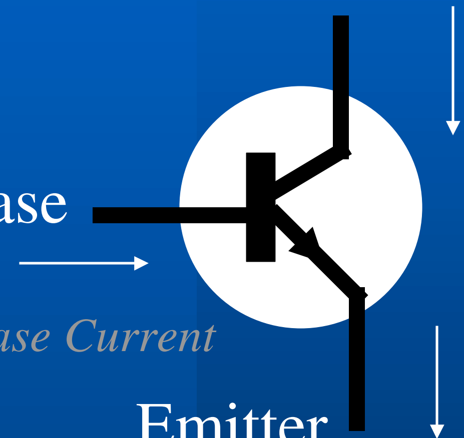
Transistors

Costas Foudas, Imperial College,
Rm: 508, x47590

Review : What is a Transistor ?



NPN Transistor Rules:

$V_C > V_E$

$V_B = V_E + 0.6$ Volts

$I_C = I_B * \beta$

$$I_E = I_C + I_B \Rightarrow$$
$$I_E = (1+\beta)\, I_B$$

FOR MORE INFO...

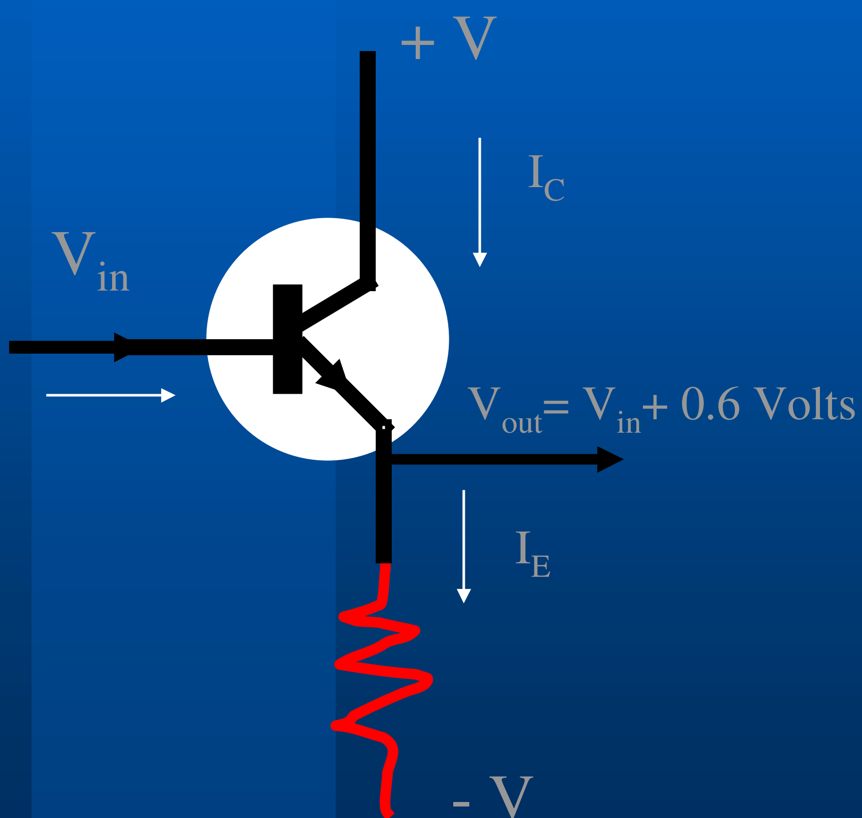
Relevant Books: Art of Electronics + Lab: *Harowitz and Hill*

Electronic Circuits: *E.C. Lowenberg, SCHAUM SERIES*

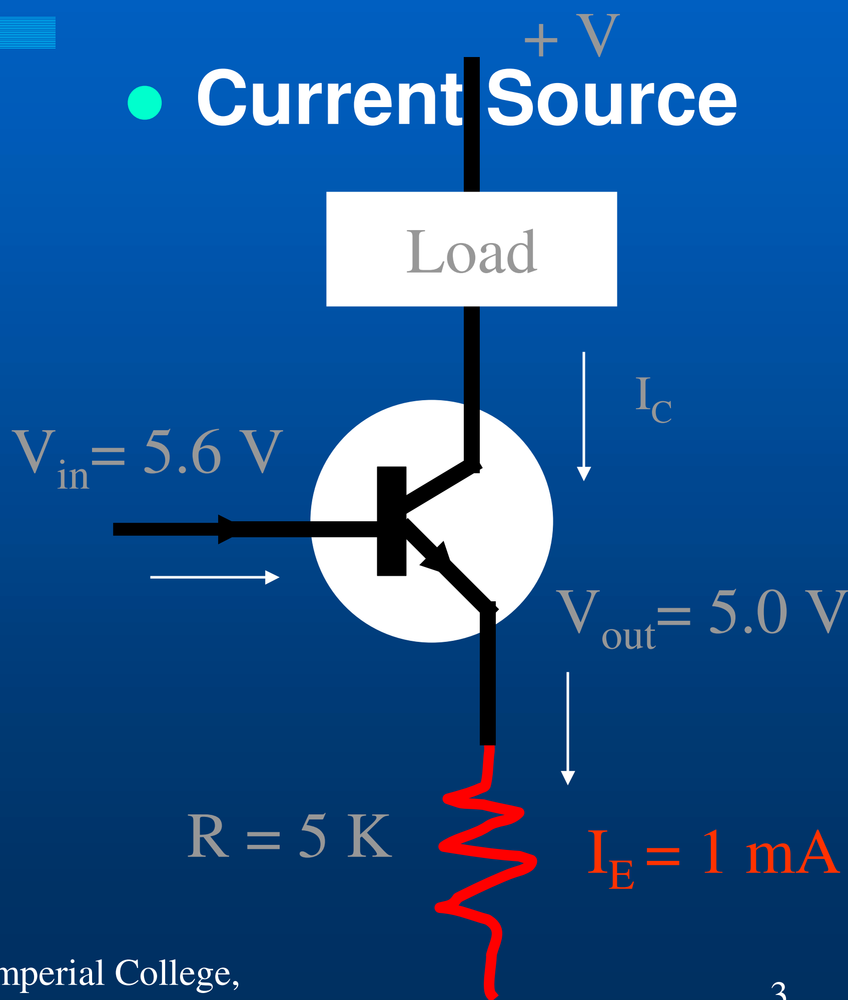
Electric Circuits: *J.A. EDMINISTER SCHAUM SERIES*

Some Transistor Applications I

- **Follower:**

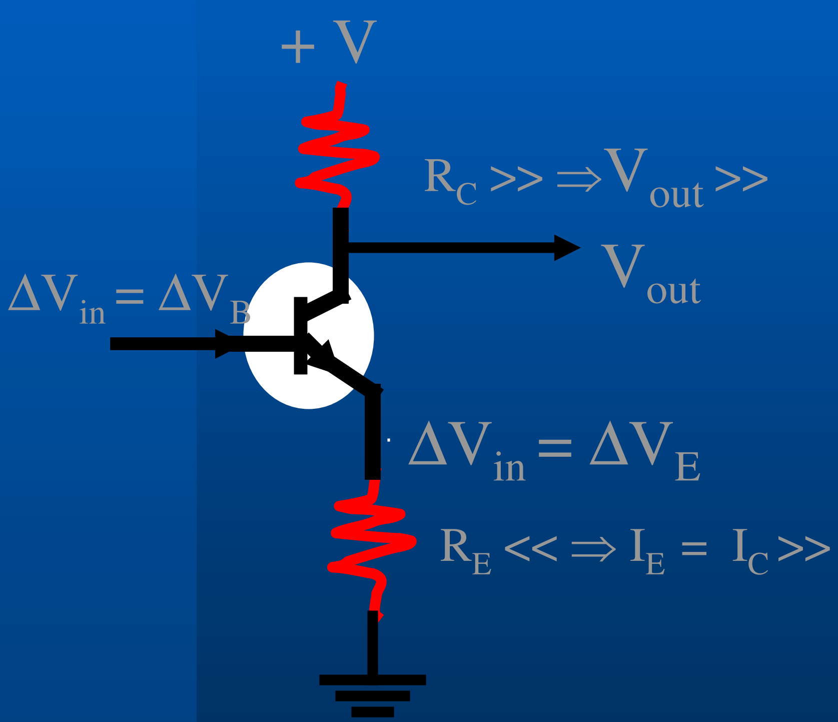


- **Current Source**

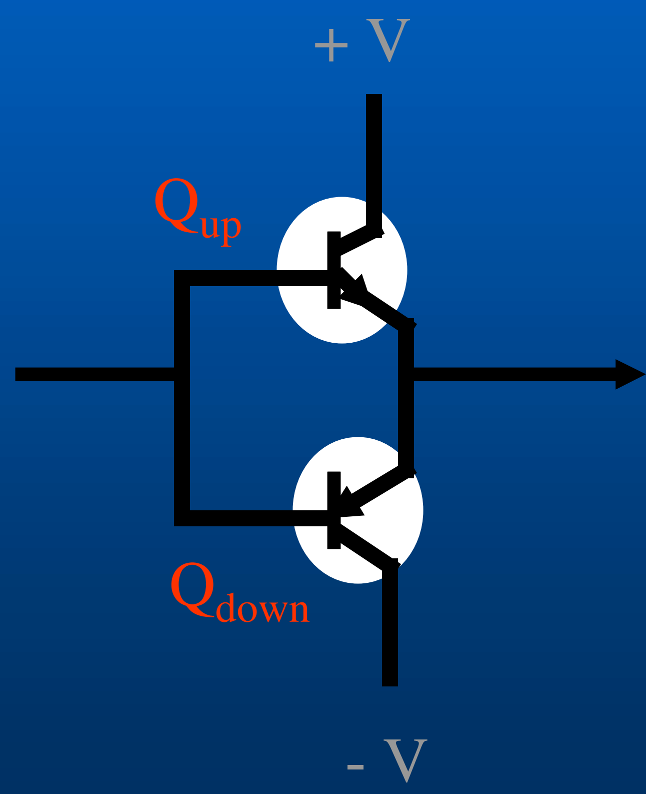


Some Transistor Applications II

- **Common Emitter Amplifier :**



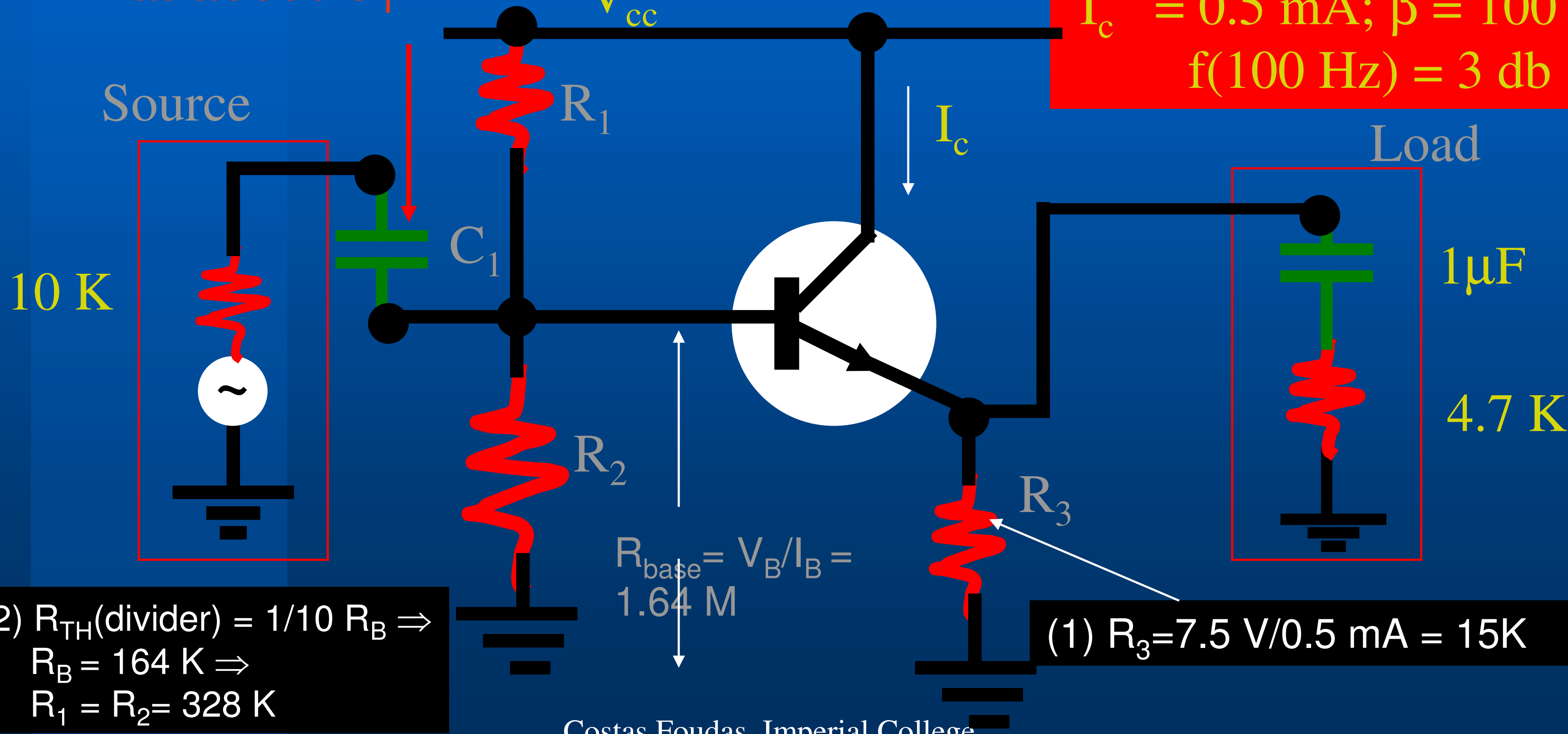
- **Push-Pull :**



The Emitter Follower I

Given : V_{cc} = 15 Volts
I_c = 0.5 mA; β = 100
f(100 Hz) = 3 db

What about C_1 ?



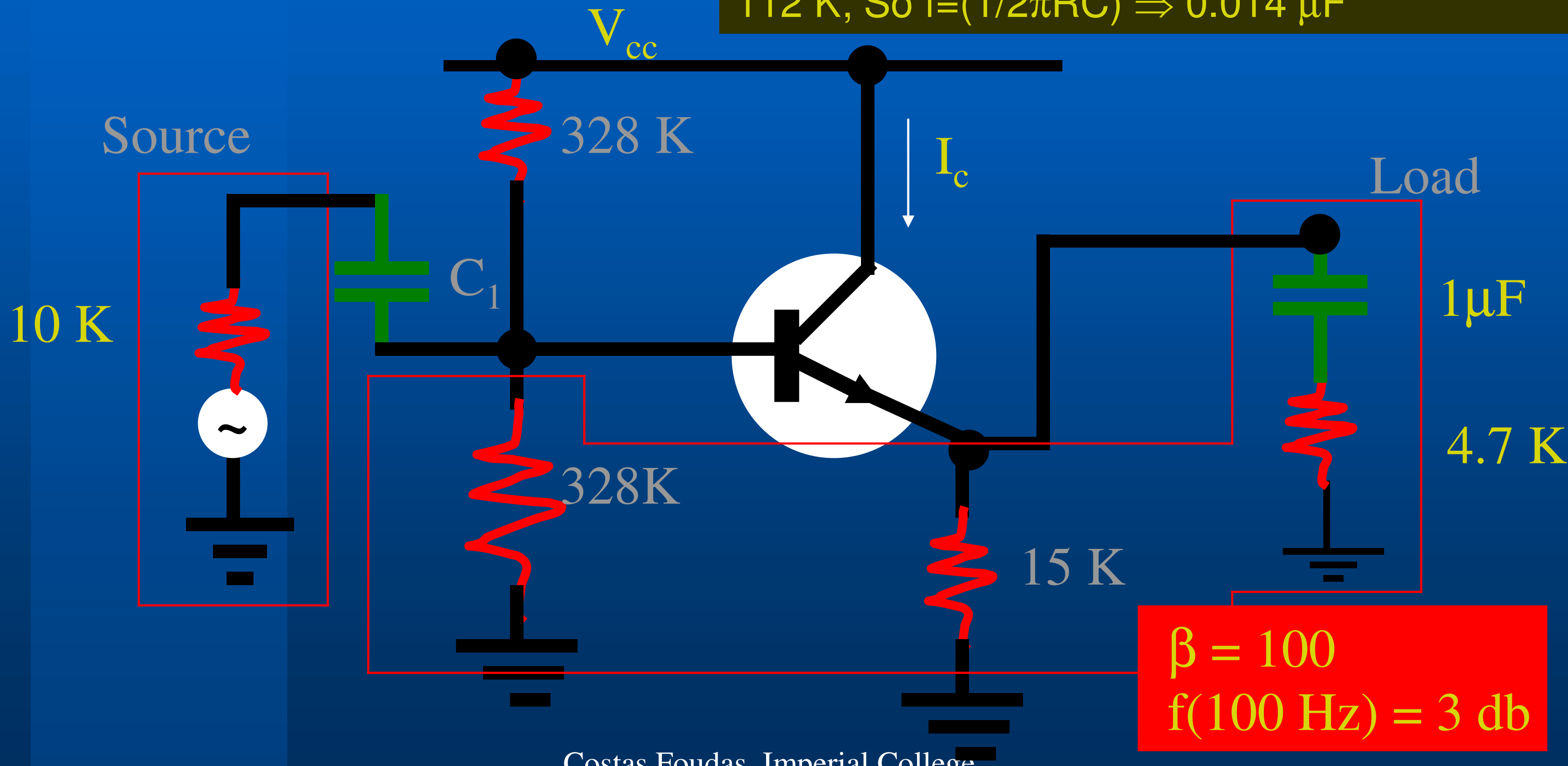
R_{base}= V_B/I_B = 1.64 M

(1) R_3=7.5 V/0.5 mA = 15K

(2) R_{TH}(divider) = 1/10 R_B ⇒
R_B = 164 K ⇒
R_1 = R_2= 328 K

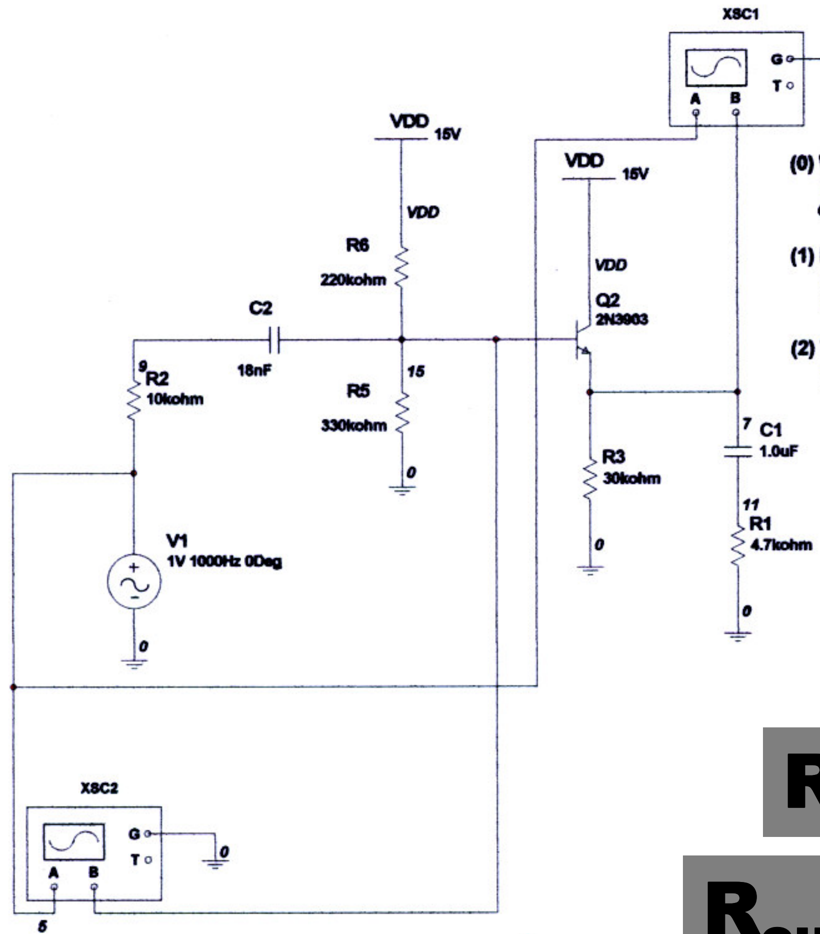
The Emitter Follower II

(3) Think of an RC filter (high-pass) .
15K is parallel to 4.7 K and the whole think times β
⇒ 358 K ; parallel with 328 K ⇒
112 K; So f=(1/2πRC) ⇒ 0.014 μF



β = 100
f(100 Hz) = 3 db

Emitter Follower (a bit diff.)



(0) We choose to operate the output at about 7.5 Volts. Note also that the Source has an impedance of 10 K so the receiving end should have at least a factor of 10 larger impedance.

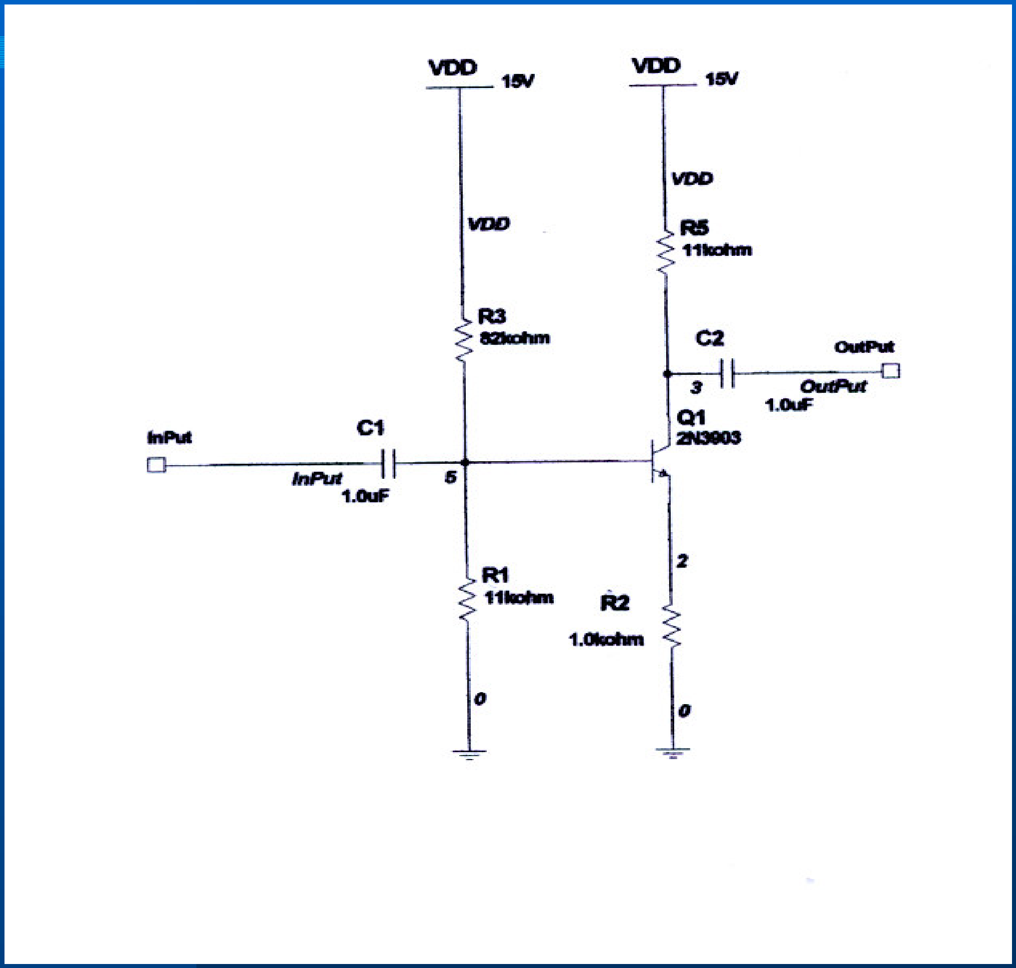
(1) First pick the Collector Current: 2N3903 can operate up to currents of 200 mA. We choose ~0.250 mA as opeartion point and 0.25 mA x 30 K is 7.5 Volts..If not we can correct it later.

(2) The Beta is measured to be 74...base inpout resistance = 74*30 K = 2.22 MOhm; Thevenin divider = 132 K less than 1/10 of the Base Emitter input resistance; the output voltage is now 7.847 Volts and Vbe= 8.475 Volts

$$R_{in}=R_{load}(1+\beta)$$

$$R_{out}=R_{source}/(1+\beta)$$

Common Emitter Amplifier



Gain = R5/R2

$R_{out}=R_5$

Common Emitter Amplifier II

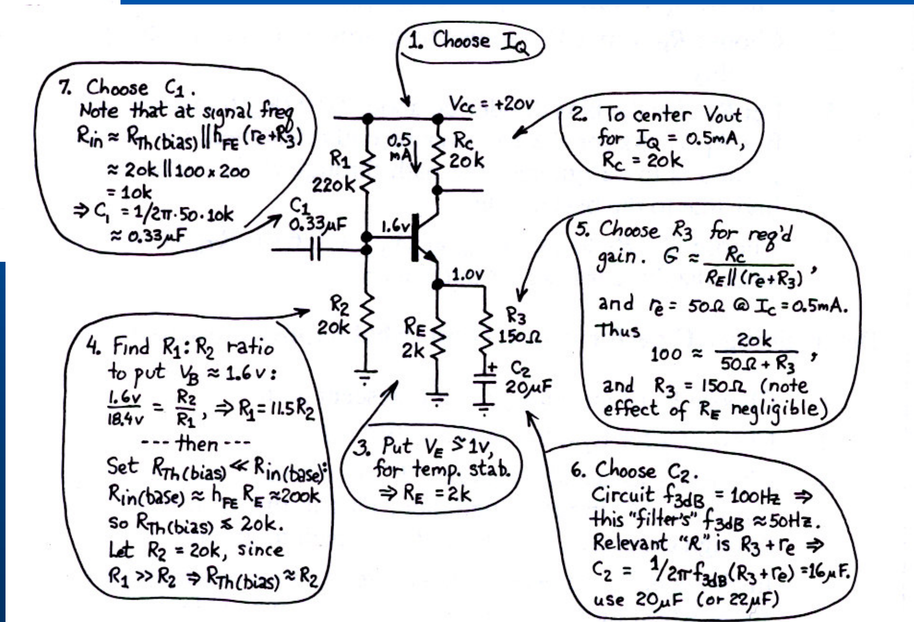
Problem: common emitter amp

Design a common-emitter amp to the following specs:

- $V+ = 20V$
- f_{3dB} = 100 Hz (approx.)
- gain = –100 at quiescent point.
- I_C quiescent = 0.5 mA

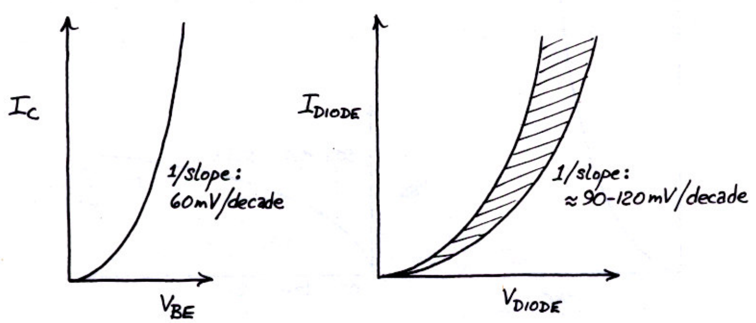
Questions:

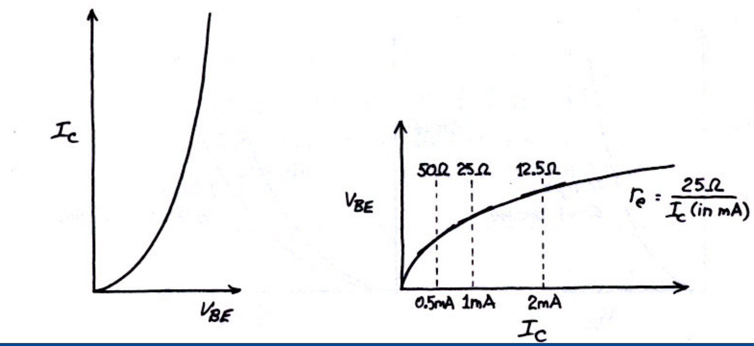
- What is the amp's gain—
  - when the output swings to about + 15v?
  - when the output swings to about + 5v?
- What is the amp's Z_{out}?

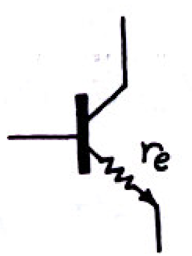


The Ebers-Moll Model for BJT

Class 5: Tr II: Corrections to the first model: Ebers-Moll







Ebers-Moll

$$I_C = I_S(e^{V_{BE}/(kT/q)} - 1)$$

(grows fast with temperature; more on this later) (negligible)

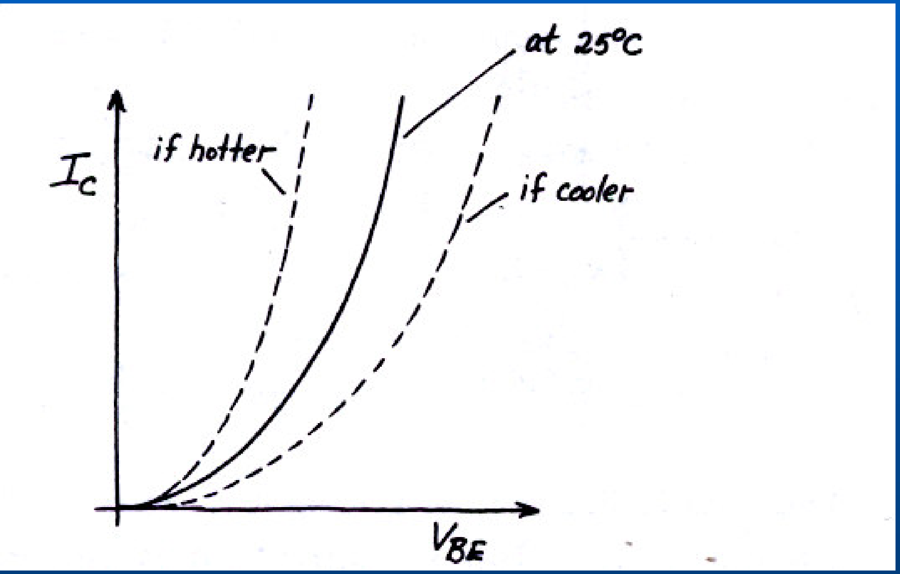
Ignoring the "-1" term, we can say simply that I_C grows exponentially with V_{BE}.

In addition, we might as well plug in the room-temperature value for that complicated expression "kT/q:" 25 mV. Then Ebers-Moll doesn't look so bad:

Ebers-Moll: (slightly simplified)

$$I_C \approx I_S\, e^{V_{BE}/25\text{mV}}$$

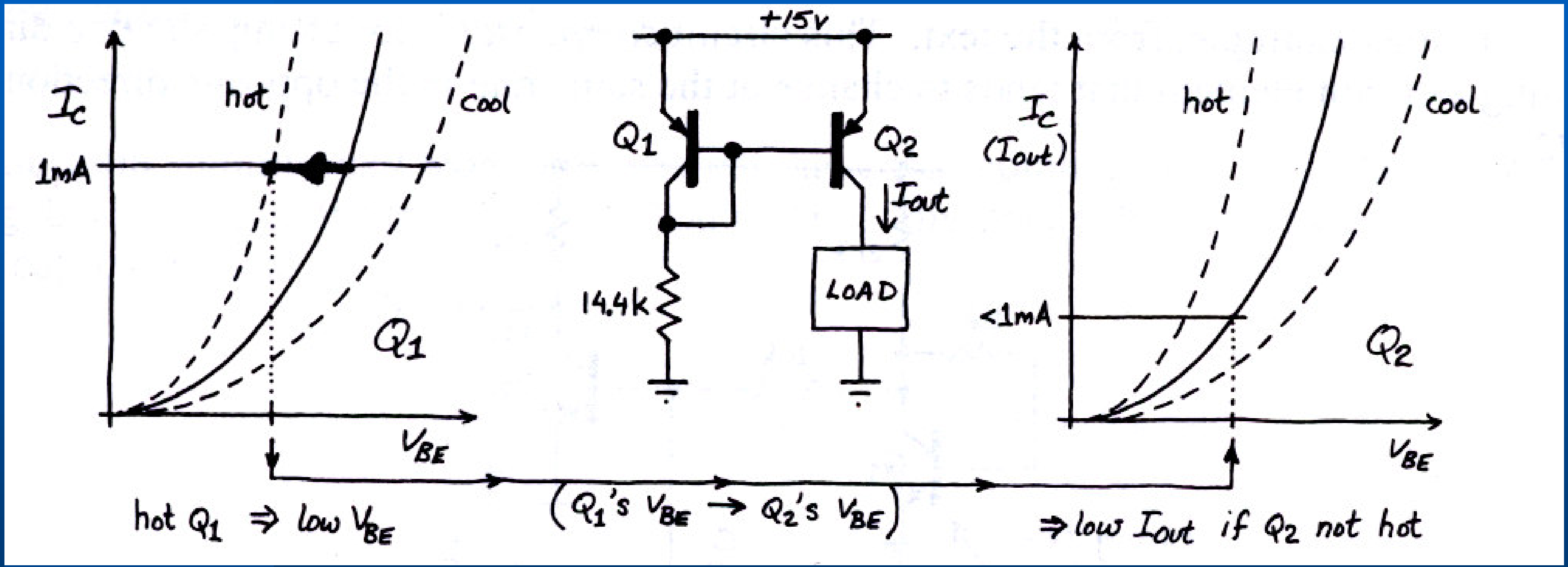
Temperature Effects



Temperature Effects: ***two equivalent formulations***

- I_C grows at about 9%/°C, if you hold V_{BE} ***constant***.
- V_{BE} falls at 2mV/°C, if you hold I_C ***constant*** (This is the text's formulation.)

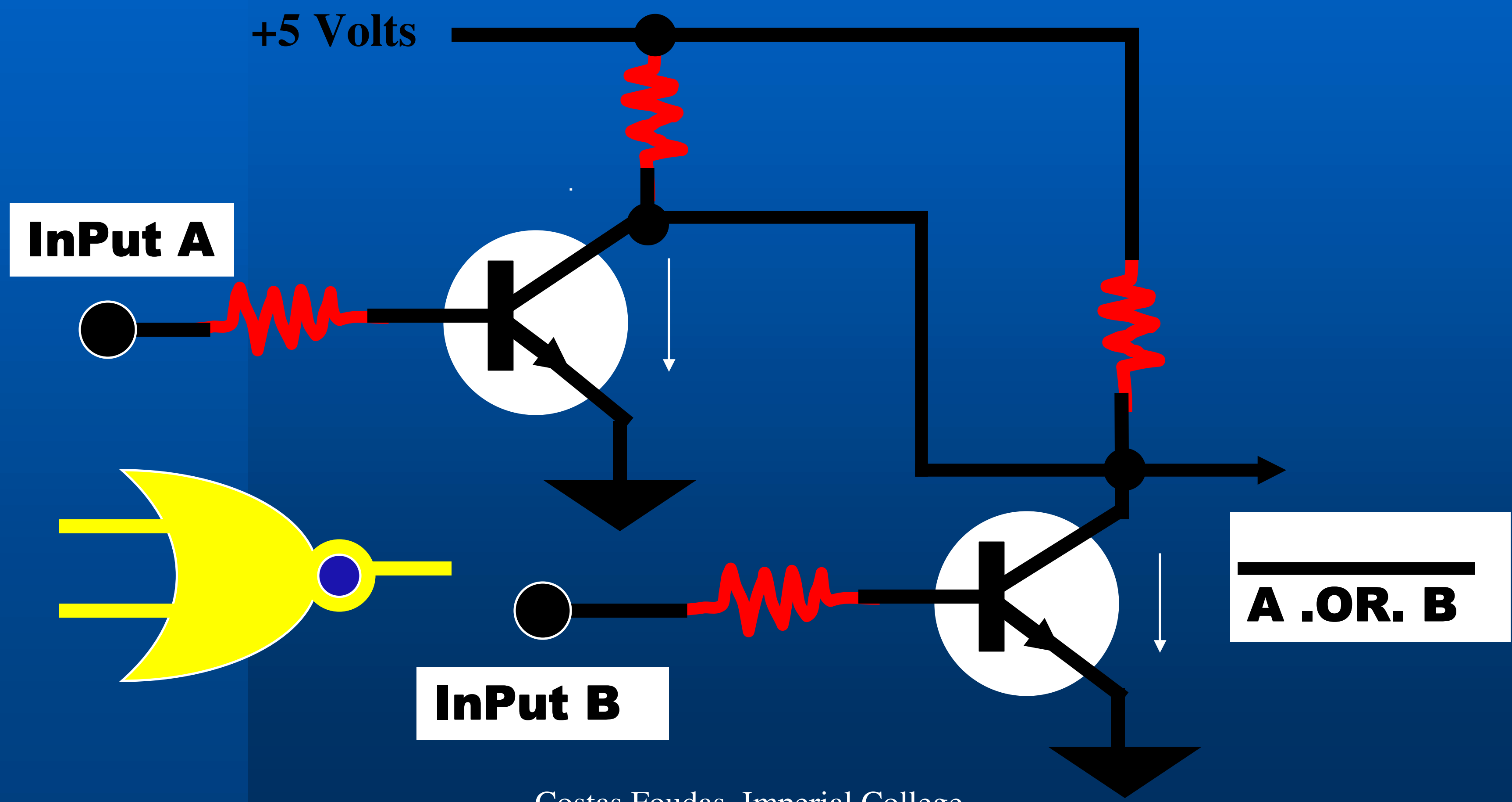
Temperature Effects and Current Mirrors



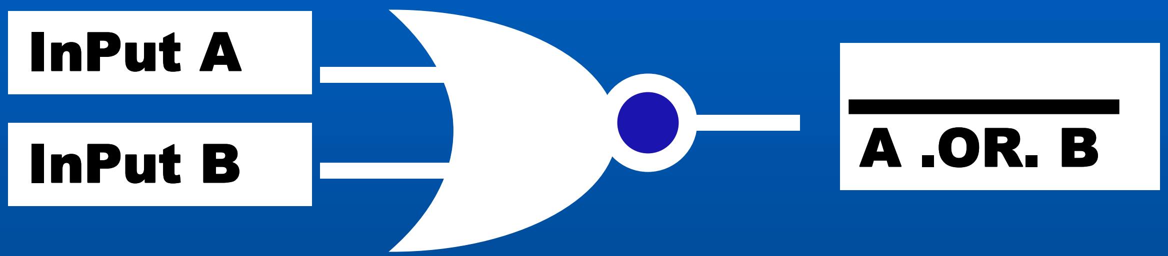
Exercises

- Make a Current Source using a transistor
- Make common emitter follower
- Make a Common Emitter Amplifier

Making Gates using Transistors I



Making Gates using Transistors II



Here is what we have made

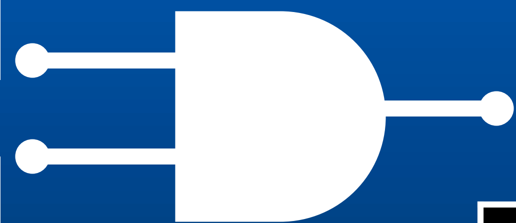
A	A	OUT
1	0	0
1	1	0
0	1	0
0	0	1

Exercise I

Design and construct an AND gate using transistors and resistors :

InPut A

InPut B



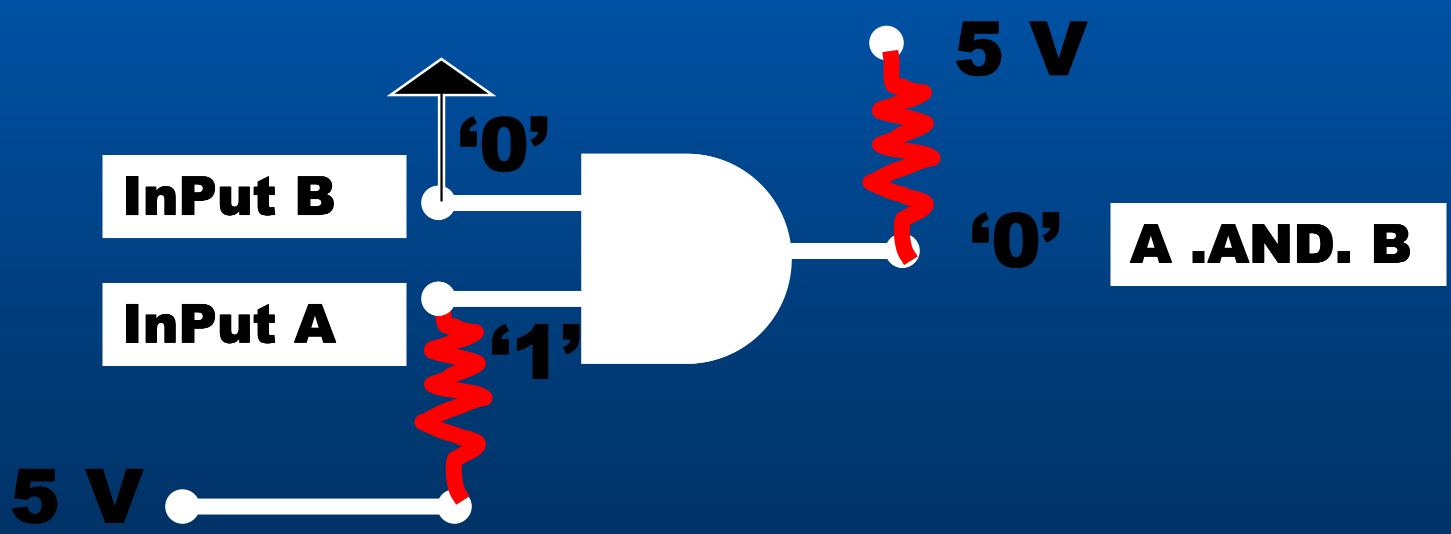
A .AND. B

The AND gate TRUTH table

A	A	OUT
1	0	0
1	1	1
0	1	0
0	0	0

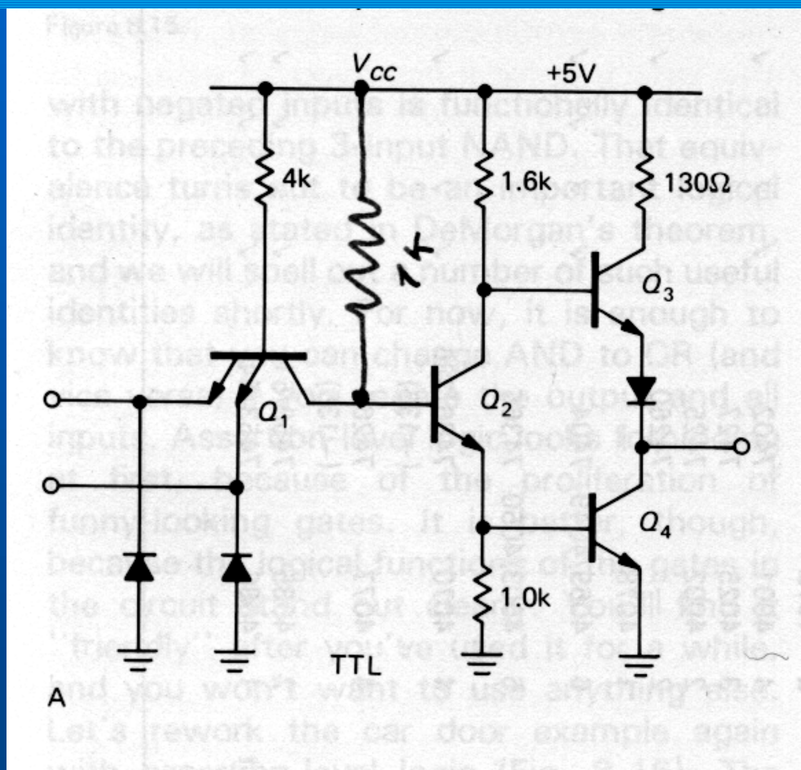
Exercise I continued

Verify the truth table ! You can set an input to '1' by connecting it to +5 V by a resistor of 1K and you set it to '0' by grounding it.

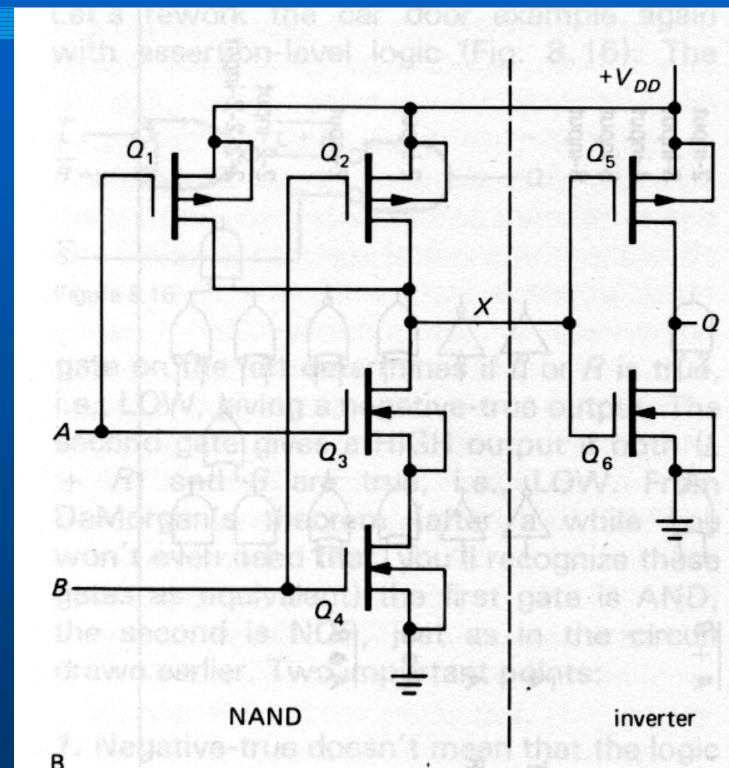


Answer (almost):

TTL



CMOS



Not quite because this is a NAND gate but we do know by now how to invert using a transistor

Important conclusion

You may understand by now that the inputs have no ability to set signals high or low. In contrast to this the outputs can drive signals to High or Low

Remember:

<u>Inputs</u> draw no current. 1KΩ resistors to +5 V can set inputs to high or they can be set low by connecting to ground.

<u>Outputs</u> can draw current and can force lines to low or high.