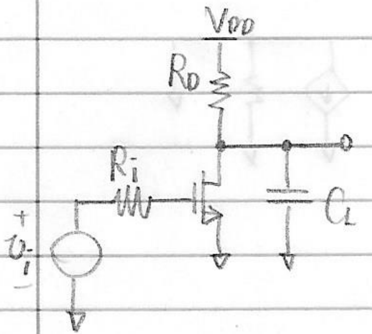
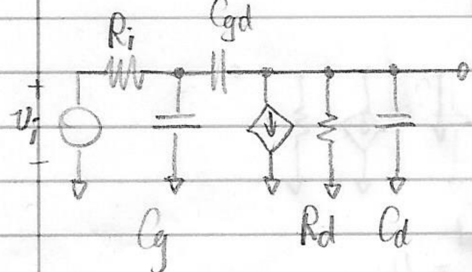
ECE 264A Common Source w/o Source Degen





$$\frac{v_d}{v_i} = \frac{\frac{Y_{gi} Y_{dg}}{Y_{gg} Y_{dd}}}{1 - \frac{Y_{dg} Y_{gd}}{Y_{gg} Y_{dd}}} = \frac{Y_{gi} Y_{dg}}{Y_{gg} Y_{dd} - Y_{dg} Y_{gd}}$$

$$= \frac{\frac{1}{R_i}(sC_{gd} - g_m)}{\left(\frac{1}{R_i} + sC_g + sC_{gd}\right)\left(\frac{1}{R_d} + sC_d + sC_{gd}\right) - sC_{gd}(sC_{gd} - g_m)}$$

$$= \frac{\frac{1}{R_i}(sC_{gd} - g_m)}{\left(\frac{1}{R_i} + sC_g\right)\left(\frac{1}{R_d} + sC_d\right) + sC_{gd}\left(\frac{1}{R_i} + sC_g + \frac{1}{R_d} + sC_d + g_m\right)}$$

$$= \frac{-g_m R_d\left(1 - \frac{s}{g_m/C_{gd}}\right)}{(1 + sC_g R_i)(1 + sC_d R_d) + sC_{gd}(R_d + R_i + (g_m + sC_g + sC_d) R_i R_d)}$$

$$= \frac{\cdots}{1 + s(C_g R_i + C_d R_d) + s^2 C_g C_d R_i R_d + sC_{gd}(R_d + R_i + g_m R_d R_i) + s^2 C_{gd}(C_g + C_d) R_i R_d}$$

$$g_m \to \infty, \quad \frac{v_d}{v_i} = -\frac{g_m R_d}{sC_{gd}\, g_m R_d R_i} = -\frac{1}{sC_{gd} R_i}$$

1. KCL and KVL

KCL at gate

$$\left(\frac{1}{R_i} + sC_g + sC_{gd}\right) v_g = \frac{1}{R_i} v_i + sC_{gd} v_d$$

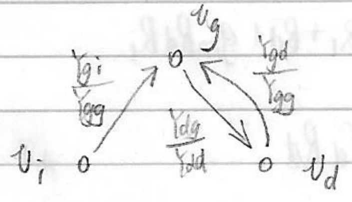
KCL at drain

$$\left(sC_{gd} + sC_d + \frac{1}{R_d}\right) v_d + g_m v_g = sC_{gd} v_g$$

1.1. SFG

$$v_g = \underbrace{\frac{1}{\frac{1}{R_i} + sC_g + sC_{gd}}}_{Y_{gg}} \left(\underbrace{\frac{1}{R_i}}_{Y_{gi}} v_i + \underbrace{sC_{gd}}_{Y_{gd}} v_d\right)$$

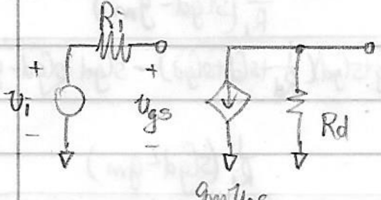
$$v_d = \underbrace{\frac{1}{\frac{1}{R_d} + sC_d + sC_{gd}}}_{Y_{dd}} \underbrace{(sC_{gd} - g_m)}_{Y_{dg}} v_g$$



2. TTC

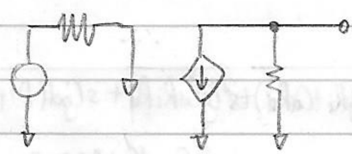
2.1. H

2.1.1. H^0



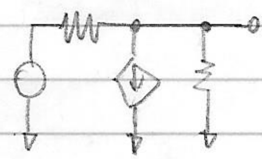
$$H^0 = -g_m R_d = A_{vdc}$$

2.1.2. H^g



$$H^g = 0$$

H^{gd}

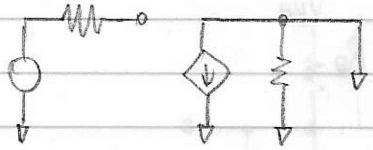


$$H^{gd} = \frac{\frac{1}{g_m} // R_d}{R_i + (\frac{1}{g_m} // R_d)}$$

$$= \frac{\frac{R_d}{1+g_m R_d}}{R_i + \frac{R_d}{1+g_m R_d}}$$

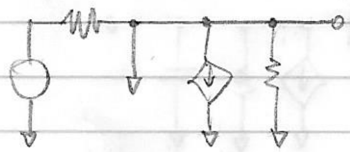
$$= \frac{R_d}{R_i(1+g_m R_d) + R_d}$$

H^d



$$H^d = 0$$

2.1.3. $H^{g,gd}$



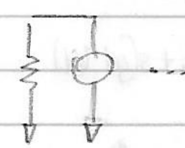
$$H^{g,gd} = 0$$

$$H^{g,d} = H^{gd,d} = 0$$

2.1.4. $H^{g,gd,d} = 0$

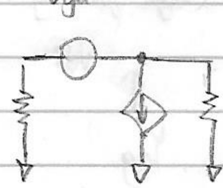
2.2. τ

2.2.1. τ_g^0



$R_g^0 = R_i$, $\tau_g^0 = C_g R_i$

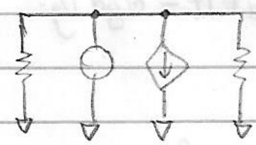
τ_{gd}^0



$$R_{gd}^0 = R_i + R_d + g_m R_d R_i$$

$$\tau_d^0 = C_d R_d$$

2.2.2 τ_g^{gd}

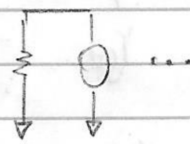


$R_g^{gd} = R_i // \frac{1}{g_m} // R_d$

$= R_i // \frac{R_d}{1+g_m R_d}$

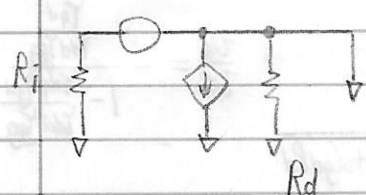
$= \frac{R_i R_d}{R_i(1+g_m R_d) + R_d}$

τ_g^{d}



$R_g^{d} = R_i$

τ_{gd}^{d}



$R_{gd}^{d} = R_i$

2.2.3 $\tau_g^{gd,d} = 0$

2.3. b

2.3.1. $b_1 = \tau_g^0 + \tau_{gd}^0 + \tau_d^0$

$= C_g R_i + C_{gd}(R_i + R_d + g_m R_d R_i) + C_d R_d$

2.3.2. $b_2 = \tau_{gd}^0 \tau_g^{gd} + \tau_d^0 \tau_g^d + \tau_d^0 \tau_{gd}^d$

$= C_{gd}(R_i + R_d + g_m R_d R_i) C_g \frac{R_i R_d}{R_i + R_d + g_m R_d R_i}$

$+ C_d R_d C_g R_i + C_d R_d C_{gd} R_i$

$= (C_{gd} C_g + C_d C_g + C_d C_{gd}) R_d R_i$

2.3.3. $b_3 = \tau_d^0 \tau_{gd}^d \tau_g^{gd,d} = 0$

2.4. a

2.4.1. $a_1 = \tau_g^0 H^g + \tau_{gd}^0 H^{gd} + \tau_d^0 H^d$

$= C_g R_i \cdot 0 + C_{gd}(R_d + R_i + g_m R_d R_i) \frac{R_d}{R_d + R_i + g_m R_i R_d}$

$+ C_d R_d \cdot 0$

$= C_{gd} R_d$

2.4.2. $a_2 = \tau_{gd}^0 \tau_g^{gd} H^{g,gd} + \tau_d^0 \tau_g^d H^{g,d} + \tau_d^0 \tau_{gd}^d H^{gd,d}$

$= 0$

2.5 $H(s) = \frac{H_0 + a_1 s}{1 + b_1 s + b_2 s^2}$

$$= \frac{-g_m R_d + s C_{gd} R_d}{1 + (C_g R_i + C_{gd}(R_i + R_d + g_m R_d R_i) + C_d R_d)s + (C_{gd} C_g + C_d C_g + C_d C_{gd}) R_i R_d s^2}$$

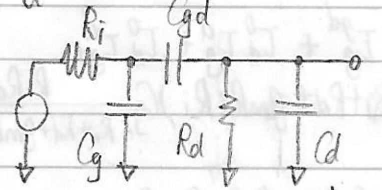
3. RR

$$A = \frac{A_\infty R}{1+R} + \frac{d}{1+R}$$

KCL at drain

$$\left(\frac{1}{R_d} + sC_d + sC_{gd}\right) v_d + i_t = sC_{gd} v_g$$

3.1. d



KCL at gate

$$\left(\frac{1}{R_i} + sC_g + sC_{gd}\right) v_g = sC_{gd} v_d$$

$$v_d = \underbrace{\frac{1}{\frac{1}{R_d} + sC_d + sC_{gd}}}_{Y_{dd}} \left(\underbrace{sC_{gd}}_{Y_{dg}} v_g - i_t\right)$$

$$v_g = \underbrace{\frac{1}{\frac{1}{R_i} + sC_g + sC_{gd}}}_{Y_{gg}} \underbrace{sC_{gd}}_{Y_{gd}} v_d$$

$$d = \frac{R_d // \frac{1}{sC_d}}{\frac{1}{sC_{gd}} + \left(R_d // \frac{1}{sC_d}\right)} \cdot \frac{\frac{1}{sC_g} // \left(\frac{1}{sC_{gd}} + \left(R_d // \frac{1}{sC_d}\right)\right)}{R_i + \left(\frac{1}{sC_g} // \left(\frac{1}{sC_{gd}} + \left(R_d // \frac{1}{sC_d}\right)\right)\right)}$$

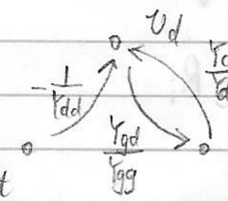
$$= \left(R_d // \frac{1}{sC_d}\right) \frac{\frac{\frac{1}{sC_g}}{\frac{1}{sC_g} + \frac{1}{sC_{gd}} + \left(R_d // \frac{1}{sC_d}\right)}}{R_i + \frac{\frac{1}{sC_g}\left(\frac{1}{sC_{gd}} + \left(R_d // \frac{1}{sC_d}\right)\right)}{\frac{1}{sC_g} + \frac{1}{sC_{gd}} + \left(R_d // \frac{1}{sC_d}\right)}}$$

$$= \left(R_d // \frac{1}{sC_d}\right) \frac{\frac{1}{sC_g}}{R_i\left(\frac{1}{sC_g} + \frac{1}{sC_{gd}} + R_d // \frac{1}{sC_d}\right) + \frac{1}{sC_g}\left(\frac{1}{sC_{gd}} + \left(R_d // \frac{1}{sC_d}\right)\right)}$$

$$= \frac{\frac{1}{sC_g} \frac{R_d}{1 + sC_dR_d}}{R_i\left(\frac{1}{sC_g} + \frac{1}{sC_{gd}} + \frac{R_d}{1+sC_dR_d}\right) + \frac{1}{sC_g}\left(\frac{1}{sC_{gd}} + \frac{R_d}{1+sC_dR_d}\right)}$$

$$= \frac{sC_{gd}R_d}{R_i\left((sC_{gd} + sC_g)(1 + sC_dR_d) + s^2C_gC_{gd}R_d\right) + \left(1 + sC_dR_d + sC_{gd}R_d\right)}$$

$$= \frac{sC_{gd}R_d}{sC_{gd}R_i + sC_gR_i + s^2C_{gd}C_dR_iR_d + s^2C_gC_dR_iR_d + s^2C_gC_{gd}R_iR_d + 1 + sC_dR_d + sC_{gd}R_d}$$

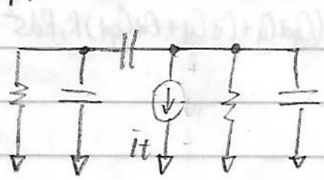


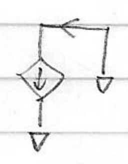
$$\frac{v_g}{i_t} = -\frac{\frac{Y_{gd}}{Y_{dd}Y_{gg}}}{1 - \frac{Y_{dg}Y_{gd}}{Y_{dd}Y_{gg}}}$$

$$= -\frac{Y_{gd}}{Y_{dd}Y_{gg} - Y_{dg}Y_{gd}}$$

$$= -\frac{sC_{gd}}{\left(\frac{1}{R_d} + sC_d + sC_{gd}\right)\left(\frac{1}{R_i} + sC_g + sC_{gd}\right) - sC_{gd}sC_{gd}}$$

3.2. R

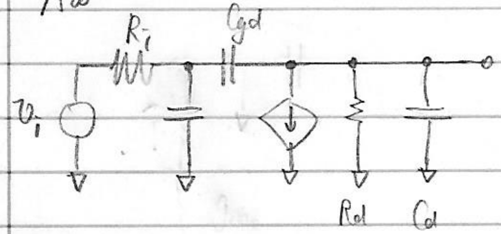




$$R = -\frac{i_r}{i_t} = -\frac{g_m v_g}{i_t} = \frac{sg_mC_{gd}}{\left(\frac{1}{R_d} + sC_d\right)\left(\frac{1}{R_i} + sC_g\right) + sC_{gd}\left(\frac{1}{R_d} + sC_d + \frac{1}{R_i} + sC_g\right)}$$

$$= \frac{sg_mC_{gd}R_dR_i}{(1 + sC_dR_d)(1 + sC_gR_i) + sC_{gd}\left(R_d + R_i + (sC_d + sC_g)R_dR_i\right)}$$

3.3. A_∞



$$\frac{1}{R_i} v_i + sC_{gd} v_d = 0$$

$$A_\infty = \frac{v_d}{v_i} = -\frac{1}{sC_{gd}R_i}$$

$$\left(\frac{1}{R_i} + sC_g + sC_{gd}\right) v_g = \frac{1}{R_i} v_i + sC_{gd} v_d$$

$v_g \to 0 \Rightarrow$

3.4. $$A = \frac{-\frac{1}{sC_{gd}R_i} \frac{sC_{gd}g_m R_d R_i}{(\cdots)} + \frac{sC_{gd}R_d}{(\cdots)}}{1 + \frac{sC_{gd}g_m R_d R_i}{(\cdots)}}$$

$$= \frac{-g_m R_d + sC_{gd}R_d}{sC_{gd}g_m R_d R_i + (\cdots)}$$