FS2514

High Precision CC / CV Primary-Side Power Switch

July 2016

GENERAL DESCRIPTION

The FS2514 is a high performance offline PSR power switch for low power AC/DC charger and adapter applications. It operates in primary-side sensing and regulation. Consequently, opto-coupler and TL431 could be eliminated. Proprietary Constant Voltage (CV) and Constant Current (CC) control is integrated as shown in the figure below.

In CC control, the current and output power setting can be adjusted externally by the sense resistor Rs at CS pin. In CV control, multi-mode operations are utilized to achieve high performance and high efficiency. In addition, good load regulation is achieved by the built-in cable drop compensation. Device operates in PFM in CC mode as well at large load condition and it operates in PWM with frequency reduction at light/medium load. The chip consumes very low operation current, it can achieve less than 75mW standby power.

FS2514 offers comprehensive protection coverage with auto-recovery features including Cycle-by-Cycle current limiting, VDD over voltage protection, short circuit protection, built-in leading edge blanking, VDD under voltage lockout (UVLO), OTP etc.

FS2514 is offered in SOP7 package.

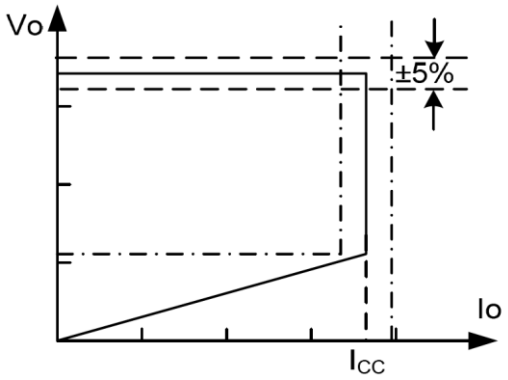


Figure.1. Typical CC / CV Curve

FEATURES

- Primary-side sensing and regulation without TL431 and opto-coupler
- High precision constant voltage and current regulation at universal AC input
- Multi-mode PWM/PFM operation for efficiency improving
- Good dynamic response
- Programmable CV and CC regulation
- Built-in line voltage and primary winding inductance compensation
- Programmable cable drop compensation
- No need for control loop compensation
- Audio noise free operation
- Internal BJT switch
- Built-in leading edge blanking (LEB)
- Comprehensive protection coverage with auto-recovery
  - VDD over voltage protection
  - VDD under voltage lockout with hysteresis (UVLO)
  - Cycle-by-cycle current limiting
  - Feedback loop open protection
  - Output short circuit protection
  - Over temperature protection (OTP)

APPLICATIONS

- Low Power AC/DC offline SMPS for
  - Cell Phone Charger
  - Digital Cameras Charger
  - Small Power Adapter
  - Auxiliary Power for PC, TV etc.

TYPICAL APPLICATION CIRCUIT

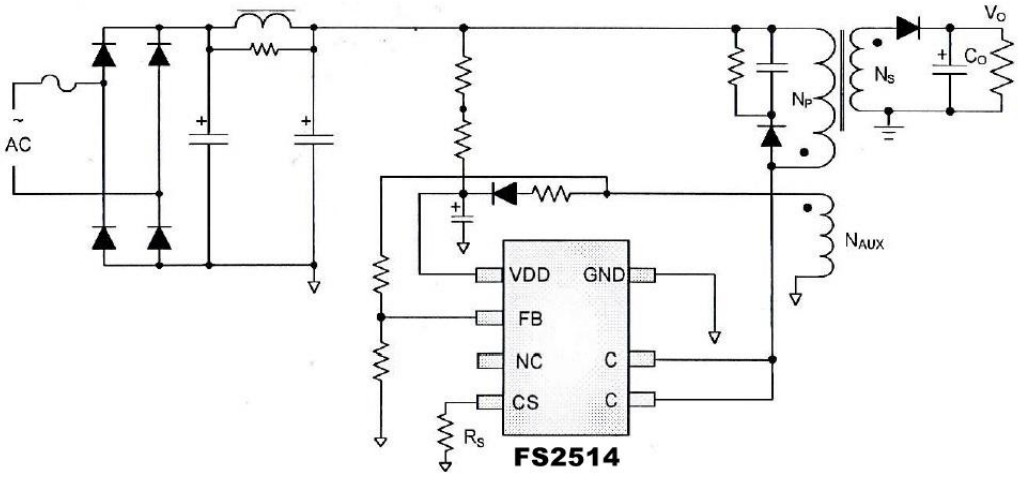
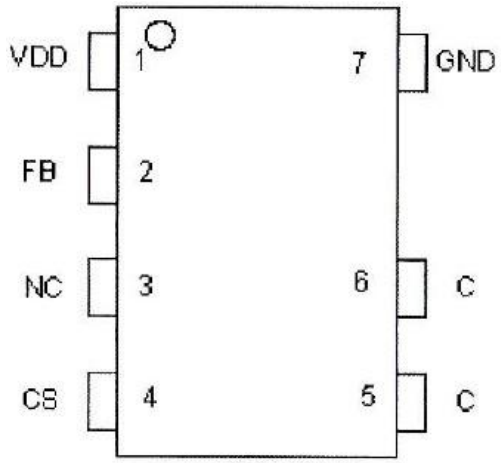


Figure 1 Typical Application Circuit

FS2514

PIN CONFIGURATION

Package	Pin Configuration (Top View)
SOP7	

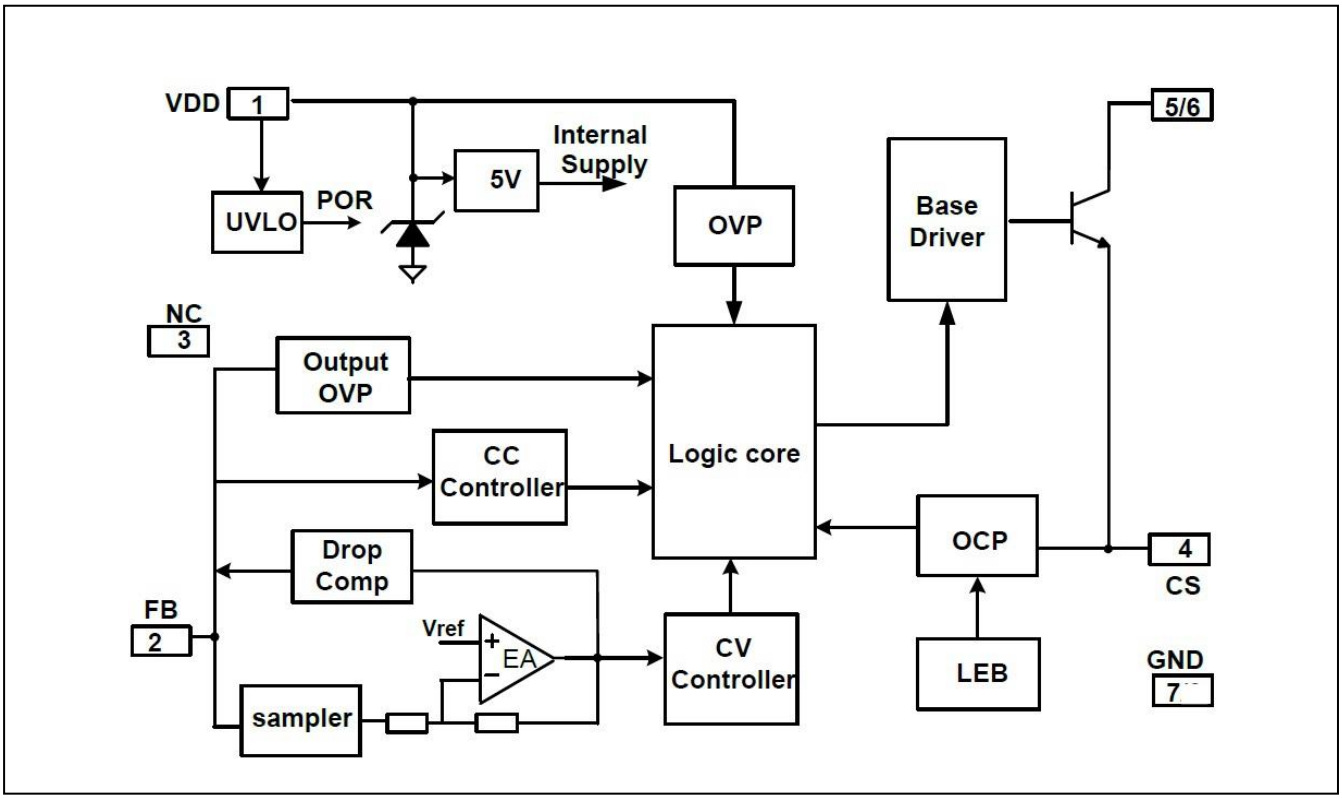
PIN DESCRIPTION

No.	Pin	Description
1	VDD	Power supply.
2	FB	The voltage feedback from auxiliary winding. Connected to resistor divider from auxiliary winding reflecting output voltage.
3	NC	No connection.
4	CS	Current sense input.
5, 6	C	HV BJT collector pin.
7	GND	Ground.

ORDERING INFORMATION
Industrial Range: -40°C to +125°C

Order Part No.	Package	QTY
FS2514CA-G-13TR	SOIC7, Pb-Free	2500/Reel
FS2514CA-G-T	SOIC7, Pb-Free	100/Tube

FUNCTIONAL BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

C-B Voltage		700V
V_{DD} Voltage		-0.3V ~ 30V
FB Input Voltage		-0.3V ~ 7V
CS Input Voltage		-0.3V ~ 7V
Operating temperature range, T_A		-40°C~+125°C
Storage temperature range, T_{STG}		-65°~+150°C
Package Thermal Resistance	Junction to Ambient, $R_{th\text{-}JA}$	90 °C/w (SOIC8) 75 °C/w (PDIP8)
	Junction to Case, $R_{th\text{-}JC}$	15 °C/w (SOIC8) 12 °C/w (PDIP8)
ESD (HBM)		2000 V
ESD (CDM)		200 V

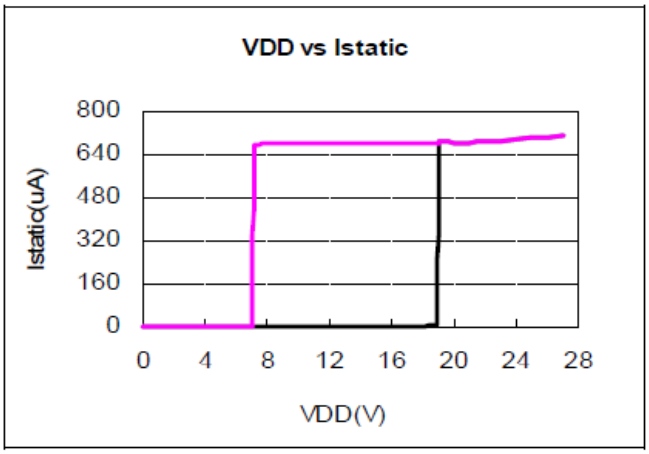
Note:
Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other condition beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

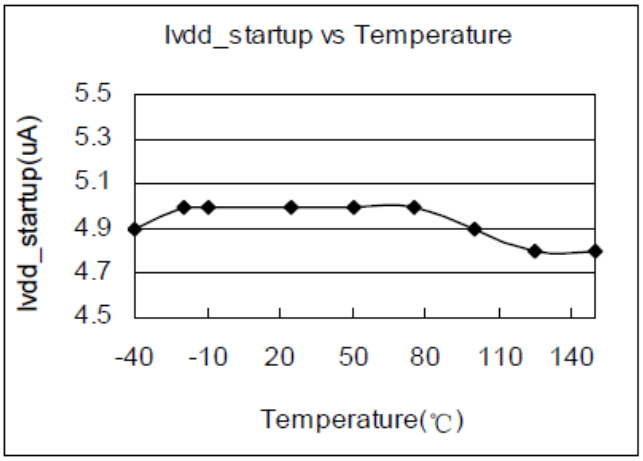
ELECTRICAL CHARACTERISTICS (TBD)

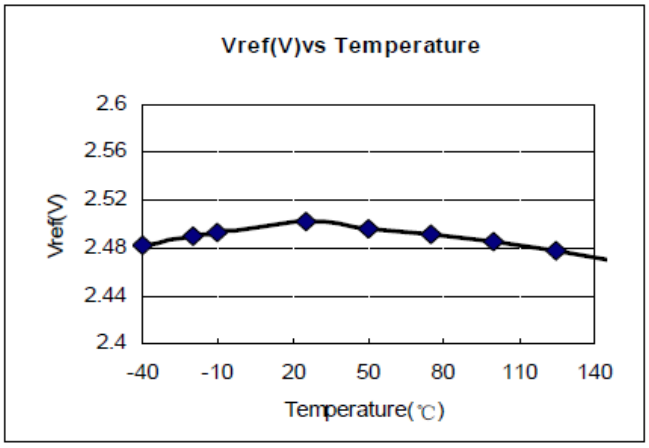
Test condition is T_A = −40°C ~ +125°C. Typical values are at T_A = 25°C, V_{DD} = 15V, unless otherwise specified.

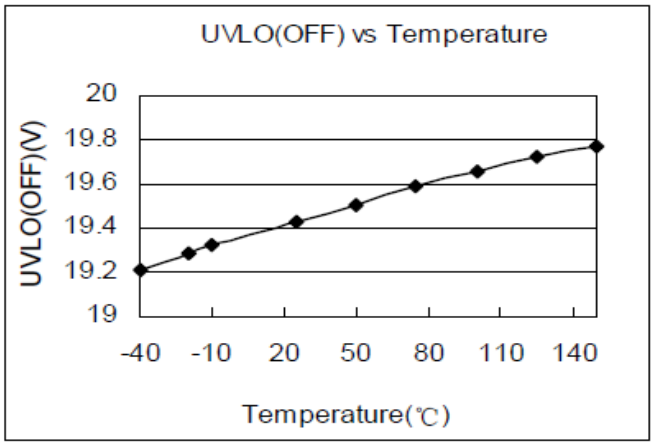
Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
Supply Voltage (V_{DD}) Section						
V_{DD}	Input voltage operation range		9.0		26	V
$I_{SART-UP}$	Start-up current	V_{DD} = $UVLO_{OFF}$-1V		5	15	uA
I_{STATIC}	Static current			0.72	1.0	mA
$UVLO_{OFF}$	Under voltage lockout exit		18.4	19.4	20.4	V
$UVLO_{ON}$	Under voltage lockout enter		6.5	7.1	7.8	V
V_{DD_OVP}	V_{DD} over voltage protection		26.5	28.0	29.5	V
Current Sense Input Section						
t_{LEB}	LEB time			0.5		us
$V_{th\_OCP\_MIN}$	Minimum over current threshold		485	500	515	mV
$V_{th\_OCP\_MAX}$	Maximum over current threshold			555		mV
V_{cs_mini}	Minimum CS threshold			100		mV
t_{ON_MAX}	Maximum ‘ON’ time			50		us
t_{D_OCP}	OCP propagation delay			100		ns
FB Input Section						
V_{FB}	Reference voltage for feedback threshold		2.475	2.500	2.525	V
t_{PALSE_MIN}	Minimum ‘OFF’ time			2.0		Us
f_{REQ_MIN}	Minimum frequency		720	800	880	Hz
I_{COMP_CABLE}	Maximum cable compensation current			48		uA
$V_{th\_cc\_shutdown}$	CC mode shutdown threshold			1.55		V
$T_{d\_cc\_shutdown}$	CC mode shutdown debounce		1024		1536	cycle
Output Over Voltage Protection						
V_{OUT_OVP}	Output over voltage protection threshold		2.85	3.00	3.15	V
On Chip Over Temperature Section						
T_{SD}	Thermal shutdown temperature			150		°C
T_{SD_HYS}	Thermal shutdown hysteresis			15		°C
Power BJT Section						
V_{CEO}	Collector-Emitter breakdown voltage	I_C = 10mA, IB = 0mA	450			V
V_{CBO}	Collector-Base breakdown voltage	I_C = 10mA	700			V
I_C	Collector peak current			1.0		A

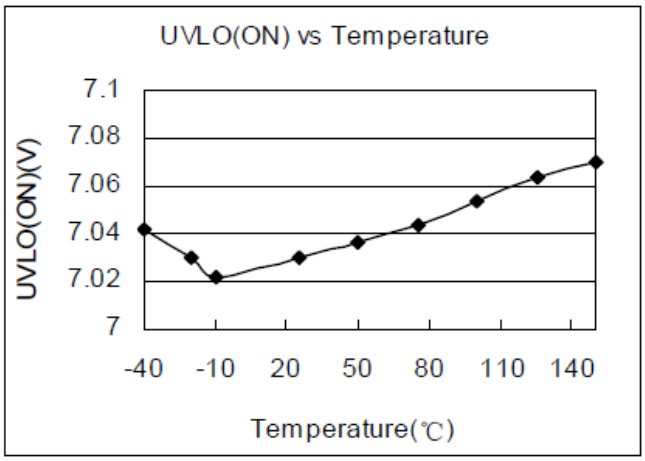
CHARACTERIZATION PLOTS











OPERATION DISCRIPTION

FS2514 is a cost effective PSR power switch optimized for off-line low power AC/DC applications including battery chargers. It operates in primary side sensing and regulation, thus opto-coupler and TL431 are not required. Proprietary built-in CV and CC control can achieve high precision CC/CV control meeting most charger application requirements.

Start-up current and start-up control

Start-up current of FS2514 is designed to be very low so that VDD can be charged up quickly. A large value startup resistor can therefore be used to minimize the power loss in application.

Operating Current

The operating current of FS2514 is as low as 720uA (typical). Good efficiency and low standby power is achieved with the low operating current.

CC/CV Operation

FS2514 is designed to produce good CC/CV control characteristic as shown in the Figure. 1. In charger applications, a discharged battery charging starts in the CC portion of the curve until it is nearly full charged and smoothly switches to operate in CV portion of the curve. The CC portion provides output current limiting. In CV operation, the output voltage is regulated through the primary side control. In CC operation mode, FS2514 will regulate the output current constant regardless of the output voltage drop.

Principle of Operation

To support FS2514 proprietary CC/CV control, system needs to be designed in DCM mode for flyback system (Refer to Typical Application Diagram on page1).
In the DCM flyback converter, the output voltage can be sensed via the auxiliary winding. During BJT turn-on time, the load current is supplied from the output filter capacitor, Co. The current in the primary winding ramps up. When BJT turns off, the energy stored in the primary winding is transferred to the secondary side such that the current in the secondary winding is

$$I_S = \frac{N_P}{N_S} \cdot I_P \quad (1)$$

The auxiliary voltage reflects the output voltage as shown in Figure. 2 and it is given by

$$V_{AUX} = \frac{N_{AUX}}{N_S} \cdot (V_O + \Delta V) \quad (2)$$

Where Δ V indicates the drop voltage of the output Diode. Via a resistor divider connected between the auxiliary winding and FB (pin 1), the auxiliary voltage is sampled at the middle of the de-magnetization and it is hold until the next sampling. The sampled voltage is compared with Vref (typical 2.5V) and the error is amplified. The error amplifier output reflects the load condition and controls the switching off time to regulate the output voltage, thus constant output voltage can be achieved.

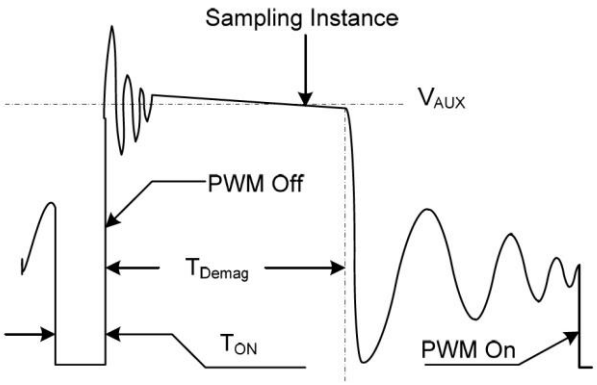


Figure.2. Auxiliary voltage waveform

When the sampled voltage is below Vref and the error amplifier output reaches its minimum, the switching frequency is controlled by the sampled voltage to regulate the output current, thus the constant output current can be achieved.

Adjustable CC Point and Output Power

In FS2514, the CC point and maximum output power can be externally adjusted by external current sense resistor Rs at CS pin as illustrated in typical application diagram. The larger Rs, the smaller CC point is, and the smaller output power becomes, and vice versa as shown in Figure.3.

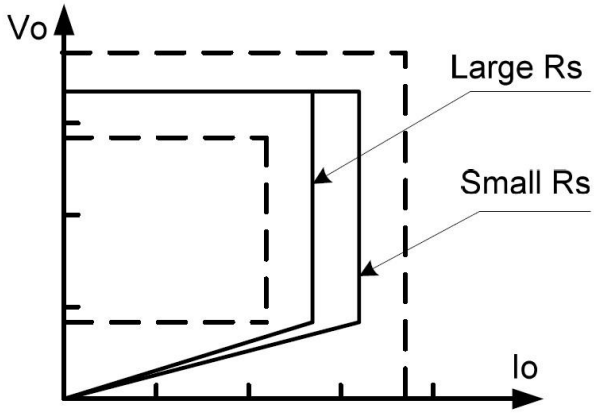


Figure 3. Adjustable output power by changing Rs

On Time OCP Compensation

The variation of max output current in CC mode can be rather large if no compensation is provided. The OCP threshold value is self adjusted higher at higher AC voltage. This OCP threshold slope adjustment helps to compensate the increased output current limit at higher AC voltage. In FS2514, a proprietary OCP compensation block is integrated and no external components are needed. The OCP threshold in FS2514 is a function of the switching ON time. For the ON time less than 3.7us (typical), the OCP threshold changes linearly from 500mV (typical) to 555mV (typical). For the ON time larger than 3.7us (typical), the OCP threshold is clamped to 555mV (typical), as shown in Figure 4.

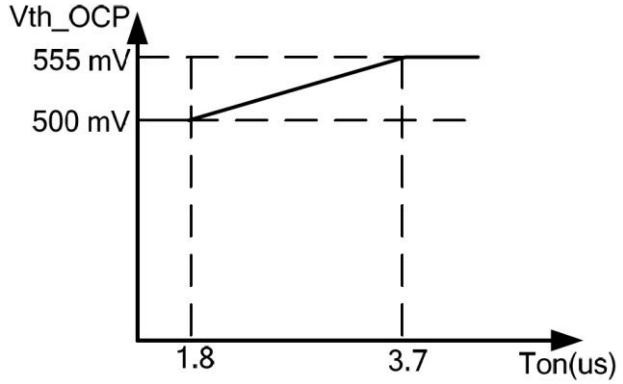


Figure.4 On time OCP compensation

Operation Switching Frequency

The switching frequency of FS2514 is adaptively controlled according to the load conditions and the operation modes.
For flyback operating in DCM, The maximum output power is given by

$$P_{OUTMAX} = \frac{1}{2} \cdot L_P \cdot F_{SW} \cdot I_P^2 \quad (3)$$

Where Lp indicate the inductance of primary winding and Ip is the peak current of primary winding. Refer to the equation 3, the change of the primary winding inductance results in the change of the maximum output power and the constant output current in CC mode. To compensate the change from variations of primary winding inductance, the switching frequency is locked by an internal loop such that the switching frequency is

$$F_{SW} = \frac{1}{2T_{Demag}} \quad (4)$$

Since TDemag is inversely proportional to the inductance, as a result, the product Lp and fsw is constant, thus the maximum output power and constant current in CC mode will not change as primary winding inductance changes. Up to ±7% variation of the primary winding inductance can be compensated.

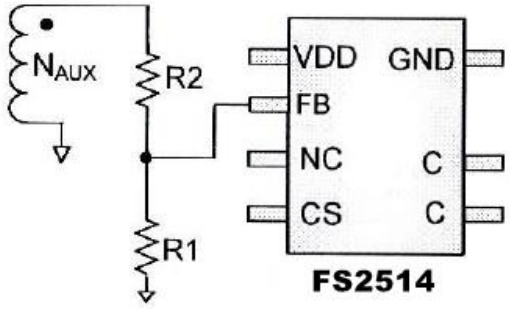
Programmable Cable Drop Compensation

In FS2514, cable drop compensation is implemented to achieve good load regulation. An offset voltage is generated at FB pin by an internal current flowing into the resister divider. The current is proportional to the switching off time, as a result, it is inversely proportional to the output load current, thus the drop due to the cable loss can be compensated. As the load current decreases from full-load to no-load, the offset voltage at FB will increase. It can also be programmed by adjusting the resistance of the divider to compensate the drop for various cable lines used. The percentage of maximum compensation is

$$\frac{\Delta V}{V_{OUT}} = \frac{I_{comp\_cable} \times R_1 // R_2 \times 10^{-6}}{2.5} \times 100\%$$

Δ V is load compensation voltage and Vout is output voltage;
For example: R_1//R_2=6.2Kohm, the percentage of maximum compensation is

$$\frac{\Delta V}{V_{OUT}} = \frac{48 \times 6200 \times 10^{-6}}{2.5} \times 100\% = 11.9\%$$



Current Sensing and Leading Edge Blanking

Cycle-by-Cycle current limiting is offered in FS2514. The switch current is detected by a sense resistor into the CS pin. An internal leading edge blanking circuit chops off the sensed voltage spike at initial power BJT on state so that the external RC filtering on sense input is no longer needed.

Protection Control

Good power supply system reliability is achieved with its rich protection features including Cycle-by-Cycle current limiting (OCP), Output over voltage protection, VDD over voltage protection, short circuit protection, Under Voltage Lockout on VDD (UVLO) and over temperature protection (OTP). VDD is supplied by transformer auxiliary winding output. The output of FS2514 is shut down when VDD drops below UVLO (ON) and the power converter enters power on start-up sequence thereafter. To prevent the circuit being damaged under abnormal conditions, FS2514 provides over thermal protection function. When the die temperature rises above over temperature threshold T_otp, the FS2514 will shut down the base output and then latch the power supply off. The controller will remains latched until the die temperature drops below the recovery threshold T_otp_rec and the FS2514 will reset at the same time.

CLASSIFICATION REFLOW PROFILES

Profile Feature	Pb-Free Assembly
Preheat & Soak Temperature min (Tsmin) Temperature max (Tsmax) Time (Tsmin to Tsmax) (ts)	150°C 200°C 60-120 seconds
Average ramp-up rate (Tsmax to Tp)	3°C/second max.
Liquidous temperature (TL) Time at liquidous (tL)	217°C 60-150 seconds
Peak package body temperature (Tp)*	Max 260°C
Time (tp)** within 5°C of the specified classification temperature (Tc)	Max 30 seconds
Average ramp-down rate (Tp to Tsmax)	6°C/second max.
Time 25°C to peak temperature	8 minutes max.

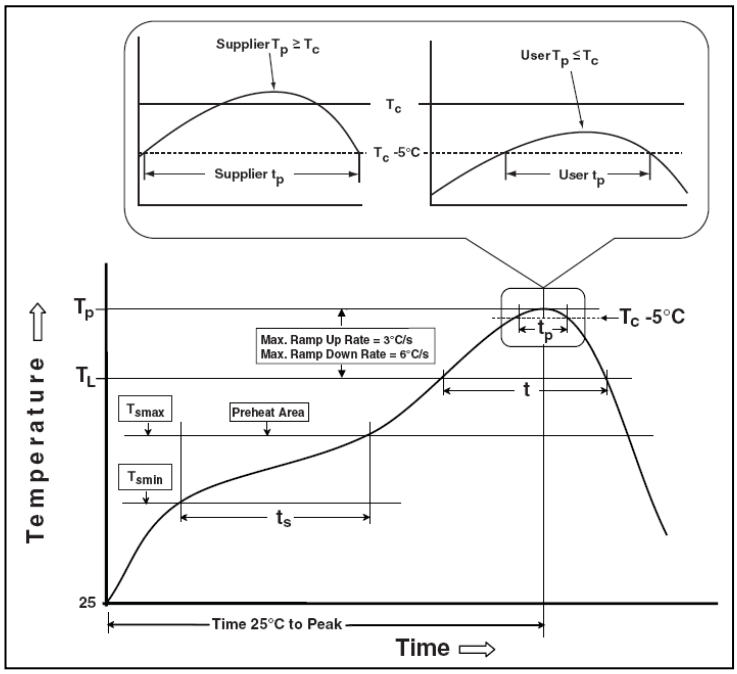
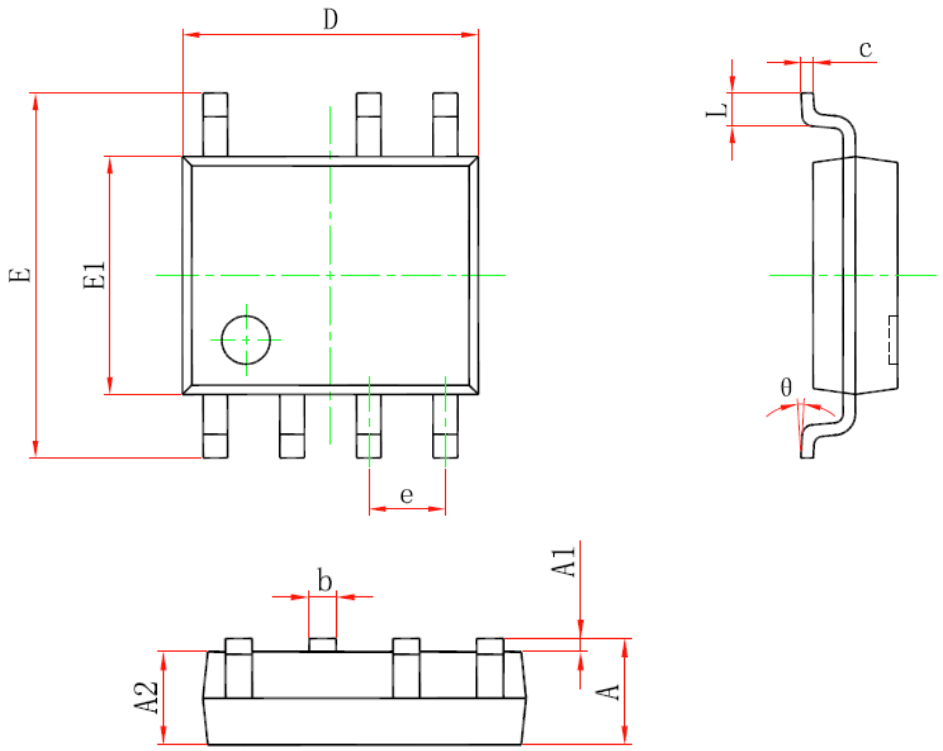


Figure 2 Classification Profile

PACKAGE INFORMATION

SOP7



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	**Max**	**Min**	**Max**
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
e	1.270 (BSC)		0.050 (BSC)	
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

Note: All dimensions in millimeters unless otherwise stated.