2787SIAU Wide VCC Range HF QR Controller with GaN Integrated

1. Description

The 2787SIAU 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 2787SIAU is self-adaptive to operate at DCM/QR. At light load, it will work in Burst mode to improve efficiency.

The 2787SIAU offers various protection features including output over-voltage protection (OVP), output over power protection (OPP), VCC over-voltage protection, Brown in/out, Secondary side SR short circuit protection (SSCP), and CS short protection.

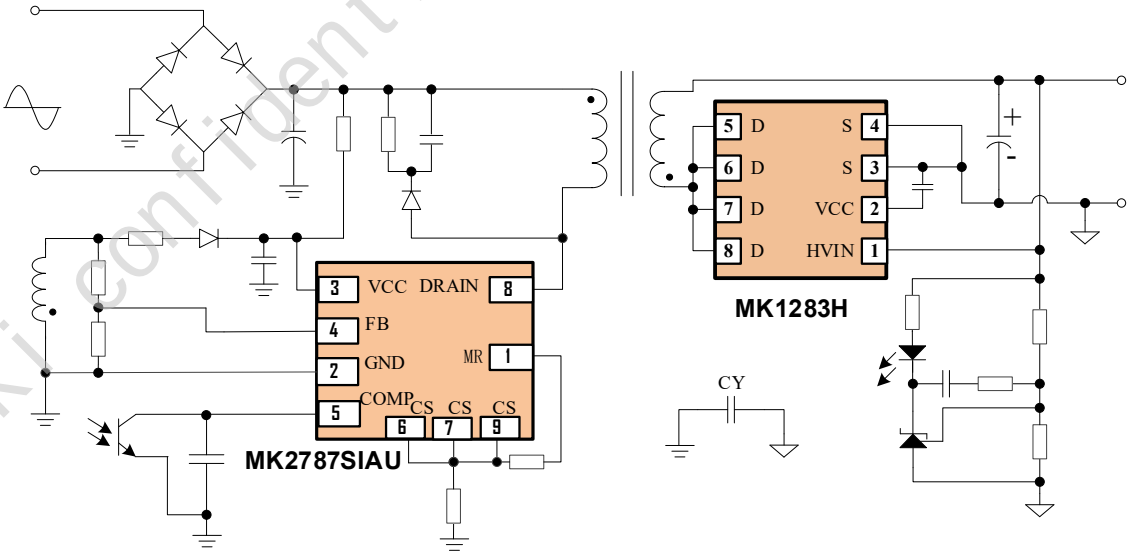
2. Typical Applications

- 30W AC/DC PD/Adapter
- High Power Density Power Supply

3. Features

- Built-in 700V 580mR GaN FET
- 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
- VCC OVP/VO OVP Protection
- Support PPS Wide Range Output
- Tiny ESOP-7 Package

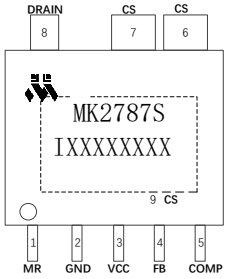
4. Simplified Application



5. Ordering Information

Ordering No.	Description
2787SIAU	ESOP-7, 5000 pcs/reel

6. Package Reference



XXXXXXXX: Lot Code
ESOP-7 Top View

6.1 Absolute Maximum Ratings(1)

VCC..... -0.3V to +100V
COMP, FB..... -0.3V to +5.5V
CS..... -0.7V to +5.5V
EM..... -3V to +5.5V
DRAIN.....-3V to +700V
I_D.....4A(2)
Junction Temperature ..... +155℃

6.2 Recommended Operation Conditions

VCC .....9V to 85V
Maximum Junction Temp. (T_J).....+125°C

6.3 Thermal Resistance(4)

θ_{JA}.....45 °C/W
θ_{JC}.....2°C/W

Notes:

(1) Exceeding these ratings may damage the device;

(2) Tc = 25 °C；Limit was extracted from characterization test, not measured during production;

(3) Measured on JESDSD51-7, 4 layers PCB.

7. Pin Functions

Pin #	Name	Description
1	MR	Mega Resistor pin, connected to CS through a 5.1 MΩ resistor
2	GND	Ground
3	VCC	Power Supply
4	FB	Auxiliary Voltage Sense
5	COMP	Voltage Feedback
6、7、9/EP	CS	Current Sense Input
8	DRAIN	HV Power GaN Drain

8. Block Diagram

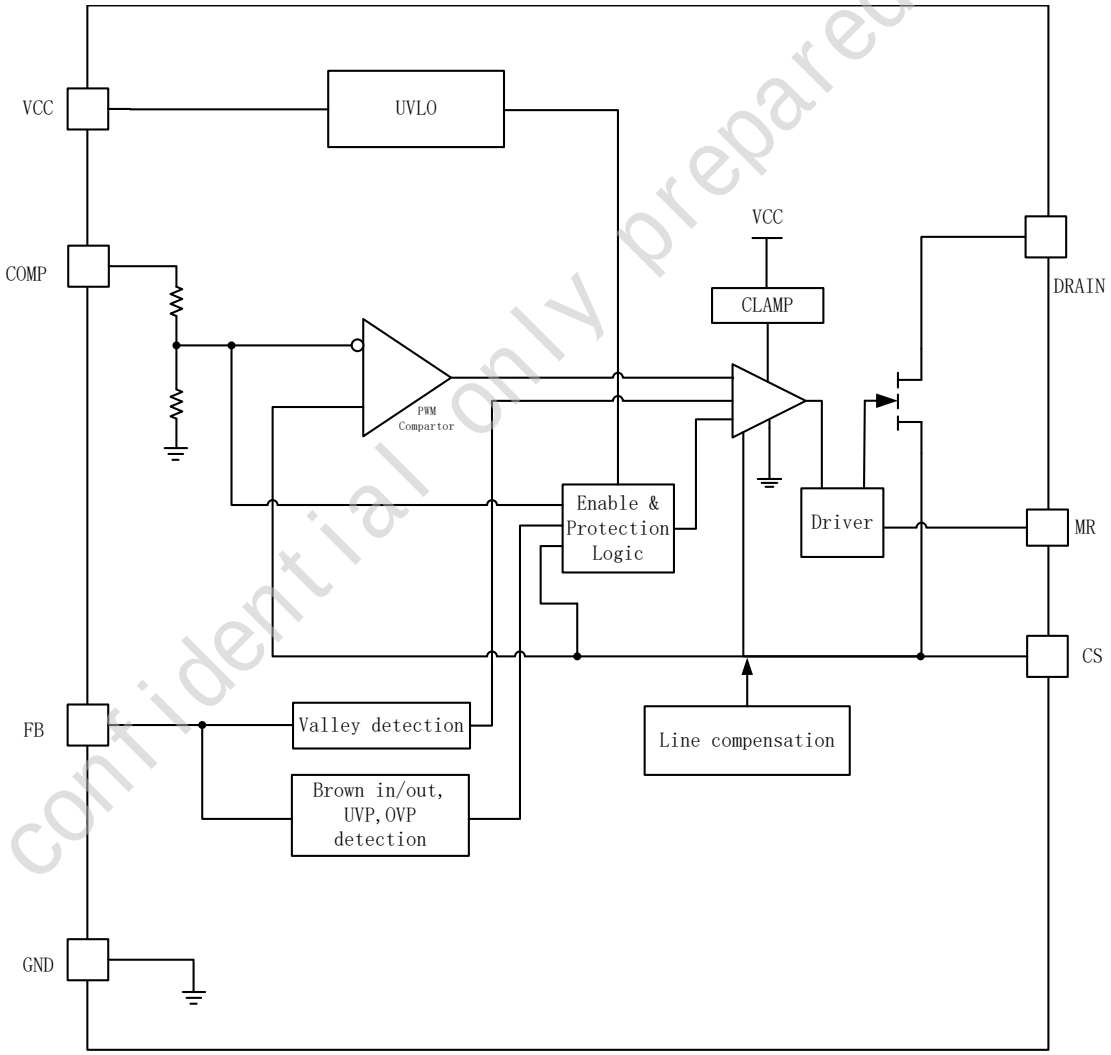


Figure 1. Functional Block Diagram

9. Electrical Characteristics

VCC=12V, T_A=25°C, unless otherwise noted.

Parameter	Symbol	Conditions	Min	Typ	Max	Units
GaN Section						
Maximum Drain Voltage	V_{DS_max}		700			V
Static Drain to Source on Resistance	$R_{DS(on)}$	I_D=1A		580		mΩ
Supply Management Section						
VCC UVLO Rising	V_{CC_ON}		15.5	17.2	19.9	V
VCC UVLO Falling	V_{CC_OFF}		6	7.3	8.4	V
VCC UVLO Hysteresis	V_{CC_HYST}		8.5	10	11.2	V
VCC Startup Current	$I_{STARTUP}$		2	5	8	uA
VCC Normal Operating Current	I_{OP}	COMP=2V	0.3	0.6	1.5	mA
Burst Operating Current	I_{BURST}	COMP=0V, GATE=1nF to GND	240	290	340	uA
VCC OVP Threshold	V_{CC_OVP}		87	93	100	V
VCC Clamp Threshold	V_{CC_CLAMP}		89	102	110	V
Comp Input Section						
COMP Open Voltage	V_{COMP_OP}	COMP Pin Open-circuited	4	4.4	4.8	V
COMP Short-circuit Current	I_{COMP_SHORT}	COMP=0V	130	160	190	uA
Burst Mode Entry Voltage	V_{BM_ET}		0.27	0.30	0.33	V
Burst Mode Hysteresis	V_{BM_HY}		0.02	0.05	0.09	V
OPP Protection Threshold	V_{OPP}		2.8	3.0	3.2	V
OPP Deglitch Time*	T_{D_OPP}			T_{SS}*6		ms
Current Sense Input Section						
Soft Start Time of CS Threshold	T_{SS}		4	7	10	ms
Secondary Rectifier Short-circuit trigger voltage (OC FAULT)	V_{SR_SH}		1.1	1.2	1.3	V
SR Short-circuit Deglitch cycles*				3		cycles
Cycle by Cycle Current Limit (low line)	V_{CS_CBCL}	V_{FB}<1V, I_{FB}=100uA	0.77	0.83	0.89	V

Cycle by Cycle Current Limit(high line)	V_{CS_CBCH}	V_{FB}<1V,I_{FB}=300uA	0.52	0.59	0.66	V
CS Short Protection Threshold	V_{CS_SH}			0.05		V
CS Short Deglitch cycles*	T_{CS_SH}			3		cycles
FB Input Section						
Brown-in Detection Threshold	I_{BNI}		78	94	109	uA
Brown-out Detection Threshold	I_{BNO}		69	85	100	uA
Brown-out Deglitch Time*	T_{BL_BNO}			T_{SS}*7		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}		0.27	0.30	0.33	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
Control Law						
Normal Mode Frequency	F_{SW_max}		110	130	150	kHz
Green Mode Frequency	F_{SW_green}		21	25	29	kHz
Dithering Range*				±6		%
Dithering Period*				8		ms
Maximum Toff Time	T_{off_MAX}		80	110	140	us
Thermal Shutdown Threshold*	Th_{SD}			155		℃
Thermal Shutdown Hysteresis*	Th_{SD_hys}			30		℃

Note:

* Guaranteed by design

10. Operation Descriptions

VCC and Start-up

The 2787SIAU's start-up current $I_{STARTUP}$ is only ~5uA so that a large value of start-up resistor can be used to charge up VCC while minimizing power loss during start-up. Once VCC rises above the V_{CC_ON} (~17.2V) threshold, the 2787SIAU begins switching.

Soft Start

The 2787SIAU features an internal soft start T_{SS} (~7ms) to reduce electrical stress in the power system during start-up. To further reduce voltage stresses from high peak current and high frequency switching, the 2787SIAU operates at optimized frequencies and control modes accordingly to the output voltages and the start-up status of the synchronous rectifier controller.

Mega Resistor (MR)

The resistor connected between the MR pin and CS pin is used as a bleeder for the internal GaN device. A common value for this resistor is 5.1 MΩ.

Operation Curve

The 2787SIAU has multiple working modes, which can be switched by monitoring the voltage change of COMP. Since the voltage change of COMP is consistent with the load change, the 2787SIAU can automatically switch to the optimal operating mode according to different load conditions. The operation curve of the 2787SIAU operating mode is shown in Figure 2.

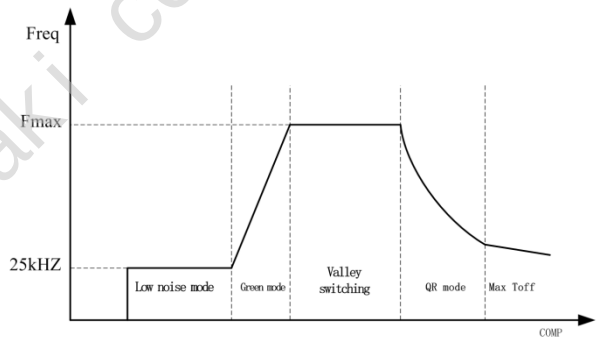


Figure 2 Operating Curve

Brown in/ Brown out

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:

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

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.

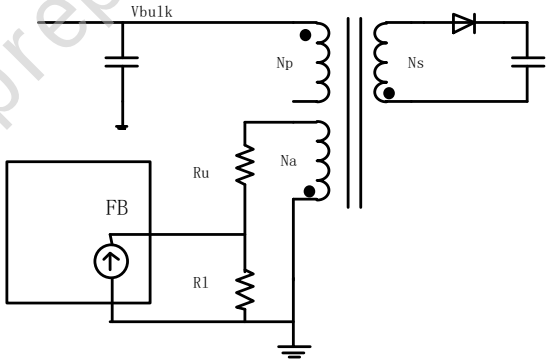


Figure 3 Brown in/Brown out

Current Sense

The 2787SIAU is current mode PWM controller. The voltage detected at the CS pin is compared with the internal voltage loop feedback voltage to determine the duty ratio. When the COMP pin is at its maximum level, the 2787SIAU also limits the primary-side peak current during each switching cycle; its maximum current limit value is calculated as V_{CS_CBC}/Rcs.

Due to the voltage drop caused by the drive current across the CS resistor, as well as the influence of the converted capacitor C_{SW} at the drain node, a spike across the CS resistor at the moment the driver is turned on. This spike may cause the PWM controller to falsely generate extremely narrow duty cycle pulses. Therefore, a leading-edge blanking time of ~300ns has been added to the chip's CS sampling circuit.

Line Compensation

The 2787SIAU uses the detected input line voltage, via the current at the FB pin, to generate an offset voltage. This offset voltage is added to the internal current signal to compensate the output OPP power level. This mechanism helps to achieve a flat OPP power level across different input voltages.

Voltage Feedback Loop

COMP is the voltage loop feedback pin which is connected to TL431 output via an opto-coupler. To support a wide COMP range, a 1/2.5 resistor divider ratio is used before the signal enters PWM comparator.

It is recommended that a ceramic capacitor be placed in parallel with the resistor connected in series with the opto-coupler diode.

FB Voltage Detection

The 2787SIAU detects the transformer core demagnetization by monitoring the signal at the auxiliary windings through the FB pin.

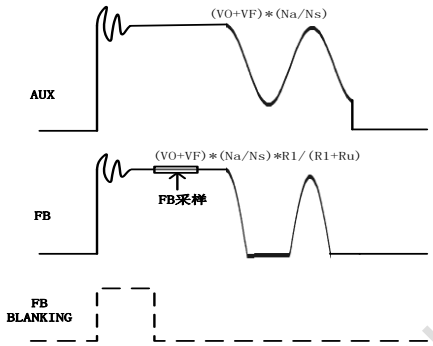


Figure 4 FB Detection

After a period of transformer demagnetization time (~1.4us), the FB sampling voltage is compared against various thresholds. The 2787SIAU can perform the following functions:

1. Output over-voltage protection (OVP): Triggered when FB exceeds V_{FB_OVP} (~3.6V) for 7 switching cycles;
2. Output under-voltage protection (including output short circuit protection): Triggered when FB drops below V_{FB_ST} (~0.3V) for 7 switching cycles;
3. Determination of the operating control curve based on the detected output voltage.

Valley Switching

After secondary-side rectification is complete, the drain voltage starts oscillating with a frequency of approximately $1/2\,\pi\sqrt{Coss \times Lp}$, where Lp is the inductance of the transformer's primary winding and C_{OSS} is the output capacitance at the drain of the primary GaN device. When the oscillating ringing at the auxiliary winding drops below 0V, the 2787SIAU clamps the FB pin to 0V and senses the current at the FB pin. Once the current flowing out of FB reaches the designed value, a "possible" valley is locked and the 2787SIAU turns on after a 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.

Once the protection triggers, 2787SIAU will stop the drive, and the VCC discharge current makes the VCC capacitor voltage drop. When the VCC voltage drops to V_{CC_OFF} (~7.3V), the VCC capacitor starts charging and reaches V_{CC_ON} (~17.2V), restarting the drive and completing the restart.

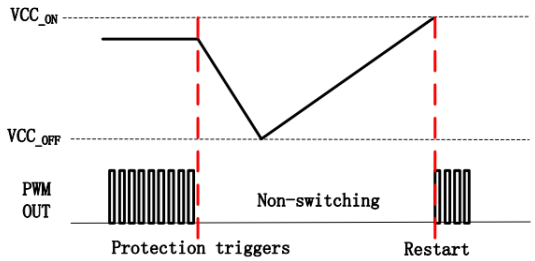


Figure 5 Restart Mode

2787SIAU Protection Features	2787SIAU Protection Schemes
OPP	Restart
VO_OVP	Restart
VCC_OVP	Restart
CS_SHORT	Restart
SSCP	Restart
FB_UVP (VO_SCP)	Restart

Over Power Protection

The OPP protection is achieved by monitoring COMP voltage. If COMP voltage is above V_{OPP} (~3V) for at least 6 times of soft-start time, i.e. Tss*6 (~42ms), the 2787SIAU enters restart mode.

Cycle by Cycle Current Limiting

The current-mode controller 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 2787SIAU 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 driver output.

Secondary Side SR Short Circuit Protection

If the secondary side synchronous rectifier experiences a short circuit, the peak current increases rapidly after the power GaN is turned on. Therefore, the protection circuit is needed to react with a shorter response time. The 2787SIAU reduces current sense blanking time to 90ns when the CS pin detects a voltage above V_{SR_SH} (~1.2V) threshold. It immediately stops the driver output. If this condition persists for three consecutive cycles, the 2787SIAU determines that a secondary SR short circuit has occurred, and it stops the driver and enters the restart mode.

CS Short Protection

If CS still fails to reach V_{CS_SH} (~0.05V) after 5us of primary GaN turning on, the 2787SIAU will force driver shutdown. If this condition occurs for three consecutive periods, the 2787SIAU enters restart mode.

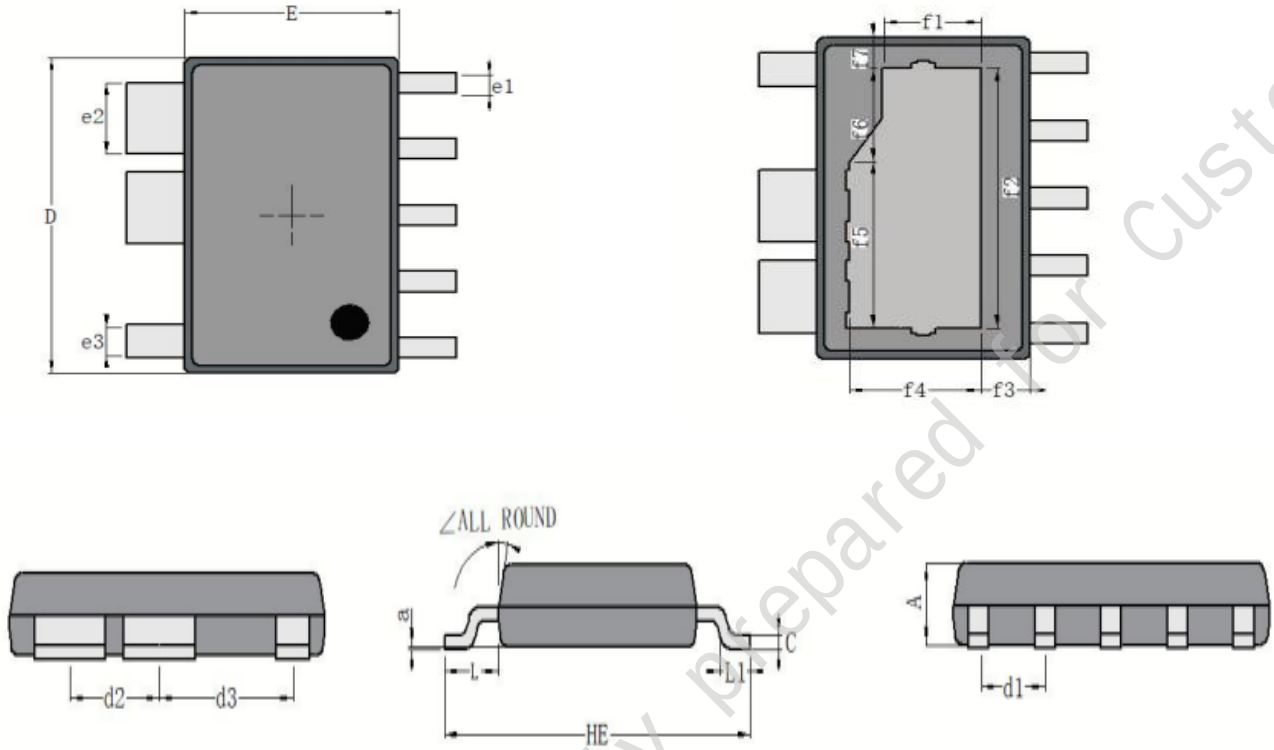
VCC OVP

Whenever the VCC voltage is higher than the OVP threshold voltage V_{CC_OVP} (~93V), the output gate drive circuit will be shut down to stop the switching of the power GaN, and the 2787SIAU enters the restart mode.

OTP

The 2787SIAU provides internal over-temperature protection with a trigger point of ~155°C and a hysteresis temperature of ~30°C.

11. Package Information (ESOP-7)



Symbol	Dimensions In Millimeters		
	MIN	NOM	MAX
A	1.05	1.15	1.25
C	0.15	0.20	0.25
D	6.00	6.20	6.40
E	3.70	3.90	4.10
HE	5.90	6.00	6.10
d1	1.25	1.30	1.35
d2	1.70	1.75	1.80
e1	0.35	0.40	0.45
e2	1.35	1.40	1.45
L	0.95	1.05	1.15
L1	0.40	/	0.80
a	0.00	/	0.20
∠	12°		

Note:

Unit: Millimeter(mm)