

## 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 240μ A with No Switching
- Internal switching frequency 1.3MHz
- No Schottky Diode needed
- Low Dropout Operation: 100% Duty Cycle
- Shutdown current < 1μ A
- 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)

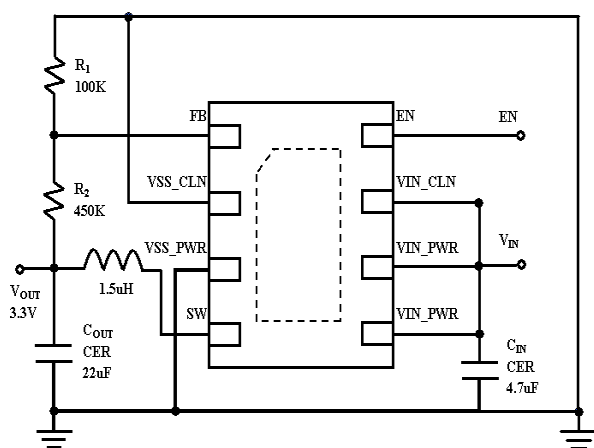


Fig. 1

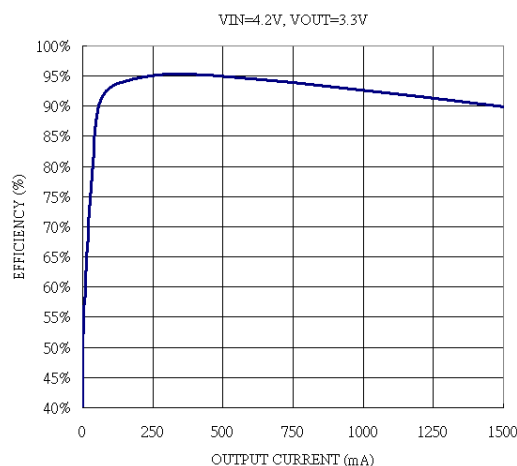
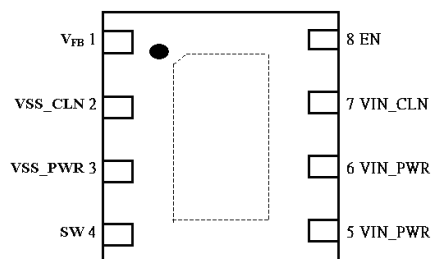


Fig. 2

## Connection Diagram

### TDFN-8 Package



## Order information

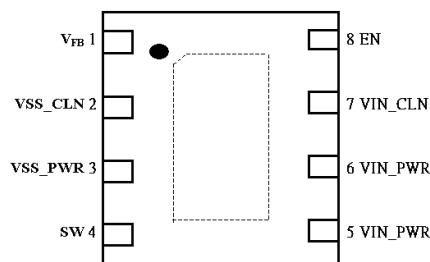
EML3416-00FF08NRR

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	<p>The marking diagram shows the chip layout with pins 1 through 8 labeled. The text on the chip reads: ESMT, EML3416, and Tracking Code. A 'FINI DOT' is indicated at pin 1.</p>	5Kpcs Tape & Reel

## Package configuration



## Pin Functions

Pin #	Pin Name	Function
1	<b>V<sub>FB</sub></b> (Adjustable)	Feedback Pin. Receives the feedback voltage from an external resistive divider across the output.
	<b>V<sub>OUT</sub></b> (Fixed voltage)	Output Voltage Pin. An internal resistive divider divides the output voltage down for comparison to the internal reference voltage.
2	<b>VSS_CLN</b>	Analog Ground Pin.
3	<b>VSS_PWR</b>	Power Ground Pin.
4	<b>SW</b>	Switch Pin. Must be connected to Inductor. This pin connects to the drains of the internal main and synchronous power MOSFET switches.
5, 6	<b>V<sub>IN_PWR</sub></b>	Power Input Pin. Must be closely decoupled to GND pin with a 4.7μF or greater ceramic capacitor.
7	<b>V<sub>IN_CLN</sub></b>	Analog Input Pin. Must be closely decoupled to GND pin with a 4.7μF or greater ceramic capacitor.
8	<b>EN</b>	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.
<b>Exposed pad</b>		Connect to Ground.

## Absolute Maximum Ratings

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

Input Voltage -----	-0.3V to 6V	Operating Temperature Range -----	-40°C to 85°C
EN, V <sub>FB</sub> Voltages -----	-0.3V to V <sub>IN</sub>	Junction Temperature (Notes 1, 3) -----	125°C
SW Voltage -----	-0.3V to (V <sub>IN</sub> + 0.3V)	Storage Temperature Range -----	-65°C to 150°C
PMOS Switch Source Current (DC) -----	2A	Lead Temperature (Soldering, 5 sec)-----	260°C
NMOS Switch Sink Current (DC) -----	2A	ESD Susceptibility HBM -----	2KV
Peak Switch Sink and Source Current -----	3.5A	MM -----	200V

## Thermal data

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

## Electrical Characteristics

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are T<sub>A</sub> = 25°C. V<sub>IN</sub> = 5V unless otherwise specified.

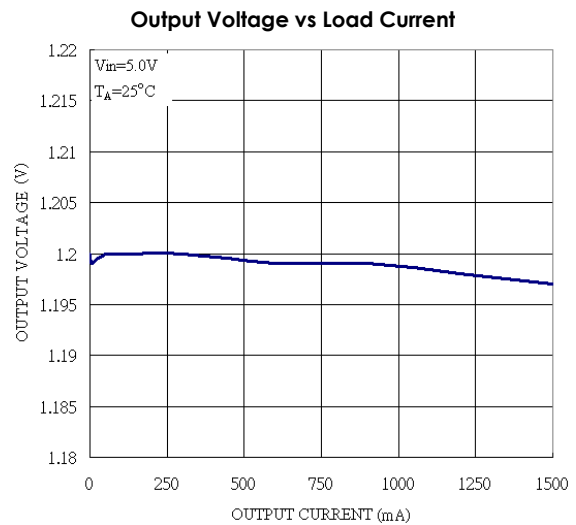
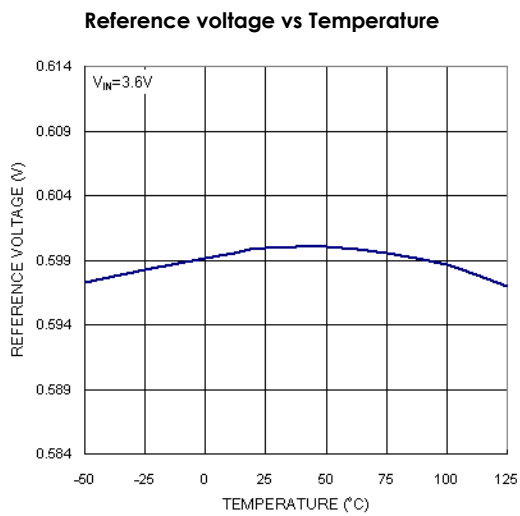
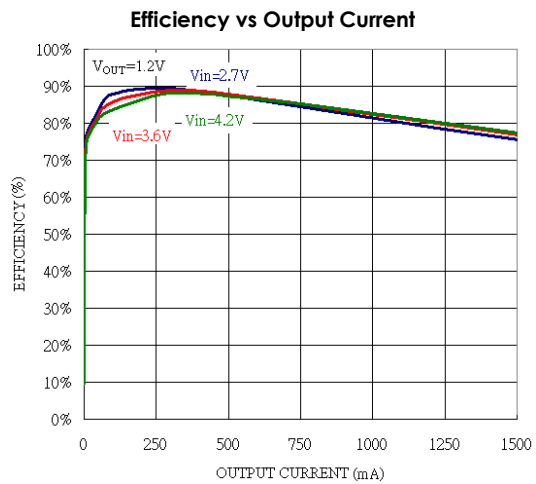
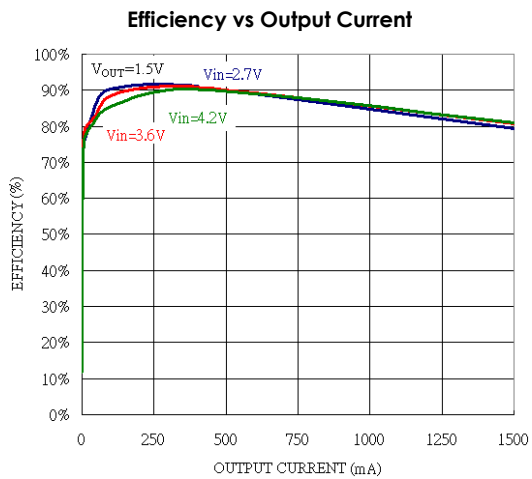
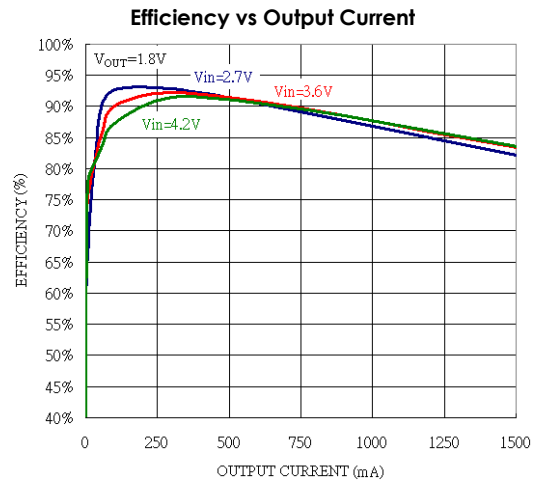
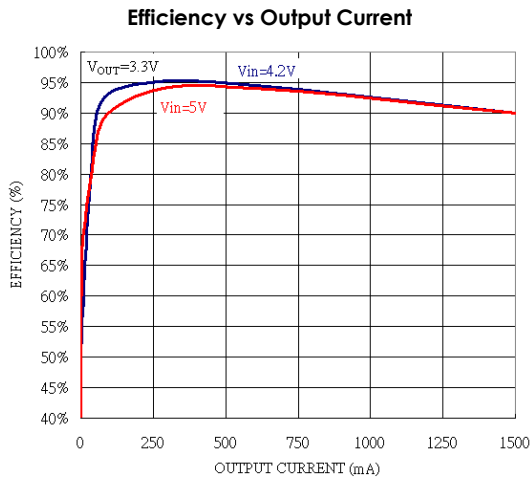
Symbol	Parameter	Conditions	Min	Typ	Max	Units	
I <sub>VFB</sub>	Feedback Current				±100	nA	
V <sub>FB</sub>	Regulated Feedback Voltage	T <sub>A</sub> = 25°C	0.588	0.6	0.612	V	
		-40°C ≤ T <sub>A</sub> ≤ 85°C	● 0.585	0.6	0.615		
V <sub>OUT</sub> %	Output Voltage Accuracy		● -3		3	%	
Δ V <sub>FB</sub>	Reference Voltage Line Regulation	V <sub>IN</sub> = 2.5V to 5.5V	●		0.4	%/V	
Δ V <sub>OVL</sub>	Output Over-voltage Lockout	Δ V <sub>OVL</sub> = V <sub>OVL</sub> - V <sub>FB</sub> , EML3416		20	50	80	mV
		Δ V <sub>OVL</sub> = V <sub>OVL</sub> - V <sub>OUT</sub> , EML3416-Fixed		2.5	7.8	13	%
Δ V <sub>OUT</sub>	Output Voltage Line Regulation	V <sub>IN</sub> = 2.5V to 5.5V	●		0.2	0.4	%/V
I <sub>PK</sub>	Peak Inductor Current	V <sub>IN</sub> = 3V, V <sub>FB</sub> = 0.5V or V <sub>OUT</sub> = 90%, Duty Cycle < 35%			2.4		A
V <sub>LOADREG</sub>	Output Voltage Load Regulation	I <sub>OUT</sub> = 10mA to 1.5A			0.2		%/A
I <sub>S</sub>	Quiescent Current (Note 2)	V <sub>FB</sub> = 0.5V or V <sub>OUT</sub> = 90%			240	340	μ A
	Shutdown	V <sub>EN</sub> = 0V, V <sub>IN</sub> = 4.2V			0.1	1	μ A
f <sub>OSC</sub>	Oscillator Frequency	V <sub>FB</sub> = 0.6V or V <sub>OUT</sub> = 100%	● 1.04	1.30	1.56	MHz	
R <sub>PFET</sub>	R <sub>DS(ON)</sub> of PMOS	I <sub>SW</sub> = 750mA			0.18		Ω
R <sub>NFET</sub>	R <sub>DS(ON)</sub> of NMOS	I <sub>SW</sub> = -750mA			0.16		Ω
I <sub>LSW</sub>	SW Leakage	V <sub>EN</sub> = 0V, V <sub>SW</sub> = 0V or 5V, V <sub>IN</sub> = 5V				±1	μ A
V <sub>EN</sub>	Enable Threshold		● 1.2				V
	Shutdown Threshold		●			0.4	V
I <sub>EN</sub>	EN Leakage Current		●			±1	μ A

**Note 1:** T<sub>J</sub> is a function of the ambient temperature T<sub>A</sub> and power dissipation P<sub>D</sub> ( T<sub>J</sub> = T<sub>A</sub> + (P<sub>D</sub>)(55°C/W) )

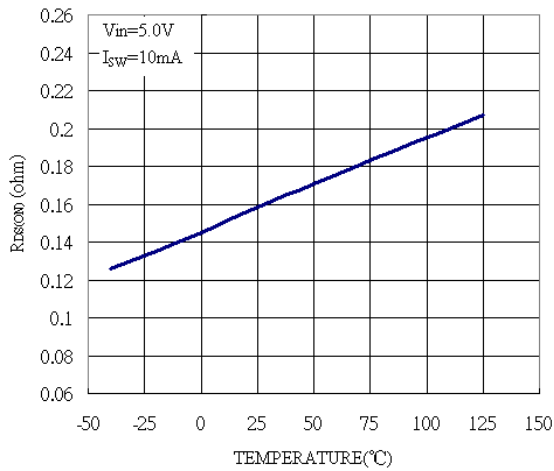
**Note 2:** Dynamic quiescent current is higher due to the gate charge being delivered at the switching frequency.

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

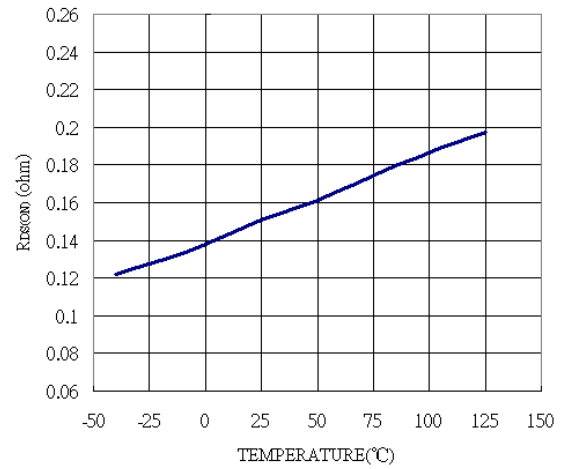
## Typical Performance Characteristics



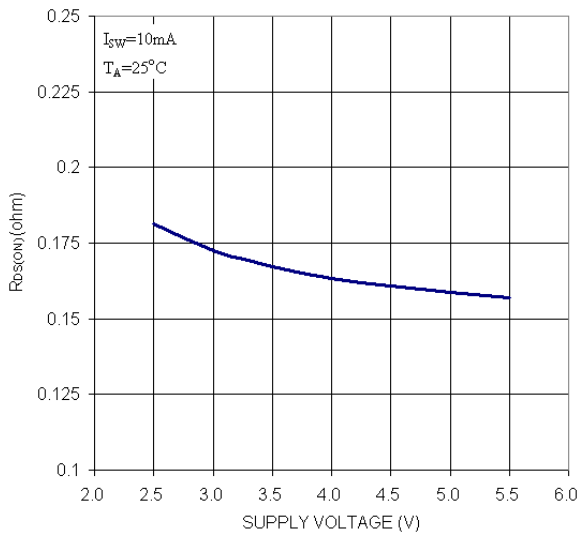
**PMOS  $R_{DS(ON)}$  vs Temperature**



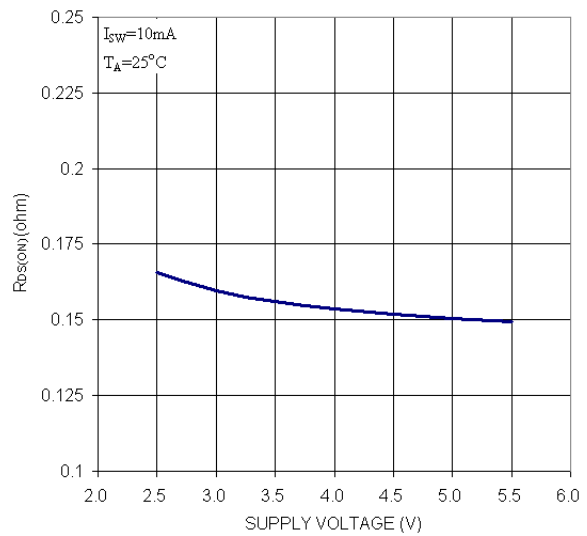
**NMOS  $R_{DS(ON)}$  vs Temperature**



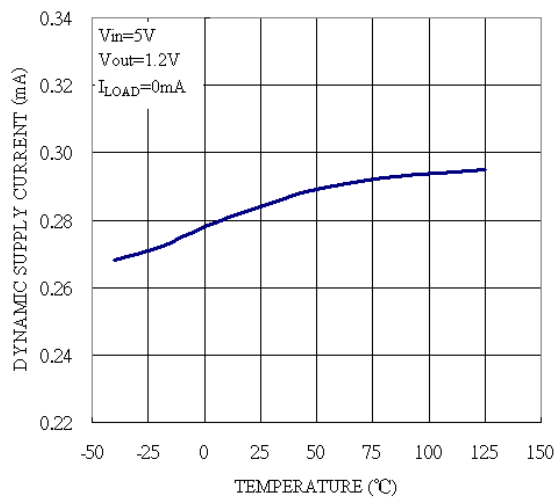
**PMOS  $R_{DS(ON)}$  vs Supply Voltage**



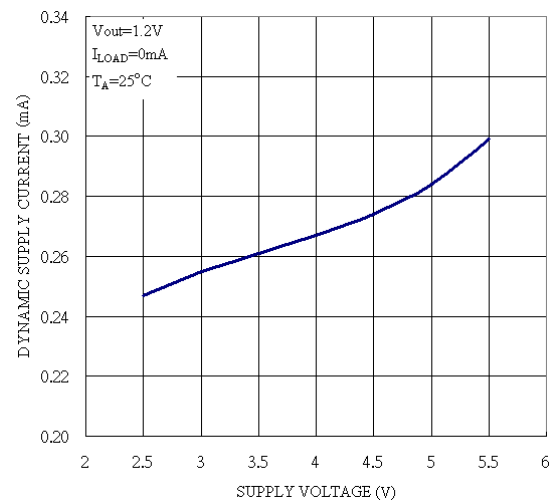
**NMOS  $R_{DS(ON)}$  vs Supply Voltage**



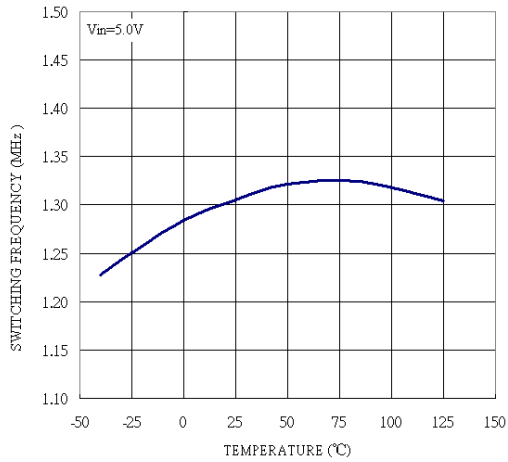
**Dynamic Supply Current vs Temperature**



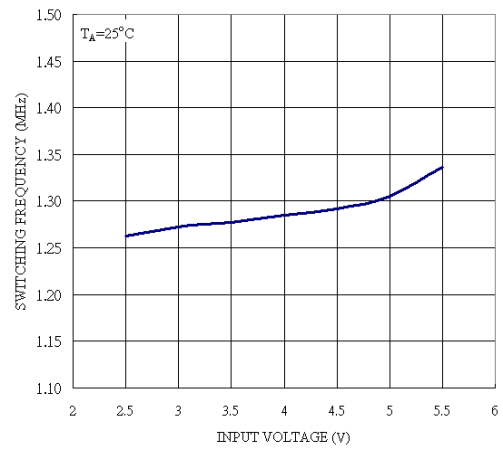
**Dynamic Supply Current vs Supply Voltage**



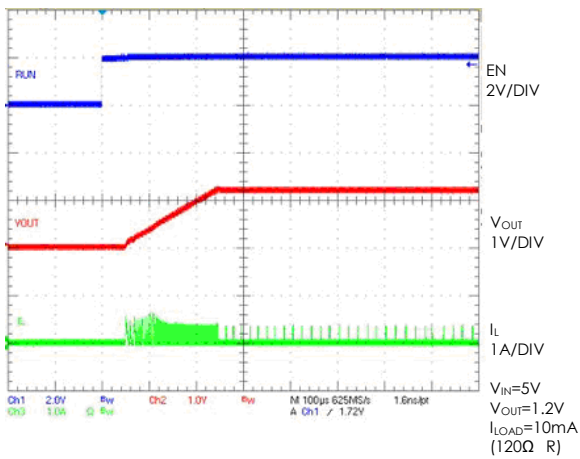
**Switching Frequency vs Temperature**



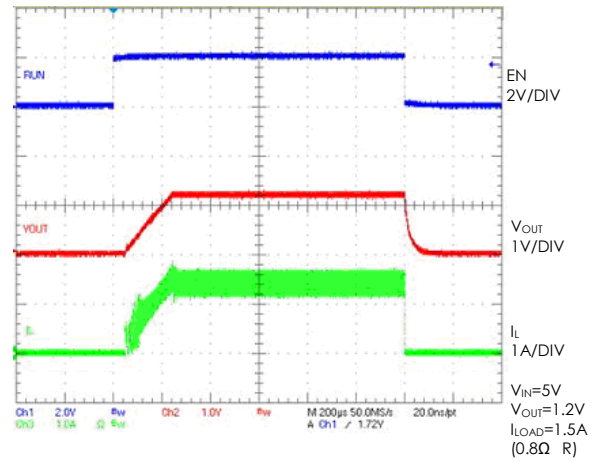
**Switching Frequency vs Supply Voltage**



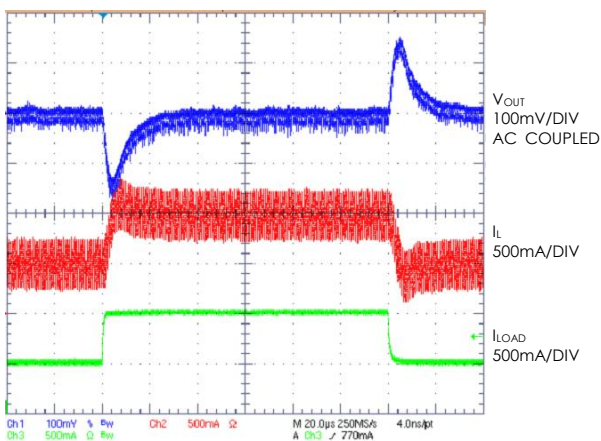
**Start-up From Shutdown**



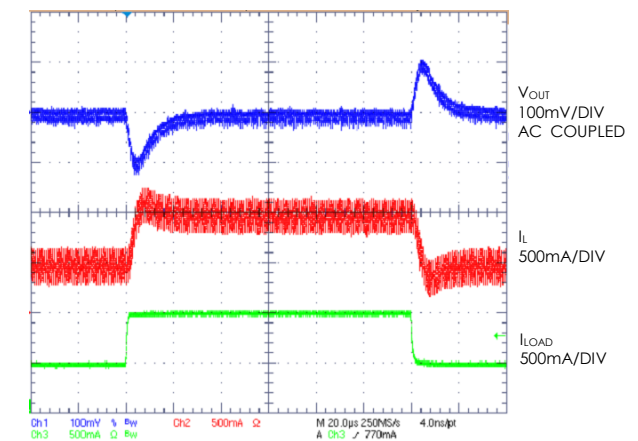
**Start-up From Shutdown**



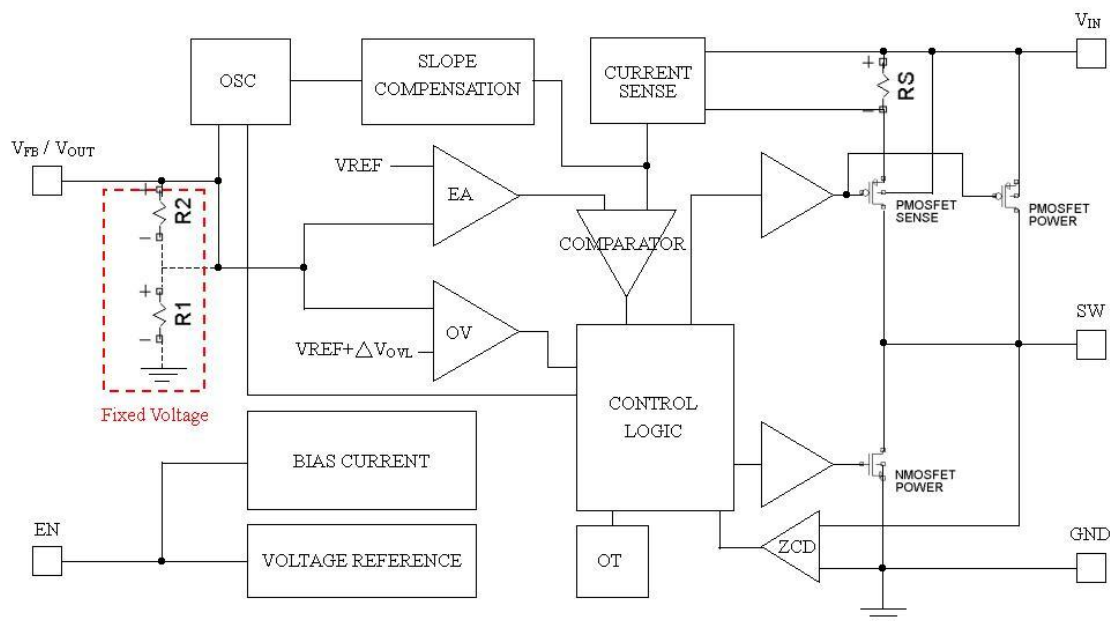
**Load Step**



**Load Step**



## Functional Block Diagram

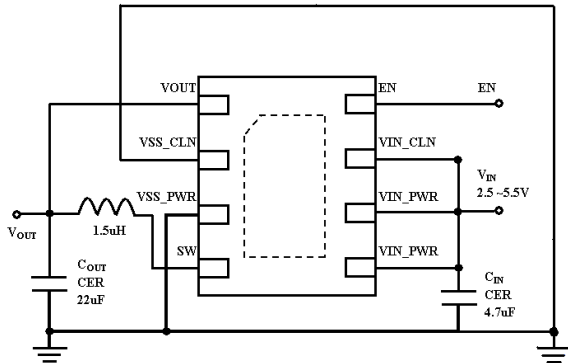




## Applications

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 current are two factors considered to decide the Inductor value.

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

The Eq. 1 shows the inductor ripple current is a function of frequency, inductance,  $V_{IN}$  and  $V_{OUT}$ . 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:

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

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  $C_{out}$  selection since  $C_{out}$  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.

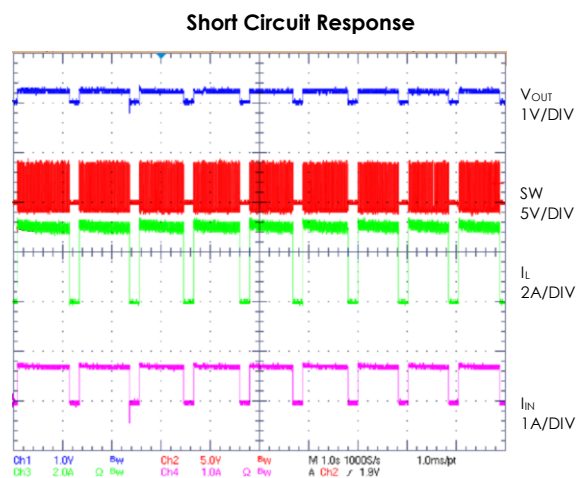
### Output Voltage (EML3416 adjustable)

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

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

### 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  $V_{IN}=5V$  to  $V_{OUT}=1.2V$ , shorting  $V_{out}$  to ground makes over-current and over-temperature protection active. The waveform is shown as the following diagram.



## Thermal Considerations

Although thermal shutdown is built-in in EML3416 that protect the device from thermal damage, the total power dissipation that EML3416 can sustain should be based 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.

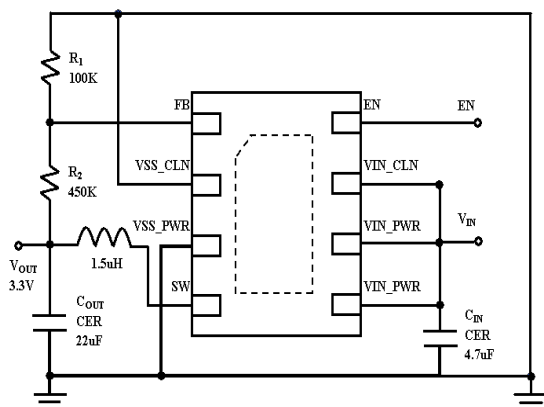
## Guidelines for PCB Layout

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

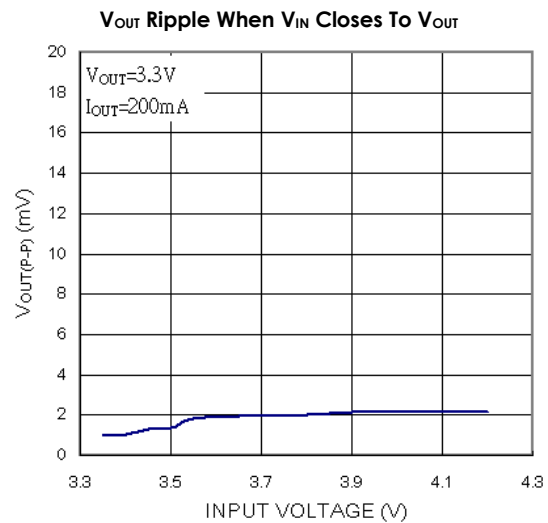
A self-enable function could be used when EML3416 is connected as the following diagram:



The resistor ratio  $R_3:R_4=1:1.5$  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.



## 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  $V_{OUT} = 1.8V$ ,  $V_{IN} = 4.2V$ ,  $\Delta I_L = 600mA$  and  $f = 1.3MHz$  in eq. 1 gives:

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

A 1.5 $\mu H$  inductor could be chosen 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.

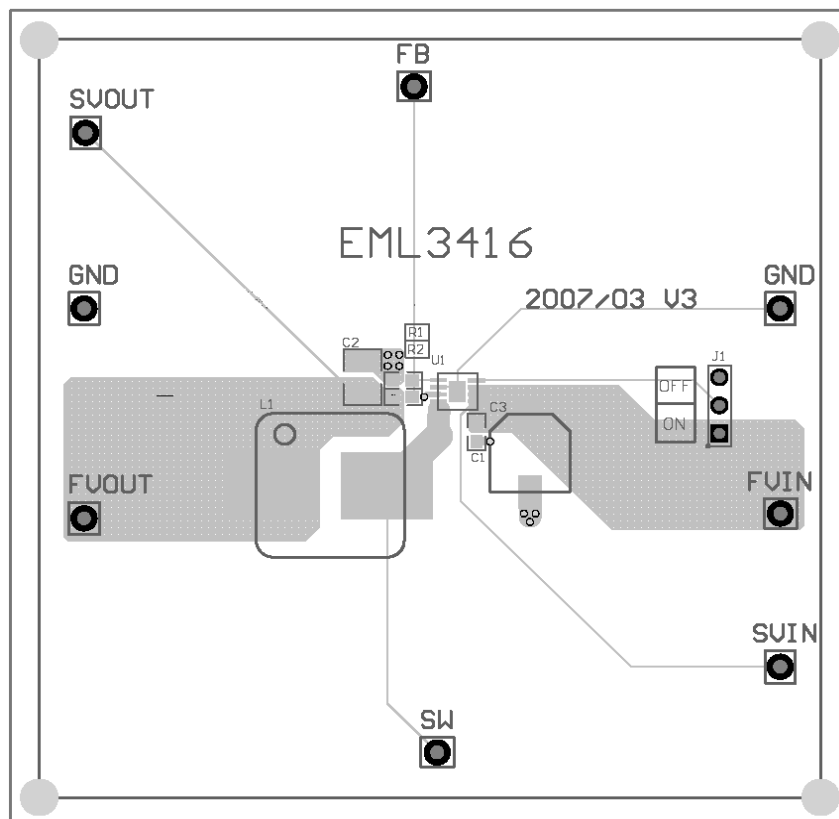
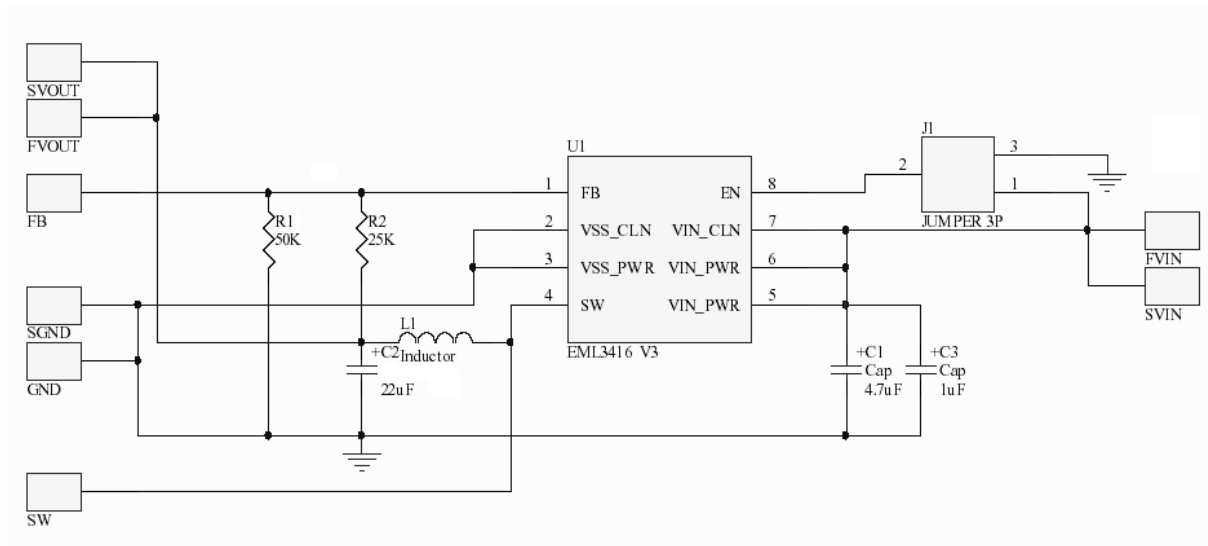
**Recommended Components**

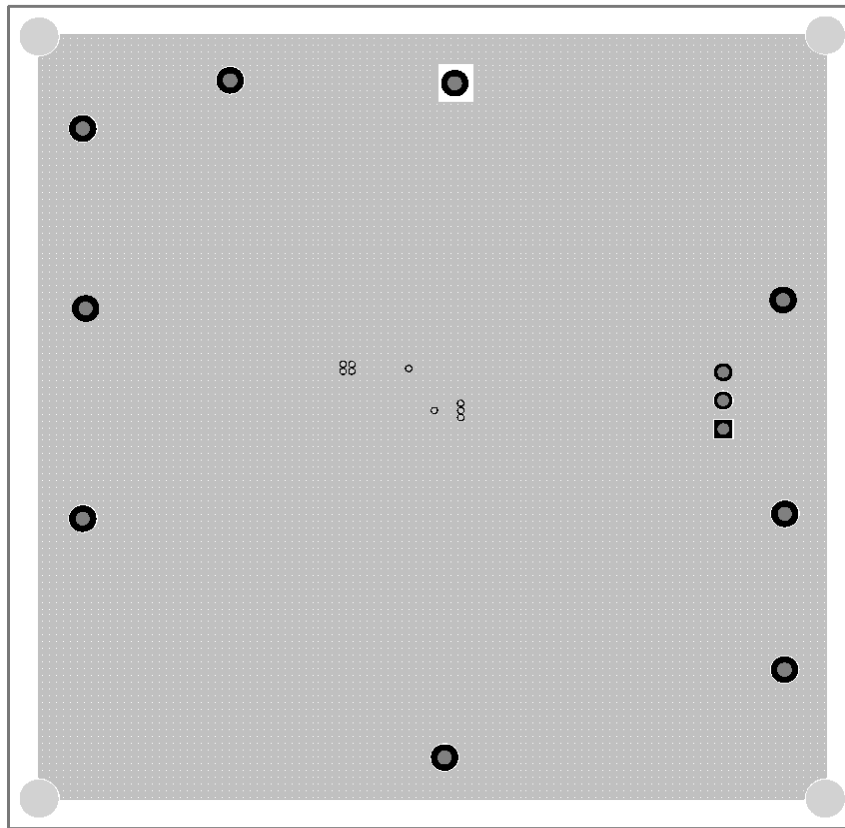
Supplier	Inductance ( $\mu\text{H}$ )	$I_{\text{sat}}$ (A)	$\text{DCR}_{\text{max}}$ ( $\text{m}\Omega$ )	Dimensions (mm)	Part Number
Coilcraft	1.5	14	13	12.3 x 12.3 x 6	MSS1260-152NLB

Supplier	Capacitance ( $\mu\text{F}$ )	Package	Part Number
YAGEO	4.7	0805	CC0805KKX5R6BB475
TAIYO YUDEN	22	1812	EMK432BJ226KM-T

## Application (Continued)

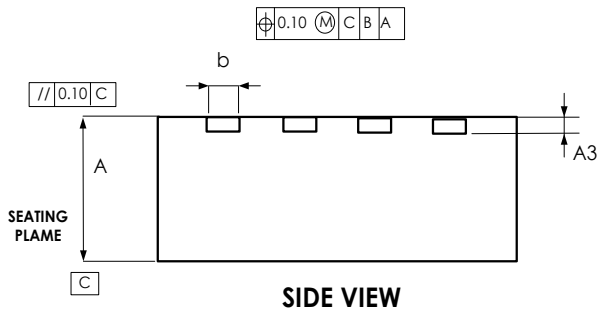
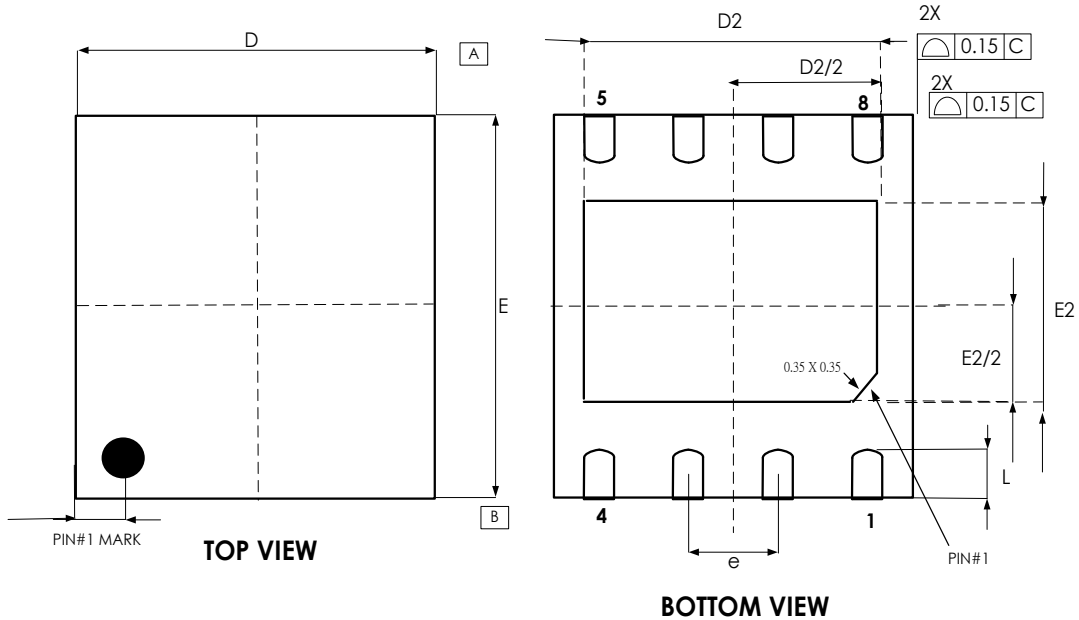
### Typical schematic for PCB layout





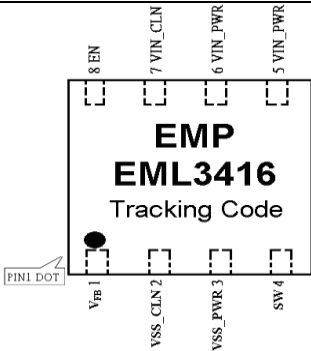
## Package Information

### 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

## Old Order, Marking & Packing Information

Product ID	Package	Vout (V)	Marking	Packing
EML3416-00FF08NRR	TDFN-8	adjustable	 <p>The marking diagram shows a square package with pins 1 through 8. Pin 1 is labeled 'FINI DOT' with a dot. Pin 2 is 'VFB 1', pin 3 is 'VSS_CLN 2', pin 4 is 'VSS_PWR 3', and pin 5 is 'SW 4'. The top pins are labeled 8 EN, 7 VIN_CLN, 6 VIN_PWR, and 5 VIN_PWR. The marking text reads: <b>EMP</b>, <b>EML3416</b>, and Tracking Code.</p>	5Kpcs Tape & Reel

**Revision History**

<b>Revision</b>	<b>Date</b>	<b>Description</b>
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)
7.4	2013.11.01	Modify marking



**Important Notice**

All rights reserved.

No part of this document may be reproduced or duplicated in any form or by any means without the prior permission of ESMT.

The contents contained in this document are believed to be accurate at the time of publication. ESMT assumes no responsibility for any error in this document, and reserves the right to change the products or specification in this document without notice.

The information contained herein is presented only as a guide or examples for the application of our products. No responsibility is assumed by ESMT for any infringement of patents, copyrights, or other intellectual property rights of third parties which may result from its use. No license, either express, implied or otherwise, is granted under any patents, copyrights or other intellectual property rights of ESMT or others.

Any semiconductor devices may have inherently a certain rate of failure. To minimize risks associated with customer's application, adequate design and operating safeguards against injury, damage, or loss from such failure, should be provided by the customer when making application designs.

ESMT's products are not authorized for use in critical applications such as, but not limited to, life support devices or system, where failure or abnormal operation may directly affect human lives or cause physical injury or property damage. If products described here are to be used for such kinds of application, purchaser must do its own quality assurance testing appropriate to such applications.