Benha University
Faculty of Engineering at Shoubra

ECE-312
Electronic Circuits (A)

Lecture #2
BJT Review

Instructor:
Dr. Ahmad El-Banna

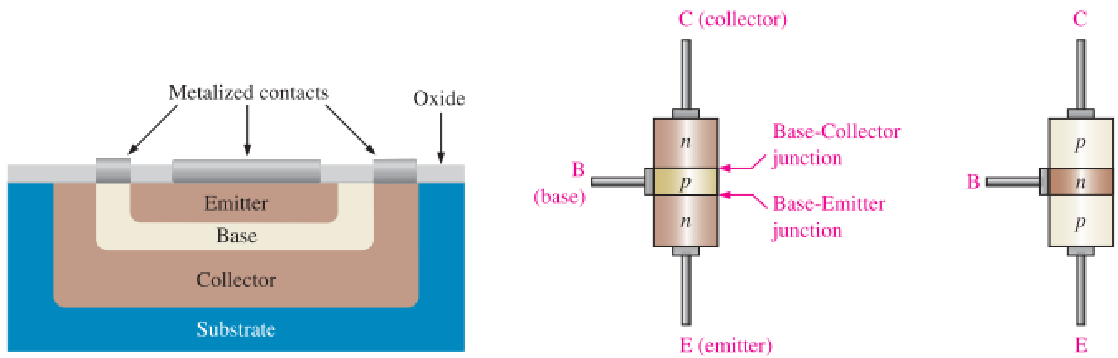
October 2014

Agenda

- Transistor Construction & Operation
- Transistor Configurations
- Transistor Testing & Terminal Identification

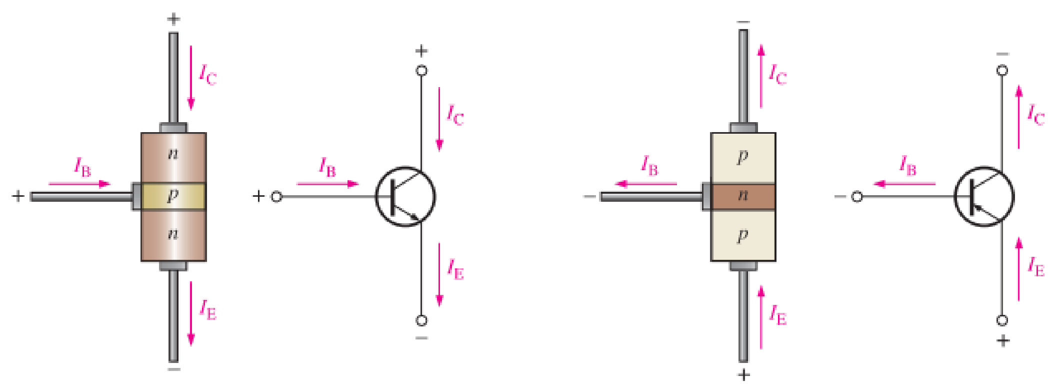
Transistor Construction

- Basic BJT Constructions



(a) Basic epitaxial planar structure (b) *npn* (c) *pnp*

- Basic BJT symbols and Currents

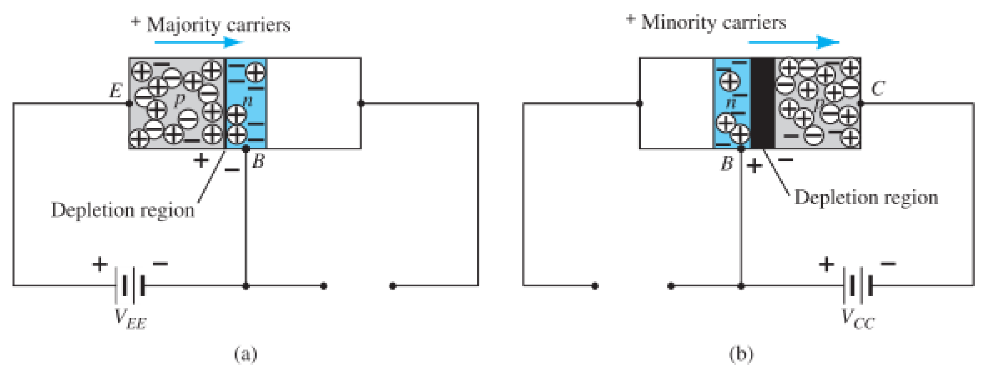


(a) *npn* (b) *pnp*

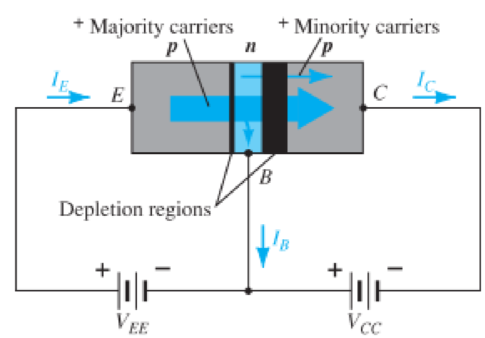
Transistor Operation

- Basic Operation using *pnp* transistor.

- Biasing a transistor:
  (a) forward-bias
  (b) reverse-bias.



- Majority and minority carrier flow of a *pnp* transistor.



$$I_E = I_C + I_B$$

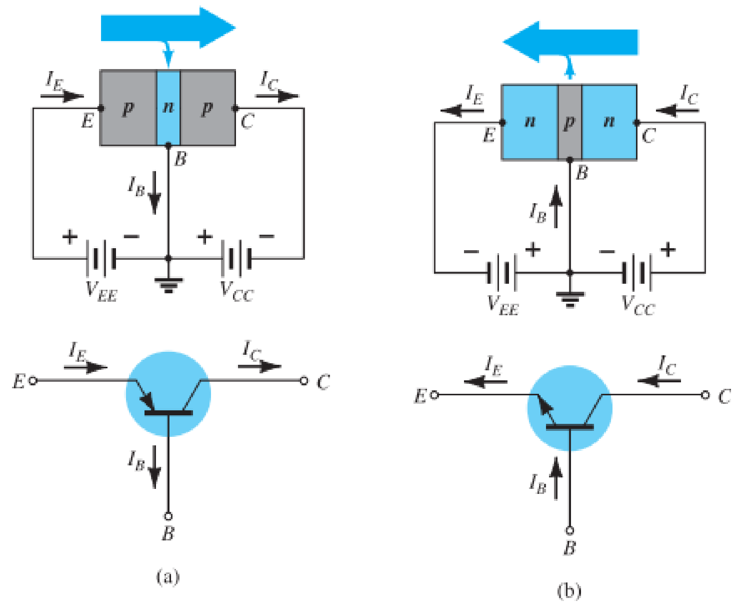
$$I_C = I_{C_{\text{majority}}} + I_{CO_{\text{minority}}}$$

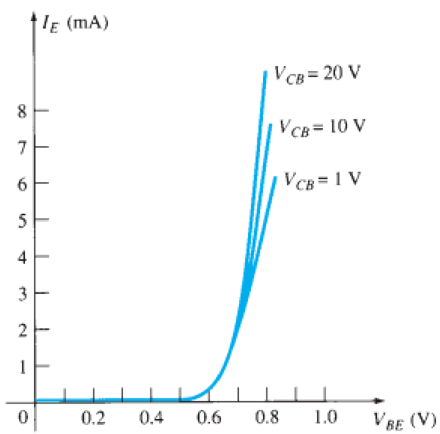
- Common Base
- Common Emitter
- Common Collector

BJT CONFIGURATIONS

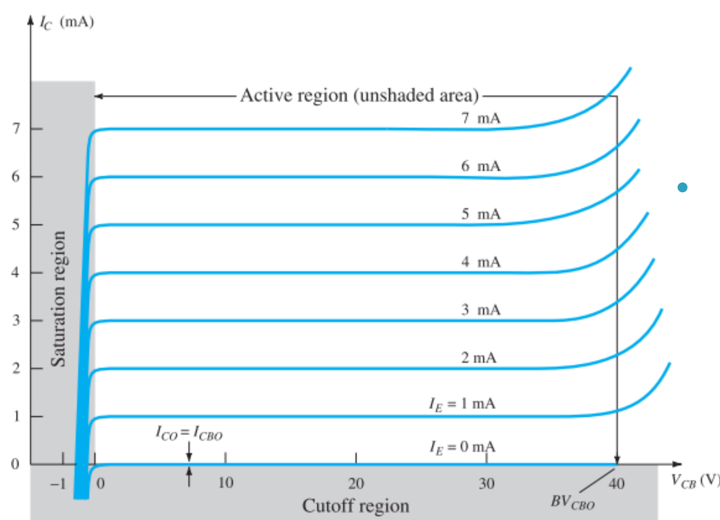
Configurations: Common Base

- Notation and symbols used with the common-base configuration: (a) pnp transistor; (b) npn transistor.





- Input or driving point characteristics for a common-base silicon transistor amplifier.



- Output or collector characteristics for a common-base transistor amplifier.

Configurations: Common Base..

- Formulas:

$$I_C \cong I_E$$

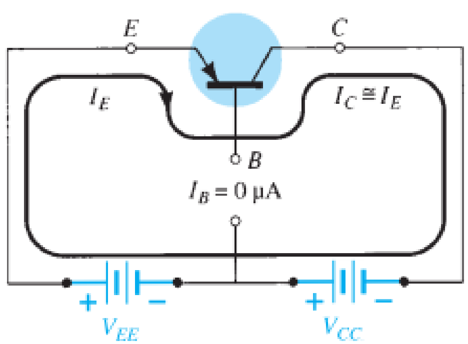
$$V_{BE} \cong 0.7\text{ V}$$

$$\alpha_{dc} = \frac{I_C}{I_E}$$

$$I_C = \alpha I_E + I_{CBO}$$

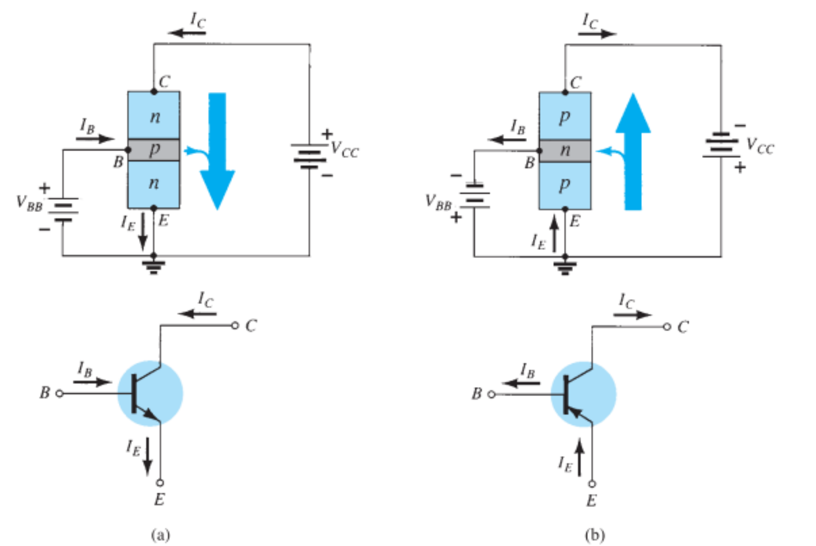
$$\alpha_{ac} = \frac{\Delta I_C}{\Delta I_E}\bigg|_{V_{CB}=\text{constant}}$$

- Biasing of a CB pnp tr. in the active region:

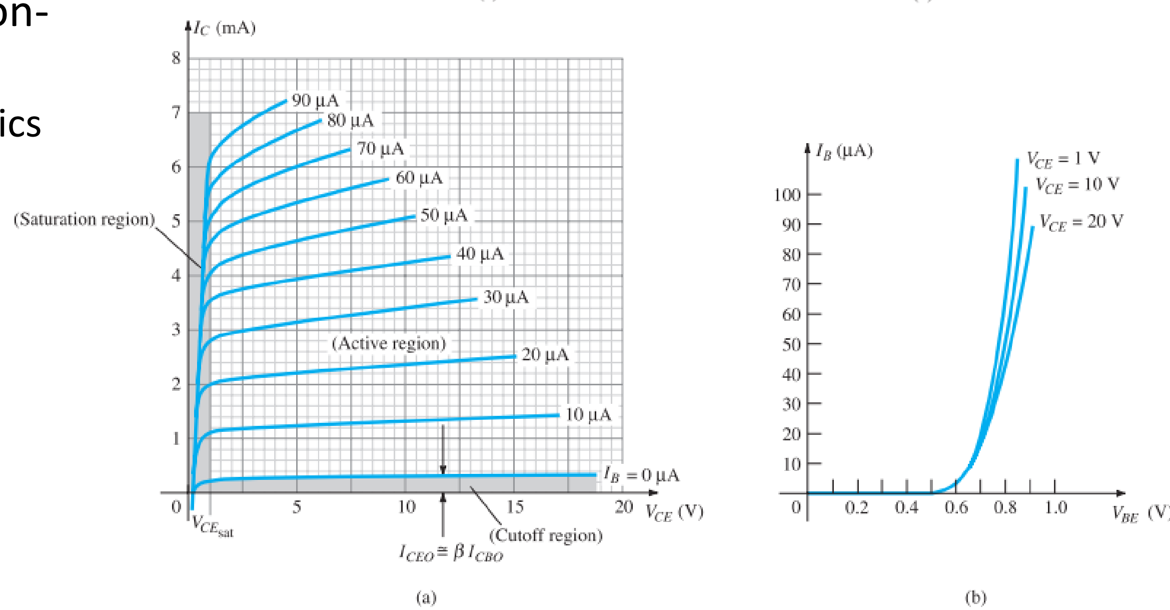


Configurations: Common Emitter

- Notation and symbols used with the common-emitter configuration:
  - (a) pnp transistor
  - (b) npn transistor.



- Characteristics of a silicon transistor in the common-emitter configuration:
  - (a) collector characteristics
  - (b) base characteristics.



Configurations: Common Emitter..

- Formulas:

$$\beta_{dc} = \frac{I_C}{I_B}$$

$$\beta_{ac} = \left.\frac{\Delta I_C}{\Delta I_B}\right|_{V_{CE}=\text{constant}}$$

$$\alpha = \frac{\beta}{\beta + 1}$$

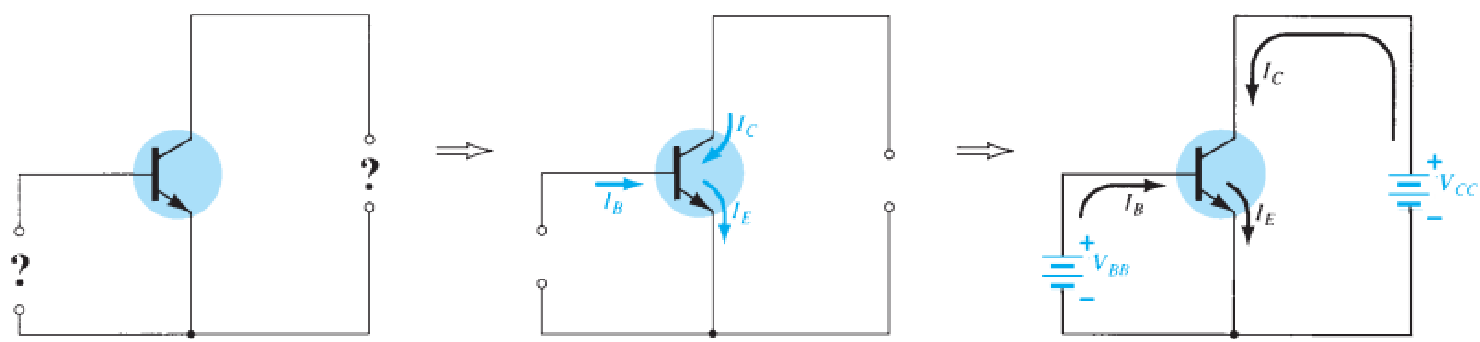
$$\beta = \frac{\alpha}{1 - \alpha}$$

$$I_{CEO} \cong \beta I_{CBO}$$

$$I_C = \beta I_B$$

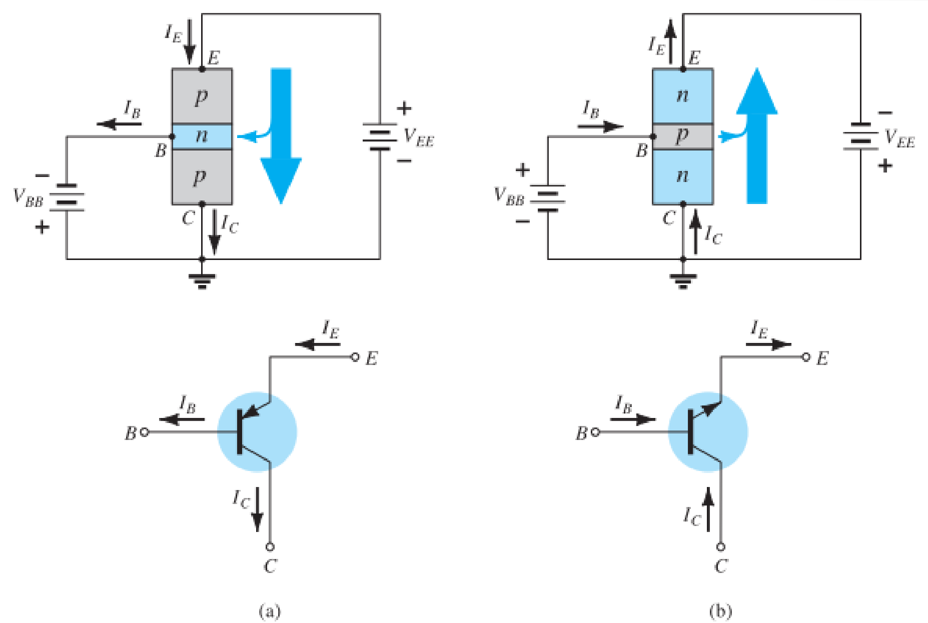
$$I_E = (\beta + 1) I_B$$

- Biasing of a CE npn tr. in the active region:

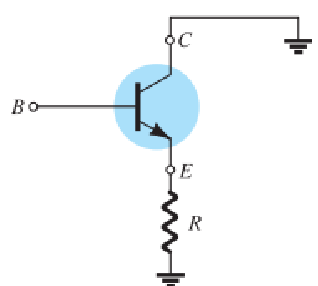


Configurations: Common Collector

- Notation and symbols used with the common-collector configuration: (a) pnp transistor; (b) npn transistor.



- Common-collector configuration used for impedance-matching purposes.



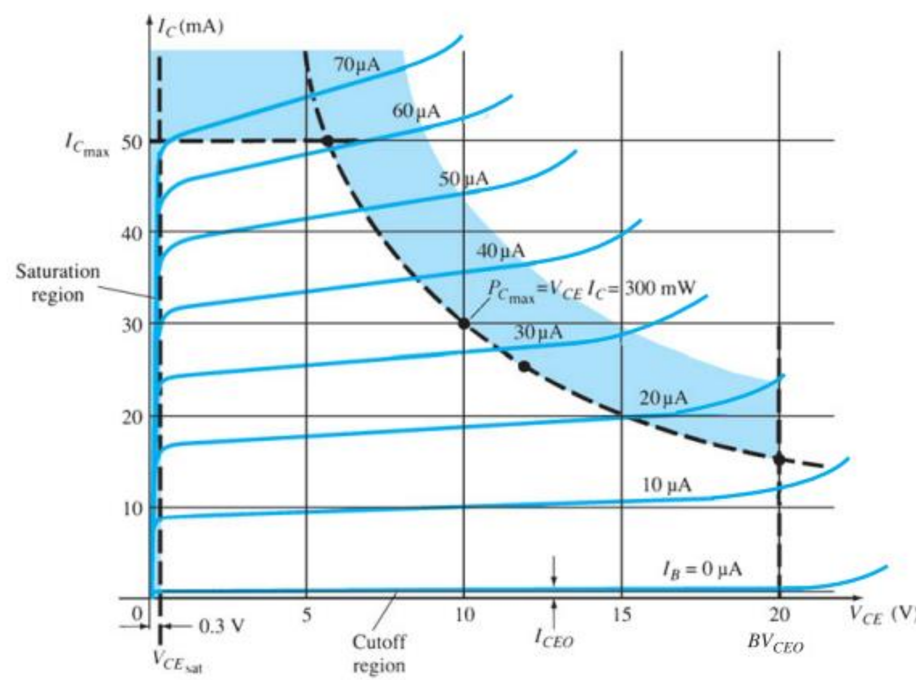
Configurations: Common Collector..

- Formulas:

$$P_{C_{max}} = V_{CE} I_C$$

$$I_{CEO} \leqq I_C \leqq I_{C_{max}}$$
$$V_{CE_{sat}} \leqq V_{CE} \leqq V_{CE_{max}}$$
$$V_{CE} I_C \leqq P_{C_{max}}$$

- Defining the linear (undistorted) region of operation for a transistor.



- Transistor Spec. Sheets
- Transistor Testing
- Transistor Casing and terminals identification
- Transistor Development

PRACTICAL VIEW

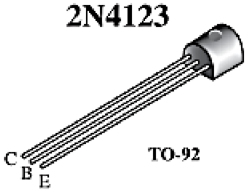
Transistor Specification Sheets

MAXIMUM RATINGS

Rating	Symbol	2N4123	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector-Base Voltage	V_{CBO}	40	Vdc
Emitter-Base Voltage	V_{EBO}	5.0	Vdc
Collector Current – Continuous	I_C	200	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	625 5.0	mW mW°C
Operating and Storage Junction Temperature Range	T_j, T_{stg}	–55 to +150	°C

FAIRCHILD
SEMICONDUCTOR ™

2N4123



General Purpose Transistor NPN Silicon

THERMAL CHARACTERISTICS

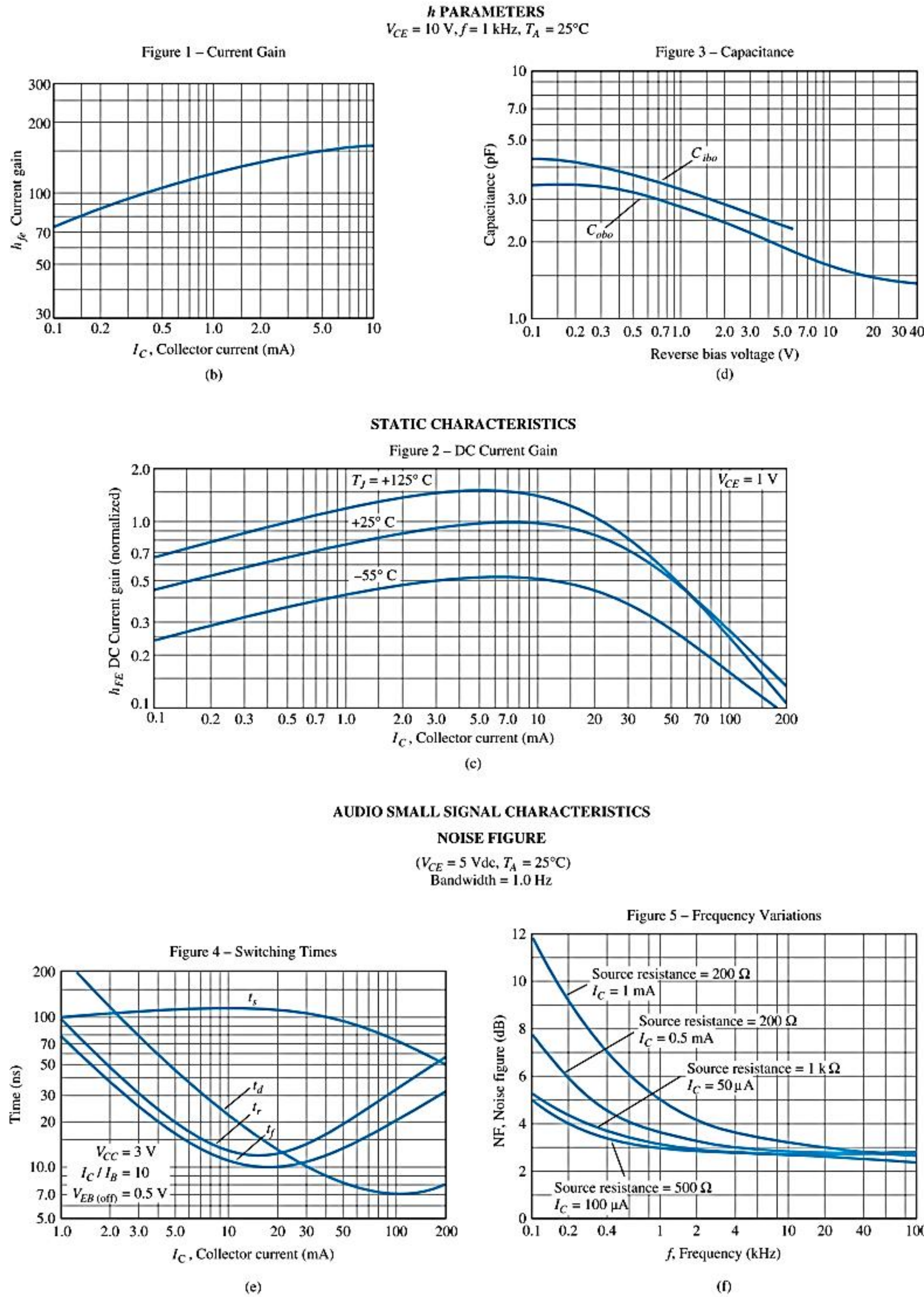
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	83.3	°C W
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	200	°C W

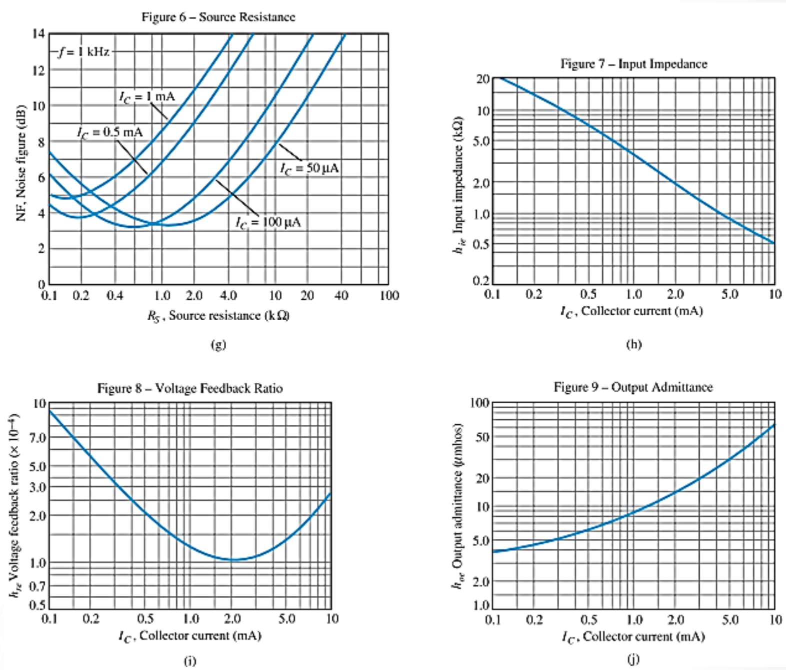
ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (1) ($I_C = 1.0$ mAdc, $I_E = 0$)	$V_{(BR)CEO}$	30		Vdc
Collector-Base Breakdown Voltage ($I_C = 10$ µAdc, $I_E = 0$)	$V_{(BR)CBO}$	40		Vdc
Emitter-Base Breakdown Voltage ($I_E = 10$ µAdc, $I_C = 0$)	$V_{(BR)EBO}$	5.0	–	Vdc
Collector Cutoff Current ($V_{CB} = 20$ Vdc, $I_E = 0$)	I_{CBO}	–	50	nAdc
Emitter Cutoff Current ($V_{BE} = 3.0$ Vdc, $I_C = 0$)	I_{EBO}	–	50	nAdc
ON CHARACTERISTICS				
DC Current Gain(1) ($I_C = 2.0$ mAdc, $V_{CE} = 1.0$ Vdc) ($I_C = 50$ mAdc, $V_{CE} = 1.0$ Vdc)	h_{FE}	50 25	150 –	–
Collector-Emitter Saturation Voltage(1) ($I_C = 50$ mAdc, $I_B = 5.0$ mAdc)	$V_{CE(sat)}$	–	0.3	Vdc
Base-Emitter Saturation Voltage(1) ($I_C = 50$ mAdc, $I_B = 5.0$ mAdc)	$V_{BE(sat)}$	–	0.95	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain – Bandwidth Product ($I_C = 10$ mAdc, $V_{CE} = 20$ Vdc, f = 100 MHz)	f_T	250		MHz
Output Capacitance ($V_{CB} = 5.0$ Vdc, $I_E = 0$, f = 100 MHz)	C_{obo}	–	4.0	pF
Input Capacitance ($V_{BE} = 0.5$ Vdc, $I_C = 0$, f = 100 kHz)	C_{ibo}	–	8.0	pF
Collector-Base Capacitance ($I_E = 0$, $V_{CB} = 5.0$ V, f = 100 kHz)	C_{cb}	–	4.0	pF
Small-Signal Current Gain ($I_C = 2.0$ mAdc, $V_{CE} = 10$ Vdc, f = 1.0 kHz)	h_{fe}	50	200	–
Current Gain – High Frequency ($I_C = 10$ mAdc, $V_{CE} = 20$ Vdc, f = 100 MHz) ($I_C = 2.0$ mAdc, $V_{CE} = 10$ V, f = 1.0 kHz)	h_{fe}	2.5 50	– 200	–
Noise Figure ($I_C = 100$ µAdc, $V_{CE} = 5.0$ Vdc, $R_S = 1.0$ k ohm, f = 1.0 kHz)	NF	–	6.0	dB

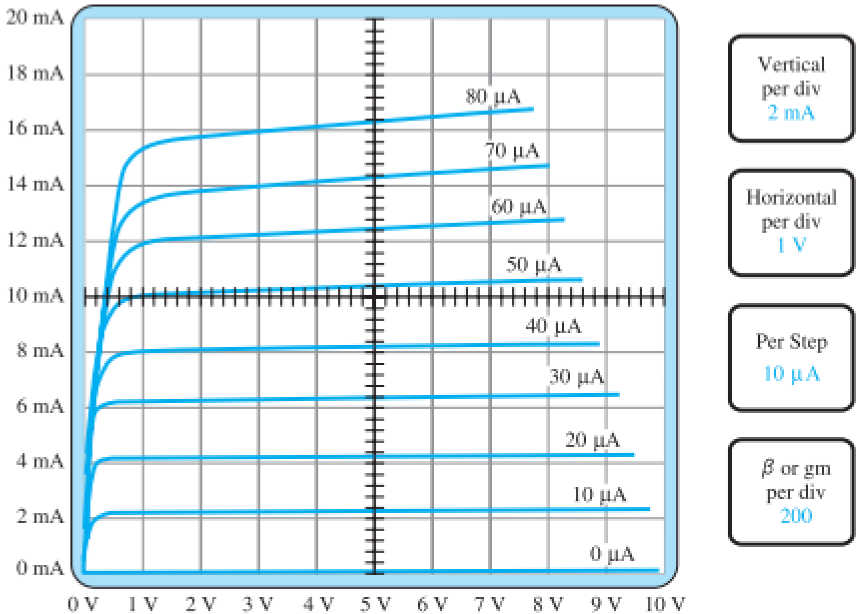
(1) Pulse Test: Pulse Width = 300 µs, Duty Cycle = 2.0%

Transistor Specification Sheets..

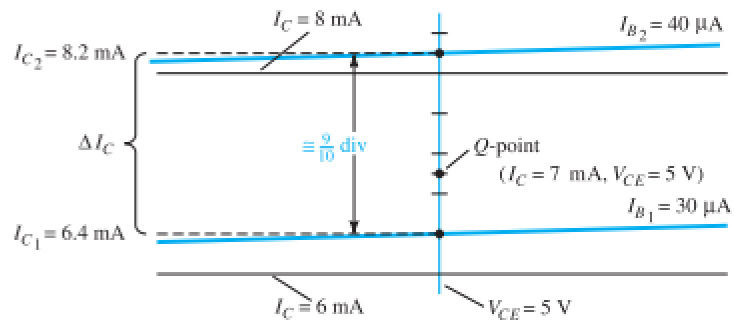




Transistor Testing using Curve Tracer



Curve tracer response to 2N3904 npn transistor.



Determining β_{ac} for the transistor characteristics of 2N3904 npn transistor at $I_C = 7\ mA$ and $V_{CE} = 5\ V$.

$$\beta_{ac} = \frac{9}{10}\,\text{div}\left(\frac{200}{\text{div}}\right) = \mathbf{180}$$

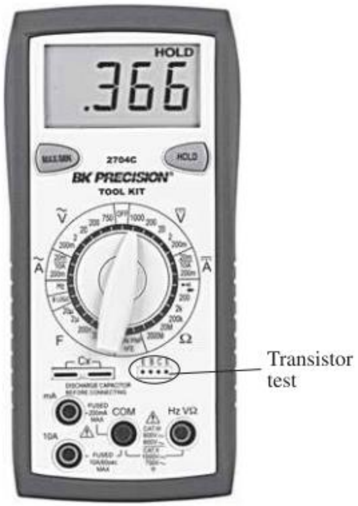
- Check the beta value:

$$\beta_{ac} = \left.\frac{\Delta I_C}{\Delta I_B}\right|_{V_{CE}=\text{constant}}$$

$$\beta_{ac} = \left.\frac{\Delta I_C}{\Delta I_B}\right|_{V_{CE}=\text{constant}} = \frac{I_{C_1} - I_{C_1}}{I_{B_2} - I_{B_1}} = \frac{8.2\text{ mA} - 6.4\text{ mA}}{40\ \mu\text{A} - 30\ \mu\text{A}} = \frac{1.8\text{ mA}}{10\ \mu\text{A}} = \mathbf{180}$$

Transistor Testing using Transistor Tester

- Transistor testers:
  (a) digital meter
  (b) dedicated testers.

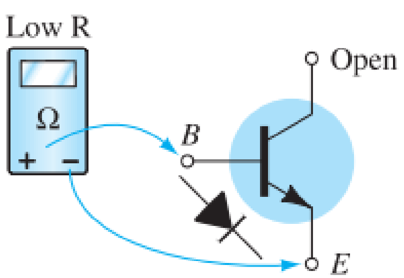


(a)

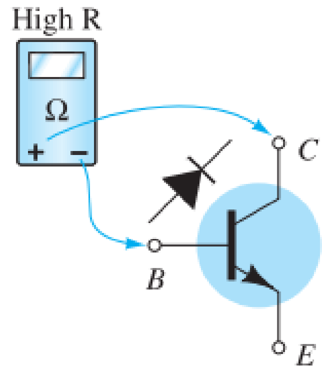
(b)

Transistor Testing using Ohmmeter

- Checking the forward-biased base-to-emitter junction of an *npn* transistor.

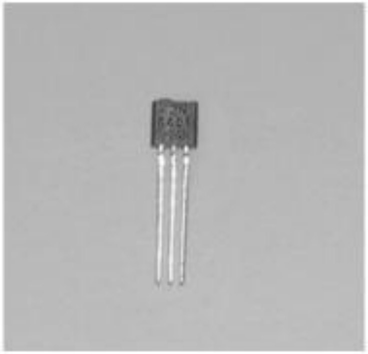


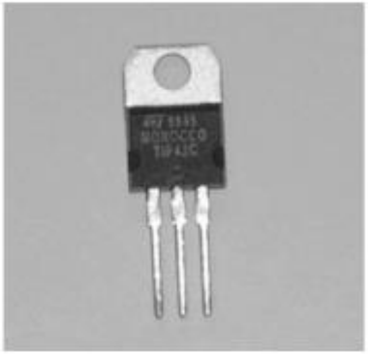
- Checking the reverse-biased base-to-collector junction of an *npn* transistor.



Transistor Casing

- Various types of general-purpose or switching transistors:
  (a) low power
  (b) medium power
  (c) medium to high power.

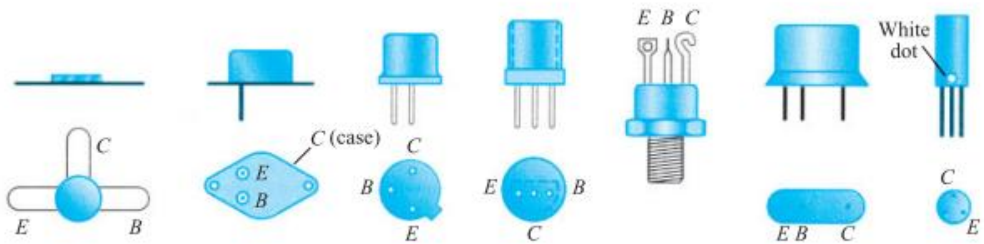

(a)


(b)

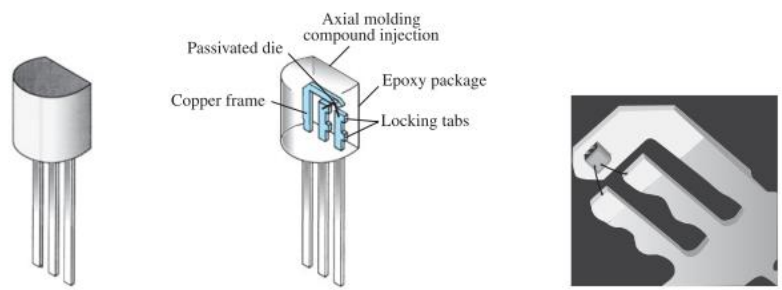

(c)

Terminal Identification

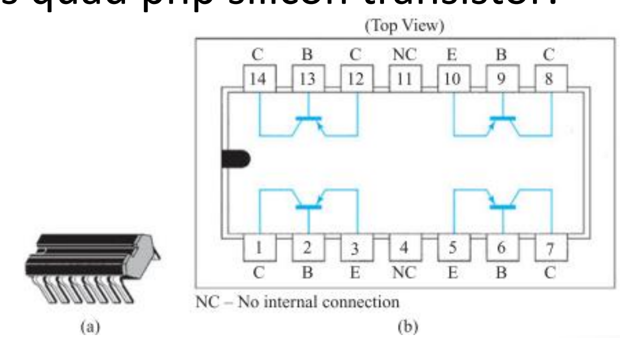
- Transistor terminal identification.



- Internal construction of a Fairchild transistor in a TO-92 package.

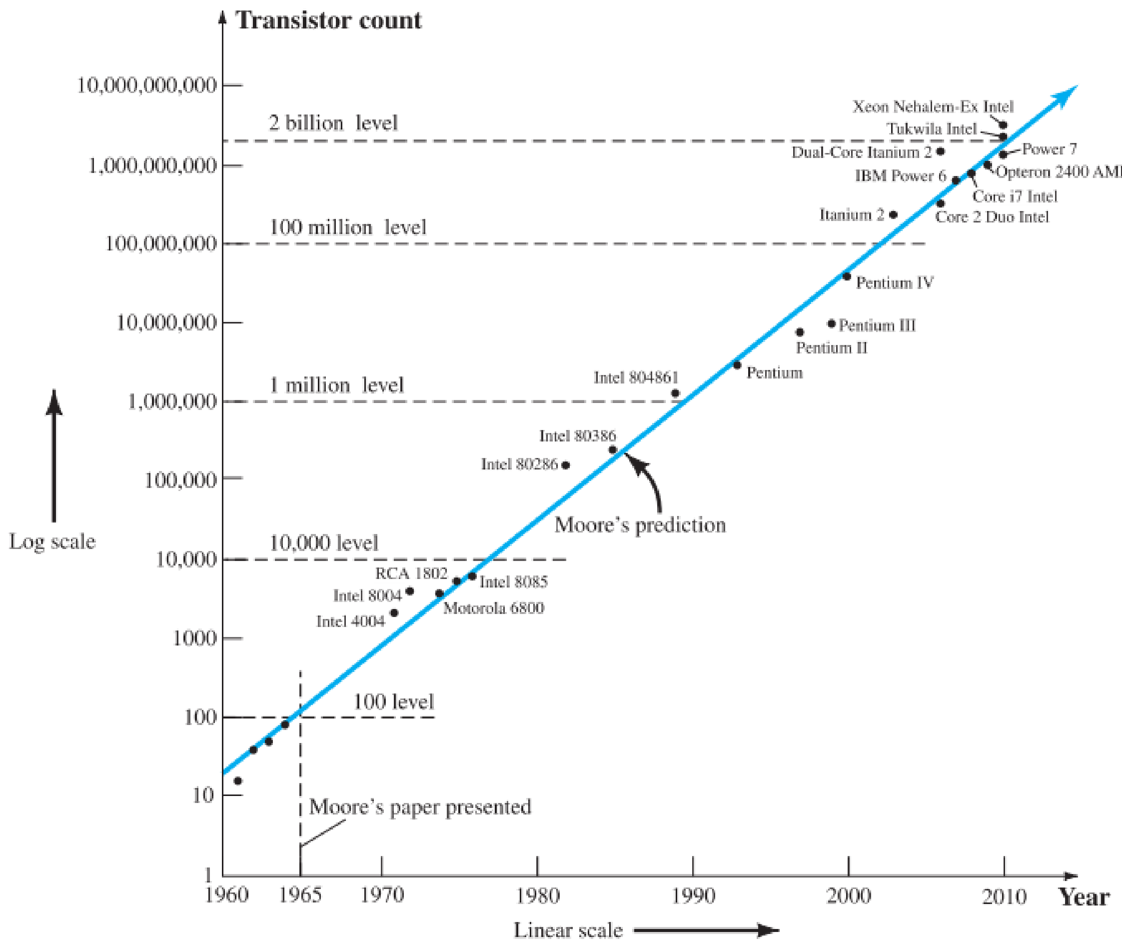


- Type Q2T2905 Texas Instruments quad pnp silicon transistor:
  (a) Appearance
  (b) pin connections.



Transistor Development

- Transistor IC count versus time for the period 1960 to the present



- For more details, refer to:
  - Chapter 3 at R. Boylestad, **Electronic Devices and Circuit Theory**, 11th edition, Prentice Hall.
  - Text books for ECE-121.
- The lecture is available online at:
  - https://speakerdeck.com/ahmad_elbanna
- For inquires, send to:
  - ahmad.elbanna@fes.bu.edu.eg
  - ahmad.elbanna@ejust.edu.eg