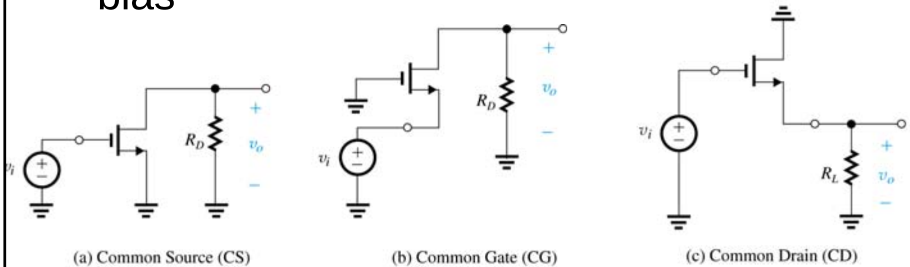
MOSFET Amplifier Configuration

- Single stage
- The signal is fed to the amplifier represented as v_{sig} with an internal resistance R_{sig}.
- MOSFET is represented by its small signal model.
- Generally interested in gain, input and output resistance (overall amplifier circuit not only the small signal model).

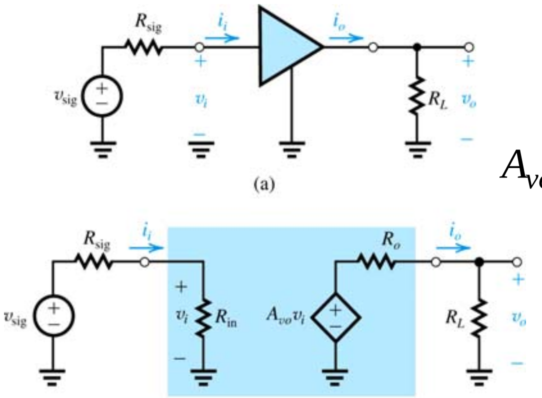
MOSFET Amplifier Configuration

- Considering only the small signal not the bias



Characterizing Amplifiers

- Find gain, input and output resistance



(a)

(b)

$$R_{in} = \frac{v_i}{i_i}$$

$$A_{vo} = \left.\frac{v_o}{v_i}\right|_{R_L=\infty}, A_v = \frac{v_o}{v_i}$$

$$G_v = \frac{v_o}{v_{sig}}$$ Overall voltage gain

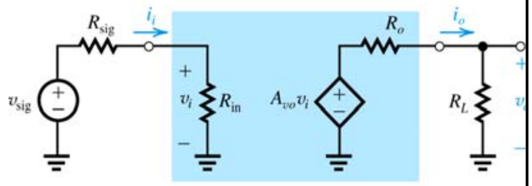
Amplifier Configuration

- Common Source
- Common Source with a source resistance
- Common gate
- Common drain or voltage follower

Amplifiers

$$v_o = A_{vo} v_i \frac{R_L}{R_L + R_o}$$

$$v_i = v_{sig} \frac{R_{in}}{R_{in} + R_{sig}}$$



(b)

$$A_v = A_{vo} \frac{R_L}{R_L + R_o}$$

$$G_v = \frac{v_o}{v_{sig}} = \frac{R_{in}}{R_{in} + R_{sig}} A_{vo} \frac{R_L}{R_L + R_o}$$

Common Source

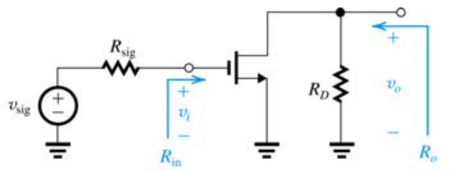
- Most widely used configuration
- In multistage amplifiers, the bulk of the gain is from common source.
- The source is grounded, making it common between input and output.
- We can use hybrid π model.

Common Source

For R_o, set v_i=0

$$R_o = r_0 \parallel R_D$$

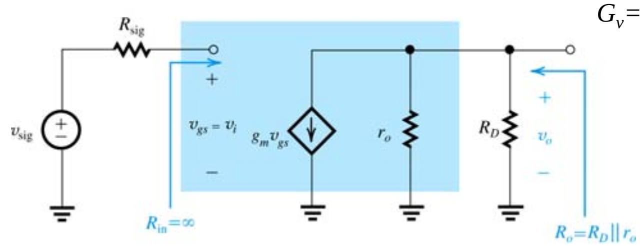
$$A_{vo} = -g_m(r_0 \parallel R_D)$$



$$R_i = \infty$$

(a)

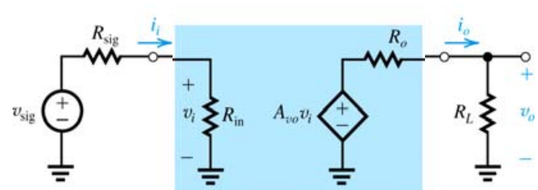
A_V= ?
G_v=?



(b)

Example

CS at I_D=0.25 mA, V_{OV}=0.25V, R_D=20k Ω,
Signal source has a resistance of 100KΩ, and 20K Ω load
Find:
R_{in}, A_{vo}, R_o, A_v, and G_v

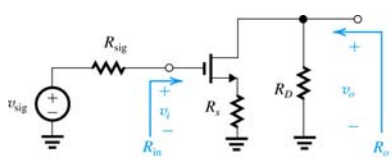


(b)

Common Source with Source R

- For simplicity, r_0 is not included.
- No effect on discrete implementation, not so for IC's
- R_s provides a negative feedback to control the magnitude of the signal to prevent nonlinear distortion.
- Also reduces the voltage gain and extends the useful bandwidth.

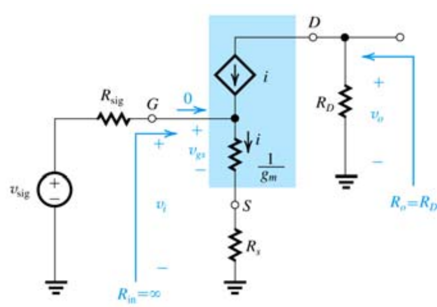
Common Source with Source R



(a)

$$v_{gs} = v_i \frac{1/g_m}{1/g_m + R_S}$$

$$v_{gs} = \frac{v_i}{1 + g_m R_S}$$

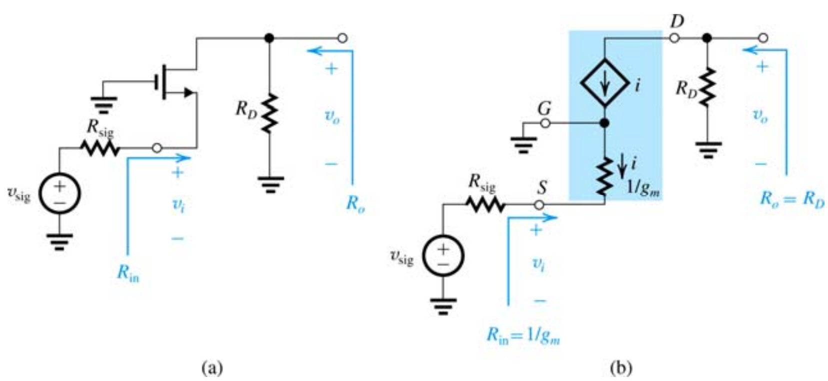


(b)

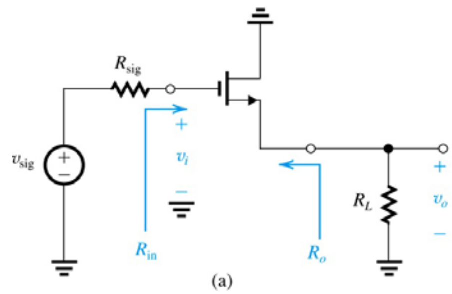
Example

In the previous example, vin=50 mV, the output was 1V
Now, we have vsig = 0.2V, we want to modify the circuit to keep vgs unchanged, what value we should use for Rs

Common Gate Amplifier

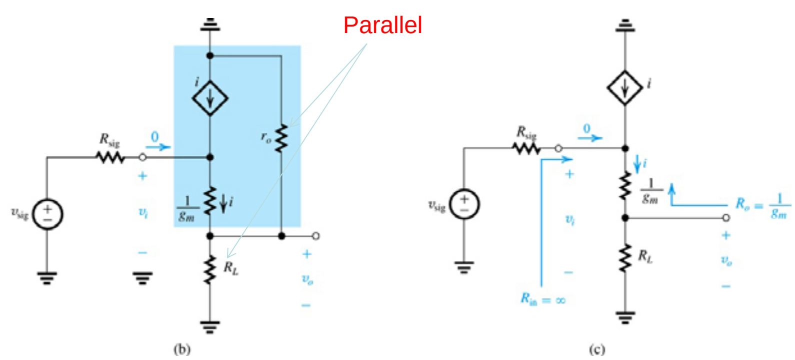


Common Drain Amplifier – Voltage Follower



Since there is a resistance RL connected to the source, it is easier to use the T-model

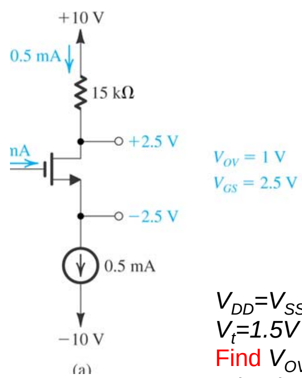
Common Drain– Voltage Follower

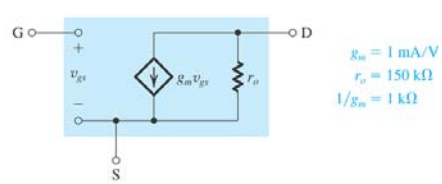


$R_i = \infty$

Comparison

	CS	CS+RS	CG	CD
Rin	∞	∞	$\frac{1}{g_m}$	∞
Rout	RD || ro	R_D	R_D	$1/g_m$
G	$-g_m(R_D \|\| R_L \|\| r_o)$	$A_v = \frac{g_m(R_D \|\| R_L)}{1+g_m R_s}$	$G_v = \frac{(R_D \|\| R_L)}{1/g_m + R_{sis}}$	$G_v = A_v = \frac{R_L}{1/g_m + R_L}$



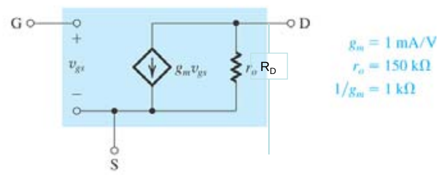


V_{DD}=V_{SS}=10V, I=0.5 mA, R_G=4.7MΩ, R_D=15K Ω, V_t=1.5V k_n=1mA/V^2 V_A=75V

Find *V_{OV}, V_{GS}, V_G, V_S, V_D, g_m, r_o*

What is the max. possible voltage swing at drain and the MOSFET remains in saturation?

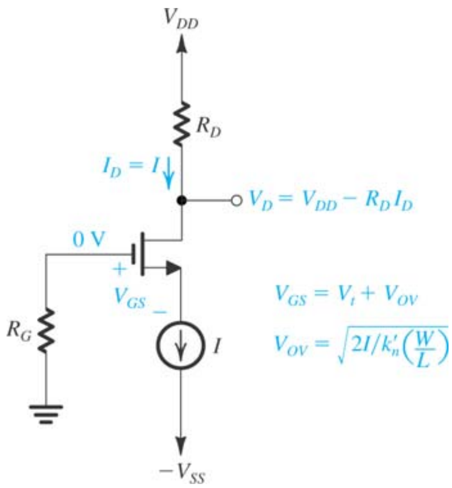
Find R_{in}, A_{vo}, R_o, G_v, *with and without* r_o R_{sig}=100KΩ and R_L = 15 KΩ



Discrete CMOS Amplifiers

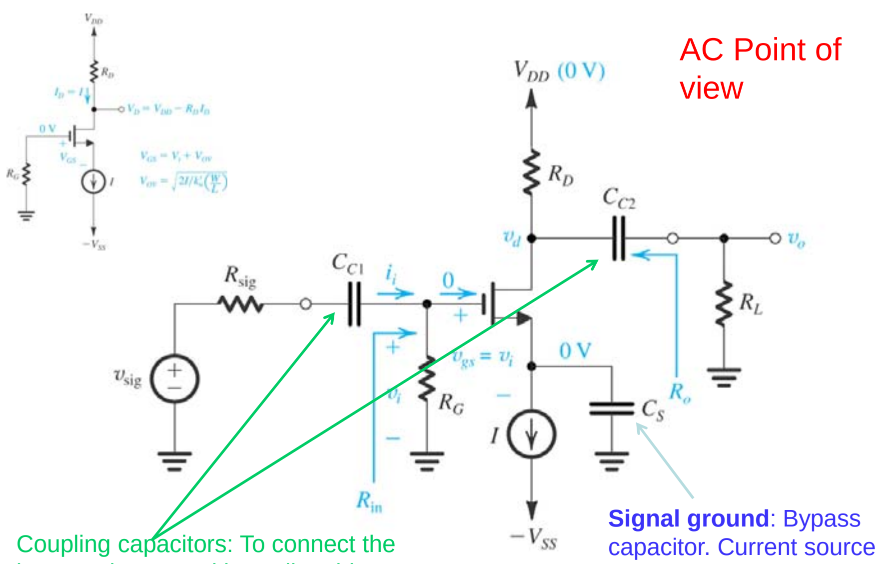
- MOS are mostly used in IC's
- However, we present practical circuits for discrete implementation.
- Good if you are building a circuit on a breadboard (in the lab).

Common Source



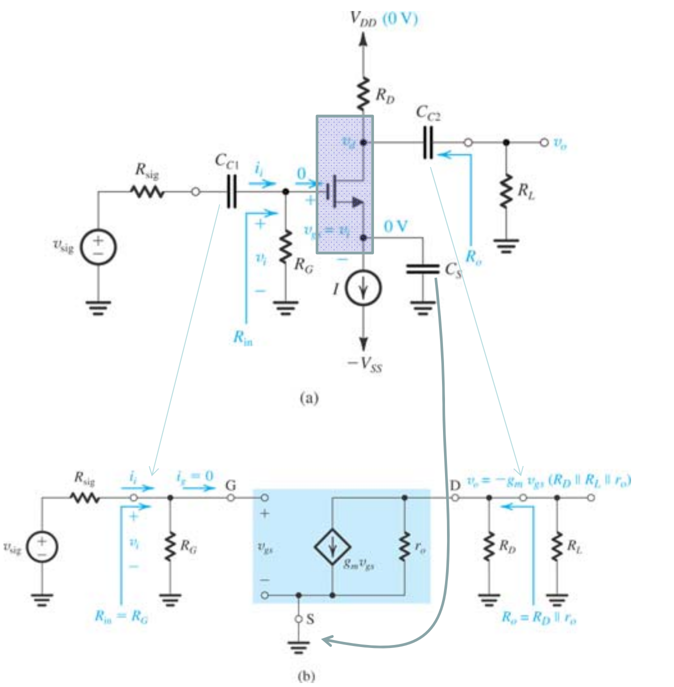
- DC Analysis
- Can use any biasing technique we studied
- Calculate the bias (Q) point

AC Point of view

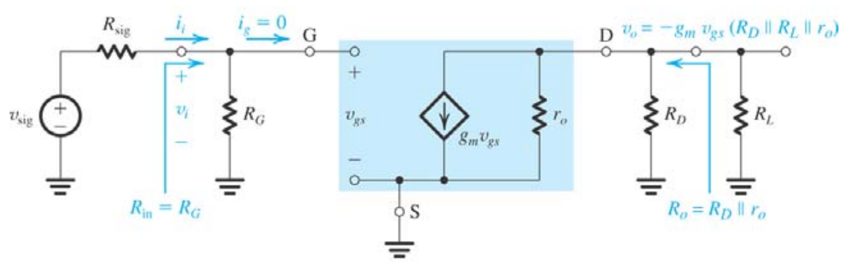


Coupling capacitors: To connect the input and output without disturbing the bias.
C is large enough to have very low (zero) impedance at signal frequency.

Signal ground: Bypass capacitor. Current source is an open circuit, provide a path to ground (source is ground for signal).

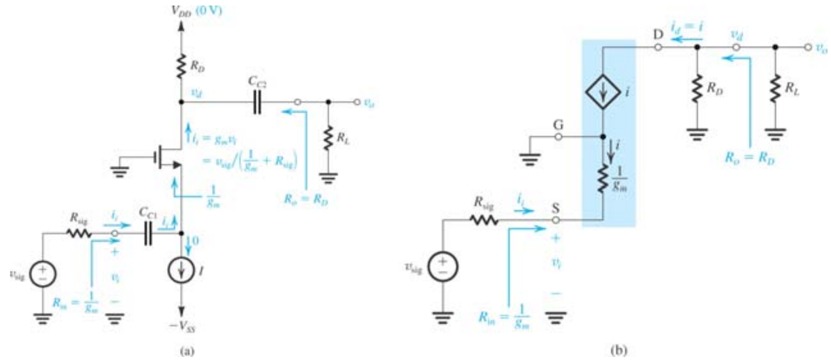


Time
varying
(signal)



(b)

Common Gate



Voltage Follower

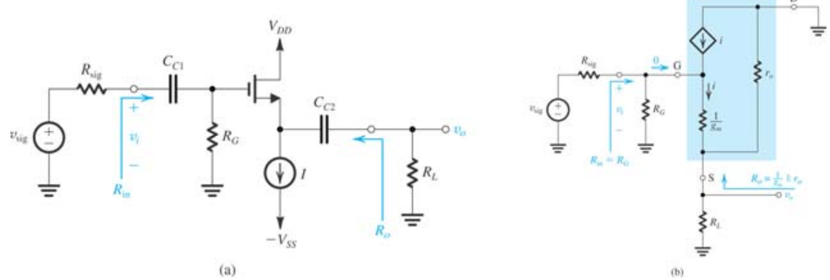


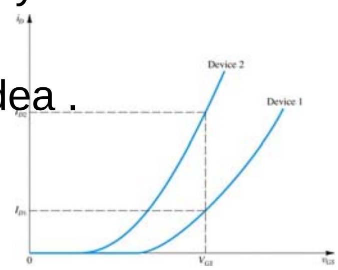
Figure 5.60 (a) A source-follower amplifier. (b) Small-signal, equivalent-circuit model.

Biasing in MOS Amplifiers

- How to choose the operating point?
- Want a stable Q-point (known I_D and V_{DS}) to ensure operation in the saturation region.

Biasing -- Fixing V_{GS}

- I_D depends on μ, C_{ox}, W/L and V_t, and V_{GS}
- C_{ox}, V_{GS} (even W/L) can vary across devices of the same type.
- Constant V_{GS} Not a good idea .
- μ,C_{ox} are a f(t)



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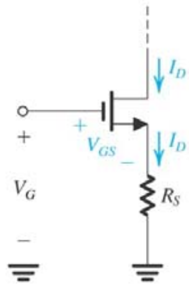
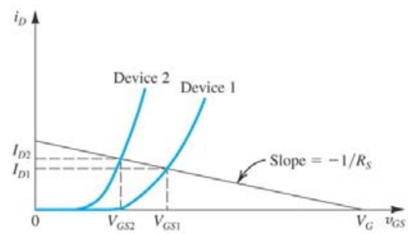
Biasing – Fixing V_G and R_S

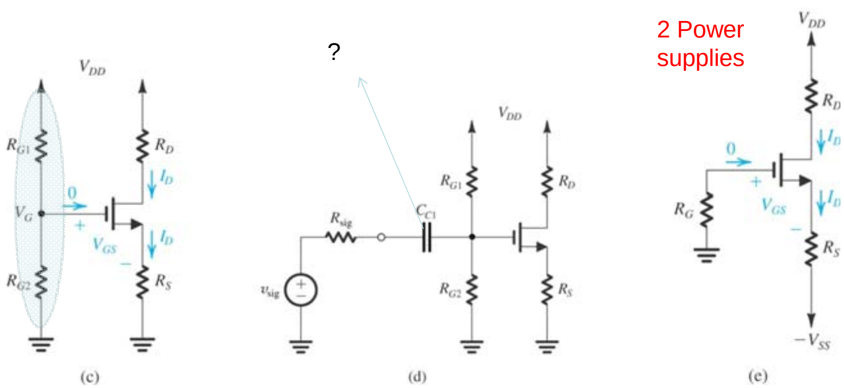
- R_S provides a negative feedback to stabilize I_D





Biasing – Fixing V_G and R_S

- Uses one power supply
- What is the effect on input resistance when you add v_{gs} signal



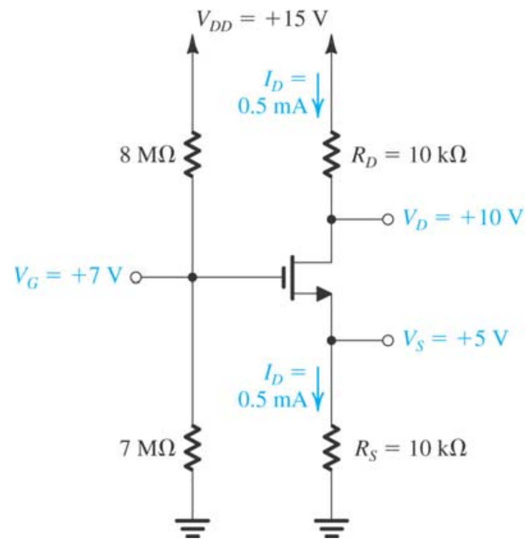
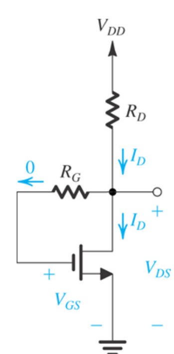


Figure 5.53 Circuit for Example 5.12.

Biasing – D-to-G Resistor

- $V_{GS} = V_{DS} = V_{DD} - I_D R_D$
- $V_{DD} = V_{GS} + I_D R_D$
- Provides a feedback resistor to Stabilize I_D



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Biasing – Constant Current Source

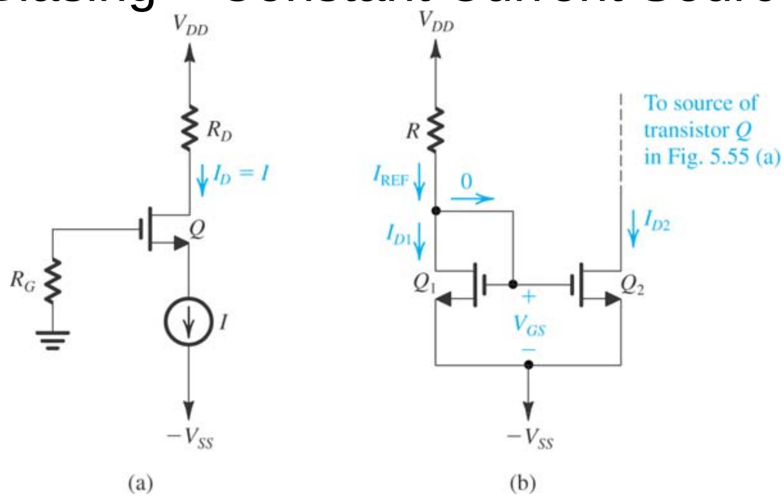

Figure 5.55 (a) Biasing the MOSFET using a constant-current source *I*. (b) Implementation of the constant-current source *I* using a current mirror.

Frequency Response