Power Factor Controller **SG6961**

FEATURES

- Boundary Mode PFC Controller
- Low Input Current THD
- Controlled On-Time PWM
- Zero-Current Detection
- Cycle-by-Cycle Current Limiting
- Leading-Edge Blanking instead of RC Filtering
- Low Start-up Current (10uA TYP.)
- Low Operating Current (4.5mA TYP.)
- Feedback Open Loop Protection
- Programmable Maximum On-Time (MOT)
- Output Over-Voltage Clamping Protection
- Clamped Gate Output Voltage 16.5V

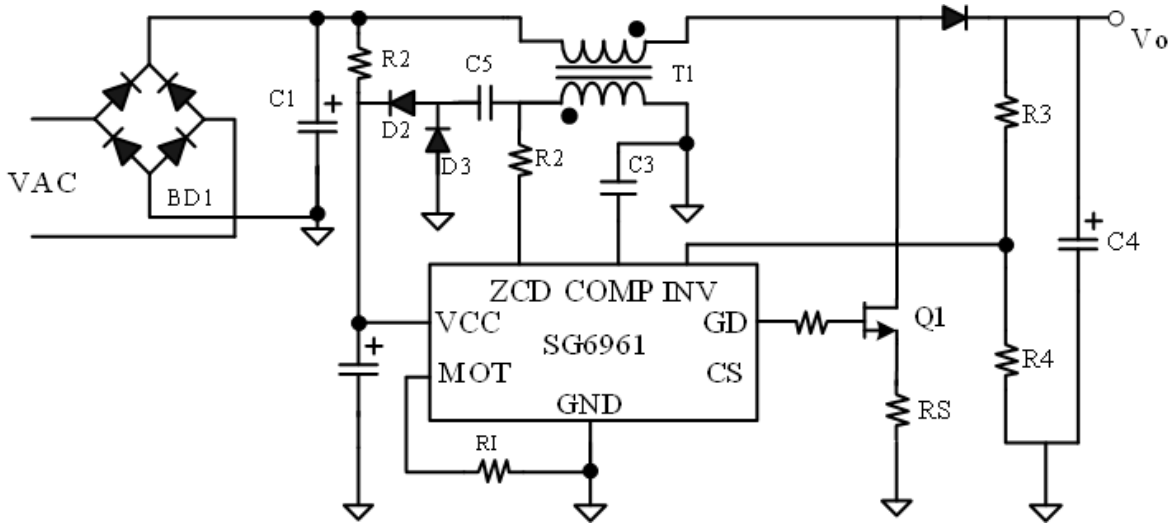
APPLICATIONS

- Electric Lamp Ballasts
- AC-DC Switching Mode Power Converter
- Open Frame Power Supplies and Power Adapters
- Flyback Power Converters with ZCS/ZVS

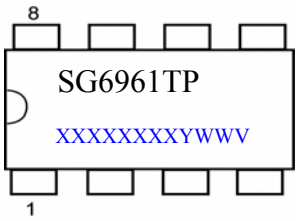
DESCRIPTION

The SG6961 is an 8-pin boundary mode PFC controller IC intended for controlling PFC pre-regulators. The SG6961 has many new features. It provides a controlled on-time to regulate the output DC voltage and achieve natural power factor correction. The maximum on-time of the external switch is programmable to ensure safe operation during AC brownouts. An innovative multi-vector error amplifier is built in to provide rapid transient response and precise output voltage clamping. A built in circuit will disable the controller if the output feedback loop is opened. The start up current is lower than 20uA and the operating current has been shrunk to under 4.5mA. The supply voltage can be up to 20 volts, maximizing application flexibility.

TYPICAL APPLICATION

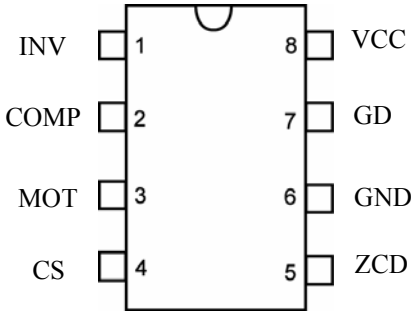


MARKING DIAGRAMS



T: D = DIP, S = SOP
P : Z =Lead Free + ROHS Compatible
Null=regular package
XXXXXXXX: Wafer Lot
Y: Year; WW: Week
V: Assembly Location

PIN CONFIGURATION



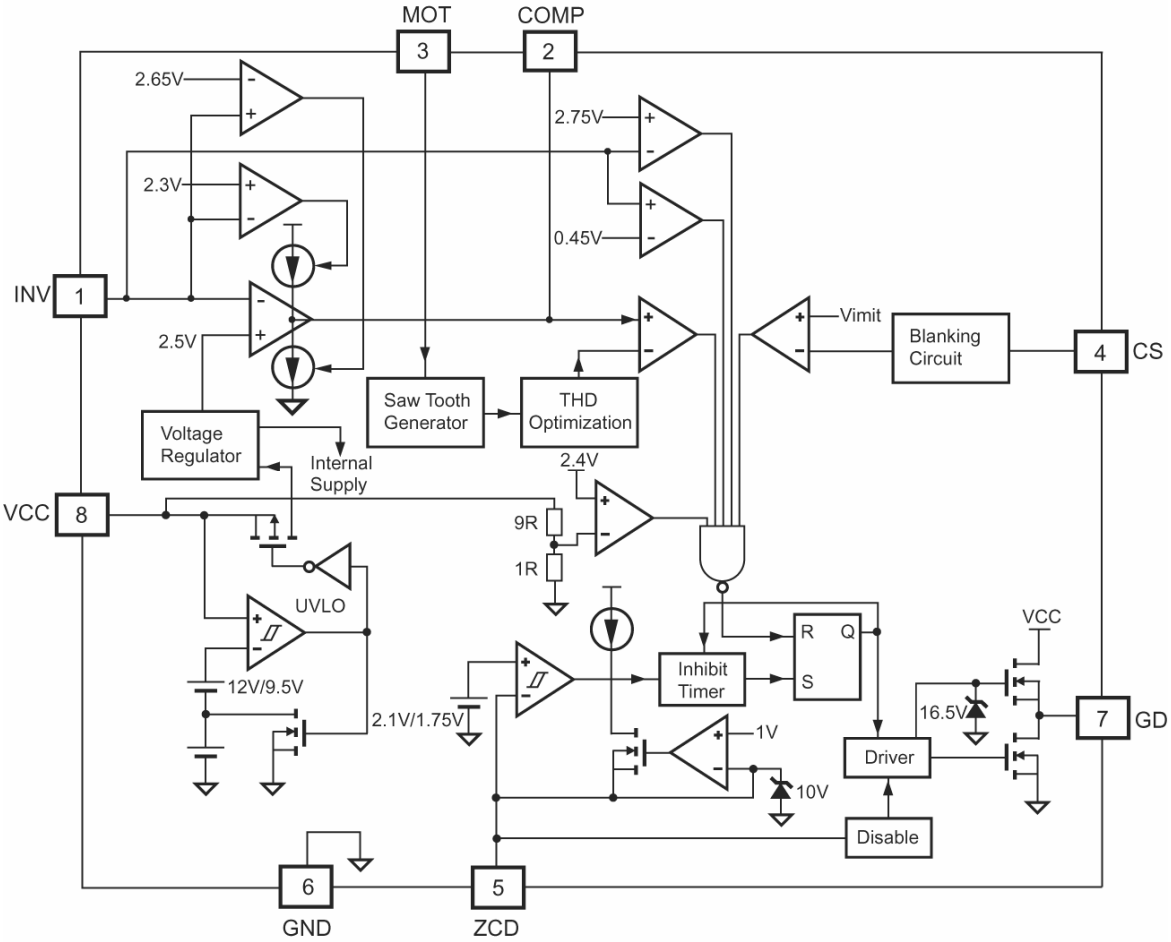
ORDERING INFORMATION

Part Number	Package
SG6961SZ	8-Pin SOP (Lead Free)
SG6961DZ	8-Pin DIP (Lead Free)

PIN DESCRIPTIONS

Pin No.	Symbol	Description
1	INV	Inverting input of the error amplifier. INV is connected to the converter output via a resistive divider. This pin is also used for over-voltage clamping and open loop feedback protection.
2	COMP	The output of the error amplifier. In order to create a precise clamping protection, a compensation network between this pin and GND is suggested.
3	MOT	A resistor from MOT to GND is used to determine the maximum on-time of the external power MOSFET. The maximum output power of the converter is a function of the maximum ON-time.
4	CS	Input to the over-current protection comparator. When the sensed voltage across the sense resistor reaches the internal threshold (0.82V), the switch will be turned off to activate cycle-by-cycle current limiting.
5	ZCD	Zero Current Detection. This pin is connected to an auxiliary winding via a resistor to detect the zero crossing of the switch current. When the zero crossing is detected, a new switching cycle is started. If it is connected to GND, the device is disabled.
6	GND	The power ground and signal ground. Placing a 0.1uF decoupling capacitor between VCC and GND is recommended.
7	GD	Totem-pole driver output to drive the external power MOSFET. The clamped gate output voltage is 16.5V.
8	VCC	Driver and control circuit supply voltage.

BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter		Value	Unit
V_{DD}	DC Supply Voltage*		25	V
V_{HIGH}	GD		-0.3 to 25	V
V_{LOW}	Others (INV, COMP, MOT, CS,)		-0.3 to 7	V
V_{zcd}	Input Voltage to Zcd Pin		-0.3 to 12	V
P_D	Power Dissipation	DIP-8 SOP-8	800 400	mW
$R_{\theta J-A}$	Thermal Resistance (Junction to Air)	DIP-8 SOP-8	48.45 62.7	°C/W
T_J	Operating Junction Temperature		-40 to +125	°C
T_{STG}	Storage Temperature Range		-65 to +150	°C
T_L	Lead Temperature (Wave soldering or IR, 10 seconds)		260	°C
	ESD Capability, Human Body Model		2.0	kV
	ESD Capability, Machine Model		200	V

* All voltage values, except differential voltages, are given with respect to GND pin.

* Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device.

ELECTRICAL CHARACTERISTICS (VCC = 15V, T_A = -20°C~125°C, unless noted)

VCC Section

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
V_{OP}	Continuously Operating Voltage				20	V
V_{TH-ON}	Turn-on Threshold Voltage		11	12	13	V
V_{TH-OFF}	Turn-off Voltage		8.2	9.5	10.5	V
I_{CC-ST}	Start-Up Current	VCC = V_{TH-ON} –0.16V		10	20	uA
I_{CC-OP}	Operating Current	VCC = 12V, V_{CS}=0, C_L=3nF, F_{SW}=50KHz		4.5	6	mA
VCC_{-OVP}	VCC Over Voltage Protection		23.5	24.5	25.5	V
$T_{VCC-OVP}$	VCC OVP Debounce Time			30		usec

Error Amplifier Section

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
V_{REF}	Reference Voltage		2.45	2.5	2.55	V
Gm	Transconductance	T_A=25℃	100	125	150	umho
V_{INVH}	Clamp High Feedback Voltage			2.65	2.7	V
V_{INVL}	Clamp Low Feedback Voltage		2.22	2.3		V
$V_{OUT\ HIGH}$	Output High Voltage		4.8			V
V_{OZ}	Zero Duty Cycle Output Voltage		1.15	1.35	1.45	V
$V_{INV-OVP}$	Over Voltage Protection for INV Input		2.7	2.75	2.8	V
$V_{INV-UVP}$	Under Voltage Protection for INV Input		0.4	0.45	0.5	V
I_{COMP}	Source Current	V_{INV}=2.35V, V_{COMP}=1.5	7	20		uA
		V_{INV}=1.5V	450	800		uA
	Sink Current	V_{INV}=2.65V, V_{COMP}=5	10	20		uA

Current Sense Section (V_{limit})

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
V_{PK}	Threshold Voltage for Peak Current Limit Cycle by Cycle Limit	Vcomp=5v	0.77	0.82	0.87	V
T_{PKD}	Propagation Delay				200	nsec
T_{BNK}	Leading-Edge Blanking Time	R_{MOT}= 24k		400	550	nsec

Gate Section

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
VZ-$_{OUT}$	Output Voltage Maximum (clamp)	VCC= 20V	15.5	16.5	17.5	V
V_{OL}	Output Voltage Low	VCC = 15V, I_O = 100mA			1.4	V
V_{OH}	Output Voltage High	VCC = 14V, I_O = 100mA	8			V
T_R	Rising Time	VCC =12V, C_L=3nF, 20~80%	50	80	160	nsec
T_F	Falling Time	VCC =12V, C_L=3nF, 80~20%	30	40	70	nsec

Zero Current Detection Section

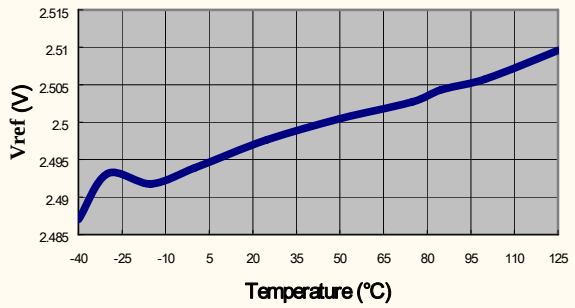
Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
V_{ZCD}	Input Threshold Voltage Rising Edge	V_{ZCD} increasing	1.9	2.1	2.3	V
H_{YS} of V_{ZCD}	Threshold Voltage Hysteresis	V_{ZCD} decreasing	0.25	0.35	0.5	V
$V_{ZCD-HIGH}$	Upper Clamp Voltage	I_{ZCD} = 3 mA	8	10	12	V
$V_{ZCD-LOW}$	Lower Clamp Voltage	I_{ZCD} = -0.5 mA	0			V
T_{DEAD}	Maximum Delay from ZCD to Output Turn-On	Vcomp=5v, F_{SW}=60KHz	100		400	nsec
$T_{RESTART}$	Restart Time	Output Turned Off by ZCD	300	500	700	usec
T_{INHIB}	Inhibit Time (Maximum Switching Frequency limit)	R_{MOT} =24k	1.5	2.5	3	usec
V_{DIS}	Disable Threshold		200	250	300	mV
$T_{ZCD-DIS}$	ZCD Disable Debounce time	R_{MOT}=24k, ZCD=100mV	800			usec

Maximum On-Time Section

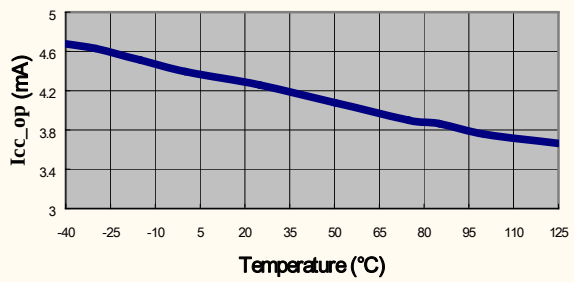
Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
V_{MOT}	MOT Voltage		1.25	1.3	1.35	V
T_{ON-MAX}	Maximum On-Time Programming (resistor based)	R_{MOT} =24k, V_{CS}=0, Vcomp=5v	21	25	27	usec

TYPICAL CHARACTERISTIC

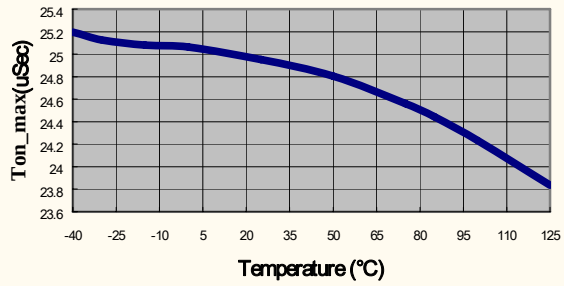
Turn-on Threshold Voltage (Vref) vs Temperature



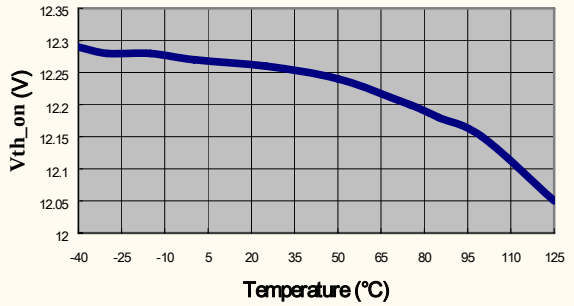
Continuously Operating Voltage (Icc_op) vs Temperature



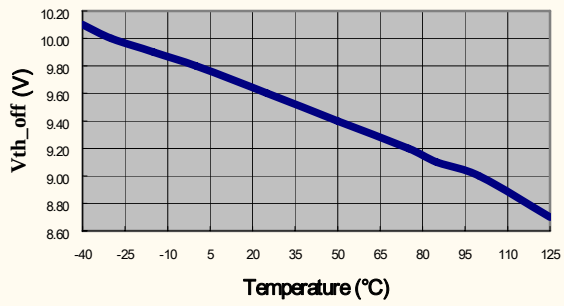
Maximum On-Time Programming-resistor based (Ton_max) vs Temperature



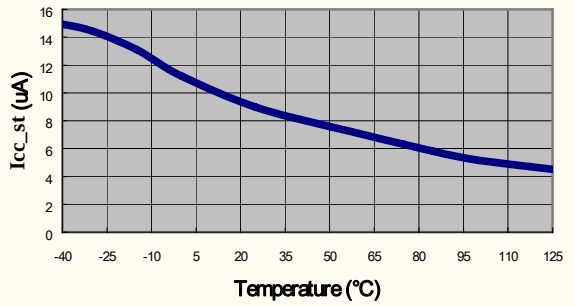
Turn-on Threshold Voltage (Vth_on) vs Temperature



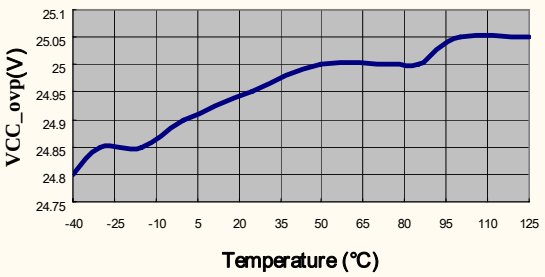
Turn-off Voltage (Vth_off) vs Temperature



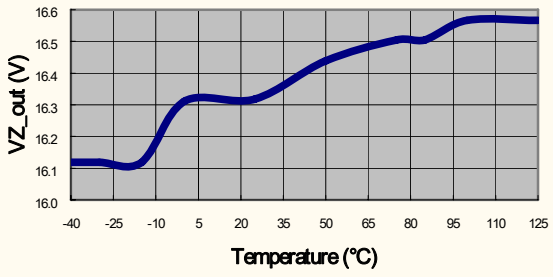
Start_Up Current (Icc_st) vs Temperature



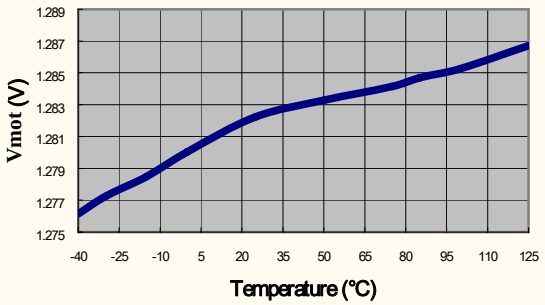
VCC Over Voltage Protection (VCC_ovp) vs Temperature



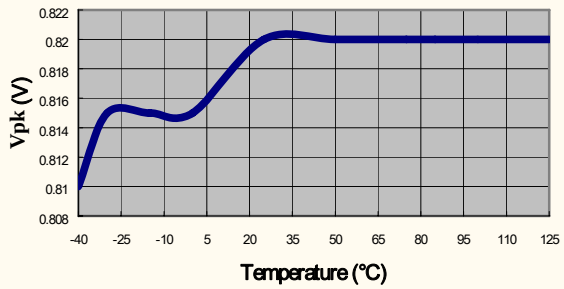
Output Voltage Maximum-clamp (VZ_out) vs Temperature



MOT Voltage (Vmot) vs Temperature



Threshold Voltage for Peak Current Limit Cycle by Cycle Limit (Vpk) vs Temperature



OPERATION DESCRIPTION

Error Amplifier

The inverting input of the error amplifier is referenced to INV. The output of the error amplifier is referenced to COMP. The non-inverting input is internally connected to a fixed 2.5V ± 2% voltage. The output of the error amplifier is used to determine the on-time of the PWM output and hence regulate the output voltage. To achieve a low input current THD, the variation of the on-time within one input AC cycle should be very small. A multi-vector error amplifier is built in to provide fast transient response and precise output voltage clamping.

For SG6961, connecting a capacitance such as 1uF between COMP and GND is suggested. The error amplifier is a trans-conductance amplifier that converts voltage to current with a 125umho.

Start-Up Current

Typical start-up current is less than 20uA. This ultra low start-up current allows the usage of high resistance, low-wattage start-up resistor. For example, 1 MΩ/0.25W start-up resistor and a 10uF/25V (V_{CC} hold-up) capacitor are recommended for an AC-to-DC power adaptor with a wide input range 85-265V_{AC}.

Operating Current

Operating current is typically 4.5mA. The low operating current enables a better efficiency and reduces the requirement of V_{CC} hold-up capacitance.

Maximum On-Time Operation

Given a fixed inductor value and maximum output power, the relation between on-time and line voltage is

$$t_{on} = \frac{2 \cdot L \cdot P_o}{V_{rms}^{\ 2} \cdot \eta} \text{ ----------(1)}$$

If the line voltage is too low or the inductor value is too high, T_{ON} will be too long. To avoid extra low operating frequency and achieve brownout protection, the maximum value of T_{ON} is programmable by one Resistor R_I connected between MOT and GND. A 24kΩ resistor R_I generates corresponds to 25us maximum on-time.

$$t_{on(\max)} = R_I(k\Omega) \cdot \frac{25}{24}(uS) \text{ ----------(2)}$$

The range of the maximum on-time is designed as 10 ~ 50us.

Peak Current Limiting

The switch current is sensed by one resistor. The signal is feed into CS pin and hence an input terminal of a comparator. A high voltage in CS pin will terminate a switching cycle immediately and hence cycle-by-cycle current limit is achieved. The designed threshold of the protection point is 0.82V.

Leading Edge Blanking

A turn on spike on CS pin will inevitably appear when the power MOSFET is switched on. At the beginning of each switching pulse, the current-limit comparator is disabled for around 400nsec to avoid premature termination. The gate drive output cannot be switched off during the blanking period. Conventional RC filtering is not necessary such that the propagation delay of current limit protection can be minimized.

Under-Voltage Lockout (UVLO)

The turn-on and turn-off threshold voltage is fixed internally at 12V/9.5V for SG6961. This hysteresis behavior will guarantee a one shot start-up with proper start-up resistor and hold-up capacitor. With an ultra low start-up current of 20uA, one 1MΩ R_{IN} will be sufficient for start-up under low input line voltage, 85Vrms. Power dissipation on R_{IN} would then be less than 0.1W even under high line (V_{AC} = 265Vrms) condition.

Output Driver

With low ON-resistance and high current driving capability, the output driver can easily drive an external capacitive load larger than 3000pF. Cross conduction current has been avoided to minimize heat dissipation, such that efficiency and reliability can be improved. This output driver is internally equipped with clamped by a 16.5V Zener diode.

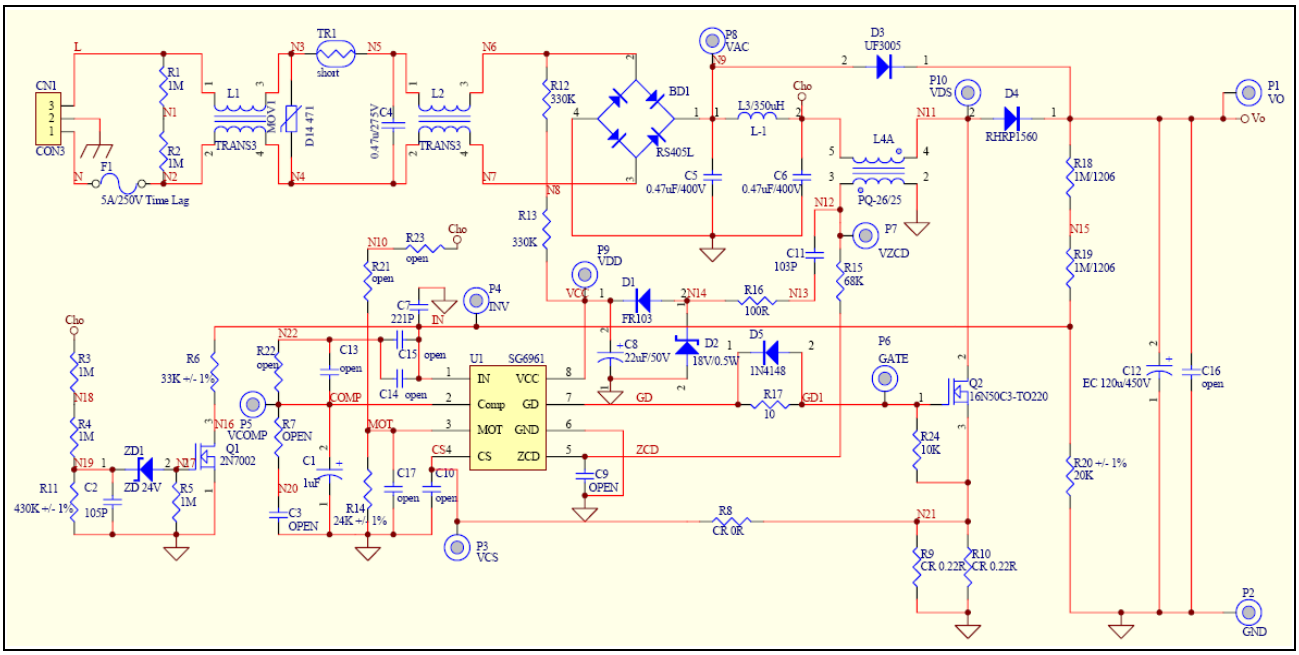
Zero Current Detection

The zero current detection of the inductor is achieved using its auxiliary winding. When the stored energy of the inductor is fully released to output. The voltage on ZCD will go down and a new switching cycle will be enabled after a ZCD trigger. The power MOSFET will always be turned on with zero inductor current such that turn on loss and noise can be minimized. The converter will work in boundary mode that the peak inductor current is always exactly twice of the average current. Moreover, a natural power factor correction function is achieved with the low-bandwidth on time modulation. An inherent maximum off time is built in to ensure proper start-up operation. In addition, this pin can be used as a Synchronous Input.

Noise Immunity

Noise on the current sense or control signal can cause significant pulse width jitter, particularly in the boundary-mode operation. Slope compensation and built-in debounce circuit can alleviate this problem. Note that the SG6961 has a single ground pin. Therefore, high sink current at the output cannot be returned separately. Good high frequency or RF layout practices should be followed. Avoiding long PCB traces and component leads. Locating compensation and filter components near to the SG6961, and increasing the power MOSFET gate resistance will always help.

REFERENCE CIRCUIT: SG6961 180W



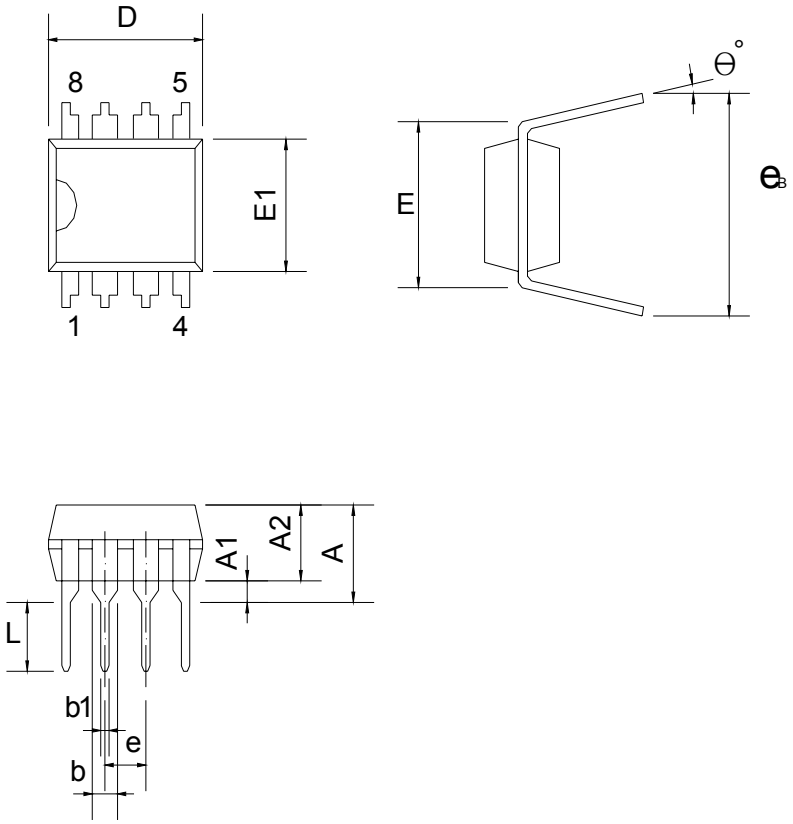
BOM

Component	Symbol
Resistor 1MΩ +/- 5% SMD 1206	R1,R2,R3,R4,R5,R18,R19
Resistor 33KΩ +/- 1% SMD 1206	R6
Resistor 0Ω +/- 1% SMD 1206	R8
Metal-Oxide Resistor 1W-S 0Ω22 +/-5%	R9,R10
Resistor 430KΩ +/-1% SMD 0805	R11
Resistor 330KΩ +/-1% SMD 1206	R12,R13
Resistor 24KΩ +/-1% SMD 1206	R14
Resistor 68KΩ +/-5% SMD 1206	R15
Resistor 100Ω +/-5% SMD 1206	R16
Resistor 10Ω +/-1% SMD 1206	R17
Resistor 20KΩ +/-1% SMD 1206	R20
Electrolytic Capacitor 1uF 50V 105℃	C1
MLCC 105P 50V SMD 1206	C2
X1 Capacitor 0.47uF 275V +/-20%	C4
MPE Capacitor 0.47uF 450V +/-10%	C5,C6
MLCC 221P 50V +/-10% SMD 0805	C7
Electrolytic Capacitor 22uF 50V 85℃	C8

MLCC 103P 50V +/-10% SMD 1206	C11
Electrolytic Capacitor 120uF 450V 105℃	C12
FUSE 250V 5A Ceramic Time-Lag	F1
TRN0194 Common Choke 4.5mH	L1
TRN0195 Common Choke 7.5mH(min)	L2
TRN0193 Inductor(T80-26) 350uH	L3
TRN0196 PFC Choke 210uH PQ-26/25	L4A
Varistor 14ψ 471	MOV1
JUMPER WIRE 0.8ψ(mm)	JP1,JP2,JP3,JP4,TR1
Rectifier KBL06 4A 600V	BD1
Diode FR103 TAPING	D1
Zener Diode1/2W 18V	D2
Diode UF3005 3A 600V	D3
Diode Fairchild RHRP1560 15A 600V TO-220	D4
Diode 1N4148 SMD	D5
ZENER Diode 1/2W 24V SMD	ZD1
Diode 2N7002 SMD	Q1
MOSFET Infineon 16N50C3 16A 500V TO-220	Q2

PACKAGE INFORMATION

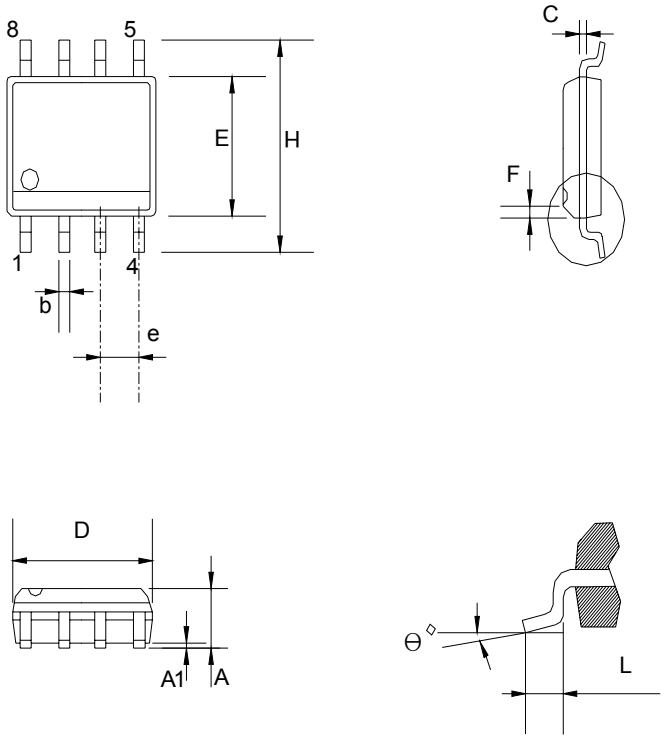
8PINS-DIP(D)



Dimensions

Symbol	Millimeter			Inch		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			5.334			0.210
A1	0.381			0.015		
A2	3.175	3.302	3.429	0.125	0.130	0.135
b		1.524			0.060	
b1		0.457			0.018	
D	9.017	9.271	10.160	0.355	0.365	0.400
E		7.620			0.300	
E1	6.223	6.350	6.477	0.245	0.250	0.255
e		2.540			0.100	
L	2.921	3.302	3.810	0.115	0.130	0.150
e_B	8.509	9.017	9.525	0.335	0.355	0.375
θ°	0°	7°	15°	0°	7°	15°

8PINS-SOP(S)



Dimensions

Symbol	Millimeter			Inch		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	1.346		1.752	0.053		0.069
A1	0.101		0.254	0.004		0.010
b		0.406			0.016	
c		0.203			0.008	
D	4.648		4.978	0.183		0.196
E	3.810		3.987	0.150		0.157
e	1.016	1.270	1.524	0.040	0.050	0.060
F		0.381X45°			0.015X45°	
H	5.791		6.197	0.228		0.244
L	0.406		1.270	0.016		0.050
θ°	0°		8°	0°		8°

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