

TL081, TL081A, TL081B, TL082, TL082A, TL082B TL082Y, TL084, TL084A, TL084B, TL084Y JFET-INPUT OPERATIONAL AMPLIFIERS

SLOS081C – FEBRUARY 1977 – REVISED SEPTEMBER 1996

24 DEVICES COVER COMMERCIAL, INDUSTRIAL, AND MILITARY TEMPERATURE RANGES

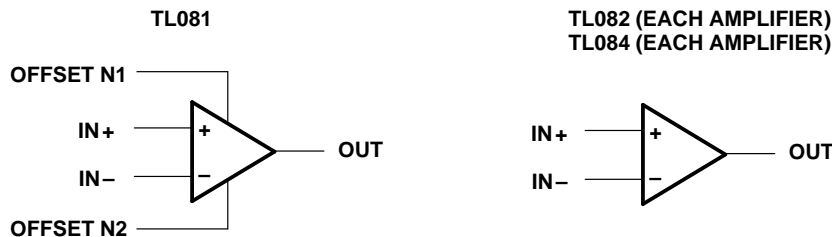
- Low Power Consumption
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- Low Total Harmonic Distortion . . . 0.003% Typ
- High Input Impedance . . . JFET-Input Stage
- Latch-Up-Free Operation
- High Slew Rate . . . 13 V/ μ s Typ
- Common-Mode Input Voltage Range Includes V_{CC+}

description

The TL08x JFET-input operational amplifier family is designed to offer a wider selection than any previously developed operational amplifier family. Each of these JFET-input operational amplifiers incorporates well-matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit. The devices feature high slew rates, low input bias and offset currents, and low offset voltage temperature coefficient. Offset adjustment and external compensation options are available within the TL08x family.

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 85°C. The M-suffix devices are characterized for operation over the full military temperature range of –55°C to 125°C.

symbols



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**

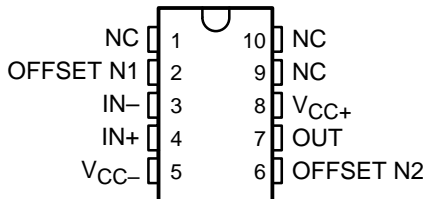
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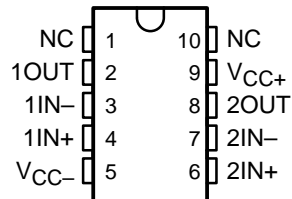
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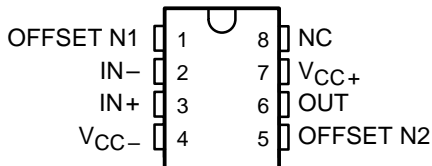
**TL081, TL081A, TL081B
U PACKAGE
(TOP VIEW)**



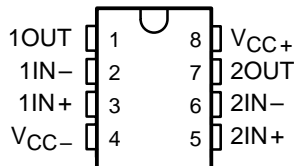
**TL082, TL082A, TL082B
U PACKAGE
(TOP VIEW)**



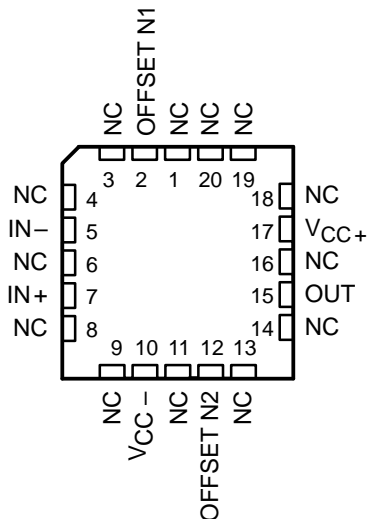
**TL081, TL081A, TL081B
D, JG, P, OR PW PACKAGE
(TOP VIEW)**



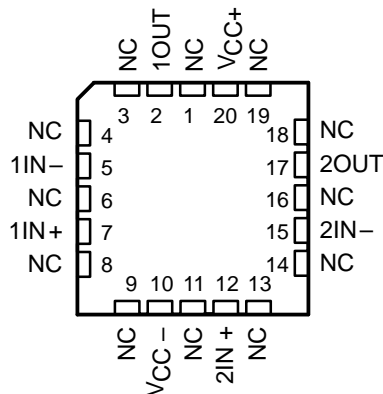
**TL082, TL082A, TL082B
D, JG, P, OR PW PACKAGE
(TOP VIEW)**



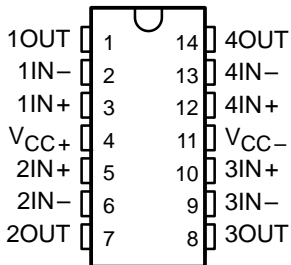
**TL081M . . . FK PACKAGE
(TOP VIEW)**



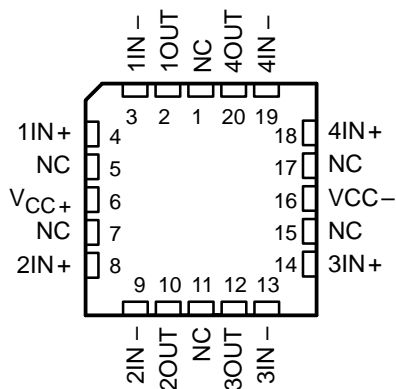
**TL082M . . . FK PACKAGE
(TOP VIEW)**



**TL084, TL084A, TL084B
D, J, N, PW, OR W PACKAGE
(TOP VIEW)**



**TL084M . . . FK PACKAGE
(TOP VIEW)**



NC – No internal connection

TL081, TL081A, TL081B, TL082, TL082A, TL082B
 TL082Y, TL084, TL084A, TL084B, TL084Y
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AVAILABLE OPTIONS

TA	V _{IO} max AT 25°C	PACKAGED DEVICES										CHIP FORM (Y)				
		SMALL OUTLINE (D008)	SMALL OUTLINE (D014)	CHIP CARRIER (FK)	CERAMIC DIP (J)	CERAMIC DIP (JG)	PLASTIC DIP (N)	PLASTIC DIP (P)	TSSOP (PW)	FLAT PACK (U)	FLAT PACK (W)					
0°C to 70°C	15 mV	TL081CD	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	6 mV	TL081ACD	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3 mV	TL081BCD	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15 mV	6 mV	TL082CD	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	6 mV	TL082ACD	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3 mV	TL082BCD	—	—	—	—	—	—	—	—	—	—	—	—	—	—
-40°C to 85°C	15 mV	—	TL084CD	—	—	—	—	—	—	—	—	—	—	—	—	—
	6 mV	—	TL084ACD	—	—	—	—	—	—	—	—	—	—	—	—	—
	3 mV	—	TL084BCD	—	—	—	—	—	—	—	—	—	—	—	—	—
-55°C to 125°C	6 mV	TL081ID	TL084ID	—	—	—	—	—	—	—	—	—	—	—	—	—
	6 mV	TL082ID	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	6 mV	TL084ID	—	—	—	—	—	—	—	—	—	—	—	—	—	—
-55°C to 125°C	6 mV	—	—	TL081MFK	TL084MJ	TL081MJG	—	—	—	—	—	—	—	—	—	—
	6 mV	—	—	TL082MFK	—	TL082MJG	—	—	—	—	—	—	—	—	—	—
	9 mV	—	—	TL084MFK	—	—	—	—	—	—	—	—	—	—	—	—
																TL084MW

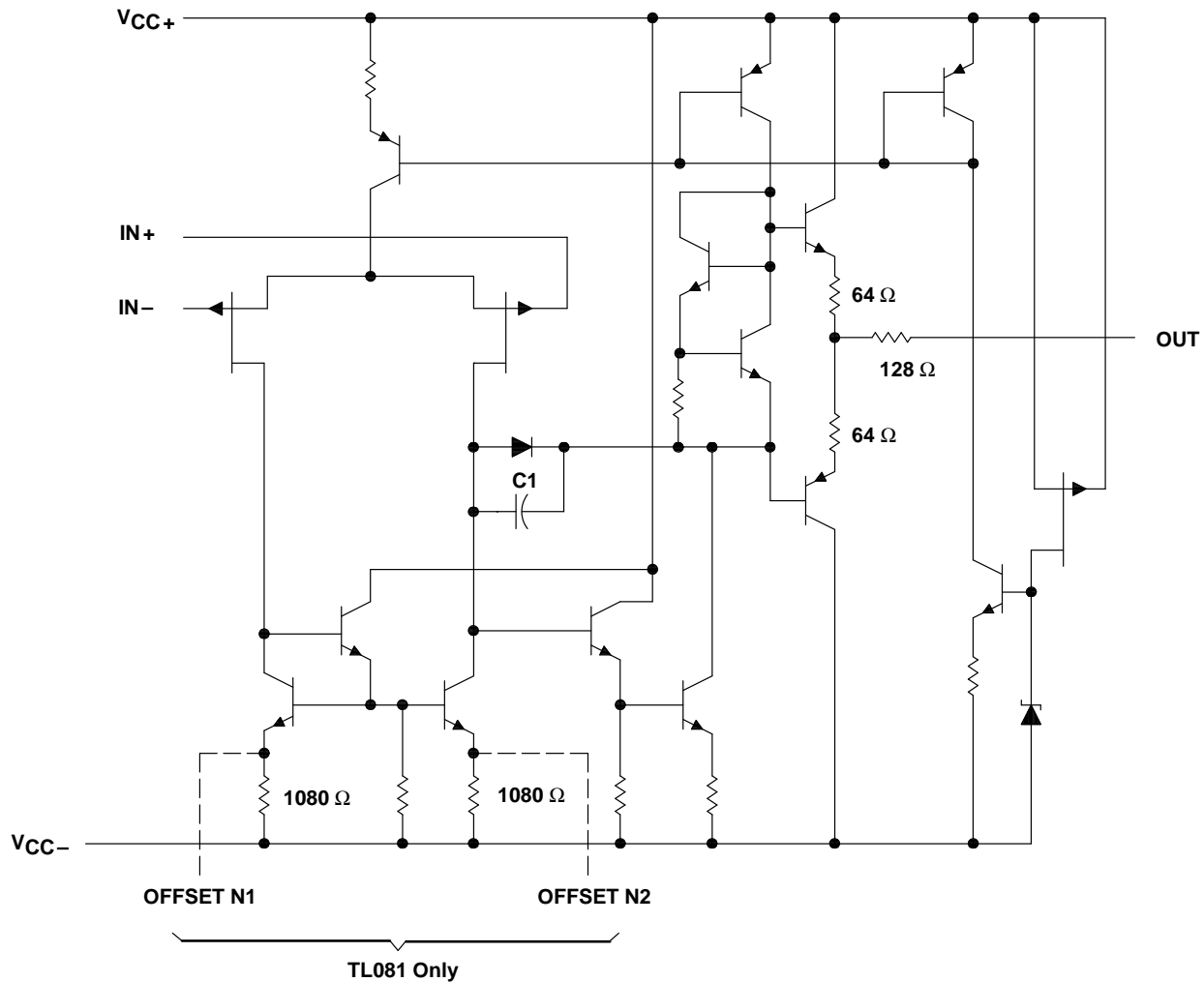
The D package is available taped and reeled. Add R suffix to the device type (e.g., TL081CDR).



**TL081, TL081A, TL081B, TL082, TL082A, TL082B
 TL082Y, TL084, TL084A, TL084B, TL084Y
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schematic (each amplifier)



Component values shown are nominal.

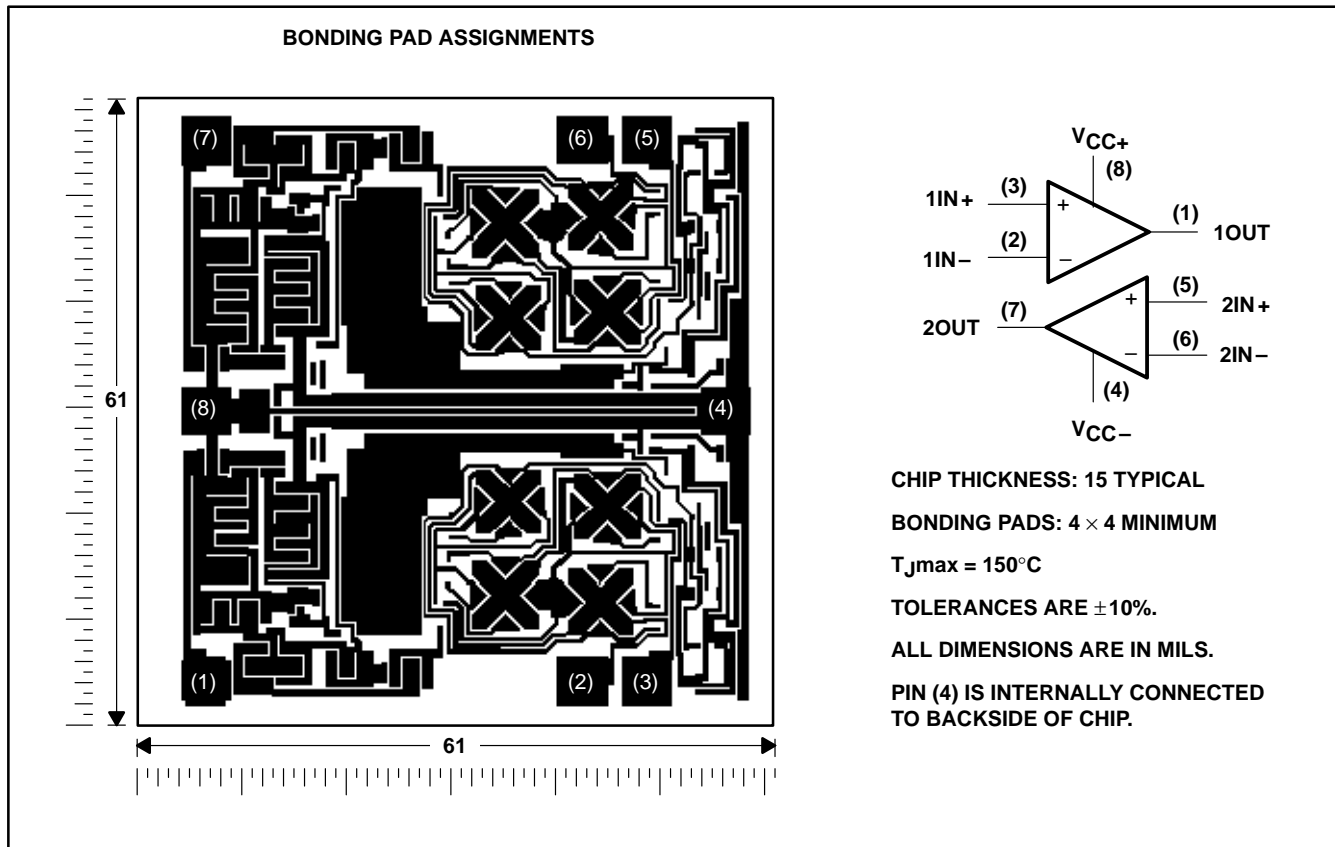


TL081, TL081A, TL081B, TL082, TL082A, TL082B
 TL082Y, TL084, TL084A, TL084B, TL084Y
JFET-INPUT OPERATIONAL AMPLIFIERS

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TL082Y chip information

These chips, when properly assembled, display characteristics similar to the TL082. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.

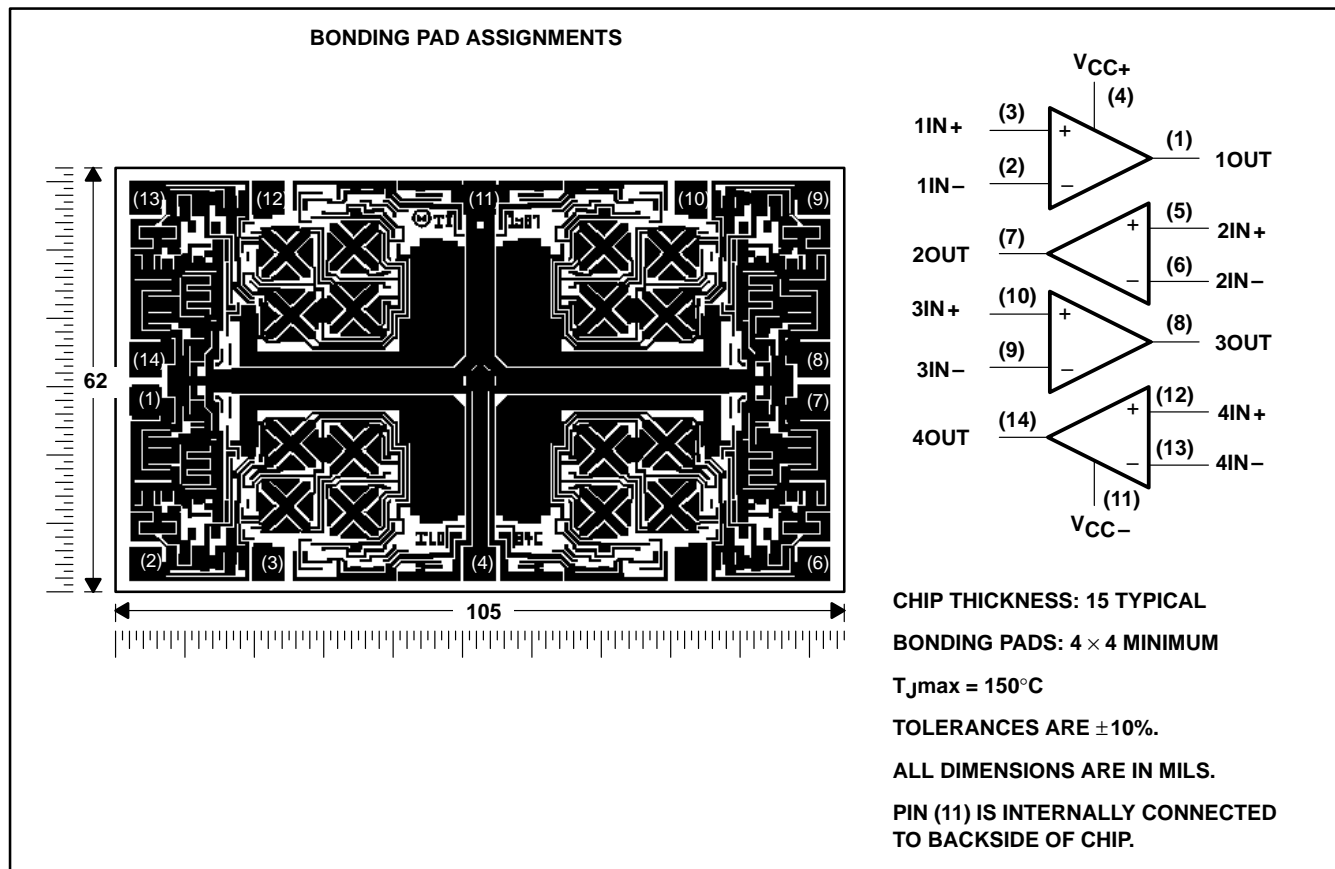


**TL081, TL081A, TL081B, TL082, TL082A, TL082B
TL082Y, TL084, TL084A, TL084B, TL084Y
JFET-INPUT OPERATIONAL AMPLIFIERS**

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TL084Y chip information

These chips, when properly assembled, display characteristics similar to the TL084. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



TL081, TL081A, TL081B, TL082, TL082A, TL082B TL082Y, TL084, TL084A, TL084B, TL084Y JFET-INPUT OPERATIONAL AMPLIFIERS

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

	TL08_C TL08_AC TL08_BC	TL08_I	TL08_M	UNIT
Supply voltage, V_{CC+} (see Note 1)	18	18	18	V
Supply voltage V_{CC-} (see Note 1)	-18	-18	-18	V
Differential input voltage, V_{ID} (see Note 2)	± 30	± 30	± 30	V
Input voltage, V_I (see Notes 1 and 3)	± 15	± 15	± 15	V
Duration of output short circuit (see Note 4)	unlimited	unlimited	unlimited	
Continuous total power dissipation	See Dissipation Rating Table			
Operating free-air temperature range, T_A	0 to 70	-40 to 85	-55 to 125	°C
Storage temperature range, T_{stg}	-65 to 150	-65 to 150	-65 to 150	°C
Case temperature for 60 seconds, T_C	FK package			260
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	J or JG package			300
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D, N, P, or PW package			260

† 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 $IN-$.
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
 4. The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A = 85^\circ\text{C}$ POWER RATING	$T_A = 125^\circ\text{C}$ POWER RATING
D (8 pin)	680 mW	5.8 mW/°C	32°C	460 mW	373 mW	N/A
D (14 pin)	680 mW	7.6 mW/°C	60°C	604 mW	490 mW	N/A
FK	680 mW	11.0 mW/°C	88°C	680 mW	680 mW	273 mW
J	680 mW	11.0 mW/°C	88°C	680 mW	680 mW	273 mW
JG	680 mW	8.4 mW/°C	69°C	672 mW	546 mW	210 mW
N	680 mW	9.2 mW/°C	76°C	680 mW	597 mW	N/A
P	680 mW	8.0 mW/°C	65°C	640 mW	520 mW	N/A
PW (8 pin)	525 mW	4.2 mW/°C	25°C	336 mW	N/A	N/A
PW (14 pin)	700 mW	5.6 mW/°C	25°C	448 mW	N/A	N/A
U	675 mW	5.4 mW/°C	25°C	432 mW	351 mW	135 mW
W	680 mW	8.0 mW/°C	65°C	640 mW	520 mW	200 mW



**TL081, TL081A, TL081B, TL082, TL082A, TL082B
TL082Y, TL084, TL084A, TL084B, TL084Y
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electrical characteristics, $V_{CC\pm} = \pm 15\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_A †	TL081C TL082C TL084C			TL081AC TL082AC TL084AC			TL081BC TL082BC TL084BC			TL081I TL082I TL084I			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	$V_O = 0, R_S = 50\ \Omega$	25°C	3	15	6	3	6	3	6	2	3	3	6	mV	
α_{VIO}	$V_O = 0, R_S = 50\ \Omega$	Full range		20	7.5				5				9		
I_{IO}	$V_O = 0$	Full range	18			18			18			18		$\mu\text{V}/^\circ\text{C}$	
I_{IB}	$V_O = 0$	25°C	5	200	100	5	100	100	5	100	100	5	100	pA	
		Full range		2	2				2				10	nA	
V_{ICR}	Common-mode input voltage range	25°C	±11	-12 to 15		±11	-12 to 15		±11	-12 to 15		±11	-12 to 15	V	
		Full range	±12	±13.5		±12	±13.5		±12	±13.5		±12	±13.5	V	
V_{OM}	Maximum peak output voltage swing	25°C	±12	±13.5		±12	±13.5		±12	±13.5		±12	±13.5	V	
		Full range	±10	±12		±10	±12		±10	±12		±10	±12	V	
		Full range	±10	±12		±10	±12		±10	±12		±10	±12	V	
A_{VD}	Large-signal differential voltage amplification	25°C	25	200		25	200		25	200		25	200	V/mV	
		Full range	15			25			25			25		V/mV	
B_1	Unity-gain bandwidth	25°C	3			3			3			3	MHz		
r_i	Input resistance	25°C	10 ¹²			10 ¹²			10 ¹²			10 ¹²	Ω		
CMRR	Common-mode rejection ratio	25°C	70	86		75	86		75	86		75	86	dB	
kSVR	Supply voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	25°C	70	86		80	86		80	86		80	86	dB	
ICC	Supply current (per amplifier)	25°C	1.4	2.8		1.4	2.8		1.4	2.8		1.4	2.8	mA	
V_{O1}/V_{O2}	Crosstalk attenuation	25°C	120			120			120			120		dB	

† All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified. Full range for T_A is 0°C to 70°C for TL08_C, TL08_AC, TL08_BC and -40°C to 85°C for TL08_I.

‡ Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 17. Pulse techniques must be used that maintain the junction temperature as close to the ambient temperature as possible.



**TL081, TL081A, TL081B, TL082, TL082A, TL082B
TL082Y, TL084, TL084A, TL084B, TL084Y
JFET-INPUT OPERATIONAL AMPLIFIERS**

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electrical characteristics, $V_{CC} \pm = \pm 15$ V (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	T_A	TL081M, TL082M			TL084M			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_O = 0, R_S = 50 \Omega$	25°C		3	6		3	9	mV
		-55°C to 125°C			9			15	
α_{VIO} Temperature coefficient of input offset voltage	$V_O = 0, R_S = 50 \Omega$	-55°C to 125°C		18			18		$\mu V/^\circ C$
I_{IO} Input offset current‡	$V_O = 0$	25°C		5	100		5	100	pA
		125°C			20			20	nA
I_{IB} Input bias current‡	$V_O = 0$	25°C		30	200		30	200	pA
		125°C			50			50	nA
V_{ICR} Common-mode input voltage range		25°C	± 11	± 12 to 15		± 11	± 12 to 15		V
V_{OM} Maximum peak output voltage swing	$R_L = 10 k\Omega$	25°C	± 12	± 13.5		± 12	± 13.5		V
	$R_L \geq 10 k\Omega$	-55°C to 125°C	± 12			± 12			
	$R_L \geq 2 k\Omega$		± 10	± 12		± 10	± 12		
A_{VD} Large-signal differential voltage amplification	$V_O = \pm 10$ V, $R_L \geq 2 k\Omega$	25°C	25	200		25	200		V/mV
	$V_O = \pm 10$ V, $R_L \geq 2 k\Omega$	-55°C to 125°C	15			15			
B_1 Unity-gain bandwidth		25°C		3			3		MHz
r_i Input resistance		25°C		10^{12}			10^{12}		Ω
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICRmin}, V_O = 0, R_S = 50 \Omega$	25°C	80	86		80	86		dB
k_{SVR} Supply voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_{CC} = \pm 15$ V to ± 9 V, $V_O = 0, R_S = 50 \Omega$	25°C	80	86		80	86		dB
I_{CC} Supply current (per amplifier)	$V_O = 0, \text{ No load}$	25°C		1.4	2.8		1.4	2.8	mA
V_{O1}/V_{O2} Crosstalk attenuation	$A_{VD} = 100$	25°C		120			120		dB

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified.

‡ Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 17. Pulse techniques must be used that maintain the junction temperatures as close to the ambient temperature as is possible.

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR Slew rate at unity gain	$V_I = 10$ V, $R_L = 2 k\Omega, C_L = 100$ pF, See Figure 1	8*	13		V/ μs
	$V_I = 10$ V, $R_L = 2 k\Omega, C_L = 100$ pF, $T_A = -55^\circ C$ to $125^\circ C$, See Figure 1	5*			
t_r Rise time	$V_I = 20$ mV, $R_L = 2 k\Omega, C_L = 100$ pF, See Figure 1		0.05		μs
Overshoot factor			20%		
V_n Equivalent input noise voltage	$R_S = 20 \Omega$	$f = 1$ kHz	18		nV/\sqrt{Hz}
		$f = 10$ Hz to 10 kHz	4		μV
I_n Equivalent input noise current	$R_S = 20 \Omega, f = 1$ kHz		0.01		pA/\sqrt{Hz}
THD Total harmonic distortion	$V_{O(rms)} = 10$ V, $R_S \leq 1 k\Omega, R_L \geq 2 k\Omega, f = 1$ kHz		0.003%		

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



**TL081, TL081A, TL081B, TL082, TL082A, TL082B
TL082Y, TL084, TL084A, TL084B, TL084Y
JFET-INPUT OPERATIONAL AMPLIFIERS**

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

PARAMETER	TEST CONDITIONST	TL082Y, TL084Y			UNIT
		MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_O = 0$, $R_S = 50\ \Omega$,		3	15	mV
αV_{IO} Temperature coefficient of input offset voltage	$V_O = 0$, $R_S = 50\ \Omega$,		18		$\mu\text{V}/^\circ\text{C}$
I_{IO} Input offset current†	$V_O = 0$,		5	200	pA
I_{IB} Input bias current‡	$V_O = 0$,		30	400	pA
V_{ICR} Common-mode input voltage range		± 11	-12 to 15		V
V_{OM} Maximum peak output voltage swing	$R_L = 10\ \text{k}\Omega$,	± 12	± 13.5		V
A_{VD} Large-signal differential voltage amplification	$V_O = \pm 10\ \text{V}$, $R_L \geq 2\ \text{k}\Omega$	25	200		V/mV
B_1 Unity-gain bandwidth			3		MHz
r_i Input resistance			10^{12}		Ω
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICRmin}$, $V_O = 0$, $R_S = 50\ \Omega$	70	86		dB
k_{SVR} Supply voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$)	$V_{CC} = \pm 15\ \text{V}$ to $\pm 9\ \text{V}$, $V_O = 0$, $R_S = 50\ \Omega$	70	86		dB
I_{CC} Supply current (per amplifier)	$V_O = 0$, No load		1.4	2.8	mA
V_{O1}/V_{O2} Crosstalk attenuation	$A_{VD} = 100$		120		dB

† All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified.

‡ Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 17. Pulse techniques must be used that maintain the junction temperature as close to the ambient temperature as possible.

operating characteristics, $V_{CC\pm} = \pm 15\ \text{V}$, $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR Slew rate at unity gain	$V_I = 10\ \text{V}$, $R_L = 2\ \text{k}\Omega$, $C_L = 100\ \text{pF}$, See Figure 1	8	13		V/ μs
t_r Rise time	$V_I = 20\ \text{mV}$, $R_L = 2\ \text{k}\Omega$, $C_L = 100\ \text{pF}$, See Figure 1		0.05		μs
Overshoot factor			20%		
V_n Equivalent input noise voltage	$R_S = 20\ \Omega$	$f = 1\ \text{kHz}$	18		$\text{nV}/\sqrt{\text{Hz}}$
		$f = 10\ \text{Hz}$ to $10\ \text{kHz}$	4		μV
I_n Equivalent input noise current	$R_S = 20\ \Omega$, $f = 1\ \text{kHz}$		0.01		$\text{pA}/\sqrt{\text{Hz}}$
THD Total harmonic distortion	$V_{O(rms)} = 10\ \text{V}$, $R_S \leq 1\ \text{k}\Omega$, $R_L \geq 2\ \text{k}\Omega$, $f = 1\ \text{kHz}$		0.003%		



PARAMETER MEASUREMENT INFORMATION

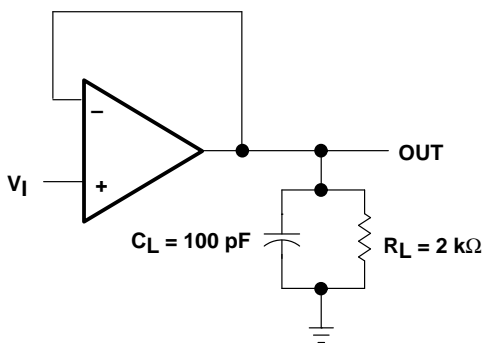


Figure 1

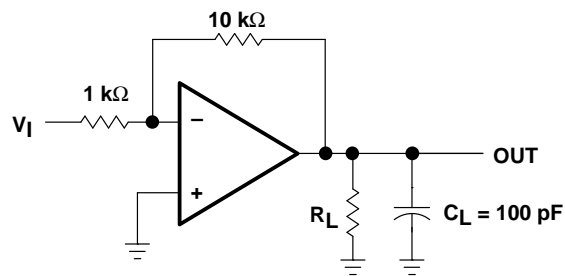


Figure 2

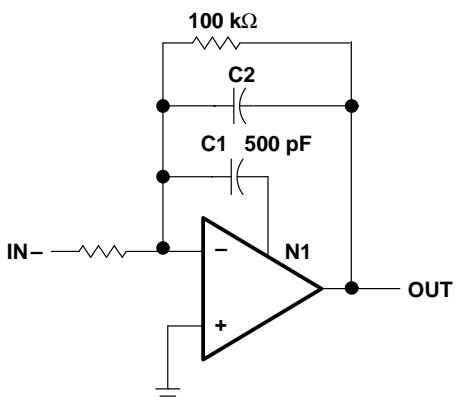


Figure 3

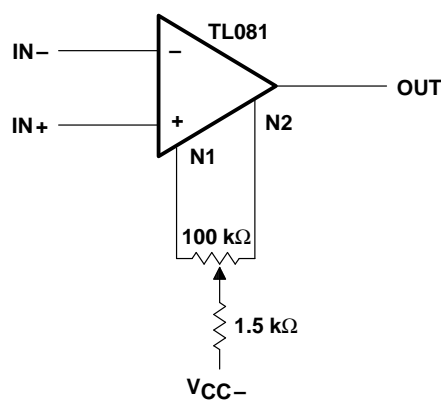


Figure 4

**TL081, TL081A, TL081B, TL082, TL082A, TL082B
TL082Y, TL084, TL084A, TL084B, TL084Y
JFET-INPUT OPERATIONAL AMPLIFIERS**

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TYPICAL CHARACTERISTICS

Table of Graphs

		FIGURE
V _{OM}	Maximum peak output voltage	vs Frequency
		vs Free-air temperature
		vs Load resistance
		vs Supply voltage
A _{VD}	Large-signal differential voltage amplification	5, 6, 7
	Differential voltage amplification	8, 9, 10
P _D	Total power dissipation	11, 12
I _{CC}	Supply current	13
I _{IB}	Input bias current	14
	Large-signal pulse response	15
V _O	Output voltage	16
CMRR	Common-mode rejection ratio	17
V _n	Equivalent input noise voltage	18
THD	Total harmonic distortion	19, 20, 21, 22

**MAXIMUM PEAK OUTPUT VOLTAGE
vs
FREQUENCY**

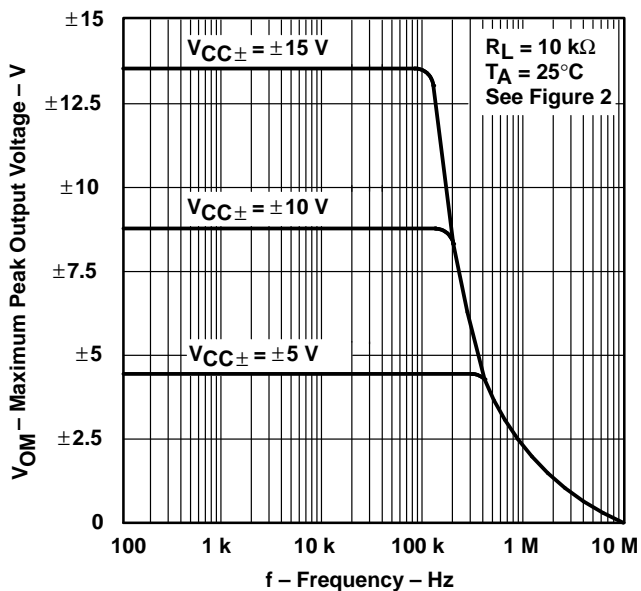


Figure 5

**MAXIMUM PEAK OUTPUT VOLTAGE
vs
FREQUENCY**

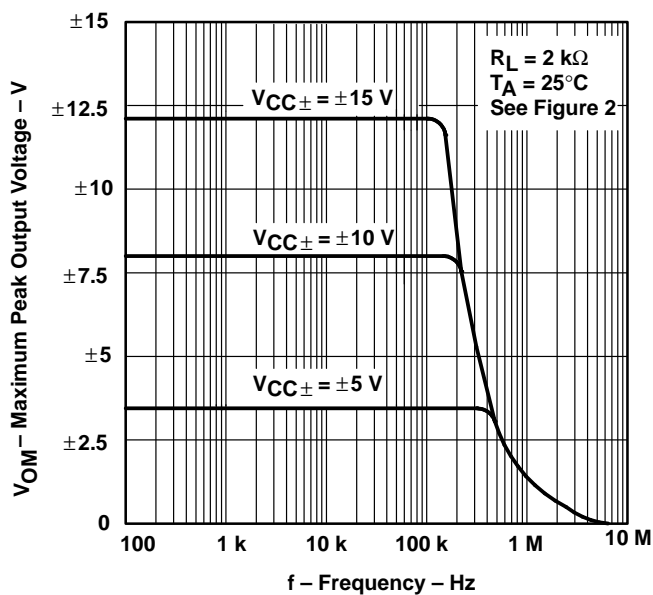


Figure 6

TYPICAL CHARACTERISTICS†

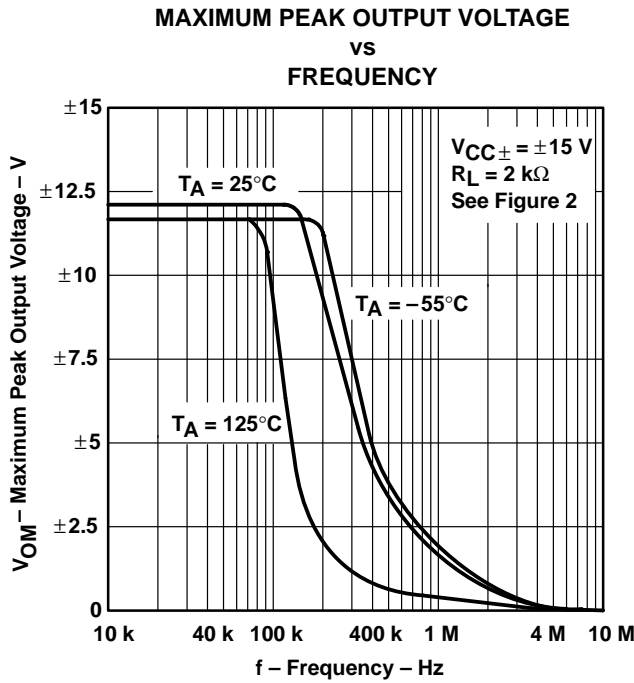


Figure 7

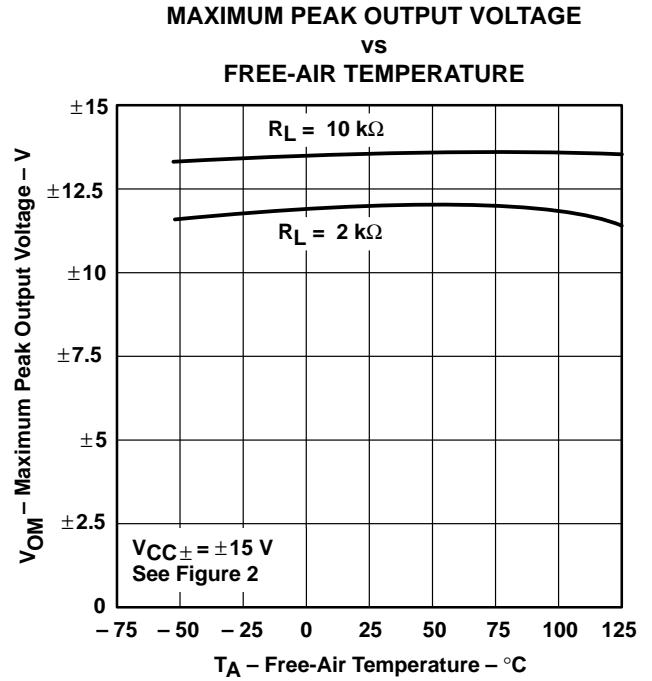


Figure 8

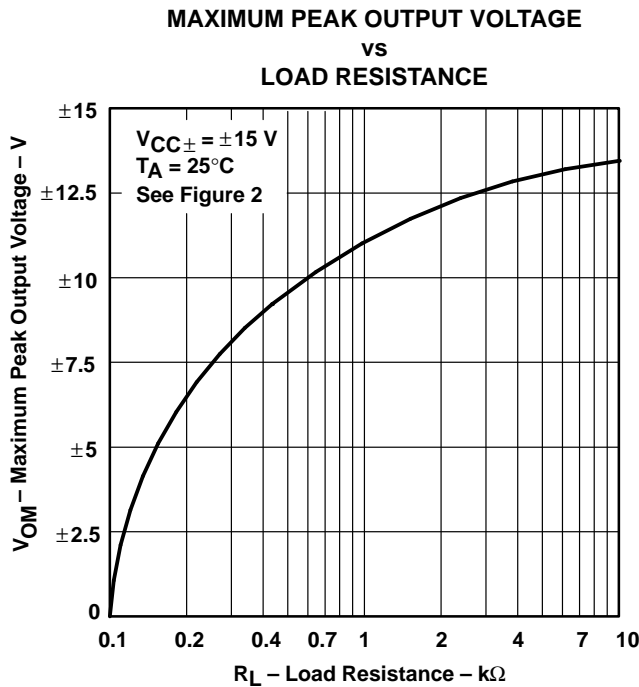


Figure 9

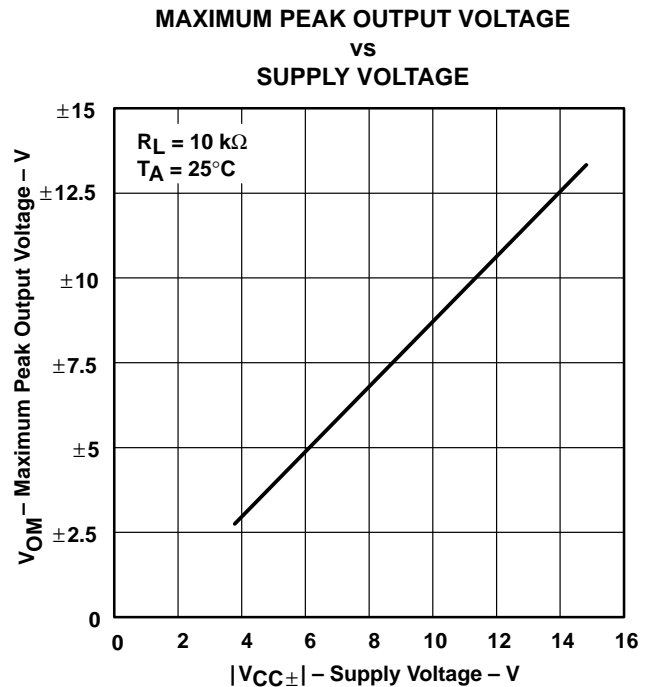


Figure 10

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

**TL081, TL081A, TL081B, TL082, TL082A, TL082B
 TL082Y, TL084, TL084A, TL084B, TL084Y
 JFET-INPUT OPERATIONAL AMPLIFIERS**

SLOS081C – FEBRUARY 1977 – REVISED SEPTEMBER 1996

TYPICAL CHARACTERISTICS†

**LARGE-SIGNAL
 DIFFERENTIAL VOLTAGE AMPLIFICATION
 vs
 FREE-AIR TEMPERATURE**

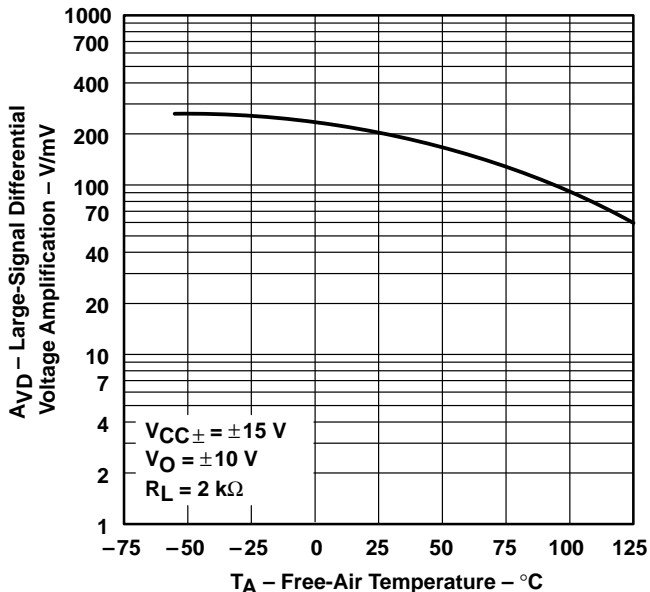


Figure 11

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

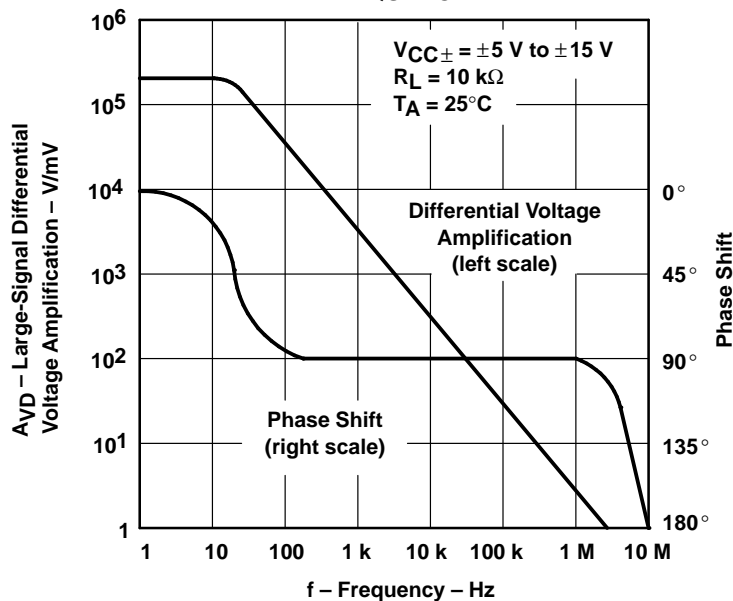


Figure 12

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



TYPICAL CHARACTERISTICS†

DIFFERENTIAL VOLTAGE AMPLIFICATION
 vs
 FREQUENCY WITH FEED-FORWARD COMPENSATION

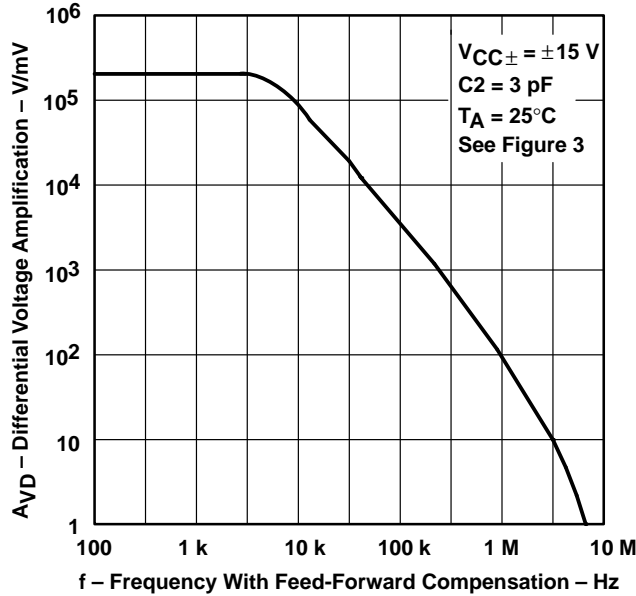


Figure 13

TOTAL POWER DISSIPATION
 vs
 FREE-AIR TEMPERATURE

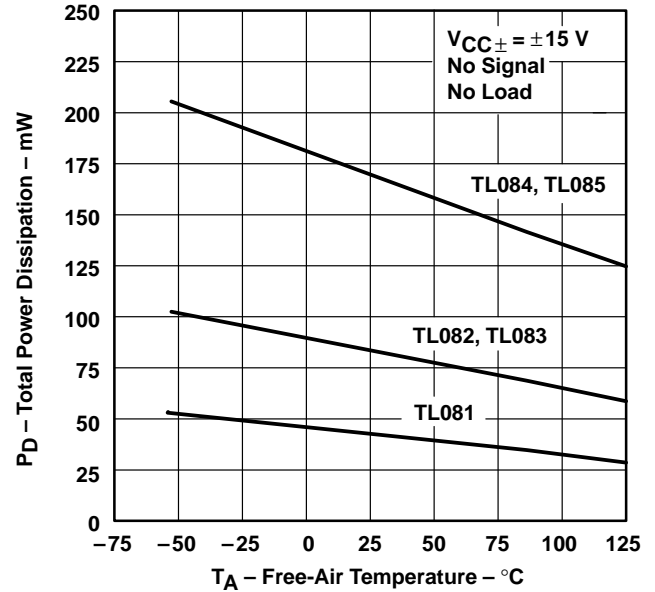


Figure 14

SUPPLY CURRENT PER AMPLIFIER
 vs
 FREE-AIR TEMPERATURE

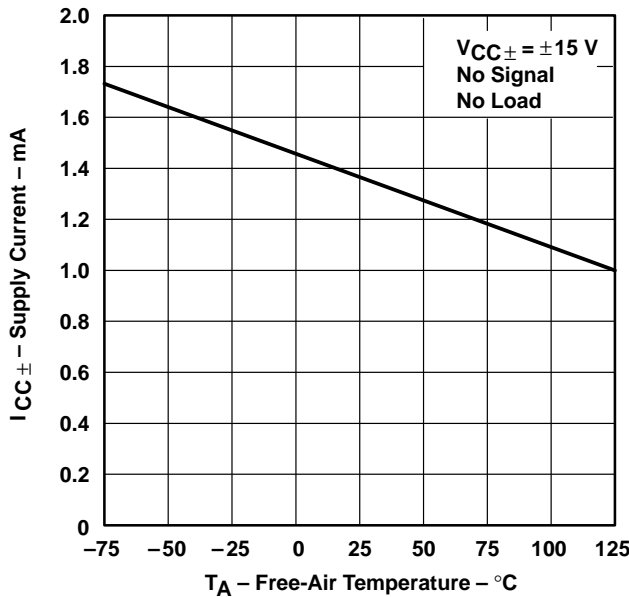


Figure 15

SUPPLY CURRENT
 vs
 SUPPLY VOLTAGE

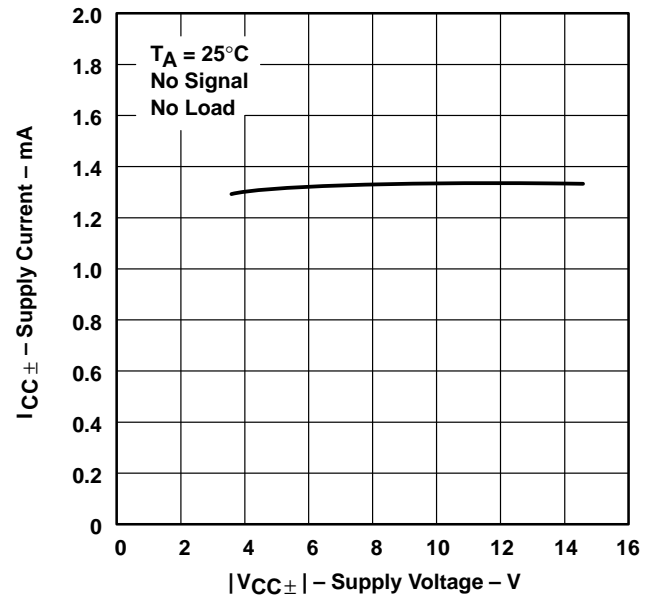


Figure 16

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

TYPICAL CHARACTERISTICS†

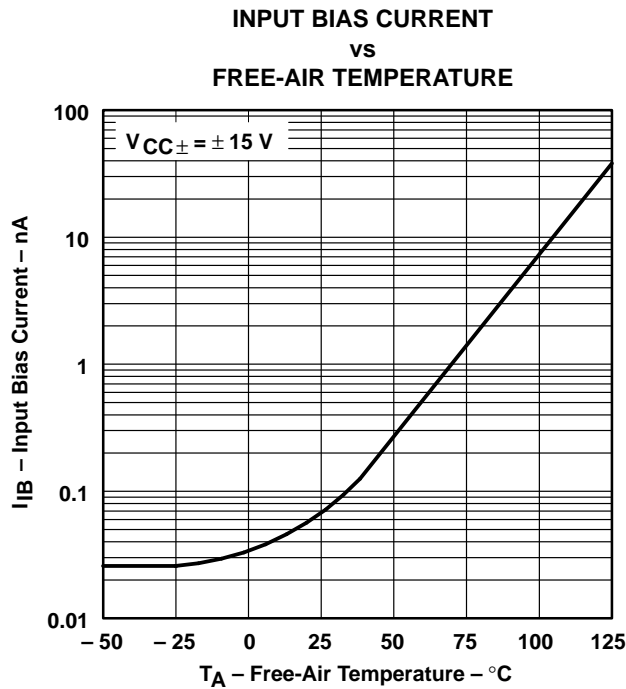


Figure 17

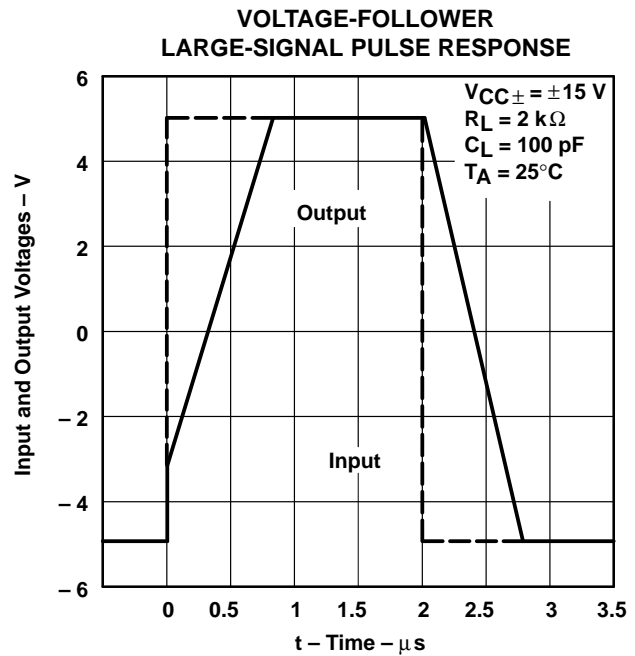


Figure 18

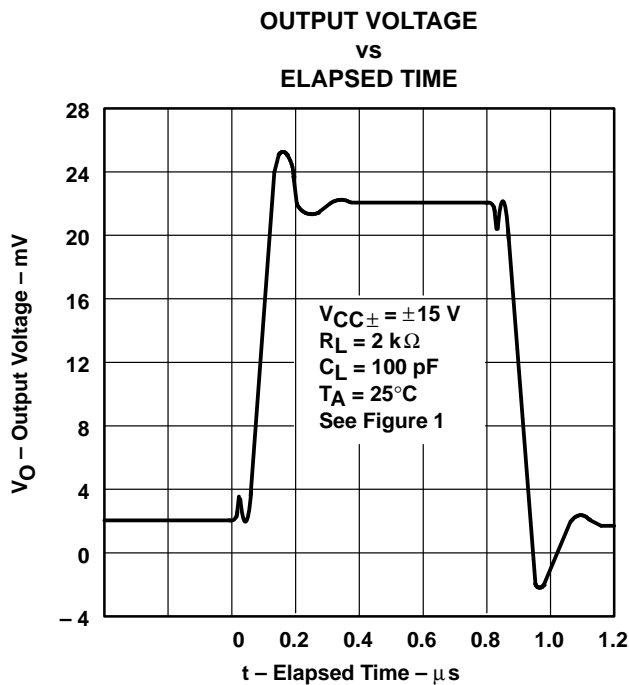


Figure 19

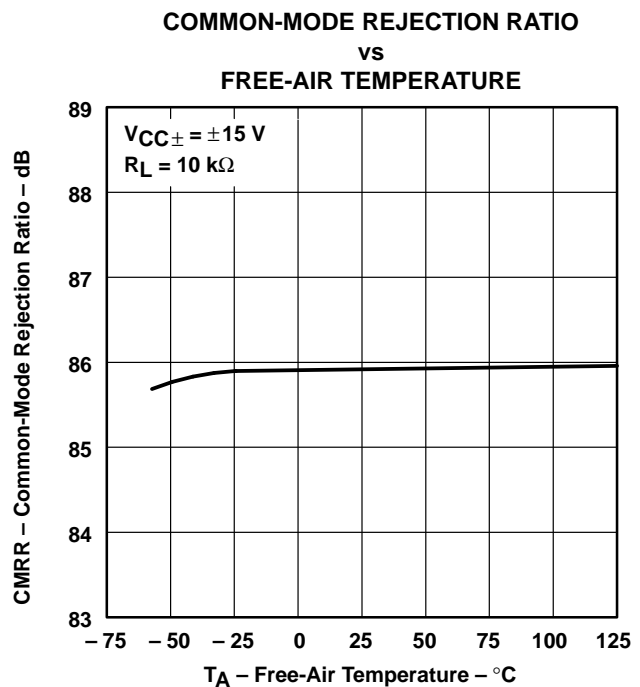


Figure 20

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

TYPICAL CHARACTERISTICS†

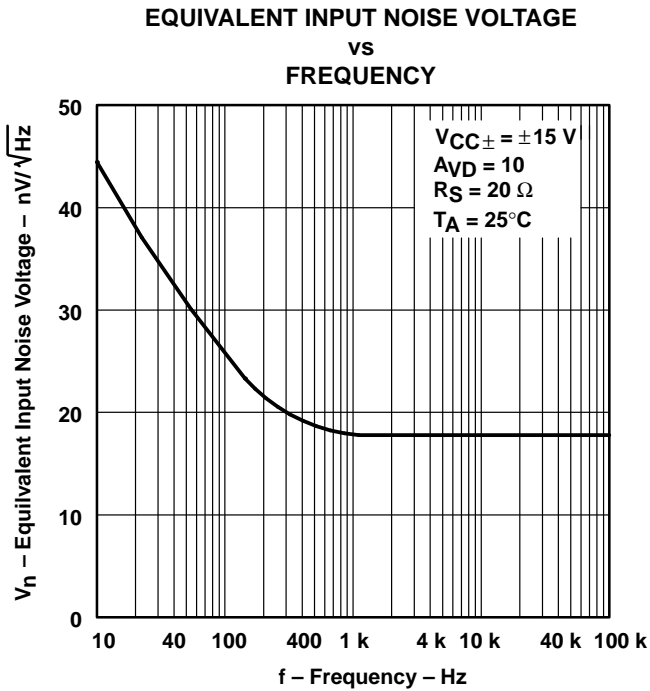


Figure 21

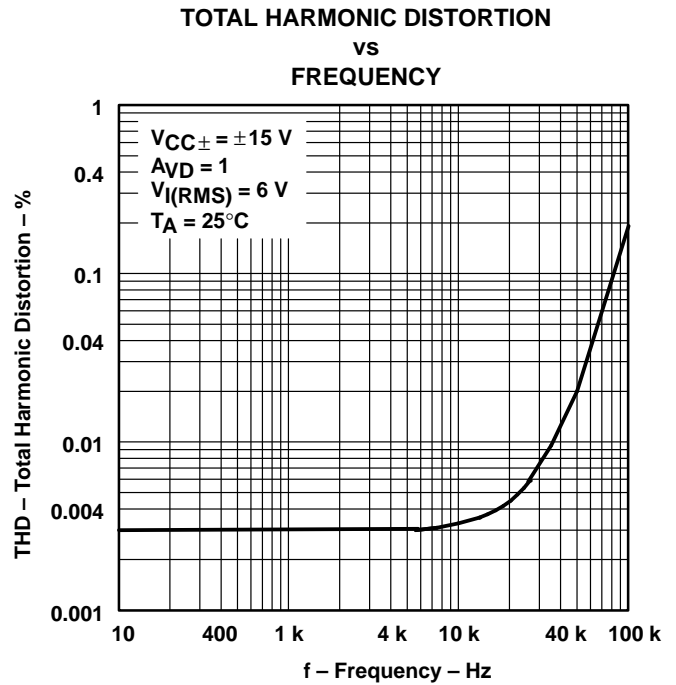


Figure 22

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

APPLICATION INFORMATION

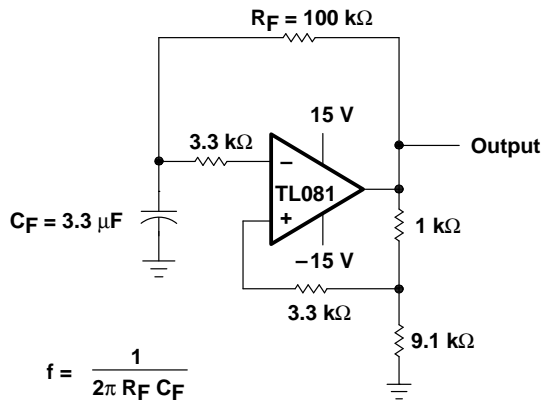


Figure 23

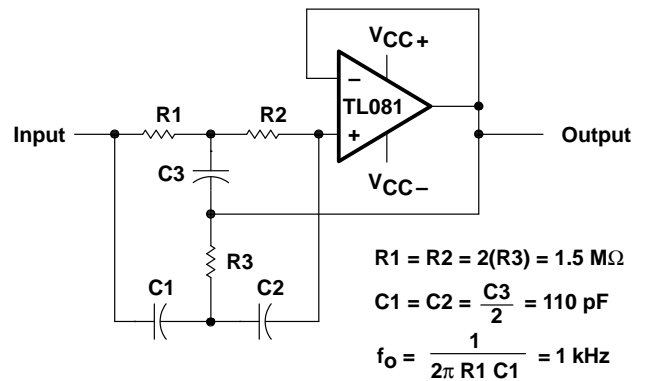


Figure 24

APPLICATION INFORMATION

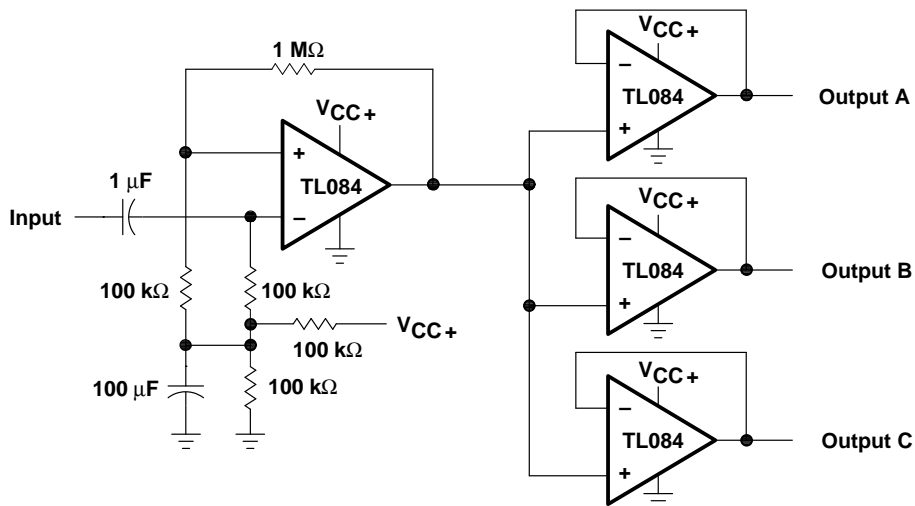
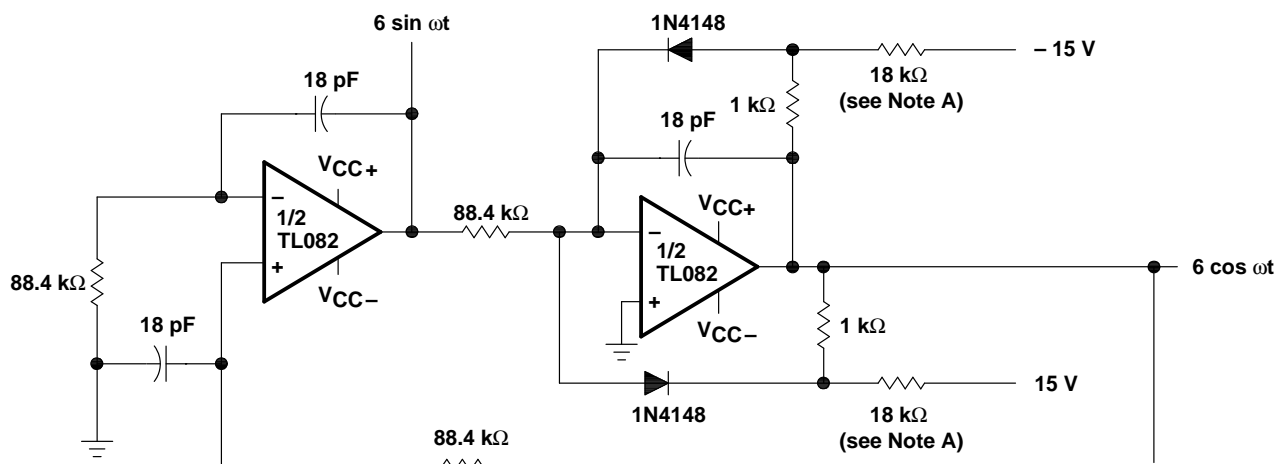


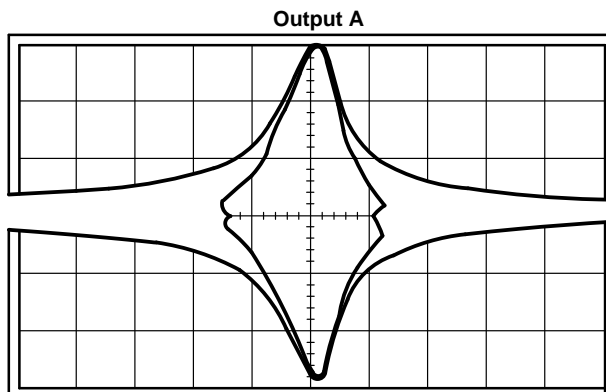
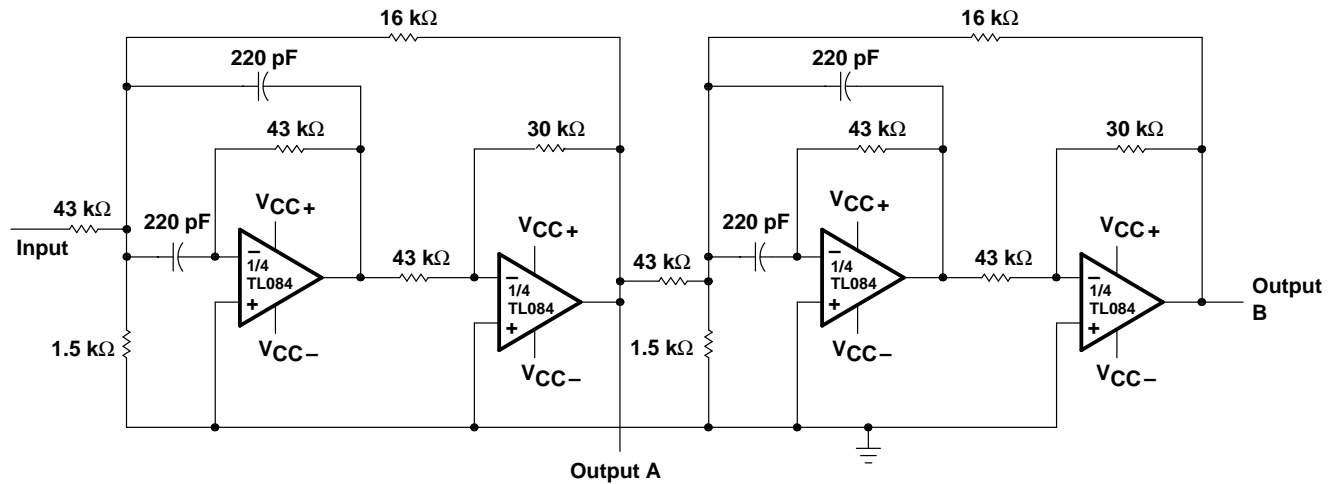
Figure 25. Audio-Distribution Amplifier



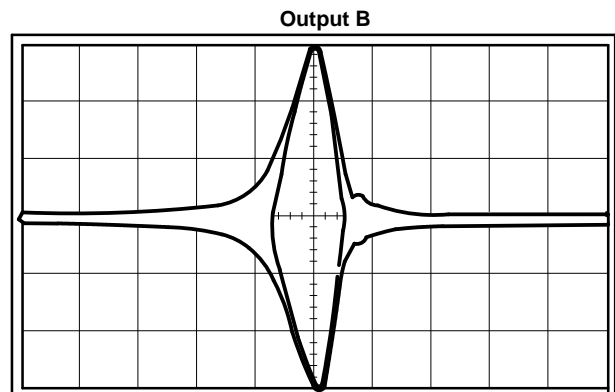
NOTE A: These resistor values may be adjusted for a symmetrical output.

Figure 26. 100-KHz Quadrature Oscillator

APPLICATION INFORMATION



2 kHz/div
 Second-Order Bandpass Filter
 $f_0 = 100 \text{ kHz}$, $Q = 30$, GAIN = 4



2 kHz/div
 Cascaded Bandpass Filter
 $f_0 = 100 \text{ kHz}$, $Q = 69$, GAIN = 16

Figure 27. Positive-Feedback Bandpass Filter

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