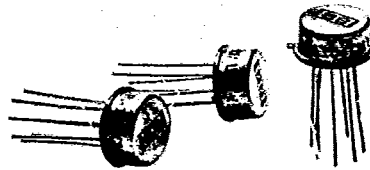


**BURR-BROWN®**  
**BB**

T-79-15  
**OPA104**



## Ultra-Low Bias Current Low Drift FET Input OPERATIONAL AMPLIFIER

### FEATURES

- SPECIFICATIONS GUARANTEED OVER TEMPERATURE
- ULTRA-LOW BIAS CURRENT, 75fA, max
- HIGH INPUT IMPEDANCE,  $10^{15}\Omega$
- LOW DRIFT,  $10\mu\text{V}/^\circ\text{C}$ , max
- LOW OFFSET VOLTAGE, 0.5mV, max
- LOW QUIESCENT CURRENT, 1.5mA, max

### DESCRIPTION

The OPA104 is a precision low bias current operational amplifier. Guaranteed low initial offset voltage (0.5mV, max) and associated drift versus temperature ( $10\mu\text{V}/^\circ\text{C}$ , max) is achieved by laser-adjusting the amplifier during manufacturing. The low offset, in addition to the guaranteed low bias current (75fA, max), allows greater system accuracy with no external components.

Quiescent current (1.5mA, max) is unaffected by changes in ambient temperature or power supply voltage. Other characteristics of the OPA104 include internal compensation for unity-gain stability and

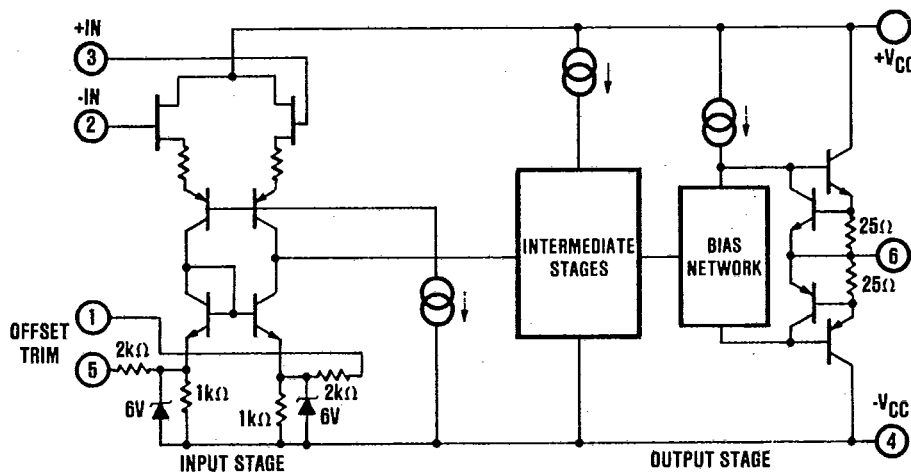
### APPLICATIONS

- CURRENT TO VOLTAGE CONVERSION
- LONG TERM PRECISION INTEGRATION
- PRECISION VOLTAGE AMPLIFICATION FOR HIGH INPUT IMPEDANCE APPLICATIONS SUCH AS:
  - photo current detectors
  - pH electrodes
  - biological probes/transducers

rapid thermal response for quick stabilization after turn-on or ambient temperature changes.

The amplifier is free from latch-up and is protected for continuous output shorts to common. As an added protection feature, either of the trim pins can be accidentally shorted to a potential greater than the negative supply voltage without damage.

The standard pin configuration (741 type) of the OPA104 allows the user drop-in replacement capability. A pin 8 case connection permits the reduction of noise and leakage by employing guarding techniques.



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# SPECIFICATIONS

## ELECTRICAL

At  $T_A = +25^\circ\text{C}$  and  $\pm V_{CC} = \pm 15\text{VDC}$  unless otherwise noted.

MODEL	OPA104AM			OPA104BM			OPA104CM			UNITS
	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
<b>OPEN-LOOP GAIN, DC, <math>V_{OUT} = \pm 10\text{V}</math></b>										
Rated Load, $R_L \geq 2\text{k}\Omega$	100	108		*	*		*	*		dB
$R_L \geq 10\text{k}\Omega$	106	112		*	*		*	*		dB
$T_A = -25^\circ\text{C}$ to $+85^\circ\text{C}$ , $R_L \geq 2\text{k}\Omega$	92	100		*	*		*	*		dB
<b>RATED OUTPUT</b>										
Voltage at $R_L = 2\text{k}\Omega$ , $T_A = -25^\circ\text{C}$ to $+85^\circ\text{C}$	$\pm 10$	$\pm 12$		*	*		*	*		V
$R_L = 10\text{k}\Omega$ , $T_A = -25^\circ\text{C}$ to $+85^\circ\text{C}$	$\pm 12$	$\pm 13$		*	*		*	*		V
Current $T_A = -25^\circ\text{C}$ to $+85^\circ\text{C}$	$\pm 5$	$\pm 10$		*	*		*	*		mA
Output Impedance		3		*	*		*	*		k $\Omega$
Load Capacitance(1)	500	1000		*	*		*	*		pF
Short Circuit Current	10	25		*	*		*	*		mA
<b>FREQUENCY RESPONSE</b>										
Unity Gain, Small Signal		1		*	*		*	*		MHz
Full Power Response	25	35		*	*		*	*		kHz
Slew Rate	1.6	2.2		*	*		*	*		V/ $\mu\text{sec}$
Settling Time (0.1%), $A_V = -1$ , $V_O = 0$ to $\pm 10\text{V}$		6		*	*		*	*		$\mu\text{sec}$
Settling Time (0.01%), $A_V = -1$ , $V_O = 0$ to $\pm 10\text{V}$		18		*	*		*	*		$\mu\text{sec}$
Overload Recovery(2), 50% overdrive		4	15	*	*		*	*		$\mu\text{sec}$
<b>INPUT OFFSET VOLTAGE</b>										
Initial Offset, $T_A = +25^\circ\text{C}$		$\pm 200$	$\pm 1000$		$\pm 200$	$\pm 500$		$\pm 200$	$\pm 500$	$\mu\text{V}$
vs Temperature, $T_A = -25^\circ\text{C}$ to $+85^\circ\text{C}$		$\pm 15$	$\pm 25$		$\pm 10$	$\pm 15$		$\pm 5$	$\pm 10$	$\mu\text{V}/^\circ\text{C}$
vs Supply Voltage, $T_A = +25^\circ\text{C}$		$\pm 10$	$\pm 100$		*	*		*	*	$\mu\text{V}/\text{V}$
vs Supply Voltage, $T_A = -25^\circ\text{C}$ to $+85^\circ\text{C}$		$\pm 20$	$\pm 150$		*	*		*	*	$\mu\text{V}/\text{V}$
<b>INPUT BIAS CURRENT(3)</b>										
Initial Bias, $T_A = +25^\circ\text{C}$			-300			-150			-75	fA
vs Supply Voltage		1								fA/V
<b>INPUT DIFFERENCE CURRENT</b>										
Initial Difference, $T_A = +25^\circ\text{C}$		$\pm 80$			$\pm 80$			$\pm 40$		fA
<b>INPUT IMPEDANCE</b>										
Differential		$10^{14} \parallel 0.5$			*			*		$\Omega \parallel \text{pF}$
Common-mode		$10^{15} \parallel 1.0$			*			*		$\Omega \parallel \text{pF}$
<b>INPUT NOISE</b>										
Voltage, $f_o = 10\text{Hz}$		75			*			*		nV/ $\sqrt{\text{Hz}}$
$f_o = 100\text{Hz}$		55			*			*		nV/ $\sqrt{\text{Hz}}$
$f_o = 1\text{kHz}$		35			*			*		nV/ $\sqrt{\text{Hz}}$
$f_o = 10\text{kHz}$		35			*			*		nV/ $\sqrt{\text{Hz}}$
$f_B = 0.1\text{Hz}$ to $10\text{Hz}$		6			*			*		$\mu\text{V}$ , p-p
Current, $f_B = 0.1\text{Hz}$ to $10\text{Hz}$		3			*			*		fA, p-p
$f_B = 10\text{Hz}$ to $10\text{kHz}$		10			*			*		fA, rms
$f_o = 1\text{kHz}$		0.25			*			*		fA/ $\sqrt{\text{Hz}}$
<b>INPUT VOLTAGE RANGE</b>										
Differential	$\pm 20$			*	*		*	*		V
Common-mode, $T_A = -25^\circ\text{C}$ to $+85^\circ\text{C}$	$\pm 10$	$\pm 12$		*	*		*	*		V
Common-mode Rejection at $V_{IN} = \pm 10\text{V}$	66	76		*	*		80	90		dB
Maximum Safe Input Voltage		$\pm V_S$		*	*		*	*		V
<b>POWER SUPPLY</b>										
Rated Voltage		$\pm 15$		*	*		*	*		VDC
Voltage Range, derated performance	$\pm 5$		$\pm 20$	*	*		*	*		VDC
Current, quiescent $T_A = -25^\circ\text{C}$ to $+85^\circ\text{C}$		1.0	1.5	*	*		*	*		mA
<b>TEMPERATURE RANGE (ambient)</b>										
Specification	-25		+85	*	*		*	*		$^\circ\text{C}$
Operating	-55		+125	*	*		*	*		$^\circ\text{C}$
Storage	-65		+150	*	*		*	*		$^\circ\text{C}$
$\theta$ junction - ambient		235		*	*		*	*		$^\circ\text{C}/\text{W}$

\*Specifications same as for OPA104AM.

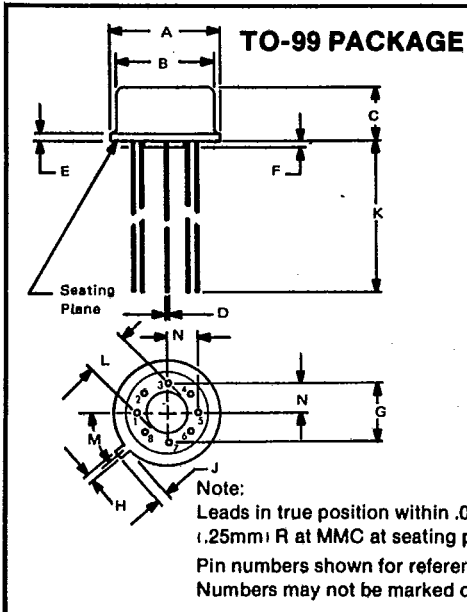
**NOTES:**

1. Stability guaranteed with load capacitance  $\leq 500\text{pF}$ .
2. Overload recovery is defined as the time required for the output to return from saturation to linear operation following the removal of a 50% input overdrive signal.
3. Bias current is tested and guaranteed after 5 minutes of operation at  $T_A = +25^\circ\text{C}$ . For higher temperature the bias current doubles approximately every  $+10^\circ\text{C}$ .

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MECHANICAL

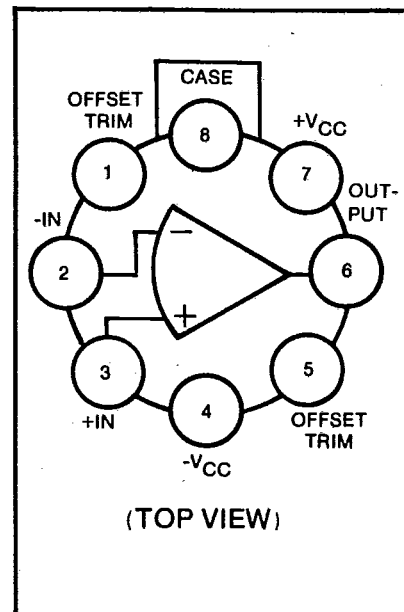
CONNECTION DIAGRAM



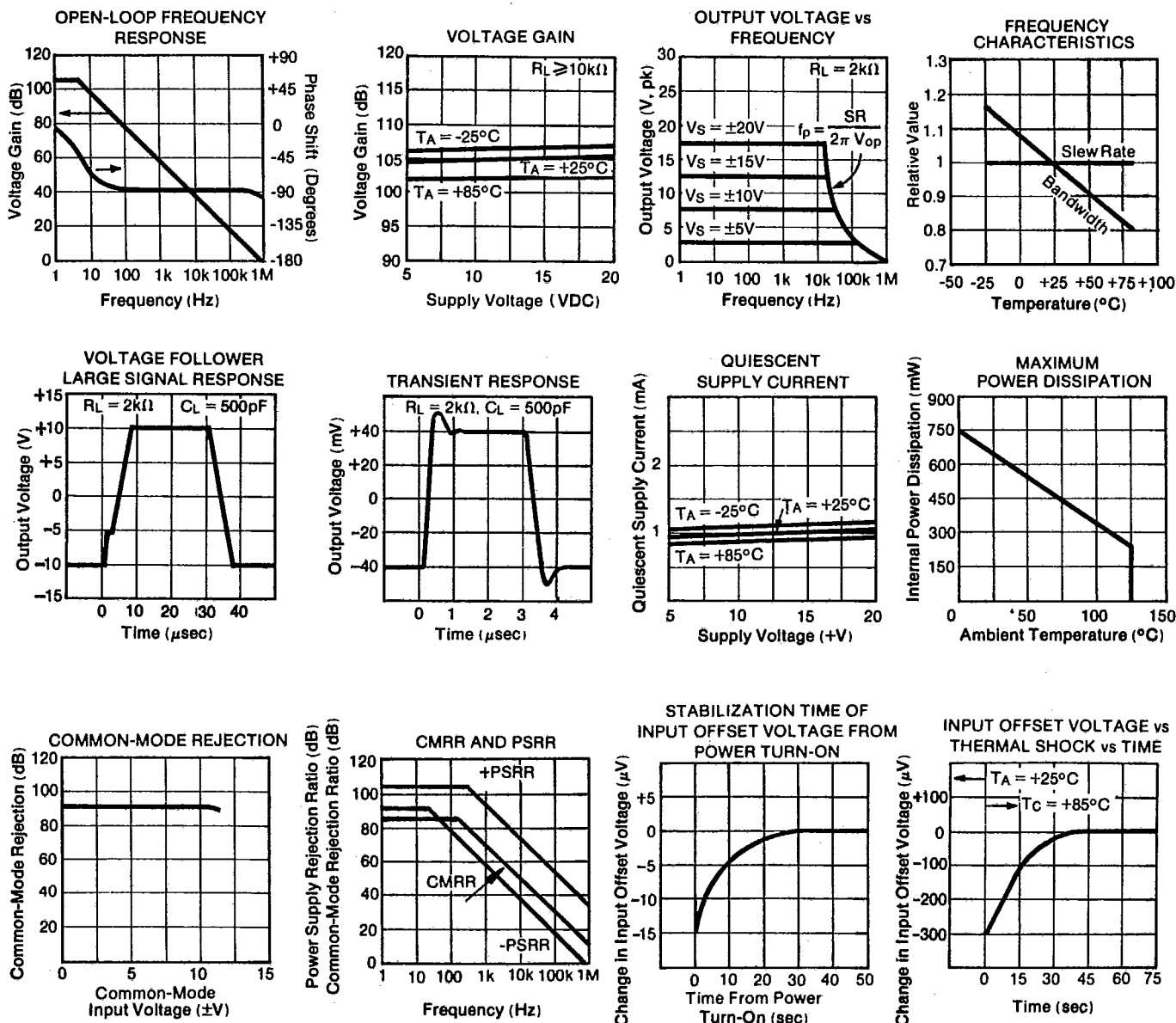
DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.335	.370	8.51	9.40
B	.305	.335	7.75	8.51
C	.165	.185	4.19	4.70
D	.016	.021	0.41	0.53
E	.010	.040	0.25	1.02
F	.010	.040	0.25	1.02
G	.200 BASIC		5.08 BASIC	
H	.028	.034	0.71	0.86
J	.029	.045	0.74	1.14
K	.500	---	12.7	---
L	.110	.160	2.79	4.06
M	45° BASIC		45° BASIC	
N	.095	.105	2.41	2.67

Weight: 1 gram

Pin material and plating composition conform to Method 2003 (solderability of MIL-STD-883 except paragraph 3.2).



TYPICAL PERFORMANCE CURVES



## APPLICATIONS INFORMATION

### THERMAL RESPONSE TIME

Thermal response time is an important parameter in low drift operational amplifiers like the OPA104. A low drift specification would be of little value if the amplifier took a long time to stabilize after turn-on or ambient temperature change. The TO-99 package and careful circuit design provide the necessary quick thermal response. Typical warm-up drift of the OPA104 is approximately 20 seconds (see Typical Performance Curves).

### GUARDING AND SHIELDING

The ultra-low bias current and high input impedance of the OPA104 are well-suited to a number of stringent applications. However, careless signal wiring of printed circuit board layout can degrade circuit performance several orders of magnitude below the capability of the OPA104.

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 OPA104. To avoid leakage problems, it is recommended that the signal input lead of the OPA104 be wired to a Teflon standoff. If the OPA104 is to be soldered directly into a printed circuit board, utmost care must be used in planning the board layout. A "guard" pattern should completely surround the two amplifier input leads and should be connected to a low impedance point which is at the signal input potential.

The amplifier case should be connected to any input shield or guard via pin 8. This insures that the amplifier itself is fully surrounded by guard potential, minimizing both leakage and noise pickup. Figure 1 illustrates the use of the guard.

value of  $C_2$  (0.5pF to 2pF) is what would be typically required to compensate for the pole generated by the capacitance at the input node. A larger value of  $C_2$  could be used to limit the bandwidth and reduce the voltage noise at higher frequencies.

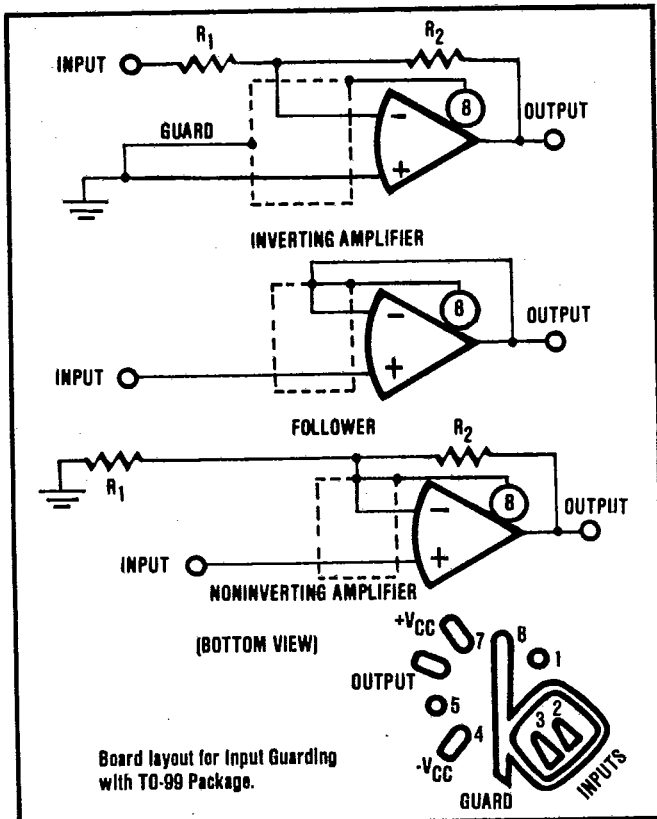


FIGURE 1. Connection of Input Guard.

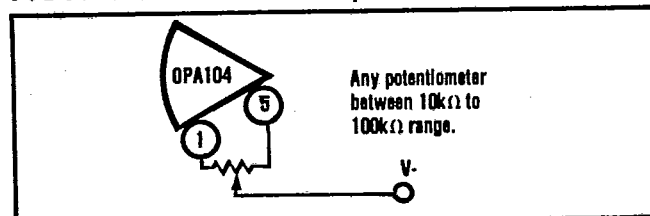


FIGURE 2. External Nulling of Offset Voltage.

### OFFSET VOLTAGE ADJUSTMENT

Although the OPA104 has a low initial offset voltage (500μV), some applications may require external nulling of this small offset. Figure 2 shows the recommended circuit for adjustment of the offset voltage. External offset voltage adjustment changes the laser adjusted offset voltage temperature drift slightly. The drift will change approximately 0.3μV/°C, for every 100μV of offset adjustment.

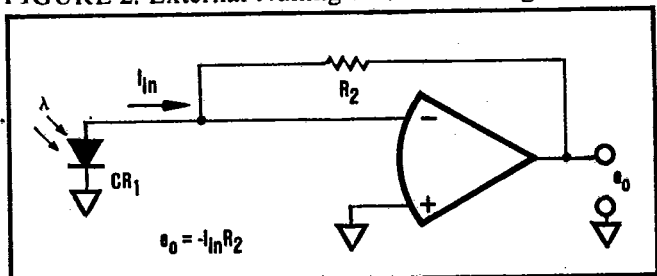


FIGURE 3. Pin Photodiode Application.

### TYPICAL APPLICATION

The circuit in Figure 3 is a common application of a low noise FET amplifier. Noise calculations are often important when using low current photodiodes.

CR1 is a PIN photodiode connected in the photovoltaic mode (no bias voltage) which produces an output current  $i_{in}$  when exposed to the light,  $\lambda$ .

A more complete circuit is shown in Figure 4. The values shown for  $C_1$  and  $R_1$  are typical for small geometry PIN diodes with sensitivities in the range of 0.5 A/W. The

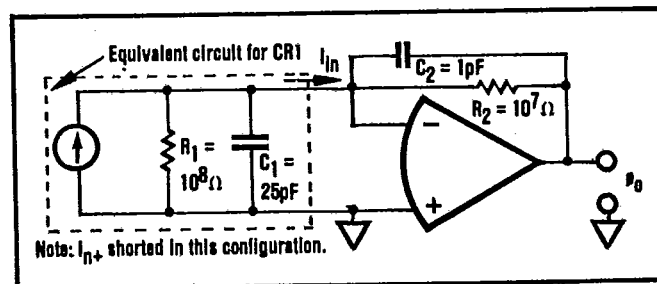


FIGURE 4. Model of Photodiode Application.