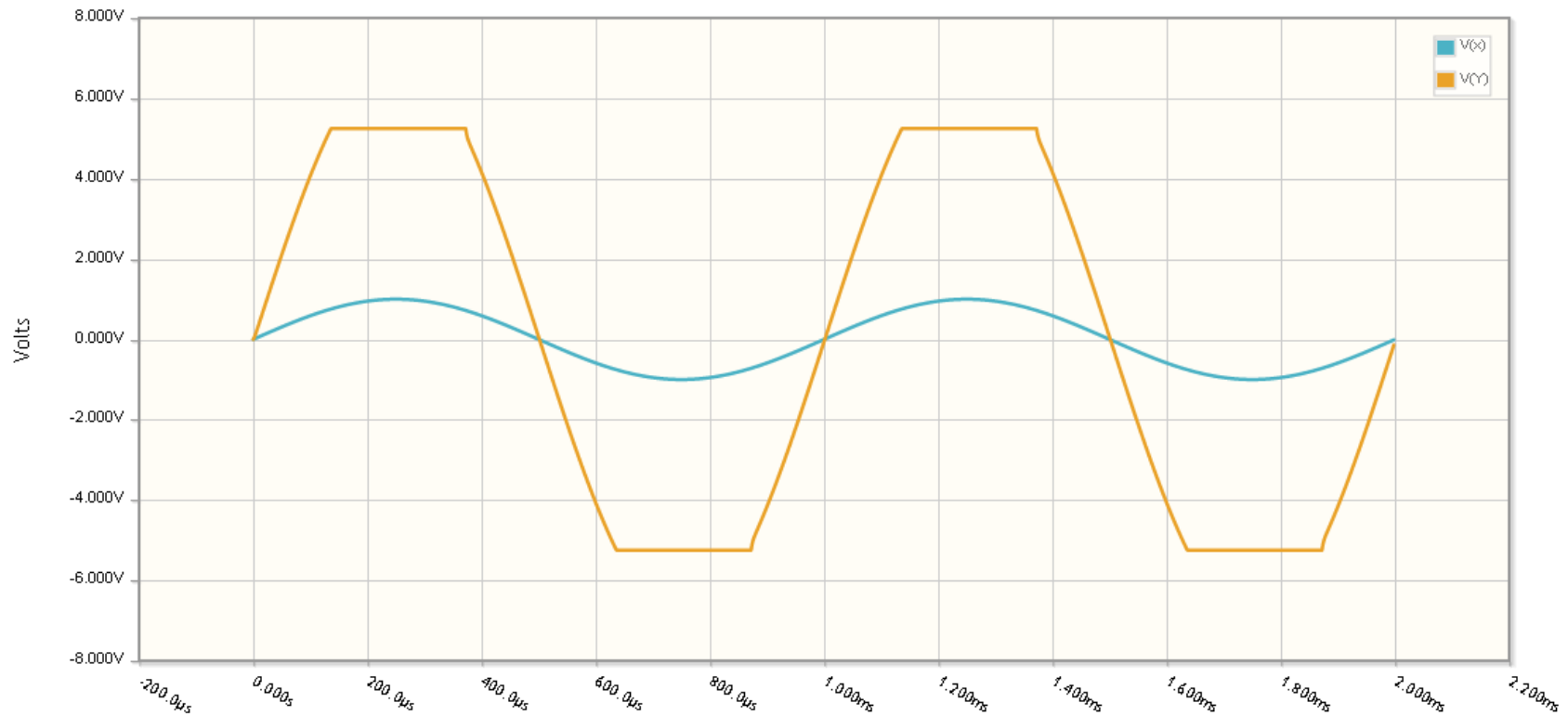
- $Y = 7X$
- limited to $-6V < Y < +6V$



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

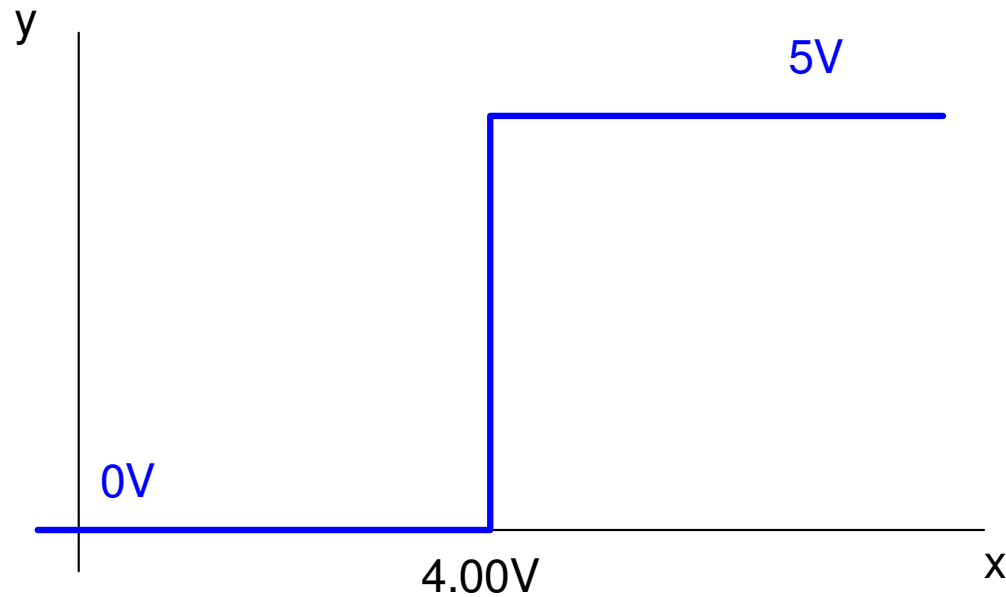
Example:

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



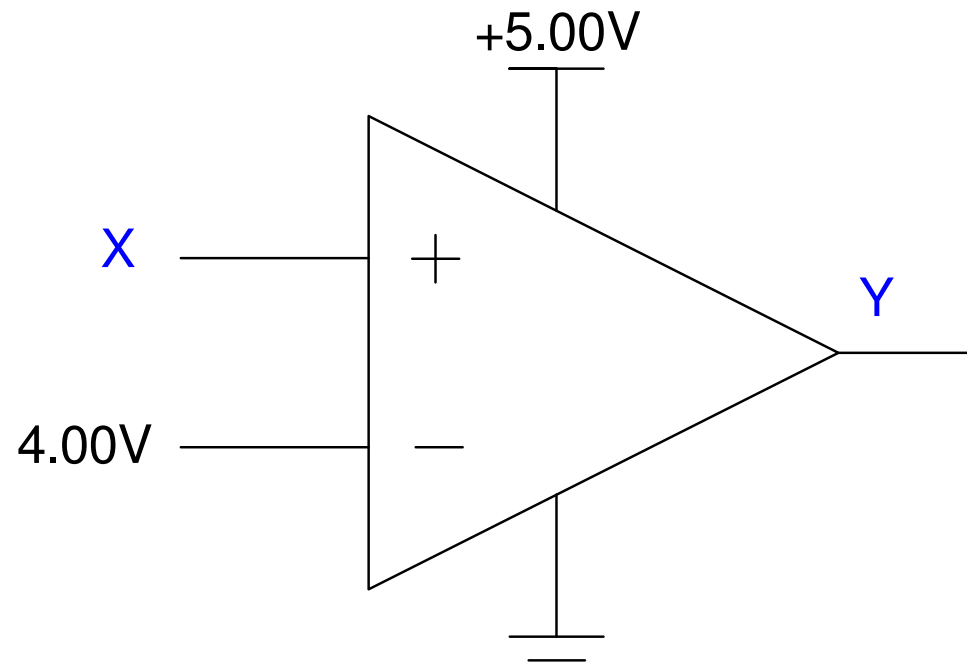
Comparitors:

- Outputs a binary signal (0V, 5V typical)
- Turn a motor on (5V) or off (0V)
- Turn a light on (5V) or off (0V)



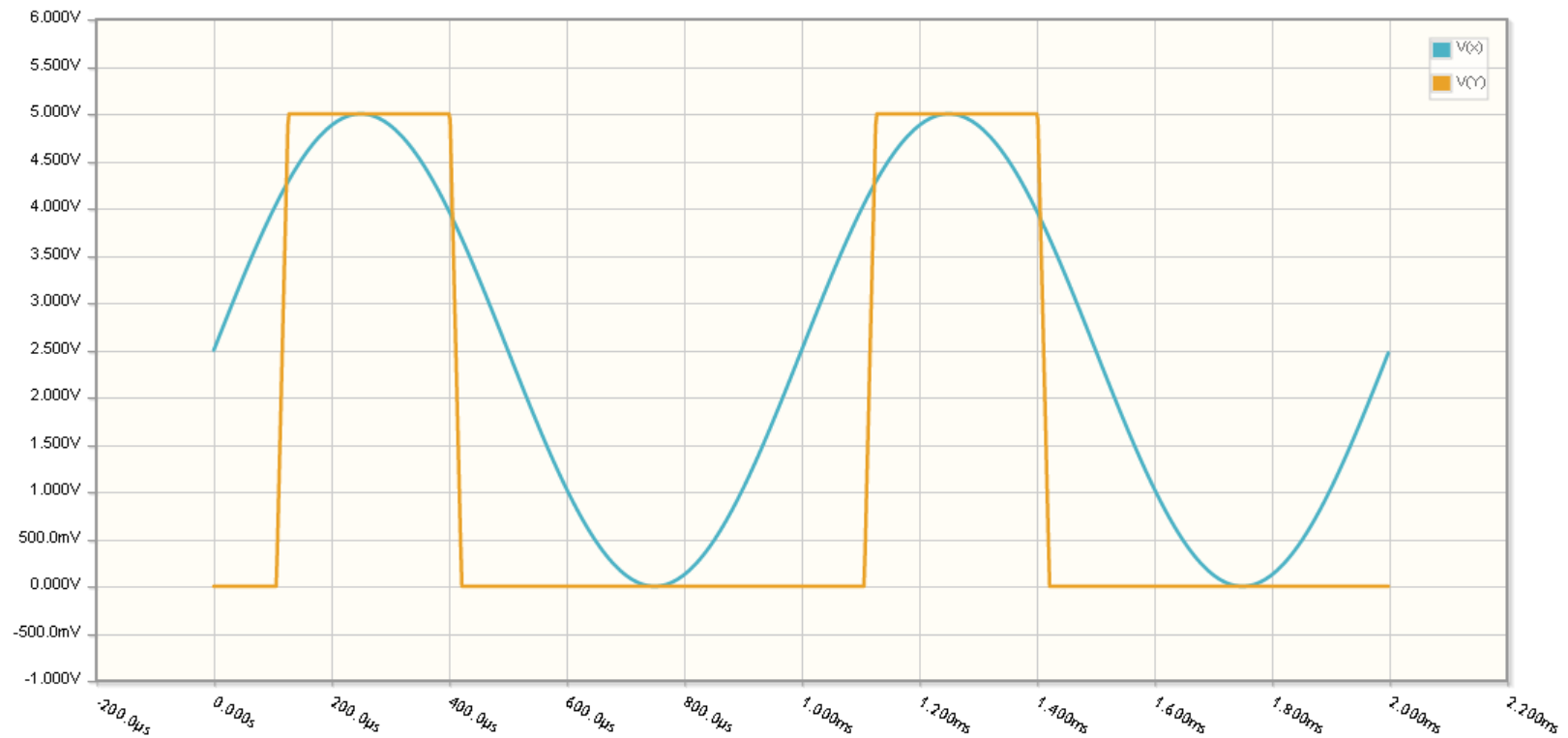
For example, design a circuit which outputs

- +5V when the input is more than 4.0V
- 0V when the input is less than 4.0V



CircuitLab Example:

- $X = 1V_p, 1kHz$ sine wave
- $y(t) = \begin{cases} 5V & x > 4.0V \\ 0V & otherwise \end{cases}$



Temperature Sensor: Output

- +5V when the temperature is above +20C
- 0V when the temperature is below +20C

Use a thermistor where

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

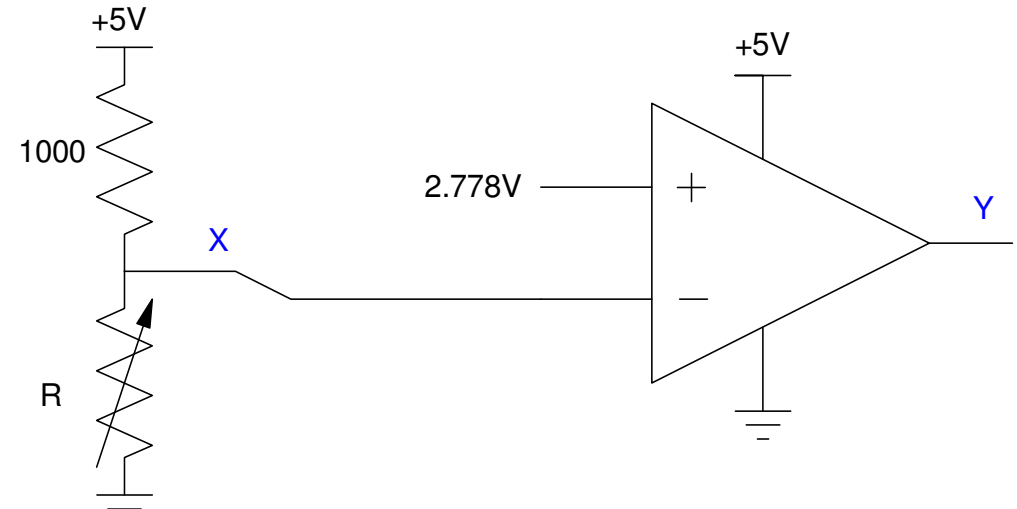
Solution: Use a voltage divider

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

As temperature goes up

- R goes down
- X goes down, and
- Y goes up (to +5V)

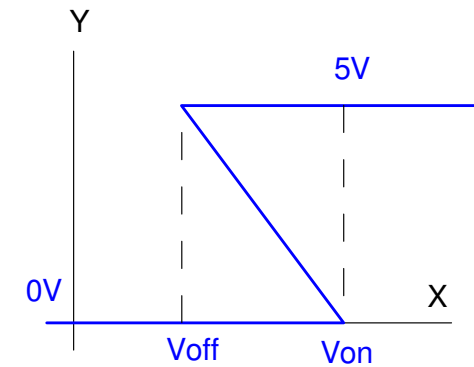
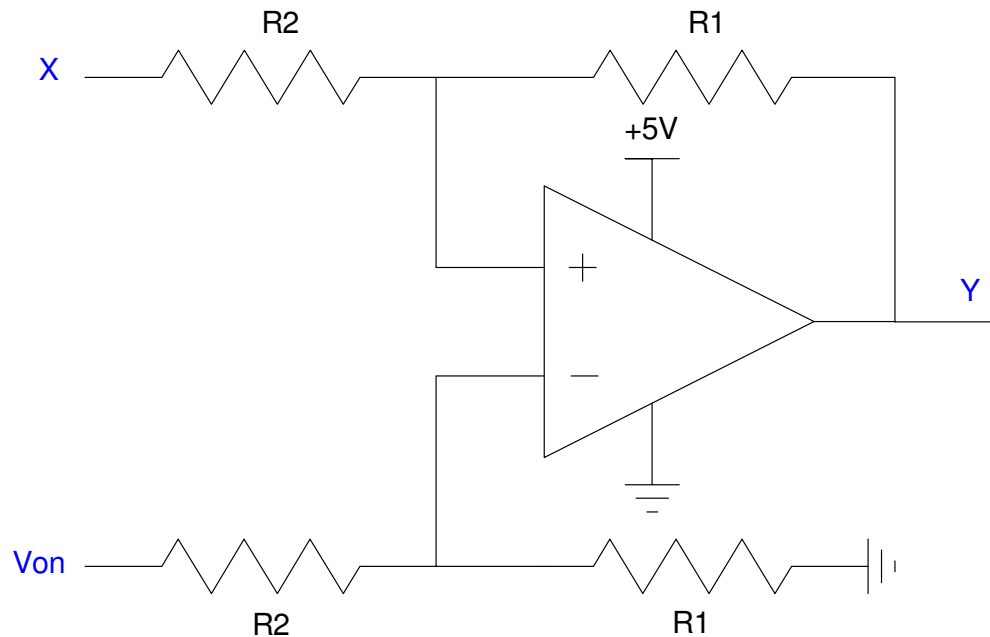
Connect the voltage divider to the negative input.



Schmitt Trigger

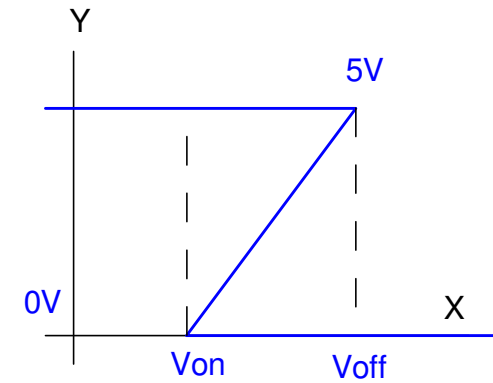
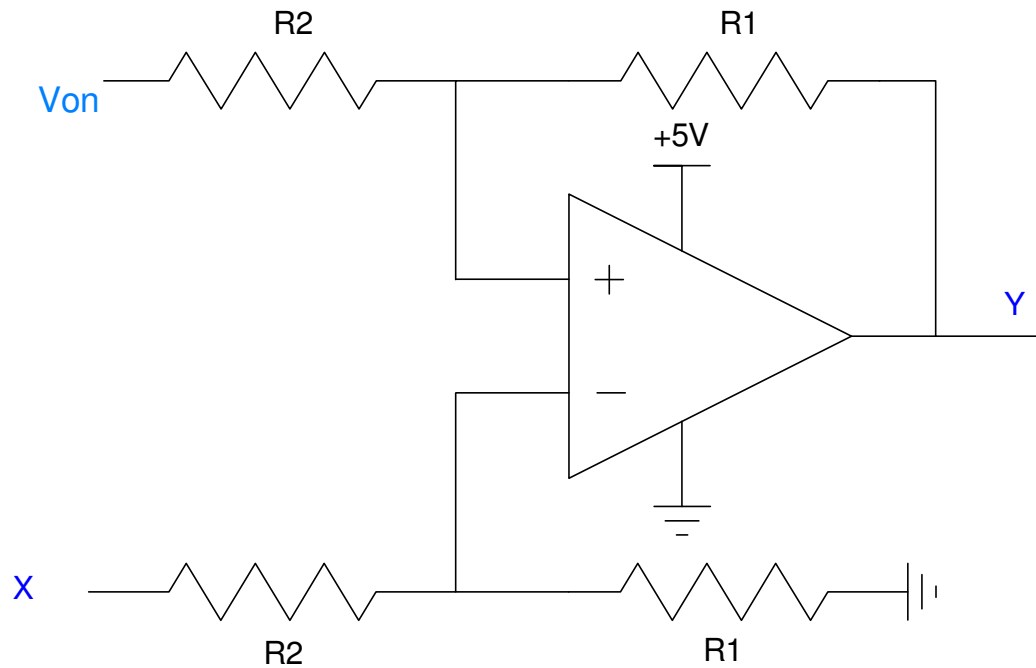
- Comparators chatter when $V_p = V_m$
- To avoid this chatter, add hysteresis

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



Flip inputs to get opposite relationship (Y = off when X is large)

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



Example: Design a circuit which outputs

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

Solution: Use a Schmitt Trigger. First, convert temperature to resistance and voltage. Assume a thermistor where

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

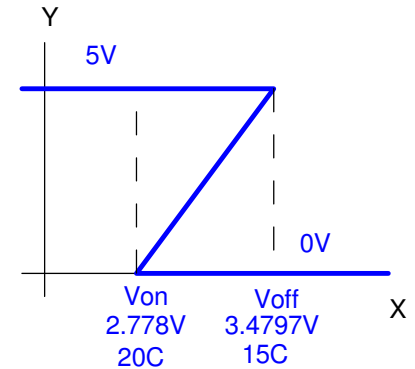
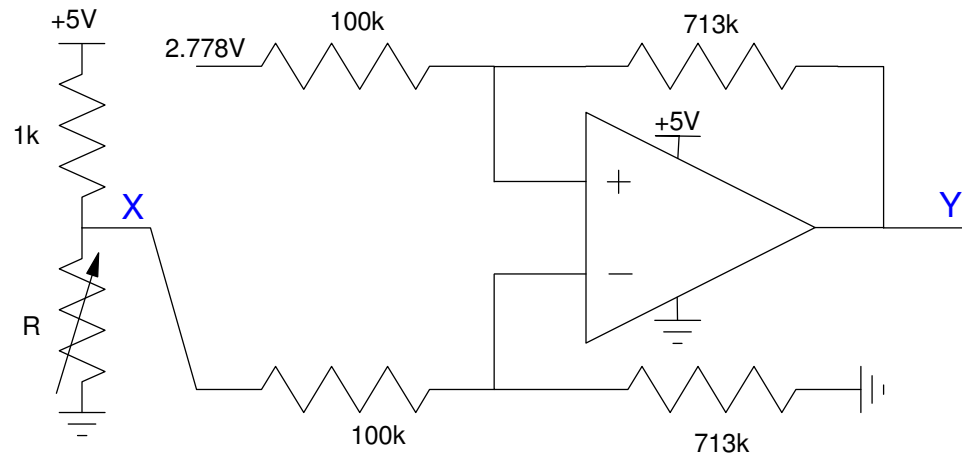
along with a voltage divider with a 1k resistor.

At 20C (on)

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

At 15C (off)

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



As X goes up, Y goes down. Connect to the minus input.

Y turns on at 2.7784V. Make the offset 2.7784V.

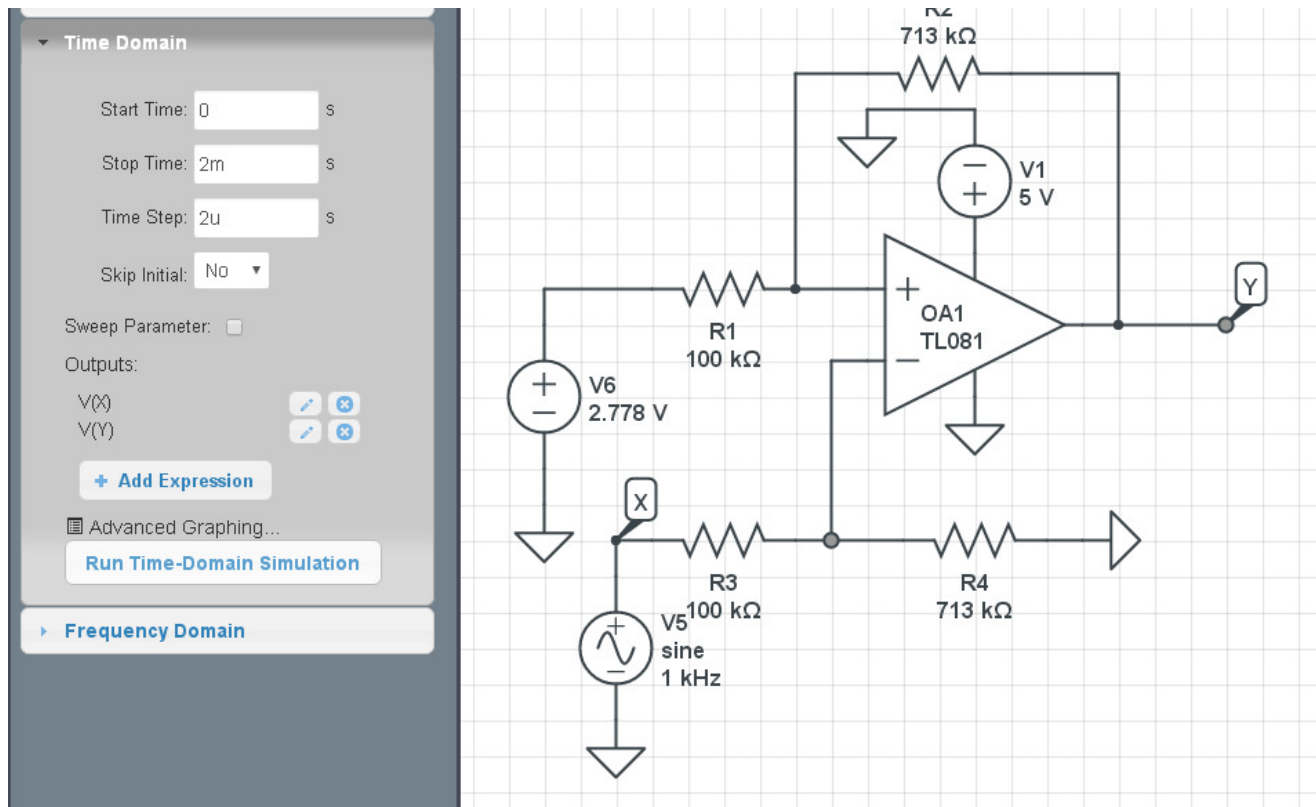
The gain required is

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

Pick R1 and R2 in a 7.1296 : 1 ratio

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



X = blue

Y = orange

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

