

INA116

## Ultra Low Input Bias Current INSTRUMENTATION AMPLIFIER

### FEATURES

- **LOW INPUT BIAS CURRENT:** 3fA typ
- **BUFFERED GUARD DRIVE PINS**
- **LOW OFFSET VOLTAGE:** 2mV max
- **HIGH COMMON-MODE REJECTION:** 84dB (G = 10)
- **LOW QUIESCENT CURRENT:** 1mA
- **INPUT OVER-VOLTAGE PROTECTION:** ±40V

### APPLICATIONS

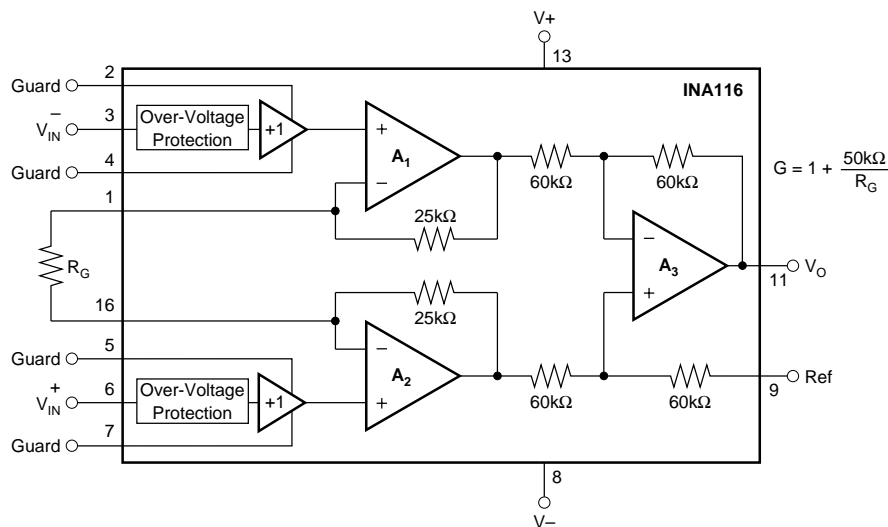
- **LABORATORY INSTRUMENTATION**
- **pH MEASUREMENT**
- **ION-SPECIFIC PROBES**
- **LEAKAGE CURRENT MEASUREMENT**

### DESCRIPTION

The INA116 is a complete monolithic FET-input instrumentation amplifier with extremely low input bias current. *Difet*® inputs and special guarding techniques yield input bias currents of 3fA at 25°C, and only 25fA at 85°C. Its 3-op amp topology allows gains to be set from 1 to 1000 by connecting a single external resistor.

Guard pins adjacent to both input connections can be used to drive circuit board and input cable guards to maintain extremely low input bias current.

The INA116 is available in 16-pin plastic DIP and SOL-16 surface-mount packages, specified for the -40°C to +85°C temperature range.



*Difet*®; Burr-Brown Corporation

International Airport Industrial Park • Mailing Address: PO Box 11400, Tucson, AZ 85734 • Street Address: 6730 S. Tucson Blvd., Tucson, AZ 85706 • Tel: (520) 746-1111 • Twx: 910-952-1111  
Internet: <http://www.burr-brown.com/> • FAXLine: (800) 548-6133 (US/Canada Only) • Cable: BBRCORP • Telex: 066-6491 • FAX: (520) 889-1510 • Immediate Product Info: (800) 548-6132

# SPECIFICATIONS

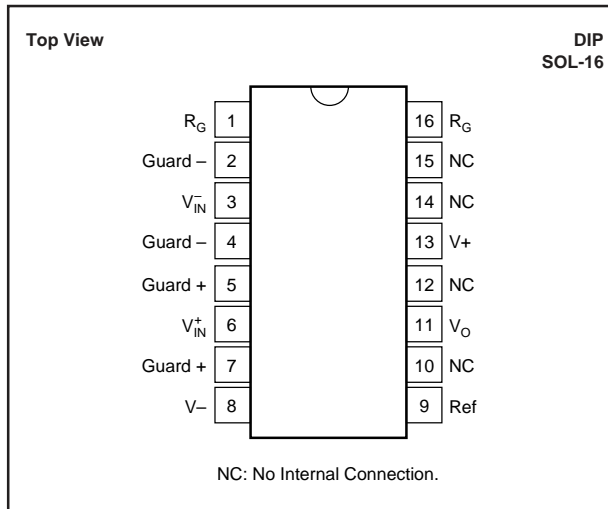
AT  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 15\text{V}$ ,  $R_L = 10\text{k}\Omega$ , unless otherwise noted.

PARAMETER	CONDITIONS	INA116P, U			INA116PA, UA			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
<b>INPUT</b>								
Offset Voltage, RTI	$T_A = +25^\circ\text{C}$ $T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$ $V_S = \pm 4.5\text{V}$ to $\pm 18\text{V}$		$\pm 0.5 \pm 0.5/\text{G}$	$\pm 2 \pm 2/\text{G}$		*	$\pm 5 \pm 5/\text{G}$	mV
Initial vs Temperature			See Typical Curve			*		
vs Power Supply			$\pm 10 \pm 15/\text{G}$	$\pm 50 \pm 100/\text{G}$		*	$\pm 100 \pm 200/\text{G}$	$\mu\text{V}/\text{V}$
Long-Term Stability			$\pm 1 \pm 5/\text{G}$			*		$\mu\text{V}/\text{mo}$
Bias Current			$\pm 3$	$\pm 25$		*	$\pm 100$	fA
vs Temperature			See Typical Curve			*		
Offset Current			$\pm 1$	$\pm 25$		*	$\pm 100$	fA
vs Temperature			See Typical Curve			*		
Impedance, Differential			$>10^{15}/0.2$			*		$\Omega/\text{pF}$
Common-Mode			$>10^{15}/7$			*		$\Omega/\text{pF}$
Common-Mode Voltage Range		(V+)-4 (V-)+4 $\pm 40$	(V+)-2 (V-)+2.4		*	*	V	
Safe Input Voltage					*		V	
Common-Mode Rejection	$V_{\text{CM}} = \pm 11\text{V}$ , $\Delta R_S = 1\text{k}\Omega$							
	G = 1	80	89		73	*	dB	
	G = 10	84	92		78	*	dB	
	G = 100	86	94		80	*	dB	
	$V_{\text{CM}} = \pm 5\text{V}$ , G = 1000	86	94		80	*	dB	
<b>NOISE</b>								
Voltage Noise, RTI	G = 1000, $R_S = 0\Omega$		28			*		$\text{nV}/\sqrt{\text{Hz}}$
f = 1kHz			2			*		$\mu\text{Vp-p}$
$f_B = 0.1\text{Hz}$ to 10Hz				0.1			*	$\text{fA}/\sqrt{\text{Hz}}$
Current Noise						*		
f = 1kHz						*		
<b>GAIN</b>								
Gain Equation		1	$1+(50\text{k}\Omega/R_G)$	1000	*	*	*	V/V
Range of Gain						*	0.1	V/V
Gain Error	G = 1		$\pm 0.01$	$\pm 0.05$		*	$\pm 0.5$	%
	G = 10		$\pm 0.25$	$\pm 0.4$		*	$\pm 0.5$	%
	G = 100		$\pm 0.35$	$\pm 0.5$		*	$\pm 0.7$	%
	G = 1000		$\pm 1.25$			*		%
Gain vs Temperature <sup>(1)</sup>	G = 1		$\pm 5$	$\pm 10$		*	$\pm 20$	ppm/ $^\circ\text{C}$
50k $\Omega$ Resistance <sup>(1)(2)</sup>			$\pm 25$	$\pm 100$		*	$\pm 100$	ppm/ $^\circ\text{C}$
Nonlinearity	G = 1		$\pm 0.0005$	$\pm 0.005$		*	$\pm 0.01$	% of FSR
	G = 10		$\pm 0.001$	$\pm 0.005$		*	$\pm 0.01$	% of FSR
	G = 100		$\pm 0.001$	$\pm 0.005$		*	$\pm 0.01$	% of FSR
	G = 1000		$\pm 0.005$			*		% of FSR
<b>GUARD OUTPUTS</b>								
Offset Voltage			$\pm 15$	$\pm 50$		*	*	mV
Output Impedance			650			*		$\Omega$
Current Drive			$+2/-0.05$			*		mA
<b>OUTPUT</b>								
Voltage Positive	$R_L = 10\text{k}\Omega$	(V+) -1	(V+) -0.7		*	*		V
Negative	$R_L = 10\text{k}\Omega$	(V-) +0.35	(V-) +0.2		*	*		V
Load Capacitance Stability			1000			*		pF
Short-Circuit Current			$+5/-12$			*		mA
<b>FREQUENCY RESPONSE</b>								
Bandwidth, -3dB	G = 1		800			*		kHz
	G = 10		500			*		kHz
	G = 100		70			*		kHz
	G = 1000		7			*		kHz
Slew Rate	G = 10 to 200		0.8			*		V/ $\mu\text{s}$
Settling Time, 0.01%	10V Step, G = 1		22			*		$\mu\text{s}$
	G = 10		25			*		$\mu\text{s}$
	G = 100		145			*		$\mu\text{s}$
	G = 1000		400			*		$\mu\text{s}$
Output Overload Recovery	50% Overdrive		20			*		$\mu\text{s}$
<b>POWER SUPPLY</b>								
Voltage Range		$\pm 4.5$	$\pm 15$	$\pm 18$	*	*	*	V
Current	$V_{\text{IN}} = 0\text{V}$		$\pm 1$	$\pm 1.4$		*	*	mA
<b>TEMPERATURE RANGE</b>								
Specification		-40		85	*		*	$^\circ\text{C}$
Operating		-40		125	*		*	$^\circ\text{C}$
$\theta_{\text{JA}}$			80			*		$^\circ\text{C}/\text{W}$

\* Specification same as INA116P

NOTE: (1) Guaranteed by wafer test. (2) Temperature coefficient of the "50k $\Omega$ " term in the gain equation.

## PIN CONFIGURATION



## ABSOLUTE MAXIMUM RATINGS

Supply Voltage .....	±18V
Input Voltage Range .....	±40V
Output Short-Circuit (to ground) .....	Continuous
Operating Temperature .....	-40°C to +125°C
Storage Temperature .....	-40°C to +125°C
Junction Temperature .....	+150°C
Lead Temperature (soldering, 10s) .....	+300°C

## 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.

## PACKAGE INFORMATION

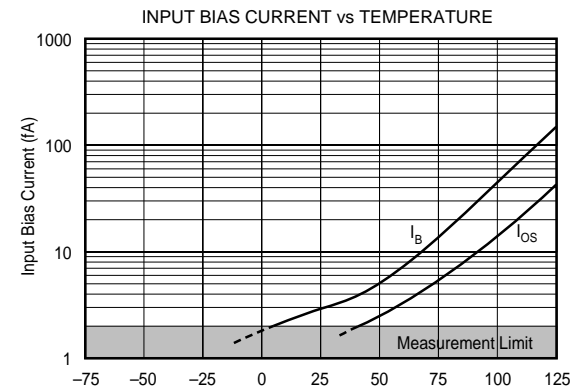
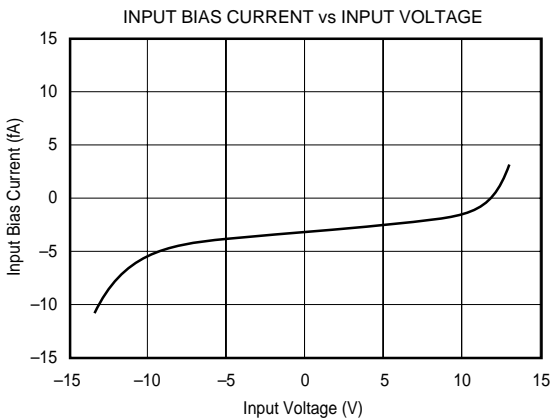
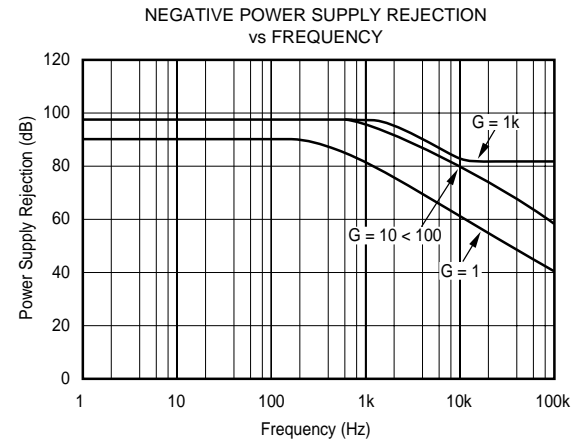
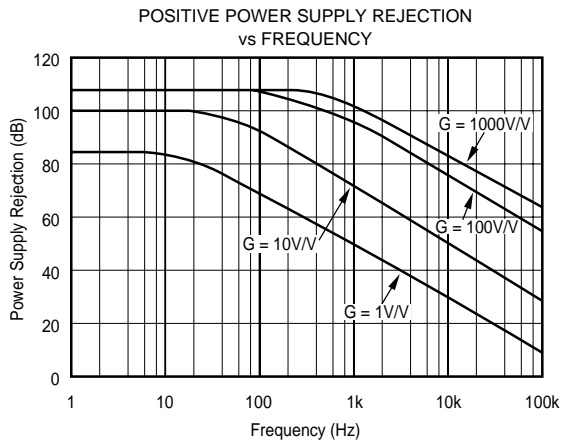
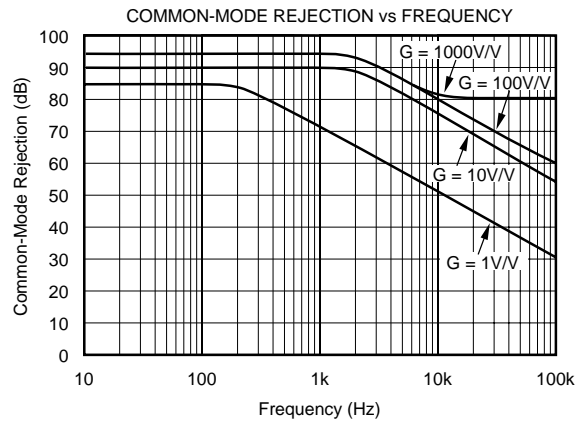
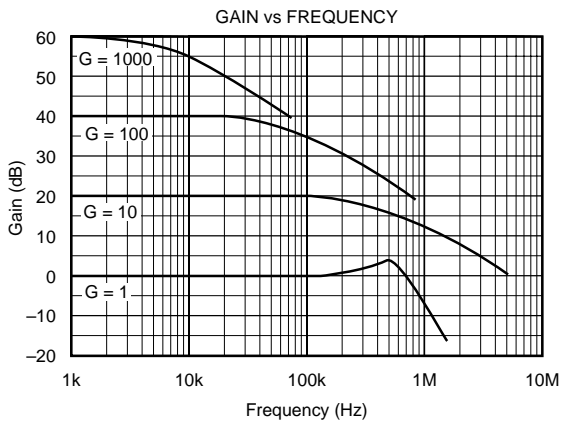
PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER <sup>(1)</sup>
INA116PA	16-Pin Plastic DIP	180
INA116P	16-Pin Plastic DIP	180
INA116UA	SOL-16 Surface-Mount	211
INA116U	SOL-16 Surface-Mount	211

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

The information provided herein is believed to be reliable; however, BURR-BROWN assumes no responsibility for inaccuracies or omissions. BURR-BROWN assumes no responsibility for the use of this information, and all use of such information shall be entirely at the user's own risk. Prices and specifications are subject to change without notice. No patent rights or licenses to any of the circuits described herein are implied or granted to any third party. BURR-BROWN does not authorize or warrant any BURR-BROWN product for use in life support devices and/or systems.

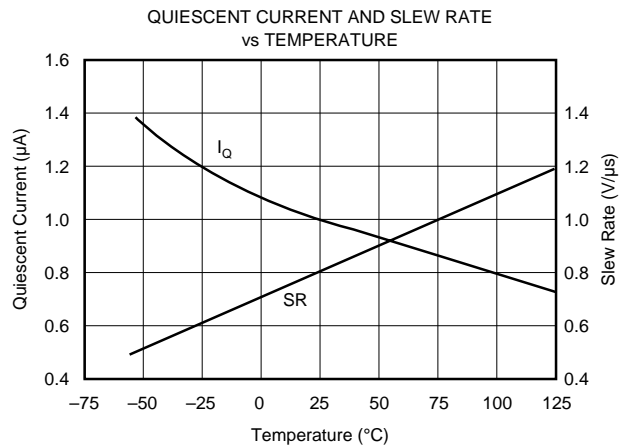
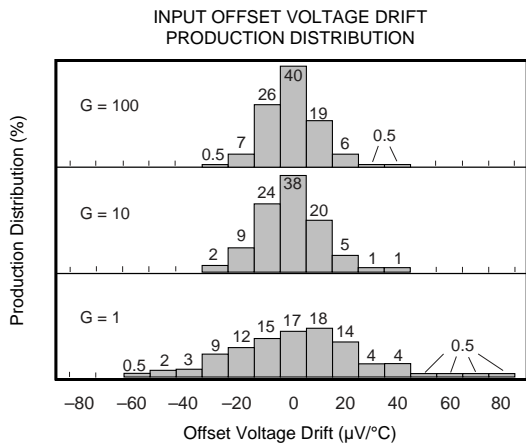
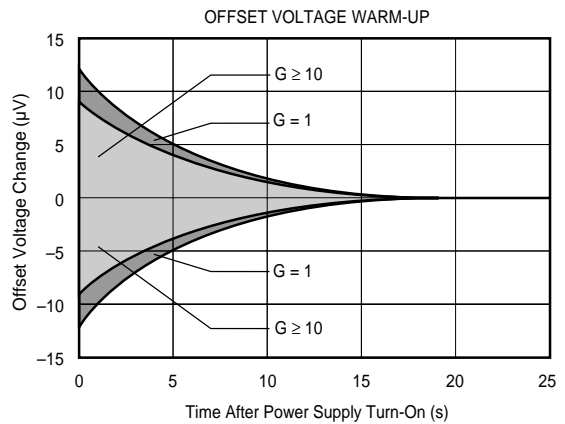
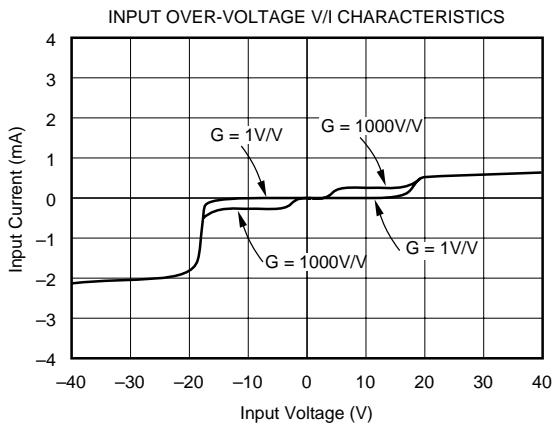
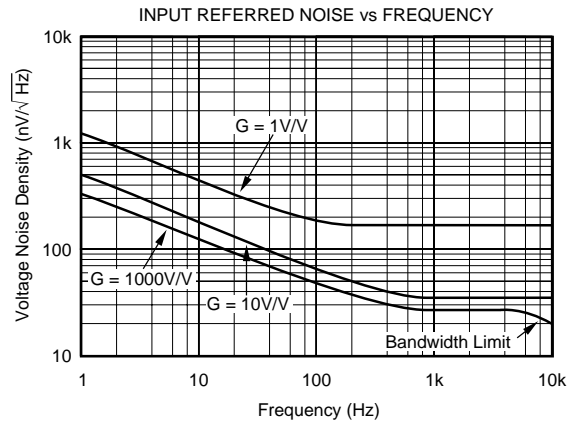
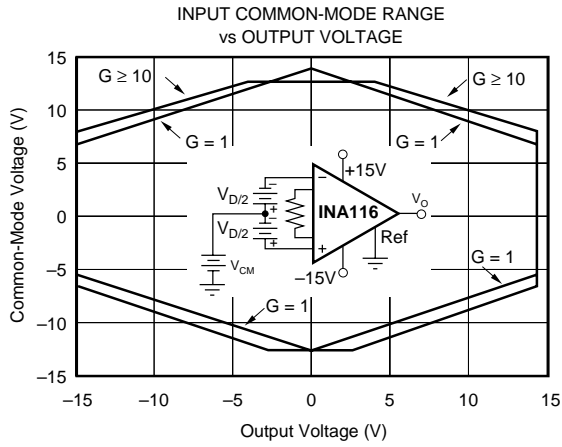
# TYPICAL PERFORMANCE CURVES

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 15\text{V}$ ,  $R_L = 10\text{k}\Omega$ , unless otherwise noted.



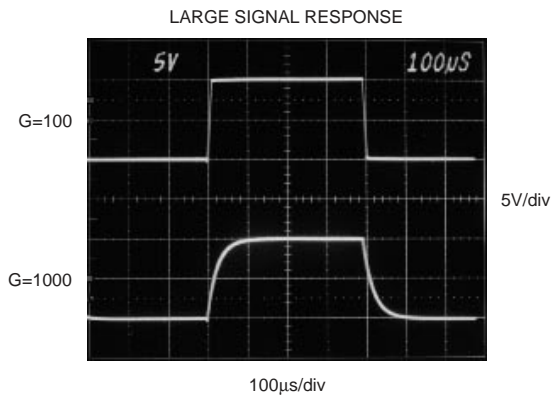
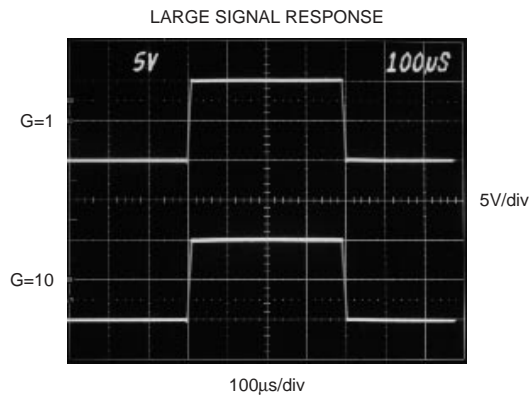
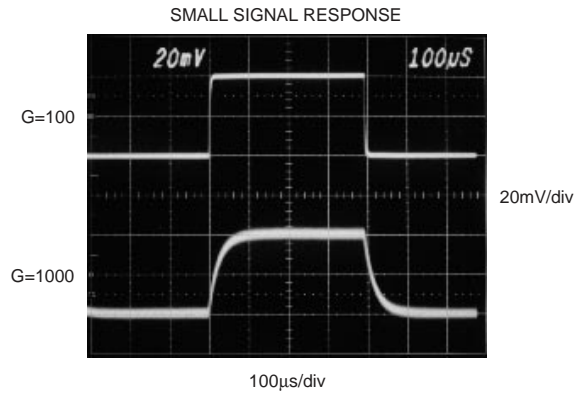
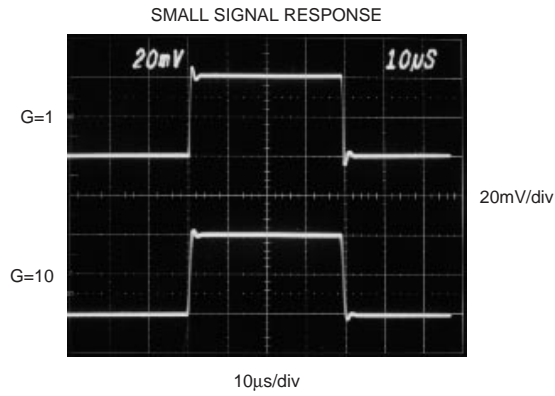
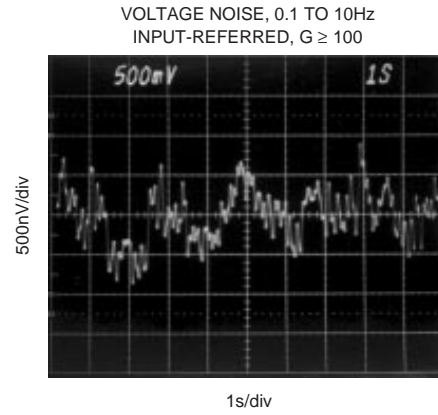
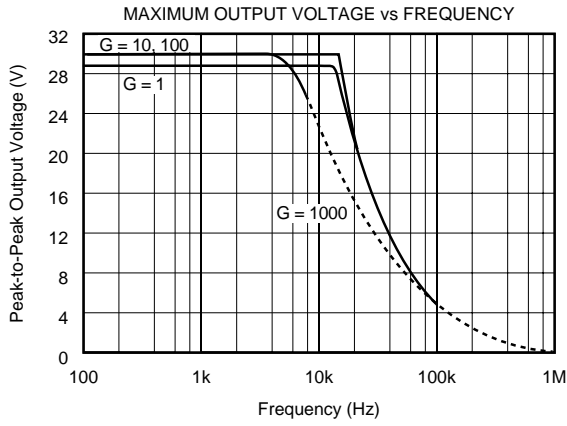
# TYPICAL PERFORMANCE CURVES (CONT)

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 15\text{V}$ ,  $R_L = 10\text{k}\Omega$ , unless otherwise noted.



# TYPICAL PERFORMANCE CURVES (CONT)

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 15\text{V}$ ,  $R_L = 10\text{k}\Omega$ , unless otherwise noted.



# APPLICATIONS INFORMATION

Figure 1 shows the connections required for basic operation of the INA116. Applications with noisy or high impedance power supplies may require decoupling capacitors close to the supply pins as shown.

The output is referred to the output reference (Ref) terminal which is normally grounded. This must be a low impedance connection to assure good common-mode rejection. A resistance of 30Ω in series with this connection will cause a typical device to degrade to approximately 72dB CMR at G = 1.

## SETTING THE GAIN

Gain of the INA116 is set by connecting a single external resistor, R<sub>G</sub>, as shown. The gain is—

$$G = 1 + \frac{50k\Omega}{R_G} \quad (1)$$

Commonly used gains and resistor values are shown in Figure 1.

The 50kΩ term in equation 1 is the sum of the two feedback resistors of A<sub>1</sub> and A<sub>2</sub>. These on-chip metal film resistors are laser trimmed to accurate absolute values. The accuracy and temperature coefficient of these resistors are included in the gain accuracy and drift specifications of the INA116.

The stability and temperature drift of R<sub>G</sub> also affect gain. R<sub>G</sub>'s contribution to gain accuracy and drift can be directly inferred from the gain equation (1). Low resistor values required for high gain make wiring resistance important. Sockets add to the wiring resistance that will contribute additional gain error in gains of approximately 100 or greater.

## OFFSET TRIMMING

The INA116 is laser trimmed for low offset voltage and offset voltage drift; most applications require no external offset adjustment. Figure 2 shows an optional circuit for trimming the output offset voltage. A voltage applied to the Ref terminal is summed at the output. Op amp A<sub>1</sub> provides a low source impedance for the Ref terminal, assuring good common-mode rejection.

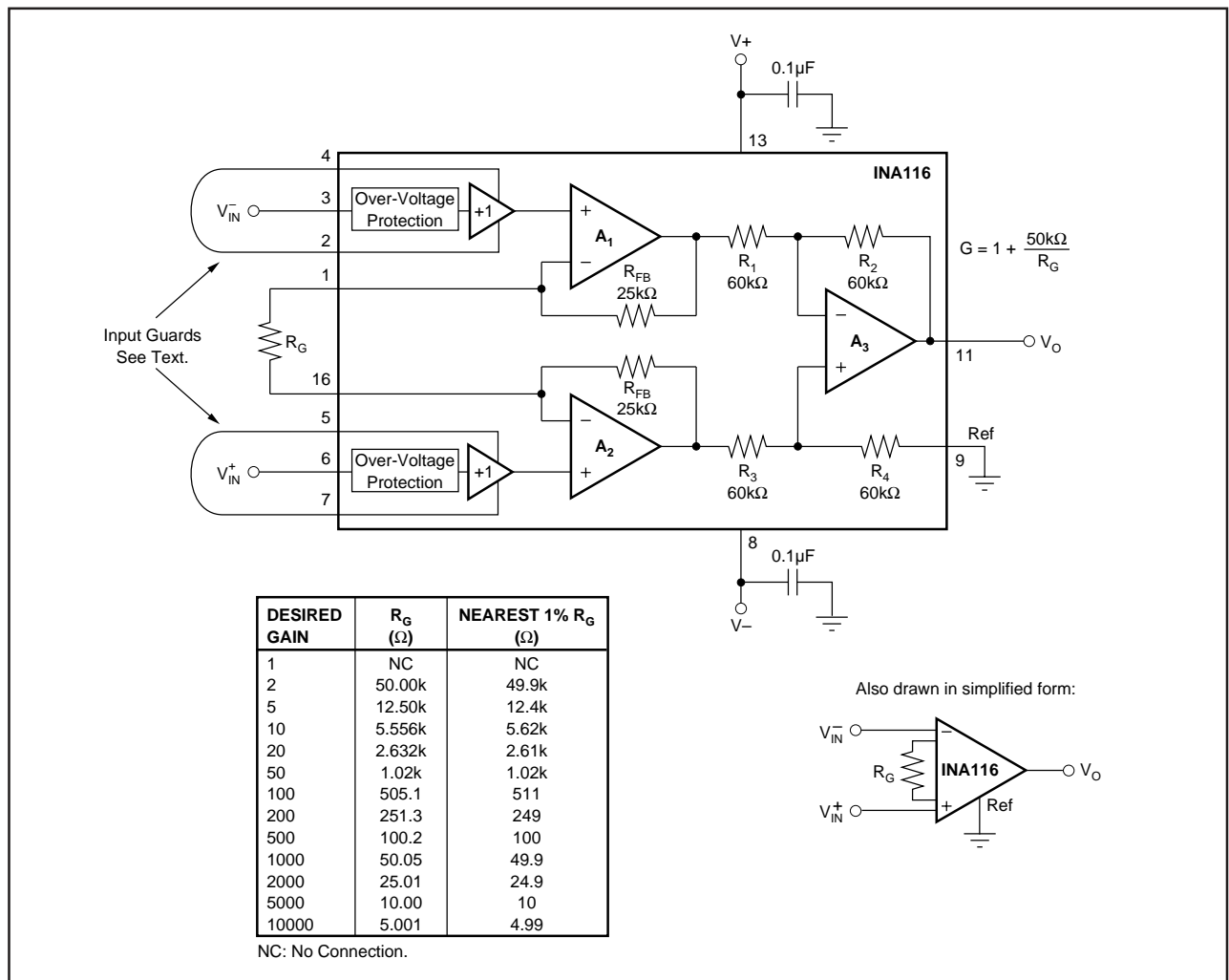


FIGURE 1. Basic Connections.

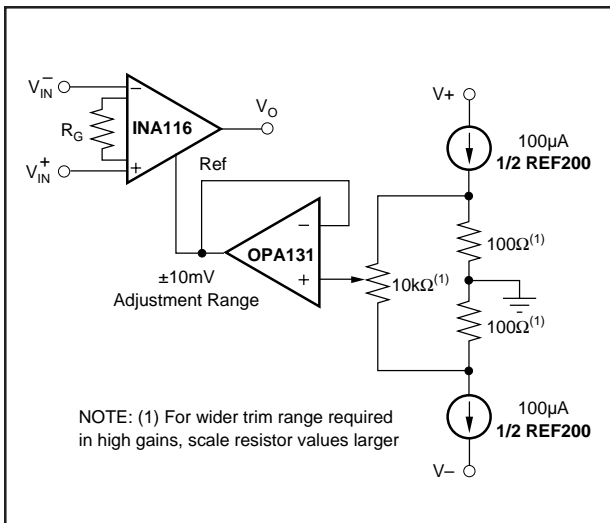


FIGURE 2. Optional Trimming of Output Offset Voltage.

### INPUT BIAS CURRENT RETURN PATH

Input circuitry must provide an input bias current path for proper operation. Figure 3 shows resistors  $R_1$  and  $R_2$  to provide an input current path. Without these resistors, the inputs would eventually float to a potential that exceeds the common-mode range of the INA116 and the input amplifiers would saturate. Because of its exceedingly low input bias current, improperly biased inputs may operate normally for a period of time after power is first applied, or operate intermittently.

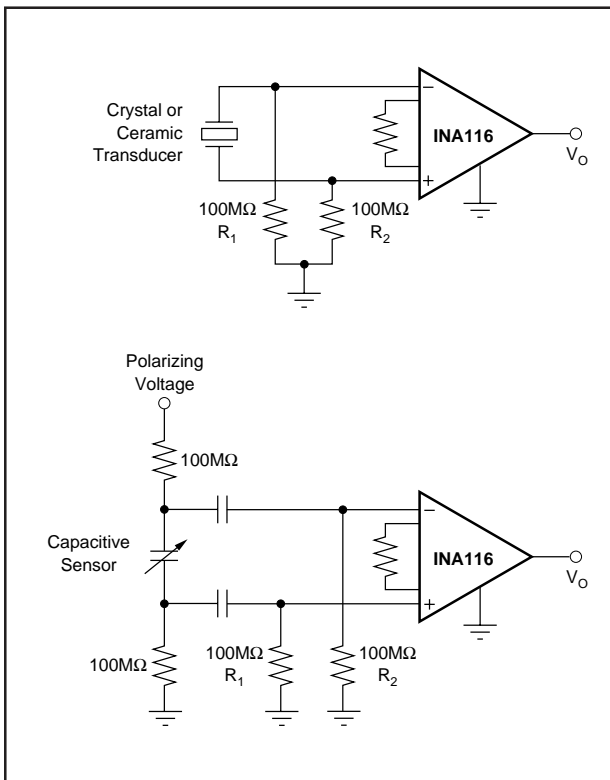


FIGURE 3. Providing An Input Bias Current Path.

### CIRCUIT BOARD LAYOUT AND ASSEMBLY

Careful circuit board layout and assembly techniques are required to achieve the exceptionally low input bias current performance of the INA116. Guard terminals adjacent to both inputs make it easy to properly guard the critical input terminal layout. Since traces are not required to run between device pins, this layout is easily accomplished, even with the surface mount package. The guards should completely encircle their respective input connections—see Figure 4. Both sides of the circuit board should be guarded, even if only one side has an input terminal conductor. Route any time-varying signals away from the input terminals. Solder mask should not cover the input and guard traces since this can increase leakage.

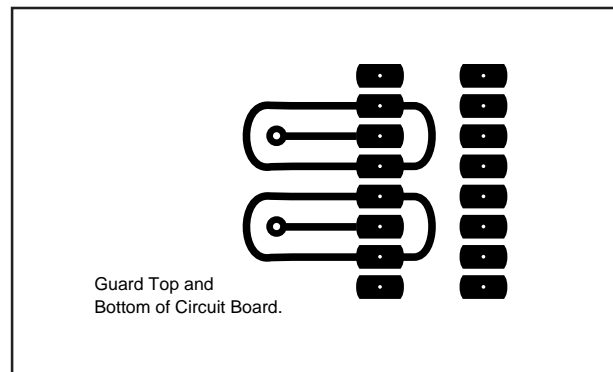


FIGURE 4. Circuit Board Guard Layout.

After assembly, the circuit board should be cleaned. Commercial solvents should be chosen according to the soldering method and flux used. Solvents should be cleaned and replaced often. Solvent cleaning should be followed by a de-ionized water rinse and 85°C bake out.

Sockets can be used, but select and evaluate them carefully for best results. Use caution when installing the INA116 in a socket. Careless handling can contaminate the plastic near the input pins, dramatically increasing leakage current.

A proven low leakage current assembly method is to bend the input pins outward so they do not contact the circuit board. Input connections are made in air and soldered directly to the input pin. This technique is often not practical or production-worthy. It is, however, a useful technique for evaluation and testing and provides a benchmark with which to compare other wiring techniques. The circuit board guarding techniques discussed normally reduce leakage to acceptable levels.

A solid mechanical assembly is required for good results. Nearby plastic parts can be especially troublesome since a static charge can develop and the slightest motion or vibration will couple charge to the inputs. Place a Faraday shield around the whole amplifier and input connection assembly to eliminate stray fields.



## INPUT CONNECTIONS

Some applications must make high impedance input connections to external sensors or input connectors. To assure low leakage, the input should be guarded all the way to the signal source—see Figure 5. Coaxial cable can be used with the shield driven by the guard. A separate connection is required to provide a ground reference at the signal source. Triaxial cable may reduce noise pickup and provides the ground reference at the source. Drive the inner shield at guard

potential and ground the outer shield. Two separate guarded lines are required if both the inverting and non-inverting inputs are brought to the source.

The guard drive output current is limited to approximately  $+2\text{mA}/-50\mu\text{A}$ . For slow input signals the internal guard output can directly drive a cable shield. With fast input signals, however, the guard may not provide sufficient output current to rapidly charge the cable capacitance. An op amp buffer may be required as shown in Figure 6.

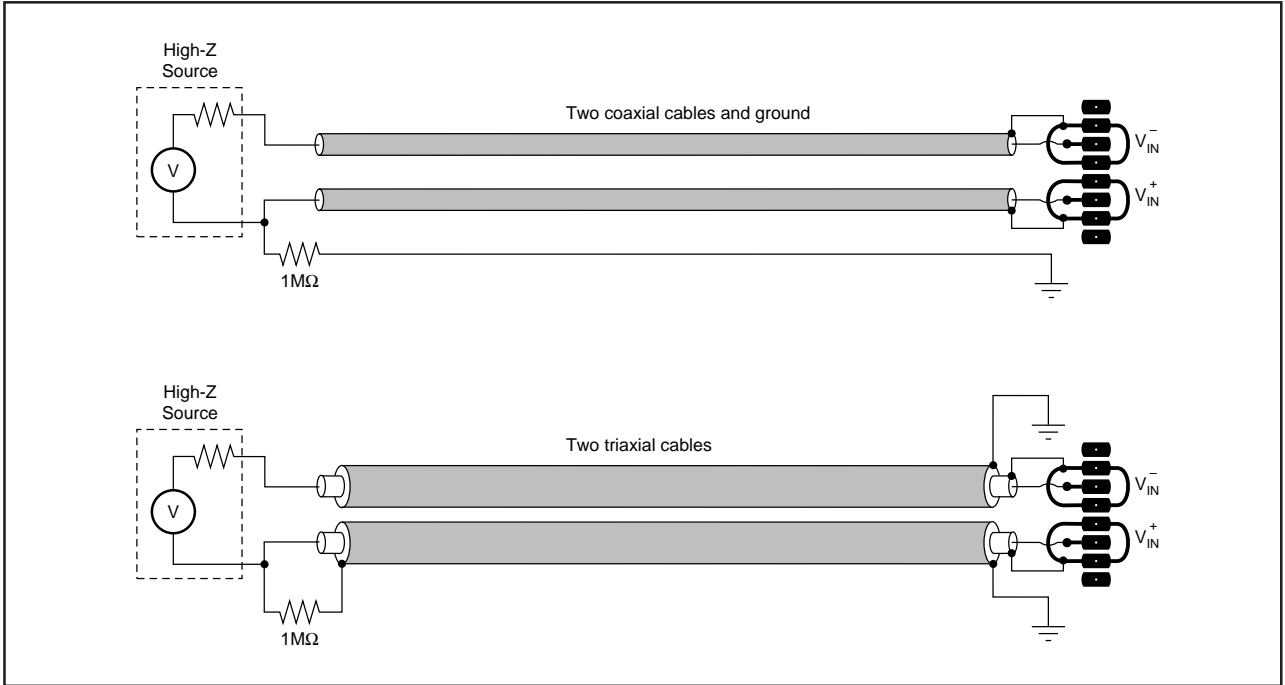


FIGURE 5. Input Cable Guarding Circuits.

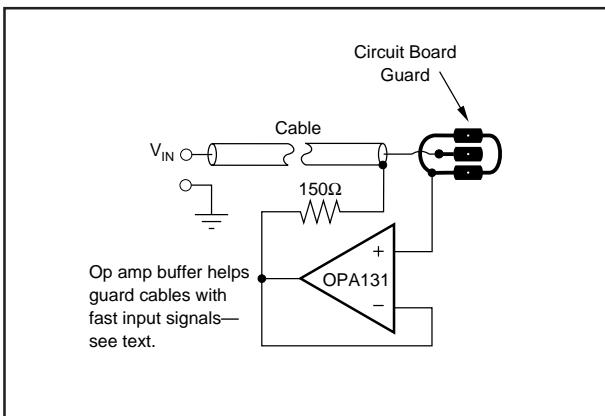


FIGURE 6. Buffered Guard Drive.

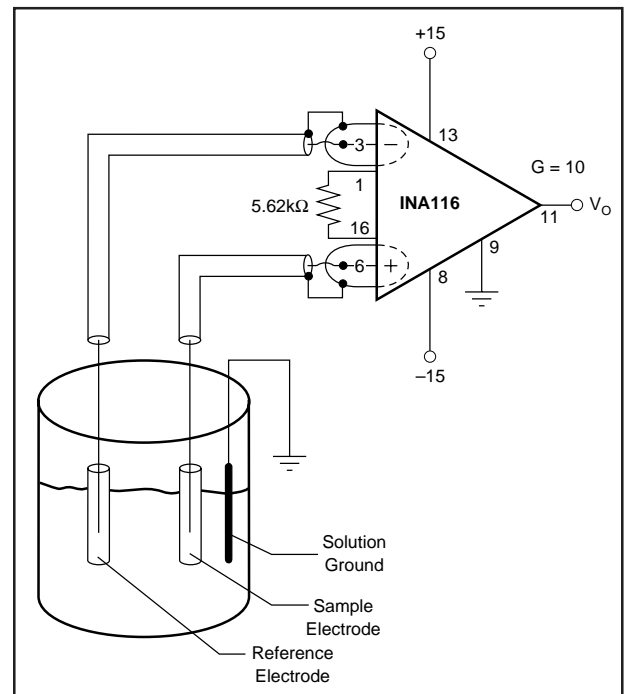


FIGURE 7. pH or Ion Measurement System.

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
INA116PA	ACTIVE	PDIP	N	16	25	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type
INA116PAG4	ACTIVE	PDIP	N	16	25	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type
INA116UA	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR
INA116UAG4	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR

<sup>(1)</sup> 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.

<sup>(2)</sup> 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)

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

**Important Information and Disclaimer:**The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

### Products

Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
RF/IF and ZigBee® Solutions	<a href="http://www.ti.com/lprf">www.ti.com/lprf</a>

### Applications

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Automotive	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
Broadband	<a href="http://www.ti.com/broadband">www.ti.com/broadband</a>
Digital Control	<a href="http://www.ti.com/digitalcontrol">www.ti.com/digitalcontrol</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Military	<a href="http://www.ti.com/military">www.ti.com/military</a>
Optical Networking	<a href="http://www.ti.com/opticalnetwork">www.ti.com/opticalnetwork</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Telephony	<a href="http://www.ti.com/telephony">www.ti.com/telephony</a>
Video & Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>
Wireless	<a href="http://www.ti.com/wireless">www.ti.com/wireless</a>

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2009, Texas Instruments Incorporated