FIELD-EFFECT TRANSISTOR

INTRODUCTION

prepared by:

Gyro A. Madrona
Electronics Engineer

TOPIC OUTLINE

JFET Construction

Regions of Operation

Transconductance Curve

JFET CONSTRUCTION

HISTORY

Julius Edgar Lilienfeld

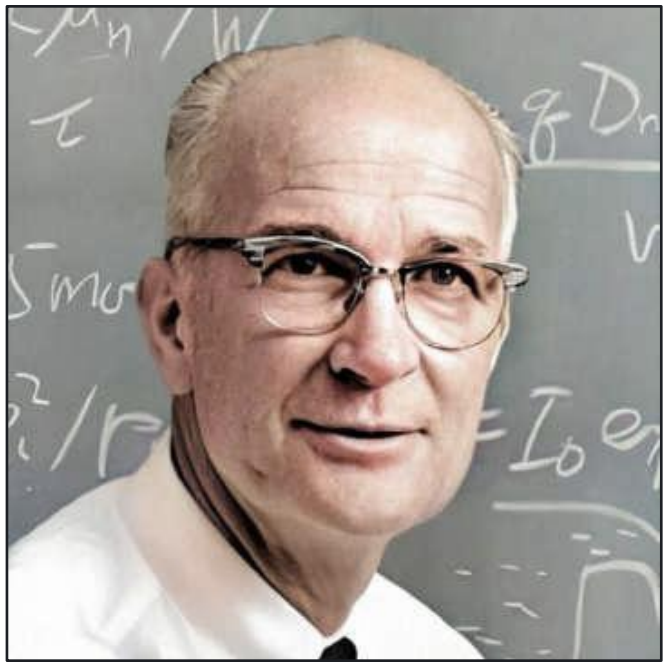
The concept of the field-effect transistor was first proposed by Julius Edgar Lilienfeld in a 1925 patent, but he **never built** a working device due to material limitations of the era.

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.

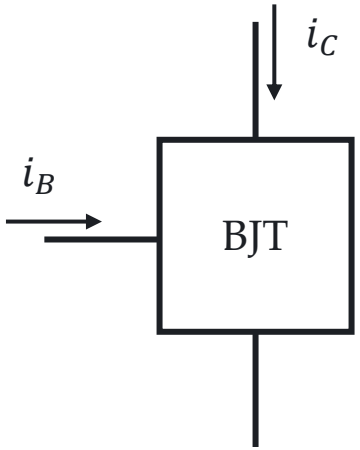
HISTORY

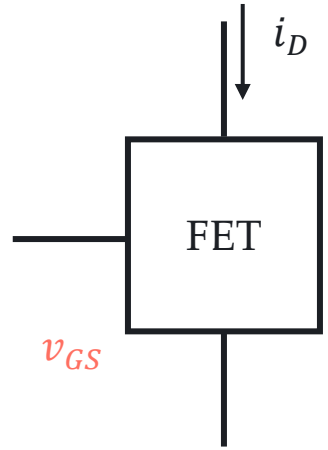


Dr. William Shockley

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

Voltage-controlled device

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

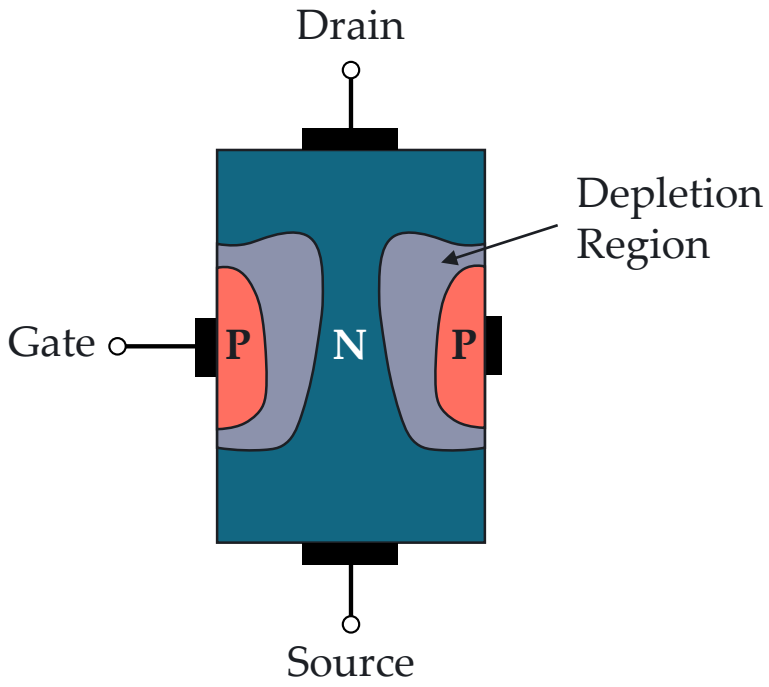
Unipolar device

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

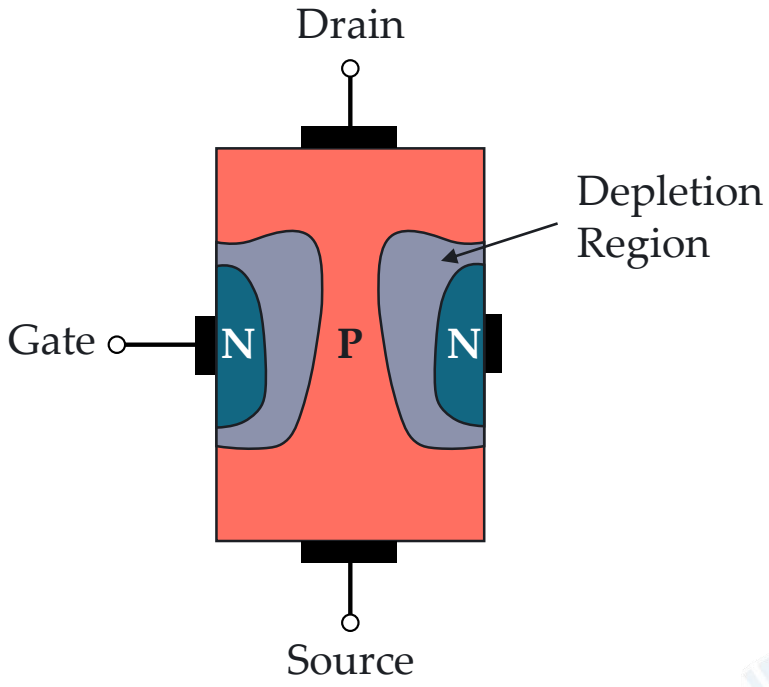
CONSTRUCTION

JFET

Junction Field-Effect Transistor



N-Channel

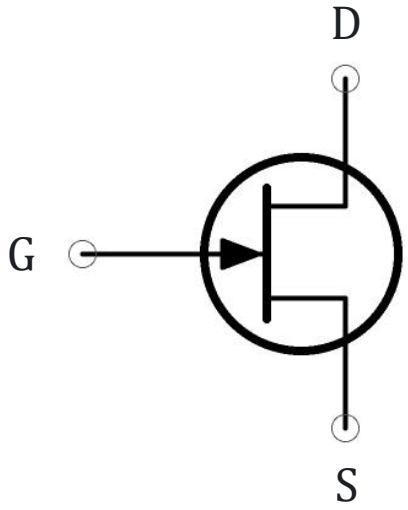


P-Channel

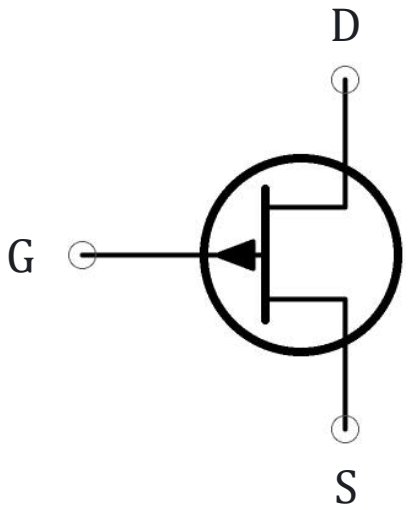
SCHEMATIC SYMBOL

JFET

Junction Field-Effect Transistor



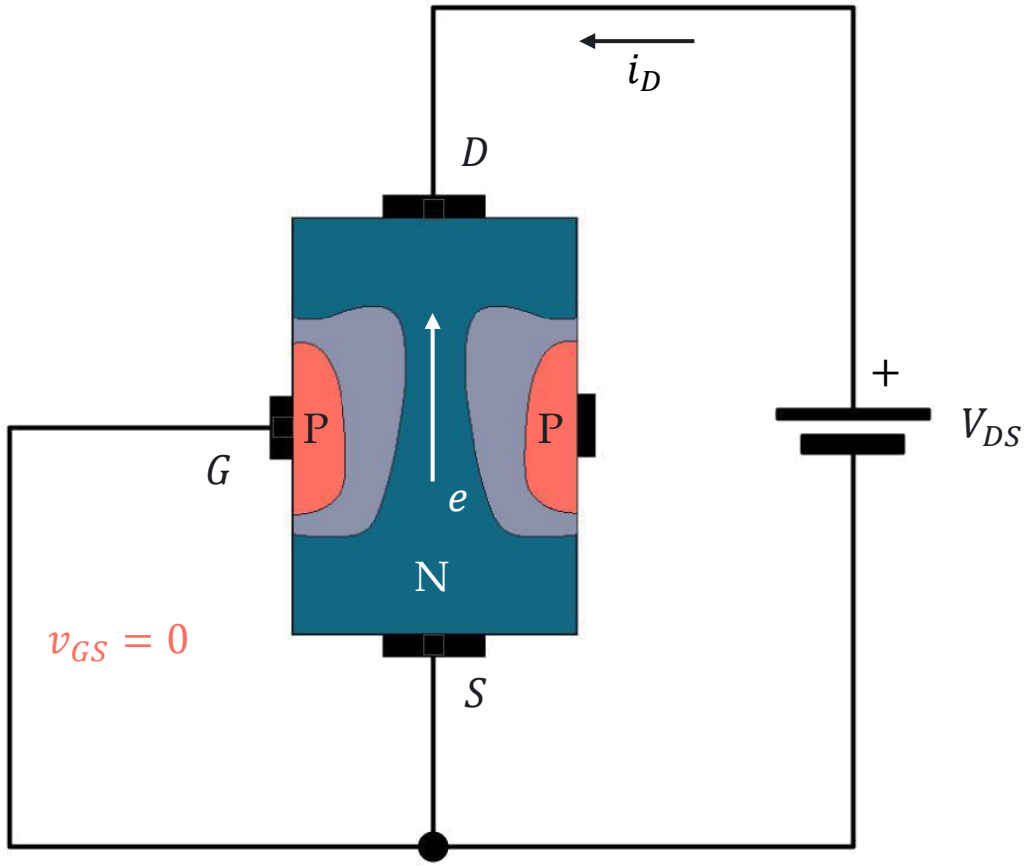
N-Channel



P-Channel

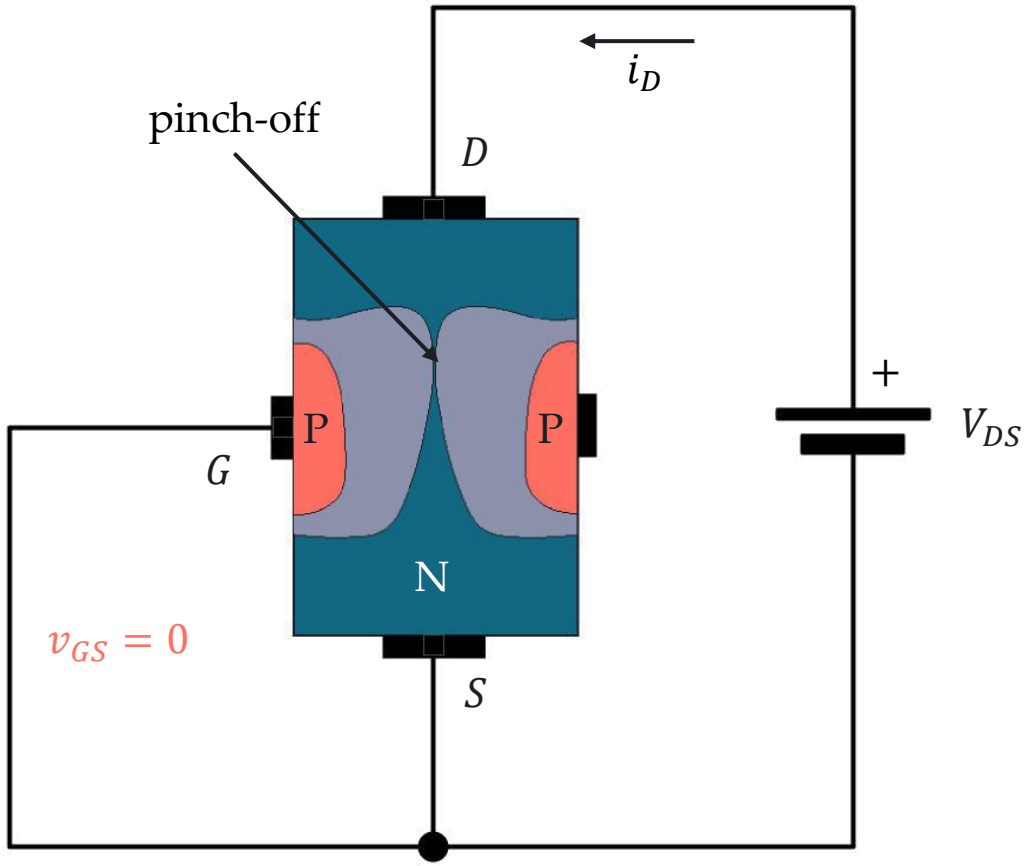
REGIONS OF OPERATION

NORMALLY "ON" DEVICE



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

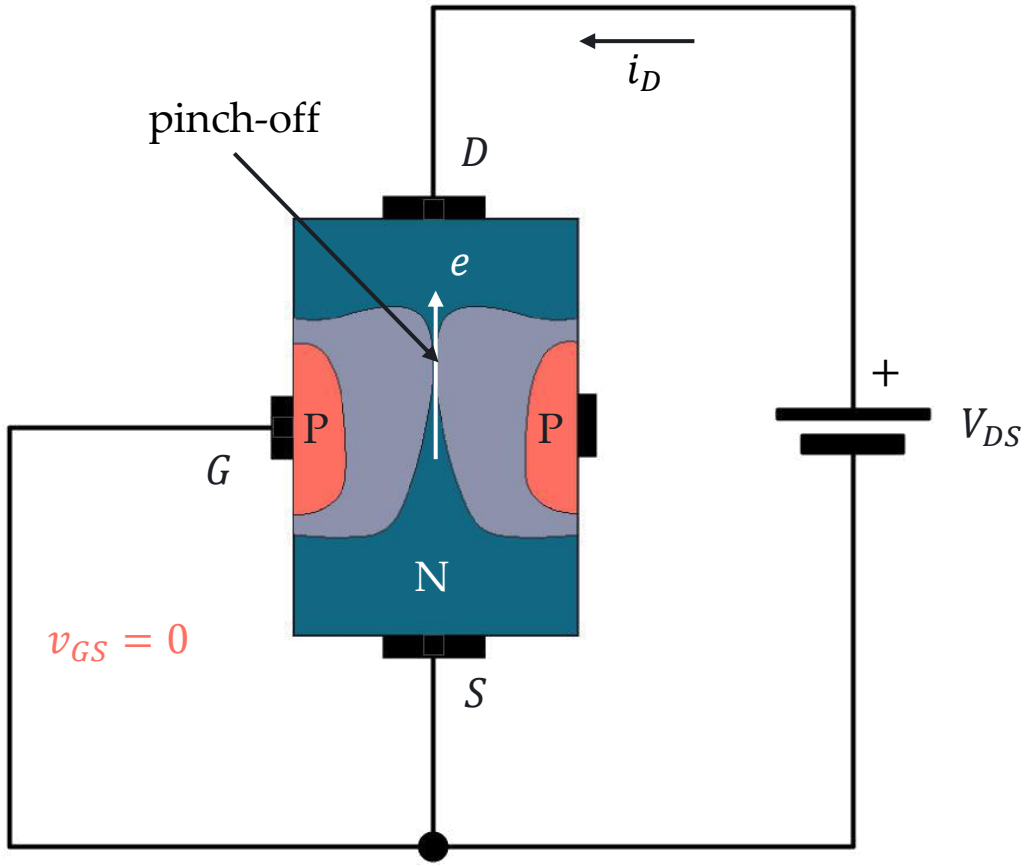
PINCH-OFF VOLTAGE



If $\boldsymbol{V_{DS}}$ 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 $\boldsymbol{V_{DS}}$ that established this condition is referred to as **pinch-off voltage**, $\boldsymbol{V_P}$.

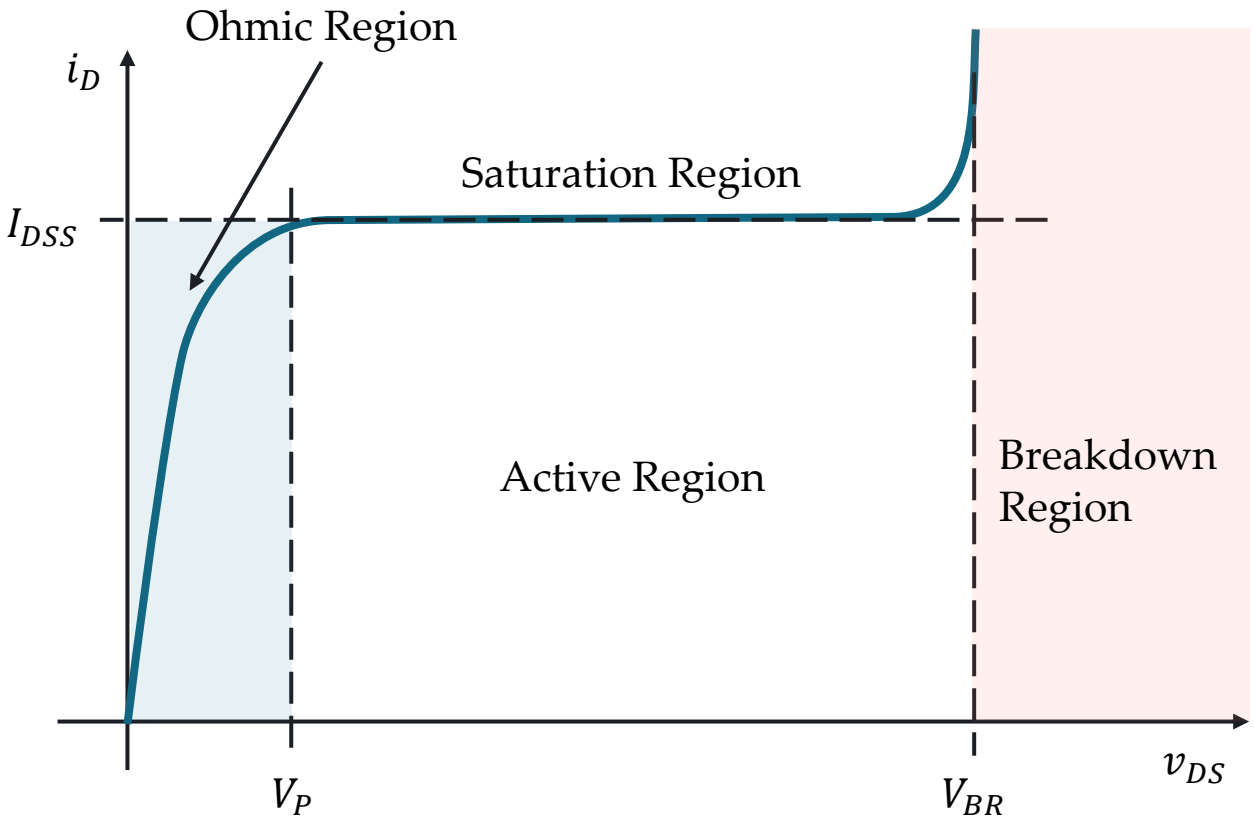
PINCH-OFF VOLTAGE



$\boldsymbol{i_D}$ does not drop off at pinch-off and maintains **saturation level** defined as $\boldsymbol{I_{DSS}}$ (Drain-to-Source current with a Short-circuit connection from gate to source).

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

DRAIN CURVE



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

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

EXERCISE

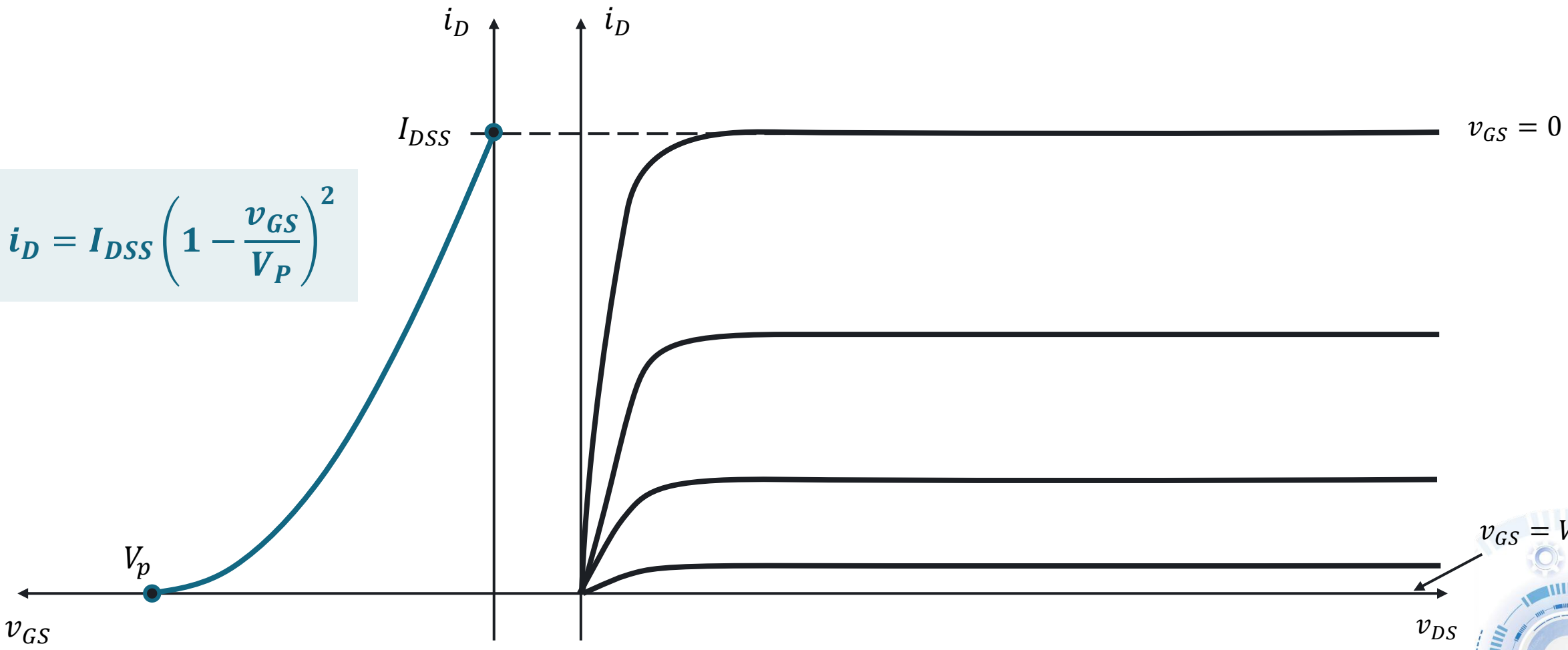
An MPF4857 has $V_p = 6\text{V}$ and $I_{DSS} = 100\ m\text{A}$. What is the ohmic resistance? The gate-source cutoff voltage?

Solution

TRANSCONDUCTANCE CURVE

SHOCKLEY'S EQUATION

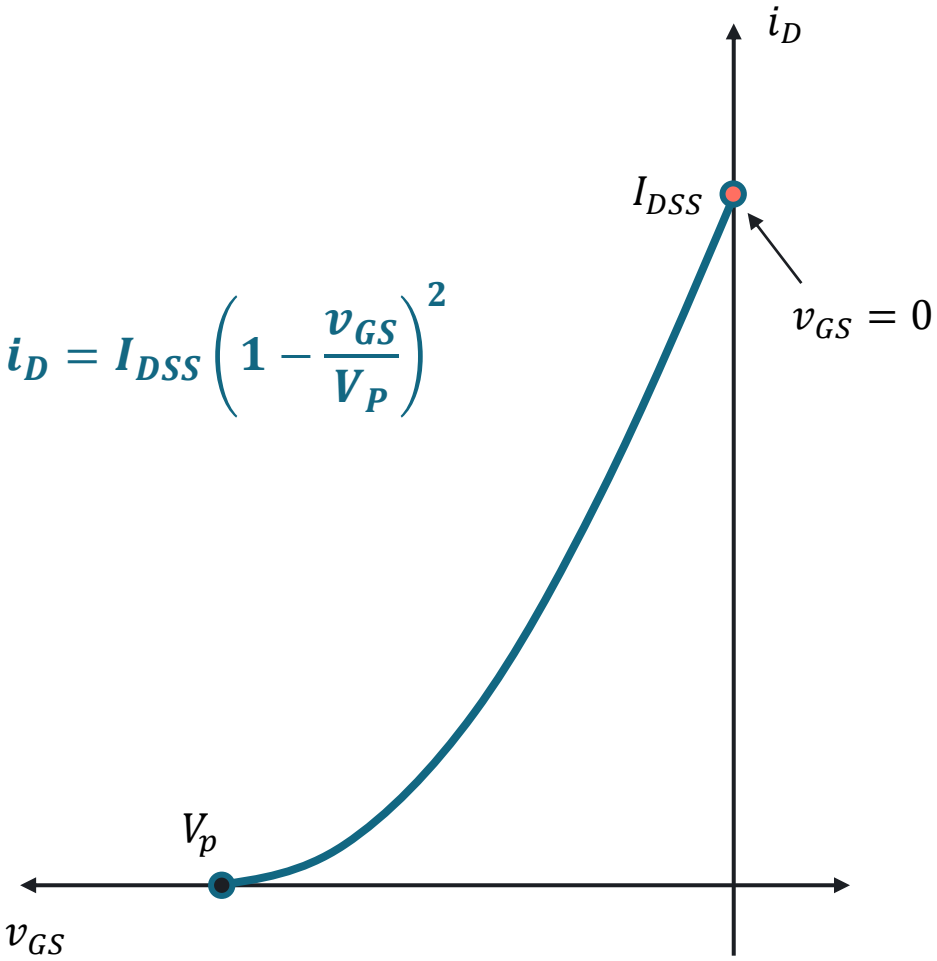
$$i_D = I_{DSS}\left(1 - \frac{v_{GS}}{V_P}\right)^2$$



Transconductance Curve

Drain Curve

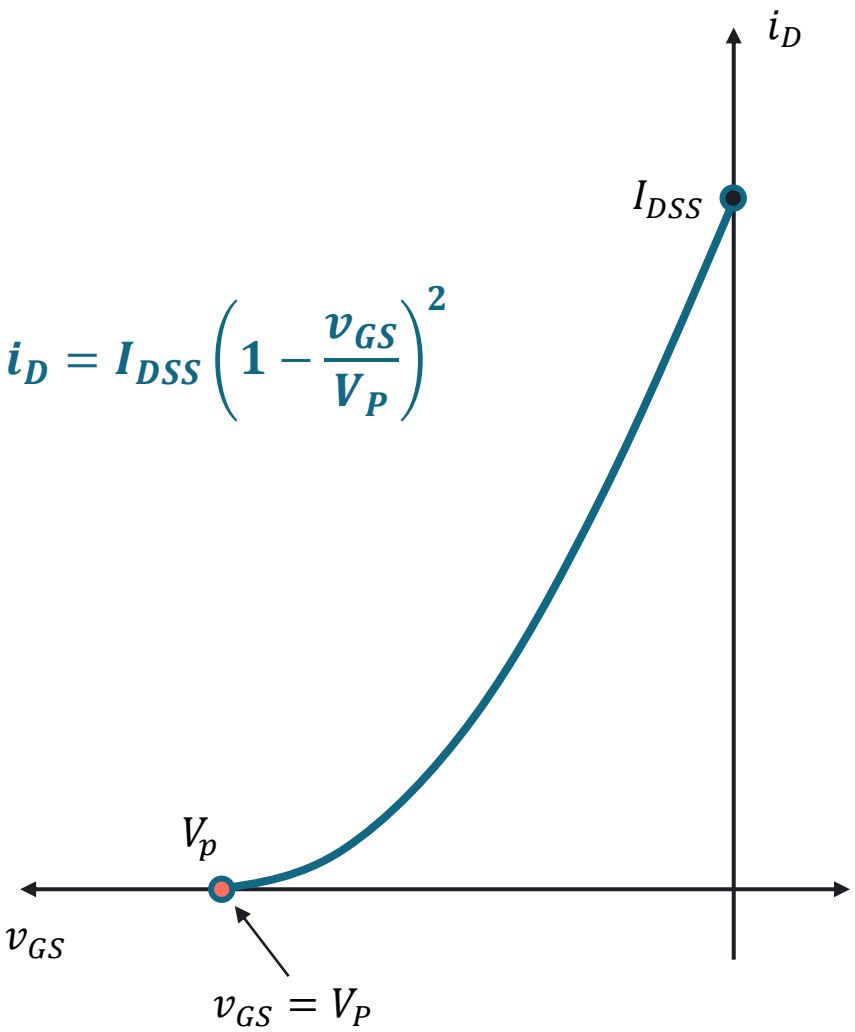
TRANSCONDUCTANCE CURVE



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

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

TRANSCONDUCTANCE CURVE

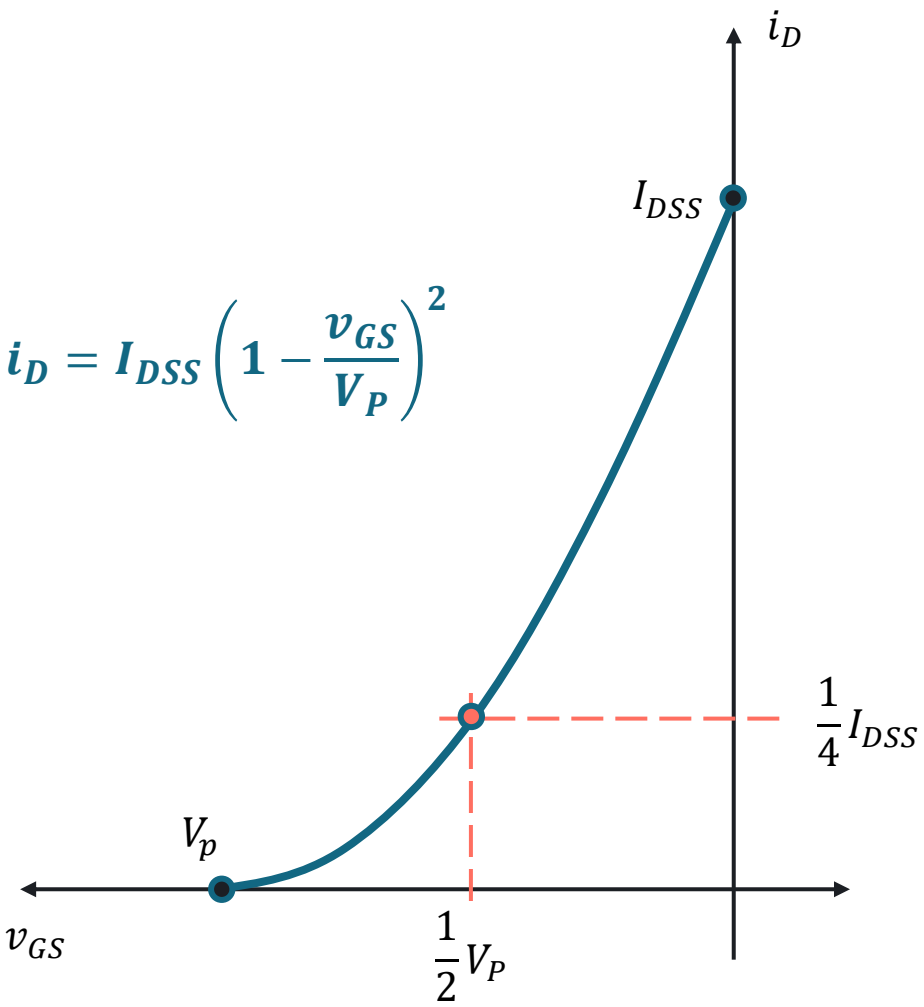


$$i_D = I_{DSS}\left(1 - \frac{v_{GS}}{V_P}\right)^2$$

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

TRANSCONDUCTANCE CURVE

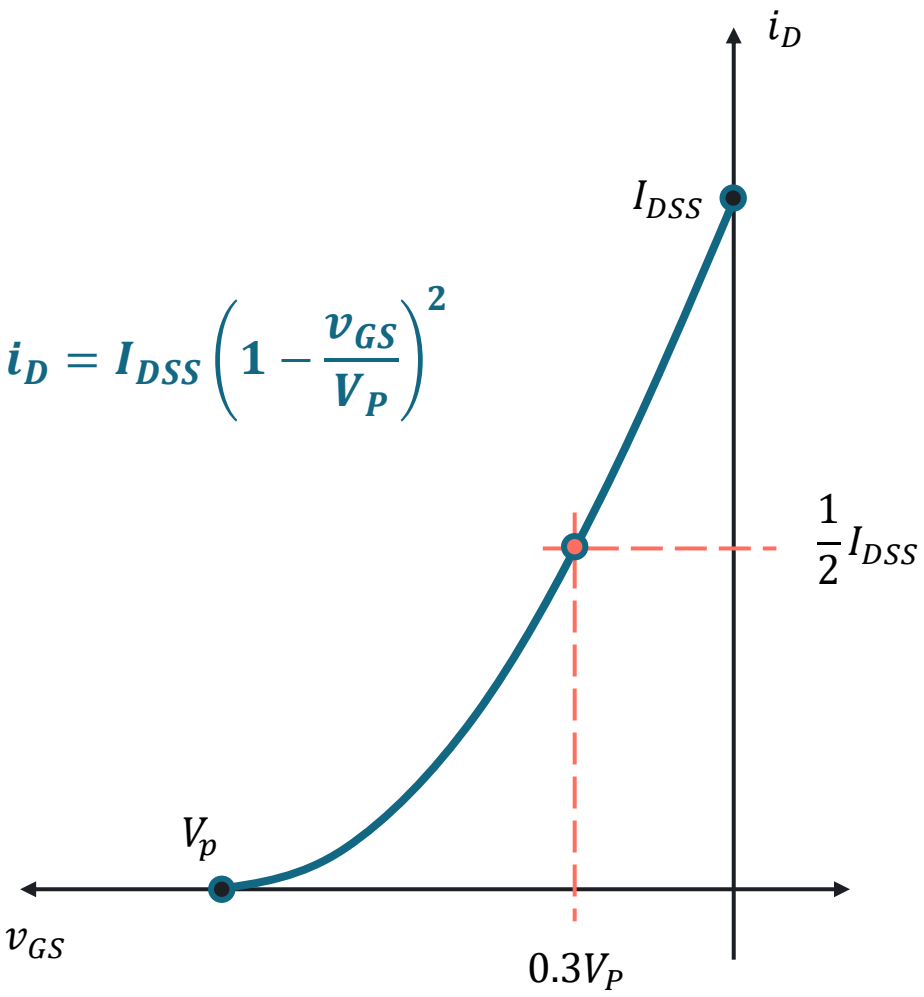
$$i_D = I_{DSS}\left(1 - \frac{v_{GS}}{V_P}\right)^2$$



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

TRANSCONDUCTANCE CURVE

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



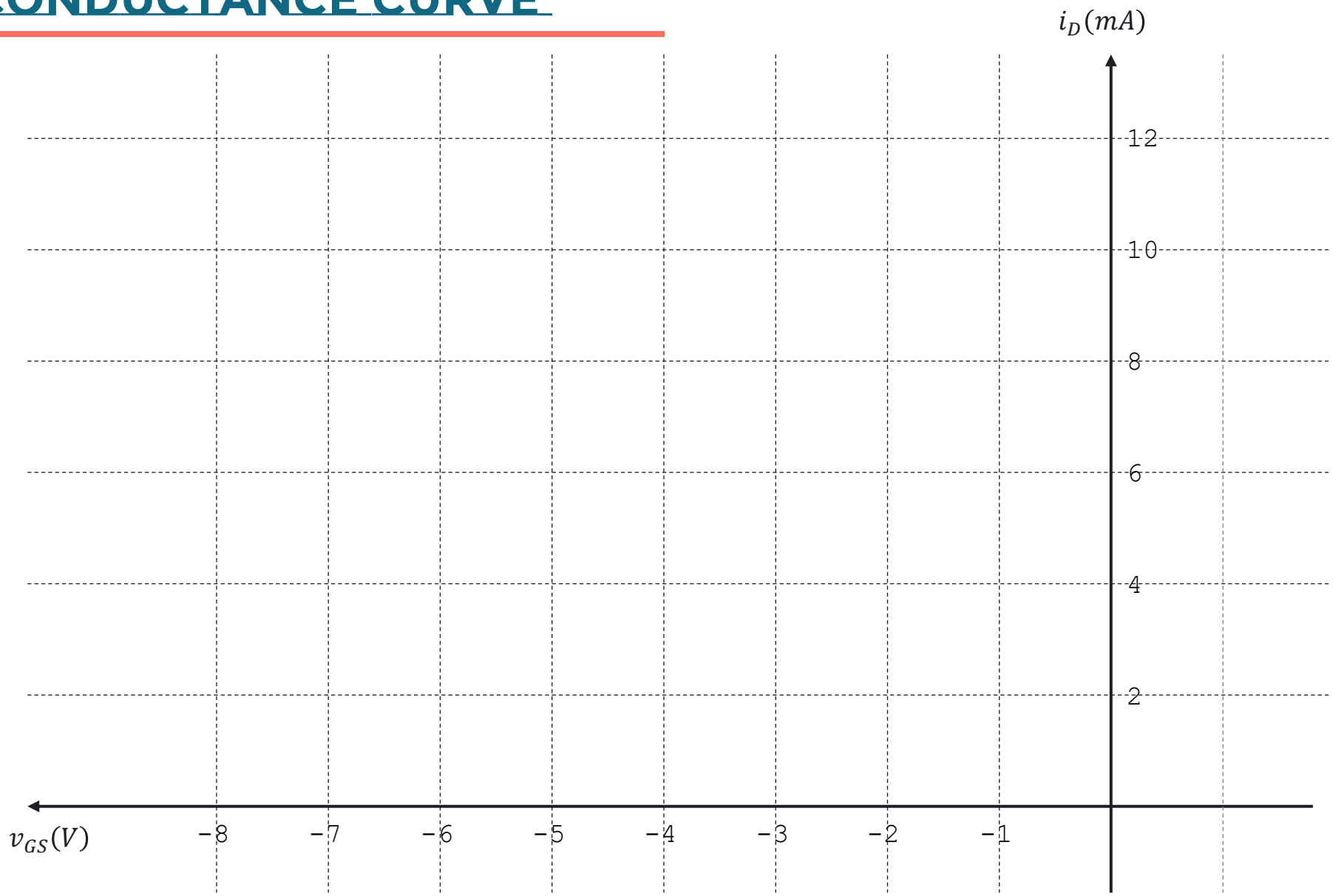
$$v_{GS} = 0.3V_P\Big|_{i_D=\frac{1}{2}I_{DSS}}$$

EXERCISE

Sketch the transconductance curve defined by $I_{DSS} = 12mA$ and $V_P = -6V$.

Solution

TRANSCONDUCTANCE CURVE



LABORATORY