1.3MHz 1.5A, Synchronous Step-Down Regulator

General Description

EML3416 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 1.5A output current capability. High 1.3MHz 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. EML3416 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 TDFN-8 package.

Features

- Achieve 95% efficiency
- Input Voltage : 2.5V to 5.5V
- Output Current up to 1.5A
- Reference voltage 0.6V
- Quiescent Current 240 μA with No Switching
- Internal switching frequency 1.3MHz
- No Schottky Diode needed
- Low Dropout Operation: 100% Duty Cycle
- Shutdown current < 1 μA
- Excellent Line and Load Transient Response
- Over-current and 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)

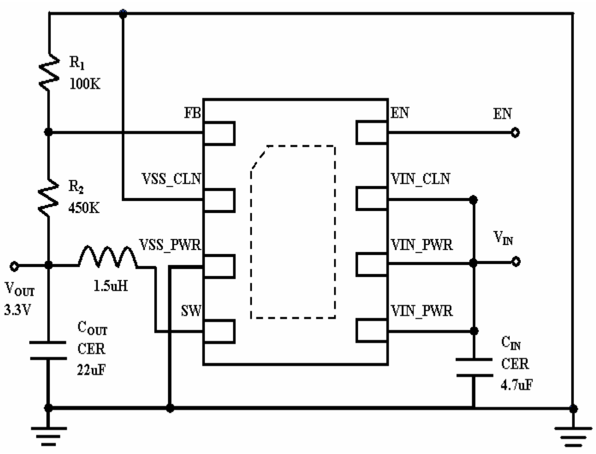


Fig. 1

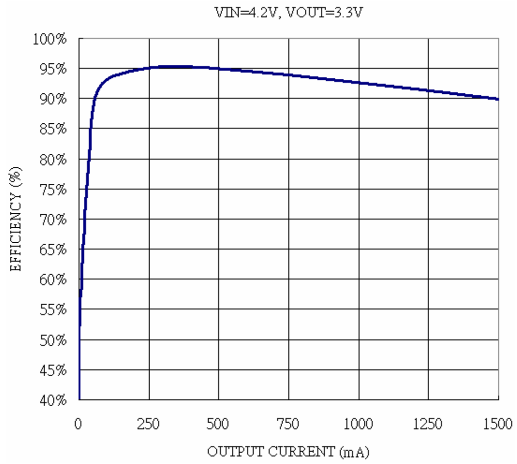
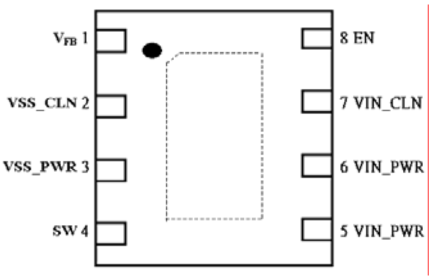


Fig. 2

Connection Diagram

TDFN-8 Package

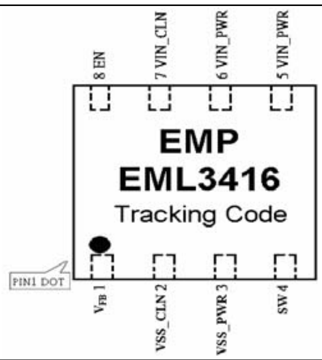


Order information

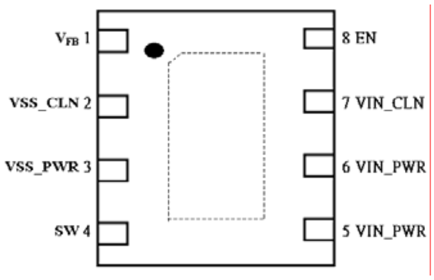
EML3416-00FF08NRR

50	5.0V Operation
FF08	TDFN-8 Package
NRR	Green (RoHS & Halogen Free) Commercial Grade Temperature Rating: -40 to 85°C Package in Tape & Reel

Order, Marking & Packing Information

Product ID	Package	Vout (V)	Marking	Packing
EML3416-00FF08NRR	**TDFN-8**	**adjustable**		**5Kpcs** **Tape & Reel**

Package configuration



Pin Functions

Pin #	Pin Name	Function
1	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.
2	VSS_CLN	Analog Ground Pin.
3	VSS_PWR	Power Ground Pin.
4	SW	Switch Pin. Must be connected to Inductor. This pin connects to the drains of the internal main and synchronous power MOSFET switches.
5, 6	V_{IN_PWR}	Power Input Pin. Must be closely decoupled to GND pin with a 4.7μF or greater ceramic capacitor.
7	V_{IN_CLN}	Analog Input Pin. Must be closely decoupled to GND pin with a 4.7μF or greater ceramic capacitor.
8	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.
Exposed pad		Connect to Ground.

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) ------------------------ 2A
NMOS Switch Sink Current (DC) ---------------------------- 2A
Peak Switch Sink and Source Current ---------------- 3.5A

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, 5 sec)----------------- 260°C
ESD Susceptibility HBM -------------------------------------- 2KV
MM ------------------------------------ 200V

Thermal data

Thermal resistance	Parameter	Value
θ_{JA}	Junction-ambient	55°C/W
θ_{JC}	Junction-case	10°C/W

Electrical Characteristics

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are T_A = 25°C. V_{IN} = 5V unless otherwise specified.

Symbol	Parameter	Conditions		Min	Typ	Max	Units
I_{VFB}	Feedback Current					±100	nA
V_{FB}	Regulated Feedback Voltage	T_A = 25°C		0.588	0.6	0.612	V
		–40°C ≤ T_A ≤ 85°C	●	0.585	0.6	0.615	
V_{OUT}%	Output Voltage Accuracy		●	-3		3	%
ΔV_{FB}	Reference Voltage Line Regulation	V_{IN} = 2.5V to 5.5V	●			0.4	%/V
ΔV_{OVL}	Output Over-voltage Lockout	$\Delta V_{OVL} = V_{OVL} - V_{FB}$, EML3416		20	50	80	mV
		$\Delta V_{OVL} = V_{OVL} - V_{OUT}$, EML3416-Fixed		2.5	7.8	13	%
ΔV_{OUT}	Output Voltage Line Regulation	V_{IN} = 2.5V to 5.5V	●		0.2	0.4	%/V
I_{PK}	Peak Inductor Current	V_{IN} = 3V, V_{FB} = 0.5V or V_{OUT} = 90%, Duty Cycle < 35%			2.4		A
$V_{LOADREG}$	Output Voltage Load Regulation	I_{OUT}=10mA to 1.5A			0.2		%/A
I_S	Quiescent Current (Note 2)	V_{FB} = 0.5V or V_{OUT} = 90%			240	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%	●	1.04	1.30	1.56	MHz
R_{PFET}	$R_{DS(ON)}$ of PMOS	I_{SW} = 750mA			0.18		Ω
R_{NFET}	$R_{DS(ON)}$ of NMOS	I_{SW} = –750mA			0.16		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

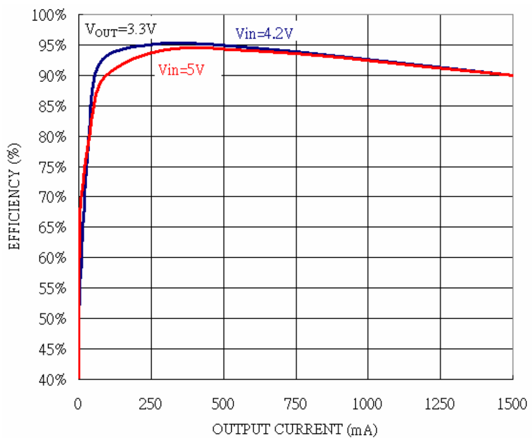
Note 1: T_J is a function of the ambient temperature T_A and power dissipation P_D ($T_J = T_A + (P_D)(55°C/W)$)

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

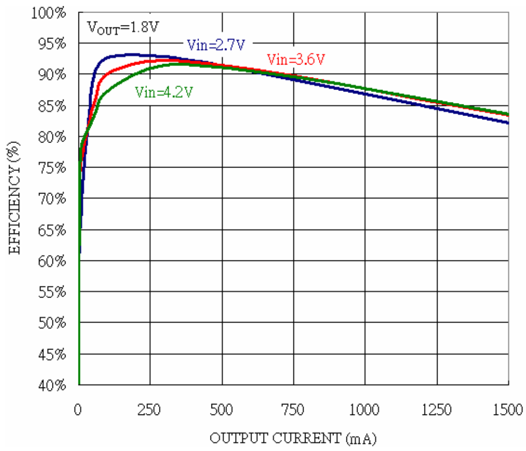
Note 3: This IC is build-in over-temperature protection to avoid damage from overload conditions.

Typical Performance Characteristics

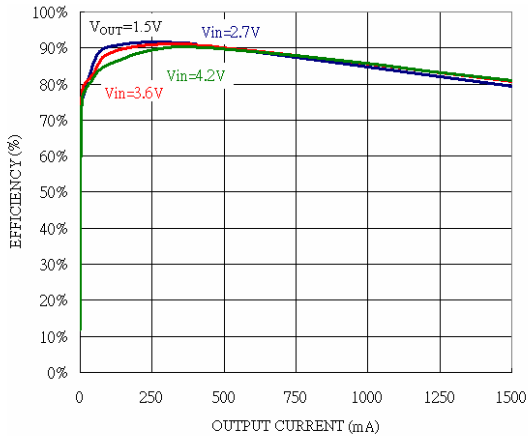
Efficiency vs Output Current



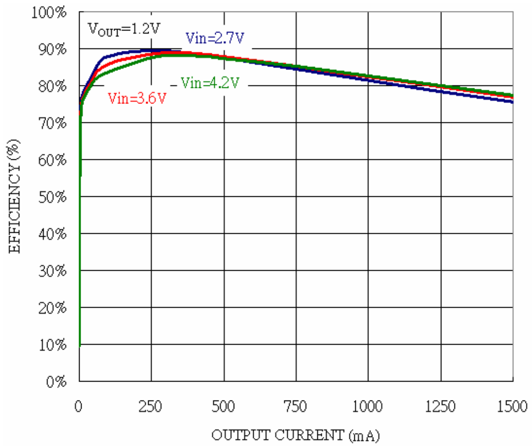
Efficiency vs Output Current



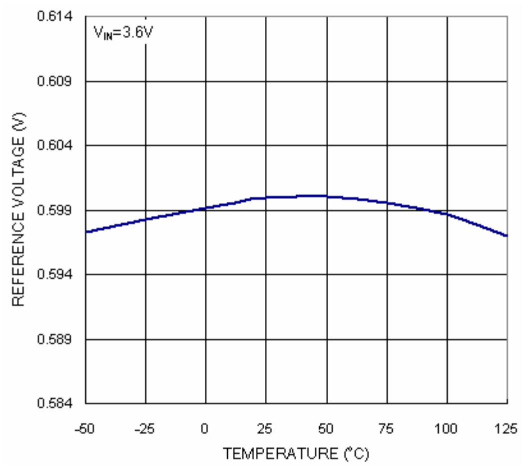
Efficiency vs Output Current



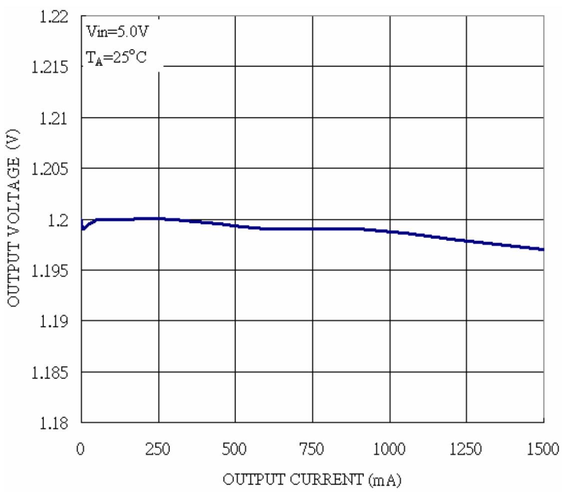
Efficiency vs Output Current



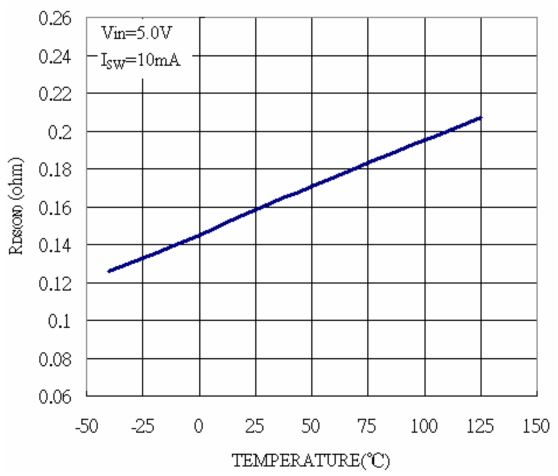
Reference voltage vs Temperature



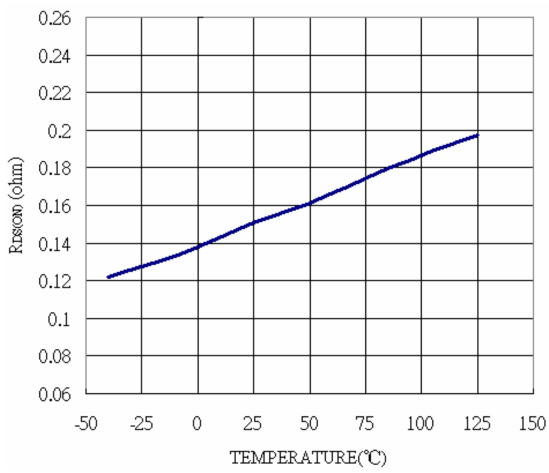
Output Voltage vs Load Current



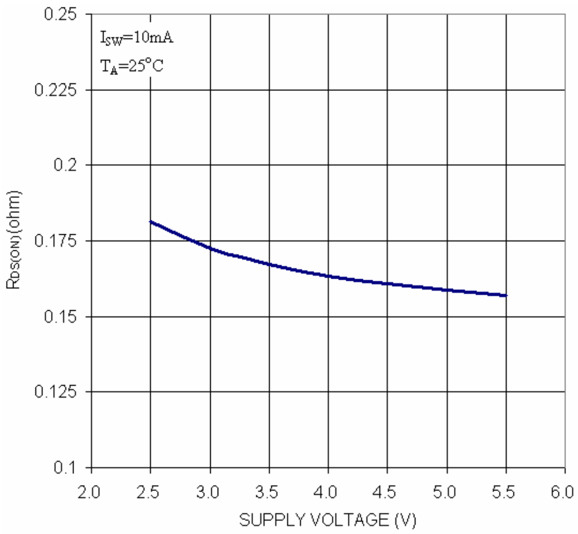
PMOS $R_{DS(ON)}$ vs Temperature



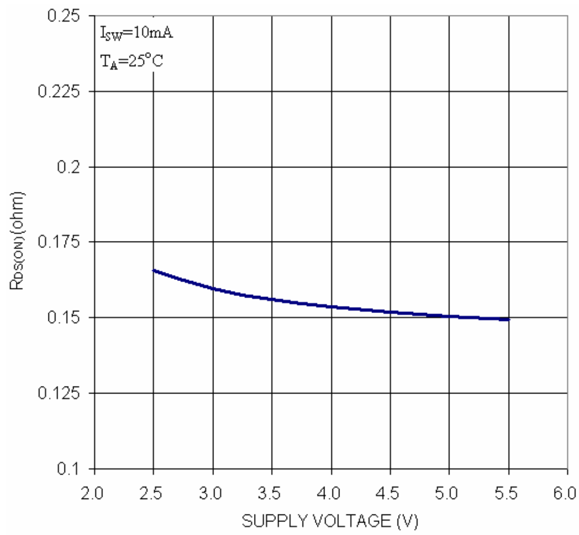
NMOS $R_{DS(ON)}$ vs Temperature



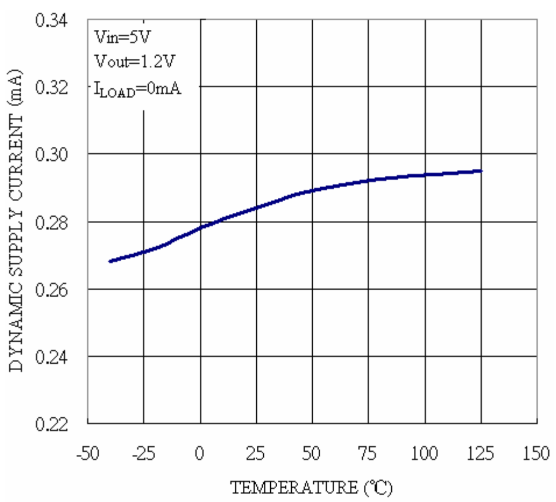
PMOS $R_{DS(ON)}$ vs Supply Voltage



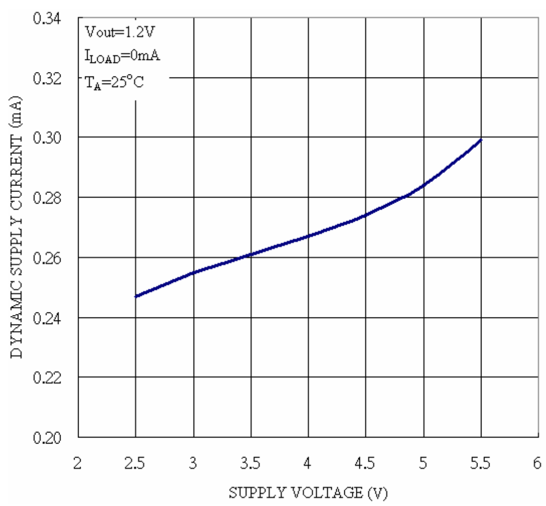
NMOS $R_{DS(ON)}$ vs Supply Voltage



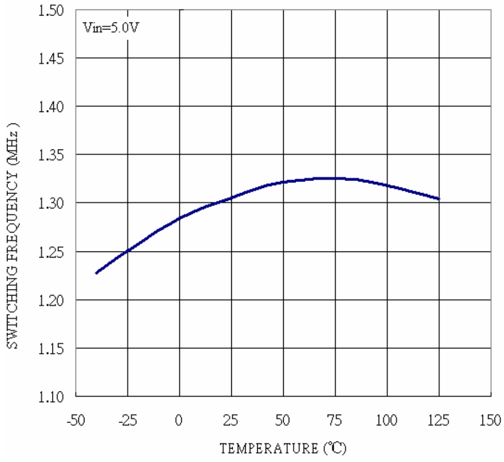
Dynamic Supply Current vs Temperature



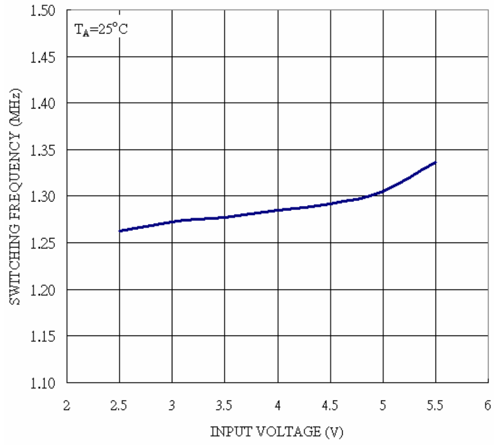
Dynamic Supply Current vs Supply Voltage



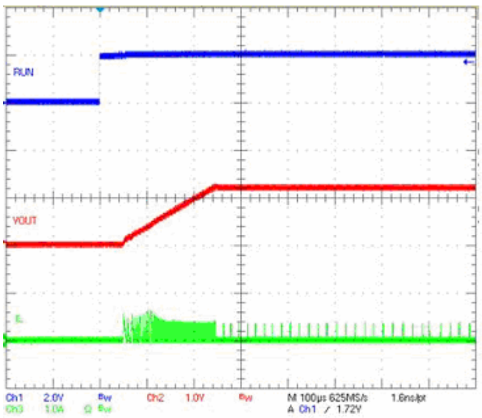
Switching Frequency vs Temperature



Switching Frequency vs Supply Voltage



Start-up From Shutdown



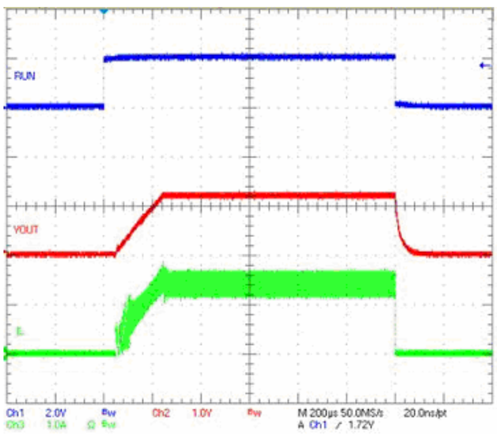
EN
2V/DIV

V_{OUT}
1V/DIV

I_L
1A/DIV

V_{IN}=5V
V_{OUT}=1.2V
I_{LOAD}=10mA
(120Ω R)

Start-up From Shutdown



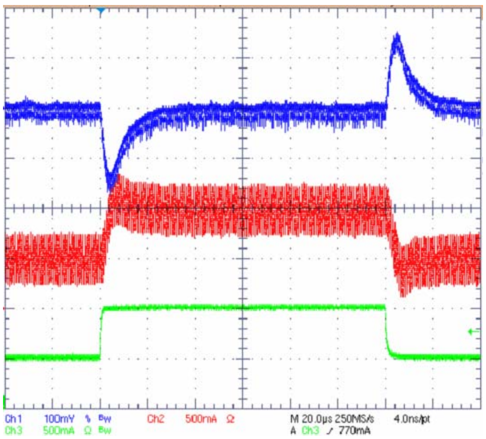
EN
2V/DIV

V_{OUT}
1V/DIV

I_L
1A/DIV

V_{IN}=5V
V_{OUT}=1.2V
I_{LOAD}=1.5A
(0.8Ω R)

Load Step



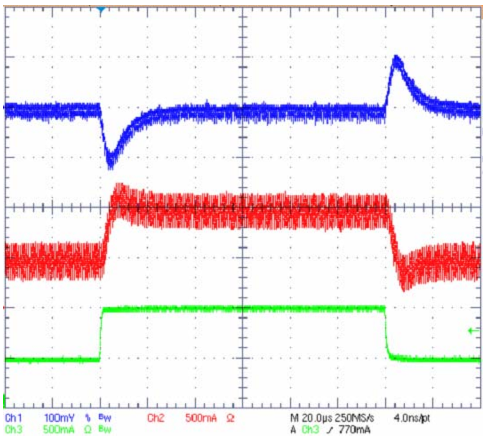
V_{OUT}
100mV/DIV
AC COUPLED

I_L
500mA/DIV

I_{LOAD}
500mA/DIV

V_{IN}=5.0V, V_{OUT}=2.5V, I_{LOAD}=500mA to 1A

Load Step



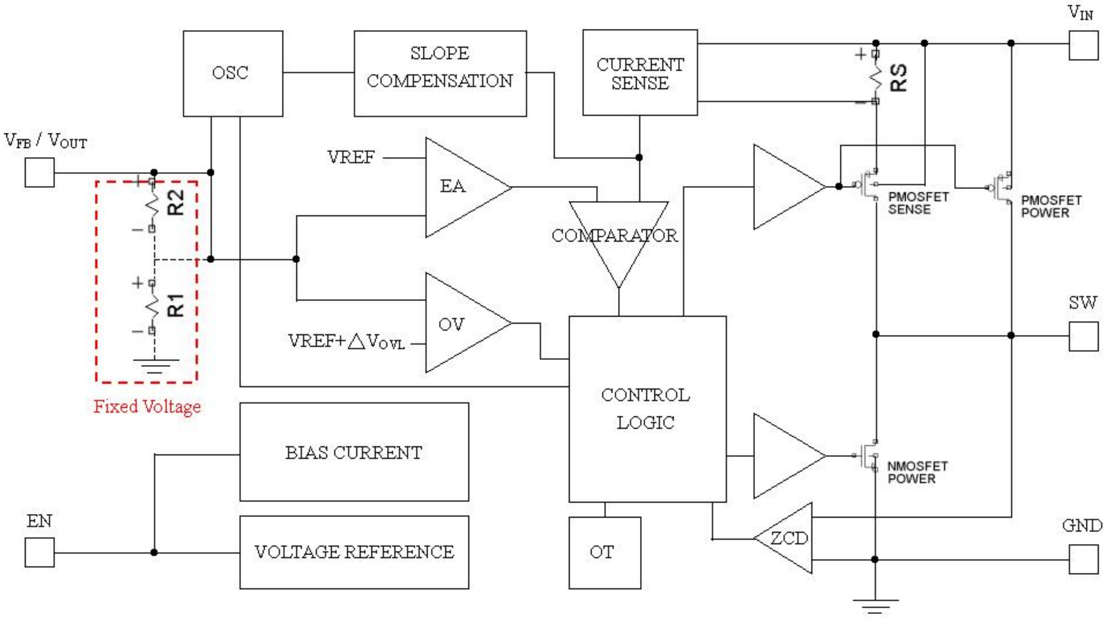
V_{OUT}
100mV/DIV
AC COUPLED

I_L
500mA/DIV

I_{LOAD}
500mA/DIV

V_{IN}=3.3V, V_{OUT}=1.5V, I_{LOAD}=500mA to 1A

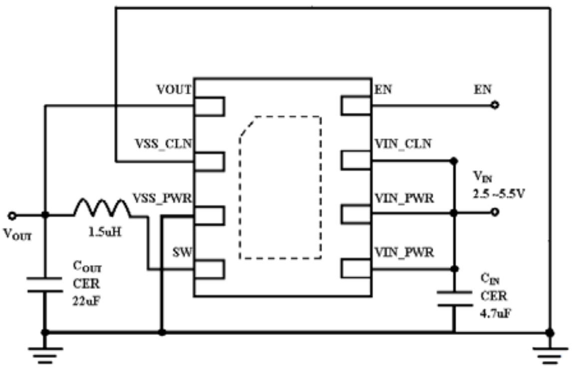
Functional Block Diagram



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 current 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:

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

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 (EML3416 adjustable)

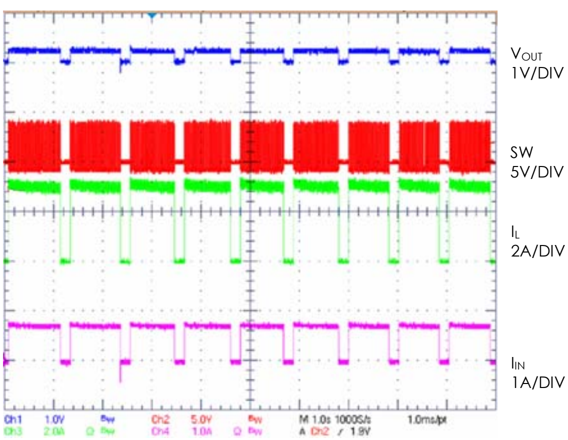
In the adjustable version, the output voltage can be determined by:

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

Short Circuit Behavior

EML3416 has over-current and over-temperature protection. Over-current protection cycle by cycle limits P-driver FET current to prevent inductor current from losing control. Over-temperature protection function turns off driver FETs when junction temperature is high and recovers to normal operation after it is cool enough. When EML3416 is used to transfer Vin=5V to Vout=1.2V, shorting Vout to ground makes over-current and over-temperature protection active. The waveform is shown as the following diagram.

Short Circuit Response



Thermal Considerations

Although thermal shutdown is build-in in EML3416 that protect the device from thermal damage, the total power dissipation that EML3416 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 EML3416 from exceeding the maximum junction temperature, the user will need to do some thermal analysis.

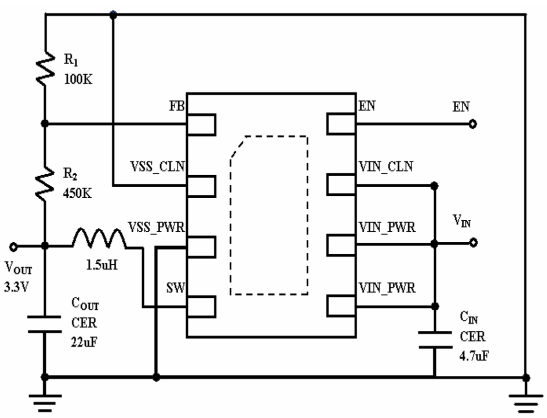
Guidelines for PCB Layout

To ensure proper operation of the EML3416, 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.
6. Connect all analog grounds to a common node and connect the common node to power ground through an independent path.

Self-Enable Application

A self-enable function could be used when EML3416 is connected as the following diagram:

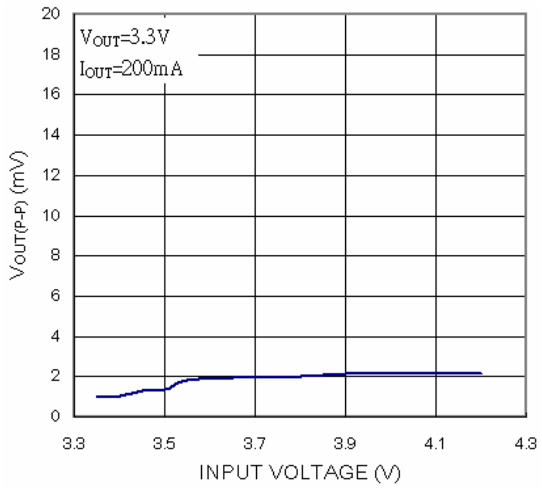


The resistor ratio R3:R4=1:1.5 is recommended.

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

EML3416 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 EML3416 provides 200mA load current.

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



Design Example

Assume the EML3416 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 = 600mA and f = 1.3MHz in eq. 1 gives:

$$L = \frac{1.8V}{1.3MHz \cdot 600mA} \left(1 - \frac{1.8V}{4.2V} \right) = 1.32uH$$

A 1.5μH 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.

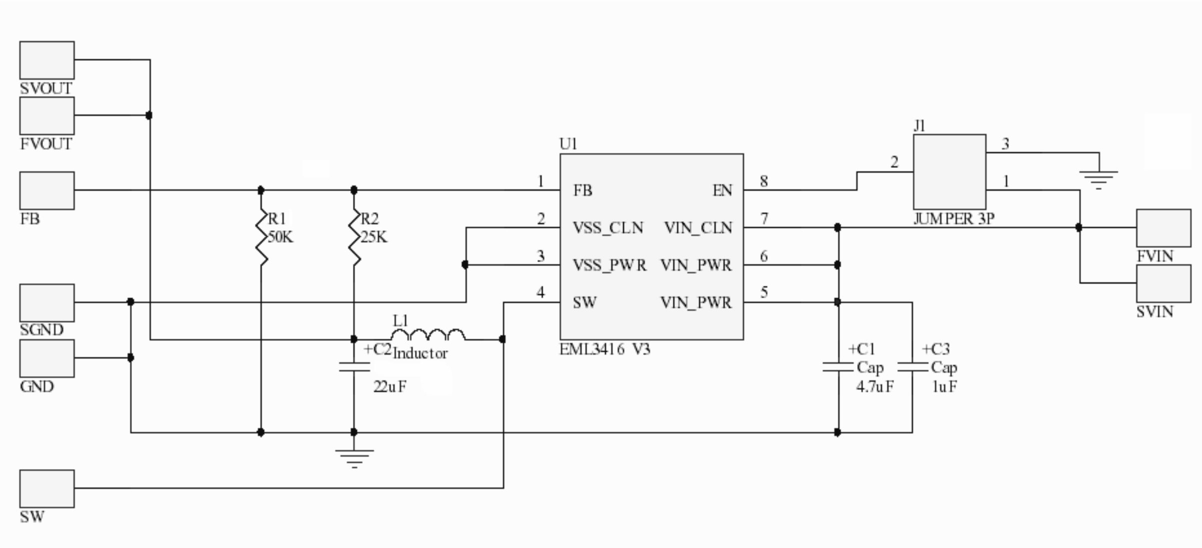
Recommended Components

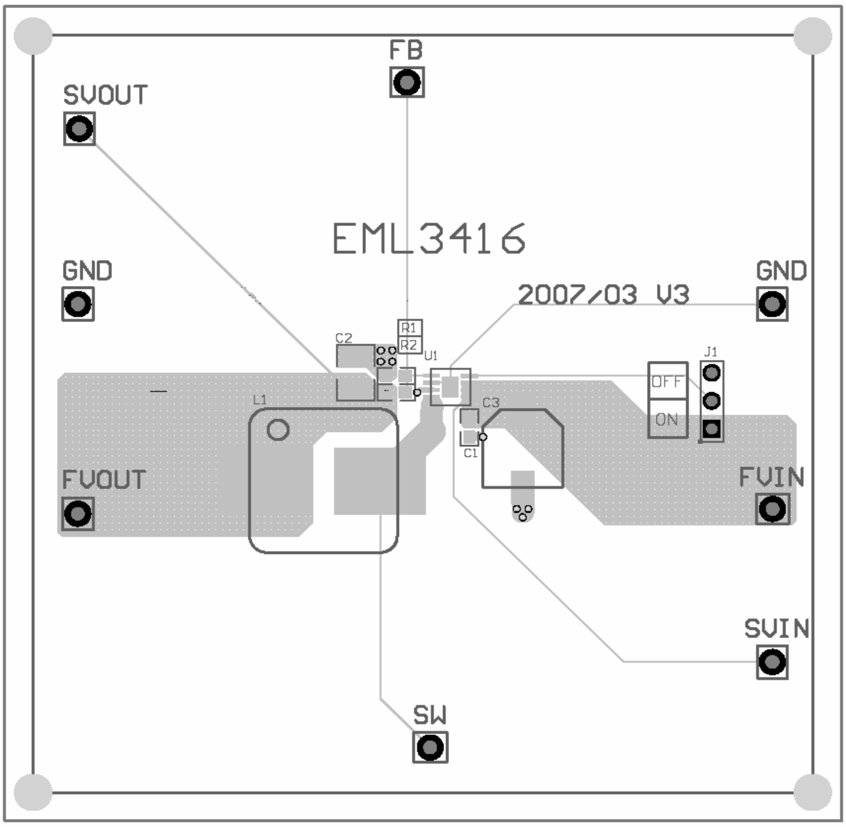
Supplier	Inductance (uH)	I_{sat} (A)	DCR_{max} (mΩ)	Dimensions (mm)	Part Number
Coilcraft	1.5	14	13	12.3 x 12.3 x 6	MSS1260-152NLB

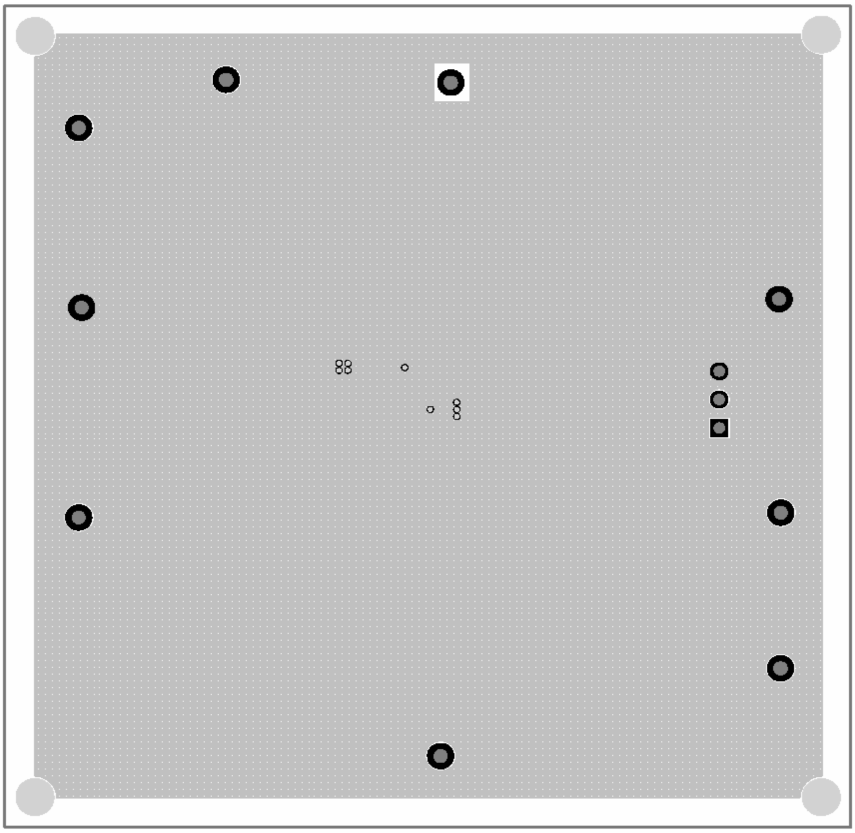
Supplier	Capacitance (uF)	Package	Part Number
YAGEO	4.7	0805	CC0805KKX5R6BB475
TAIYO YUDEN	22	1812	EMK432BJ226KM-T

Application (Continued)

Typical schematic for PCB layout

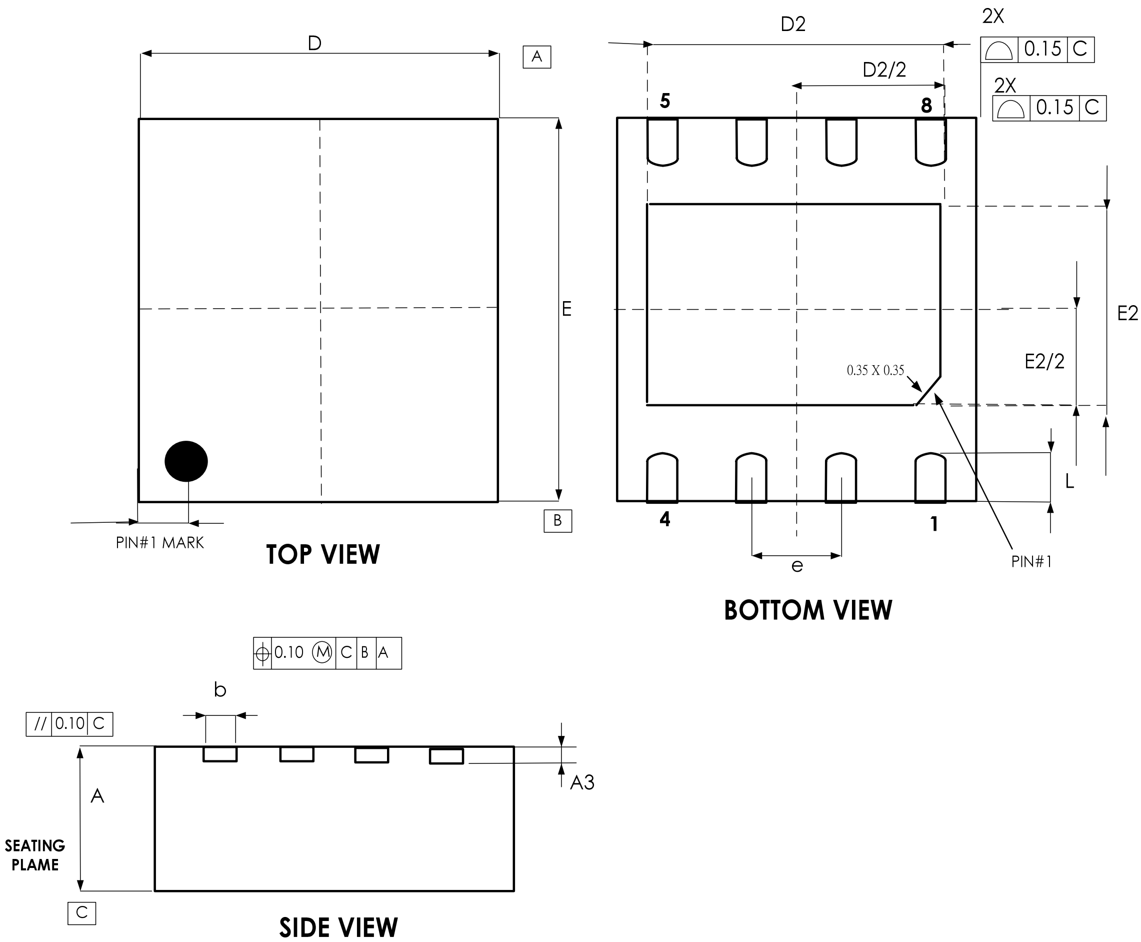






Package Information

TDFN-8



SYMBOL	COMMON					
	DIMENSIONS MILLIMETER			DIMENSIONS INCH		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.70	0.75	0.80	0.028	0.030	0.031
A3	0.203 BSC			0.008 BSC		
b	0.25	0.30	0.35	0.010	0.012	0.014
D	3.00 BSC			0.118BSC		
D2	1.60	-	2.50	0.063	-	0.098
E	3.00 BSC			0.118BSC		
E2	1.35	-	1.75	0.053	-	0.069
e	0.650 BSC			0.026 BSC		
L	0.30	0.40	0.50	0.012	0.016	0.020

Revision History

Revision	Date	Description
7.0	2009.03.18	EMP transferred from version 6.4
7.1	2010.06.02	To revise circuitry
7.2	2010.09.30	Package dimension update
7.3	2011.01.28	Revise electrical characteristics(VEN)

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