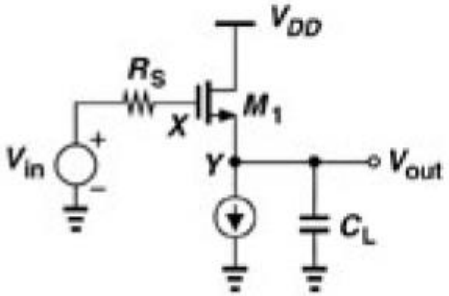
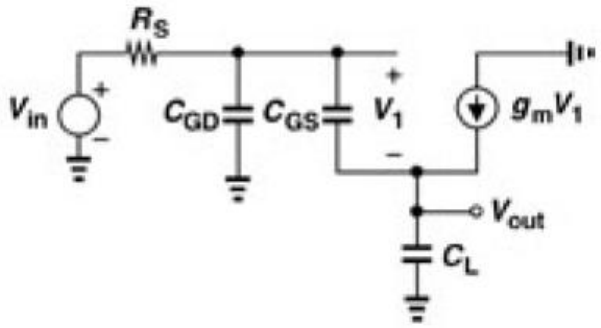
Lecture 6
IL2218 Analog electronics, advanced course

- Chapter 6, Frequency response of amplifiers
  - Source follower, transfer function
  - Source follower, input impedance
  - Source follower, output impedance
  - Cascode amplifier
  - Differential amplifier

Source follower



(a)



(b)

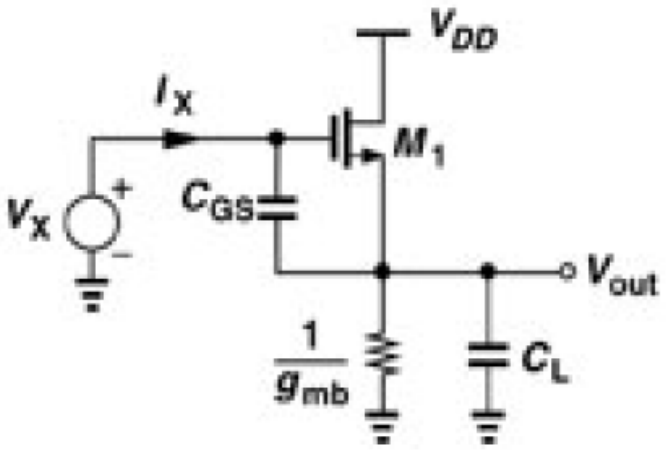
zero in left half plane

$$\frac{vo}{vi} = \frac{g_m + sC_{GS}}{s^2 R_S (C_{GS}C_L + C_{GS}C_{GD} + C_{GD}C_L) + s\left(g_m R_S C_{GD} + C_L + C_{GS}\right) + g_m}$$

Dominating pole $f_{p1} \approx \frac{g_m}{2\pi(g_m R_S C_{GD} + C_L + C_{GS})}$, assuming $f_{p2} >> f_{p1}$

$$= \frac{1}{2\pi\left(R_S C_{GD} + \frac{C_L + C_{GS}}{g_m}\right)}$$

Source follower, input impedance



Neglecting C_{GD} ,

$$Z_{in} \approx \frac{1}{sC_{GS}} + \left(1 + \frac{g_m}{sC_{GS}}\right)\frac{1}{g_{mb} + sC_L}$$

At low frequencies, $g_{mb} >> |sC_L|$

$$Z_{in} \approx \frac{1}{sC_{GS}}\left(1 + g_m / g_{mb}\right) + 1/g_{mb}$$

$$\therefore C_{in} = C_{GS} g_{mb} / (g_m + g_{mb}) + C_{GD} \quad ???$$

Error in book page 179?

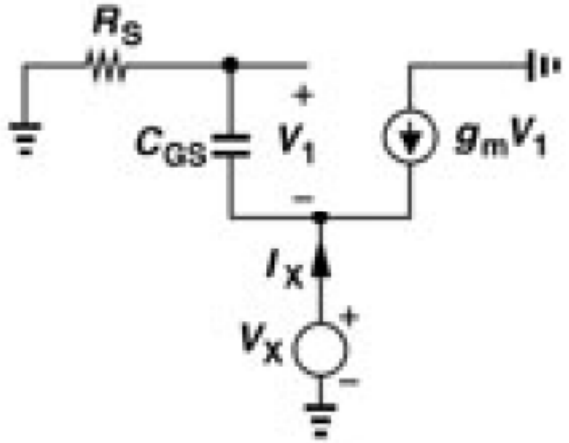
Source follower, input impedance

At high frequencies, $g_{mb} << |sC_L|$

$$Z_{in} \approx \frac{1}{sC_{GS}} + \frac{1}{sC_L} + \frac{g_m}{s^2 C_{GS} C_L}$$

At a particular frequency, input impedance includes C_{GD} in parallel with series combination of C_{GS} and C_L and a *negative* resistance equal to $-g_m/(C_{GS}C_L\omega^2)$.

Source follower, output impedance

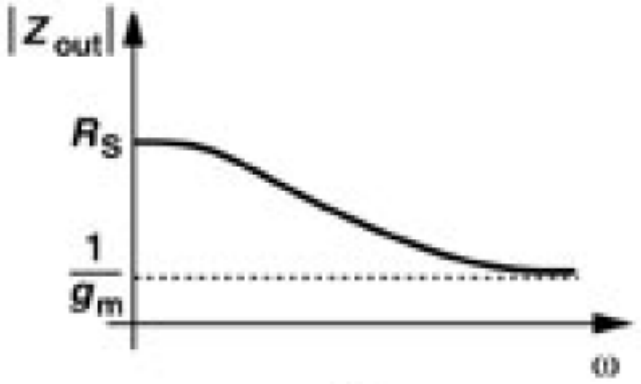


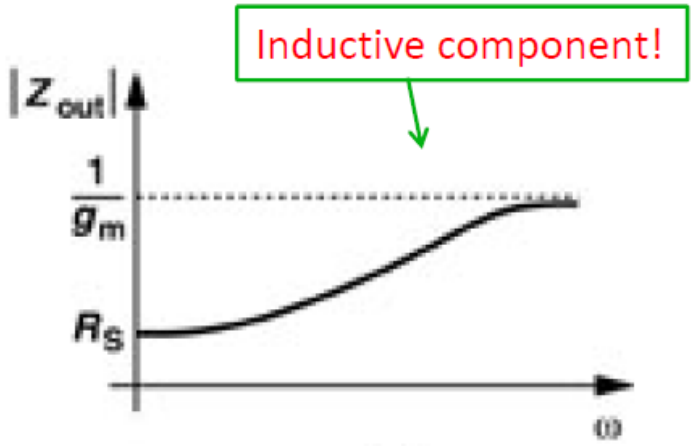
$$Z_{OUT} = V_X / I_X$$

$$= \frac{sR_S C_{GS} + 1}{gm + sC_{GS}}$$

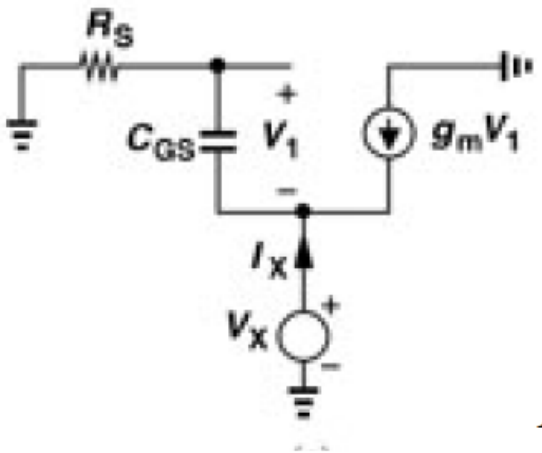
$$\approx 1/g_m \ , \ at \ \ low \ \ frequencies$$

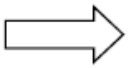
$$\approx R_S \ , \ at \ \ high \ \ frequencies$$

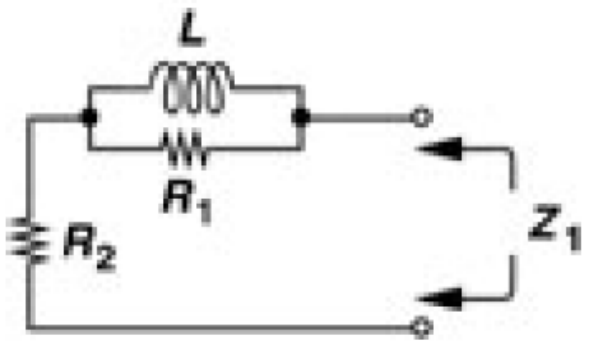




Source follower - equivalent output impedance







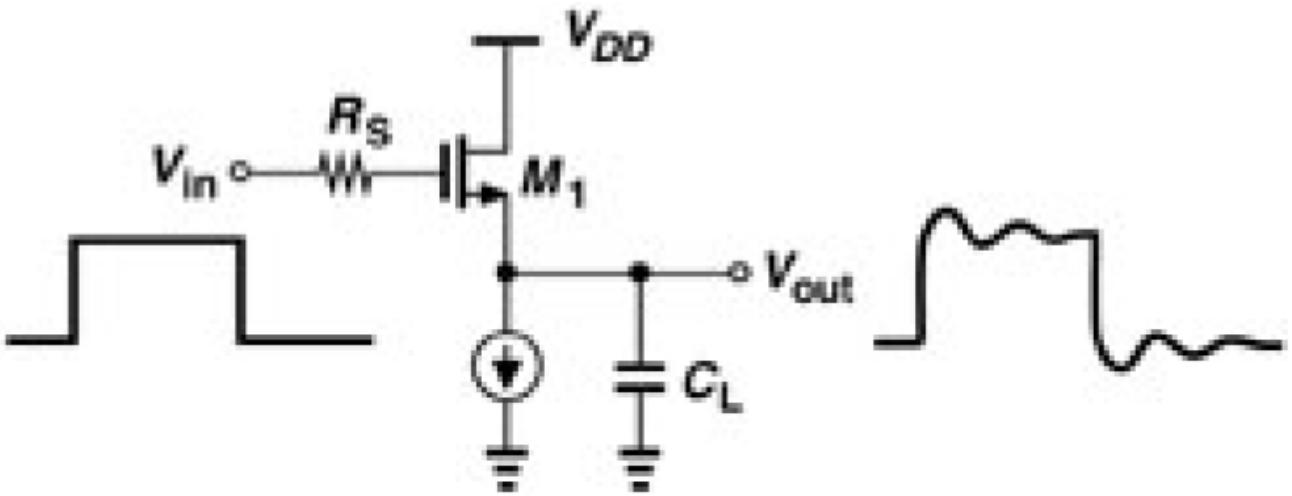
$$R_2 = 1/g_m$$

$$R_1 = R_S - 1/g_m$$

$$L = \frac{C_{GS}}{g_m}\left(R_S - 1/g_m\right)$$

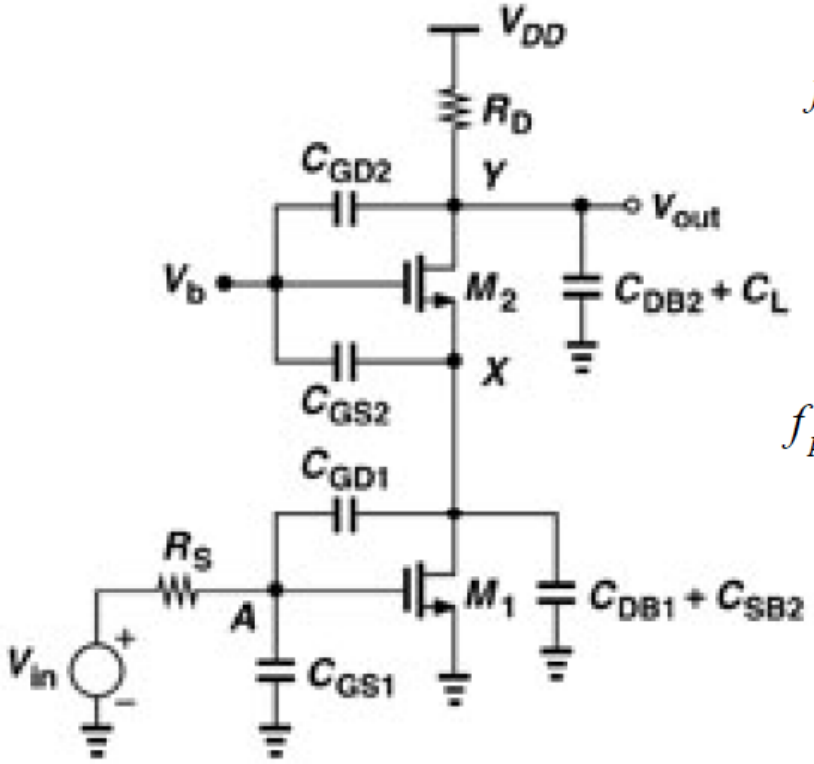
Output impedance inductance dependent on source impedance, R_S!

Step response, output ringing



Output ringing due to tuned circuit formed with C_L and inductive component of output impedance.

Cascode stage

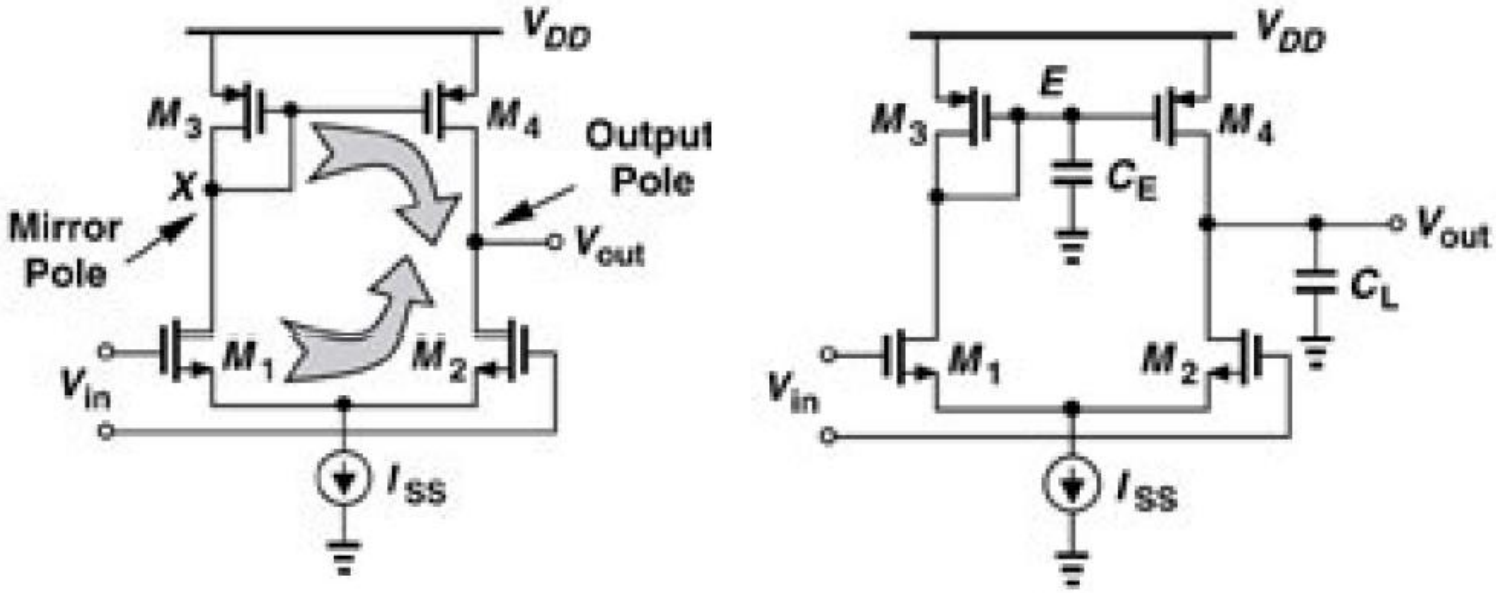


$$f_{pA} = \frac{1}{2\pi R_S\left[C_{GS1} + C_{GD1}\left(1 + \frac{g_{m1}}{g_{m2} + g_{mb2}}\right)\right]}$$

$$f_{pX} = \frac{g_{m2} + g_{mb2}}{2\pi\left(2C_{GD1} + C_{DB1} + C_{SB2} + C_{GS2}\right)}$$

$$f_{pY} = \frac{1}{2\pi R_D\left(C_{DB2} + C_L + C_{GD2}\right)}$$

Differential amplifier



$$f_{p1} \approx \frac{1}{2\pi(r_{oN} \,//\, r_{oP})C_L} \qquad f_{p2} = \frac{g_{mP}}{2\pi C_E} \qquad f_Z = 2f_{p2} = \frac{2g_{mP}}{2\pi C_E}$$