

1.5MHz 600mA, Synchronous Step-Down Regulator

General Description

EML3406 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 6.0V 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. EML3406 is designed base on pulse width modulation (PWM) for low output voltage ripple and fixed frequency noise, low dropout mode provides 100% duty cycle operation. Low reference voltage is designed for achieving regulated output down to 0.6V.

The device is available in an adjustable version and fixed output voltages of 1.2V, 1.5V, 1.8V and 3.3V. The EML3406 is available in SOT-25 package.

Features

- Achieve 95% efficiency
- Input Voltage : 2.5V to 6.0V
- Output Current up to 600mA
- Reference voltage 0.6V
- Quiescent Current 200 μ A with No Load
- Internal switching frequency 1.5MHz
- No Schottky Diode needed
- Low Dropout Operation: 100% Duty Cycle
- Shutdown current < 1 μ 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 (adjustable)

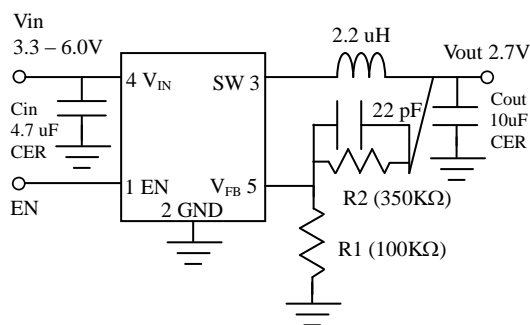


Fig. 1

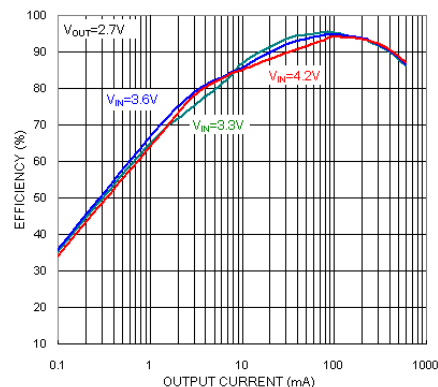
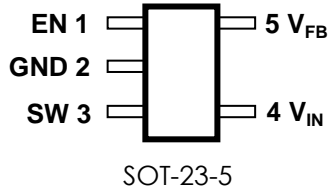


Fig. 2

CONNECTION DIAGRAM



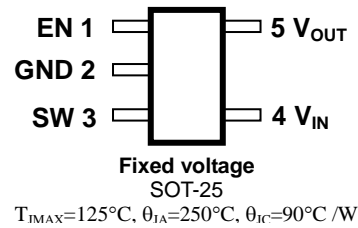
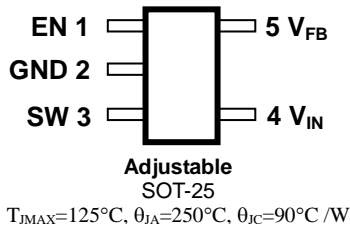
ORDER INFORMATION

EML3406-XXVF05GRR
 XX Output voltage
 VF05 SOT-23-5 Package
 GRR RoHS Package
 Rating: -40 to 85°C
 Package in Tape & Reel
 NRR RoHS & Halogen free package (By Request)

Order, Mark & Packing Information

Package	Vout	Product ID	Marking		Packing
			New	Old	
SOT-23-5	1.2	EML3406-12VF05GRR		L601 Date code	Tape & Reel 3Kpcs
	1.5	EML3406-15VF05GRR		L604 Date code	
	1.8	EML3406-18VF05GRR		L607 Date code	
	3.3	EML3406-33VF05GRR		L60M Date code	
SOT-23-5	adjustable	EML3406-00VF05GRR	L600 Date code		

Package configuration



Pin Functions

Pin #	Pin Name	Function
1	EN	Enable Pin. Minimum 1.2V to enable the device. Maximum 0.4V to shut down the device. Do not leave this pin floating.
2	GND	Ground Pin.
3	SW	Switch Pin. Must be connected to Inductor. This pin connects to the drains of the internal main and synchronous power MOSFET switches.
4	V _{IN}	Input voltage Pin. Must be closely decoupled to GND pin with a 4.7μF or greater ceramic capacitor.
5	V _{FB} (Adjustable)	Feedback Pin. Receives the feedback voltage from an external resistive divider across the output.
	V _{OUT} (Fixed voltage)	Output Voltage Pin. An internal resistive divider divides the output voltage down for comparison to the internal reference voltage.

Absolute Maximum Ratings

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

Input Voltage -----	- 0.3V to 6.5V	Operating Temperature Range	-40°C to 85°C
EN, V _{FB} Voltages -----	- 0.3V to V _{IN}	Junction Temperature (Notes 1, 3) -----	125°C
SW Voltage -----	- 0.3V to (V _{IN} + 0.3V)	Storage Temperature Range - -	65°C to 150°C
PMOS Switch Source Current (DC) ----	800mA	Lead Temperature (Soldering, 10 sec)----	240°C
NMOS Switch Sink Current (DC) -----	800mA	ESD Susceptibility	
Peak Switch Sink and Source Current ----	1.3A	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	
I _{VFB}	Feedback Current				±30	nA	
V _{FB}	Regulated Feedback Voltage	T _A = 25°C	0.588	0.600	0.612	V	
ΔV _{FB}	Reference Voltage Line Regulation	V _{IN} = 2.5V to 5.5V	●		0.4	%/V	
V _{OUT} %	Output Voltage Accuracy		●	-3	3	%	
ΔV _{OVL}	Output Over-voltage Lockout	ΔV _{OVL} = V _{OVL} - V _{FB} , EML3406			50	mV	
		ΔV _{OVL} = V _{OVL} - V _{OUT} , EML3406-Fixed			7.8	%	
ΔV _{OUT}	Output Voltage Line Regulation	V _{IN} = 2.5V to 5.5V	●		0.4	%/V	
I _{PK}	Peak Inductor Current	V _{IN} = 3V, V _{FB} = 0.5V or V _{OUT} = 90%, Duty Cycle < 35%			1.0	A	
V _{LOADREG}	Output Voltage Load Regulation				0.5	%	
I _S	Quiescent Current (Note 2)	V _{FB} = 0.5V or V _{OUT} = 90%			200	340	μA
	Shutdown	V _{EN} = 0V, V _{IN} = 2.5V to 6.0V			0.1	1	μA
f _{OSC}	Oscillator Frequency	V _{FB} = 0.6V or V _{OUT} = 100%	●	1.2	1.5	1.8	MHz
		V _{FB} = 0V or V _{OUT} = 0V	●		290		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
I _{LSW}	SW Leakage	V _{EN} = 0V, V _{SW} = 0V or 6.0V, V _{IN} = 6.0V				±1	μA
V _{EN}	Enable Threshold		●	1.2			V
	Shutdown Threshold		●			0.4	V
I _{EN}	EN Leakage Current	V _{IN} = 2.5V to 6.0V	●			±1	μA

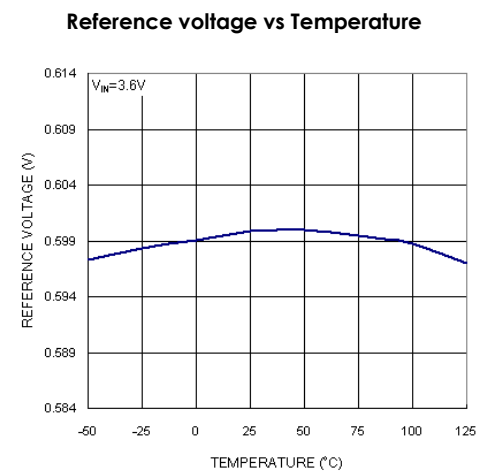
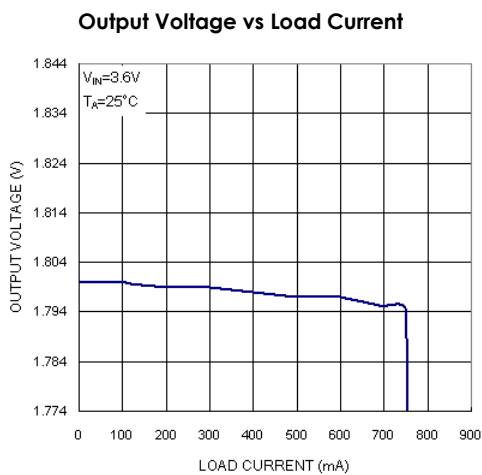
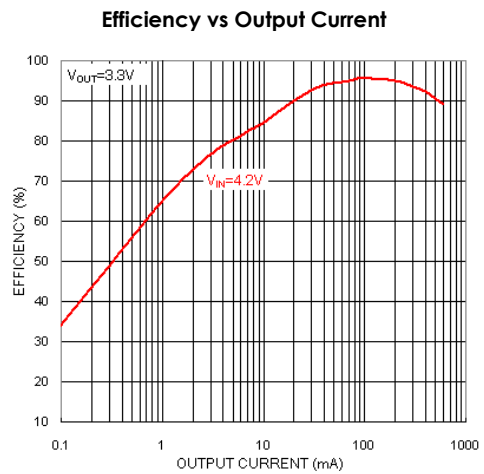
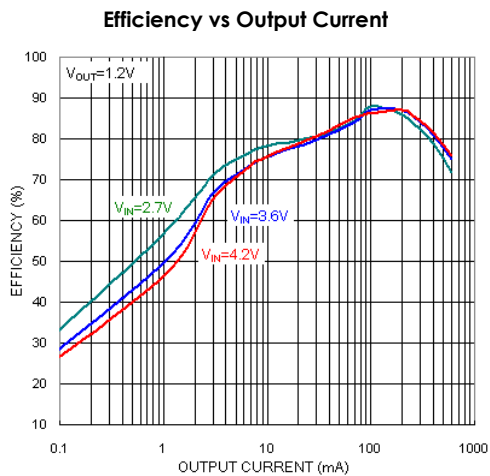
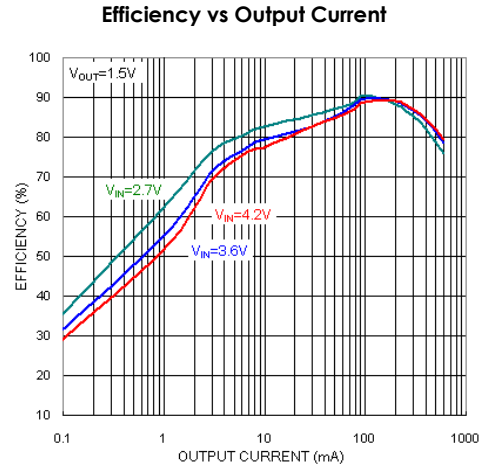
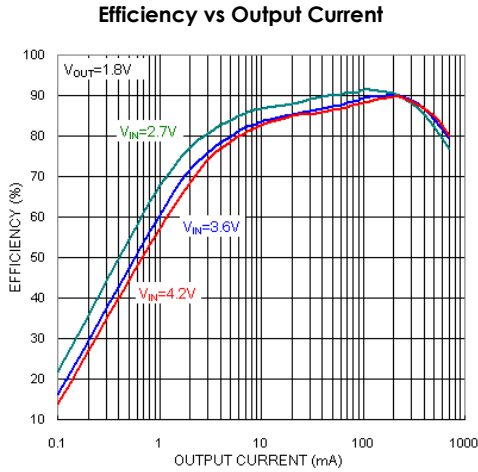
Note 1: T_J is a function of the ambient temperature T_A and power dissipation P_D (T_J = T_A + (P_D)(250°C/W))

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

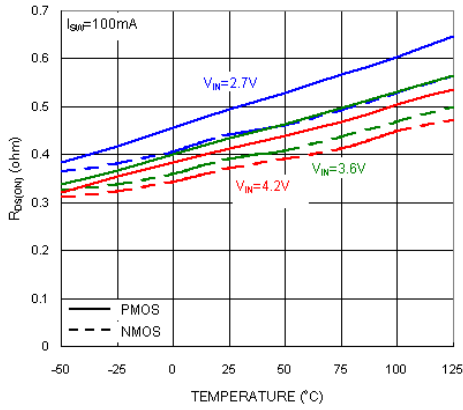
Note 3: This IC is build-in over-temperature protection to avoid damage from overload conditions.

Typical Performance Characteristics

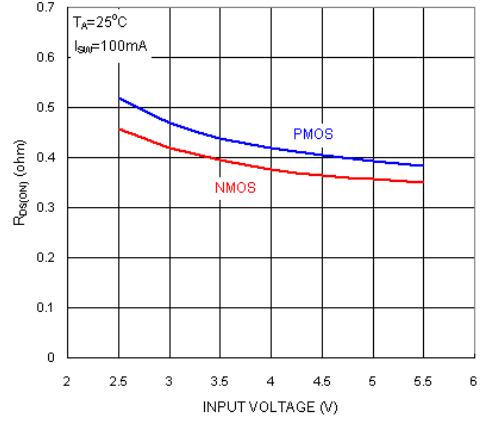
$T_A = 25^\circ\text{C}$. $V_{IN} = 3.6\text{V}$ unless otherwise specified.



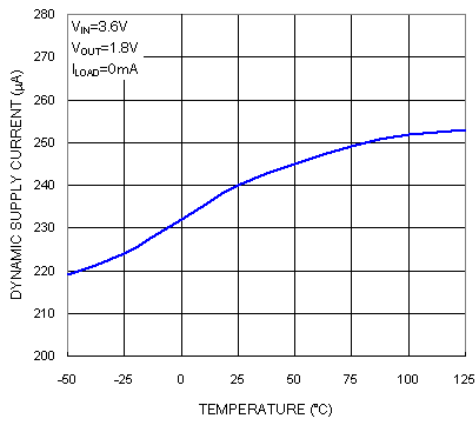
$R_{DS(ON)}$ vs Temperature



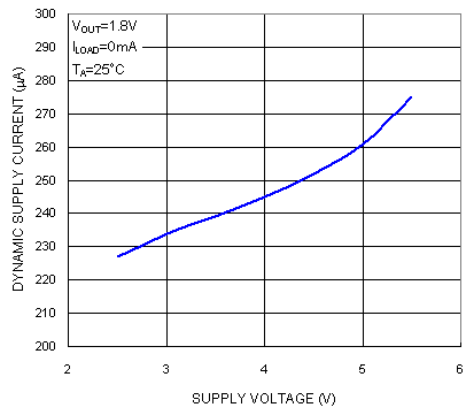
$R_{DS(ON)}$ vs Input Voltage



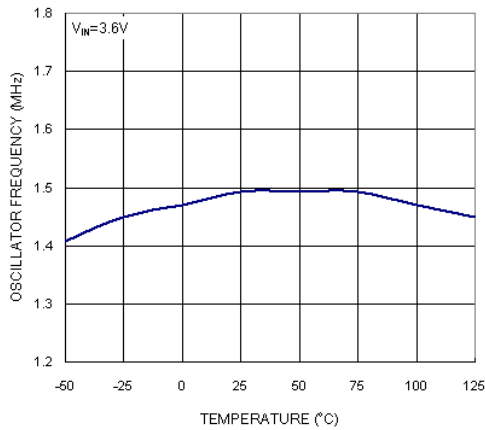
Dynamic Supply Current vs Temperature



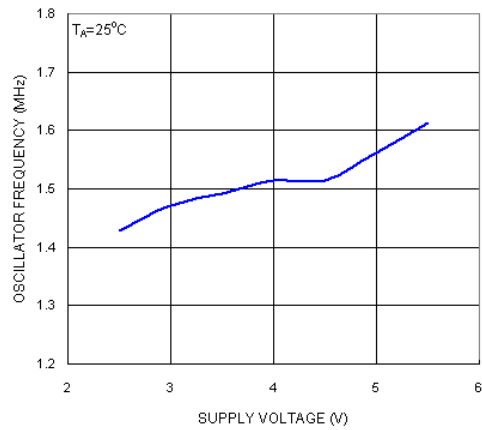
Dynamic Supply Current vs Supply Voltage



Oscillator Frequency vs Temperature



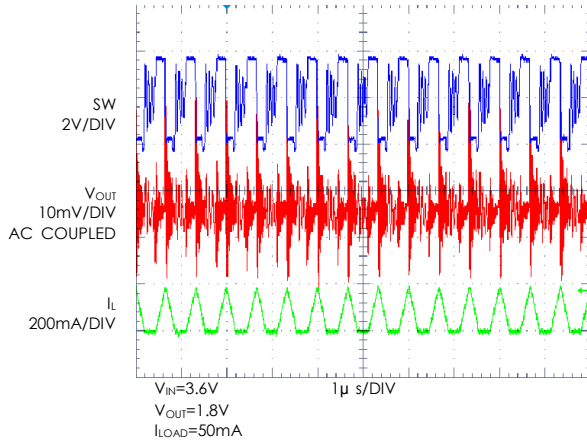
Oscillator Frequency vs Supply Voltage



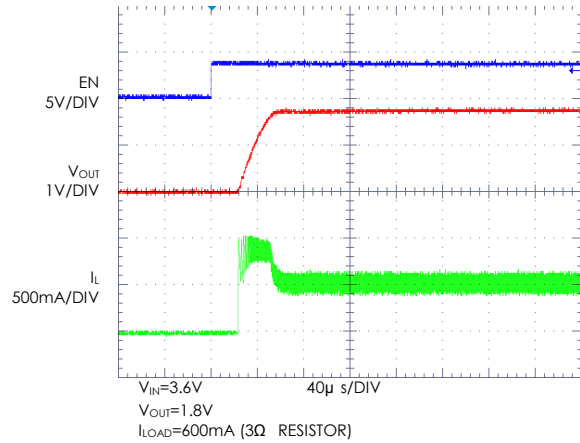
Typical Performance Characteristics

$T_A = 25^\circ\text{C}$. $V_{IN} = 3.6\text{V}$ unless otherwise specified.

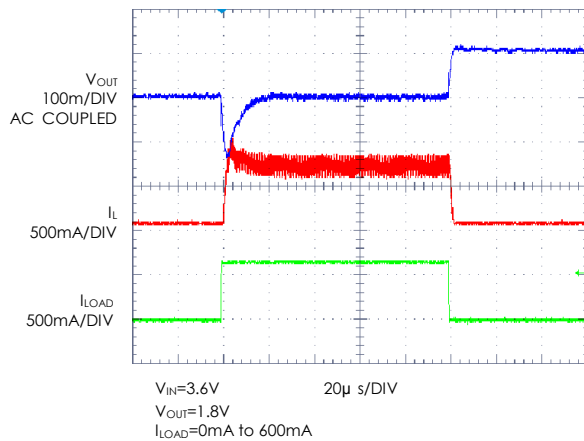
Discontinuous Operation



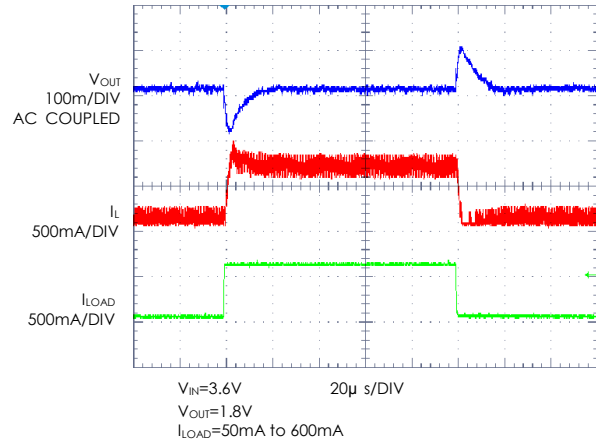
Start-up From Shutdown



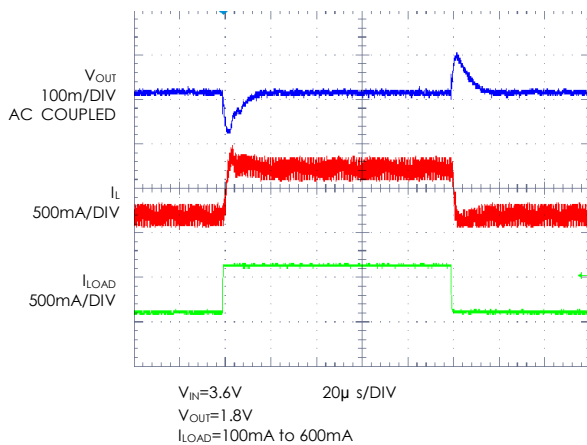
Load Step



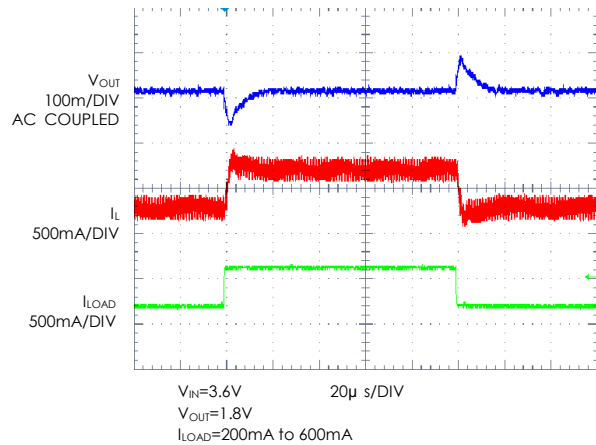
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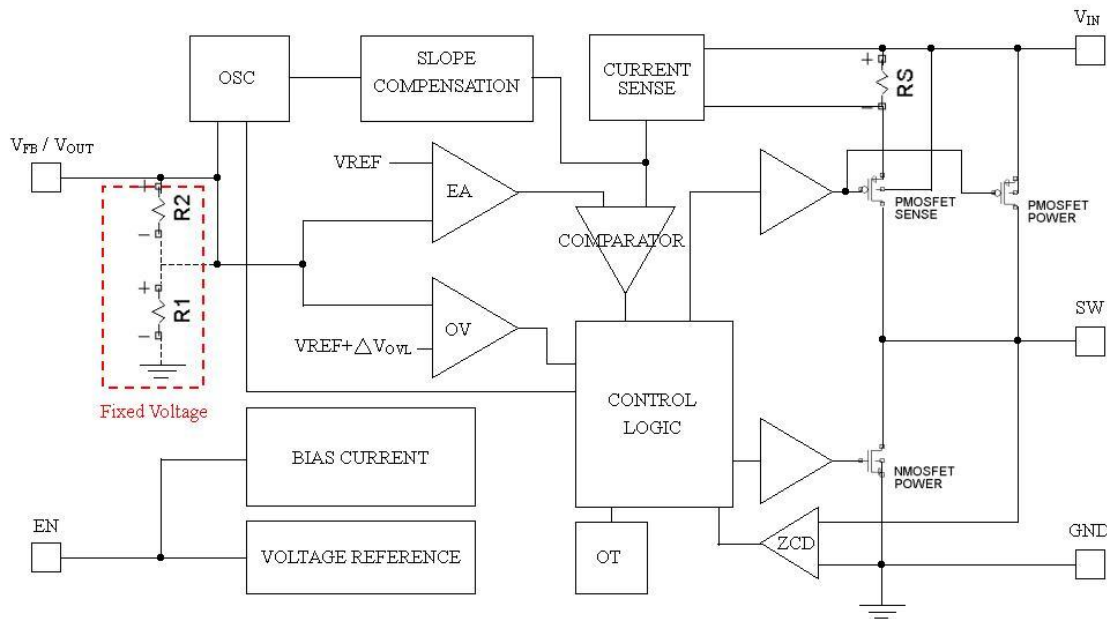
Load Step



Load Step



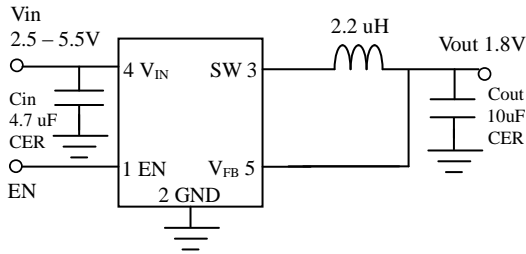
Functional Block Diagram



Applications

The typical application circuit of adjustable version is shown in Fig.1.

Fixed voltage version is shown below:



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.

CIN and COUT Selection

A low ESR input capacitor can prevent large voltage transients at VIN. The RMS current of input capacitor is required larger than IRMS calculated by:

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

ESR is an important parameter to select COUT. The output ripple VOUT 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.

Output Voltage (EML3406 adjustable)

In the adjustable version, the output voltage can be determined by:

$$V_{OUT} = 0.6V \left(1 + \frac{R_2}{R_1} \right) \quad \text{Eq. 4}$$

Thermal Considerations

Although thermal shutdown is build-in in EML3406 that protect the device from thermal damage, the total power dissipation that EML3406 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 EML3406 from exceeding the maximum junction temperature, the user will need to do some thermal analysis.

Guidelines for PCB Layout

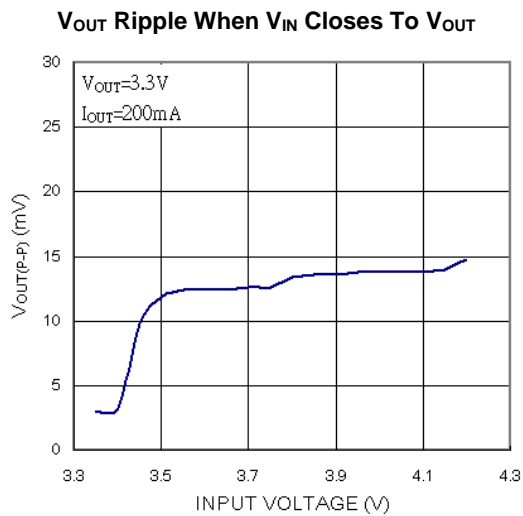
To ensure proper operation of the EML3406, please note the following PCB layout guidelines:

1. The GND trace, the SW trace and the VIN trace should be kept short, direct and wide.
2. VFB pin must be connected directly to the feedback resistors. Resistive divider R1/R2 must be connected and parallel to the output capacitor COUT.
3. The Input capacitor CIN must be connected to pin VIN as closely as possible.
4. Keep SW node away from the sensitive VFB node since this node is with high frequency and voltage swing.
5. Keep the (-) plates of CIN and COUT as close as possible.

Applications (continued)

Output Voltage Ripple When V_{IN} Closes To V_{OUT} , EML3406 goes into LDO mode when input voltage closes to output voltage. The transition from PWM mode to LDO mode is smooth. Bottom diagram shows the relationship of output voltage ripple versus input voltage when output voltage is 3.3V and EML3406 provides 200mA load current.

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.



Design Example

Assume the EML3406 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 $V_{OUT} = 1.8V$, $V_{IN} = 4.2V$, $I_L = 240mA$ and $f = 1.5MHz$ in eq. 1 gives:

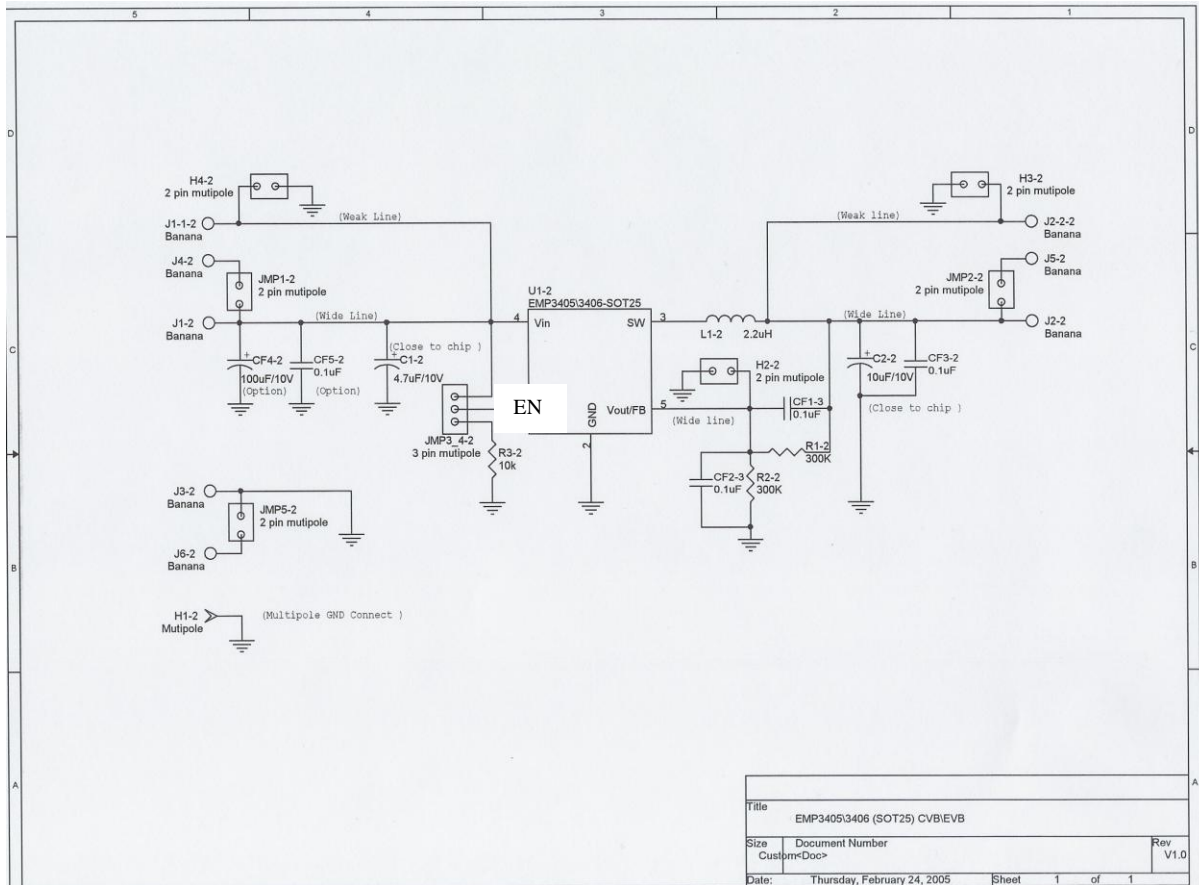
$$L = \frac{1.8V}{1.5MHz \cdot 240mA} \left(1 - \frac{1.8V}{4.2V} \right) = 2.86\mu H$$

A 2.2 μH inductor could be chose with this application.

A greater inductor with less equivalent series

Application (Continued)

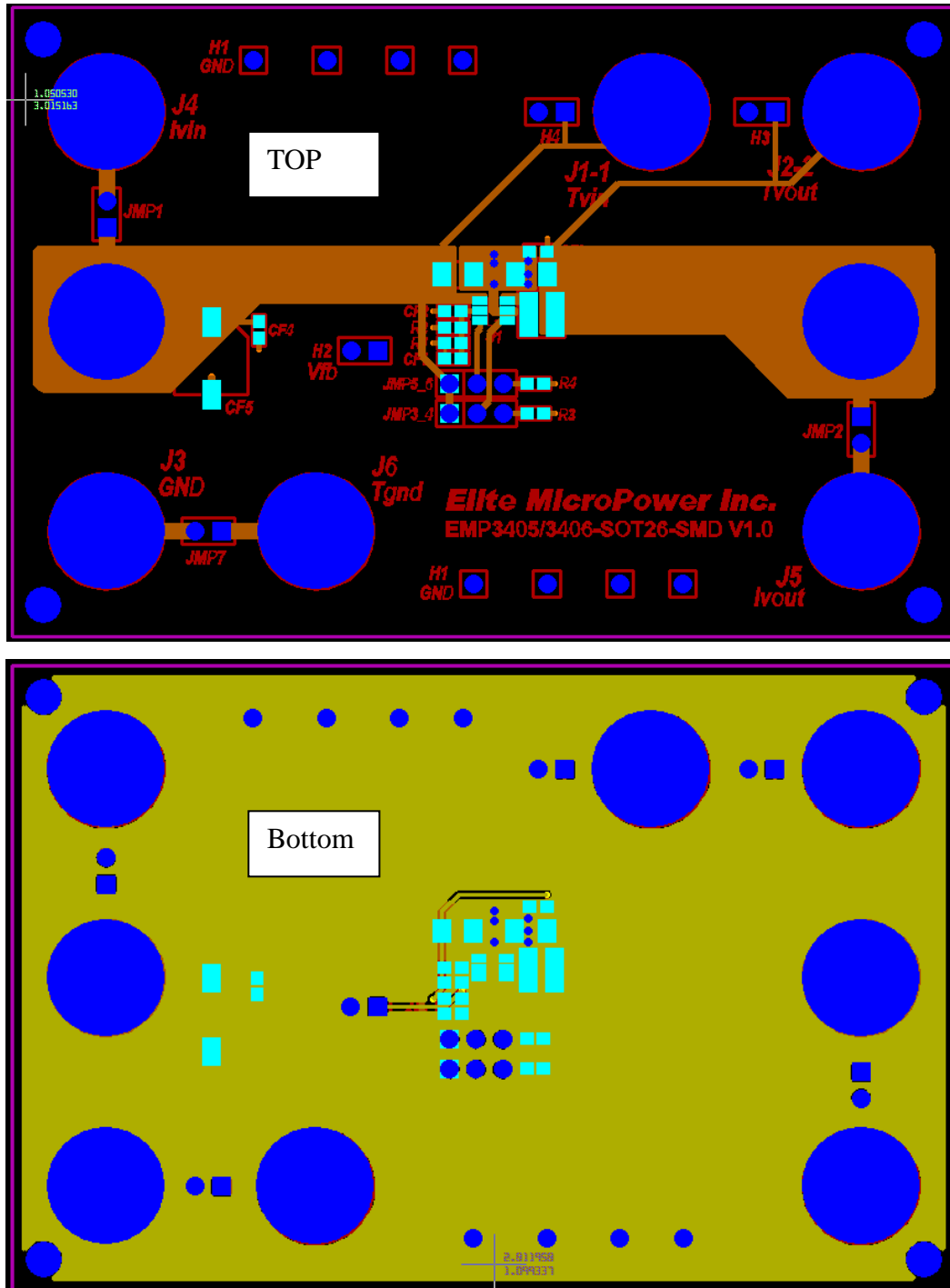
Typical schematic



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EMP3405/3406 (SOT25) CVB/EVB		
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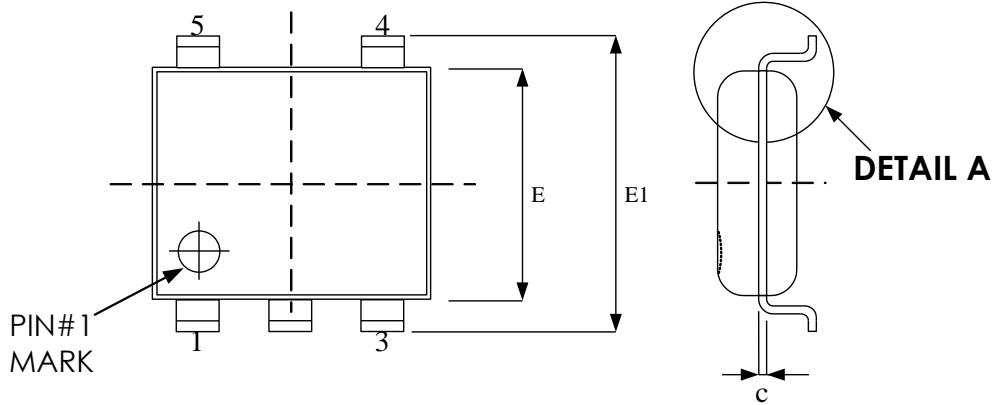
Application (Continued)

Typical PCB layout

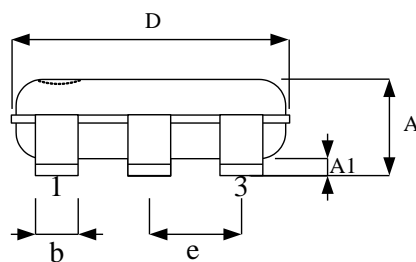


Package Outline Drawing

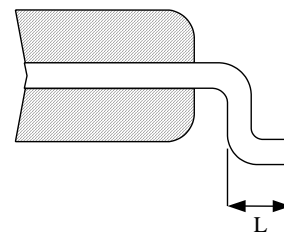
SOT-23-5



TOP VIEW



SIDE VIEW



DETAIL A

Symbol	Dimension in mm	
	Min.	Max.
A	0.90	1.45
A1	0.00	0.15
b	0.30	0.50
c	0.08	0.25
D	2.70	3.10
E	1.40	1.80
E1	2.60	3.00
e	0.95 BSC	
L	0.30	0.60

Revision History

Revision	Date	Description
8.0	2009.03.16	EMP transferred form version 7.3
8.1	2011.01.28	Revise electrical characteristics(VEN)
8.2	2011.03.22	Cancel the max and the min spec of ΔV_{OVL} in electrical characteristics section
8.3	2011.05.23	Revise outline spec in Jedec dimension
8.4	2013.04.16	1) Updated Vin supports to 6.0V. 2) Removed product ID (Adj) for the marking of "A64A". 3) Updated package outline drawing following ESMT standard.

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