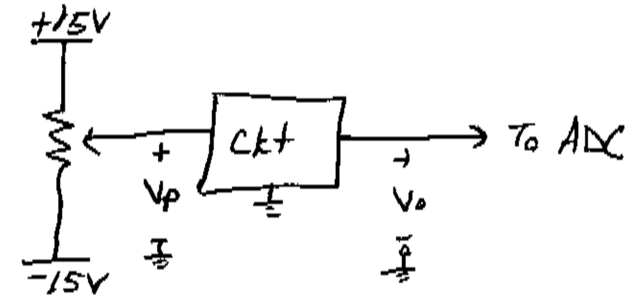
ENGR 210 HW 9 Solutions Spring '05

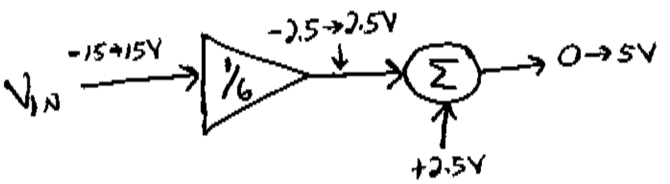
#1 Leg position sensor for Biorobot



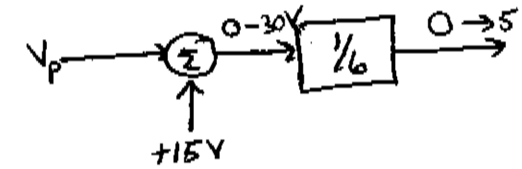

$V_o$ needs to be $0 \rightarrow 5V$

$V_{in} = V_p = (-15 \rightarrow 15)V$

We need to <u>scale</u> as well as <u>shift</u>.

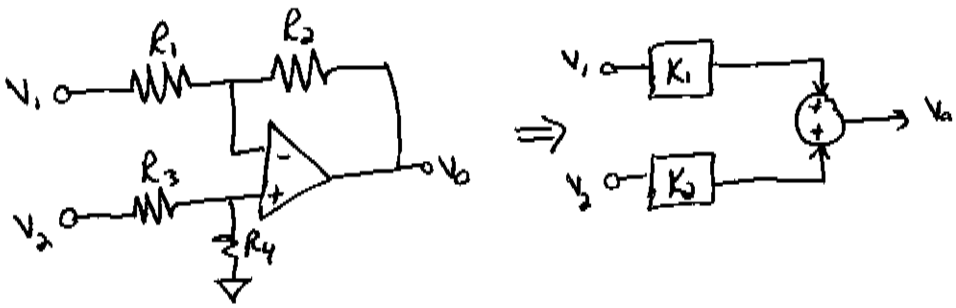



OR




Either design (as well as others) will work.

Let's use a Subtractor circuit.




$K_1 = -\frac{R_2}{R_1}$

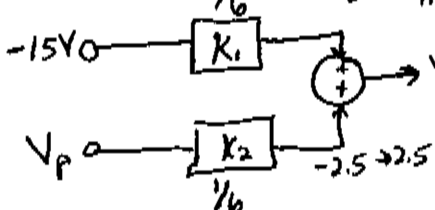
$K_2 = \left(\frac{R_1+R_2}{R_1}\right)\left(\frac{R_4}{R_3+R_4}\right)$

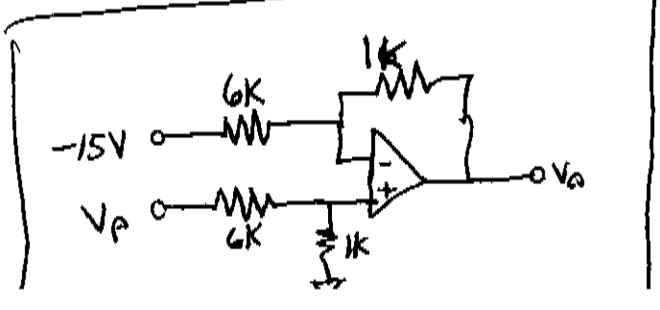
Since $K_2$ doesn't invert input let's put $V_p$ on this node.

Choose $|K_1| = |K_2| = 1/6$ for ease

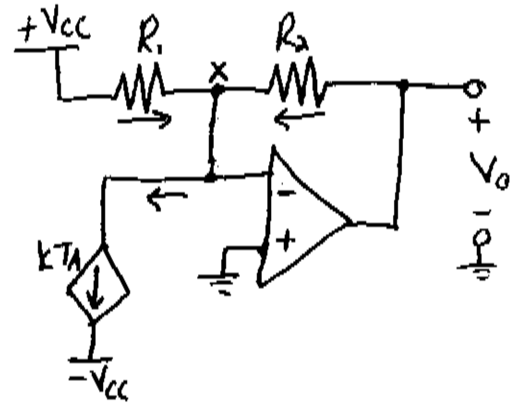
$$\boxed{\frac{R_2}{R_1} = \frac{1}{6} \quad \frac{R_4}{R_3} = \frac{1}{6}}$$

if this node is to be +2.5V input must be -15V



## #2 Temperature Sensor




$k = 1\frac{\mu A}{K}$

$V_{cc} = 10V$

$\frac{dV_o}{dT} = 100\frac{mV}{°C}$

KCL @ x

$$\frac{V_{cc} - 0}{R_1} + \frac{V_o - 0}{R_2} = kT_A$$

$$V_o = R_2\left\{kT_A - \frac{V_{cc}}{R_1}\right\}$$

$$\text{sensitivity} = \frac{dV_o}{dT} = R_2 k = 100\frac{mV}{°C}$$

$$R_2 = \frac{100\,mV/K}{1\frac{\mu A}{K}} = \underline{\underline{100k\Omega}}$$

We also want $V_o$ to be proportional to °C (not K) so we need to have an offset.

We want $V_o = 0$ if $T_A = 273$

$$0 = R_2 kT_A - \frac{R_2}{R_1}V_{cc} = (100k)\left(1\frac{\mu A}{K}\right)(273K) - \frac{100k}{R_1}(10)$$

$$R_1 = \frac{(\cancel{100}k)(10)}{(\cancel{100}k)\left(1\frac{\mu A}{K}\right)(273K)}$$

$\boxed{R_1 = 36.6k\Omega}$ $\boxed{R_2 = 100k\Omega}$

## #3

$V = 5 \quad t = 5ms$

$V = 3.5 \quad t = 7ms$

$V = V_A e^{-t/\tau}$ ← General Exponential Waveform.

a)

① $5 = V_A e^{-5m/\tau}$

② $3.5 = V_A e^{-7m/\tau}$

$$\frac{①}{②} = \frac{5}{3.5} = e^{2m/\tau}$$

$$\ln(5/3.5) = \frac{2m}{\tau}$$

$$\tau = \frac{2m}{\ln(5/3.5)} \quad \boxed{\tau = 5.6ms}$$

Plug into eqn ① or ② to find $V_A$. $\quad 5 = V_A e^{-5m/5.6m}$ $\quad \boxed{V_A = 12.2V}$

Plug values into general eqv. and solve.

b) $V = 12.2\,e^{-2m/5.6m}$

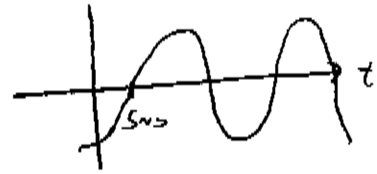
$\boxed{V = 8.54V}$

#4

$f = 100\text{kHz}$

$A = 75\text{V}$

$v(t) = A\cos(2\pi f(t - T_s))$ ← General form of a cosine.




$v(t) = 75\cos(2\pi(100k)(t - T_s))$

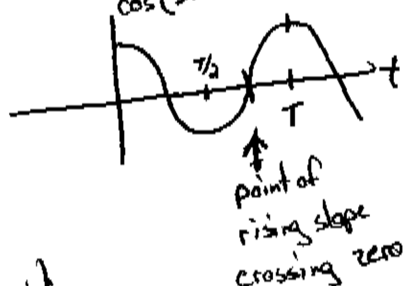
$\cos(a+b) = \cos a \cos b - \sin a \sin b$

$v(t) = 75\left[\cos(2\pi 100k\, t)\cos(2\pi 100k(-T_s)) - \sin(2\pi 100k t)\sin(2\pi 100k(-T_s))\right]$

$v(t) = a\cos(2\pi f t) + b \sin(2\pi f t)$

Fourier Coefficients
$$\begin{cases} a = 75\cos(2\pi 100k(-T_s)) \\ b = -75\sin(2\pi 100k(-T_s)) \end{cases}$$

$\cos(2\pi f t)$ ← No Time Shift




What is $T_s$?

$T = 1/f = \frac{1}{100k} = 10\mu s$

$\boxed{T_s = -2.5\mu s}$ if waveform is shifted left by 2.5μs then the zero crossing with positive slope would be at 5μs.

$$\boxed{\begin{aligned} a &= 75\cos(\pi/2) = 0 \\ b &= -75(\sin(\pi/2)) = -75 \end{aligned}}$$

What about phase angle?

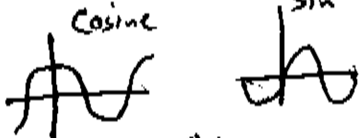
$v(t) = A\cos(2\pi f t + \phi)$ Another way to write general cosine eqn.

$\phi = -2\pi f T_s = -2\pi(100k)(-2.5\mu s)$

$\boxed{\phi = \pi/2}$

All of the above assumed we were dealing with a cosine wave. Using a sine wave would affect $T_s$ and $\phi$ but will not affect the fourier coefficients.

Cosine Sin

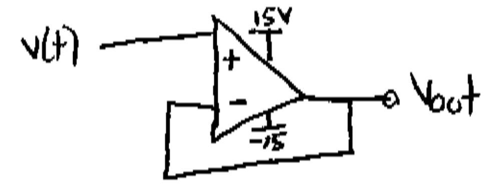


shift by $+\frac{\pi}{2}$

$\Rightarrow$ For Sin wave

$$\boxed{\begin{aligned} &\phi = \pi \\ &T_s = 5\mu s \text{ or } -5\mu s \end{aligned}}$$

Voltage Follower




Buffer $V_{out} = V(t)$

#5 $v(t) = V_0 + 10\cos(200\pi t)$

$V_{cc} = \pm 15V$

$|V_{OUT}|_{max} = 15V$

$|v(t) = |V_0| + |10\cos(200\pi t)|$

$|v(t)| = V_0 + 10$

$V_{0_{max}} = +5 \rightarrow V_{out} = 15$

$V_{0_{min}} = -25 \rightarrow V_{out} = -15$

$$\boxed{-5 \le V_0 \le +5}$$