

LOW-NOISE, VERY LOW DRIFT, PRECISION VOLTAGE REFERENCE

Check for Samples: [REF5020-EP](#), [REF5025-EP](#), [REF5040-EP](#), [REF5050-EP](#)

FEATURES

- **LOW TEMPERATURE DRIFT:**
5 ppm/°C (max)
- **HIGH ACCURACY:**
0.08% (max)
- **LOW NOISE:** 3 μ V_{pp}/V
- **HIGH OUTPUT CURRENT:** \pm 10 mA

APPLICATIONS

- 16-BIT DATA ACQUISITION SYSTEMS
- ATE EQUIPMENT
- INDUSTRIAL PROCESS CONTROL
- MEDICAL INSTRUMENTATION
- OPTICAL CONTROL SYSTEMS
- PRECISION INSTRUMENTATION

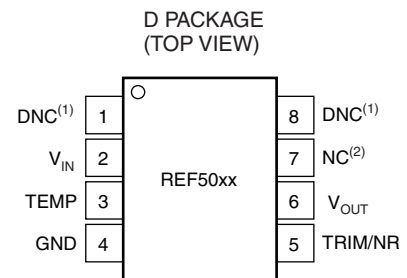
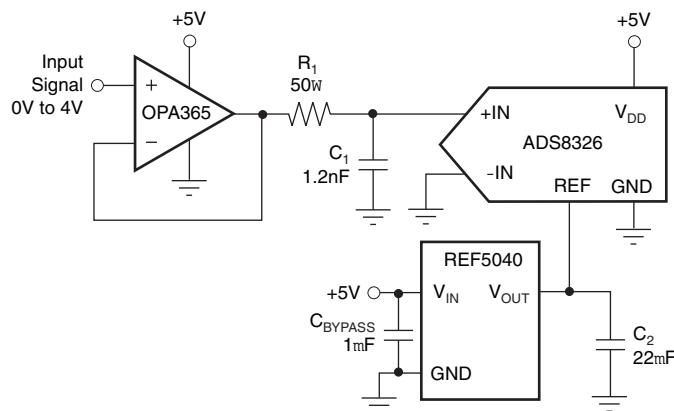
SUPPORTS DEFENSE, AEROSPACE, AND MEDICAL APPLICATIONS

- **Controlled Baseline**
- **One Assembly/Test Site**
- **One Fabrication Site**
- **Available in Military (–55°C/125°C)
Temperature Range⁽¹⁾**
- **Extended Product Life Cycle**
- **Extended Product-Change Notification**
- **Product Traceability**

DESCRIPTION

The REF50xx is a family of low-noise, low-drift, very high precision voltage references. These references are capable of both sinking and sourcing, and are very robust with regard to line and load changes.

(1) Custom temperature ranges available



NOTES: (1) DNC = Do not connect.
(2) NC = No internal connection.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

All trademarks are the property of their respective owners.



This integrated circuit can be damaged by ESD. Texas Instruments 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.

ORDERING INFORMATION⁽¹⁾

PRODUCT	OUTPUT VOLTAGE	PACKAGE ⁽²⁾	ORDERABLE PART NUMBER	TOP-SIDE MARKING
REF5020MDREP	2.048 V	SOIC-D	REF5020MDREP	5020EP
REF5025MDTEP	2.5 V	SOIC-D	REF5025MDTEP	5025EP
REF5040MDREP	4.096 V	SOIC-D	REF5040MDREP	5040EP
REF5050MDREP	5 V	SOIC-D	REF5050MDREP	5050EP

- (1) For the most current package and ordering information see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.
- (2) Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

ABSOLUTE MAXIMUM RATINGS⁽¹⁾

PARAMETER		REF50xx	UNIT
Input Voltage		18	V
Output Short-Circuit		30	mA
Operating Temperature Range		–55 to 125	°C
Storage Temperature Range		–65 to 150	°C
Junction Temperature (T _J max)		150	°C
ESD Rating	Human Body Model (HBM)	3000	V
	Charged Device Model (CDM)	1000	V

- (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.

ELECTRICAL CHARACTERISTICS: PER DEVICE

Boldface limits apply over the specified temperature range, $T_A = -55^{\circ}\text{C}$ to 125°C .

At $T_A = 25^{\circ}\text{C}$, $I_{\text{LOAD}} = 0$, $C_L = 1\ \mu\text{F}$, and $V_{\text{IN}} = (V_{\text{OUT}} + 0.2\ \text{V})$ to 18 V, unless otherwise noted.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
REF5020 ($V_{\text{OUT}} = 2.048\text{V}$)⁽¹⁾					
OUTPUT VOLTAGE					
Output Voltage V_{OUT}	$2.7\ \text{V} < V_{\text{IN}} < 18\ \text{V}$		2.048		V
Initial Accuracy		–0.05		0.05	%
Over Temperature		–0.08		0.08	%
NOISE					
Output Voltage Noise	$f = 0.1\ \text{Hz}$ to 10 Hz		6		μV_{PP}
REF5025 ($V_{\text{OUT}} = 2.5\ \text{V}$)					
OUTPUT VOLTAGE					
Output Voltage V_{OUT}			2.5		V
Initial Accuracy		–0.05		0.05	%
NOISE					
Output Voltage Noise	$f = 0.1\ \text{Hz}$ to 10 Hz		7.5		μV_{PP}
REF5040 ($V_{\text{OUT}} = 4.096\text{V}$)					
OUTPUT VOLTAGE					
Output Voltage V_{OUT}			4.096		V
Initial Accuracy		–0.05		0.05	%
Over Temperature		–0.08		0.08	%
NOISE					
Output Voltage Noise	$f = 0.1\ \text{Hz}$ to 10 Hz		12		μV_{PP}
REF5050 ($V_{\text{OUT}} = 5\ \text{V}$)					
OUTPUT VOLTAGE					
Output Voltage V_{OUT}			5		V
Initial Accuracy		–0.05		0.05	%
Over Temperature		–0.08		0.08	%
NOISE					
Output Voltage Noise	$f = 0.1\ \text{Hz}$ to 10 Hz		15		μV_{PP}

(1) For $V_{\text{OUT}} \leq 2.5\ \text{V}$, the minimum supply voltage is 2.7 V.

ELECTRICAL CHARACTERISTICS: ALL DEVICES

Boldface limits apply over the specified temperature range, $T_A = -55^{\circ}\text{C}$ to 125°C .

At $T_A = 25^{\circ}\text{C}$, $I_{\text{LOAD}} = 0$, $C_L = 1\ \mu\text{F}$, and $V_{\text{IN}} = (V_{\text{OUT}} + 0.2\ \text{V})$ to 18 V, unless otherwise noted.

PARAMETER	CONDITIONS	REF50xx			UNIT
		MIN	TYP	MAX	
OUTPUT VOLTAGE TEMPERATURE DRIFT					
Output Voltage Temperature Drift dV_{OUT}/dT					
REF5025			4	6.5	ppm/ $^{\circ}\text{C}$
REF5050			4	6.5	ppm/ $^{\circ}\text{C}$
All other devices			3	5	ppm/ $^{\circ}\text{C}$
LINE REGULATION					
Line Regulation $dV_{\text{OUT}}/dV_{\text{IN}}$					
REF5020 ⁽¹⁾	$V_{\text{IN}} = 2.7\ \text{V}$ to 18 V		0.1	1	ppm/V
All other devices	$V_{\text{IN}} = V_{\text{OUT}} + 0.2\ \text{V}$		0.1	1	ppm/V
Over Temperature			1	3	ppm/V
LOAD REGULATION					
Load Regulation $dV_{\text{OUT}}/dI_{\text{LOAD}}$					
REF5020	$-10\ \text{mA} < I_{\text{LOAD}} < +10\ \text{mA}$, $V_{\text{IN}} = 3\ \text{V}$		20	30	ppm/mA
All other devices	$-10\ \text{mA} < I_{\text{LOAD}} < +10\ \text{mA}$, $V_{\text{IN}} = V_{\text{OUT}} + 0.75\ \text{V}$		20	30	ppm/mA
Over Temperature				60	ppm/mA
SHORT-CIRCUIT CURRENT					
Short-Circuit Current I_{SC}	$V_{\text{OUT}} = 0$		25		mA
TEMP PIN					
Voltage Output	At $T_A = 25^{\circ}\text{C}$		575		mV
Temperature Sensitivity			2.64		mV/ $^{\circ}\text{C}$
TURN-ON SETTLING TIME					
Turn-On Settling Time	To 0.1% with $C_L = 1\ \mu\text{F}$		200		μs
POWER SUPPLY					
Supply Voltage V_S	See Note ⁽¹⁾	$V_{\text{OUT}} + 0.2^{(1)}$		18	V
Quiescent Current			0.8	1	mA
Over Temperature				1.25	mA
TEMPERATURE RANGE					
Specified Range		-55		125	$^{\circ}\text{C}$
Operating Range		-55		125	$^{\circ}\text{C}$
Thermal Resistance θ_{JA}			150		$^{\circ}\text{C}/\text{W}$

(1) For $V_{\text{OUT}} \leq 2.5\ \text{V}$, the minimal supply voltage is 2.7 V.

TYPICAL CHARACTERISTICS

At $T_A = 25^\circ\text{C}$, $I_{\text{LOAD}} = 0$, and $V_S = V_{\text{OUT}} + 0.2\text{ V}$, unless otherwise noted.
For $V_{\text{OUT}} \leq 2.5\text{ V}$, the minimum supply voltage is 2.7 V.

**TEMPERATURE DRIFT
(0°C to $+85^\circ\text{C}$)**

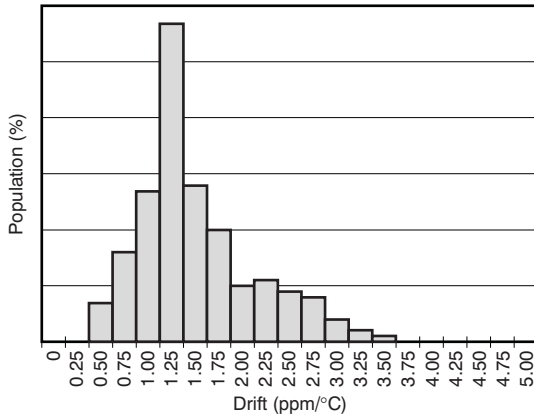


Figure 1.

**TEMPERATURE DRIFT
(-40°C to $+125^\circ\text{C}$)**

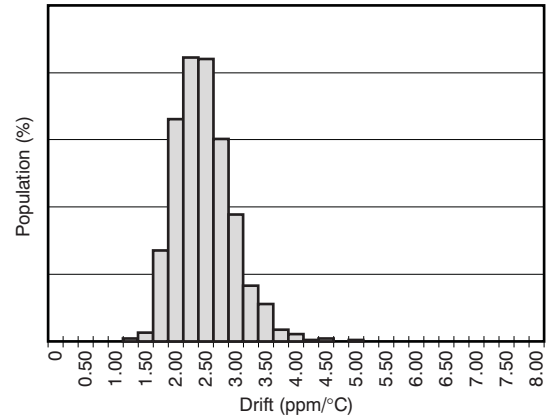


Figure 2.

**OUTPUT VOLTAGE
INITIAL ACCURACY**

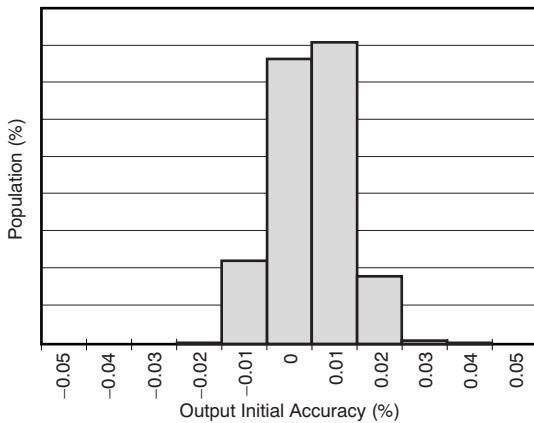


Figure 3.

**OUTPUT VOLTAGE ACCURACY
vs
TEMPERATURE**

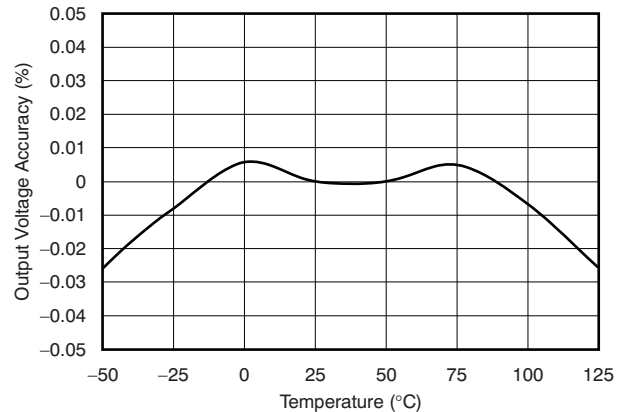


Figure 4.

TYPICAL CHARACTERISTICS (continued)

At $T_A = 25^\circ\text{C}$, $I_{\text{LOAD}} = 0$, and $V_S = V_{\text{OUT}} + 0.2\text{ V}$, unless otherwise noted.

For $V_{\text{OUT}} \leq 2.5\text{ V}$, the minimum supply voltage is 2.7 V.

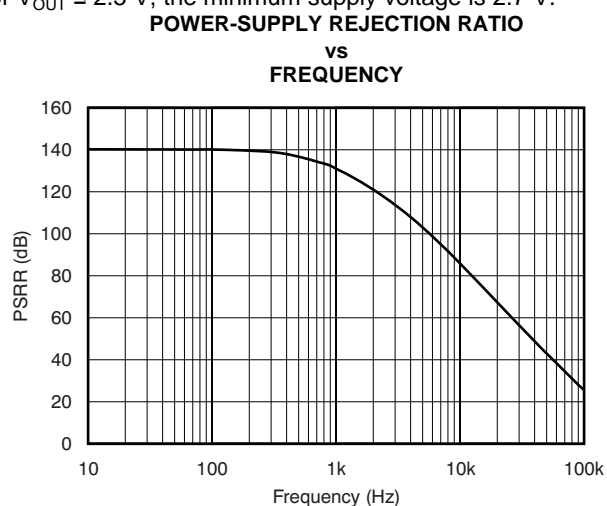


Figure 5.

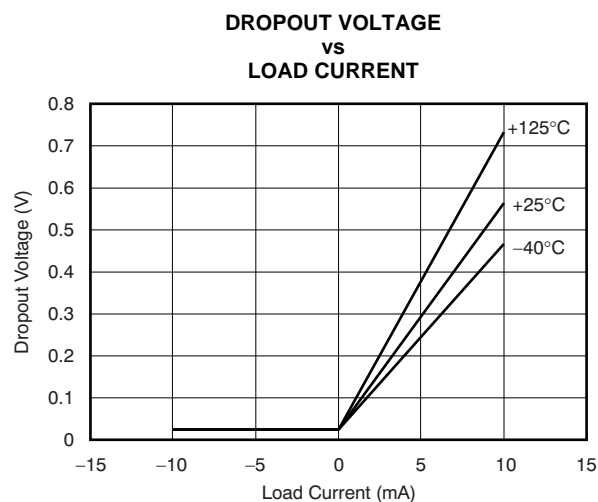


Figure 6.

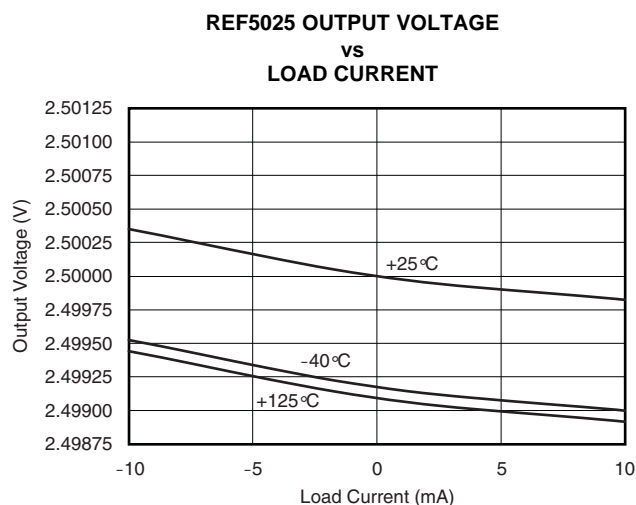


Figure 7.

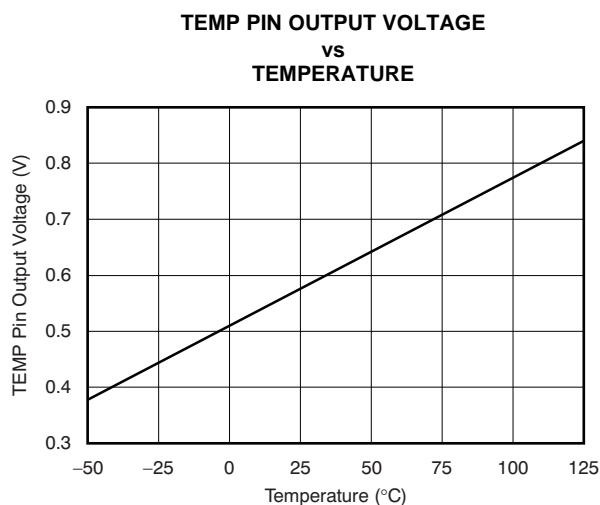


Figure 8.

TYPICAL CHARACTERISTICS (continued)

At $T_A = 25^\circ\text{C}$, $I_{\text{LOAD}} = 0$, and $V_S = V_{\text{OUT}} + 0.2\text{ V}$, unless otherwise noted.

For $V_{\text{OUT}} \leq 2.5\text{ V}$, the minimum supply voltage is 2.7 V.

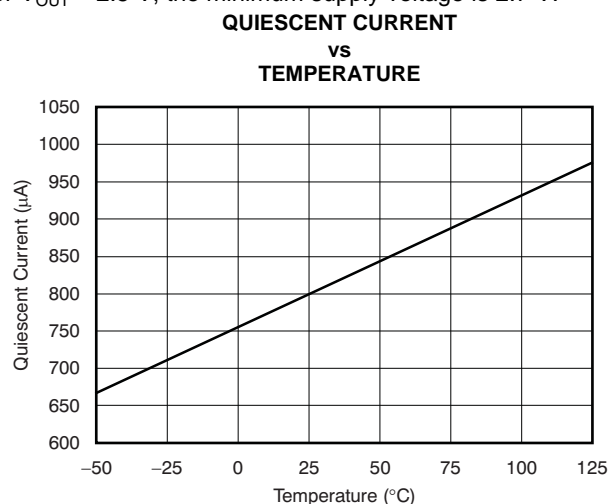


Figure 9.

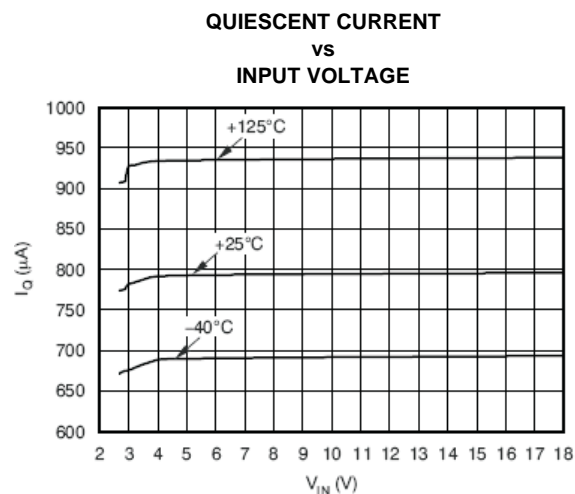


Figure 10.

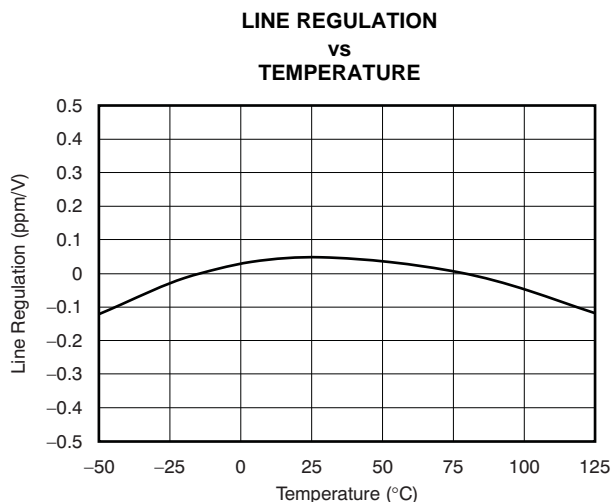


Figure 11.

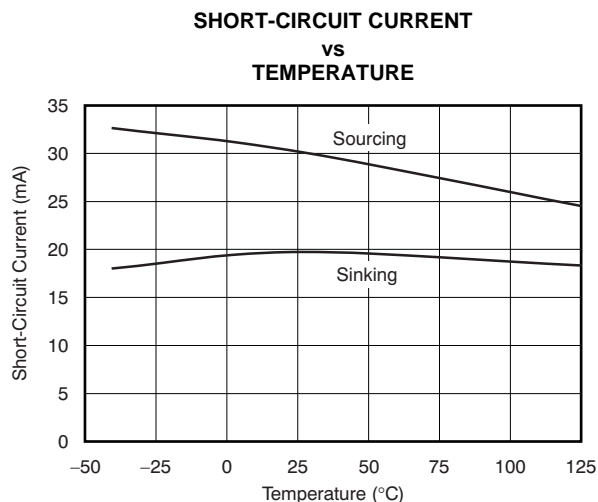


Figure 12.

TYPICAL CHARACTERISTICS (continued)

At $T_A = 25^\circ\text{C}$, $I_{\text{LOAD}} = 0$, and $V_S = V_{\text{OUT}} + 0.2\text{ V}$, unless otherwise noted.

For $V_{\text{OUT}} \leq 2.5\text{ V}$, the minimum supply voltage is 2.7 V.

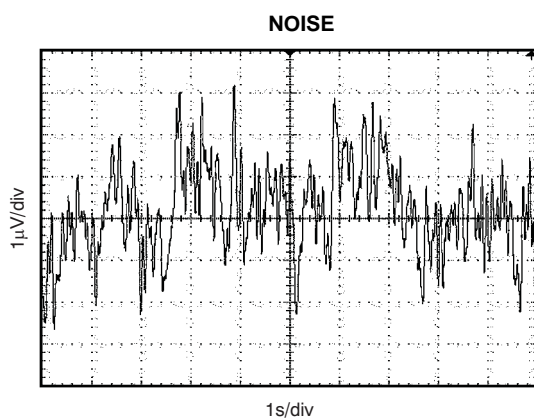


Figure 13.

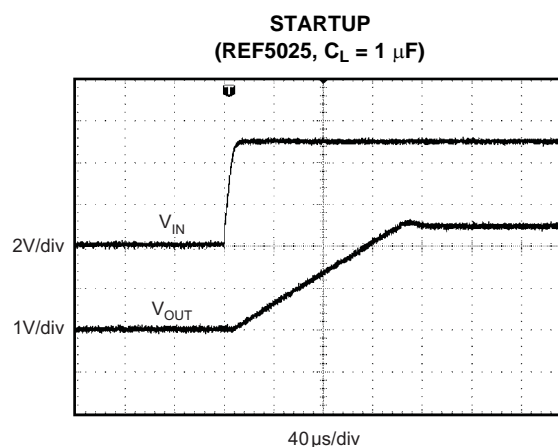


Figure 14.

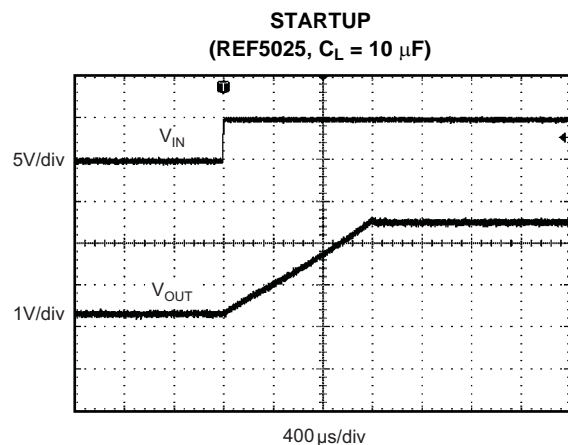


Figure 15.

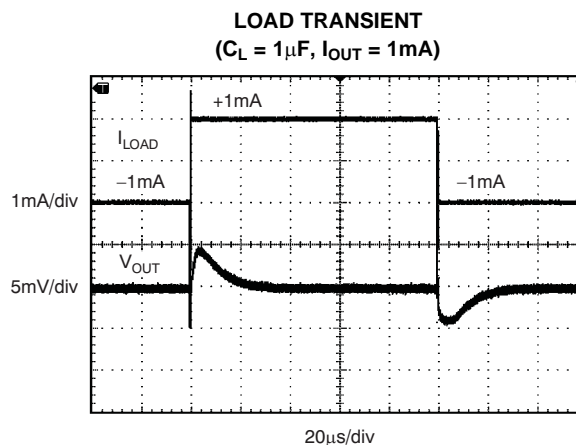


Figure 16.

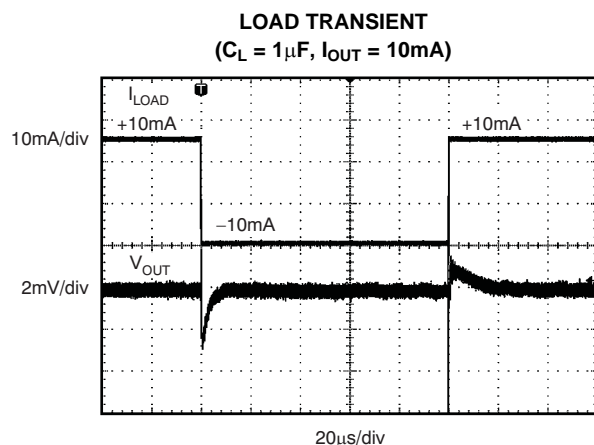


Figure 17.

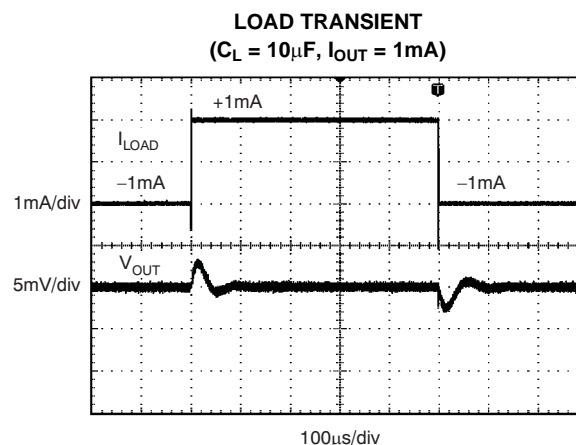


Figure 18.

TYPICAL CHARACTERISTICS (continued)

At $T_A = 25^\circ\text{C}$, $I_{\text{LOAD}} = 0$, and $V_S = V_{\text{OUT}} + 0.2\text{ V}$, unless otherwise noted.

For $V_{\text{OUT}} \leq 2.5\text{ V}$, the minimum supply voltage is 2.7 V.

LOAD TRANSIENT
($C_L = 10\mu\text{F}$, $I_{\text{OUT}} = 10\text{mA}$)

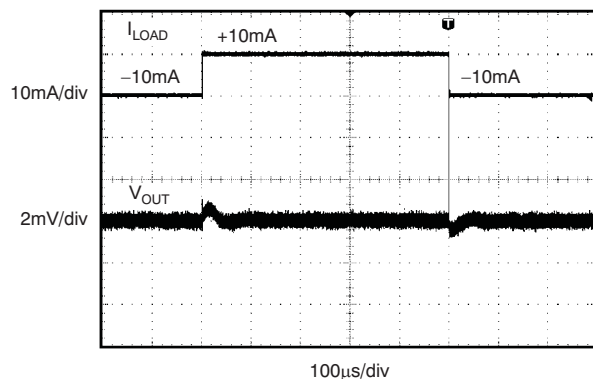


Figure 19.

LINE TRANSIENT
($C_L = 1\mu\text{F}$)

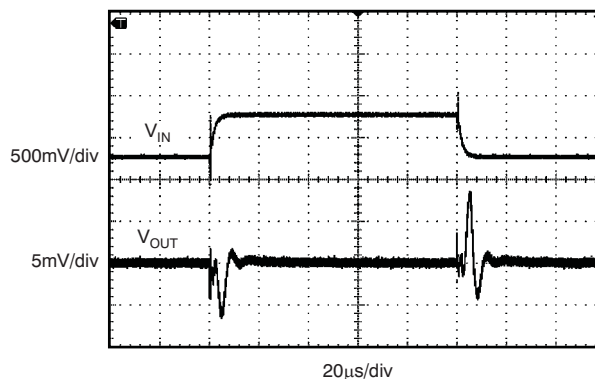


Figure 20.

LINE TRANSIENT
($C_L = 10\mu\text{F}$)

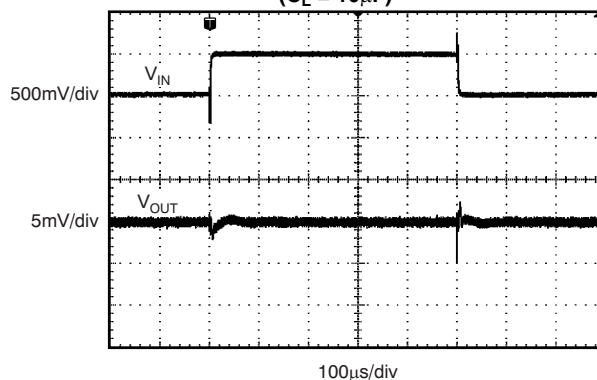


Figure 21.

APPLICATION INFORMATION

The REF50xx is family of low-noise, precision bandgap voltage references that are specifically designed for excellent initial voltage accuracy and drift. [Figure 22](#) shows a simplified block diagram of the REF50xx.

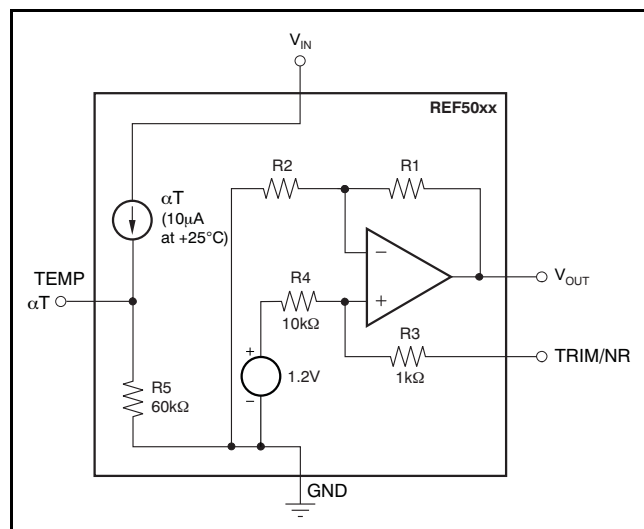


Figure 22. REF50xx Simplified Block Diagram

BASIC CONNECTIONS

[Figure 23](#) shows the typical connections for the REF50xx. A supply bypass capacitor ranging between 1 μ F to 10 μ F is recommended. A 1- μ F to 50- μ F output capacitor (C_L) must be connected from V_{OUT} to GND. The ESR value of C_L must be less than or equal to 1.5 Ω to ensure output stability. To minimize noise, the recommended ESR of C_L is between 1 Ω and 1.5 Ω .

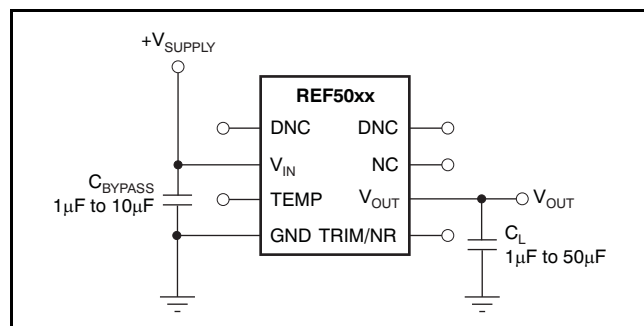


Figure 23. Basic Connections

SUPPLY VOLTAGE

The REF50xx family of voltage references features extremely low dropout voltage. With the exception of the REF5020, which has a minimum supply requirement of 2.7 V, these references can be operated with a supply of 200 mV above the output voltage in an unloaded condition. For loaded conditions, a typical dropout voltage versus load plot is shown in [Figure 6](#) of the Typical Characteristics.

OUTPUT ADJUSTMENT USING THE TRIM/NR PIN

The REF50xx provides a very accurate, factory-trimmed voltage output. However, V_{OUT} can be adjusted using the trim and noise reduction pin (TRIM/NR, pin 5). [Figure 24](#) shows a typical circuit that allows an output adjustment of ± 15 mV.

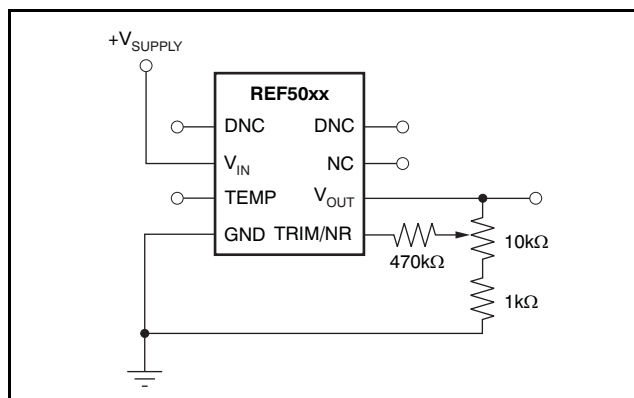


Figure 24. V_{OUT} Adjustment Using the TRIM/NR Pin

The REF50xx allows access to the bandgap through the TRIM/NR pin. Placing a capacitor from the TRIM/NR pin to GND (see [Figure 25](#)) in combination with the internal R_3 and R_4 resistors creates a low-pass filter. A capacitance of 1 μ F creates a low-pass filter with the corner frequency between 10 Hz and 20 Hz. Such a filter decreases the overall noise measured on the V_{OUT} pin by half. Higher capacitance results in a lower filter cutoff frequency, further reducing output noise. Note that use of this capacitor increases startup time.

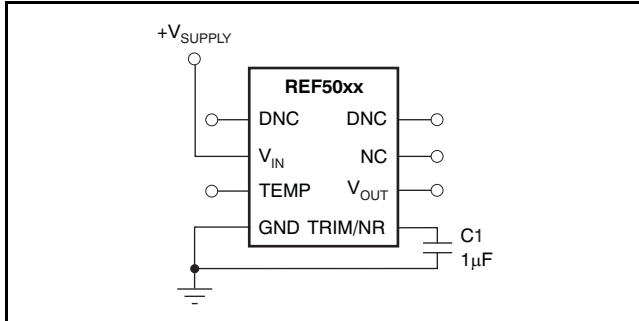


Figure 25. Noise Reduction Using the TRIM/NR Pin

TEMPERATURE DRIFT

The REF50xx is designed for minimal drift error, which is defined as the change in output voltage over temperature. The drift is calculated using the box method, as described by the following equation:

$$\text{Drift} = \left(\frac{V_{\text{OUTMAX}} - V_{\text{OUTMIN}}}{V_{\text{OUT}} \times \text{Temp Range}} \right) \times 10^6 (\text{ppm}) \quad (1)$$

The REF50xx features a maximum drift coefficient of 3 ppm/°C for the high-grade version, and 8 ppm/°C for the standard-grade.

TEMPERATURE MONITORING

The temperature output terminal (TEMP, pin 3) provides a temperature-dependent voltage output with approximately 60-kΩ source impedance. As seen in Figure 8, the output voltage follows the nominal relationship:

$$V_{\text{TEMP PIN}} = 509 \text{ mV} + 2.64 \times T(^{\circ}\text{C})$$

This pin indicates general chip temperature, accurate to approximately ±15°C. Although it is not generally suitable for accurate temperature measurements, it can be used to indicate temperature changes or for temperature compensation of analog circuitry. A temperature change of 30°C corresponds to an approximate 79 mV change in voltage at the TEMP pin.

The TEMP pin has high output impedance (see Figure 22). Loading this pin with a low-impedance circuit induces a measurement error; however, it does not have any effect on V_{OUT} accuracy. To avoid errors caused by low-impedance loading, buffer the TEMP pin output with a suitable low-temperature drift op amp, such as the OPA333, OPA335, or OPA376, as shown in Figure 26.

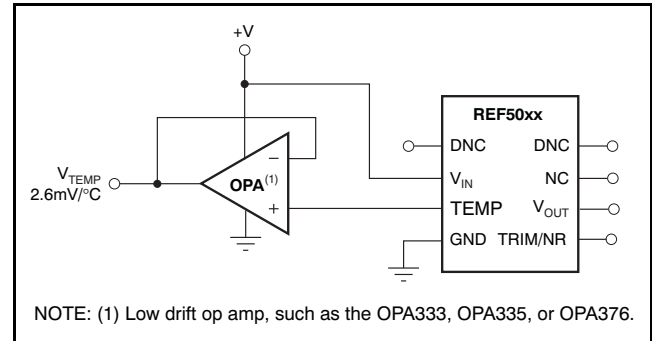


Figure 26. Buffering the TEMP Pin Output

POWER DISSIPATION

The REF50xx family is specified to deliver current loads of ±10 mA over the specified input voltage range. The temperature of the device increases according to the equation:

$$T_J = T_A + P_D \times \theta_{JA} \quad (2)$$

Where:

T_J = Junction temperature (°C)

T_A = Ambient temperature (°C)

P_D = Power dissipated (W)

θ_{JA} = Junction-to-ambient thermal resistance (°C/W)

The REF50xx junction temperature must not exceed the absolute maximum rating of +150°C.

NOISE PERFORMANCE

Typical 0.1-Hz to 10-Hz voltage noise for each member of the REF50xx family is specified in the [Electrical Characteristics: Per Device](#) table. The noise voltage increases with output voltage and operating temperature. Additional filtering can be used to improve output noise levels, although care should be taken to ensure the output impedance does not degrade performance.

APPLICATION CIRCUITS

NEGATIVE REFERENCE VOLTAGE

For applications requiring a negative and positive reference voltage, the REF50xx and OPA735 can be used to provide a dual-supply reference from a 5-V supply. Figure 27 shows the REF5020 used to provide a 2.5-V supply reference voltage. The low drift performance of the REF50xx complements the low offset voltage and zero drift of the OPA735 to provide an accurate solution for split-supply applications. Care must be taken to match the temperature coefficients of R_1 and R_2 .

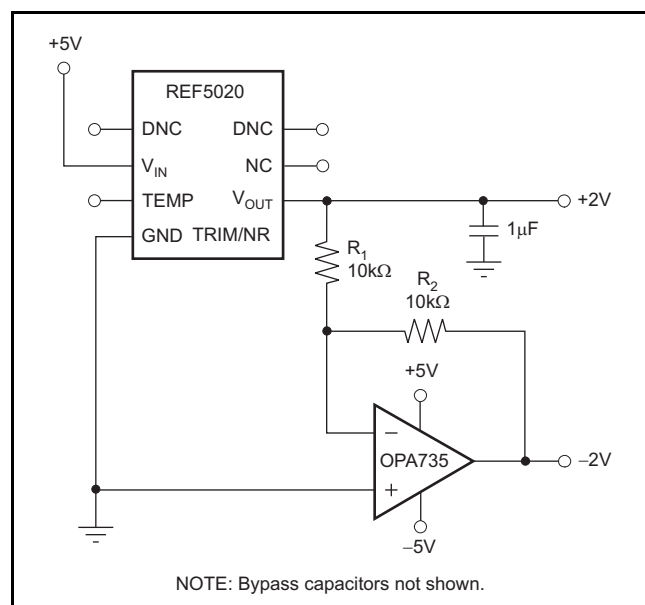


Figure 27. The REF5020 and OPA735 Create Positive and Negative Reference Voltages

DATA ACQUISITION

Data acquisition systems often require stable voltage references to maintain accuracy. The REF50xx family features low noise, very low drift, and high initial accuracy for high-performance data converters. Figure 28 shows the REF5040 in a basic data acquisition system.

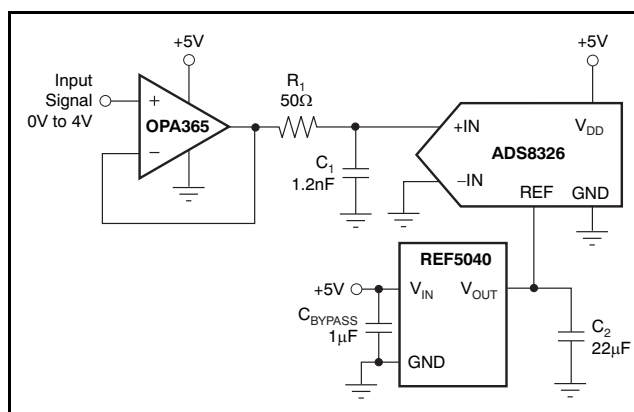


Figure 28. Basic Data Acquisition System

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
REF5020MDREP	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-55 to 125	5020EP	Samples
REF5025MDTEP	ACTIVE	SOIC	D	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR		5025EP	Samples
REF5040MDREP	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-55 to 125	5040EP	Samples
REF5050MDREP	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-55 to 125	5050EP	Samples
V62/10613-01XE	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-55 to 125	5020EP	Samples
V62/10613-02XE	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-55 to 125	5040EP	Samples
V62/10613-03XE	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-55 to 125	5050EP	Samples
V62/10613-04XE	ACTIVE	SOIC	D	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR		5025EP	Samples

(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.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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.

OTHER QUALIFIED VERSIONS OF REF5020-EP, REF5025-EP, REF5040-EP, REF5050-EP :

- Catalog: [REF5020](#), [REF5025](#), [REF5040](#), [REF5050](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

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
REF5020MDREP	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
REF5025MDTEP	SOIC	D	8	250	180.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
REF5040MDREP	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
REF5050MDREP	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
REF5020MDREP	SOIC	D	8	2500	367.0	367.0	35.0
REF5025MDTEP	SOIC	D	8	250	210.0	185.0	35.0
REF5040MDREP	SOIC	D	8	2500	367.0	367.0	35.0
REF5050MDREP	SOIC	D	8	2500	367.0	367.0	35.0

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



NOTES:

- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- $\triangle C$ Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
- $\triangle D$ Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
- E. Reference JEDEC MS-012 variation AA.

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



4211283-2/E 08/12

- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Publication IPC-7351 is recommended for alternate designs.
 - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
 - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

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

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

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license 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 significant portions 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. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

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

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products

Audio	www.ti.com/audio
Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DLP® Products	www.dlp.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
OMAP Applications Processors	www.ti.com/omap
Wireless Connectivity	www.ti.com/wirelessconnectivity

Applications

Automotive and Transportation	www.ti.com/automotive
Communications and Telecom	www.ti.com/communications
Computers and Peripherals	www.ti.com/computers
Consumer Electronics	www.ti.com/consumer-apps
Energy and Lighting	www.ti.com/energy
Industrial	www.ti.com/industrial
Medical	www.ti.com/medical
Security	www.ti.com/security
Space, Avionics and Defense	www.ti.com/space-avionics-defense
Video and Imaging	www.ti.com/video

TI E2E Community

e2e.ti.com