1.5MHz 600mA, Synchronous Step-Down Regulator

General Description

EML9366 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. EML9366 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 EML9366 is available in SOT package.

Features

- Achieve 95% efficiency
- Input Voltage : 2.5V to 5.5V
- Output Current up to 600mA
- Reference voltage 0.6V
- Quiescent Current 200 μA with No Load
- Internal switching frequency 1.5MHz
- No Schottky Diode needed
- Low Dropout Operation: 100% Duty Cycle
- Shutdown current < 1 μA
- 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)

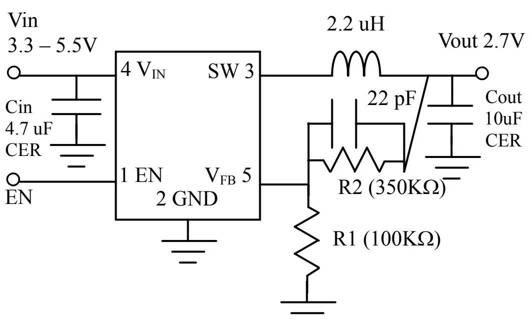


Fig. 1

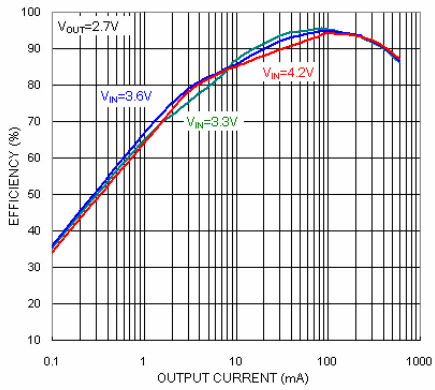
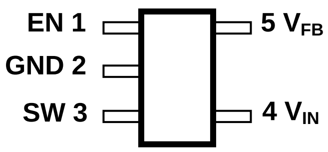


Fig. 2

CONNECTION DIAGRAM

SOT-23-5



ORDER INFORMATION

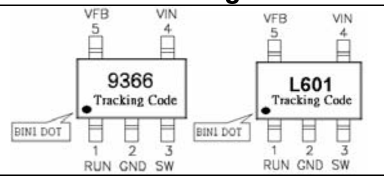
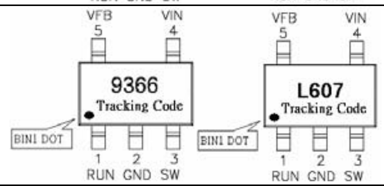
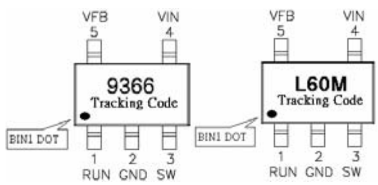
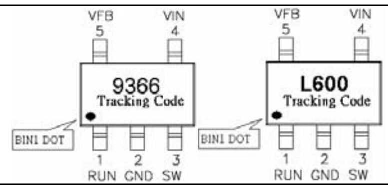
EML9366-XXVF05GRR/NRR

XX Output voltage

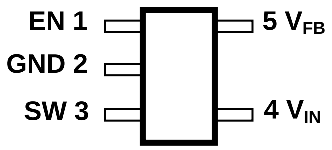
VF05 SOT-23-5Package

GRR RoHS (Pb Free)
Rating: -40 to 85°C
Package in Tape & Reel

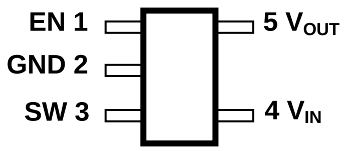
NRR RoHS & Halogen free (By Request)
Rating: -40 to 85°C
Package in Tape & Reel

Package	Vout	Product ID	Marking	Packing
SOT-23-5	1.2	EML9366-12VF05GRR		Tape & Reel 3Kpcs
	1.8	EML9366-18VF05GRR		
	3.3	EML9366-33VF05GRR		
SOT-23-5	adjustable	EML9366-00VF05GRR		

Package configuration



Adjustable
SOT-23-5
T_{JMAX}=125°C, θ_{JA}=250°C, θ_{JC}=90°C /W



Fixed voltage
SOT-23-5
T_{JMAX}=125°C, θ_{JA}=250°C, θ_{JC}=90°C /W

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 and enable the chip after Vin is in the input voltage range.
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 6V
EN, V_{FB} 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
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	$\Delta V_{OVL} = V_{OVL} - V_{FB}$, EML9366		20	50	80	mV
		$\Delta V_{OVL} = V_{OVL} - V_{OUT}$, EML9366-Fixed		2.5	7.8	13	%
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} = 4.2V			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 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

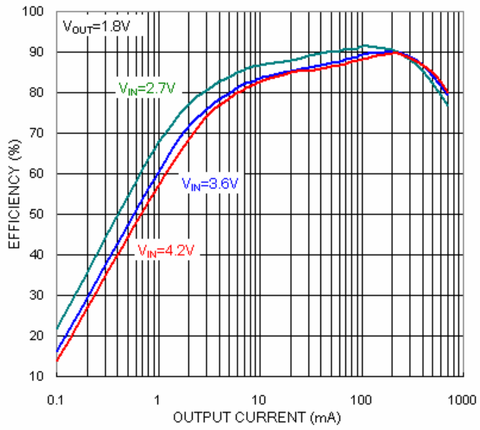
Note 1: T_J is a function of the ambient temperature T_A and power dissipation P_D ($T_J = T_A + (P_D)(250°C/W)$)

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

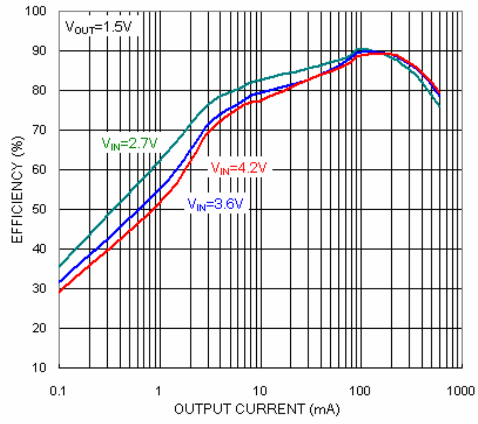
Note 3: This IC is build-in over-temperature protection to avoid damage from overload conditions.

Typical Performance Characteristics

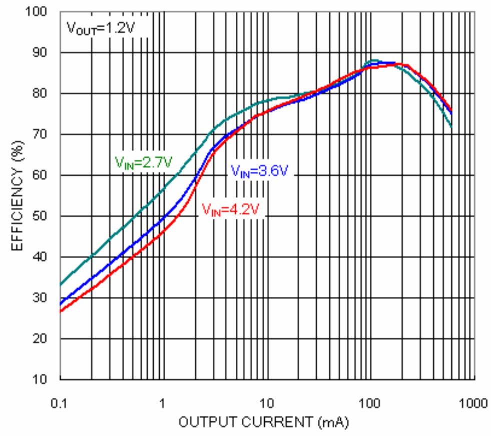
Efficiency vs Output Current



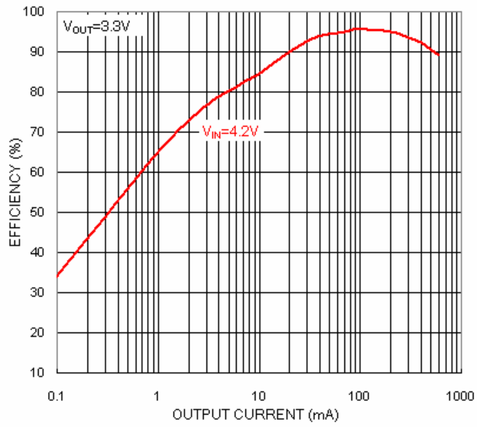
Efficiency vs Output Current



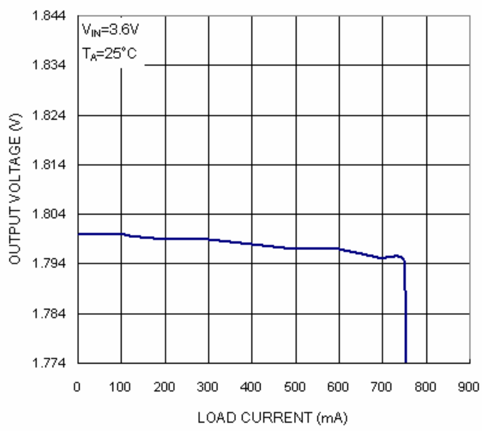
Efficiency vs Output Current



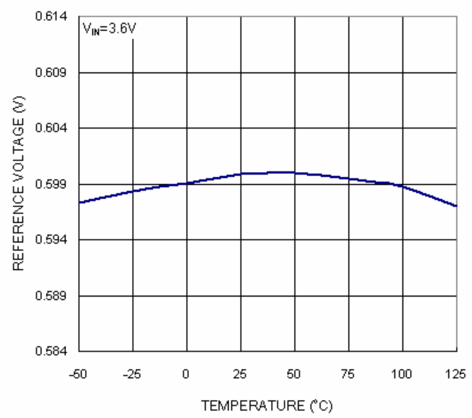
Efficiency vs Output Current



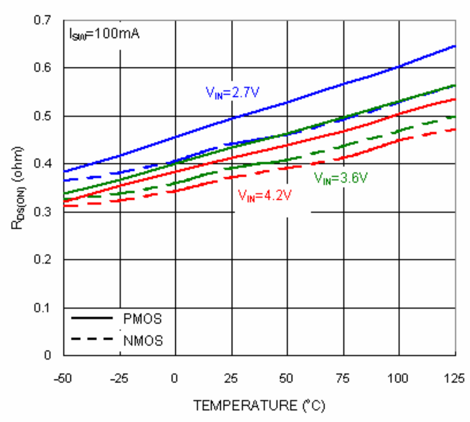
Output Voltage vs Load Current



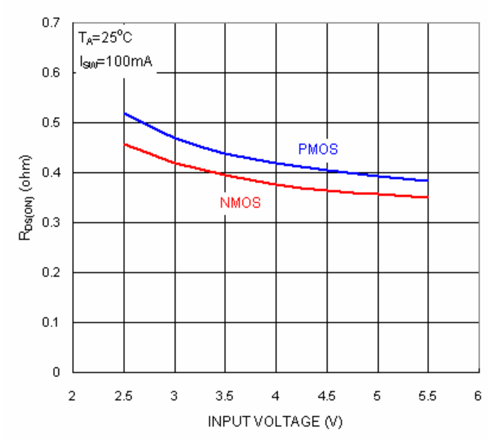
Reference voltage vs Temperature



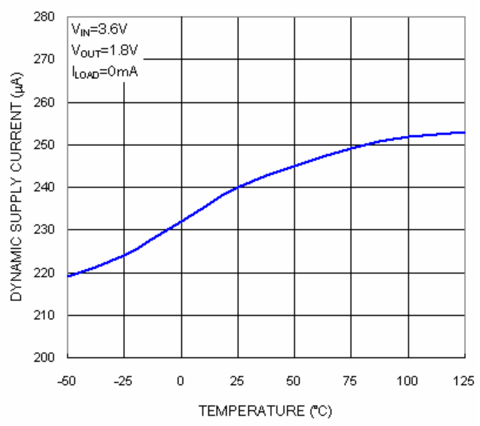
$R_{DS(ON)}$ vs Temperature



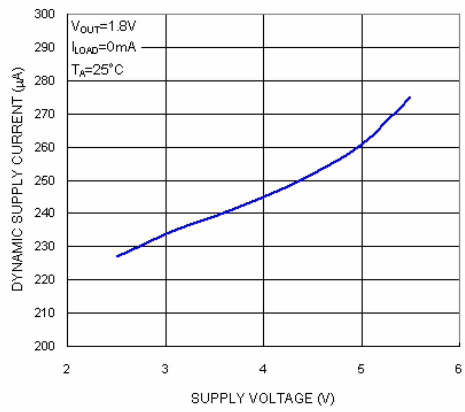
$R_{DS(ON)}$ vs Input Voltage



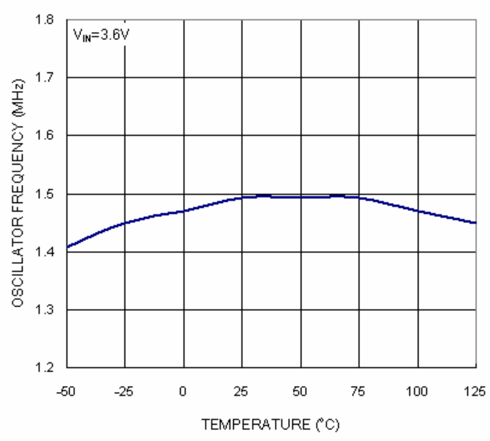
Dynamic Supply Current vs Temperature



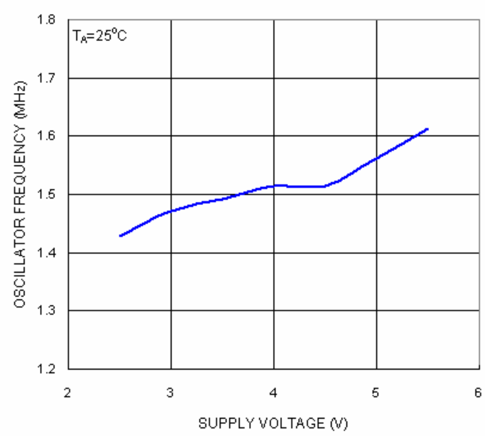
Dynamic Supply Current vs Supply Voltage



Oscillator Frequency vs Temperature

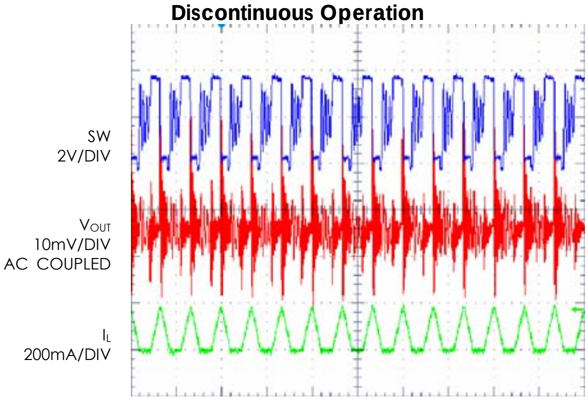


Oscillator Frequency vs Supply Voltage



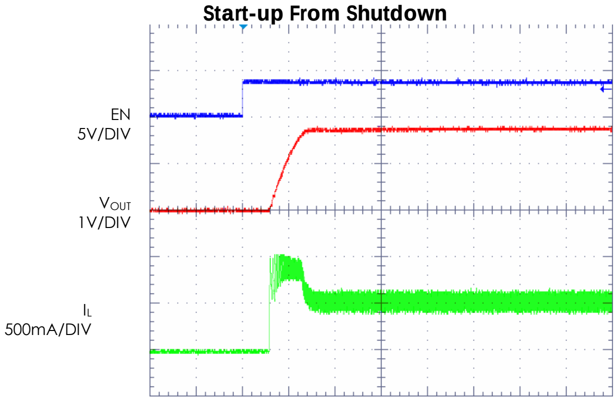
Typical Performance Characteristics

Discontinuous Operation



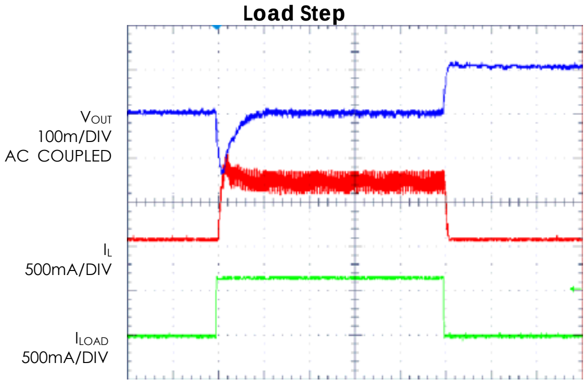
V_{IN}=3.6V 1μs/DIV
V_{OUT}=1.8V
I_{LOAD}=50mA

Start-up From Shutdown



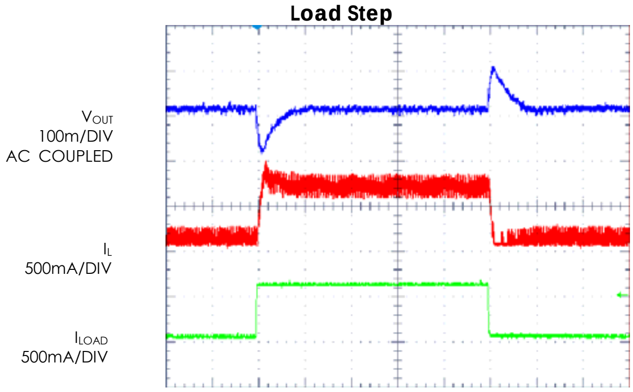
V_{IN}=3.6V 40μs/DIV
V_{OUT}=1.8V
I_{LOAD}=600mA (3Ω RESISTOR)

Load Step



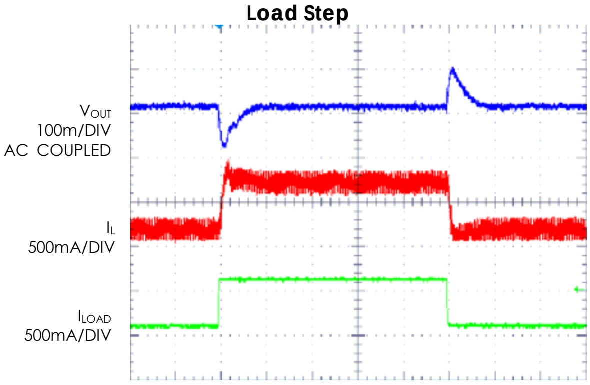
V_{IN}=3.6V 20μs/DIV
V_{OUT}=1.8V
I_{LOAD}=0mA to 600mA

Load Step



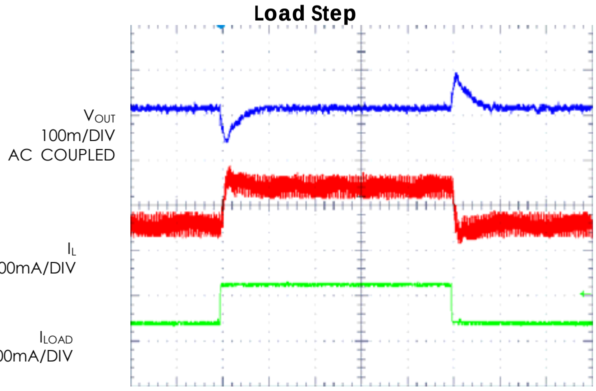
V_{IN}=3.6V 20μs/DIV
V_{OUT}=1.8V
I_{LOAD}=50mA to 600mA

Load Step



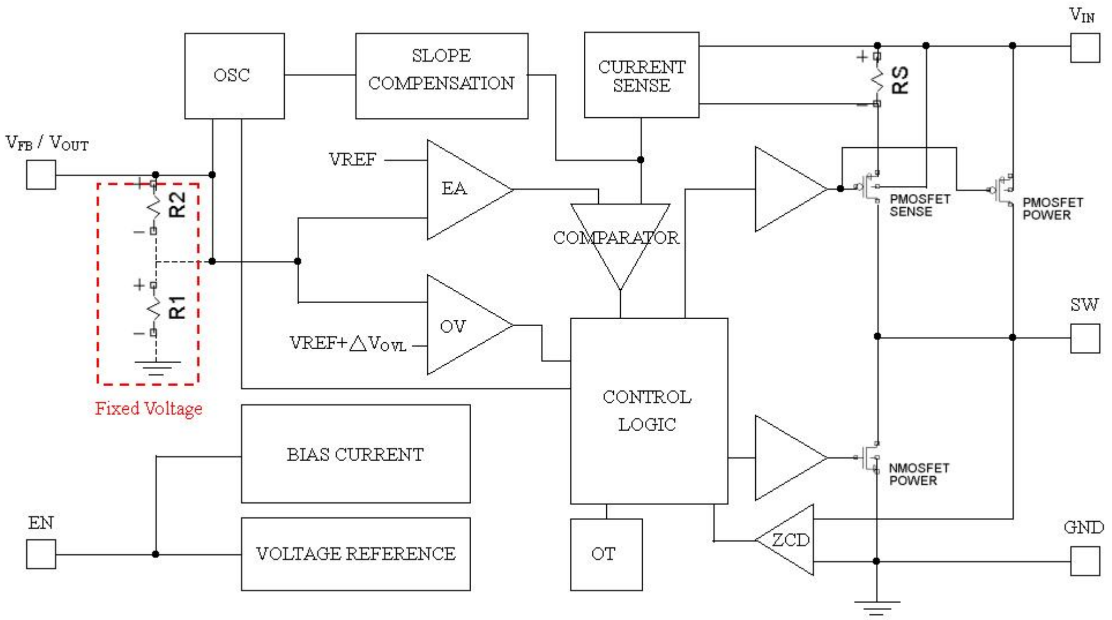
V_{IN}=3.6V 20μs/DIV
V_{OUT}=1.8V
I_{LOAD}=100mA to 600mA

Load Step



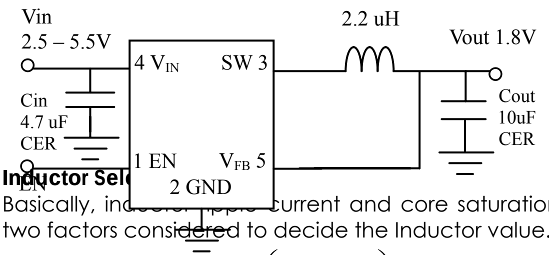
V_{IN}=3.6V 20μs/DIV
V_{OUT}=1.8V
I_{LOAD}=200mA to 600mA

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.

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

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:

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

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

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

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 (EML9366 adjustable)

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

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

Thermal Considerations

Although thermal shutdown is build-in in EML9366 that protect the device from thermal damage, the total power dissipation that EML9366 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 EML9366 from exceeding the maximum junction temperature, the user will need to do some thermal analysis.

Guidelines for PCB Layout

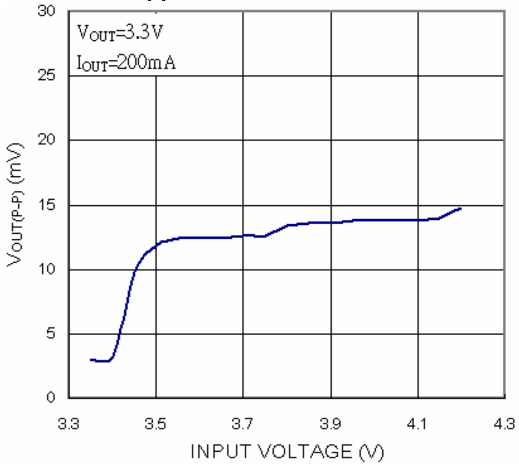
To ensure proper operation of the EML9366, please note the following PCB layout guidelines:
1. The GND trace, the SW trace and the V_{IN} trace should be kept short, direct and wide.
2. V_{FB} pin must be connected directly to the feedback resistors. Resistive divider R_1/R_2 must be connected and parallel to the output capacitor C_{OUT}.
3. The Input capacitor C_{IN} must be connected to pin V_{IN} as closely as possible.
4. Keep SW node away from the sensitive V_{FB} node since this node is with high frequency and voltage swing.
5. Keep the (–) plates of C_{IN} and C_{OUT} as close as possible.

Applications (continued)

Output Voltage Ripple When V_{IN} Closes To V_{OUT}

EML9366 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 EML9366 provides 200mA load current.

V_{OUT} Ripple When V_{IN} Closes To V_{OUT}



Design Example

Assume the EML9366 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, ΔI_L = 240mA and f = 1.5MHz in eq. 1 gives:

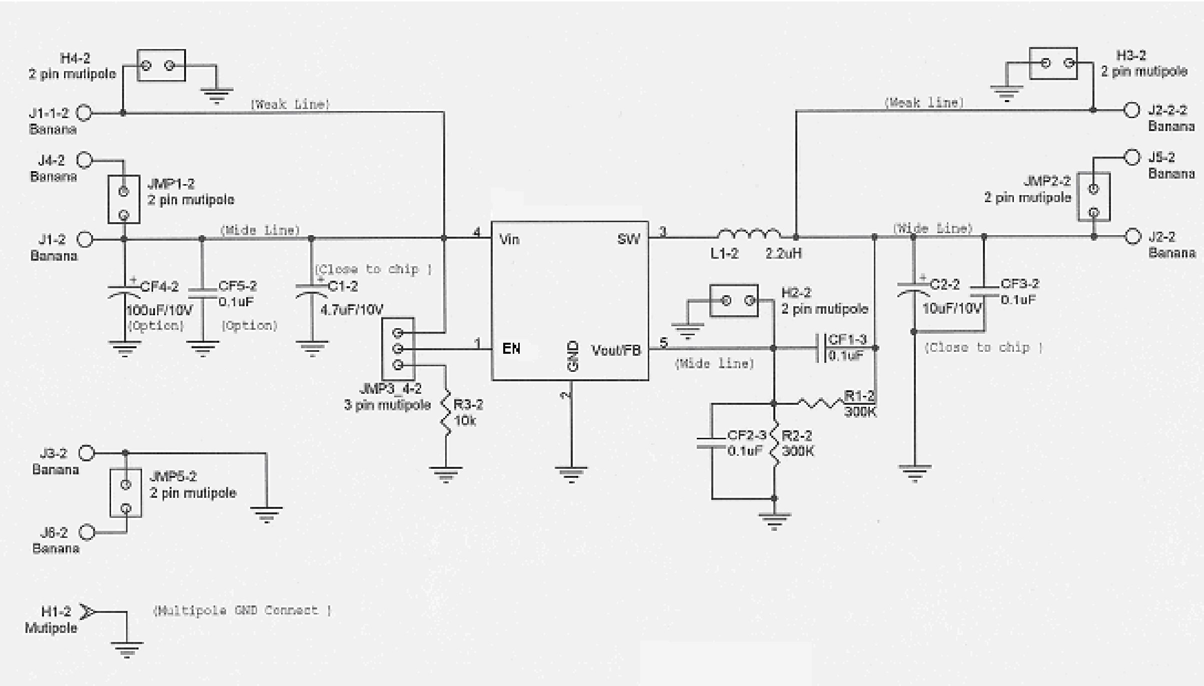
$$L = \frac{1.8V}{1.5MHz \cdot 240mA} \left(1 - \frac{1.8V}{4.2V} \right) = 2.86\mu H$$

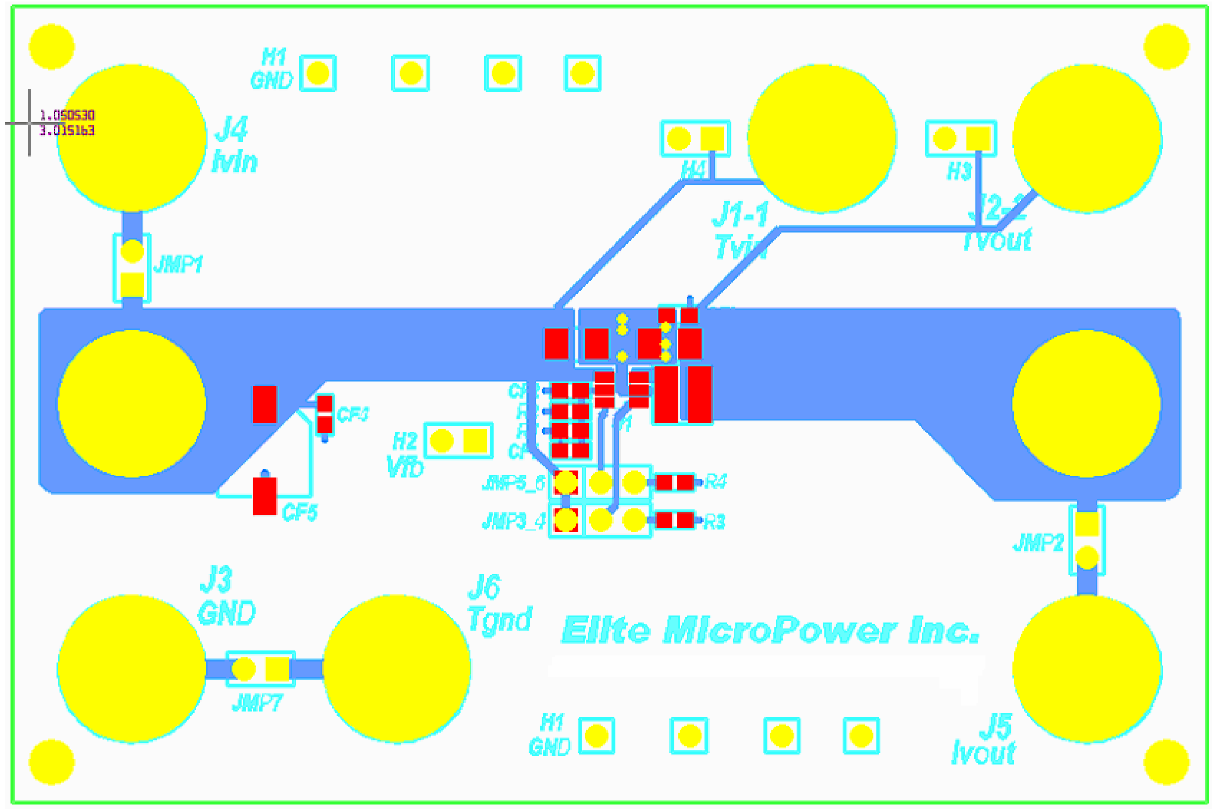
A 2.2µH inductor could be chose with this application.

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.

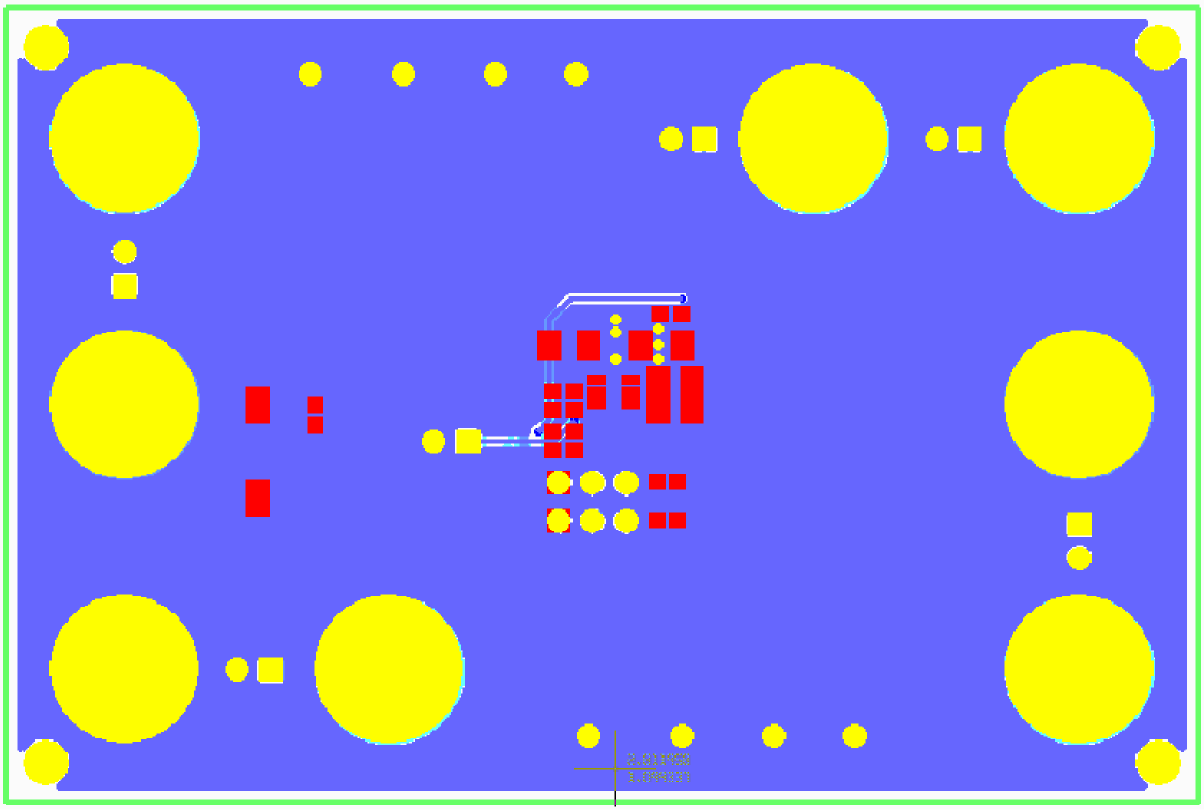
Application (Continued)

Typical schematic for PCB layout



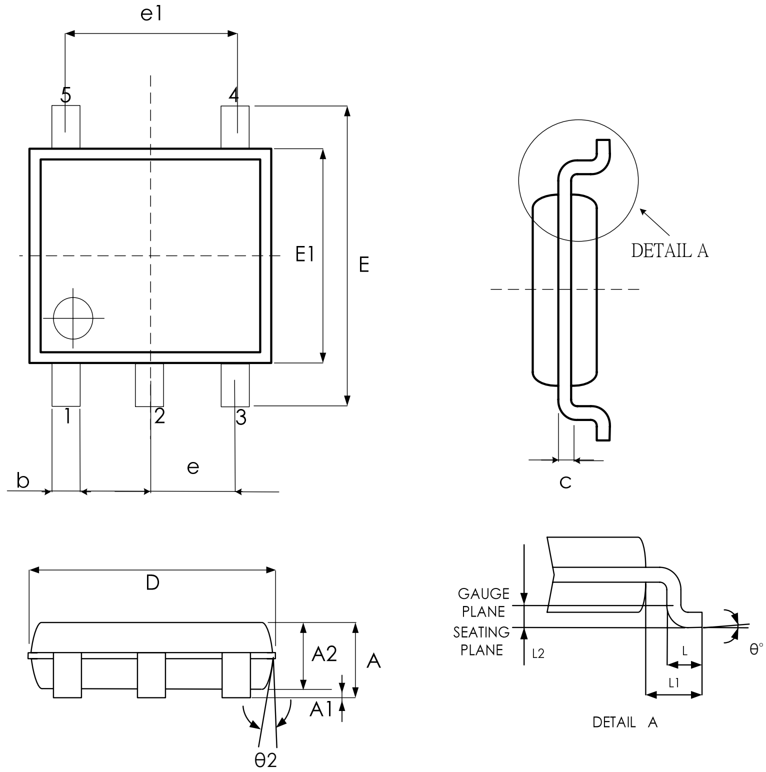


1.050530
3.015163
H1
GND
J4
Ivin
H4
H3
J1-1
Tvin
J2-2
Tvout
JMP1
CF3
H2
Vfb
JMP5_6
JMP3_4
R4
R3
CF5
JMP2
J3
GND
J6
Tgnd
Elite MicroPower Inc.
JMP7
H1
GND
J5
Ivout



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

Revision History

Revision	Date	Description
2.0	2009.06.09	EMP transferred from version 1.1
2.1	2011.01.28	Revise electrical characteristics (VEN)

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