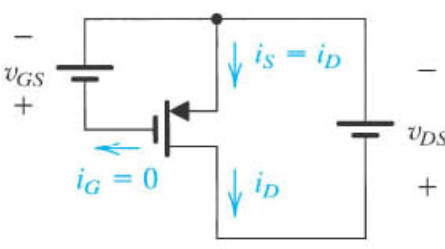
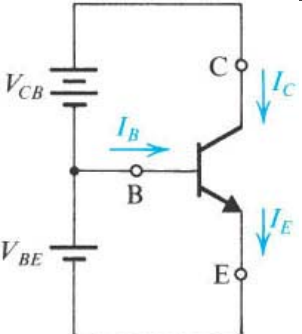
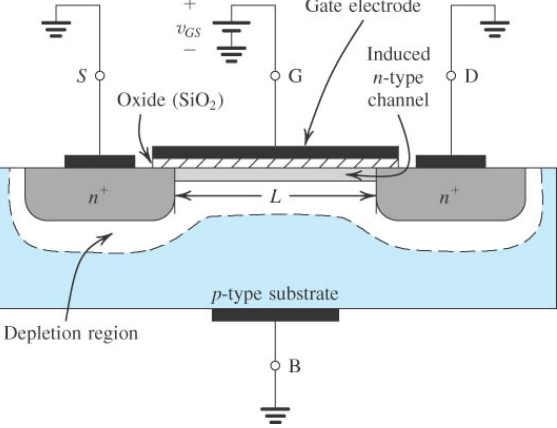
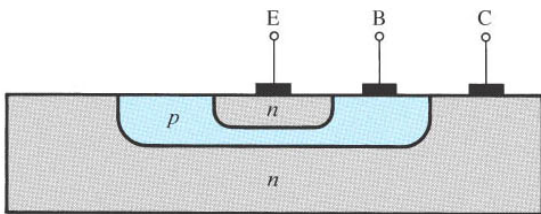


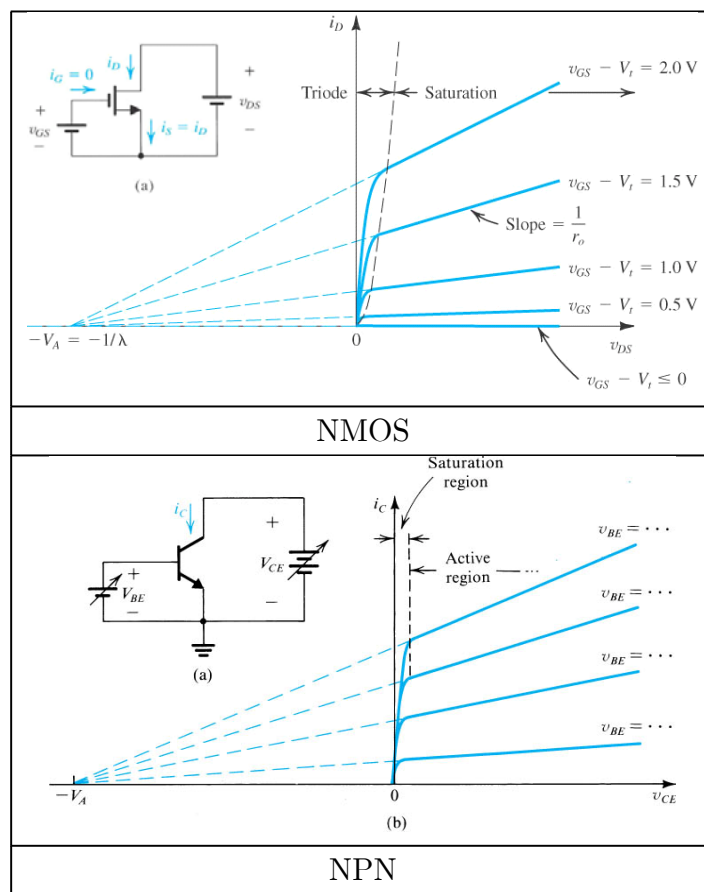
Comparisons of BJT and MOSFET

8.1 NMOS and NPN Transistors

- Circuit symbols and physical structures
 - NMOS has symmetric structure for drain and source.
 - NPN has asymmetric structure for collector and emitter.
- Current
 - NMOS: current flows from drain to source.
 - NPN: current flows from collector to emitter.
- Voltage
 - NMOS: $v_D > v_S$, $v_G > v_S$.
 - NPN: $v_B > v_E$, $v_C > v_E$.

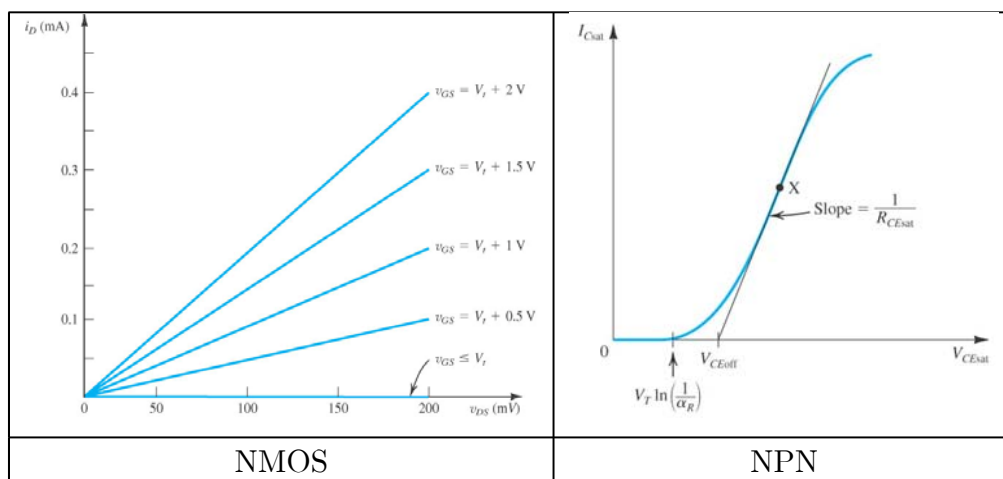
	
NMOS	NPN
	
NMOS	NPN

- $i_D - v_{DS}$ (common source) v.s. $i_C - v_{CE}$ (common emitter)



8.1.1 NMOS Triode v.s. NPN Saturation

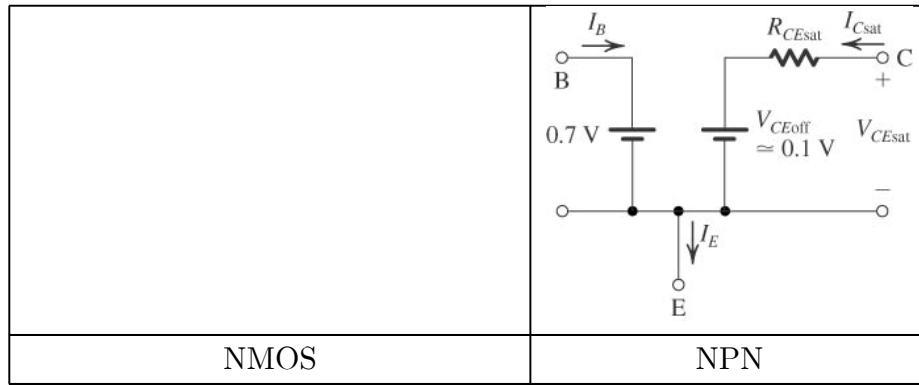
- NMOS Triode $i_D - v_{DS}$ v.s. NPN Saturation $i_C - v_{CE}$



- NMOS
 - The two terminals drain and source act as a resistor controlled by $(v_{GS} - V_t)$.
- NPN
 - The two terminals collector and emitter act as a resistor controlled by I_B (or v_{BE}).

	NMOS Triode	NPN Saturation
Bias	$v_{GS} > V_t, v_{DS} < v_{GS} - V_t$	$v_{BE} > 0.5, v_{CE} < v_{BE} - 0.4 \simeq 0.3$
$i - v$	$i_D = k'_n \frac{W}{L} \left[(v_{GS} - V_t)v_{DS} - \frac{1}{2}v_{DS}^2 \right]$	$i_C \simeq I_S e^{v_{BE}/V_T} - \frac{I_S}{\alpha_R} e^{v_{BC}/V_T}$
r_o	$r_{DS} \simeq \left[k'_n \frac{W}{L} (v_{GS} - V_t) \right]^{-1} \simeq \frac{v_{DS}}{i_D}$	$r_{CE} \simeq 1/10 \beta_F I_B$

- Equivalent large signal model

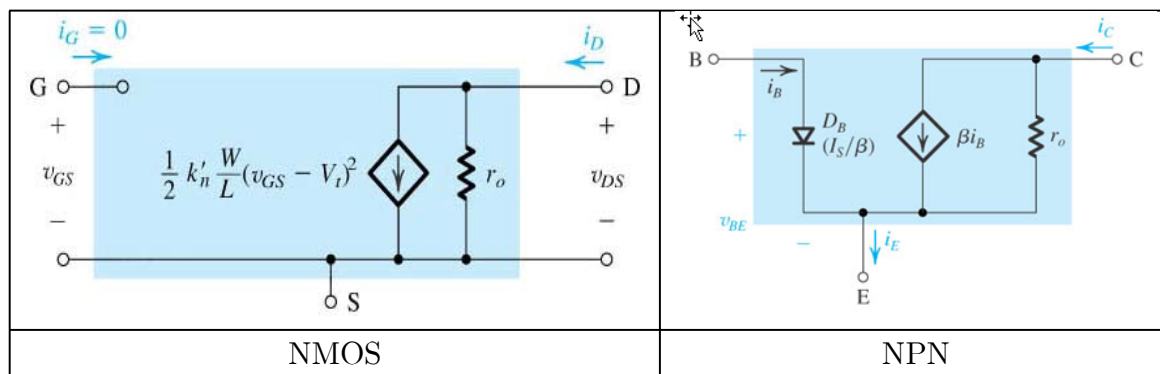


8.1.2 NMOS Saturation v.s. NPN Forward Active

- NMOS
 - The two terminals drain and source act as a current source controlled by $(v_{GS} - V_t)$.
- NPN
 - The two terminals collector and emitter act as a current source controlled by I_B (or v_{BE}).

	NMOS Saturation	NPN Active
Bias	$v_{GS} > V_t, v_{DS} > v_{GS} - V_t$	$v_{BE} > 0.5, v_{CE} > v_{BE} - 0.4 \simeq 0.3$
$i - v$	$I_D = \frac{1}{2} k'_n \frac{W}{L} (v_{GS} - V_t)^2$	$I_C \simeq I_S e^{v_{BE}/V_T} = \beta i_B$
Early Effect	$i_D = I_D(1 + \lambda v_{DS}), \lambda = 1/V_A$	$i_C = I_C(1 + \lambda v_{CE}), \lambda = 1/V_A$
r_o	$r_{DS} = V_A/I_D$	$r_{CE} \simeq V_A/I_C$

- Equivalent large signal model

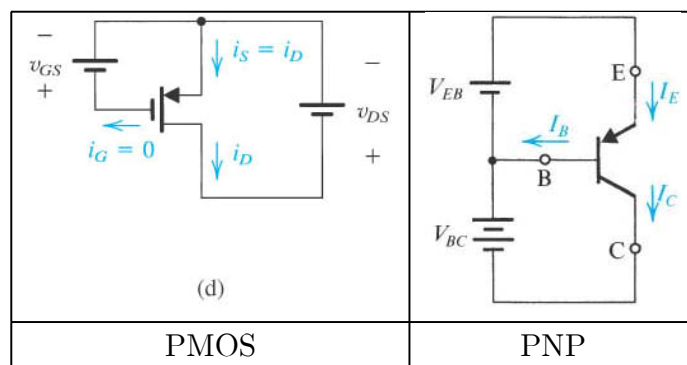


8.1.3 NMOS Cut-off v.s. NPN Cut-off

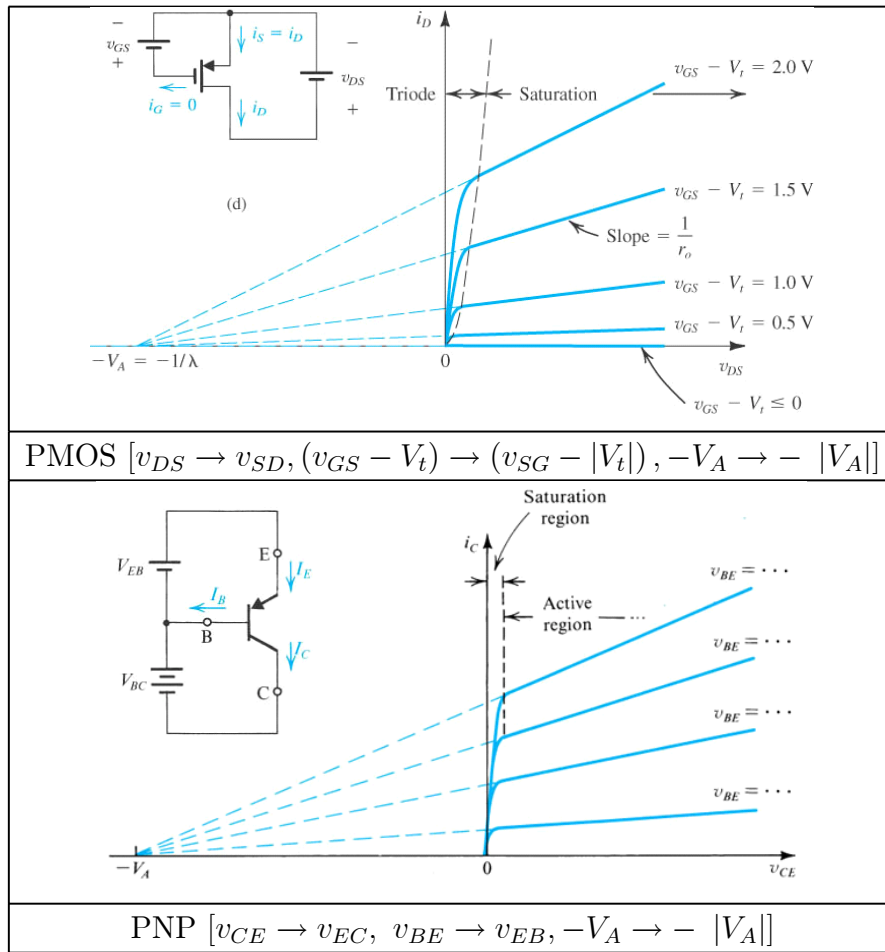
- NMOS
 - $V_{GS} < V_t$.
- NPN
 - $V_{BE} < 0.5$, $V_{BC} < 0.4$.

8.2 PMOS and PNP Transistors

- Circuit symbols and physical structures
 - PMOS has symmetric structure for drain and source.
 - PNP has asymmetric structure for collector and emitter.
- Current
 - PMOS: current flows from source to drain.
 - PNP: current flows from emitter to collector.
- Voltage
 - PMOS: $v_D < v_S$, $v_G < v_S$.
 - PNP: $v_B < v_E$, $v_C < v_E$.

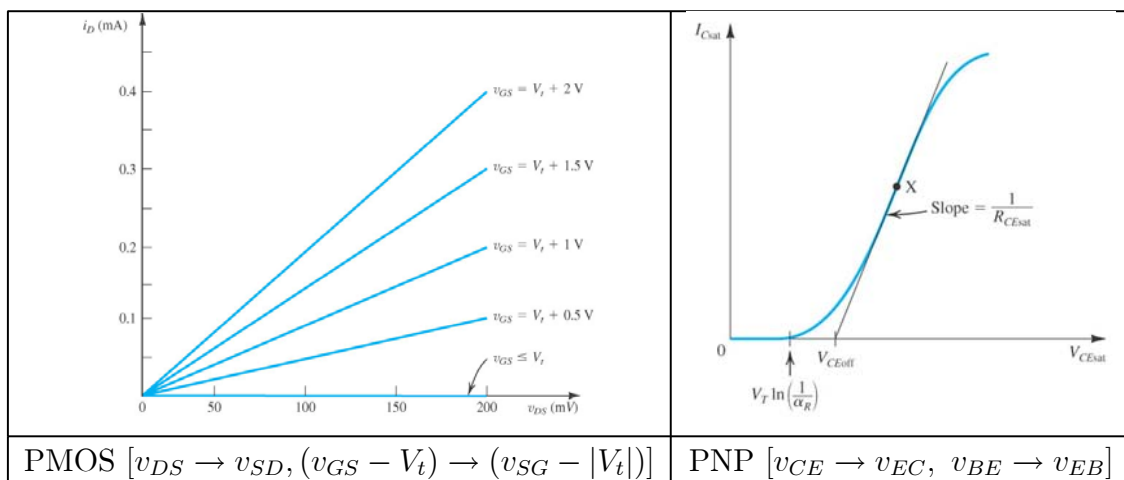


- $i_D - v_{DS}$ (common source) v.s. $i_C - v_{CE}$ (common emitter)



8.2.1 PMOS Triode v.s. PNP Saturation

- NMOS Triode $i_D - v_{SD}$ v.s. NPN Saturation $i_C - v_{EC}$



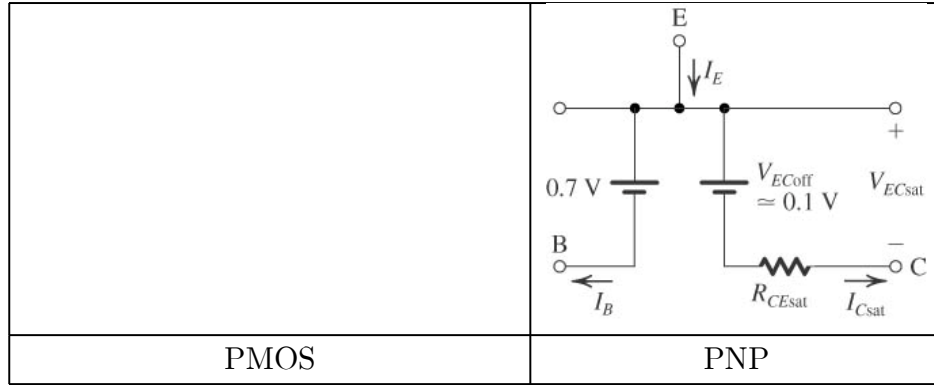
- PMOS
 - The two terminals source and drain acts as a resistor controlled by $v_{SG} - |V_t|$.

- NPN

- The two terminals emitter and collector acts as a resistor controlled by I_B .

	PMOS Triode	PNP Saturation
Bias	$v_{SG} > V_t , v_{SD} < v_{SG} - V_t $	$v_{EB} > 0.5, v_{EC} < v_{EB} - 0.4 \simeq 0.3$
$i - v$	$i_D = k'_p \frac{W}{L} [(v_{SG} - V_t)v_{SD} - \frac{1}{2}v_{SD}^2]$	$i_C \simeq I_S e^{v_{EB}/V_T} - \frac{I_S}{\alpha_R} e^{v_{CB}/V_T}$
r_o	$r_{SD} \simeq [k'_p \frac{W}{L} (v_{SG} - V_t)]^{-1} \simeq \frac{v_{SD}}{i_D}$	$r_{EC} \simeq 1/10\beta_F I_B$

- Equivalent large signal model



8.2.2 PMOS Saturation v.s. PNP Forward Active

- NMOS

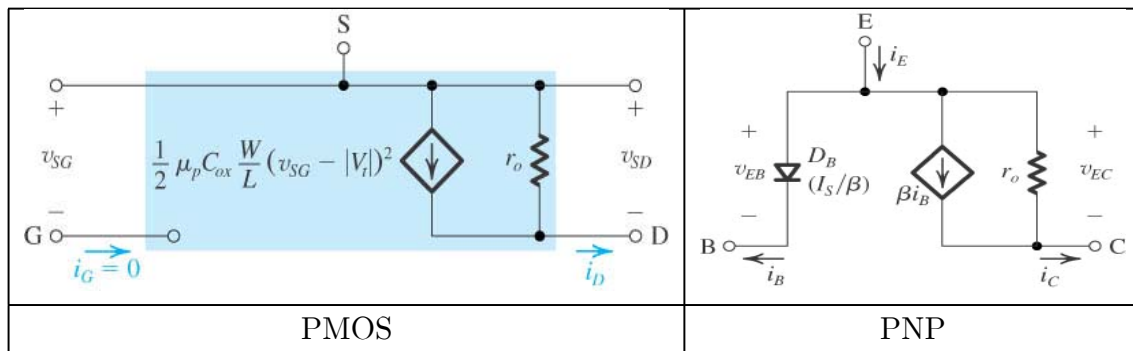
- The two terminals source and drain acts as a current source controlled by $v_{SG} - |V_t|$.

- PNP

- The two terminals emitter and collector acts as a current source controlled by I_B (or v_{EB}).

	PMOS Saturation	PNP Active
Bias	$v_{SG} > V_t , v_{SD} > v_{SG} - V_t $	$v_{EB} > 0.5, v_{EC} > v_{EB} - 0.4 \simeq 0.3$
$i - v$	$I_D = \frac{1}{2}k'_p \frac{W}{L} (v_{SG} - V_t)^2$	$I_C \simeq I_S e^{v_{EB}/V_T} = \beta i_B$
Early Effect	$i_D = I_D(1 + \lambda v_{SD}), \lambda = 1/ V_A $	$i_C = I_C(1 + \lambda v_{EC}), \lambda = 1/ V_A $
r_o	$r_{DS} = V_A /I_D$	$r_{CE} \simeq V_A /I_C$

- Equivalent large signal model



8.2.3 PMOS Cut-off v.s. PNP Cut-off

- PMOS
 - $V_{SG} < |V_t|$.
- PNP
 - $V_{EB} < 0.5, V_{CB} < 0.4$.