XR5116F

3A，40V Asynchronous Step-Down Converter

DESCRIPTION

The XR5116F is a current mode monolithic buck switching regulator. Operating with an input range of 4.7-40V, the XR5116F delivers 3A of continuous output current with an integrated high side N-Channel MOSFET. At light loads, XR5116F operates in low frequency to maintain high efficiency and low output voltage ripple. Current mode control provides tight load transient response and cycle-by-cycle current limiting.

The XR5116F guarantees robustness with input under-voltage lockout, start-up current run-away protection, output short protection and thermal protection.

The XR5116F is available in SOP8 and ESOP8 package, which provides a compact solution with minimal external components.

FEATURES

- 4.7V to 40V operating input range 3A output current
- Up to 92% efficiency
- High efficiency (>78%) at light load
- Internal soft-start
- Adjustable switch frequency
- Input under-voltage lockout
- Start-up current run-away protection
- Output short protection
- Thermal protection
- Available in SOP8 and ESOP8 package

APPLICATIONS

- Distributed Power Systems
- Networking Systems
- FPGA, DSP, ASIC Power Supplies
- Green Electronics/ Appliances
- Notebook Computers

TYPICAL APPLICATION

Step Down Regulators

Efficiency@Vout=5V
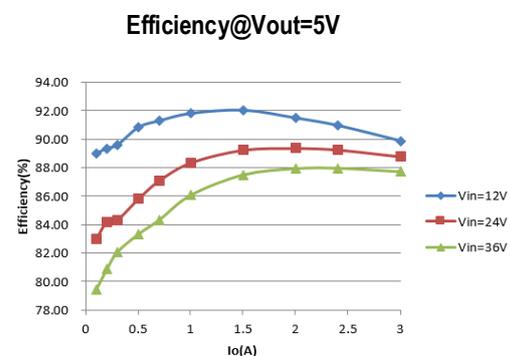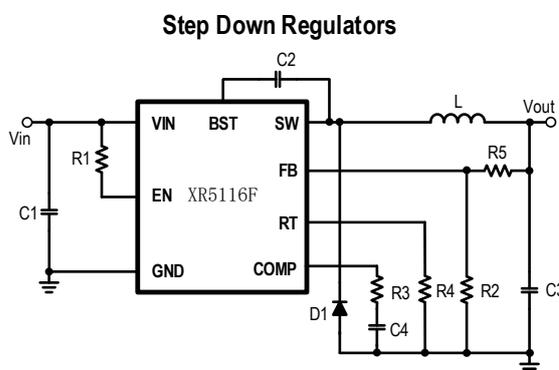
ORDER INFORMATION

DEVICE[1]	PACKAGE	TOP MARKING[2]
XR5116FSOPB#TRPBF	SOP8	XR5116F YWLLL
XR5116FESOP#TRPBF	ESOP8	XR5116F YWLLL

Notes：

1) XR [___] [___] # TRPBF
   - PB Free
   - Tape and Reel(If"TR"is not shown, it means tube)
   - Package Code
   - Part No.

2) Line1: XRPNCD — Product code

   Line2: YWLLL
   - Lot number
   - Week code
   - Year code
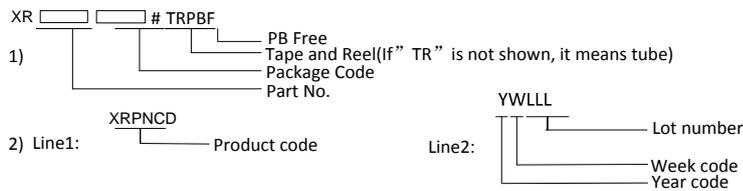
PIN CONFIGURATION

TOP VIEW

SW	1		8	BST
EN	2		7	VIN
COMP	3		6	RT
FB	4		5	GND

SOP8

ESOP8 (GND)
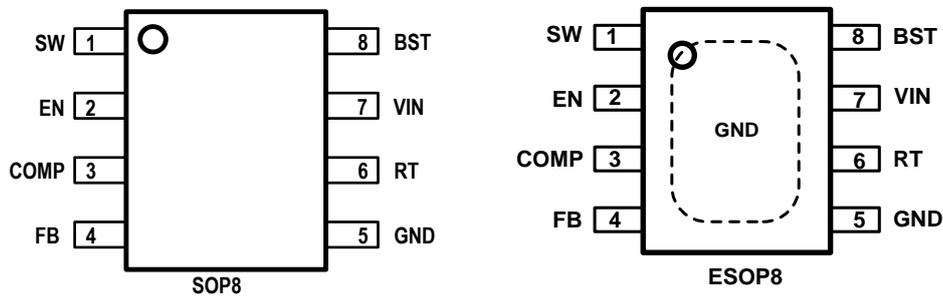
ABSOLUTE MAXIMUM RATING[1]

VIN, EN, SW Pin   .   -0.3V to 45V
BST Pin   . SW-0.3V to SW+5V
All other pins   .   -0.3V to 6V
Junction Temperature[2][3] .   150ºC
Lead Temperature   .   260ºC
Storage Temperature .   -65ºC to +150ºC

RECOMMENDED OPERATING CONDITIONS

Input Voltage VIN . ...4.7V to 40V

Output voltage Vout . ...0.8V to 37V

Operating Junction Temp.   ……..-40ºC to 125ºC

THERMAL PERFORMANCE[4] θ_{JA} θ_{Jc}

SOP8 ....……….……................…...96....45ºC/W

ESOP8 ....……….……................…..50....10ºC/W

Note：

1) Exceeding these ratings may damage the device.

2) The XR5116F guarantees robust performance from -40°C to 150°C junction temperature. The junction temperature range specification is assured by design, characterization and correlation with statistical process controls.

3) The XR5116F includes thermal protection that is intended to protect the device in overload conditions. Thermal protection is active when junction temperature exceeds the maximum operating junction temperature. Continuous operation over the specified absolute maximum operating junction temperature may damage the device.

4) Measured on JESD51-7, 4-layer PCB.

ELECTRICAL CHARACTERISTICS

Item	Symbol	Condition	Min.	Typ.	Max.	Units
V_{IN} Under-voltage Lockout Threshold	V_{IN_MIN}	V_{IN} falling	3.5	3.8	4.1	V
V_{IN} Under-voltage Lockout Hysteresis[5]	$V_{IN\_MIN\_HYST}$	V_{IN} rising		400		mV
Shutdown Supply Current	I_{SD}	$V_{EN}=0V$		1.6	5	μA
Supply Current	I_Q	$V_{EN}=5V$, $V_{FB}=1.2V$		65	100	μA
Feedback Voltage	V_{FB}	$4.7V<V_{VIN}<40V$	0.780	0.8	0.820	V
Top Switch Resistance[5]	$R_{DS(ON)T}$			63	78	mΩ
Top Switch Leakage Current	I_{LEAK_TOP}	$V_{IN}=40V$, $V_{EN}=0V$, $V_{SW}=0V$			1	uA
Top Switch Current Limit[5]	I_{LIM_TOP}	Minimum Duty Cycle	3.6	4.5		A
Error Amp Min Source Current		FB=0.4V		15		uA
Error Amp Min Sink Current		FB=1.2V		-15		uA
Switch Frequency	F_{SW}	$R_{RT}=260k$	100	160	220	kHz
Minimum On Time[5]	T_{ON_MIN}			120		ns
Minimum Off Time	T_{OFF_MIN}	$V_{FB}=0V$		150		ns
EN Shutdown Threshold	V_{EN_TH}	V_{EN} rising, FB=1V	1.0	1.3	1.6	V
EN shut down hysteresis[5]	V_{EN_HYST}	V_{EN} rising, FB=1V		100		mV
Thermal Shutdown[5]	T_{TSD}			137		°C
Thermal Shutdown Recovery Hysteresis[5]	T_{TSDR}			15		°C

Note: 5) Guaranteed by design.

PIN DESCRIPTION

PIN SOP8	PIN ESOP8	Name	Description
1	1	SW	SW is the switching node that supplies power to the output. Connect the output LC filter from SW to the output load.
2	2	EN	Drive EN pin high to turn on the regulator and low to turn off the regulator.
3	3	COMP	Compensation pin. Comp is used to compensate the regulation control loop. Connect a series RC network from COMP to GND to compensate the regulation control loop. One ceramic cap such as several tens pF is usually connected from COMP to GND to decouple the voltage noise.
4	4	FB	Output feedback pin. FB senses the output voltage and is regulated by the control loop to FB reference voltage 0.8V. Connect a resistive divider at FB.
5	5/ EP	GND	Ground.
6	6	RT	Voltage at the RT pin is regulated at 1.2V. Switch frequency of the regulator can be adjusted by connecting a resistor at the RT pin to ground.
7	7	VIN	Input voltage pin. VIN supplies power to the IC. Connect a 4.7V to 40V supply to VIN and bypass VIN to GND with a suitably large capacitor to eliminate noise on the input pin to the IC.
8	8	BST	Bootstrap pin for top switch. A 0.1uF or larger capacitor should be connected between this pin and SW pin to supply current to the top switch and top switch driver.

BLOCK DIAGRAM
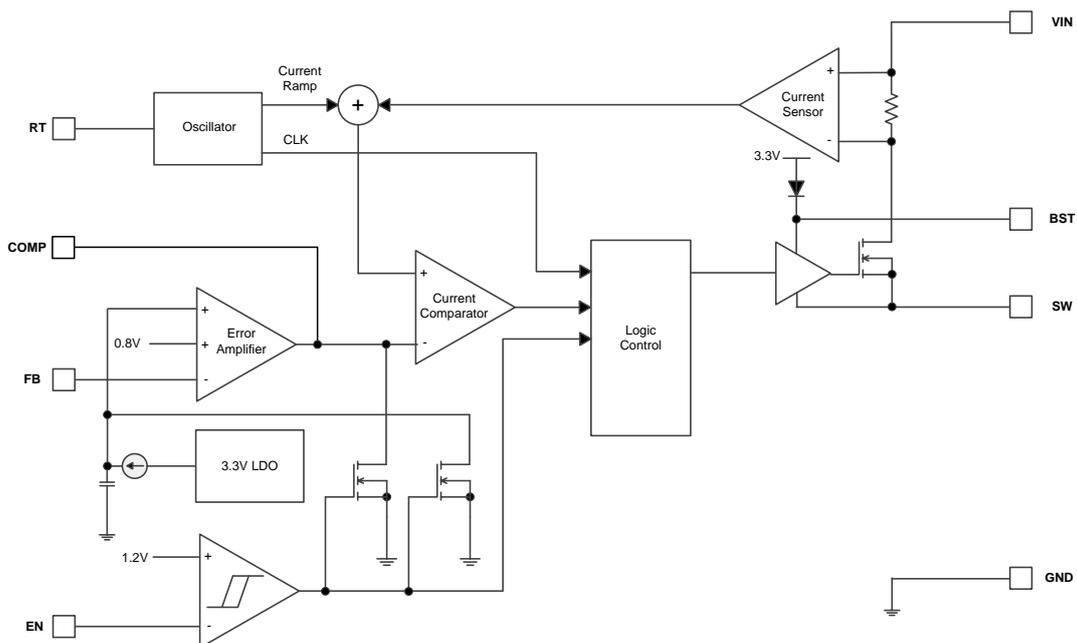
FUNCTIONAL DESCRIPTION

The XR5116F is an asynchronous, current-mode, step-down regulator. It regulates input voltages from 4.7V to 40V down to an output voltage as low as 0.8V, and is capable of supplying up to 3A of load current.

Current-Mode Control

The XR5116F utilizes current-mode control to regulate the output voltage. The output voltage is measured at the FB pin through a resistive divider and the error is amplified by the internal transconductance error amplifier. The output of internal error amplifier is compared to the switch current measured internally to control the output current limit.

PFM Mode

The XR5116F operates in PFM mode at light load. In PFM mode, switch frequency is continuously controlled in proportion to the load current, i.e. switch frequency is decreased when load current drops to boost power efficiency at light load by reducing switch-loss, while switch frequency is increased when load current rises, minimizing both load current and output voltage ripples.

Power Switch

An N-Channel MOSFET switch is integrated on the XR5116F to down convert the input voltage to the regulated output voltage. Since the top MOSFET needs a gate voltage great than the input voltage, a boost capacitor connected between BST and SW pins is required to drive the gate of the top switch. The boost capacitor is charged by the internal 3.3V rail when SW is low.

VIN Under-Voltage Protection

XR5116F can regulate a wide range input voltage down to an output voltage. If the input voltage decreases to under voltage lockout threshold, the regulator enters into UVLO protection to shutdown internal logic and function blocks.

Enable Pin

EN pin is a analog control pin that turns the regulator on and off. Drive EN pin high to turn on the regulator and drive it low to turn it off. A resistor such as 100KΩ can be connected between EN pin and VIN pin for automatic startup.

COMP Voltage

The current limit is decided by the maximum comp voltage which is around 2.5V. Comp voltage is also adjusted with the output current. The comp voltage decreases as load current drop. When comp voltage keeps the maximum value for around 12480 cycle, the over load protection is triggered. IC enters into the hiccup mode during the OLP.

Output Current Run-Away Protection

At start-up, due to the high voltage at input and low voltage at output, current inertia of output inductance can be easily built up, resulting in a large start-up output current. COMP value is limited and rise up slowly for a period of time when start up. By such control mechanism, the output current at start-up is well controlled.

Output Short Protection

When the output is shorted to ground, output current rapidly rises and if it hits the OCP (over

current protection) limit, which is 1.3A above the normal peak current limit, switch frequency is halved to allow time for the inductor current to fall to a safe level. If the OCP limit is hit again in the next cycle, switch frequency is halved again. In the extreme case, switch frequency can be decreased to 1/128 of the original frequency set by the resistor at the RT pin.

Thermal Protection

When XR5116F inner temperature rises above the Over Temperature Protection threshold, it is forced into thermal shut-down. Only when IC inner temperature drops below Over Temperature Recovery threshold can the regulator becomes active again.

APPLICATION INFORMATION

Setting the Output Voltage

The output voltage is set using a resistive divider from the output voltage to FB pin as Figure 1. The voltage divider divides the output voltage down to the feedback voltage by the ratio:

$$V_{FB} = V_{OUT} \cdot \frac{R2}{R2 + R5}$$
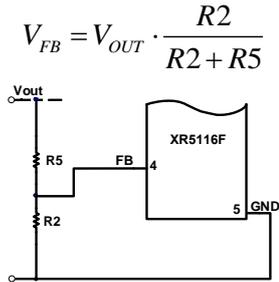
Figure 1: Output Voltage Setup

Where V_{FB} is the feedback voltage and V_{OUT} is the output voltage.

The output voltage is:

$$V_{OUT} = V_{FB} \cdot \frac{R2 + R5}{R2}$$

V_{FB} is 0.8V reference. R2 can be as high as 100KΩ, but a typical value is 10 KΩ~20 KΩ. For example, R2 is 22 KΩ, R5 is determined by:

$$R5 = 27.5 \times (V_{OUT} - 0.8)(K\Omega)$$

Operating Frequency

XR5116F working frequency can be adjusted in different application. Set the resistor connected to RT pin to setup the working frequency as Figure 2 and following expression.

$$f_s = \frac{1}{22.77 \times 10^{-12}.R_4 + 0.315 \times 10^{-6}} Hz$$
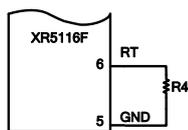
Figure 2: Operating Frequency Setup

EN Function

EN pin is a analog input that turns the regulator ON or OFF. Drive EN pin high to turn on the regulator and drive it low to turn off regulator.

Usually, pull up with 100KΩ(R1) resistor for automatic startup (R6=NC).

Low input voltage protection can be setup through EN pin to adjust the R1 and R6 as Figure 3. EN pin voltage below 1.2V to turn off XR5116F when low input voltage.
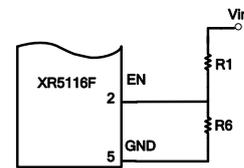

Figure 3: Input Voltage UVLO Setup

For example, Vin=12V, setup the Vin=10V to trigger the low input voltage protection.

So, R1 and R6 can be configured as R1=1MΩ and R6=136.3KΩ.

BST Capacitor

BST cap supplies the drive for the high-side N-MOSFE switch, connected from the BST pin to SW pin as Figure 4.
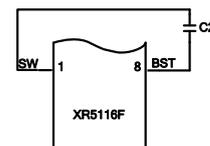

Figure 4: BST Cap

The BST cap is charged by the internal 3.3V rail when SW is low. Usually, one ceramic cap 0.1uF or greater capacitor is ok for high side MOS driver.

Compensation Loop

COMP is used to compensate the regulation control loop for system stability and transient response. Connect a series RC network

(Pole-zero combination) from COMP to GND to optimize the control loop as Figure 5.
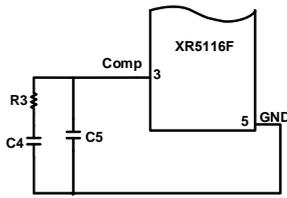

Figure 5: Compensation Loop

In some cases, an additional ceramic capacitor (C5 such as 47pF) from COMP to GND is required to eliminate the high frequency noise influence.

Normally application with 5V/3.3V output, 12V/24V input, the below table parameter is recommended.

R3 (KΩ)	C4 (pF)	C5 (pF)
50 ~200	330~1500	NC/22~100

Power Inductor

The inductor is required to supply constant current to the output load. A larger value inductor results in less current ripple and also lower output ripple. However, the larger value inductor has a larger physical size, bigger series resistance, high cost or lower saturation current.

A good rule to determining the inductance is to allow the peak-to-peak ripple current in the inductor.

It's recommended to allow inductor ripple current $\triangle I_{PP}$ of 30% maximum peak current. So we can get the proper inductor value as follow.

$$L = \frac{V_{OUT}}{f_S \cdot \Delta I_{PP}} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where V_{OUT} is output voltage, V_{IN} is input voltage, f_S is switching frequency and $\triangle I_{PP}$ is the peak-to-peak inductor ripple current.

Choose an inductor that will not be saturate under the maximum inductor peak current. The peak inductor current can be calculated by following expression:

$$I_{LP} = I_{OUT} + \frac{V_{OUT}}{2 \cdot f_S \cdot L} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where I_{OUT} is the load current.

Freewheel Diode

Freewheel diode supply the current route when high side MOS turns off. The system efficiency is worse if the forward voltage drop is high. So, this diode is recommended to use the schottky diode with lower forward voltage drop to improve overall efficiency.

For example, the B540 (5A/40V) schottky diode performs well in application.

Input Capacitor

Use low ESR capacitors for the best performance. Ceramic capacitors are preferred, but tantalum or low-ESR electrolytic capacitors may also suffice. It's recommended to choose X5R or X7R dielectrics when using ceramic capacitors.

The RMS current in the input capacitor can be estimated by following expression:

$$I_{C1} = I_{OUT} * \sqrt{\frac{V_{OUT}}{V_{IN}} * \left(1 - \frac{V_{OUT}}{V_{IN}}\right)}$$

Choose the input capacitor whose RMS current rating greater than I_{C1}.

Input voltage ripple for low ESR capacitors can be estimated as follow:

$$\Delta V_{IN} = \frac{I_{OUT}}{f_S * C_1} * \frac{V_{OUT}}{V_{IN}} * \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

It should increase the input capacitor if the input voltage ripple is big. Besides, one ceramic cap such as 0.1uF is suggested to be placed as close to the IC as possible.

Output Capacitor

The output capacitor is required to maintain the DC output voltage. The output voltage ripple can be estimated by following.

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S * L} * \left(1 - \frac{V_{OUT}}{V_{IN}}\right) * \left(R_{ESR} + \frac{1}{8 * f_S * C_3}\right)$$

Where C_3 is the output capacitance value and R_{ESR} is the equivalent series resistance (ESR) value of the output capacitor.

Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low.

PCB LAYOUT

PCB layout is very important to achieve stable operation. It is highly recommended to duplicate EVB layout as follow these guidelines.

1. Keep the path of switching current short and minimize the loop area formed by input cap, high-side MOSFET and freewheel diode.

2. Bypass ceramic capacitors are suggested to be put close to the Vin Pin.

3. Ensure all feedback connections are short and direct. Place the feedback

resistors and compensation components as close to the chip as possible.

4. Route SW away from sensitive analog areas such as FB.

5. Connect VIN, SW, and especially GND respectively to a large copper area to cool the chip to improve thermal performance and long-term reliability. The 2os copper thickness is suggested for better thermal performance in real application.
Figure 6 is the PCB layout reference.
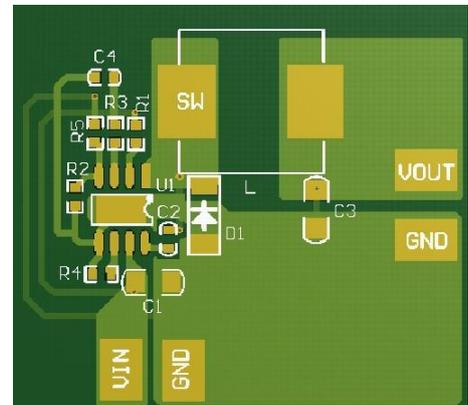

Figure 6: PCB Layout Reference

REFERENCE DESIGN

Reference 1:

Vin: 8V~36V

Vout: 5V

Iout: 0~3A
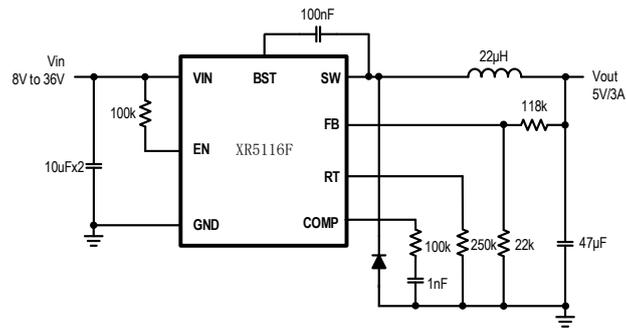
Reference 2:

Vin: 5V~36V

Vout: 3.3V

Iout: 0~3A
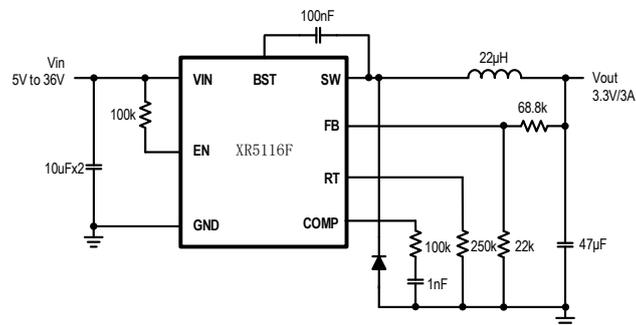
PACKAGE OUTLINE

SOP8				UNIT: mm
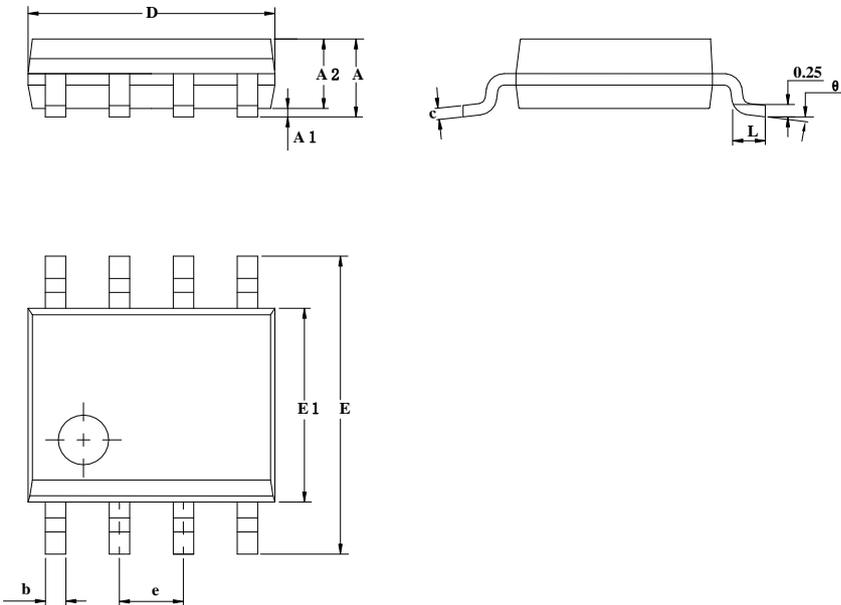
Symbol	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.75
A1	0.05	0.15	0.25
A2	1.25	1.40	1.65
b	0.32	0.42	0.52
c	0.10	0.20	0.30
D	4.50	5.00	5.50
E	5.50	6.00	6.50
E1	3.50	3.90	4.30
e	1.27TYP		
L	0.40	—	1.27
θ	0°	—	8°

ESOP8   UNIT: mm

0.42±0.10

6.0±0.5

1.27TYP

TOP VIEW

Plated-Thru Holes
(0.38Dia,0.76Pitch)

3.81

3.56

7.62

2.03

1.27

0.51
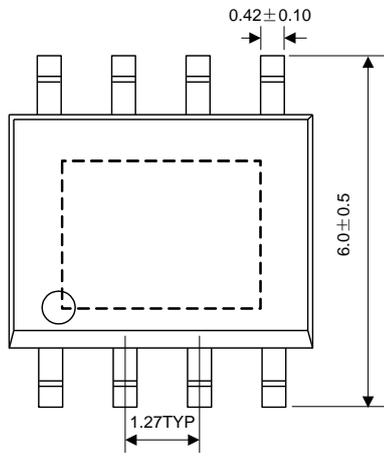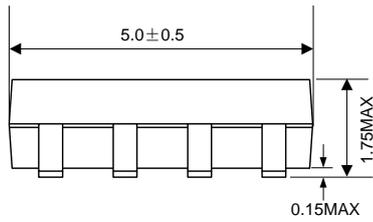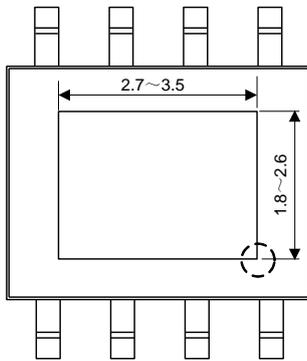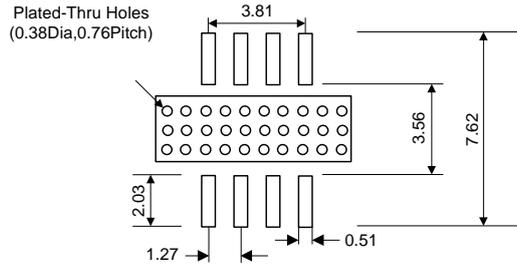
RECOMMENDED LAND PATTERN

5.0±0.5

1.75MAX

0.15MAX

FRONT VIEW

SEE DETAIL "A"

3.9±0.4

0.20±0.10

SIDE VIEW

2.7~3.5

1.8~2.6

BOTTOM VIEW

0.25~0.50

0.25

0~8°

0.4~1.27

DETAIL "A"