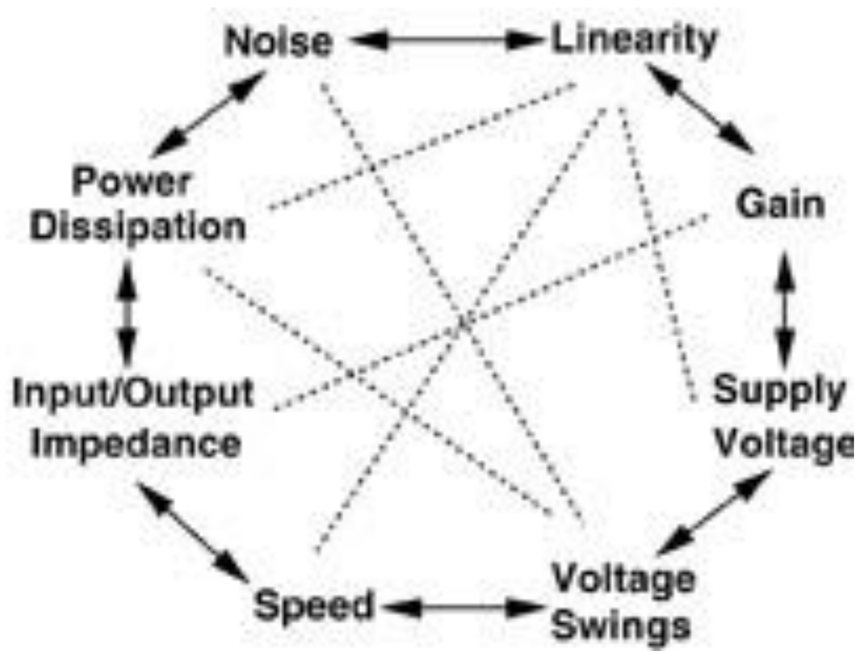
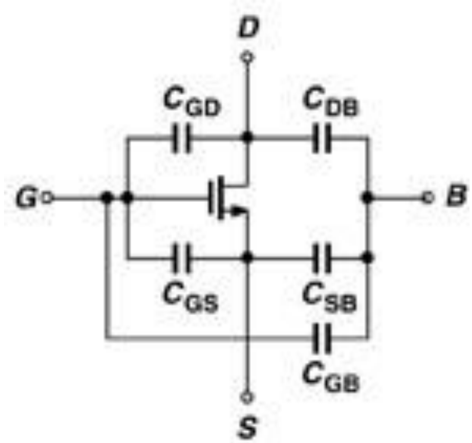
Lecture 5
IL2218 Analog electronics, advanced course

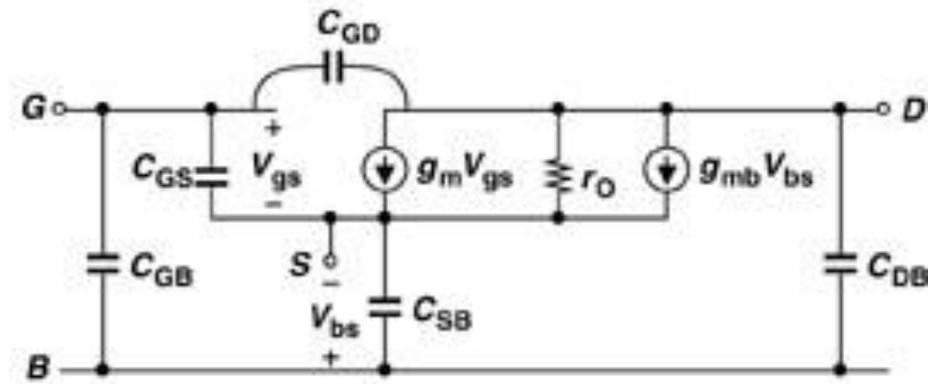
- Some reflections of what we have done this far in the course
- Capacitances in MOS transistor
- Miller theorem
- Poles associated to nodes, approximation
- Poles and zeroes in CS amplifier stage
- Exact transfer function of CS amplifier

Trade offs in analog design

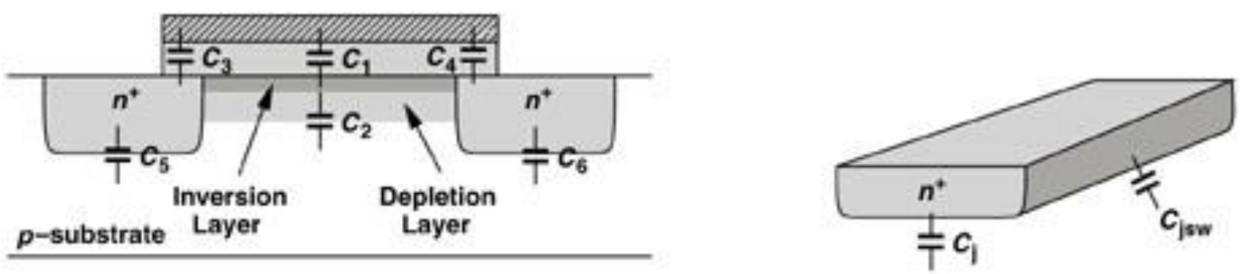


Complete small signal model with capacitances



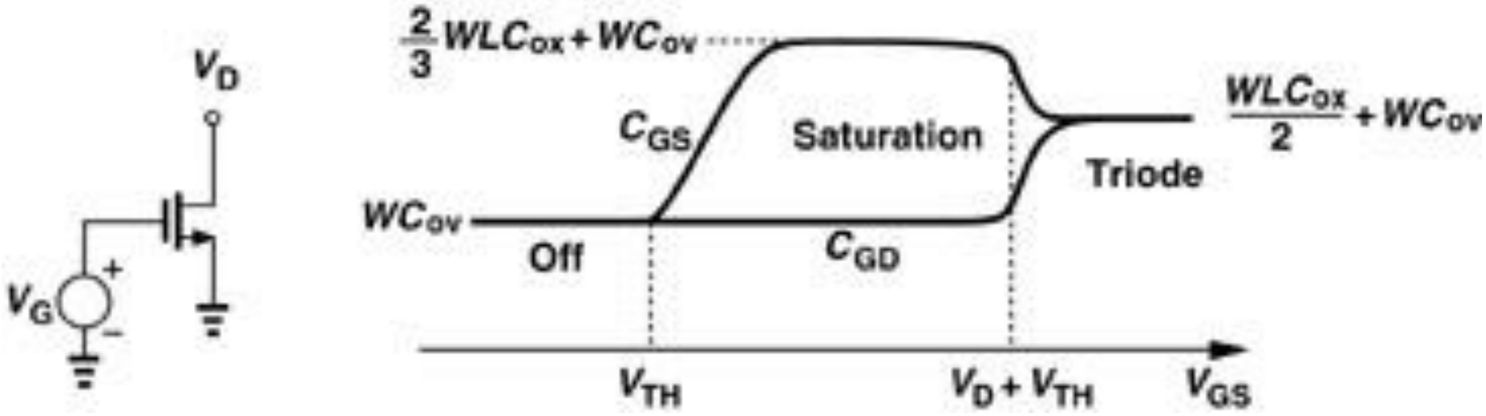


Explain the capacitances!

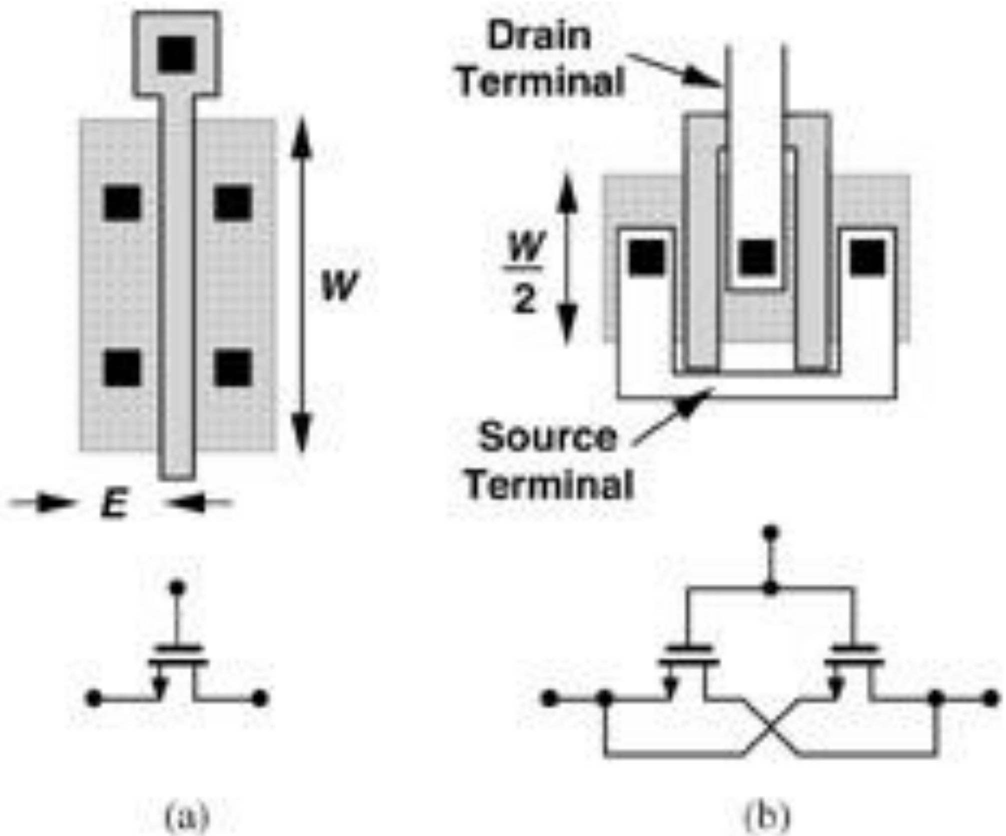


(a) (b)

Gate-source and gate-drain capacitance



MOS layout



From ”Introduction to Pspice”, page 13

Something to think about:
Why are some of the capacitances zero?

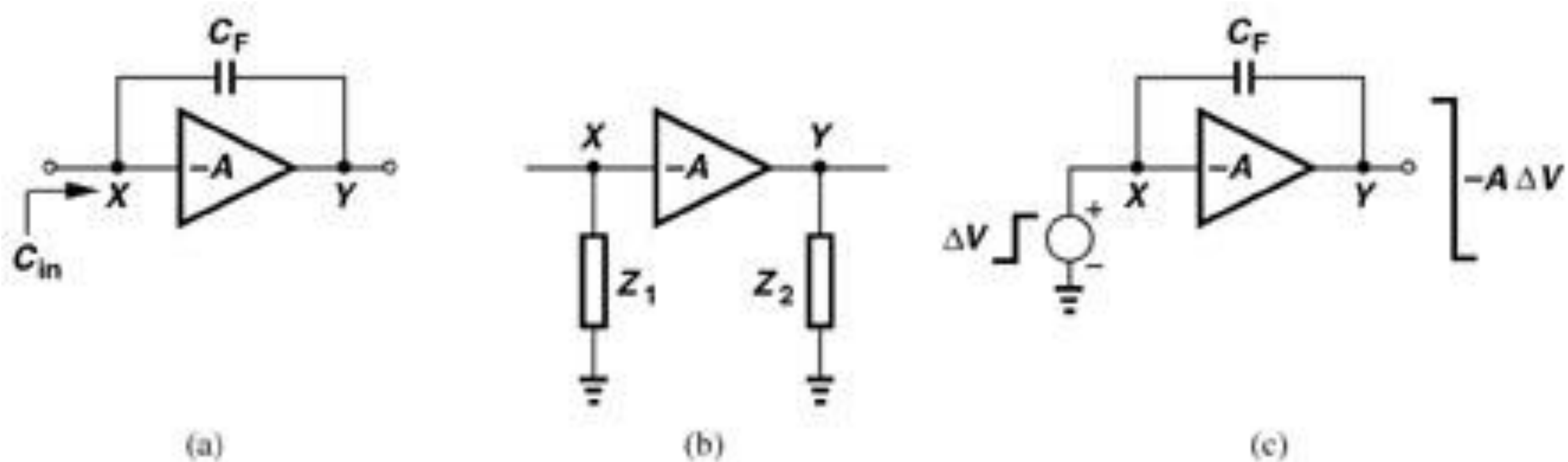
From Pspice output file

CBD	2.73E-14
CBS	4.24E-14
CGSOV	0.00E+00
CGDOV	1.50E-14
CGBOV	0.00E+00
CGS	4.35E-14
CGD	0.00E+00
CGB	0.00E+00

Table 2.1

```
.model nMOS NMOS
+ LEVEL=1     VTO=0.7     GAMMA=0.45   PHI=0.9
+ NSUB=9E+14  LD=0.08E-6  UO=350       LAMBDA=0.1
+ TOX=9E-9    PB=0.9      CJ=0.56E-3   CJSW=0.35E-11
+ MJ=0.45     MJSW=0.2    CGDO=0.3E-9  JS=1.0E-8
```

Miller capacitance

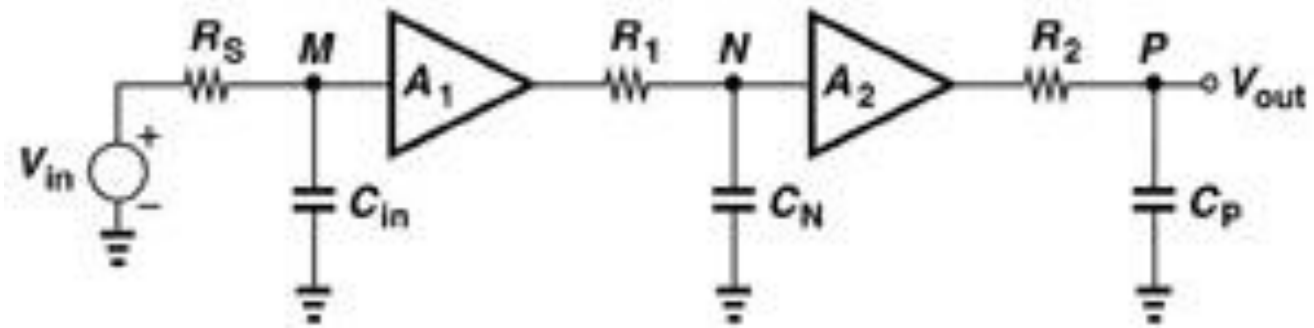


$$C_1 = (1 + A) C_F$$

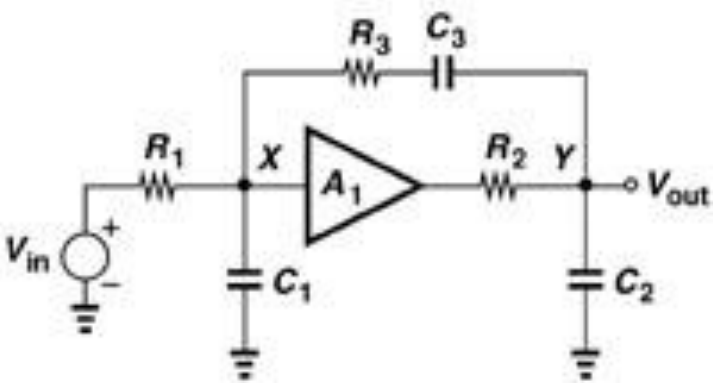
$$C_2 = C_F (1 + \frac{1}{A}) \approx C_F$$

Poles associated to nodes

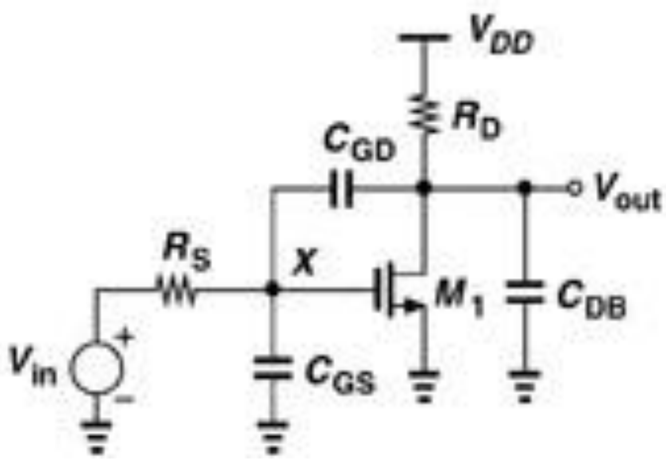
Non-Interacting Poles



Interacting Poles



CS amplifier

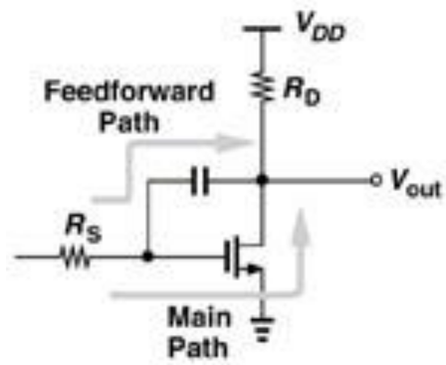


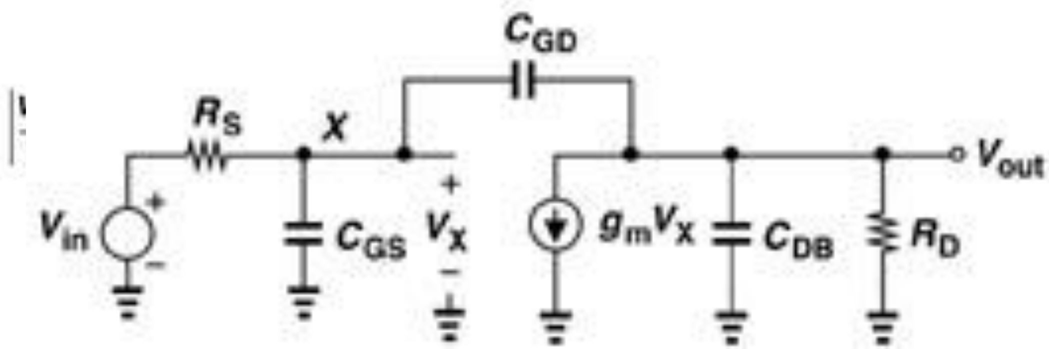
Neglecting input/output interaction,

$$f_{p,in} = \frac{1}{2\pi R_S\left[C_{GS} + (1 + g_m R_D)C_{GD}\right]}$$

$$f_{p,out} = \frac{1}{2\pi\left[(C_{GD} + C_{DB})R_D\right]}$$

CS amplifier, exact transfer function





$$\frac{V_{out}}{V_{in}}(s) = \frac{(sC_{GD} - g_m)R_D}{s^2 R_S R_D (C_{GS}C_{GD} + C_{GS}C_{SB} + C_{GD}C_{DB}) + s\left[R_S(1+g_m R_D)C_{GD} + R_S C_{GS} + R_D(C_{GD} + C_{DB})\right] + 1}$$

$$Assume\ |\omega_{p2}| >> |\omega_{p1}| \quad D = \left(\frac{s}{\omega_{p1}} + 1\right)\left(\frac{s}{\omega_{p2}} + 1\right) \approx \frac{s^2}{\omega_{p1}\omega_{p2}} + \frac{s}{\omega_{p1}} + 1,$$

$$f_{p,in} = \frac{1}{2\pi\left(R_S\left[C_{GS} + (1+g_m R_D)C_{GD}\right] + R_D(C_{GD} + C_{DB})\right)}$$

$$f_{p,out} = \frac{R_S(1+g_m R_D)C_{GD} + R_S C_{GS} + R_D(C_{GD} + C_{DB})}{2\pi R_S R_D(C_{GS}C_{GD} + C_{GS}C_{DB} + C_{GD}C_{DB})}$$

$$f_{p,out} \approx \frac{1}{2\pi R_D(C_{GD} + C_{DB})} \;, \quad \text{for large } C_{GS}$$

$$f_{p,out} \approx \frac{g_m R_S R_D C_{GD}}{2\pi R_S R_D(C_{GS}C_{GD} + C_{GS}C_{DB} + C_{GD}C_{DB})}$$

$$\approx \frac{gm}{2\pi(C_{GS} + C_{DB})} \;, \quad \text{for large } C_{GD}$$

Zero in transfer function

Right half plane zero

$$\frac{V_{out}}{V_{in}}(s)=\frac{(sC_{GD}-g_m)R_D}{s^2R_SR_D(C_{GS}C_{GD}+C_{GS}C_{SB}+C_{GD}C_{DB})+s\left[R_S(1+g_mR_D)C_{GD}+R_SC_{GS}+R_D(C_{GD}+C_{DB})\right]+1}$$

$$\frac{sC_{GD}-g_m}{\ldots} \quad\rightarrow\quad f_z=\frac{+g_m}{2\pi C_{GD}}$$

Feedforward path