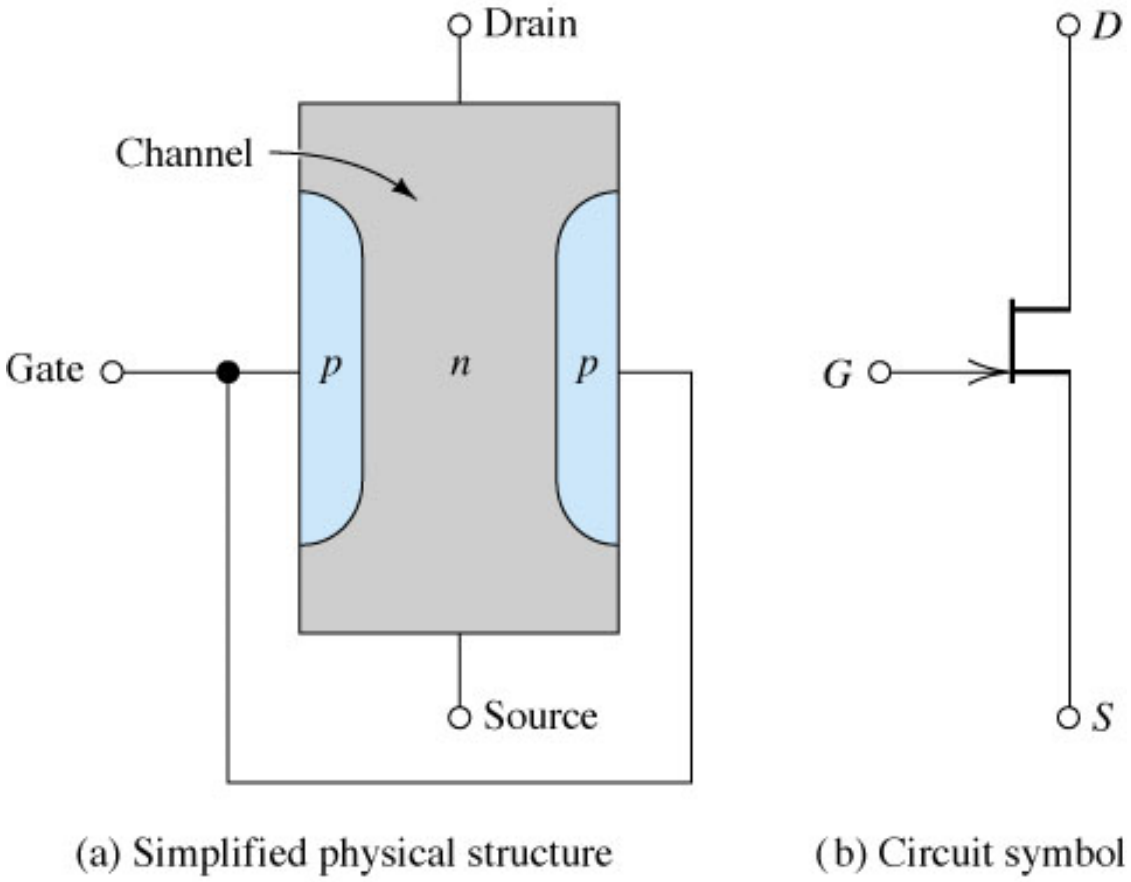
Fundamentals of Microelectronics

- CH1 Why Microelectronics?
- CH2 Basic Physics of Semiconductors
- CH3 Diode Circuits
- CH4 Physics of Bipolar Transistors
- CH5 Bipolar Amplifiers
- CH6 Physics of MOS Transistors
- CH7 CMOS Amplifiers
- CH8 JFET Transistor

Chapter 8 JFET Transistor

- Physics of Operation
- I/V Characteristic
- Biasing
- Small-Signal Model
- JFET Amplifier

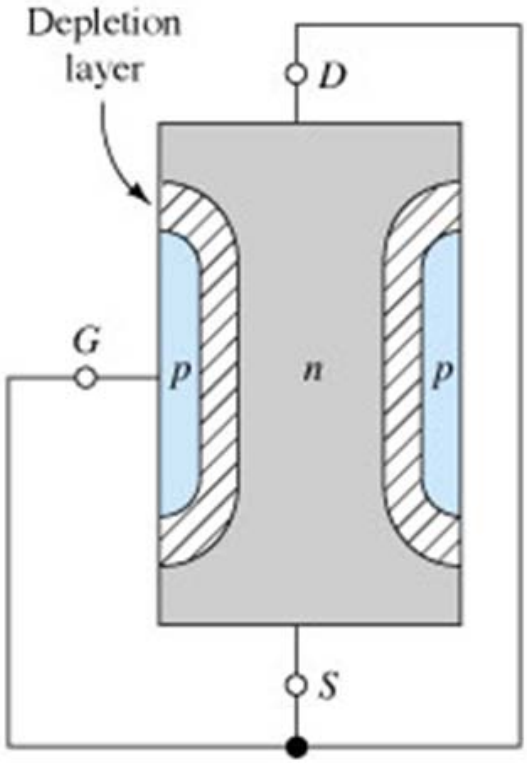
ساختار فیزیکی JFET
Junction Field Effect Transistor



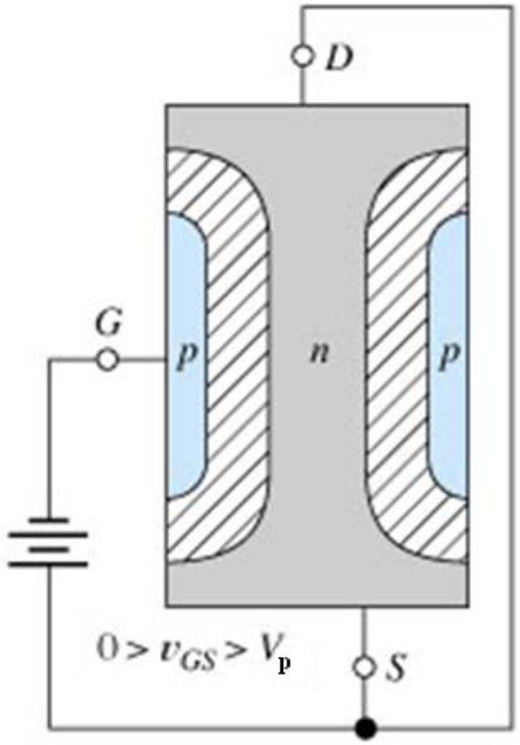
(a) Simplified physical structure (b) Circuit symbol

Figure: *n*-Channel JFET.

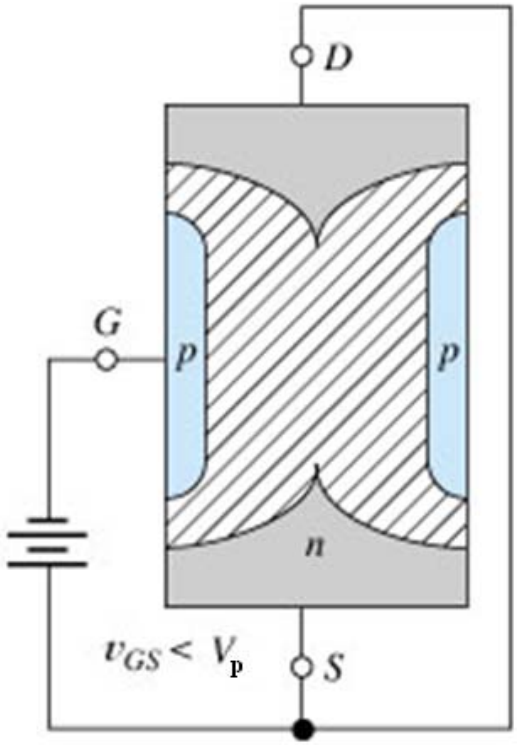
عملکرد JFET به ازای ولتاژ های مختلف گیت



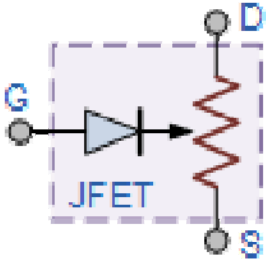
(a) Bias is zero and depletion layer is thin; low-resistance channel exists between the drain and the source



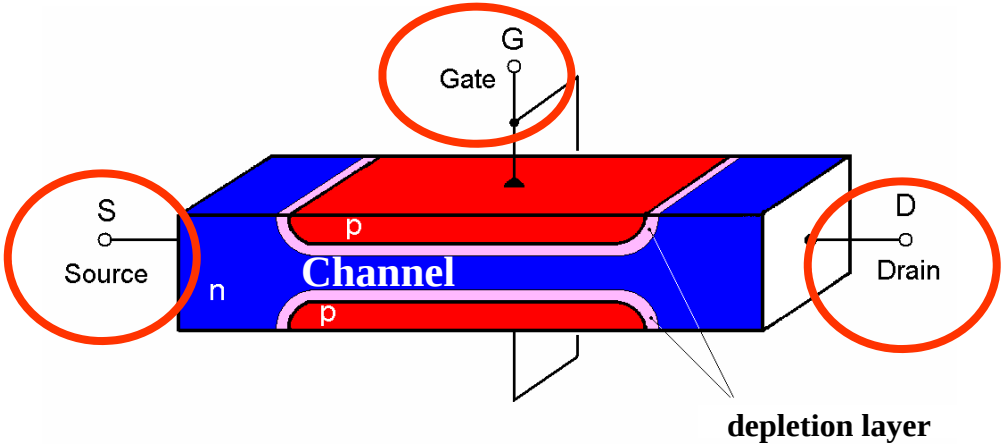
(b) Moderate gate-to-channel reverse bias results in narrower channel



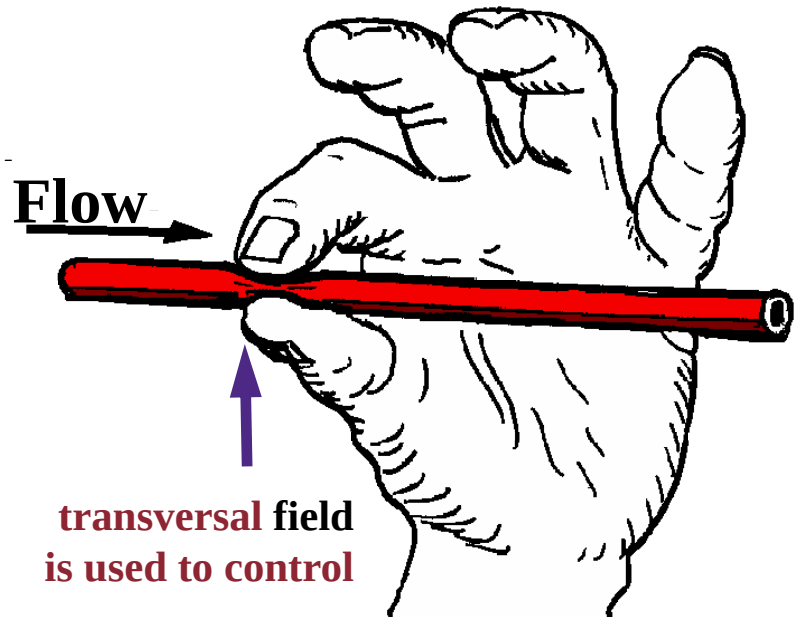
(c) Bias greater than pinch-off voltage; no conductive path from drain to source



ادامه



JUNCTION FET: depletion layers of pn-junctions close the channel



- در این ترانزیستور عبور حامل های بار تحت تاثیر پتانسیل گیت و یا به عبارت دیگر میدان الکتریکی عرضی ناشی از گیت است.
- این ترانزیستور جزء دسته ترانزیستورهای تک قطبی (Unipolar) است چراکه در آن فقط حامل های اکثریت در برقراری جریان ایفای نقش می کنند.

مشخصه جریان-ولتاژ JFET نوع N

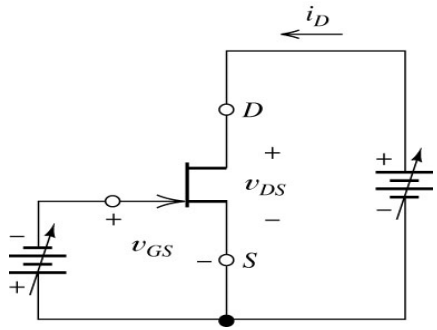


Figure: Circuit for drain characteristics of the *n*-channel JFET and its Drain characteristics.

ناحیه اهمی یا مقاومتی یا تریود یا خطی : $0 > V_{GS} > V_P, \quad V_{GD} > V_P$

$$I_D = \frac{I_{DSS}}{V_P^2}\left[2(V_{GS} - V_P)V_{DS} - V_{DS}^2\right], \quad I_G = 0$$

ناحیه اشباع یا فعال یا pinch-off $0 > V_{GS} > V_P, \quad V_{GD} < V_P$

$$I_D = \frac{I_{DSS}}{V_P^2}\left[(V_{GS} - V_P)^2\right], \quad I_G = 0 \qquad \text{or} \qquad I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

در روابط بالا V_p را ولتاژ pinch-off و I_{DSS} را جریان درین در ناحیه اشباع ترانزیستور به ازای اتصال کوتاه گره های G و S به یکدیگر تعریف شده است.

ناحیه قطع: $V_{GS} < V_P$

$$I_D = 0, \quad I_G = 0$$

مشخصه I_D/V_{GS} در ناحیه Pinch-off

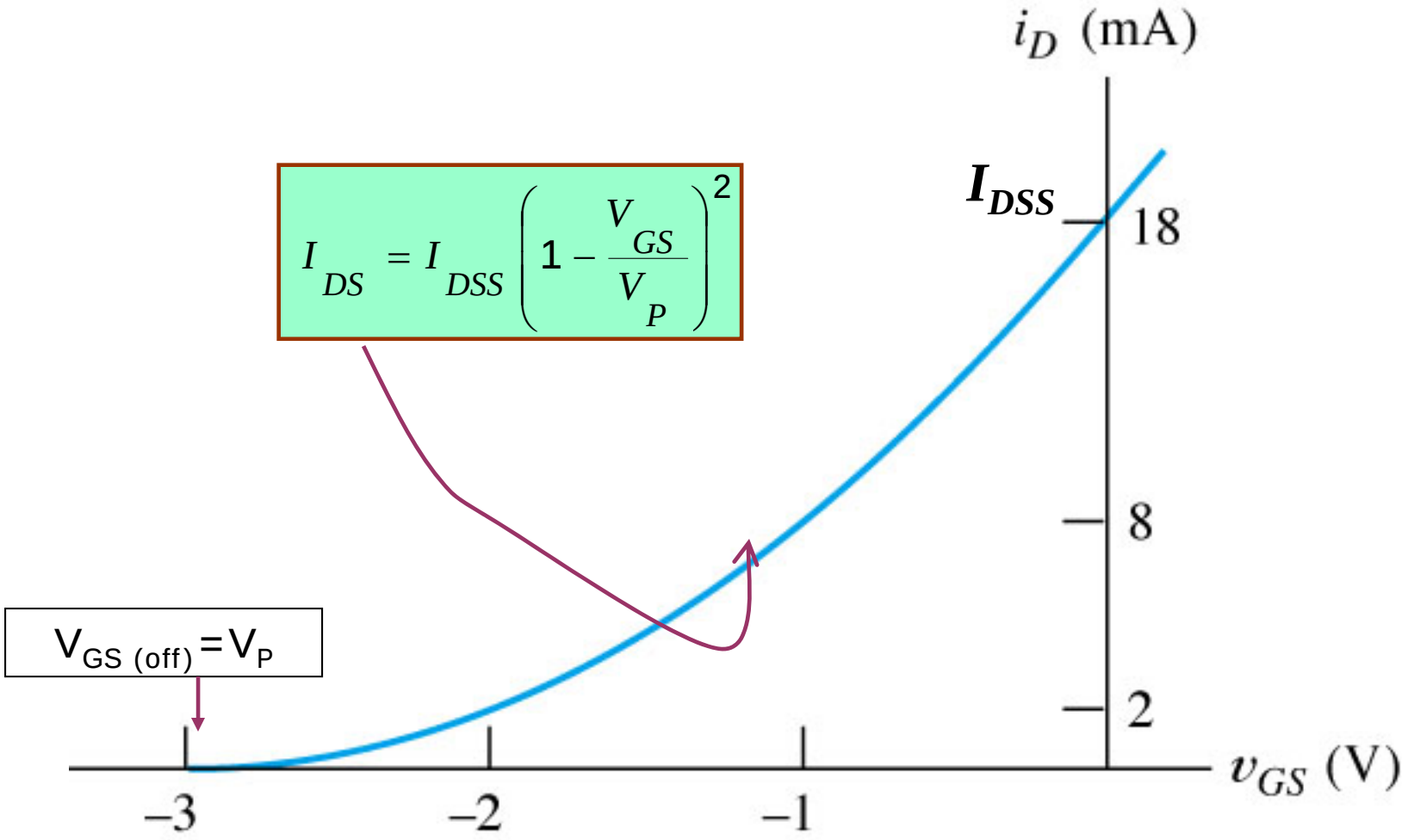
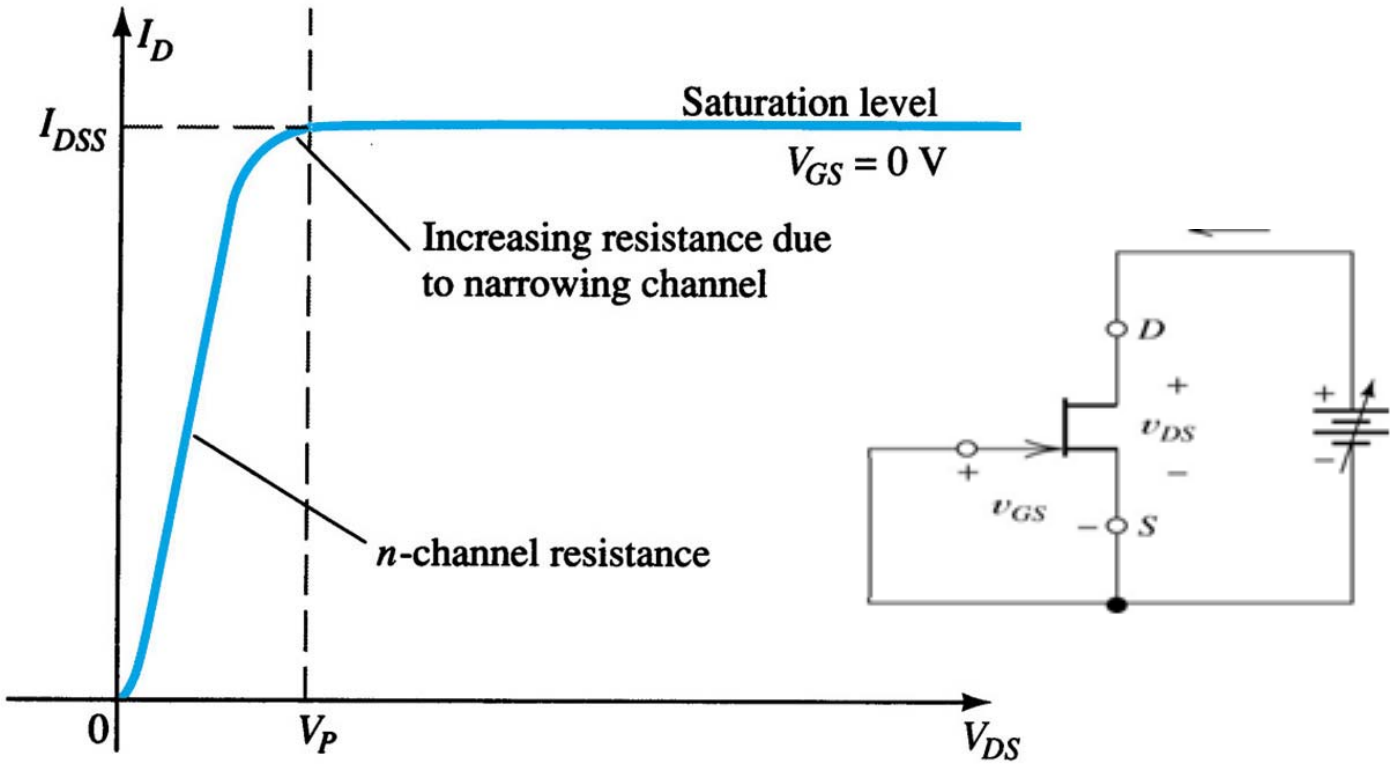


Figure: Transfer (or Mutual) Characteristics of n-Channel JFET

مشخصه I_D/V_{DS}



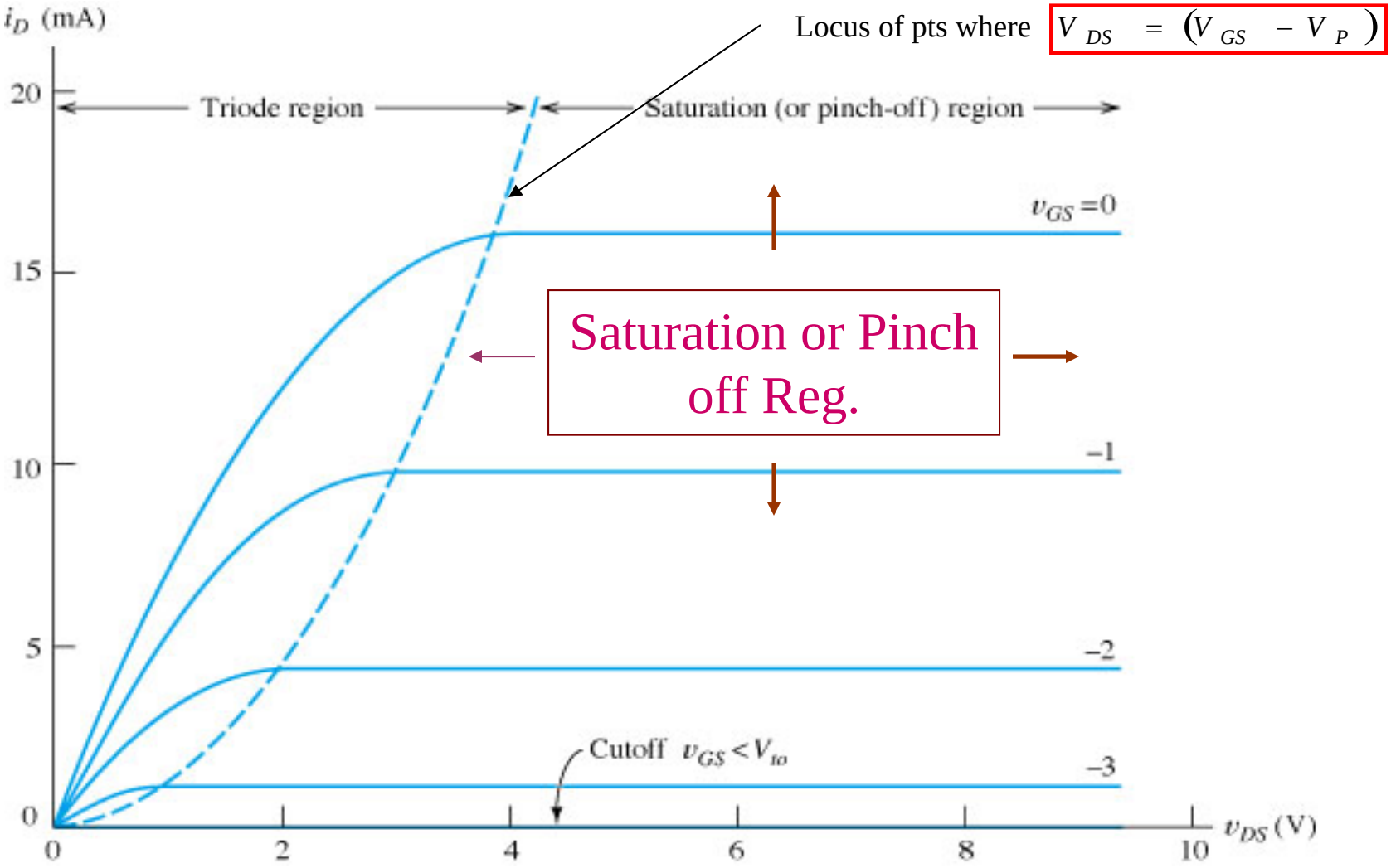
$$I_D = \frac{I_{DSS}}{V_P^2}\left[2(V_{GS} - V_P)V_{DS} - V_{DS}^2\right]$$

$V_{GD} > V_P$

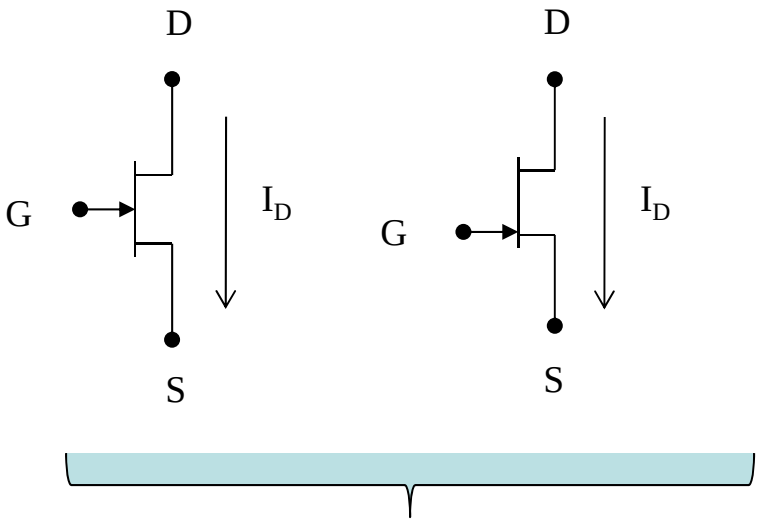
$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$V_{GD} < V_P$

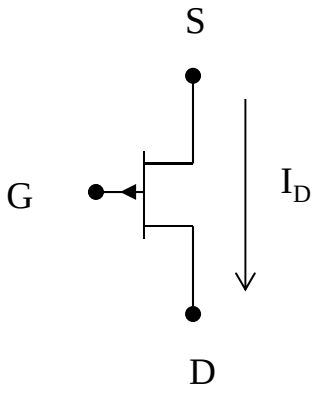
مشخصه I_D/V_{DS}


i_D (mA)
Locus of pts where $V_{DS} = (V_{GS} - V_P)$
Triode region
Saturation (or pinch-off) region
$v_{GS}=0$
Saturation or Pinch off Reg.
−1
−2
−3
Cutoff $v_{GS} < V_{to}$
20
15
10
5
0
0
2
4
6
8
10
v_{DS} (V)

نماد الکتریکی



n-channel JFET

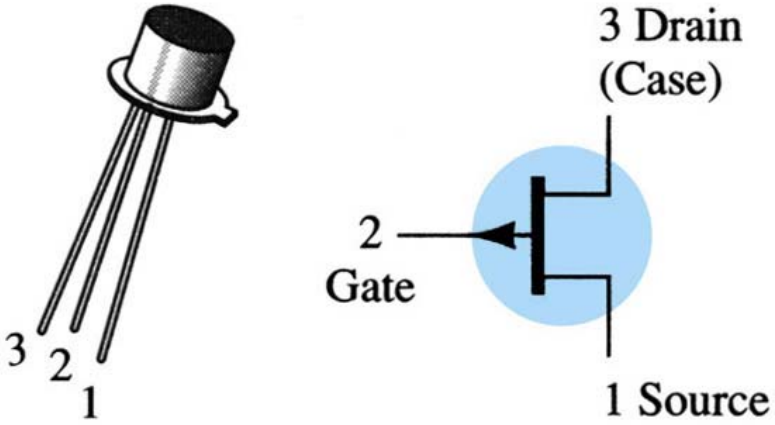


p-channel JFET

نمونه ای از یک JFET

2N2844

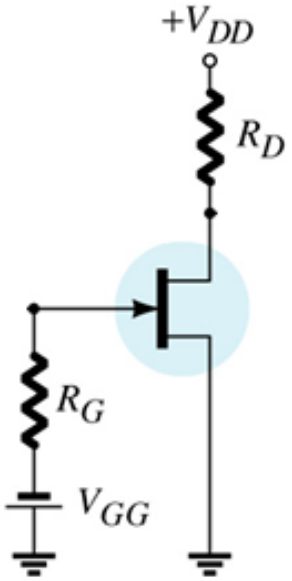
CASE 22-03, STYLE 12
TO-18 (TO-206AA)



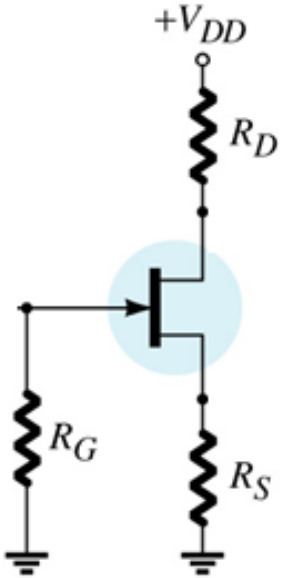
JFETs
GENERAL PURPOSE
P-CHANNEL

بایاس JFET

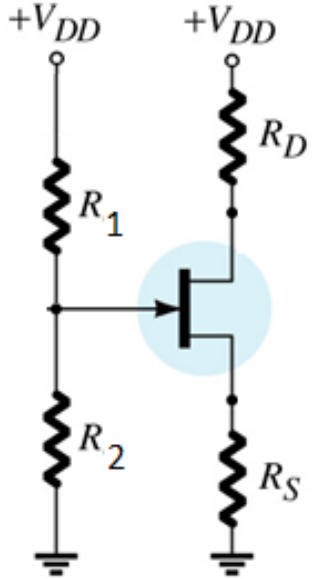
Fixed-bias



Self-bias

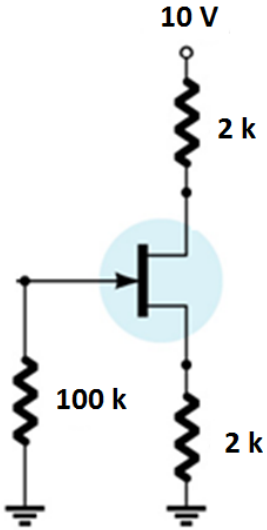


Voltage Divider



مثال

Determine the operating point.



$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$V_P = -3V$$

$$I_{DSS} = 9\,mA$$

Assume pinch-off region:

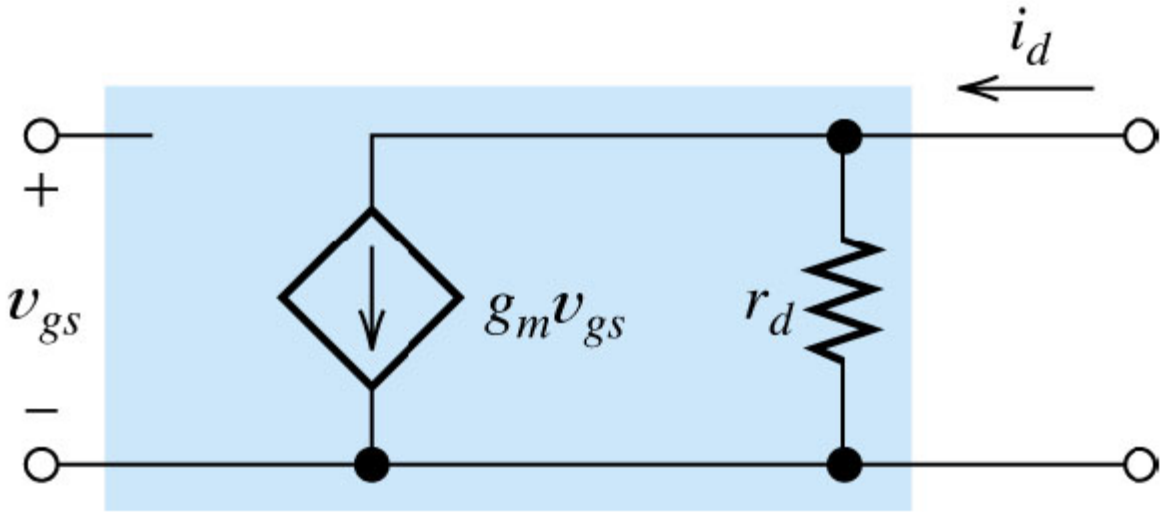
$$\left.\begin{aligned} I_D &= 9\left(1 + \frac{V_{GS}}{3}\right)^2 \\ V_s &= 2\,k \times I_D \Longrightarrow V_{GS} = -2\,I_D \end{aligned}\right\} \Longrightarrow I_D = 9\left(1 - \frac{2\,I_D}{3}\right)^2 \Longrightarrow I_D = 1\,mA \quad or \quad I_D = 2\,mA$$

$$\begin{cases} I_D = 1mA \Longrightarrow V_{GS} = -2V \overset{?}{>} V_P \\ I_D = 2mA \Longrightarrow V_{GS} = -4V \overset{?}{>} V_P \end{cases}$$

So I_D=2mA is not acceptable.

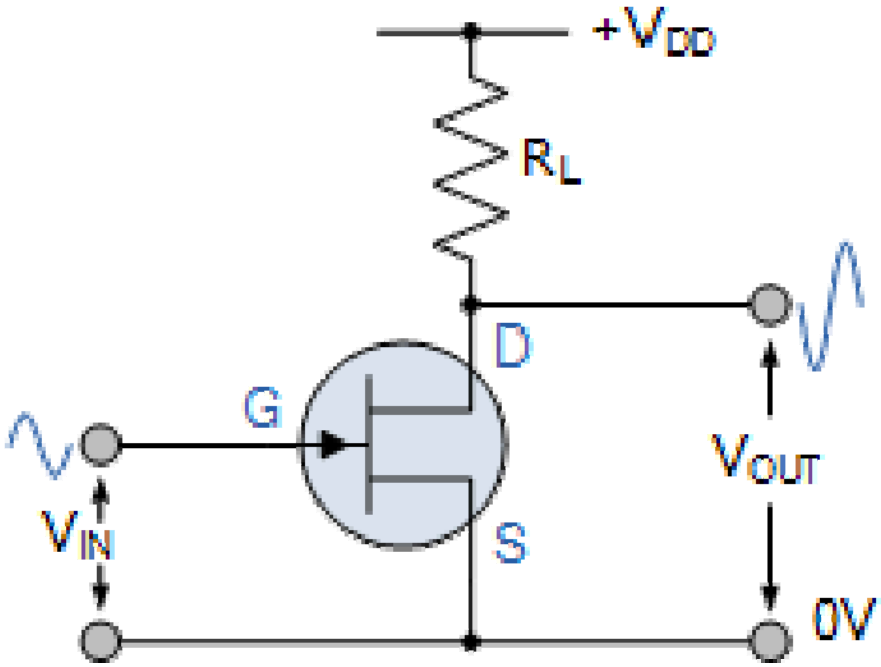
$$I_D = 1mA \Longrightarrow V_{DS} = 10 - 2k \times I_D - 2k \times I_D = 6V \quad V_{DS} \overset{?}{>} V_{GS} - V_P \quad 6 > -2 - (-3)$$

مدل سیگنال کوچک



$$g_m = \frac{2}{|V_P|}\sqrt{I_D I_{DSS}}$$

تقویت کننده سورس-مشترک

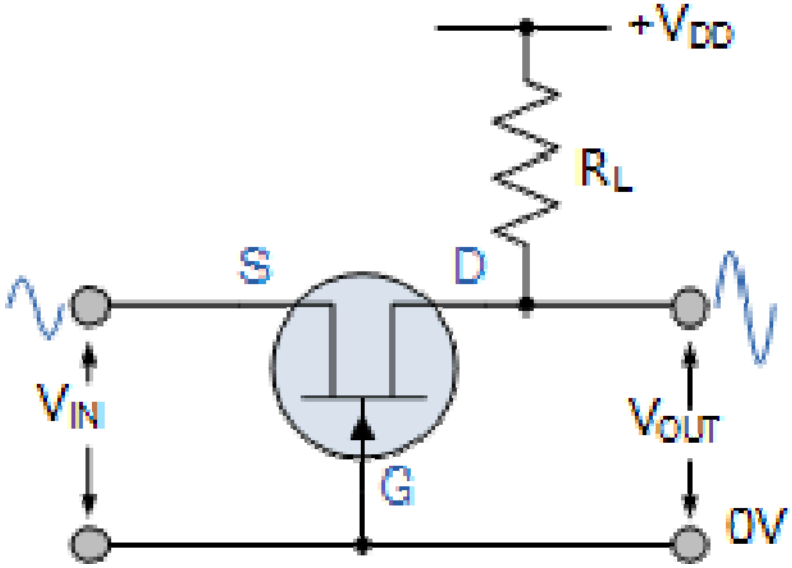


$$A_V = -g_m \left(R_L \parallel r_d \right)$$

$$R_{in} = \infty$$

$$R_{out} = R_L \parallel r_d$$

تقویت کننده گیت-مشترک

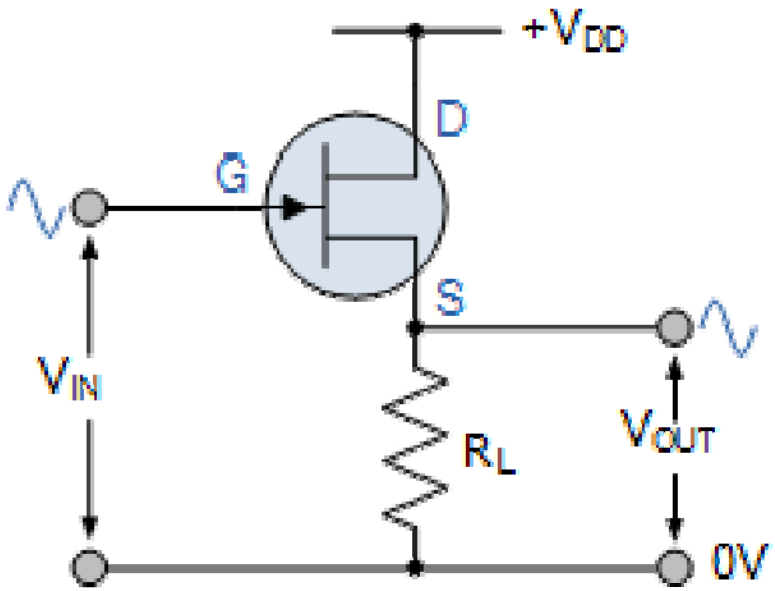


$$A_V = g_m (R_L \parallel r_d)$$

$$R_{in} = \frac{r_d + R_L}{1 + g_m r_d} \quad if \quad r_d = \infty \quad ==> \quad R_{in} = \frac{1}{g_m}$$

$$R_{out} = R_L \parallel r_d$$

تقویت کننده درین-مشترک



$$A_V = \frac{R_L \parallel r_d}{R_L \parallel r_d + \frac{1}{g_m}}$$

$$R_{in} = \infty$$

$$R_{out} = R_L \parallel \frac{r_d}{1 + g_m r_d}$$