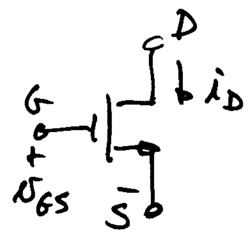
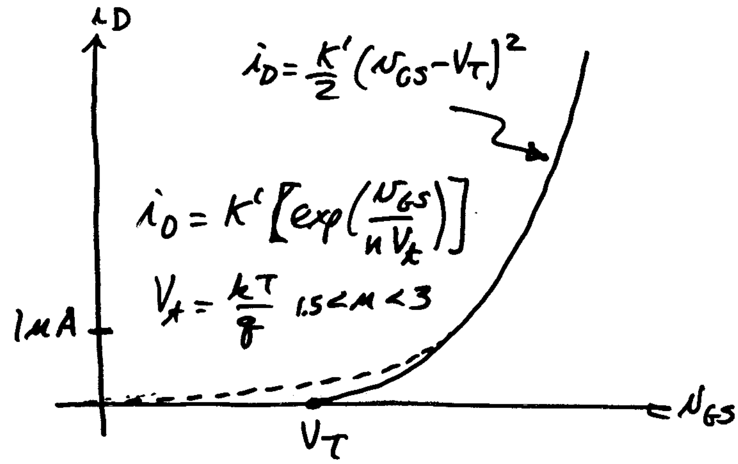
Quiz #12 due by noon today.

What is weak inversion operation for a MOSFET? (Subthreshold)

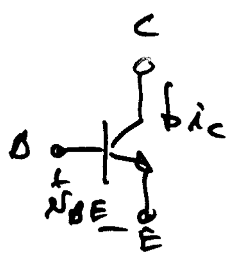




$$i_D = \frac{K'}{2}(v_{GS} - V_T)^2$$

$$i_D = K'\left[\exp\left(\frac{v_{GS}}{nV_t}\right)\right]$$

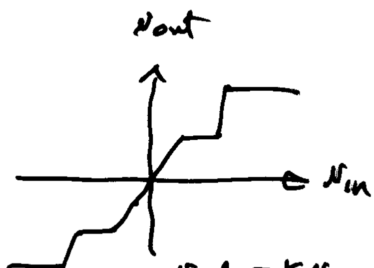
$$V_t = \frac{kT}{q} \quad 1.5 < n < 3$$

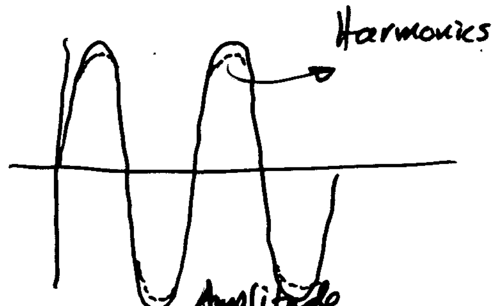


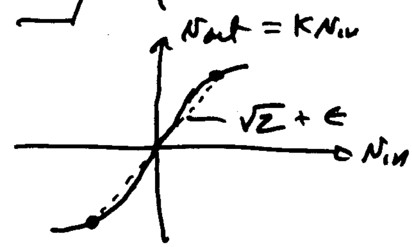
$$i_C = I_S \exp\left(\frac{v_{BE}}{V_t}\right)$$

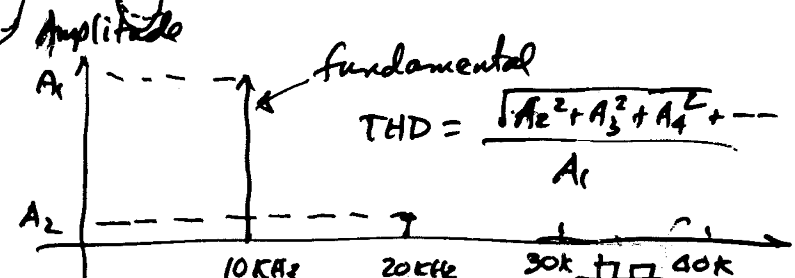
CHAPTER 12, SECTION 5

1.) Waveshaping Circuits



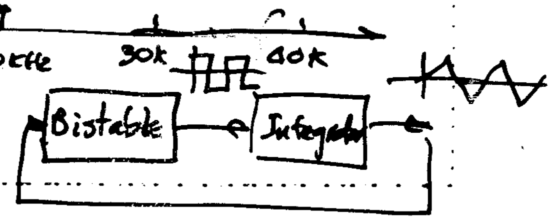






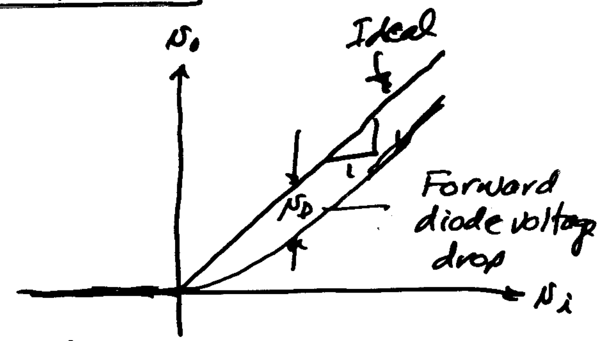
$$THD = \frac{\sqrt{A_2^2 + A_3^2 + A_4^2 + \cdots}}{A_1}$$

2.) Nonsinusoidal oscillators

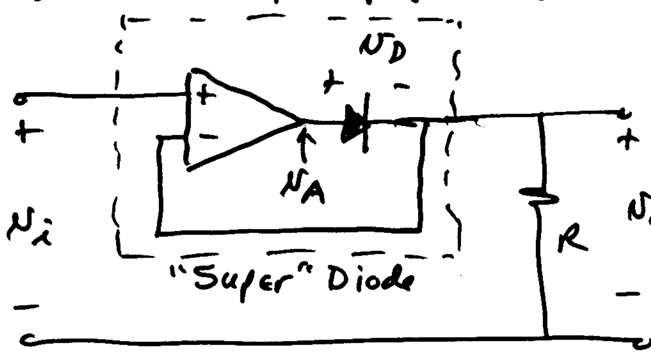


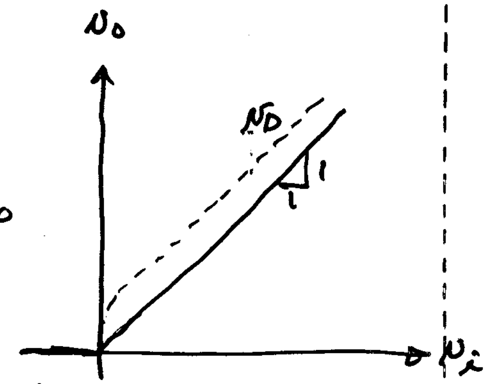
Rectification using the Op Amp

1.) No op amp (no fb)



2.) With the op amp (w. fb.)





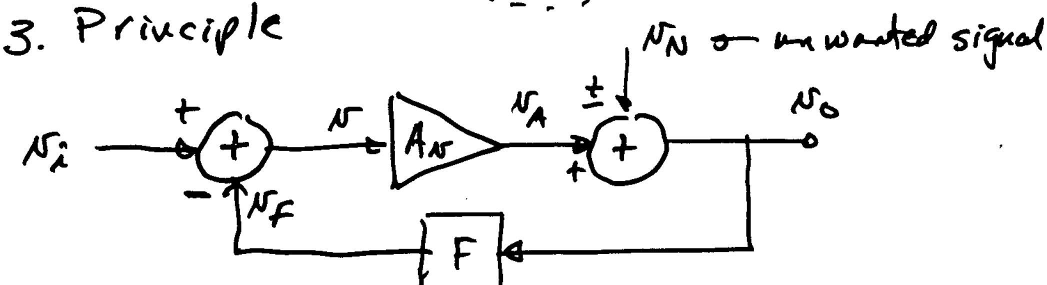
Assume A_v is large but not infinity

$$\left.\begin{aligned} v_o &= v_A - v_D \\ v_A &= A_v(v_i - v_o) \end{aligned}\right\} \quad v_o = A_v(v_i - v_o) - v_D$$

$$v_o(1 + A_v) = A_v v_i - v_D$$

or $$v_o = \frac{A_v v_i}{1 + A_v} - \frac{v_D}{1 + A_v}$$ if $A_v \to \infty$, then $v_o = v_i$

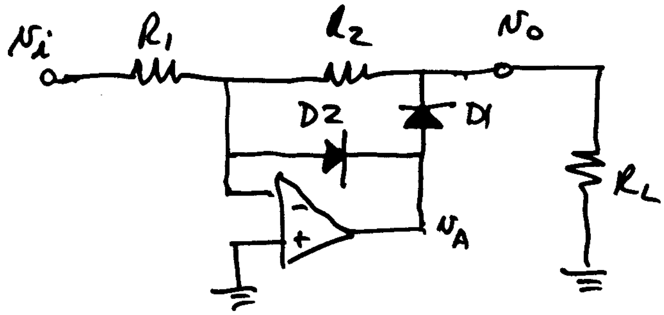
3. Principle



$$v_o = v_A \pm v_N = A_v(v_i - v_f) \pm v_N = A_v(v_i - Fv_o) \pm v_N$$

$$v_o[1 + A_v F] = A_v v_i \pm v_N \rightarrow v_o = \frac{A_v v_i}{1 + A_v F} \pm \frac{v_N}{1 + A_v F}$$

Precision Diode – The Op Amp Rectifier



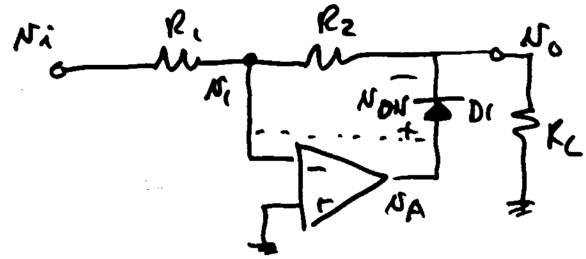
State of

v_i	D1	D2
	~~OFF~~	~~OFF~~
>0	OFF	ON
<0	ON	OFF
	~~ON~~	~~ON~~

Note: Only D1 or D2 is ON, not both

1.) D1 OFF D2 OFF is not a valid state

2.) D1 ON D2 OFF $\Rightarrow v_i < 0$

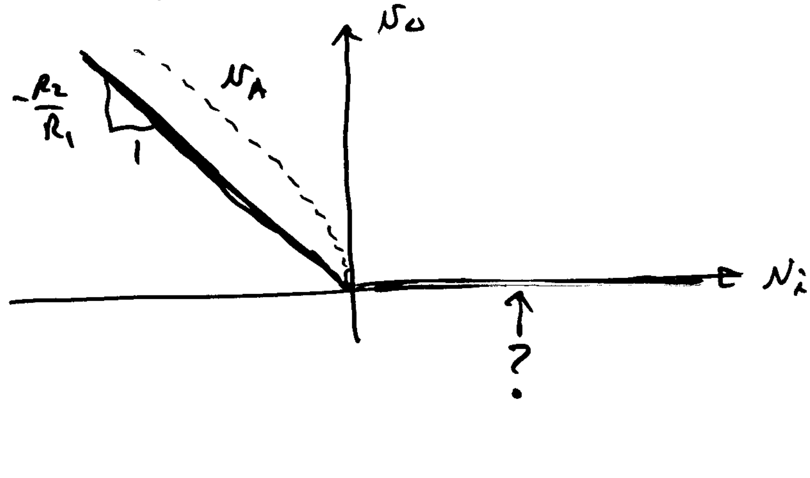


$v_o = v_A - V_{ON}$

$v_o = -A_v v_1 - V_{ON}$

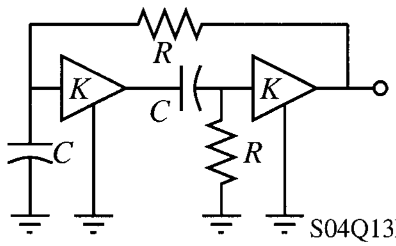
$v_1 = \frac{R_2}{R_1+R_2} v_i + \frac{R_1}{R_1+R_2} v_o$

$$v_o = \left(\frac{-A_v \frac{R_2}{R_1+R_2}}{1 + A_v \frac{R_1}{R_1+R_2}}\right) v_i - \frac{V_{ON}}{1 + A_v \frac{R_1}{R_1+R_2}} \qquad \underline{\underline{v_i < 0}}$$



RC Oscillator Example

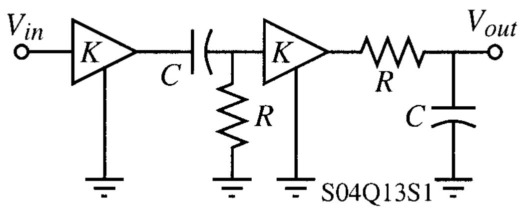
Find the loop gain of the feedback circuit shown, $T(s)$, if the amplifier is an ideal voltage amplifier with a gain of K. Identify the oscillation frequency and the value of K necessary to oscillate.



S04Q13P1

Solution

Opening the loop gives,



S04Q13S1

$$T(s) = \frac{V_{out}}{V_{in}} = \left(\frac{KR}{R+(1/sC)}\right)\left(\frac{K(1/sC)}{R+(1/sC)}\right)$$

$$= \frac{K^2RCs}{(sRC+1)(sRC+1)} = \frac{K^2RCs}{s^2R^2C^2+s2RC+1}$$

$$\therefore \quad \boxed{T(s) = \frac{K^2RCs}{s^2R^2C^2+s2RC+1}}$$

$$T(s) = \frac{sK^2RC}{s^2R^2C^2 + 2RCs + 1} \quad \rightarrow \quad T(j\omega) = \frac{j\omega K^2RC}{-\omega^2R^2C^2 + j\omega 2RC + 1}$$

or $$T(j\omega) = \frac{j\omega K^2RC}{1-\omega^2R^2C^2 + j\omega 2RC} = 1+j0$$

To make $T(j\omega) = 1$, the term $1-\omega^2R^2C^2$ in the denominator must go to zero. Therefore we get

$$1-\omega_{osc}{}^2R^2C^2 = 0 \quad \rightarrow \quad \boxed{f_{osc} = \frac{1}{2\pi RC}}$$

Substituting this relationship back into $T(j\omega_{osc})$ gives,

$$T(j\omega_{osc}) = \frac{j\omega_{osc}K^2RC}{j\omega_{osc}2RC} = \frac{K^2}{2} \quad \rightarrow \quad \boxed{K = \sqrt{2}}$$

KEY PRINCIPLE OF OSCILLATORS

1.) Find the open-loop gain, $T(j\omega)$.

2.) Set $T(j\omega) = 1+j0$

3.) Solve for the two equations,

Re[$T(j\omega)$] = 1 and Im[$T(j\omega)$] = 0

4.) If these equations cannot be solved for real numbers for frequency and gain, then the circuit is not an oscillator.