Comparitors and Schmitt Triggers

EE 206 Circuits I

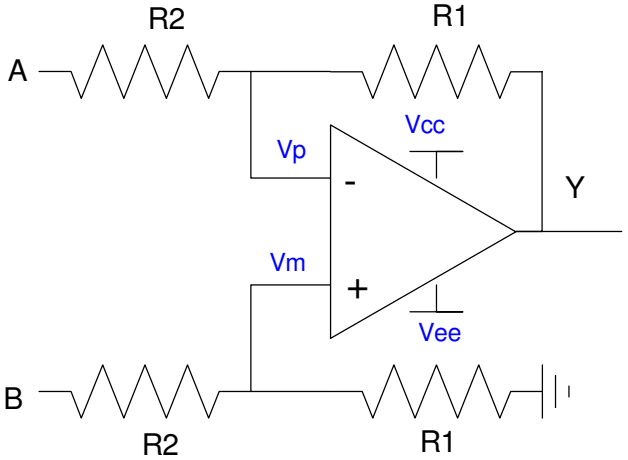
Jake Glower - Lecture #16

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

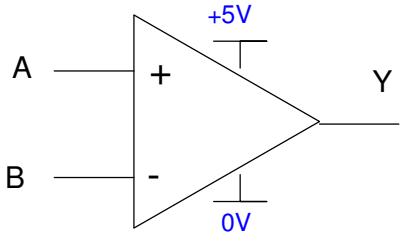
Comparitors and Schmitt Triggers

Vp = Vm does not *always* hold

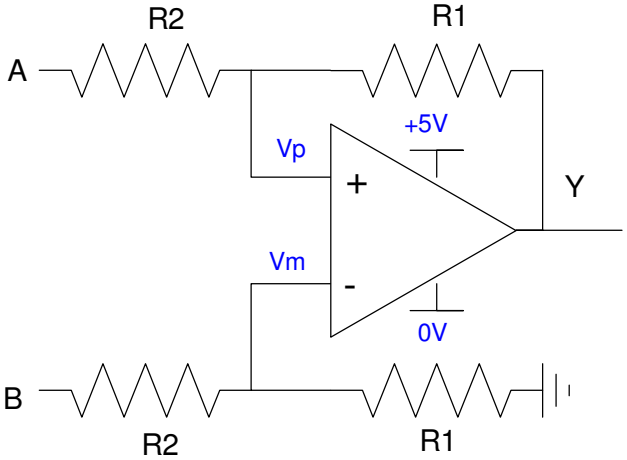
- Clipping (if you try to output Y > Vcc, Y clips at Vcc)
- A comparitor circuit (no feedback), or
- A Schmitt trigger (positive feedback).



Clipping: Vee < Y < Vcc



Comparitor

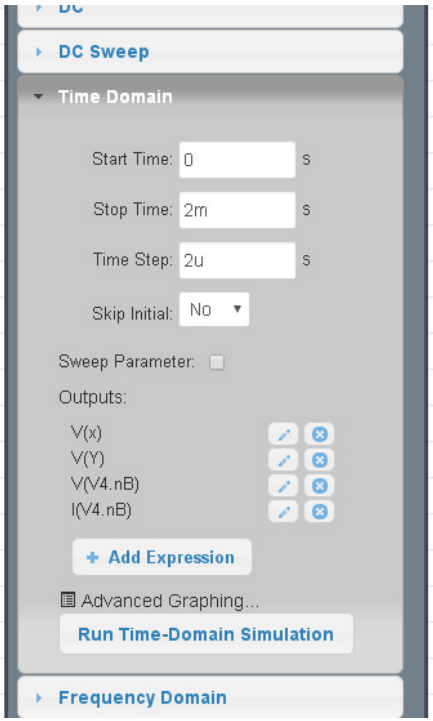


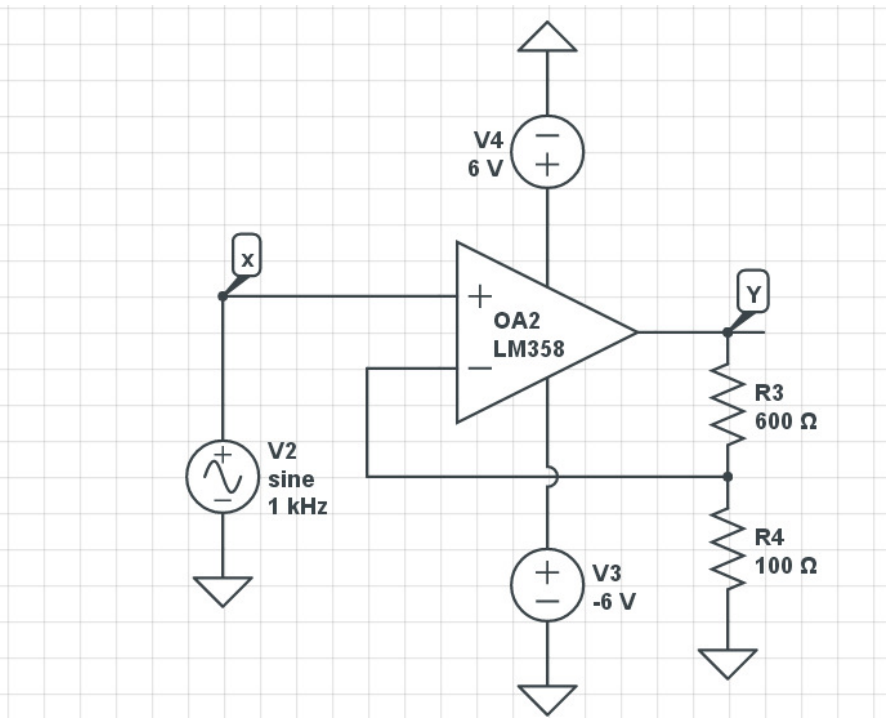
Schmitt Trigger

Clipping

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

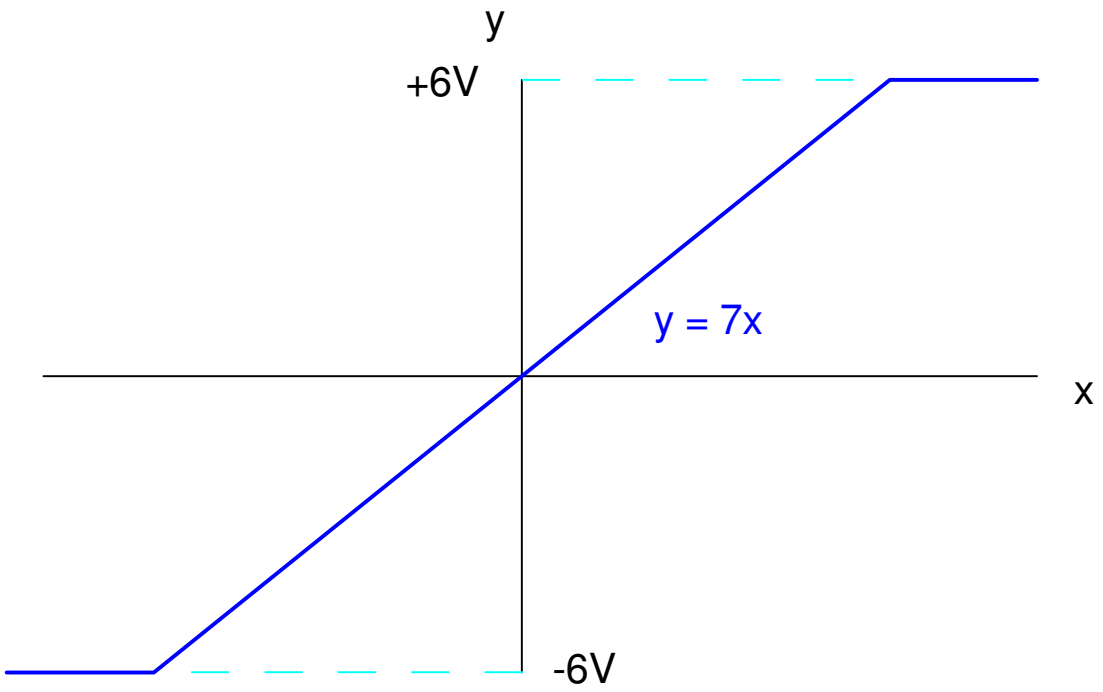
Example: $y = 7.00x$





With a +6V and -6V power supply

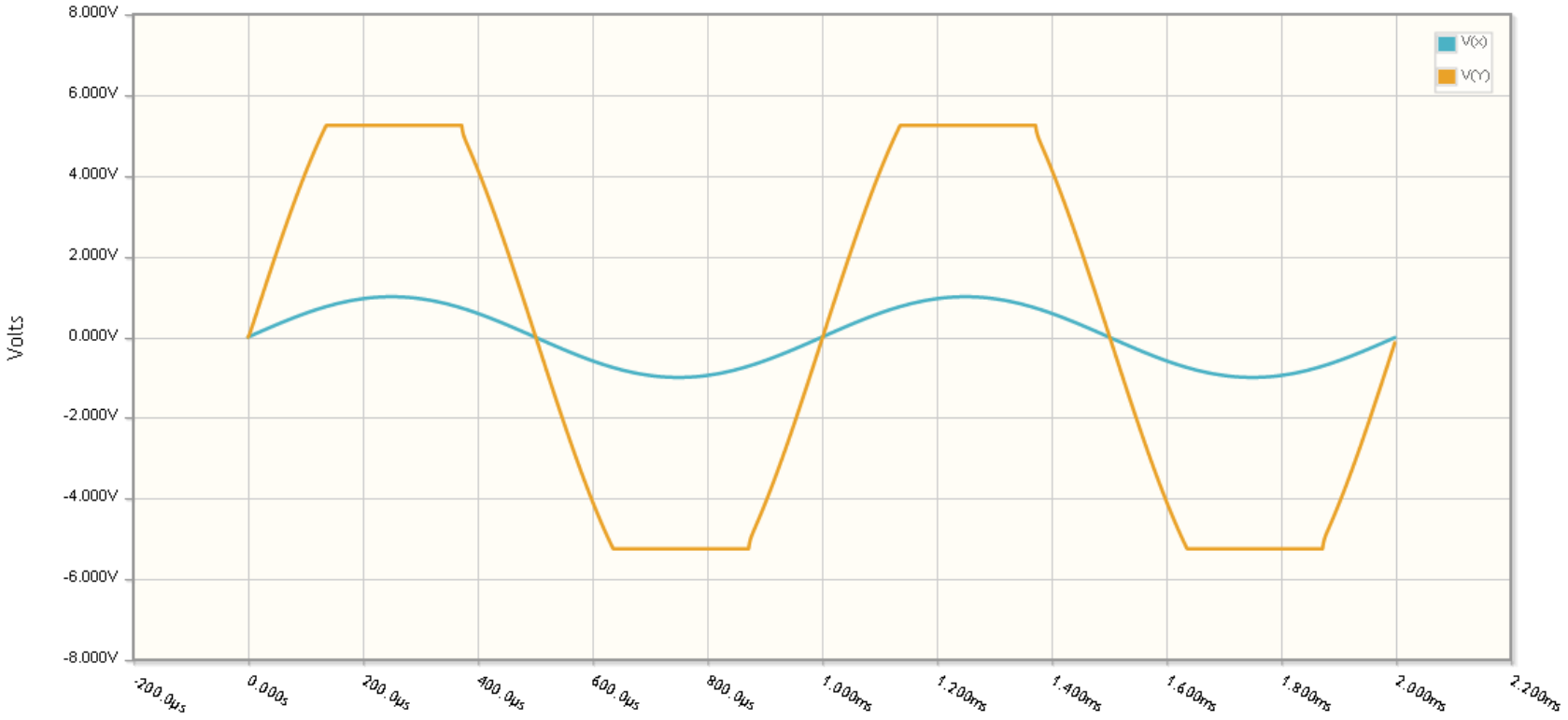
- Y = 7X
- limited to -6V < Y < +6V



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

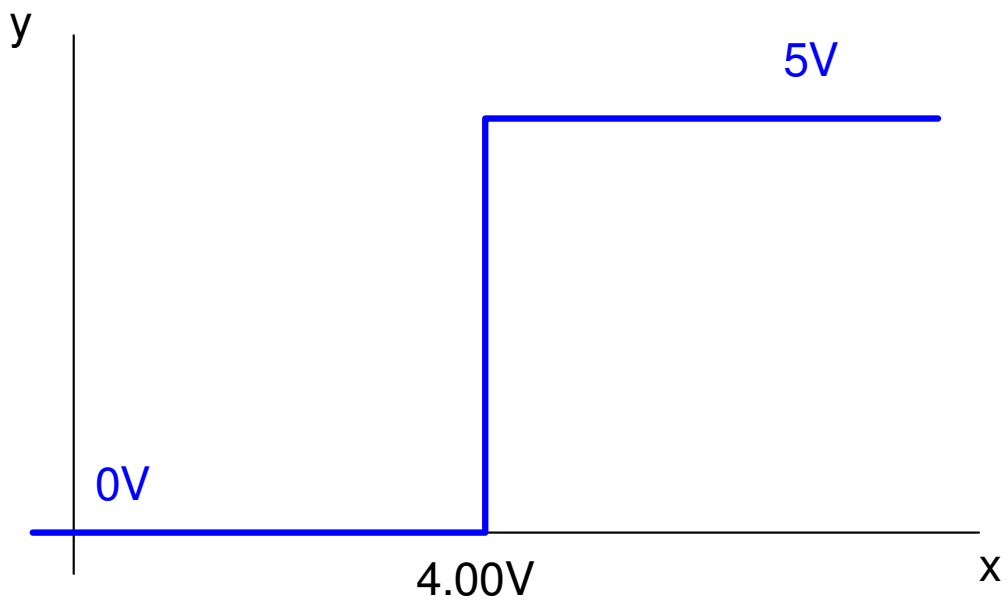
Example:

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



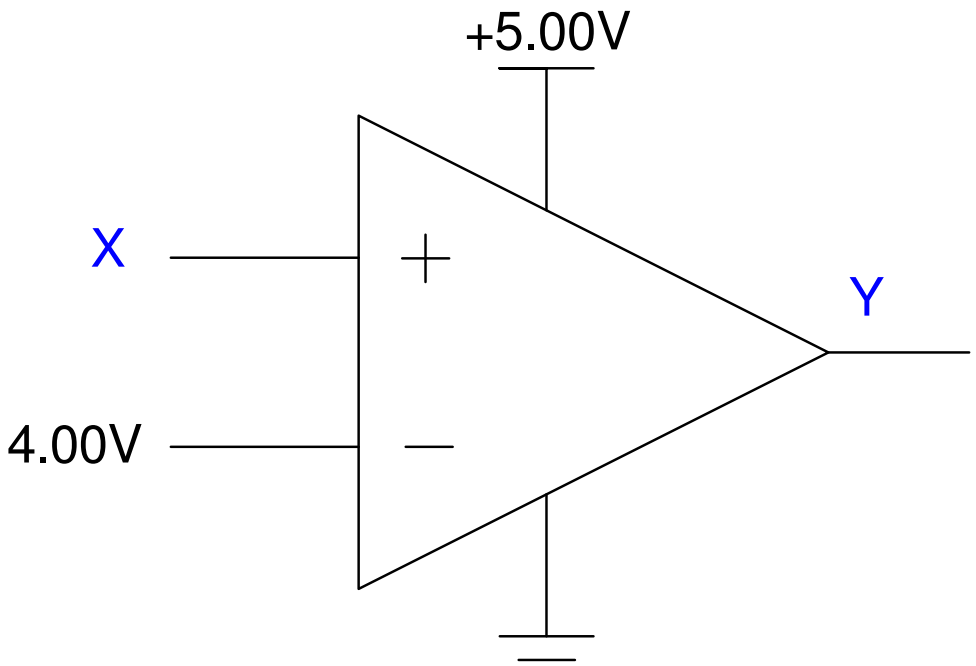
Comparitors:

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



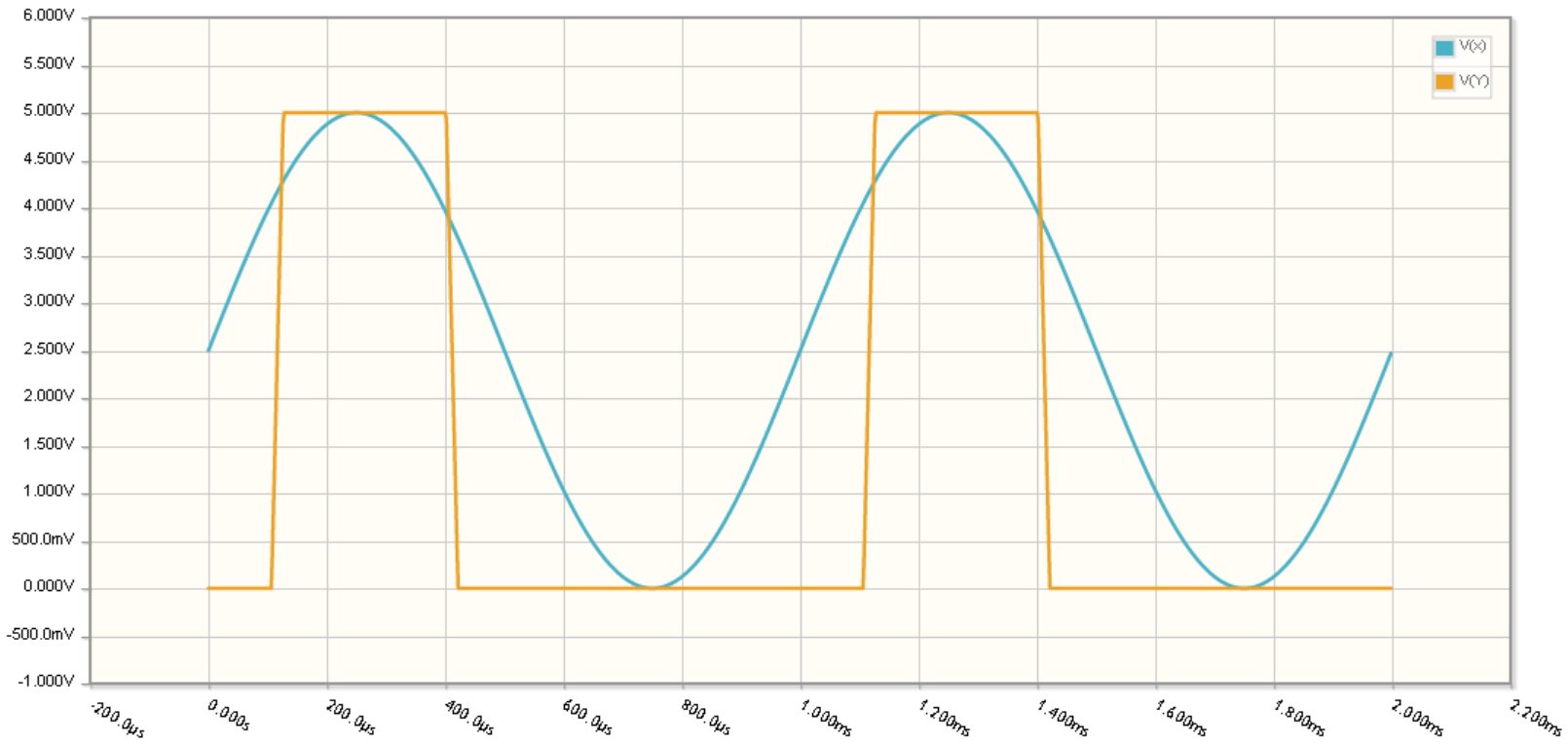
For example, design a circuit which outputs

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



CircultLab Example:

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

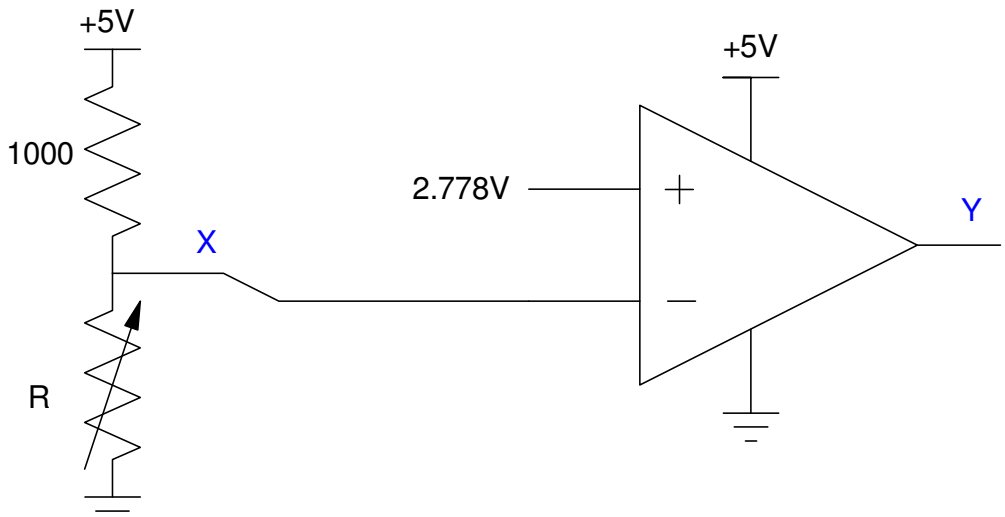


Temperature Sensor: Output

- +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 Ohms
- X = 2.7784V

As temperature goes up

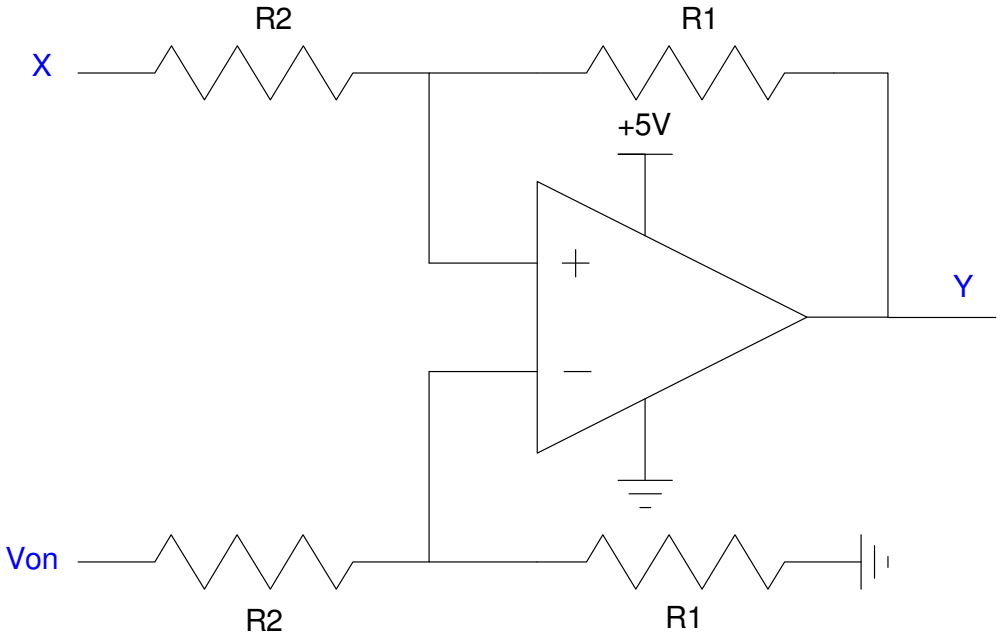
- R goes down
- X goes down, and
- Y goes up (to +5V)

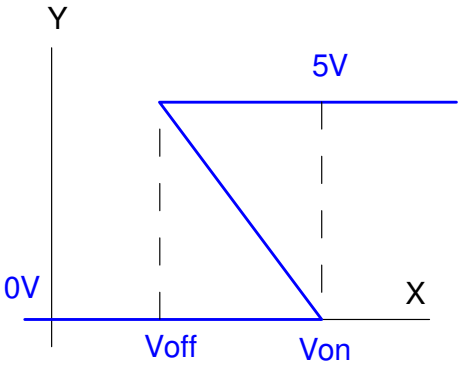
Connect the voltage divider to the negative input.

Schmitt Trigger

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

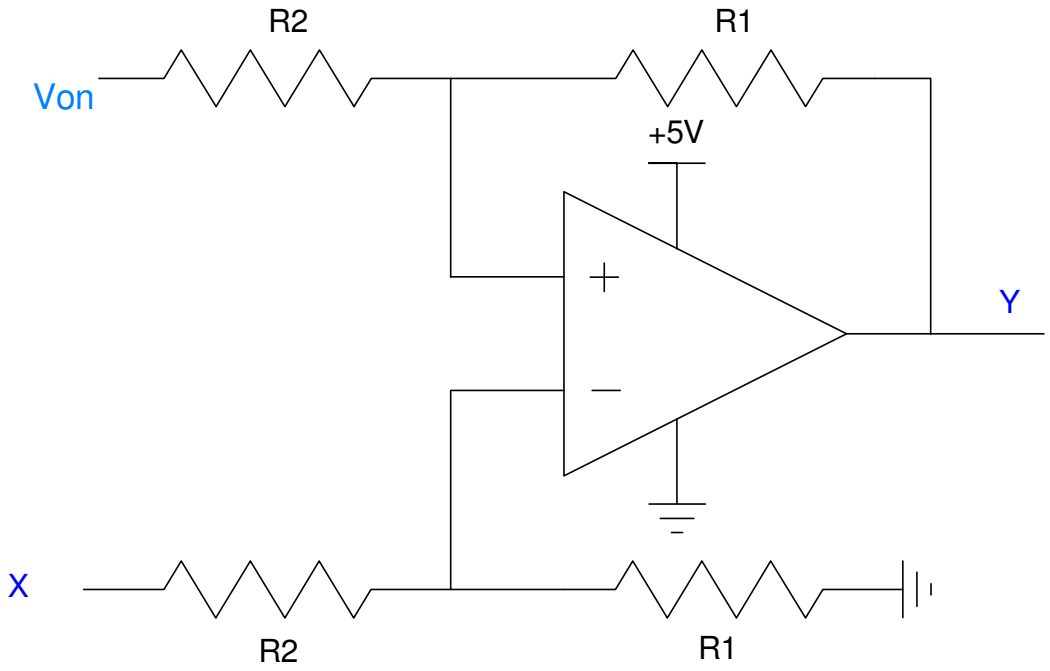
$$Y = \begin{cases} 5V & X > V_{on} \\ 0V & X < V_{off} \\ \text{no change} & V_{off} < X < V_{on} \end{cases}$$

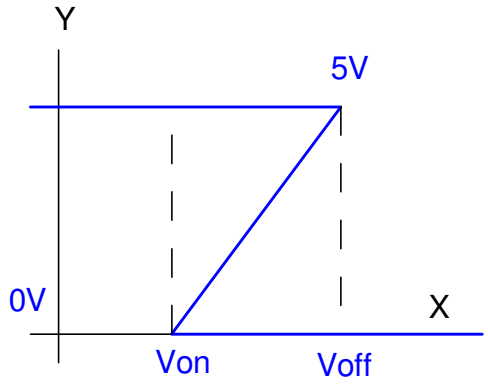




Flip inputs to get opposite relationship (Y = off when X is large)

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





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

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

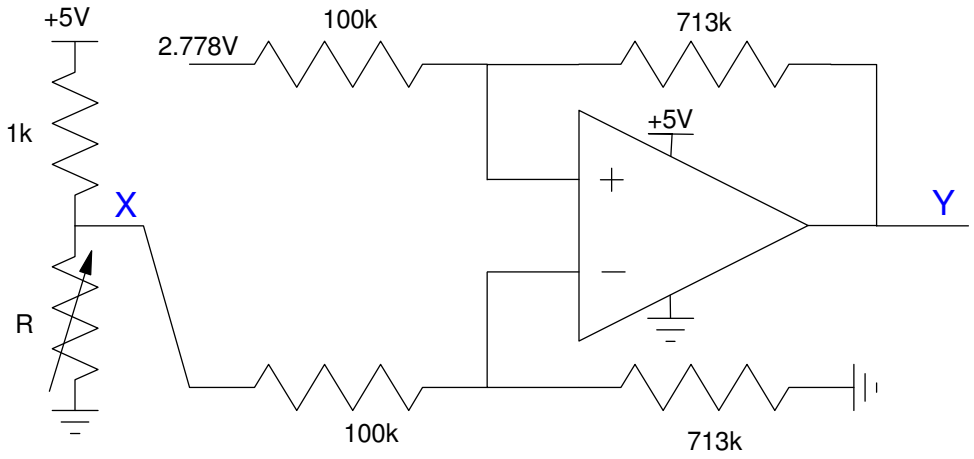
along with a voltage divider with a 1k resistor.

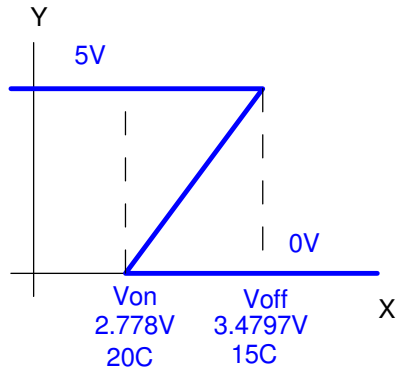
At 20C (on)

- R = 1250.59 Ohms
- X = 2.7784V
- Y = 5.00V

At 15C (off)

- R = 1576.17 Ohms
- X = 3.0591 V
- Y = 0.00V





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

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

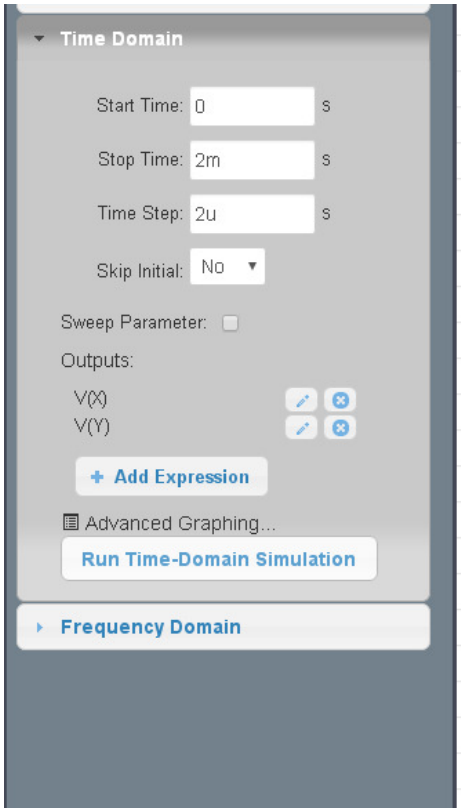
The gain required is

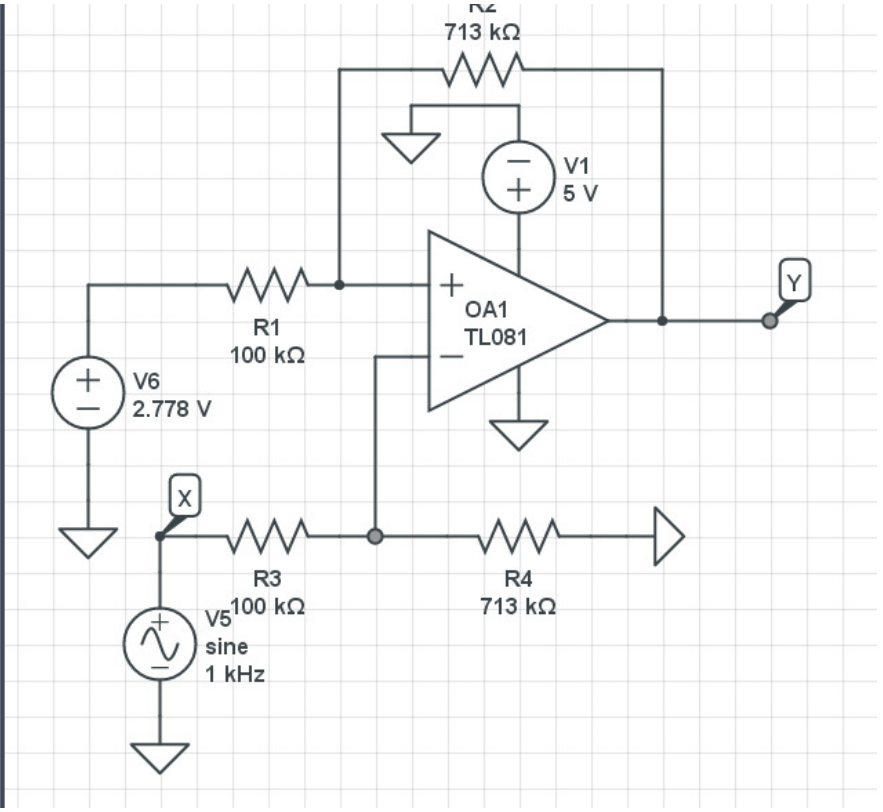
$$gain = \left(\frac{5V - 0V}{3.4797V - 2.7784V}\right) = 7.1296$$

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

- Von = 2.760V
- Voff = 3.514V