

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

SG6858

FEATURES

- Green-mode PWM
- Supports the “Blue Angel” standard
- Low start-up current (10μA)
- Low operating current (2.5mA)
- Leading-edge blanking
- Constant output power limit
- Universal input
- Built-in synchronized slope compensation
- Current-mode operation
- Cycle-by-cycle current limiting
- Under voltage lockout (UVLO)
- Programmable PWM frequency
- V_{DD} over-voltage protection (auto restart)
- Gate output voltage clamped at 17V
- Low cost
- Few external components required
- Small SOT-26 and DIP-8 packages

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 5V standby power

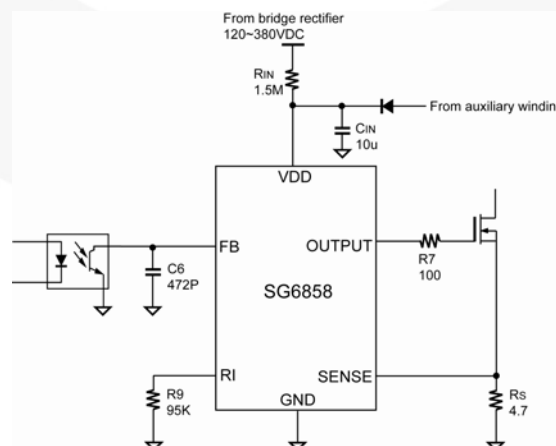
DESCRIPTION

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 linearly decrease the switching frequency under light-load conditions. This green-mode function enables the power supply to meet even the strictest power conservation requirements.

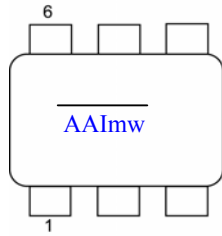
The BiCMOS fabrication process enables reducing the start-up current to 10μA and the operating current to 2.5mA. To further improve power conservation, a large start-up resistance can be used. Built-in synchronized slope compensation ensures the stability of peak current mode control. Proprietary internal compensation provides a constant output power limit over a universal AC input range (90V_{AC} to 264V_{AC}). Pulse-by-pulse current limiting ensures safe operation even during short-circuits.

To protect the external power MOSFET from being damaged by supply over-voltage events, the SG6858’s output driver is clamped at 17V. SG6858 controllers can be used to improve the performance and reduce the production cost of power supplies and can replace linear and RCC-mode power adapters. It is available in 8-pin DIP and 6-pin SOT-26 packages.

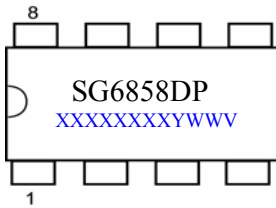
TYPICAL APPLICATION



MARKING DIAGRAMS

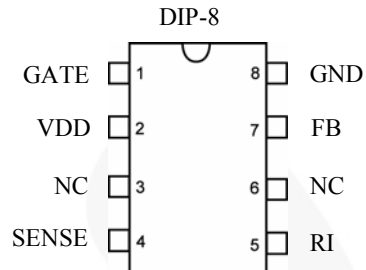
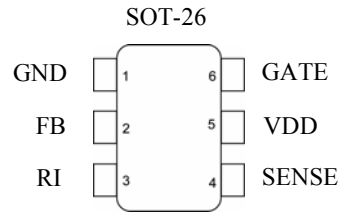


AAI: SG6858
 m: Mask Version
 w: Week code A~Z=W1~W26
 A~Z=W27~W52
 _____: Lead Free Package



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

PIN CONFIGURATION



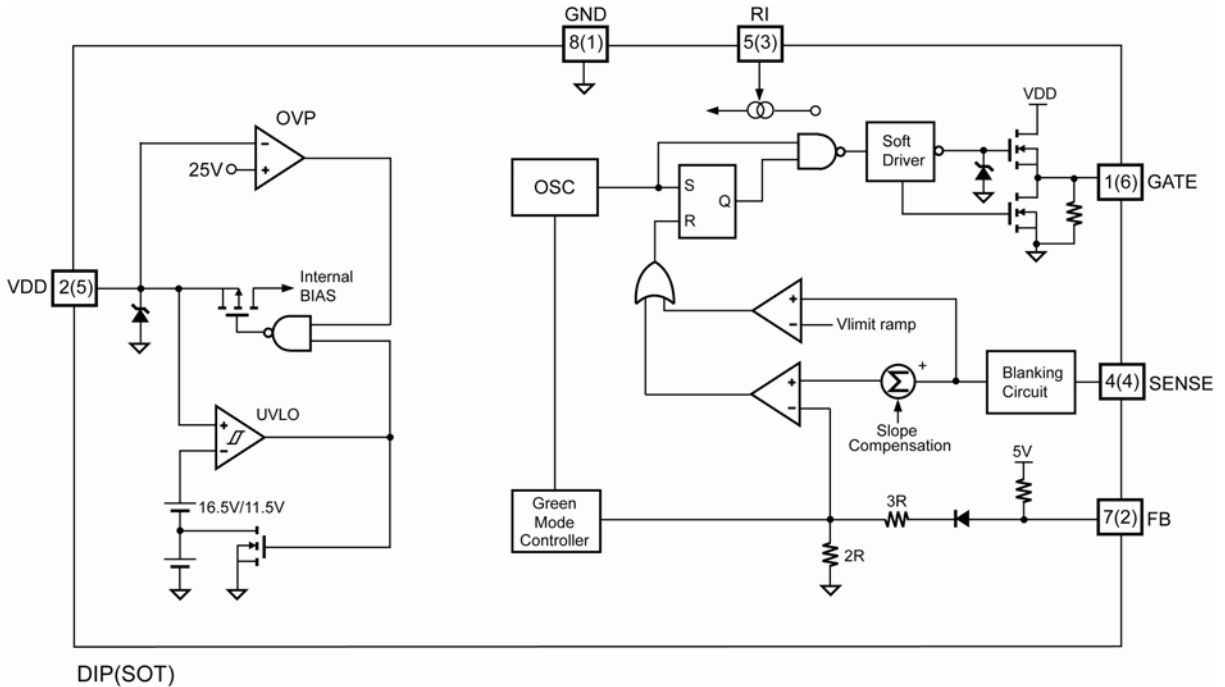
ORDERING INFORMATION

| Part Number | Pb-Free | Package |
|-------------|---------|--------------|
| SG6858TZ | | 6-pin SOT-26 |
| SG6858DZ | | 8-pin DIP-8 |

PIN DESCRIPTIONS

| Name | Pin No. | | Type | Function |
|-------|---------|--------|---------------------|--|
| | DIP-8 | SOT-26 | | |
| GATE | 1 | 6 | Driver Output | The totem-pole output driver for driving the power MOSFET. |
| VDD | 2 | 5 | Supply | Power supply. |
| NC | 3 | | No Connection | NC pin. |
| SENSE | 4 | 4 | Analog Input | 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. |
| RI | 5 | 3 | Analog Input/Output | A resistor connected from the RI pin to ground generates a constant current source used to charge an internal capacitor and determines the switching frequency. Increasing the resistance reduces the amplitude of the current source and reduce the switching frequency. A 95kΩ resistor, R _i , results in a 50μA constant current I _i and a 70kHz switching frequency. |
| NC | 6 | | No Connection | NC pin. |
| FB | 7 | 2 | Analog Input | 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. |
| GND | 8 | 1 | Supply | Ground. |

BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

| Symbol | Parameter | Value | Unit |
|----------------------|---|-------------|------------|
| V _{VDD} | DC Supply Voltage* | 30 | V |
| V _{FB} | Input Voltage to FB Pin | -0.3 to 7.0 | V |
| V _{SENSE} | Input Voltage to Sense Pin | -0.3 to 7.0 | V |
| T _J | Operating Junction Temperature | -40 to +125 | °C |
| R _{θ JA} | Thermal Resistance (Junction-to-Air) | SOT | 208.4 °C/W |
| | | DIP | 82.5 °C/W |
| T _{STG} | Storage Temperature Range | -55 to +150 | °C |
| T _L | Lead Temperature (Wave Soldering or Infrared, 10 Seconds) | 260 | °C |
| V _{ESD-HBM} | Electrostatic Discharge Capability, Human Body Model | 3.0 | kV |
| V _{ESD-MM} | 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.

RECOMMENDED OPERATING CONDITIONS

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

* For proper operation.

ELECTRICAL CHARACTERISTICS

V_{DD}=15V, T_A = 25°C, unless otherwise noted.

V_{DD} Section

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit |
|-----------------------|--|---|----------------------------|----------------------------|----------------------------|------|
| V _{DD-OP} | Continuously Operation Voltage | | | | 22 | V |
| V _{DD-ON} | Turn-on Threshold Voltage | | 15.5 | 16.5 | 17.5 | V |
| V _{DD-OFF} | Turn-off Threshold Voltage | | 10.5 | 11.5 | 12.5 | V |
| I _{DD-ST} | Start-up Current | V _{DD} =V _{DD-ON} - 0.1V | | 10 | 15 | μA |
| I _{DD-OP} | Operating Supply Current | V _{DD} =15V, GATE with 1nF to GND | | 2.5 | 3.5 | mA |
| V _{DD-OVP} | V _{DD} Over-Voltage Protection Level | | 24 | 25 | 26 | V |
| t _{D-VDDOVP} | V _{DD} Over-Voltage Protection Debounce | | 50 | 125 | 200 | μs |
| V _{DD-G OFF} | V _{DD} Low Threshold Voltage to Exit Green-off Mode | | V _{DD-OFF} + 0.95 | V _{DD-OFF} + 1.10 | V _{DD-OFF} + 1.25 | V |

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Feedback Input Section

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit |
|---------------|--|-----------------|------|------|------|------------|
| A_V | FB Input to Current Comparator Attenuation | | | 2/5 | | V/V |
| Z_{FB} | Input Impedance | | | 5 | | k Ω |
| $V_{FB-OPEN}$ | FB Output High Voltage | | 4.5 | 5.0 | 5.5 | V |
| V_{FB-N} | Green-Mode Entry FB Voltage | | | 2.85 | | V |
| V_{FB-G} | Green-Mode Ending FB Voltage | | | 2.20 | | V |
| S_G | Green-Mode Modulation Slope | $R_I=95k\Omega$ | | 75 | | Hz/mV |

Current-Sense Section

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit |
|-------------|--|-----------------|------|------|------|------------|
| Z_{SENSE} | Input Impedance | | 10 | | | k Ω |
| t_{PD} | Delay to Output | | | 60 | 100 | ns |
| V_{STHFL} | Flat Threshold Voltage for Current Limit | | | 0.96 | | V |
| V_{STHVA} | Valley Threshold Voltage for Current Limit | | 0.75 | 0.80 | 0.85 | V |
| t_{LEB} | Leading-edge Blanking Time | | 250 | 300 | 350 | ns |
| DCY_{SAW} | Duty Cycle of SAW Limit | Max. Duty Cycle | | 45 | | % |

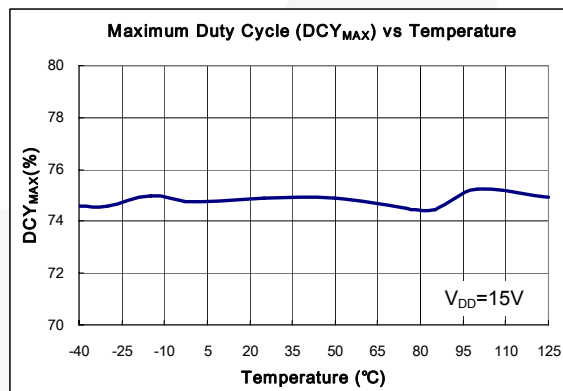
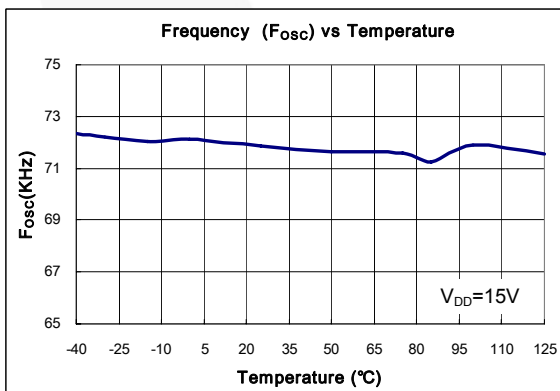
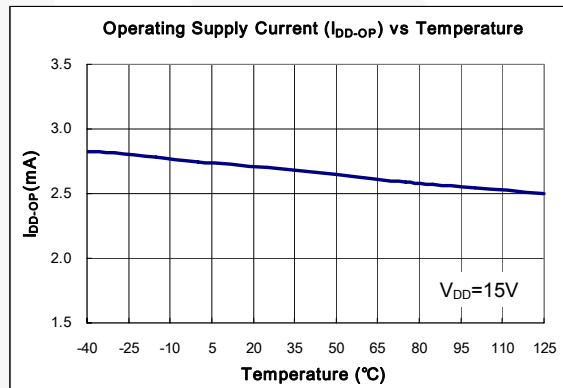
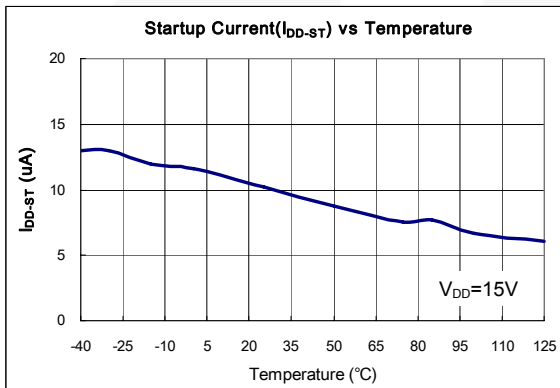
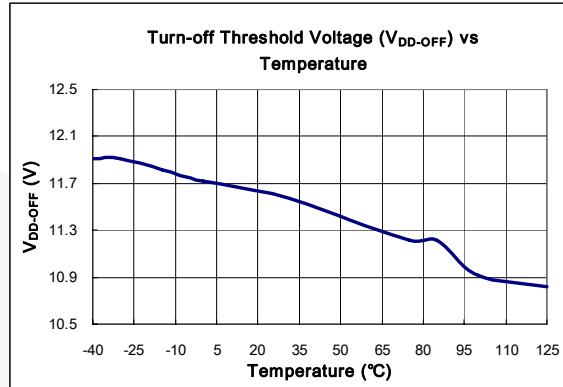
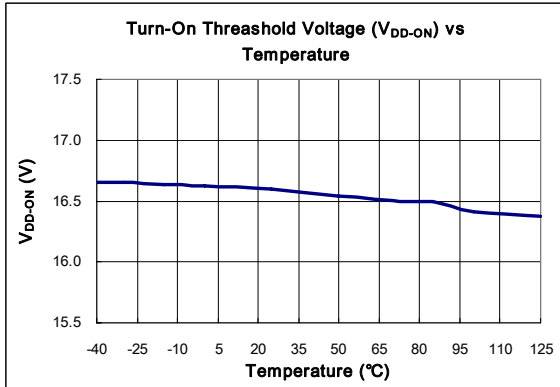
Oscillator Section

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit |
|-------------|---|-----------------------|------|------|------|------|
| F_{OSC} | Frequency | $R_I=95k\Omega$ | 65 | 70 | 75 | kHz |
| F_{OSC-G} | Green-Mode Frequency | $R_I=95k\Omega$ | | 22 | | kHz |
| F_{DV} | Frequency Variation vs. V_{DD} Deviation | $V_{DD}=13.5V$ to 22V | 0 | 0.02 | 2.00 | % |
| F_{DT} | Frequency Variation vs. Temperature Deviation | $T_A=-20$ to 85°C | | | 2 | % |

Output Section

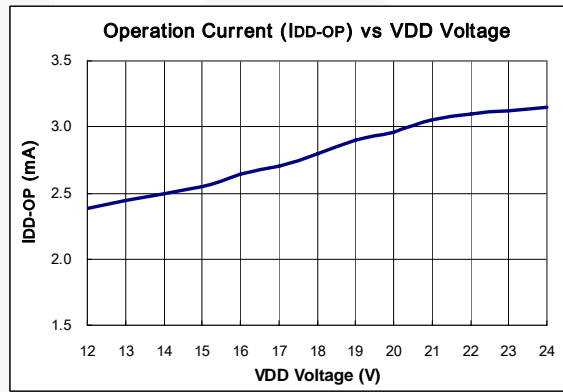
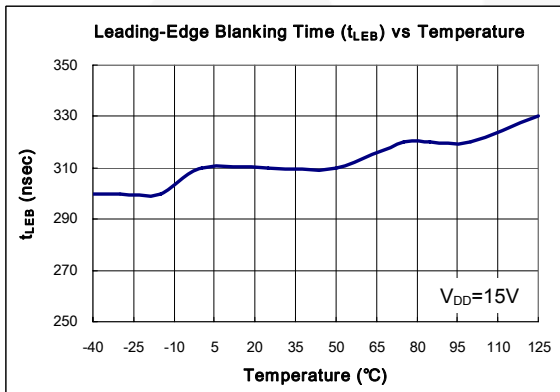
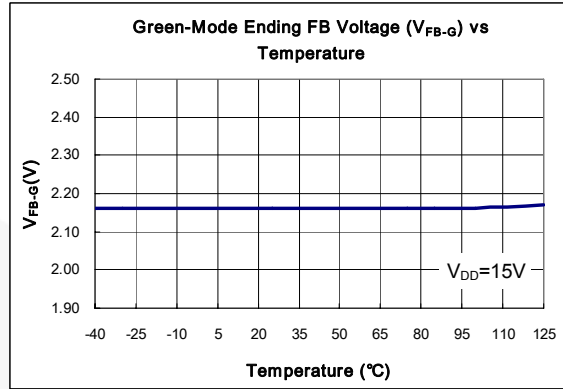
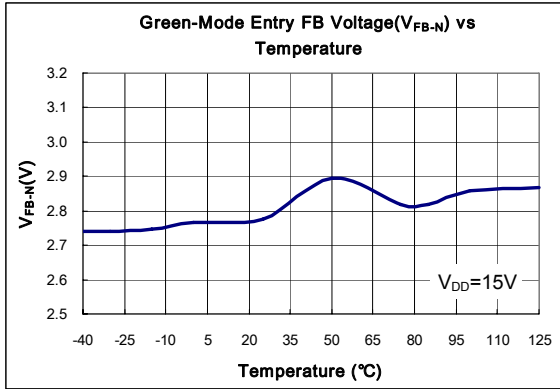
| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit |
|------------------|----------------------|---------------------------|------|------|------|------|
| DCY_{MAX} | Maximum Duty Cycle | | 70 | 75 | 80 | % |
| V_{GATE-L} | Output Voltage Low | $V_{DD}=15V, I_o=20mA$ | | | 1.5 | V |
| V_{GATE-H} | Output Voltage High | $V_{DD}=13.5V, I_o=-20mA$ | 8 | | | V |
| t_R | Rising Time | $V_{DD}=15V, C_L=1nF$ | 150 | 200 | 250 | ns |
| t_F | Falling Time | $V_{DD}=15V, C_L=1nF$ | 35 | 55 | 75 | ns |
| $V_{GATE-CLAMP}$ | Output Clamp Voltage | $V_{DD}=22V$ | 16 | 17 | 18 | V |

TYPICAL CHARACTERISTICS



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

SG6858



OPERATION DESCRIPTION

SG6858 devices integrate many useful designs into one controller for low-power switch-mode power supplies. The following descriptions highlight some of the features of the SG6858 series.

Start-up Current

The start-up current is only 10μA, which allows a start-up resistor with a high resistance and a low-wattage to supply the start-up power for the controller. A 1.5MΩ, 0.25W, start-up resistor and a 10μF/25V V_{DD} hold-up capacitor are sufficient for an AC-to-DC power adapter with a wide input range (100V_{AC} to 240V_{AC}).

Operating Current

The operating current has been reduced to 2.5mA. The low operating current results in higher efficiency and reduces the V_{DD} 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 SG6858 can 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 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 the switching frequency. A 95kΩ resistor, R_I, results in a 50μA constant current, I_I, and a 70kHz switching

frequency. The relationship between R_I and the switching frequency is:

$$f_{\text{PWM}} = \frac{6650}{R_I \text{ (k}\Omega\text{)}} \text{ (kHz)} \quad (1)$$

Leading-Edge Blanking

Each time the power MOSFET is switched on, a turn-on spike occurs at the sense-resistor. To avoid premature termination of the switching pulse, a 300ns 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 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 0.96V), the output GATE drive is turned off following a short propagation delay t_{PD}.

This propagation delay introduces 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_RAMP}).

This ramp signal rises from 0.80V to 0.96V, then flattens out at 0.96V. 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 (90V_{AC} to 264V_{AC}).

Under-Voltage Lockout (UVLO)

The turn-on and turn-off thresholds of the SG6858 are fixed internally at 16.5V/11.5V. During start-up, the hold-up capacitor must be charged to 16.5V through the start-up resistor to enable SG6858. 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 11.5V during this start-up process. This UVLO hysteresis window ensures that hold-up capacitor is adequate to supply V_{DD} during start-up.

V_{DD} Over-Voltage Protection

V_{DD} over-voltage protection has been built in to prevent damage due to over-voltage conditions. When the voltage V_{DD} exceeds the internal threshold due to abnormal conditions, PWM output is turned off until the V_{DD} voltage drops below the UVLO, then starts up again. Over-voltage conditions are usually caused by open-feedback loops.

Gate Output

The 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 to protect power MOSFET transistors against undesired over-voltage gate signals.

Built-in Slope Compensation

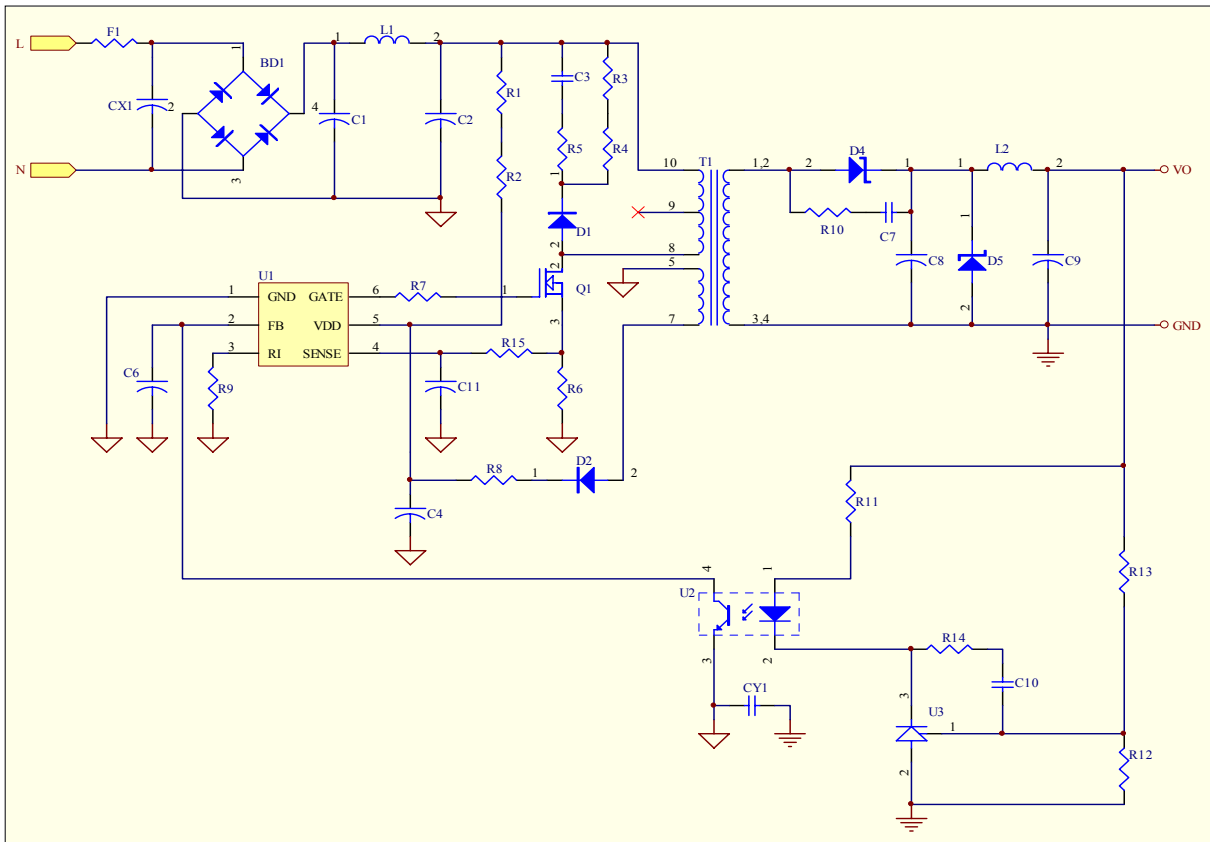
The sensed voltage across the current sense resistor is used for current-mode control and pulse-by-pulse current limiting. Built-in slope compensation improves stability and prevents sub-harmonic oscillations due to peak-current mode control. The SG6858 has a synchronized, positively-sloped ramp built-in at each switching cycle. The slope of the ramp is:

$$\frac{0.36 \times \text{Duty}}{\text{Duty(max.)}} \quad (2)$$

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 still be taken. Good placement and layout practices should be followed. Avoiding long PCB traces and component leads, locating compensation and filter components near the SG6858, and increasing the power MOS gate resistance improves performance.

REFERENCE CIRCUIT

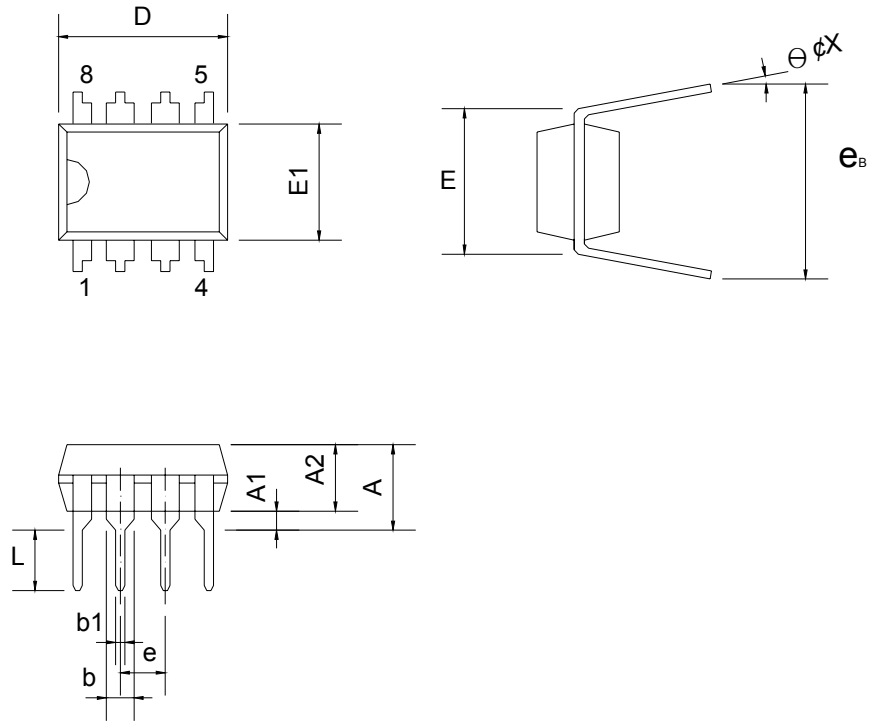


BOM

| Reference | Component | Reference | Component |
|----------------|---------------------|----------------|-------------------|
| BD1 | BD 1A/500V | L2 | Inductor 10μH 6mm |
| CX1 (Optional) | XC 0.1μF | Q1 | MOSFET 1A/600V |
| CY1 (Optional) | YC 1000pF/400V (Y1) | R1,R2 | R 750KΩ 1206 |
| C1 | CC 10nF/500V | R4,R3 | R 47KΩ 1206 |
| C2 | EC 10μF/400V 105°C | R5 | R 47Ω 1206 |
| C3 | CC 1000pF/500V | R6 | R 4.7Ω 1206 |
| C4 | EC 10μF/50V | R7 | R 100Ω 0805 |
| C6 | CC 1000pF 0805 | R8 | R 10Ω 1206 |
| C7 (Optional) | CC 1000pF/100V 1206 | R9 | R 100KΩ 0805 |
| C8 | EC 470μF/10V 105°C | R10 (Optional) | R 10Ω 1206 |
| C9 | EC 220μF/10V 105°C | R11 | R 100Ω 1/8W |
| C10 | CC 2200pF 0805 | R12 | R 33KΩ 0805 |
| C11 | N.C. | R13 | R 33KΩ 1/8W |
| D1 | Diode FRI07 | R14 | R 4.7KΩ 0805 |
| D2 | Diode FR102 | R15 | R 0Ω 0805 |
| D4 | Diode SB360 | T1 | Transformer EE-16 |
| D5 (Optional) | ZD 6.8V 0.5W | U1 | IC SG6858 |
| F1 | R 1Ω/0.5W | U2 | IC PC817 |
| L1 | Inductor 20mH 6x8mm | U3 | IC TL431 |

PACKAGE INFORMATION

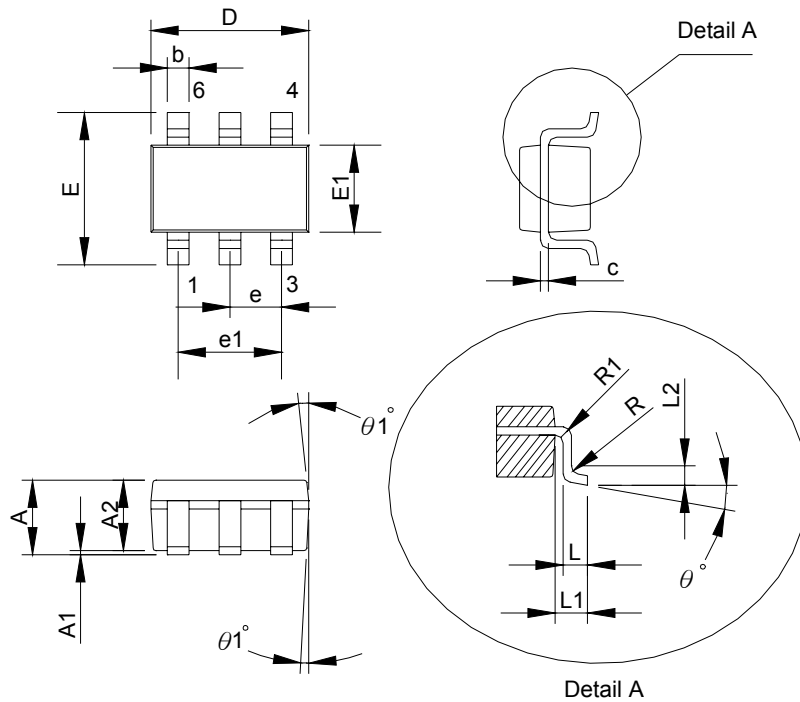
8 PINS - DIP (D)



Dimensions

| Symbol | Millimeters | | | Inches | | |
|----------------|-------------|-------|--------|--------|-------|-------|
| | 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° |

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 | 0.024 |
| L1 | | 0.60 | | | 0.024 | |
| L2 | | 0.25 | | | 0.010 | |
| R | 0.10 | | | 0.004 | | |
| R1 | 0.10 | | 0.25 | 0.004 | | 0.010 |
| θ° | 0° | 4° | 8° | 0° | 4° | 8° |
| $\theta 1^\circ$ | 5° | 10° | 15° | 5° | 10° | 15° |


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SG6858



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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

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|--------------------------|------------------------|--|
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