LM34927 Integrated Secondary-Side Bias Regulator for Isolated DC-DC Converters

1 Features

- Wide 7.5-V to 100-V Input Range
- Integrated 600-mA High-Side and Low-Side Switches
- No Schottky Required
- Constant On-Time Control
- No Loop Compensation Required
- Ultra-Fast Transient Response
- Nearly Constant Operating Frequency
- Intelligent Peak Current Limit
- Adjustable Output Voltage From 1.225 V
- Precision 2% Feedback Reference
- Frequency Adjustable to 1 MHz
- Adjustable Undervoltage Lockout (UVLO)
- Remote Shutdown
- Thermal Shutdown
- Packages:
  - WSON-8
  - SO PowerPAD™-8

2 Applications

- Isolated Telecom Bias Supply
- Isolated Automotive and Industrial Electronics

3 Description

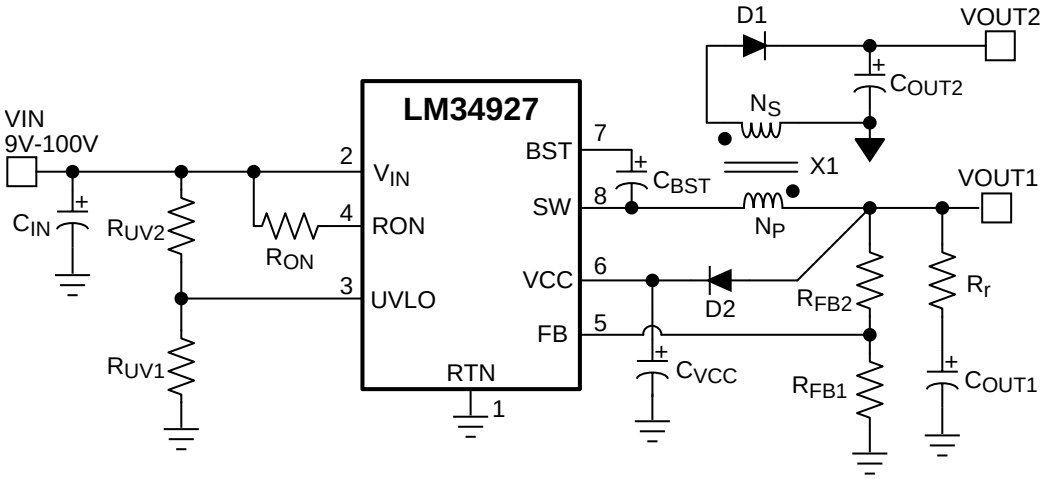
The LM34927 regulator features all of the functions needed to implement a low-cost, efficient, isolated bias regulator. This high-voltage regulator contains two 100-V N-channel MOSFET switches — a high-side buck switch and a low-side synchronous switch. The Constant on-time (COT) control scheme employed in the LM34927 device requires no loop compensation and provides excellent transient response. The regulator operates with an on-time that is inversely proportional to the input voltage. This feature allows the operating frequency to remain relatively constant. An intelligent peak current limit is implemented with integrated sense circuit. Other features include a programmable input undervoltage comparator to inhibit operation during low-voltage conditions. Protection features include thermal shutdown and V_{CC} Undervoltage Lockout (UVLO). The LM34927 device is offered in WSON-8 and SO PowerPAD-8 plastic packages.

Device Information[1]

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM34927	SO PowerPAD (8)	4.89 mm x 3.90 mm
	WSON (8)	4.00 mm x 4.00 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

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 Revision History

Changes from Revision F (December 2013) to Revision G — **Page**

- Added *Pin Configuration and Functions* section, *Handling Rating* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section ... 1
- Changed *Thermal Information* table ... 4
- Changed T_{ON} *vs* V_{IN} *and* R_{ON} in *Typical Characteristics* ... 6
- Deleted *3-W Isolated Bias Application Schematic, Lowest Part Count Isolated Application Schematic,* and *Typical Buck Configuration* graphics ... 8
- Changed *Control Overview* section ... 10
- Changed *Soft-Start Circuit*, *Isolated Fly-Buck Converter* graphics. ... 14

Changes from Revision E (December 2013) to Revision F — **Page**

- Added Thermal Parameters. ... 4
- Added Thermal Derating Curve ... 21

Changes from Revision D (September 2013) to Revision E — **Page**

- Changed formatting throughout document to the TI standard ... 1
- Changed minimum operating input voltage from 9 V to 7.5 V in *Features* ... 1
- Changed minimum operating input voltage from 9 V to 7.5 V in *Typical Application* ... 1
- Added Absolute Maximum Junction Temperature ... 4
- Changed minimum operating input voltage from 9 V to 7.5 V in *Recommended Operating Ratings* ... 4

Changes from Revision C (July 2013) to Revision D — **Page**

- Added SW to RTN (100 ns transient) to *Absolute Maximum Ratings* ... 4

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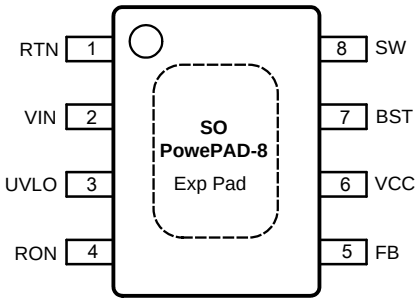
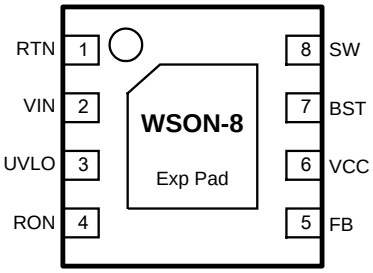
5 Pin Configuration and Functions

8-Pin SO PowerPAD
DDA Package
Top View



Connect Exposed Pad to RTN

8-Pin WSON With Exposed Thermal Pad
NGU Package
Top View



Pin Functions

PIN		I/O	DESCRIPTION	APPLICATION INFORMATION
NO.	NAME			
1	RTN	—	Ground	Ground connection of the integrated circuit.
2	VIN	I	Input Voltage	Operating input range is 7.5 V to 100 V.
3	UVLO	I	Input Pin of Undervoltage Comparator	Resistor divider from V_{IN} to UVLO to GND programs the undervoltage detection threshold. An internal current source is enabled when UVLO is above 1.225 V to provide hysteresis. When UVLO pin is pulled below 0.66 V externally, the parts goes in shutdown mode.
4	RON	I	On-Time Control	A resistor between this pin and V_{IN} sets the switch on-time as a function of V_{IN}. Minimum recommended on-time is 100 ns at max input voltage.
5	FB	I	Feedback	This pin is connected to the inverting input of the internal regulation comparator. The regulation level is 1.225 V.
6	VCC	O	Output from the Internal High Voltage Series Pass Regulator. Regulated at 7.6 V.	The internal V_{CC} regulator provides bias supply for the gate drivers and other internal circuitry. A 1.0-µF decoupling capacitor is recommended.
7	BST	I	Bootstrap Capacitor	An external capacitor is required between the BST and SW pins (0.01-µF ceramic). The BST pin capacitor is charged by the V_{CC} regulator through an internal diode when the SW pin is low.
8	SW	O	Switching Node	Power switching node. Connect to the output inductor and bootstrap capacitor.
—	EP	—	Exposed Pad	Exposed pad must be connected to RTN pin. Connect to system ground plane on application board for reduced thermal resistance.

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6 Specifications

6.1 Absolute Maximum Ratings(1)

	MIN	MAX	UNIT
V_{IN}, UVLO to RTN	–0.3	100	V
SW to RTN	–1.5	V_{IN} + 0.3	V
SW to RTN (100 ns transient)	–5	V_{IN} + 0.3	V
BST to V_{CC}		100	V
BST to SW		13	V
R_{ON} to RTN	–0.3	100	V
V_{CC} to RTN	–0.3	13	V
FB to RTN	–0.3	5	V
Lead Temperature(2)		200	°C
Maximum Junction Temperature(3)		150	°C
Storage temperature range	–55	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) For detailed information on soldering plastic SO PowerPAD package, refer to the Packaging Data Book. Max solder time not to exceed 4 seconds.
(3) High junction temperatures degrade operating lifetimes. Operating lifetime is de-rated for junction temperatures greater than 125°C.

6.2 ESD Ratings

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

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

6.3 Recommended Operating Conditions

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

	MIN	MAX	UNIT
V_{IN} Voltage	7.5	100	V
Operating Junction Temperature(1)	–40	125	°C

(1) High junction temperatures degrade operating lifetimes. Operating lifetime is de-rated for junction temperatures greater than 125°C.

6.4 Thermal Information

THERMAL METRICS(1)		LM34927		UNIT
		WSON NGU	SO PowerPAD DDA	
		8-PINS		
$R_{\theta JA}$	Junction-to-ambient thermal resistance	41.3	41.1	°C/W
$R_{\theta JCbot}$	Junction-to-case (bottom) thermal resistance	3.2	2.4	
Ψ_{JB}	Junction-to-board thermal characteristic parameter	19.2	24.4	
$R_{\theta JB}$	Junction-to-board thermal resistance	19.1	30.6	
$R_{\theta JCtop}$	Junction-to-case (top) thermal resistance	34.7	37.3	
Ψ_{JT}	Junction-to-top thermal characteristic parameter	0.3	6.7	

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report (SPRA953).

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6.5 Electrical Characteristics

Typical values correspond to T_J = 25°C. Minimum and maximum limits apply over –40°C to 125°C junction temperature range, unless otherwise stated. V_{IN} = 48 V unless otherwise stated. See(1).

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{CC} SUPPLY						
V_{CC} Reg	V_{CC} Regulator Output	V_{IN} = 48 V, I_{CC} = 20 mA	6.25	7.6	8.55	V
	V_{CC} Current Limit	V_{IN} = 48 V(2)	26			mA
	V_{CC} UVLO Threshold (V_{CC} increasing)		4.15	4.5	4.9	V
	V_{CC} UVLO Hysteresis			300		mV
	V_{CC} Drop Out Voltage	V_{IN} = 8 V, I_{CC} = 20 mA		2.3		V
	I_{IN} Operating Current	Nonswitching, FB = 3 V		1.75		mA
	I_{IN} Shutdown Current	UVLO = 0 V		50	225	µA
UNDERVOLTAGE SENSING FUNCTION						
	UV Threshold	UV Rising	1.19	1.225	1.26	V
	UV Hysteresis Input Current	UV = 2.5 V	–10	–20	–29	µA
	Remote Shutdown Threshold	Voltage at UVLO Falling	0.32	0.66		V
	Remote Shutdown Hysteresis			110		mV
REGULATION AND OVERVOLTAGE COMPARATORS						
	FB Regulation Level	Internal Reference Trip Point for Switch ON	1.2	1.225	1.25	V
	FB Overvoltage Threshold	Trip Point for Switch OFF		1.62		V
	FB Bias Current			60		nA
SWITCH CHARACTERISTICS						
	Buck Switch $R_{DS(ON)}$	I_{TEST} = 200 mA, BST-SW = 7 V		0.8	1.8	Ω
	Synchronous $R_{DS(ON)}$	I_{TEST} = 200 mA		0.45	1	Ω
	Gate Drive UVLO	$V_{BST} - V_{SW}$ Rising	2.4	3	3.6	V
	Gate Drive UVLO Hysteresis			260		mV
CURRENT LIMIT						
	Current Limit Threshold		0.7	1.02	1.3	A
	Current Limit Response Time	Time to Switch Off		150		ns
	OFF-Time Generator (Test 1)	FB = 0.1 V, V_{IN} = 48 V		12		µs
	OFF-Time Generator (Test 2)	FB = 1.0 V, V_{IN} = 48 V		2.5		µs
THERMAL SHUTDOWN						
T_{sd}	Thermal Shutdown Temperature			165		°C
	Thermal Shutdown Hysteresis			20		°C

(1) All limits are specified by design. All electrical characteristics having room temperature limits are tested during production at T_A = 25°C. All hot and cold limits are specified by correlating the electrical characteristics to process and temperature variations and applying statistical process control.
(2) V_{CC} provides self bias for the internal gate drive and control circuits. Device thermal limitations limit external loading.

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6.6 Switching Characteristics

Typical values correspond to T_J = 25°C. Minimum and maximum limits apply over –40°C to 125°C junction temperature range unless otherwise stated. V_{IN} = 48 V unless otherwise stated.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
ON-TIME GENERATOR					
T_{ON} Test 1	V_{IN} = 32 V, R_{ON} = 100 kΩ	270	350	460	ns
T_{ON} Test 2	V_{IN} = 48 V, R_{ON} = 100 kΩ	188	250	336	ns
T_{ON} Test 3	V_{IN} = 75 V, R_{ON} = 250 kΩ	250	370	500	ns
T_{ON} Test 4	V_{IN} = 10 V, R_{ON} = 250 kΩ	1880	3200	4425	ns
MINIMUM OFF-TIME					
Minimum Off-Timer	FB = 0 V		144		ns

6.7 Typical Characteristics

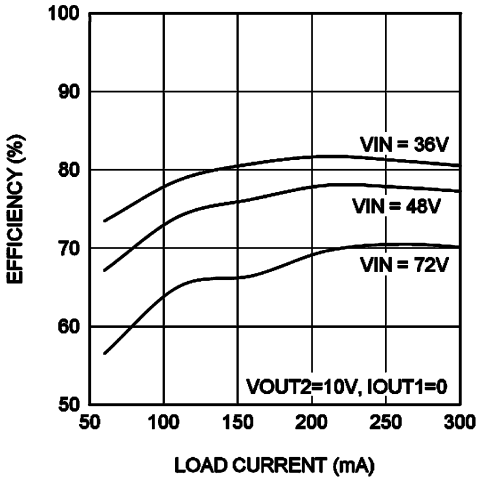

Figure 1. Efficiency at 750 kHz, V_{OUT1} = 10 V

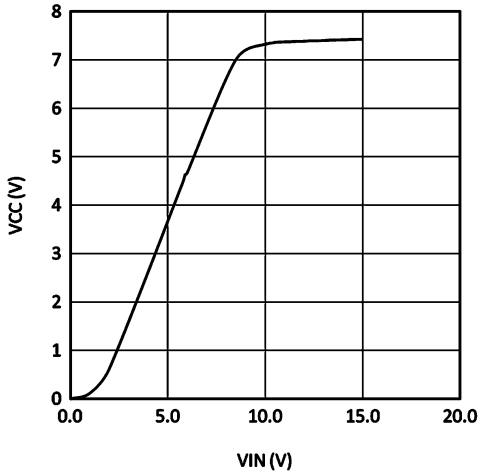

Figure 2. V_{CC} vs V_{IN}

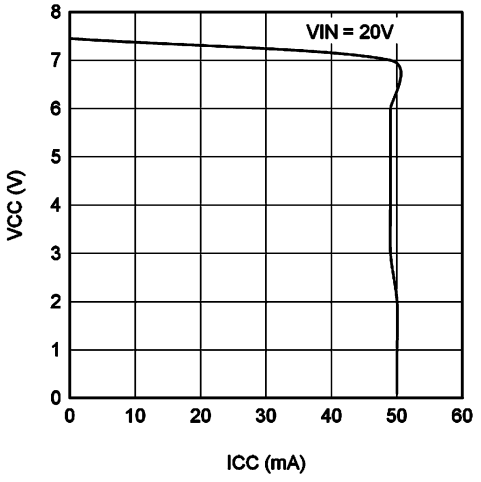

Figure 3. V_{CC} vs I_{CC}

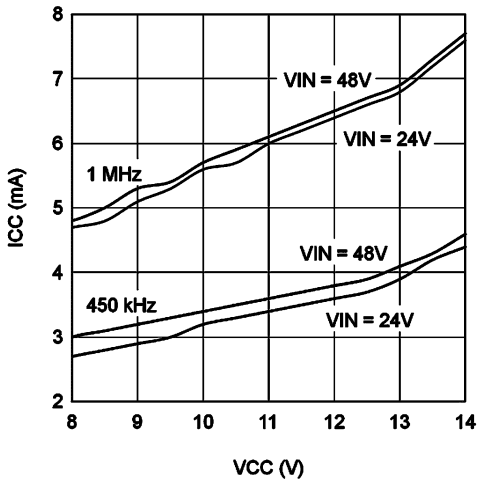

Figure 4. I_{CC} vs External V_{CC}

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Typical Characteristics (continued)

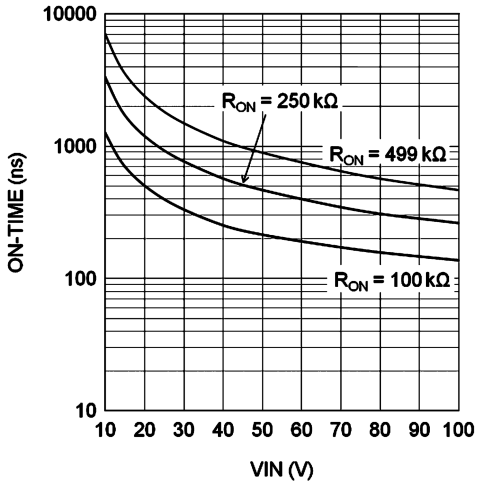

Figure 5. T_{ON} vs V_{IN} and R_{ON}

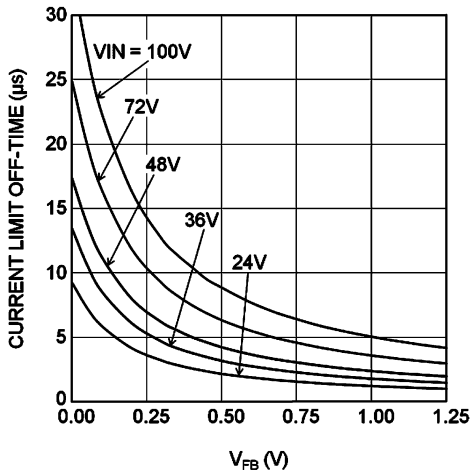

Figure 6. T_{OFF} (I_{LIM}) vs V_{FB} and V_{IN}

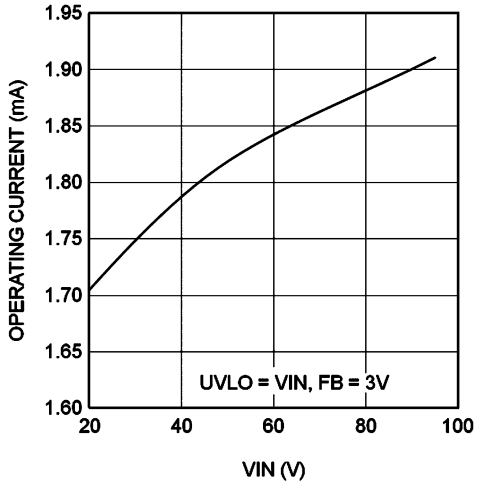

Figure 7. I_{IN} vs V_{IN} (Operating, Nonswitching)

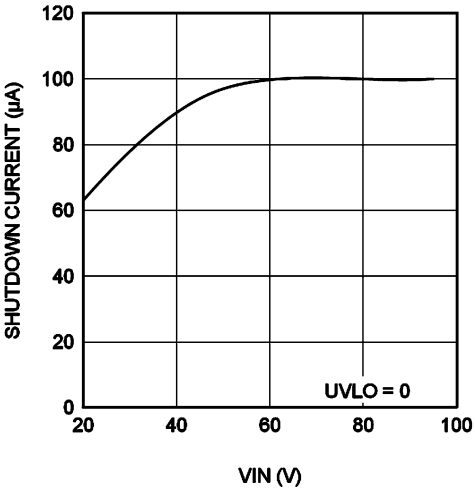

Figure 8. I_{IN} vs V_{IN} (Shutdown)

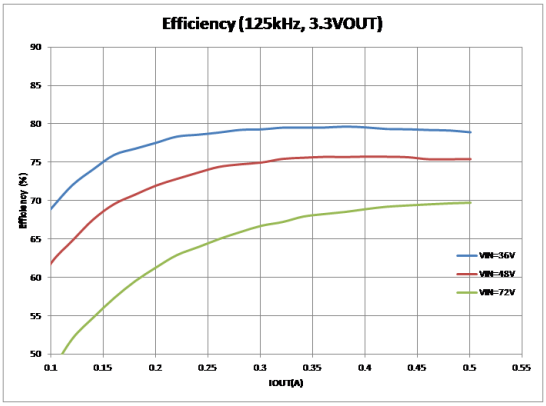

Figure 9. Efficiency

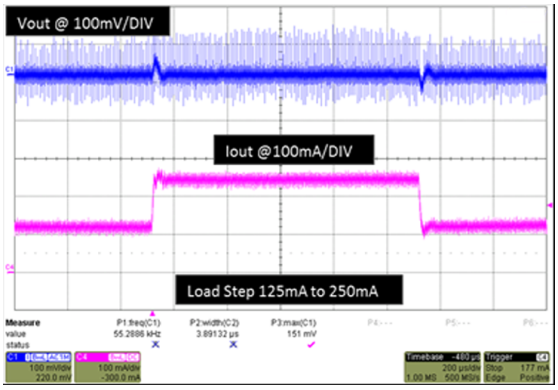

Figure 10. Buck Transient Response 36 V_{IN}

Typical Characteristics (continued)

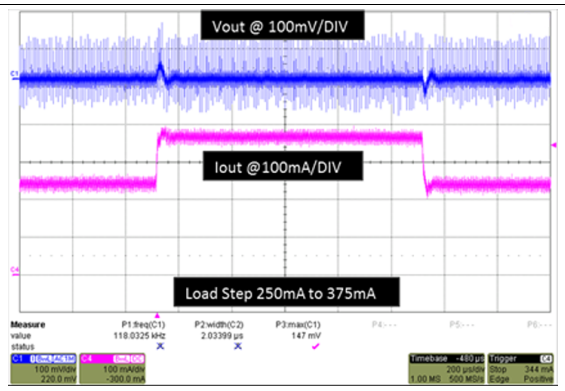

Figure 11. Buck Transient Response 36 V_{IN}

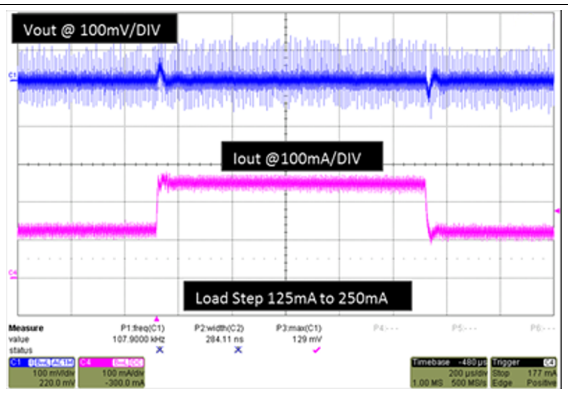

Figure 12. Buck Transient Response 48 V_{IN}

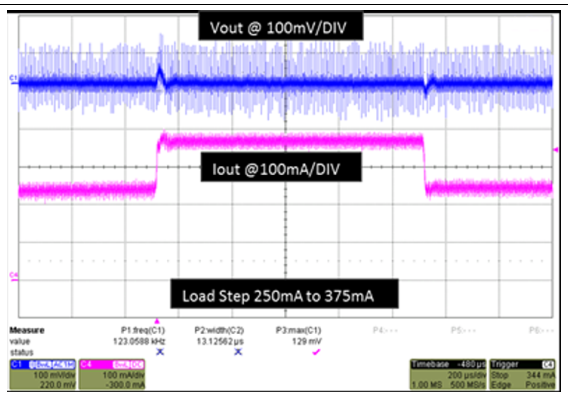

Figure 13. Buck Transient Response 48 V_{IN}

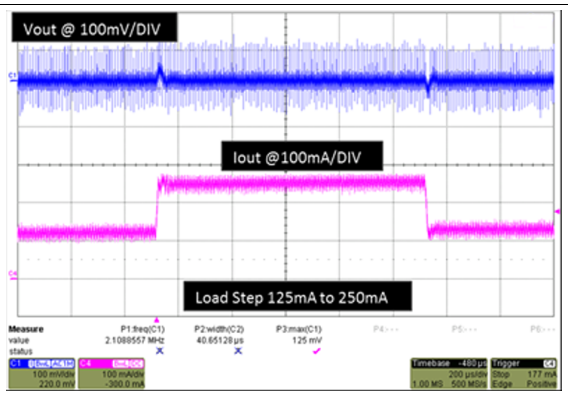

Figure 14. Buck Transient Response 72 V_{IN}

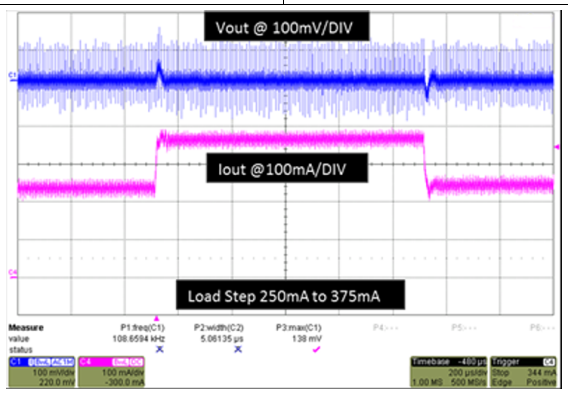

Figure 15. Buck Transient Response 72 V_{IN}

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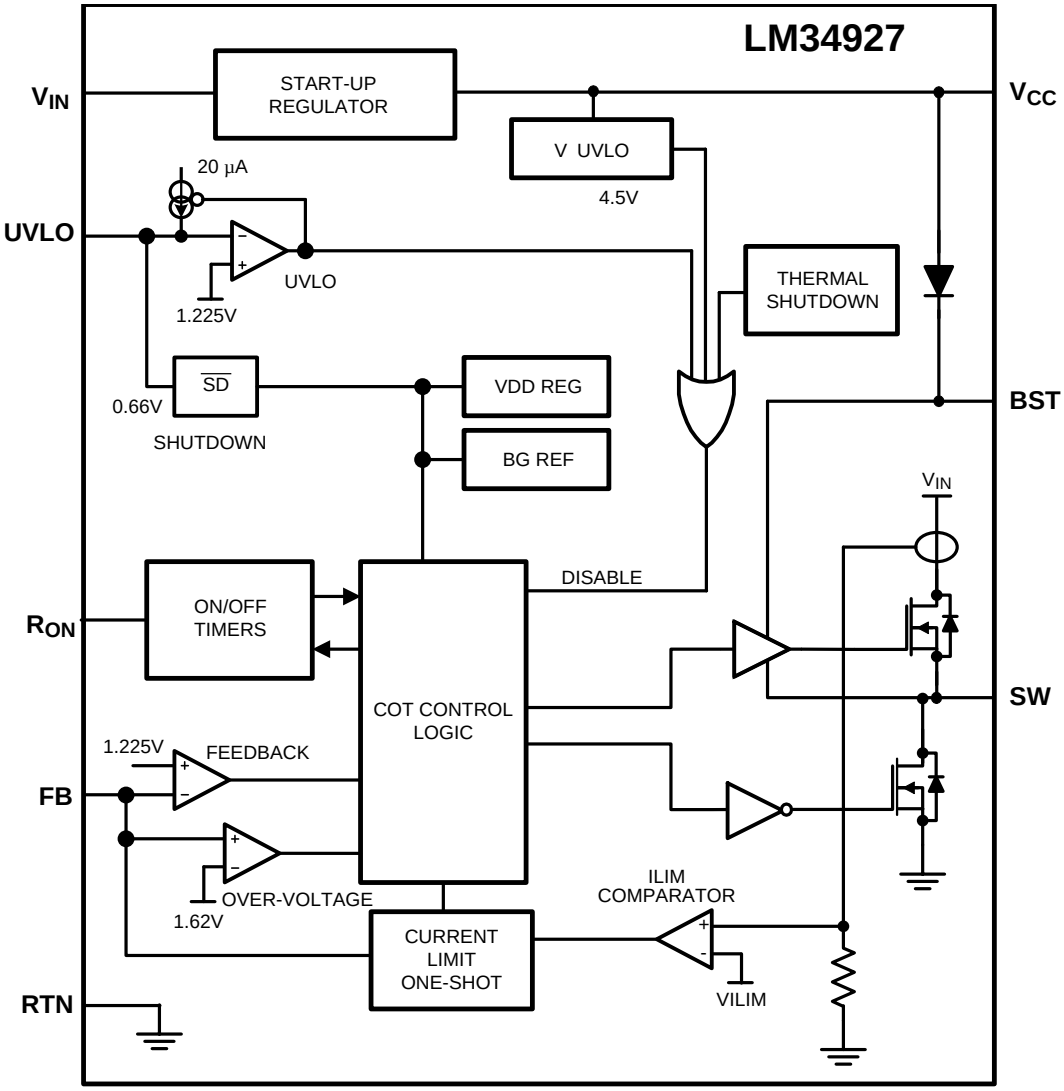
7 Detailed Description

7.1 Overview

The LM34927 step-down switching regulator features all the functions needed to implement a low-cost, efficient, isolated-bias supply. This high-voltage regulator contains 100 V, N-channel buck and synchronous switches, is easy to implement, and is provided in thermally enhanced SO PowerPAD-8 and WSON-8 packages. The regulator operation is based on a constant on-time control scheme using an on-time inversely proportional to V_{IN}. This control scheme does not require loop compensation. Current limit is implemented with forced off-time inversely proportional to V_{OUT}. This scheme ensures short-circuit protection while providing minimum foldback. The simplified block diagram of the LM34927 device is shown in *Functional Block Diagram*.

The LM34927 device can be applied in numerous applications to efficiently regulate down higher voltages. This regulator is well suited for 48-V telecom and automotive power bus ranges. Protection features include: thermal shutdown, UVLO, minimum forced off-time, and an intelligent current limit.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Control Overview

The LM34927 regulator employs a control principle based on a comparator and a one-shot on-timer, with the output voltage feedback (FB) compared to an internal reference (1.225 V). If the FB voltage is below the reference the internal buck switch is switched on for the one-shot timer period, which is a function of the input voltage and the programming resistor (RT). Following the on-time the switch remains off until the FB voltage falls below the reference, and the forced minimum off-time has expired. When the FB pin voltage falls below the reference and the off-time one-shot period expires, the buck switch is then turned on for another on-time one-shot period. This continues until regulation is achieved and the FB voltage is approximately equal to 1.225 V (typ).

In a synchronous buck converter, the low-side (sync) FET is on when the high side (buck) FET is off. The inductor current ramps up when the high-side switch is on and ramps down when the high side switch is off. There is no diode emulation feature in this IC, and therefore, the inductor current may ramp in the negative direction at light load. This causes the converter to operate in continuous conduction mode (CCM) regardless of the output loading. The operating frequency remains relatively constant with load and line variations. The operating frequency can be calculated as shown in Equation 1.

$$f_{SW} = \frac{V_{OUT1}}{K \times R_{ON}} \tag{1}$$

Where $K = 9 \times 10^{-11}$

The output voltage (V_{OUT}) is set by two external resistors (R_{FB1}, R_{FB2}). The regulated output voltage is calculated as shown in Equation 2.

$$V_{OUT} = 1.225V \times \frac{R_{FB2} + R_{FB1}}{R_{FB1}} \tag{2}$$

This regulator regulates the output voltage based on ripple voltage at the feedback input, requiring a minimum amount of ESR for the output capacitor (C_{OUT}). A minimum of 25 mV of ripple voltage at the feedback pin (FB) is required for the LM34927 device. In cases where the capacitor ESR is too small, additional series resistance may be required (R_C in Figure 16).

For applications where lower output voltage ripple is required, the output can be taken directly from a low ESR output capacitor, as shown in Figure 16. However, R_C slightly degrades the load regulation.

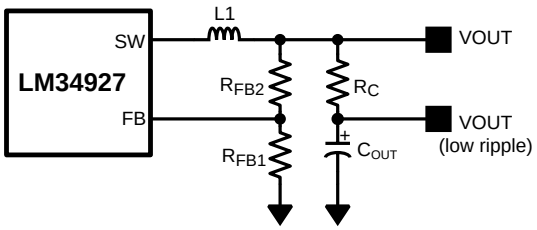


Figure 16. Low Ripple Output Configuration

7.3.2 V_{CC} Regulator

The LM34927 device contains an internal high voltage linear regulator with a nominal output of 7.6 V. The input pin (V_{IN}) can be connected directly to the line voltages up to 100 V. The V_{CC} regulator is internally current limited to 30 mA. The regulator sources current into the external capacitor at V_{CC}. This regulator supplies current to internal circuit blocks including the synchronous MOSFET driver and the logic circuits. When the voltage on the V_{CC} pin reaches the UVLO threshold of 4.5 V, the IC is enabled.

The V_{CC} regulator contains an internal diode connection to the BST pin to replenish the charge in the gate drive boot capacitor when SW pin is low.

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Feature Description (continued)

At high input voltages, the power dissipated in the high-voltage regulator is significant and can limit the overall achievable output power. As an example, with the input at 48 V and switching at high frequency, the V_{CC} regulator may supply up to 7 mA of current resulting in 48 V × 7 mA = 336 mW of power dissipation. If the V_{CC} voltage is driven externally by an alternate voltage source, from 8.55 V to 14 V, the internal regulator is disabled. This reduces the power dissipation in the IC.

7.3.3 Regulation Comparator

The feedback voltage at FB is compared to an internal 1.225 V reference. In normal operation, when the output voltage is in regulation, an on-time period is initiated when the voltage at FB falls below 1.225 V. The high-side switch will stay on for the on-time, causing the FB voltage to rise above 1.225 V. After the on-time period, the high-side switch will stay off until the FB voltage again falls below 1.225 V. During start-up, the FB voltage will be below 1.225 V at the end of each on-time causing the high-side switch to turn on immediately after the minimum forced off-time of 144 ns. The high-side switch can be turned off before the on-time is over if peak current in the inductor reaches the current limit threshold.

7.3.4 Overvoltage Comparator

The feedback voltage at FB is compared to an internal 1.62-V reference. If the voltage at FB rises above 1.62 V the on-time pulse is immediately terminated. This condition can occur if the input voltage and/or the output load changes suddenly. The high-side switch will not turn on again until the voltage at FB falls below 1.225 V.

7.3.5 On-Time Generator

The on-time for the LM34927 device is determined by the R_{ON} resistor, and is inversely proportional to the input voltage (V_{IN}), resulting in a nearly constant frequency as V_{IN} is varied over its range. The on-time equation for the LM34927 device is shown in Equation 3.

$$T_{ON} = \frac{10^{-10} \times R_{ON}}{V_{IN}} \tag{3}$$

See Figure 5. R_{ON} should be selected for a minimum on-time (at maximum V_{IN}) greater than 100 ns for proper operation. This requirement limits the maximum frequency for each application.

7.3.6 Current Limit

The LM34927 device contains an intelligent current limit off-timer. If the current in the buck switch exceeds 1.02 A, the present cycle is immediately terminated, and a nonresetable off-timer is initiated. The length of off-time is controlled by the FB voltage and the input voltage V_{IN}. As an example, when FB = 0 V and V_{IN} = 48 V, a maximum off-time is set to 16 µs. This condition occurs when the output is shorted, and during the initial part of start up. This amount of time ensures safe short circuit operation up to the maximum input voltage of 100 V.

In cases of overload where the FB voltage is above zero volts (not a short circuit) the current limit off-time is reduced. Reducing the off-time during less severe overloads reduces the amount of foldback, recovery time, and start-up time. The off-time is calculated from Equation 4.

$$T_{OFF(ILIM)} = \frac{0.07 \times V_{IN}}{V_{FB} + 0.2\,V}\ \mu s \tag{4}$$

The current limit protection feature is peak limited, the maximum average output will be less than the peak.

7.3.7 N-Channel Buck Switch and Driver

The LM34927 device integrates an N-Channel Buck switch and associated floating high-voltage gate driver. The gate driver circuit works in conjunction with an external bootstrap capacitor and an internal high-voltage diode. A 0.01-µF ceramic capacitor connected between the BST pin and SW pin provides the voltage to the driver during the on-time. During each off-time, the SW pin is at approximately 0 V and the bootstrap capacitor charges from V_{CC} through the internal diode. The minimum off-timer, set to 144 ns, ensures a minimum time each cycle to recharge the bootstrap capacitor.

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Feature Description (continued)

7.3.8 Synchronous Rectifier

The LM34927 device provides an internal synchronous N-channel MOSFET rectifier. This MOSFET provides a path for the inductor current to flow when the high-side MOSFET is turned off.

The synchronous rectifier has no diode emulation mode, and is designed to keep the regulator in continuous conduction mode even during light loads which would otherwise result in discontinuous operation. This feature specifically lets the user design a secondary regulator using a transformer winding off the main inductor to generate the alternate regulated output voltage.

7.3.9 Undervoltage Detector

The LM34927 device contains a dual-level UVLO circuit. When the UVLO pin voltage is below 0.66 V, the controller is in a low current shutdown mode. When the UVLO pin voltage is greater than 0.66 V but less than 1.225 V, the controller is in standby mode. In standby mode the V_{CC} bias regulator is active while the regulator output is disabled. When the V_{CC} pin exceeds the V_{CC} undervoltage thresholds and the UVLO pin voltage is greater than 1.225 V, normal operation begins. An external set-point voltage divider from V_{IN} to GND can be used to set the minimum operating voltage of the regulator.

UVLO hysteresis is accomplished with an internal 20-µA current source that is switched on or off into the impedance of the set-point divider. When the UVLO threshold is exceeded, the current source is activated to quickly raise the voltage at the UVLO pin. The hysteresis is equal to the value of this current times the resistance R_{UV2}.

If the UVLO pin is wired directly to the V_{IN} pin, the regulator will begin operation once the V_{CC} undervoltage is satisfied.

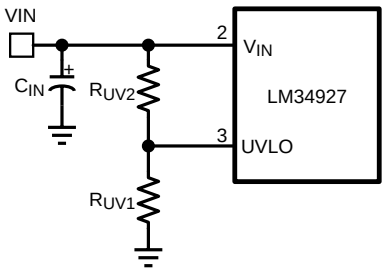

Figure 17. UVLO Resistor Setting

7.3.10 Thermal Protection

The LM34927 device should be operated so the junction temperature does not exceed 150°C during normal operation. An internal Thermal Shutdown circuit is provided to protect the LM34927 in the event of a higher than normal junction temperature. When activated, typically at 165°C, the controller is forced into a low-power reset state, disabling the buck switch and the V_{CC} regulator. This feature prevents catastrophic failures from accidental device overheating. When the junction temperature reduces below 145°C (typical hysteresis = 20°C), the V_{CC} regulator is enabled, and normal operation is resumed.

7.3.11 Ripple Configuration

LM34927 uses COT control scheme, in which the on-time is terminated by an on-timer, and the off-time is terminated by the feedback voltage (V_{FB}) falling below the reference voltage (V_{REF}). Therefore, for stable operation, the feedback voltage must decrease monotonically, in phase with the inductor current during the off-time. Furthermore this change in feedback voltage (ΔV_{FB}) during off-time must be large enough to suppress any noise component present at the feedback node.

Table 1 shows three different methods for generating appropriate voltage ripple at the feedback node. Type 1 and Type 2 ripple circuits couple the ripple at the output of the converter to the feedback node (FB). The output voltage ripple has two components:

- Capacitive ripple caused by the inductor current ripple charging/discharging the output capacitor.
- Resistive ripple caused by the inductor current ripple flowing through the ESR of the output capacitor.

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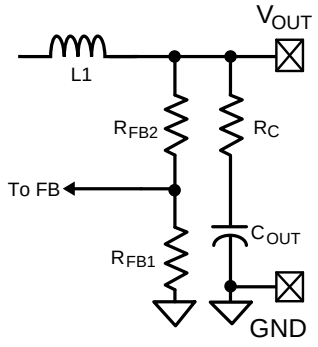
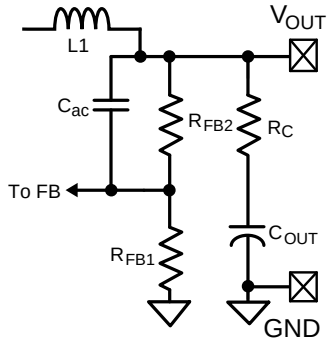
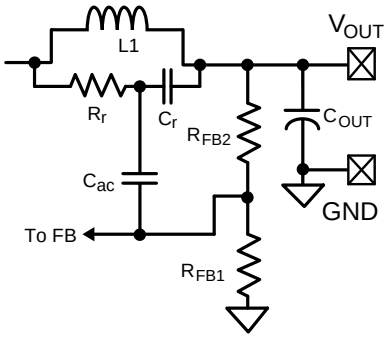
Feature Description (continued)

The capacitive ripple is not in phase with the inductor current. As a result, the capacitive ripple does not decrease monotonically during the off-time. The resistive ripple is in phase with the inductor current and decreases monotonically during off-time. The resistive ripple must exceed the capacitive ripple at the output node (V_{OUT}) for stable operation. If this condition is not satisfied, unstable switching behavior is observed in COT converters, with multiple on-time bursts in close succession followed by a long off-time.

Type 3 ripple method uses R_r and C_r and the switch node (SW) voltage to generate a triangular ramp. This triangular ramp is ac coupled using C_{ac} to the feedback node (FB). Because this circuit does not use the output voltage ripple, it is ideally suited for applications where low output voltage ripple is required. See *AN-1481 Controlling Output Ripple and Achieving ESR Independence in Constant On-Time (COT) Regulator Designs* (SNVA166) for more details for each ripple generation method.

Table 1. Ripple Configuration

TYPE 1 LOWEST COST CONFIGURATION	TYPE 2 REDUCED RIPPLE CONFIGURATION	TYPE 3 MINIMUM RIPPLE CONFIGURATION
		
$R_C \geq \frac{25\ mV}{\Delta I_{L(MIN)}} \times \frac{V_{OUT}}{V_{REF}}$ (5)	$C \geq \frac{5}{f_{sw}(R_{FB2} \| \| R_{FB1})}$ $R_C \geq \frac{25\ mV}{\Delta I_{L(MIN)}}$ (6)	$C_r = 3300\ pF$ $C_{ac} = 100\ nF$ $R_r C_r \leq \frac{(V_{IN(MIN)} - V_{OUT}) \times T_{ON}}{25\ mV}$ (7)

7.3.12 Soft Start

A soft-start feature can be implemented with the LM34927 device using an external circuit. As shown in Figure 18, the soft-start circuit consists of one capacitor C_1, two resistors R_1 and R_2, and a diode D. During the initial start-up, the VCC voltage is established prior to the V_{OUT} voltage. Capacitor C_1 is discharged and D is thereby forward biased to pull up the FB voltage. The FB voltage exceeds the reference voltage (1.225 V) and switching is therefore disabled. As capacitor C_1 charges, the voltage at node B gradually decreases and switching commences. V_{OUT} will gradually rise to maintain the FB voltage at the reference voltage. Once the voltage at node B is less than a diode drop above the FB voltage, the soft-start sequence is finished and D is reverse biased.

During the initial part of the start up, the FB voltage can be approximated as shown in Equation 8. The effect of R_1 has been ignored to simplify the calculation.

$$V_{FB} = (VCC - V_D) \times \frac{R_{FB1} \times R_{FB2}}{R_2 \times (R_{FB1} + R_{FB2}) + R_{FB1} \times R_{FB2}} \quad (8)$$

C1 is charged after the first start up. Diode D1 is optional and can be added to discharge C1 and initialize the soft-start sequence when the input voltage experiences a momentary drop.

To achieve the desired soft start, the following design guidance is recommended:

- R_2 is selected so that V_{FB} is higher than 1.225 V for a V_{CC} of 4.5 V, but is lower than 5 V when V_{CC} is 8.55 V. If an external V_{CC} is used, V_{FB} should not exceed 5 V at maximum V_{CC}.

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- C_1 is selected to achieve the desired start-up time which can be determined from Equation 9.

$$t_S = C_1 \times \left(R_2 + \frac{R_{FB1} \times R_{FB2}}{R_{FB1} + R_{FB2}}\right) \quad (9)$$

- R_1 is used to maintain the node B voltage at zero after the soft start is finished. A value larger than the feedback resistor divider is preferred. The effect of resistor R1 is ignored.

Using component values shown in Figure 19, selecting C_1 = 1 µF, R_2 = 1 kΩ, R_1 = 30 kΩ results in a soft-start time of about 2 ms.

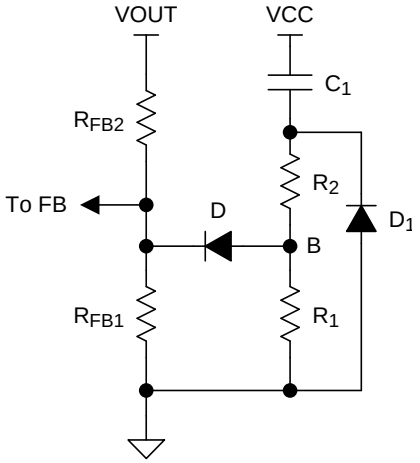

Figure 18. Soft-Start Circuit

7.4 Device Functional Modes

Table 2. Undervoltage Detector

UVLO	V_{CC}	MODE	DESCRIPTION
< 0.66 V	Disabled	Shutdown	V_{CC} regulator disabled. Switching disabled.
0.66 V to 1.225 V	Enabled	Standby	V_{CC} regulator enabled. Switching disabled.
> 1.225 V	V_{CC} < 4.5 V	Standby	V_{CC} regulator enabled. Switching disabled.
	V_{CC} > 4.5 V	Operating	V_{CC} enabled. Switching enabled.

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8 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. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The LM34927 device is step-down DC-DC converter. The device is typically used to convert a higher DC voltage to a lower DC voltage with a maximum available output current of 600 mA. Use the following design procedure to select component values for the LM34927 device. Alternately, use the WEBENCH® software to generate a complete design. The WEBENCH software uses an iterative design procedure and accesses a comprehensive database of components when generating a design. This section presents a simplified discussion of the design process.

8.2 Typical Application

8.2.1 Application Circuit: 20-V to 95-V Input and 10-V, 300-mA Output Isolated Fly-Buck™ Converter

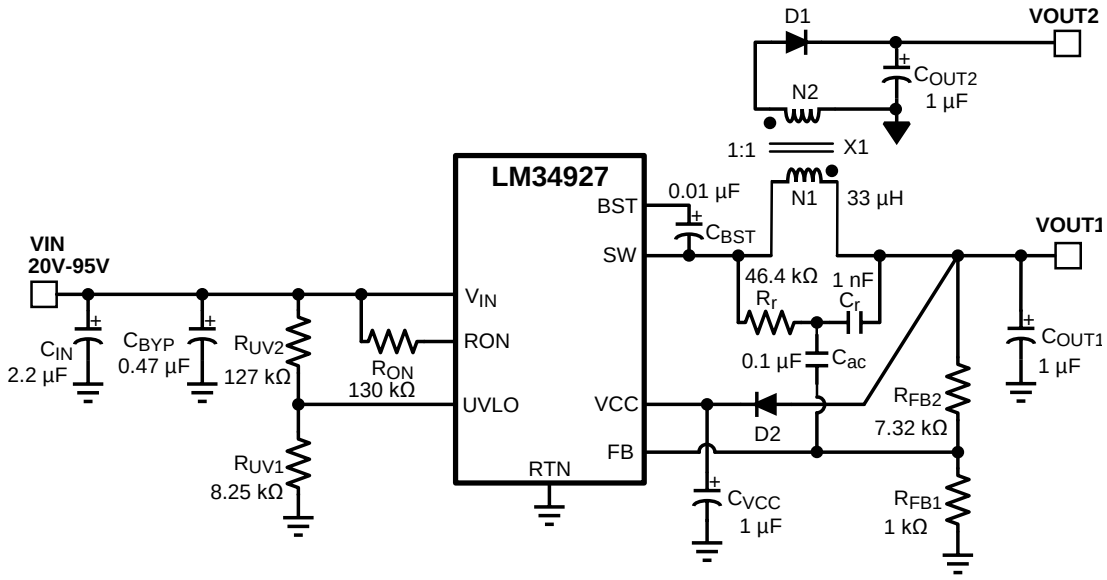

Figure 19. Isolated Fly-Buck Converter Using LM34927

8.2.1.1 Design Requirements

Selection of external components is illustrated through a design example. The design example specifications are shown in Table 3.

Table 3. Buck Converter Design Specifications

DESIGN PARAMETERS	VALUE
Input Voltage Range	20 V to 95 V
Primary Output Voltage	10 V
Secondary (Isolated) Output Voltage	9.5 V
Maximum Output Current (Primary + Secondary)	300 mA
Maximum Power Output	3 W
Nominal Switching Frequency	750 kHz

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8.2.1.2 Detailed Design Procedure

8.2.1.2.1 Transformer Turns Ratio

The transformer turns ratio is selected based on the ratio of the primary output voltage to the secondary (isolated) output voltage. In this design example, the two outputs are nearly equal and a 1:1 turns ratio transformer is selected. Therefore, N2 / N1 = 1.

If the secondary (isolated) output voltage is significantly higher or lower than the primary output voltage, a turns ratio less than or greater than 1 is recommended. The primary output voltage is normally selected based on the input voltage range such that the duty cycle of the converter does not exceed 50% at the minimum input voltage. This condition is satisfied if VOUT1 < V_{IN_MIN} / 2.

8.2.1.2.2 Total I_{OUT}

The total primary referred load current is calculated by multiplying the isolated output loads by the turns ratio of the transformer as shown in Equation 10.

$$I_{OUT(MAX)} = I_{OUT1} + I_{OUT2} \times \frac{N2}{N1} = 0.3\,A \tag{10}$$

8.2.1.2.3 RFB1, RFB2

The feedback resistors are selected to set the primary output voltage. The selected value for R_{FB1} is 1 kΩ. R_{FB2} can be calculated using the following equations to set V_{OUT1} to the specified value of 10 V. A standard resistor value of 7.32 kΩ is selected for R_{FB2}.

$$V_{OUT1} = 1.225V \text{ x } \left(1 + \frac{R_{FB2}}{R_{FB1}}\right) \tag{11}$$

$$\rightarrow R_{FB2} = \left(\frac{V_{OUT1}}{1.225} - 1\right) \text{ x } R_{FB1} = 7.16\ k\Omega \tag{12}$$

8.2.1.2.4 Frequency Selection

Equation 13 is used to calculate the value of R_{ON} required to achieve the desired switching frequency.

$$f_{SW} = \frac{V_{OUT1}}{K \text{ x } R_{ON}}$$

where

- $K = 9 \times 10^{-11}$ (13)

V_{OUT1} of 10 V and f_{SW} of 750 kHz, the calculated value of R_{ON} is 148 kΩ. A lower value of 130 kΩ is selected for this design to allow for second-order effects at high switching frequency that are not included in Equation 13.

8.2.1.2.5 Transformer Selection

A coupled inductor or a flyback-type transformer is required for this topology. Energy is transferred from primary to secondary when the low-side synchronous switch of the buck converter is conducting.

The maximum inductor primary ripple current that can be tolerated without exceeding the buck switch peak current limit threshold (0.7 A minimum) is given by Equation 14.

$$\Delta I_{L1} = \left(0.7 - I_{OUT1} - I_{OUT2} \times \frac{N2}{N1}\right) \times 2 = 0.8\,A \tag{14}$$

Using the maximum peak-to-peak inductor ripple current ΔI_{L1} from Equation 14, the minimum inductor value is given by Equation 15.

$$L1 = \frac{V_{IN(MAX)} - V_{OUT}}{\Delta I_{L1} \times f_{SW}} \times \frac{V_{OUT}}{V_{IN(MAX)}} = 14.9\,\mu H \tag{15}$$

A higher value of 33 µH is selected to insure the high-side switch current does not exceed the minimum peak current limit threshold. With this inductance, the inductor current ripple is ΔI_{L1}= 0.36 A at the maximum V_{IN}.

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8.2.1.2.6 Primary Output Capacitor

In a conventional buck converter the output ripple voltage is calculated as shown in Equation 16.

$$\Delta V_{OUT} = \frac{\Delta I_{L1}}{8 \times f \times C_{OUT1}} \tag{16}$$

To limit the primary output ripple voltage ΔV_{OUT1} to approximately 50 mV, an output capcitor C_{OUT1} of 1.2 µF would be required for a conventional buck.

Figure 20 shows the primary winding current waveform (I_{L1}) of a Fly-Buck converter. The reflected secondary winding current adds to the primary winding current during the buck switch off-time. Because of this increased current, the output voltage ripple is not the same as in conventional buck converter. The output capacitor value calculated in Equation 16 should be used as the starting point. Optimization of output capacitance over the entire line and load range must be done experimentally. If the majority of the load current is drawn from the secondary isolated output, a better approximation of the primary output voltage ripple is given by Equation 17.

$$\Delta V_{OUT1} = \frac{\left(I_{OUT2} \times \frac{N2}{N1}\right) \times T_{ON(MAX)}}{C_{OUT1}} \approx 67\,mV \tag{17}$$

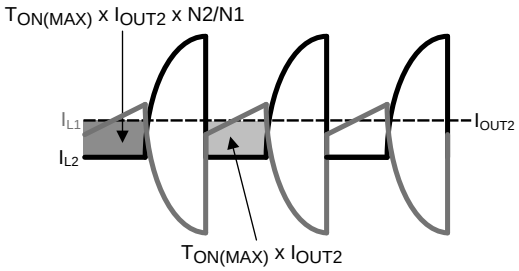

Figure 20. Current Waveforms for C_{OUT1} Ripple Calculation

A standard 1-µF, 25-V capacitor is selected for this design. If lower output voltage ripple is required, a higher value should be selected for C_{OUT1} and/or C_{OUT2}.

8.2.1.2.7 Secondary Output Capacitor

A simplified waveform for secondary output current (I_{OUT2}) is shown in Figure 21.

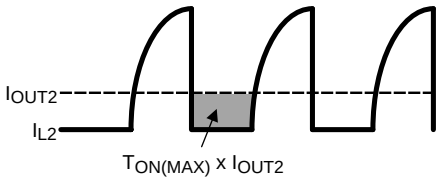

Figure 21. Secondary Current Waveforms for C_{OUT2} Ripple Calculation

The secondary output current (I_{OUT2}) is sourced by C_{OUT2} during on-time of the buck switch, T_{ON}. Ignoring the current transition times in the secondary winding, the secondary output capacitor ripple voltage can be calculated using Equation 18.

$$\Delta V_{OUT2} = \frac{I_{OUT2} \times T_{ON\,(MAX)}}{C_{OUT2}} \tag{18}$$

For a 1:1 transformer turns ratio, the primary and secondary voltage ripple equations are identical. Therefore, C_{OUT2} is chosen to be equal to C_{OUT1} (1 µF) to achieve comparable ripple voltages on primary and secondary outputs.

If lower output voltage ripple is required, a higher value should be selected for C_{OUT1} and/or C_{OUT2}.

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8.2.1.2.8 Type III Feedback Ripple Circuit

Type III ripple circuit as described in *Ripple Configuration* is required for the Fly-Buck topology. Type I and Type II ripple circuits use series resistance and the triangular inductor ripple current to generate ripple at V_{OUT} and the FB pin. The primary ripple current of a Fly-Buck is the combination or primary and reflected secondary currents as illustrated in Figure 20. In the Fly-Buck topology, Type I and Type II ripple circuits suffer from large jitter as the reflected load current affects the feedback ripple.

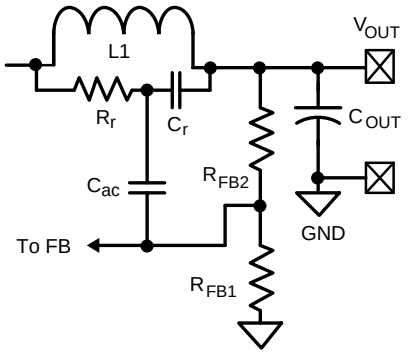

Figure 22. Type III Ripple Circuit

Selecting the Type III ripple components using the equations from *Ripple Configuration* will ensure that the FB pin ripple is be greater than the capacitive ripple from the primary output capacitor C_{OUT1}. The feedback ripple component values are chosen as shown in Equation 19.

C_r = 1000 pF

C_{ac} = 0.1 µF

$$R_r C_r \leq \frac{(V_{IN\,(MIN)} - V_{OUT}) \times T_{ON}}{50\ mV} \tag{19}$$

The calculated value for Rr is 66 kΩ. This value provides the minimum ripple for stable operation. A smaller resistance should be selected to allow for variations in T_{ON}, C_{OUT1} and other components. For this design, Rr value of 46.4 kΩ is selected.

8.2.1.2.9 Secondary Diode

The reverse voltage across secondary-rectifier diode D1 when the high-side buck switch is off can be calculated using Equation 20.

$$V_{D1} = \frac{N2}{N1} V_{IN} \tag{20}$$

For a V_{IN_MAX} of 95 V and the 1:1 turns ratio of this design, a 100-V Schottky is selected.

8.2.1.2.10 V_{CC} and Bootstrap Capacitor

A 1-µF capacitor of 16 V or higher rating is recommended for the V_{CC} regulator bypass capacitor.

A good value for the BST pin bootstrap capacitor is 0.01-µF with a voltage rating of 16 or higher.

8.2.1.2.11 Input Capacitor

The input capacitor is typically a combination of a smaller bypass capacitor located near the regulator IC and a larger bulk capacitor. The total input capacitance should be large enough to limit the input voltage ripple to a desired amplitude. For input ripple voltage ΔV_{IN}, C_{IN} can be calculated using Equation 21.

$$C_{IN} \geq \frac{I_{OUT(MAX)}}{4 \times f \times \Delta V_{IN}} \tag{21}$$

Choosing a ΔV_{IN} of 0.5 V gives a minimum C_{IN} of 0.2 µF. A standard value of 0.47 µF is selected for C_{BYP} in this design. A bulk capacitor of higher value reduces voltage spikes due to parasitic inductance between the power source to the converter. A standard value of 2.2 µF is selected for for C_{IN} in this design. The voltage ratings of the two input capacitors should be greater than the maximum input voltage under all conditions.

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8.2.1.2.12 UVLO Resistors

UVLO resistors R_{UV1} and R_{UV2} set the undervoltage lockout threshold and hysteresis according to Equation 22 and Equation 23.

$$V_{IN\,(HYS)} = I_{HYS} \times R_{UV2} \tag{22}$$

$$V_{IN}(\text{UVLO, rising}) = 1.225\text{V} \times \left(\frac{R_{UV2}}{R_{UV1}} + 1\right) \tag{23}$$

Where I_{HYS} = 20 µA, typical.

For a UVLO hysteresis of 2.5 V and UVLO rising threshold of 20 V, Equation 22 and Equation 23 require R_{UV1} of 8.25 kΩ and R_{UV2} of 127 kΩ and these values are selected for this design example.

8.2.1.2.13 V_{CC} Diode

Diode D2 is an optional diode connected between V_{OUT1} and the V_{CC} regulator output pin. When V_{OUT1} is more than one diode drop greater than the V_{CC} voltage, the V_{CC} bias current is supplied from V_{OUT1}. This results in reduced power losses in the internal V_{CC} regulator which improves converter efficiency. V_{OUT1} must be set to a voltage at least one diode drop higher than 8.55 V (the maximum V_{CC} voltage) if D2 is used to supply bias current.

8.2.1.3 Application Curves

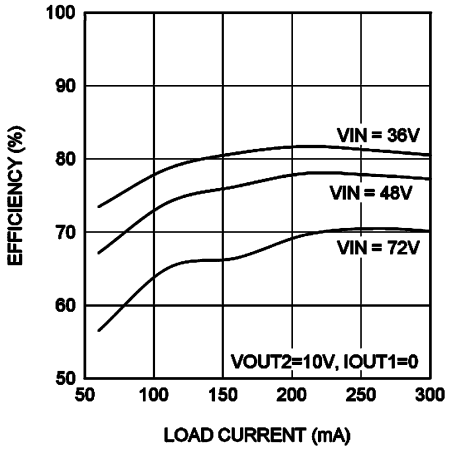

Figure 23. Efficiency at 750 kHz, VOUT1 = 10 V

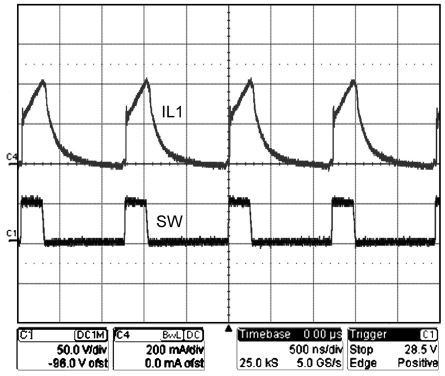

Figure 24. Steady State Waveform (VIN = 48 V, IOUT1 = 100 mA, IOUT2 = 200 mA)

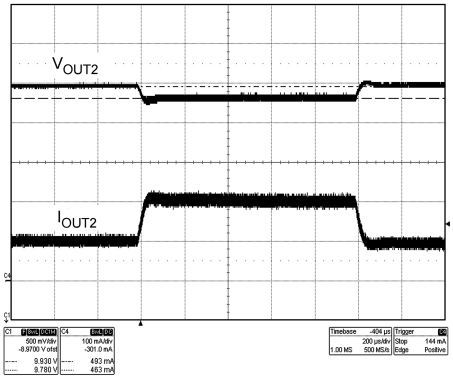

Figure 25. Step Load Response (VIN = 48 V, IOUT1 = 0, Step Load on IOUT2 = 100 mA to 200 mA)

9 Power Supply Recommendations

LM34927 is a power-management device. The power supply for the device is any dc voltage source within the specified input range.

10 Layout

10.1 Layout Guidelines

A proper layout is essential for optimum performance of the circuit. In particular, the following guidelines should be observed:

1. C_{IN}: The loop consisting of input capacitor (C_{IN}), V_{IN} pin, and RTN pin carries switching currents. Therefore the input capacitor should be placed close to the IC, directly across V_{IN} and RTN pins and the connections to these two pins should be direct to minimize the loop area. In general it is not possible to accommodate all of input capacitance near the IC. A good practice is to use a 0.1-µF or 0.47-µF capacitor directly across the V_{IN} and RTN pins close to the IC, and the remaining bulk capacitor as close as possible (see Figure 26 Placement of Bypass Capacitors).
2. C_{VCC} and C_{BST}: The V_{CC} and bootstrap (BST) bypass capacitors supply switching currents to the high- and low-side gate drivers. These two capacitors should also be placed as close to the IC as possible, and the connecting trace lengths and loop area should be minimized (See Figure 26).
3. The Feedback trace carries the output voltage information and a small ripple component that is necessary for proper operation of LM34927 device. Therefore take care while routing the feedback trace so avoid coupling any noise to this pin. In particular, feedback trace should not run close to magnetic components, or parallel to any other switching trace.
4. SW trace: SW node switches rapidly between V_{IN} and GND every cycle and is therefore a possible source of noise. SW node area should be minimized. In particular SW node should not be inadvertently connected to a copper plane or pour.

10.2 Layout Example

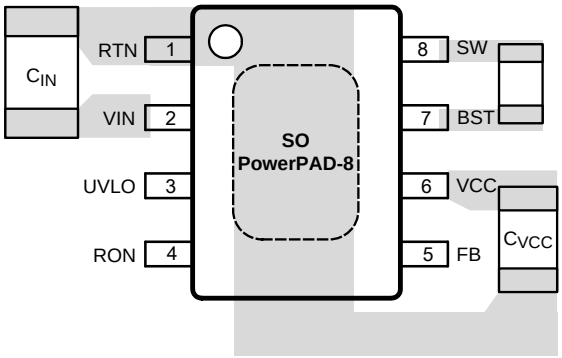

Figure 26. Placement of Bypass Capacitors

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10.3 Thermal Curves

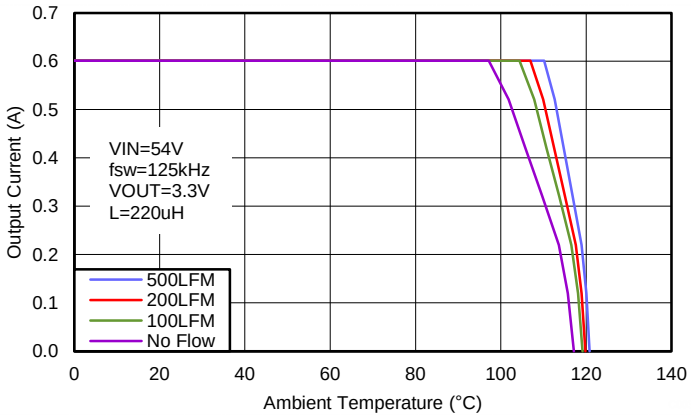

Figure 27. Thermal Derating Curve

11 Device and Documentation Support

11.1 Trademarks

PowerPAD, Fly-Buck are trademarks of Texas Instruments.
WEBENCH is a registered trademark of Texas Instruments.
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11.2 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.3 Glossary

SLYZ022 — *TI Glossary*.

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

12 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 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
LM34927MR/NOPB	ACTIVE	SO PowerPAD	DDA	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-3-260C-168 HR		L34927	Samples
LM34927MRX/NOPB	ACTIVE	SO PowerPAD	DDA	8	2500	Green (RoHS & no Sb/Br)	CU SN	Level-3-260C-168 HR		L34927	Samples
LM34927SD/NOPB	ACTIVE	WSON	NGU	8	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM		L34927	Samples
LM34927SDX/NOPB	ACTIVE	WSON	NGU	8	4500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM		L34927	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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

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

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

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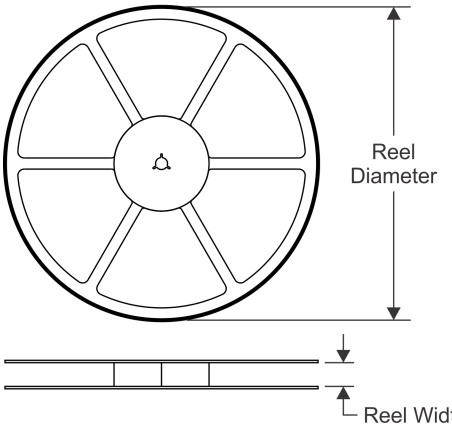
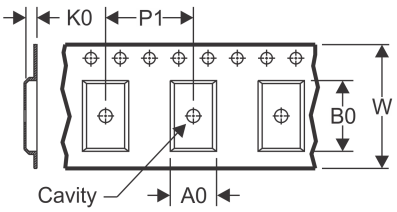
TAPE AND REEL INFORMATION

REEL DIMENSIONS

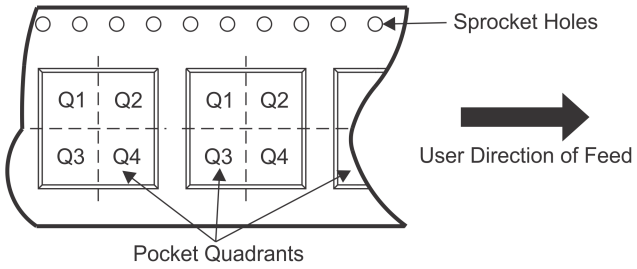


TAPE DIMENSIONS



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

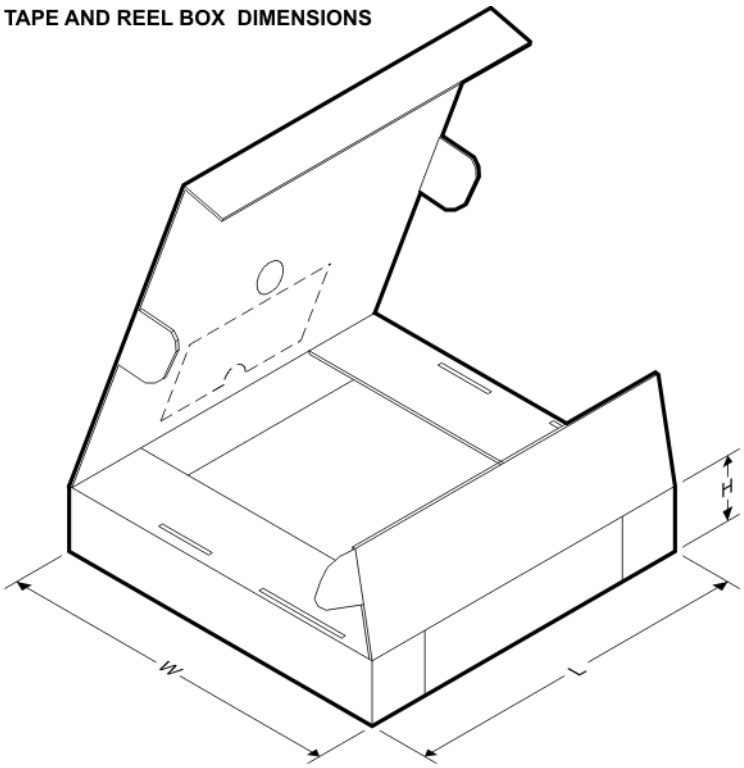
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
LM34927MRX/NOPB	SO Power PAD	DDA	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LM34927SD/NOPB	WSON	NGU	8	1000	178.0	12.4	4.3	4.3	1.3	8.0	12.0	Q1
LM34927SDX/NOPB	WSON	NGU	8	4500	330.0	12.4	4.3	4.3	1.3	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM34927MRX/NOPB	SO PowerPAD	DDA	8	2500	367.0	367.0	35.0
LM34927SD/NOPB	WSON	NGU	8	1000	210.0	185.0	35.0
LM34927SDX/NOPB	WSON	NGU	8	4500	367.0	367.0	35.0

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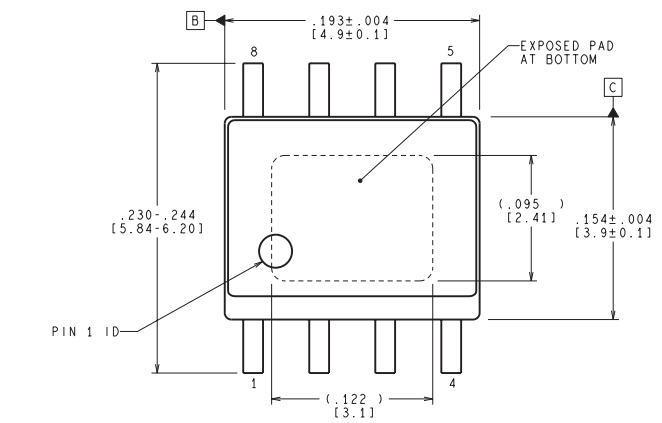
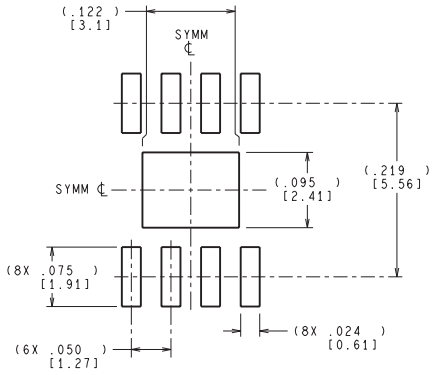
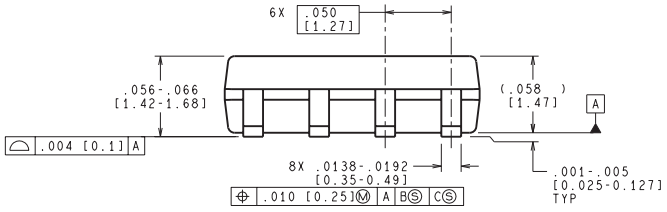
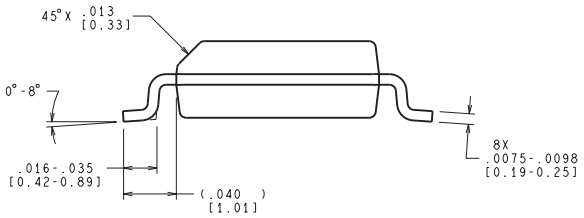




RECOMMENDED LAND PATTERN





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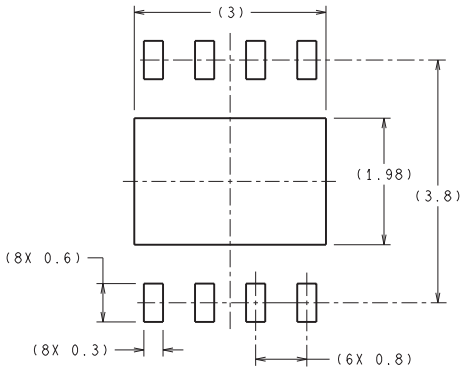

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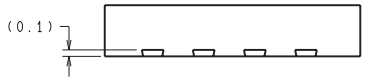

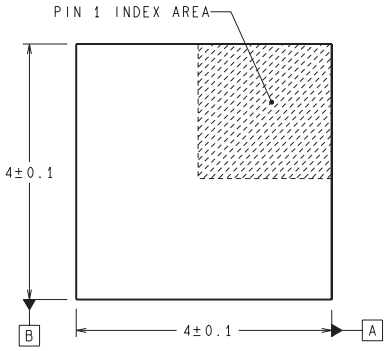

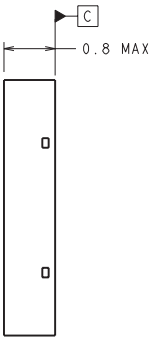

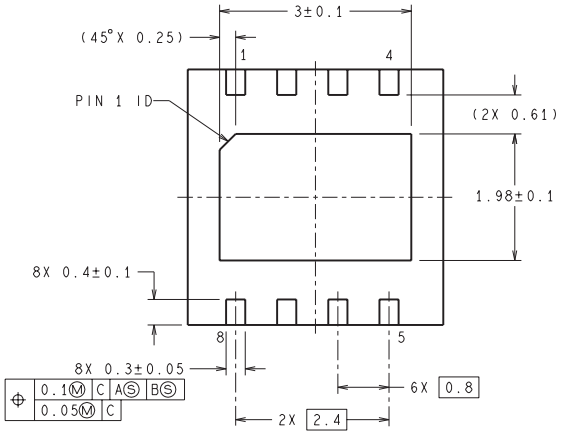

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