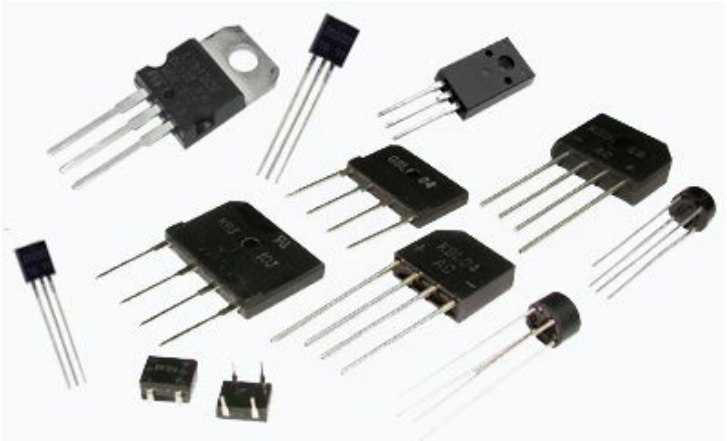
Introduction

Electrical & Electronic Circuits and Elements

Embedded Systems & Embedded Programming

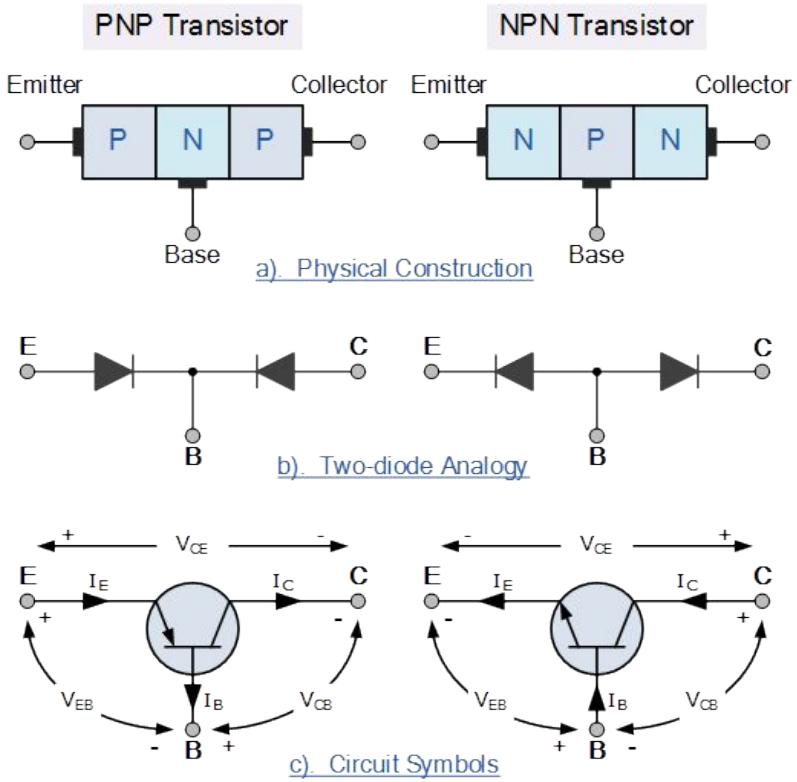
Fundamentals of Electronic Circuits (Transistors)

- A transistor is an active device that **controls** or **switches** the current flow
- Transistor is a combination of two words; **trans**fer and res**istor**
- They are mainly classified into two types
  - Bipolar Junction Transistor (**BJT**)
  - Field Effect Transistor (**FET**)
- They are mainly used
  - As **switch**es and signal **amplifier**s
  - In all digital and electronic devices including **IC**s
  - Analog circuits like sensors, RF and etc.
- Some IC technologies: **TTL, CMOS** and etc.



Fundamentals of Electronic Circuits (BJT)

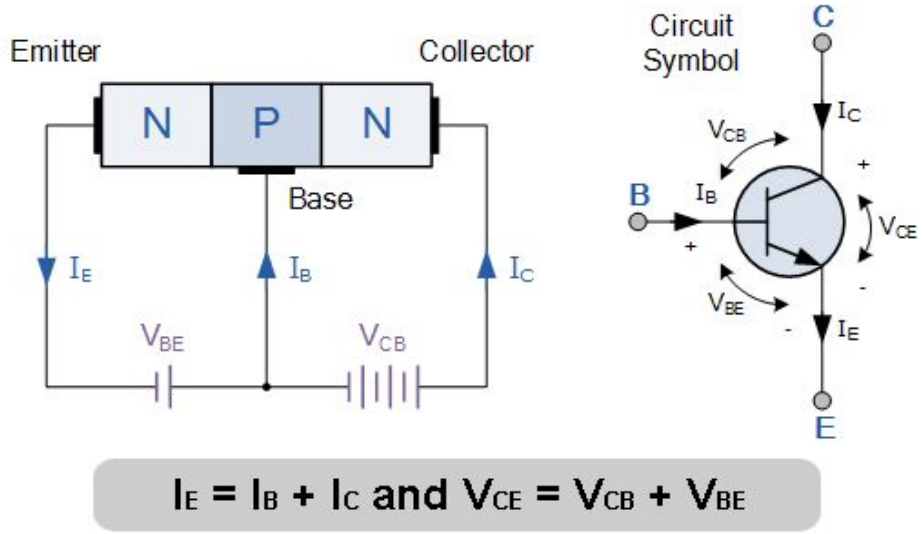
- Bipolar Junction Transistor (**BJT**)
- Is made by joining together two diodes back-to-back
  - Therefore we have **NPN** and **PNP** types of BJT
- Both the **electrons** and **holes** are charge carriers
- Can operate within three different modes:
  - Active (**amplifier**), Saturation (**ON**) and Cutoff (**OFF**)
- The principle of operation of the **PNP** and **NPN** types is the same and the only difference is biasing and the polarity of the power supply for each type.



- Was invented by **John Bardeen**, **William Shockley** and **Walter Brattain** in **1948**

Fundamentals of Electronic Circuits (BJT - NPN)

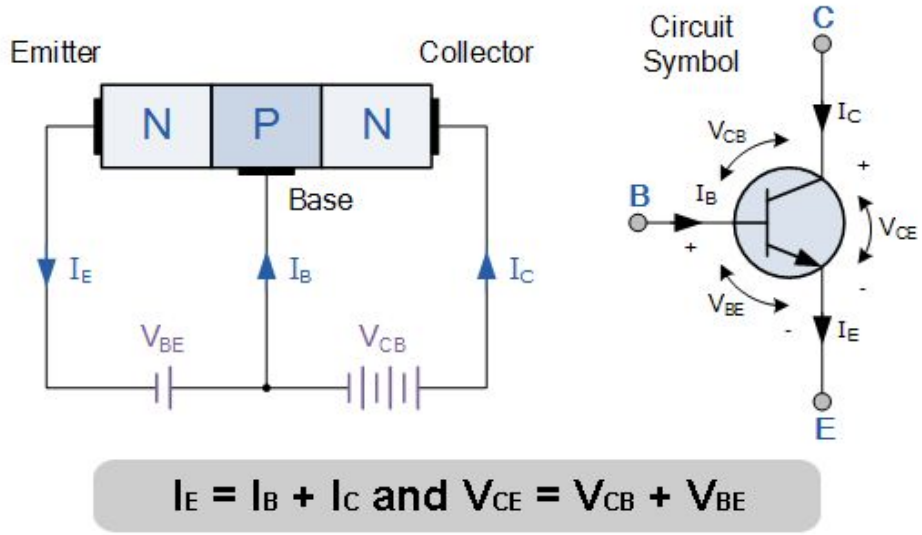
- **Cutoff** mode
  - Both the junctions of the BJT are reverse biased
  - No current flows through the device ($I_C = 0$)
  - It is in **OFF** state and acts like an **open switch**
  - $V_C > V_B < V_E$ ($V_{BE} < 0.7V$ for Silicon)
- **Saturation** mode
  - Both the junctions of the BJT are forward biased
  - Huge current flows through the device ($I_C = I_{Saturation}$)
  - Increasing I_B doesn't increase I_C ($I_C < \beta * I_B$)
  - It is in **ON** state and acts like a **closed switch**
  - $V_B > V_C > V_E$ ($V_{BE} > 0.7$ V for Silicon)
  - Collector to emitter saturation voltage $V_{CE(sat)}$ is around 0.05 - 0.2V



$I_E = I_B + I_C$ and $V_{CE} = V_{CB} + V_{BE}$

Fundamentals of Electronic Circuits (BJT - NPN)

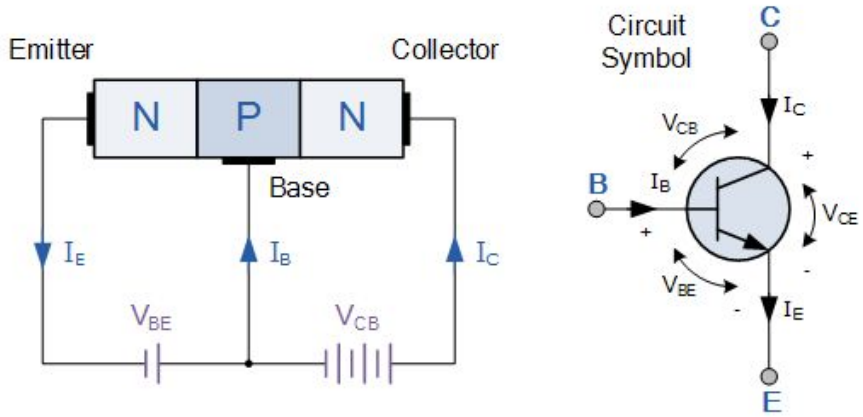
- **Active** mode
  - Emitter to base junction is forward biased
  - Collector to base junction is reverse biased
  - It operates as an **amplifier** and $I_C = \beta * I_B$
  - $V_C > V_B > V_E$ ($V_{BE} > 0.7$ V for Silicon)
  - **β** (h_{fe}) is the **DC Current Gain** of the BJT
  - **β** is generally in the range between 50 - 200
  - The collector to emitter current gain is called Alpha, $I_C = \alpha * I_E$
  - **α** and **β** are specified in the datasheet of the device
  - $\alpha = \beta / (\beta + 1)$



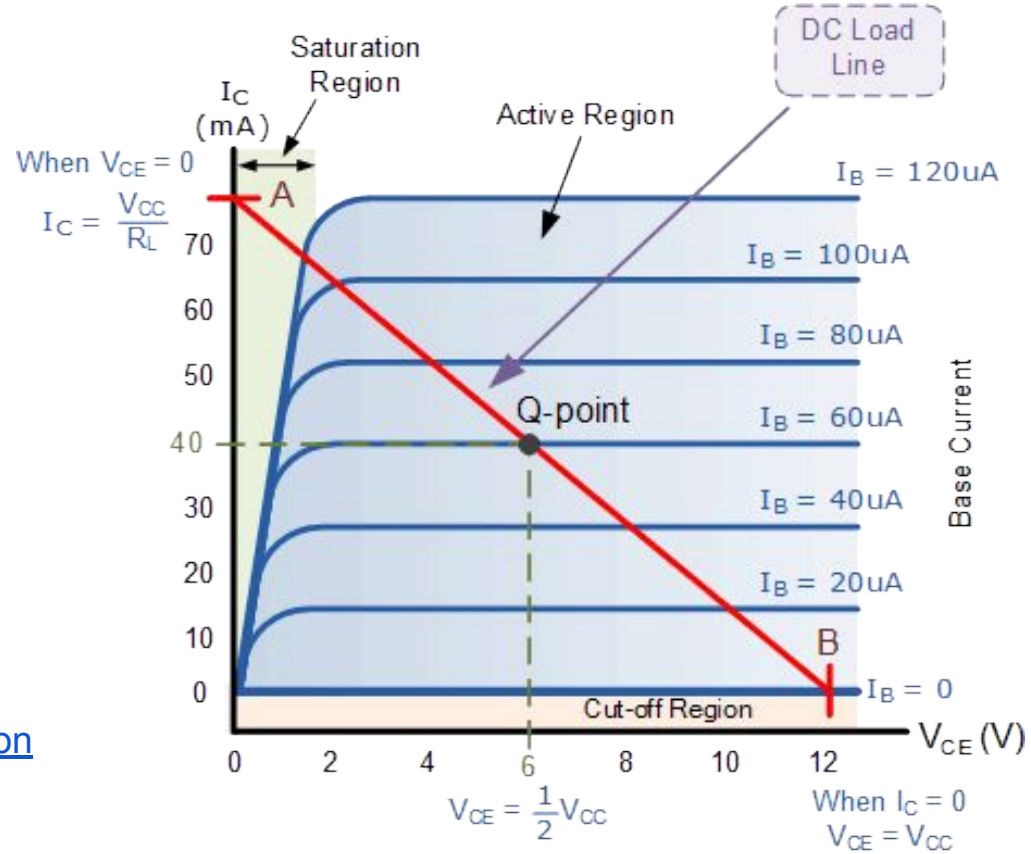
$I_E = I_B + I_C$ and $V_{CE} = V_{CB} + V_{BE}$

Fundamentals of Electronic Circuits (BJT - NPN)

- **i-v** characteristic of BJT



$$I_E = I_B + I_C \text{ and } V_{CE} = V_{CB} + V_{BE}$$



BJT Operating Regions

[NPN Transistor]

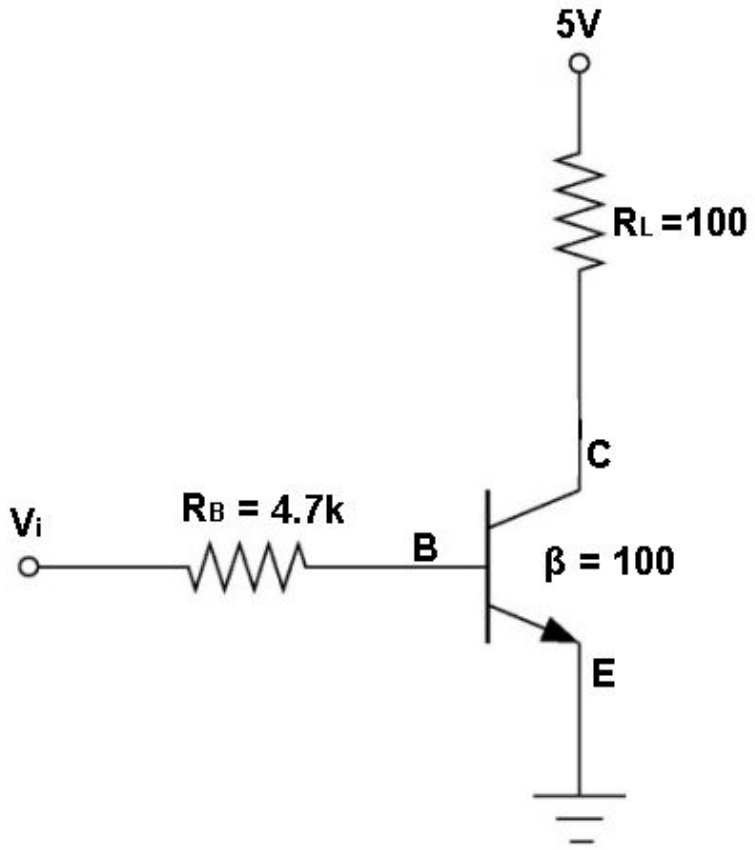
[How does a Transistor Work? A Simple Explanation]

[Transistors, How do they work?]

[Transistors Explained - How transistors work]

Fundamentals of Electronic Circuits (BJT - NPN)

- Find the operation **mode**, I_B, I_C, I_E, V_{BC} and V_{CE} if
  - V_i = 0.5 V (Cutoff, 0 A, 0 A, 0 A, -4.5 V, 5 V)
  - V_i = 2.0 V (Active, 0.28 mA, 28 mA, 28.28 mA, -1.5 V, 2.2 V)
  - Vi = 4.0 V (Saturation, 0.7 mA, 50 mA, 50.7 mA, 0.7 V, 0 V)
- Find the minimum V_i and I_B to get the BJT saturated
  - V_i = 3.05 V
  - I_B = 0.5 mA

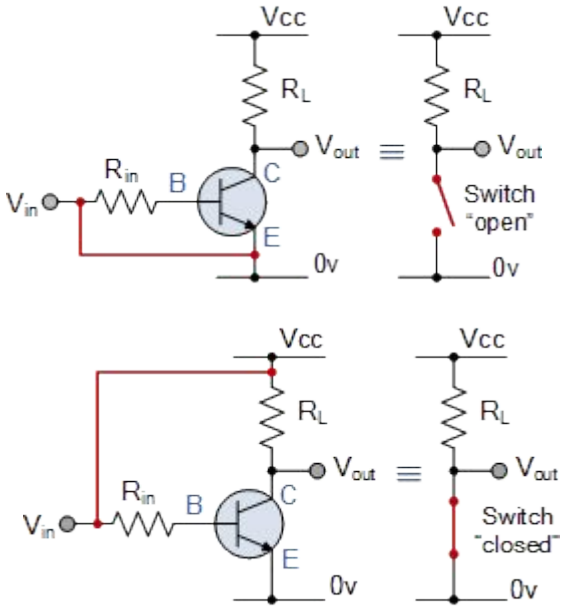


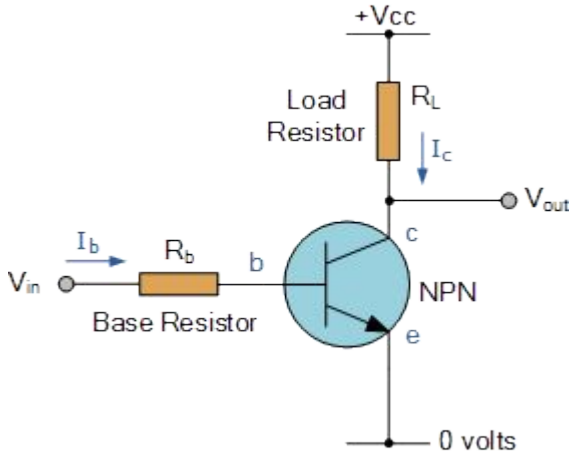
KCL: $I_E = I_B + I_C$

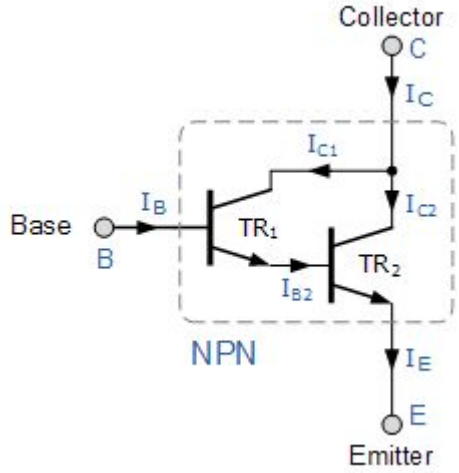
KVL: $V_{CE} = V_{CB} + V_{BE}$

Fundamentals of Electronic Circuits (BJT - NPN)

- Darlington Transistor (BJT as amplifier)
  - When large currents or voltages need to be controlled
- BJT as a switch
  - Can be used to switch and control lamps, relays or even motors







$I_C = (\beta_1 + \beta_2 + \beta_1.\beta_2).\ I_B$

$\beta = (\beta_1 + \beta_2 + \beta_1.\beta_2)$

$V_{BE} > 1.4$ V (for silicon)

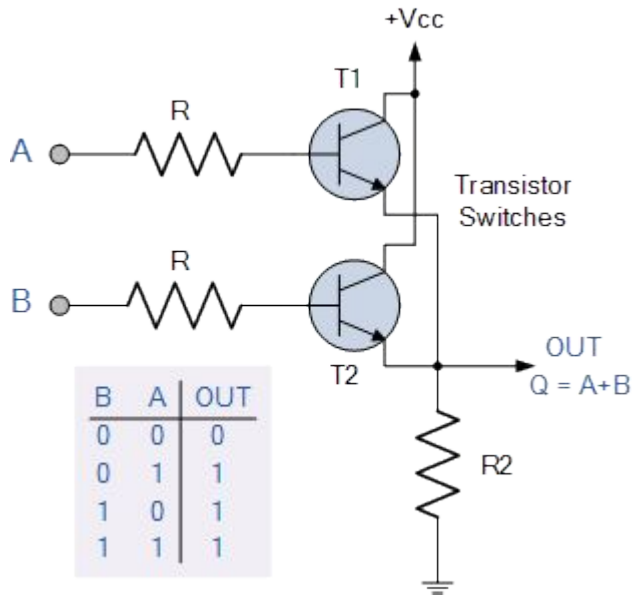
Transistors

Transistors as a Switch

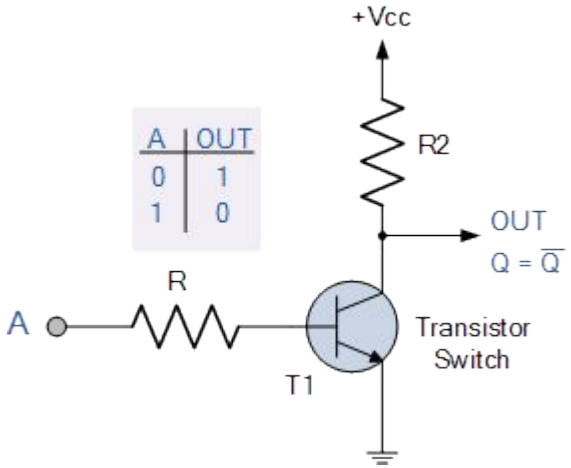
Transistor as a Switch

Fundamentals of Electronic Circuits (BJT - NPN)

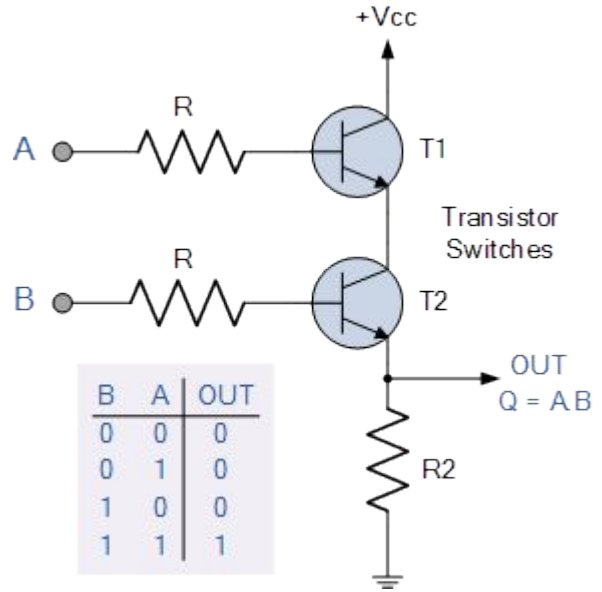
- BJTs and Logic Gates



Logic OR Gate



Logic NOT Gate

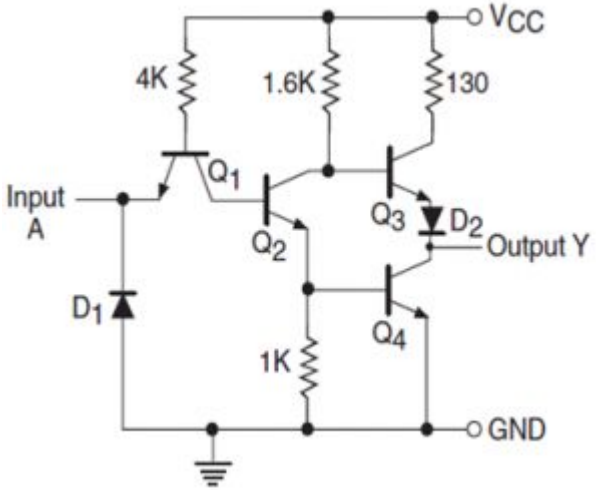


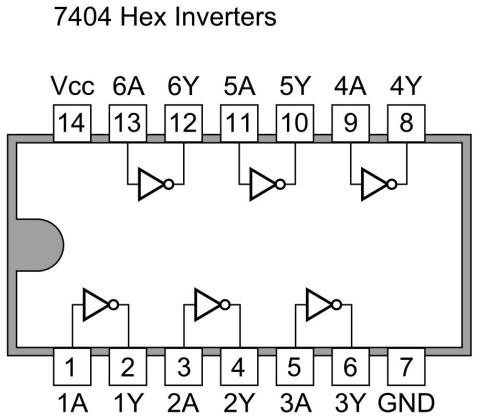
Logic AND Gate

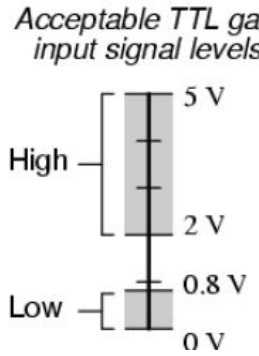
Logic Gates

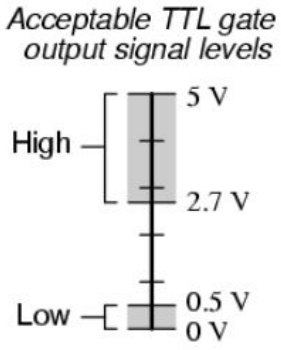
Fundamentals of Electronic Circuits (BJT - NPN)

- TTL (Transistor–transistor logic) family
  - Is a logic family built from bipolar junction transistors
  - Introduced in integrated circuit form in 1963 by Sylvania
  - The **7400** series by Texas Instruments became particularly popular









TTL Inverter (NOT) IC

Fundamentals of Electronic Circuits

- Some useful links
  - Bipolar Transistor
  - Bipolar Junction Transistor
  - Introduction to Transistors
  - How to Identify an PNP or NPN Transistor
  - Transistor–Transistor Logic (TTL)
  - Emitter-coupled logic
  - The Basics of Emitter-Coupled Logic
  - Emitter-Coupled Logic
  - BJTs as Transistor Switches