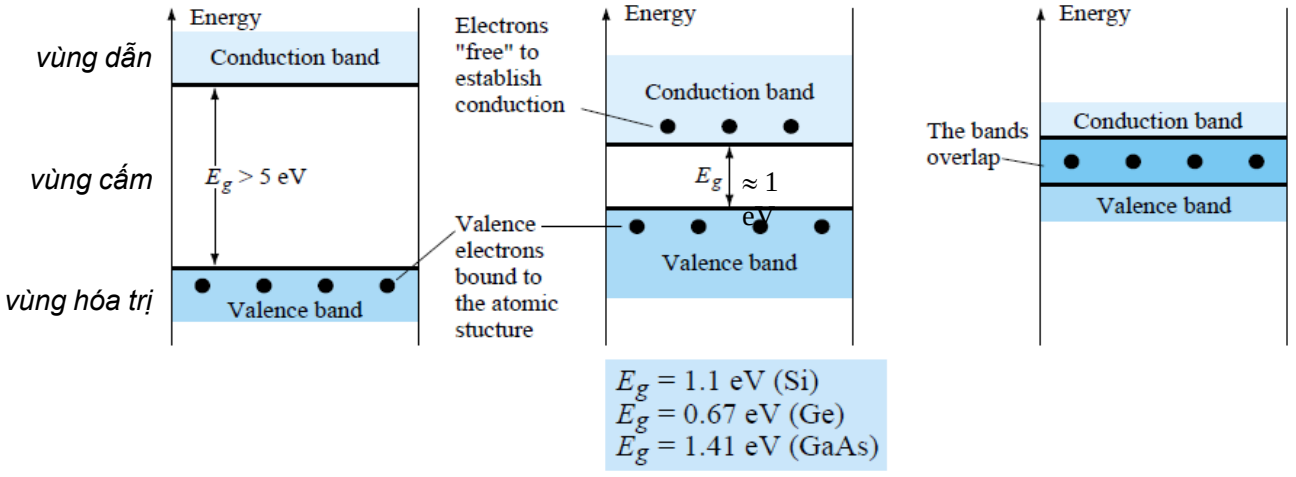
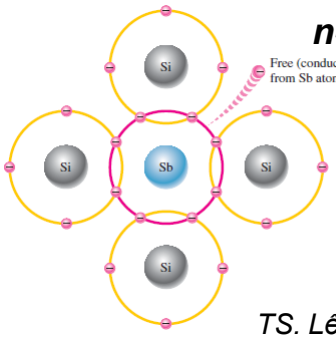
1.2 Transistor lưỡng cực: cấu tạo và đặc tính cơ bản

Bán dẫn *(semiconductor)*



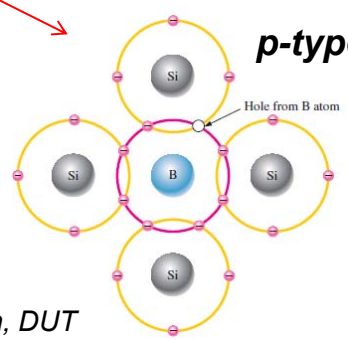
$E_g = 1.1$ eV (Si)
$E_g = 0.67$ eV (Ge)
$E_g = 1.41$ eV (GaAs)

Insulator | Semiconductor | Conductor



n-type

free electrons

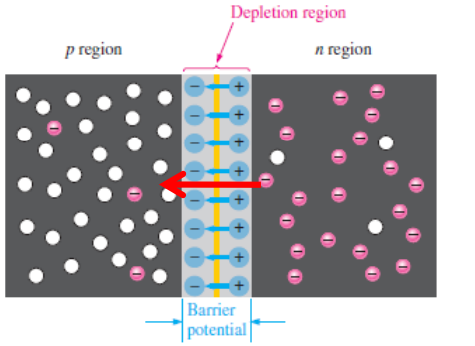


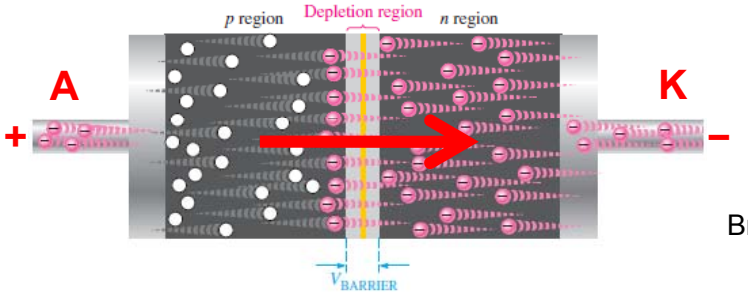
p-type

free holes

1.2 Transistor lưỡng cực: cấu tạo và đặc tính cơ bản

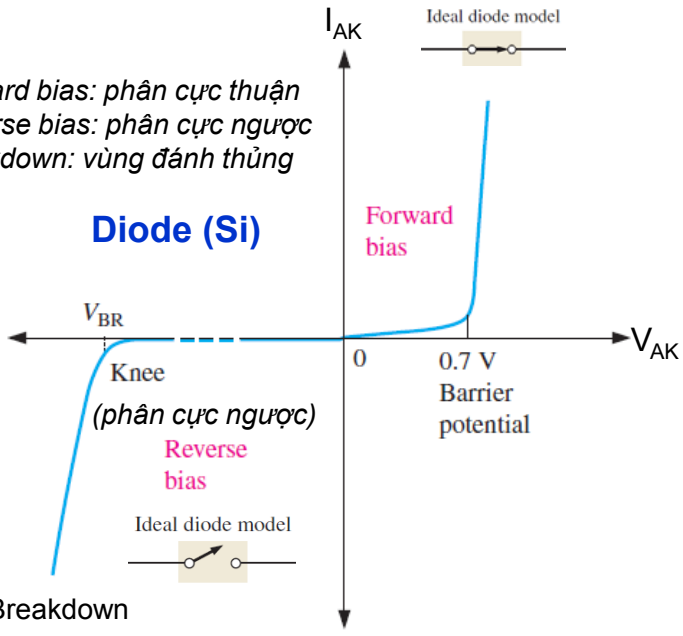
p-n junction (tiếp giáp p-n)

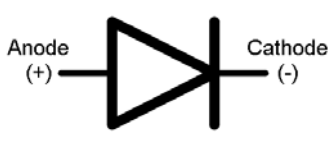




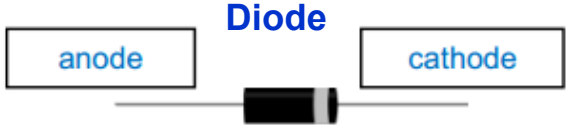
- *Forward bias: phân cực thuận*
- *Reverse bias: phân cực ngược*
- *Breakdown: vùng đánh thủng*

Diode (Si)





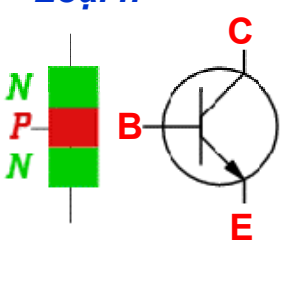
Diode

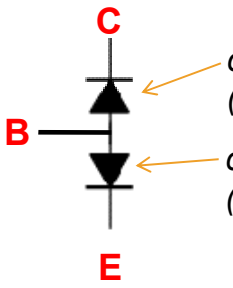


1.2 Transistor lưỡng cực: cấu tạo và đặc tính cơ bản

❖ Transistor lưỡng cực *(BJT – Bipolar Junction Transistor)*: *cấu tạo*

Loại n





chuyển tiếp collector (Collector-Base junction)

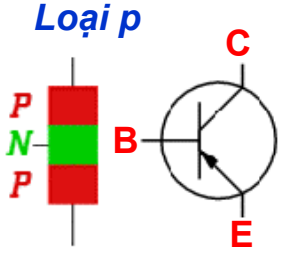
chuyển tiếp emitter (Emitter-Base junction)

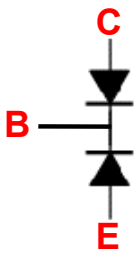
** Kiểm tra transistor:*

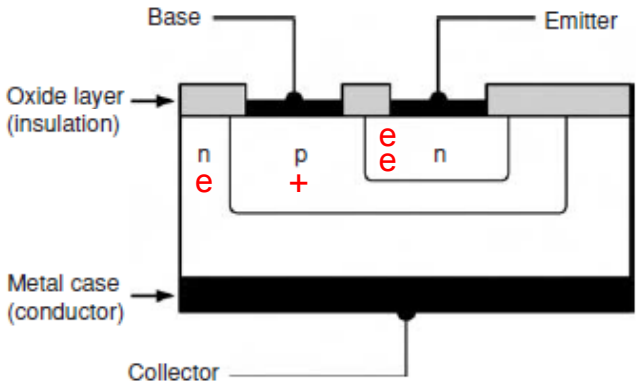
1) $R_{CB(forward)} \leq 1\ k\Omega$
   $R_{CB(reverse)} >>$
2) $R_{BE(forward)} \leq 1\ k\Omega$
   $R_{BE(reverse)} >>$
3) $R_{CE} >>$

- *C – Collector (cực thu)*
- *B – Base (cực ba-zơ)*
- *E – Emitter (cực phát)*

Loại p



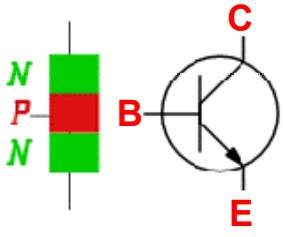


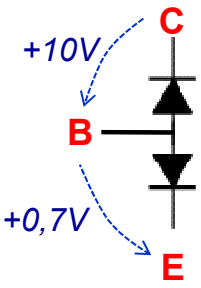


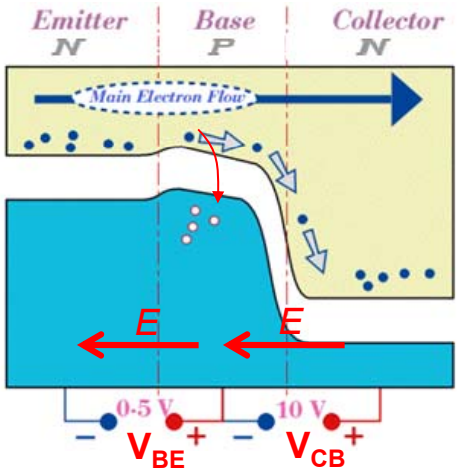
1.2 Transistor lưỡng cực: cấu tạo và đặc tính cơ bản

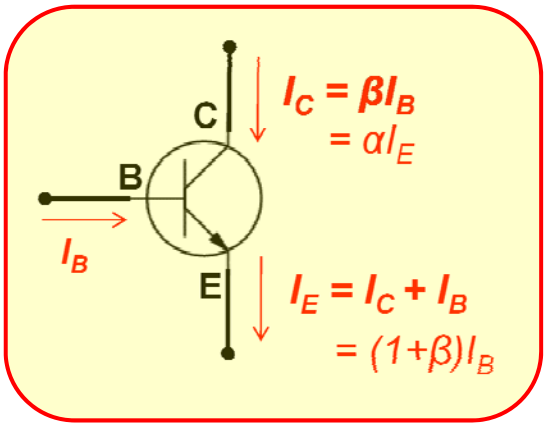
❖ Transistor lưỡng cực *(BJT – Bipolar Junction Transistor)*: *hoạt động*

Loại n









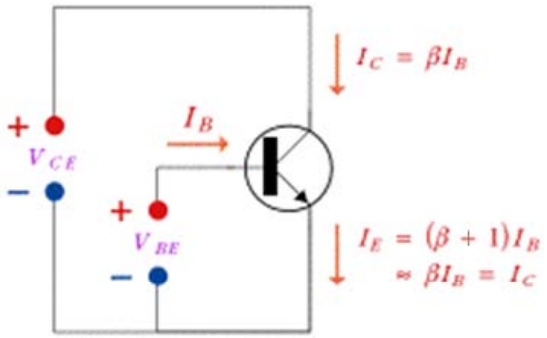
Đặc tính điều khiển: I_B "điều khiển" I_C

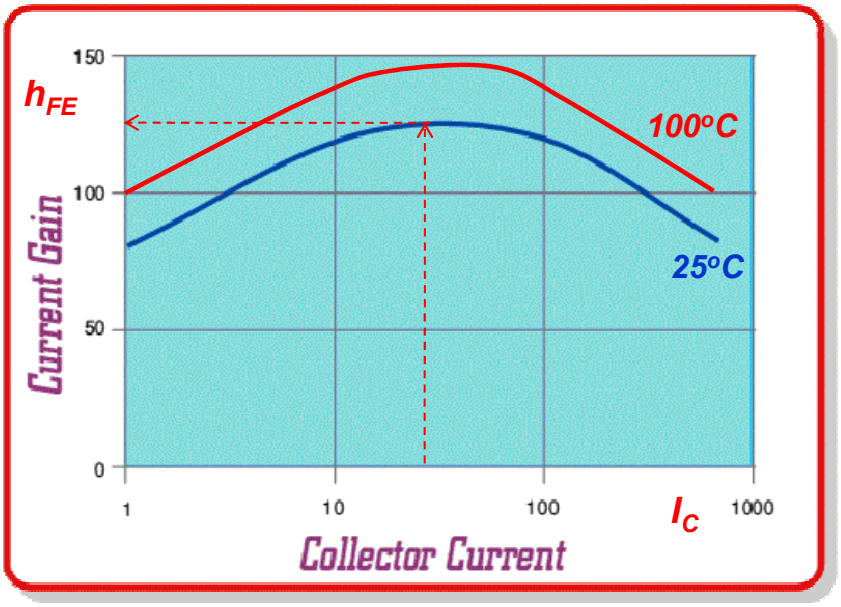
- *$\beta = I_C/I_B$: hệ số KĐ dòng điện một chiều ($\approx$100) (DC current gain, DC beta, h_{FE})*
- *$\alpha = I_C/I_E$: hệ số truyền đạt dòng điện (0,9÷1) (DC alpha)*

1.2 Transistor lưỡng cực: cấu tạo và đặc tính cơ bản

- Transistor lưỡng cực *(BJT – Bipolar Junction Transistor)*: đặc tính

Đặc tuyến truyền đạt (DC current gain): $\beta = f(I_C, T)$
(beta curve)





* *Datasheet:*
h_{FE} – *typical value*
$h_{FE(ave)} = sqrt(h_{FEmin} \times h_{FEmax})$

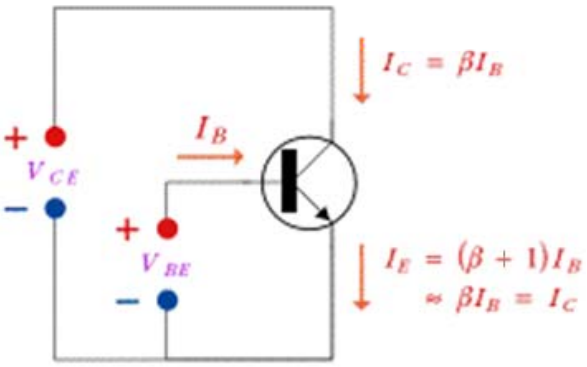
- β – hệ số KĐ dòng (h_{FE}, DC current gain ≈ 100)
- h_{fe} – small signal current gain (ac beta)

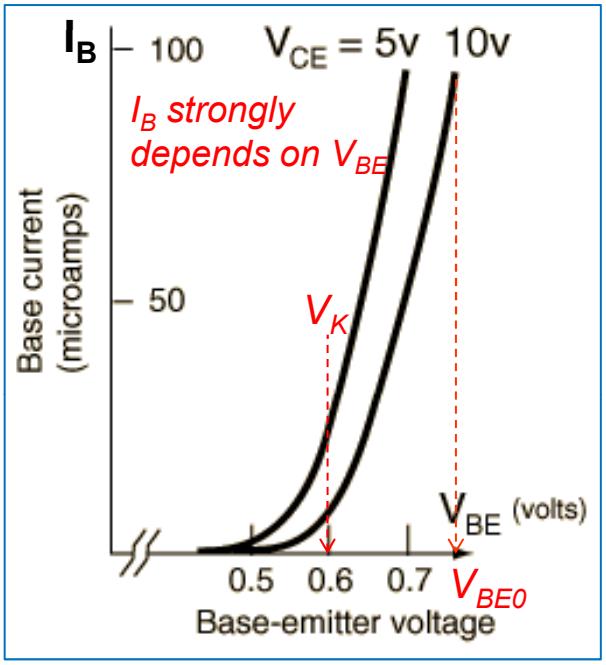
h_{fe}, β phụ thuộc cấu tạo, nhiệt độ, I_C…

1.2 Transistor lưỡng cực: cấu tạo và đặc tính cơ bản

- Transistor lưỡng cực *(BJT – Bipolar Junction Transistor)*: đặc tính

Đặc tuyến vào: $I_B = f(V_{BE})$
(base characteristic curve)





Static (or d.c.) input resistance $= \frac{V_{BE}}{I_B}$

(from corresponding points on the graph)

Dynamic (or a.c.) input resistance $= \frac{\Delta V_{BE}}{\Delta I_B}$

(from the slope of the graph)

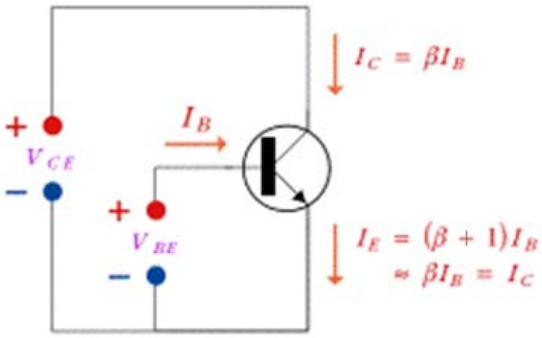
$V_{BE} \approx 0{,}7 \div 1$ V (Si); 0,3 V (Ge)

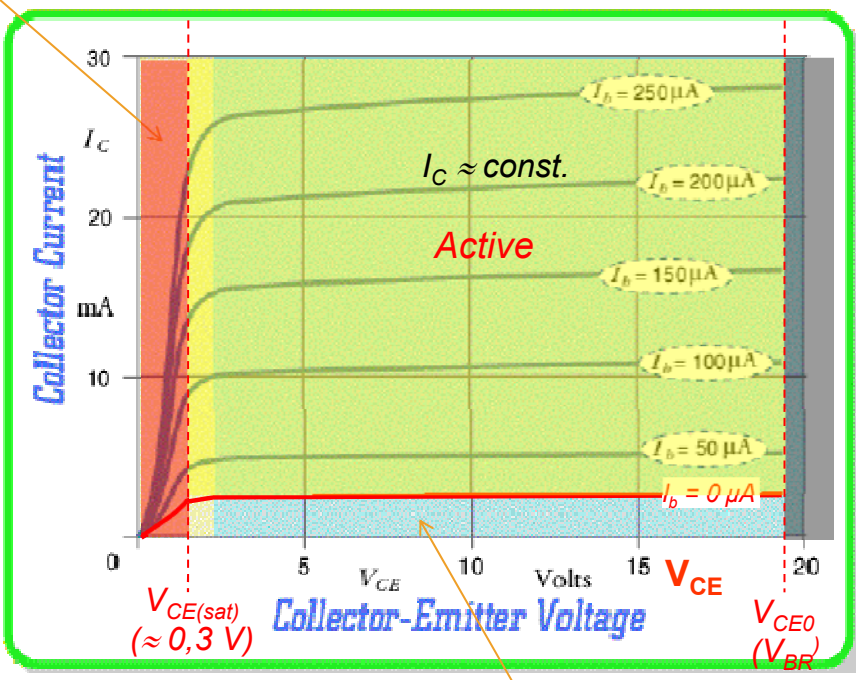
1.2 Transistor lưỡng cực: cấu tạo và đặc tính cơ bản

- Transistor lưỡng cực *(BJT – Bipolar Junction Transistor)*: đặc tính

Đặc tuyến ra (static characteristic): $I_C = f(V_{CE})$
(collector characteristic curve)

Saturation
$V_{CE} \approx 0$
(vùng bão hòa)





- $I_{Cmax} \approx 10^2$ mA $\rightarrow$ A
- $I_{Bmax} = I_{Cmax}/\beta_{max}$

Cut-off (vùng khóa)
$I_C \approx 0$

1.2 Transistor lưỡng cực: cấu tạo và đặc tính cơ bản

- BJT – typical values and applications

Table 12.2 Transistor characteristics and maximum ratings

Device	Type	I_C max.	V_{CE} max.	P_{TOT} max.	h_{FE} typical	Application
BC108	n-p-n	100 mA	20 V	300 mW	125	General-purpose small-signal amplifier
BCY70	n-p-n	200 mA	–40 V	360 mW	150	General-purpose small-signal amplifier
2N3904	n-p-n	200 mA	40 V	310 mW	150	Switching
BF180	n-p-n	20 mA	20 V	150 mW	100	RF amplifier
2N3053	n-p-n	700 mA	40 V	800 mW	150	Low-frequency amplifier/driver
2N3055	n-p-n	15 A	60 V	115 W	50	Low-frequency power

1.2 Transistor lưỡng cực: cấu tạo và đặc tính cơ bản

BC 546B
Fairchild

C B E

Electrical Characteristics

Values are at T_A = 25°C unless otherwise noted.

Symbol	Parameter		Conditions	Min.	Typ.	Max.	Unit
I_{CBO}	Collector Cut-Off Current		V_{CB} = 30 V, I_E = 0			15	nA
h_{FE}	DC Current Gain		V_{CE} = 5 V, I_C = 2 mA	110		800	
V_{CE}(sat)	Collector-Emitter Saturation Voltage		I_C = 10 mA, I_B = 0.5 mA		90	250	mV
			I_C = 100 mA, I_B = 5 mA		250	600	
V_{BE}(sat)	Base-Emitter Saturation Voltage		I_C = 10 mA, I_B = 0.5 mA		700		mV
			I_C = 100 mA, I_B = 5 mA		900		
V_{BE}(on)	Base-Emitter On Voltage		V_{CE} = 5 V, I_C = 2 mA	580	660	700	mV
			V_{CE} = 5 V, I_C = 10 mA			720	
f_T	Current Gain Bandwidth Product		V_{CE} = 5 V, I_C = 10 mA, f = 100 MHz		300		MHz
C_{ob}	Output Capacitance		V_{CB} = 10 V, I_E = 0, f = 1 MHz		3.5	6.0	pF
C_{ib}	Input Capacitance		V_{EB} = 0.5 V, I_C = 0, f = 1 MHz		9		pF
NF	Noise Figure	BC546 / BC547 / BC548	V_{CE} = 5 V, I_C = 200 µA, f = 1 kHz, R_G = 2 kΩ		2.0	10.0	dB
		BC549 / BC550			1.2	4.0	
		BC549	V_{CE} = 5 V, I_C = 200 µA, R_G = 2 kΩ, f = 30 to 15000 MHz		1.4	4.0	
		BC550			1.4	3.0	

h_{FE} Classification

Classification	A	B	C
h_{FE}	110 ~ 220	200 ~ 450	420 ~ 800

1.2 Transistor lưỡng cực: cấu tạo và đặc tính cơ bản

BC 546B
Fairchild

C B E

Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only. Values are at T_A = 25°C unless otherwise noted.

Symbol	Parameter		Value	Unit
V_{CBO}	Collector-Base Voltage	BC546	80	V
		BC547 / BC550	50	
		BC548 / BC549	30	
V_{CEO}	Collector-Emitter Voltage	BC546	65	V
		BC547 / BC550	45	
		BC548 / BC549	30	
V_{EBO}	Emitter-Base Voltage	BC546 / BC547	6	V
		BC548 / BC549 / BC550	5	
I_C	Collector Current (DC)		100	mA
P_C	Collector Power Dissipation		500	mW
T_J	Junction Temperature		150	°C
T_{STG}	Storage Temperature Range		-65 to +150	°C

High-Voltage transistor	$V_{CE0} \approx 10^2$ V	2N5655, 2N5657	TV, CRT..
High-Current	$I_{Cmax} \approx$ A	2N4237	current regulator..
High-Power transistor	$P_D \approx 10^2$ W	2N3771	linear or SWP..
Integrated transistor	many transistors		

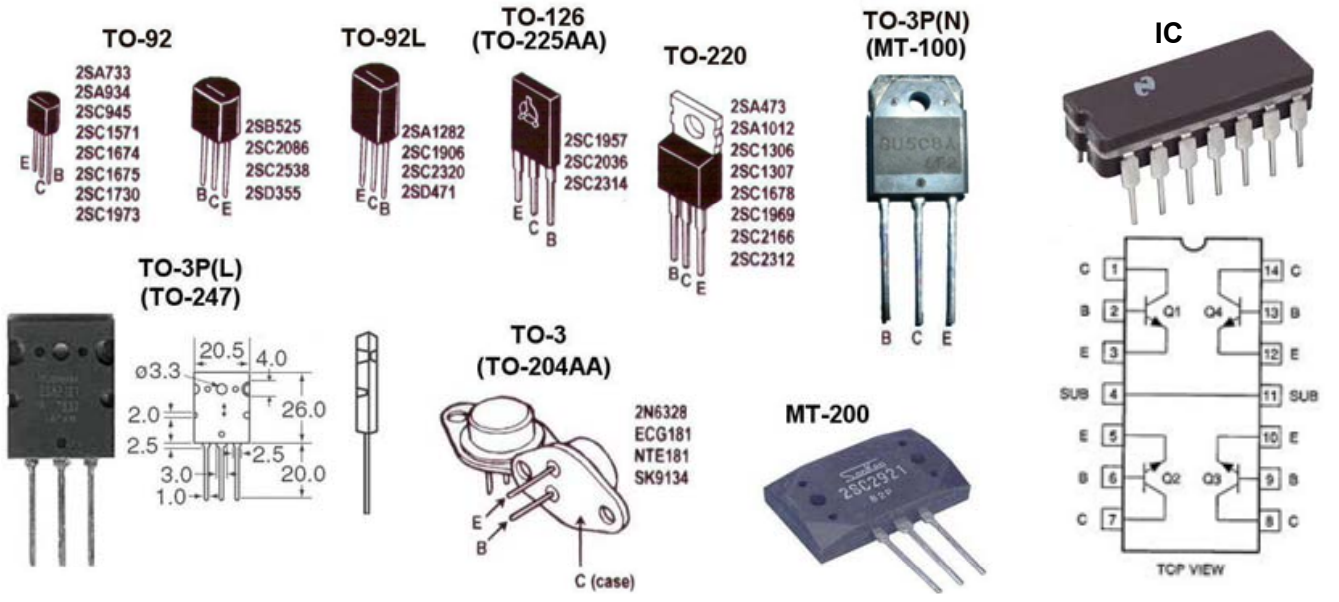
1.2 Transistor lưỡng cực: cấu tạo và đặc tính cơ bản

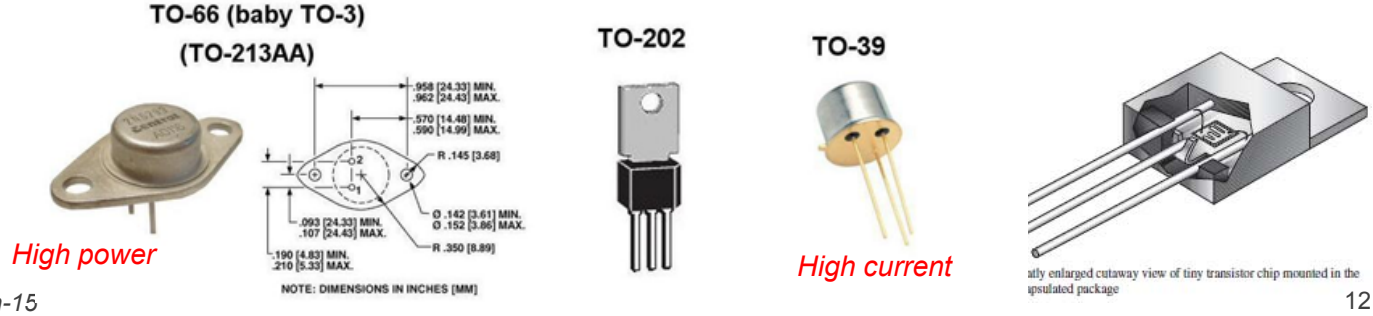
- Phân loại transistor

Table 12.1 Transistor classification

Low-frequency	Transistors designed specifically for audio low-frequency applications (below 100 kHz)
High-frequency	Transistors designed specifically for high radio-frequency applications (100 kHz and above)
Switching	Transistors designed for switching applications
Low-noise	Transistors that have low-noise characteristics and which are intended primarily for the amplification of low-amplitude signals
High-voltage	Transistors designed specifically to handle high voltages
Driver	Transistors that operate at medium power and voltage levels and which are often used to precede a final (power) stage which operates at an appreciable power level
Small-signal	Transistors designed for amplifying small voltages in amplifiers and radio receivers
Power	Transistor designed to handle high currents and voltages

1.2 Transistor lưỡng cực: cấu tạo và đặc tính cơ bản



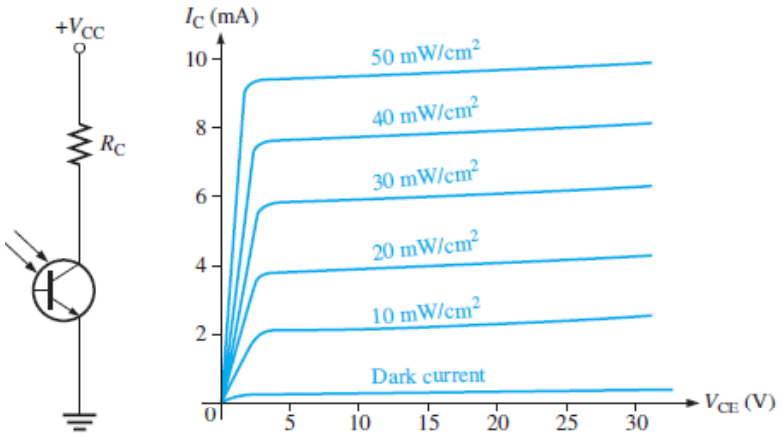


High power

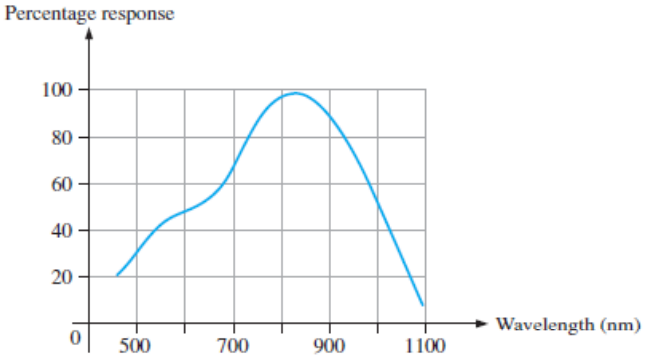
High current

atly enlarged cutaway view of tiny transistor chip mounted in the apsulated package

- Phototransistor (tranzito quang)

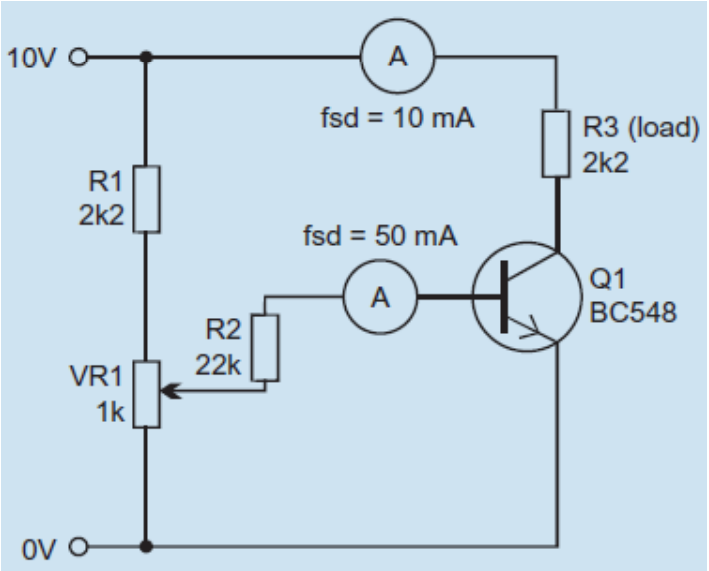


Phototransistor circuit and typical collector characteristic curves.



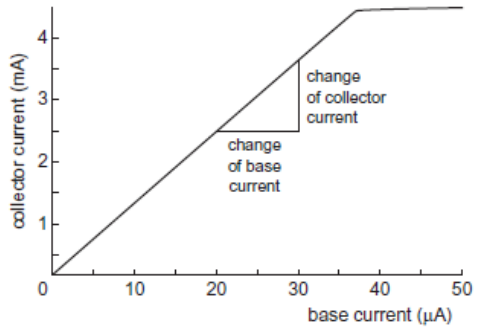
Typical phototransistor spectral response.

- Experiment 1: BC548, BC337, 2N2222A, 2N3904…



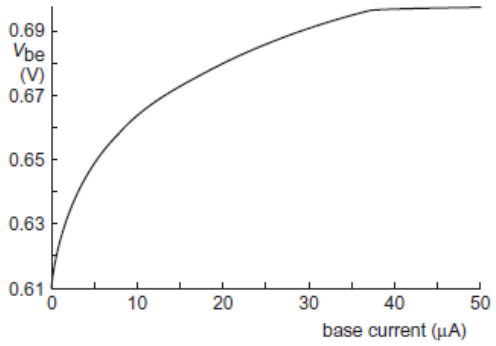
1. Adjust VR1 so that there is zero base current (i_b). Read the collector current (i_c). Record your results in a table.
2. Without altering the setting of VR1, use the voltmeter to measure v_{be}, the voltage difference between the base and emitter. Also measure v_{ce}, the voltage difference between collector and emitter.
3. Repeat steps (1) and (2) with i_b equal to 5 μA to 50 μA (if possible) in steps of 5 μA.
4. Plot a graph of collector current against base current. What does this tell you about the relationship between the currents?
5. Plot a graph of base voltage against base current. What does this show as base current increases?
6. Plot a graph of collector voltage against base current. What does this tell us about the voltage across the load as collector current increases?

- Experiment 1 (cont.): BC548, BC337, 2N2222A, 2N3904…

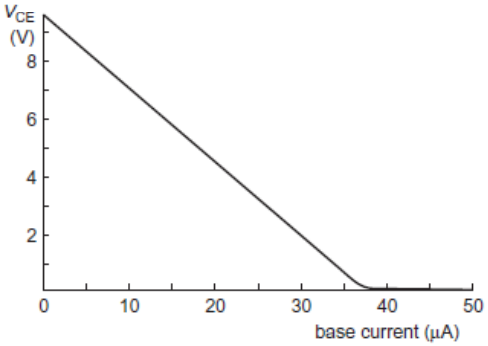


Collector current is directly proportional to base current.

The current gain ≈ 100.



The base-emitter voltage is close to 0.7 V



- Experiment 2: Transistor Switches
  (BC548, BC337, 2N2222A, 2N3904…)

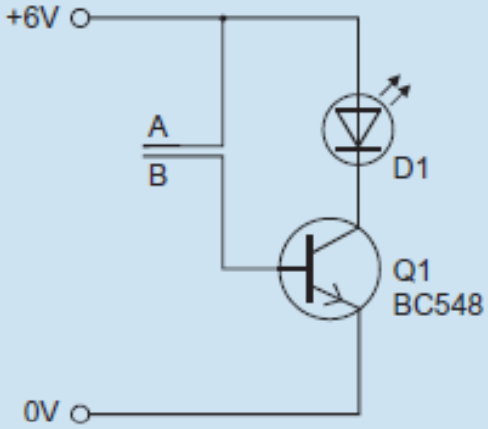
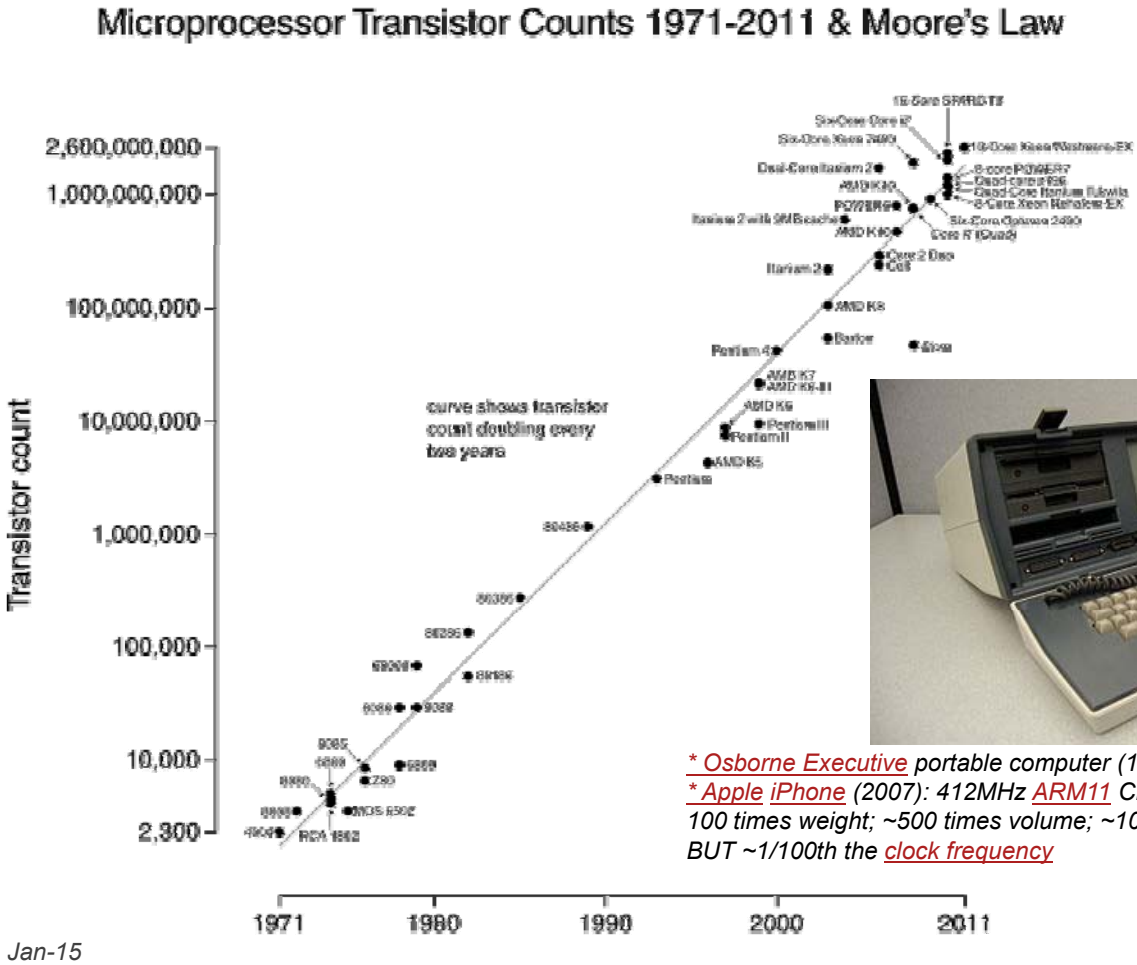


FIGURE 24.1

1 Check that there is no connection between A and B.
2 Connect the power supply. The LED should not light.
3 Press your finger on A and B to bridge the gap between them (but NOT to force them into contact with each other!)

1.2 Transistor lưỡng cực: cấu tạo và đặc tính cơ bản



** Osborne Executive portable computer (1982): Zilog Z80 4MHz CPU*
** Apple iPhone (2007): 412MHz ARM11 CPU*
100 times weight; ~500 times volume; ~10 times cost;
BUT ~1/100th the clock frequency