



# 4-20mA Current-Loop Transmitter

## FEATURES

- LOW QUIESCENT CURRENT: 130µA
- 5V REGULATOR FOR EXTERNAL CIRCUITS
- LOW SPAN ERROR: 0.05%
- LOW NONLINEARITY ERROR: 0.003%
- WIDE-LOOP SUPPLY RANGE: 7.5V to 40V
- MSOP-8 AND DFN-8 PACKAGES

## APPLICATIONS

- TWO-WIRE, 4-20mA CURRENT LOOP TRANSMITTER
- SMART TRANSMITTER
- INDUSTRIAL PROCESS CONTROL
- TEST SYSTEMS
- CURRENT AMPLIFIER
- VOLTAGE-TO-CURRENT AMPLIFIER

## DESCRIPTION

The XTR117 is a precision current output converter designed to transmit analog 4-20mA signals over an industry-standard current loop. It provides accurate current scaling and output current limit functions.

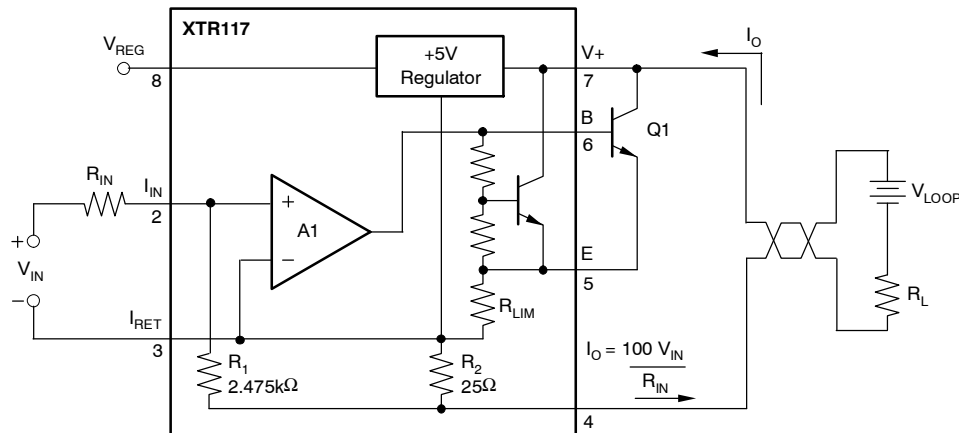
The on-chip voltage regulator (5V) can be used to power external circuitry. A current return pin ( $I_{RET}$ ) senses any current used in external circuitry to assure an accurate control of the output current.

The XTR117 is a fundamental building block of smart sensors using 4-20mA current transmission. The XTR117 is specified for operation over the extended industrial temperature range,  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

## RELATED 4-20mA PRODUCTS

XTR115	5V regulator output and 2.5V reference output
XTR116	5V regulator output and 4.096V reference output

NOTE: For 4-20mA complete bridge and RTO conditioner solutions, see the XTR product family website at [www.ti.com](http://www.ti.com).



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.

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**ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>**

Power Supply, V+ (referenced to I <sub>O</sub> pin)	+50V
Input Voltage, (referenced to I <sub>RET</sub> pin)	0V to V+
Output Current Limit	Continuous
V <sub>REG</sub> , Short-Circuit	Continuous
Operating Temperature Range	-55°C to +125°C
Storage Temperature Range	-55°C to +150°C
Junction Temperature	+165°C
ESD Rating (Human Body Model)	2000V
(Charged Device Model)	1000V

(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.

**ELECTROSTATIC DISCHARGE SENSITIVITY**



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.

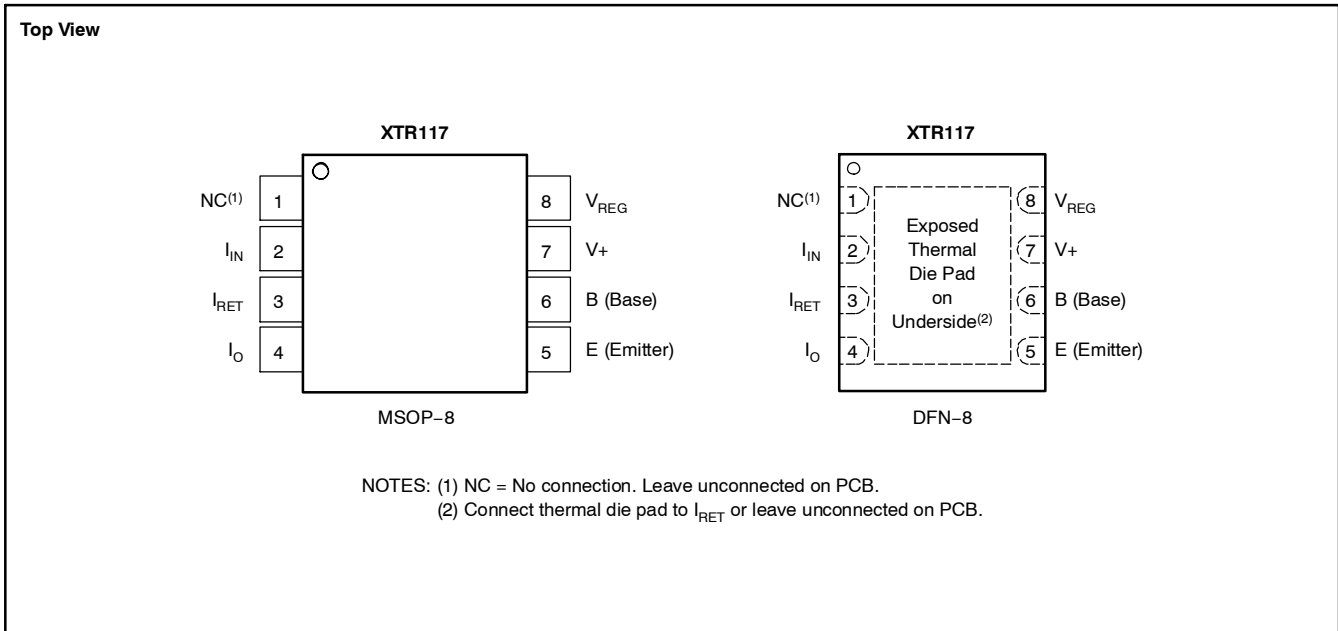
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

**PACKAGE/ORDERING INFORMATION<sup>(1)</sup>**

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR	PACKAGE MARKING
XTR117	MSOP-8	DGK	BOZ
XTR117	DFN-8	DRB	BOY

(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.

**PIN ASSIGNMENTS**



**ELECTRICAL CHARACTERISTICS: V+ = +24V**
**Boldface** limits apply over the temperature range,  $T_A = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ .

 All specifications at  $T_A = +25^\circ\text{C}$ ,  $V_+ = 24\text{V}$ ,  $R_{IN} = 20\text{k}\Omega$ , and TIP29C external transistor, unless otherwise noted.

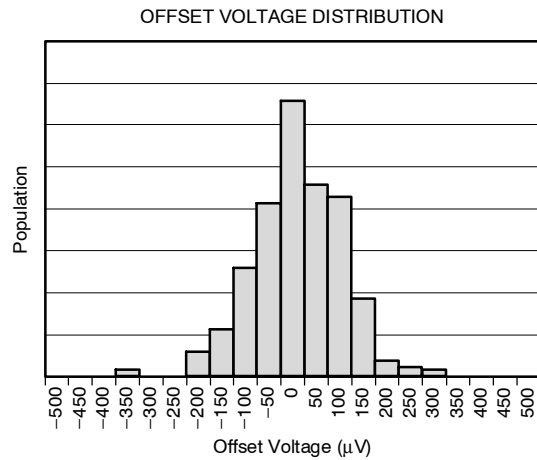
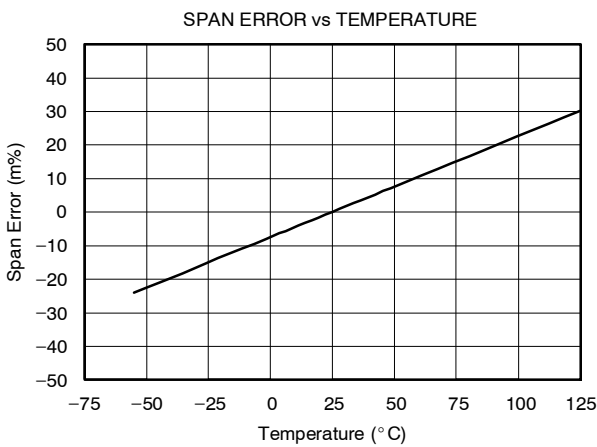
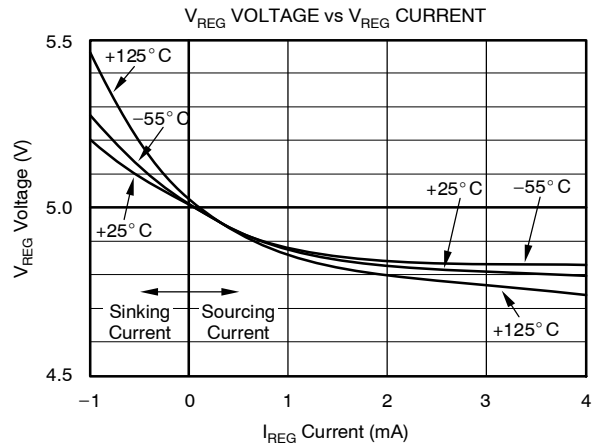
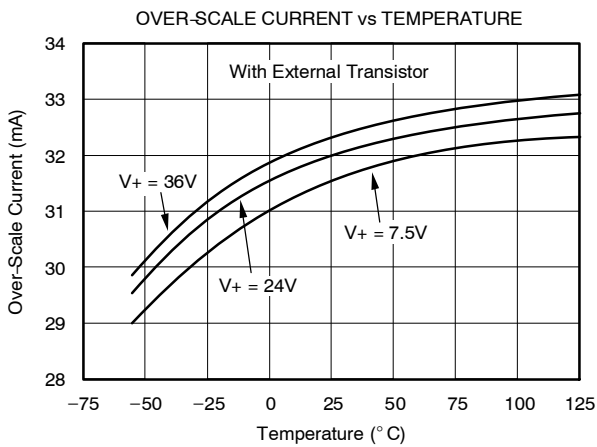
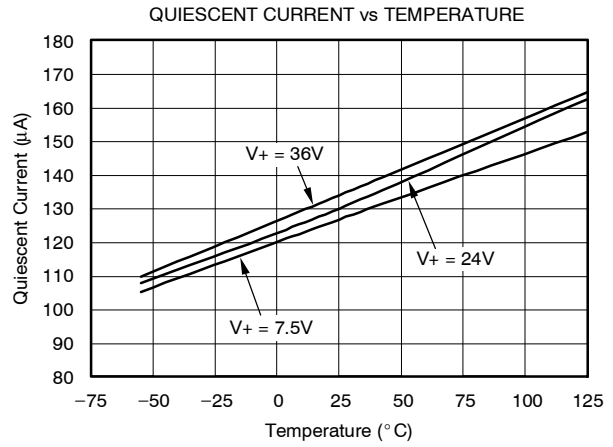
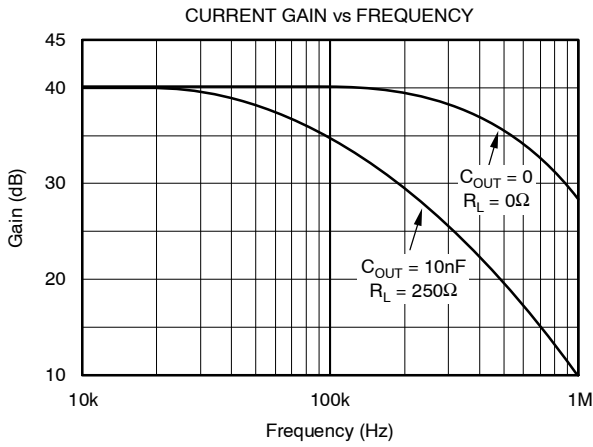
PARAMETER	CONDITION	XTR117			UNITS
		MIN	TYP	MAX	
<b>OUTPUT</b>					
Output Current Equation	$I_O$		$I_O = I_{IN} \times 100$		
Output Current, Linear Range		0.20		25	mA
Over-Scale Limit	$I_{LIM}$		32		mA
Under-Scale Limit	$I_{MIN}$		0.13	0.20	mA
<b>SPAN</b>					
Span (Current Gain)	S		100		A/A
Error <sup>(1)</sup>			$\pm 0.05$	$\pm 0.4$	%
<b>vs Temperature</b>			$\pm 3$	$\pm 20$	ppm/ $^\circ\text{C}$
Nonlinearity			$\pm 0.003$	$\pm 0.02$	%
<b>INPUT</b>					
Offset Voltage (Op Amp)	$V_{OS}$		$\pm 100$	$\pm 500$	$\mu\text{V}$
<b>vs Temperature</b>			$\pm 0.7$	$\pm 6$	$\mu\text{V}/^\circ\text{C}$
vs Supply Voltage, V+			+0.1	+2	$\mu\text{V}/\text{V}$
Bias Current	$I_B$		-35		nA
<b>vs Temperature</b>			<b>150</b>		pA/ $^\circ\text{C}$
Noise: 0.1Hz to 10Hz	$e_n$		0.6		$\mu\text{V}_{PP}$
<b>DYNAMIC RESPONSE</b>					
Small-Signal Bandwidth			380		kHz
Slew Rate			3.2		mA/ $\mu\text{s}$
<b>V<sub>REG</sub><sup>(2)</sup></b>					
Voltage			5		V
Voltage Accuracy			$\pm 0.05$	$\pm 0.1$	V
<b>vs Temperature</b>			$\pm 0.1$		mV/ $^\circ\text{C}$
vs Supply Voltage, V+			1		mV/V
vs Output Current			See Typical Characteristics		
Short-Circuit Current			12		mA
<b>POWER SUPPLY</b>					
Specified Voltage Range	V+		+24		V
Operating Voltage Range		+7.5		+40	V
Quiescent Current	$I_Q$		130	200	$\mu\text{A}$
<b>Over Temperature</b>				<b>250</b>	$\mu\text{A}$
<b>TEMPERATURE RANGE</b>					
Specified Range		-40		+125	$^\circ\text{C}$
Operating Range		-55		+125	$^\circ\text{C}$
Storage Range		-55		+150	$^\circ\text{C}$
Thermal Resistance	$\theta_{JA}$				$^\circ\text{C}/\text{W}$
MSOP			150		$^\circ\text{C}/\text{W}$
DFN			53		$^\circ\text{C}/\text{W}$

 (1) Does not include initial error or temperature coefficient of  $R_{IN}$ .

 (2) Voltage measured with respect to  $I_{RET}$  pin.

**TYPICAL CHARACTERISTICS:  $V_+ = +2.7V$  to  $+5.5V$**

At  $T_A = +25^\circ C$ ,  $V_+ = 24V$ ,  $R_{IN} = 20k\Omega$ , and TIP29C external transistor, unless otherwise noted.



## APPLICATIONS INFORMATION

### BASIC OPERATION

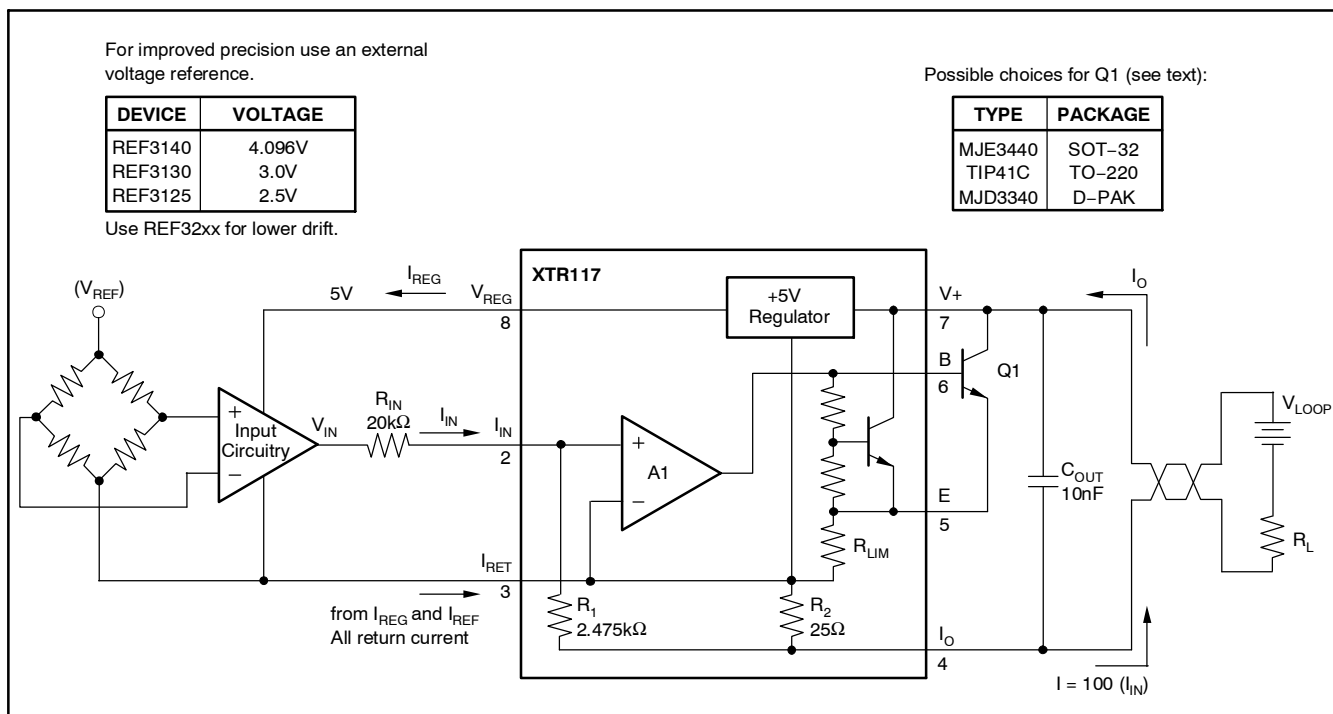
The XTR117 is a precision current output converter designed to transmit analog 4-20mA signals over an industry-standard current loop. Figure 1 shows basic circuit connections with representative simplified input circuitry. The XTR117 is a two-wire current transmitter. Its input current (pin 2) controls the output current. A portion of the output current flows into the V+ power supply, pin 7. The remaining current flows in Q<sub>1</sub>. External input circuitry connected to the XTR117 can be powered from V<sub>REG</sub>. Current drawn from these terminals must be returned to I<sub>RET</sub>, pin 3. The I<sub>RET</sub> pin is a *local ground* for input circuitry driving the XTR117.

The XTR117 is a current-input device with a gain of 100. A current flowing into pin 2 produces I<sub>O</sub> = 100 × I<sub>IN</sub>. The input voltage at the I<sub>IN</sub> pin is zero (referred to the I<sub>RET</sub> pin). A voltage input is converted to an input current with an external input resistor, R<sub>IN</sub>, as shown in Figure 1. Typical full-scale input voltages range from 1V and upward. Full-scale inputs greater than 0.5V are recommend to minimize the effects of offset voltage and drift of A1.

### EXTERNAL TRANSISTOR

The external transistor, Q<sub>1</sub>, conducts the majority of the full-scale output current. Power dissipation in this transistor can approach 0.8W with high loop voltage (40V) and 20mA output current. The XTR117 is designed to use an external transistor to avoid on-chip, thermal-induced errors. Heat produced by Q<sub>1</sub> will still cause ambient temperature changes that can influence the XTR117 performance. To minimize these effects, locate Q<sub>1</sub> away from sensitive analog circuitry, including XTR117. Mount Q<sub>1</sub> so that heat is conducted to the outside of the transducer housing.

The XTR117 is designed to use virtually any NPN transistor with sufficient voltage, current and power rating. Case style and thermal mounting considerations often influence the choice for any given application. Several possible choices are listed in Figure 1. A MOSFET transistor will not improve the accuracy of the XTR117 and is not recommended.



**Figure 1. Basic Circuit Connections**

### MINIMUM OUTPUT CURRENT

The quiescent current of the XTR117 (typically 130 $\mu$ A) is the lower limit of its output current. Zero input current ( $I_{IN} = 0$ ) will produce an  $I_O$  equal to the quiescent current. Output current will not begin to increase until  $I_{IN} > I_Q/100$ . Current drawn from  $V_{REG}$  will be added to this minimum output current. Up to 3.8mA is available to power external circuitry while still allowing the output current to go below 4mA.

### OFFSETTING THE INPUT

A low-scale output of 4mA is produced by creating a 40 $\mu$ A input current. This input current can be created with the proper value resistor from an external reference voltage ( $V_{REF}$ ) as shown in Figure 2.  $V_{REG}$  can be used as shown in Figure 2 but will not have the temperature stability of a high quality reference such as the REF3125.

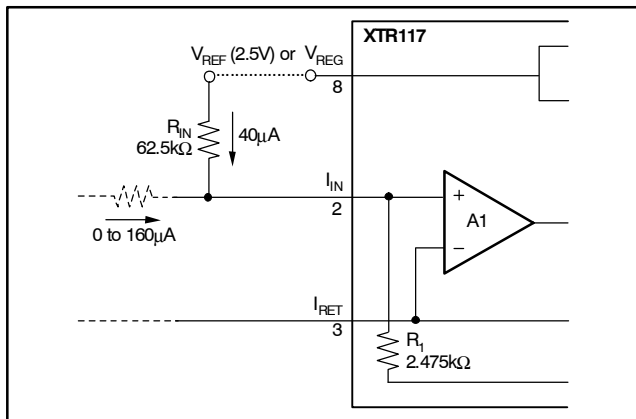


Figure 2. Creating Low-Scale Offset

### MAXIMUM OUTPUT CURRENT

The XTR117 provides accurate, linear output up to 25mA. Internal circuitry limits the output current to approximately 32mA to protect the transmitter and loop power/measurement circuitry.

It is possible to extend the output current range of the XTR117 by connecting an external resistor from pin 3 to pin 5, to change the current limit value. Since all output current must flow through internal resistors, it is possible to cause internal damage with excessive current. Output currents greater than 45mA may cause permanent damage.

### REVERSE-VOLTAGE PROTECTION

The XTR117 low compliance voltage rating (minimum operating voltage) of 7.5V permits the use of various voltage protection methods without compromising operating range. Figure 3 shows a diode bridge circuit which allows normal operation even when the voltage connection lines are reversed. The bridge causes a two diode drop (approximately 1.4V) loss in loop supply voltage. This voltage drop results in a compliance voltage of approximately 9V—satisfactory for most applications. A diode can be inserted in series with the loop supply voltage and the V+ pin to protect against reverse output connection lines with only a 0.7V loss in loop supply voltage.

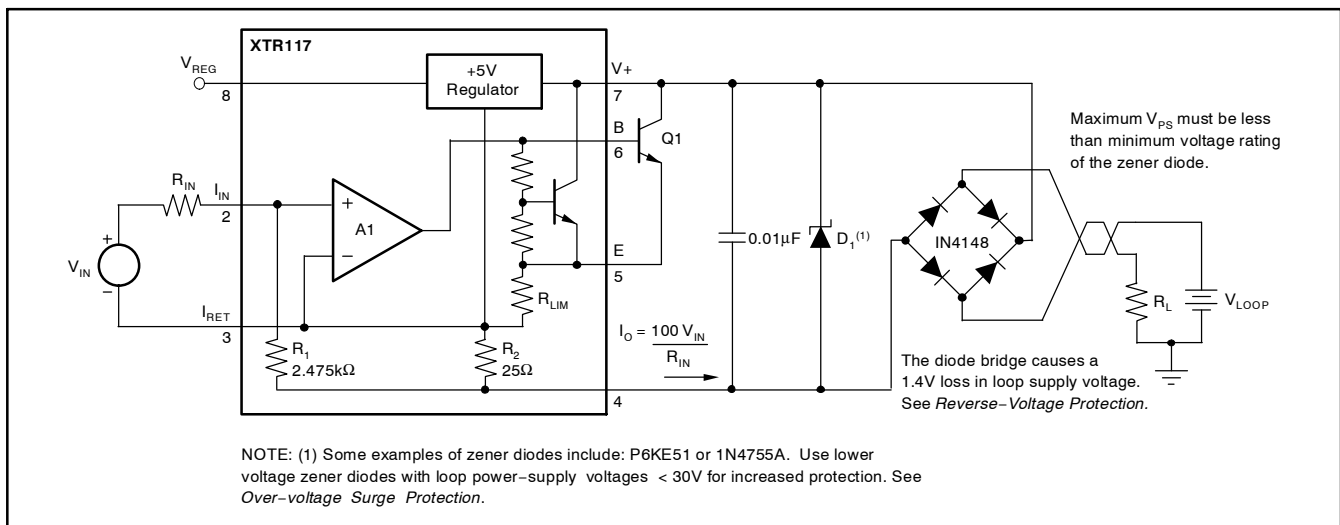


Figure 3. Reverse Voltage Operation and Over-Voltage Surge Protection

## OVER-VOLTAGE SURGE PROTECTION

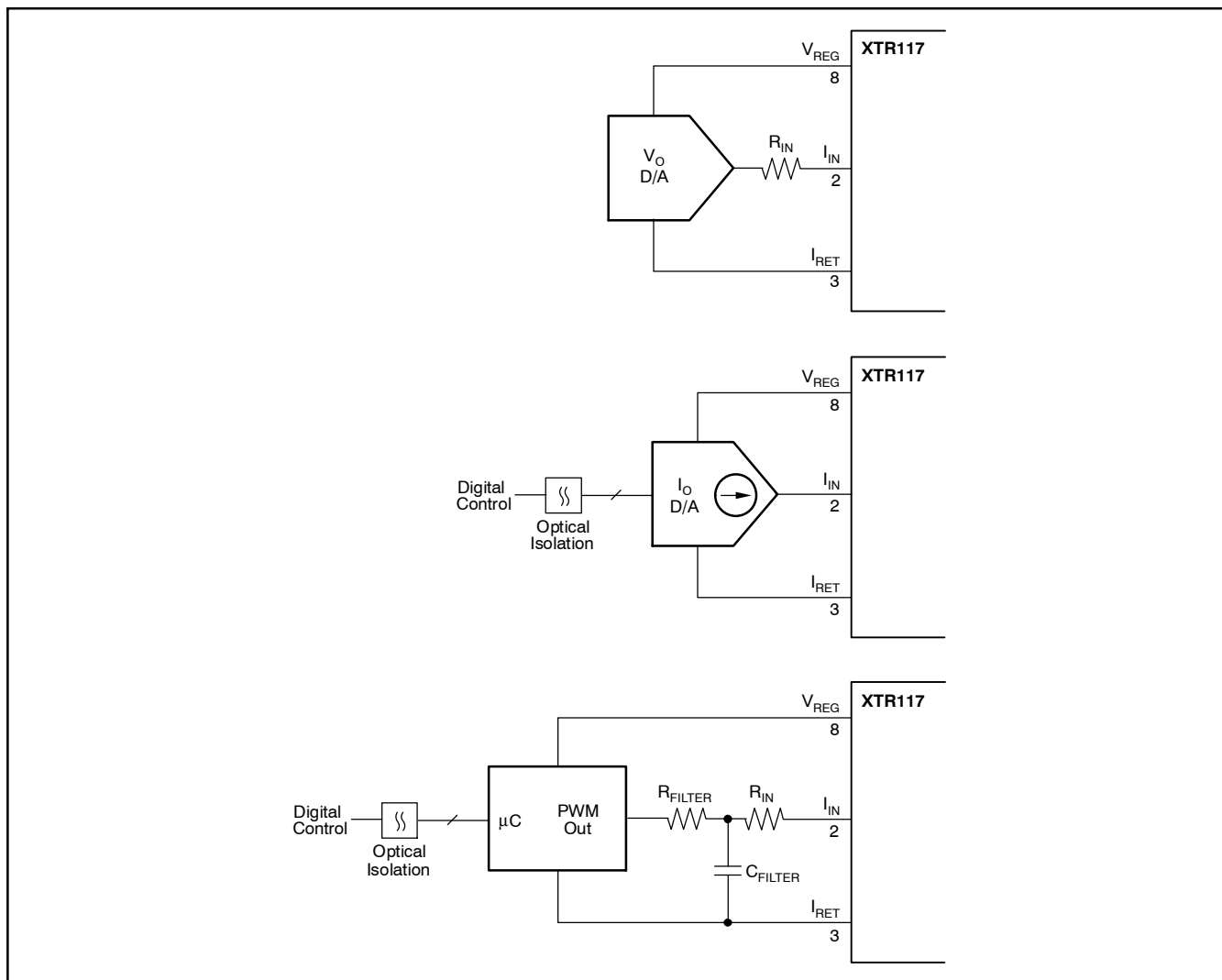
Remote connections to current transmitters can sometimes be subjected to voltage surges. It is prudent to limit the maximum surge voltage applied to the XTR117 to as low as practical. Various zener diode and surge clamping diodes are specially designed for this purpose. Select a clamp diode with as low a voltage rating as possible for best protection. Absolute maximum power-supply rating on the XTR117 is specified at +50V. Keep overvoltages and transients below +50V to ensure reliable operation when the supply returns to normal (7.5V to 40V).

Most surge protection zener diodes have a diode characteristic in the forward direction that will conduct excessive current, possibly damaging receiving-side circuitry if the loop connections are reversed. If a surge

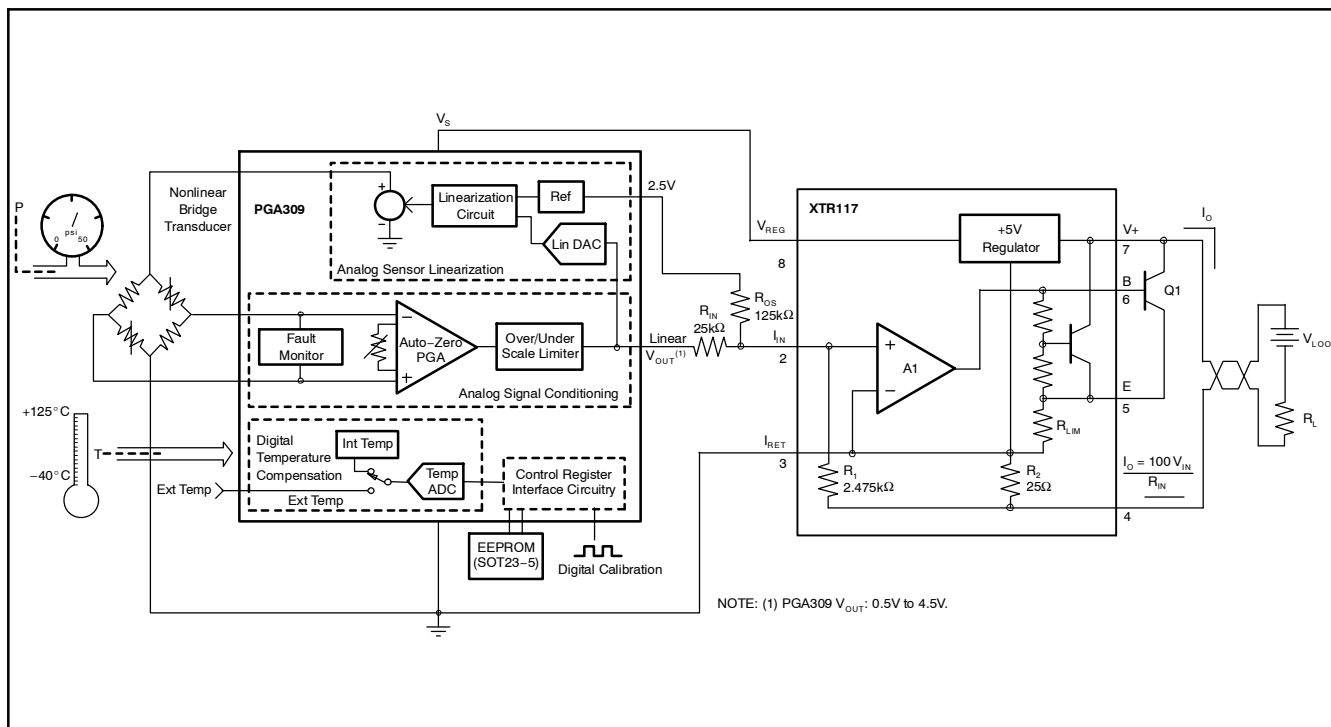
protection diode is used, a series diode or diode bridge should be used for protection against reversed connections.

## RADIO FREQUENCY INTERFERENCE

The long wire lengths of current loops invite radio frequency (RF) interference. RF interference can be rectified by the input circuitry of the XTR117 or preceding circuitry. This effect generally appears as an unstable output current that varies with the position of loop supply or input wiring. Interference may also enter at the input terminals. For integrated transmitter assemblies with short connections to the sensor, the interference more likely comes from the current loop connections.



**Figure 4. Digital Control Methods**



**Figure 5. Complete 4-20mA Pressure Transducer Solution with PGA309 and XTR117**

## DFN PACKAGE

The XTR117 is offered in a DFN-8 package (also known as SON). The DFN is a QFN package with lead contacts on only two sides of the bottom of the package. This leadless package maximizes board space and enhances thermal and electrical characteristics through an exposed pad.

DFN packages are physically small, have a smaller routing area, improved thermal performance, and improved electrical parasitics. Additionally, the absence of external leads eliminates bent-lead issues.

The DFN package can be easily mounted using standard printed circuit board (PCB) assembly techniques. See Application Note, *QFN/SON PCB Attachment* (SLUA271) and Application Report, *Quad Flatpack No-Lead Logic Packages* (SCBA017), both available for download at [www.ti.com](http://www.ti.com).

**The exposed leadframe die pad on the bottom of the package should be connected to  $I_{RET}$  or left unconnected.**

## LAYOUT GUIDELINES

The exposed leadframe die pad on the DFN package should be soldered to a thermal pad on the PCB. A mechanical drawing showing an example layout is attached at the end of this data sheet. Refinements to this layout may be required based on assembly process requirements. Mechanical drawings located at the end of this data sheet list the physical dimensions for the package and pad. The five holes in the landing pattern are optional, and are intended for use with thermal vias that connect the leadframe die pad to the heatsink area on the PCB.

Soldering the exposed pad significantly improves board-level reliability during temperature cycling, key push, package shear, and similar board-level tests. Even with applications that have low power dissipation, the exposed pad must be soldered to the PCB to provide structural integrity and long-term stability.



**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
COMBOSENSOR	ACTIVE			0		TBD	Call TI	Call TI			<a href="#">Samples</a>
XTR117AIDGKR	ACTIVE	VSSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU   CU NIPDAUAG	Level-3-260C-168 HR	-40 to 125	BOZ	<a href="#">Samples</a>
XTR117AIDGKRG4	ACTIVE	VSSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 125	BOZ	<a href="#">Samples</a>
XTR117AIDGKT	ACTIVE	VSSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU   CU NIPDAUAG	Level-3-260C-168 HR	-40 to 125	BOZ	<a href="#">Samples</a>
XTR117AIDGKTG4	ACTIVE	VSSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 125	BOZ	<a href="#">Samples</a>
XTR117AIDRBR	ACTIVE	SON	DRB	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 125	BOY	<a href="#">Samples</a>
XTR117AIDRBRG4	ACTIVE	SON	DRB	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 125	BOY	<a href="#">Samples</a>
XTR117AIDRBT	ACTIVE	SON	DRB	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 125	BOY	<a href="#">Samples</a>
XTR117AIDRBTG4	ACTIVE	SON	DRB	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 125	BOY	<a href="#">Samples</a>

(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.

**OBSELETE:** 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.

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**TAPE AND REEL INFORMATION**

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**


\*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
XTR117AIDGKR	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
XTR117AIDGKT	VSSOP	DGK	8	250	180.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
XTR117AIDRBR	SON	DRB	8	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
XTR117AIDRBT	SON	DRB	8	250	180.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
XTR117AIDGKR	VSSOP	DGK	8	2500	367.0	367.0	35.0
XTR117AIDGKT	VSSOP	DGK	8	250	210.0	185.0	35.0
XTR117AIDRBR	SON	DRB	8	3000	367.0	367.0	35.0
XTR117AIDRBT	SON	DRB	8	250	210.0	185.0	35.0





- 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.

DRB (S-PVSON-N8)

PLASTIC SMALL OUTLINE NO-LEAD



- NOTES:
- All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - This drawing is subject to change without notice.
  - Small Outline No-Lead (SON) package configuration.
  - The package thermal pad must be soldered to the board for thermal and mechanical performance.
  - See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.

# THERMAL PAD MECHANICAL DATA

DRB (S-PVSON-N8)

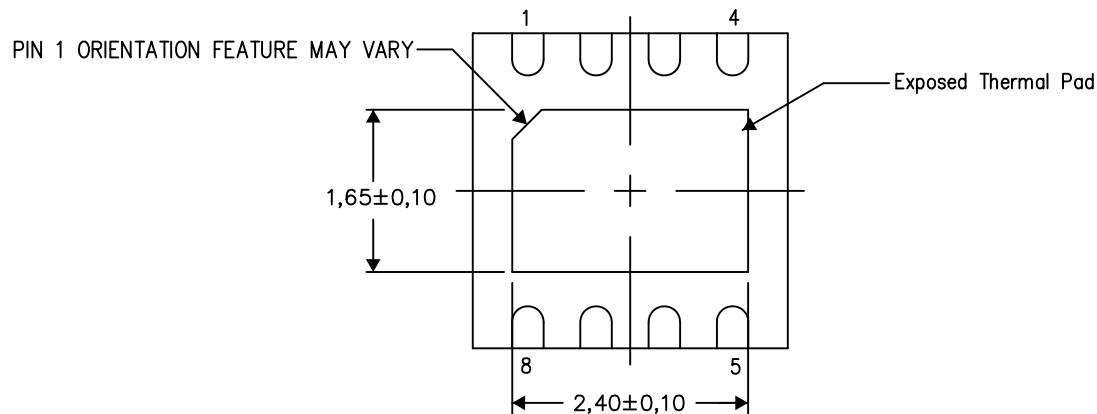
PLASTIC SMALL OUTLINE NO-LEAD

## THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No-Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.



Bottom View

Exposed Thermal Pad Dimensions

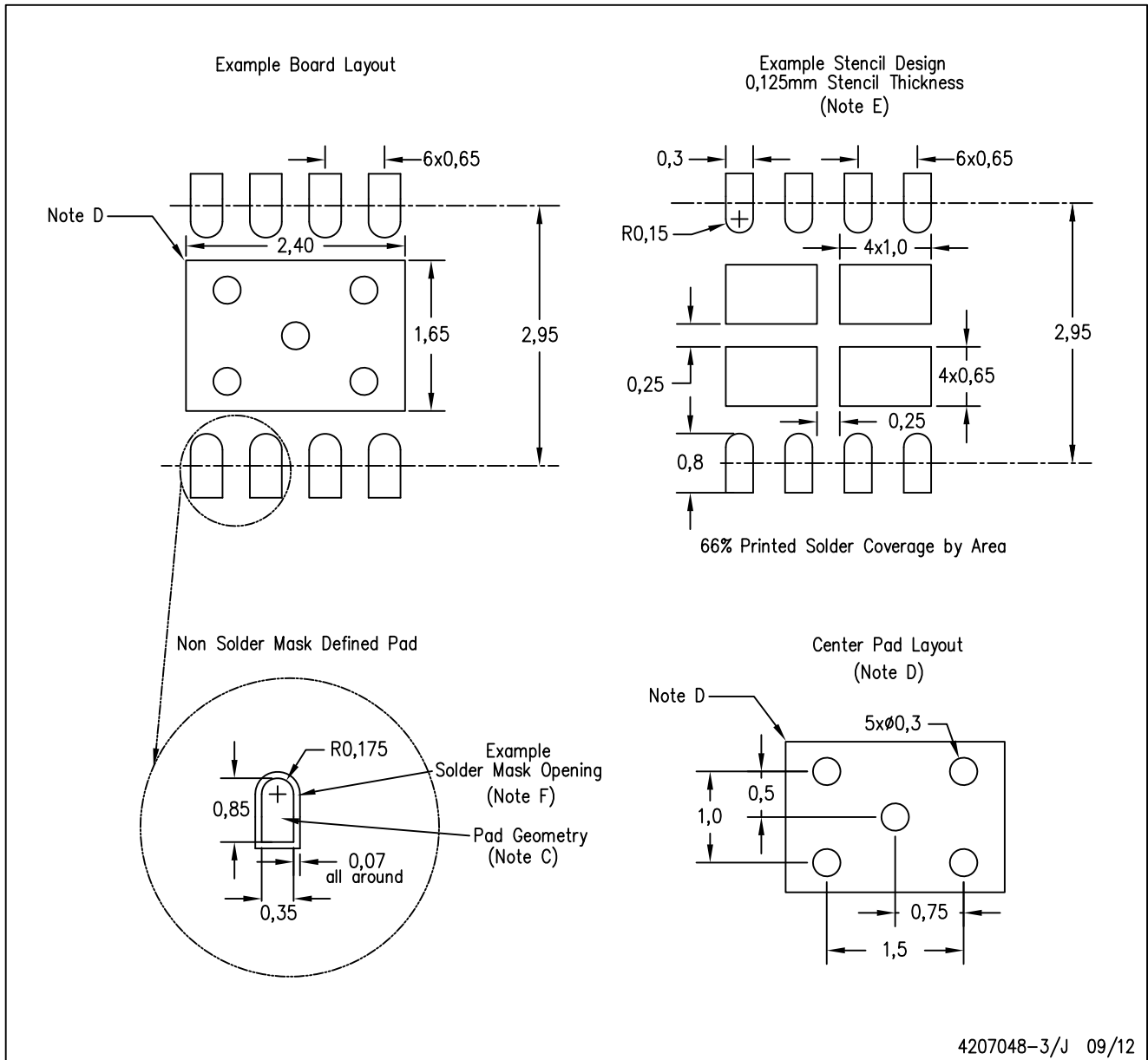
4206340-3/N 09/12

NOTE: All linear dimensions are in millimeters



DRB (S-PVSON-N8)

PLASTIC SMALL OUTLINE NO-LEAD



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, QFN Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - 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 stencil design considerations.
  - Customers should contact their board fabrication site for solder mask tolerances.

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