Power Electronics

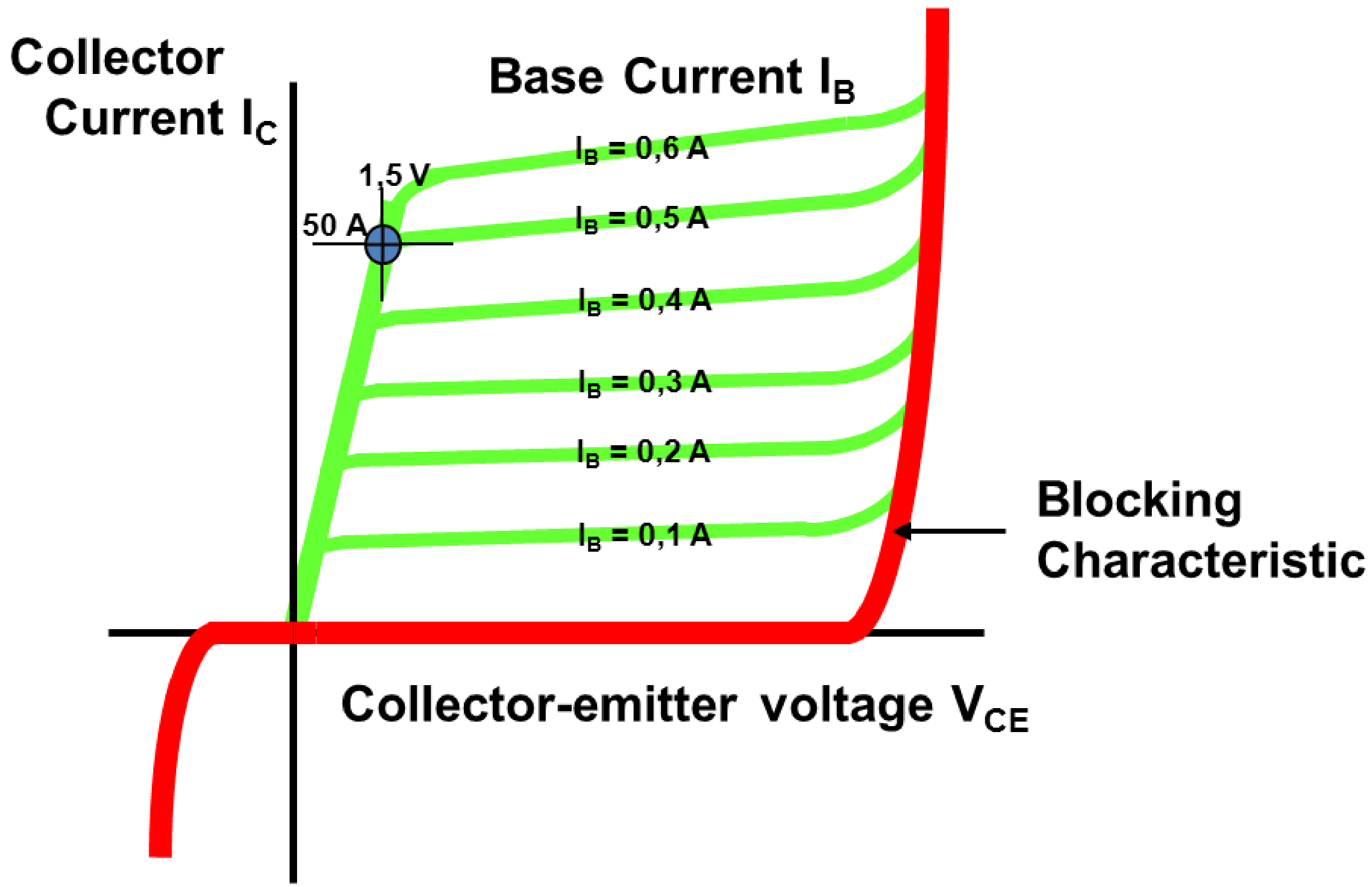
Lesson 5:

Outlines:

- The BJT dynamic response

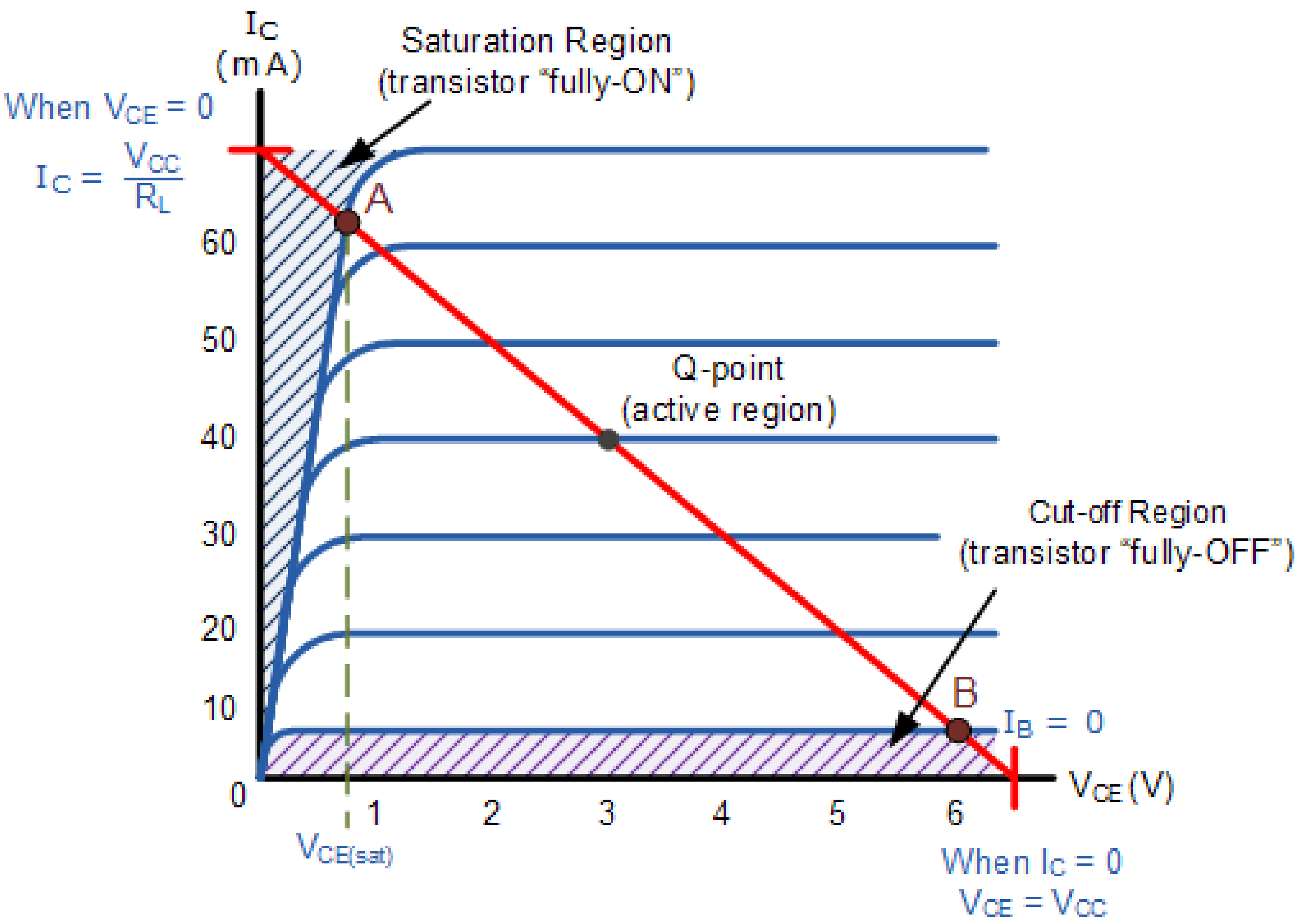
Lecturer: Xavier Domínguez

The BJT dynamic response

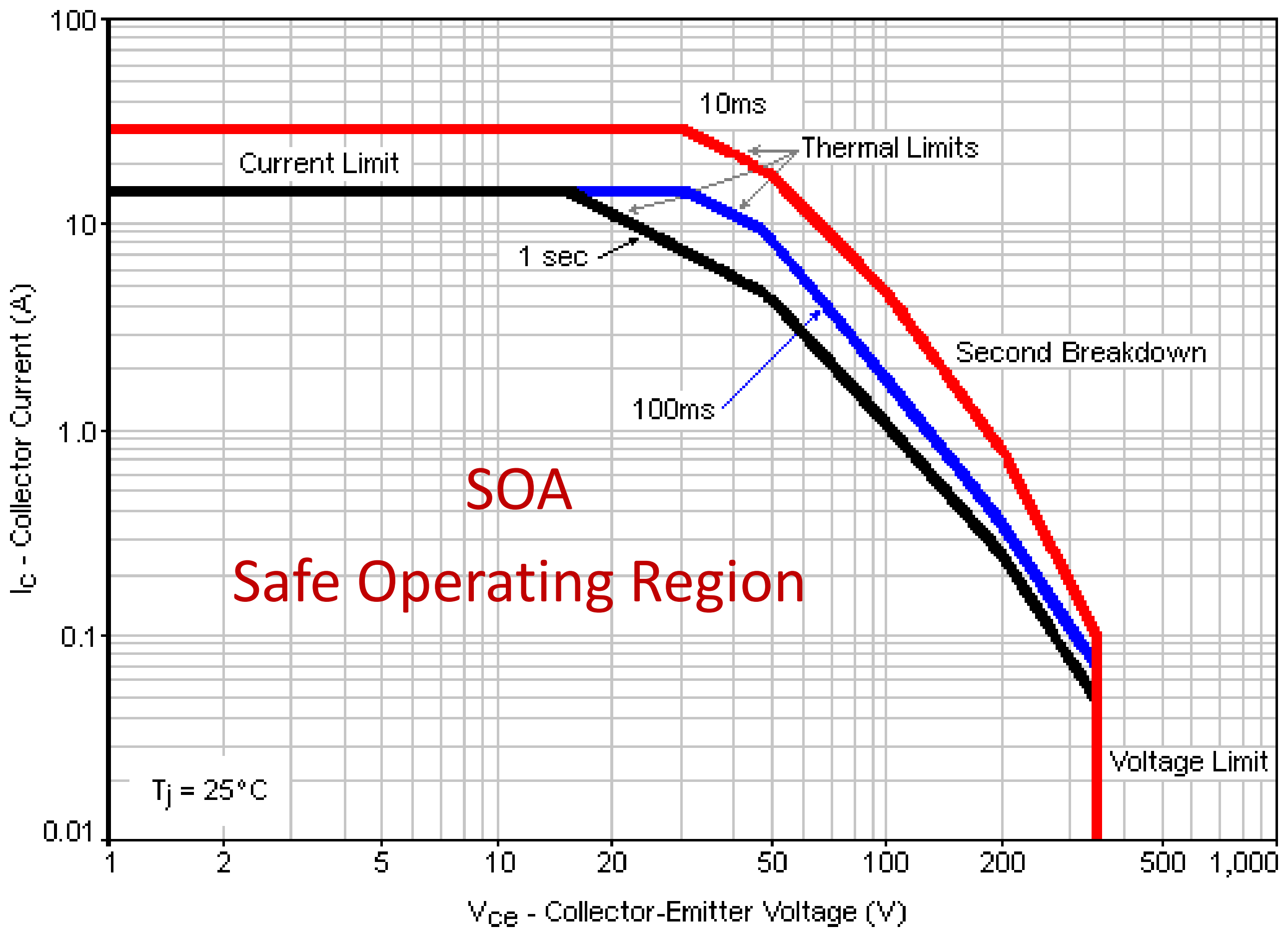


Ref: http://www.powerguru.org/bipolar-junction-transistor/

The BJT The BJT dynamic response

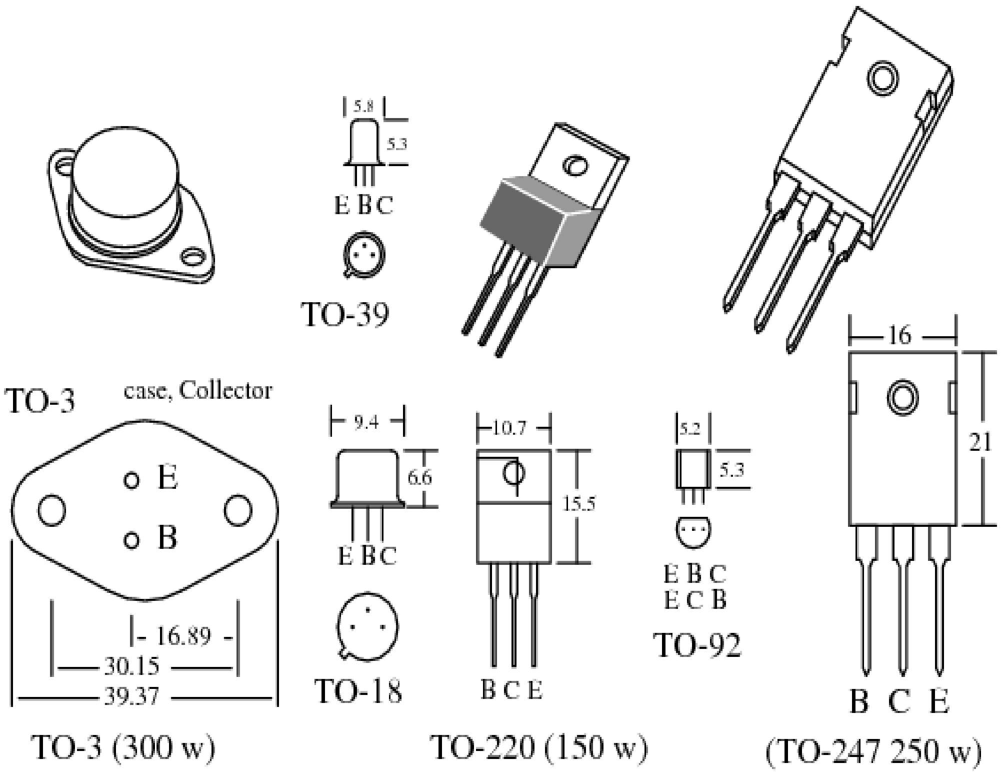


The BJT dynamic response



Ref: http://sound.westhost.com/soa.htm

The BJT curve



Ref : www.allaboutcircuits.com/textbook/semiconductors/chpt-4/transistor-ratings-packages-bjt/

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The BJT curve

Power Electronics

Power Transistors - 2N Series

Part No.	Description	More Info	In Stock	Package	Package Qty.	Price US$
2N2955	2N2955 PNP Power Transistor		Yes	TO-3	1	$0.65
2N3019	2N3019 NPN Power Transistor		Yes	TO-39	1	$1.40
2N3053	2N3053 NPN Power Transistor		No	TO-39	1	$0.65
2N3055	2N3055 NPN Power Transistor		Yes	TO-3	1	$0.95
2N3585	2N3585 NPN High Voltage Transistor		Yes	TO-66	1	$1.60
2N3771	2N3771 NPN Power Transistor		Yes	TO-3	1	$1.90
2N3772	2N3772 NPN Power Transistor		Yes	TO-3	1	$1.90
2N3773	2N3773 NPN Power Transistor		Yes	TO-3	1	$2.20
2N4920	2N4920 PNP Power Transistor		Yes	TO-225	1	$0.28
2N5179	2N5179 NPN VHF/UHF Transistor		Yes	TO-72	1	$5.90
2N5190	2N5190 NPN Power Transistor		Yes	TO-225	1	$0.95
2N5191	2N5191 NPN Power Transistor		Yes	TO-225	1	$0.50
2N5194	2N5194 PNP Power Transistor		Yes	TO-225	1	$0.65
2N5195	2N5195 PNP Power Transistor		Yes	TO-225	1	$0.60
2N5686	2N5686 NPN Power Transistor		No	TO-3	1	$1.90
2N5881	2N5881 NPN Power Transistor		Yes	TO-3	1	$1.60
2N5884	2N5884 PNP Power Transistor		Yes	TO-3	1	$4.50
2N5886	2N5886 NPN Power Transistor		Yes	TO-3	1	$2.90
2N6039	2N6039 NPN Power Transistor		Yes	TO-126	1	$0.35
2N6055	2N6055 NPN Darlington Power Transistor		Yes	TO-3	1	$2.20
2N6056	2N6056 NPN Darlington Power Transistor		Yes	TO-3	1	$2.50
2N6101	2N6101 NPN Power Transistor		Yes	TO-220	1	$1.20

Ref: https://www.futurlec.com/TransPower2N.shtml

The BJT curve

Power Electronics

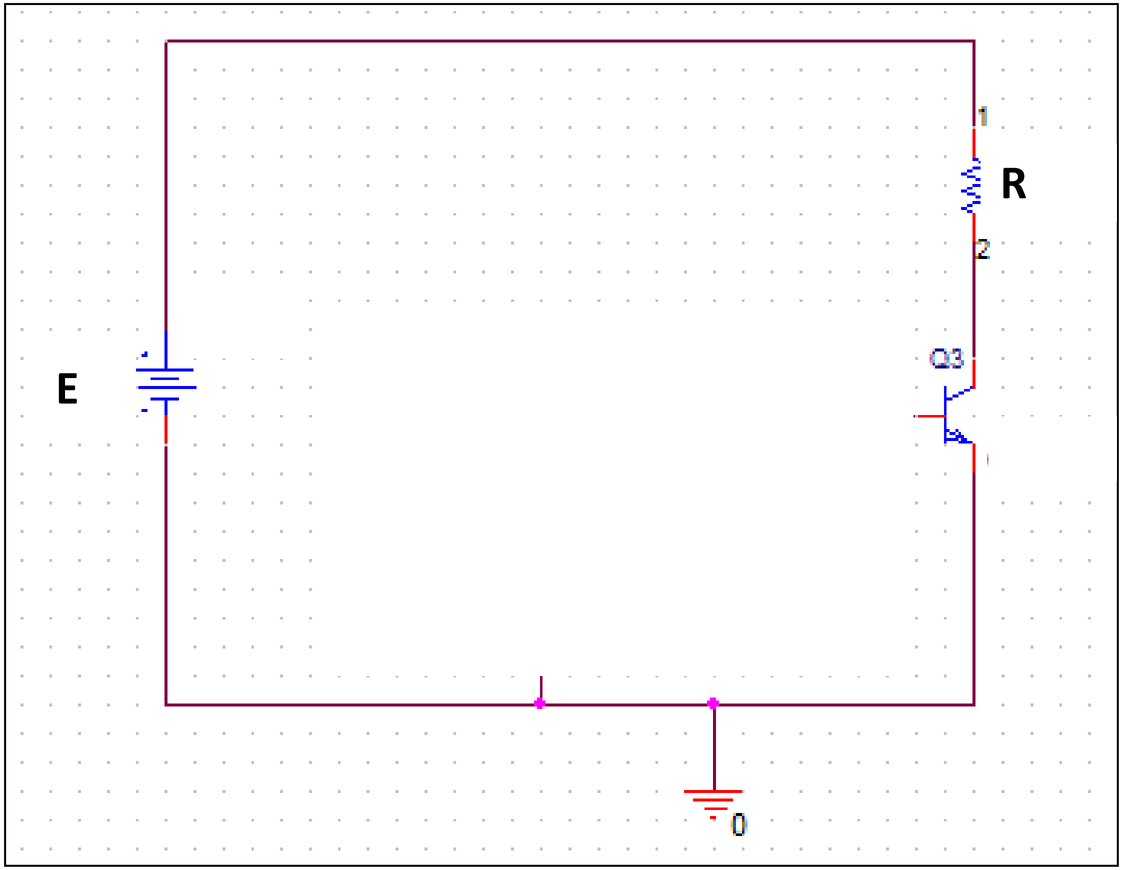
- The 2n6292 datasheet (https://www.futurlec.com/Transistors/2N6292pr.shtml)

- Example datasheet

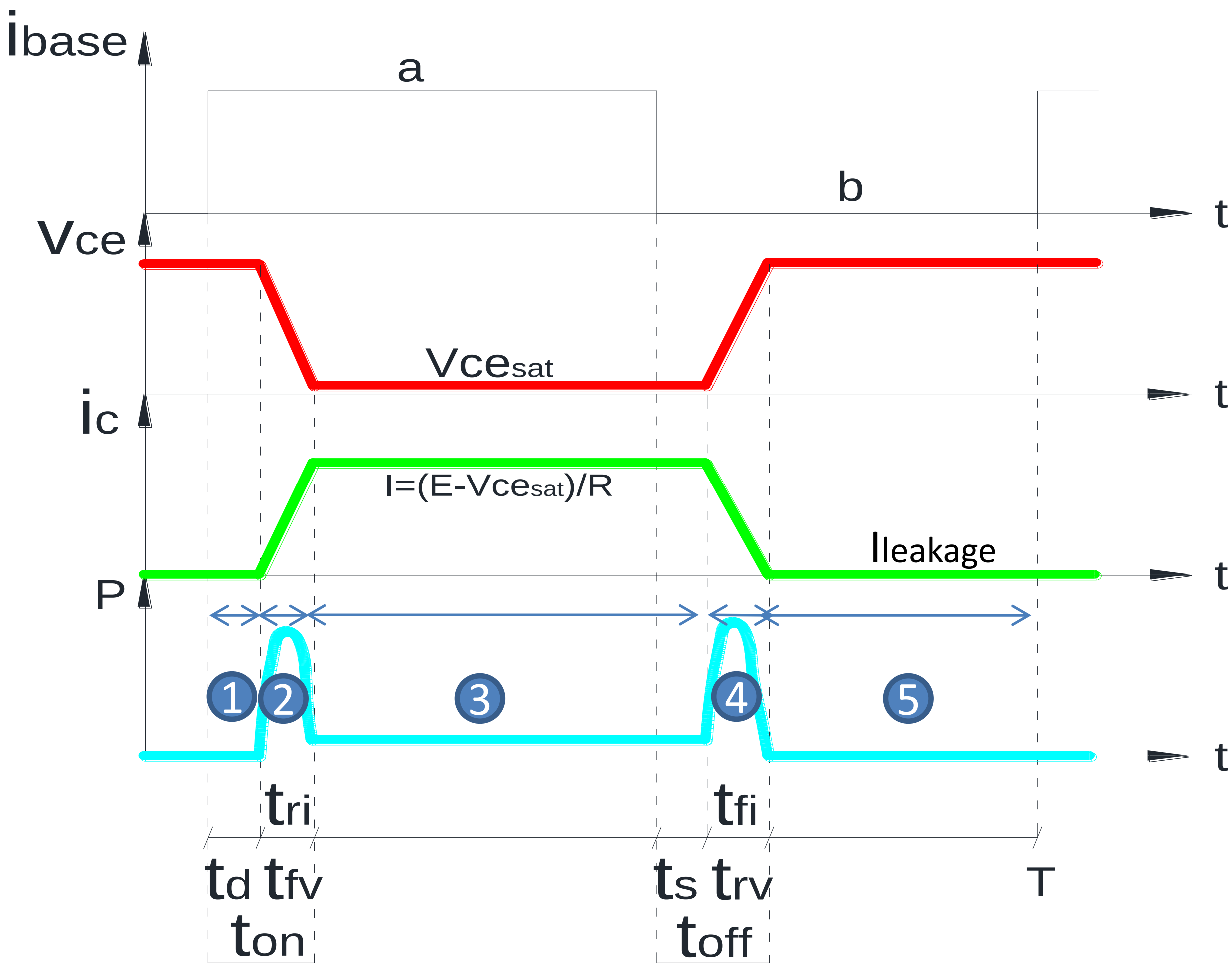
Characteristic		Symbol	Min	Typ	Max	Unit
ON CHARACTERISTICS (Note 2)						
DC Current Gain (I_C = 2.0 Adc, V_{CE} = 5.0 Vdc) (I_C = 5.0 Adc, V_{CE} = 5.0 Vdc)		h_{FE}	 8.0 5.0	 – –	 40 30	–
Collector–Emitter Saturation Voltage (I_C = 2.0 Adc, I_B = 0.4 Adc) (I_C = 5.0 Adc, I_B = 1.0 Adc) (I_C = 8.0 Adc, I_B = 2.0 Adc) (I_C = 5.0 Adc, I_B = 1.0 Adc, T_C = 100°C)		$V_{CE(sat)}$	 – – – –	 – – – –	 1.0 2.0 3.0 3.0	Vdc
Base–Emitter Saturation Voltage (I_C = 2.0 Adc, I_B = 0.4 Adc) (I_C = 5.0 Adc, I_B = 1.0 Adc) (I_C = 5.0 Adc, I_B = 1.0 Adc, T_C = 100°C)		$V_{BE(sat)}$	 – – –	 – – –	 1.2 1.6 1.5	Vdc
SWITCHING CHARACTERISTICS						
Resistive Load (Table 1)						
Delay Time	(V_{CC} = 125 Vdc, I_C = 5.0 A, I_{B1} = I_{B2} = 1.0 A, t_p = 25 μs, Duty Cycle ≤ 1.0%)	t_d	–	0.025	0.1	μs
Rise Time		t_r	–	0.5	1.5	
Storage Time		t_s	–	1.8	3.0	
Fall Time		t_f	–	0.23	0.7	

The BJT curve

- The BJT power losses (Resistive load)

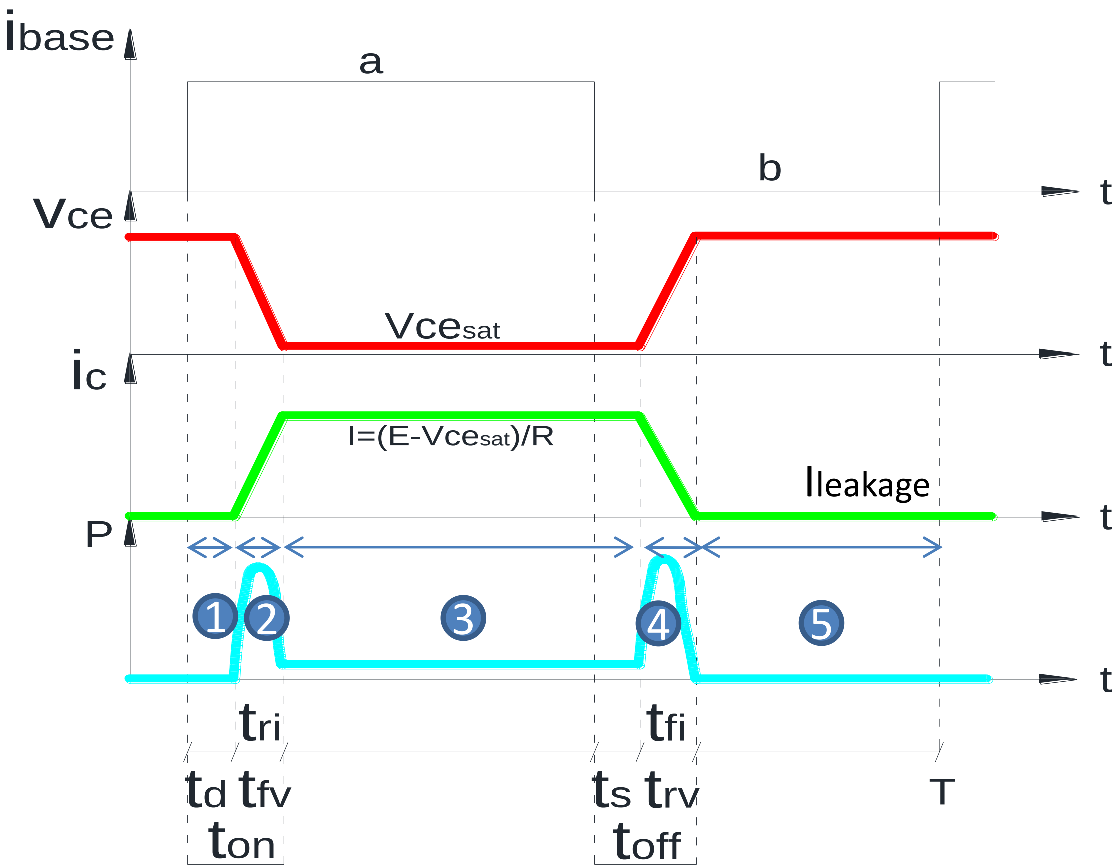


The BJT curve



td delay time
tfv Voltage falling time
ts storage time
trv Voltage rise time
tri Current rise time
tfi Current falling time

The BJT curve



$$P = \frac{1}{T}\int_{o}^{T} v(t).\, i(t)$$

$$P = \frac{1}{T}\int_{o}^{T} (P\_1 + P\_2 + P\_3 + P\_4 + P\_5)\ \mathrm{dt}$$

P1=

P2=

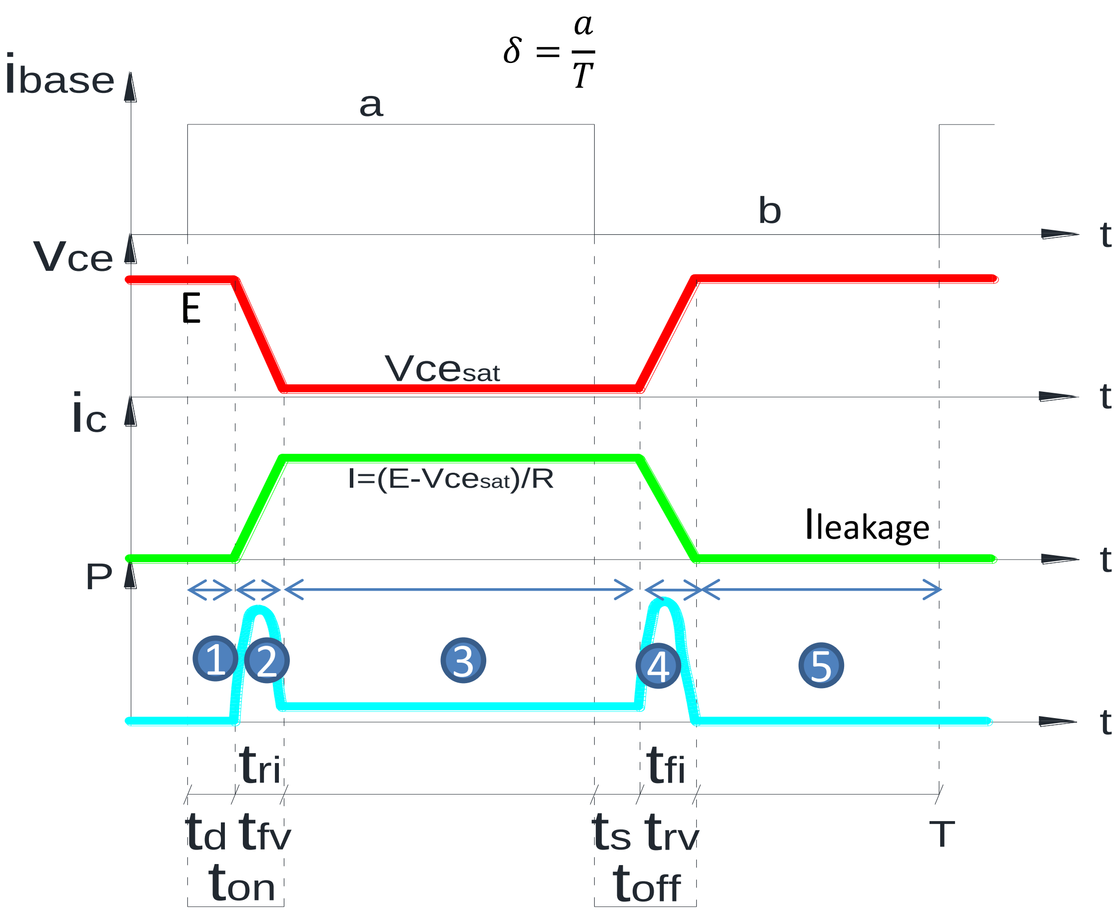
P3=

P4=

P5=

?

The BJT curve

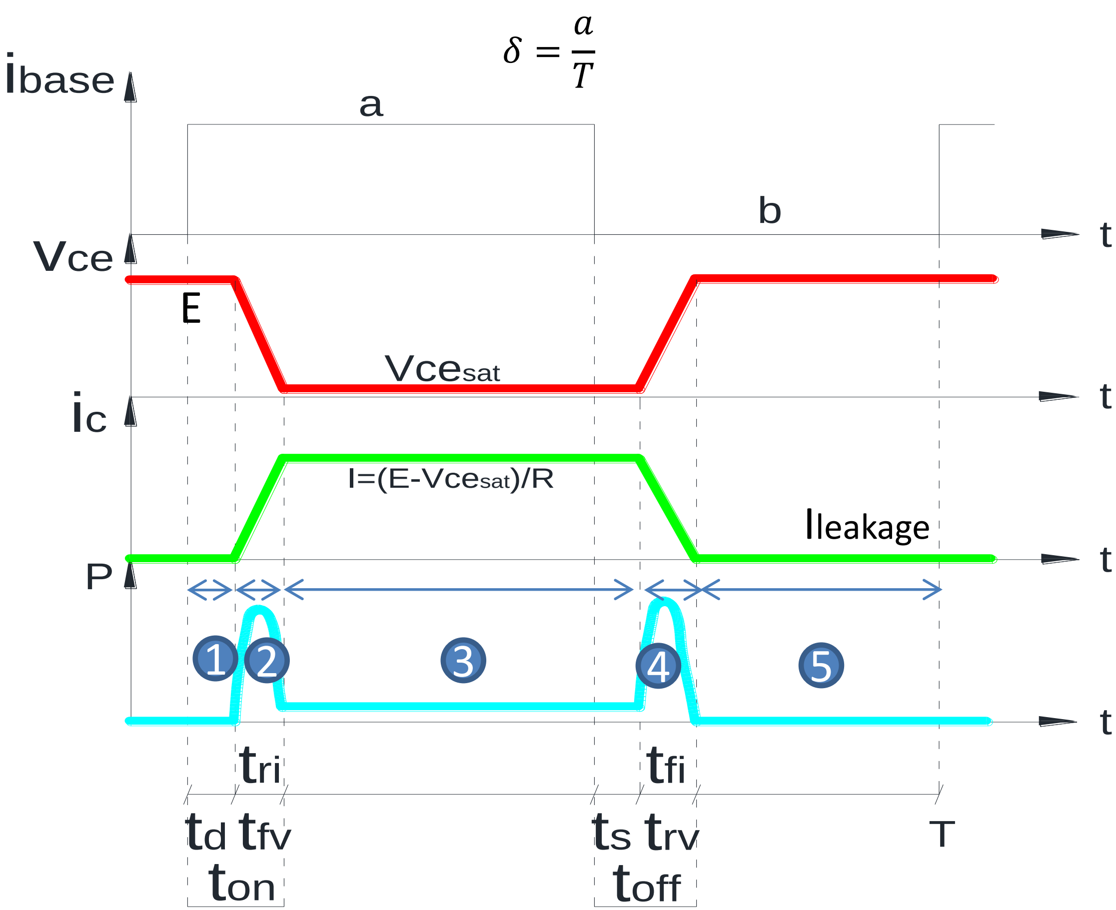


$$P = \frac{1}{T}\int_{o}^{T} v(t).\, i(t)$$

$$P = \frac{1}{T}\int_{o}^{T} (P\_1 + P\_2 + P\_3 + P\_4 + P\_5)\, dt$$

$$P1 = P5 = 0 \quad (I_{leakage} \approx 0)$$

The BJT curve



$$P = \frac{1}{T}\int_o^T v(t).i(t)$$

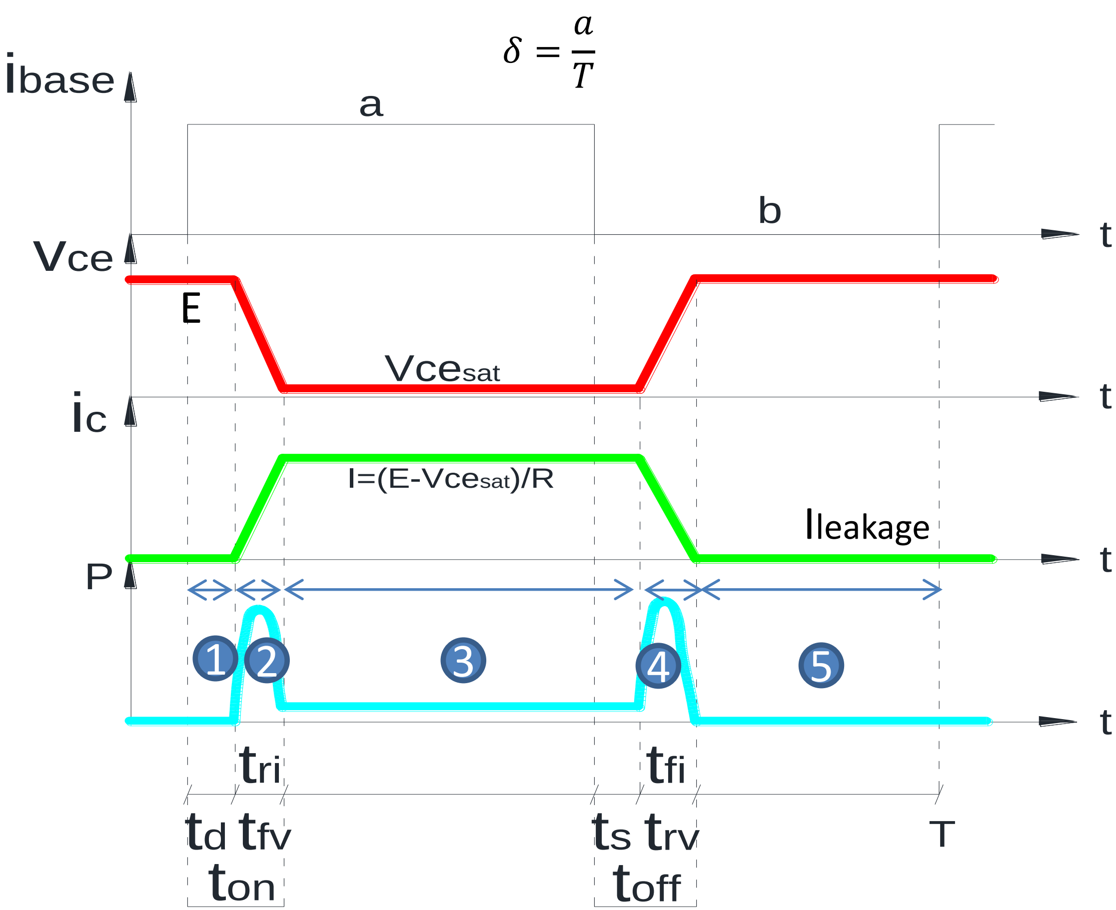
$$P = \frac{1}{T}\int_o^T (P\_1 + P\_2 + P\_3 + P\_4 + P\_5)\ \mathrm{dt}$$

$$P1 = P5 = 0 \quad (I_{leakage} \approx 0)$$

$$P2 = \frac{1}{T}\int_0^{tfv} Vce(t).ic(t)dt$$

$$P2 = \frac{1}{T}\int_0^{tfv}\left(E + \frac{Vce_{sat} - E}{tfv}t\right)\left(I_{leak} + \frac{I - I_{leak}}{tfv}t\right)dt$$

The BJT curve



$$P = \frac{1}{T}\int_{o}^{T} v(t).i(t)$$

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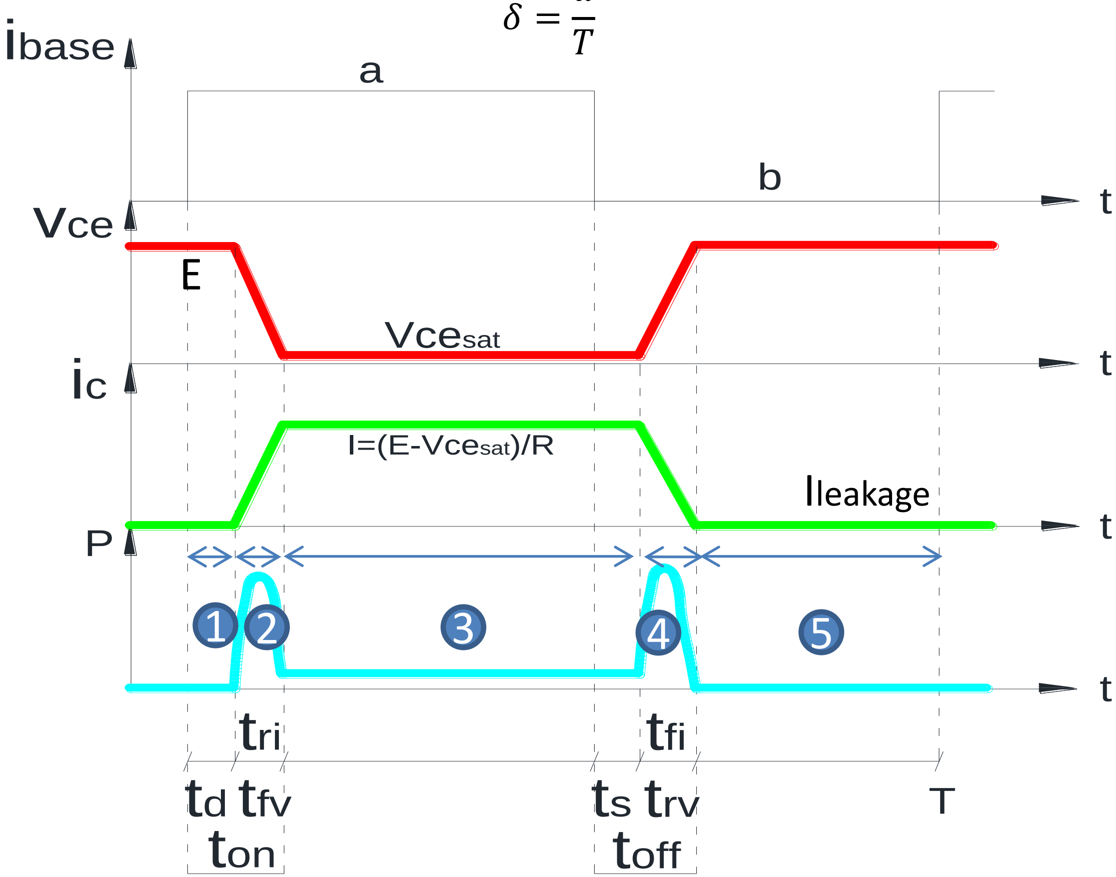
$$P2 = \frac{1}{T}\int_{0}^{tfv} Vce(t).ic(t)dt$$

$$P2 = \frac{1}{T}\int_{0}^{tfv}\left(E + \frac{Vce_{sat} - E}{tfv}t\right)\left(I_{leak} + \frac{I - I_{leak}}{tfv}t\right)dt$$

$$P3 = \frac{1}{T}\int_{0}^{\delta T - td - tfv + ts} Vce_{sat}.\frac{E - Vce_{sat}}{R}dt$$

The BJT curve

$$\delta = \frac{a}{T}$$



$$P = \frac{1}{T}\int_o^T v(t).i(t)$$

$$P = \frac{1}{T}\int_o^T (P\_1 + P\_2 + P\_3 + P\_4 + P\_5)\ dt$$

$$P1 = P5 = 0 \quad (I_{leakage} \approx 0)$$

$$P2 = \frac{1}{T}\int_0^{tfv} Vce(t).ic(t)dt$$

$$P2 = \frac{1}{T}\int_0^{tfv}\left(E + \frac{Vce_{sat} - E}{tfv}t\right)\left(I_{leak} + \frac{I - I_{leak}}{tfv}t\right)dt$$

$$P3 = \frac{1}{T}\int_0^{\delta T - td - tfv + ts} Vce_{sat}.\frac{E - Vce_{sat}}{R}dt$$

$$P4 = \frac{1}{T}\int_0^{tfi}\left(Vce_{sat} + \frac{E - Vce_{sat}}{tfi}t\right)\left(I + \frac{I_{leak} - I}{tfi}t\right)dt$$

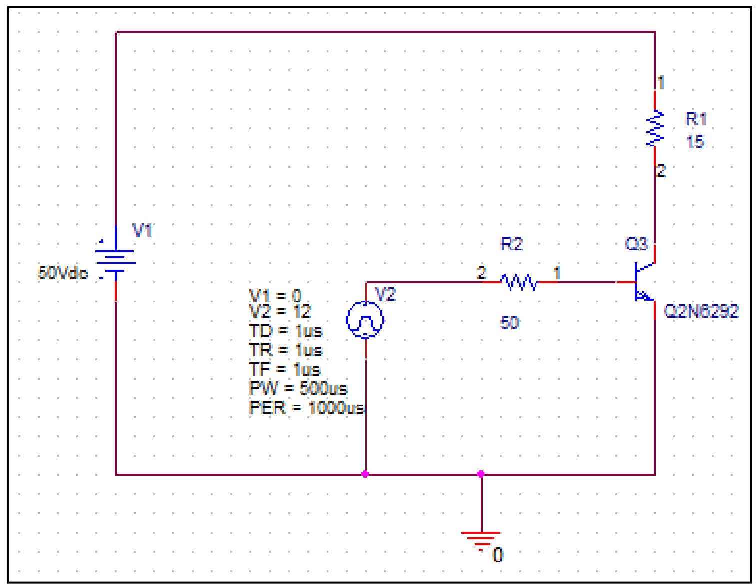
$P1 + P3 + P5 = Pstatic$ $\qquad$ $P2 + P4 = Pdynamic$

HOMEWORK

- **Homework 5_1: For the shown circuit (E=50 V, R=15 ohms):**

Calculate mathematically the power losses in the BJT for the following conditions:

a) f=100 Hz, δ=0.3
b) f=100 Hz, δ=0.7
c) f=5 kHz, δ=0.3
d) f=5 kHz, δ=0.7



Q2N6282/DARLNGTN
Q2N6284/DARLNGTN
Q2N6287/DARLNGTN
Q2N6288/PWRBJT
Q2N6290/PWRBJT
Q2N6292/Design Cache
Q2N6292/PWRBJT
Q2N6388/DARLNGTN
Q2N6427/DARLNGTN
Q2N6465/PWRBJT
Q2N6473/PWRBJT
Q2N6474/PWRBJT
Q2N6475/PWRBJT
Q2N6476/PWRBJT
Q2N6486/PWRBJT
Q2N6487/PWRBJT
Q2N6488/PWRBJT
Q2N6489/PWRBJT

- **Homework 5_2:** For one of the previous cases (a,b,c,d), calculate the power losses in the BJT using PSPICE. Each student has to use his corresponding BJT model. Compare the simulation results with the analytical ones. Infer some conclusions about the static and dynamic losses when varying the frequency and the duty cycle.
- Nota: El link para subir la tarea estará habilitado hasta el miércoles 21 de octubre hasta las 11:55 pm. Adjuntar archivo pdf y archivos de simulación.