Low-Power Green-Mode PWM Flyback Power Controller without Secondary Feedback **SGP400**

FEATURES

- Linearly decreasing PWM frequency
- Green-mode under light-load and zero-load conditions
- Constant voltage (CV) and constant current (CC)
- No secondary feedback
- Low startup current (8uA)
- Low operating current (2.5mA)
- Leading-edge blanking
- Constant power limit
- Universal AC input range
- Synchronized slope compensation
- 140°C OTP sensor with hysteresis
- V_{DD} over voltage clamping
- Cycle-by-cycle current limiting
- Under voltage lockout (UVLO)
- Fixed PWM frequency (65KHz or 100KHz) with hopping
- Gate output maximum voltage clamped at 17V
- Small SOT-26 package

APPLICATIONS

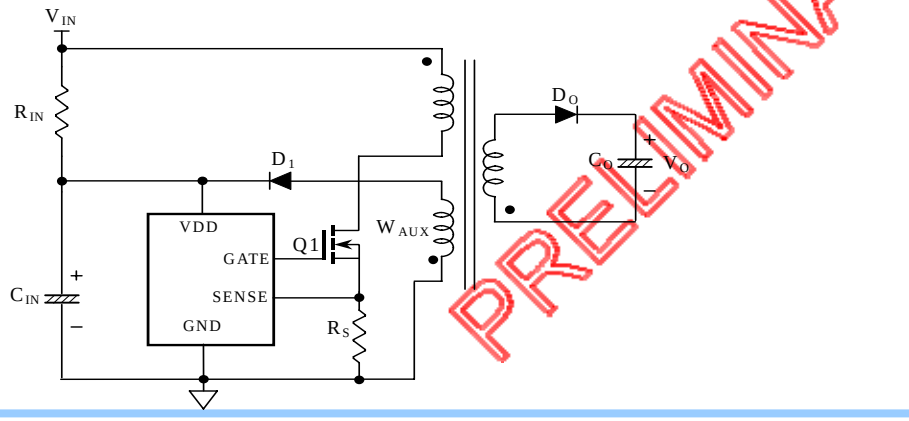
Low-power flyback power converters, such as

- Battery chargers for cellular phones, cordless phones, PDAs, digital cameras, and power tools.
- Power adapters for ink jet printers, video game consoles, and portable audio players.
- Open-frame SMPS for TV/DVD standby and other auxiliary supplies, home appliances, consumer electronics, and PC 5V standby-power.
- Replacements for linear transformers and RCC SMPS.

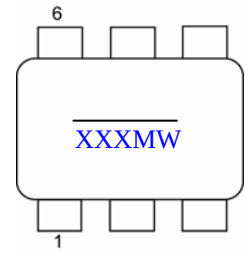
DESCRIPTION

This highly integrated PWM controller provides several features to enhance the performance of low power flyback converters. To minimize standby power consumption, the proprietary green-mode function provides off-time modulation to linearly decrease the switching frequency under light-load and zero-load conditions. This green-mode function enables the power supply to easily meet international power conservation requirements. The supply voltage V_{DD} is also used for feedback compensation, to regulate the output voltage without requiring a conventional TL431 and a photo-coupler. Another advantage of the SGP400 is that the typical startup current is only 8uA, while the typical operating current can be as low as 2.5mA. A large startup resistance could be used to achieve even higher power conversion efficiency. SGP400 integrates frequency hopping function internally. The frequency Hopping function helps to reduce EMI emission of a power supply with minimum line filters. Also, Built-in synchronized slope compensation maintains the stability of peak current-mode control. Proprietary internal compensation ensures constant output power limiting over a universal range of AC input voltages, from 90VAC to 264VAC.The SGP400 provides many protection functions. Pulse-by-pulse current limiting ensures a constant output current, even if a short circuit occurs. Also, the internal protection circuit will disable PWM output, if V_{DD} exceeds 22.7V. The gate output is clamped at 16.7V to protect the power MOS from over-voltage damage. The built-in over temperature protection (OTP) function will shutdown the controller at 140°C with a 30°C hysteresis. The SGP400 is designed to provide a low-cost total solution for flyback converters. It is available in a small footprint, 6-pin, SOT-26 package.

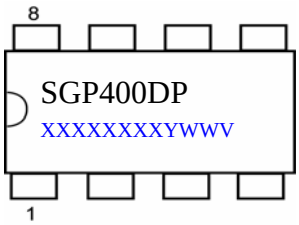
TYPICAL IC APPLICATION



MARKING INFORMATION

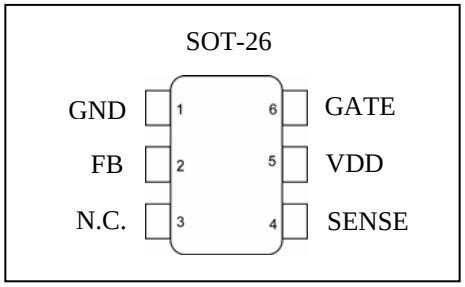


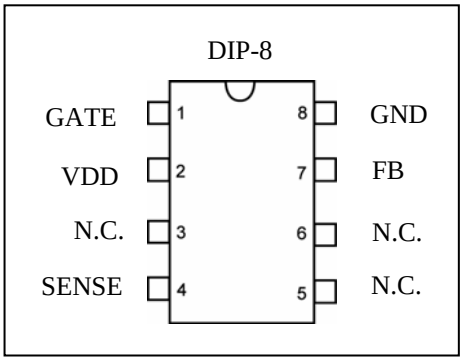
XXX: AAK=SGP400;
—: Lead Free
M: Mask Version
W: Week code A~Z=W1~W26
A~Z=W27~W52



D: D=DIP
P: Z=Lead free
Null=Regular package
XXXXXXXX: Wafer Lot
Y: Year
WW: Week
V: Assembly Location

PIN CONFIGURATION





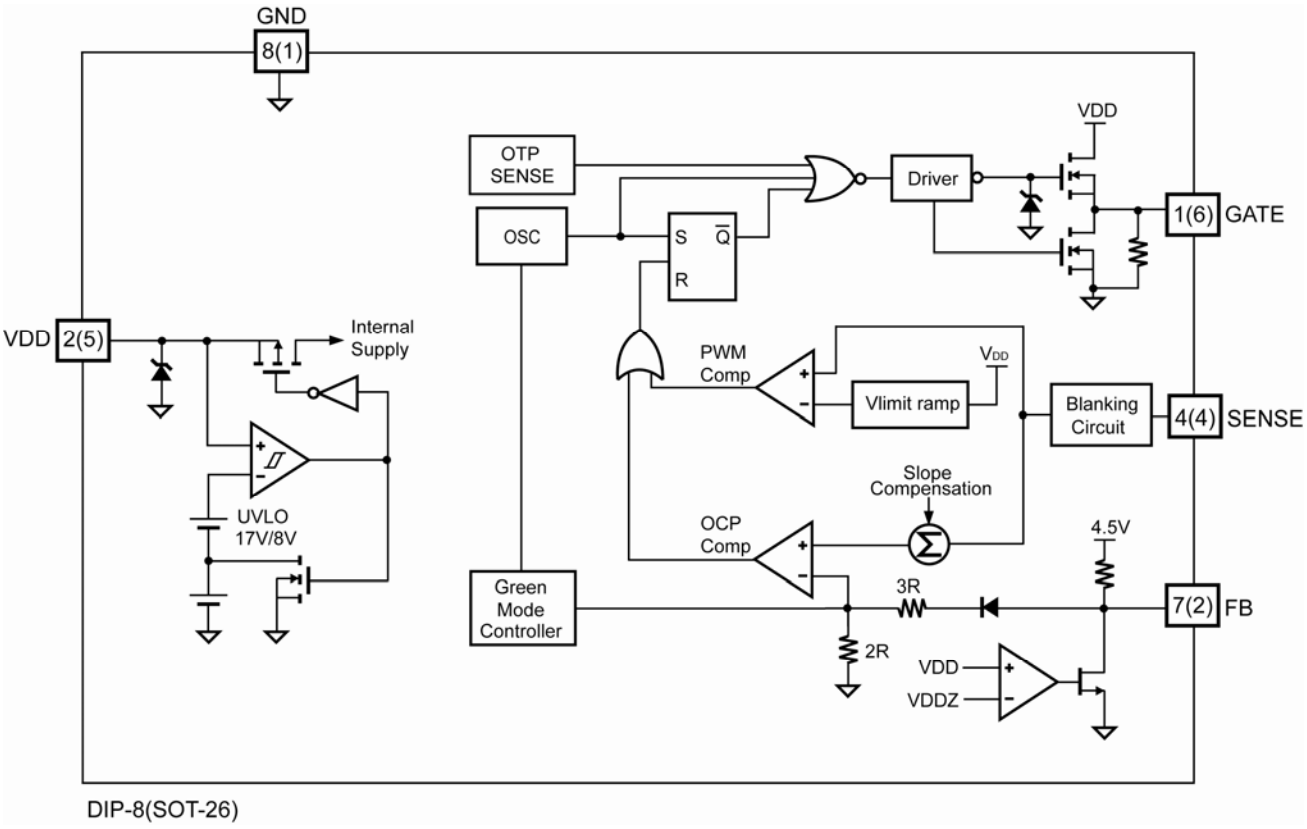
ORDERING INFORMATION

Part Number	PWM Frequency	Package
SGP400TZ	65KHz	6-Pin SOT-26 (Lead Free)
SGP400DZ	65KHz	8-Pin DIP-8 (Lead Free)

PIN DESCRIPTIONS

Name	Pin No.		Type	Function
	DIP-8	SOT-26		
GATE	1	6	Driver Output	The totem-pole output driver to drive the power MOSFET.
VDD	2	5	Supply	Power supply.
NC	3	NA		NC pin.
SENSE	4	4	Analog Input	Current sense. It senses the voltage across a sensed resistor. To provide over-current protection, PWM output is disabled if the voltage exceeds an internal threshold. This pin also provides current information for current-mode control.
NC	5	3		NC pin.
NC	6	NA		NC pin.
FB	7	2	Analog Input	Feedback. The FB pin provides feedback information to the internal PWM comparator. This feedback is used to control the duty cycle. When no feedback is provided, this pin is left open.
GND	8	1	Supply	Ground.

BLOCK DIAGRAM



DIP-8(SOT-26)

ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value		Unit
V_{VDD}	DC Supply Voltage*	30		V
V_{FB}	FB Pin Input Voltage	-0.3 to 7		V
V_{SENSE}	Sense Pin Input Voltage	-0.3 to 7		V
P_D	Power Dissipation (T_A=85°C)	SOT-26 DIP-8	247 478	mW
$R_{\theta j\text{-}a}$	Thermal Resistance (Junction to Air)**	SOT-26 DIP-8	263.3 135.7	°C/W
$R_{\theta j\text{-}c}$	Thermal Resistance (Junction to Case)**	SOT-26 DIP-8	119.6 67.1	°C/W
T_J	Operating Junction Temperature	-40 to +125		°C
T_{STG}	Storage Temperature Range	-55 to +150		°C
T_L	Lead Temperature (Wave soldering or IR, 10 seconds)	260		°C
	ESD Capability, Human Body Model	3.0		KV

* All voltage values, except differential voltages, are given with respect to the network ground terminal.
* Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device
** Thermal JA test board size: SOT 18x12x1.6mm/FR4; DIP 40x35x1.6mm/FR4

RECOMMENDED OPERATING CONDITIONS

Symbol	Parameter		Value	Unit
V_{DD}	DC Supply Voltage	with Secondary Feedback	<20	V
		without Secondary Feedback	<22.7	V
T_A	Operating Ambient Temperature		-20 to +85	°C

* For proper operation

ELECTRICAL CHARACTERISTICS (VDD = 15V, T_A = 25°C, unless noted)

VDD Section

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
$V_{DD\text{-}ON}$	Turn-On Threshold Voltage		16	17	18	V
$V_{DD\text{-}OFF}$	Turn-Off Threshold Voltage		7.5	8	8.5	V
$I_{DD\text{-}ST}$	Startup Current	V_{DD}=$V_{DD\text{-}ON}$-0.1V		8	20	uA
$I_{DD\text{-}OP}$	Operating Supply Current	V_{DD}=15V, C_L=1nF		3.6	4.6	mA
$V_{DD\text{-}G\ OFF}$	V_{DD} Low-threshold Voltage to Exit Green-off Mode			$V_{DD\text{-}OFF}$+ 1.2		V

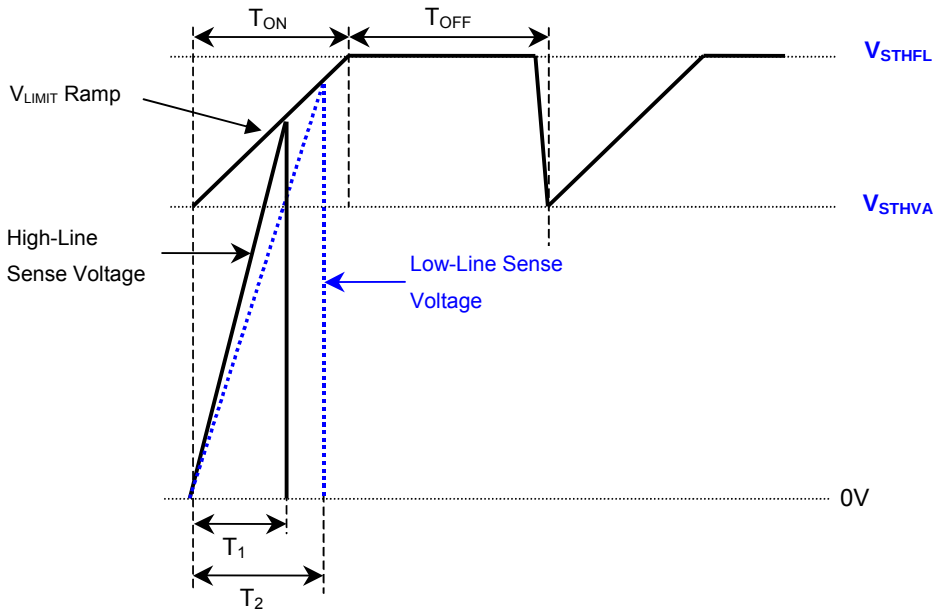
Feedback Input Section

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
A_V	Input-Voltage to Current-Sense Attenuation			2/5		V/V
$V_{FB\text{-}OPEN}$	Open Loop Voltage		4.5			V
Z_{FB}	Input Impedance	I_{FB}=0.1mA to 0.2mA		2.4		KΩ
$V_{DD\text{-}FB}$	V_{DD} Feedback Threshold Voltage*	FB is Open	20.7	22.7	24.7	V
		I_{FB}=0.4mA	18.4	20.4	22.4	V

* The feedback input is pulled by a transistor that is controlled by the V_{DD} signal while $V_{DD} \leq V_{DDZ}$.

Current Sense Section

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
t_{PD}	Propagation Delay			100	150	ns
V_{STHVA}	Current Limiting Valley Threshold Voltage	V_{DD}=18V		0.84		V
		V_{DD}=15V		0.76		V
		V_{DD}=10V		0.62		V
V_{STHFL}	Current Limiting Flat Threshold Voltage	V_{DD}=18V		0.98		V
		V_{DD}=15V		0.88		V
		V_{DD}=10V		0.71		V
t_{LEB}	Leading Edge Blanking Time		210	310	410	ns



Oscillator Section

Symbol	Parameter		Test Condition	Min.	Typ.	Max.	Unit
F_{OSC-65}	Frequency	Center Frequency		62	65	68	KHz
		Hopping Range		±4.1	±4.6	±5.1	
t_{HOP-65}	Hopping Period			4.1	4	5.1	ms
F_{OSC-G}	Green-Mode Frequency			19.5	22	24.5	KHz
V_{FB-N}	Green-Mode Entry FB Voltage			2.4	2.6	2.8	V
V_{FB-G}	Green-Mode Ending FB Voltage				V_{FB-N}-0.7		V
S_G	Green-Mode Modulation Slope			40	70	100	Hz/mV
F_{DV}	Frequency Variation Versus V_{DD} Deviation		V_{DD}=10 to 20V			2	%
F_{DT}	Frequency Variation Versus Temp. Deviation		T_A=-20 to 85°C		1.5	5	%

Output Section

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
DCY_{MAX}	Maximum Duty Cycle		70	75	80	%
V_{GATE-L}	GATE Low Voltage	V_{DD}=15V, I_O=10mA			1.5	V
V_{GATE-H}	GATE High Voltage	V_{DD}=15V, I_O=-10mA	8			V
tr	GATE Rising Time	V_{DD}=15V, C_L=1nF	150	200	250	ns
tf	GATE Falling Time	V_{DD}=15V, C_L=1nF	35	55	75	ns
$V_{GATE-CLAMP}$	GATE Output Clamping Voltage	V_{DD}=20V	16	17	18	V

Over Temperature Protection (OTP)

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
$Temp_{-OTP}$	Protection Junction Temperature*1			140		°C
Temp-Restart	Restart Junction Temperature*2			110		°C

*1 When activated, the output is disabled and the latch is turned off.

*2 This is the threshold temperature for enabling the output again and resetting the latch, after over temperature protection has been activated.

OPERATION DESCRIPTION

SGP400 devices integrate many useful functions for low power switch mode power supplies. The following descriptions highlight the key features of the SGP400.

Startup Current

The required startup current is only 8uA. This allows a high-resistance, low-wattage startup resistor to be used to supply the controller's startup power. A 1.5 MΩ/0.25W startup resistor can be used over a wide input range (100V-240V AC) with very little power loss.

Operating Current

The operating current is normally 2.5mA. The low operating current results in higher efficiency and reduces the required V_{DD} hold-up capacitance. A 10uF/25V V_{DD} hold-up capacitor can be used over a wide input range (100V-240V AC) with very little power loss.

Green Mode Operation

The proprietary green-mode function provides off-time modulation to linearly decrease the switching frequency under light-load and zero-load conditions. The on-time is limited to provide better protection against brownouts and other abnormal conditions.

This green-mode function dramatically reduces power consumption under light-load and zero-load conditions. Power supplies using the SGP400 can easily meet international restrictions regarding standby power-consumption.

Constant Voltage (CV) and Constant Current (CC) without Feedback

The SGP400 can tightly regulate the output voltage and provide over current protection without requiring secondary-side feedback signals. For improved CV and CC accuracy, the transformer leakage inductance should be reduced as much as possible.

Over Temperature Protection (OTP)

The SGP400 has a built-in temperature sensing circuit to shut down PWM output once the junction temperature exceeds 140°C. While PWM output is shut down, the V_{DD} voltage will gradually drop to the UVLO voltage. Some of the SGP400's internal circuits will be shut down, and V_{DD} will gradually start increasing again. When V_{DD} reaches 17V, all the internal circuits, including the temperature sensing circuit, will start operating normally. If the junction temperature is still higher than 140°C, the PWM controller will be shut down immediately. This situation will continue until the temperature drops below 110°C. The PWM output will then be turned back on. The temperature hysteresis window for the OTP circuit is 30°C.

V_{DD} Over Voltage Clamping

V_{DD} over voltage clamping is built in to prevent damage from over-voltage conditions. When V_{DD} exceeds 22.7V, PWM output is shut down. Over-voltage conditions may be caused by an open photo-coupler loop or a short circuit in the output.

Oscillator Operation

The oscillation frequency is fixed at 65KHz for the SGP400.

Leading Edge Blanking

Each time the power MOSFET is switched on, a turn-on spike will inevitably occur at the sense-resistor. To avoid premature termination of the switching pulse, a 310ns leading-edge blanking time is built in. Conventional RC filtering is not necessary. During this blanking period, the current-limit comparator is disabled, and it cannot switch off the gate drive.

Constant Output Power Limit

When the SENSE voltage across the sense resistor R_S reaches the threshold voltage (around 1.0V), the output GATE drive will be turned off following a small propagation delay t_{PD}. This propagation delay will

introduce an additional current proportional to $t_{PD}*V_{IN}/L_P$. The propagation delay is nearly constant regardless of the input line voltage V_{IN}. Higher input line voltages will result in larger additional currents. Thus, under high input-line voltages the output power limit will be higher than under low input-line voltages.

Over a wide range of AC input voltages, the variation can be significant. To compensate for this, the threshold voltage is adjusted by adding a positive ramp (Vlimit ramp). This ramp signal can vary from 0.77V to 1.05V for SGP400, and it flattens out at 1.05V. A smaller threshold voltage forces the output GATE drive to terminate earlier, thus reducing total PWM turn-on time and making the output power equal to that of the low line input. This proprietary internal compensation feature ensures a constant output power limit over a wide range of AC input voltages (90VAC to 264VAC).

Under Voltage Lockout (UVLO)

The turn-on/turn-off thresholds of the SGP400 are fixed internally at 17V/8V. To enable the SGP400 during startup, the hold-up capacitor must first be charged to 17V through the startup resistor.

The hold-up capacitor will continue to supply V_{DD} before energy can be delivered from the auxiliary winding of the main transformer. V_{DD} must not drop below 8V during this startup process. This UVLO hysteresis window ensures that the hold-up capacitor can adequately supply V_{DD} during startup.

Gate Output

The SGP400 BiCMOS output stage is a fast totem pole gate driver. Cross-conduction has been avoided to minimize heat dissipation, increase efficiency, and enhance reliability. The output driver is clamped by an internal 17V Zener diode in order to protect the power MOSFET transistors against any harmful over-voltage gate signals.

Slope Compensation

The sensed voltage across the current sense resistor is used for current mode control and pulse-by-pulse current limiting. The built-in slope compensation function improves power supply stability. Furthermore, it prevents sub-harmonic oscillations that normally would occur because of peak current mode control. A positively sloped, synchronized ramp is activated by the SGP400 with every switching cycle. The slope of the ramp is

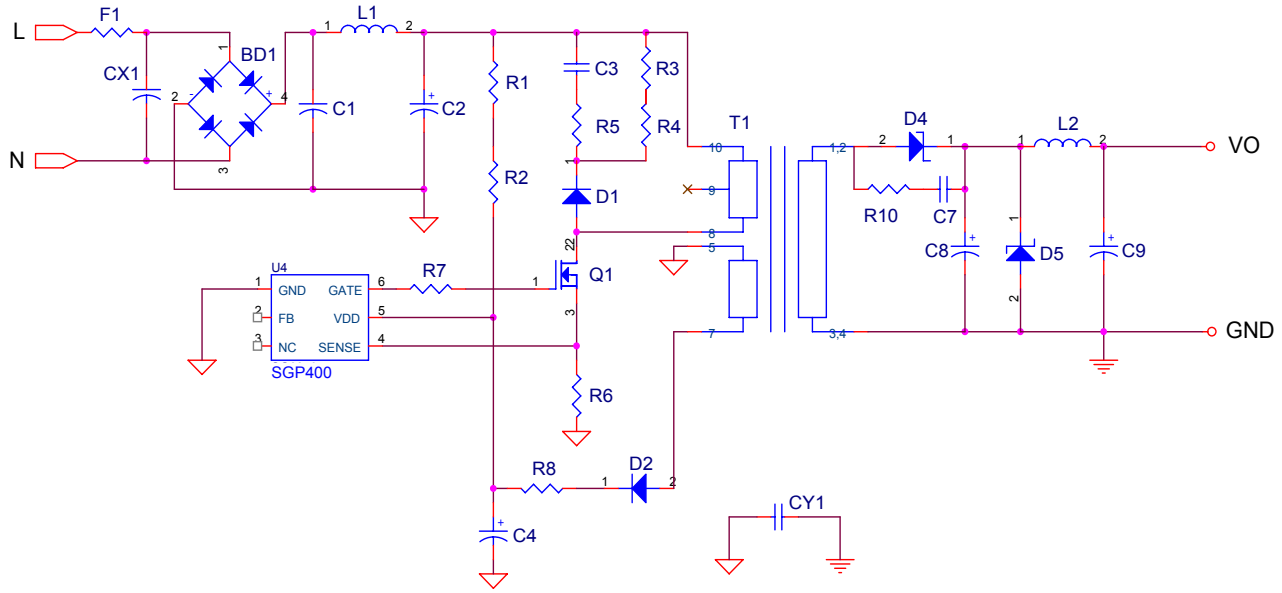
$$\frac{0.33\times Duty}{Duty(\max)}.$$

Noise Immunity

Noise from the current sense or the control signal may cause significant pulse width jitter, particularly in continuous-conduction mode. Slope compensation helps alleviate this problem. Good placement and layout practices should be followed. The designer should avoid long PCB traces and component leads. Compensation and filter components should be located near the SGP400. Finally, increasing the power-MOS gate resistance is advised.

REFERENCE CIRCUIT

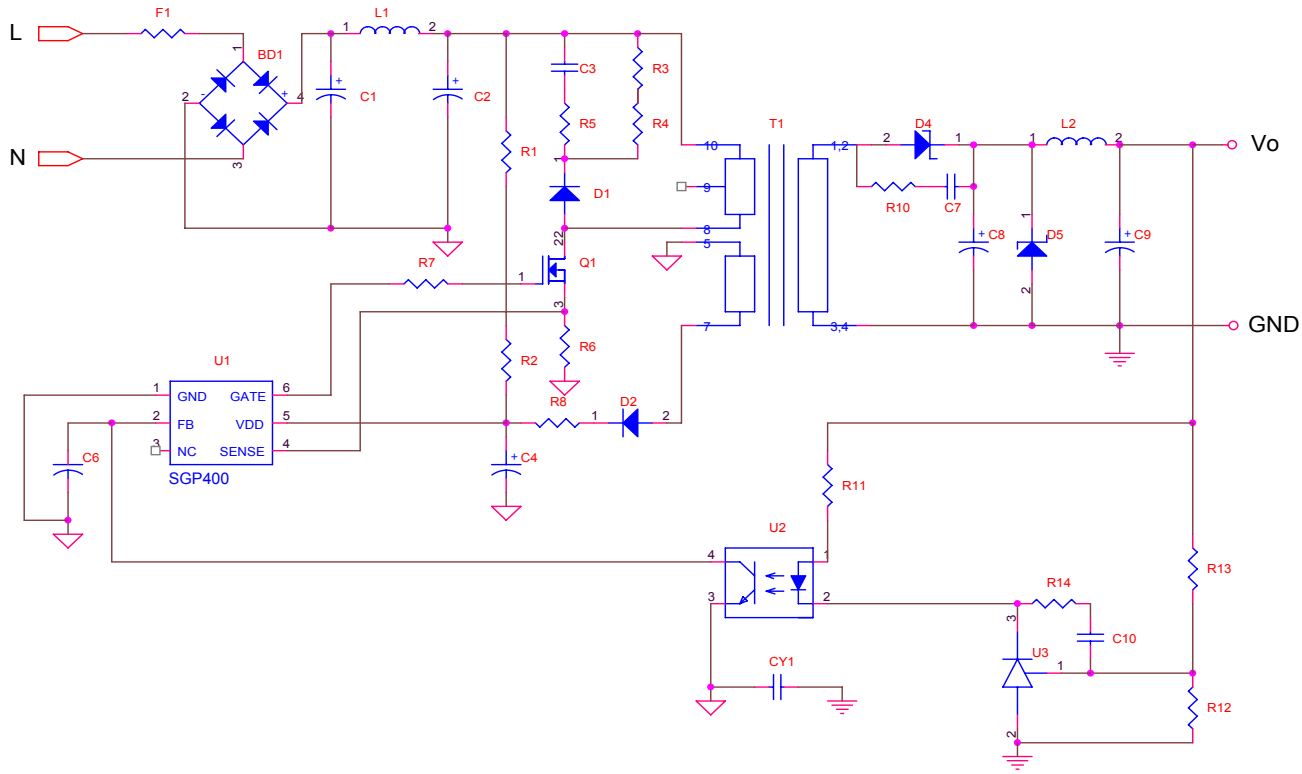
3W Flyback 5V/0.6A Circuit, without Secondary-Side Feedback



BOM

Symbol	Component	Symbol	Component
BD1 (Reference only)	BD DI106 1A/600V	F1	R 1Ω/0.5W
CX1 (Option)	YC 472pF/400V (Y1)	L1	Inductor 20mH 6*8mm
CY1 (Option)	YC 102pF/400V (Y1)	L2	Inductor 10uH 6mm
C1	CC 0.01uF/500V	Q1	MOSFET 1A/600V
C2	EC 10uF/400V 105℃	R1,R2	R 750kΩ/1206
C3	CC 1000pF/500V	R3,R4	R 47kΩ/1206
C4	EC 10uF/50V	R5	R 47Ω/1206
C7 (Option)	CC 102pF/100V 1206	R6	R 4.7Ω/0.5W
C8	EC 470uF/10V 105℃	R7	R 100Ω/0805
C9	EC 220uF/10V 105℃	R8	R 10Ω/1206
D1	Diode FRI07	R10 (Option)	R 10Ω/1206
D2	Diode FR102	T1	Transformer EE-16
D4	Diode SB360	U4	IC SGP400 (Green PWM IC)
D5 (Option)	ZD 6.8V/0.5W		

3W Flyback 5V/0.6A Circuit, with Secondary-Side Feedback

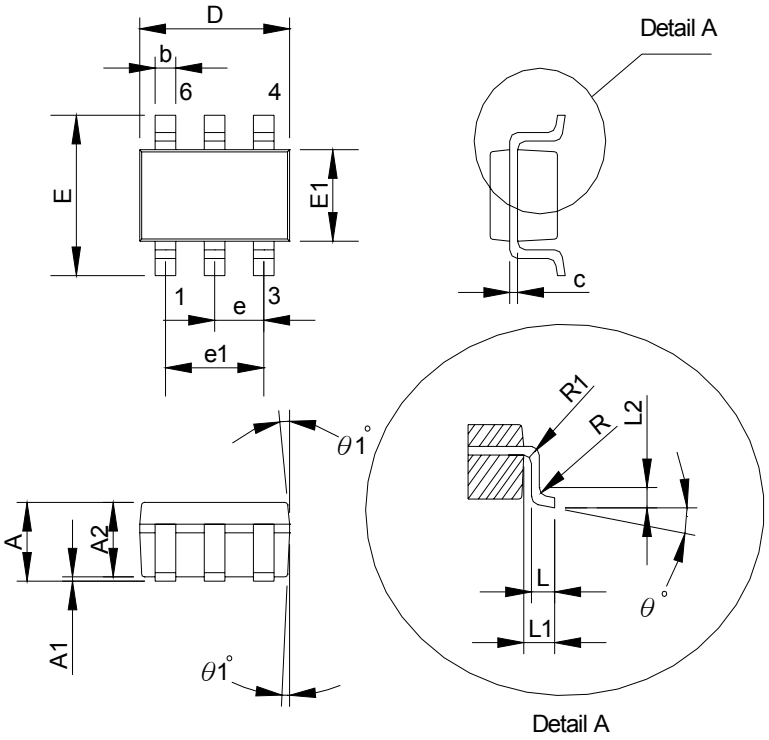


BOM

Symbol	Component	Symbol	Component
BD1 (Reference only)	BD DI106 1A/600V	L2	Inductor 10uH 6mm
CY1 (Option)	YC 102p/400V	Q1	MOSFET 1A/600V
C1	CC 0.01uF/500V	R1,R2	R 750kΩ/1206
C2	EC 10uF/400V 105℃	R4,R3	R 47kΩ/1206
C3	CC 1000p/500V	R5	R 47Ω/1206
C4	EC 10u/50V	R6	R 4.7Ω/0.5W
C6	CC 472p/0805	R7	R 100Ω/0805
C7	CC 102p/100V 1206	R10	R 10Ω/1206
C8	EC 470u/10V 105℃	R8	R 10Ω/1206
C9	EC 470u/10V 105℃	R11	R 100Ω/ 1/8W
C10	CC 222p/0805	R12	R 33kΩ/0805
D1	Diode FR107	R13	R 33kΩ/ 1/8W
D2	Diode FR102	R14	R 4.7kΩ/0805
D4	Diode SB360	T1	Transformer EE-16
D5 (Option)	ZD 6.8V/0.5W	U1	IC SGP400 (Green PWM IC)
F1	R 1Ω/0.5W Resistor	U2	IC PC817
L1	Inductor 20mH 6*8mm	U3	IC TL431

PACKAGE INFORMATION

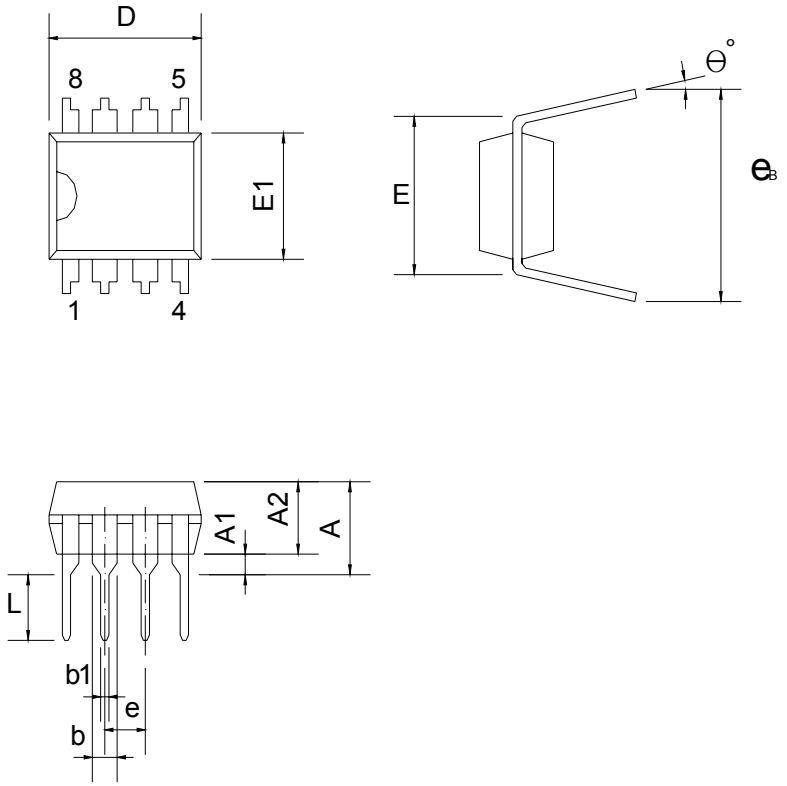
6 PINS-SOT (T)



Dimensions:

Symbol	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.45			0.057
A1			0.15			0.006
A2	0.90	1.15	1.30	0.036	0.045	0.051
b	0.30		0.50	0.011		0.020
c	0.08		0.22	0.003		0.009
D		2.90			0.114	
E		2.80			0.110	
E1		1.60			0.063	
e		0.95			0.037	
e1		1.90			0.075	
L	0.30	0.45	0.60	0.020	0.018	0.24
L1		0.60			0.024	
L2		0.25			0.010	
R	0.10			0.004		
R1	0.10		0.25	0.004		0.25
θ°	0°	4°	8°	0°	4°	8°
θ1°	5°	10°	15°	5°	10°	15°

8 PINS-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

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