TLE2161, TLE2161A, TLE2161B EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE μPOWER OPERATIONAL AMPLIFIERS

D3371, NOVEMBER 1989

NOTICE
SEE ORDER OF DATA FOR ERRATA INFORMATION T-79-15

available features

- Excellent Output Drive Capability . . .
  V_O = ±2.5 V Min at R_L = 100 Ω,
  $V_{CC\pm}$ = ±5 V
  V_O = ±12.5 V Min at R_L = 600 Ω,
  $V_{CC\pm}$ = ±15 V
- Low Supply Current . . . 255 μA Typ
- Decompensated for High Slew Rate and Gain-Bandwidth Product . . .
  A_{VD} = 5 Min
  Slew Rate = 10 V/μs Typ
  Gain-Bandwidth Product = 6.5 MHz Typ
- Macromodel Included
- Wide Operating Supply Voltage Range . . .
  $V_{CC\pm}$ = ±3.5 V to ±20 V
- High Open-Loop Gain . . . 280 V/mV Typ
- Low Offset Voltage . . . 500 μV Max
- Low Offset Voltage Drift with Time . . .
  0.04 μV/mo Typ
- Low Input Bias Current . . . 5 pA Typ

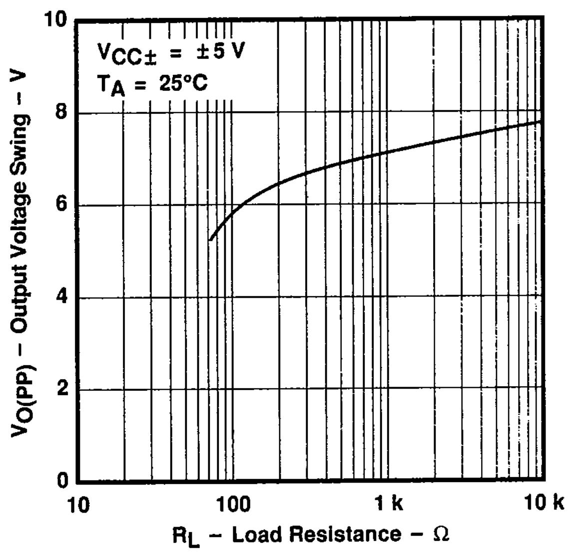
description

The TLE2161, TLE2161A, and TLE2161B are JFET-input, low-power, precision operational amplifiers manufactured using Texas Instruments Excalibur process. Decompensated for stability with a minimum closed-loop gain of 5, these devices combine outstanding output drive capability with low power consumption, excellent dc precision, and high gain-bandwidth product.

In addition to maintaining the traditional JFET advantages of fast slew rates and low input bias and offset currents, the Excalibur process offers outstanding parametric stability over time and temperature. This results in a device that remains precise even with changes in temperature and over years of use.

A variety of available options includes small-outline packages and chip-carrier versions for high-density system applications.

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE SWING
vs
LOAD RESISTANCE



AVAILABLE OPTIONS

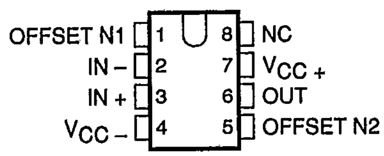
T_A	V_{IO} max AT 25°C	PACKAGE SMALL-OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	METAL CAN (L)	PLASTIC DIP (P)
0°C to 70°C	500 μV	—	—	TLE2161BCJG	TLE2161BCL	TLE2161BCP
	1.5 mV	TLE2161ACD	—	TLE2161ACJG	TLE2161ACL	TLE2161ACP
	3 mV	TLE2161CD	—	TLE2161CJG	TLE2161CL	TLE2161CP
−40°C to 85°C	500 μV	—	—	TLE2161BIJG	TLE2161BIL	TLE2161BIP
	1.5 mV	TLE2161AID	—	TLE2161AIJG	TLE2161AIL	TLE2161AIP
	3 mV	TLE2161ID	—	TLE2161IJG	TLE2161IL	TLE2161IP
−55°C to 125°C	500 μV	—	—	TLE2161BMJG	TLE2161BML	TLE2161BMP
	1.5 mV	TLE2161AMD	TLE2161AMFK	TLE2161AMJG	TLE2161AML	TLE2161AMP
	3 mV	TLE2161MD	TLE2161MFK	TLE2161MJG	TLE2161ML	TLE2161MP

D packages are available taped-and-reeled. Add "R" suffix to device type (e.g., TLE2161ACDR).

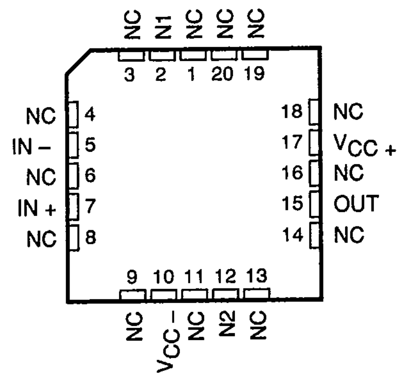
description (continued)

The M-suffix devices are characterized for operation over the full military temperature range of −55°C to 125°C. The I-suffix devices are characterized for operation from −40°C to 85°C. The C-suffix devices are characterized for operation from 0°C to 70°C.

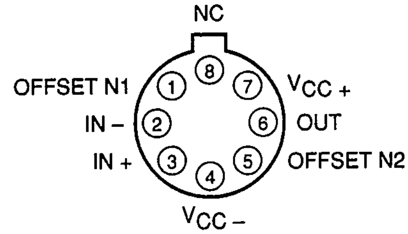
D, JG, OR P PACKAGE
(TOP VIEW)



FK PACKAGE
(TOP VIEW)



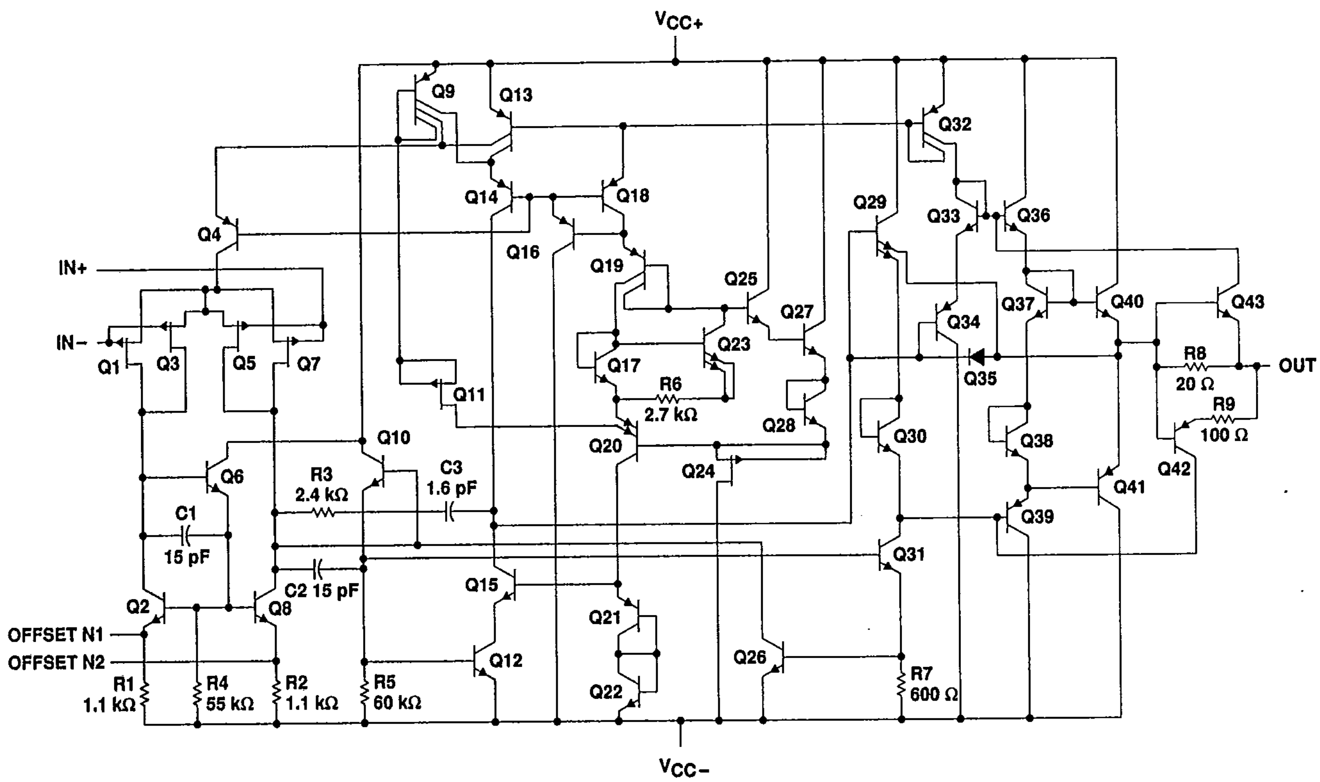
L PACKAGE
(TOP VIEW)



Pin 4 of the L package is in electrical contact with the case.

NC – No internal connection

equivalent schematic



All component values are nominal.

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

Supply voltage, V_{CC+} (see Note 1)	22 V
Supply voltage, V_{CC-}	−22 V
Differential input voltage (see Note 2)	±44 V
Input voltage range, V_I (any input)	$V_{CC\pm}$
Input current, I_I (each input)	±1 mA
Output current, I_O	±80 mA
Total current into V_{CC+} terminal	80 mA
Total current out of V_{CC-} terminal	80 mA
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T_A: M-suffix	−55°C to 125°C
I-suffix	−40°C to 85°C
C-suffix	0°C to 70°C
Storage temperature range	−65°C to 150°C
Case temperature for 60 seconds: 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 or L package	300°C

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 the noninverting input with respect to the inverting input.
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	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE T_A = 25°C	T_A = 70°C POWER RATING	T_A = 85°C POWER RATING	T_A = 125°C POWER RATING
D	725 mW	5.8 mW/°C	464 mW	377 mW	145 mW
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
L	650 mW	5.2 mW/°C	416 mW	338 mW	130 mW
P	1000 mW	8.0 mW/°C	640 mW	520 mW	200 mW

recommended operating conditions

		M-SUFFIX		I-SUFFIX		C-SUFFIX		UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	
Supply voltage, $V_{CC\pm}$		± 3.5	± 20	± 3.5	± 20	± 3.5	± 20	V
Common-mode input voltage, V_{IC}	$V_{CC\pm}$ = ± 5 V	− 1.6	4	− 1.6	4	− 1.6	4	V
	$V_{CC\pm}$ = ± 15 V	− 11	13	− 11	13	− 11	13	
	$V_{CC\pm}$ = ± 20 V	− 15	16.5	− 15	16.5	− 15	16.5	
Operating free-air temperature, T_A		− 55	125	− 40	85	0	70	°C

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V

PARAMETER			TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	TLE2161M	$V_{IC} = 0$, $R_S = 50\ \Omega$	25°C		0.8	3.1	mV
				Full range			6	
		TLE2161AM		25°C		0.6	2.6	
				Full range			4.6	
		TLE2161BM		25°C		0.5	1.9	
				Full range			3.1	
α_{VIO}	Temperature coefficient of input offset voltage			Full range		6		μV/°C
	Input offset voltage long-term drift (see Note 4)			25°C		0.04		μV/mo
I_{IO}	Input offset current			25°C		1		pA
				Full range			15	nA
I_{IB}	Input bias current			25°C		3		pA
				Full range			30	nA
V_{ICR}	Common-mode input voltage range			25°C	− 1.6 to 4	− 2 to 6		V
				Full range	− 1.6 to 4			V
V_{OM+}	Maximum positive peak output voltage swing		$R_L = 10\ k\Omega$	25°C	3.5	3.7		V
				Full range	3			
		FK, JG, and L packages	$R_L = 600\ \Omega$	25°C	2.5	3.6		
				Full range	2			
		D and P packages	$R_L = 100\ \Omega$	25°C	2.5	3.1		
				Full range	2			
V_{OM-}	Maximum negative peak output voltage swing		$R_L = 10\ k\Omega$	25°C	− 3.7	− 3.9		V
				Full range	− 3			
		FK, JG, and L packages	$R_L = 600\ \Omega$	25°C	− 2.5	− 3.5		
				Full range	− 2			
		D and P packages	$R_L = 100\ \Omega$	25°C	− 2.5	− 2.7		
				Full range	− 2			
A_{VD}	Large-signal differential voltage amplification		$V_O = \pm 2.8$ V, $R_L = 10\ k\Omega$	25°C	15	80		V/mV
				Full range	2			
		FK, JG, and L packages	$V_O = 0$ to 2.5 V, $R_L = 600\ \Omega$	25°C	1	65		
				Full range	0.5			
			$V_O = 0$ to − 2.5 V, $R_L = 600\ \Omega$	25°C	1	16		
				Full range	0.5			
		D and P packages	$V_O = 0$ to 2 V, $R_L = 100\ \Omega$	25°C	0.75	45		
				Full range	0.5			
			$V_O = 0$ to − 2 V, $R_L = 100\ \Omega$	25°C	0.75	3		
				Full range	0.5			

†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°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted) (continued)

PARAMETER		TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
r_i	Input resistance		25°C		10^{12}		Ω
c_i	Input capacitance		25°C		4		pF
z_o	Open-loop output impedance	$I_O = 0$	25°C		560		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$	25°C	65	82		dB
			Full range	60			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$)	$V_{CC\pm} = \pm 5$ V to ± 20 V, $R_S = 50\ \Omega$	25°C	75	93		dB
			Full range	65			
I_{CC}	Supply current	$V_O = 0$, No load	25°C		255	310	μA
			Full range			330	
ΔI_{CC}	Supply current change over operating temperature range		Full range		39		μA

†Full range is – 55°C to 125°C

operating characteristics, $V_{CC\pm} = \pm 5$V, $T_A = 25°C$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate (see Figure 1)	$A_{VD} = 5$, $R_L = 10$ kΩ, $C_L = 100$ pF		10		V/μs
V_n	Equivalent input noise voltage (see Figure 2)	$R_S = 100\ \Omega$, f = 10 Hz		59		nV/√Hz
		$R_S = 100\ \Omega$, f = 1 kHz		43		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz		1.1		μV
I_n	Equivalent input noise current	f = 1 kHz		1		fA/√Hz
THD	Total harmonic distortion	$A_{VD} = 5$, $V_{O(PP)} = 2$ V, f = 10 kHz, $R_L = 10$ kΩ		0.025%		
	Gain-bandwidth product (see Figure 3)	f = 100 kHz, $R_L = 10$ kΩ, $C_L = 100$ pF		5.8		MHz
		f = 100 kHz, $R_L = 600\ \Omega$, $C_L = 100$ pF		4.3		
	Settling time	ε = 0.1%		5		μs
		ε = 0.01%		10		
B_{OM}	Maximum output-swing bandwidth	$A_{VD} = 5$, $R_L = 10$ kΩ		420		kHz
ϕ_m	Phase margin (see Figure 3)	$A_{VD} = 5$, $R_L = 10$ kΩ, $C_L = 100$ pF		70°		
		$A_{VD} = 5$, $R_L = 600\ \Omega$, $C_L = 100$ pF		84°		

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

PARAMETER			TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	TLE2161M	$V_{IC} = 0$, $R_S = 50\ \Omega$	25°C		0.6	3	mV
				Full range			6	
		TLE2161AM		25°C		0.5	1.5	
				Full range			3.6	
		TLE2161BM		25°C		0.3	0.5	
				Full range			1.7	
α_{VIO}	Temperature coefficient of input offset voltage			Full range		6		μV/°C
	Input offset voltage long-term drift (see Note 4)			25°C		0.04		μV/mo
I_{IO}	Input offset current			25°C		2		pA
				Full range			20	nA
I_{IB}	Input bias current			25°C		4		pA
				Full range			40	nA
V_{ICR}	Common-mode input voltage range			25°C	−11 to 13	−12 to 16		V
				Full range	−11 to 13			V
V_{OM+}	Maximum positive peak output voltage swing		$R_L = 10\ k\Omega$	25°C	13.2	13.7		V
				Full range	12.5			
			$R_L = 600\ \Omega$	25°C	12.5	13.2		
				Full range	12			
V_{OM-}	Maximum negative peak output voltage swing		$R_L = 10\ k\Omega$	25°C	−13.2	−13.7		V
				Full range	−12.5			
			$R_L = 600\ \Omega$	25°C	−12.5	−13		
				Full range	−12			
A_{VD}	Large-signal differential voltage amplification		$V_O = \pm 10$ V, $R_L = 10\ k\Omega$	25°C	30	230		V/mV
				Full range	20			
			$V_O = 0$ to 8 V, $R_L = 600\ \Omega$	25°C	25	100		
				Full range	7			
			$V_O = 0$ to −8 V, $R_L = 600\ \Omega$	25°C	3	25		
				Full range	1			
r_i	Input resistance			25°C		10^{12}		Ω
c_i	Input capacitance			25°C		4		pF
z_o	Open-loop output impedance		$I_O = 0$	25°C		560		Ω
CMRR	Common-mode rejection ratio		$V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$	25°C	72	90		dB
				Full range	65			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$)		$V_{CC\pm} = \pm 5$ V to ±15 V, $R_S = 50\ \Omega$	25°C	75	93		dB
				Full range	65			
I_{CC}	Supply current		$V_O = 0$, No load	25°C		265	320	μA
				Full range			340	
ΔI_{CC}	Supply current change over operating temperature range			Full range		46		μA

†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 $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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

PARAMETER		TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
SR	Slew rate (see Figure 1)	A_{VD} = 5, R_L = 10 kΩ, C_L = 100 pF	25°C	7	10		V/µs
			Full range	5			
V_n	Equivalent input noise voltage (see Figure 2)	R_S = 100 Ω, f = 10 Hz	25°C		70		nV/√Hz
		R_S = 100 Ω, f = 1 kHz			40		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz	25°C		1.1		µV
I_n	Equivalent input noise current	f = 1 kHz	25°C		1.1		fA/√Hz
THD	Total harmonic distortion	A_{VD} = 5, $V_{O(PP)}$ = 2 V, f = 10 kHz, R_L = 10 kΩ	25°C		0.025%		
	Gain-bandwidth product (see Figure 3)	f = 100 kHz, R_L = 10 kΩ, C_L = 100 pF	25°C		6.4		MHz
		f = 100 kHz, R_L = 600 Ω, C_L = 100 pF			5.6		
	Settling time	ε = 0.1%	25°C		5		µs
		ε = 0.01%			10		
B_{OM}	Maximum output-swing bandwidth	A_{VD} = 5, R_L = 10 kΩ	25°C		116		kHz
ϕ_m	Phase margin (see Figure 3)	A_{VD} = 5, R_L = 10 kΩ, C_L = 100 pF	25°C		72°		
		A_{VD} = 5, R_L = 600 Ω, C_L = 100 pF			78°		

†Full range is – 55°C to 125°C

TLE2161M, TLE2161AM, TLE2161BM EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE μPOWER OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

PARAMETER			TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	TLE2161M	$V_{IC} = 0$, $R_S = 50\ \Omega$	25°C		0.6	3	mV
				Full range			6	
		TLE2161AM		25°C		0.6	1.6	
				Full range			3.6	
		TLE2161BM		25°C		0.3	0.5	
				Full range			1.7	
α_{VIO}	Temperature coefficient of input offset voltage			Full range		6		μV/°C
	Input offset voltage long-term drift (see Note 4)			25°C		0.04		μV/mo
I_{IO}	Input offset current			25°C		3		pA
				Full range			20	nA
I_{IB}	Input bias current			25°C		5		pA
				Full range			40	nA
V_{ICR}	Common-mode input voltage range			25°C	−15 to 16.5	−17 to 21		V
				Full range	−15 to 16.5			V
V_{OM+}	Maximum positive peak output voltage swing		$R_L = 10\ k\Omega$	25°C	18.2	18.7		V
				Full range	17.5			
			$R_L = 600\ \Omega$	25°C	15	18.1		
				Full range	12			
V_{OM-}	Maximum negative peak output voltage swing		$R_L = 10\ k\Omega$	25°C	−18.2	−18.7		V
				Full range	−17.5			
			$R_L = 600\ \Omega$	25°C	−15	−18		
				Full range	−12			
A_{VD}	Large-signal differential voltage amplification		$V_O = \pm 15$ V, $R_L = 10\ k\Omega$	25°C	30	280		V/mV
				Full range	20			
			$V_O = 0$ to 10 V, $R_L = 600\ \Omega$	25°C	25	80		
				Full range	10			
			$V_O = 0$ to −10 V, $R_L = 600\ \Omega$	25°C	3	20		
				Full range	1			
r_i	Input resistance			25°C		10^{12}		Ω
c_i	Input capacitance			25°C		4		pF
z_o	Open-loop output impedance		$I_O = 0$	25°C		560		Ω
CMRR	Common-mode rejection ratio		$V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$	25°C	75	91		dB
				Full range	65			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$)		$V_{CC\pm} = \pm 5$ V to ±20 V, $R_S = 50\ \Omega$	25°C	75	93		dB
				Full range	65			
I_{CC}	Supply current		$V_O = 0$, No load	25°C		270	330	μA
				Full range			350	
ΔI_{CC}	Supply current change over operating temperature range			Full range		50		μA

†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 $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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operating characteristics, $V_{CC\pm} = \pm 20$ V, $T_A = 25°C$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate (see Figure 1)	$A_{VD} = 5$, $R_L = 10$ kΩ, $C_L = 100$ pF		10		V/μs
V_n	Equivalent input noise voltage (see Figure 2)	$R_S = 100$ Ω, f = 10 Hz		75		nV/√Hz
		$R_S = 100$ Ω, f = 1 kHz		40		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz		1.1		μV
I_n	Equivalent input noise current	f = 1 kHz		1.3		fA/√Hz
THD	Total harmonic distortion	$A_{VD} = 5$, $V_{O(PP)} = 2$ V, f = 10 kHz, $R_L = 10$ kΩ		0.025%		
	Gain-bandwidth product (see Figure 3)	f = 100 kHz, $R_L = 10$ kΩ, $C_L = 100$ pF		6.5		MHz
		f = 100 kHz, $R_L = 600$ Ω, $C_L = 100$ pF		5.7		
	Settling time	ε = 0.1%		5		μs
		ε = 0.01%		10		
B_{OM}	Maximum output-swing bandwidth	$A_{VD} = 5$, $R_L = 10$ kΩ		85		kHz
ϕ_m	Phase margin (see Figure 3)	$A_{VD} = 5$, $R_L = 10$ kΩ, $C_L = 100$ pF		72°		
		$A_{VD} = 5$, $R_L = 600$ Ω, $C_L = 100$ pF		78°		

TLE2161I, TLE2161AI, TLE2161BI EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE μPOWER OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

PARAMETER			TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	TLE2161I	$V_{IC} = 0$, $R_S = 50\ \Omega$	25°C		0.8	3.1	mV
				Full range			4.4	
		TLE2161AI		25°C		0.6	2.6	
				Full range			3.9	
		TLE2161BI		25°C		0.5	1.9	
				Full range			2.7	
α_{VIO}	Temperature coefficient of input offset voltage			Full range		6		μV/°C
	Input offset voltage long-term drift (see Note 4)			25°C		0.04		μV/mo
I_{IO}	Input offset current			25°C		1		pA
				Full range			2	nA
I_{IB}	Input bias current			25°C		3		pA
				Full range			4	nA
V_{ICR}	Common-mode input voltage range			25°C	−1.6 to 4	−2 to 6		V
				Full range	−1.6 to 4			V
V_{OM+}	Maximum positive peak output voltage swing		$R_L = 10\ k\Omega$	25°C	3.5	3.7		V
				Full range	3.1			
			$R_L = 100\ \Omega$	25°C	2.5	3.1		
				Full range	2			
V_{OM-}	Maximum negative peak output voltage swing		$R_L = 10\ k\Omega$	25°C	−3.7	−3.9		V
				Full range	−3.1			
			$R_L = 100\ \Omega$	25°C	−2.5	−2.7		
				Full range	−2			
A_{VD}	Large-signal differential voltage amplification		$V_O = \pm 2.8$ V, $R_L = 10\ k\Omega$	25°C	15	80		V/mV
				Full range	2			
			$V_O = 0$ to 2 V, $R_L = 100\ \Omega$	25°C	0.75	45		
				Full range	0.5			
			$V_O = 0$ to −2 V, $R_L = 100\ \Omega$	25°C	0.75	3		
				Full range	0.5			
r_i	Input resistance			25°C		10^{12}		Ω
c_i	Input capacitance			25°C		4		pF
z_o	Open-loop output impedance		$I_O = 0$	25°C		560		Ω
CMRR	Common-mode rejection ratio		$V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$	25°C	65	82		dB
				Full range	65			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$)		$V_{CC\pm} = \pm 5$ V to ± 20 V, $R_S = 50\ \Omega$	25°C	75	93		dB
				Full range	65			
I_{CC}	Supply current		$V_O = 0$, No load	25°C		255	310	μA
				Full range			325	
ΔI_{CC}	Supply current change over operating temperature range			Full range		29		μA

†Full range is − 40°C to 85°C

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

T-79-15

operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5V$

PARAMETER		TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
SR	Slew rate (see Figure 1)	$A_{VD} = 5$, $R_L = 10\ k\Omega$, $C_L = 100\ pF$	25°C	7	10		V/μs
			Full range	5			
V_n	Equivalent input noise voltage (see Figure 2)	$R_S = 100\ \Omega$, $f = 10\ Hz$	25°C		59	100	nV/√Hz
		$R_S = 100\ \Omega$, $f = 1\ kHz$			43	60	
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz	25°C		1.1		μV
I_n	Equivalent input noise current	f = 1 kHz	25°C		1		fA/√Hz
THD	Total harmonic distortion	$A_{VD} = 5$, $V_{O(PP)} = 2\ V$, $f = 10\ kHz$, $R_L = 10\ k\Omega$	25°C		0.025%		
	Gain-bandwidth product (see Figure 3)	$f = 100\ kHz$, $R_L = 10\ k\Omega$, $C_L = 100\ pF$	25°C		5.8		MHz
		$f = 100\ kHz$, $R_L = 100\ \Omega$, $C_L = 100\ pF$			4.3		
	Settling time	$\varepsilon = 0.1\%$	25°C		5		μs
		$\varepsilon = 0.01\%$			10		
B_{OM}	Maximum output-swing bandwidth	$A_{VD} = 5$, $R_L = 10\ k\Omega$	25°C		420		kHz
ϕ_m	Phase margin (see Figure 3)	$A_{VD} = 5$, $R_L = 10\ k\Omega$, $C_L = 100\ pF$	25°C		70°		
		$A_{VD} = 5$, $R_L = 100\ \Omega$, $C_L = 100\ pF$			84°		

†Full range is – 40°C to 85°C

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

PARAMETER			TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	TLE2161I	V_{IC} = 0, R_S = 50 Ω	25°C		0.6	3	mV
				Full range			4.3	
		TLE2161AI		25°C		0.5	1.5	
				Full range			2.9	
		TLE2161BI		25°C		0.3	0.5	
				Full range			1.3	
α_{VIO}	Temperature coefficient of input offset voltage			Full range		6		μV/°C
	Input offset voltage long-term drift (see Note 4)			25°C		0.04		μV/mo
I_{IO}	Input offset current			25°C		2		pA
				Full range			3	nA
I_{IB}	Input bias current			25°C		4		pA
				Full range			5	nA
V_{ICR}	Common-mode input voltage range			25°C	−11 to 13	−12 to 16		V
				Full range	−11 to 13			V
V_{OM+}	Maximum positive peak output voltage swing		R_L = 10 kΩ	25°C	13.2	13.7		V
				Full range	13			
			R_L = 600 Ω	25°C	12.5	13.2		
				Full range	12			
V_{OM-}	Maximum negative peak output voltage swing		R_L = 10 kΩ	25°C	−13.2	−13.7		V
				Full range	−13			
			R_L = 600 Ω	25°C	−12.5	−13		
				Full range	−12			
A_{VD}	Large-signal differential voltage amplification		V_O = ±10 V, R_L = 10 kΩ	25°C	30	230		V/mV
				Full range	20			
			V_O = 0 to 8 V, R_L = 600 Ω	25°C	25	100		
				Full range	10			
			V_O = 0 to −8 V, R_L = 600 Ω	25°C	3	25		
				Full range	1			
r_i	Input resistance			25°C		10^{12}		Ω
c_i	Input capacitance			25°C		4		pF
z_o	Open-loop output impedance		I_O = 0	25°C		560		Ω
CMRR	Common-mode rejection ratio		V_{IC} = V_{ICR} min, R_S = 50 Ω	25°C	72	90		dB
				Full range	65			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)		$V_{CC\pm}$ = ±5 V to ±15 V, R_S = 50 Ω	25°C	75	93		dB
				Full range	65			
I_{CC}	Supply current		V_O = 0, No load	25°C		265	320	μA
				Full range			335	
ΔI_{CC}	Supply current change over operating temperature range			Full range		34		μA

†Full range is −40°C to 85°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°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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

PARAMETER		TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
SR	Slew rate (see Figure 1)	$A_{VD} = 5$, $R_L = 10\ k\Omega$, $C_L = 100\ pF$	25°C	7	10		V/μs
			Full range	5			
V_n	Equivalent input noise voltage (see Figure 2)	$R_S = 100\ \Omega$, f = 10 Hz	25°C		70	100	nV/√Hz
		$R_S = 100\ \Omega$, f = 1 kHz			40	60	
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz	25°C		1.1		μV
I_n	Equivalent input noise current	f = 1 kHz	25°C		1.1		fA/√Hz
THD	Total harmonic distortion	$A_{VD} = 5$, $V_{O(PP)} = 2\ V$, f = 10 kHz, $R_L = 10\ k\Omega$	25°C		0.025%		
	Gain-bandwidth product (see Figure 3)	f = 100 kHz, $R_L = 10\ k\Omega$, $C_L = 100\ pF$	25°C		6.4		MHz
		f = 100 kHz, $R_L = 600\ \Omega$, $C_L = 100\ pF$			5.6		
	Settling time	$\varepsilon = 0.1\%$	25°C		5		μs
		$\varepsilon = 0.01\%$			10		
B_{OM}	Maximum output-swing bandwidth	$A_{VD} = 5$, $R_L = 10\ k\Omega$	25°C		116		kHz
ϕ_m	Phase margin (see Figure 3)	$A_{VD} = 5$, $R_L = 10\ k\Omega$, $C_L = 100\ pF$	25°C		72°		
		$A_{VD} = 5$, $R_L = 600\ \Omega$, $C_L = 100\ pF$			78°		

†Full range is – 40°C to 85°C

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
V_{IO} Input offset voltage	TLE2161I	$V_{IC} = 0$, $R_S = 50\ \Omega$	25°C		0.6	3	mV
			Full range			4.3	
	TLE2161AI		25°C		0.6	1.6	
			Full range			2.9	
	TLE2161BI		25°C		0.3	0.5	
			Full range			1.3	
α_{VIO} Temperature coefficient of input offset voltage			Full range		6		μV/°C
Input offset voltage long-term drift (see Note 4)			25°C		0.04		μV/mo
I_{IO} Input offset current			25°C		3		pA
			Full range			3	nA
I_{IB} Input bias current			25°C		5		pA
			Full range			5	nA
V_{ICR} Common-mode input voltage range			25°C	−15 to 16.5	−17 to 21		V
			Full range	−15 to 16.5			V
V_{OM+} Maximum positive peak output voltage swing		$R_L = 10\ k\Omega$	25°C	18.2	18.7		V
			Full range	18			
		$R_L = 600\ \Omega$	25°C	15	18.1		
			Full range	12			
V_{OM-} Maximum negative peak output voltage swing		$R_L = 10\ k\Omega$	25°C	−18.2	−18.7		V
			Full range	−18			
		$R_L = 600\ \Omega$	25°C	−15	−18		
			Full range	−12			
A_{VD} Large-signal differential voltage amplification		$V_O = \pm 15$ V, $R_L = 10\ k\Omega$	25°C	30	280		V/mV
			Full range	20			
		$V_O = 0$ to 10 V, $R_L = 600\ \Omega$	25°C	25	80		
			Full range	10			
		$V_O = 0$ to −10 V, $R_L = 600\ \Omega$	25°C	3	20		
			Full range	1			
r_i Input resistance			25°C		10^{12}		Ω
c_i Input capacitance			25°C		4		pF
z_o Open-loop output impedance		$I_O = 0$	25°C		560		Ω
CMRR Common-mode rejection ratio		$V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$	25°C	75	91		dB
			Full range	65			
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$)		$V_{CC\pm} = \pm 5$ V to ±20 V, $R_S = 50\ \Omega$	25°C	75	93		dB
			Full range	65			
I_{CC} Supply current		$V_O = 0$, No load	25°C		270	330	μA
			Full range			345	
ΔI_{CC} Supply current change over operating temperature range			Full range		36		μA

†Full range is −40°C to 85°C

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

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operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V

PARAMETER		TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
SR	Slew rate (see Figure 1)	$A_{VD} = 5$, $R_L = 10$ kΩ, $C_L = 100$ pF	25°C	7	10		V/µs
			Full range	5			
V_n	Equivalent input noise voltage (see Figure 2)	$R_S = 100\ \Omega$, f = 10 Hz	25°C		75	100	nV/√Hz
		$R_S = 100\ \Omega$, f = 1 kHz			40	60	
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz	25°C		1.1		µV
I_n	Equivalent input noise current	f = 1 kHz	25°C		1.3		fA/√Hz
THD	Total harmonic distortion	$A_{VD} = 5$, $V_{O(PP)} = 2$ V, f = 10 kHz, $R_L = 10$ kΩ	25°C		0.025%		
	Gain-bandwidth product (see Figure 3)	f = 100 kHz, $R_L = 10$ kΩ, $C_L = 100$ pF	25°C		6.5		MHz
		f = 100 kHz, $R_L = 600\ \Omega$, $C_L = 100$ pF			5.7		
	Settling time	ε = 0.1%	25°C		5		µs
		ε = 0.01%			10		
B_{OM}	Maximum output-swing bandwidth	$A_{VD} = 5$, $R_L = 10$ kΩ	25°C		85		kHz
ϕ_m	Phase margin (see Figure 3)	$A_{VD} = 5$, $R_L = 10$ kΩ, $C_L = 100$ pF	25°C		72°		
		$A_{VD} = 5$, $R_L = 600\ \Omega$, $C_L = 100$ pF			78°		

†Full range is – 40°C to 85°C

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

PARAMETER			TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	TLE2161C	$V_{IC} = 0$, $R_S = 50\ \Omega$	25°C		0.8	3.1	mV
				Full range			4	
		TLE2161AC		25°C		0.6	2.6	
				Full range			3.5	
		TLE2161BC		25°C		0.5	1.9	
				Full range			2.4	
α_{VIO}	Temperature coefficient of input offset voltage			Full range		6		μV/°C
	Input offset voltage long-term drift (see Note 4)			25°C		0.04		μV/mo
I_{IO}	Input offset current			25°C		1		pA
				Full range			0.8	nA
I_{IB}	Input bias current			25°C		3		pA
				Full range			2	nA
V_{ICR}	Common-mode input voltage range			25°C	−1.6 to 4	−2 to 6		V
				Full range	−1.6 to 4			V
V_{OM+}	Maximum positive peak output voltage swing		$R_L = 10\ k\Omega$	25°C	3.5	3.7		V
				Full range	3.3			
			$R_L = 100\ \Omega$	25°C	2.5	3.1		
				Full range	2			
V_{OM-}	Maximum negative peak output voltage swing		$R_L = 10\ k\Omega$	25°C	−3.7	−3.9		V
				Full range	−3.3			
			$R_L = 100\ \Omega$	25°C	−2.5	−2.7		
				Full range	−2			
A_{VD}	Large-signal differential voltage amplification		$V_O = \pm 2.8$ V, $R_L = 10\ k\Omega$	25°C	15	80		V/mV
				Full range	2			
			$V_O = 0$ to 2 V, $R_L = 100\ \Omega$	25°C	0.75	45		
				Full range	0.5			
			$V_O = 0$ to −2 V, $R_L = 100\ \Omega$	25°C	0.75	3		
				Full range	0.5			
r_i	Input resistance			25°C		10^{12}		Ω
c_i	Input capacitance			25°C		4		pF
z_o	Open-loop output impedance		$I_O = 0$	25°C		560		Ω
CMRR	Common-mode rejection ratio		$V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$	25°C	65	82		dB
				Full range	65			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$)		$V_{CC\pm} = \pm 5$ V to ± 20 V, $R_S = 50\ \Omega$	25°C	75	93		dB
				Full range	75			
I_{CC}	Supply current		$V_O = 0$, No load	25°C		255	310	μA
				Full range			320	
ΔI_{CC}	Supply current change over operating temperature range			Full range		29		μA

†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 $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5V$

PARAMETER		TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
SR	Slew rate (see Figure 1)	$A_{VD} = 5$, $R_L = 10\ k\Omega$, $C_L = 100\ pF$	25°C	7	10		V/μs
			Full range	5			
V_n	Equivalent input noise voltage (see Figure 2)	$R_S = 100\ \Omega$, $f = 10\ Hz$	25°C		59	100	nV/√Hz
		$R_S = 100\ \Omega$, $f = 1\ kHz$			43	60	
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\ Hz$ to $10\ Hz$	25°C		1.1		μV
I_n	Equivalent input noise current	$f = 1\ kHz$	25°C		1		fA/√Hz
THD	Total harmonic distortion	$A_{VD} = 5$, $V_{O(PP)} = 2\ V$, $f = 10\ kHz$, $R_L = 10\ k\Omega$	25°C		0.025%		
	Gain-bandwidth product (see Figure 3)	$f = 100\ kHz$, $R_L = 10\ k\Omega$, $C_L = 100\ pF$	25°C		5.8		MHz
		$f = 100\ kHz$, $R_L = 100\ \Omega$, $C_L = 100\ pF$			4.3		
	Settling time	$\varepsilon = 0.1\%$	25°C		5		μs
		$\varepsilon = 0.01\%$			10		
B_{OM}	Maximum output-swing bandwidth	$A_{VD} = 5$, $R_L = 10\ k\Omega$	25°C		420		kHz
ϕ_m	Phase margin (see Figure 3)	$A_{VD} = 5$, $R_L = 10\ k\Omega$, $C_L = 100\ pF$	25°C		70°		
		$A_{VD} = 5$, $R_L = 100\ \Omega$, $C_L = 100\ pF$			84°		

†Full range is 0°C to 70°C

TLE2161C, TLE2161AC, TLE2161BC EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE μPOWER OPERATIONAL AMPLIFIERS

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

PARAMETER			TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	TLE2161C	$V_{IC} = 0$, $R_S = 50\ \Omega$	25°C		0.6	3	mV
				Full range			3.9	
		TLE2161AC		25°C		0.5	1.5	
				Full range			2.5	
		TLE2161BC		25°C		0.3	0.5	
				Full range			1	
α_{VIO}	Temperature coefficient of input offset voltage			Full range		6		μV/°C
	Input offset voltage long-term drift (see Note 4)			25°C		0.04		μV/mo
I_{IO}	Input offset current			25°C		2		pA
				Full range			1	nA
I_{IB}	Input bias current			25°C		4		pA
				Full range			3	nA
V_{ICR}	Common-mode input voltage range			25°C	−11 to 13	−12 to 16		V
				Full range	−11 to 13			V
V_{OM+}	Maximum positive peak output voltage swing		$R_L = 10\ k\Omega$	25°C	13.2	13.7		V
				Full range	13			
			$R_L = 600\ \Omega$	25°C	12.5	13.2		
				Full range	12			
V_{OM-}	Maximum negative peak output voltage swing		$R_L = 10\ k\Omega$	25°C	−13.2	−13.7		V
				Full range	−13			
			$R_L = 600\ \Omega$	25°C	−12.5	−13		
				Full range	−12			
A_{VD}	Large-signal differential voltage amplification		$V_O = \pm 10$ V, $R_L = 10\ k\Omega$	25°C	30	230		V/mV
				Full range	20			
			$V_O = 0$ to 8 V, $R_L = 600\ \Omega$	25°C	25	100		
				Full range	10			
			$V_O = 0$ to −8 V, $R_L = 600\ \Omega$	25°C	3	25		
				Full range	1			
r_i	Input resistance			25°C		10^{12}		Ω
c_i	Input capacitance			25°C		4		pF
z_o	Open-loop output impedance		$I_O = 0$	25°C		560		Ω
CMRR	Common-mode rejection ratio		$V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$	25°C	72	90		dB
				Full range	70			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$)		$V_{CC\pm} = \pm 5$ V to ± 15 V, $R_S = 50\ \Omega$	25°C	75	93		dB
				Full range	75			
I_{CC}	Supply current		$V_O = 0$, No load	25°C		265	320	μA
				Full range			330	
ΔI_{CC}	Supply current change over operating temperature range			Full range		34		μA

†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 $T_A = 150$°C extrapolated to $T_A = 25$°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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

PARAMETER		TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
SR	Slew rate (see Figure 1)	A_{VD} = 5, R_L = 10 kΩ, C_L = 100 pF	25°C	7	10		V/μs
			Full range	5			
V_n	Equivalent input noise voltage (see Figure 2)	R_S = 100 Ω, f = 10 Hz	25°C		70	100	nV/√Hz
		R_S = 100 Ω, f = 1 kHz			40	60	
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz	25°C		1.1		μV
I_n	Equivalent input noise current	f = 1 kHz	25°C		1.1		fA/√Hz
THD	Total harmonic distortion	A_{VD} = 5, $V_{O(PP)}$ = 2 V, f = 10 kHz, R_L = 10 kΩ	25°C		0.025%		
	Gain-bandwidth product (see Figure 3)	f = 100 kHz, R_L = 10 kΩ, C_L = 100 pF	25°C		6.4		MHz
		f = 100 kHz, R_L = 600 Ω, C_L = 100 pF			5.6		
	Settling time	ε = 0.1%	25°C		5		μs
		ε = 0.01%			10		
B_{OM}	Maximum output-swing bandwidth	A_{VD} = 5, R_L = 10 kΩ	25°C		116		kHz
ϕ_m	Phase margin (see Figure 3)	A_{VD} = 5, R_L = 10 kΩ, C_L = 100 pF	25°C		72°		
		A_{VD} = 5, R_L = 600 Ω, C_L = 100 pF			78°		

†Full range is 0°C to 70°C

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

PARAMETER			TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	TLE2161C	$V_{IC} = 0$, $R_S = 50\ \Omega$	25°C		0.6	3	mV
				Full range			3.9	
		TLE2161AC		25°C		0.6	1.6	
				Full range			2.5	
		TLE2161BC		25°C		0.3	0.5	
				Full range			1	
α_{VIO}	Temperature coefficient of input offset voltage			Full range		6		μV/°C
	Input offset voltage long-term drift (see Note 4)			25°C		0.04		μV/mo
I_{IO}	Input offset current			25°C		3		pA
				Full range			1	nA
I_{IB}	Input bias current			25°C		5		pA
				Full range			3	nA
V_{ICR}	Common-mode input voltage range			25°C	−15 to 16.5	−17 to 21		V
				Full range	−15 to 16.5			V
V_{OM+}	Maximum positive peak output voltage swing		$R_L = 10\ k\Omega$	25°C	18.2	18.7		V
				Full range	18			
			$R_L = 600\ \Omega$	25°C	15	18.1		
				Full range	12			
V_{OM-}	Maximum negative peak output voltage swing		$R_L = 10\ k\Omega$	25°C	−18.2	−18.7		V
				Full range	−18			
			$R_L = 600\ \Omega$	25°C	−15	−18		
				Full range	−12			
A_{VD}	Large-signal differential voltage amplification		$V_O = \pm 15$ V, $R_L = 10\ k\Omega$	25°C	30	280		V/mV
				Full range	20			
			$V_O = 0$ to 10 V, $R_L = 600\ \Omega$	25°C	25	80		
				Full range	10			
			$V_O = 0$ to −10 V, $R_L = 600\ \Omega$	25°C	3	20		
				Full range	1			
r_i	Input resistance			25°C		10^{12}		Ω
c_i	Input capacitance			25°C		4		pF
z_o	Open-loop output impedance		$I_O = 0$	25°C		560		Ω
CMRR	Common-mode rejection ratio		$V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$	25°C	75	91		dB
				Full range	70			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$)		$V_{CC\pm} = \pm 5$ V to ±20 V, $R_S = 50\ \Omega$	25°C	75	93		dB
				Full range	70			
I_{CC}	Supply current		$V_O = 0$, No load	25°C		270	330	μA
				Full range			340	
ΔI_{CC}	Supply current change over operating temperature range			Full range		18		μA

†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 $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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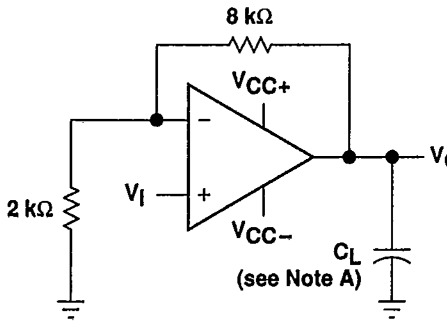
operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V

PARAMETER		TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
SR	Slew rate (see Figure 1)	$A_{VD} = 5$, $R_L = 10$ kΩ, $C_L = 100$ pF	25°C	7	10		V/μs
			Full range	5			
V_n	Equivalent input noise voltage (see Figure 2)	$R_S = 100$ Ω, f = 10 Hz	25°C		75	100	nV/√Hz
		$R_S = 100$ Ω, f = 1 kHz			40	60	
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz	25°C		1.1		μV
I_n	Equivalent input noise current	f = 1 kHz	25°C		1.3		fA/√Hz
THD	Total harmonic distortion	$A_{VD} = 5$, $V_{O(PP)} = 2$ V, f = 10 kHz, $R_L = 10$ kΩ	25°C		0.025%		
	Gain-bandwidth product (see Figure 3)	f = 100 kHz, $R_L = 10$ kΩ, $C_L = 100$ pF	25°C		6.5		MHz
		f = 100 kHz, $R_L = 600$ Ω, $C_L = 100$ pF			5.7		
	Settling time	ε = 0.1%	25°C		5		μs
		ε = 0.01%			10		
B_{OM}	Maximum output-swing bandwidth	$A_{VD} = 5$, $R_L = 10$ kΩ	25°C		85		kHz
ϕ_m	Phase margin (see Figure 3)	$A_{VD} = 5$, $R_L = 10$ kΩ, $C_L = 100$ pF	25°C		72°		
		$A_{VD} = 5$, $R_L = 600$ Ω, $C_L = 100$ pF			78°		

†Full range is 0°C to 70°C

PARAMETER MEASUREMENT INFORMATION



NOTE A: C_L includes fixture capacitance.

FIGURE 1. SLEW RATE TEST CIRCUIT

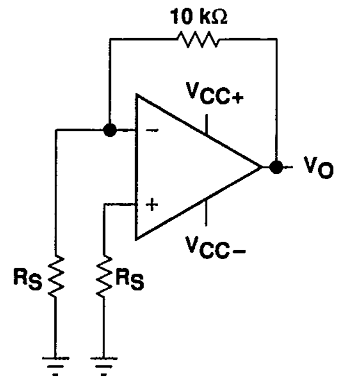
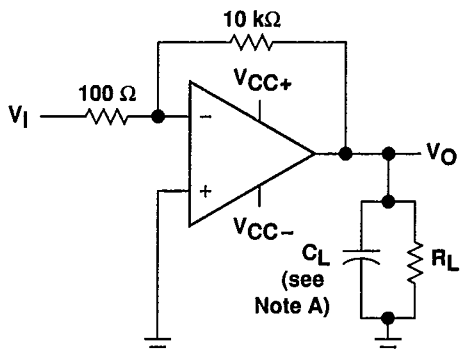


FIGURE 2. NOISE VOLTAGE TEST CIRCUIT



NOTE A: C_L includes fixture capacitance.

FIGURE 3. GAIN-BANDWIDTH PRODUCT and PHASE MARGIN TEST CIRCUIT

typical values

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

input bias and offset current

At the picoampere bias-current level typical of the TLE2161, TLE2161A, and TLE2161B, accurate measurement of the bias current becomes difficult. Not only does this measurement require a picoammeter, but test socket leakages can easily exceed the actual device bias currents. To accurately measure these small currents, Texas Instruments uses a two-step process. The socket leakage is measured using picoammeters with bias voltages applied but with no device in the socket. The device is then inserted into the socket and a second test that measures both the socket leakage and the device input bias current is performed. The two measurements are then subtracted algebraically to determine the bias current of the device.

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TYPICAL CHARACTERISTICS

table of graphs

			FIGURE
V_{IO}	Input offset voltage	Distribution	4
I_{IB}	Input bias current	vs Common-mode voltage	5
		vs Temperature	6
I_{IO}	Input offset current	vs Temperature	6
V_{ICR}	Common-mode input voltage range limits	vs Temperature	7
V_{OM}	Maximum peak output voltage swing	vs Output current	8, 9
		vs Supply voltage	10, 11, 12
$V_{O(PP)}$	Maximum peak-to-peak output voltage	vs Frequency	13, 14, 15
A_{VD}	Differential voltage amplification	vs Frequency	16
		vs Temperature	17
I_{OS}	Short-circuit output current	vs Time	18
		vs Temperature	19
z_o	Output impedance	vs Frequency	20
CMRR	Common-mode rejection ratio	vs Frequency	21
I_{CC}	Supply current	vs Supply voltage	22
		vs Temperature	23
	Pulse response	Small-signal	24, 25
		Large-signal	26, 27
	Noise voltage (referred to input)	0.1 to 10 Hz	28
V_n	Equivalent input noise voltage	vs Frequency	29
THD	Total harmonic distortion	vs Frequency	30, 31
	Gain-bandwidth product	vs Supply voltage	32
		vs Temperature	33
ϕ_m	Phase margin	vs Supply voltage	34
		vs Temperature	35
ϕ	Phase shift	vs Frequency	16

TYPICAL CHARACTERISTICS†

TLE2161
DISTRIBUTION OF
INPUT OFFSET VOLTAGE

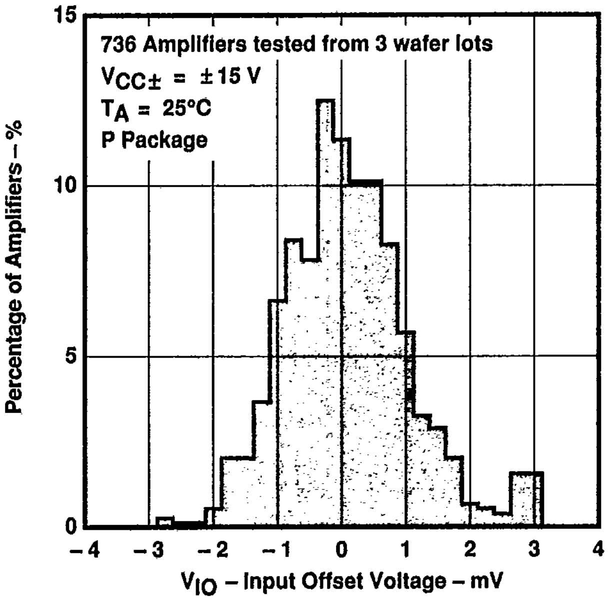

FIGURE 4

INPUT BIAS CURRENT
vs
COMMON-MODE INPUT VOLTAGE

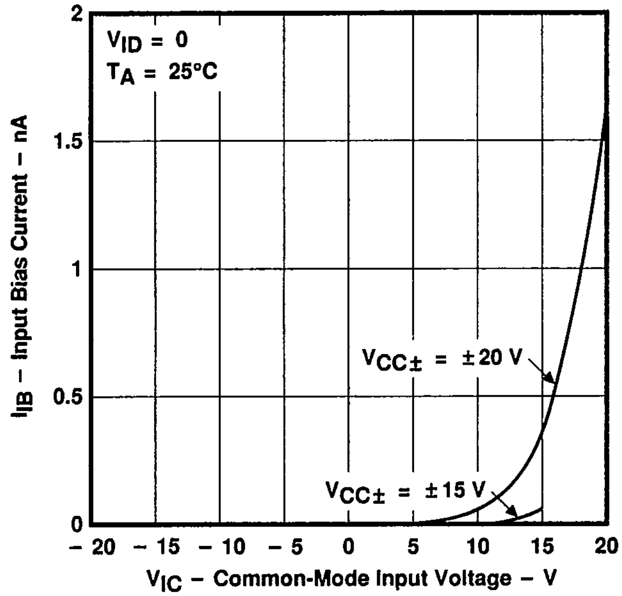

FIGURE 5

INPUT BIAS CURRENT
and INPUT OFFSET CURRENT
vs
FREE-AIR TEMPERATURE

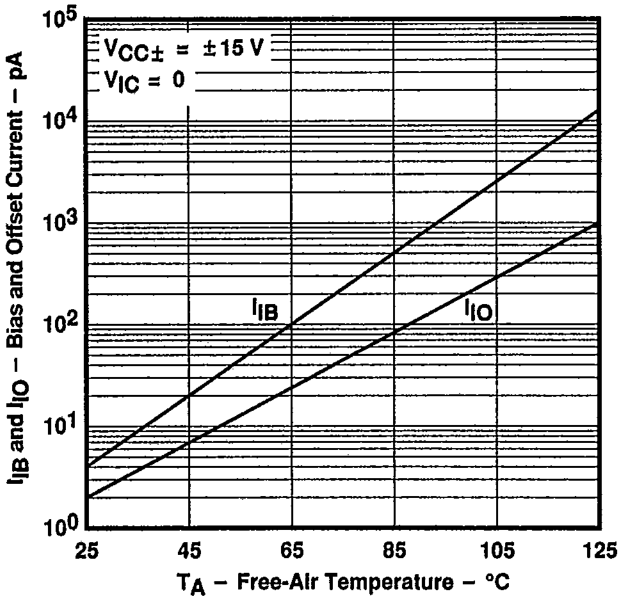

FIGURE 6

COMMON-MODE
INPUT VOLTAGE RANGE LIMITS
vs
FREE-AIR TEMPERATURE

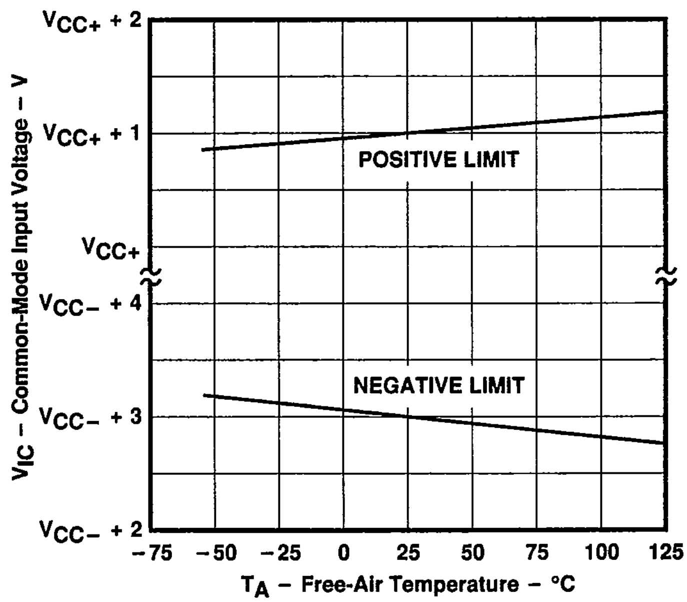

FIGURE 7

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

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TYPICAL CHARACTERISTICS

MAXIMUM POSITIVE PEAK OUTPUT VOLTAGE
vs
OUTPUT CURRENT

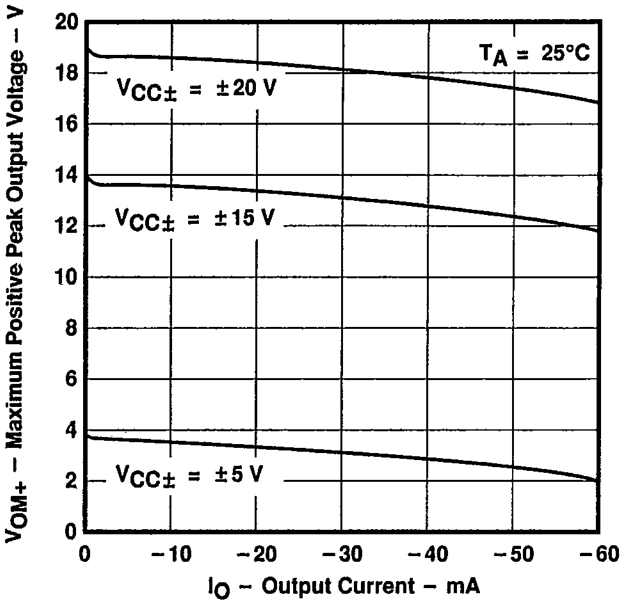

FIGURE 8

MAXIMUM NEGATIVE PEAK OUTPUT VOLTAGE
vs
OUTPUT CURRENT

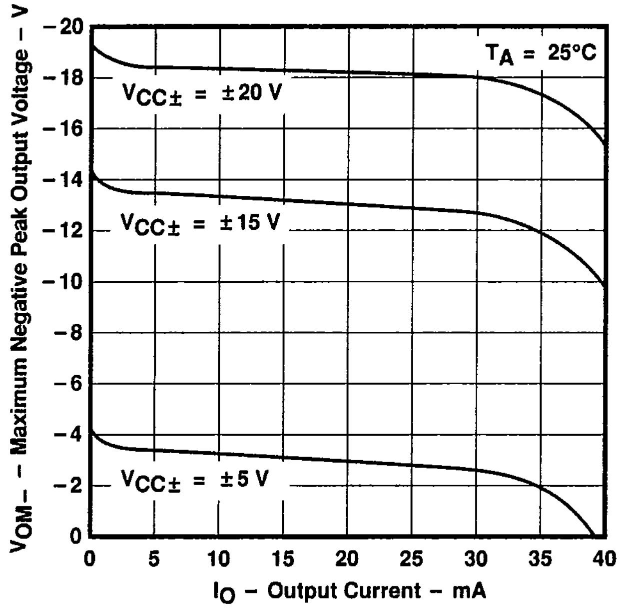

FIGURE 9

MAXIMUM PEAK OUTPUT VOLTAGE
vs
SUPPLY VOLTAGE

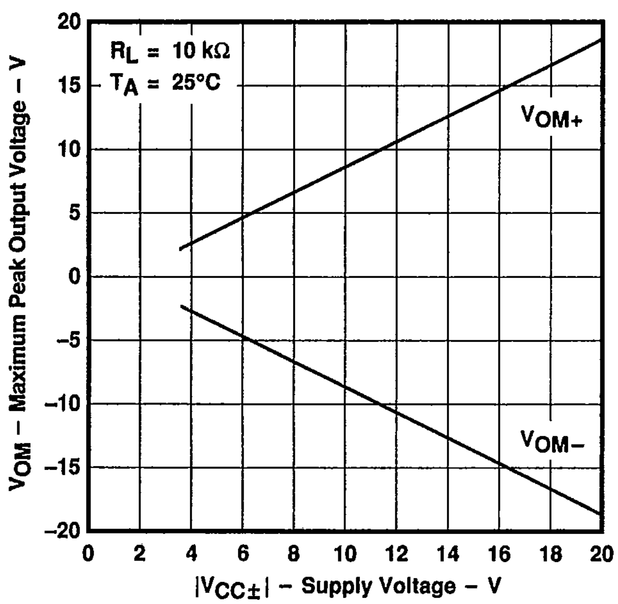

FIGURE 10

MAXIMUM PEAK OUTPUT VOLTAGE
vs
SUPPLY VOLTAGE

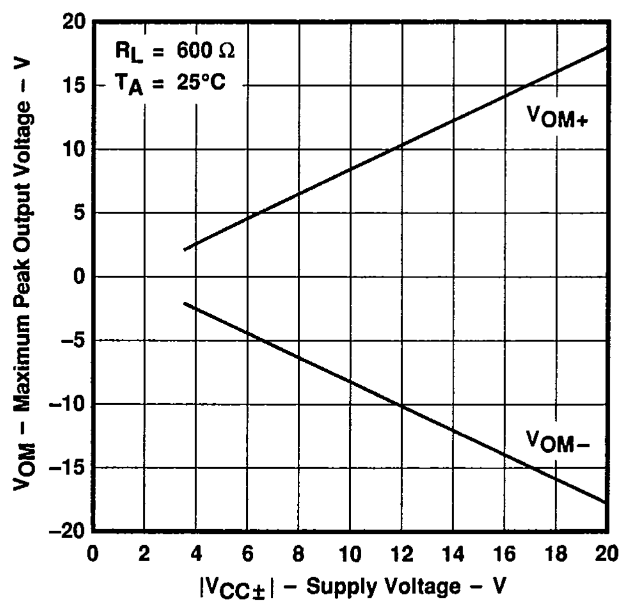

FIGURE 11

TYPICAL CHARACTERISTICS

MAXIMUM PEAK OUTPUT VOLTAGE
vs
SUPPLY VOLTAGE

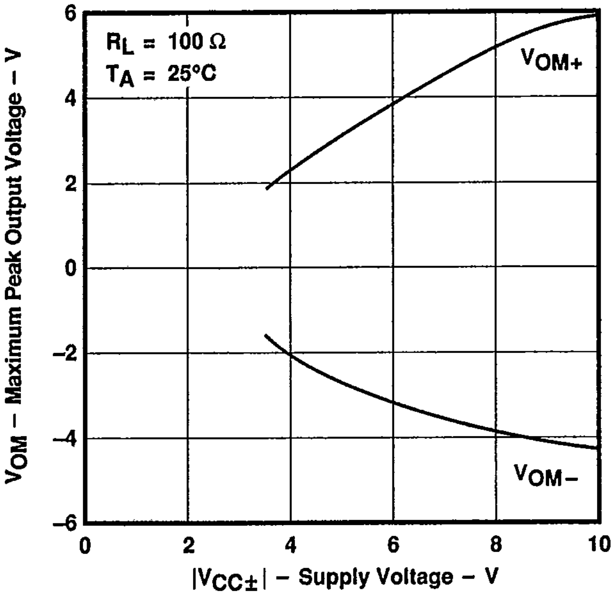

FIGURE 12

MAXIMUM PEAK-TO-PEAK
OUTPUT VOLTAGE
vs
FREQUENCY

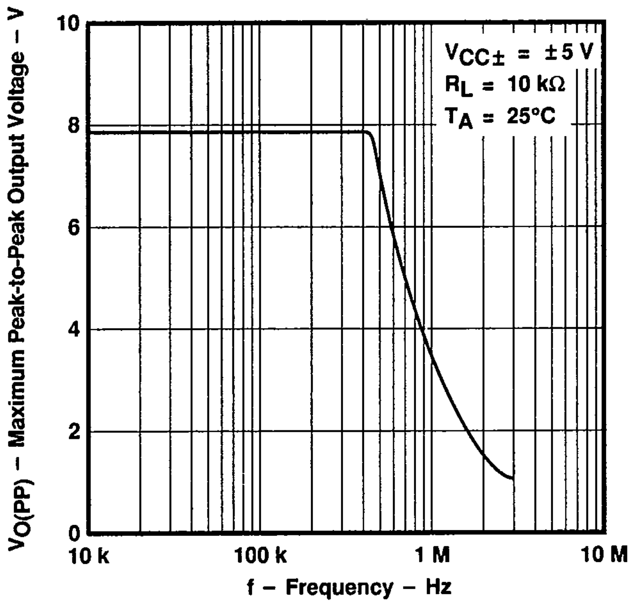

FIGURE 13

MAXIMUM PEAK-TO-PEAK
OUTPUT VOLTAGE
vs
FREQUENCY

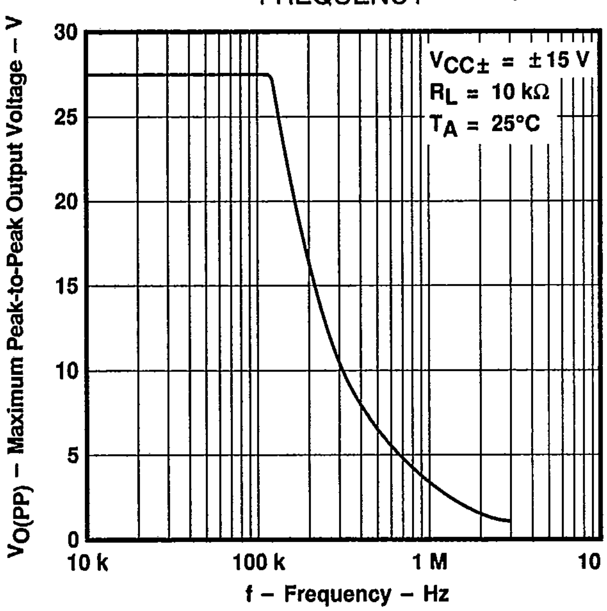

FIGURE 14

MAXIMUM PEAK-TO-PEAK
OUTPUT VOLTAGE
vs
FREQUENCY

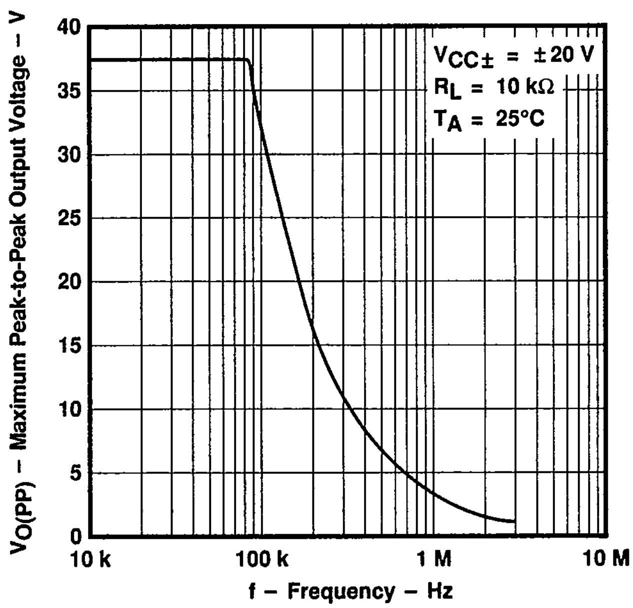

FIGURE 15

TYPICAL CHARACTERISTICS†

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION and PHASE SHIFT
vs
FREQUENCY

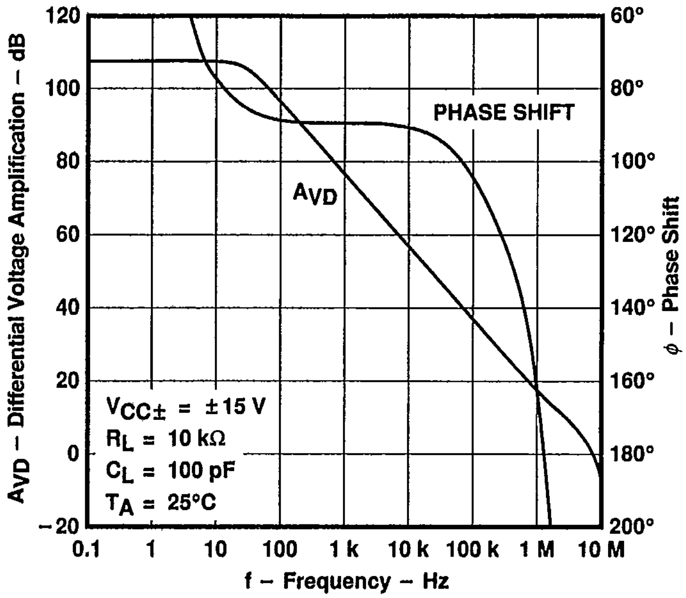

FIGURE 16

LARGE-SIGNAL VOLTAGE AMPLIFICATION
vs
FREE-AIR TEMPERATURE

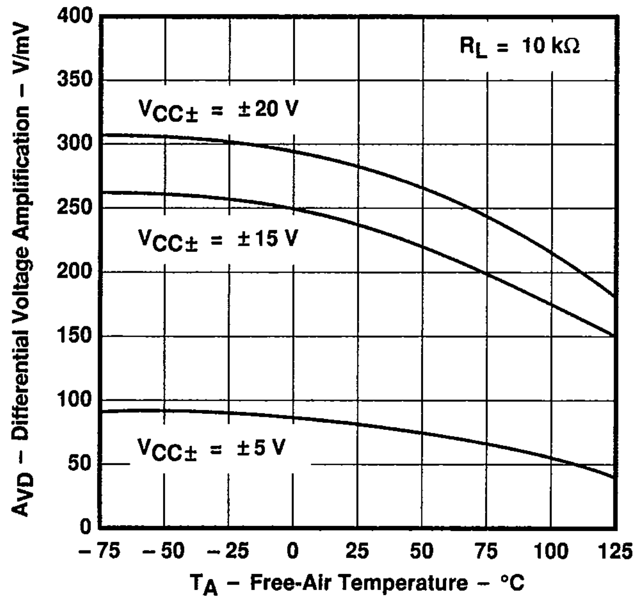

FIGURE 17

SHORT-CIRCUIT OUTPUT CURRENT
vs
ELAPSED TIME

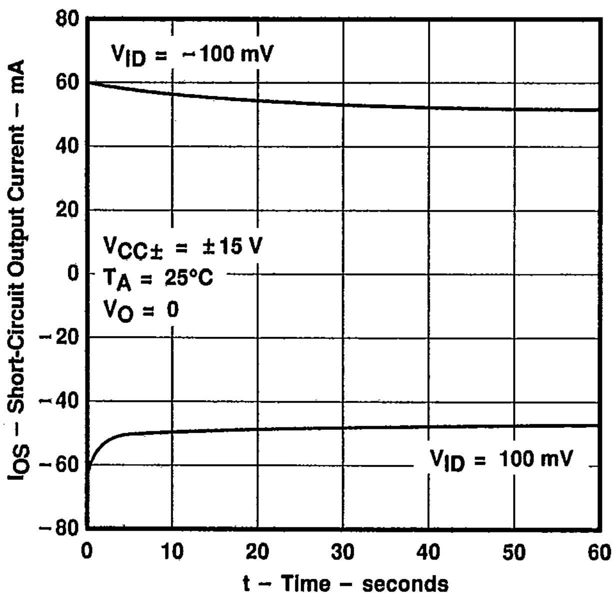

FIGURE 18

SHORT-CIRCUIT OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

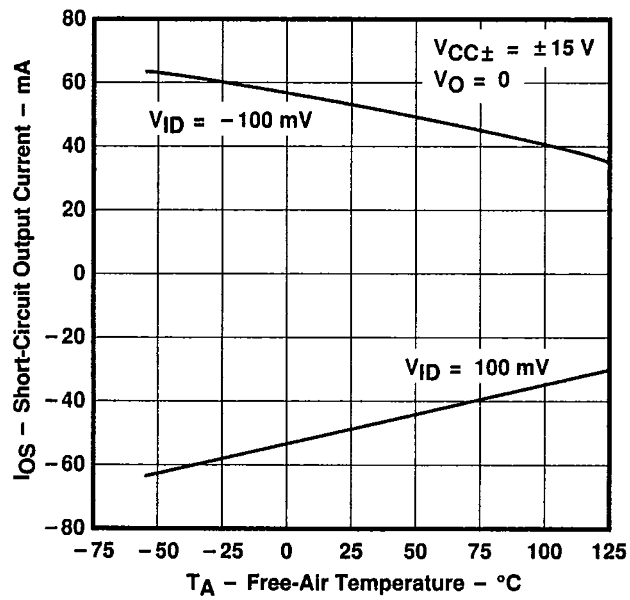

FIGURE 19

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

TYPICAL CHARACTERISTICS†

OUTPUT IMPEDANCE
vs
FREQUENCY

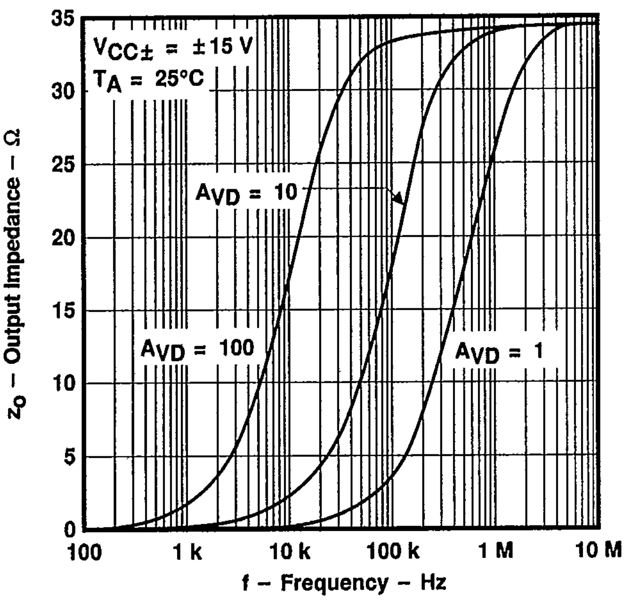

FIGURE 20

COMMON-MODE REJECTION RATIO
vs
FREQUENCY

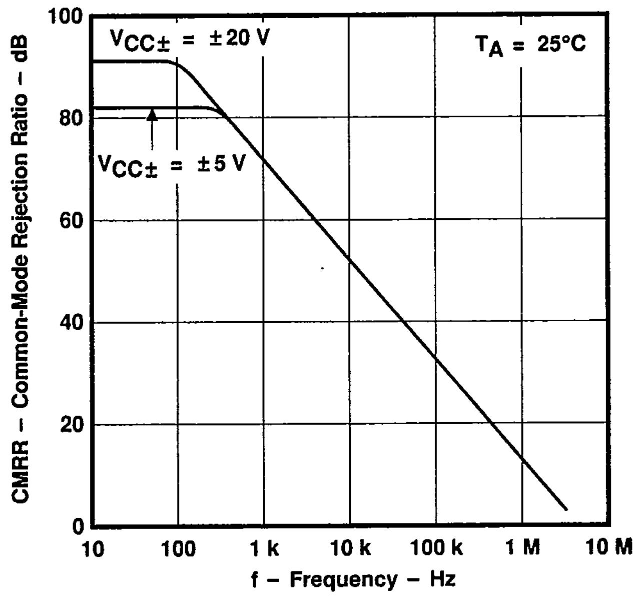

FIGURE 21

SUPPLY CURRENT
vs
SUPPLY VOLTAGE

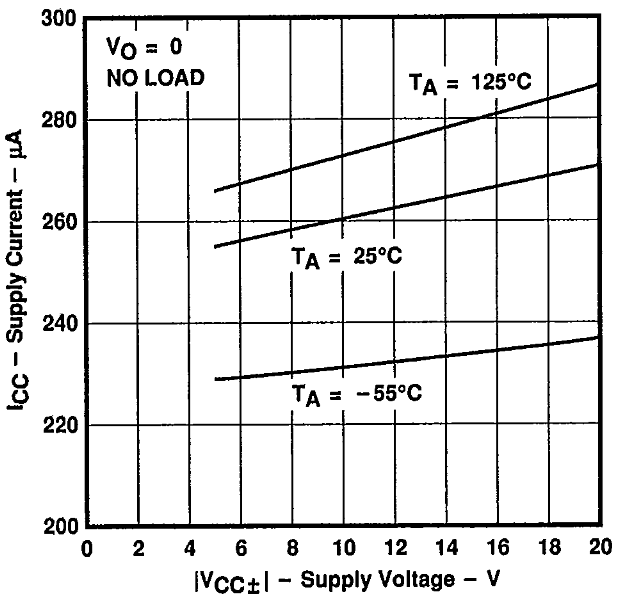

FIGURE 22

SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE

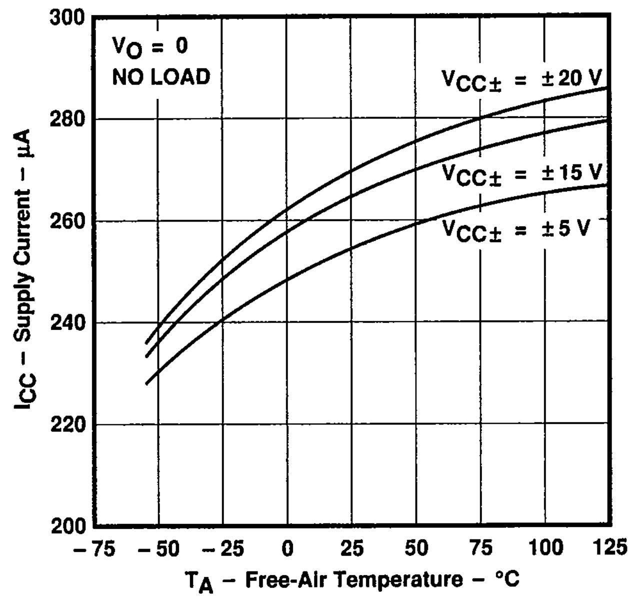

FIGURE 23

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

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TYPICAL CHARACTERISTICS

SMALL-SIGNAL
PULSE RESPONSE

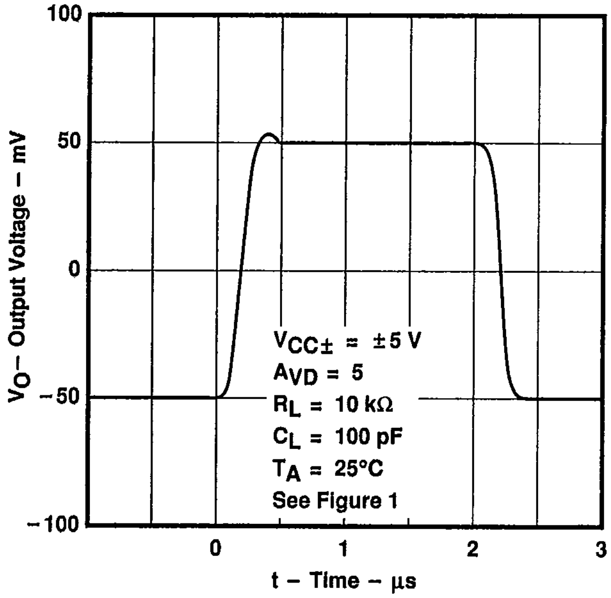

FIGURE 24

SMALL-SIGNAL
PULSE RESPONSE

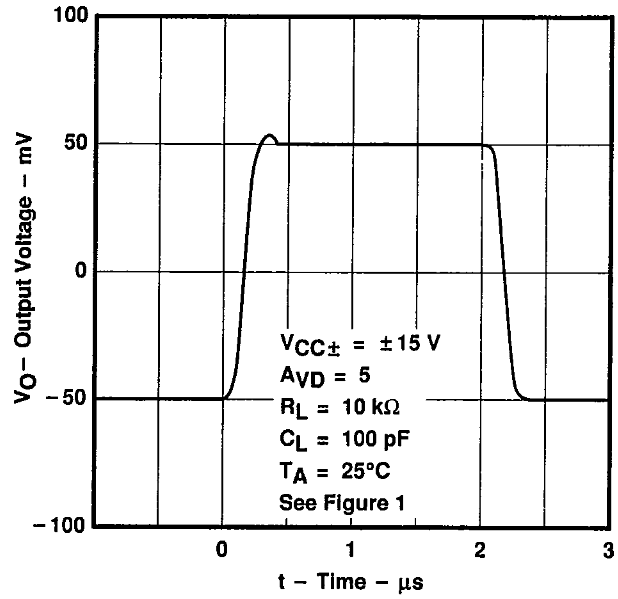

FIGURE 25

LARGE-SIGNAL
PULSE RESPONSE

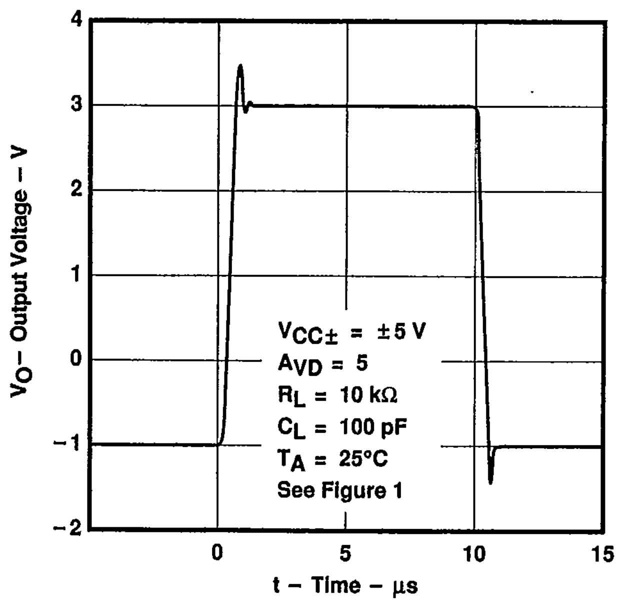

FIGURE 26

LARGE-SIGNAL
PULSE RESPONSE

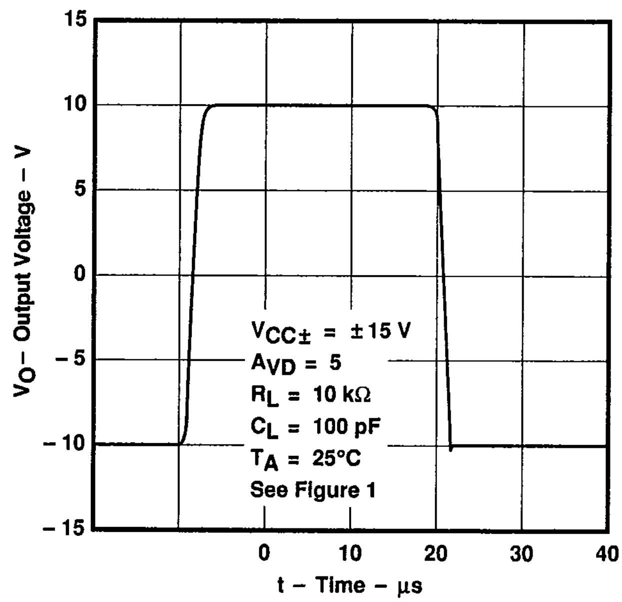

FIGURE 27

TYPICAL CHARACTERISTICS

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

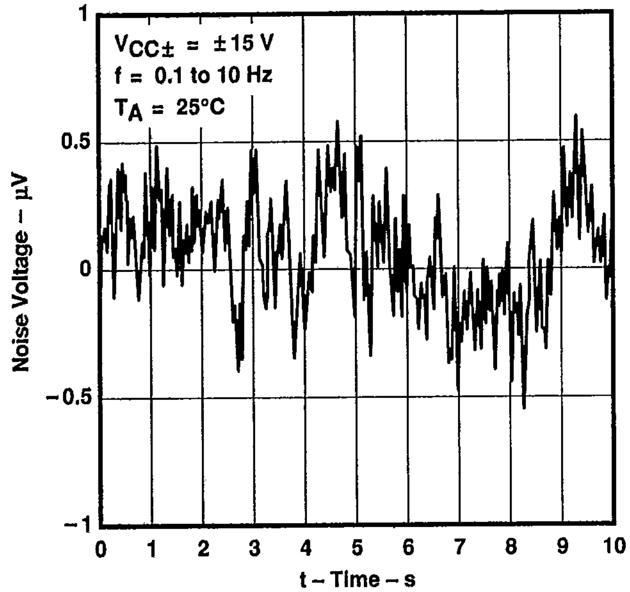

FIGURE 28

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

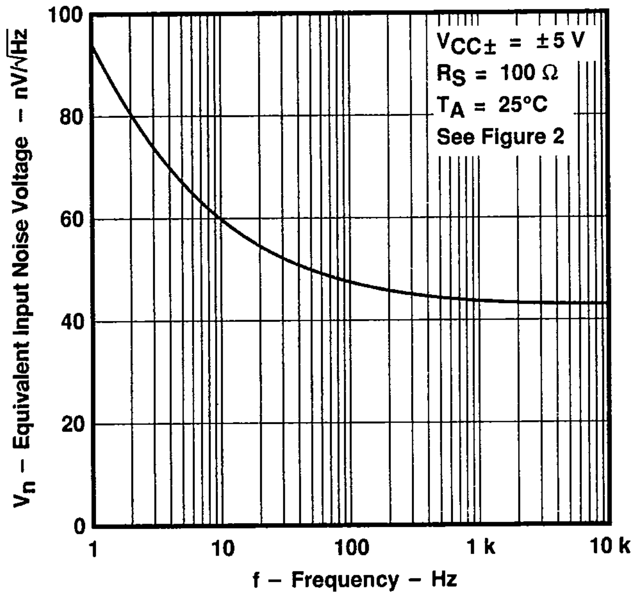

FIGURE 29

TOTAL HARMONIC DISTORTION
vs
FREQUENCY

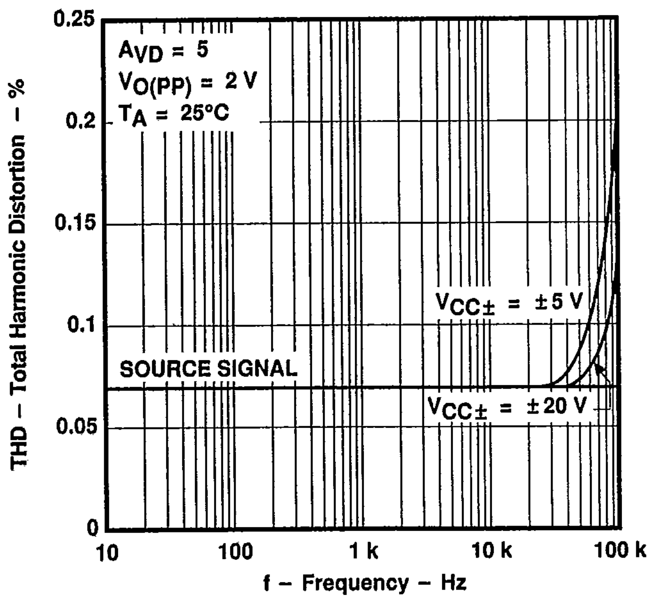

FIGURE 30

TOTAL HARMONIC DISTORTION
vs
FREQUENCY

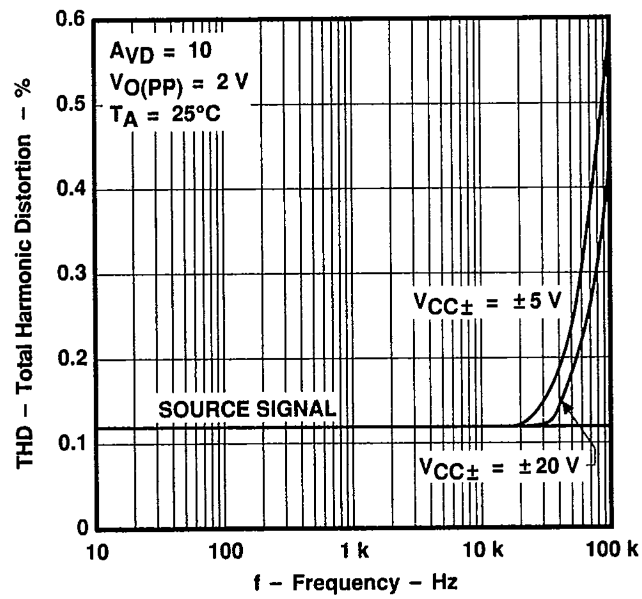

FIGURE 31

TYPICAL CHARACTERISTICS†

GAIN-BANDWIDTH PRODUCT
vs
SUPPLY VOLTAGE

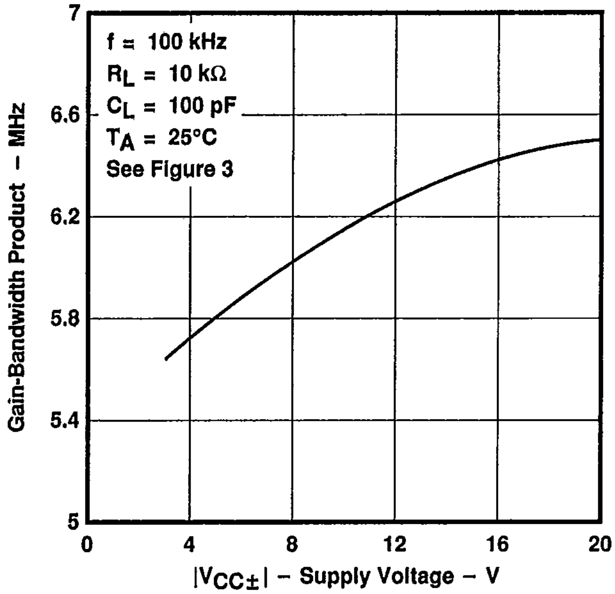

FIGURE 32

GAIN-BANDWIDTH PRODUCT
vs
FREE-AIR TEMPERATURE

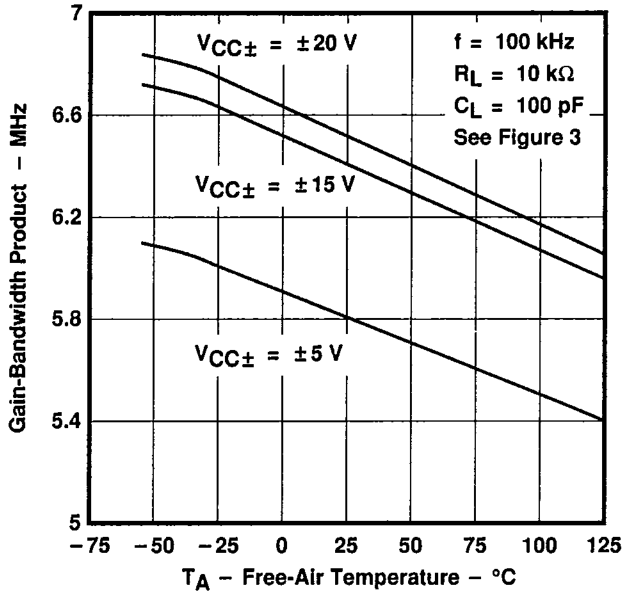

FIGURE 33

PHASE MARGIN
vs
SUPPLY VOLTAGE

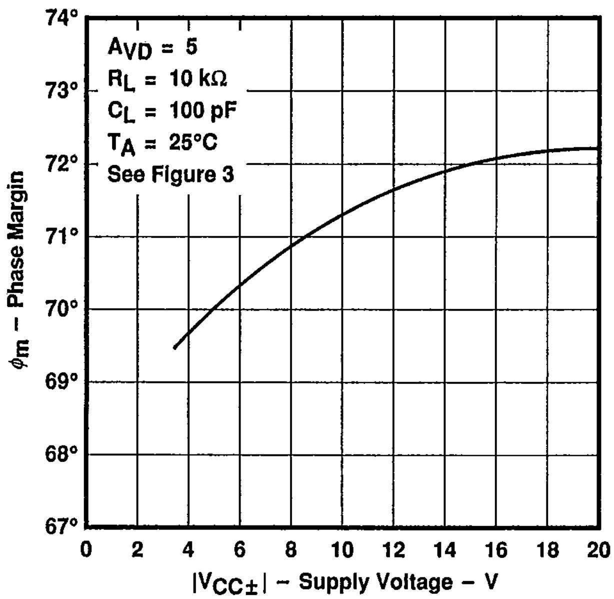

FIGURE 34

PHASE MARGIN
vs
FREE-AIR TEMPERATURE

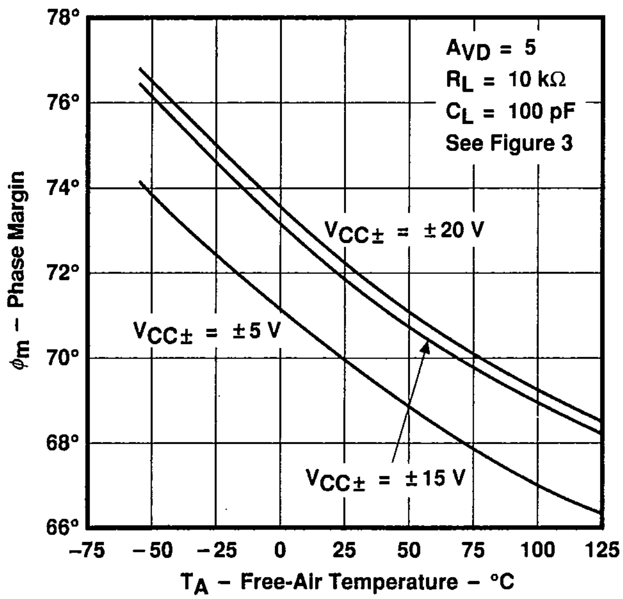

FIGURE 35

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

TYPICAL APPLICATION DATA

macromodel information

Macromodel information provided was derived using *PSpice*® *Parts*™ model generation software. The Boyle macromodel (see Note 5) and subcircuit in Figures 36 and 37 were generated using the TLE2161 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

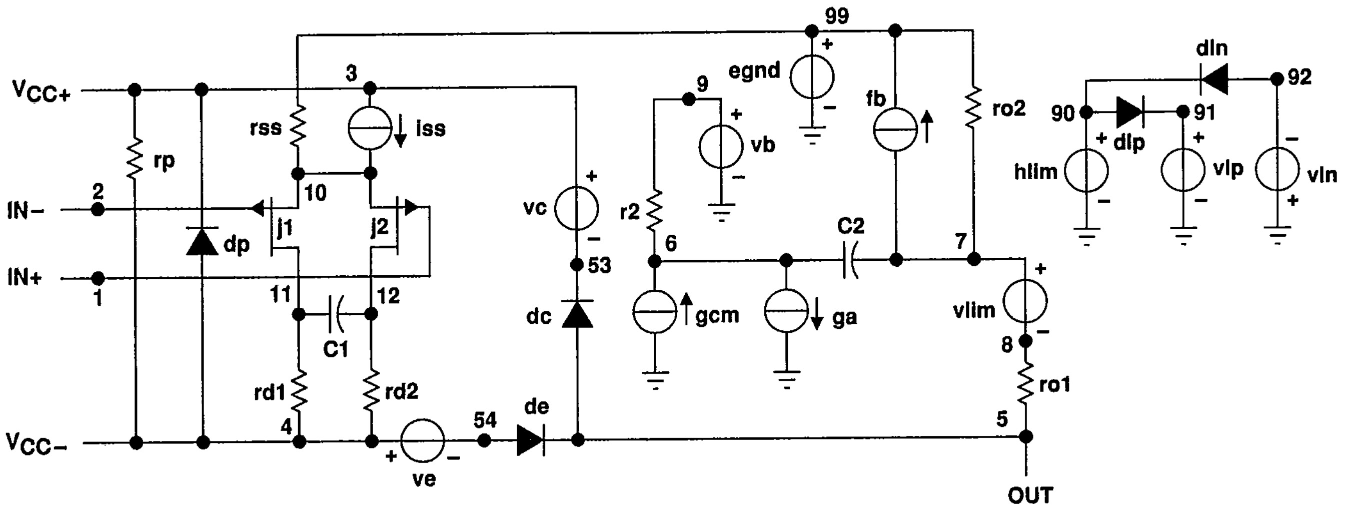

FIGURE 36. BOYLE MACROMODEL

NOTE 5: 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).

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TYPICAL APPLICATION DATA

macromodel information (continued)

```
.subckt TLE2161  1 2 3 4 5
  c1     11 12 125.4E-14
  c2      6  7 5.000E-12
  dc      5 53 dx
  de     54  5 dx
  dlp    90 91 dx
  dln    92 90 dx
  dp      4  3 dx
  egnd 99  0 poly(2) (3,0) (4,0) 0 .5 .5
  fb      7 99 poly(5) vb vc ve vlp vln 0 4.085E6 -4E6 4E6 4E6 -4E6
  ga      6  0 11 12 201.1E-6
  gcm     0  6 10 99 3.576E-9
  iss     3 10 dc 45.00E-6
  hlim 90  0 vlim 1K
  j1     11  2 10 jx
  j2     12  1 10 jx
  r2      6  9 100.0E3
  rd1     4 11 4.973E3
  rd2     4 12 4.973E3
  ro1     8  5 280
  ro2     7 99 280
  rp      3  4 113.2E3
  rss    10 99 4.444E6
  vb      9  0 dc 0
  vc      3 53 dc 2
  ve     54  4 dc 2
  vlim    7  8 dc 0
  vlp    91  0 dc 50
  vln     0 92 dc 50
.model dx D(Is=800.0E-18)
.model jx PJF(Is=1.000E-12 Beta=480E-6 Vto=-1)
.ends
```

FIGURE 37. MACROMODEL SUBCIRCUIT

TYPICAL APPLICATION DATA

input characteristics

The TLE2161, TLE2161A and TLE2161B are specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction.

Because of the extremely high input impedance and resulting low bias-current requirements, the TLE2161, TLE2161A, and TLE2161B are well-suited for low-level signal processing; however, leakage currents on printed circuit boards and sockets can easily exceed bias-current requirements and cause degradation in system performance. It is a good practice to include guard rings around inputs (see Figure 38). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input.

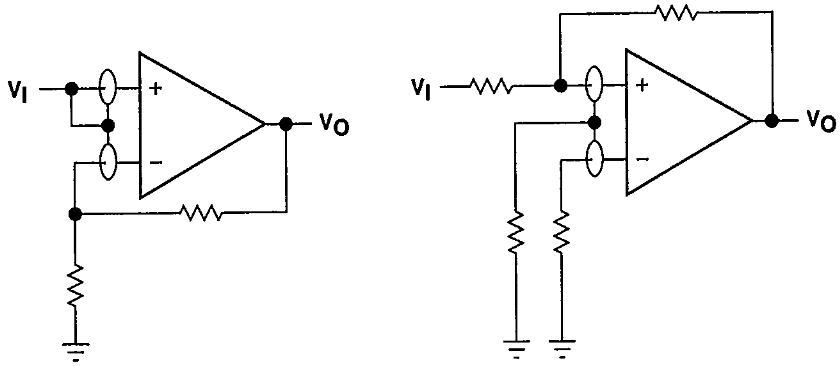

FIGURE 38. USE OF GUARD RINGS

input offset voltage nulling

The TLE2161 series offers external null pins that can be used to further reduce the input offset voltage. The circuit of Figure 39 can be connected as shown if the feature is desired. If external nulling is not needed, the null pins may be left disconnected.

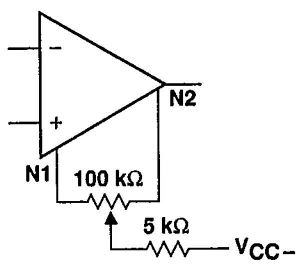

FIGURE 39. INPUT OFFSET VOLTAGE NULLING