EE 204 - Analog Circuits
Lecture 15

Harsh S Roniyar

October 11, 2023

Contents

1 MOSFET

MOSFET stands for metal-oxide-semiconductor field-effect-transistor. MOSFETs are another type of transistor that has become essential in modern electronics due to their low power consumption and ability to be easily integrated into integrated circuits.

1.1 History of MOSFET

The basic principle of the field-effect transistor was first patented by Julius Edgar Lilienfeld in 1925.

The main advantage of a MOSFET is that it requires almost no input current to control the load current, when compared with bipolar transistors (bipolar junction transistors/BJTs).

The structure resembling the MOS transistor was proposed by Bell scientists William Shockley, John Bardeen and Walter Houser Brattain, during their investigation that led to discovery of the transistor effect.

1.2 Basics of MOSFET

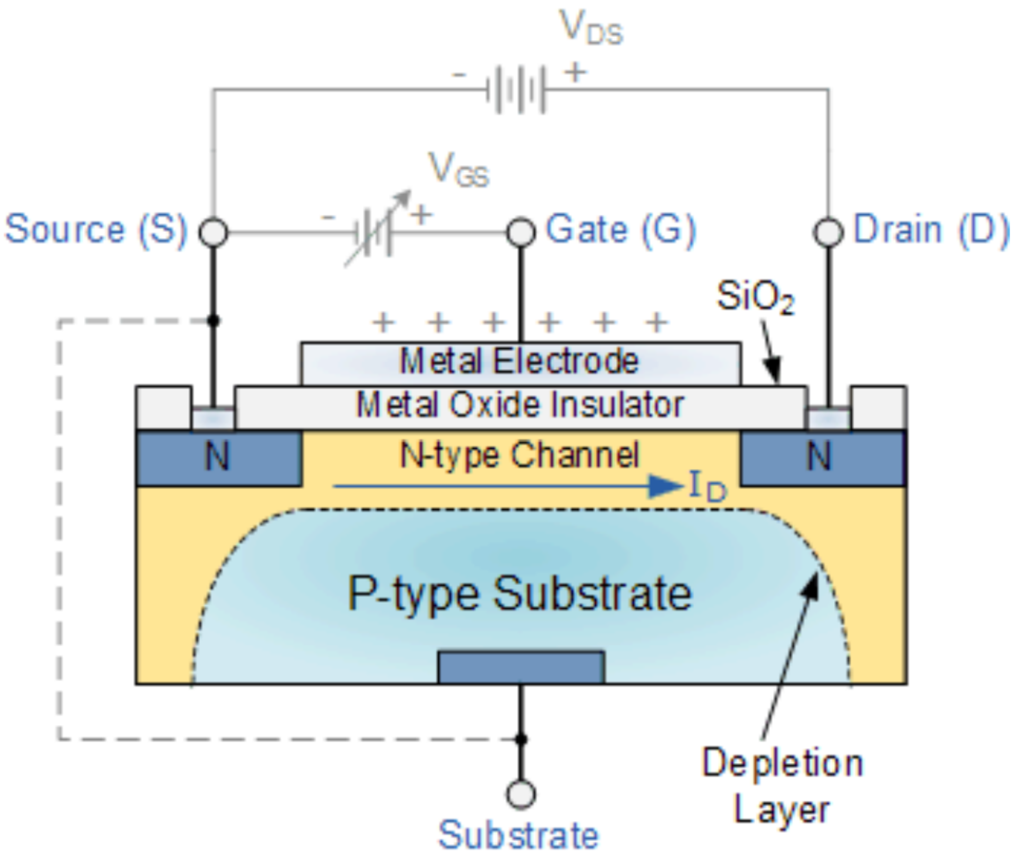


Figure 1: A typical MOSFET

MOSFETs have three terminals: gate, source, and drain. The gate terminal controls the flow of current between the source and drain terminals through an electric field generated by the voltage applied to the gate.

1.3 MOSFET as an Inverter

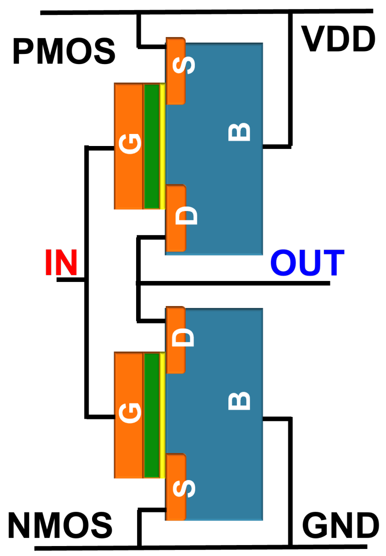


Figure 2: Elaborate diagram for Inverter using MOSFET

One common application of MOSFETs is in inverters. An inverter is a circuit that takes an input signal and produces an inverted output signal (1s become 0s and vice versa).

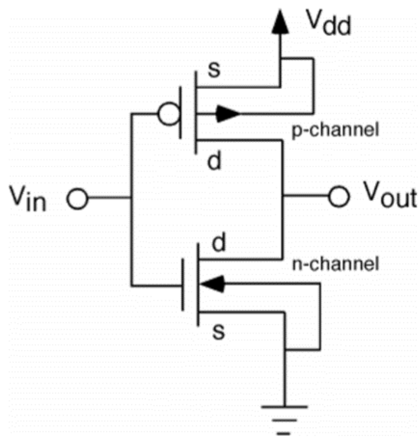


Figure 3: Compact diagram for an Inverter

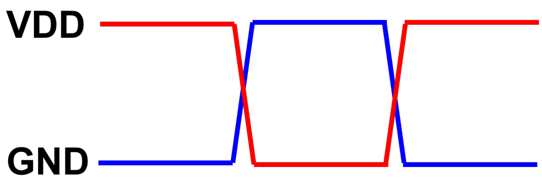


Figure 4: Typical Output of an Inverter

MOSFETs in an inverter are used to switch between two voltage levels (typically high and low) based on the input signal. When the input signal is low, the MOSFET is off, and the output is high; when the input is high, the MOSFET is on, and the output is low.

1.4 MOSFET Diagram

The top and front view of a MOSFET looks like the following -

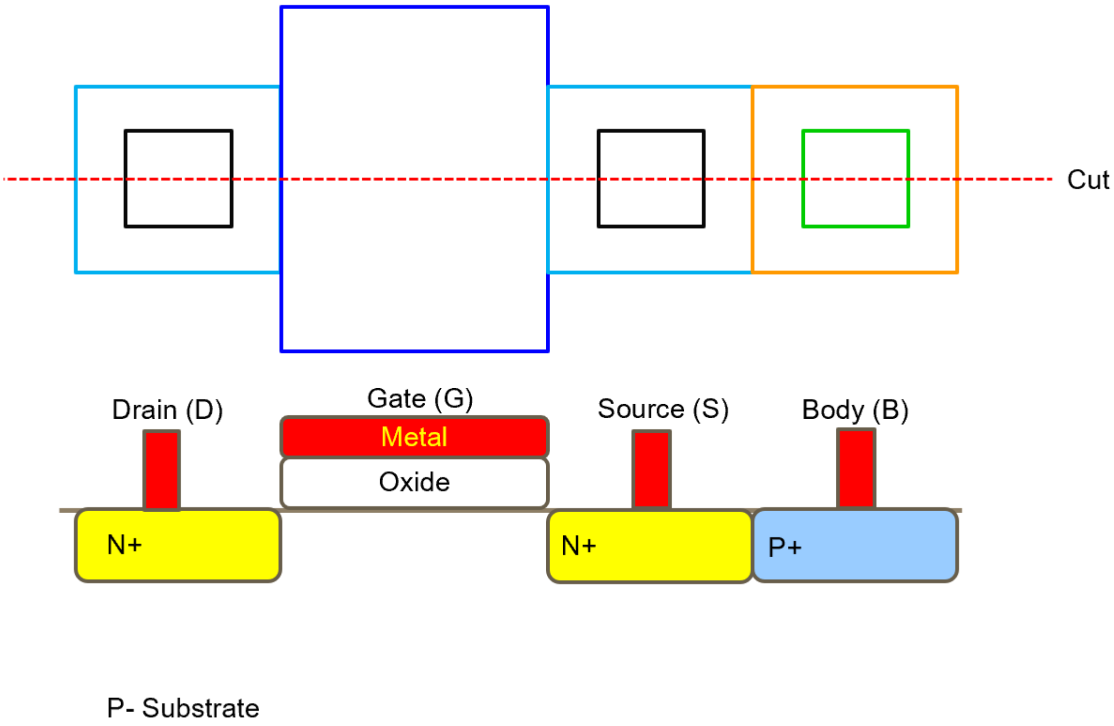


Figure 5: Top-View and Front-View of a MOSFET

In the diagram we can clearly see the arrangement of the drain (D), gate (G) and source (S).

The 3D view of the same MOSFET looks like -

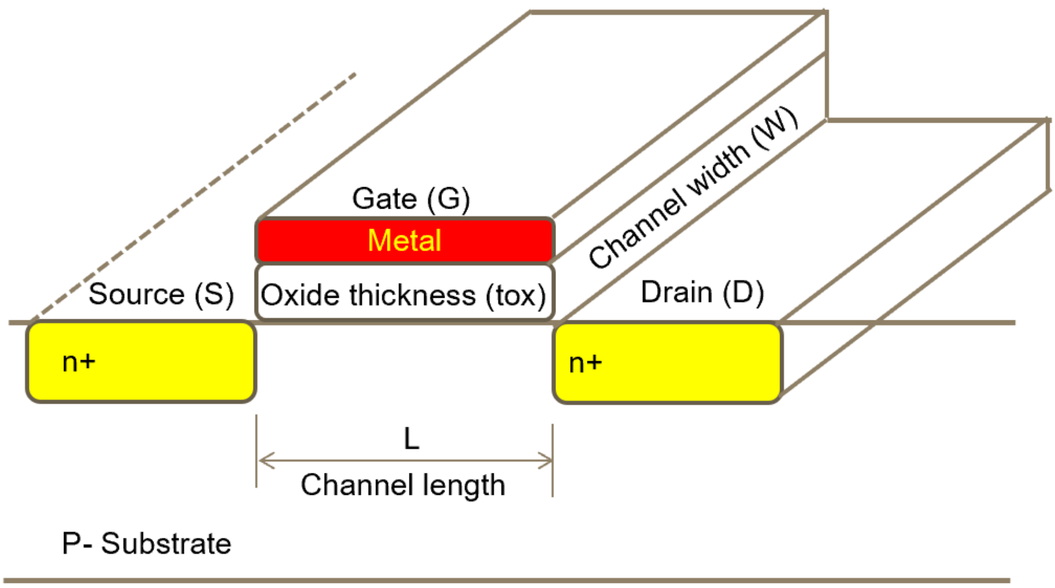
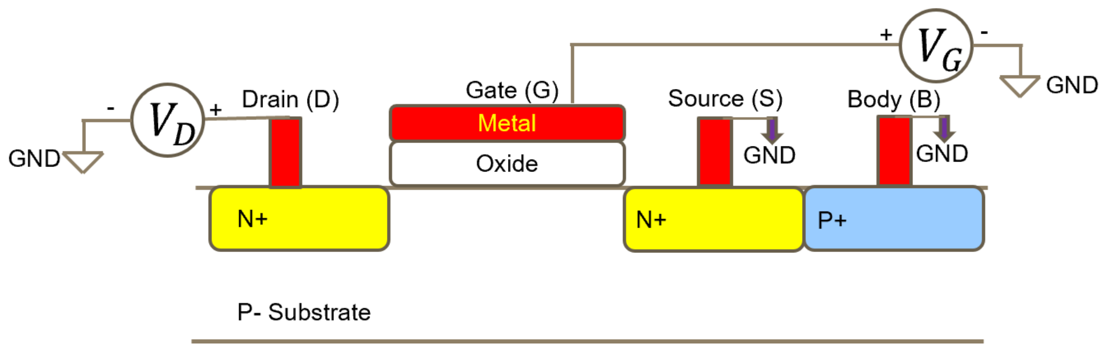


Figure 6: 3D View of a MOSFET

The thickness of the oxide layer typically ranges from $10 - 20A^{\circ}$.

1.5 MOSFET Connections

The connections in the MOSFET diagram are as follows -



A simplified diagram using the symbols for the MOSFET is the following -

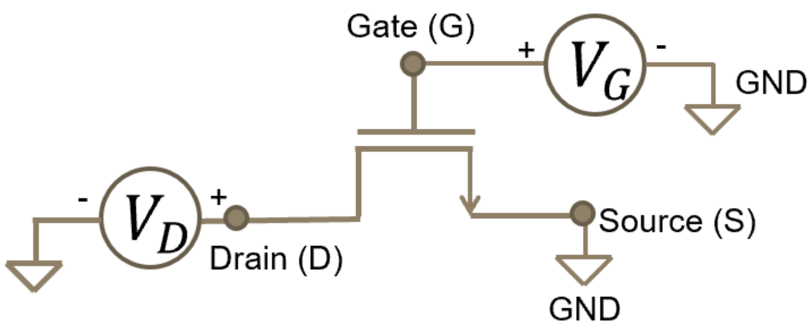
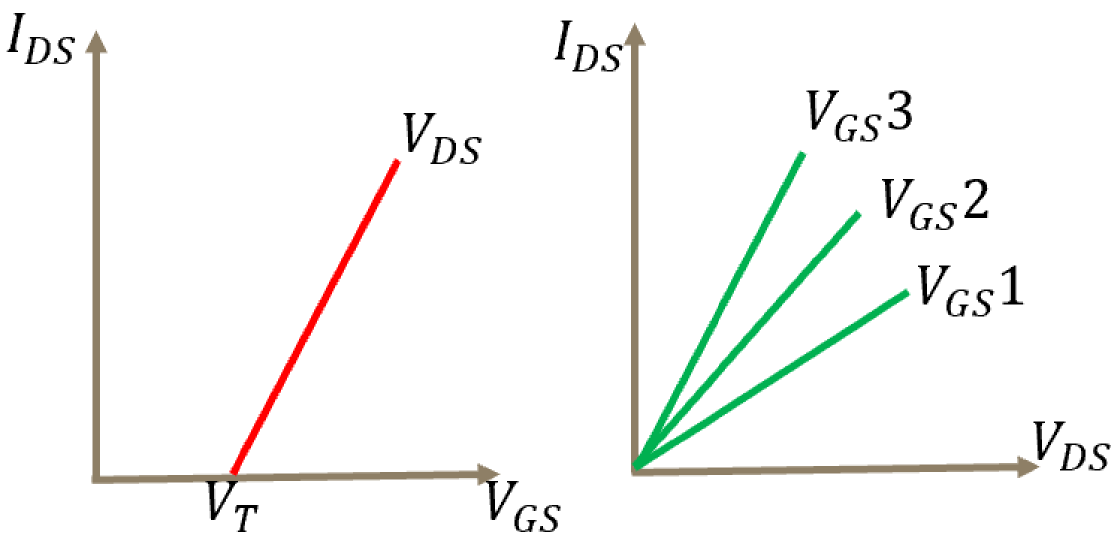


Figure 7: Circuit Diagram of a MOSFET

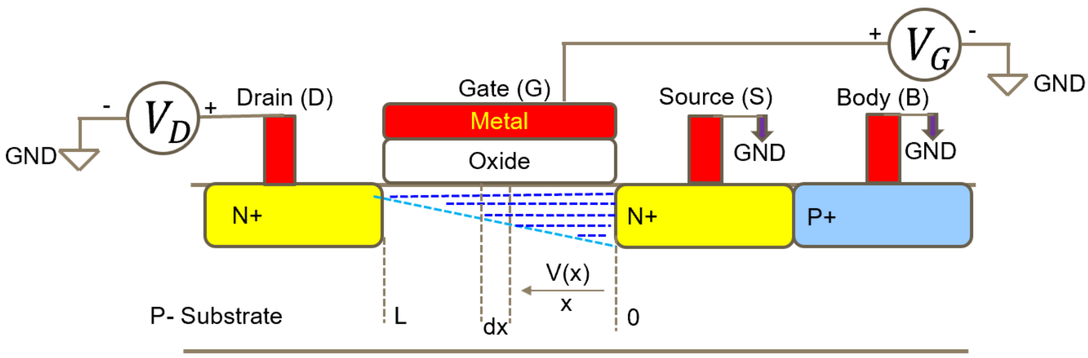
The corresponding I-V plots for the MOSFET are the following -



2 Operation of a MOSFET

When there are no mobile charges in the channel,

$$Q_{ch} = WC_{ox}(V_{GS} - VTH)$$



When there are mobile chargers along channel x, $V(x)$ goes from 0 to V_{DS}

$$Q_d = WC_{ox}(V_{GS} - V(x) - V_{TH})$$

and current through channel would be,

$$I_{DS} = Q_d(x)v$$

where, v is the velocity and

$$v = \mu_n \frac{dV(x)}{dx}$$

On substituting the relations and solving for I_{DS}, we get -

$$I_{DS} = \mu_n \frac{W}{L} C_{ox}(V_{GS} - V_{TH})V_{DS} - \frac{V_{DS}^2}{2}$$

Therefore,

$$I_{DS} \propto \mu_n, \frac{W}{L}, C_{ox} \quad \text{(Device aspect ratio)}$$
$$I_{DS} \propto (V_{GS} - V_{TH})$$
$$I_{DS} \propto V_{DS}$$