

## MK2786L Wide VCC Range HF QR Controller with GaN Integrated

### 1. Description

The MK2786L is a high frequency QR controller optimized for PD/Fast charge applications. Its wide VCC operating voltage range (9V-85V) allows it to cover PD/PPS from 3.3V-21V output range without the need to use additional VCC windings or linear step-down circuits.

In order to achieve high efficiency from universal line across different load, the MK2786L is self-adaptive to operate at DCM/QR. At light load, it will work in Burst mode to improve efficiency.

The MK2786L offers various protection features including output over-voltage protection (OVP), output over power protection (OPP), input bus over-voltage protection(LOVP), VCC over-voltage protection, Brown in/out, Secondary side SR short circuit protection (SSCP), and CS short protection.

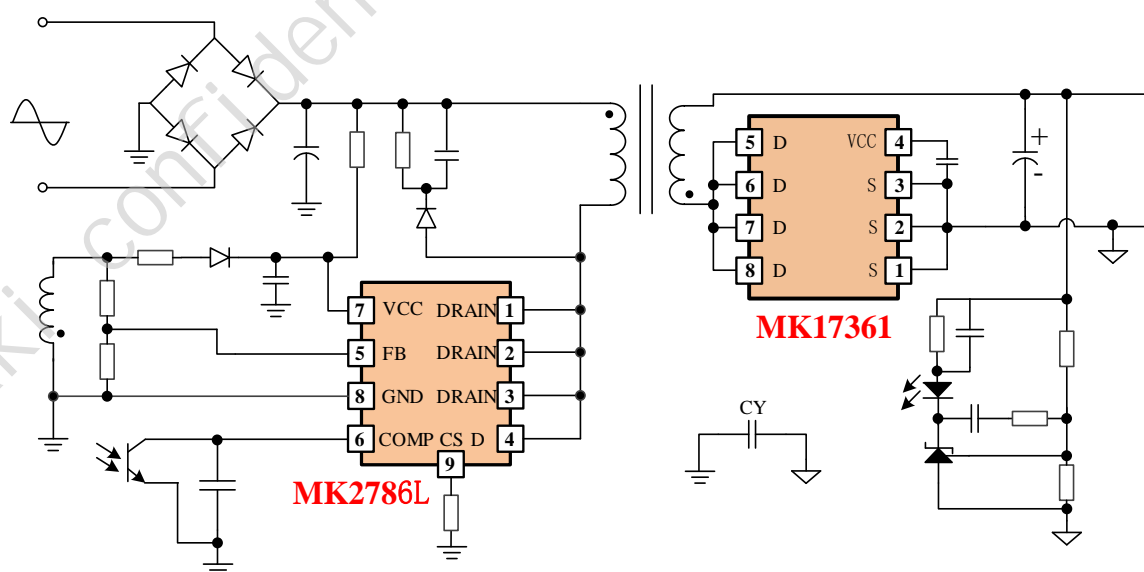
### 2. Typical Applications

- 20W AC/DC PD/Adapter
- High Power Density Power Supply

### 3. Features

- Built-in 700V 1 $\Omega$  GaNFET
- Wide VCC Operating Range(9V-85V)
- Operating Frequency up to 130kHz
- Proprietary Soft-start Scheme to Achieve Low SR Vds Stress
- Optimized Efficiency to Easily Meets Energy Efficiency Standards
- CS Short Protection
- OPP/SSCP Protection
- Brown in /Brown out Function
- Line OVP Function
- VCC OVP/VO OVP Protection
- Support PPS Wide Range Output
- Tiny ESOP-8 Package

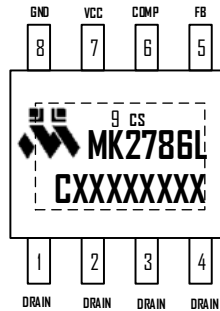
### 4. Simplified Application



## 5. Ordering Information

Ordering No.	Description
MK2786LCAD	ESOP-8, 4000 pcs/reel

## 6. Package Reference



**XXXXXXXXX: Lot Code**  
**ESOP-8 Top View**

## 7. Specifications

### 7.1 Absolute Maximum Ratings<sup>(1)</sup>

VCC.....	-0.3V to +100V
COMP, FB.....	-0.3V to +5.5V
CS.....	-0.7V to +5.5V
DRAIN.....	-3V to +700V
I <sub>D</sub> .....	1.4A <sup>(2)</sup>
I <sub>DM</sub> .....	3A <sup>(3)</sup>
Junction Temperature .....	+155°C

### 7.2 Recommended Operation Conditions

VCC .....	9V to 85V
Maximum Junction Temperature (T <sub>J</sub> ).....	+125°C

### 7.3 Thermal Resistance<sup>(4)</sup>

θ <sub>JA</sub> .....	58 °C/W
θ <sub>JC</sub> .....	3 °C/W

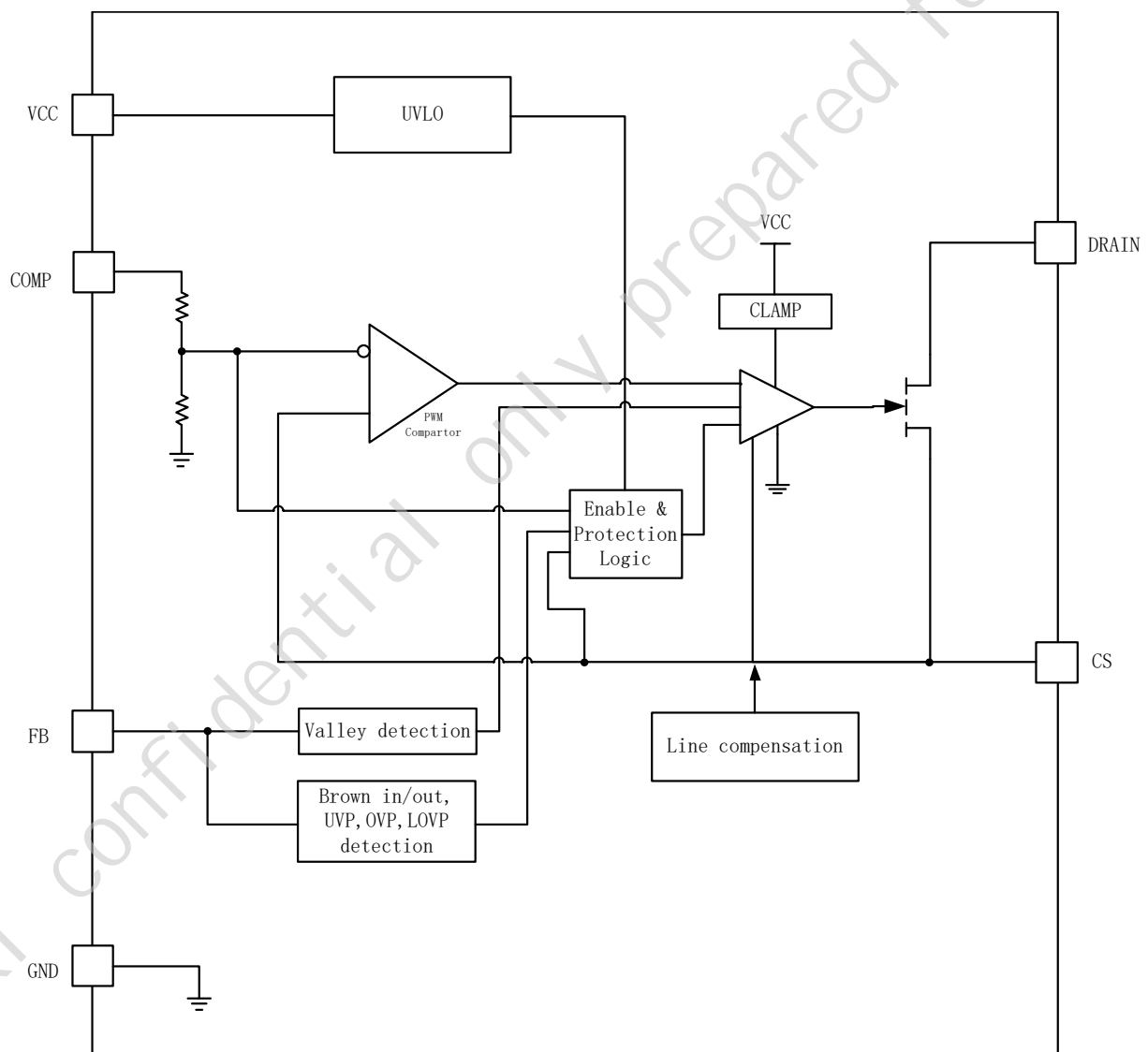
#### Notes:

- (1) Exceeding these ratings may damage the device;
- (2) T<sub>J</sub>=125°C, The maximum continuous drain current is calculated based on the maximum allowable junction temperature;
- (3) T<sub>C</sub>=25°C, Pulse≤10us; Limit was extracted from characterization test, not measured during production;
- (4) Measured on JESDSD51-7, 4 layers PCB.

## 8. Pin Functions

Pin #	Name	Description
1、2、3、4	DRAIN	HV Power GaN Drain
5	FB	Auxiliary Winding Voltage Sense
6	COMP	Control Loop Voltage Feedback
7	VCC	Power Supply
8	GND	Ground
9	CS	Current Sense Input

## 9. Block Diagram



**Figure 1. Functional Block Diagram**

## 10. Electrical Characteristics

VCC=12V, T<sub>A</sub>=25°C, unless otherwise noted.

Parameter	Symbol	Conditions	Min	Typ	Max	Units
<b>GaN Section</b>						
Maximum Drain Voltage	V <sub>DS_max</sub>		700			V
Static Drain to Source on Resistance	R <sub>DS(on)</sub>	I <sub>D</sub> =1A		1.0	1.2	Ω
<b>Supply Management Section</b>						
VCC UVLO Rising	V <sub>CC_ON</sub>		15.5	17.2	19.9	V
VCC UVLO Falling	V <sub>CC_OFF</sub>		6	7.2	8.4	V
VCC UVLO Hysteresis	V <sub>CC_HYST</sub>			10		V
VCC Startup Current	I <sub>STARTUP</sub>		2	5	8	uA
VCC Normal Operating Current	I <sub>OP</sub>	COMP=2V	0.3	0.45	0.6	mA
Burst Operating Current	I <sub>BURST</sub>	COMP=0V, GATE=1nF to GND	240	290	340	uA
VCC Hold Threshold	V <sub>CC_HOLD</sub>		7	8	9.5	V
VCC OVP Threshold	V <sub>CC_OVP</sub>		88	93	100	V
VCC Clamp Threshold	V <sub>CC_CLAMP</sub>		89	102	110	V
<b>Comp Input Section</b>						
COMP Open Voltage	V <sub>COMP_OP</sub>	COMP Pin Open-circuited	4	4.4	4.8	V
COMP Short-circuit Current	I <sub>COMP_SHOR</sub> T	COMP=0V	130	160	190	uA
Burst Mode Entry Voltage	V <sub>BM_ET</sub>		0.27	0.3	0.33	V
Burst Mode Hysteresis	V <sub>BM_HY</sub>			0.05		V
OPP Protection Threshold	V <sub>OPP</sub>		2.8	3.0	3.2	V
OPP Deglitch Time*	T <sub>D_OPP</sub>			T <sub>SS</sub> *6		ms
<b>Current Sense Input Section</b>						
Soft Start Time of CS Threshold	T <sub>SS</sub>		4	7	10	ms
Secondary Rectifier Short-circuit trigger voltage (OC FAULT)	V <sub>SR_SH</sub>		1.1	1.2	1.3	V
SR Short-circuit Deglitch cycles*				3		cycles
Cycle by Cycle Current Limit	V <sub>CS_CBC</sub>	V <sub>FB</sub> <1V, I <sub>FB</sub> =100uA	0.79	0.85	0.91	V

Cycle by Cycle Current Limit	$V_{CS\_CBC}$	$V_{FB} < 1V, I_{FB} = 300\mu A$	0.56	0.63	0.7	V
CS Short Protection Threshold	$V_{CS\_SH}$			0.05		V
CS Short Deglitch cycles*	$T_{CS\_SH}$			3		cycles
<b>FB Input Section</b>						
Brown-in Detection Threshold	$I_{BNI}$		78	94	109	$\mu A$
Brown-out Detection Threshold	$I_{BNO}$		69	85	100	$\mu A$
Brown-out Deglitch Time*	$T_{BL\_BNO}$			$T_{SS} * 7$		ms
Line OVP Detection Threshold	$I_{OVP}$		368	410	452	$\mu A$
Line OVP Detection Time*	$T_{L\_OVP}$			$T_{SS} * 14$		ms
FB OVP Threshold	$V_{FB\_OVP}$		3.3	3.6	3.9	V
FB OVP Deglitch Time*	$T_{BL\_OVP}$			7		
FB UVP Threshold (Output Short)	$V_{FB\_ST}$		0.17	0.2	0.23	V
FB UVP Threshold (Output Short) Deglitch Time*	$T_{BL\_ST}$			7		cycles
UVP Blanking Time after SS*	$T_{D\_ST}$			$T_{SS} * 2$		ms
FB High Threshold	$V_{FB\_H}$		1.7	1.9	2.1	V
FB Middle Threshold	$V_{FB\_M}$		1	1.1	1.2	V
<b>Control Law</b>						
Normal Mode Frequency	$F_{SW\_max}$		110	130	150	kHz
Green Mode Frequency	$F_{SW\_green}$		21	25	29	kHz
Dithering Range*				$\pm 6$		%
Dithering Period*				8		ms
Maximum Toff Time	$T_{off\_MAX}$		80	110	140	$\mu s$
Thermal Shutdown Threshold*	$Th_{SD}$			165		$^{\circ}C$
Thermal Shutdown Hysteresis*	$Th_{SD\_hys}$			30		$^{\circ}C$

**Note:**

\* Guaranteed by design

## 11. Operation Descriptions

### Vcc and Startup

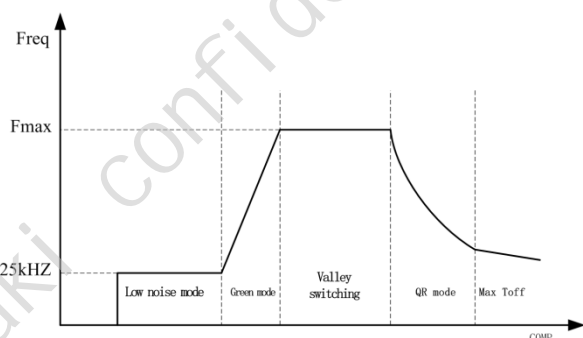
The MK2786L's start-up current  $I_{STARTUP}$  is approximately only 5uA. Therefore, a large value of start-up resistor can be used to charge up VCC while minimizing power loss during start-up. Once VCC surpasses the  $V_{CC\_ON}$  threshold, approximately 17.2V, the MK2786L begins switching.

### Soft Start

The MK2786L incorporates an internal  $T_{SS}$  (soft-start) with a duration of approximately 7ms to mitigate electrical stress in the power system during start-up. Additionally, to minimize voltage stresses resulting from high peak current and high-frequency switching, the MK2786L operates at optimized frequencies and control modes tailored to the output voltages and the start-up status of the synchronous rectifier controller.

### Operation Curve

The MK2786L has multiple working modes, which can be switched by monitoring the voltage change of COMP. Since the COMP voltage changes in the same direction as the load variation, the IC can automatically switch to the optimal operating mode based on different load conditions. Figure 2 illustrates the switching characteristics of the MK2786L operating modes.



**Figure 2: operation curve**

### Brown in, Brown out and Line OVP

When the power GaN is turned on, the voltage at auxiliary windings is negative, which makes

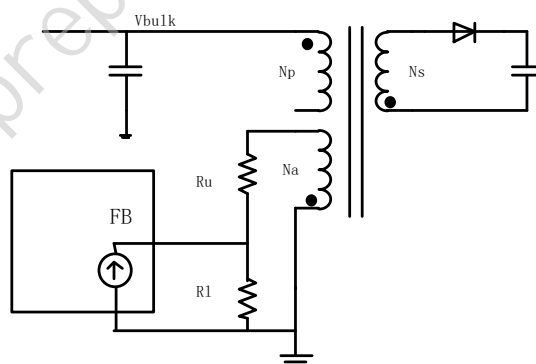
Brown-in/Brown-out protection feasible by detecting the current at FB pin. When the system starts up, and the power GaN is turned on, the current flowing out of FB pin is equal to:

$$\frac{V_{BULK} * N_a}{R_u * N_p}$$

If this current is larger than  $I_{BNI}$  for four switching cycles, the controller enables soft start. Otherwise Brown-in restart protection is triggered.

During normal operation, if the current at FB is less than  $I_{BNO}$  for at least  $T_{BL\_BNO}$  (~49ms), the controller enters Brown-out restart protection.

During the increase in input voltage, if the current at FB is more than  $I_{OVP}$  for fourteen soft start times (~98ms), the controller enters Line OVP restart protection.



**Figure 3: Brown in/Brown out**

## Current Sense

The MK2786L is a current mode PWM controller. The voltage detected on CS pin is compared with the voltage loop feedback voltage inside the chip to determine the duty ratio. When COMP is at its maximum, the MK2786L also limits the peak current of the primary edge every switching cycle, and its maximum current limit value is  $V_{CS\_CBC}/R_{CS}$ .

Due to the voltage of the drive current on the CS resistance and the influence of the converted capacitor  $C_{SW}$  on the drain node, there will be a spike in the CS resistance at the moment when the drive is switched on. This spike could trigger PWM controller to falsely generate very narrow duty cycle pulse. Therefore, the leading-edge blanking time  $\sim 300\text{ns}$  was added to the CS sampling circuit inside the chip.

## Line Compensation

The MK2786L uses the detected input line voltage through the current at FB pin to generate the offset voltage added on internal current signal to compensate the output OPP power level. This mechanism helps to achieve flat OPP power level over different input voltage.

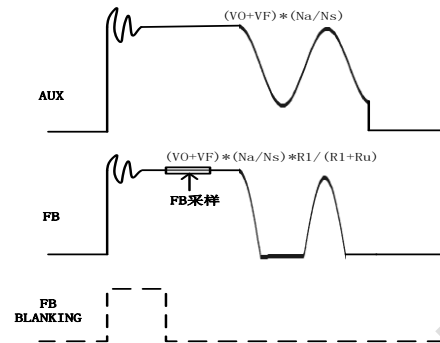
## Voltage Feedback Loop

COMP is the voltage loop feedback pin which is connected to TL431's output through opto-coupler. In order to support a wide COMP range, a ratio of 1/2.5 resistor divider is used before it goes into PWM comparator.

A ceramic capacitor is suggested to be placed parallel to the resistor which is series with opto-coupler diode.

## FB Voltage Detection

The MK2786L detects the transformer core demagnetization by monitoring the signal at the auxiliary windings through FB pin.



**Figure 4:FB detection**

After a period of demagnetization time of the transformer, the FB sampling voltage is compared with different thresholds. The MK2786L can complete the following functions:

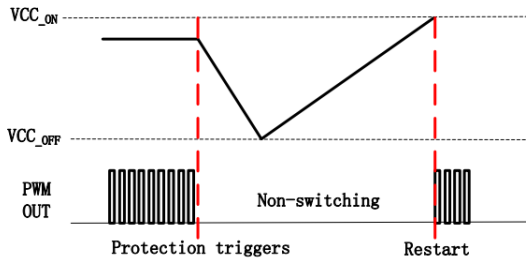
1. Output over voltage protection (OVP): FB is above  $V_{FB\_OVP}$  ( $\sim 3.6\text{V}$ ) for 7 switching cycles;
2. Output under voltage protection (output short circuit protection): FB is below  $V_{FB\_ST}$  ( $\sim 0.2\text{V}$ ) for 7 switching cycles;
3. Based on the detected output voltage, the operating control curve is determined.

## Valley Switching

After secondary side rectification is complete, the drain voltage starts oscillating with a frequency of approximately  $\frac{1}{2} \pi \sqrt{C_{OSS} \times L_p}$ , where  $L_p$  is the inductance of primary winding of the transformer and  $C_{OSS}$  is capacitance on the drain of primary GaN. When the oscillation ringing is below 0V at the auxiliary winding, the MK2786L clamps the FB pin to 0V, and senses the current at the FB pin. When the current out of FB reaches a designed value, a “possible” valley is locked and the MK2786L turns on after propagation delay.

## Protection Function

Reliable power supply system is achieved with restart protections including cycle-by-cycle current limit, over-power protection (OPP), output over-voltage protection, etc. Detailed protection features are described in the following sessions.



**Figure 5: Restart mode**

MK2786L PROTECTION FEATURES	MK2786L PROTECTION SCHEMES
OPP	RESTART
VO_OVP	RESTART
VCC_OVP	RESTART
CS_SHORT	RESTART
SSCP	RESTART
FB_UVP (VO_SCP)	RESTART
Line_OVP	RESTART

### Over Power Protection

The OPP protection is achieved by monitoring COMP voltage. If COMP voltage is above  $V_{OPP}(\sim 3V)$  for at least 6 times of soft-start time, i.e.  $T_{ss} \times 6(\sim 42ms)$ , the MK2786L enters restart mode.

### Cycle by Cycle Current Limiting

The current-mode control chip continuously compares the CS signal with the COMP signal cycle-by-cycle. However, during an output short circuit or an open opto-coupler fault, the COMP voltage can rise excessively, leading to high peak currents and transformer saturation. To mitigate this, the MK2786L implements an additional protection scheme, which compares the CS voltage with  $V_{CS\_CBC}$  cycle-by-cycle. After the blanking time of approximately 300ns, if the CS

voltage reaches  $V_{CS\_CBC}$ , the chip immediately halts the drive output.

### Secondary Side SR Short Circuit Protection

If the secondary side synchronous rectifier experiences a short circuit, the peak current significantly increases after the power GaN is turned on. Therefore, the protection circuit is needed to react with a shorter response time. The MK2786L reduces the current sense blanking time to 90ns when the CS pin detects a voltage exceeding the  $V_{SR\_SH}$  threshold ( $\sim 1.2V$ ), and immediately halts the current output. If this condition persists for three consecutive cycles, the MK2786L identifies a secondary SR short circuit. It ceases driving and enters restart mode.

### CS Short Protection

If CS still fails to reach  $V_{CS\_SH}(\sim 0.05V)$  after 5us of primary GaN turning on, the MK2786L will force drive shutdown. If this condition occurs for three consecutive periods, the MK2786L enters restart mode.

### Vcc OVP

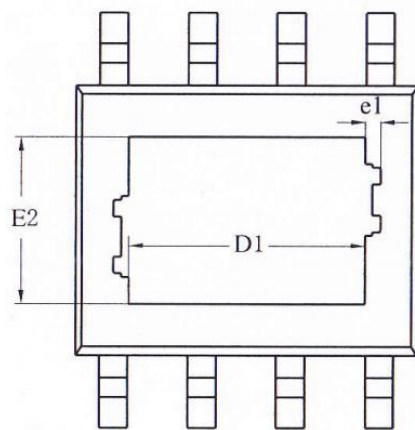
Whenever the VCC voltage is higher than the OVP threshold voltage  $V_{CC\_OVP}(\sim 93V)$ , the output gate drive circuit will be shut down to stop the switching of the power GaN, and the MK2786L enters restart mode.

### OTP

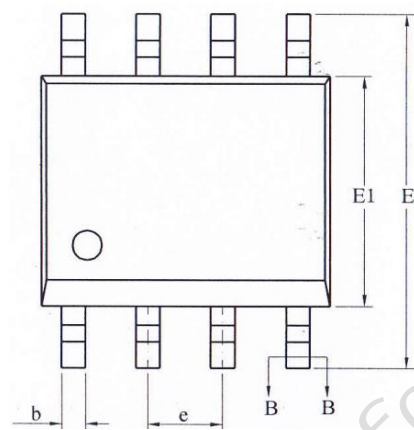
The MK2786L provides internal over-temperature protection with a trigger point of  $\sim 165^{\circ}C$  and a hysteresis temperature of  $\sim 30^{\circ}C$ .



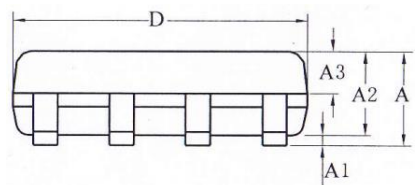
## 12. Package Information (ESOP-8)



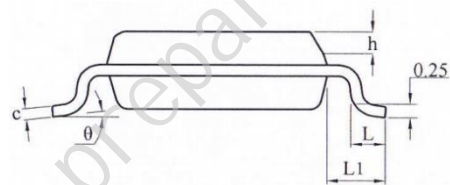
**BOTTOM VIEW**



**TOP VIEW**



**FRONT VIEW**



**SIDE VIEW**

Symbol	Dimensions In Millimeters		
	MIN	NOM	MAX
A	-	1.50	1.65
A1	0.05	-	0.15
A2	1.30	1.40	1.50
b	0.39	-	0.47
c	0.20	-	0.24
D	4.80	4.90	5.00
E	5.80	6.00	6.20
E1	3.80	3.90	4.00
D1	3.1REF		
E2	2.21REF		
e	1.27(BSC)		
L	0.5	-	0.8
$\theta$	0°	-	8°

**Note:**

(1) Unit: Millimeter(mm)