Switching Mode Power Supply PWM Controller WS2393BN

Features

- Low startup current (<5uA)
- Low operation current (2.0mA)
- 0.5mA operation current at no-load
- Standby power <75mw
- Multi-Mode Operation(PFM,PWM,QR)
- Current mode operation
- Advanced frequency jittering control
- Programmable Bulk Capacitor Brown-in/Brown-out Protection
- Programmable external OTP and OVP
- Cycle by cycle Over Current Protection (OCP)
- CS PIN open protection
- Internal OTP (Over Temperature Protection)
- Soft-start function
- VDD over voltage protection and clamp
- VDD Under voltage lockout with hysteresis (UVLO）
- Wide operation voltage (8-32V)
- Driver Output clamped (12V)
- Soft-driver function for reducing EMI
- Constant output power limited
- Over load protection(OLP)

Applications

Universal switching mode power supply and offline AC/DC flyback converter:

- Battery Charger
- Power Adaptor
- Set-Top Box Power Supplies
- Open-frame SMPS

Description

In order to enhance the efficiency performance, the WS2393BN integrates the multi-mode PWM controller, which consists of Quasi-Resonant (QR) PWM control for light load condition and Continue Conduction Mode (CCM) for heavy load condition. For lower standby power consumption and higher energy saving requirement, the IC has the Burst Mode function and very low startup current and operating current. At the condition of no load or light load, the IC operates in extended 'burst mode' to minimize switching loss by lower the switching frequency. The patented technologies of energy-saving at no-load contribute to minimize the power consumption (<75mw) and meet the efficiency standard of DoE or ErP VI.

The WS2393BN applies advanced frequency jittering control to improve EMI performance at half load and light-load. Besides, it covers wide supply voltage(8-32V), which greatly facilitate the transformer design and the compatibility of the system.

The internal synchronous slope compensation circuit improves system large signal stability and reduces the possibility of the sub-harmonic oscillation at high PWM duty cycle output. Leading-edge blanking on current sense input removes the signal glitch due to snubber circuit diode reverse recovery and thus greatly reduces the external component count and system cost in the design.

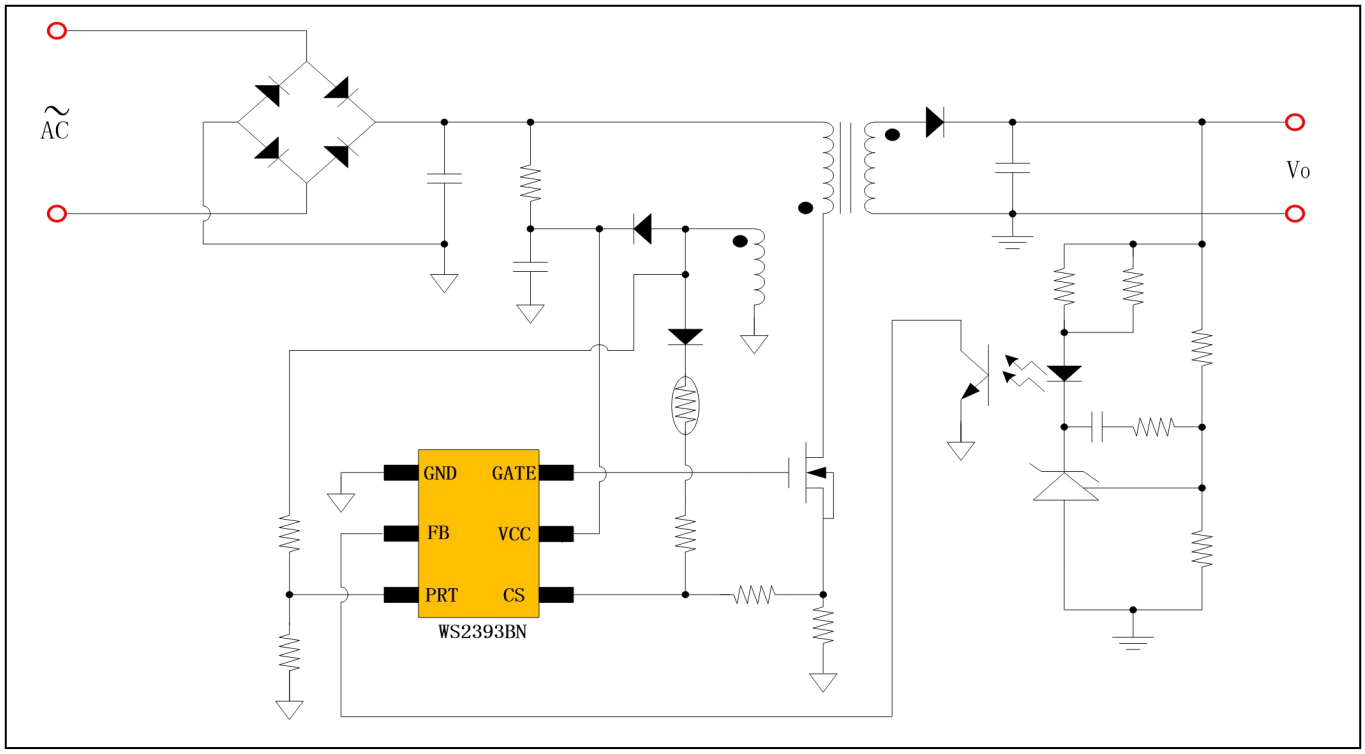
The WS2393BN offers complete protection coverage with automatic self-recovery feature including cycle by cycle over current protection (OCP), over load protection (OLP), over temperature protection (OTP), VDD over Voltage Protection (OVP), under voltage lockout (UVLO), and external programmable OTP and OVP with high precision. The gate-driven output is clamped to maximum 12V to protect the external MOSFET.

Excellent EMI performance is achieved by using the frequency jitter and the soft-switching at the totem pole gate drive output. The audio energy at below 22KHz is minimized in the design and audio noise is eliminated during operation.

The WS2393BN can be used as the best alternative products of the linear power supply or the RCC-mode power to improve the whole performance of the switching power system and lower the cost.

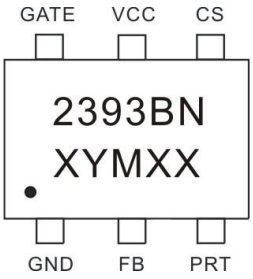
The WS2393BN is available in SOT23-6 package.

Typical Application Circuit



Pin Configuration and Marking Information

The WS2393BN is available in SOT23-6 Package. The top marking is shown as below:

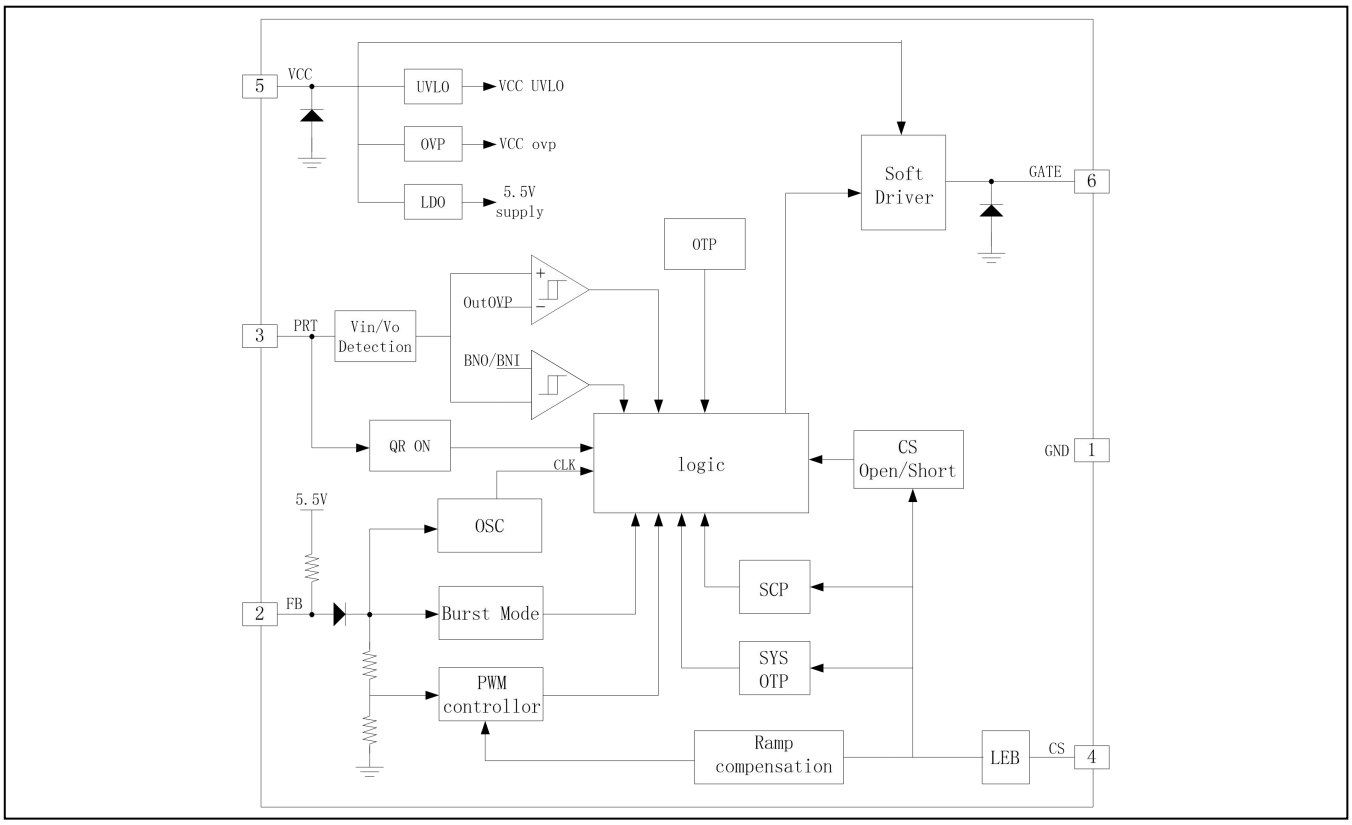


2293BN：Product Code
X：Product Code
YM：Production Date
XX：Internal Code for QC

Pin Definition

Pin Name	Pin No.	Pin Type	Function Description
GND	1	Ground	Ground
FB	2	Feedback Input	Feedback input pin. The PWM duty cycle is determined by voltage into this pin and the current-sense signal at Pin 4
PRT	3	Protection Setting	Multiple functions pin.Connecting two resistors from Vaux to ground can adjust output OVP trigger voltage , Brown-in/Brown-out trigger current and detect transformer core demagnetization.
SENSE	4	Current Monitoring	Current Sense Input. The current sense resistor between this pin and GND is used for current limit setting.
VDD	5	Power	Power Supply
GATE	6	Output	Gate Driver Output for External Power MOSFET.

Internal Block Diagram



Ordering Information

Package	Marking	Part Number
6-Pin SOT23-6, Pb-free	2393BN	WS2393BNYP

Recommended Operation Conditions

Symbol	Parameter	Value	Unit
VDD	VDD Supply Voltage	10~30	V
T_A	Operating temperature	-20~85	℃

Absolute Maximum Ratings

Symbol	Parameter	Value	Unit
VDD	DC Power Supply	32.5	V
V_{FB}	FB input voltage	-0.3~7	V
V_{SENSE}	SENSE input voltage	-0.3~7	V
V_{RI}	RI input voltage	-0.3~7	V
T_J	Operation Junction Temperature	-20~150	℃
T_{STG}	Storage Temperature	-40~150	℃
V_{CV}	Vcc Clamp Voltage	31.5	V
I_{CC}	Vcc Clamp Continuous Current	10	mA

Note: Stresses above those listed Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, functional operation of the device should not over these or any of these absolute maximum ratings. Operating above the absolute maximum-rated conditions may affect device reliability.

Electrical Characteristics

Symbol	Parameter	Test Conditions	Min	Typ.	Max	Unit
Supply Voltage(VCC)						
Istartup	VCC Start up current	VCC=UVLO(OFF)-1V,measure leakage current into VCC		2		uA
I_VCC_operation	Operation Current	VCC=18V,CS=4V,FB=3.5V,measure I_{VCC}		2		mA
I_VCC _Burst	Burst Current	CS=0V,FB=0.5V,measure I_{VCC}		0.5		mA
UVLO(ON)	VCC Under Voltage Lockout Enter		6.5	7.5	8.5	V
UVLO(OFF)	VCC Under Voltage Lockout Enter		15.8	17.0	18.2	V
Vpull-up	Pull-up PMOS active			10		V
OVP	VCC over voltage protection threshold voltage	FB=3.5V,CS=0V. Slowly ramp VCC, until no gate switching	27	28.0	29.0	V
VDD_clamp	VDD clamp voltage		31	32.5	34	V
Feedback Input Section(FB)						
V_{FB}_open	V_{FB} open loop voltage		4.9	5.1		V
A_{VCS}	PWM input gain $\Delta V_{FB}/\Delta V_{CS}$			3.5		V/V
Maximum duty cycle	Max duty cycle @VCC=18V,VFB=3V,VCS=0V			80		%
Vref_green	The threshold enter green mode			2.3		V
Vref_burst_H	The threshold exit burst mode			1.33		V
Vref_burst_L	The threshold enter burst mode			1.23		V
I_{FB}_short	FB short circuit current	Short FB pin to GND and measure current		0.21		mA
Vth_OLP	Open loop protection, FB threshold voltage			4.4		V
Td_OLP	Open loop protection, Debounce time			60		ms
Z_{FB}_in	Input Impedance			30		KΩ
V_{FB}_open	V_{FB} open loop voltage		4.9	5.1		V
A_{VCS}	PWM input gain $\Delta V_{FB}/\Delta V_{CS}$			3.5		V/V
Current Sence Input(CS)						
SST_CS	Soft start time for CS peak			2		ms
T_blanking	Leading edge blanking time			300		ns
Td_oc	Over Current Detection and Control Delay	From over current occurs till the gate driver output start to turn off		90		ns

Vth_OC	Internal Current Limiting threshold voltage with zero duty cycle			0.45		V
Vth_oc_clamp	OCP CS voltage clamper			0.72		V
Vth_otp	CS external OTP threshold			0.30		V
TD_OTP	External OTP debounce time	FB>vref_burst_H		60		ms
PRT						
Ibrown-in	Brown-in threshold current			110		uA
Ibrown-out	Brown-out threshold current			100		uA
V_{OVP}	Threshold voltage for external OVP		2.85	3.0	3.15	V
Td_output_ovp	Output OVP debounce time			7		cycle
In-chip OTP						
OTP enter				150		℃
OTP exit				120		℃
Oscillator						
F_{OSC}	Normal Oscillation Frequency	VDD=18V,FB=3.5V,CS=0V	60	65	70	KHz
ΔF_OSC	Frequency jittering			+/-6		%
F_shuffling	Shuffling frequency			32		Hz
ΔF_Temp	Frequency Temperature Stability			1		%
ΔF_VCC	Frequency Voltage Stability			1		%
F_burst	Burst Mode Switch Frequency			23		KHz
Gate driver						
VOL	Output low level @VCC=18V,I_O=5mA				1	V
VOH	Output high level @VCC=18V,I_O=20mA		6			V
Vclamp	Output clamp voltage			12		V
Tr	Output rising time 1.2V~10V@CL=2nf			200		ns
Tf	Output falling time 1.2V~10V@CL=2nf			40		ns

Application Information

The WS2393BN is built in the multi-mode PWM controller, in which operates a constant frequency to achieve the CCM as heavy load. For demanding higher power efficiency and power-saving in light load condition, the WS2393BN implements QR function to allow the valley switching and accomplish zero voltage switching . Under different load conditions, WS2393BN provides the different solutions for achieving higher efficiency and performance. The WS2393BN also has multiform auto-recovery protection. The main functions are described as below.

Startup Current and Startup Control

Startup current of the WS2393BN is designed to be very low（5uA） so that VDD could be charged up above UVLO threshold level and starts up quickly. A large value startup resistor can be used to minimize the power loss, predigest the design of startup circuit and provide reliable startup in application. For the design of AC/DC adaptor with universal input range, a startup resistor of 2 MΩ, 1/8 W could be used together with a VDD capacitor to provide a fast star-up and low power dissipation solution.

Operating Voltage

The WS2393BN covers wide supply voltage from 8V to 32V, which helps easing the transformer design, and a same transformer can be used to design different output voltage, so that the compatibility is improved.

Operating Current

The operating current of the WS2393BN is very low(2.0mA). Good efficiency is achieved with low operating current together with extended burst mode control circuit which can decrease the value of VDD capacitor.

Soft-start

WS2393BN features an internal 2.5ms(typical) soft start to soften the electrical stress occurring in the power supply during starup. It is activated during the power on sequence. As soon as VCC reaches UVLO(OFF), the CS peak voltage is gradually increased from 0.05V to the maximum level.Every restart is followed by a soft start.

Multi Mode Operation

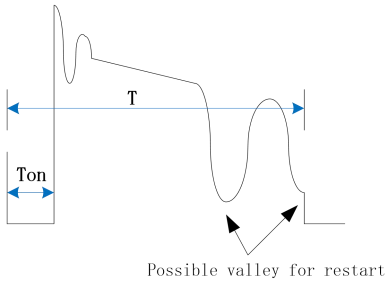
WS2393BN is a multi mode controller. The controller changes the mode of operation according to the FB pin Voltage. At the normal operating condition, the IC operates in traditional fix frequency(65kHz) PWM mode. As the output load current is decreased, the IC enter into green mode smoothly from the PWM mode. In this mode, the switching frequency will start to linearly decrease from 65kHz to 23kHz, meanwhile the valley turn on can be realized by monitoring the voltage activity on auxiliary windings through the PRT pin. So the switching loss is minimized and the high conversion efficiency can be achieved.

At light load condition, most of the power dissipation in a switching mode power in a switching mode power supply is from switching loss of the MOSFET, the core loss of the transformer and the loss of the snubber circuit. The magnitude of power loss is in proportion to the switching frequency. Lower switching frequency leads to the reduction on the power loss and thus conserves the energy.

At no load or very light load conditions, WS2393BN operates in burst mode.In the extended burst mode, the switching frequency at below 23kHz is minimized to avoid audio noise during operation.

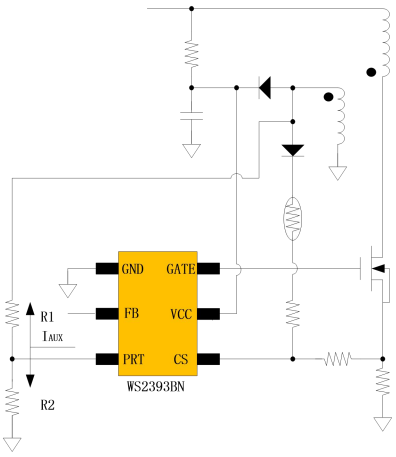
Demagnetization Detection

The transformer core demagnetization is detected by monitoring the voltage activity on the auxiliary windings through PRT pin. This voltage features a flyback polarity. After the on time, the switch is off and the flyback stroke starts. After the flyback stroke, the drain voltage shows an oscillation with $1/(2\pi\sqrt{L_P C_d})$,where Lp is the primary self inductance of primary winding of the transformer and Cd is the capacitance on the drain node.The typical detection level is fixed at -75mV at the PRT pin. Demagnetization is recognized by detection of a possible “valley” when the voltage at PRT is below -75mV in falling edge.



Multiple Functions of PRT PIN

When the power MOSFET is turn on, the voltage on auxiliary windings is negative which make our Brown-in/Brown-out protection feasible.



$$I_{AUX} = \frac{0.1}{R2} + \frac{0.1 - V_{AUX}}{R1}$$

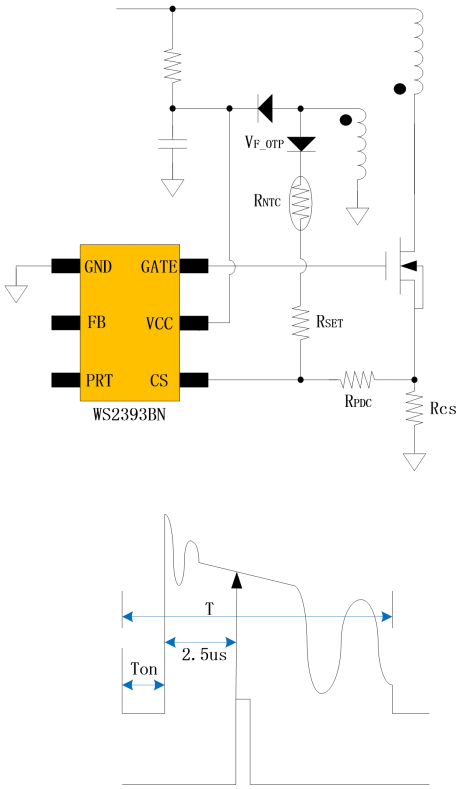
R1: The resistor connected from PRT to AUX.

R2: The resistor connected from PRT to ground. When system starts up, if I_{AUX} < Ibrown_in, Brown-in auto-recovery protection is triggered after 2 cycles debounce. When the system enters the normal operation mode, if I_{AUX} < Ibrown_out, Brown- out auto-recovery protection is triggered after 30ms debounce.For output OVP detection, when Gate is off, V_{PRT} is equal to V_{AUX}*R2/(R1+R2). If V_{PRT} is larger than 3V (typical), OVP auto-recovery protection is triggered after 6 cycles debounce. By selecting proper R1 and R2 resistance, output OVP level can be programmed.

Where N_S is turns ration of secondary-side winding, N_{AUX} is turns ration of auxiliary winding, and VF is the forward voltage of output schottky diode.

Programmable external Over Temperature Protection

WS2393BN has over temperature protection. The auxiliary winding voltage is a well-defined replica of the output voltage. The OTP works by sampling the plateau voltage at CS pin during the flyback phase. WS2393BN can sample this voltage level after a delay time to perform over temperature protection. This delay time (2.5us typical)is used to ignore the voltage ringing from leakage inductance of PWM transformer.



$$V_{OTP\_TH} = [(V_O + V_F) * \frac{N_{AUX}}{N_S} - V_{F\_OTP}] * \frac{R_{PDC} + R_{CS}}{R_{NTC\_OTP} + R_{SET} + R_{PDC} + R_{CS}}$$

The sampling voltage level is compared with internal threshold voltage 0.3V. If the sampling voltage exceeds the OTP trip level, ab internal counters starts counting subsequent OTP events. If OTP events are detected in consecutive 60ms, the controller assumes a true OTP and the system enters into atuo recovery.

Advanced Frequency Jittering Control and Optimizing the frequency curve

The WS2393BN integrates the maximum operating frequency of 65 KHz. The frequency jittering range is in proportion to the switching frequency in traditional PWM controller, so that at half load or light load, the switching frequency is decreased, and the frequency jittering range is also decreased, which deteriorates the EMI performance.

WS2393BN optimized the vibrating frequency and frequency curve.It makes the whole load range can keep good EMI performance.

Current Sensing and Leading Edge Blanking

Cycle-by-Cycle current limiting is offered in WS2393BN. The switching current is detected by a sense resistor at the SENSE pin. The internal Leading-edge blanking chops off the sense voltage spike at initial MOSFET on state due to snubber diode circuit reverse recovery and thus reduce the external RC filter circuit. The current limitation comparator is disabled and cannot turn off the external MOSFET during the blanking period. PWM duty cycle is determined by voltage level at SENSE pin and FB pin.

Internal Synchronized Slope Compensation

Built-in slope compensation circuit adds slope voltage onto the current sense input voltage for PWM generation. This greatly improves the close loop stability at CCM and prevents the sub-harmonic oscillation and thus reduces the output ripple voltage.

CS Open Protection

When the CS pin is opened, the WS2393BN will shut down after a few cycles. The controller enters into UVLO auto recovery until the fault is removed.

Gate Driver

GATE pin of the WS2393BN is connected to the gate of an external MOSFET. If the gate drive capacity is too weak will cause higher switching loss of MOSFET, while too strong gate drive output cause EMI problem. A good tradeoff between output capacity and dead time control is achieved through the design of the built-in totem pole driver in the WS2393BN. The low standby dissipation and good EMI system design is easier to achieve through this dedicated device. For MOSFET gate protection, an internal 12V clamp is added.

Protection Controls

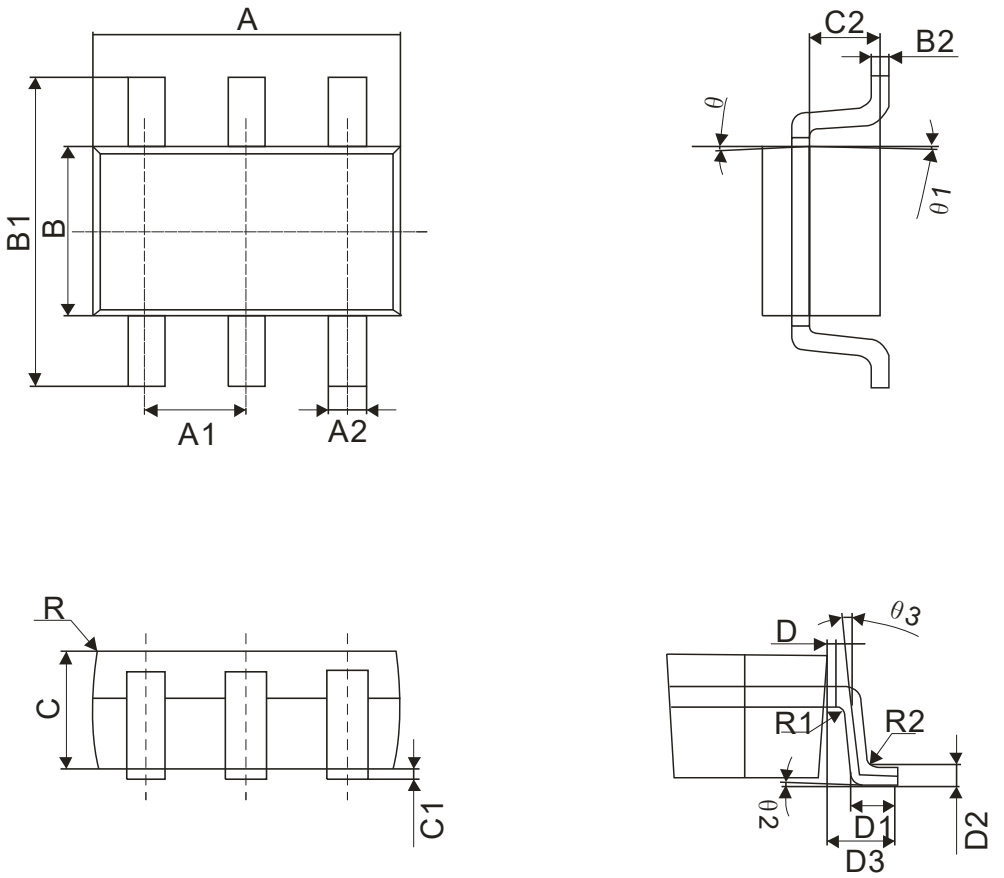
Good power supply system reliability is achieved with auto-recovery protection features including Cycle-by-Cycle current limiting (OCP), Over Load Protection (OLP), Over Temperature Protection (OTP), CS open protection, Secondary Rectifier Short Protection, Under Voltage Lockout on VDD (UVLO), , and VDD over Voltage Protection & VDD clamp, and external programmable OTP and OVP.

Internal line voltage compensation of OCP helps to achieve constant output power limit over the universal input voltage range.

Package Information

SOT23-6 Package Outline Dimensions

Unit:mm



Symbol	Winsemi			
	Dimensions in Millimeters		Dimensions in Inches	
	Min	Max	Min	Max
A	2.72	3.12	0.107	0.123
B	1.40	1.80	0.055	0.071
C	1.00	1.20	0.039	0.047
A1	0.90	1.00	0.035	0.039
A2	0.30	0.50	0.012	0.020
B1	2.60	3.00	0.102	0.118
B2	0.119	0.135	0.005	0.005
C1	0.03	0.15	0.001	0.006
C2	0.55	0.75	0.022	0.030
D	0.03	0.13	0.001	0.005
D1	0.30	0.60	0.012	0.024
D2	0.25TYP		0.01TYP	
D3	0.60	0.70	0.024	0.028

NOTE:

1.We strongly recommend customers check carefully on the trademark when buying our product, if there is any question, please don't be hesitate to contact us.

2.Please do not exceed the absolute maximum ratings of the device when circuit designing.

3.Winsemi Microelectronics Co., Ltd reserved the right to make changes in this specification sheet and is subject to change without prior notice.

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