

TL060, TL060A, TL060B, TL061, TL061A, TL061B
TL062, TL062A, TL062B, TL064, TL064A, TL064B
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS
 D2392, NOVEMBER 1978—REVISED NOVEMBER 1988

**20 DEVICES COVER MILITARY, INDUSTRIAL, AND
 COMMERCIAL TEMPERATURE RANGES**

- Very Low Power Consumption
- Typical Supply Current . . . 200 μ A (per Amplifier)
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Common-Mode Input Voltage Range Includes V_{CC+}
- Output Short-Circuit Protection
- High Input Impedance . . . JFET-Input Stage
- Internal Frequency Compensation (Except TL060)
- Latch-Up-Free Operation
- High Slew Rate . . . 3.5 V/ μ s Typ

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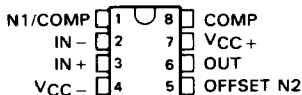
description

The JFET-input operational amplifiers of the TL061 series are designed as low-power versions of the TL081 series amplifiers. They feature high input impedance, wide bandwidth, high slew rate, and low input offset and bias currents. The TL061 series features the same terminal assignments as the TL071 and TL081 series. Each of these JFET-input operational amplifiers incorporates well-matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit.

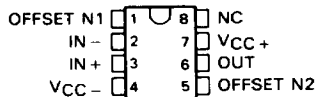
M-suffix devices are characterized for operation over the full military temperature range of -55°C to 125°C . I-suffix devices are characterized for operation from -40°C to 85°C , and C-suffix devices are characterized for operation from 0°C to 70°C .

Operational Amplifiers

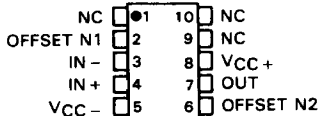
TL060, TL060A, TL060B
D, JG, OR P PACKAGE
 (TOP VIEW)



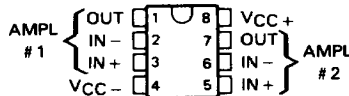
TL061, TL061A, TL061B
D, JG, OR P PACKAGE
 (TOP VIEW)



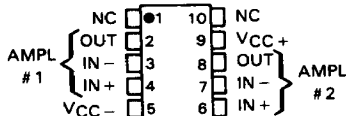
TL061 . . . U PACKAGE
 (TOP VIEW)



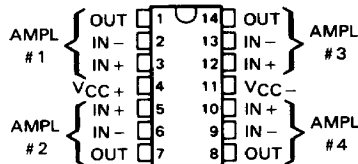
TL062, TL062A, TL062B
D, JG, OR P PACKAGE
 (TOP VIEW)



TL062 . . . U PACKAGE
 (TOP VIEW)



TL064 . . . D, J, N, OR W PACKAGE
TL064A, TL064B . . . D, J, OR N PACKAGE
 (TOP VIEW)



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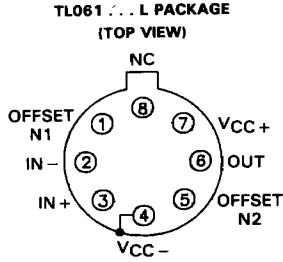
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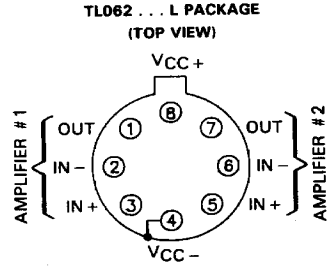
**TL060, TL060A, TL060B, TL061, TL061A, TL061B
TL062, TL062A, TL064, TL064A, TL064B
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

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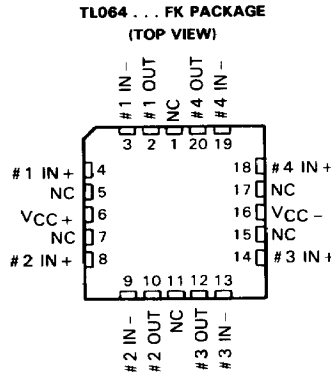
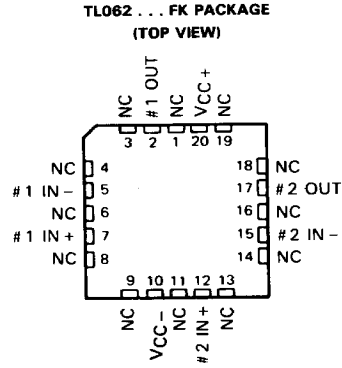
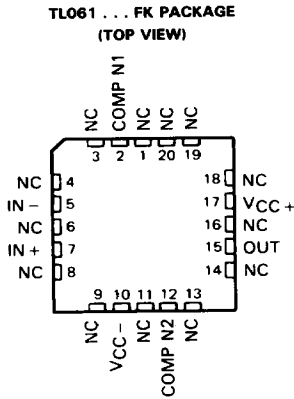
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PIN 4 IS IN ELECTRICAL CONTACT WITH THE CASE



PIN 4 IS IN ELECTRICAL CONTACT WITH THE CASE



NC—No internal connection

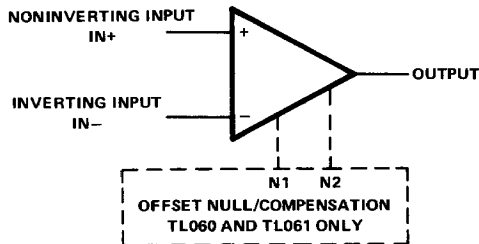
**TL060, TL060A, TL060B, TL061, TL061A, TL061B
TL062, TL062A, TL062B, TL064, TL064A, TL064B
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

AVAILABLE OPTIONS

T _A	V _{IO} MAX at 25°C	PACKAGE								
		SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	CERAMIC DIP (JG)	PLUG- IN (L)	PLASTIC DIP (N)	PLASTIC DIP (P)	FLAT PACK (U)	FLAT PACK (W)
0°C to 70°C	15 mV	TL060CD			TL060CJG			TL060CP		
	6 mV	TL060ACD			TL060ACJG			TL060ACP		
	3 mV	TL060BCD			TL060BCJG			TL060BCP		
	15 mV	TL061CD			TL061CJG			TL061CP		
	6 mV	TL061ACD			TL061ACJG			TL061ACP		
	3 mV	TL061BCD			TL061BCJG			TL061BCP		
	15 mV	TL062CD			TL062CJG			TL062CP		
	6 mV	TL062ACD			TL062ACJG			TL062ACP		
	3 mV	TL062BCD			TL062BCJG			TL062BCP		
	15 mV	TL064CD		TL064CJ			TL064CN			
	6 mV	TL064ACD		TL064ACJ			TL064ACN			
	3 mV	TL064BCD		TL064BCJ			TL064BCN			
-40°C to 85°C	6 mV	TL060ID			TL060IJG			TL060IP		
	6 mV	TL061ID			TL061IJG			TL061IP		
	6 mV	TL062ID			TL062IJG			TL062IP		
	6 mV	TL064ID		TL064IJ			TL064IN			
-55°C to 125°C	6 mV		TL061MFK		TL061MJG	TL061ML			TL061MU	
	6 mV		TL062MFK		TL062MJG	TL062ML			TL062MU	
	9 mV		TL064MFK	TL064MJ						TL064MW

The D package is available taped and reeled. Add the suffix R to the device type (e.g., TL061CDR).

symbol (each amplifier)



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**TEXAS
INSTRUMENTS**

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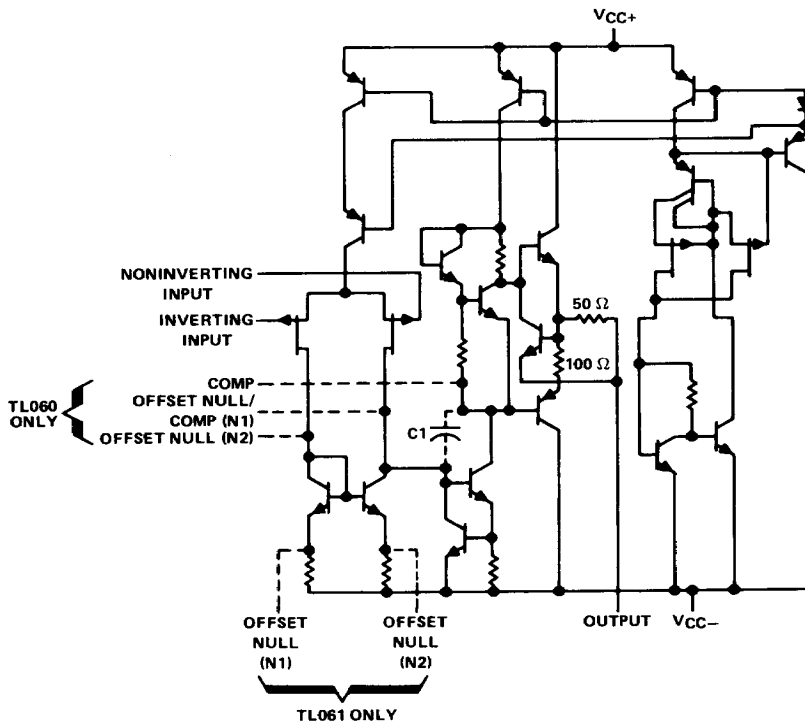
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**TL060, TL060A, TL060B, TL061, TL061A, TL061B
 TL062, TL062A, TL064, TL064A, TL064B
 LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

schematic (each amplifier)

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Operational Amplifiers



C1 = 10 pF ON TL061, TL062, AND TL064 ONLY
 COMPONENT VALUES SHOWN ARE NOMINAL

**TL060, TL060A, TL060B, TL061, TL061A, TL061B
TL062, TL062A, TL062B, TL064, TL064A, TL064B
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

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

	TL06_M	TL06_I	TL06_C, TL06_AC, TL06_BC	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 (see Note 2)	± 30	± 30	± 30	V
Input voltage (see Notes 1 and 3)	± 15	± 15	± 15	V
Voltage between power-control terminal and V_{CC-}	± 0.5	± 0.5	± 0.5	V
Duration of output short circuit (see Note 4)	unlimited	unlimited	unlimited	
Continuous total dissipation	See Dissipation Rating Table			
Operating free-air temperature range	-55 to 125	-40 to 85	0 to 70	$^{\circ}\text{C}$
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	$^{\circ}\text{C}$
Case temperature for 60 seconds	FK package	260		$^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	J, JG, U or W package	300	300	$^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D, N or P package		260	$^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	L package	300		$^{\circ}\text{C}$

- 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 terminal with respect to the inverting input terminal.
 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	$T_A \leq 25^{\circ}\text{C}$	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70^{\circ}\text{C}$	$T_A = 85^{\circ}\text{C}$	$T_A = 125^{\circ}\text{C}$
	POWER RATING			POWER RATING	POWER RATING	POWER RATING
D (8-pin)	680 mW	5.8 mW/ $^{\circ}\text{C}$	33 $^{\circ}\text{C}$	464 mW	377 mW	N/A
D (14-pin)	680 mW	7.6 mW/ $^{\circ}\text{C}$	60 $^{\circ}\text{C}$	608 mW	494 mW	N/A
FK	680 mW	11.0 mW/ $^{\circ}\text{C}$	88 $^{\circ}\text{C}$	680 mW	680 mW	275 mW
J (TL06_M)	680 mW	11.0 mW/ $^{\circ}\text{C}$	88 $^{\circ}\text{C}$	680 mW	680 mW	275 mW
J (all others)	680 mW	8.2 mW/ $^{\circ}\text{C}$	67 $^{\circ}\text{C}$	656 mW	533 mW	N/A
JG (TL06_M)	680 mW	8.4 mW/ $^{\circ}\text{C}$	69 $^{\circ}\text{C}$	672 mW	546 mW	210 mW
JG (all others)	680 mW	6.6 mW/ $^{\circ}\text{C}$	47 $^{\circ}\text{C}$	528 mW	429 mW	N/A
L	680 mW	6.6 mW/ $^{\circ}\text{C}$	47 $^{\circ}\text{C}$	528 mW	429 mW	165 mW
N	680 mW	9.2 mW/ $^{\circ}\text{C}$	76 $^{\circ}\text{C}$	680 mW	598 mW	N/A
P	680 mW	8.0 mW/ $^{\circ}\text{C}$	65 $^{\circ}\text{C}$	640 mW	520 mW	N/A
U	675 mW	5.4 mW/ $^{\circ}\text{C}$	25 $^{\circ}\text{C}$	432 mW	351 mW	135 mW
W	680 mW	8.0 mW/ $^{\circ}\text{C}$	65 $^{\circ}\text{C}$	640 mW	520 mW	200 mW

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Operational Amplifiers



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TL061M, TL062M, TL064M
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

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

PARAMETER	TEST CONDITIONS†	TL061M TL062M			TL064M			UNIT	
		MIN	TYP	MAX	MIN	TYP	MAX		
V_{IO} Input offset voltage	$V_O = 0,$ $R_S = 50 \Omega,$	$T_A = 25^\circ\text{C}$			3	6	9	mV	
		$T_A = -55^\circ\text{C to } 125^\circ\text{C}$			9				
α_{VIO} Temperature coefficient of input offset voltage	$V_O = 0,$ $R_S = 50 \Omega,$ $T_A = -55^\circ\text{C to } 125^\circ\text{C}$	10			10			$\mu\text{V}/^\circ\text{C}$	
I_{IO} Input offset current‡	$V_O = 0$	$T_A = 25^\circ\text{C}$			5	100	5	100	pA
		$T_A = -55^\circ\text{C to } 125^\circ\text{C}$			20			20	nA
I_{IB} Input bias current	$V_O = 0$	$T_A = 25^\circ\text{C}$			30	200	30	200	pA
		$T_A = -55^\circ\text{C to } 125^\circ\text{C}$			50			50	nA
V_{ICR} Common-mode input voltage range	$T_A = 25^\circ\text{C}$	-12 to +15			-12 to +15			V	
V_{OM} Maximum peak output voltage swing	$R_L = 10 \text{ k}\Omega,$ $T_A = 25^\circ\text{C}$	± 10			± 10			V	
	$R_L \geq 10 \text{ k}\Omega,$ $T_A = -55^\circ\text{C to } 125^\circ\text{C}$	± 10			± 10				
A_{VD} Large-signal differential voltage amplification	$V_O = \pm 10 \text{ V},$ $R_L \geq 10 \text{ k}\Omega,$	$T_A = 25^\circ\text{C}$			4	6	4	6	V/mV
		$T_A = -55^\circ\text{C to } 125^\circ\text{C}$			4				
B_1 Unity-gain bandwidth	$R_L = 10 \text{ k}\Omega,$ $T_A = 25^\circ\text{C}$							MHz	
r_i Input resistance	$T_A = 25^\circ\text{C}$	10^{12}			10^{12}			Ω	
$CMRR$ Common-mode rejection ratio	$V_{IC} = V_{ICR \text{ min}},$ $R_S = 50 \Omega,$ $T_A = 25^\circ\text{C}$	80	86		80	86		dB	
k_{SVR} Supply voltage rejection ratio ($\Delta V_{CC} \pm / \Delta V_{IO}$)	$V_{CC} = \pm 15 \text{ V to } \pm 9 \text{ V},$ $R_S = 50 \Omega,$ $T_A = 25^\circ\text{C}$	80	95		80	95		dB	
P_D Total power dissipation (each amplifier)	No load, $T_A = 25^\circ\text{C}$	$V_O = 0,$			6	7.5	6	7.5	mW
I_{CC} Supply current (each amplifier)	No load, $T_A = 25^\circ\text{C}$	$V_O = 0,$			200	250	200	250	μA
V_{O1}/V_{O2} Crosstalk attenuation	$A_{VD} = 100,$ $T_A = 25^\circ\text{C}$				120			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 will maintain the junction temperature as close to the ambient temperature as possible.

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Operational Amplifiers

**TL060, TL060A, TL060B, TL061, TL061A, TL061B
TL062, TL062A, TL062B, TL064, TL064A, TL064B
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

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

PARAMETER	TEST CONDITIONS [†]	TL0601			TL060C			TL060AC			TL060BC			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage $V_O = 0$, $R_S = 50 \Omega$	3	6	9	3	15	20	3	6	7.5	2	3	mV	
e_{NIO}	Temperature coefficient of input offset voltage	$R_S = 50 \Omega$, $V_O = 0$, $T_A = \text{full range}$											$\mu\text{V}/^\circ\text{C}$	
I_{IO}	Input offset current [‡]	5	100		5	200		5	100		5	100	pA	
I_{IB}	Input bias current [‡]	30	200		30	400		30	200		30	200	pA	
V_{ICR}	Common-mode input voltage range	-12 to ± 11.5	± 13.5		-12 to ± 11	± 13.5		-12 to ± 11.5	± 13.5		-12 to ± 11.5	± 13.5	V	
V_{OM}	Maximum peak output voltage swing	$R_L \geq 10 \text{ k}\Omega$, $V_O = \pm 10 \text{ V}$	$T_A = 25^\circ\text{C}$		$R_L \geq 10 \text{ k}\Omega$, $V_O = \pm 10 \text{ V}$	$T_A = 25^\circ\text{C}$		$R_L \geq 10 \text{ k}\Omega$, $V_O = \pm 10 \text{ V}$	$T_A = 25^\circ\text{C}$		$R_L \geq 10 \text{ k}\Omega$, $V_O = \pm 10 \text{ V}$	$T_A = 25^\circ\text{C}$	V	
A_{VD}	Large-signal differential voltage amplification	4	6		3	6		4	6		4	6	V/mV	
B_1	Unity-gain bandwidth	4			3			4			4		MHz	
f_i	Input resistance	$R_L = 10 \text{ k}\Omega$, $T_A = 25^\circ\text{C}$			10 ¹²			10 ¹²			10 ¹²		Ω	
CMRR	Common-mode rejection ratio	80	86		70	86		80	86		80	86	dB	
k_{SVR}	Supply voltage rejection ratio	$V_{IC} = V_{ICR} \text{ min}$, $V_O = 0$, $R_S = 50 \Omega$, $T_A = 25^\circ\text{C}$											dB	
k_{SVR}	Supply voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$)	$V_{CC} = \pm 15 \text{ V}$ to $\pm 9 \text{ V}$, $V_O = 0$, $R_S = 90 \Omega$, $T_A = 25^\circ\text{C}$											dB	
P_D	Total power dissipation (each amplifier)	No load, $V_O = 0$, $T_A = 25^\circ\text{C}$	6	7.5	6	7.5	6	7.5	6	7.5	6	7.5	mW	
I_{CC}	Supply current (each amplifier)	No load, $V_O = 0$, $T_A = 25^\circ\text{C}$	200	250	200	250	200	250	200	250	200	250	μA	
V_{O1}/V_{O2}	Crosstalk attenuation	$AVD = 100$, $T_A = 25^\circ\text{C}$	120		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 -40°C to 85°C for TL060, and 0°C to 70°C for TL060C, TL060AC, and TL060BC.

[‡] 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 will maintain the junction temperature as close to the ambient temperature as possible.

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Operational Amplifiers



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**TL060, TL060A, TL060B, TL061, TL061A, TL061B
TL062, TL062A, TL062B, TL064, TL064A, TL064B
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

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	$V_I = 10\text{ V}$, $C_L = 100\text{ pF}$,	$R_L = 10\text{ k}\Omega$, See Figure 1	1.5	3.5		$\text{V}/\mu\text{s}$
t_r Rise time	$V_I = 20\text{ mV}$,	$R_L = 10\text{ k}\Omega$, See Figure 1		0.2		μs
Overshoot factor	$C_L = 100\text{ pF}$,	See Figure 1		10%		
V_n Equivalent input noise voltage	$R_S = 100\ \Omega$,	$f = 1\text{ kHz}$		42		$\text{nV}/\sqrt{\text{Hz}}$

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Operational Amplifiers

PARAMETER MEASUREMENT INFORMATION

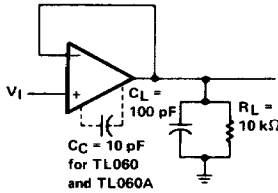


FIGURE 1. UNITY-GAIN AMPLIFIER

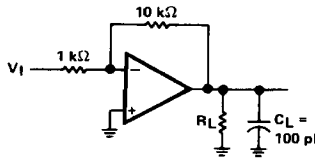


FIGURE 2. GAIN-OF-10
INVERTING AMPLIFIER

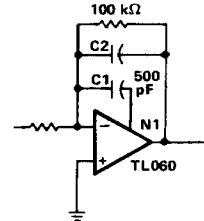
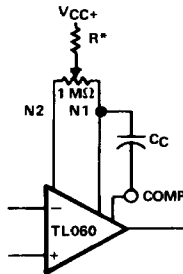


FIGURE 3. FEED-FORWARD
COMPENSATION

INPUT OFFSET VOLTAGE NULL CIRCUITS



*For best results use $R = 20\text{ M}\Omega$ for $V_{CC\pm} = \pm 15\text{ V}$ to $R = 5\text{ M}\Omega$ for $V_{CC\pm} = \pm 3\text{ V}$.

FIGURE 4

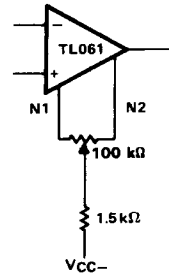


FIGURE 5

**TL060, TL060A, TL060B, TL061, TL061A, TL061B
TL062, TL062A, TL062B, TL064, TL064A, TL064B
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

TYPICAL CHARACTERISTICS†

**MAXIMUM PEAK OUTPUT VOLTAGE
vs
SUPPLY VOLTAGE**

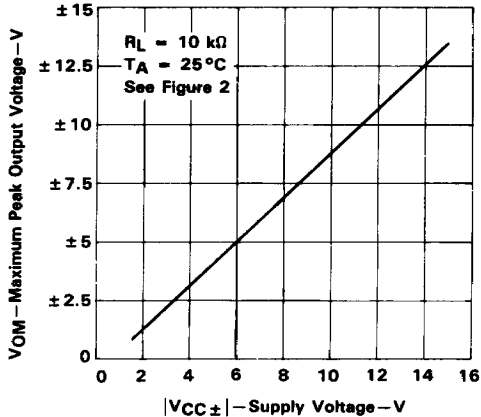


FIGURE 6

**MAXIMUM PEAK OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE**

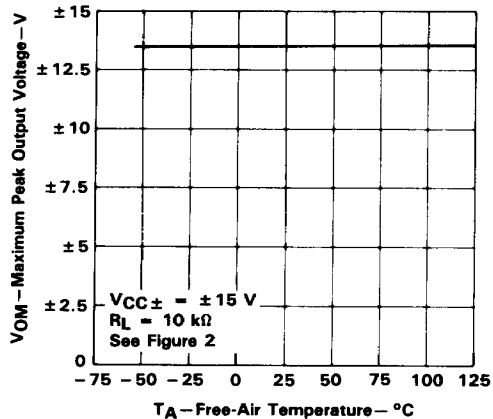


FIGURE 7

**MAXIMUM PEAK OUTPUT VOLTAGE
vs
LOAD RESISTANCE**

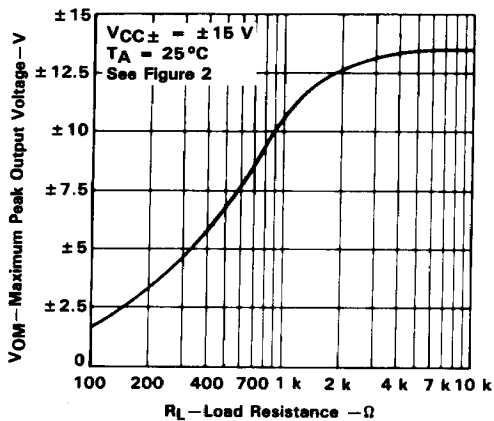


FIGURE 8

**MAXIMUM PEAK OUTPUT VOLTAGE
vs
FREQUENCY**

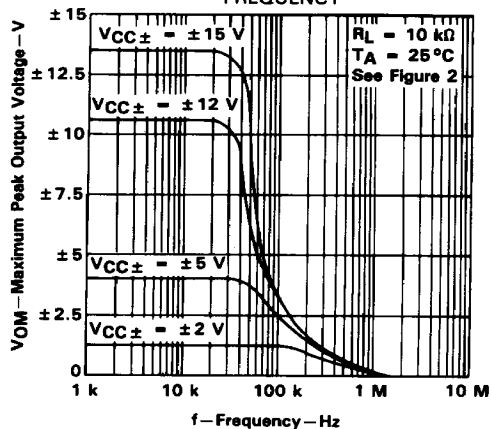


FIGURE 9

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. A 10-pF compensation capacitor is used with TL060 and TL060A.

**TL060, TL060A, TL060B, TL061, TL061A, TL062B
TL062, TL062A, TL062B, TL064, TL064A, TL064B
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

TYPICAL CHARACTERISTICS†

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Operational Amplifiers

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

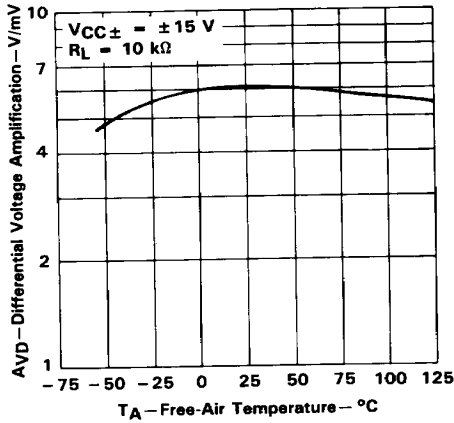


FIGURE 10

**SUPPLY CURRENT
vs
SUPPLY VOLTAGE**

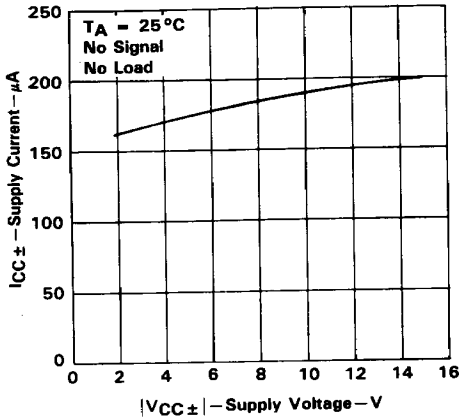


FIGURE 12

**LARGE-SIGNAL
DIFFERENTIAL VOLTAGE AMPLIFICATION
AND PHASE SHIFT
vs
FREQUENCY**

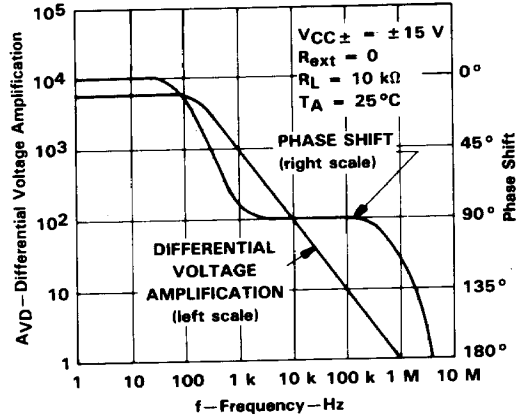


FIGURE 11

**SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE**

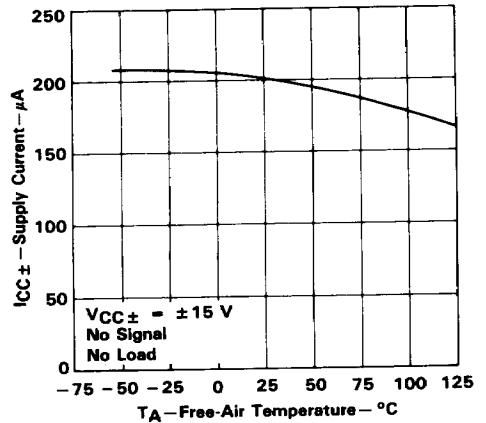


FIGURE 13

†A 10-pF compensation capacitor is used with TL060 and TL060A.

**TL060, TL060A, TL060B, TL061, TL061A, TL061B
TL062, TL062A, TL062B, TL064, TL064A, TL064B
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

TYPICAL CHARACTERISTICS†

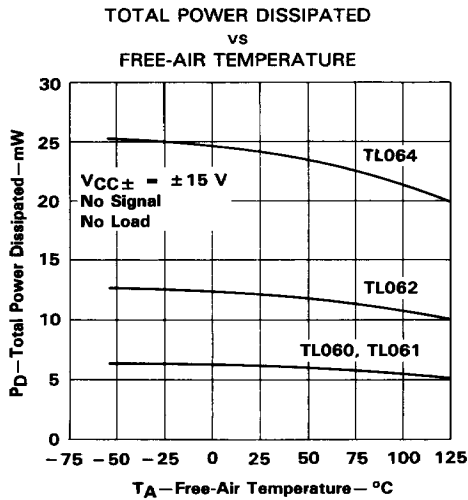


FIGURE 14

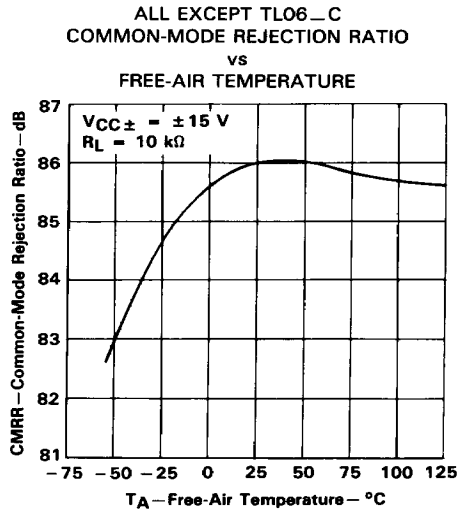


FIGURE 15

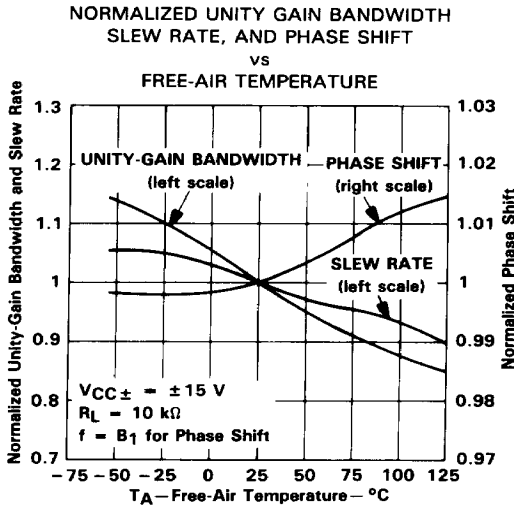


FIGURE 16

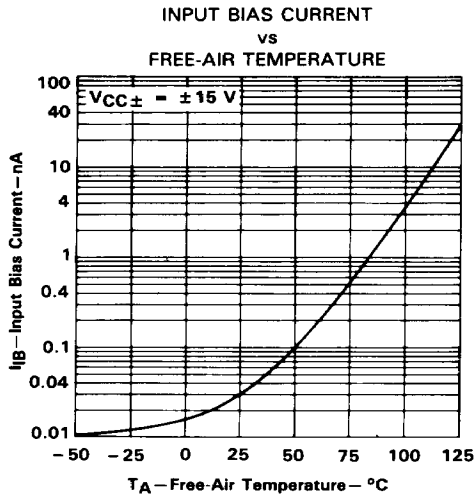


FIGURE 17

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. A 10-pF compensation capacitor is used with TL060 and TL060A.

**TL060, TL060A, TL060B, TL061, TL061A, TL061B
TL062, TL062A, TL062B, TL064, TL064A, TL064B
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

TYPICAL CHARACTERISTICS†

2
Operational Amplifiers

**VOLTAGE FOLLOWER
LARGE SIGNAL PULSE RESPONSE**

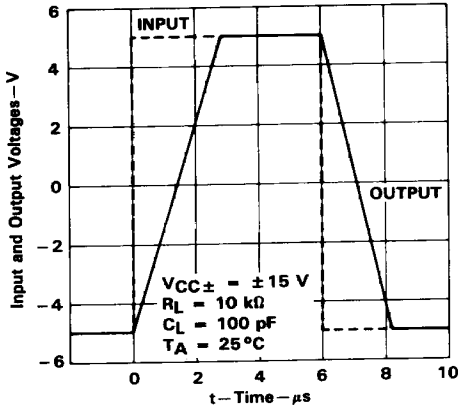


FIGURE 18

**OUTPUT VOLTAGE
vs
ELAPSED TIME**

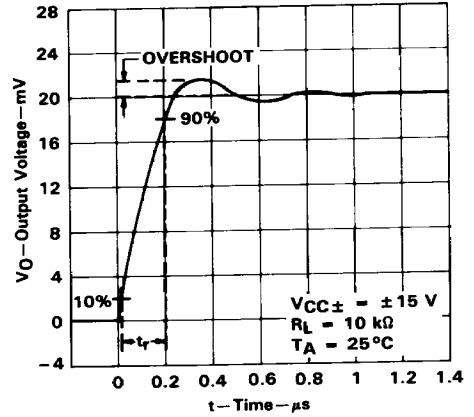


FIGURE 19

**EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY**

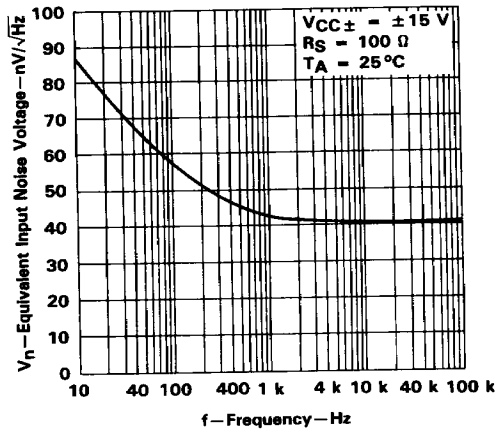


FIGURE 20

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. A 10-pF compensation capacitor is used with TL060 and TL060A.

**TL060, TL060A, TL060B, TL061, TL061A, TL061B
TL062, TL062A, TL062B, TL064, TL064A, TL064B
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

TYPICAL APPLICATION DATA

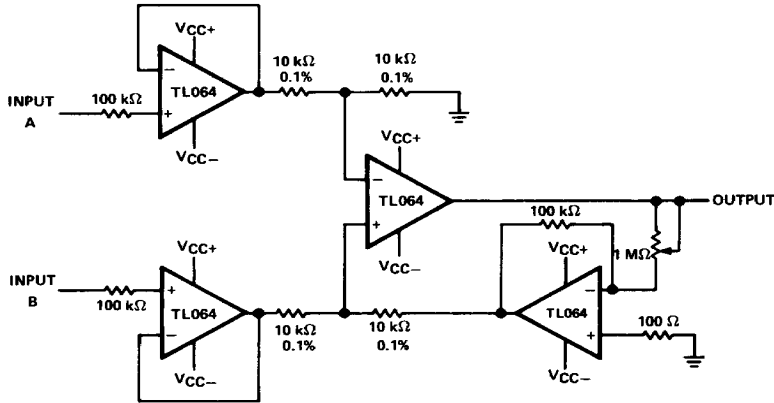


FIGURE 21. INSTRUMENTATION AMPLIFIER

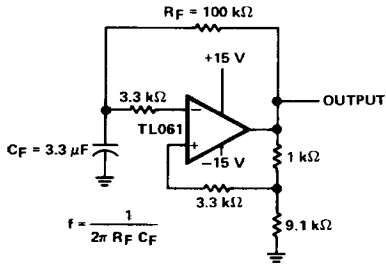


FIGURE 22. 0.5-Hz SQUARE-WAVE OSCILLATOR

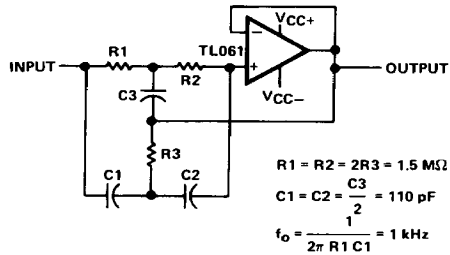


FIGURE 23. HIGH-Q NOTCH FILTER

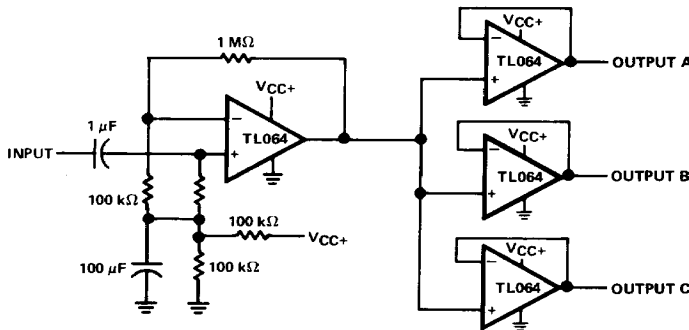


FIGURE 24. AUDIO DISTRIBUTION AMPLIFIER

**TL060, TL060A, TL060B, TL061, TL061A, TL062B
TL062, TL062A, TL062B, TL064, TL064A, TL064B
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

TYPICAL APPLICATION DATA

2

Operational Amplifiers

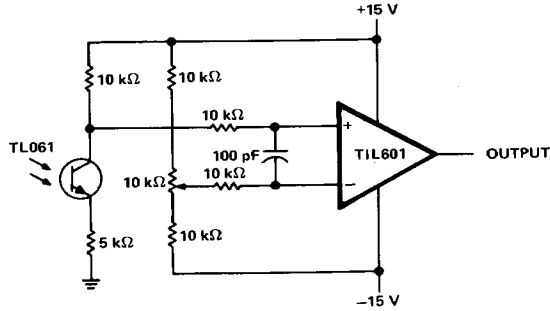


FIGURE 25. LOW-LEVEL LIGHT DETECTOR PREAMPLIFIER

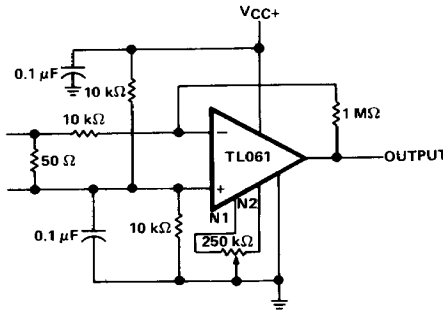


FIGURE 26. AC AMPLIFIER

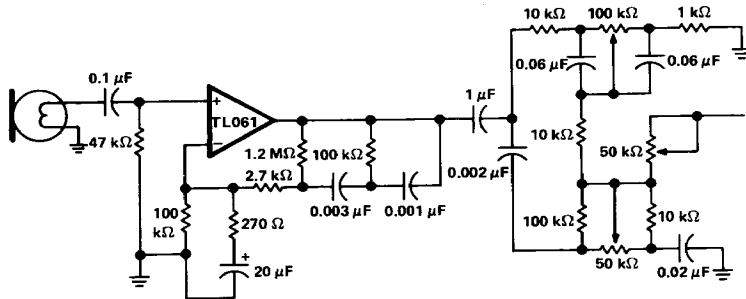


FIGURE 27. MICROPHONE PREAMPLIFIER WITH TONE CONTROL

**TL060, TL060A, TL060B, TL061, TL061A, TL061B
TL062, TL062A, TL062B, TL064, TL064A, TL064B
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

TYPICAL APPLICATION DATA

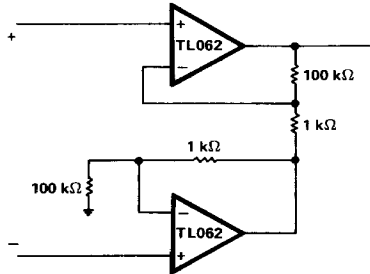


FIGURE 28. INSTRUMENTATION AMPLIFIER

IC PREAMPLIFIER RESPONSE CHARACTERISTICS

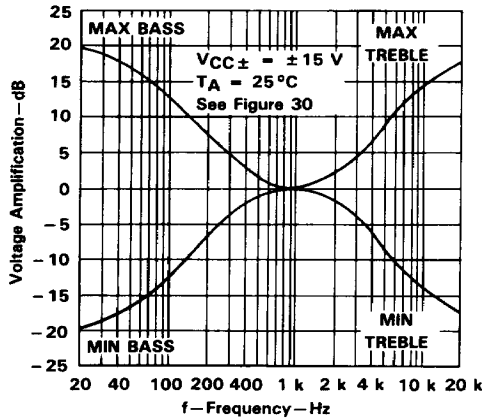


FIGURE 29

**TL060, TL060A, TL060B, TL061, TL061A, TL061B
TL062, TL062A, TL062B, TL064, TL064A, TL064B
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

TYPICAL APPLICATION DATA

2

Operational Amplifiers

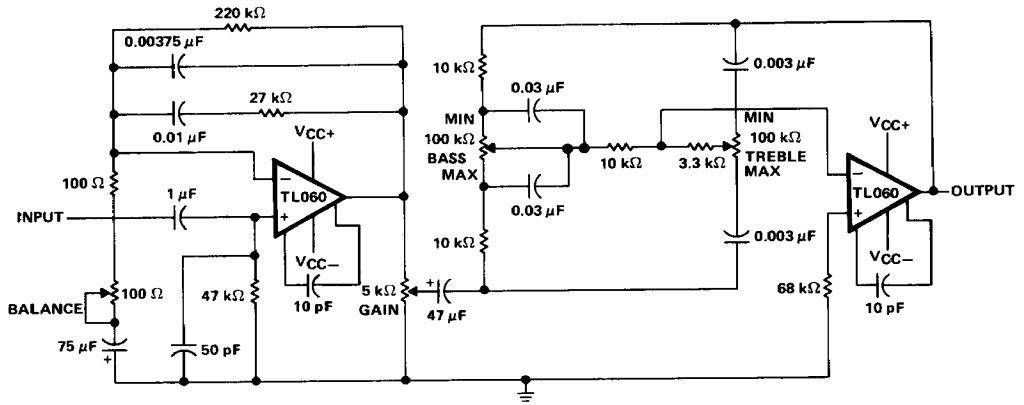


FIGURE 30. IC PREAMPLIFIER