دانشگاه صنعتی امیرکبیر
(پلی تکنیک تهران)

Electrical and Electronic Circuits

chapter 11. Transistor

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عظیم فرقدان

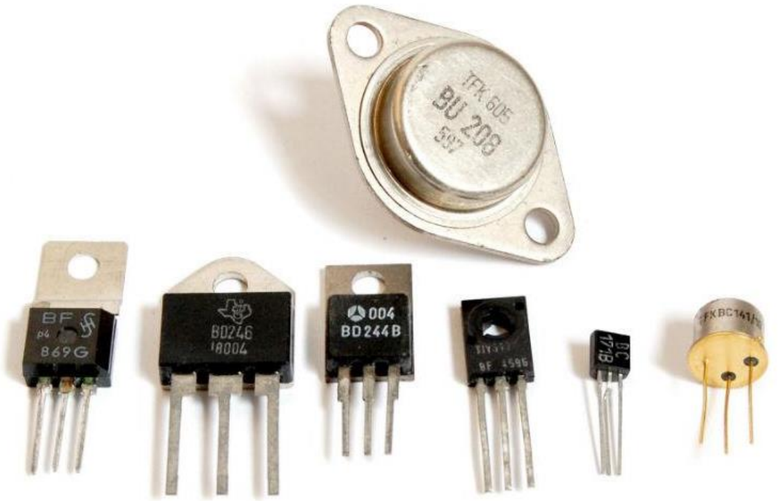
مهر ۱۴۰۳

Objectives of the Lecture

- Types of Transistors
- Applications of Transistors
- Transistor Modeling in Digital Circuits
  - Ideal Switch

Transistor

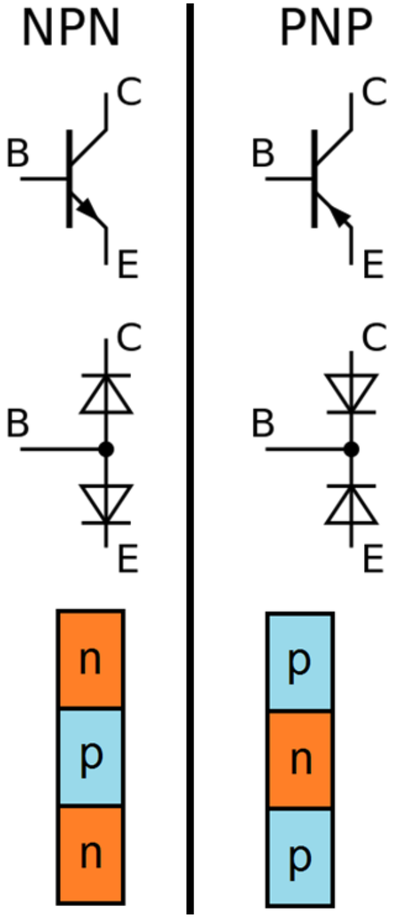
- A three-terminal component, available in two types.
  - ✓ BJT
  - ✓ MOSFET

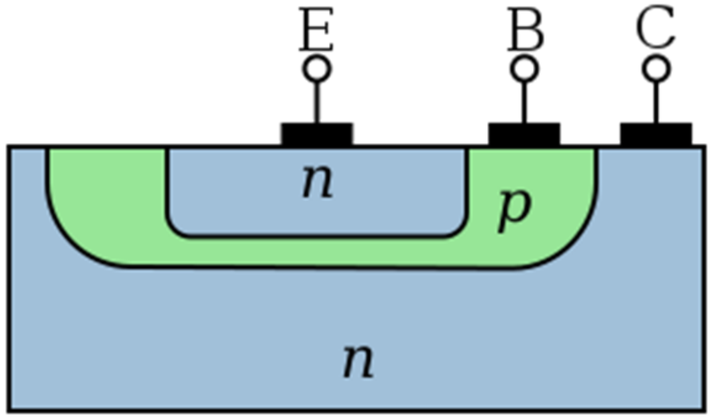


- ✓ BJT: Bipolar Junction Transistor
- ✓ MOSFET: Metal-Oxide-Semiconductor Field Effect Transistor

Transistor BJT (Bipolar Junction Transistor)

- It has three terminals named:
  - ✓ B (Base)
  - ✓ C (Collector)
  - ✓ E (Emitter)

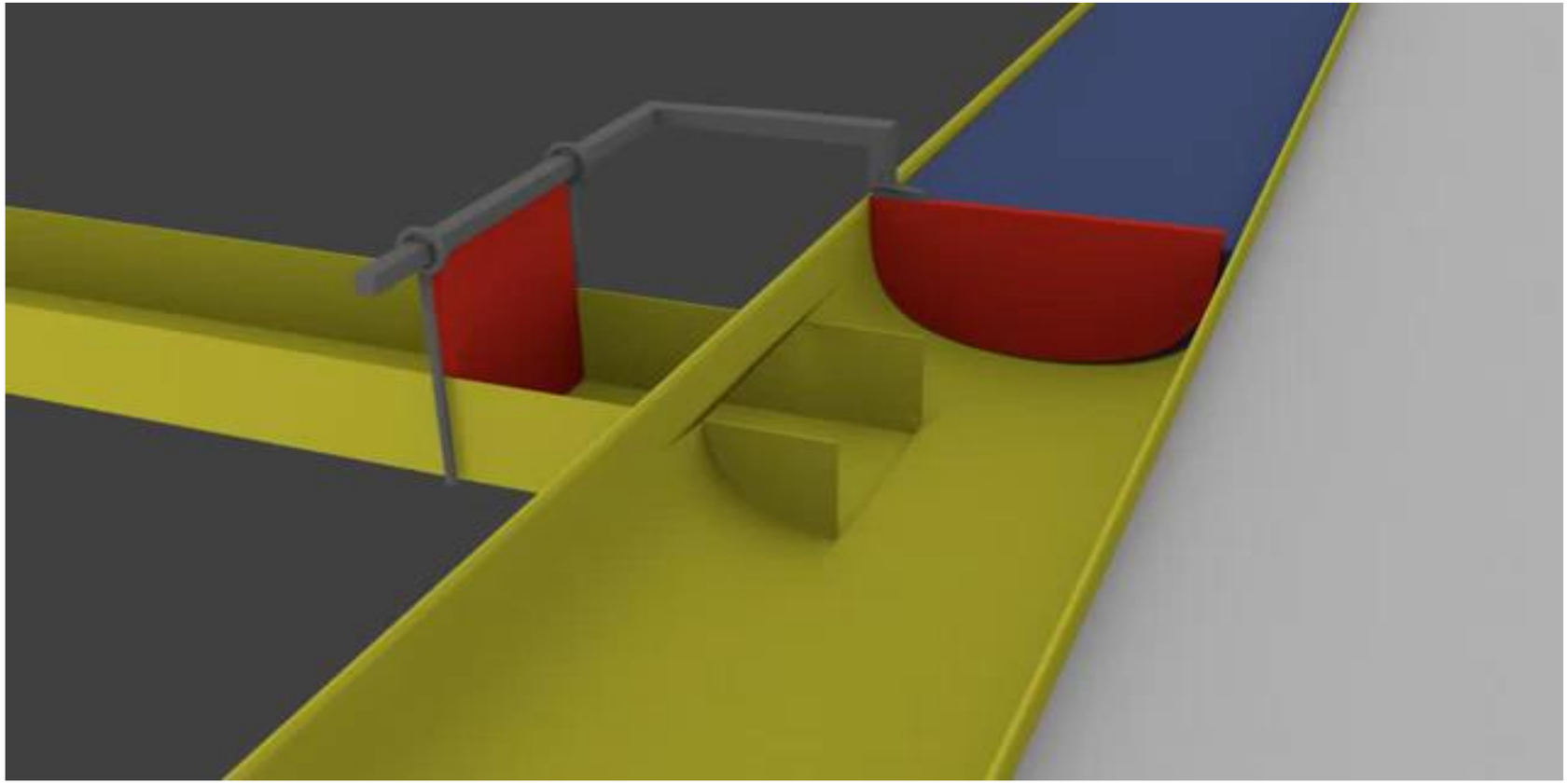




Transistor BJT

Operation of a BJT Transistor

- The passage of a small current through the base allows a larger current to flow between the collector and the emitter.



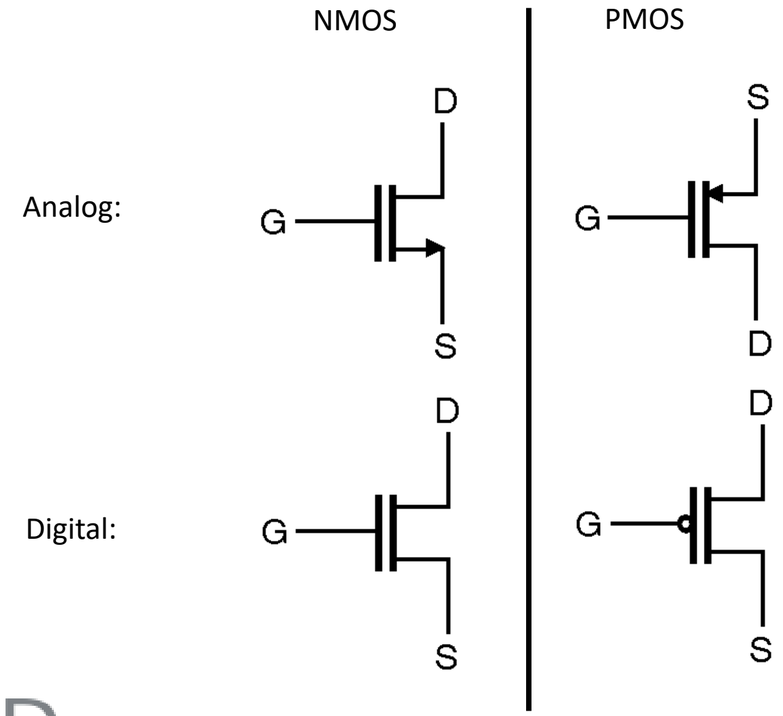
MOSFET Transistor

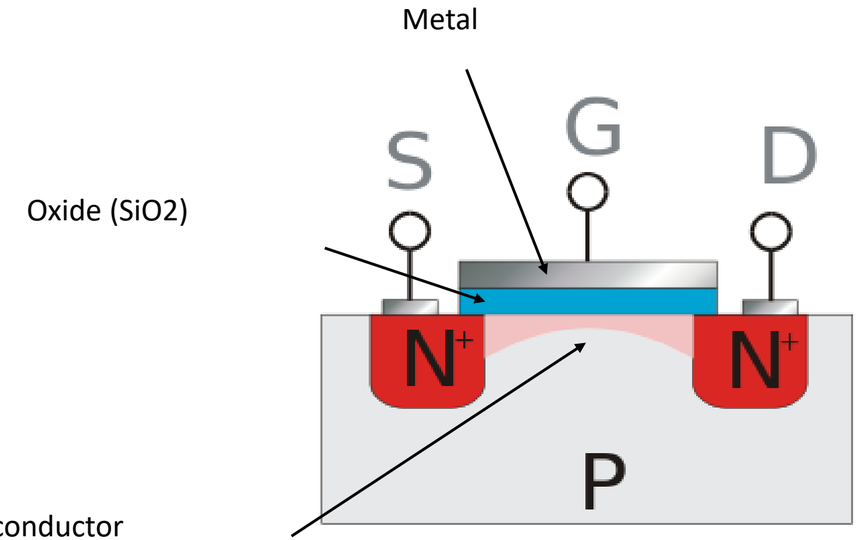
- It has three terminals named:

  G (Gate)

  S (Source)

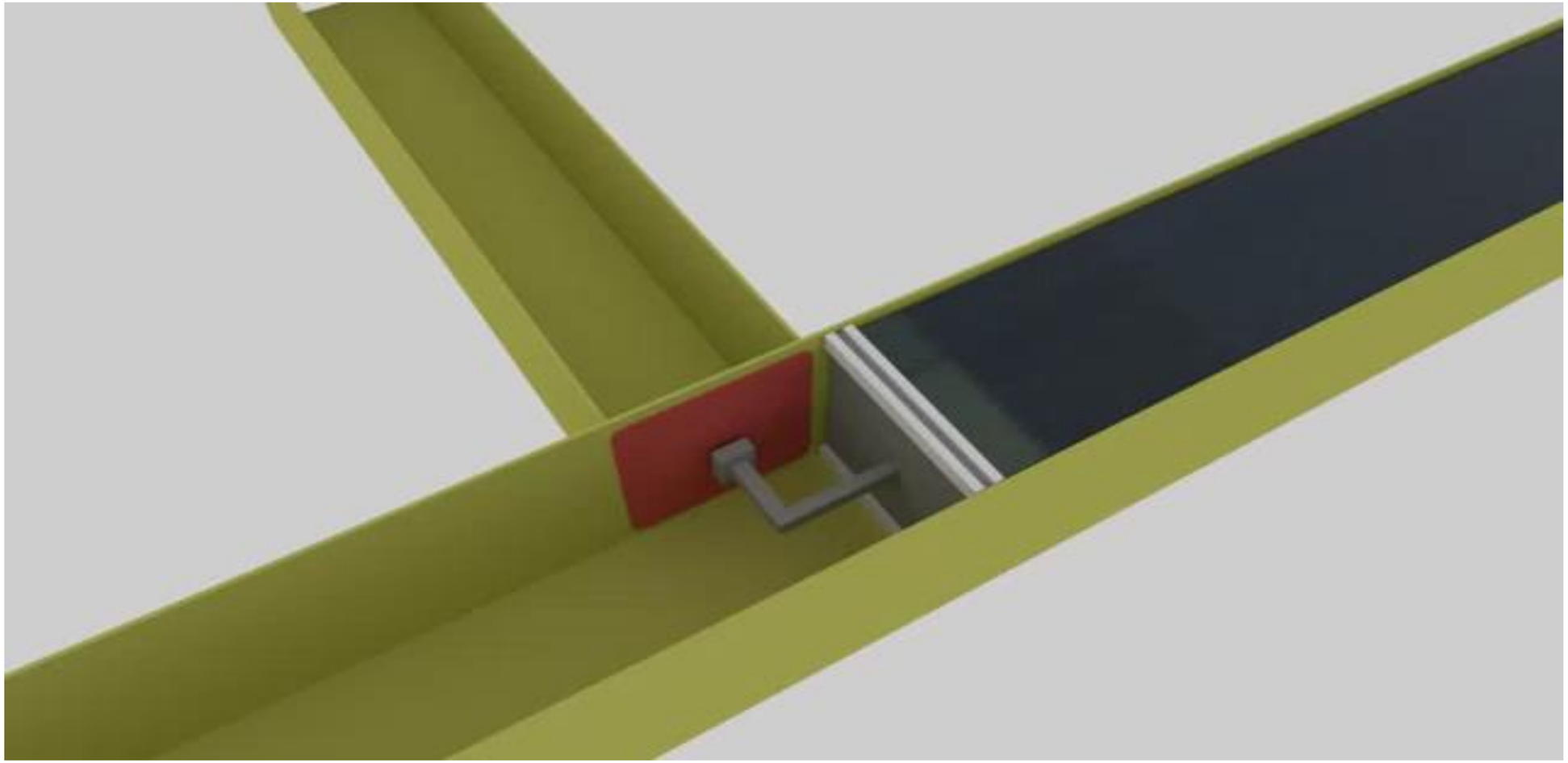
  D (Drain)





Operation of a MOSFET Transistor

- Applying a sufficient voltage to the gate enables a proportional current flow between the drain and the source.

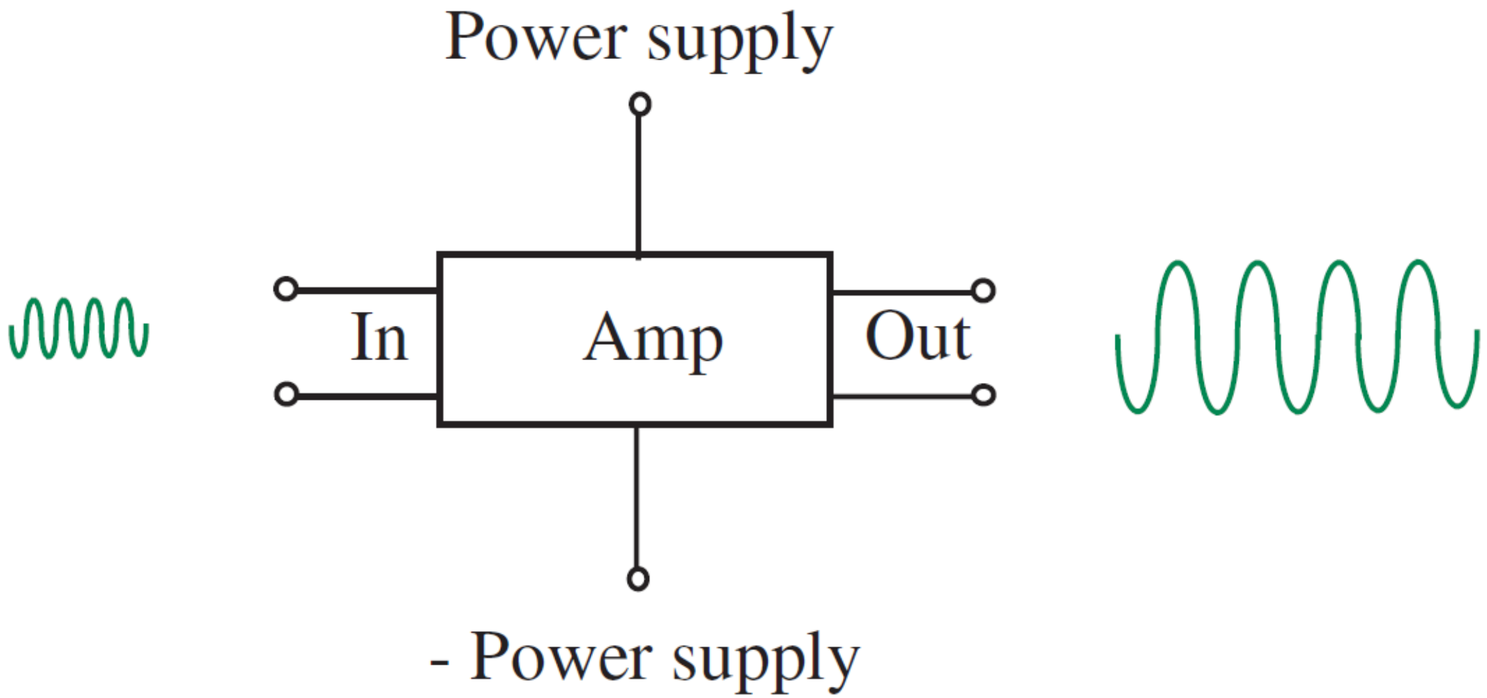


Differences Between BJT and MOSFET Transistors

BJT	MOSFET
ساختار نامتقارن	ساختار متقارن
جریان بیس، جریان کلکتور-امیتر را کنترل می‌کند.	ولتاژ گیت، جریان سورس-درین را کنترل می‌کند.
توان مصرفی زیاد (به دلیل غیرصفر بودن جریان ورودی)	توان مصرفی کم و مناسب برای مدارها با تعداد بسیار زیاد ترانزیستور
مناسب برای مدارهای آنالوگ فرکانس بالا	مناسب برای مدارهای آنالوگ و دیجیتال
وابستگی زیاد بهره به دما	وابستگی کم بهره به دما

Applications of Transistors

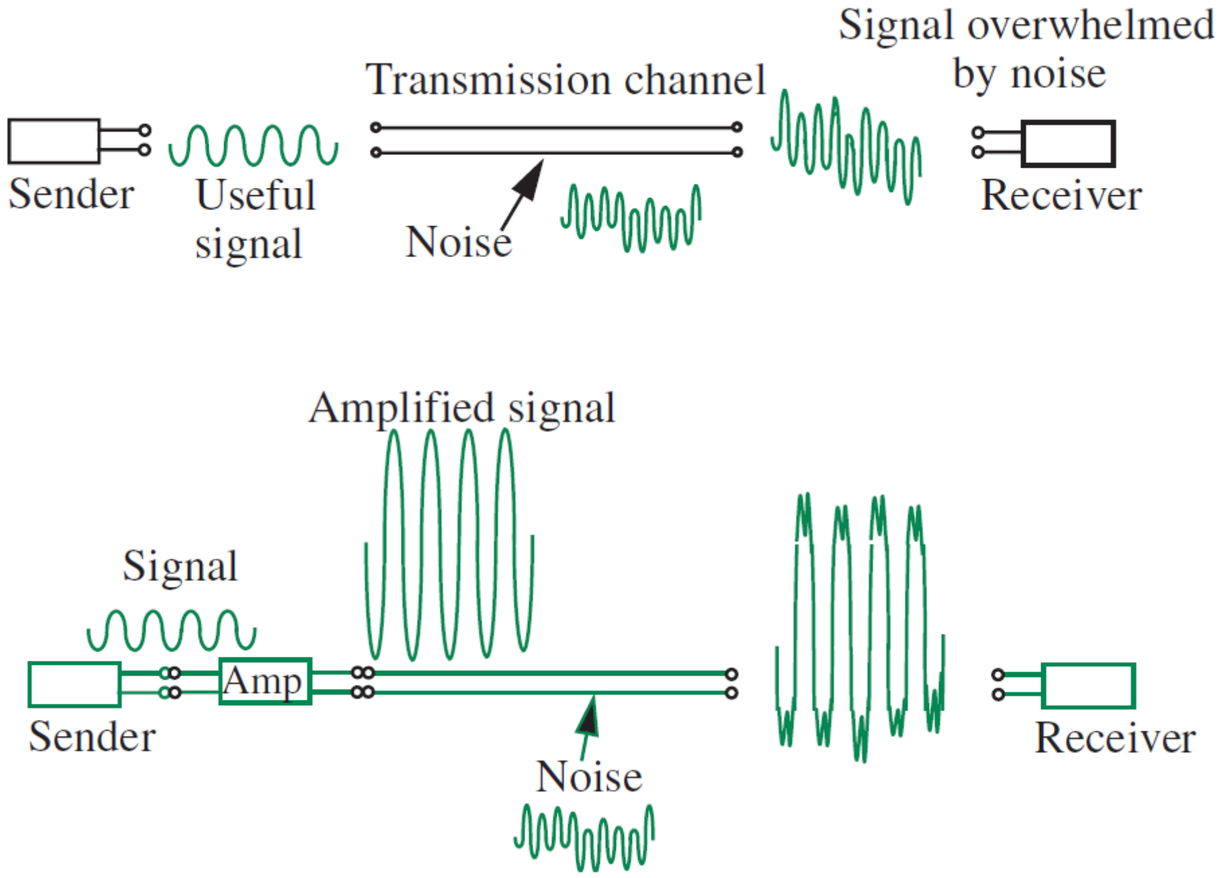
In analog circuits, transistors are utilized as amplifiers.



Example: Amplifying the audio signal received from a microphone.

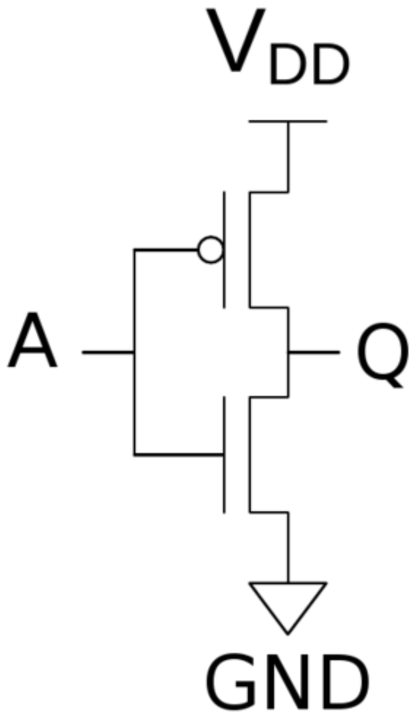
Applications of Transistors

In analog circuits, transistors are utilized as amplifiers.



Applications of Transistors

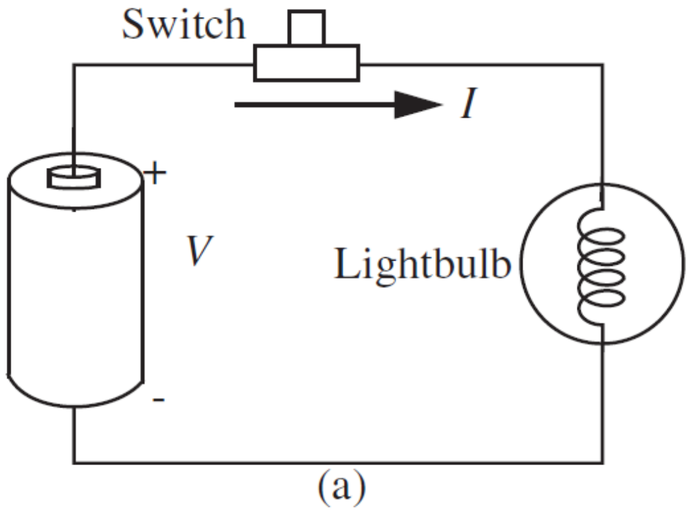
In digital circuits, transistors are used as switches.



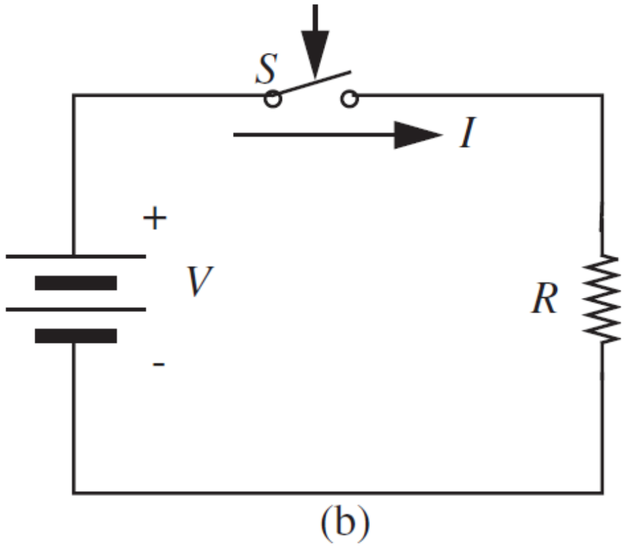
Example: Inverter gate.

Transistor Model as a Switch

Example: Turning a lamp on and off using a switch.



Physical Circuit



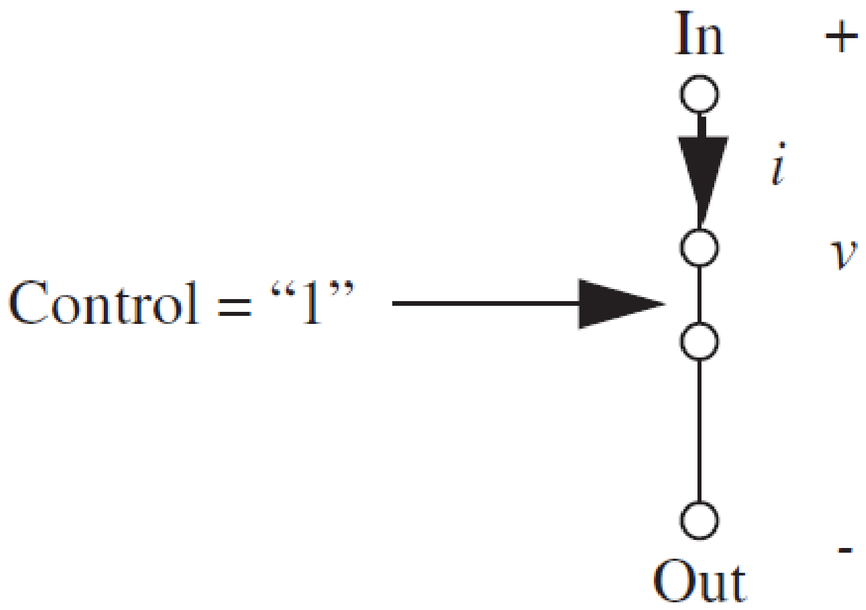
Electrical Model

In many applications, a switch is required that can be controlled electronically by an electrical signal.

NMOS Transistor as a Switch

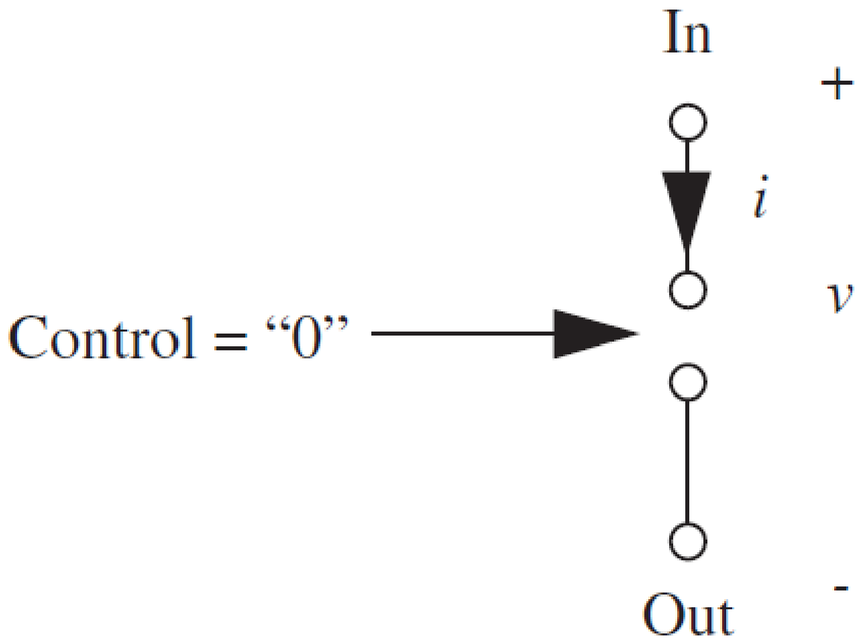
➢ON State

$$\boldsymbol{Control = 1 \rightarrow v = 0}$$

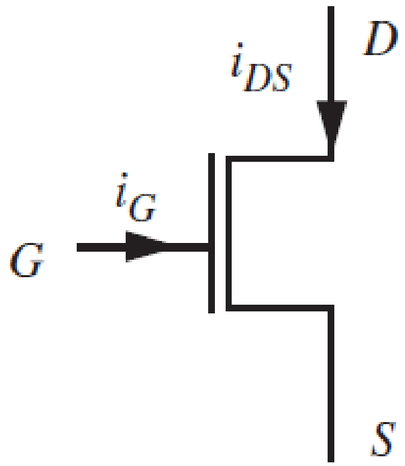


➢Off State

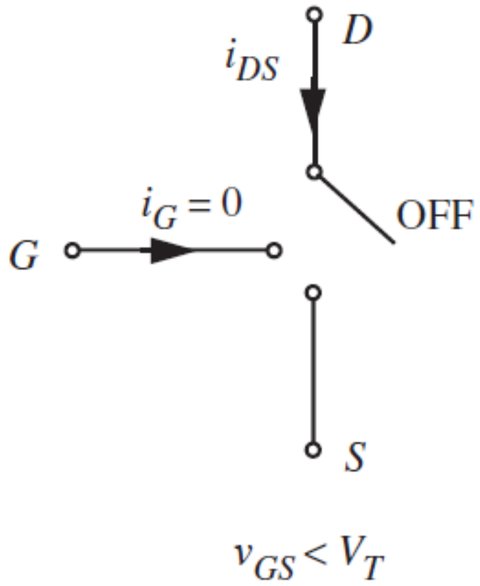
$$\boldsymbol{Control = 0 \rightarrow i = 0}$$



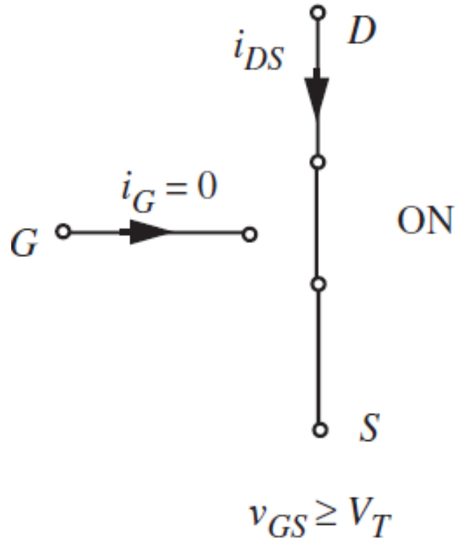
NMOS Transistor as a Switch



NMOS Transistor



Disconnected State (OFF)

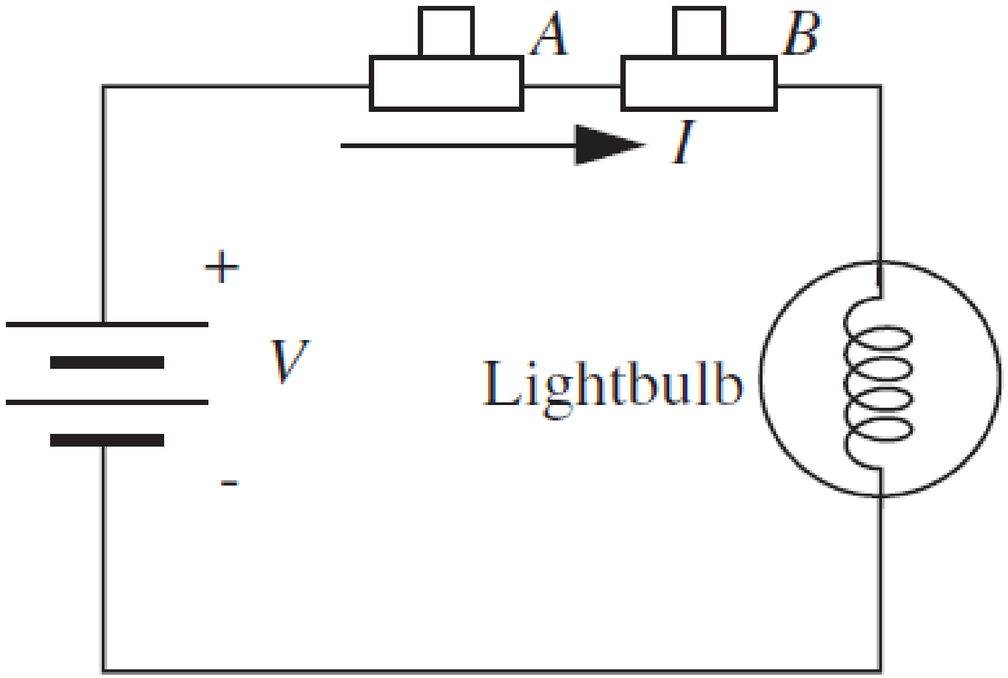


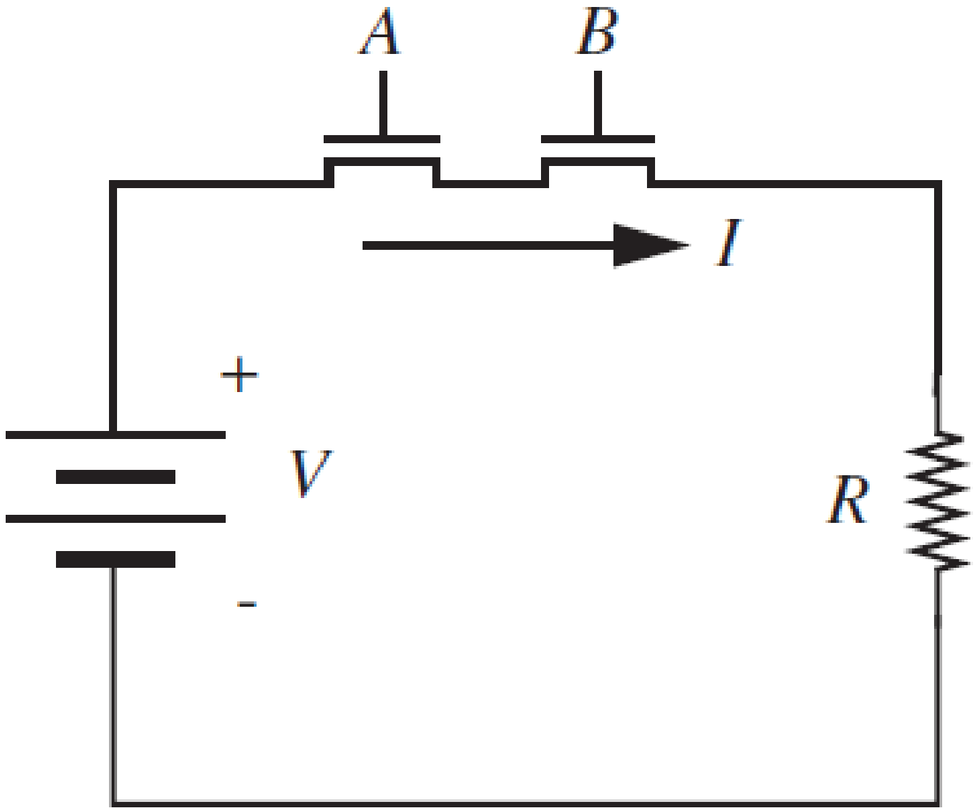
Connected State (ON)

The threshold voltage (V_T) of an NMOS transistor is a positive value that defines the minimum gate-to-source voltage (V_{GS}) required to form a conductive channel between the drain and source.

Construction of Logical Gates

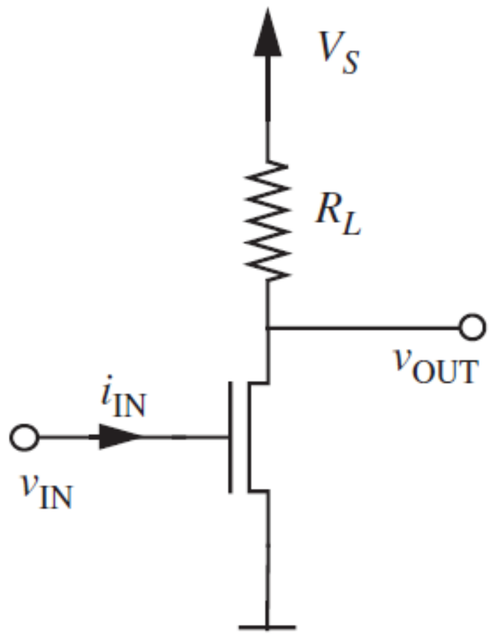
➢Example: Series connection of two switches

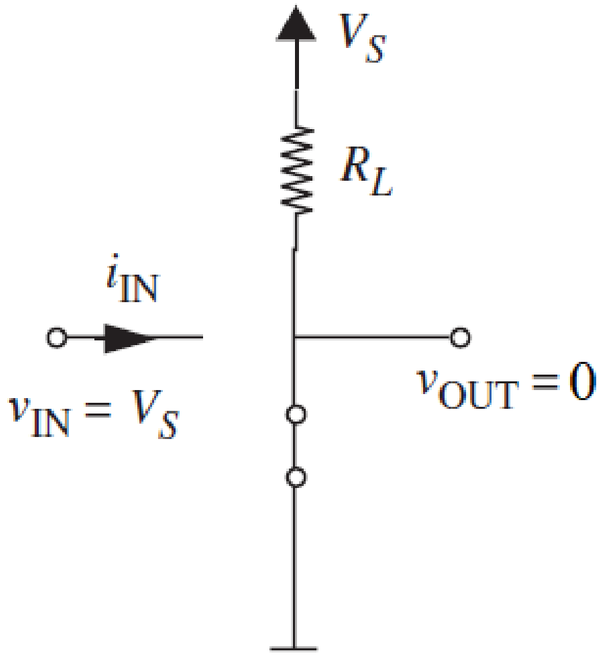


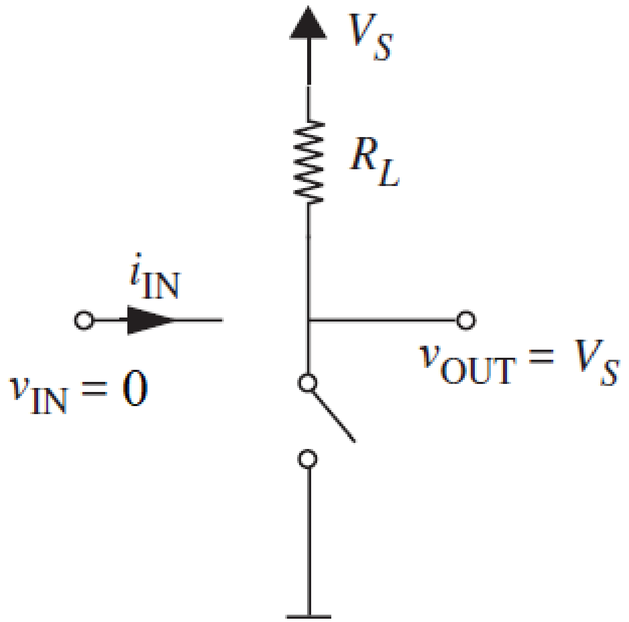


Construction of Logical Gates

- Not Gate

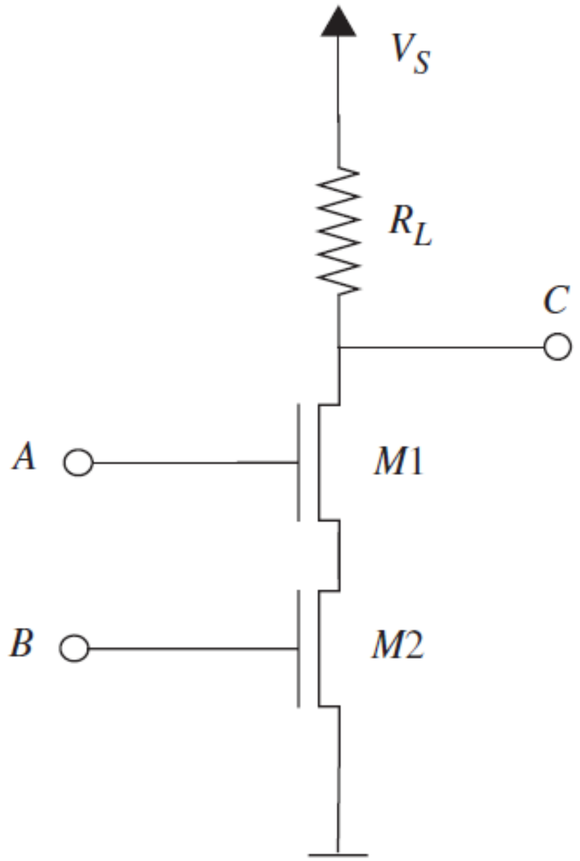






Example

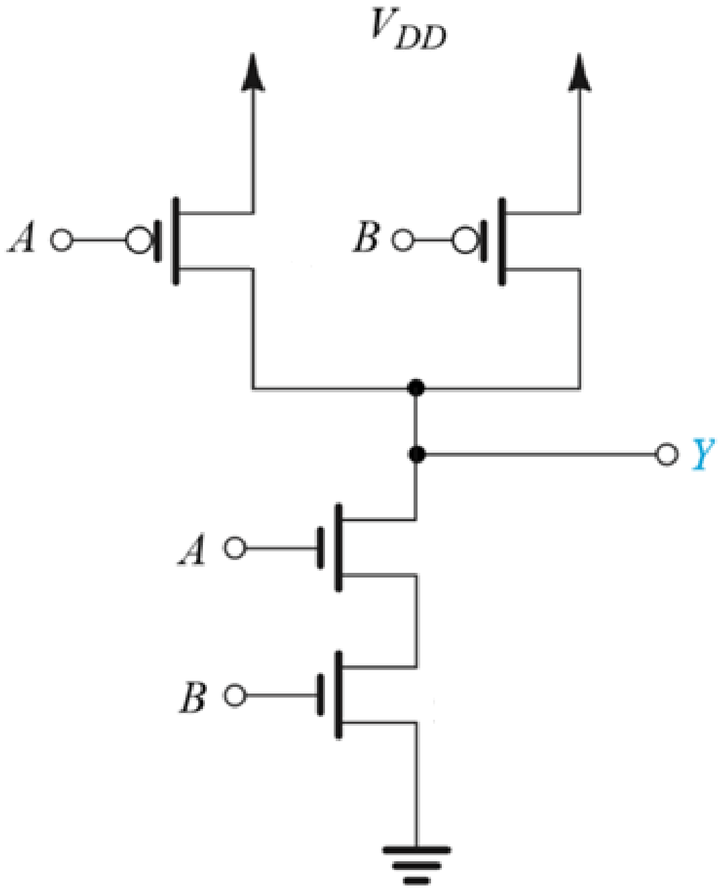
✓ What gate is the circuit opposite?



CMOS technology

Using NMOS transistors on the bottom and PMOS gates on the top

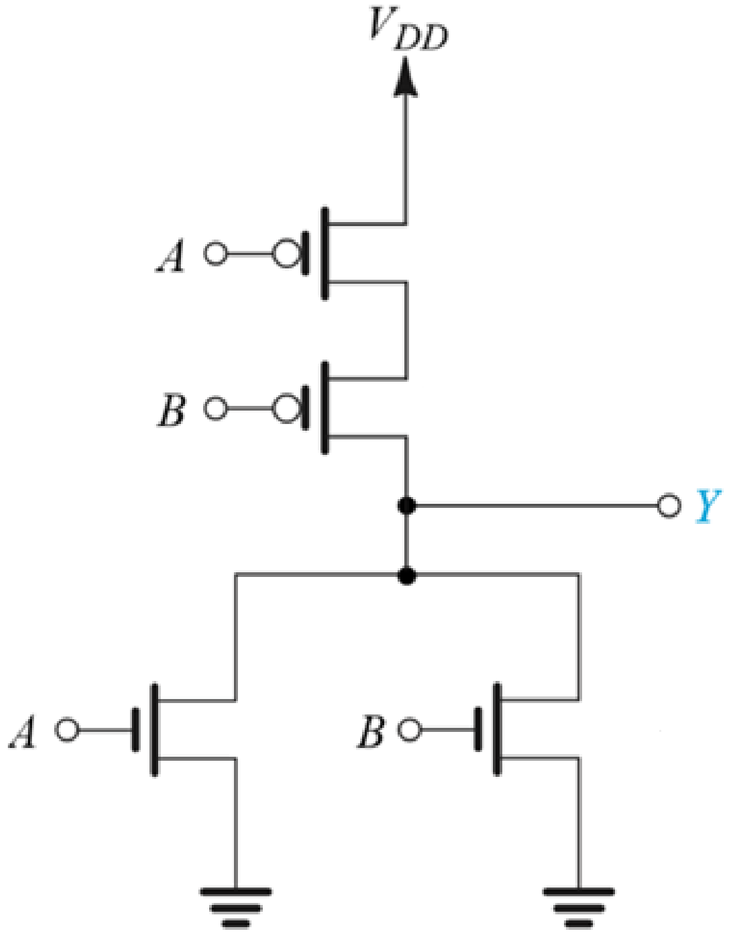
What gate is the circuit opposite?



What advantage does it have over the implementation with NMOS and resistors?

Exercise 1

✓ What type of gate is represented by the circuit below?



Implement the Boolean function $Y = \overline{A(B + CD)}$?

- Using **NMOS transistors and resistors** ?
- **CMOS structure?**

Thanks