POLITECNICO DI TORINO

ESAME DI STATO PER L'ABILITAZIONE ALLA PROFESSIONE DI INGEGNERE

SEZIONE A – RAMO "ELETTRONICA" – TEMA 1

PROVA PRATICA DEL 26 NOVEMBRE 2002

Nell'ambito dello sviluppo di un sistema di comunicazioni, è necessario progettare un circuito per la compressione della dinamica caratterizzato da una funzione di trasferimento ingresso-uscita con pendenza pari a 40 mV/dB, con tensione di ingresso variabile tra 1 mV (e V_{out}=0 V per questo valore dell'ingresso) e 10 V. Sulla base dei data sheet a disposizione, si richiede di:

1. identificare il tipo di circuito analogico che meglio realizza la funzione richiesta;

2. progettare tale sistema, sapendo di avere a disposizione una alimentazione in continua a ±12 V e minimizzando l'effetto della temperatura.

Si richede inoltre al candidato di produrre un breve saggio sulle norme deontologiche che caratterizzano la professione di ingegnere.

Nota: si ricorda che il parametro h_{ie} presente nelle caratteristiche del transistore è composto della resistenza di base e del parametro h_{ie} intrinseco, quest'ultimo inversamente proporzionale alla corrente di collettore.

Symbols of Resistance Temperature Characteristics

Symbol	Resistance Temperature Characteristic
T	±10ppm/°C
E	±25ppm/°C
C	±50ppm/°C
K	±100ppm/°C
D	±200ppm/°C

Symbols of Resistance Value tolerance

Symbol	A	B	C	D	F	G	J
Tolerance	±0.05%	±0.1%	±0.25%	±0.5%	±1.0%	±2.0%	±5.0%

Symbol	K	L	M	T	Y	S
Tolerance	±10%	±15%	±20%	±25%	±50%	+0%, -30%

Resistance Tolerance (±%)

E192	E96	E24	E12	E6
0.1% 0.25% 0.5%	1%	2% 5%	10%	20%
10.0	10.0	10.0	10.0	10.0
10.1	-	-	-	-
10.2	10.2	-	-	-
10.4	-	-	-	-
10.5	10.5	-	-	-
10.6	-	-	-	-
10.7	10.7	-	-	-
10.9	-	-	-	-
11.0	11.0	11.0	-	-
11.1	-	-	-	-
11.3	11.3	-	-	-
11.4	-	-	-	-
11.5	11.5	-	-	-
11.7	-	-	-	-
11.8	11.8	-	-	-
12.0	-	12.0	12.0	-
12.1	12.1	-	-	-
12.3	-	-	-	-
12.4	12.4	-	-	-
12.6	-	-	-	-
12.7	12.7	-	-	-
12.9	-	-	-	-
13.0	13.0	13.0	-	-
13.2	-	-	-	-
13.3	13.3	-	-	-
13.5	-	-	-	-
13.7	13.7	-	-	-
13.8	-	-	-	-
14.0	14.0	-	-	-
14.2	-	-	-	-
14.3	14.3	-	-	-
14.5	-	-	-	-
14.7	14.7	-	-	-
14.9	-	-	-	-
15.0	15.0	15.0	15.0	15.0
15.2	-	-	-	-
15.4	15.4	-	-	-
15.6	-	-	-	-

E192	E96	E24	E12	E6
0.1% 0.25% 0.5%	1%	2% 5%	10%	20%
15.8	15.8	-	-	-
16.0	-	16.0	-	-
16.2	16.2	-	-	-
16.4	-	-	-	-
16.5	15.5	-	-	-
16.7	-	-	-	-
16.9	16.9	-	-	-
17.2	-	-	-	-
17.4	17.4	-	-	-
17.6	-	-	-	-
17.8	17.8	-	-	-
18.0	-	18.0	18.0	-
18.2	18.2	-	-	-
18.4	-	-	-	-
18.7	18.7	-	-	-
18.9	-	-	-	-
19.1	19.1	-	-	-
19.3	-	-	-	-
19.6	19.6	-	-	-
19.8	-	-	-	-
20.0	20.0	20.0	-	-
20.3	-	-	-	-
20.5	20.5	-	-	-
20.8	-	-	-	-
21.0	21.0	-	-	-
21.3	-	-	-	-
21.5	21.5	-	-	-
21.8	-	-	-	-
22.1	22.1	22.0	22.0	22.0
22.3	-	-	-	-
22.6	22.6	-	-	-
22.9	-	-	-	-
23.2	23.2	-	-	-
23.4	-	-	-	-
23.7	23.7	-	-	-
24.0	-	24.0	-	-
24.3	24.3	-	-	-
24.6	-	-	-	-

E192	E96	E24	E12	E6
0.1% 0.25% 0.5%	1%	2% 5%	10%	20%
24.9	24.9	-	-	-
25.2	-	-	-	-
25.5	25.5	-	-	-
25.8	-	-	-	-
26.1	26.1	-	-	-
26.4	-	-	-	-
26.7	26.7	-	-	-
27.1	-	27.0	27	-
27.4	27.4	-	-	-
27.7	-	-	-	-
28.0	28.0	-	-	-
28.4	-	-	-	-
28.7	28.7	-	-	-
29.1	-	-	-	-
29.4	29.4	-	-	-
29.8	-	-	-	-
30.1	30.1	30.0	-	-
30.5	-	-	-	-
30.9	30.9	-	-	-
31.2	-	-	-	-
31.6	31.6	-	-	-
32.0	-	-	-	-
32.4	32.4	-	-	-
32.8	-	-	-	-
33.2	33.2	33.0	33.0	33.0
33.6	-	-	-	-
34.0	34.0	-	-	-
34.4	-	-	-	-
34.8	34.8	-	-	-
35.2	-	-	-	-
35.7	35.7	-	-	-
36.1	-	36.0	-	-
36.5	36.5	-	-	-
37.0	-	-	-	-
37.4	37.4	-	-	-
37.9	-	-	-	-
38.3	38.3	-	-	-
38.8	-	-	-	-

E192	E96	E24	E12	E6
0.1% 0.25% 0.5%	1%	2% 5%	10%	20%
39.2	39.2	39.0	39.0	-
39.7	-	-	-	-
40.2	40.2	-	-	-
40.7	-	-	-	-
41.2	41.2	-	-	-
41.7	-	-	-	-
42.2	42.2	-	-	-
42.7	-	-	-	-
43.2	43.2	43.0	-	-
43.7	-	-	-	-
44.2	44.2	-	-	-
44.8	-	-	-	-
45.3	45.3	-	-	-
45.9	-	-	-	-
46.4	46.4	-	-	-
47.0	-	47.0	47.0	47.0
47.5	47.5	-	-	-
48.1	-	-	-	-
48.7	48.7	-	-	-
49.3	-	-	-	-
49.9	49.9	-	-	-
50.5	-	-	-	-
51.1	51.1	51.0	-	-
51.7	-	-	-	-
52.3	52.3	-	-	-
53.0	-	-	-	-
53.6	53.6	-	-	-
54.2	-	-	-	-
54.9	54.9	-	-	-
55.6	-	-	-	-
56.2	56.2	56.0	56.0	-
56.95	-57.6	-	-	-
7.6	-	-	-	-
58.3	59.0	-	-	-
59.0	-	-	-	-
59.7	60.4	-	-	-
60.4	-	-	-	-
61.2	61.9	-	-	-
61.9		62.0	-	-

E192	E96	E24	E12	E6
0.1% 0.25% 0.5%	1%	2% 5%	10%	20%
62.6	-	-	-	-
63.4	63.4	-	-	-
64.2	-	-	-	-
64.9	64.9	-	-	-
65.7	-	-	-	-
66.5	66.5	-	-	-
67.3	-	-	-	-
68.1	68.1	68.0	68.0	68.0
69.0	-	-	-	-
69.8	69.8	-	-	-
70.6	-	-	-	-
71.5	71.5	-	-	-
72.3	-	-	-	-
73.2	73.2	-	-	-
74.1	-	-	-	-
75.0	75.0	75.0	-	-
75.9	-	-	-	-
76.8	76.8	-	-	-
77.7	-	-	-	-
78.7	78.7	-	-	-
79.6	-	-	-	-
80.6	80.6	-	-	-
81.6	-	-	-	-
82.5	82.5	82.0	82.0	-
83.5	-	-	-	-
84.5	84.5	-	-	-
85.6	-	-	-	-
86.6	86.6	-	-	-
87.6	-	-	-	-
88.7	88.7	-	-	-
89.8	-	-	-	-
90.9	90.9	91.0	-	-
92.0	-	-	-	-
93.1	93.1	-	-	-
94.2	-	-	-	-
95.3	95.3	-	-	-
96.5	-	-	-	-
97.6	97.6	-	-	-
98.8	-	-	-	-

Numerical Symbols & Multiplier

Symbol	T (tera)	G (giga)	M (mega)	K (kilo)	m (milli)	μ (micro)	n (nano)	p (pico)	Å (angstrom)	ppm
Multiplier	10^{12}	10^{9}	10^{6}	10^{3}	10^{-3}	10^{-6}	10^{-9}	10^{-12}	10^{-7} mm	10^{-6}

2

National Semiconductor

August 2000

LM741
Operational Amplifier

General Description

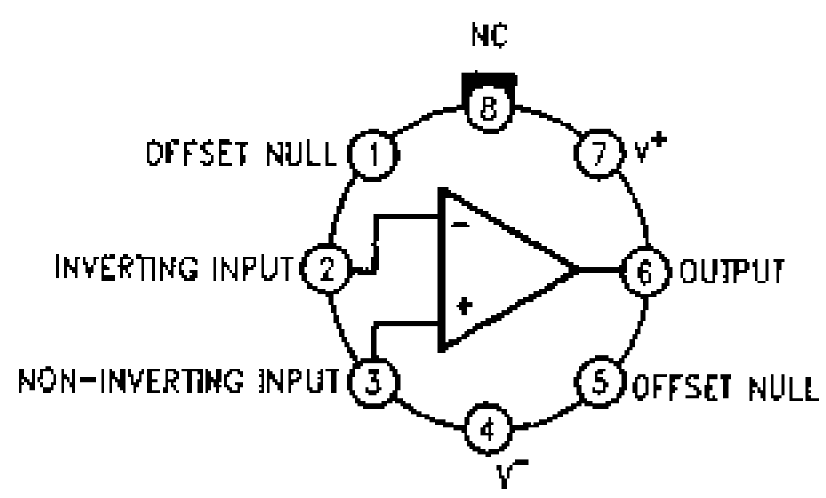
The LM741 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439 and 748 in most applications.

The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

The LM741C is identical to the LM741/LM741A except that the LM741C has their performance guaranteed over a 0°C to +70°C temperature range, instead of -55°C to +125°C.

Connection Diagrams

Metal Can Package

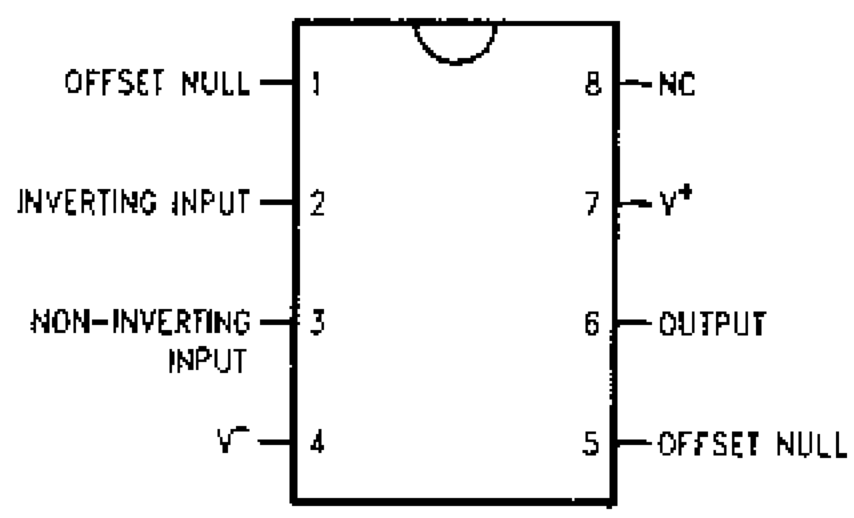


DS009341-2

Note 1: LM741H is available per JM38510/10101

Order Number LM741H, LM741H/883 (Note 1), LM741AH/883 or LM741CH
See NS Package Number H08C

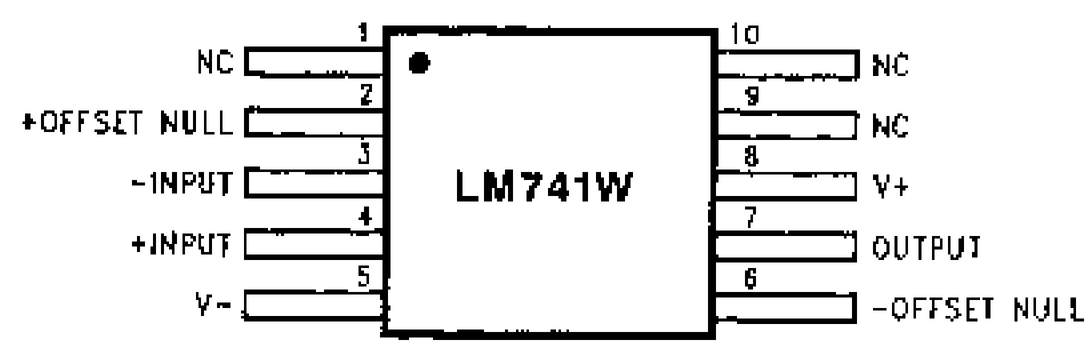
Dual-In-Line or S.O. Package



DS009341-3

Order Number LM741J, LM741J/883, LM741CN
See NS Package Number J08A, M08A or N08E

Ceramic Flatpak

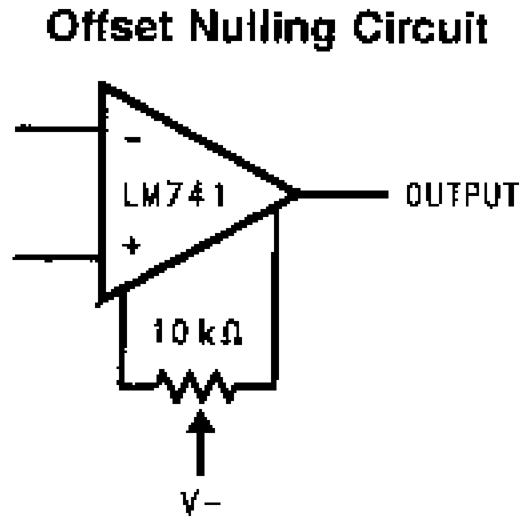


DS009341-6

Order Number LM741W/883
See NS Package Number W10A

Typical Application

Offset Nulling Circuit



DS009341-7

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Absolute Maximum Ratings (Note 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

(Note 7)

	LM741A	LM741	LM741C
Supply Voltage	±22V	±22V	±18V
Power Dissipation (Note 3)	500 mW	500 mW	500 mW
Differential Input Voltage	±30V	±30V	±30V
Input Voltage (Note 4)	±15V	±15V	±15V
Output Short Circuit Duration	Continuous	Continuous	Continuous
Operating Temperature Range	-55°C to +125°C	-55°C to +125°C	0°C to +70°C
Storage Temperature Range	-65°C to +150°C	-65°C to +150°C	-65°C to +150°C
Junction Temperature	150°C	150°C	100°C
Soldering Information			
N-Package (10 seconds)	260°C	260°C	260°C
J- or H-Package (10 seconds)	300°C	300°C	300°C
M-Package			
Vapor Phase (60 seconds)	215°C	215°C	215°C
Infrared (15 seconds)	215°C	215°C	215°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

	LM741A	LM741	LM741C
ESD Tolerance (Note 8)	400V	400V	400V

Electrical Characteristics (Note 5)

Parameter	Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	$T_A = 25°C$										
	$R_S \leq 10\ k\Omega$					1.0	5.0		2.0	6.0	mV
	$R_S \leq 50\Omega$		0.8	3.0							mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	$R_S \leq 50\Omega$			4.0							mV
	$R_S \leq 10\ k\Omega$						6.0			7.5	mV
Average Input Offset Voltage Drift				15							μV/°C
Input Offset Voltage Adjustment Range	$T_A = 25°C$, $V_S = \pm 20V$	±10				±15			±15		mV
Input Offset Current	$T_A = 25°C$		3.0	30		20	200		20	200	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			70		85	500			300	nA
Average Input Offset Current Drift				0.5							nA/°C
Input Bias Current	$T_A = 25°C$		30	80		80	500		80	500	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			0.210			1.5			0.8	μA
Input Resistance	$T_A = 25°C$, $V_S = \pm 20V$	1.0	6.0		0.3	2.0		0.3	2.0		MΩ
	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $V_S = \pm 20V$	0.5									MΩ
Input Voltage Range	$T_A = 25°C$							±12	±13		V
	$T_{AMIN} \leq T_A \leq T_{AMAX}$				±12	±13					V

Electrical Characteristics (Note 5) (Continued)

Parameter	Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Large Signal Voltage Gain	$T_A = 25°C$, $R_L \geq 2\ k\Omega$										
	$V_S = \pm 20V$, $V_O = \pm 15V$	50									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				50	200		20	200		V/mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$,										
	$R_L \geq 2\ k\Omega$,										
	$V_S = \pm 20V$, $V_O = \pm 15V$	32									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				25			15			V/mV
	$V_S = \pm 5V$, $V_O = \pm 2V$	10									V/mV
Output Voltage Swing	$V_S = \pm 20V$										
	$R_L \geq 10\ k\Omega$	±16									V
	$R_L \geq 2\ k\Omega$	±15									V
	$V_S = \pm 15V$										
	$R_L \geq 10\ k\Omega$				±12	±14		±12	±14		V
	$R_L \geq 2\ k\Omega$				±10	±13		±10	±13		V
Output Short Circuit Current	$T_A = 25°C$	10	25	35		25			25		mA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$	10		40							mA
Common-Mode Rejection Ratio	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	$R_S \leq 10\ k\Omega$, $V_{CM} = \pm 12V$				70	90		70	90		dB
	$R_S \leq 50\Omega$, $V_{CM} = \pm 12V$	80	95								dB
Supply Voltage Rejection Ratio	$T_{AMIN} \leq T_A \leq T_{AMAX}$,										
	$V_S = \pm 20V$ to $V_S = \pm 5V$										
	$R_S \leq 50\Omega$	86	96								dB
	$R_S \leq 10\ k\Omega$				77	96		77	96		dB
Transient Response	$T_A = 25°C$, Unity Gain										
Rise Time			0.25	0.8		0.3			0.3		μs
Overshoot			6.0	20		5			5		%
Bandwidth (Note 6)	$T_A = 25°C$	0.437	1.5								MHz
Slew Rate	$T_A = 25°C$, Unity Gain	0.3	0.7			0.5			0.5		V/μs
Supply Current	$T_A = 25°C$					1.7	2.8		1.7	2.8	mA
Power Consumption	$T_A = 25°C$										
	$V_S = \pm 20V$		80	150							mW
	$V_S = \pm 15V$					50	85		50	85	mW
LM741A	$V_S = \pm 20V$										
	$T_A = T_{AMIN}$			165							mW
	$T_A = T_{AMAX}$			135							mW
LM741	$V_S = \pm 15V$										
	$T_A = T_{AMIN}$					60	100				mW
	$T_A = T_{AMAX}$					45	75				mW

Note 2: "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits.

Electrical Characteristics (Note 5) (Continued)

Note 3: For operation at elevated temperatures, these devices must be derated based on thermal resistance, and T_j max. (listed under "Absolute Maximum Ratings"). $T_j = T_A + (\theta_{jA} P_D)$.

Thermal Resistance	Cerdip (J)	DIP (N)	HO8 (H)	SO-8 (M)
θ_{jA} (Junction to Ambient)	100°C/W	100°C/W	170°C/W	195°C/W
θ_{jC} (Junction to Case)	N/A	N/A	25°C/W	N/A

Note 4: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

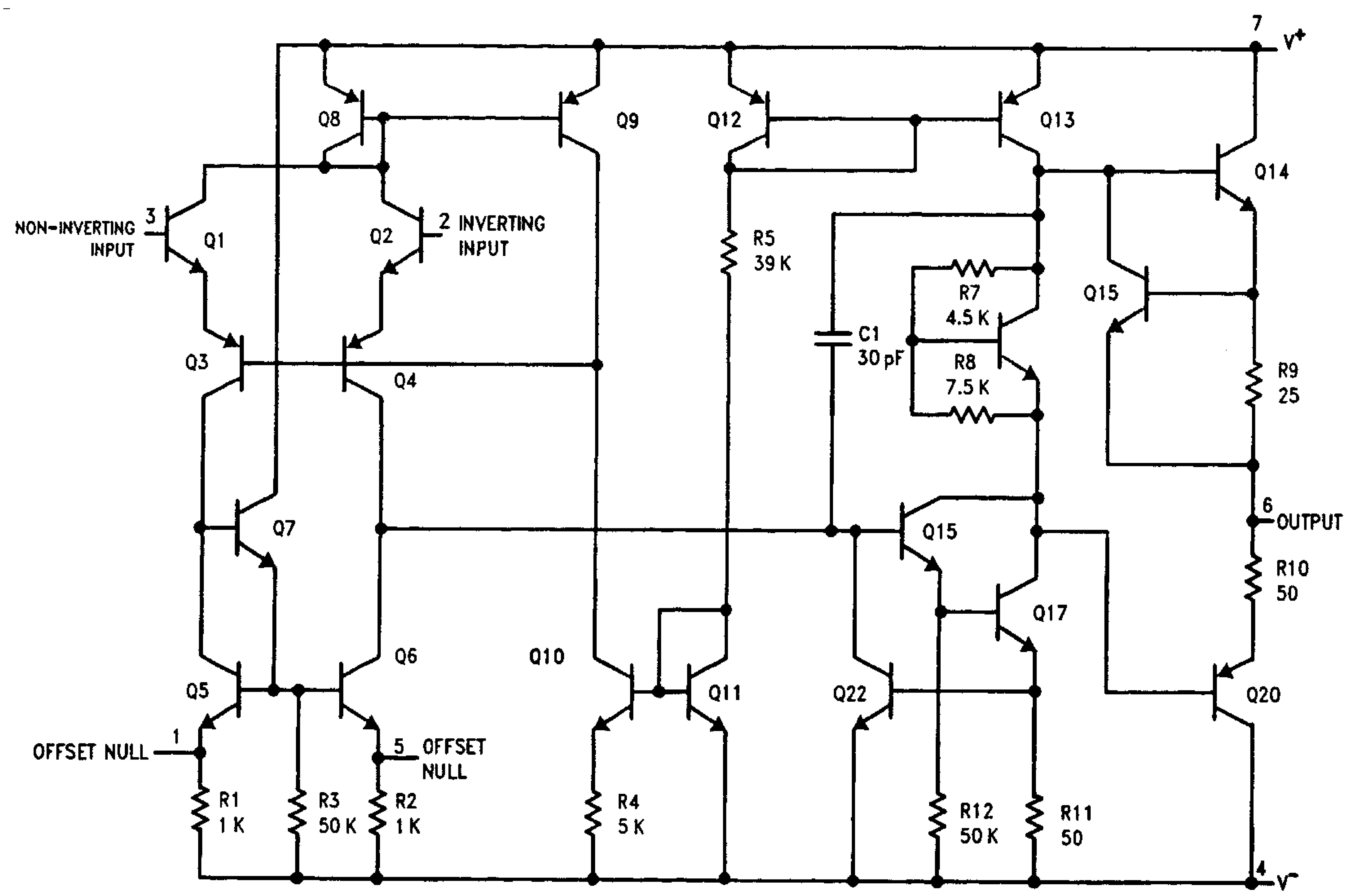
Note 5: Unless otherwise specified, these specifications apply for V_S = ±15V, −55°C ≤ T_A ≤ +125°C (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to 0°C ≤ T_A ≤ +70°C.

Note 6: Calculated value from: BW (MHz) = 0.35/Rise Time(μs).

Note 7: For military specifications see RETS741X for LM741 and RETS741AX for LM741A.

Note 8: Human body model, 1.5 kΩ in series with 100 pF.

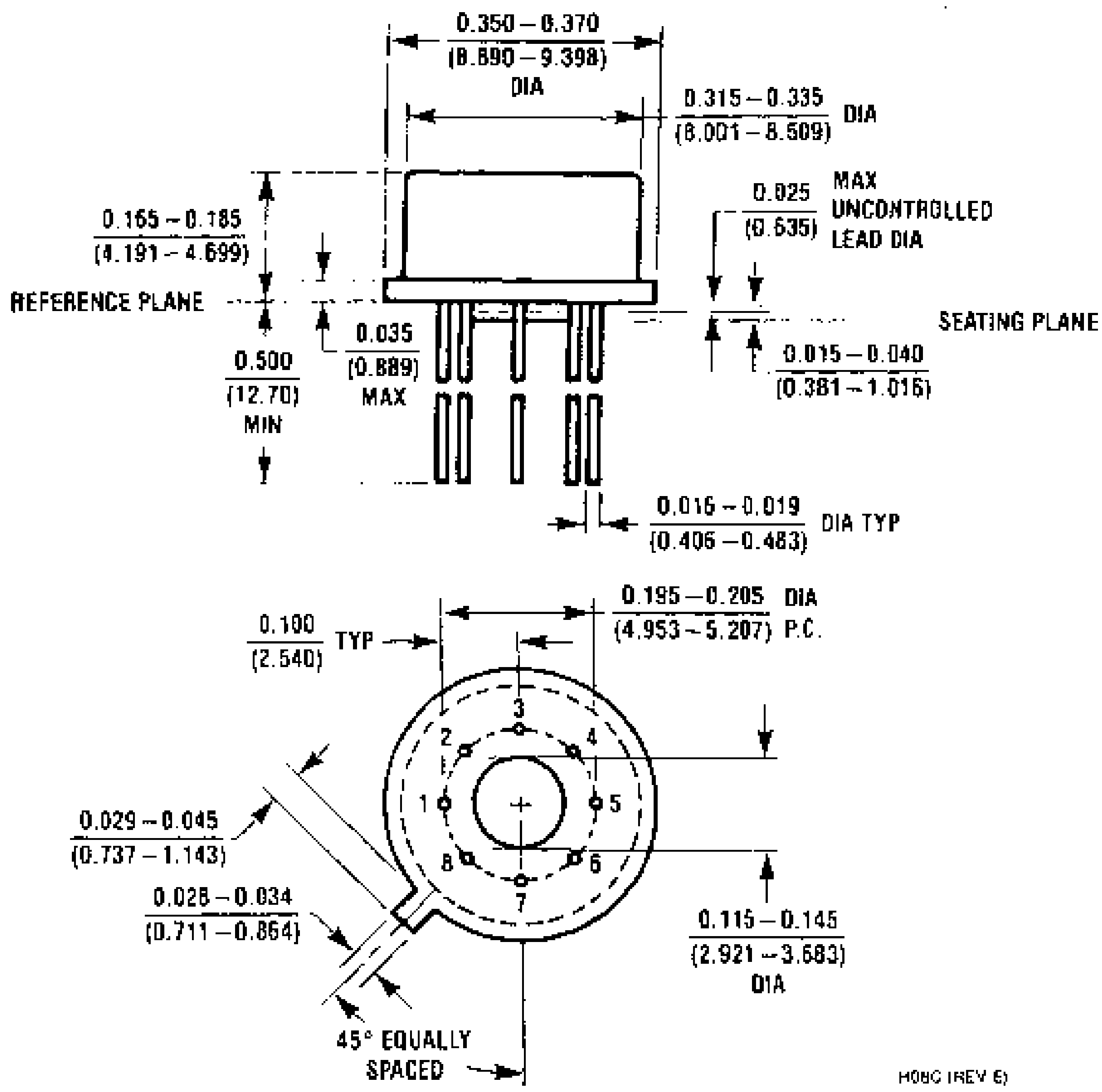
Schematic Diagram



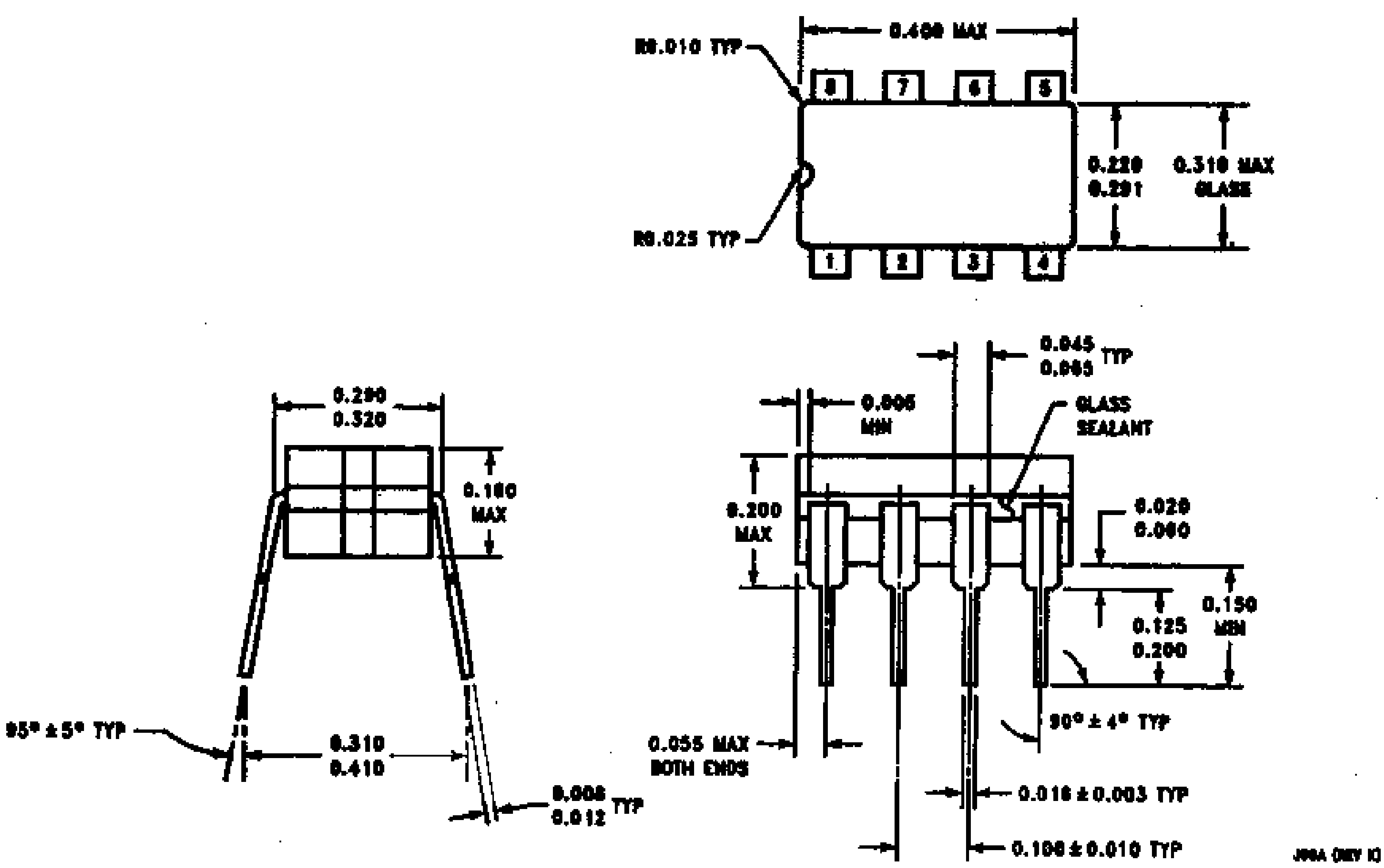
DS009341-1

6

Physical Dimensions inches (millimeters) unless otherwise noted



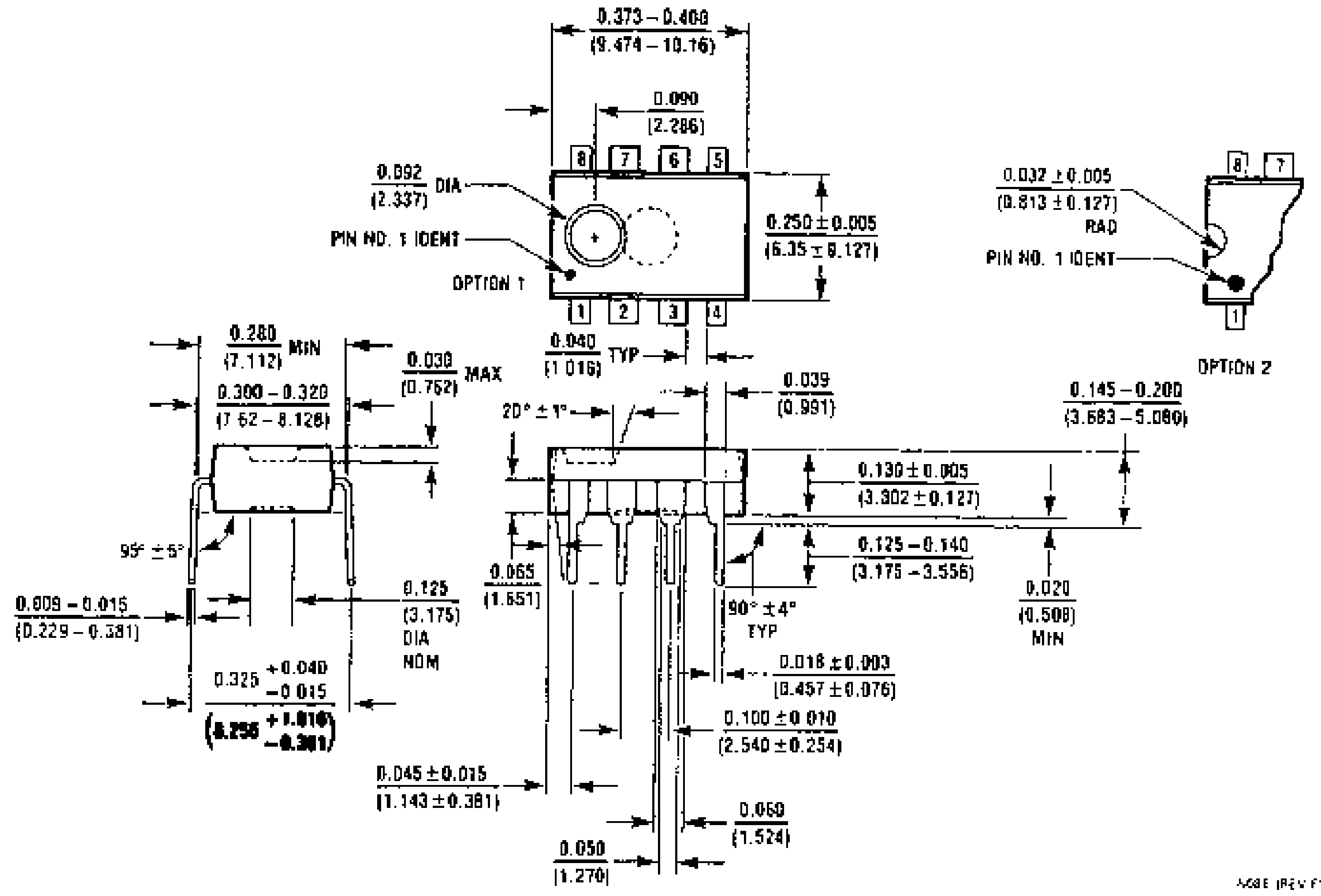
Metal Can Package (H)
Order Number LM741H, LM741H/883, LM741AH/883, LM741AH-MIL or LM741CH
NS Package Number H08C



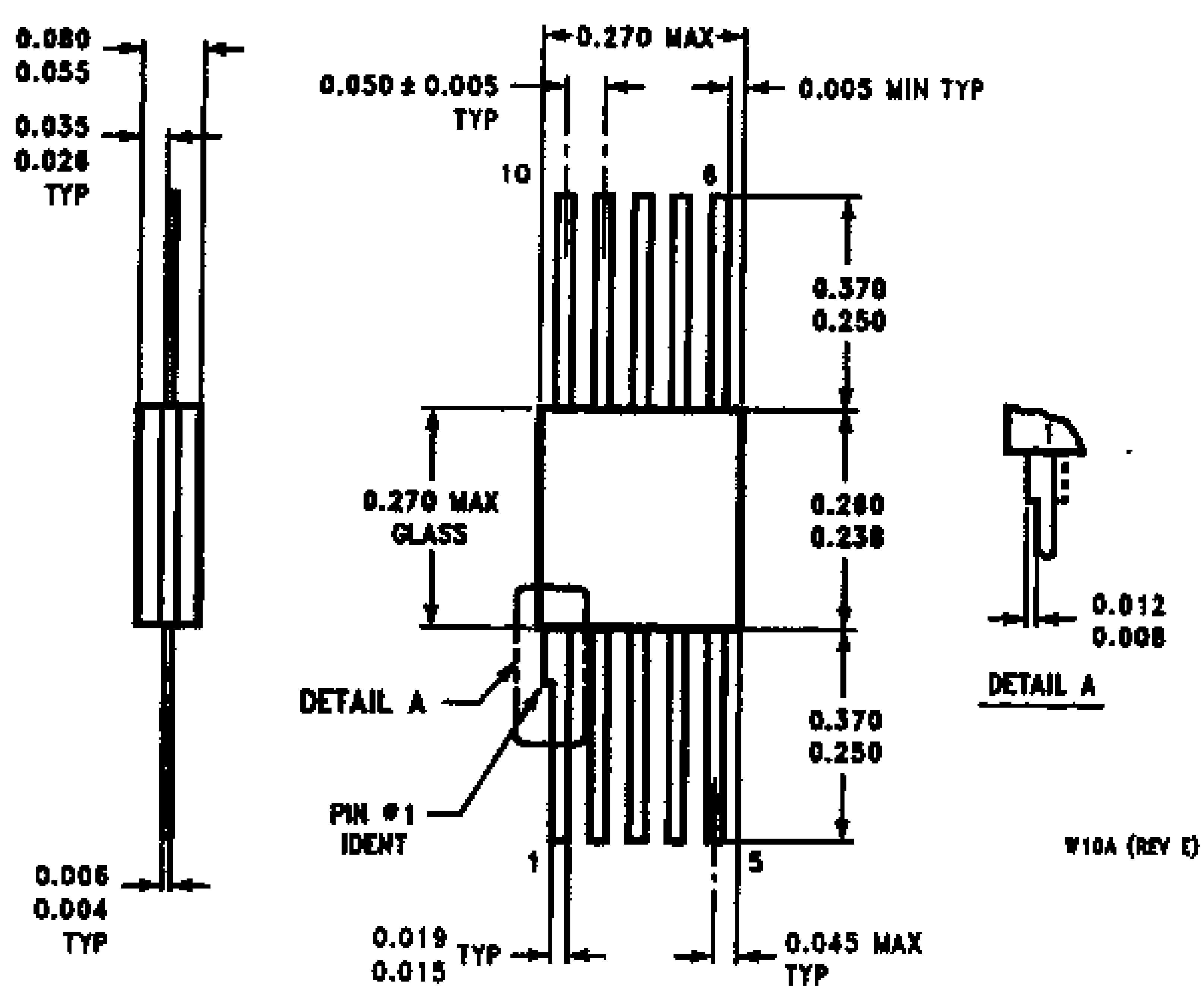
Ceramic Dual-In-Line Package (J)
Order Number LM741J/883
NS Package Number J08A

7

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



Dual-In-Line Package (N)
Order Number LM741CN
NS Package Number N08E



10-Lead Ceramic Flatpak (W)
Order Number LM741W/883, LM741WG-MPR or LM741WG/883
NS Package Number W10A

Notes

National Semiconductor Corporation
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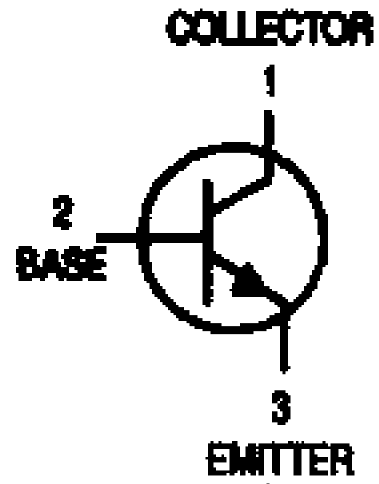
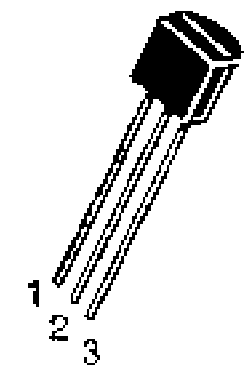
Amplifier Transistors
NPN Silicon

P2N2222A





CASE 29–04, STYLE 17
TO–92 (TO–226AA)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector–Emitter Voltage	V_{CEO}	40	Vdc
Collector–Base Voltage	V_{CBO}	75	Vdc
Emitter–Base Voltage	V_{EBO}	6.0	Vdc
Collector Current — Continuous	I_C	600	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	625 5.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.5 12	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	–55 to +150	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	200	°C/W
Thermal Resistance, Junction to Case	$R_{\theta JC}$	83.3	°C/W

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector–Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)	$V_{(BR)CEO}$	40	—	Vdc
Collector–Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	$V_{(BR)CBO}$	75	—	Vdc
Emitter–Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	$V_{(BR)EBO}$	6.0	—	Vdc
Collector Cutoff Current (V_{CE} = 60 Vdc, $V_{EB(off)}$ = 3.0 Vdc)	I_{CEX}	—	10	nAdc
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0) (V_{CB} = 60 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	 — —	 0.01 10	μAdc
Emitter Cutoff Current (V_{EB} = 3.0 Vdc, I_C = 0)	I_{EBO}	—	10	nAdc
Collector Cutoff Current (V_{CE} = 10 V)	I_{CEO}	—	10	nAdc
Base Cutoff Current (V_{CE} = 60 Vdc, $V_{EB(off)}$ = 3.0 Vdc)	I_{BEX}	—	20	nAdc

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted) (Continued)

Characteristic	Symbol	Min	Max	Unit
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			—
(I_C = 0.1 mAdc, V_{CE} = 10 Vdc)		35	—	
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)		50	—	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)		75	—	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, T_A = −55°C)		35	—	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)(1)		100	300	
(I_C = 150 mAdc, V_{CE} = 1.0 Vdc)(1)		50	—	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)(1)		40	—	
Collector–Emitter Saturation Voltage(1)	$V_{CE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		—	0.3	
(I_C = 500 mAdc, I_B = 50 mAdc)		—	1.0	
Base–Emitter Saturation Voltage(1)	$V_{BE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		0.6	1.2	
(I_C = 500 mAdc, I_B = 50 mAdc)		—	2.0	
SMALL–SIGNAL CHARACTERISTICS				
Current–Gain — Bandwidth Product(2) (I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	300	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{obo}	—	8.0	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)	C_{ibo}	—	25	pF
Input Impedance	h_{ie}			kΩ
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		2.0	8.0	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		0.25	1.25	
Voltage Feedback Ratio	h_{re}			X 10^{-4}
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		—	8.0	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		—	4.0	
Small–Signal Current Gain	h_{fe}			—
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		50	300	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		75	375	
Output Admittance	h_{oe}			μmhos
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		5.0	35	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		25	200	
Collector Base Time Constant (I_E = 20 mAdc, V_{CB} = 20 Vdc, f = 31.8 MHz)	$r_b'C_c$	—	150	ps
Noise Figure (I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 1.0 kΩ, f = 1.0 kHz)	N_F	—	4.0	dB
SWITCHING CHARACTERISTICS				
Delay Time — (V_{CC} = 30 Vdc, $V_{BE(off)}$ = −2.0 Vdc, I_C = 150 mAdc, I_{B1} = 15 mAdc) (Figure 1)	t_d	—	10	ns
Rise Time — (V_{CC} = 30 Vdc, $V_{BE(off)}$ = −2.0 Vdc, I_C = 150 mAdc, I_{B1} = 15 mAdc) (Figure 1)	t_r	—	25	ns
Storage Time — (V_{CC} = 30 Vdc, I_C = 150 mAdc, I_{B1} = I_{B2} = 15 mAdc) (Figure 2)	t_s	—	225	ns
Fall Time — (V_{CC} = 30 Vdc, I_C = 150 mAdc, I_{B1} = I_{B2} = 15 mAdc) (Figure 2)	t_f	—	60	ns

1. Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.
2. f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

SWITCHING TIME EQUIVALENT TEST CIRCUITS

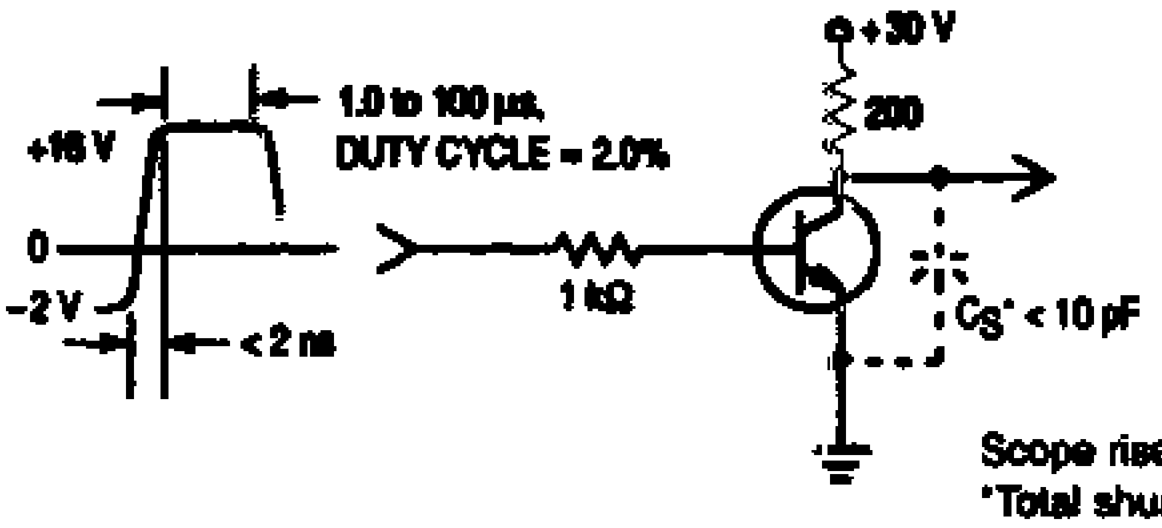


Figure 1. Turn–On Time

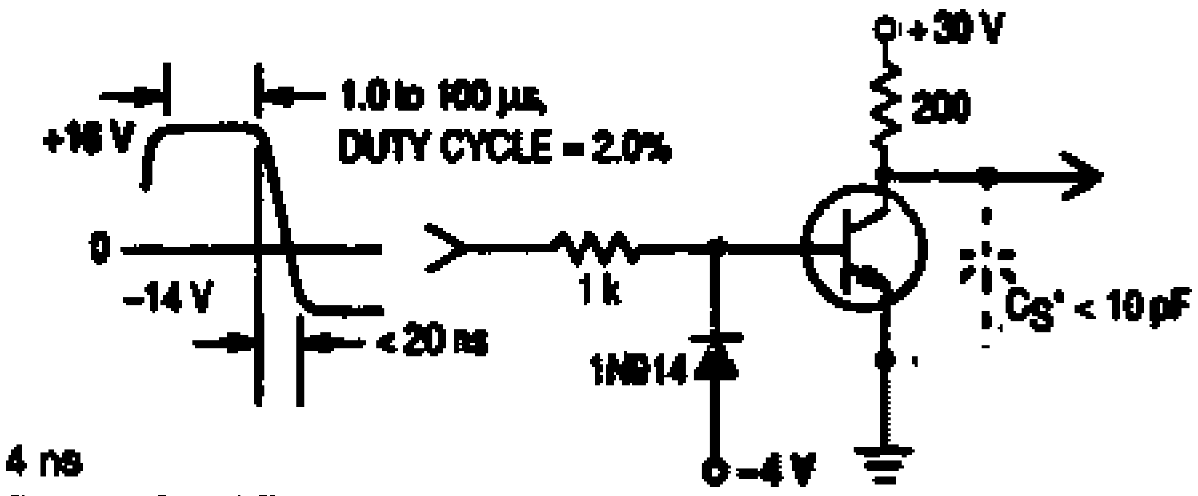


Figure 2. Turn–Off Time

Scope rise time < 4 ns
*Total shunt capacitance of test jig, connectors, and oscilloscope.

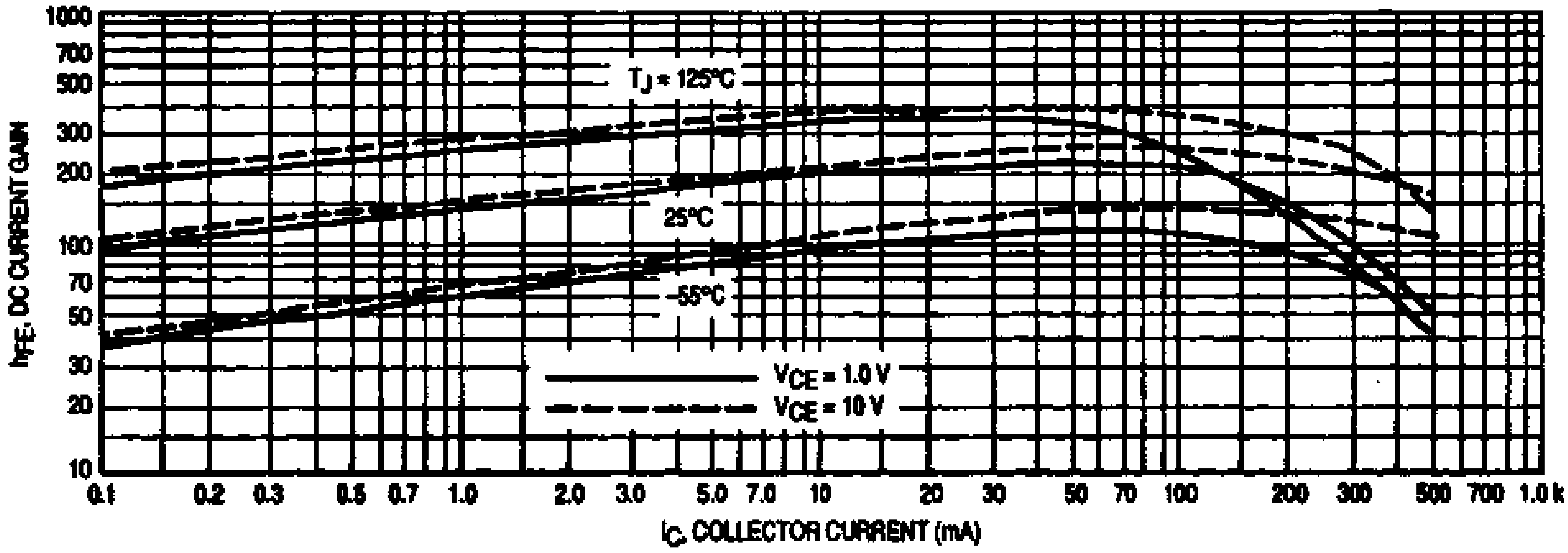
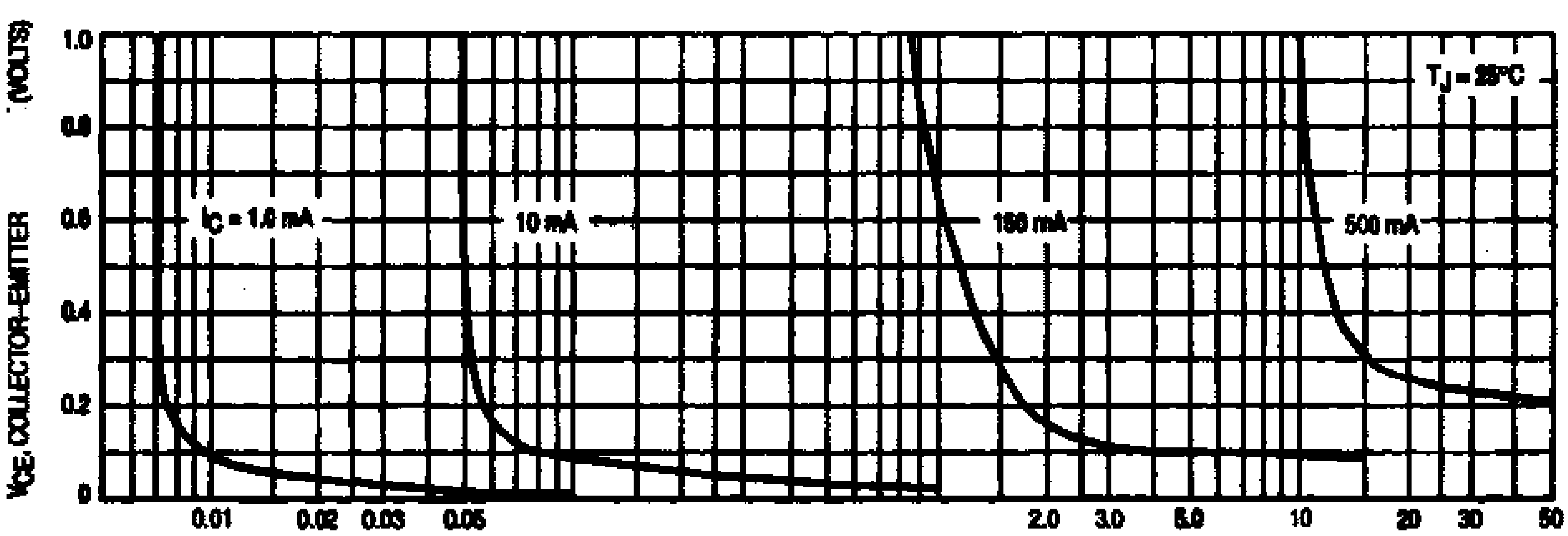


Figure 3. DC Current Gain



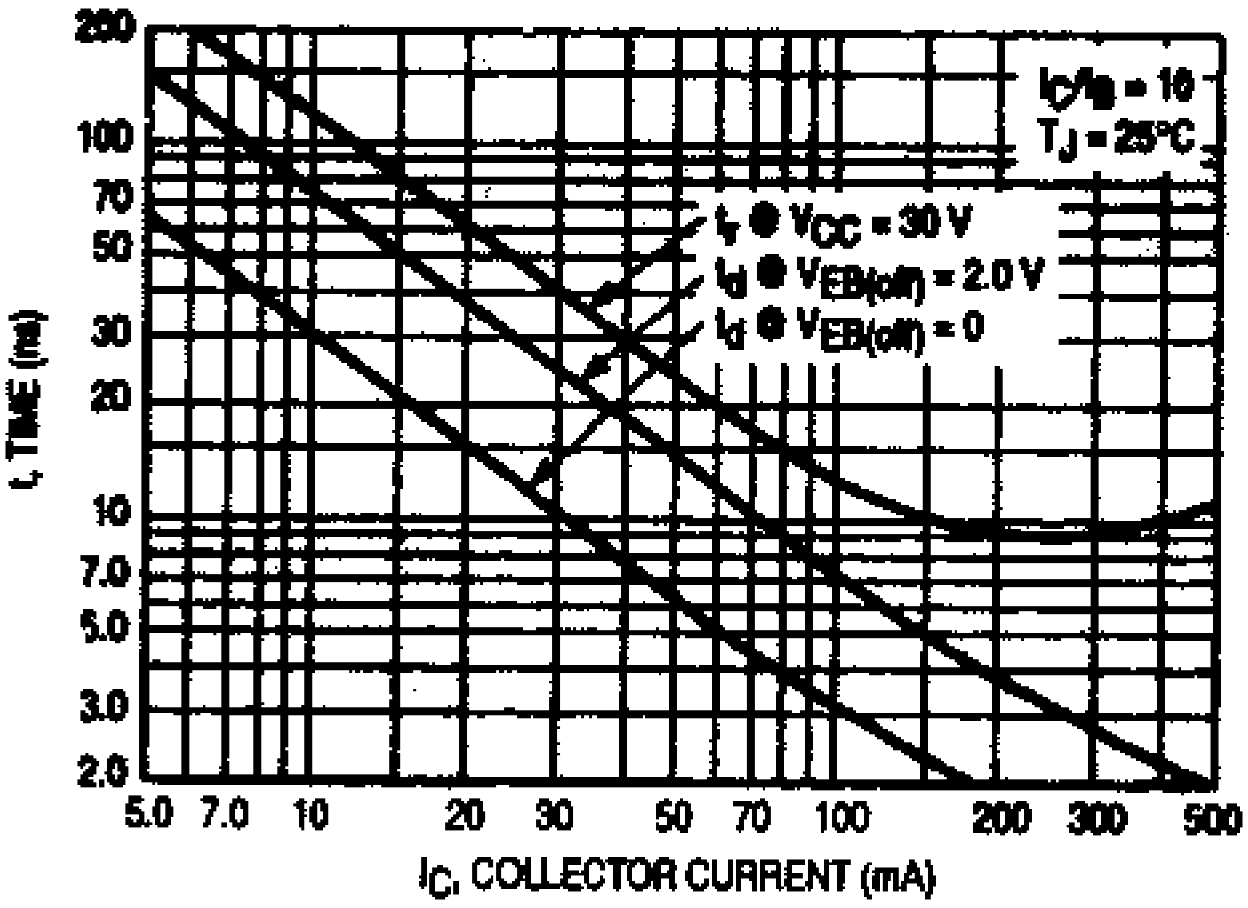


Figure 5. Turn–On Time

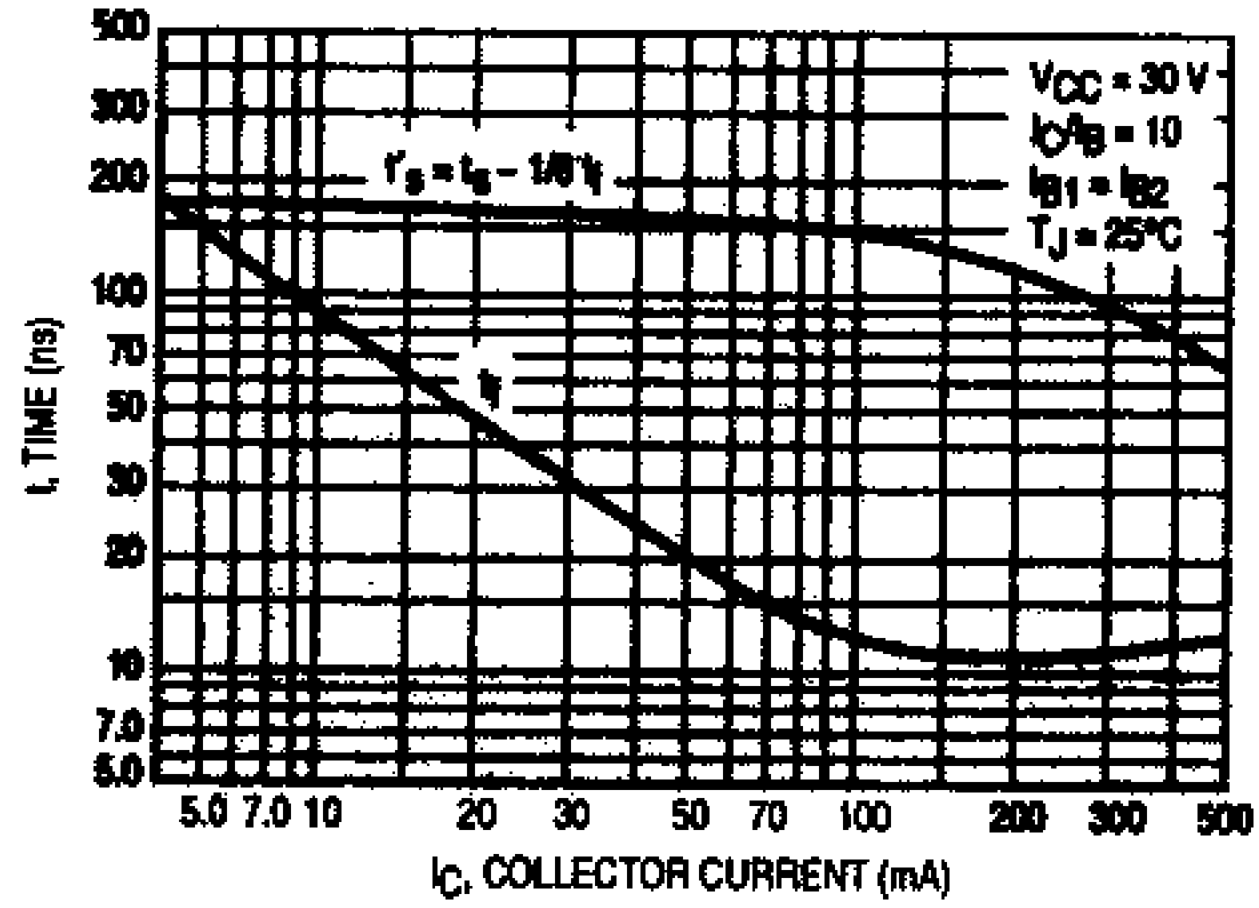


Figure 6. Turn–Off Time

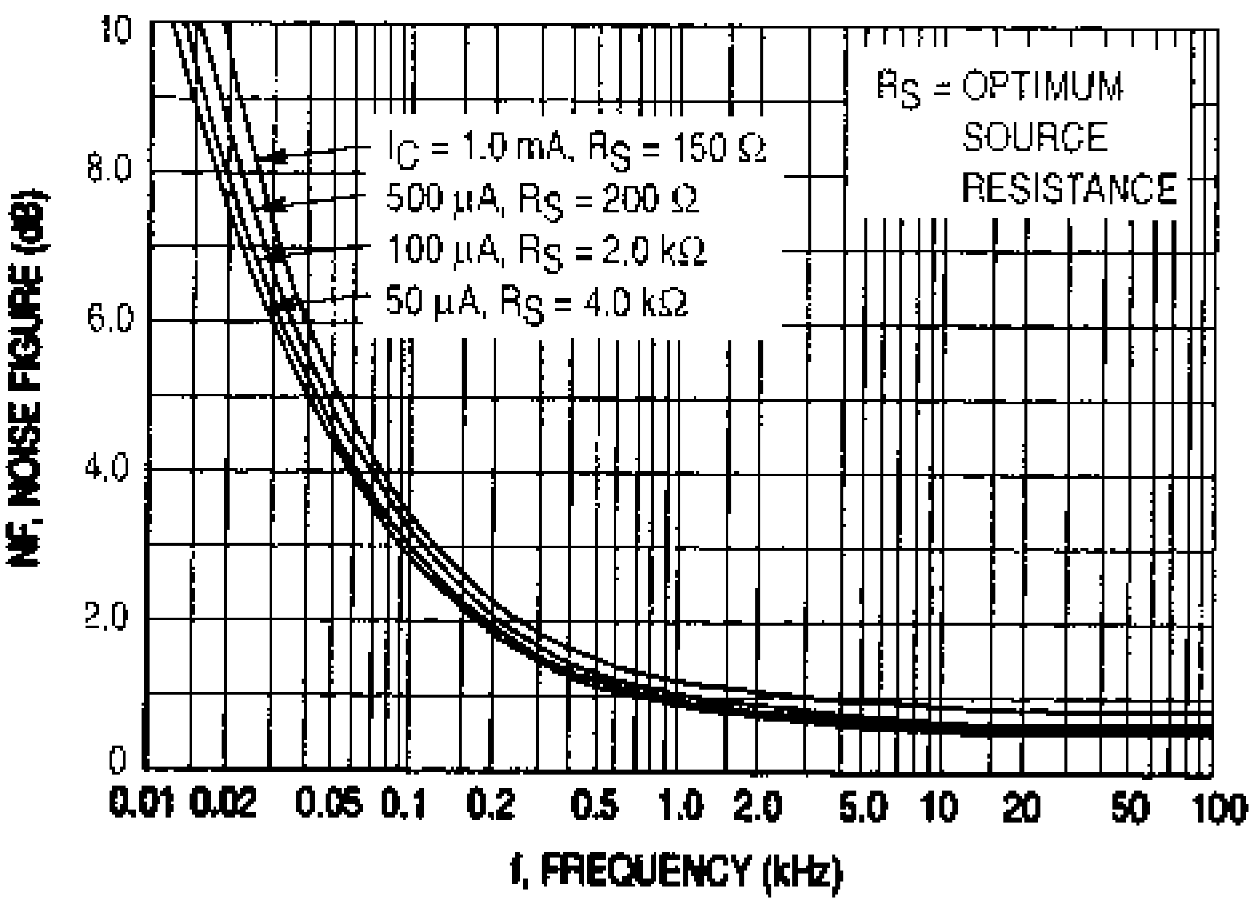


Figure 7. Frequency Effects

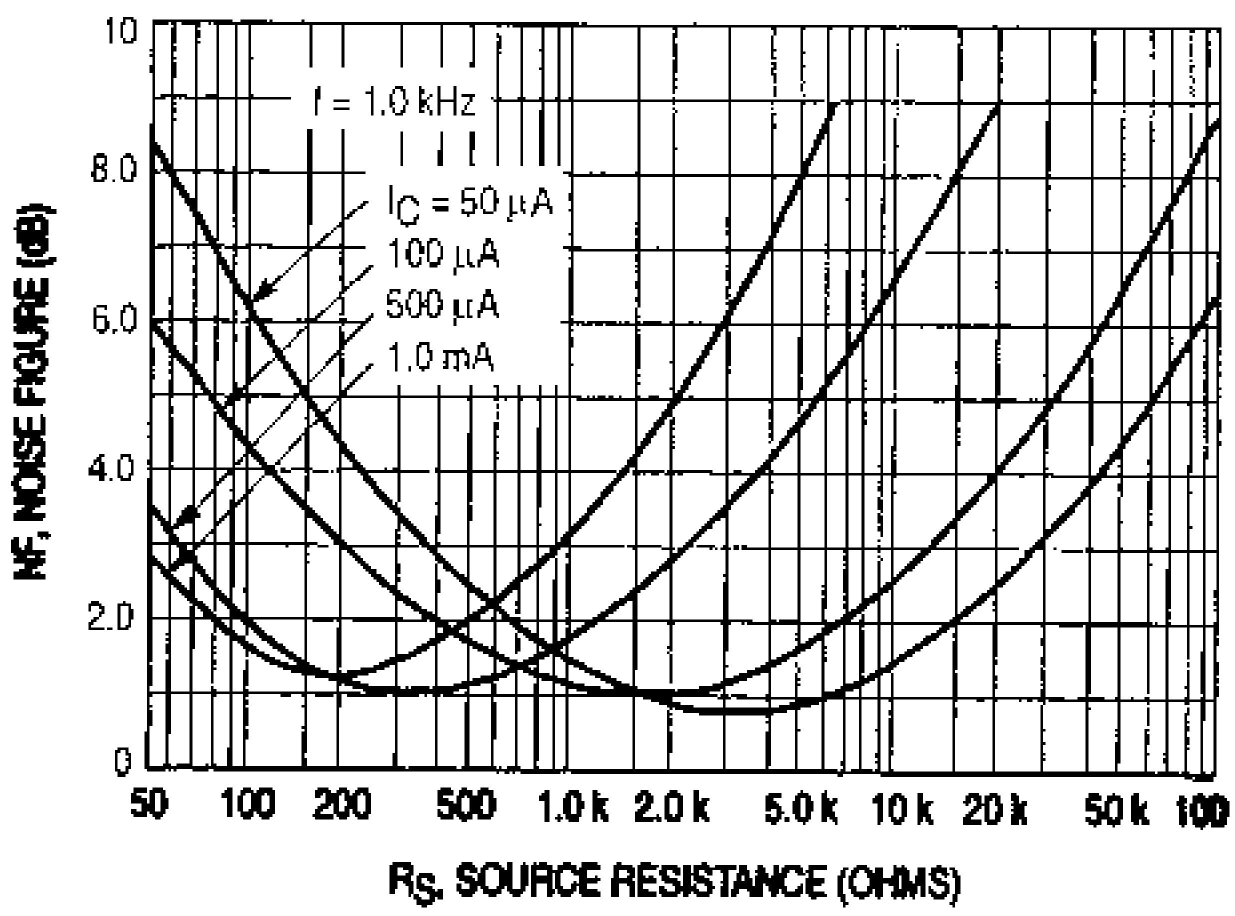


Figure 8. Source Resistance Effects

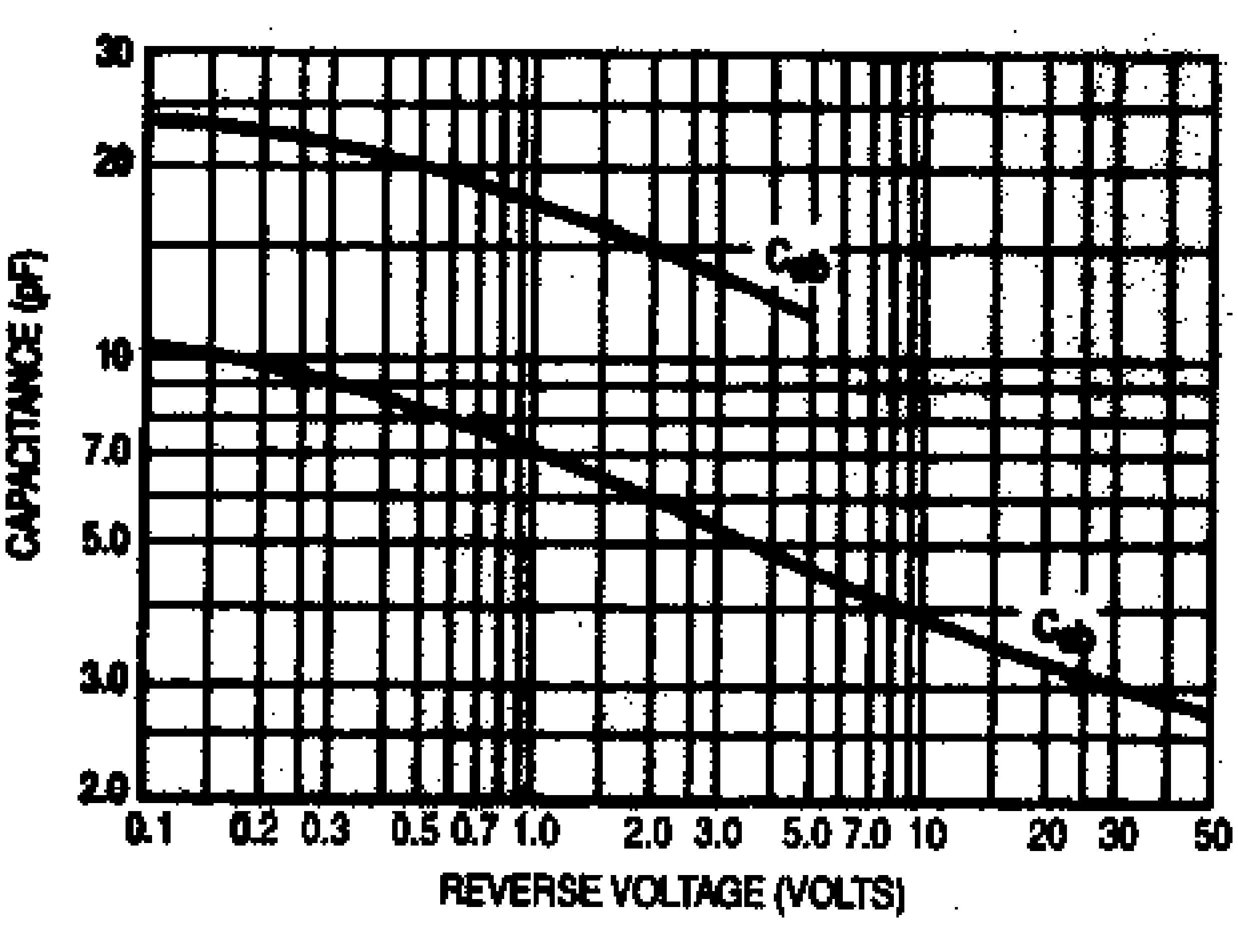


Figure 9. Capacitances

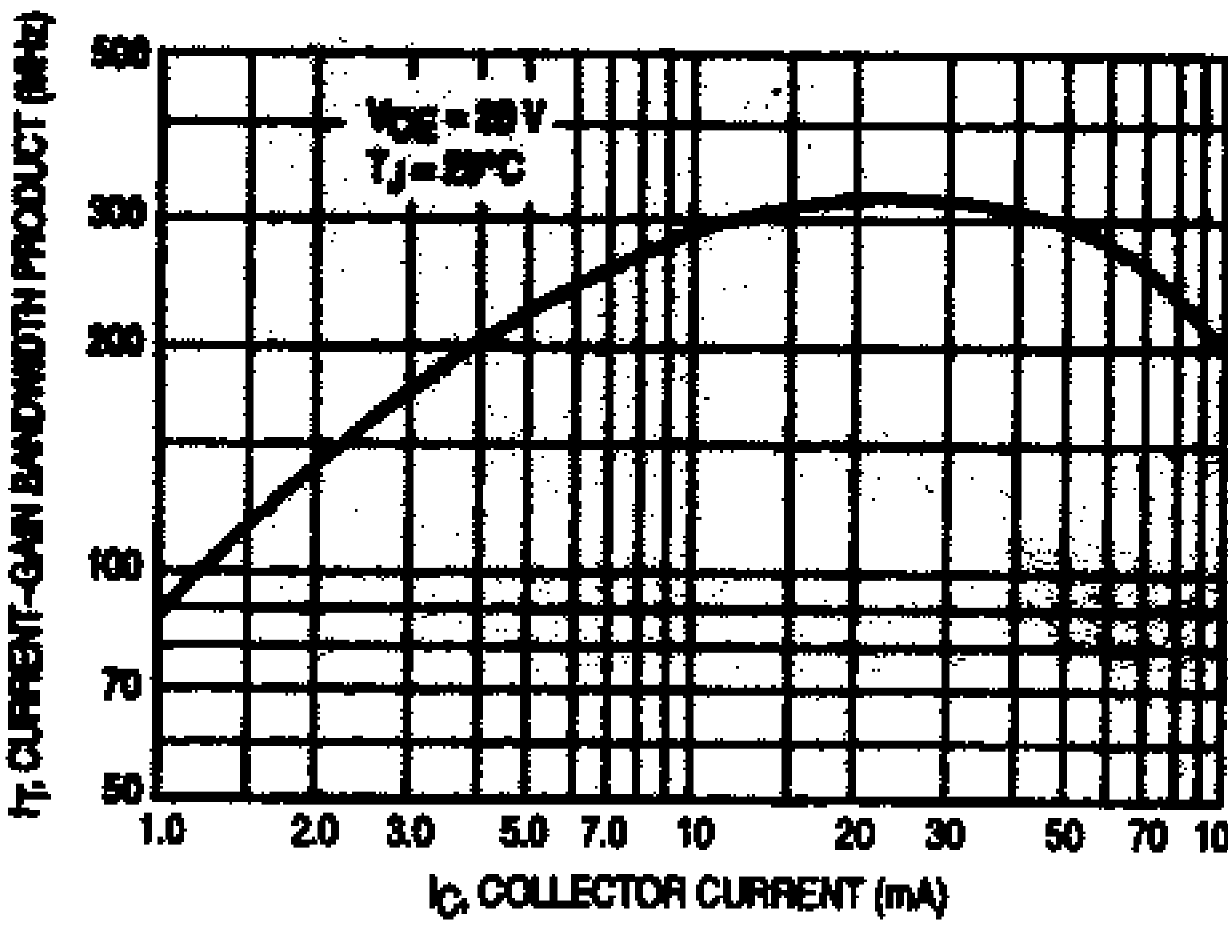


Figure 10. Current–Gain Bandwidth Product

13

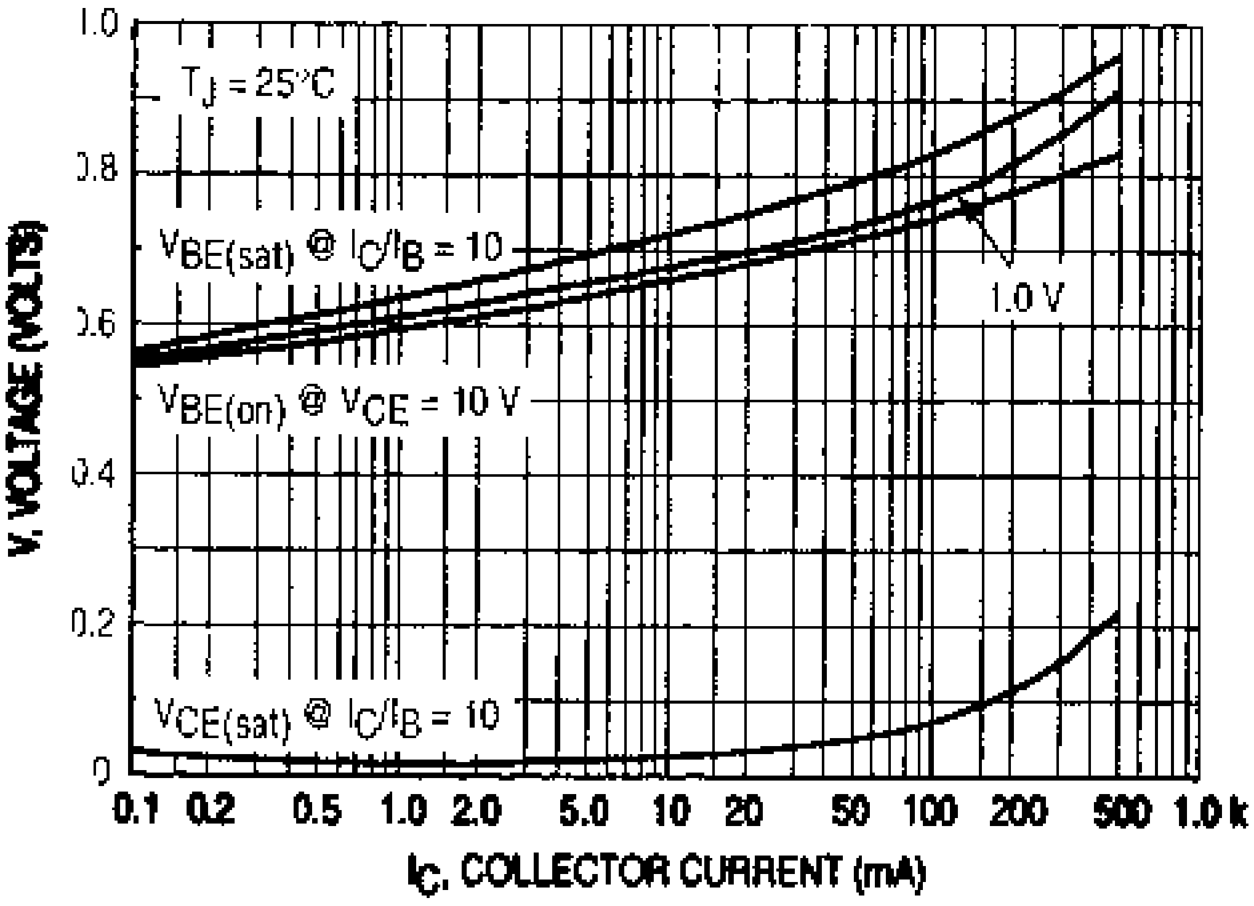


Figure 11. "On" Voltages

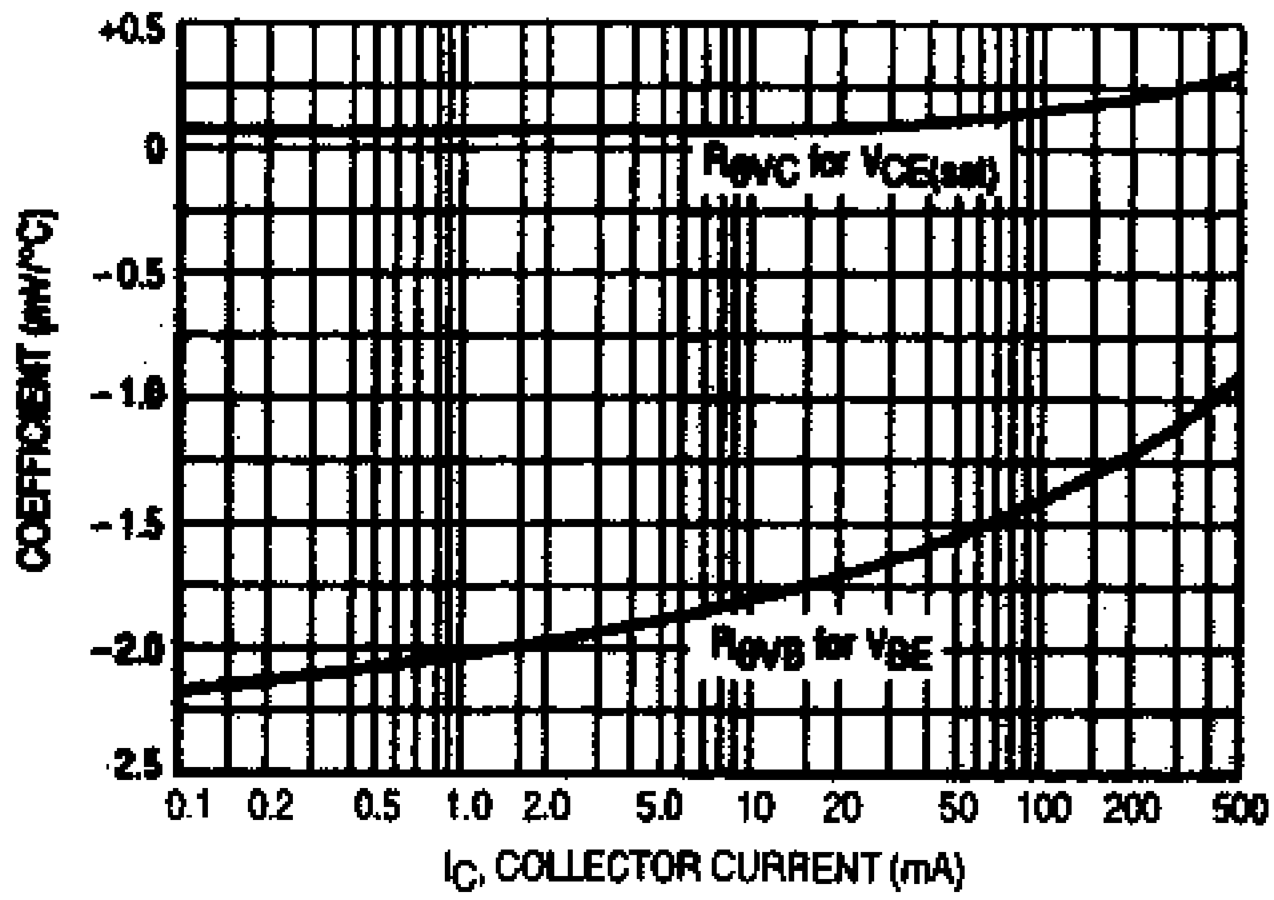
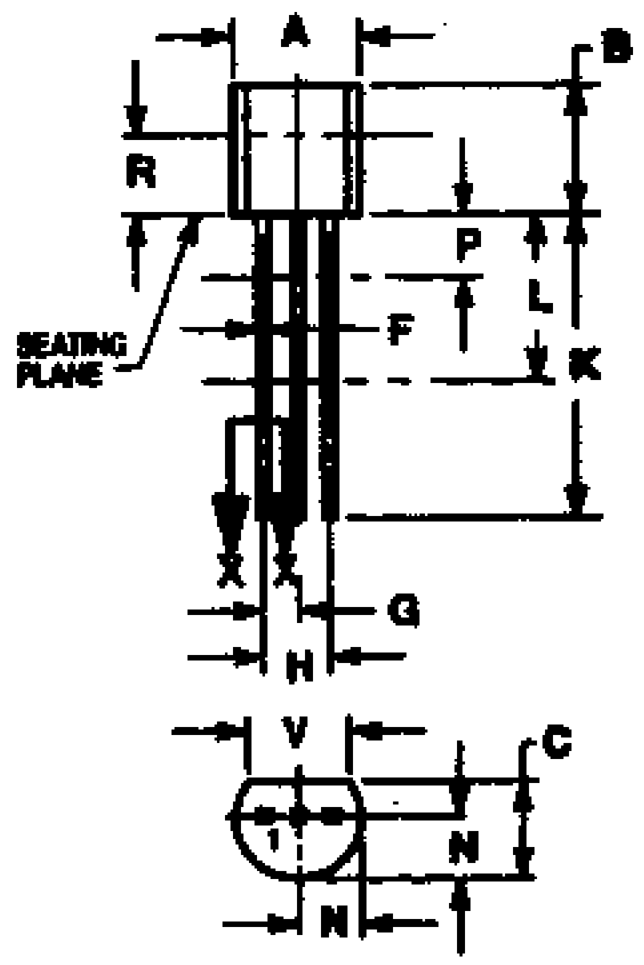
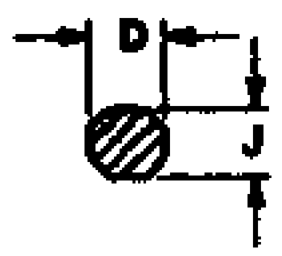


Figure 12. Temperature Coefficients

13 b

PACKAGE DIMENSIONS





SECTION X–X

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. CONTOUR OF PACKAGE BEYOND DIMENSION R IS UNCONTROLLED.
4. DIMENSION F APPLIES BETWEEN P AND L. DIMENSION D AND J APPLY BETWEEN L AND K MINIMUM. LEAD DIMENSION IS UNCONTROLLED IN P AND BEYOND DIMENSION K MINIMUM.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.175	0.205	4.45	5.20
B	0.170	0.210	4.32	5.33
C	0.125	0.165	3.18	4.19
D	0.016	0.022	0.41	0.55
F	0.016	0.019	0.41	0.48
G	0.045	0.055	1.15	1.39
H	0.095	0.105	2.42	2.66
J	0.015	0.020	0.39	0.50
K	0.500	—	12.70	—
L	0.250	—	6.35	—
N	0.080	0.105	2.04	2.66
P	—	0.100	—	2.54
R	0.115	—	2.93	—
V	0.135	—	3.43	—

CASE 029–04
(TO–226AA)
ISSUE AD

STYLE 17:
PIN 1. COLLECTOR
2. BASE
3. EMITTER

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