



INA104

Very-High Accuracy INSTRUMENTATION AMPLIFIER

FEATURES

- VERSATILE FOUR OP AMP DESIGN
- ULTRA-LOW VOLTAGE DRIFT:
0.25 μ V/ $^{\circ}$ C, max
- LOW OFFSET VOLTAGE: 25 μ V, max
- LOW NONLINEARITY: 0.002%, max
- LOW NOISE: 13nV/ $\sqrt{\text{Hz}}$ at $f_0 = 1\text{kHz}$
- HIGH CMR: 106dB at 60Hz, min
- HIGH INPUT IMPEDANCE: $10^{10}\Omega$
- LOW COST

APPLICATIONS

- AMPLIFICATION OF SIGNALS FROM SOURCES SUCH AS:
Strain Gages
Thermocouples
RTDs
- REMOTE TRANSDUCER AMPLIFIER
- LOW LEVEL SIGNAL CONDITIONER
- MEDICAL INSTRUMENTATION

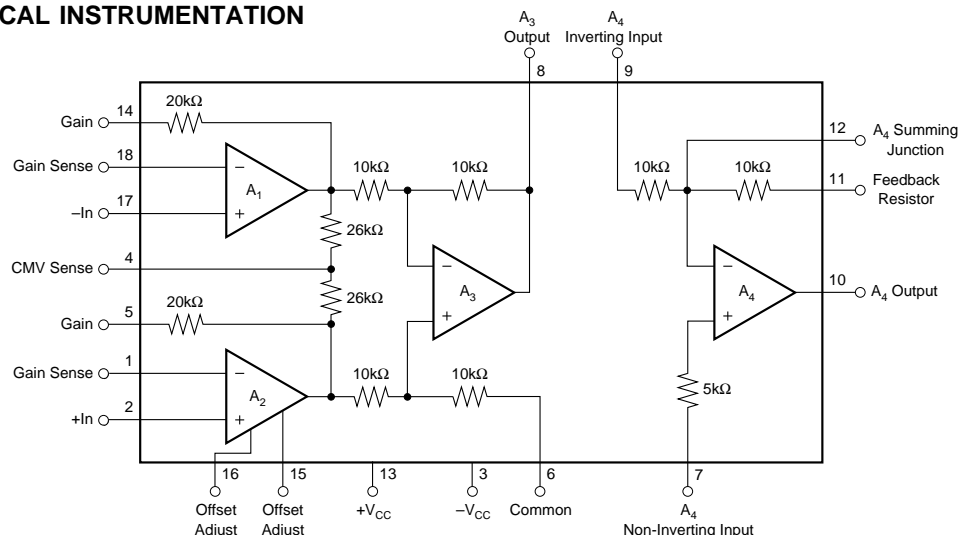
DESCRIPTION

The INA104 is a high accuracy, multistage, integrated-circuit instrumentation amplifier designed for signal conditioning requirements where very high performance is desired.

A multi-amplifier, monolithic design, which uses Burr-Brown's ultra-low drift, low-noise technology, provides the highest performance with maximum versatility at the lowest cost and makes the INA104 ideal for even high volume applications.

Burr-Brown's compatible thin-film resistors and laser-trimming techniques are used for minimizing offset voltage and temperature drift. This advanced technique also maximizes common-mode rejection and gain accuracy.

The INA104 also contains a fourth operational amplifier, specified separately, which can conveniently be used for some important applications such as single capacitor active low-pass filtering, easy output level shifting, common-mode voltage active guard drive, and increased gain ($\times 10,000$ and greater).



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SPECIFICATIONS—INSTRUMENTATION AMPLIFIER

At $T_A = +25^\circ\text{C}$, $V_S = \pm 15\text{V}$ power supply and in circuit of Figure 1 unless otherwise noted.

PARAMETER	INA104AM			INA104BM, SM			INA104CM			UNITS
	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
GAIN										
Range of Gain	1		1000	*	*	*	*	*	*	V/V
Gain Equation		$G = 1 + (40k/R_G)$			*	*		*	*	V/V
Error From Equation, DC ⁽¹⁾		$\pm(0.08 - 0.05/G)$	$\pm(0.15 - 0.1/G)$		*	*		*	*	% of FS
Gain Temp. Coefficient ⁽²⁾					*	*		*	*	ppm/°C
G = 1		2	5		*	*		*	*	ppm/°C
G = 10		20	100		*	*		-10	-50	ppm/°C
G = 100		22	110		*	*		-11	-55	ppm/°C
G = 1000		22	110		*	*		-11	-55	ppm/°C
Nonlinearity, DC		$\pm(0.002 + 10^{-5}G)$	$\pm(0.005 + 2 \times 10^{-5}G)$		$\pm(0.001 + 10^{-5}G)$	$\pm(0.002 + 10^{-5}G)$		$\pm(0.001 + 10^{-5}G)$	$\pm(0.002 + 10^{-5}G)$	% of FS, p-p
RATED OUTPUT										
Voltage	± 10	+11.5, -12.5		*	*		*	*		V
Current	± 5	+11.5, -12.5		*	*		*	*		mA
Output Impedance		0.2			*			*		Ω
INPUT OFFSET VOLTAGE										
Initial Offset at +25°C ⁽³⁾		$\pm 25 \pm 200/G$	$\pm 50 \pm 400/G$		$\pm 10 \pm 100/G$	$\pm 25 \pm 200/G$		$\pm 10 \pm 100/G$	$\pm 25 \pm 200/G$	μV
vs Temperature			$\pm 2 \pm 20/G$			$\pm 0.75 \pm 10/G$			$\pm 0.25 \pm 10/G$	$\mu\text{V}/^\circ\text{C}$
vs Supply		$\pm(1 + 50/G)$			*			*		$\mu\text{V}/\text{V}$
vs Time		$\pm(1 + 20/G)$			*			*		$\mu\text{V}/\text{mo}$
INPUT BIAS CURRENT										
Initial Bias Current (each input)		± 15	± 30		± 10	*		± 5	± 20	nA
vs Temperature		± 0.2			*			*		nA/°C
vs Supply		± 0.1			*			*		nA/V
Initial Offset Current		± 5	± 30		± 2	*		± 2	± 20	nA
vs Temperature		± 0.5			*			*		nA/°C
INPUT IMPEDANCE										
Differential		$10^{10} \parallel 3$			*			*		$\Omega \parallel \text{pF}$
Common-Mode		$10^{10} \parallel 3$			*			*		$\Omega \parallel \text{pF}$
INPUT VOLTAGE RANGE										
Range, Linear Response	± 10			*			*			V
CMR with 1k Ω Source Imbalance										
DC to 60Hz, G = 1	80	90		*	*		*	*		dB
DC to 60Hz, G = 10	96	106		*	*		*	*		dB
DC to 60Hz, G = 100 to 1000	106	110		*	*		*	*		dB
INPUT NOISE										
Input Voltage Noise										
$f_B = 0.1\text{Hz}$ to 10Hz		0.8			*			*		μV , p-p
Density, G = 1000					*			*		$\text{nV}/\sqrt{\text{Hz}}$
$f_O = 10\text{Hz}$		18			*			*		$\text{nV}/\sqrt{\text{Hz}}$
$f_O = 100\text{Hz}$		15			*			*		$\text{nV}/\sqrt{\text{Hz}}$
$f_O = 1\text{kHz}$		13			*			*		$\text{nV}/\sqrt{\text{Hz}}$
Input Current Noise										
$f_B = 0.01\text{Hz}$ to 10Hz		50			*			*		pA, p-p
Density					*			*		$\text{pA}/\sqrt{\text{Hz}}$
$f_O = 10\text{Hz}$		0.8			*			*		$\text{pA}/\sqrt{\text{Hz}}$
$f_O = 100\text{Hz}$		0.46			*			*		$\text{pA}/\sqrt{\text{Hz}}$
$f_O = 1\text{kHz}$		0.35			*			*		$\text{pA}/\sqrt{\text{Hz}}$
DYNAMIC RESPONSE										
Small Signal, $\pm 3\text{dB}$ Flatness										
G = 1		300			*			*		kHz
G = 10		140			*			*		kHz
G = 100		25			*			*		kHz
G = 1000		2.5			*			*		kHz
Small Signal, $\pm 1\%$ Flatness										
G = 1		20			*			*		kHz
G = 10		10			*			*		kHz
G = 100		1			*			*		kHz
G = 1000		200			*			*		Hz
Full Power, G = 1 - 100		6.4			*			*		kHz
Slew Rate, G = 1 - 100	0.2	0.4		*	*		*	*		V/ μs
Settling Time (0.1%)										
G = 1		30	40		*	*		*	*	μs
G = 100		40	55		*	*		*	*	μs
G = 1000		350	470		*	*		*	*	μs
Settling Time (0.01%)										
G = 1		30	45		*	*		*	*	μs
G = 100		50	70		*	*		*	*	μs
G = 1000		500	650		*	*		*	*	μs

SPECIFICATIONS—OUTPUT AMPLIFIER, A₄

At T_A = +25°C, V_S = ±15V power supply and in circuit of Figure 1 unless otherwise noted.

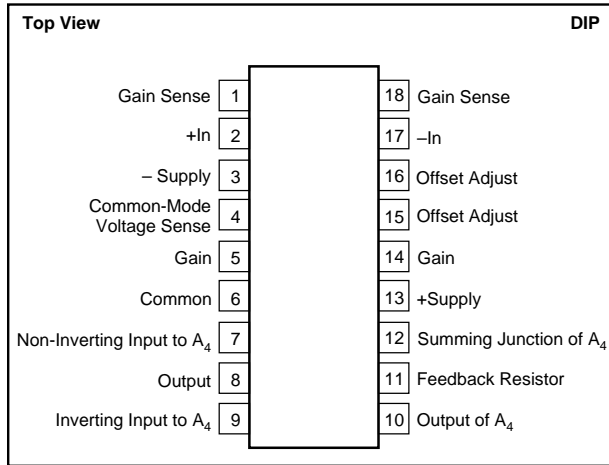
PARAMETER	INA104AM			INA104BM, SM			INA104CM			UNITS
	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
OPEN-LOOP GAIN , V _o = ±100 Rated Load R _L ≥ 2kΩ R _L ≥ 10kΩ	100	115		*	*		*	*		dB
	110	125		*	*		*	*		dB
RATED OUTPUT Voltage at R _L = 2kΩ R _L = 10kΩ Current Output Impedance Load Capacitance (Unity-Gain Inverting) Short Circuit Current	10	+13, -14.5		*	*		*	*		V
		+13, -14.5		*	*		*	*		V
	5	7.5		*	*		*	*		mA
		2			*			*		kΩ
		2000			*			*		pF
		10			*			*		mA
FREQUENCY RESPONSE Unity Gain, Small Signal Full Power Slew Rate Settling Time (Unity-Gain) 0.1% 0.01%		1			*			*		MHz
		9			*			*		kHz
	0.35	0.55		*	*		*	*		V/μs
		37			*			*		μs
		40			*			*		μs
INPUT OFFSET VOLTAGE Initial, T _A = +25°C vs Temperature		±1	±2		*	*		*	*	mV
		±5			*			*		μV/°C
INPUT BIAS CURRENT		+55	+150		*	*		*	*	nA
INPUT IMPEDANCE Differential Common-Mode		500			*			*		kΩ
		100			*			*		MΩ
RESISTORS, 10kΩ Accuracy Drift Ratio Match Drift		0.5	5		*	*		*	*	%
		30	50		*	*		*	*	ppm/°C
		0.06	0.12		*	*		*	*	%
		5			*			*		ppm/°C
INPUT VOLTAGE NOISE f _b = 0.1Hz to 10Hz Density f _o = 10Hz f _o = 100Hz f _o = 1kHz		1.5			*			*		μV, p-p
		35			*			*		nV√Hz
		33			*			*		nV√Hz
		32			*			*		nV√Hz
						*			*	
POWER SUPPLY Rated Voltage Voltage Range Quiescent Current		±15			*			*		V
	±5		±20	*		*	*	*	*	V
		±8.1	±9.6		*	*		*	*	mA
TEMPERATURE RANGE Specification: AM, BM, CM SM Operation: AM, BM, CM, SM Storage: AM, BM, CM, SM θ _{JC} θ _{JA}	-25		+85	*		*	*	*	*	°C
	-55		+125	*		*	*	*	*	°C
	-55		+125	*		*	*	*	*	°C
	-65		+150	*		*	*	*	*	°C
		115			*	*		*	*	°C/W
		130			*	*		*	*	°C/W
						*		*	*	

* Specifications same as for INA104AM.

NOTES: (1) Typically the tolerance of R_G will be the major source of gain error. (2) Not including the TCR of R_G. (3) Adjustable to zero at any one gain.

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PIN CONFIGURATION



ABSOLUTE MAXIMUM RATINGS

Supply	$\pm 20V$
Internal Power Dissipation	980mW
Input Voltage Range	$\pm V_{CC}$
Output Short-Circuit (to ground)	Continuous
Operating Temperature	$-40^{\circ}C$ to $+125^{\circ}C$
Storage Temperature	$-40^{\circ}C$ to $+125^{\circ}C$
Lead Temperature (soldering, 10s)	$+300^{\circ}C$

ORDERING INFORMATION

MODEL	PACKAGE	TEMPERATURE RANGE
INA104AM	18-Pin Hermetic DIP	$-25^{\circ}C$ to $+85^{\circ}C$
INA104BM	18-Pin Hermetic DIP	$-25^{\circ}C$ to $+85^{\circ}C$
INA104CM	18-Pin Hermetic DIP	$-25^{\circ}C$ to $+85^{\circ}C$
INA104SM	18-Pin Hermetic DIP	$-55^{\circ}C$ to $+125^{\circ}C$

PACKAGE INFORMATION⁽¹⁾

MODEL	PACKAGE	PACKAGE DRAWING NUMBER
INA104AM	18-Pin Hermetic DIP	108
INA104BM	18-Pin Hermetic DIP	108
INA104CM	18-Pin Hermetic DIP	108
INA104SM	18-Pin Hermetic DIP	108

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



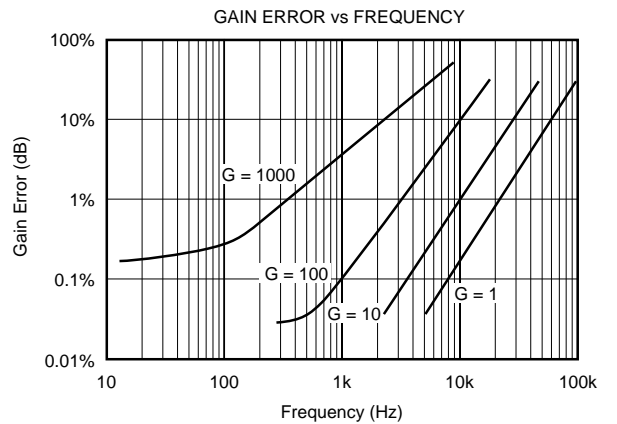
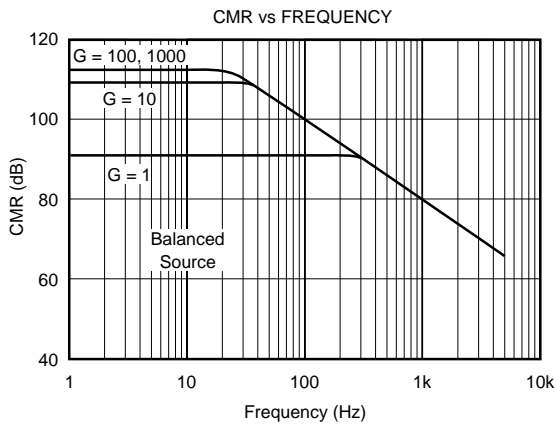
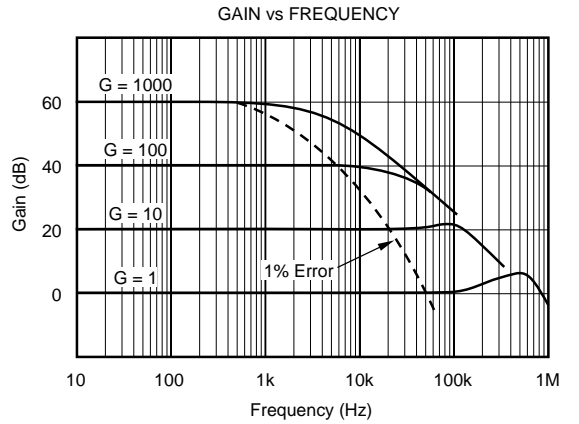
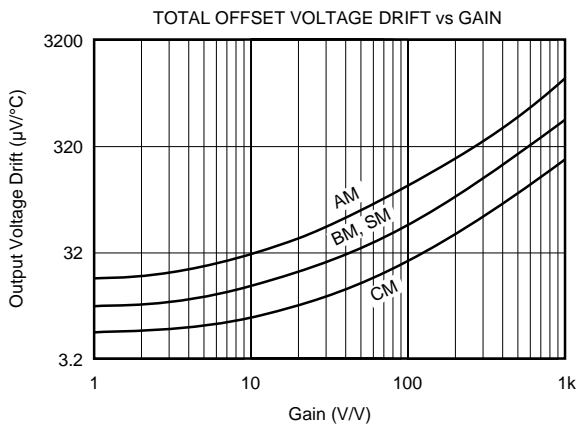
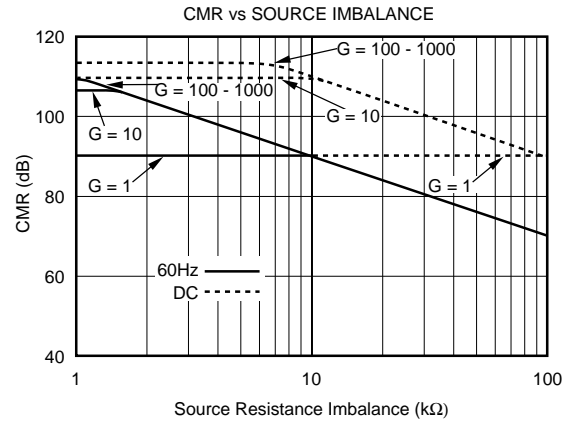
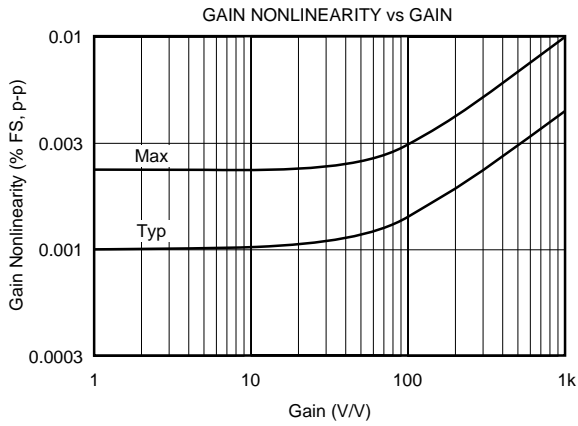
ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

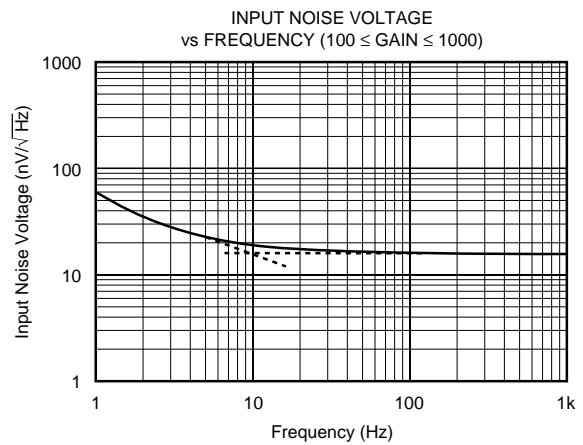
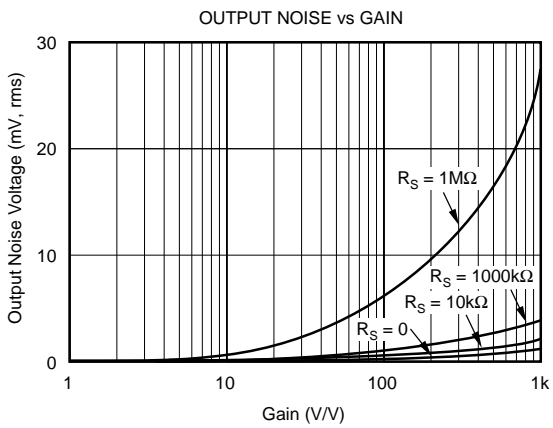
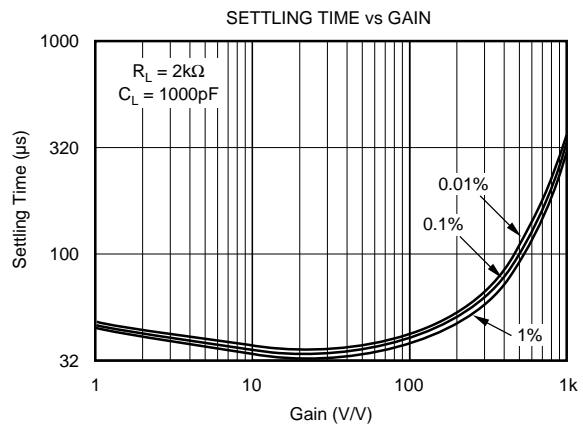
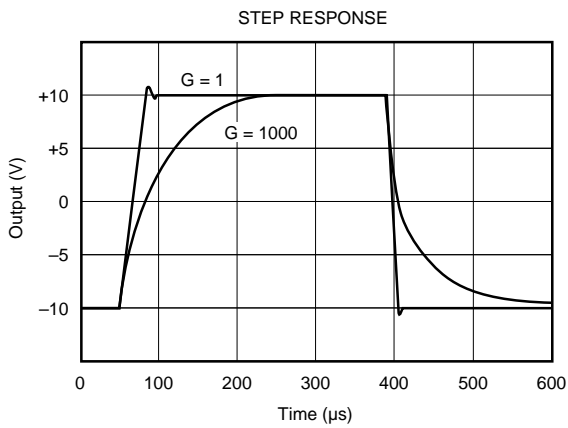
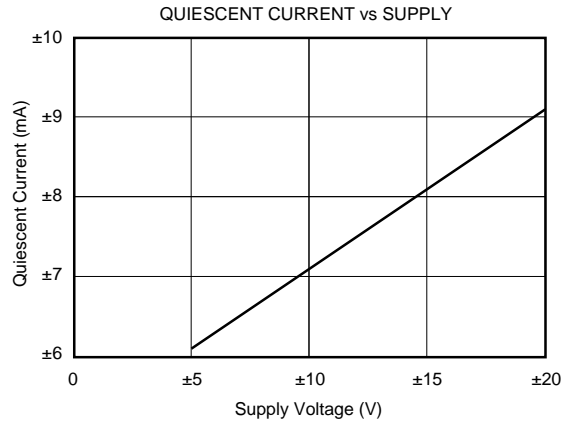
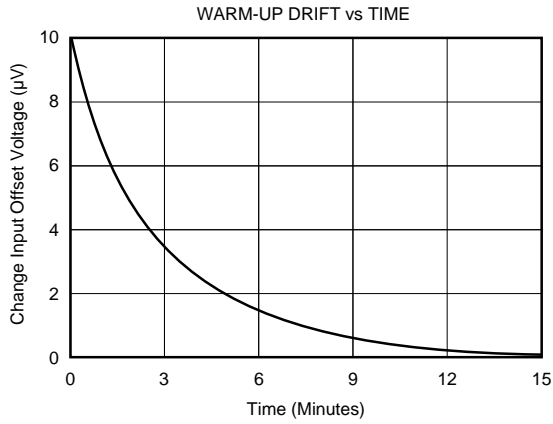
TYPICAL PERFORMANCE CURVES

At $T_A = +25^\circ\text{C}$, $V_{CC} = 15\text{V}$, and in circuit of Figure 1, unless otherwise specified.



TYPICAL PERFORMANCE CURVES (CONT)

At $T_A = +25^\circ\text{C}$, $V_{CC} = 15\text{V}$, and in circuit of Figure 1, unless otherwise specified.



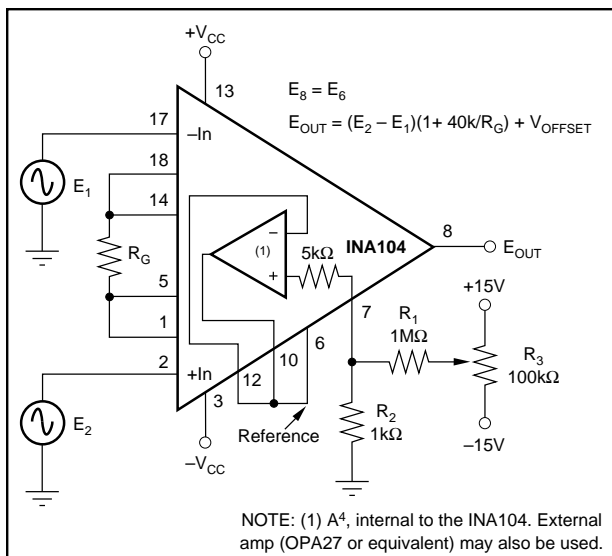


FIGURE 2. Optional Output Offset Nulling or Offsetting Using an Amplifier (Low Impedance to Pin 6).

OPTIONAL OFFSET ADJUSTMENT PROCEDURE

It is frequently desirable to null the input component of offset (Figure 1) and occasionally that of the output (Figure 2). The quality of the potentiometer will affect the results, therefore, choose one with good temperature and mechanical-resistance stability. The procedure is as follows:

1. Set $E_1 = E_2 = 0V$ (be sure a good ground return path exists to the input).
2. Set the gain to the desired value (greater than 1) by choosing R_G .
3. Adjust the 100kΩ potentiometer in Figure 1 until the output reads $0V \pm 1mV$ or desired setting. Note that the offset will change when the gain is changed.
4. If the output component of offset is to be removed or if it is desired to establish an intentional offset, adjust the 100kΩ potentiometer in Figure 2 until the output reads $0V \pm 1mV$ or desired setting. Note that the offset will not change with gain, but be sure to use a stable amplifier with good DC characteristics. The range of adjustment is $\pm 15mV$ as shown. For larger ranges, change the ratio of R_1 to R_2 . The op amp is used to maintain a low resistance ($<0.1\Omega$) from pin 6 to Common to avoid CMR degradation.

BASIC CIRCUIT CONNECTION

The basic circuit connection for the INA104 is shown in Figure 1. The output voltage is a function of the differential input voltage times the gain. Figure 1 does not include additional internal op amp A_4 . Power supply bypassing with a $1\mu F$ tantalum capacitor or equivalent is always recommended.

In applications which do not use the fourth internal amplifier (A_4 —pins 7, 9, 10, 11, and 12), pin 7 should be connected to Common and pins 10 and 11 should be connected together. This will prevent the output of A_4 from saturating (“locking-up”) and affecting the offset of the instrumentation amplifier, A_1 , A_2 , and A_3 .

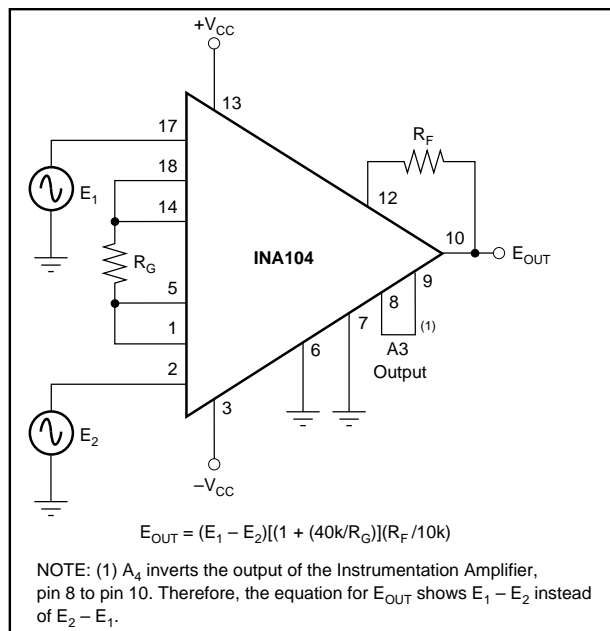


FIGURE 3. Additional Gain From Output Stage.

TYPICAL APPLICATIONS

Many applications of instrumentation amplifiers involve the amplification of low-level differential signals from bridges and transducers such as strain gages, thermocouples, and RTDs. Some of the important parameters include common-mode rejection (differential cancellation of common-mode offset and noise), input impedance, offset voltage and drift, gain accuracy, linearity, and noise. The INA104 accomplishes all of these with high precision.

Figure 3 shows how the output stage may be used to provide additional gain. If gains greater than 1000V/V (10,000 up to 100,000 and greater) are desired, it is better to place some gain in the output amplifier rather than the input stage due

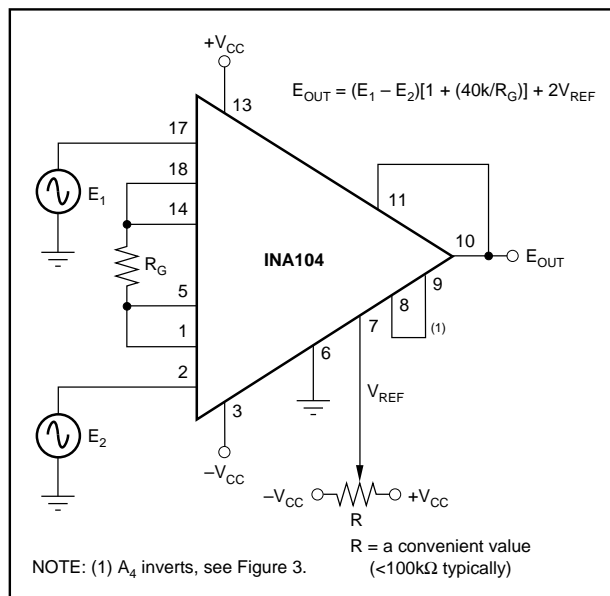


FIGURE 4. Output Offsetting.

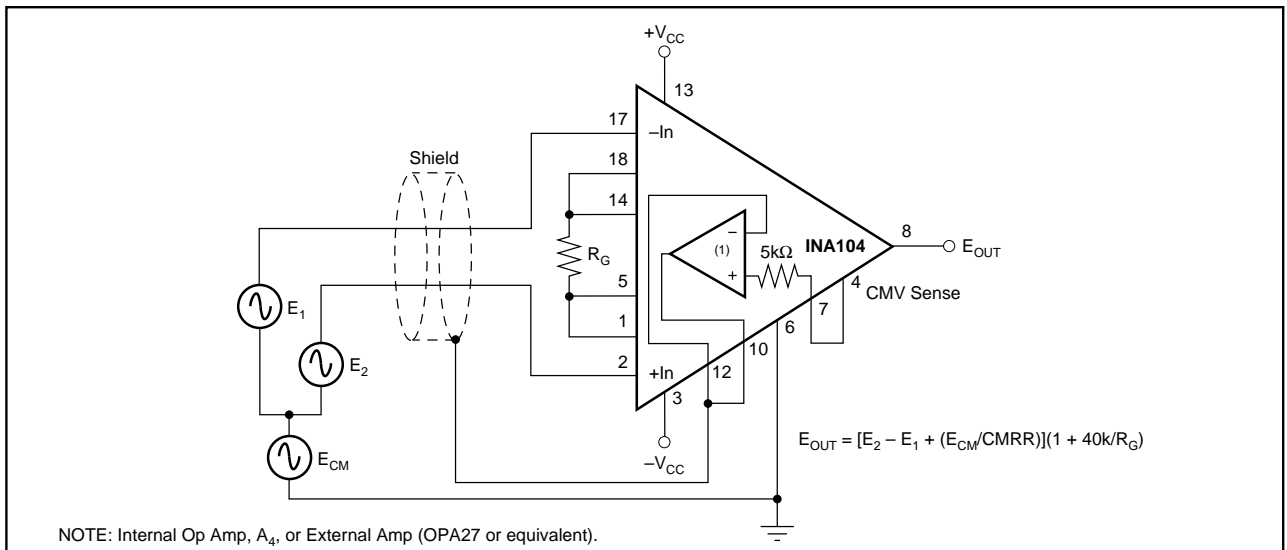


FIGURE 5. Use of Guard Drive.

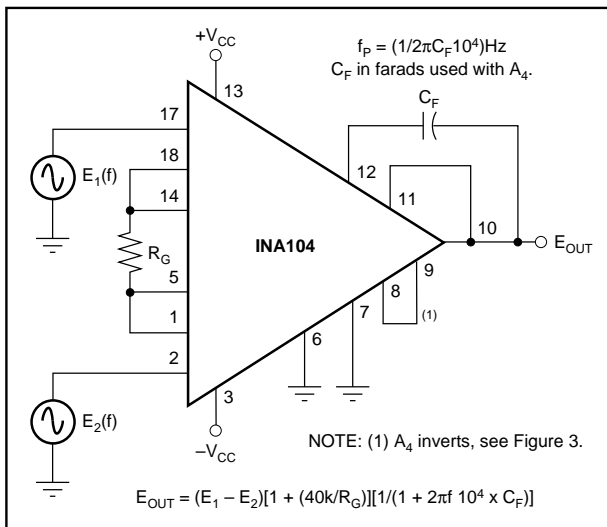


FIGURE 6. Active Low-Pass Filtering.

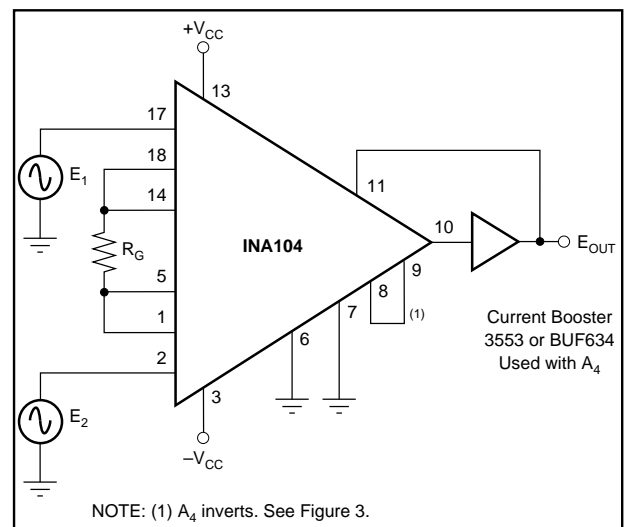


FIGURE 7. Output Power Boosting.

to the low values of R_G required ($R_G < 40\Omega$ for $(1 + 40k/R_G) > 1000$). Note, however, that accuracy can degrade due to high amplification of offset, drift, and noise errors.

Output offsetting (“zero suppression” or “zero elevation”) may be more easily accomplished with the INA104 than with most other IC instrumentation amplifiers as shown in Figure 4. The use of the extra internal op amp, A₄, means that CMR of the instrumentation amp is not disturbed, and that a convenient value of variable resistor can be used. The circuit shown in Figure 2 can also be used to achieve the desired offsetting by scaling the resistors R_1 and R_2 . A low impedance path from pin 6 to Common should be provided to achieve the high CMR specified. Resistance above 0.1Ω will cause the CMR to fall below 106dB.

Amplifier A₄ also allows active low-pass filtering to be implemented conveniently with a single capacitor. Filtering can be used for noise reduction or band-limiting of the output signal as shown in Figure 6.

The common-mode voltage from the 26k Ω resistors in the input section appears at pin 4. Figure 5 shows how this voltage can be used to drive the shield of the input cable. Since the cable is driven at the common-mode voltage, the effects of distributed capacitance is reduced and the AC system common-mode rejection may be improved. Amplifier A₄ buffers the CMV at pin 4 from the input cable.

Some typical application circuits are shown in Figures 9 through 11.

GENERAL RECOMMENDED HANDLING PROCEDURES FOR INTEGRATED CIRCUITS

All semiconductor devices are vulnerable, in varying degrees, to damage from the discharge of electrostatic energy. Such damaging can cause performance degradation or failure, either immediate or latent. As a general practice, we recommend the following handling procedures to reduce the risk of electrostatic damage.

1. Remove static-generating materials, such as untested plastics, from all areas that handle microcircuits.

2. Ground all operators, equipment, and work stations.

3. Transport and ship microcircuits, or products incorporating microcircuits, in static-free, shielded containers.

4. Connect together all leads of each device by means of a conductive material, when the device is not connected into a circuit.

5. Control relative humidity to as high a value as practical (50% is recommended).

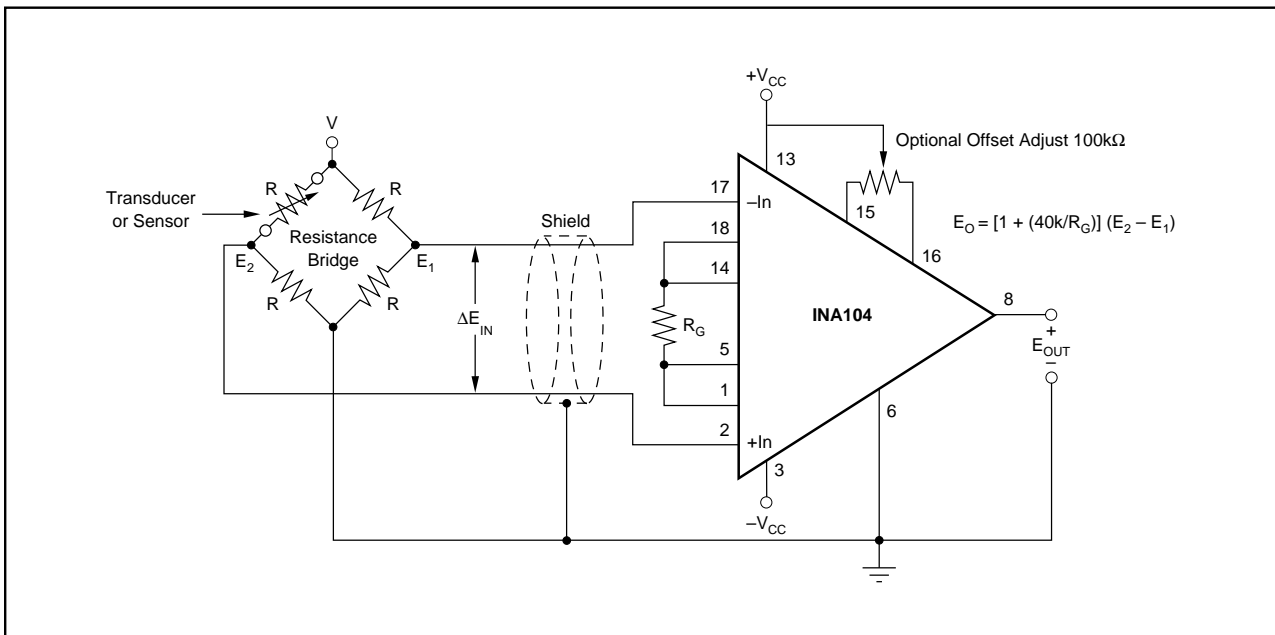


FIGURE 8. Amplification of a Differential Voltage From a Resistance Bridge.

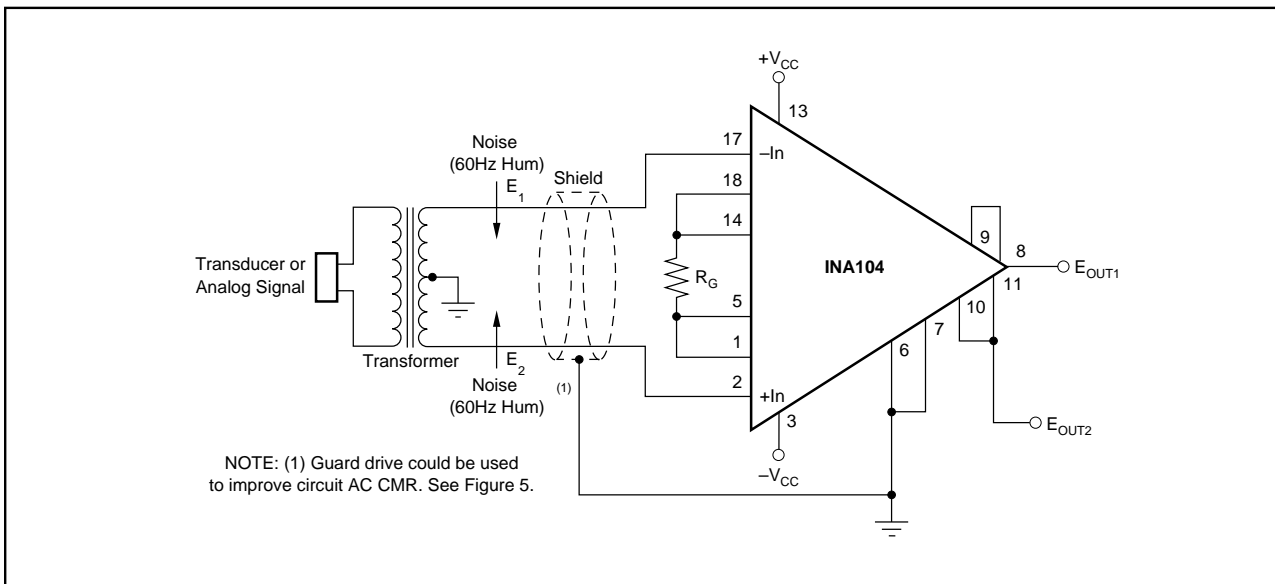


FIGURE 9. Amplification of a Transformer Coupled Analog Signal.

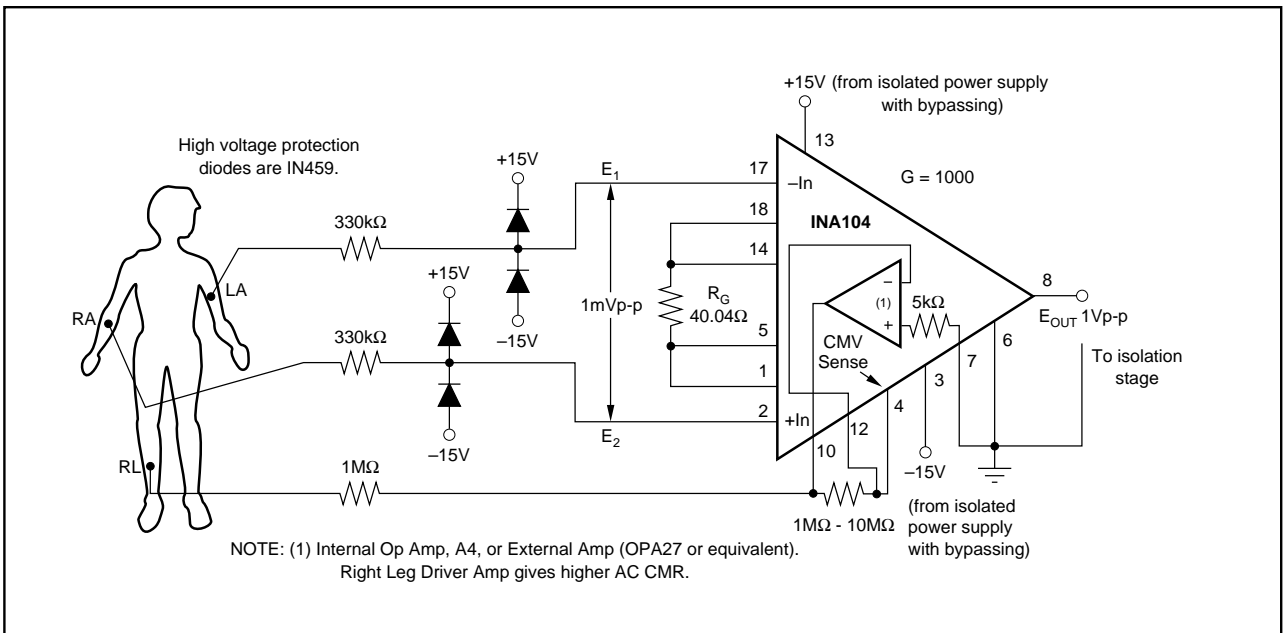


FIGURE 10. ECG Amplifier or Recorder Pre-Amp for Biological Signals.

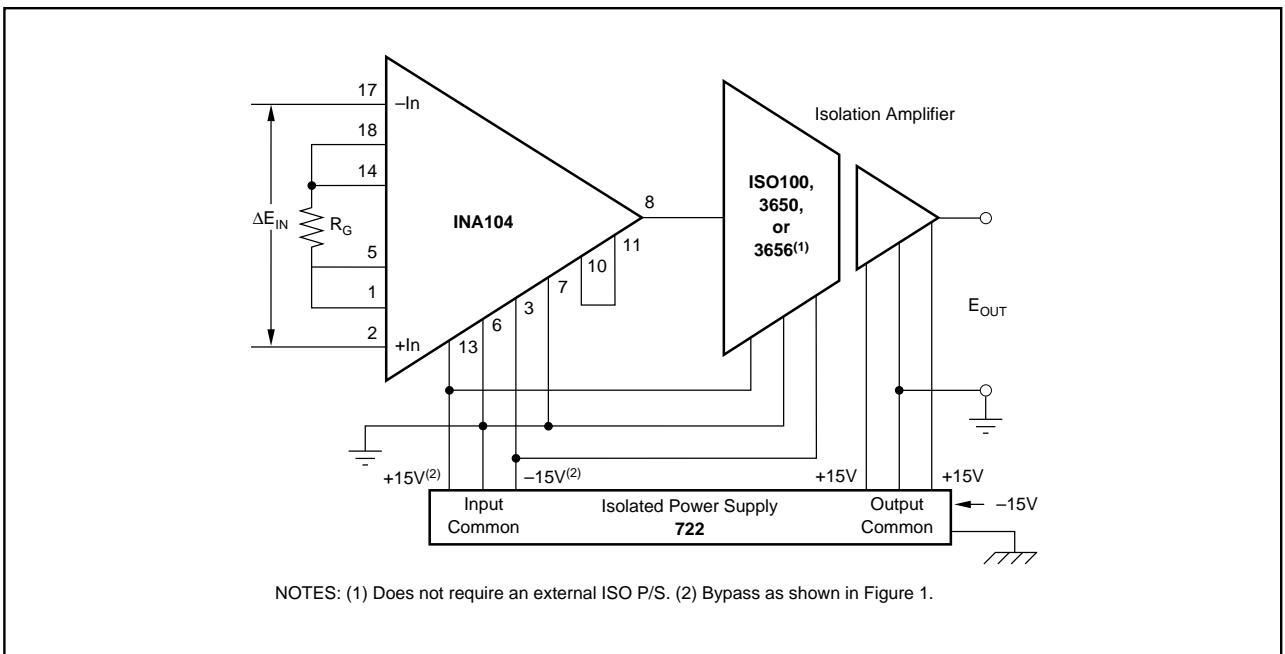
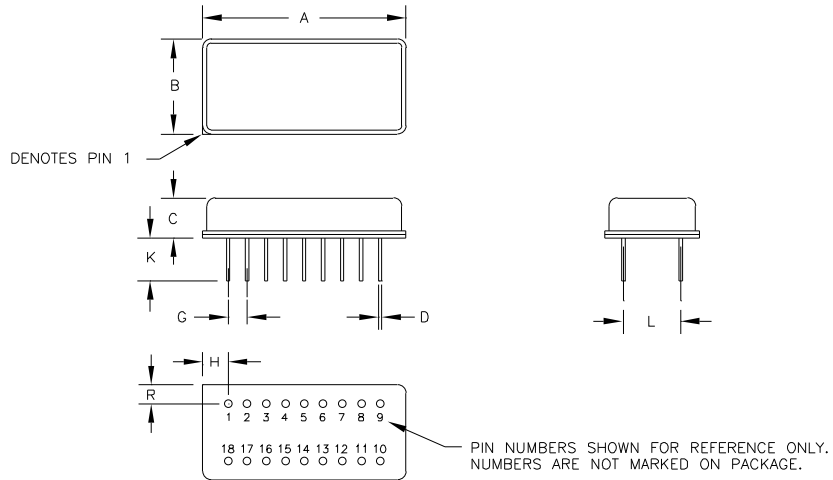


FIGURE 11. Precision Isolated Instrumentation Amplifier.

PACKAGE DRAWING

Package Number 108 - 18-Pin Hermetic Metal DIP



DIM	INCHES		MILLIMETERS		NOTE	DIM	INCHES		MILLIMETERS		NOTE
	MIN.	MAX.	MIN.	MAX.			MIN.	MAX.	MIN.	MAX.	
A	1.060	1.080	26.92	27.43							
B	.490	.510	12.45	12.95							
C	.170	.250	4.32	6.35							
D	.016	.021	0.41	0.53							
G	.100	BASIC	2.54	BASIC							
H	.115	.155	2.92	3.94							
K	.150	.300	3.81	7.62							
L	.300	BASIC	7.62	BASIC							
R	.080	.120	2.03	3.05							

NOTES:
 1. LEADS IN TRUE POSITION WITHIN .010" (.25mm) R @ MMC AT SEATING PLANE.

PACKAGE NUMBER: ZZ108 REV.: A
 JEDEC NUMBER: UNKNOWN