TYPES 2N4004, 2N4005
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTORS

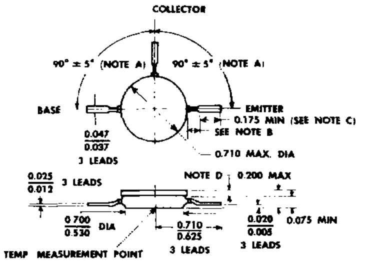
TYPES 2N4004, 2N4005
BULLETIN NO. DL-S 669607, SEPTEMBER 1966

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

- **20 A Rated Collector Current**
- **40 Watts at 100°C Case Temperature**
- **Maximum $V_{CE(sat)}$ of 1 V at 20 A**
- **Maximum V_{BE} of 1.6 V at 20 A**
- **Maximum t_{on} of 1 μs at 10 A**

*mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



NOTES:
- A. Measured where leads emerge from package.
- B. Lead cross-section and shape are optional in this area of each lead.
- C Specified lead width and thickness apply within this dimension of each lead.
- D. Contour of package is optional within this area.
- E. Dimensions are in inches unless otherwise specified.

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

	2N4004	2N4005
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	← 20 A →	
Peak Collector Current (See Note 2)	← 30 A →	
Continuous Base Current	← 10 A →	
Continuous Emitter Current	← 20 A →	
Safe Operating Region at (or below) 100°C Case Temperature	See Figure 7	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	← 40 W →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 1.2 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 $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.4 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 6.87 mW/deg.

*Indicates JEDEC registered data.

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

PARAMETER		TEST CONDITIONS	2N4004		2N4005		UNIT
			MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$, See Note 5	80		100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 40$ V, $I_B = 0$		2			mA
		$V_{CE} = 50$ V, $I_B = 0$				2	
I_{CES}	Collector Cutoff Current	$V_{CE} = 90$ V, $V_{BE} = 0$		1			mA
		$V_{CE} = 110$ V, $V_{BE} = 0$				1	
		$V_{CE} = 90$ V, $V_{BE} = 0$, $T_C = 150$°C		2			
		$V_{CE} = 110$ V, $V_{BE} = 0$, $T_C = 150$°C				2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		100		100	µA
		$V_{EB} = 8$ V, $I_C = 0$		50		50	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 20$ A, See Notes 5 and 6	15		15		
		$V_{CE} = 4$ V, $I_C = 10$ A, See Notes 5 and 6	30	150	30	150	
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V, $I_C = 20$ A, See Notes 5 and 6		1.6		1.6	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 3$ A, $I_C = 20$ A, See Notes 5 and 6		1		1	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 1$ A, $f = 1$ kHz	30		30		
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 1$ A, $f = 10$ MHz	3		3		

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. The voltage-sensing contacts are separate from current-carrying contacts.

*thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	2.5	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	146	deg/W

*Indicates JEDEC registered data.

*switching characteristics at 25°C case temperature

PARAMETER	TEST CONDITIONS†	MAX	UNIT
t_{on} Turn-On Time	$I_C = 10$ A, $I_{B(1)} = 0.8$ A, $I_{B(2)} = -0.8$ A,	1	µs
t_{off} Turn-Off Time	$V_{BE(off)} = -1$ V, $R_L = 3\ \Omega$, See Figure 1	4	

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

*PARAMETER MEASUREMENT INFORMATION

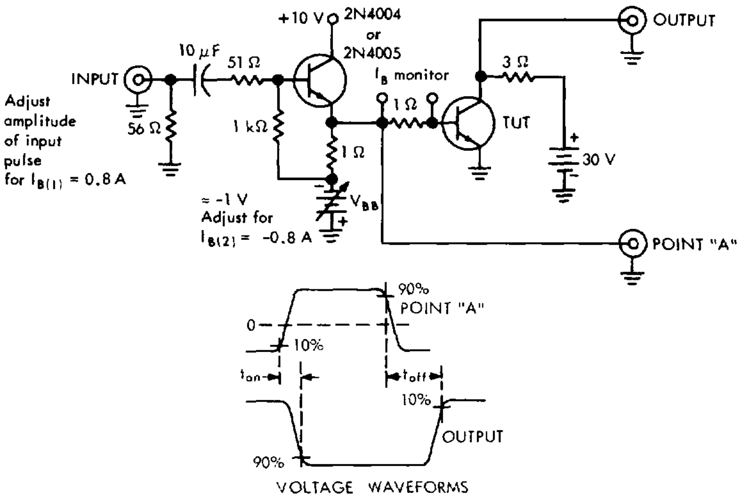


FIGURE 1

NOTES:
a. The input waveform at point "A" has the following characteristics: $t_r \leq 100$ ns, $t_f \leq 100$ ns, $t_p = 20$ µs, duty cycle ≤ 0.2%.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 5$ ns, $R_{in} \geq 1$ MΩ, $C_{in} \leq 5$ pF.
c. Resistors must be noninductive types.
d. The d-c power supplies may require additional bypassing in order to minimize ringing.

*Indicates JEDEC registered data.

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

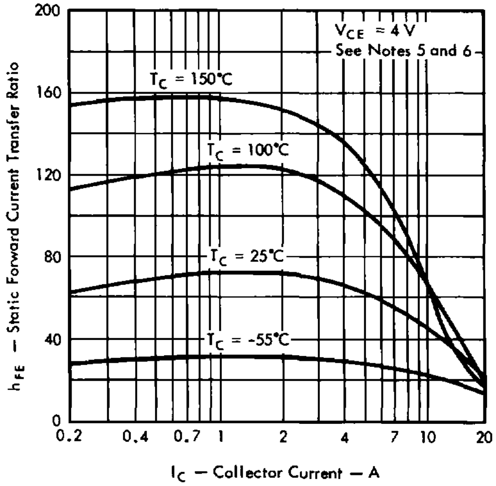


FIGURE 2

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

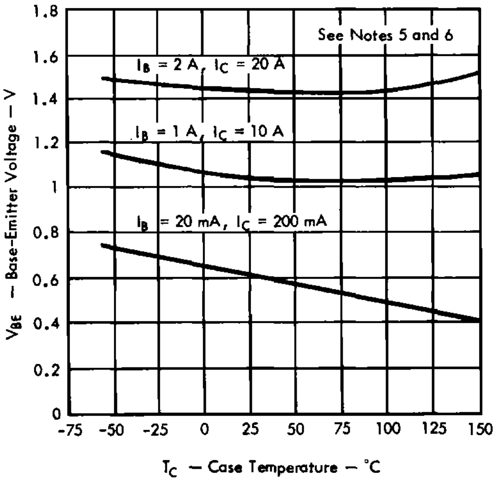


FIGURE 3

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

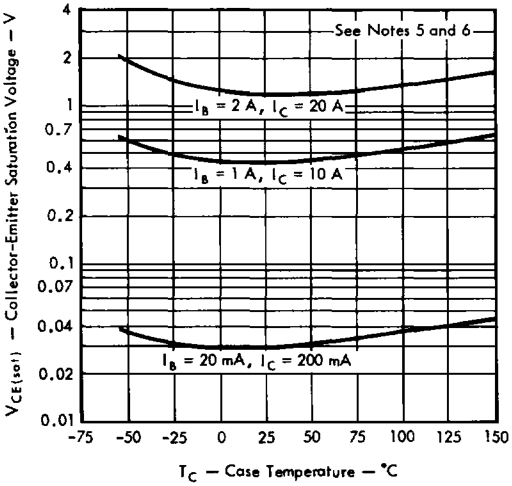


FIGURE 4

TYPICAL CHARACTERISTICS

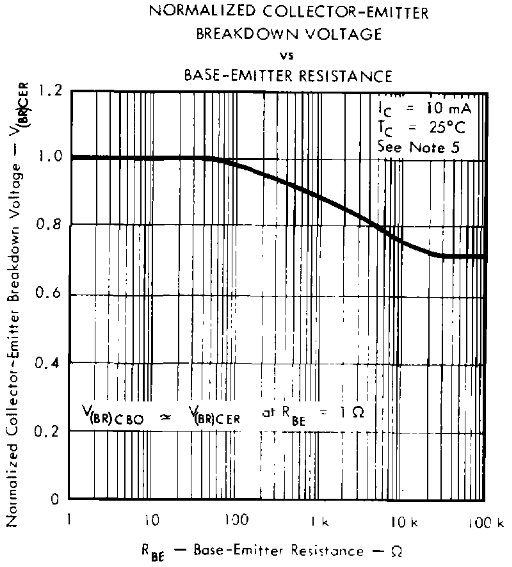


FIGURE 5

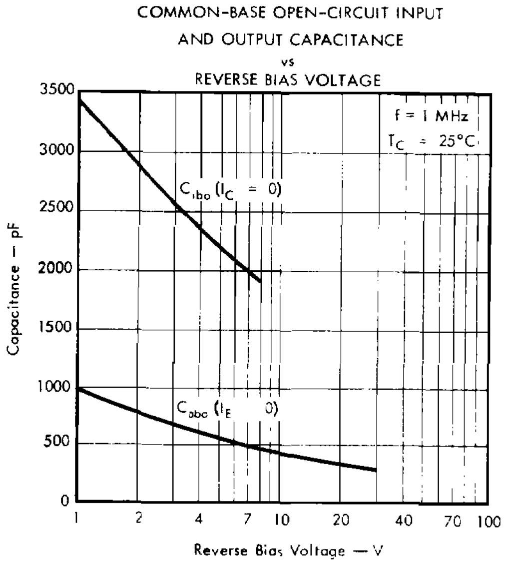


FIGURE 6

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

MAXIMUM SAFE OPERATING REGION

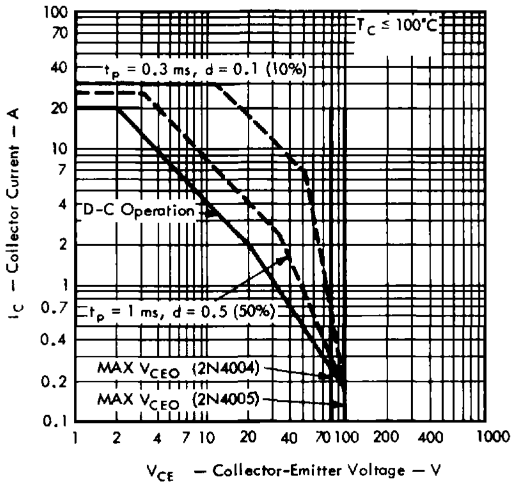


FIGURE 7

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THERMAL INFORMATION

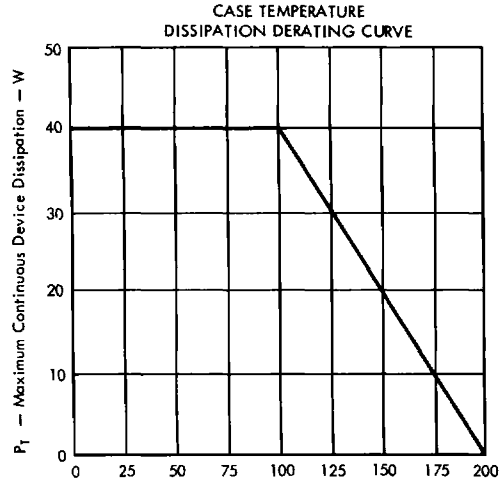

FIGURE 8

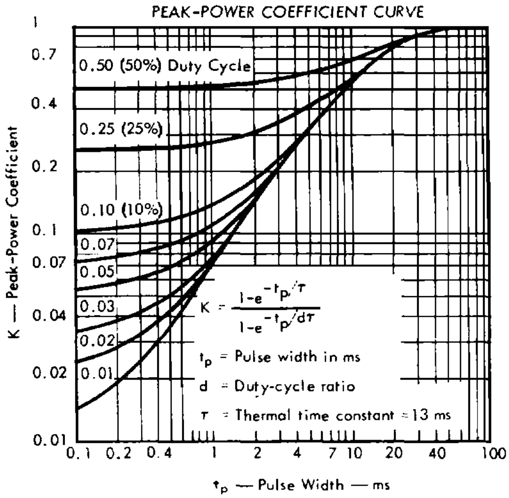

FIGURE 9

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	146	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	2.5	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	143.5	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	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 9	
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.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 100°\text{C} \leq T_C \leq 200°\text{C, as in Figure 8}$$

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

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

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

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

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

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

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

OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 2.5$ deg/W (From information supplied with heat sink.)

$T_{J(avg)}$ (design limit) $= 200°\text{C}$
$T_A = 50°\text{C}$
$d = 10\%\ (0.1)$
$t_p = 0.1$ ms

Solution:

From Figure 9, Peak-Power Coefficient
K = 0.1 and by use of equation No. 3

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

$$P_{T(max)} = \frac{200 - 50}{0.1(2.5) + 0.1(2.5)} = 300\ \text{W}$$