

**TL070, TL070A, TL071, TL071A, TL071B,
TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075**
LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

D2393, SEPTEMBER 1978—REVISED JANUARY 1989

19 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
- Common-Mode Input Voltage Range Includes V_{CC+}
- Low Noise . . . $V_n = 18 \text{ nV}/\sqrt{\text{Hz}}$ Typ
- High Input Impedance . . . JFET-Input Stage
- Internal Frequency Compensation (Except TL070, TL070A)
- Latch-Up-Free Operation
- High Slew Rate . . . $13 \text{ V}/\mu\text{s}$ Typ

T-79-15

NOTICE

SEE ORDER OF DATA FOR ERRATA INFORMATION

2

Operational Amplifiers

description

The JFET-input operational amplifiers in the TL07__ series are designed as low-noise versions of the TL08__ series amplifiers with low input bias and offset currents and fast slew rate. The low harmonic distortion and low noise make the TL07__ series ideally suited as amplifiers for high-fidelity and audio preamplifier applications. Each amplifier features JFET-inputs (for high input impedance) coupled with bipolar output stages all integrated on a single monolithic chip.

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 , and the C suffix devices are characterized for operation from 0°C to 70°C .

AVAILABLE OPTIONS

TA	V _{IO} MAX AT 25°C	PACKAGE							
		SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	CERAMIC DIP (JG)	METAL CAN (L)	PLASTIC DIP (N)	PLASTIC DIP (P)	FLAT PACK (W)
0°C to 70°C	10 mV	TL070CD			TL070CJG			TL070CP	
	6 mV	TL070ACD			TL070ACJG			TL070ACP	
	10 mV	TL071CD			TL071CJG			TL071CP	
	6 mV	TL071ACD			TL071ACJG			TL071ACP	
	3 mV	TL071BCD			TL071BCJG			TL071BCP	
	10 mV	TL072CD			TL072CJG			TL072CP	
	6 mV	TL072ACD			TL072ACJG			TL072ACP	
	3 mV	TL072BCD			TL072BCJG			TL072BCP	
	10 mV	TL074CD		TL074CJ			TL074CN		
	6 mV	TL074ACD		TL074ACJ			TL074ACN		
	3 mV	TL074BCD		TL074BCJ			TL074BCN		
	10 mV						TL075CN		
-40°C to 85°C	-6 mV	TL070ID			TL070IJG			TL070IP	
	6 mV	TL071ID			TL071IJG			TL071IP	
	6 mV	TL072ID			TL072IJG			TL072IP	
	6 mV	TL074ID		TLQ74IJ			TL074IN		
-55°C to 125°C	6 mV		TL071MFK		TL071MJG	TL071ML			
	6 mV		TL072MFK		TL072MJG	TL072ML			
	9 mV		TL074MFK	TL074MJ					TL074MW

The D package is available taped and reeled. Add the suffix R to the device type (e.g., TL071CDR).

PRODUCTION DATA documents contain information 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.



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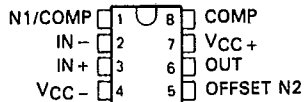
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**TL070, TL070A, TL071, TL071A, TL071B,
TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075**
LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

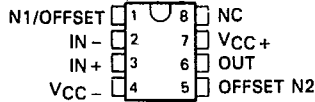
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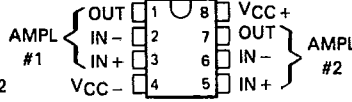
TL070, TL070A
D, JG, OR P PACKAGE
(TOP VIEW)



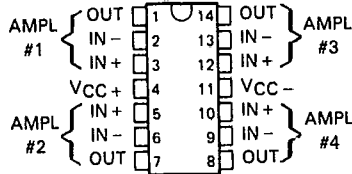
TL071, TL071A, TL071B
D, JG, OR P PACKAGE
(TOP VIEW)



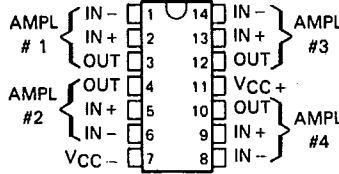
TL072, TL072A, TL072B
D, JG, OR P PACKAGE
(TOP VIEW)



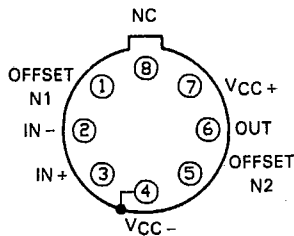
TL074, TL074A, TL074B
D, J, OR N PACKAGE
TL074...W PACKAGE
(TOP VIEW)



TL075
N PACKAGE
(TOP VIEW)

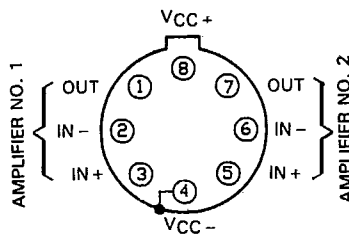


TL071...L PACKAGE
(TOP VIEW)



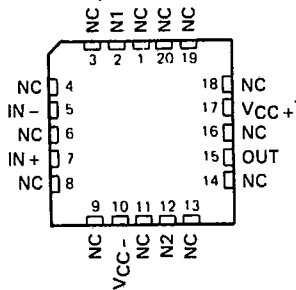
PIN 4 IS IN ELECTRICAL CONTACT WITH THE CASE

TL072...L PACKAGE
(TOP VIEW)

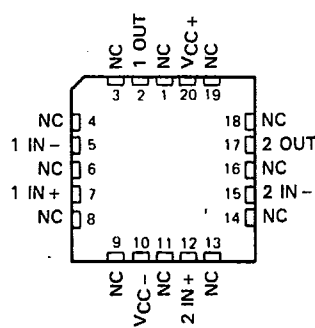


PIN 4 IS IN ELECTRICAL CONTACT WITH THE CASE

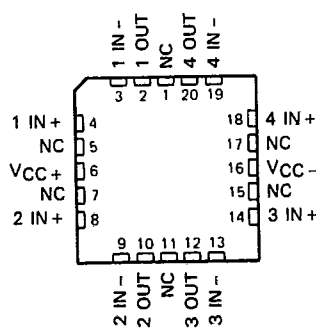
TL071
FK PACKAGE
(TOP VIEW)



TL072
FK PACKAGE
(TOP VIEW)



TL074
FK PACKAGE
(TOP VIEW)

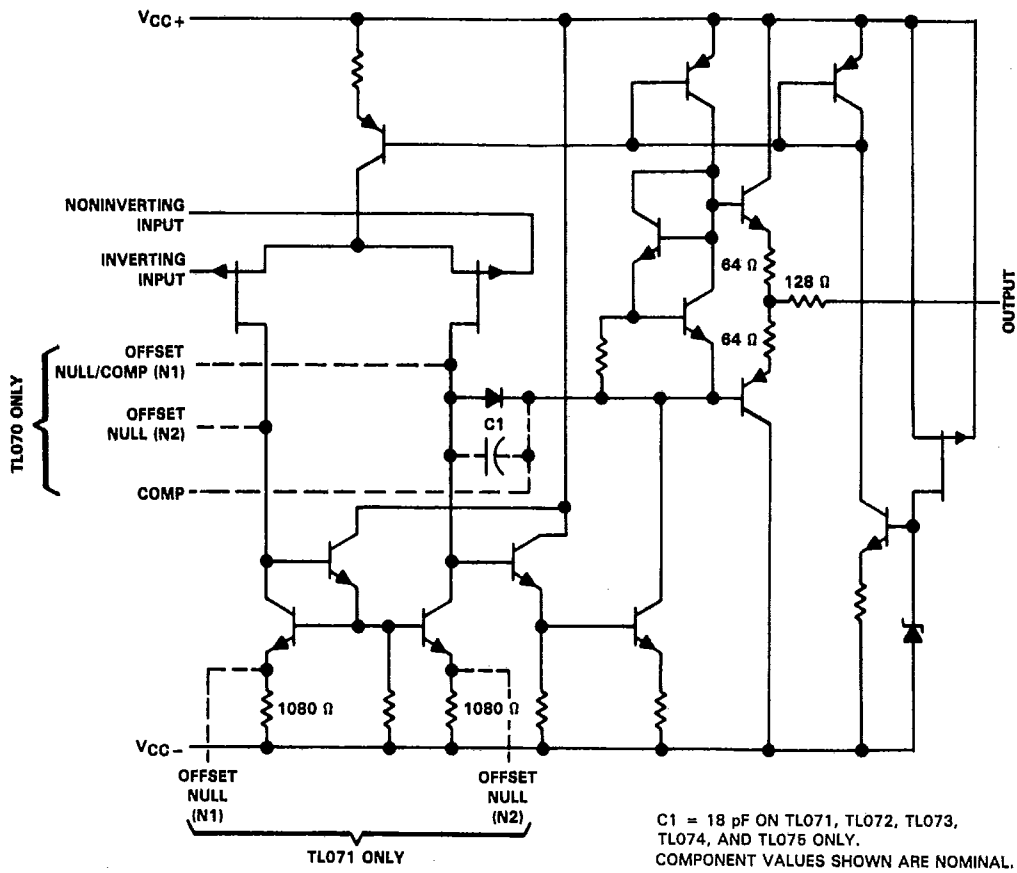


NC—No internal connection.

**TL070, TL070A, TL071, TL071A, TL071B,
TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075
LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS**

schematic (each amplifier)

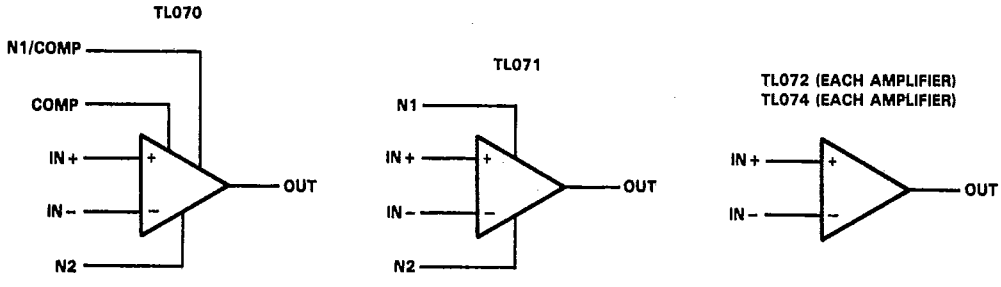
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Operational Amplifiers

C1 = 18 pF ON TL071, TL072, TL073,
TL074, AND TL075 ONLY.
COMPONENT VALUES SHOWN ARE NOMINAL.

symbols



**TL070, TL070A, TL071, TL071A, TL071B,
TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075
LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS**

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

	TL07_M	TL07_J	TL07_C TL07_AC TL07_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
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	°C
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C
Case temperature for 60 seconds	FK package	260		°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	J, JG, or W package	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D, N, or P package		260	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	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 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 ≤ 25°C POWER RATING	DERATING FACTOR	DERATE ABOVE T _A	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D (8-pin)	680 mW	5.8 mW/°C	33°C	464 mW	377 mW	N/A
D (14-pin)	680 mW	7.6 mW/°C	60°C	608 mW	494 mW	N/A
FK	680 mW	11.0 mW/°C	88°C	680 mW	680 mW	275 mW
J (TL07_M)	680 mW	11.0 mW/°C	88°C	680 mW	680 mW	275 mW
J (all others)	680 mW	8.2 mW/°C	67°C	656 mW	533 mW	N/A
JG (TL07_M)	680 mW	8.4 mW/°C	69°C	672 mW	546 mW	210 mW
JG (all others)	680 mW	6.6 mW/°C	47°C	528 mW	429 mW	N/A
L	680 mW	6.6 mW/°C	25°C	528 mW	429 mW	165 mW
N	680 mW	9.2 mW/°C	76°C	680 mW	598 mW	N/A
P	680 mW	8.0 mW/°C	65°C	640 mW	520 mW	N/A
W	680 mW	8.0 mW/°C	65°C	640 mW	520 mW	200 mW

2 Operational Amplifiers

TL071M, TL072M, TL074M
LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

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

PARAMETER	TEST CONDITIONS†		TL071M TL072M			TL074M			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_O = 0,$ $R_S = 50 \Omega,$	$T_A = 25^\circ\text{C}$ $T_A = -55^\circ\text{C to } 125^\circ\text{C}$	3	6	8	3	9	15	mV
αV_{IO} Temperature coefficient of input offset voltage	$V_O = 0,$ $R_S = 50 \Omega,$	$T_A = -55^\circ\text{C to } 125^\circ\text{C}$	18			18			$\mu\text{V}/^\circ\text{C}$
I_{IO} Input offset current‡	$V_O = 0$	$T_A = 25^\circ\text{C}$ $T_A = -55^\circ\text{C to } 125^\circ\text{C}$	5	100	20	5	100	20	pA nA
I_{IB} Input bias current	$V_O = 0$	$T_A = 25^\circ\text{C}$ $T_A = -55^\circ\text{C to } 125^\circ\text{C}$	65	200	50	65	200	50	pA nA
V_{ICR} Common-mode input voltage range	$T_A = 25^\circ\text{C}$		± 11	-12 to +15	± 11	-12 to +15			V
V_{OM} Maximum peak output voltage swing	$R_L = 10 \text{ k}\Omega$ $R_L \geq 10 \text{ k}\Omega$ $R_L \geq 2 \text{ k}\Omega$	$T_A = 25^\circ\text{C}$ $T_A = -55^\circ\text{C to } 125^\circ\text{C}$	± 12	± 13.5	± 12	± 13.5			V
A_{VD} Large-signal differential voltage amplification	$V_O = \pm 10 \text{ V},$ $R_L \geq 2 \text{ k}\Omega$	$T_A = 25^\circ\text{C}$ $T_A = -55^\circ\text{C to } 125^\circ\text{C}$	35	200	15	35	200	15	V/mV
B_1 Unity-gain bandwidth	$T_A = 25^\circ\text{C}$		3			3			MHz
r_i Input resistance	$T_A = 25^\circ\text{C}$		10 ¹²			10 ¹²			Ω
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR} \text{ min},$ $V_O = 0,$ $R_S = 50 \Omega,$	$T_A = 25^\circ\text{C}$	80	86	80	86			dB
kSVR Supply voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_{CC} = \pm 15 \text{ V to } \pm 9 \text{ V},$ $V_O = 0,$ $R_S = 50 \Omega,$	$T_A = 25^\circ\text{C}$	80	86	80	86			dB
I_{CC} Supply current (each amplifier)	No load, $T_A = 25^\circ\text{C}$	$V_O = 0,$	1.4	2.5	1.4	2.5			mA
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 6. 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

TL070, TL070A, TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075
LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

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2
Operational Amplifiers

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

PARAMETER	TEST CONDITIONS†	TL070†			TL070C			TL070AC			TL070BC			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_O = 0$, $R_S = 50 \Omega$ $T_A = 25^\circ C$	3	6	8	3	10	13	3	6	8	3	6	8	mV
Temperature coefficient of input offset voltage	$V_O = 0$, $R_S = 50 \Omega$, $T_A = \text{full range}$	18			18			18			18			$\mu V/^\circ C$
I_{IO} Input offset current‡	$V_O = 0$ $T_A = 25^\circ C$	5	100		5	100		5	100		5	100	pA	
I_{IB} Input bias current‡	$V_O = 0$ $T_A = 25^\circ C$	65	200		65	200		65	200		65	200	nA	
V_{ICR} Common-mode input voltage range	$T_A = 25^\circ C$	-12	to	+15	-12	to	+15	-12	to	+15	-12	to	+15	V
V_{OM} Maximum peak output voltage swing	$R_L = 10 k\Omega$ $T_A = 25^\circ C$	± 12	± 13.5		± 12	± 13.5		± 12	± 13.5		± 12	± 13.5		V
	$R_L \geq 2 k\Omega$ $T_A = \text{full range}$	± 10			± 10			± 10			± 10			
AVD Large-signal differential voltage amplification	$V_O = \pm 10$ V, $R_L \geq 2 k\Omega$ $T_A = 25^\circ C$	50	200		25	200		50	200		50	200	V/mV	
B_1 Unity-gain bandwidth	$T_A = 25^\circ C$	3			3			3			3		MHz	
r_i Input resistance	$T_A = 25^\circ C$	10^{12}			10^{12}			10^{12}			10^{12}		Ω	
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR \text{ min}}$, $V_O = 0$, $R_S = 50 \Omega$, $T_A = 25^\circ C$	80	100		70	100		80	100		80	100	dB	
KSVR Supply voltage rejection ratio ($\Delta V_{CC} \pm / \Delta V_{IO}$)	$V_{CC} = \pm 15$ V to ± 9 V, $V_O = 0$, $R_S = 50 \Omega$, $T_A = 25^\circ C$	80	100		70	100		80	100		80	100	dB	
I _{CC} Supply current (each amplifier)	No load, $V_O = 0$, $T_A = 25^\circ C$	1.4	2.5		1.4	2.5		1.4	2.5		1.4	2.5	mA	
V_{O1}/V_{O2} Crosstalk attenuation	$A_{VD} = 100$, $T_A = 25^\circ C$	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 $-40^\circ C$ to $85^\circ C$ for TL071 and $0^\circ C$ to $70^\circ C$ for TL070, TL070A, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, and TL075.
‡ Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 6. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

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

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PARAMETER	TEST CONDITIONS	TL07_M			ALL OTHERS			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
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		8	13		$\text{V}/\mu\text{s}$
t_r	Rise time overshoot factor $V_i = 20\text{ mV}$, $R_L = 2\text{ k}\Omega$, $C_L = 100\text{ pF}$, See Figure 1		0.1			0.1		μs
			20			20		%
V_n	Equivalent input noise voltage $R_S = 100\ \Omega$	$f = 1\text{ kHz}$		18		18		$\text{nV}/\sqrt{\text{Hz}}$
		$f = 10\text{ Hz to } 10\text{ kHz}$		4		4		μV
I_n	Equivalent input noise current $R_S = 100\ \Omega$, $f = 1\text{ kHz}$		0.01		0.01		$\text{pA}/\sqrt{\text{Hz}}$	
THD	Total harmonic distortion $V_{O(\text{rms})} = 10\text{ V}$, $R_S \leq 1\text{ k}\Omega$, $R_L \geq 2\text{ k}\Omega$, $f = 1\text{ kHz}$		0.003		0.003		%	

2

Operational Amplifiers

PARAMETER MEASUREMENT INFORMATION

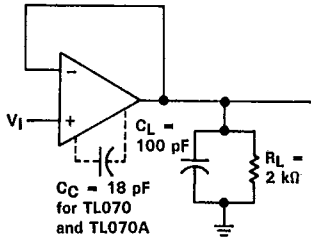


FIGURE 1. UNITY-GAIN AMPLIFIER

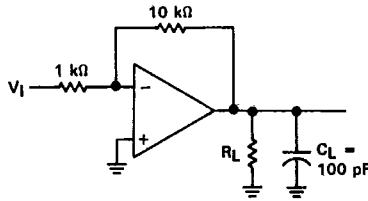


FIGURE 2. GAIN-OF-10
INVERTING AMPLIFIER

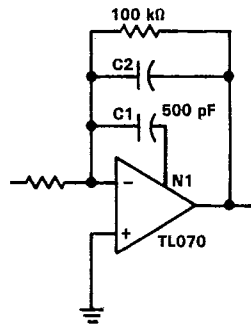


FIGURE 3. FEED-FORWARD
COMPENSATION

INPUT OFFSET VOLTAGE NULL CIRCUITS

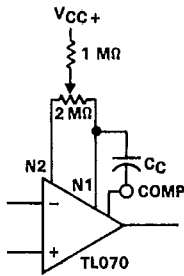


FIGURE 4

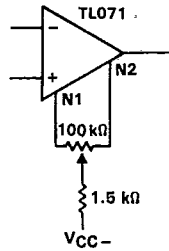


FIGURE 5

TL070, TL070A, TL071, TL071A, TL071B,
 TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075
 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

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TYPICAL CHARACTERISTICS†

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Operational Amplifiers

INPUT BIAS CURRENT
 vs
 FREE-AIR TEMPERATURE

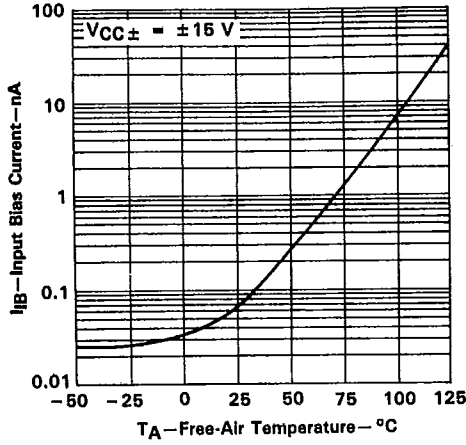


FIGURE 6

MAXIMUM PEAK OUTPUT VOLTAGE
 vs
 FREQUENCY

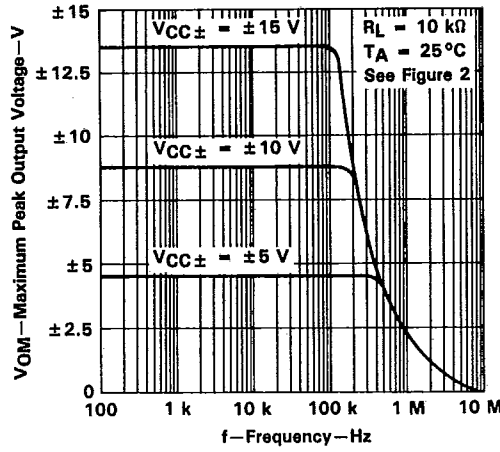


FIGURE 7

MAXIMUM PEAK OUTPUT VOLTAGE
 vs
 FREQUENCY

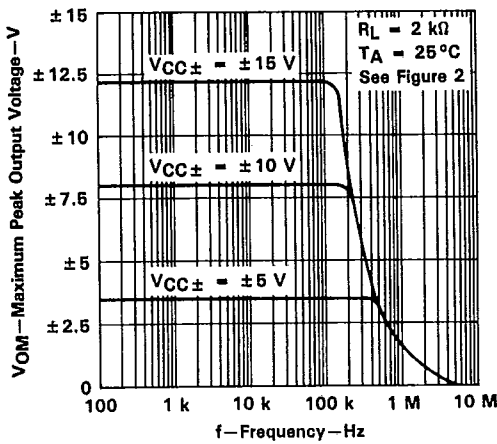


FIGURE 8

MAXIMUM PEAK OUTPUT VOLTAGE
 vs
 FREQUENCY

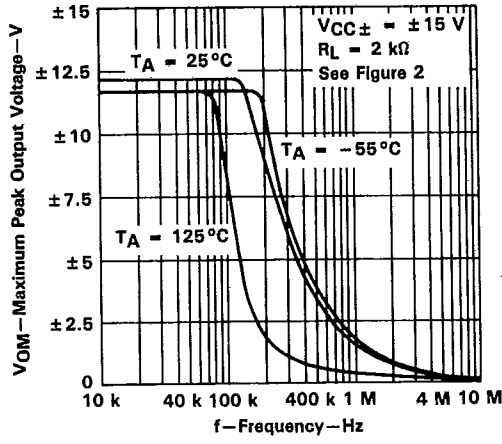


FIGURE 9

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. An 18-pF compensation capacitor is used with TL070 and TL070A.

TL070, TL070A, TL071, TL071A, TL071B
 TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075
 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

TYPICAL CHARACTERISTICS†

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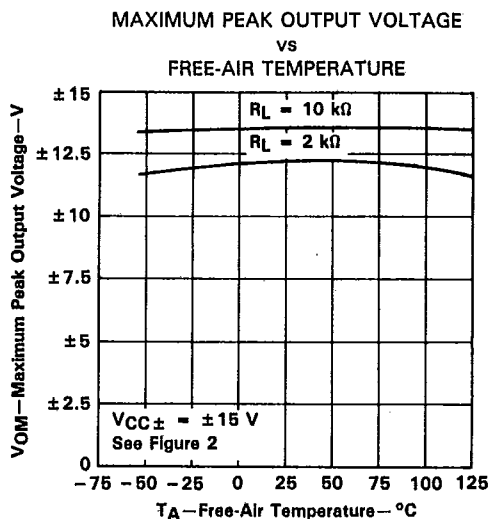


FIGURE 10

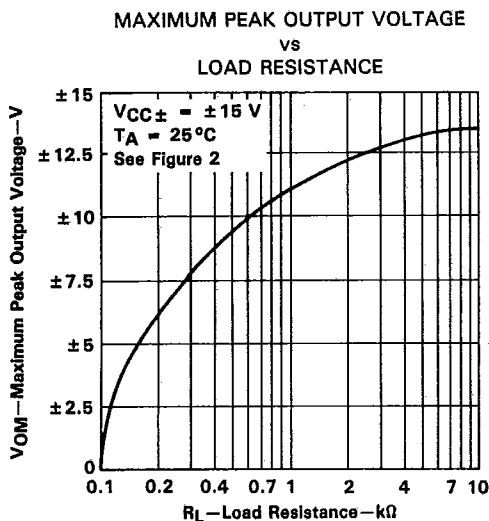


FIGURE 11

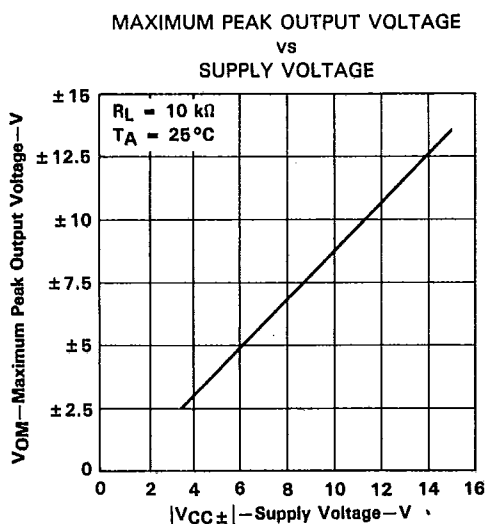


FIGURE 12

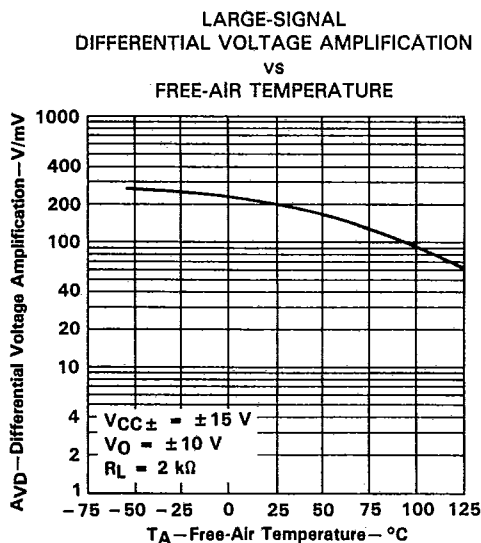


FIGURE 13

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. An 18-pF compensation capacitor is used with TL070 and TL070A.

2
 Operational Amplifiers

TYPICAL CHARACTERISTICS†

2 Operational Amplifiers

TL070
 DIFFERENTIAL VOLTAGE AMPLIFICATION
 vs
 FREQUENCY WITH FEED-FORWARD
 COMPENSATION

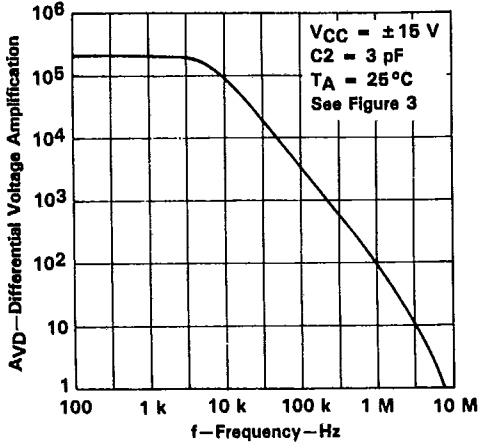


FIGURE 14

LARGE-SIGNAL
 DIFFERENTIAL VOLTAGE AMPLIFICATION
 and PHASE SHIFT
 vs
 FREQUENCY

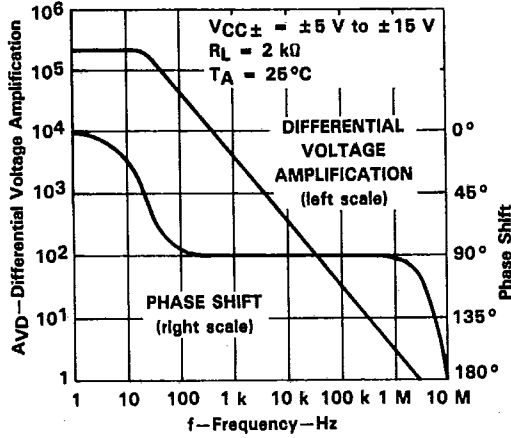


FIGURE 15

NORMALIZED UNITY-GAIN BANDWIDTH
 and PHASE SHIFT
 vs
 FREE-AIR TEMPERATURE

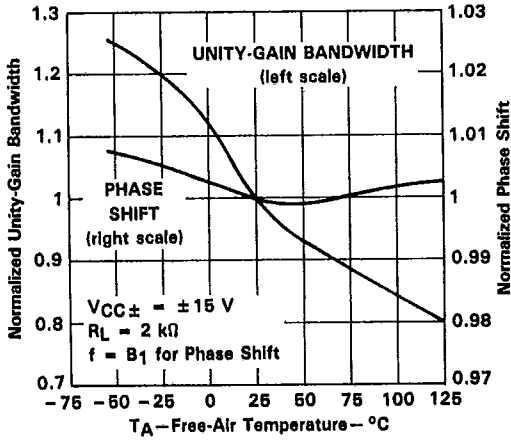


FIGURE 16

COMMON-MODE REJECTION RATIO
 vs
 FREE-AIR TEMPERATURE

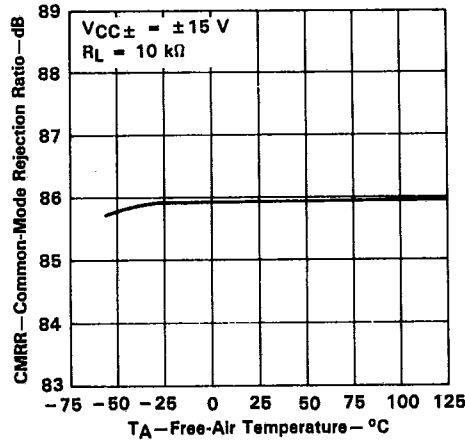


FIGURE 17

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. An 18-pF compensation capacitor is used with TL070 and TL070A.

TL070, TL070A, TL071, TL071A, TL071B
 TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075
 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

TYPICAL CHARACTERISTICS†

T-79-15

SUPPLY CURRENT PER AMPLIFIER
 vs
 SUPPLY VOLTAGE

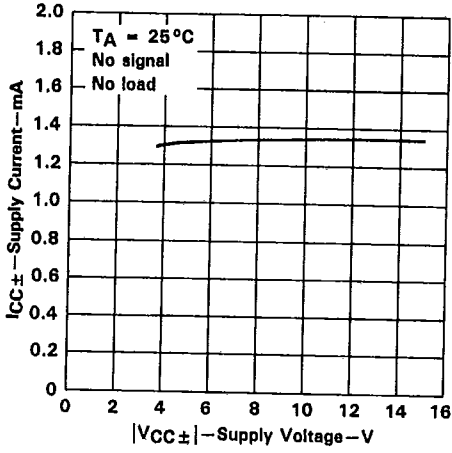


FIGURE 18

SUPPLY CURRENT PER AMPLIFIER
 vs
 FREE-AIR TEMPERATURE

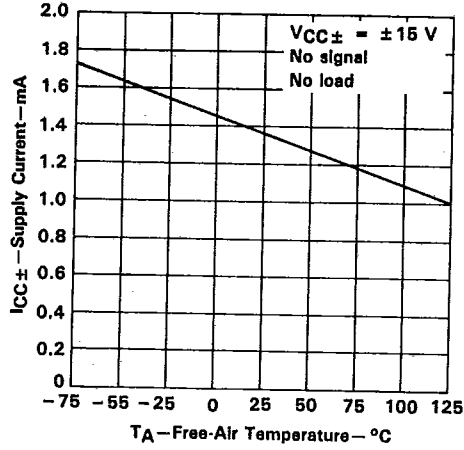


FIGURE 19

TOTAL POWER DISSIPATED
 vs
 FREE-AIR TEMPERATURE

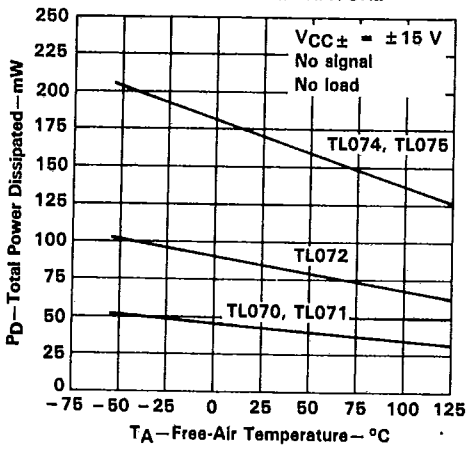


FIGURE 20

NORMALIZED SLEW RATE
 vs
 FREE-AIR TEMPERATURE

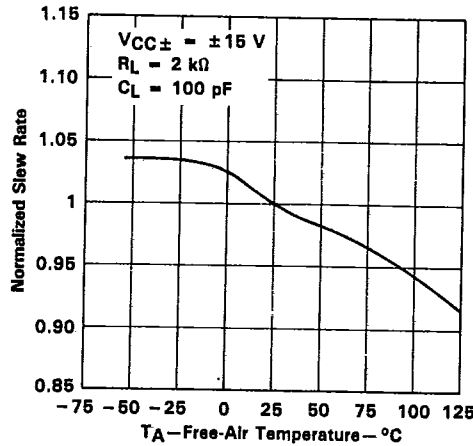


FIGURE 21

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. An 18-pF compensation capacitor is used with TL070 and TL070A.

2
 Operational Amplifiers

TL070, TL070A, TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075
LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

T-79-15

TYPICAL CHARACTERISTICS

EQUIVALENT INPUT NOISE VOLTAGE
VS
FREQUENCY

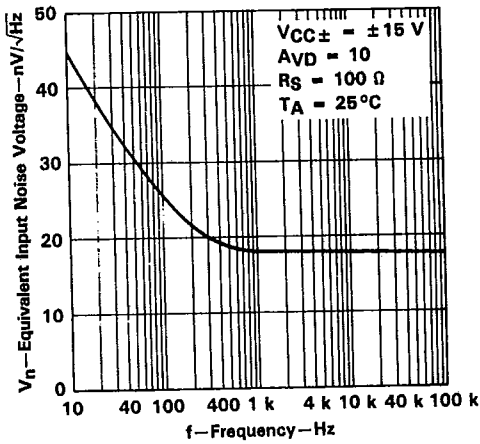


FIGURE 22

TOTAL HARMONIC DISTORTION
VS
FREQUENCY

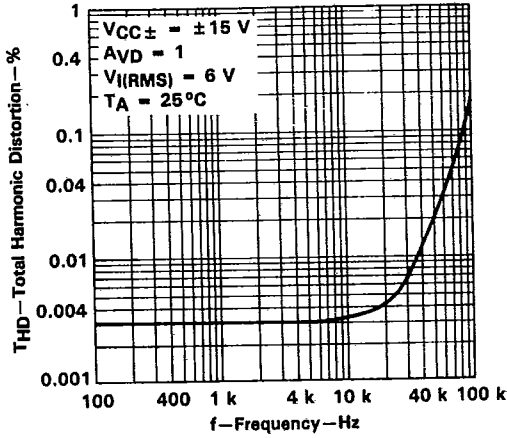


FIGURE 23

VOLTAGE-FOLLOWER
LARGE-SIGNAL PULSE RESPONSE

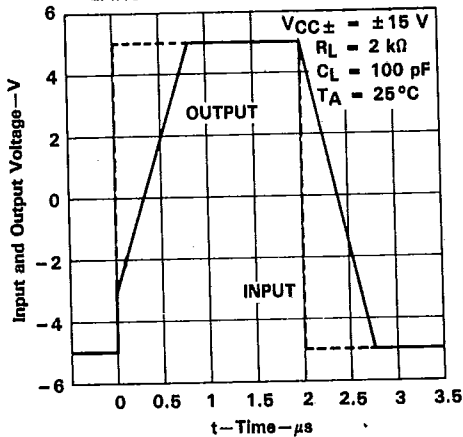


FIGURE 24

OUTPUT VOLTAGE
VS
ELAPSED TIME

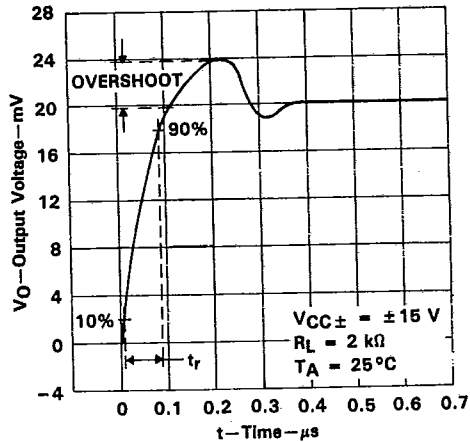


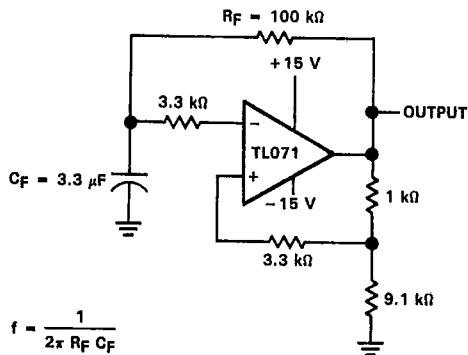
FIGURE 25

2
Operational Amplifiers

TL070, TL070A, TL071, TL071A, TL071B
 TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075
 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

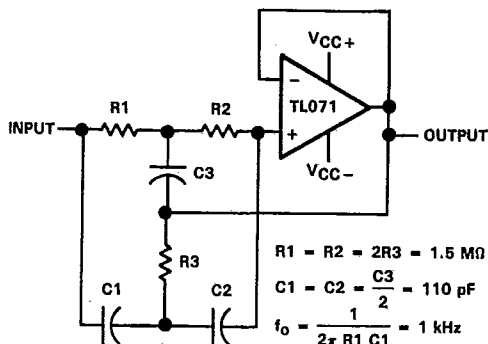
TYPICAL APPLICATION DATA

T-79-15



$$f = \frac{1}{2\pi R_F C_F}$$

FIGURE 26. 0.5-Hz SQUARE-WAVE OSCILLATOR

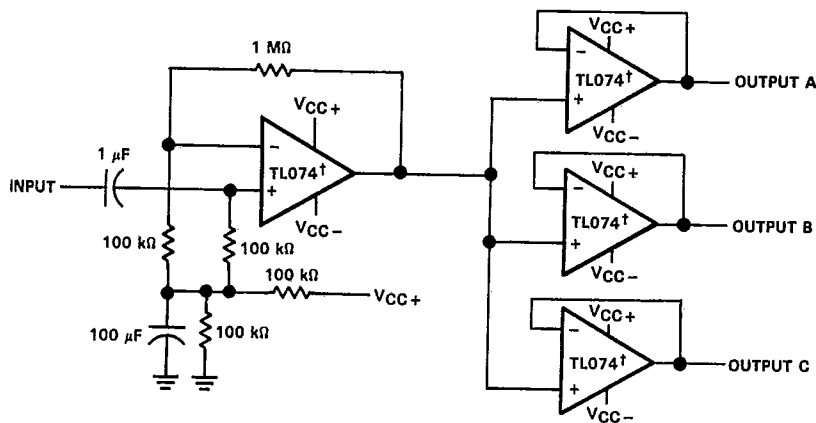


$$R_1 = R_2 = 2R_3 = 1.5 \text{ M}\Omega$$

$$C_1 = C_2 = \frac{C_3}{2} = 110 \text{ pF}$$

$$f_o = \frac{1}{2\pi R_1 C_1} = 1 \text{ kHz}$$

FIGURE 27. HIGH-Q NOTCH FILTER



† or TL075

FIGURE 28. AUDIO DISTRIBUTION AMPLIFIER

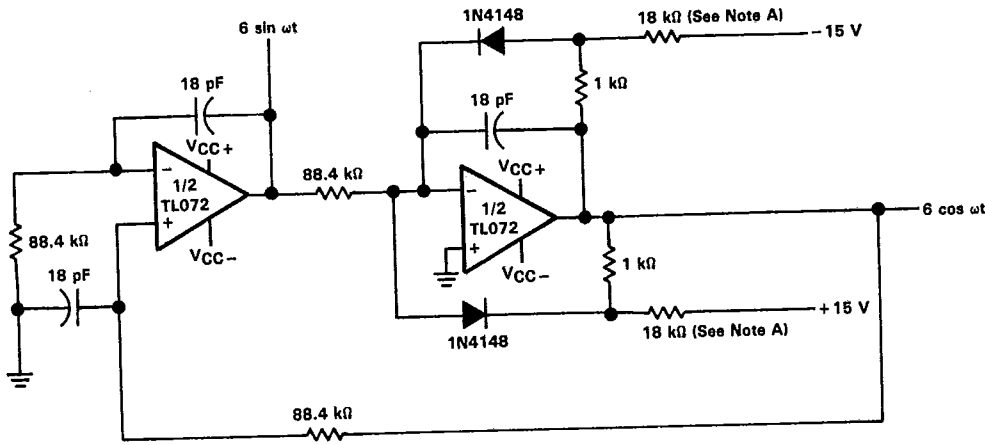
2
Operational Amplifiers

TL070, TL070A, TL071, TL071A, TL071B,
 TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075
 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

T-79-15

TYPICAL APPLICATION DATA

2
 Operational Amplifiers



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

FIGURE 29. 100-kHz QUADRATURE OSCILLATOR

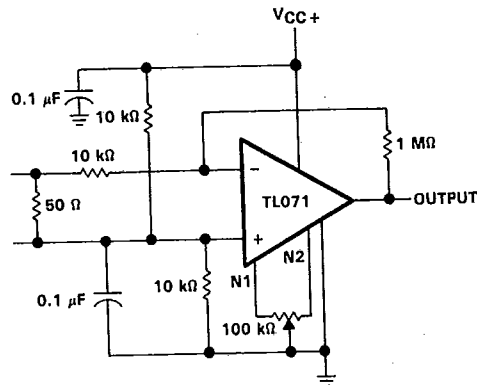


FIGURE 30. AC AMPLIFIER

TL070, TL070A, TL071, TL071A, TL071B
 TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075
 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

TYPICAL APPLICATION DATA

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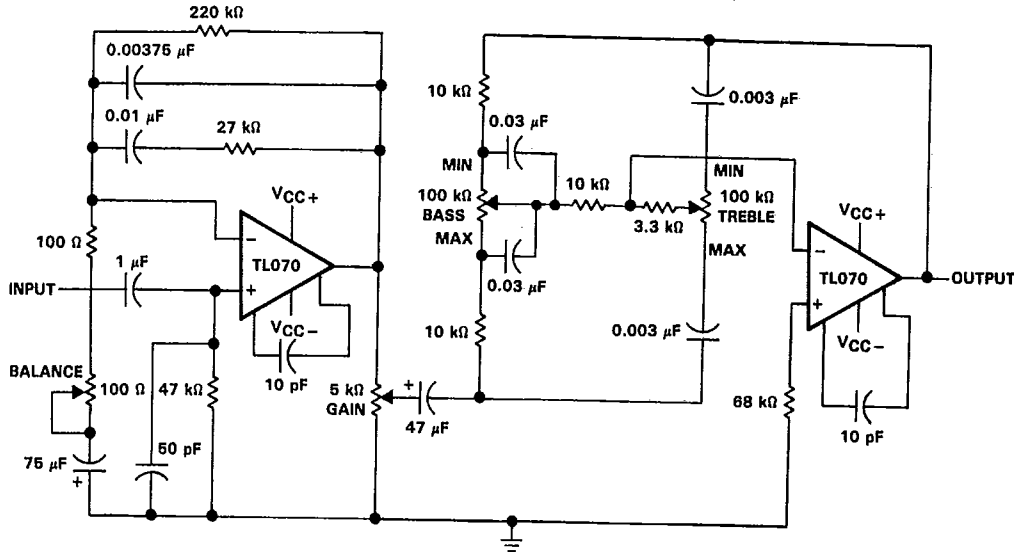


FIGURE 31. IC PREAMPLIFIER

2
Operational Amplifiers

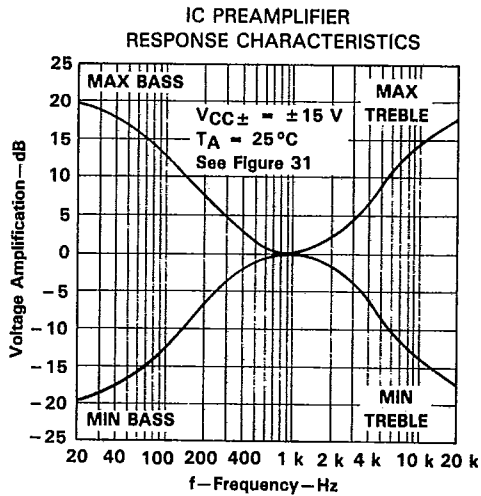


FIGURE 32