High Efficiency Offline PWM Controller with Wide VCC Range

1. Description

MK2687L is a highly integrated multiple-mode PWM controller for high performance, low standby current and cost-effective offline flyback converter applications.

In order to achieve high efficiency from universal line across different load, MK2687L is self-adaptive to operate at DCM/QR/CCM optimally. At light load, it works in Burst mode to improve efficiency. In response to the need for peak power of audio loads, MK2687L provides the Peak Load function.

MK2687L offers comprehensive protection features including output over-voltage protection (OVP), output over power protection (OPP), VCC over-voltage protection, Line over-voltage protection and Secondary side SR short circuit protection, Pin OPEN/SHORT protection.

MK2687L is available in SOT23-6 package.

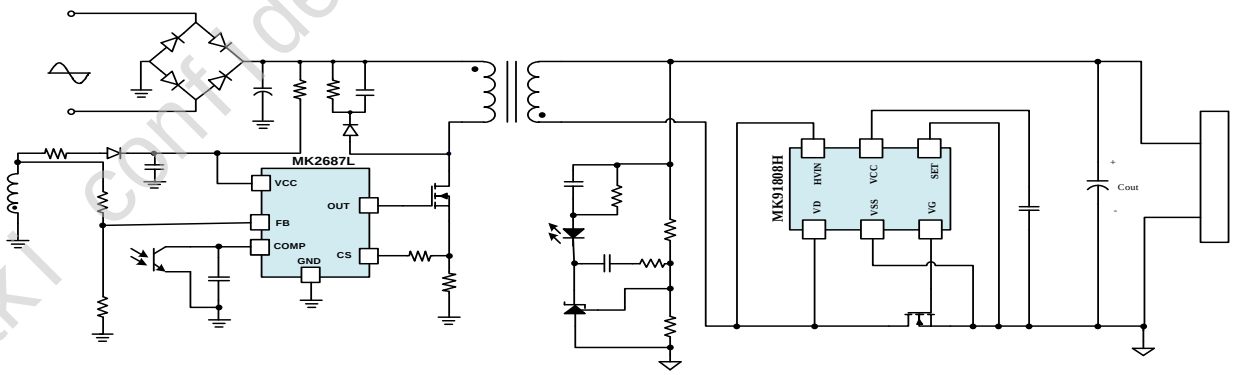
2. Typical Applications

- AC/DC PD adapter
- AC/DC general power supply

3. Features

- Wide VCC operating range
- Adaptive Multi-mode control optimized for different output voltages and load currents
- Proprietary soft-start scheme to achieve low SR Vds stress
- Optimized efficiency - easily meets energy efficiency standards
- Peak Load mode
- OCP/OPP/SSCP protection
- Line OVP function
- VCC OVP protection
- PIN OPEN/SHORT protection
- External programmable OTP protection
- Support PPS wide range output
- Frequency dithering to improve EMI performance
- SOT23-6 Package

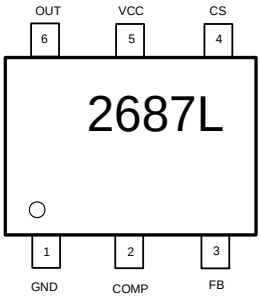
4. Simplified Application



5. Ordering Information

Ordering No.	Description
MK2687LGSA	SOT23-6,3000pcs/reel

6. Package Reference



SOT23-6

7. ESD Performance

		Value	Units
Electrostatic discharge V_{ESD}	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001	±2000	V
	Charged device model (CDM), per JEDEC specification JESD22-C101	±1000	V

Notes:

(1) According to the requirements of the JEDEC JEP155 standard, the human body model (HBM) ESD level required for standard safety production is 500V

(2) According to the requirements of the JEDEC JEP157 standard, the component charging model (CDM) ESD level required for standard safety production is 250V

Absolute Maximum Ratings *(1)*

VCC..... ...–0.3V to +100V
COMP, FB..... –0.3V to +5.5V
CS.....-0.7V to +5.5V
OUT.....–0.3V to +20V
Operating Junction Temperature (T_J)-40℃to +150℃
Soldering
Temperature(10s) .....260℃

Recommended Operation Conditions

VCC .....10V to 88V
Maximum Junction Temp. (T_J) ...-40-+125°C

Thermal Resistance *(2)*	θ_{JA}	θ_{JC}
SOT23-6.....	100	66 °C/W

Notes:

(1) Exceeding these ratings may damage the device.

(2) Measured on JESDSD51-7, 4 layers PCB

8. Electrical Characteristics

TA=25°C, VCC=13V unless otherwise noted.

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Supply Management Section						
VCC UVLO rising	V_{CC_ON}	VCC rises to turn on	15.5	17	19.5	V
VCC UVLO falling	V_{CC_OFF}	VCC falls to turn off	6.9	7.5	8.5	V
VCC UVLO hysteresis	V_{CC_HYST}			9.5		V
VCC HOLD threshold	V_{CC_HL}		V_{CC_OFF} +0.3	V_{CC_OFF} +0.5	V_{CC_OFF} +1	V
VCC startup current	$I_{STARTUP}$	VCC=15V	2	4	10	uA
VCC normal operating current	I_{OP}	COMP=2V, FB=150uA, CS=1V, GATE=1nF to GND	1	1.4	1.9	mA
Burst operating current	I_{BURST}	COMP=0V, GATE=1nF to GND	240	290	340	uA
VCC OVP threshold	V_{CC_OVP}		89	93	98	V
VCC clamp threshold	V_{CC_CLAMP}		89	103	110	V
Comp Input Section						
COMP open voltage	V_{COMP_OP}	COMP pin open-circuited	4	4.4	4.7	V
COMP short-circuit current	I_{COMP_SHORT}	COMP=0V	130	160	190	uA
Burst mode entry voltage	V_{BM_ON}		0.3	0.35	0.4	V
Burst mode end voltage	V_{BM_OFF}		0.25	0.3	0.35	V
OPP protection threshold	V_{OPP}		3.4	3.6	3.8	V
OPP deglitch time(1)	T_{D_OPP}			Tss*9		ms
COMP to CS gain	A_{VCS}		2.3	2.5	2.7	V/V
Current Sense Input (CS Pin) Section						
Soft start time of cs threshold	T_{SS}		4	7	10	ms
Secondary rectifier short circuit trigger voltage (OC FAULT)	V_{SR_SH}			1.2		V
SR short circuit deglitch cycles(1)	T_{SR_SH}			3		Cycles
Cycle by cycle current limit	V_{CS_CBC}	V_{FB}<1V, I_{FB}=100uA	0.72	0.77	0.82	V
Slope compensation saturation voltage	V_{SLOPE}	Duty=75%	200	300	400	mV
FB Input Section						
Valley detection threshold	I_{FB_VALLEY}		5	10	25	uA

Line ovp detection threshold	$I_{\_OVP}$		340	370	410	uA
Line ovp deglitch time	T_{L_OVP}			100		ms
Fb ovp threshold	V_{FB_OVP}		3.4	3.6	3.8	V
Fb uvp threshold (output short) (1)	V_{FB_ST}		0.25	0.3	0.35	V
Fb uvp threshold (output short) deglitch time(1)	T_{BL_ST}			7		cycles
Uvp blanking time after ss	T_{D_ST}			Tss*2		ms
Fb sampling time	T_{SAMPL}	CS=0.5V	1.8	2.2	2.6	us
Fb medium threshold	V_{FB_M}		0.9	1	1.1	V
Fb high threshold	V_{FB_H}		1.9	2.05	2.2	V
Gate Drive (OUT Pin) Section						
Gate low level	V_{G_L}			0.2	0.5	V
Gate high level	V_{G_H}		9	9.6	10.2	V
Gate clamp voltage(1)	V_{G_HC}	VCC>15V	10.5	11.3	12	V
Gate rising time	T_R	Cload=1nF	200	250	400	ns
Gate falling time	T_R	Cload=1nF	10	25	60	ns
Control Law						
Normal mode frequency	F_{SW_NOM}	1.3<COMP<2.6V,V_{FB}>2V	60	65	70	kHz
Peak load mode frequency	F_{SW_PEAK}	COMP>2.9V,V_{FB}>2V	110	130	150	kHz
Green mode frequency	F_{SW_GREEN}		21	26	30	kHz
Dithering range(1)				±6		%
Dithering period(1)				8		ms
Maximum duty cycle	D_{MAX}		74	77	80	%
Thermal Shutdown Threshold(1)	Th_{SD}			155		℃
Thermal Shutdown Hysteresis(1)	Th_{SD_hys}			30		℃

Notes:

1. Values are verified by characterization on bench, not tested in production
2. Optional function

9. Block Diagram

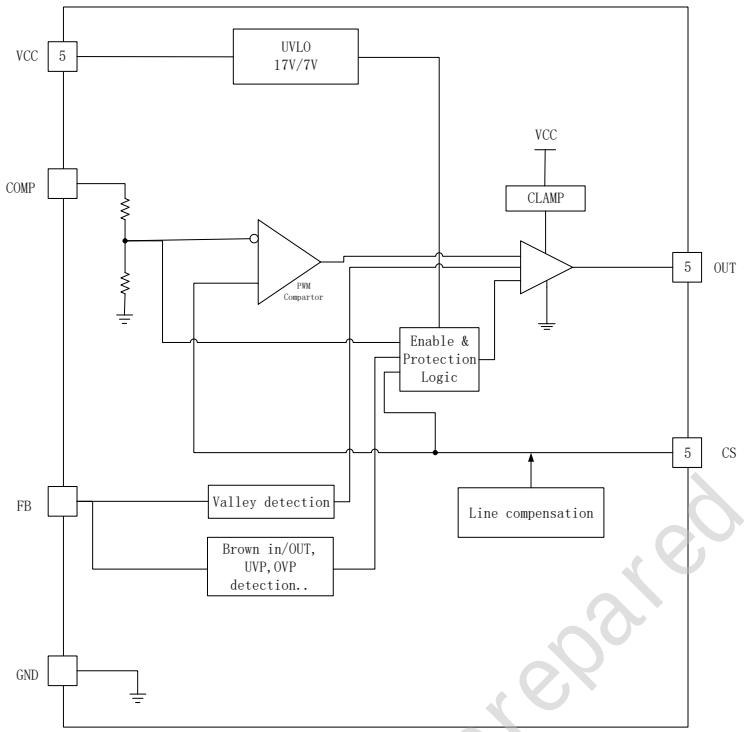


Figure 1 Functional Block Diagram

10. Pin Functions

Pin#	Name	Description
1	GND	Ground
2	COMP	Voltage feedback pin
3	FB	Auxiliary voltage sense
4	CS	Current Sense input
5	VCC	Power supply
6	OUT	Output to drive MOSFET

11. Operation Descriptions

VCC And Start-up

MK2687L's start-up current is only ~4 uA so that a large value of start-up resistor can be used to charge up VCC, while minimize power loss during start-up. Once VCC reaches above UVLO threshold V_{CC_ON}, MK2687L starts switching.

Soft Start

MK2687L features an internal ~7ms soft-start to reduce electrical stress in power system during start-up. In order to reduce the voltage stresses from high peak current and high frequency switching further, MK2687L operates at optimized frequencies and control modes accordingly to output voltages and synchronous rectifier controller start-up status.

Oscillator Frequency

For PD applications, the chip has different operating frequency curves at different output voltages. The chip detects the FB pin voltage during the secondary side freewheeling period to determine the output voltage and uses different frequency curves to optimize the efficiency of each output voltage point.

In order to improve the impact of EMI, the chip also adopts frequency jittering technology, and the frequency will be distributed within the range of ±6%.

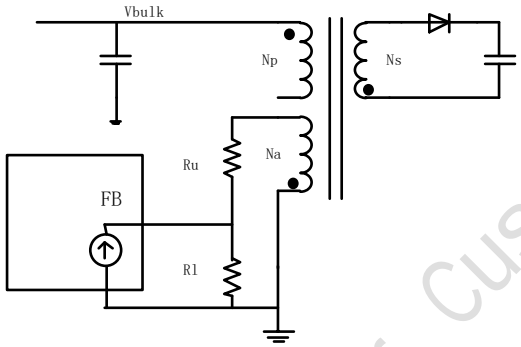
In response to the need for peak power of audio type loads, MK2687L supports peak load mode.

Line Over-Voltage Protection

The current flow out of FB pin during power MOS on is equal to:

$$\frac{V_{BULK} * Na}{Ru * Np}$$

When current at FB is greater than $I_{\_OVP}$ (~370uA) for at least T_{L_OVP}, BULK voltage is considered to be too high. Line over-voltage protection occurs and the drive output turns off. MK2687L enters the restart process.



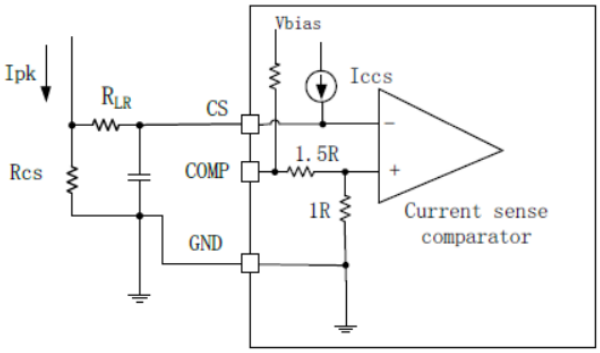
Current Sense

MK2687L is current mode PWM controller With cycle-by-cycle current limit. The switching current is detected by a sense resistor at CS pin. An internal leading-edge blanking circuit with blanking time (TLEB) blocks the sensed voltage spikes at initial power MOSFET ON state due to snubber diode reverse recovery and surge gate current at power MOSFET. The maximum cycle-by-cycle current limit is set by VCS_CBC/RCS.

MK2687L also clamps the maximum duty cycle to DMAX. The output turns off after DMAX duty cycle is reached.

Line Compensation

MK2687L uses the detected input line voltage through the current at FB pin (IFB) to generate the Iccs current going out of CS pin with external line compensation resistor RLR to achieve more constant actual peak current regardless of line voltage.



Internal Slope Compensation

The built-in slope compensation circuitry adds linear ramp which is proportional to duty cycle, into the current sense input voltage for PWM generation. This greatly improves the close loop stability at CCM and prevents the subharmonic oscillation and thus reduces the output ripple.

Voltage Feedback Loop

COMP is the voltage loop feedback pin which is connected to TL431 output through optocoupler. It is compared with the current signal to generate the drive signal.

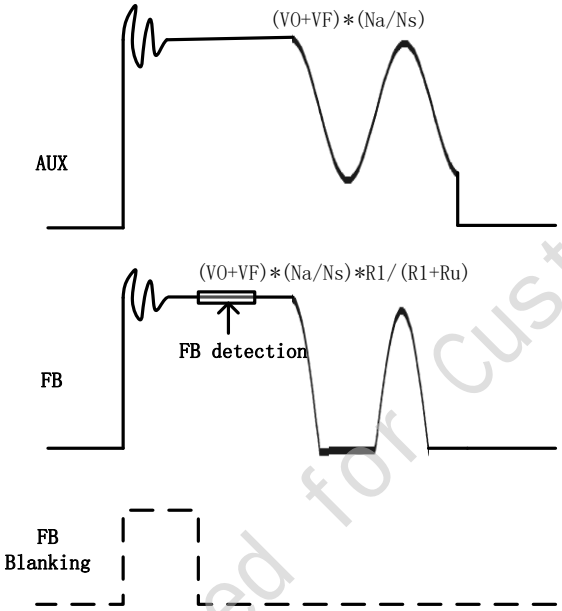
From the perspective of loop debugging, it is recommended to put a ceramic capacitor parallel with the resistor connected in series with the secondary side optocoupler diode.

FB Voltage Detection

During the freewheeling time of the secondary side current, the voltage on the FB pin is the partial voltage of the auxiliary winding voltage, which indirectly reflects the output voltage.

By sampling the voltage of FB during the transformer demagnetization time and comparing it with different thresholds, the following functions can be accomplished.

1. Output over-voltage protection. The output over-voltage protection threshold V_{FB_OVP} is about ~3.6V.
2. Output short circuit protection. The output short-circuit protection threshold V_{FB_ST} is about ~0.3V.
3. Based on the detected output voltage, the control curve is determined to optimize the efficiency.



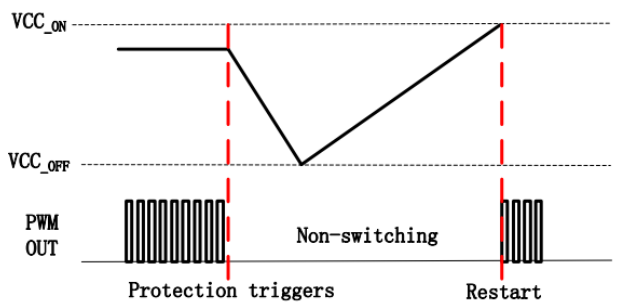
MK2687L implements a FB blanking time to block the excessive ringing at the beginning of the transformer demagnetizing time. The FB blanking time is proportional to Vcs since the excessive ringing is generally considerable with larger peak current.

Valley Switching

After secondary side rectification is done, the drain voltage starts oscillating with a frequency of approximately $^1/_2\,\pi\sqrt{\mathrm{Coss}\times\mathrm{Lp}}$, where Lp is the inductance of primary winding of the transformer and C_{OSS} is capacitance on the drain of primary MOSFET. When the oscillation ringing is below 0V at auxiliary winding, MK2687L clamps FB pin to ~0V, and senses the current at FB pin. When the current out of FB reaches a design value, a “possible” valley is locked and MK2687L turns on after propagation delay.

Protection Function

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



MK2687L Protection Features	MK2687L Protection Schemes
OPP	Restart (auto-recovery)
VOUT OVP	Restart (auto-recovery)
VCC_OVP	Restart (auto-recovery)
CS_SHORT	Restart (auto-recovery)
SSCP	Restart (auto-recovery)
VOUT SCP	Restart (auto-recovery)
VOUT SHORT	Restart (auto-recovery)

Over Power Protection

OPP is achieved by monitoring COMP voltage. If COMP voltage is above V_{OPP} for at least 7 times of soft-start time, MK2687L enters auto-recovery OPP protection.

Cycle By Cycle Current Limit

The current-mode control IC compares the CS signal with the COMP cycle by cycle, but when the output is short-circuited or the optocoupler is open, the COMP voltage may rise very high, resulting in excessive I_{PK} current and causing transformer saturation. Therefore, MK2687L adds an addition protection level, the CS voltage will be compared with V_{CS_CBC} (~0.77V) cycle by cycle. After the blanking time T_{LEB}, as long as the CS reaches V_{CS_CBC}, MK2687L will chop drive signal immediately.

Secondary Side SR Short Circuit Protection (SSCP)

If secondary side synchronous rectifier is short circuit, peak current increases rapidly after power MOSFET is turned on, thus the protection needs to reactrapidly.MK2687L shortens current sense blanking time to 90ns if CS pin detects a voltage above V_{SR_SH} threshold, and turn off power MOSFET immediately in the switching cycle. If this happens for consecutive three switching cycles, MK2687L enters into auto-recovery SSCP protection.

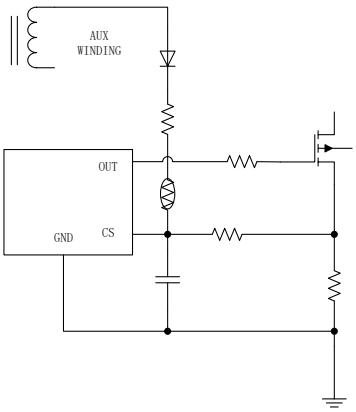
VCC Over-Voltage Protection

Whenever the VCC voltage is higher than the OVP threshold voltage V_{CC_OVP}, the output gate drive circuit will be shut down simultaneously and stop switching until next V_{CC_ON}.

Over Temperature Protection

MK2687L provides internal over-temperature protection with a trigger point of Thsd and a hysteresis temperature of Thsd_hys.

Customers can also implement over-temperature protection on the CS pin by adding an external NTC resistor. when the temperature of the board rises, the resistance value of the NTC resistor becomes lower, If V_{CS} is greater than V_{CS_CBC} and continues for 15 cycles, OTP is triggered, MK2687L goes to auto-recovery OTP protection.

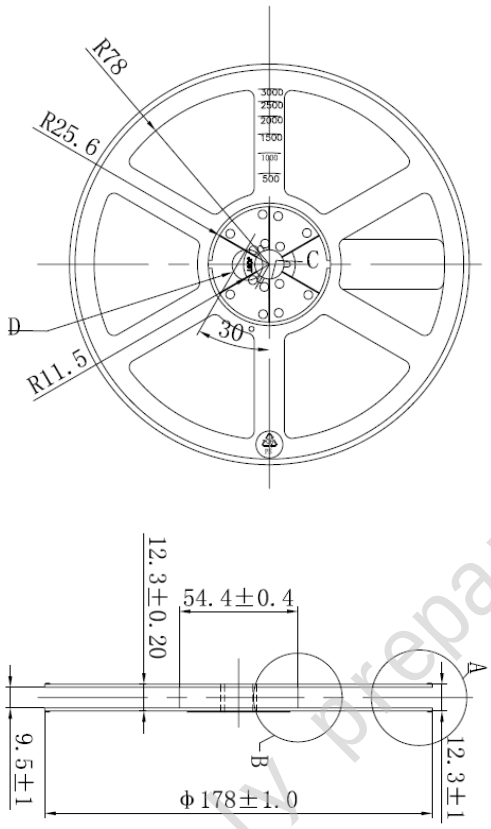


Pin Open Short Protection

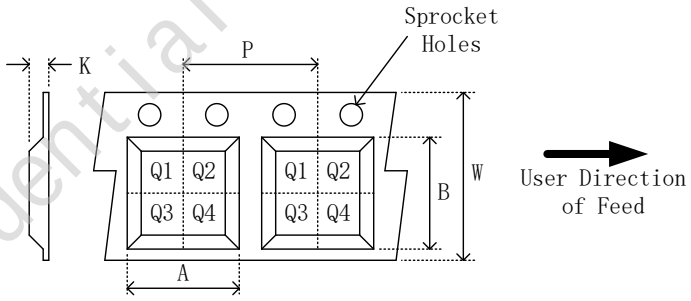
There are several critical protections designed in the MK2687L to prevent the power supply at fault state. In case listed below, MK2687L will trigger protection:

1. Adjacent PINS short
2. PINS open
3. CS short

12. Tape And Reel Information



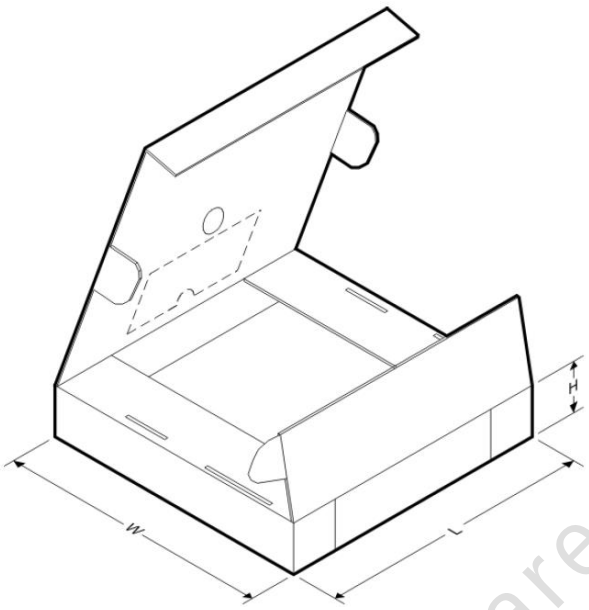
Reel Dimensions



Device	Package Type	Pins	SPQ (pcs)	A (mm)	B (mm)	K (mm)	P (mm)	W (mm)	Pin1 Quadrant
MK2687LGSA	SOT23-6	6	3000	3.23	3.17	1.37	4	8	Q3

Tape Dimensions and Quadrant Assignments for PIN 1 Orientation in Tape

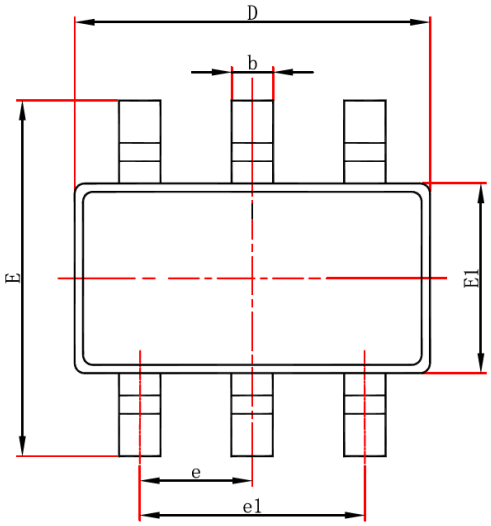
13.Tape And Reel Box Dimensions

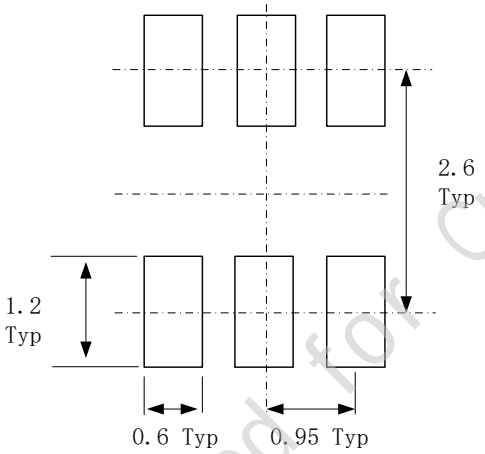


Box Dimensions

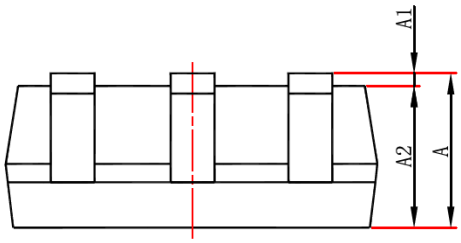
Device	Package Type	Pins	SPQ (pcs)	L (mm)	W (mm)	H (mm)
MK2687LGSA	SOT23-6	6	30000	203	203	195

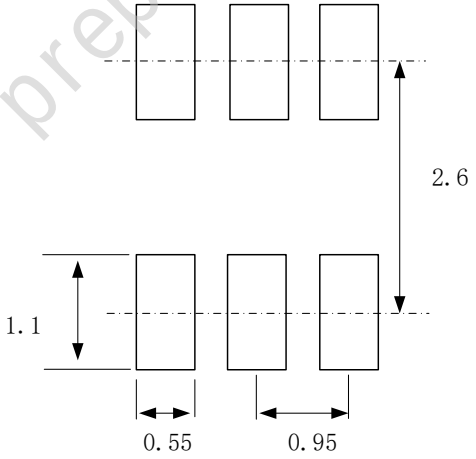
14. Package Information (SOT23-6)

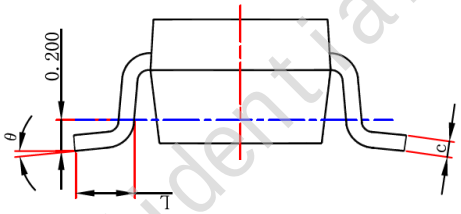




Recommended Land Pattern







Recommended Stencil Openings

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E1	1.500	1.700	0.059	0.067
E	2.650	2.950	0.104	0.116
e	0.950(BSC)		0.037(BSC)	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°