

High Voltage, Low Quiescent Current Inverting Charge Pump

FEATURES

- 4.5V to 32V V_{IN} Range
- Inverting Charge Pump Generates $-V_{IN}$
- 60 μ A Quiescent Current in Burst Mode[®] Operation
- Charge Pump Output Current Up to 100mA
- 50kHz to 500kHz Programmable Oscillator Frequency
- Short-Circuit/Thermal Protection
- Low Profile Thermally Enhanced 12-Pin MSOP Package

APPLICATIONS

- Bipolar/Inverting Supplies
- Industrial/Instrumentation Bias Generators
- Portable Medical Equipment
- Portable Instruments

DESCRIPTION

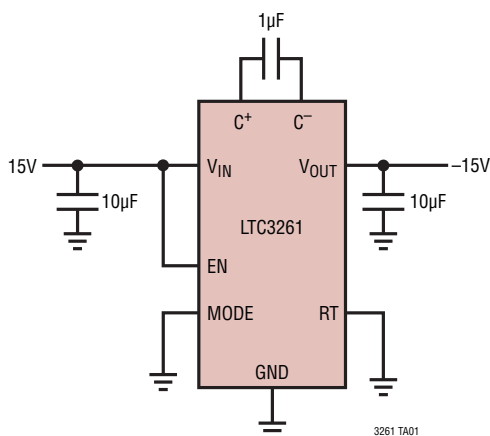
The LTC[®]3261 is a high voltage inverting charge pump that operates over a wide 4.5V to 32V input range and is capable of delivering up to 100mA of output current.

The charge pump employs either low quiescent current Burst Mode operation or low noise constant frequency mode. In Burst Mode operation the charge pump V_{OUT} regulates to $-0.94 \cdot V_{IN}$ and the LTC3261 draws only 60 μ A of quiescent current. In constant frequency mode the charge pump produces an output equal to $-V_{IN}$ and operates at a fixed 500kHz or to a programmed frequency between 50kHz to 500kHz using an external resistor. The LTC3261 is available in a thermally enhanced 12-pin MSOP package.

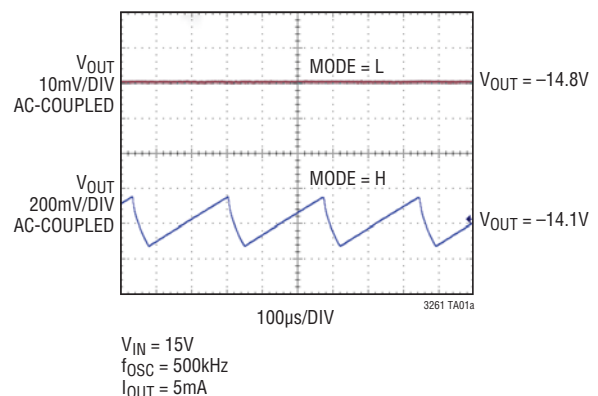
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TYPICAL APPLICATION

15V to -15V Inverter



V_{OUT} Ripple



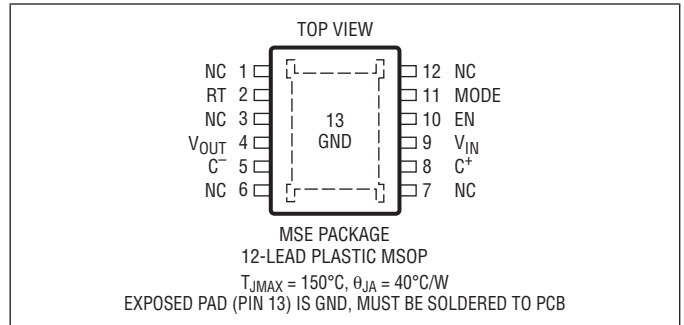
LTC3261

ABSOLUTE MAXIMUM RATINGS

(Notes 1, 3)

V_{IN} , EN, MODE.....	-0.3V to 36V
V_{OUT}	-36V to 0.3V
RT	-0.3V to 6V
V_{OUT} Short-Circuit Duration	Indefinite
Operating Junction Temperature Range (Note 2).....	-40°C to 125°C
Storage Temperature Range	-65°C to 150°C
Lead Temperature (Soldering, 10 sec).....	300°C

PIN CONFIGURATION



ORDER INFORMATION

LEAD FREE FINISH	TAPE AND REEL	PART MARKING*	PACKAGE DESCRIPTION	TEMPERATURE RANGE
LTC3261EMSE#PBF	LTC3261EMSE#TRPBF	3261	12-Lead Plastic MSOP	-40°C to 125°C
LTC3261IMSE#PBF	LTC3261IMSE#TRPBF	3261	12-Lead Plastic MSOP	-40°C to 125°C

Consult LTC Marketing for parts specified with wider operating temperature ranges. *The temperature grade is identified by a label on the shipping container. Consult LTC Marketing for information on non-standard lead based finish parts.

For more information on lead free part marking, go to: <http://www.linear.com/leadfree/>

For more information on tape and reel specifications, go to: <http://www.linear.com/tapeandree/>

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$ (Note 2). $V_{IN} = EN = 12\text{V}$, $MODE = 0\text{V}$, $RT = 200\text{k}\Omega$.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Charge Pump						
V_{IN}	Input Voltage Range		● 4.5		32	V
V_{UVLO}	V_{IN} Undervoltage Lockout Threshold	V_{IN} Rising V_{IN} Falling	● 3.4	● 3.8 ● 3.6	4	V V
I_{VIN}	V_{IN} Quiescent Current	Shutdown, $EN = 0\text{V}$ $MODE = V_{IN}$, $I_{VOUT} = 0\text{mA}$ $MODE = 0\text{V}$, $I_{VOUT} = 0\text{mA}$		2 60 3.5	5 120 5.5	μA μA mA
V_{RT}	RT Regulation Voltage			1.200		V
V_{OUT}	V_{OUT} Regulation Voltage	$MODE = 12\text{V}$ $MODE = 0\text{V}$		$-0.94 \cdot V_{IN}$ $-V_{IN}$		V V
f_{OSC}	Oscillator Frequency	$RT = \text{GND}$	450	500	550	KHz
R_{OUT}	Charge Pump Output Impedance	$MODE = 0\text{V}$, $RT = \text{GND}$		32		Ω
I_{SHORT_CKT}	Max I_{VOUT} Short-Circuit Current	$V_{OUT} = \text{GND}$, $RT = \text{GND}$	● 100	160	250	mA
$V_{MODE(H)}$	MODE Threshold Rising		●	1.1	2	V
$V_{MODE(L)}$	MODE Threshold Falling		● 0.4	1.0		V
I_{MODE}	MODE Pin Internal Pull-Down Current	$V_{IN} = MODE = 32\text{V}$		0.7		μA
$V_{EN(H)}$	EN Threshold Rising		●	1.1	2	V
$V_{EN(L)}$	EN Threshold Falling		● 0.4	1.0		V
I_{EN}	EN Pin Internal Pull-Down Current	$V_{IN} = EN = 32\text{V}$		0.7		μA

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 reliability and lifetime.

Note 2: The LTC3261 is tested under pulsed load conditions such that $T_J \approx T_A$. The LTC3261E is guaranteed to meet specifications from 0°C to 85°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 LTC3261I is guaranteed over the -40°C to 125°C operating junction temperature range. High junction temperatures degrade operating lifetimes; operating lifetime is derated for junction temperatures greater than 125°C . Note that the maximum ambient temperature consistent with these specifications is determined by specific operating conditions in

conjunction with board layout, the rated package thermal impedance and other environmental factors.

The junction temperature (T_J , in $^\circ\text{C}$) is calculated from the ambient temperature (T_A , in $^\circ\text{C}$) and power dissipation (P_D , in Watts) according to the formula:

$$T_J = T_A + (P_D \cdot \theta_{JA}),$$

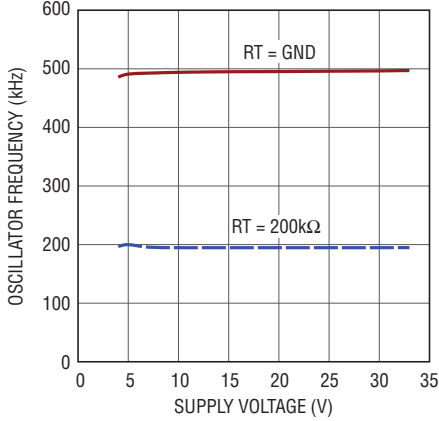
where $\theta_{JA} = 40^\circ\text{C}/\text{W}$ is the package thermal impedance.

Note 3: This IC includes overtemperature protection that is intended to protect the device during momentary overload conditions. Junction temperatures will exceed 150°C when overtemperature protection is active. Continuous operation above the specified maximum operating junction temperature may result in device degradation or failure.

TYPICAL PERFORMANCE CHARACTERISTICS

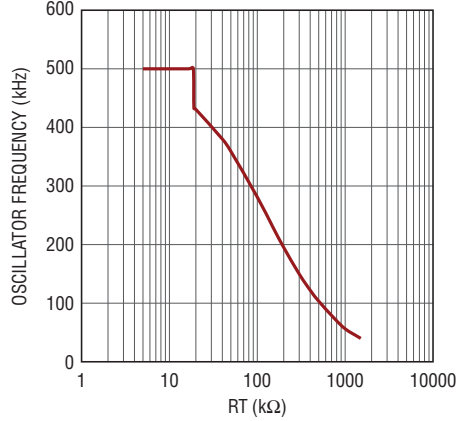
($T_A = 25^\circ\text{C}$, $C_{\text{FLY}} = 1\mu\text{F}$, $C_{\text{IN}} = C_{\text{OUT}} = 10\mu\text{F}$ unless otherwise noted)

Oscillator Frequency vs Supply Voltage



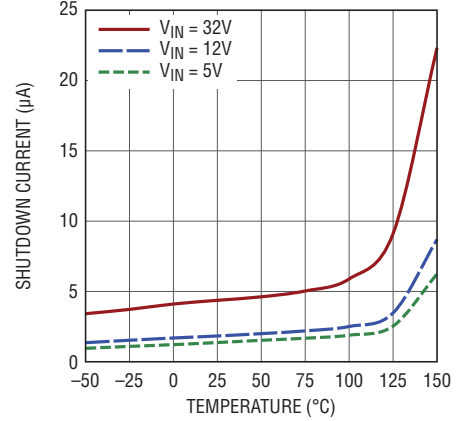
3261 G01

Oscillator Frequency vs RT



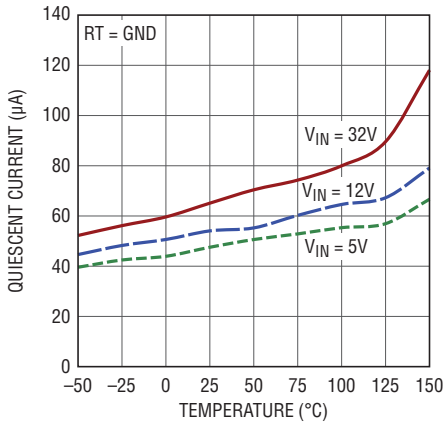
3261 G02

Shutdown Current vs Temperature



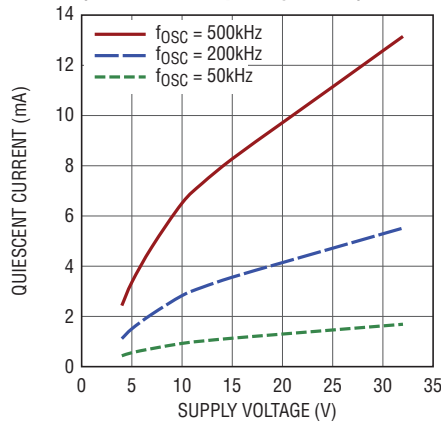
3261 G03

Quiescent Current vs Temperature (Burst Mode Operation)



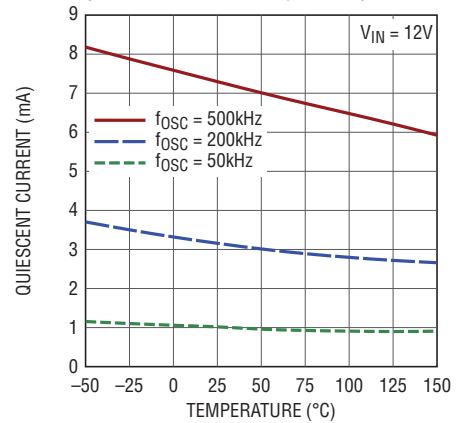
3261 G04

Quiescent Current vs Supply Voltage (Constant Frequency Mode)



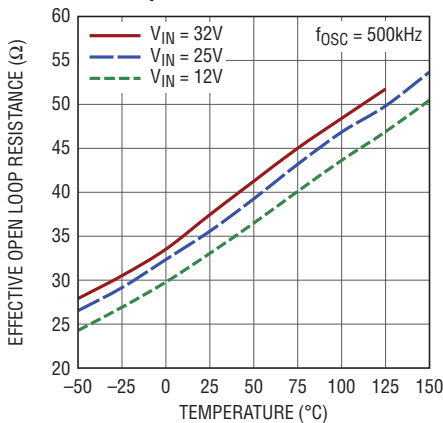
3261 G05

Quiescent Current vs Temperature (Constant Frequency Mode)



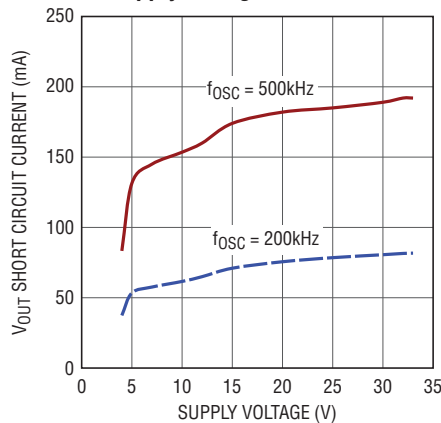
3261 G06

Effective Open-Loop Resistance vs Temperature



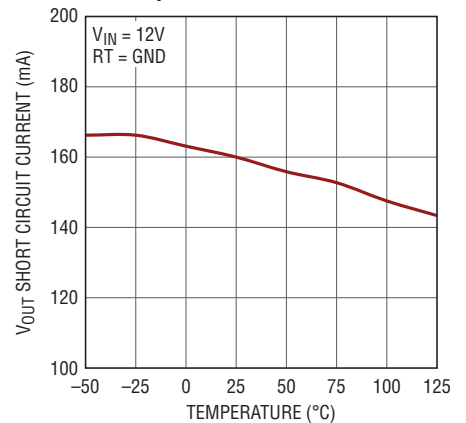
3261 G07

VOUT Short-Circuit Current vs Supply Voltage



3261 G08

VOUT Short Circuit Current vs Temperature

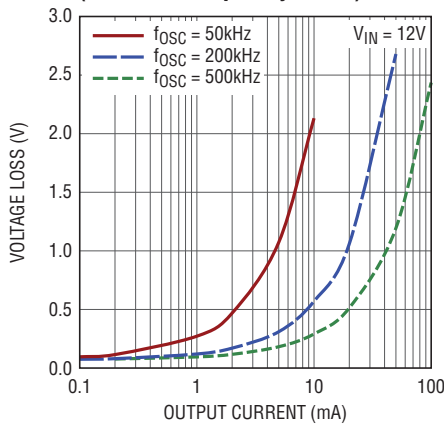


3261 G8b

TYPICAL PERFORMANCE CHARACTERISTICS

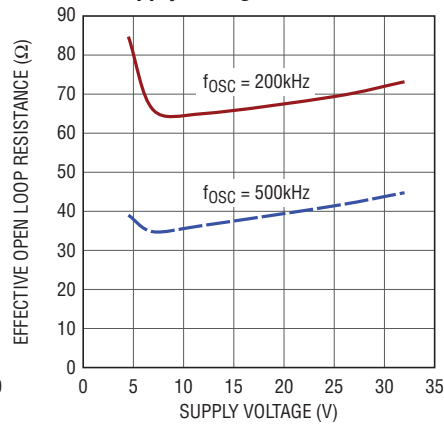
($T_A = 25^\circ\text{C}$, $C_{\text{FLY}} = 1\mu\text{F}$, $C_{\text{IN}} = C_{\text{OUT}} = 10\mu\text{F}$ unless otherwise noted)

Voltage Loss ($V_{\text{IN}} - |V_{\text{OUT}}|$) vs Output Current (Constant Frequency Mode)



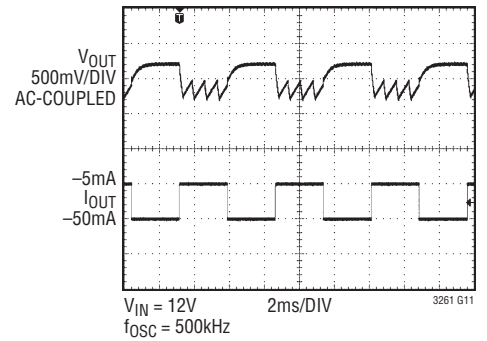
3261 G09

Effective Open-Loop Resistance vs Supply Voltage



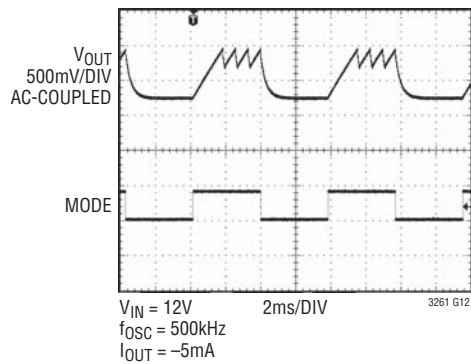
3261 G10

V_{OUT} Load Transient Burst Mode Operation (MODE = H)



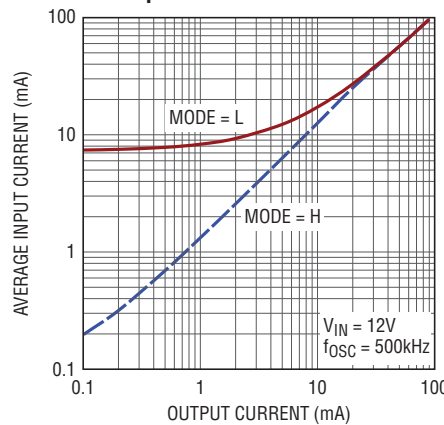
3261 G11

V_{OUT} Transient (MODE = Low to High)



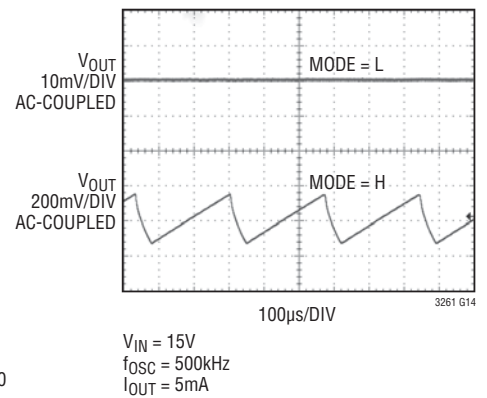
3261 G12

Average Input Current vs Output Current



3261 G13

V_{OUT} Ripple



3261 G14

PIN FUNCTIONS

NC (Pins 1, 3, 6, 7, 12): No Connect Pins. These pins are not connected to the LTC3261 die. These pins should be left floating or connected to ground. Pins 6 and 7 can also be shorted to adjacent pins.

RT (Pin 2): Input Connection for Programming the Switching Frequency. The RT pin serves to a fixed 1.2V when the EN pin is driven to a logic “high”. A resistor from RT to GND sets the charge pump switching frequency. If the RT pin is tied to GND, the switching frequency defaults to a fixed 500kHz.

V_{OUT} (Pin 4): Charge Pump Output Voltage. In constant frequency mode (MODE = low) this pin is driven to $-V_{IN}$. In Burst Mode operation, (MODE = high) this pin voltage is regulated to $-0.94 \cdot V_{IN}$ using an internal burst comparator with hysteretic control.

C⁻ (Pin 5): Flying Capacitor Negative Connection.

C⁺ (Pin 8): Flying Capacitor Positive Connection.

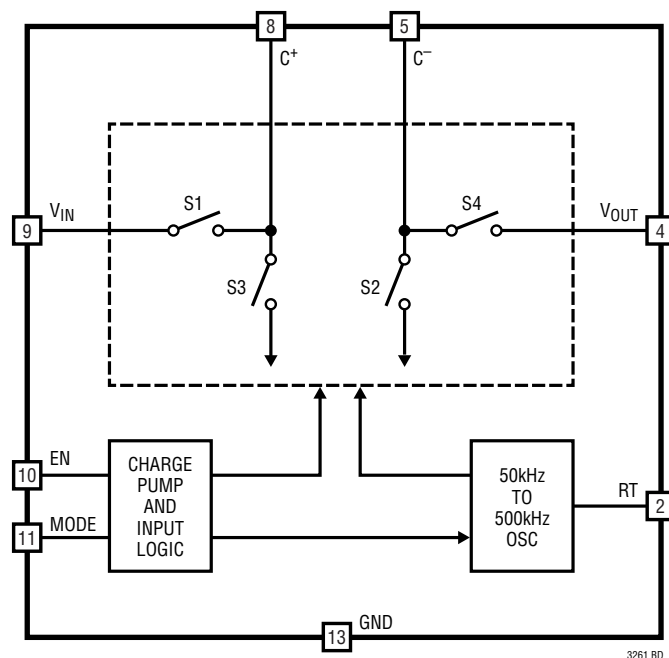
V_{IN} (Pin 9): Input Voltage for the Charge Pump. V_{IN} should be bypassed with a low impedance ceramic capacitor.

EN (Pin 10): Logic Input. A logic “high” on the EN pin enables the inverting charge pump.

MODE (Pin 11): Logic Input. The MODE pin determines the charge pump operating mode. A logic “high” on the MODE pin forces the charge pump into Burst Mode operation regulating V_{OUT} to approximately $-0.94 \cdot V_{IN}$ with hysteretic control. A logic “low” on the MODE pin forces the charge pump to operate as an open-loop inverter with a constant switching frequency. The switching frequency in both modes is determined by an external resistor from the RT pin to GND. In Burst Mode, this represents the frequency of the burst cycles before the part enters the low quiescent current sleep state.

GND (Exposed Pad Pin 13): Ground. The exposed package pad is ground and must be soldered to the PC board ground plane for proper functionality and for rated thermal performance.

BLOCK DIAGRAM



OPERATION (Refer to the Block Diagram)

The LTC3261 is a high voltage inverting charge pump. It supports a wide input power supply range from 4.5V to 32V.

Shutdown Mode

In shutdown mode, all circuitry except the internal bias is turned off. The LTC3261 is in shutdown when a logic low is applied to the enable input (EN). The LTC3261 only draws 2 μ A (typical) from the V_{IN} supply in shutdown.

Constant Frequency Operation

The LTC3261 provides low noise constant frequency operation when a logic low is applied to the MODE pin. The charge pump and oscillator circuit are enabled using the EN pin. At the beginning of a clock cycle, switches S1 and S2 are closed. The external flying capacitor across the C^+ and C^- pins is charged to the V_{IN} supply. In the second phase of the clock cycle, switches S1 and S2 are opened, while switches S3 and S4 are closed. In this configuration the C^+ side of the flying capacitor is grounded and charge is delivered through the C^- pin to V_{OUT} . In steady state the V_{OUT} pin regulates at $-V_{IN}$ less any voltage drop due to the load current on V_{OUT} .

The charge transfer frequency can be adjusted between 50kHz and 500kHz using an external resistor on the RT pin. At slower frequencies the effective open-loop output resistance (R_{OL}) of the charge pump is larger and it is able to provide smaller average output current. Figure 1 can be used to determine a suitable value of RT to achieve a required oscillator frequency. If the RT pin is grounded, the part operates at a constant frequency of 500kHz.

Burst Mode Operation

The LTC3261 provides low power Burst Mode operation when a logic high is applied to the MODE pin. In Burst Mode operation, the charge pump charges the V_{OUT} pin to $-0.94 \cdot V_{IN}$ (typical). The part then shuts down the internal oscillator to reduce switching losses and goes into a low current state. This state is referred to as the sleep state in which the IC consumes only about 60 μ A. When the output voltage droops enough to overcome the burst comparator hysteresis, the part wakes up and commences charge pump cycles until output voltage exceeds $-0.94 \cdot V_{IN}$ (typical). This mode provides lower operating current at the cost of higher output ripple and is ideal for light load operation.

The frequency of charging cycles is set by the external resistor on the RT pin. The charge pump has a lower R_{OL} at higher frequencies. For Burst Mode operation it is recommended that the RT pin be tied to GND. This minimizes the charge pump R_{OL} , quickly charges the output up to the burst threshold and optimizes the duration of the low current sleep state.

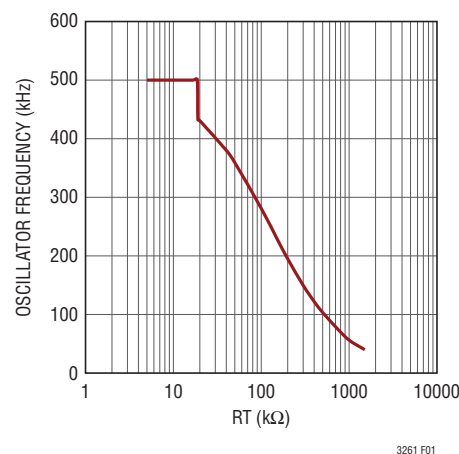


Figure 1. Oscillator Frequency vs RT

Soft-Start

The LTC3261 has built in soft-start circuitry to prevent excessive current flow during start-up. The soft-start is achieved by internal circuitry that slowly ramps the amount of current available at the output storage capacitor. The soft-start circuitry is reset in the event of a commanded shutdown or thermal shutdown.

Short-Circuit/Thermal Protection

The LTC3261 has built-in short-circuit current limit as well as overtemperature protection. During a short-circuit condition, the part automatically limits its output current to approximately 160mA. If the junction temperature exceeds approximately 175°C the thermal shutdown circuitry disables current delivery to the output. Once the junction temperature drops back to approximately 165°C current delivery to the output is resumed. When thermal protection is active the junction temperature is beyond the specified operating range. Thermal protection is intended for momentary overload conditions outside normal operation. Continuous operation above the specified maximum operating junction temperature may impair device reliability.

APPLICATIONS INFORMATION

Effective Open-Loop Output Resistance

The effective open-loop output resistance (R_{OL}) of a charge pump is a very important parameter which determines the strength of the charge pump. The value of this parameter depends on many factors such as the oscillator frequency (f_{OSC}), value of the flying capacitor (C_{FLY}), the nonoverlap time, the internal switch resistances (R_S) and the ESR of the external capacitors.

Typical R_{OL} values as a function of temperature are shown in Figure 2

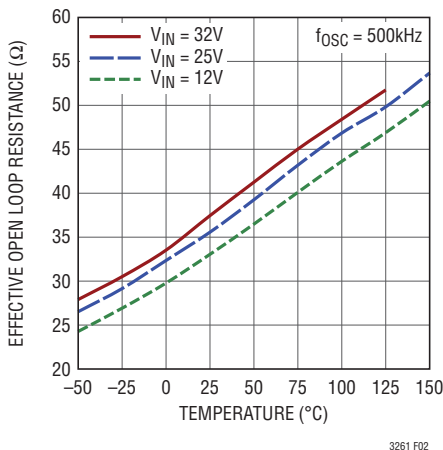


Figure 2. Typical R_{OL} vs Temperature

Input/Output Capacitor Selection

The style and value of capacitors used with the LTC3261 determine several important parameters such as regulator control loop stability, output ripple, charge pump strength and minimum turn-on time. To reduce noise and ripple, it is recommended that low ESR ceramic capacitors be used for the charge pump output. The charge pump output capacitor should retain at least $2\mu F$ of capacitance over operating temperature and bias voltage. Tantalum and aluminum capacitors can be used in parallel with a ceramic capacitor to increase the total capacitance but should not be used alone because of their high ESR. In constant frequency mode, the value of C_{OUT} directly controls the amount of output ripple for a given load current. Increasing the size of C_{OUT} will reduce the output ripple at the expense of higher minimum turn-on time. The peak-to-peak output ripple at the V_{OUT} pin is approximately given by the expression:

$$V_{RIPPLE(P-P)} \approx \frac{I_{OUT}}{C_{OUT}} \cdot \left(\frac{1}{f_{OSC}} - t_{ON} \right)$$

where f_{OSC} is the oscillator frequency t_{ON} is the on-time of the oscillator ($1\mu s$) typical and C_{OUT} is the value of the output capacitor.

Just as the value of C_{OUT} controls the amount of output ripple, the value of C_{IN} controls the amount of ripple present at the input (V_{IN}) pin. The amount of bypass capacitance required at the input depends on the source impedance driving V_{IN} . For best results it is recommended that V_{IN} be bypassed with at least $2\mu F$ of low ESR capacitance. A high ESR capacitor such as tantalum or aluminum will have higher input noise than a low ESR ceramic capacitor. Therefore, a ceramic capacitor is recommended as the main bypass capacitance with a tantalum or aluminum capacitor used in parallel if desired.

Flying Capacitor Selection

The flying capacitor controls the strength of the charge pump. A $1\mu F$ or greater ceramic capacitor is suggested for the flying capacitor for applications requiring the full rated output current of the charge pump.

For very light load applications, the flying capacitor may be reduced to save space or cost. For example, a $0.2\mu F$ capacitor might be sufficient for load currents up to 20mA. A smaller flying capacitor leads to a larger effective open-loop resistance (R_{OL}) and thus limits the maximum load current that can be delivered by the charge pump.

Ceramic Capacitors

Ceramic capacitors of different materials lose their capacitance with higher temperature and voltage at different rates. For example, a capacitor made of X5R or X7R material will retain most of its capacitance from $-40^{\circ}C$ to $85^{\circ}C$ whereas a Z5U or Y5V style capacitor will lose considerable capacitance over that range. Z5U and Y5V capacitors may also have a poor voltage coefficient causing them to lose 60% or more of their capacitance when the rated voltage is applied. Therefore when comparing different capacitors, it is often more appropriate to compare the amount of achievable capacitance for a given case size rather than discussing the specified capacitance value. The capacitor manufacturer's data sheet

3261f

APPLICATIONS INFORMATION

should be consulted to ensure the desired capacitance at all temperatures and voltages. Table 1 is a list of ceramic capacitor manufacturers and their websites.

Table 1

AVX	www.avxcorp.com
Kemet	www.kemet.com
Murata	www.murata.com
Taiyo Yuden	www.t-yuden.com
Vishay	www.vishay.com
TDK	www.component.tdk.com

Layout Considerations

Due to high switching frequency and high transient currents produced by LTC3261, careful board layout is necessary for optimum performance. A true ground plane and short connections to all the external capacitors will improve performance and ensure proper regulation under all conditions. Figure 3 shows an example layout for the LTC3261.

The flying capacitor nodes C⁺ and C⁻ switch large currents at a high frequency. These nodes should not be routed close to sensitive pins such as the RT pin.

Thermal Management

At high input voltages and maximum output current, there can be substantial power dissipation in the LTC3261. If the junction temperature increases above approximately 175°C, the thermal shutdown circuitry will automatically deactivate the output. To reduce the maximum junction temperature, a good thermal connection to the PC board ground plane is recommended. Connecting the exposed pad of the package to a ground plane under the device on two layers of the PC board can reduce the thermal resistance of the package and PC board considerably.

Derating Power at High Temperatures

To prevent an overtemperature condition in high power applications, Figure 4 should be used to determine the maximum combination of ambient temperature and power dissipation.

The power dissipated in the LTC3261 should always fall under the line shown for a given ambient temperature.

The power dissipated in the LTC3261 is:

$$P_D = (V_{IN} - |V_{OUT}|) \cdot (I_{OUT})$$

where I_{OUT} denotes output current at the V_{OUT} pin.

The derating curve in Figure 4 assumes a maximum thermal resistance, θ_{JA} , of 40°C/W for the package. This can be achieved from a printed circuit board layout with a solid ground plane and a good connection to the exposed pad of the LTC3261 package.

It is recommended that the LTC3261 be operated in the region corresponding to $T_J \leq 150^\circ\text{C}$ for continuous operation as shown in Figure 4. Short-term operation may be acceptable for $150^\circ\text{C} < T_J < 175^\circ\text{C}$ but long-term operation in this region should be avoided as it may reduce the life of the part or cause degraded performance. For $T_J > 175^\circ\text{C}$ the part will be in thermal shutdown.

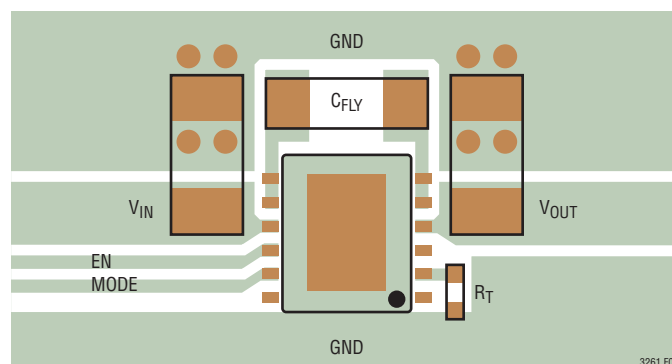


Figure 3. Recommended Layout

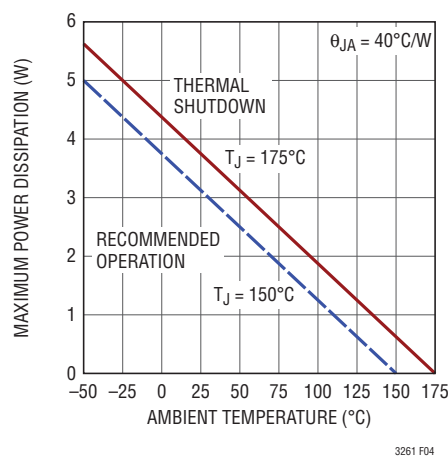
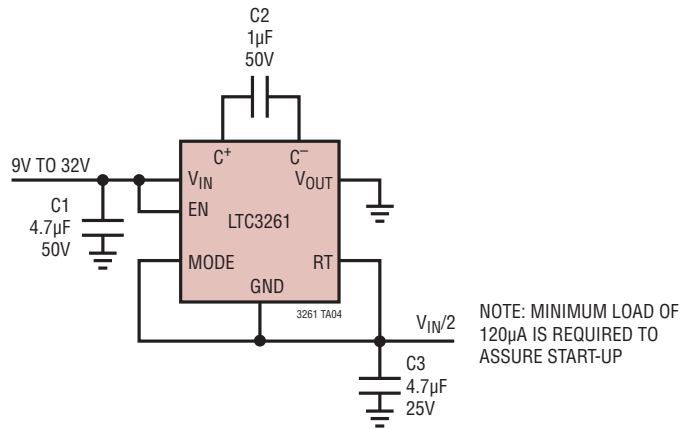


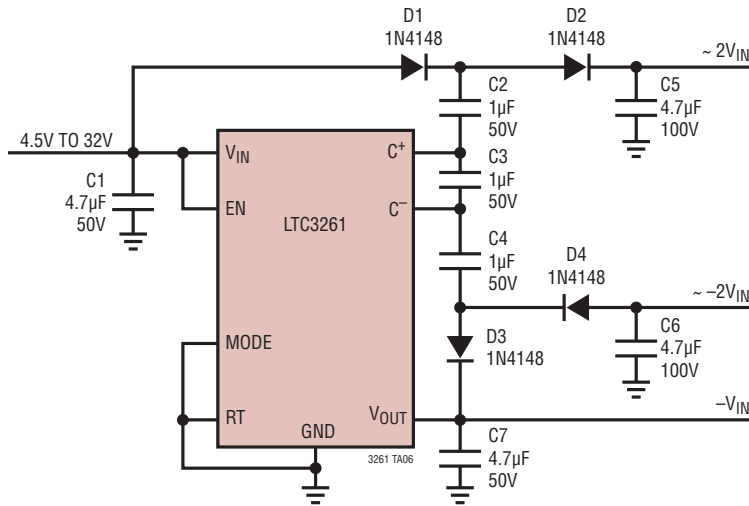
Figure 4. Maximum Power Dissipation vs Ambient Temperature

TYPICAL APPLICATIONS

High Input Divide by 2 Voltage Divider

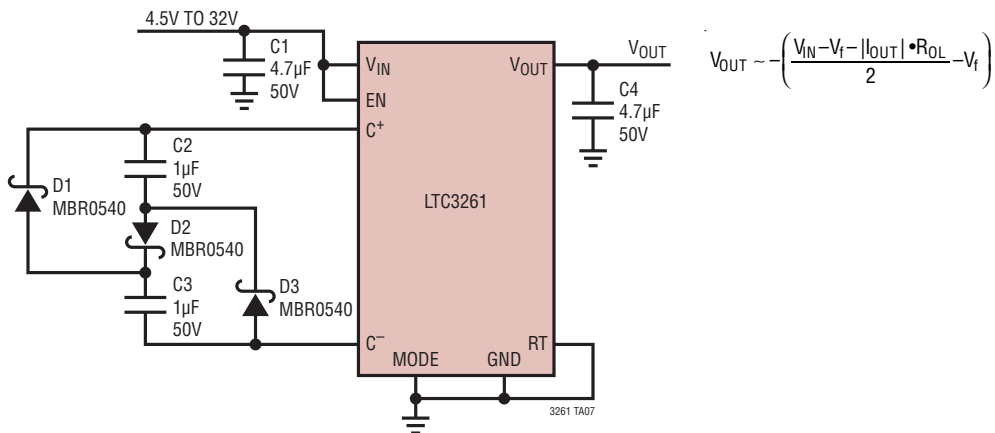


Inverting Charge Pump with Bipolar Doubler



NOTE: $I_{2V_{IN}} \cdot 2 + I_{-2V_{IN}} \cdot 2 + I_{OUT} \leq 100\text{mA}$

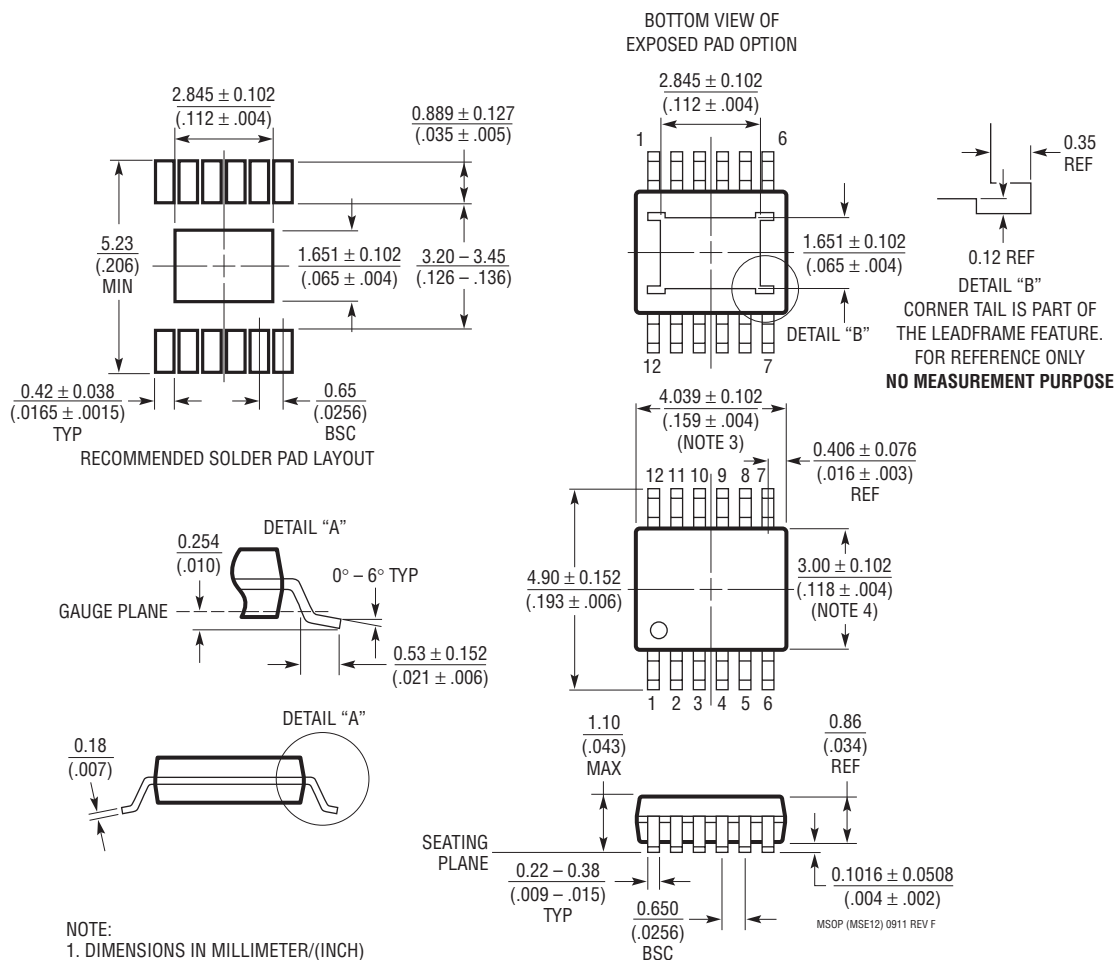
High Voltage to Inverted Low Voltage Charge Pump



PACKAGE DESCRIPTION

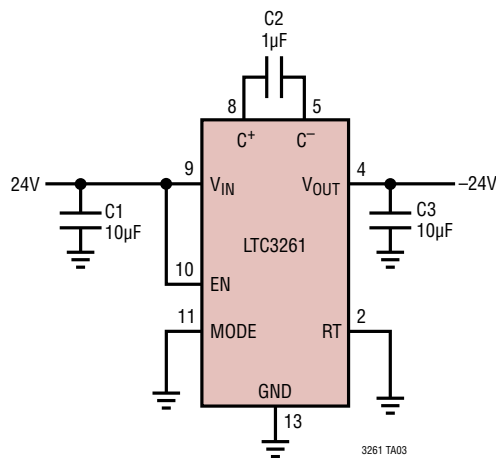
Please refer to <http://www.linear.com/designtools/packaging/> for the most recent package drawings.

MSE Package 12-Lead Plastic MSOP, Exposed Die Pad (Reference LTC DWG # 05-08-1666 Rev F)



TYPICAL APPLICATION

24V to -24V Inverter



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC1144	Switched-Capacitor Wide Input Range Voltage Converter with Shutdown	Wide Input Voltage Range: 2V to 18V, $I_{SD} < 8\mu A$, SO8 Package
LTC1514/LTC1515	Step-Up/Step-Down Switched-Capacitor DC/DC Converters	V_{IN} : 2V to 10V, V_{OUT} : 3.3V to 5V, $I_Q = 60\mu A$, SO8 Package
LT [®] 1611	150mA Output, 1.4MHz Micropower Inverting Switching Regulator	V_{IN} : 0.9V to 10V, $V_{OUT} = \pm 34V$, ThinSOT [™] Package
LT1614	250mA Output, 600kHz Micropower Inverting Switching Regulator	V_{IN} : 0.9V to 6V, $V_{OUT} = \pm 30V$, $I_Q = 1mA$, MS8, SO8 Packages
LTC1911	250mA, 1.5MHz Inductorless Step-Down DC/DC Converter	V_{IN} : 2.7V to 5.5V, $V_{OUT} = 1.5V/1.8V$, $I_Q = 180\mu A$, MS8 Package
LTC3250/LTC3250-1.2/ LTC3250-1.5	Inductorless Step-Down DC/DC Converters	V_{IN} : 3.1V to 5.5V, $V_{OUT} = 1.2V, 1.5V$, $I_Q = 35\mu A$, ThinSOT Package
LTC3251	500mA Spread Spectrum Inductorless Step-Down DC/DC Converter	V_{IN} : 2.7V to 5.5V, V_{OUT} : 0.9V to 1.6V, 1.2V, 1.5V, $I_Q = 9\mu A$, MS10E Package
LTC3252	Dual 250mA, Spread Spectrum Inductorless Step-Down DC/DC Converter	V_{IN} : 2.7V to 5.5V, V_{OUT} : 0.9V to 1.6V, $I_Q = 50\mu A$, DFN12 Package
LT1054/LT1054L	Switched-Capacitor Voltage Converters with Regulator	V_{IN} : 3.5V to 15V/7V, $I_{OUT} = 100mA/125mA$, N8, SO8, SO16 Packages