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Demo 5.1 – BJT Characteristics

XMUT204 Electronic Design

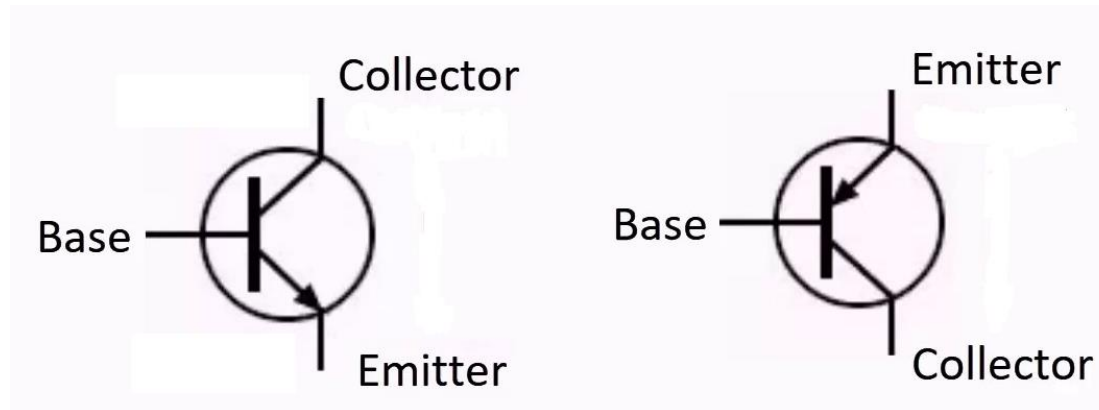
Overview

- Datasheet of a BJT.
- Parameters data.
- Graphical data.



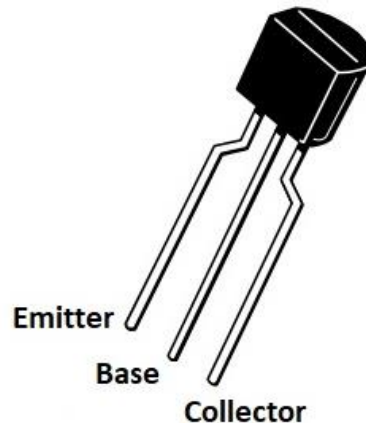
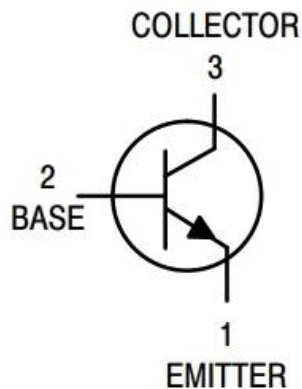
Datasheet of BJT

- In this demo, we discuss the manufacturer datasheet of a Bipolar Junction Transistor (BJT).
- The topics will be covered are characteristics and properties of this active device in electronics e.g. linear and non-linear behaviours of the transistor device.



Datasheet of BJT (cont.)

- 2N3904 BJT transistor which is commonly used as an NPN general purpose amplifier is used as an example in this exercise.
- This device is designed for applications such as a general purpose amplifier and switch.
- The useful dynamic range of this transistor extends to 100 mA current rating as a switch and to 100 MHz frequency bandwidth as an amplifier.

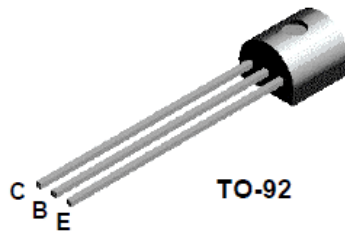


C-E Voltage: 40V
C-B Voltage: 60V
Collector Current: 200mA

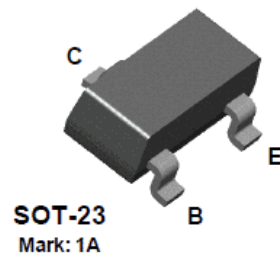
Datasheet of BJT (cont.)

- In terms of packaging, you might see the following variants of 2N3904:
 - TO92 (Through Hole)
 - SOT-23 (SMD)
 - SOT-223 (SMD)

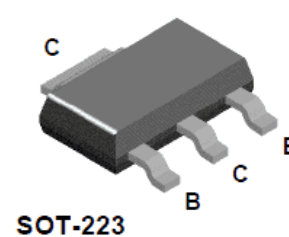
2N3904



MMBT3904



PZT3904



Parameters of BJT

- An absolute maximum ratings for the 2N3904 npn transistor is shown in the figure below.
- Notice that the maximum collector-emitter voltage (V_{CEO}) is 40 V.
- The CEO subscript indicates that the voltage is measured from collector (C) to emitter (E) with the base open (O).
- In the datasheet, we use V_{CE} (max) for this parameter.

Absolute Maximum Ratings* $T_A = 25^\circ\text{C}$ unless otherwise noted

Symbol	Parameter	Value	Units
V_{CEO}	Collector-Emitter Voltage	40	V
V_{CBO}	Collector-Base Voltage	60	V
V_{EBO}	Emitter-Base Voltage	6.0	V
I_C	Collector Current - Continuous	200	mA
T_J, T_{stg}	Operating and Storage Junction Temperature Range	-55 to +150	$^\circ\text{C}$

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

NOTES:

- 1) These ratings are based on a maximum junction temperature of 150 degrees C.
- 2) These are steady state limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.

Parameters of BJT (cont.)

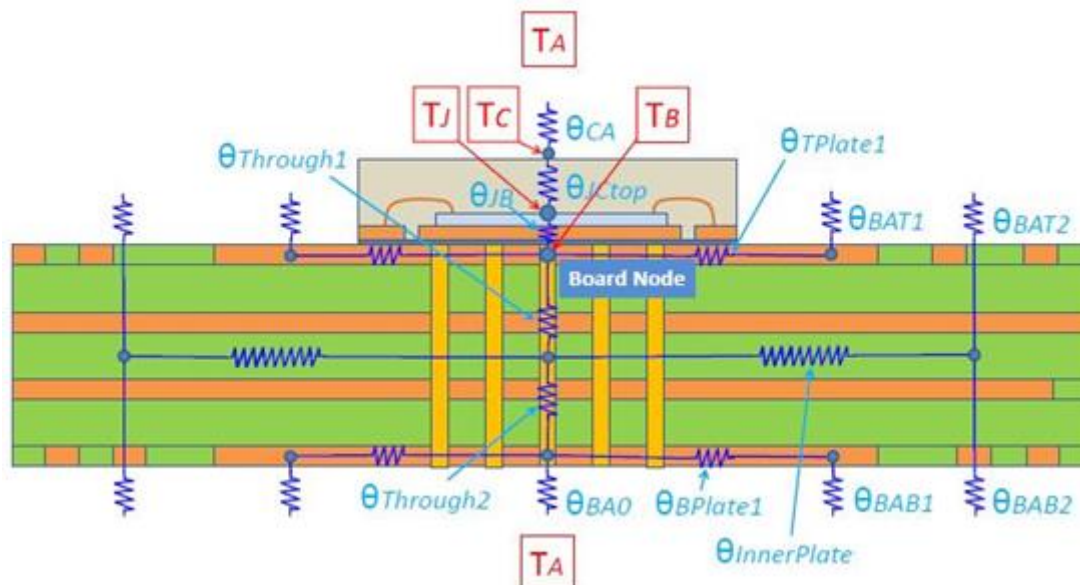
- See thermal characteristics of the BJT (device power dissipation and thermal resistance factors).

Thermal Characteristics $T_A = 25^\circ\text{C}$ unless otherwise noted

Symbol	Characteristic	Max			Units
		2N3904	*MMBT3904	**PZT3904	
P_D	Total Device Dissipation	625	350	1,000	mW
	Derate above 25°C	5.0	2.8	8.0	$\text{mW}/^\circ\text{C}$
$R_{\theta JC}$	Thermal Resistance, Junction to Case	83.3			$^\circ\text{C}/\text{W}$
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	200	357	125	$^\circ\text{C}/\text{W}$

* Device mounted on FR-4 PCB 1.6" X 1.6" X 0.06."

** Device mounted on FR-4 PCB 36 mm X 18 mm X 1.5 mm; mounting pad for the collector lead min. 6 cm^2 .



Parameters of BJT (cont.)

- Also notice that the maximum collector current is 200 mA.
- The β_{DC} (h_{FE}) is specified for several values of I_C .
- As you can see, h_{FE} varies with I_C as we previously discussed.
- The collector-emitter saturation voltage, V_{CE} (sat) is 0.2 V maximum for I_C (sat) = 10 mA and increases with the current.

Electrical Characteristics <small>$T_A = 25^\circ\text{C}$ unless otherwise noted</small>					
Symbol	Parameter	Test Conditions	Min	Max	Units
OFF CHARACTERISTICS					
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 1.0 \text{ mA}, I_B = 0$	40		V
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 10 \mu\text{A}, I_E = 0$	60		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10 \mu\text{A}, I_C = 0$	6.0		V
I_{BL}	Base Cutoff Current	$V_{CE} = 30 \text{ V}, V_{EB} = 3 \text{ V}$		50	nA
I_{CEX}	Collector Cutoff Current	$V_{CE} = 30 \text{ V}, V_{EB} = 3 \text{ V}$		50	nA
ON CHARACTERISTICS*					
h_{FE}	DC Current Gain	$I_C = 0.1 \text{ mA}, V_{CE} = 1.0 \text{ V}$ $I_C = 1.0 \text{ mA}, V_{CE} = 1.0 \text{ V}$ $I_C = 10 \text{ mA}, V_{CE} = 1.0 \text{ V}$ $I_C = 50 \text{ mA}, V_{CE} = 1.0 \text{ V}$ $I_C = 100 \text{ mA}, V_{CE} = 1.0 \text{ V}$	40 70 100 60 30	300	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 10 \text{ mA}, I_B = 1.0 \text{ mA}$ $I_C = 50 \text{ mA}, I_B = 5.0 \text{ mA}$		0.2 0.3	V V
$V_{BE(sat)}$	Base-Emitter Saturation Voltage	$I_C = 10 \text{ mA}, I_B = 1.0 \text{ mA}$ $I_C = 50 \text{ mA}, I_B = 5.0 \text{ mA}$	0.65	0.85 0.95	V V

Graphical Data of BJT

- Several graphical data which are of particular interest for analysis and design of BJT transistor circuits.
- These graphs are related closely to the properties and characteristics of the BJT transistors.
- Focus on the properties and characteristics of the BJT transistor in terms on two most common types of BJT transistor application e.g. switching and amplification.
- Several properties and characteristics of BJT transistor are typically common for both switching and amplification applications such as: power dissipation, on voltage, turn on time, saturations, cut-off current, output admittance, input impedance, operating frequency and noise characteristics.

Graphical Data of BJT (cont.)

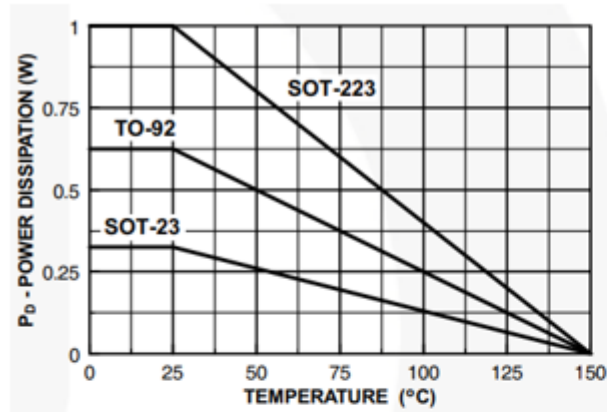


Figure 4: Power Dissipation vs. Ambient Temperature

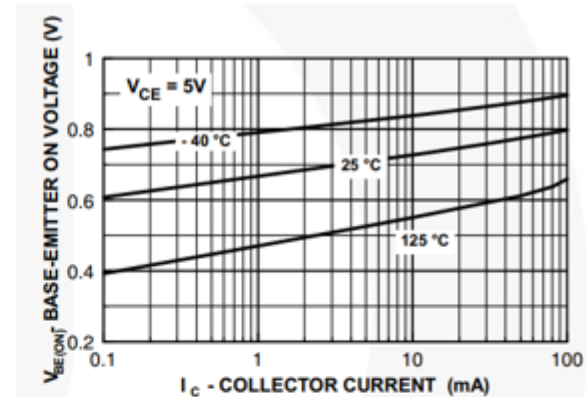


Figure 5: Base-Emitter On Voltage vs. Collector Current

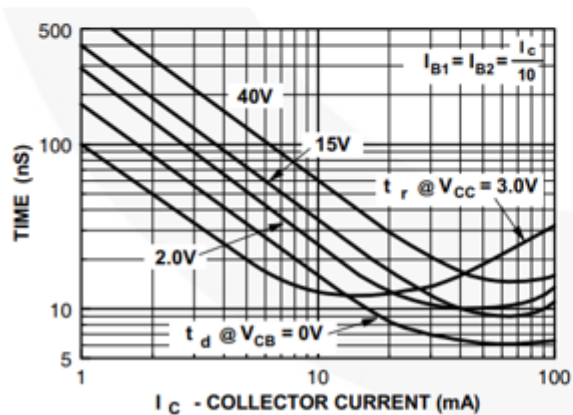


Figure 6: Turn-On Time vs. Collector Current

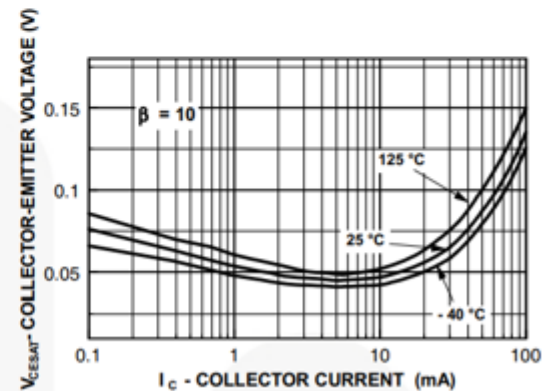


Figure 7: Collector-Emitter Saturation Voltage vs. Collector Current

Graphical Data of BJT (cont.)

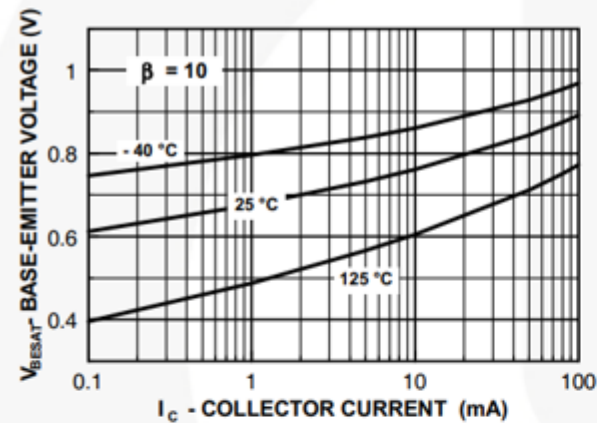


Figure 8: Base-Emitter Saturation Voltage vs. Collector Current

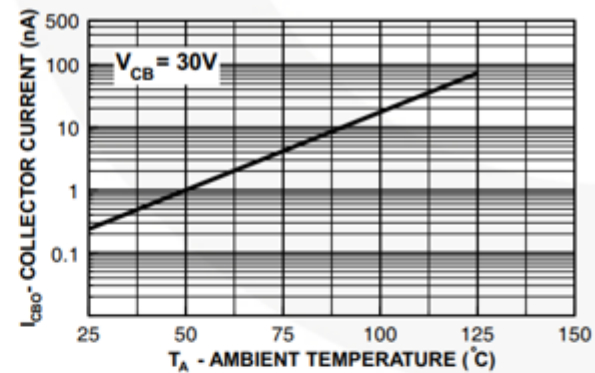


Figure 9: Collector Cut-Off Current vs. Ambient Temperature

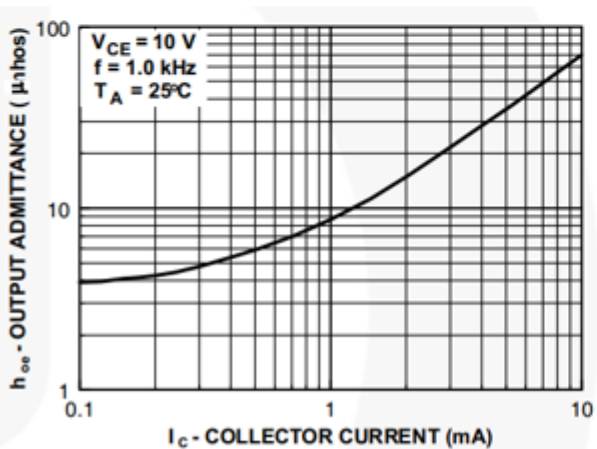


Figure 10: Output Admittance vs. Collector Current

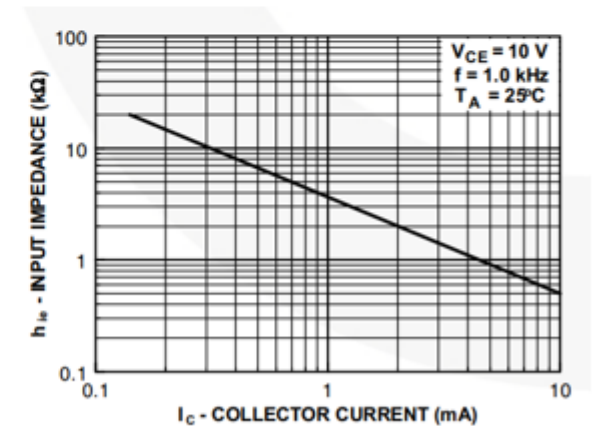


Figure 11: Input Impedance vs. Collector Current

Graphical Data of BJT (cont.)

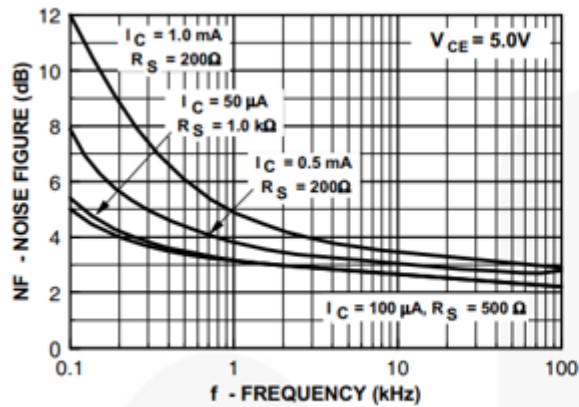


Figure 12: Noise Figure vs. Frequency

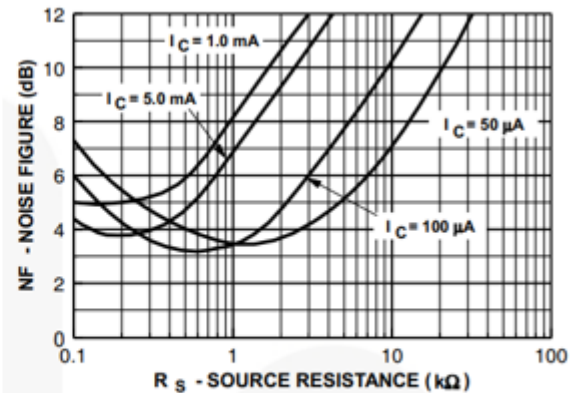


Figure 13: Noise Figure vs. Source Resistance

Graphical Data of BJT (cont.)

- For switching application properties and characteristics such as rise time, storage time, fall time, and capacitance at reversed bias are important information for the design of the switching circuit.
- How fast switching operation can be performed depends on the nature of the timing (rise time and fall time) of the signal pulses.
- How fast the transistor can recover depends on the value of capacitance of the transistor and hence the storage time.
- As capacitance in the transistor limits the amount of time for the transistor to be ready for the next cycle of pulses.

Graphical Data of BJT (cont.)

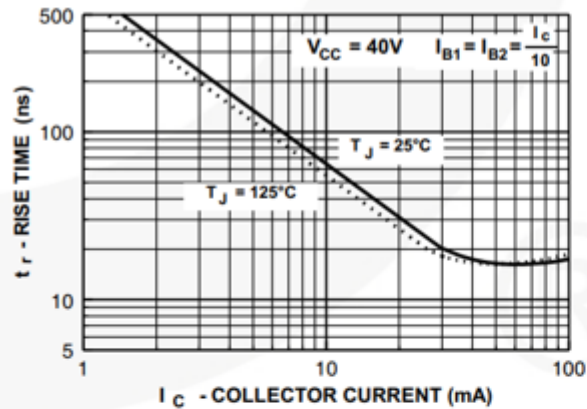


Figure 14: Rise Time vs Collector Current

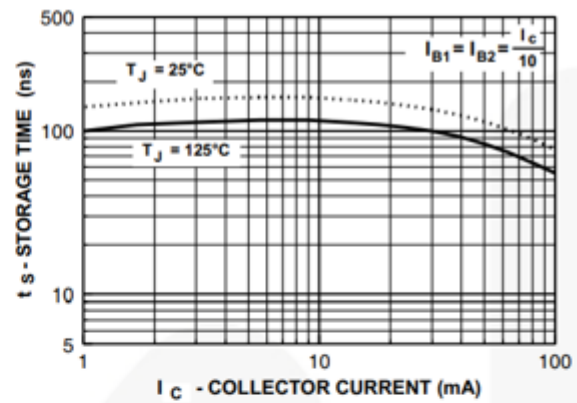


Figure 15: Storage Time vs. Collector Current

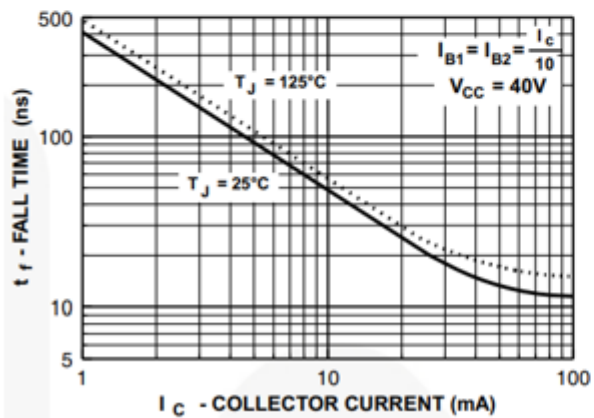


Figure 16: Fall Time vs. Collector Current

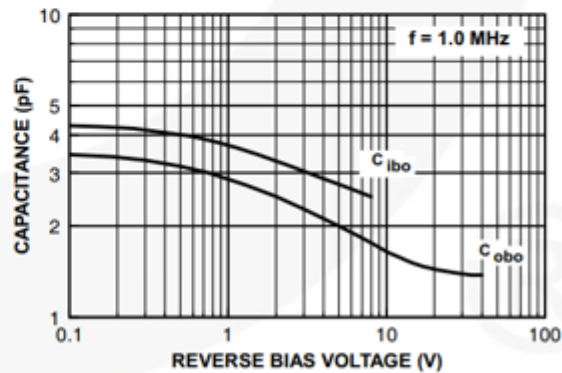


Figure 17: Capacitance vs. Reverse Bias Voltage

Graphical Data of BJT (cont.)

- Properties and characteristics of BJT transistor such as voltage and current gain, frequency bandwidth and voltage feedback characteristics are essential to know for amplification application.
- How much signal can be amplified depends on the gain of the transistor.
- What frequency of operation (e.g. maximum and minimum frequencies) can be safely amplified in the circuit depends on the bandwidth of the transistor.
- Voltage feedback characteristics will determine the ability of the transistor to be put into feedback arrangement, typical set up for amplifier circuit design.

Graphical Data of BJT (cont.)

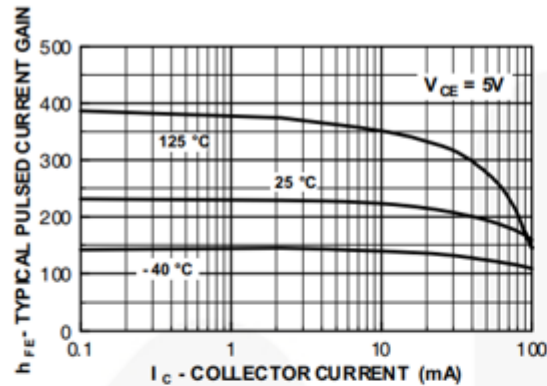


Figure 18: Typical Pulsed Current Gain vs Collector Current

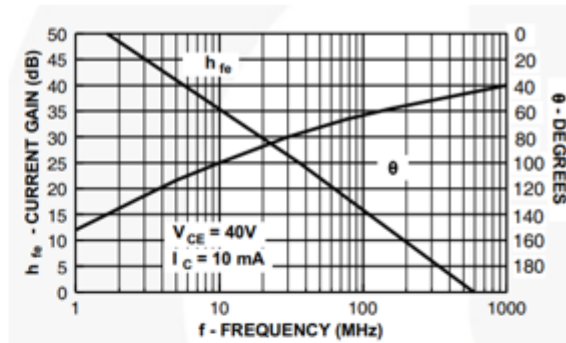


Figure 19: Current Gain and Phase Angle vs. Frequency

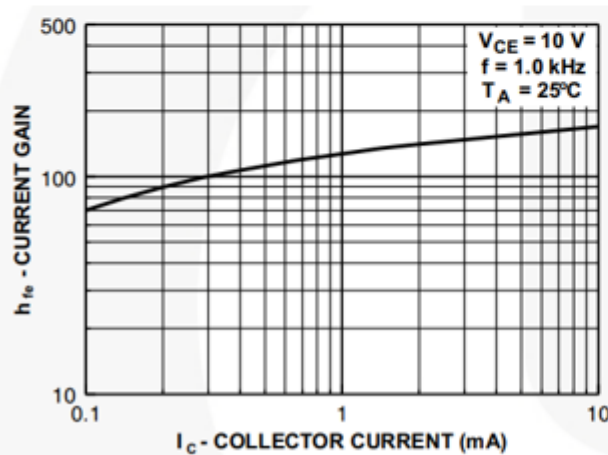


Figure 20: Current Gain vs. Collector Current

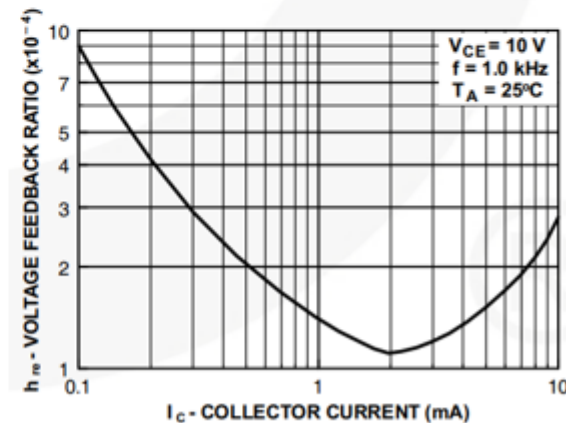


Figure 21: Voltage Feedback Ratio vs. Collector Current