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SG5701

Low-Cost, Green-Mode PWM Controller for Flyback Converters

Features

- Green-Mode PWM Controller
- Supports the “Blue Angel” Standard
- Low Startup Current: 10 μ A
- Low Operating Current: 2 mA
- Programmable PWM Frequency
- Leading-Edge Blanking
- Built-in Synchronized Slope Compensation
- Cycle-by-Cycle Current Limiting
- Constant Output Power Limit
- Current Mode Operation
- Under-Voltage Lockout (UVLO)
- Universal Input
- Gate Output Voltage Clamped at 17 V
- Low Cost
- Few External Components Required
- Small SSOT-6 Package

Applications

General-purpose switching mode power supplies and 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 auxiliary supplies, home appliances, and consumer electronics
- Replacements for linear transformers and RCC SMPS
- PC 5 V standby power

Description

This highly integrated PWM controller provides several special enhancements designed to meet the low standby-power needs of low-power SMPS. To minimize standby power consumption, the proprietary green-mode function provides off-time modulation to continuously decrease the switching frequency under light-load conditions. This green-mode function enables the power supply to easily meet even the strictest power conservation requirements.

The BiCMOS fabrication process enables reducing the startup current to 10 μ A, and the operating current to 2 mA. As a result, a large startup resistance can be used. To further improve power conservation, a large startup resistance can be used. Built-in synchronized slope compensation ensures the stability of peak-current-mode control. Proprietary internal compensation provides a constant output power limit over a universal AC input range (90 V_{AC} to 264 V_{AC}). Pulse-by-pulse current limiting ensures safe operation during short-circuits.

To protect the external power MOSFET from being damaged by supply over-voltage, the SG5701's output driver is clamped at 17 V. The SG5701's controllers can be used to improve the performance and reduce the production cost of power supplies. The SG5701 is the best choice for replacing linear and RCC power supplies. It is available in DIP-8 and SSOT-6 packages.

Ordering Information

Part Number	Operating Temperature Range	Package	Packing Method
SG5701TZ	-40 to +105°C	6-Lead, SUPERSOT6, JEDEC MO-193, 1.6 mm Wide	Tape & reel
SG5701DZ		8-Lead, MDIP, JEDEC MS-001, .300" Wide, Two Dap	Tube
SG5701DY			

For Fairchild's definition of “green” Eco Status, please visit: http://www.fairchildsemi.com/company/green/rohs_green.html.

Application Diagram

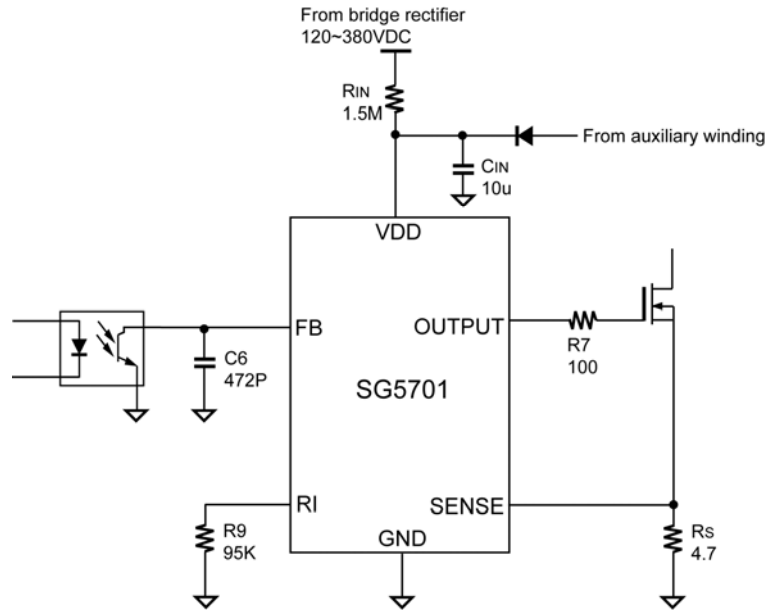


Figure 1. Typical Application

Internal Block Diagram

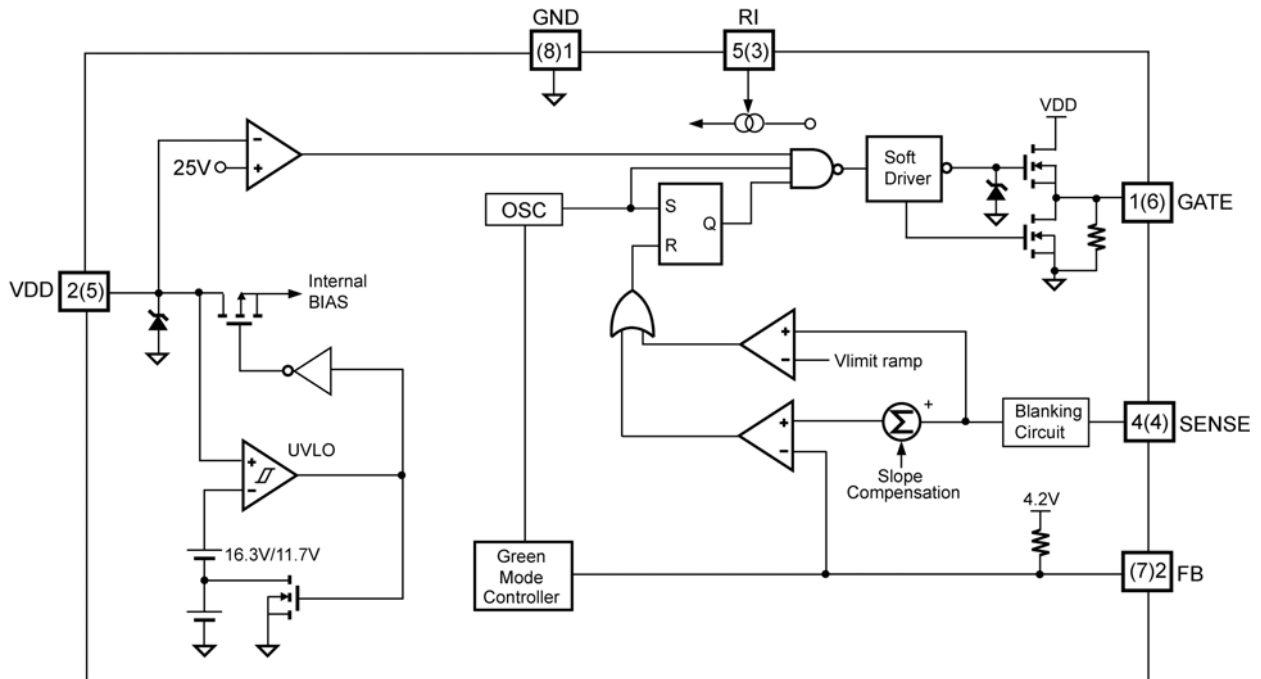
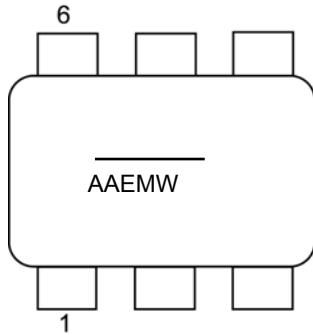


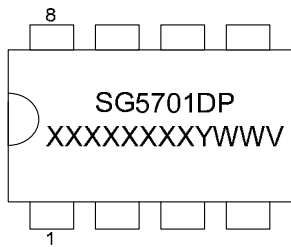
Figure 2. Functional Block Diagram

Marking Information



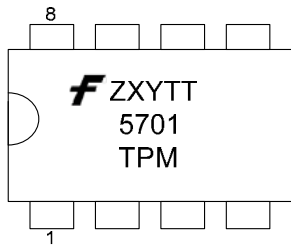
AAE: SG5701
 M: Mask Version
 W: Week
 : Lead Free

Marking for SG5701TZ (Pb-free)



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

Marking for SG5701DZ (Pb-free)



F: Fairchild Logo
 Z: Plant Code
 X: 1-Digit Year Code
 Y: 1-Digit Week Code
 TT: 2-Digit Die Run Code
 T: Package Type (D=DIP)
 P: Z: Pb-free, Y: Green Package
 M: Manufacture Flow Code

Marking for SG5701DY (Green Compound)

Figure 3. Top Mark

Pin Configurations

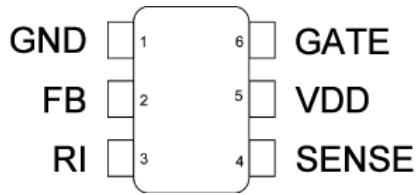


Figure 4. SSOT-6 Pin Configuration

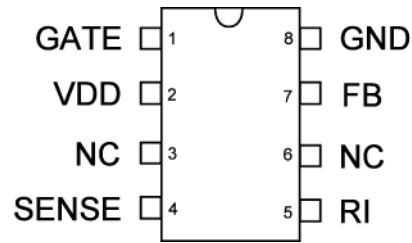


Figure 5. DIP-8 Pin Configuration

Pin Definitions

DIP Pin #	SSOT Pin #	Name	Description
1	6	GATE	The totem-pole output driver for driving the power MOSFET.
2	5	VDD	Power supply.
3		NC	No connection
4	4	SENSE	Current sense. This pin senses the voltage across a resistor. When the voltage reaches the internal threshold, PWM output is disabled. This activates over-current protection. This pin also provides current amplitude information for current-mode control.
5	3	RI	A resistor connected from the RI pin to ground generates a constant current source used to charge an internal capacitor and determine the switching frequency. Increasing the resistance reduces the amplitude of the current source and the switching frequency. A 95 kΩ resistor R_I results in a 50 μA constant current I_I and a 70 kHz switching frequency.
6		NC	No connection
7	2	FB	Feedback. The FB pin provides the output voltage regulation signal. It provides feedback to the internal PWM comparator, so that the PWM comparator can control the duty cycle.
8	1	GND	Ground.

Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.

Symbol	Parameter	Min.	Max.	Unit	
V _{VDD}	DC Supply Voltage ^(1, 2)		30	V	
V _{FB}	Input Voltage to FB Pin	-0.3	7.0	V	
V _{SENSE}	Input Voltage to Sense Pin	-0.3	7.0	V	
T _J	Operating Junction Temperature	-40	125	°C	
PD	Power Dissipation at T _A =85°C	SSOT		247	mW
		DIP		478	
θ _{JA}	Thermal Resistance; Junction-to-Air ⁽³⁾	SSOT		263	°C/W
		DIP		236	°C/W
T _{STG}	Storage Temperature Range	-55	+150	°C	
T _L	Lead Temperature; Wave Soldering or IR, 10 Seconds		+260	°C	
ESD	Human Body Model, JESD22-A114		3.0	kV	

Notes:

1. All voltage values, except differential voltages, are given with respect to GND pin.
2. Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device.
3. Thermal J_A test board size: SOT 18x12x1.6 mm/FR4; DIP 40x35x1.6 mm/FR4.

Recommended Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance. Fairchild does not recommend exceeding them or designing to Absolute Maximum Ratings.

Symbol	Parameter	Min.	Max.	Unit
V _{DD}	DC Supply Voltage		≤22	V
T _A	Operating Ambient Temperature	-20	+85	°C

Electrical Characteristics

Unless otherwise noted, $V_{DD}=15\text{ V}$ and $T_A=25^\circ\text{C}$.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
V_{DD} Section						
V _{DD-OP}	Continuously Operation Voltage				22	V
V _{DD-ON}	Turn-On Threshold Voltage		15.3	16.3	17.3	V
V _{DD-OFF}	Turn-Off Threshold Voltage		10.9	11.7	12.5	V
I _{DD-ST}	Startup Current	$V_{DD}=V_{DD-ON}-0.1\text{V}$		10	30	μA
I _{DD-OP}	Operating Supply Current	$V_{DD}=15\text{ V}$		2	5	mA
V _{DD-CLAMP}	VDD Clamping Voltage		24.5	25.0	26.5	V
Feedback Input Section						
I _{FB-N}	Green Mode Entry FB Current			0.85		mA
I _{FB-G}	Green Mode Ending FB Current			1.05		mA
I _{FB-ZDC}	Zero-duty FB Current			1.3	2.0	mA
I _{FB-G} - I _{FB-ZDC}			95			μA
V _{FB-OPEN}	FB Output High Voltage			4.2		V
Current-Sense Section						
Z _{CS}	Input Impedance		10			kΩ
t _{PD}	Delay to Output			60	100	ns
V _{STHFL}	Flat Threshold Voltage for Current Limit			1.0		V
V _{STHVA}	Valley Threshold Voltage for Current Limit		0.80	0.85	0.90	V
Oscillator Section						
f _{OSC}	Frequency	R _I =95 kΩ	65	70	75	kHz
f _{OSC-G}	Green-Mode Frequency	R _I =95 kΩ		13	5	kHz
I _{FB-G}	Green-Mode Ending FB Current			1.05		mA
I _{FB-N}	Green-Mode Entry FB Current			0.85		mA
S _G	Green-Mode Modulation Slope	R _I =95 kΩ		300		Hz/μA
f _{DV}	Frequency Variation vs. V _{DD} Deviation	$V_{DD}=12\text{ to }20\text{ V}$		0.02	2.00	%
f _{DT}	Frequency Variation vs. Temperature Deviation	$T_A=-20\text{ to }85^\circ\text{C}$			2	%
PWM Section						
DCY _{MAX}	Maximum Duty Cycle		70	75	80	%
DCY _{MIN}	Minimum Duty Cycle			1	2	%
t _{LEB}	Leading-Edge Blanking Time			200		ns
Output Section						
V _{GATE-L}	Output Voltage Low	$V_{DD}=15\text{ V}, I_O=20\text{ mA}$			1.5	V
V _{GATE-H}	Output Voltage High	$V_{DD}=15\text{ V}, I_O=20\text{ mA}$	8			V
t _r	Rising Time	$V_{DD}=15\text{ V}, C_L=1\text{ nF}$		250	350	ns
t _f	Falling Time	$V_{DD}=15\text{ V}, C_L=1\text{ nF}$		60	150	ns
V _{GATE-CLAMP}	Output Clamp Voltage	$V_{DD}=22\text{ V}$	16	17	18	V

Typical Performance Characteristics

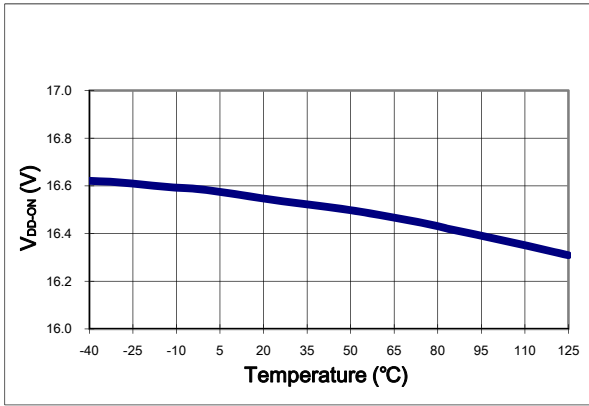


Figure 6. Start Threshold Voltage (V_{DD-ON}) vs. Temperature

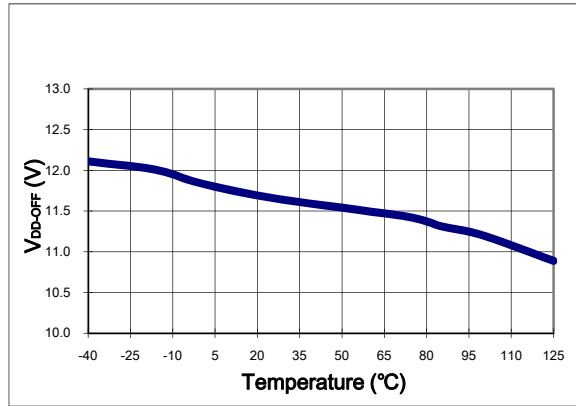


Figure 7. Minimum Operating Voltage (V_{DD-OFF}) vs. Temperature

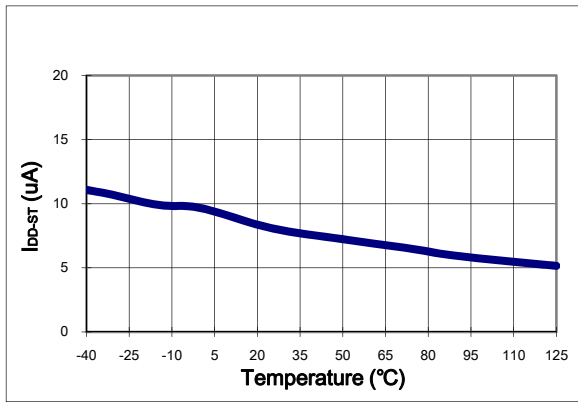


Figure 8. Startup Current (I_{DD-ST}) vs. Temperature

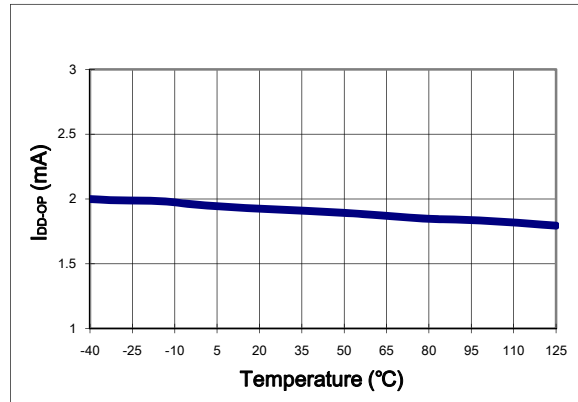


Figure 9. Operation Current (I_{DD-OP}) vs. Temperature

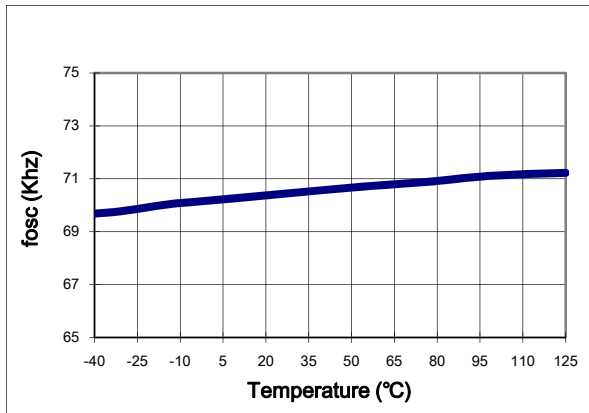


Figure 10. Frequency (f_{OSC}) vs. Temperature

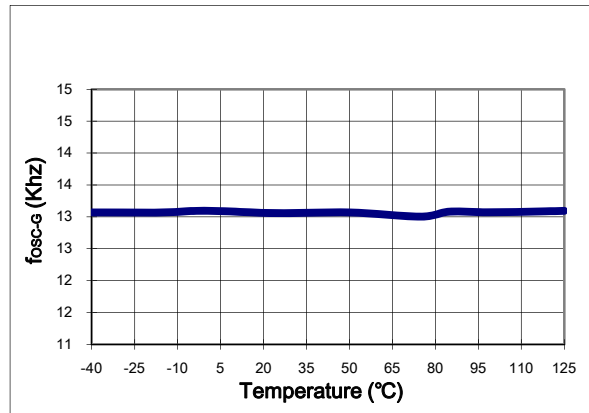


Figure 11. Green Mode Frequency (f_{OSC-G}) vs. Temperature

Typical Performance Characteristics (Continued)

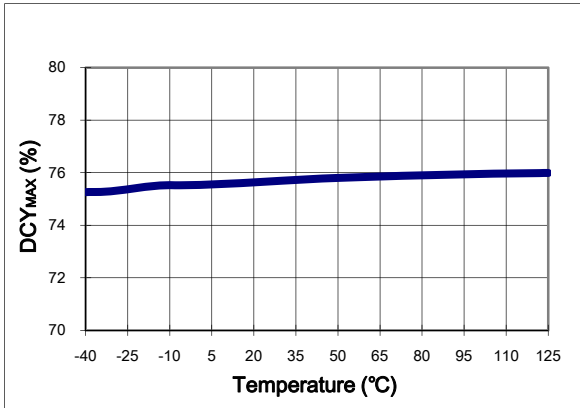


Figure 12. Maximum Duty Cycle (DCY_{MAX}) vs. Temperature

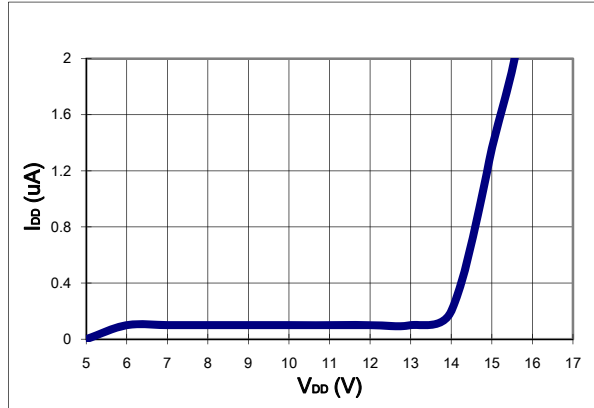


Figure 13. DC Supply Voltage (V_{DD}) vs. I_{DD}

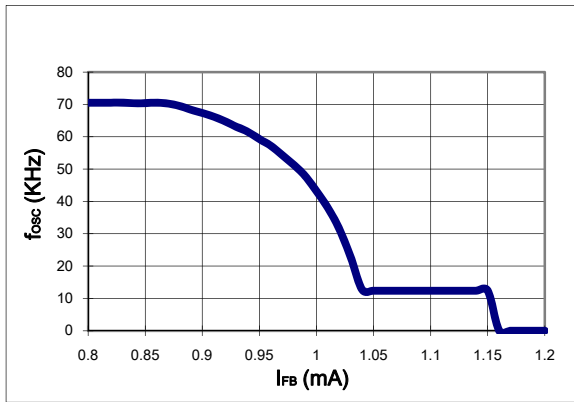


Figure 14. PWM Frequency (f_{osc}) vs. I_{FB}

Operation Description

The SG5701 devices integrate many useful functions into one controller for low-power switching mode power supplies. The following descriptions highlight some of the features of the SG5701.

Startup Current

The startup current is only 10 μ A. Low startup current allows a startup resistor with a high resistance and a low-wattage to supply the startup power for the controller. A 1.5 M Ω , 0.25 W, startup resistor and a 10 μ F/25 V V_{DD} hold-up capacitor would be sufficient for an AC-to-DC power adapter with a wide input range (100 V_{AC} to 240 V_{AC}).

Operating Current

The operating current has been reduced to 2 mA. The low operating current results in higher efficiency and reduces the V_{CC} hold-up capacitance requirement.

Green-Mode Operation

The proprietary green-mode function provides off-time modulation to linearly decrease the switching frequency under light-load conditions. On-time is limited to provide stronger protection against brownouts and other abnormal conditions. The feedback current, which is sampled from the voltage feedback loop, is taken as the reference. Once the feedback current exceeds the threshold current, the switching frequency starts to decrease. This green-mode function dramatically reduces power consumption under light-load and zero-load conditions. Power supplies using the SG5701 can easily meet even the strictest regulations regarding standby power consumption.

Oscillator Operation

A resistor connected from the RI pin to ground generates a constant current source for the SG5701. This current is used to charge an internal capacitor. The charge-time determines the internal clock speed and the switching frequency. Increasing the resistance reduces the amplitude of the input current and reduces the switching frequency. A 95 k Ω resistor R_i results in a 50 μ A constant current I_i and a 70 kHz switching frequency. The relationship between R_i and the switching frequency is:

$$f_{PWM} = \frac{6650}{R_i \text{ (k}\Omega\text{)}} \text{ (kHz)} \quad \theta_e = \tan^{-1} \left(\frac{-e_\alpha}{e_\beta} \right) \quad (1)$$

The range of the oscillation frequency is designed to be within 50 kHz ~ 100 kHz.

Leading-Edge Blanking

Each time the power MOSFET is switched on, a turn-on spike inevitably occurs at the sense-resistor. To avoid premature termination of the switching pulse, a 200 ns leading-edge blanking time is built in. Conventional RC filtering can therefore be omitted. During this blanking period, the current-limit comparator is disabled and it cannot switch off the gate driver.

Constant Output Power Limit

When the SENSE voltage across the sense resistor R_S reaches the threshold voltage (around 1.0 V), the output GATE drive is turned off following a short propagation delay t_{PD} . This propagation delay introduces 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 result in larger additional currents. At high input line voltages, the output power limit is higher than at low input line voltages.

To compensate for this output power limit variation across a wide AC input range, the threshold voltage is adjusted by adding a positive ramp ($V_{limit \text{ ramp}}$). This ramp signal rises from 0.85 V to 1.0 V, and then flattens out at 1.0 V. A smaller threshold voltage forces the output GATE drive to terminate earlier. This reduces the total PWM turn-on time and makes the output power equal to that of low line input. This proprietary internal compensation ensures a constant output power limit for a wide AC input voltage range (90 V_{AC} to 264 V_{AC}).

Under-Voltage Lockout (UVLO)

The turn-on and turn-off thresholds of the SG5701 are fixed internally at 16.3 V/11.7 V. During startup, the hold-up capacitor must be charged to 16.3 V through the startup resistor, so that the SG5701 is enabled. The hold-up capacitor continues to supply V_{DD} until power can be delivered from the auxiliary winding of the main transformer. V_{DD} must not drop below 11.7 V during this startup process. This UVLO hysteresis window ensures that hold-up capacitor is adequate to supply V_{DD} during startup.

Gate Output

The SG5701 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 17 V Zener diode in order to protect power MOSFET transistors against undesired over-voltage gate signals.

Built-In Slope Compensation

The sensed voltage across the current sense resistor is used for current mode control and pulse-by-pulse current limiting. Built-in slope compensation improves stability and prevents sub-harmonic oscillations due to peak-current mode control. The SG5701 has a synchronized, positively-sloped ramp built-in at each switching cycle. The slope of the ramp is:

$$\frac{0.33 \times Duty}{Duty(max)} \quad (2)$$

Noise Immunity

Noise from the current sense or the control signal can cause significant pulse width jitter, particularly in continuous-conduction mode. While slope compensation helps alleviate these problems, further precautions should be taken. Good placement and layout practices should be followed. Avoiding long PCB traces and component leads, locating compensation and filter components near the SG5701, and increasing the power MOS gate resistance is advised.

Applications Information

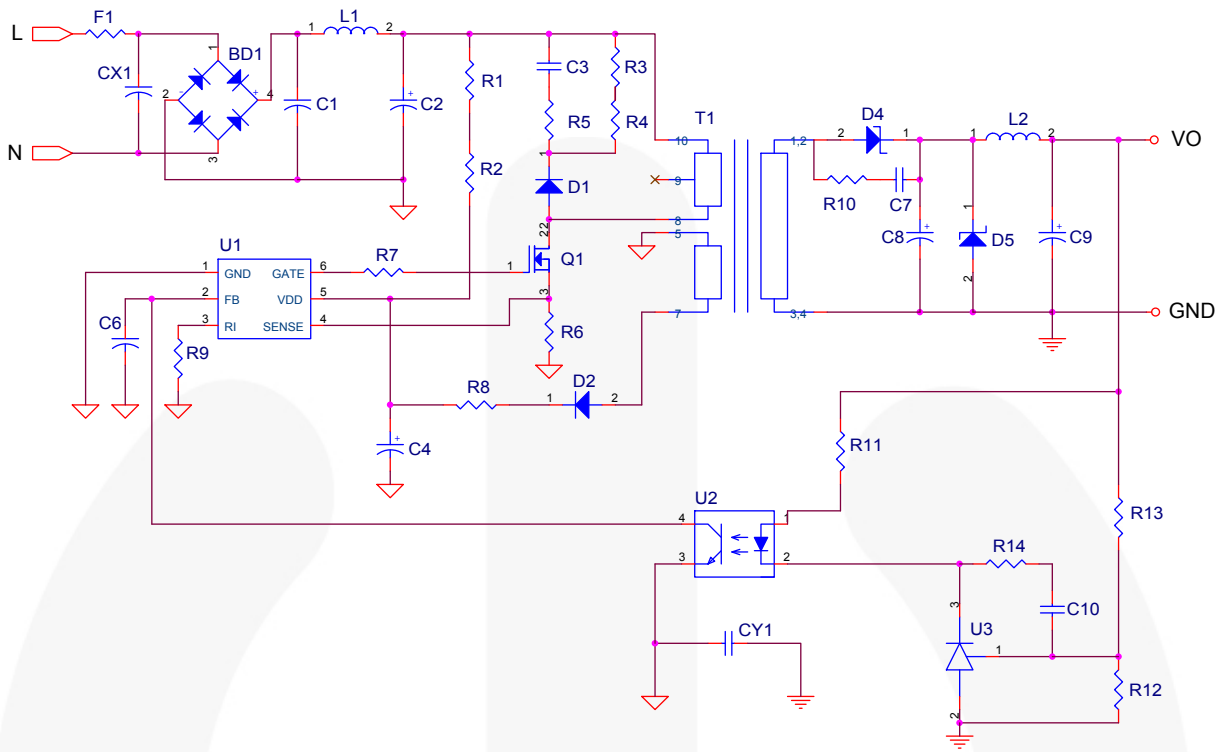


Figure 15. Reference Circuit

BOM

Reference	Component	Reference	Component
BD1	BD 1 A/500 V	L2	Inductor 10 μ H 6 mm
CX1 (Optional)	XC 0.1 μ F	Q1	MOSFET 1A/600 V
CY1 (Optional)	YC 1000 pF/400 V (Y1)	R1, R2	R 750 K Ω 1206
C1	CC 10 nF/500V	R3, R4	R 47 K Ω 1206
C2	EC 10 μ F/400 V 105 $^{\circ}$ C	R5	R 47 Ω 1206
C3	CC 1000 pF/500 V	R6	R 4.7 Ω 1206
C4	EC 10 μ F/50 V	R7	R 100 Ω 0805
C6	CC 1000 pF 0805	R8	R 10 Ω 1206
C7 (Optional)	CC 1000 pF/100 V 1206	R9	R 100 K Ω 0805
C8	EC 470 μ F/10 V 105 $^{\circ}$ C	R10 (Optional)	R 10 Ω 1206
C9	EC 220 μ F/1 0V 105 $^{\circ}$ C	R11	R 100 Ω 1/8 W
C10	CC 2200 pF 0805	R12	R 33 K Ω 0805
D1	Diode FRI07	R13	R 33 K Ω 1/8 W
D2	Diode FR102	R14	R 4.7 K Ω 0805
D4	Diode SB360	T1	Transformer EE-16
D5 (Optional)	ZD 6.8 V 0.5 W	U1	IC SG5701 (Green PWM IC)
F1	R 1 Ω /0.5 W	U2	IC PC817
L1	Inductor 20 mH 6*8 mm	U3	IC TL431
BD1	BD 1 A/500 V	L2	Inductor 10 μ H 6 mm

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