TYPES 2N2987 THRU 2N2994
BULLETIN NO. DL-S 6810508, DECEMBER 1968

TYPES 2N2987 THRU 2N2994
N-P-N TRIPLE-DIFFUSED PLANAR SILICON POWER TRANSISTORS

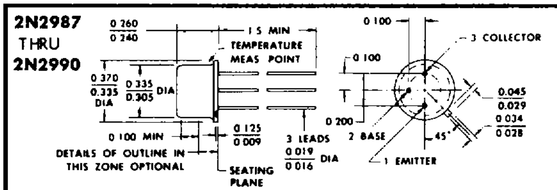
5

HIGH-FREQUENCY INTERMEDIATE-POWER TRANSISTORS

- **15 Watts at 100°C Case Temperature**
- **Typ $V_{CE(sat)}$ of 0.2 V at 200 mA**
- **Typ V_{BE} of 0.8 V at 200 mA**
- **Typ f_T of 50 MHz at 10 V, 100 mA**

*mechanical data

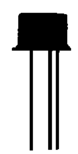
2N2987 THRU 2N2990



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE

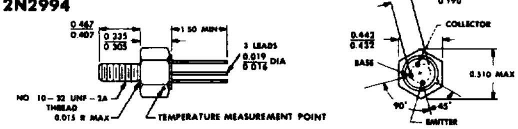
ALL JEDEC TO-5 DIMENSIONS AND NOTES ARE APPLICABLE

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



CASE TEMPERATURE IS MEASURED 0.144 INCH ± 0.010 INCH DOWN FROM TOP OF CAN

2N2991 THRU 2N2994

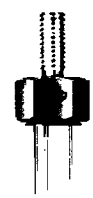


THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE

POSITION OF THE LEADS IN RELATION TO THE HEX IS NOT CONTROLLED

MAXIMUM RECOMMENDED MOUNTING TORQUE: 15 IN.-LB.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N2987 2N2989	2N2988 2N2990	2N2991 2N2993	2N2992 2N2994
* Collector-Base Voltage	95 V	155 V	95 V	155 V
* Collector-Emitter Voltage (See Note 1)	80 V	100 V	80 V	100 V
* Emitter-Base Voltage	← 7 V →			
* Continuous Collector Current	← 1 A →			
Peak Collector Current (See Note 2)	← 1.5 A →			
* Continuous Base Current	← 0.2 A →			
Safe Operating Region at (or below) 100°C Case Temperature	See Figure 10			
* Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	← 15 W →			
* Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 1 W →		← 2 W →	
* Operating Case Temperature Range	← −65°C to 200°C →			
* Storage Temperature Range	← −65°C to 200°C →			
* Lead Temperature 1/16 Inch from Case for 10 Seconds	← 230°C →			

NOTES: 1. This value applies between 1 mA and 30 mA collector current when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 150 mW/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 5.7 mW/deg for the 2N2987 through 2N2990 and 11.4 mW/deg for the 2N2991 through 2N2994.

*Indicates JEDEC registered data

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*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N2987 2N2991 MIN	2N2987 2N2991 MAX	2N2988 2N2992 MIN	2N2988 2N2992 MAX	2N2989 2N2993 MIN	2N2989 2N2993 MAX	2N2990 2N2994 MIN	2N2990 2N2994 MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$, See Note 5	80		100		80		100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 50$ V, $I_B = 0$		0.1				0.1			μA
		$V_{CE} = 90$ V, $I_B = 0$				0.1				0.1	μA
I_{CEV}	Collector Cutoff Current	$V_{CE} = 90$ V, $V_{BE} = -1.5$ V		25				25			nA
		$V_{CE} = 150$ V, $V_{BE} = -1.5$ V				25				25	nA
		$V_{CE} = 90$ V, $V_{BE} = -1.5$ V, $T_C = 175°C$		15				15			μA
		$V_{CE} = 150$ V, $V_{BE} = -1.5$ V, $T_C = 175°C$				15				15	μA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 7$ V, $I_C = 0$		25		25		25		25	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 1$ mA	20		20		40		40		
		$V_{CE} = 5$ V, $I_C = 200$ mA, See Notes 5 and 6	25	75	25	75	60	120	60	120	
		$V_{CE} = 5$ V, $I_C = 500$ mA, See Notes 5 and 6	20		20		40		40		
		$V_{CE} = 10$ V, $I_C = 100$ mA, See Notes 5 and 6	25		25		50		50		
		$V_{CE} = 5$ V, $I_C = 200$ mA, $T_C = -55°C$, See Notes 5 and 6	10		10		20		20		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 5$ V, $I_C = 200$ mA, See Notes 5 and 6		0.9		0.9		0.9		0.9	V
		$I_B = 20$ mA, $I_C = 200$ mA, See Notes 5 and 6		1		1		1		1	V
		$I_B = 50$ mA, $I_C = 500$ mA, See Notes 5 and 6		1.4		1.4		1.4		1.4	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 20$ mA, $I_C = 200$ mA, See Notes 5 and 6		0.8		0.8		0.8		0.8	V
		$I_B = 50$ mA, $I_C = 500$ mA, See Notes 5 and 6		3		3		3		3	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 100$ mA, $f = 1$ kHz	25	85	25	85	50	170	50	170	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 100$ mA, $f = 30$ MHz	1		1		1		1		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ V, $I_E = 0$, $f = 1$ MHz		50		50		50		50	pF

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300$ μs, duty cycle $\leq 2\%$.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

*Indicates JEDEC registered data

thermal characteristics

PARAMETER		2N2987 THRU 2N2990 MAX	2N2991 THRU 2N2994 MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	6.67	6.67	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	175	87.5	deg/W

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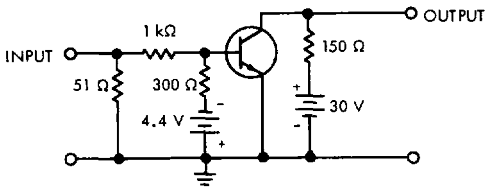
switching characteristics at 25°C case temperature

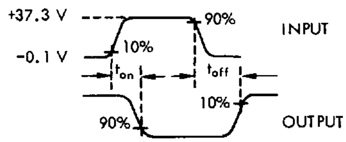
PARAMETER	TEST CONDITIONS†	TYP	UNIT
t_{on} Turn-On Time	I_C = 200 mA, $I_{B(1)}$ = 20 mA, $I_{B(2)}$ = −20 mA,	0.14	μs
t_{off} Turn-Off Time	$V_{BE(off)}$ = −3.4 V, R_L = 150 Ω, See Figure 1	2.6	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle ≤ 2%.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

TYPICAL CHARACTERISTICS

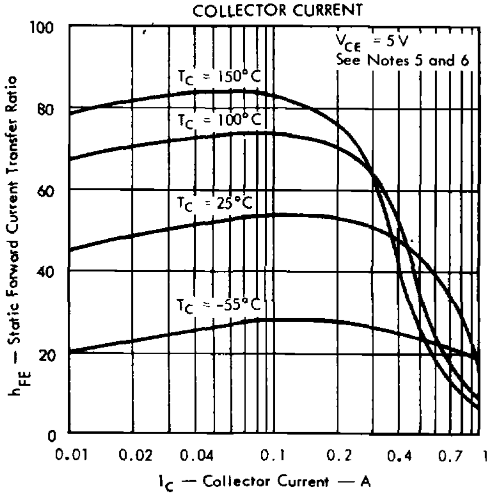


FIGURE 2

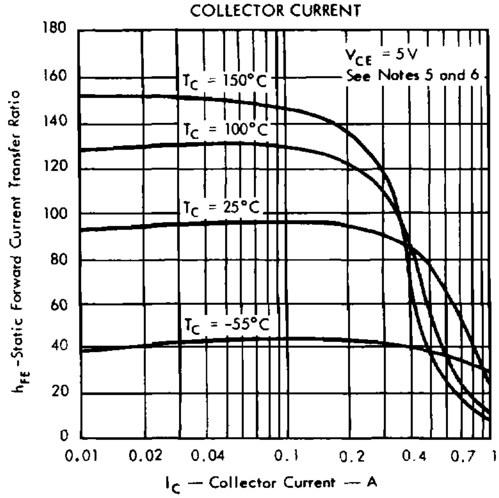


FIGURE 3

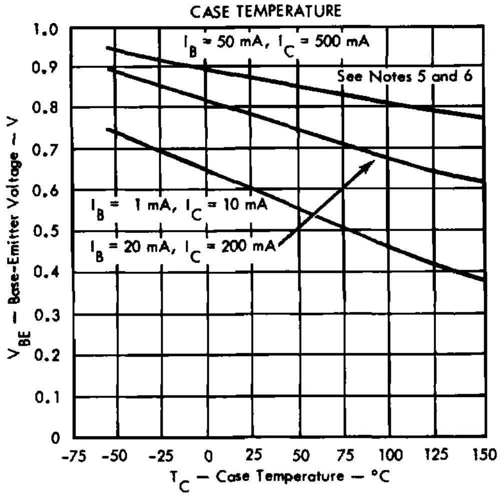


FIGURE 4

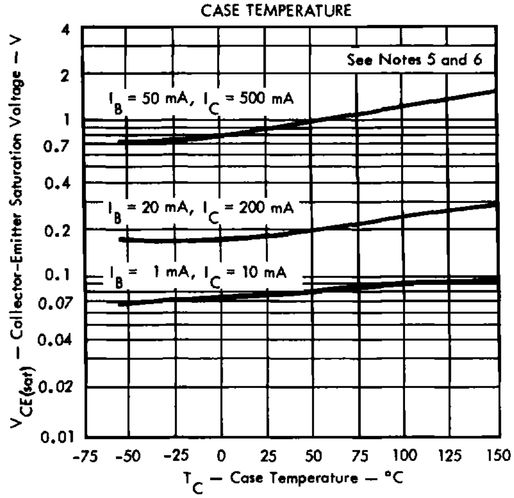


FIGURE 5

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

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TYPICAL CHARACTERISTICS

NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE
vs
BASE-EMITTER RESISTANCE

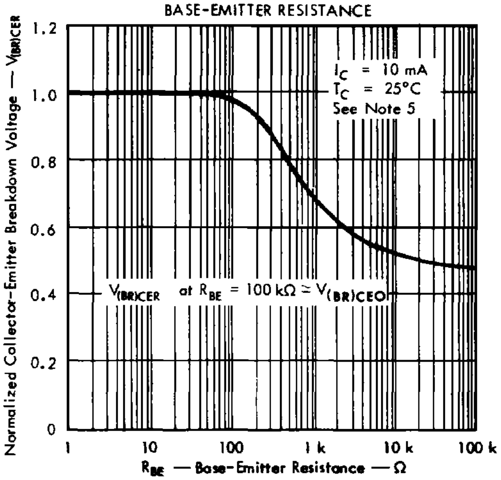

FIGURE 6

COMMON-BASE OPEN-CIRCUIT
INPUT AND OUTPUT CAPACITANCE
vs
REVERSE BIAS VOLTAGE

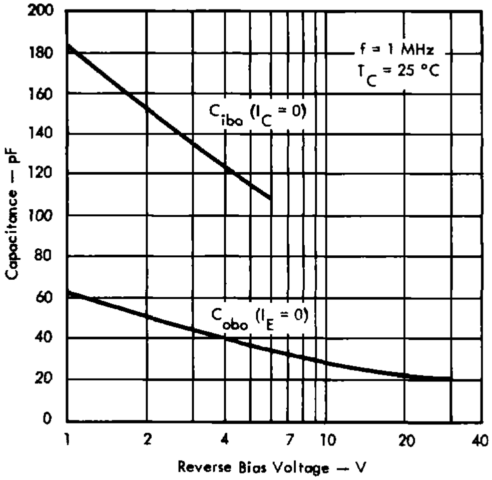

FIGURE 7

2N2987, 2N2988
2N2991, 2N2992
SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
FREQUENCY

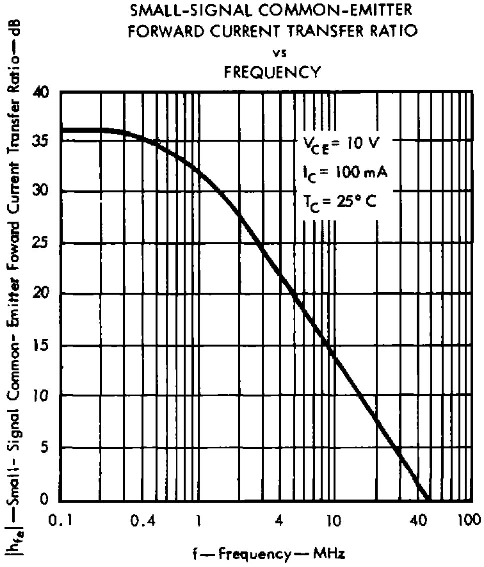

FIGURE 8

2N2989, 2N2990
2N2993, 2N2994
SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
FREQUENCY

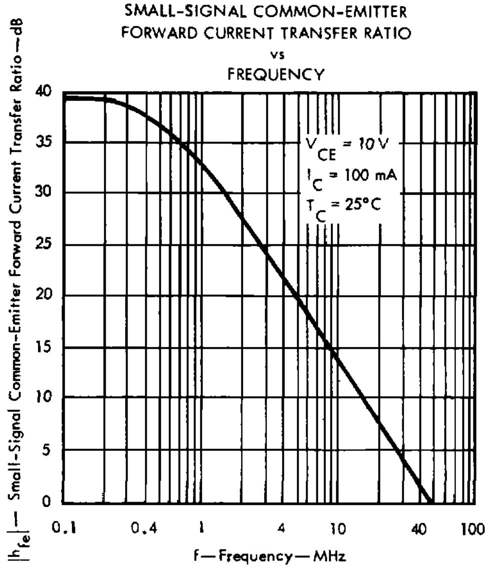

FIGURE 9

NOTE 5: This parameter must be measured using pulse techniques, $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

MAXIMUM SAFE OPERATING REGION

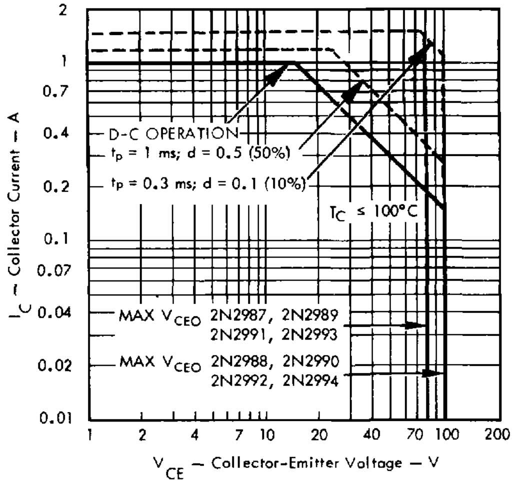

FIGURE 10

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THERMAL INFORMATION

2N2987 THRU 2N2990
FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

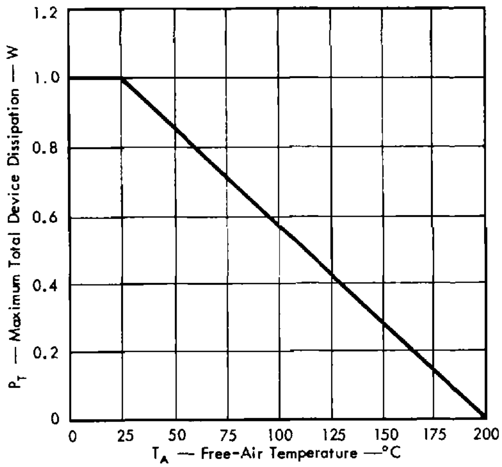

FIGURE 11

2N2991 THRU 2N2994
FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

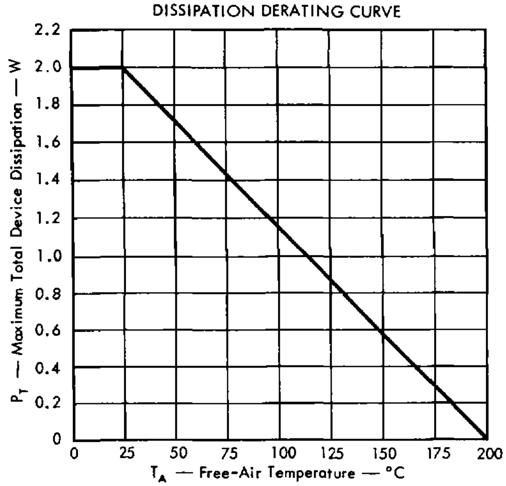

FIGURE 12

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THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

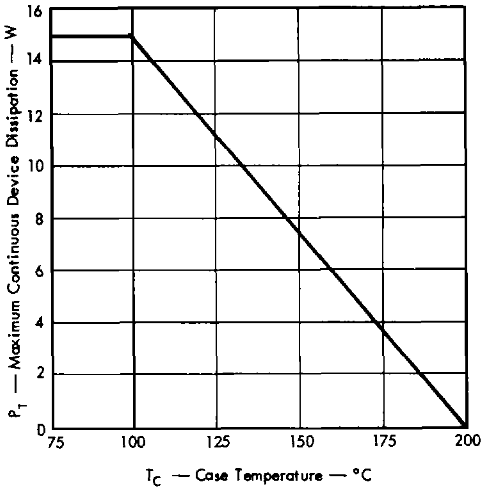

FIGURE 13

PEAK-POWER COEFFICIENT CURVE

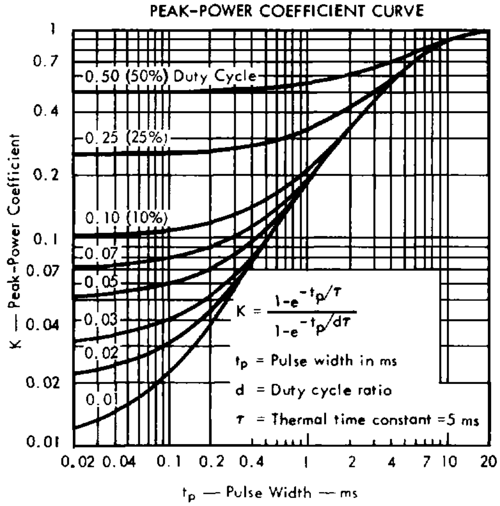

FIGURE 14

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE 2N2987 THRU 2N2990	VALUE 2N2991 THRU 2N2994	UNIT
$P_{T(av)}$	Average Power Dissipation			W
$P_{T(max)}$	Peak Power Dissipation			W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	175	87.5	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	6.67	6.67	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	168	81	deg/W
$\theta_{C\text{-}HS}$	Case-to-Heat-Sink Thermal Resistance			deg/W
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance			deg/W
T_A	Free-Air Temperature			°C
T_C	Case Temperature			°C
$T_{J(av)}$	Average Junction Temperature	≤ 200		°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200		°C
K	Peak-Power Coefficient	See Figure 14		
t_p	Pulse Width			ms
t_x	Pulse Period			ms
d	Duty-Cycle Ratio (t_p/t_x)			

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 100°C \leq T_C \leq 200°C \text{ as in figure 13}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}A}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}} \quad \text{for } 100°C \leq T_C \leq 200°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C\text{-}A} + K\,\theta_{J\text{-}C}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Example — Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 7$ deg/W (from information supplied with heat sink)

$T_{J(av)}$ (design limit) $= 200°C$

$T_A = 50°C$

$d = 10\%$ (0.1)

$t_p = 0.1$ ms

Solution

From Figure 14, Peak-Power Coefficient $K = 0.11$ and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1\,(7) + 0.11\,(6.67)} = 105 \text{ W}$$

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