LINEAR TECHNOLOGY

High Voltage Step-Up/Step-Down DC/DC Converter

September 2003

FEATURES

- **Automatic Step-Up and Step-Down Conversion**
- **Uses a Single Inductor**
- **Wide 4V to 60V Input Voltage Range**
- **V_{OUT} from 3.3V to 20V**
- **Dual Internal 500mA Switches**
- 100µA No-Load Quiescent Current
- Low Current Shutdown
- ±1% Output Voltage Accuracy
- 200kHz Operating Frequency
- Boosted Supply Pin to Saturate High Side Switch
- Frequency Foldback Protection
- Current Limit Foldback Protection
- Current Limit Unaffected by Duty Cycle
- 16-lead Thermally Enhanced TSSOP Package

APPLICATIONS

- 12V Automotive Systems
- Wall Adapter Powered Systems
- Battery Power Voltage Buffering

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Burst Mode is a registered trademark of Linear Technology Corporation.

DESCRIPTION

The LT®3433 is a 200kHz fixed-frequency current mode switching regulator that provides both step-up and step-down regulation using a single inductor. The IC operates over a 4V to 60V input voltage range making it suitable for use in various wide input voltage range applications such as automotive electronics that must withstand both load dump and cold crank conditions.

Internal control circuitry monitors system conditions and converts from single switch buck operation to dual switch bridged operation when required, seamlessly changing between step-down and step-up voltage conversion.

Optional Burst Mode® operation reduces no-load quiescent current to 100µA and maintains high efficiencies with light loads.

Current limit foldback and frequency foldback help prevent inductor current runaway during start-up. Programmable soft-start helps prevent output overshoot at start-up.
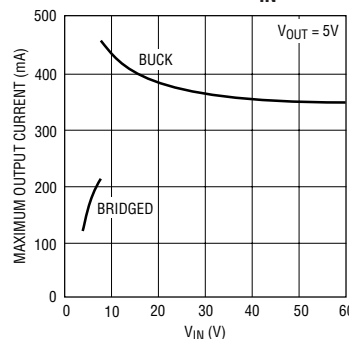
The LT3433 is available in a 16-lead thermally enhanced TSSOP package.
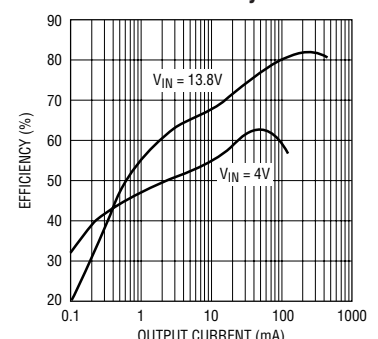
TYPICAL APPLICATION

4V to 60V to 5V DC/DC Converter
with Burst Mode Operation
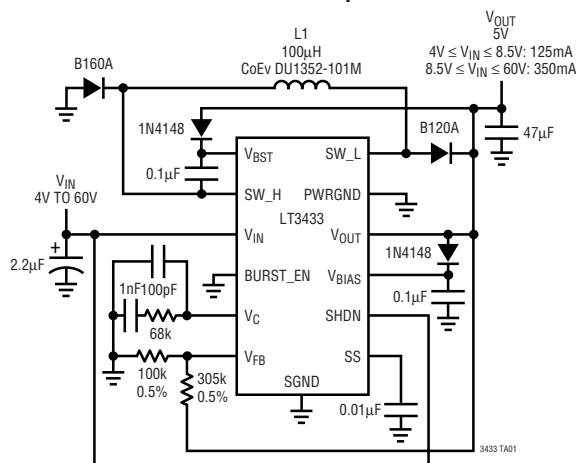
Maximum Output Current vs V_{IN}

Efficiency

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1

LT3433

ABSOLUTE MAXIMUM RATINGS

Input Supply (V_{IN}) .... −0.3V to 60V
Boosted Supply (V_{BST}) .... −0.3V to V_{SW_H} + 30V
($V_{BST(MAX)}$ = 80V)
Internal Supply (V_{BIAS}) .... −0.3V to 30V
SW_H Switch Voltage .... −2V to 60V
SW_L Switch Voltage .... −0.3V to 30V
Feedback Voltage (V_{FB}) .... −0.3V to 5V
Operating Junction Temperature Range (Note 5)
   LT3433E (Note 6) .... −40°C to 125°C
   LT3433I .... −40°C to 125°C
Storage Temperature Range .... −65°C to 150°C
Lead Temperature (Soldering, 10 sec)................ 300°C

PACKAGE/ORDER INFORMATION

TOP VIEW		ORDER PART NUMBER	
SGND ☐ 1	16 ☐ SGND		
V_{BST} ☐ 2	15 ☐ SW_L	LT3433EFE	
SW_H ☐ 3	14 ☐ PWRGND	LT3433IFE	
V_{IN} ☐ 4	17	13 ☐ V_{OUT}	
BURST_EN ☐ 5	12 ☐ V_{BIAS}		
V_C ☐ 6	11 ☐ SHDN	FE PART MARKING	
V_{FB} ☐ 7	10 ☐ SS		
SGND ☐ 8	9 ☐ SGND	3433EFE	
		3433IFE	

FE PACKAGE
16-LEAD PLASTIC TSSOP

T_{JMAX} = 125°C, θ_{JA} = 40°C/W, θ_{JC} = 10°C/W
EXPOSED PAD (PIN 17) MUST BE SOLDERED TO SGND

Consult LTC Marketing for parts specified with wider operating temperature ranges.

ELECTRICAL CHARACTERISTICS

The ● denotes specifications that apply over the full operating temperature range, otherwise specifications are at T_A = 25°C.
V_{IN} = 13.8V, V_{FB} = 1.25V, V_{OUT} = 5V, V_{BURST_EN} = 0V, $V_{BST} − V_{IN}$ = 5V, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{IN}	Operating Voltage Range		●	4		60	V
$V_{IN(UVLO)}$	Undervoltage Lockout	Enable Threshold	●		3.4	3.95	V
	Undervoltage Lockout Hysteresis				160		mV
V_{OUT}	Operating Voltage Range		●	3.3		20	V
V_{BST}	Operating Voltage Range	$V_{BST} < V_{SW\_H}$ + 20V	●			75	V
		$V_{BST} − V_{SW\_H}$	●	3.3		20	V
I_{VIN}	Normal Operation	(Notes 2, 3)	●		580	940	µA
	Burst Mode Operation	$V_{VC} < 0.6V$	●		100	190	µA
	Shutdown	$V_{SHDN} < 0.4V$	●		10	25	µA
V_{BIAS}	Internal Supply Output Voltage		●		2.6	2.9	V
	Operating Voltage Range		●			20	V
I_{VBIAS}	Normal Operation		●		660	990	µA
	Burst Mode Operation	$V_{VC} < 0.6V$			0.1		µA
	Shutdown	$V_{SHDN} < 0.4V$			0.1		µA
	Short-Circuit Current Limit				4.5		mA
$R_{SWH(ON)}$	Boost Supply Switch On-Resistance	I_{SW} = 500mA	●		0.8	1.2	Ω
$R_{SWL(ON)}$	Output Supply Switch On-Resistance	I_{SW} = 500mA	●		0.6	1	Ω
V_{SHDN}	Shutdown Pin Thresholds	Disable	●	0.4			V
		Enable	●			1	V
I_{VBST}/I_{SW}	Boost Supply Switch Drive Current	High Side Switch On, I_{SW} = 500mA	●		30	50	mA/A
I_{VOUT}/I_{SW}	Output Supply Switch Drive Current	Low Side Switch On, I_{SW} = 500mA	●		30	50	mA/A
I_{LIM}	Switch Current Limit		●	0.5	0.7	0.9	A
	Foldback Current Limit	V_{FB} = 0V			0.35		A
I_{SS}	Soft-Start Output Current		●	3	5	9	µA
V_{FB}	Feedback Reference Voltage			1.224	1.231	1.238	V
			●	1.215		1.245	V

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ELECTRICAL CHARACTERISTICS

The ● denotes specifications that apply over the full operating temperature range, otherwise specifications are at $T_A = 25°C$.
$V_{IN} = 13.8V$, $V_{FB} = 1.25V$, $V_{OUT} = 5V$, $V_{BURST\_EN} = 0V$, $V_{BST} - V_{IN} = 5V$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
ΔV_{FB}	Feedback Reference Line Regulation	$5.5V \leq V_{IN} \leq 60V$	●		0.002	0.01	%/V
I_{FB}	V_{FB} Pin Input Bias Current		●		35	100	nA
g_m	Error Amplifier Transconductance		●	200	270	330	umhos
A_V	Error Amplifier Voltage Gain				66		dB
I_{SW}/V_{VC}	Control Voltage to Switch Transconductance				0.55		A/V
f_O	Operating Frequency	$V_{FB} > 1V$	●	185 170	200	215 230	kHz kHz
	Foldback Frequency	$V_{FB} = 0V$			50		kHz
$t_{ON(MIN)}$	Minimum Switch On Time	$R_L = 35\Omega$ (Note 4)	●		250	450	ns
$t_{OFF(MIN)}$	Minimum Switch Off Time	$R_L = 35\Omega$ (Note 4)	●		500	800	ns

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

Note 2: Supply current specification does not include switch drive currents. Actual supply currents will be higher.
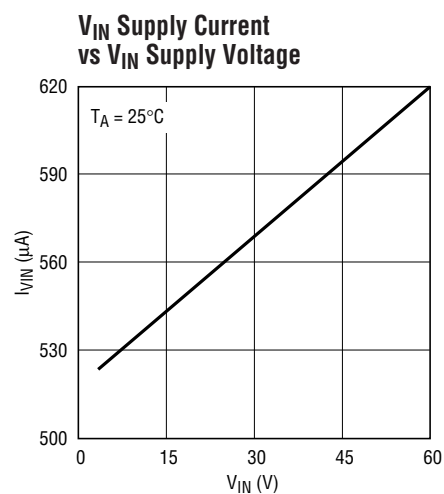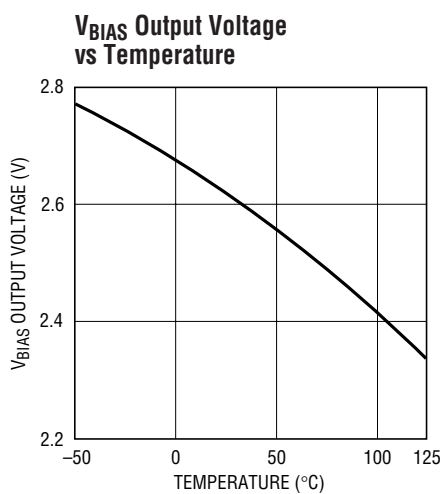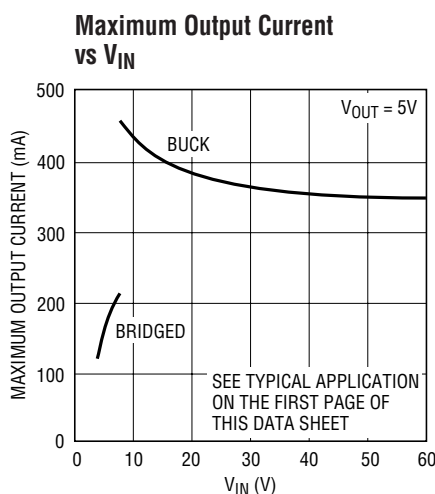
Note 3: "Normal Operation" supply current specification does not include I_{BIAS} currents. Powering the V_{BIAS} pin externally reduces I_{CC} supply current.

Note 4: Minimum times are tested using the high side switch with a 35Ω load to ground.

Note 5: This IC includes overtemperature protection that is intended to protect the device during momentary overload conditions. Junction temperature will exceed 125°C when overtemperature protection is active. Continuous operation above the specified maximum operating junction temperature may impair device reliability.
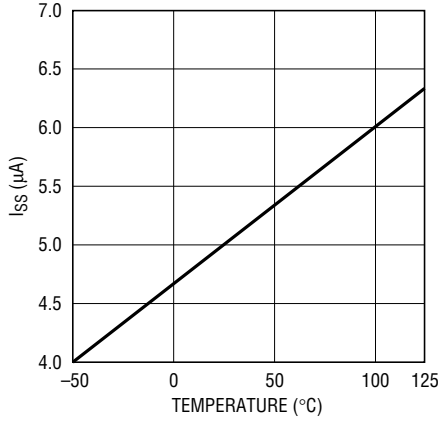
Note 6: The LT3433E is guaranteed to meet performance specifications from 0°C to 125°C junction temperature. Specifications over the –40°C to 125°C operating junction temperature range are assured by design, characterization and correlation with statistical process controls. The LT3433I is guaranteed over the full –40°C to 125°C operating junction temperature range.
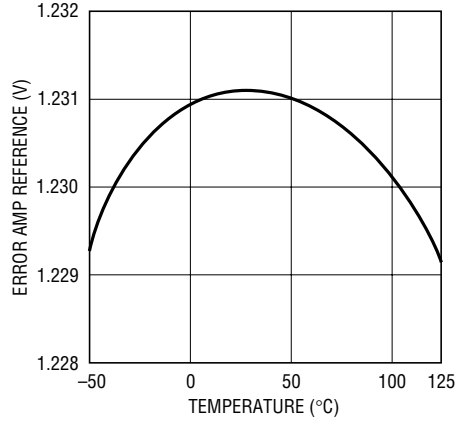
TYPICAL PERFORMANCE CHARACTERISTICS

Maximum Output Current vs V_{IN}

3433 G11

V_{BIAS} Output Voltage vs Temperature

3433 G01

V_{IN} Supply Current vs V_{IN} Supply Voltage

3433 G02

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TYPICAL PERFORMANCE CHARACTERISTICS

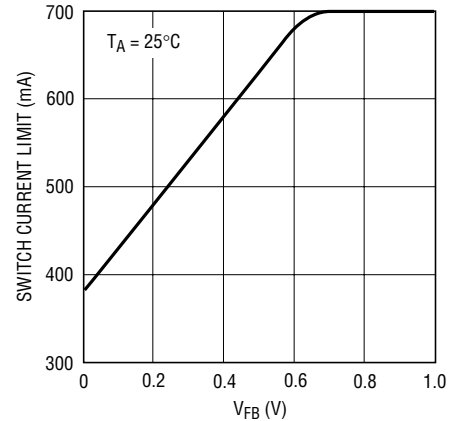**Soft-Start Current vs Temperature**

3433 G03

Error Amp Reference vs Temperature
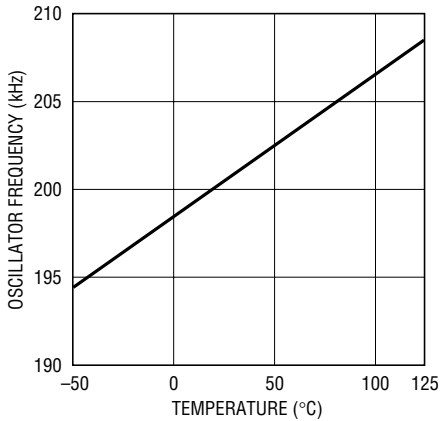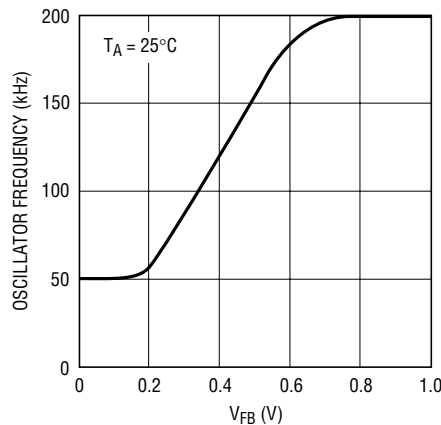

3433 G04

Switch Current Limit vs V$_{FB}$

3433 G05

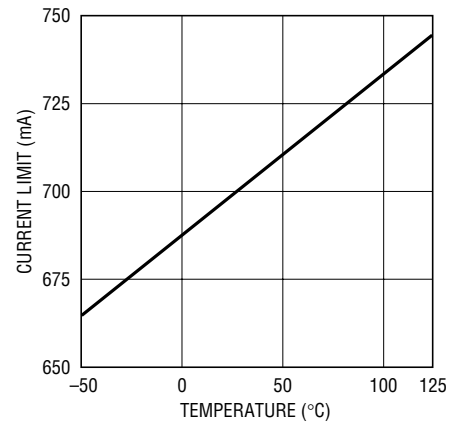**Oscillator Frequency vs Temperature**

3433 G06

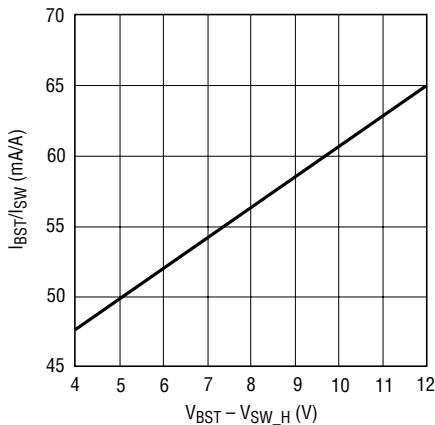**Oscillator Frequency vs V$_{FB}$**

3433 G07

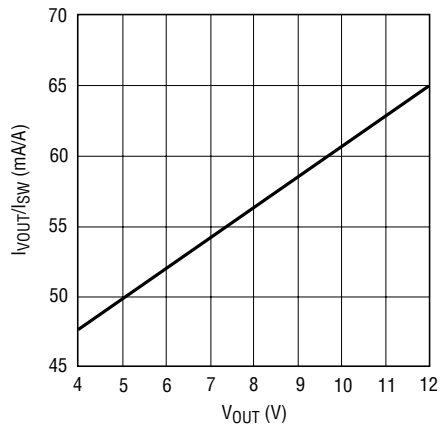**Switch Current Limit vs Temperature**

3433 G08

Maximum Boost Supply Switch Drive Current vs Boost Supply Voltage

3433 G09

Maximum Output Supply Switch Drive Current vs Output Supply Voltage

3433 G10

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4

PIN FUNCTIONS

SGND (Pins 1, 8, 9, 16): Low Noise Ground Reference.

V_{BST} (Pin 2): Boosted Switch Supply. This "boosted" supply rail is referenced to the SW_H pin. Supply voltage is maintained by a bootstrap capacitor tied from the V_{BST} pin to the SW_H pin. A 1µF capacitor is generally adequate for most applications.

The charge on the bootstrap capacitor is refreshed through a diode, typically connected from the converter output (V_{OUT}), during the switch-off period. Minimum off-time operation assures that the boost capacitor is refreshed each switch cycle. The LT3433 supports operational V_{BST} supply voltages up to 75V (absolute maximum) as referenced to ground.

SW_H (Pin 3): Boosted Switch Output. This is the current return for the boosted switch and corresponds to the emitter of the switch transistor. The boosted switch shorts the SW_H pin to the V_{IN} supply when enabled. The drive circuitry for this switch is boosted above the V_{IN} supply through the V_{BST} pin, allowing saturation of the switch for maximum efficiency. The "ON" resistance of the boosted switch is 0.8Ω.

V_{IN} (Pin 4): Input Power Supply. This pin supplies power to the boosted switch and corresponds to the collector of the switch transistor. This pin also supplies power to most of the IC's internal circuitry if the V_{BIAS} pin is not driven externally. This supply will be subject to high switching transient currents so this pin requires a high quality bypass capacitor that meets whatever application-specific input ripple current requirements exist. See Applications Information.

BURST_EN (Pin 5): Burst Mode Enable Pin. Shorting this pin to SGND enables Burst Mode operation. If Burst Mode operation is not desired, connecting this pin to V_{BIAS} or V_{OUT} will disable the burst function.

V_C (Pin 6): Error Amplifier Output. The voltage on the V_C pin corresponds to the maximum switch current per oscillator cycle. The error amplifier is typically configured as an integrator circuit by connecting an RC network from this pin to ground. This circuit typically creates the dominant pole for the converter regulation feedback loop. Specific integrator characteristics can be configured to optimize transient response. See Applications Information.

V_{FB} (Pin 7): Error Amplifier Inverting Input. The noninverting input of the error amplifier is connected to an internal 1.231V reference. The V_{FB} pin is connected to a resistor divider from the converter output. Values for the resistor connected from V_{OUT} to V_{FB} (R_{FB1}) and the resistor connected from V_{FB} to ground (R_{FB2}) can be calculated to program converter output voltage (V_{OUT}) via the following relation:

$$V_{OUT} = 1.231 \bullet (R_{FB1} + R_{FB2})/R_{FB2}$$

The V_{FB} pin input bias current is 35nA, so use of extremely high value feedback resistors could cause a converter output that is slightly higher than expected. Bias current error at the output can be estimated as:

$$\Delta V_{OUT(BIAS)} = 35nA \bullet R_{FB1}$$

The voltage on V_{FB} also controls the LT3433 oscillator frequency through a "frequency-foldback" function. When the V_{FB} pin voltage is below 0.8V, the oscillator runs slower than the 200kHz typical operating frequency. The oscillator frequency slows with reduced voltage on the pin, down to 50kHz when V_{FB} = 0V.

The V_{FB} pin voltage also controls switch current limit through a "current-limit foldback" function. At V_{FB} = 0V, the maximum switch current is reduced to half of the normal value. The current limit value increases linearly until V_{FB} reaches 0.6V when the normal maximum switch current level is restored. The frequency and current-limit foldback functions add robustness to short-circuit protection and help prevent inductor current runaway during start-up.

SS (Pin 10): Soft Start. Connect a capacitor (C_{SS}) from this pin to ground. The output voltage of the LT3433 error amplifier corresponds to the peak current sense amplifier output detected before resetting the switch output(s). The soft-start circuit forces the error amplifier output to a zero peak current for start-up. A 5µA current is forced from the SS pin onto an external capacitor. As the SS pin voltage ramps up, so does the LT3433 internally sensed peak current limit. This forces the converter output current to ramp from zero until normal output regulation is achieved. This function reduces output overshoot on converter start-up.

LT3433

PIN FUNCTIONS

The time from V_{SS} = 0V to maximum available current can be calculated given a capacitor C_{SS} as:

$$t_{SS} = (2.7 \bullet 10^5)C_{SS} \text{ or } 0.27s/\mu F$$

SHDN (Pin 11): Shutdown. If the SHDN pin is externally pulled below 0.5V, low current shutdown mode is initiated. During shutdown mode, all internal functions are disabled, and I_{CC} is reduced to 10μA. This pin is intended to receive a digital input, however, there is a small amount of input hysteresis built into the SHDN circuit to help assure glitch-free mode switching. If shutdown is not desired, connect the SHDN pin to V_{IN}.

V_{BIAS} (Pin 12): Internal Local Supply. Much of the LT3433 circuitry is powered from this supply, which is internally regulated to 2.5V through an on-board linear regulator. Current drive for this regulator is sourced from the V_{IN} pin. The V_{BIAS} supply is short-circuit protected to 5mA.

The V_{BIAS} supply only sources current, so forcing this pin above the regulated voltage allows the use of external power for much of the LT3433 circuitry. When using external drive, this pin should be driven above 3V to assure the internal supply is completely disabled. This pin is typically diode-connected to the converter output to maximize conversion efficiency. This pin must be bypassed with at least a 0.1μF ceramic capacitor to SGND.

V_{OUT} (Pin 13): Converter Output Pin. This pin voltage is compared with the voltage on V_{IN} internally to control operation in single or 2-switch mode. When the ratios of the two voltages are such that a >75% duty cycle is required for regulation, the low side switch is enabled. Drive bias for the low side switch is also derived directly from this pin.

PWRGND (Pin 14): High Current Ground Reference. This is the current return for the low side switch and corresponds to the emitter of the low side switch transistor.

SW_L (Pin 15): Ground Referenced Switch Output. This pin is the collector of the low side switch transistor. The low side switch shorts the SW_L pin to PWRGND when enabled. The series impedance of the ground-referenced switch is 0.6Ω.

BLOCK DIAGRAM
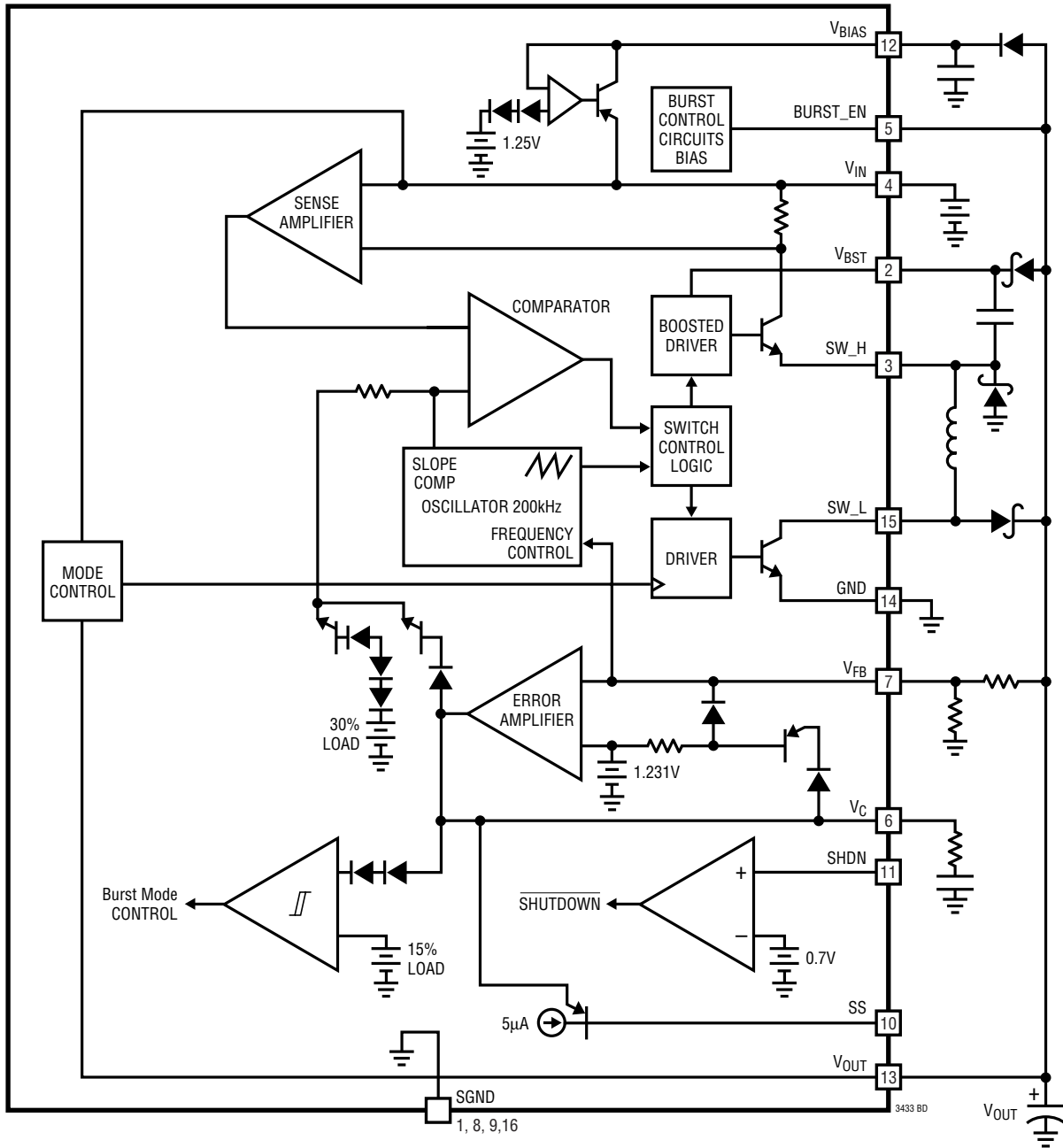
LT3433

APPLICATIONS INFORMATION

Overview

The LT3433 is a high input voltage range, step-up/step-down DC/DC converter IC using a 200kHz constant frequency, current mode architecture. Dual internal switches allow the full input voltage to be imposed across the switched inductor, such that both step-up and step-down modes of operation can be realized using the same single inductor topology.

The LT3433 has provisions for high efficiency, low load operation for battery-powered applications. Burst Mode operation reduces average quiescent current to 100μA in no load conditions. A low current shutdown mode can also be activated, reducing total quiescent current to 10μA.

Much of the LT3433's internal circuitry is biased from an internal low voltage linear regulator. The output of this regulator is brought out to the V_{BIAS} pin, allowing bypassing of the internal regulator. The associated internal circuitry can be powered directly from the output of the converter, increasing overall converter efficiency. Using externally derived power also eliminates the IC's power dissipation associated with the internal V_{IN} to V_{BIAS} regulator.

Theory of Operation (See Block Diagram)

The LT3433 senses converter output voltage via the V_{FB} pin. The difference between the voltage on this pin and an internal 1.231V reference is amplified to generate an error voltage on the V_C pin which is, in turn, used as a threshold for the current sense comparator.

During normal operation, the LT3433 internal oscillator runs at 200kHz. At the beginning of each oscillator cycle, the switch drive is enabled. The switch drive stays enabled until the sensed switch current exceeds the V_C-derived threshold for the current sense comparator and, in turn, disables the switch driver. If the current comparator threshold is not obtained for the entire oscillator cycle, the switch driver is disabled at the end of the cycle for 250ns. This minimum off-time mode of operation assures regeneration of the V_{BST} bootstrapped supply.

If the converter input and output voltages are close together, proper operation in normal buck configuration would require high duty cycles. The LT3433 senses this condition as requiring a duty cycle greater than 75%. If such a condition exists, a second switch is enabled during the switch on time, which acts to pull the output side of the inductor to ground. This "bridged" operation allows voltage conversion to continue when V_{OUT} approaches or exceeds V_{IN}.

Shutdown

The LT3433 incorporates a low current shutdown mode where all IC functions are disabled and the V_{IN} current is reduced to 10μA. Pulling the SHDN pin down to 0.4V or less activates shutdown mode.

Burst Mode Operation

The LT3433 employs low current Burst Mode functionality to maximize efficiency during no load and low load conditions. Burst Mode function is disabled by shorting the BURST_EN pin to either V_{BIAS} or V_{OUT}. Burst Mode function is enabled by shorting BURST_EN to SGND.

When the required switch current, sensed via the V_C pin voltage, is below 30% of maximum, the Burst Mode function is employed. When the voltage on V_C drops below the 30% load level, that level of sense current is latched into the IC. If the output load requires less than this latched current level, the converter will overdrive the output slightly during each switch cycle. This overdrive condition forces the voltage on the V_C pin to continue to drop. When the voltage on V_C drops below the 15% load level, switching is disabled, and the LT3433 shuts down most of its internal circuitry, reducing quiescent current to 100μA. When the voltage on the V_C pin climbs back to 20% load level, the IC returns to normal operation and switching resumes.

Antislope Compensation

Most current mode switching controllers use slope compensation to prevent current mode instability. The LT3433 is no exception. A slope compensation circuit imposes an artificial ramp on the sensed current to increase the rising slope as duty cycle increases. Unfortunately, this additional ramp corrupts the sensed current value, reducing the achievable current limit value by the same amount as the added ramp represents. As such, current limit is typically reduced as duty cycles increase.

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8

APPLICATIONS INFORMATION

The LT3433 contains circuitry to eliminate the current limit reduction associated with slope-compensation, or anti-slope compensation. As the slope compensation ramp is added to the sensed current, a similar ramp is added to the current limit threshold reference. The end result is that current limit is not compromised so the LT3433 can provide full power regardless of required duty cycle.

Mode Switching

The LT3433 senses operational duty cycle by directly monitoring V_{IN} and V_{OUT}. Voltage drops associated with pass and catch diodes are estimated internally such that mode switching occurs when the duty cycle required for continuous buck operation is greater than 75%. If such a condition exists, a second switch is enabled during the switch on time, changing operation to a dual switch bridged configuration. Because the voltage available across the switched inductor is greater in bridged mode, duty cycle will decrease.

The output current in bridged mode is not continuous, so switch currents are considerably higher than while operating in buck mode. In order to maximize available output power, continuous operation and low ripple currents are recommended. Switch currents will increase by a factor of $1/(1 - DC)$ during bridged mode, so this mode of operation is typically the gating item for converter drive capability.

$$I_{OUT(MAX)} = I_{SW(MAX)} \bullet (1 - DC)$$
$$= [0.5A - (\Delta I_L / 2)] \bullet (1 - DC)$$

where ΔI_L is the ripple current in the inductor.

It is also important to note that I_{OUT} cannot be considered equivalent to I_{LOAD} during bridged operation. Most of the converter's switch drive power is derived from the generated output supply, so I_{OUT} must also accommodate this current requirement. During single-switch buck operational conditions, switch drive current is negligible in terms of output current; however, during bridged operation, these currents can become significant. These output derived switch drive currents will increase the current loading on V_{IN} by the same $1/(1 - DC)$ factor as the switch currents. As maximum switch current is referenced to that coming from the V_{IN} supply, the available maximum switch current will be reduced by this required drive current.

$$I_{DRIVE} = DC \bullet 2 \bullet I_{SW(MAX)} \bullet I_{SWDRIVE(MAX)}$$

Using 50mA/A for the required drive current for each switch yields the portion of switch current used to drive the switches is:

$$I_{SW(DRIVE)} = DC \bullet 2 \bullet I_{SW(MAX)} \bullet 0.05/(1 - DC)$$

Removing drive currents from the available maximum switch current yields:

$$I_{SW(MAX)}' = I_{SW(MAX)} \bullet [1 - DC \bullet 2 \bullet I_{SW(MAX)} \bullet 0.05/(1 - DC)]$$
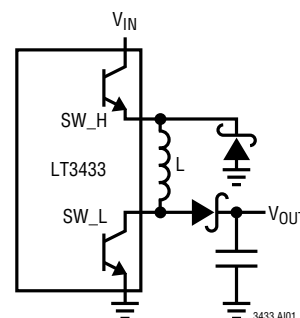
where $I_{SW(MAX)}'$ is maximum switch current available to the load during bridged operation. The maximum load current can then be calculated as:

$$I_{LOAD(MAX)} = I_{SW(MAX)}' \bullet (1 - DC)$$

which reduces to:

$$I_{LOAD(MAX)} = [0.5A - (\Delta I_L/2)] \bullet (1 - 1.1 \bullet DC)$$

Design Equations

3433 AI01

Constants:

V_{SWH} = voltage drop across boosted switch

V_{SWL} = voltage drop across grounded switch

V_F = forward drop of external Schottky diodes

f_O = operating frequency

Duty Cycle (continuous operation):

$$DC_{BUCK} = (V_{OUT} + 2V_F)/(V_{IN} - V_{SWH} + V_F)$$
$$DC_{BRIDGED} = (V_{OUT} + 2V_F)/(V_{OUT} + V_{IN} + 2V_F - V_{SWH} - V_{SWL})$$

APPLICATIONS INFORMATION

Ripple current:

$$\Delta I_{L(P-P)} = \frac{(V_{OUT} + 2V_F) \bullet (1 - DC)}{L \bullet f_0}$$

Inductor Selection

The primary criterion for inductor value selection in LT3433 applications is the ripple current created in that inductor. Design considerations for ripple current are the amount of output ripple and the ability of the internal slope compensation waveform to prevent current mode instability.

The LT3433 maximizes available dynamic range using a slope compensation generator that generates a continuously increasing slope as duty cycle increases. The slope compensation waveform is calibrated at 80% duty cycle to compensate for ripple currents up to 12.5% of I_{MAX}, or ~60mA.

Ripple current can be calculated as:

$$\Delta I_{L(P-P)} = \frac{(V_{OUT} + 2V_F) \bullet (1 - DC)}{L \bullet f_0}$$

This relation can be used to determine minimum inductance sizes for various values of V_{OUT} using the DC = 80% calibration:

$$L_{MIN} = (V_{OUT} + 1.5V) \bullet (1 - 0.8) \ 60mA \bullet 200kHz)$$

V_{OUT}	L_{MIN}
4V	92µH
5V	108µH
9V	175µH
12V	225µH

Discontinuous operation occurs when the ripple current in the inductor is greater than twice the load current (I_{LOAD}) in buck mode, or greater than $I_{LOAD}/(1 - DC)$ during bridged mode. Current mode instability is not a concern during discontinuous operation so inductor values smaller than L_{MIN} can be used. If such a small inductor is used, however, it must be assured that the converter never enters continuous operation at duty cycles greater than 50% to prevent current mode instability.

Design Example

$V_{IN(MIN)}$ = 4V, V_{OUT} = 5V, L = 150µH
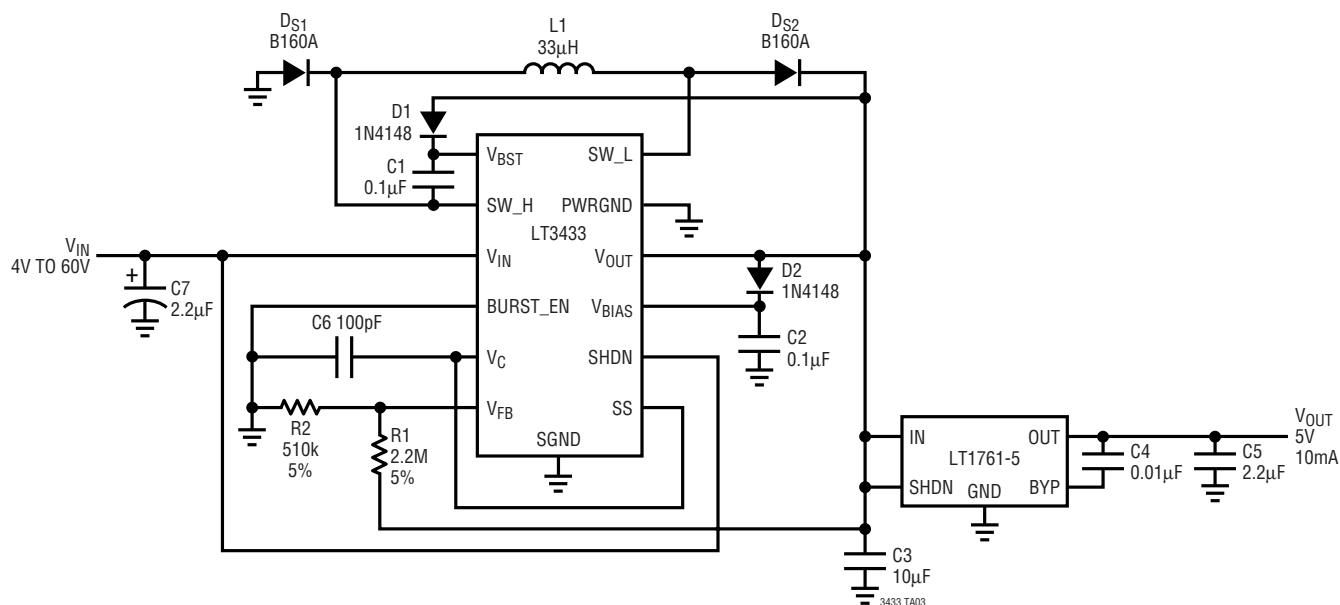
Using V_F = 0.75V yields:

$$\begin{aligned} DC &= (V_{OUT} + 2V_F)/(V_{OUT} + V_{IN} + 2V_F - V_{SWH} - V_{SWL}) \\ &= (5V + 1.5V)/(4V + 5V + 1.5V - 0.6V - 0.5V) \\ &= 0.69 \end{aligned}$$

$$\begin{aligned} \Delta I_L &= (V_{OUT} + 2V_F) \bullet (1 - DC) \bullet (L \bullet f_0)^{-1} \\ &= (5V + 1.5V) \bullet (1 - 0.69) \bullet (150µH \bullet 200kHz)^{-1} \\ &= 67mA \end{aligned}$$

$$I_{LOAD(MAX)} = I_{SW(MAX)} \bullet (1 - 1.1 \bullet DC)$$
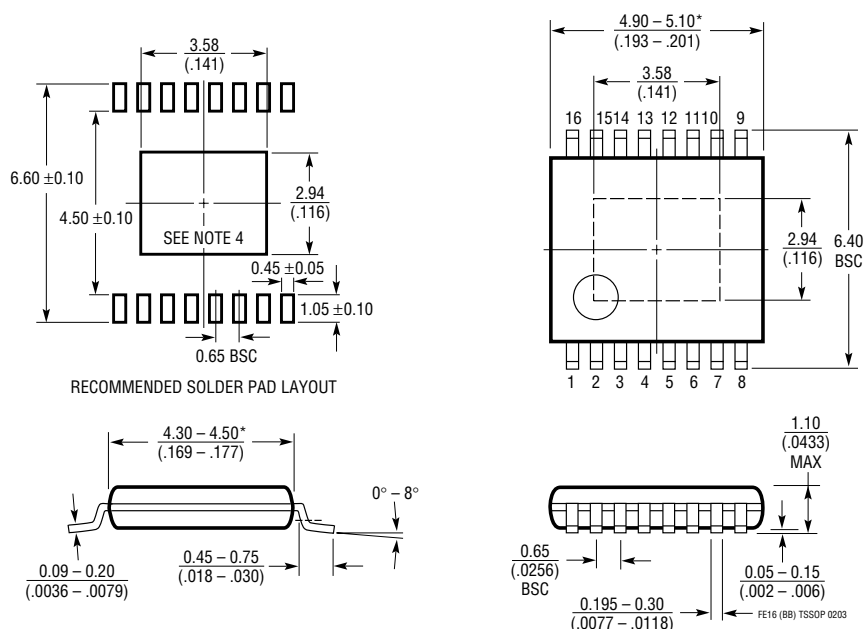$$= [0.5A - (1/2 \bullet 0.07)](1 - 1.1 \bullet 0.69) = 0.112A$$

TYPICAL APPLICATION

**Burst Only Low Noise 5V Maintenance Supply**

PACKAGE DESCRIPTION

FE Package
16-Lead Plastic TSSOP (4.4mm)
(Reference LTC DWG # 05-08-1663)

Exposed Pad Variation BB

RECOMMENDED SOLDER PAD LAYOUT

NOTE:
1. CONTROLLING DIMENSION: MILLIMETERS

2. DIMENSIONS ARE IN $\frac{\text{MILLIMETERS}}{\text{(INCHES)}}$

3. DRAWING NOT TO SCALE

4. RECOMMENDED MINIMUM PCB METAL SIZE
   FOR EXPOSED PAD ATTACHMENT

*DIMENSIONS DO NOT INCLUDE MOLD FLASH. MOLD FLASH
SHALL NOT EXCEED 0.150mm (.006") PER SIDE

FE16 (BB) TSSOP 0203

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11

LT3433

TYPICAL APPLICATION

4V-60V to 5V at 100mA DC/DC Converter Burst Disabled

3433 TA02
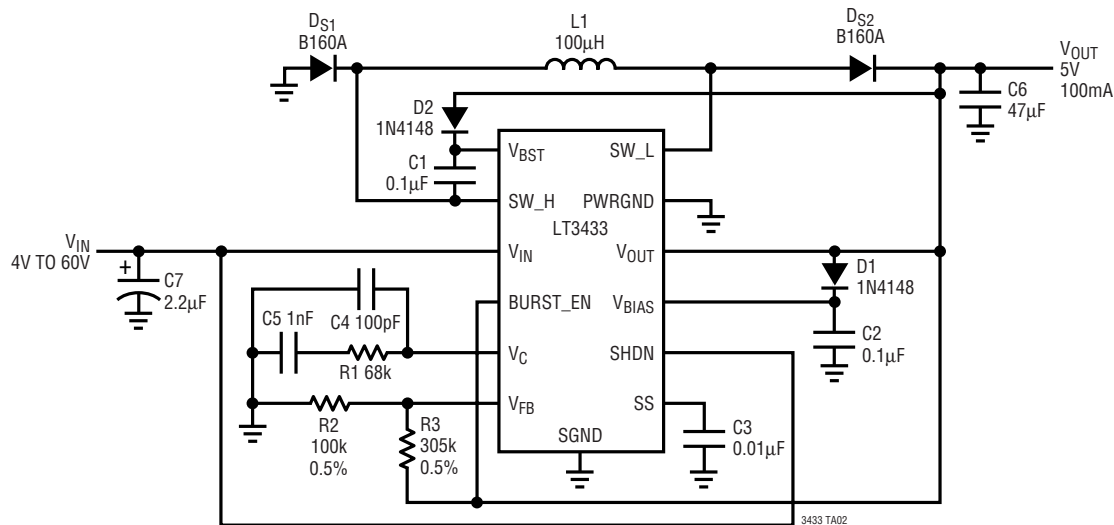
RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1076/LT1076HV	1.6A (I_{OUT}), 100kHz High Efficiency Step-Down DC/DC Converters	V_{IN}: 7.3V to 45V/64V, $V_{OUT(MIN)}$: 2.21V, I_Q: 8.5mA, I_{SD}: 10µA, DD5/DD7, TO220-5/TO220-7
LT1676	60V, 440mA (I_{OUT}), 100kHz High Efficiency Step-Down DC/DC Converter	V_{IN}: 7.4V to 60V, $V_{OUT(MIN)}$: 1.24V, I_Q: 3.2mA, I_{SD}: 2.5µA, SO-8
LT1765	25V, 2.75A (I_{OUT}), 1.25MHz High Efficiency Step-Down DC/DC Converter	V_{IN}: 3V to 25V, $V_{OUT(MIN)}$: 1.20V, I_Q: 1mA, I_{SD}: 15µA, SO-8, TSSOP16E
LT1766/LT1956	60V, 1.2A (I_{OUT}), 200kHz/500kHz High Efficiency Step-Down DC/DC Converters	V_{IN}: 5.5V to 60V, $V_{OUT(MIN)}$: 1.20V, I_Q: 2.5mA, I_{SD}: 25µA, TSSOP16/TSSOP16E
LT1767	25V, 1.2A (I_{OUT}), 1.25MHz High Efficiency Step-Down DC/DC Converter	V_{IN}: 3V to 25V, $V_{OUT(MIN)}$: 1.20V, I_Q: 1mA, I_{SD}: 6µA, MS8/MS8E
LT1776	40V, 550mA (I_{OUT}), 200kHz High Efficiency Step-Down DC/DC Converter	V_{IN}: 7.4V to 40V, $V_{OUT(MIN)}$: 1.24V, I_Q: 3.2mA, I_{SD}: 30µA, N8, SO-8
LT1976	60V, 1.2A (I_{OUT}), 200kHz High Efficiency Micropower (I_Q < 100µA) Step-Down DC/DC Converter	V_{IN}: 3.3V to 60V, $V_{OUT(MIN)}$: 1.20V, I_Q: 100µA, I_{SD}: <1µA, TSSOP16E
LT3010	80V, 50mA Low Noise Linear Regulator	V_{IN}: 1.5V to 80V, $V_{OUT(MIN)}$: 1.28V, I_Q: 30µA, I_{SD}: <1µA, MS8E
LTC3412/LTC3414	2.5A (I_{OUT}), 4MHz Synchronous Step-Down DC/DC Converters	V_{IN}: 2.5V to 5.5V, $V_{OUT(MIN)}$: 0.8V, I_Q: 60µA, I_{SD}: <1µA, TSSOP16E
LTC3414	4A (I_{OUT}), 4MHz Synchronous Step-Down DC/DC Converter	V_{IN}: 2.3V to 5.5V, $V_{OUT(MIN)}$: 0.8V, I_Q: 64µA, I_{SD}: <1µA, TSSOP20E
LTC3727/LTC3727-1	36V, 500kHz High Efficiency Step-Down DC/DC Controllers	V_{IN}: 4V to 36V, $V_{OUT(MIN)}$: 0.8V, I_Q: 670µA, I_{SD}: 20µA, QFN32, SSOP28
LT3430/LT3431	60V, 2.75A (I_{OUT}), 200kHz/500kHz High Efficiency Step-Down DC/DC Converters	V_{IN}: 5.5V to 60V, $V_{OUT(MIN)}$: 1.20V, I_Q: 2.5mA, I_{SD}: 30µA, TSSOP16E
LTC3440	600mA (I_{OUT}), 2MHz Synchronous Buck-Boost DC/DC Converter with 95% Efficiency	V_{IN}: 2.5V to 5.5V, $V_{OUT(MIN)}$: 2.5V, I_Q: 25µA, I_{SD}: <1µA, MS10

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