

## Precision Voltage Reference

### FEATURES

- ◆ +1.250, +2.500, +4.096 V Output
- ◆ Initial Error:  $\pm 0.05\%$  Max.
- ◆ Temperature Drift: 1.0 ppm/°C Max.
- ◆ Low Noise: 2.2  $\mu\text{V}_{\text{P-P}}$  (0.1 Hz-10 Hz, 1.024 V)
- ◆ Low Thermal Hysteresis: 20 ppm
- ◆  $\pm 8$  mA Output Source
- ◆ Power Down Mode
- ◆ Industry Standard SOIC 8-pin Package
- ◆ Commercial and Industrial Temp Ranges
- ◆ Second source for ADR29X, REF19X, LT1460, LT1461, LT1798, MAX616X, REF102

### APPLICATIONS

This series is recommended for use as a reference for 14, 16, or 18-bit data converters which require a precision reference. The series offers superior performance over standard on-chip references commonly found with data converters.

### DESCRIPTION

The VRE4112/VRE4125/VRE4141 are low cost, high precision bandgap references that operate from +5 V. These devices feature low noise, digital error correction, and an SOIC-8 package. The ultra stable output is 0.05% accurate with a temperature coefficient as low as 1.0 ppm/°C. The improvement in overall accuracy is made possible by using EEPROM registers and CMOS DAC's for temperature and initial error correction. The DAC trimming is done after assembly which eliminates assembly related shifts.

### SELECTION GUIDE

Model	Output (V)	Temp. Coeff. (ppm/°C)	Temp. Range (°C)
VRE4112C	+1.250	2.0	0°C to +70°C
VRE4112K	+1.250	3.0	-40°C to +85°C
VRE4125B	+2.500	1.0	0°C to +70°C
VRE4125K	+2.500	3.0	-40°C to +85°C
VRE4141B	+4.096	1.0	0°C to +70°C
VRE4141K	+4.096	3.0	-40°C to +85°C



**8-pin SOIC  
Package Style FX**

## 1. CHARACTERISTICS AND SPECIFICATIONS

### ABSOLUTE MAXIMUM RATINGS

Power Supply to any input pin ..... -0.3V to +5.6V  
 Operating Temp. (B,C)..... 0°C to 70°C  
 Operating Temp. (K) ..... -40°C to +85°C  
 Storage Temperature Range ..... -65°C to +150°C

Output Short Circuit Duration ..... Indefinite  
 ESD Susceptibility Human Body Model..... 2kV  
 ESD Susceptibility Machine Model..... 200V  
 Lead Temperature (soldering, 10 sec)..... +260°C

### ELECTRICAL SPECIFICATIONS

$V_{PS} = +3\text{ V}$  for VRE4112,  $V_{PS} = +5\text{ V}$  for VRE4125 and VRE4141.  $T = +25^\circ\text{C}$ ,  $I_{LOAD} = 1\text{ mA}$ ,  $C_{OUT} = 1\mu\text{F}$  Unless Otherwise Noted.

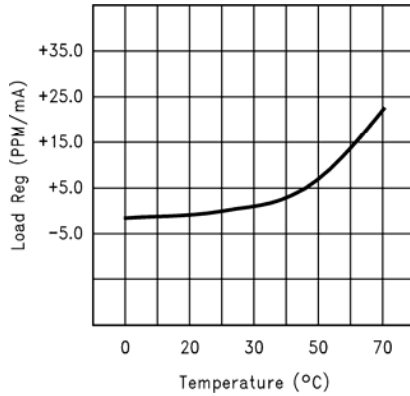
Parameter	Symbol	Conditions	Min	Typ	Max	Units
Input Voltage	$V_{IN}$		+1.8		+5.5	V
Output Voltage Error (Note 1)	$V_{OUT}$	B Grade		$\pm 0.025$	$\pm 0.050$	%
		C/K Grade		$\pm 0.040$	$\pm 0.080$	
Output Voltage Temperature Coefficient (Note 2)	$TCV_{OUT}$	B Grade		+0.5	+1.0	ppm/°C
		C Grade		+1.0	+2.0	
		K Grade		+1.5	+3.0	
Dropout Voltage (Note 3)	$V_{IN} - V_{OUT}$	$I_L = 8\text{ mA}$		160	235	mV
Turn-On Settling Time	$T_{ON}$	To 0.01% of final value		2		$\mu\text{s}$
Output Noise Voltage (Note 4)	$E_n$	$0.1\text{ Hz} < f < 10\text{ Hz}$		2.2		$\mu\text{Vp-p}$
Temperature Hysteresis		Note 5		20		ppm
Long Term Stability	$\Delta V_{OUT/T}$	1000 Hours		50		ppm
Supply Current	$I_{IN}$	$V_{LOAD} = 0\text{ mA}$		230	320	$\mu\text{A}$
Load Regulation (Note 6)	$\Delta V_{OUT} / \Delta I_{OUT}$	$1\text{ mA} \leq I_{LOAD} \leq 8\text{ mA}$		1	20	ppm/mA
Line Regulation (Note 6)	$\Delta V_{OUT} / \Delta V_{IN}$	$V_{REF} + 200\text{ mV} \leq V_{IN} \leq 5.5\text{ V}$		20	200	ppm/V
Logic High Input Voltage	$V_H$		0.8			V
Logic High Input Current	$I_H$			2		nA
Logic Low Input Voltage	$V_L$				0.4	V
Logic Low Input Current	$I_L$			1		nA

#### NOTES:

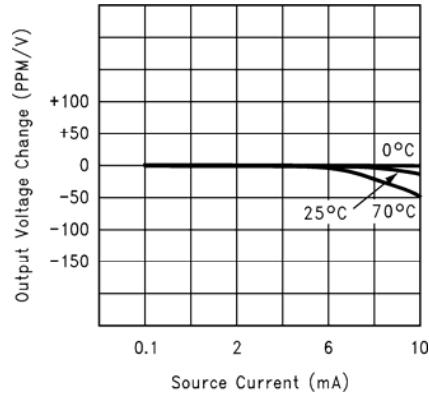
1. High temperature and mechanical stress can effect the initial accuracy of this reference series. See discussion on output accuracy.
2. The temperature coefficient is determined by the box method. See discussion on temperature performance. All units are 100% tested over temperature.
3. The minimum input to output differential voltage at which the output voltage drops by 0.5% from nominal.
4. Based on 1.024 V output. Noise is linearly proportional to  $V_{REF}$ .
5. Defined as change in 25°C output voltage after cycling device over operating temperature range.
6. Line and load regulation are measured with pulses and do not include output voltage changes due to self heating.

## 2. TYPICAL PERFORMANCE CURVES

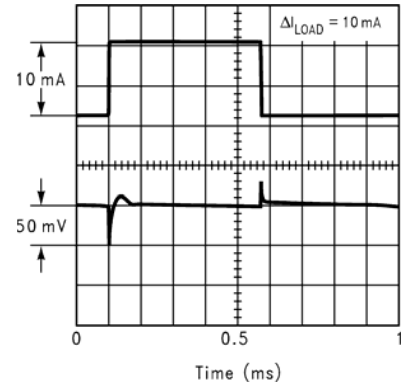
Load Regulation vs Temperature



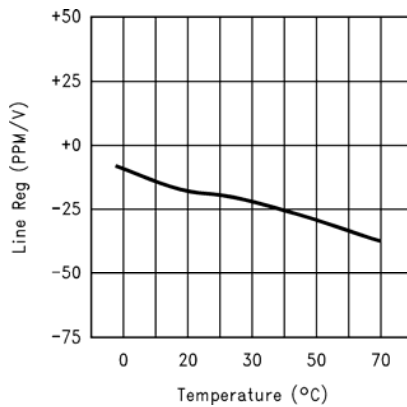
Output Voltage vs Load Current



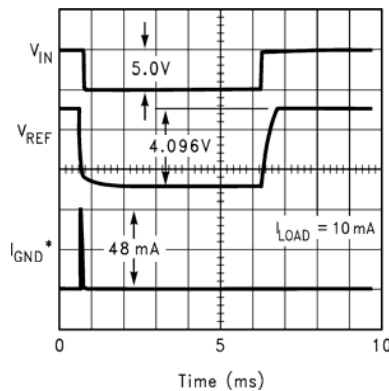
Load Transient Response



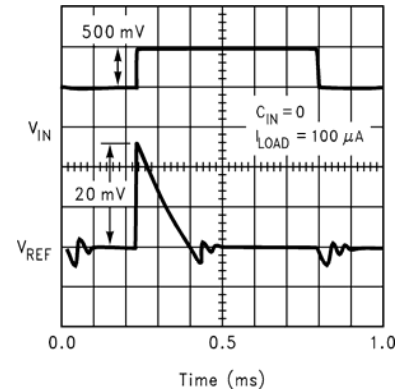
Line Regulation vs Temperature



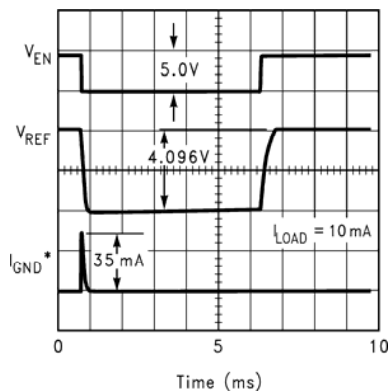
Power Up/Down Ground Current



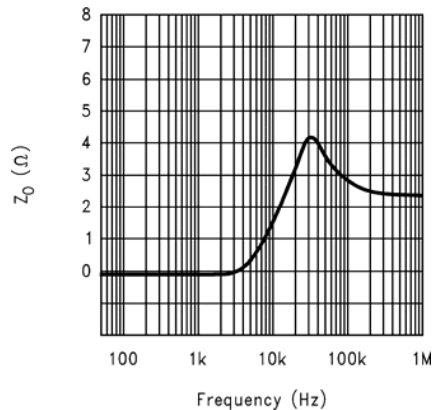
Line Transient Response



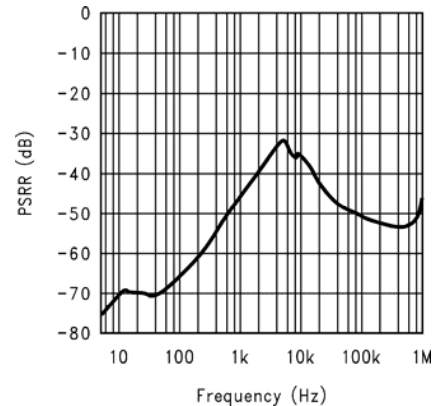
Enable Response

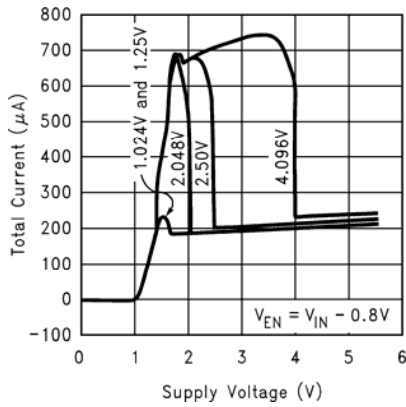
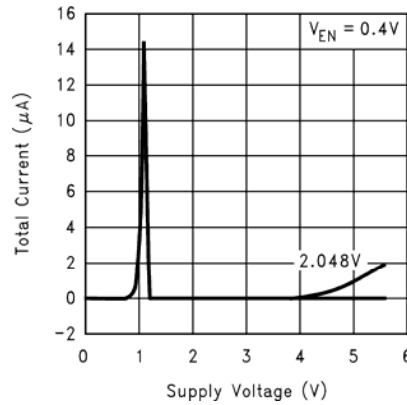


Output Impedance

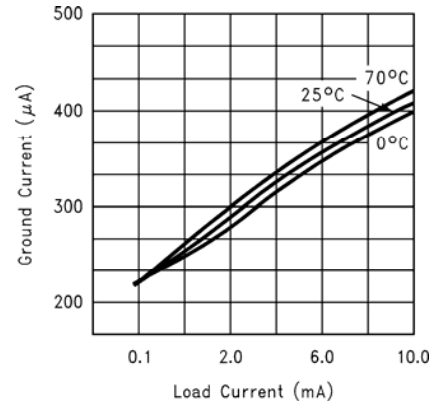
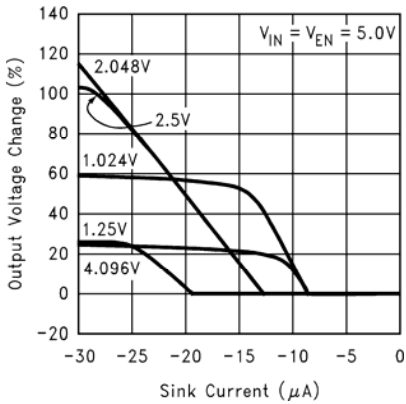


Power Supply Rejection Ratio

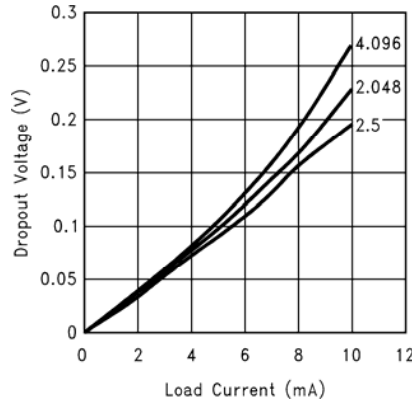
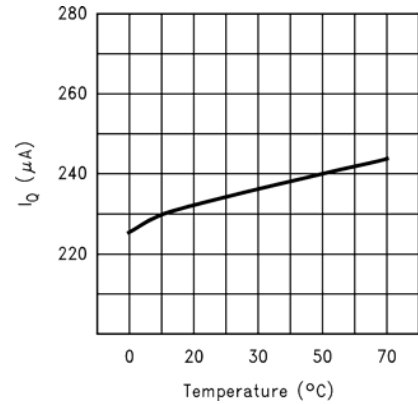
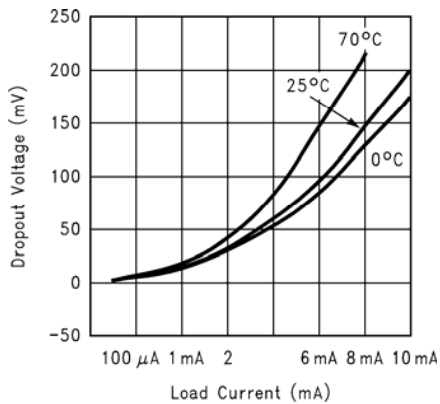


Total Current ( $I_{S(ON)}$ ) vs Supply VoltageTotal Current ( $I_{S(OFF)}$ ) vs Supply Voltage

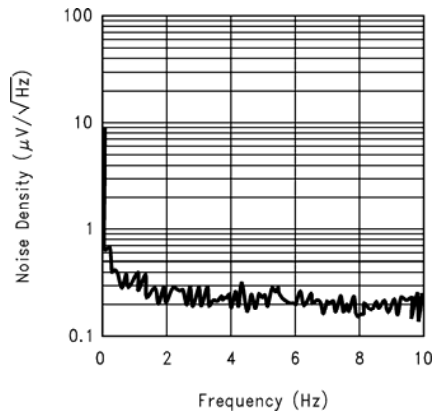
Ground Current vs Load Current

Output Voltage Change vs Sink Current  $I_{(SINK)}$ 

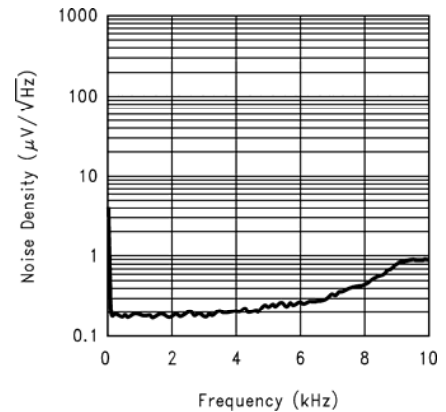
Dropout Voltage vs Load Current

 $I_Q$  vs TemperatureDropout Voltage vs Load Current ( $V_{OUT} = 2.0V$ )

Spectral Noise Density (0.1Hz to 10Hz)



Spectral Noise Density (10Hz to 100kHz)



### 3. TEMPERATURE PERFORMANCE

This series is designed for applications where the initial error at room temperature and drift over temperature are important to the user. For many instrument manufacturers, a voltage reference with a temperature coefficient of 1ppm/°C makes it possible to eliminate a system temperature calibration, a slow and costly process.

Of the three TC specification methods (slope, butterfly, and box), the box method is most commonly used. A box is formed by the min/max limits for the nominal output voltage over the operating temperature range. The equation follows:

$$TC = \frac{V_{MAX} - V_{MIN}}{V_{NOMINAL} \times (T_{MAX} - T_{MIN})} \times 10^6$$

This method corresponds more accurately to the method of test and provides a closer estimate of actual error than the other methods. The box method guarantees limits for the temperature error but does not specify the exact shape or slope of the device under test.

### 4. BASIC CIRCUIT CONNECTION

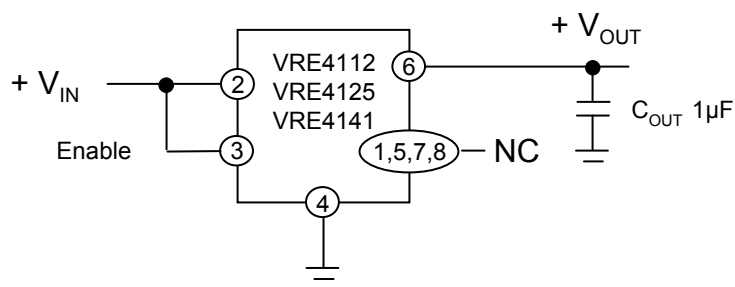
The proper connection for the VRE4112/VRE4125/VRE4141 series voltage references is shown below.

To achieve the specified performance, pay careful attention to the layout. Commons should be connected to a single point to minimize interconnect resistances. This will reduce voltage errors, noise pickup, and noise coupled from the power supply.

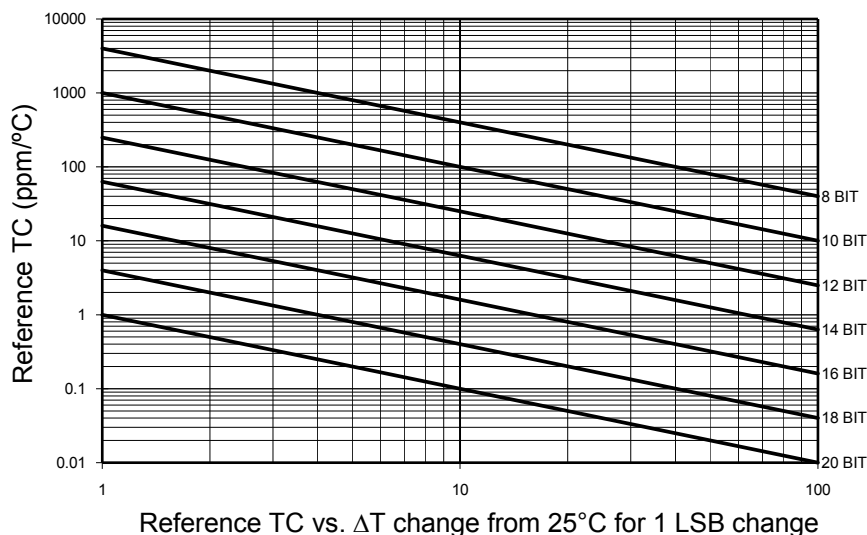
### PIN DESCRIPTION

4	GND	These must be connected to ground
2	V <sub>IN</sub>	Positive power supply input
3	Enable	Pulled to V <sub>IN</sub> for nominal operation
1,5,7,8	NC	This pin must be left open
6	V <sub>OUT</sub>	Reference output

### EXTERNAL CONNECTIONS



For example a designer who needs a 14-bit accurate data acquisition system over the industrial temperature range ( $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ ), will need a voltage reference with a temperature coefficient (TC) of  $1.0\text{ppm}/^{\circ}\text{C}$  if the reference is allowed to contribute an error equivalent to 1LSB. The required reference TC vs.  $\Delta T$  change from  $25^{\circ}\text{C}$  for resolution ranging from 8 bits to 20 bits is shown below.



Reference TC vs.  $\Delta T$  change from  $25^{\circ}\text{C}$  for 1 LSB change

## 4. OPERATIONAL NOTES

### INPUT CAPACITOR

An input capacitor is recommended for the VRE4112/VRE4125/VRE4141. A supply bypass capacitor on the input will assure that the reference is working from a low impedance source which will improve stability. It can improve the transient response when the load current is suddenly increased.

### OUTPUT CAPACITOR

This series requires a  $1\text{ }\mu\text{F}$  output capacitor for loop stabilization (compensation) as well as transient response. When the load current changes, the output capacitor must source or sink current during the time it takes the control loop of the device to respond.

The output capacitor must meet the requirements of minimum capacitance and equivalent series resistance (ESR) range. See Capacitor Selection below.

### CAPACITOR SELECTION

A minimum value of  $0.2\text{ }\mu\text{F}$  over the operating temperature range is recommended. For a  $0.22\text{ }\mu\text{F}$  capacitor the ESR range for  $0^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$  is 0.9 to 6.0;  $1.0\text{ }\mu\text{F}$  is 0.8 to 6.0; and  $10\text{ }\mu\text{F}$  is 0.4 to 7.0.

Surface mount tantalum capacitors offer small size for the value and ESR in the range required for this series. The optimum performance for the output capacitor is achieved with a  $1.0\text{ }\mu\text{F}$  value.

Aluminum electrolytic capacitors have a relatively large size for the value. They meet the ESR requirements at  $1.0\text{ }\mu\text{F}$  as long as the temperature is above  $0^{\circ}\text{C}$ . Below  $0^{\circ}\text{C}$ , the ESR increases and it may exceed the limits indicated in the figures.

Multilayer ceramic capacitors have a small size for the value, are available in surface mount, and have excellent RF characteristics. They may not meet the minimum ESR requirements and have a large change in value with temperature.

## REVERSE CURRENT PATH

The P-channel pass transistor used in this series has an inherent diode connected between the  $V_{IN}$  and  $V_{OUT}$  pins. Forcing the output to voltages higher than the input or pulling  $V_{IN}$  below the voltage stored in the output capacitor by more than the  $V_{be}$  will forward bias this diode and current will flow from the  $V_{OUT}$  pin to  $V_{IN}$ . This will not damage the device as long as the current does not exceed 50 mA.

## ON/OFF OPERATION

This series features a sleep mode that is activated by pulling the enable pin low. To turn the reference on, the enable pin is pulled high. If this feature is not used, the enable pin should be tied to  $V_{IN}$  to keep the reference on at all times. The enable pin must not be left unconnected (floating).

When powered off, these devices will quickly reduce both  $V_{OUT}$  and  $I_Q$  to zero. During power down, the charge across the output capacitor is discharged to ground through the internal circuitry. On power up, the  $V_{OUT}$  is restored in less than 200  $\mu s$ .

The signal source used to drive the enable pin can come from either a totem-pole output or an open collector output with a pull-up resistor to the input voltage. The signal source must be able to swing above and below the voltage thresholds to guarantee an ON or OFF state. It must not exceed the absolute maximum rating for the enable pin.

## OUTPUT ACCURACY

The output accuracy after assembly at room temperature is made up of three components: initial accuracy of the device, thermal hysteresis, and mechanical stress. The initial accuracy is measured at the factory and may not reflect the actual output voltage when the devices are mounted to a PCB. The effects of mechanical stress and thermal hysteresis can shift the output voltage.

## THERMAL HYSTERESIS

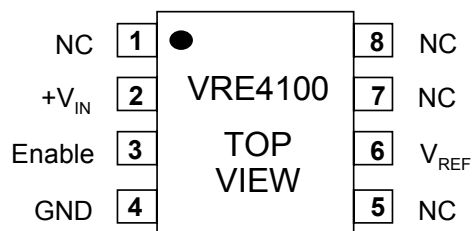
Thermal hysteresis is a change in output voltage as a result of a temperature change. When references experience a temperature change and return to the initial temperature, they do not always have the same initial voltage. Thermal hysteresis is difficult to correct and is a major error source in systems that experience temperature changes greater than 25°C. Reference vendors are starting to include this important specification in their datasheets

## MECHANICAL HYSTERESIS

Recommendations to minimize mechanical stress:

- 1) Mount the VRE4112/VRE4125/VRE4141 near the edges or corners of the PCB. The center of the board generally has the highest mechanical and thermal stress.
- 2) Mechanically isolate the device by cutting a U shaped slot around the package. This provides some mechanical and thermal isolation from the rest of the circuit.

## PIN CONFIGURATION



---

## CONTACTING CIRRUS LOGIC SUPPORT

For all Apex Precision Power product questions and inquiries, call toll free 800-546-2739 in North America.

For inquiries via email, please contact [tucson.support@cirrus.com](mailto:tucson.support@cirrus.com).

International customers can also request support by contacting their local Cirrus Logic Sales Representative.

To find the one nearest to you, go to [www.cirrus.com](http://www.cirrus.com)

---

### IMPORTANT NOTICE

Cirrus Logic, Inc. and its subsidiaries ("Cirrus") believe that the information contained in this document is accurate and reliable. However, the information is subject to change without notice and is provided "AS IS" without warranty of any kind (express or implied). Customers are advised to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgment, including those pertaining to warranty, indemnification, and limitation of liability. No responsibility is assumed by Cirrus for the use of this information, including use of this information as the basis for manufacture or sale of any items, or for infringement of patents or other rights of third parties. This document is the property of Cirrus and by furnishing this information, Cirrus grants no license, express or implied under any patents, mask work rights, copyrights, trademarks, trade secrets or other intellectual property rights. Cirrus owns the copyrights associated with the information contained herein and gives consent for copies to be made of the information only for use within your organization with respect to Cirrus integrated circuits or other products of Cirrus. This consent does not extend to other copying such as copying for general distribution, advertising or promotional purposes, or for creating any work for resale.

CERTAIN APPLICATIONS USING SEMICONDUCTOR PRODUCTS MAY INVOLVE POTENTIAL RISKS OF DEATH, PERSONAL INJURY, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE ("CRITICAL APPLICATIONS"). CIRRUS PRODUCTS ARE NOT DESIGNED, AUTHORIZED OR WARRANTED TO BE SUITABLE FOR USE IN PRODUCTS SURGICALLY IMPLANTED INTO THE BODY, AUTOMOTIVE SAFETY OR SECURITY DEVICES, LIFE SUPPORT PRODUCTS OR OTHER CRITICAL APPLICATIONS. INCLUSION OF CIRRUS PRODUCTS IN SUCH APPLICATIONS IS UNDERSTOOD TO BE FULLY AT THE CUSTOMER'S RISK AND CIRRUS DISCLAIMS AND MAKES NO WARRANTY, EXPRESS, STATUTORY OR IMPLIED, INCLUDING THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR PARTICULAR PURPOSE, WITH REGARD TO ANY CIRRUS PRODUCT THAT IS USED IN SUCH A MANNER. IF THE CUSTOMER OR CUSTOMER'S CUSTOMER USES OR PERMITS THE USE OF CIRRUS PRODUCTS IN CRITICAL APPLICATIONS, CUSTOMER AGREES, BY SUCH USE, TO FULLY INDEMNIFY CIRRUS, ITS OFFICERS, DIRECTORS, EMPLOYEES, DISTRIBUTORS AND OTHER AGENTS FROM ANY AND ALL LIABILITY, INCLUDING ATTORNEYS' FEES AND COSTS, THAT MAY RESULT FROM OR ARISE IN CONNECTION WITH THESE USES.

Cirrus Logic, Cirrus, and the Cirrus Logic logo designs, Apex Precision Power, Apex and the Apex Precision Power logo designs are trademarks of Cirrus Logic, Inc. All other brand and product names in this document may be trademarks or service marks of their respective owners.