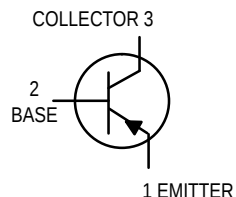
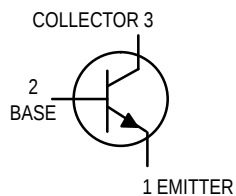


# Amplifier Transistors



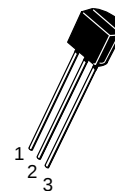
**NPN**  
**MPS6520**  
**MPS6521\***  
**PNP**  
**MPS6523**

Voltage and current are negative  
for PNP transistors

\*Motorola Preferred Device

## MAXIMUM RATINGS

| Rating                                                                                 | Symbol         | NPN         | PNP     | Unit                          |
|----------------------------------------------------------------------------------------|----------------|-------------|---------|-------------------------------|
| Collector–Emitter Voltage<br>MPS6520, MPS6521<br>MPS6523                               | $V_{CEO}$      | 25<br>—     | —<br>25 | Vdc                           |
| Collector–Base Voltage<br>MPS6520, MPS6521<br>MPS6523                                  | $V_{CBO}$      | 40<br>—     | —<br>25 | Vdc                           |
| Emitter–Base Voltage                                                                   | $V_{EBO}$      | 4.0         |         | Vdc                           |
| Collector Current — Continuous                                                         | $I_C$          | 100         |         | mAdc                          |
| Total Device Dissipation @ $T_A = 25^\circ\text{C}$<br>Derate above $25^\circ\text{C}$ | $P_D$          | 625<br>5.0  |         | mW<br>mW/ $^\circ\text{C}$    |
| Total Device Dissipation @ $T_C = 25^\circ\text{C}$<br>Derate above $25^\circ\text{C}$ | $P_D$          | 1.5<br>12   |         | Watts<br>mW/ $^\circ\text{C}$ |
| Operating and Storage Junction<br>Temperature Range                                    | $T_J, T_{stg}$ | –55 to +150 |         | $^\circ\text{C}$              |



CASE 29–04, STYLE 1  
TO–92 (TO–226AA)

## THERMAL CHARACTERISTICS

| Characteristic                                                              | Symbol          | Max  | Unit               |
|-----------------------------------------------------------------------------|-----------------|------|--------------------|
| Thermal Resistance, Junction to Ambient<br>(Printed Circuit Board Mounting) | $R_{\theta JA}$ | 200  | $^\circ\text{C/W}$ |
| Thermal Resistance, Junction to Case                                        | $R_{\theta JC}$ | 83.3 | $^\circ\text{C/W}$ |

## ELECTRICAL CHARACTERISTICS ( $T_A = 25^\circ\text{C}$ unless otherwise noted)

| Characteristic | Symbol | Min | Max | Unit |
|----------------|--------|-----|-----|------|
|----------------|--------|-----|-----|------|

## OFF CHARACTERISTICS

|                                                                                                                    |               |        |              |                 |
|--------------------------------------------------------------------------------------------------------------------|---------------|--------|--------------|-----------------|
| Collector–Emitter Breakdown Voltage<br>( $I_C = 0.5 \text{ mAdc}$ , $I_B = 0$ )                                    | $V_{(BR)CEO}$ | 25     | —            | Vdc             |
| Emitter–Base Breakdown Voltage<br>( $I_E = 10 \text{ }\mu\text{Adc}$ , $I_C = 0$ )                                 | $V_{(BR)EBO}$ | 4.0    | —            | Vdc             |
| Collector Cutoff Current<br>( $V_{CB} = 30 \text{ Vdc}$ , $I_E = 0$ )<br>( $V_{CB} = 20 \text{ Vdc}$ , $I_E = 0$ ) | $I_{CBO}$     | —<br>— | 0.05<br>0.05 | $\mu\text{Adc}$ |

Preferred devices are Motorola recommended choices for future use and best overall value.

**NPN MPS6520 MPS6521 PNP MPS6523****ELECTRICAL CHARACTERISTICS** ( $T_A = 25^\circ\text{C}$  unless otherwise noted) (Continued)

| Characteristic                                                                                                                                                           | Symbol        | Min | Max | Unit |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-----|-----|------|
| <b>ON CHARACTERISTICS</b>                                                                                                                                                |               |     |     |      |
| DC Current Gain<br>( $I_C = 100\ \mu\text{Adc}$ , $V_{CE} = 10\ \text{Vdc}$ )                                                                                            | $h_{FE}$      | 100 | —   | —    |
| MPS6520                                                                                                                                                                  |               | 150 | —   | —    |
| MPS6521                                                                                                                                                                  |               | 200 | 400 | —    |
| ( $I_C = 2.0\ \text{mAdc}$ , $V_{CE} = 10\ \text{Vdc}$ )                                                                                                                 |               | 300 | 600 | —    |
| ( $I_C = 100\ \mu\text{Adc}$ , $V_{CE} = 10\ \text{Vdc}$ )                                                                                                               | $h_{FE}$      | 150 | —   | —    |
| MPS6523                                                                                                                                                                  |               | 300 | 600 | —    |
| ( $I_C = 2.0\ \text{mAdc}$ , $V_{CE} = 10\ \text{Vdc}$ )                                                                                                                 |               |     |     |      |
| Collector–Emitter Saturation Voltage<br>( $I_C = 50\ \text{mAdc}$ , $I_B = 5.0\ \text{mAdc}$ )                                                                           | $V_{CE(sat)}$ | —   | 0.5 | Vdc  |
| <b>SMALL–SIGNAL CHARACTERISTICS</b>                                                                                                                                      |               |     |     |      |
| Output Capacitance<br>( $V_{CB} = 10\ \text{Vdc}$ , $I_E = 0$ , $f = 1.0\ \text{MHz}$ )                                                                                  | $C_{obo}$     | —   | 3.5 | pF   |
| Noise Figure<br>( $I_C = 10\ \mu\text{Adc}$ , $V_{CE} = 5.0\ \text{Vdc}$ , $R_S = 10\ \text{k}\Omega$ ,<br>Power Bandwidth = 15.7 kHz, 3.0 dB points @ 10 Hz and 10 kHz) | NF            | —   | 3.0 | dB   |

NPN  
MPS6520, MPS6521

EQUIVALENT SWITCHING TIME TEST CIRCUITS

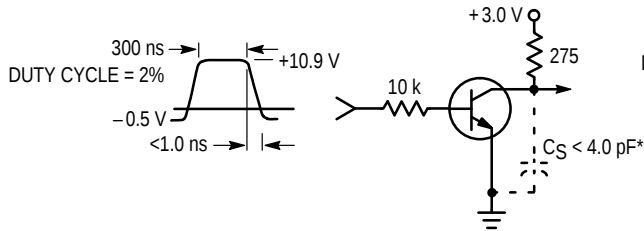


Figure 1. Turn-On Time

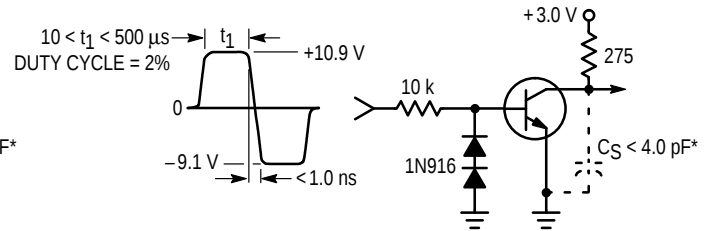


Figure 2. Turn-Off Time

TYPICAL NOISE CHARACTERISTICS

( $V_{CE} = 5.0 \text{ Vdc}$ ,  $T_A = 25^\circ\text{C}$ )

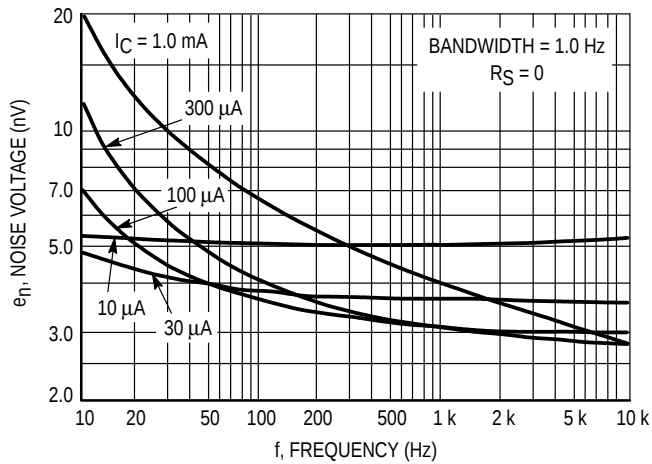


Figure 3. Noise Voltage

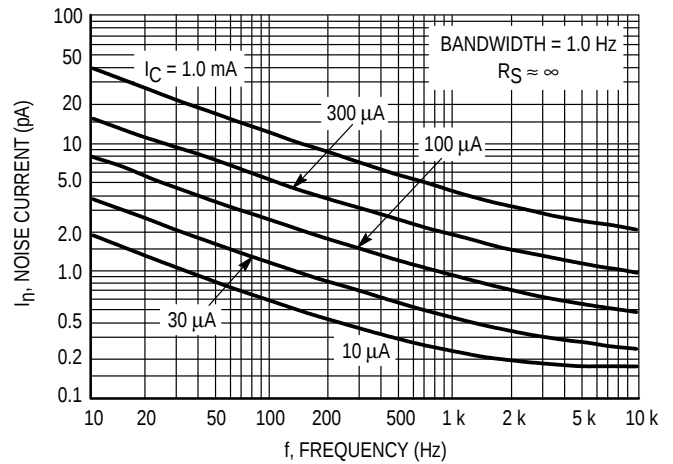
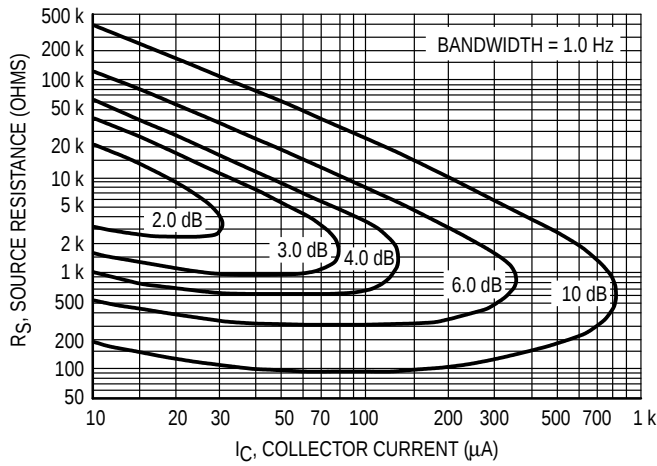


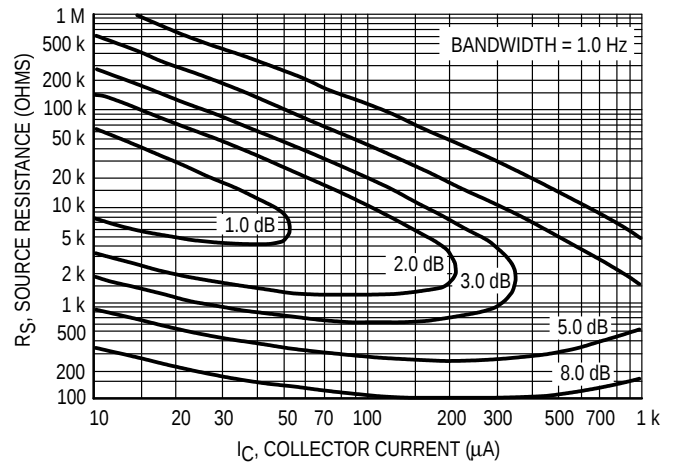
Figure 4. Noise Current

**NPN  
MPS6520, MPS6521**

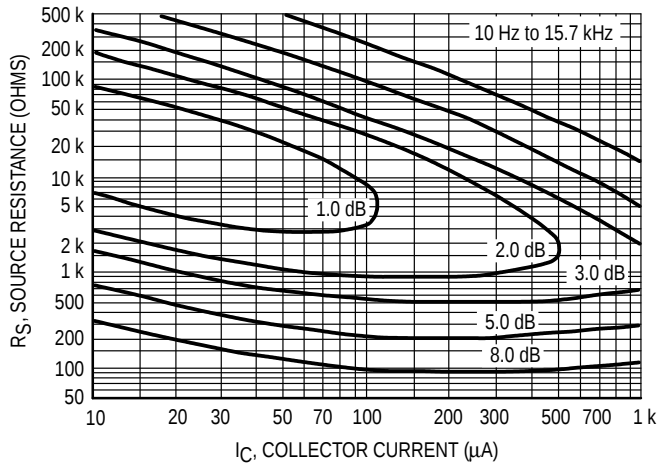
**NOISE FIGURE CONTOURS**  
( $V_{CE} = 5.0 \text{ Vdc}$ ,  $T_A = 25^\circ\text{C}$ )



**Figure 5. Narrow Band, 100 Hz**



**Figure 6. Narrow Band, 1.0 kHz**



**Figure 7. Wideband**

Noise Figure is defined as:

$$NF = 20 \log_{10} \left( \frac{e_n^2 + 4KTR_S + I_n^2 R_S^2}{4KTR_S} \right)^{1/2}$$

$e_n$  = Noise Voltage of the Transistor referred to the input. (Figure 3)

$I_n$  = Noise Current of the Transistor referred to the input. (Figure 4)

$K$  = Boltzman's Constant ( $1.38 \times 10^{-23} \text{ J/}^\circ\text{K}$ )

$T$  = Temperature of the Source Resistance ( $^\circ\text{K}$ )

$R_S$  = Source Resistance (Ohms)

NPN  
MPS6520, MPS6521

## TYPICAL STATIC CHARACTERISTICS

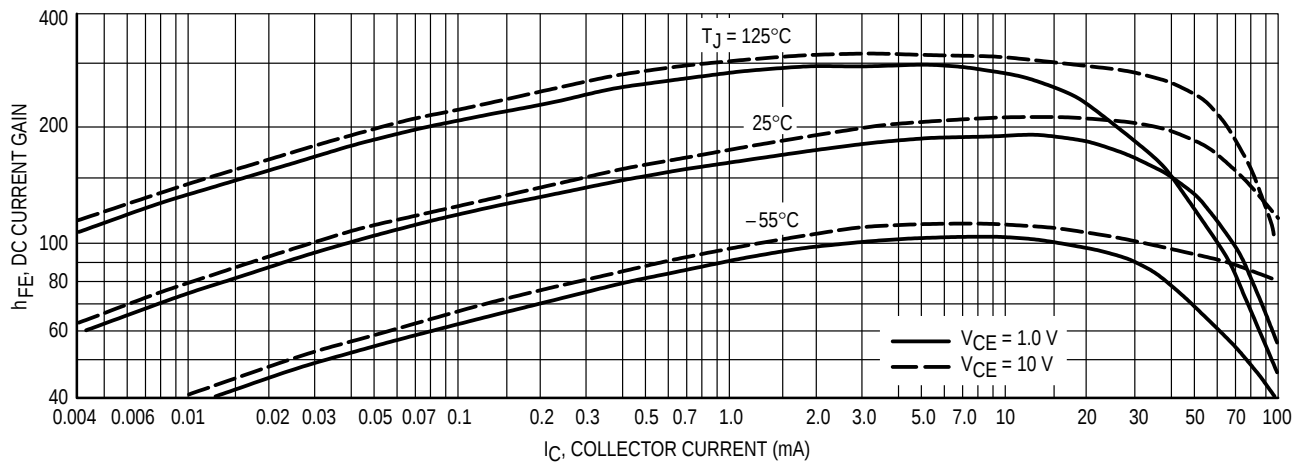


Figure 8. DC Current Gain

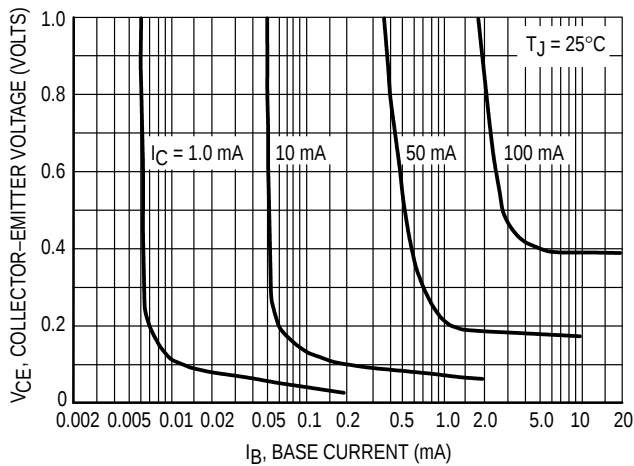


Figure 9. Collector Saturation Region

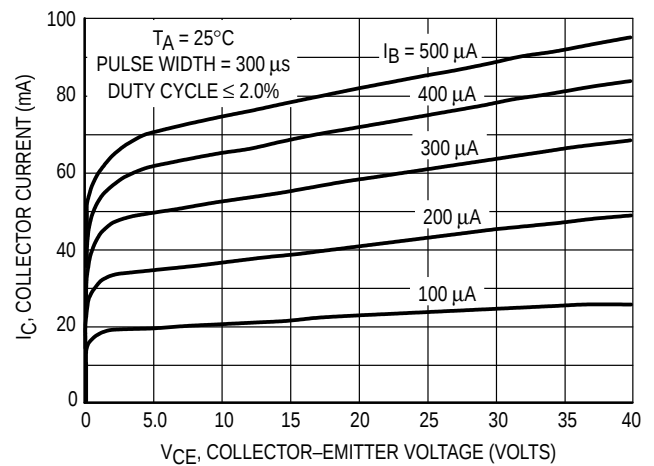


Figure 10. Collector Characteristics

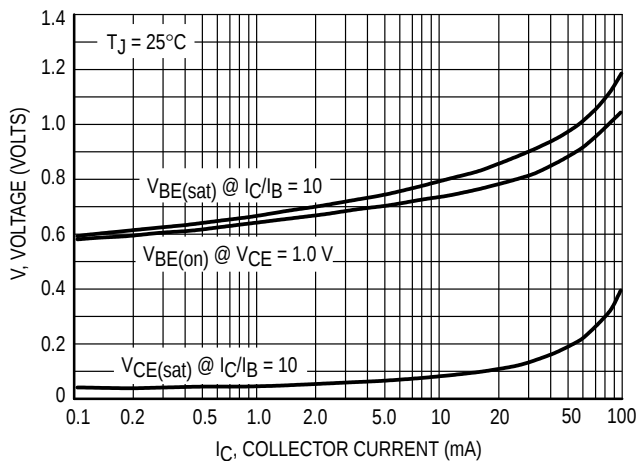


Figure 11. "On" Voltages

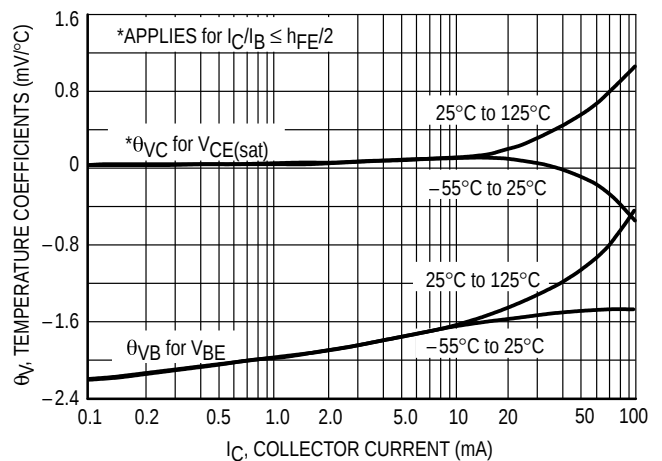
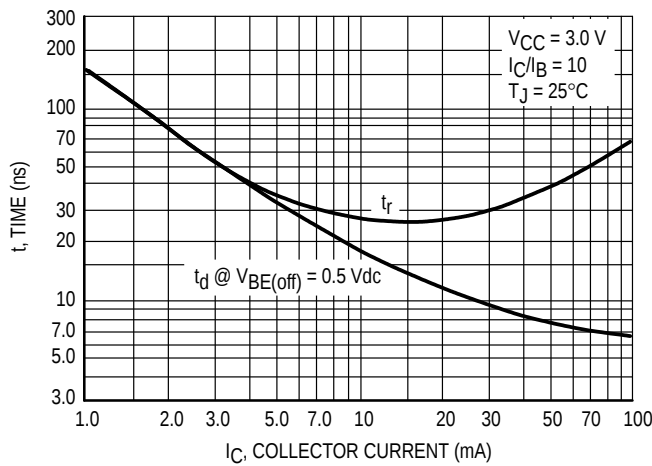
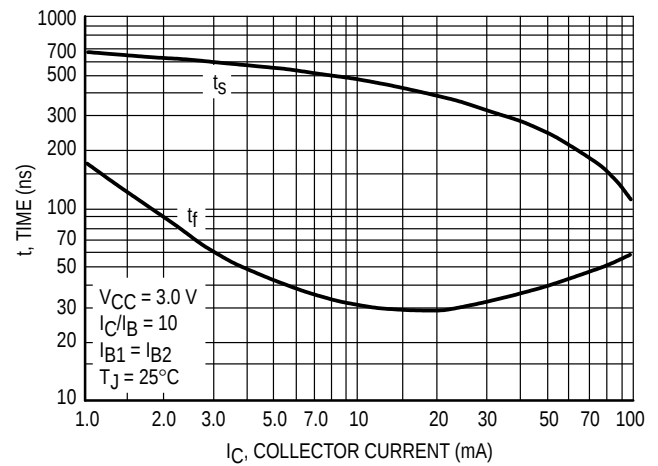


Figure 12. Temperature Coefficients

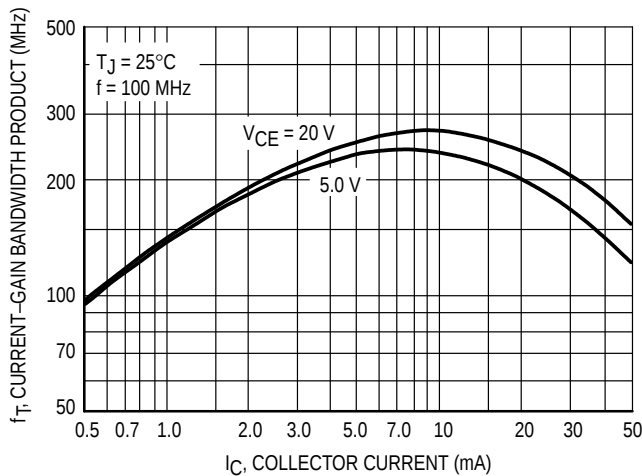
**TYPICAL DYNAMIC CHARACTERISTICS**



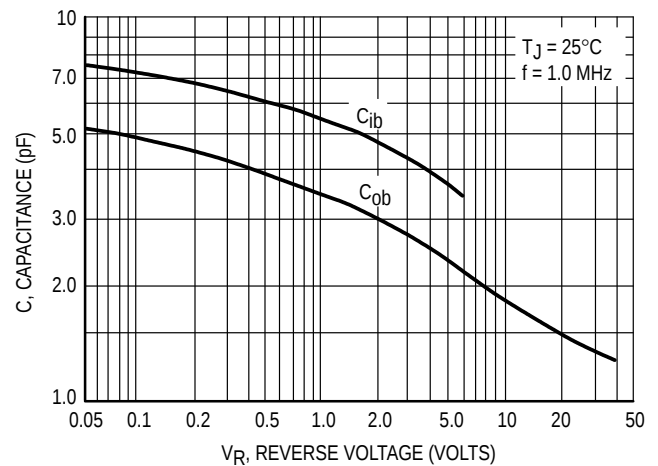
**Figure 13. Turn-On Time**



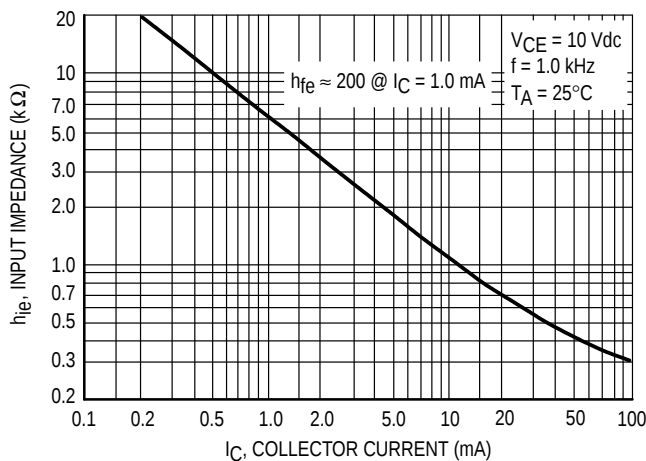
**Figure 14. Turn-Off Time**



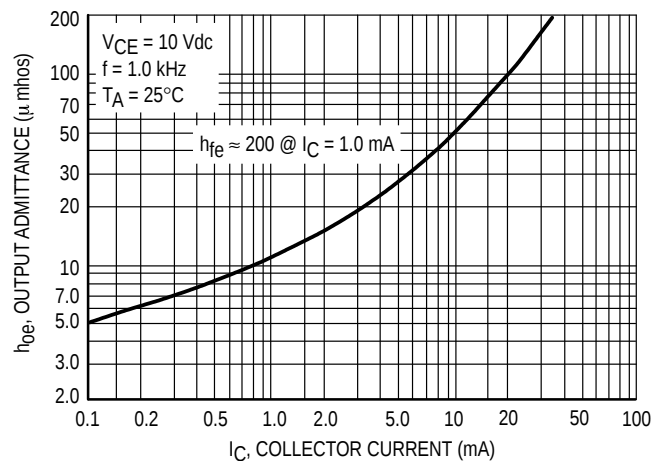
**Figure 15. Current-Gain — Bandwidth Product**



**Figure 16. Capacitance**



**Figure 17. Input Impedance**



**Figure 18. Output Admittance**

NPN  
MPS6520, MPS6521

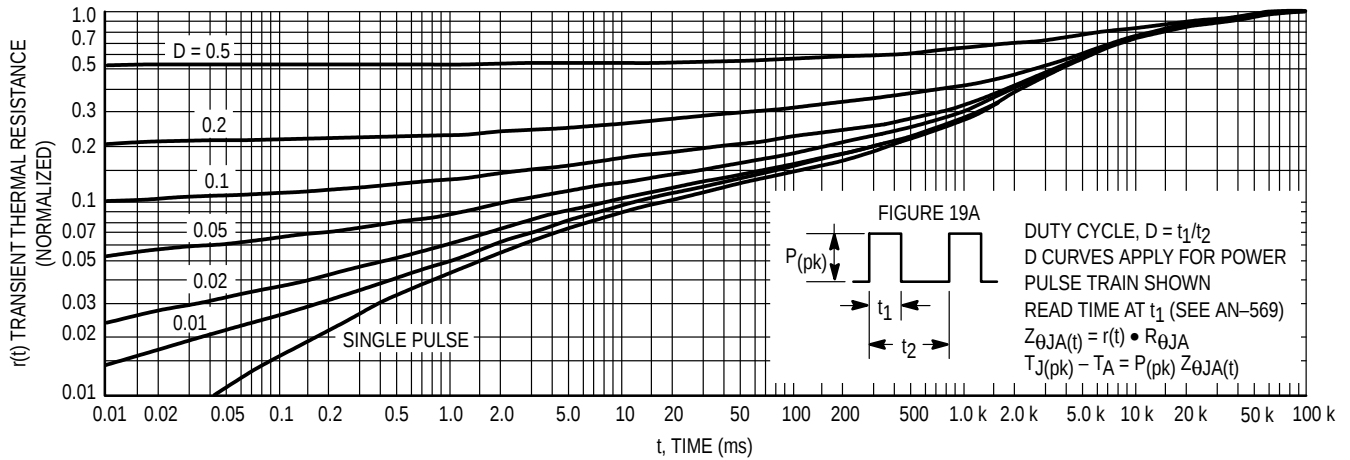


Figure 19. Thermal Response

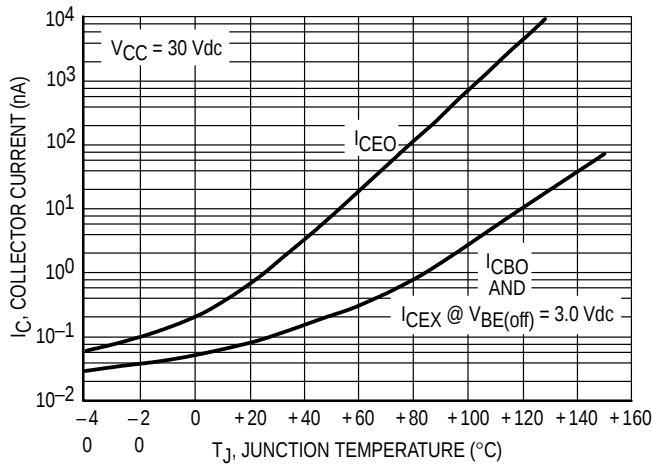


Figure 19A.

DESIGN NOTE: USE OF THERMAL RESPONSE DATA

A train of periodical power pulses can be represented by the model as shown in Figure 19A. Using the model and the device thermal response the normalized effective transient thermal resistance of Figure 19 was calculated for various duty cycles.

To find  $Z_{\theta JA}(t)$ , multiply the value obtained from Figure 19 by the steady state value  $R_{\theta JA}$ .

Example:

The MPS3904 is dissipating 2.0 watts peak under the following conditions:

$t_1 = 1.0$  ms,  $t_2 = 5.0$  ms. ( $D = 0.2$ )

Using Figure 19 at a pulse width of 1.0 ms and  $D = 0.2$ , the reading of  $r(t)$  is 0.22.

The peak rise in junction temperature is therefore

$$\Delta T = r(t) \times P(pk) \times R_{\theta JA} = 0.22 \times 2.0 \times 200 = 88^\circ\text{C}.$$

For more information, see AN-569.

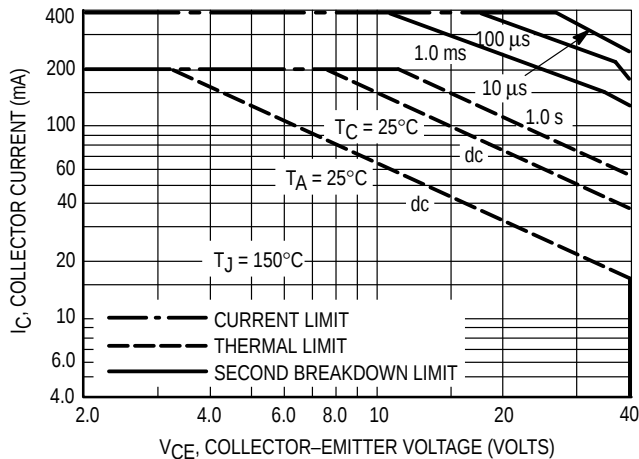


Figure 20.

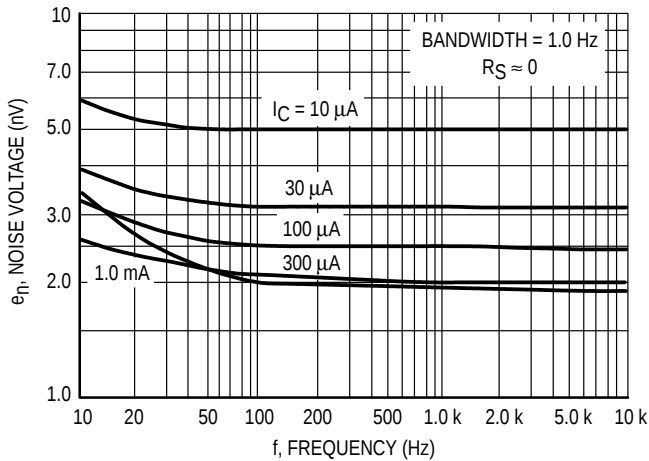
The safe operating area curves indicate  $I_C$ - $V_{CE}$  limits of the transistor that must be observed for reliable operation. Collector load lines for specific circuits must fall below the limits indicated by the applicable curve.

The data of Figure 20 is based upon  $T_{J(pk)} = 150^\circ\text{C}$ ;  $T_C$  or  $T_A$  is variable depending upon conditions. Pulse curves are valid for duty cycles to 10% provided  $T_{J(pk)} \leq 150^\circ\text{C}$ .  $T_{J(pk)}$  may be calculated from the data in Figure 19. At high case or ambient temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown.

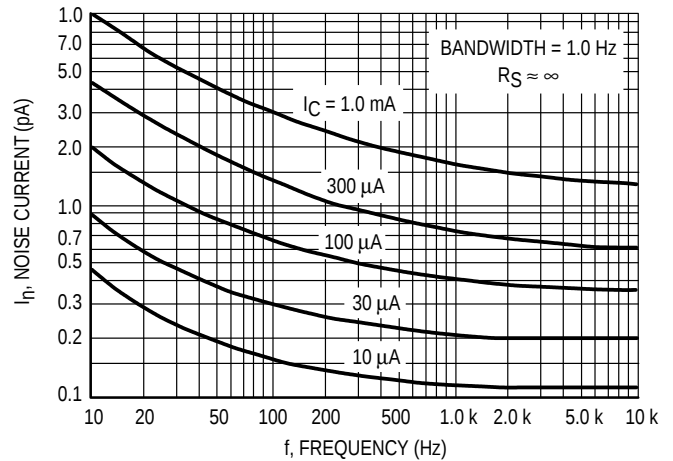
**PNP  
MPS6523**

**TYPICAL NOISE CHARACTERISTICS**

( $V_{CE} = -5.0$  Vdc,  $T_A = 25^\circ\text{C}$ )



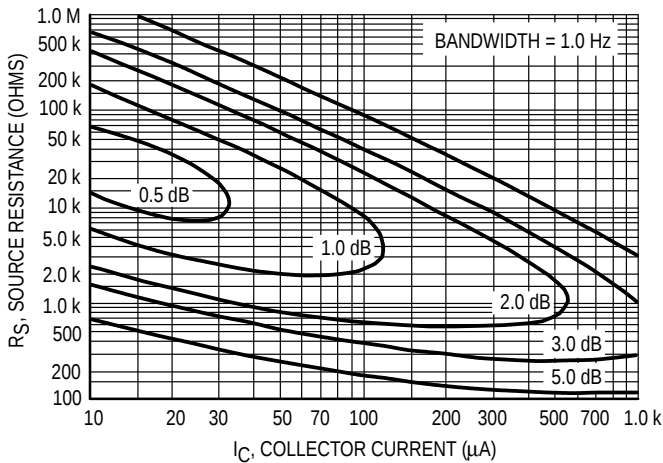
**Figure 21. Noise Voltage**



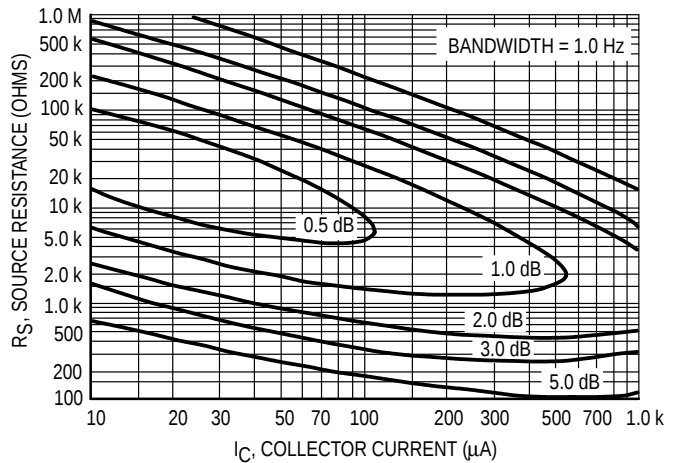
**Figure 22. Noise Current**

**NOISE FIGURE CONTOURS**

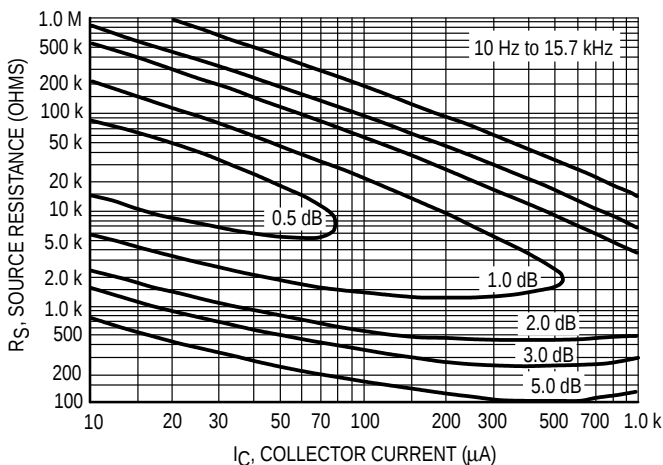
( $V_{CE} = -5.0$  Vdc,  $T_A = 25^\circ\text{C}$ )



**Figure 23. Narrow Band, 100 Hz**



**Figure 24. Narrow Band, 1.0 kHz**



**Figure 25. Wideband**

Noise Figure is Defined as:

$$NF = 20 \log_{10} \left[ \frac{e_n^2 + 4KTR_S + I_n^2 R_S^2}{4KTR_S} \right]^{1/2}$$

$e_n$  = Noise Voltage of the Transistor referred to the input. (Figure 3)

$I_n$  = Noise Current of the Transistor referred to the input. (Figure 4)

$K$  = Boltzman's Constant ( $1.38 \times 10^{-23}$  j/°K)

$T$  = Temperature of the Source Resistance (°K)

$R_S$  = Source Resistance (Ohms)

PNP  
MPS6523

## TYPICAL STATIC CHARACTERISTICS

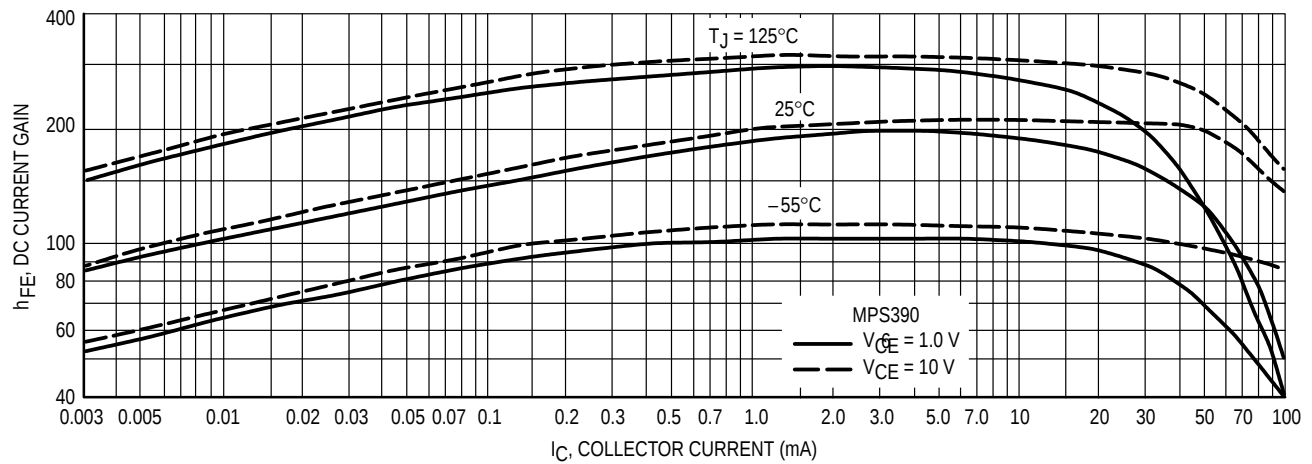


Figure 26. DC Current Gain

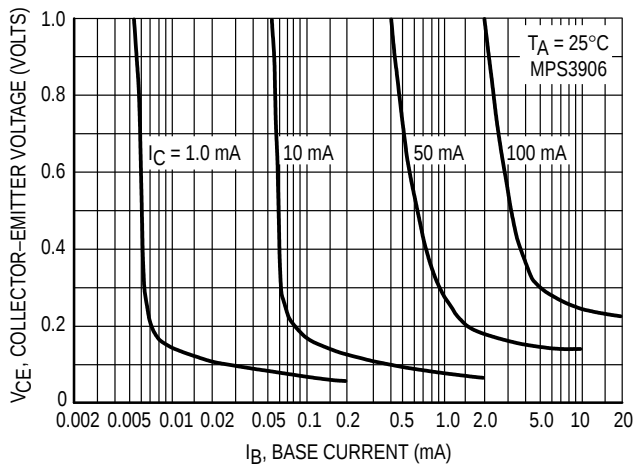


Figure 27. Collector Saturation Region

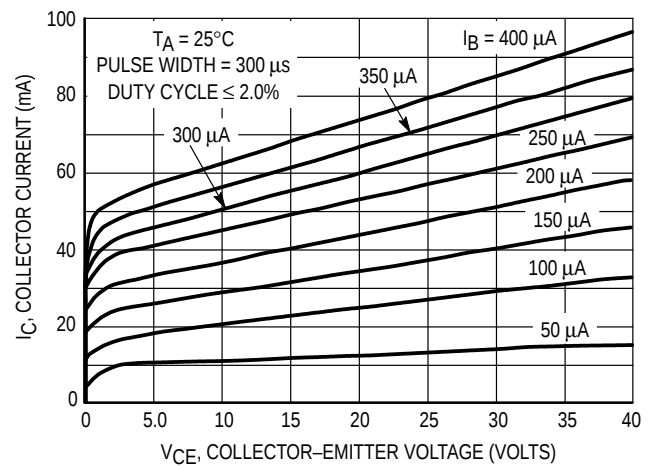


Figure 28. Collector Characteristics

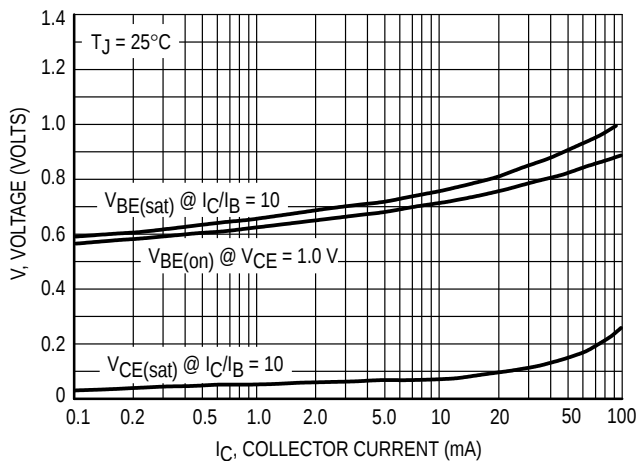


Figure 29. "On" Voltages

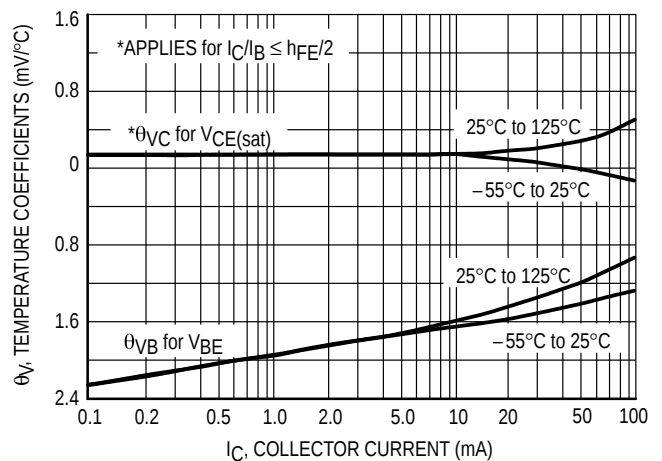


Figure 30. Temperature Coefficients

## TYPICAL DYNAMIC CHARACTERISTICS

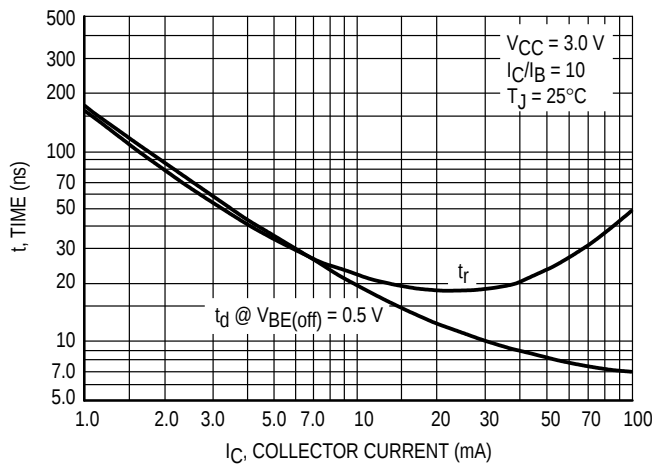


Figure 31. Turn-On Time

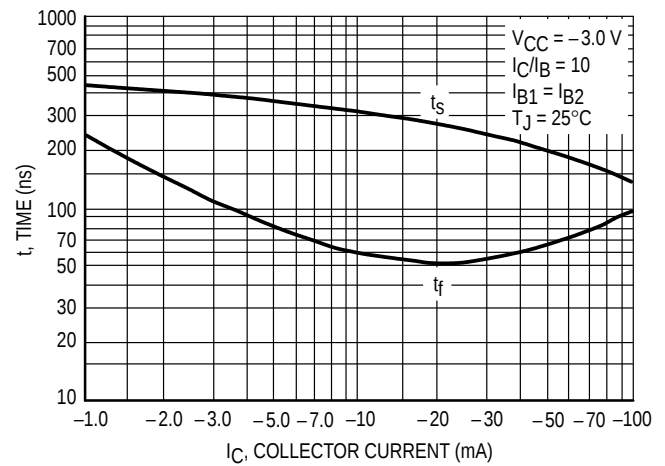


Figure 32. Turn-Off Time

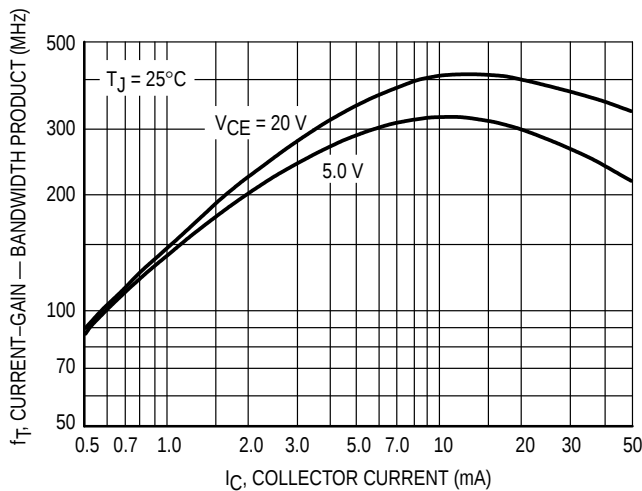


Figure 33. Current-Gain — Bandwidth Product

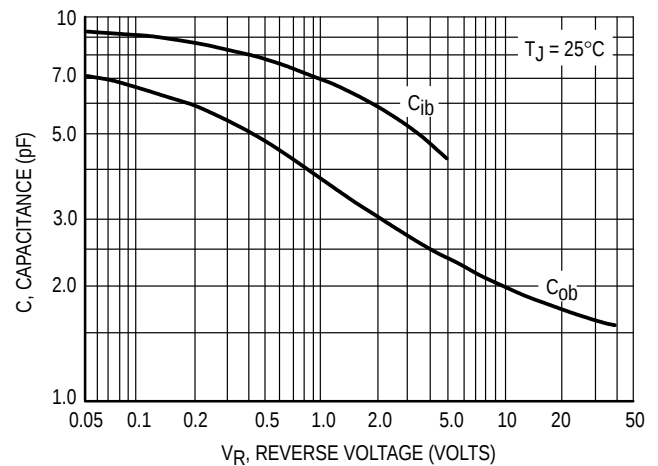


Figure 34. Capacitance

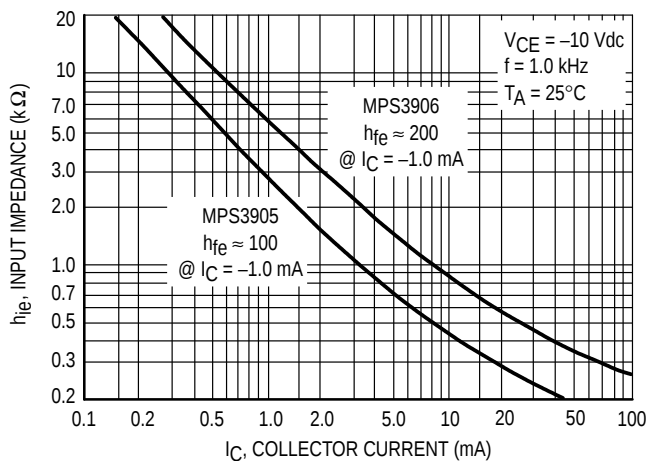


Figure 35. Input Impedance

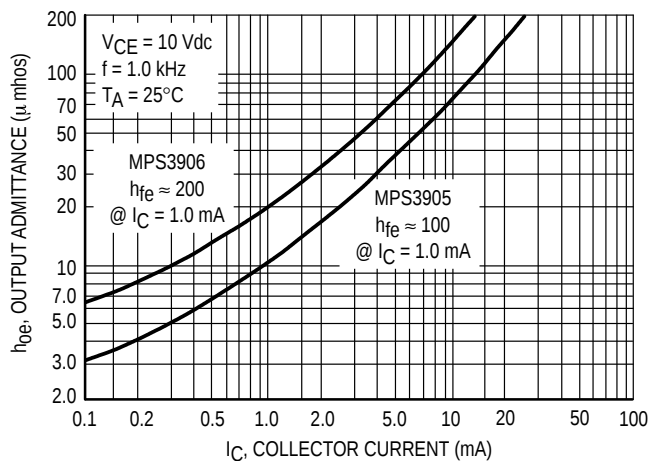


Figure 36. Output Admittance

PNP  
MPS6523

## TYPICAL DYNAMIC CHARACTERISTICS

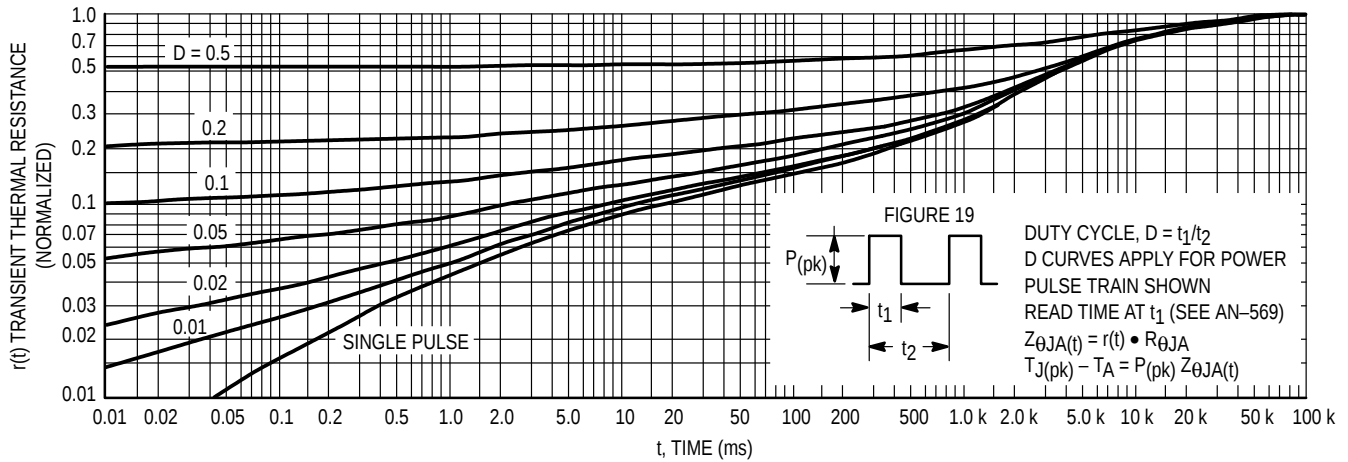


Figure 37. Thermal Response

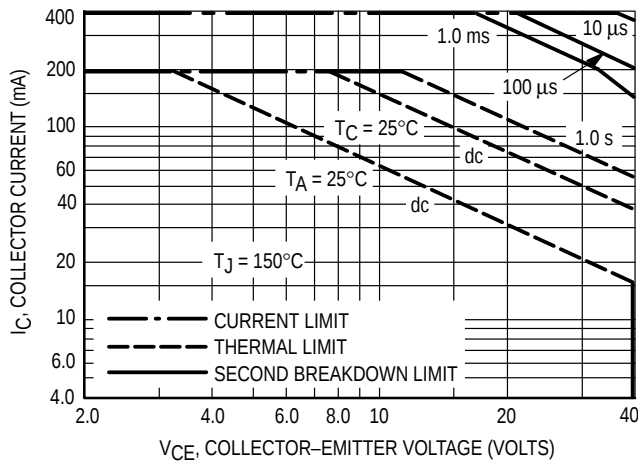


Figure 38. Active-Region Safe Operating Area

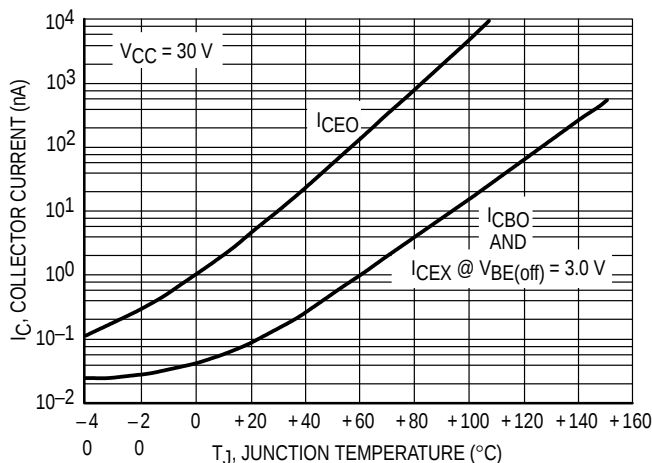


Figure 39. Typical Collector Leakage Current

The safe operating area curves indicate  $I_C$ - $V_{CE}$  limits of the transistor that must be observed for reliable operation. Collector load lines for specific circuits must fall below the limits indicated by the applicable curve.

The data of Figure 18 is based upon  $T_{J(pk)} = 150^\circ\text{C}$ ;  $T_C$  or  $T_A$  is variable depending upon conditions. Pulse curves are valid for duty cycles to 10% provided  $T_{J(pk)} \leq 150^\circ\text{C}$ .  $T_{J(pk)}$  may be calculated from the data in Figure 17. At high case or ambient temperatures, thermal limitations will reduce the power than can be handled to values less than the limitations imposed by second breakdown.

## DESIGN NOTE: USE OF THERMAL RESPONSE DATA

A train of periodical power pulses can be represented by the model as shown in Figure 19. Using the model and the device thermal response the normalized effective transient thermal resistance of Figure 17 was calculated for various duty cycles.

To find  $Z_{\theta JA}(t)$ , multiply the value obtained from Figure 17 by the steady state value  $R_{\theta JA}$ .

Example:

The MPS3905 is dissipating 2.0 watts peak under the following conditions:

$$t_1 = 1.0 \text{ ms}, t_2 = 5.0 \text{ ms} (D = 0.2)$$

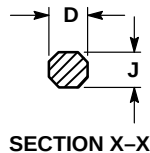
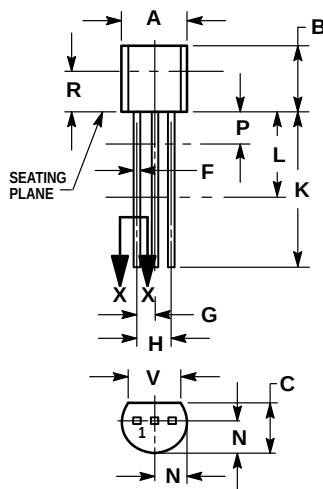
Using Figure 17 at a pulse width of 1.0 ms and  $D = 0.2$ , the reading of  $r(t)$  is 0.22.

The peak rise in junction temperature is therefore

$$\Delta T = r(t) \times P(pk) \times R_{\theta JA} = 0.22 \times 2.0 \times 200 = 88^\circ\text{C}.$$

For more information, see AN-569.

## PACKAGE DIMENSIONS



**CASE 029-04  
(TO-226AA)  
ISSUE AD**

## NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. CONTOUR OF PACKAGE BEYOND DIMENSION R IS UNCONTROLLED.
4. DIMENSION F APPLIES BETWEEN P AND L. DIMENSION D AND J APPLY BETWEEN L AND K. MINIMUM LEAD DIMENSION IS UNCONTROLLED IN P AND BEYOND DIMENSION K MINIMUM.

| DIM | INCHES |       | MILLIMETERS |      |
|-----|--------|-------|-------------|------|
|     | MIN    | MAX   | MIN         | MAX  |
| A   | 0.175  | 0.205 | 4.45        | 5.20 |
| B   | 0.170  | 0.210 | 4.32        | 5.33 |
| C   | 0.125  | 0.165 | 3.18        | 4.19 |
| D   | 0.016  | 0.022 | 0.41        | 0.55 |
| F   | 0.016  | 0.019 | 0.41        | 0.48 |
| G   | 0.045  | 0.055 | 1.15        | 1.39 |
| H   | 0.095  | 0.105 | 2.42        | 2.66 |
| J   | 0.015  | 0.020 | 0.39        | 0.50 |
| K   | 0.500  | —     | 12.70       | —    |
| L   | 0.250  | —     | 6.35        | —    |
| N   | 0.080  | 0.105 | 2.04        | 2.66 |
| P   | —      | 0.100 | —           | 2.54 |
| R   | 0.115  | —     | 2.93        | —    |
| V   | 0.135  | —     | 3.43        | —    |

## STYLE 1:

1. PIN 1. EMITTER
2. BASE
3. COLLECTOR

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