

# LM4125

## Precision Micropower Low Dropout Voltage Reference

### General Description

The LM4125 is a precision low power low dropout bandgap voltage reference with up to 5 mA output current source and sink capability.

This series reference operates with input voltages as low as 2V and up to 6V consuming 160  $\mu$ A (Typ.) supply current. In power down mode, device current drops to less than 2  $\mu$ A.

The LM4125 comes in two grades (A and Standard) and three voltage options for greater flexibility. The best grade devices (A) have an initial accuracy of 0.2%, while the standard have an initial accuracy of 0.5%, both with a tempco of 50ppm/ $^{\circ}$ C guaranteed from  $-40^{\circ}$ C to  $+125^{\circ}$ C.

The very low dropout voltage, low supply current and power-down capability of the LM4125 makes this product an ideal choice for battery powered and portable applications.

The device performance is guaranteed over the industrial temperature range ( $-40^{\circ}$ C to  $+85^{\circ}$ C), while certain specs are guaranteed over the extended temperature range ( $-40^{\circ}$ C to  $+125^{\circ}$ C). Please contact National for full specifications over the extended temperature range. The LM4125 is available in a standard 5-pin SOT-23 package.

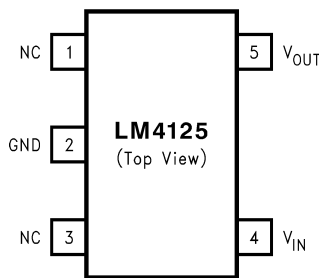
### Features

- Small SOT23-5 package
- Low dropout voltage: 120 mV Typ @ 1 mA
- High output voltage accuracy: 0.2%
- Source and Sink current output:  $\pm 5$  mA
- Supply current: 160  $\mu$ A Typ.
- Low Temperature Coefficient: 50 ppm/ $^{\circ}$ C
- Fixed output voltages: 2.048, 2.5, and 4.096
- Industrial temperature Range:  $-40^{\circ}$ C to  $+85^{\circ}$ C
- (For extended temperature range,  $-40^{\circ}$ C to  $125^{\circ}$ C, contact National Semiconductor)

### Applications

- Portable, battery powered equipment
- Instrumentation and process control
- Automotive & Industrial
- Test equipment
- Data acquisition systems
- Precision regulators
- Battery chargers
- Base stations
- Communications
- Medical equipment

### Connection Diagram



20069802

Refer to the Ordering Information Table in this Data Sheet for Specific Part Number

**SOT23-5 Surface Mount Package**

## Ordering Information

Industrial Temperature Range ( $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ )

Initial Output Voltage Accuracy at $25^{\circ}\text{C}$ And Temperature Coefficient	LM4125 Supplied as 1000 Units, Tape and Reel	LM4125 Supplied as 3000 Units, Tape and Reel	Top Marking
0.2%, 50 ppm/ $^{\circ}\text{C}$ max (A grade)	LM4125AIM5-2.0	LM4125AIM5X-2.0	R80A
	LM4125AIM5-2.5	LM4125AIM5X-2.5	R81A
	LM4125AIM5-4.1	LM4125AIM5X-4.1	R82A
0.5%, 50 ppm/ $^{\circ}\text{C}$ max	LM4125IM5-2.0	LM4125IM5X-2.0	R80B
	LM4125IM5-2.5	LM4125IM5X-2.5	R81B
	LM4125IM5-4.1	LM4125IM5X-4.1	R82B

### SOT-23 Package Marking Information

Only four fields of marking are possible on the SOT-23's small surface. This table gives the meaning of the four fields.

Field Information
First Field: R = Reference Second and third Field: 80 = 2.048V Voltage Option 81 = 2.500V Voltage Option 82 = 4.096V Voltage Option Fourth Field: A-B = Initial Reference Voltage Tolerance A = $\pm 0.2\%$ B = $\pm 0.5\%$

**Absolute Maximum Ratings** (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Maximum Voltage on input or enable pins	-0.3V to 8V
Output Short-Circuit Duration	Indefinite
Power Dissipation ( $T_A = 25^\circ\text{C}$ ) (Note 2):	
MA05B package – $\theta_{JA}$	280°C/W
Power Dissipation	350 mW
ESD Susceptibility (Note 3)	
Human Body Model	2 kV
Machine Model	200V

Lead Temperature:

Soldering, (10 sec.)	+260°C
Vapor Phase (60 sec.)	+215°C
Infrared (15 sec.)	+220°C

**Operating Range** (Note 1)

Storage Temperature Range	-65°C to +150°C
Ambient Temperature Range	-40°C to +85°C
Junction Temperature Range	-40°C to +125°C

**Electrical Characteristics**

**LM4125-2.048V and 2.5V** Unless otherwise specified  $V_{IN} = 3.3\text{V}$ ,  $I_{LOAD} = 0$ ,  $C_{OUT} = 0.01\mu\text{F}$ ,  $T_A = T_j = 25^\circ\text{C}$ . Limits with standard typeface are for  $T_j = 25^\circ\text{C}$ , and limits in **boldface type** apply over the  $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$  temperature range.

Symbol	Parameter	Conditions	Min (Note 5)	Typ (Note 4)	Max (Note 5)	Units
$V_{OUT}$	Output Voltage Initial Accuracy LM4125A-2.048 LM4125A-2.500				±0.2	%
		LM4125-2.048 LM4125-2.500			±0.5	%
$TCV_{OUT}/^\circ\text{C}$	Temperature Coefficient	$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		14	50	ppm/°c
$\Delta V_{OUT}/\Delta V_{IN}$	Line Regulation	$3.3\text{V} \leq V_{IN} \leq 6\text{V}$		0.0007	0.008 <b>0.01</b>	%/V
$\Delta V_{OUT}/\Delta I_{LOAD}$	Load Regulation	$0\text{ mA} \leq I_{LOAD} \leq 1\text{ mA}$		0.03	0.08 <b>0.17</b>	%mA
		$1\text{ mA} \leq I_{LOAD} \leq 5\text{ mA}$		0.01	0.04 <b>0.1</b>	
		$-1\text{ mA} \leq I_{LOAD} \leq 0\text{ mA}$		0.04	0.12	
		$-5\text{ mA} \leq I_{LOAD} \leq -1\text{ mA}$		0.01		
$V_{IN}-V_{OUT}$	Dropout Voltage (Note 6)	$I_{LOAD} = 0\text{ mA}$		45	65 <b>100</b>	mV
		$I_{LOAD} = +1\text{ mA}$		120	150 <b>200</b>	
		$I_{LOAD} = +5\text{ mA}$		180	210 <b>300</b>	
$V_N$	Output Noise Voltage (Note 8)	0.1 Hz to 10 Hz		20		$\mu\text{V}_{PP}$
		10 Hz to 10 kHz		36		$\mu\text{V}_{PP}$
$I_S$	Supply Current			160	257 <b>290</b>	$\mu\text{A}$
$I_{SC}$	Short Circuit Current	$V_{IN} = 3.3\text{V}$ , $V_{OUT} = 0$		15		mA
			<b>6</b>		<b>30</b>	
		$V_{IN} = 6\text{V}$ , $V_{OUT} = 0$		17		
			<b>6</b>		<b>30</b>	
Hyst	Thermal Hysteresis (Note 7)	$-40^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$		0.5		mV/V

## Electrical Characteristics

**LM4125-2.048V and 2.5V** Unless otherwise specified  $V_{IN} = 3.3V$ ,  $I_{LOAD} = 0$ ,  $C_{OUT} = 0.01\mu F$ ,  $T_A = T_j = 25^\circ C$ .

Limits with standard typeface are for  $T_j = 25^\circ C$ , and limits in **boldface type** apply over the  $-40^\circ C \leq T_A \leq +85^\circ C$  temperature range. (Continued)

Symbol	Parameter	Conditions	Min (Note 5)	Typ (Note 4)	Max (Note 5)	Units
$\Delta V_{OUT}$	Long Term Stability (Note 9)	1000 hrs. @ $25^\circ C$		100		ppm

## Electrical Characteristics

### LM4125-4.096V

Unless otherwise specified  $V_{IN} = 5V$ ,  $I_{LOAD} = 0$ ,  $C_{OUT} = 0.01\mu F$ ,  $T_A = T_j = 25^\circ C$ . Limits with standard typeface are for  $T_j = 25^\circ C$ , and limits in **boldface type** apply over the  $-40^\circ C \leq T_A \leq +85^\circ C$  temperature range.

Symbol	Parameter	Conditions	Min (Note 5)	Typ (Note 4)	Max (Note 5)	Units
$V_{OUT}$	Output Voltage Initial Accuracy LM4125A-4.096				$\pm 0.2$	%
	LM4125-4.096				$\pm 0.5$	%
$TCV_{OUT}/^\circ C$	Temperature Coefficient	$-40^\circ C \leq T_A \leq +125^\circ C$		14	50	ppm/ $^\circ C$
$\Delta V_{OUT}/\Delta V_{IN}$	Line Regulation	$5V \leq V_{IN} \leq 6V$		0.0007	0.008 <b>0.01</b>	%/V
$\Delta V_{OUT}/\Delta I_{LOAD}$	Load Regulation	$0 mA \leq I_{LOAD} \leq 1 mA$		0.03	0.08 <b>0.17</b>	%mA
		$1 mA \leq I_{LOAD} \leq 5 mA$		0.01	0.04 <b>0.1</b>	
		$-1 mA \leq I_{LOAD} \leq 0 mA$		0.04	0.12	
		$-5 mA \leq I_{LOAD} \leq -1 mA$		0.01		
$V_{IN}-V_{OUT}$	Dropout Voltage (Note 6)	$I_{LOAD} = 0 mA$		45	65 <b>100</b>	mV
		$I_{LOAD} = +1 mA$		120	150 <b>200</b>	
		$I_{LOAD} = +5 mA$		180	210 <b>300</b>	
$V_N$	Output Noise Voltage (Note 8)	0.1 Hz to 10 Hz		20		$\mu V_{PP}$
		10 Hz to 10 kHz		36		$\mu V_{PP}$
$I_S$	Supply Current			160	257 <b>290</b>	$\mu A$
$I_{SC}$	Short Circuit Current	$V_{OUT} = 0$		15		mA
		$V_{IN} = 6V$ , $V_{OUT} = 0$	<b>6</b>		<b>30</b>	
			<b>6</b>		<b>30</b>	
Hyst	Thermal Hysteresis (Note 7)	$-40^\circ C \leq T_A \leq 125^\circ C$		0.5		mV/V
$\Delta V_{OUT}$	Long Term Stability (Note 9)	1000 hrs. @ $25^\circ C$		100		ppm

**Note 1:** "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.

**Note 2:** Without PCB copper enhancements. The maximum power dissipation must be de-rated at elevated temperatures and is limited by  $T_{JMAX}$  (maximum junction temperature),  $\theta_{J-A}$  (junction to ambient thermal resistance) and  $T_A$  (ambient temperature). The maximum power dissipation at any temperature is:  $P_{DissMAX} = (T_{JMAX} - T_A)/\theta_{J-A}$  up to the value listed in the Absolute Maximum Ratings.

**Note 3:** The human body model is a 100 pF capacitor discharged through a 1.5 k $\Omega$  resistor into each pin. The machine model is a 200 pF capacitor discharged directly into each pin.

**Note 4:** Typical numbers are at 25°C and represent the most likely parametric norm.

**Note 5:** Limits are 100% production tested at 25°C. Limits over the operating temperature range are guaranteed through correlation using Statistical Quality Control (SQC) methods. The limits are used to calculate National's Averaging Outgoing Quality Level (AOQL).

**Note 6:** Dropout voltage is the differential voltage between  $V_{OUT}$  and  $V_{IN}$  at which  $V_{OUT}$  changes  $\leq 1\%$  from  $V_{OUT}$  at  $V_{IN} = 3.3V$  for 2.0V, 2.5V and 5V for 4.1V. A parasitic diode exists between input and output pins; it will conduct if  $V_{OUT}$  is pulled to a higher voltage than  $V_{IN}$ .

**Note 7:** Thermal hysteresis is defined as the change in +25°C output voltage before and after exposing the device to temperature extremes.

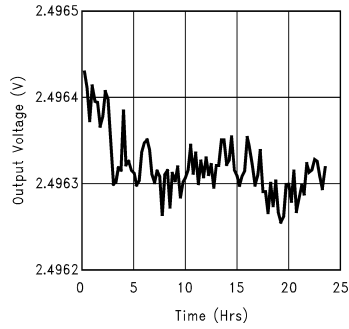
**Note 8:** Output noise voltage is proportional to  $V_{OUT}$ .  $V_N$  for other voltage option is calculated using  $(V_{N(1.8V)/1.8}) * V_{OUT}$ .  $V_N(2.5V) = (36\mu V_{PP}/1.8) * 2.5 = 46\mu V_{PP}$ .

**Note 9:** Long term stability is change in  $V_{REF}$  at 25°C measured continuously during 1000 hrs.

# LM4125 Typical Operating Characteristics

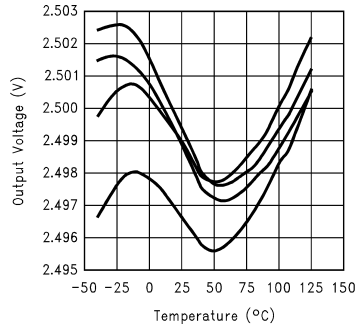
Unless otherwise specified,  $V_{IN} = 3.3V$ ,  $V_{OUT} = 2.5V$ ,  $I_{LOAD} = 0$ ,  $C_{OUT} = 0.022\mu F$  and  $T_A = 25^\circ C$ .

**Long Term Drift**



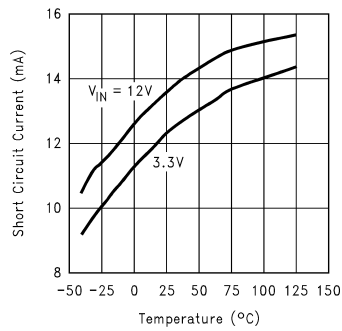
20069812

**Typical Temperature Drift**



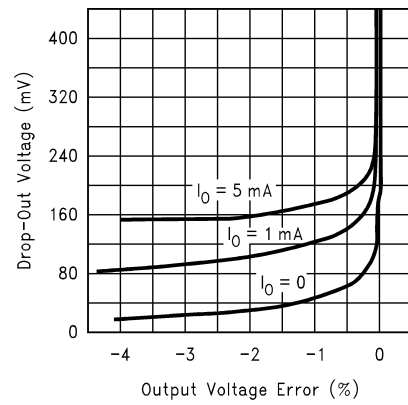
20069813

**Short Circuit Current vs Temperature**



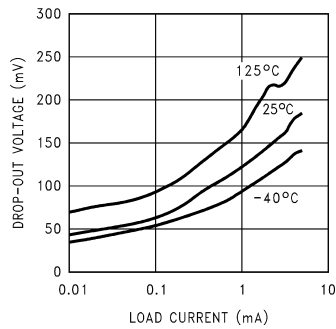
20069814

**Dropout Voltage vs Output Error**



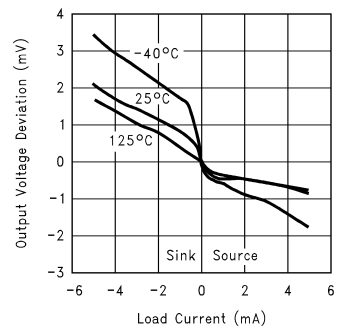
20069815

**Dropout Voltage vs Load Current**



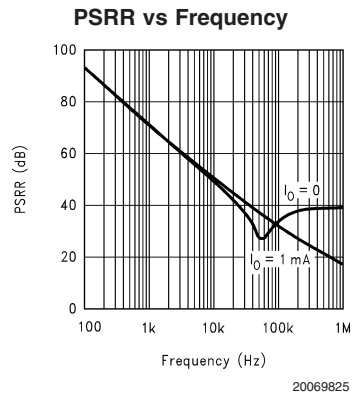
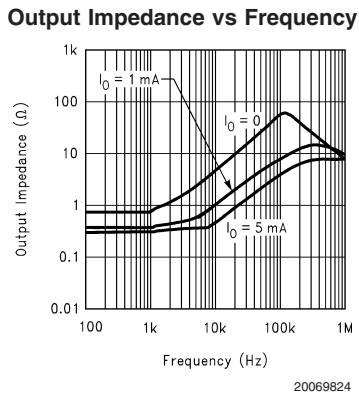
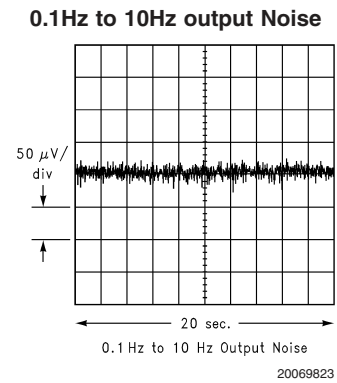
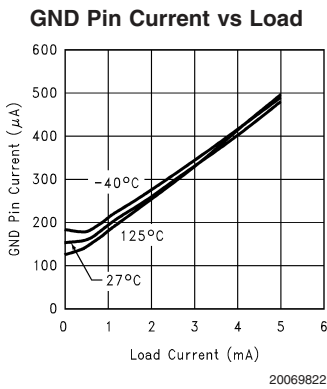
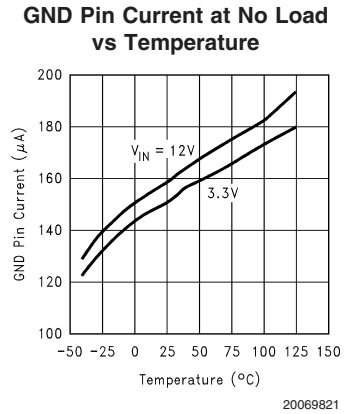
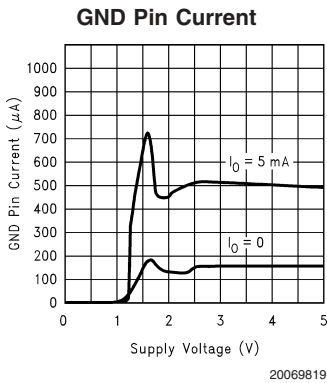
20069833

**Load Regulation**



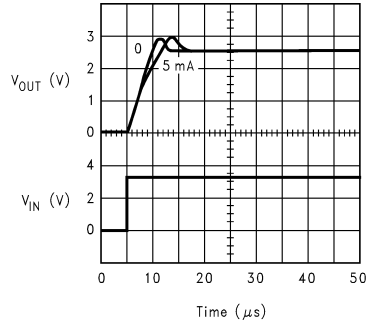
20069818

**LM4125 Typical Operating Characteristics** Unless otherwise specified,  $V_{IN} = 3.3V$ ,  $V_{OUT} = 2.5V$ ,  $I_{LOAD} = 0$ ,  $C_{OUT} = 0.022\mu F$  and  $T_A = 25^\circ C$ . (Continued)



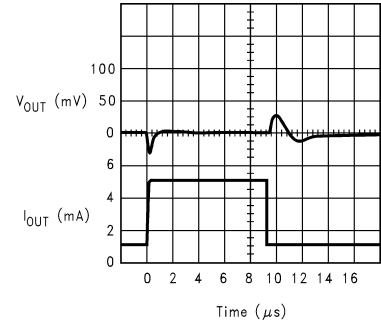
**LM4125 Typical Operating Characteristics** Unless otherwise specified,  $V_{IN} = 3.3V$ ,  $V_{OUT} = 2.5V$ ,  $I_{LOAD} = 0$ ,  $C_{OUT} = 0.022\mu F$  and  $T_A = 25^\circ C$ . (Continued)

**Start-Up Response**



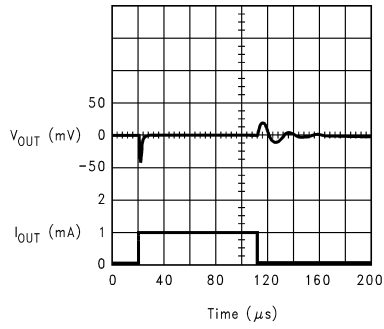
20069826

**Load Step Response**



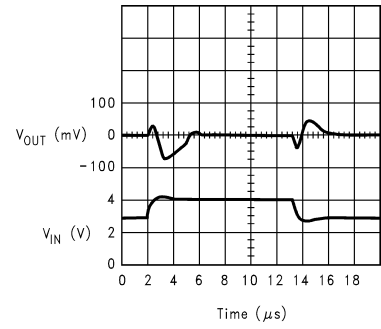
20069828

**Load Step Response**



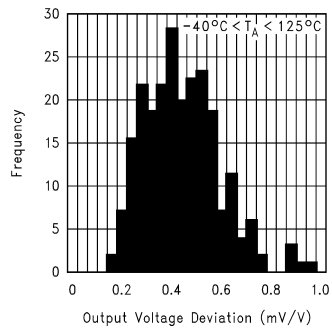
20069829

**Line Step Response**



20069830

**Thermal Hysteresis**



20069831



## Pin Functions

**Output (Pin 5):** Reference Output.

**Input (Pin 4):** Positive Supply.

**Ground (Pin 2):** Negative Supply or Ground Connection.

## Application Hints

The standard application circuit for the LM4125 is shown in *Figure 1*. It is designed to be stable with ceramic output capacitors in the range of 0.022 $\mu$ F to 0.1 $\mu$ F. Note that 0.022 $\mu$ F is the minimum required output capacitor. These capacitors typically have an ESR of about 0.1 to 0.5 $\Omega$ . Smaller ESR can be tolerated, however larger ESR can not. The output capacitor can be increased to improve load transient response, up to about 1 $\mu$ F. However, values above 0.047 $\mu$ F must be tantalum. With tantalum capacitors, in the 1 $\mu$ F range, a small capacitor between the output and the reference pin is required. This capacitor will typically be in the 50pF range. Care must be taken when using output capacitors of 1 $\mu$ F or larger. These application must be thoroughly tested over temperature, line and load.

An input capacitor is typically not required. However, a 0.1 $\mu$ F ceramic can be used to help prevent line transients from entering the LM4125. Larger input capacitors should be tantalum or aluminium.

The typical thermal hysteresis specification is defined as the change in +25 $^{\circ}$ C voltage measured after thermal cycling. The device is thermal cycled to temperature -40 $^{\circ}$ C and then measured at 25 $^{\circ}$ C. Next the device is thermal cycled to temperature +125 $^{\circ}$ C and again measured at 25 $^{\circ}$ C. The resulting  $V_{OUT}$  delta shift between the 25 $^{\circ}$ C measurements is thermal hysteresis. Thermal hysteresis is common in preci-

sion references and is induced by thermal-mechanical package stress. Changes in environmental storage temperature, operating temperature and board mounting temperature are all factors that can contribute to thermal hysteresis.

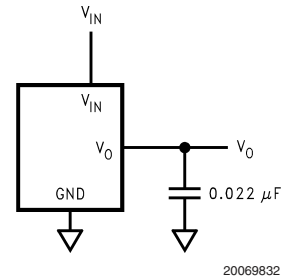


FIGURE 1.

### INPUT CAPACITOR

Noise on the power-supply input can effect the output noise, but can be reduced by using an optional bypass capacitor between the input pin and the ground.

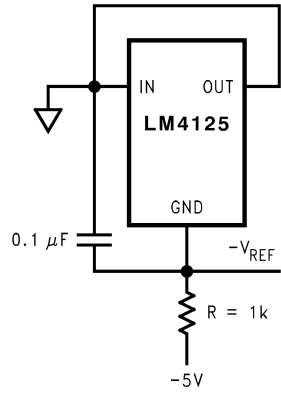
### PRINTED CIRCUIT BOARD LAYOUT CONSIDERATION

The mechanical stress due to PC board mounting can cause the output voltage to shift from its initial value. References in SOT packages are generally less prone to assembly stress than devices in Small Outline (SOIC) package.

To reduce the stress-related output voltage shifts, mount the reference on the low flex areas of the PC board such as near to the edge or the corner of the PC board.

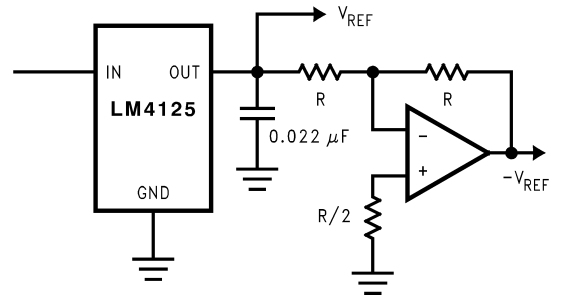
# Typical Application Circuits

Voltage Reference with Negative Output



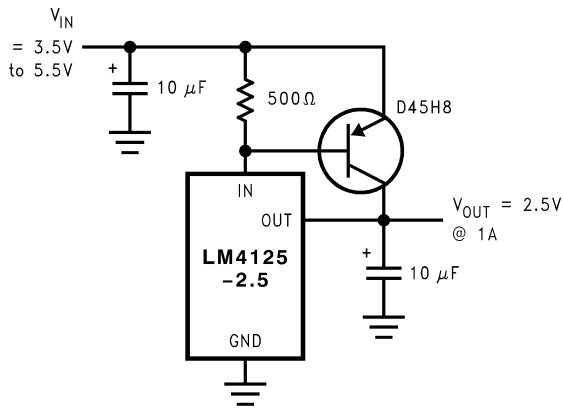
20069803

Voltage Reference with Complimentary Output



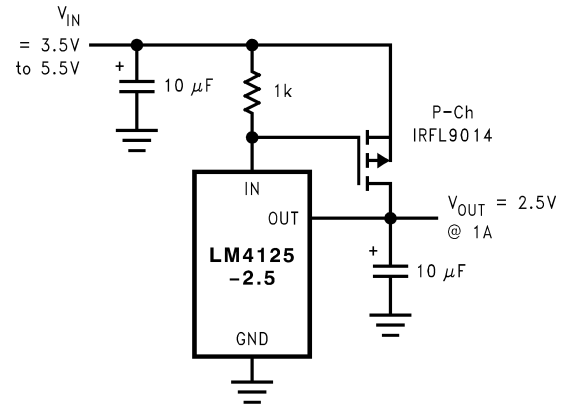
20069806

Precision High Current Low Dropout Regulator



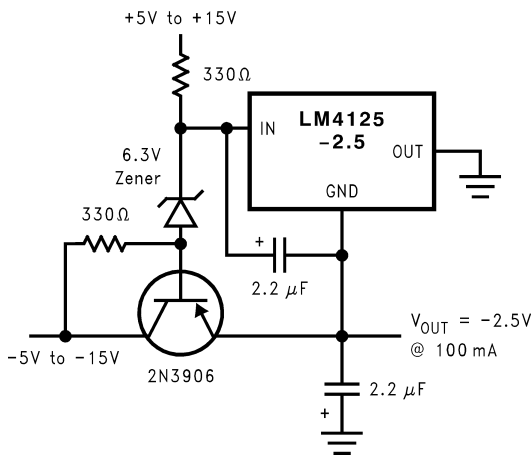
20069804

Precision High Current Low Dropout Regulator



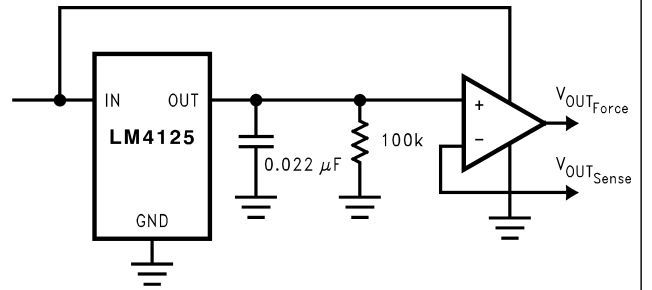
20069807

Precision High Current Negative Voltage Regulator



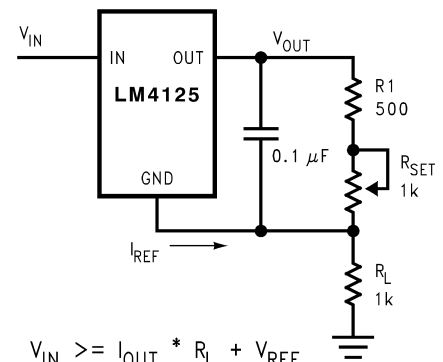
20069805

Precision Voltage Reference with Force and Sense Output



20069809

Programmable Current Source



$$V_{IN} \geq I_{OUT} * R_L + V_{REF}$$

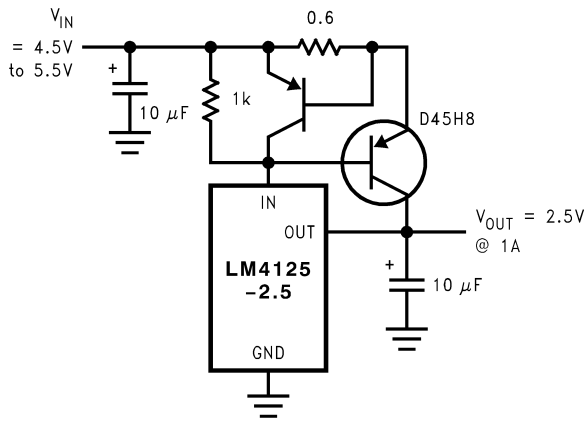
$$I_{OUT} = (V_{REF} / (R_1 + R_{SET})) + I_{OUT}$$

20069810

# Typical Application Circuits

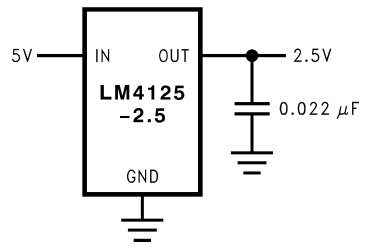
(Continued)

## Precision Regulator with Current Limiting Circuit



20069811

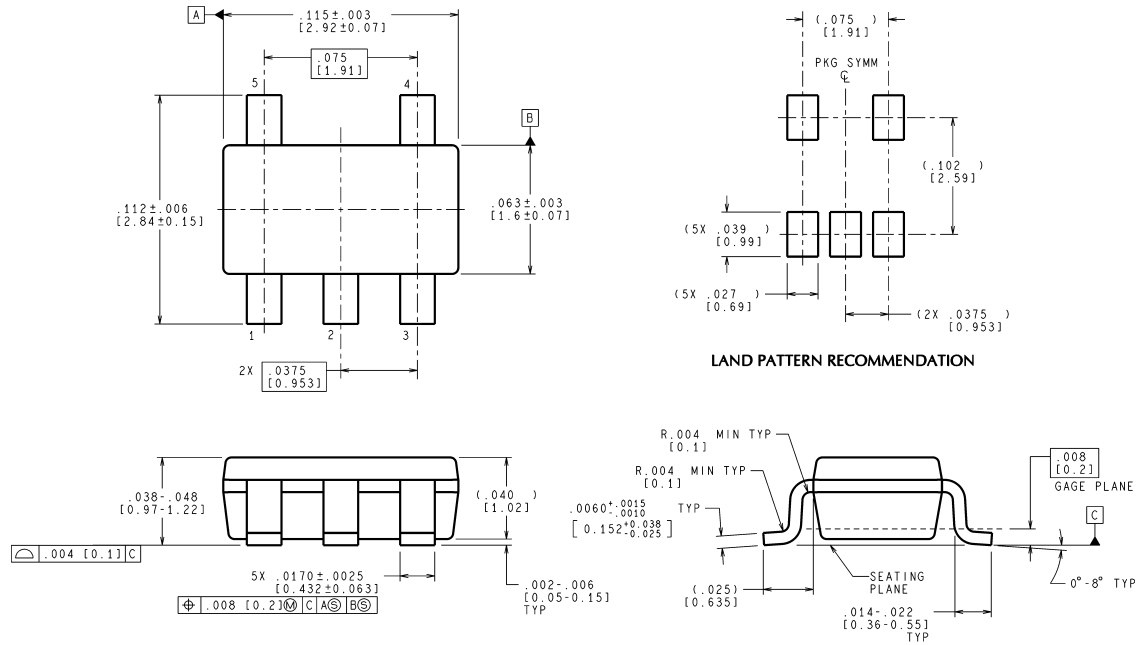
## Power Supply Splitter



20069820

## Physical Dimensions inches (millimeters)

unless otherwise noted



MF05A (Rev B)

### LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

### BANNED SUBSTANCE COMPLIANCE

National Semiconductor certifies that the products and packing materials meet the provisions of the Customer Products Stewardship Specification (CSP-9-111C2) and the Banned Substances and Materials of Interest Specification (CSP-9-111S2) and contain no "Banned Substances" as defined in CSP-9-111S2.



**National Semiconductor**  
Americas Customer  
Support Center  
Email: new.feedback@nsc.com  
Tel: 1-800-272-9959

**National Semiconductor**  
Europe Customer Support Center  
Fax: +49 (0) 180-530 85 86  
Email: europe.support@nsc.com  
Deutsch Tel: +49 (0) 69 9508 6208  
English Tel: +44 (0) 870 24 0 2171  
Français Tel: +33 (0) 1 41 91 8790

**National Semiconductor**  
Asia Pacific Customer  
Support Center  
Email: ap.support@nsc.com

**National Semiconductor**  
Japan Customer Support Center  
Fax: 81-3-5639-7507  
Email: jpn.feedback@nsc.com  
Tel: 81-3-5639-7560

www.national.com