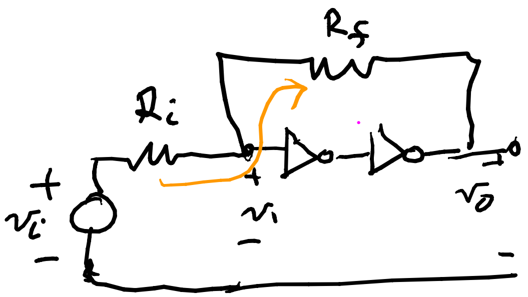
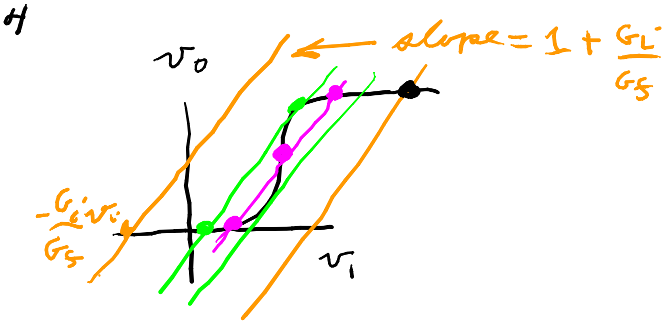
Hysteresis, p. 1357 – 1364

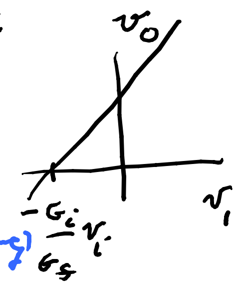


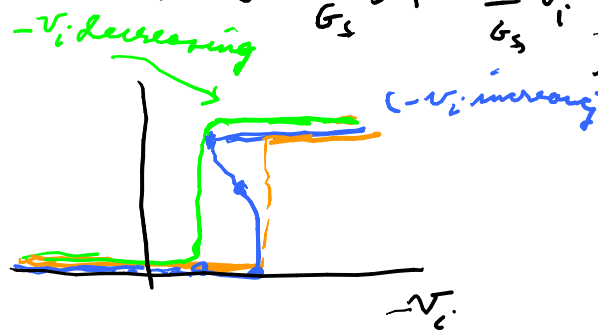


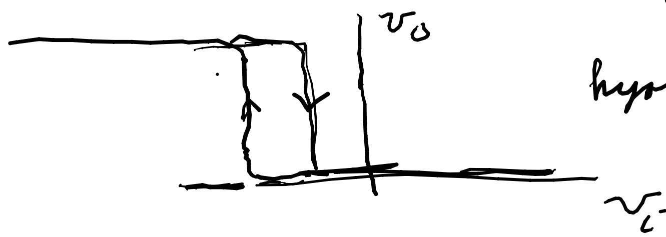
$$G_i(v_i - v_1) = G_f(v_1 - v_o)$$

$$G_f v_o = (G_i + G_f)v_1 - G_i v_i$$

$$v_o = \left(1 + \frac{G_i}{G_f}\right)v_1 - \frac{G_i}{G_f}v_i$$

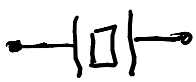






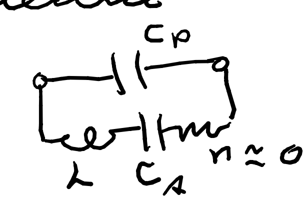
hysteresis

CMOS inverter crystal oscillator



piezoelectric

$z(s) \Rightarrow$



$$y(s) = \frac{1}{z(s)}$$

$$= C_p s + \frac{1}{r + Ls + \frac{1}{C_s s}} \Bigg|_{r \to 0} = C_p s + \frac{C_s s}{1 + LC_s s^2}$$

$$= \frac{C_p s + LC_s C_p s^3 + C_s s}{1 + LC_s s^2}$$

sinusoidal steady state

$\downarrow$

P_{ave} quartz $= Re\, V^* I$

$= \dfrac{V^* I + V I^*}{2}$

$= [V^* y(j\omega) V + V y^*(j\omega) V^*]/2$

$= V^* \dfrac{(y(j\omega) + y(-j\omega))}{2} V = 0 \quad = Re\, y(j\omega) = 0$

as quartz is lossless if $r = 0$

$$z(s) = \frac{LC_s s^2 + 1}{s(LC_s C_p s^2 + C_p + C_s)}$$

(positive real lossless (is $r = 0 \Rightarrow$ lossless, not lossless if $r \neq 0$)

$$y(j\omega) = \frac{j\omega(-LC_s C_p \omega^2 + C_p + C_s)}{1 - LC\omega^2}$$

is purely imaginary

$2\, Re\, f(s) = f(s) + f^*(s)$

if $s = j\omega \Rightarrow 2\, Re\, f(s)\big|_{s=j\omega} = f(j\omega) + f(-j\omega)$

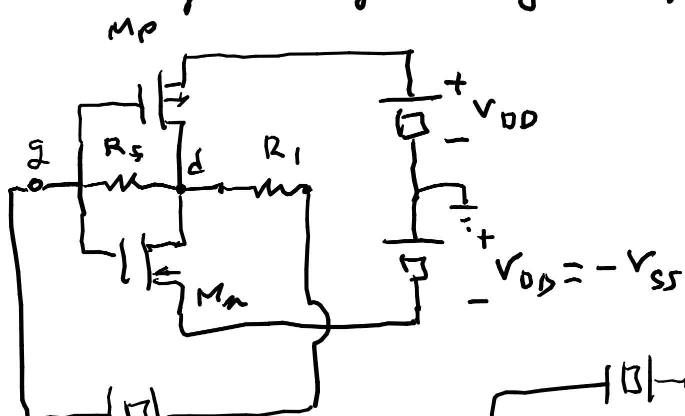
$2\, Ev\, f(s) = f(s) + f(-s)$

$2\, Ev\, f(j\omega) = 2\, Re\, f(j\omega)$ if $f^*(j\omega) = f((j\omega)^*) = f(-j\omega)$

as $Re\, z(j\omega) = 0 \Rightarrow Ev\, z(s) = 0$

$Re\, y(j\omega) = 0 \Rightarrow Ev\, y(s) = 0 \Rightarrow y(s)$ is an odd function of for a lossless circuit

the circuit for oscillation give signals of the form $e^{j\omega_0 t}$

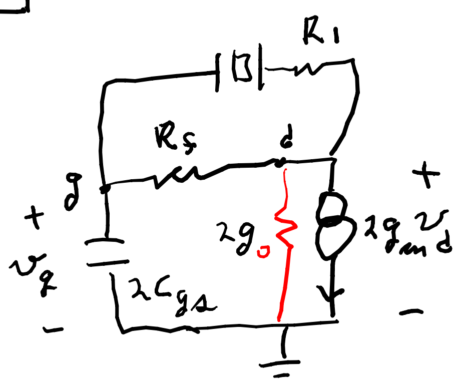


for $C_{gd} = 0$
$C_{gs} = \frac{2}{3} WLC_{ox}$ } saturation

p.702

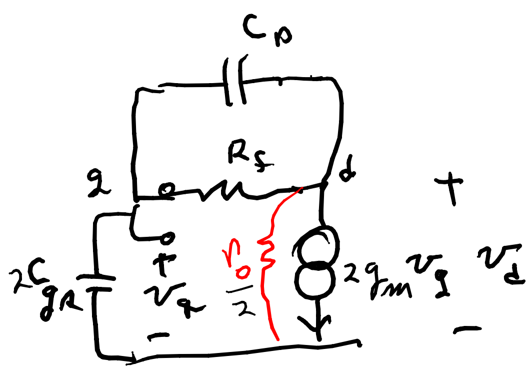
$\uparrow$
as $V_{DS} \geq V_{GS}$ by bias

$\Rightarrow$



Pierce oscillator

⇓ simplify $R_1=0, g_o=0, r=0$



1) $$2g_m v_g = G_s(v_g - v_d) + C_p s(v_g - v_d)$$

2) $$2C_{gs} s \cdot v_g = sC_p(v_d - v_g) + G_s(v_d - v_g)$$

3) $$2(-C_{gs} s + g_m) v_g = 0 \Rightarrow v_g \neq 0$$

if $s = g_m / C_{gs}$

$\Rightarrow$ unstable if $R_1, r, g_o = 0$

so can't ignore

(most important is g_o)

For $g_o = 0$, add $2g_o v_d$ to 1) & 3) $\Rightarrow$ $v_d = \dfrac{C_{gs}s - g_m}{g_o} v_g$

or 1) becomes

$$\left[2g_m - G_s - C_p s + (C_p s + G_s)\frac{(C_{gs}s - g_m)}{g_o}\right] v_g = 0$$

and if $v_g \neq 0$ then the coefficient $= 0$, set it $= 0$ & look for roots for oscillations of type $s = j\omega$

$$\left[2g_m - G_s - j\omega C_p + (G_s + j\omega C_p)\left(j\omega \frac{C_{gs}}{g_o} - \frac{g_m}{g_o}\right)\right] = 0$$

∴ set the real part $= 0$ & imaginary $= 0$

Re: $$2g_m - G_s - G_s\frac{g_m}{g_o} - \omega^2 \frac{C_p C_{gs}}{g_o} = 0 \Rightarrow g_m\left(2 - \frac{G_s}{g_o}\right) - \left(G_s + \omega^2\frac{C_p C_{gs}}{g_o}\right) = 0$$

Im: $$-\omega C_p + \omega G_s \frac{C_{gs}}{g_o} - \omega C_p \frac{g_m}{g_o} \Rightarrow \frac{G_s C_{gs}}{g_o} - C_p\left[1 + \frac{g_m}{g_o}\right] = 0$$

∴ can design for a desired $\omega = \omega_o$ via G_s & g_m (g_m via biasing) (note $g_o \neq 0$ is needed) over limited ranges