

super-PFC/PSR™ Controller for LED Lighting

FEATURES

- ◆ **super-PFC/PSR™** Control Supports Both Primary Side Regulation (PSR) and Secondary Side Regulation (SSR)
- ◆ Pin Compatible with Popular PFC Controllers
- ◆ THD<10% using **min-THD™** Technique
- ◆ Built-in AC Line and Load Compensation for High Precision LED Output Current
- ◆ Highly Linear Analog Multiplier with “Frequency Adjusting” for High PF
- ◆ Max. 90KHz Frequency Clamping for EMI
- ◆ LED Open/Short Protection
- ◆ Burst Mode Control @ Light Loading
- ◆ Trimmed 1.5% Internal Voltage Reference
- ◆ Very Low Startup Current
- ◆ Under Voltage Lockout with 11.7V Hysteresis
- ◆ Built-in Soft Start
- ◆ Clear External EA Feedback Network before Power On
- ◆ Cycle-by-Cycle Current Limiting
- ◆ Built-in Leading Edge Blanking (LEB)
- ◆ VCC Over Voltage Protection (OVP)
- ◆ Audio Noise Free Operation
- ◆ 10V to 32V Wide Range of VCC Voltage
- ◆ 500mA Drive Capability

APPLICATIONS

- ◆ LED Lighting Application

SFL900C is a high performance, high power factor flyback PWM controller special for LED lighting applications. The IC adopts unique **super-PFC/PSR™** which can support both PSR and SSR applications.

SFL900C is pin compatible with mainstream PFC controllers such as XX6561/6562, XX7527, etc. SFL900C also integrates proprietary **min-THD™**, technique, which can achieve less than 10% THD for universal line input.

SFL900C has built-in **Load CC Compensation** and **AC Line CC Compensation** function, which can further increase LED output CC accuracy. The IC has Max. 90KHz Frequency Clamping function and soft totem pole Gate driver to improve system conduction and radiation EMI. The IC will Clear External EA Feedback Network before IC power on, which can reduce startup LED current spike. The IC also has Soft Start control during power on period.

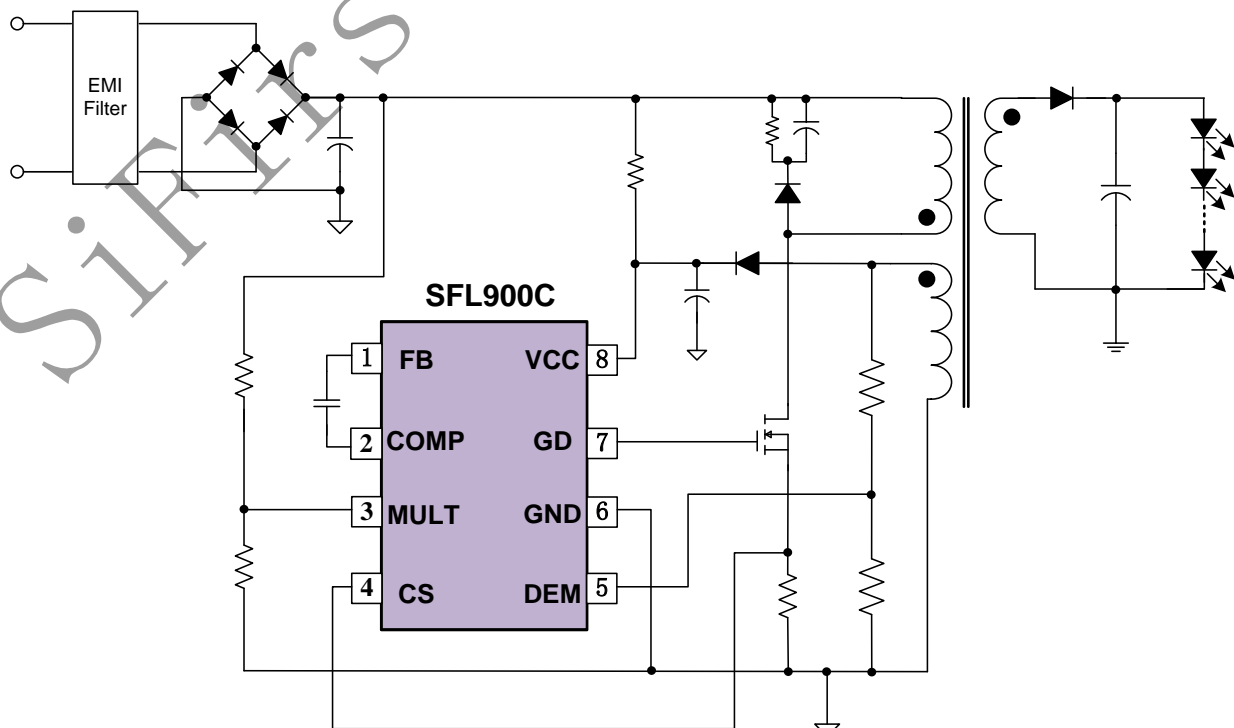
In SFL900C, the proprietary “Frequency Adjusting” can help to improve THD performance, while ensures audio noise free operation.

SFL900C integrates functions and protections of Under Voltage Lockout (UVLO), LED Open/Short Protection, VCC Over Voltage Protection (OVP), Load Over Voltage Protection (Load OVP), Soft Start, Cycle-by-cycle Current Limiting (OCP), Burst Mode Control @ Light Loading, GD Clamping, VCC Clamping, etc.

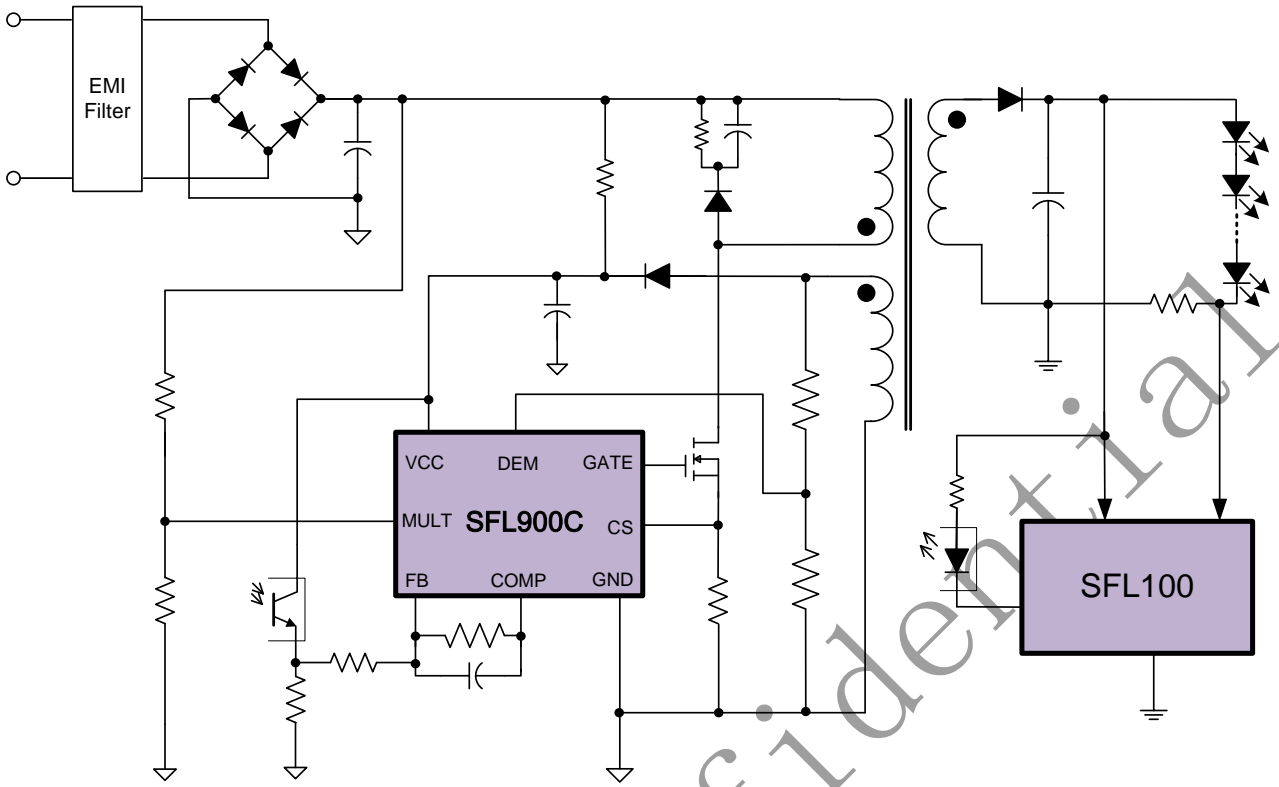
SFL900C is available in SOP-8 and DIP-8 packages.

GENERAL DESCRIPTION

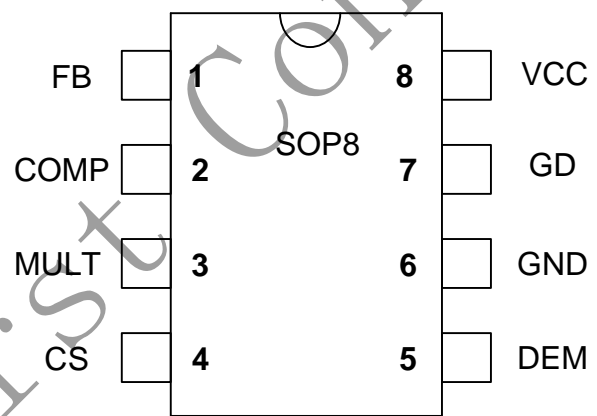
TYPICAL APPLICATION (PSR Application)



TYPICAL APPLICATION (SSR Application)

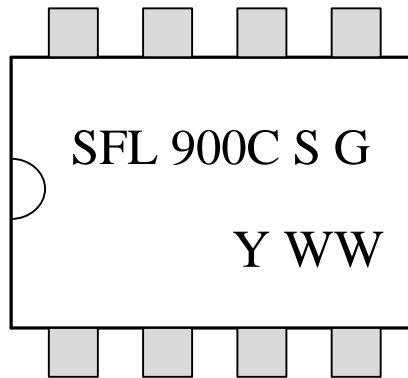


Pin Configuration



Ordering Information

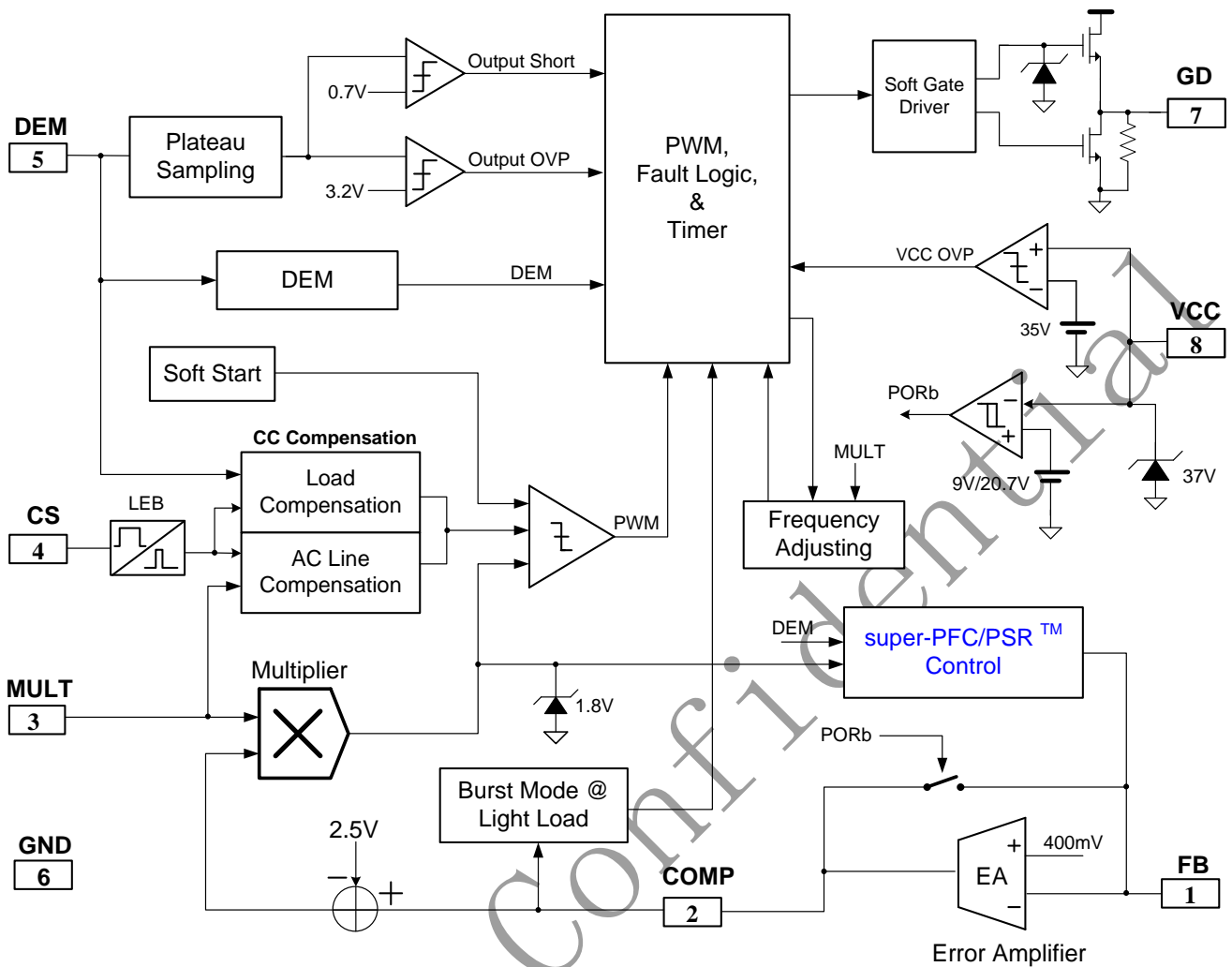
Part Number	Top Mark	Package		Tape & Reel
SFL900CSG	SFL900CSG	SOP8	Green	
SFL900CSGT	SFL900CSG	SOP8	Green	Yes

Marking Information


YWW: Year&Week code

Pin Description

Pin Num	Pin Name	I/O	Description
1	FB	I	Inverting input of the error amplifier. Before power on, this pin is internally shorted to COMP pin to clear external feedback network.
2	COMP	O	Output of the error amplifier. A feedback network is placed between this pin and pin 1. In PSR application, the feedback network can be a capacitor (1uF recommended). The voltage of COMP and pin CS generates PWM duty cycle.
3	MULT	I	Input to the multiplier stage. This pin is connected to the rectified mains voltage via a resistor divider and provides the sinusoidal reference to the current loop.
4	CS	I	Current sense input pin.
5	DEM	I	Demagnetization detection input from auxiliary winding for super-PFC/PSR™ control. This pin is also used for output over voltage protection and output short circuit protection.
6	GND	P	IC ground pin.
7	GD	O	Totem-pole gate driver output to drive the external MOSFET.
8	VCC	P	IC power supply pin.

Block Diagram

Absolute Maximum Ratings (Note 1)

Parameter	Value	Unit
VCC DC Supply Voltage	37	V
VCC DC Clamp Current	10	mA
GD pin	20	V
FB, COMP, MULT, CS, voltage range	-0.3 to 7	V
DEM Pin Max. Sink/Source Current	50(source) /10(sink)	mA
Package Thermal Resistance (SOP-8)	150	°C/W
Maximum Junction Temperature	150	°C
Operating Temperature Range	-40 to 85	°C
Storage Temperature Range	-65 to 150	°C
Lead Temperature (Soldering, 10sec.)	260	°C
ESD Capability, HBM (Human Body Model)	3	kV
ESD Capability, MM (Machine Model)	250	V

Recommended Operation Conditions (Note 2)

Parameter	Value	Unit
Supply Voltage, VCC	10 to 32	V
Operating Ambient Temperature	-40 to 85	°C

ELECTRICAL CHARACTERISTICS

 (T_A = 25°C, VCC=22V if not otherwise noted)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
Supply Voltage Section (VCC Pin)						
I _{vcc_Startup}	VCC Start up Current	Measure current into VCC		5	15	uA
UVLO(ON)	VCC Under Voltage Lockout Exit (Startup)		19.5	20.7	21.9	V
UVLO(OFF)	VCC Under Voltage Lockout Enter		8.0	9	10	V
UVLO(Hys)	UVLO Hysteresis	UVLO(ON)-UVLO(OFF)		11.7		V
VCC_OVP	VCC Over Voltage Protection trigger		33	35	37	V
VCC_Clamp	VCC Zener Clamp Voltage	I(VCC) = 5mA	35	37	39	V
I_VCC_Op	Operation Current	@70KHZ, GD=1nF		4	5.5	mA
I_VCC_quiet	Quiescent Current	No Switching		3	4	mA
T_Softstart	Soft Start Time			8		mSec
Error Amplifier Section (FB and COMP Pin)						
V _{FBREF}	Voltage Feedback Input Threshold		494	400	406	mV
Δ V _{FB_line}	Line Regulation	10V<VCC<32V		1	2	mV
Δ V _{FB_Temp}	Temperature Stability	-40°C <T _A <125°C		1		mV
G _v	Voltage Gain	Note 3	60	80		dB
GBW	Unit Gain Bandwidth	Note 3		1.2		MHz
I _{COMP_source}	Source Current	V _{COMP} =3.6V, V _{FB} =2.4V	-2	-4.8	-10	mA
I _{COMP_sink}	Sink Current	V _{COMP} =3.6V, V _{FB} =2.6V	-2	-4.8		mA
V _{COMP_Clamp_U}	Upper Clamp Voltage	I _{COMP} (source)=0.5mA		5.4		V
V _{COMP_min_duty}	COMP under voltage gate clock is off			2.25		V
Multiplier Section (MULT Pin)						
V _{mult}	Linear Operating Range		0~3.5			V
K	Multiplier Gain	V _{MULT} =1V, V _{COMP} =3.5V	0.9	1.0	1.1	1/V
ΔV _{cs} / ΔV _{mult}	Output Max. Slope	V _{MULT} =from 0 to 0.5V, V _{COMP} =Upper Clamp Voltage		1.8		V/V
Current Sense Section (CS Pin)						
V _{CS_clamp}	Current Sense Reference Clamp			1.8		V
T _{blanking}	CS Input Leading Edge Blanking Time			250		nSec
T _{D_OC}	Over Current Detection and Control Delay	GD=1nF		100		nSec
Demagnetization Detection Section (DEM Pin)						
V _{TH_DEM}	DEM Comparator Threshold Voltage (Negative going edge)			0.3		V
V _{TH_DEM_hys}	Hysteresis for DEM Comparator			0.1		V
V _{DEM_clamp_H}	High clamp voltage		5.4	6	6.6	V
V _{DEM_clamp_L}	Low clamp voltage	I(DEM)=-2.5mA		0		V
V _{TH_OVP}	Output over voltage protection threshold			3.2		V
N _{TRUE_OVP}	Number of subsequent cycles to be true OVP			2		Cycle
V _{TH_Output_short}	Output Short Circuit Protection Threshold			0.7		V
T _{min_OFF}	Minimum OFF time	Note 3		2.3		uSec

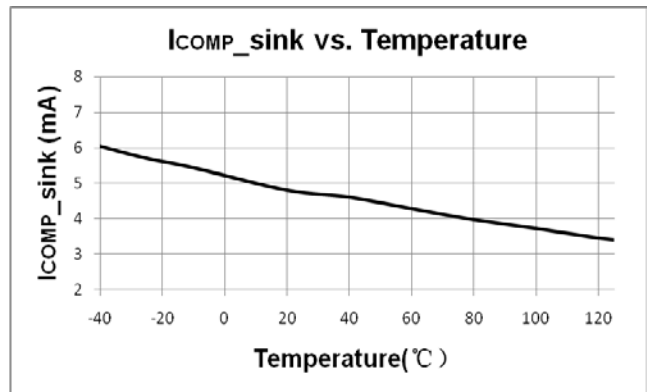
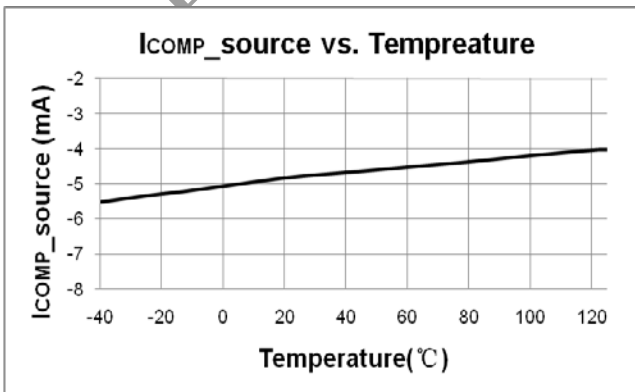
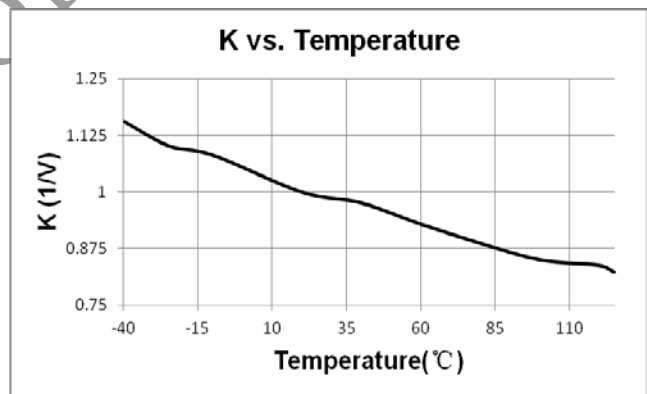
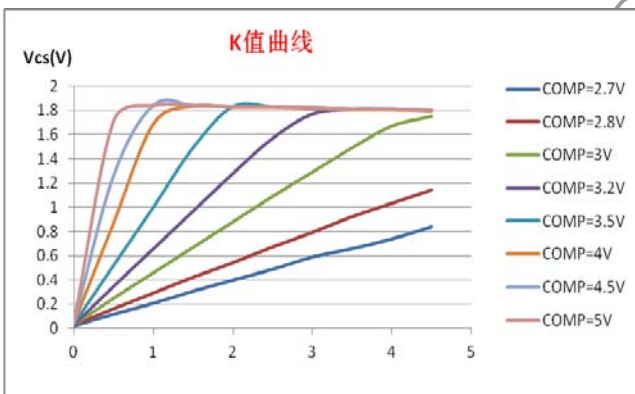
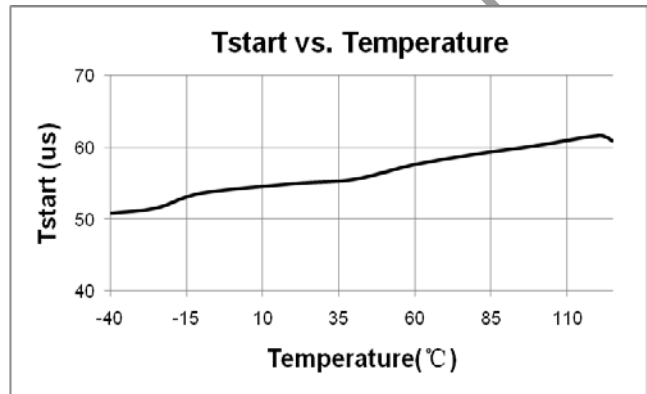
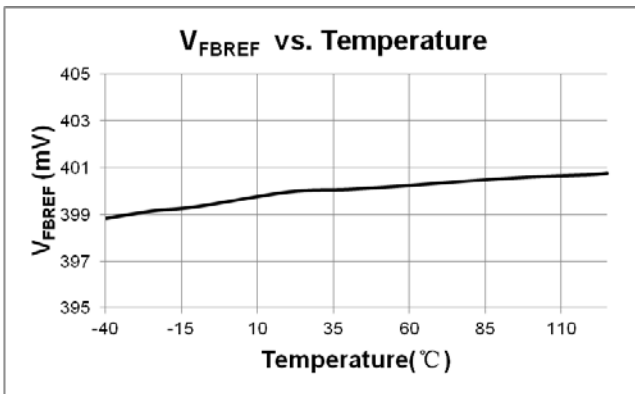
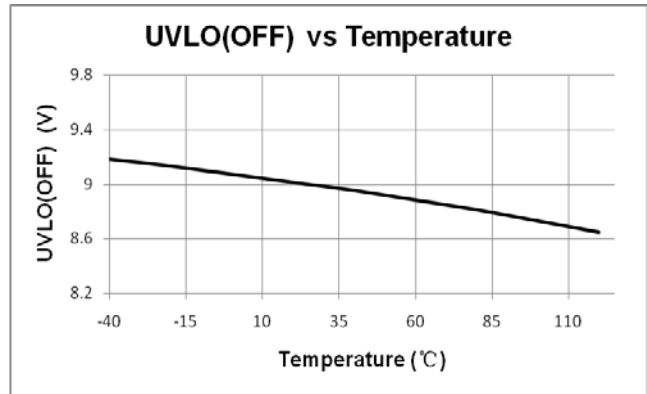
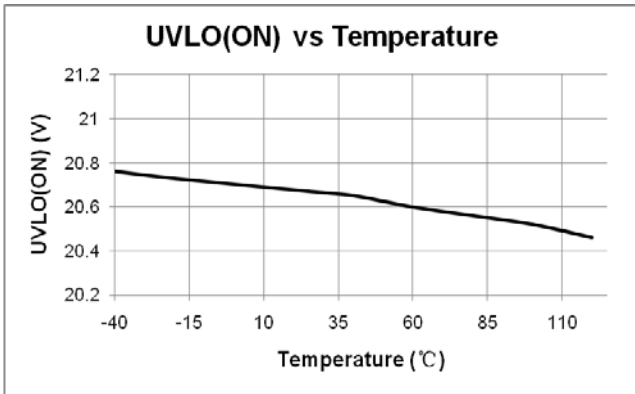
IDEM_source	Source Capability	Current		-2.5		-5	mA
IDEM_sink	Sink Capability	Current	Note 3	3			mA
Starter and Max Switching Frequency Limitation Section							
T_start	Start Timer Period			45	55	65	us
fsw_max	Max switching frequency				90		KHz
Gate Drive Section (GD Pin)							
VOL	Output Low Level	Io = 20 mA (sink)				0.5	V
VOH	Output High Level	Io = 20 mA (source)	12				V
GD_Clamp	Output Clamp Voltage Level	VCC=24V			16		V
T_r	Output Rising Time	GD = 1nF			80		nSec
T_f	Output Falling Time	GD = 1nF			50		nSec

Note 1. Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Note 2. The device is not guaranteed to function outside its operating conditions.

Note 3. Guaranteed by design.

CHARACTERIZATION PLOTS



OPERATION DESCRIPTION

SFL900C is a high performance, high power factor flyback PWM controller special for LED lighting applications. The IC adopts unique **super-PFC/PSR™** which can support both PSR and SSR applications.

◆ **super-PFC/PSR™ Support Both Primary Side Regulation (PSR) and Secondary Side Regulation (SSR)**

PSR topology requires no secondary feedback circuit (such as TL431, photo-coupler, etc), which reduces system cost greatly. SSR can achieve high accuracy CC (constant current) and CV (constant voltage) performance. Therefore, in small power applications, PSR is the popular topology, while SSR is superior topology in large power applications.

In SFL900C, a proprietary **super-PFC/PSR™** is adopted, which can support PSR (primary side regulation) and SSR (Secondary side regulation) simultaneously.

◆ **min-THD™ to Achieve Less than 10% THD Performance for Universal Input**

In SFL900C, a proprietary **min-THD™** technique is built in to improve system THD performance. In general, less than 10% system THD can be achieved.

◆ **LED Constant Current (CC) Regulation in PSR Application**

When used in primary side regulation occasion, SFL900C can accurately control the LED current by the current feedback control loop. The LED mean current can be approximately expressed as:

$$I_{LED} (mA) = \frac{N}{2} \times \frac{400(mV)}{R_{cs}(\Omega)}$$

In the equation above,
 N---The turn ratio of primary side winding to secondary side winding.
 Rcs--- the sensing resistor connected between the MOSFET source to GND.

◆ **UVLO (with 8V Hysteresis) and 5uA Startup Current**

Fig.1 shows a typical startup circuit. Before the IC begins switching operation, it consumes only startup current (typically 5uA) and current supplied through the startup resistor Rst charges the VDD hold-up capacitor Cdd. When VDD reaches UVLO turn-on voltage of 20.7V(typical), SFL900C begins switching and the IC current consumed increased to 3mA (typical). The hold-up capacitor Cdd continues to supply VDD before the energy can be delivered from auxiliary winding Na. During this process, VDD must not drop below UVLO turn-off voltage (typical 9V). The selection of Rst and Cdd should be a trade off between the power loss and startup time.

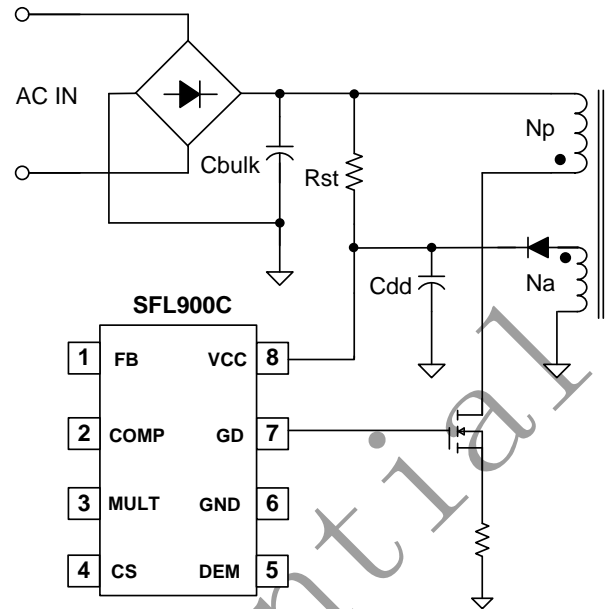


Fig.1

◆ **Low Operating Current**

The operating current in SFL900C is as small as 3mA (typical). The small operating current results in higher efficiency and reduces the VDD hold-up capacitance requirement.

◆ **Error Amplifier (EA)**

The inverting input of the EA is compared to an internal reference voltage (400mV, internally trimmed with 1.5% precision) to regulate LED output current. An external loop compensation network is placed between COMP and FB. When COMP voltage is below 2.25V, PWM cycle will stop.

◆ **Burst Mode Control @ Light Loading**

When the loading is very small, the system enters into burst mode. When VCOMP drops below 2.3V(typical), SFL900C will stop switching and output voltage starts to drop, which causes the VCOMP to rise. Once VFB rises above 2.3V, switching resumes. Burst mode control alternately enables and disables switching, thereby reducing switching loss in standby mode.

◆ **Clear External EA Feedback Network**

SFL900C features a control that clear the external EA feedback network before IC power on, as shown in Fig.2. This control can ensure the system start up softly by clearing the residue voltage on C1 and reduce the output LED current spike when system does the ON/OFF testing.

It is recommended that a 1uF capacitor connected between FB pin and COMP pin for loop compensation when used in PSR application

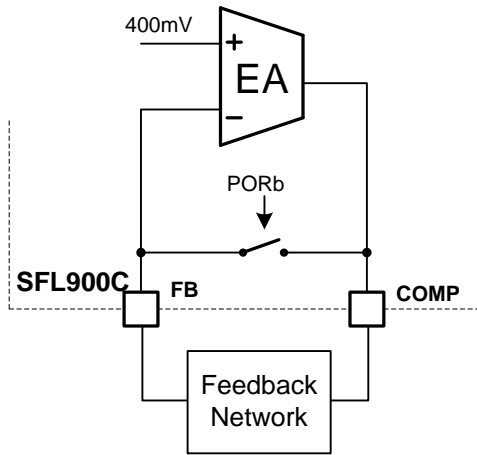


Fig.2

◆ **Analog Multiplier for Power Factor Correction**

The analog multiplier output limits the MOSFET peak current with respect to the AC half wave rectified input voltage. The multiplier in SFL900C has two inputs. One is the error amplifier (EA) output voltage (V_{COMP}), while the other is V_{MULT} which is obtained by a resistor divider from the rectified line. The multiplier output can be expressed as the following equation:

$$V_{\text{Multiplier}} = 1.0 \times V_{\text{MULT}} \times (V_{\text{COMP}} - 2.5V)$$

The analog multiplier in SFL900C is specially designed to achieve high linearity over a wide dynamic range. The multiplier output is clamped to 1.8V internally.

◆ **Frequency Adjusting**

In SFL900C, a proprietary function of “Frequency adjusting” is integrated. By setting a low frequency clamp which tracks the variation of the AC half wave rectified input voltage, the PFC THD performance can be improved, as shown in Fig.3.

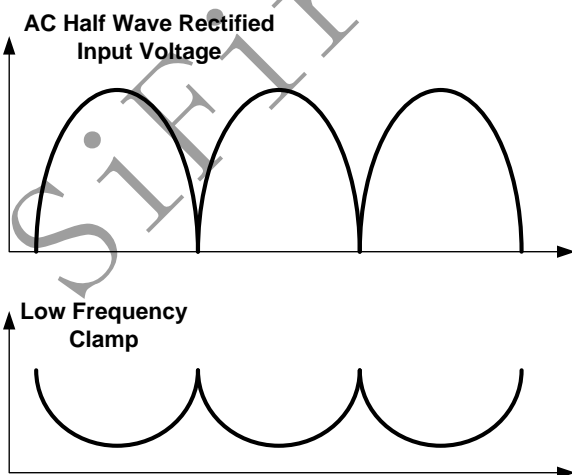


Fig.3

◆ **Leading Edge Blanking (LEB)**

Each time the power MOSFET is switched on, a turn-on spike occurs across the sensing resistor. To avoid premature termination of the switching pulse, an internal leading edge blanking circuit is built in. During this blanking period (250ns, typical), the current limiting comparator is disabled and cannot switch off the gate driver. Thus, conventional RC filtering is not necessary and the propagation delay of current limit protection can be minimized.

◆ **Soft Start**

SFL900C features an internal 8ms (typical) soft start that slowly increases the threshold of cycle-by-cycle current limiting comparator during startup sequence. It helps to prevent transformer saturation and reduce the stress on the secondary diode during startup. Every restart attempt is followed by a soft start activation.

◆ **2.3us Minimum OFF Time**

In SFL900C, a minimum OFF time (typically 2.3us) is implemented to suppress ringing when GATE is off.

The minimum OFF time is necessary in applications where the transformer has a large leakage inductance, particularly at low output voltages or startup.

◆ **90KHz Maximum Frequency Clamping for EMI**

In SFL900C, the maximum system switching frequency is clamped to 90KHz, which can improve system conduction EMI performance. Therefore, SFL900C is actual a mixed control of TM (Transition Mode, or Boundary Conduction Mode) mode and DCM (Discontinuous Conduction Mode) mode. .

◆ **Demagnetization Detection**

SFL900C can perform demagnetization detection by using an auxiliary winding of the inductor. When the stored energy is fully released to the output, the voltage on DEM goes down. If DEM pin voltage drops below 0.1V, an internal DEM comparator is triggered and a new switching cycle is initiated following the DEM triggering. The power MOSFET is always turned on with zero inductor current such that the turn-on loss and noise can be minimized.

An internal restart timer (55us, typical) is built in to ensure proper start up operation.

The maximum and minimum voltage of DEM pin is internally clamped to 5.8V and 0V respectively.

◆ **Built-in Load and AC Line CC Compensation**

In conventional PSR system, the output CC (Constant Current) point can vary with output and AC line voltage. In SFL900C, the IC has built-in blocks to compensate the variation, as shown in Fig.4. The IC can adjust CC point based on sensed

output voltage and AC line input voltage. In this way, CC accuracy can be improved.

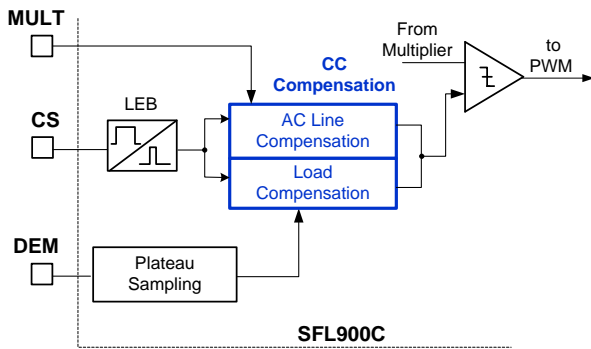


Fig.4

Typically, extra external CC compensation circuits are not needed. If a more precise CC point is needed, conventional external compensation network can be added.

◆ **Output Over Voltage Protection (Output OVP) / LED String Open Protection**

In SFL900C, the output OVP is integrated by plateau sampling the auxiliary winding in flyback phase. The threshold voltage for output OVP is 3.2V, as shown in Fig.5.

If the sampled plateau voltage exceeds the OVP threshold (3.2V), an internal counter starts counting subsequent OVP events. If OVP events are detected in successive 2 cycles, the controller assumes a true OVP and it stops all switching operations. The counter has been added to prevent incorrect OVP detection which might occur during ESD or lightning events. If the output voltage exceeds the OVP threshold less than 2 successive cycles, the internal counter will be cleared and no fault is asserted.

Output OVP is auto-recovery mode protection (mentioned below).

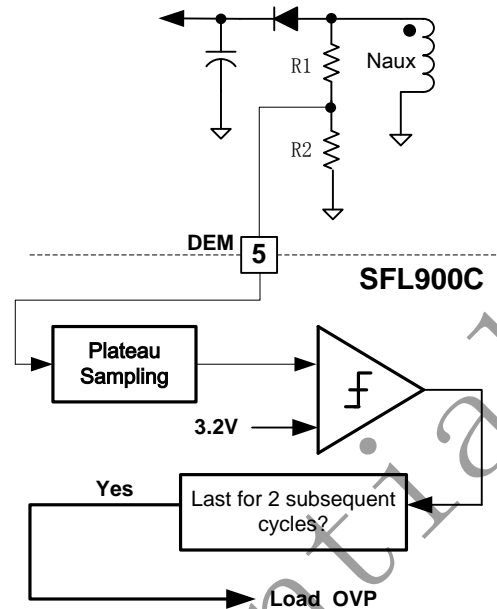


Fig.5

◆ **Output Short Circuit Protection / LED String Short Protection**

When the output short circuit happens, the positive plateau of auxiliary winding voltage is near zero and DEM voltage is low. If the voltage at DEM pin is lower than a threshold of 0.7V (typical) and lasts for more than 20ms, the IC will shut down and enter into auto-recovery mode protection (as mentioned below).

◆ **Pins Floating Protection**

In SFL900C, if pin floating situation occurs, the IC is designed to have no damage to system.

◆ **VCC OVP (Over Voltage Protection)**

When VCC voltage is higher than 35V (typical), VCC OVP (Over Voltage Protection) will be triggered in SFL900C and it is a protection of auto recovery mode (as mentioned below).

◆ **Auto Recovery Mode Protection**

As shown in Fig.6, once a fault condition (VCC OVP) is detected, switching will stop. This will cause VCC to fall because no power is delivered from the auxiliary winding. When VCC falls to UVLO(OFF) (typical 9V), the protection is reset and the operating current reduces to the startup current, which causes VCC to rise, as shown in Fig.6. However, if the fault still exists, the system will experience the above mentioned process. If the fault has gone, the system resumes normal operation. In this manner, the auto restart can alternatively enable and disable the switching until the fault condition is disappeared.

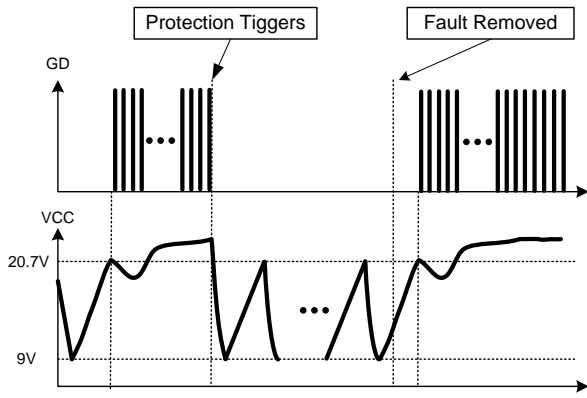


Fig.6

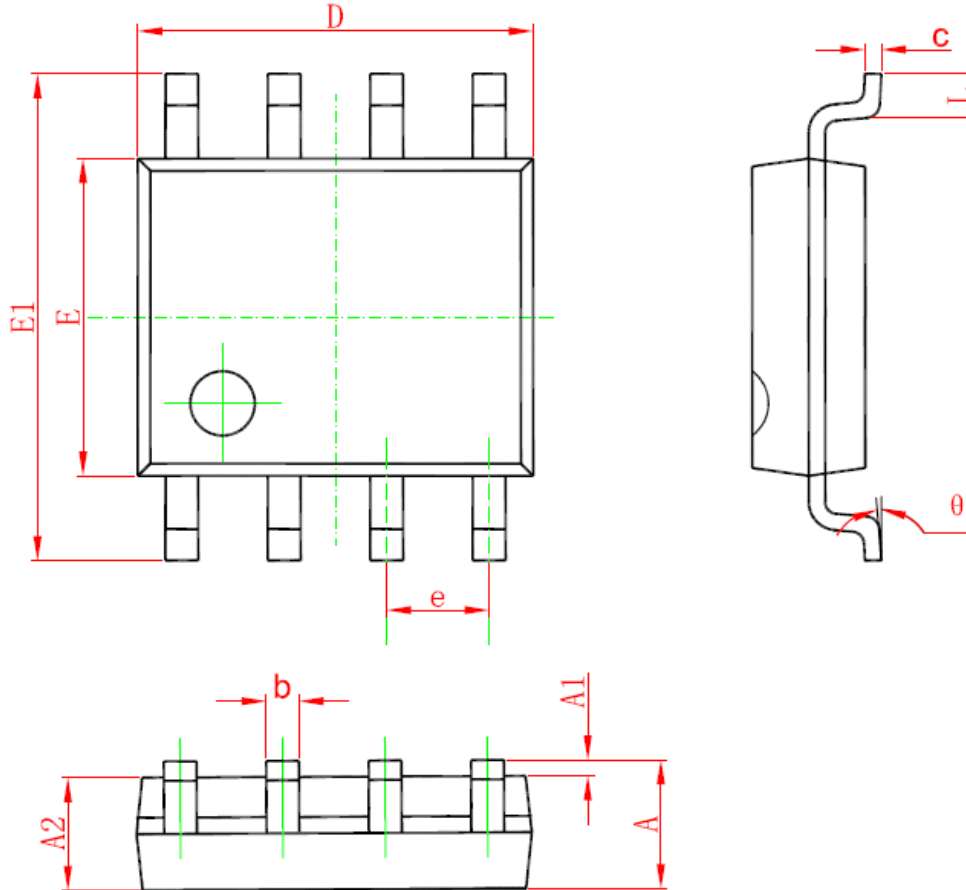
◆ **Soft Gate Drive**

SFL900C has a fast totem-pole gate driver with 500mA capability. Cross conduction has been avoided to minimize heat dissipation, increase efficiency, and enhance reliability. An internal 16V clamp is added for MOSFET gate protection at higher than expected VCC input. A soft driving waveform is implemented to minimize EMI.

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PACKAGE MECHANICAL DATA

SOP8 PACKAGE OUTLINE DIMENSIONS



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.650	0.049	0.065
b	0.310	0.510	0.012	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.150	0.185	0.203
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.270 (BSC)		0.05 (BSC)	
L	0.400	1.270	0.016	0.050
theta	0°	8°	0°	8°

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