Electronic Instrumentation

Re exam 15/2/2011

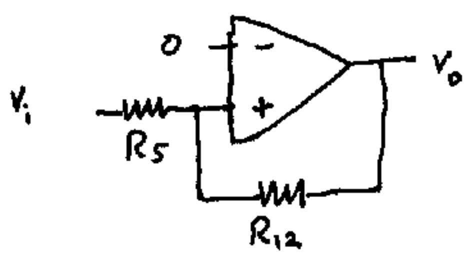
Question 1 see lecture notes

Question 2 a) $A = \infty \Rightarrow V_p = V_n$ or saturation

$r_{in} = \infty$

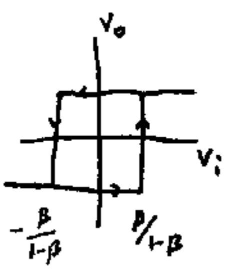
$r_{out} = 0$

b) The left opamp is configured as a comparator with hysteresis, (positive feedback)



$R_{12} = R_1 + R_2$

$\beta = \dfrac{R_5}{R_5 + R_{12}}$



$V_o = -V_{cc}$, $\quad V_p = -V_{cc}\,\beta + V_i(1-\beta)$

commutation : $V_p = V_n = 0 \Rightarrow -\beta V_{cc} + V_i(1-\beta) = 0$

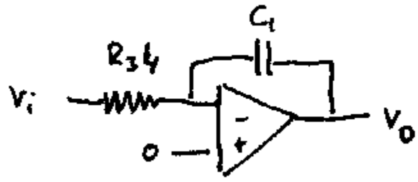
$\Rightarrow V_i = \dfrac{\beta}{1-\beta} V_{cc}$

$V_o = +V_{cc}$, $\quad V_p = +V_{cc}\,\beta + V_i(1-\beta)$

commutation : $V_p = V_n = 0 \Rightarrow \beta V_{cc} + V_i(1-\beta) = 0$

$\Rightarrow V_i = -\dfrac{\beta}{1-\beta} V_{cc}$

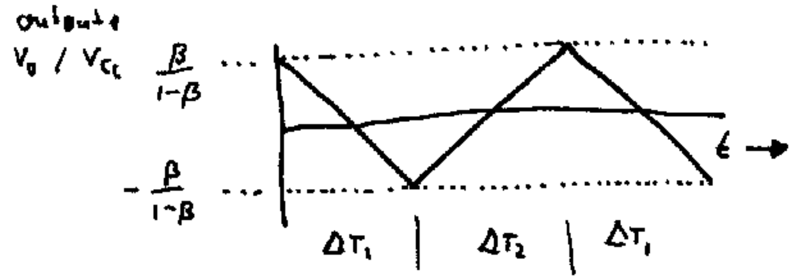
The right opamp is configured as an ~~comparator~~ integrator, see lecture notes



$V_o = -\dfrac{1}{R_{34}C_1}\int V_i(t)\,dt + V_{o\phi}$

Combining the two circuits results in an oscillator

Imagine output z is high $(+V_{cc})$.



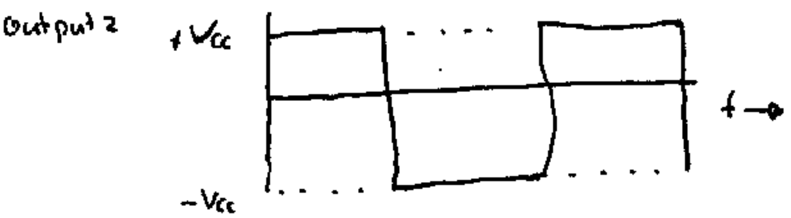
amplitude $= \frac{\beta}{1-\beta} V_{cc}$

$$= \frac{\frac{R_5}{R_5+R_{12}}}{\frac{R_5+R_{12}-R_5}{R_5+R_{12}}} V_{cc} = \frac{R_5}{R_{12}} V_{cc}$$

$$\Delta T_1 : \; V_0 = \frac{\beta}{1-\beta} V_{cc} - \frac{V_{cc}}{R_{34} C_1} t = -\frac{\beta}{1-\beta} V_{cc}$$

$$\Delta T_1 = \Delta T_2 \Rightarrow t = \frac{2 R_5}{R_{12}} \times R_{34} C_1$$

$\Delta T_1 + \Delta T_2 = \Delta T = \frac{4 R_5}{R_{12}} \times R_{34} C_1$



c) 1V and 1 kHz : example

$R_5 = 10\ k\Omega$, $V_{cc} = 10\ V$

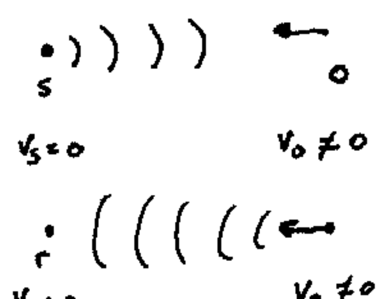
$R_1 = 10\ k\Omega$, $R_2 = 90\ k\Omega$

$C_1 = 1\ yF$, $R_{34} = 2.5\ k\Omega$

$(R_4 = 2.2\ k\Omega$, $R_3 = 0.3\ k\Omega)$

Question 3 See lecture notes (it is for removing offset)

Question 4 similar to example in lecture notes.



$$f_0 = \left(\frac{v+v_0}{v}\right) f_s$$

reflected $f_s' = f_0$

$$f_r = \left(\frac{v}{v-v_0}\right) f_s' = \left(\frac{v+v_0}{v-v_0}\right) f_s$$

$$\approx \left(\frac{v+2v_0}{v}\right) f_s = \left(1 + 2\frac{v_0}{v}\right) f_s$$

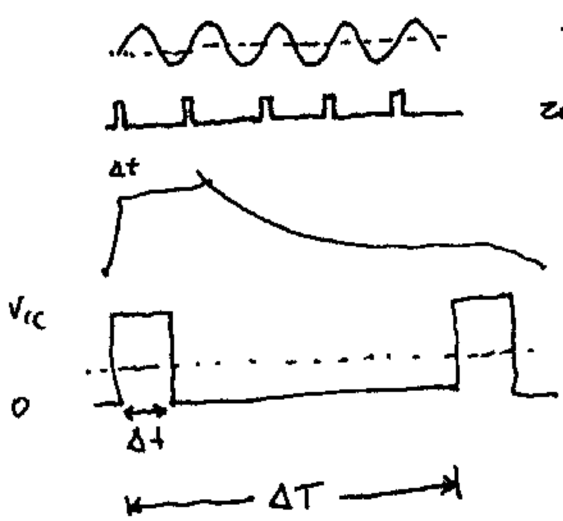
$v = 300 \text{ m/s}$, $f_s = 40 \text{ kHz}$

$$f_r - f_s = \left(1 + 2\frac{v_0}{v}\right) f_s - f_s = \frac{2 v_0}{v} f_s < 10 \text{ Hz}$$

$$v_0 < \frac{(10 \text{ Hz}) \times v}{2 f_s}$$

$$< \frac{(10 \text{ Hz}) \times (300 \text{ m/s})}{2 \times (40 \text{ kHz})} = 3{,}75 \text{ cm/s}$$

- Frequency can be converted into voltage by a PLL (phase-locked loop) or by a NE555 pulse generator



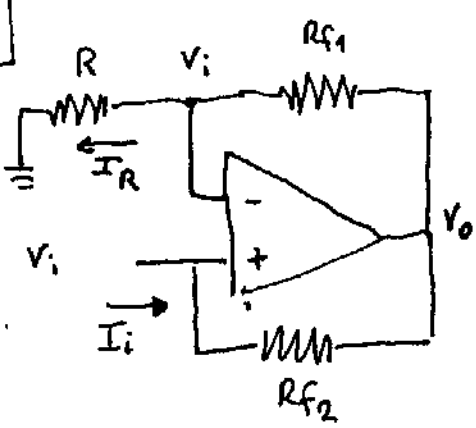
zero crossing detector (comparator) fed into fixed-width pulse Δt.

$$\Delta T = \frac{1}{f}$$

RC (low pass) filter. Average:

$$V(f) = V_{cc} \frac{\Delta t}{\Delta T} = \Delta t \, V_{cc} \, f$$

Question 5

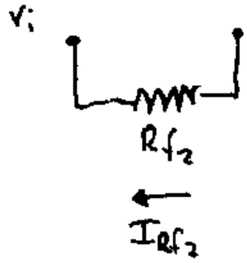


$$v_p = v_n = V_i$$

$$\Rightarrow I_R = \frac{V_i}{R}$$

This current cannot come from V_n (input of opamp). Must come from Rf_1

That makes V_o equal to $V_i + I_R = V_i + \frac{V_i}{R} Rf$



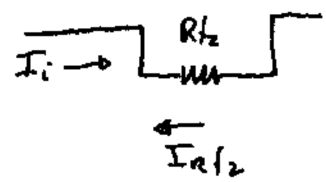
$V_o = V_i + \frac{V_i}{R}$.

The current I_{Rf_2} is then

$$I_{Rf_2} = \frac{V_o - V_i}{Rf} = \frac{\left(V_i + \frac{V_i}{R} Rf\right) - V_i}{Rf} = \frac{V_i}{R}$$

This current must come from outside (V_i) because input resistance of V_p of op amp is infinite.

Thus



$$I_i = -I_{Rf_2} = -\frac{V_i}{R}$$

Ohm's Law: $R_i = \frac{V_i}{I_i} = \frac{V_i}{-V_i/R} = -R$

Question 6

a) $$R(L, r, \rho) = \frac{\rho L}{\pi r^2} = \frac{\rho(L)\, L}{\pi\, r(L)^2}$$

$$\frac{dR}{dL} = \frac{\rho}{\pi r^2}\frac{dL}{dL} - \frac{2\rho L}{\pi r^3}\frac{dr}{dL} + \frac{L}{\pi r^2}\frac{d\rho}{dL}$$

$$K \equiv \frac{dR/R}{dL/L} = \frac{dR}{dL} \times \frac{L}{R} = \frac{dR}{dL} \times \frac{\pi r^2}{\rho}$$

$$= \frac{\rho}{\pi r^2}\frac{dL}{dL} \times \frac{\pi r^2}{\rho} - \frac{2\rho L}{\pi r^3}\frac{dr}{dL}\frac{\pi r^2}{\rho} + \frac{L}{\pi r^2}\frac{d\rho}{dL} \times \frac{\pi r^2}{\rho}$$

$$= 1 - 2\frac{L}{r}\frac{dr}{dL} + \frac{L}{\rho}\frac{d\rho}{dL} = 1 - 2\frac{dr/r}{dL/L} + \frac{d\rho/\rho}{dL/L}$$

$$= 1 + 2\nu + \frac{d\rho/\rho}{\varepsilon}$$ q.e.d.

b) $V = L \pi r^2 = L \pi r(L)^2$

$$\frac{dV}{dL} = \pi r^2 \cdot \frac{dL}{dL} + 2 \pi L r \frac{dr}{dL} = 0$$

divide by πr^2

$$1 + 2 \frac{L}{r} \cdot \frac{dr}{dL} = 0 \Rightarrow$$

$$\frac{dr/r}{dL/L} = -0.5 \Rightarrow \nu = +0.5$$

$$K = 1 + 2\nu = 2.0$$

c) $\frac{\Delta L}{L} = 1\% \Rightarrow \frac{\Delta R}{R} = K \frac{\Delta L}{L} = 2\%$

$$R = 1\ k\Omega \Rightarrow \Delta R = 20\ \Omega$$

$$R' = R + \Delta R = 1020\ \Omega$$

d) us an extensometer, that is for example for measuring earthquaques.