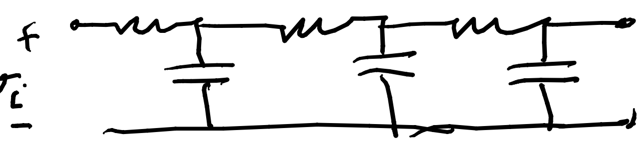
EE 303

02/29/12

Note Title 2/27/2012

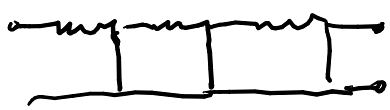
$\therefore$ $$V_{in}(s) = \frac{1}{T(s)} = (R_1C_1R_2C_2R_3C_3)s^3 + (R_1C_2R_3C_3 + R_1C_1R_2C_2 + R_1C_1R_2C_3 + R_1C_1R_3C_3 + R_2C_2R_3C_3)s^2 + (R_1C_2 + R_1C_3 + R_1C_1 + R_2C_2 + R_2C_3 + R_3C_3)s + 1$$

$= -K$ for oscillations (when close the loop)



$$T(s) = \frac{v_o}{v_i}(s)$$

as $s \to \infty$



$v_o \to 0$ as 3rd power of s

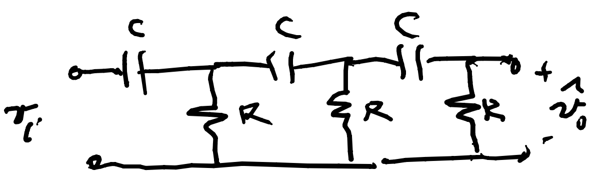
$T(s)\big|_{s\to\infty} \sim \frac{k}{s^3} \Rightarrow$ low pass

here $k = 1/R^3C^3$

if $C_1 = C_2 = C_3 = C$, $R_1 = R_2 = R_3 = R$

$$T(s) = \frac{1}{R^3C^3s^3 + 5R^2C^2s^2 + 6RCs + 1}$$

if $R \to \frac{1}{\hat{C}s}$, $sC \to \frac{1}{\hat{R}}$

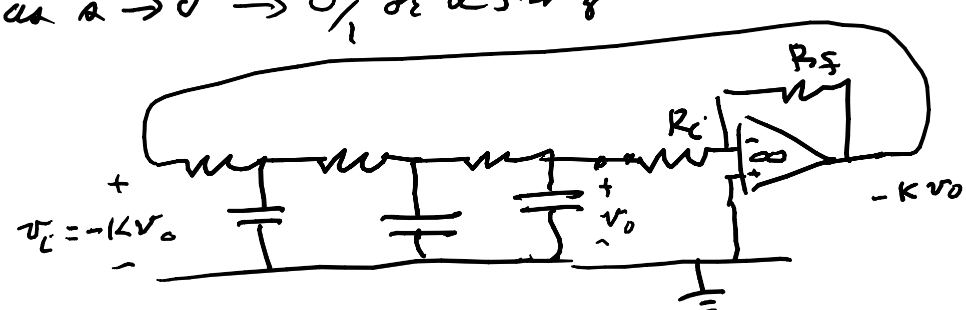


$$\hat{T}(s) = \frac{\hat{v}_o}{v_i} = \frac{1}{\left(\frac{1}{\hat{C}s}\right)^3\left(\frac{1}{\hat{R}}\right)^3 + 5\left(\frac{1}{\hat{C}s}\right)^2\left(\frac{1}{\hat{R}}\right)^2 + 6\frac{1}{\hat{C}s}\cdot\frac{1}{\hat{R}} + 1}$$

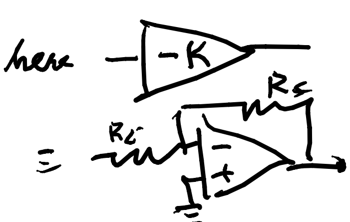
$$= \frac{\hat{C}^3\hat{R}^3s^3}{1 + 5\hat{C}\hat{R}s + 6\hat{C}^2\hat{R}^2s^2 + (\hat{C}\hat{R})^3s^3}$$

here as $s \to \infty$ we get $\hat{C}^3\hat{R}^3$

as $s \to 0 \to 0^3/1$ or a 3rd zero at DC $\Rightarrow$ high pass



here



need $R_i \to \infty$

$$v_o/v_i = -R_f/R_i = -K$$

$$T(s) = \frac{v_o}{v_i} = \frac{v_o}{-Kv_o} = -\frac{1}{K}$$

$\Rightarrow$ for behavior $\frac{1}{T(s)} = -K$

$$1 + 6RCs + 5R^2C^2s^2 + R^3C^3s^3 = -K$$

For sinusoids, a sine wave oscillator, $s = j\omega$

$$1 + j6RC\omega - 5R^2C^2\omega^2 - jR^3C^3\omega^3 = -K$$

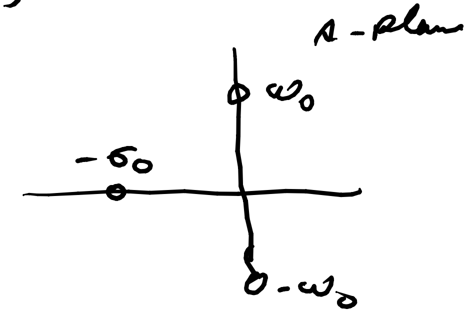
Re: $1 + K - 5R^2C^2\omega^2 = 0$

Im $6RC\omega - R^3C^3\omega^3 = 0 \Rightarrow$ if $\omega \neq 0$ & $RC \neq 0 \Rightarrow 6 - R^2C^2\omega^2 = 0$

$$\omega_0^2 = \frac{6}{R^2C^2} \quad ; \quad 1+K = 5R^2C^2 \times \frac{6}{R^2C^2} = 30 \Rightarrow K = 29$$

we can design for a given $\omega \Rightarrow s^2 + \omega_0^2$ is a factor of the degree three polynomial $\frac{1}{T(s)} + K = P(s)$

$$P(s) = K + \frac{1}{T(s)} = (s^2 + \omega_0^2)(s + \sigma_0)K_0$$



$s + \sigma_0$ found by long division of $s^2 + \omega_0^2$ into $P(s)$

This is for low pass ladder

For high pass one

$$-K = \frac{1}{\hat{T}(s)} = \frac{1 + 5\hat{C}\hat{R}s + 6\hat{C}\hat{R}s^2 + s^3\hat{C}^3\hat{R}^3}{s^3\hat{C}^3\hat{R}^3} \Rightarrow$$

$$\left(K\hat{C}^3\hat{R}^3s^3 + s^3\hat{C}^3\hat{R}^3 + 5\hat{C}\hat{R}s\right) + \left(1 + 6\hat{C}^2\hat{R}^2s^2\right) = \hat{P}(s)$$

desire $\hat{P}(s) = 0$; $\hat{P}(s) = \text{Od}\,\hat{P}(s) + \text{Ev}\,\hat{P}(s)$

$s = j\omega$ Od: $j\omega(-\omega^2(K+1)\hat{C}^3\hat{R}^3 + 5\hat{C}\hat{R}) = 0$

Ev: $1 - 6\hat{C}^2\hat{R}^2\omega^2 = 0$

$$\hat{\omega}_0^2 = \frac{1}{6\hat{R}^2\hat{C}^2} \quad ; \quad -\omega^2(K+1)\hat{C}^3\hat{R}^3 + 5\hat{C}\hat{R} = 0$$

$$\equiv -(K+1)\frac{\hat{C}\hat{R}}{6} + 5\hat{C}\hat{R} = 0 \Rightarrow K + 1 = 30$$

$K = 29$

$$\hat{P}(s) = (s^2 + \hat{\omega}_0^2)(s + \hat{\sigma}_0)\hat{K}_0$$

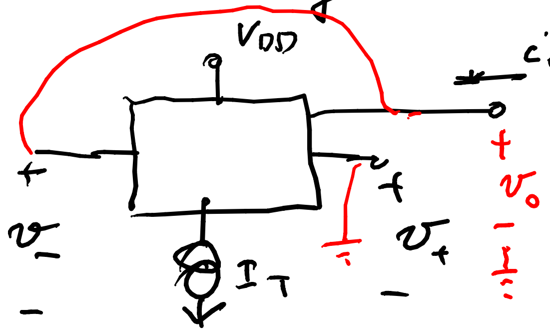
Ex: $R = 20K\Omega$, $C = 10\,\text{nFd} \Rightarrow RC = 2\times10^4 \times 10 \times 10^{-9}$

$= 2\times10^{-4} \Rightarrow 4\times10^{-8} = R^2C^2$

$$\hat{\omega}_0^2 = \frac{1}{6\times4\times10^{-8}} \qquad \hat{\omega}_0 = \frac{1}{2\sqrt{6}}\times10^4$$

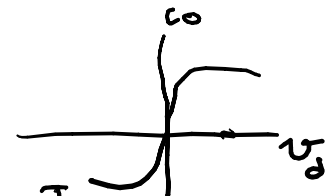
$$\hat{f}_0 = \frac{1}{2\pi}\times\frac{1}{2\sqrt{6}}\times10^4 = \frac{10{,}000}{31} \approx 325\ \text{Hz}$$

To make a negative resistor



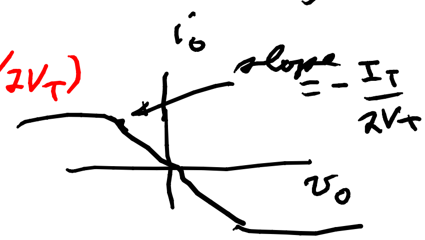
$$i_o = I_T \tanh\left(v_d/2V_T\right), \quad v_d = v_+ - v_-$$

$$\approx I_T \cdot \frac{v_d}{2V_T} + \cdots$$



$$i_o = G_m \cdot v_d, \quad G_m = \frac{I_T}{2V_T}$$

$$i_o = I_T \tanh\left(-v_-/2V_T\right) \approx -\frac{I_T}{2V_T} v_o$$



$\Rightarrow$ a negative resistor

$$i = gv, \quad g < 0$$

(result $\Rightarrow$ "any" linear circuit can be made with OTA's and capacitors)

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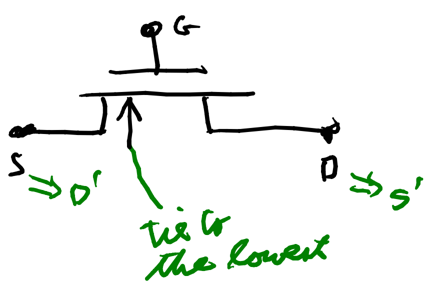
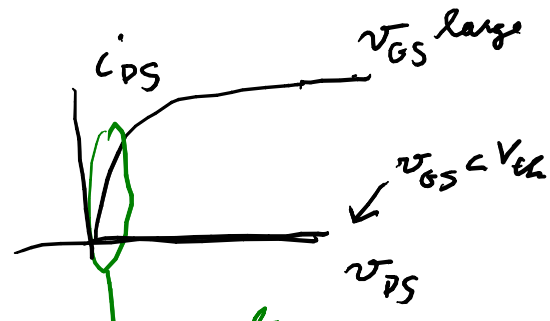
pass transistors p. 1153





off if $v_{GS} < V_{th}$, $\Rightarrow$ v_G small $\Rightarrow$ D$\to$S = open

if v_G = large $\Rightarrow$ D$\to$S like a short & current flows

desire to operate here as then the voltage difference from S to D is small

stops signal from S to D if G is a binary 0

Then passes signal from S to D if G is a binary 1