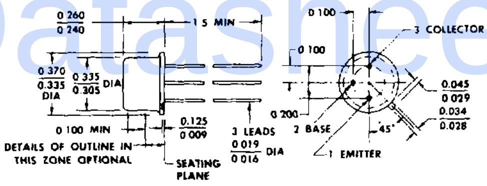
TYPES 2N4000, 2N4001
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTORS

TYPES 2N4000, 2N4001
BULLETIN NO. DL-S 668214, MARCH 1966

FOR HIGH-SPEED POWER SWITCHING APPLICATIONS

- **15 W at 100°C Case Temperature**
- **Max $V_{CE(sat)}$ of 0.3 V at 0.5 A I_C**
- **Max t_{on} of 300 ns at 0.5 A I_C**
- **Min f_T of 40 MHz**

*mechanical data

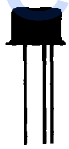


THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE

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.



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

	2N4000	2N4001
Collector-Base Voltage	100 V	120 V
Collector-Emitter Voltage (See Note 1)	80 V	100 V
Emitter-Base Voltage	← 8 V →	
Continuous Collector Current	← 1 A →	
Peak Collector Current (See Note 2)	← 3 A →	
Continuous Base Current	← 0.5 A →	
Safe Operating Region at (or below) 100°C Case Temperature	See Figure 8	
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 →	
Operating Collector Junction 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. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 1$ ms, duty cycle $\leq 50\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.15 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 5.72 mW/°C.

*JEDEC registered data

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

PARAMETER		TEST CONDITIONS	2N4000 MIN	2N4000 MAX	2N4001 MIN	2N4001 MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$, See Note 5	80		100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 60$ V, $I_B = 0$		10			μA
		$V_{CE} = 80$ V, $I_B = 0$				10	
I_{CES}	Collector Cutoff Current	$V_{CE} = 90$ V, $V_{BE} = 0$		2			μA
		$V_{CE} = 110$ V, $V_{BE} = 0$				2	
		$V_{CE} = 90$ V, $V_{BE} = 0$, $T_C = 150°C$		50			
		$V_{CE} = 110$ V, $V_{BE} = 0$, $T_C = 150°C$				50	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		500		500	nA
		$V_{EB} = 8$ V, $I_C = 0$		10		10	μA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 2$ V, $I_C = 50$ mA	10		20		
		$V_{CE} = 2$ V, $I_C = 0.5$ A, See Note 5	30	120	40	120	
		$V_{CE} = 5$ V, $I_C = 1$ A, See Note 5	10		20		
		$V_{CE} = 2$ V, $I_C = 0.5$ A, $T_C = -55°C$, See Note 5	10		15		
V_{BE}	Base-Emitter Voltage	$I_B = 50$ mA, $I_C = 0.5$ A, See Note 5		1		1	V
		$I_B = 100$ mA, $I_C = 1$ A, See Note 5		1.2		1.2	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 50$ mA, $I_C = 0.5$ A, See Note 5		0.3		0.3	V
		$I_B = 100$ mA, $I_C = 1$ A, See Note 5		0.5		0.5	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 0.5$ A, $f = 20$ MHz	2		2		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ V, $I_E = 0$, $f = 1$ MHz		60		60	pF

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

***thermal characteristics**

PARAMETER		MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	6.67	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	175	

***switching characteristics at 25°C case temperature**

PARAMETER		TEST CONDITIONS†	MAX	UNIT
t_{on}	Turn-On Time	$I_C = 0.5$ A, $I_{B(1)} = 50$ mA, $I_{B(2)} = -50$ mA,	0.3	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = -4$ V, $R_L = 20\ \Omega$, See Figure 1	2	

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

*JEDEC registered data

PARAMETER MEASUREMENT INFORMATION

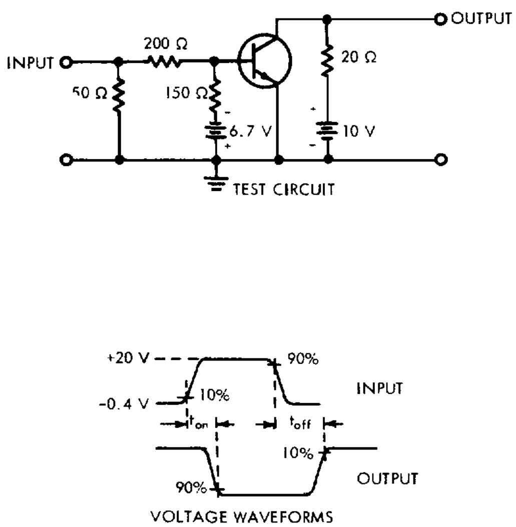

FIGURE 1

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

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 5$ pF.

c. Resistors must be noninductive types.

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

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TYPICAL CHARACTERISTICS

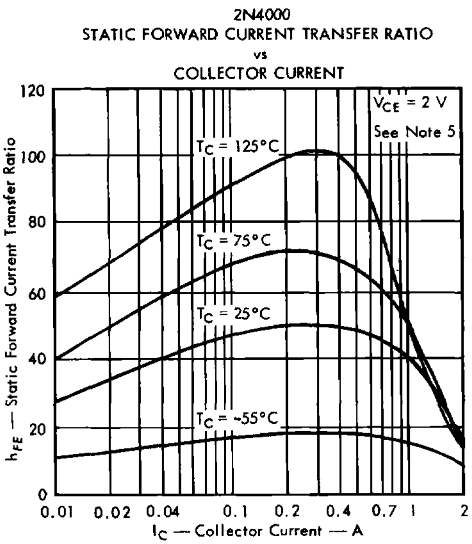

FIGURE 2

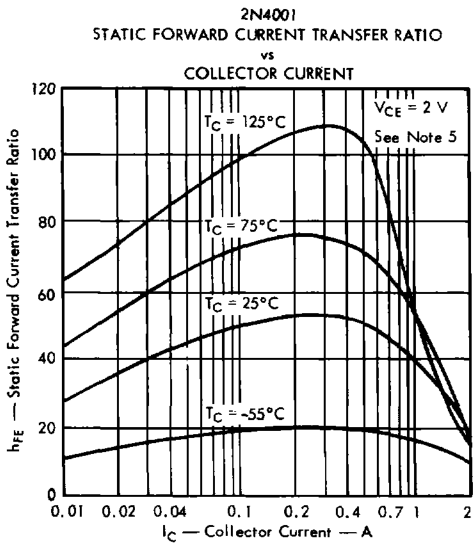

FIGURE 3

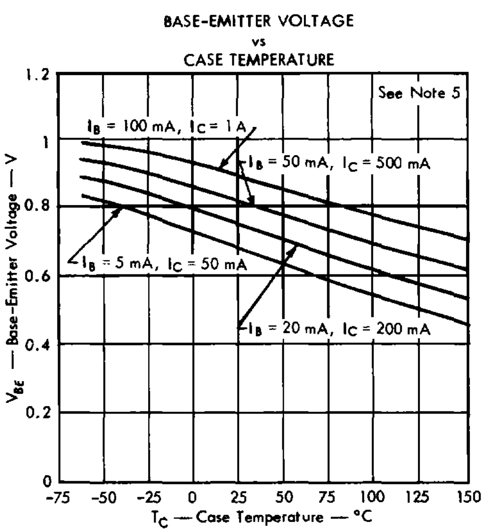

FIGURE 4

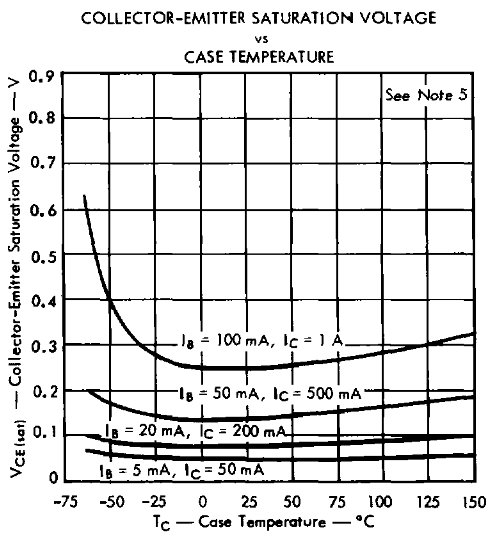

FIGURE 5

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

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TYPICAL CHARACTERISTICS

NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE
vs
BASE-EMITTER RESISTANCE

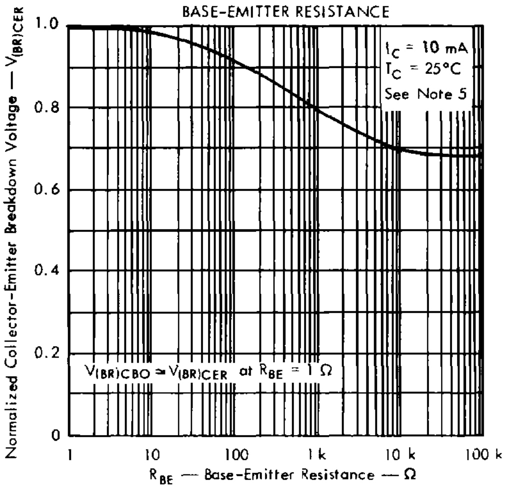

FIGURE 6

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

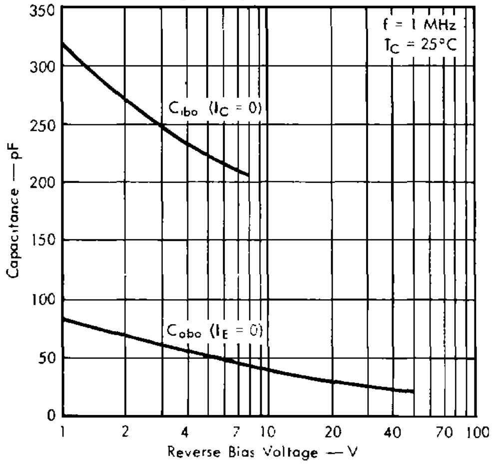

FIGURE 7

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

MAXIMUM SAFE OPERATING REGION

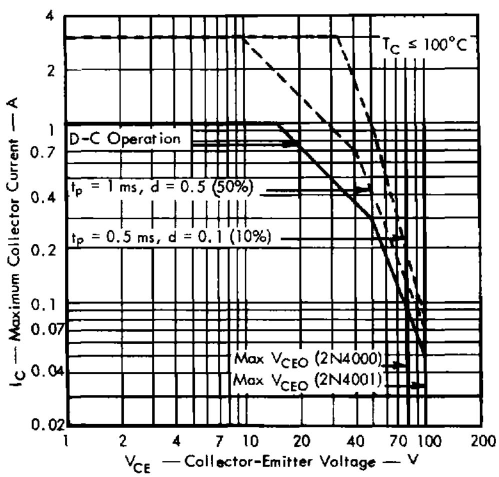

FIGURE 8

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THERMAL INFORMATION

CASE TEMPERATURE DISSIPATION DERATING CURVE

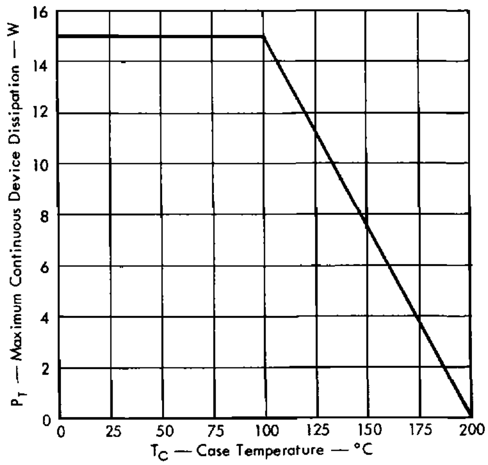

FIGURE 9

PEAK-POWER COEFFICIENT CURVE

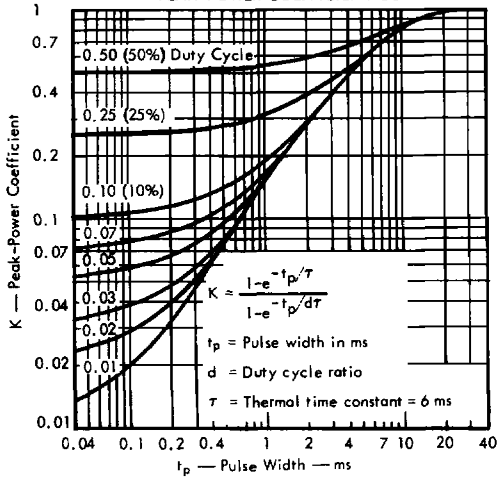

FIGURE 10

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(avg)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	175	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	6.67	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	168.33	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
$T_{J(avg)}$	Average Junction Temperature	$\leq$ 200	°C
$T_{J(max)}$	Peak Junction Temperature	$\leq$ 200	°C
K	Peak-Power Coefficient	See Figure 10	
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.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 100°C \leq T_C \leq 200°C \text{ as in Figure 9}$$

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

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

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.)

$T_{J(avg)}$ (design limit) = 200°C

$T_A = 50°C$

d = 10% (0.1)

$t_p = 1$ ms

Solution:

From Figure 10, Peak-Power Coefficient K = 0.19 and by use of equation No. 3

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

$$P_{T(max)} = \frac{200 - 50}{0.1\,(7) + (0.19)\,(6.67)} = 76\text{ W}$$

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