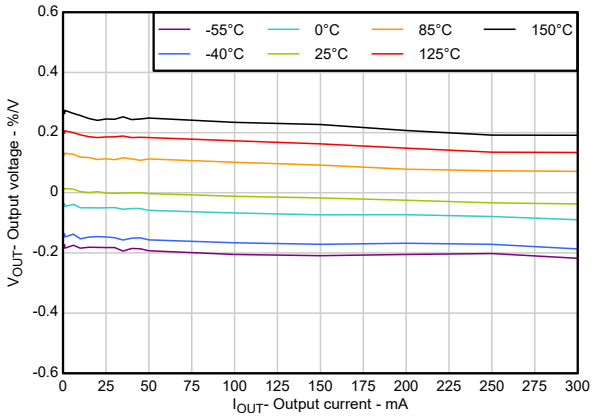
TPS7E72 300mA, 30V, Ultra-Low I_Q Low-Dropout Regulator

1 Features

- Input voltage range: 3.0V to 30V (32V max)
- Available output voltage options:
  - Fixed: 1.8V to 12V
  - Adjustable: 1.2V to 28V
- Output current: Up to 300mA
- ±1.2% accuracy across line, load and temperature
- Ultra-low I_Q: 2.8µA at I_{OUT} = 0mA
- Stable with 4.7µF or larger ceramic capacitors
  - ESR range: 0Ω to 1Ω
- Dropout voltage: 900mV (typical) at 300mA
- High PSRR:
  - 70dB at 1kHz
  - 45dB at 100kHz
- Over-current, over-power and over-temperature limiting
- Package:
  - 5-pin SOT-23 (DBV) [$R_{\theta JA}$: 190.9°C/W]
  - 6-pin WSON (DRV) [$R_{\theta JA}$: 90.2°C/W]
- Operating junction temperature: –40°C to +125°C
  - Extended range, M version: –40°C to +150°C

2 Applications

- Appliances
- Home and building automation
- Retail automation and payment
- Grid infrastructure
- Medical applications
- Lighting applications



V_{IN} = 5.3V, V_{OUT} = 3.3V

V_{OUT} Accuracy vs I_{OUT}

3 Description

The TPS7E72 low-dropout (LDO) linear voltage regulator is a low quiescent current device and supports wide input voltage range from 3V to 30V. The wide output range is from 1.2V to 28V for the adjustable configuration, 1.8V to 12V for the fixed configuration, and a load current of up to 300mA is supported. With only a 2.8µA quiescent current at no-load, the device is designed to power microcontrollers and other low-power loads for battery-powered applications.

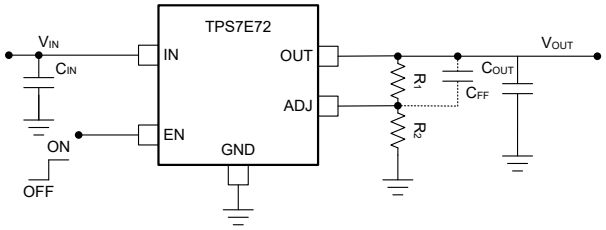
The TPS7E72 supports very tight DC accuracy of ±1.2% over line, load and temperature range. The device responds quickly to line and load transients. The low quiescent current (2.8µA typically) during regulation and controlled I_Q even in dropout operation (12µA typically in no-load dropout) makes this device designed for battery-powered or always-on systems that require very little idle-state power dissipation.

The TPS7E72 supports a low dropout of typically 900mV at 300mA of load current. The device has built-in protection mechanism for over-current, over-temperature and over-power delivery for reliable operation of the LDO. The TPS7E72 is stable with an output capacitor range of 4.7µF to 100µF.

Package Information

PART NUMBER	PACKAGE(1)	PACKAGE SIZE(2)
TPS7E72	DBV (SOT-23, 5)	2.9mm × 2.8mm
	DRV (WSON, 6)	2.0mm × 2.0mm

(1) For more information, see the *Mechanical, Packaging, and Orderable Information* section.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.



Typical Application

An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

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4 Pin Configuration and Functions

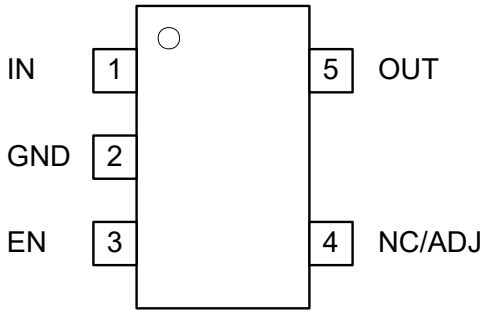


Figure 4-1. DBV Package, (Fixed/ADJ), 5-Pin SOT-23(Top View)

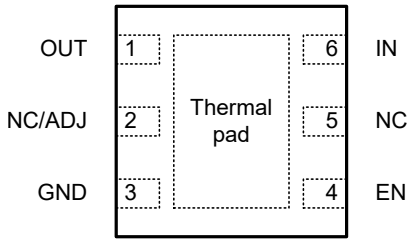


Figure 4-2. DRV Package (Fixed/ADJ),6-Pin WSON(Top View)

Table 4-1. Pin Functions

PIN			TYPE	DESCRIPTION
NAME	No.			
	DBV	DRV		
GND	2	3	—	Ground pin.
IN	1	6	Input	Input supply pin. See the *Recommended Operating Conditions* table and the *Input and Output Capacitor Selection* section for more information.
OUT	5	1	Output	Output of the regulator. A capacitor is required from OUT to ground for stability. For best transient response, use the nominal recommended value or larger ceramic capacitor from OUT to ground; see the *Recommended Operating Conditions* table and the *Input and Output Capacitor Selection* section. Place the output capacitor as close to output of the device as possible.
EN	3	4	Input	Enable pin. Driving the enable pin high enables the device. Driving this pin low disables the device. High and low thresholds are listed in the *Electrical Characteristics* table. This pin has a weak internal pullup and can be left floating to enable the device or the pin can be connected to the input pin. Refer to the *Enable (EN)* section for more details.
NC/ADJ	4	2	Input	When using the adjustable device, this pin sets the output voltage with the help of a feedback divider. In the adjustable configuration, this pin must be connected through a resistor divider to the output for the device to function. If using a fixed output device, this pin is not internally connected and can either be left floating or connected to GND.
NC	—	5	—	Not internally connected. Leave this pin open or connected to any potential. Tie this pin to ground for improved thermal performance.
Thermal pad				Thermal pad. Connect the pad to GND for the best possible thermal performance. See the *Layout* section for more information.

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5 Specifications

5.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
Voltage	V_{IN}	–0.3	32.0	V
	V_{OUT} (for fixed device only)	–0.3	2 × $V_{OUT(nom)}$ or V_{IN} + 0.3 or 15.0 (whichever is lower)	
	V_{OUT} (for adjustable device only)	–0.3	V_{IN} + 0.3 (2)	
	V_{ADJ} (Feedback voltage)	–0.3	3.6	
	V_{EN} (Enable voltage)	–0.3	32.0	
Current	I_{OUT} (Output current)	Internally limited		mA
Temperature	T_J, Operating junction	–55	150	°C
	T_{stg}, Storage	–65	150	°C

(1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. *Absolute Maximum Ratings* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If used outside the *Recommended Operating Conditions* but within the *Absolute Maximum Ratings*, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
(2) The absolute maximum rating is V_{IN} + 0.3V or 32.0V, whichever is smaller.

5.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/ JEDEC JS-001, all pins(1)	±2000	V
		Charged device model (CDM), per JEDEC specification JESD22-C101, all pins(2)	±750	

(1) JEDEC document JEP155 states that 500V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250V CDM allows safe manufacturing with a standard ESD control process.

5.3 Recommended Operating Conditions

over operating junction temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
V_{IN}	Input supply voltage range	3.0		30	V
V_{OUT}	Output voltage range (Fixed only)(1)	1.8		12	V
V_{OUT}	Output voltage range (Adjustable only)(1)	1.2		28	V
V_{EN}	Enable voltage range	0		30	V
I_{OUT}	Output current	0		300	mA
C_{IN}	Input capacitor(2)		0.47		µF
C_{OUT}	Output capacitor (3)	4.7		100	µF
ESR	Output capacitor ESR requirements	0		1	Ω
C_{ADJ}	ADJ to GND (feedback) capacitor(4)			15	pF
C_{FF}	Feed-forward capacitor (5)		10		nF
T_J	Operating junction temperature	–40		125	°C
	Operating junction temperature (M version only)	–40		150	°C

(1) This output voltage range does not include device accuracy or accuracy of the feedback resistors.
(2) An input capacitor is not required for LDO stability. However, an input capacitance with an effective value of 0.1µF minimum is recommended to counteract the effect of source resistance and inductance, which can in some cases cause symptoms of system level instability such as ringing or oscillation, especially in the presence of load transients.
(3) All capacitor values listed are the nominal value and the effective capacitance is assumed to derate up-to 50% of the nominal capacitor value.

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(4) The upper limit for the capacitor on the ADJ pin with respect to GND impacts the stable operation of the voltage regulator in adjustable configuration. For C_{ADJ} capacitor higher than limits mentioned in *Recommended Operating Conditions* table, use C_{FF} capacitor.
(5) The C_{FF} capacitor improves transient, noise, and PSRR performance, but is not required for regulator stability. Using a higher capacitance C_{FF} is permissible but start-up time increases.

5.4 Thermal Information

THERMAL METRIC (1)		TPS7E72		UNIT
		DRV (WSON) (2)	DBV (SOT-23) (2)	
		6 PINS	5 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	90.2	190.9	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	113.5	89.6	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	55.7	60.0	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	13.0	28.3	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	55.3	59.7	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	30.6	n/a	°C/W

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application note.
(2) Thermal performance results are based on the JEDEC standard of 2s2p PCB configuration. These thermal metric parameters are further improved by 35-55% based on thermally optimized PCB layout designs. See the analysis of the Impact of board layout on LDO thermal performance application note.

5.5 Electrical Characteristics

Over operating junction temperature range (T_J = –40°C to +125°C, extended range for M version: T_J = –40°C to +150°C), V_{IN} = 3.0V or V_{IN} = $V_{OUT(nom)}$ + 0.5V (whichever is greater), I_{OUT} = 1mA, V_{EN} = 2.0V, C_{IN} = 1.0µF, C_{OUT} = 4.7µF, unless otherwise noted. Typical values are at T_J = 25°C.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{ADJ}	Feedback voltage			1.2		V
V_{UVLO+}	Rising input supply UVLO	V_{IN} rising		2.8	2.91	V
V_{UVLO-}	Falling input supply UVLO	V_{IN} falling	2.6	2.7		V
$V_{UVLO(HYST)}$	V_{UVLO} hysteresis			100		mV
V_{OUT}	Output voltage	V_{IN} = V_{OUT} + 0.5V, I_{OUT} = 1mA, T_J = 25℃	–0.3		0.3	%
V_{OUT}	Output voltage	V_{OUT} + 2.0V ≤ V_{IN} ≤ 30V, I_{OUT} = 35mA, T_J = 25℃	–0.7		0.7	%
		V_{OUT} + 2.0V ≤ V_{IN} ≤ 30V, I_{OUT} = 35mA	–1.2		1.2	
		1mA ≤ I_{OUT} ≤ 300mA, 2.0V ≤ V_{IN} – V_{OUT} ≤ 15V	–1.2		1.2	
$\Delta V_{OUT(\Delta VIN)}$	Line regulation	I_{OUT} = 1mA, V_{OUT} + 0.5V ≤ V_{IN} ≤ 30V			10	mV
$\Delta V_{OUT(\Delta IOUT)}$	Load regulation	1mA ≤ I_{OUT} ≤ 300mA, V_{IN} = V_{OUT} + 2.0V, 1.2V ≤ V_{OUT} < 5.0V			11	mV
		1mA ≤ I_{OUT} ≤ 300mA, V_{IN} = V_{OUT} + 2.0V, 5.0V ≤ V_{OUT} < 12.0V			22	mV
$\Delta\%V_{OUT}/\Delta I_{OUT}$	Load regulation	1mA ≤ I_{OUT} ≤ 300mA, V_{IN} = V_{OUT} + 2.0V, 12.0V ≤ V_{OUT}			0.65	%/A
V_{DO}	Dropout voltage	I_{OUT} = 300mA		0.95	1.8	V
		I_{OUT} = 300mA, for adjustable		0.96	1.8	
V_{DO}	Dropout voltage	I_{OUT} = 100mA		0.3	0.55	V
		I_{OUT} = 100mA, for adjustable		0.32	0.56	
I_{LIM}	Output current limit	V_{OUT} forced at 0.9 × $V_{OUT(nom)}$, V_{IN} = $V_{OUT(nom)}$ + 2.0V	350	500	625	mA
I_{SC}	Short-circuit current limit	R_{LOAD} = 20 mΩ	30	55	80	mA
I_{PLIMIT}	Current limit at max headroom	V_{IN} = 30V, V_{OUT} = 1.2V			35	mA
$V_{HEADROOM}$	Max headroom at full load	V_{OUT} = 1.2V			15	V
I_{ADJ}	Feedback current	V_{IN} = 30V			25	nA

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5.5 Electrical Characteristics (continued)

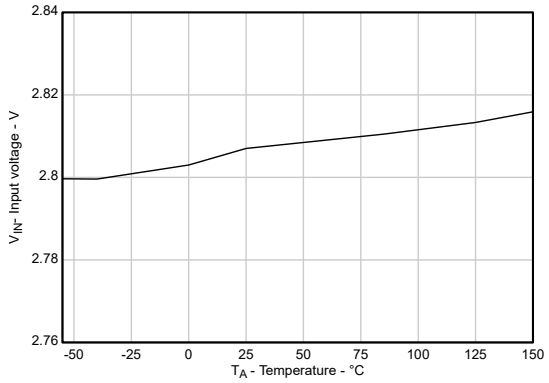
Over operating junction temperature range (T_J = –40°C to +125°C, extended range for M version: T_J = –40°C to +150°C), V_{IN} = 3.0V or V_{IN} = $V_{OUT(nom)}$ + 0.5V (whichever is greater), I_{OUT} = 1mA, V_{EN} = 2.0V, C_{IN} = 1.0µF, C_{OUT} = 4.7µF, unless otherwise noted. Typical values are at T_J = 25°C.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_Q	Quiescent current	3.0V ≤ V_{IN} ≤ V_{OUT} – 0.2V , I_{OUT} = 0mA		12.5	25	µA
		I_{OUT} = 0mA		2.8	6.0	
		V_{OUT} + 0.5V ≤ V_{IN} ≤ 30V , I_{OUT} = 0mA			7.6	
I_{GND}	Ground current	I_{OUT} = 1mA		16.5	25	µA
I_{GND}	Ground current	V_{IN} = V_{OUT} + 2.0V, I_{OUT} = 300mA			600	µA
$I_{SHUTDOWN}$	Shutdown current	V_{EN} = 0V, T_J = 25°C		0.45		µA
		V_{OUT} + 0.5V ≤ V_{IN} ≤ 30V , V_{EN} = 0V			1.5	
$T_{start-up}$	Start-up time	V_{IN}, V_{EN} tied together, V_{IN} ramped to $V_{OUT(nom)}$ + 0.5V, I_{OUT} = 0mA		500		µs
I_{EN}	EN pin current	0V ≤ V_{EN} ≤ 30V, V_{IN} and V_{EN} tied together			0.3	µA
		0V ≤ V_{IN} ≤ 30V, V_{EN} = 0V	–0.5			
$V_{IL(EN)}$	EN pin low-level input voltage (disable device)				0.46	V
$V_{IH(EN)}$	EN pin high-level input voltage (enable device)		1.1			
$V_{HYST(EN)}$	EN pin hysteresis (enable device)			0.13		V
PSRR	Power-supply ripple rejection	V_{IN} – V_{OUT} = 3.0 V, I_{OUT} = 300mA, f = 100kHz		45		dB
V_n	Output noise voltage	Bandwidth = 10Hz to 100kHz, V_{IN} – V_{OUT} = 3.0 V, I_{OUT} = 300mA		650		μV_{RMS}
T_{sd+}	Thermal shutdown temperature increasing	Shutdown, temperature increasing	163			°C
T_{sd-}	Thermal shutdown temperature decreasing	Reset, temperature decreasing	150			°C
$R_{Discharge}$	Output discharge resistance	V_{IN} = 3.0V, V_{EN} = 0V, T_J = 25°C, I_{OUT} = 1mA		780		Ω
I_{SINK}	Sink current on output	V_{OUT} = V_{OUT} × 1.05, T_J = 25°C		3.3		mA

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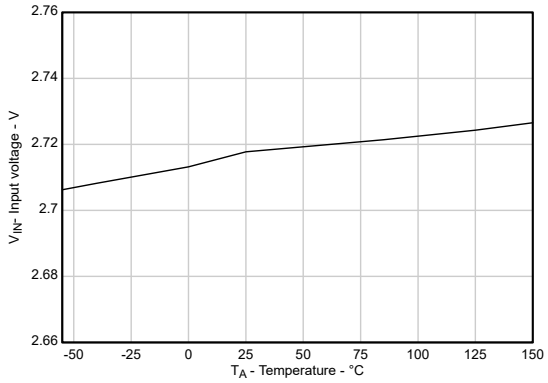
5.6 Typical Characteristics

at operating junction temperature T_J = 25°C, V_{IN} = 3.0V or V_{IN} = V_{OUT}(nom) + 1.0V (whichever is greater), C_{IN} = 1µF, C_{OUT} = 4.7µF, V_{EN} = 2V, and I_{OUT} = 1mA; temperatures given in terms of T_J (unless otherwise noted)



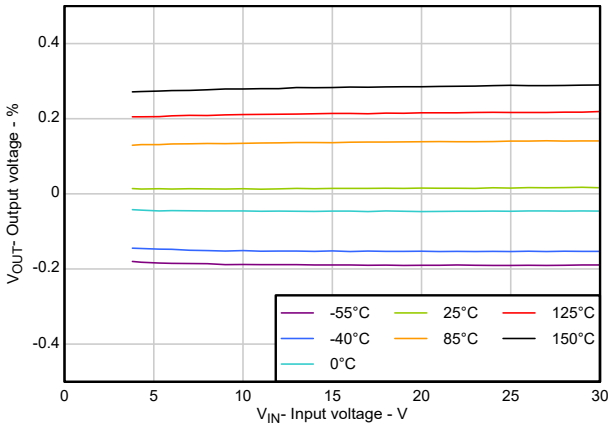
V_{OUT} = 3.3V

Figure 5-1. Rising Input Supply UVLO vs Temperature



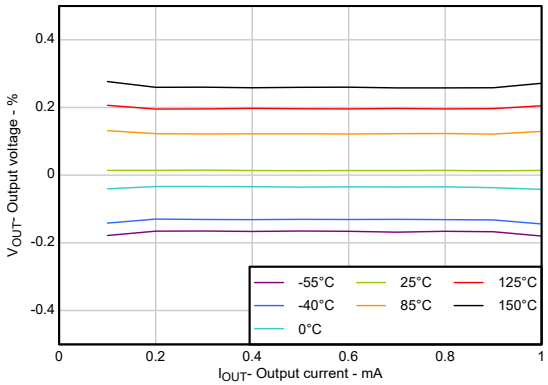
V_{OUT} = 3.3V

Figure 5-2. Falling Input Supply UVLO vs Temperature



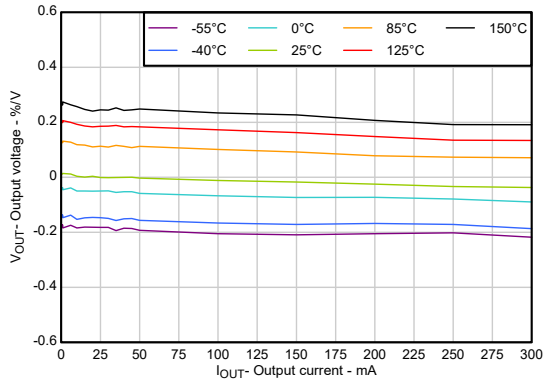
V_{OUT} = 3.3V

Figure 5-3. Accuracy vs Input Voltage



V_{IN} = 3.8V

Figure 5-4. Accuracy vs Output Current



V_{IN} = 5.3V

Figure 5-5. Accuracy vs Output Current

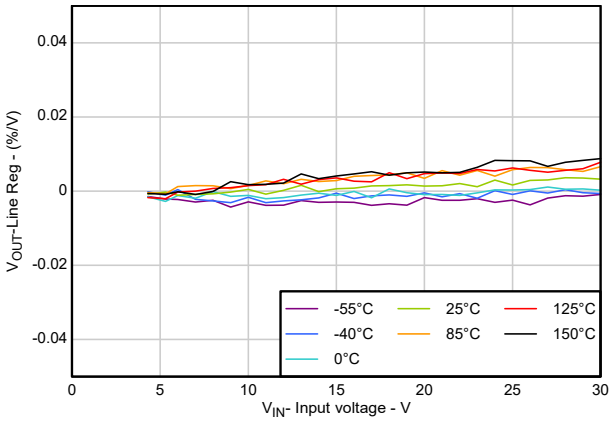


Figure 5-6. Line Regulation vs Input Voltage

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5.6 Typical Characteristics (continued)

at operating junction temperature T_J = 25°C, V_{IN} = 3.0V or V_{IN} = V_{OUT}(nom) + 1.0V (whichever is greater), C_{IN} = 1µF, C_{OUT} = 4.7µF, V_{EN} = 2V, and I_{OUT} = 1mA; temperatures given in terms of T_J (unless otherwise noted)

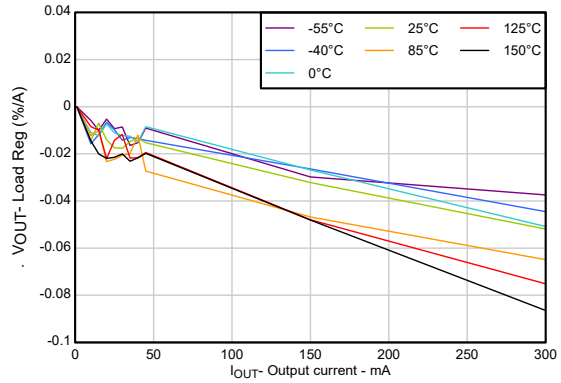


Figure 5-7. Load Regulation vs Output Current

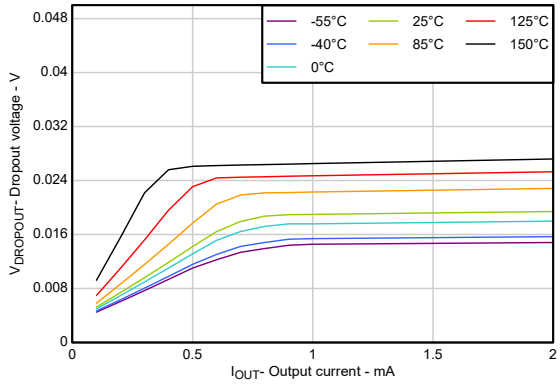


Figure 5-8. Dropout Voltage vs Output Current, Light Loads

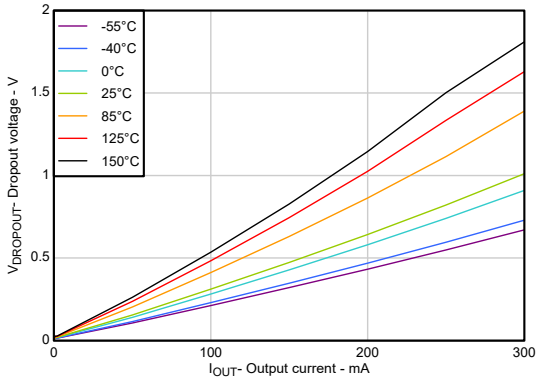
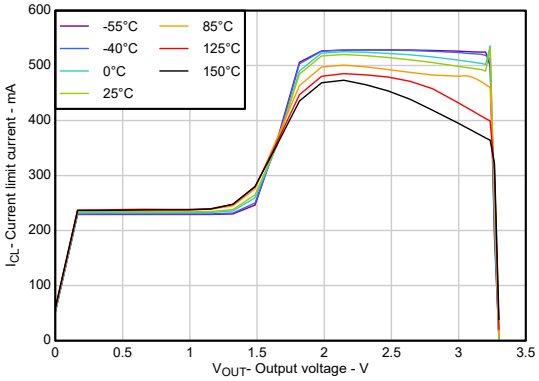
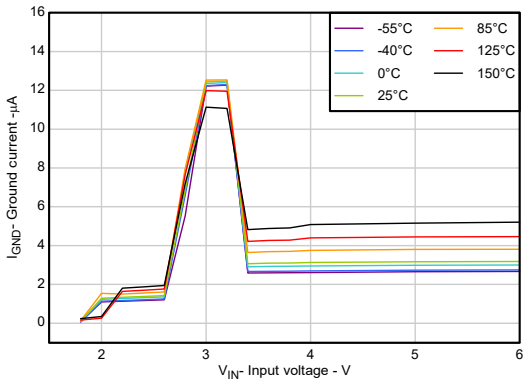


Figure 5-9. Dropout vs Output Current



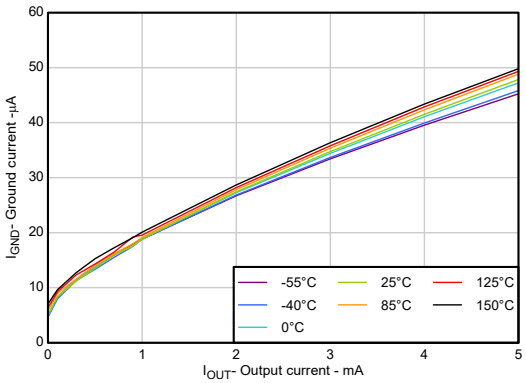
V_{IN} = 5.3V

Figure 5-10. Current Limit vs Output Voltage



I_{OUT} = 0mA, V_{OUT} = 3.3V

Figure 5-11. Controlled Quiescent Current in Dropout



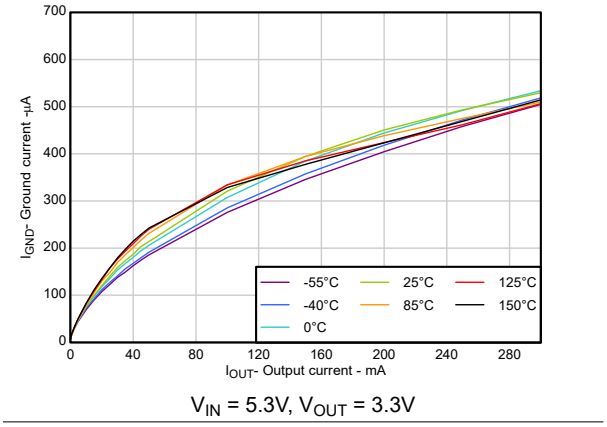
V_{IN} = 3.8V, V_{OUT} = 3.3V

Figure 5-12. Ground Current vs Output Current

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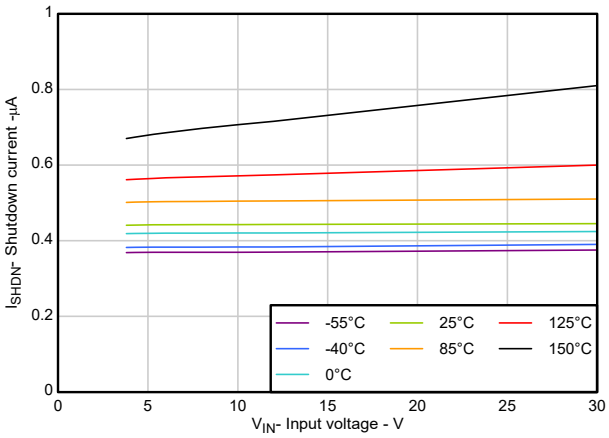
5.6 Typical Characteristics (continued)

at operating junction temperature T_J = 25°C, V_{IN} = 3.0V or V_{IN} = V_{OUT}(nom) + 1.0V (whichever is greater), C_{IN} = 1µF, C_{OUT} = 4.7µF, V_{EN} = 2V, and I_{OUT} = 1mA; temperatures given in terms of T_J (unless otherwise noted)



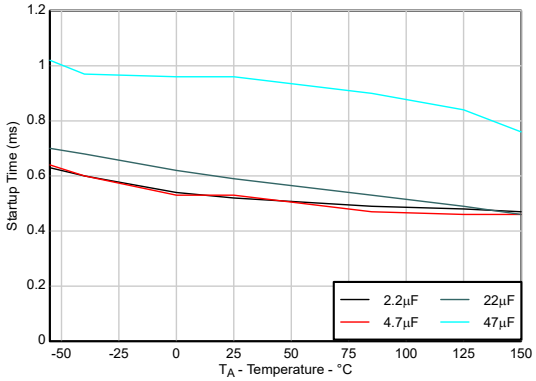
V_{IN} = 5.3V, V_{OUT} = 3.3V

Figure 5-13. Ground Current vs Output Current



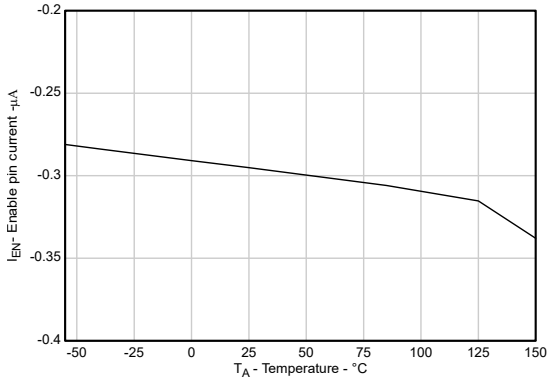
V_{EN} = 0V, I_{OUT} = 0mA

Figure 5-14. Shutdown Current vs Input Voltage



V_{OUT} = 3.3V, I_{OUT} = 0mA

Figure 5-15. Start-up Time vs Temperature, C_{OUT}



I_{OUT} = 0mA

Figure 5-16. Enable Pin Leakage Current vs Temperature

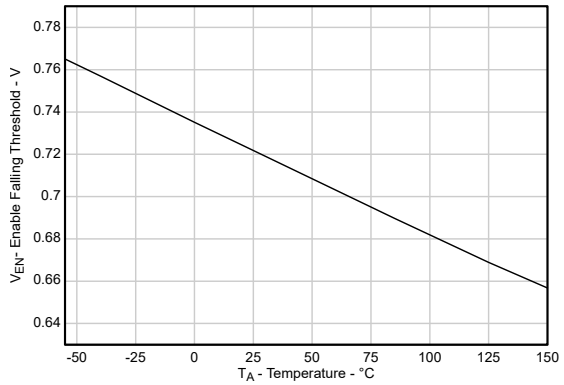


Figure 5-17. Enable Pin Low-Level Input Voltage vs Temperature

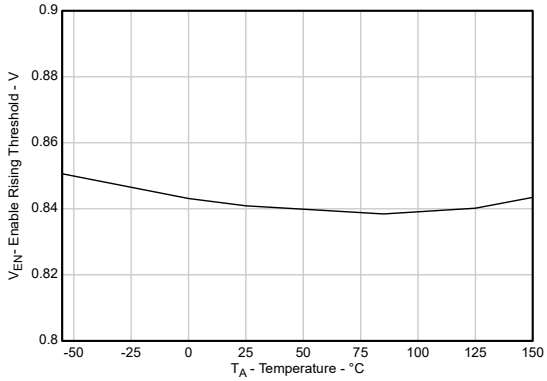
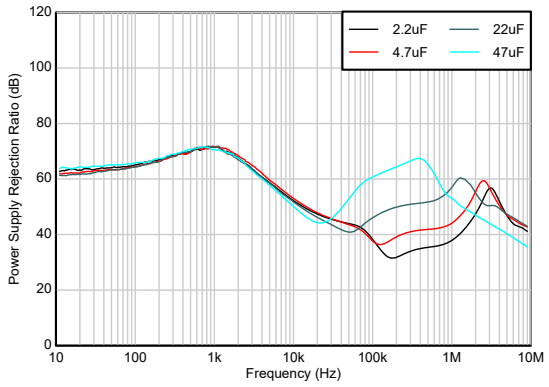


Figure 5-18. Enable Pin High-Level Input Voltage vs Temperature

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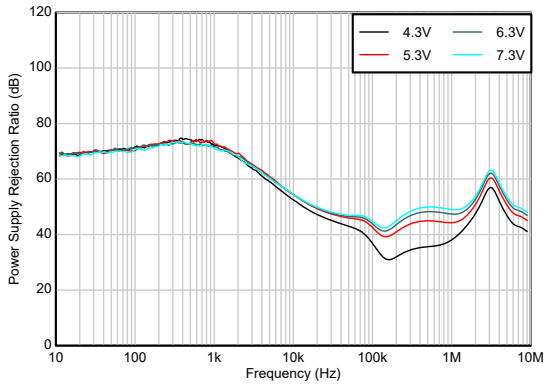
5.6 Typical Characteristics (continued)

at operating junction temperature T_J = 25°C, V_{IN} = 3.0V or V_{IN} = V_{OUT}(nom) + 1.0V (whichever is greater), C_{IN} = 1µF, C_{OUT} = 4.7µF, V_{EN} = 2V, and I_{OUT} = 1mA; temperatures given in terms of T_J (unless otherwise noted)



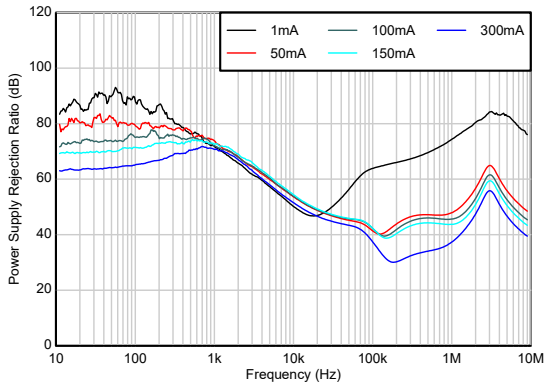
V_{IN} = 5.3V, V_{OUT} = 3.3V, I_{OUT} = 300mA

Figure 5-19. Ripple Rejection vs Frequency, C_{OUT}



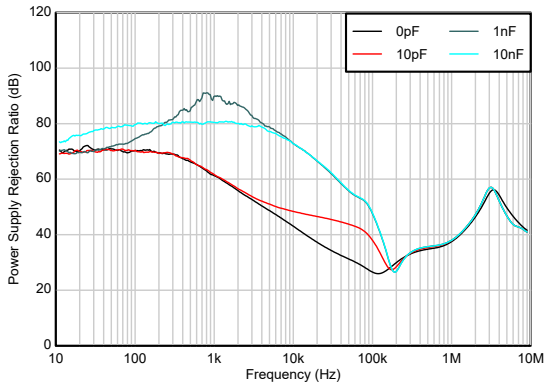
V_{OUT} = 3.3V, I_{OUT} = 150mA

Figure 5-20. Ripple Rejection vs Frequency, Input Voltage



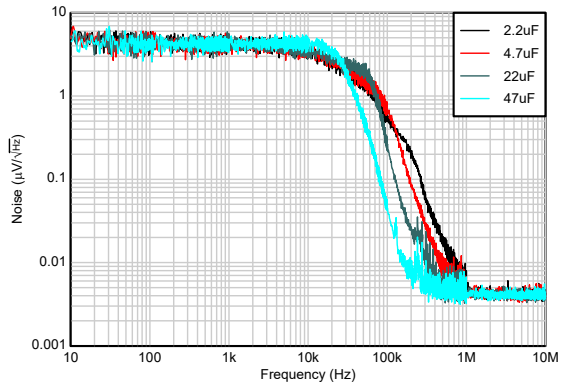
V_{IN} = 5.3V, V_{OUT} = 3.3V

Figure 5-21. Ripple Rejection vs Frequency, Output Current



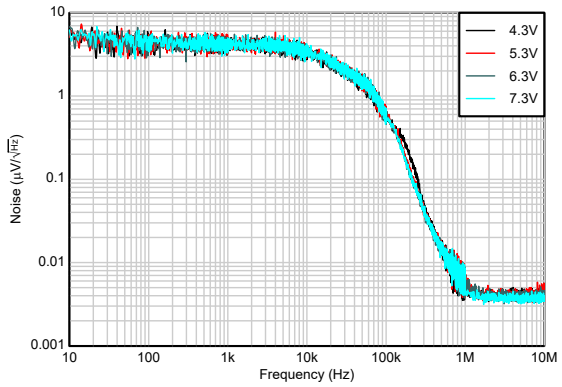
V_{OUT} = 3.3V, I_{OUT} = 150mA

Figure 5-22. Ripple Rejection vs Frequency, C_{FF}



V_{IN} = 5.3V, V_{OUT} = 3.3V, I_{OUT} = 300mA

Figure 5-23. Output Noise vs Frequency, C_{OUT}



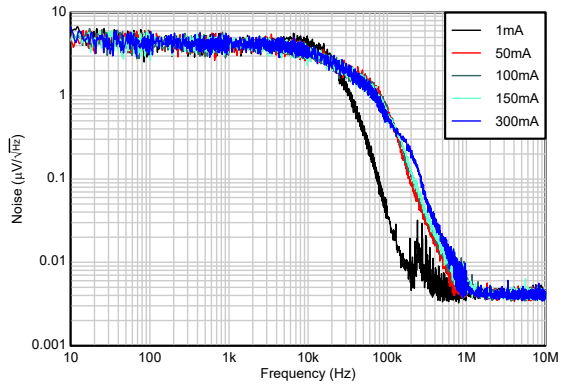
V_{OUT} = 3.3V, I_{OUT} = 150mA

Figure 5-24. Output Noise vs Frequency, Input Voltage

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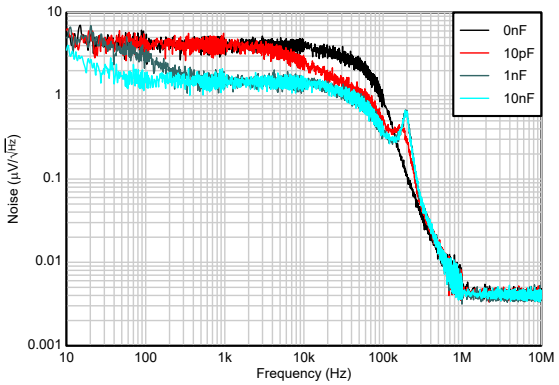
5.6 Typical Characteristics (continued)

at operating junction temperature T_J = 25°C, V_{IN} = 3.0V or V_{IN} = V_{OUT}(nom) + 1.0V (whichever is greater), C_{IN} = 1µF, C_{OUT} = 4.7µF, V_{EN} = 2V, and I_{OUT} = 1mA; temperatures given in terms of T_J (unless otherwise noted)



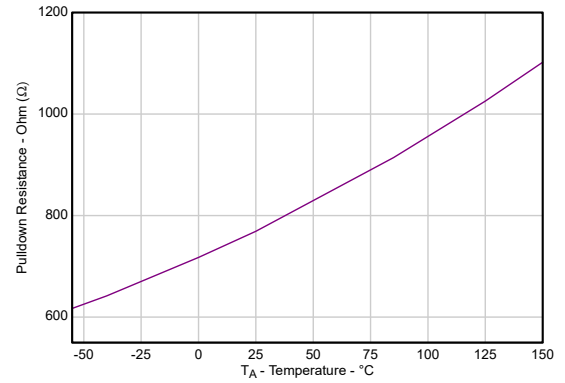
V_{IN} = 5.3V, V_{OUT} = 3.3V

Figure 5-25. Output Noise vs Frequency, Output Current



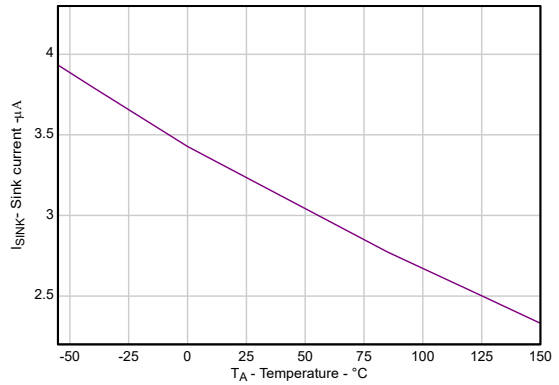
V_{OUT} = 3.3V, I_{OUT} = 150mA

Figure 5-26. Output Noise vs Frequency, C_{FF}



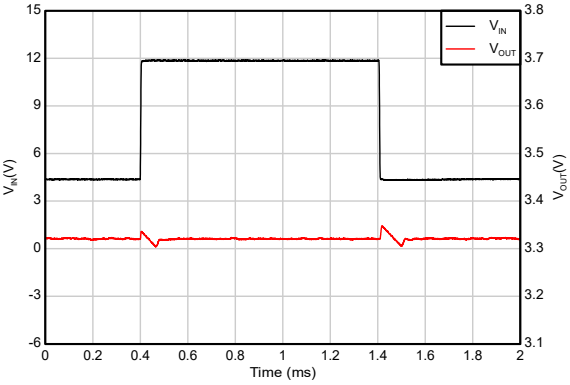
V_{EN} = 0V

Figure 5-27. Output Discharge Resistance vs Temperature



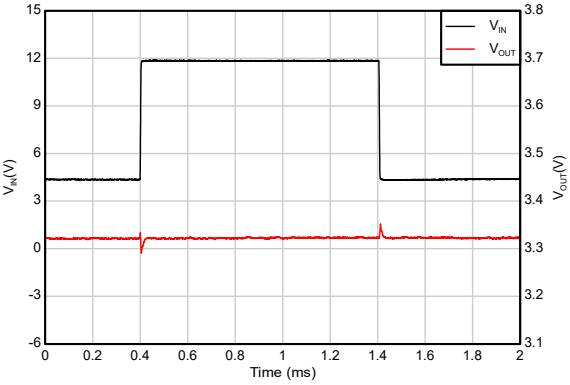
V_{EN} = V_{IN}, V_{OUT} = 1.05 × $V_{OUT(nom)}$

Figure 5-28. Output Sink Current vs Temperature



V_{IN} = 4.3V to 12V, V_{OUT} = 3.3V, slew rate = 2V/µs

Figure 5-29. Line Transient



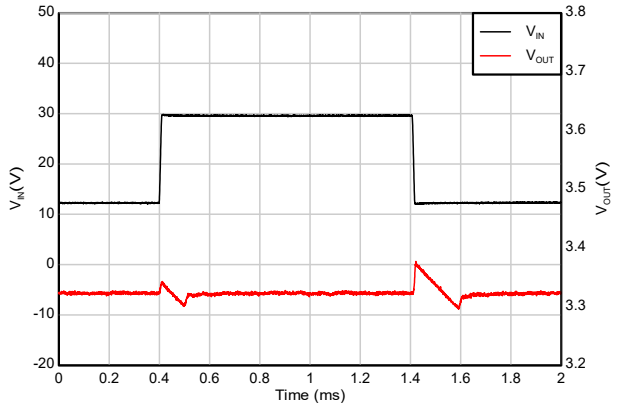
V_{IN} = 4.3V to 12V, V_{OUT} = 3.3V, I_{OUT} = 150mA, slew rate = 2V/µs

Figure 5-30. Line Transient

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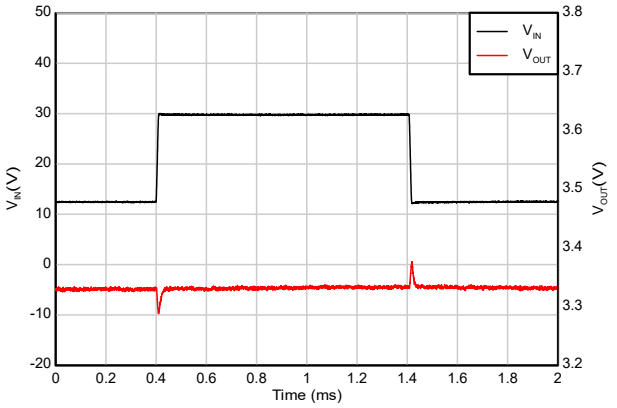
5.6 Typical Characteristics (continued)

at operating junction temperature T_J = 25°C, V_{IN} = 3.0V or V_{IN} = V_{OUT}(nom) + 1.0V (whichever is greater), C_{IN} = 1µF, C_{OUT} = 4.7µF, V_{EN} = 2V, and I_{OUT} = 1mA; temperatures given in terms of T_J (unless otherwise noted)



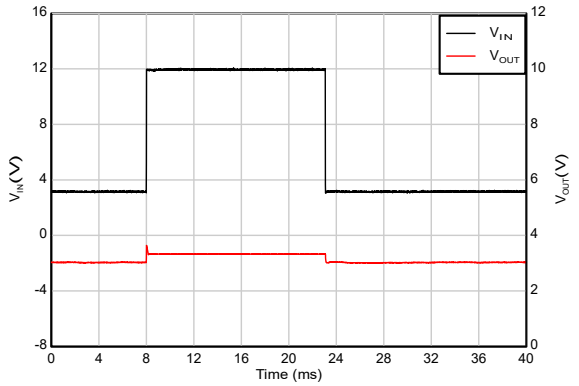
V_{IN} = 12V to 30V, V_{OUT} = 3.3V, slew rate = 2V/µs

Figure 5-31. Line Transient



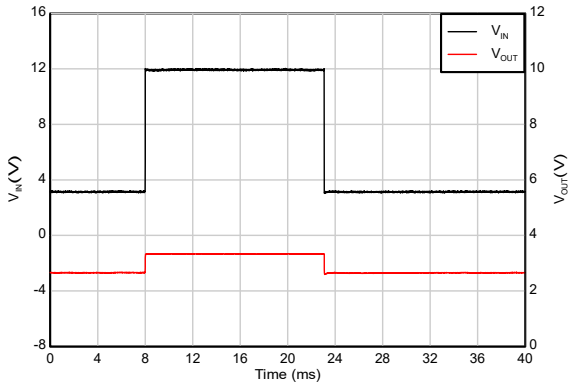
V_{IN} = 12V to 30V, V_{OUT} = 3.3V, I_{OUT} = 150mA, slew rate = 2V/µs

Figure 5-32. Line Transient



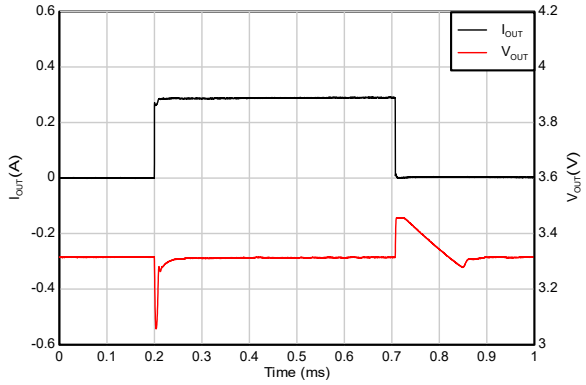
V_{IN} = 3V to 12V, V_{OUT} = 3.3V, slew rate = 2V/µs

Figure 5-33. Line Transient



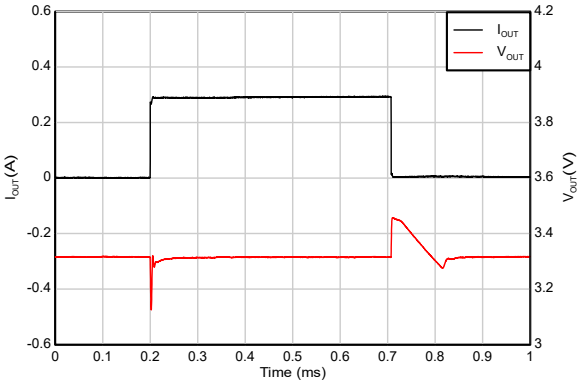
V_{IN} = 3V to 12V, V_{OUT} = 3.3V, I_{OUT} = 150mA, slew rate = 2V/µs

Figure 5-34. Line Transient



I_{OUT} = 0mA to 300mA, V_{IN} = 5.3V, V_{OUT} = 3.3V, slew rate = 2A/µs

Figure 5-35. Load Transient



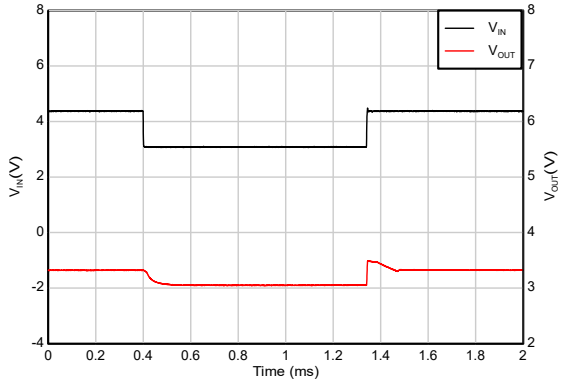
I_{OUT} = 1mA to 300mA, V_{IN} = 5.3V, V_{OUT} = 3.3V, slew rate = 2A/µs

Figure 5-36. Load Transient

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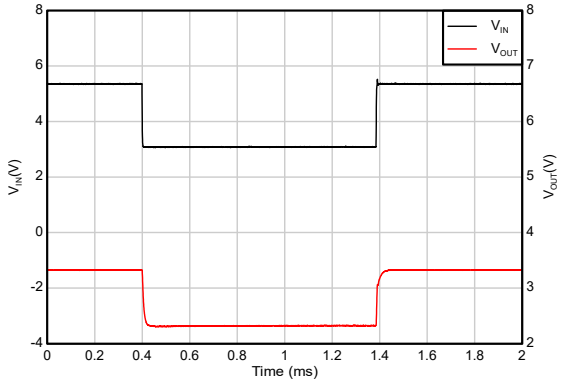
5.6 Typical Characteristics (continued)

at operating junction temperature T_J = 25°C, V_{IN} = 3.0V or V_{IN} = V_{OUT}(nom) + 1.0V (whichever is greater), C_{IN} = 1µF, C_{OUT} = 4.7µF, V_{EN} = 2V, and I_{OUT} = 1mA; temperatures given in terms of T_J (unless otherwise noted)



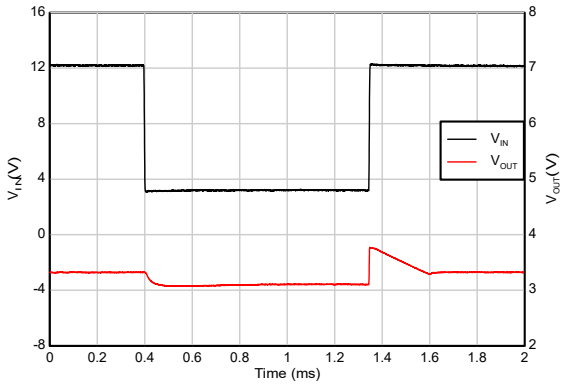
V_{IN} = 4.3V to 3V, V_{OUT} = 3.3V, slew rate = 2V/µs

Figure 5-37. Dropout Recovery



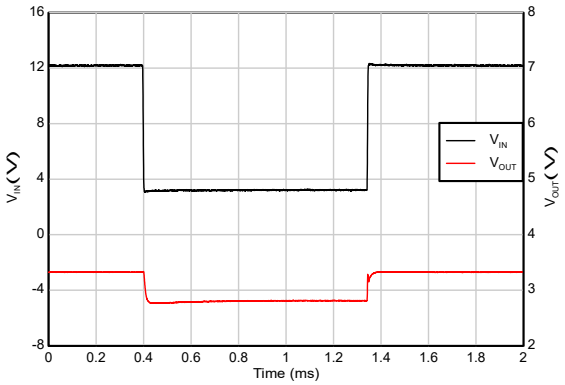
V_{IN} = 5.3V to 3V, V_{OUT} = 3.3V, I_{OUT}= 300mA, slew rate = 2V/µs

Figure 5-38. Dropout Recovery



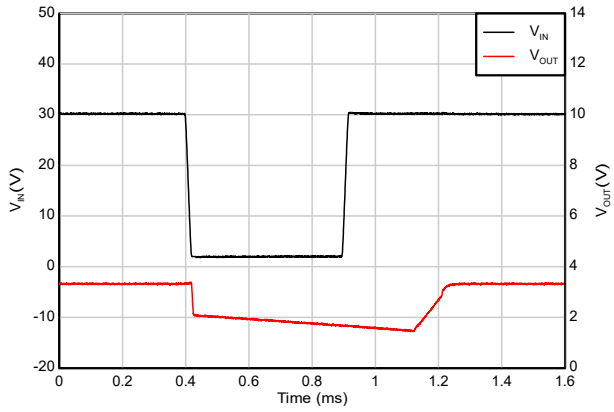
V_{IN} = 12V to 3V, V_{OUT} = 3.3V, slew rate = 2V/µs

Figure 5-39. Dropout Recovery



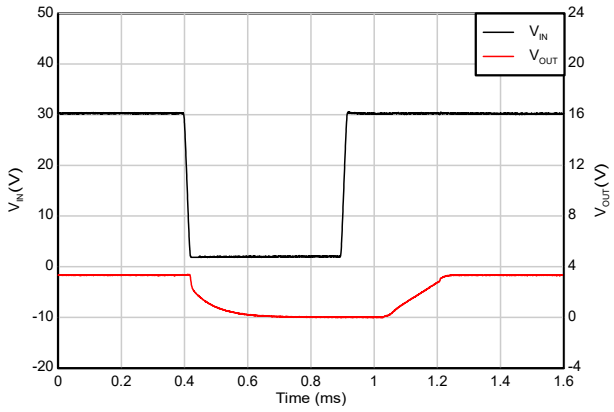
V_{IN} = 12V to 3V, V_{OUT} = 3.3V, I_{OUT}= 100mA, slew rate = 2V/µs

Figure 5-40. Dropout Recovery



V_{IN} = 30V to 2V, V_{OUT} = 3.3V, slew rate = 2V/µs

Figure 5-41. Brownout Recovery



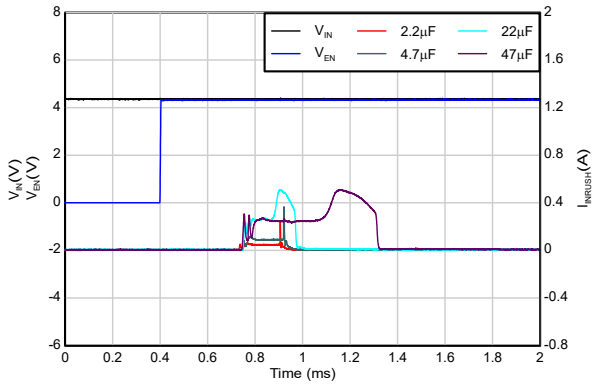
V_{IN} = 30V to 2V, V_{OUT} = 3.3V, I_{OUT}= 50mA, slew rate = 2V/µs

Figure 5-42. Brownout Recovery

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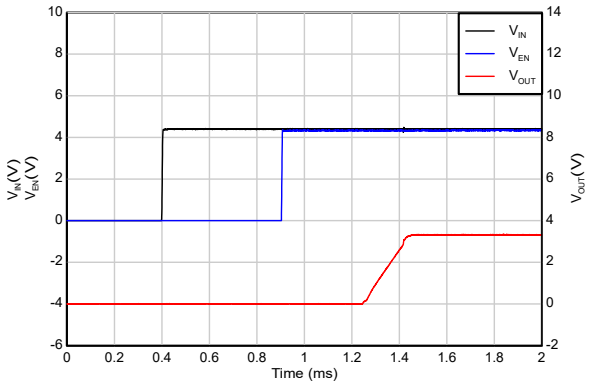
5.6 Typical Characteristics (continued)

at operating junction temperature T_J = 25°C, V_{IN} = 3.0V or V_{IN} = V_{OUT}(nom) + 1.0V (whichever is greater), C_{IN} = 1µF, C_{OUT} = 4.7µF, V_{EN} = 2V, and I_{OUT} = 1mA; temperatures given in terms of T_J (unless otherwise noted)



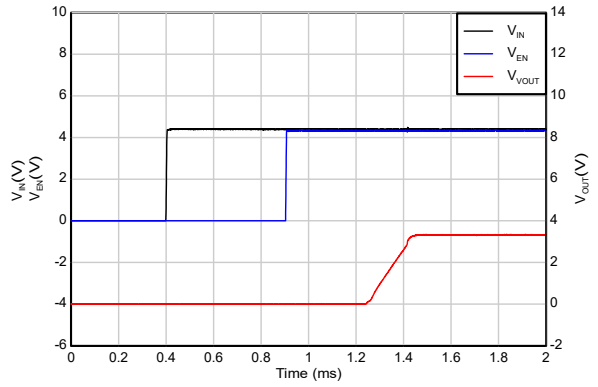
V_{OUT} = 3.3V, I_{OUT} = 0mA, slew rate = 1V/µs

Figure 5-43. Start-up Inrush Current Profile vs C_{OUT}



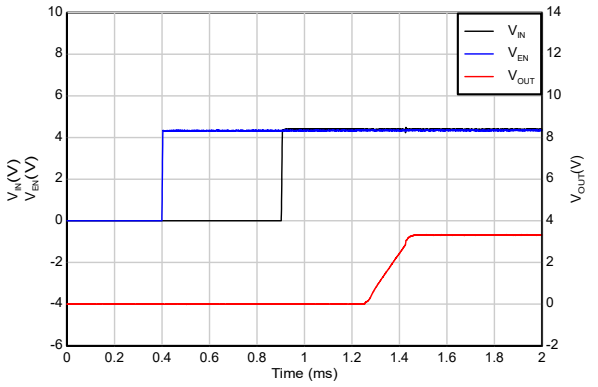
V_{OUT} = 3.3V, slew rate = 1V/µs

Figure 5-44. Start-up With Sequencing (EN after IN)



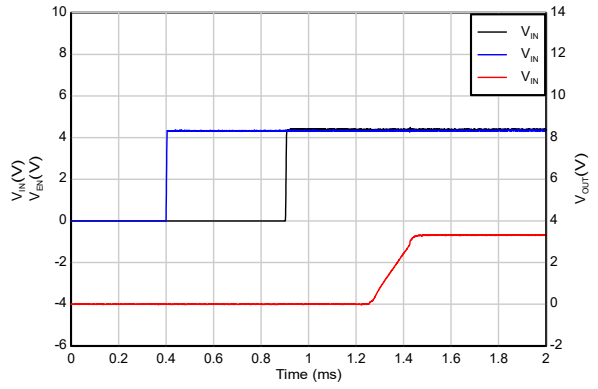
V_{OUT} = 3.3V, I_{OUT} = 50mA, slew rate = 1V/µs

Figure 5-45. Start-up With Sequencing (EN after IN)



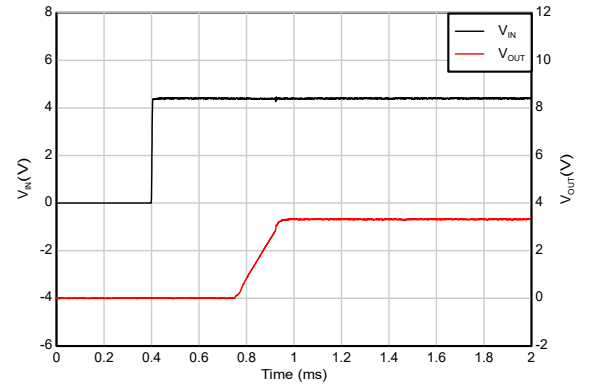
V_{OUT} = 3.3V, slew rate = 1V/µs

Figure 5-46. Start-up With Sequencing (IN after EN)



V_{OUT} = 3.3V, I_{OUT} = 50mA, slew rate = 1V/µs

Figure 5-47. Start-up With Sequencing (IN after EN)



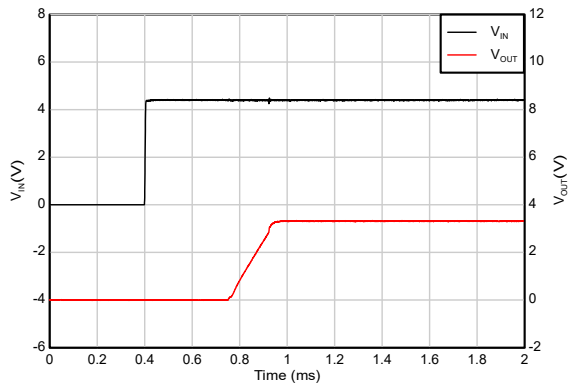
V_{EN} = V_{IN}, V_{OUT} = 3.3V, slew rate = 1V/µs

Figure 5-48. Start-up With IN and EN Tied Together

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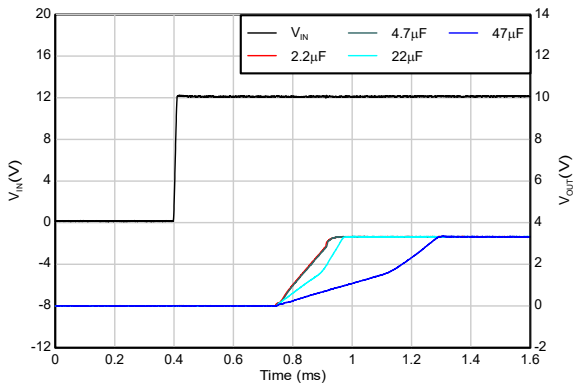
5.6 Typical Characteristics (continued)

at operating junction temperature T_J = 25°C, V_{IN} = 3.0V or V_{IN} = V_{OUT}(nom) + 1.0V (whichever is greater), C_{IN} = 1µF, C_{OUT} = 4.7µF, V_{EN} = 2V, and I_{OUT} = 1mA; temperatures given in terms of T_J (unless otherwise noted)



V_{EN} = V_{IN}, V_{OUT} = 3.3V, I_{OUT} = 50mA, slew rate = 1V/µs

Figure 5-49. Start-up With IN and EN Tied Together



V_{EN} = V_{IN}, V_{OUT} = 3.3V, slew rate = 1V/µs

Figure 5-50. Start-up With IN and EN Tied Together, C_{OUT}

6 Detailed Description

6.1 Overview

The TPS7E72 low-dropout regulator (LDO) consumes ultra-low quiescent current (2.8µA (typ)) at no-load current. The device offers a wide input voltage range (3.0V to 30V) and wide output range (1.2V to 28V, in adjustable configuration) and supports up to 300mA of load current. The device is stable with the output capacitor range of 4.7µF to 100µF.

The low quiescent current across the complete load current range and controlled I_Q in no-load dropout situations makes the TPS7E72 designed for powering battery-operated applications. The TPS7E72 has an internal soft-start mechanism that provides a uniform start-up with controlled inrush current. This LDO also has over-current (fold-back), over-power and thermal protection during a load-short or fault condition on the output for better reliability.

6.2 Functional Block Diagrams

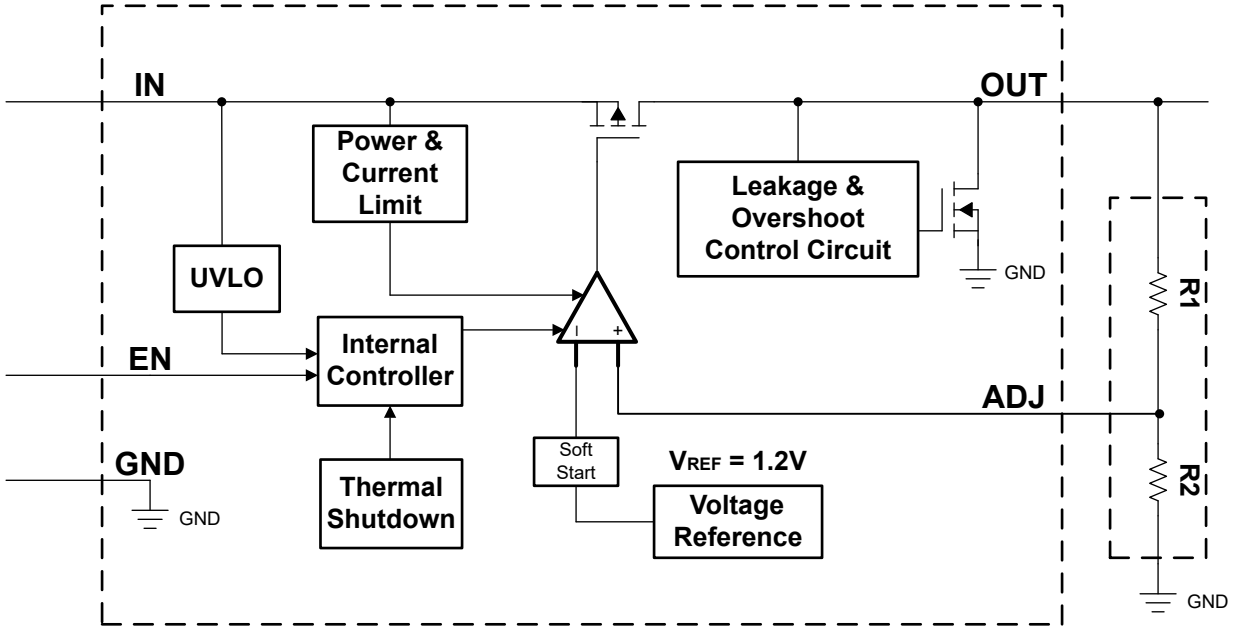


Figure 6-1. Functional Block Diagram: Adjustable Version

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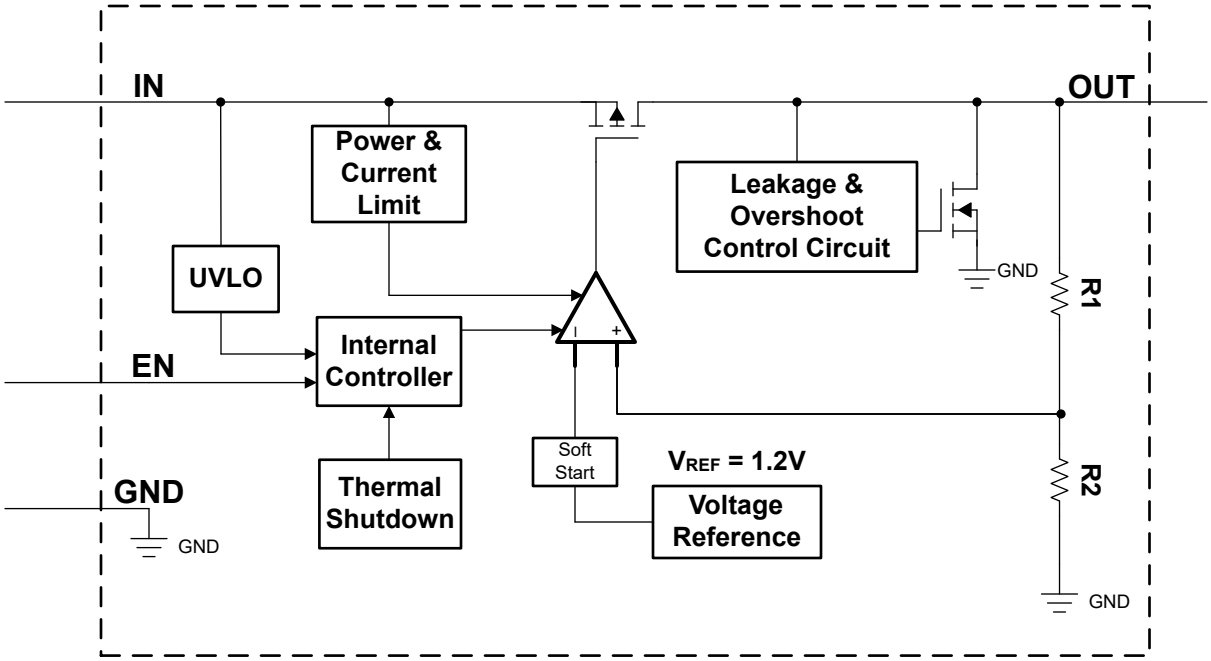


Figure 6-2. Functional Block Diagram: Fixed Version

6.3 Feature Description

6.3.1 Enable (EN)

The enable pin for the device is an active-high pin. The output voltage is enabled when the voltage of the enable pin is greater than the high-level input voltage (V_{IH}) of the EN pin and disabled with the enable pin voltage is less than the low-level input voltage (V_{IL}) of the EN pin. High and low thresholds are listed in *Section 5.5*. If independent control of the output voltage is not needed, connect the enable pin to the input of the device.

The EN pin also has a weak internal pull-up and the EN pin can be left floating to enable the device. The internal pull-up current on the EN pin is captured in *Section 5.5* as enable pull-up current. However, care must be taken to verify that pin leakage (from board pollution or some other source) does not inadvertently pull this pin low. Leakage must be restricted to 25nA or less to avoid unintentional disabling of the device.

6.3.2 Dropout Voltage

Dropout voltage (V_{DO}) is defined as the input voltage minus the output voltage ($V_{IN} – V_{OUT}$) at the rated output current (I_{RATED}), where the pass transistor is fully on. I_{RATED} is the maximum I_{OUT} listed in the *Recommended Operating Conditions* table. The pass transistor is in the ohmic or triode region of operation, and acts as a switch. The dropout voltage indirectly specifies a minimum input voltage greater than the nominal programmed output voltage at which the output voltage is expected to stay in regulation. If the input voltage falls to less than this voltage, then the output voltage falls as well.

For a CMOS regulator, the dropout voltage is determined by the drain-source on-state resistance ($R_{DS(ON)}$) of the pass transistor. Therefore, if the linear regulator operates at less than the rated current, the dropout voltage for that current scales accordingly. The following equation calculates the $R_{DS(ON)}$ of the device.

$$R_{DS(ON)} = \frac{V_{DO}}{I_{RATED}} \quad (1)$$

6.3.3 Undervoltage Lockout

The device has an independent undervoltage lockout (UVLO) circuit that monitors the input voltage, allowing a controlled and consistent turn on and off of the output voltage. To prevent the device from turning off if the input drops during turn on, the UVLO has in-built hysteresis. The UVLO limits are specified in the *Electrical Characteristics* table.

6.3.4 Thermal Shutdown

The device contains a thermal shutdown protection circuit to disable the device when the junction temperature (T_J) of the pass transistor rises to T_{SD+} (typical). The device resets (turns on) when the temperature falls to T_{SD-} (typical).

The thermal time-constant of the semiconductor die is fairly short, thus the device can cycle on and off when thermal shutdown is reached until power dissipation is reduced. Power dissipation during startup can be high from large $V_{IN} – V_{OUT}$ voltage drops across the device or from high inrush currents charging large output capacitors. Under some conditions, the thermal shutdown protection disables the device before startup completes.

For reliable operation, limit the junction temperature to the maximum listed in the *Recommended Operating Conditions* table. Operation above this maximum temperature causes the device to exceed the operational specifications. Although the internal protection circuitry of the device is designed to protect against thermal overload conditions, this circuitry is not intended to replace proper heat sinking. Continuously running the device into thermal shutdown or above the maximum recommended junction temperature reduces long-term reliability.

6.3.5 Foldback Current Limit

The device has an internal current limit circuit that protects the regulator during transient high-load current faults or shorting events. The current limit is a hybrid brickwall-foldback scheme. The current limit transitions from a brickwall scheme to a foldback scheme at the foldback voltage ($V_{FOLDBACK}$). In a high-load current fault with the output voltage above $V_{FOLDBACK}$, the brickwall scheme limits the output current to the current limit (I_{CL}).

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When the voltage drops below $V_{FOLDBACK}$, a foldback current limit activates that scales back the current as the output voltage approaches GND. When the output is shorted, the device supplies a typical current called the short-circuit current limit (I_{SC}). I_{CL} and I_{SC} are listed in the *Section 5.5* table.

The output voltage is not regulated when the device is in current limit. When a current limit event occurs, the device begins to heat up because of the increase in power dissipation. When the device is in brickwall current limit, the pass transistor dissipates power [(V_{IN} – V_{OUT}) × I_{CL}]. When the device output is shorted and the output is below $V_{FOLDBACK}$, the pass transistor dissipates power [(V_{IN} – V_{OUT}) × I_{SC}]. If thermal shutdown is triggered, the device turns off. After the device cools down, the internal thermal shutdown circuit turns the device back on. If the output current fault condition continues, the device cycles between current limit and thermal shutdown. For more information on current limits, see the *Know Your Limits* application note.

Figure 6-3 shows a diagram of the foldback current limit.

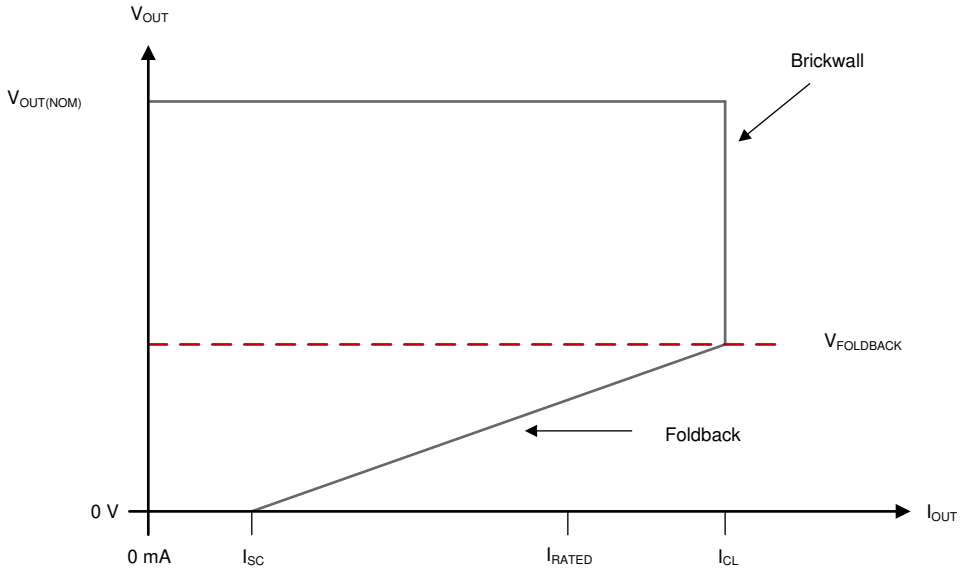


Figure 6-3. Foldback Current Limit

6.3.6 Power Limit

The device has an internal over-power limit circuit that limits the power dissipated across the LDO within the internal SOA (safe operating area) limits. The SOA limits for the LDO factor in safe operation for both silicon components and bondwires used in packaging. These limits maintain reliable operation of the device and prevent device failure from overheating, breakdown, or other damaging effects.

The power dissipated (P_{Dissip}) across the LDO is defined by voltage drop across LDO (V_{IN} - V_{OUT}) and load current (I_{OUT}) flowing through.

$$P_{Dissip} = (V_{IN} - V_{OUT}) \times I_{OUT} \quad (2)$$

The power limiting circuit monitors both the voltage drop (headroom, V_{IN} - V_{OUT}) across LDO and output load current (I_{OUT}) flowing through the LDO. If P_{Dissip} crosses the defined SOA limits, the power limiting circuit limits the load current (I_{OUT}) flowing through the LDO. The output voltage is not regulated when the device is in power limit operation. The maximum supported current (I_{PLIMIT}) at full headroom (V_{IN} - V_{OUT} = 30V) and maximum supported headroom ($V_{HEADROOM}$) at full load current are captured in *Section 5.5*.

Figure 6-4 shows a diagram of the power limiting.

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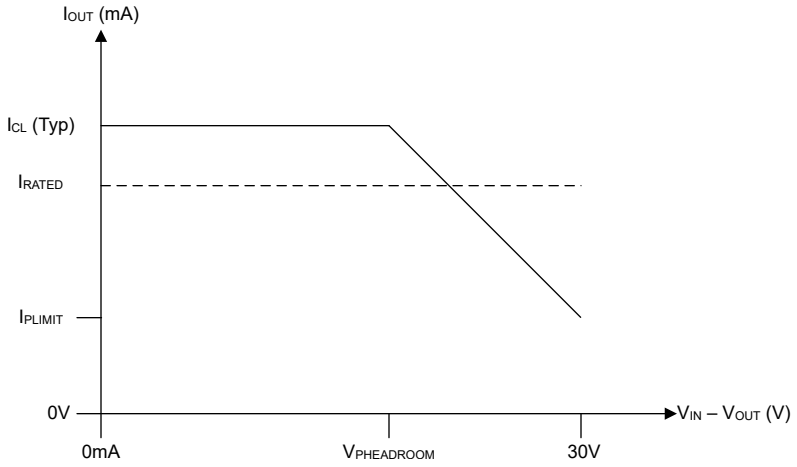


Figure 6-4. Power Limiting

6.3.7 Output Pulldown

The device has an output pulldown circuit. V_{OUT} pulldown sink to ground capability is listed in the *Section 5.5* table. The output pulldown activates under the following conditions:

- $V_{EN} < V_{IL(EN)}$
- $1.0V < V_{IN} < V_{UVLO}$

The output pulldown resistance for this device is 780Ω typical, listed as $R_{Discharge}$ in the *Section 5.5* table.

Do not rely on the output pulldown circuit for discharging a large amount of output capacitance after the input supply has collapsed because reverse current can flow from the output to the input. This reverse current flow can cause damage to the device. See the *Reverse Current* section for more details.

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6.4 Device Functional Modes

6.4.1 Device Functional Mode Comparison

Table 6-1 shows the conditions that lead to the different modes of operation. See the *Section 5.5* table for parameter values.

Table 6-1. Device Functional Mode Comparison

OPERATING MODE	PARAMETER			
	V_{IN}	V_{EN}	I_{OUT}	T_J
Normal operation	$V_{IN} > V_{OUT(nom)} + V_{DO}$ and $V_{IN} > V_{IN(min)}$	$V_{EN} > V_{EN(HI)}$	$I_{OUT} < I_{OUT(max)}$	$T_J < T_{SD(shutdown)}$
Dropout operation	$V_{IN(min)} < V_{IN} < V_{OUT(nom)} + V_{DO}$	$V_{EN} > V_{EN(HI)}$	$I_{OUT} < I_{OUT(max)}$	$T_J < T_{SD(shutdown)}$
Disabled (any true condition disables the device)	$V_{IN} < V_{UVLO}$	$V_{EN} < V_{EN(LOW)}$	Not applicable	$T_J > T_{SD(shutdown)}$

6.4.2 Normal Operation

The device regulates to the nominal output voltage under the following conditions:

- The input voltage is greater than the nominal output voltage plus the dropout voltage ($V_{OUT(nom)} + V_{DO}$)
- The headroom across the LDO ($V_{IN} - V_{OUT}$) is less than $V_{HEADROOM}$ for required I_{OUT}, such that power limit is not engaged
- The output current is less than the current limit ($I_{OUT} < I_{LIM}$)
- The device junction temperature is within the range given in the *Recommended Operating Conditions* table.
- The device junction temperature is less than the thermal shutdown temperature ($T_J < T_{SD}$)
- The enable voltage has previously exceeded the enable rising threshold voltage and has not yet decreased to less than the enable falling threshold

6.4.3 Dropout Operation

If the input voltage is lower than the nominal output voltage plus the specified dropout voltage, but all other conditions are met for normal operation, the device operates in dropout mode. In this mode, the output voltage tracks the input voltage. During this mode, the transient performance of the device becomes significantly degraded because the pass transistor is in the ohmic or triode region, and acts as a switch. Line or load transients in dropout can result in large output-voltage deviations.

When the device is in a steady dropout state (defined as when the device is in dropout, $V_{IN} < V_{OUT(NOM)} + V_{DO}$, directly after being in a normal regulation state, but *not* during startup), the pass transistor is driven into the ohmic or triode region. When the input voltage returns to a value greater than or equal to the nominal output voltage plus the dropout voltage ($V_{OUT(NOM)} + V_{DO}$), the output voltage can overshoot for a short period of time while the device pulls the pass transistor back into the linear region.

The TPS7E72 keeps the I_Q controlled in dropout operation to much lower values (12µA (typ) in no-load dropout) compared to conventional linear voltage regulators. This avoids battery drainage in cases which the battery level falls below the input voltage level required for the TPS7E72 to regulate.

6.4.4 Disabled

The output of the device can be shut down by forcing the voltage of the enable pin to less than the maximum EN pin low-level input voltage, $V_{IL(EN)}$ (see *Section 5.5*). When disabled, the pass transistor is turned off, internal circuits are shut down, and the output voltage is actively discharged to ground by an internal discharge circuit from the output to ground.

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7 Application and Implementation

Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

7.1 Application Information

7.1.1 Adjustable Device Feedback Resistor Selection

The adjustable-version device requires external feedback divider resistors to set the output voltage. V_{OUT} is set using the feedback divider resistors, R_1 and R_2, according to the following equation:

$$V_{OUT} = V_{ADJ} \times (1 + R_1 / R_2) \quad (3)$$

V_{ADJ} (or V_{FB}) is the feedback voltage and refers to the voltage on the ADJ pin. During normal operation of the adjustable device, the device regulates such that V_{ADJ} is equal to the internal reference voltage of the device.

To ignore the feedback pin current error term in the V_{OUT} equation, set the feedback divider current to 100x the feedback pin current (I_{ADJ}) listed in the *Section 5.5* table. This setting provides the maximum feedback divider series resistance, as shown in the following equation:

$$R_1 + R_2 \leq V_{OUT} / (I_{ADJ} \times 100) \quad (4)$$

7.1.2 Recommended Capacitor Types

The device is designed to be stable using low equivalent series resistance (ESR) ceramic capacitors at the input and output. Multilayer ceramic capacitors have become the industry standard for these types of applications and are recommended, but must be used with good judgment. Ceramic capacitors that employ X7R-, X5R-, and C0G-rated dielectric materials provide relatively good capacitive stability across temperature, whereas the use of Y5V-rated capacitors is discouraged because of large variations in capacitance.

Regardless of the ceramic capacitor type selected, the effective capacitance varies with operating voltage and temperature. As a general rule, expect the effective capacitance to decrease by as much as 50%. The input and output capacitors recommended in the *Recommended Operating Conditions* table account for an effective capacitance of approximately 50% of the nominal value.

7.1.3 Input and Output Capacitor Selection

The TPS7E72 requires an output capacitor of 4.7µF or larger (2.2µF or larger capacitance) for stability and an equivalent series resistance (ESR) between 0.0Ω and 1.0Ω. For best transient performance, use X5R- and X7R-type ceramic capacitors because these capacitors have minimal variation in value and ESR over temperature. When choosing a capacitor for a specific application, be mindful of the DC bias characteristics for the capacitor. Higher output voltages cause a significant derating of the capacitor. For best performance, the maximum recommended output capacitor is 100µF.

Although an input capacitor is not required for stability, good analog design practice is to connect a capacitor from IN to GND. Some input supplies have a high impedance, thus placing the input capacitor on the input supply helps reduce the input impedance. This capacitor counteracts reactive input sources and improves transient response, input ripple, and PSRR. If the input supply has a high impedance over a large range of frequencies, several input capacitors can be used in parallel to lower the impedance over frequency. Use a higher-value capacitor if large, fast, rise-time load transients are anticipated, or if the device is located several inches from the input power source.

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7.1.4 Reverse Current

Excessive reverse current can damage this device. Reverse current flows through the intrinsic body diode of the pass transistor instead of the normal conducting channel. At high magnitudes, this current flow degrades the long-term reliability of the device.

Conditions where reverse current can occur are outlined in this section, all of which can exceed the absolute maximum rating of $V_{OUT} \leq V_{IN} + 0.3V$.

- If the device has a large C_{OUT} and the input supply collapses with little or no load current
- The output is biased when the input supply is not established
- The output is biased above the input supply

If reverse current flow is expected in the application, external protection is recommended to protect the device. Reverse current is not limited in the device, so external limiting is required if extended reverse voltage operation is anticipated.

Figure 7-1 shows one approach for protecting the device.

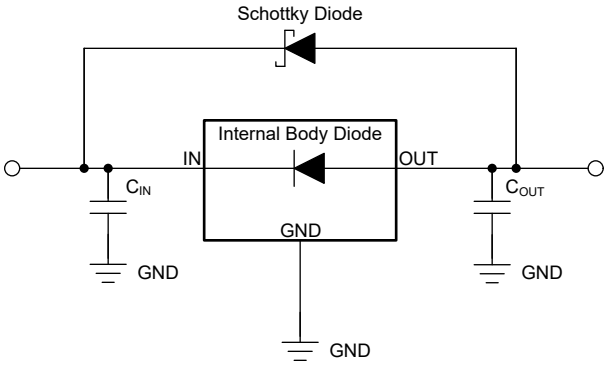


Figure 7-1. Example Circuit for Reverse Current Protection Using a Schottky Diode

7.1.5 Feed-Forward Capacitor

For the adjustable-voltage version device, a feed-forward capacitor (C_{FF}) can be connected from the OUT pin to the ADJ pin. C_{FF} improves transient, noise, and PSRR performance, but is not required for regulator stability. Recommended C_{FF} values are listed in the *Recommended Operating Conditions* table. A higher capacitance C_{FF} can be used; however, the start-up time increases. For a detailed description of C_{FF} tradeoffs, see the *Pros and Cons of Using a Feedforward Capacitor with a Low-Dropout Regulator* application note.

C_{FF} and R_1 form a zero in the loop gain at frequency f_Z, while C_{FF}, R_1, and R_2 form a pole in the loop gain at frequency f_P. C_{FF} zero and pole frequencies can be calculated from the following equations:

$$f_Z = 1 / (2 \times \pi \times C_{FF} \times R_1) \quad (5)$$

$$f_P = 1 / (2 \times \pi \times C_{FF} \times (R_1 \parallel R_2)) \quad (6)$$

7.1.6 Dropout Voltage

Dropout voltage (V_{DO}) is defined as the input voltage minus the output voltage ($V_{IN} – V_{OUT}$) at the rated output current (I_{RATED}), where the pass transistor is fully on. I_{RATED} is the maximum I_{OUT} listed in the *Recommended Operating Conditions* table. The pass transistor is in the ohmic or triode region of operation, and acts as a switch. The dropout voltage indirectly specifies a minimum input voltage greater than the nominal programmed output voltage at which the output voltage is expected to stay in regulation. If the input voltage falls to less than the nominal output regulation, then the output voltage falls as well.

For a CMOS regulator, the dropout voltage is determined by the drain-source on-state resistance ($R_{DS(ON)}$) of the pass transistor. Therefore, if the linear regulator operates at less than the rated current, the dropout voltage for that current scales accordingly. The following equation calculates the $R_{DS(ON)}$ of the device.

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$$R_{DS(ON)} = \frac{V_{DO}}{I_{RATED}} \quad (7)$$

7.1.7 Estimating Junction Temperature

The JEDEC standard now recommends using psi (Ψ) thermal metrics to estimate the linear regulator junction temperatures when in-circuit on a typical PCB board application. These metrics are not thermal resistance parameters and instead offer a practical and relative way to estimate junction temperature. These psi metrics are determined to be significantly independent of the copper area available for heat-spreading. The *Section 5.4* table lists the primary thermal metrics, which are the junction-to-top characterization parameter (ψ_{JT}) and junction-to-board characterization parameter (ψ_{JB}). These parameters provide two methods for calculating the junction temperature (T_J), as described in the following equations. Use the junction-to-top characterization parameter (ψ_{JT}) with the temperature at the center-top of device package (T_T) to calculate the junction temperature. Use the junction-to-board characterization parameter (ψ_{JB}) with the printed circuit board (PCB) surface temperature 1mm from the device package (T_B) to calculate the junction temperature.

$$T_J = T_T + \psi_{JT} \times P_D \quad (8)$$

where:

- P_D is the dissipated power
- T_T is the temperature at the center-top of the device package

$$T_J = T_B + \psi_{JB} \times P_D \quad (9)$$

where:

- T_B is the PCB surface temperature measured 1mm from the device package and centered on the package edge

For detailed information on the thermal metrics and how to use the metrics, see the *Semiconductor and IC Package Thermal Metrics* application note.

7.1.8 Power Dissipation (P_D)

Circuit reliability requires proper consideration of the device power dissipation, location of the circuit on the printed circuit board (PCB), and correct sizing of the thermal plane. Verify the PCB area around the regulator has few or no other heat-generating devices that cause added thermal stress.

To first-order approximation, power dissipation in the regulator depends on the input-to-output voltage difference and load conditions. The following equation calculates power dissipation (P_D).

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT} \quad (10)$$

Note

Power dissipation is minimized, and thus greater efficiency achieved, by proper selection of the system voltage rails. Proper selection allows the minimum input-to-output voltage differential to be obtained. The low dropout of the device allows for maximum efficiency across a wide range of output voltages.

For devices with a thermal pad, the primary heat conduction path for the device package is through the thermal pad to the PCB. Solder the thermal pad to a copper pad area under the device. This pad area contains an array of plated vias that conduct heat to additional copper planes for increased heat dissipation.

The maximum power dissipation determines the maximum allowable ambient temperature (T_A) for the device. Power dissipation and junction temperature are most often related by the $R_{\theta JA}$ of the combined PCB and device package and the T_A. $R_{\theta JA}$ is the junction-to-ambient thermal resistance and T_A is the temperature of the ambient air. The following equation describes this relationship.

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$$T_J = T_A + (R_{\theta JA} \times P_D) \quad (11)$$

The following equation rearranges this relationship for output current.

$$I_{OUT} = (T_J - T_A) / [R_{\theta JA} \times (V_{IN} - V_{OUT})] \quad (12)$$

Thermal resistance ($R_{\theta JA}$) is highly dependent on the heat-spreading capability built into the particular PCB design. This resistance therefore varies according to the total copper area, copper weight, and location of the planes. The junction-to-ambient thermal resistance listed in the *Section 5.4* table is determined by the JEDEC standard PCB and copper-spreading area. $R_{\theta JA}$ is used as a relative measure of package thermal performance. For packages with thermal pad and a well-designed thermal layout, $R_{\theta JA}$ is actually the sum of the package's $R_{\theta JCbot}$ plus the thermal resistance contribution by the PCB copper. $R_{\theta JCbot}$ is the junction-to-case (bottom) thermal resistance, as given in the *Section 5.4* table.

7.1.9 Power Dissipation Versus Ambient Temperature

Figure 7-2 and Figure 7-3 are based off of a JESD51-7 4-layer, high-K board. The allowable power dissipation is estimated using the following equation. As discussed in the *An empirical analysis of the impact of board layout on LDO thermal performance* application note, thermal dissipation can be improved in the JEDEC high-K layout by adding top layer copper and increasing the number of thermal vias. If a good thermal layout is used, the allowable thermal dissipation can be improved by up to 50%. Maintain the junction temperature of the device within recommended operating temperature range to maximize device lifetime and reliability, see the *Recommended Operating Conditions*.

$$T_A + R_{\theta JA} \times P_D \leq T_J(max) \quad (13)$$

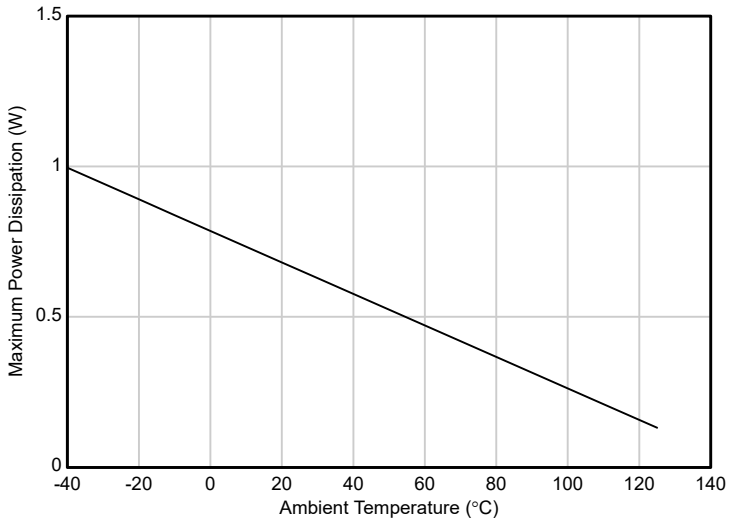


Figure 7-2. TPS7E72 (DBV) Allowable Power Dissipation

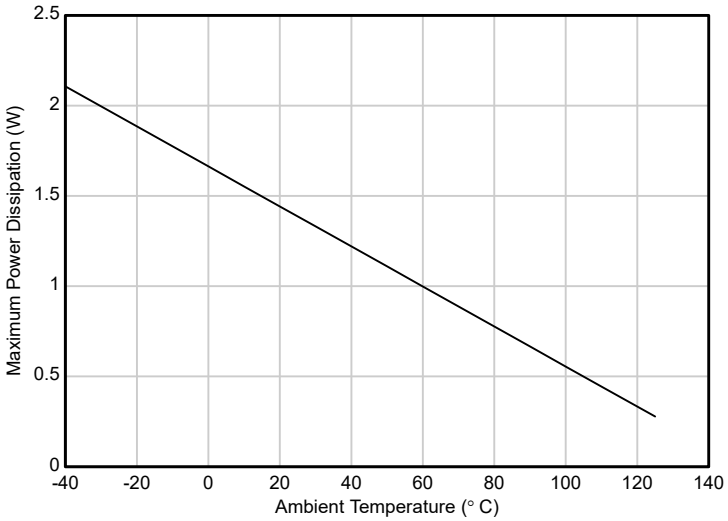


Figure 7-3. TPS7E72 (DRV) Allowable Power Dissipation

7.2 Typical Application

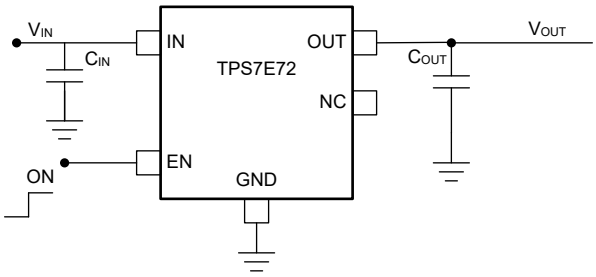


Figure 7-4. TPS7E72 Typical Application Circuit (Fixed-Voltage Version)

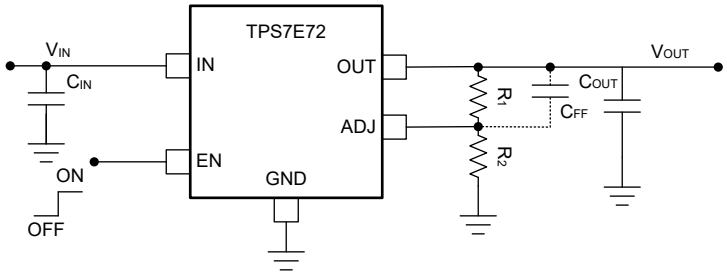


Figure 7-5. TPS7E72 Adjustable LDO Regulator Programming

NOTE: Dotted lines indicate an optional input capacitor and feed-forward capacitor. See the *Input and Output Capacitor Selection* and *Feed-Forward Capacitor* sections and the *Recommended Operating Conditions* table.

Table 7-1. Adjustable Output Voltage for Resistors R_1 and R_2

OUTPUT VOLTAGE (V)	R_1 (MΩ)	R_2 (MΩ)
1.8	0.499	1
2.8	1.33	1
3.3	1.75	1
5.0	3.16	1

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7.2.1 Design Requirements

For this design example, use the parameters listed in Table 7-2 as the input parameters.

Table 7-2. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Input voltage range	6V to 30V
Output voltage	3.3V
Output current	150mA
Output capacitor	4.7µF

7.2.2 Detailed Design Procedure

For this design example, a nominal 6.0V input supply is assumed, with line transients up to 30V expected. Use a nominal 0.47µF input capacitor to minimize the effect of resistance and inductance between the 6.0V source and LDO input. Use a nominal 4.7µF output capacitor (minimum 2.2µF output capacitance) for stability and good load transient response.

If using the adjustable version of the device, refer to the *Choose Feedback Resistors* section and Design Parameters for guidance setting the output voltage.

Operating at a 3.3V output voltage and 150mA output current, the dropout voltage (V_{DO}) of the device is 900mV maximum. To maintain headroom with this dropout voltage, V_{IN} must be above 4.2V. As V_{IN} is 6V, sufficient headroom is provided.

The expected line transients of up to 30V are within the rated input voltage of the device.

7.2.2.1 Choose Feedback Resistors

For this design example, V_{OUT} is set to 3.3V. The following equations set the feedback divider resistors for the desired output voltage:

$$V_{OUT} = V_{ADJ} \times (1 + R_1 / R_2) \quad (14)$$

$$R_1 + R_2 \leq V_{OUT} / (I_{ADJ} \times 100) \quad (15)$$

For improved output accuracy, use Equation 15 and I_{ADJ} = 10nA as listed in the *Section 5.5* table to calculate the upper limit for series feedback resistance ($R_1 + R_2 \leq 3.3M\Omega$).

The control-loop error amplifier drives the ADJ pin to the same voltage as the internal reference (V_{ADJ} = 1.2V, as listed in the *Section 5.5* table). Use Equation 14 to determine the ratio of $R_1 / R_2 = 1.75$ Use this ratio and solve Equation 15 for R_1. Now calculate the upper limit for $R_1 \leq 2.1M\Omega$. Select a standard value resistor for $R_1 = 1.75M\Omega$.

Reference Equation 16 and solve for R_2:

$$R_2 = R_1 / [(V_{OUT} / V_{ADJ}) - 1] \quad (16)$$

From Equation 16, $R_2 = 1M\Omega$ is determined. Select a standard value resistor for $R_2 = 1M\Omega$. Verify that the feedback divider current is greater than the minimum value in the *Recommended Operating Conditions* table.

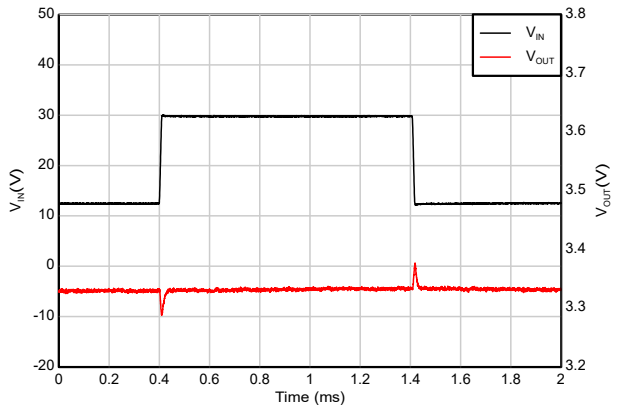
The following equation calculates the feedback divider current.

$$I_{FB_Divider} = V_{OUT} / (R_1 + R_2) \quad (17)$$

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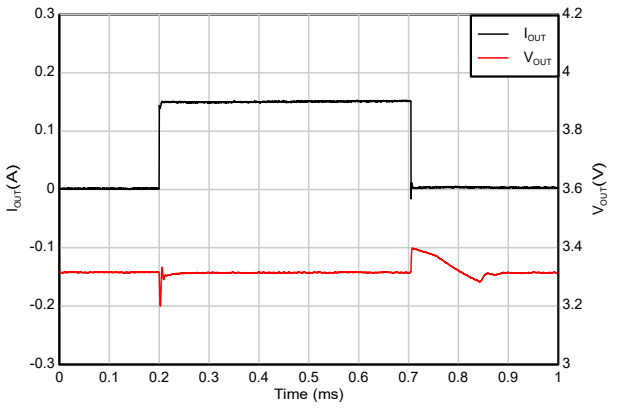
7.2.2.2 Application Curves

at operating junction temperature T_J = 25°C, V_{IN} = 3.0V or V_{IN} = V_{OUT}(nom) + 1.0V (whichever is greater), C_{IN} = 1µF, C_{OUT} = 4.7µF, V_{EN} = 2V, and I_{OUT} = 1mA (unless otherwise noted)



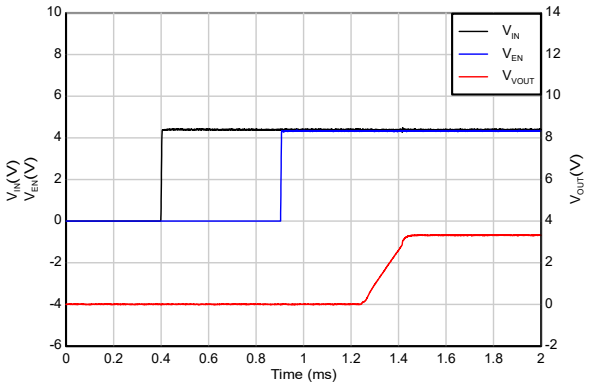
V_{IN} = 12V to 30V, V_{OUT} = 3.3V, I_{OUT} = 150mA, slew rate = 2V/µs

Figure 7-6. Line Transient



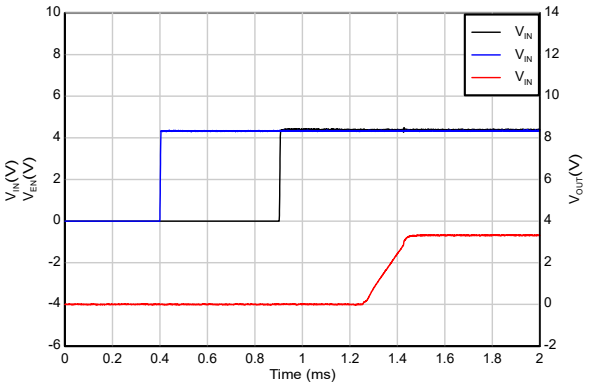
I_{OUT} = 1mA to 150mA, V_{OUT} = 3.3V, slew rate = 2A/µs

Figure 7-7. Load Transient



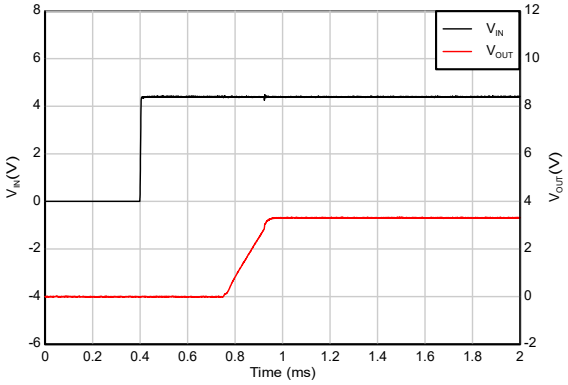
V_{OUT} = 3.3V, I_{OUT} = 50mA, slew rate = 1V/µs

Figure 7-8. Start-up With Sequencing (EN after IN)



V_{OUT} = 3.3V, I_{OUT} = 50mA, slew rate = 1V/µs

Figure 7-9. Start-up With Sequencing (IN after EN)



V_{EN} = V_{IN}, V_{OUT} = 3.3V, I_{OUT} = 50mA, slew rate = 1V/µs

Figure 7-10. Start-up With IN and EN Tied Together

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7.2.3 Power Supply Recommendations

The TPS7E72 is designed to operate from an input voltage supply range between 3.0V and 30V. The input voltage range provides adequate headroom for the device to have a regulated output. If the input supply is noisy, additional input capacitors with low ESR help improve output noise performance.

7.2.4 Layout

7.2.4.1 Layout Guidelines

For best overall performance, follow the guidelines in this section. Place all circuit components on the same side of the printed circuit board (PCB) and as near as practical to the respective LDO pin connections. Place ground return connections for the input and output capacitors as close to the GND pin as possible, using wide, component-side, copper planes or traces. Avoid using vias and long traces to create LDO circuit connections to the input capacitor, output capacitor, or resistor divider, as parasitic inductance in these connections negatively affects system performance. This grounding and layout scheme minimizes inductive parasitics and thereby reduces output voltage transients due to load current changes, minimizes noise, and increases circuit stability.

Use of a solid ground plane is recommended for best performance. This plane should be placed on the layer immediately beneath the component-side routing, or on the solder-side (bottom) layer in a two-layer PCB. A solid ground plane helps minimize parasitic inductance between the LDO and load, improving transient response, and helps to minimize noise pickup from external sources.

To improve the thermal performance of the device, and to maximize the current output at high ambient temperature, spread the copper under the thermal pad as far as possible and place thermal vias on the copper under the thermal pad to help conduct heat to copper on the opposite side of the PCB. If assembly requirements permit, a solid connection without thermal relief should be made between the thermal pad and connected copper. Figure 7-11 and Figure 7-12 show example layout for TPS7E72 packages.

7.2.4.2 Layout Example

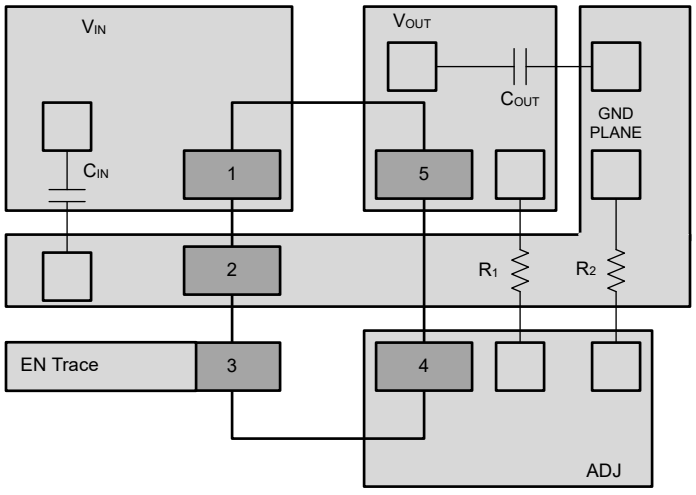


Figure 7-11. Example Layout for TPS7E72 DBV Package

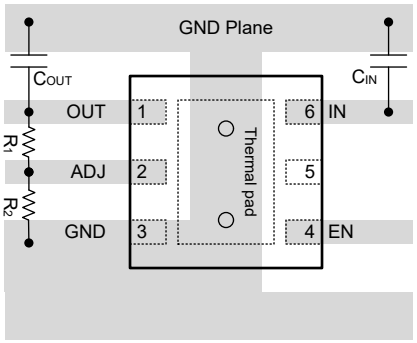


Figure 7-12. Example Layout for TPS7E72 DRV Package

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8 Device and Documentation Support

TI offers an extensive line of development tools. Tools and software to evaluate the performance of the device, generate code, and develop solutions are listed in this section.

8.1 Device Support

8.1.1 Development Support

An evaluation module (EVM) is available to assist in the initial circuit performance evaluation using the TPS7E72. The Universal EVM (and related user's guide) can be requested at the TI website through the product folders or purchased directly from the TI eStore.

8.1.2 Device Nomenclature

Table 8-1. Device Nomenclature

PRODUCT(1)	DESCRIPTION
TPS7E72**xx(xx)(M)yyyz**	**xx(xx)** is the nominal output voltage. For example, 33 = 3.3V, 50 = 5.0V, 12V0 = 12V, 01 = Adjustable. **yyy** is the package designator. For example, DBV = SOT-23, DRV = WSON. **(M)** indicates that a device is qualified to extended temperature range. See the *Recommended Operating Conditions*. **z** indicates the package quantity. R is for large reel (3000 pieces).

(1) For the most current package and ordering information see the Package Option Addendum at the end of this document, or visit the device product folder on www.ti.com.

8.2 Documentation Support

8.2.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, *An empirical analysis of the impact of board layout on LDO thermal performance* application note
- Texas Instruments, *Know Your Limits* application note

8.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

8.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

8.5 Trademarks

TI E2E™ is a trademark of Texas Instruments.
All trademarks are the property of their respective owners.

8.6 Electrostatic Discharge Caution



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.

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8.7 Glossary

TI Glossary This glossary lists and explains terms, acronyms, and definitions.

9 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision * (April 2026) to Revision A (October 2026)	Page
• Updated DRV package pin numbering within the Pin Functions table in the *Pin Configuration and Functions* section	3
• Added ESR range of COUT to the Recommended Operating Conditions	4
• Added "temperatures given in terms of T_J" to the conditions in *Typical Characteristics* for clarity	7
• Changed "Ground Current vs Input Voltage" graph title to "Controlled Quiescent Current in Dropout" in *Typical Characteristics*	7
• Changed "Start-up Inrush Current" graph title to "Start-up Inrush Current Profile vs C_{OUT}" in *Typical Characteristics*	7
• Changed "Cold Crank Recovery" graph titles to "Line Transient" in *Typical Characteristics*	7
• Changed "Leakage Control/Sink Circuit" name to "Leakage & Overshoot Control Circuit" in both *Functional Block Diagrams* for clarity	16
• Deleted a typographical error in the *Enable (EN)* section	18
• Updated the wording of the *Dropout Voltage* section for clarity	18
• Deleted a typographical error in the *Thermal Shutdown* section	18
• Updated the description of thermal shutdown hysteresis behavior for clarity in the *Thermal Shutdown* section.	18
• Updated wording in *Power Limit* for clarity	19
• Changed "shutdown" to "shut down" in the *Disabled* section	21
• Deleted duplicate paragraph from the *Estimating Junction Temperature* section	24
• Added resistor values corresponding to 3.3V output to the *Adjustable Output Voltage for Resistors R1 and R2* table	26
• Updated wording of the *Detailed Design Procedure* for clarity	27
• Updated the text of the *Layout Guidelines* for clarity	29
• Added 12V0 = 12V as an example for output voltage options in the *Device Nomenclature* table	31

10 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

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PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TPS7E7201DBVR	Active	Production	SOT-23 (DBV) | 5	3000 | LARGE T&R	Yes	Call TI	Level-1-260C-UNLIM	-40 to 150	47IF
TPS7E7201DRVR	Active	Production	WSON (DRV) | 6	3000 | LARGE T&R	Yes	Call TI	Level-1-260C-UNLIM	-40 to 150	3WXH
TPS7E7201MDRVR	Active	Production	WSON (DRV) | 6	3000 | LARGE T&R	Yes	Call TI	Level-1-260C-UNLIM	-40 to 150	47PH
TPS7E7225DBVR	Active	Production	SOT-23 (DBV) | 5	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 150	47JF
TPS7E7233DBVR	Active	Production	SOT-23 (DBV) | 5	3000 | LARGE T&R	Yes	Call TI	Level-1-260C-UNLIM	-40 to 150	47KF
TPS7E7233DRVR	Active	Production	WSON (DRV) | 6	3000 | LARGE T&R	Yes	Call TI	Level-1-260C-UNLIM	-40 to 150	3X1H
TPS7E7233MDRVR	Active	Production	WSON (DRV) | 6	3000 | LARGE T&R	Yes	Call TI	Level-1-260C-UNLIM	-40 to 150	47QH
TPS7E7250DBVR	Active	Production	SOT-23 (DBV) | 5	3000 | LARGE T&R	Yes	Call TI	Level-1-260C-UNLIM	-40 to 150	47LF
TPS7E7250DRVR	Active	Production	WSON (DRV) | 6	3000 | LARGE T&R	Yes	Call TI	Level-1-260C-UNLIM	-40 to 150	3X3H
TPS7E7250MDRVR	Active	Production	WSON (DRV) | 6	3000 | LARGE T&R	Yes	Call TI	Level-1-260C-UNLIM	-40 to 150	47RH

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

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

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

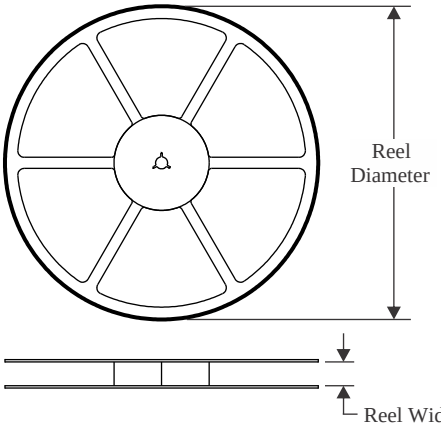
Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative

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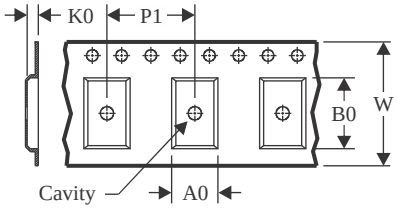
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

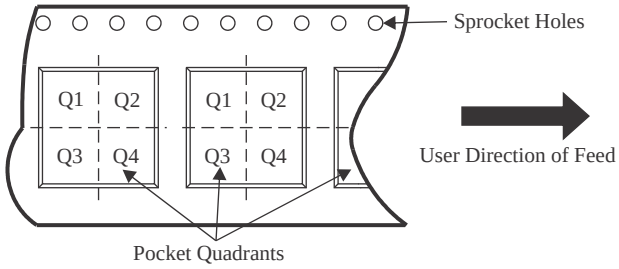


TAPE DIMENSIONS



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

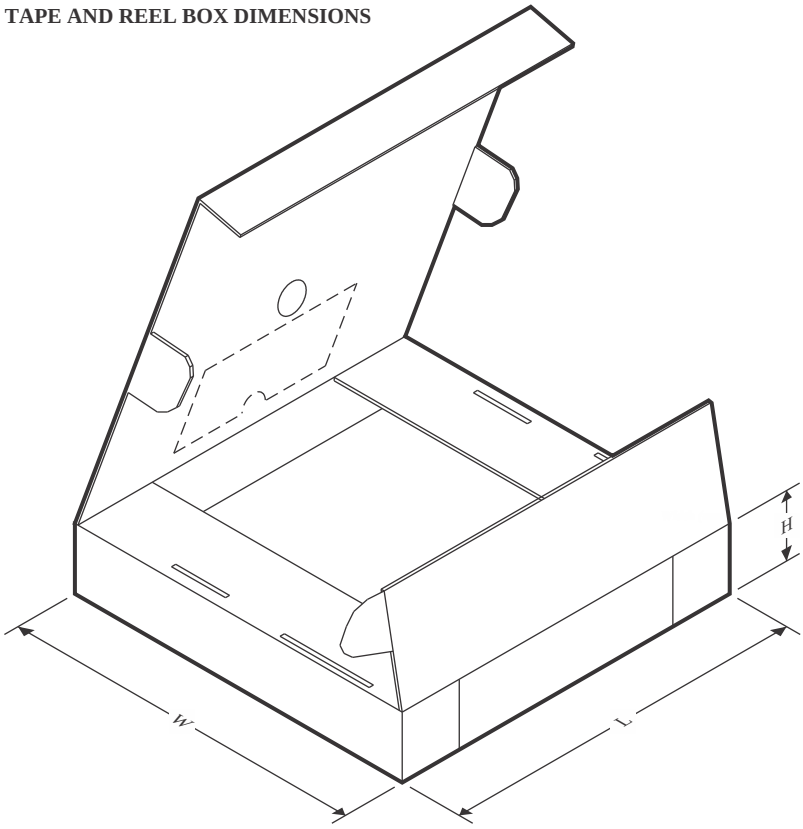
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
TPS7E7201DBVR	SOT-23	DBV	5	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TPS7E7201DRVR	WSON	DRV	6	3000	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q2
TPS7E7201MDRVR	WSON	DRV	6	3000	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q2
TPS7E7225DBVR	SOT-23	DBV	5	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TPS7E7233DBVR	SOT-23	DBV	5	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TPS7E7233DRVR	WSON	DRV	6	3000	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q2
TPS7E7233MDRVR	WSON	DRV	6	3000	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q2
TPS7E7250DBVR	SOT-23	DBV	5	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TPS7E7250DRVR	WSON	DRV	6	3000	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q2
TPS7E7250MDRVR	WSON	DRV	6	3000	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q2

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

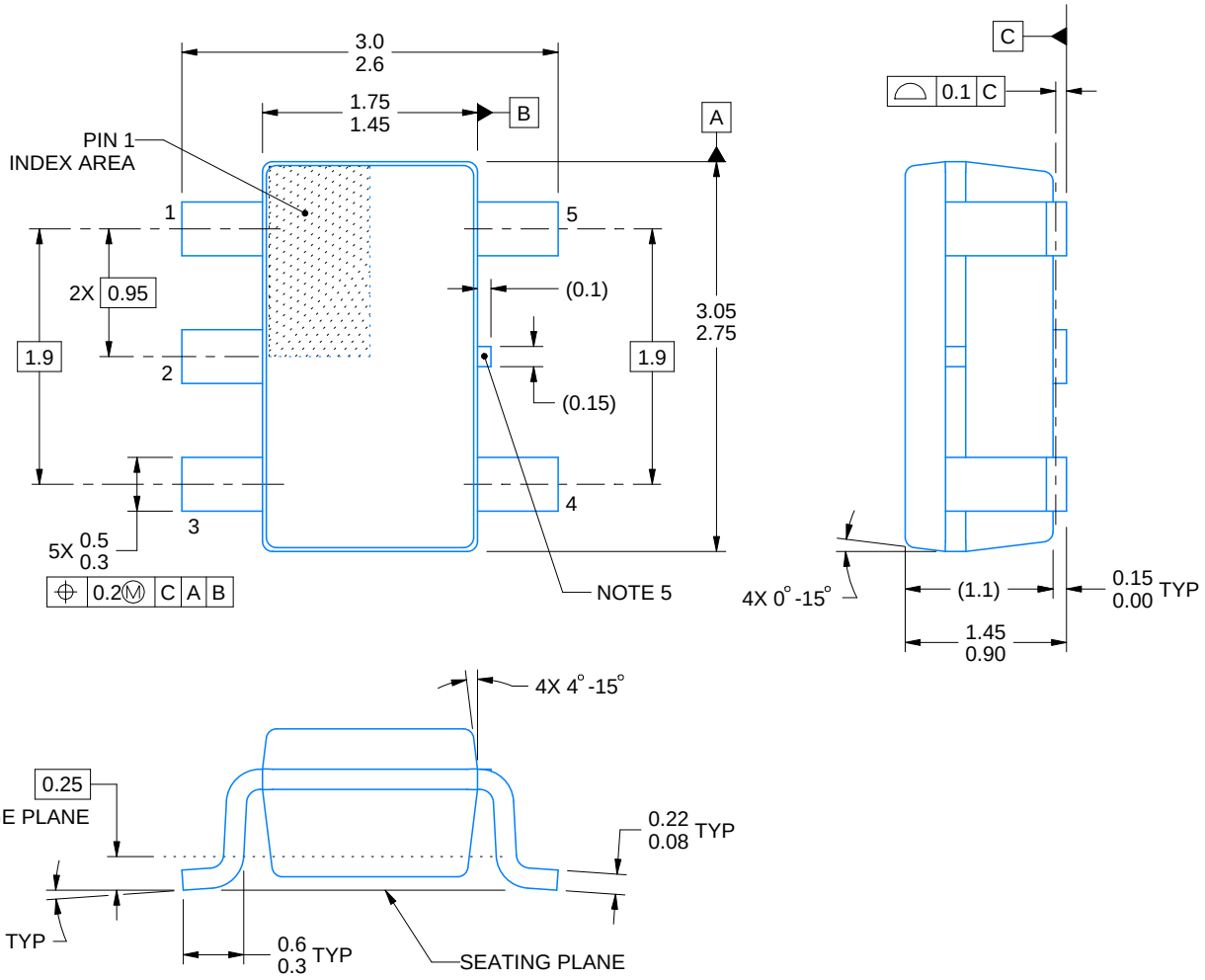
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS7E7201DBVR	SOT-23	DBV	5	3000	210.0	185.0	35.0
TPS7E7201DRVR	WSON	DRV	6	3000	210.0	185.0	35.0
TPS7E7201MDRVR	WSON	DRV	6	3000	210.0	185.0	35.0
TPS7E7225DBVR	SOT-23	DBV	5	3000	210.0	185.0	35.0
TPS7E7233DBVR	SOT-23	DBV	5	3000	210.0	185.0	35.0
TPS7E7233DRVR	WSON	DRV	6	3000	210.0	185.0	35.0
TPS7E7233MDRVR	WSON	DRV	6	3000	210.0	185.0	35.0
TPS7E7250DBVR	SOT-23	DBV	5	3000	210.0	185.0	35.0
TPS7E7250DRVR	WSON	DRV	6	3000	210.0	185.0	35.0
TPS7E7250MDRVR	WSON	DRV	6	3000	210.0	185.0	35.0

PACKAGE OUTLINE

DBV0005A

SOT-23 - 1.45 mm max height

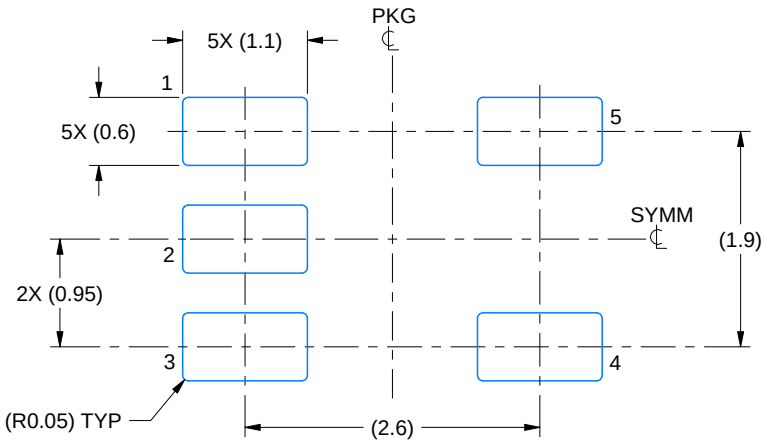
SMALL OUTLINE TRANSISTOR



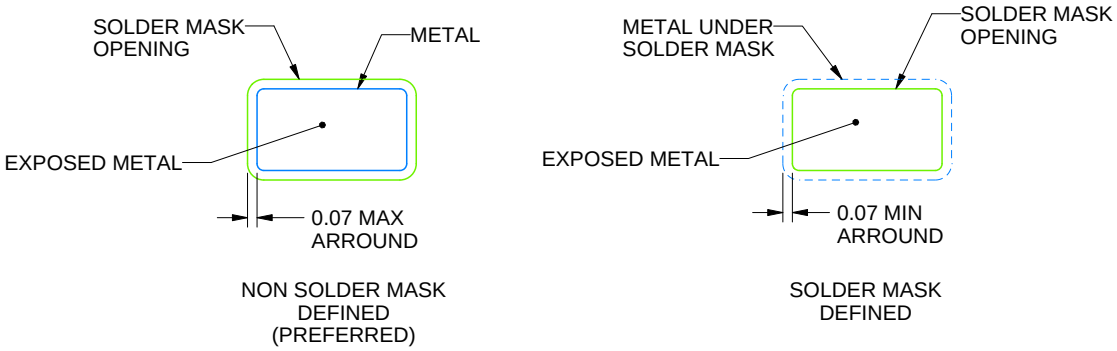
4214839/K 08/2024

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Refernce JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25 mm per side.
5. Support pin may differ or may not be present.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X

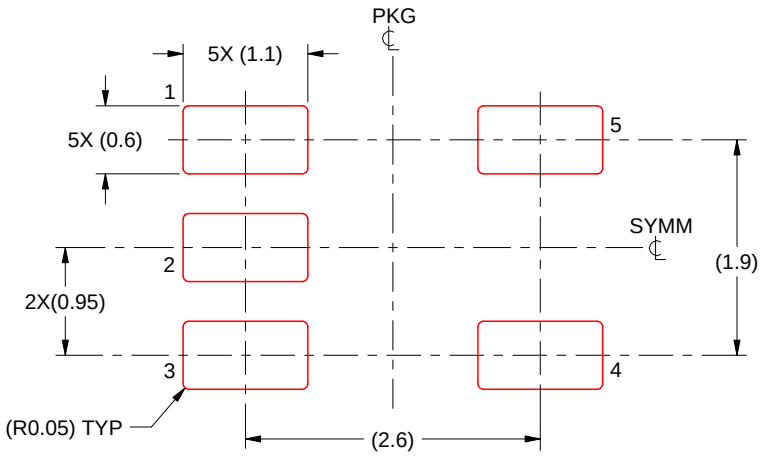


SOLDER MASK DETAILS

4214839/K 08/2024

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

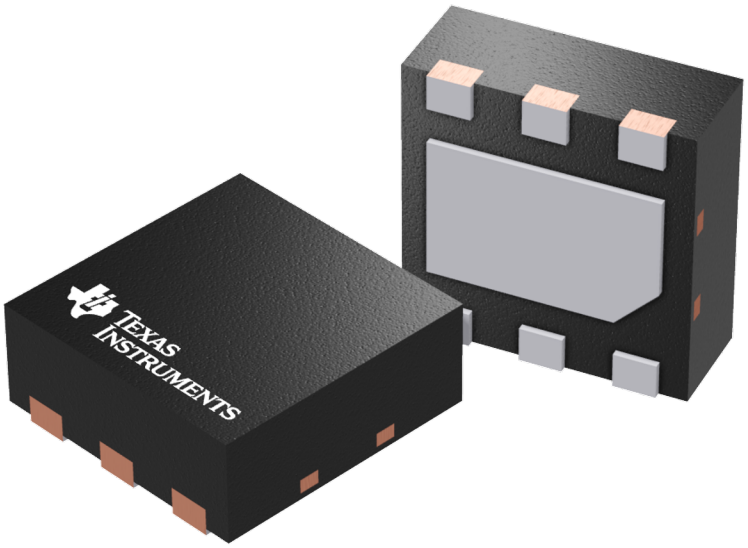
4214839/K 08/2024

NOTES: (continued)

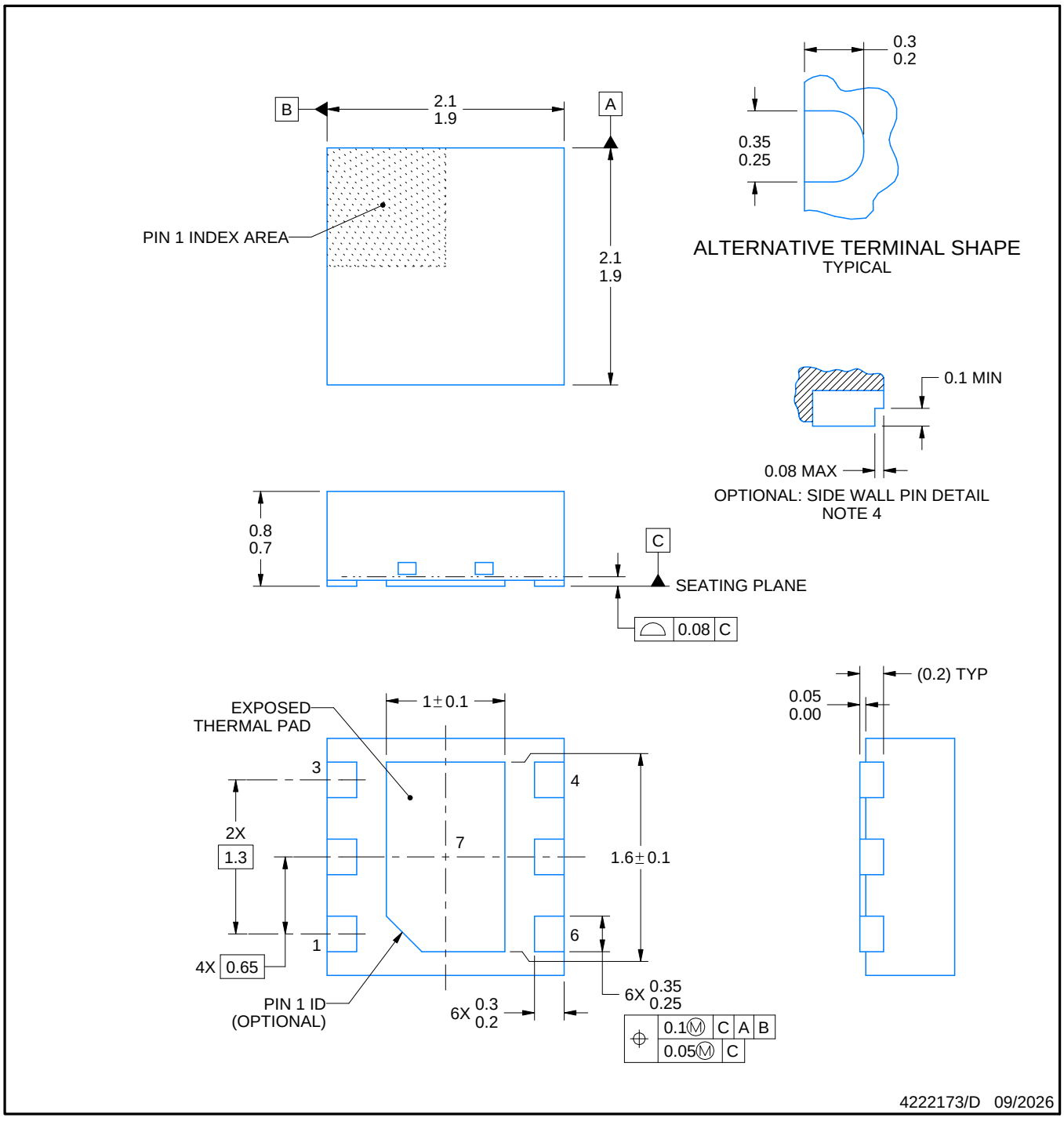
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

DRV 6 WSON - 0.8 mm max height

PLASTIC SMALL OUTLINE - NO LEAD

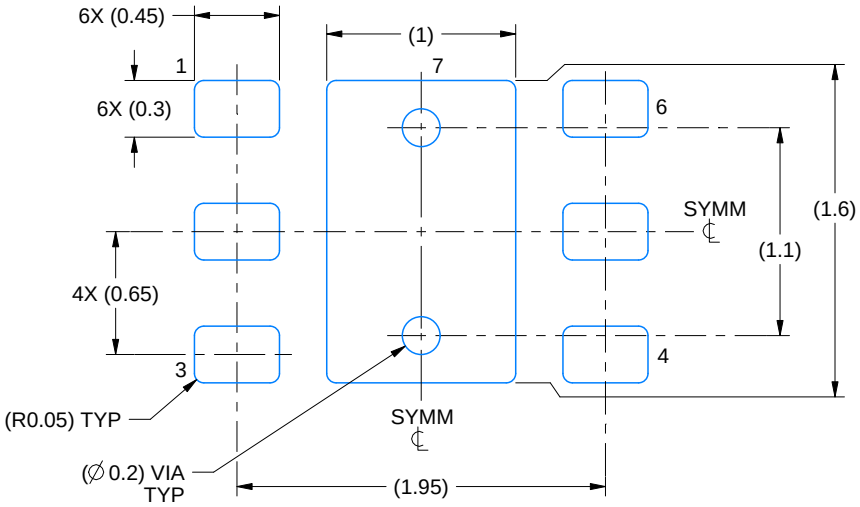


Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

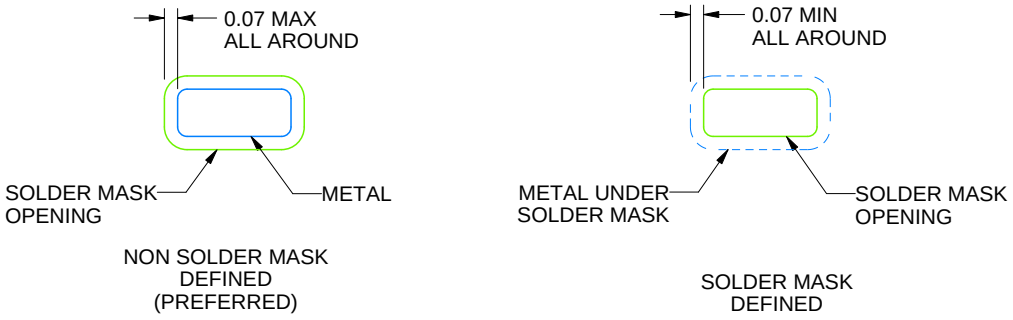


NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.
4. Minimum 0.1 mm solder wetting on pin side wall. Available for wettable flank version only.



LAND PATTERN EXAMPLE
SCALE:25X

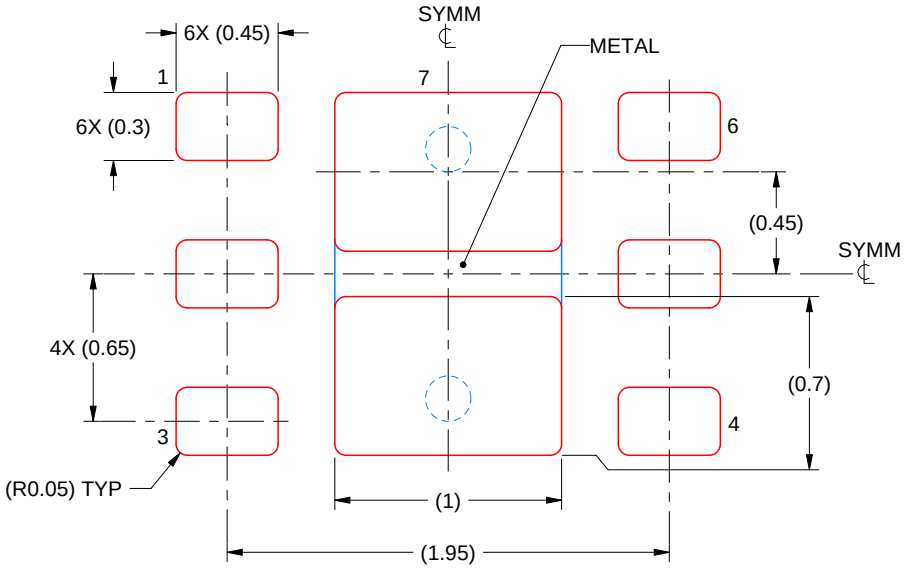


SOLDER MASK DETAILS

4222173/D 09/2026

NOTES: (continued)

5. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
6. Vias are optional depending on application, refer to device data sheet. If some or all are implemented, recommended via locations are shown.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD #7
88% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
SCALE:30X

4222173/D 09/2026

NOTES: (continued)

7. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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