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### Features

- ◆ Less than 75mW standby power consumption at 230VAC with typical application circuit
- ◆ Integrated 650V MOSFET
- ◆ Less than  $\pm 5\%$  constant voltage and current regulation at universal AC input
- ◆ Primary-side sensing and regulation without TL431 and opto-coupler
- ◆ Adjustable constant current and output power setting
- ◆ Compensates for input line voltage variations
- ◆ Eliminates all control loop compensation circuitry
- ◆ Start-up and static current as low as 5uA and 600uA.
- ◆ Built-in Leading Edge Blanking(LEB)
- ◆ Programmable cable voltage drop compensation
- ◆ Multi-mode PWM and PFM operation for efficiency improving and audio noise free operation
- ◆ SOP8 Package

### Applications

- ◆ Small Power Adapter
- ◆ Cell Phone Charger
- ◆ Digital Cameras Charger
- ◆ Linear Regulator/RCC Replacement

### General Description

SP2689AFB is a high performance offline PSR power switch for low power AC/DC charger and adapter applications. Using 3D packaging technology, integrated 5A/650V MOSFET in the SOP8 package. It operates in primary-side sensing and regulation. Thus, opto-coupler and TL431 are not required. In CC control, the output current and power setting can be adjusted externally by the sense resistor  $R_{CS}$  at CS PIN. In CV control, multi-mode operations are utilized to achieve high performance and high efficiency. In addition, good load regulation is achieved by the built-in cable drop compensation. SP2689AFB operates in PFM in CC mode, and it operates in PWM+PFM in CV mode with frequency reduction at light/medium load. The chip consumes very low operation current. It achieves less than 75mW standby power to meet all global energy efficiency regulations.

SP2689AFB offers comprehensive protection coverage with auto-recovery feature including Cycle-by-Cycle current limiting, VDD over voltage protection (OVP), FB over voltage protection, load short circuit protection, VDD under voltage lockout (UVLO), OTP etc.

SP2689AFB is offered in SOP8 packages.

### Simplified Application

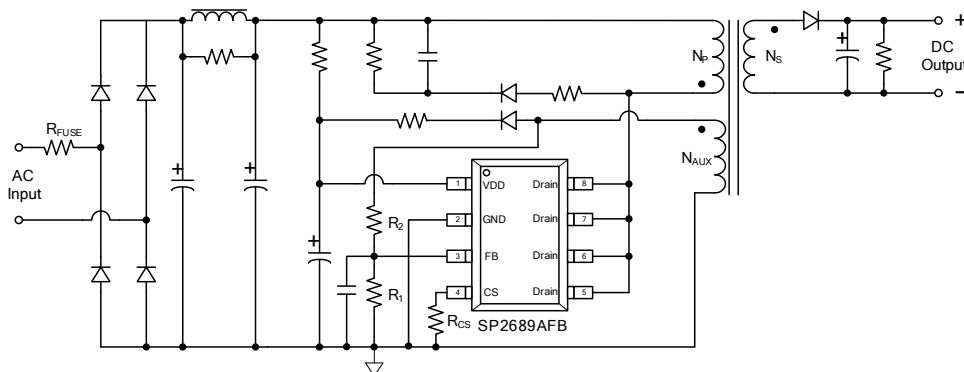
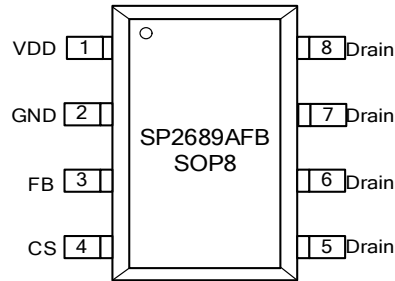


Figure 1. Simplified Application of SP2689AFB

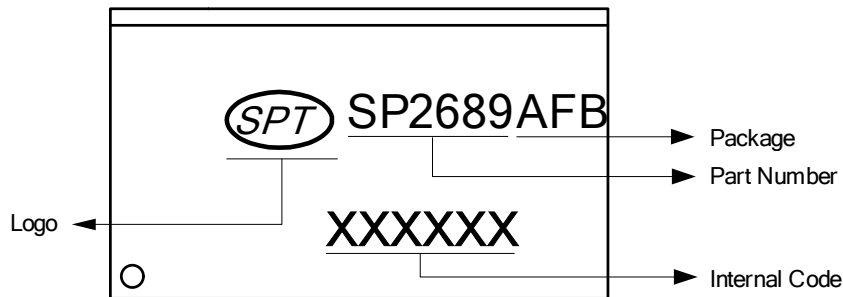
### Pin Function Description



Pin No.	Pin Name	Function Description
1	VDD	Power Supply for IC
2	GND	Ground
3	FB	The voltage feedback from auxiliary winding
4	CS	Current Sense Input Pin
5,6,7,8	Drain	Connected to the Drain of Internal Power MOSFET

### Ordering and Marking Information

Part Number	Package Description	Top Marking	Package Form
SP2689AFB	SOP8, Pb-free	SP2689AFB	SOP8



### Package Dissipation Rating

Package	$\theta_{JC}$ ( $^{\circ}C/W$ )	$\theta_{JA}$ ( $^{\circ}C/W$ )
SOP8	50	130

### Absolute Maximum Ratings

Symbol	Description	Value	Units
VDRAIN_MAX	Drain Input Voltage	-0.3 to 650	V
VDD	VDD Input Voltage	-0.3 to 30	V
VFB,VCS	FB,CS Input Voltage	-0.3 to 7	V
TJ	Operating Junction Temperature	-40 to 150	°C
TSTORAGE	Min/Max Storage Temperature	-55 to 150	°C
TL	Lead Temperature (Soldering. 10secs)	260	°C

**Note:** Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated under recommended operating conditions is not implied. Exposure to absolute maximum-rated conditions for extended periods may affect device reliability.

### Recommended Operating Conditions

Symbol	Description	Value	Units
VDD	VDD Supply Voltage	9 ~ 22	V

### Output Power Table

Part Number	90VAC to 265VAC	
	Adapter <sup>1</sup>	Open Frame <sup>2</sup>
SP2689AFB	15W	18W

**Note:**

1. Maximum continuous power in a typical non-ventilated enclosed adapter measured at +50°C ambient,  $T_{CASE} < 120^{\circ}C$ .
2. Maximum continuous power in an open frame design with adequate heatsinking measured at +25°C ambient,  $T_{CASE} < 120^{\circ}C$ .

### Block Diagram

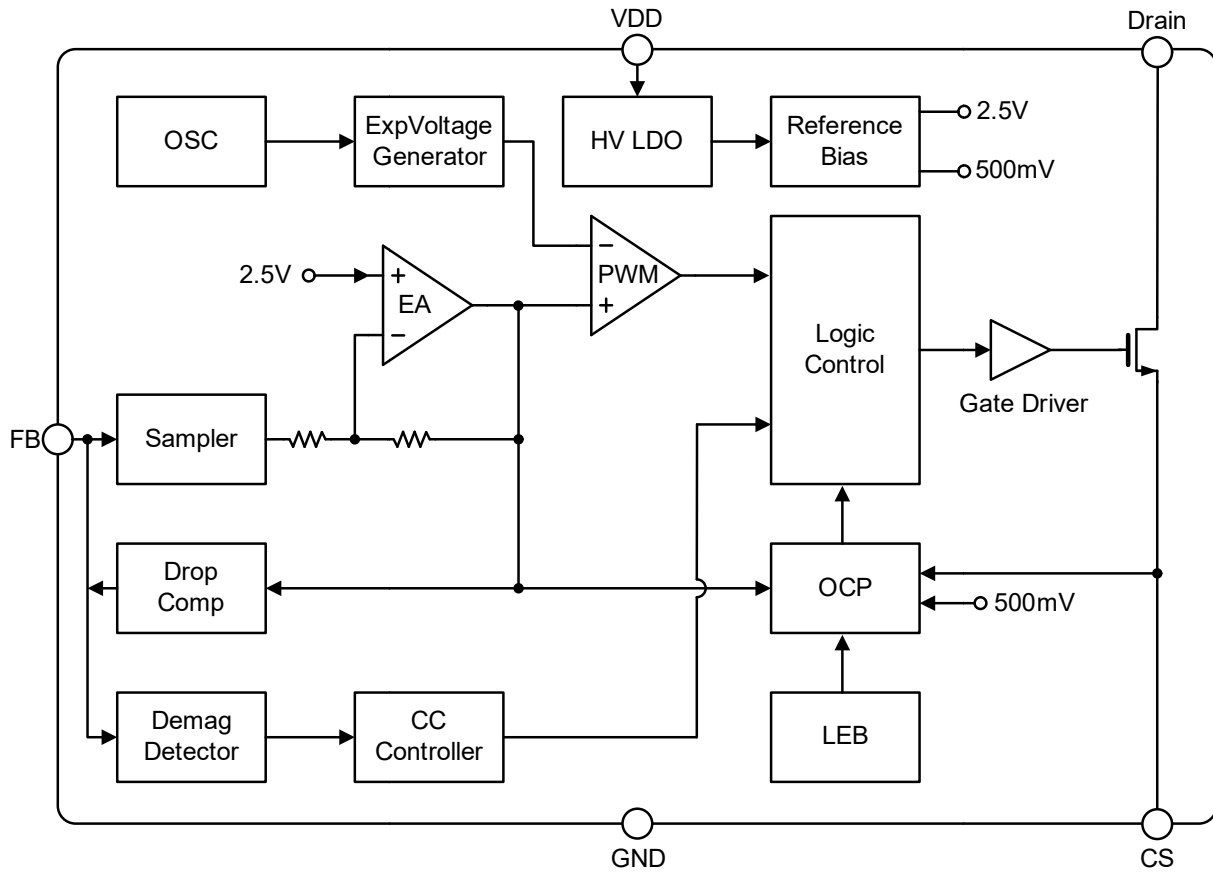
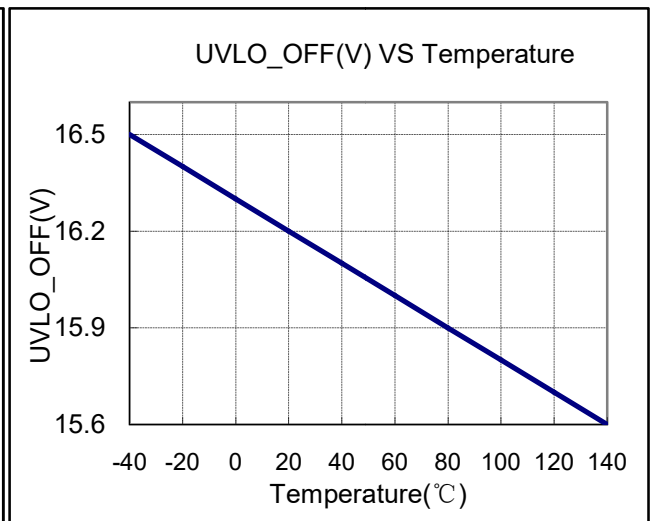
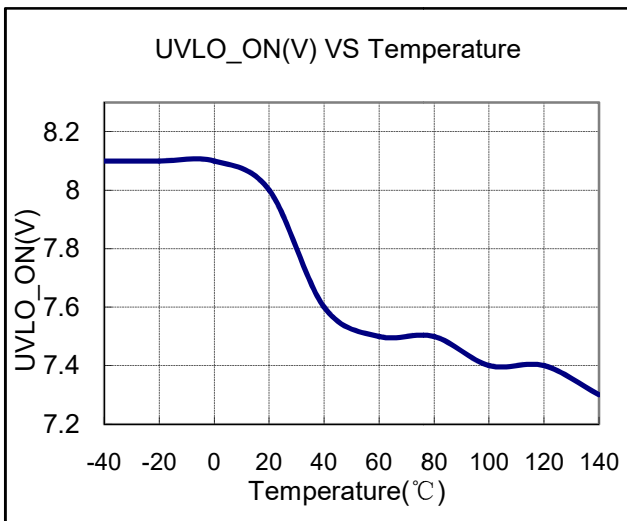
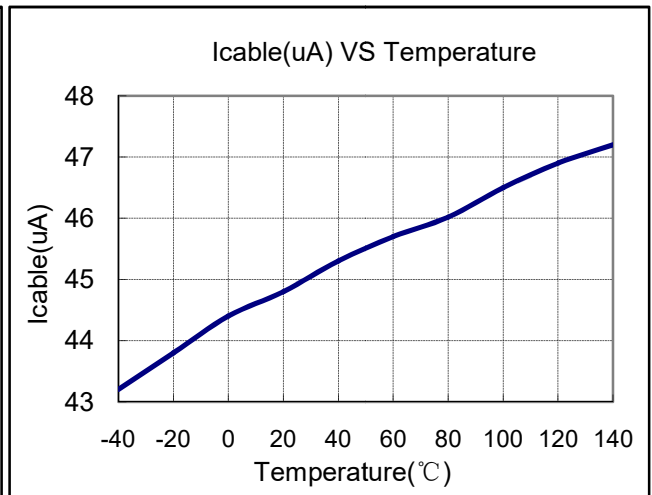
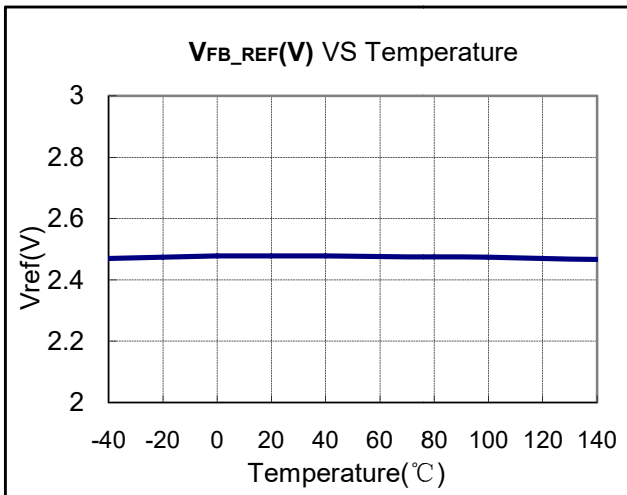
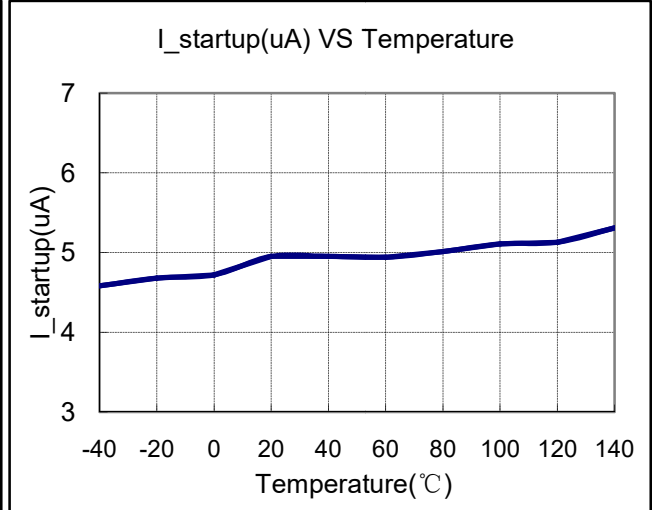
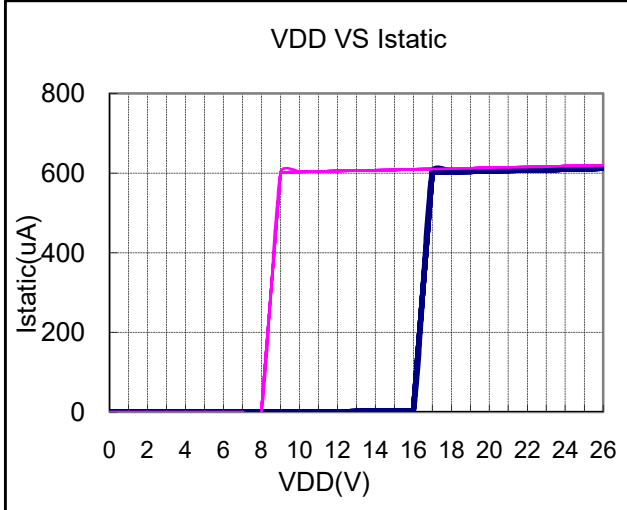


Figure 2. Block diagram of SP2689AFB

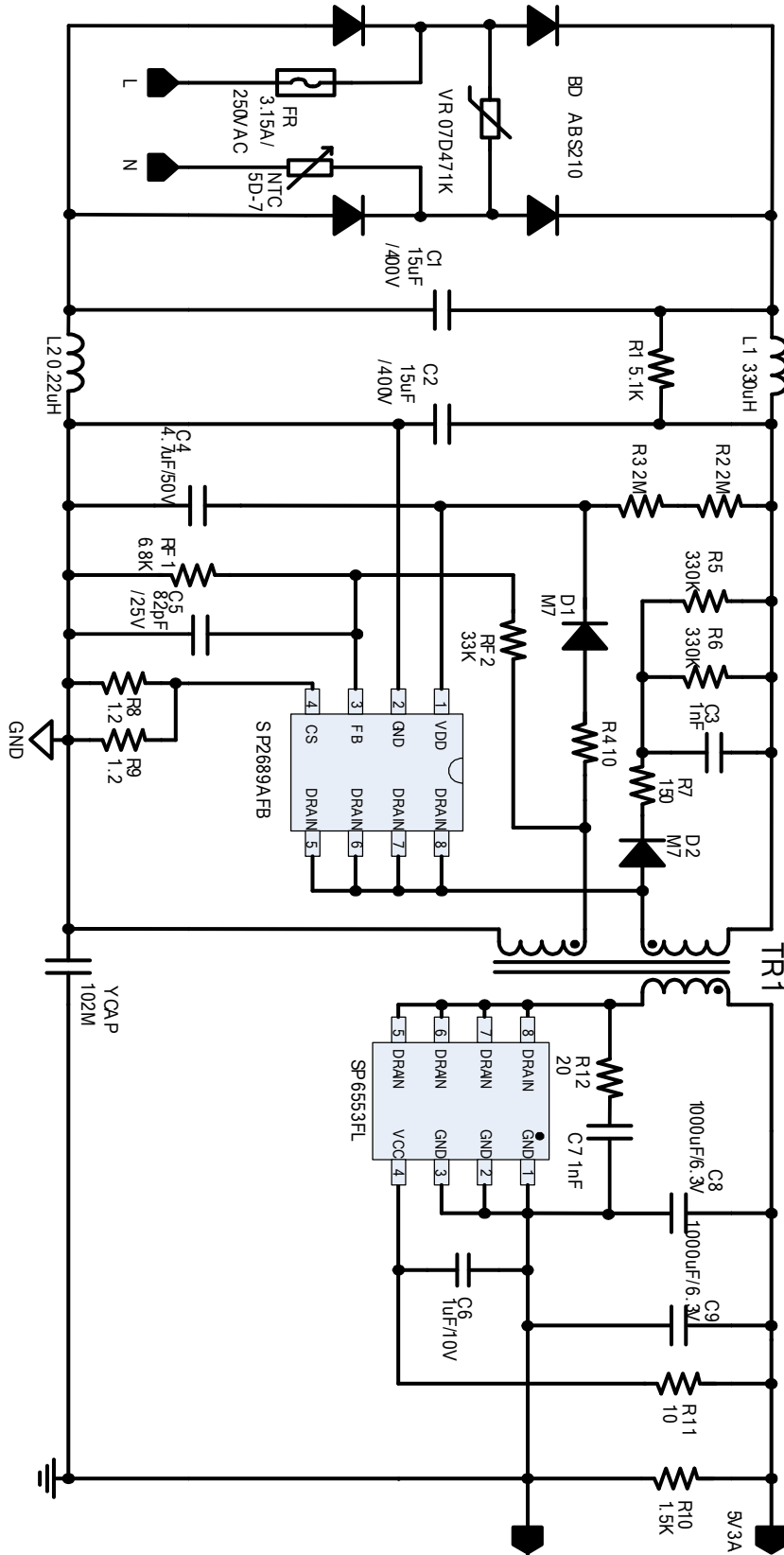
### Electrical Characteristics

VDD=18V, TA=25°C, unless otherwise noted.						
Symbol	Description	Test Conditions	Min.	Typ.	Max.	Units
<b>Supply Voltage Section</b>						
I <sub>start-up</sub>	Start up current	VDD=UVLO_OFF-1V		5	15	μA
I <sub>static</sub>	Static Current			0.6	1.0	mA
UVLO(OFF)	VDD under voltage lockout exit	VDD Going Up	15	16	17	V
UVLO(ON)	VDD under voltage lockout enter	VDD Going Down	7	8	9	V
VDD_OVP	VDD under voltage protection		25.2	26.2	27.2	V
<b>Current Sense Input Section</b>						
TLEB	LEB time			330		ns
VTH_OCP_MIN	Minimum over current threshold		485	500	515	mV
VTH_OCP_MAX	Maximum over current threshold			580		mV
VCS_MIN	Minimum CS threshold			100		mV
TDemag_MIN	Minimum TDemag			5		μs
TON_MAX	Maximum Ton			60		μs
<b>FB Input Section</b>						
V <sub>FB_REF</sub>	Reference voltage for FB threshold		2.475	2.50	2.525	V
F <sub>SW_MIN</sub>	Minimum switch frequency		400	465	530	Hz
F <sub>SW_MAX</sub>	Maximum frequency		70			KHz
I <sub>CABLE_MAX</sub>	Maximum cable compensation current		40	45	50	μA
V_OVP	Output Over voltage threshold		2.9	3.0	3.1	V
<b>MOSFET Section</b>						
RDSON	Static drain to source on resistance	V <sub>GS</sub> =10V, I <sub>DS</sub> =1A		1.6		Ω
BVDSS	Drain-Source Breakdown Voltage	V <sub>GS</sub> =0V, I <sub>DS</sub> =250μA	650			V
<b>On Chip Over Temperature Section</b>						
T <sub>OTP</sub>	Over temperature trigger point			160		°C
T <sub>OTP_REC</sub>	Over temperature recovery point			125		°C

### Characterization Plots



### Applications Example



### Functional Description

SP2689AFB is a cost effective PSR power switch optimized for off-line low power AC/DC application including battery chargers and adapter. It operates in primary side sensing and regulation, thus opto-coupler and TL431 are not required. Proprietary built-in CV and CC control can achieve high precision CC/CV control. Easily meets all global energy efficiency regulations.

#### Fast Start up Control

Startup current of SP2689AFB is designed to be very low, so the voltage of the capacitance in VDD could be charged up to the turn-on level quickly and then IC starts to work. Thus a large value resistor can be used in the startup circuit which will minimize the power loss when startup process is still reliable.

#### Operating Current

The Operating current of SP2689AFB is as low as 600uA (typical). Good efficiency and less than 75mW standby power is achieved with the low operating current.

#### CC/CV Operation

SP2689AFB is designed to produce good CC/CV control characteristic. 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 mode, the output voltage is regulated through the primary side control. In CC operation mode, SP2689AFB will regulate the output current constant regardless of the output voltage drop.

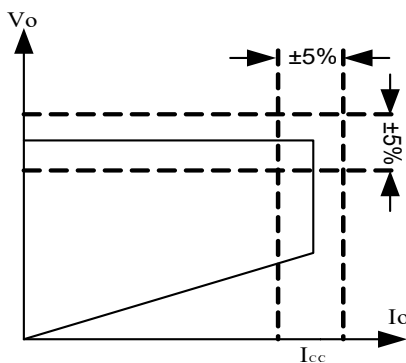


Figure 3. Typical CC/CV Curve

#### Principle of Operation

To support SP2689AFB proprietary CC/CV control, system needs to be designed in DCM mode for flyback system.

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, and the current in the primary winding ramps up. When MOSFET turns off, the primary current transfers to the secondary at the amplitude as below:

$$I_S = \frac{N_P}{N_S} \cdot I_P \quad (1)$$

The auxiliary voltage reflects the output voltage as shown in Figure 4. and it is given by

$$V_{AUX} = \frac{N_{AUX}}{N_S} \cdot (V_O + \Delta V) \quad (2)$$

Where  $\Delta V$  indicates the voltage drop of the output diode.

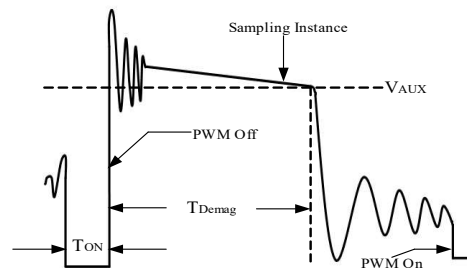


Figure 4. Auxiliary voltage waveform

Via a resistor divider connected between the auxiliary winding and FB (Pin 3), the auxiliary voltage is sampled at the end of the demagnetization and it is hold until the next sampling. The sampled voltage is compared with reference voltage  $V_{ref}$  (typical 2.5V) and the error is amplified. The error amplifier output reflects the load condition and controls the PWM switching frequency to regulate the output voltage, thus constant output voltage can be achieved.

When sampled voltage is below  $V_{ref}$  and the error amplifier output reaches its maximum, the switching frequency is controlled by the sampled voltage to regulate the output, thus the constant output current can be achieved.

### Adjustable CC point and Output Power

In SP2689AFB, the CC point and maximum output power can be externally adjusted by external current sense resistor  $R_{cs}$  at CS pin. The output power is adjusted through CC point change. The larger  $R_{cs}$ , the smaller CC point is, and the output power becomes smaller which is shown in Fig.5.

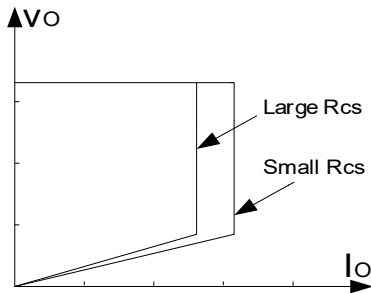


Figure 5. Adjustable output power by changing  $R_s$

### On time OCP compensation

The variation of max output current in CC mode can be rather large if no compensation is provided. The OCP threshold value is self adjusted higher at higher AC voltage. This OCP threshold slope adjustment helps to compensate the increased output current limit at higher AC voltage. In SP2689AFB, a proprietary OCP compensation block is integrated and no external components are needed. The OCP threshold in SP2689AFB is a function of the switching ON time. For the ON time between 1.8 $\mu$ s to 3.7 $\mu$ s (typical), the OCP threshold changes linearly from 500mV to 580mV. For the ON time larger than 3.7 $\mu$ s, the OCP threshold is clamped to 580mV, as shown in Figure 6.

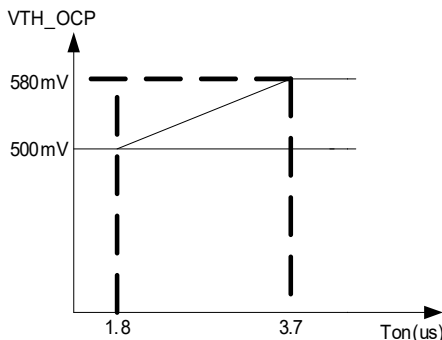


Figure 6 On time OCP compensation

### Operation Switching Frequency

The switching frequency of SP2689AFB is adaptively controlled according to the load conditions and the operation modes. For flyback operating in DCM, the maximum output power is given by 1

$$P_{O\_MAX} = \frac{1}{2} \cdot L_P \cdot F_{SW} \cdot I_P^2 \quad (3)$$

Where  $L_p$  indicate the inductance of primary winding and  $I_p$  is the peak current of primary winding and  $I_p$  is the peak current of primary winding. Refer to the equation 3, 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 and the switching frequency is

$$F_{SW} = \frac{1}{2 \cdot T_{Demag}} \quad (4)$$

Since  $T_{Demag}$  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 change, Up to  $\pm 7\%$  variation of the primary winding inductance can be compensated.

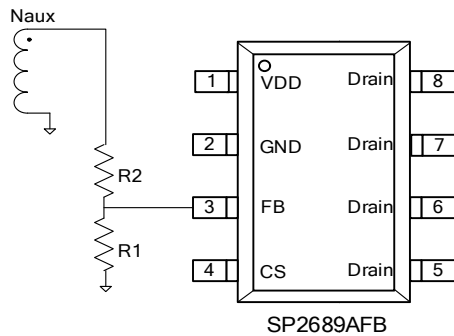
### Programmable Cable Drop Compensation

In SP2689AFB, cable drop compensation is implemented to achieve good load regulation. An offset voltage is generated at FB by an internal current flowing into the resistor divider. The current 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 maximum load compensation voltage is

$$\Delta V = (I_{CABLE\_MAX} \cdot R_2 \cdot 10^{-6}) \cdot N \quad (5)$$

When  $N$  is the ratio of auxiliary windings and secondary windings.



### Current Sensing and Leading Edge Blanking

Cycle-by-Cycle current limiting is offered in SP2689AFB. The switch current is detected by a sense resistor into the CS pin. An internal leading edge blanking circuit chops off the sense voltage spike at initial power MOSFET on state so that the external RC filtering on sense input is no longer needed. The current limiting comparator is determined by the current sense input voltage and the EA output voltage.

### Power MOSFET Driver

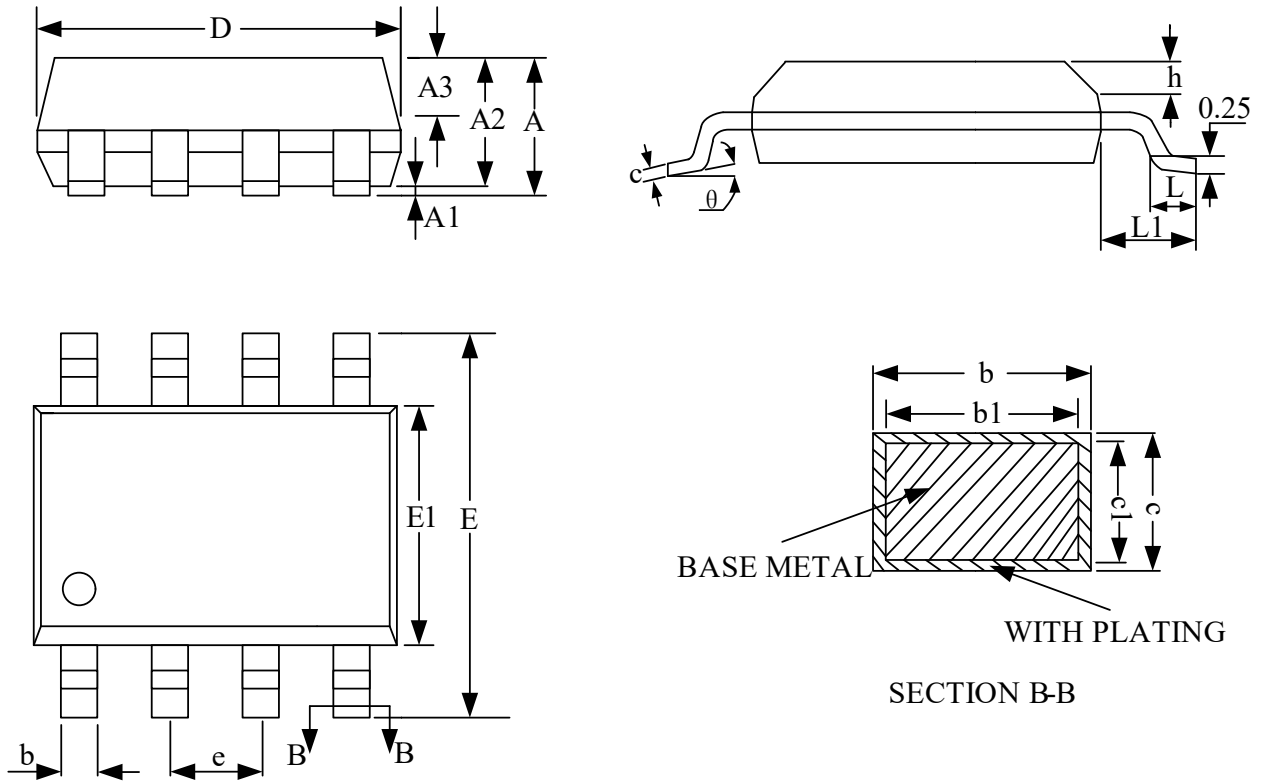
For most SMPS, too weak gate driving strength results in higher conduction and switching loss of power MOSFET while too strong gate driving strength results the compromise of EMI. A good tradeoff is achieved through the built-in totem pole gate design with proper output strength and dead time control. Low idle loss and improved EMI is easier to achieve with this dedicated control scheme.

### Protection Control

Good power supply system reliability is achieved with its rich protection features including Cycle-by-Cycle current limiting, VDD over voltage protection(OVP), FB over voltage protection, load short circuit protection, VDD under voltage lockout (UVLO), OTP etc.

VDD is supplied by transformer auxiliary winding output. The output of SP2659P is shut down when VDD drops below UVLO(ON) limit and the power converter enters power on start-up sequence thereafter.

### Package Information (Units:mm)



SYMBOL	MILLIMETER			SYMBOL	MILLIMETER		
	MIN	NOM	MAX		MIN	NOM	MAX
A	—	—	1.75	D	4.70	4.90	5.10
A1	0.05	—	0.25	E	5.80	6.00	6.20
A2	1.30	1.40	1.50	E1	3.70	3.90	4.10
A3	0.60	0.65	0.70	e	1.27BSC		
b	0.39	—	0.48	h	0.25	—	0.50
b1	0.38	0.41	0.43	L	0.50	—	0.80
c	0.21	—	0.26	L1	1.05BSC		
c1	0.19	0.20	0.21	θ	0	—	8°

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