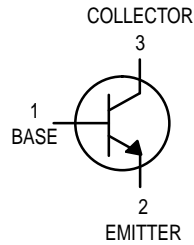
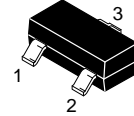


# General Purpose Transistors

## NPN Silicon



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



CASE 318-08, STYLE 6  
SOT-23 (TO-236AB)

### MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector–Emitter Voltage	$V_{CE0}$	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 <sup>(1)</sup> $T_A = 25^\circ\text{C}$ Derate above $25^\circ\text{C}$	$P_D$	225	mW
		1.8	mW/ $^\circ\text{C}$
Thermal Resistance Junction to Ambient	$R_{\theta JA}$	556	$^\circ\text{C/W}$
Total Device Dissipation Alumina Substrate, <sup>(2)</sup> $T_A = 25^\circ\text{C}$ Derate above $25^\circ\text{C}$	$P_D$	300	mW
		2.4	mW/ $^\circ\text{C}$
Thermal Resistance Junction to Ambient	$R_{\theta JA}$	417	$^\circ\text{C/W}$
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 ( $I_C = 2.0 \text{ mAdc}, I_E = 0$ )	$V_{(BR)CE0}$	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 ( $V_{EB} = 4.0 \text{ Vdc}, I_C = 0$ )	$I_{EBO}$	—	20	nAdc

- FR-5 =  $1.0 \times 0.75 \times 0.062 \text{ in.}$
- Alumina =  $0.4 \times 0.3 \times 0.024 \text{ in.}$  99.5% alumina.

Thermal Clad is a trademark of the Bergquist Company

# BCW60ALT1 BCW60BLT1 BCW60DLT1

## ELECTRICAL CHARACTERISTICS (T<sub>A</sub> = 25°C unless otherwise noted) (Continued)

Characteristic	Symbol	Min	Max	Unit
<b>ON CHARACTERISTICS</b>				
DC Current Gain (I <sub>C</sub> = 10 μAdc, V <sub>CE</sub> = 5.0 Vdc)	h <sub>FE</sub>	20	—	—
	BCW60A	30	—	
	BCW60B	100	—	
(I <sub>C</sub> = 2.0 mAdc, V <sub>CE</sub> = 5.0 Vdc)	BCW60A	120	220	
	BCW60B	175	310	
	BCW60D	380	630	
(I <sub>C</sub> = 50 mAdc, V <sub>CE</sub> = 1.0 Vdc)	BCW60A	60	—	
	BCW60B	70	—	
	BCW60D	100	—	
AC Current Gain (V <sub>CE</sub> = 5.0 Vdc, I <sub>C</sub> = 2.0 mAdc, f = 1.0 kHz)	h <sub>fe</sub>	125	250	—
	BCW60A	175	350	
	BCW60D	350	700	
Collector–Emitter Saturation Voltage (I <sub>C</sub> = 50 mAdc, I <sub>B</sub> = 1.25 mAdc) (I <sub>C</sub> = 10 mAdc, I <sub>B</sub> = 0.25 mAdc)	V <sub>CE(sat)</sub>	—	0.55 0.35	Vdc
Base–Emitter Saturation Voltage (I <sub>C</sub> = 50 mAdc, I <sub>B</sub> = 1.25 mAdc) (I <sub>C</sub> = 50 mAdc, I <sub>B</sub> = 0.25 mAdc)	V <sub>BE(sat)</sub>	0.7 0.6	1.05 0.85	Vdc
Base–Emitter On Voltage (I <sub>C</sub> = 2.0 mAdc, V <sub>CE</sub> = 5.0 Vdc)	V <sub>BE(on)</sub>	0.6	0.75	Vdc

## SMALL–SIGNAL CHARACTERISTICS

Current–Gain — Bandwidth Product (I <sub>C</sub> = 10 mAdc, V <sub>CE</sub> = 5.0 Vdc, f = 100 MHz)	f <sub>T</sub>	125	—	MHz
Output Capacitance (V <sub>CE</sub> = 10 Vdc, I <sub>C</sub> = 0, f = 1.0 MHz)	C <sub>obo</sub>	—	4.5	pF
Noise Figure (V <sub>CE</sub> = 5.0 Vdc, I <sub>C</sub> = 0.2 mAdc, R <sub>S</sub> = 2.0 kΩ, f = 1.0 kHz, BW = 200 Hz)	NF	—	6.0	dB

## SWITCHING CHARACTERISTICS

Turn–On Time (I <sub>C</sub> = 10 mAdc, I <sub>B1</sub> = 1.0 mAdc)	t <sub>on</sub>	—	150	ns
Turn–Off Time (I <sub>B2</sub> = 1.0 mAdc, V <sub>BB</sub> = 3.6 Vdc, R <sub>1</sub> = R <sub>2</sub> = 5.0 kΩ, R <sub>L</sub> = 990 Ω)	t <sub>off</sub>	—	800	ns

## EQUIVALENT SWITCHING TIME TEST CIRCUITS

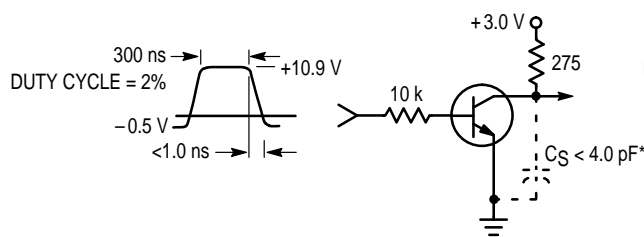


Figure 1. Turn–On Time

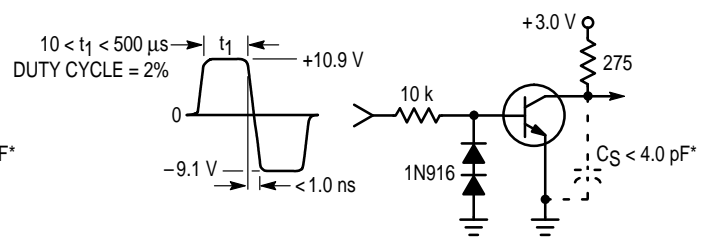
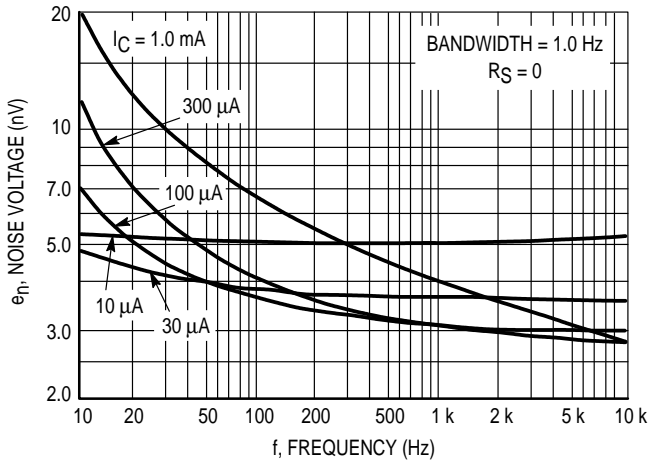


Figure 2. Turn–Off Time

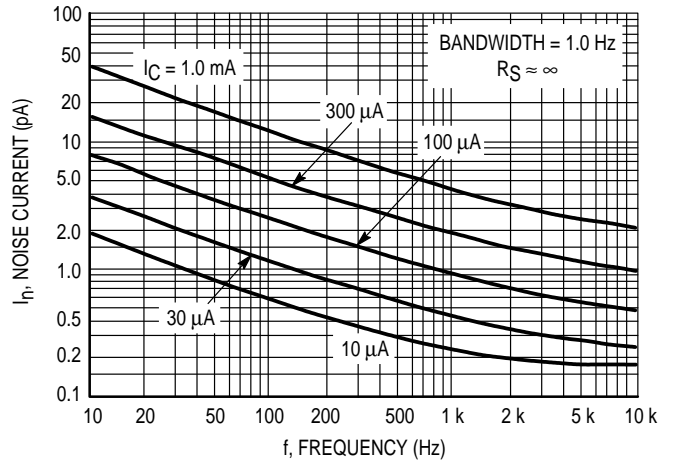
\*Total shunt capacitance of test jig and connectors

**TYPICAL NOISE CHARACTERISTICS**

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



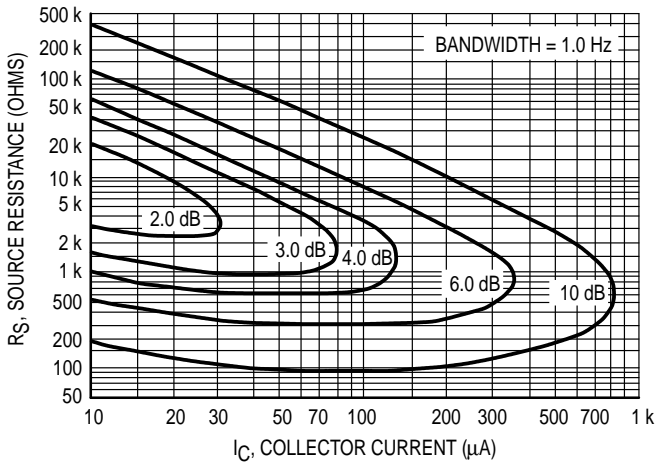
**Figure 3. Noise Voltage**



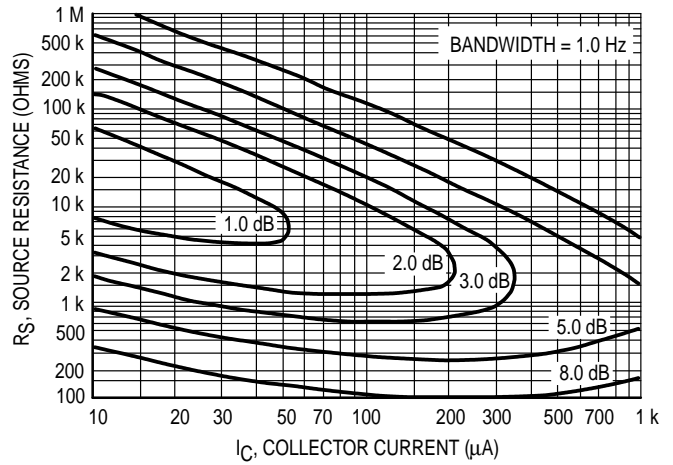
**Figure 4. Noise Current**

**NOISE FIGURE CONTOURS**

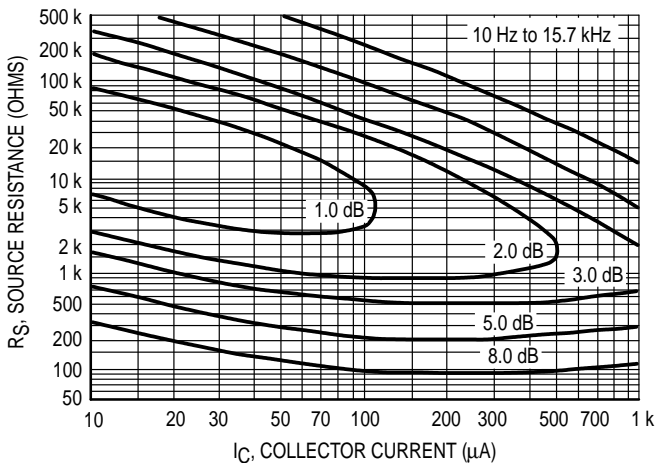
( $V_{CE} = 5.0 \text{ Vdc}$ ,  $T_A = 25^\circ\text{C}$ )



**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 (Ohms)

TYPICAL STATIC CHARACTERISTICS

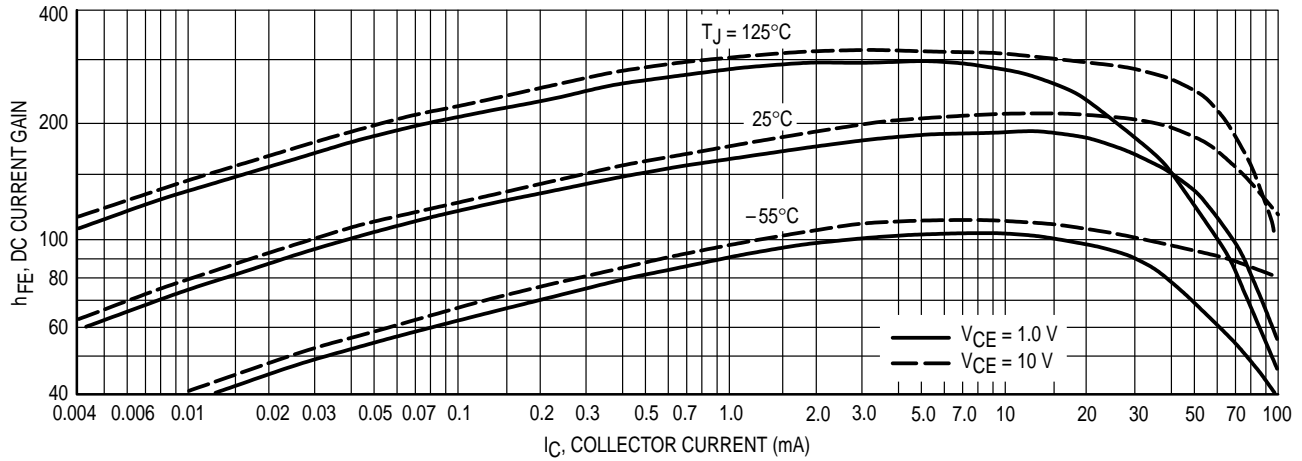


Figure 8. DC Current Gain

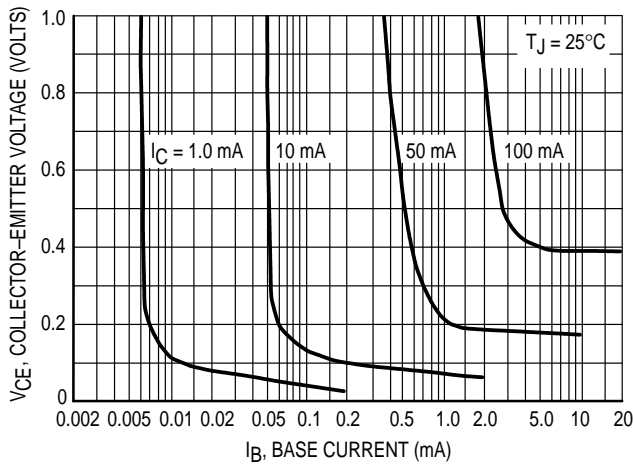


Figure 9. Collector Saturation Region

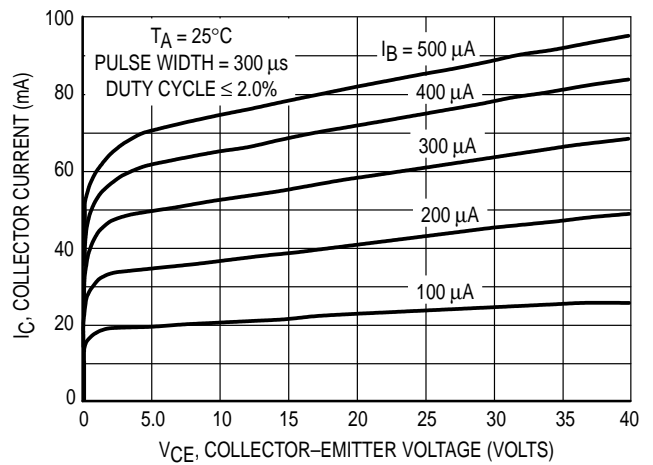


Figure 10. Collector Characteristics

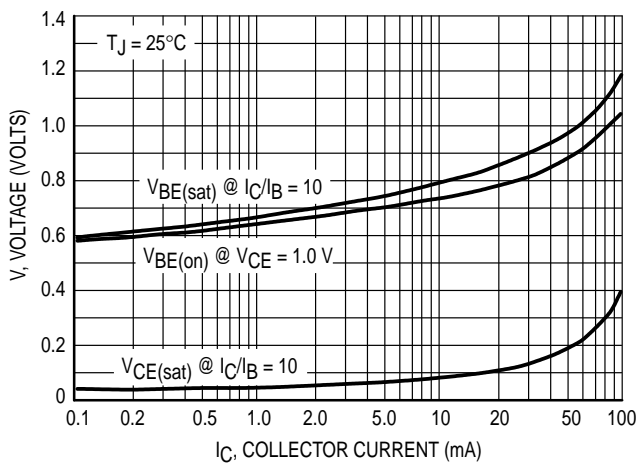


Figure 11. "On" Voltages

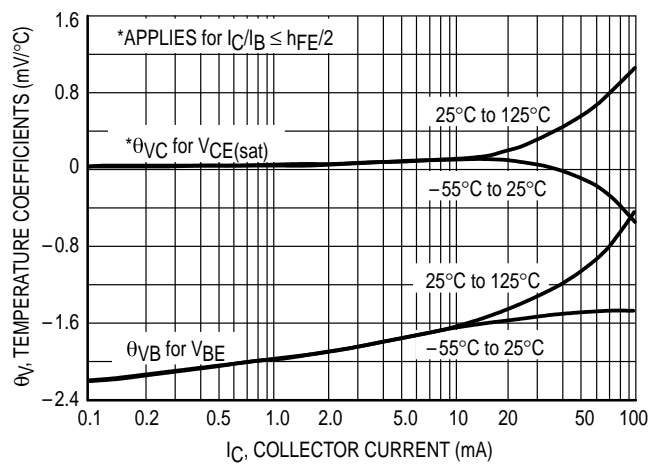


Figure 12. Temperature Coefficients

TYPICAL DYNAMIC CHARACTERISTICS

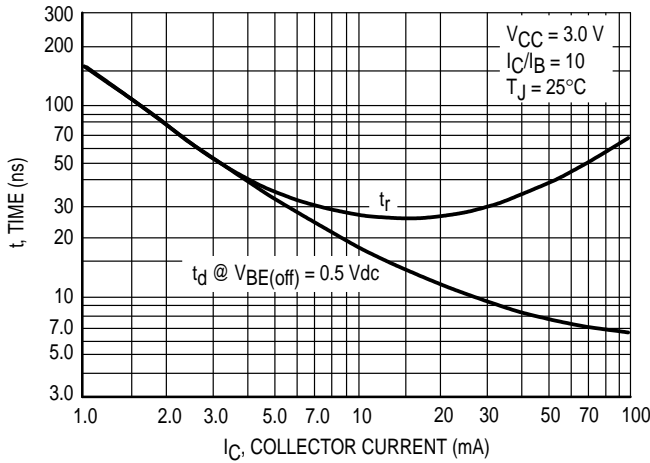


Figure 13. Turn-On Time

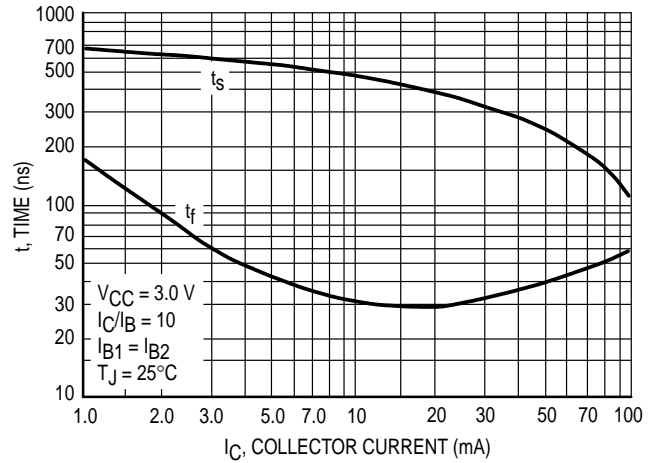


Figure 14. Turn-Off Time

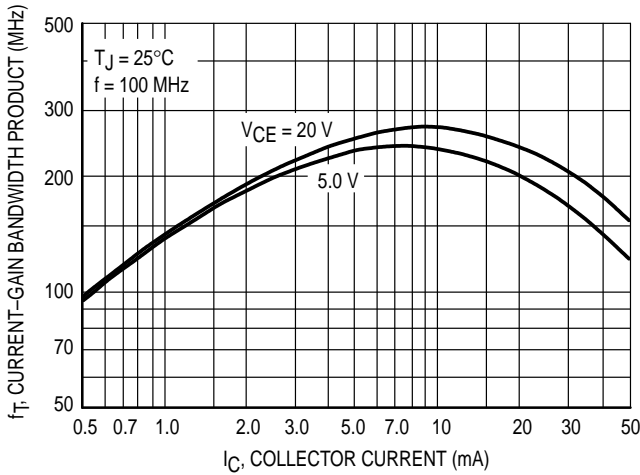


Figure 15. Current-Gain — Bandwidth Product

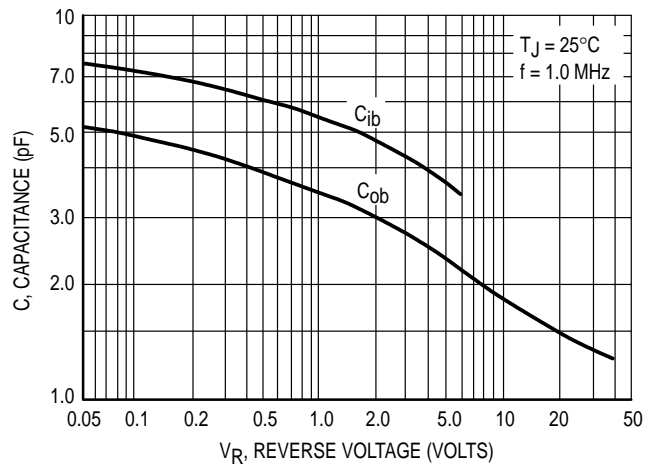


Figure 16. Capacitance

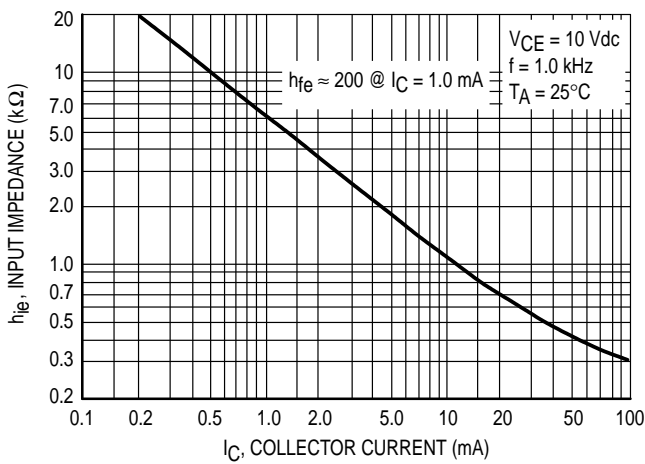


Figure 17. Input Impedance

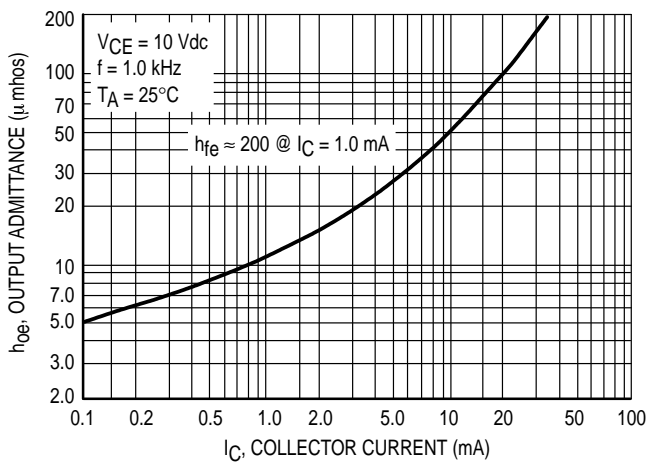
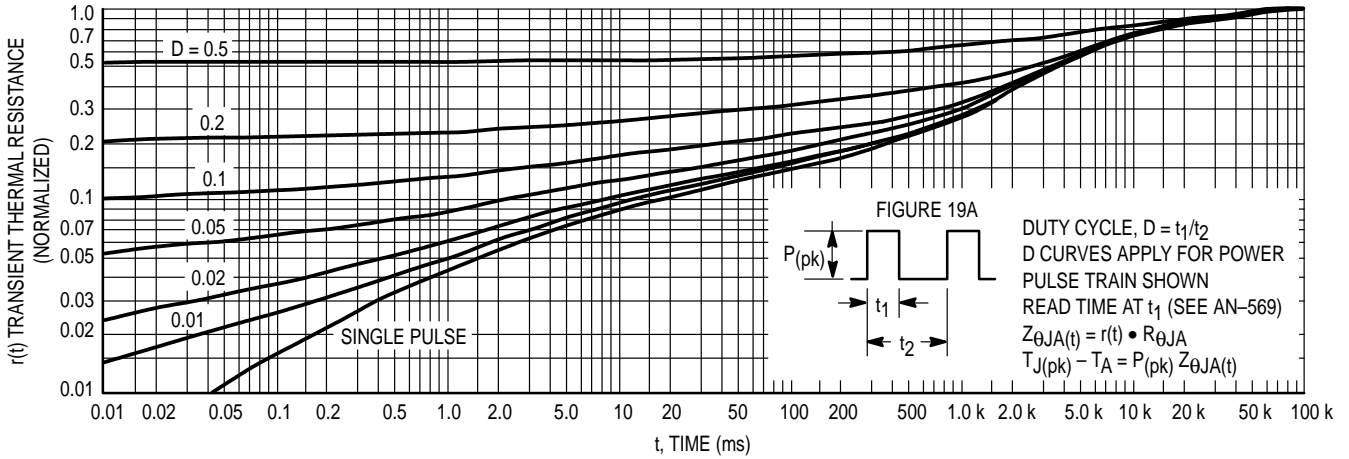
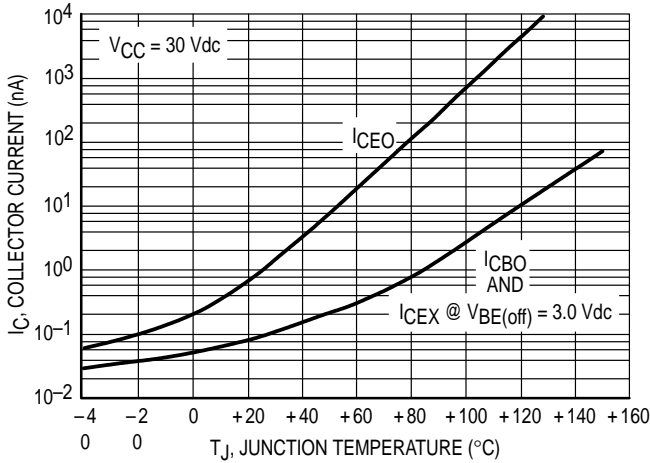


Figure 18. Output Admittance

**BCW60ALT1 BCW60BLT1 BCW60DLT1**



**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:

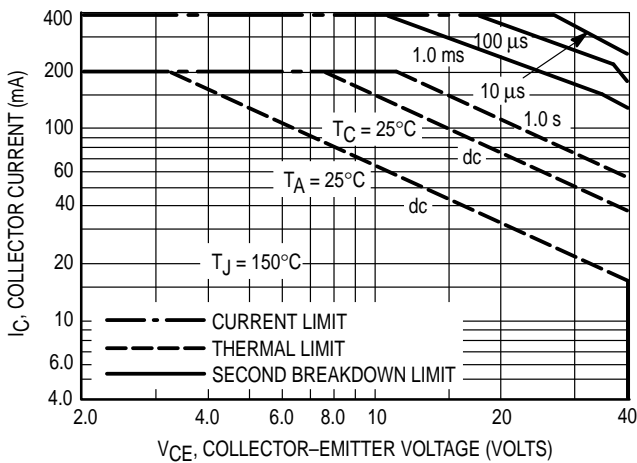
$t_1 = 1.0$  ms,  $t_2 = 5.0$  ms. ( $D = 0.2$ )

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.

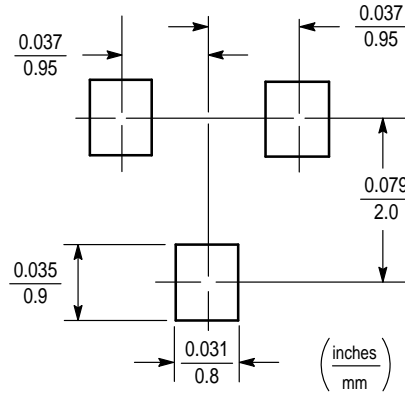
The data of Figure 20 is based upon  $T_{J(pk)} = 150^\circ\text{C}$ ;  $T_C$  or  $T_A$  is variable depending upon conditions. Pulse curves are valid for duty cycles to 10% provided  $T_{J(pk)} \leq 150^\circ\text{C}$ .  $T_{J(pk)}$  may be calculated from the data in Figure 19. At high case or ambient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

INFORMATION FOR USING THE SOT-23 SURFACE MOUNT PACKAGE

MINIMUM RECOMMENDED FOOTPRINT FOR SURFACE MOUNTED APPLICATIONS

Surface mount board layout is a critical portion of the total design. The footprint for the semiconductor packages must be the correct size to insure proper solder connection

interface between the board and the package. With the correct pad geometry, the packages will self align when subjected to a solder reflow process.



SOT-23

SOT-23 POWER DISSIPATION

The power dissipation of the SOT-23 is a function of the pad size. This can vary from the minimum pad size for soldering to a pad size given for maximum power dissipation. Power dissipation for a surface mount device is determined by  $T_{J(max)}$ , the maximum rated junction temperature of the die,  $R_{\theta JA}$ , the thermal resistance from the device junction to ambient, and the operating temperature,  $T_A$ . Using the values provided on the data sheet for the SOT-23 package,  $P_D$  can be calculated as follows:

$$P_D = \frac{T_{J(max)} - T_A}{R_{\theta JA}}$$

The values for the equation are found in the maximum ratings table on the data sheet. Substituting these values into the equation for an ambient temperature  $T_A$  of 25°C, one can calculate the power dissipation of the device which in this case is 225 milliwatts.

$$P_D = \frac{150^\circ\text{C} - 25^\circ\text{C}}{556^\circ\text{C/W}} = 225 \text{ milliwatts}$$

The 556°C/W for the SOT-23 package assumes the use of the recommended footprint on a glass epoxy printed circuit board to achieve a power dissipation of 225 milliwatts. There are other alternatives to achieving higher power dissipation from the SOT-23 package. Another alternative would be to use a ceramic substrate or an aluminum core board such as Thermal Clad™. Using a board material such as Thermal Clad, an aluminum core board, the power dissipation can be doubled using the same footprint.

SOLDERING PRECAUTIONS

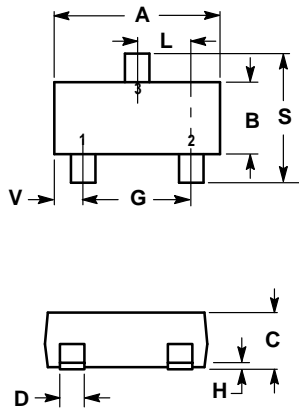
The melting temperature of solder is higher than the rated temperature of the device. When the entire device is heated to a high temperature, failure to complete soldering within a short time could result in device failure. Therefore, the following items should always be observed in order to minimize the thermal stress to which the devices are subjected.

- Always preheat the device.
- The delta temperature between the preheat and soldering should be 100°C or less.\*
- When preheating and soldering, the temperature of the leads and the case must not exceed the maximum temperature ratings as shown on the data sheet. When using infrared heating with the reflow soldering method, the difference shall be a maximum of 10°C.
- The soldering temperature and time shall not exceed 260°C for more than 10 seconds.
- When shifting from preheating to soldering, the maximum temperature gradient shall be 5°C or less.
- After soldering has been completed, the device should be allowed to cool naturally for at least three minutes. Gradual cooling should be used as the use of forced cooling will increase the temperature gradient and result in latent failure due to mechanical stress.
- Mechanical stress or shock should not be applied during cooling.

\* Soldering a device without preheating can cause excessive thermal shock and stress which can result in damage to the device.

**BCW60ALT1 BCW60BLT1 BCW60DLT1**

**PACKAGE DIMENSIONS**



- NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
  2. CONTROLLING DIMENSION: INCH.
  3. MAXIMUM LEAD THICKNESS INCLUDES LEAD FINISH THICKNESS. MINIMUM LEAD THICKNESS IS THE MINIMUM THICKNESS OF BASE MATERIAL.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.1102	0.1197	2.80	3.04
B	0.0472	0.0551	1.20	1.40
C	0.0350	0.0440	0.89	1.11
D	0.0150	0.0200	0.37	0.50
G	0.0701	0.0807	1.78	2.04
H	0.0005	0.0040	0.013	0.100
J	0.0034	0.0070	0.085	0.177
K	0.0180	0.0236	0.45	0.60
L	0.0350	0.0401	0.89	1.02
S	0.0830	0.0984	2.10	2.50
V	0.0177	0.0236	0.45	0.60

- STYLE 6:
- PIN 1. BASE
  - EMITTER
  - COLLECTOR

**CASE 318-08  
ISSUE AE  
SOT-23 (TO-236AB)**

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