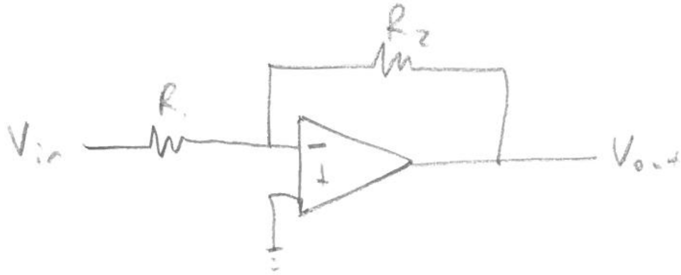


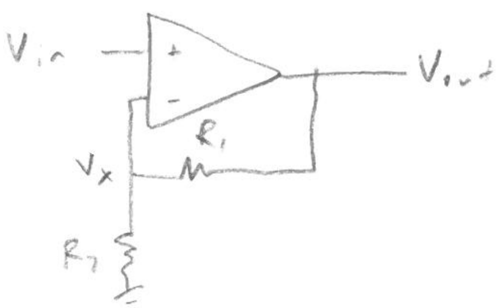
KCL

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

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

If $R_1 = 10k\Omega$
$R_2 = 1k\Omega$

$$\frac{V_{out}}{V_{in}} = -\frac{1k\Omega}{10k\Omega} = -\frac{1}{10} = -0.1$$



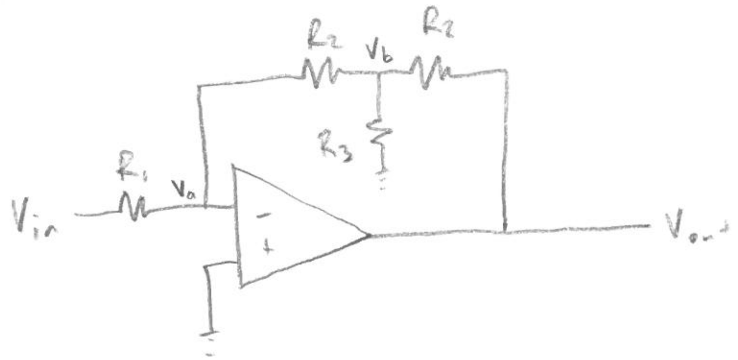
$$V_x = V_{out}\frac{R_2}{R_1+R_2}$$

Negative Feedback $\Rightarrow V_{in} = V_x$

$$\frac{V_{out}}{V_{in}} = \frac{R_1 + R_2}{R_2} = 1 + \frac{R_1}{R_2}$$

If $R_1 = 10k\Omega$
$R_2 = 1k\Omega$

$$\frac{V_{out}}{V_{in}} = 1 + \frac{10k\Omega}{1k\Omega} = 11$$



Negative Feedback $\Rightarrow V_a = 0$

$$V_b = V_{out} \frac{R_2 // R_3}{R_2 + R_2 // R_3}$$

KCL @ V_a

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

$$\frac{V_b}{V_{in}} = -\frac{R_2}{R_1}$$

$$\frac{V_{out}}{V_{in}} \frac{R_2 // R_3}{R_2 + R_2 // R_3} = -\frac{R_2}{R_1}$$

$$\frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1}\left(\frac{R_2 + R_2 // R_3}{R_2 // R_3}\right) = -\frac{R_2}{R_1}\left(1 + \frac{R_2}{R_2 // R_3}\right)$$

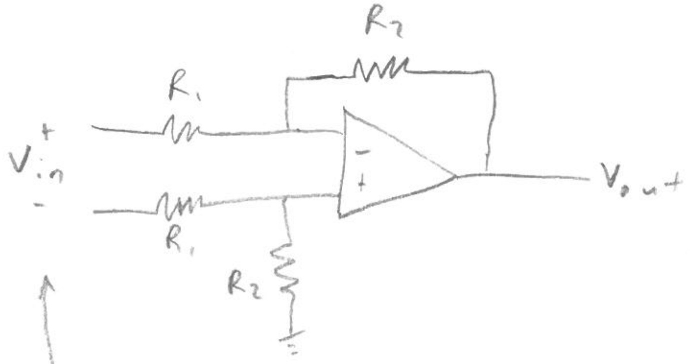
$$\frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1}\left(1 + \frac{R_2}{\frac{R_2 R_3}{R_2 + R_3}}\right) = -\frac{R_2}{R_1}\left(1 + \frac{R_2 + R_3}{R_3}\right)$$

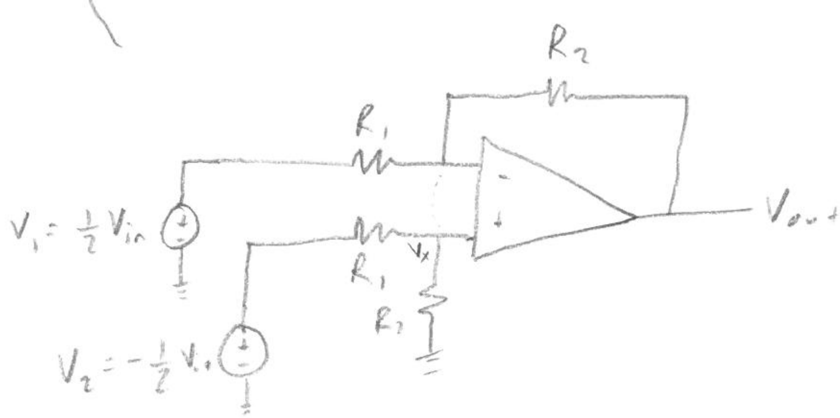
$$\frac{V_{out}}{V_{in}} = \frac{-R_2}{R_1}\left(2 + \frac{R_2}{R_3}\right)$$

If $R_1 = 1k\Omega$, $R_2 = 10k\Omega$, $R_3 = 100\Omega$

$$\frac{V_{out}}{V_{in}} = -1020$$

Note - This "T-configuration" provides more gain than a simple inverting amplifier for smaller total resistance values (assuming R_{in} is fixed)





$$V_x = V_2 \frac{R_2}{R_1 + R_2}$$

$$\text{KCL} \Rightarrow \quad \frac{V_1 - V_x}{R_1} + \frac{V_{out} - V_x}{R_2} = 0$$

$$V_{out} = -\frac{R_2}{R_1} V_1 + \left(1 + \frac{R_2}{R_1}\right) V_x$$

$$V_{out} = -\frac{R_2}{R_1} V_1 + \frac{R_2}{R_1} V_2 = -\frac{R_2}{R_1} \left(V_1 - V_2\right)$$

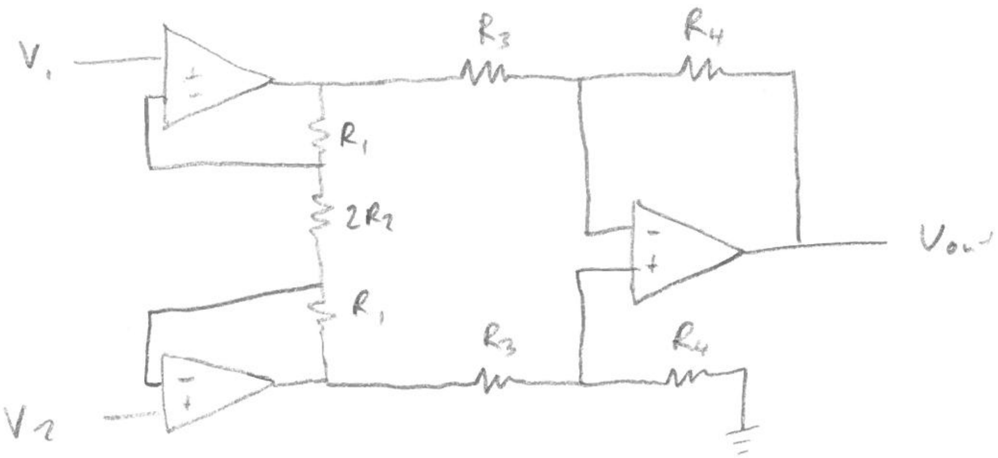
$$V_1 - V_2 = \frac{1}{2} V_{in} - \left(\frac{-1}{2}\right) V_{in} = V_{in}$$

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

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

If $R_1 = 1 k\Omega$, $R_2 = 10 k\Omega$

$$\frac{V_{out}}{V_{in}} = \frac{-10 k\Omega}{1 k\Omega} = -10$$



Instrumentation Amplifier

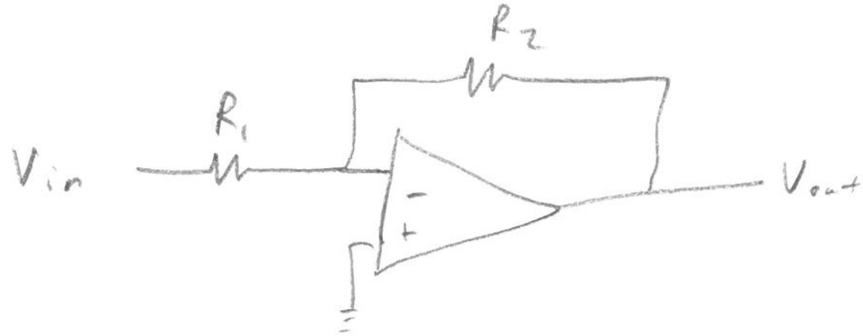
$$\frac{V_{out}}{V_1 - V_2} = \left(-\frac{R_4}{R_3}\right)\left(1 + \frac{R_1}{R_2}\right)$$

If $R_1 = 1k\Omega$, $R_2 = 100\Omega$, $R_3 = 100\Omega$, $R_4 = 1k\Omega$

$$\frac{V_{out}}{V_1 - V_2} = 110$$

Design an amplifier with $R_{in} = 50\Omega$ and $|Gain| = 1000$

The inverting amplifier permits setting a specific input impedance



$$\frac{V_{out}}{V_{in}} =$$

$R_{in} = R_1$

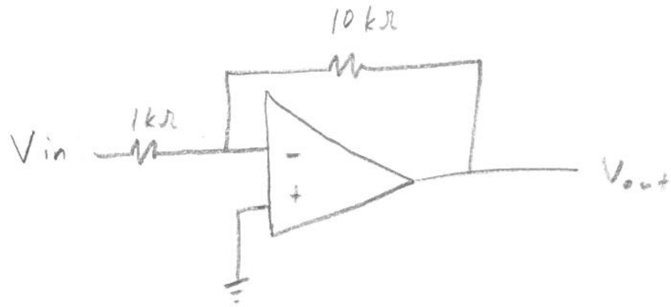
Let $R_1 = 50\Omega$

$$R_2 = -R_1\left(\frac{V_{out}}{V_{in}}\right) = (-50\Omega)(-1000) = 50k\Omega$$

Summary

$R_1 = 50\Omega$

$R_2 = 50k\Omega$



$$\frac{V_{out}}{V_{in}} = \frac{-10k\Omega}{1k\Omega} = -10 \Rightarrow \text{Gain}$$

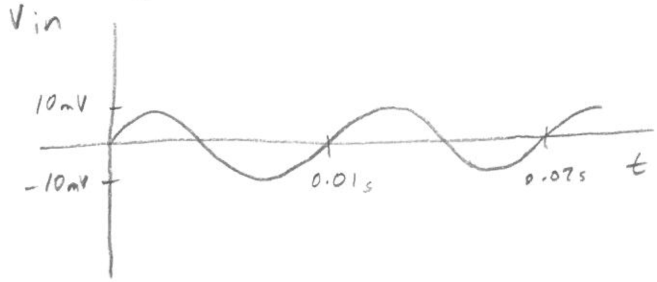
$$V_{in} = (10mV)\sin\left(2\pi(100Hz)t\right)$$

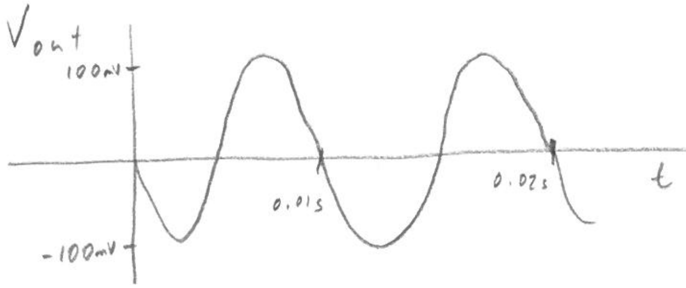
$$\omega = (2\pi)(100Hz)$$

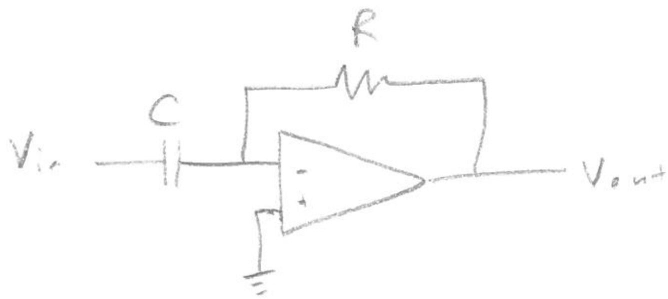
$$f = 100Hz$$

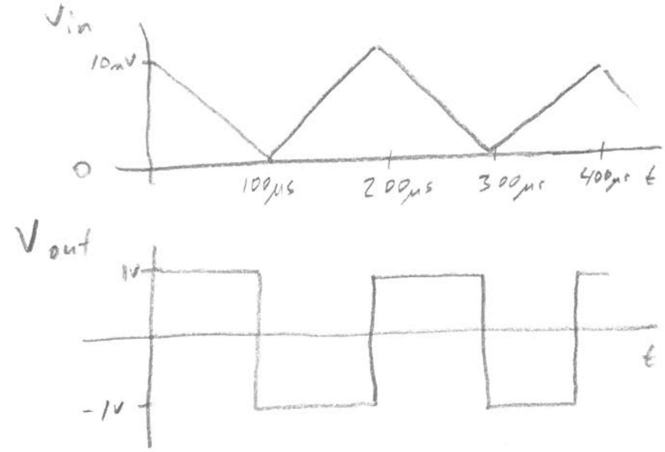
$$\frac{1}{f} = T = \frac{1}{100Hz} = 0.01\,s$$

period of the input signal









Let $C = 10\mu F$ Find R

This is a differentiator circuit

KCL

$$C\frac{dV_{in}}{dt} + \frac{V_{out}}{R} = 0$$

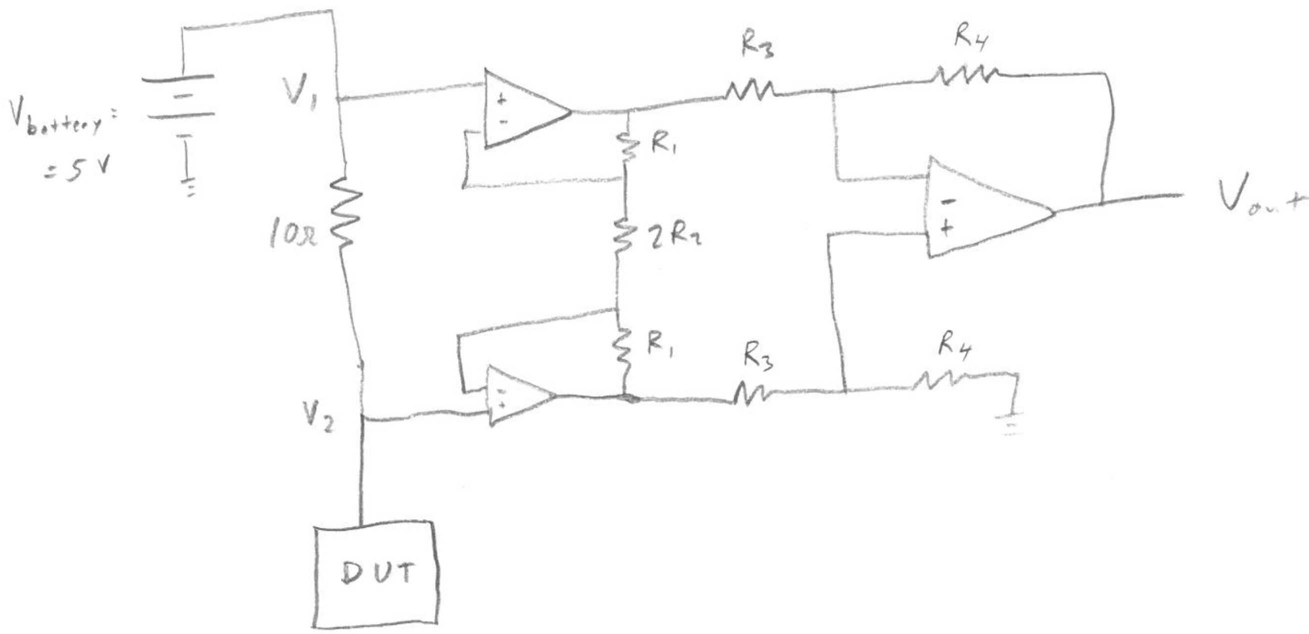
$$V_{out} = -RC\frac{dV_{in}}{dt}$$

This circuit finds the negative of the slope

slope = $\frac{rise}{run}$ and slope must equal ± 1

$$V_{out} = 1V = -RC\frac{-10mV}{100\mu S}$$

$$R = \frac{-1V}{C}\left(\frac{-100\mu S}{10mV}\right) = \boxed{1k\Omega}$$



Let $R_1 = 100k\Omega$, $R_2 = 100\Omega$, $R_3 = 1k\Omega$, $R_4 = 100k\Omega$

$V_{out} = -1V$

Determine how much current flows through the 10Ω resistor?

This is an instrumentation amplifier, so

$$V_{out} = -\left(\frac{R_4}{R_3}\right)\left(1 + \frac{R_1}{R_2}\right)(V_1 - V_2)$$

$V_1 - V_2$ is the voltage drop across the 10Ω resistor

$$V_1 - V_2 = \frac{V_{out}}{-\left(\frac{R_4}{R_3}\right)\left(1 + \frac{R_1}{R_2}\right)} = 9.99\mu V$$

$V = IR$

$$\therefore I = \frac{V_1 - V_2}{R} = \frac{9.99\mu V}{10\Omega} = \boxed{999\, nA}$$