# 1.5MHz 600mA, Synchronous Step-Down Regulator

## General Description

EML9206 is designed with high efficiency step down DC/DC converter for portable devices applications. It features with extreme low quiescent current with no load which is the best fit for extending battery life during the standby mode. The device operates from 2.5V to 5.5V input voltage and up to 600mA output current capability. High 1.5MHz internal frequency makes small surface mount inductors and capacitors possible and reduces overall PCB board space. Further, build-in synchronous switch makes external Schottky diode is no longer needed and efficiency is improved. EML9206 is designed base on Pulse Width Modulation (PWM) for low output voltage ripple and fixed frequency noise, while Pulse Frequency Modulation (PFM) is used to improve light load efficiency, and Low Dropout (LDO) Mode provides 100% duty cycle operation. The device is available in fixed output voltages of 1.2V, 1.8V and 3.3V in SOT-23-5 package.

## Features

- Achieve 95% efficiency
- Input Voltage : 2.5V to 5.5V
- Output Current up to 600mA
- Quiescent Current 35 $\mu$A with No Load
- Internal switching frequency 1.5MHz
- No Schottky Diode needed
- Low Dropout Operation: 100% Duty Cycle
- Shutdown current < 1 $\mu$A
- Excellent Line and Load Transient Response
- Over-temperature Protection

## Applications

- Blue-Tooth devices
- Cellular and Smart Phones
- Personal multi-media Player (PMP)
- Wireless networking
- Digital Still Cameras
- Portable applications

## Typical Application (fixed-3.3V)

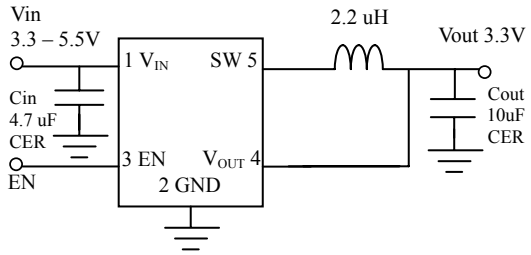



Fig. 1

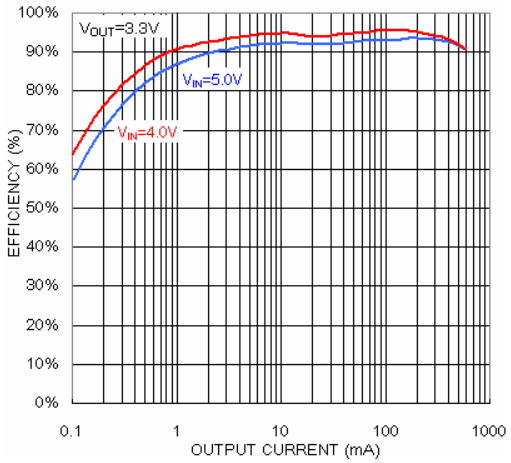
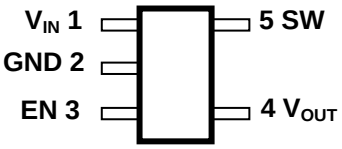



Fig. 2

## Connection Diagram

SOT-23-5



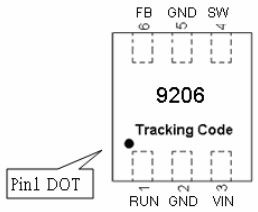
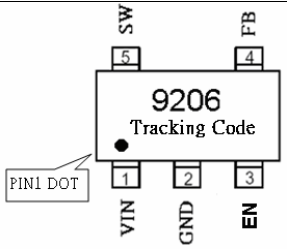

TDFN-6

## Order Information

EML9206-XXVF05GRR/NRR
XX Output voltage
VF05 SOT-23-5 Package
GRR RoHS (Pb Free)
Rating: -40 to 85°C
Package in Tape & Reel
NRR RoHS & Halogen free (By Request)
Rating: -40 to 85°C
Package in Tape & Reel

EML9206-XXFE06GRR/NRR
XX Output voltage
VF05 TDFN-6 Package
GRR RoHS (Pb Free) (By Request)
Rating: -40 to 85°C
Package in Tape & Reel
NRR RoHS & Halogen free
Rating: -40 to 85°C
Package in Tape & Reel

## Order, Mark & Packing Information

| Package | Vout | Product ID | Marking | Packing |
|---|---|---|---|---|
| TDFN-6 | 1.8 | EML9206-18FE06NRR |   | Tape & Reel 3Kpcs |
| SOT-23-5 | 1.2 | EML9206-12VF05GRR |   | Tape & Reel 3Kpcs |
| | 1.8 | EML9206-18VF05GRR | | |
| | 3.3 | EML9206-33VF05GRR | | |

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## Pin Functions

| Pin Name | Function |
|---|---|
| $V_{IN}$ | Input voltage Pin.<br>Must be closely decoupled to GND pin with a 4.7μF or greater ceramic capacitor. |
| GND | Ground Pin. |
| EN/RUN | Enable Pin.<br>Minimum 1.2V to enable the device. Maximum 0.4V to shut down the device. Do not leave this pin floating. |
| $V_{OUT}$/FB | Output Voltage Pin.<br>An internal resistive divider divides the output voltage down for comparison to the internal reference voltage. |
| SW | Switch Pin.<br>Must be connected to Inductor. This pin connects to the drains of the internal main and synchronous power MOSFET switches. |

## Absolute Maximum Ratings

**Devices are subjected to failure if they stay above absolute maximum ratings.**

Input Voltage ---------- – 0.3V to 6V
EN, $V_{OUT}$ Voltages ---------- – 0.3V to $V_{IN}$
SW Voltage ---------- – 0.3V to ($V_{IN}$ + 0.3V)
PMOS Switch Source Current (DC) ---------- 800mA
NMOS Switch Sink Current (DC) ---------- 800mA
Peak Switch Sink and Source Current ---------- 1.3A

Operating Temperature Range ---------- –40°C to 85°C
Junction Temperature (Notes 1, 3) ---------- 125°C
Storage Temperature Range ---------- – 65°C to 150°C
Lead Temperature (Soldering, 10 sec) ---------- 240°C
ESD Susceptibility HBM ---------- 2KV
MM ---------- 200V

## Electrical Characteristics

**The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are $T_A$ = 25°C. $V_{IN}$ = 3.6V unless otherwise specified.**

| Symbol | Parameter | Conditions | | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|---|
| $V_{OUT}$% | Output Voltage Accuracy | $I_{OUT}$=200mA | ● | -3 | | +3 | % |
| $\Delta V_{OVL}$ | Output Over-voltage Lockout | $\Delta V_{OVL} = V_{OVL} – V_{OUT}$, EML9206-Fixed | | 2.5 | 7.8 | 13 | % |
| $\Delta V_{OUT}$ | Output Voltage Line Regulation | $V_{IN}$ = 2.5V to 5.5V, $I_{OUT}$=200mA | ● | | | 0.4 | %/V |
| $I_{PK}$ | Peak Inductor Current | $V_{IN}$ = 3V, $V_{OUT}$ = 90% | | | 1.1 | | A |
| $I_S$ | PWM Quiescent Current (Note 2) | $V_{OUT}$ = 90% | | | 180 | 340 | μA |
| | PFM Quiescent Current | $V_{OUT}$ = 105% | | | 35 | 70 | μA |
| | Shutdown | $V_{EN}$ = 0V, $V_{IN}$ = 4.2V | | | 0.1 | | μA |
| $f_{OSC}$ | Oscillator Frequency | $V_{OUT}$ = 100% | ● | 1.2 | 1.5 | 1.8 | MHz |
| | | $V_{OUT}$ = 0V | ● | | 320 | | kHz |
| $R_{PFET}$ | $R_{DS(ON)}$ of PMOS | $I_{SW}$ = 100mA | | | 0.45 | 0.55 | Ω |
| $R_{NFET}$ | $R_{DS(ON)}$ of NMOS | $I_{SW}$ = –100mA | | | 0.40 | 0.5 | Ω |
| $V_{UVLO}$ | Under Voltage Lock Out | | | 1.44 | 1.8 | 2.16 | V |
| $I_{LSW}$ | SW Leakage | $V_{EN}$ = 0V, $V_{SW}$ = 0V or 5V, $V_{IN}$ = 5V | | | | ±1 | μA |
| $V_{EN}$ | Enable Threshold | | ● | 1.2 | | | V |
| | Shutdown Threshold | | ● | | | 0.4 | V |
| $I_{EN}$ | EN Leakage Current | | ● | | | ±1 | μA |

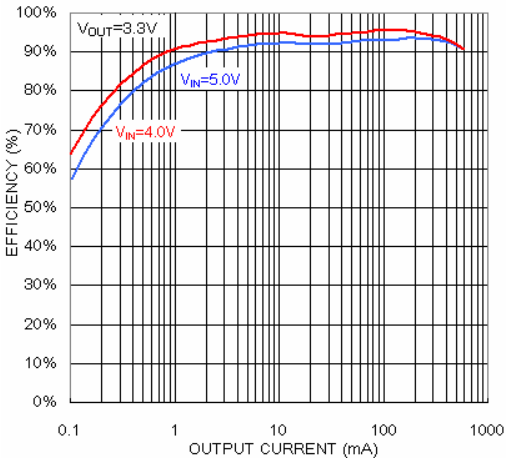
**Note 1:** $T_J$ is a function of the ambient temperature $T_A$ and power dissipation $P_D$ ( $T_J = T_A + (P_D)(250°C/W)$ )

**Note 2:** Dynamic quiescent current is higher due to the gate charge being delivered at the switching frequency.

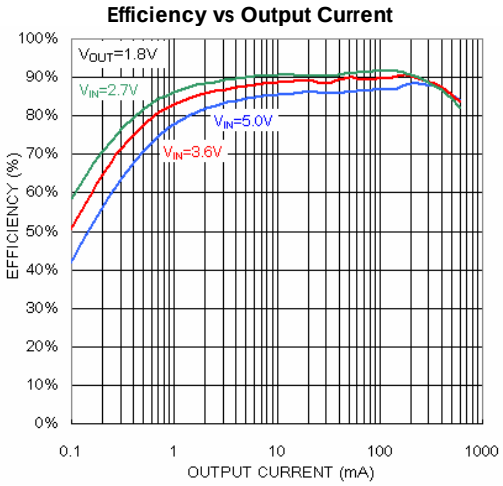
**Note 3:** This IC is build-in over-temperature protection to avoid damage from overload conditions.

## Typical Performance Characteristics

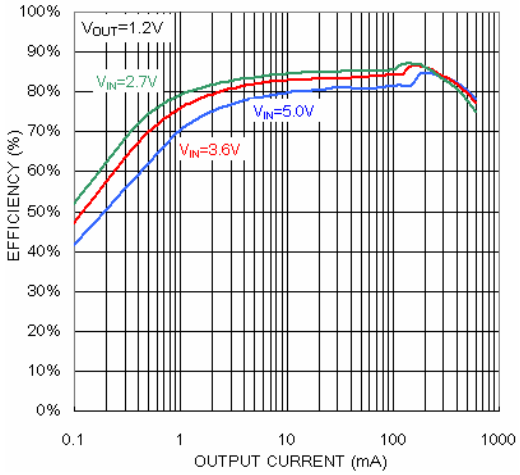
**Efficiency vs Output Current**



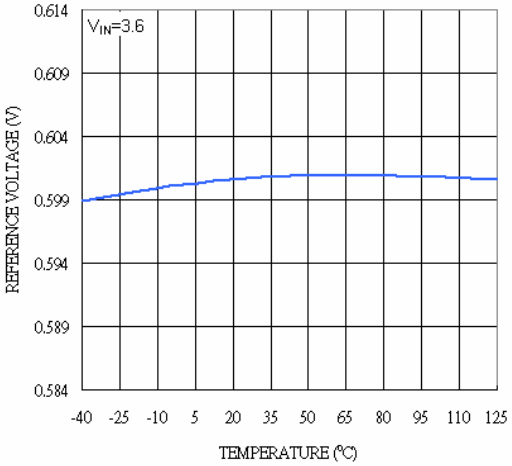

**Efficiency vs Output Current**



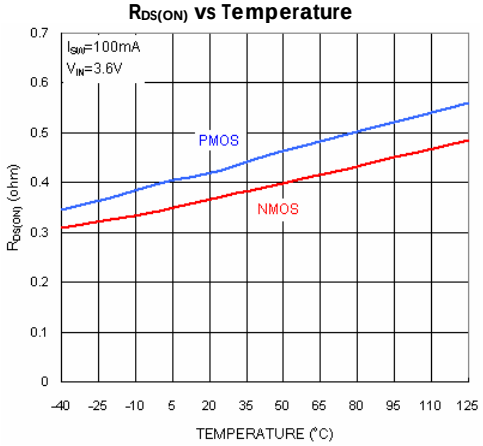

**Efficiency vs Output Current**



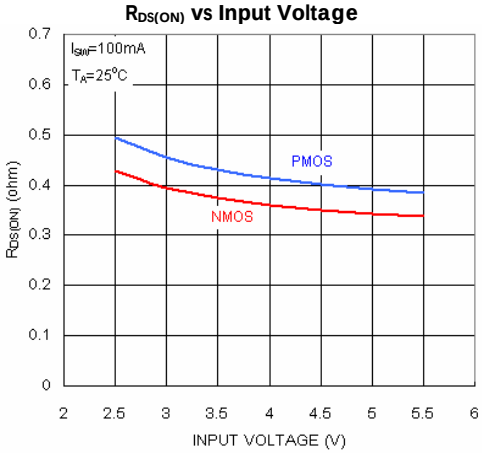

**Reference voltage vs Temperature**



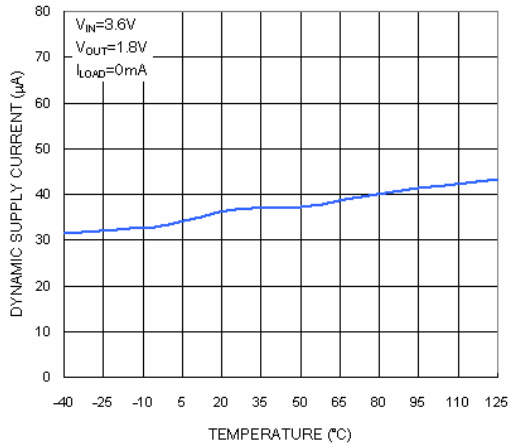

**$R_{DS(ON)}$ vs Temperature**



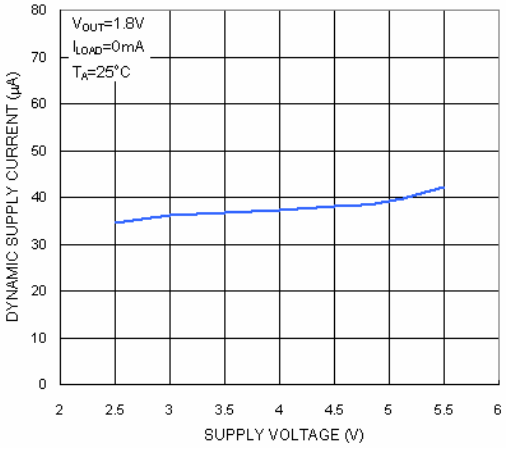

**$R_{DS(ON)}$ vs Input Voltage**



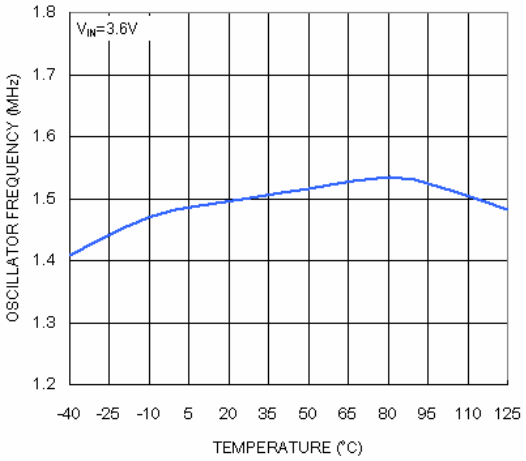
**Dynamic Supply Current vs Temperature**



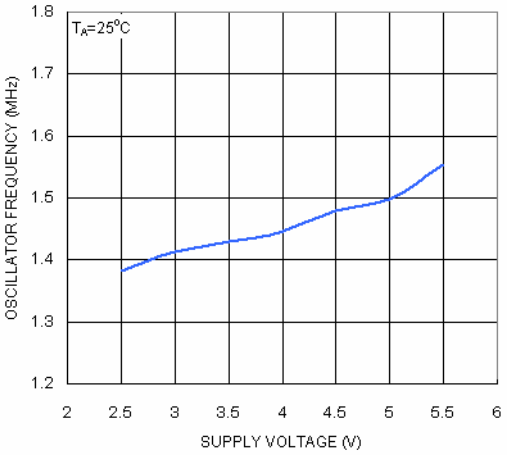

**Dynamic Supply Current vs Supply Voltage**



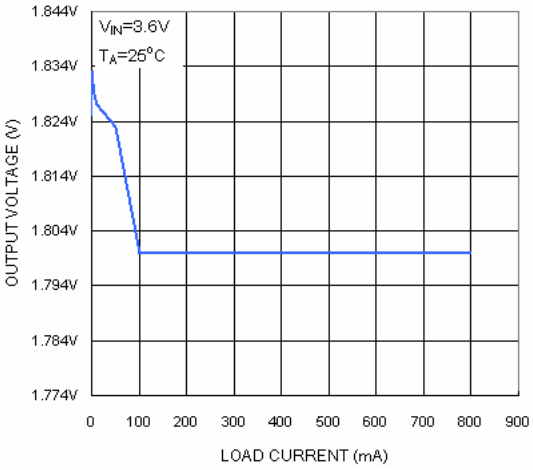

**Oscillator Frequency vs Temperature**



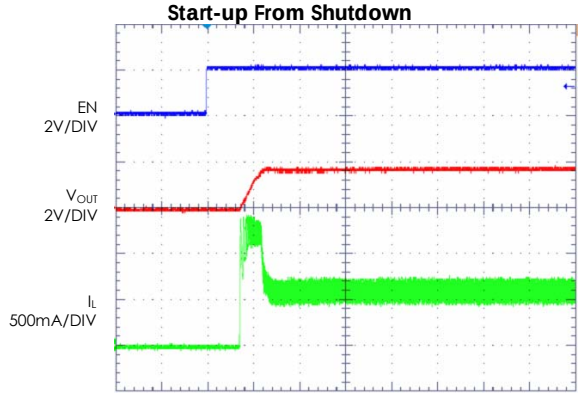

**Oscillator Frequency vs Supply Voltage**




**Output Voltage vs Load Current**

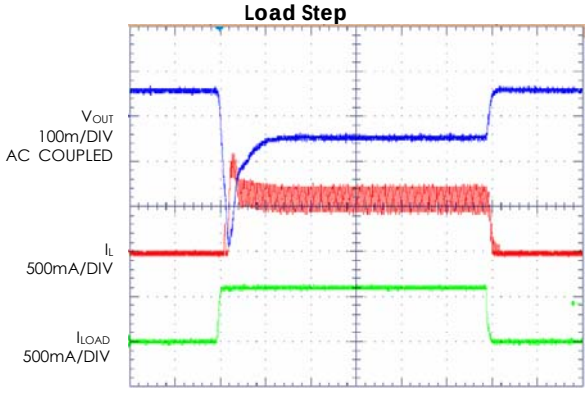


**Start-up From Shutdown**



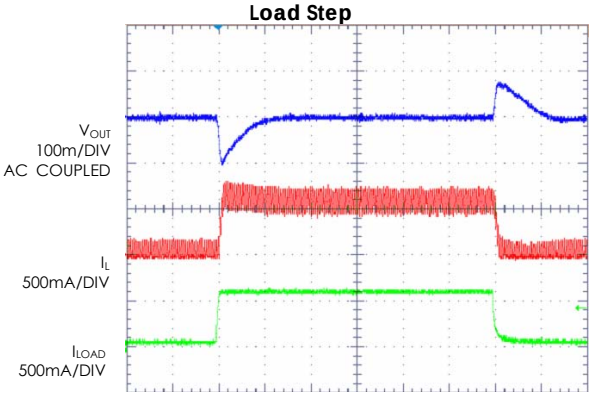

$V_{IN}$=3.6V 40 μs/DIV
$V_{OUT}$=1.8V
$I_{LOAD}$=600mA (3Ω RESISTOR)

**Load Step**



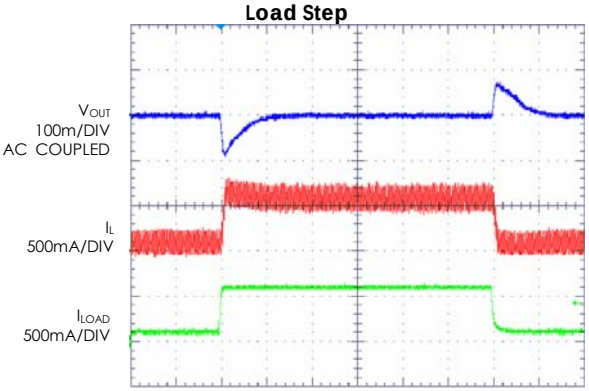

$V_{IN}$=3.6V 20 μs/DIV
$V_{OUT}$=1.8V
$I_{LOAD}$=0mA to 600mA

**Load Step**



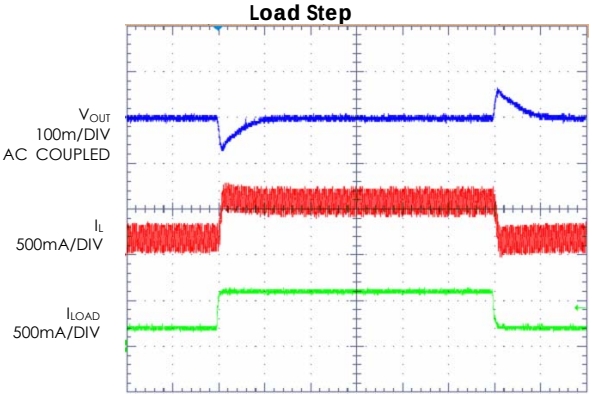

$V_{IN}$=3.6V 20 μs/DIV
$V_{OUT}$=1.8V
$I_{LOAD}$=50mA to 600mA

**Load Step**



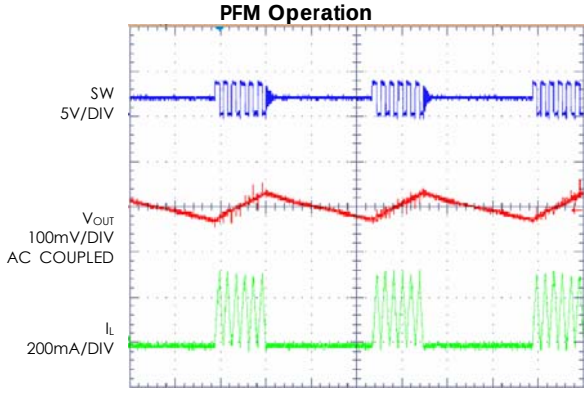

$V_{IN}$=3.6V 20 μs/DIV
$V_{OUT}$=1.8V
$I_{LOAD}$=100mA to 600mA

**Load Step**



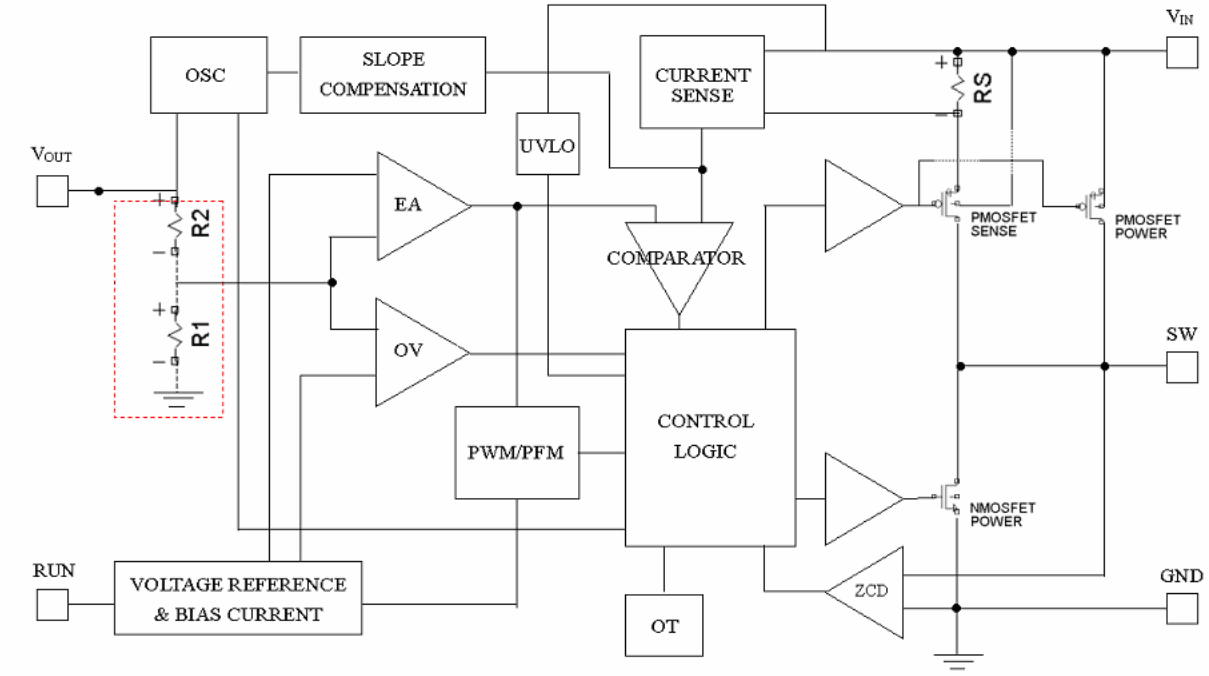

$V_{IN}$=3.6V 20 μs/DIV
$V_{OUT}$=1.8V
$I_{LOAD}$=200mA to 600mA

**PFM Operation**




$V_{IN}$=3.6V 4 μs/DIV
$V_{OUT}$=1.8V
$I_{LOAD}$=50mA

## Functional Block Diagram



## Applications

**Inductor Selection**

Basically, inductor ripple current and core saturation are two factors considered to decide the Inductor value.

$$\Delta I_L = \frac{1}{f \cdot L} V_{OUT}\left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad \text{Eq. 1}$$

The Eq. 1 shows the inductor ripple current is a function of frequency, inductance, Vin and Vout. It is recommended to set ripple current to 40% of max. load current. A low ESR inductor is preferred.

**$C_{IN}$ and $C_{OUT}$ Selection**

A low ESR input capacitor can prevent large voltage transients at $V_{IN}$. The RMS current of input capacitor is required larger than $I_{RMS}$ calculated by:

$$I_{RMS} \cong I_{OMAX} \frac{\sqrt{V_{OUT}\left(V_{IN} - V_{OUT}\right)}}{V_{IN}} \quad \text{Eq. 2}$$

ESR is an important parameter to select $C_{OUT}$. The output ripple $V_{OUT}$ is determined by:

$$\Delta V_{OUT} \cong \Delta I_L \left(ESR + \frac{1}{8 \cdot f \cdot C_{OUT}}\right) \quad \text{Eq. 3}$$

Higher values, lower cost ceramic capacitors are now available in smaller sizes. These ceramic capacitors have high ripple currents, high voltage ratings and low ESR that make them ideal for switching regulator applications. Optimize very low output ripple and small circuit size is doable from Cout selection since Cout does not affect the internal control loop stability. It is recommended to use the X5R or X7R which have the best temperature and voltage characteristics of all the ceramics for a given value and size.

**Thermal Considerations**

Although thermal shutdown is build-in in EML9206 that protect the device from thermal damage, the total power dissipation that EML9206 can sustain should be base on the package thermal capability. The formula to ensure the safe operation is shown in Note 1.

To avoid the EML9206 from exceeding the maximum junction temperature, the user will need to do some thermal analysis.

**Guidelines for PCB Layout**

To ensure proper operation of the EML9206, please note the following PCB layout guidelines:

1. The GND trace, the SW trace and the $V_{IN}$ trace should be kept short, direct and wide.
2. $V_{OUT}$ pin must be connected directly to the output voltage terminal of the load.
3. The Input capacitor $C_{IN}$ must be connected to pin $V_{IN}$ as closely as possible.
4. Keep SW trace away from the sensitive $V_{OUT}$ pin since this node is with high frequency and voltage swing.
5. Keep the (–) plates of $C_{IN}$ and $C_{OUT}$ as close as possible.

**Design Example**

Assume the EML9206 is used in a single lithium-ion battery-powered application. The $V_{IN}$ range will be about 2.7V to 4.2V. Output voltage is 1.8V.

With this information we can calculate L using equation:

$$L = \frac{1}{f \cdot \Delta I_L} V_{OUT}\left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Substituting $V_{OUT}$ = 1.8V, $V_{IN}$ = 4.2V, $\Delta I_L$ = 240mA and f = 1.5MHz in eq. 1 gives:

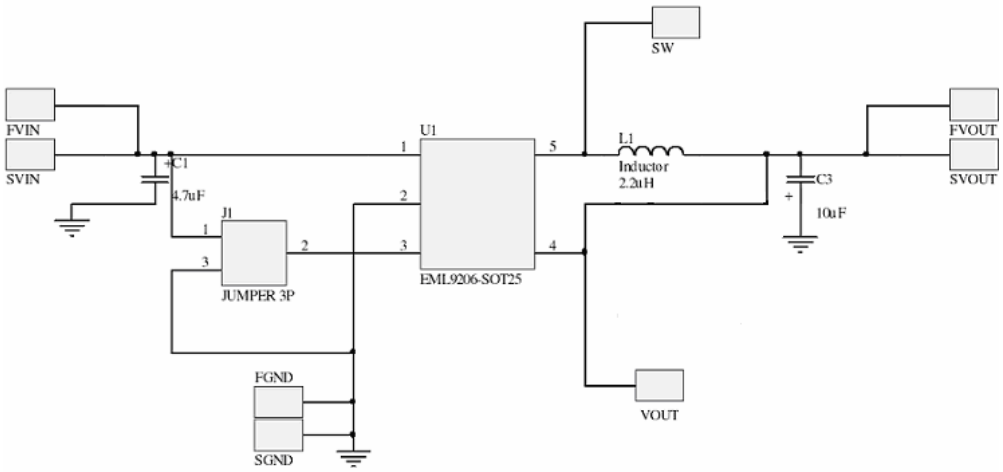
$$L = \frac{1.8V}{1.5MHz \cdot 240mA}\left(1 - \frac{1.8V}{4.2V}\right) = 2.86\mu H$$

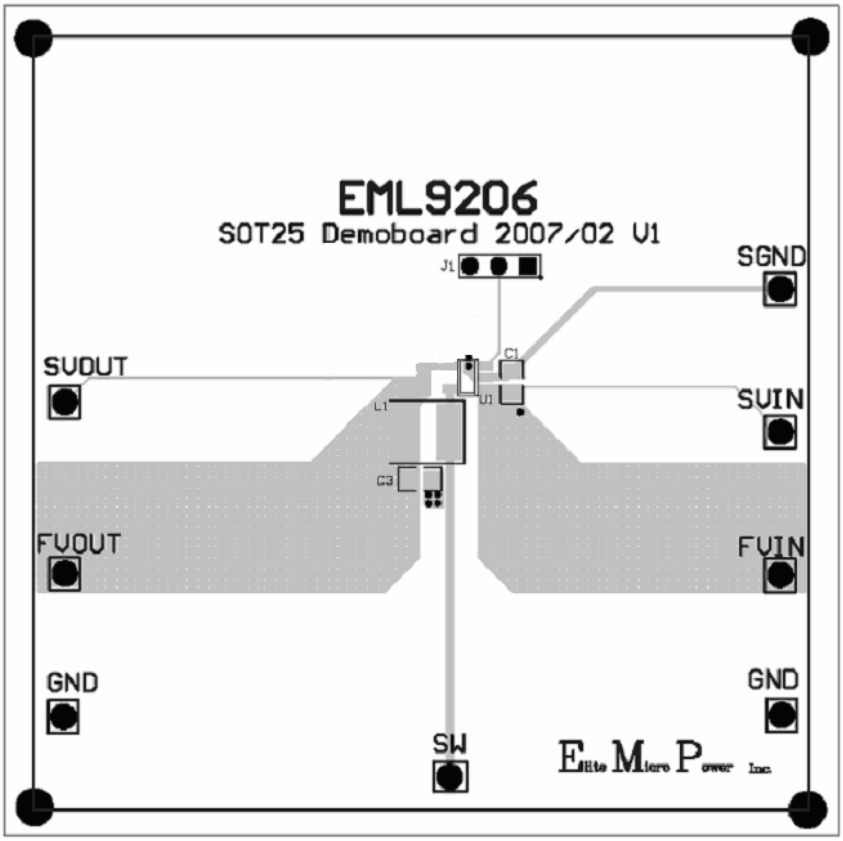
A 2.2µH inductor could be chose with this application.

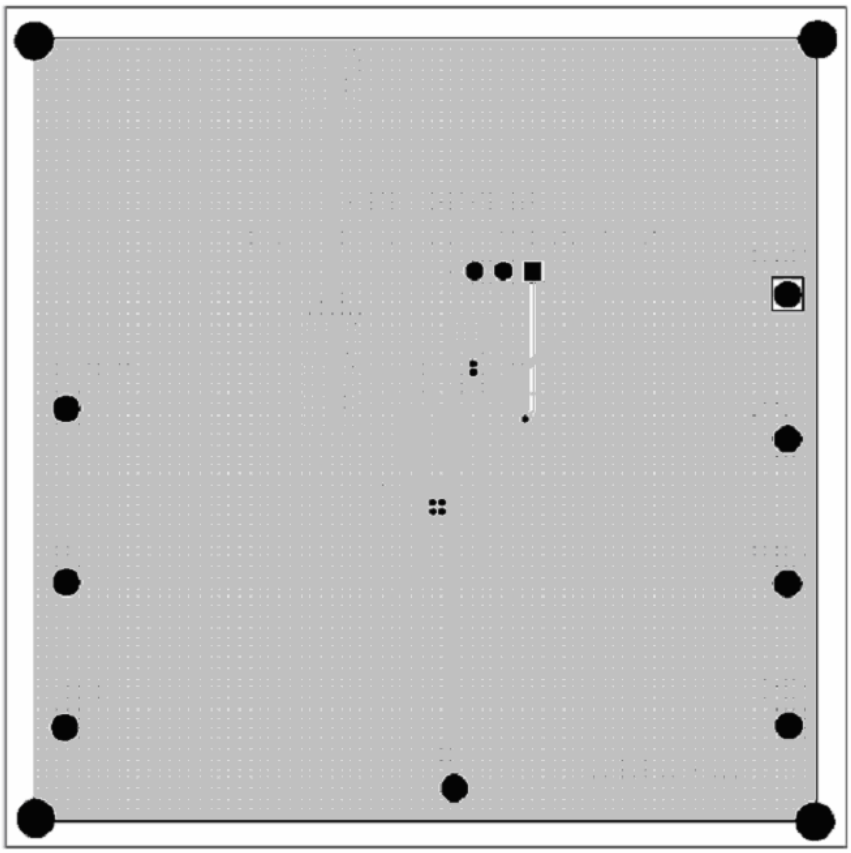
A greater inductor with less equivalent series resistance makes best efficiency. $C_{IN}$ will require an RMS current rating of at least $I_{LOAD(MAX)}/2$ and low ESR. In most cases, a ceramic capacitor will satisfy this requirement.

## Application (Continued)

### Typical schematic for PCB layout

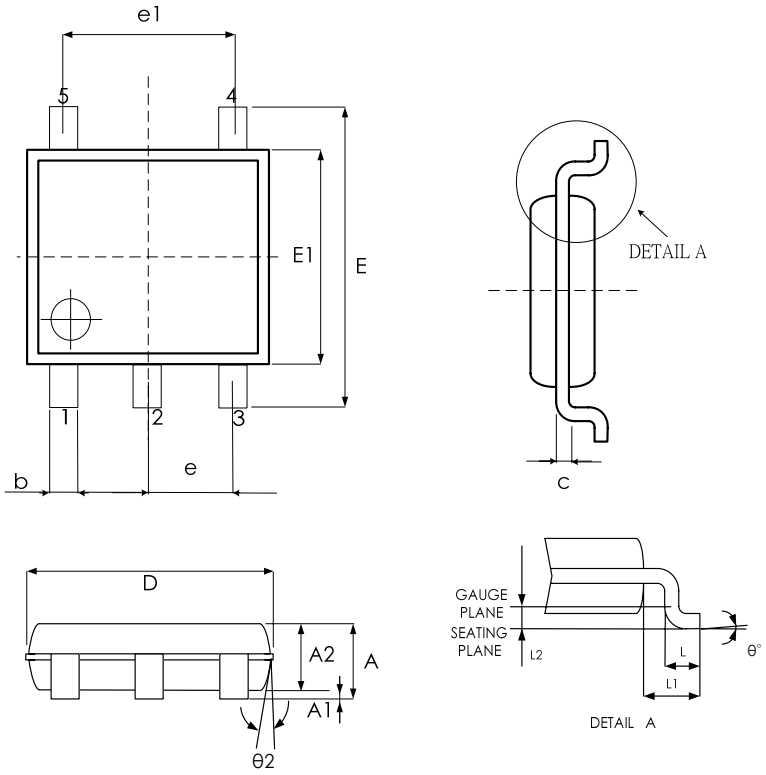



EML9206
SOT25 Demoboard 2007/02 V1
J1
SGND
SVOUT
C1
L1
U1
SVIN
C3
FVOUT
FVIN
GND
GND
SW
E Lite M icro P ower Inc.



## Package Information

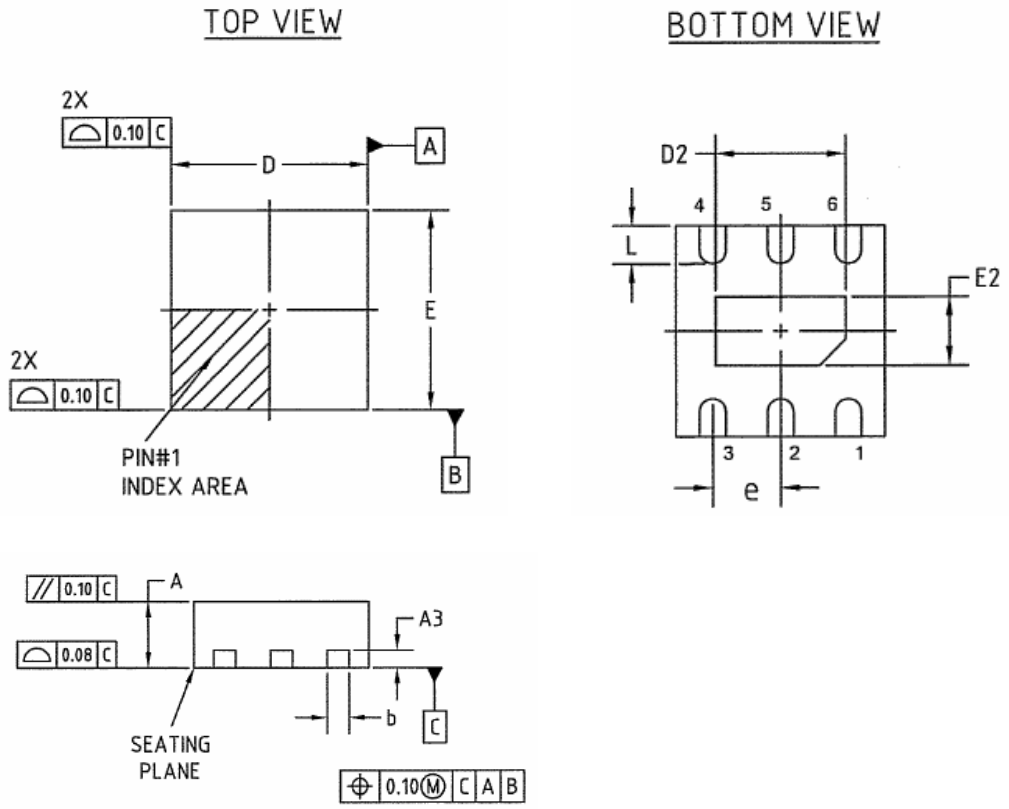
### SOT-23-5




| SYMBPLS | MIN. | NOM. | MAX. |
|---|---|---|---|
| A | 1.05 | 1.20 | 1.35 |
| A1 | 0.05 | 0.10 | 0.15 |
| A2 | 1.00 | 1.10 | 1.20 |
| b | 0.30 | — | 0.50 |
| c | 0.08 | — | 0.20 |
| D | 2.80 | 2.90 | 3.00 |
| E | 2.60 | 2.80 | 3.00 |
| E1 | 1.50 | 1.60 | 1.70 |
| e | 0.95 BSC | | |
| e1 | 1.90 BSC | | |
| L | 0.30 | 0.45 | 0.55 |
| L1 | 0.60 REF | | |
| θ° | 0 | 5 | 10 |
| θ2° | 6 | 8 | 10 |

UNIT: MM

**TDFN-6**




| SYMBOL | COMMON | | | | | |
|---|---|---|---|---|---|---|
| | DIMENSIONS MILLIMETER | | | DIMENSIONS INCH | | |
| | MIN. | NOM. | MAX. | MIN. | NOM. | MAX. |
| A | 0.70 | 0.75 | 0.80 | 0.027 | 0.029 | 0.031 |
| A3 | | 0.200 BSC | | | 0.008 BSC | |
| b | 0.25 | 0.30 | 0.35 | 0.010 | 0.012 | 0.014 |
| D | | 2.00 BSC | | | 0.079 BSC | |
| D2 | 1.35 | 1.40 | 1.45 | 0.053 | 0.055 | 0.057 |
| E | | 2.00 BSC | | | 0.079 BSC | |
| E2 | 0.55 | 0.60 | 0.65 | 0.022 | 0.024 | 0.026 |
| e | | 0.650 BSC | | | 0.026 BSC | |
| L | 0.25 | 0.30 | 0.35 | 0.010 | 0.012 | 0.014 |

Revision History

| Revision | Date | Description |
|---|---|---|
| 2.0 | 2009.06.05 | EMP transferred from version 1.0 |
| 2.1 | 2009.06.23 | 1. Add TDFN-6 package, order information (P2)<br>2. Delete pin number (P3)<br>3. Add TDFN-6 outline (P13) |
| 2.2 | 2011.01.28 | Revise electrical characteristics (VEN) |

Important Notice

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