MK2789 Wide VCC Range HF QR Controller with GaN Integrated

1. Description

The MK2789 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 MK2789 is self-adaptive to operate at DCM/QR. At light load, it will work in Burst mode to improve efficiency.

The MK2789 offers comprehensive 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, and CS short protection.

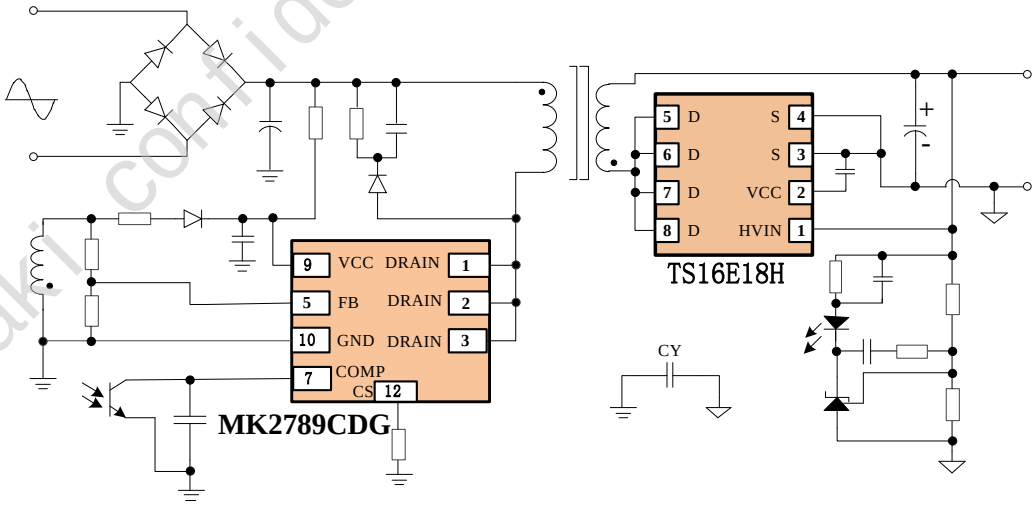
2. Typical Applications

- 65W AC/DC PD/Adapter
- High Power Density Power Supply

3. Features

- Built-in 700V 165mR GaN FET
- Wide VCC Operating Range(9V-85V)
- Working Frequency up to 130kHz
- Proprietary Soft-start Scheme to Achieve Low SR Vds Stress
- Optimized Efficiency-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 DFN6X8 Package

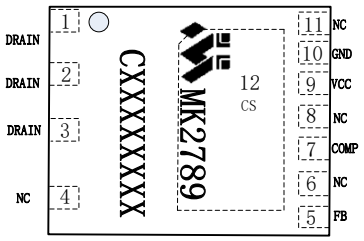
4. Simplified Application



5. Ordering Information

Ordering No.	Description
MK2789CDG	DFN6X8, 3000 pcs/reel

6. Package Reference



XXXXXXXX: Lot Code

DFN6X8 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

DRAIN.....-3V to +700V

I_D.....7.5A(2)

I_{DM}.....22A(3)

Junction Temperature ..... +155℃

6.2 Recommended Operation Conditions

VCC .....9V to 85V

Maximum Junction Temp. (T_J).....+125°C

6.4 Thermal Resistance(4)

θ_{JA}.....45 °C/W

θ_{JC}.....2°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) Pulse≤300us;

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

7. Pin Functions

Pin #	Name	Description
1、2、3	DRAIN	HV Power GaN Drain
4、6、8、11	NC	NC
5	FB	Auxiliary Voltage Sense
7	COMP	Voltage Feedback
9	VCC	Power Supply
10	GND	Ground
12	CS	Current Sense Input

8. Block Diagram

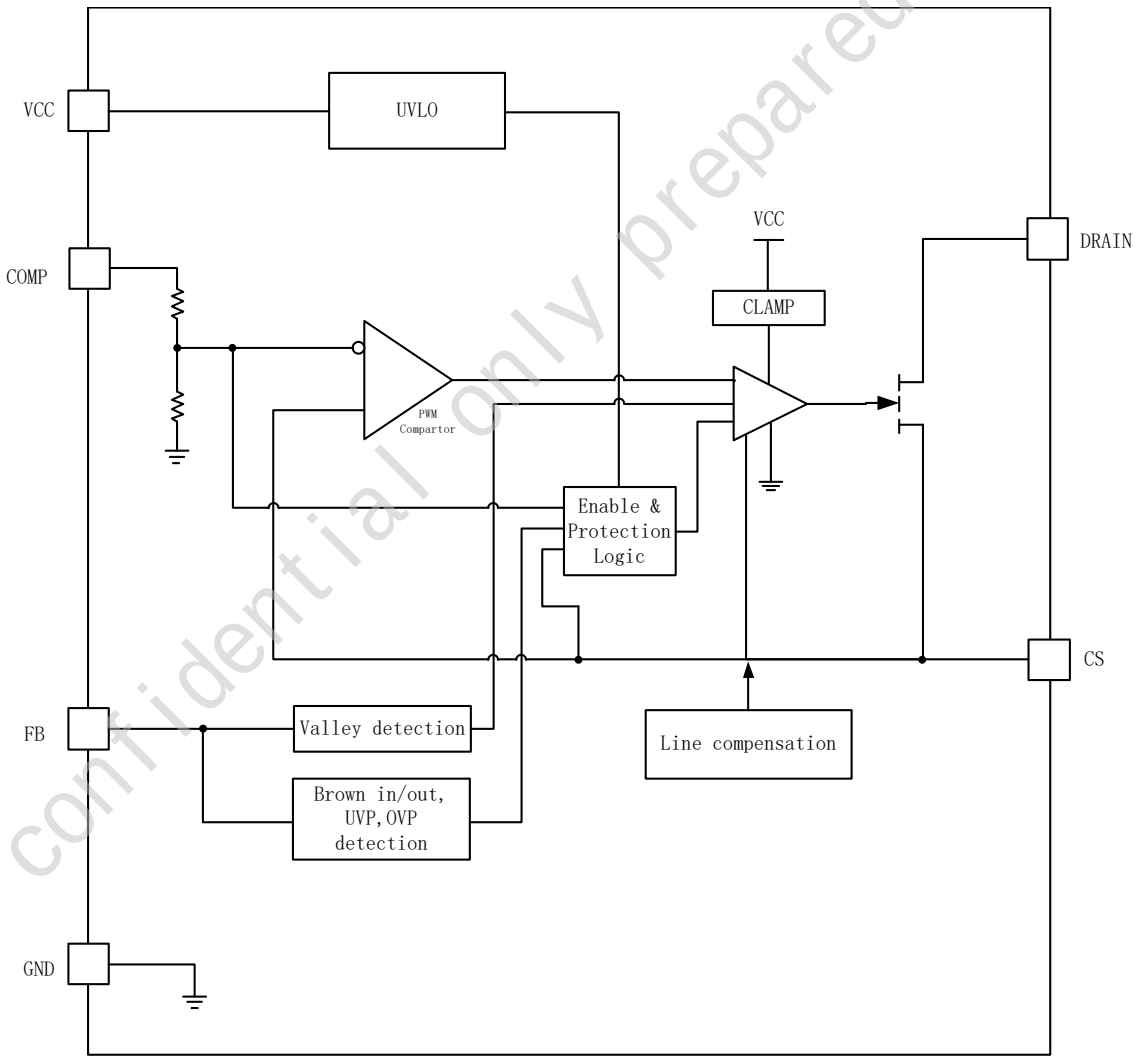


Figure 1. Functional Block Diagram

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		165		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	0.79	0.85	0.91	V

Cycle by Cycle Current Limit(high line)	V_{CS_CBCH}	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	0.20	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}			165		℃
Thermal Shutdown Hysteresis*	Th_{SD_hys}			30		℃

Note:

* Guaranteed by design

10. Important Parameter Temperature Curve

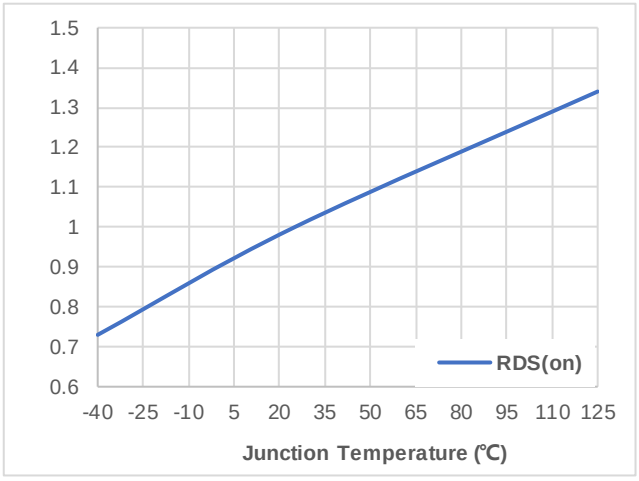


Figure 1: drain-source on resistance VS temperature

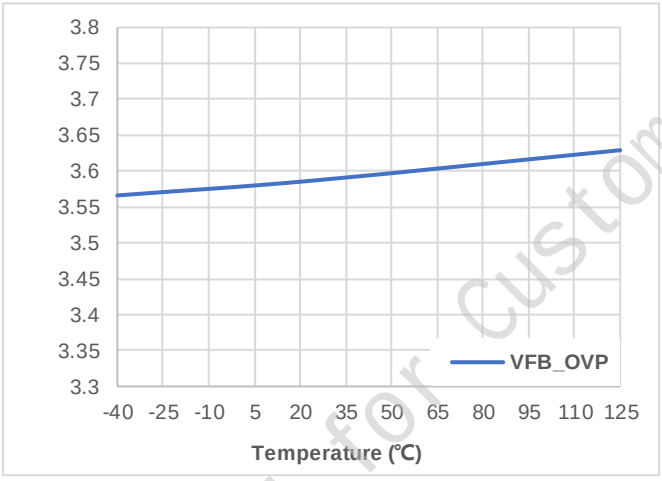


Figure 2: VFB_OVP VS temperature

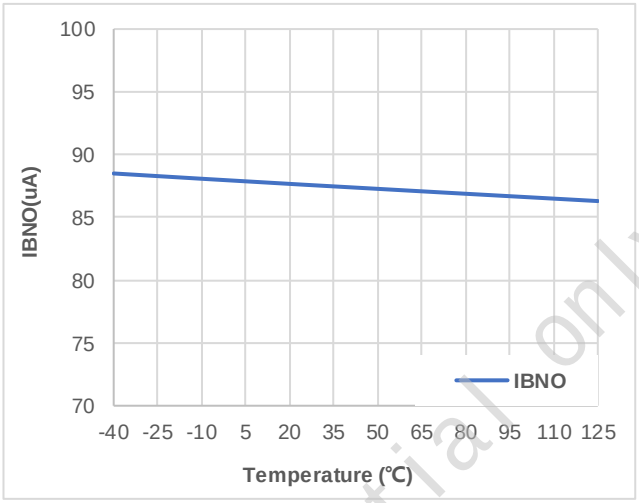


Figure 3: IBNO VS temperature

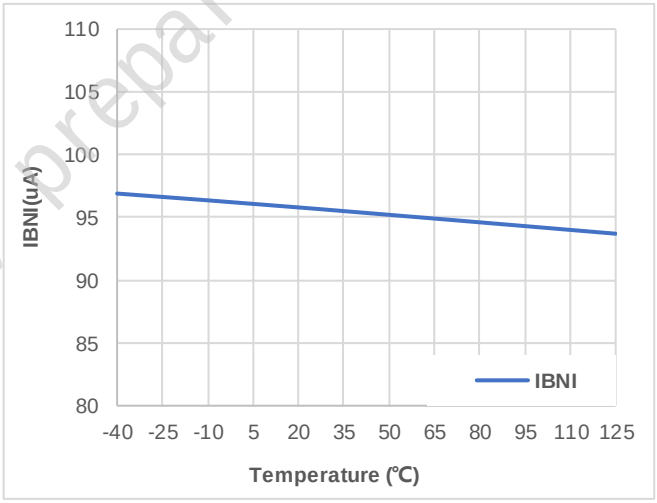


Figure 4: I_{BNI} VS temperature

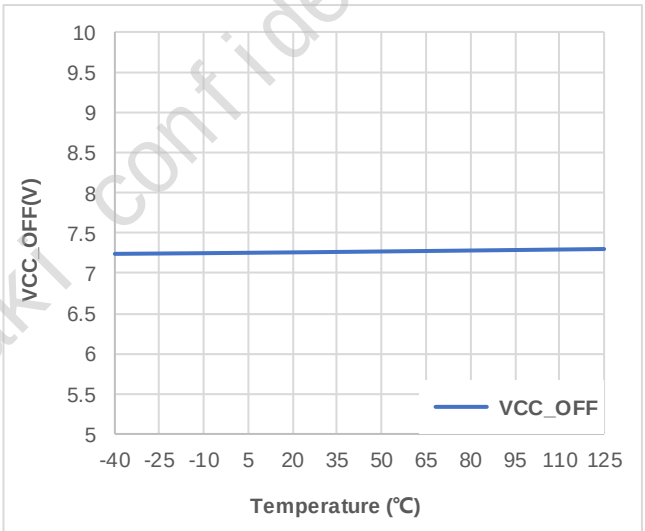


Figure 5: V_{CC_OFF} VS temperature

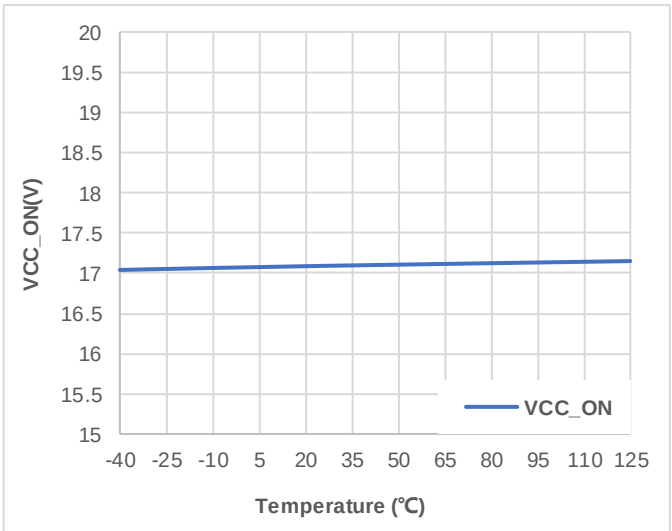


Figure 6: V_{CC_ON} VS temperature

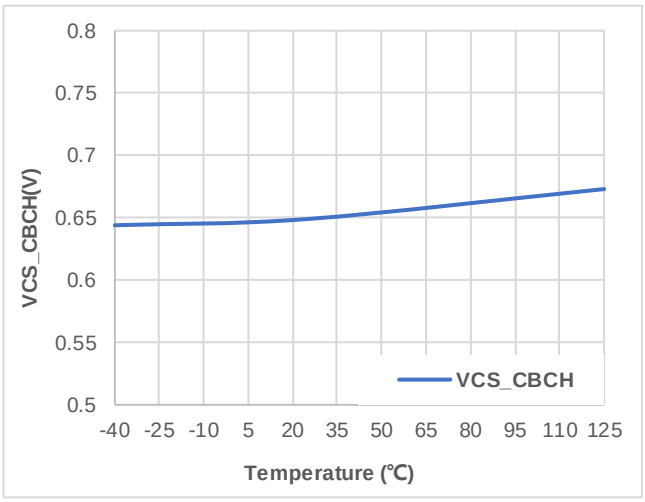


Figure 7: V_{CS_CBCH} VS temperature

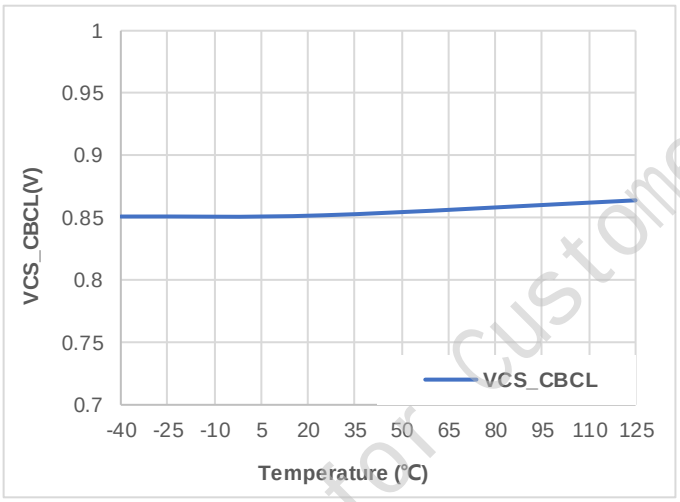


Figure 8: V_{CS_CBCL} VS temperature

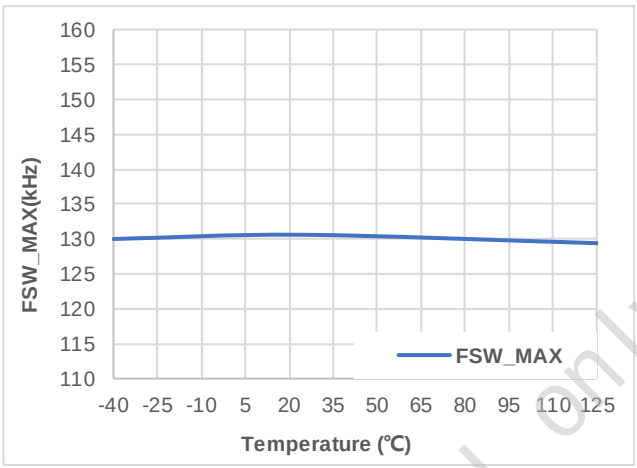


Figure 9: F_{SW_MAX} VS temperature

11. Operation Descriptions

Vcc and Start-up

The MK2789's start-up current is only $I_{STARTUP}$ (~5uA) so a large value of start-up resistor can be used to charge up VCC while minimizing power loss during start-up. Once VCC reaches above the V_{CC_ON}(~17.2V) threshold, the MK2789 starts switching.

Soft Start

The MK2789 features an internal T_{SS}(~7ms) soft-start 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 MK2789 operates at optimized frequencies and control modes accordingly to output voltages and synchronous rectifier controller start-up status.

Operation Curve

The MK2789 has a variety of working modes, which can be switched by monitoring the voltage change of COMP. The voltage change of COMP is consistent with the direction of load change, so the MK2789 can automatically switch to a better working mode according to different loads. The operation curve of the MK2789 working mode is shown as follows:

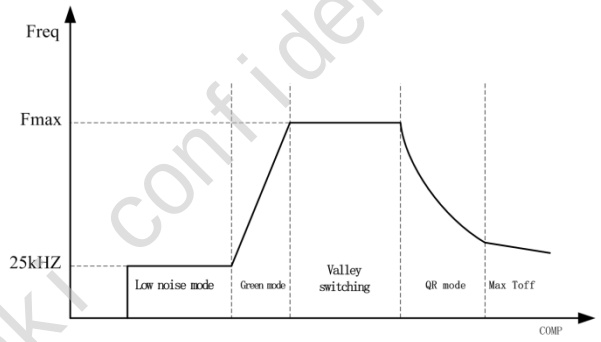


Figure10 operation curve

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. When system starts up, 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 starts to soft start. Otherwise Brown-in restart protection is triggered.

During normal operation, when the power GaN is turned on, the current at FB is less than I_{BNO} for at least T_{BL_BNO}(~49ms), the controller enters Brown-out restart protection.

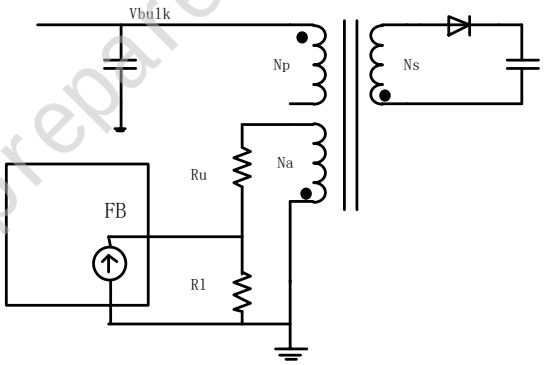


Figure11 Brown in/Brown out

Current Sense

The MK2789 is 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 MK2789 will also limit the peak current of the primary edge cyclically, and its maximum cycle term current point 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. If not processed, the duty cycle from the chip will be too small or lead to misprotection. Therefore, the leading edge blanking time ~300nS was added to the CS sampling circuit inside the chip.

Line Compensation

The MK2789 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 achieve flat OPP power level over different input voltage.

Voltage Feedback Loop

COMP is the voltage loop feedback pin which is connected to TL431 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 with the resistor which is series with opto-coupler diode.

FB Voltage Detection

The MK2789 detects the transformer core demagnetization by monitoring the signal at the auxiliary windings through FB pin.

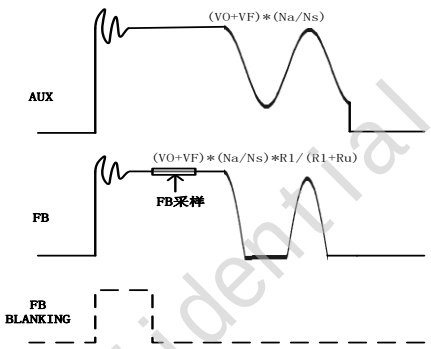


Figure12 FB detection

In the demagnetization time of the transformer, after a period of demagnetization time (~1.4us), the FB sampling voltage is compared with different thresholds. The MK2789 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 work 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 MK2789 clamps the FB pin to 0V, and senses the current at the FB pin. When the current out of FB reaches a design value, a “possible” valley is locked and the MK2789 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.

The MK2789 protection triggers, will stop the drive, the VCC discharge current makes the VCC capacitor voltage drop. When the VCC voltage drops to V_{CC_OFF}(~7.2V) , the VCC capacitor starts charging and reaches V_{CC_ON}(~17.2V) , restarting the drive and completing the restart.

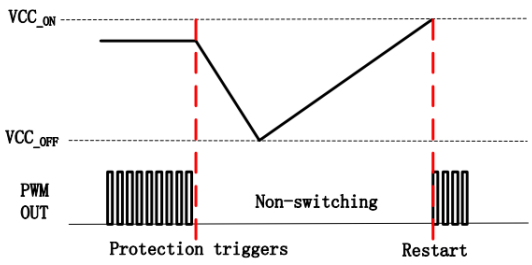


Figure13 Restart mode

MK2789 PROTECTION FEATURES	MK2789 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 MK2789 enters restart mode.

Cycle by Cycle Current Limiting

The current-mode control chip itself compares the CS signal with the COMP cycle-by-cycle.

However when the output is short-circuited or the opto-coupler is open, the COMP voltage may rise very high, resulting in excessive peak current and causing transformer saturation. Therefore, the MK2789 adds another layer of protection, the CS voltage will be compared with V_{CS_CBC} cycle-by-cycle. After the blanking time ~300nS, as soon as CS reaches V_{CS_CBC}, the chip immediately chop drive.

Secondary Side SR Short Circuit Protection

If the secondary side synchronous rectifier is short circuited, the peak current increases rapidly after the power GaN is turned on. Therefore the protection needs to react in much less wait time. The MK2789 shortens current sense blanking time to 90ns if CS pin detects a voltage above V_{SR_SH}(~1.2V) threshold. It immediately stops the current driver output. If this happens for three consecutive cycles, the MK2789 considers that a secondary SR short circuit has occurred. It stops driving, and enters the restart mode.

CS Short Protection

If CS still fails to reach V_{CS_SH}(~0.05V) after 5us of primary GaN opening, the MK2789 will force drive shutdown. If this condition occurs for three consecutive periods, the MK2789 enters restart mode.

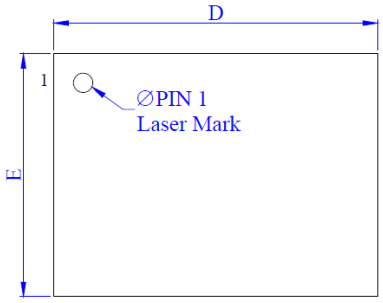
Vcc OVP

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, the MK2789 enters the restart mode.

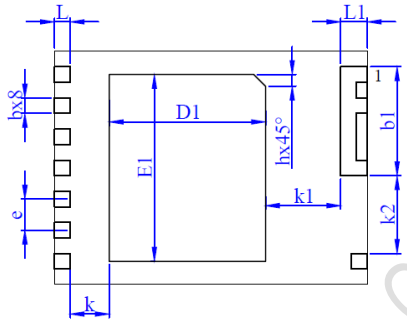
OTP

The MK2789 provides internal over-temperature protection with a trigger point of ~165°C and a hysteresis temperature of ~30°C.

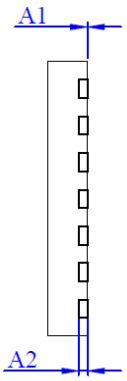
12. Package Information (DFN6X8)



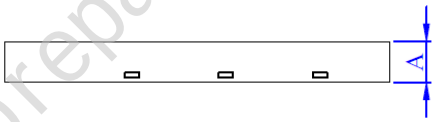
Top view



Bottom view



Side view

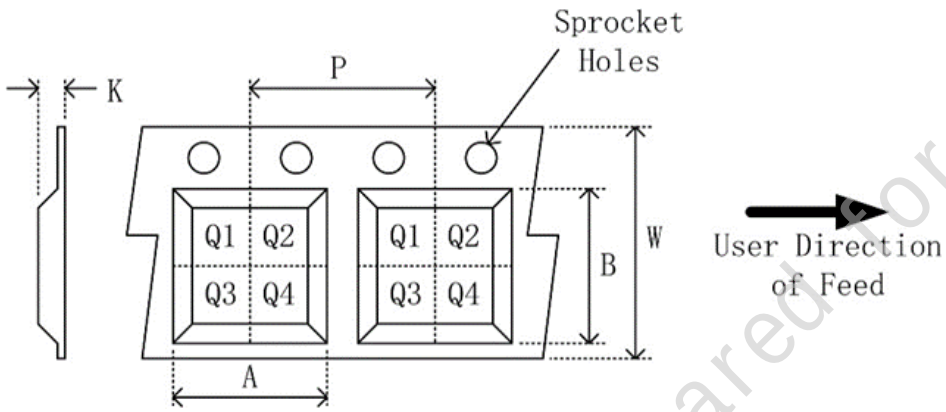


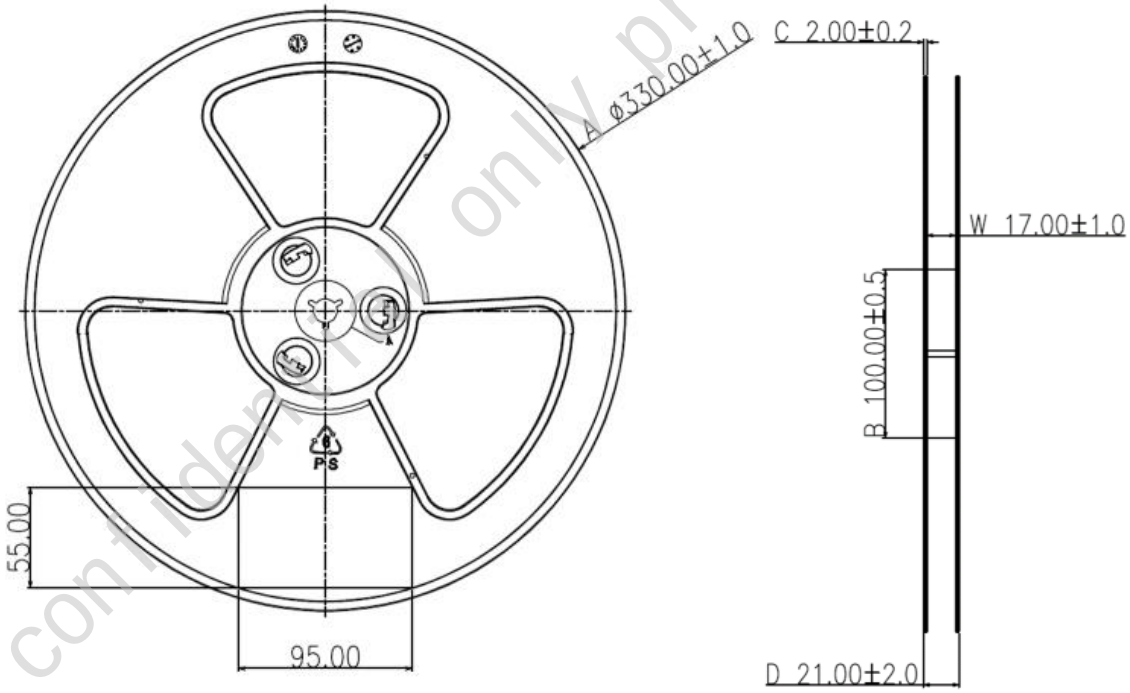
Side view

Symbol	Dimensions In Millimeters		
	MIN	NOM	MAX
A	0.80	0.85	0.90
A1	0.00	-	0.05
b	0.35	0.40	0.45
b1	2.70	2.80	2.90
D	7.90	8.00	8.10
D1	3.90	4.00	4.10
E	5.90	6.00	6.10
E1	4.70	4.80	4.90
e	0.8 BSC		
h	0.20	0.30	0.40
k	0.8 MIN		
K1	1.7 MIN		
K2	1.8 MIN		
L	0.30	0.40	0.50
L1	0.575	0.675	0.775

13. Tape and Reel Information

Device	Package Type	Pins	SPQ (pcs)	A (mm)	B (mm)	K (mm)	P (mm)	W (mm)	Pin1 Quadrant
MK2789CDG	DFN6x8-11L	11	3000	6.3±0.1	8.3±0.1	1.0±0.1	8.0±0.1	16.0±0.3	Q2





14. Tape and Reel Box Dimensions

Device	Package Type	Pins	SPQ (pcs)	Length (mm)	Width (mm)	Height (mm)
MK2789CDG	DFN6x8-11L	11	6000	360	360	65