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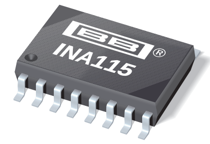


INA115

Precision INSTRUMENTATION AMPLIFIER

FEATURES

- LOW OFFSET VOLTAGE: 50µV max
- LOW DRIFT: 0.25µV/°C max
- LOW INPUT BIAS CURRENT: 2nA max
- HIGH COMMON-MODE REJECTION: 115dB min
- INPUT OVER-VOLTAGE PROTECTION: ±40V
- WIDE SUPPLY RANGE: ±2.25 TO ±18V
- LOW QUIESCENT CURRENT: 3mA max
- SOL-16 SURFACE-MOUNT PACKAGE

APPLICATIONS

- SWITCHED-GAIN AMPLIFIER
- BRIDGE AMPLIFIER
- THERMOCOUPLE AMPLIFIER
- RTD SENSOR AMPLIFIER
- MEDICAL INSTRUMENTATION
- DATA ACQUISITION

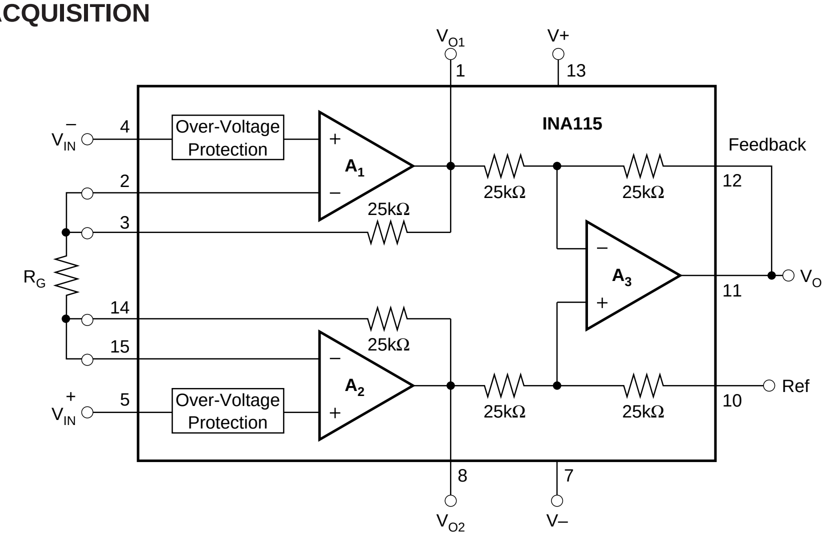
DESCRIPTION

The INA115 is a low cost, general purpose instrumentation amplifier offering excellent accuracy. Its versatile three-op amp design and small size make it ideal for a wide range of applications. Similar to the model INA114, the INA115 provides additional connections to the input op amps, A_1 and A_2, which improve gain accuracy in high gains and are useful in forming switched-gain amplifiers.

A single external resistor sets any gain from 1 to 10,000. Internal input protection can withstand up to ±40V without damage.

The INA115 is laser trimmed for very low offset voltage (50µV), drift (0.25µV/˚C) and high common-mode rejection (115dB at G=1000). It operates with power supplies as low as ±2.25V, allowing use in battery operated and single 5V supply systems. Quiescent current is 3mA maximum.

The INA115 is available in the SOL-16 surface-mount package, specified for the –40°C to +85°C temperature range.



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

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SPECIFICATIONS

ELECTRICAL

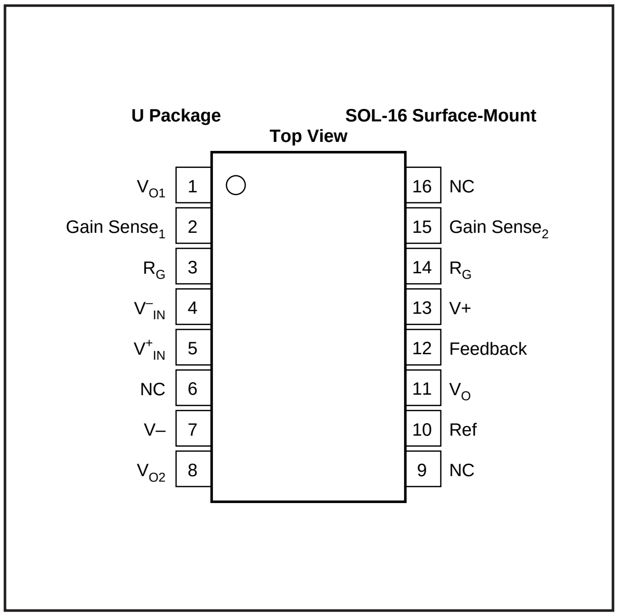
At T_A = +25°C, V_S = ±15V, R_L = 2kΩ unless otherwise noted.

PARAMETER	CONDITIONS	INA115BU			INA115AU			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
INPUT								
Offset Voltage, RTI								
Initial	T_A = +25°C		±10 + 20/G	±50 + 100/G		±25 + 30/G	±125 + 500/G	µV
vs Temperature	$T_A = T_{MIN}$ to T_{MAX}		±0.1 + 0.5/G	±0.25 + 5/G		±0.25 + 5/G	±1 + 10/G	µV/°C
vs Power Supply	V_S = ±2.25V to ±18V		0.5 + 2/G	3 + 10/G		*	*	µV/V
Long-Term Stability			±0.2 + 0.5/G			*		µV/mo
Impedance, Differential			10^{10} ‖ 6			*		Ω ‖ pF
Common-Mode			10^{10} ‖ 6			*		Ω ‖ pF
Input Common-Mode Range		±11	±13.5		*	*		V
Safe Input Voltage				±40			*	V
Common-Mode Rejection	V_{CM} = ±10V, ΔR_S = 1kΩ							
	G = 1	80	96		75	90		dB
	G = 10	96	115		90	106		dB
	G = 100	110	120		106	110		dB
	G = 1000	115	120		106	110		dB
BIAS CURRENT			±0.5	±2		*	±5	nA
vs Temperature			±8			*		pA/°C
OFFSET CURRENT			±0.5	±2		*	±5	nA
vs Temperature			±8			*		pA/°C
NOISE VOLTAGE, RTI	G = 1000, R_S = 0Ω							
f = 10Hz			15			*		nV/√Hz
f = 100Hz			11			*		nV/√Hz
f = 1kHz			11			*		nV/√Hz
f_B = 0.1Hz to 10Hz			0.4			*		µVp-p
Noise Current								
f=10Hz			0.4			*		pA/√Hz
f=1kHz			0.2			*		pA/√Hz
f_B = 0.1Hz to 10Hz			18			*		pAp-p
GAIN								
Gain Equation			1 + (50kΩ/R_G)			*		V/V
Range of Gain		1		10000	*		*	V/V
Gain Error	G = 1		±0.01	±0.05		*	*	%
	G = 10		±0.02	±0.4		*	±0.5	%
	G = 100		±0.05	±0.5		*	±0.7	%
	G = 1000		±0.5	±1		*	±2	%
Gain vs Temperature	G = 1		±2	±10		*	±10	ppm/°C
50kΩ Resistance(1)			±25	±100		*	*	ppm/°C
Nonlinearity	G = 1		±0.0001	±0.001		*	±0.002	% of FSR
	G = 10		±0.0005	±0.002		*	±0.004	% of FSR
	G = 100		±0.0005	±0.002		*	±0.004	% of FSR
	G = 1000		±0.002	±0.01		*	±0.02	% of FSR
OUTPUT(2)								
Voltage	I_O = 5mA, T_{MIN} to T_{MAX}	±13.5	±13.7		*	*		V
	V_S = ±11.4V, R_L = 2kΩ	±10	±10.5		*	*		V
	V_S = ±2.25V, R_L = 2kΩ	±1	±1.5		*	*		V
Load Capacitance Stability			1000			*		pF
Short Circuit Current			+20/–15			*		mA
FREQUENCY RESPONSE								
Bandwidth, –3dB	G = 1		1			*		MHz
	G = 10		100			*		kHz
	G = 100		10			*		kHz
	G = 1000		1			*		kHz
Slew Rate	V_O = ±10V, G = 10	0.3	0.6		*	*		V/µs
Settling Time, 0.01%	G = 1		18			*		µs
	G = 10		20			*		µs
	G = 100		120			*		µs
	G = 1000		1100			*		µs
Overload Recovery	50% Overdrive		20			*		µs
POWER SUPPLY								
Voltage Range		±2.25	±15	±18	*	*	*	V
Current	V_{IN} = 0V		±2.2	±3		*	*	mA
TEMPERATURE RANGE								
Specification		–40		+85	*		*	°C
Operating		–40		+125	*		*	°C
θ_{JA}			80			*		°C/W

* Specification same as INA115BU.

NOTE: (1) Temperature coefficient of the "50kΩ" term in the gain equation. (2) Output specifications are for output amplifier, A_3. A_1 and A_2 provide the same output voltage swing but have less output current drive. A_1 and A_2 can drive external loads of 25kΩ ‖ 200pF.

PIN CONFIGURATIONS



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.

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

PACKAGE/ORDERING INFORMATION

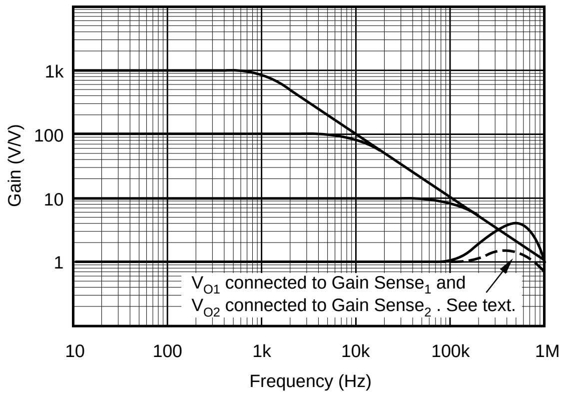
PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER(1)	TEMPERATURE RANGE
INA115AU	SOL-16 Surface-Mount	211	–40°C to +85°C
INA115BU	SOL-16 Surface-Mount	211	–40°C to +85°C

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

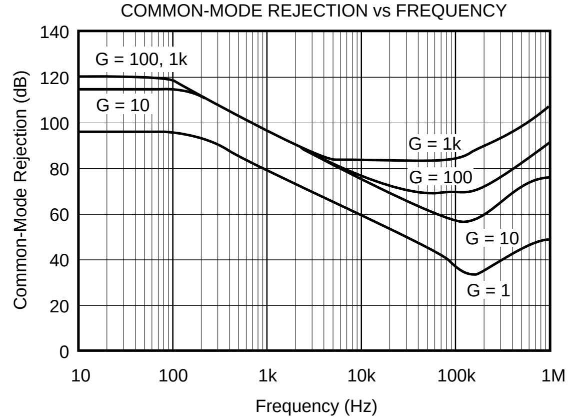
TYPICAL PERFORMANCE CURVES

At T_A = +25°C, V_S = ±15V, unless otherwise noted.

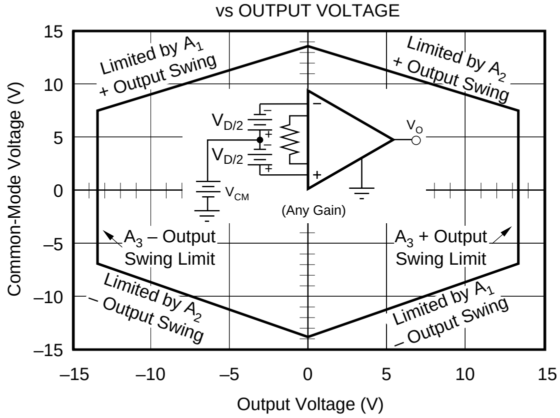
GAIN vs FREQUENCY



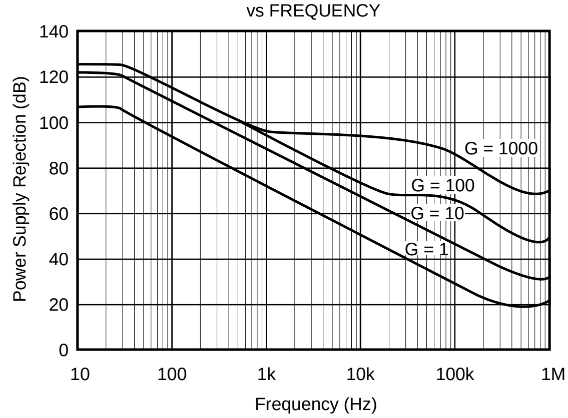
COMMON-MODE REJECTION vs FREQUENCY



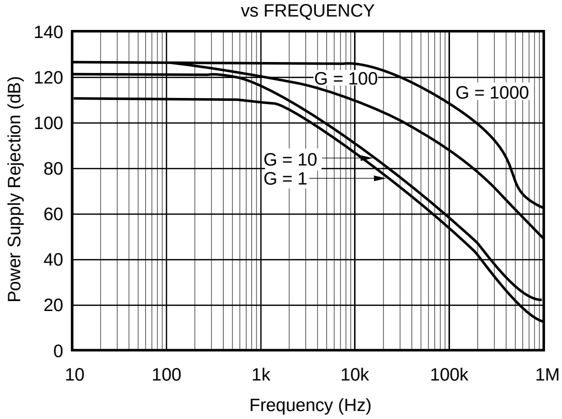
INPUT COMMON-MODE VOLTAGE RANGE vs OUTPUT VOLTAGE



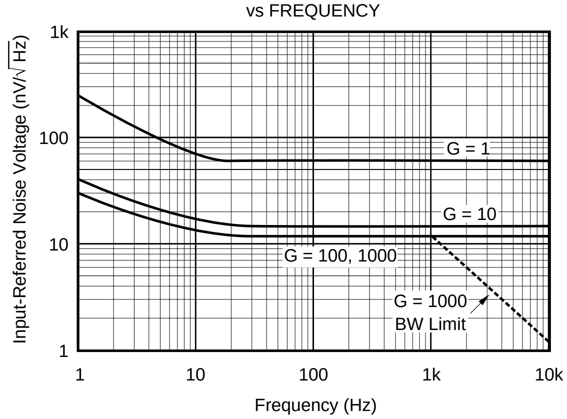
POSITIVE POWER SUPPLY REJECTION vs FREQUENCY



NEGATIVE POWER SUPPLY REJECTION vs FREQUENCY



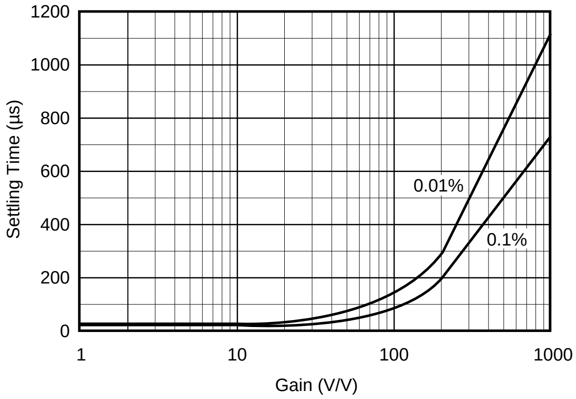
INPUT- REFERRED NOISE VOLTAGE vs FREQUENCY



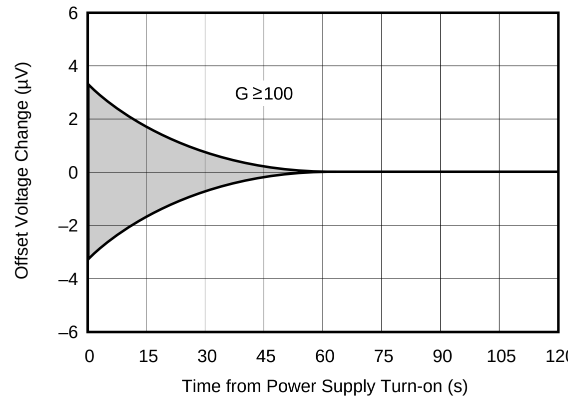
TYPICAL PERFORMANCE CURVES (CONT)

At T_A = +25°C, V_S = ±15V, unless otherwise noted.

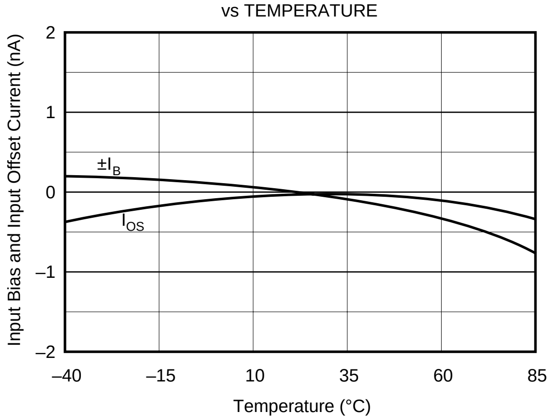
SETTLING TIME vs GAIN



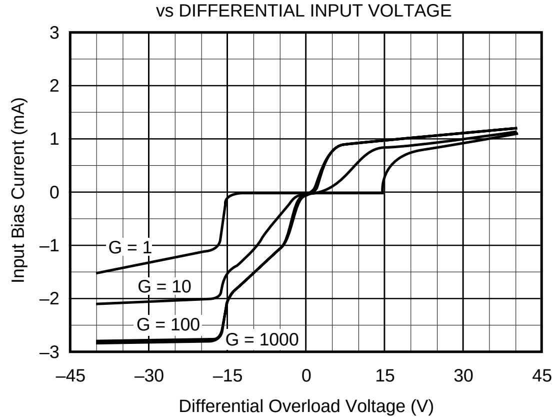
OFFSET VOLTAGE WARM-UP vs TIME



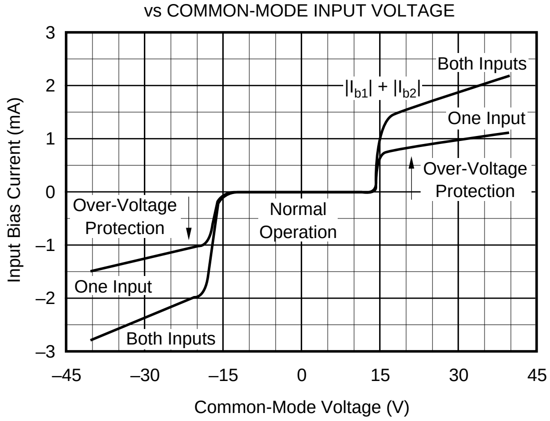
INPUT BIAS AND INPUT OFFSET CURRENT
vs TEMPERATURE



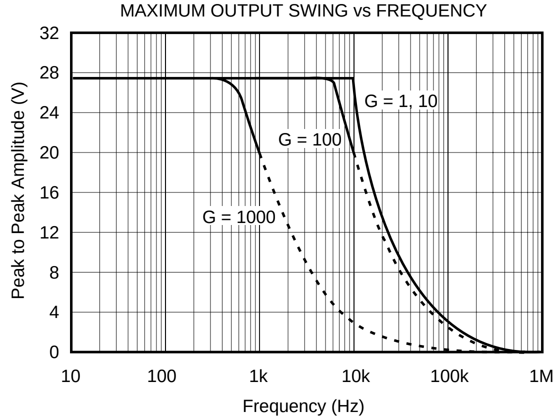
INPUT BIAS CURRENT
vs DIFFERENTIAL INPUT VOLTAGE



INPUT BIAS CURRENT
vs COMMON-MODE INPUT VOLTAGE



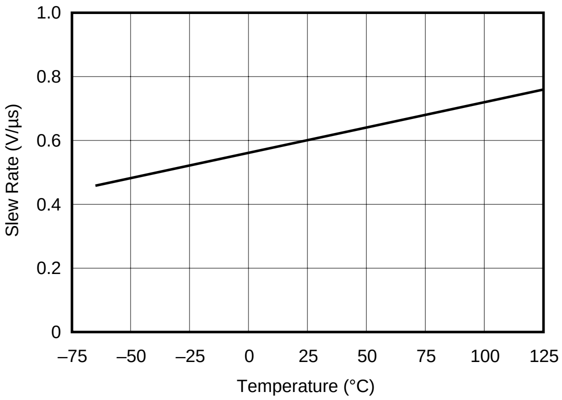
MAXIMUM OUTPUT SWING vs FREQUENCY



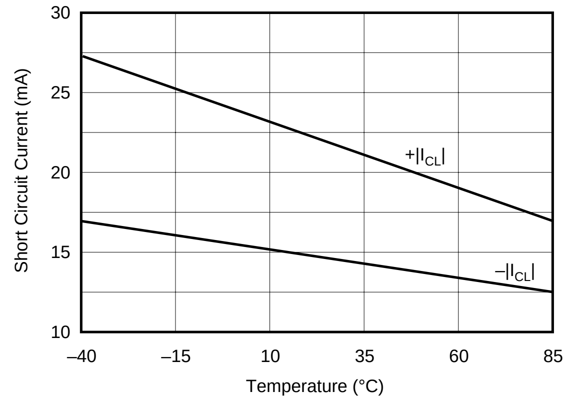
TYPICAL PERFORMANCE CURVES (CONT)

At T_A = +25°C, V_S = ±15V, unless otherwise noted.

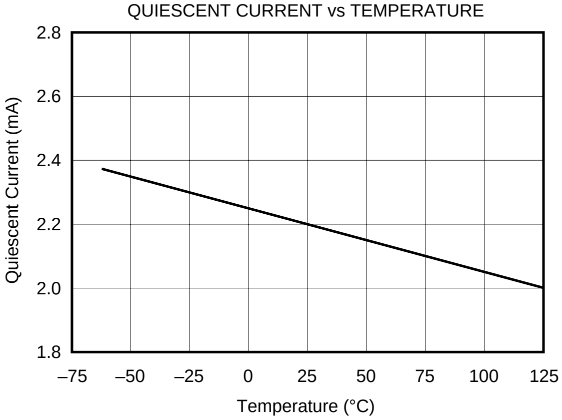
SLEW RATE vs TEMPERATURE



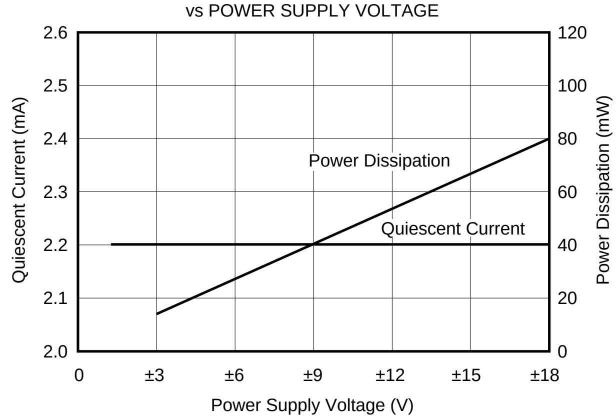
OUTPUT CURRENT LIMIT vs TEMPERATURE



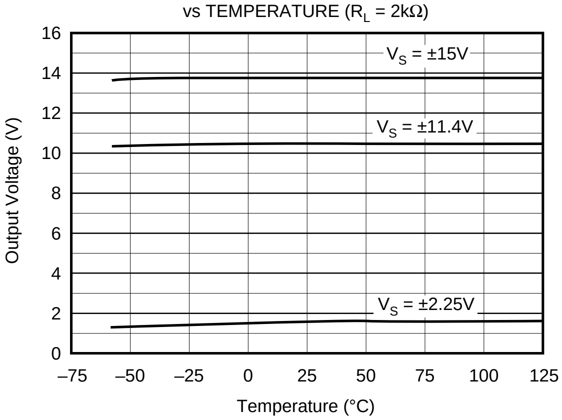
QUIESCENT CURRENT vs TEMPERATURE



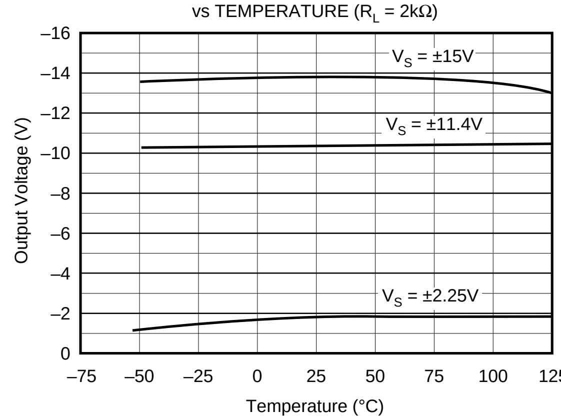
QUIESCENT CURRENT AND POWER DISSIPATION
vs POWER SUPPLY VOLTAGE



POSITIVE SIGNAL SWING
vs TEMPERATURE (R_L = 2kΩ)



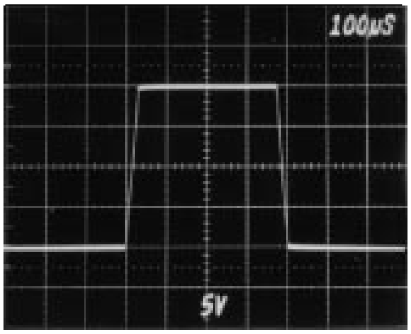
NEGATIVE SIGNAL SWING
vs TEMPERATURE (R_L = 2kΩ)



TYPICAL PERFORMANCE CURVES (CONT)

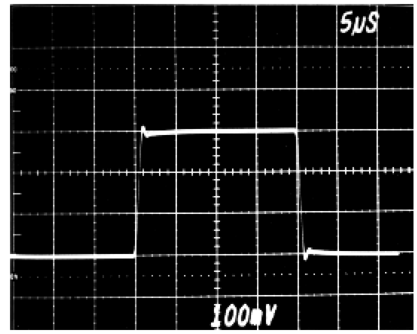
At T_A = +25°C, V_S = ±15V, unless otherwise noted.

LARGE SIGNAL RESPONSE, G = 1



+10V
0
–10V

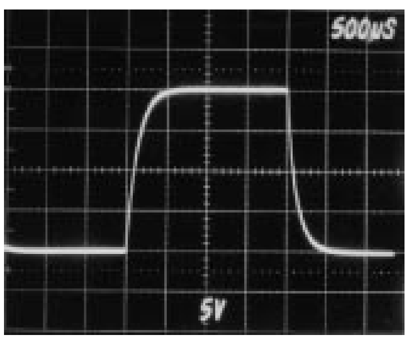
SMALL SIGNAL RESPONSE, G = 1



+100mV
0
–200mV

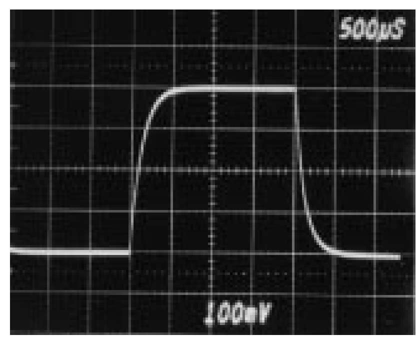
V_{O1} connected to Gain Sense$_1$ and
V_{O2} connected to Gain Sense$_2$

LARGE SIGNAL RESPONSE, G = 1000



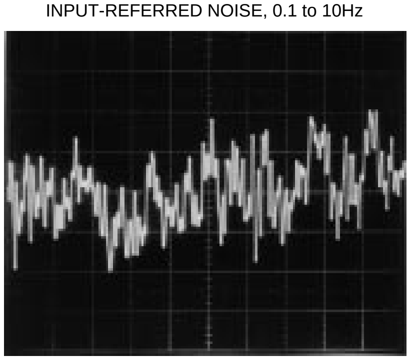
+10V
0
–10V

SMALL SIGNAL RESPONSE, G = 1000



+200mV
0
+200mV

INPUT-REFERRED NOISE, 0.1 to 10Hz



0.1µV/div

1 s/div

APPLICATION INFORMATION

Figure 1 shows the basic connections required for operation of the INA115. Applications with noisy or high impedance power supplies may require decoupling capacitors close to the device 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 5Ω in series with the Ref pin will cause a typical device to degrade to approximately 80dB CMR (G=1).

The INA115 has a separate output sense feedback connection (pin 12). Pin 12 must be connected (normally to the output terminal, pin 11) for proper operation. The output sense connection can be used to sense the output voltage directly at the load for best accuracy.

SETTING THE GAIN

Gain of the INA115 is set by connecting a single external resistor, R_G:

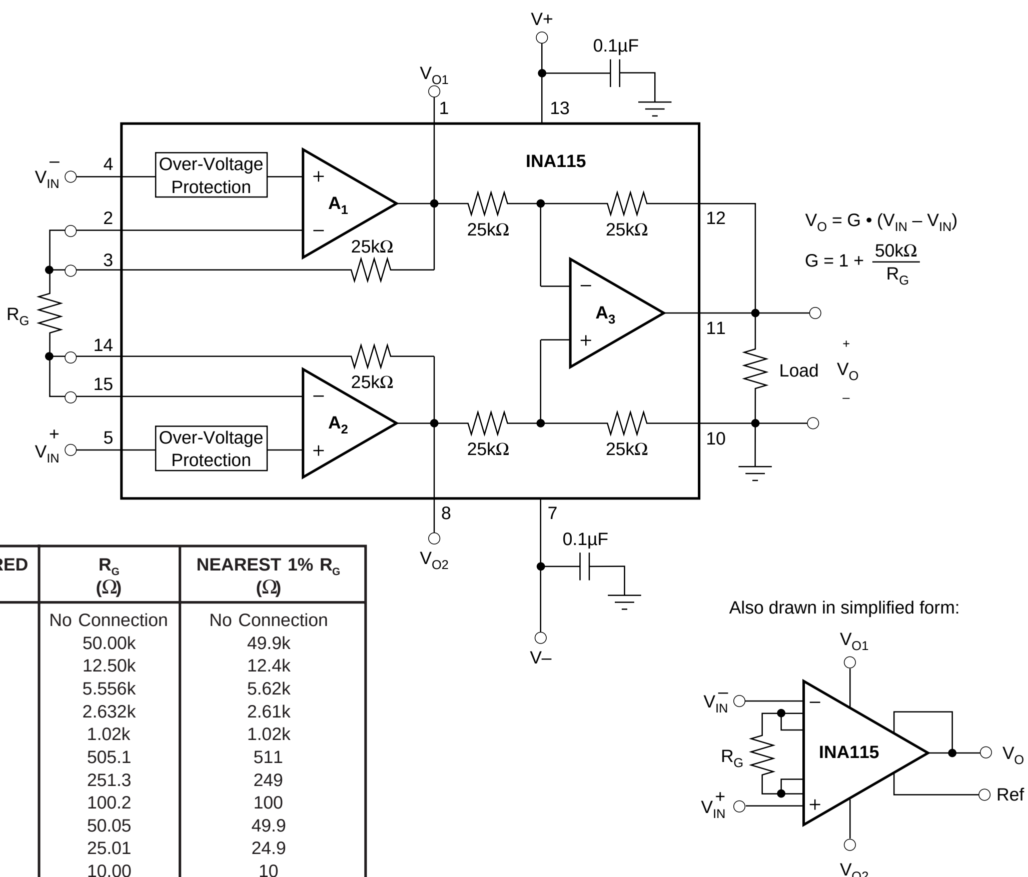
$$G = 1 + \frac{50\ k\Omega}{R_G} \qquad (1)$$

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

For G=1, no resistor is required, but connect pins 2-3 and connect pins 14-15. Gain peaking in G=1 can be reduced by shorting the internal 25kΩ feedback resistors (see typical performance curve Gain vs Frequency). To do this, connect pins 1-2-3 and connect pins 8-14-15.

The 50kΩ term in equation 1 comes from the sum of the two internal feedback resistors. These are on-chip metal film resistors which 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 INA115.

The stability and temperature drift of the external gain setting resistor, R_G, also affects gain. R_G's contribution to gain error and drift can be directly inferred from the gain equation (1). Low resistor values required for high gain can make wiring resistance important. The "force and sense" type connections illustrated in Figure 1 help reduce the effect of interconnection resistance.



DESIRED GAIN	R_G (Ω)	NEAREST 1% R_G (Ω)
1	No Connection	No Connection
2	50.00k	49.9k
5	12.50k	12.4k
10	5.556k	5.62k
20	2.632k	2.61k
50	1.02k	1.02k
100	505.1	511
200	251.3	249
500	100.2	100
1000	50.05	49.9
2000	25.01	24.9
5000	10.00	10
10000	5.001	4.99

FIGURE 1. Basic Connections.

SWITCHED GAIN

Figure 2 shows a circuit for digital selection of four gains. Multiplexer "on" resistance does not significantly affect gain. The resistor values required for some commonly used gain steps are shown. This circuit uses the internal 25kΩ feedback resistors, so the resistor values shown cannot be scaled to a different impedance level.

Figure 3 shows an alternative switchable gain configuration. This circuit does not use the internal 25kΩ feedback resistors, so the nominal values shown can be scaled to other impedance levels. This circuit is ideal for use with a precision resistor network to achieve excellent gain accuracy and lowest gain drift.

NOISE PERFORMANCE

The INA115 provides very low noise in most applications. For differential source impedances less than 1kΩ, the INA103 may provide lower noise. For source impedances greater than 50kΩ, the INA111 FET-Input Instrumentation Amplifier may provide lower noise.

Low frequency noise of the INA115 is approximately 0.4µVp-p measured from 0.1 to 10Hz. This is approximately one-tenth the noise of "low noise" chopper-stabilized amplifiers.

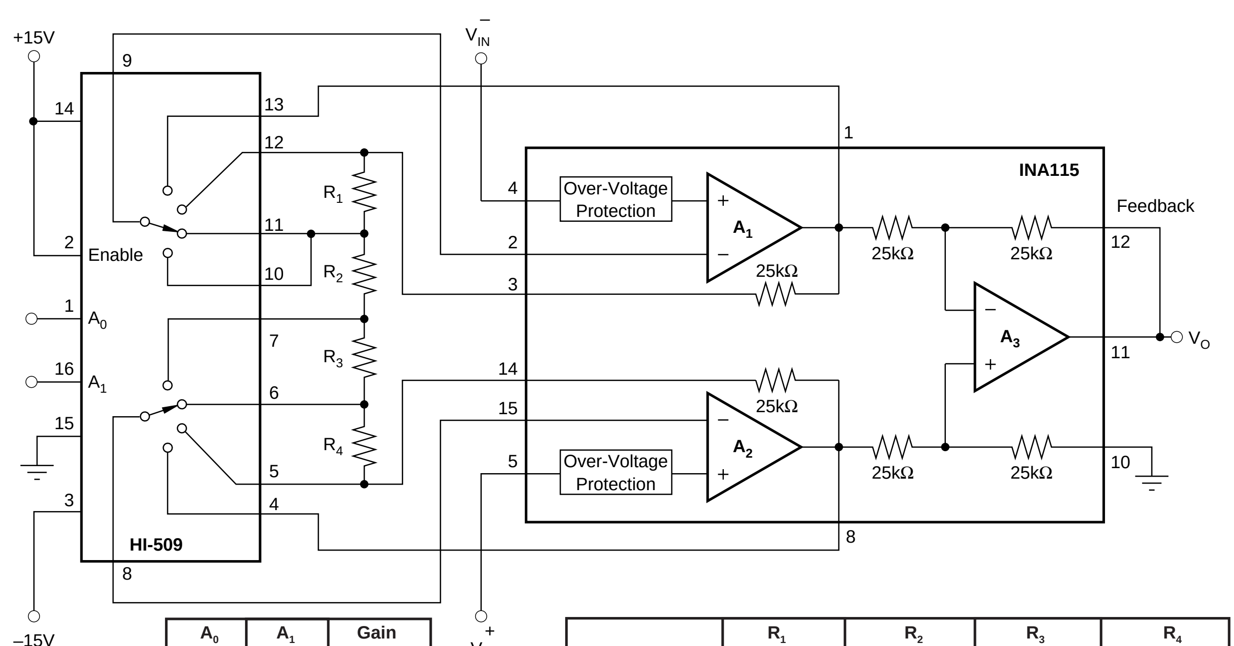
OFFSET TRIMMING

The INA115 is laser trimmed for very low offset voltage and drift. Most applications require no external offset adjustment. Figure 4 shows an optional circuit for trimming the output offset voltage. The voltage applied to Ref terminal is summed at the output. Low impedance must be maintained at this node to assure good common-mode rejection. This is achieved by buffering the trim voltage with an op amp as shown.

INPUT BIAS CURRENT RETURN PATH

The input impedance of the INA115 is extremely high—approximately $10^{10}\Omega$. However, a path must be provided for the input bias current of both inputs. This input bias current is typically less than ±1nA (it can be either polarity due to cancellation circuitry). High input impedance means that this input bias current changes very little with varying input voltage.

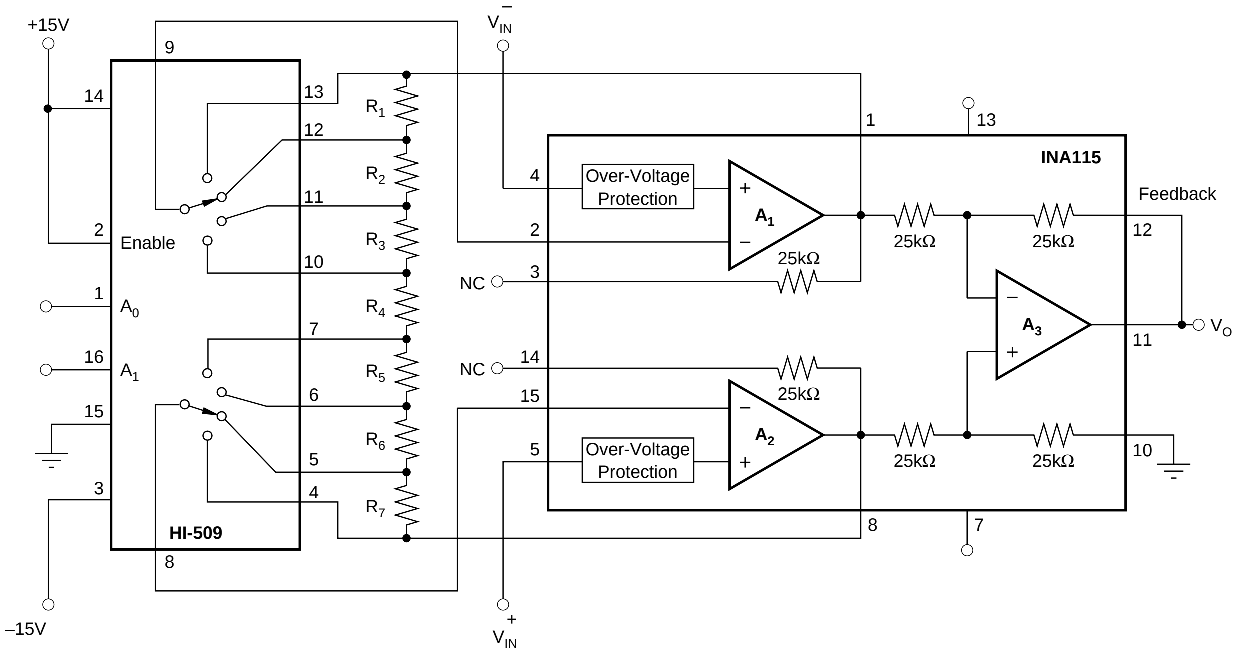
Input circuitry must provide a path for this input bias current if the INA115 is to operate properly. Figure 5 shows various provisions for an input bias current path. Without a bias current return path, the inputs will float to a potential which exceeds the common-mode range of the INA115 and the input amplifiers will saturate. If the differential source resistance is low, a bias current return path can be connected to one input (see thermocouple example in Figure 5). With higher source impedance, using two resistors provides a balanced input with possible advantages of lower input offset voltage due bias current and better common-mode rejection.



A_0	A_1	Gain
L	L	1
H	L	⋮
L	H	⋮
H	H	Highest

GAIN STEPS	R_1 (Ω)	R_2 (Ω)	R_3 (Ω)	R_4 (Ω)
1, 10, 100, 1000	2.5k	55.6	500	2.5k
1, 2, 4, 8	12.5k	12.5k	12.5k	12.5k
1, 2, 5, 10	15k	10k	10k	15k
0, +3, +6, +9dB	17.7k	60.3k	25k	17.7k

FIGURE 2. Switched-Gain Instrumentation Amplifier (minimum components).



A_0	A_1	Gain
L	L	1
H	L	⋮
L	H	⋮
H	H	Highest

GAIN STEPS	R_1 (Ω)	R_2 (Ω)	R_3 (Ω)	R_4 (Ω)	R_5 (Ω)	R_6 (Ω)	R_7 (Ω)
1, 10, 100, 1000V/V	18k	1.8k	180	40	180	1.8k	18k
1, 2, 4, 8V/V	18k	9k	4.5k	9k	4.5k	9k	18k
1, 2, 5, 10V/V	18k	10.8k	3.6k	7.2k	3.6k	10.8k	18k
0, +3, +6, +9dB	18k	12.74k	9.02k	43.7k	9.02k	12.74k	18k

FIGURE 3. Switched-Gain Instrumentation Amplifier (improved gain drift).

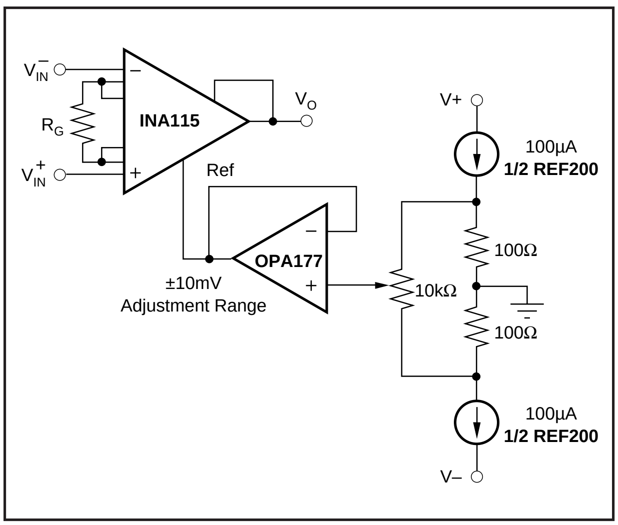


FIGURE 4. Optional Trimming of Output Offset Voltage.

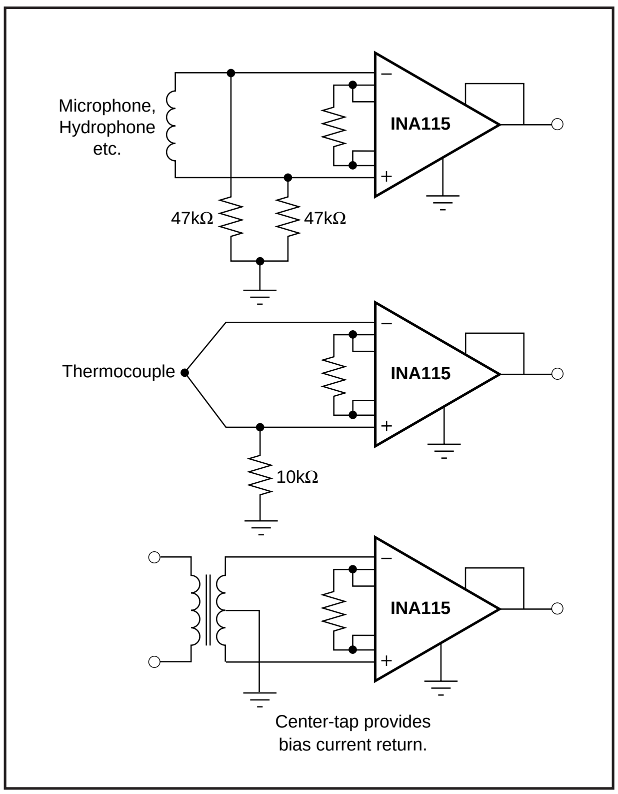


FIGURE 5. Providing an Input Common-Mode Current Path.

INPUT COMMON-MODE RANGE

The linear common-mode range of the input op amps of the INA115 is approximately ±13.75V (or 1.25V from the power supplies). As the output voltage increases, however, the linear input range will be limited by the output voltage swing of the input amplifiers, A_1 and A_2. The common-mode range is related to the output voltage of the complete amplifier—see performance curve "Input Common-Mode Range vs Output Voltage."

A combination of common-mode and differential input signals can cause the output of A_1 or A_2 to saturate. Figure 6 shows the output voltage swing of A_1 and A_2 expressed in terms of a common-mode and differential input voltages. Output swing capability of the input amplifiers, A_1 and A_2 is the same as the output amplifier, A_3. For applications where input common-mode range must be maximized, limit the output voltage swing by connecting the INA115 in a lower gain (see performance curve "Input Common-Mode Voltage Range vs Output Voltage"). If necessary, add gain after the INA115 to increase the voltage swing.

Input-overload often produces an output voltage that appears normal. For example, an input voltage of +20V on one input and +40V on the other input will obviously exceed the linear common-mode range of both input amplifiers. Since both input amplifiers are saturated to the nearly the same output voltage limit, the difference voltage measured by the output amplifier will be near zero. The output of the INA115 will be near 0V even though both inputs are overloaded.

INPUT PROTECTION

The inputs of the INA115 are individually protected for voltages up to ±40V. For example, a condition of –40V on one input and +40V on the other input will not cause damage. Internal circuitry on each input provides low series impedance under normal signal conditions. To provide equivalent protection, series input resistors would contribute excessive noise. If the input is overloaded, the protection circuitry limits the input current to a safe value (approximately 1.5mA). The typical performance curve "Input Bias Current vs Common-Mode Input Voltage" shows this input current limit behavior. The inputs are protected even if the power supply voltage is zero.

OTHER APPLICATIONS

See the INA114 data sheet for other applications circuits of general interest.

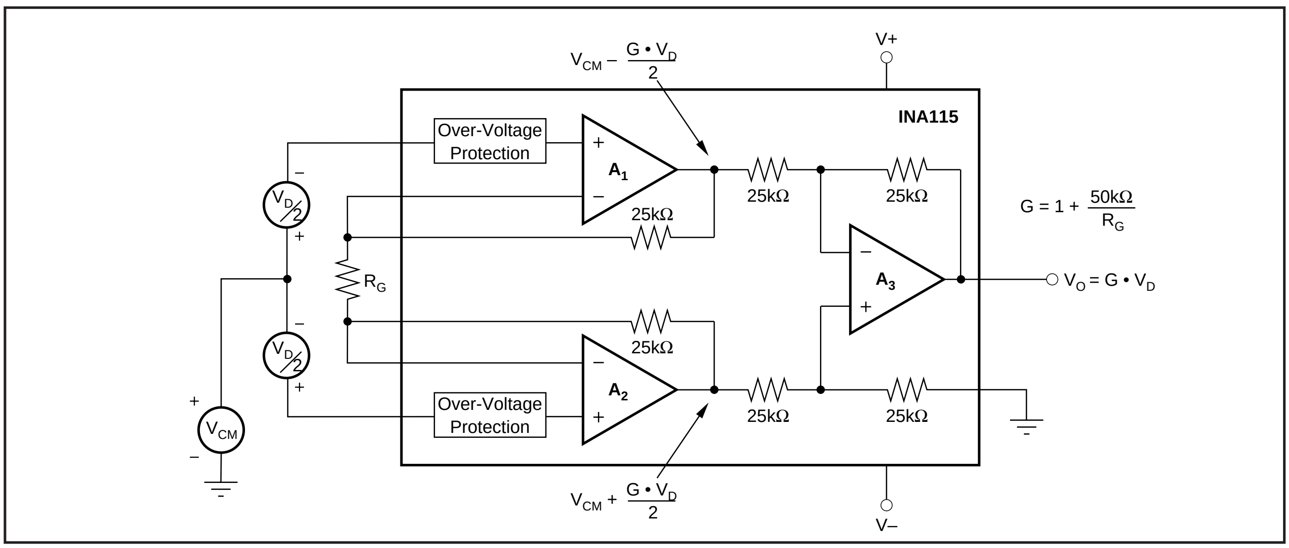


FIGURE 6. Voltage Swing of A_1 and A_2.

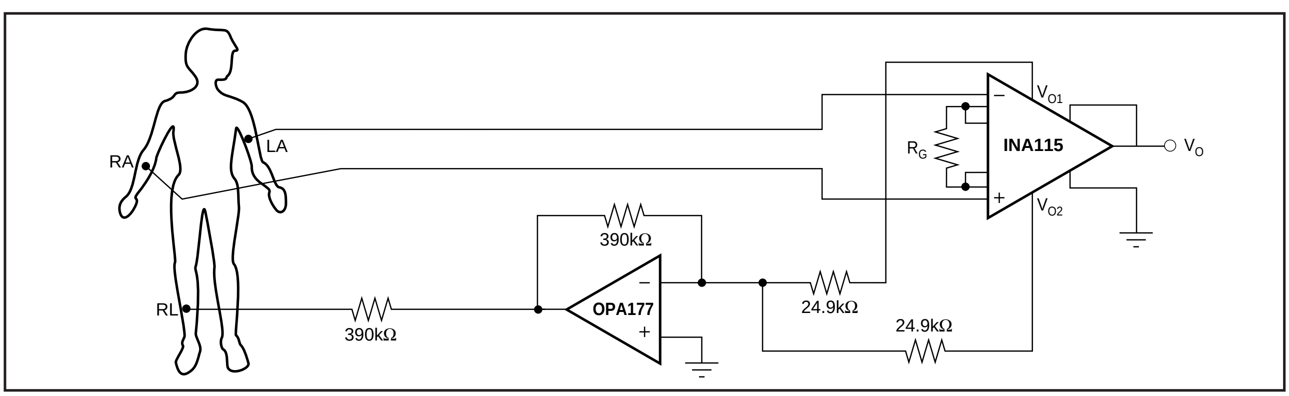


FIGURE 7. ECG Amplifier with Right Leg Drive.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/ Ball Finish	MSL Peak Temp (3)	Samples (Requires Login)
INA115AU	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	Request Free Samples
INA115AU/1K	ACTIVE	SOIC	DW	16	1000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	Purchase Samples
INA115AU/1KE4	ACTIVE	SOIC	DW	16	1000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	Purchase Samples
INA115AUG4	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	Contact TI Distributor or Sales Office
INA115BU	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	Request Free Samples
INA115BUG4	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	Contact TI Distributor or Sales Office

(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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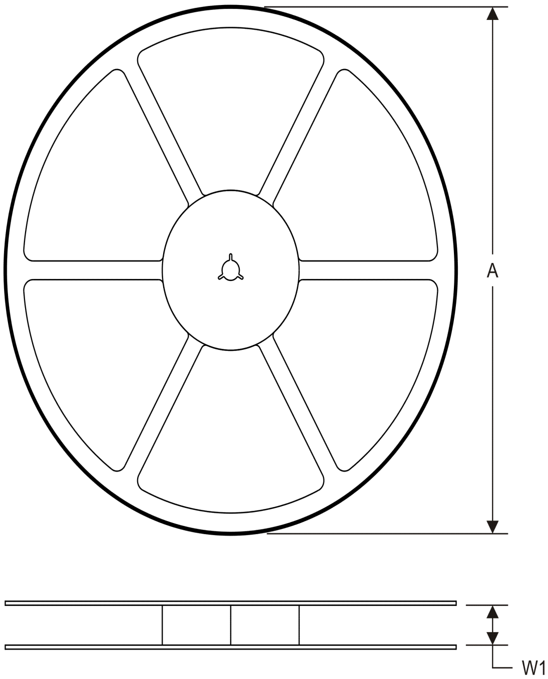
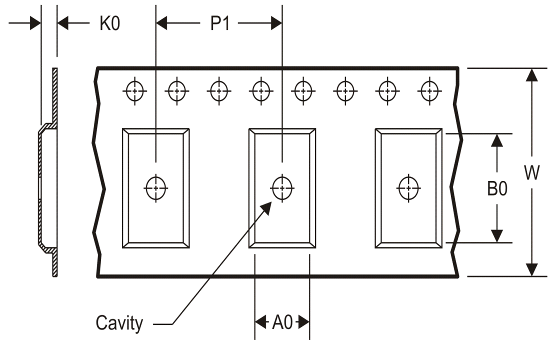
TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



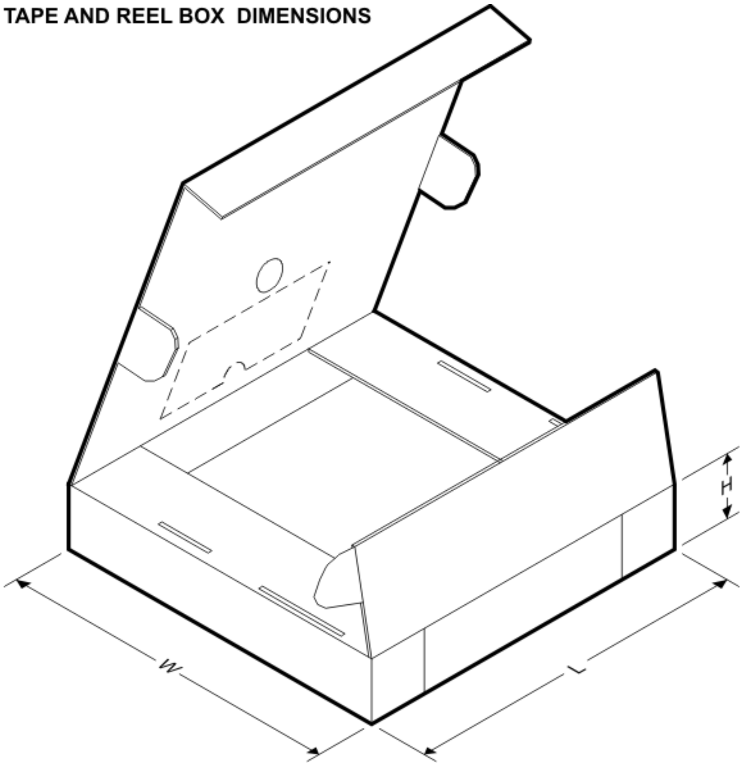
A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

TAPE AND REEL INFORMATION

*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
INA115AU/1K	SOIC	DW	16	1000	330.0	16.4	10.75	10.7	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)
INA115AU/1K	SOIC	DW	16	1000	367.0	367.0	38.0