High Precision CC/CV Primary-Side Controller ME8311

General Description

The ME8311 is a high performance offline PSR controller for low power AC/DC charger and adapter applications. ME8311 integrates a high voltage power MOSFET of 600V. 1A. It operates in primary-side sensing and regulation. Consequently, opto-coupler and ME431 could be eliminated. Proprietary Constant Voltage (CV) and Constant Current (CC) control is integrated as shown in the figure.1 below.

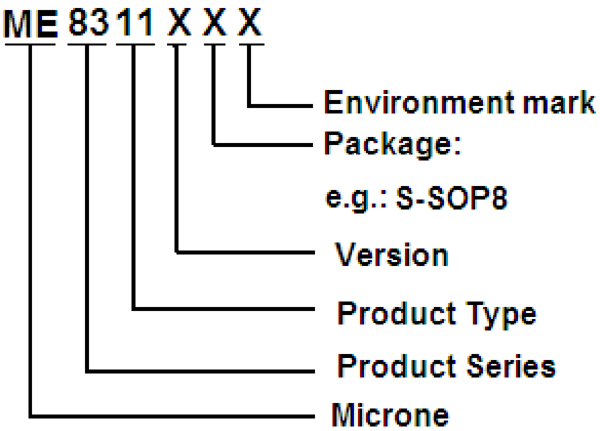
In CC control, the current and output power setting can be adjusted externally by the sense resistor R_S at CS pin. In CV control, PFM operations are utilized to achieve high performance and high efficiency. In addition, good load regulation is achieved by the built-in cable drop compensation. The chip consumes very low operation current (typical 420μA), it can achieve less than 30mW standby power to meet strict standby power standard.

ME8311 offers comprehensive protection coverage with auto-recovery features including Cycle-by-Cycle current limiting, VDD over voltage protection, feedback loop open protection, short circuit protection, built-in leading edge blanking, VDD under voltage lockout (UVLO), etc.

Features

- ●±5% Constant Voltage Regulation at universal AC input
- ●High precision constant current regulation at universal AC input
- ●Primary-side sensing and regulation without ME431 and opo-coupler
- ●Built-in primary winding inductance compensation
- ●Programmable cable drop compensation
- ●Ultra low start-up current (Typ. 1μA)
- ●VDD over voltage protection
- ●Built-in feedback loop open protection
- ●Built-in leading edge blanking (LEB)
- ●Built-in short circuit protection
- ●Cycle-by-Cycle current limiting
- ●VDD under voltage lockout with hysteresis (UVLO)
- ●SOP8 package

Selection Guide

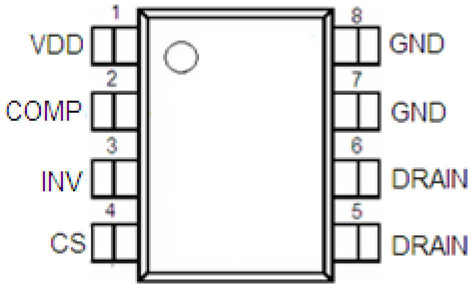


Applications

Low power AC/DC offline SMPS for:

- ●Cell phone charge
- ●Digital cameras charger
- ●Small power adapter
- ●Auxiliary power for PC, TV, etc.

Pin Configuration



Pin Assignment

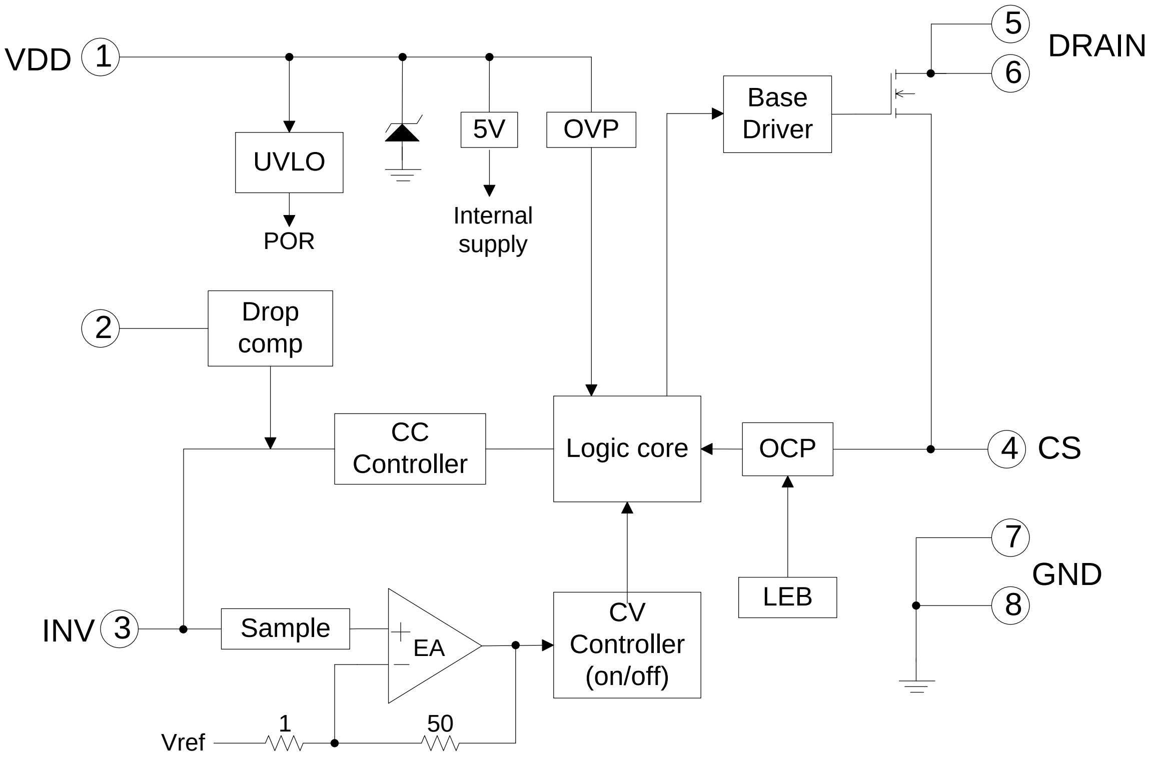
Pin Num.	Symbol	Function
1	VDD	Power supply
2	COMP	Loop Compensation for CV Stability
3	INV	The voltage feedback from the auxiliary winding. Connected to resistor divider from auxiliary winding reflecting output voltage PWM duty cycle is determined by EA output and current sense signal at pin 4.
4	CS	Current sense input pin. Connected to MOSFET current sensing resistor node.
5,6	DRAIN	HV MOSFET Drain Pin. The Drain pin is connected to the primary lead of the transformer
7,8	GND	Ground

Absolute Maximum Ratings

Parameter	Rating	Unit
Voltage at VDD pin to GND:VDD	-0.3～30	V
Voltage at CS,INV,COMP PIN to GND	-0.3～7	V
Min/Max operating Junction Temperature T_J	-40～150	°C
Lead Temperature (Soldering, 10secs)	260	°C
Min/Max Soldering temperature T_{stg}	-55～150	°C

Caution: The absolute maximum ratings are rated values exceeding which the product could suffer physical damage. These values must therefore not be exceeded under any conditions.

Block Diagram



Electrical Characteristics

（T_A =25 °C, V_{DD} =15V, unless otherwise noted.）

Item	Symbol	Test condition	Min	Typ.	Max	Unit
Supply Voltage(VDD) section						
Start-up current	$I_{start-up}$	VDD=11V	-	1	3	μA
Static current	I_{static}	VDD=15V	-	420	500	μA
VDD under voltage lockout exit	UVLO(off)		12.5	13.5	14.5	V
VDD under voltage lockout enter	UVLO(on)		7.4	8.0	8.6	V
VDD over voltage protection	V_{DD_OVP}		30	31	32	V
Max. operating voltage	V_{DD_max}		-	-	30	V
Current sense input section						
LEB time	T_{LEB}		-	0.5	-	μS
Over current threshold	V_{th_ocp}		485	500	515	mV

OCP propagation delay	Td_oc	From OCP comparator to base driver	-	100	-	nS
INV input section						
Reference voltage for feedback threshold	V_{REF_INV}	VDD=15V，V_{CS}=4V	1.94	2.00	2.10	V
Minimum pause	T_{pause_min}		-	2.0	-	μS
Maximum pause	T_{pause_max}		8	10	12	mS
Maximum cable compensation current	I_{comp_cable}	VDD=15V，V_{CS}=4V	42	45	49	μA
MOSFET SECTION						
Drain-Source Voltage	BVdss	Vgs=0	600	-	-	V
Static Drain-Source On-Resistance	Ron	V_{GS}=10V, Id=1.0A	-	10	15	Ω

Operation Description

ME8311 is a cost effective PSR controller optimized for off-line low power AC/DC applications including battery chargers. It operates in primary side sensing and regulation, thus opto-coupler and ME431 are not required. Proprietary built-in CV and CC control can achieve high precision CC/CV control meeting most charger application requirements.

●Startup Current and Start up Control

Startup current of ME8311 is designed to be very low so that VDD could be charged up above UVLO threshold and starts up quickly. A large value startup resistor can therefore be used to minimize the power loss in application.

●Operating Current

The Operating current of ME8311 is as low as 420μA. Good efficiency and very low standby power(less than 30mW) is achieved with the low operating current.

●CC/CV Operation

ME8311 is designed to produce good CC/CV control characteristic as shown in the Fig.1. In charger applications, a discharged battery charging starts in the CC portion of the curve until it is nearly full charged and smoothly switches to operate in CV portion of the curve. The CC portion provides output current limiting. In CV operation, the output voltage is regulated through the primary side control. In CC operation mode, ME8311 will regulate the output current constant regardless of the output voltage drop.

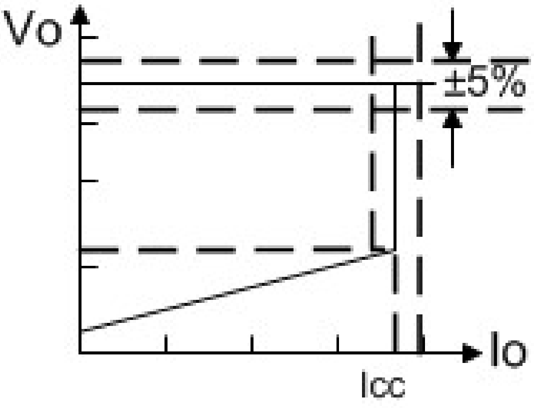


Fig.1 : Typical CC/CV curve

●Principle of Operation

To support ME8311 proprietary CC/CV control, power dissipation in a switching mode power supply is from switching loss on the MOSFET transistor, the core system needs to be designed in DCM mode for flyback system (Refer to Typical Application Diagram).

In the DCM flyback converter, the output voltage can be sensed via the auxiliary winding. During MOSFET turn-on time, the load current is supplied from the output filter capacitor, Co. The current in the primary winding ramps up. When MOSFET turns off, the energy stored in the primary winding is transferred to the secondary side such that the current in the secondary winding is : $Is = \frac{Np}{Ns} * Ip$.

The auxiliary voltage reflects the output voltage as shown in Fig.2 and it is given by $V_{AUX} = \frac{N_{AUX}}{Ns} * (Vo + \Delta V)$

Where the ΔV indicates the drop voltage of the output Diode.

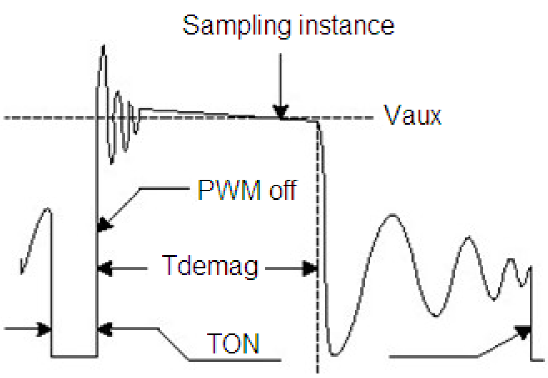


Fig.2: Auxiliary voltage waveform

Via a resistor divider connected between the auxiliary winding and INV (pin 3), the auxiliary voltage is sampled at the middle of the demagnetization and it is hold until the next sampling. The sampled voltage is compared with V_{REF} (2.0V) and the error is amplified. The error amplifier output reflects the load condition and controls the switching off time to regulate the output voltage, thus constant output voltage can be achieved. When the sampled voltage is below V_{REF} and the error amplifier output reaches its minimum, the switching frequency is controlled by the sampled voltage to regulate the output current, thus the constant output current can be achieved.

●Adjustable CC point and Output Power

In ME8311, the CC point and maximum output power can be externally adjusted by external current sense resistor Rs at CS pin as illustrated in typical application diagram. The larger Rs, the smaller CC point is, and the smaller output power becomes, and vice versa as shown in Fig.3.

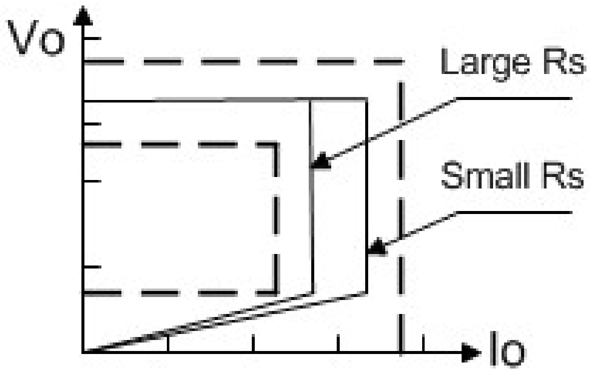


Fig.3: Adjustable output power by changing

●Operation switching frequency

The switching frequency of ME8311 is adaptively controlled according to the load conditions and the operation modes. For flyback operating in DCM, The maximum output power is given by $Po_{MAX} = \frac{1}{2} * Lp * Fsw * I^2p$

Where L_P indicates the inductance of primary winding and L_P is the peak current of primary winding. Refer to the equation below, the change of the primary winding inductance results in the change of the maximum output power and the constant output current in CC mode. To compensate the change from variations of primary winding inductance, the switching frequency is locked by an internal loop such that the switching frequency is

$$Fsw = \frac{1}{2 * Tdem}$$

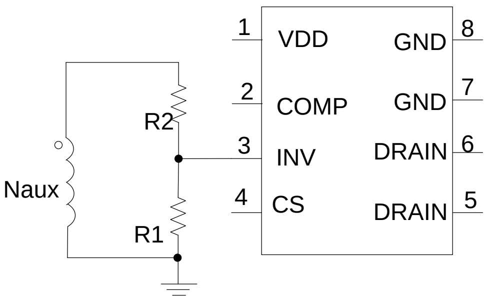
Since Tdemag is inversely proportional to the inductance, as a result, the product L_P and F_{SW} is constant, thus the maximum output power and constant current in CC mode will not change as primary winding inductance changes. Up to ±10% variation of the primary winding inductance can be compensated.

●Programmable Cable drop Compensation

In ME8311, cable drop compensation is implemented to achieve good load regulation. An offset voltage is generated at FB pin by an internal current flowing into the resister divider. The current is proportional to the switching off time, as a result, it is inversely proportional to the output load current, and the drop due to the cable loss can be compensated. As the load current decreases from full-load to no-load, the offset voltage at FB will increase. It can also be programmed by adjusting the resistance of the divider to compensate the drop for various cable lines used.

The percentage of maximum compensation is $\frac{\Delta V}{Vout} = \frac{Icomp\_cable * (R1//R2) * 10^{-6}}{2} * 100\%$

ΔV is load compensation voltage and Vout is output voltage; For example: R1//R2=3KΩ, the percentage of maximum compensation is $\frac{\Delta V}{Vout} = \frac{45 * 3000 * 10^{-6}}{2} * 100\% = 6.75\%$



●Current Sensing and Leading Edge Blanking

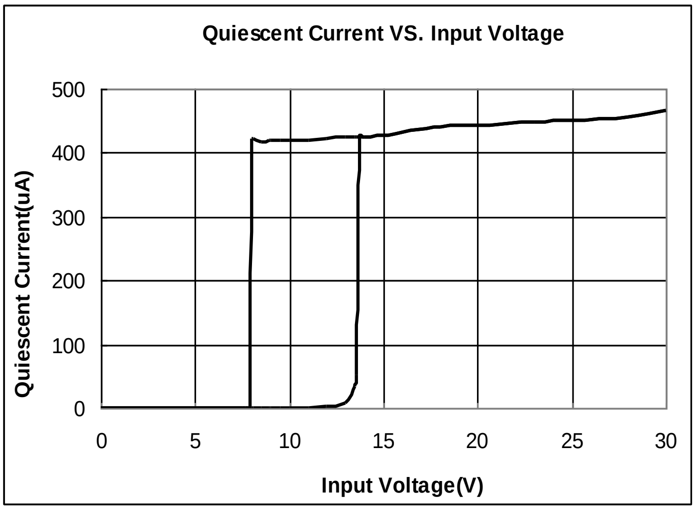
Cycle-by-Cycle current limiting is offered in ME8311. The switch current is detected by a sense resistor into the CS pin. An internal leading edge blanking circuit chops off the sensed voltage spike at initial power MOSFET on state so that the spike at initial power MOSFET on state so that the external RC filtering on sense input is no longer needed.

●Protection Control

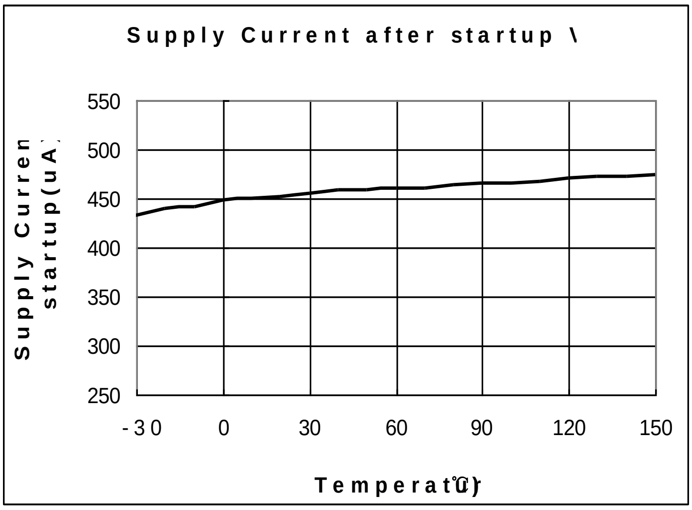
Good power supply system reliability is achieved with its rich protection features including Cycle-by-Cycle current limiting (OCP), VDD over voltage protection, feedback loop open protection, short circuit protection and Under Voltage Lockout on VDD (UVLO). VDD is supplied by transformer auxiliary winding output. The output of ME8311 is shut down when VDD drops below UVLO (ON) and the power converter enters power on start-up sequence thereafter.

Typical performance characteristics

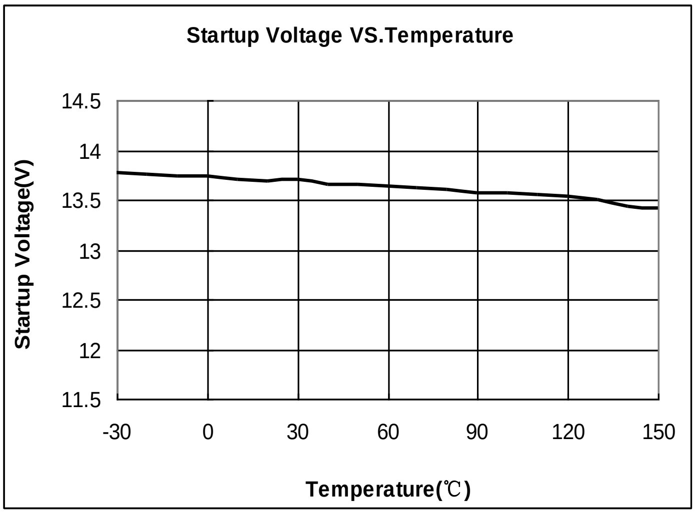
(1) IC Supply Current vs. Input Voltage



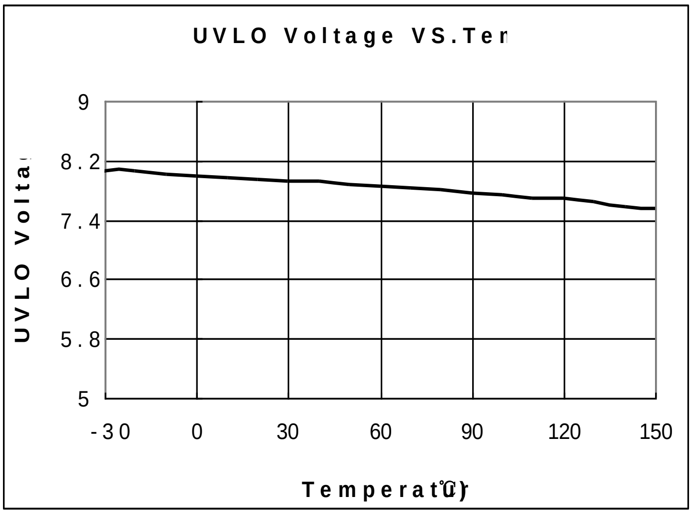
(2) Supply Current after startup vs. Temperature



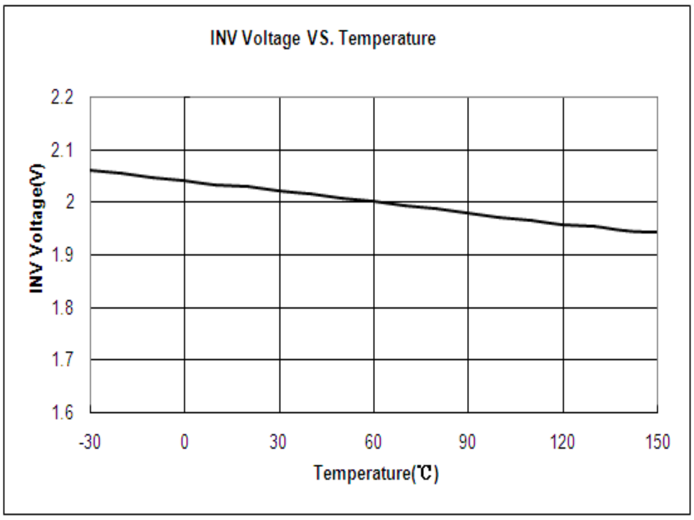
(3) Startup Voltage VS. Temperature



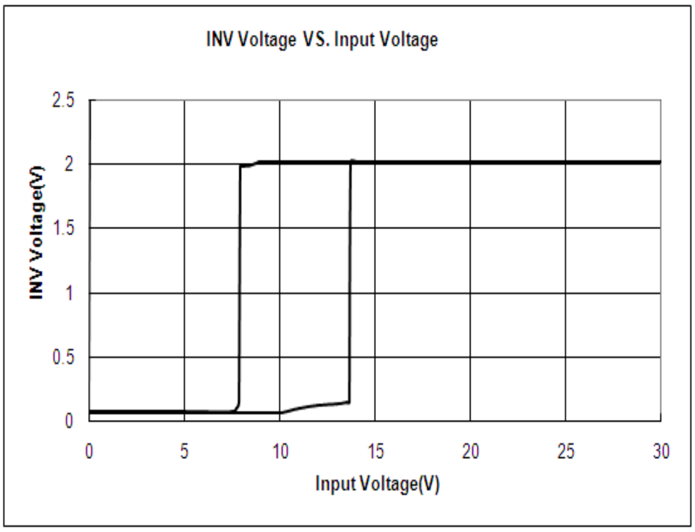
(4) VDD UVLO enter voltage vs. Temperature



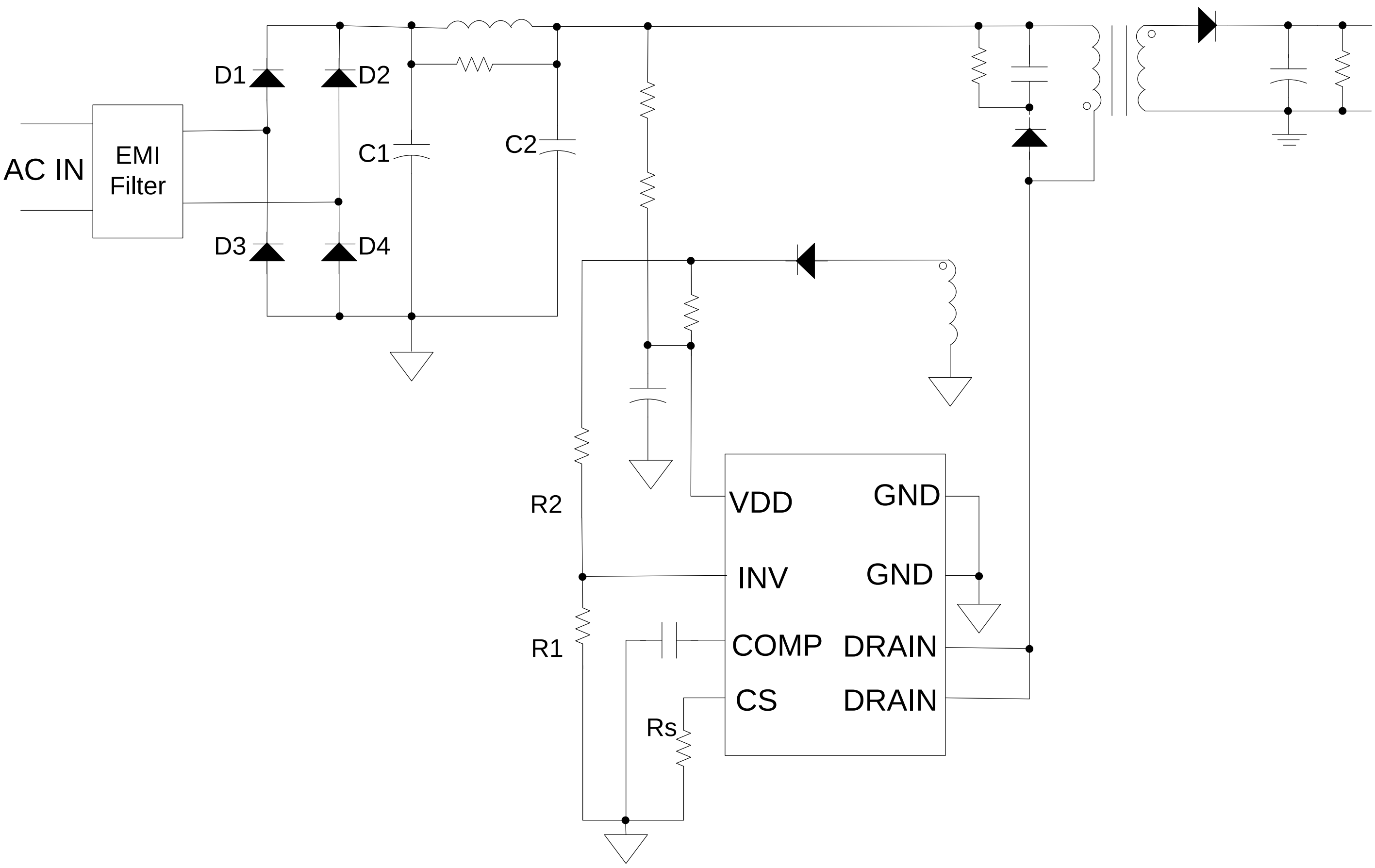
(5) INV voltage vs. Temperature



(6) INV Voltage VS. Input Voltage

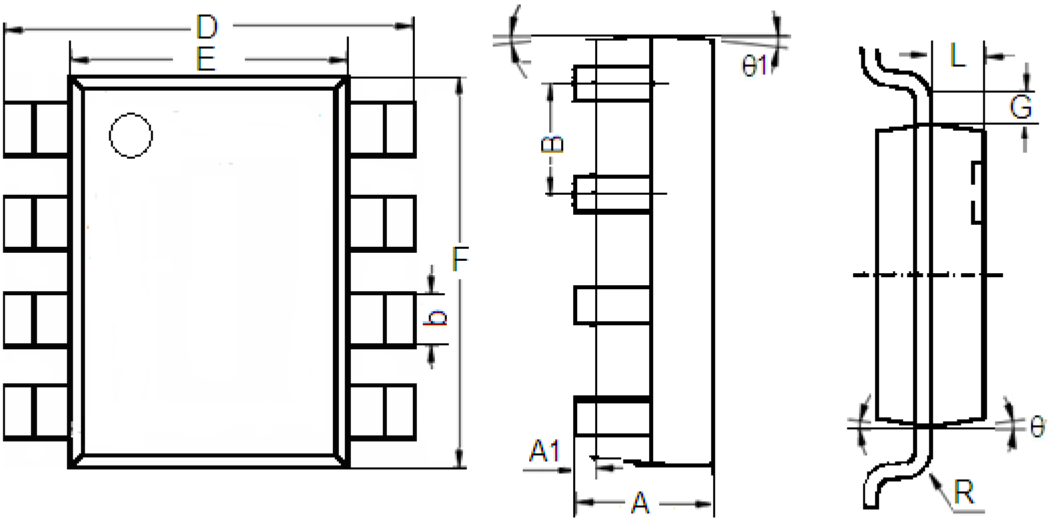


Typical Application



Package Information

Package type:SOP8 Unit:mm(inch)



Character	Dimension (mm)		Dimension (Inches)	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.1	0.3	0.004	0.012
B	1.27(Typ.)		0.05(Typ.)	
b	0.330	0.510	0.013	0.020
D	5.8	6.2	0.228	0.244
E	3.800	4.000	0.150	0.157
F	4.7	5.1	0.185	0.201
L	0.675	0.725	0.027	0.029
G	0.32(Typ.)		0.013(Typ.)	
R	0.15(Typ.)		0.006(Typ.)	
θ1	7°		7°	
θ	8°		8°	

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High Precision CC/CV Primary-Side Controller ME8313

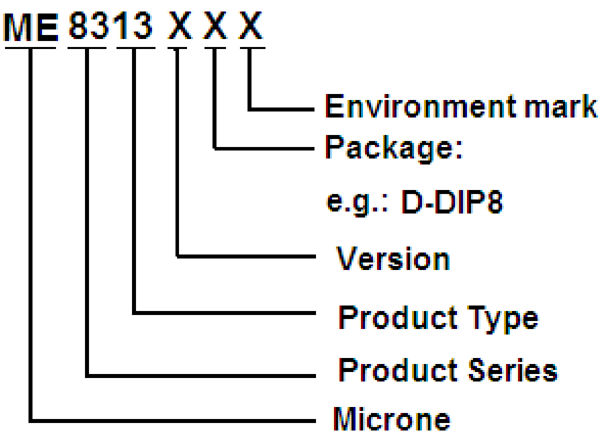
General Description

The ME8313 is a high performance offline PSR controller for low power AC/DC charger and adapter applications. ME8313 integrates a high voltage power MOSFET of 600V, 2A. It operates in primary-side sensing and regulation. Consequently, opto-coupler and ME431 could be eliminated. Proprietary Constant Voltage (CV) and Constant Current (CC) control is integrated as shown in the figure.1 below.

In CC control, the current and output power setting can be adjusted externally by the sense resistor R_S at CS pin. In CV control, PFM operations are utilized to achieve high performance and high efficiency. In addition, good load regulation is achieved by the built-in cable drop compensation. The chip consumes very low operation current (typical 420μA), it can achieve less than 30mW standby power to meet strict standby power standard.

ME8313 offers comprehensive protection coverage with auto-recovery features including Cycle-by-Cycle current limiting, VDD over voltage protection, feedback loop open protection, short circuit protection, built-in leading edge blanking, VDD under voltage lockout (UVLO), etc.

Selection Guide



Features

- ●±5% Constant Voltage Regulation at universal AC input
- ●High precision constant current regulation at universal AC input
- ●Primary-side sensing and regulation without ME431 and opo-coupler
- ●Built-in primary winding inductance compensation
- ●Programmable cable drop compensation
- ●Ultra low start-up current (Typ. 1μA)
- ●VDD over voltage protection
- ●Built-in feedback loop open protection
- ●Built-in leading edge blanking (LEB)
- ●Built-in short circuit protection
- ●Cycle-by-Cycle current limiting
- ●VDD under voltage lockout with hysteresis (UVLO)
- ●DIP8 package

Applications

Low power AC/DC offline SMPS for:

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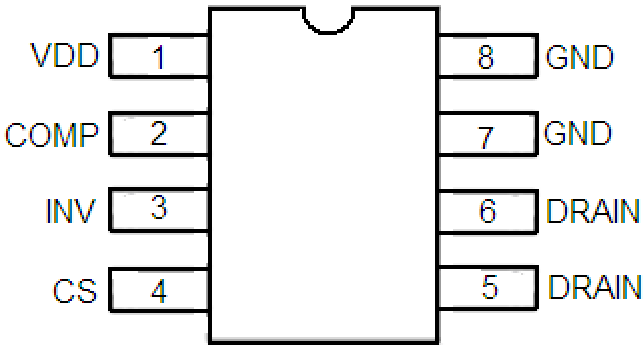
- ●Digital cameras charger
- ●Small power adapter
- ●Auxiliary power for PC, TV, etc.

Pin Configuration



Pin Assignment

Pin Num.	Symbol	Function
1	VDD	Power supply
2	COMP	Low pass filter capacitor for cable compensation
3	INV	The voltage feedback from the auxiliary winding. Connected to resistor divider from auxiliary winding reflecting output voltage
4	CS	Current sense input pin. Connected to MOSFET current sensing resistor node.
5,6	DRAIN	Drain of internal HV MOS
7,8	GND	Ground

Absolute Maximum Ratings

Parameter	Rating	Unit
Voltage at VDD pin to GND:VDD	-0.3～30	V
Voltage at CS,INV,COMP PIN to GND	-0.3～7	V
Min/Max operating Junction Temperature T_J	-40～150	°C
Lead Temperature (Soldering, 10secs)	260	°C
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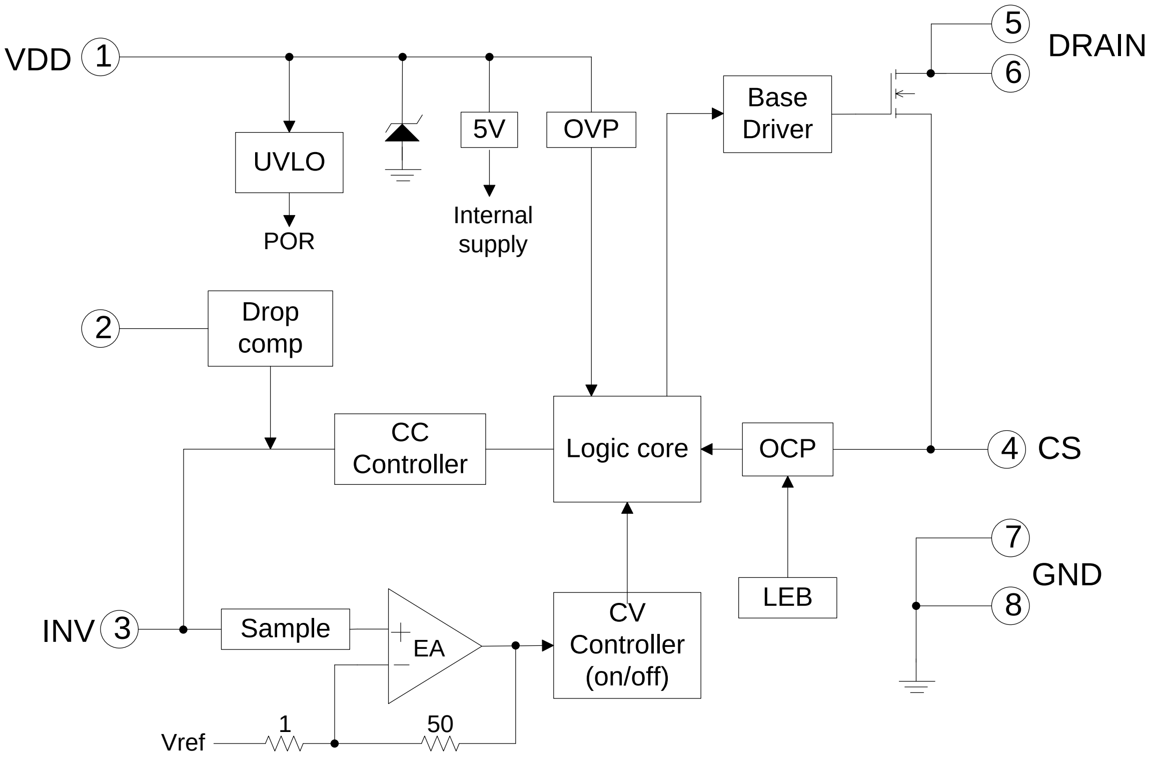
Block Diagram



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LEB time	T_{LEB}		-	0.5	-	μS
Over current threshold	V_{th_ocp}		485	500	515	mV
OCP propagation delay	Td_oc	From OCP comparator to base driver	-	100	-	nS

INV input section						
Reference voltage for feedback threshold	V_{REF_INV}	VDD=15V，V_{CS}=4V	1.94	2.00	2.10	V
Minimum pause	T_{pause_min}		-	2.0	-	μS
Maximum pause	T_{pause_max}		8	10	12	mS
Maximum cable compensation current	I_{comp_cable}	VDD=15V，V_{CS}=4V	42	45	49	μA
MOSFET SECTION						
Drain-Source Voltage	BVdss	Vgs=0	600	-	-	V
Static Drain-Source On-Resistance	Ron	V_{GS}=10V, Id=1.0A	-	-	4.7	Ω

Operation Description

ME8313 is a cost effective PSR controller optimized for off-line low power AC/DC applications including battery chargers. It operates in primary side sensing and regulation, thus opto-coupler and ME431 are not required. Proprietary built-in CV and CC control can achieve high precision CC/CV control meeting most charger application requirements.

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Startup current of ME8313 is designed to be very low so that VDD could be charged up above UVLO threshold and starts up quickly. A large value startup resistor can therefore be used to minimize the power loss in application.

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The Operating current of ME8313 is as low as 420μA. Good efficiency and very low standby power(less than 30mW) is achieved with the low operating current.

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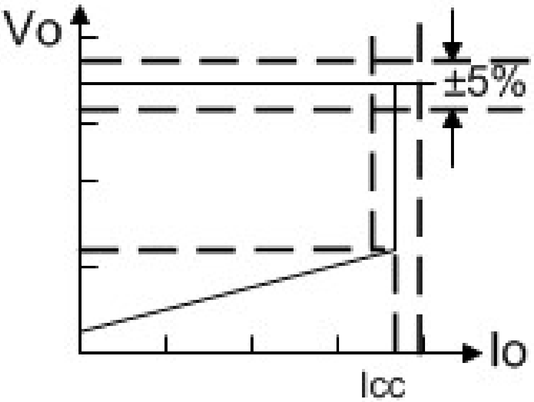


Fig.1 : Typical CC/CV curve

●Principle of Operation

To support ME8313 proprietary CC/CV control, power dissipation in a switching mode power supply is from switching loss on the MOSFET transistor, the core system needs to be designed in DCM mode for flyback system (Refer to Typical Application Diagram).

In the DCM flyback converter, the output voltage can be sensed via the auxiliary winding. During MOSFET turn-on time, the load current is supplied from the output filter capacitor, Co. The current in the primary winding ramps up. When MOSFET turns off, the energy stored in the primary winding is transferred to the secondary side such that the current in the secondary winding is : $Is = \frac{Np}{Ns} * Ip$.

The auxiliary voltage reflects the output voltage as shown in Fig.2 and it is given by $V_{AUX} = \frac{N_{AUX}}{Ns} * (Vo + \Delta V)$

Where the ΔV indicates the drop voltage of the output Diode.

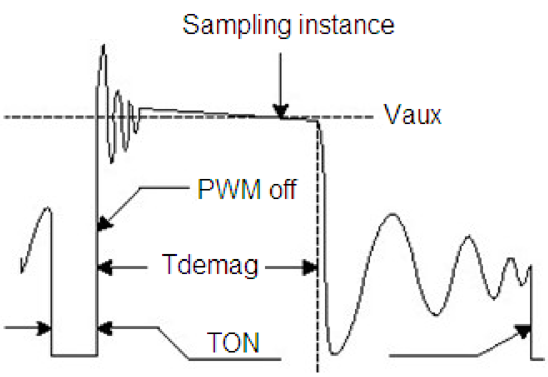


Fig.2: Auxiliary voltage waveform

Via a resistor divider connected between the auxiliary winding and INV (pin 3), the auxiliary voltage is sampled at the middle of the demagnetization and it is hold until the next sampling. The sampled voltage is compared with V_{REF} (2.0V) and the error is amplified. The error amplifier output reflects the load condition and controls the switching off time to regulate the output voltage, thus constant output voltage can be achieved. When the sampled voltage is below V_{REF} and the error amplifier output reaches its minimum, the switching frequency is controlled by the sampled voltage to regulate the output current, thus the constant output current can be achieved.

●Adjustable CC point and Output Power

In ME8313, the CC point and maximum output power can be externally adjusted by external current sense resistor Rs at CS pin as illustrated in typical application diagram. The larger Rs, the smaller CC point is, and the smaller output power becomes, and vice versa as shown in Fig.3.

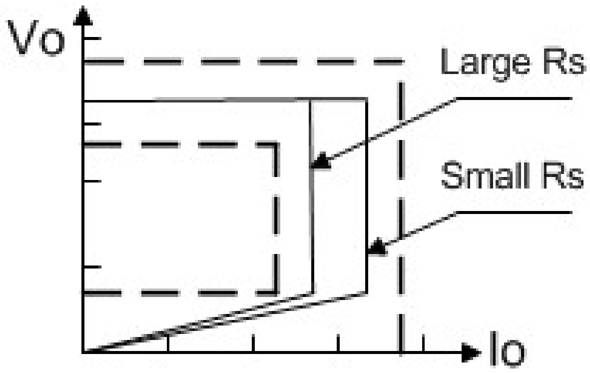


Fig.3: Adjustable output power by changing

●Operation switching frequency

The switching frequency of ME8313 is adaptively controlled according to the load conditions and the operation modes. For flyback operating in DCM, The maximum output power is given by $Po_{MAX} = \frac{1}{2} * Lp * Fsw * I^2p$

Where L_P indicates the inductance of primary winding and L_P is the peak current of primary winding. Refer to the equation below, the change of the primary winding inductance results in the change of the maximum output power and the constant output current in CC mode. To compensate the change from variations of primary winding inductance, the switching frequency is locked by an internal loop such that the switching frequency is

$$Fsw = \frac{1}{2 * Tdema}$$

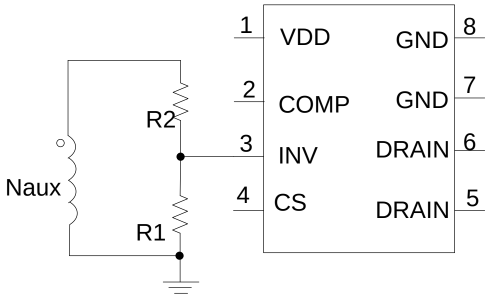
Since Tdemag is inversely proportional to the inductance, as a result, the product L_P and F_{SW} is constant, thus the maximum output power and constant current in CC mode will not change as primary winding inductance changes. Up to ±10% variation of the primary winding inductance can be compensated.

●Programmable Cable drop Compensation

In ME8313, cable drop compensation is implemented to achieve good load regulation. An offset voltage is generated at FB pin by an internal current flowing into the resister divider. The current is proportional to the switching off time, as a result, it is inversely proportional to the output load current, and the drop due to the cable loss can be compensated. As the load current decreases from full-load to no-load, the offset voltage at FB will increase. It can also be programmed by adjusting the resistance of the divider to compensate the drop for various cable lines used.

The percentage of maximum compensation is $\frac{\Delta V}{Vout} = \frac{Icomp\_cable * (R1//R2) * 10^{-6}}{2} * 100\%$

ΔV is load compensation voltage and Vout is output voltage; For example: R1∥R2=3KΩ, the percentage of maximum compensation is $\frac{\Delta V}{Vout} = \frac{45 * 3000 * 10^{-6}}{2} * 100\% = 6.75\%$



●Current Sensing and Leading Edge Blanking

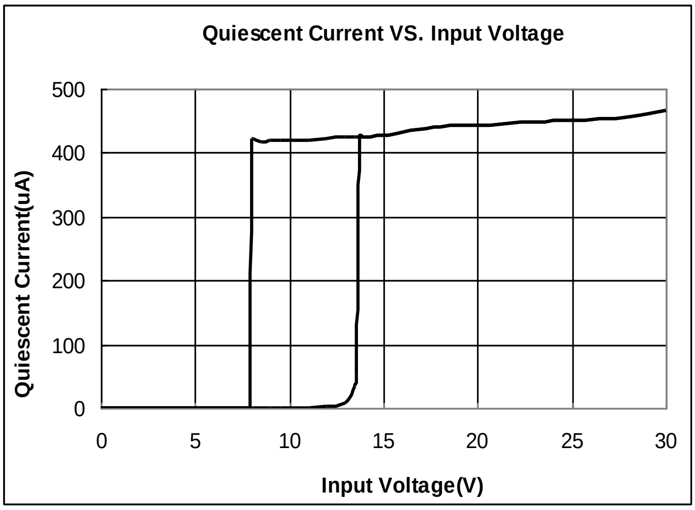
Cycle-by-Cycle current limiting is offered in ME8313. The switch current is detected by a sense resistor into the CS pin. An internal leading edge blanking circuit chops off the sensed voltage spike at initial power MOSFET on state so that the spike at initial power MOSFET on state so that the external RC filtering on sense input is no longer needed.

●Protection Control

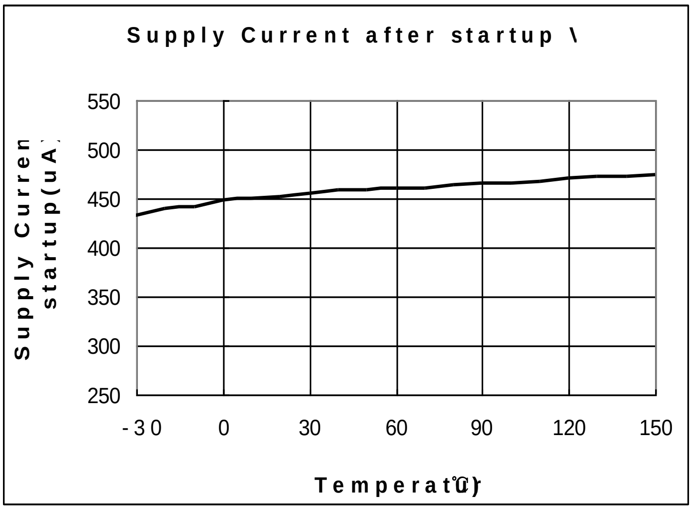
Good power supply system reliability is achieved with its rich protection features including Cycle-by-Cycle current limiting (OCP), VDD over voltage protection, feedback loop open protection, short circuit protection and Under Voltage Lockout on VDD (UVLO). VDD is supplied by transformer auxiliary winding output. The output of ME8313 is shut down when VDD drops below UVLO (ON) and the power converter enters power on start-up sequence thereafter.

Typical performance characteristics

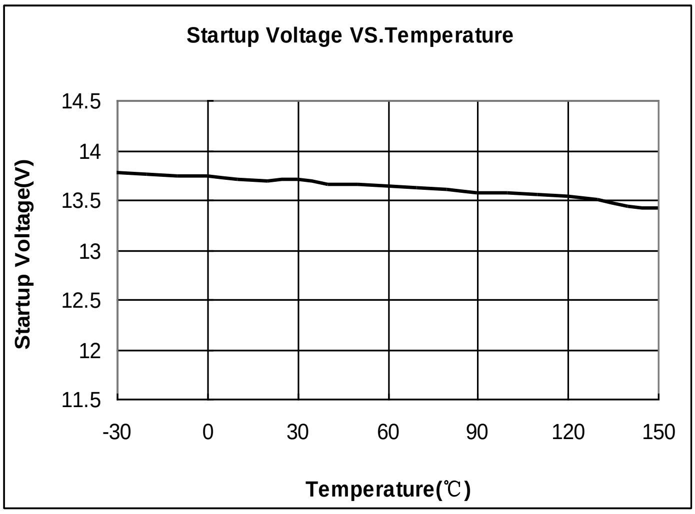
(1) IC Supply Current vs. Input Voltage



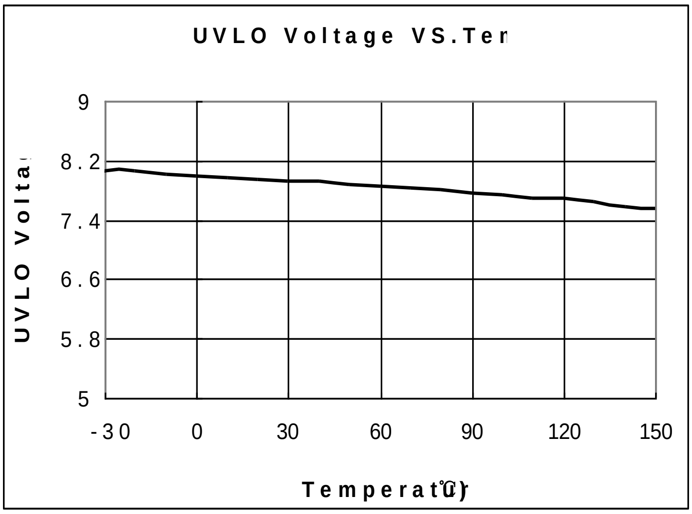
(2) Supply Current after startup vs. Temperature



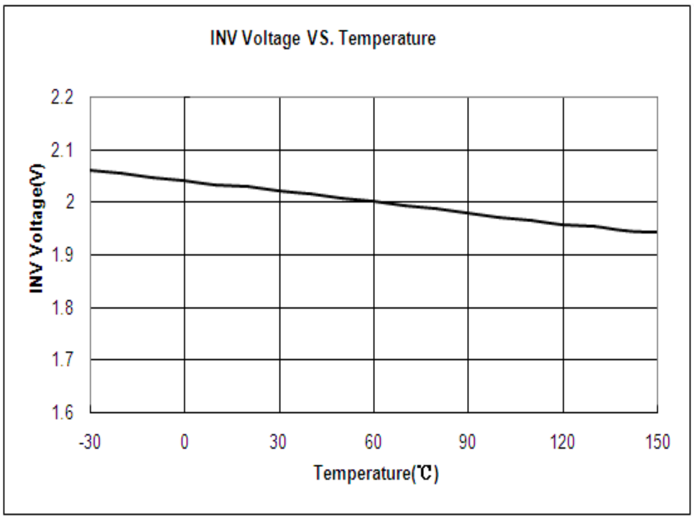
(3) Startup Voltage VS. Temperature



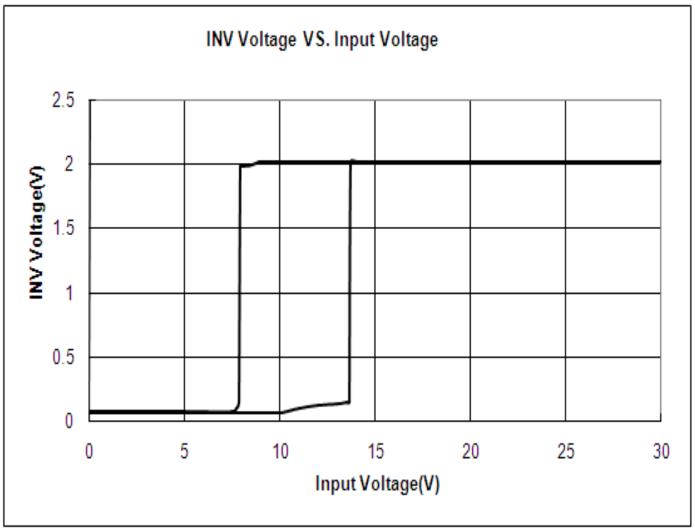
(4) VDD UVLO enter voltage vs. Temperature



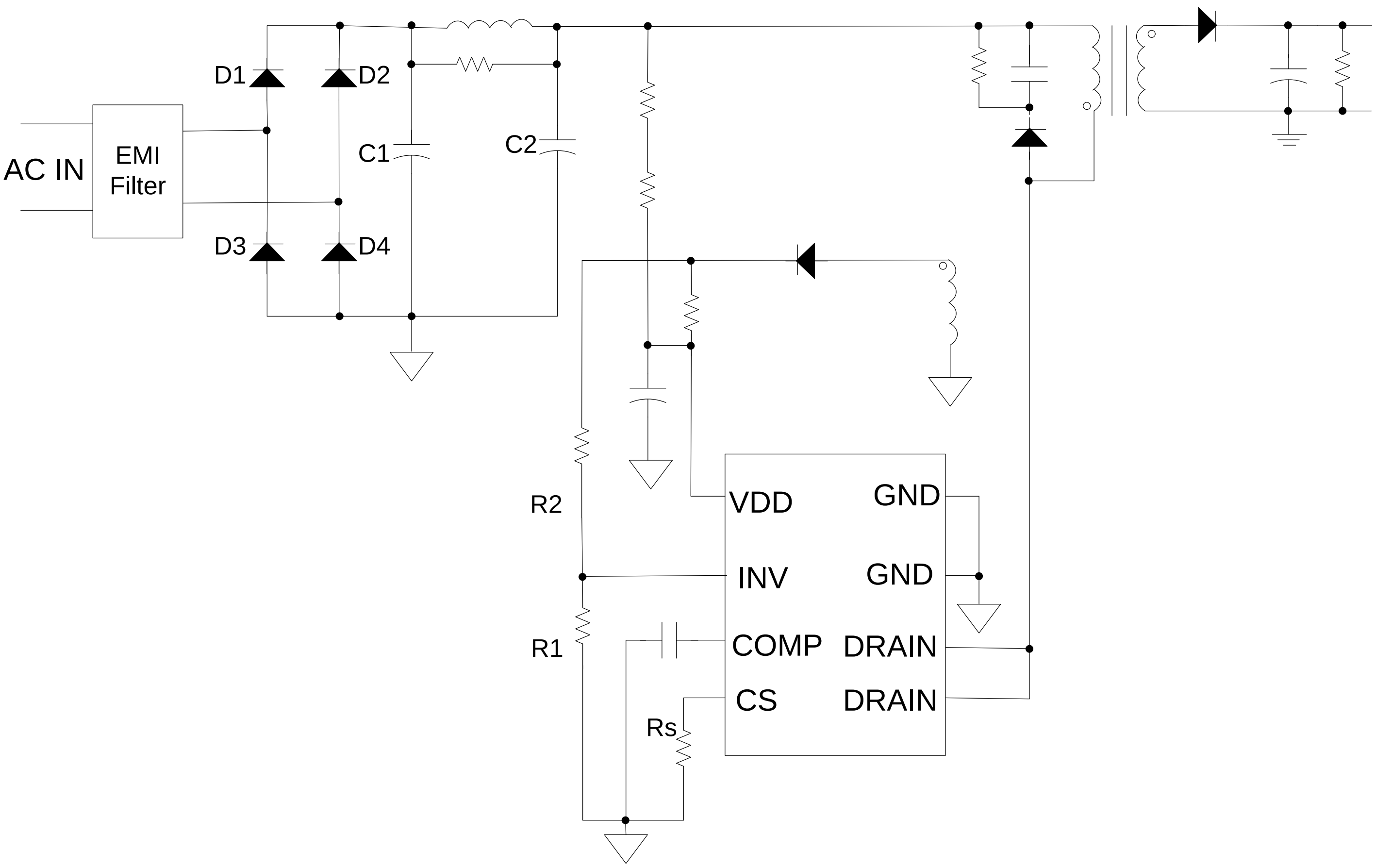
(5) INV voltage vs. Temperature



(6) INV Voltage VS. Input Voltage

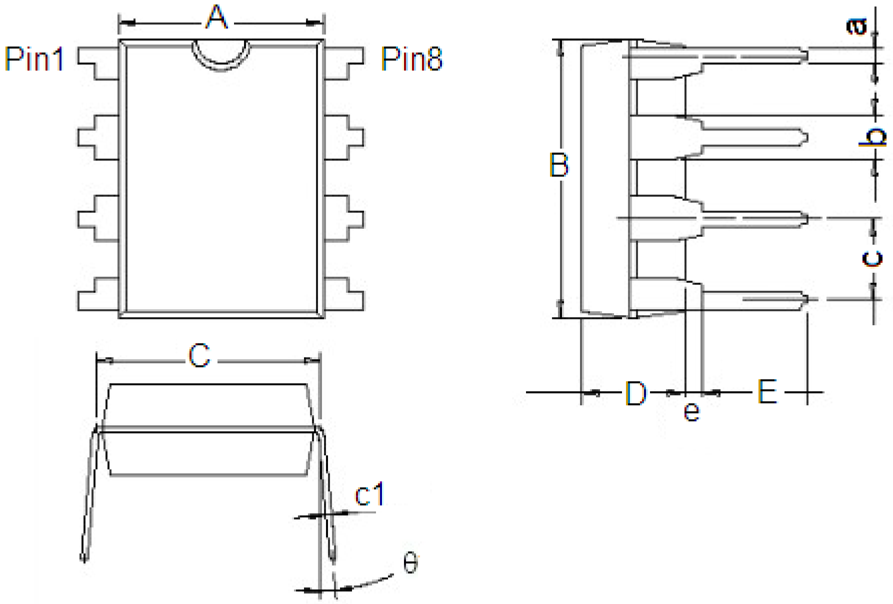


Typical Application



Package Information

Package type:DIP8   Unit:mm(inch)



Character	Dimension (mm)		Dimension (Inches)	
	Min	Max	Min	Max
A	6.200	6.600	0.244	0.260
B	9.000	9.400	0.354	0.370
C	7.620(Typ.)		0.300(Typ.)	
D	3.200	3.600	0.126	0.142
E	3.000	3.600	0.118	0.142
a	0.360	0.560	0.014	0.022
b	1.524(Typ.)		0.060(Typ.)	
c	2.54(Typ.)		0.100(Typ.)	
c1	0.204	0.360	0.008	0.014
e	0.510(Min)		0.020(Min)	
θ	0^0	15^0	0^0	150

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Single Stage, High PFC, AC-DC LED Driver ME8316

General Description

The ME8316 is a single-stage，primary side control AC-DC LED driver with high power factor. The LED current can be regulated accurately through sensing the primary side information with few external components without the need of an opto-coupler.

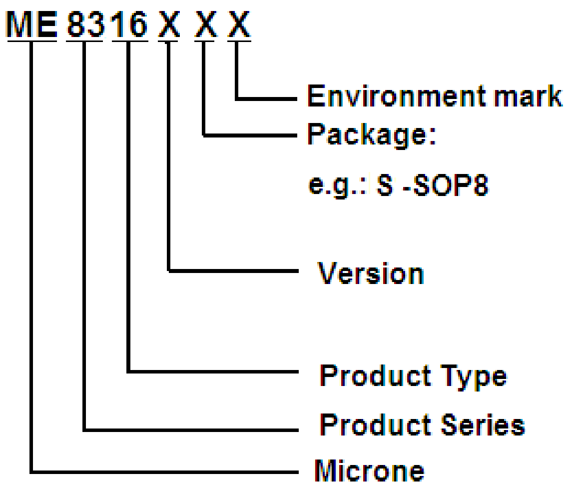
The ME8316 integrates power factor correction function and works in DCM and constant OFF time mode. A small harmonic current emission (THD) is achieved.

The ME8316 is also implemented with various protections, such as over-current protection (OCP), over-voltage protection (OVP), short-circuit protection (SCP) and over-temperature protection (OTP), etc, to ensure a reliable system.

Features

- Wide input voltage range from AC85V to AC265V
- Highly accurate constant LED current (±3%)
- Supply Voltage Range: 7.5V~18V
- Up to 50W power drivability.
- Primary-side current sensing and regulation without an opto-coupler
- Leading edge blanking (LEB) technique
- Cycle-by-cycle current limiting
- Under-voltage lockout (UVLO) protection
- VDD and output over voltage protection
- Adjustable constant current and output power setting
- Power on soft-start
- Available in SOP8 package

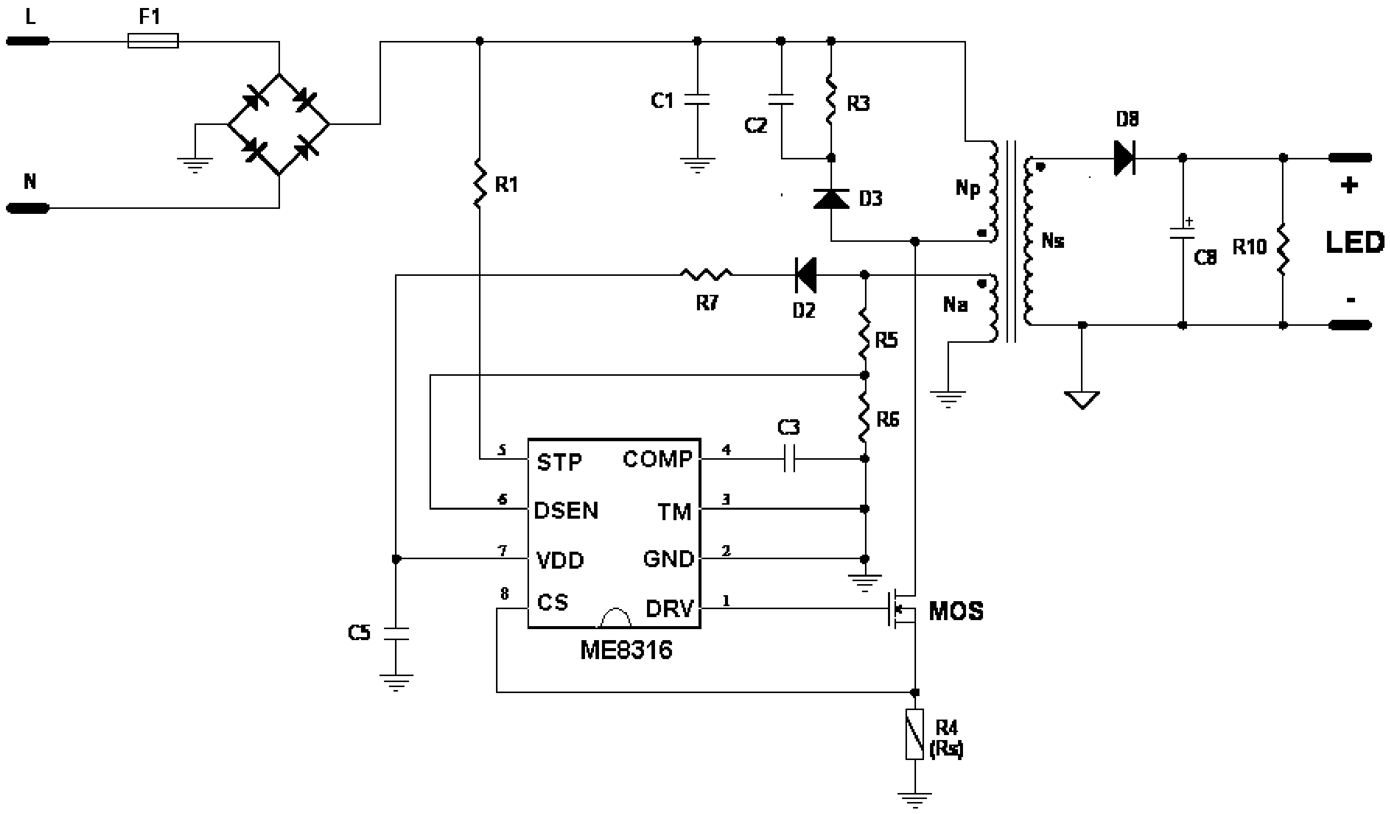
Selection Guide



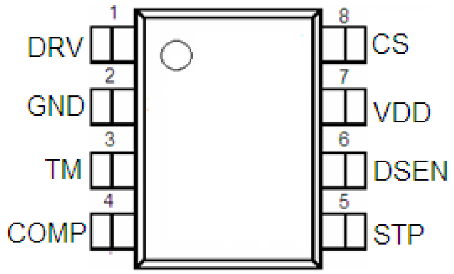
Applications

- AC/DC LED driver applications
- General purpose constant current source
- Signal and decorative LED lighting
- E14/E27/PAR30/PAR38/GU10 LED lamp

Typical Application Circuit



Pin Configuration



SOP8

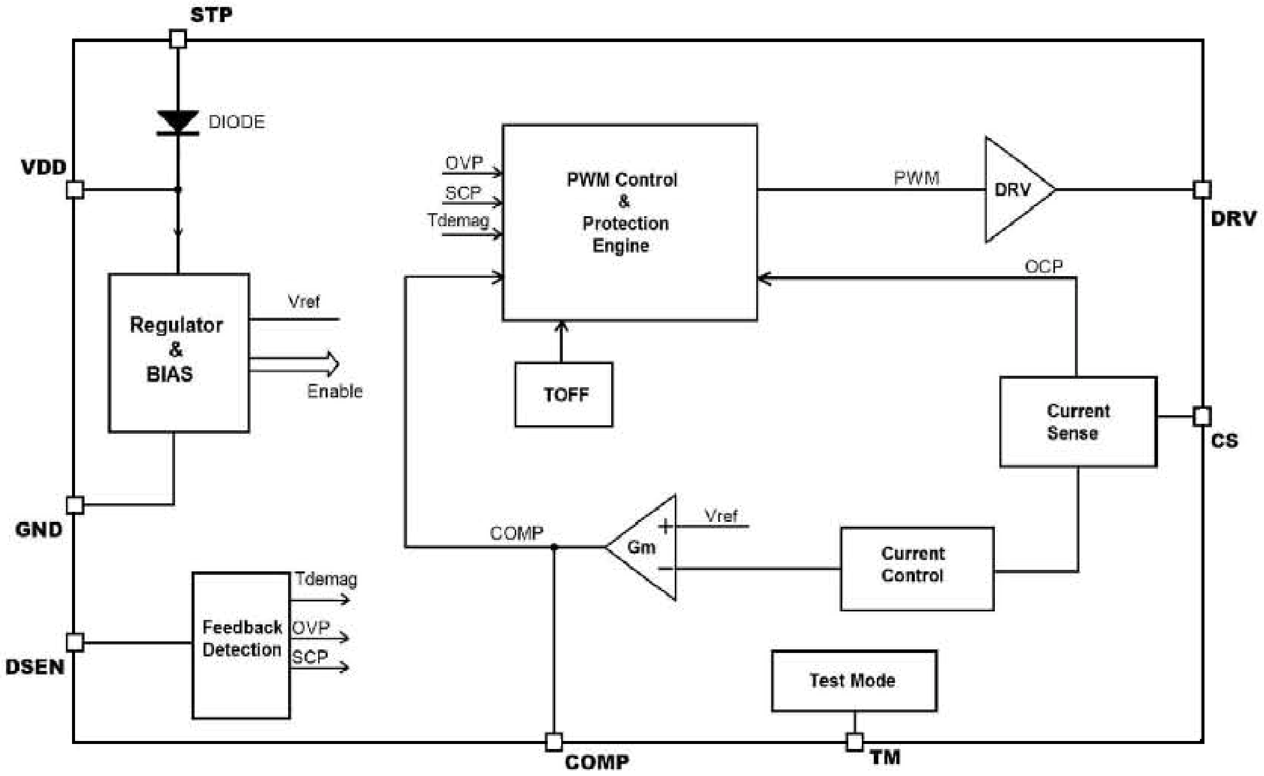
Pin Assignment

Pin Num.	Symbol	Function
1	DRV	Gate drive output for power N-MOSFET.
2	GND	Ground.
3	TM	Test pin. Always tie to ground.
4	COMP	Internal EA's output. Connect a capacitor to ground for frequency compensation.
5	STP	Start-up Pin. The MT7930 is softly started through STP Pin.
6	DSEN	The voltage feedback from auxiliary winding. Connected to a resistor divider from auxiliary winding reflecting output voltage.
7	VDD	Power Supply.
8	CS	Current Sense pin.

Absolute Maximum Ratings

Parameter	Rating	Unit
Voltage at STP, VDD, DRV to GND	-0.3～25	V
All Other Pins Voltage	-0.3～6	V
Power Dissipation	800	mW
Operating temperature	-40~105	°C
Storage Temperature	-55~+150	°C
Junction Temperature	150	°C
Thermal resistance junction-to-ambient	128	°C/W
Soldering temperature and time	+300（Recommended 10S）	°C

Block Diagram



Electrical Characteristics

（T_A =25 °C, VDD =12V, unless otherwise noted.）

Item	Symbol	Test condition	Min	Typ.	Max	Unit
Start-up(STP pin, VDD pin)						
Start up Current	I_{START}		-	30	50	μA
Lower Threshold Voltage of VDD	ULVO	VDD Pin ramp down	6.0	7.5	8.5	V
Start-up Voltage	V_{START}	VDD Pin ramp up	15.5	17.5	20	V
Supply Current						
Quiescent Current	Iq	No switching		1		mA
Operating Current	Icc	Fs=70KHZ		2		mA
Control Loop						
Primary Current Sense Voltage	VFB		392	400	408	mV
Upper Limit of COMP	V_{COMPH}		2.26	2.3	2.34	V
Off Time of DRV	T_{OFF}		11	12	13	μS
Short Circuit Protection Threshold at DSEN pin	SCP		190	200	210	mV
Over Voltage Protection Threshold at DSEN	OVP1		3.04	3.2	3.36	V
Over Voltage Protection Threshold at VDD pin	OVP2		18.2	19.2	23.5	V
Current Sense (CS pin)						
Leading Edge Blanking of CS	LEB			300		nS
Over Current Protection at CS pin	OCP			2.2	2.4	V
Thermal Protection						
Over temperature protection	OTP		-	150	-	℃
Over temperature release hysteresis			-	15	-	℃
Drive Stage(DRV pin)						
Rising Time	T_R	CL=1nF, DRV Pin Falls from VDD to 0V		50		nS
Falling Time	T_F	CL=1nF, DRV Pin Rises from 0V to VDD		30		nS

Application Information

The ME8316 is a primary-side controller for AC-DC LED driver. The LED current can be accurately regulated through sensing the primary side information to realize real current control. ME8316 integrates power factor correction function to eliminate pollution to the AC line and works in DCM and constant OFF time mode.

Real Current Control

ME8316 accurately regulate LED current through sensing the primary side information. The LED current can be easily set as following (refer to the application circuit in page 2):

$$I_{LED} = 0.94 \times \frac{1}{2} \times \frac{N_P}{N_S} \frac{V_{FB}}{R_S}$$

Where N_P is primary winding, N_S is secondary winding; V_{FB} (=400mV) is the internal voltage reference and R_S is an external current sensing resistor (Rs is R4 in page2 application circuit).

Start Up

During start-up process, VDD is charged through a start-up resistor. As VDD reaches 17.5V, the control logic starts to work, and the gate drive begins to switch. A soft-start function is implemented to prevent the transformer from entering into CCM (continuous current mode) as show in Fig.1.

The power supply is taken over by the auxiliary winding once the voltage of this winding is high enough.

After ME8316 control logic starts to work, STP pin is clamped to lower than VDD voltage about 0.2V.

The ME8316 will shut down if VDD goes below 7.5V (UVLO threshold voltage).

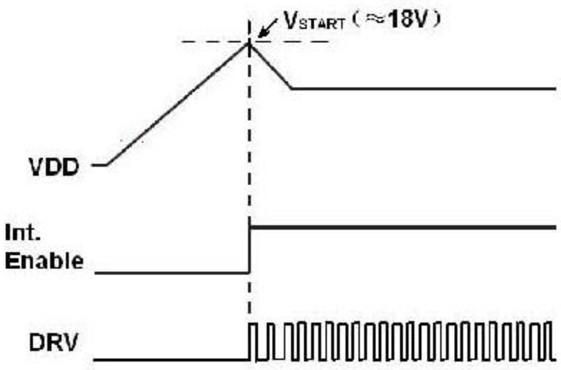


Fig.1 Start up sequence

Power Factor Correction

The primary side current increases linearly from zero to peak value, as sensed by the current sensing pin CS, during the external MOSFET on-time. When the primary current reaches the threshold, ME8316 turns off the power

MOSFET immediately. After a constant OFF time, TOFF, ME8316 turns on the power MOSFET again. The peak current threshold follows the rectified sinusoidal-shape of main line voltage. As a result, the envelope of the inductor current is sinusoidal-shaped, high power factor is therefore achieved in this way.

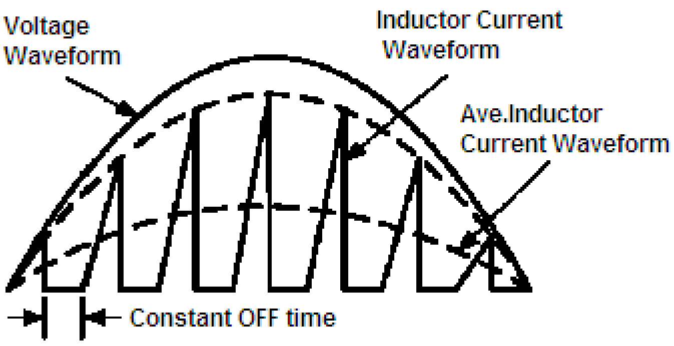


Fig.2 Power Factor Correction

Auxiliary Sensing

The ME8316 features over-voltage protection (OVP), short-circuit protection (SCP), and over-current protection (OCP) functions. Those protections are triggered by sensing the auxiliary winding waveform information, as the auxiliary winding voltage is proportional to the output voltage (secondary winding voltage) during the OFF time period. The auxiliary winding voltage is sampled by DSEN pin, one LEB (Leading Edge Blanking) time right after DRV signal is turned off.

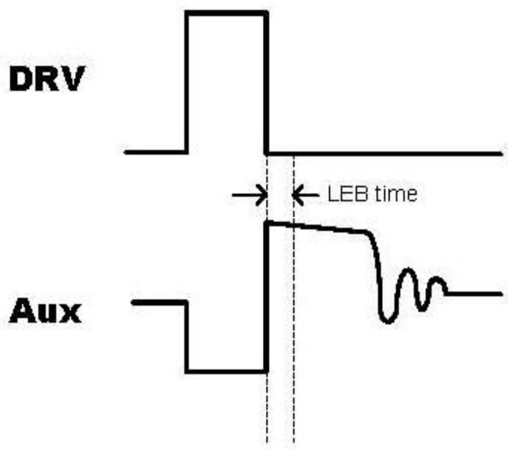


Fig.3 Auxiliary Single Sensing

Over-voltage Protection

The ME8316 is implemented with two over-voltage protection schemes: (1) If DSEN pin's voltage is detected above 3.2V for three times (refer to **Auxiliary Sensing** section), ME8316 turns off the PWM switching signal, and VDD voltage gradually drops to UVLO threshold, and the system will be re-started. The threshold voltage of over-voltage protection VOUT_OV, can be easily defined as (refer to the application circuit in page 2):

$$V_{OUT-OV} = 3.2 \times \left(1 + \frac{R5}{R6}\right) \times \frac{N_S}{N_a} - V_{D8}$$

Where N_S is the secondary winding, N_a is auxiliary winding, V_{D8} is the forward bias of the secondary side rectifier diode.

(2) If VDD pin's voltage exceeds 19.2V three times, ME8316 turns off the PWM switching signal, and VDD gradually drops to UVLO threshold, and then the system will be re-started. It is highly recommended to set up the VDD voltage between 12V and 16V by designed a proper N_a to N_S ratio of the transformer.

Short-circuit Protection

The short-circuit protection is triggered if the DSEN pin voltage is detected below 200mV for a continuous time of 640us. The gate drive switching will be turned off, and a restart process will be kicked off when the VDD voltage drops below the UVLO threshold.

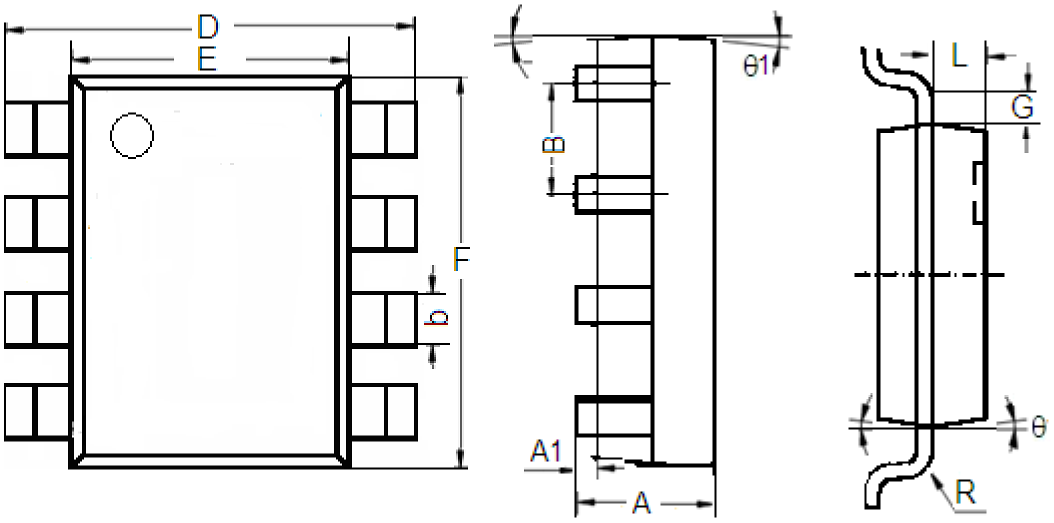
This re-start process will repeat if the short-circuit condition continues to exist.

Over-current Protection

The ME8316 immediately turns off the power MOSFET once the voltage at CS pin exceeds 2.2V. This cycle by cycle current limitation scheme prevents the relevant components, such as power MOSFET, transformer, etc. from damage.

Package Information

Package type:SOP8 Unit: mm (inch)



Character	Dimension (mm)		Dimension (Inches)	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.1	0.3	0.004	0.012
B	1.27(Typ.)		0.05(Typ.)	
b	0.330	0.510	0.013	0.020
D	5.8	6.2	0.228	0.244
E	3.800	4.000	0.150	0.157
F	4.7	5.1	0.185	0.201
L	0.675	0.725	0.027	0.029
G	0.32(Typ.)		0.013(Typ.)	
R	0.15(Typ.)		0.006(Typ.)	
θ1	7°		7°	
θ	8°		8°	

高精度原边反馈恒压恒流控制器 ME8317

概述

ME8317 是一款高精度离线式原边反馈控制器，应用于小功率 AC/DC 充电器与适配器。内部集成了 600V,2A 的高压功率 MOS 管。ME8317 使用原边反馈控制，可以省去光耦和 ME431。实现±5%的恒压恒流精度和小于 50mW 的待机功耗。

在恒流模式下，电流和输出功率可由 CS 脚外接的采样电阻 Rs 设定。在恒压模式下，PFM 工作模式可以保证较高的整体转换效率。此外，芯片内置有线电压降补偿，可得到良好的负载调整率。

ME8317 集成了诸多保护功能，包括：VDD 欠压保护(UVLO)，VDD 过压保护，短路保护，逐周期限流保护，LEB，VDD 电压钳位保护，等等。

特点

- ±5%恒压恒流精度
- 原边反馈控制，无需光耦和TL431
- 内置AC线输入电压恒流补偿
- 待机功耗小于50mW
- 低启动电流：1μA（典型值）
- 内置线压降补偿(Cable drop compensation)
- 内置600V高压MOSFET功率管
- VDD过压保护及钳位
- 输出过压保护
- 逐周期电流限制
- 内置前沿消隐(Leading edge blanking)
- VDD欠压保护(UVLO)

应用场合

- 手机/无绳电话充电器
- 数码相机充电器
- 小功率电源适配器
- 电脑/电视辅助电源

封装形式

- 7-pin SOP7
- 8-pin ESOP8

典型应用图

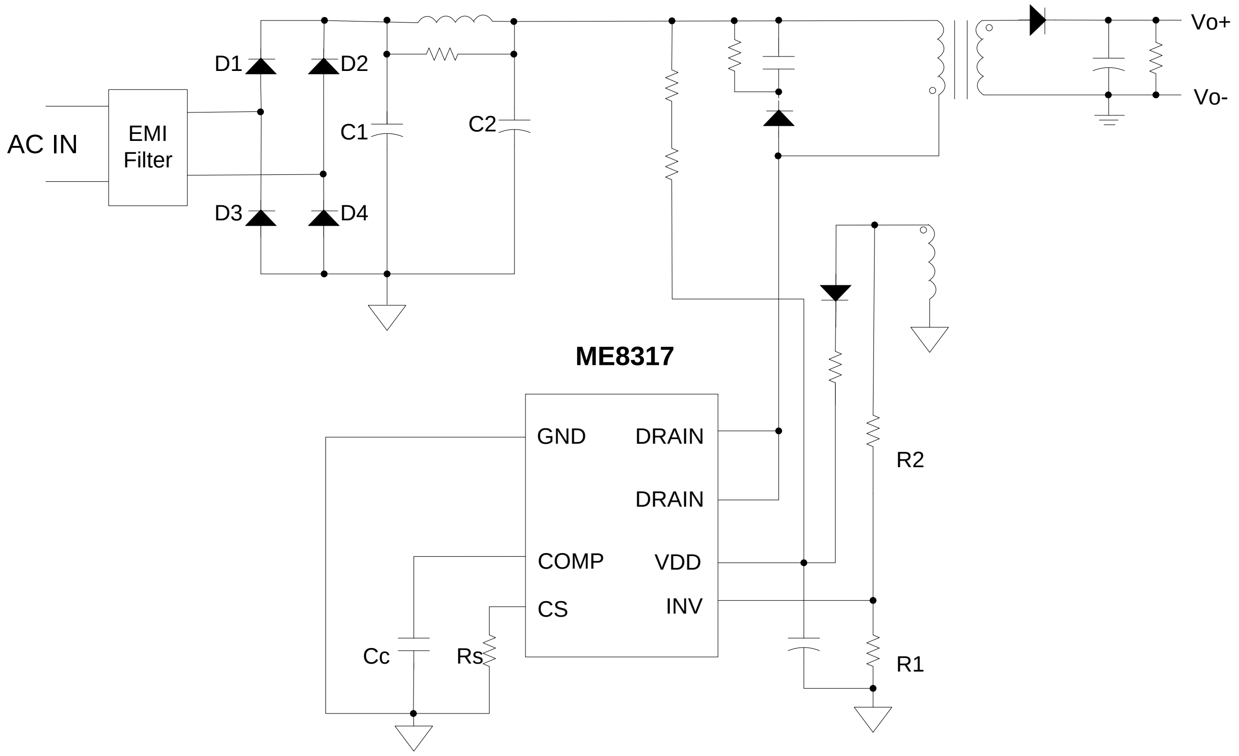
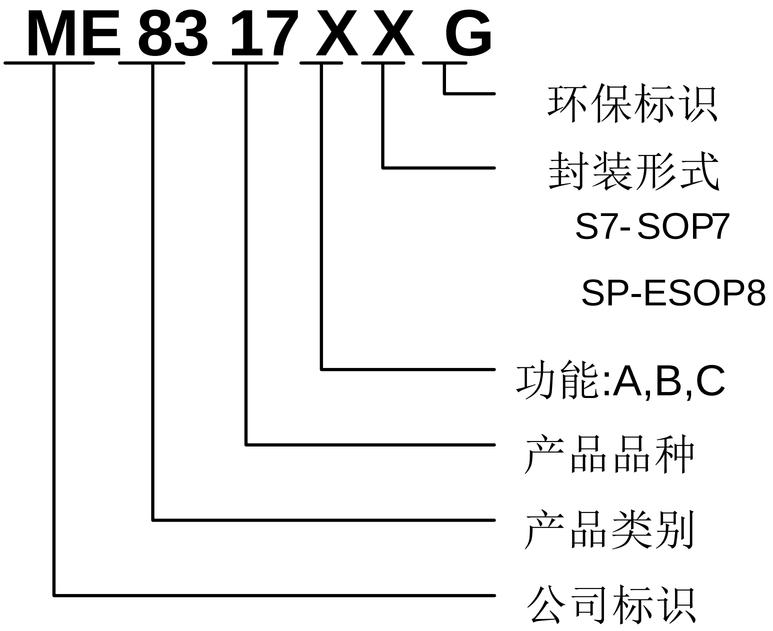


图.1　系统应用图

选购指南

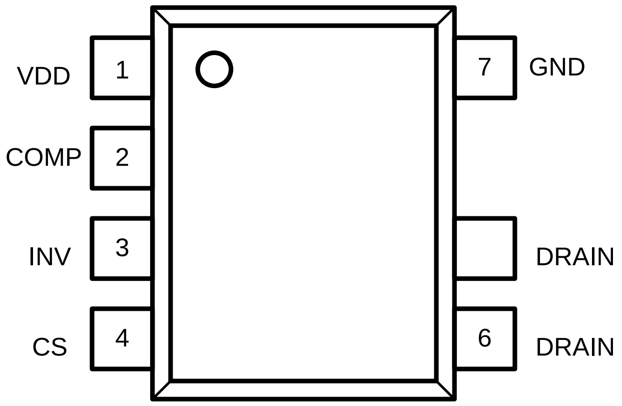
1. 产品型号说明



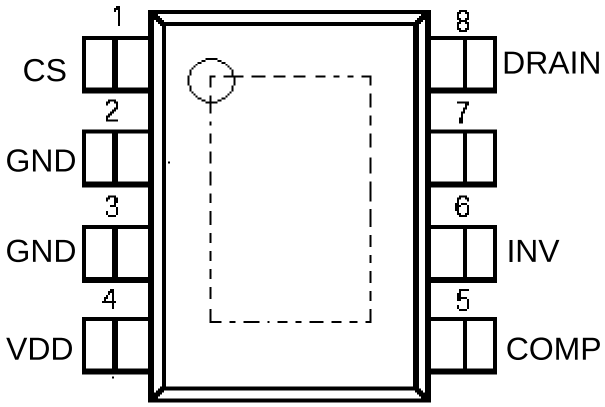
2. 产品系列说明

产品型号	产品说明
ME8317AS7G	内封 2N60 COOLMOS，适用于 8-10W
ME8317BS7G	内封普通 2N60 MOS，适用于 6-8W
ME8317CSPG	内封 2N60 COOLMOS，适用于 10-12W，底部加散热片

芯片脚位图



SOP7



ESOP8

脚位功能说明

PIN 脚位 (SOP7)	PIN 脚位 (ESOP8)	符号名	功能说明
1	4	VDD	芯片电源
2	5	COMP	外接低通滤波电容，用于线损补偿
3	6	INV	输出电压反馈输入端
4	1	CS	变压器原边电流采样端
5,6	8	DRAIN	高压MOSFET的漏极引脚，该引脚连接到变压器原边
7	2，3	GND	芯片地
	7	NC	空脚

芯片功能示意图

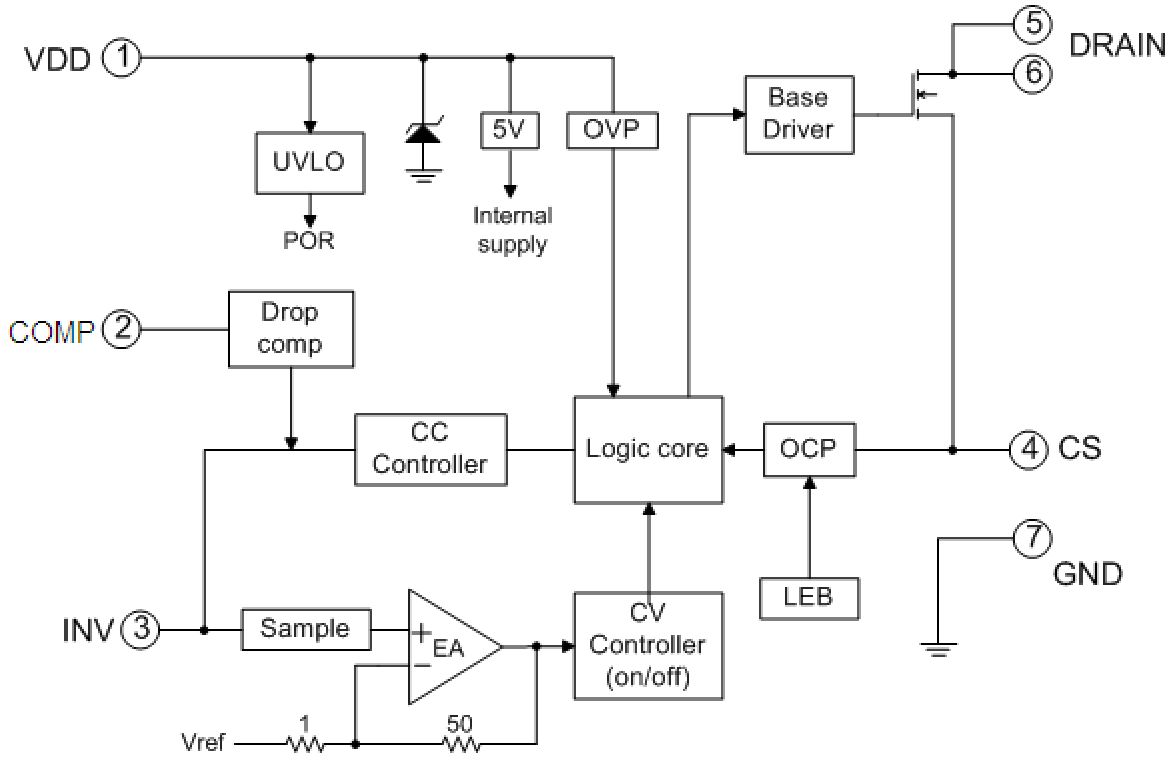


图.2　模块功能示意图

极限参数

参数	参数范围	单位
芯片电源电压	-0.3～30	V
CS,INV,COMP输入电压	-0.3 to 7	V
工作温度范围	-30~+150	℃
存储温度范围	-55~+150	℃
焊接温度(焊锡, 10 秒)	260（10S 推荐工作条件）	℃

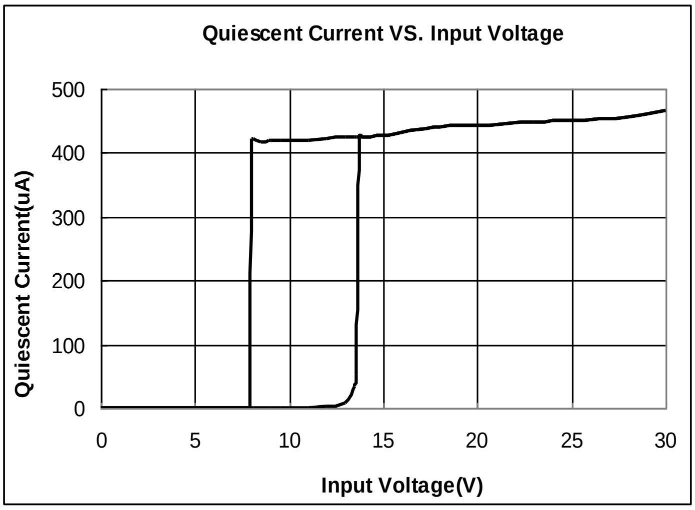
注释：超出极限参数可能损毁器件。不建议器件工作在推荐条件以外的情况。长时间运行在绝对最大额定条件下可能会影响器件的可靠性。

电气参数 (无特别说明，环境温度= 25℃，VDD输入电压=15V)

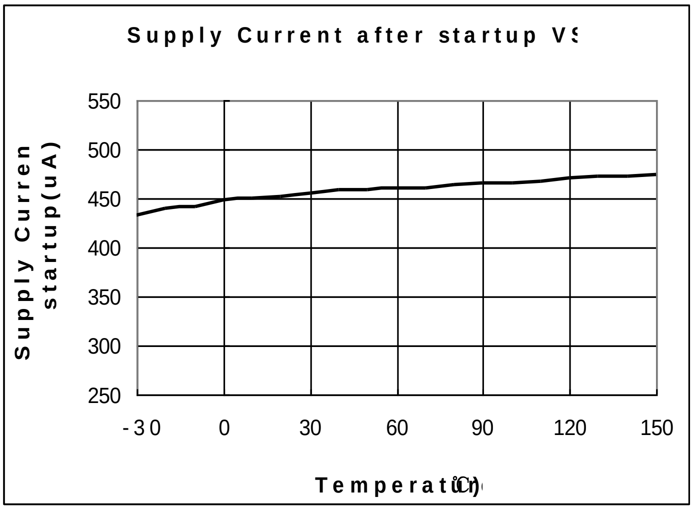
符号	参数	测试条件	最小值	典型值	最大值	单位
芯片电源部分						
$I_{start-up}$	启动电流	VDD=11V	-	1	3	μA
I_{static}	工作电流	VDD=15V	-	420	500	μA
UVLO(off)	VDD启动电压		12.5	13.5	14.5	V
UVLO(on)	VDD欠压保护		7.4	8.0	8.6	V
V_{DD_OVP}	VDD过压保护		30	31	32	V
V_{DD_max}	VDD最大工作电压		-	-	30	V
反馈输入部分						
V_{REF_INV}	反馈参考电压	VDD=15V，V_{CS}=4V	1.94	2.00	2.10	V
T_{pause_min}	最短暂停时间		-	2.0	-	μS
T_{pause_max}	最长暂停时间		8	10	12	mS
I_{comp_cable}	最大线损补偿电流	VDD=15V，V_{CS}=4V	42	45	49	μA
电流检测部分						
T_{LEB}	CS前沿消隐时间		-	0.5	-	μS
V_{th_ocp}	CS过流阈值电压		485	500	515	mV
Td_oc	过流关断延迟		-	100	-	nS
MOS功率管部分						
BVdss	MOS的漏源击穿电压	Vgs=0，Ids=250μA	600	-	-	V
Ron	导通电阻	V_{GS}=10V, Id=1.0A	-	-	2.3	Ω

典型温度特性曲线

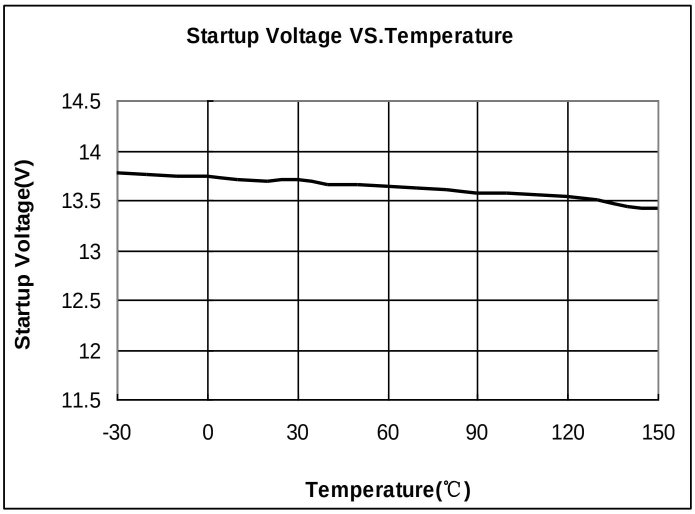
(1) IC Supply Current vs. Input Voltage



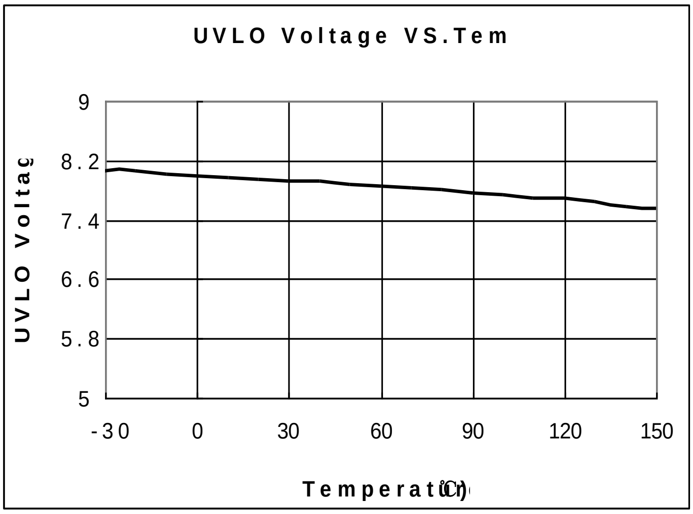
(2) Supply Current after startup vs. Temperature



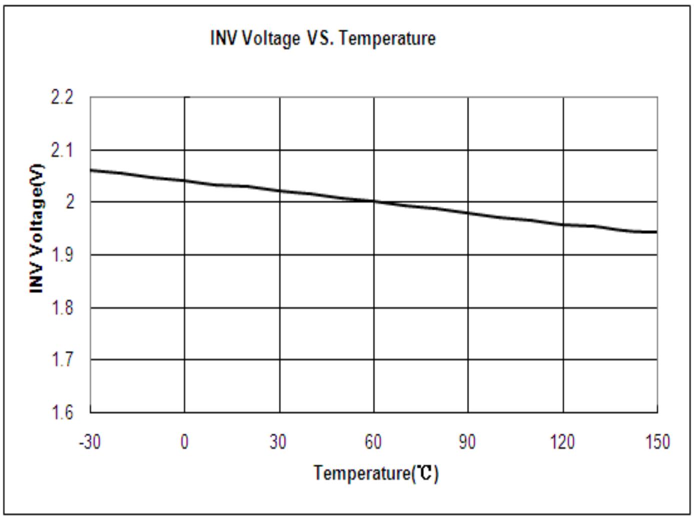
(3) Startup Voltage VS. Temperature



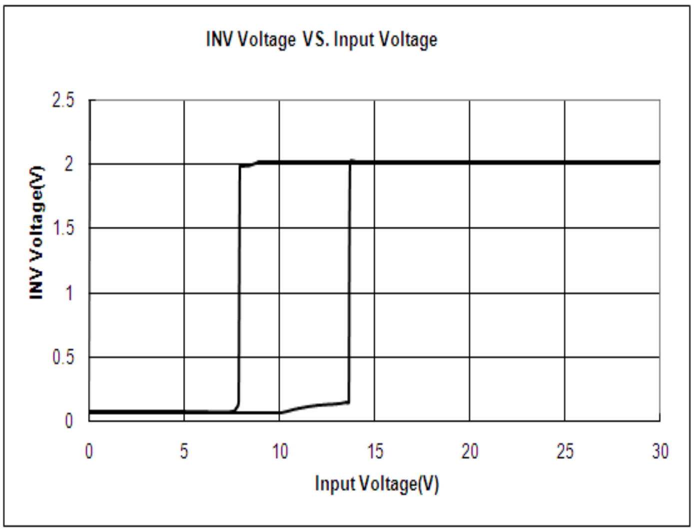
(4) VDD UVLO enter voltage vs. Temperature



(5) INV voltage vs. Temperature



(6) INV Voltage VS. Input Voltage



应用信息

功能概述

ME8317 是一款高精度离线式原边反馈控制器，应用于小功率 AC/DC 充电器与适配器。内部集成了 600V,2A 的高压功率 MOS 管。ME8317 使用原边反馈控制，可以省去光耦和 ME431。实现±5%的恒压恒流精度和小于 50mW 的待机功耗。

启动

ME8317 的启动电流非常低，所以 VDD 端电容电压可以很快充至开启电压。启动电路中可以使用一个大阻值的电阻，在满足启动要求的同时，减小工作时的损耗。

工作电流

ME8317 的工作电流低至 420μA(典型值)，所以 VDD 启动电容可以取更小值，同时可以降低待机功耗和提高系统转换效率。

恒压/恒流控制

ME8317 具有精确的恒流/恒压控制能力，电池充电器应用中通常具有两种运作模式，恒压充电和恒流充电。当电池电压过低时，充电器是恒流充电，这是对电池充电的最主要的方式，大部分的能量进入电池。当电池电压达到电池饱和电压时，充电电流逐渐变小，充电器进入恒压模式。最后，充电电流继续减小直到达到 0。工作在恒流模式下：

$$I_{OUT} = \frac{1}{4} \times \frac{V_{th\_OC}}{R_{CS}} \times \frac{N_P}{N_S}$$

其中：IOUT 为系统输出端的输出电流。

RCS 为 CS 与 GND 之间的电阻。

NP 和 NS 为变压器初级和次级线圈的匝数。

恒压控制

ME8317 的 INV 引脚可通过电阻 Ra 和 Rb 的分压检测辅助绕组反馈电压，INV 电压与参考电压间的差值通过误差放大器放大来控制开关信号的频率。为了提高输出电压的精确度，变压器的漏感应尽可能的降低。输出电压可由下式得出：

VOUT=2*(1+Ra/Rb)*（NS/NA）-ΔV

其中：Ra 和 Rb 为顶端和低端反馈电阻值。

NS 和 NA 为变压器次级和辅助线圈的匝数。

ΔV 表示输出整流二极管的压降

电流检测和前沿消隐

ME8317 提供了逐周期电流限制，功率管电流由连接在 CS 脚上的取样电阻检测。在功率开关导通时，采样电阻上会出现开启尖峰，为避免由开启尖峰所引起的误操作，在 CS 脚上设置有 500nS 的前沿消隐时间，因此 CS 脚的外部无需 RC 滤波网络。

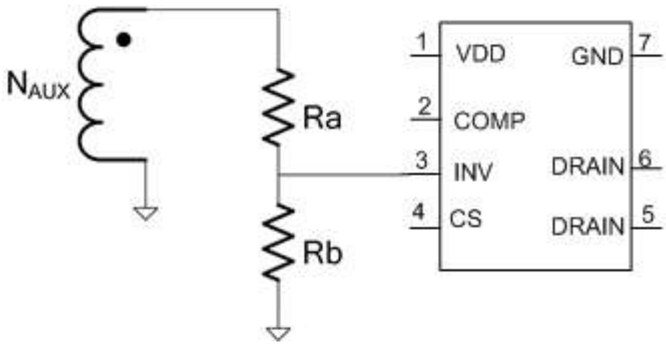
输出线压降补偿

常规芯片在恒压模式下，通过改变功率管导通时间来调节反馈电压，其不包括在电线上的压降。这样导致了由于采用不同规格不同长度的电线，会产生不同的输出电压。ME8317 内建了线压降补偿电路，以此取得更好的负载调整率。

ME8317 具有线损补偿功能，可补偿输出电压在电线上的压降。通过内置电流流入电阻分压器在 INV 脚位产生补偿电压。随着转换器负载从空载增大至峰值功率点（恒压与恒流之间的切换点），将通过增大反馈引脚参考电压对输出电缆上的压降进行补偿。控制器根据状态调节器的输出来决定输出负载以及相应补偿的程度。最大补偿比例可由下式得出

$$\frac{\Delta V}{V_{OUT}}=\frac{I_{comp}\times(R_a // R_b)\times 10^{-6}}{2}\times 100\%$$

其中，ΔV 是补偿电压，V_{OUT} 是输出电压，Ra 和 R_b 为与 INV 脚相连的分压电阻。

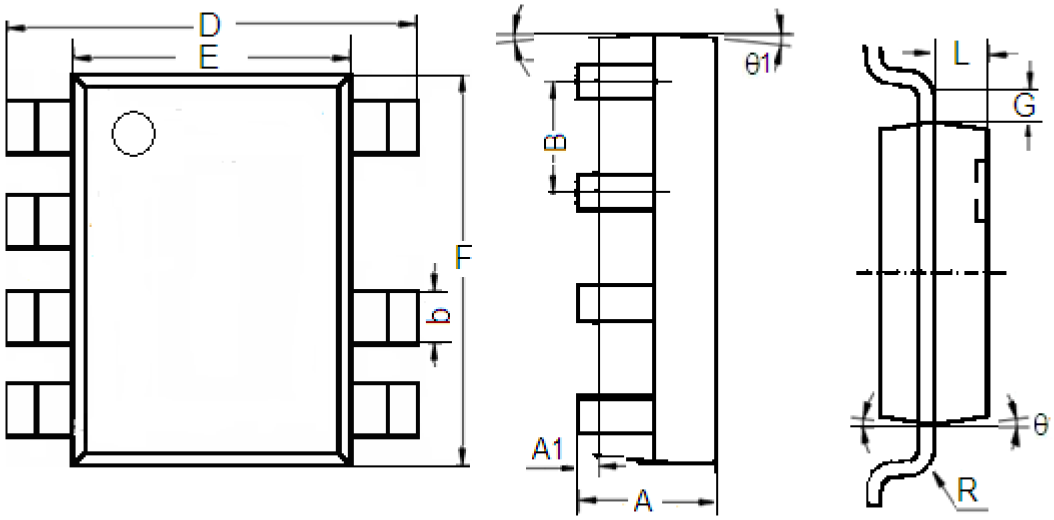


控制保护

ME8317 集成了完善的保护功能，包括 VDD 欠压保护(UVLO)，VDD 过压保护，逐周期过流保护，VDD 电压钳位保护，等等。

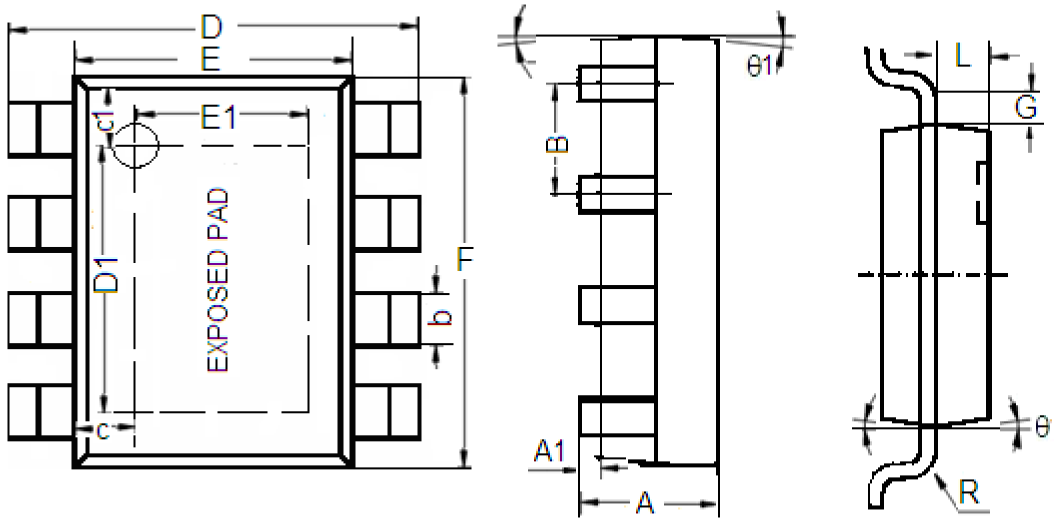
封装信息

- 封装类型: **SOP7**



参数	尺寸（mm）		尺寸（Inche）	
	最小	最大	最小	最大
A	1.350	1.750	0.053	0.069
A1	0.1	0.3	0.004	0.012
B	1.27(典型.)		0.05(典型.)	
b	0.330	0.510	0.013	0.020
D	5.8	6.2	0.228	0.244
E	3.800	4.000	0.150	0.157
F	4.7	5.1	0.185	0.201
L	0.675	0.725	0.027	0.029
G	0.32(典型.)		0.013(典型.)	
R	0.15(典型.)		0.006(典型.)	
θ1	7°		7°	
θ	8°		8°	

- **封装类型: ESOP8**



参数	尺寸 (mm)		尺寸 (Inch)	
	最小值	最大值		最小值
A	1.350	1.750	0.053	0.069
A1	0.1	0.3	0.004	0.012
B	1.27(典型.)		0.05(典型.)	
b	0.330	0.510	0.013	0.020
c	0.9(典型.)		0.035(典型.)	
c1	1.0(典型.)		0.039(典型.)	
D	5.8	6.2	0.228	0.244
D1	3.202	3.402	0.126	0.134
E	3.800	4.000	0.150	0.157
E1	2.313	2.513	0.091	0.099
F	4.7	5.1	0.185	0.201
L	0.675	0.725	0.027	0.029
G	0.32(典型.)		0.013(典型.)	
R	0.15(典型.)		0.006(典型.)	
θ1	7°		7°	
θ	8°		8°	

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原边反馈恒压恒流控制器 ME8320

概述

ME8320 是一款满足六级能效标准原边反馈准谐振模式的小功率 AC/DC 电源控制芯片，功率最大可以做到 18W，外推功率 MOS，用于充电器，适配器和 LED 驱动领域。实现±5%的恒压恒流精度和小于 100mW 的待机功耗。在恒压模式下内置了线电压补偿功能。采用准谐振控制，实现高效率和良好的 EMI 性能，满足六级能效标准要求。

该芯片集成了诸多保护功能，包括：VDD 欠压保护(UVLO)，VDD 过压保护，软启动，逐周期过流保护，所有管脚浮空保护，GATE 输出电压钳位保护，VDD 电压钳位保护，过温保护，等等。

特点

- 效率满足六级能效要求
- 原边反馈(PSR)准谐振（QR）控制技术实现高效率，无需光耦和TL431
- ±5%恒压恒流精度
- 待机功耗小于100mW
- 外推功率MOS，最大功率18W
- 恒压模式下内置线压降补偿(Cable drop compensation)
- 内置软启动
- 所有管脚浮空保护
- 输出过压保护
- 逐周期电流限制
- 内置前沿消隐(Leading edge blanking)
- VDD欠压保护(UVLO)，过压保护及钳位
- 过温保护

应用场合

- 充电器
- 适配器
- LED照明

封装形式

- SOT23-6

典型应用图

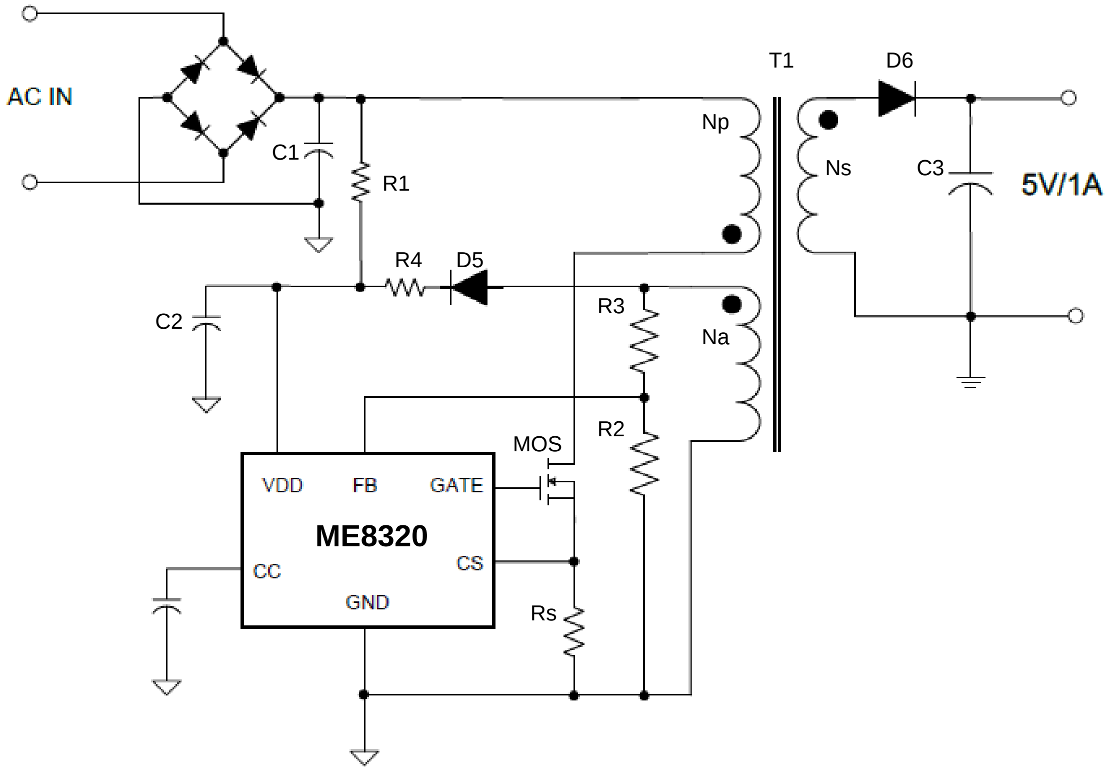
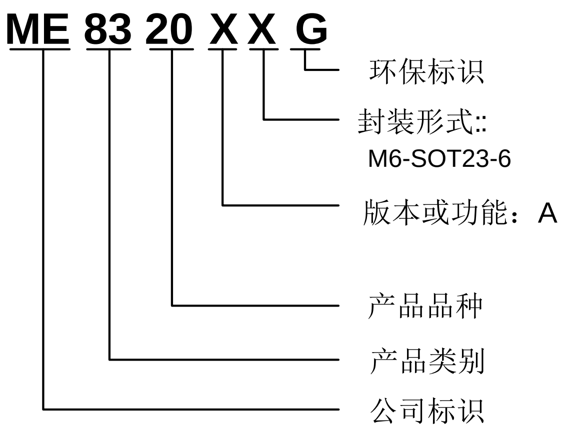


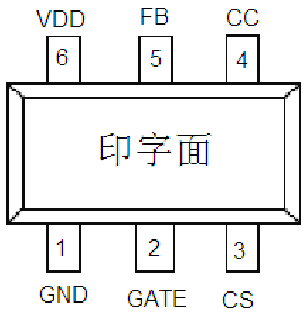
图.1 5V1A充电器系统应用图

选购指南



产品型号	产品说明
ME8320AM6G	封装形式：SOT23-6

芯片脚位图



脚位功能说明

PIN 脚位	符号名	功能说明
1	GND	芯片地
2	GATE	外置功率 MOSFET 驱动端
3	CS	变压器原边电流采样端
4	CC	外接电容，用于恒流电路
5	FB	输出电压反馈输入端
6	VDD	芯片电源

芯片功能示意图

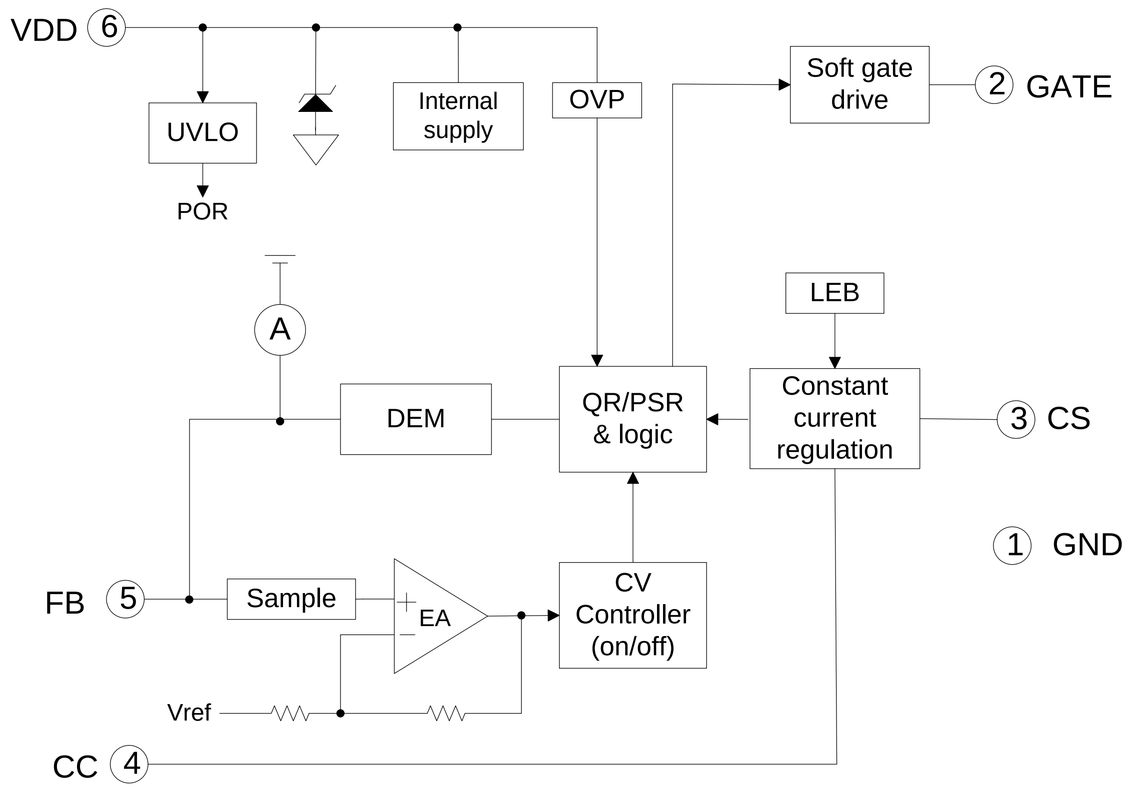


图.2　模块功能示意图

极限参数

参数	参数范围	单位
芯片电源电压	35	V
芯片VDD钳位电流	10	mA
GATE电压	20	V
CC, CS输入电压	-0.3 to 7	V
FB输入电压	-0.7 to 7	V
封装热阻(SOT23-6)	250	℃/W
储存温度范围	-65~+150	℃
最高结温	150	℃
工作温度范围	-40~+150	℃
焊接温度(焊锡, 10 秒)	260	℃
ESD 人体模型	2	KV
ESD 机器模型	250	V

注释：超出极限参数可能损毁器件。不建议器件工作在推荐条件以外的情况。长时间运行在绝对最大额定条件下可能会影响器件的可靠性。

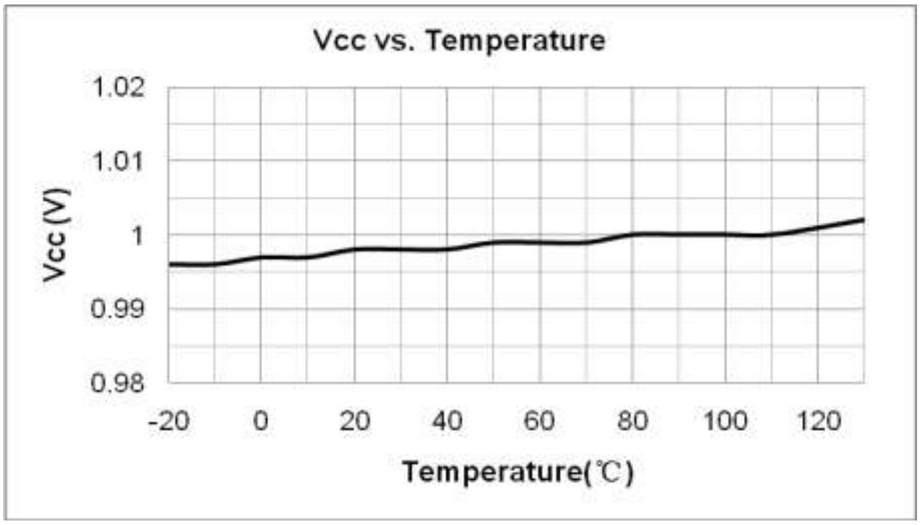
推荐工作条件

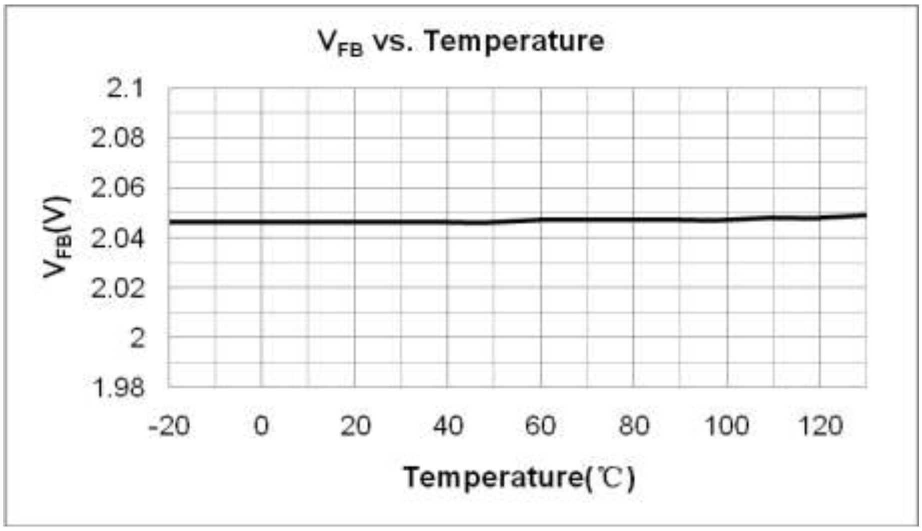
参数	最小值	典型值	最大值	单位
芯片电源电压VDD	10	-	20	V
环境工作温度	-40	-	85	℃
最大开关频率	-	120	-	KHz

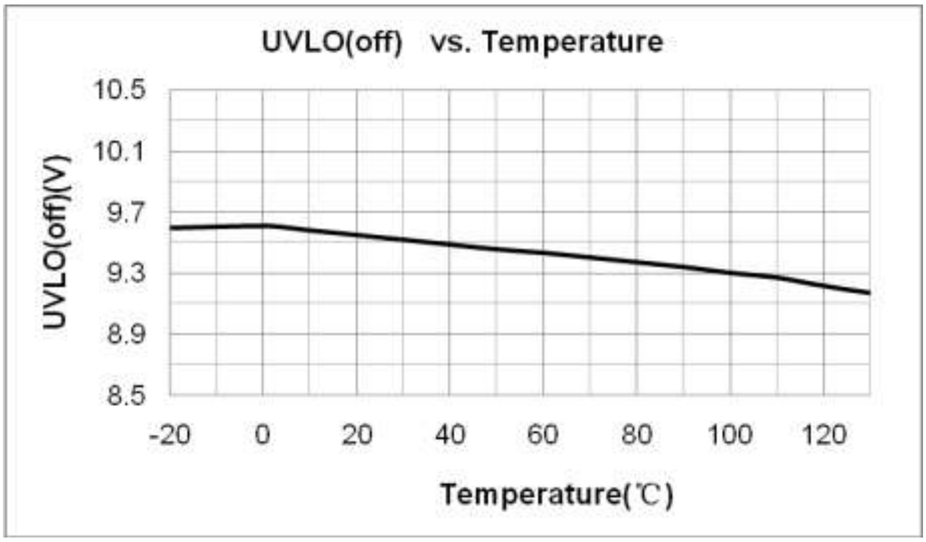
电气参数 (无特别说明，环境温度= 25℃，VDD输入电压=16V)

符号	参数	测试条件	最小	典型	最大	单位
芯片电源部分(VDD 管脚)						
I_{START}	启动电流	VDD=UVLO(ON)-1V 测试 VDD 端电流	-	2	20	μA
I_{DD}	工作电流	V_{FB}=1V, CL=0.5nF VDD=20V	-	1.0	1.5	mA
UVLO(on)	VDD欠压保护	VDD 电压下降	8.5	9.5	10.5	V
UVLO(off)	VDD启动电压	VDD 电压上升	14	15.5	16.5	V
OVP	VDD过压保护		31	33	35	V
VDD_Clamp	VDD 钳位电压	I_{VDD}=7mA	33	35	37	V
反馈输入部分(FB 管脚)						
$V_{FB\_EA\_Ref}$	反馈参考电压		1.98	2.0	2.02	V
V_{FB_OVP}	输出过压保护阈值电压		-	2.4	-	V
Tmin_off	最小关断时间		-	2	-	μS
Tmax_off	最大关断时间		-	2.3	-	mS
Icable_max	最大线损补偿电流		-	45	-	μA
电流检测部分 (CS 管脚)						
LEB	CS前沿消隐时间		-	500	-	nS
T_{D_OC}	芯片关断延迟	CL=1nF at GATE	-	100	-	nS
恒流控制部分 (CC管脚)						
$V_{\_CC\_REF}$	内部CC基准电压		490	500	510	mV
栅极驱动输出（GATE管脚）						
VOL	输出低电平	Io=20mA(sink)	-	-	1	V
VOH	输出高电平	Io=20mA(source)	7.5	-	-	V
V_{G_Clamp}	输出钳位电压	VDD=24V	-	14.5	-	V
T_R	输出上升时间	CL=0.5nF	-	700	-	nS
T_F	输出下降时间	CL=0.5nF	-	35	-	nS
T_P	过热保护温度		-	150	-	°C

典型温度特性曲线


Vcc vs. Temperature
Vcc (V)
1.02
1.01
1
0.99
0.98
-20
0
20
40
60
80
100
120
Temperature(℃)


VFB vs. Temperature
VFB(V)
2.1
2.08
2.06
2.04
2.02
2
1.98
-20
0
20
40
60
80
100
120
Temperature(℃)


UVLO(off) vs. Temperature
UVLO(off)(V)
10.5
10.1
9.7
9.3
8.9
8.5
-20
0
20
40
60
80
100
120
Temperature(℃)

应用信息

功能概述

ME8320 是一款原边反馈准谐振模式的 AC/DC 电源控制芯片，功率最大可以做到 18W，外推功率 MOS，用于充电器，适配器和 LED 驱动领域。实现±5%的恒压恒流精度和小于 100mW 的待机功耗。在恒压模式下内置了线电压补偿功能。采用准谐振控制，实现高效率和良好的 EMI 性能，满足六级能效标准要求。

启动

ME8320 的启动电流非常低，所以 VDD 端电容电压可以很快充至开启电压。启动电路中可以使用一个大阻值的电阻，在满足启动要求的同时，减小工作时的损耗。

工作电流

ME8320 的工作电流低至 1mA(典型值)，所以 VDD 启动电容可以取更小值，同时可以提高系统转换效率。

原边准谐振控制

ME8320 采用原边反馈准谐振工作模式，大大降低系统成本，实现高效率和良好的 EMI 性能。芯片在恒压和恒流工作时，采用谷底导通，减小开关损耗，最大限度利用占空比，极大的提高了系统效率，满足六级能效标准要求。

恒流控制

ME8320 具有精确的恒流/恒压控制能力，电池充电器应用中通常具有两种运作模式，恒压充电和恒流充电。当电池电压过低时，充电器是恒流充电，这是对电池充电的最主要的方式，大部分的能量进入电池。当电池电压达到电池饱和电压时，充电电流逐渐变小，充电器进入恒压模式。最后，充电电流继续减小直到达到 0。工作在恒流模式下：

$$I_{CC}(mA) = \frac{N}{2} * \frac{500(mV)}{Rcs(\Omega)}$$

其中：I_{CC} 为系统输出端的输出电流。

R_{CS} 为 CS 与 GND 之间的电阻。

N 为变压器初级和次级线圈的匝数比。

恒压控制

ME8320 的 FB 引脚可通过电阻 Ra 和 Rb 的分压检测辅助绕组反馈电压，FB 电压与参考电压间的差值通过误差放大器放大来控制开关信号的频率。为了提高输出电压的精确度，变压器的漏感应尽可能的降低。输出电压可由下式得出：

V_{OUT}=2*(1+Ra/Rb)*（N_S/N_A）-ΔV

其中：Ra 和 Rb 为顶端和低端反馈电阻值。

N_S 和 N_A 为变压器次级和辅助线圈的匝数。

ΔV 表示输出整流二极管的压降

电流检测和前沿消隐

ME8320 提供了逐周期电流限制，功率管电流由连接在 CS 脚上的取样电阻检测。在功率开关导通时，采样电阻上会出现开启尖峰，为避免由开启尖峰所引起的误操作，在 CS 脚上设置有 500nS 的前沿消隐时间，因此 CS 脚的外部无需 RC 滤波网络。

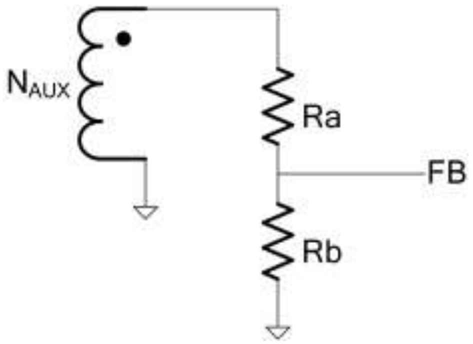
输出线压降补偿

常规芯片在恒压模式下，通过改变功率管导通时间来调节反馈电压，其不包括在电线上的压降。这样导致了由于采用不同规格不同长度的电线，会产生不同的输出电压。ME8320 内建了线压降补偿电路，以此取得更好的负载调整率。

ME8320 具有线损补偿功能，可补偿输出电压在电线上的压降。通过内置电流流入电阻分压器在 FB 脚位产生补偿电压。随着转换器负载从空载增大至峰值功率点（恒压与恒流之间的切换点），将通过增大反馈引脚参考电压对输出电缆上的压降进行补偿。控制器根据状态调节器的输出来决定输出负载以及相应补偿的程度。最大补偿比例可由下式得出

$$\frac{\Delta V}{V_{OUT}}=\frac{I_{comp}\times(R_a//R_b)\times10^{-6}}{2}\times100\%$$

其中，ΔV 是补偿电压，V_{OUT} 是输出电压，Ra 和 R_b 为与 FB 脚相连的分压电阻。



栅极驱动器

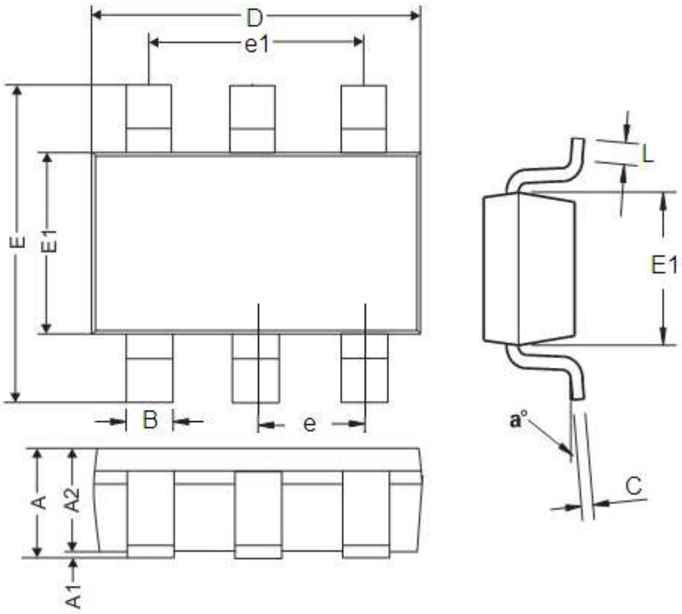
ME8320 的 GATE 脚位用于驱动外部功率 MOSFET 管，GATE 驱动端采用软驱动设计，软驱动方式改善了系统的 EMI 性能，实现了效率、可靠性和 EMI 的平衡。驱动输出端内置齐纳二极管钳位在 14.5V，以避免功率 MOSFET 管栅端出现过压信号而损坏。

控制保护

ME8320 集成了完善的保护功能，包括 VDD 欠压保护(UVLO)，VDD 过压保护，软启动，逐周期过流保护，所有管脚浮空保护，VDD 电压钳位保护，过温保护等等。

封装信息

- 封装类型: **SOT23-6**



<table>
<tr><th rowspan="2">参数</th><th colspan="2">尺寸（mm）</th><th colspan="2">尺寸（Inche）</th></tr>
<tr><th>最小值</th><th>最大值</th><th>最小值</th><th>最大值</th></tr>
<tr><td>A</td><td>0.9</td><td>1.45</td><td>0.0354</td><td>0.0570</td></tr>
<tr><td>A1</td><td>0</td><td>0.15</td><td>0</td><td>0.0059</td></tr>
<tr><td>A2</td><td>0.9</td><td>1.3</td><td>0.0354</td><td>0.0511</td></tr>
<tr><td>B</td><td>0.2</td><td>0.5</td><td>0.0078</td><td>0.0196</td></tr>
<tr><td>C</td><td>0.09</td><td>0.26</td><td>0.0035</td><td>0.0102</td></tr>
<tr><td>D</td><td>2.7</td><td>3.10</td><td>0.1062</td><td>0.1220</td></tr>
<tr><td>E</td><td>2.2</td><td>3.2</td><td>0.0866</td><td>0.1181</td></tr>
<tr><td>E1</td><td>1.30</td><td>1.80</td><td>0.0511</td><td>0.0708</td></tr>
<tr><td>e</td><td colspan="2">0.95REF</td><td colspan="2">0.0374REF</td></tr>
<tr><td>e1</td><td colspan="2">1.90REF</td><td colspan="2">0.0748REF</td></tr>
<tr><td>L</td><td>0.10</td><td>0.60</td><td>0.0039</td><td>0.0236</td></tr>
<tr><td>a^0</td><td>0^0</td><td>30^0</td><td>0^0</td><td>30^0</td></tr>
</table>

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