

## LM34919B

# Ultra Small 40V, 600 mA Constant On-Time Buck Switching Regulator

### General Description

The LM34919B Step Down Switching Regulator features all of the functions needed to implement a low cost, efficient, buck bias regulator capable of supplying 0.6A to the load. This buck regulator contains an N-Channel Buck Switch, and is available in a micro SMD package. The constant on-time feedback regulation scheme requires no loop compensation, results in fast load transient response, and simplifies circuit implementation. The operating frequency remains constant with line and load variations due to the inverse relationship between the input voltage and the on-time. The valley current limit results in a smooth transition from constant voltage to constant current mode when current limit is detected, reducing the frequency and output voltage, without the use of foldback. Additional features include: VCC under-voltage lockout, thermal shutdown, gate drive under-voltage lockout, and maximum duty cycle limiter.

### Features

- AEC-Q100 Grade 1 qualified (-40°C to 125°C)
- Maximum switching frequency: 2.6 MHz ( $V_{IN}=14V, V_o=3.3V$ )
- Input Voltage Range: 6V to 40V
- Integrated N-Channel buck switch
- Integrated start-up regulator
- No loop compensation required
- Ultra-Fast transient response
- Operating frequency remains constant with load current and input voltage
- Maximum Duty Cycle Limited During Start-Up
- Adjustable output voltage
- Valley Current Limit At 0.64A
- Precision internal reference
- Low bias current
- Highly efficient operation
- Thermal shutdown

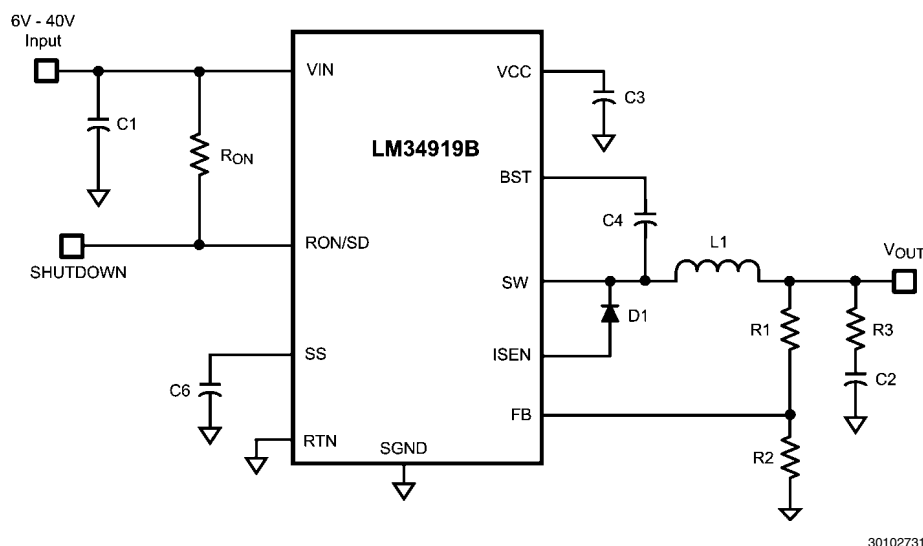
### Typical Applications

- Automotive Safety and Infotainment
- High Efficiency Point-Of-Load (POL) Regulator
- Non-Isolated Telecommunication Buck Regulator
- Secondary High Voltage Post Regulator

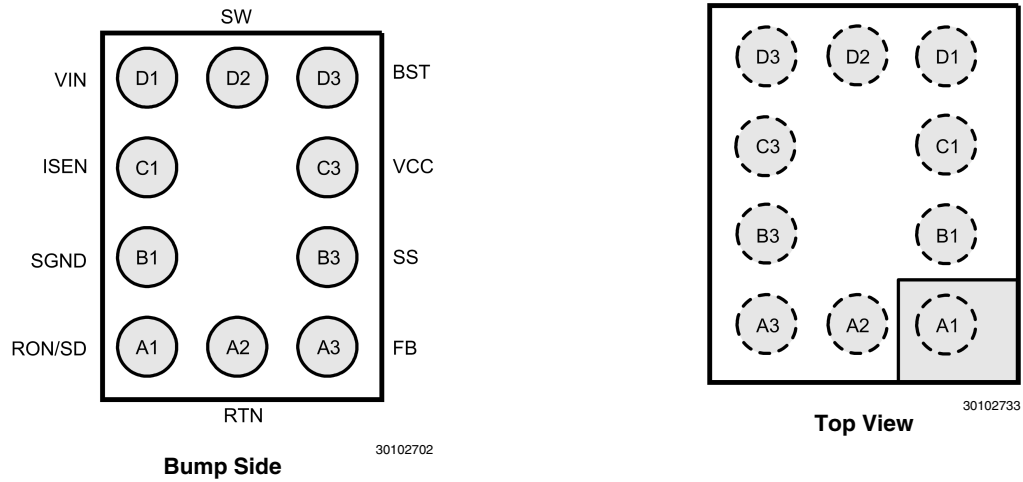
### Package

- micro SMD (2mm x 2mm)

### Basic Step Down Regulator



## Connection Diagrams



## Ordering Information

Order Number	Package Type	NSC Package Drawing	Junction Temperature Range	Supplied As	Feature
LM34919BQTL	10-Bump micro SMD	TLP10KAA	-40°C to + 125°C	250 Units on Tape and Reel	AEC-Q100 Grade 1 qualified. Automotive Grade Production Flow. *
LM34919BQTLX	10-Bump micro SMD	TLP10KAA		3000 Units on Tape and Reel	
LM34919BTL	10-Bump micro SMD	TLP10KAA	-40°C to + 125°C	250 Units on Tape and Reel	
LM34919BTLX	10-Bump micro SMD	TLP10KAA		3000 Units on Tape and Reel	

For detailed information on micro SMD packages, refer to the Application Note AN-1112.

\*Automotive grade (Q) product incorporates enhanced manufacturing and support processes for the automotive market, including defect detection methodologies. Reliability qualification is compliant with the requirements and temperature grades defined in the AEC-Q100 standard. Automotive grade products are identified with the letter Q. For more information go to <http://www.national.com/automotive>.

## Pin Descriptions

Pin Number	Name	Description	Application Information
A1	RON/SD	On-time control and shutdown	An external resistor from VIN to this pin sets the buck switch on-time. Grounding this pin shuts down the regulator.
A2	RTN	Circuit Ground	Ground for all internal circuitry other than the current limit detection.
A3	FB	Feedback input from the regulated output	Internally connected to the regulation and over-voltage comparators. The regulation level is 2.5V.
B1	SGND	Sense Ground	Re-circulating current flows into this pin to the current sense resistor.
B3	SS	Softstart	An internal current source charges an external capacitor to 2.5V, providing the softstart function.
C1	ISEN	Current sense	The re-circulating current flows through the internal sense resistor, and out of this pin to the free-wheeling diode. Current limit is nominally set at 0.64A.
C3	VCC	Output from the startup regulator	Nominally regulated at 7.0V. An external voltage (7V-14V) can be applied to this pin to reduce internal dissipation. An internal diode connects VCC to VIN.
D1	VIN	Input supply voltage	Nominal input range is 6.0V to 40V.
D2	SW	Switching Node	Internally connected to the buck switch source. Connect to the inductor, free-wheeling diode, and bootstrap capacitor.
D3	BST	Boost pin for bootstrap capacitor	Connect a 0.022 $\mu$ F capacitor from SW to this pin. The capacitor is charged from $V_{CC}$ via an internal diode during each off-time.

**Absolute Maximum Ratings** (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

V <sub>IN</sub> to RTN	44V
BST to RTN	52V
SW to RTN (Steady State)	-1.5V to 44V
ESD Rating (Note 2)	
Human Body Model	2kV
BST to V <sub>CC</sub>	44V
BST to SW	14V
V <sub>CC</sub> to RTN	14V

SGND to RTN	-0.3V to +0.3V
SS, RON/SD to RTN	-0.3V to 4V
FB to RTN	-0.3 to 7V
Storage Temperature Range	-65°C to +150°C
For soldering specs see:	
www.national.com/ms/MS/MS-SOLDERING.pdf	
Junction Temperature	150°C

**Operating Ratings** (Note 1)

V <sub>IN</sub>	6.0V to 40V
Junction Temperature	-40°C to + 125°C

**Electrical Characteristics** Specifications with standard type are for T<sub>J</sub> = 25°C only; limits in **boldface** type apply over the full Operating Junction Temperature (T<sub>J</sub>) range. Minimum and Maximum limits are guaranteed through test, design, or statistical correlation. Typical values represent the most likely parametric norm at T<sub>J</sub> = 25°C, and are provided for reference purposes only. Unless otherwise stated the following conditions apply: V<sub>IN</sub> = 12V, R<sub>ON</sub> = 20kΩ. See (Note 4).

Symbol	Parameter	Conditions	Min	Typ	Max	Units	
<b>Start-Up Regulator, V<sub>CC</sub></b>							
V <sub>CC</sub> Reg	V <sub>CC</sub> regulated output	V <sub>IN</sub> = 12V	<b>6.6</b>	7	<b>7.4</b>	V	
		V <sub>IN</sub> = 6V, I <sub>CC</sub> = 3 mA,	<b>5.3</b>	5.91			
	V <sub>IN</sub> -V <sub>CC</sub> dropout voltage	I <sub>CC</sub> = 0 mA, non-switching V <sub>CC</sub> = UVLO <sub>VCC</sub> + 250 mV		20		mV	
	V <sub>CC</sub> Output Impedance	0 mA ≤ I <sub>CC</sub> ≤ 5 mA, V <sub>IN</sub> = 6V			24	Ω	
0 mA ≤ I <sub>CC</sub> ≤ 5 mA, V <sub>IN</sub> = 8V				12			
	V <sub>CC</sub> current limit (Note 3)	V <sub>CC</sub> = 0V		15		mA	
UVLO <sub>VCC</sub>	V <sub>CC</sub> under-voltage lockout threshold measured at V <sub>CC</sub>	V <sub>CC</sub> increasing		5.25		V	
		V <sub>CC</sub> decreasing		5.1	<b>5.25</b>	V	
	UVLO <sub>VCC</sub> hysteresis, at V <sub>CC</sub>			150		mV	
	V <sub>CC</sub> under-voltage lock-out threshold measured at V <sub>IN</sub>	V <sub>IN</sub> increasing, I <sub>CC</sub> = 3 mA			5.25	<b>5.6</b>	V
		V <sub>IN</sub> decreasing, I <sub>CC</sub> = 3 mA			5.1	<b>5.4</b>	V
	UVLO <sub>VCC</sub> filter delay	100 mV overdrive		3		μs	
I <sub>Q</sub>	I <sub>IN</sub> operating current	Non-switching, FB = 3V, SW = Open		0.78	<b>1.0</b>	mA	
I <sub>SD</sub>	I <sub>IN</sub> shutdown current	RON/SD = 0V, SW = Open		215	<b>330</b>	μA	
<b>Switch Characteristics</b>							
R <sub>ds(on)</sub>	Buck Switch R <sub>ds(on)</sub>	I <sub>TEST</sub> = 200 mA		0.5	<b>1.0</b>	Ω	
UVLO <sub>GD</sub>	Gate Drive UVLO	V <sub>BST</sub> - V <sub>SW</sub> Increasing	<b>2.65</b>	3.6	<b>4.40</b>	V	
		V <sub>BST</sub> - V <sub>SW</sub> Decreasing		3.2			
	UVLO <sub>GD</sub> hysteresis			400		mV	
<b>Softstart Pin</b>							
V <sub>SS</sub>	Pull-up voltage			2.5		V	
	Internal current source	V <sub>SS</sub> = 1V		10.5		μA	
<b>Current Limit</b>							
I <sub>LIM</sub>	Threshold	Current out of ISEN	<b>0.52</b>	0.64	<b>0.76</b>	A	
	Resistance from ISEN to SGND			135		mΩ	
	Response time			50		ns	
<b>On Timer</b>							
t <sub>ON</sub> - 1	On-time	V <sub>IN</sub> = 12V, R <sub>ON</sub> = 20kΩ	<b>127</b>	170	<b>213</b>	ns	
t <sub>ON</sub> - 2	On-time	V <sub>IN</sub> = 24V, R <sub>ON</sub> = 20 kΩ		110		ns	
t <sub>ON</sub> - 3	On-time	V <sub>IN</sub> = 6V, R <sub>ON</sub> = 20 kΩ		335		ns	
	Shutdown threshold	Voltage at RON/SD rising	<b>0.4</b>	0.74	<b>1.2</b>	V	

Symbol	Parameter	Conditions	Min	Typ	Max	Units
	Threshold hysteresis	Voltage at RON/SD		40		mV
<b>Off Timer</b>						
$t_{OFF}$	Minimum Off-time	$V_{IN} = 6V, I_{CC} = 3mA$	<b>60</b>	88	<b>120</b>	ns
		$V_{IN} = 8V, I_{CC} = 3mA$	<b>58</b>	82	<b>118</b>	
<b>Regulation and Over-Voltage Comparators (FB Pin)</b>						
$V_{REF}$	FB regulation threshold	SS pin = steady state	<b>2.440</b>	2.5	<b>2.550</b>	V
	FB over-voltage threshold			2.9		V
	FB bias current	FB = 3V		1		nA
<b>Thermal Shutdown</b>						
$T_{SD}$	Thermal shutdown temperature			175		°C
	Thermal shutdown hysteresis			20		°C
<b>Thermal Resistance</b>						
$\theta_{JA}$	Junction to Ambient 0 LFPM Air Flow			61		°C/W

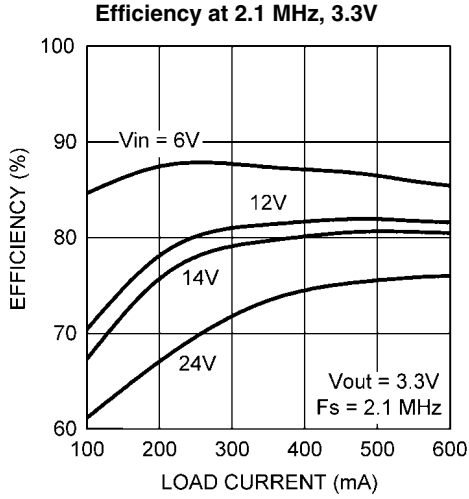
**Note 1:** Absolute Maximum Ratings are limits beyond which damage to the device may occur. Operating Ratings are conditions under which operation of the device is intended to be functional. For guaranteed specifications and test conditions, see the Electrical Characteristics.

**Note 2:** The human body model is a 100pF capacitor discharged through a 1.5k $\Omega$  resistor into each pin.

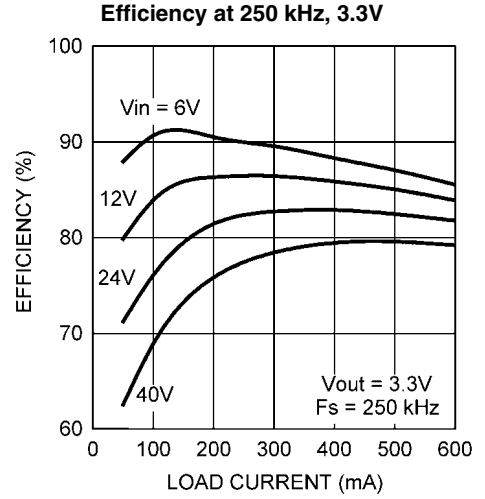
**Note 3:**  $V_{CC}$  provides self bias for the internal gate drive and control circuits. Device thermal limitations limit external loading

**Note 4:** Typical specifications represent the most likely parametric norm at 25°C operation.

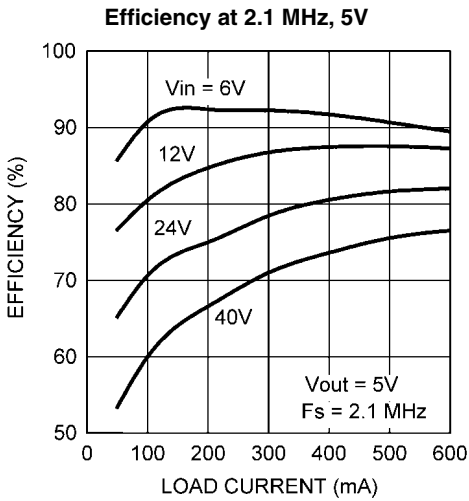
# Typical Performance Characteristics



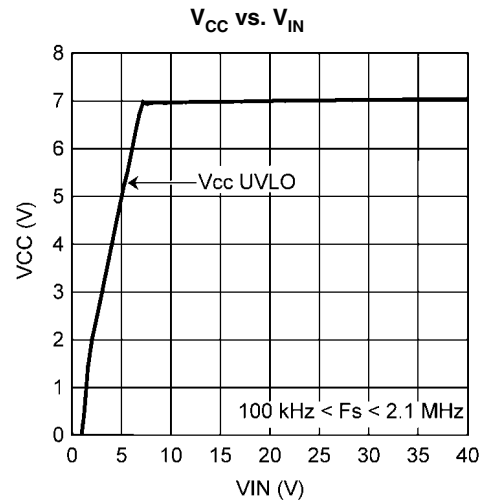
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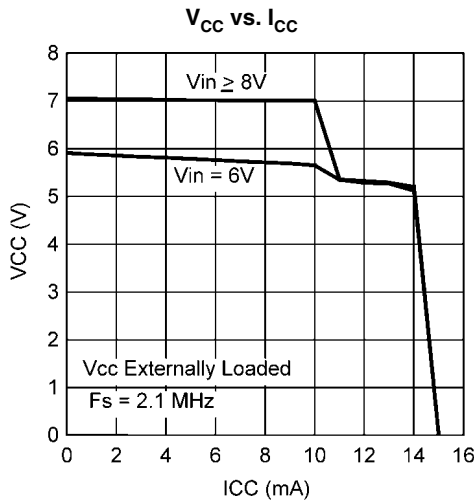
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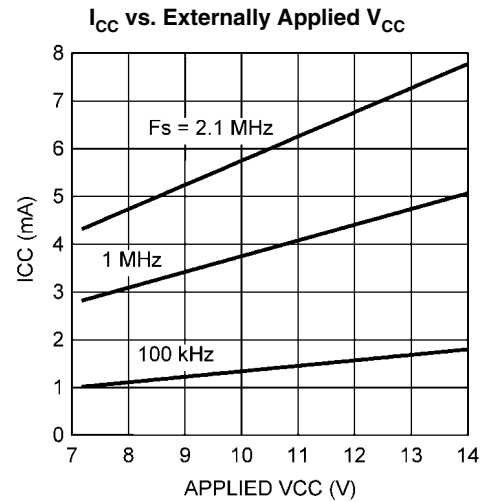
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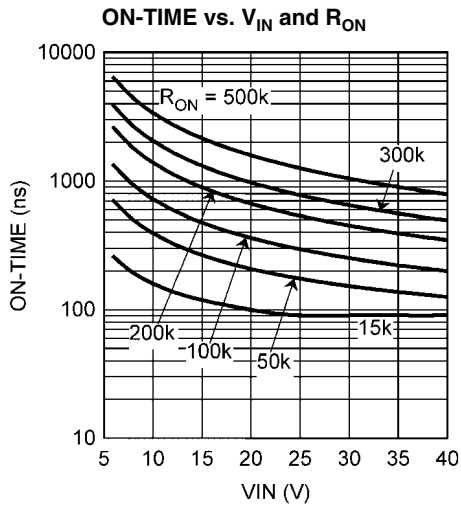
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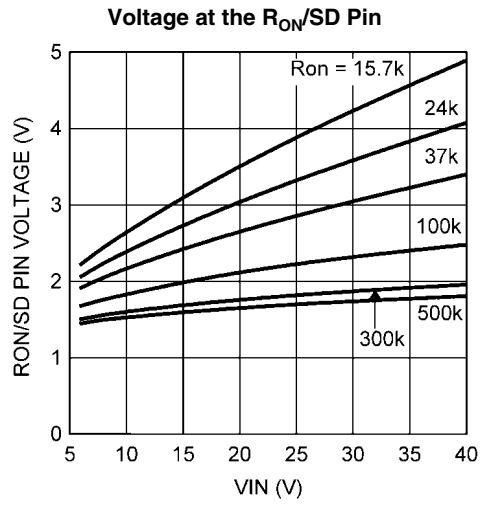
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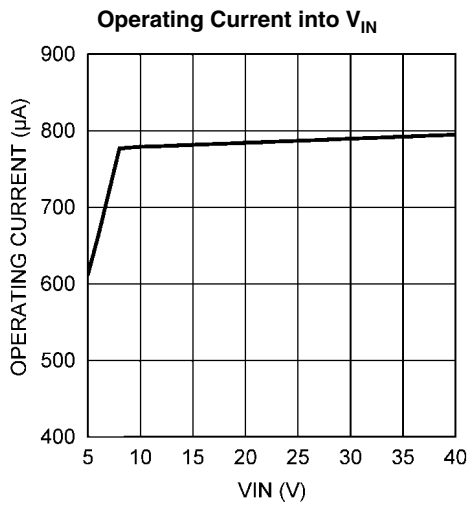
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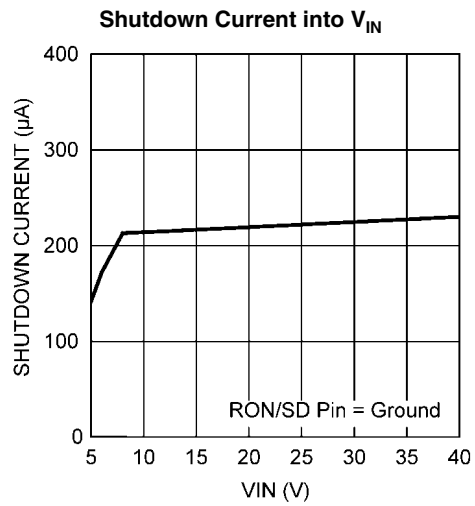
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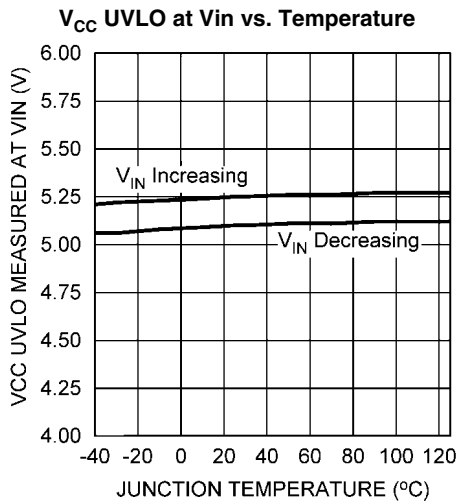
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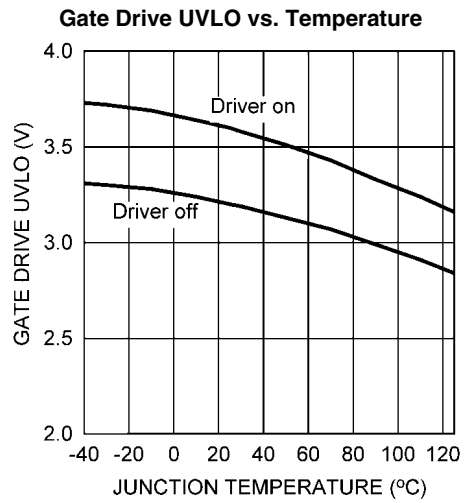
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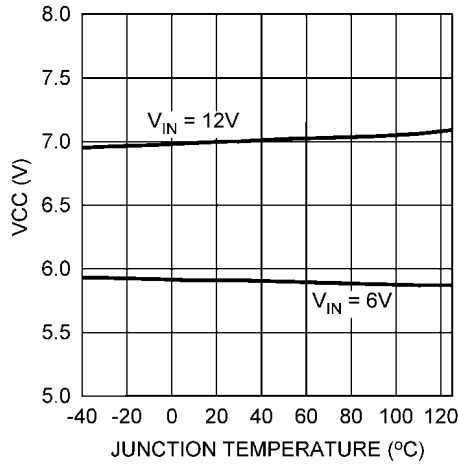


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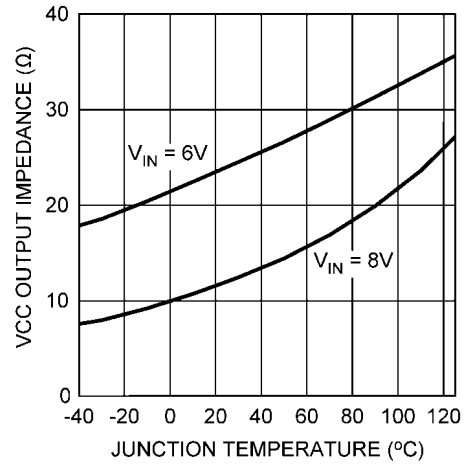
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**V<sub>CC</sub> Voltage vs. Temperature**



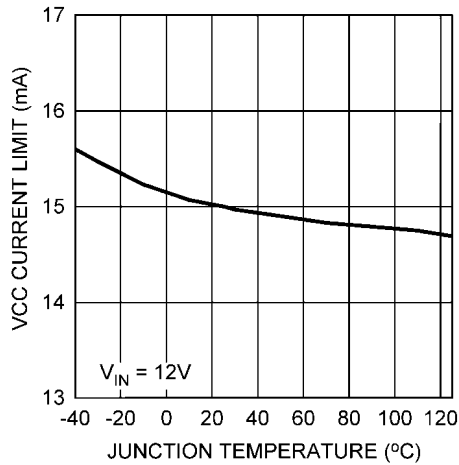
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**V<sub>CC</sub> Output Impedance vs. Temperature**



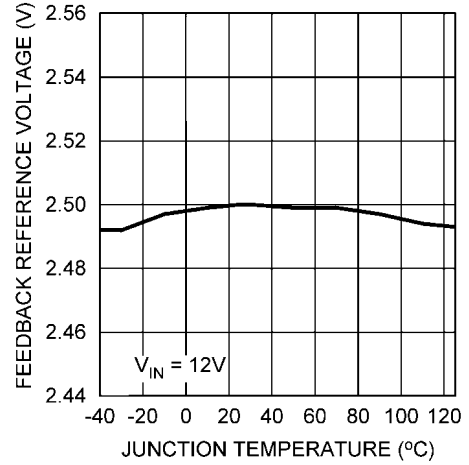
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**V<sub>CC</sub> Current Limit vs. Temperature**



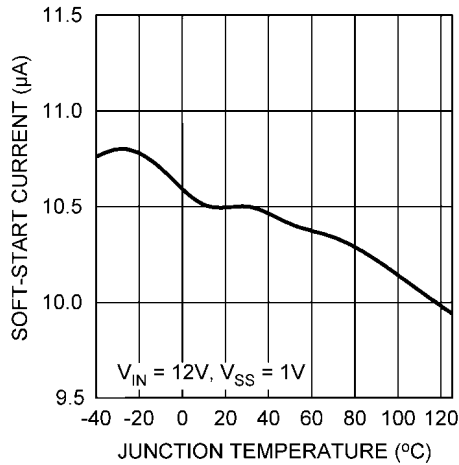
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**Reference Voltage vs. Temperature**



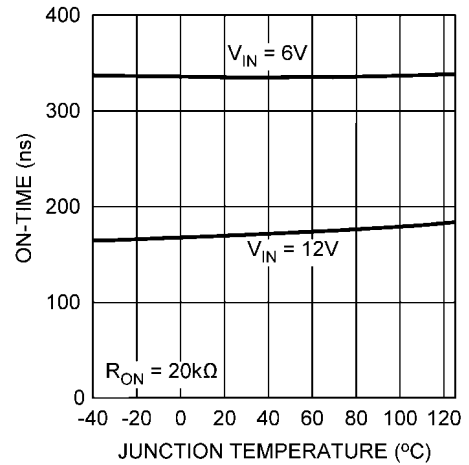
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**Soft-Start Current vs. Temperature**



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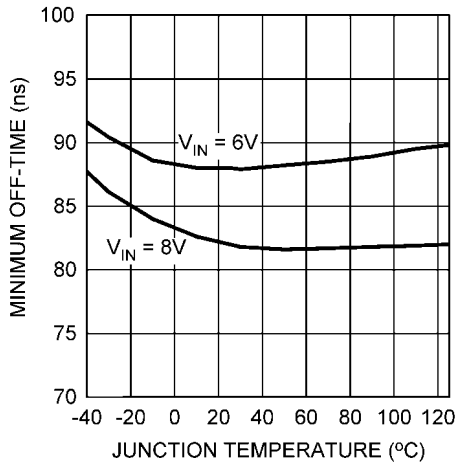
**On-Time vs. Temperature**



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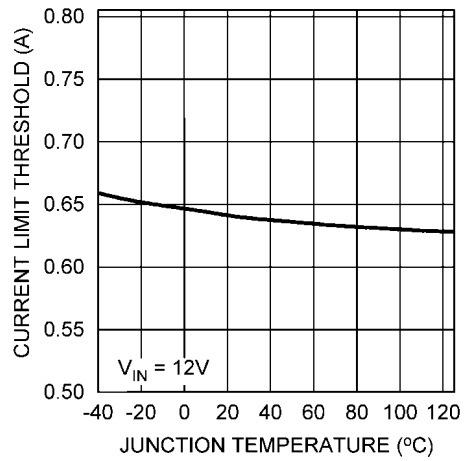


Minimum Off-Time vs. Temperature



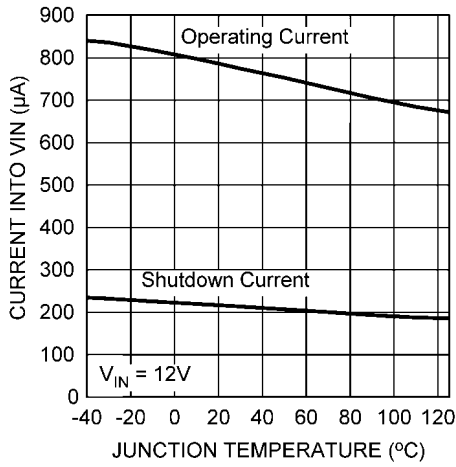
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Current Limit Threshold vs. Temperature



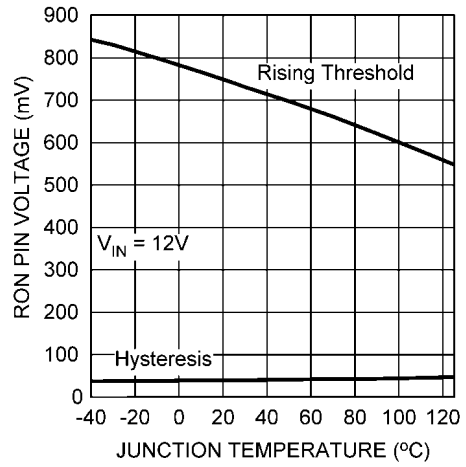
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Operating & Shutdown Current vs. Temperature



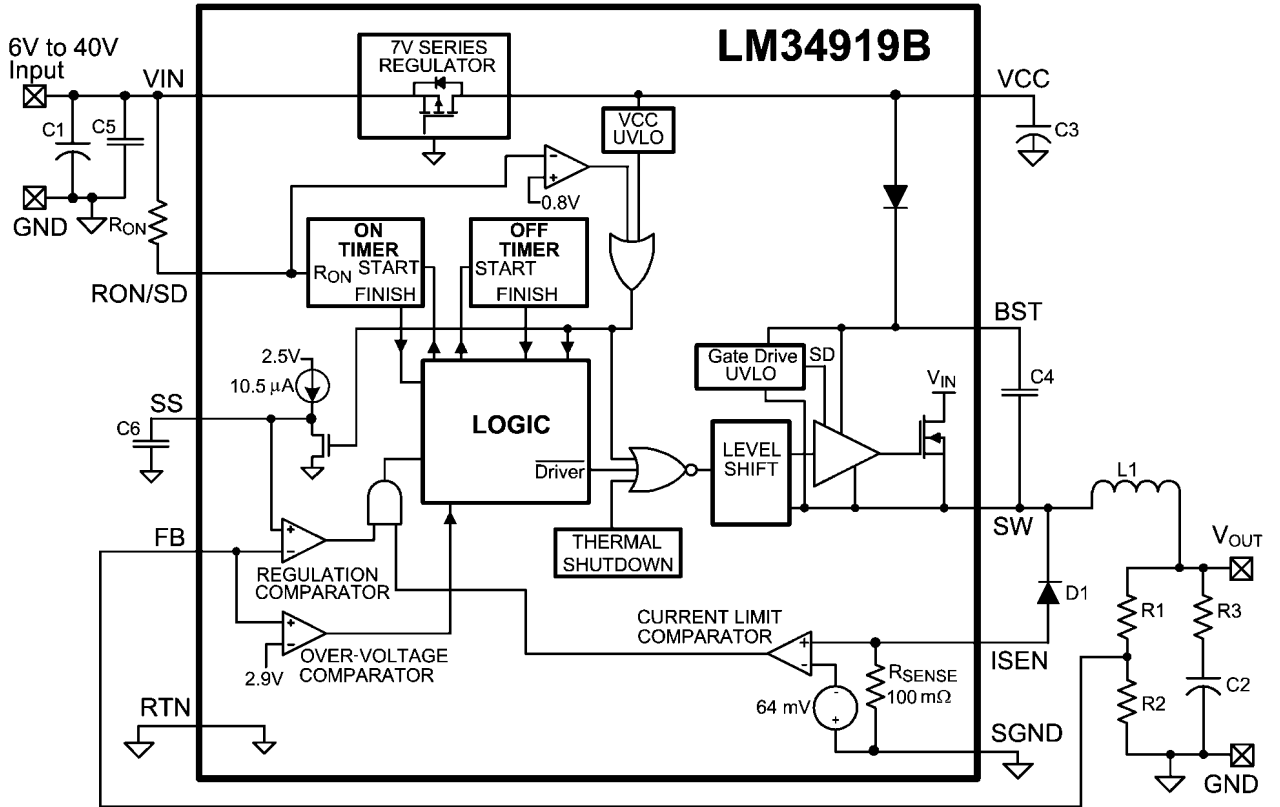
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RON Pin Shutdown Threshold vs. Temperature

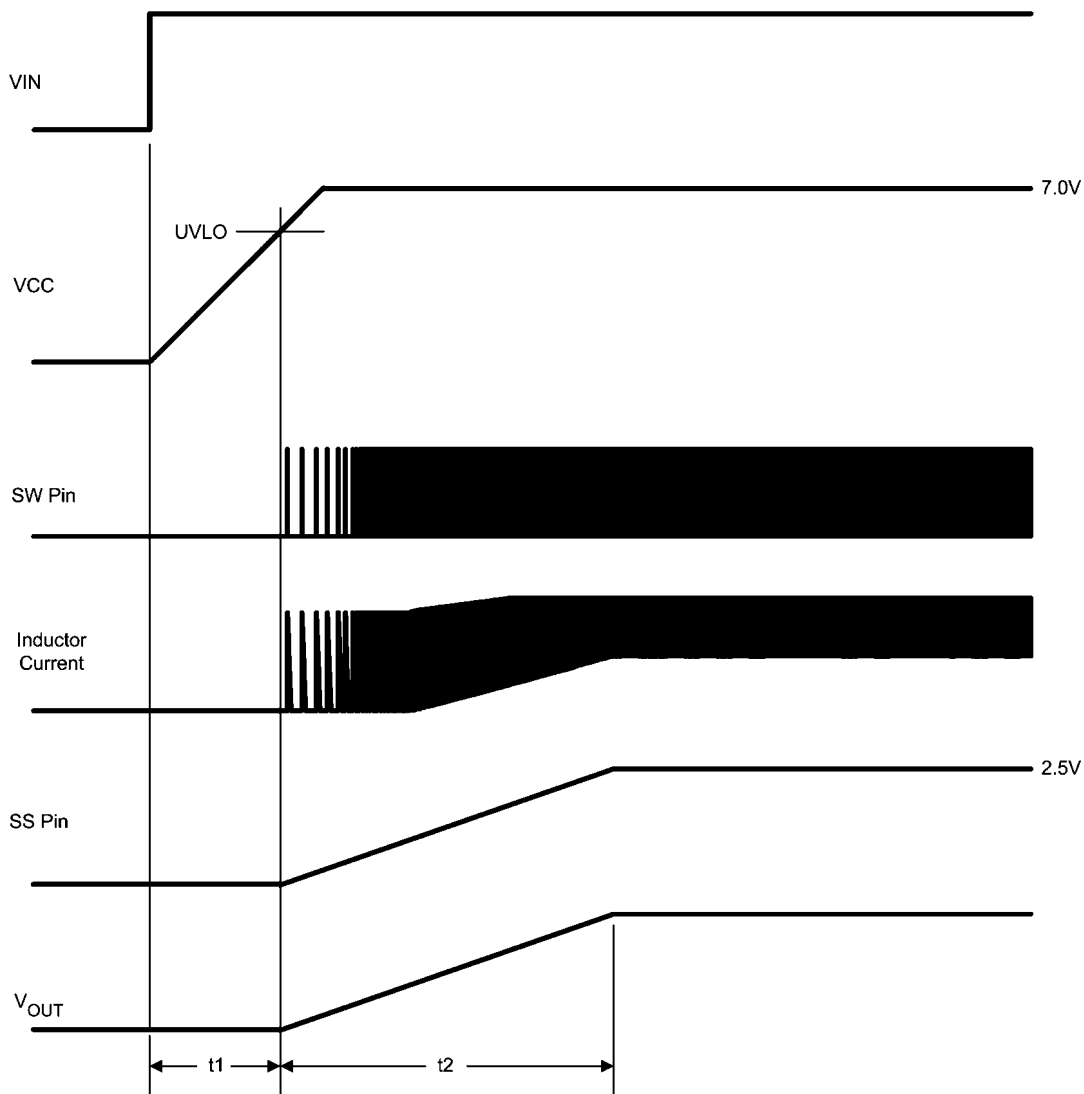


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# Block Diagram



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FIGURE 1. Start Up Sequence

## Functional Description

The LM34919B Step Down Switching Regulator features all the functions needed to implement a low cost, efficient buck bias power converter capable of supplying at least 0.6A to the load. This high voltage regulator contains an N-Channel buck switch, is easy to implement, and is available in micro SMD package. The regulator's operation is based on a constant on-time control scheme, where the on-time is determined by  $V_{IN}$ . This feature allows the operating frequency to remain relatively constant with load and input voltage variations. The feedback control requires no loop compensation resulting in very fast load transient response. The valley current limit detection circuit, internally set at 0.64A, holds the buck switch off until the high current level subsides. This scheme protects against excessively high current if the output is short-circuited when  $V_{IN}$  is high.

The LM34919B can be applied in numerous applications to efficiently regulate down higher voltages. Additional features include: Thermal shutdown,  $V_{CC}$  under-voltage lockout, gate drive under-voltage lockout, and maximum duty cycle limiter.

## Control Circuit Overview

The LM34919B buck DC-DC regulator employs a control scheme based on a comparator and a one-shot on-timer, with the output voltage feedback (FB) compared to an internal reference (2.5V). If the FB voltage is below the reference the buck switch is turned on for a time period determined by the input voltage and a programming resistor ( $R_{ON}$ ). Following the on-time the switch remains off until the FB voltage falls below the reference but not less than the minimum off-time. The buck switch then turns on for another on-time period. Typically, during start-up, or when the load current increases suddenly, the off-times are at the minimum. Once regulation is established, the off-times are longer.

When in regulation, the LM34919B operates in continuous conduction mode at heavy load currents and discontinuous conduction mode at light load currents. In continuous conduction mode current always flows through the inductor, never reaching zero during the off-time. In this mode the operating frequency remains relatively constant with load and line variations. The minimum load current for continuous con-

duction mode is one-half the inductor's ripple current amplitude. The operating frequency is approximately:

$$F_s = \frac{V_{OUT} \times (V_{IN} - 1.5V)}{0.565 \times 10^{-10} \times (R_{ON} + 1.4 \text{ k}\Omega) \times V_{IN}} \quad (1)$$

The buck switch duty cycle is approximately equal to:

$$DC = \frac{t_{ON}}{t_{ON} + t_{OFF}} = \frac{V_{OUT}}{V_{IN}} \quad (2)$$

In discontinuous conduction mode current through the inductor ramps up from zero to a peak during the on-time, then ramps back to zero before the end of the off-time. The next on-time period starts when the voltage at FB falls below the reference - until then the inductor current remains zero, and the load current is supplied by the output capacitor. In this mode the operating frequency is lower than in continuous conduction mode, and varies with load current. Conversion efficiency is maintained at light loads since the switching losses decrease with the reduction in load and frequency. The approximate discontinuous operating frequency can be calculated as follows:

$$F_s = \frac{V_{OUT}^2 \times L_1 \times 6.27 \times 10^{20}}{R_L \times (R_{ON})^2} \quad (3)$$

where  $R_L$  = the load resistance.

The output voltage is set by two external resistors (R1, R2). The regulated output voltage is calculated as follows:

$$V_{OUT} = 2.5 \times (R1 + R2) / R2$$

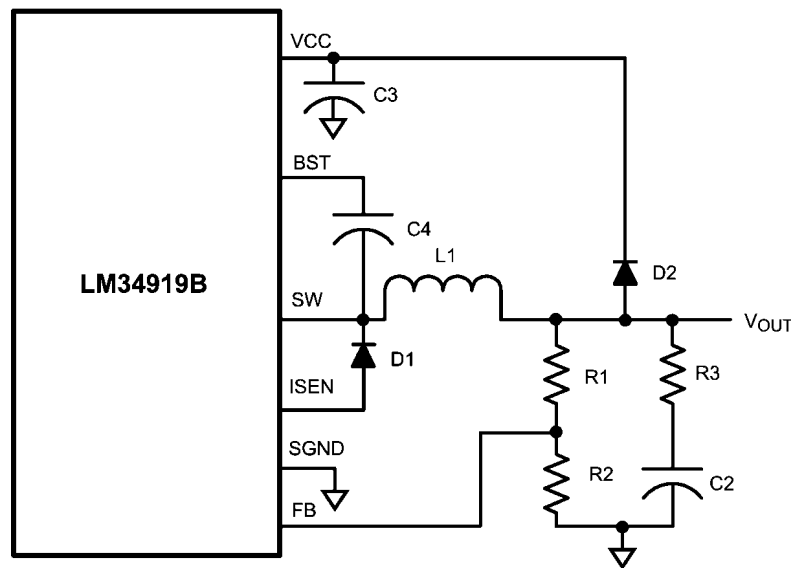
Output voltage regulation is based on ripple voltage at the feedback input, normally obtained from the output voltage ripple through the feedback resistors. The LM34919B requires a minimum of 25 mV of ripple voltage at the FB pin. In cases where the capacitor's ESR is insufficient additional series resistance may be required (R3).

## Start-Up Regulator, $V_{CC}$

The start-up regulator is integral to the LM34919B. The input pin (VIN) can be connected directly to line voltage up to 40V, with transient capability to 44V. The  $V_{CC}$  output regulates at 7.0V, and is current limited at 15 mA. Upon power up, the regulator sources current into the external capacitor at VCC (C3). When the voltage on the VCC pin reaches the under-voltage lockout threshold of 5.25V, the buck switch is enabled and the Softstart pin is released to allow the Softstart capacitor (C6) to charge up.

The minimum input voltage is determined by the  $V_{CC}$  UVLO falling threshold ( $\approx 5.1V$ ). When  $V_{CC}$  falls below the falling threshold the  $V_{CC}$  UVLO activates to shut off the output. If  $V_{CC}$  is externally loaded, the minimum input voltage increases.

To reduce power dissipation in the start-up regulator, an auxiliary voltage can be diode connected to the  $V_{CC}$  pin. Setting the auxiliary voltage to between 7V and 14V shuts off the internal regulator, reducing internal power dissipation. The sum of the auxiliary voltage and the input voltage ( $V_{CC} + V_{IN}$ ) cannot exceed 52V. Internally, a diode connects VCC to VIN. See Figure 2.



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FIGURE 2. Self Biased Configuration

## Regulation Comparator

The feedback voltage at FB is compared to the voltage at the Softstart pin (2.5V). In normal operation (the output voltage is regulated), an on-time period is initiated when the voltage at FB falls below 2.5V. The buck switch stays on for the programmed on-time, causing the FB voltage to rise above 2.5V. After the on-time period, the buck switch stays off until the FB voltage falls below 2.5V. Input bias current at the FB pin is less than 100 nA over temperature.

## Over-Voltage Comparator

The voltage at FB is compared to an internal 2.9V reference. If the voltage at FB rises above 2.9V the on-time pulse is immediately terminated. This condition can occur if the input voltage or the output load changes suddenly, or if the inductor (L1) saturates. The buck switch remains off until the voltage at FB falls below 2.5V.

## ON-Time Timer, and Shutdown

The on-time is determined by the  $R_{ON}$  resistor and the input voltage ( $V_{IN}$ ), and is calculated from:

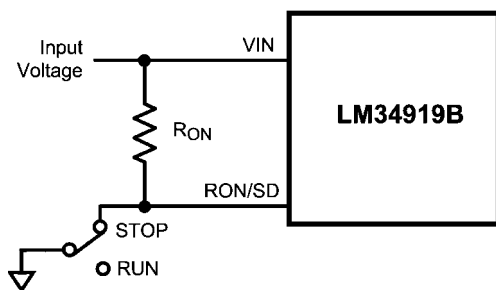
$$t_{ON} = \frac{0.565 \times 10^{-10} \times (R_{ON} + 1.4 \text{ k}\Omega)}{V_{IN} - 1.5V} + 55 \text{ ns} \quad (4)$$

The inverse relationship with  $V_{IN}$  results in a nearly constant frequency as  $V_{IN}$  is varied. To set a specific continuous conduction mode switching frequency ( $F_S$ ), the  $R_{ON}$  resistor is determined from the following:

$$R_{ON} = \frac{V_{OUT} \times (V_{IN} - 1.5V)}{F_S \times 0.565 \times 10^{-10} \times V_{IN}} - 1.4 \text{ k}\Omega \quad (5)$$

In high frequency applications the minimum value for  $t_{ON}$  is limited by the maximum duty cycle required for regulation and the minimum off-time. The minimum off-time limits the maximum duty cycle achievable with a low voltage at  $V_{IN}$ . At high values of  $V_{IN}$ , the minimum on-time is limited to  $\approx 90$  ns.

The LM34919B can be remotely shut down by taking the RON/SD pin low. See Figure 3. In this mode the SS pin is internally grounded, the on-timer is disabled, and bias currents are reduced. Releasing the RON/SD pin allows normal operation to resume. The voltage at the RON/SD pin is between 1.4V and 5.0V, depending on  $V_{IN}$  and the  $R_{ON}$  resistor.



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FIGURE 3. Shutdown Implementation

## Current Limit

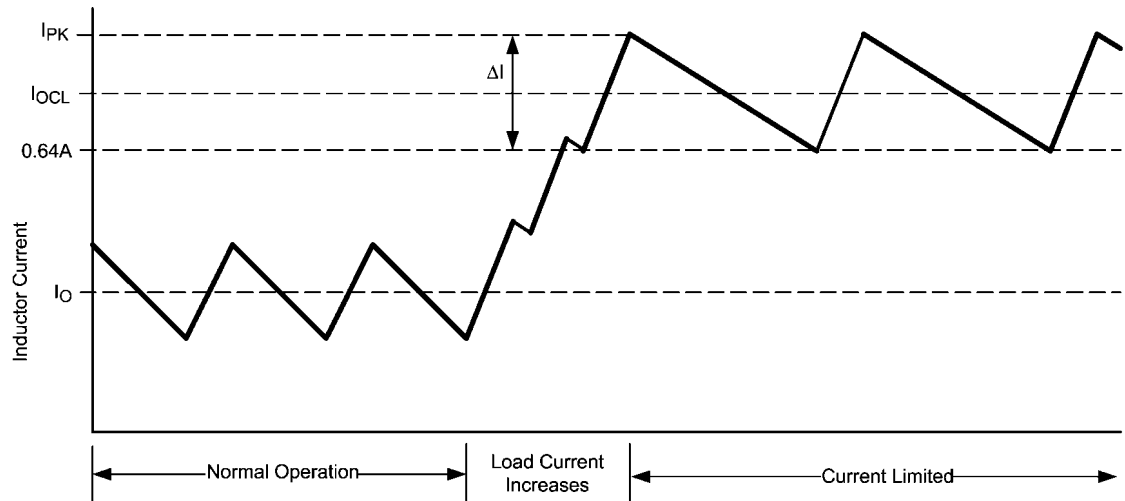
Current limit detection occurs during the off-time by monitoring the recirculating current through the free-wheeling diode (D1). Referring to the Block Diagram, when the buck switch is turned off the inductor current flows through the load, into SGND, through the sense resistor, out of ISEN and through D1. If that current exceeds 0.64A the current limit comparator output switches to delay the start of the next on-time period. The next on-time starts when the current out of ISEN is below 0.64A and the voltage at FB is below 2.5V. If the overload condition persists causing the inductor current to exceed 0.64A during each on-time, that is detected at the beginning of each off-time. The operating frequency is lower due to longer-than-normal off-times.

Figure 4 illustrates the inductor current waveform. During normal operation the load current is  $I_O$ , the average of the ripple waveform. When the load resistance decreases the current ratchets up until the lower peak reaches 0.64A. During the Current Limited portion of Figure 4, the current ramps down to 0.64A during each off-time, initiating the next on-time (assuming the voltage at FB is  $< 2.5V$ ). During each on-time the current ramps up an amount equal to:

$$\Delta I = (V_{IN} - V_{OUT}) \times t_{ON} / L1$$

During this time the LM34919B is in a constant current mode, with an average load current ( $I_{OCL}$ ) equal to  $0.64A + \Delta I/2$ .

Generally, in applications where the switching frequency is higher than  $\approx 300$  kHz and uses a small value inductor, the higher  $dI/dt$  of the inductor's ripple current results in an effectively lower valley current limit threshold due to the response time of the current limit detection circuit. However, since the small value inductor results in a relatively high ripple current amplitude ( $\Delta I$  in Figure 4), the load current ( $I_{OCL}$ ) at current limit is typically in excess of 640 mA.



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FIGURE 4. Inductor Current - Current Limit Operation

## N - Channel Buck Switch and Driver

The LM34919B integrates an N-Channel buck switch and associated floating high voltage gate driver. The peak current allowed through the buck switch is 1.5A, and the maximum allowed average current is 1A. The gate driver circuit works in conjunction with an external bootstrap capacitor and an internal high voltage diode. A 0.022  $\mu$ F capacitor (C4) connected between BST and SW provides the voltage to the driver during the on-time. During each off-time, the SW pin is at approximately -1V, and C4 charges from  $V_{CC}$  through the internal diode. The minimum off-time forced by the LM34919B ensures a minimum time each cycle to recharge the bootstrap capacitor.

## Softstart

The softstart feature allows the converter to gradually reach a steady state operating point, thereby reducing start-up stresses and current surges. Upon turn-on, after  $V_{CC}$  reaches the under-voltage threshold, an internal 10.5  $\mu$ A current source charges up the external capacitor at the SS pin to 2.5V. The ramping voltage at SS (and the non-inverting input of the regulation comparator) ramps up the output voltage in a controlled manner.

An internal switch grounds the SS pin if  $V_{CC}$  is below the under-voltage lockout threshold, or if the RON/SD pin is grounded.

## Thermal Shutdown

The LM34919B should be operated so the junction temperature does not exceed 125°C. If the junction temperature increases, an internal Thermal Shutdown circuit, which activates (typically) at 175°C, takes the controller to a low power reset state by disabling the buck switch. This feature helps prevent catastrophic failures from accidental device overheating. When the junction temperature reduces below 155°C (typical hysteresis = 20°C) normal operation resumes.

## Applications Information

### EXTERNAL COMPONENTS

The procedure for calculating the external components is illustrated with the following design example. Referring to the Block Diagram, the circuit is to be configured for the following specifications:

- $V_{OUT} = 3.3V$
- $V_{IN} = 6V$  to 24V
- Minimum load current = 200 mA
- Maximum load current = 600 mA
- Switching Frequency = 1.5 MHz
- Soft-start time = 5 ms

**R1 and R2:** These resistors set the output voltage. The ratio of the feedback resistors is calculated from:

$$R1/R2 = (V_{OUT}/2.5V) - 1$$

For this example,  $R1/R2 = 0.32$ . R1 and R2 should be chosen from standard value resistors in the range of 1.0 k $\Omega$  - 10 k $\Omega$  which satisfy the above ratio. For this example, 2.49k $\Omega$  is chosen for R2 and 787 $\Omega$  for R1.

**R<sub>ON</sub>:** This resistor sets the on-time, and (by default) the switching frequency. The switching frequency must be less than 1.53 MHz to ensure the minimum forced on-time does not interfere with the circuit's proper operation at the maximum input voltage. The  $R_{ON}$  resistor is calculated from the following equation, using the minimum input voltage.

$$R_{ON} = \frac{V_{OUT} \times (V_{IN(min)} - 1.5V)}{F_S \times 0.565 \times 10^{-10} \times V_{IN(min)}} - 1.4 \text{ k}\Omega = 27.8 \text{ k}\Omega$$

Check that this value resistor does not set an on-time less than 90 ns at maximum  $V_{IN}$ .

A standard value 28 k $\Omega$  resistor is used, resulting in a nominal frequency of 1.49 MHz. The minimum on-time is  $\approx 129$  ns at  $V_{in} = 24V$ , and the maximum on-time is  $\approx 424$  ns at  $V_{in} = 6V$ . Alternately,  $R_{ON}$  can be determined using Equation 4 if a specific on-time is required.

**L1:** The main parameter affected by the inductor is the inductor current ripple amplitude ( $I_{OR}$ ). The minimum load current is used to determine the maximum allowable ripple in order to maintain continuous conduction mode, where the lower peak does not reach 0 mA. This is not a requirement of the LM34919B, but serves as a guideline for selecting L1. For this case the maximum ripple current is:

$$I_{OR(MAX)} = 2 \times I_{OUT(min)} = 400 \text{ mA} \quad (6)$$

If the minimum load current is zero, use 20% of  $I_{OUT(max)}$  for  $I_{OUT(min)}$  in equation 6. The ripple calculated in Equation 6 is then used in the following equation:

$$L1 = \frac{(V_{IN(max)} - V_{OUT}) \times t_{ON(min)}}{I_{OR(max)}} = 6.67 \text{ } \mu\text{H} \quad (7)$$

A standard value 8.2  $\mu\text{H}$  inductor is selected. The maximum ripple amplitude, which occurs at maximum  $V_{IN}$ , calculates to 325 mA p-p, and the peak current is 763 mA at maximum load current. Ensure the selected inductor is rated for this peak current.

**C2 and R3:** Since the LM34919B requires a minimum of 25 mVp-p ripple at the FB pin for proper operation, the required ripple at  $V_{OUT}$  is increased by R1 and R2. This necessary ripple is created by the inductor ripple current flowing through R3, and to a lesser extent by C2 and its ESR. The minimum inductor ripple current is calculated using equation 7, rearranged to solve for  $I_{OR}$  at minimum  $V_{IN}$ .

$$I_{OR(min)} = \frac{(V_{IN(min)} - V_{OUT}) \times t_{on(max)}}{L1} = 140 \text{ mA}$$

The minimum value for R3 is equal to:

$$R3_{(min)} = \frac{25 \text{ mV} \times (R1 + R2)}{R2 \times I_{OR (min)}} = 0.24 \Omega$$

A standard value 0.27  $\Omega$  resistor is used for R3 to allow for tolerances. C2 should generally be no smaller than 3.3  $\mu\text{F}$ , although that is dependent on the frequency and the desired output characteristics. C2 should be a low ESR good quality ceramic capacitor. Experimentation is usually necessary to determine the minimum value for C2, as the nature of the load may require a larger value. A load which creates significant transients requires a larger value for C2 than a non-varying load.

**C1 and C5:** C1's purpose is to supply most of the switch current during the on-time, and limit the voltage ripple at  $V_{IN}$ , on the assumption that the voltage source feeding  $V_{IN}$  has an output impedance greater than zero.

At maximum load current, when the buck switch turns on, the current into  $V_{IN}$  suddenly increases to the lower peak of the

inductor's ripple current, ramps up to the upper peak, then drops to zero at turn-off. The average current during the on-time is the load current. For a worst case calculation, C1 must supply this average load current during the maximum on-time, without letting the voltage at  $V_{IN}$  drop more than 0.5V. The minimum value for C1 is calculated from:

$$C1 = \frac{I_{OUT (max)} \times t_{ON}}{\Delta V} = 0.5 \text{ } \mu\text{F}$$

where  $t_{ON}$  is the maximum on-time, and  $\Delta V$  is the allowable ripple voltage (0.5V). C5's purpose is to minimize transients and ringing due to long lead inductance leading to the  $V_{IN}$  pin. A low ESR, 0.1  $\mu\text{F}$  ceramic chip capacitor must be located close to the  $V_{IN}$  and  $RTN$  pins.

**C3:** The capacitor at the VCC pin provides noise filtering and stability for the Vcc regulator. C3 should be no smaller than 0.1  $\mu\text{F}$ , and should be a good quality, low ESR, ceramic capacitor. C3's value, and the  $V_{CC}$  current limit, determine a portion of the turn-on-time ( $t_1$  in Figure 1).

**C4:** The recommended value for C4 is 0.022  $\mu\text{F}$ . A high quality ceramic capacitor with low ESR is recommended as C4 supplies a surge current to charge the buck switch gate at each turn-on. A low ESR also helps ensure a complete recharge during each off-time.

**C6:** The capacitor at the SS pin determines the softstart time, i.e. the time for the output voltage, to reach its final value ( $t_2$  in Figure 1). The capacitor value is determined from the following:

$$C6 = \frac{t_2 \times 10.5 \text{ } \mu\text{A}}{2.5\text{V}} = 0.021 \text{ } \mu\text{F}$$

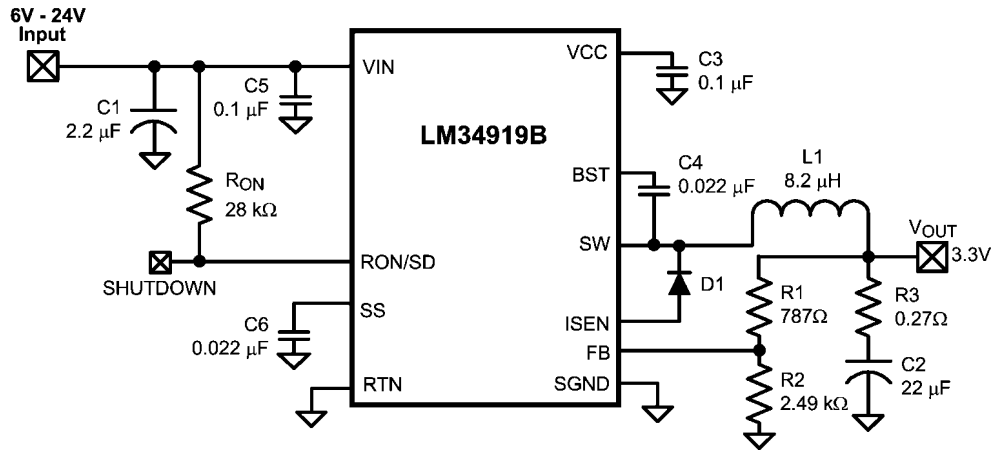
**D1:** A Schottky diode is recommended. Ultra-fast recovery diodes are not recommended as the high speed transitions at the SW pin may inadvertently affect the IC's operation through external or internal EMI. The diode should be rated for the maximum input voltage, the maximum load current, and the peak current which occurs when the current limit and maximum ripple current are reached simultaneously. The diode's average power dissipation is calculated from:

$$P_{D1} = V_F \times I_{OUT} \times (1-D)$$

where  $V_F$  is the diode's forward voltage drop, and D is the on-time duty cycle.

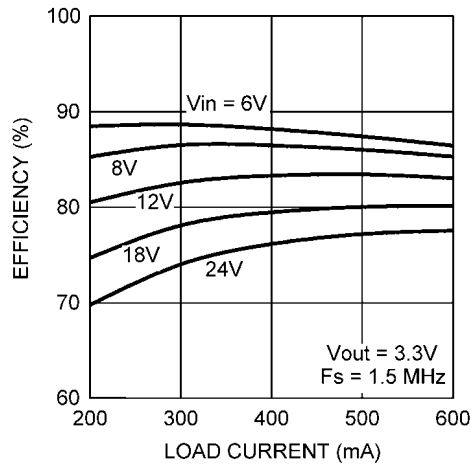
## FINAL CIRCUIT

The final circuit is shown in Figure 5, and its performance is shown in Figure 6 and Figure 7. Current limit measured approximately 780 mA at 6V, and 812 mA at 24V.



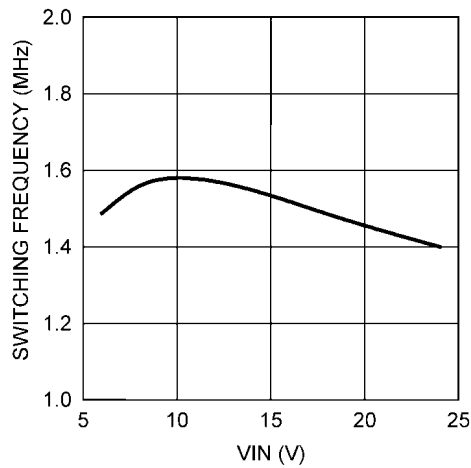
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FIGURE 5. Example Circuit



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FIGURE 6. Efficiency (Circuit of Figure 5)



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FIGURE 7. Frequency vs.  $V_{IN}$  (Circuit of Figure 5)



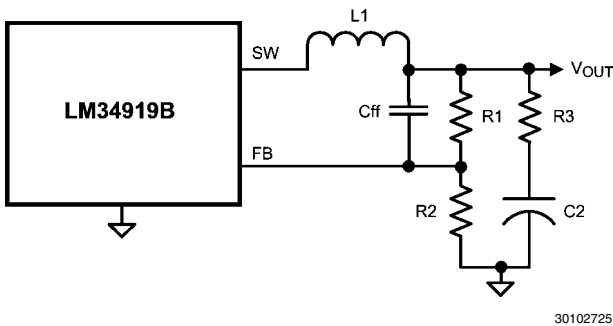
## LOW OUTPUT RIPPLE CONFIGURATIONS

For applications where lower ripple at  $V_{OUT}$  is required, the following options can be used to reduce or nearly eliminate the ripple.

**a) Reduced ripple configuration:** In Figure 8, Cff is added across R1 to AC-couple the ripple at  $V_{OUT}$  directly to the FB pin. This allows the ripple at  $V_{OUT}$  to be reduced to a minimum of 25 mVp-p by reducing R3, since the ripple at  $V_{OUT}$  is not attenuated by the feedback resistors. The minimum value for Cff is determined from:

$$C_{ff} = \frac{t_{ON(max)} \times 3}{(R1/R2)}$$

where  $t_{ON(max)}$  is the maximum on-time, which occurs at  $V_{IN(min)}$ . The next larger standard value capacitor should be used for Cff. R1 and R2 should be each be towards the upper end of the 2 k $\Omega$  to 10 k $\Omega$  range.



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FIGURE 8. Reduced Ripple Configuration

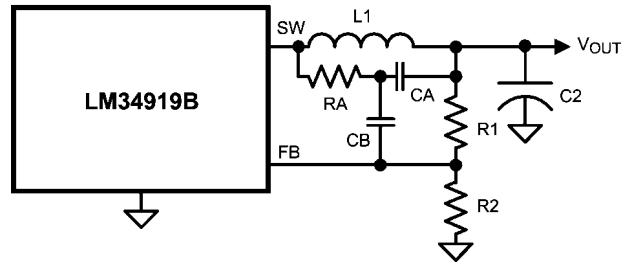
**b) Minimum ripple configuration:** The circuit of Figure 9 provides minimum ripple at  $V_{OUT}$ , determined primarily by C2's characteristics and the inductor's ripple current since R3 is removed. RA and CA are chosen to generate a sawtooth waveform at their junction, and that voltage is AC-coupled to the FB pin via CB. To determine the values for RA, CA and CB, use the following procedure:

$$\text{Calculate } V_A = V_{OUT} - (V_{SW} \times (1 - (V_{OUT}/V_{IN(min)})))$$

where  $V_{SW}$  is the absolute value of the voltage at the SW pin during the off-time (typically 1V).  $V_A$  is the DC voltage at the RA/CA junction, and is used in the next equation.

$$RA \times CA = \frac{(V_{IN(min)} - V_A) \times t_{ON}}{\Delta V}$$

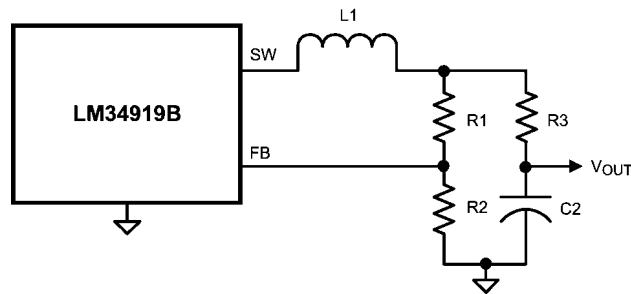
where  $t_{ON}$  is the maximum on-time (at minimum input voltage), and  $\Delta V$  is the desired ripple amplitude at the RA/CA junction, typically 50 mV. RA and CA are then chosen from standard value components to satisfy the above product. Typically CA is 3000 pF to 5000 pF, and RA is 10 k $\Omega$  to 300 k $\Omega$ . CB is then chosen large compared to CA, typically 0.1  $\mu$ F. R1 and R2 should be each be towards the upper end of the 2 k $\Omega$  to 10 k $\Omega$  range.



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FIGURE 9. Minimum Output Ripple Using Ripple Injection

**c) Alternate minimum ripple configuration:** The circuit in Figure 10 is the same as that in Figure 5, except the output voltage is taken from the junction of R3 and C2. The ripple at  $V_{OUT}$  is determined by the inductor's ripple current and C2's characteristics. However, R3 slightly degrades the load regulation. This circuit may be suitable if the load current is fairly constant.



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FIGURE 10. Alternate Minimum Output Ripple Configuration

### Minimum Load Current

The LM34919B requires a minimum load current of 1 mA. If the load current falls below that level, the bootstrap capacitor (C4) may discharge during the long off-time, and the circuit will either shutdown, or cycle on and off at a low frequency. If the load current is expected to drop below 1 mA in the application, R1 and R2 should be chosen low enough in value so they provide the minimum required current at nominal  $V_{OUT}$ .

### PC BOARD LAYOUT

Refer to application note AN-1112 for PC board guidelines for the Micro SMD package.

The LM34919B regulation, over-voltage, and current limit comparators are very fast, and respond to short duration noise pulses. Layout considerations are therefore critical for optimum performance. The layout must be as neat and compact as possible, and all of the components must be as close as possible to their associated pins. The two major current loops have currents which switch very fast, and so the loops should be as small as possible to minimize conducted and radiated EMI. The first loop is that formed by C1, through the VIN to SW pins, L1, C2, and back to C1. The second current loop is formed by D1, L1, C2 and the SGND and ISEN pins.

The power dissipation within the LM34919B can be approximated by determining the total conversion loss ( $P_{IN} - P_{OUT}$ ), and then subtracting the power losses in the free-wheeling diode and the inductor. The power loss in the diode is approximately:

$$P_{D1} = I_{out} \times V_F \times (1-D)$$

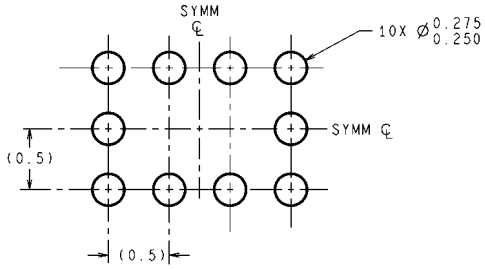
where  $I_{out}$  is the load current,  $V_F$  is the diode's forward voltage drop, and  $D$  is the on-time duty cycle. The power loss in the inductor is approximately:

$$P_{L1} = I_{out}^2 \times R_L \times 1.1$$

where  $R_L$  is the inductor's DC resistance, and the 1.1 factor is an approximation for the AC losses. If it is expected that the

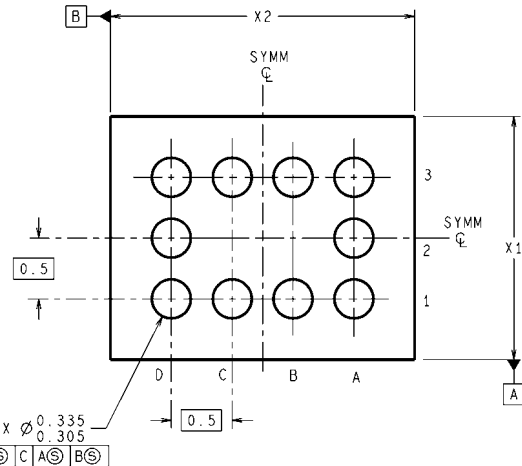
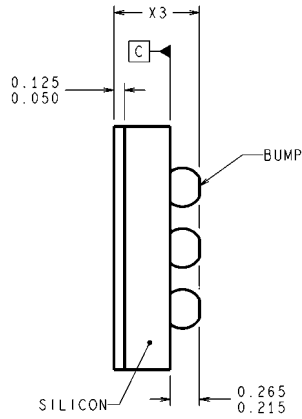
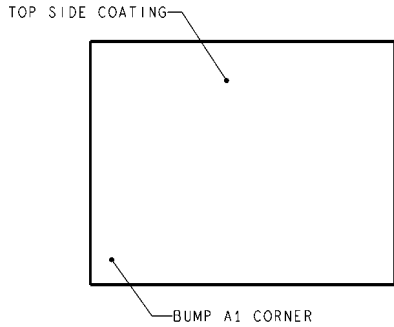
internal dissipation of the LM34919B will produce excessive junction temperatures during normal operation, good use of the PC board's ground plane can help to dissipate heat. Additionally the use of wide PC board traces, where possible, can help conduct heat away from the IC. Judicious positioning of the PC board within the end product, along with the use of any available air flow (forced or natural convection) can help reduce the junction temperatures.

**Physical Dimensions** inches (millimeters) unless otherwise noted



**DIMENSIONS ARE IN MILLIMETERS**  
DIMENSIONS IN ( ) FOR REFERENCE ONLY

**LAND PATTERN RECOMMENDATION**



⌀	0.005	S	C	A	⊗	B	S
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TLP10XXX (Rev D)

**Note:** X1 = 1.753 mm, ±0.030 mm  
X2 = 1.987 mm, ±0.030 mm  
X3 = 0.60 mm, ±0.075 mm

**10 Bump micro SMD Package**  
**NS Package Number TLP10KAA**

## Notes

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Interface	<a href="http://www.national.com/interface">www.national.com/interface</a>	Eval Boards	<a href="http://www.national.com/evalboards">www.national.com/evalboards</a>
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Voltage References	<a href="http://www.national.com/vref">www.national.com/vref</a>	Design Made Easy	<a href="http://www.national.com/easy">www.national.com/easy</a>
PowerWise® Solutions	<a href="http://www.national.com/powerwise">www.national.com/powerwise</a>	Applications & Markets	<a href="http://www.national.com/solutions">www.national.com/solutions</a>
Serial Digital Interface (SDI)	<a href="http://www.national.com/sdi">www.national.com/sdi</a>	Mil/Aero	<a href="http://www.national.com/milaero">www.national.com/milaero</a>
Temperature Sensors	<a href="http://www.national.com/tempensors">www.national.com/tempensors</a>	SolarMagic™	<a href="http://www.national.com/solarmagic">www.national.com/solarmagic</a>
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