



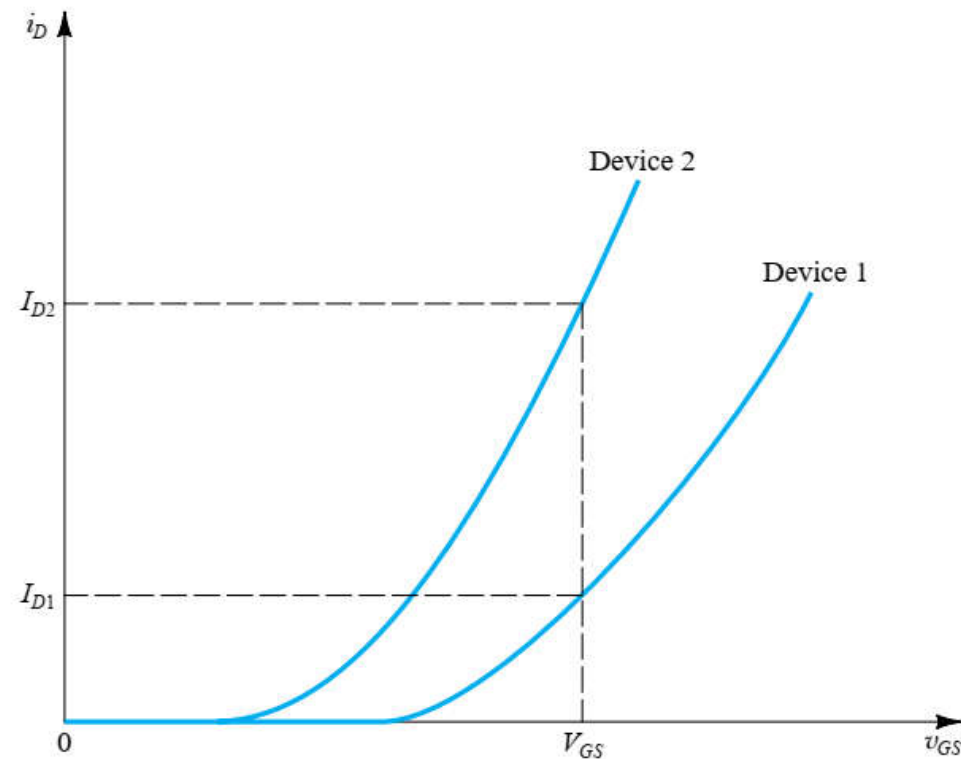
Electronic Principles and Circuits / BEC303

Module-2

Biassing in MOS amplifier circuits: Fixing V_{GS} , Fixing V_G , Drain to Gate feedback resistor. Small signal operation and modelling: The DC bias point, signal current in drain, voltage gain, small signal equivalent circuit models, transconductance, The T equivalent circuit model. MOSFET Amplifier configuration: Basic configurations, characterizing amplifiers, CS amplifier with and without source resistance, The Common Gate Amplifier, Source follower

Biasing in MOS Amplifier Circuits

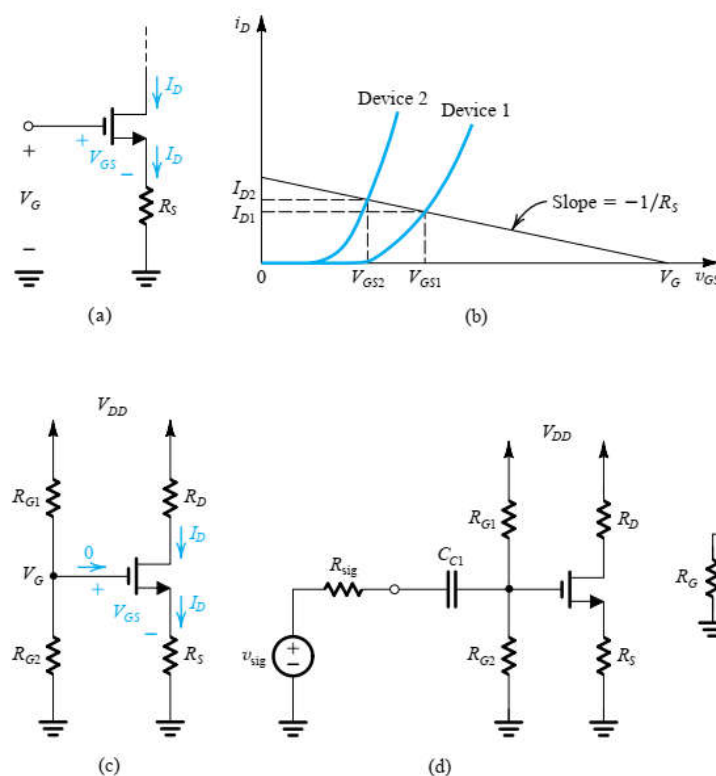
Biasing by Fixing V_{GS}



The use of fixed bias (constant V_{GS}) can result in a large variability in the value of I_D . Devices 1 and 2 represent extremes among units of the same type.

Biassing in MOS Amplifier Circuits

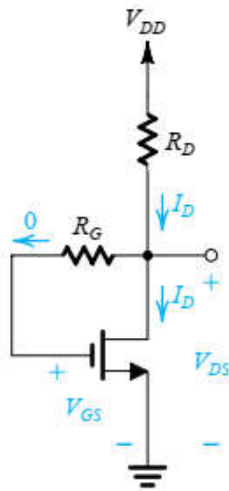
Biassing by Fixing V_G and Connecting a Resistance in the Source



Biassing using a fixed voltage at the gate, V_G , and a resistance in the source lead, R_S : (a) basic arrangement;
 (b) reduced variability in I_D ;
 (c) practical implementation using a single supply;
 (d) coupling of a signal source to the gate using a capacitor C_{C1} ;
 (e) practical implementation using two supplies

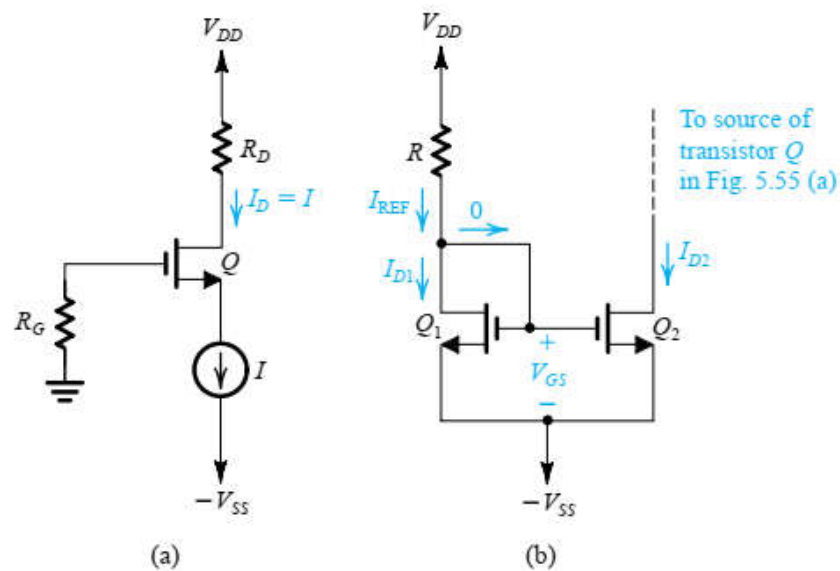
Biasing in MOS Amplifier Circuits

Biasing Using a Drain-to-Gate Feedback Resistor



Biasing in MOS Amplifier Circuits

Biasing Using a Constant-Current Source



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

Small-Signal Operation and Models

The DC Bias Point

The dc bias current I_D can be found by setting the signal v_{gs} to zero; thus,

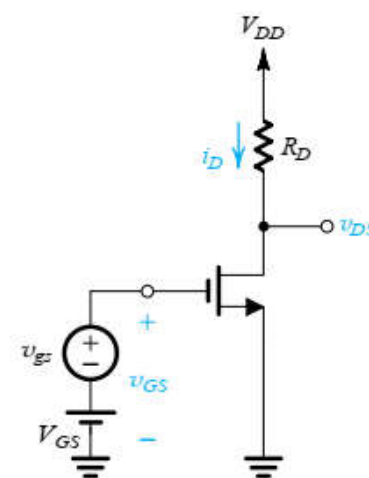
$$I_D = \frac{1}{2} k_n (V_{GS} - V_t)^2 = \frac{1}{2} k_n V_{OV}^2$$

voltage at the drain, V_{DS} , will be

$$V_{DS} = V_{DD} - R_D I_D$$

To ensure saturation-region operation, we must have

$$V_{DS} > V_{OV}$$



Conceptual circuit utilized to study the operation of the MOSFET as a small-signal amplifier

Small-Signal Operation and Models

The Signal Current in the Drain Terminal

The total instantaneous gate-to source voltage will be

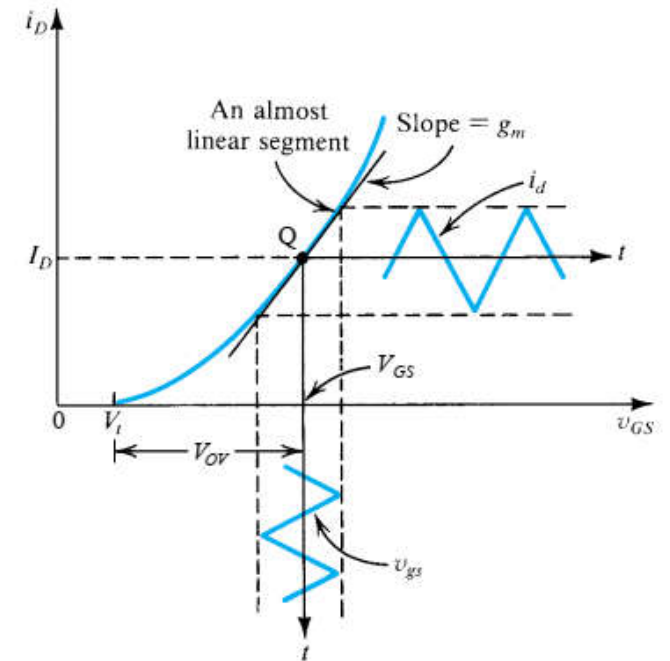
$$v_{GS} = V_{GS} + v_{gs}$$

resulting in a total instantaneous drain current i_D

$$\begin{aligned} i_D &= \frac{1}{2} k_n (V_{GS} + v_{gs} - V_t)^2 \\ &= \frac{1}{2} k_n (V_{GS} - V_t)^2 + k_n (V_{GS} - V_t) v_{gs} + \frac{1}{2} k_n v_{gs}^2 \end{aligned}$$

To reduce the nonlinear distortion introduced by the MOSFET, the input signal should be kept so small that

$$\frac{1}{2} k_n v_{gs}^2 \ll k_n (V_{GS} - V_t) v_{gs}$$



Small-Signal Operation and Models

The Signal Current in the Drain Terminal

resulting in

$$v_{gs} \ll 2(V_{GS} - V_t)$$

or, equivalently,

$$v_{gs} \ll 2V_{OV}$$

If this small-signal condition is satisfied

$$i_D \doteq I_D + i_d$$

$$i_d = k_n (V_{GS} - V_t) v_{gs}$$

The parameter that relates i_d and v_{gs} is the MOSFET **transconductance** g_m ,

$$g_m \equiv \frac{i_d}{v_{gs}} = k_n (V_{GS} - V_t)$$

or in terms of the overdrive voltage V_{OV} ,

$$g_m = k_n V_{OV}$$

Small-Signal Operation and Models

The Voltage Gain

the total instantaneous drain voltage v_{DS} as follows:

$$v_{DS} = V_{DD} - R_D i_D$$

Under the small-signal condition, we have

$$v_{DS} = V_{DD} - R_D (I_D + i_d)$$

which can be rewritten as

$$v_{DS} = V_{DS} - R_D i_d$$

Thus the signal component of the drain voltage is

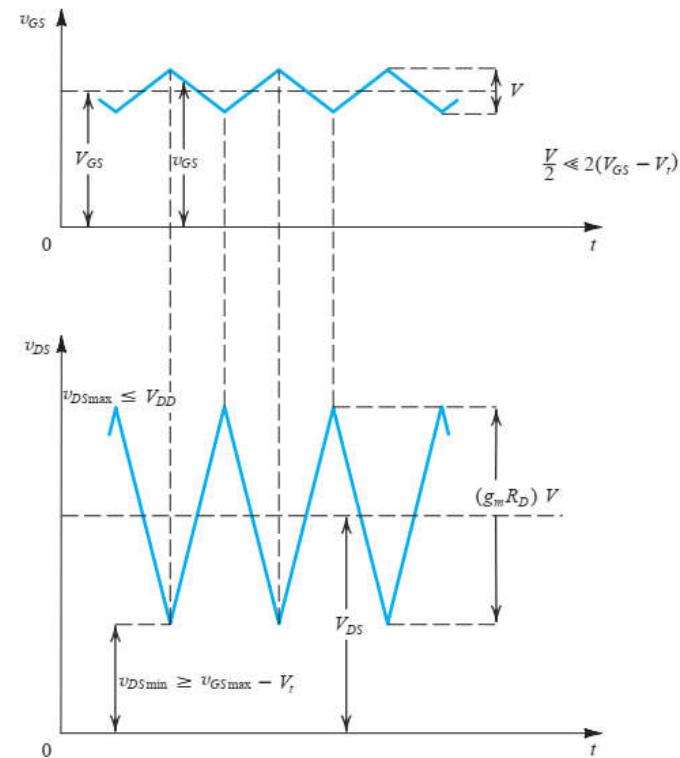
$$v_{ds} = -i_d R_D = -g_m v_{gs} R_D$$

which indicates that the voltage gain is given by

$$A_v \equiv \frac{v_{ds}}{v_{gs}} = -g_m R_D$$

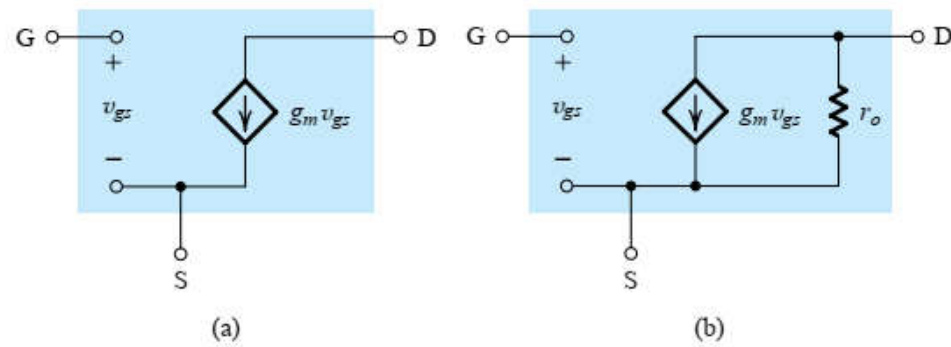
Small-Signal Operation and Models

Separating the DC Analysis and the Signal Analysis



Small-Signal Operation and Models

Small-Signal Equivalent-Circuit Models



Small-Signal Operation and Models

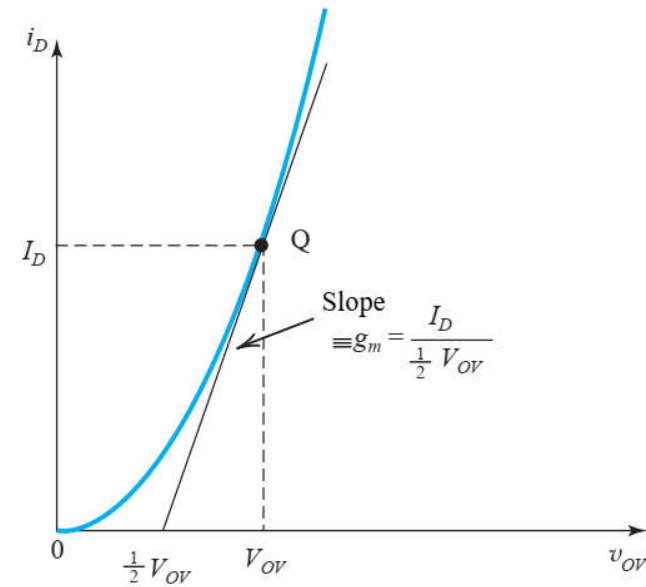
The Transconductance g_m

We shall now take a closer look at the MOSFET transconductance given by

$$g_m = k'_n (W/L) (V_{GS} - V_t) = k'_n (W/L) V_{OV}$$

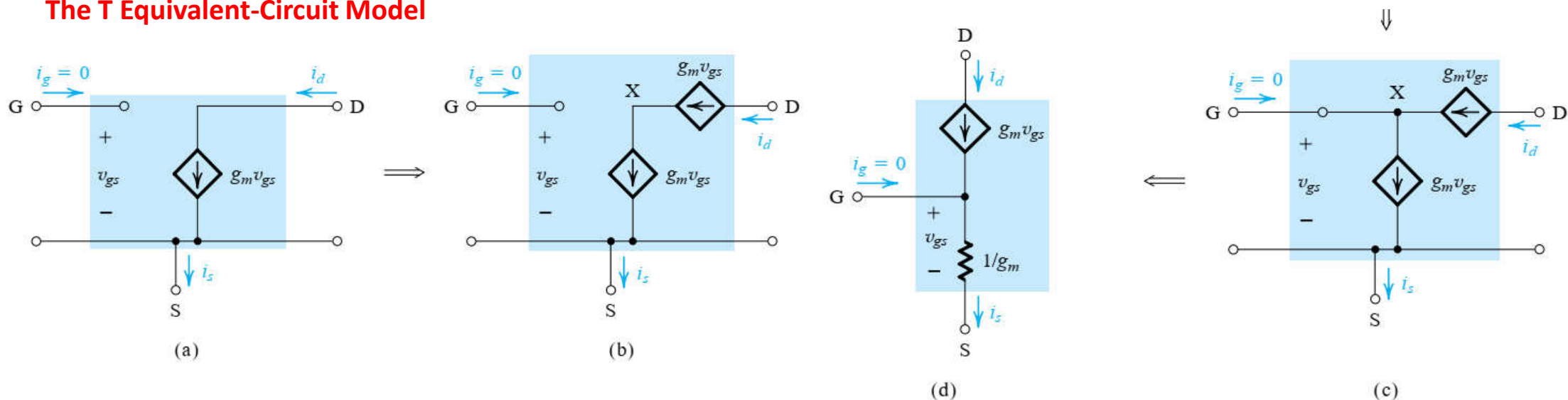
$$g_m = \sqrt{2k'_n} \sqrt{W/L} \sqrt{I_D}$$

$$g_m = \frac{2I_D}{V_{GS} - V_t} = \frac{2I_D}{V_{OV}}$$



Small-Signal Operation and Models

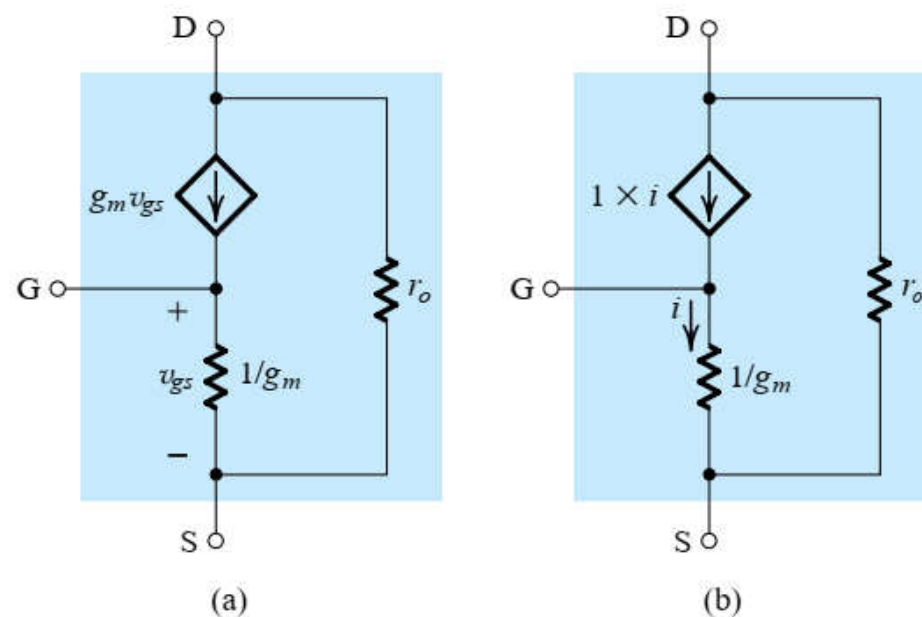
The T Equivalent-Circuit Model



Development of the T equivalent-circuit model for the MOSFET. For simplicity, r_o has been omitted; however, it may be added between D and S in the T model of (d).

Small-Signal Operation and Models

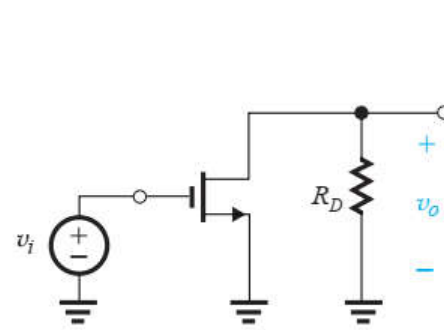
The T Equivalent-Circuit Model



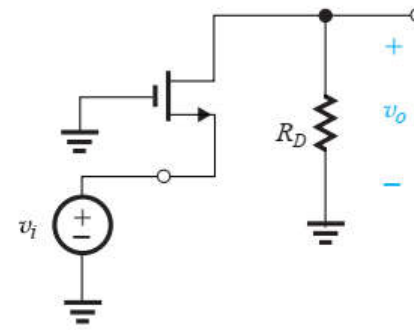
- (a) The T model of the MOSFET augmented with the drain-to-source resistance r_o .
- (b) An alternative representation of the T model

Basic MOSFET Amplifier Configurations

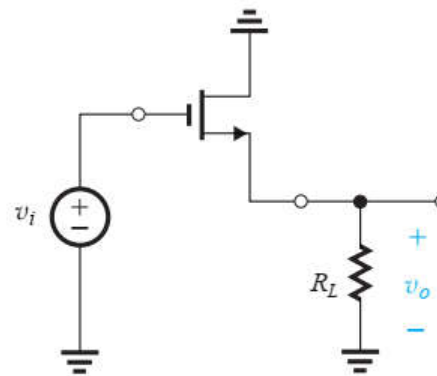
The Three Basic Configurations



(a) Common Source (CS)



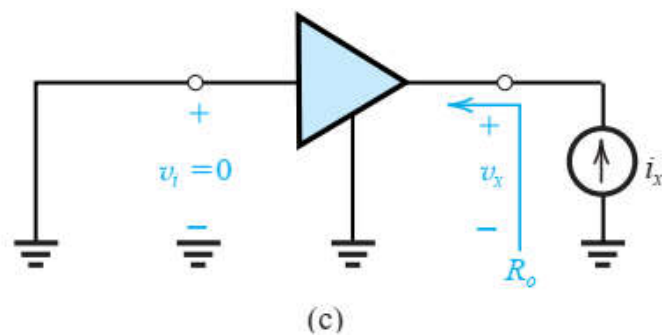
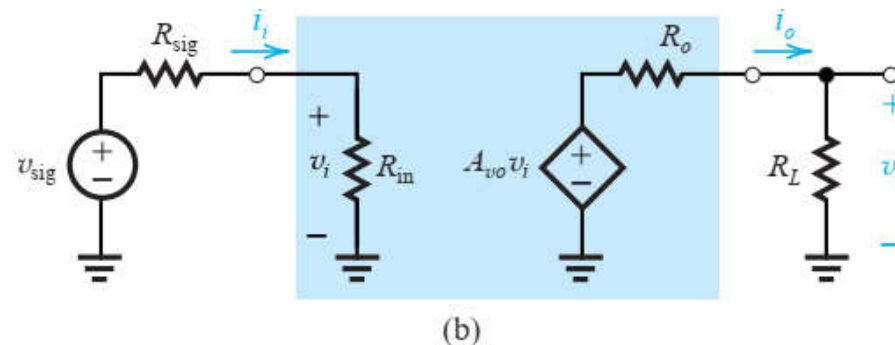
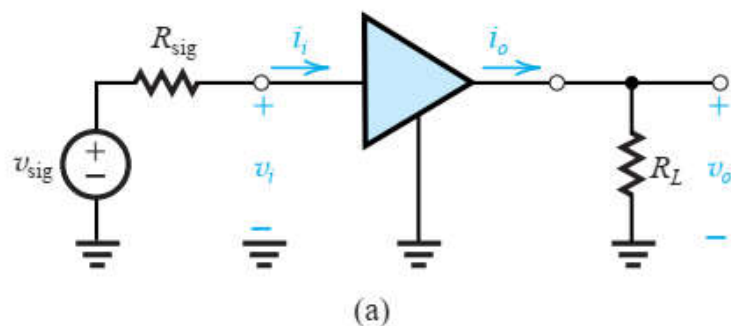
(b) Common Gate (CG)



(c) Common Drain (CD)

Basic MOSFET Amplifier Configurations

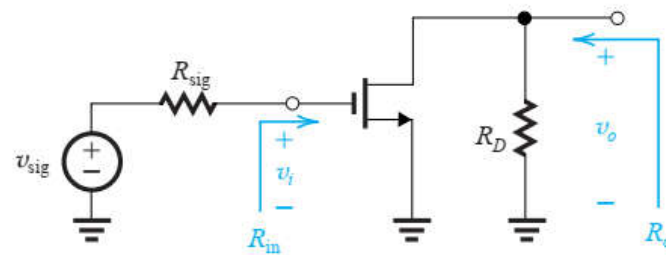
Characterizing Amplifiers



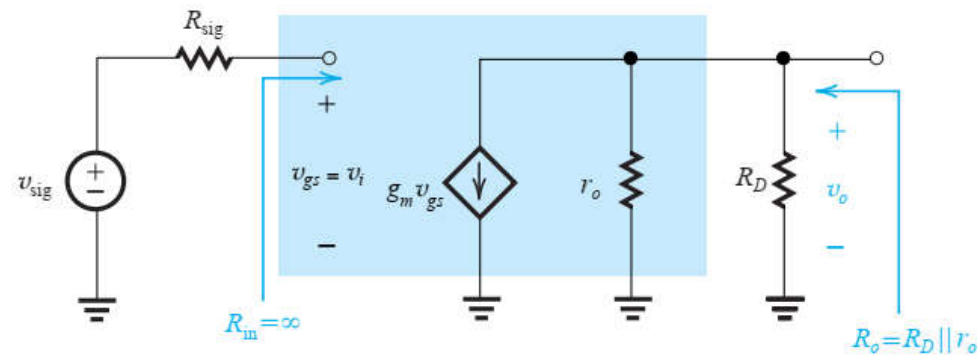
Characterization of the amplifier as a functional block: (a) An amplifier fed with a voltage signal v_{sig} having a source resistance R_{sig} , and feeding a load resistance R_L ; (b) Equivalent-circuit representation of the circuit in (a); (c) Determining the amplifier output resistance R

Basic MOSFET Amplifier Configurations

The Common-Source (CS) Amplifier



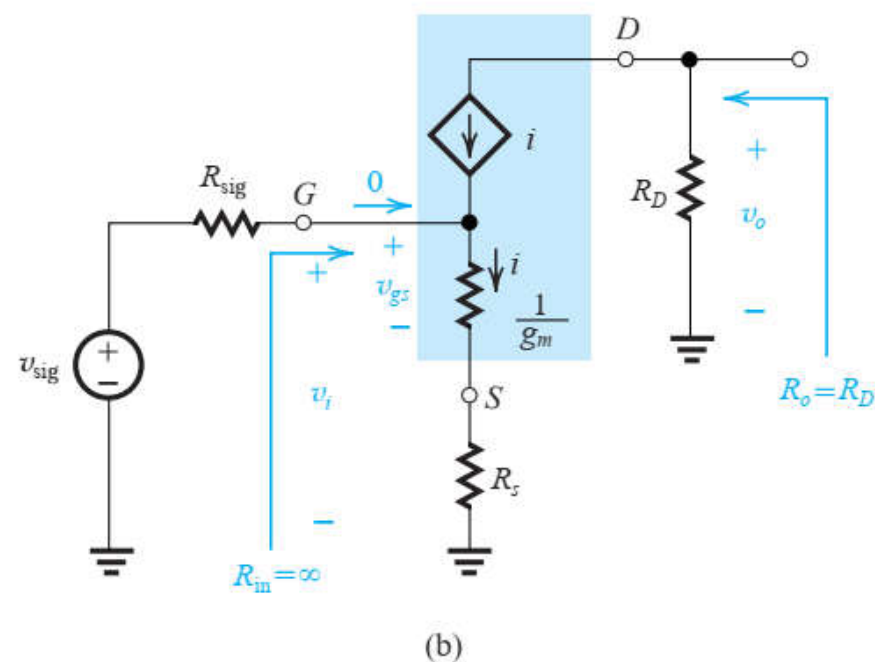
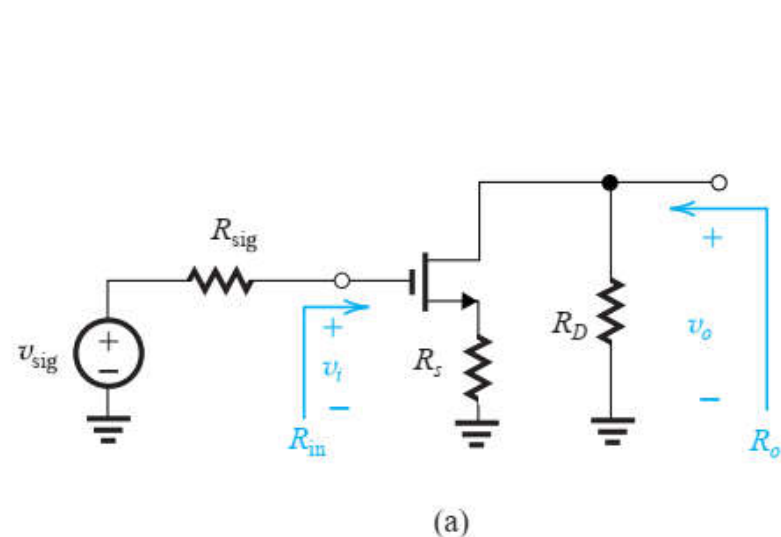
(a)



(b)

Basic MOSFET Amplifier Configurations

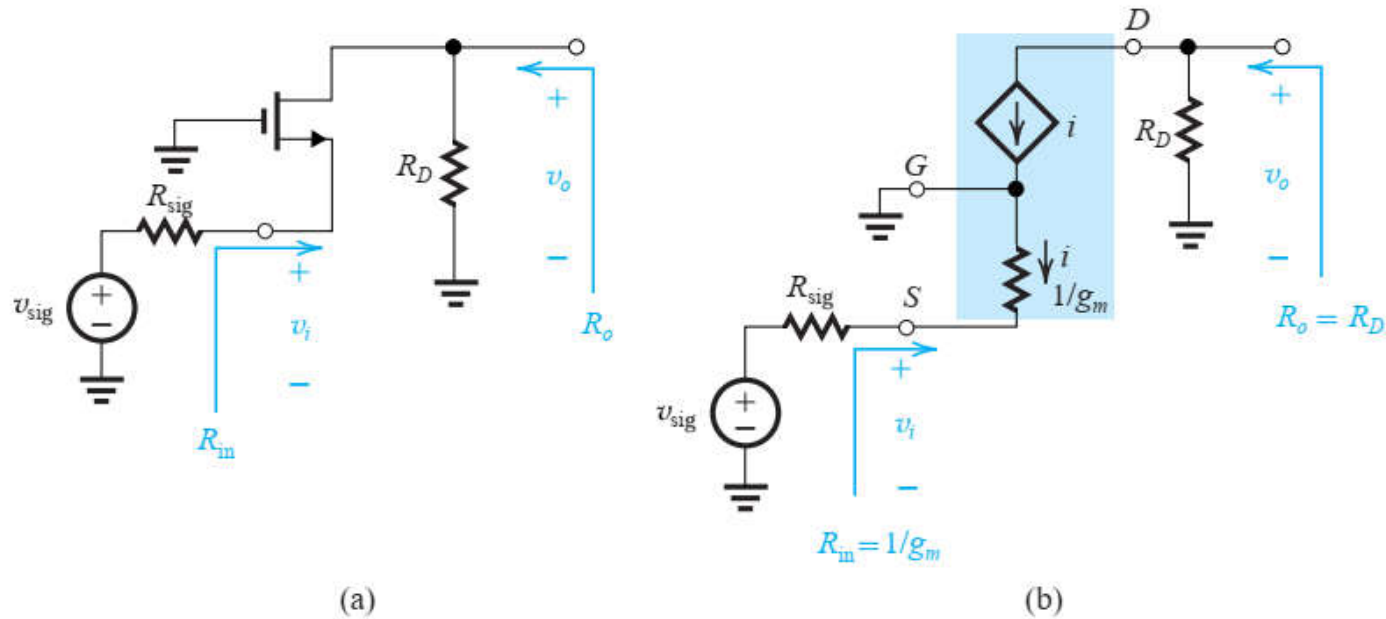
The Common-Source Amplifier with a Source Resistance



The CS amplifier with a source resistance R_s : (a) Circuit without bias details; (b) Equivalent circuit with the MOSFET represented by its T model.

Basic MOSFET Amplifier Configurations

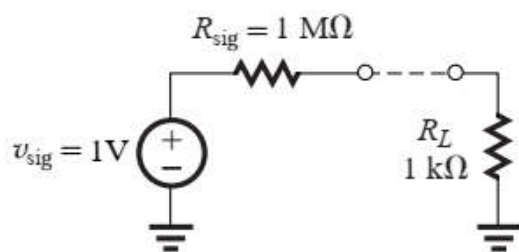
The Common-Gate (CG) Amplifier



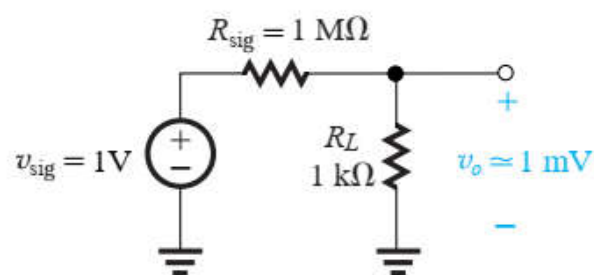
(a) Common-gate (CG) amplifier with bias arrangement omitted. (b) Equivalent circuit of the CG amplifier with the MOSFET replaced with its T model.

Basic MOSFET Amplifier Configurations

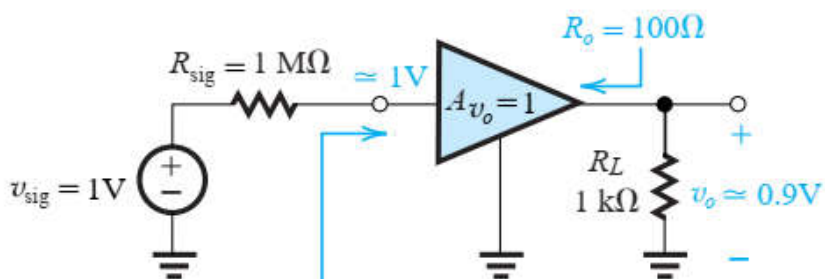
The Common-Drain Amplifier or Source Follower



(a)



(b)

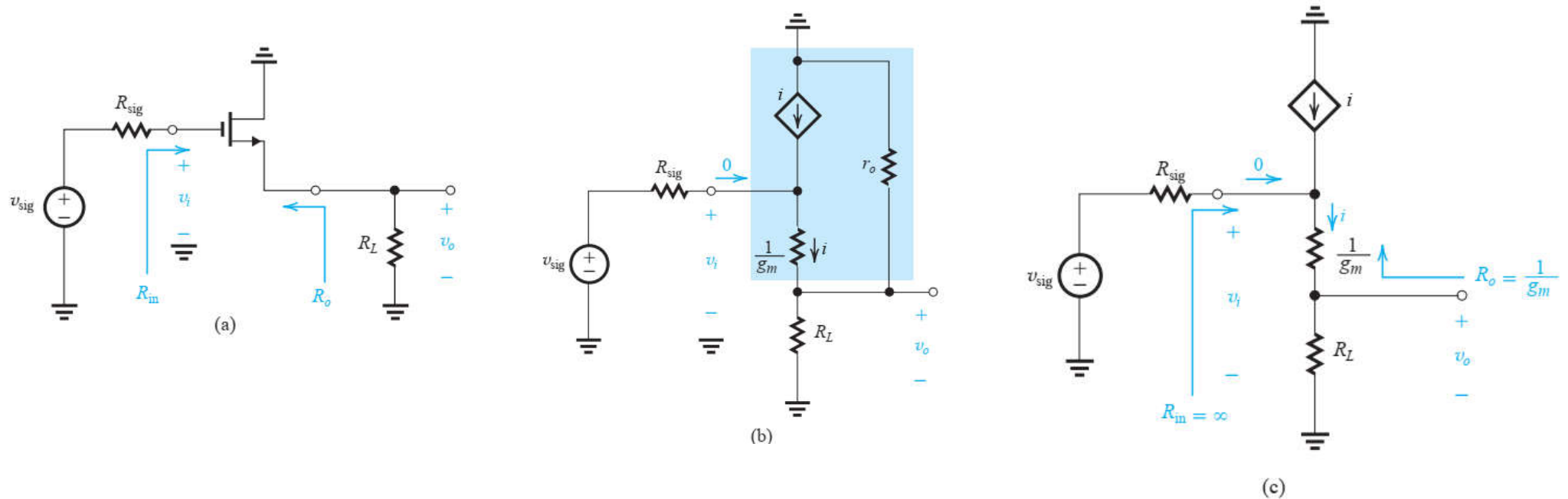


R_{in} very large

(c)

Basic MOSFET Amplifier Configurations

The Common-Drain Amplifier or Source Follower



(a) Common-drain amplifier or source follower. (b) Equivalent circuit of the source follower obtained by replacing the MOSFET with its T model. Note that r_o appears in parallel with R_L and in discrete circuits, $r_o \parallel R_L$. Neglecting r_o , we obtain the simplified equivalent circuit in (c)

Basic MOSFET Amplifier Configurations

Amplifier type	Characteristics ^{a, b}				
	R_{in}	A_{vo}	R_o	A_v	G_v
Common source (Fig. 5.45)	∞	$-g_m R_D$	R_D	$-g_m(R_D \parallel R_L)$	$-g_m(R_D \parallel R_L)$
Common source with R_s (Fig. 5.47)	∞	$-\frac{g_m R_D}{1 + g_m R_s}$	R_D	$-\frac{g_m(R_D \parallel R_L)}{1 + g_m R_s}$	$-\frac{g_m(R_D \parallel R_L)}{1 + g_m R_s}$
				$-\frac{R_D \parallel R_L}{1/g_m + R_s}$	$-\frac{R_D \parallel R_L}{1/g_m + R_s}$
Common gate (Fig. 5.48)	$\frac{1}{g_m}$	$g_m R_D$	R_D	$g_m(R_D \parallel R_L)$	$\frac{R_D \parallel R_L}{R_{sig} + 1/g_m}$
Source follower (Fig. 5.50)	∞	1	$\frac{1}{g_m}$	$\frac{R_L}{R_L + 1/g_m}$	$\frac{R_L}{R_L + 1/g_m}$