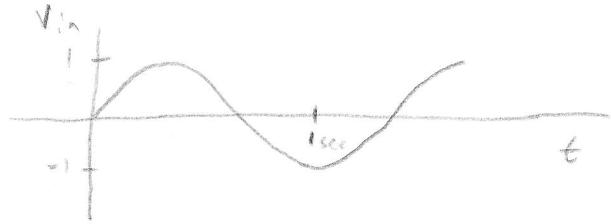
Sketch the time-domain response to

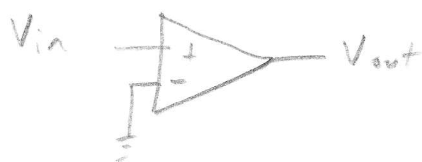
$V_{in}(t) = \sin(2\pi t)$

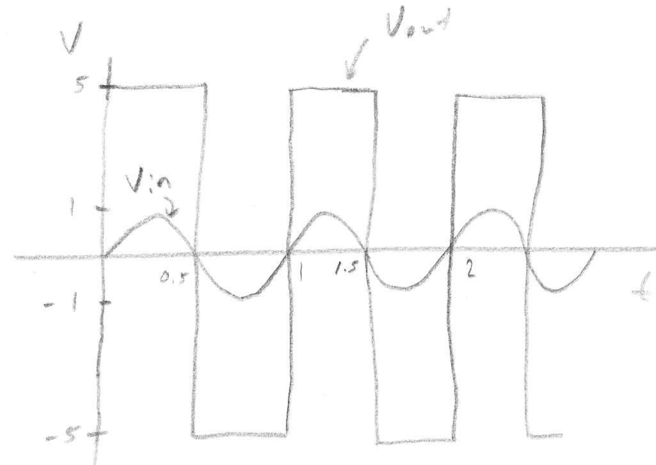
$\omega = 2\pi$

$\therefore f = 1\,Hz$ $\quad V_A = 1V$

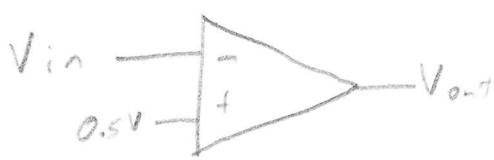


a)

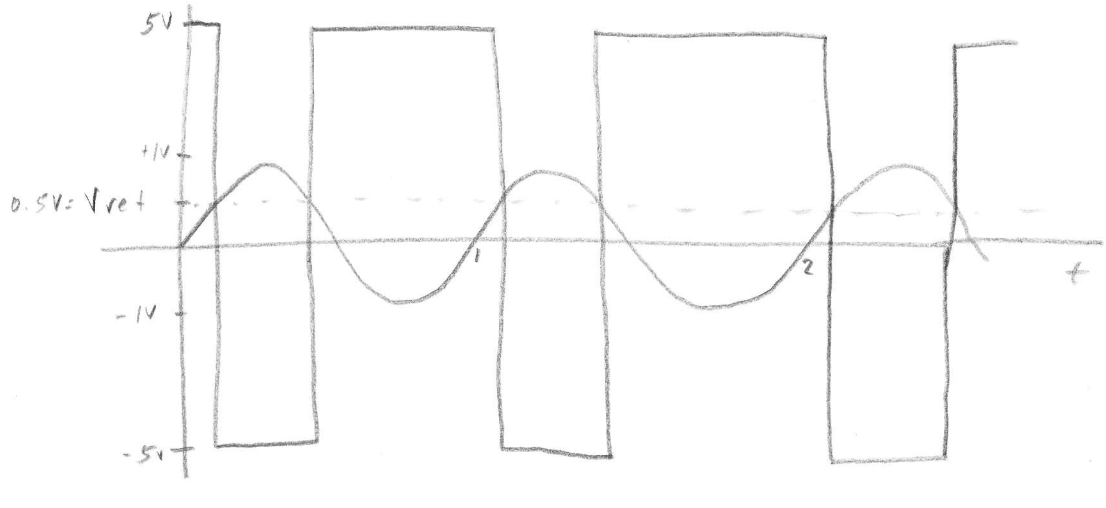




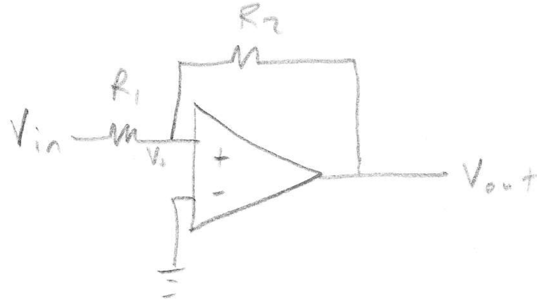
b)



when $V_{in} > 0.5 \Rightarrow V_{out} = -V_{sat}$



c)



$$\frac{V_{in}-V_+}{R_1} + \frac{V_{out}-V_+}{R_2} = 0$$

$$V_{in} = -\frac{R_1}{R_2} V_{out} + \left(1+\frac{R_1}{R_2}\right) V_+$$

$$V_+ = \frac{R_2}{R_1+R_2} V_{in} + \frac{R_1}{R_1+R_2} V_{out}$$

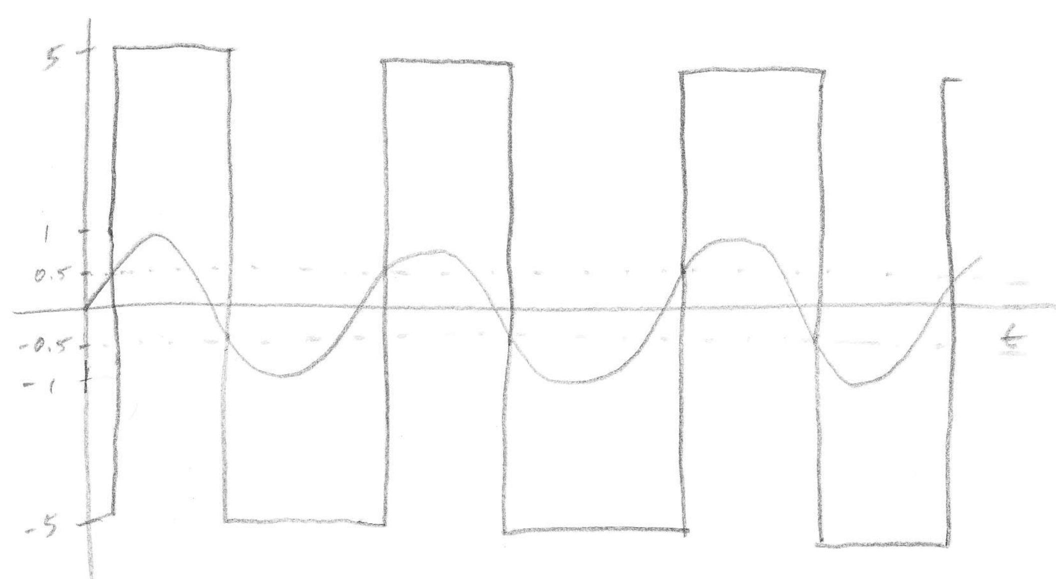
Trip point when $V_+ = V_- = 0V$

And $V_{out} = \pm V_{sat}$

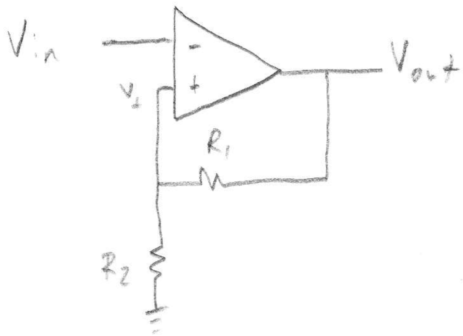
$$V_+ = \frac{R_2}{R_1+R_2} V_{in} \pm \frac{R_1}{R_1+R_2} V_{sat}$$

$$V_{in} = \mp \frac{R_1}{R_2} V_{sat}$$ for the trip points

$$V_{trip} = \mp \frac{R_1}{R_2} V_{sat} = \mp \frac{1k\Omega}{10k\Omega}(5V) = \mp 0.5V$$



d)



$$V_+ = V_{out}\left(\frac{R_2}{R_1+R_2}\right)$$

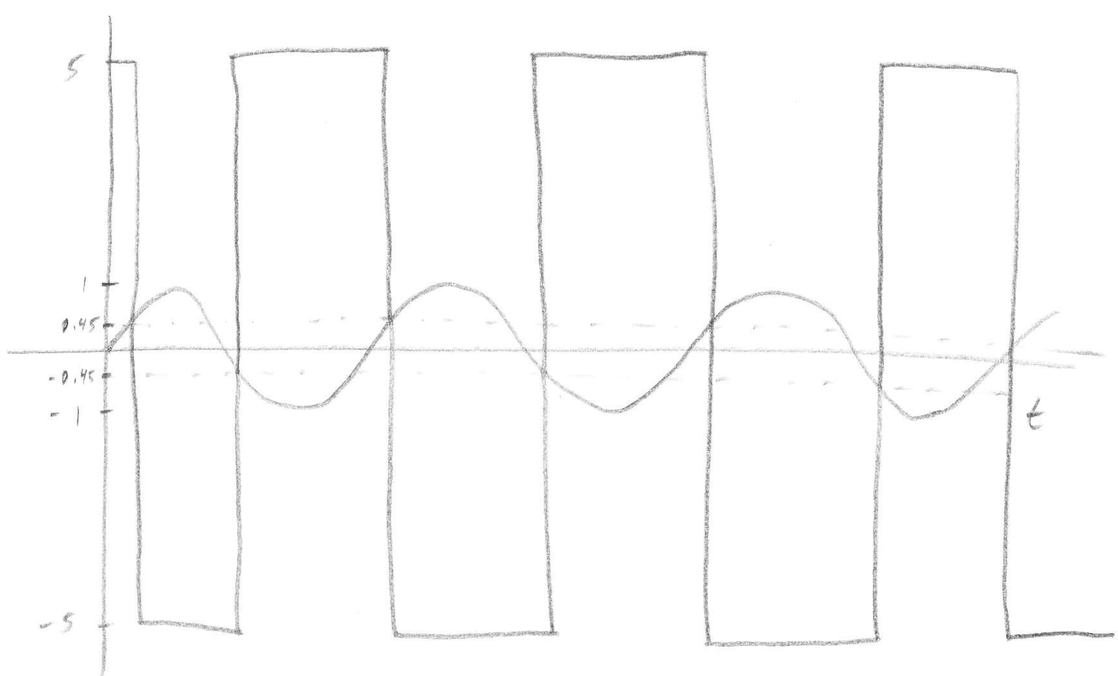
$$V_{out} = \pm V_{sat}$$

$$V_+ = \pm V_{sat}\left(\frac{R_2}{R_1+R_2}\right)$$

$$\therefore V_{trip} = \pm V_{sat}\left(\frac{R_2}{R_1+R_2}\right) =$$

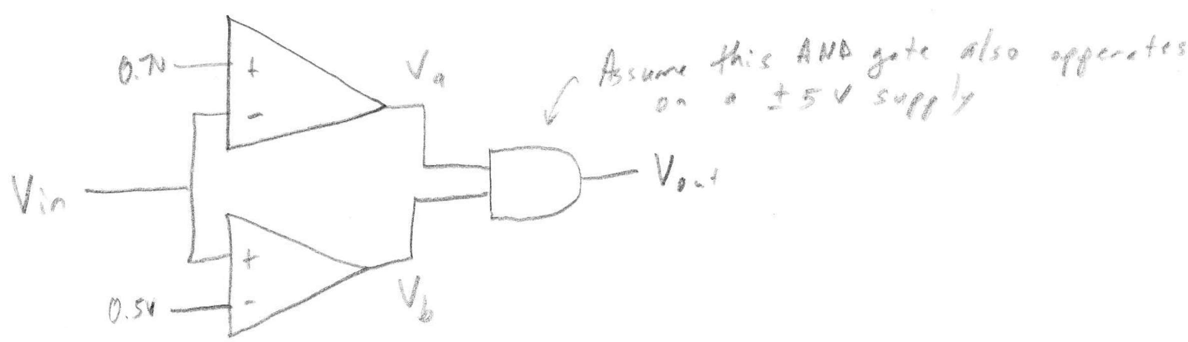
$$= (\pm 5V)\left(\frac{1k\Omega}{10k\Omega+1k\Omega}\right)$$

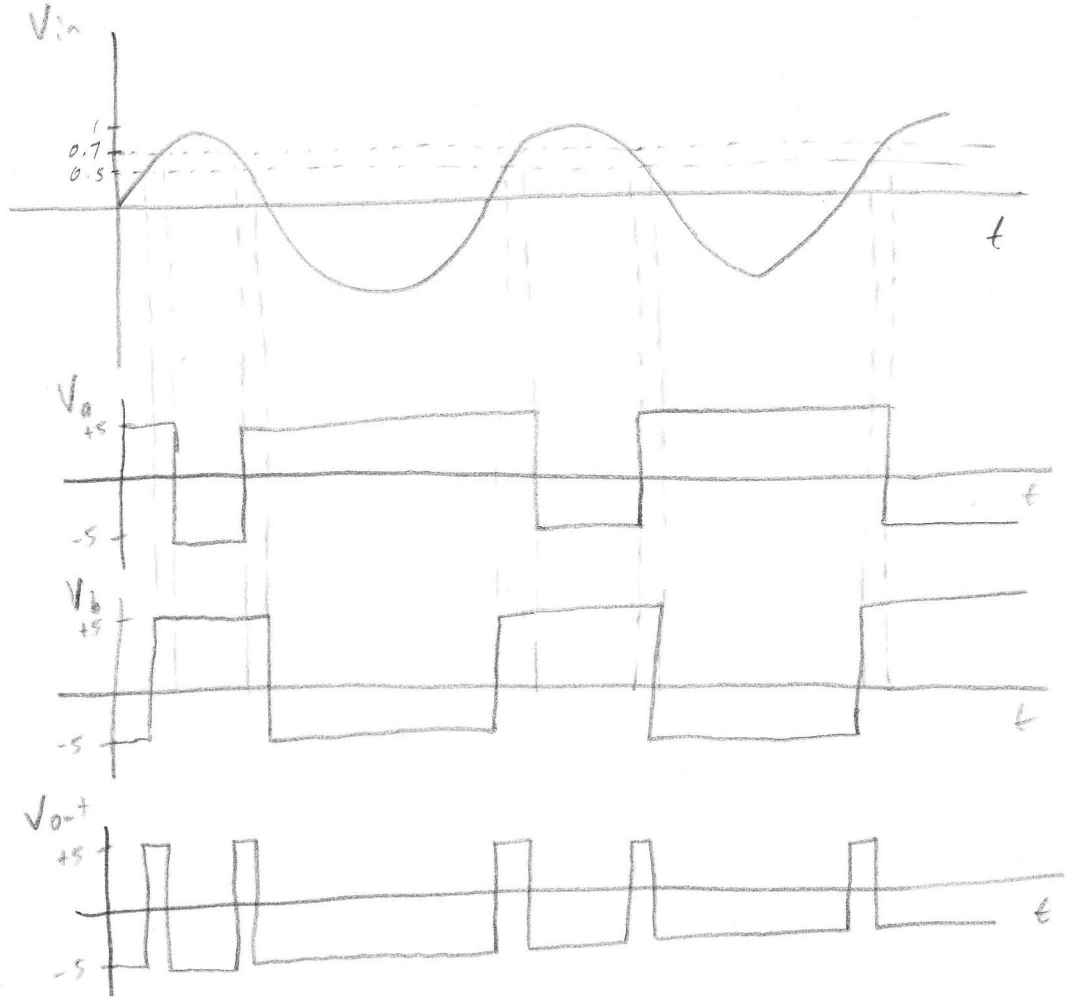
$$= \pm 0.45\ V$$



If $V_{in} > V_+$, then $V_{out} = -V_{sat}$

e)



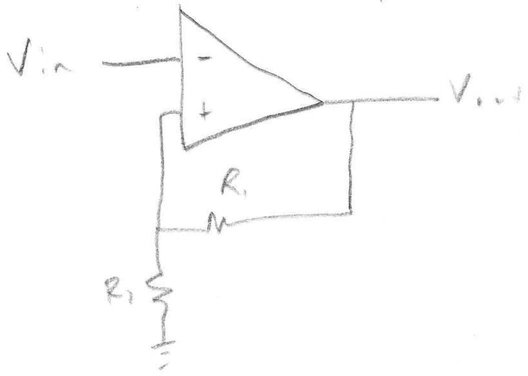


This circuit is called a Window Detector because it only ever outputs a high voltage when the input voltage is within a predefined range of voltages

Design Schmitt Triggers

a) Inverting Operation

Total hysteresis = 10 mV (±5mV) centered on 0V



← Inverting Schmitt Trigger

Need to solve for R_1 and R_2

$$V_{trip} = V_+ = \pm V_{sat} \frac{R_2}{R_1+R_2}$$

$$\therefore +V_{trip} = +V_{sat} \frac{R_2}{R_1+R_2}$$

$$V_{trip}(R_1+R_2) = V_{sat} R_2$$

$$R_1 = \frac{V_{sat}}{V_{trip}} R_2 - R_2$$

$$\therefore R_1 = \frac{5V}{5mV} R_2 - R_2 = 1000R_2 - R_2$$

$$R_1 = 999 R_2$$

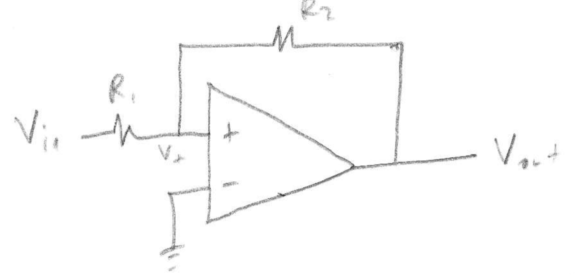
Choose a value for R_2

(it can be any reasonable value)

$$\boxed{\begin{array}{l}\text{Let } R_2 = 100\Omega \\ \text{Then } R_1 = 99.9k\Omega\end{array}}$$

b) Non-inverting Schmitt Trigger

1V total hysteresis ($\pm 0.5V$) centered at 0V



Noninverting configuration

Find values for R_1 and R_2

The output will trip when $V_+ = 0V$

$V_{out} = \pm V_{sat}$

$$\therefore V_{in} = \pm \frac{R_1}{R_2} V_{sat}$$

$$+V_{trip} = + \frac{R_1}{R_2} V_{sat}$$

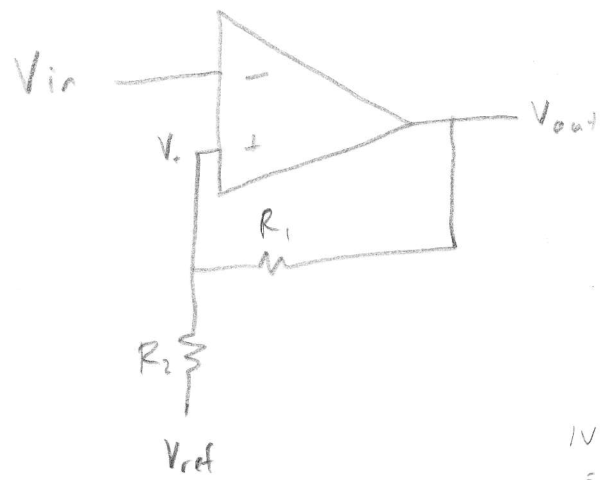
$$\therefore R_1 = \frac{V_{trip}}{V_{sat}} R_2 = \frac{0.5V}{5V} R_2 = 0.1 R_2$$

Choose any reasonable value for R_2

$$\boxed{\begin{array}{l} \text{Let } R_2 = 1k\Omega \\ \text{Then } R_1 = 100\Omega \end{array}}$$

c) Design an inverting Schmitt Trigger with 100mV total hysteresis ($\pm 50mV$) centered around 1V

Inverting Configuration



Find values for R_1, R_2, and V_{ref}

$$V_+ = V_{out}\frac{R_2}{R_1+R_2} + V_{ref}\frac{R_1}{R_1+R_2}$$

$$V_{out} = \pm V_{sat}$$

$$\underset{\substack{1V + 50mV \\ = 1.05V}}{+V_{trip}} = \underbrace{+\underset{5V}{V_{sat}}\frac{R_2}{R_1+R_2}}_{\text{hysteresis portion}} + \underbrace{V_{ref}\frac{R_1}{R_1+R_2}}_{\text{offset}}$$

$$V_{offset} = V_{ref}\frac{R_1}{R_1+R_2} = 1V$$

$$V_{ref} = \left(\frac{R_1+R_2}{R_1}\right)V_{offset}$$

$$\Delta V_{hysteresis} = V_{sat}\frac{R_2}{R_1+R_2} = 50mV$$

$$R_1 = \frac{V_{sat}}{\Delta V_{hysteresis}}R_2 - R_2 = \left(\frac{5V}{50mV}\right)R_2 - R_2$$

$$R_1 = 99R_2$$

Choose $R_2 = 1k\Omega$
Then $R_1 = 99k\Omega$

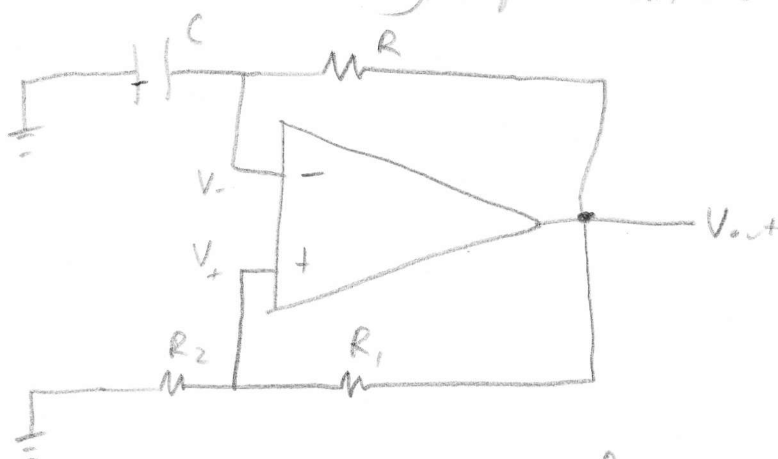
$$\boxed{V_{ref} = \frac{R_1 + R_2}{R_2}V_{offset} = 1.01V}$$

Design a relaxation oscillator with the following specifications

Trip points @ $\pm 1V$

$C = 1\mu F$

$f_o = 10\ Hz$



$V_{out} = \pm V_{sat}$

Trip points when $V_- = V_+ = V_{out} \frac{R_2}{R_1+R_2} = \pm V_{sat} \frac{R_2}{R_1+R_2}$

$$+V_{trip} = +V_{sat} \frac{R_2}{R_1+R_2}$$

$$R_1 + R_2 = \frac{V_{sat}}{V_{trip}} R_2$$

$$R_1 = \frac{V_{sat}}{V_{trip}} R_2 - R_2 = \left(\frac{5V}{1V}\right) R_2 - R_2 = 4R_2$$

$$\boxed{\begin{array}{ll} \text{Choose} & R_2 = 1k\Omega \\ \text{Then} & R_1 = 4k\Omega \end{array}}$$

$$f_o = \frac{1}{2RC \ln\left(1 + \frac{2R_2}{R_1}\right)}$$

$$R = \frac{1}{2 f_o C \ln\left(1 + \frac{2R_2}{R_1}\right)} = \frac{1}{(2)(10Hz)(1\mu F)\ln(1.5)}$$

$$\boxed{R = 123.32\ k\Omega}$$