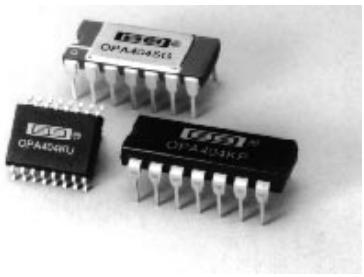
BURR-BROWN®



OPA404

Quad High-Speed Precision *Difet*® OPERATIONAL AMPLIFIER

FEATURES

- WIDE BANDWIDTH: 6.4MHz
- HIGH SLEW RATE: 35V/μs
- LOW OFFSET: ±750μV max
- LOW BIAS CURRENT: ±4pA max
- LOW SETTLING: 1.5μs to 0.01%
- STANDARD QUAD PINOUT

APPLICATIONS

- PRECISION INSTRUMENTATION
- OPTOELECTRONICS
- SONAR, ULTRASOUND
- PROFESSIONAL AUDIO EQUIPMENT
- MEDICAL EQUIPMENT
- DETECTOR ARRAYS

DESCRIPTION

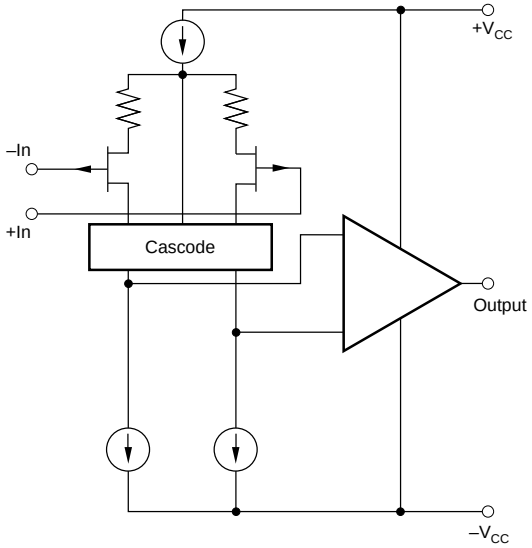
The OPA404 is a high performance monolithic ***Difet***®(dielectrically-isolated FET) quad operational amplifier. It offers an unusual combination of very-low bias current together with wide bandwidth and fast slew rate.

Noise, bias current, voltage offset, drift, and speed are superior to BIFET® amplifiers.

Laser-trimming of thin-film resistors gives very low offset and drift—the best available in a quad FET op amp.

The OPA404's input cascode design allows high precision input specifications and uncompromised high-speed performance.

Standard quad op amp pin configuration allows upgrading of existing designs to higher performance levels. The OPA404 is unity-gain stable.



OPA404 Simplified Circuit
(Each Amplifier)

Difet®, Burr-Brown Corp.
BIFET®, National Semiconductor Corp.

International Airport Industrial Park • Mailing Address: PO Box 11400 • Tucson, AZ 85734 • Street Address: 6730 S. Tucson Blvd. • Tucson, AZ 85706
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SBOS149

SPECIFICATIONS

ELECTRICAL

At V_{CC} = ±15VDC and T_A = +25°C unless otherwise noted.

PARAMETER	CONDITIONS	OPA404AG, KP, KU [1] MIN	OPA404AG, KP, KU [1] TYP	OPA404AG, KP, KU [1] MAX	OPA404BG MIN	OPA404BG TYP	OPA404BG MAX	OPA404SG MIN	OPA404SG TYP	OPA404SG MAX	UNITS
INPUT											
NOISE											
Voltage: f_O = 10Hz			32			*			*		nV/√Hz
f_O = 100Hz			19			*			*		nV/√Hz
f_O = 1kHz			15			*			*		nV/√Hz
f_O = 10kHz			12			*			*		nV/√Hz
f_B = 10Hz to 10kHz			1.4			*			*		µVrms
f_B = 0.1Hz to 10Hz			0.95			*			*		µVp-p
Current: f_B = 0.1Hz to 10Hz			12			*			*		fA, p-p
f_O = 0.1Hz thru 20kHz			0.6			*			*		fA/√Hz
OFFSET VOLTAGE											
Input Offset Voltage	V_{CM} = 0VDC		±260	±1mV		*	±750		*	*	µV
KP, KU			±750	±2.5mV							µV
Average Drift	$T_A = T_{MIN}$ to T_{MAX}		±3			*			*		µV/°C
KP, KU			±5								µV/°C
Supply Rejection	$\pm V_{CC}$ = 12V to 18V	80	100		86	*		*	*		dB
KP, KU		76	100								dB
Channel Separation	100Hz, R_L = 2kΩ		125			*			*		dB
BIAS CURRENT											
Input Bias Current	V_{CM} = 0VDC		±1	±8		*	±4		*	*	pA
KP, KU			±1	±12							pA
OFFSET CURRENT											
Input Offset Current	V_{CM} = 0VDC		0.5	8		*	4		*	*	pA
KP, KU			0.5	12							pA
IMPEDANCE											
Differential			10^{13} || 1			*			*		Ω || pF
Common-Mode			10^{14} || 3			*			*		Ω || pF
VOTAGE RANGE											
Common-Mode Input Range		±10.5	+13, –11		*	*		*	*		V
Common-Mode Rejection	V_{IN} = ±10VDC	88	100		92	*		*	*		dB
KP, KU		84	100								dB
OPEN-LOOP GAIN, DC											
Open-Loop Voltage Gain	$R_L \geq$ 2kΩ	88	100		92	*		*	*		dB
FREQUENCY RESPONSE											
Gain Bandwidth	Gain = 100	4	6.4		5	*		*	*		MHz
Full Power Response	20Vp-p, R_L = 2kΩ		570			*			*		kHz
Slew Rate	V_O = ±10V, R_L = 2kΩ	24	35		28	*		*	*		V/µs
Settling Time: 0.1%	Gain = –1, R_L = 2kΩ		0.6			*			*		µs
0.01%	C_L = 100 pF, 10V Step		1.5			*			*		µs
RATED OUTPUT											
Voltage Output	R_L = 2kΩ	±11.5	+13.2, –13.8		*	*		*	*		V
Current Output	V_O = ±10VDC	±5	±10		*	*		*	*		mA
Output Resistance	1MHz, Open Loop		80			*			*		Ω
Load Capacitance Stability	Gain = +1		1000			*			*		pF
Short Circuit Current		±10	±27	±40	*	*	*	*	*	*	mA
POWER SUPPLY											
Rated Voltage			±15			*			*		VDC
Voltage Range,											
Derated Performance		±5		±18	*		*	*		*	VDC
Current, Quiescent	I_O = 0mADC		9	10		*	*		*	*	mA
TEMPERATURE RANGE											
Specification	Ambient Temperature	–25		+85	*		*	–55		+125	°C
KP, KU		0		+70							°C
Operating	Ambient Temperature	–55		+125	*		*	*		*	°C
KP, KU		–25		+85							°C
Storage	Ambient Temperature	–65		+150	*		*	*		*	°C
KP, KU		–40		+125							°C
θ Junction-Ambient			100			*			*		°C/W
KP, KU			120/100								°C/W

*Specifications same as OPA404AG.
NOTE: (1) OPA404KU may be marked OPA404U.

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ELECTRICAL (FULL TEMPERATURE RANGE SPECIFICATIONS)

At V_{CC} = ±15VDC and $T_A = T_{MIN}$ to T_{MAX} unless otherwise noted.

PARAMETER	CONDITIONS	OPA404AG, KP, KU			OPA404BG			OPA404SG			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
TEMPERATURE RANGE											
Specification Range	Ambient Temperature	–25		+85	*		*	–55		+125	°C
KP, KU		0		+70							°C
INPUT											
OFFSET VOLTAGE											
Input Offset Voltage	V_{CM} = 0VDC		±450	2mV		*	±1.5mV		±550	±2.5mV	µV
KP KU			±1	±3.5							mV
Average Drift			±3			*			*		µV/°C
KP, KU			±5								µV/°C
Supply Rejection		75	96		80	*		70	93		dB
BIAS CURRENT											
Input Bias Current	V_{CM} = 0VDC		±32	±200		*	±100		±500	±5nA	pA
OFFSET CURRENT											
Input Offset Current	V_{CM} = 0VDC		17	100		*	50		260	2.5nA	pA
VOLTAGE RANGE											
Common-Mode Input Range		±10	±12.7, –10.6		*	*		±10	+12.6, –10.5		V
Common-Mode Rejection	V_{IN} = ±10VDC	82	99		86	*		80	88		dB
KP, KU		80	99								dB
OPEN-LOOP GAIN, DC											
Open-Loop Voltage Gain	$R_L \geq 2k\Omega$	82	94		86	*		80	88		dB
RATED OUTPUT											
Voltage Output	R_L = 2kΩ	±11.5	±12.9, –13.8		*	*		±11	+12.7, –13.8		V
Current Output	V_O = ±10VDC	±5	±9		*	*		*	±8		mA
Short Circuit Current	V_O = 0VDC	±8	±20	±50	*	*	*	*	*	*	mA
POWER SUPPLY											
Current, Quiescent	I_O = 0mADC		9.3	10.5		*	*		9.4	11	mA

* Specification same as OPA404AG.

ORDERING INFORMATION

MODEL	PACKAGE	TEMPERATURE RANGE
OPA404KP	14-Pin Plastic DIP	0°C to +70°C
OPA404KU(1)	16-Pin Plastic SOIC	0°C to +70°C
OPA404AG	14-Pin Ceramic DIP	–25°C to +85°C
OPA404BG	14-Pin Ceramic DIP	–25°C to +85°C
OPA404SG	14-Pin Ceramic DIP	–55°C to +125°C

NOTE: (1) OPA404KU may be marked OPA404U.

PACKAGE INFORMATION

MODEL	PACKAGE	PACKAGE DRAWING NUMBER(1)
OPA404KP	14-Pin Plastic DIP	010
OPA404KU(2)	16-Pin Plastic SOIC	211
OPA404AG	14-Pin Ceramic DIP	169
OPA404BG	14-Pin Ceramic DIP	169
OPA404SG	14-Pin Ceramic DIP	169

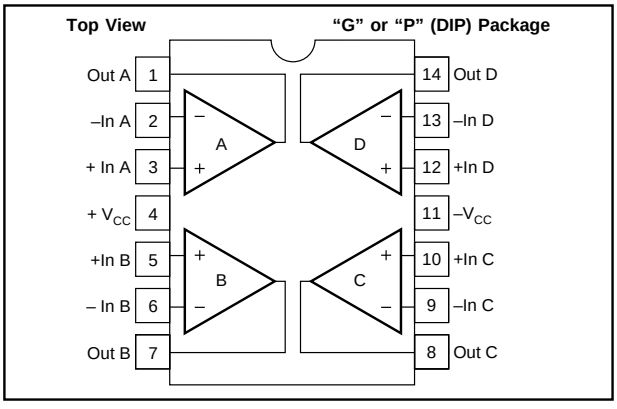
NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix D of Burr-Brown IC Data Book. (2) OPA404KU may be marked OPA404U.

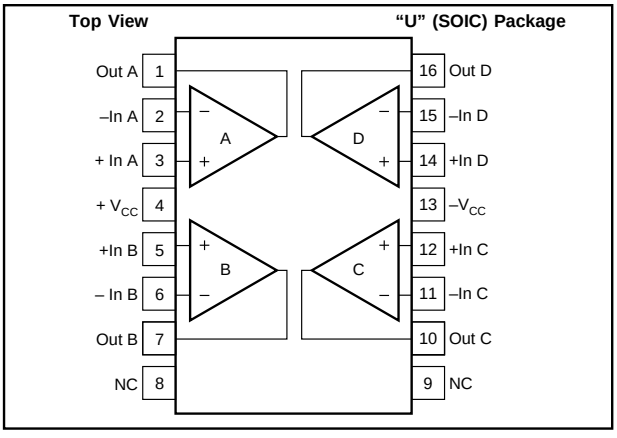
ABSOLUTE MAXIMUM RATINGS

Supply ..... ±18VDC
Internal Power Dissipation(1) 1000mW
Differential Input Voltage(2) ..... ±36VDC
Input Voltage Range(2) ..... ±18VDC
Storage Temperature Range ... P, U = –40°C/+125°C, G = –65°C/+150°C
Operating Temperature Range .. P, U = –25°C/+85°C, G = –55°C/+125°C
Lead Temperature (soldering, 10s) ..... 300°C
SOIC (soldering, 3s) ..... +260°C
Output Short-Circuit Duration(3) ..... Continuous
Junction Temperature ..... +175°C

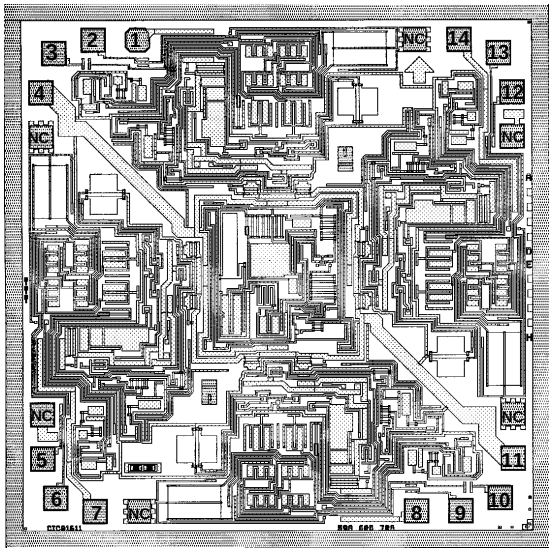
NOTES: (1) Packages must be derated based on θ_{JC} = 30°C/W or θ_{JA} = 120°C/W. (2) For supply voltages less than ±18VDC the absolute maximum input voltage is equal to: 18V > V_{IN} > $-V_{CC}$ – 8V. See Figure 2. (3) Short circuit may be to power supply common only. Rating applies to +25°C ambient. Observe dissipation limit and T_J.

PIN CONFIGURATION





DICE INFORMATION



OPA404 DIE TOPOGRAPHY

PAD	FUNCTION	PAD	FUNCTION
1	Output A	8	Output C
2	–Input A	9	–Input C
3	+Input A	10	+Input C
4	$+V_{CC}$	11	$-V_{CC}$
5	+Input B	12	+Input D
6	–Input B	13	–Input D
7	Output B	14	Output D

Substrate Bias: $-V_{CC}$
NC: No connection

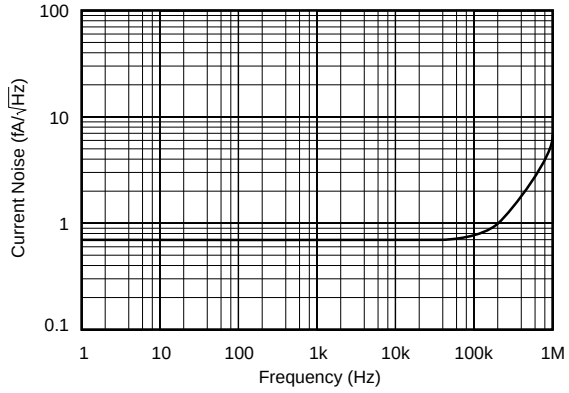
MECHANICAL INFORMATION

	MILS (0.001")	MILLIMETERS
Die Size	108 x 108 ±5	2.74 x 2.74 ±0.13
Die Thickness	20 ±3	0.51 ±0.08
Min. Pad Size	4 x 4	0.10 x 0.10
Backing		None

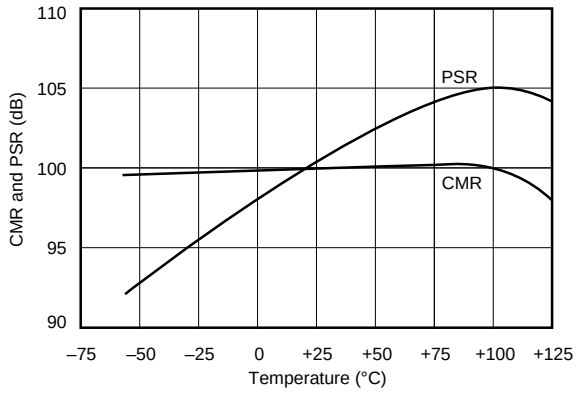
TYPICAL PERFORMANCE CURVES

T_A = +25°C, V_{CC} = ±15VDC unless otherwise noted.

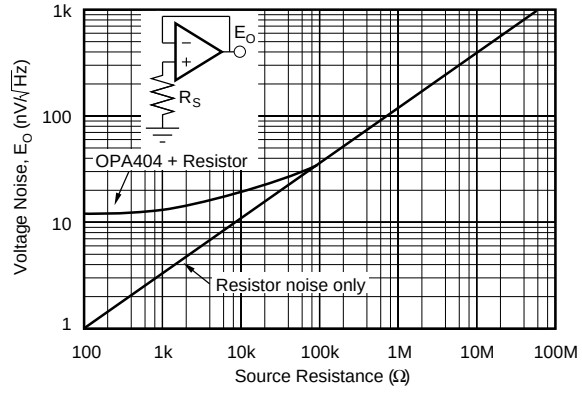
INPUT CURRENT NOISE SPECTRAL DENSITY



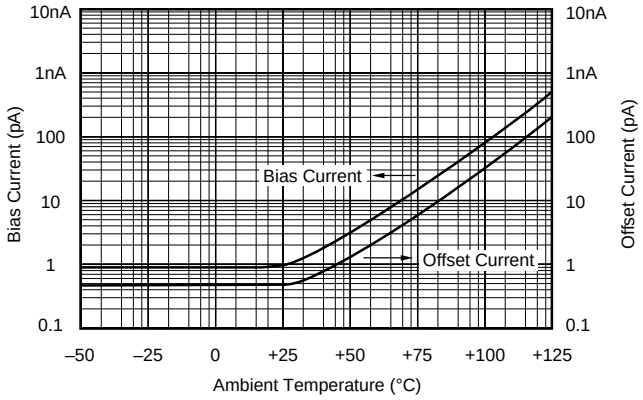
POWER SUPPLY REJECTION AND COMMON-MODE REJECTION vs TEMPERATURE



TOTAL INPUT VOLTAGE NOISE SPECTRAL DENSITY AT 1kHz vs SOURCE RESISTANCE



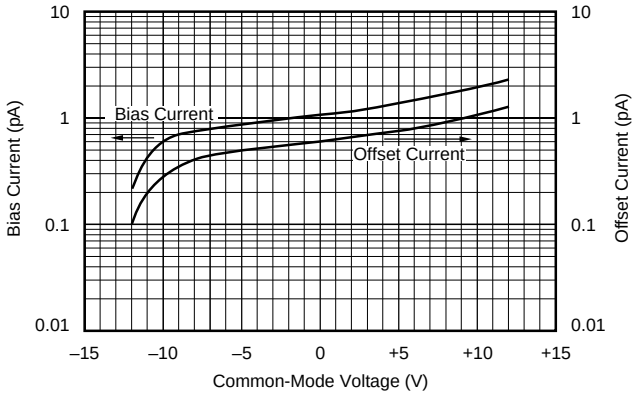
BIAS AND OFFSET CURRENT vs TEMPERATURE



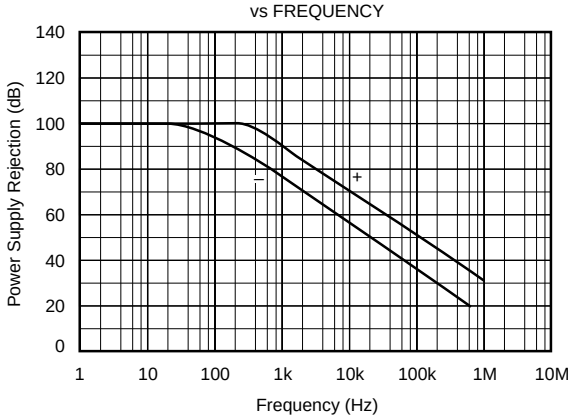
TYPICAL PERFORMANCE CURVES (CONT)

T_A = +25°C, V_{CC} = ±15VDC unless otherwise noted.

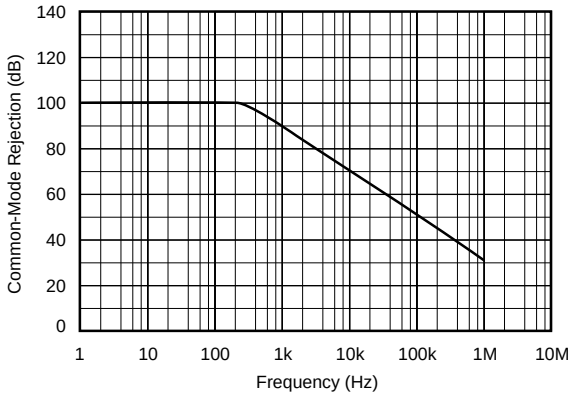
BIAS AND OFFSET CURRENT
vs INPUT COMMON-MODE VOLTAGE



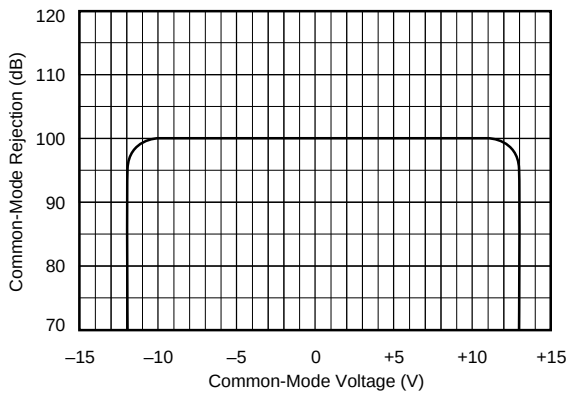
POWER SUPPLY REJECTION
vs FREQUENCY



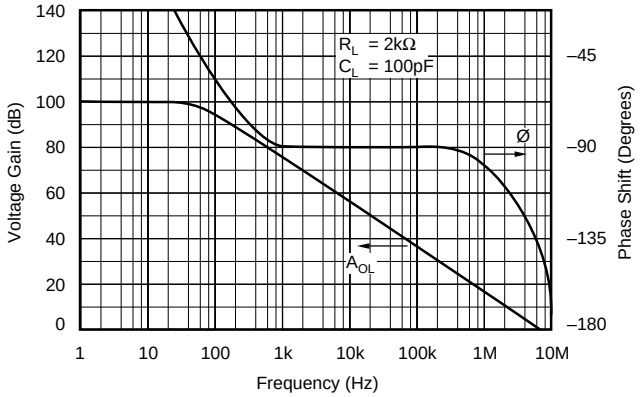
COMMON-MODE REJECTION
vs FREQUENCY



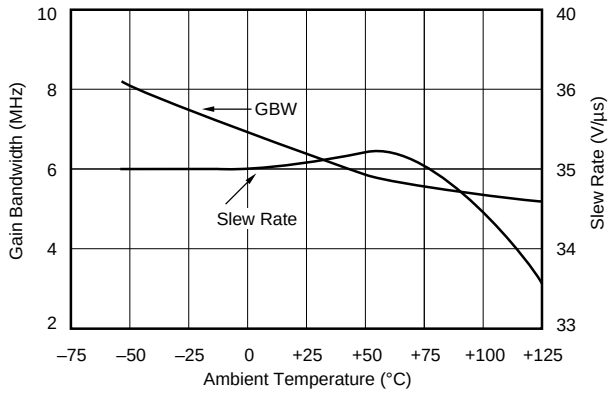
COMMON-MODE REJECTION
vs INPUT COMMON-MODE VOLTAGE



OPEN-LOOP FREQUENCY RESPONSE



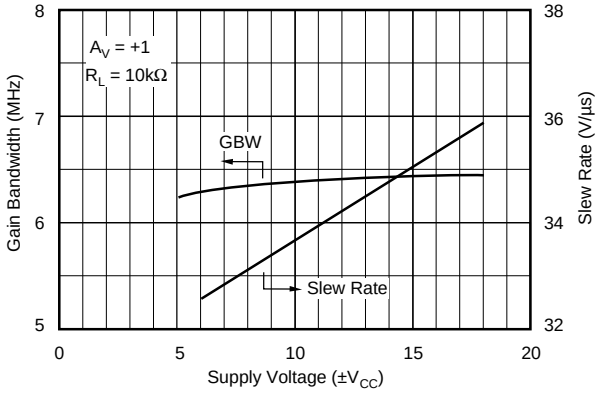
GAIN BANDWIDTH AND SLEW RATE
vs TEMPERATURE



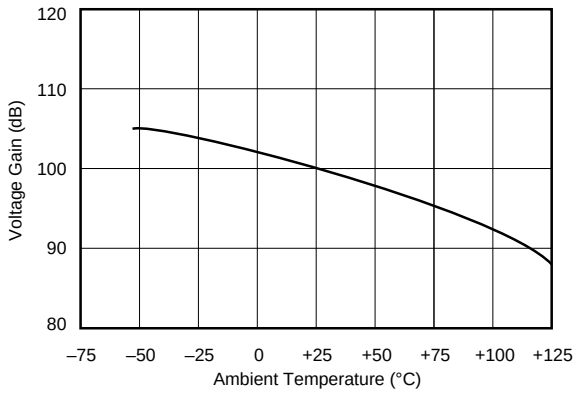
TYPICAL PERFORMANCE CURVES (CONT)

T_A = +25°C, V_{CC} = ±15VDC unless otherwise noted.

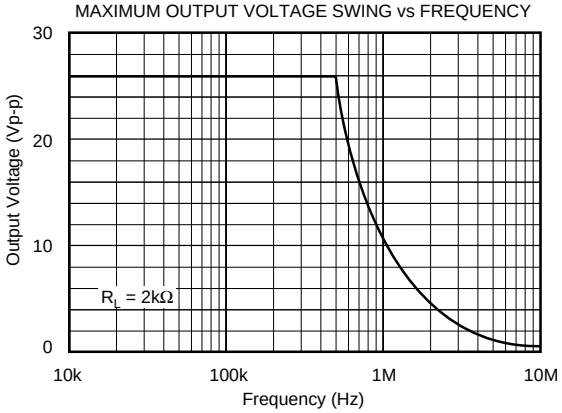
GAIN-BANDWIDTH AND SLEW RATE vs SUPPLY VOLTAGE



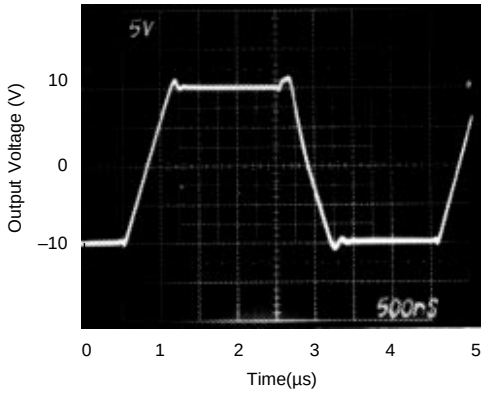
OPEN-LOOP GAIN vs TEMPERATURE



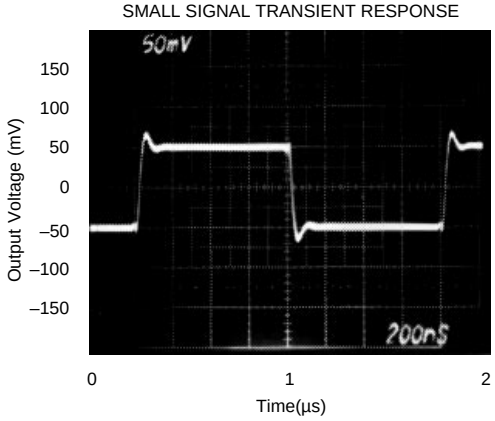
MAXIMUM OUTPUT VOLTAGE SWING vs FREQUENCY



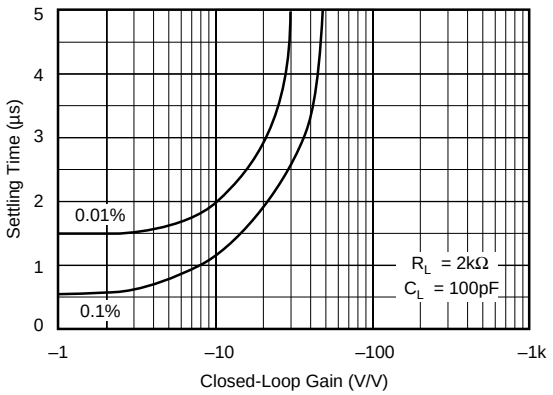
LARGE SIGNAL TRANSIENT RESPONSE



SMALL SIGNAL TRANSIENT RESPONSE



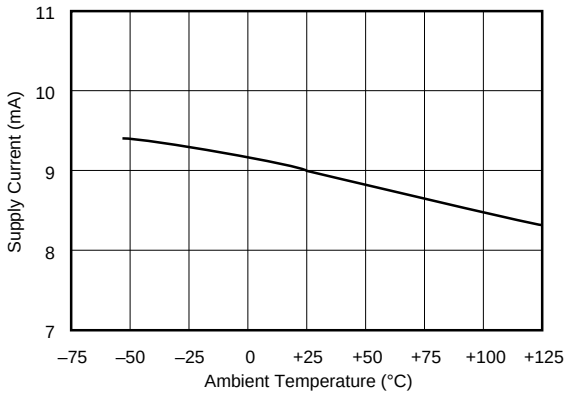
SETTLING TIME vs CLOSED-LOOP GAIN



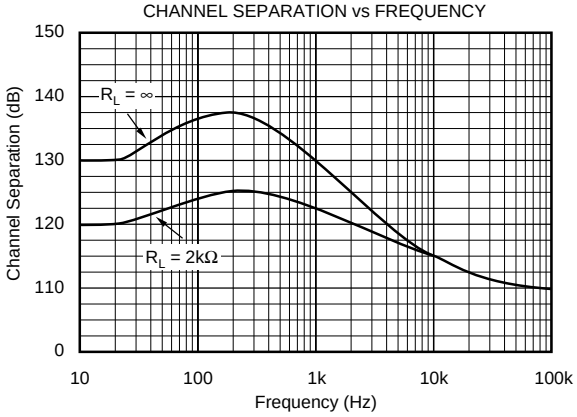
TYPICAL PERFORMANCE CURVES (CONT)

T_A = +25°C, V_{CC} = ±15VDC unless otherwise noted.

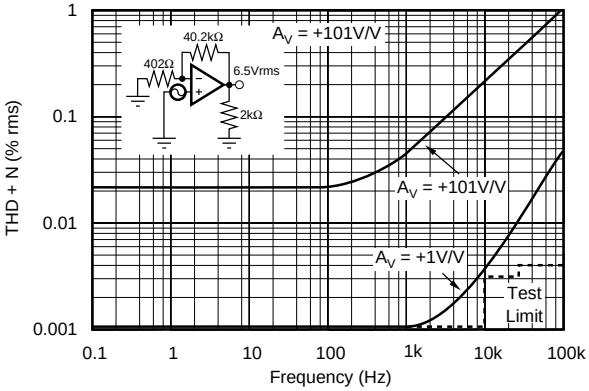
SUPPLY CURRENT vs TEMPERATURE



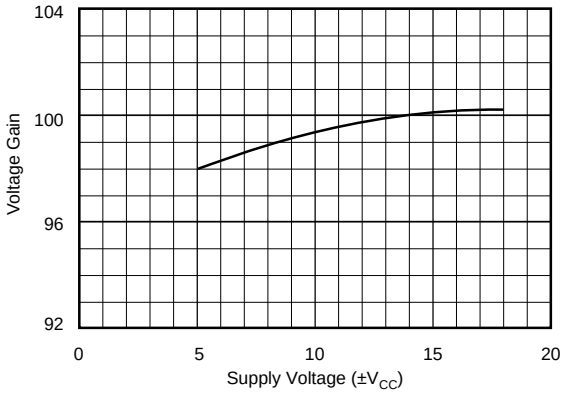
CHANNEL SEPARATION vs FREQUENCY



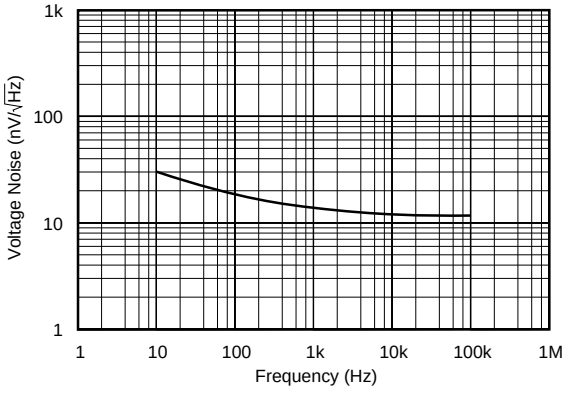
TOTAL HARMONIC DISTORTION vs FREQUENCY



OPEN-LOOP GAIN vs SUPPLY VOLTAGE



INPUT VOLTAGE NOISE SPECTRAL DENSITY



APPLICATIONS INFORMATION

OFFSET VOLTAGE ADJUSTMENT

The OPA404 offset voltage is laser-trimmed and will require no further trim for most applications. If desired, offset voltage can be trimmed by summing (see Figure 1). With this trim method there will be no degradation of input offset drift.

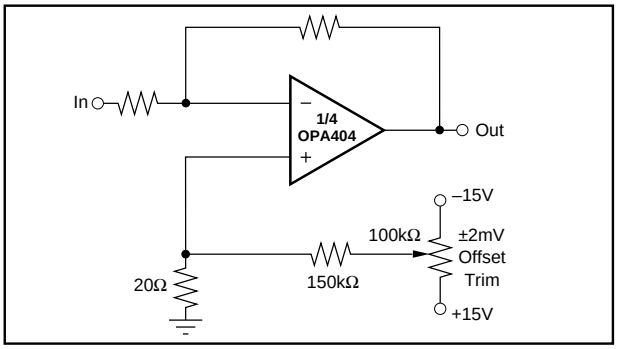


FIGURE 1. Offset Voltage Trim.

INPUT PROTECTION

Conventional monolithic FET operational amplifiers require external current-limiting resistors to protect their inputs against destructive currents that can flow when input FET gate-to-substrate isolation diodes are forward-biased. Most BIFET amplifiers can be destroyed by the loss of $-V_{CC}$.

Unlike BIFET amplifiers, the ***Difet*** OPA404 requires input current limiting resistors only if its input voltage is greater than 8 volts more negative than $-V_{CC}$. A 10kΩ series resistor will limit the input current to a safe value with up to ±15V input levels even if both supply voltages are lost. (See Figure 2 and Absolute Maximum Ratings).

Static damage can cause subtle changes in amplifier input characteristics without necessarily destroying the device. In precision operational amplifiers (both bipolar and FET types), this may cause a noticeable degradation of offset voltage and drift.

Static protection is recommended when handling any precision IC operational amplifier.

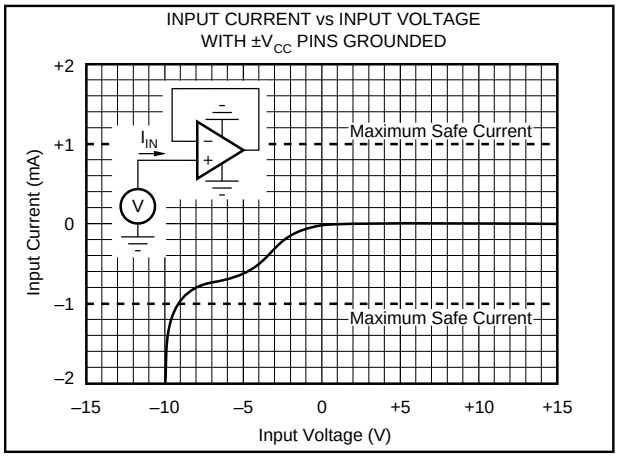


FIGURE 2. Input Current vs Input Voltage with $\pm V_{CC}$ Pins Grounded.

GUARDING AND SHIELDING

As in any situation where high impedances are involved, careful shielding is required to reduce "hum" pickup in input leads. If large feedback resistors are used, they should also be shielded along with the external input circuitry.

Leakage currents across printed circuit boards can easily exceed the bias current of the OPA404. To avoid leakage, utmost care must be used in planning the board layout. A "guard" pattern should completely surround the high impedance input leads and should be connected to a low-impedance point which is at the signal input potential. (See Figure 3).

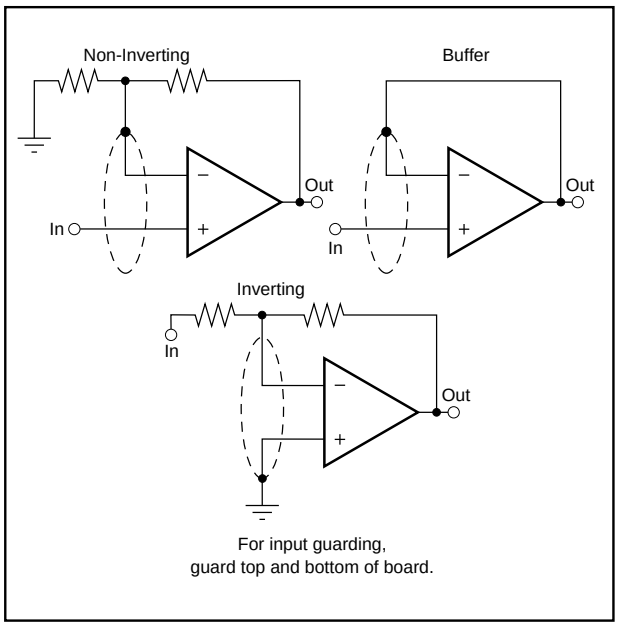


FIGURE 3. Connection of Input Guard.

HANDLING AND TESTING

Measuring the unusually low bias current of the OPA404 is difficult without specialized test equipment; most commercial benchtop testers cannot accurately measure the OPA404 bias current. Low-leakage test sockets and special test fixtures are recommended if incoming inspection of bias current is to be performed.

To prevent surface leakage between pins, the DIP package should not be handled by bare fingers. Oils and salts from fingerprints or careless handling can create leakage currents that exceed the specified OPA404 bias currents.

If necessary, DIP packages and PC board assemblies can be cleaned with Freon TF®, baked for 30 minutes at 85°C, rinsed with de-ionized water, and baked again for 30 minutes at 85°C. Surface contamination can be prevented by the application of a high-quality conformal coating to the cleaned PC board assembly.

BIAS CURRENT CHANGE vs COMMON-MODE VOLTAGE

The input bias currents of most popular BIFET operational amplifiers are affected by common-mode voltage (Figure 4). Higher input FET gate-to-drain voltage causes leakage and ionization (bias) currents to increase. Due to its cascode input stage, the extremely low bias current of the OPA404 is not compromised by common-mode voltage.

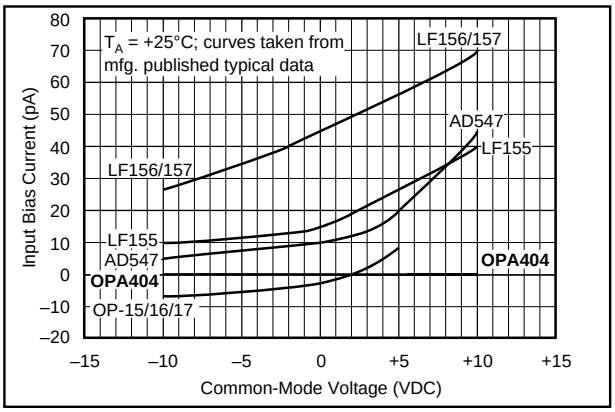


FIGURE 4. Input Bias Current vs Common-Mode Voltage.

APPLICATIONS CIRCUITS

Figures 5 through 11 are circuit diagrams of various applications for the OPA404.

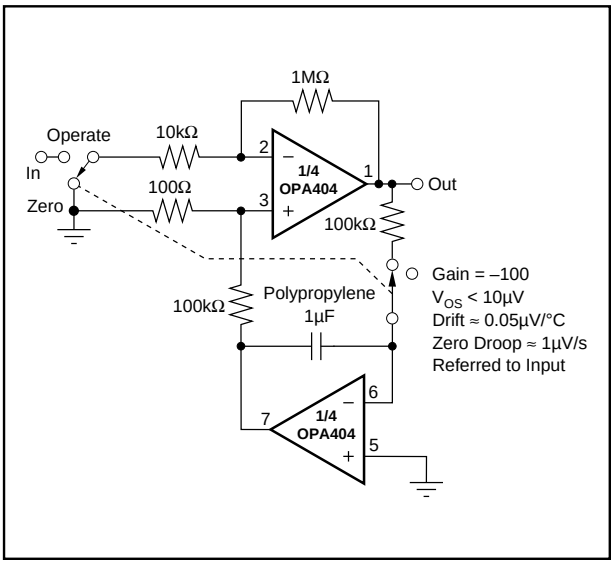


FIGURE 5. Auto-Zero Amplifier.

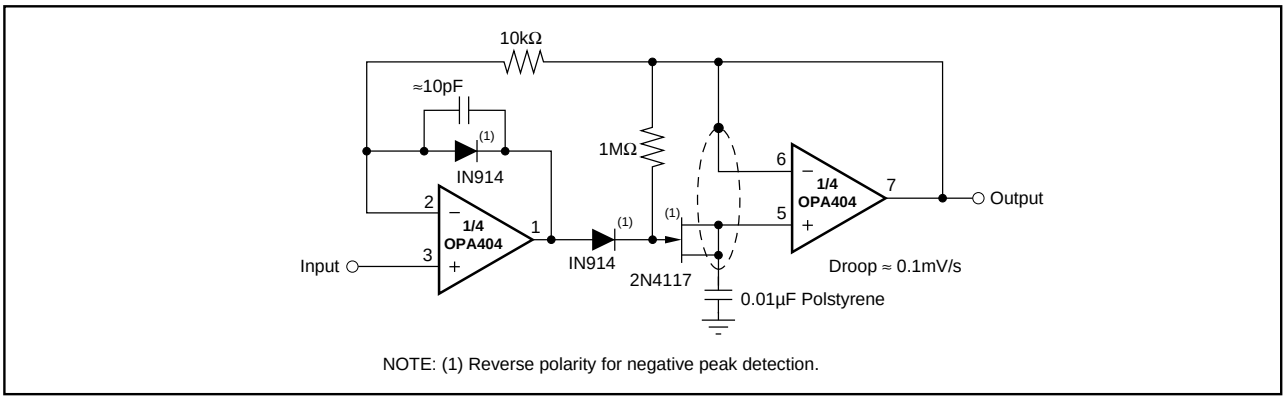


FIGURE 6. Low-Droop Positive Peak Detector.

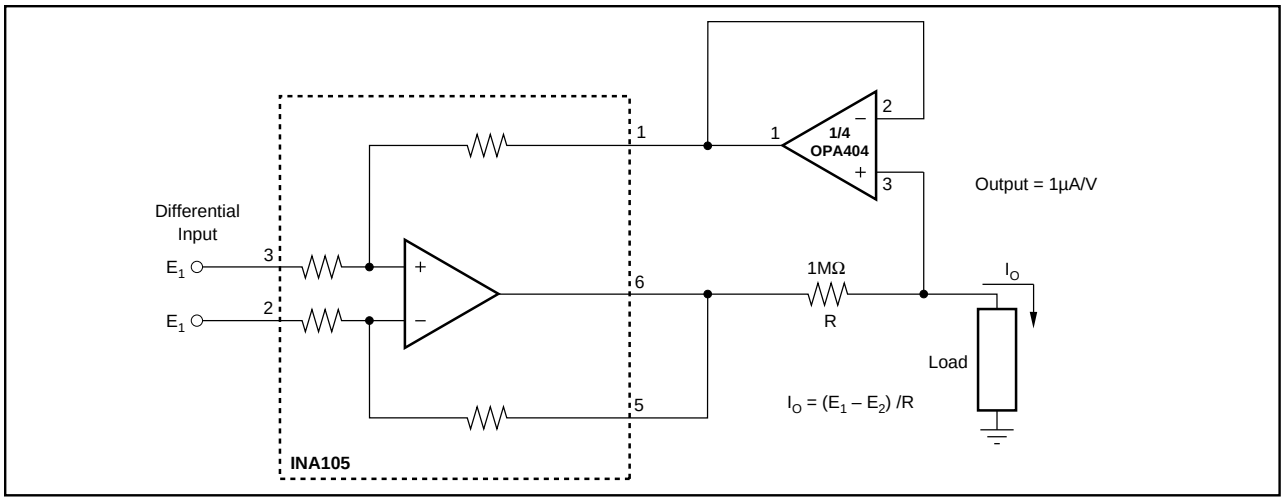


FIGURE 7. Voltage-Controlled Microamp Current Source.

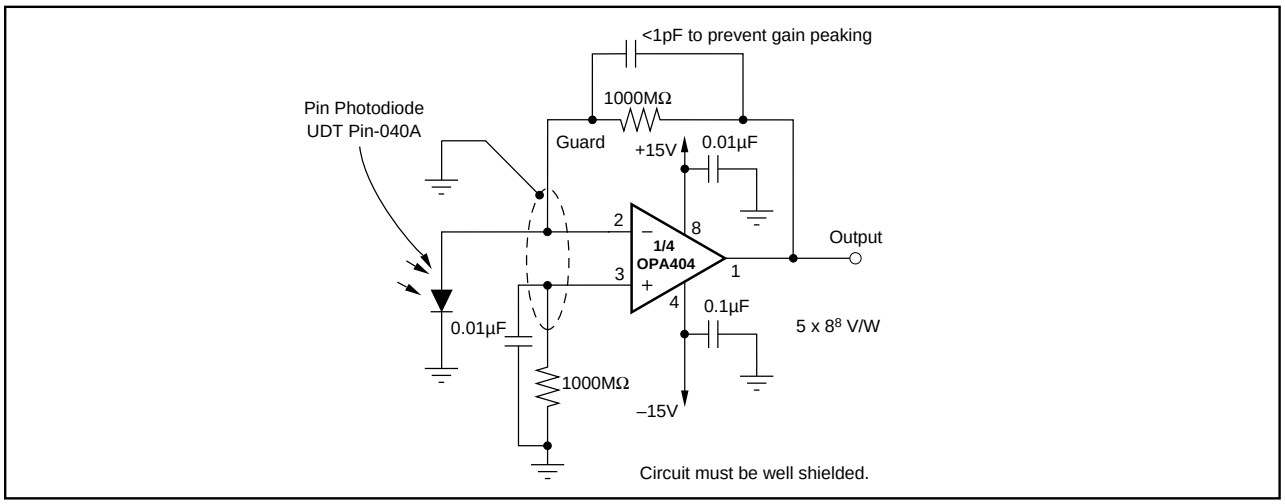


FIGURE 8. Sensitive Photodiode Amplifier.

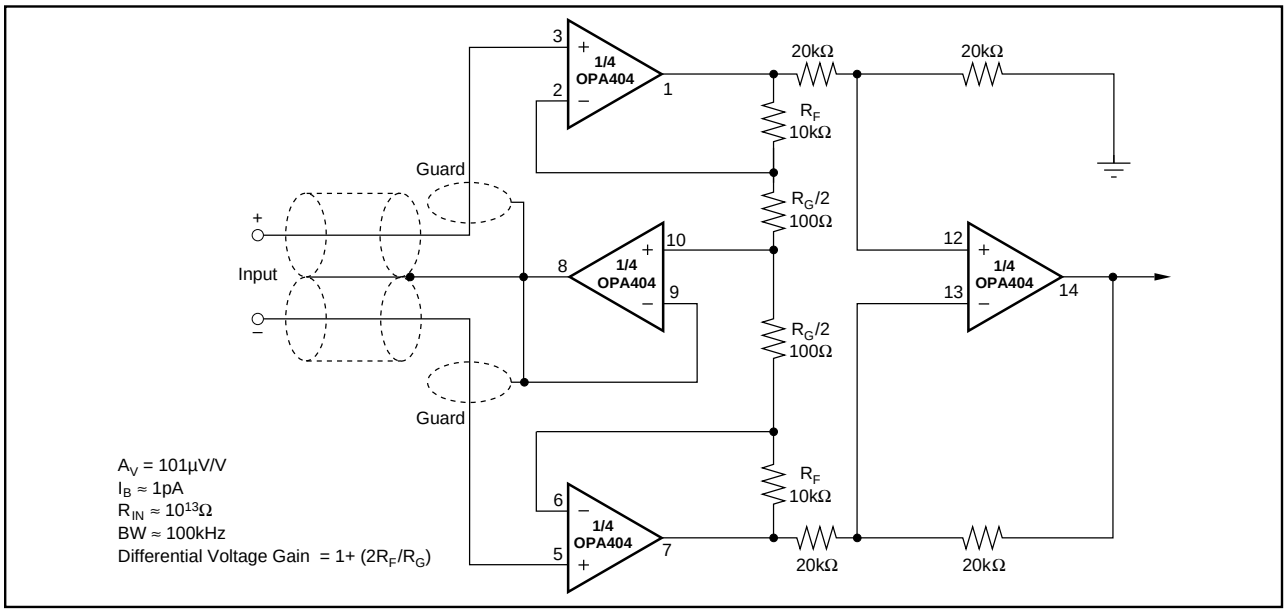


FIGURE 9. FET Instrumentation Amplifier with Shield Driver.

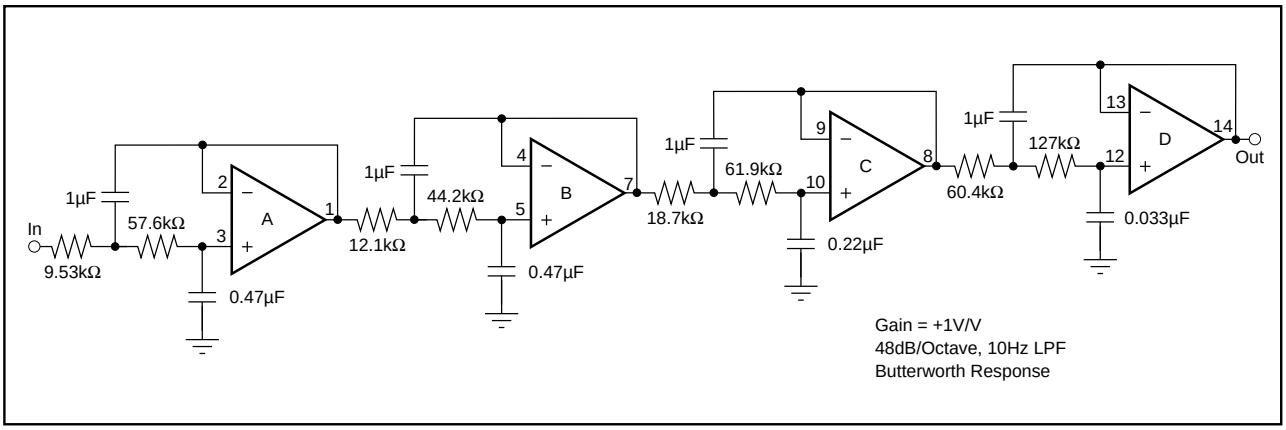


FIGURE 10. 8-Pole 10Hz Low-Pass Filter.

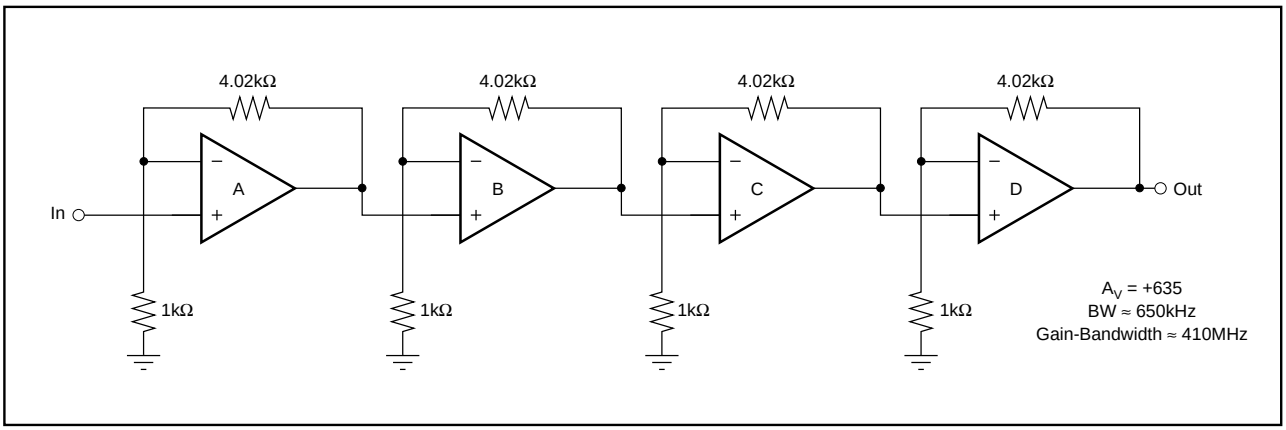


FIGURE 11. Wide-Band Amplifier.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
OPA404AG	NRND	CDIP SB	JD	14	27	Green (RoHS & no Sb/Br)	Call TI	N / A for Pkg Type
OPA404BG	NRND	CDIP SB	JD	14	27	Green (RoHS & no Sb/Br)	Call TI	N / A for Pkg Type
OPA404KP	ACTIVE	PDIP	N	14	25	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type
OPA404KPG4	ACTIVE	PDIP	N	14	25	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type
OPA404KU	ACTIVE	SOIC	DW	16	48	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR
OPA404KU/1K	ACTIVE	SOIC	DW	16	1000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR
OPA404KU/1KE4	ACTIVE	SOIC	DW	16	1000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR
OPA404KUG4	ACTIVE	SOIC	DW	16	48	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR
OPA404SG	NRND	CDIP SB	JD	14	27	Green (RoHS & no Sb/Br)	Call TI	N / A for Pkg Type

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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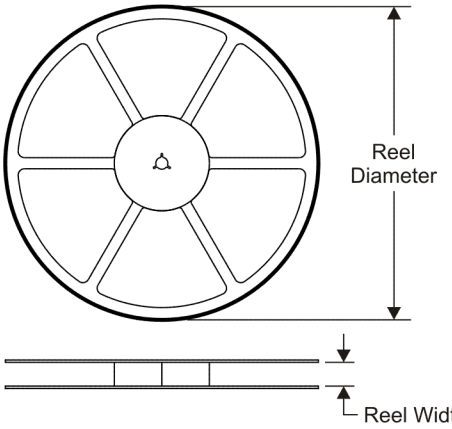
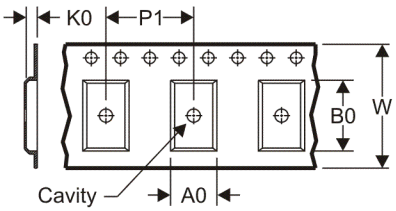
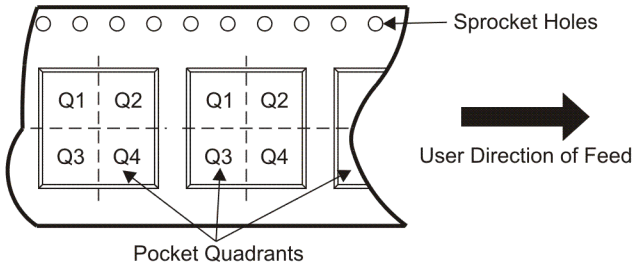


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

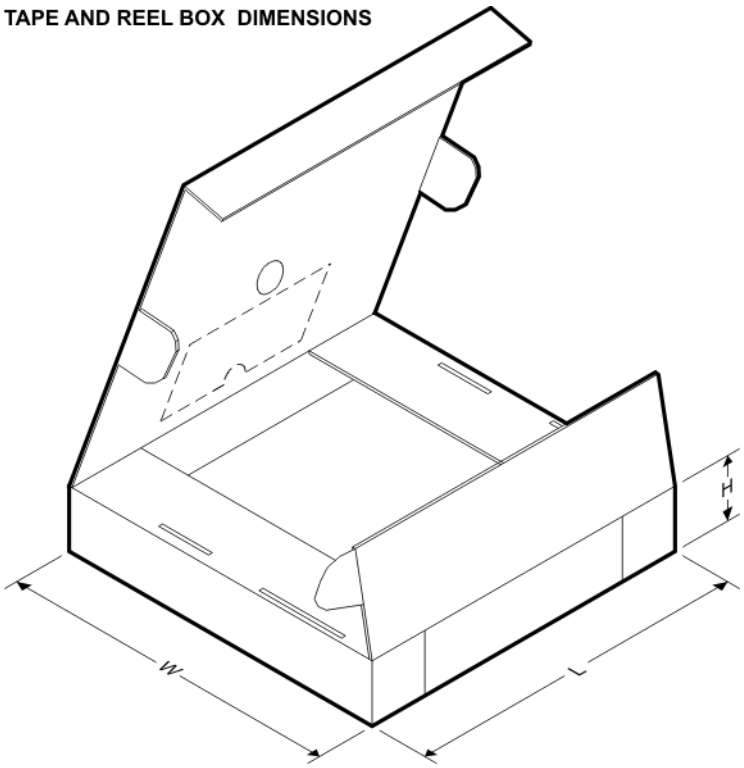
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
OPA404KU/1K	SOIC	DW	16	1000	330.0	16.4	10.85	10.8	2.7	12.0	16.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
OPA404KU/1K	SOIC	DW	16	1000	346.0	346.0	33.0

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