

TLE2027, TLE2027A, TLE2027Y EXCALIBUR LOW-NOISE HIGH-SPEED PRECISION OPERATIONAL AMPLIFIERS

SLOS054D – MAY 1990 – REVISED SEPTEMBER 1996

- **Outstanding Combination of dc Precision and AC Performance:**

Unity-Gain Bandwidth . . . 15 MHz Typ

V_n 3.3 nV/ $\sqrt{\text{Hz}}$ at $f = 10$ Hz Typ,
2.5 nV/ $\sqrt{\text{Hz}}$ at $f = 1$ kHz Typ

V_{IO} 25 μV Max

A_{VD} . . . 45 V/ μV Typ With $R_L = 2$ k Ω ,
19 V/ μV Typ With $R_L = 600$ Ω

- **Available in Standard-Pinout Small-Outline Package**

- **Output Features Saturation Recovery Circuitry**

- **Macromodels and Statistical information**

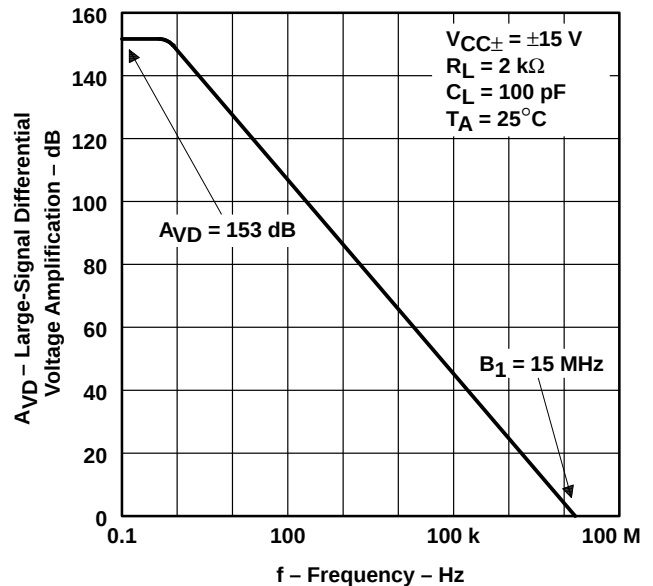
description

The TLE2027 and TLE2027A contain innovative circuit design expertise and high-quality process control techniques to produce a level of ac performance and dc precision previously unavailable in single operational amplifiers. Manufactured using Texas Instruments state-of-the-art Excalibur process, these devices allow upgrades to systems that use lower-precision devices.

In the area of dc precision, the TLE2027 and TLE2027A offer maximum offset voltages of 100 μV and 25 μV , respectively, common-mode rejection ratio of 131 dB (typ), supply voltage rejection ratio of 144 dB (typ), and dc gain of 45 V/ μV (typ).

The ac performance is highlighted by a typical unity-gain bandwidth specification of 15 MHz, 55° of phase margin, and noise voltage specifications of 3.3 nV/ $\sqrt{\text{Hz}}$ and 2.5 nV/ $\sqrt{\text{Hz}}$ at frequencies of 10 Hz and 1 kHz respectively.

**LARGE-SIGNAL
DIFFERENTIAL VOLTAGE AMPLIFICATION
VS
FREQUENCY**



AVAILABLE OPTIONS

T_A	$V_{IO\text{max}}$ AT 25°C	PACKAGED DEVICES				CHIP FORM (Y)
		SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)	
0°C to 70°C	25 μV 100 μV	TLE2027ACD TLE2027CD	— —	— —	TLE2027ACP TLE2027CP	— TLE2027Y
–40°C to 105°C	25 μV 100 μV	TLE2027AID TLE2027ID	— —	— —	TLE2027AIP TLE2027IP	— —
–55°C to 125°C	25 μV 100 μV	TLE2027AMD TLE2027MD	TLE2027AMFK TLE2027MFK	TLE2027AMJG TLE2027MJG	TLE2027AMP TLE2027MP	— —

The D packages are available taped and reeled. Add R suffix to device type (e.g., TLE2027ACDR).



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

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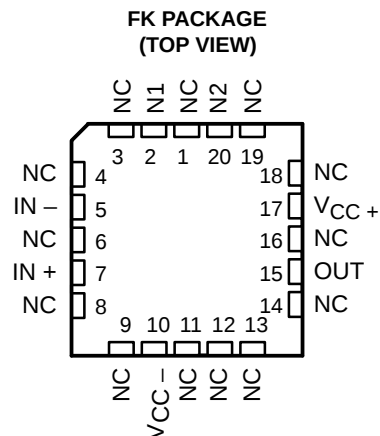
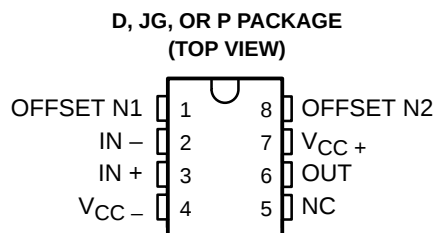
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On products compliant to MIL-PRF-38535, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

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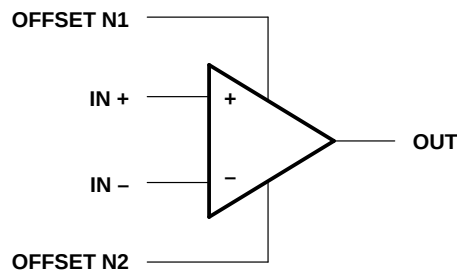
description (continued)

Both the TLE2027 and TLE2027A are available in a wide variety of packages, including the industry-standard 8-pin small-outline version for high-density system applications. The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from –40°C to 105°C. The M-suffix devices are characterized for operation over the full military temperature range of –55°C to 125°C.



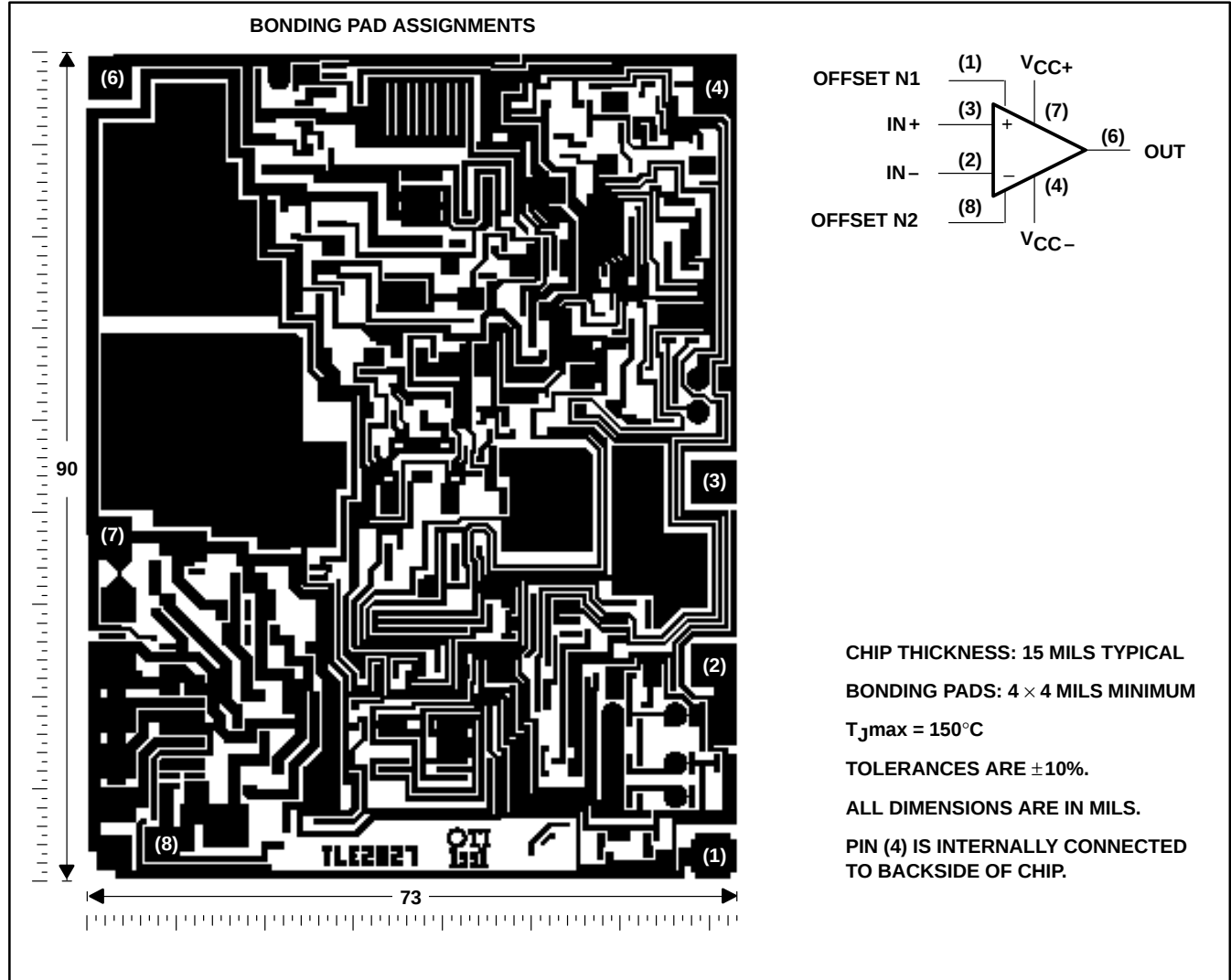
NC – No internal connection

symbol



TLE2027Y chip information

This chip, when properly assembled, displays characteristics similar to the TLE2027C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. The chip may be mounted with conductive epoxy or a gold-silicon preform.

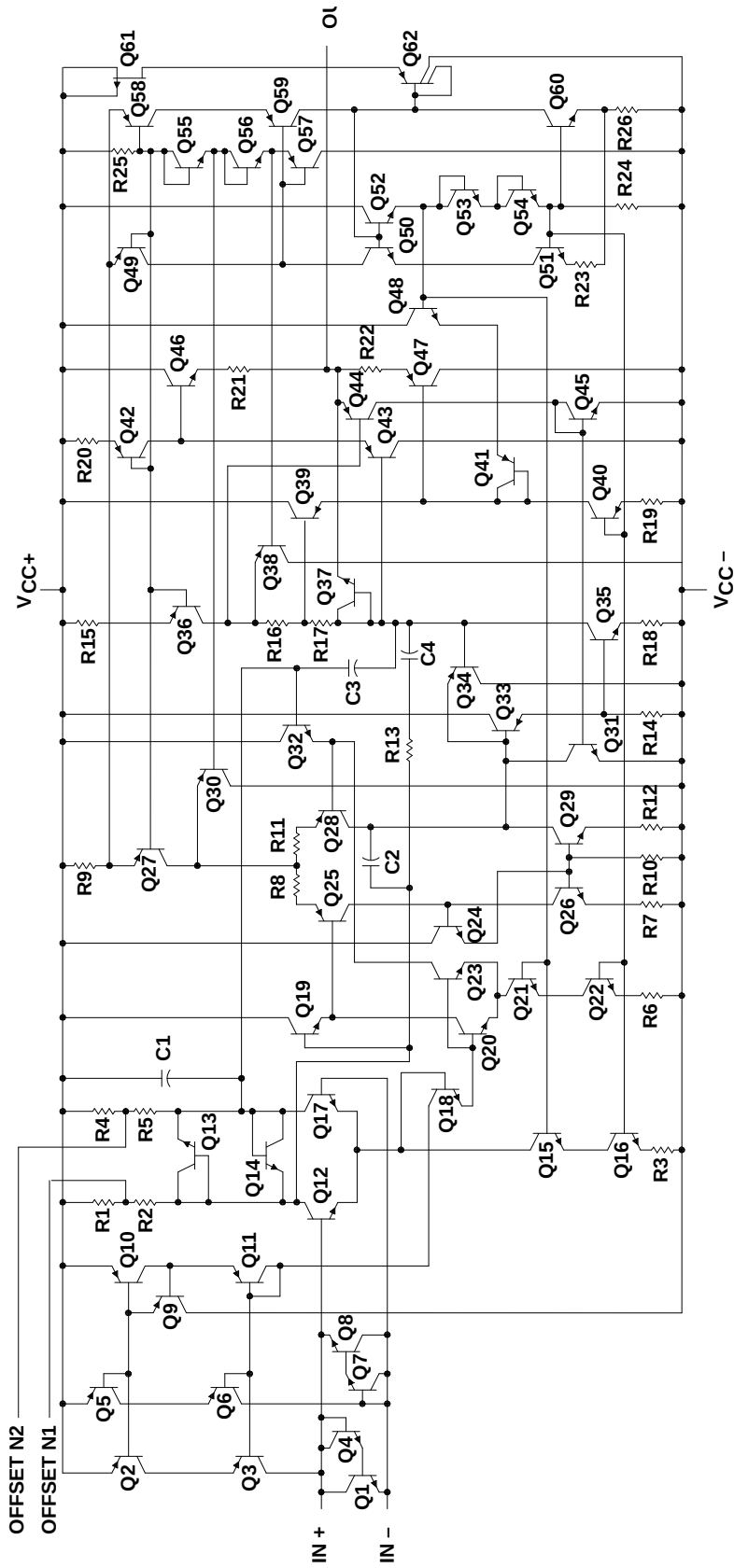


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equivalent schematic



COMPONENT COUNT			
Transistors	61		
Resistors	26		
Capacitors	4		
epi FET	1		

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)[†]

Supply voltage, V_{CC+} (see Note 1)	19 V
Supply voltage, V_{CC-}	– 19 V
Differential input voltage, V_{ID} (see Note 2)	± 1.2 V
Input voltage range, V_I (any input)	$V_{CC\pm}$
Input current, I_I (each Input)	± 1 mA
Output current, I_O	± 50 mA
Total current into V_{CC+}	50 mA
Total current out of V_{CC-}	50 mA
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range, T_A : C suffix	0°C to 70°C
I suffix	– 40°C to 105°C
M suffix	– 55°C to 125°C
Storage temperature range, T_{stg}	– 65°C to 150°C
Case temperature for 60 seconds, T_C : FK package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300°C

[†] Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{CC+} and V_{CC-} .
2. Differential voltages are at $IN+$ with respect to $IN-$. Excessive current flows if a differential input voltage in excess of approximately ± 1.2 V is applied between the inputs unless some limiting resistance is used.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A = 105^\circ\text{C}$ POWER RATING	$T_A = 125^\circ\text{C}$ POWER RATING
D	725 mW	5.8 mW/°C	464 mW	261 mW	145 mW
FK	1375 mW	11.0 mW/°C	880 mW	495 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	378 mW	210 mW
P	1000 mW	8.0 mW/°C	640 mW	360 mW	200 mW

recommended operating conditions

		C SUFFIX		I SUFFIX		M SUFFIX		UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	
Supply voltage, $V_{CC\pm}$		± 4	± 19	± 4	± 19	± 4	± 19	V
Common-mode input voltage, V_{IC}	$T_A = 25^\circ\text{C}$	–11	11	–11	11	–11	11	V
	$T_A = \text{Full range}^\ddagger$	–10.5	10.5	–10.4	10.4	–10.2	10.2	
Operating free-air temperature, T_A		0	70	–40	105	–55	125	°C

[‡] Full range is 0°C to 70°C for C-suffix devices, –40°C to 105°C for I-suffix devices, and –55°C to 125°C for M-suffix devices.

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electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T _A [†]	TLE2027C			TLE2027AC			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO}	Input offset voltage	V _{IC} = 0, R _S = 50 Ω	25°C	20 100		10 25		μV		
			Full range	145		70				
α _{VIO}	Temperature coefficient of input offset voltage		Full range	0.4 1		0.2 1		μV/°C		
	Input offset voltage long-term drift (see Note 4)		25°C	0.006 1		0.006 1		μV/mo		
I _{IO}	Input offset current		25°C	6 90		6 90		nA		
			Full range	150		150				
I _{IB}	Input bias current		25°C	15 90		15 90		nA		
			Full range	150		150				
V _{ICR}	Common-mode input voltage range	R _S = 50 Ω	25°C	-11 to 11	-13 to 13	-11 to 11	-13 to 13	V		
			Full range	-10.5 to 10.5		-10.5 to 10.5				
V _{OM} +	Maximum positive peak output voltage swing	R _L = 600 Ω	25°C	10.5		10.5		V		
			Full range	10		10				
		R _L = 2 kΩ	25°C	12		12				
			Full range	11		11				
V _{OM} -	Maximum negative peak output voltage swing	R _L = 600 Ω	25°C	-10.5	-13	-10.5	-13	V		
			Full range	-10		-10				
		R _L = 2 kΩ	25°C	-12	-13.5	-12	-13.5			
			Full range	-11		-11				
A _{VD}	Large-signal differential voltage amplification	V _O = ±11 V, R _L = 2 kΩ	25°C	5	45	10	45	V/μV		
		V _O = ±10 V, R _L = 2 kΩ	Full range	2		4				
		V _O = ±10 V, R _L = 1 kΩ	25°C	3.5	38	8	38			
			Full range	1		2.5				
		V _O = ±10 V, R _L = 600 Ω	25°C	2	19	5	19			
			Full range	0.5		2				
C _i	Input capacitance		25°C	8		8		pF		
z _o	Open-loop output impedance	I _O = 0	25°C	50		50		Ω		
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICRmin} , R _S = 50 Ω	25°C	100	131	117	131	dB		
			Full range	98		114				
k _{SVR}	Supply-voltage rejection ratio (ΔV _{CC±} /ΔV _{IO})	V _{CC±} = ±4 V to ±18 V, R _S = 50 Ω	25°C	94	144	110	144	dB		
		V _{CC±} = ±4 V to ±18 V, R _S = 50 Ω	Full range	92		106				
I _{CC}	Supply current	V _O = 0, No load	25°C	3.8	5.3	3.8	5.3	mA		
			Full range	5.6		5.6				

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150^\circ\text{C}$ extrapolated to $T_A = 25^\circ\text{C}$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

operating characteristics at specified free-air temperature, $V_{CC} \pm = \pm 15\text{ V}$

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLE2027C			TLE2027AC			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR Slew rate at unity gain	$R_L = 2\text{ k}\Omega$, $C_L = 100\text{ pF}$, See Figure 1	25°C	1.7	2.8		1.7	2.8		V/ μs
		Full range	1.2			1.2			
V_n Equivalent input noise voltage (see Figure 2)	$R_S = 20\text{ }\Omega$, $f = 10\text{ Hz}$	25°C		3.3	8		3.3	4.5	nV/ $\sqrt{\text{Hz}}$
	$R_S = 20\text{ }\Omega$, $f = 1\text{ kHz}$			2.5	4.5		2.5	3.8	
$V_{N(PP)}$ Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz}$ to 10 Hz	25°C		50	250		50	130	nV
I_n Equivalent input noise current	$f = 10\text{ Hz}$	25°C		1.5	4		1.5	4	pA/ $\sqrt{\text{Hz}}$
	$f = 1\text{ kHz}$			0.4	0.6		0.4	0.6	
THD Total harmonic distortion	$V_O = +10\text{ V}$, $A_{VD} = 5$, See Note 5	25°C	<0.002%			<0.002%			
B_1 Unity-gain bandwidth (see Figure 3)	$R_L = 2\text{ k}\Omega$, $C_L = 100\text{ pF}$	25°C	7	13		9	13		MHz
B_{OM} Maximum output-swing bandwidth	$R_L = 2\text{ k}\Omega$	25°C		30			30		kHz
ϕ_m Phase margin at unity gain (see Figure 3)	$R_L = 2\text{ k}\Omega$, $C_L = 100\text{ pF}$	25°C		55°			55°		

† Full range is 0°C to 70°C.

NOTE 5: Measured distortion of the source used in the analysis was 0.002%.

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electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T _A [†]	TLE2027I			TLE2027AI			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO}	Input offset voltage	V _{IC} = 0, R _S = 50 Ω	25°C	20	100	10	25	μV		
			Full range	180			105			
α _{VIO}	Temperature coefficient of input offset voltage		Full range	0.4	1	0.2	1	μV/°C		
	Input offset voltage long-term drift (see Note 4)		25°C	0.006	1	0.006	1	μV/mo		
I _{IO}	Input offset current		25°C	6	90	6	90	nA		
			Full range	150			150			
I _{IB}	Input bias current		25°C	15	90	15	90	nA		
			Full range	150			150			
V _{ICR}	Common-mode input voltage range	R _S = 50 Ω	25°C	–11 to 11	–13 to 13	–11 to 11	–13 to 13	V		
			Full range	–10.4 to 10.4		–10.4 to 10.4				
V _{OM} +	Maximum positive peak output voltage swing	R _L = 600 Ω	25°C	10.5		10.5		V		
			Full range	10		10				
		R _L = 2 kΩ	25°C	12		12				
			Full range	11		11				
V _{OM} –	Maximum negative peak output voltage swing	R _L = 600 Ω	25°C	–10.5	–13	–10.5	–13	V		
			Full range	–10		–10				
		R _L = 2 kΩ	25°C	–12	–13.5	–12	–13.5			
			Full range	–11		–11				
A _{VD}	Large-signal differential voltage amplification	V _O = ±11 V, R _L = 2 kΩ	25°C	5	45	10	45	V/μV		
		V _O = ±10 V, R _L = 2 kΩ	Full range	2		3.5				
		V _O = ±10 V, R _L = 1 kΩ	25°C	3.5	38	8	38			
			Full range	1		2.2				
		V _O = ±10 V, R _L = 600 Ω	25°C	2	19	5	19			
			Full range	0.5		1.1				
C _i	Input capacitance		25°C	8		8		pF		
z _o	Open-loop output impedance	I _O = 0	25°C	50		50		Ω		
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICRmin} , R _S = 50 Ω	25°C	100	131	117	131	dB		
			Full range	96		113				
k _{SVR}	Supply-voltage rejection ratio (ΔV _{CC±} /ΔV _{IO})	V _{CC±} = ±4 V to ±18 V, R _S = 50 Ω	25°C	94	144	110	144	dB		
		V _{CC±} = ±4 V to ±18 V, R _S = 50 Ω	Full range	90		105				
I _{CC}	Supply current	V _O = 0, No load	25°C	3.8	5.3	3.8	5.3	mA		
			Full range	5.6		5.6				

† Full range is –40°C to 105°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150^\circ\text{C}$ extrapolated to $T_A = 25^\circ\text{C}$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.



operating characteristics at specified free-air temperature, $V_{CC} \pm = \pm 15\text{ V}$

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLE2027I			TLE2027AI			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain $R_L = 2\text{ k}\Omega$, $C_L = 100\text{ pF}$, See Figure 1	25°C	1.7	2.8		1.7	2.8		V/ μs
		Full range	1.1			1.1			
V_n	Equivalent input noise voltage (see Figure 2)	25°C		3.3	8		3.3	4.5	nV/ $\sqrt{\text{Hz}}$
				2.5	4.5		2.5	3.8	
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage $f = 0.1\text{ Hz to }10\text{ Hz}$	25°C		50	250		50	130	nV
I_n	Equivalent input noise current $f = 10\text{ Hz}$	25°C		1.5	4		1.5	4	pA/ $\sqrt{\text{Hz}}$
				0.4	0.6		0.4	0.6	
THD	Total harmonic distortion $V_O = +10\text{ V}$, $A_{VD} = 1$, See Note 5	25°C	< 0.002%			< 0.002%			
B_1	Unity-gain bandwidth (see Figure 3) $R_L = 2\text{ k}\Omega$, $C_L = 100\text{ pF}$	25°C	7	13		9	13		MHz
B_{OM}	Maximum output-swing bandwidth $R_L = 2\text{ k}\Omega$	25°C		30			30		kHz
ϕ_m	Phase margin at unity gain (see Figure 3) $R_L = 2\text{ k}\Omega$, $C_L = 100\text{ pF}$	25°C		55°			55°		

[†] Full range is – 40°C to 105°C.

NOTE 5: Measured distortion of the source used in the analysis was 0.002%.

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electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T _A [†]	TLE2027M			TLE2027AM			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO}	Input offset voltage	V _{IC} = 0, R _S = 50 Ω	25°C	20	100	10	25	μV		
			Full range	200			105			
α _{VIO}	Temperature coefficient of input offset voltage		Full range	0.4	1*	0.2	1*	μV/°C		
	Input offset voltage long-term drift (see Note 4)		25°C	0.006	1*	0.006	1*	μV/mo		
I _{IO}	Input offset current		25°C	6	90	6	90	nA		
			Full range	150			150			
I _{IB}	Input bias current		25°C	15	90	15	90	nA		
			Full range	150			150			
V _{ICR}	Common-mode input voltage range	R _S = 50 Ω	25°C	–11 to 11	–13 to 13	–11 to 11	–13 to 13	V		
			Full range	–10.3 to 10.3		–10.4 to 10.4				
V _{OM} +	Maximum positive peak output voltage swing	R _L = 600 Ω	25°C	10.5		10.5		V		
			Full range	10		10				
		R _L = 2 kΩ	25°C	12		12				
			Full range	11		11				
V _{OM} –	Maximum negative peak output voltage swing	R _L = 600 Ω	25°C	–10.5 –13		–10.5 –13		V		
			Full range	–10		–10				
		R _L = 2 kΩ	25°C	–12 –13.5		–12 –13.5				
			Full range	–11		–11				
A _{VD}	Large-signal differential voltage amplification	V _O = ±11 V, R _L = 2 kΩ	25°C	5	45	10	45	V/μV		
		V _O = ±10 V, R _L = 2 kΩ	Full range	2.5		3.5				
		V _O = ±10 V, R _L = 1 kΩ	25°C	3.5	38	8	38			
			Full range	1.8		2.2				
		V _O = ±10 V, R _L = 600 Ω	25°C	2	19	5	19			
C _i	Input capacitance		25°C	8			8		pF	
Z _O	Open-loop output impedance	I _O = 0	25°C	50			50		Ω	
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICRmin} , R _S = 50 Ω	25°C	100	131	117	131	dB		
			Full range	96			113			
k _{SVR}	Supply-voltage rejection ratio (ΔV _{CC±} /ΔV _{IO})	V _{CC±} = ±4 V to ±18 V, R _S = 50 Ω	25°C	94	144	110	144	dB		
		V _{CC±} = ±4 V to ±18 V, R _S = 50 Ω	Full range	90			105			
I _{CC}	Supply current	V _O = 0, No load	25°C	3.8	5.3	3.8	5.3	mA		
			Full range	5.6			5.6			

* On products compliant to MIL-PRF-38535, this parameter is not production tested.

† Full range is – 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150^\circ C$ extrapolated to $T_A = 25^\circ C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.



operating characteristics at specified free-air temperature, $V_{CC} \pm = \pm 15\text{ V}$

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLE2027M			TLE2027AM			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR Slew rate at unity gain	$R_L = 2\text{ k}\Omega$, $C_L = 100\text{ pF}$, See Figure 1	25°C	1.7	2.8		1.7	2.8		V/ μs
		Full range	1			1			
V_n Equivalent input noise voltage (see Figure 2)	$R_S = 20\text{ }\Omega$, $f = 10\text{ Hz}$	25°C		3.3	8*		3.3	4.5*	nV/ $\sqrt{\text{Hz}}$
	$R_S = 20\text{ }\Omega$, $f = 1\text{ kHz}$			2.5	4.5*		2.5	3.8*	
$V_{N(PP)}$ Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }10\text{ Hz}$	25°C		50	250*		50	130*	nV
I_n Equivalent input noise current	$f = 10\text{ Hz}$	25°C		1.5	4*		1.5	4*	pA/ $\sqrt{\text{Hz}}$
	$f = 1\text{ kHz}$			0.4	0.6*		0.4	0.6*	
THD Total harmonic distortion	$V_O = +10\text{ V}$, $A_{VD} = 1$, See Note 5	25°C	< 0.002%			< 0.002%			
B_1 Unity-gain bandwidth (see Figure 3)	$R_L = 2\text{ k}\Omega$, $C_L = 100\text{ pF}$	25°C	7*	13		9*	13		MHz
B_{OM} Maximum output-swing bandwidth	$R_L = 2\text{ k}\Omega$	25°C		30			30		kHz
ϕ_m Phase margin at unity gain (see Figure 3)	$R_L = 2\text{ k}\Omega$, $C_L = 100\text{ pF}$	25°C		55°			55°		

* On products compliant to MIL-PRF-38535, this parameter is not production tested.

† Full range is – 55°C to 125°C.

NOTE 5: Measured distortion of the source used in the analysis was 0.002%.

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electrical characteristics, $V_{CC\pm} = \pm 15$ V, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TLE2027Y			UNIT
			MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_{IC} = 0, \quad R_S = 50 \, \Omega$		20	100	μV
	Input offset voltage long-term drift (see Note 4)			0.006		$\mu\text{V}/\text{mo}$
I_{IO}	Input offset current			6		nA
I_{IB}	Input bias current			15		nA
V_{ICR}	Common-mode input voltage range	$R_S = 50 \, \Omega$		–13 to 13		V
V_{OM}	Maximum negative peak output voltage swing	$R_L = 600 \, \Omega$		–13		V
		$R_L = 2 \, \text{k}\Omega$		–13.5		
A_{VD}	Large-signal differential voltage amplification	$V_O = \pm 11 \, \text{V}, \quad R_L = 2 \, \text{k}\Omega$		45		V/ μV
		$V_O = \pm 10 \, \text{V}, \quad R_L = 1 \, \text{k}\Omega$		38		
		$V_O = \pm 10 \, \text{V}, \quad R_L = 600 \, \Omega$		19		
C_i	Input capacitance			8		pF
z_o	Open-loop output impedance	$I_O = 0$		50		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR\text{min}}, \quad R_S = 50 \, \Omega$		131		dB
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$)	$V_{CC\pm} = \pm 4 \, \text{V}$ to $\pm 18 \, \text{V}, \quad R_S = 50 \, \Omega$		144		dB
I_{CC}	Supply current	$V_O = 0, \quad \text{No load}$		3.8		mA

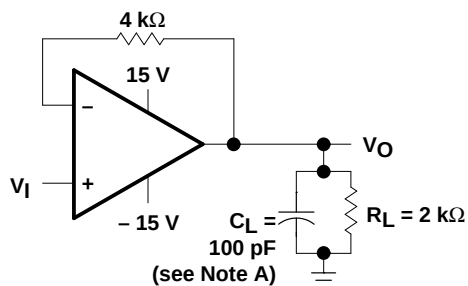
NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150^\circ\text{C}$ extrapolated to $T_A = 25^\circ\text{C}$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

operating characteristics at specified free-air temperature, $V_{CC} \pm = \pm 15\text{ V}$

PARAMETER		TEST CONDITIONS	TLE2027Y			UNIT
			MIN	TYP	MAX	
SR	Slew rate at unity gain	$R_L = 2\text{ k}\Omega$, $C_L = 100\text{ pF}$, See Figure 1		2.8		$\text{V}/\mu\text{s}$
V_n	Equivalent input noise voltage (see Figure 2)	$R_S = 20\text{ }\Omega$, $f = 10\text{ Hz}$		3.3		$\text{nV}/\sqrt{\text{Hz}}$
		$R_S = 20\text{ }\Omega$, $f = 1\text{ kHz}$		2.5		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }10\text{ Hz}$		50		nV
I_n	Equivalent input noise current	$f = 10\text{ Hz}$		1.5		$\text{pA}/\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$		0.4		
THD	Total harmonic distortion	$V_O = +10\text{ V}$, $A_{VD} = 5$, See Note 5		<0.002%		
B_1	Unity-gain bandwidth (see Figure 3)	$R_L = 2\text{ k}\Omega$, $C_L = 100\text{ pF}$		13		MHz
B_{OM}	Maximum output-swing bandwidth	$R_L = 2\text{ k}\Omega$		30		kHz
ϕ_m	Phase margin at unity gain (see Figure 3)	$R_L = 2\text{ k}\Omega$, $C_L = 100\text{ pF}$		55°		

NOTE 5: Measured distortion of the source used in the analysis was 0.002%.

PARAMETER MEASUREMENT INFORMATION



NOTE A: C_L includes fixture capacitance.

Figure 1. Slew-Rate Test Circuit

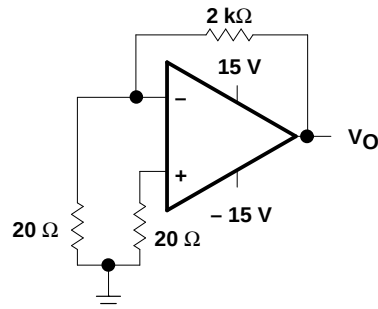
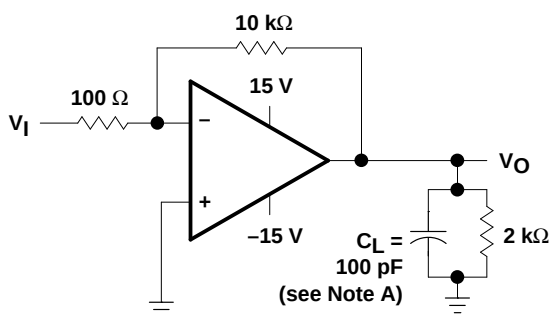
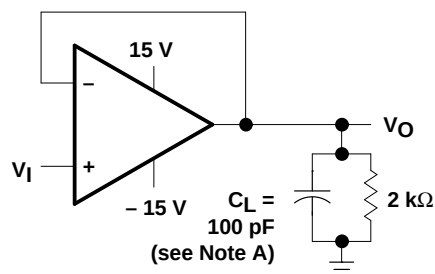


Figure 2. Noise-Voltage Test Circuit



NOTE A: C_L includes fixture capacitance.

Figure 3. Unity-Gain Bandwidth and Phase-Margin Test Circuit



NOTE A: C_L includes fixture capacitance.

Figure 4. Small-Signal Pulse-Response Test Circuit

typical values

Typical values presented in this data sheet represent the median (50% point) of device parametric performance.

initial estimates of parameter distributions

In the ongoing program of improving data sheets and supplying more information to our customers, Texas Instruments has added an estimate of not only the typical values but also the spread around these values. These are in the form of distribution bars that show the 95% (upper) points and the 5% (lower) points from the characterization of the initial wafer lots of this new device type (see Figure 5). The distribution bars are shown at the points where data was actually collected. The 95% and 5% points are used instead of ± 3 sigma since some of the distributions are not true Gaussian distributions.

The number of units tested and the number of different wafer lots used are on all of the graphs where distribution bars are shown. As noted in Figure 5, there were a total of 835 units from two wafer lots. In this case, there is a good estimate for the within-lot variability and a possibly poor estimate of the lot-to-lot variability. This is always the case on newly released products since there can only be data available from a few wafer lots.

The distribution bars are not intended to replace the minimum and maximum limits in the electrical tables. Each distribution bar represents 90% of the total units tested at a specific temperature. While 10% of the units tested fell outside any given distribution bar, this should not be interpreted to mean that the same individual devices fell outside every distribution bar.

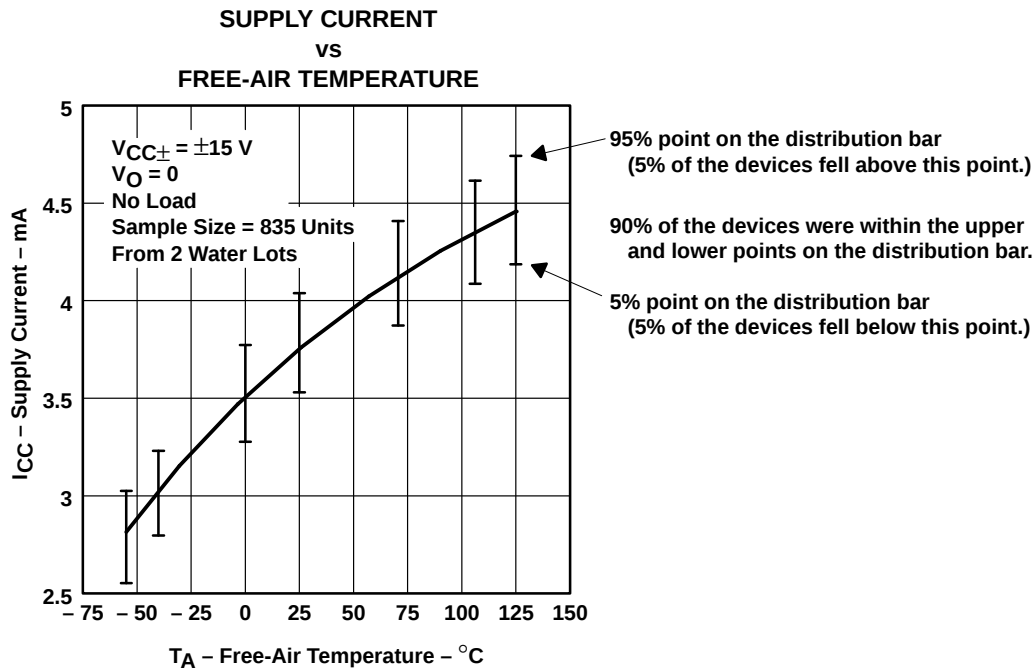


Figure 5. Sample Graph With Distribution Bars

TLE2027, TLE2027A, TLE2027Y
EXCALIBUR LOW-NOISE HIGH-SPEED
PRECISION OPERATIONAL AMPLIFIERS

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TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V_{IO}	Input offset voltage	Distribution	6
ΔV_{IO}	Input offset voltage change	vs Time after power on	7, 8
I_{IO}	Input offset current	vs Free-air temperature	9
I_{IB}	Input bias current	vs Common-mode input voltage	10
		vs Free-air temperature	11
I_I	Input current	vs Differential input voltage	12
$V_{O(PP)}$	Maximum peak-to-peak output voltage	vs Frequency	13
V_{OM}	Maximum (positive/negative) peak output voltage	vs Load resistance	14, 15
		vs Free-air temperature	16, 17
A_{VD}	Large-signal differential voltage amplification	vs Supply voltage	18
		vs Load resistance	19
		vs Frequency	20, 21
		vs Free-air temperature	22
z_o	Output impedance	vs Frequency	23
CMRR	Common-mode rejection ratio	vs Frequency	24
k_{SVR}	Supply voltage rejection ratio	vs Frequency	25
I_{OS}	Short-circuit output current	vs Supply voltage	26, 27
		vs Elapsed time	28, 29
		vs Free-air temperature	30, 31
I_{CC}	Supply current	vs Supply voltage	32
		vs Free-air temperature	33
	Pulse response	Small signal	34
		Large signal	35
V_n	Equivalent input noise voltage	vs Frequency	36
	Noise voltage (referred to input)	vs Time	37
B_1	Unity-gain bandwidth	vs Supply voltage	38
		vs Load capacitance	39
SR	Slew rate	vs Free-air temperature	40
ϕ_m	Phase margin	vs Supply voltage	41
		vs Load capacitance	42
		vs Free-air temperature	43
	Phase shift	vs Frequency	20, 21



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TYPICAL CHARACTERISTICS

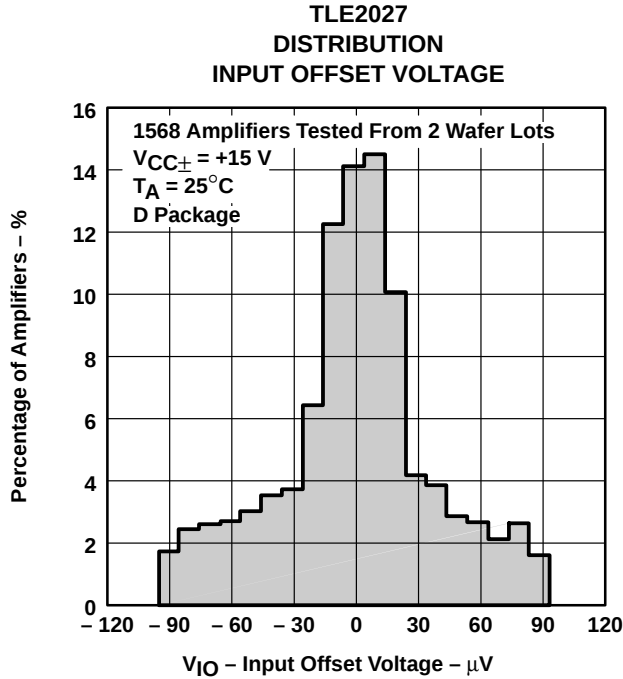


Figure 6

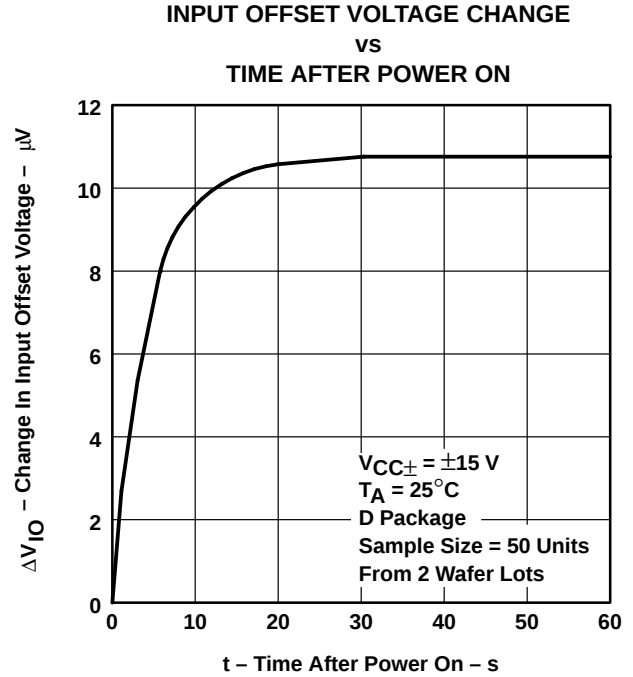


Figure 7

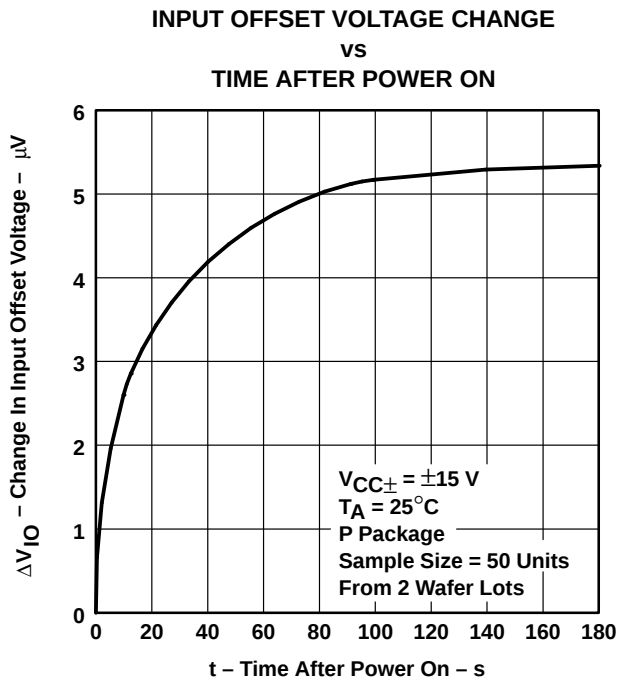
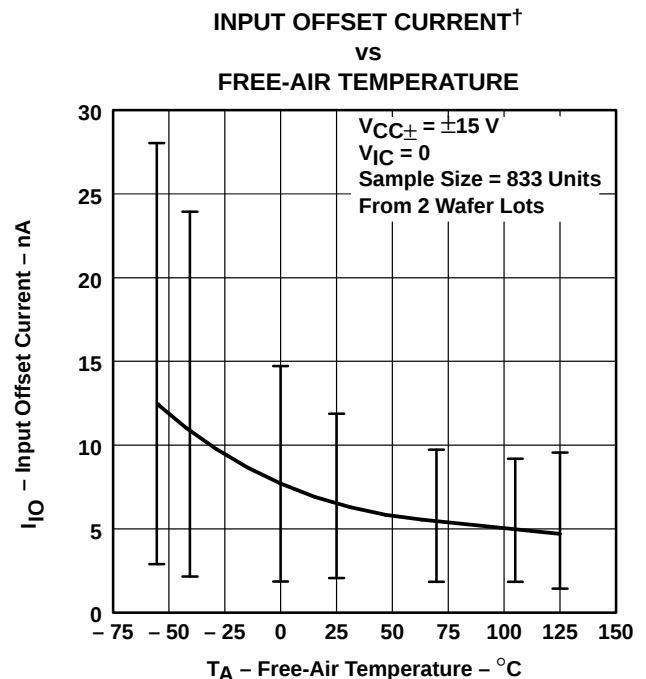


Figure 8



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Figure 9

TYPICAL CHARACTERISTICS

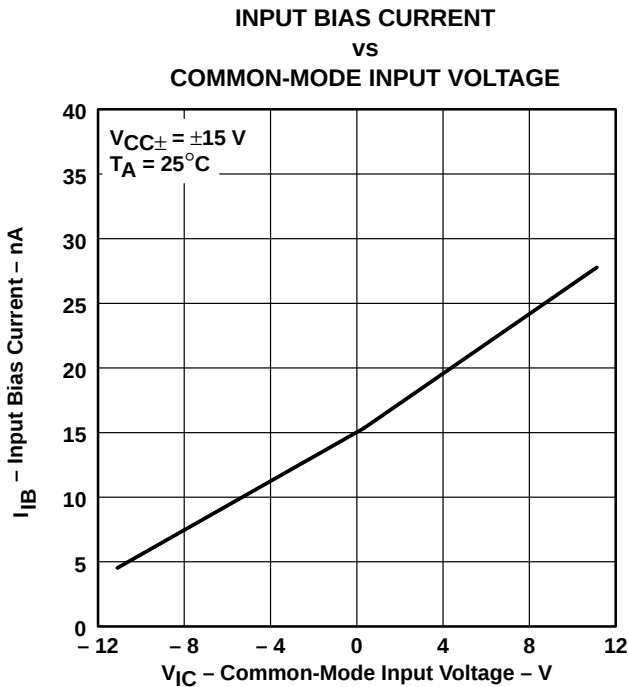
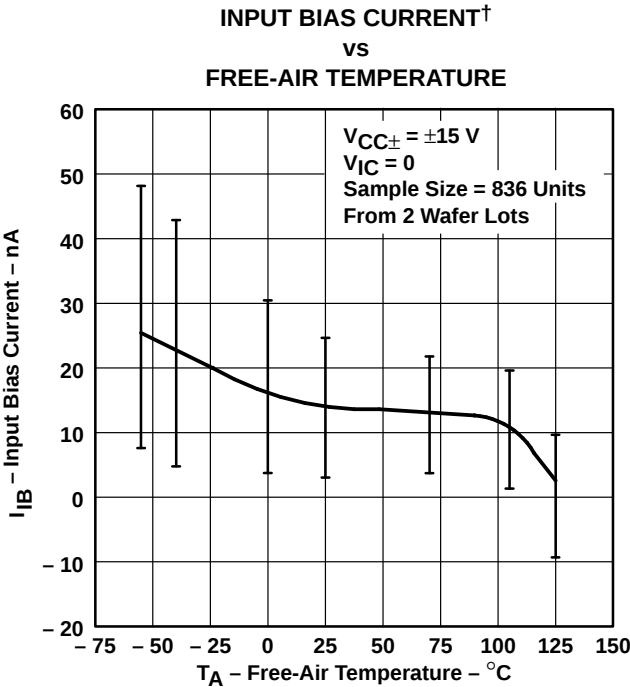


Figure 10



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Figure 11

TYPICAL CHARACTERISTICS

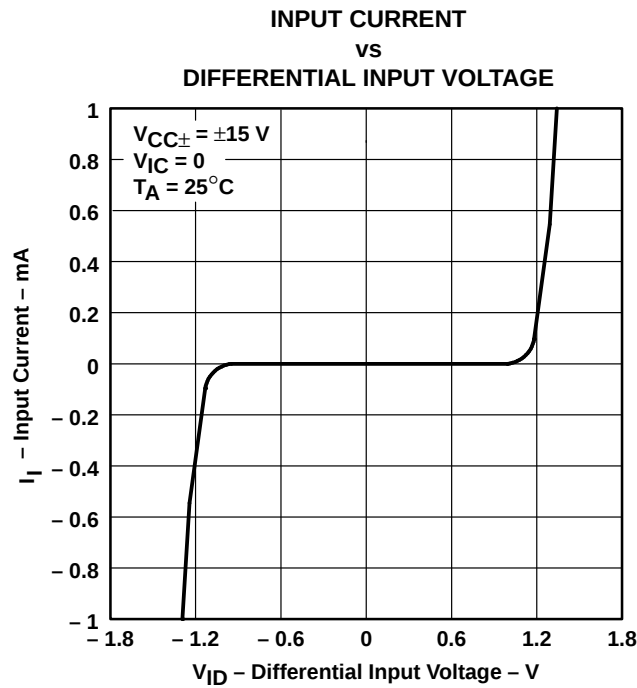
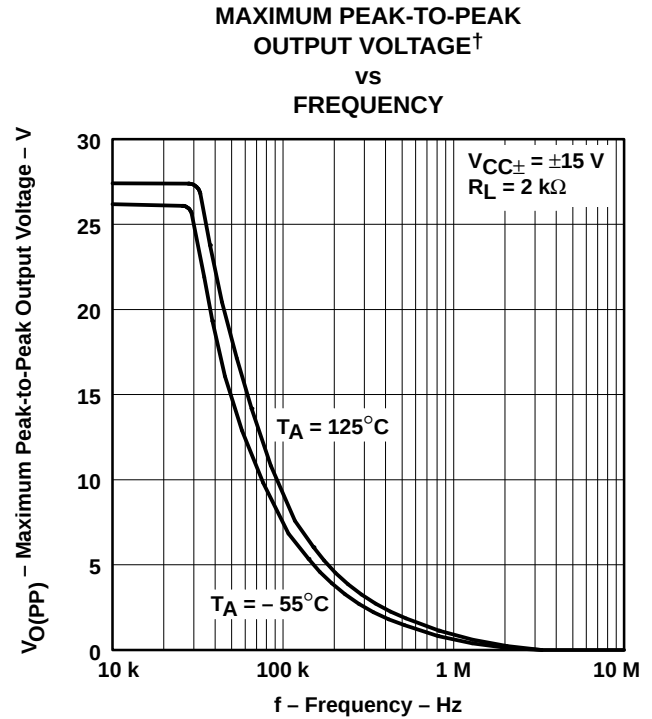


Figure 12



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Figure 13

TYPICAL CHARACTERISTICS

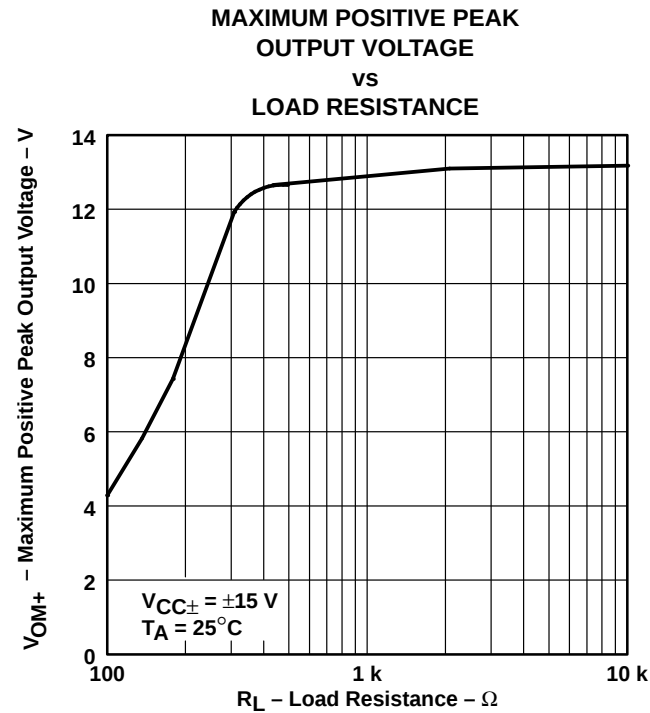


Figure 14

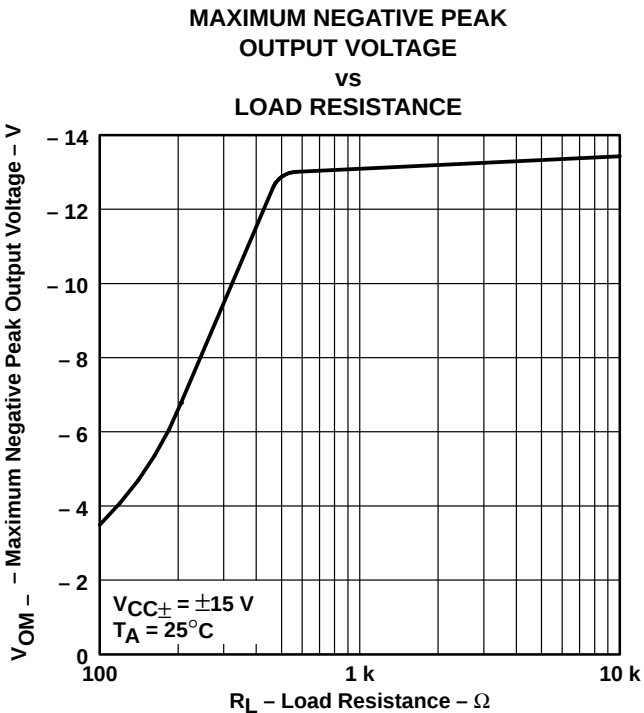
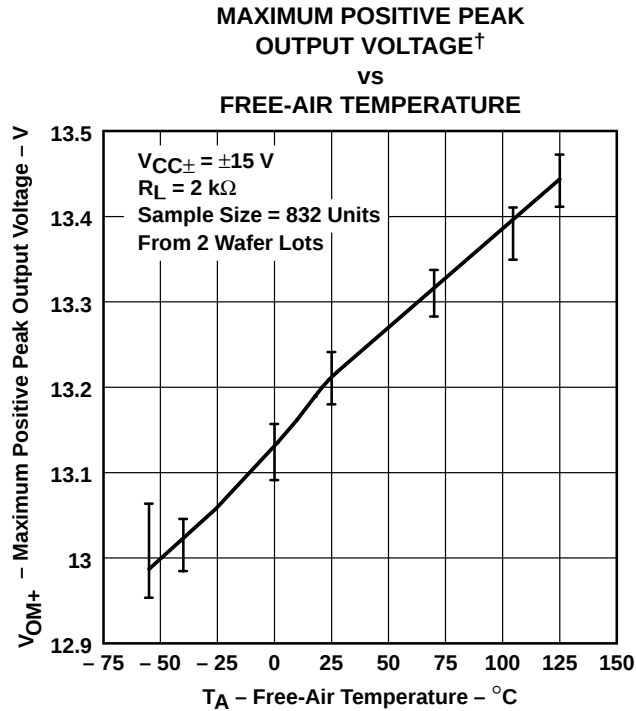


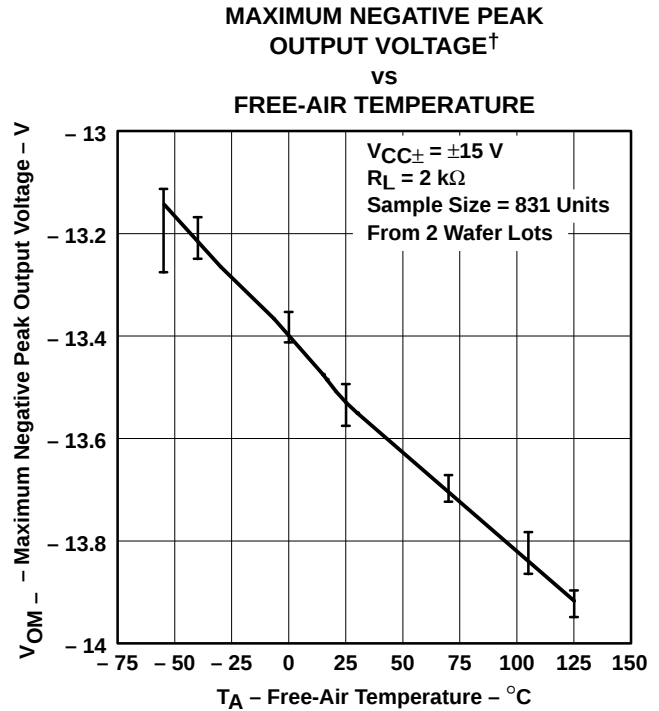
Figure 15

TYPICAL CHARACTERISTICS



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Figure 16



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Figure 17

TYPICAL CHARACTERISTICS

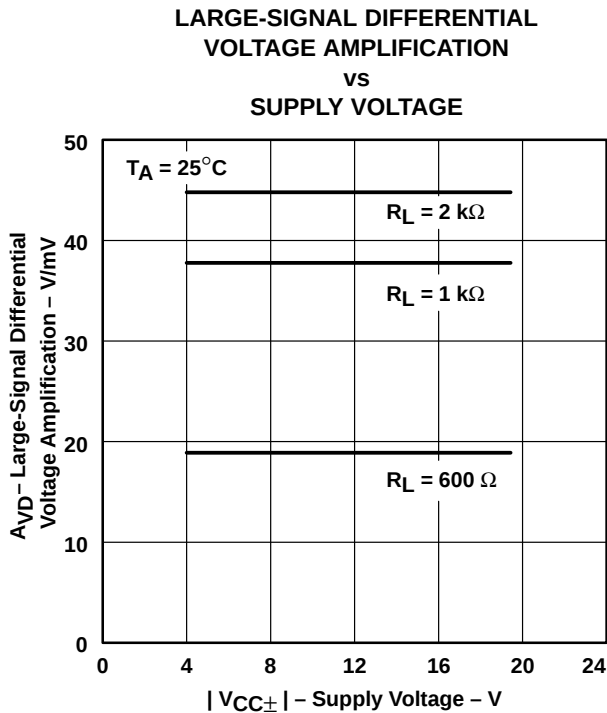


Figure 18

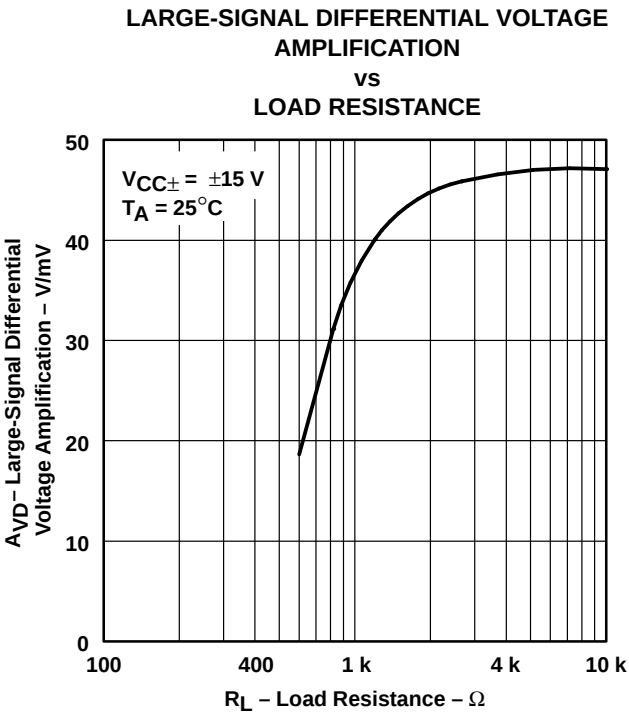


Figure 19

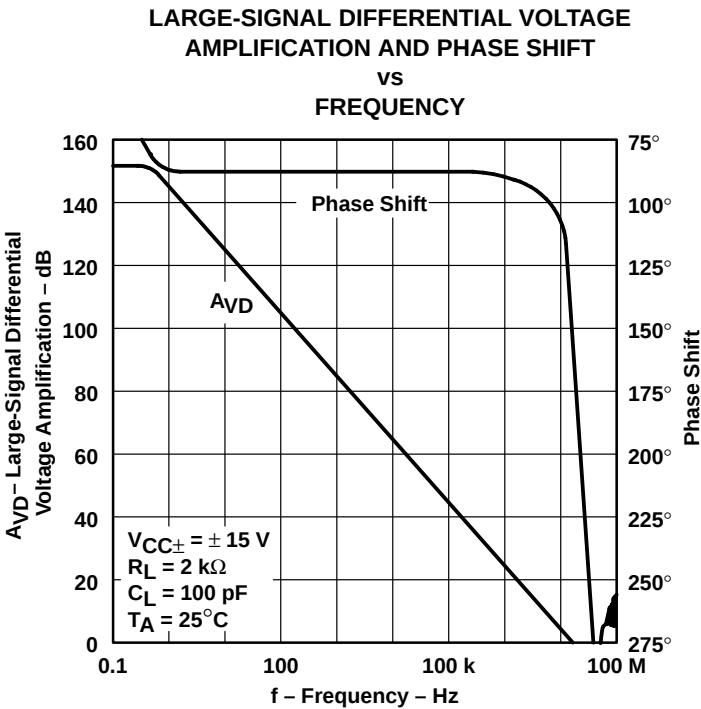


Figure 20

TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

VS
FREQUENCY

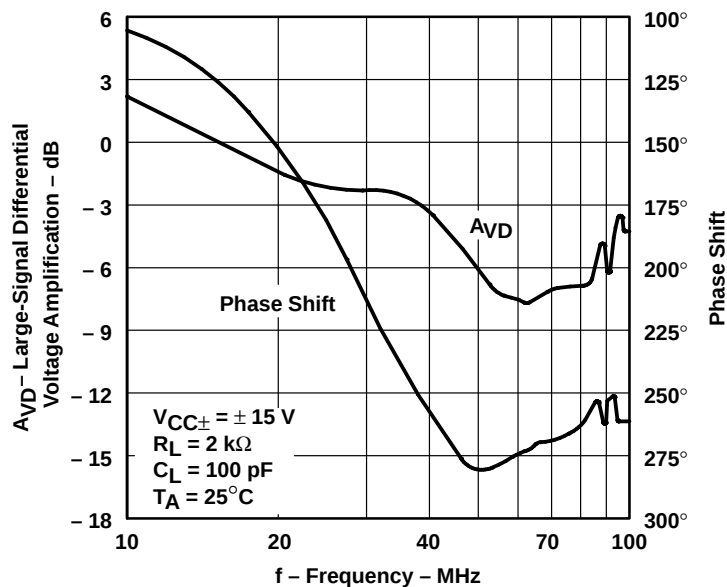
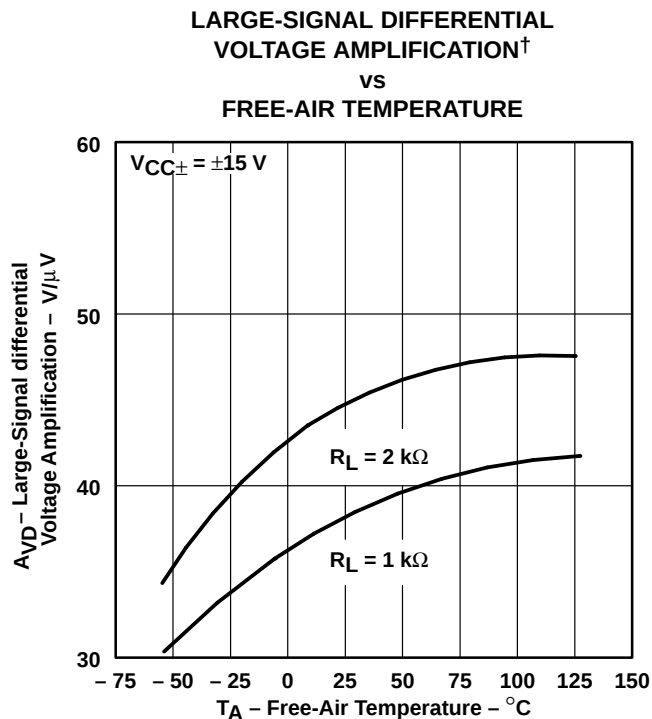


Figure 21

TLE2027, TLE2027A, TLE2027Y
EXCALIBUR LOW-NOISE HIGH-SPEED
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TYPICAL CHARACTERISTICS



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Figure 22

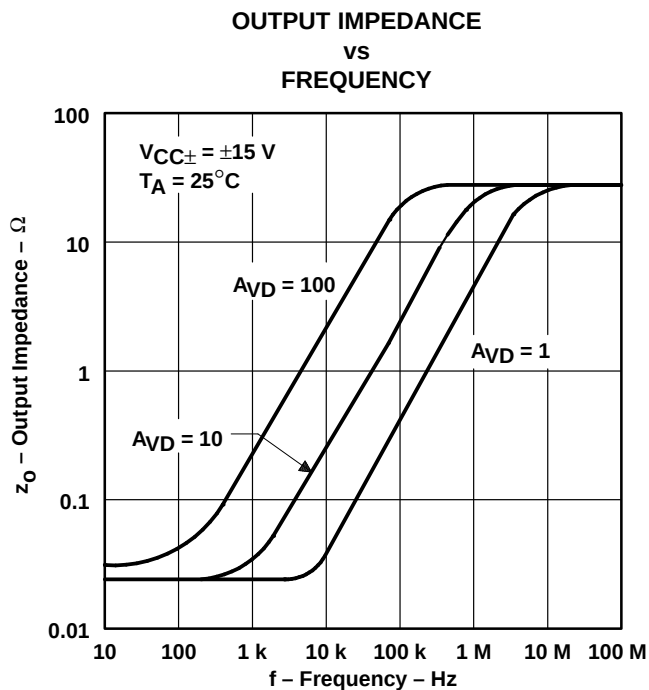


Figure 23

TYPICAL CHARACTERISTICS

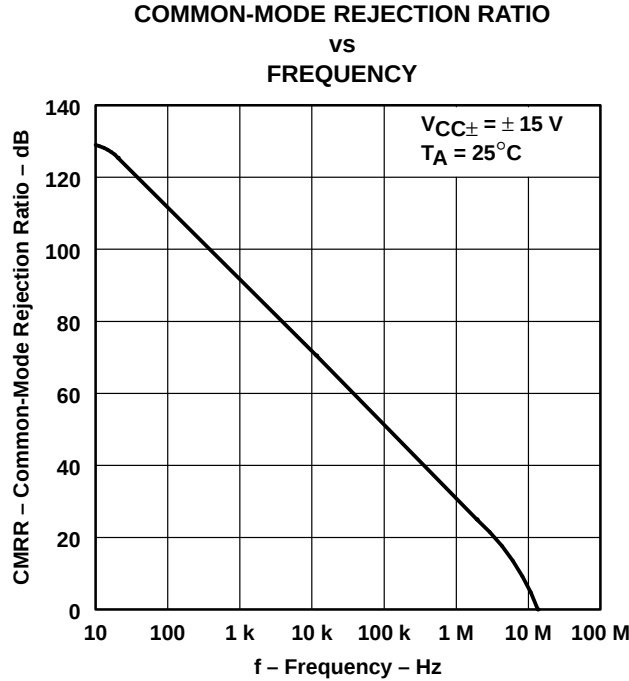


Figure 24

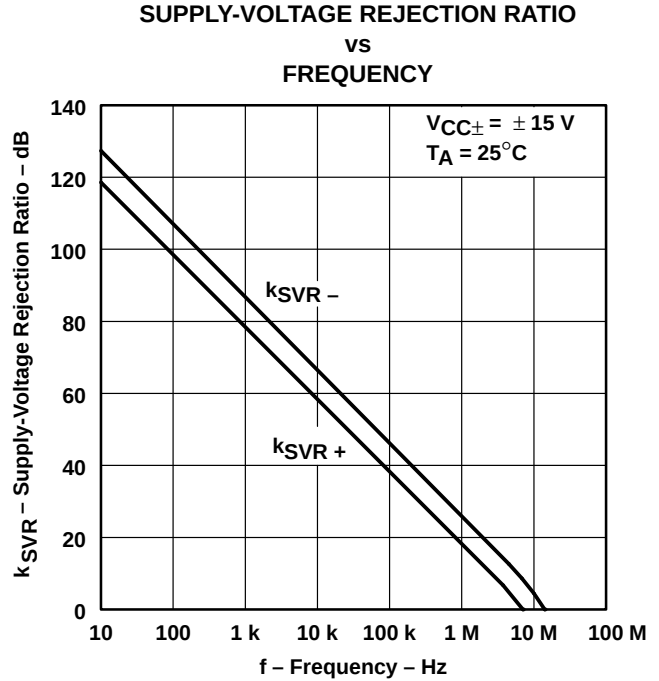


Figure 25

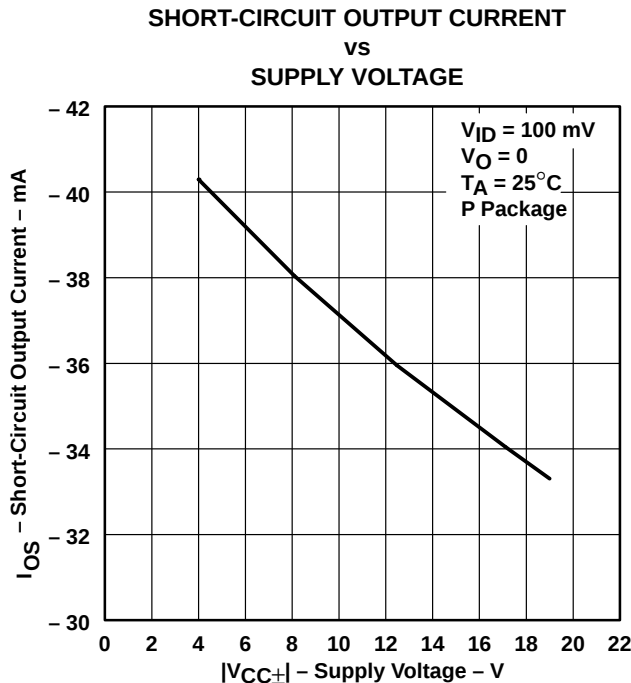


Figure 26

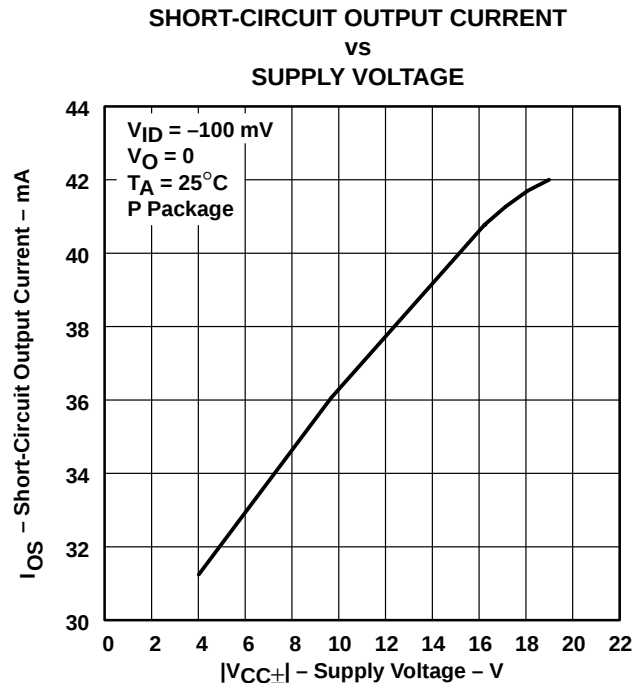


Figure 27

TYPICAL CHARACTERISTICS

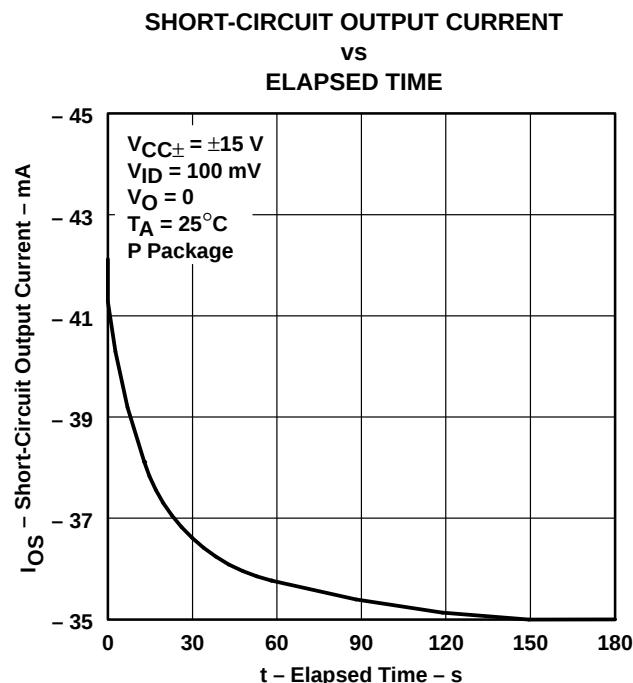


Figure 28

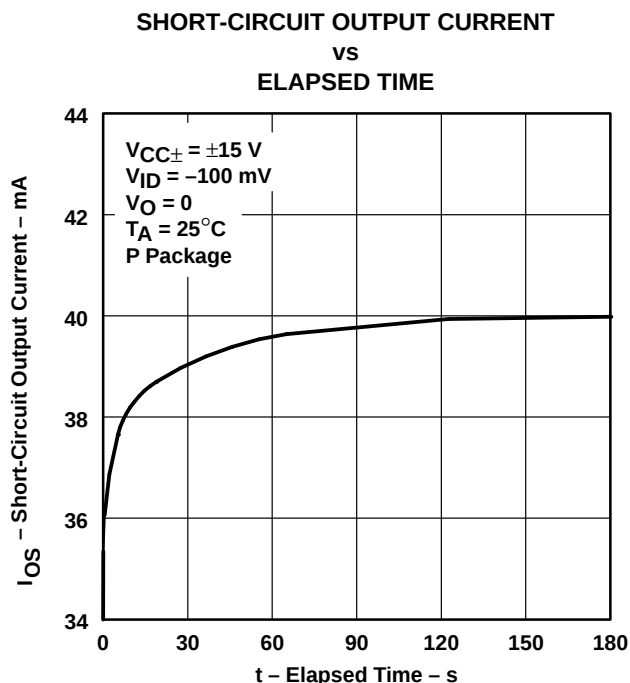
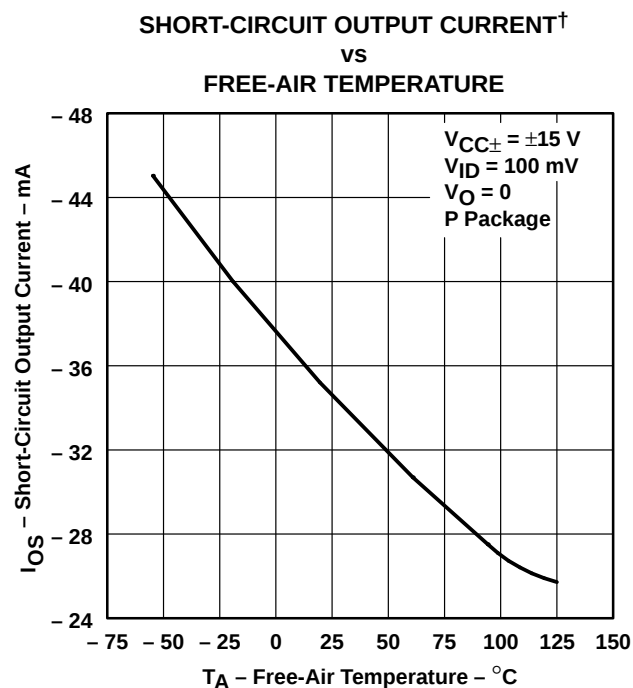
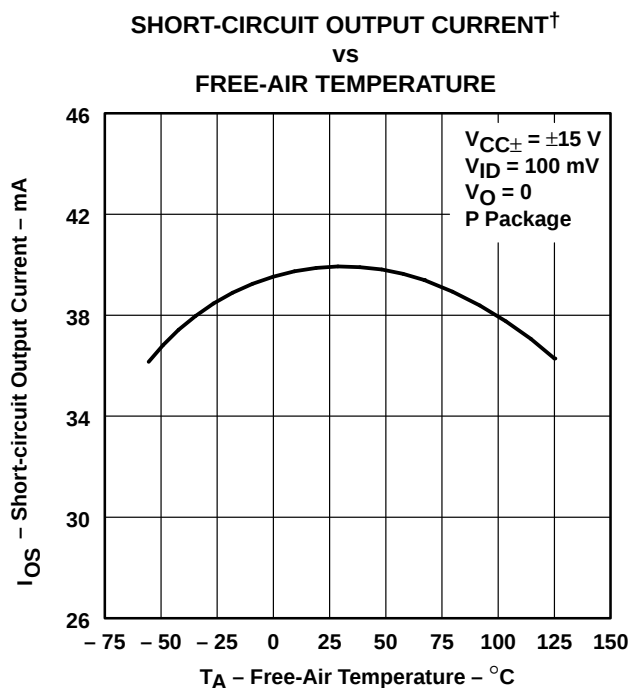


Figure 29



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

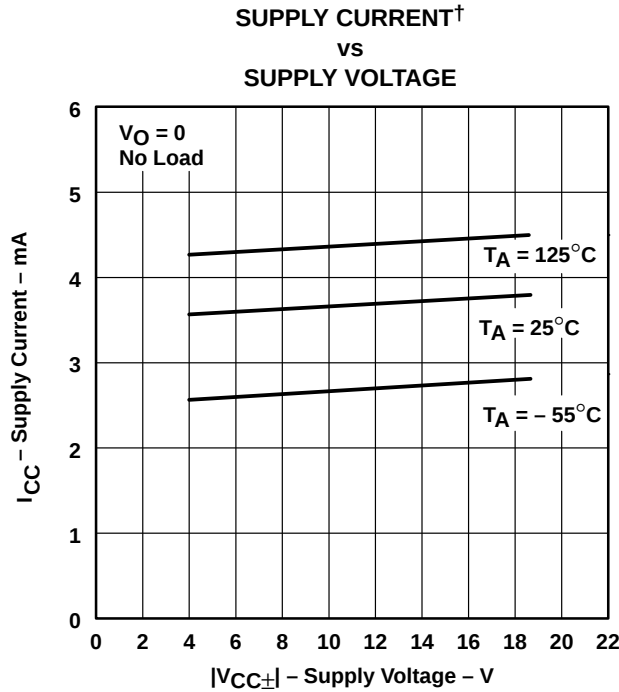
Figure 30



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

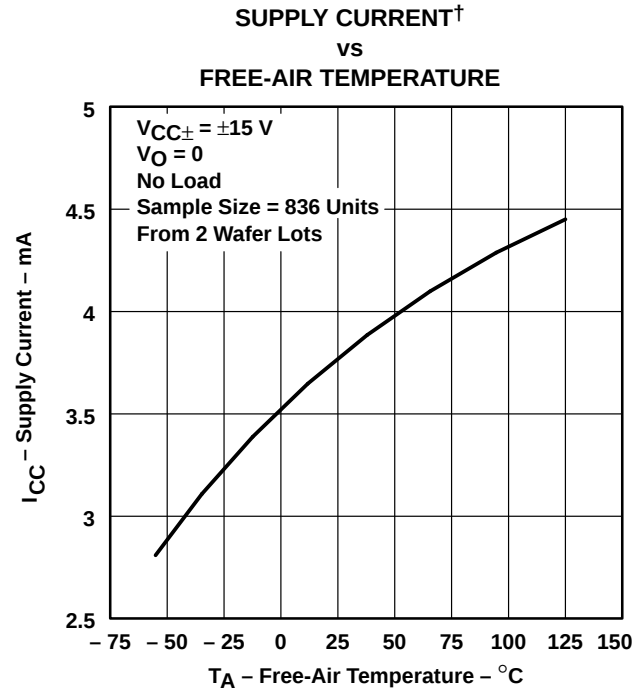
Figure 31

TYPICAL CHARACTERISTICS



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Figure 32



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Figure 33

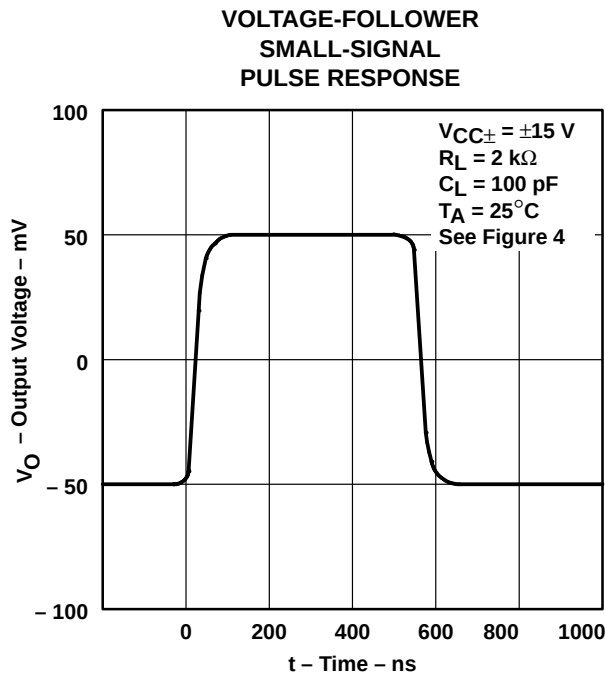


Figure 34

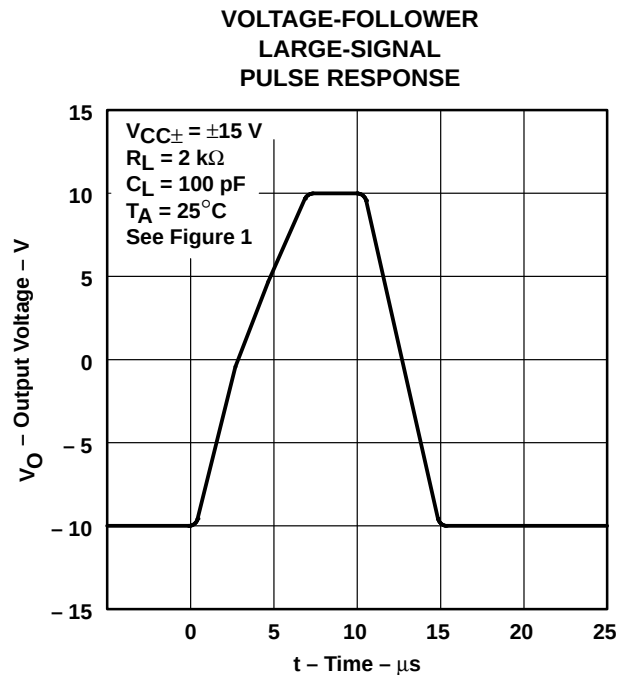


Figure 35

TYPICAL CHARACTERISTICS

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

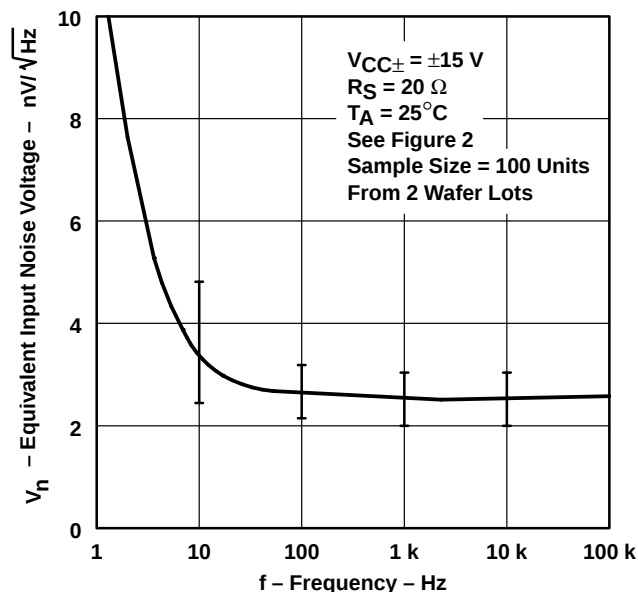


Figure 36

NOISE VOLTAGE
(REFERRED TO INPUT)
OVER A 10-SECOND INTERVAL

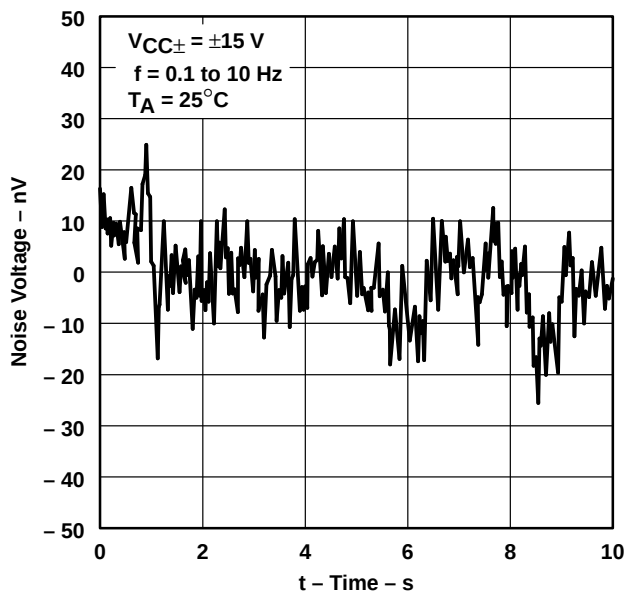


Figure 37

UNITY-GAIN BANDWIDTH
vs
SUPPLY VOLTAGE

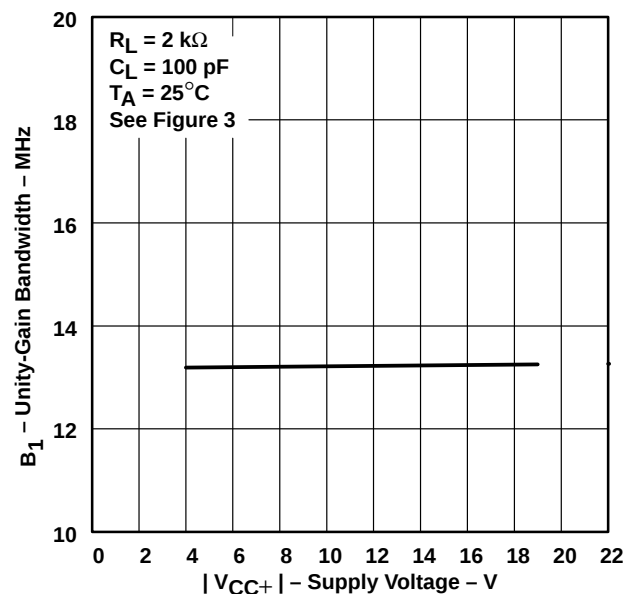


Figure 38

UNITY-GAIN BANDWIDTH
vs
LOAD CAPACITANCE

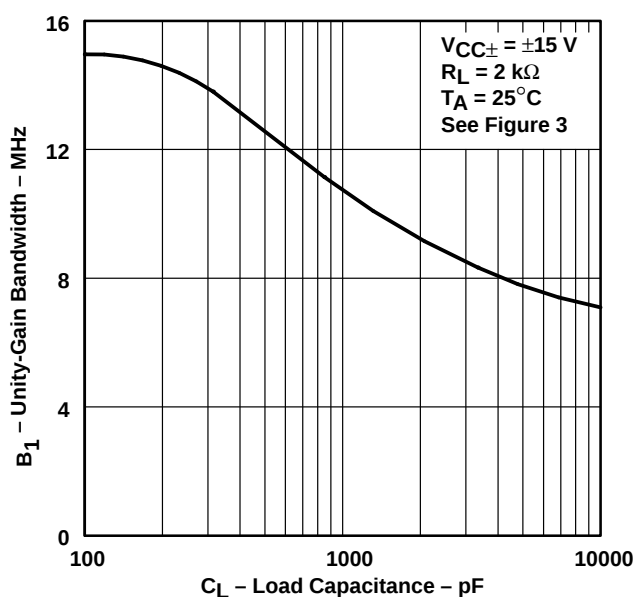
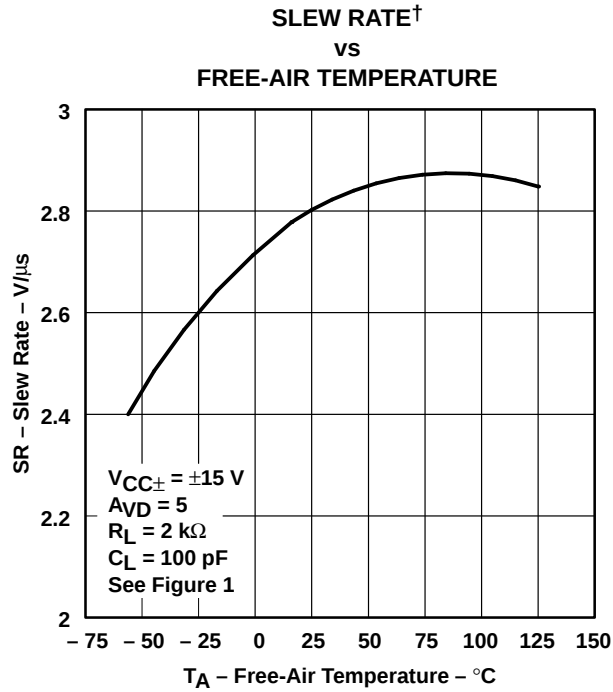


Figure 39

TYPICAL CHARACTERISTICS



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Figure 40

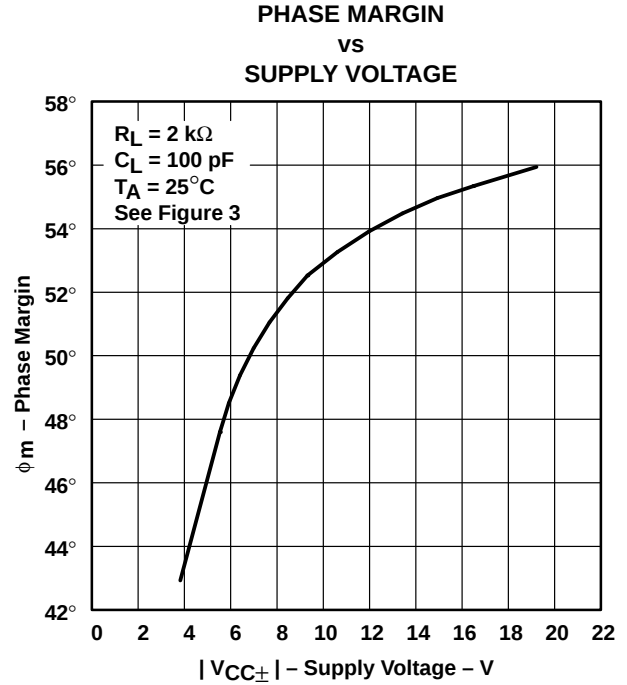


Figure 41

TYPICAL CHARACTERISTICS

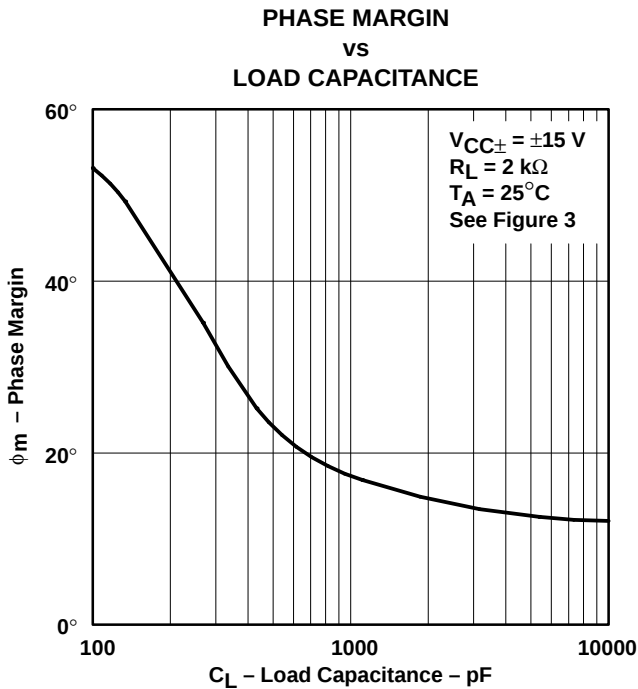
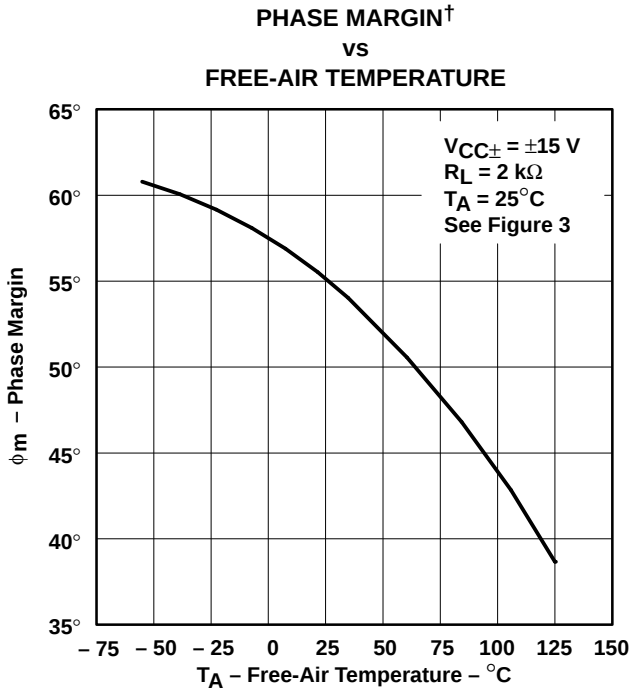


Figure 42



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Figure 43

APPLICATION INFORMATION

macromodel information

Macromodel information provided was derived using *PSpice™ Parts™* model generation software. The Boyle macromodel (see Note 6) and subcircuit in Figures 44 and 45 were generated using the TLE2027 typical electrical and operating characteristics at 25°C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification
- Gain-bandwidth product
- Common-mode rejection ratio
- Phase margin
- dc output resistance
- ac output resistance
- Short-circuit output current limit

NOTE 6: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers", *IEEE Journal of Solid-State Circuits*, SC-9, 353 (1974).

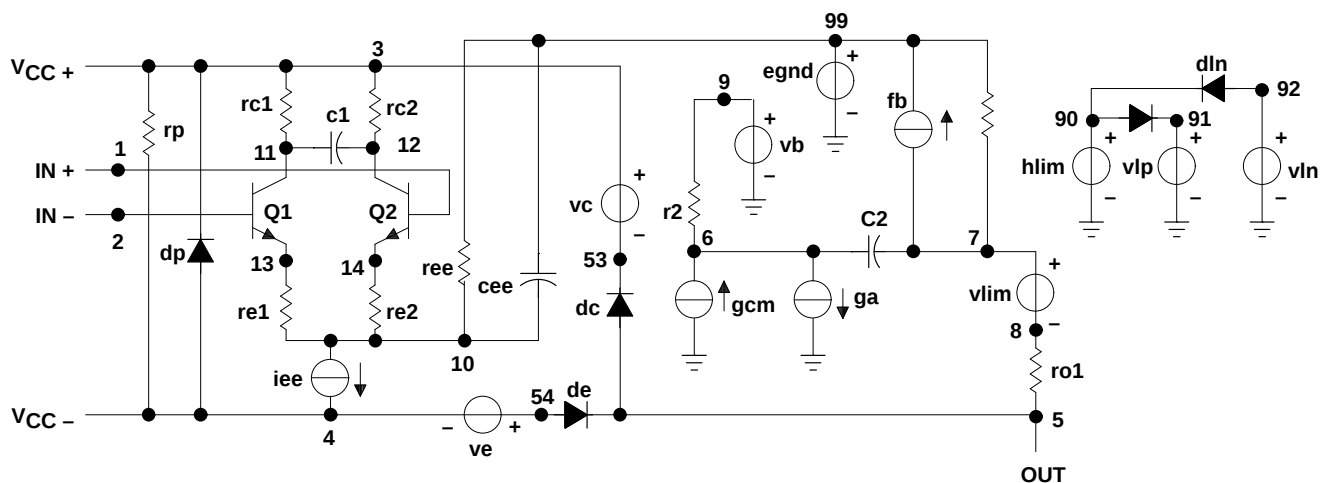


Figure 44. Boyle Macromodel

TLE2027, TLE2027A, TLE2027Y EXCALIBUR LOW-NOISE HIGH-SPEED PRECISION OPERATIONAL AMPLIFIERS

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APPLICATION INFORMATION

macromodel information (continued)

```
.subckt TLE2027 1 2 3 4 5
*
c1      11    12    4.003E-12
c2      6      7    20.00E-12
dc      5      53    dz
de      54     5     dz
dlp     90     91    dz
dln     92     90    dx
dp      4      3     dz
egnd    99     0    poly(2) (3,0) (4,0) 0 5 .5
fb      7      99    poly(5) vb vc ve vlp vln 0 954.8E6 -1E9 1E9 1E9 -1E9
ga      6      0     11 12    2.062E-3
gcm     0      6     10 99    531.3E-12
iee     10     4     dc 56.01E-6
hlim    90     0     vlim 1K
q1      11     2     13 qx
q2      12     1     14 qx
r2      6      9    100.0E3
rc1     3      11    530.5
rc2     3      12    530.5
re1     13     10    -393.2
re2     14     10    -393.2
ree     10     99    3.571E6
ro1     8      5     25
ro2     7      99    25
rp      3      4     8.013E3
vb      9      0     dc 0
vc      3      53    dc 2.400
ve      54     4     dc 2.100
vlim    7      8     dc 0
vlp     91     0     dc 40
vln     0      92    dc 40
.modeldx D(Is=800.0E-18)
.modelqx NPN(Is=800.0E-18 Bf=7.000E3)
.ends
```

Figure 45. Macromodel Subcircuit

APPLICATION INFORMATION

voltage-follower applications

The TLE2027 circuitry includes input-protection diodes to limit the voltage across the input transistors; however, no provision is made in the circuit to limit the current if these diodes are forward biased. This condition can occur when the device is operated in the voltage-follower configuration and driven with a fast, large-signal pulse. It is recommended that a feedback resistor be used to limit the current to a maximum of 1 mA to prevent degradation of the device. Also, this feedback resistor forms a pole with the input capacitance of the device. For feedback resistor values greater than 10 k Ω , this pole degrades the amplifier phase margin. This problem can be alleviated by adding a capacitor (20 pF to 50 pF) in parallel with the feedback resistor (see Figure 46).

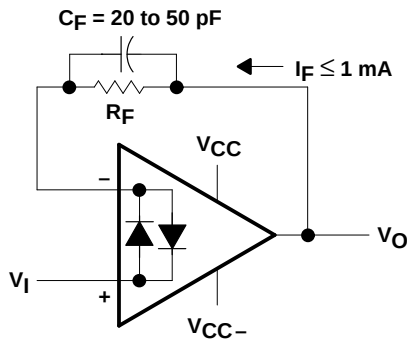


Figure 46. Voltage Follower

Input offset voltage nulling

The TLE2027 series offers external null terminals that can further reduce the input offset voltage. The circuits of Figure 47 can be connected as shown if the feature is desired. If external nulling is not needed, the null terminals may be left disconnected.



Figure 47. Input Offset-Voltage Nulling Circuits

TLE2027, TLE2027A, TLE2027Y EXCALIBUR LOW-NOISE HIGH-SPEED PRECISION OPERATIONAL AMPLIFIERS

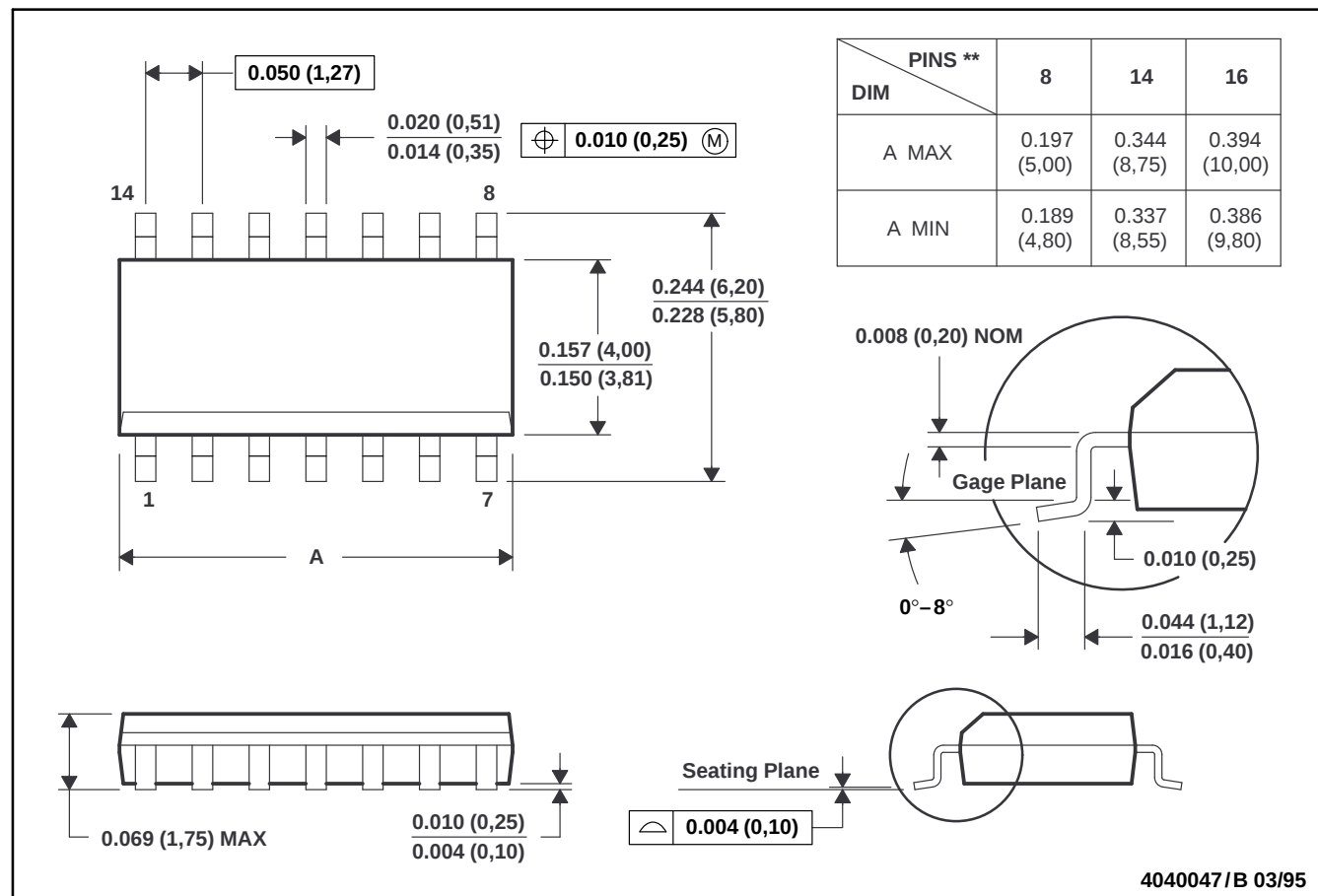
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MECHANICAL INFORMATION

D (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

14 PIN SHOWN



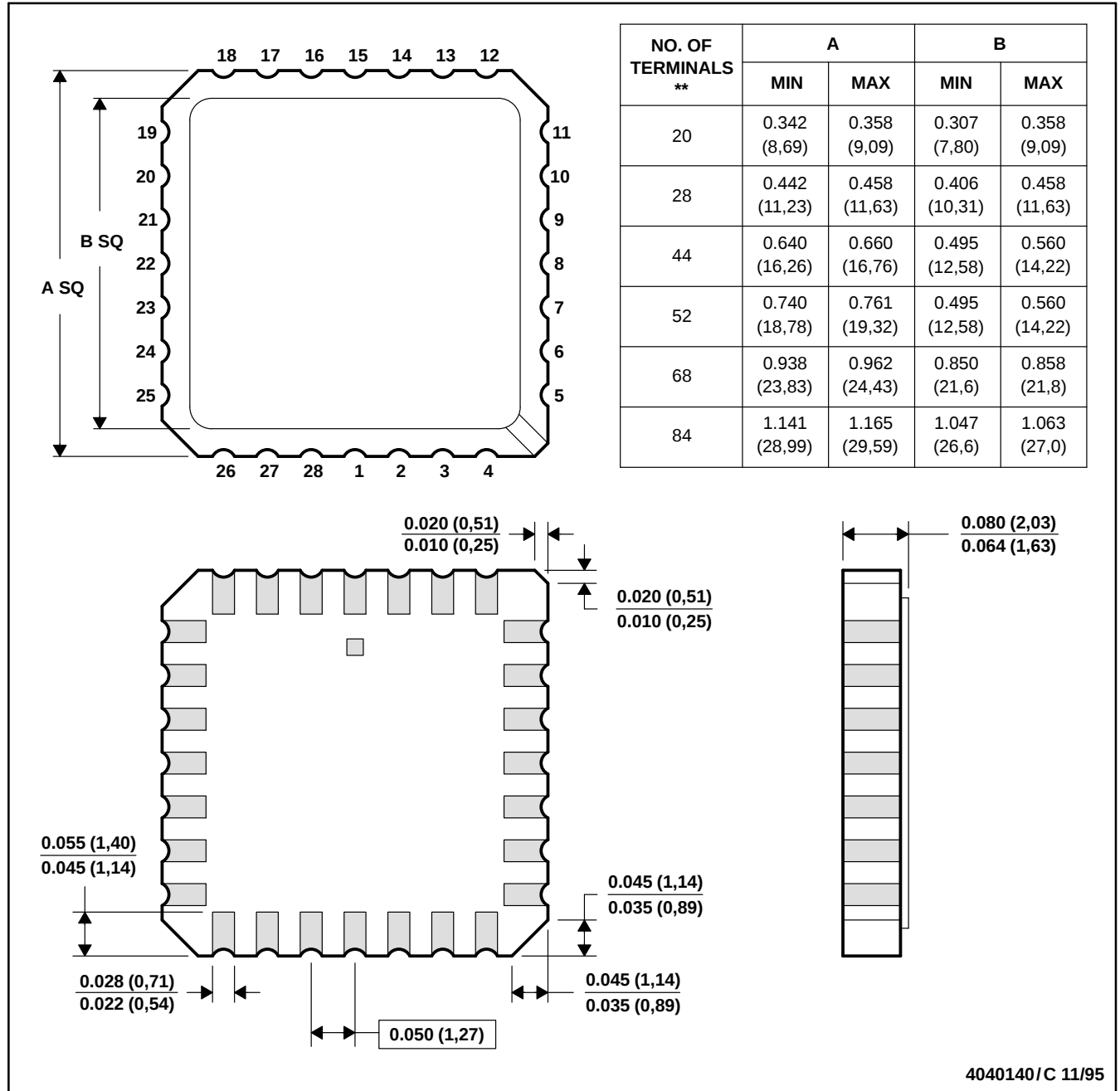
- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
 D. Four center pins are connected to die mount pad.
 E. Falls within JEDEC MS-012

MECHANICAL INFORMATION

FK (S-CQCC-N)**

LEADLESS CERAMIC CHIP CARRIER

28 TERMINAL SHOWN



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. This package can be hermetically sealed with a metal lid.
 - D. The terminals are gold plated.
 - E. Falls within JEDEC MS-004

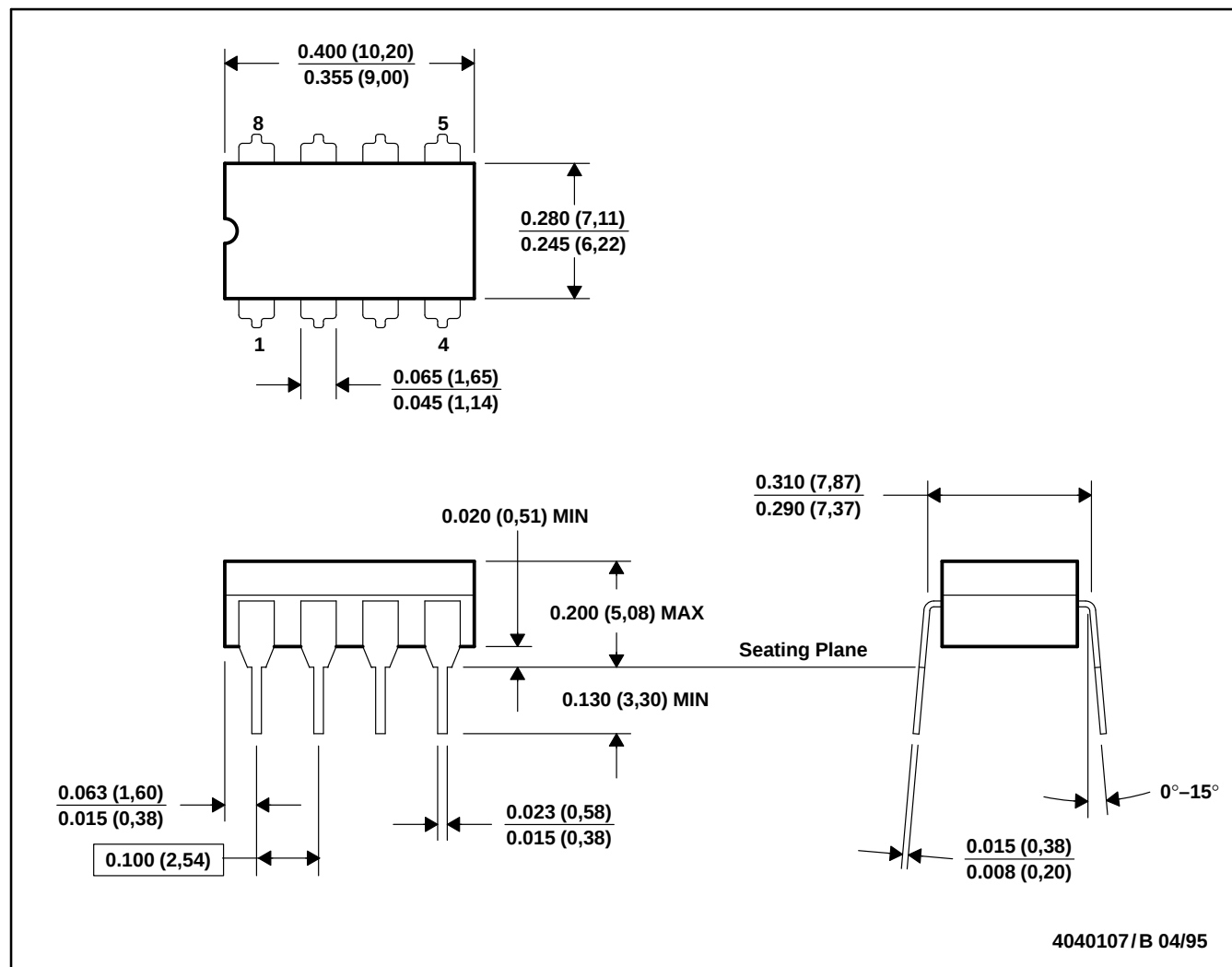
TLE2027, TLE2027A, TLE2027Y
EXCALIBUR LOW-NOISE HIGH-SPEED
PRECISION OPERATIONAL AMPLIFIERS

SLOS054D – MAY 1990 – REVISED SEPTEMBER 1996

MECHANICAL INFORMATION

JG (R-GDIP-T8)

CERAMIC DUAL-IN-LINE PACKAGE

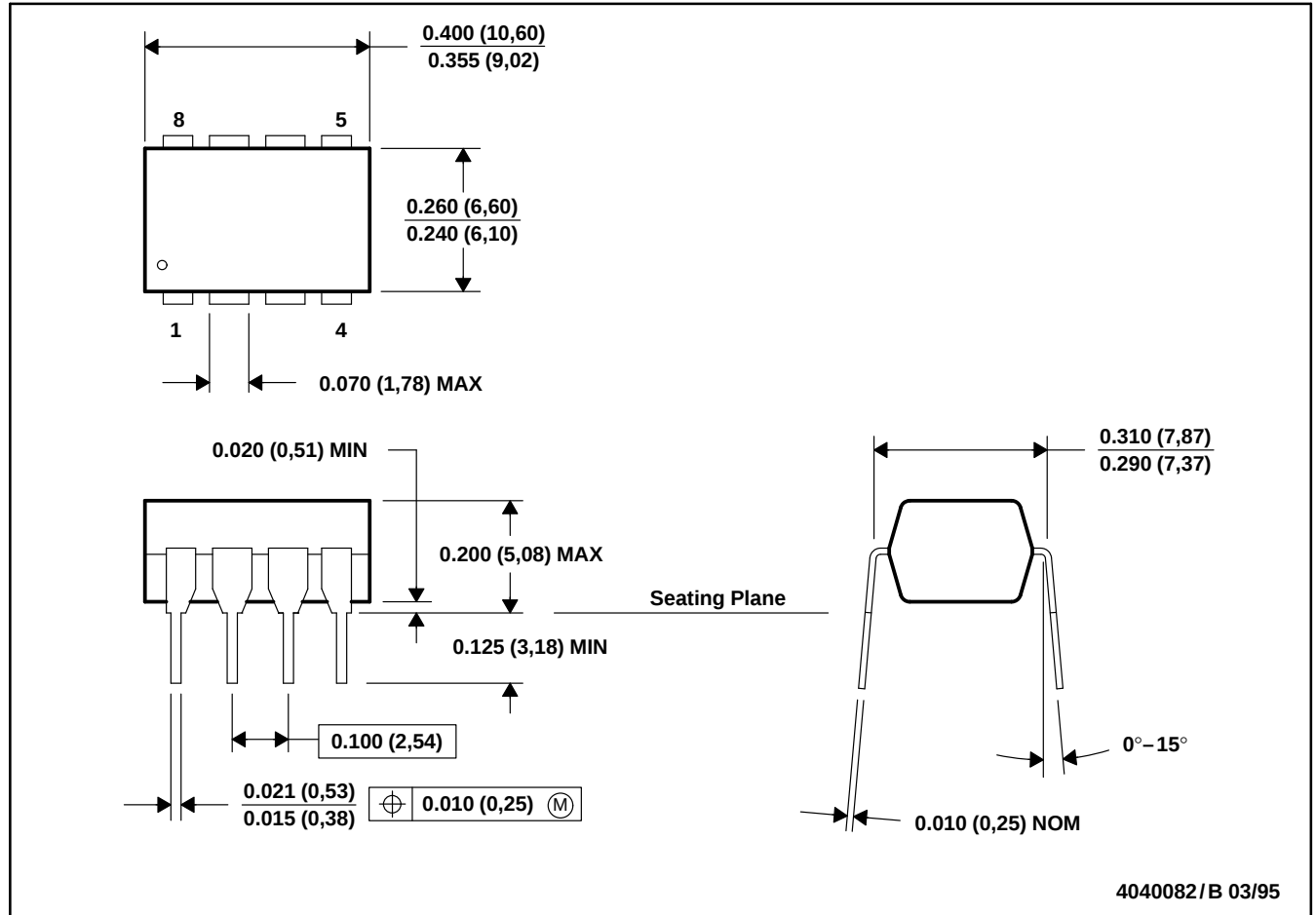


- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. This package can be hermetically sealed with a ceramic lid using glass frit.
 D. Index point is provided on cap for terminal identification only on press ceramic glass frit seal only
 E. Falls within MIL-STD-1835 GDIP1-T8

MECHANICAL INFORMATION

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE PACKAGE



- NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-001

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