# LR8506

**1.5MHz 600mA Synchronous Step-Down Converter**

## ■ INTRODUCTION

**The LR8506** is a 1.5MHz constant frequency, slope compensated current mode PWM synchronous step-down converter. High switching frequency allows the use of small surface mount inductors and capacitors. The internal synchronous switch increases efficiency and eliminates the need for an external Schottky diode. It is ideal for powering portable equipment which runs from a single cell Lithium-Ion battery. 100% duty cycle provides low dropout operation, extending battery life in portable systems. Low output voltages are easily supported with the 0.6V feedback reference voltage.

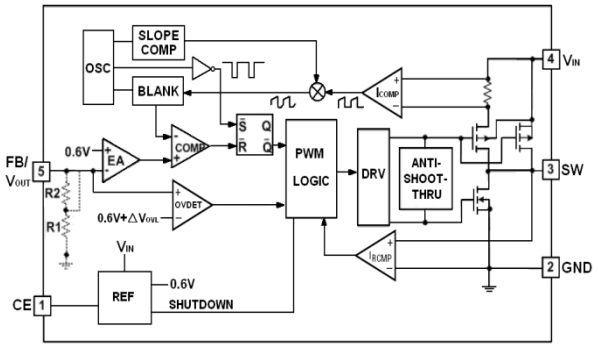
## ■ FEATURE

- High efficiency : Up to 96%
- Output Current: 600mA（Typ）
- 1.5MHz Constant Switching Frequency
- No Schottky Diode Required
- Input Voltage: 2.5V to 5.5V
- Output Voltage:1.2V,1.5V,1.8V & Adjustable
- Low Dropout: 100% duty Cycle
- Low Quiescent Current: 300μA
- Shutdown Current: <1μA
- Current Mode Operation for Excellent Line and Load Transient Response
- Built-in Thermal Protection
- Short Circuit Protection
- Package: SOT23-5

## ■ APPLICATION

- Cellular and Smart Phones
- Personal Information Appliances
- Wireless and DSL Modems
- Portable Instruments
- Digital Still and Video Cameras
- Microprocessors Core Supplies

## ■ BLOCK DIAGRAM

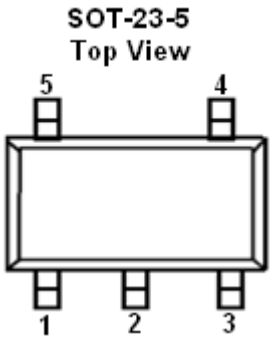



## ■ ORDER INFORMATION

LR8506①②③④

| DESIGNATOR | SYMBOL | DESCRIPTION |
|---|---|---|
| ① | A | Standard |
| ② ③ | Integer | Output Voltage,<br>e.g. 1.5V= ②:1, ③:5<br>exp.: ADJ = ②③: |
| ④ | M | Package：SOT23-5 |

## ■ PIN CONFIGURATION




| PIN NUMBER | PIN NAME | FUNCTION |
|---|---|---|
| 1 | CE | Chip Enable Pin |
| 2 | GND | Ground |
| 3 | SW | External Inductor Connection Pin |
| 4 | $V_{IN}$ | Power input |
| 5 | $V_{OUT}$/FB | Output Pin/ Feedback( Adj Version) |

## ■ ABSOLUTE MAXIMUM RATINGS

| PARAMETER | | SYMBOL | Rating | UNIT |
|---|---|---|---|---|
| Input Voltage | | $V_{IN}$ | -0.3~6 | V |
| CE,SW,FB/$V_{OUT}$ Voltage | | | -0.3~$V_{IN}$+0.3 | V |
| Peak SW Sink and Source Current | | $I_{SWMAX}$ | 1500 | mA |
| Power Dissipation | SOT23 | Pd | 400 | mW |
| Operating Temperature | | $T_{Opr}$ | -40~+85 | ℃ |
| Junction Temperature | | $T_j$ | 125 | ℃ |
| Storage Temperature | | $T_{stg}$ | -65~+150 | ℃ |
| Soldering Temperature & Time | | $T_{solder}$ | 300℃, 10s | |

## ■ TYPICAL APPLICATION CIRCUIT

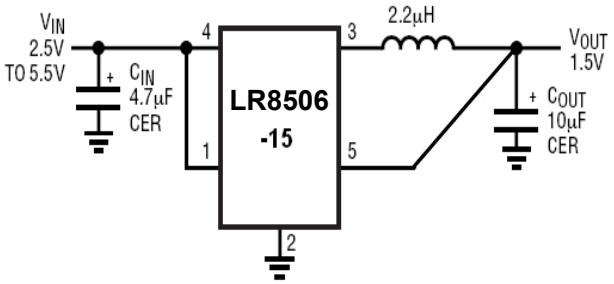



Figure 1.1 LR8506-15 Application Circuit

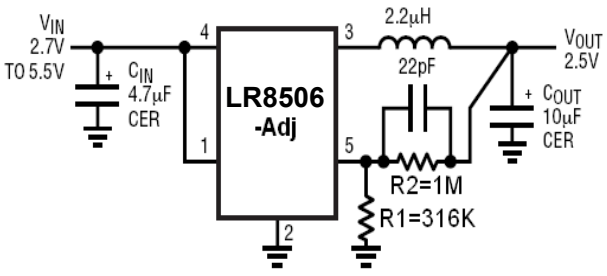



Figure 1.2 LR8506-Adj Application Circuit

**Figure 1 Basic Application Circuit**

## ■ ELECTRICAL CHARACTERISTICS

**(VIN=CE=3.6V, $T_A$=25℃, Test Circuit Figure1, unless otherwise specified)**

| PARAMETER | | SYMBOL | CONDITIONS | MIN. | TYP. | MAX. | UNITS |
|---|---|---|---|---|---|---|---|
| Output Voltage | LR8506-12 | $V_{OUT}$ | $I_{OUT}$ =100mA | 1.176 | 1.200 | 1.224 | V |
| | LR8506-15 | | | 1.470 | 1.500 | 1.530 | |
| | LR8506-18 | | | 1.764 | 1.800 | 1.836 | |
| Feedback Voltage | | $V_{FB}$ | $T_A$=25℃ | 0.5880 | 0.600 | 0.6120 | V |
| | | | 0℃≤$T_A$≤85℃ | 0.5865 | 0.600 | 0.6135 | |
| | | | -40℃≤$T_A$≤85℃ | 0.5850 | 0.600 | 0.6150 | |
| Input Voltage | | $V_{IN}$ | | 2.5 | | 5.5 | V |
| Supply Current | | $I_{SS}$ | $V_{FB}$=0.5V | | 300 | 400 | μA |
| Standby Current | | $I_{Standby}$ | $V_{CE}$=GND | | 0.1 | 1 | μA |
| Feedback Current | | $I_{FB}$ | $V_{FB}$=0.65V | | | ±30 | nA |
| Maximum Output Current | | $I_{OUT}$ | — | 600 | | | mA |
| $V_{FB}$ Line Regulation | | $\Delta V_{FB}$ | $V_{IN}$= 2.5V~5.5V | | 0.10 | 0.40 | %/V |
| Output Voltage Line Regulation | | $\Delta V_{OUT}$ | $V_{IN}$= 2.5V~5.5V<br>$I_{OUT}$=10mA | | 0.10 | 0.40 | %/V |
| Output Voltage Load Regulation | | $\Delta V_{LOAD}$ | $I_{OUT}$ =1mA~600mA | | 0.001 | | %/mA |
| Oscillator Frequency | | $f_{osc}$ | $V_{FB}$=0.6V or<br>$V_{OUT}$=100% | 1.2 | 1.5 | 1.8 | MHz |
| Peak Inductor Current | | $I_{PK}$ | $V_{IN}$=3V,$V_{FB}$=0.5V<br>or VOUT=90% | | 1 | | A |
| $R_{DS(ON)}$ OF P-CH FET | | $R_{PFET}$ | $I_{SW}$ = 100mA | | 0.35 | 0.5 | |
| $R_{DS(ON)}$ OF N-CH FET | | $R_{NFET}$ | $I_{SW}$ = -100mA | | 0.25 | 0.45 | |
| SW Leakage | | $I_{LSW}$ | CE=0,$V_{SW}$=0 or 5V,<br>$V_{IN}$=5V | | ±0.01 | ±1 | μA |
| CE "High" Voltage(1) | | $V_{CE}$"H" | | 1.5 | | $V_{IN}$ | V |
| CE "Low" Voltage(2) | | $V_{CE}$"L" | | | | 0.3 | V |
| CE Leakage Current | | $I_{CE}$ | | | ±0.1 | ±1 | μA |

**NOTE :**

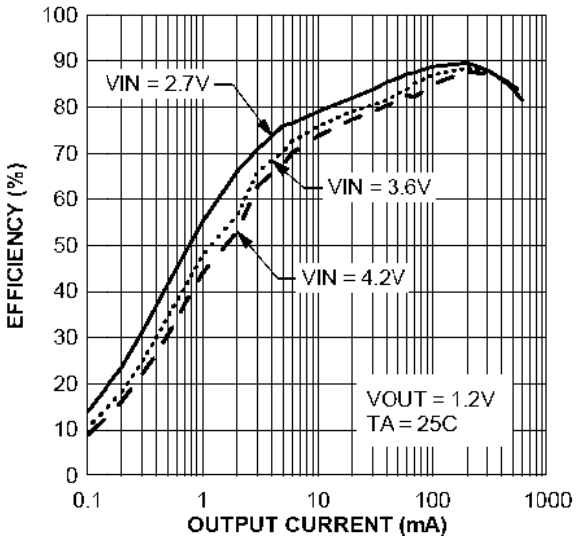
(1) High Voltage：Forcing CE above 1.5V enables the part.

(2) Low Voltage：Forcing CE below 0.3V shuts down the device. In shutdown, all functions are disabled drawing <1μA supply current. Do not leave CE floating.

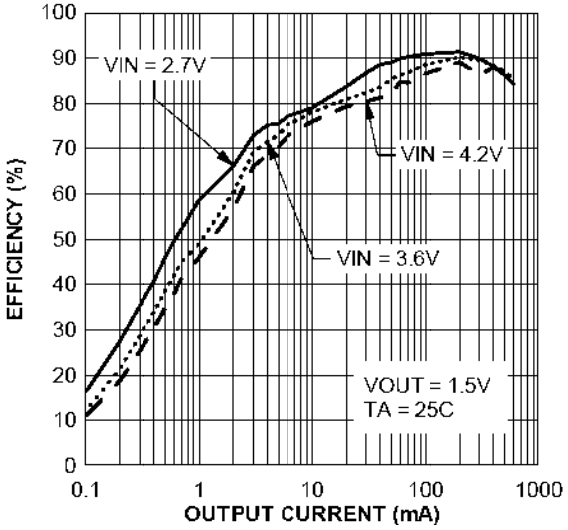
## ■ TYPICAL PERFORMANCE CHARACTERISTICS

**(Test Figure 1 above unless otherwise specified)**

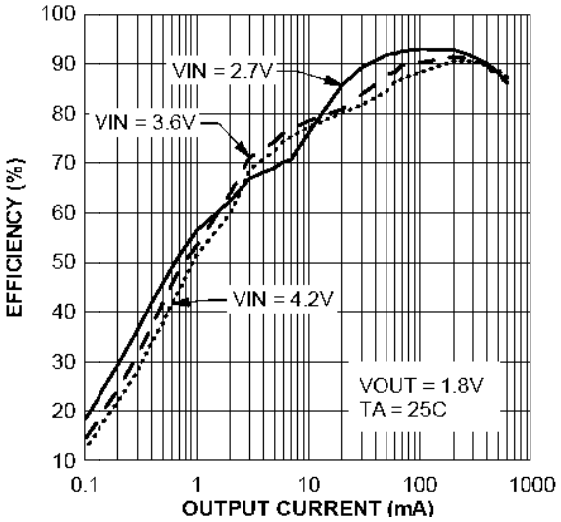
Efficiency vs Output Current



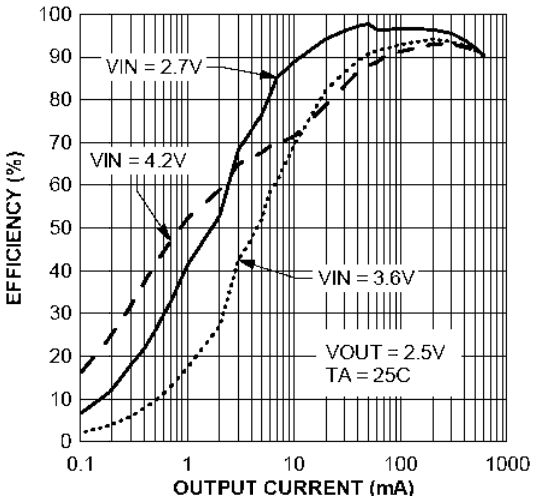

Efficiency vs Output Current



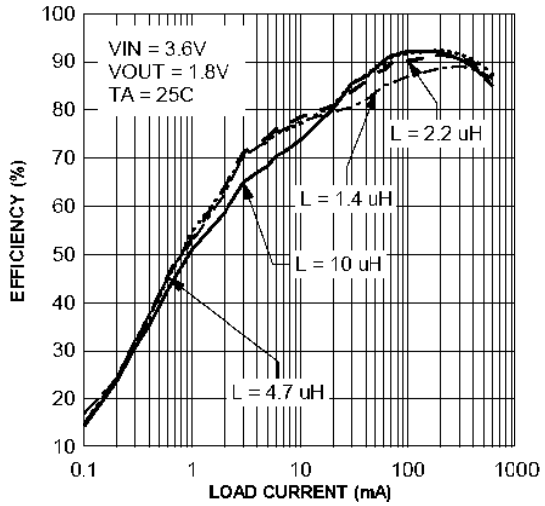

Efficiency vs Output Current



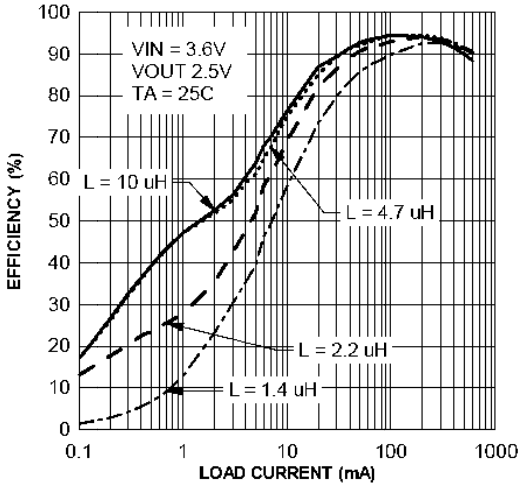

Efficiency vs Output Current




Efficiency vs Load Current



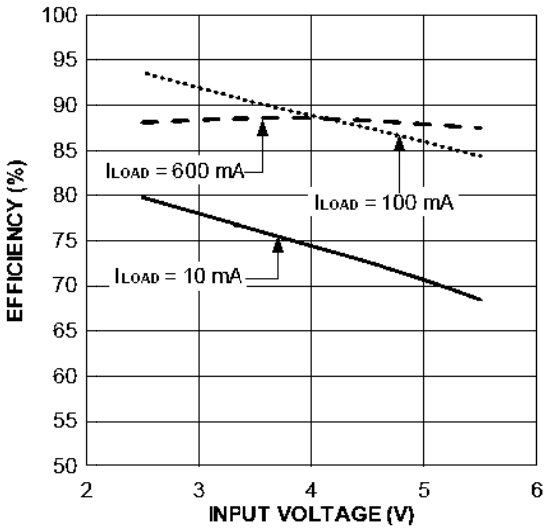

Efficiency vs Load Current



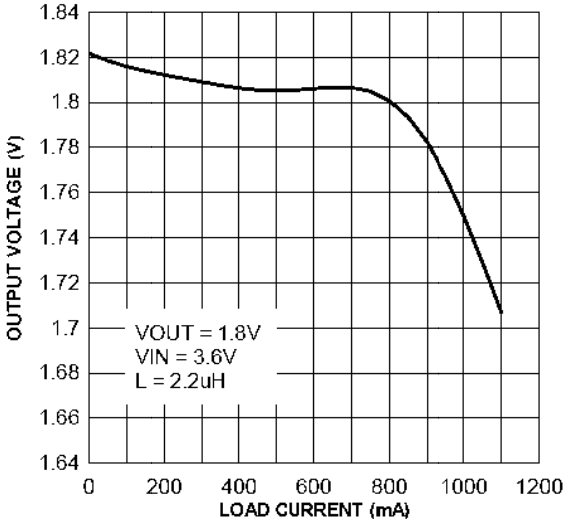
# TYPICAL PERFORMANCE CHARACTERISTICS

## (Test Figure 1 above unless otherwise specified)

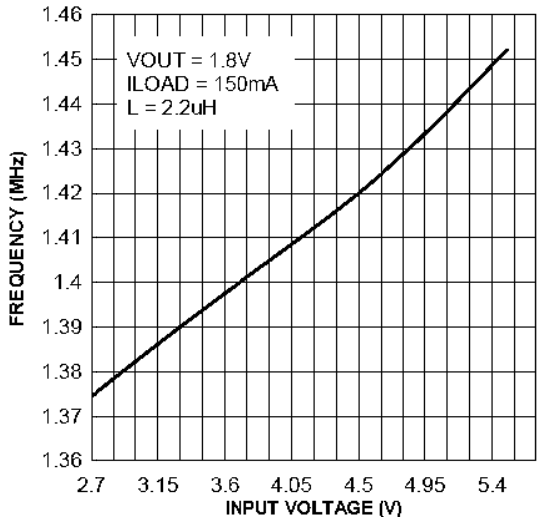
Efficiency vs Input Voltage



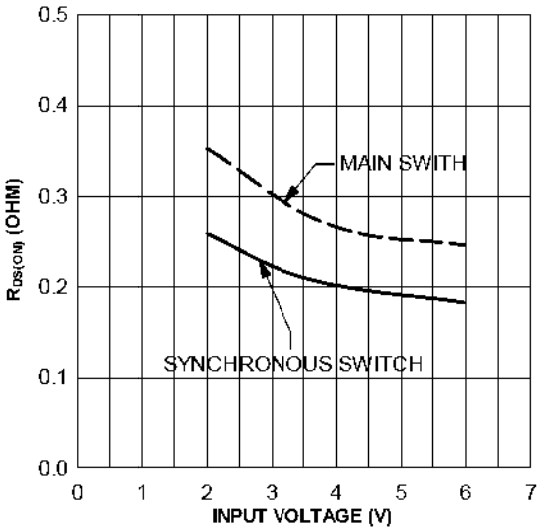

Outpu Voltage vs Load Current



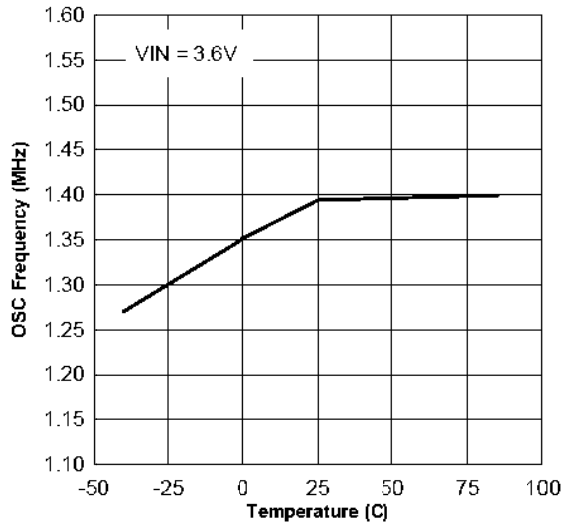

Frequency vs Input Voltage



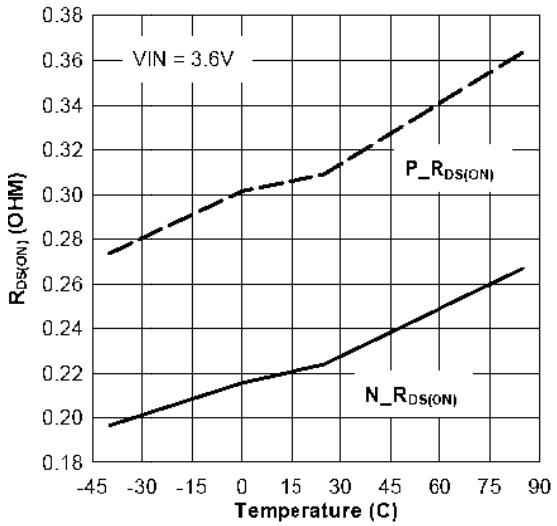

$R_{DS(ON)}$ vs Input Voltage




Frequency vs Temperature



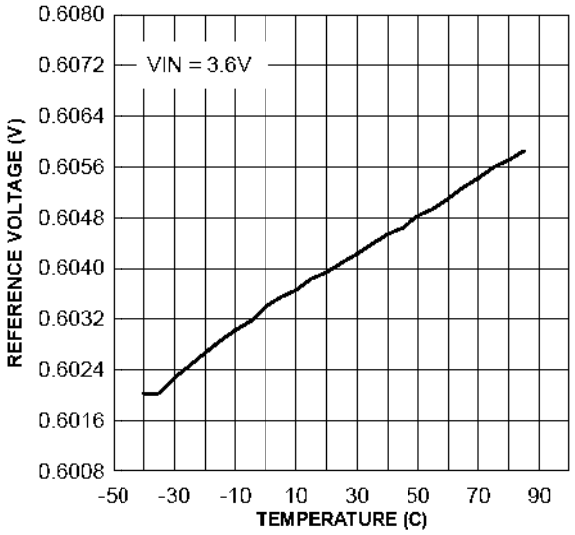

$R_{DS(ON)}$ vs Temperature



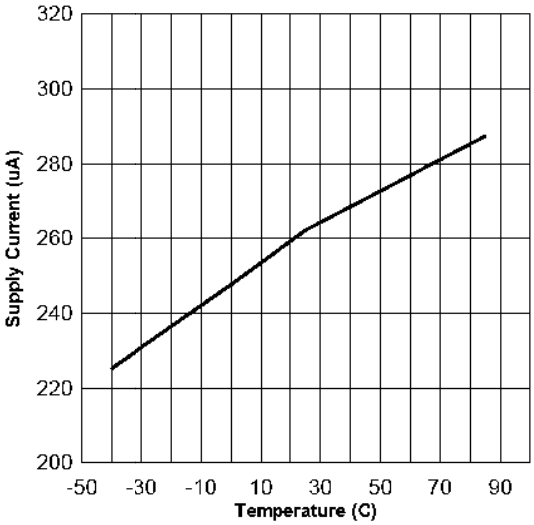
## TYPICAL PERFORMANCE CHARACTERISTICS

**(Test Figure 1 above unless otherwise specified)**

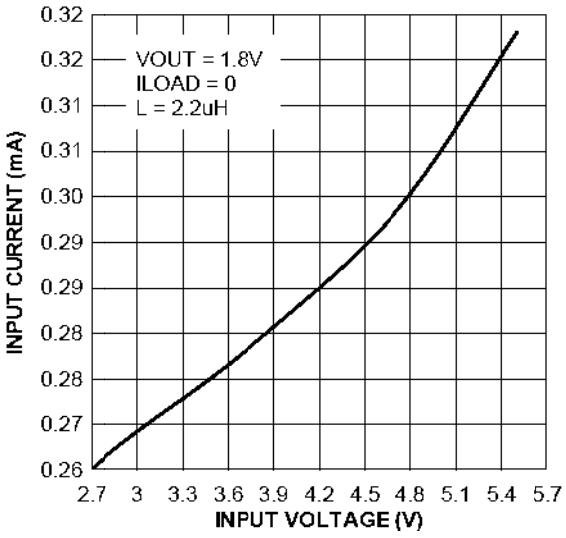
Reference Voltage vs Temperature



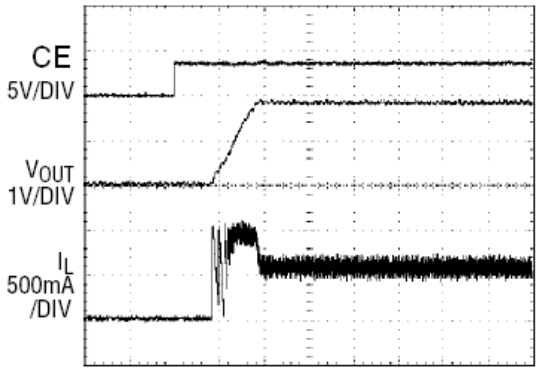

Supply Current vs Temperature




Input Current vs Input Voltage

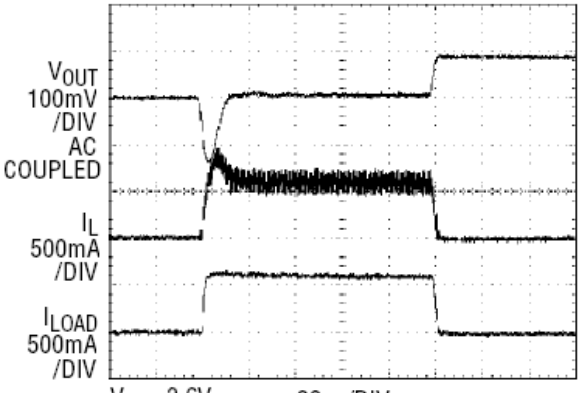



Start-Up from Shutdown



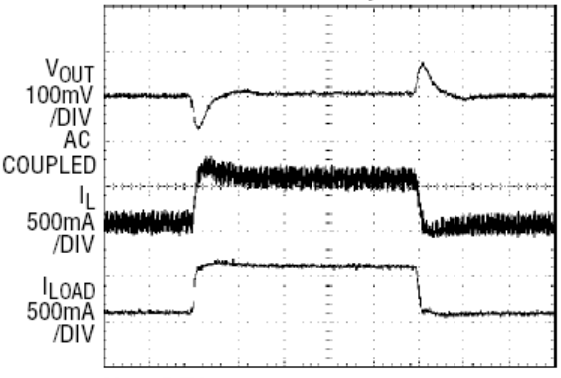

$V_{IN}$ = 3.6V 40µs/DIV
$V_{OUT}$ = 1.8V
$I_{LOAD}$ = 600mA (LOAD: 3Ω RESISTOR)

Load Step




$V_{IN}$ = 3.6V 20µs/DIV
$V_{OUT}$ = 1.8V $I_{LOAD}$ = 0mA TO 600mA

Load Step




$V_{IN}$ = 3.6V 20µs/DIV
$V_{OUT}$ = 1.8V $I_{LOAD}$ = 100mA TO 600mA

## ■ OPERATION

### MAIN CONTROL LOOP

**The LR8506** uses a constant frequency, current mode step-down architecture. Both the main (P-channel MOSFET) and synchronous (N-channel MOSFET) switches are internal. During normal operation, the internal top power MOSFET is turned on each cycle when the oscillator sets the RS latch, and turned off when the current comparator, $I_{COMP}$, resets the RS latch. The peak inductor current at which $I_{COMP}$ resets the RS latch, is controlled by the output of error amplifier EA. When the load current increases, it causes a slight decrease in the feedback voltage, FB, relative to the 0.6V reference, which in turn, causes the EA amplifier's output voltage to increase until the average inductor current matches the new load current. While the top MOSFET is off, the bottom MOSFET is turned on until either the inductor current starts to reverse, as indicated by the current reversal comparator $I_{RCMP}$, or the beginning of the next clock cycle. The OVDET comparator controls output transient overshoots by turning the main switch off and keeping it off until the fault is removed.

### MAXIMUM LOAD CURRENT

The LR8506 will operate with input voltage as low as 2.5V, however, the maximum load current decreases at lower input due to large IR drop on the main switch and synchronous rectifier. The slope compensation signal reduces the peak inductor current as a function of the duty cycle to prevent sub-harmonic oscillations at duty cycles greater than 50%.Conversely the current limit increase as the duty cycle decreases.

### PULSE SKIPPING MODE

At light loads, the inductor current may reach zero reverse on each pulse. The bottom MOSFET is turned off by the current reversal comparator, $I_{RCMP}$, and the switch voltage will ring. This is discontinuous mode operation, and is normal behavior for the switching regulator. At very light loads, the LR8506 will automatically skip pulses in pulse skipping mode operation to maintain output regulation.

### SLOPE COMPENSATION

Slope compensation provides stability in constant frequency architecture by preventing subharmonic oscillations at high duty cycles. It is accomplished internally by adding a compensating ramp to the inductor current signal at duty cycles in excess of 50%. This slope compensated current mode PWM control provides stable switching and cycle-by-cycle current limit for excellent load and line response.

### DROPOUT OPERATION

As the input supply voltage decreases to a value approaching the output voltage, the duty cycle increases toward the maximum on-time. Further reduction of the supply voltage forces the main switch to remain on for more than one cycle until reaches 100% duty cycle. The output voltage will then be determined by the input voltage minus the voltage drop across the P-channel MOSFET and the inductor.

An important detail to remember is that at low inputs supply voltages, the $R_{DS(ON)}$ of the P-channel switch increases. Therefore, the user should calculate the power dissipation when the LR8506 is used at 100% duty cycle with low input voltage.

## ■ APPLICATION INFORMATION

The basic LR8506 application circuits are shown in Figure 1.External component selection is driven by the load requirement and begins with the selection of L followed by $C_{IN}$ and $C_{OUT}$.

### SETTING THE OUTPUT VOLTAGE

Figure 1.2 shows the basic application circuit with LR8506 adjustable output version. The external resistor sets the output voltage according to the following equation:

$$V_{OUT} \quad 0.6V \quad 1\frac{R2}{R1}$$

Table 1.Resistor select for output voltage setting

| $V_{OUT}$ | R1 | R2 |
|---|---|---|
| 1.2V | 316K | 316K |
| 1.5V | 316K | 470K |
| 1.8V | 316K | 634K |
| 2.5V | 316K | 1M |

### INPUT CAPACITOR SELECTION

In continuous mode, the source current of the top MOSFET is a square wave of duty cycle $V_{OUT}/V_{IN}$. To prevent large voltage transients, a low ESR input capacitor sized for the maximum RMS current must be used. The maximum RMS capacitor current is given by:

$$C_{IN} \text{ required } I_{RMS} \cong I_{OMAX} \frac{[V_{OUT}(V_{IN} \quad V_{OUT})]^{1/2}}{V_{IN}}$$

This formula has a maximum at $V_{IN} = 2V_{OUT}$, where $I_{RMS} = I_{OUT}/2$. This simple worst-case condition is commonly used for design because even significant deviations do not offer much relief. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. A 4.7μF ceramic capacitor for most application is sufficient.

### INDUCTOR SELECTION

For most applications, the value of the inductor will fall in the range of 1μH to 4.7μH. Its value is chosen based on the desired ripple current. Large value inductor lower ripple current and small value inductor result in higher ripple currents. Higher $V_{IN}$ or $V_{OUT}$ also increases the ripple current as shown in the following equation:

$$\Delta I_L \quad \frac{V_{OUT} \quad (V_{IN} \quad V_{OUT})}{V_{IN} \quad L \quad f_{sc}}$$

A reasonable starting point for setting ripple current is $\triangle I_L$=240mA (40% of 600mA). The DC current rating of the inductor should be at least equal to the maximum load current plus half the ripple current to prevent core saturation.

Different core materials and shapes will change the size/current and price/current relationship of an inductor. The choice of which style inductor to use often depends more on the price vs size requirements and any radiated field/EMI requirements than on what the LR8506 requires to operate. Table 2 shows some typical surface mount inductors that work well in LR8506 applications.

Table 2.Representative Surface Mount Inductors

| PART NUMBER | VALUE (μH) | MAX DCR (m ) | MAX DC CURRENT (A) | SIZE W×L×H ($mm^3$) |
|---|---|---|---|---|
| Sumida | 2.2 | 75 | 1.20 | |
| CDRH | 3.3 | 110 | 1.10 | 3.8×3.8 |
| 3D16 | 4.7 | 162 | 0.90 | ×1.8 |
| Sumida | 2.2 | 71.2 | 1.75 | |
| CR43 | 3.3 | 86.2 | 1.44 | 4.5×4.0 |
| | 4.7 | 108.7 | 1.15 | ×3.5 |
| Sumida | 2.2 | 75 | 1.32 | 4.7×4.7 |
| CDRH | 3.3 | 110 | 1.04 | ×2.0 |
| 4D18 | 4.7 | 162 | 0.84 | |

## OUTPUT CAPACITOR SELECTION

The selection of $C_{OUT}$ is driven by the required effective series resistance (ESR). Typically, once the ESR requirement for $C_{OUT}$ has been met, the RMS current rating generally far exceeds the $I_{RIPPLE}$ requirement. The output ripple $\triangle V_{OUT}$ is determined by:

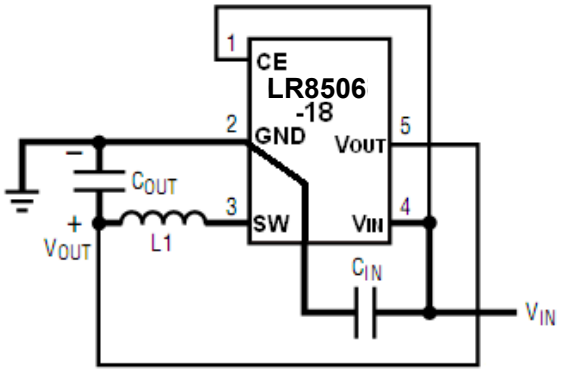
$$\Delta V_{OUT} \cong \Delta I_L \quad ESR \quad \frac{1}{8fC_{OUT}}$$

Where f = operating frequency, $C_{OUT}$ = output capacitance and $\triangle I_L$ = ripple current in the inductor. For a fixed output voltage, the output ripple is highest at maximum input voltage since $\triangle I_L$ increase with input voltage. Ceramic capacitors with X5R or X7R dielectrics are recommended due to their low ESR and high ripple current.

## PCB LAYOUT GUIDANCE

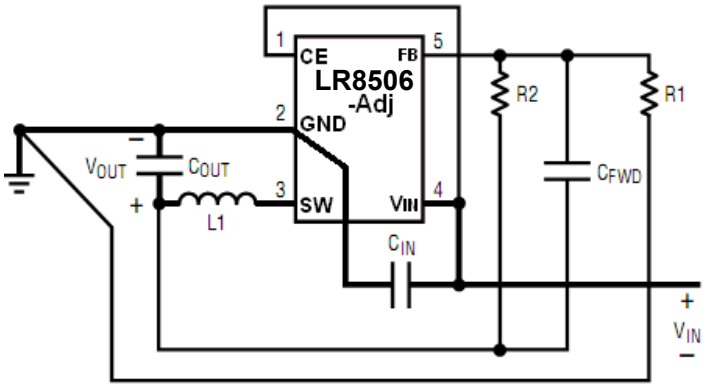
When laying out the printed circuit board, the following suggestions should be taken to ensure proper operation of the LR8506. These items are also illustrated graphically in Figure 2 and Figure 3.

1. The power traces, including the GND trace, the SW trace and the $V_{IN}$ trace should be kept short, direct and wide to allow large current flow. Put enough multiply-layer pads when they need to change the trace layer.
2. Keep the switching node, SW, away from the sensitive FB node.
3. The FB pin should directly connect to the feedback resistors. The resistive divider R1/R2 must be connected between the (+) plate of $C_{OUT}$ and ground.
4. Connect the (+) plate of $C_{IN}$ to the $V_{IN}$ pin as closely as possible.
5. Keep the (-) plate of $C_{IN}$ and $C_{OUT}$ as close as possible.




BOLD LINES INDICATE HIGH CURRENT PATHS

**Figure 2a. LR8506-18 layout Diagram**




BOLD LINES INDICATE HIGH CURRENT PATHS

**Figure 2b. LR8506-Adj Layout Diagram**

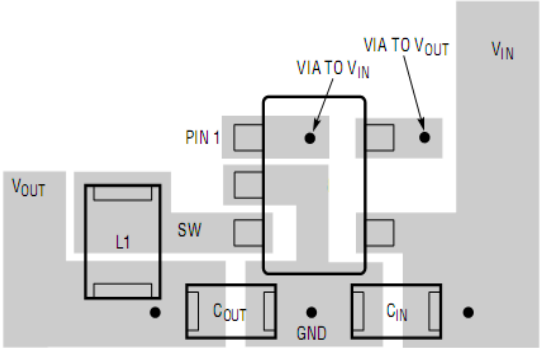



**Figure 3a. LR8506-18 Suggested Layout**

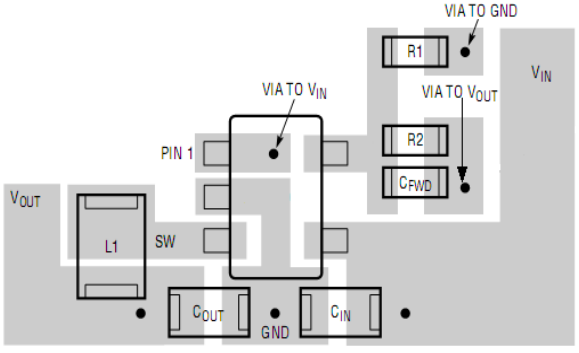
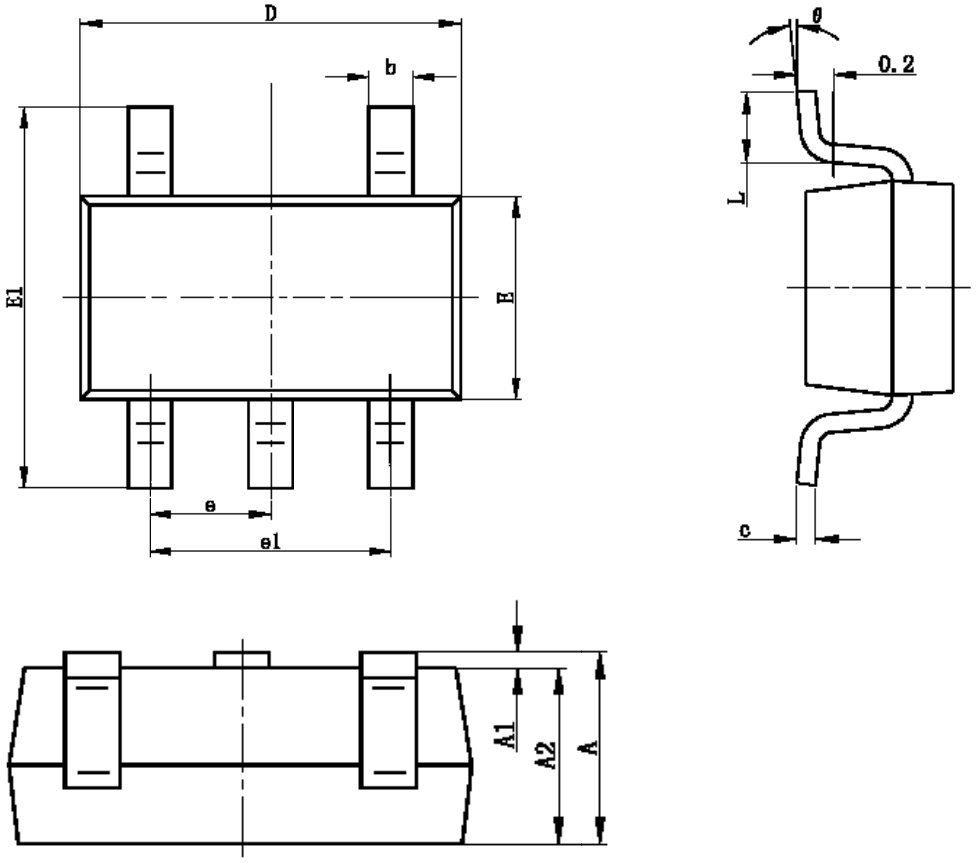



**Figure 3b. LR8506-Adj Suggested Layout**

## ■ PACKAGING INFORMATION

- **SOT-23-5 Package Outline Dimensions**




| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| A | 1.050 | 1.250 | 0.041 | 0.049 |
| A1 | 0.000 | 0.100 | 0.000 | 0.004 |
| A2 | 1.050 | 1.150 | 0.041 | 0.045 |
| b | 0.300 | 0.500 | 0.012 | 0.020 |
| c | 0.100 | 0.200 | 0.004 | 0.008 |
| D | 2.820 | 3.020 | 0.111 | 0.119 |
| E | 1.500 | 1.700 | 0.059 | 0.067 |
| E1 | 2.650 | 2.950 | 0.104 | 0.116 |
| e | 0.950(BSC) | | 0.037(BSC) | |
| e1 | 1.800 | 2.000 | 0.071 | 0.079 |
| L | 0.300 | 0.600 | 0.012 | 0.024 |
| θ | 0° | 8° | 0° | 8° |