

## 450nA Ultra-low Iq, COT Synchronous Buck Module with Integrated Inductor and Capacitor

### DESCRIPTION

The EM3707/A/B is a high-efficiency, step-down buck converter module with built-in power MOSFETs, inductor and capacitor. The integrated structure simplifies the power system design. EM3707/EM3707T features 450nA ultra-low quiescent current, can provide programmable output voltages from 1.2V to 3.3V, and capable to deliver up to 1A of output current. EM3707A/EM3707AT features 450nA ultra-low quiescent current, can provide programmable output voltages from 0.7V to 3.1V, and capable to deliver up to 500mA of output current. EM3707B/EM3707BT features 450nA ultra-low quiescent current, can provide programmable output voltages from 0.5V to 1.9V, and capable to deliver up to 500mA of output current.

EM3707 series adopts an adaptive COT control scheme that enables fast transient response and provides a very smooth transition when the output varies from light load to heavy load. During light load, EM3707 goes into a PFM mode that saves switching loss to achieve high efficiency. The adaptive COT control also maintains a constant switching frequency across line and load. The internal soft-start control circuitry reduces inrush current. Over current and temperature protection improve design reliability.

EM3707/A/B is available in similar DFN3x3 package with 1.21mm thickness. EM3707T/AT/BT is available in similar DFN3x3 package with 0.91mm thickness.

### FEATURES

- ◆ Wide Input Voltage Range: 2.1V-5.5V
- ◆ Less than 450nA Typical Quiescent Current
- ◆ Integrated Inductor and Capacitor
- ◆ Up to 1A(EM3707) and 500mA(EM3707A/B) Max Output Current
- ◆ Up to 94% Efficiency
- ◆ 1.2MHz Switching Frequency
- ◆ Programmable Output Voltage
- ◆ Adaptive COT Control
- ◆ Ultra-fast Load Transient Response
- ◆ High Efficiency PFM Mode at Light Load
- ◆ Over Current Protection
- ◆ Over Temperature Protection
- ◆ Similar DFN3x3 Package
- ◆ 1.2mm and 0.91mm Package Thickness
- ◆ Pb Free, RoHS and REACH Compliant
- ◆ Halogen Free and “Green” Device

### APPLICATIONS

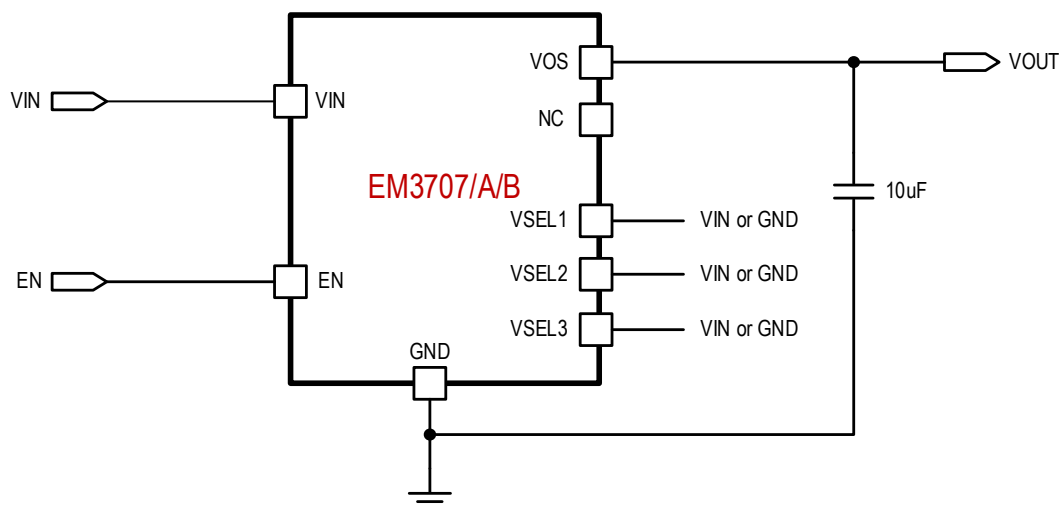
- ◆ LDO Replacement
- ◆ Optical Modules
- ◆ Wearable, IoT and Space Limited Applications

### ORDERING

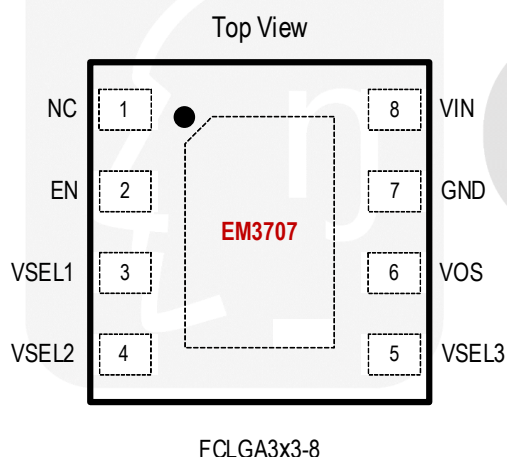
### INFORMATION

PART No.	PACKAGE	TOP MARK	Pcs/Reel
EM3707FL3I	FCLGA3x3-8	EM3707	4000
EM3707TFL3I	FCLGA3x3-8	EM3707T	4000
EM3707AFL3I	FCLGA3X3-8	EM3707A	4000
EM3707ATFL3I	FCLGA3X3-8	EM3707AT	4000
EM3707BFL3I	FCLGA3X3-8	EM3707B	4000
EM3707BTFL3I	FCLGA3X3-8	EM3707BT	4000

## TYPICAL APPLICATION



## PIN CONFIGURATION



## ABSOLUTE MAXIMUM RATINGS

(Note: Exceeding these limits may damage the device. Exposure to absolute maximum rating conditions for long periods may affect device reliability.)

VIN, EN, VOS to GND Voltage .....	-0.3V to 6V
VSEL1, VSEL2, VSEL3 to GND Voltage ...	-0.3V to 6V
Junction Temperature .....	150°C
Storage Temperature Range .....	-55°C to 150°C
Thermal Resistance $\Theta_{JA}$ $\Theta_{JC}$	
FCLGA3x3-8.....	43.....5.5..... °C/W
Lead Temperature (Soldering 10sec) .....	260°C
ESD HBM (Human Body Mode) .....	3KV
ESD CDM (Charged Device Mode) .....	1KV

## RECOMMENDED OPERATING CONDITIONS

(Note: The device is not guaranteed to function outside its operating conditions.)

Ambient Temperature Range .....	-40°C to 85°C
Junction Temperature Range .....	-40°C to 125°C

## PIN DESCRIPTION

PIN #	NAME	DESCRIPTION
1	NC	No Connect. Keep the pin float
2	EN	Enable pin for the IC. Drive this pin high to enable the IC, low to disable. This pin must be terminated.
3	VSEL1	Output voltage selection pin. This pin must be terminated.

PIN #	NAME	DESCRIPTION
4	VSEL2	Output voltage selection pin. This pin must be terminated.
5	VSEL3	Output voltage selection pin. This pin must be terminated.
6	VOS	Output pin. Bypass with a 10uF or larger ceramic capacitor closely between this pin and GND.
7	GND	Ground.
8	VIN	Supply voltage pin.
EP		Expose pad, Connect to GND

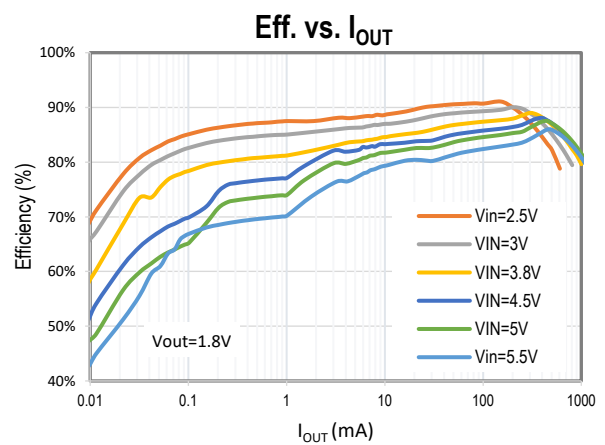
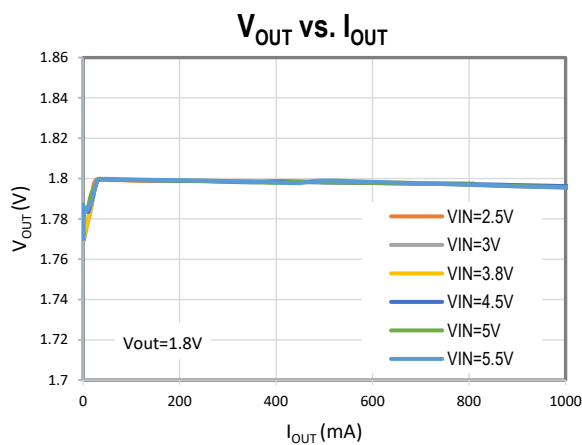
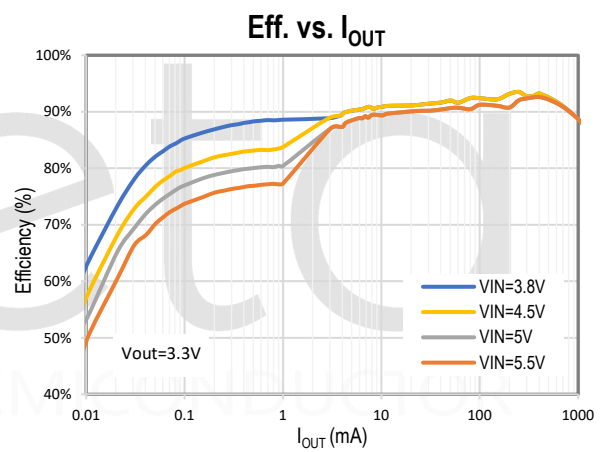
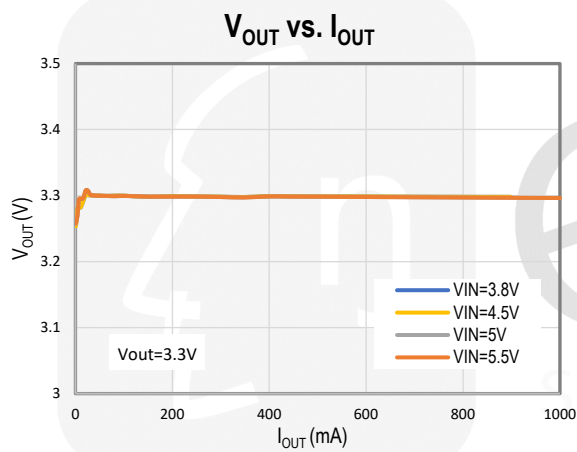
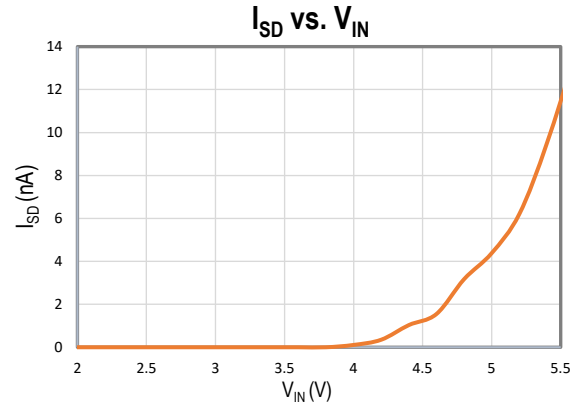
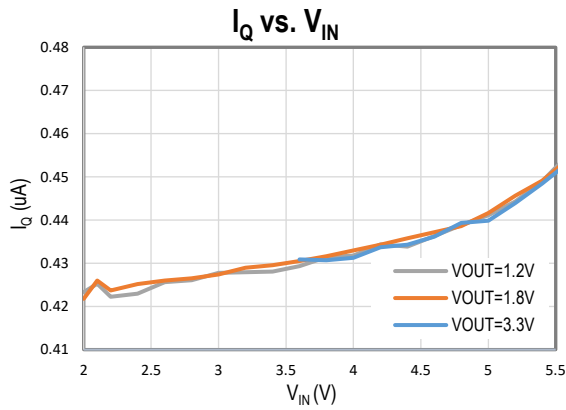
## ELECTRICAL CHARACTERISTICS

( $V_{IN} = 3.6V$ , unless otherwise specified. Typical values are at  $T_A = 25^{\circ}C$ .)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
Input Voltage Range		2.1		5.5	V
Input UVLO	Rising, Hysteresis=200mV		2.0	2.2	V
Input Supply Current	No Switching		360	1000	nA
Input Shutdown Current	$V_{EN}=0V$		0	1	$\mu A$
Output Voltage Accuracy	$V_{OUT}=1.8V, I_{OUT}=10mA$	-2.5		2.5	%
	$V_{OUT}=1.8V, I_{OUT}=100mA$	2		2	%
Load Regulation	PFM to PWM, $V_{OUT}=1.8V$		0.002		%/mA
	Only PWM, $V_{OUT}=1.8V$		0.0005		%/mA
Line Regulation	$V_{IN}=2.1V$ to $5.5V$ , $V_{OUT}=1.8V$		0.1		%/V
Switching Frequency			1.2		MHz
Soft Start Time	$V_{OUT}$ rise from 10% to 90%		0.5		mS
100% Duty Threshold	$V_{IN}$ Rising, Exiting 100% $V_{IN}=V_{OUT}+V_{TH\_100+}$		250		mV
	$V_{IN}$ Failing, Entering 100% $V_{IN}=V_{OUT}+V_{TH\_100-}$		200		mV
VOS Input Leakage Current	$V_{OUT} = 2V$ , $EN=VIN$		100		nA
Output Discharge Resistance	$EN=GND$		10		$\Omega$
Output Current	EM3707/EM3707T		1000		mA
	EM3707A/AT/B/BT		500		
EN,VSEL1,VSEL2, VSEL3 Logic High Threshold	Rising	1.2			V
EN,VSEL1,VSEL2, VSEL3 Logic Low Threshold	Falling			0.4	V
EN,VSEL1,VSEL2, VSEL3 Input Bias Current	$V_{EN}=2V$		10		nA
Thermal Shutdown	Rising, Hysteresis=34 $^{\circ}C$		150		$^{\circ}C$

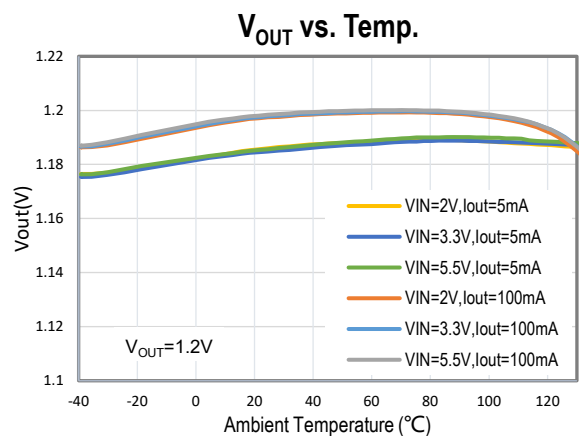
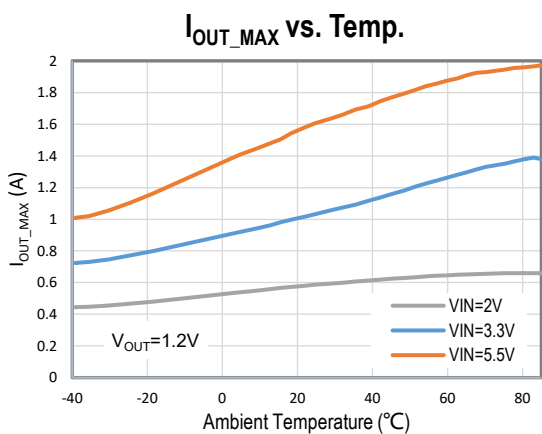
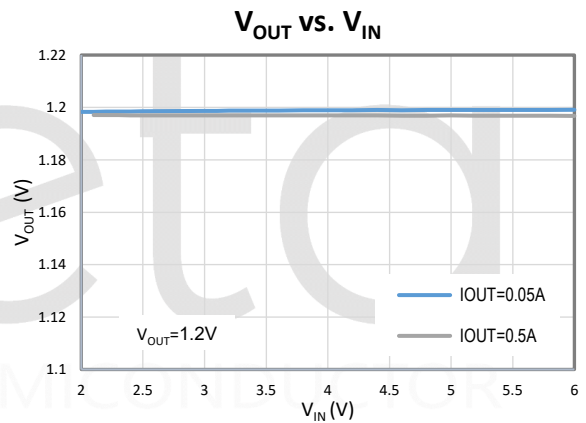
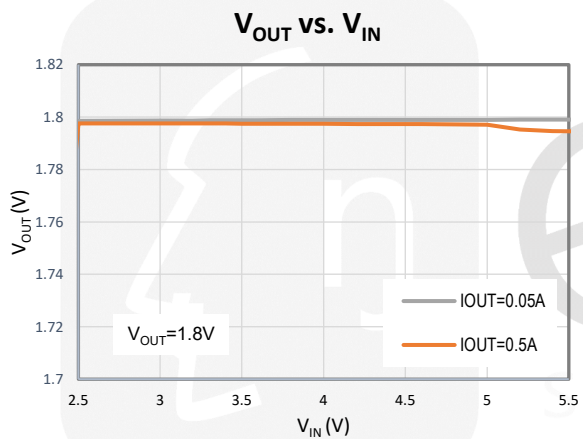
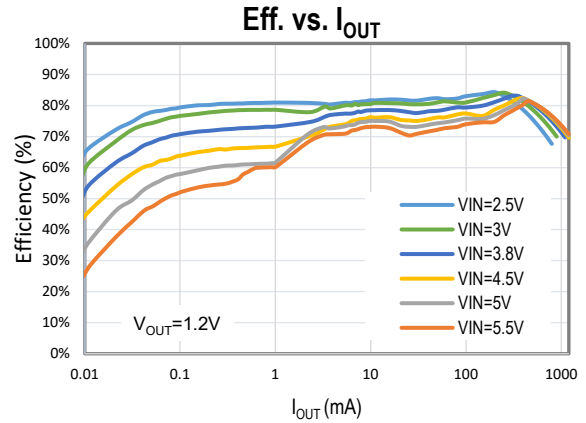
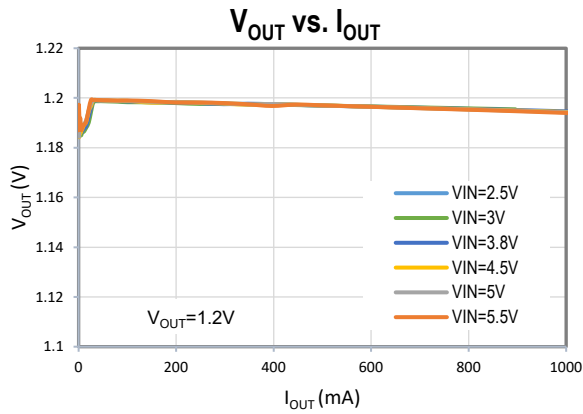
## EM3707 TYPICAL CHARACTERISTICS

(Typical values are at  $T_A = 25^\circ$ ,  $V_{IN} = 5.0V$ , unless otherwise specified.)



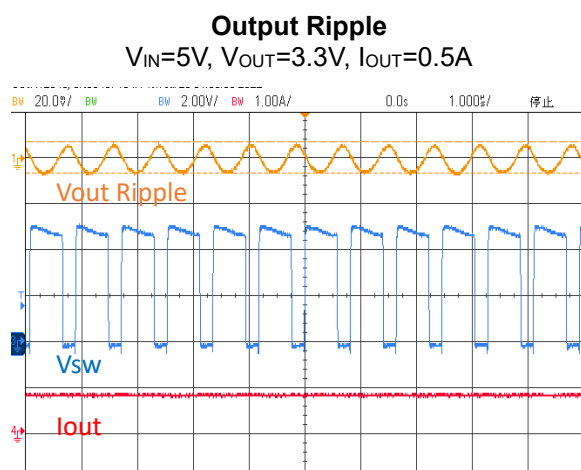
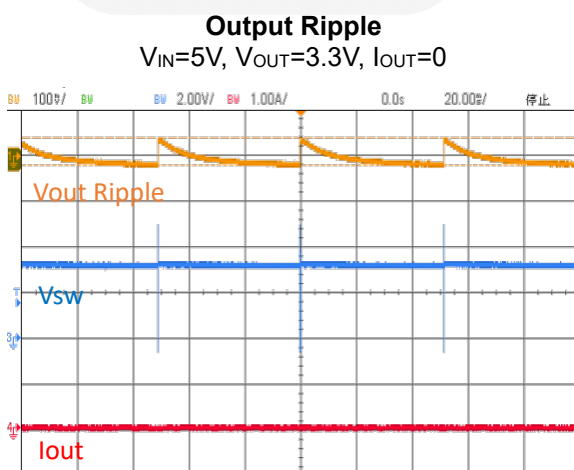
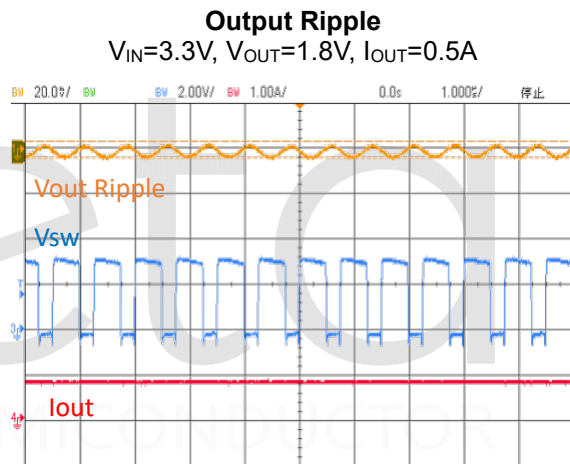
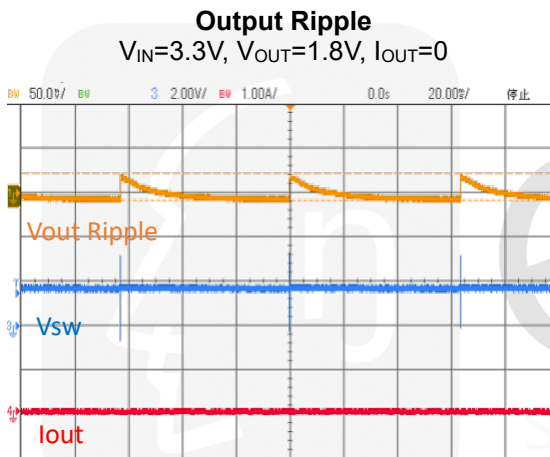
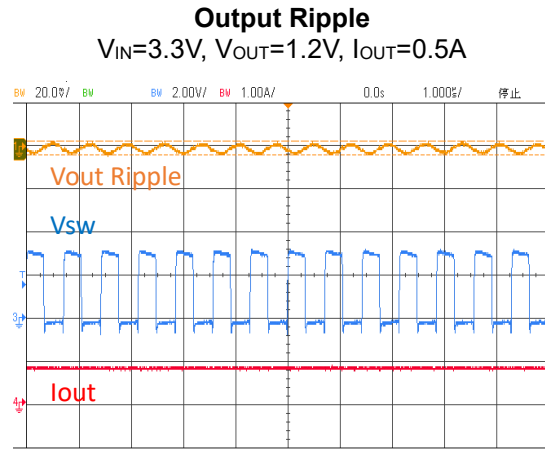
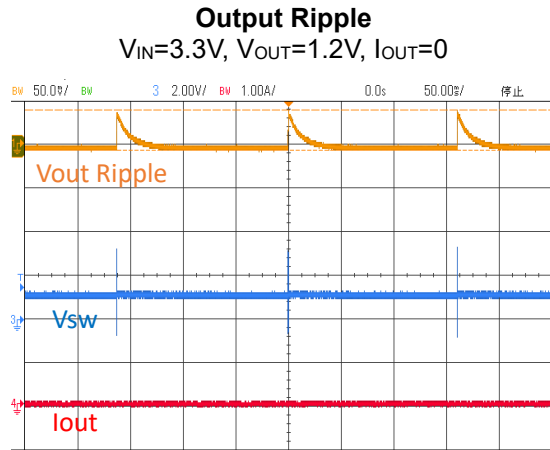
## EM3707 TYPICAL CHARACTERISTICS

(Typical values are at  $T_A = 25^\circ$ ,  $V_{IN} = 5.0V$ , unless otherwise specified.)



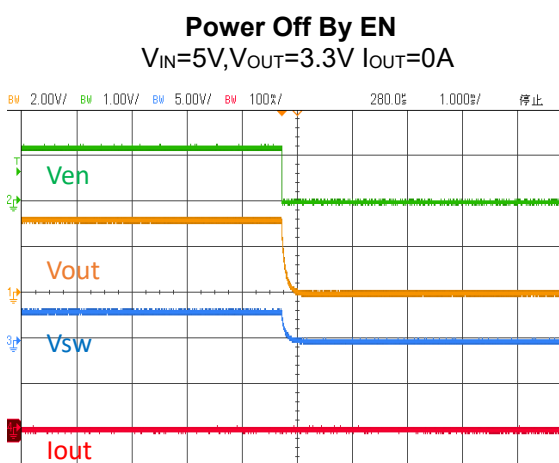
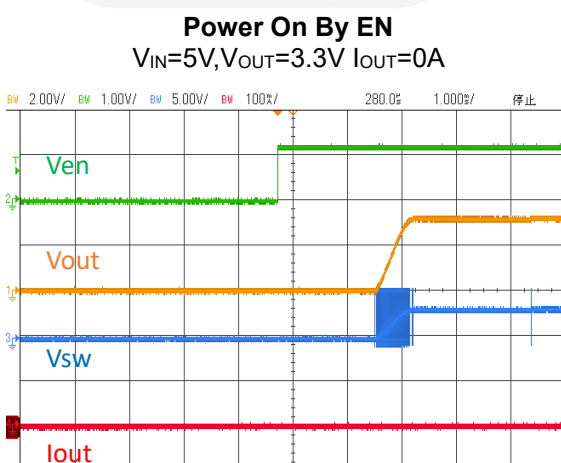
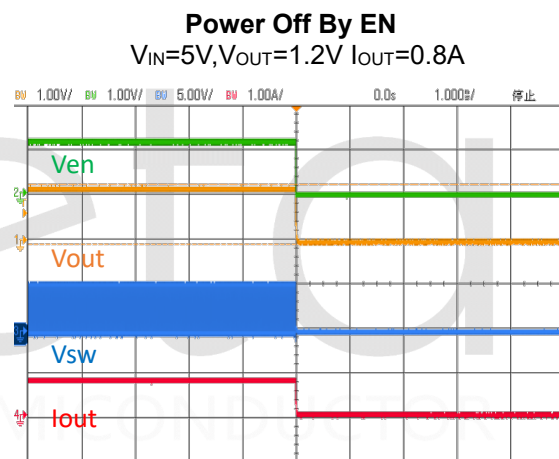
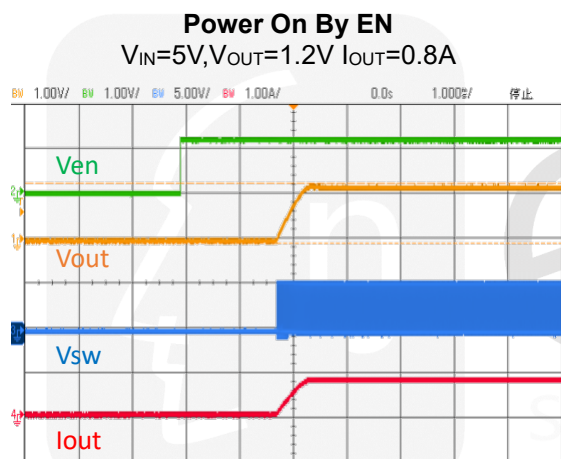
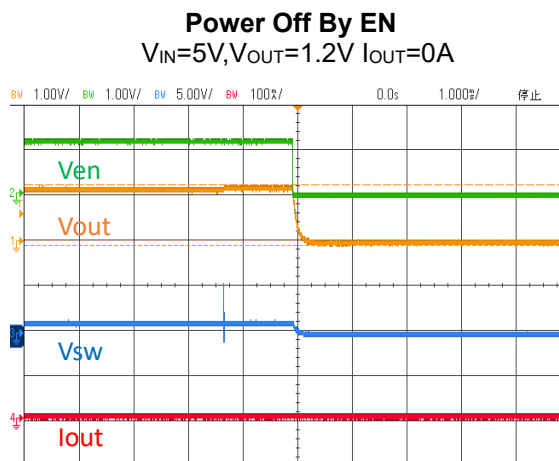
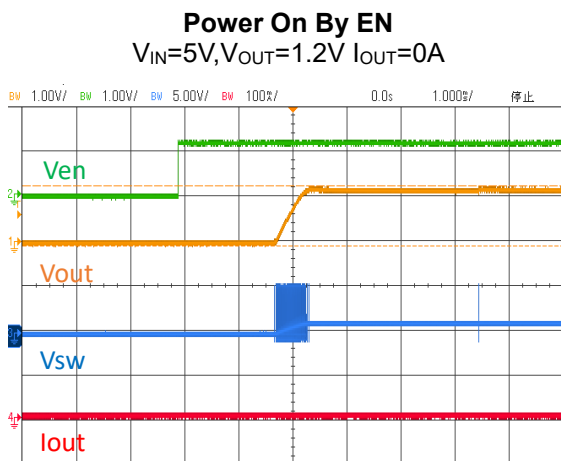
## EM3707 TYPICAL CHARACTERISTICS

(Typical values are at  $T_A = 25^\circ$ ,  $V_{IN} = 5.0V$ , unless otherwise specified.)



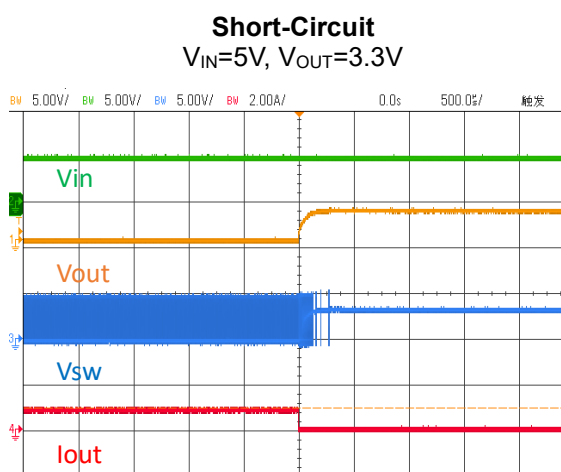
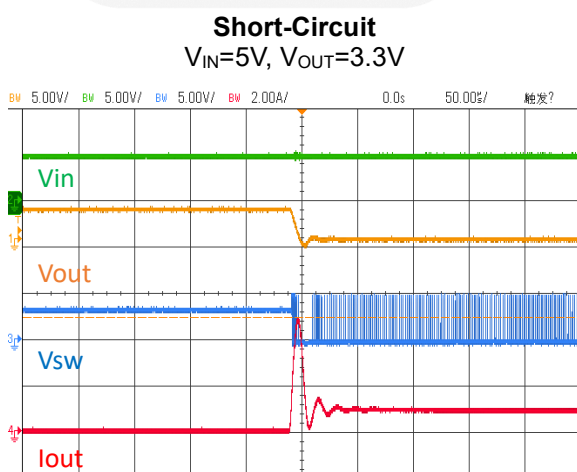
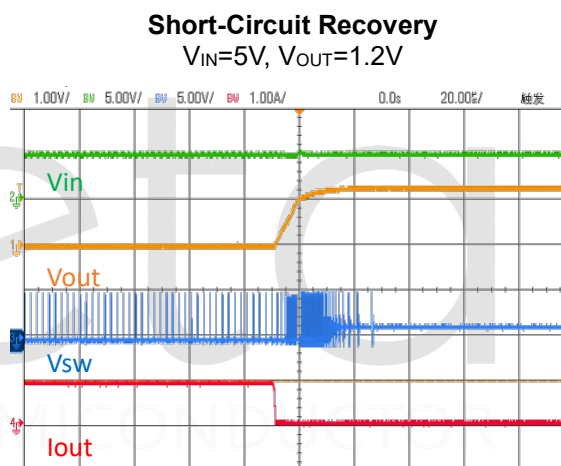
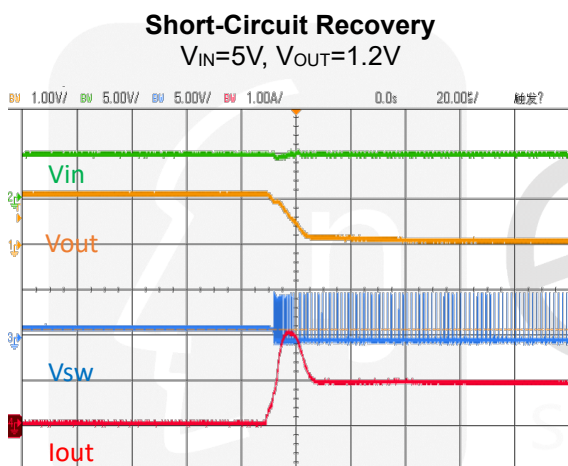
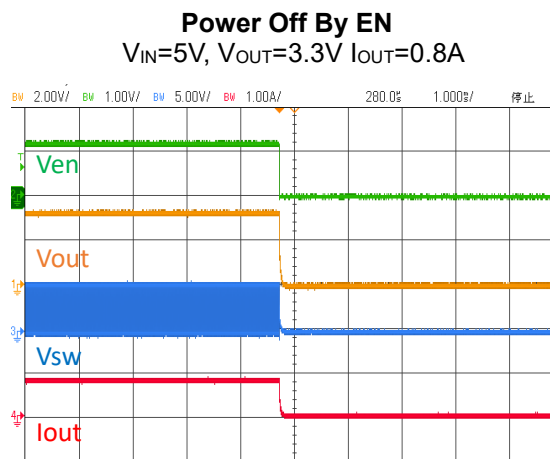
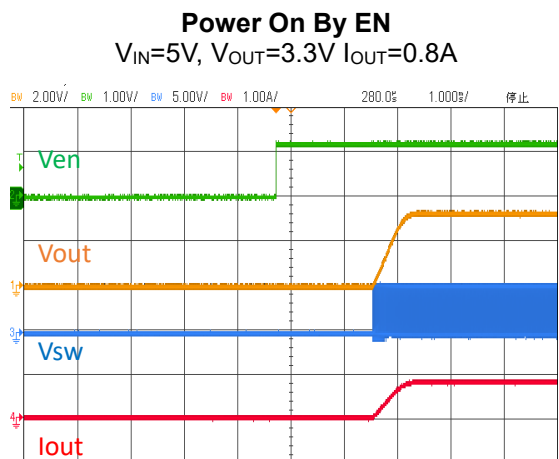
## EM3707 TYPICAL CHARACTERISTICS

(Typical values are at  $T_A = 25^\circ$ ,  $V_{IN} = 5.0V$ , unless otherwise specified.)



## EM3707 TYPICAL CHARACTERISTICS

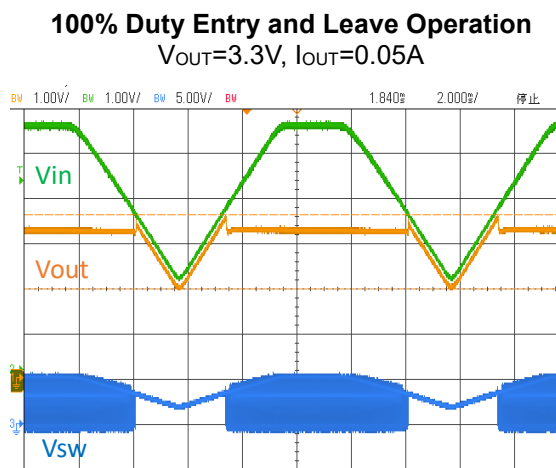
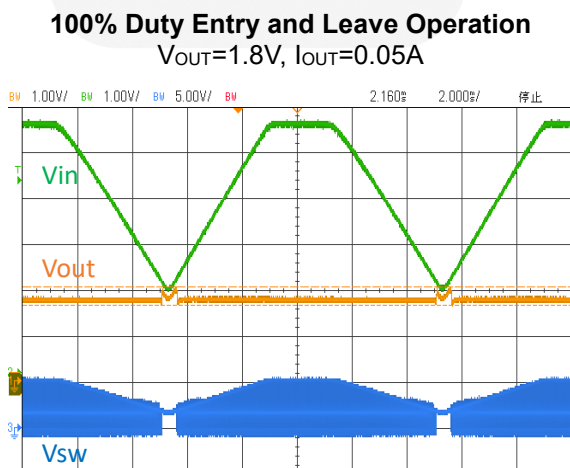
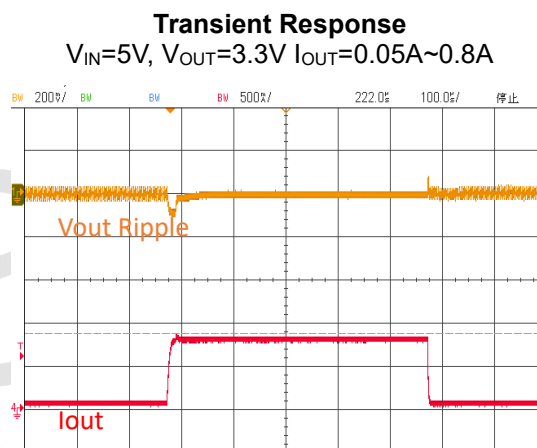
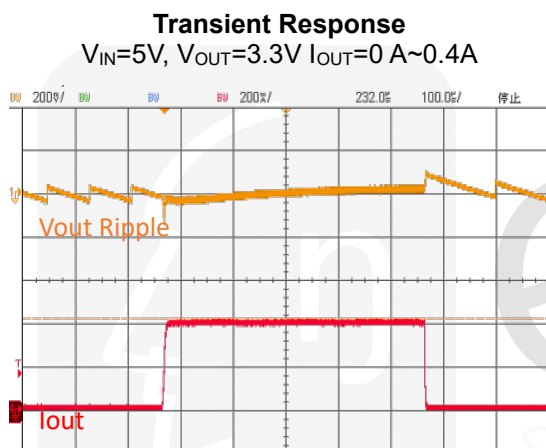
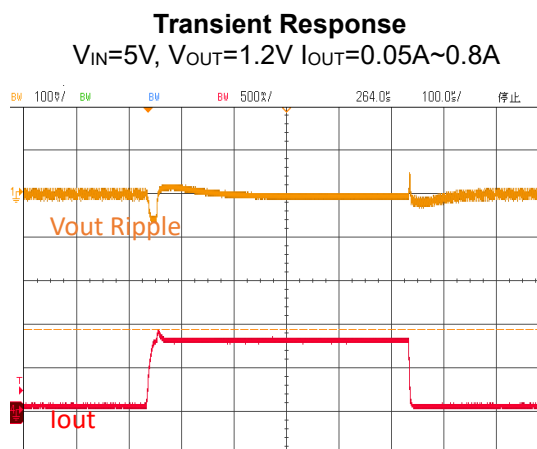
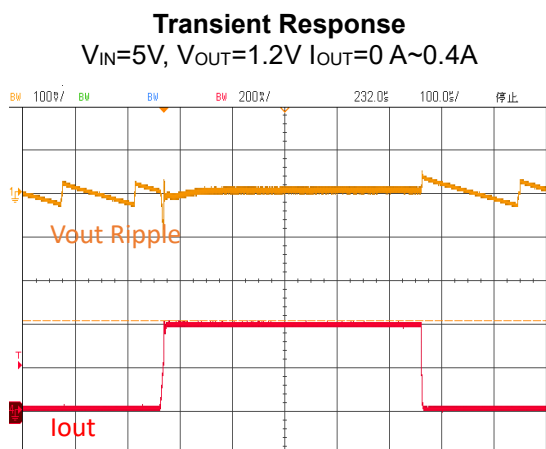
(Typical values are at  $T_A = 25^\circ$ ,  $V_{IN} = 5.0V$ , unless otherwise specified.)



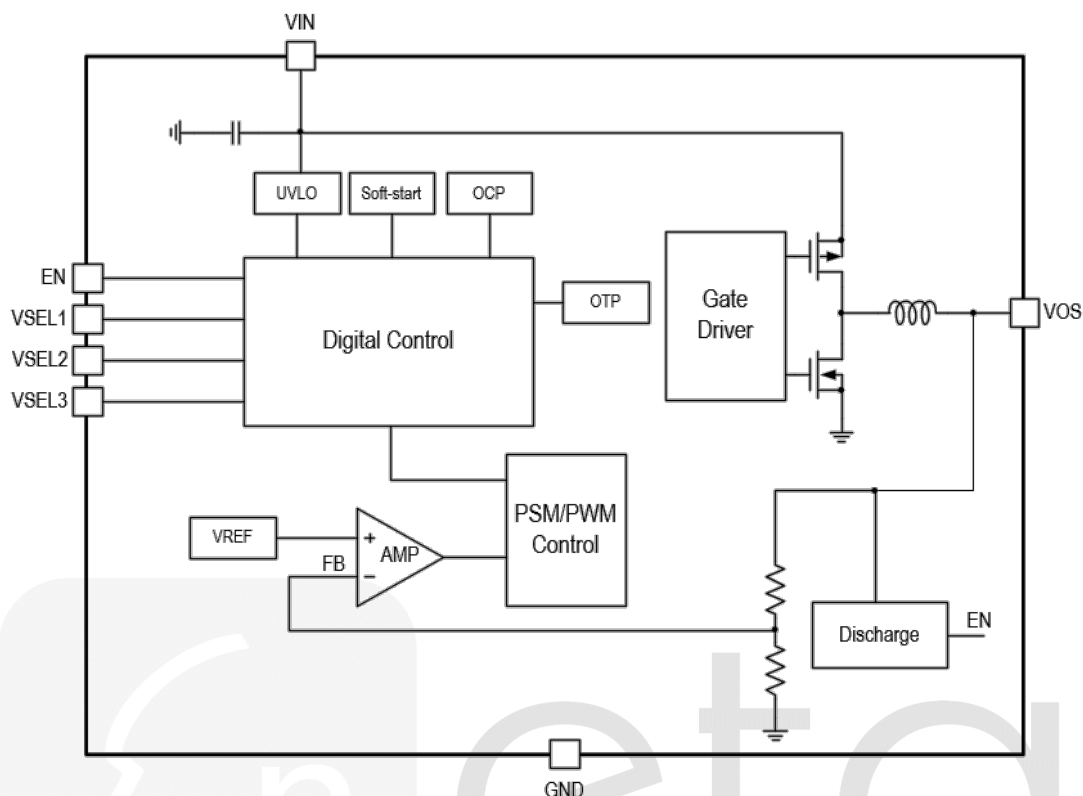


## EM3707 TYPICAL CHARACTERISTICS

(Typical values are at  $T_A = 25^\circ$ ,  $V_{IN} = 5.0V$ , unless otherwise specified.)



## FUNCTIONAL BLOCK DIAGRAM



## FUNCTIONAL DESCRIPTION

EM3707 series is high-efficiency and high-frequency DC-to-DC step-down buck converter module with built-in power MOSFETs, inductor and capacitor, EM3707/EM3707T is capable of delivering up to 1A output current, EM3707A/ EM3707B/ EM3707AT/ EM3707BT is capable of delivering up to 500mA output current. It adopts an adaptive COT control scheme that enables very fast transient response and provides a very smooth transition when the output varies from light load to heavy load. It compares the sum of the FB voltage and a ripple voltage that mimics the voltage due to the output ESR and capacitance. The constant-on-time timer varies with line to achieve relative constant switching frequency across line.

### Light Load Operation

Traditionally, a fixed constant frequency PWM DC-DC regulator always switches even when the output load is small. When energy is shuffling back and forth through the power MOSFET, power is lost due to the finite  $R_{ds(on)}$  of the MOSFET and parasitic capacitances. At light load, this loss is prominent and efficiency is therefore very low. EM3707 goes into a power save mode during light load, thereby extending the range of high efficiency operation.

### 100% Duty Cycle Operation

If the input voltage decreases and the difference voltage between input and output is lower than  $V_{TH\_100-}$ , EM3707 will enter 100% duty cycle operation, and the output voltage follows the input voltage minus the voltage drop across the internal PMOSFET and the inductor. Once the input voltage increases and trips the threshold  $V_{TH\_100+}$ , the IC will exit 100% duty cycle operation to switch normally.

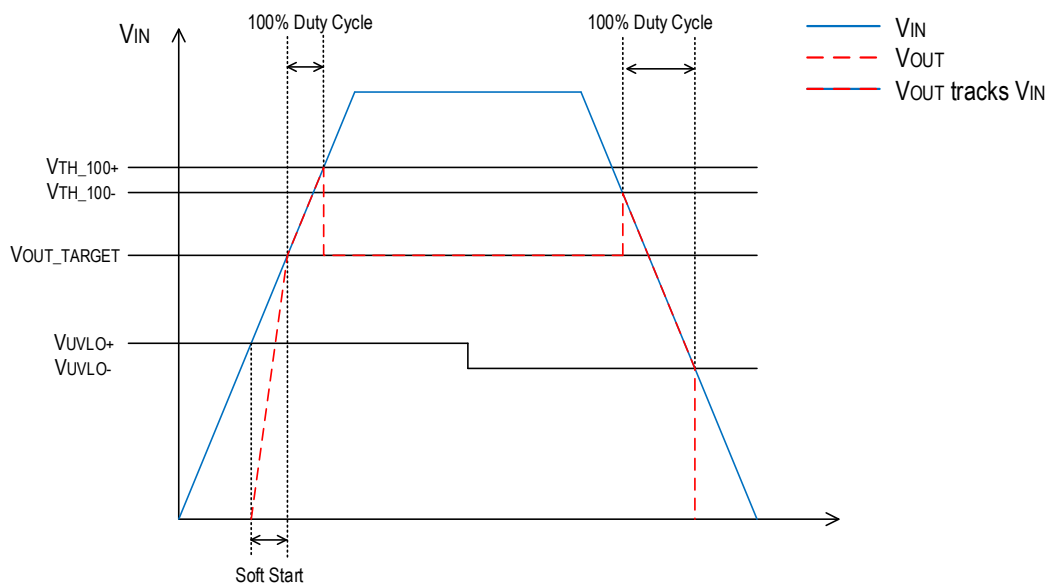


Figure 1. 100% Duty Cycle Entry and Leave Operation

### Output Voltage Selection

The output voltage of EM3707 can be programmed by the three pins VSEL1, VSEL2 and VSEL3. To set the output voltage, please refer to the table below.

Table1. Output Voltage Setting

Device	VOUT(V)	VSEL3	VSEL2	VSEL1
EM3707/ EM3707T	1.2	0	0	0
	1.5	0	0	1
	1.8	0	1	0
	2.1	0	1	1
	2.5	1	0	0
	2.8	1	0	1
	3	1	1	0
	3.3	1	1	1
EM3707A/ EM3707AT	0.7	0	0	0
	1	0	0	1
	1.3	0	1	0
	1.6	0	1	1
	1.9	1	0	0
	2	1	0	1
	2.9	1	1	0
	3.1	1	1	1

Device	VOUT(V)	VSEL3	VSEL2	VSEL1
ETA3707B/ ETA3707BT	0.7	0	0	0
	1	0	0	1
	1.3	0	1	0
	1.6	0	1	1
	1.9	1	0	0
	0.8	1	0	1
	0.6	1	1	0
	0.5	1	1	1

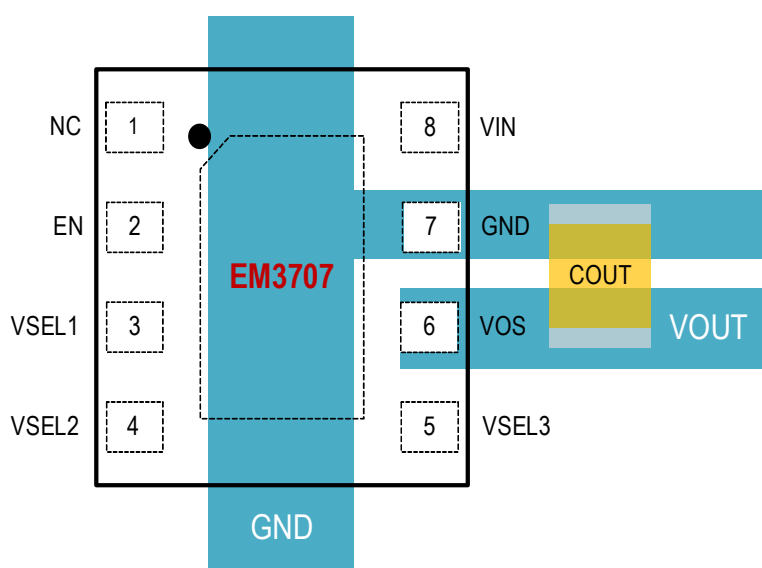
### Over-Temperature Protection

Thermal protection disables the output when the junction temperature rises to approximately 150°C, allowing the device to cool down. When the junction temperature cools to approximately 115°C, the output circuitry is again enabled. Depending on power dissipation, thermal resistance, and ambient temperature, the thermal protection circuit may cycle on and off. This cycling limits regulator dissipation, protecting the device from damage as a result of overheating.

## PCB LAYOUT GUIDE

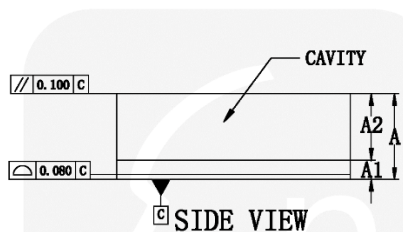
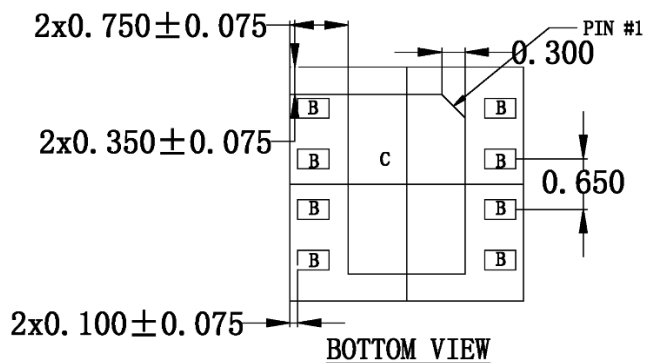
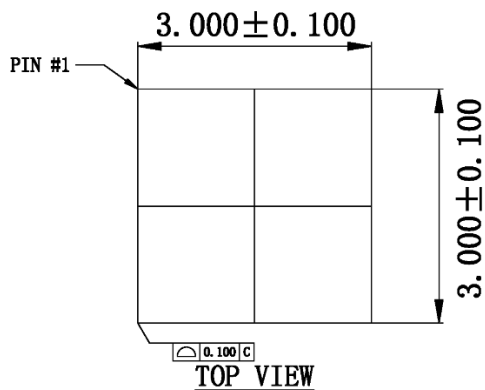
PCB layout is very important to achieve stable operation. It is highly recommended to duplicate EVB layout for optimum performance.

- 1) Bypass ceramic capacitors are suggested to be put close to the Vin pin.
- 2) Keep SW/NC away from sensitive analog areas such as FB.
- 3) Connect IN, VOS and especially GND respectively to a large copper area to cool the chip to improve thermal performance and long-term reliability.



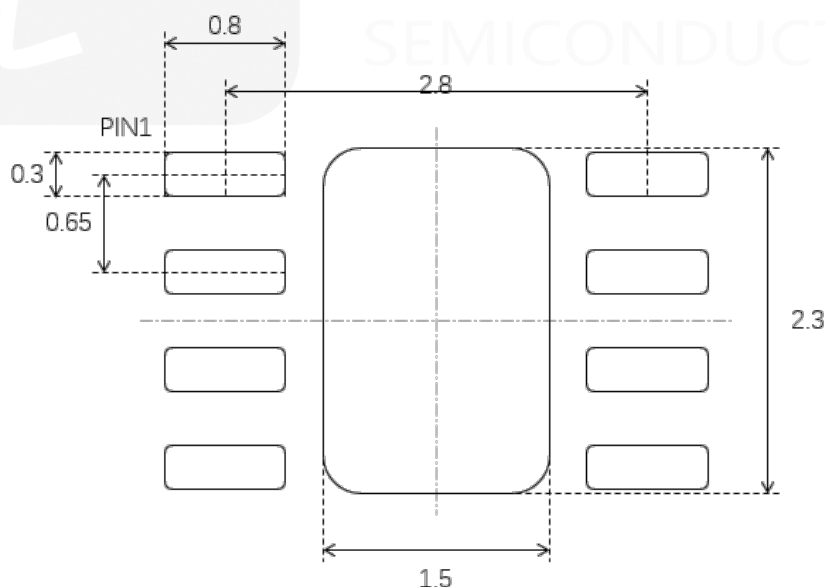
EM3707FL3I/ EM3707AFL3I/ EM3707BFL3I PACKAGE OUTLINE

Package: FCLGA3x3-8



Unit: mm

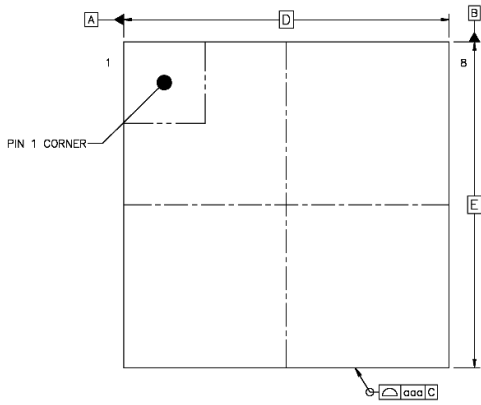
Symbol	Minimum	Normal	Maximum
A	1.160	1.210	1.260
A1	0.180	0.210	0.240
A2		1.00	
B	0.250x0.400		
C	1.500x2.300		
Pitch	0.650		



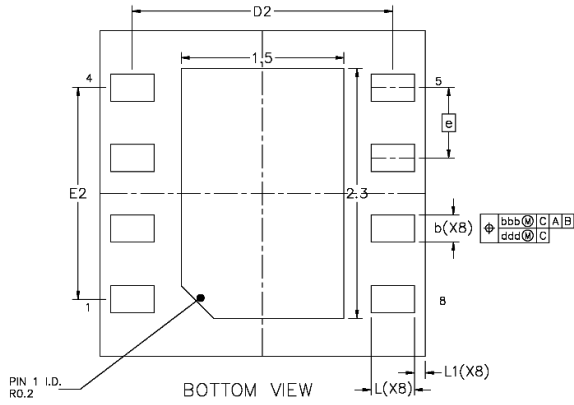
RECOMMENDED LAND PATTERN

EM3707TFL3I/EM3707ATFL3I/EM3707BTFL3I PACKAGE OUTLINE

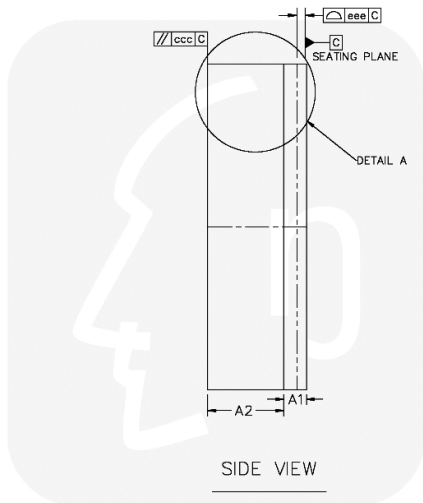
Package: FCLGA3x3-8



TOP VIEW

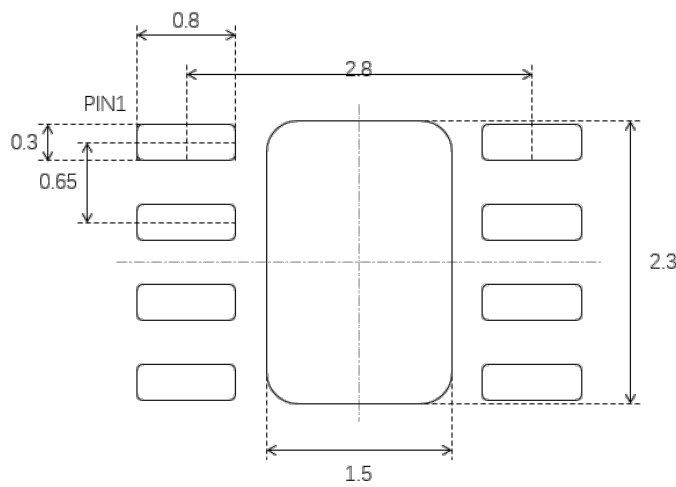


BOTTOM VIEW



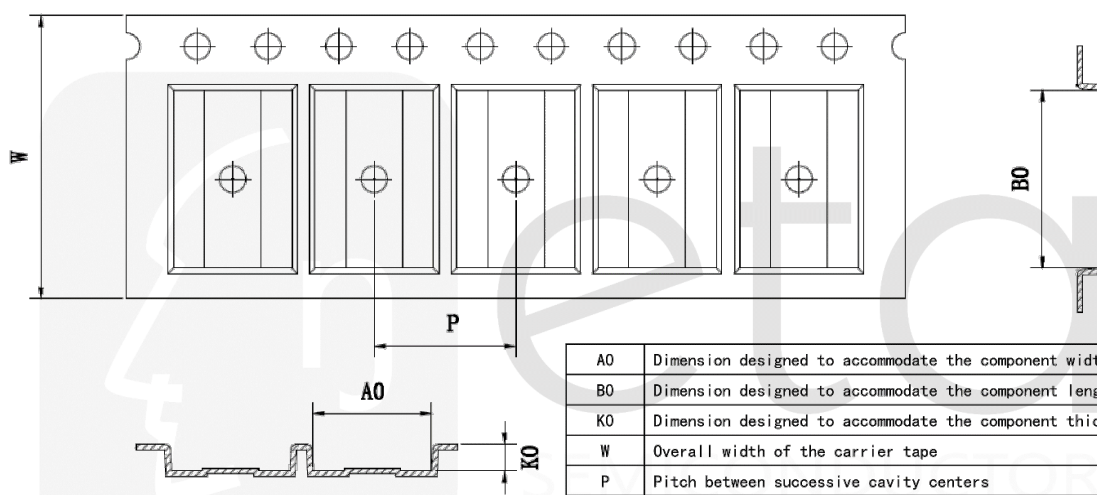
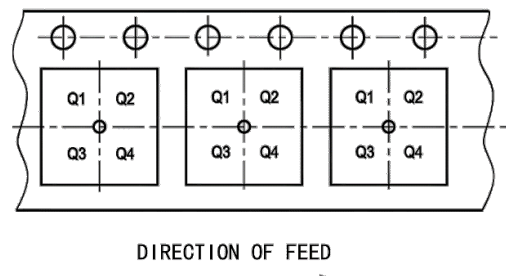
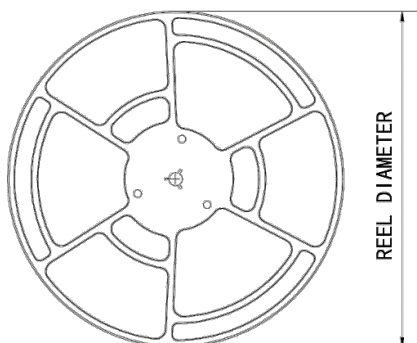
SIDE VIEW

	SYMBOL	MIN	NOM	MAX	
TOTAL THICKNESS	A	0.86	0.91	0.96	
MOLD CAP	A2	---	0.7	---	
SUBSTRATE THICKNESS	A1	0.18	0.21	0.24	
LEAD WIDTH	b	0.2	0.25	0.3	
BODY SIZE	X	D	2.9	3	3.1
	Y	E	2.9	3	3.1
LEAD PITCH	e		0.65 BSC		
EDGE PAD CENTER TO CENTER	D2		2.4 BSC		
	E2		1.95 BSC		
LEAD LENGTH	L	0.35	0.4	0.45	
LEAD TIP TO PKG EDGE	L1		0.1 REF		
PACKAGE EDGE TOLERANCE	aaa		0.1		
MOLD FLATNESS	ccc		0.1		
COPLANARITY	eee		0.08		
LEAD OFFSET	bbb		0.1		
	ddd		0.08		



RECOMMENDED LAND PATTERN

TAPE AND REEL INFORMATION



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P	Pitch between successive cavity centers

Device	Package Type	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P (mm)	W (mm)	Pin1 Quadrant
EM3707FL3I	FCLGA3x3-8	8	4000	330	12.4	3.3	3.3	1.5	8	12	Q1
EM3707TFL3I	FCLGA3x3-8	8	4000	330	12.4	3.25	3.25	1.15	8	12	Q1
EM3707AFL3I	FCLGA3x3-8	8	4000	330	12.4	3.3	3.3	1.5	8	12	Q1
EM3707BFL3I	FCLGA3x3-8	8	4000	330	12.4	3.3	3.3	1.5	8	12	Q1
EM3707ATFL3I	FCLGA3x3-8	8	4000	330	12.4	3.25	3.25	1.15	8	12	Q1
EM3707BTFL3I	FCLGA3x3-8	8	4000	330	12.4	3.25	3.25	1.15	8	12	Q1