P3360/AEP3630

Lecture 22

MOSFET circuits

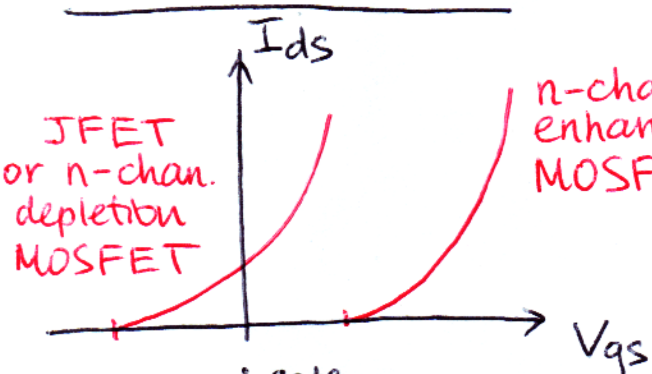
- analogous to BJT's

1) switching
   - analog (e.g. "power MOSFETs" can drive ~kW loads)
   - digital (e.g. complimentary MOS = "CMOS" digit. family) — LM Ch. 8

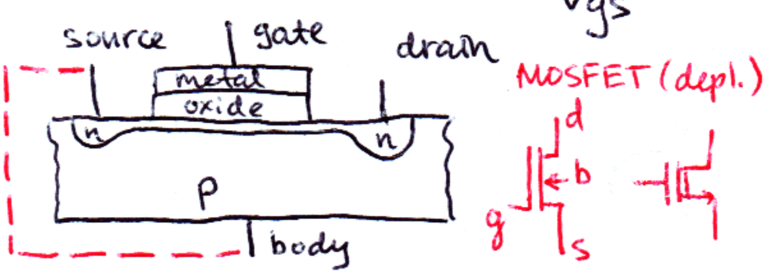
2) amplifiers
   - common (drain, source, gate)
   - differential amplifier

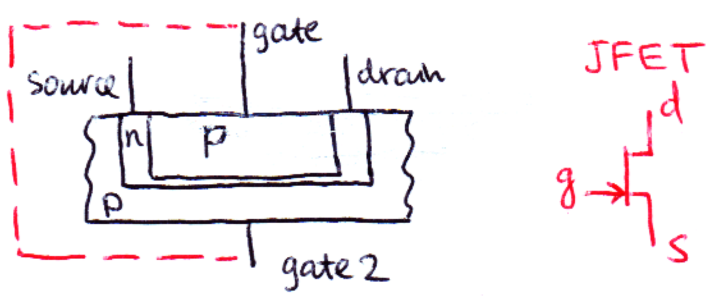
   } like ~ BJT's

FET variants



- depletion n-chan. MOSFET — $V_{gs} = 0$, then n-channel ON
- junction FET (JFET)





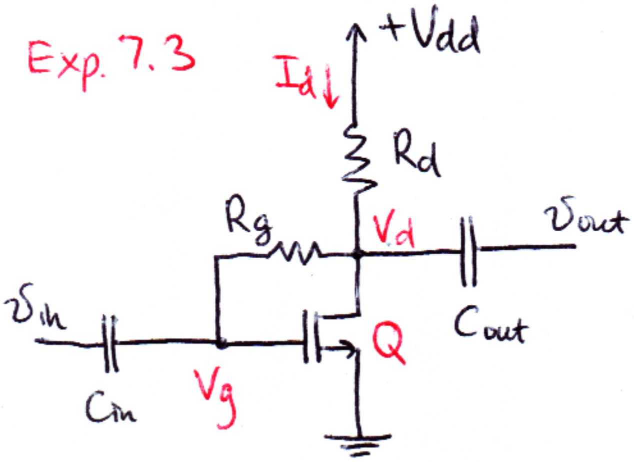
MOSFET pros & cons (vs BJT's)

+ Z_{in} ~ huge
+ better rad. hardness
+ less T dep.

− more distortions
− Q-pt depends on K, V_T

MOSFET analysis example

Exp. 7.3



Q: what amp. configuration?

A: common source

Suggestions in the LM

$V_{dd} = +5V$

$R_d = 270\,\Omega$

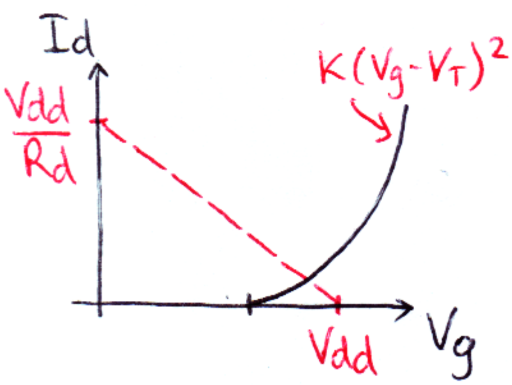
$R_g \sim 1M\Omega$

– This biasing is called "self-bias", and R_g – "bias resistor"

Q: why? A: No current thru R_g, $\Rightarrow V_d|_{Q\text{-}pt} = V_g|_{Q\text{-}pt}$

① Find Q-pt.

$$\left.\begin{aligned} I_d &= K(V_g - V_T)^2 \\ I_d &= \frac{V_{dd} - V_g}{R_d} \end{aligned}\right\} \text{ can solve for } I_d, V_g$$



– for "large" K, $V_g|_{Q\text{-}pt} \gtrsim V_T$

typical $K \simeq 100\,\frac{mA}{V^2}$, $V_T \sim 2V$

(varies from trans. to trans. but not so much with temperature)

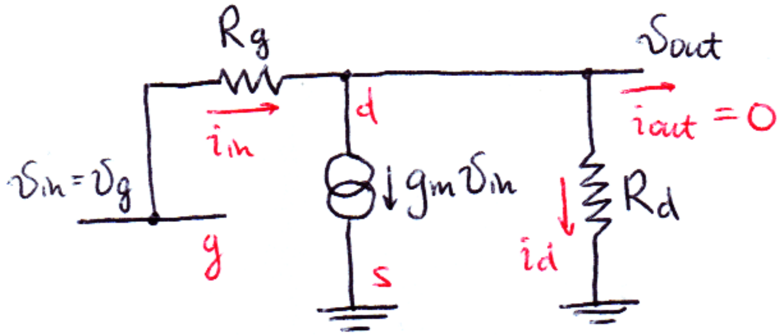
Approximately (too lazy to solve quadr. equ.)

$$V_g \simeq V_T \;:\; I_d = \frac{5V - 2V}{270\,\Omega} \approx 11\,mA$$

$$g_m \equiv \left.\frac{\partial I_d}{\partial V_{gs}}\right|_{Q\text{-}pt} = 2\sqrt{K I_d|_{Q\text{-}pt}}$$

$$g_m = 2\sqrt{100\,\frac{mA}{V^2} \cdot 11\,mA} = 0.065\,\Omega^{-1} = (15\,\Omega)^{-1}$$

(2) small-signal equivalent



KVL & KCL:

$$i_{in} = \frac{v_{in} - v_{out}}{R_g} = g_m v_{in} + \underbrace{i_d}_{\frac{v_{out}}{R_d}}$$

$$v_{in}\left(\frac{1}{R_g} - g_m\right) = \frac{v_{out}}{R_d \| R_g}$$

$$G = \frac{v_{out}}{v_{in}} = R_d \| R_g \left(\frac{1}{R_g} - g_m\right), \text{ using } R_g \gg R_d \quad G \approx -g_m \cdot R_d$$

$$G = -(15\Omega)^{-1}(270\Omega) = -18$$

input impedance: $R_{in} = \frac{v_{in}}{i_{in}} = \frac{v_{in} \cdot R_g}{v_{in} - v_{out}} = R_g \frac{1}{1-G} \approx 53k\Omega$

output impedance: $R_{out} = \frac{v_{out}}{i_{out,sc}} = \frac{v_{out}}{\frac{v_{in}}{R_g} - g_m v_{in}} = \frac{G}{\frac{1}{R_g} - g_m} \approx \underset{R_d}{270\Omega}$

choosing caps:

$|Z_{C_{in}}| \ll R_{in}$, $|Z_{C_{out}}| \ll R_{out}$

E.g. for 1kHz sine wave:

$C_{in} \gg 0.003\mu F$, e.g. $C_{in} \approx 0.1\mu F$

$C_{out} \gg 0.59\mu F$, e.g. $C_{out} \approx 20\mu F$

1) Build LTspice circuit (2N7000)
2) perform Q-pt analysis (.op)
3) transient analysis (.tran)
4) ac small signal

} check gain. why different?

$K \sim 300 mA/V^2$
$V_T \sim 3V$
} LTspice 2N7000