MK2787 Wide VCC Range HF QR Controller with GaN Integrated

1. Description

The MK2787 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 MK2787 is self-adaptive to operate at DCM/QR. At light load, it will work in Burst mode to improve efficiency.

The MK2787 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.

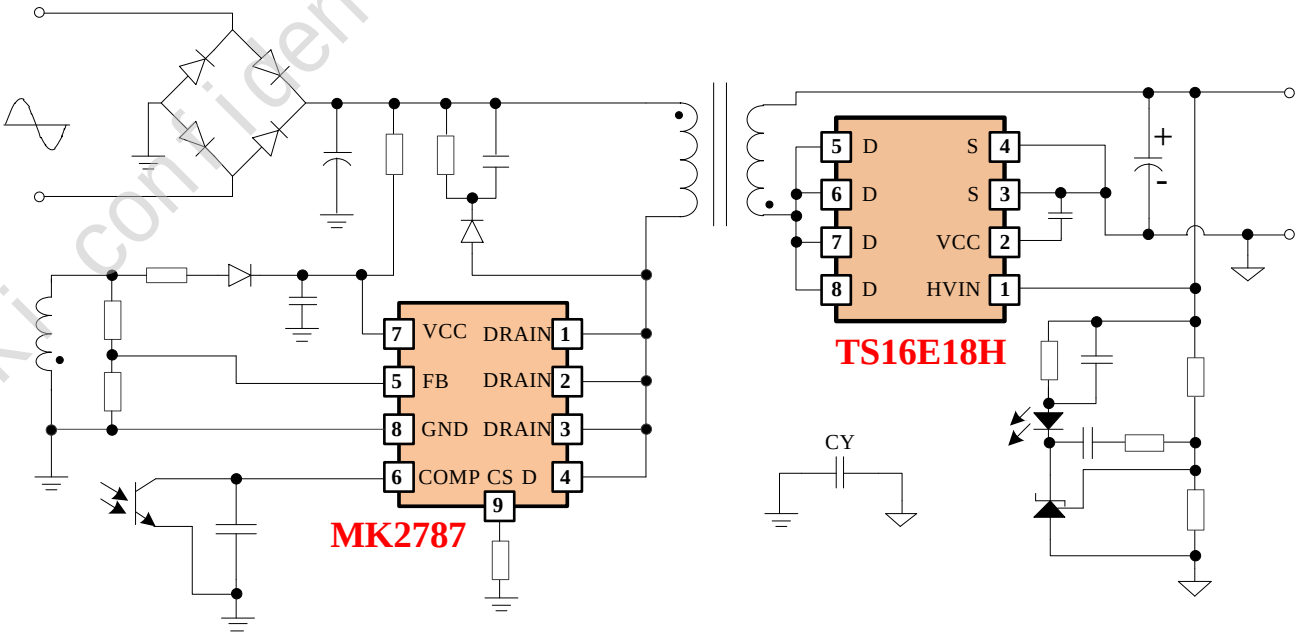
2. Typical Applications

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

3. Features

- Built-in 700V 365mR 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-8 Package

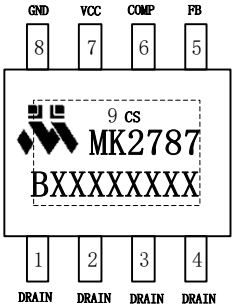
4. Simplified Application



5. Ordering Information

Ordering No.	Description
MK2787BAD	ESOP-8, 4000 pcs/reel

6. Package Reference



XXXXXXXX: Lot Code
ESOP-8 Top View

7. Specifications

7.1 Absolute Maximum Ratings(1)

VCC..... -0.3V to +100V
COMP, FB..... -0.3V to +5.5V
CS..... -0.7V to +5.5V
DRAIN.....-3V to +700V
I_D.....3A(2)
I_{DM}.....9A(3)
Junction Temperature ..... +155℃

7.2 Recommended Operation Conditions

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

7.3 Thermal Resistance(4)

θ_{JA}.....58 °C/W
θ_{JC}.....3 °C/W

Notes:

(1) Exceeding these ratings may damage the device;

(2) Tj = 125°C, The maximum continuous drain current is calculated based on the maximum allowable junction temperature;

(3) Tc = 25℃, 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

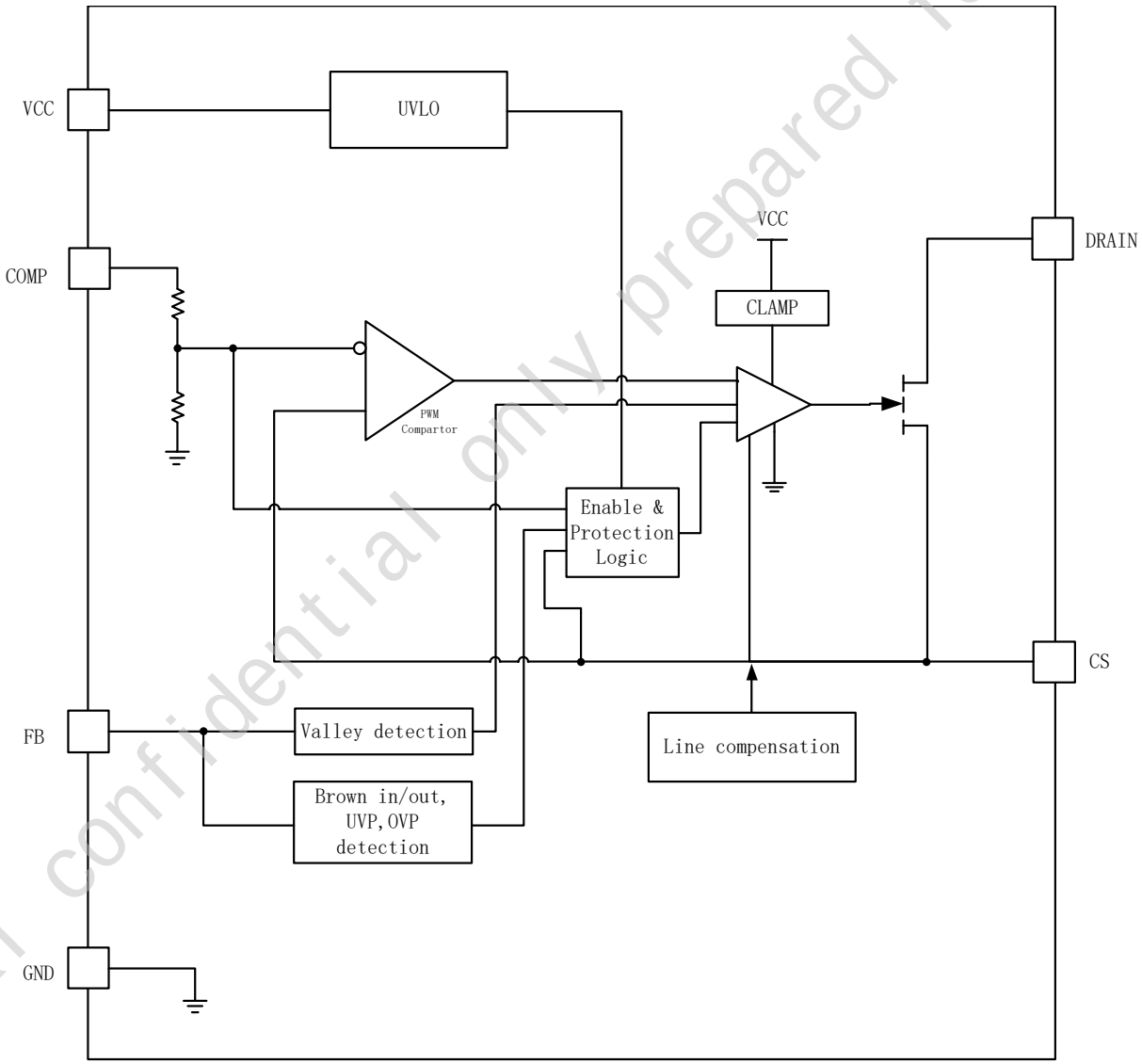


Figure 1. Functional Block Diagram

10. Electrical Characteristics

VCC=12V, T_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		0.365	0.48	Ω
Supply Management Section						
VCC UVLO Rising	V_{CC_ON}		15.5	17.2	19.9	V
VCC UVLO Falling	V_{CC_OFF}		6	7.2	8.4	V
VCC UVLO Hysteresis	V_{CC_HYST}			10		V
VCC Startup Current	$I_{STARTUP}$		2	5	8	uA
VCC Normal Operating Current	I_{OP}	COMP=2V	0.3	0.45	0.6	mA
Burst Operating Current	I_{BURST}	COMP=0V, GATE=1nF to GND	240	290	340	uA
VCC Hold Threshold	V_{CC_HOLD}		7	8	9.5	V
VCC OVP Threshold	V_{CC_OVP}		88	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	0.3	0.33	V
Burst Mode Hysteresis	V_{BM_HY}			0.05		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	V_{CS_CBC}	V_{FB}<1V, I_{FB}=100uA	0.79	0.85	0.91	V

Cycle by Cycle Current Limit	V_{CS_CBC}	V_{FB}<1V, I_{FB}=300uA	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
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}		0.17	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
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

11. Operation Descriptions

VCC and Startup

The MK2787'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 MK2787 begins switching.

Soft Start

The MK2787 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 MK2787 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 MK2787 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 MK2787 operating modes:

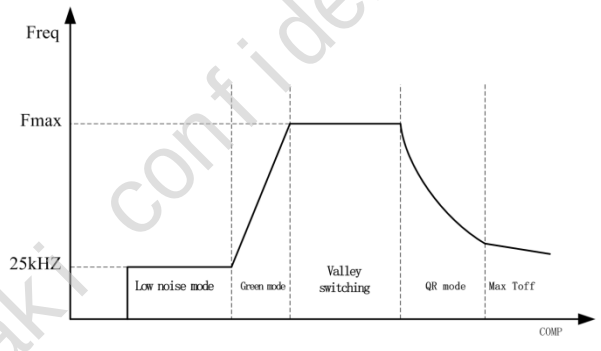


Figure 2: operation curve

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 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.

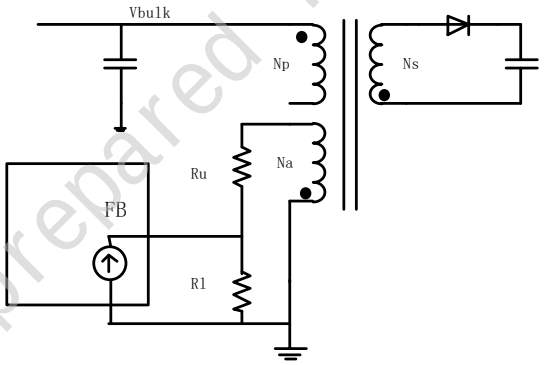


Figure 3: Brown in/Brown out

Current Sense

The MK2787 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 MK2787 also limits the peak current of the primary edge every switching cycle, and its maximum current limit value is V_{CS_CBC}/Rcs.

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 false trigger PWM controller to falsely generate very narrow duty cycle pulse. Therefore, the leading-edge blanking time ~300nS was added to the CS sampling circuit inside the chip.

Line Compensation

The MK2787 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 MK2787 detects the transformer core demagnetization by monitoring the signal at the auxiliary windings through FB pin.

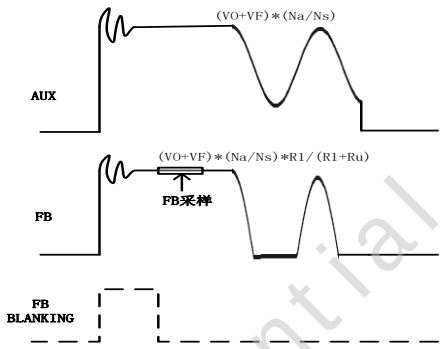


Figure 4:FB detection

After a period of demagnetization time of the transformer, the FB sampling voltage is compared with different thresholds. The MK2787 can complete the following functions:

1. Output over voltage protection (OVP): FB is above V_{FB_OVP} (~3.6V) for 7 switching cycles;
2. Output under voltage protection (output short circuit protection): FB is below V_{FB_ST} (~0.2V) 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 $1/2\,\pi\sqrt{Coss \times Lp}$, where Lp 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 MK2787 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 MK2787 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.

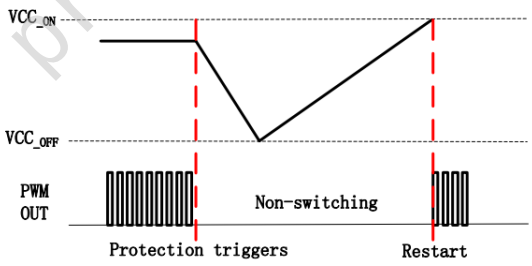


Figure 5:Restart mode

MK2787 PROTECTION FEATURES	MK2787 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 MK2787 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 MK2787 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 MK2787 reduces the current sense blanking time to 90ns when the CS pin detects a voltage exceeding the V_{SR_SH} threshold (~1.2V), and immediately halts the current output. If this condition persists for three consecutive cycles, the MK2787 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} (~0.05V) after 5us of primary GaN turning on, the MK2787 will force drive shutdown. If this condition occurs for three consecutive periods, the MK2787 enters restart mode.

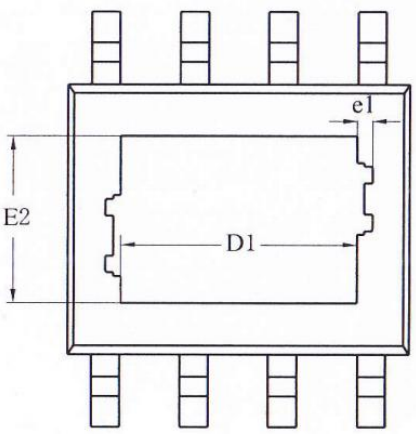
VCC OVP

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 MK2787 enters restart mode.

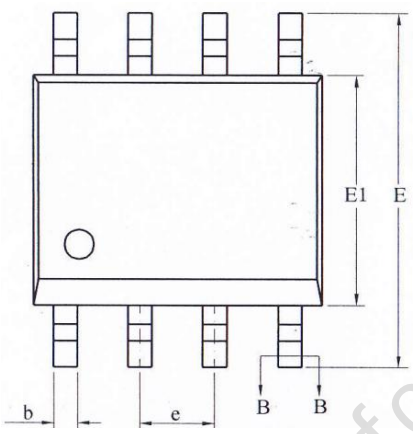
OTP

The MK2787 provides internal over-temperature protection with a trigger point of ~155°C and a hysteresis temperature of ~30°C.

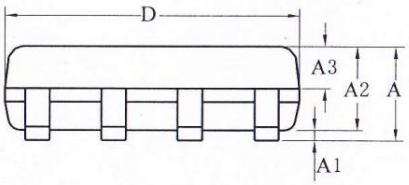
12. Package Information (ESOP-8)



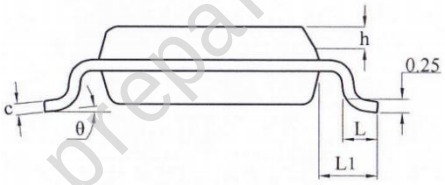
BOTTOM VIEW



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
θ	0°	-	8°

Note:

1. Unit: Millimeter(mm)