

Transistor and Transistor Logic

4190.309

2008 Fall Semester

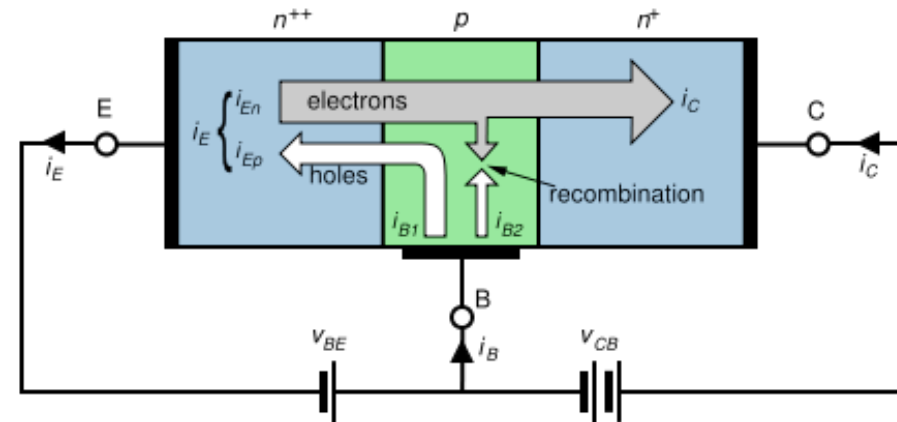
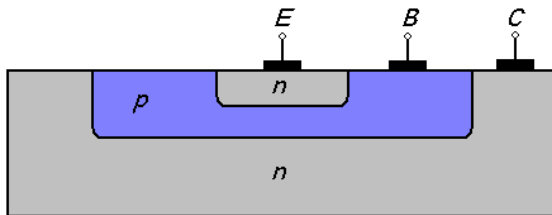
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Seoul National University

Bipolar transistors

- Considered as two diodes with a shared anode region
- The emitter–base junction is forward biased
- The base–collector junction is reverse biased

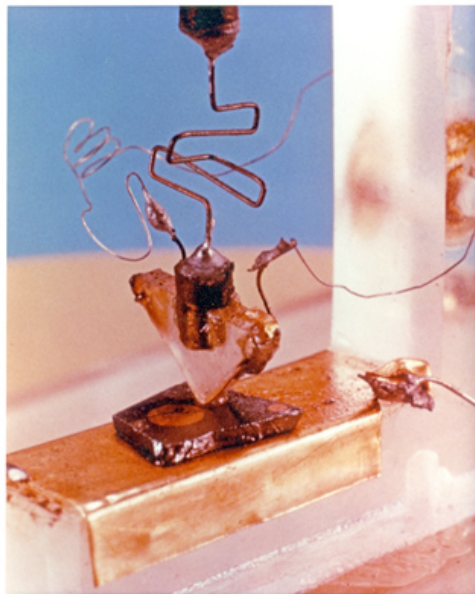


www.wikipedia.com

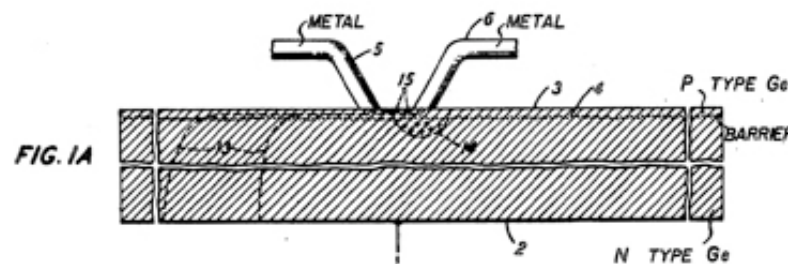
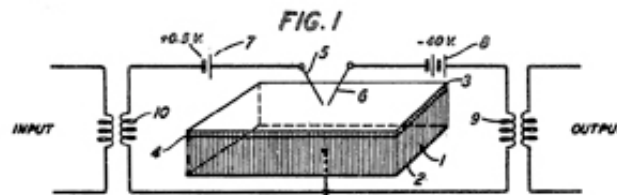


Bipolar transistors

- NPN and PNP transistors



Oct. 3, 1950 J. BARDEEN ET AL 2,524,035
 THREE-ELECTRODE CIRCUIT ELEMENT UTILIZING SEMICONDUCTIVE MATERIALS
 Filed June 17, 1948 3 Sheets-Sheet 1



Bell Laboratories "Type A" transistor.

Courtesy of: Bob McGarrah.

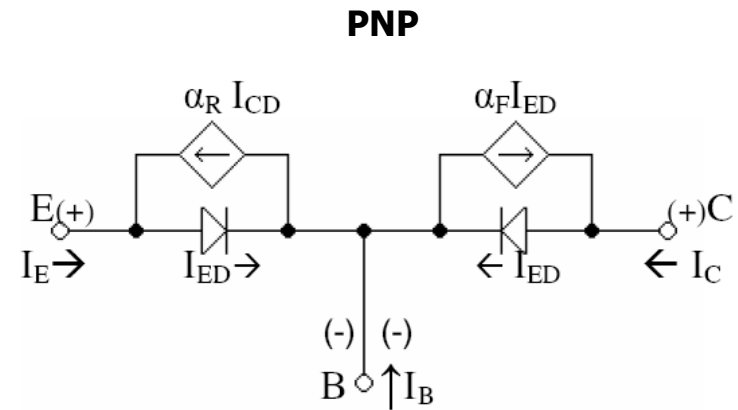
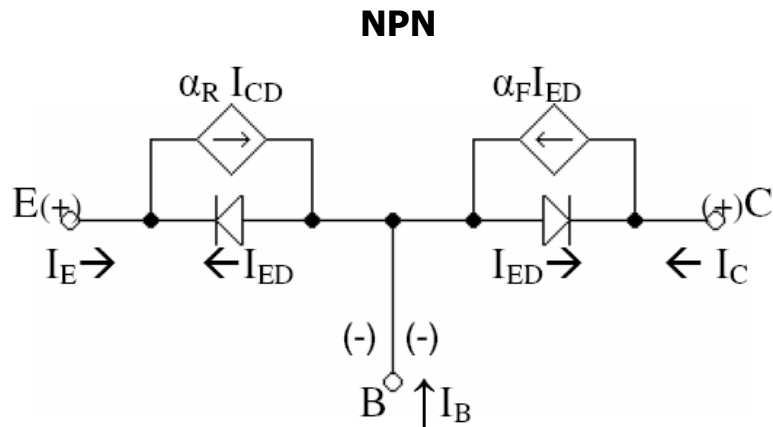
Bardeen and Brattain's first point-contact transistor.

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Transistor models

- NPN and PNP transistor equivalent circuits

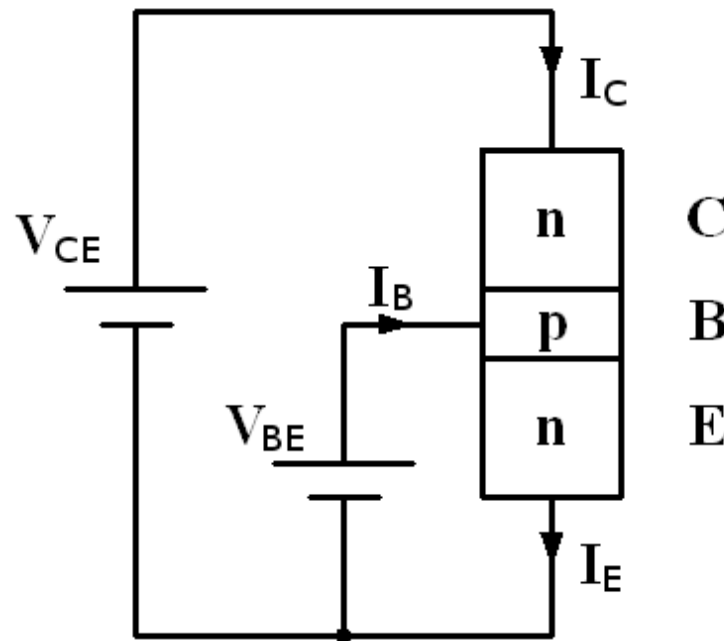


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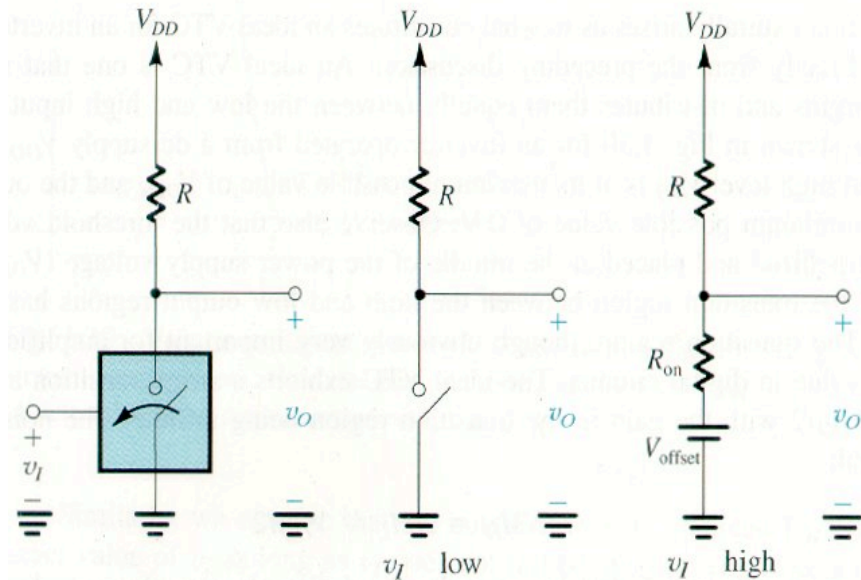
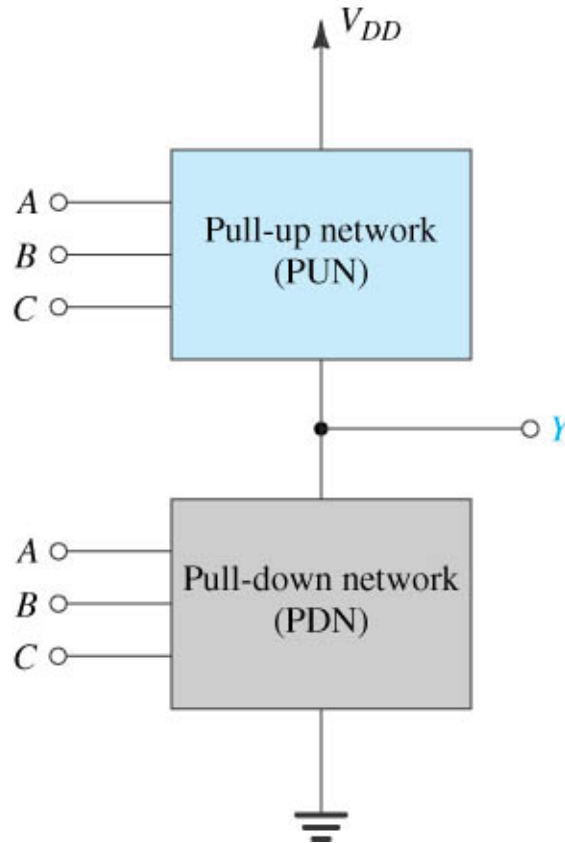
Emitter common circuits

- $I_E = I_B + I_C$



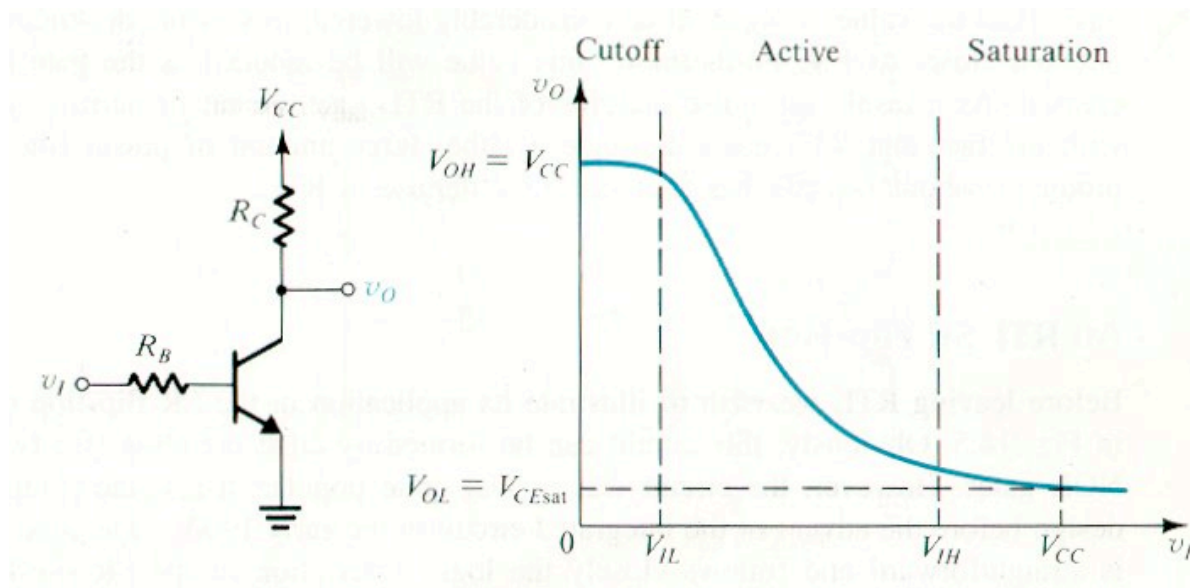
Transistor switches

- Diode switches versus transistor switches



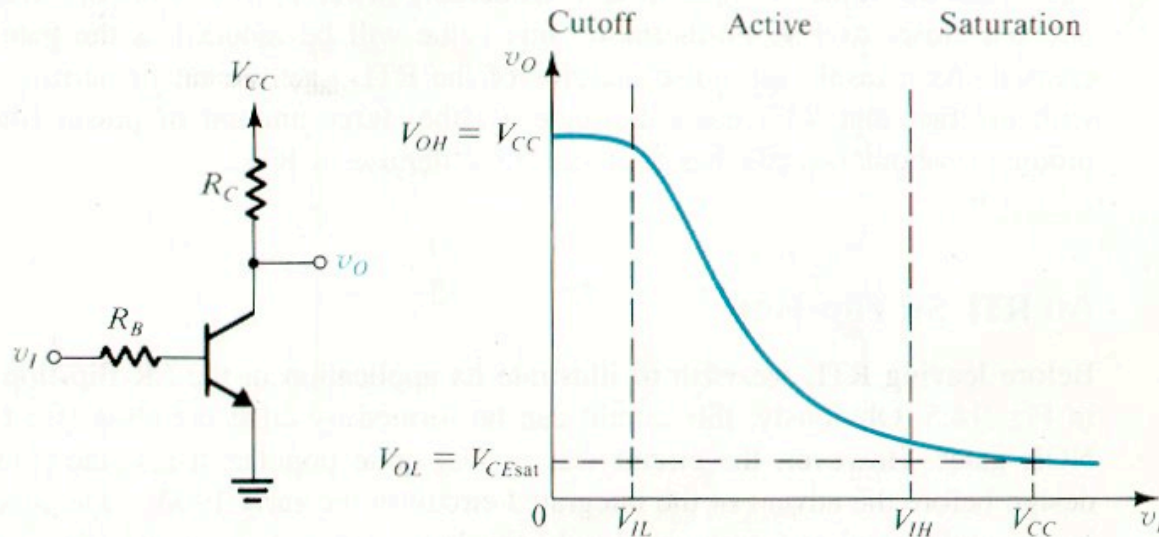
Transistor switches

- Transistor switch
 - Base resistor
 - Collector resistor



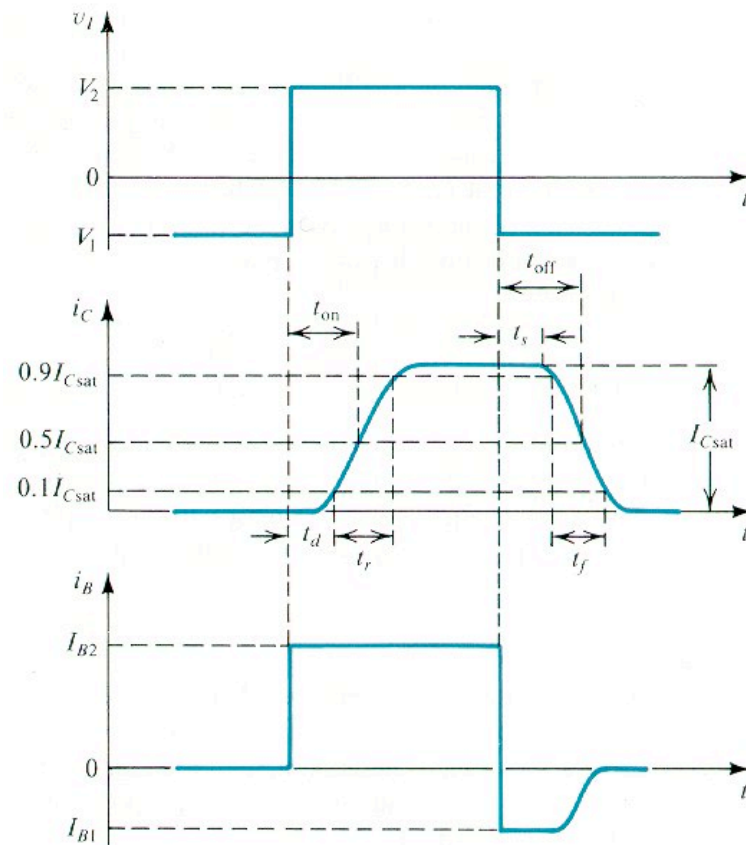
Transistor switches

- Transistor switch
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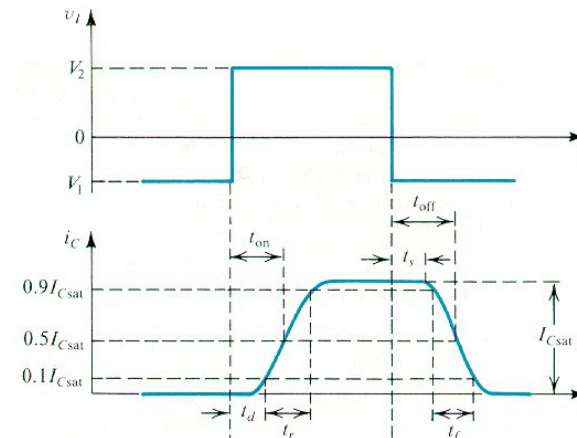
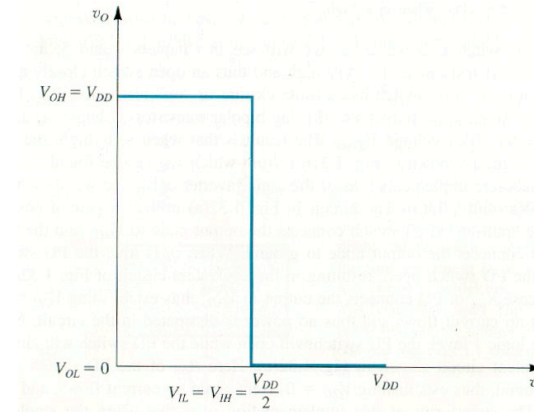
Transistor switches

- Characteristics of a simple inverter



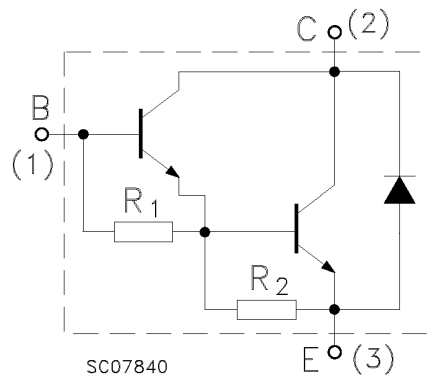
Ideal inverter

- Basic primitive gate
 - Rail-to-rail swing
 - 1/2 VDD threshold
 - Zero output impedance
 - Infinite slew rate
 - Zero propagate delay
 - Characteristics
 - Propagation delay TPD
 - Rise time TR
 - Fall time TF
 - Output characteristics
 - VOH, VOL, ROH and ROL



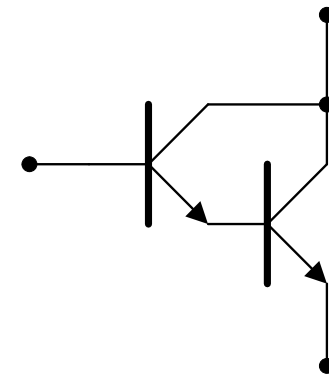
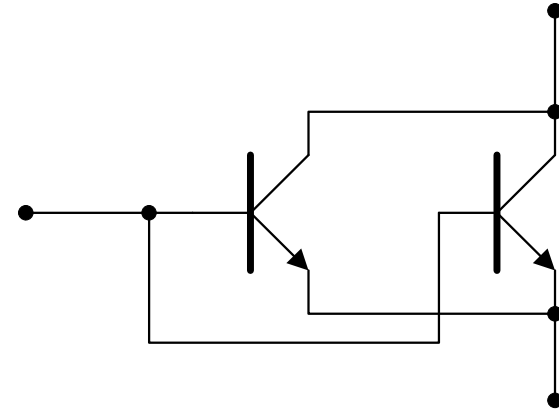
Transistor connections

- Parallel connection
 - current hogging
- Darlington transistor



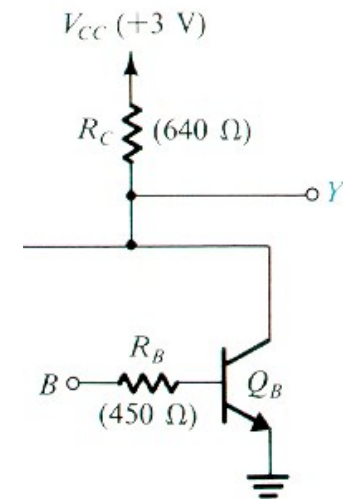
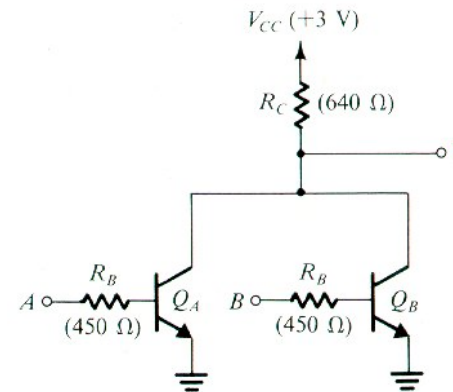
R_1 Typ. = 10 K Ω

R_2 Typ. = 160 Ω



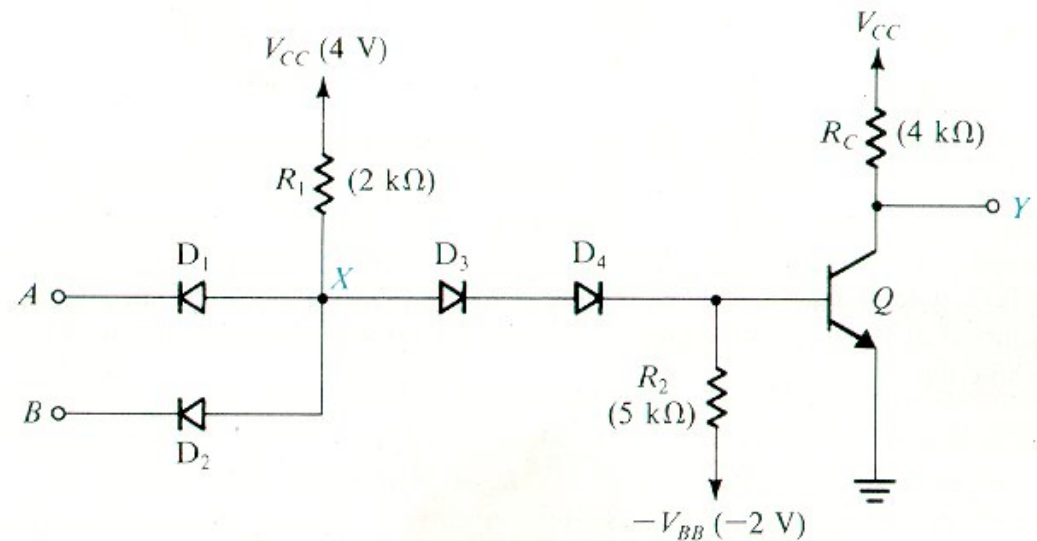
RTL

- Fast 1 to 0 transition
- Slow 0 to 1 transition
- Low ROL
- High ROH
- Fan-out sensitive VOH
- Quiescent power consumption when output is 0.



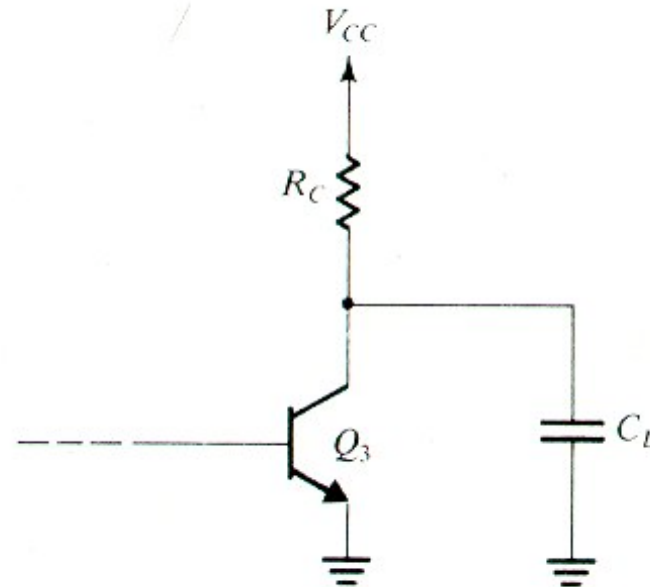
DTL

- Less fan-out sensitive VOH
- Improved threshold
- Worse 0 to 1 transition delay
- Improved quiescent power consumption



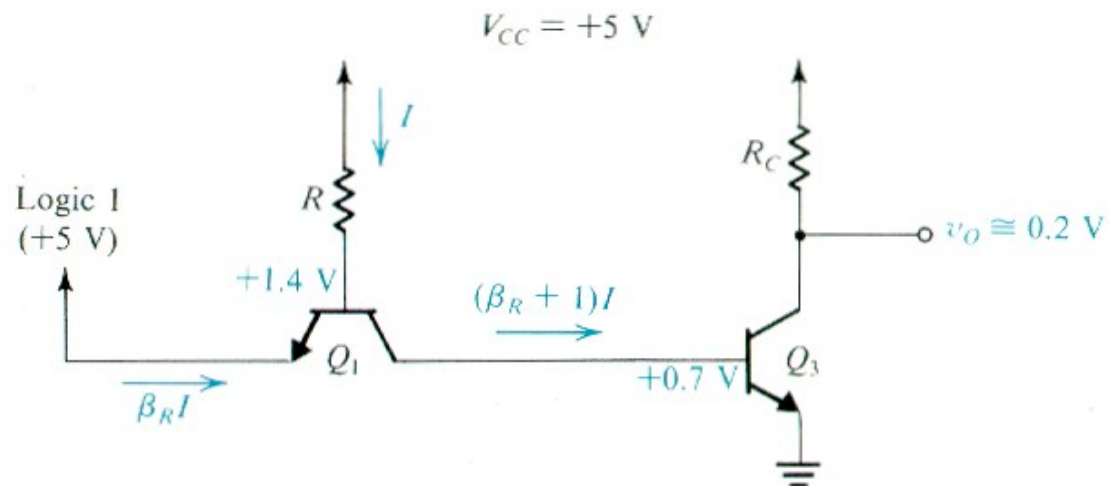
Emitter common switch

- Emitter common switch
 - Saturation
- Fast turn on
- Slow turn off



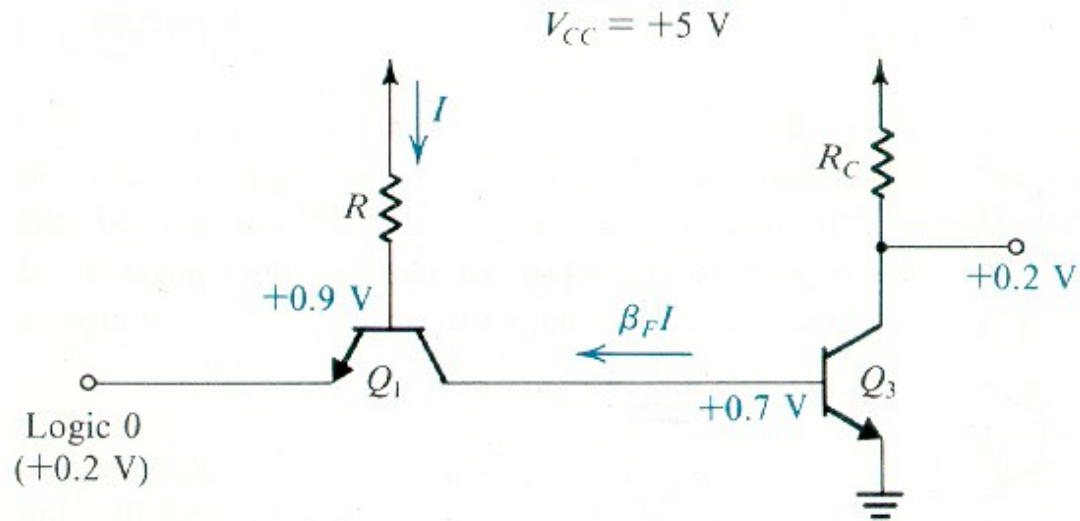
TTL

- Input is high



TTL (contd.)

- Speed up turn-off switching



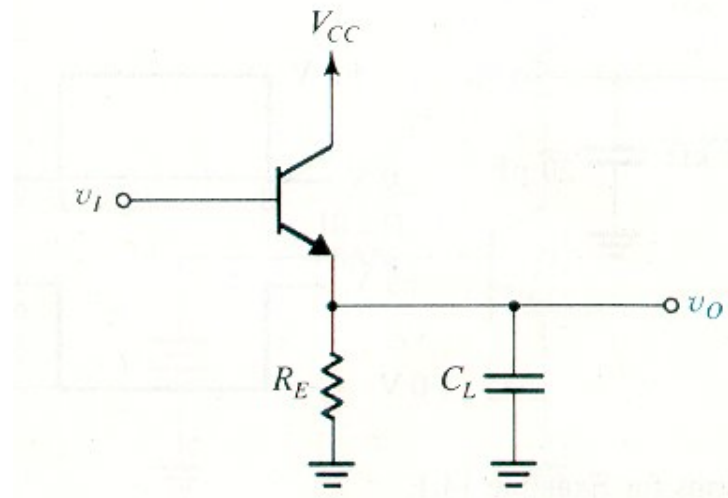
TTL (contd.)

- Evolution from RTL
 - * Fast 1 to 0 transition?
 - * Slow 0 to 1 transition?
 - * Low ROL?
 - * High ROH?
 - * Fan-out sensitive VOH?
 - * Quiescent power consumption when output is 0?



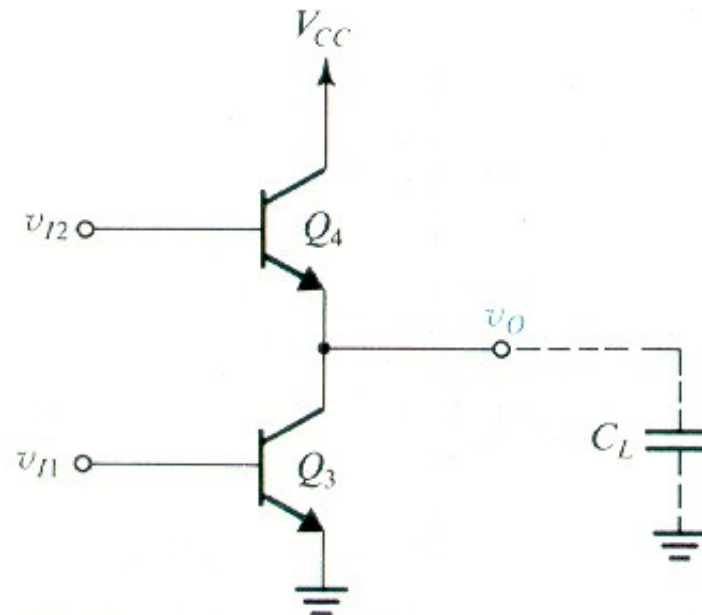
TTL (contd.)

- Fast 0 to 1 switching
- Low ROH



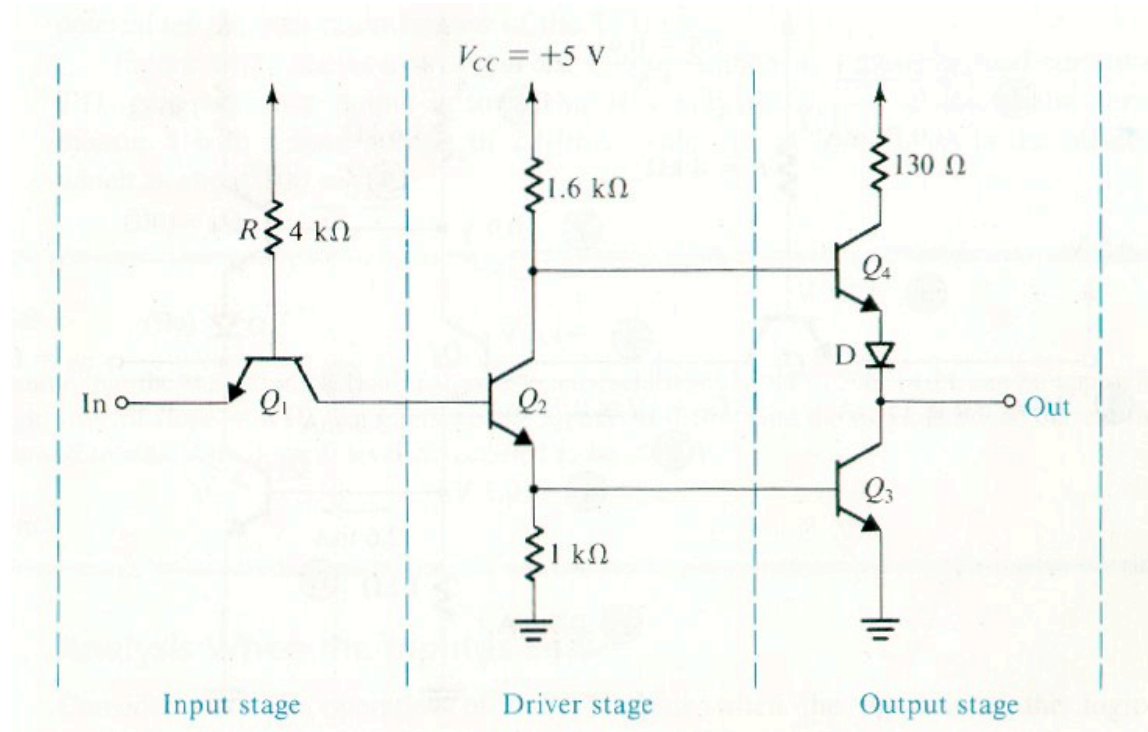
TTL (contd.)

- Totem Pole
 - Pulling up and down



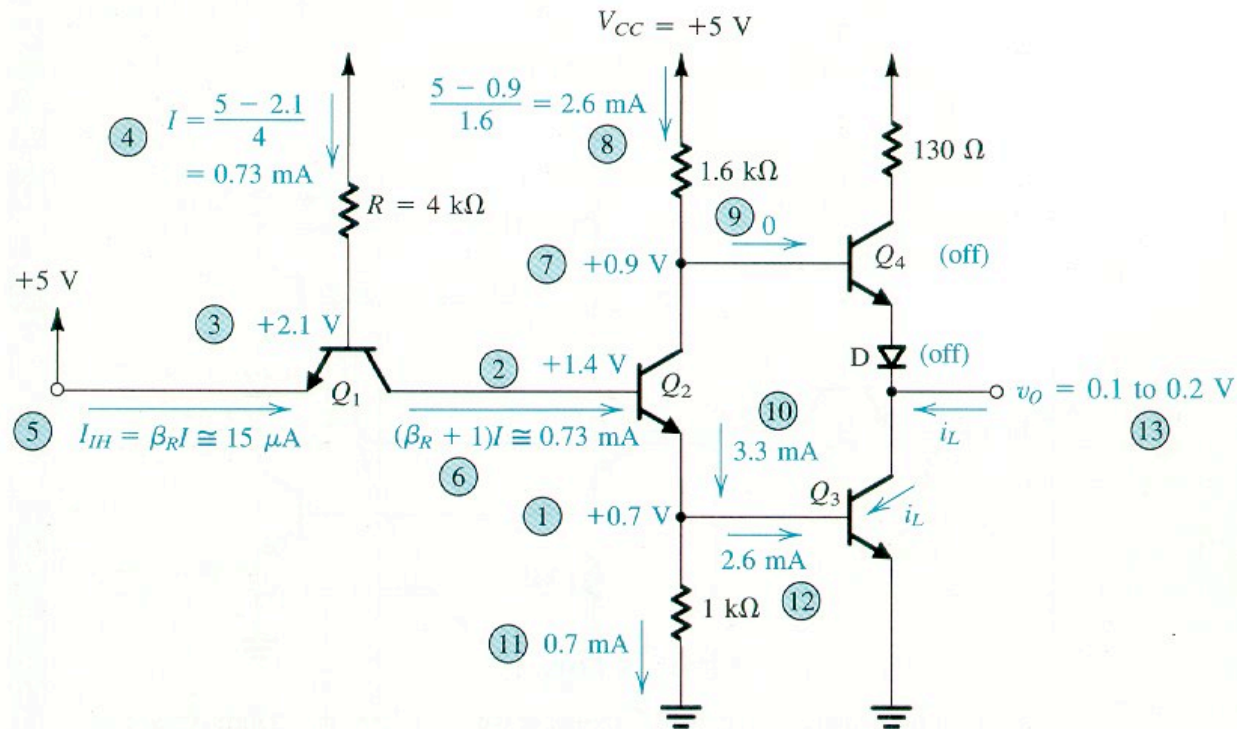
TTL (contd.)

- Driver stage
- Output stage
 - Resistor
 - Diode



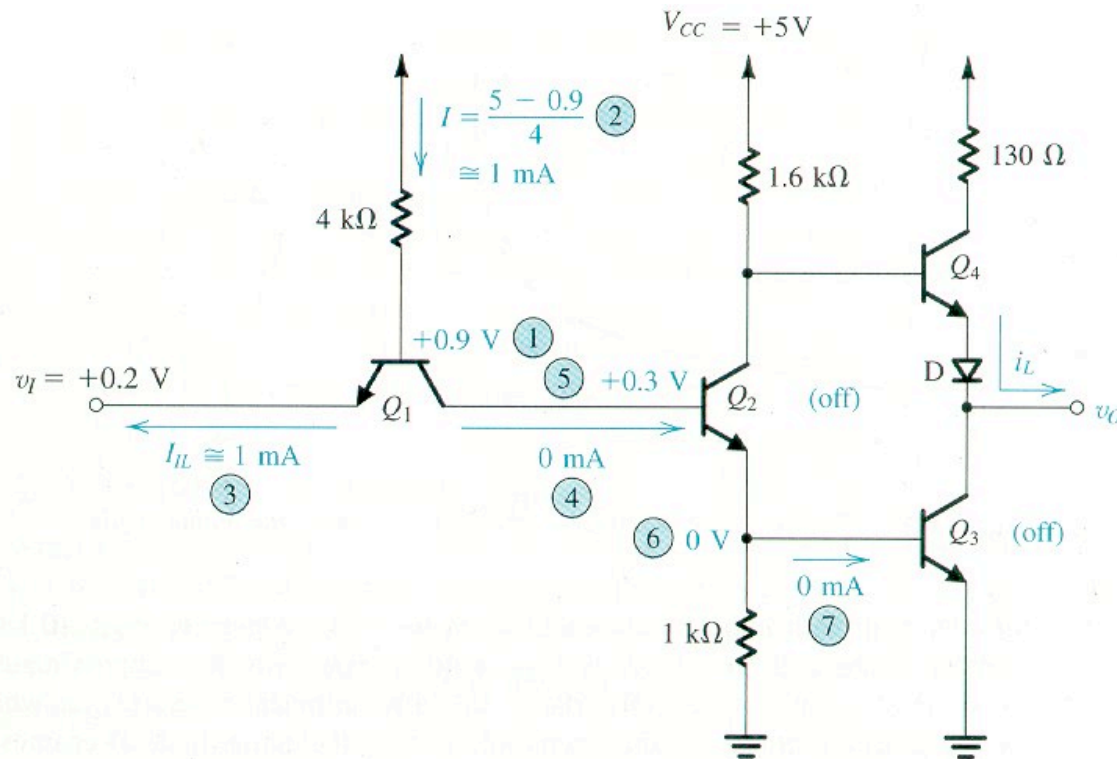
TTL (contd.)

- $V_{in} = \text{High}$



TTL (contd.)

- $V_{in} = \text{Low}$



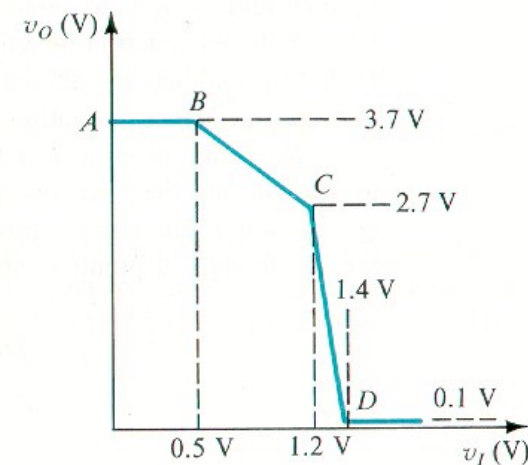
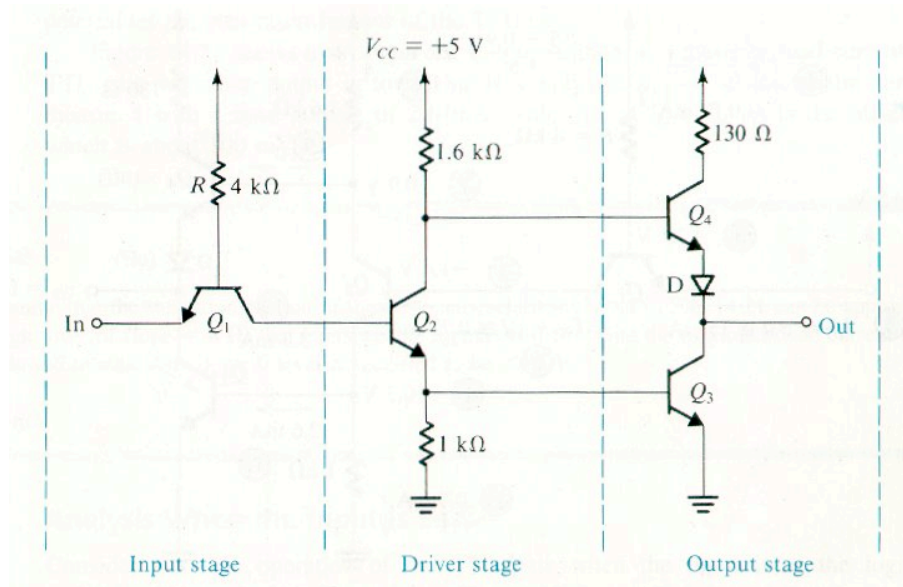
TTL (contd.)

- Threshold voltage
- Input current
 - when logic is high/when logic is low
- Quiescent power consumption
 - when logic is high/when logic is low
- Totem pole output stage
 - Diode and resistor
 - V_{OH}/V_{OL} , R_{OH}/R_{OL}



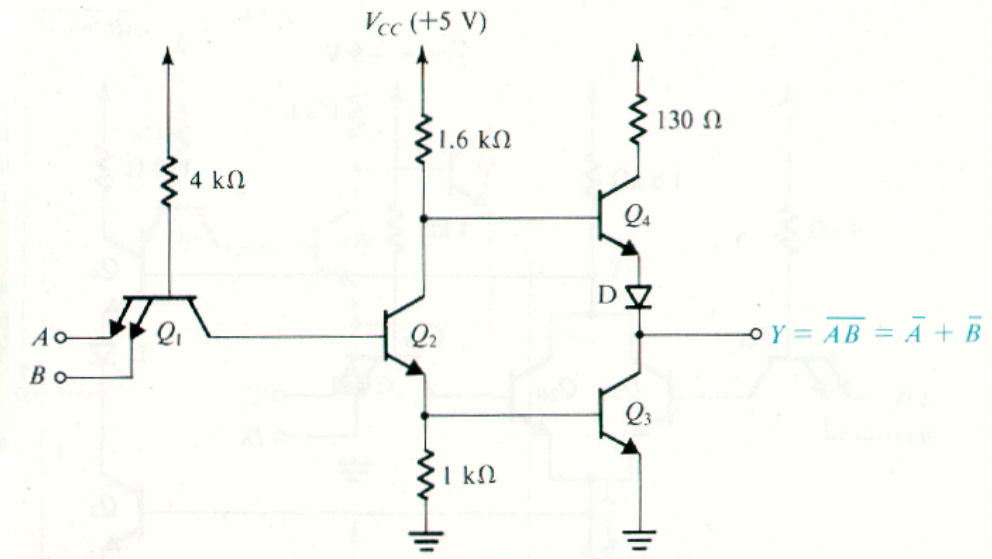
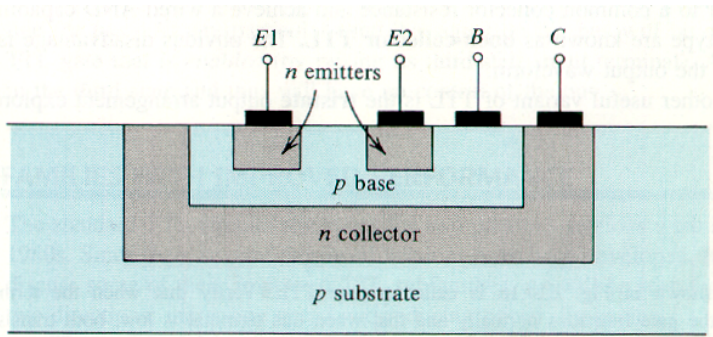
Standard TTL

- AB: Q1 saturated/ Q2 and Q3 off/ Q4 and D4 on
- BC: Q1 saturated/ Q2 active/ Q3 off/ Q4 emitter follower/ D4 on
- CD: Q1 saturated/ Q2, Q3 and Q4 active/ D4 on
- D: Q1, Q2 and Q3 saturate/ Q4 cut off/ D4 off



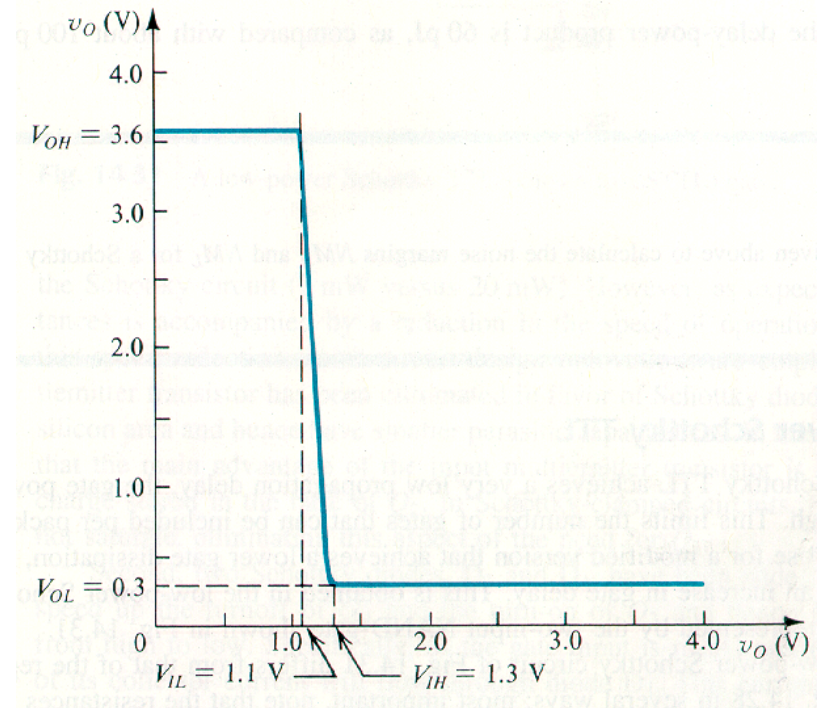
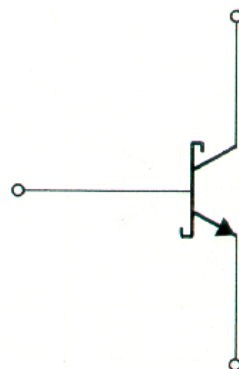
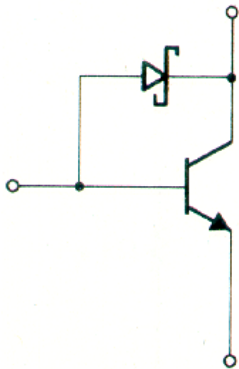
Multi-emitter

- Easy to expand the number of inputs



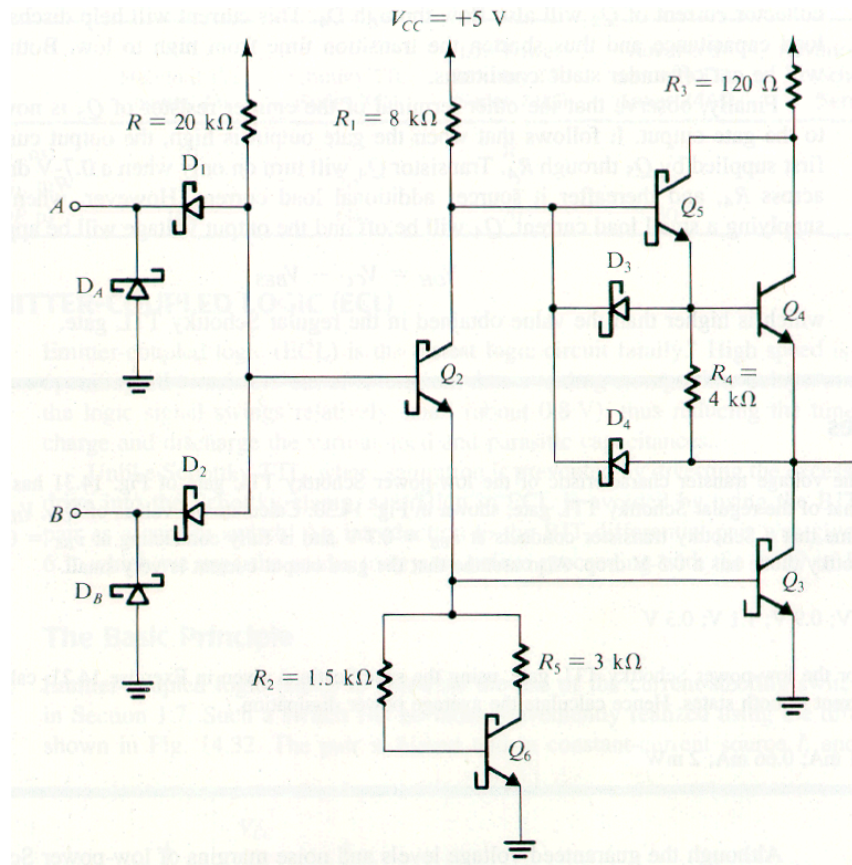
Shottky TTL

- Shottky diode and Shottky clamping



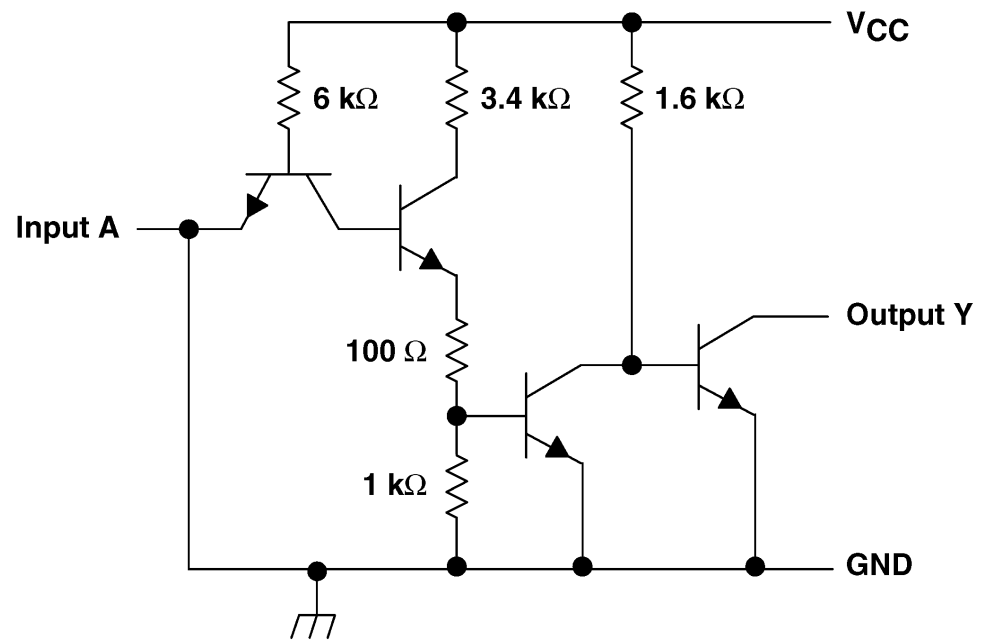
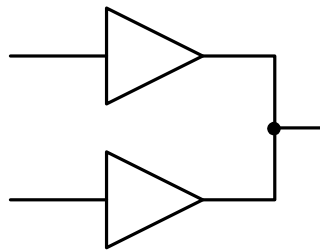
LSTTL

- Low-power Shottky TTL



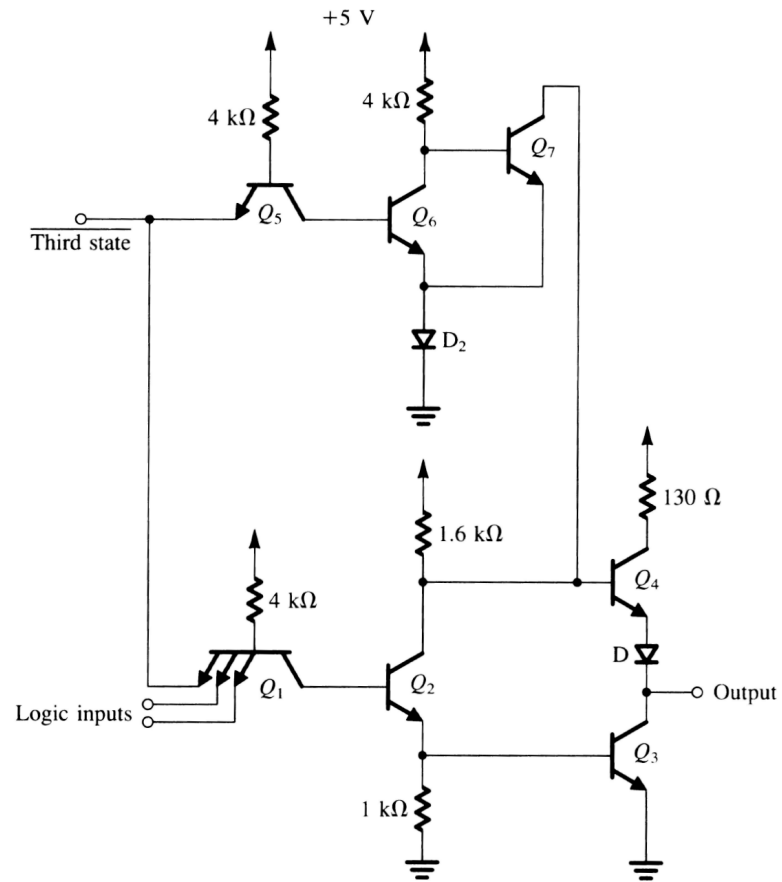
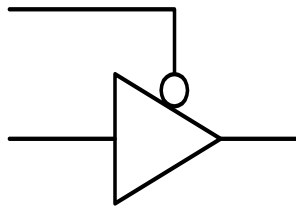
Open Collector

- For wired logic



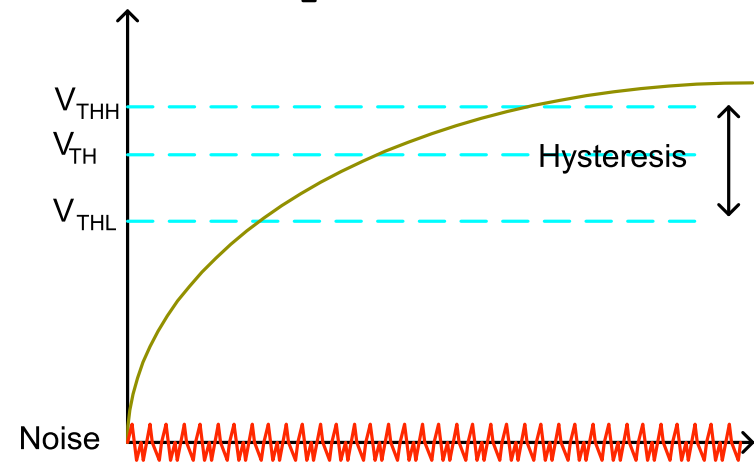
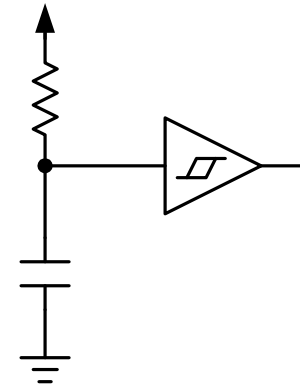
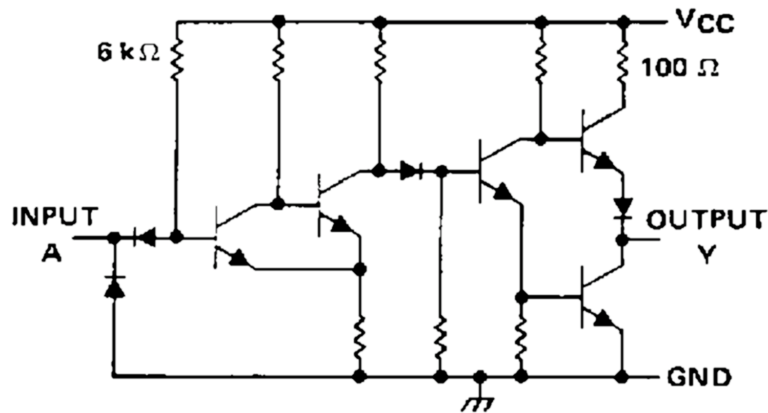
Three State

- High impedance output
- Bus signal



Schmitt Trigger

- Hysteresis

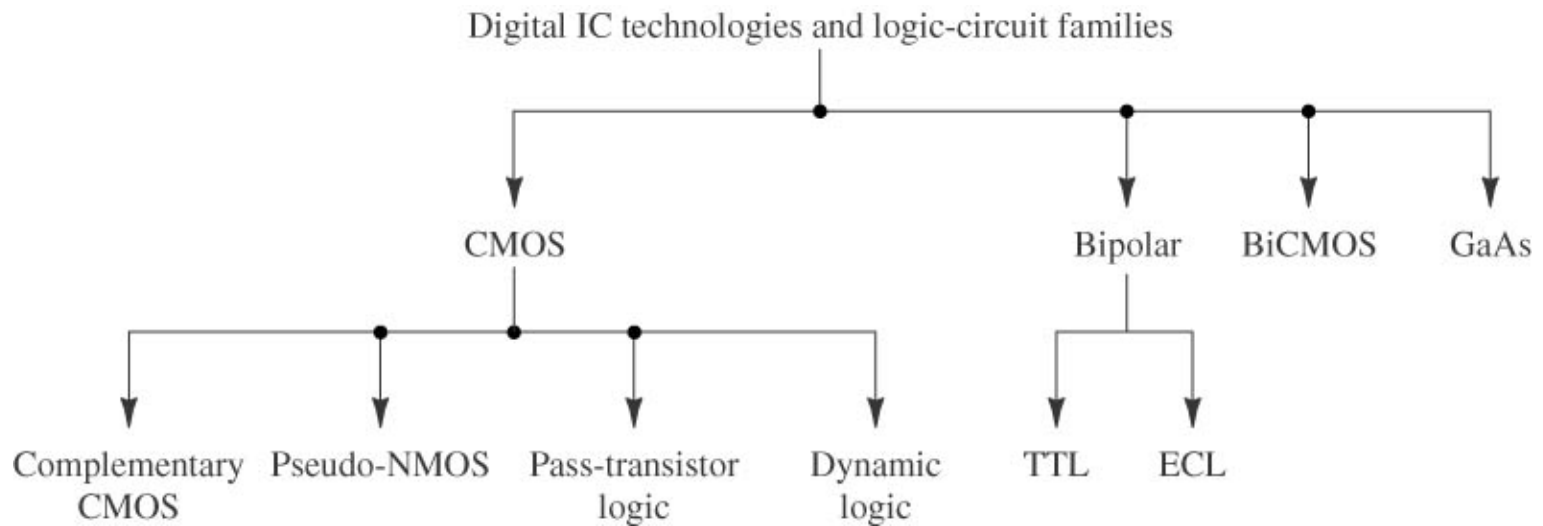


Advanced Logic Devices

- LSTTL: 74LS245
 - ALS, AS, F, etc.
- HCMOS: 74HC245
 - HCT, ACT, FCT, etc.
- BiCMOS
 - BTL, GTL, ABT, etc.
 - Low voltage, small logic swing



Digital logic classification



Note: Some figures are from Microelectronic Circuits fourth edition by Sedra and Smith, Oxford.

