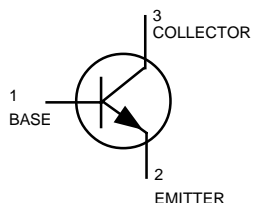


# General Purpose Transistors

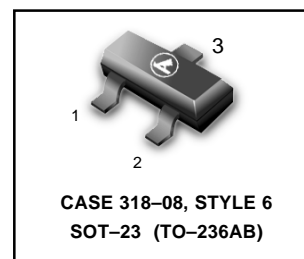
## NPN Silicon



**BCW60ALT1**  
**BCW60BLT1**  
**BCW60DLT1**

### MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector–Emitter Voltage	$V_{CEO}$	32	Vdc
Collector–Base Voltage	$V_{CBO}$	32	Vdc
Emitter–Base Voltage	$V_{EBO}$	5.0	Vdc
Collector Current — Continuous	$I_C$	100	mAdc



### THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Total Device Dissipation FR– 5 Board, (1) $T_A = 25^\circ\text{C}$ Derate above $25^\circ\text{C}$	$P_D$	225	mW
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	556	$^\circ\text{C}/\text{W}$
Total Device Dissipation Alumina Substrate, (2) $T_A = 25^\circ\text{C}$ Derate above $25^\circ\text{C}$	$P_D$	300	mW
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	417	$^\circ\text{C}/\text{W}$
Junction and Storage Temperature	$T_J, T_{stg}$	–55 to +150	$^\circ\text{C}$

### DEVICE MARKING

BCW60ALT1 = AA, BCW60BLT1 = AB, BCW60DLT1 = AD

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

Characteristic	Symbol	Min	Max	Unit
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### OFF CHARACTERISTICS

Collector–Emitter Breakdown Voltage ( $I_C = 2.0\text{mAdc}, I_E = 0$ )	$V_{(BR)CEO}$	32	—	Vdc
Emitter–Base Breakdown Voltage ( $I_E = 1.0\ \mu\text{Adc}, I_C = 0$ )	$V_{(BR)EBO}$	5.0	—	Vdc
Collector Cutoff Current ( $V_{CE} = 32\ \text{Vdc},$ ) ( $V_{CE} = 32\ \text{Vdc}, T_A = 150^\circ\text{C}$ )	$I_{CES}$	—	20	nAdc $\mu\text{Adc}$
Emitter Cutoff Current ( $I_{EB} = 4.0\ \text{Vdc}, I_C = 0$ )	$I_{EBO}$	—	20	nAdc

1. FR– 5 = 1.0 x 0.75 x 0.062 in.

2. Alumina = 0.4 x 0.3 x 0.024 in. 99.5% alumina.

**BCW60ALT1 BCW60BLT1 BCW60DLT1**

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

Characteristic	Symbol	Min	Max	Unit
<b>ON CHARACTERISTICS</b>				
DC Current Gain ( $I_C = 10 \mu\text{Adc}$ , $V_{CE} = 5.0 \text{ Vdc}$ )	$h_{FE}$			—
	BCW60A	20	—	
	BCW60B	30	—	
	BCW60D	100	—	
( $I_C = 2.0 \text{ mAdc}$ , $V_{CE} = 5.0 \text{ Vdc}$ )	$h_{FE}$			—
	BCW60A	120	220	
	BCW60B	175	310	
	BCW60D	380	630	
( $I_C = 50 \text{ mAdc}$ , $V_{CE} = 1.0 \text{ Vdc}$ )	$h_{FE}$			—
	BCW60A	60	—	
	BCW60B	70	—	
	BCW60D	100	—	
AC Current Gain ( $V_{CE} = 5.0 \text{ Vdc}$ , $I_C = 2.0 \text{ mAdc}$ , $f = 1.0 \text{ kHz}$ )	$h_{FE}$			—
	BCW60A	125	250	
	BCW60B	175	350	
	BCW60D	350	700	
Collector–Emitter Saturation Voltage ( $I_C = 50 \text{ mAdc}$ , $I_B = 1.25 \text{ mAdc}$ ) ( $I_C = 10 \text{ mAdc}$ , $I_B = 0.25 \text{ mAdc}$ )	$V_{CE(sat)}$			Vdc
		—	0.55	
		—	0.35	
Base–Emitter Saturation Voltage ( $I_C = 50 \text{ mAdc}$ , $I_B = 1.25 \text{ mAdc}$ ) ( $I_C = 50 \text{ mAdc}$ , $I_B = 0.25 \text{ mAdc}$ )	$V_{BE(sat)}$			Vdc
		0.7	1.05	
		0.6	0.85	
Base–Emitter On Voltage ( $I_C = 2.0 \text{ mAdc}$ , $V_{CE} = 5.0 \text{ Vdc}$ )	$V_{BE(on)}$			Vdc
		0.6	0.75	

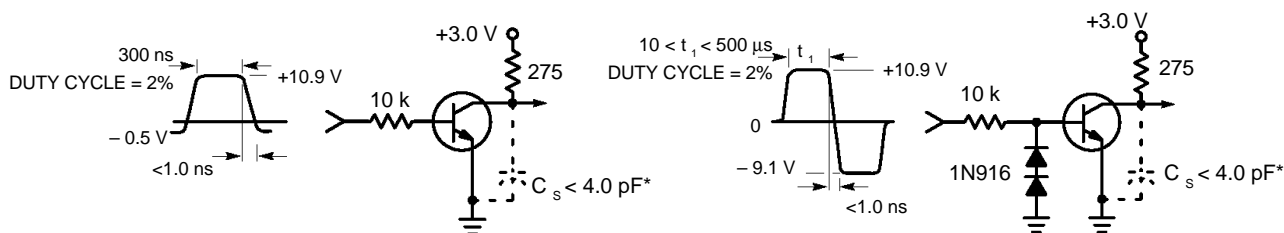
**SMSMALL–SIGNAL CHARACTERISTICS**

Current–Gain — Bandwidth Product ( $I_C = 10 \text{ mAdc}$ , $V_{CE} = 5.0 \text{ Vdc}$ , $f = 100 \text{ MHz}$ )	$f_T$	125	—	MHz
Output Capacitance ( $V_{CE} = 10 \text{ Vdc}$ , $I_C = 0$ , $f = 1.0 \text{ MHz}$ )	$C_{obo}$	—	4.5	pF
Noise Figure ( $V_{CE} = 5.0 \text{ Vdc}$ , $I_C = 0.2 \text{ mAdc}$ , $R_S = 2.0 \text{ k}\Omega$ , $f = 1.0 \text{ kHz}$ , $BW = 200 \text{ Hz}$ )	NF	—	6.0	dB

**SWITCHING CHARACTERISTICS**

Turn–On Time ( $I_C = 10 \text{ mAdc}$ , $I_{B1} = 1.0 \text{ mAdc}$ )	$t_{on}$	—	150	ns
Turn–Off Time ( $I_{B2} = 1.0 \text{ mAdc}$ , $V_{BB} = 3.6 \text{ Vdc}$ , $R_1 = R_2 = 5.0 \text{ k}\Omega$ , $R_L = 990 \Omega$ )	$t_{off}$	—	800	ns

**EQUIVALENT SWITCHING TIME TEST CIRCUITS**



\*Total shunt capacitance of test jig and connectors

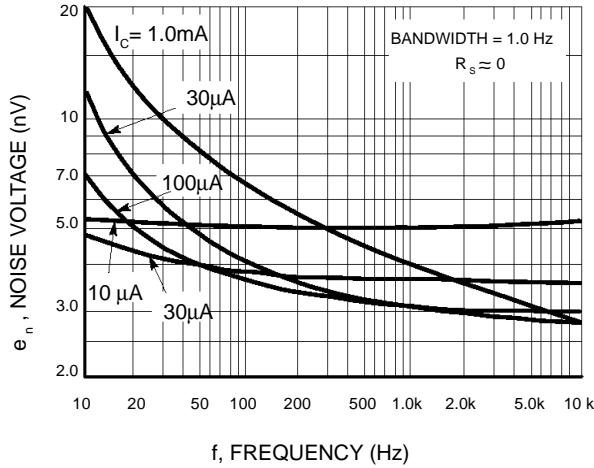
Figure 1. Turn–On Time

Figure 2. Turn–Off Time

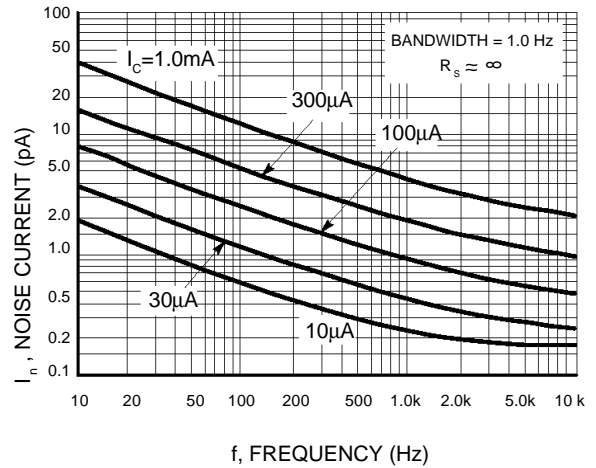
**BCW60ALT1 BCW60BLT1 BCW60DLT1**

**TYPICAL NOISE CHARACTERISTICS**

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



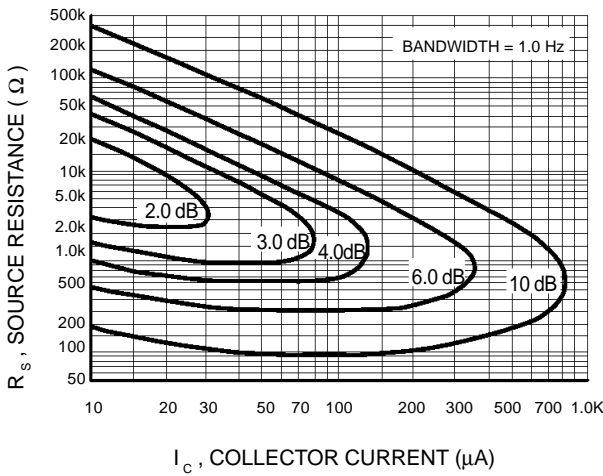
**Figure 3. Noise Voltage**



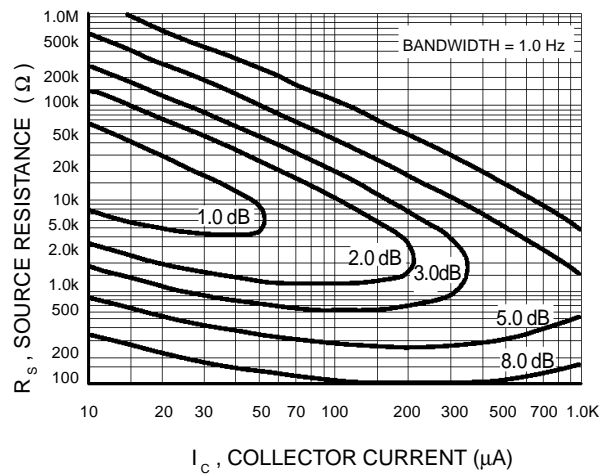
**Figure 4. Noise Current**

**NOISE FIGURE CONTOURS**

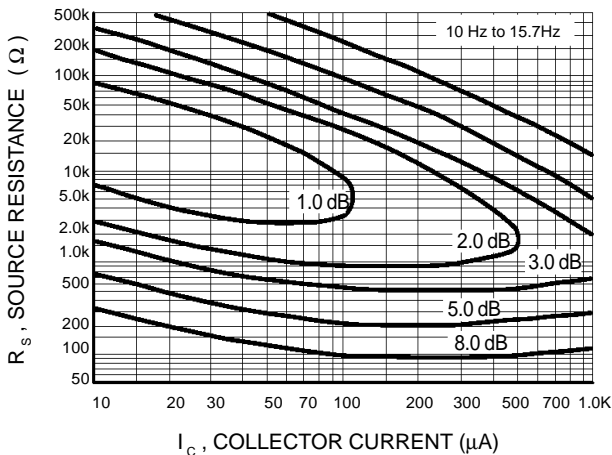
( $V_{CE} = 5.0 \text{ Vdc}$ ,  $T_A = 25^\circ\text{C}$ )



**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 ( $\Omega$ )

BCW60ALT1 BCW60BLT1 BCW60DLT1

TYPICAL NOISE CHARACTERISTICS

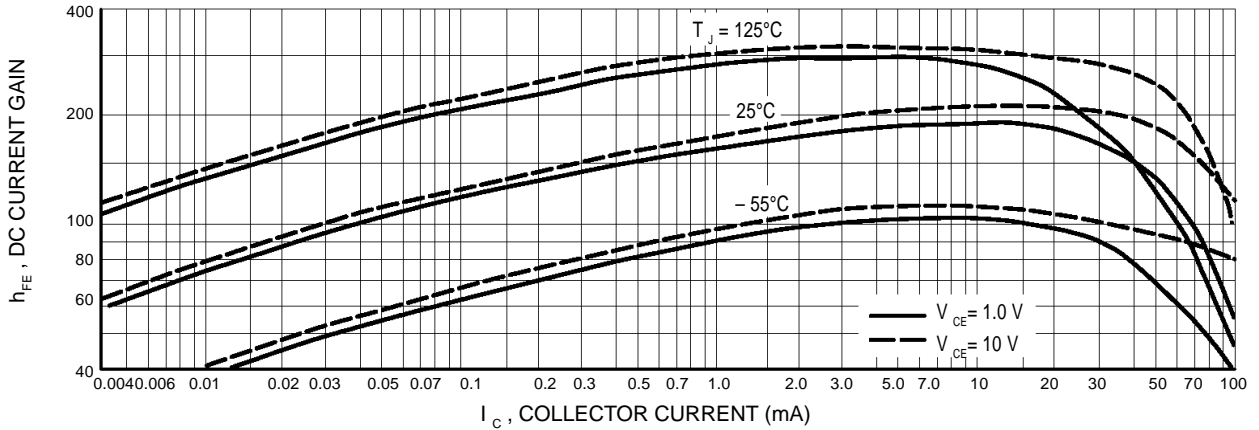


Figure 8. DC Current Gain

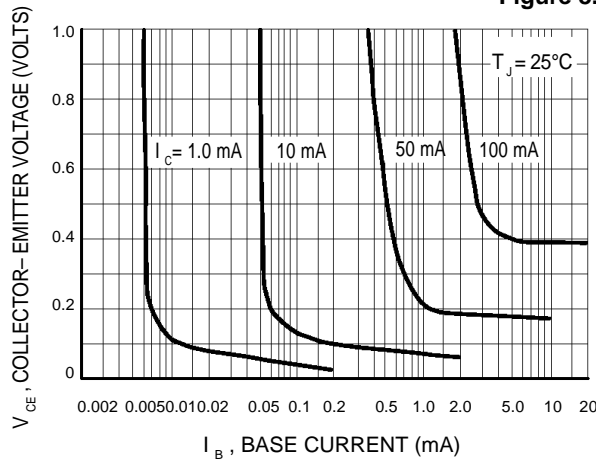


Figure 9. Collector Saturation Region

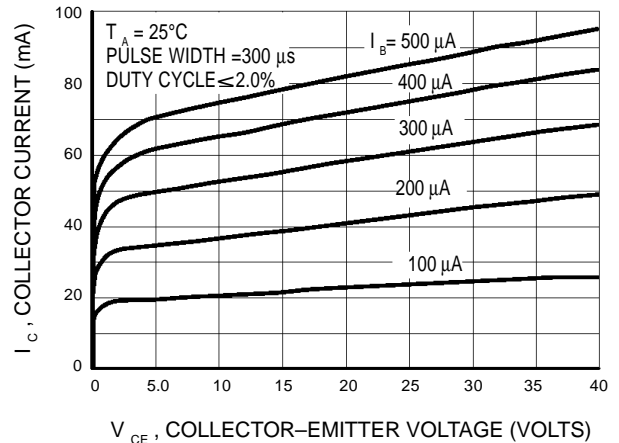


Figure 10. Collector Characteristics

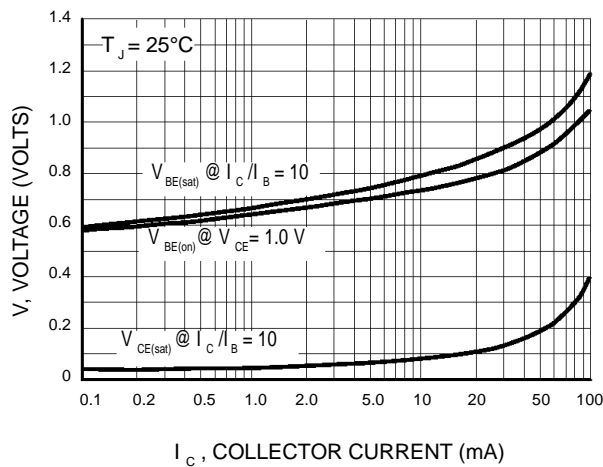


Figure 11. "On" Voltages

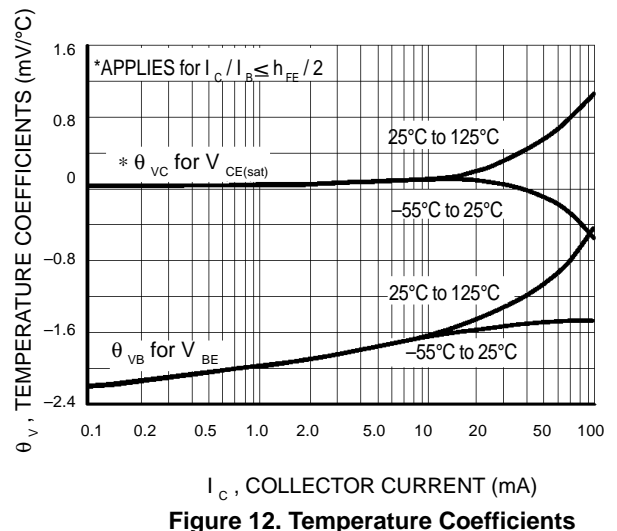
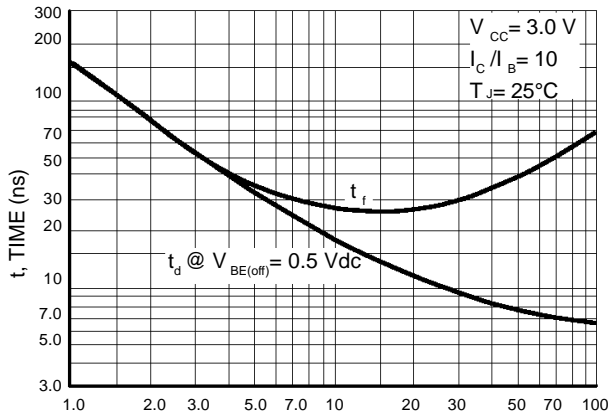


Figure 12. Temperature Coefficients

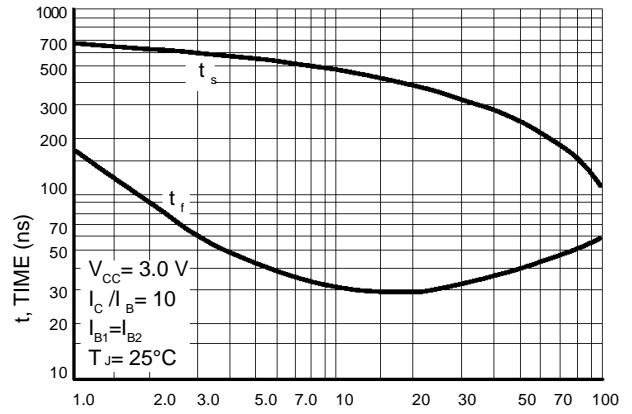
BCW60ALT1 BCW60BLT1 BCW60DLT1

TYPICAL DYNAMIC CHARACTERISTICS



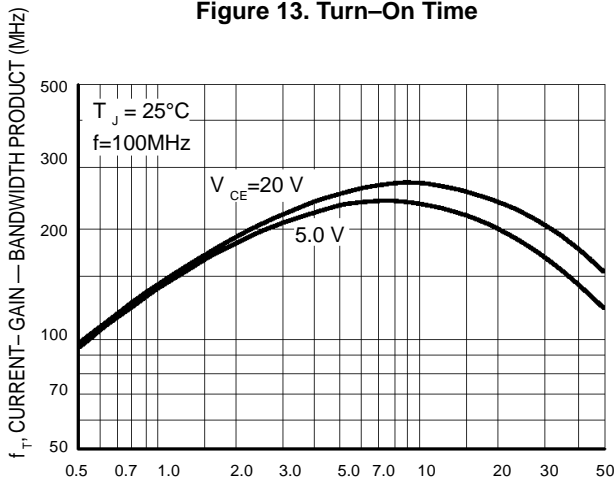
$I_C$ , COLLECTOR CURRENT (mA)

Figure 13. Turn-On Time



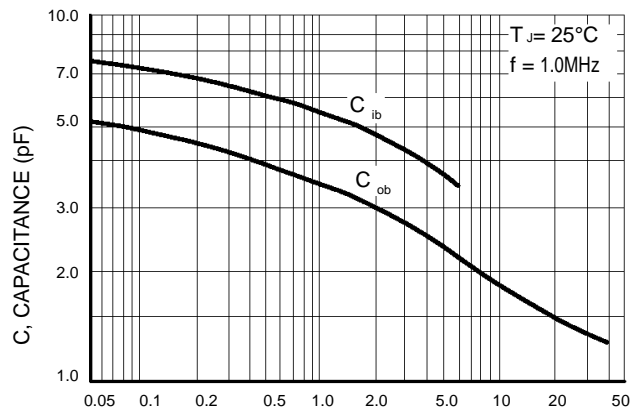
$I_C$ , COLLECTOR CURRENT (mA)

Figure 14. Turn-Off Time



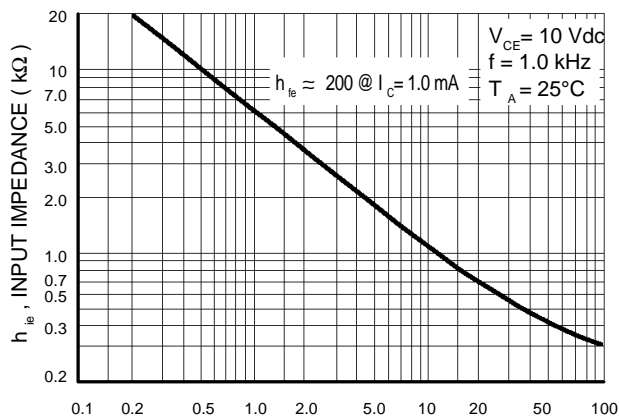
$I_C$ , COLLECTOR CURRENT (mA)

Figure 15. Current-Gain — Bandwidth Product



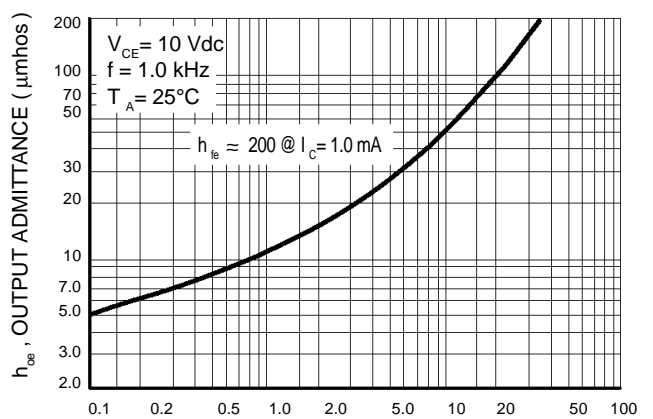
$V_R$ , REVERSE VOLTAGE (VOLTS)

Figure 16. Capacitance



$I_C$ , COLLECTOR CURRENT (mA)

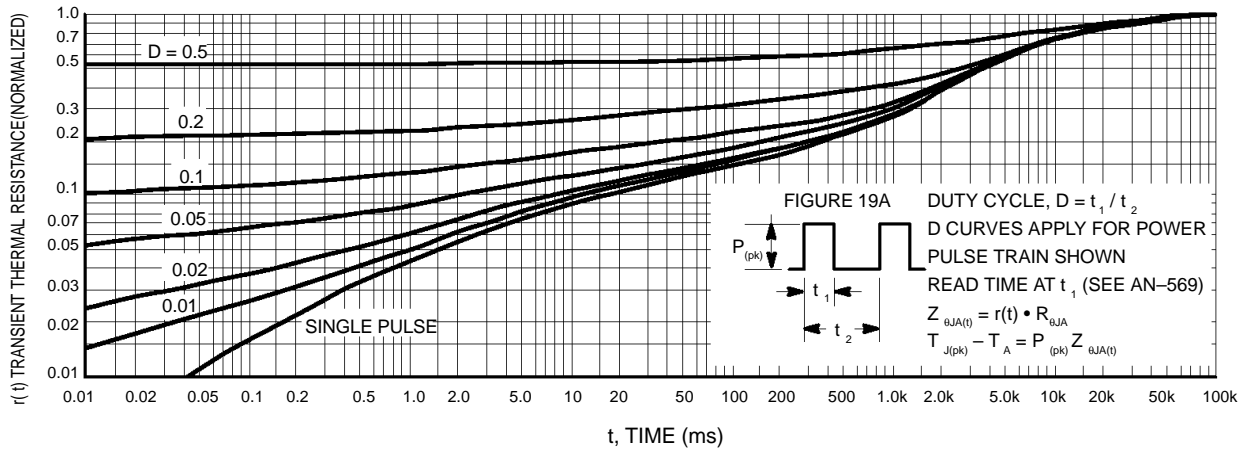
Figure 17. Input Impedance



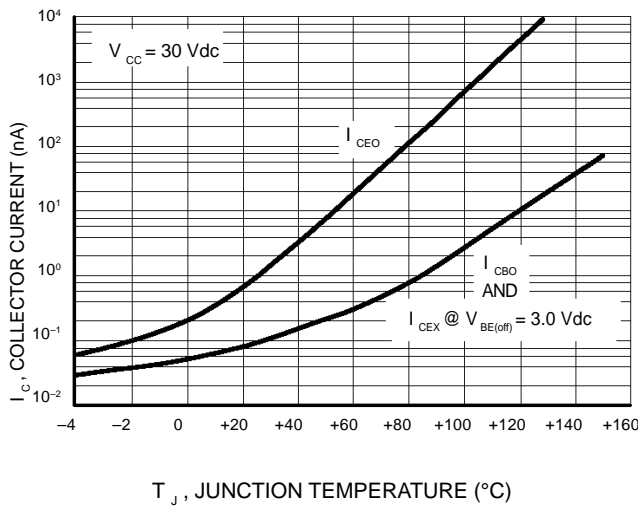
$I_C$ , COLLECTOR CURRENT (mA)

Figure 18. Output Admittance

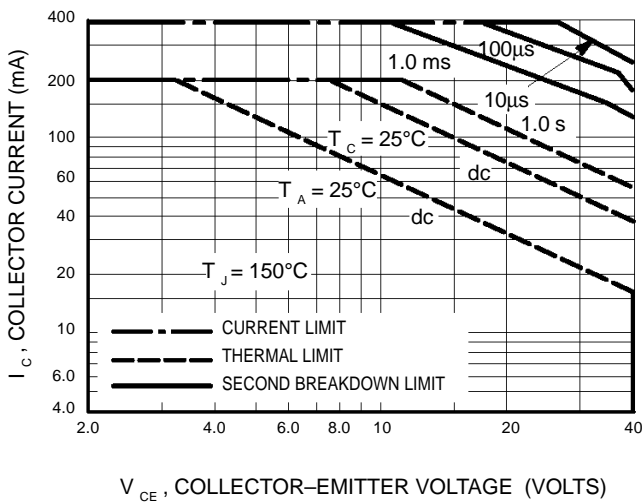
**BCW60ALT1 BCW60BLT1 BCW60DLT1**



**Figure 19. Thermal Response**



**Figure 19A.**



**Figure 20.**

**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:

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

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.

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.