Logic Families

Logic Families

Based on the fabrication technology, logic families are classified into two types: Bipolar logic family and Unipolar logic family.

- Unipolar Logic Family: In unipolar logic families, unipolar devices are the key element. MOSFET (Metal Oxide Semiconductor Field Effect Transistor) is a unipolar device, in which the current flows because of only one type of charge carriers (that is, either electrons or holes). The examples of unipolar families include PMOS, NMOS, and CMOS

- Bipolar Logic Family: Transistors and diodes are bipolar devices, in which the current flows because of both the charge carriers (electrons and holes). In bipolar logic families, transistors and diodes are used as key element.

Basic Characteristics of Logic Families

- The main characteristics of Logic families include:
  - Speed
  - Fan-in
  - Fan-out
  - Noise Immunity
  - Power Dissipation
  - Operating temperature range
  - Power supply requirements
  - Figure of merit

Basic Characteristics of Logic Families

- **Speed:** Speed of a logic circuit is determined by the time between the application of input and change in the output of the circuit.
- **Fan-in:** It determines the number of inputs the logic gate can handle.
- **Fan-out:** Determines the number of circuits that a gate can drive. (also known as loading factor)
- **Noise Immunity:** Maximum noise that a circuit can withstand without affecting the output.
- **Power:** When a circuit switches from one state to the other, power dissipates. This is the amount of power dissipated in an IC. It is determined by the current, I_{cc}. that it draws from the V_{cc} supply and equals $V_{cc}*I_{cc}$ where I_{cc} is average value of $I_{cc}(0)$ and $I_{cc}(1)$.

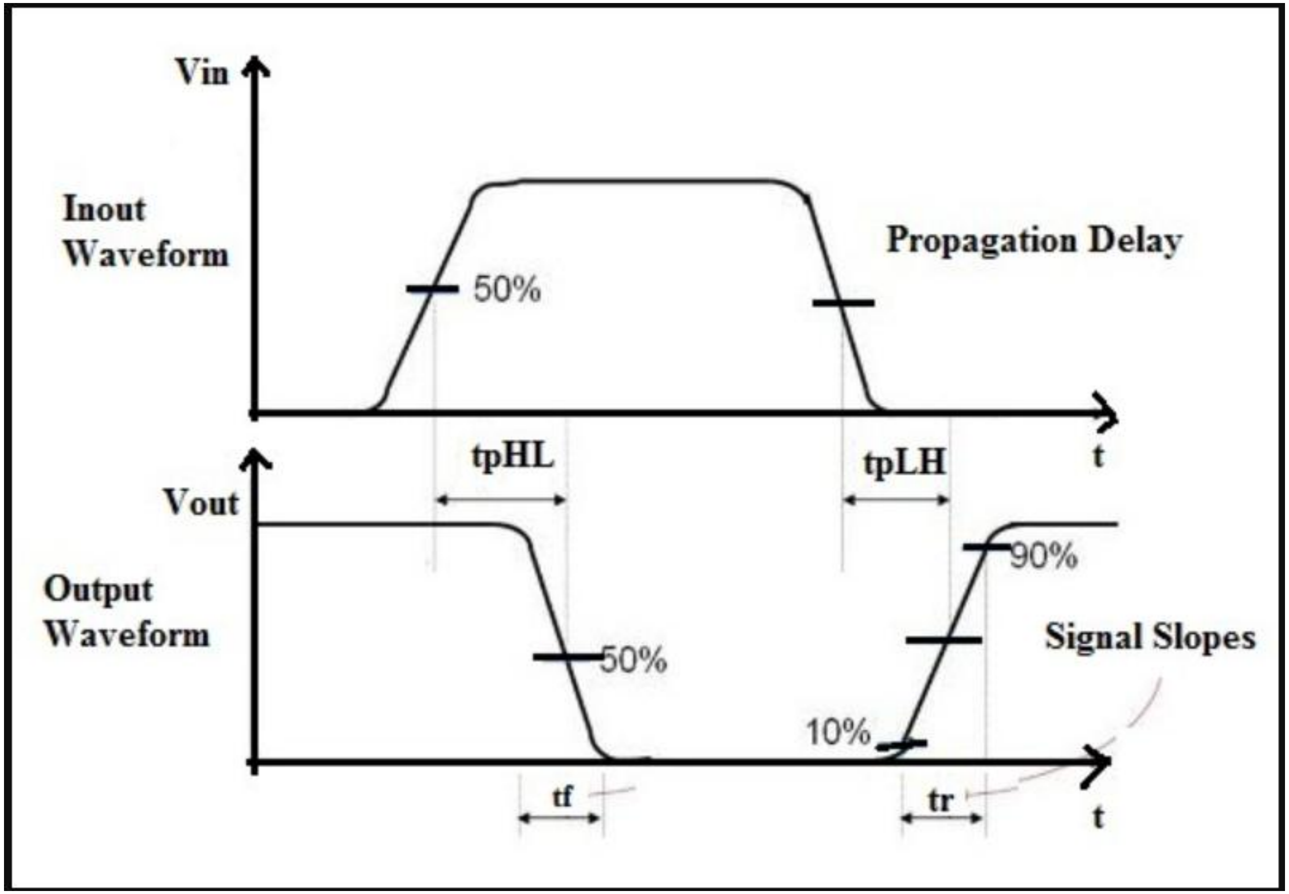
Basic Characteristics of Logic Families

- **Operating Temperature Range:** Digital ICs should be capable of operating for temperature ranging from 0^0C to 70^0C for consumers and from -55^0C to $+125^0$C for military applications.
- **Power Supply Requirements**: Every IC requires a certain amount of electrical power to operate. Usually there is only one power-supply terminal on the chip and it is marked V_{cc} for TTL or V_{DD} for for MOS devices. Obviously low power consumption is desirable features in any digital ICs.
- **Figure of merit (FOM):**

FOM= Propagation delay(ns)*power (mW) [Measured in pico joules (pJ)] A low value of speed-power product is desirable. In a digital circuit if high speed or low propagation delay is desired, then there will be corresponding increase in power dissipation and vice-versa

Propagation delay

- Due to finite switching speed of transistors and circuit capacitances
- t_{PHL}: Delay in changing output from High to Low
- t_{PLH}: Delay in changing output from Low to High
- Propagation delay, $t_{PD} = (t_{PHL} + t_{PLH})/2$
- t_r: Rise time 10% to 90% of max.
- t_f: Fall time 90% to 10% …



Power dissipation

Static power dissipation –
when transistor is either ON or OFF -depends on current drawn in each case, power dissipation, (PD) is average of these two-significant in switching of Bipolar Junction Transistor
Dynamic power dissipation -when transistor switches -depends on switching speed -significant in switching of CMOS Transistor

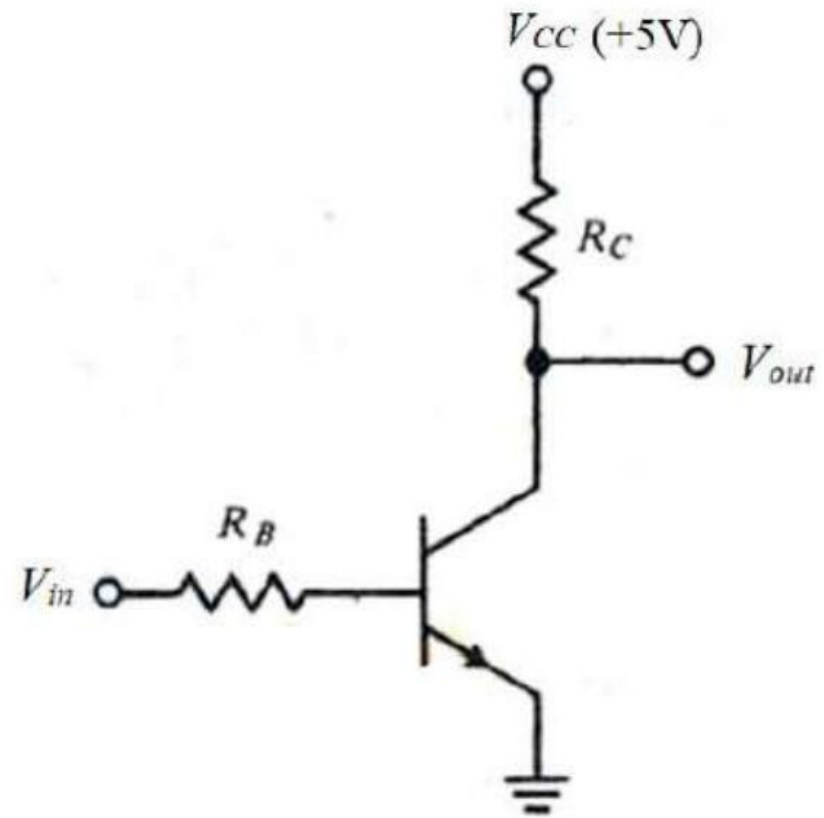
Transistor as a Switch

Cut-off region:
V_{BE}<0.7 V, I_B=0

Active region:
V_{in}>0.7 V

$I_B=(V_{in}-V_{BE})/R_B$
$I_C=\beta I_B$
$V_{out}=V_{cc}-I_C R_C$

Saturation region:
As V_{in} increases a transition point is reached when
$V_{out}=V_{CE(sat)}$
$I_{c,sat}=(V_{cc}-V_{CE})/R_C$



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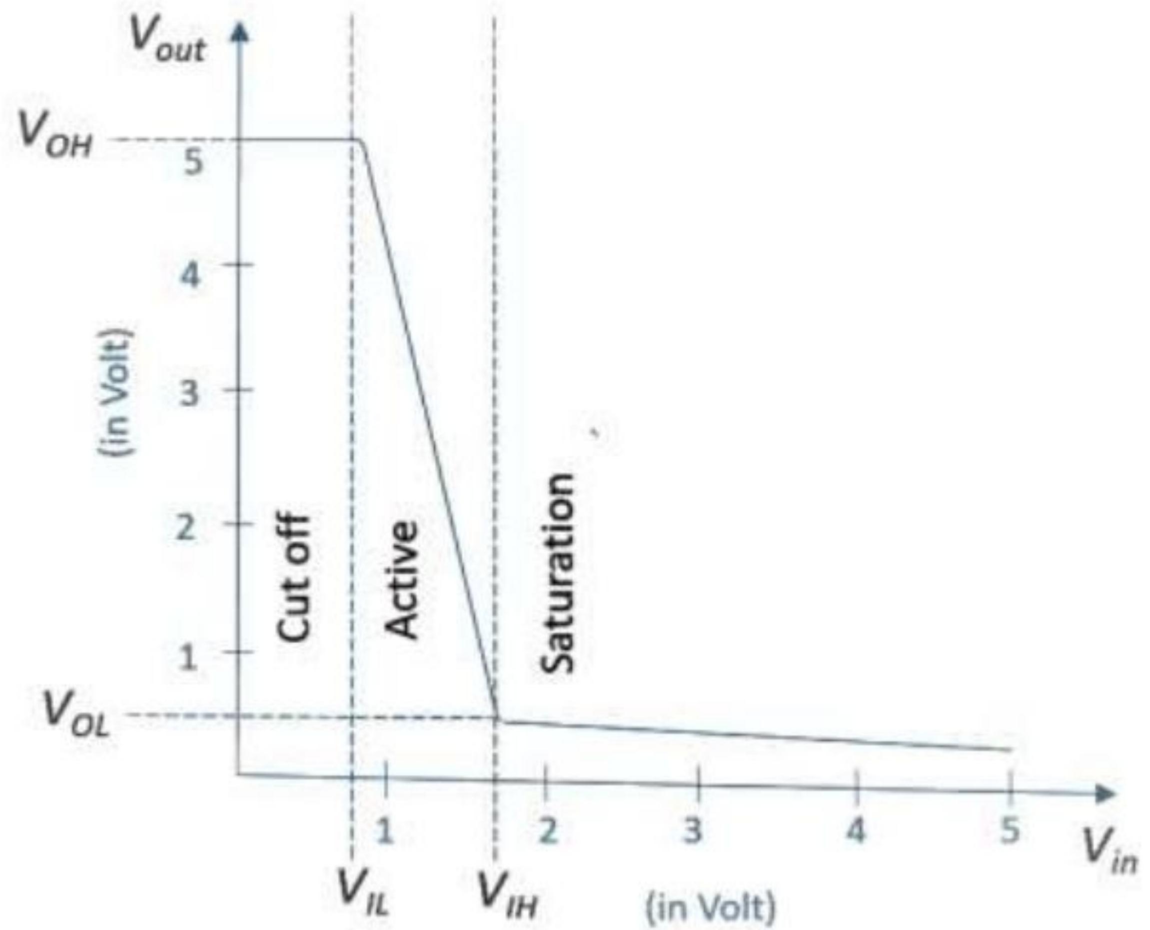
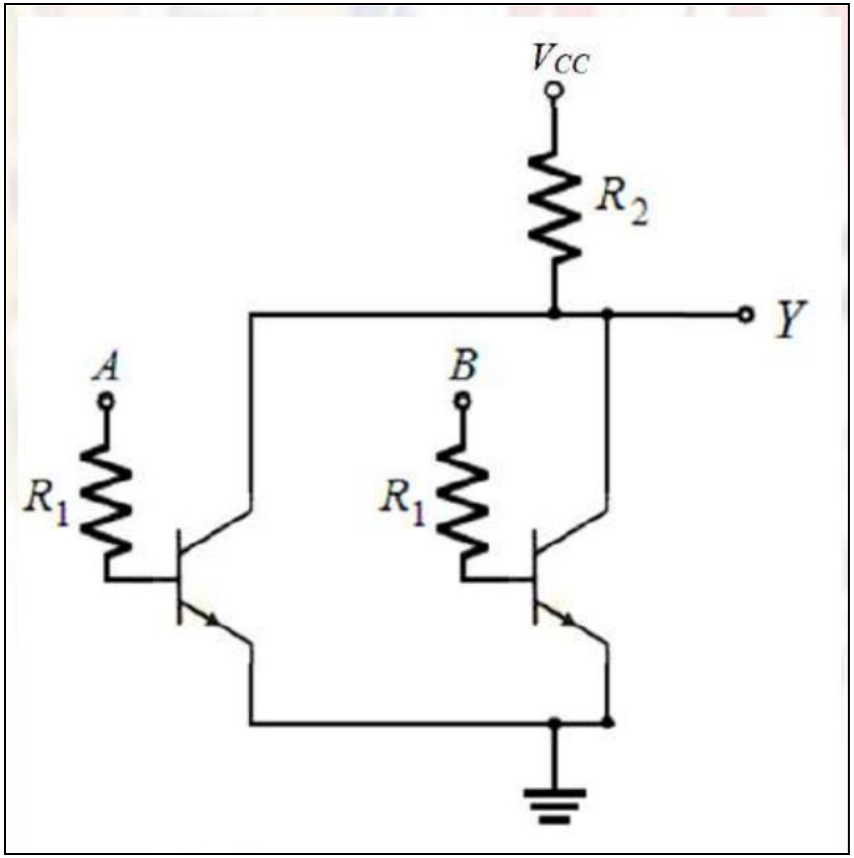


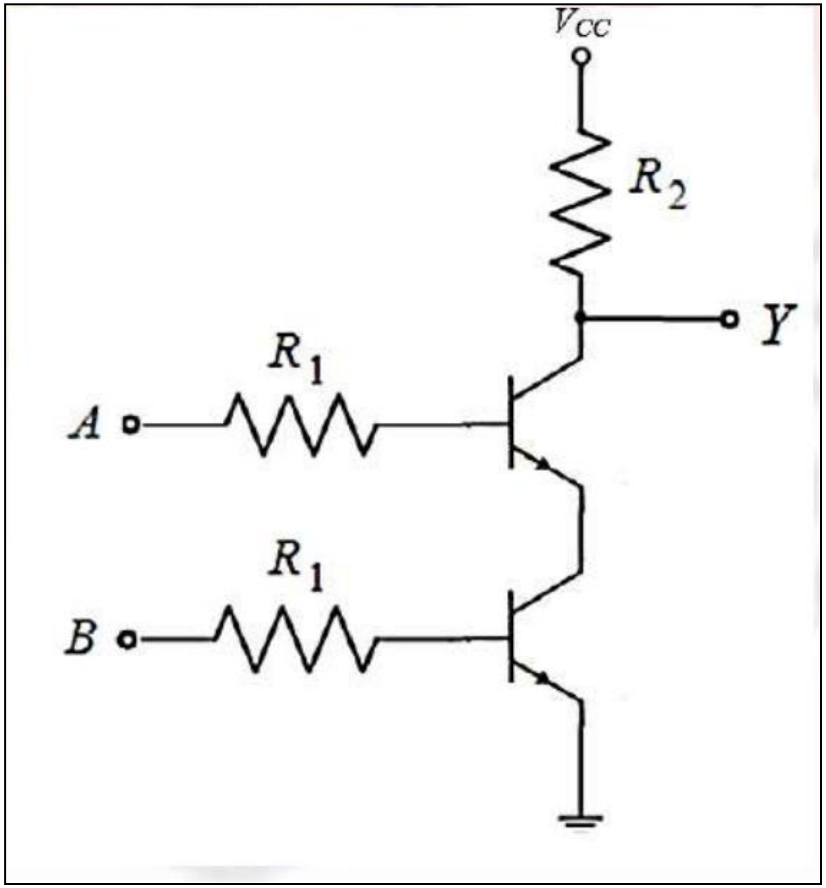
Logic families Types

- **RTL-** Resistor Transistor Logic
- **DTL-** Diode transistor Logic
- **TTL** – transistor-transistor logic based on bipolar transistors.
- **CMOS** – complementary metal-oxide semiconductor logic based on metal-oxide-semiconductor field effect transistors (MOSFETs).
- **ECL** – emitter coupled logic based on bipolar transistors.

RTL



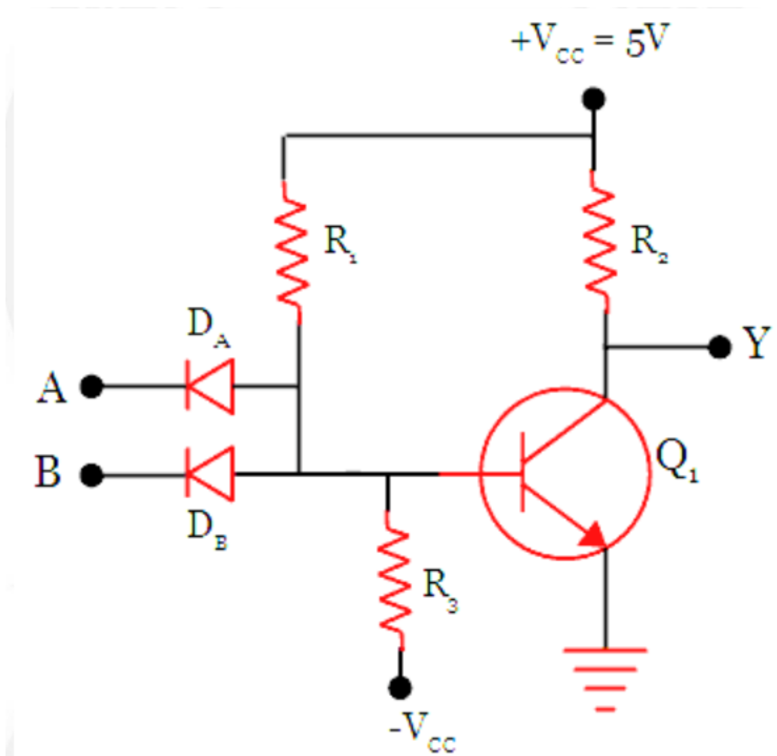
RTL NOR gate



RTL NAND gate

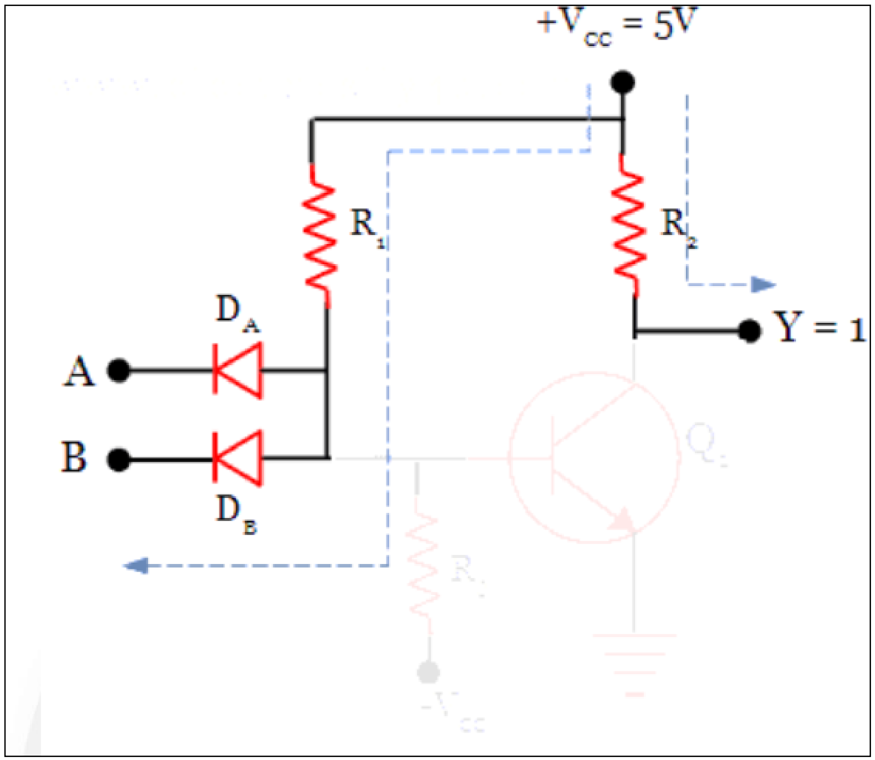
DTL

This logic circuit has diodes at the input side and transistor at the output side and so the name diode transistor logic. It has more advantages than resistor transistor logic(RTL).

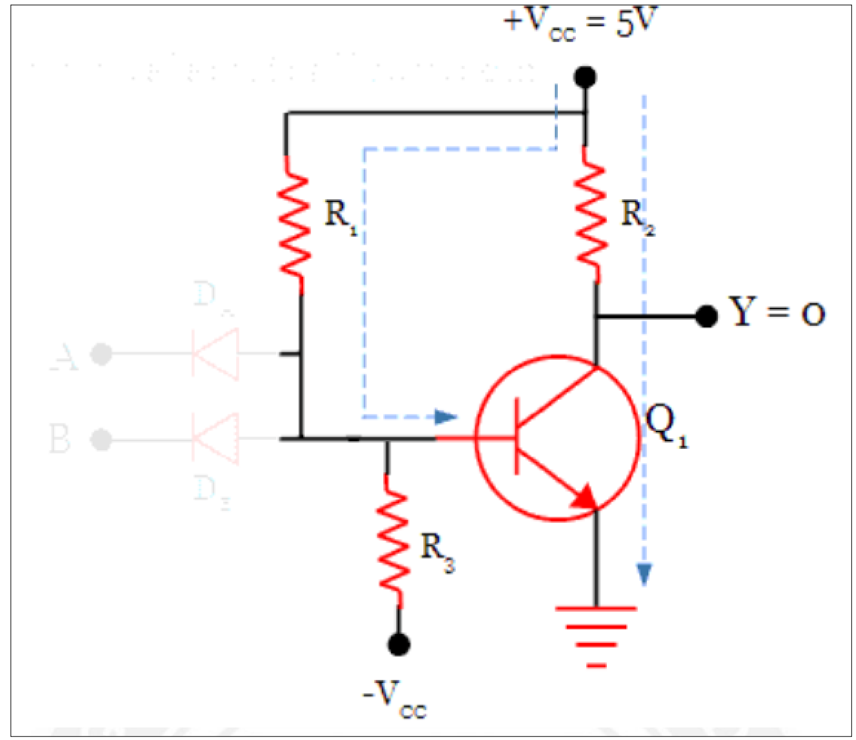


2 input NAND gate

DTL Working

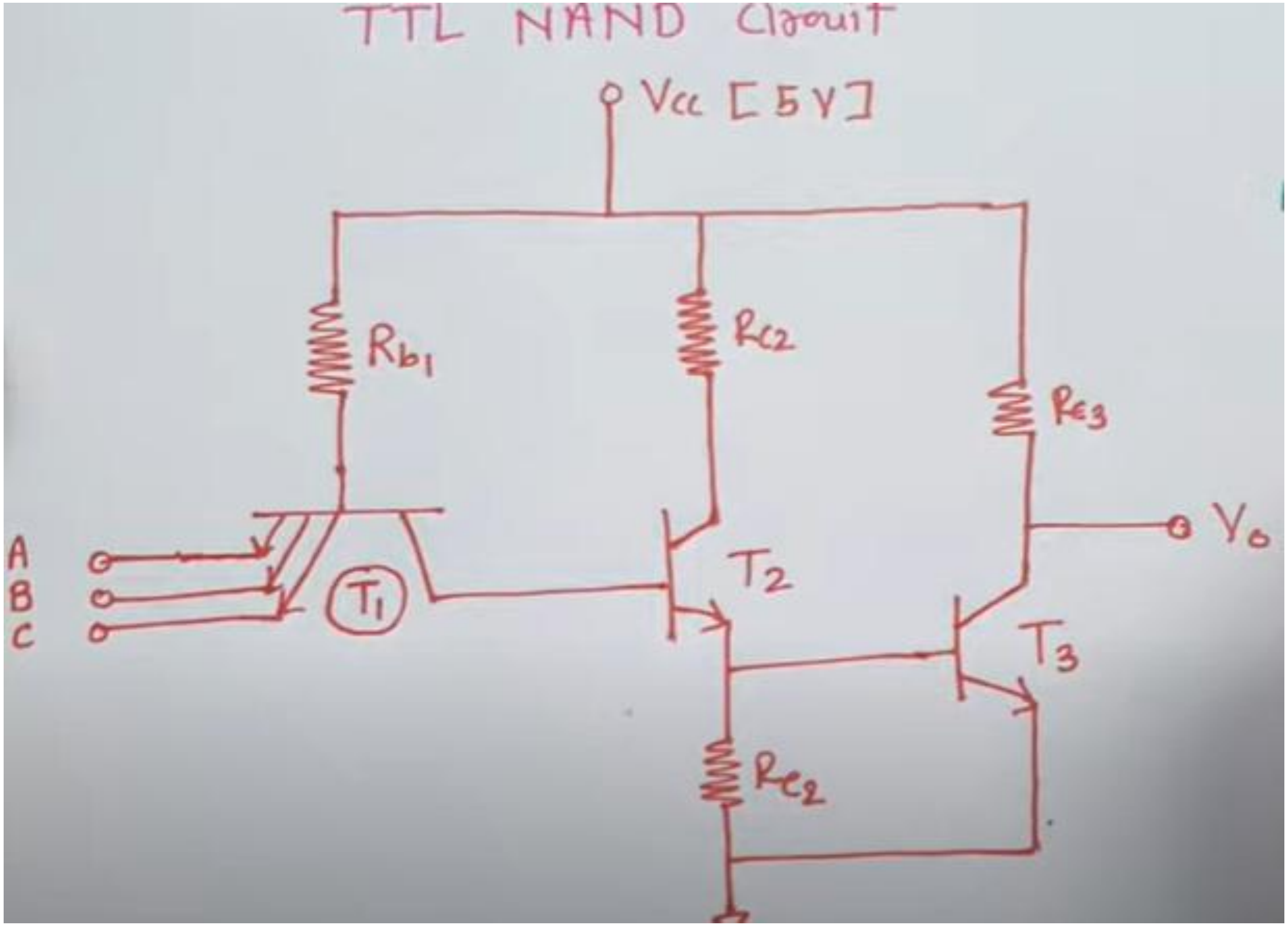


Inputs A,B="00"



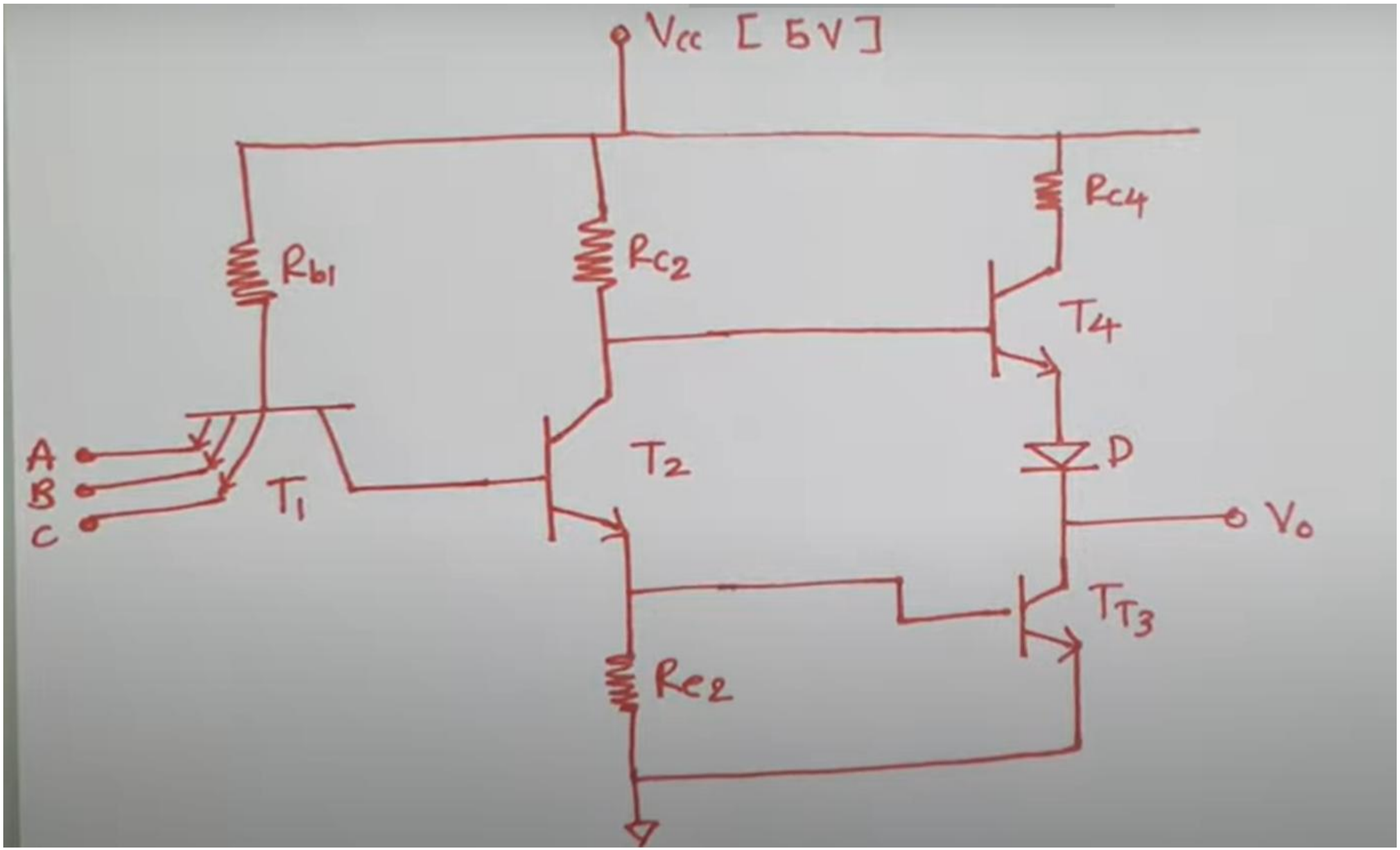
Inputs A,B="11"

Standard TTL Logic



NAND logic

TTL NAND with Totem Pole Output



Complementary metal oxide semiconductor (CMOS)

– most widely used family for large-scale devices

– combines high speed with low power consumption

– usually operates from a single supply of 5 – 15 V

– excellent noise immunity of about 30% of supply voltage (ideal: 50% of supply voltage)

– can be connected to a large number of gates (about 50)

A CMOS inverter