



FIELD-EFFECT TRANSISTOR

INTRODUCTION

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TOPIC OUTLINE

JFET Construction

Regions of Operation

Transconductance Curve



JFET CONSTRUCTION



HISTORY



Julius Edgar Lilienfeld

The concept of the field-effect transistor was first proposed by Julius Edgar Lilienfeld in a 1925 patent, but he never built a working device due to material limitations of the era.

technology limitations



HISTORY



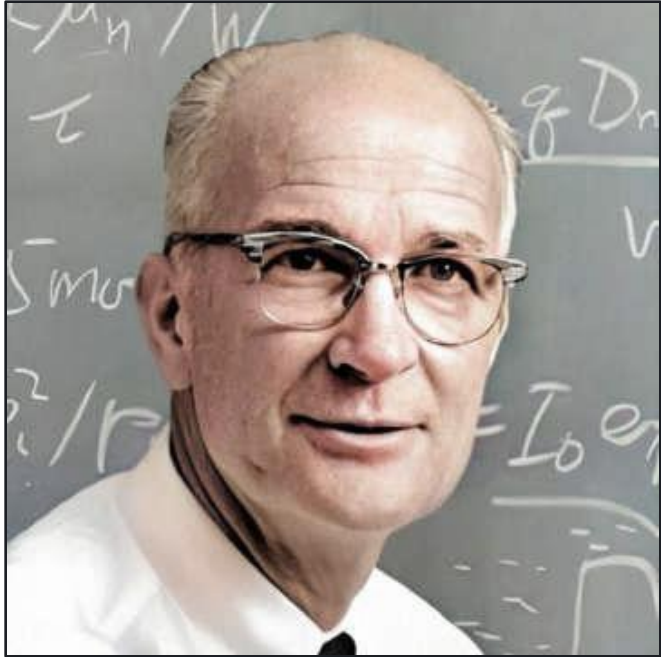
Dr. Ian Munro Ross

Dr. George Clement Dacey

They worked on methods to characterize and understand the behavior of field-effect transistors (FETs), which were still **experimental** at that time (1940s – 1950s). Their contributions were crucial for validating the theoretical principles of FET operation.



HISTORY

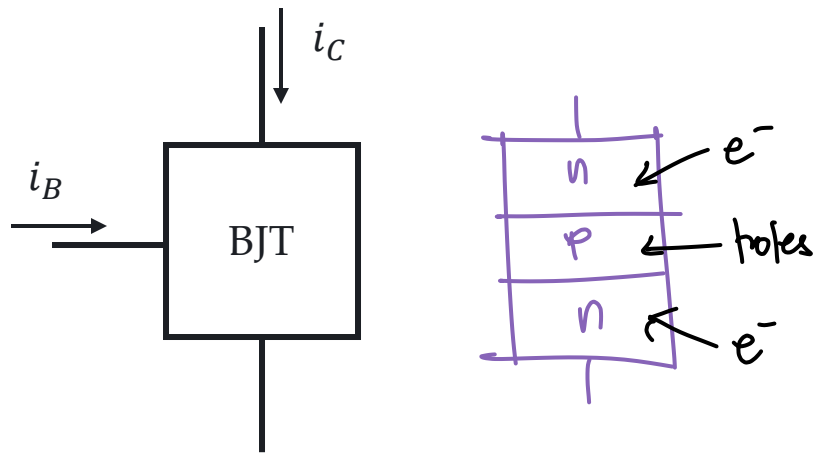


Dr. William Shockley

The first practical junction field-effect transistor (JFET) was successfully built by William Shockley and his team at Bell Labs around 1952. Shockley had theorized about FETs even before inventing the bipolar junction transistor in 1947, but the technology to make them work came later.



BJT VS FET



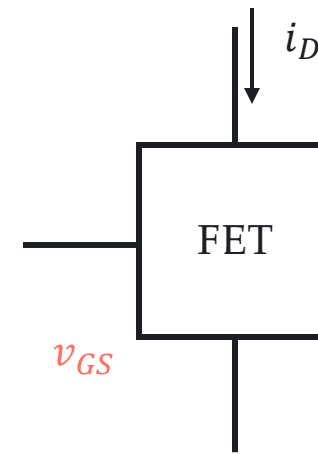
Current-controlled device

Output current (i_C) is controlled by base current (i_B)

Bipolar device

Majority carriers are both electrons and holes

n-type *p-type*



Voltage-controlled device

Output current (i_D) is controlled by gate-to-source voltage (v_{GS})

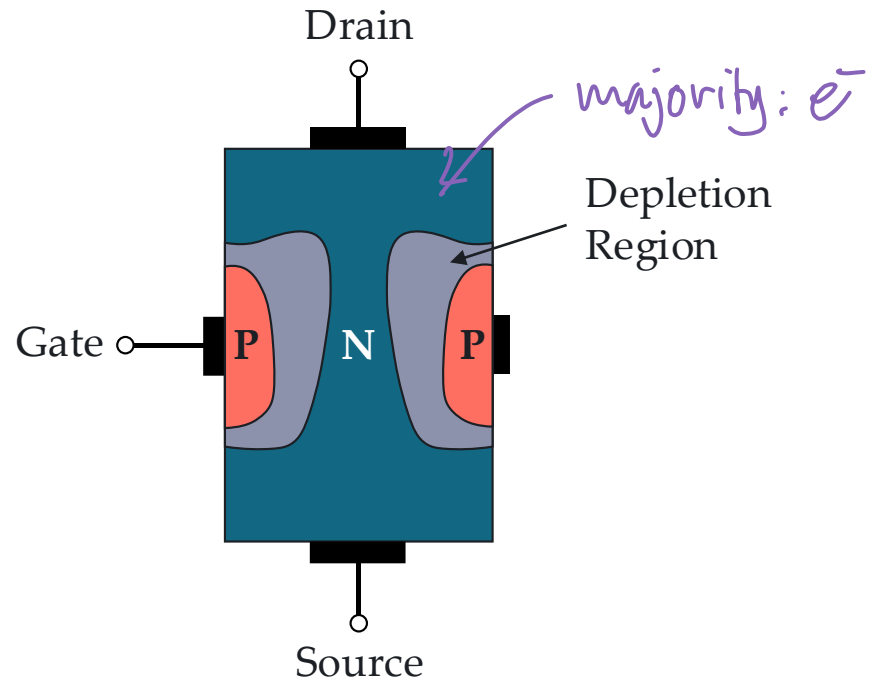
Unipolar device

Majority carrier is either electrons (n-channel) or holes (p-channel)

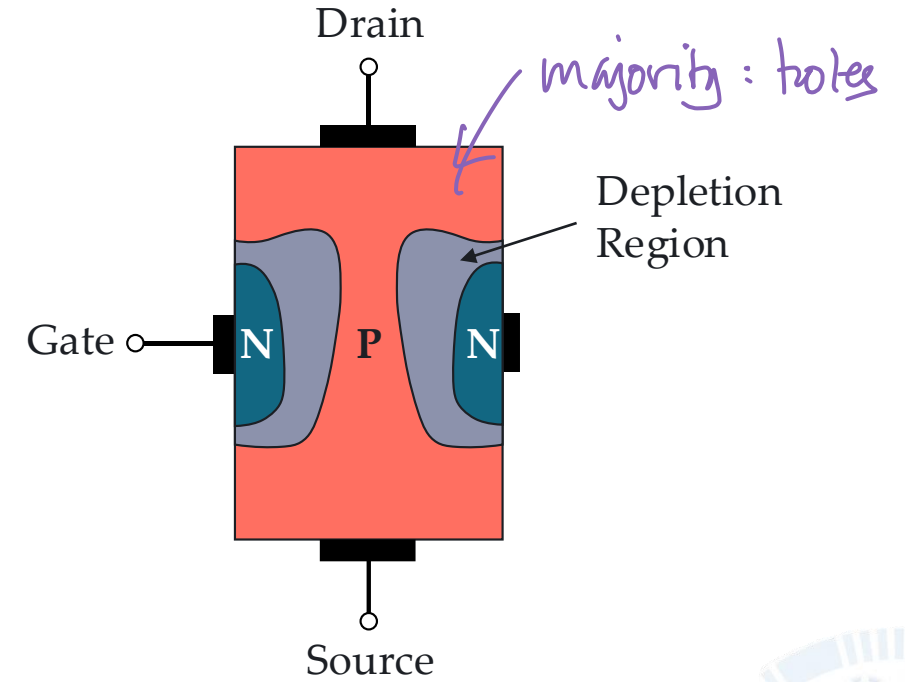
CONSTRUCTION

JFET

Junction Field-Effect Transistor



N-Channel

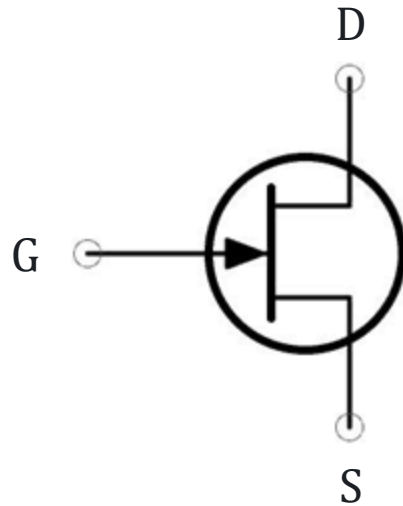


P-Channel

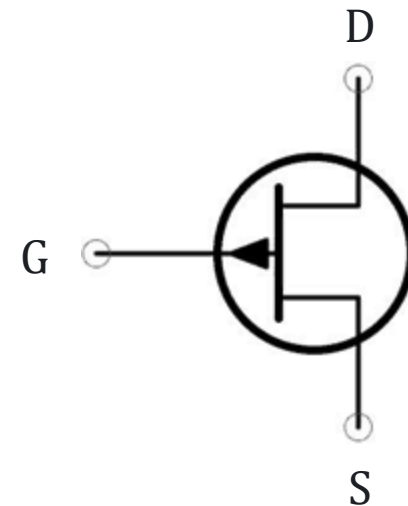
SCHEMATIC SYMBOL

JFET

Junction Field-Effect Transistor



N-Channel

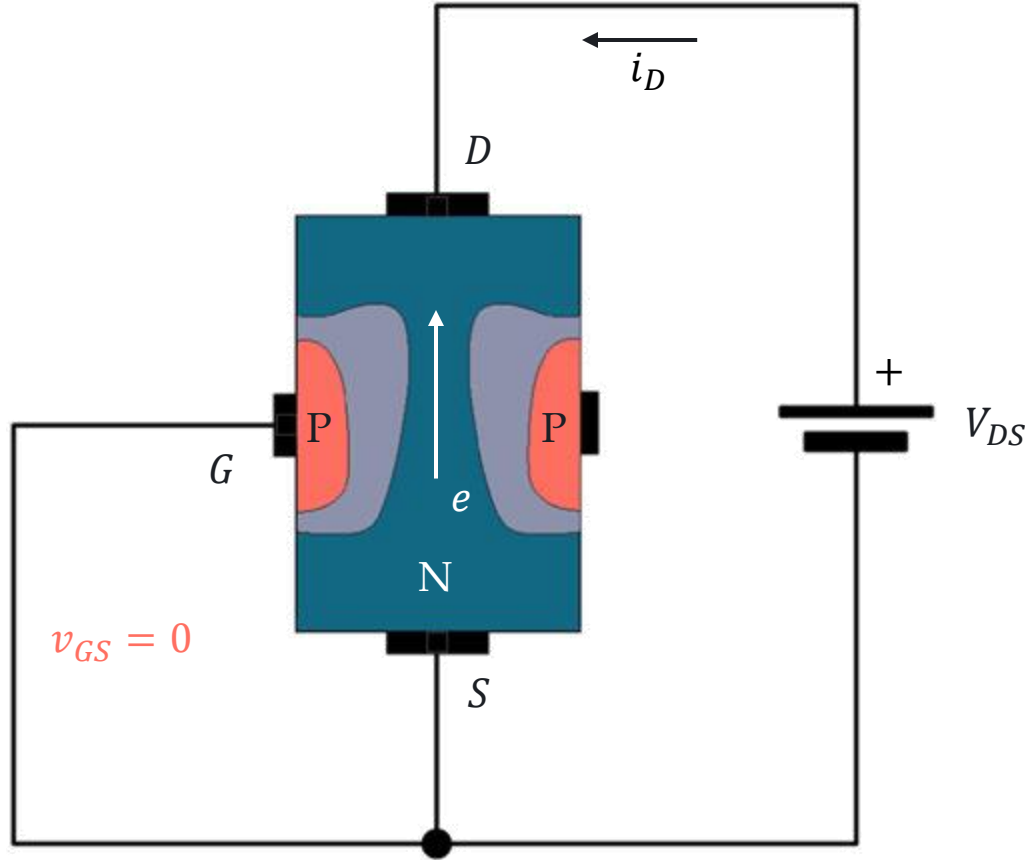


P-Channel

REGIONS OF OPERATION



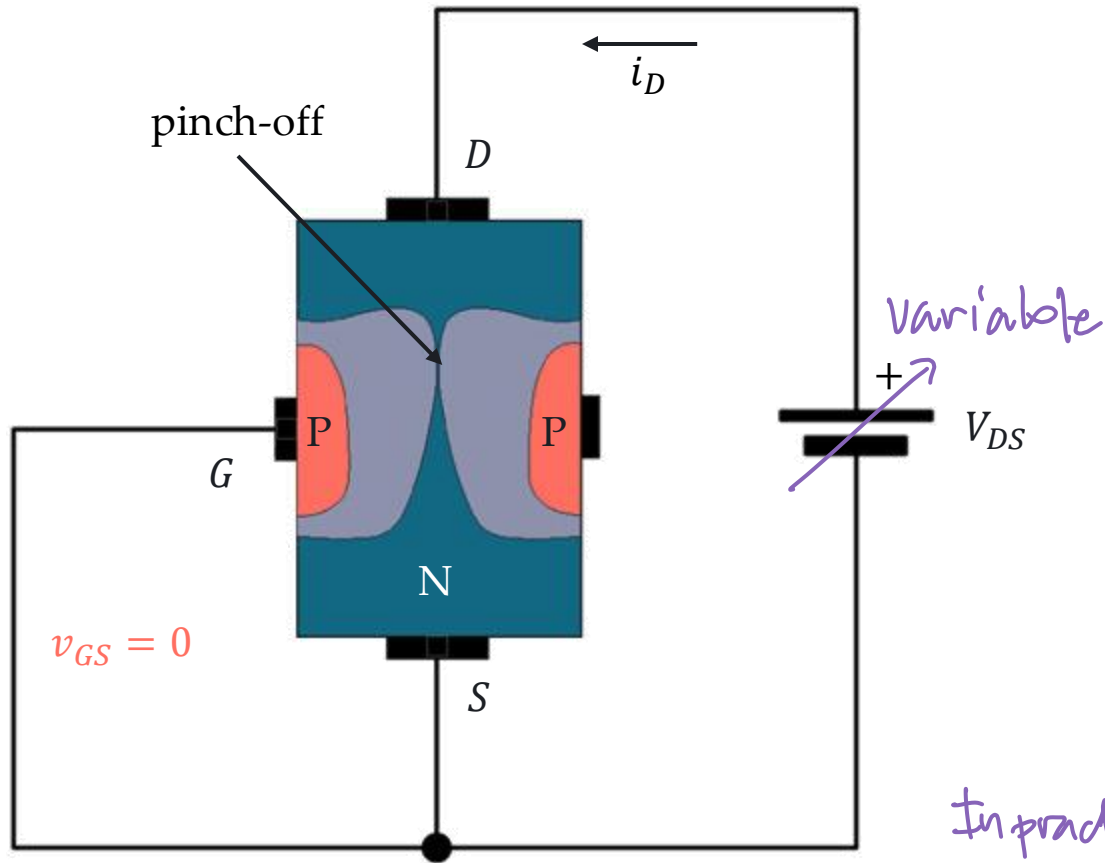
NORMALLY “ON” DEVICE



When v_{GS} **is zero**, maximum drain (i_D) current flows between the source and the drain.



PINCH-OFF VOLTAGE



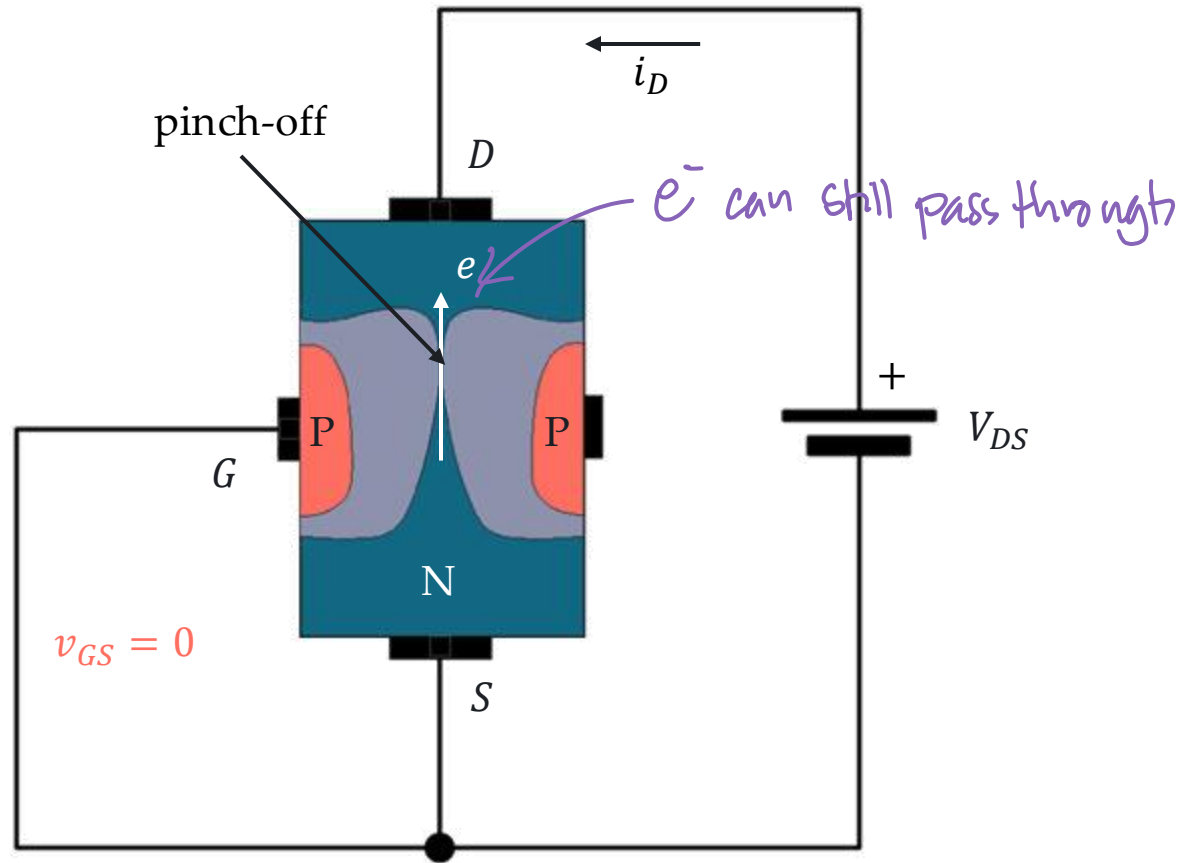
If V_{DS} is increased to a level where it appears that two regions would “touch”, a condition referred to as pinch-off will result.

The level of V_{DS} that established this condition is referred to as pinch-off voltage, V_P .

*In practical application,
 V_{GS} is variable*



PINCH-OFF VOLTAGE

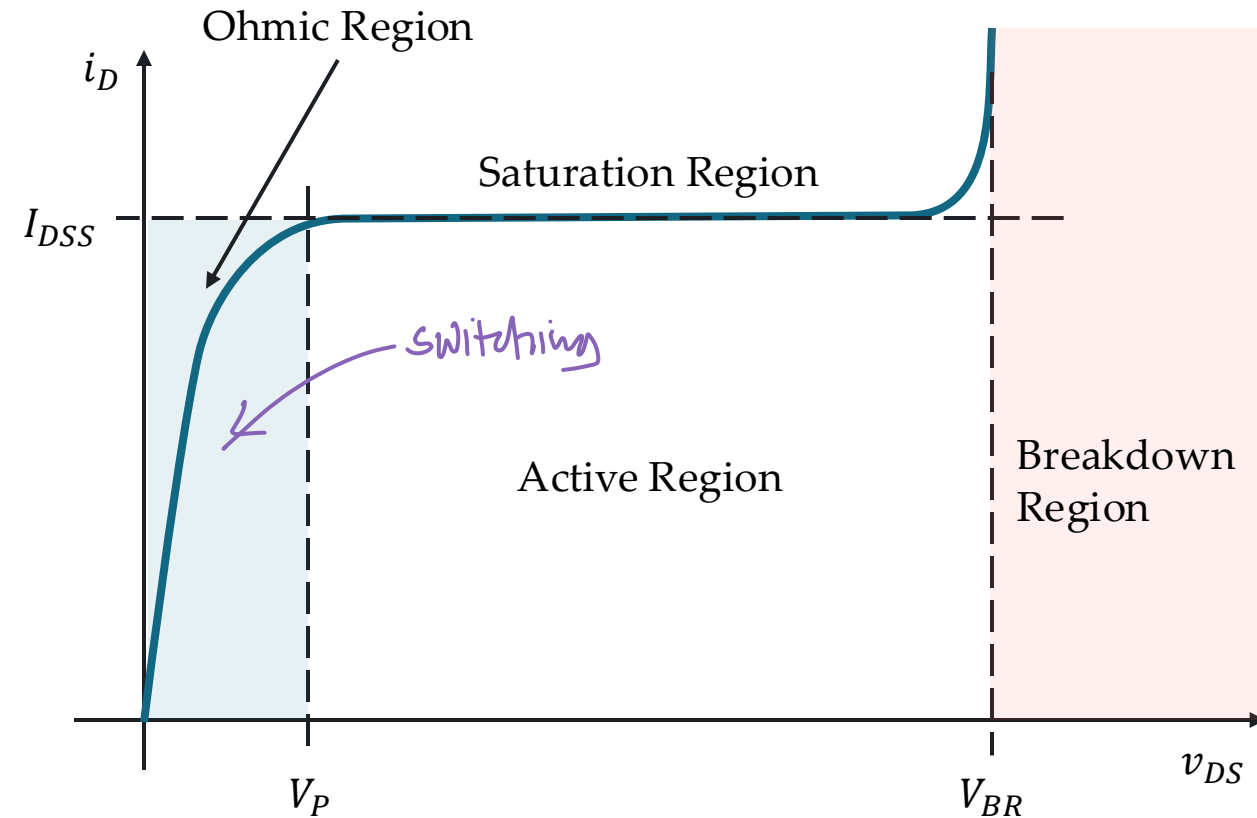


i_D does not drop off at pinch-off and maintains **saturation level** defined as I_{DSS} (**D**rain-to-**S**ource current with a **S**hort-circuit connection from gate to source).

I_{DSS} is the maximum drain current when $v_{GS} = 0$.



DRAIN CURVE



When operated in the ohmic region, a JFET is equivalent to a resistor with a value of approximately:

$$R_{DS} = \frac{V_P}{I_{DSS}}$$

ohm's law



EXERCISE

An MPF4857 has $V_p = 6V$ and $I_{DSS} = 100\text{ mA}$. What is the ohmic resistance? The gate-source cutoff voltage?

Solution

Ohmic Resistance

$$R_{DS} = \frac{V_p}{I_{DSS}}$$

$$R_{DS} = \frac{6}{100\text{ m}}$$

$$R_{DS} = 60\ \Omega$$

ans

Gate-source cutoff voltage

$$V_{GS(off)} = -V_p$$

$$V_{GS(off)} = -6V$$

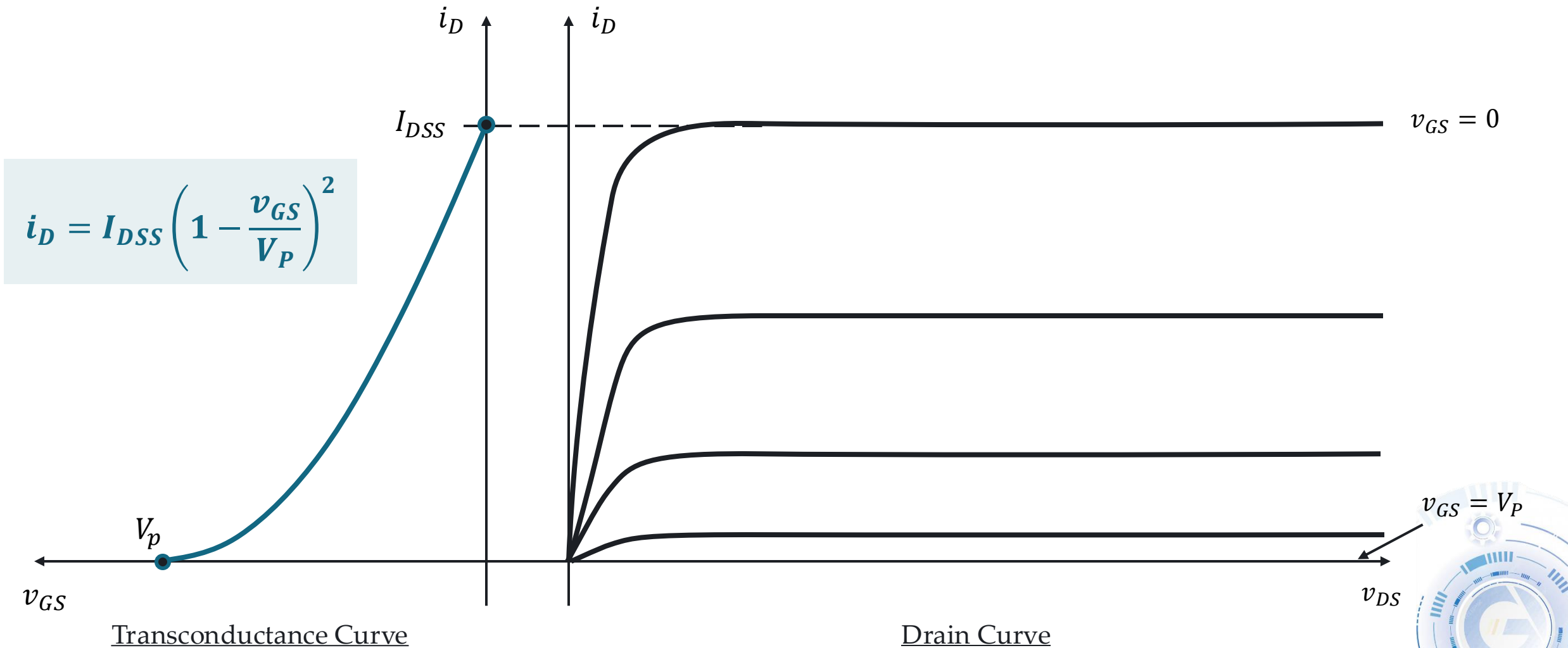
ans



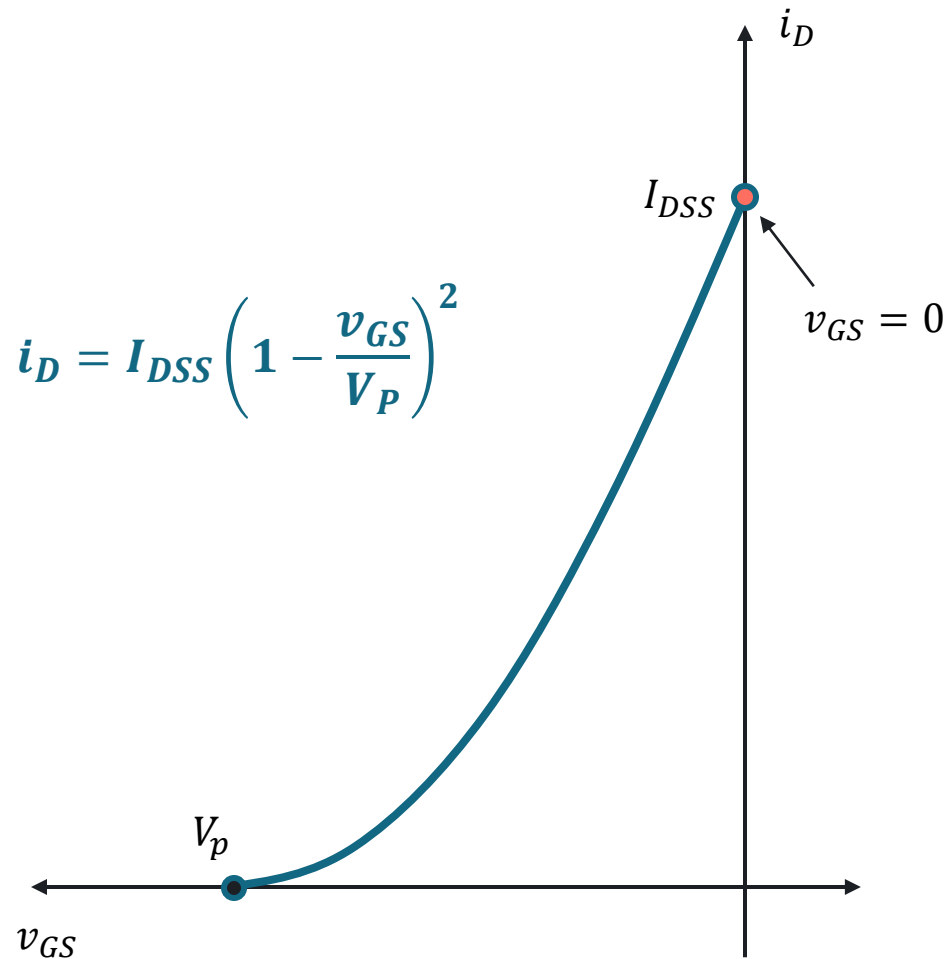
TRANSCONDUCTANCE CURVE



SHOCKLEY'S EQUATION



TRANSCONDUCTANCE CURVE



$$i_D = I_{DSS} \Big|_{v_{GS}=0}$$

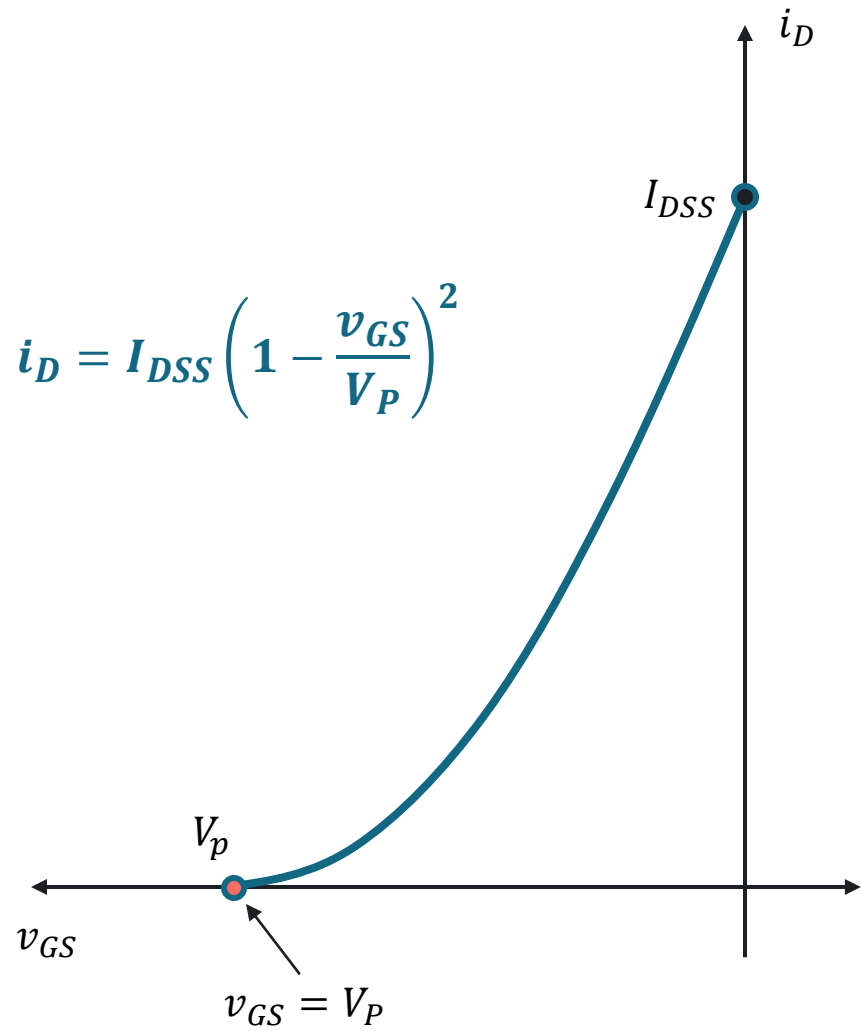
$$i_D = I_{DSS} \left(1 - \frac{v_{GS}}{V_p} \right)^2$$

$$i_D = I_{DSS} (1 - 0)^2$$

$$\underline{i_D = I_{DSS}}$$



TRANSCONDUCTANCE CURVE



$$i_D = 0 \Big|_{v_{GS}=V_p}$$

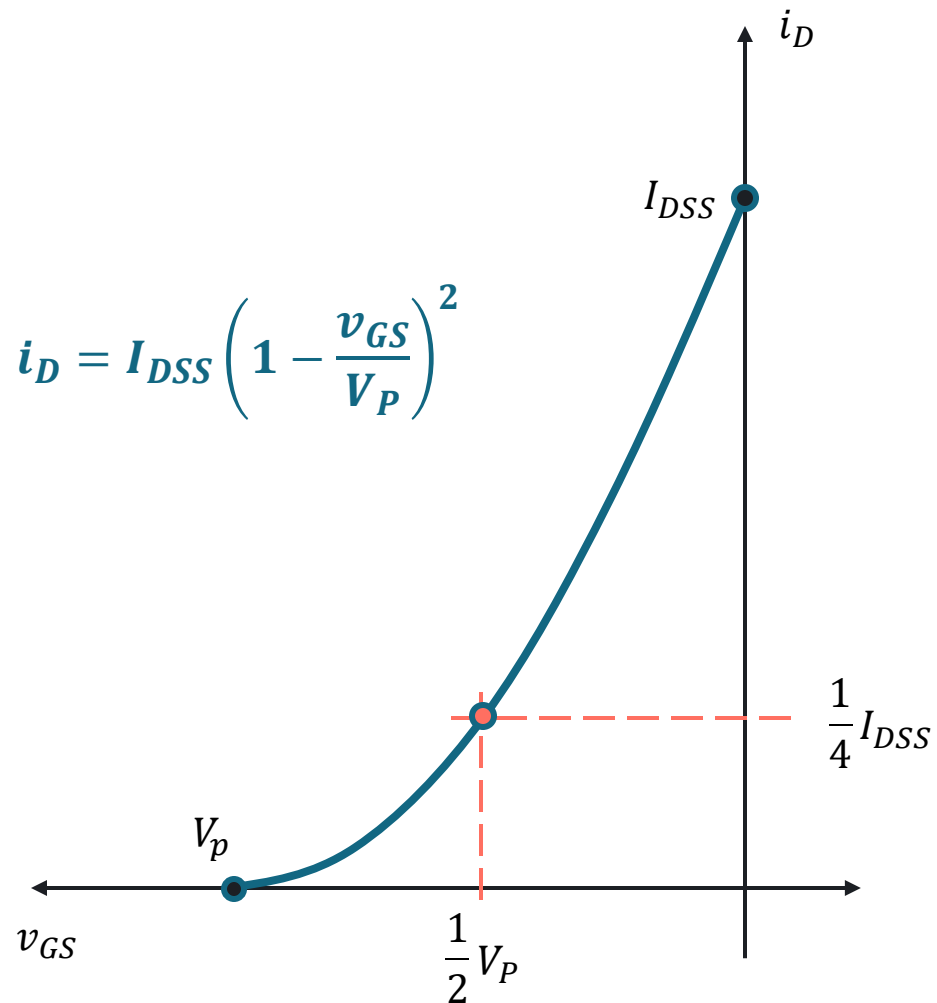
$$i_D = I_{DSS} \left(1 - \frac{v_{GS}}{V_p}\right)^2$$

$$i_D = I_{DSS} (1 - 1)^2$$

$$\underline{i_D = 0}$$



TRANSCONDUCTANCE CURVE



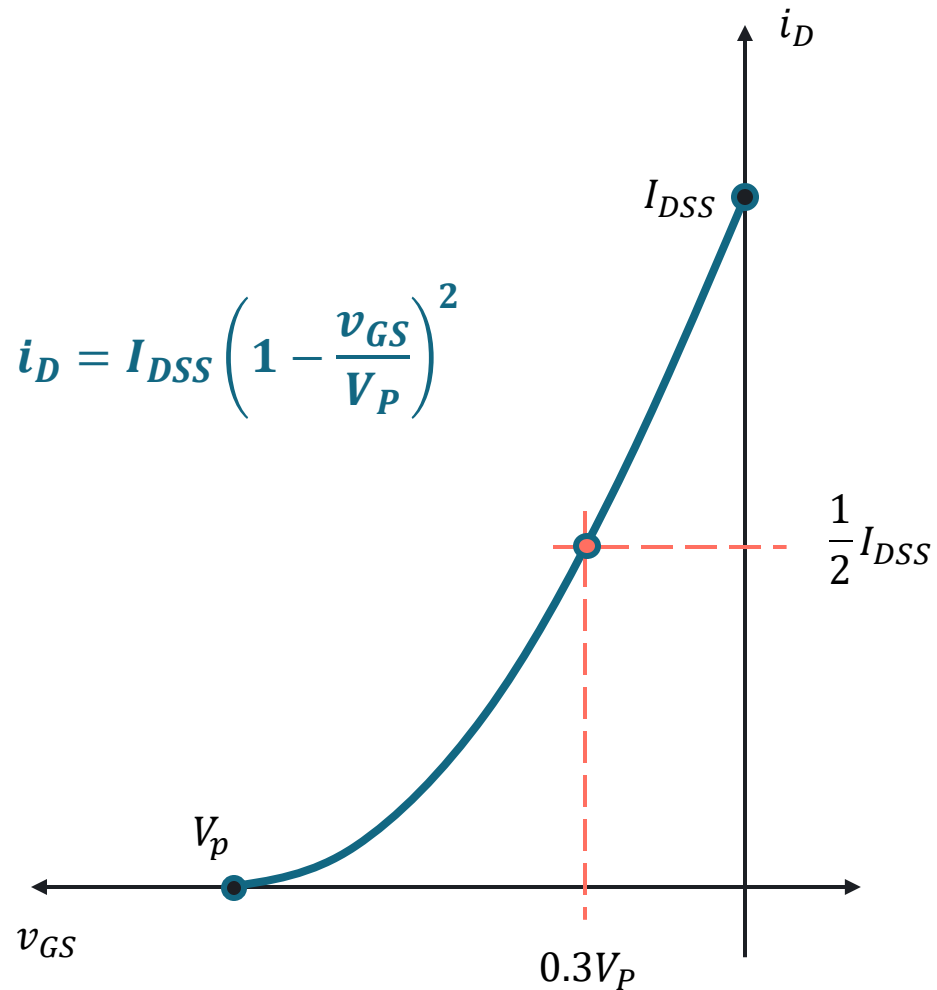
$$i_D = \frac{1}{4} I_{DSS} \Big|_{v_{GS} = \frac{1}{2} V_p}$$

$$i_D = I_{DSS} \left(1 - \frac{0.5 V_p}{V_p} \right)^2$$

$$i_D = I_{DSS} (1 - 0.5)^2$$

$$\underline{i_D = 0.25 I_{DSS}}$$

TRANSCONDUCTANCE CURVE



$$v_{GS} = 0.3V_p \Big|_{i_D = \frac{1}{2}I_{DSS}}$$

$$i_D = I_{DSS} \left(1 - \frac{v_{GS}}{V_p} \right)^2$$

$$\sqrt{0.5} = \left(1 - \frac{v_{GS}}{V_p} \right)$$

$$\frac{v_{GS}}{V_p} = 1 - \sqrt{0.5}$$

$$\underline{v_{GS} = 0.3V_p}$$



EXERCISE

Sketch the transconductance curve defined by

$$I_{DSS} = 12\text{mA} \text{ and } V_p = -6\text{V}.$$

Solution

$$\underline{\text{Let } V_{GS} = 0.5 V_p}$$

$$i_D = \frac{1}{4} I_{DSS} \quad \left| \quad V_{GS} = \frac{1}{2} V_p \right.$$

$$i_D = \frac{1}{4} (12\text{m}) \quad \left| \quad V_{GS} = -3 \right.$$

$$\underline{i_D = 3\text{mA} @ V_{GS} = -3\text{V}}$$

$$\underline{\text{Let } i_D = 0.5 I_{DSS}}$$

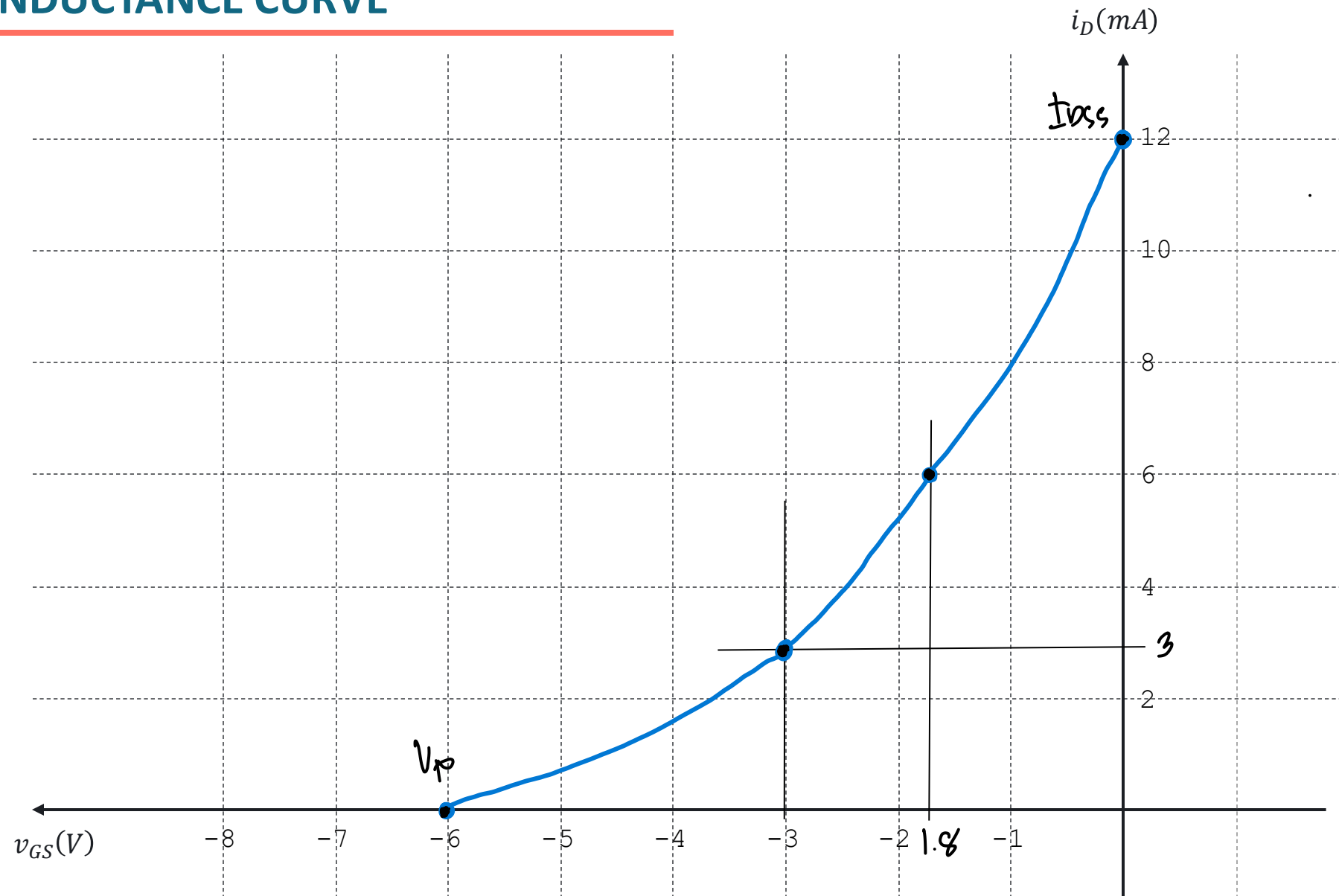
$$V_{GS} = 0.5 V_p \quad \left| \quad i_D = \frac{1}{2} I_{DSS} \right.$$

$$V_{GS} = 0.5 (-6) \quad \left| \quad i_D = 6 \right.$$

$$\underline{V_{GS} = -1.8\text{V} @ i_D = 6\text{mA}}$$



TRANSCONDUCTANCE CURVE



LABORATORY

