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 (10μA Typical)
- Low Operating Current (4.5mA Typical)
- Feedback Open-Loop Protection
- Programmable Maximum On-Time (MOT)
- Output Over-Voltage Clamping Protection
- Clamped Gate Output Voltage 16.5V

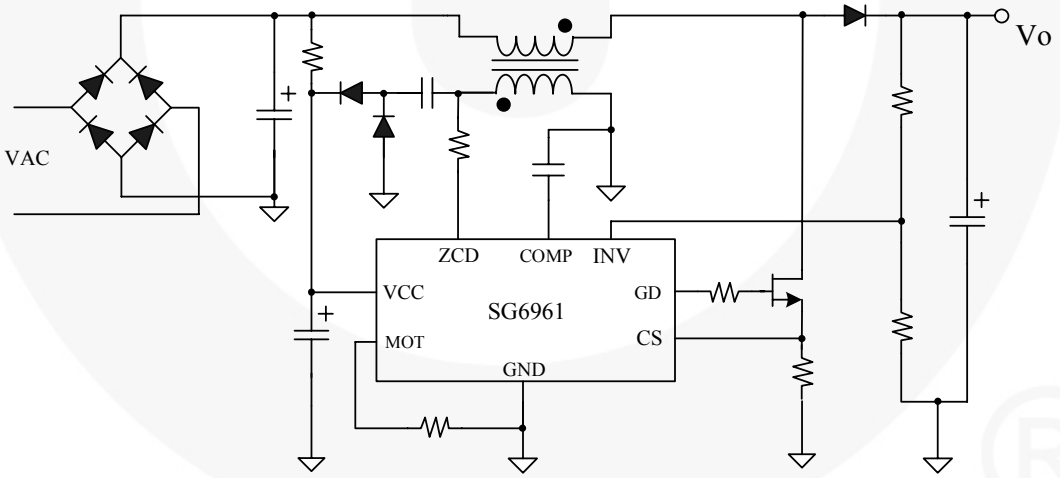
DESCRIPTION

The SG6961 is an 8-pin boundary mode PFC controller IC intended for controlling PFC pre-regulators. The SG6961 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 disables the controller if the output feedback loop is opened. The start-up current is lower than 20μA and the operating current is under 4.5mA. The supply voltage can be up to 20V, maximizing application flexibility.

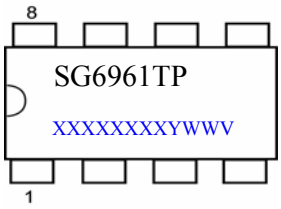
APPLICATIONS

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

TYPICAL APPLICATION

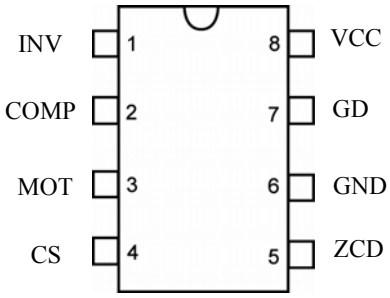


MARKING DIAGRAMS



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



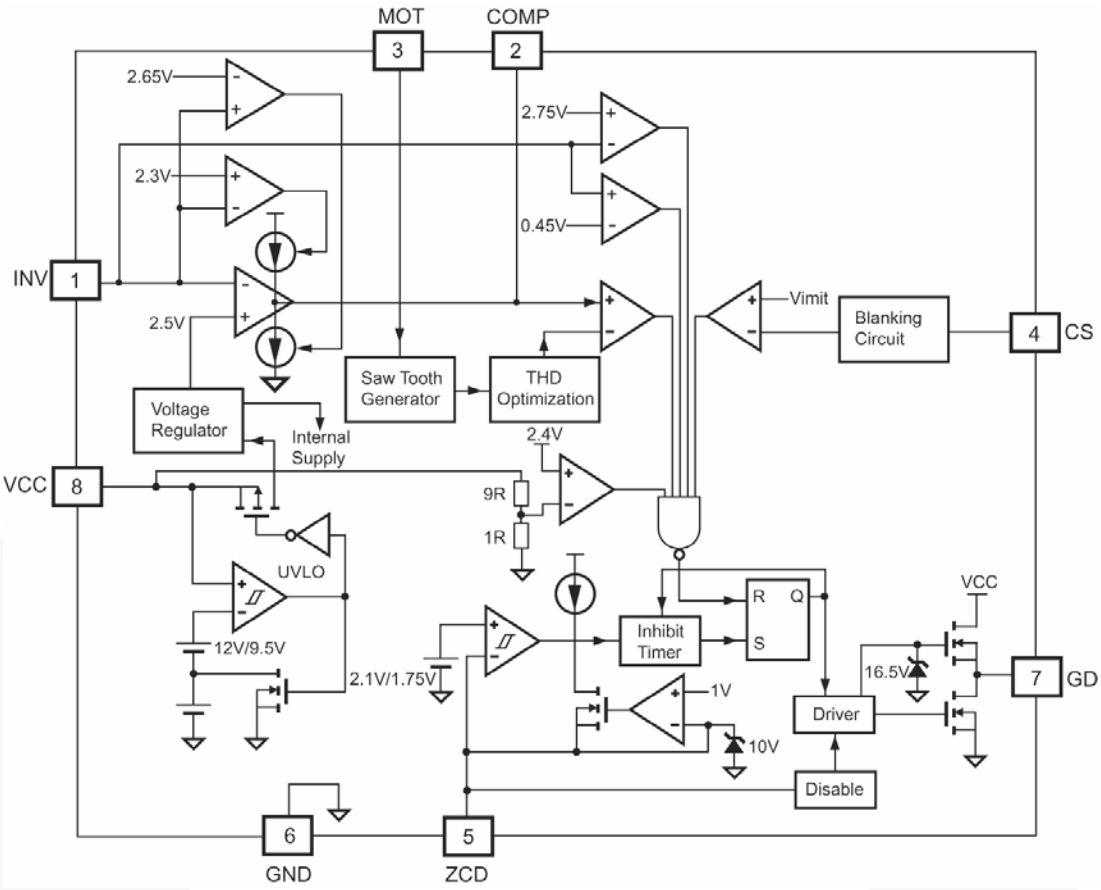
ORDERING INFORMATION

Part Number	Pb-Free	Package
SG6961SZ		8-Pin SOP
SG6961DZ		8-Pin DIP

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. 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 is 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 0.1μF decoupling capacitor between the VCC and GND pins 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 25.0	V
V_{LOW}	Others (INV, COMP, MOT, CS,)		-0.3 to 7.0	V
V_{zcd}	Input Voltage to ZCD Pin		-0.3 to 12.0	V
P_D	Power Dissipation	DIP-8	800	mW
		SOP-8	400	
$R_{\theta J-A}$	Thermal Resistance (Junction-to-Air)	DIP-8	48.45	°C/W
		SOP-8	62.70	
T_J	Operating Junction Temperature		-40 to + 150	°C
T_{STG}	Storage Temperature Range		-65 to + 150	°C
T_L	Lead Temperature (Wave Soldering or Infrared, 10 Seconds)		260	°C
ESD	Electrostatic Discharge Capability, Human Body Model		2.0	kV
	Electrostatic Discharge 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

V_{CC}=15V, T_A=-20°C~125°C, unless otherwise noted.

V_{CC} 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	$V_{CC}=V_{TH-ON}$ –0.16V		10	20	μA
I_{CC-OP}	Operating Current	V_{CC}=12V, V_{CS}=0, C_L=3nF, F_{SW}=50KHz		4.5	6.0	mA
V_{CC-OVP}	V_{CC} Over-Voltage Protection*			24		V
$T_{VCC-OVP}$	V_{CC} OVP Debounce Time*			30		μs

* Guaranteed by design.

Error Amplifier Section

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
V_{REF}	Reference Voltage		2.45	2.50	2.55	V
Gm	Transconductance*	T_A=25°C	100	125	150	μmho
V_{INVH}	Clamp High Feedback Voltage			2.65	2.70	V
V_{INVL}	Clamp Low Feedback Voltage		2.22	2.30		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*			2.75		V
$V_{INV-UVP}$	Under-Voltage Protection for INV Input		0.40	0.45	0.50	V
I_{COMP}	Source Current	V_{INV}=2.35V, V_{COMP}=1.5V	7	20		μA
		V_{INV}=1.5V	450	800		μA
	Sink Current	V_{INV}=2.65V, V_{COMP}=5V	10	20		μA

* Guaranteed by design.

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	V_{COMP}=5V	0.77	0.82	0.87	V
T_{PKD}	Propagation Delay				200	ns
T_{BNK}	Leading-Edge Blanking Time	R_{MOT}=24kΩ		400	550	ns

Gate Section

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

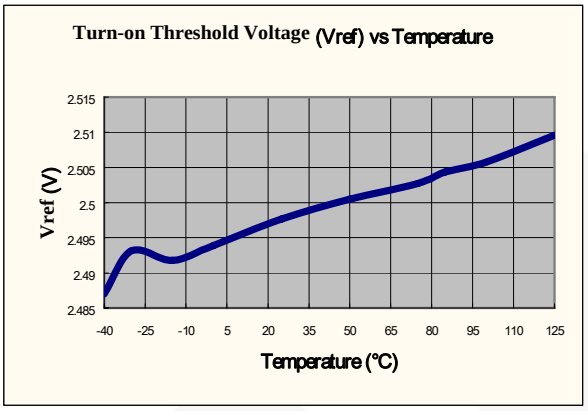
Zero Current Detection Section

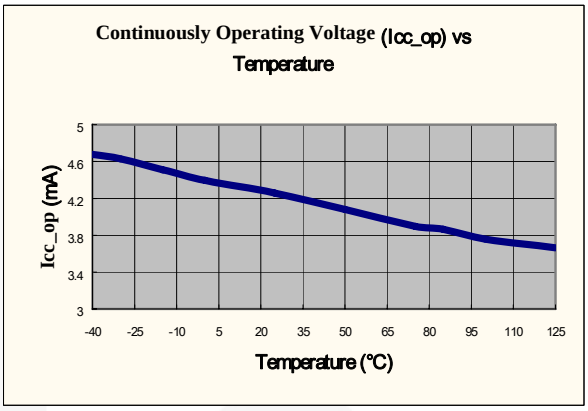
Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
V_{ZCD}	Input Threshold Voltage Rising Edge	V_{ZCD} Increasing	1.9	2.1	2.3	V
H_{YS} of V_{ZCD}	Threshold Voltage Hysteresis	V_{ZCD} Decreasing	0.25	0.35	0.50	V
$V_{ZCD-HIGH}$	Upper Clamp Voltage	I_{ZCD}=3mA	8	10	12	V
$V_{ZCD-LOW}$	Lower Clamp Voltage	I_{ZCD}=-0.5mA	0			V
T_{DEAD}	Maximum Delay from ZCD to Output Turn-On	V_{COMP}=5V, F_{SW}=60KHz	100		400	ns
$T_{RESTART}$	Restart Time	Output Turned Off by ZCD	300	500	700	µs
T_{INHIB}	Inhibit Time (Maximum Switching Frequency Limit)	R_{MOT}=24kΩ	1.5	2.5	3.0	µs
V_{DIS}	Disable Threshold		200	250	300	mV
$T_{ZCD-DIS}$	ZCD Disable Debounce Time	R_{MOT}=24kΩ, ZCD=100mV	800			µs

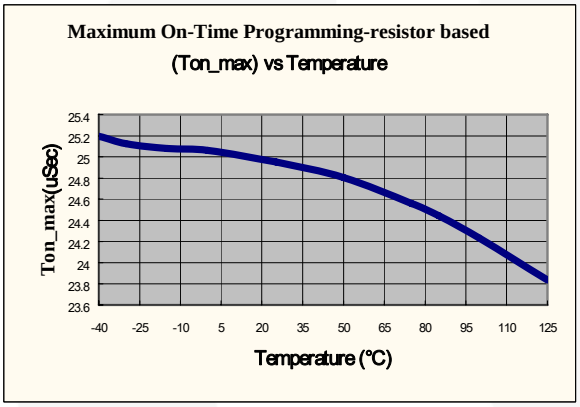
Maximum On-Time Section

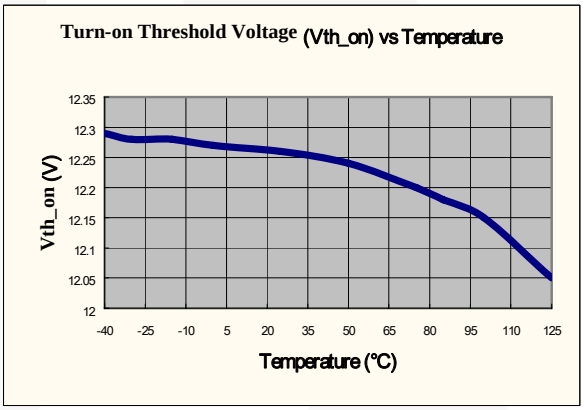
Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
V_{MOT}	MOT Voltage		1.25	1.30	1.35	V
T_{ON-MAX}	Maximum On-Time Programming (Resistor Based)	R_{MOT}=24kΩ, V_{CS}=0, V_{COMP}=5V	21	25	27	µs

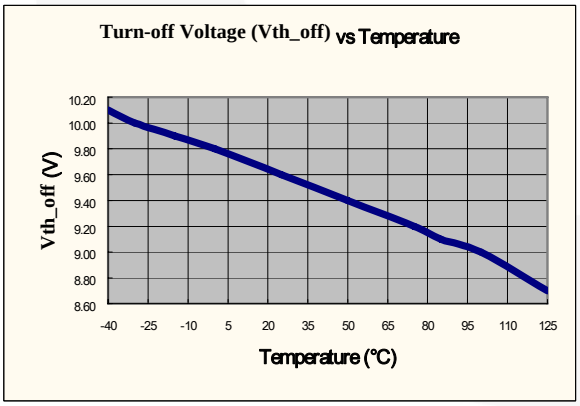
TYPICAL CHARACTERISTICS

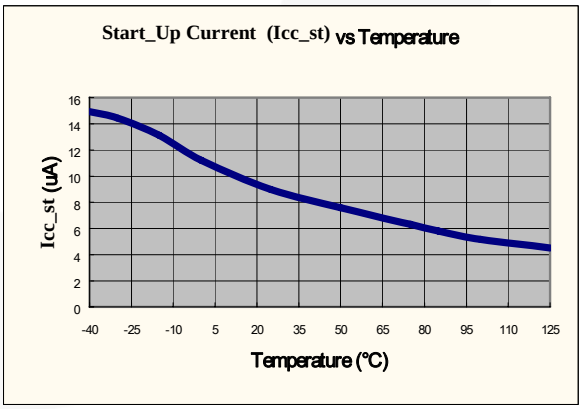




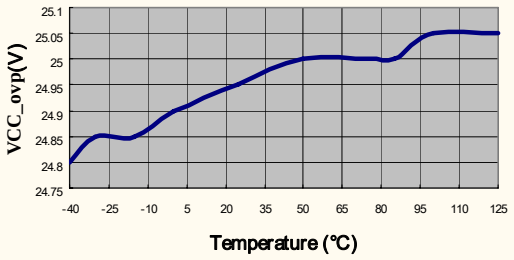




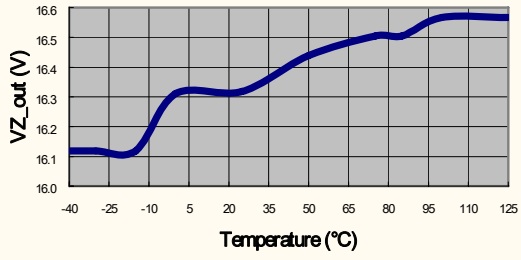




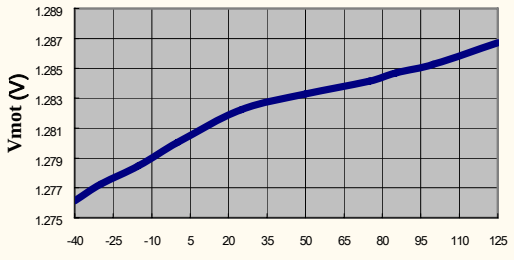
VCC Over Voltage Protection (VCC_ovp) vs Temperature



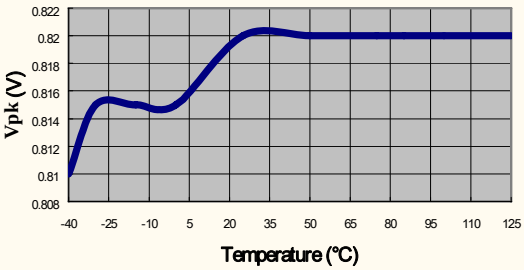
Output Voltage Maximum-clamp (VZ_out) vs Temperature



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 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 1µF, between COMP and GND is suggested. The error amplifier is a transconductance amplifier that converts voltage to current with a 125µmho.

Start-Up Current

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

Operating Current

Operating current is typically 4.5mA. The low operating current enables 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:

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

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

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

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

Peak Current Limiting

The switch current is sensed by one resistor. The signal is fed into CS pin and an input terminal of a comparator. A high voltage in the CS pin terminates a switching cycle immediately and 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 occurs when the power MOSFET is switched on. At the beginning of each switching pulse, the current-limit comparator is disabled for ~400ns to avoid premature termination. The gate drive output cannot be switched off during the blanking period. Conventional RC filtering is not necessary; the propagation delay of current limit protection can be minimized.

Under-Voltage Lockout (UVLO)

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

Output Driver

With low on resistance and high current driving capability, the output driver can drive an external capacitive load larger than 3000pF. Cross conduction current is 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.

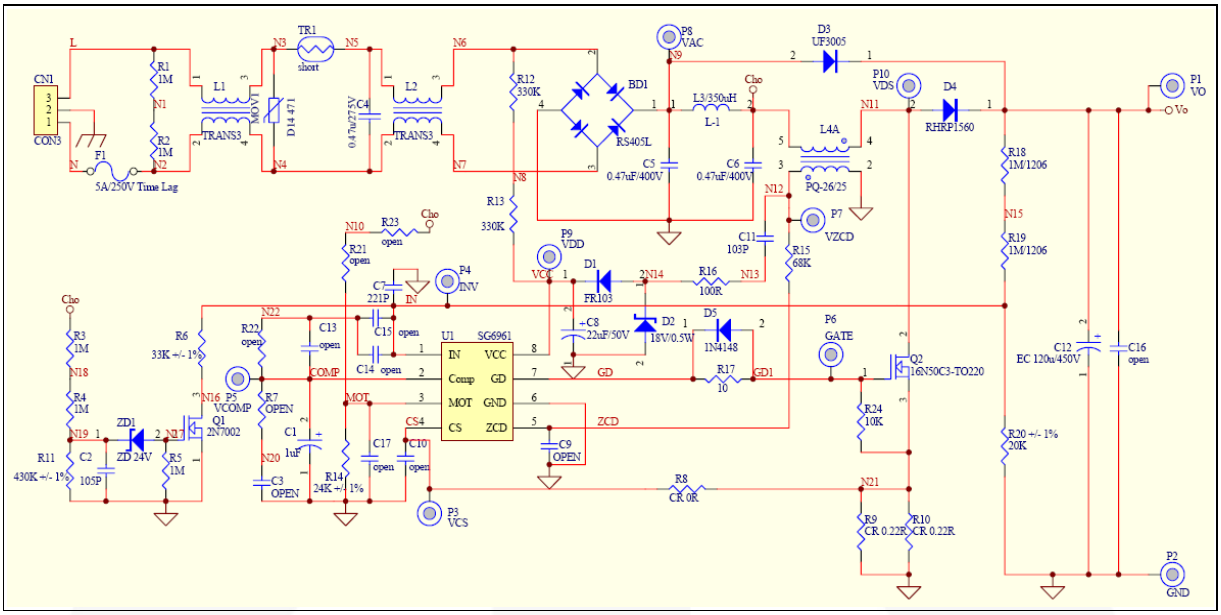
Zero Current Detection

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 goes down and a new switching cycle is enabled after a ZCD trigger. The power MOSFET is always turned on with zero inductor current, such that turn-on loss and noise can be minimized. The converter works in boundary mode, such 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 circuitry 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. Avoid long PCB traces and component leads. Locating compensation and filter components near to the SG6961 and increasing the power MOSFET gate resistance improve performance.

REFERENCE CIRCUIT: SG6961 180W



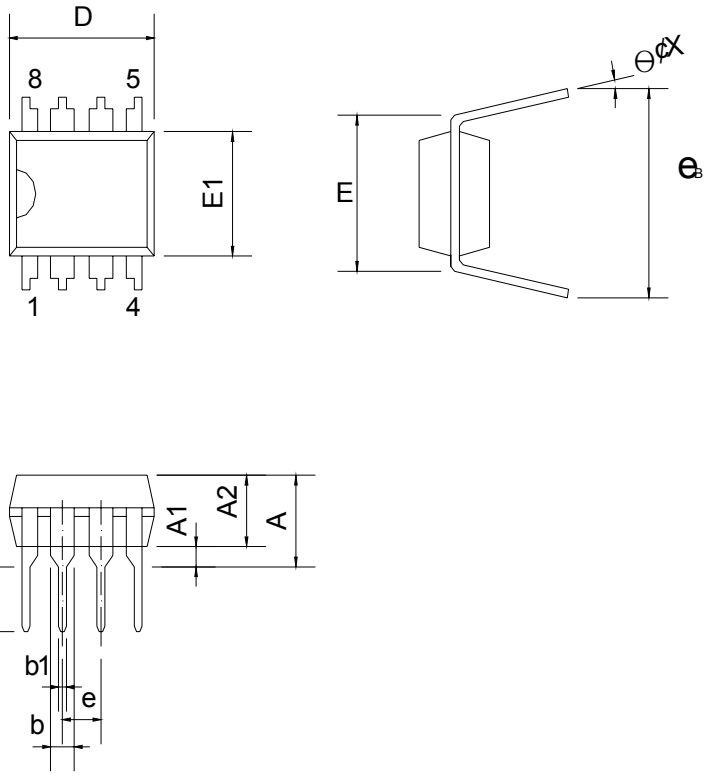
BOM

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 1μF 50V 105°C	C1
MLCC 105P 50V SMD 1206	C2
X1 Capacitor 0.47μF 275V +/-20%	C4
MPE Capacitor 0.47μF 450V +/-10%	C5,C6
MLCC 221P 50V +/-10% SMD 0805	C7
Electrolytic Capacitor 22μF 50V 85°C	C8
MLCC 103P 50V +/-10% SMD 1206	C11
Electrolytic Capacitor 120μF 450V 105°C	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) 350μH	L3

Component	Symbol
TRN0196 PFC Choke 210μH 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

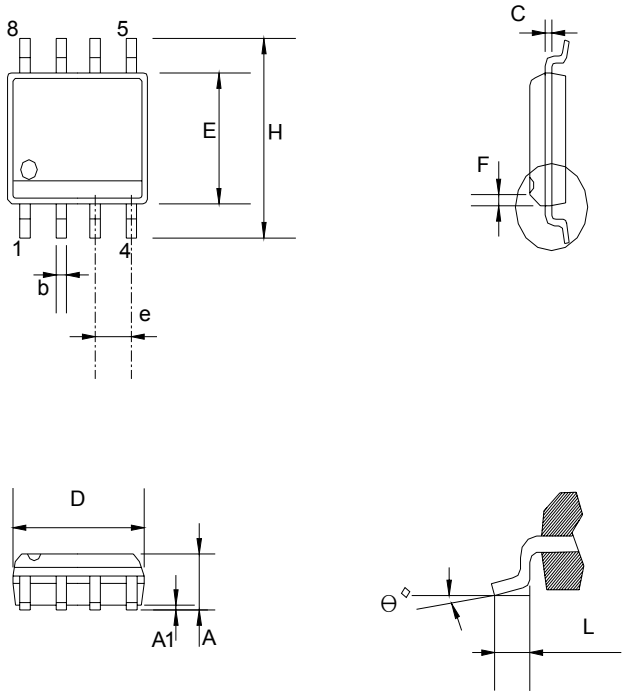
8PINS-DIP(D)



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°

FAIRCHILD SEMICONDUCTOR®

TRADEMARKS

The following are registered and unregistered trademarks and service marks Fairchild Semiconductor owns or is authorized to use and is not intended to be an exhaustive list of all such trademarks.

ACEx®
Build it Now™
CorePLUS™
CROSSVOLT™
CTL™
Current Transfer Logic™
EcoSPARK®
F®
Fairchild®
Fairchild Semiconductor®
FACT Quiet Series™
FACT®
FAST®
FastvCore™
FPS™
FRFET®
Global Power Resource℠
Green FPS™
Green FPS™ e-Series™
GTO™
i-Lo™
IntelliMAX™
ISOPLANAR™
MegaBuck™
MICROCOUPLER™
MicroFET™
MicroPak™
MillerDrive™
Motion-SPM™
OPTOLOGIC®
OPTOPLANAR®
®
PDP-SPM™
Power220®
Power247®
POWEREDGE®
Power-SPM™
PowerTrench®
Programmable Active Droop™
QFET®
QS™
QT Optoelectronics™
Quiet Series™
RapidConfigure™
SMART START™
SPM®
STEALTH™
SuperFET™
SuperSOT™-3
SuperSOT™-6
SuperSOT™-8
SyncFET™
The Power Franchise®
the power franchise
TinyBoost™
TinyBuck™
TinyLogic®
TINYOPTO™
TinyPower™
TinyPWM™
TinyWire™
µSerDes™
UHC®
UniFET™
VCX™

DISCLAIMER

FAIRCHILD SEMICONDUCTOR RESERVES THE RIGHT TO MAKE CHANGES WITHOUT FURTHER NOTICE TO ANY PRODUCTS HEREIN TO IMPROVE RELIABILITY, FUNCTION, OR DESIGN. FAIRCHILD DOES NOT ASSUME ANY LIABILITY ARISING OUT OF THE APPLICATION OR USE OF ANY PRODUCT OR CIRCUIT DESCRIBED HEREIN; NEITHER DOES IT CONVEY ANY LICENSE UNDER ITS PATENT RIGHTS, NOR THE RIGHTS OF OTHERS. THESE SPECIFICATIONS DO NOT EXPAND THE TERMS OF FAIRCHILD'S WORLDWIDE TERMS AND CONDITIONS, SPECIFICALLY THE WARRANTY THEREIN, WHICH COVERS THESE PRODUCTS.

LIFE SUPPORT POLICY

FAIRCHILD'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF FAIRCHILD SEMICONDUCTOR CORPORATION.

As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body or (b) support or sustain life, and (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury of the user.
2. A critical component in any component of a life support, device, or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

PRODUCT STATUS DEFINITIONS

Definition of Terms

Datasheet Identification	Product Status	Definition
Advance Information	Formative or In Design	This datasheet contains the design specifications for product development. Specifications may change in any manner without notice.
Preliminary	First Production	This datasheet contains preliminary data; supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve design.
No Identification Needed	Full Production	This datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve design.
Obsolete	Not In Production	This datasheet contains specifications on a product that has been discontinued by Fairchild Semiconductor. The datasheet is printed for reference information only.

Rev. I31