1.5A, 3MHz Synchronous Step-Up DC/DC Converter with Output Disconnect

FEATURES

- **700mA Continuous/1A Pulsed Output Current for Li-Ion to 5V Applications**
- **Synchronous Rectification: Up to 96% Efficiency**
- **True Output Disconnect**
- **Inrush Current Limiting**
- **Adjustable Automatic Burst Mode® Operation**
- Low Noise, Fixed Frequency Operation from 100kHz to 3MHz
- 0.5V to 4.5V Input Range
- 2.25V to 5.25V Adjustable Output Voltage
- Guaranteed 1V Start-Up
- Programmable Soft-Start
- Synchronizable Oscillator
- Low Quiescent Current: 25µA
- <1µA Shutdown Current
- Anti-Ringing Control
- Small (3mm × 3mm × 0.75mm) Thermally Enhanced 10-Pin DFN Package

APPLICATIONS

- Wireless Handsets
- Handheld Computers
- GPS Receivers
- MP3 Players

DESCRIPTION

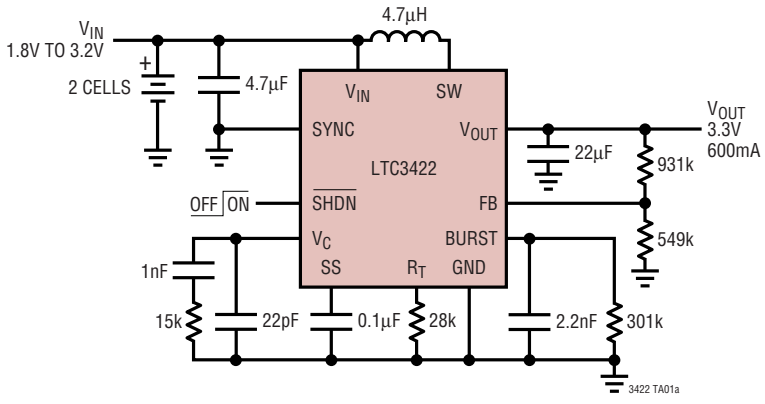
The LTC®3422 is a high efficiency, current mode, fixed frequency, step-up DC/DC converter with true output disconnect and inrush current limiting. The part is guaranteed to start up from an input voltage of 1V. The device includes a 0.20Ω N-channel MOSFET switch and a 0.24Ω P-channel MOSFET synchronous rectifier. The output voltage, switching frequency, soft-start time, Burst Mode threshold and loop compensation are all simply programmed using tiny external passive components.

Quiescent current is only 25µA during Burst Mode operation, maximizing battery life in portable applications. The oscillator frequency can be programmed up to 3MHz and can be synchronized to an external clock applied to the SYNC pin.

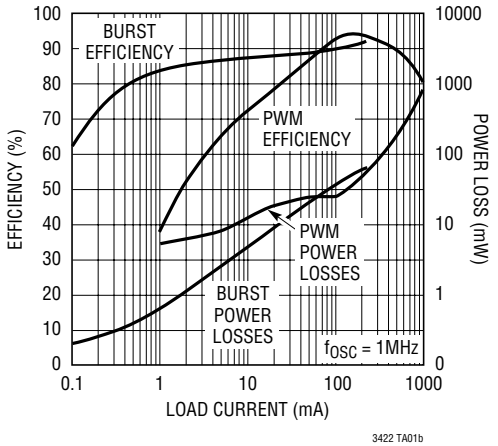
Other features include 1µA shutdown, short-circuit protection, anti-ringing control, thermal shutdown and current limit. The LTC3422 is available in a (3mm×3mm×0.75mm) 10-pin DFN package.

LT, LTC and LTM are registered trademarks of Linear Technology Corporation.
Burst Mode is a registered trademark of Linear Technology Corporation.
All other trademarks are the property of their respective owners.

TYPICAL APPLICATION



2.4V to 3.3V Efficiency and Power Loss

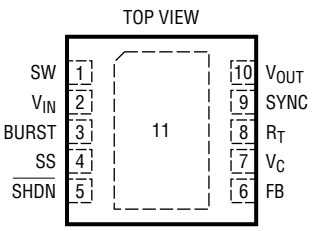


ABSOLUTE MAXIMUM RATINGS

(Note 1)

V_{IN}, V_{OUT}, SYNC Voltages ..... –0.3V to 6V
FB, SS, BURST, $\overline{SHDN}$ Voltages ..... –0.3V to 6V
SW Voltage
DC ..... –0.3V to 6V
Pulsed < 100ns ..... –0.3V to 7V
Operating Temperature Range
(Notes 2, 5) ..... –40°C to 85°C
Storage Temperature Range ..... –65°C to 125°C

PACKAGE/ORDER INFORMATION



DD PACKAGE
10-LEAD (3mm × 3mm) PLASTIC DFN
T_{JMAX} = 125°C, θ_{JA} = 43°C/W
EXPOSED PAD (PIN 11) IS GND, MUST BE SOLDERED TO PCB

ORDER PART NUMBER	DD PART MARKING
LTC3422EDD	LBRN

Order Options Tape and Reel: Add #TR
Lead Free: Add #PBF Lead Free Tape and Reel: Add #TRPBF
Lead Free Part Marking: http://www.linear.com/leadfree/

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

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{IN} = 1.2V, V_{OUT} = 3.3V, R_T = 28k, unless otherwise noted. (Note 2)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Minimum V_{IN} Start-Up Voltage	I_{LOAD} < 1mA			0.88	1	V
Minimum V_{IN} Operating Voltage	(Note 3)	●			0.5	V
Output Voltage Adjust Range		 ●	2.25 2.40		5.25 5.25	V V
Feedback Voltage		●	1.192	1.216	1.240	V
Feedback Input Current	V_{FB} = 1.216V			1	50	nA
Quiescent Current—Burst Mode Operation	V_C = 0V (Note 4)			25	42	µA
Quiescent Current—Shutdown	$\overline{SHDN}$ = 0V, V_{OUT} = 0V			0.1	1	µA
Quiescent Current—Active	V_C = 0V (Note 4)			0.75	1.1	mA
NMOS Switch Leakage				0.1	5	µA
PMOS Switch Leakage	V_{OUT} = 2V			0.1	10	µA
NMOS Switch On Resistance	V_{OUT} = 3.3V			0.20		Ω
PMOS Switch On Resistance	V_{OUT} = 3.3V			0.24		Ω
NMOS Current Limit—Steady State NMOS Current Limit—Pulsed NMOS Current Limit—Short Circuit	 Duty Cycle Not to Exceed 5% V_{OUT} = 500mV, V_{IN} = 2.5V	●	1.5 2	 2.5 0.75	 1.5	A A A
NMOS Burst Current Limit				600		mA
Maximum Duty Cycle		●	84	91		%
Minimum Duty Cycle		●			0	%
Frequency		●	0.85	1	1.15	MHz
SYNC Input High		●	2.2			V
SYNC Input Low		●			0.8	V
SYNC Input Current				0.01	1	µA

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{IN} = 1.2V, V_{OUT} = 3.3V, R_T = 28k, unless otherwise noted. (Note 2)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
$\overline{SHDN}$ Input High	V_{OUT} = 0V (Turn-On Threshold, Initial Start-Up) V_{OUT} > 2.4V (Stay-On Threshold)		1 0.65			V V
$\overline{SHDN}$ Input Low	Turn-Off Threshold				0.25	V
$\overline{SHDN}$ Input Current	$V_{\overline{SHDN}}$ = 3.3V	●		0.01	1	µA
Error Amp Transconductance				50		µS
Soft-Start Current Source	V_{SS} = 1V		–5	–2.4	–1.2	µA
BURST Threshold Voltage	Falling Edge, Sensed at the BURST Pin		0.79	0.88	0.97	V

Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliabilty and lifetime.

Note 2: The LTC3422E is guaranteed to meet performance specifications from 0°C to 85°C. Specifications over the –40°C to 85°C operating temperature range are assured by design, characterization and correlation with statistical process controls.

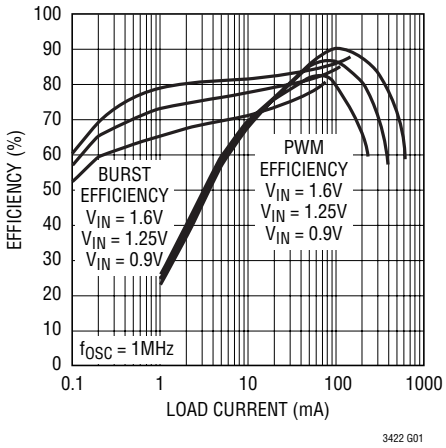
Note 3: Once V_{OUT} is greater than 2.4V, the LTC3422 is not dependent on the V_{IN} supply.

Note 4: Current is measured into the V_{OUT} pin since the supply current is bootstrapped to the output. The current will reflect to the input supply by (V_{OUT}/V_{IN}) • Efficiency. The outputs are not switching.

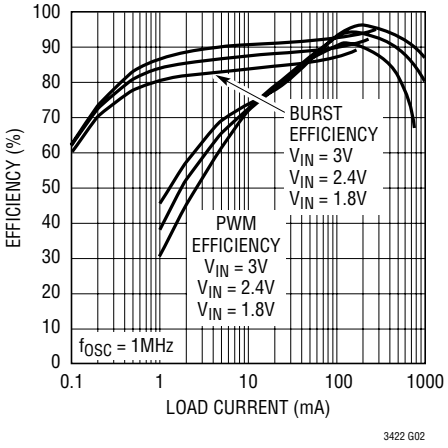
Note 5: This IC includes overtemperature protection that is intended to protect the device during momentary overload conditions. Junction temperature will exceed 125°C when overtemperature protection is active. Continuous operation above the specified maximum operating junction temperature may impair device reliability.

TYPICAL PERFORMANCE CHARACTERISTICS (T_A = 25°C, unless otherwise specified)

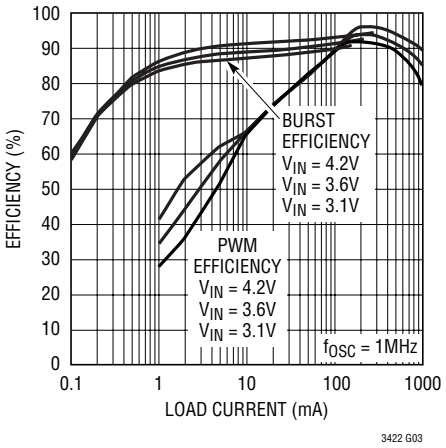
Single Cell to 3.3V Efficiency



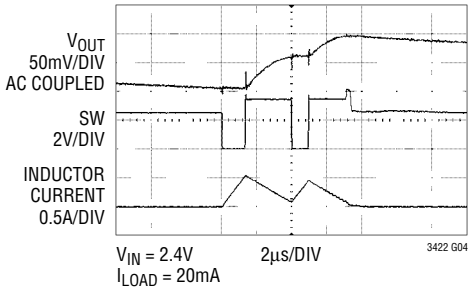
2-Cell to 3.3V Efficiency



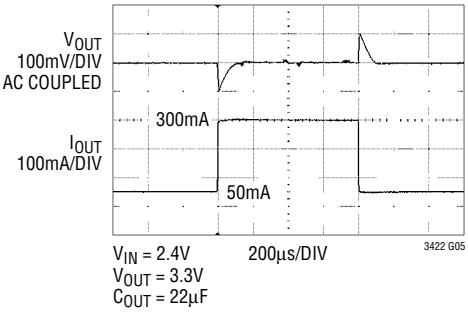
Li-Ion to 5V Efficiency



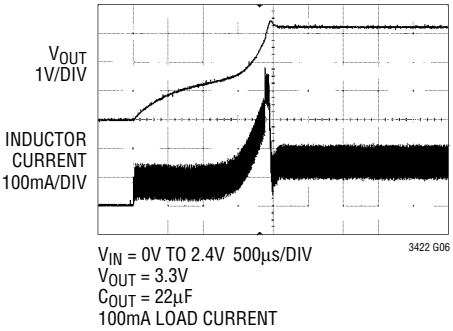
Burst Mode Operation



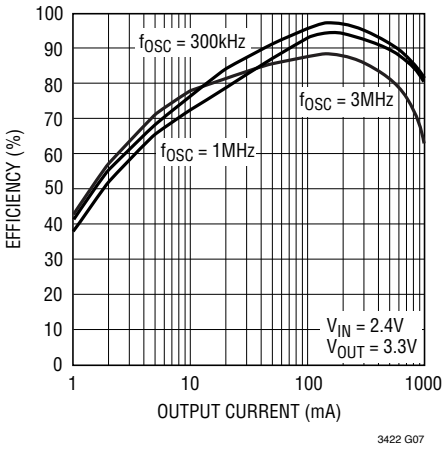
Load Transient Response



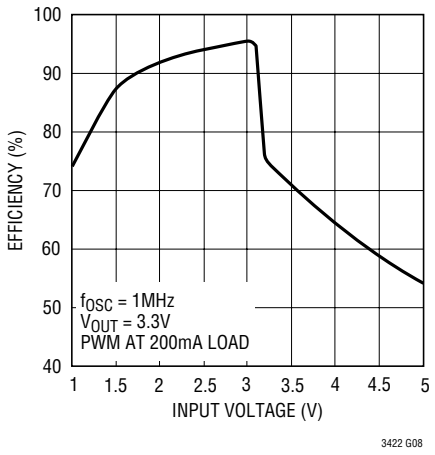
Inrush Current Control



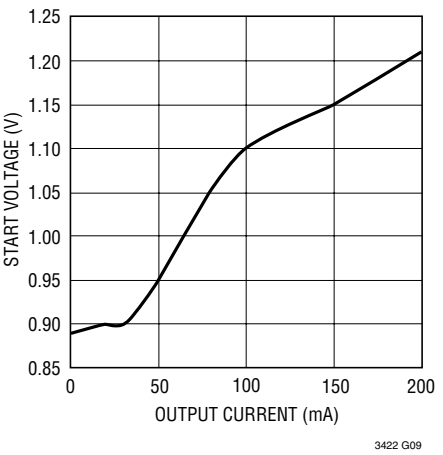
Efficiency vs Frequency



Efficiency vs V_{IN}

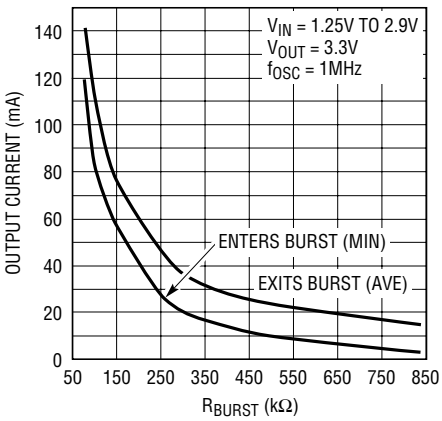


Start-Up Voltage vs Output Current

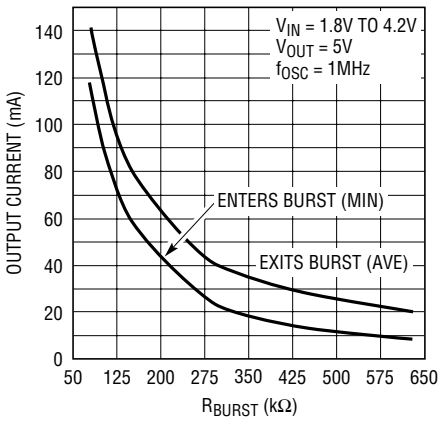


TYPICAL PERFORMANCE CHARACTERISTICS (T_A = 25°C, unless otherwise specified)

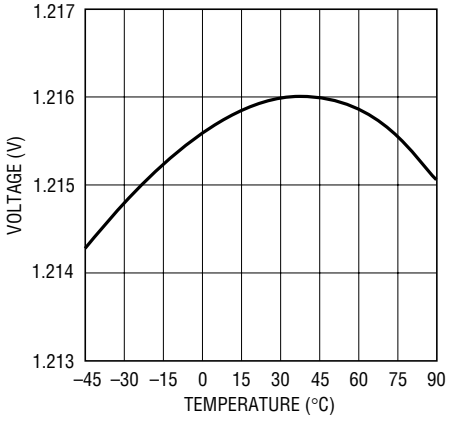
Burst Mode Output Current Threshold vs R_{BURST} (3.3V Output)



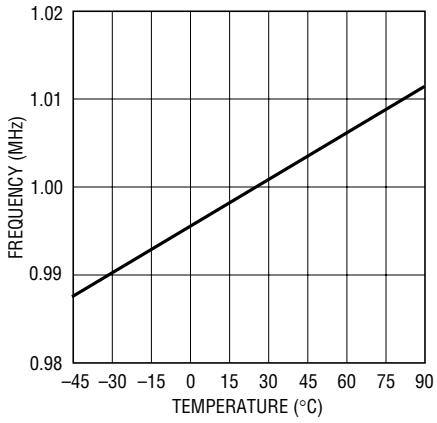
Burst Mode Output Current Threshold vs R_{BURST} (5V Output)



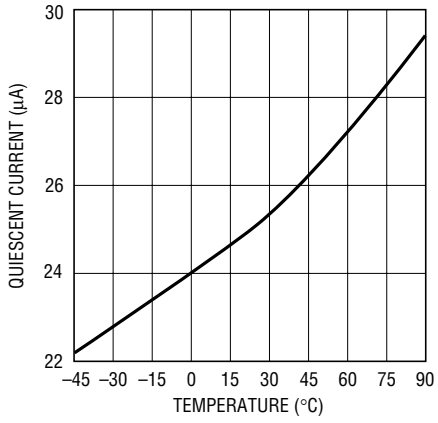
FB Voltage vs Temperature



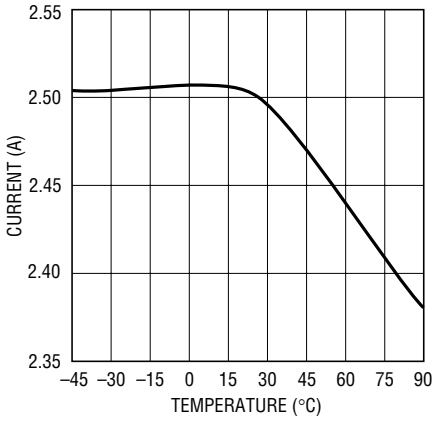
Frequency vs Temperature (Normalized About 1MHz)



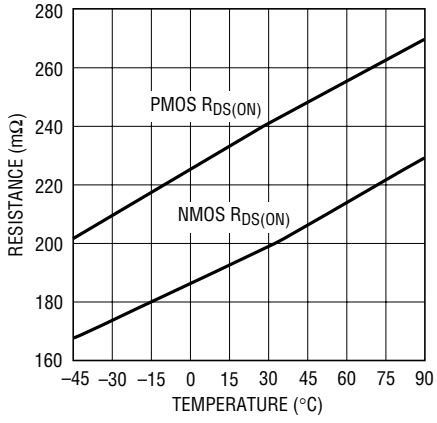
Burst Mode Quiescent Current vs Temperature



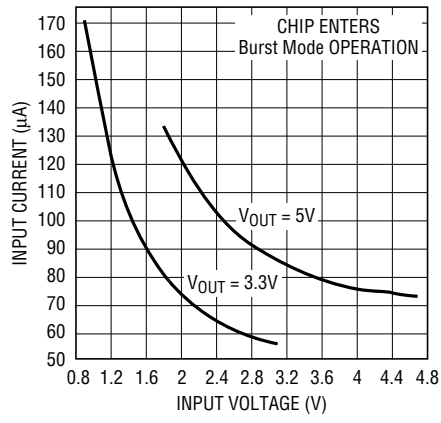
Current Limit vs Temperature



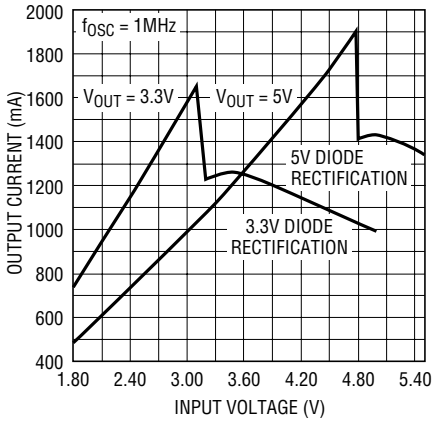
$R_{DS(ON)}$ vs Temperature



No-Load Input Current vs V_{IN}



Maximum Output Current vs V_{IN}



PIN FUNCTIONS

SW (Pin 1): Switch Pin for the Inductor Connection. Minimize trace length between SW and inductor. For discontinuous inductor current, a controlled impedance is internally connected from SW to V_{IN} to eliminate high frequency ringing, reducing EMI radiation.

V_{IN} (Pin 2): Input Supply Voltage. Connect V_{IN} to the input supply and decouple with a 4.7µF or larger ceramic capacitor as close to V_{IN} as possible.

BURST (Pin 3): Burst Mode Threshold Adjust. Automatic Burst Mode Operation: A resistor/capacitor combination from BURST to ground programs the average load current at which automatic Burst Mode operation is exited, according to the formula:

$$R_B = \frac{12}{I_{EXITBURST}}$$

where R_B is in kΩ and $I_{EXITBURST}$ is in amps

$$C_B \geq \frac{C_{OUT} \bullet V_{OUT}}{64{,}000}$$

where $C_{B(MIN)}$ and C_{OUT} are in µF.

Please refer to the Burst Mode Output Current Threshold vs R_{BURST} Typical Performance Chacteristic curves.

Note that during Burst Mode operation the peak inductor current will be approximately 600mA and return to zero on each cycle. In Burst Mode operation the frequency is variable, providing a significant efficiency improvement at light loads. The LTC3422 only allows Burst Mode operation to be entered once V_{OUT} exceeds approximately 2.2V.

Manually Implementing Burst Mode Operation: Ground BURST to force Burst Mode operation or connect it to V_{OUT} to force fixed frequency PWM mode. Note that BURST must not be pulled higher than V_{OUT}.

SS (Pin 4): Soft-Start. Connect a capacitor from SS to ground to set the soft-start time according to the formula:

$$t(ms) = C_{SS}(\mu F) \bullet 320$$

The nominal soft-start charging current is 2.4µA. The active range of SS is from 0.8V to 1.6V.

$\overline{SHDN}$ (Pin 5): Shutdown Input. Less than 250mV on $\overline{SHDN}$ shuts down the LTC3422. Placing 1V or more on $\overline{SHDN}$ enables the LTC3422. Once V_{OUT} exceeds 2.2V, hysteresis is applied to this pin (500nA exits the pin) allowing it to operate at a logic high while the battery can drop to 500mV.

FB (Pin 6): Feedback Input to Error Amplifier. Connect the V_{OUT} to ground resistor divider tap here. The output voltage can be adjusted from 2.25V to 5.25V according to the formula:

$$V_{OUT} = 1.216 \bullet \frac{R1+R2}{R2}$$

V_C (Pin 7): Error Amp Output. A frequency compensation network is connected from V_C to ground to compensate the loop. See the section "CIosing the Feedback Loop" for guidelines.

R_T (Pin 8): Frequency Adjust Input. Connect a resistor to ground to program the oscillator frequency according to the formula:

$$f_{OSC} = \frac{28}{R_T}$$

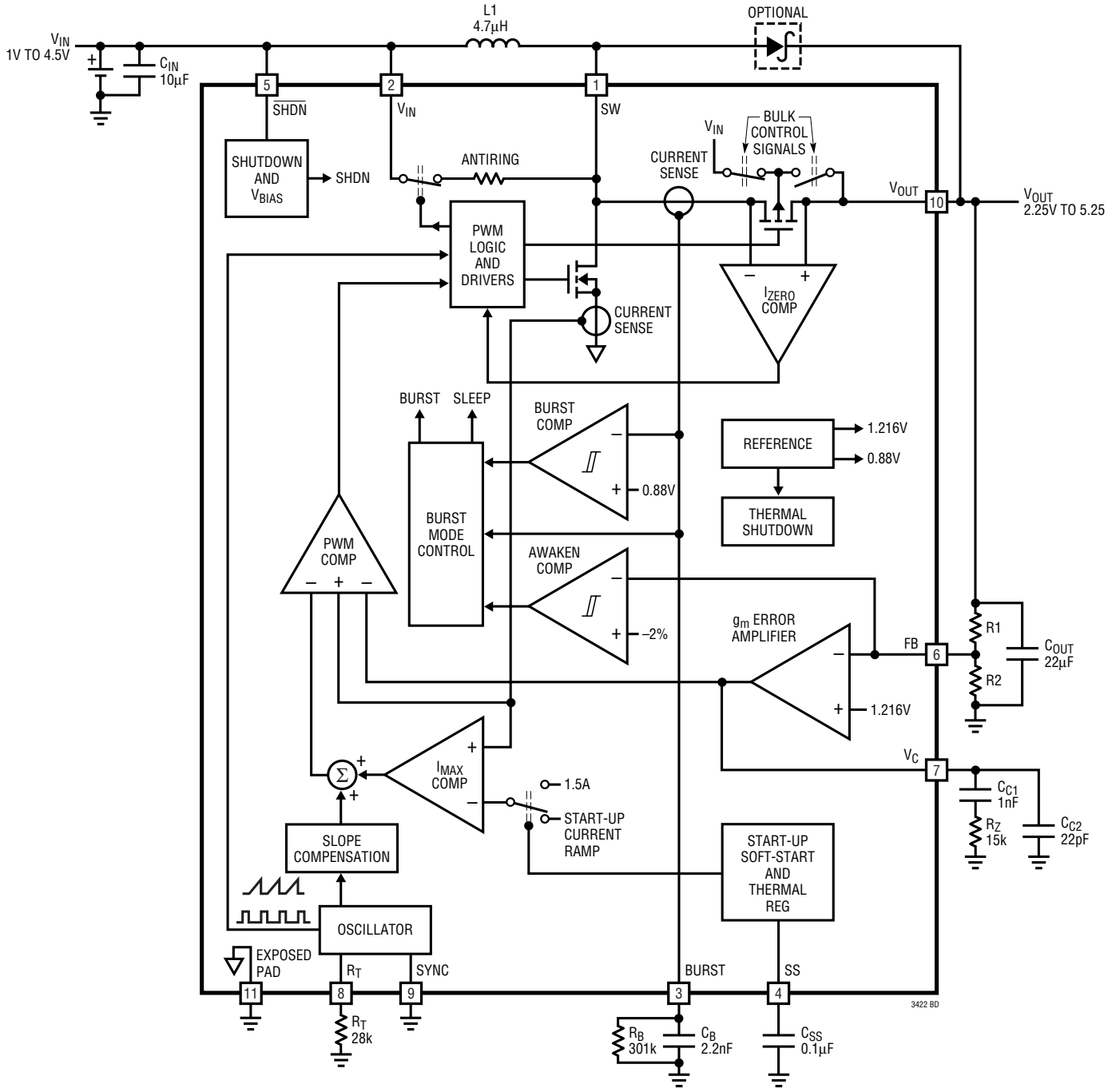
where f_{OSC} is in MHz and R_T is in kΩ.

SYNC (Pin 9): Oscillator Synchronization Input. A clock pulse width of 100ns to 2µs is required to synchronize the internal oscillator. If not used, SYNC should be grounded.

V_{OUT} (Pin 10): Output of the synchronous rectifier and bootstrapped power source for the LTC3422. A ceramic capacitor of at least 10µF is required and should be located as close to V_{OUT} and the power ground plane as possible.

Exposed Pad (Pin 11): Signal and Power Ground for the LTC3422. This pin MUST be soldered to the PCB ground plane for electrical contact and rated thermal performance.

BLOCK DIAGRAM



OPERATION

LOW VOLTAGE START-UP

The LTC3422 includes an independent start-up oscillator designed to start up at input voltages of 0.88V typical. During start-up, the peak current limit is gradually increased in conjunction with the soft-start ramp. Switching frequency is also internally controlled during start-up. The device can start up under some load (see graph of Start-Up Voltage versus Output Current). Soft-start and

OPERATION

inrush current limiting are provided during start-up as well as normal switching mode. The same soft-start capacitor is used for each operating mode.

When either V_{IN} or V_{OUT} exceeds 2.25V, the LTC3422 enters normal operating mode. Once the output voltage exceeds the input by 0.3V typical, the LTC3422 powers itself from V_{OUT} instead of V_{IN}. At this point the internal circuitry has no dependency on the V_{IN} input voltage, eliminating the requirement for a large input capacitor. The input voltage can drop as low as 0.5V without affecting circuit operation. The limiting factor for the application becomes the availability of the power source to supply sufficient energy to the output at the low voltages and the maximum duty cycle, which is clamped at 91% typical.

LOW NOISE FIXED FREQUENCY OPERATION

Shutdown

The part is shutdown by pulling $\overline{SHDN}$ below 0.25V, and activated by pulling the pin initially above 1V. Once V_{OUT} exceeds 2.2V typical, hysteresis is applied to this pin allowing it to maintain a logic high state down to 0.65V. Note that $\overline{SHDN}$ can be driven above V_{IN} or V_{OUT} as long as it is limited to less than the absolute maximum rating.

Soft-Start

The soft-start time is programmed with an external capacitor from SS to ground. An internal current source charges it with a nominal 2.4µA. The ramping voltage on SS dictates the gradually increasing peak current limit until the voltage on the capacitor exceeds 1.6V, after which the internally set peak current limit is maintained. In the event of a commanded shutdown or a thermal shutdown, the capacitor on SS is discharged to ground automatically. Note that Burst Mode operation is inhibited during the soft-start time.

$$t\ (ms) = C_{SS}\ (\mu F) \bullet 320$$

Oscillator

The frequency of operation is set through a resistor from R_T to ground. A precision timing capacitor resides inside the LTC3422. The oscillator can be synchronized with an external clock applied to SYNC. When synchronizing the oscillator, the free running frequency must be set at least 20% lower than the desired synchronized frequency.

$$f_{OSC} = \frac{28}{R_T}$$

where f_{OSC} is in MHz and R_T is in kΩ.

Current Sensing

Lossless current sensing converts the peak current signal to a voltage to sum in with the internal slope compensation. This summed signal is compared to the error amplifier output to provide a peak current control command for the PWM. The LTC3422 incorporates slope compensation which is adaptive to the input and output voltages. Therefore, the converter provides the proper amount of slope compensation to ensure stability, but not an excess which would cause a loss of phase margin in the converter.

Error Amplifier

The error amplifier is a transconductance amplifier, with its positive input internally connected to the 1.216V reference and its negative input connected to FB. A simple compensation network is placed from V_C to ground. Internal clamps limit the minimum and maximum error amplifier output voltage for improved large-signal transient response.

Current Limit

The current limit circuitry shuts off the internal N-channel MOSFET switch when the current limit threshold is reached. In Burst Mode operation, the current limit is reduced to approximately 600mA.

Zero Current Amplifier

The zero current amplifier monitors the inductor current to the output and shuts off the synchronous rectifier once the current falls below 50mA typical, preventing negative inductor current.

Anti-Ringing Control

The anti-ringing control connects a resistor across the inductor to dampen the ringing on SW during discontinuous conduction mode. The LC_{SW} ringing (L = inductor,

OPERATION

C_{SW} = SW Capacitance) is low energy, but can cause EMI radiation.

Burst Mode OPERATION

Burst Mode operation can be automatic or user controlled. In automatic operation, the LTC3422 will automatically enter Burst Mode operation at light load and return to fixed frequency PWM mode for heavier loads. The user can program the average load current at which the mode transition occurs using a single resistor connected from BURST to GND.

The oscillator is shut down during Burst Mode operation, since the on time is determined by the time it takes the inductor current to reach a fixed 600mA peak current and the off time is determined by the time it takes for the inductor current to return to zero.

In Burst Mode operation, the LTC3422 delivers energy to the output until it is regulated and then enters a sleep state, where the switches are kept off while the LTC3422 consumes only 25µA of quiescent current. In this mode the output ripple has a variable frequency component with load current and will be typically 2% peak-peak. This maximizes efficiency at very light loads by minimizing switching and quiescent losses. Burst Mode operation ripple can be reduced slightly by increasing the output capacitance (47µF or greater). This additional capacitance does not need to be a low ESR type if low ESR ceramics are also used. Another method of reducing Burst Mode operation ripple is to place a small feed-forward capacitor (10pF to 100pF) across the upper resistor in the V_{OUT} feedback divider network.

In Burst Mode operation, the compensation network is not used and V_C is disconnected from the error amplifier. During long periods of Burst Mode operation, leakage currents in the external components or on the PC board could cause the compensation capacitor to charge (or discharge), which could result in a large output transient when returning to fixed frequency mode of operation, even at the same load current. To prevent this, the LTC3422 incorporates an active clamp circuit that holds the voltage on V_C at an optimal voltage during Burst Mode operation. This minimizes any output transient when returning to fixed frequency mode operation.

Automatic Burst Mode Operation Control

For automatic operation, an RC network should be connected from BURST to ground. The value of the resistor will control the average load current (I_{BURST}) at which Burst Mode operation will be entered and exited (there is hysteresis to prevent oscillation between modes). The equation given for the capacitor on BURST is the minimum value to prevent ripple on BURST from causing the part to oscillate in and out of Burst Mode operation at the current where the mode transition occurs. The equation given for the resistor on BURST is the typical average load current at which automatic Burst Mode operation is exited.

$$R_B = \frac{12}{I_{EXITBURST}}$$

where R_B is in kΩ and $I_{EXITBURST}$ is in amps.

$$C_B \geq \frac{C_{OUT} \bullet V_{OUT}}{64{,}000}$$

where $C_{B(MIN)}$ and C_{OUT} are in µF.

Please refer to the Burst Mode Output Current Threshold vs R_{BURST} Typical Performance Chacteristic curves.

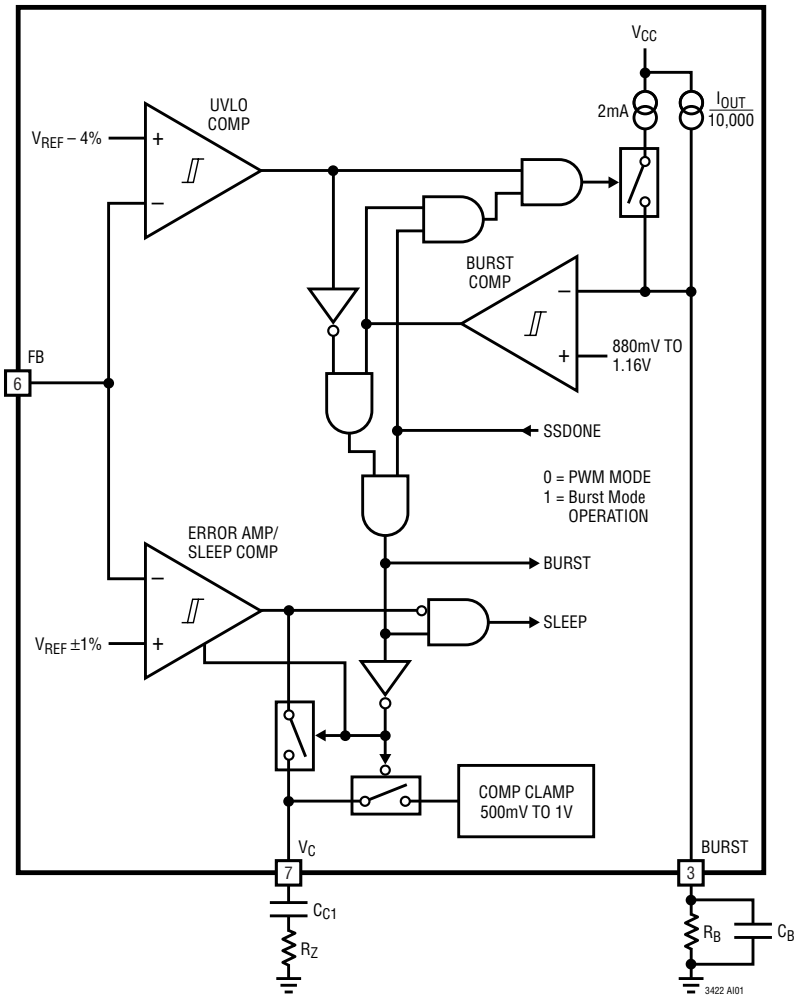
In the event that a load transient causes FB to drop by more than 4% from the regulation value while in Burst Mode operation, the LTC3422 will immediately switch to fixed frequency operation and an internal pull-up will be momentarily applied to BURST, rapidly charging the BURST capacitor. This prevents the LTC3422 from immediately re-entering Burst Mode operation once the output achieves regulation.

Manual Burst Mode Operation

For optimum transient response with large dynamic loads, the operating mode should be controlled manually by the host. By commanding fixed frequency PWM operation prior to a sudden increase in load, output voltage droop can be minimized. For manual control of Burst Mode operation, the RC network connected to BURST can be eliminated. To force fixed frequency PWM mode, BURST should be connected to V_{OUT}. To force Burst Mode operation, BURST should be grounded. When commanding Burst Mode operation manually, the circuit connected to

OPERATION

Simplified Diagram of Automatic Burst Mode Control Circuit



BURST must be able to sink up to 4mA. Burst Mode operation is inhibited during soft-start.

If V_{IN} is greater than V_{OUT} – 300mV, the part will exit Burst Mode operation and the synchronous rectifier will be disabled.

Note that if the load current applied during *forced* Burst Mode operation (BURST is grounded) exceeds the current that can be supplied, the output voltage will start to droop and the LTC3422 will automatically come out of Burst Mode operation and enter fixed frequency mode, raising V_{OUT}. Once regulation is achieved, the LTC3422 will then enter Burst Mode operation once again (since the user is still *commanding* this by grounding BURST) and the cycle will repeat, resulting in about 4% output ripple. The maximum average current that can be supplied in Burst Mode operation is given by:

$$I_{OUT(MAX)} = \frac{275 \bullet V_{IN}}{V_{OUT}} \text{ in mA}$$

Output Disconnect and Inrush Current Limiting

The LTC3422 is designed to allow true output disconnect by eliminating body diode conduction of the internal P-channel MOSFET rectifier. This allows V_{OUT} to go to zero volts during shutdown without drawing any current from

OPERATION

the input source. It also allows for inrush current limiting at turn-on, minimizing surge currents seen by the input supply. Note that to obtain the advantages of output disconnect, there must not be any external Schottky diodes connected between the SW pin and V_{OUT}.

It should also be noted that the LTC3422 provides inrush current limiting without reducing the maximum load current capability during start-up. The internally set peak current command of the LTC3422 is allowed to gradually increase during the soft-start period until it reaches the nominal maximum level.

APPLICATIONS INFORMATION

Note: Board layout is extremely critical to minimize voltage overshoot on SW due to stray inductance. Keep the output filter capacitors as close as possible to V_{OUT} and use very low ESR/ESL ceramic capacitors tied to a good ground plane.

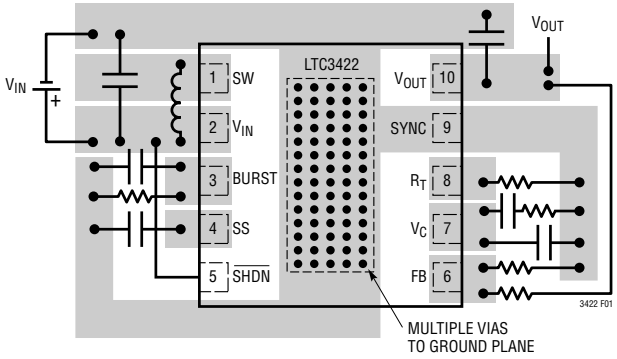


Figure 1. Recommended Component Placement. Traces Carrying High Current are Direct (GND, SW, V_{IN}, V_{OUT}). Trace Area at FB and V_C are Kept Low. Lead Length to Battery Should be Kept Short. V_{IN} and V_{OUT} Ceramic Capacitors Should be as Close to the LTC3422 Pins as Possible

COMPONENT SELECTION

Inductor Selection

The high frequency operation of the LTC3422 allows the use of small surface mount inductors. The minimum inductance value is proportional to the operating frequency and is limited by the following constraints:

$$L > \frac{3}{f} \text{ and } L > \frac{V_{IN(MIN)} \bullet \left(V_{OUT(MAX)} - V_{IN(MIN)}\right)}{f \bullet Ripple \bullet V_{OUT(MAX)}}$$

where:

f = Operating Frequency in MHz

Ripple = Allowable Inductor Current Ripple (Amps Peak-Peak)

$V_{IN(MIN)}$ = Minimum Input Voltage

$V_{OUT(MAX)}$ = Maximum Output Voltage

The inductor current ripple is typically set 20% to 40% of the maximum inductor current.

For high efficiency, choose an inductor with high frequency core material, such as ferrite, to reduce core losses. The inductor should have low ESR (equivalent series resistance) to reduce the I^2R losses and must be able to handle the peak inductor current without saturating. Molded chokes or chip inductors usually do not have enough core to support peak inductor currents in the 2A to 3A region. To minimize radiated noise, use a toroidal or shielded inductor. See Table 1 for suggested inductor suppliers and Table 2 for a list of capacitor suppliers.

Table 1. Inductor Vendor Information

SUPPLIER	PHONE	FAX	WEB SITE
Coilcraft	(847) 639-6400	(847) 639-1469	www.coilcraft.com
CoEv Magnetics	(800) 277-7040	(650) 361-2508	www.circuitprotection.com/magnetics.asp
Murata	USA: (814) 237-1431 (800) 831-9172	USA: (814) 238-0490	www.murata.com
Sumida	USA: (847) 956-0666 Japan: 81-3-3607-5111	USA: (847) 956-0702 Japan: 81-3-3607-5144	www.sumida.com
TDK	(847) 803-6100	(847) 803-6296	www.component.tdk.com
TOKO	(847) 297-0070	(847) 669-7864	www.toko.com
Wurth	(201) 785-8800	(201) 785-8810	www.we-online.com

APPLICATIONS INFORMATION

Output Capacitor Selection

The output voltage ripple has two components to it. The bulk value of the capacitor is set to reduce the ripple due to charge into the capacitor each cycle. The maximum ripple due to charge is given by:

$$V_{R(BULK)} = \frac{I_P \bullet V_{IN}}{C_{OUT} \bullet V_{OUT} \bullet f}$$

where I_P = peak inductor current

The ESR (equivalent series resistance) is usually the most dominant factor for ripple in most power converters. The ripple due to capacitor ESR is simply given by:

$$V_{RCESR} = I_P \bullet C_{ESR}$$

where C_{ESR} = capacitor equivalent series resistance.

Low ESR capacitors should be used to minimize output voltage ripple. For most applications, Murata or Taiyo Yuden X5R ceramic capacitors are recommended.

Input Capacitor Selection

The input filter capacitor reduces peak currents drawn from the input source and reduces input switching noise. Since the LTC3422 can operate at voltages below 0.5V once the output is regulated, the demand on the input capacitor is much less. In most applications 1µF per Amp of peak input current is recommended. Taiyo Yuden offers very low ESR ceramic capacitors, for example the 1µF in a 0603 case (JMK107BJ105MA).

Table 2. Capacitor Vendor Information

SUPPLIER	PHONE	FAX	WEB SITE
AVX	(803) 448-9411	(803) 448-1943	www.avxcorp.com
Sanyo	(619) 661-6322	(619) 661-1055	www.sanyovideo.com
TDK	(847) 803-6100	(847) 803-6296	www.component.tdk.com
Murata	USA: (814) 237-1431 (800) 831-9172	USA: (814) 238-0490	www.murata.com
Taiyo Yuden	(408) 573-4150	(408) 573-4159	www.t-yuden.com

Operating Frequency Selection

There are several considerations in selecting the operating frequency of the converter, such as, what are the sensitive frequency bands that cannot tolerate any spectral noise. Another consideration is the physical size of the converter. As the operating frequency goes up, the inductor and filter capacitors go down in value and size. The trade off is in efficiency since the switching losses due to gate charge are proportionally increasing with frequency. For example, as shown in Figure 2, for a 2.4V to 3.3V converter, the efficiency at 160mA is 9% less at 3MHz versus 300kHz.

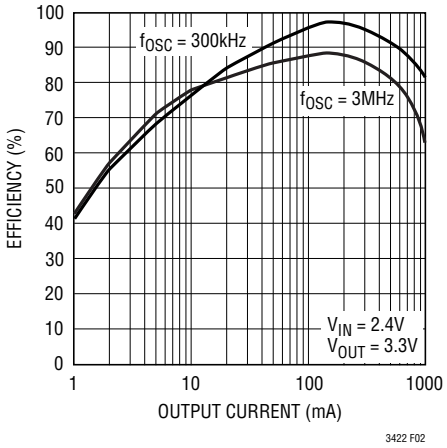


Figure 2. 2.4V to 3.3V Efficiency vs Frequency of Operation

The final consideration is whether the application can allow "pulse skipping." In this mode, the minimum on time of the converter cannot support the duty cycle, so the converter ripple will go up and there will be a low frequency component of the output ripple. In many applications where physical size is the main criterion, running the converter in this mode is acceptable. In applications where it is preferred not to enter this mode, the maximum operating frequency is given by:

$$f_{MAX_NOSKIP} = \frac{V_{OUT} - V_{IN}}{V_{OUT} \bullet t_{ON(MIN)}} \text{ Hz}$$

where $t_{ON(MIN)}$ = minimum on time = 120ns.

Thermal Considerations

To deliver the power that the LTC3422 is capable of it is imperative that a good thermal path be provided to dissipate the heat generated within the package. This can be accomplished by taking advantage of the large thermal pad on the underside of the LTC3422. It is recommended that multiple vias in the printed circuit board be used to

APPLICATIONS INFORMATION

conduct heat away from the LTC3422 and into the copper plane with as much area as possible. In the event that the junction temperature gets too high, the peak current limit will automatically be decreased. If the junction temperature continues to rise, the LTC3422 will go into thermal shutdown and all switching will stop until the internal temperature drops.

$V_{IN} > V_{OUT}$ Operation

The LTC3422 will maintain voltage regulation when the input voltage is above the output voltage. This is achieved by terminating the switching of the synchronous P-channel MOSFET and applying V_{IN} statically on the gate. This will ensure the volt • seconds of the inductor will reverse during the time current is flowing to the output. Since this mode will dissipate more power in the LTC3422, the maximum output current is limited in order to maintain an acceptable junction temperature and is given by:

$$I_{OUT(MAX)} = \frac{125 - T_A}{43 \bullet ((V_{IN} + 1.5) - V_{OUT})}$$

where T_A = ambient temperature.

For example at V_{IN} = 4.5V, V_{OUT} = 3.3V and T_A = 85°C, the maximum output current is 345mA.

Short Circuit

The LTC3422 output disconnect feature allows output short circuit while maintaining a maximum internally set current limit. However, the LTC3422 also incorporates internal features such as current limit foldback and thermal shutdown for protection from an excessive overload or short circuit. During a prolonged short circuit the current limit folds back to 0.75A typical should V_{OUT} drop below approximately 666mV. This 0.75A current limit remains in effect until V_{OUT} exceeds approximately 800mV, at which time the steady-state current limit is restored.

Closing the Feedback Loop

The LTC3422 utilizes current mode control with internal adaptive slope compensation. Current mode control eliminates the 2nd order filter due to the inductor and output capacitor exhibited in voltage mode controllers, thus simplifying it to a single pole filter response. The product of 'the modulator control to output DC gain' and 'the error amp open-loop gain' gives the DC gain of the system:

$$G_{DC} = G_{CONTROL_OUTPUT} \bullet G_{EA} \bullet \frac{V_{REF}}{V_{OUT}}$$

$$G_{CONTROL_OUTPUT} = \frac{2 \bullet V_{IN}}{I_{OUT}};\ G_{EA} \approx 2000$$

The output filter pole is given by:

$$f_{FILTER_POLE} = \frac{I_{OUT}}{\pi \bullet V_{OUT} \bullet C_{OUT}}$$

where C_{OUT} is the output filter capacitor.

The output filter zero is given by:

$$f_{FILTER_ZERO} = \frac{1}{2 \bullet \pi \bullet R_{ESR} \bullet C_{OUT}}$$

where R_{ESR} is the capacitor equivalent series resistance.

A troublesome feature of the boost regulator topology is the right-half plane zero (RHP), given by:

$$f_{RHPZ} = \frac{V_{IN}^2}{2 \bullet \pi \bullet I_{OUT} \bullet L \bullet V_{OUT}}$$

At heavy loads this gain increase with phase lag can occur at a relatively low frequency. The loop gain is typically rolled off before the RHP zero frequency.

The typical error amplifier compensation is shown in Figure 3. The equations for the loop dynamics are as follows:

$$f_{POLE1} \approx \frac{1}{2 \bullet \pi \bullet 20e6 \bullet C_{C1}}$$ which is extremely close to DC

$$f_{ZERO1} \approx \frac{1}{2 \bullet \pi \bullet R_Z \bullet C_{C1}}$$

$$f_{POLE2} \approx \frac{1}{2 \bullet \pi \bullet R_Z \bullet C_{C2}}$$

APPLICATIONS INFORMATION

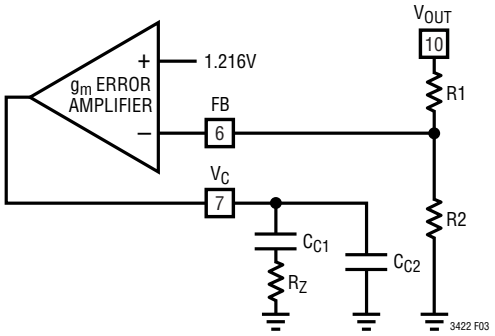
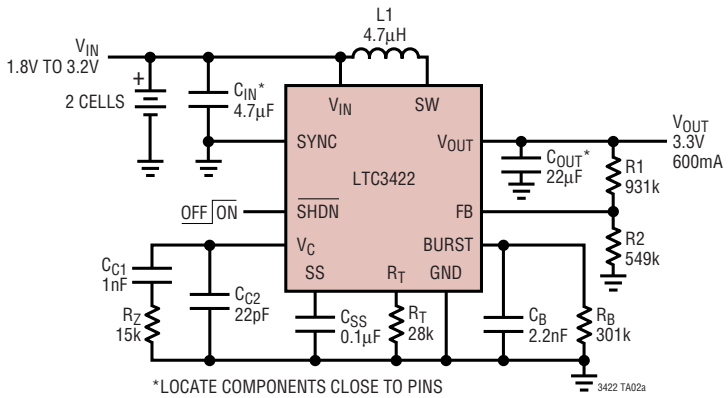


Figure 3. Typical Error Amplifier Compensation

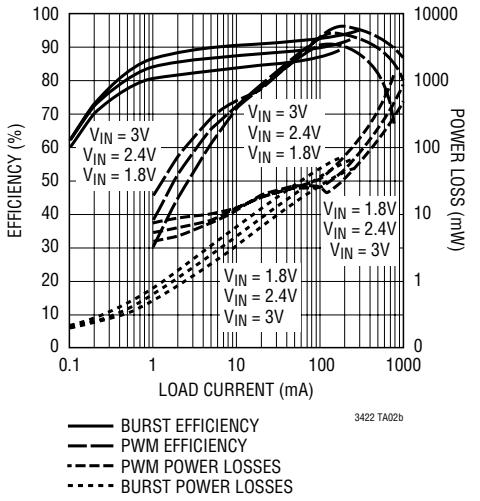
TYPICAL APPLICATIONS

2-Cell to 3.3V at 600mA Application

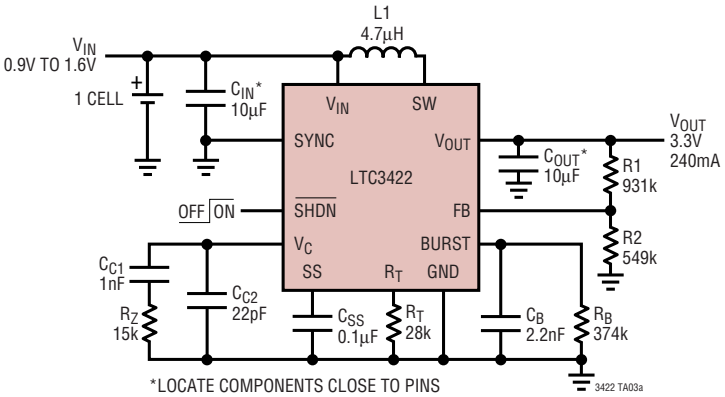


*LOCATE COMPONENTS CLOSE TO PINS
C_{IN}: TAIYO YUDEN X5R JMK212BJ475MD
C_{OUT}: TAIYO YUDEN X5R JMK325BJ226MM
L1: TDK RLF7030T-4R7M3R4

2-Cell to 3.3V Efficiency and Power Loss at 1MHz

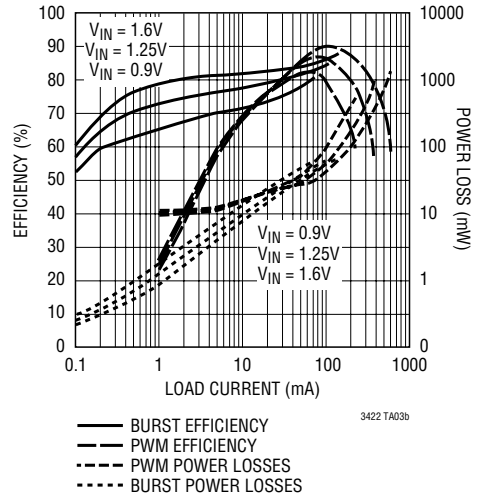


1-Cell to 3.3V at 240mA Application



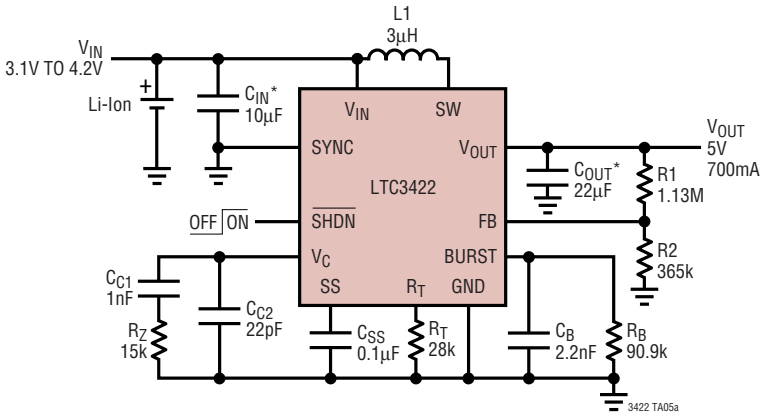
*LOCATE COMPONENTS CLOSE TO PINS
C_{IN}, C_{OUT}: TAIYO YUDEN X5R JMK212BJ106MM
L1: TDK RLF7030T-4R7M3R4

1-Cell to 3.3V Efficiency and Power Loss at 1MHz



TYPICAL APPLICATIONS

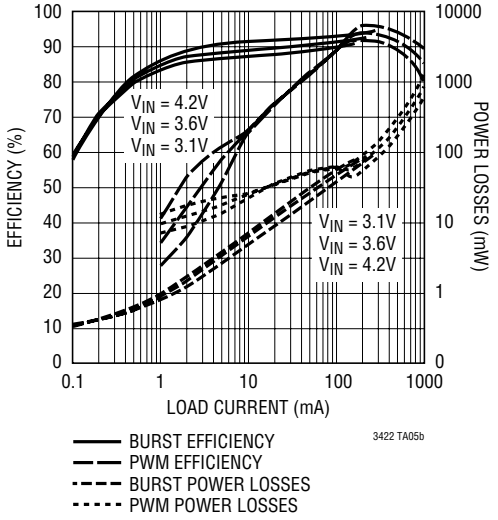
Li-Ion to 5V at 700mA Application



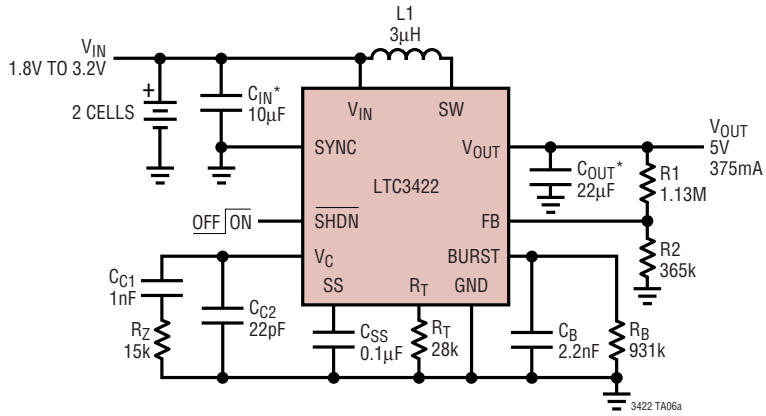
*LOCATE COMPONENTS CLOSE TO PINS
C_{IN}: TAIYO YUDEN X5R JMK212BJ106MM
C_{OUT}: TAIYO YUDEN X5R JMK325BJ226MM

L1: SUMIDA CDRH6D28-3R0

Li-Ion to 5V Efficiency and Power Loss at 1MHz



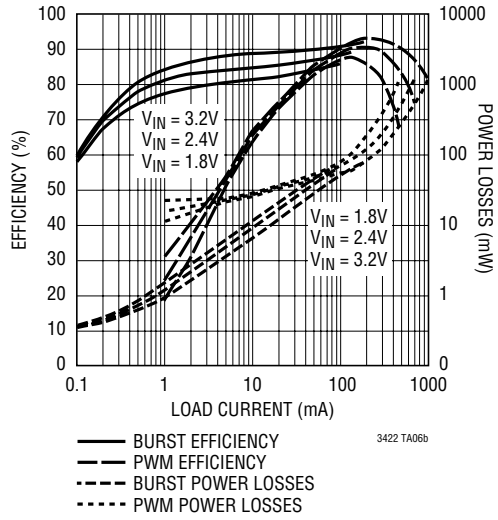
2-Cell to 5V at 375mA Application



*LOCATE COMPONENTS CLOSE TO PINS
C_{IN}: TAIYO YUDEN JMK212BJ106MM
C_{OUT}: TAIYO YUDEN JMK325BJ226MM

L1: SUMIDA CDRH6D28-3R0

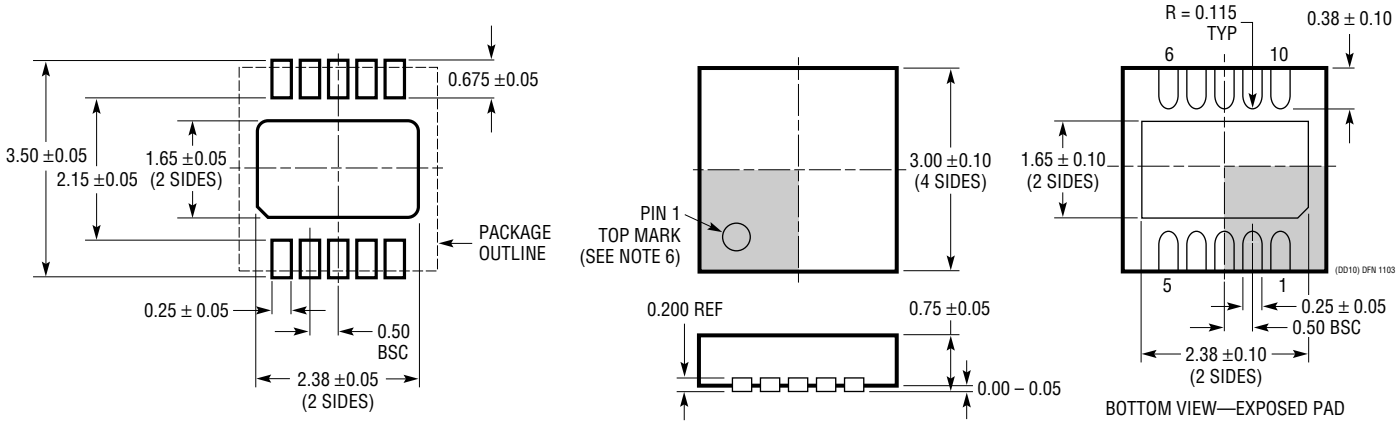
2-Cell to 5V Efficiency and Power Loss at 1MHz



Information furnished by Linear Technology Corporation is believed to be accurate and reliable. However, no responsibility is assumed for its use. Linear Technology Corporation makes no representation that the interconnection of its circuits as described herein will not infringe on existing patent rights.

PACKAGE DESCRIPTION

DD Package
10-Lead Plastic DFN (3mm × 3mm)
(Reference LTC DWG # 05-08-1699)



RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS

NOTE:
1. DRAWING TO BE MADE A JEDEC PACKAGE OUTLINE M0-229 VARIATION OF (WEED-2).
   CHECK THE LTC WEBSITE DATA SHEET FOR CURRENT STATUS OF VARIATION ASSIGNMENT
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE
   MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
5. EXPOSED PAD SHALL BE SOLDER PLATED
6. SHADED AREA IS ONLY A REFERENCE FOR PIN 1 LOCATION ON THE
   TOP AND BOTTOM OF PACKAGE

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC3400/LTC3400B	600mA (I_{SW}), 1.2MHz, Synchronous Step-Up DC/DC Converters	92% Efficiency, V_{IN}: 0.85V to 5V, $V_{OUT(MAX)}$ = 5V, I_Q = 19µA/300µA, I_{SD} < 1µA, ThinSOT™
LTC3401	1A (I_{SW}), 3MHz, Synchronous Step-Up DC/DC Converter	97% Efficiency, V_{IN}: 0.5V to 5V, $V_{OUT(MAX)}$ = 5.5V, I_Q = 38µA, I_{SD} < 1µA, MS10
LTC3402	2A (I_{SW}), 3MHz, Synchronous Step-Up DC/DC Converter	97% Efficiency, V_{IN}: 0.5V to 5V, $V_{OUT(MAX)}$ = 5.5V, I_Q = 38µA, I_{SD} < 1µA, MS10
LTC3421	3A (I_{SW}), 3MHz, Synchronous Step-Up DC/DC Converter with Output Disconnect	95% Efficiency, V_{IN}: 0.5V to 4.5V, $V_{OUT(MAX)}$ = 5.25V, I_Q = 12µA, I_{SD} < 1µA, QFN24
LTC3423/LTC3424	1A/2A (I_{SW}), 3MHz, Synchronous Step-Up DC/DC Converter	95% Efficiency, V_{IN}: 0.5V to 5.5V, $V_{OUT(MAX)}$ = 5.5V, I_Q = 38µA, I_{SD} < 1µA, MSOP10
LTC3425	5A (I_{SW}), 8MHz, (Low Ripple), 4-Phase Synchronous Step-Up DC/DC Converter with Output Disconnect	95% Efficiency, V_{IN}: 0.5V to 4.5V, $V_{OUT(MAX)}$ = 5.25V, I_Q = 12µA, I_{SD} < 1µA, QFN32
LTC3426	2A (I_{SW}), 1.2MHz, Step-Up DC/DC Converter	92% Efficiency, V_{IN}: 1.6V to 4.3V, $V_{OUT(MAX)}$ = 5V, I_{SD} < 1µA, SOT-23
LTC3428	500mA (I_{SW}), 1.25MHz/2.5MHz, Synchronous Step-Up DC/DC Converter with Output Disconnect	92% Efficiency, V_{IN}: 1.8V to 5V, $V_{OUT(MAX)}$ = 5.25V, I_{SD} < 1µA, 2mm × 2mm DFN
LTC3429	600mA (I_{SW}), 500kHz, Synchronous Step-Up DC/DC Converter with Output Disconnect and Soft-Start	96% Efficiency, V_{IN}: 0.5V to 4.4V, $V_{OUT(MAX)}$ = 5V, I_Q = 20µA/300µA, I_{SD} < 1µA, ThinSOT
LTC3525-3.3/ LTC3525-5	400mA (I_{SW}), Synchronous Step-Up DC/DC Converter in SC70 Package	94% Efficiency, V_{IN}: 0.8V to 4.5V, $V_{OUT(MAX)}$ = 5.25V, I_Q = 7µA, I_{SD} < 1µA, SC70

ThinSOT is a trademark of Linear Technology Corporation.

Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7417
(408) 432-1900 • FAX: (408) 434-0507 • www.linear.com

LT 0406 REV A PRINTED IN USA

© LINEAR TECHNOLOGY CORPORATION 2005