
Comparitors and Schmitt Triggers

ECE 320 Electronics I

Jake Glower - Lecture #14

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

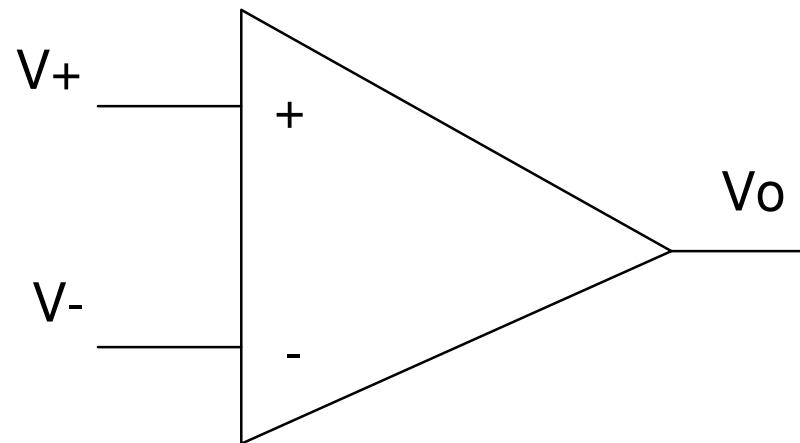


Op-Amps

An operational amplifier is a 2-input device with

$$V_o \approx k(V^+ - V^-)$$

where k is a large number. For short, the following symbol is used for an operational amplifier:



Operational Amplifier (Op-Amp): $V_o = k(V_+ - V_-)$

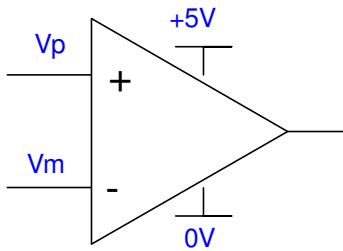
Comparitors and Schmitt Triggers

In ECE 320, we deal with digital circuits.

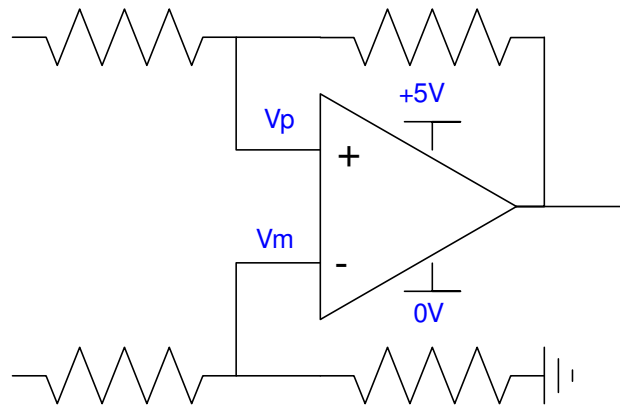
- No feedback (a comparitor), or
- Positive feedback (a Schmitt Trigger).

In ECE 321, we cover analog electronics

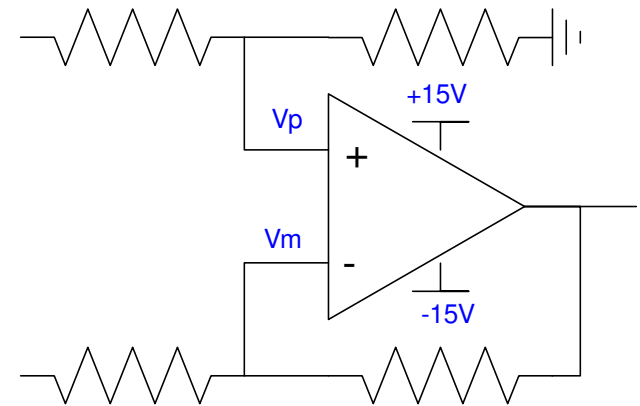
- Negative feedback (an amplifier)



Comparitor (Digital)



Schmitt Trigger (Digital)



Amplifier (Analog)

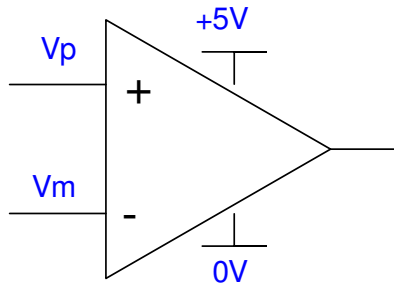
Op-Amps and Power Supplies

Analog Electronics (negative feedback)

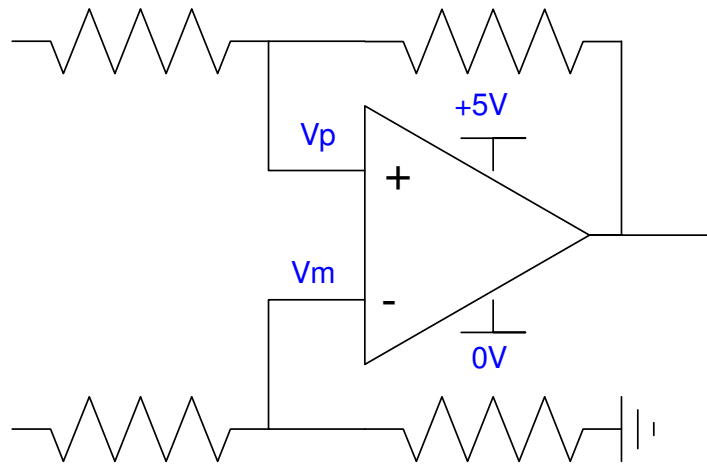
- The power supply doesn't matter

Digital Electronics

- The power supply *does* matter
- If $V_p > V_m$, the output goes to the + power supply (+5V: true)
- If $V_p < V_m$, the output goes to the - power supply (0V: false)



Comparator (Digital)



Schmitt Trigger (Digital)

Comparitors:

Binary Output

- 0V (false)
- 5V (true)

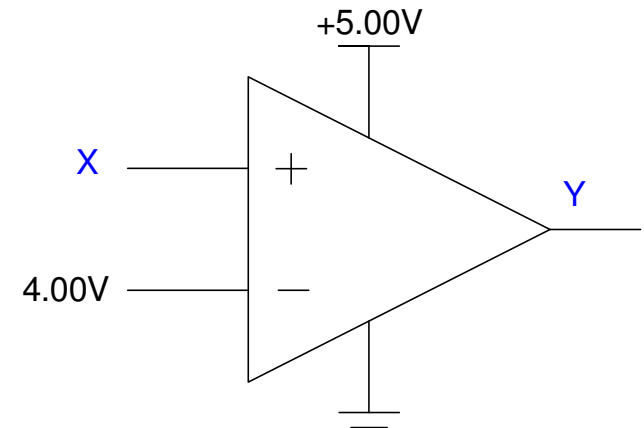
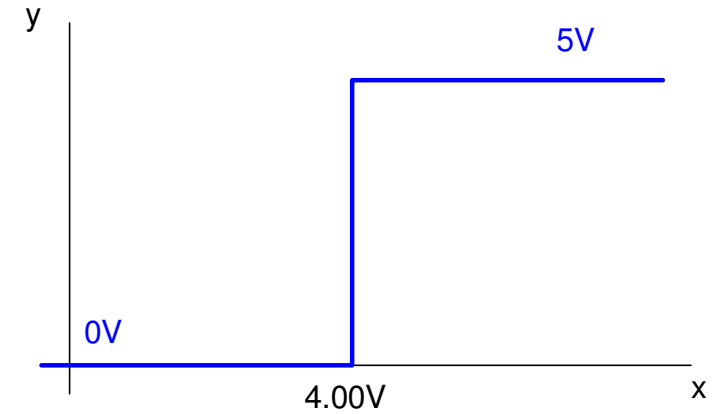
Switch at a specific voltage

Example:

- Turn off a motor (0V), or
- Turn on a motor (5V)

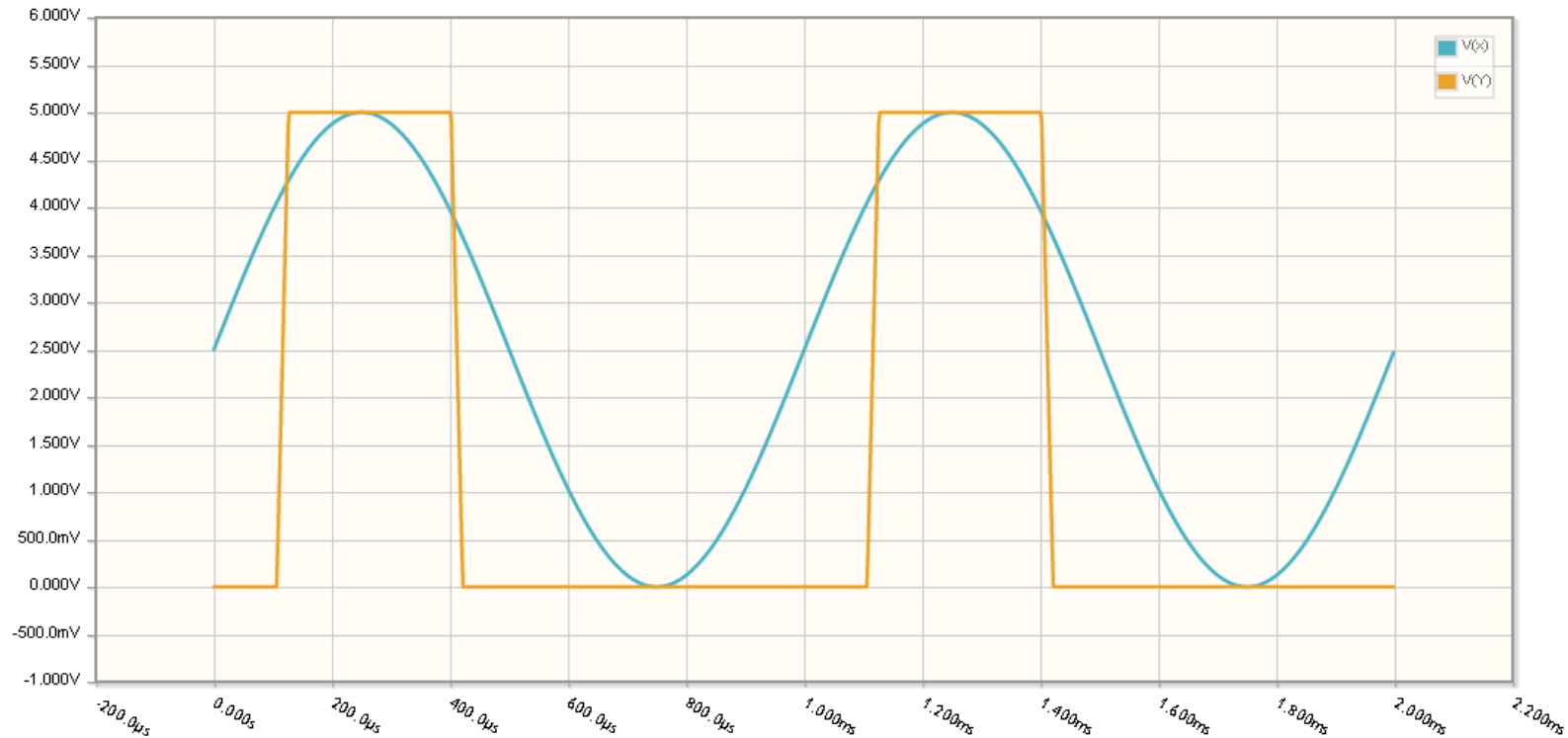
or

- Turn off a light (0V) or
- Turn on a light (5V)



CircuitLab Simulation

$$y(t) = \begin{cases} 5V & x > 4.0V \\ 0V & \text{otherwise} \end{cases}$$



Output Y (orange) of a comparator. Notice that the output is either 0V or 5V.

Comparator Example:

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

Assume a thermistor where

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

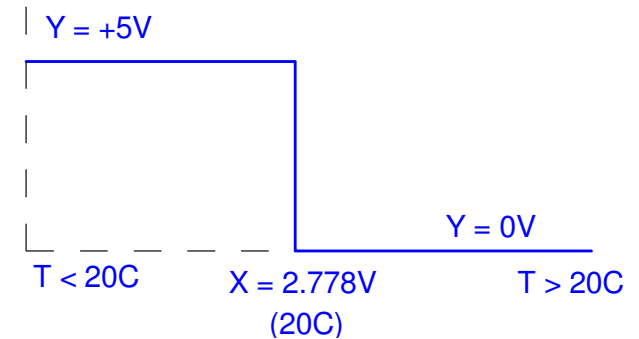
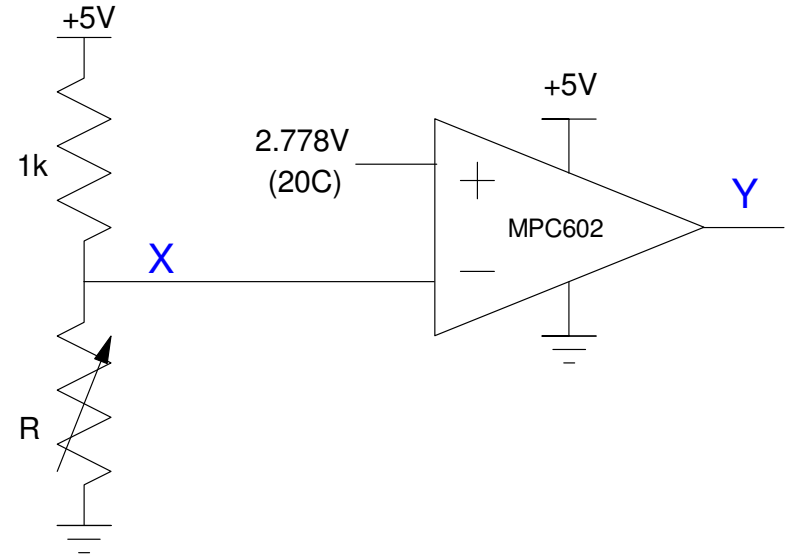
Use a voltage divider. At 20C

- $R = 1250.59$ Ohms
- $X = 2.778V$

As temperature goes up

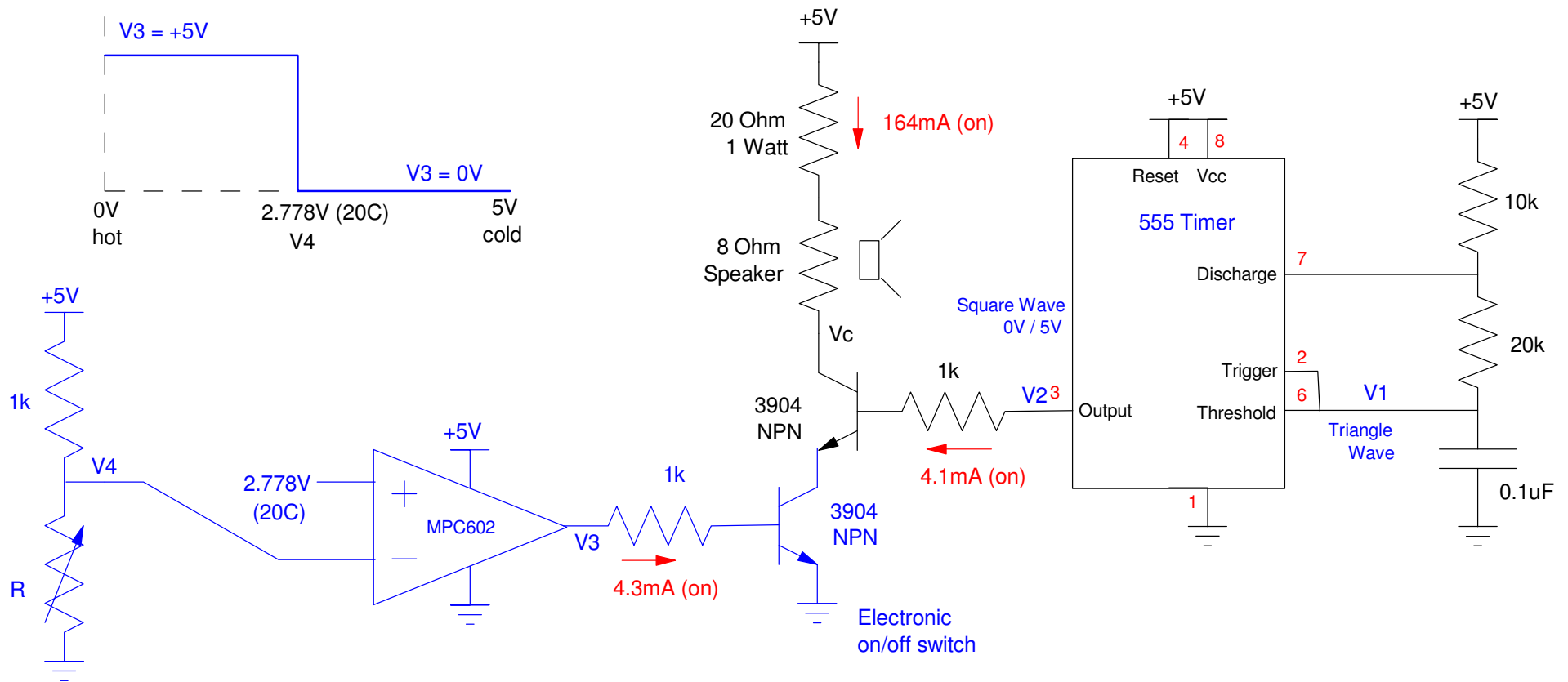
- R goes down
- X goes down, and
- Y goes up (to +5V)

Connect the voltage divider to the negative input.



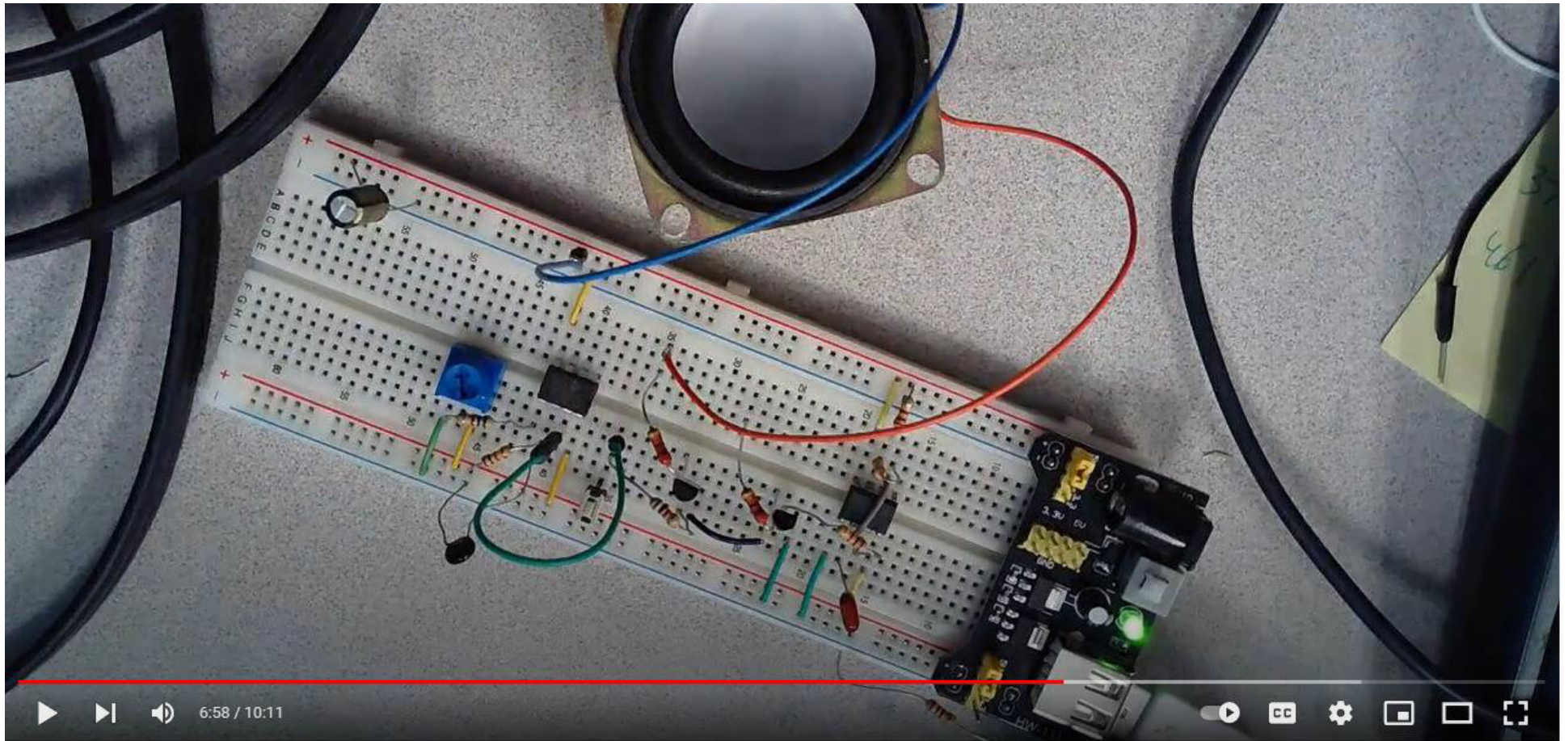
Comparitors & Temperature Alarm

- Turn on an alarm when the temperature goes above 20C
- Turn off an alarm when the temperature goes below 20C



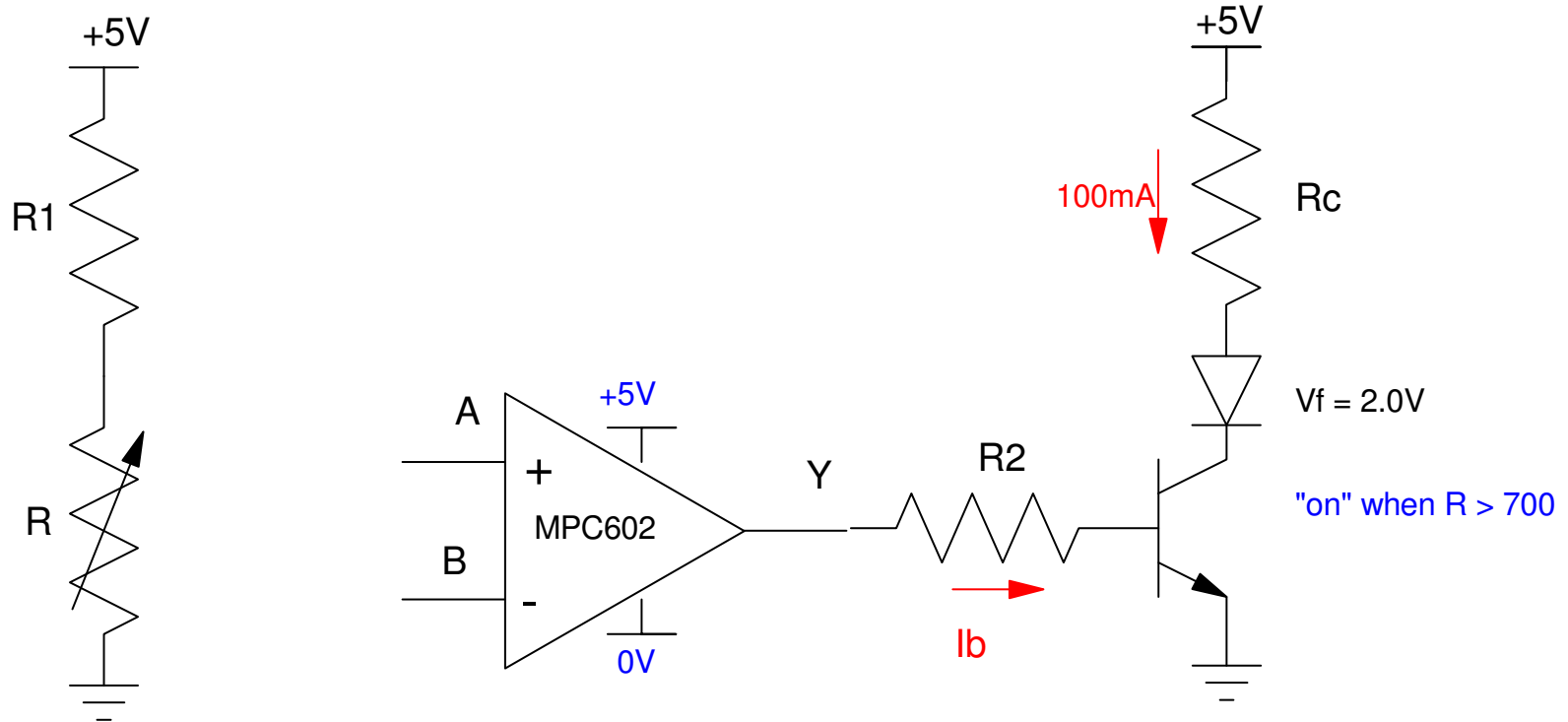
Hardware Example: 6:58 in YouTube video...

- <https://youtu.be/mgFDkJY6Lbo>



Handout: Comparitor Design

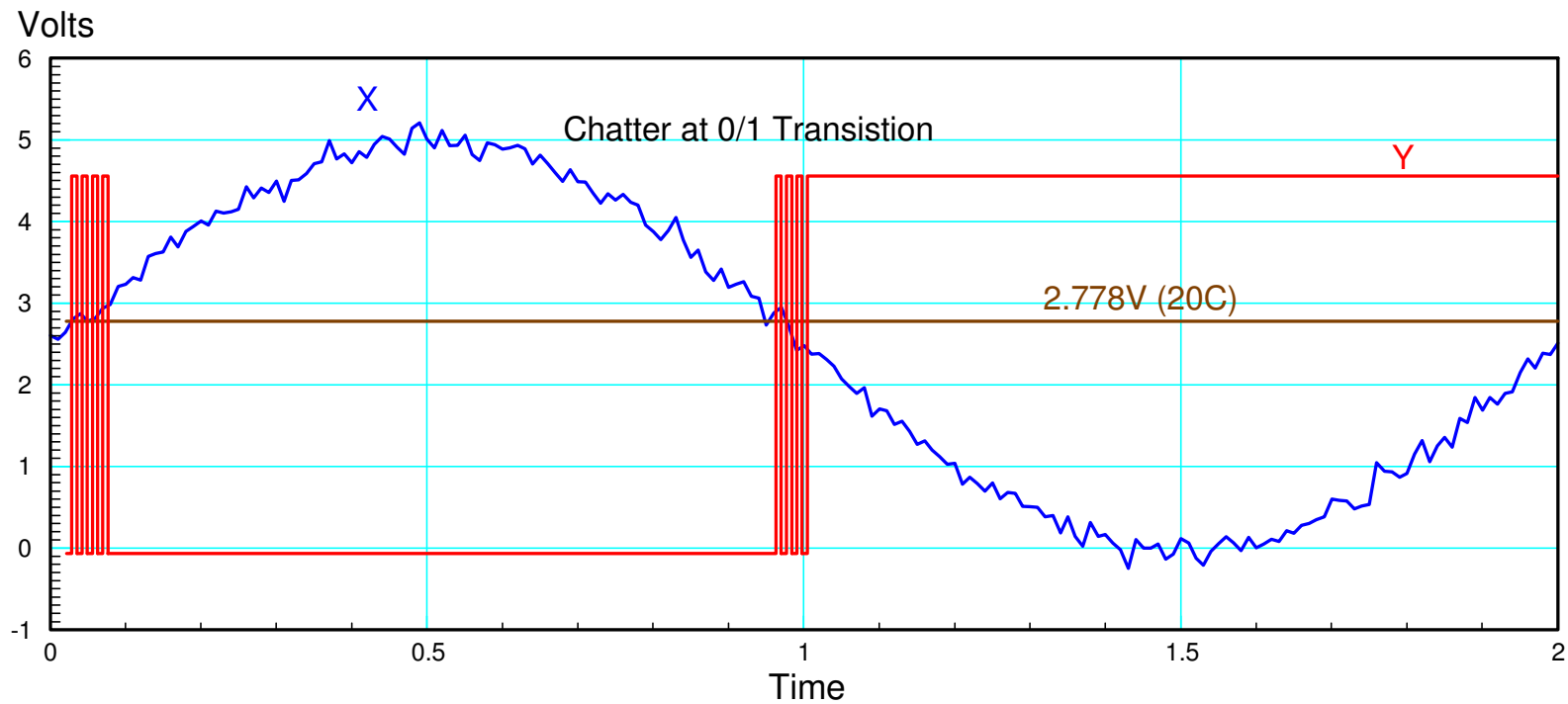
- Turn on when $R > 700$
- Turn off when $R < 600$



Comparitors & Noise:

Problem: when there is noise on the input, the output will chatter

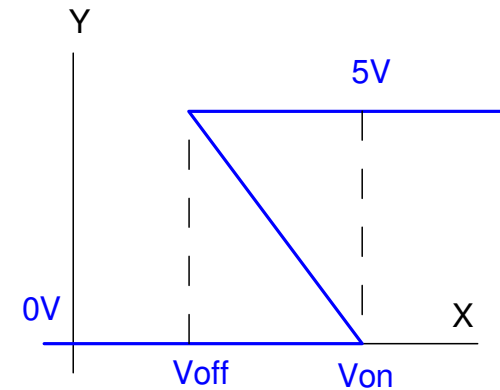
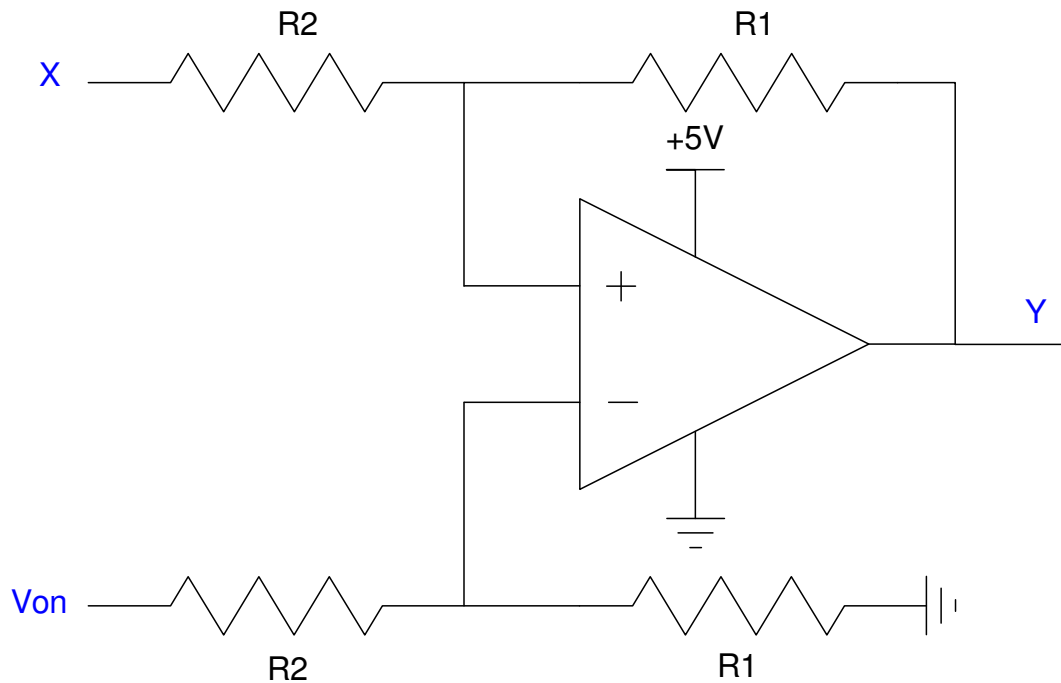
- This causes multiple counts
- This can wear out pumps and motors



Schmitt Trigger (take 1: $V_{on} > V_{off}$)

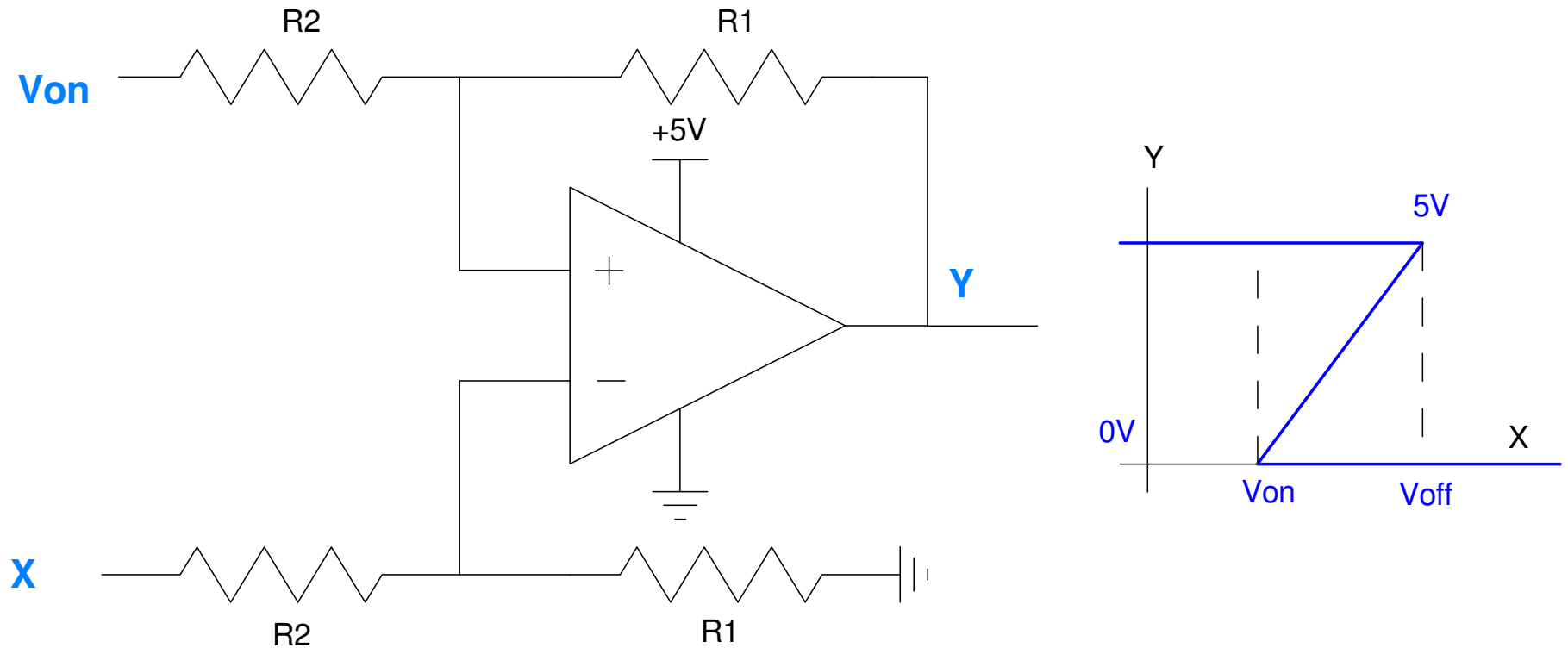
- Adding hysteresis removes the chatter
- Note: Offset = V_{on} (the voltage where the output goes high)

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



Schmitt Trigger (take 2: $V_{on} < V_{off}$)

- Flip the inputs, you get the case where Y turns off (0V) for large X



Schmitt Trigger where Y turns off (0V) for large X

Example: Design a circuit which outputs

- 5V for temperatures more than 20C
- 0V for temperatures below 7C, and
- No change of 7C < T < 20C

Step 1: Convert temperature to voltage.

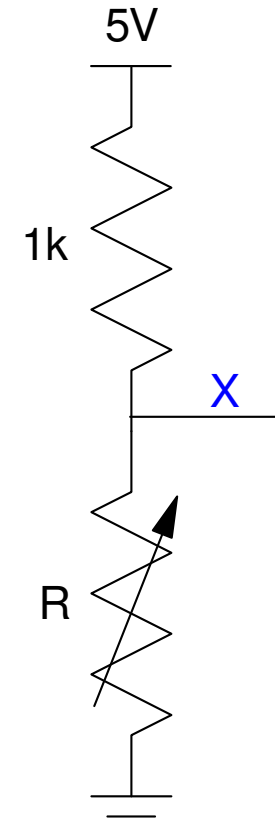
$$R = 1000 \exp\left(\frac{3905}{T+273} - \frac{3905}{298}\right) \Omega$$

At 20C (Y = 5V (on))

- R = 1250.59 Ohms
- X = 2.7784V

At 7C (Y = 0V (off))

- R = 2321 Ohms
- X = 3.495 V



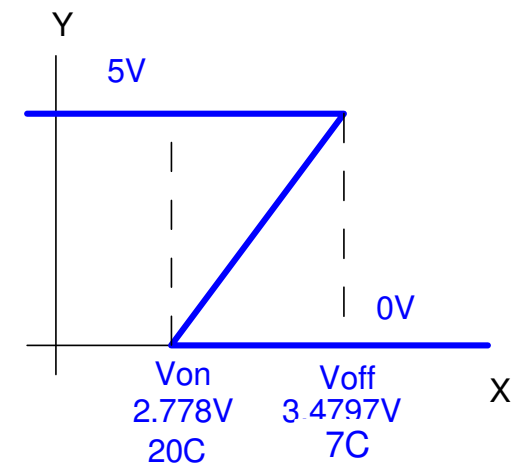
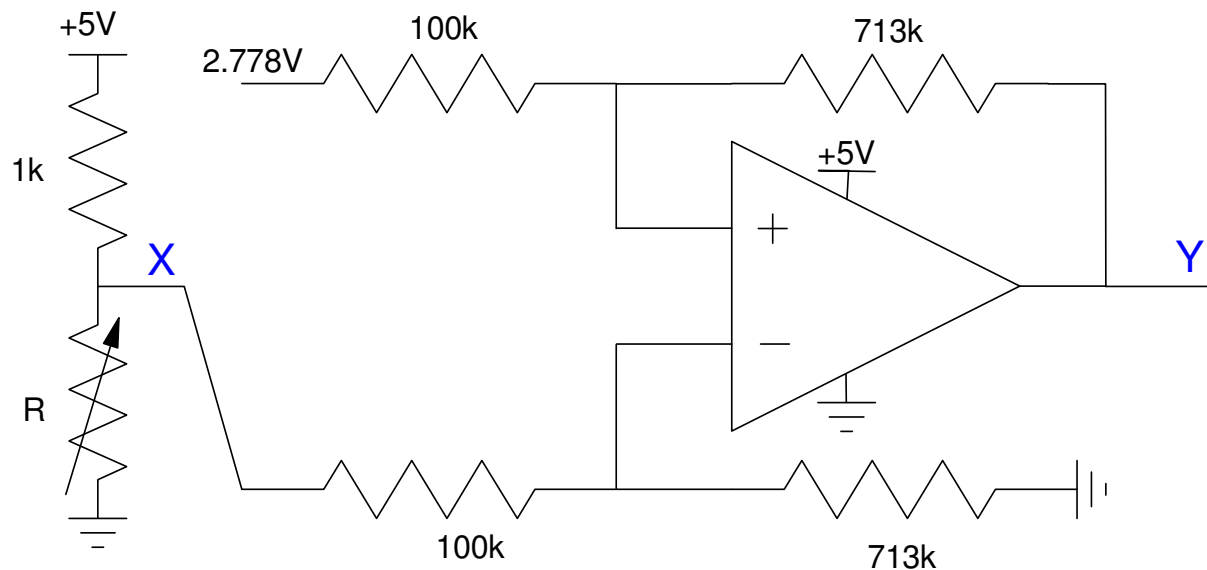
As X goes up, Y goes down. Connect to the minus input.

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

The gain required is

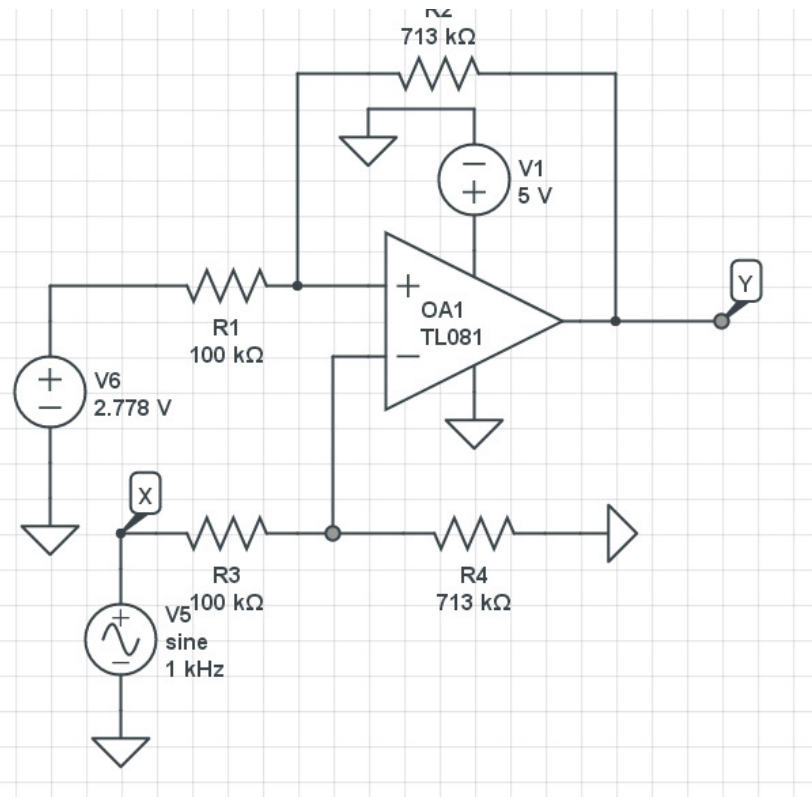
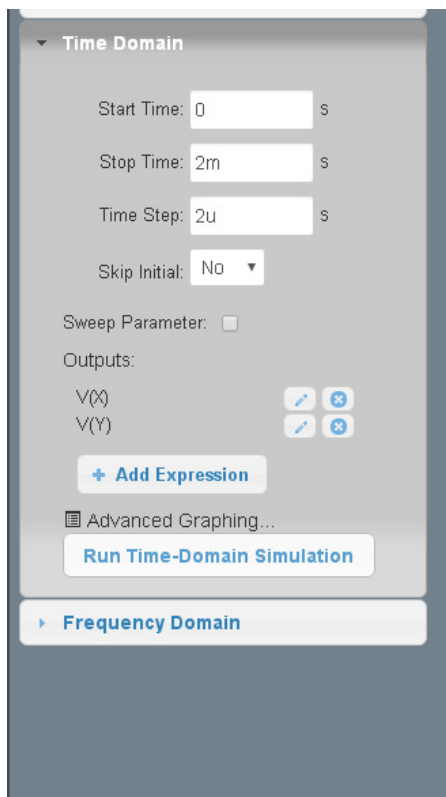
$$gain = \left(\frac{5V - 0V}{3.4797V - 2.7784V} \right) = 7.1296$$

Pick R1 and R2 in a 7.1296 : 1 ratio



Validation

- Sweep temperature and verify that Y switches at 20C and 7C, or
- Sweep R and verify that Y switches at 1250 Ohms and 2321 Ohms, or
- Sweep the voltage at X and verify that Y switches at 2.778V and 3.49V

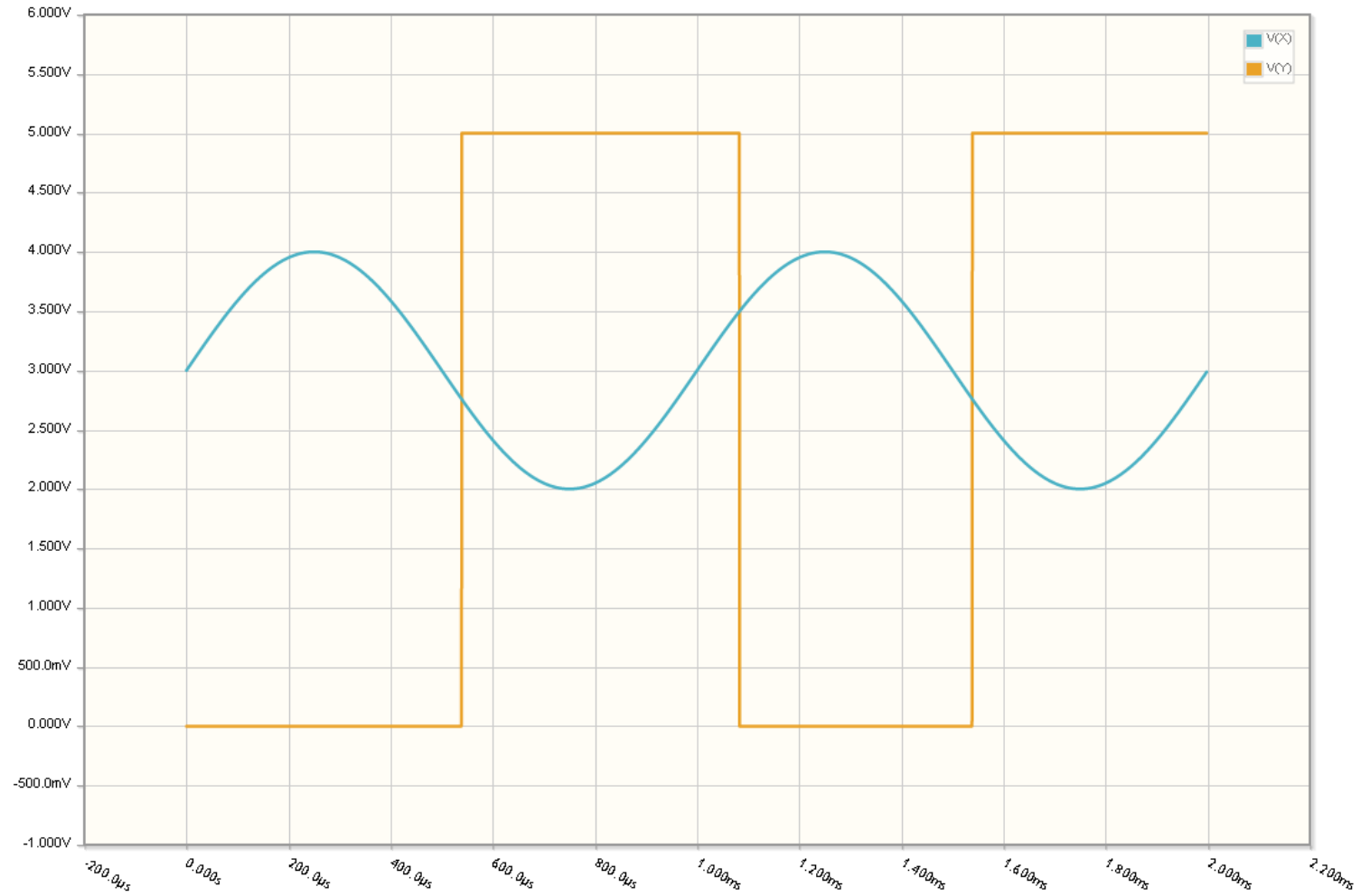


Von

- 2.760V
- 2.778V calc

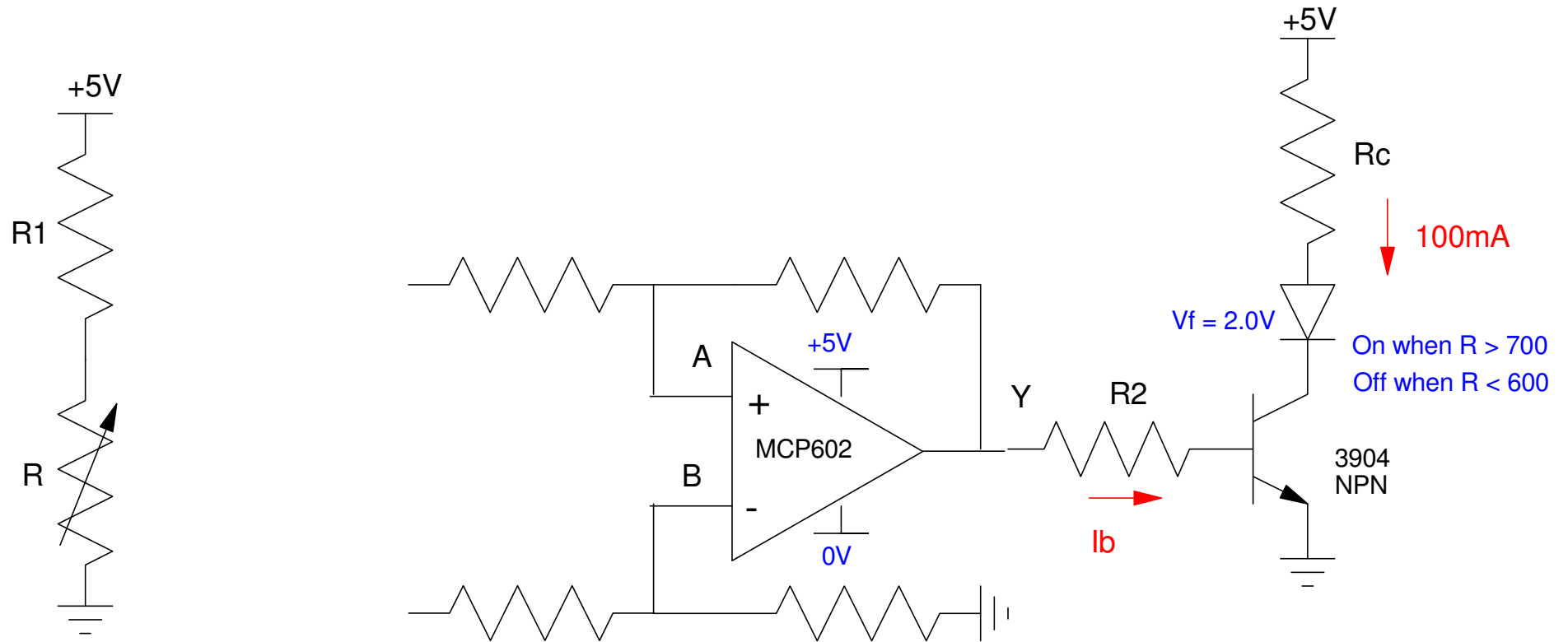
Voff

- 3.514V
- 3.49V calc



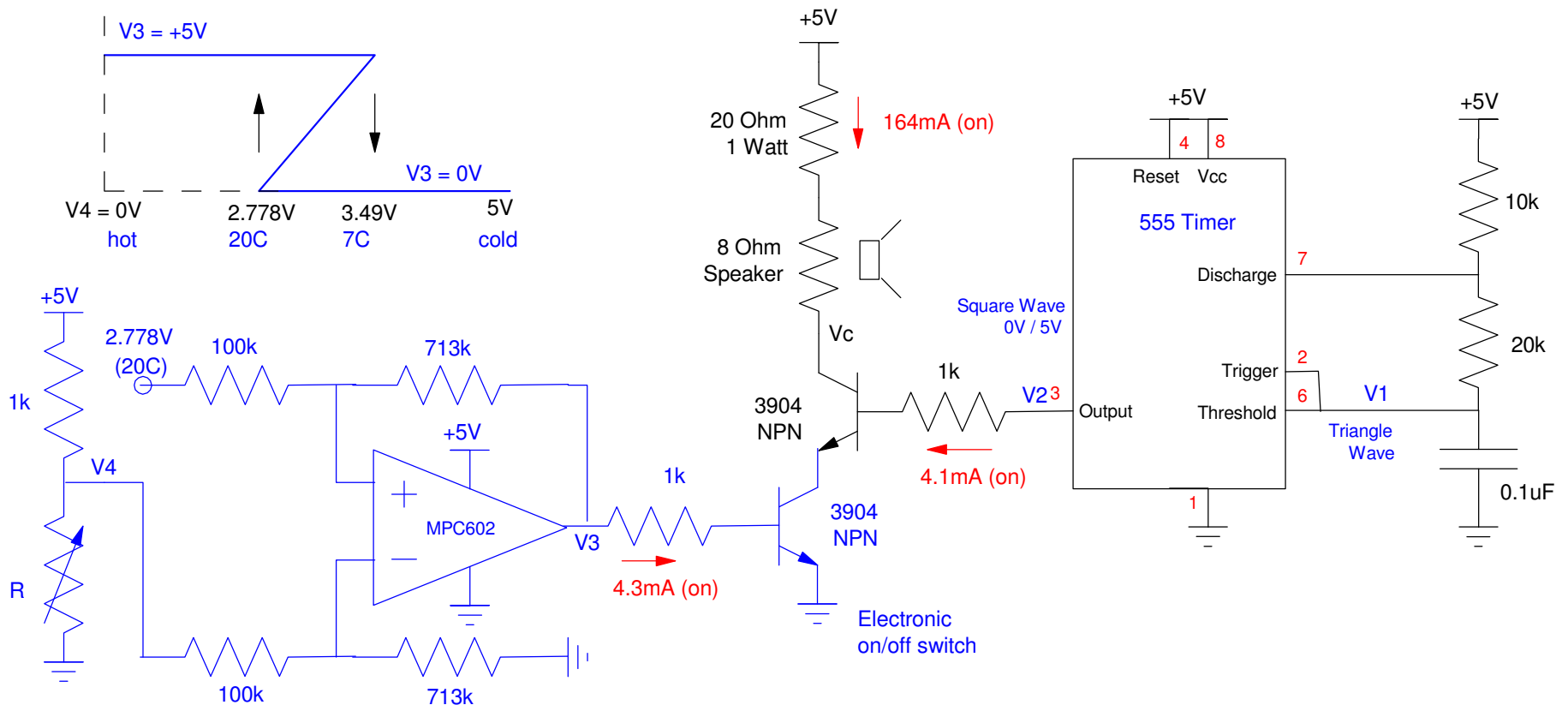
Handout:

- Turn on when $R > 700$
- Turn off when $R < 600$



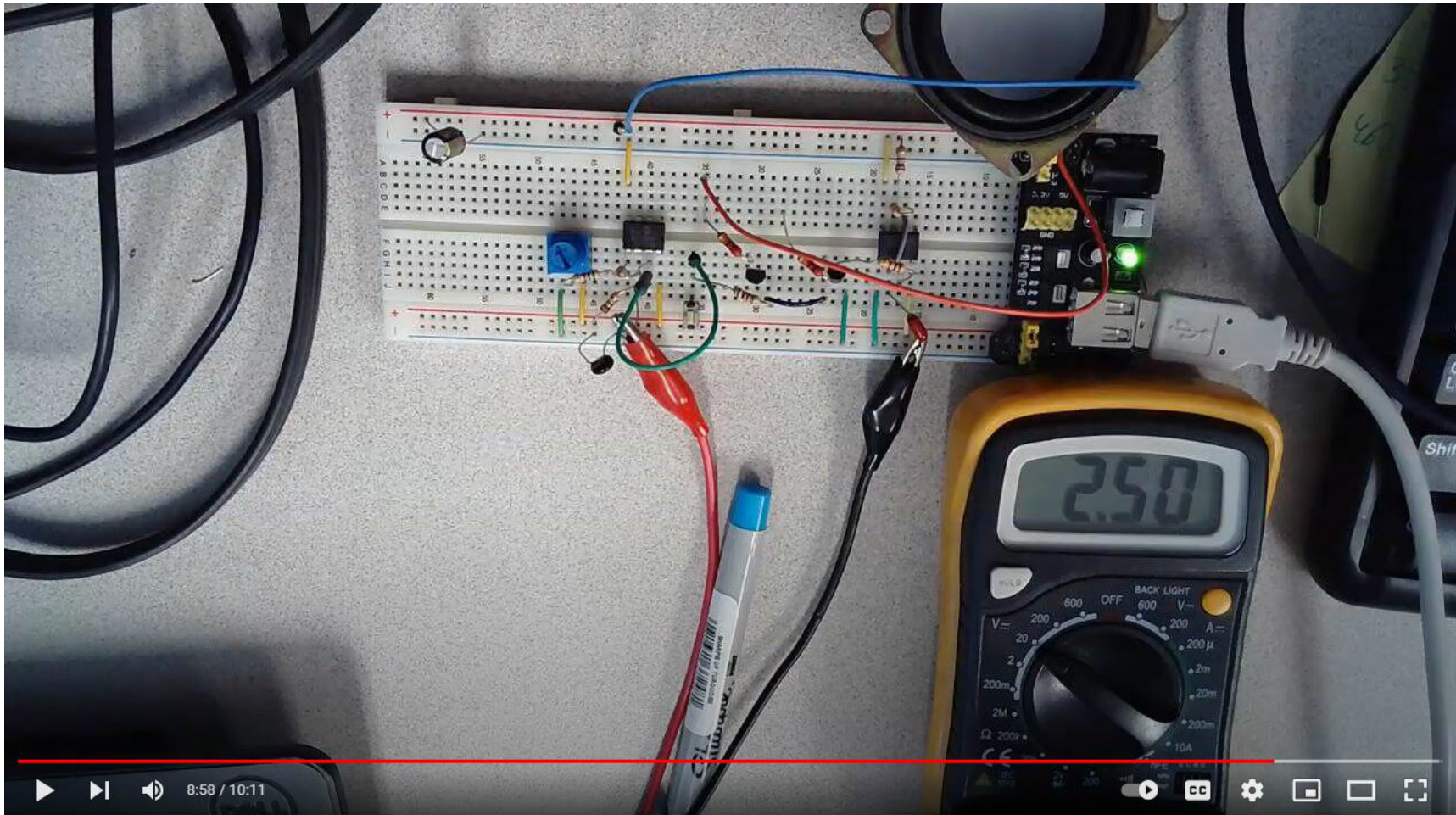
Schmitt Triggers & Temperature Alarm

- Turn on an alarm when the temperature goes above 20C
- Turn off an alarm when the temperature goes below 15C



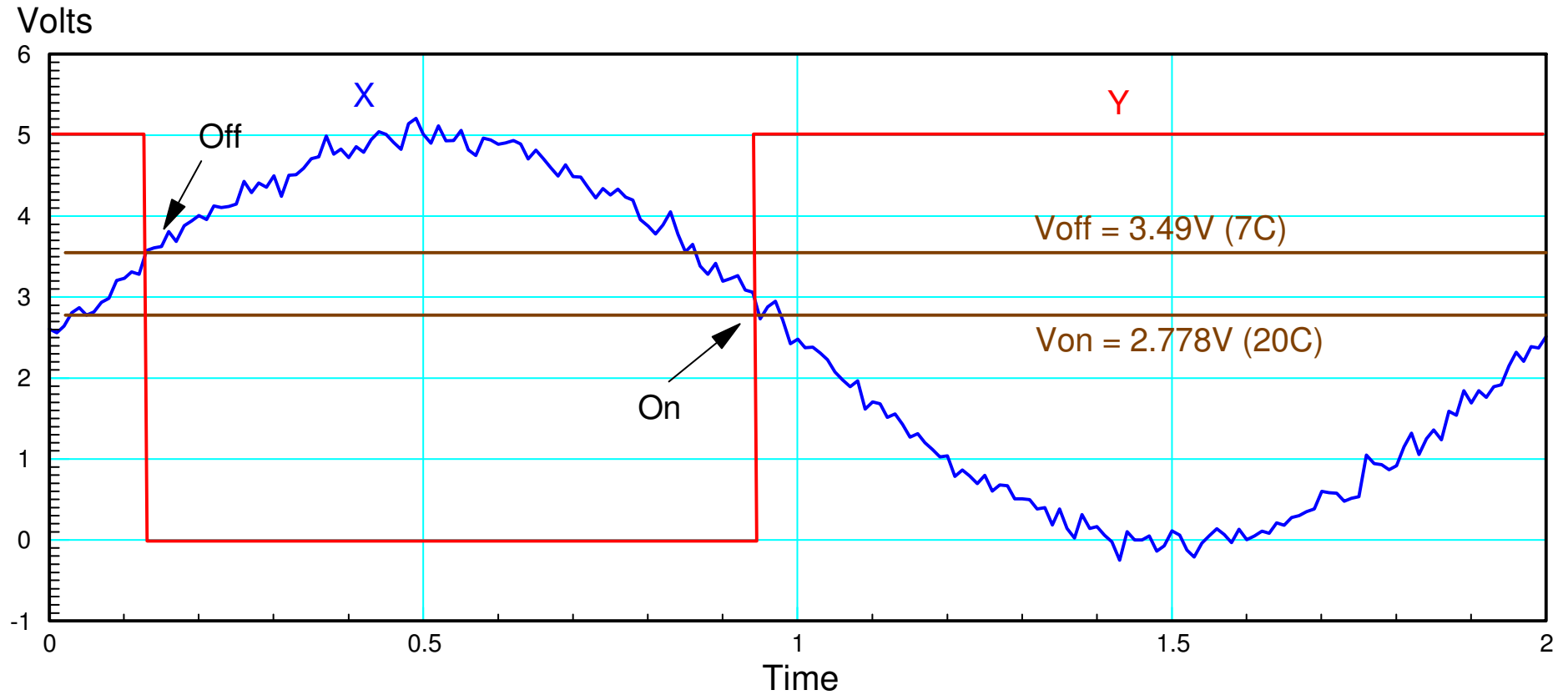
Hardware Example: 8:57 on YouTube video

- <https://youtu.be/mgFDkJY6Lbo>



Schmitt Triggers & Noise

- By making V_{on} different than V_{off} , chatter can be avoided



Summary

If you're using a transistor as a switch, you want the input to be binary:

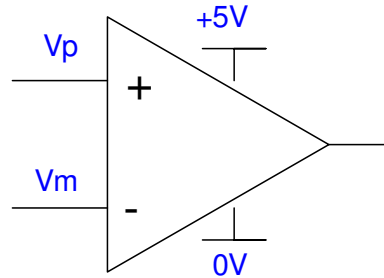
- 0V turns off the transistor
- 5V turns on the transistor

A comparator converts an analog voltage to 0V / 5V

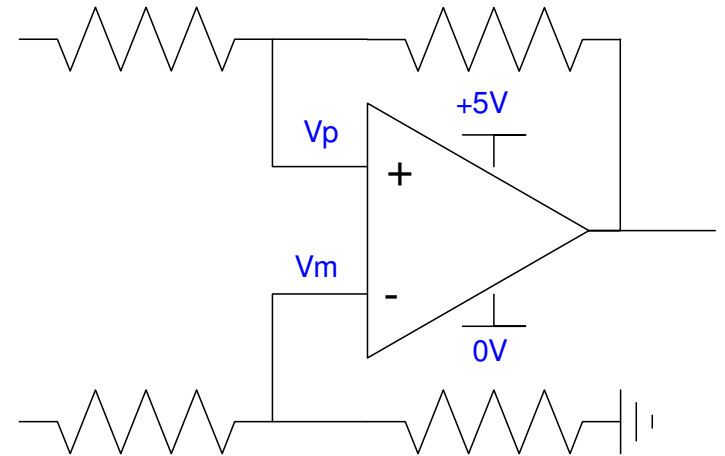
- Can result in chatter

A Schmitt Trigger converts an analog voltage to 0V / 5V

- Slightly more complicated circuit
- Avoids chatter



Comparator (Digital)



Schmitt Trigger (Digital)
