# GC3400

## 1.2 MHz, Micropower Synchronous Step-Up Converter

## GENERAL DESCRIPTION

The GC3400 is a 1.2MHz constant frequency, current mode PWM step-up converter. It can supply 3.3V output voltage at 100mA from a single AA Cell. The device integrates a main switch and a synchronous rectifier for high efficiency without an external Schottky diode.A switching frequency of 1.2MHz allows the use of tiny, low profile inductors and ceramic capacitors. The current mode PWM operation with internal compensation provides excellent line and load transient characteristics. The GC3400 features Pulse Skipping Mode operation at light loads to avoid unacceptable ripple voltage.

The GC3400 is offered in a low profile (1mm) small 6-Pin SOT23 Package.

## FEATURES

- High Efficiency: Up to 92%
- 1.2MHz Constant Switching Frequency
- 3.3V Output Voltage at $I_{OUT}$=100mA from a Single AA Cell; 3.3V Output Voltage at $I_{OUT}$=400mA from two AA cells
- Low Start-up Voltage: 0.85V
- Integrated main switch and synchronous rectifier. No Schottky Diode Required
- 2.5V to 5V Output Voltage Range
- Automatic Pulse Skipping Mode Operation
- Tiny External Components
- <1μA Shutdown Current
- Antiringing Control Reduces EMI
- Space Saving 6-Pin Thin SOT23 Package
- Compatible With LTC3400B

## APPLICATIONS

- Cellular and Smart Phones
- Microprocessors and DSP Core Supplies
- Wireless and DSL Modems
- MP3 Player
- Digital Still and Video Cameras
- Portable Instruments

## EVALUATION BOARD

| Standard Demo Board | Dimensions(mm) |
|---|---|
| EV34000712 | 60X x 60Y x 1.6Z |

## Typical Application

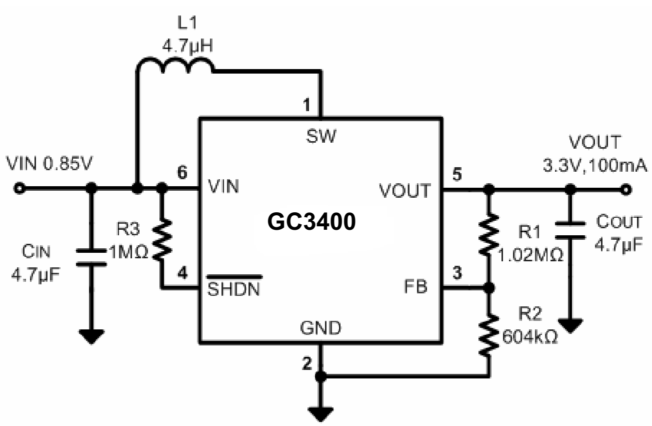
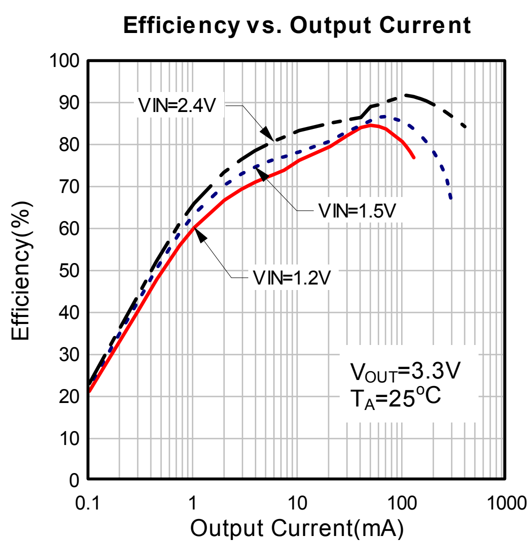



Figure 1. Basic Application Circuit with GC3400 Adjustable Version



## Absolute Maximum Rating(Note 1)

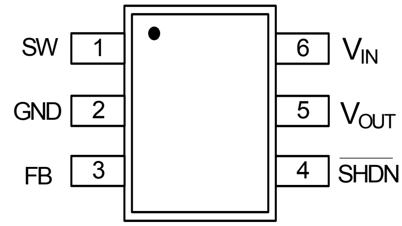
Input Supply Voltage .......................... -0.3V to +6V
SW Voltage ....................................... -0.3V to +6V
FB, SHDN Voltages........................... -0.3V to +6V
$V_{OUT}$ Voltage.................................... ..-0.3V to +6V
Operating Temperature Range(Note 2)….-40°C to +85°C
Storage Temperature Range ......-65°C to +150°C
Lead Temperature (Soldering, 10s) .......... +300°C

## Thermal Resistance (Note 3):

| Package | $\Theta_{JA}$ | $\Theta_{JC}$ |
|---|---|---|
| TSOT23-6 | 250°C /W | 110°C /W |

## Package/Order Information

(Top View)




TSOT23-6

| Part Number | Top Mark | Temp Range |
|---|---|---|
| GC3400ES5 | EAYM(Note 4) | -40°C to 85°C |
| GC3400ES5-3.3 | EHYM | |
| GC3400ES5-5.0 | EIYM | |

## Electrical Characteristics (Note 5)

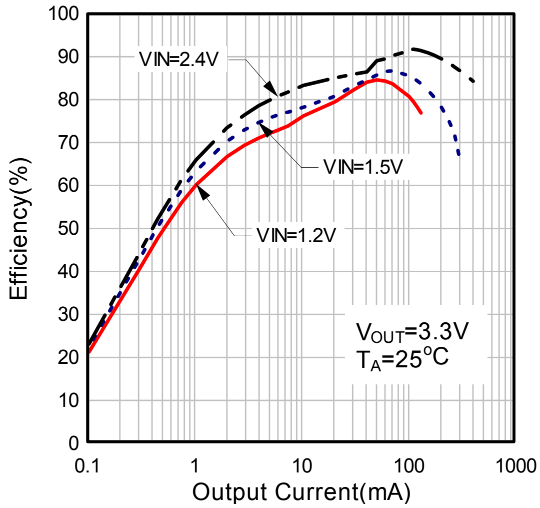
($V_{IN}$ =1.2V, $V_{OUT}$=3.3V, $T_A$ = 25°C, Test Circuit of Figure 1,unless otherwise noted.)

| Parameter | Conditions | MIN | TYP | MAX | unit |
|---|---|---|---|---|---|
| Minimum Start-Up Voltage | $I_{OUT}$ = 1mA | | 0.85 | 1 | V |
| Minimum Operating Voltage | $V_{SHDN} = V_{IN}$ | | 0.5 | 0.65 | V |
| Output Voltage Range | | 2.5 | | 5 | V |
| Feedback Voltage | $-40^oC \leq T_A \leq 85^oC$ | 1.192 | 1.230 | 1.268 | V |
| Quiescent Current(Shutdown) | $V_{SHDN}$ = 0V | | 0.01 | 1 | μA |
| Quiescent Current(Active) | Measured on $V_{OUT}$ | | 300 | 500 | μA |
| NMOS Switch Leakage | $V_{SW}$ = 5V | | 0.1 | 5 | μA |
| PMOS Switch Leakage | $V_{SW}$ = 0V | | 0.1 | 5 | μA |
| NMOS Switch ON Resistance | $V_{OUT}$ = 3.3V | | 0.40 | | Ω |
| | $V_{OUT}$ = 5V | | 0.35 | | Ω |
| PMOS Switch ON Resistance | $V_{OUT}$ = 3.3V | | 0.70 | | Ω |
| | $V_{OUT}$ = 5V | | 0.60 | | Ω |
| Output Voltage | $V_{OUT}$ = 3.3V, $I_{OUT}$ = 1mA | 3.201 | 3.300 | 3.399 | V |
| | $V_{OUT}$ = 5V , $I_{OUT}$ = 1mA, $V_{IN}$ = 2.4V | 4.850 | 5.000 | 5.150 | V |
| Line Regulation | $V_{IN}$ = 0.8V to 3.0V, $I_{OUT}$ = 10mA | | 1 | | %/V |
| Load Regulation | $I_{OUT}$ = 1mA to 100mA | | 0.02 | | %/mA |
| NMOS Current Limit | | 600 | 850 | | mA |
| Current Limit Delay to Output | Note 6 | | 40 | | ns |
| Max Duty Cycle | $V_{FB}$ = 1.15V, $-40^oC \leq T_A \leq 85^oC$ | 80 | 85 | | % |
| Switching Frequency | | 0.95 | 1.2 | 1.5 | MHz |
| | $-40^oC \leq T_A \leq 85^oC$ | 0.85 | 1.2 | 1.5 | MHz |
| SHDN Input Threshold | | 0.35 | 0.60 | 1.50 | V |
| SHDN Input Current | $V_{SHDN}$ = 5.5V | | 0.01 | 1 | μA |

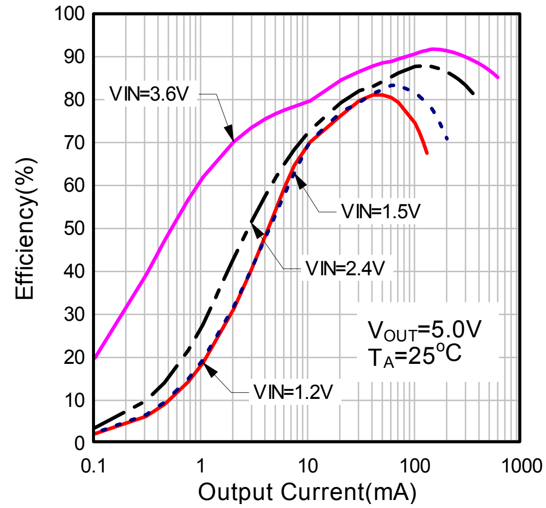
**Note 1:** Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.
**Note 2:** $T_J$ is calculated from the ambient temperature $T_A$ and power dissipation $P_D$ according to the following formula:
$T_J = T_A + (P_D) \times (250°C/W)$.
**Note 3:** Thermal Resistance is specified with approximately 1 square of 1 oz copper.
**Note 4:** A: ADJ; H: 3.3V; I: 5.0V; YM=Manufacturing Date Code. Y: Year(7=2007); M: Month (1~9,O, N,D)
**Note 5:** 100% production test at +25°C. Specifications over the temperature range are guaranteed by design and characterization.
**Note 6:** Guaranteed by design.

# Typical Performance Characteristics

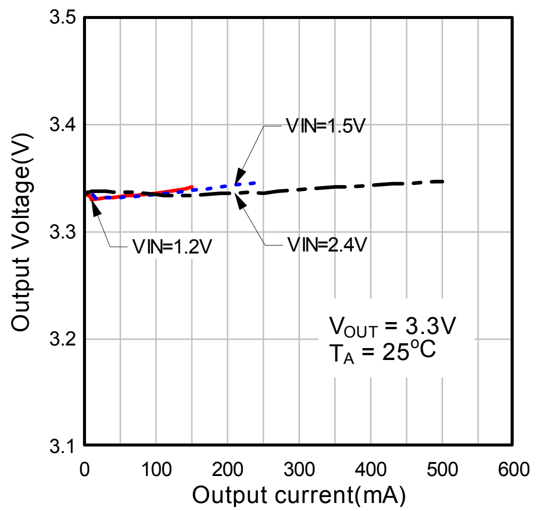
Efficiency vs. Output Current



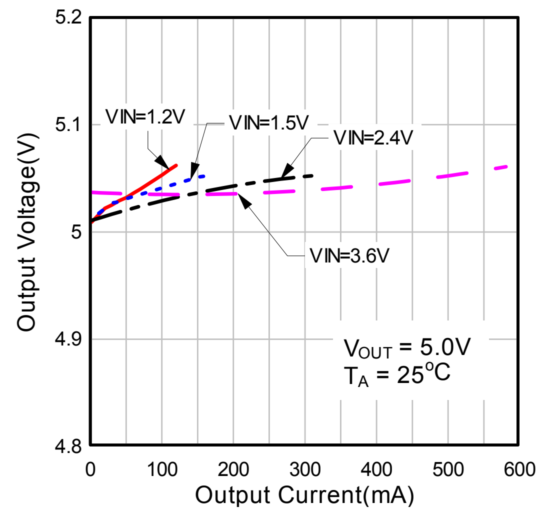

Efficiency vs. Output Current



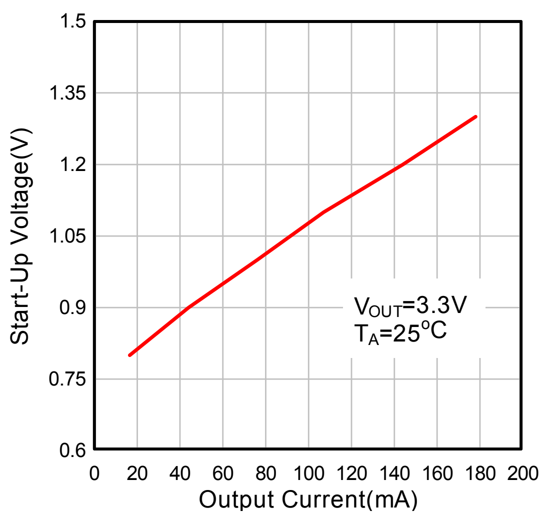

Output Voltage vs. Output Current



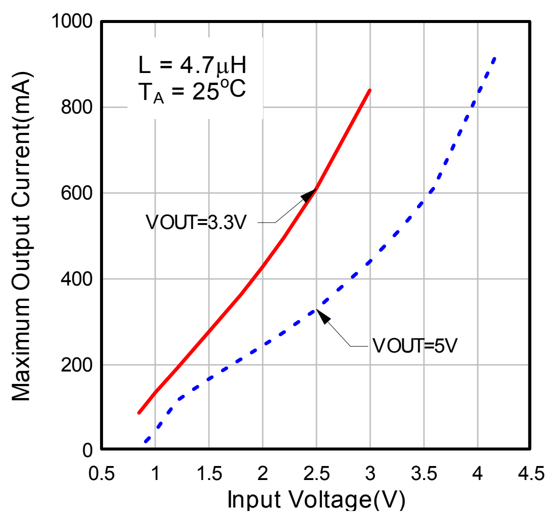

Output Voltage vs. Output Current




Minimum Start-Up Voltage vs. Output Current

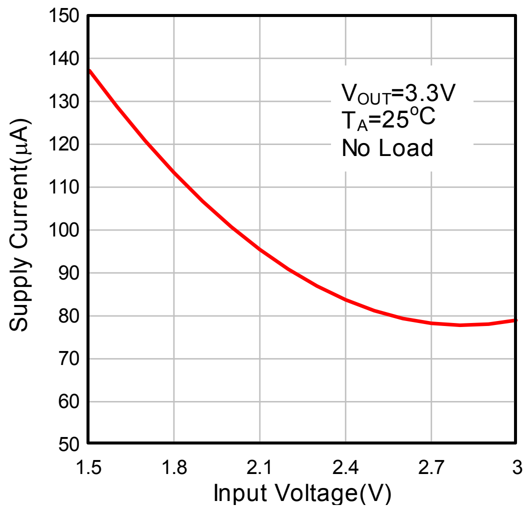



Maximum Output Current vs. Input Voltage

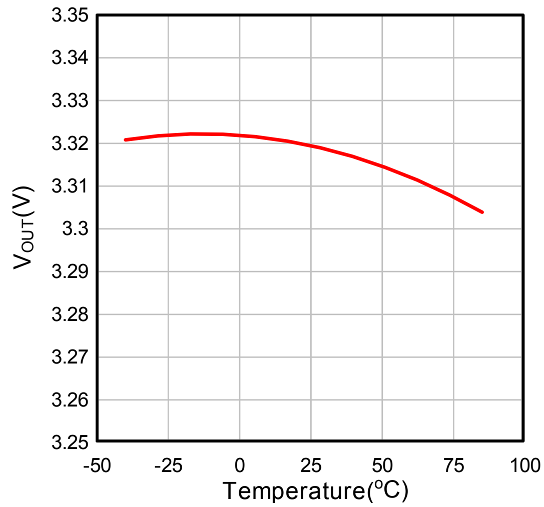


# Typical Performance Characteristics (Continued)

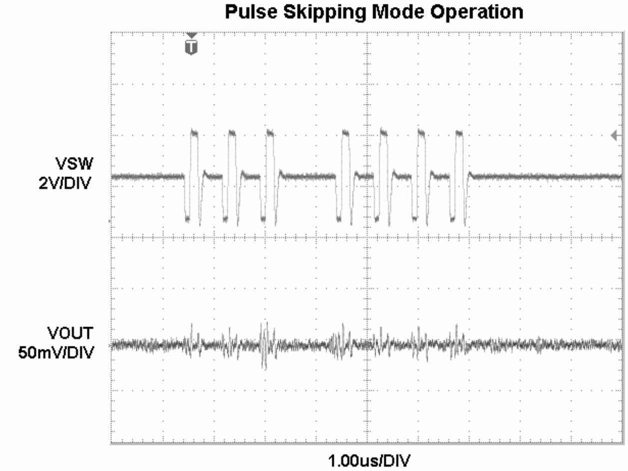
**No Load Input Current vs. Input Voltage**



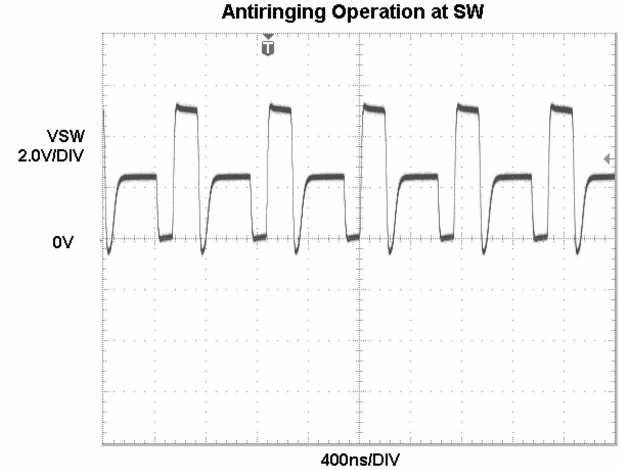

**$V_{OUT}$ vs. Temperature**



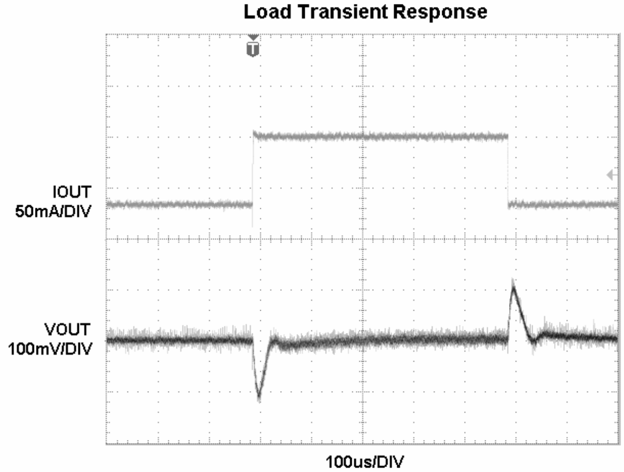

**Pulse Skipping Mode Operation**




**Antiringing Operation at SW**




**Load Transient Response**



## Pin Description

| PIN | NAME | FUNCTION |
|---|---|---|
| 1 | SW | Power Switch Pin. It is the switch node connection to Inductor. |
| 2 | GND | Ground Pin |
| 3 | FB | Feedback Input Pin. Connect FB to the center point of the external resistor divider. The feedback threshold voltage is 1.23V. |
| 4 | SHDN | Chip Shutdown Signal Input. Logic high is normal operation mode, Logic Low is Shutdown. Typically, this pin is connected to $V_{IN}$ through a 1MΩ resistor. |
| 5 | VOUT | Power Output Pin. $V_{OUT}$ is held 0.6V below than $V_{IN}$ in shutdown. |
| 6 | VIN | Power Supply Input. Must be closely decoupled to GND, Pin 2, with a 4.7µF or greater ceramic capacitor. |

## Functional Block Diagram

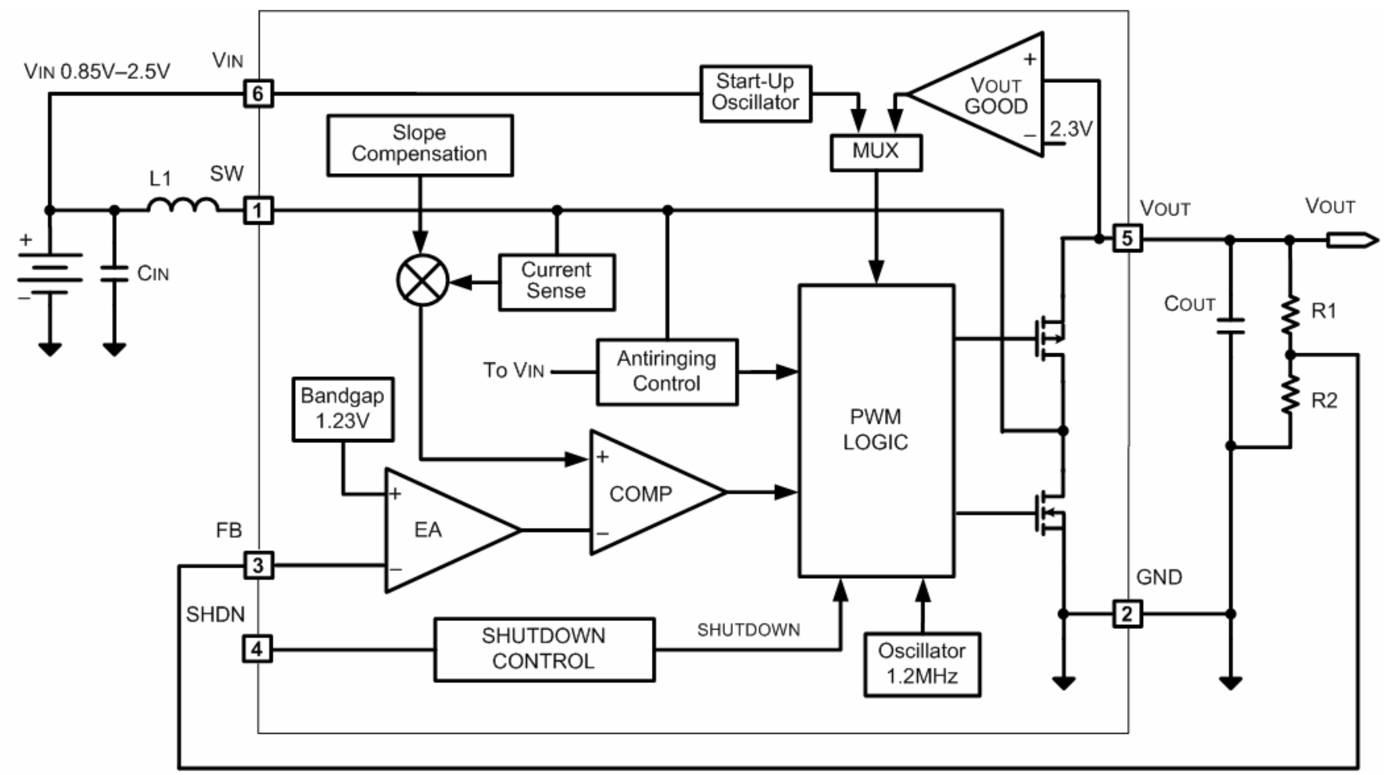



Figure 2. Function Block Diagram of GC3400

# Function Description

The GC3400 is a synchronous step-up DC-DC converter. It utilizes internal MOSFETs to achieve high efficiency over the full load current range. It operates at a fixed switching frequency of 1.2MHz, and uses the slope compensated current mode architecture. The device can operate with input voltage even below 1V and the typical start-up voltage is 0.85V.

### Synchronous Rectification

The GC3400 integrates a synchronous rectifier to improve efficiency as well as to eliminate the external Schottky diode. The synchronous rectifier is used to reduce the conduction loss contributed by the forward voltage of Schottky diode. The synchronous rectifier is realized by a P-ch MOSFET with gate control circuitry that incorporates relatively complicated timing concerns.

### Low Voltage Start-Up

The GC3400 can start up at supply voltage down to 0.85V. During start-up, the internal low voltage start-up circuitry controls the NMOS switch to maximum peak inductor current. The device leaves the start-up mode once the $V_{OUT}$ exceeds 2.3V. A Comparator ($V_{OUT}$ GOOG Comp) monitors the output voltage and allows the chip into normal operation once the $V_{OUT}$ exceeds 2.3V. The device is biased by $V_{IN}$ during start-up while biased by $V_{OUT}$ once $V_{OUT}$ exceeds $V_{IN}$ then the operation will be independent of $V_{IN}$.

### Current Mode PWM Control

The GC3400 is based on a slope compensated current mode control topology. It operates at a fixed frequency of 1.2MHz. At the beginning of each clock cycle, the main switch(NMOS) is turned on and the inductor current starts to ramp. After the maximum duty cycle or the sense current signal equals to the error amplifier(EA) output, the main switch is turned off and the synchronous switch(PMOS) is turn on. This control topology features cycle by cycle current limiting which can prevent the main switch from overstress and prevent external inductor from saturation.

### Pulse Skipping Mode

At very light load, the GC3400 automatically switches into Pulse Skipping Mode to improve efficiency. During this mode, the PWM control will skip some pulses to maintain regulation. If the load increases and the output voltage drops, the device will automatically switch back to normal PWM mode and maintain regulation.

### Antiringing Control

An antiringing circuitry is included to remove the high frequency ringing that appears on the SW pin when the inductor current goes to zero. In this case, a ringing on the SW pin is induced due to remaining energy stored in parasitic components of switch and inductor. The antiringing circuitry clamps the voltage internally to battery voltage and therefore dampens this ringing.

### Device ShutDown

When SHDN is set logic high, the GC3400 is put into operation. If SHDN is set logic low, the device is put into shutdown mode and consumes lower than 1μA current. After start-up timing, the internal circuitry is supplied by $V_{OUT}$, however, if shutdown mode is enabled, the internal circuitry will be supplied by battery again.

# Application Information

### Setting the Output Voltage

An external resistor divider is used to set the output voltage. The output voltage of the switching regulator ($V_{OUT}$) is determined by the following equation:

$$V_{OUT} = 1.23V \times \left(1 + \frac{R1}{R2}\right)$$

Table 1 list the resistor selection for output voltage setting.

Table 1. Resistor selection for output voltage setting

| $V_{OUT}$ | R1(Ω) | R2(Ω) |
|---|---|---|
| 3.3V | 1.02M | 604k |
| 5.0V | 1.02M | 332k |

### Inductor Selection

The high switching frequency of 1.2MHz allows for small surface mount inductors. For most designs, the GC3400 operates with inductors of 4.7μH to 10μH.The equation below can help to select the inductor, the maximum output current can be get by this equation; where η is the efficiency, $I_{PEAK}$ is the peak current limit, f is the switching frequency, L is the inductance value and D is the duty cycle.

$$I_{OUT} = \eta \times \left( Ipeak - \frac{VIN \times D}{2 \times f \times L} \right) \times (1 - D)$$

Larger inductors mean less inductor current ripple and usually less output voltage ripple. Larger inductors also mean more load power can be delivered. But large inductors are also with large profile and costly. The inductor ripple current is typically set for 20% to 40% of the maximum inductor current. When selecting an inductor, the DC current rating must be high enough to avoid saturation at peak current. For optimum load transient and efficiency, the low DCR should be selected. Table 2 lists some typical surface mount inductors that meet target applications for the GC3400:

Table2. Typical Surface Mount Inductors

| Part Number | L (μH) | Max DCR (mΩ) | Rated D.C. Current (A) | Size WxLxH (mm) |
|---|---|---|---|---|
| Sumida CR43 | 4.7<br>10 | 108.7<br>182 | 1.15<br>1.04 | 4.3x4.8x3.5 |
| Sumida CDRH4D28 | 4.7<br>5.6<br>6.8<br>10 | 72<br>101<br>109<br>128 | 1.32<br>1.17<br>1.12<br>1.00 | 5.0x5.0x3.0 |
| Toko D53LC | 4.7<br>6.8<br>10 | 45<br>68<br>90 | 1.87<br>1.51<br>1.33 | 5.0x5.0x3.0 |

## Output Capacitor Selection

The output capacitor is required to keep the output voltage ripple small and to ensure regulation loop stability. A 2.2μF to 10μF output capacitor is sufficient for most applications. If output capacitor is larger than 10μF, a phase lead capacitor must be included to maintain enough phase margin. The output capacitor must have low impedance at the switching frequency. Ceramic capacitors with X5R or X7R dielectrics are recommended due to their low ESR and high ripple current ratings.

## Input Capacitor Selection

The input capacitor reduces the surge current drawn from the input and switching noise from the device. A minimum 4.7μF input capacitor is needed for most applications. The input capacitor impedance at the switching frequency should be less than input source impedance to prevent high frequency switching current passing to the input. A low ESR input capacitor sized for maximum RMS current must be used. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients.

## Output Diode Selection

An Shottky diode should be included when the output voltage is above 4.5V. The Schottky diode is optional for the output voltage not more than 4.5V, but can improve efficiency by about 2% to 3%.

## Load Disconnect in Shutdown

In conventional synchronous step-up converter, a conduction path exists from battery to output through the backgate of the P-ch MOSFET during shutdown. A special applicati on circuitry is provided to disconnect the load from the battery during shutdown as below.

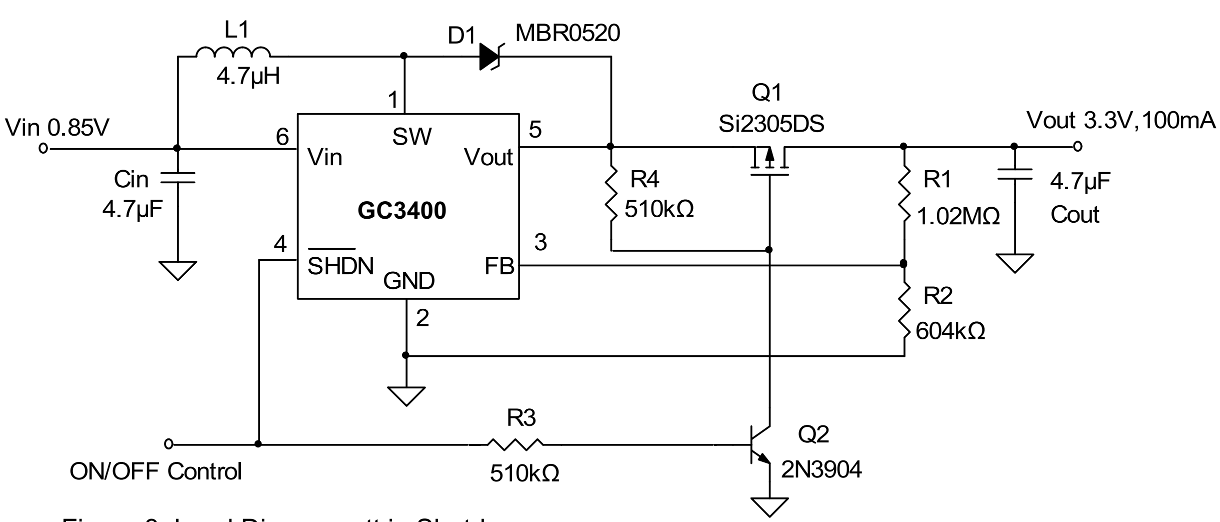



Figure 3. Load Disconnectt in Shutdown

# PCB Layout Guidance

The GC3400 operate s at 1.2MHz typically. This is a considerably high frequency for dc-dc converters. In such case PCB layout is important to guarantee satisfactory performance. It is recommended to make traces of the power loop, especially where switching node is involved as short and wide as possible. First of all, the inductor, input and output capacitor should be close to the device. Feedback and shut down circuit should avoid the proximity of large AC signals, e.g. the power inductor and switching nodes. The optional rectifier diode (D1 on Fig.3) can improve efficiency and alleviate the stress on the integrated MOSFET. The diode should also be close to the inductor and the chip to form the shortest possible switching loop. While 2 layer PCB shown in Fig.4 is enough for most applications. Large and integral multi layer ground planes are ideal for high power applications. Large area of copper has lower resistance and helps to dissipate heat on the device. The converter's ground should join the system ground to which it supplies power at one point only. Figure 3 is the schematic for a typical application for GC3400. Figure 4 is an example PCB layout for GC3400.

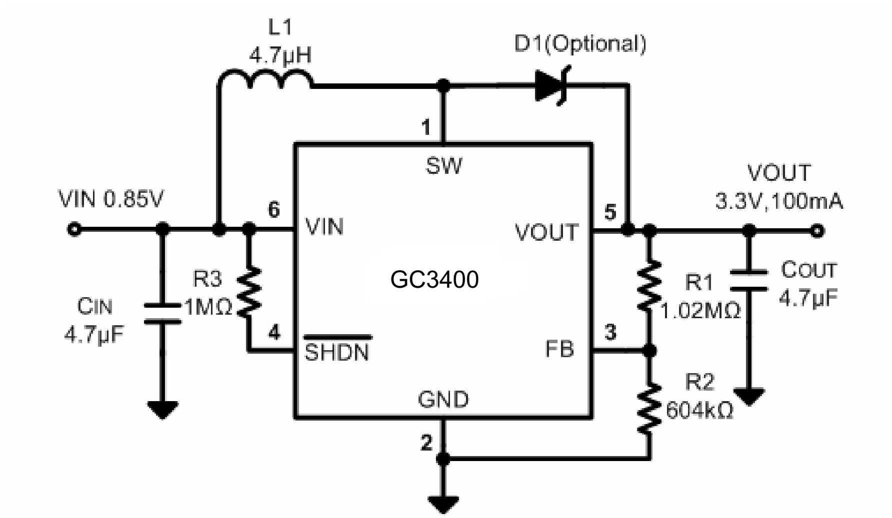
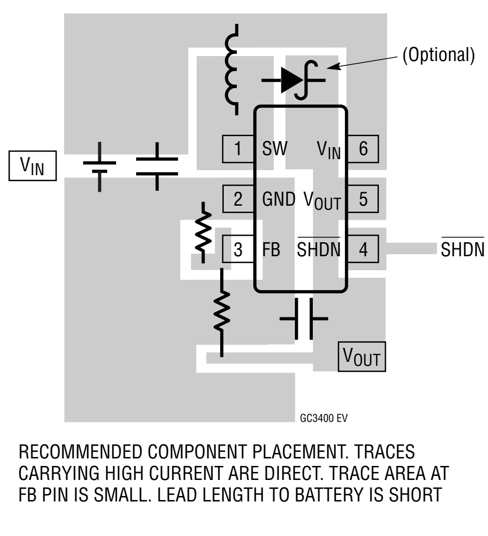


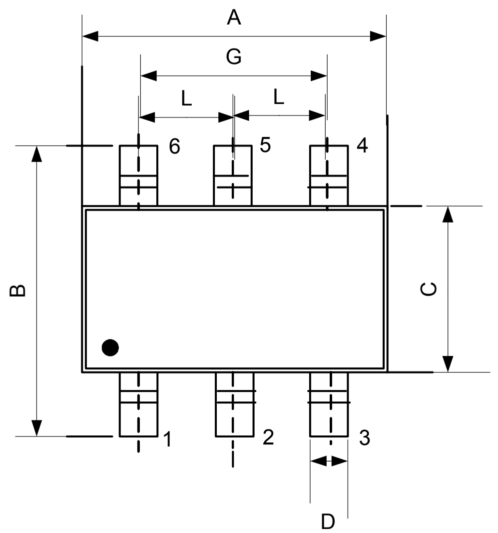

Figure 4. GC3400 Typical Application Circuit

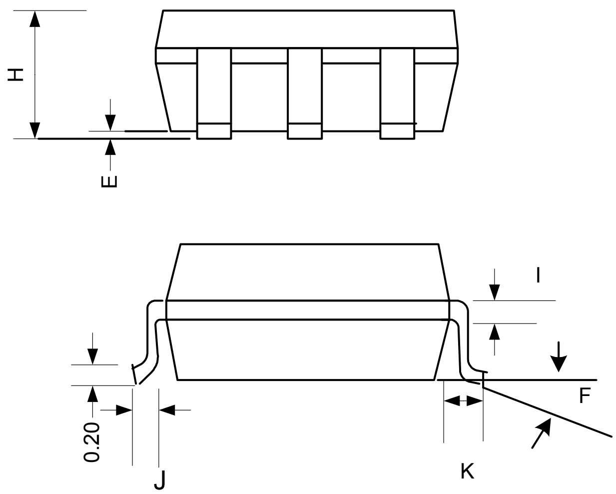



(Top View)

Figure 4. GC3400 Layout Example

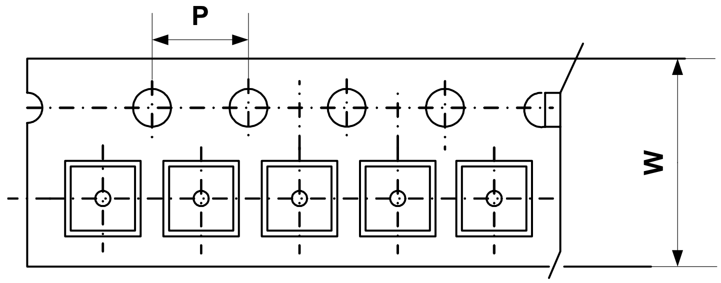
## ■ Package Information

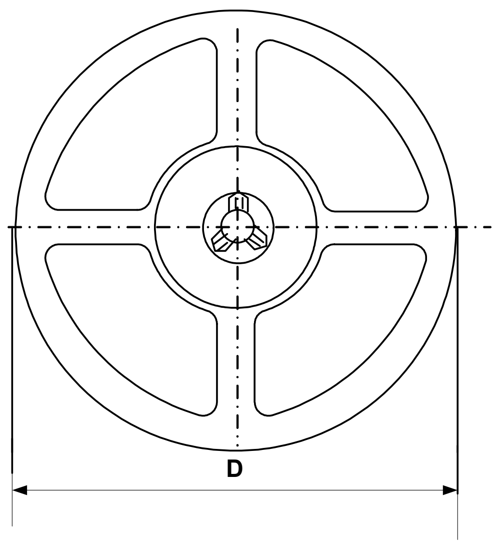



| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | Min. | Max. | Min. | Max. |
| A | 2.80 | 3.10 | 0.1102 | 0.1220 |
| B | 2.50 | 3.10 | 0.0984 | 0.1220 |
| C | 1.50 | 1.70 | 0.0591 | 0.0669 |
| D | 0.30 | 0.50 | 0.0118 | 0.0197 |
| E | 0.01 | 0.13 | 0.0004 | 0.0051 |
| F | 0° | 10° | 0° | 10° |
| G | 1.90Ref | | 0.0748Ref | |
| H | 0.90 | 1.10 | 0.0354 | 0.0433 |
| I | 0.09 | 0.20 | 0.0035 | 0.0079 |
| J | 0.20 | 0.55 | 0.0079 | 0.0217 |
| K | 0.35 | 0.80 | 0.0138 | 0.0315 |
| L | 0.95Ref | | 0.0374 Ref | |

## Packing Information




| Package Type | Carrier Width (W) | Pitch (P) | Reel Size(D) | Packing Minimum |
|---|---|---|---|---|
| TSOT23-6L | 8.0±0.1 mm | 4.0±0.1 mm | 180±1 mm | 3000pcs |

Note: Carrier Tape Dimension, Reel Size and Packing Minimum