# NB636

## High Effeciency 5A, 16V, 500kHz Synchronous Step-down Converter

The Future of Analog IC Technology

***END OF LIFE, REFER TO NB691A OR NB692***

## DESCRIPTION

The NB636 is a high frequency synchronous rectified step-down switch mode converter with built in internal power MOSFETs. It offers a very compact solution to achieve 5A continuous output current over a wide input supply range with excellent load and line regulation. The NB636 operates at high efficiency over a wide output current load range.

Current mode operation provides fast transient response and eases loop stabilization.

Full protection features include OCP and thermal shut down.

The NB636 requires a minimum number of readily available standard external components and is available in a space saving 3mm x 4mm 14-pin QFN package.

## FEATURES

- Wide 4.5V to 16V Operating Input Range
- 5A Output Current
- Low $R_{DS}$(ON) Internal Power MOSFETs
- Fixed 500KHz Switching Frequency
- Sync from 300KHz to 2MHz External Clock
- Internal Compensation
- OCP Protection and Thermal Shutdown
- Output Adjustable from 0.8V to 13V
- Available in 14-pin QFN3x4 Package

## APPLICATIONS

- Notebook Systems and I/O Power
- Networking Systems
- Digital Set Top Boxes
- Personal Video Recorders
- Flat Panel Television and Monitors
- Distributed Power Systems

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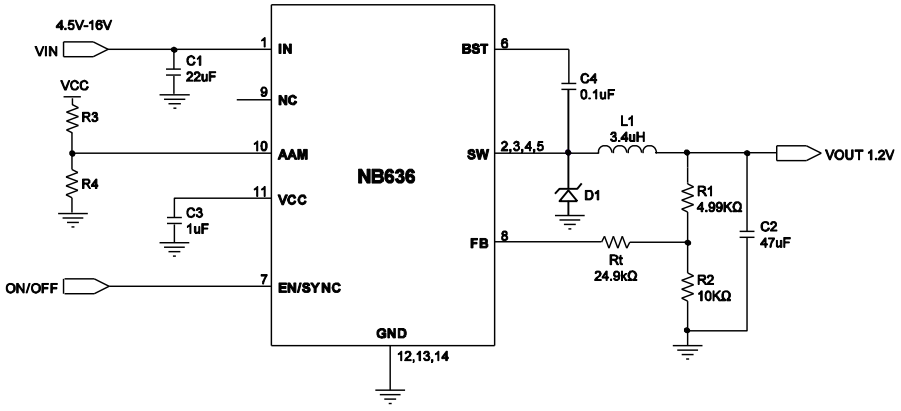
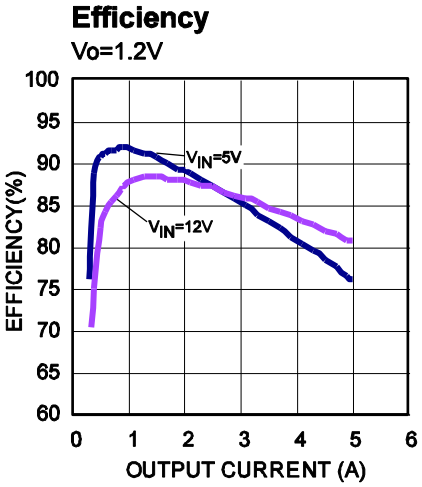
## TYPICAL APPLICATION （FOR NOTEBOOK）





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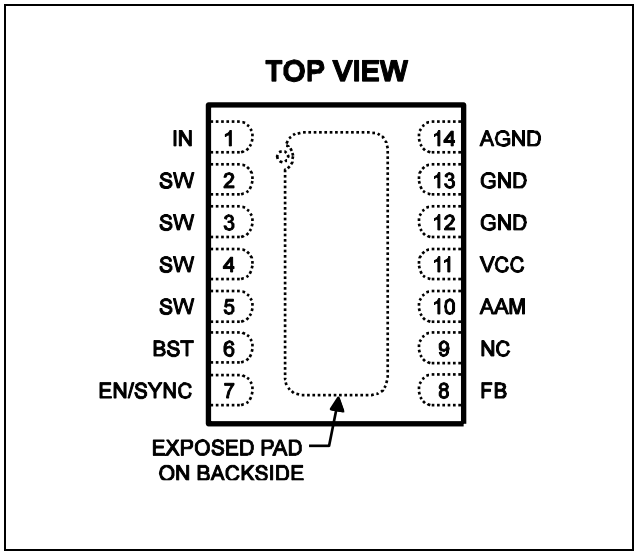
*END OF LIFE, REFER TO NB691A OR NB692*

## ORDERING INFORMATION

| Part Number* | Package | Top Marketing | Temperature |
|---|---|---|---|
| NB636DL | 3x4 QFN14 | 636D | –40°C to +85°C |

For Tape & Reel, add suffix –Z (eg. NB636DL–Z); For RoHS compliant packaging, add suffix –LF (eg. NB636DL–LF–Z)

## PACKAGE REFERENCE




## ABSOLUTE MAXIMUM RATINGS (1)

Supply Voltage $V_{IN}$ ..... 18V
$V_{SW}$ ..... –0.3V (-5V for 10ns) to $V_{IN}$ + 0.3V
$V_{BS}$ ..... $V_{SW}$ + 6V
All Other Pins..... –0.3V to +6V
Power Dissipation(2), $P_D$ @ $T_A$=25°C .... .....2.6W
Junction Temperature..... 150°C
Lead Temperature ..... 260°C
Storage Temperature..... –65°C to +150°C

## *Recommended Operating Conditions* (3)

Supply Voltage $V_{IN}$ ..... 4.5V to 16V
Output Voltage $V_{OUT}$..... 0.8V to 13V
Operating Temperature..... –40°C to +85°C

## *Thermal Resistance* (4) $\theta_{JA}$ $\theta_{JC}$

3x4 QFN14 .....48 ..... 11 ...°C/W

**Notes:**

1) Exceeding these ratings may damage the device.
2) The maximum allowable power dissipation is a function of the maximum junction temperature, $T_J$(MAX), the junction-to-ambient thermal resistance, $\theta_{JA}$ ,the ambient temperature, $T_A$ .The maximum allowable power dissipation at any ambient temperature is calculated using: PD(MAX)=($T_J$(MAX)-$T_A$)/ $\theta_{JA}$ Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) The device is not guaranteed to function outside of its operating conditions.
4) Measured on JESD51-7, 4-layer PCB.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## ELECTRICAL CHARACTERISTICS

**$V_{IN}$ = 12V, $T_A$ = +25°C, unless otherwise noted.**

| Parameters | Symbol | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Supply Current (Shutdown) | $I_{IN}$ | $V_{EN}$ = 0V | | 0 | | μA |
| Supply Current (Quiescent) | $I_{IN}$ | $V_{EN}$ = 2V, $V_{FB}$ = 1V | | 0.7 | | mA |
| HS Switch On Resistance (5) | $HS_{RDS-ON}$ | | | 120 | | mΩ |
| LS Switch On Resistance (5) | $LS_{RDS-ON}$ | | | 20 | | mΩ |
| Switch Leakage | $SW_{LKG}$ | $V_{EN}$ = 0V, $V_{SW}$ = 0V or 12V | | 0 | 10 | μA |
| Current Limit (5) | $I_{LIMIT}$ | | | 7 | | A |
| Oscillator Frequency | $F_{SW}$ | $V_{FB}$ = 0.75V | 350 | 500 | 650 | KHz |
| Fold-back Frequency | $F_{FB}$ | $V_{FB}$ = 300mV | | 0.25 | | $f_{SW}$ |
| Maximum Duty Cycle | $D_{MAX}$ | $V_{FB}$ = 700mV | 85 | 90 | | % |
| Sync Frequency Range | $F_{SYNC}$ | | 0.3 | | 2 | MHz |
| Feedback Voltage | $V_{FB}$ | | 785 | 805 | 825 | mV |
| Feedback Current | $I_{FB}$ | $V_{FB}$ = 800mV | | 10 | 50 | nA |
| EN/SYNC Input Low Voltage | $VIL_{EN}$ | | | | 0.4 | V |
| EN/SYNC Input High Voltage | $VIH_{EN}$ | | 2 | | | V |
| EN Input Current | $I_{EN}$ | $V_{EN}$ = 2V | | 2 | | μA |
| | | $V_{EN}$ = 0V | | 0 | | |
| EN Turn Off Delay | $EN_{Td-Off}$ | | | 5 | | μsec |
| $V_{IN}$ Under Voltage Lockout Threshold Rising | $INUV_{Vth}$ | | 3.8 | 4.0 | 4.2 | V |
| $V_{IN}$ Under Voltage Lockout Threshold Hysteresis | $INUV_{HYS}$ | | | 880 | | mV |
| VCC Regulator | $V_{CC}$ | | | 5 | | V |
| VCC Load Regulation | | Icc=2mA | | 5 | | % |
| Thermal Shutdown | $T_{SD}$ | | | 150 | | °C |

**Note:**

5) Guaranteed by design.


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## PIN FUNCTIONS

| Pin # | Name | Description |
|---|---|---|
| 1 | IN | Supply Voltage. The NB636 operates from a +4.5V to +16V input rail. C1 is needed to decouple the input rail. Use wide PCB traces and multiple vias to make the connection. |
| 2,3,4,5 | SW | Switch Output. Use wide PCB traces and multiple vias to make the connection. |
| 6 | BST | Bootstrap. A capacitor connected between SW and BST pins is required to form a floating supply across the high-side switch driver. |
| 7 | EN/SYNC | EN=1 to enable the NB636. External clock can be applied to EN pin for changing switching frequency. For automatic start-up, connect EN pin to VIN with 100KΩ resistor. |
| 8 | FB | Feedback. An external resistor divider from the output to GND, tapped to the FB pin, sets the output voltage. To prevent current limit run away during a short circuit fault condition the frequency fold-back comparator lowers the oscillator frequency when the FB voltage is below 500mV. |
| 9 | NC | Not connected. |
| 10 | AAM | Connect to GND forces NB636 in synchronous mode. Connect to a voltage set by 2 resistor dividers forces NB636 into asynchronous mode when light load. An external Schottky diode from GND to SW is optional for better efficiency when in asynchronous mode. |
| 11 | VCC | Bias Supply. Decouple with 1µF capacitor. |
| 12,13 | GND Exposed Pad | System Ground. Connect these pins with larger copper areas to the negative terminals of the input and output capacitors. Connect exposed pad to GND plane for proper thermal performance |
| 14 | AGND | Signal Ground. |


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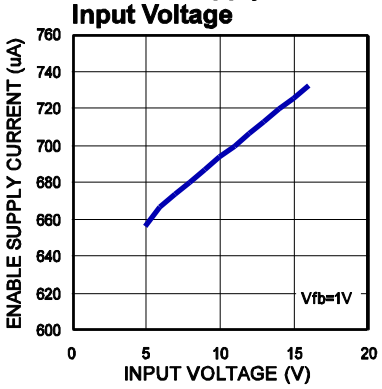
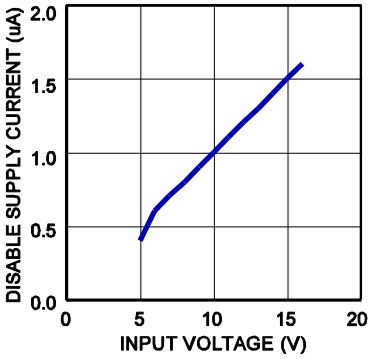
## TYPICAL PERFORMANCE CHARACTERISTICS

**$V_{IN}$=12V, $V_{OUT}$ =1.2V, $L_1$ =3.4µH, $T_A$=+25°C, unless otherwise noted.**

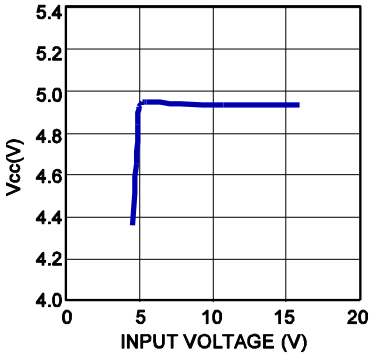
**Enabled Supply Current vs. Input Voltage**



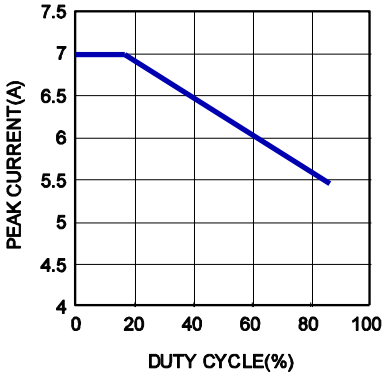

**Disabled Supply Current vs. Input Voltage**



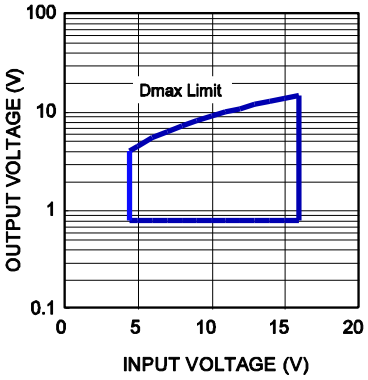

**VCC Regulator Line Regulation**



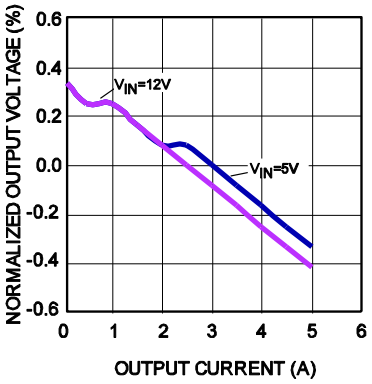

**Peak Current vs. Duty Cycle**



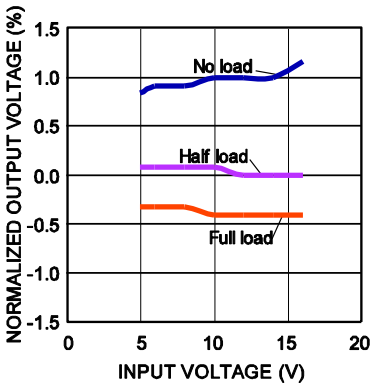

**Operating Range**



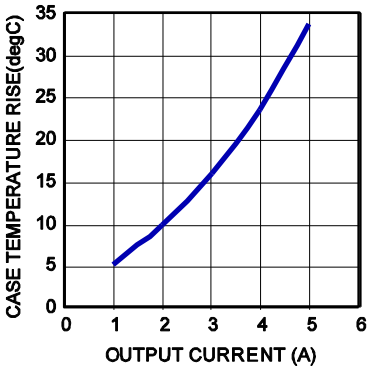

**Load Regulation**



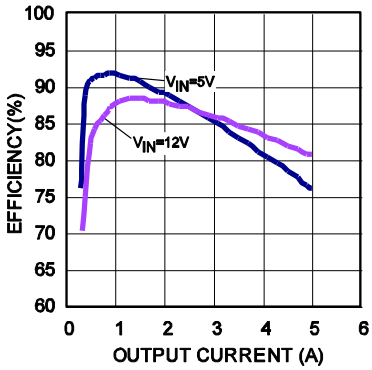

**Line Regulation**




**Case Temperature vs. Output Current**




**Efficiency**





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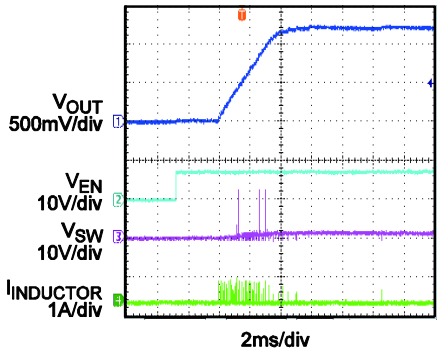
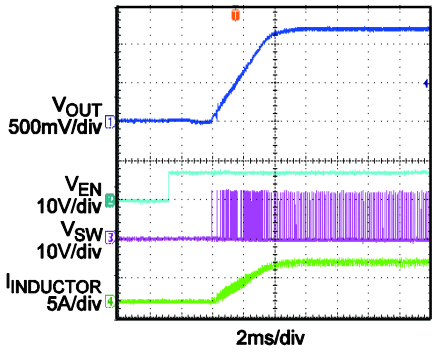
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$=12V, $V_{OUT}$ =1.2V, $L_1$=3.4µH, $T_A$=+25°C, unless otherwise noted.**

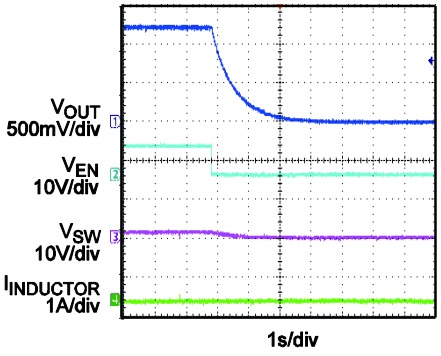
**Enable Startup**
$I_{OUT}$=0A



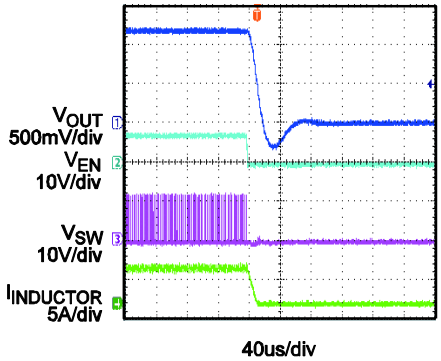

**Enable Startup**
$I_{OUT}$=5A



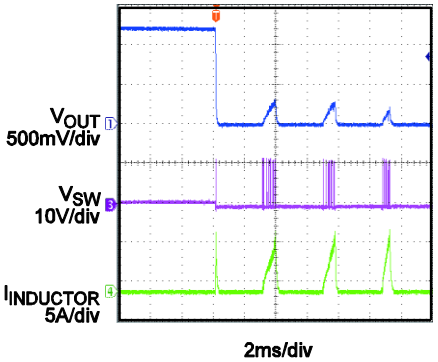

**Enable Shut Down**
$I_{OUT}$=0A



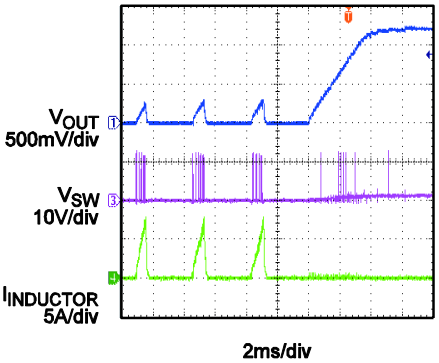

**Enable Shut Down**
$I_{OUT}$=5A



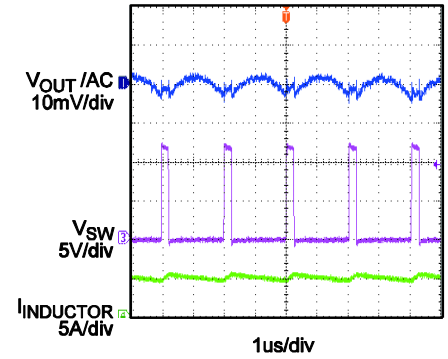

**Short Circuit Protection**



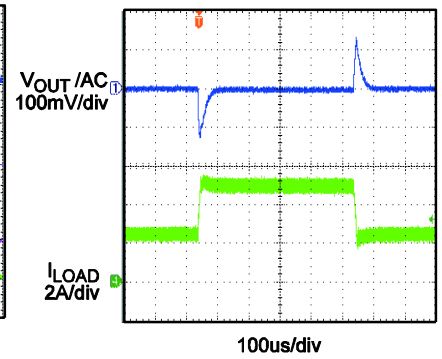

**Short Circuit Recovery**




**Output Ripple Voltage**
$I_{OUT}$=5A




**Load Transient Response**
$I_{OUT}$=2.5A-5A @ 1A/us





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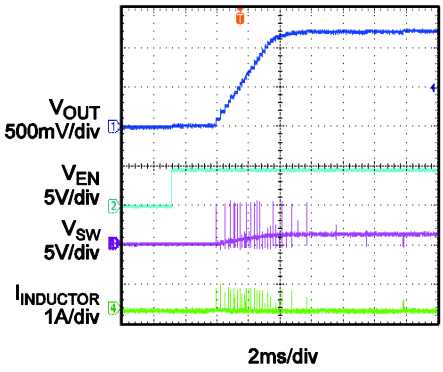
## TYPICAL PERFORMANCE CHARACTERISTICS

**$V_{IN}$=5V, $V_{OUT}$ =1.2V, $L_1$=3.4µH, $T_A$=+25°C, unless otherwise noted.**

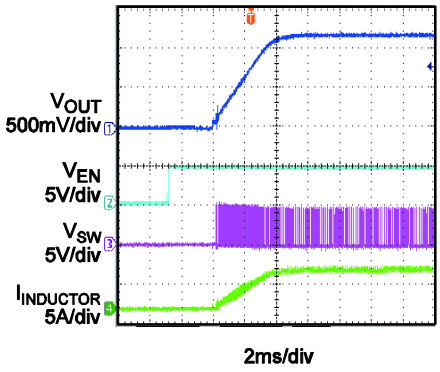
**Enable Startup**

$I_{OUT}$=0A



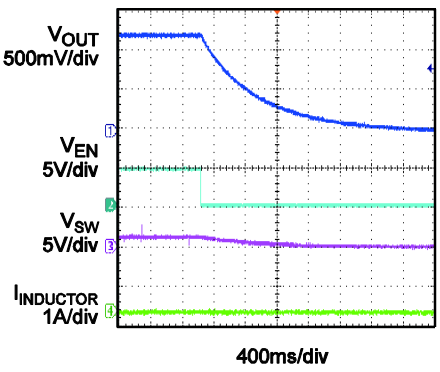

**Enable Startup**

$I_{OUT}$=5A



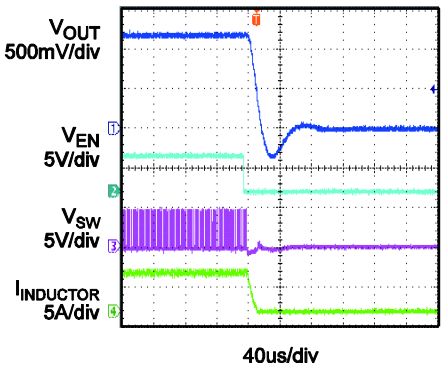

**Enable Shut Down**

$I_{OUT}$=0A



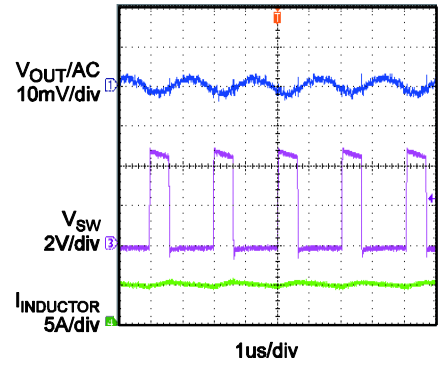

**Enable Shut Down**

$I_{OUT}$=5A



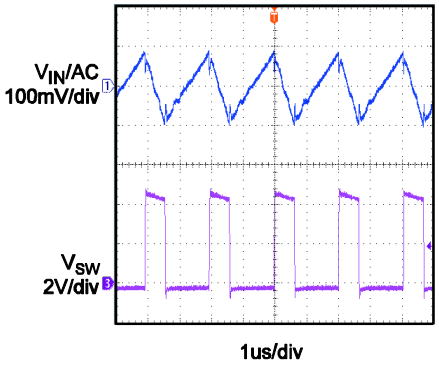

**Output Ripple Voltage**

$I_{OUT}$=5A




**Input Ripple Voltage**

$I_{OUT}$=5A





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## BLOCK DIAGRAM

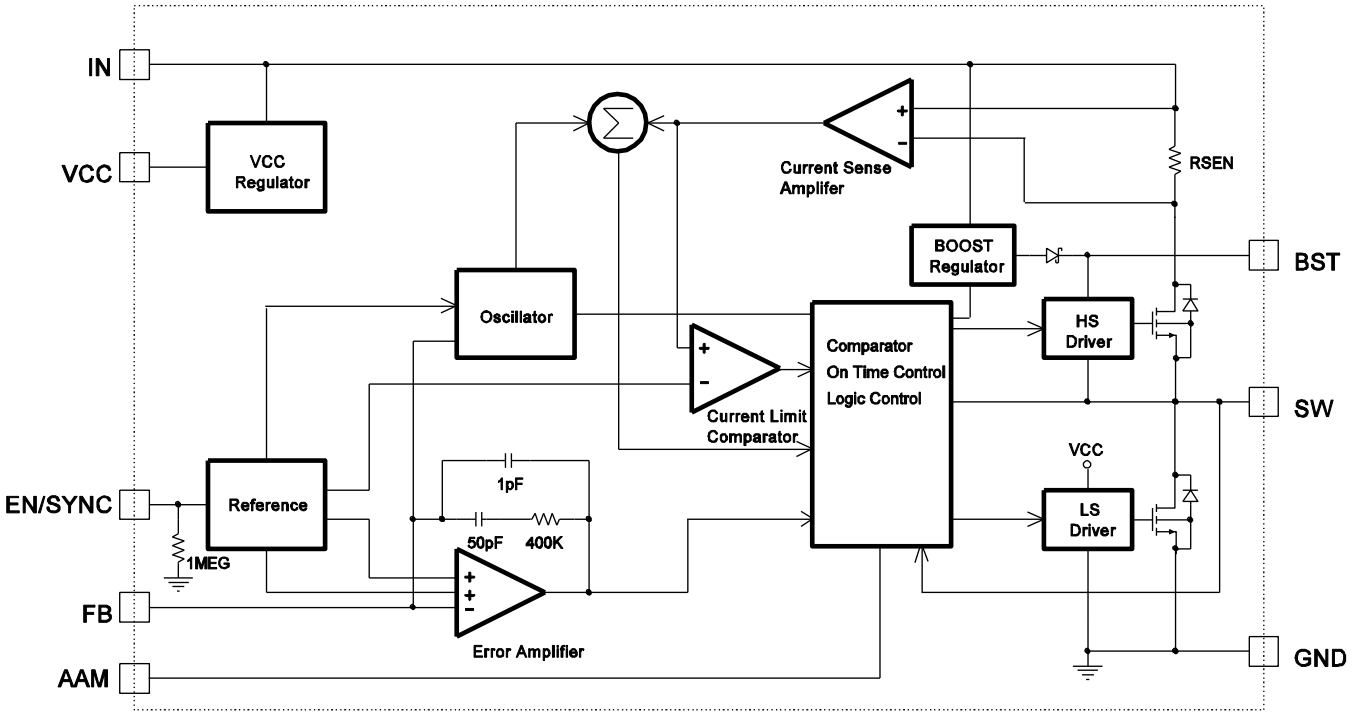


**Figure 1—Functional Block Diagram**


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## OPERATION

The NB636 is a high frequency synchronous rectified step-down switch mode converter with built in internal power MOSFETs. It offers a very compact solution to achieve 5A continuous output current over a wide input supply range with excellent load and line regulation.

The NB636 operates in a fixed frequency, peak current control mode to regulate the output voltage. A PWM cycle is initiated by the internal clock. The integrated high-side power MOSFET is turned on and remains on until its current reaches the value set by the COMP voltage. When the power switch is off, it remains off until the next clock cycle starts. If, in 90% of one PWM period, the current in the power MOSFET does not reach the COMP set current value, the power MOSFET will be forced to turn off.

### Error Amplifier

The error amplifier compares the FB pin voltage with the internal 0.8V reference (REF) and outputs a current proportional to the difference between the two. This output current is then used to charge or discharge the internal compensation network to form the COMP voltage, which is used to control the power MOSFET current. The optimized internal compensation network minimizes the external component counts and simplifies the control loop design.

### Internal Regulator

Most of the internal circuitries are powered from the 5V internal regulator. This regulator takes the VIN input and operates in the full VIN range. When VIN is greater than 5.0V, the output of the regulator is in full regulation. When VIN is lower than 5.0V, the output decreases, a 1uF ceramic capacitor for decoupling purpose is required.

### Enable/Sync Control

The NB636 has a dedicated Enable/Sync control pin (EN/SYNC). By pulling it high or low, the IC can be enabled and disabled by EN. Tie EN to VIN through a resistor for automatic start up. To disable the part, EN must be pulled low for at least 5µs.

The NB636 can be synchronized to external clock range from 300KHz up to 2MHz through the EN/SYNC pin. The internal clock rising edge is synchronized to the external clock rising edge.

### Under-Voltage Lockout (UVLO)

Under-voltage lockout (UVLO) is implemented to protect the chip from operating at insufficient supply voltage. The NB636 UVLO comparator monitors the output voltage of the internal regulator, VCC. The UVLO rising threshold is about 4.0V while its falling threshold is a consistent 3.2V.

### Internal Soft-Start

The soft-start is implemented to prevent the converter output voltage from overshooting during startup. When the chip starts, the internal circuitry generates a soft-start voltage (SS) ramping up from 0V to 1.2V. When it is lower than the internal reference (REF), SS overrides REF so the error amplifier uses SS as the reference. When SS is higher than REF, REF regains control.

### Over-Current-Protection and Hiccup

The NB636 has cycle-by-cycle over current limit when the inductor current peak value exceeds the set current limit threshold. Meanwhile, output voltage starts to drop until FB is below the Under-Voltage (UV) threshold, typically 30% below the reference. Once a UV is triggered, the NB636 enters hiccup mode to periodically restart the part. This protection mode is especially useful when the output is dead-short to ground. The average short circuit current is greatly reduced to alleviate the thermal issue and to protect the regulator. The NB636 exits the hiccup mode once the over current condition is removed.

### Thermal Shutdown

Thermal shutdown is implemented to prevent the chip from operating at exceedingly high temperatures. When the silicon die temperature is higher than 150°C, it shuts down the whole chip. When the temperature is lower than its lower threshold, typically 140°C, the chip is enabled again.

### Floating Driver and Bootstrap Charging

The floating power MOSFET driver is powered by an external bootstrap capacitor. This floating driver has its own UVLO protection. This UVLO's rising threshold is 2.2V with a hysteresis of 150mV. The bootstrap capacitor voltage is regulated internally by VIN through D2, M1, C4, L1 and C2 (Figure 2). If (VIN-VSW) is more than


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5V, U1 will regulate M1 to maintain a 5V BST voltage across C4.

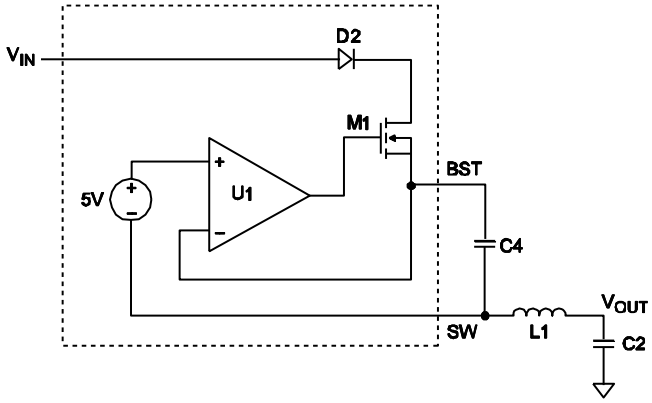


**Figure 2—Internal Bootstrap Charging Circuit**

**Startup and Shutdown**

When both VIN and EN are higher than their appropriate thresholds, the chip starts. The reference block starts first, generating stable reference voltage and currents, and then the internal regulator is enabled. The regulator provides stable supply for the remaining circuitries.

Three events can shut down the chip: EN low, VIN low and thermal shutdown. In the shutdown procedure, the signaling path is first blocked to avoid any fault triggering. The COMP voltage and the internal supply rail are then pulled down. The floating driver is not subject to this shutdown command.


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## APPLICATION INFORMATION

### Setting the Output Voltage

The external resistor divider is used to set the output voltage (see Typical Application on page 1). The feedback resistor R1 also sets the feedback loop bandwidth with the internal compensation capacitor (see Typical Application on page 1). Choose R1 to be around 40.2kΩ for optimal transient response. R2 is then given by:

$$R2 = \frac{R1}{\frac{V_{OUT}}{0.8V} - 1}$$

The T-type network is highly recommended when Vo is low, as Figure 3 shows.

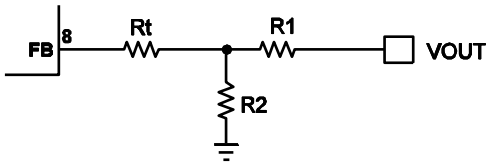


**Figure 3— T-type Network**

Table 1 lists the recommended T-type resistors value for common output voltages.

**Table 1—Resistor Selection for Common Output Voltages**

| $V_{OUT}$ (V) | R1 (kΩ) | R2 (kΩ) | Rt (kΩ) |
|---|---|---|---|
| 1.05 | 4.99(1%) | 15.8(1%) | 24.9(1%) |
| 1.2 | 4.99(1%) | 10(1%) | 24.9(1%) |
| 1.5 | 4.99(1%) | 5.76(1%) | 24.9(1%) |
| 1.8 | 4.99(1%) | 4.02(1%) | 24.9(1%) |
| 2.5 | 40.2 (1%) | 18(1%) | 0 |
| 3.3 | 40.2(1%) | 12.7(1%) | 0 |
| 5 | 40.2 (1%) | 7.68(1%) | 0 |

### Selecting the Inductor

A 1μH to 10μH inductor with a DC current rating of at least 25% percent higher than the maximum load current is recommended for most applications. For highest efficiency, the inductor DC resistance should be less than 15mΩ. For most designs, the inductance value can be derived from the following equation.

$$L_1 = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times f_{OSC}}$$

Where $\Delta I_L$ is the inductor ripple current.

Choose inductor current to be approximately 30% if the maximum load current, 5A. The maximum inductor peak current is:

$$I_{L(MAX)} = I_{LOAD} + \frac{\Delta I_L}{2}$$

Under light load conditions below 100mA, larger inductance is recommended for improved efficiency.

### Selecting the Input Capacitor

The input current to the step-down converter is discontinuous, therefore a capacitor is required to supply the AC current to the step-down converter while maintaining the DC input voltage. Use low ESR capacitors for the best performance. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. For most applications, a 22μF capacitor is sufficient.

Since the input capacitor (C1) absorbs the input switching current it requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated by:

$$I_{C1} = I_{LOAD} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)}$$

The worse case condition occurs at $V_{IN} = 2V_{OUT}$, where:

$$I_{C1} = \frac{I_{LOAD}}{2}$$

For simplification, choose the input capacitor whose RMS current rating greater than half of the maximum load current.

The input capacitor can be electrolytic, tantalum or ceramic. When using electrolytic or tantalum capacitors, a small, high quality ceramic capacitor, i.e. 0.1μF, should be placed as close to the IC as possible. When using ceramic capacitors, make sure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at input. The input voltage ripple caused by capacitance can be estimated by:

$$\Delta V_{IN} = \frac{I_{LOAD}}{f_S \times C1} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$


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**END OF LIFE, REFER TO NB691A OR NB692**

### Selecting the Output Capacitor

The output capacitor (C2) is required to maintain the DC output voltage. Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low. The output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L_1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_S \times C2}\right)$$

Where $L_1$ is the inductor value and $R_{ESR}$ is the equivalent series resistance (ESR) value of the output capacitor.

In the case of ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance. The output voltage ripple is mainly caused by the capacitance. For simplification, the output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_S^{\,2} \times L_1 \times C2} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

In the case of tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be approximated to:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L_1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times R_{ESR}$$

The characteristics of the output capacitor also affect the stability of the regulation system. The NB636 can be optimized for a wide range of capacitance and ESR values.

### External Bootstrap Diode

An external bootstrap diode may enhance the efficiency of the regulator, the applicable conditions of external BST diode are:

- $V_{OUT}$ is 5V or 3.3V; and
- Duty cycle is high: $D = \frac{V_{OUT}}{V_{IN}} > 65\%$

In these cases, an external BST diode is recommended from the VCC pin to BST pin, as shown in Figure 4.

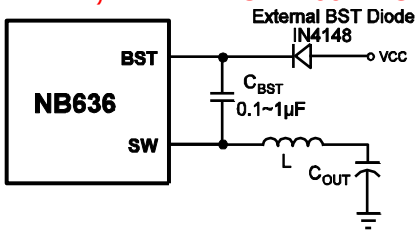
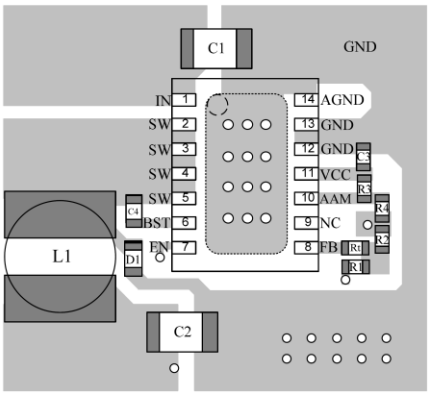



**Figure 4—Add Optional External Bootstrap Diode to Enhance Efficiency**

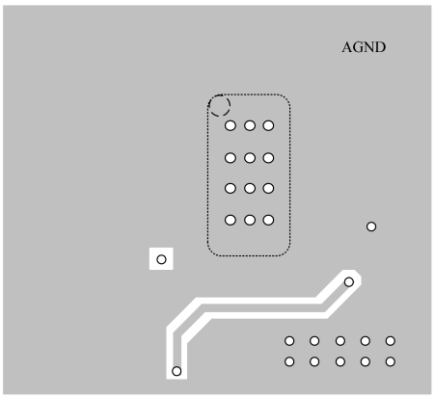
The recommended external BST diode is IN148,and the BST cap is 0.1~1uF.

### PC Board Layout

The high current paths (GND, IN and SW) should be placed very close to the device with short, direct and wide traces. The input capacitor needs to be as close as possible to the IN and GND pins. The external feedback resistors should be placed next to the FB pin. Keep the switching node SW short and away from the feedback network.




**Top Layer**




**Bottom Layer**

**Figure 5—PCB Layout**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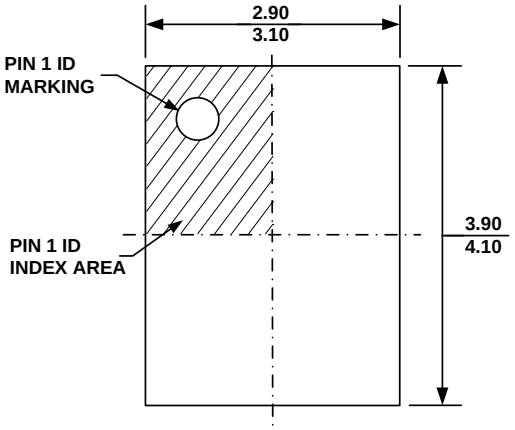
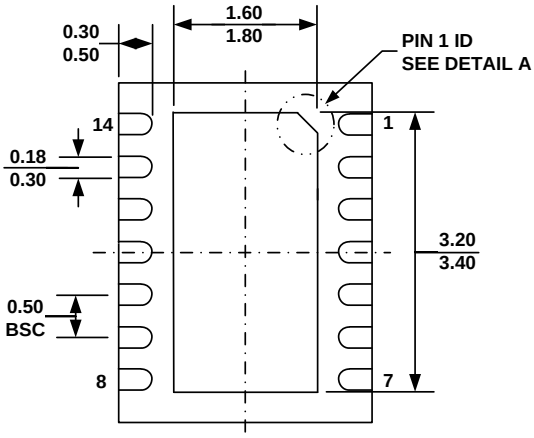
# PACKAGE INFORMATION

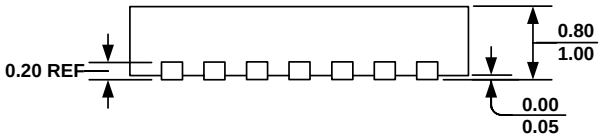
## 3mm x 4mm QFN14



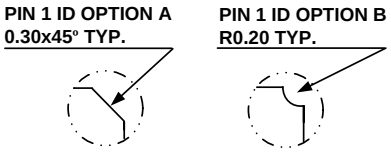

**TOP VIEW**



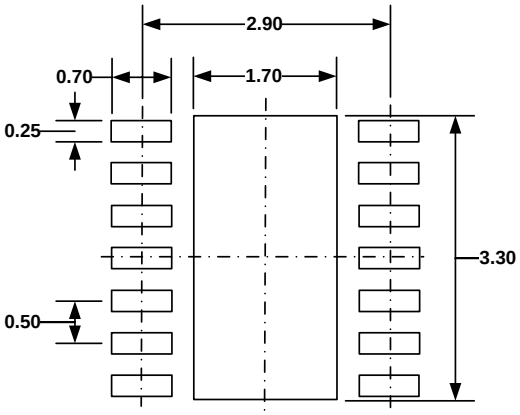

**BOTTOM VIEW**




**SIDE VIEW**




**DETAIL A**




**RECOMMENDED LAND PATTERN**

**NOTE:**

1) ALL DIMENSIONS ARE IN MILLIMETERS.
2) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH.
3) LEAD COPLANARITY SHALL BE 0.10 MILLIMETER MAX.
4) JEDEC REFERENCE IS MO-229, VARIATION VGED-3.
5) DRAWING IS NOT TO SCALE.

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