RED2545

LLC Controller for CV LED Drivers

Features

- Advanced LLC controller for use in combination with APFC
- Current Mode control for improved stability & transient response
- Low Audio noise in standby, burst mode & PWM dimming
- Low standby power
- Works with wide transformer tolerances, integrated or separate inductor
- High accuracy: current limit, frequency & burst threshold
- Protection modes:
  - Overload output including short-circuit
  - No-Load output
  - Over-Temperature protection
- Smallest SOT23-6 IC package



SOT23-6

Applications

- Active PFC CV LED drivers up to 200W

Order code

Part Number	Package	Packaging
RED2545AL-TR7	SOT23-6	Tape and reel

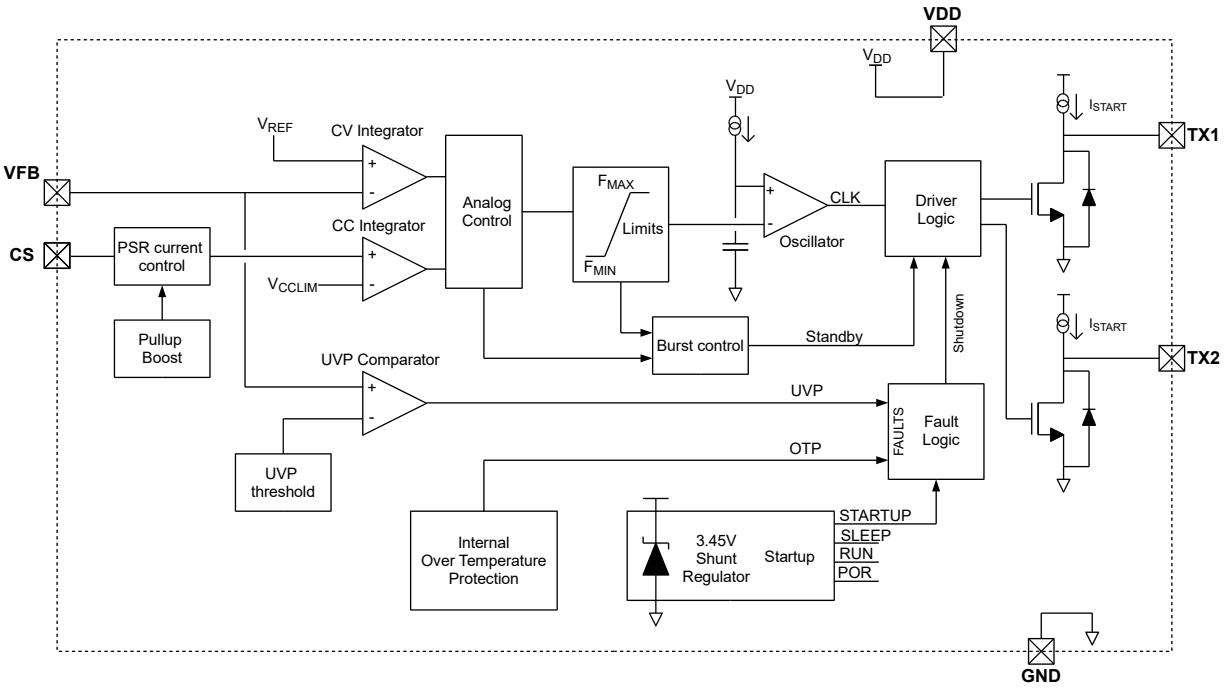


Figure 1: Block diagram

Device Pins

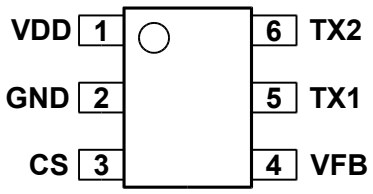


Figure 2: SOT23-6 pin connections (top view)

Pin Functions

Pin #	Name	Function
1	VDD	IC Power Supply pin
2	GND	Chip ground
3	CS	PSR Current Sense input provides output current regulation and cycle-by-cycle over-current protection. The CS pin is connected to the half-bridge current sense resistor
4	VFB	PSR Feedback input for output voltage regulation
5	TX1	Output to control transformer
6	TX2	Output to control transformer

Typical Application

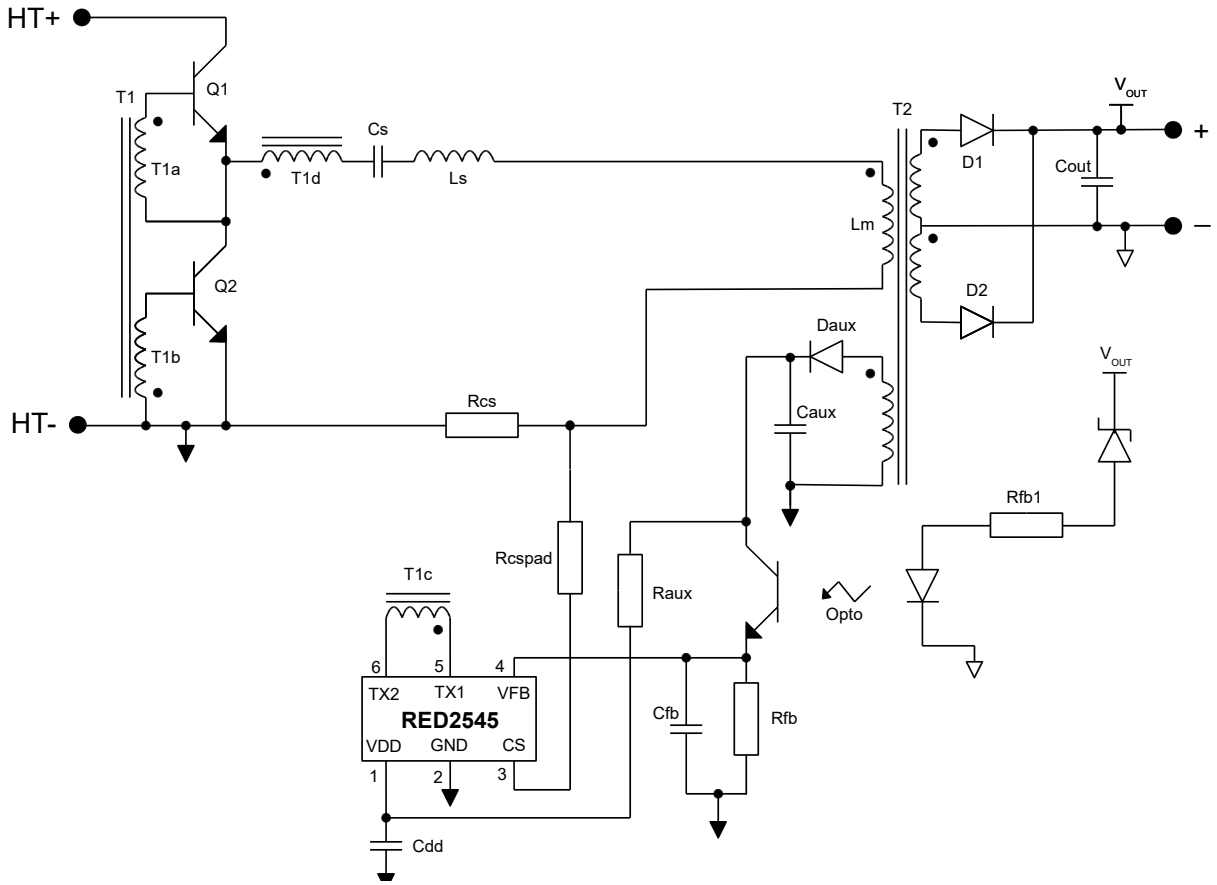


Figure 3: Typical Application Schematic: LLC converter with RED2545 CV controller

Features

RED2545 is a controller specifically intended for resonant half-bridge topology. Output voltage and current regulation are obtained by modulating the frequency.

RED2545 uses the CSOC (Controlled Self-Oscillating Converter) scheme to drive two low-cost bipolar transistors in a half-bridge configuration. RED2545 based LLC converters are able to achieve much higher efficiencies than similar flyback designs.

The RED2545 PSR scheme regulates the LED output voltage by modulating the converter frequency. Primary Side Current Control enables very accurate overload regulation and detection.

Burst mode

The IC enters a controlled burst-mode operation at light load, minimising the converter's input power consumption. The point at which the IC enters burst mode is pre-set to a value derived from the primary-side current to keep the output voltage from rising and to keep the power consumption low.

Protection Features

The IC is able to detect a number of faults that cause the IC to enter a fault mode:

- Output Overload
- Output Short Circuit
- Over-Temperature Protection

During these fault conditions, the IC will continually attempt to re-start. Depending on the fault, there can be 16 dummy re-starts between re-start attempts when the IC re-starts while the converter remains off.

If the output is short-circuited, the auxiliary power to the IC fails and the IC shuts down. The IC detects this and when it next re-starts, it does so at half output current. It continues to do so until the short has been removed. If the fault is removed, the IC will automatically return to full output current.

The IC also has an instantaneous cycle-by-cycle Over-Current Protection (OCP) level that will terminate any cycle instantaneously should the current exceed a pre-set level.

Automatic Dead-Time Control

An important feature of the Controlled Self Oscillating Converter is that the dead-time is controlled naturally. Unlike MOSFET half-bridge converters, it is not necessary to program the dead-time on RED2545. The bipolar switching transistors are turned on correctly through the self-oscillation of the converter and turned off by RED2545. This greatly simplifies the design process and improves the robustness of the LLC converter.

Capacitive Mode Protection

RED2545 includes a Capacitive Mode Protection feature which prevents the converter from entering capacitive switching mode on a cycle-by-cycle basis by limiting the minimum frequency. This always ensures the Controlled Self Oscillating Converter continues to oscillate correctly.

IC Operation

Start-up, Shutdown and Re-start

Figure 4 shows typical start-up waveforms for RED2545. In SLEEP mode the IDD current is approximately 20uA ($I_{DDSLEEP}$) which allows the IC to start up through resistors connected to the HT bus. Once VDD reaches 3.45V (V_{DDREG}) the IC enters RUN mode and the controlled Zener clamp inside the IC regulates VDD voltage to 3.45V (V_{DDREG}). The IC current rises to 155uA (I_{DDREG}) plus any excess current required to clamp VDD to 3.45V. If VDD falls below 3.45V (V_{DDREG}) the Zener clamp turns off and I_{DD} reduces to 155uA (I_{DDREG}) only. During burst mode operation VDD might fall below 3V (V_{DDSA}). In this case, the IC exits standby and continues until VDD rises above 3V again. If VDD falls below 2.75V ($V_{DDSLEEP}$) during a power outage, the IC enters SLEEP mode. In this condition IDD reduces back to $I_{DDSLEEP}$ and waits for power to be re-applied.

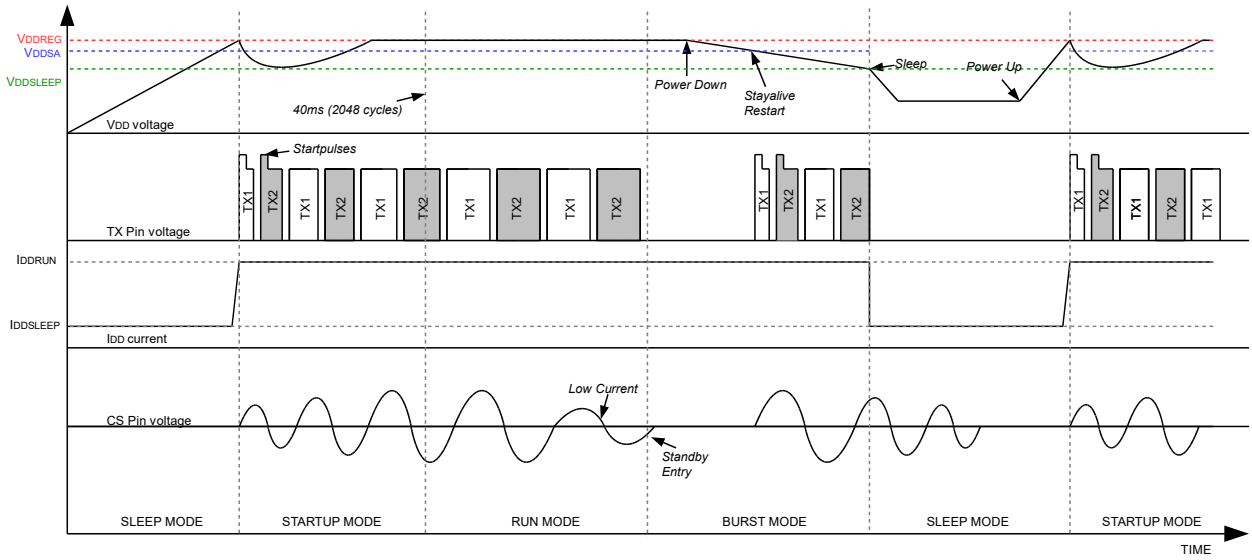


Figure 4: IC Start-up waveforms

Output stage

A diagram of the output stage can be seen in Figure 5. To start the converter oscillating the RED2545 issues start pulses through the TX pins during the first two cycles. These start pulses are 800ns long ($t_{TXSTART}$) and provide current pulses ($I_{TXSTART}$) from both TX1 and TX2 pins. After this the converter self-oscillates and no longer needs start pulses to maintain oscillation. A low on-state NMOS transistor is used to turn the bipolar transistors off. It is controlled by the oscillator off-time. The NMOS device is turned to pull TX pin low, which switches off the corresponding bipolar transistor in the power converter half-bridge.

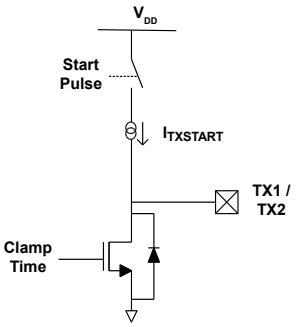


Figure 5: Output Stage

Current Mode control

The IC uses an average current mode control feedback loop for faster transient response and lower output ripple. Figure 1 shows the voltage amplifier providing a reference for the current amplifier and the current amplifier providing the control signal to the oscillator. This control voltage is fed into the oscillator comparator to select the desired operating frequency.

The voltage amplifier has a compensated integrator that compares the signal on the VFB pin to the internal reference of 1.2V. Internal compensation on the voltage and current amplifiers ensure a fast transient response to minimise output ripple, whilst being stable throughout load and line variations. A simple external control loop using a secondary side reference (e.g. TL431) and an optocoupler is typically used to complete the control loop. If the converter is overloaded however, the control signal out of the voltage amplifier is limited so that the converter provides constant current control to the output.

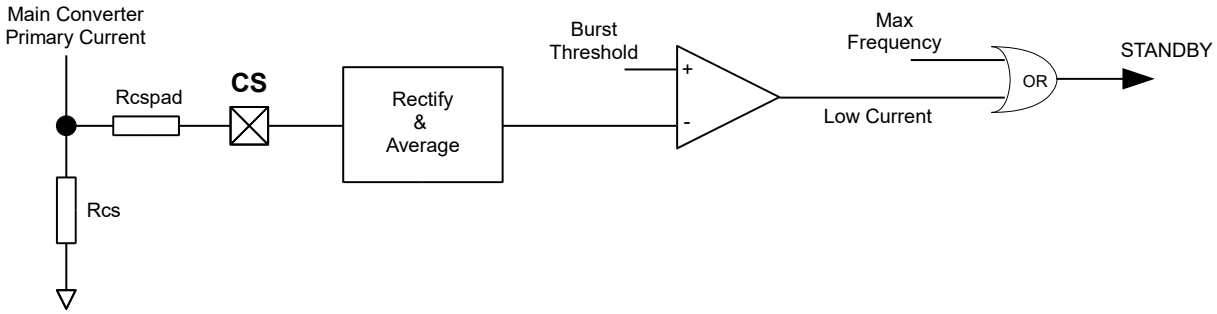


Figure 6: Standby Entry Circuit

Light loads

The IC has a burst mode that is used to lower the input power at light loads so that standby power is minimised. The standby point is set to approximately 3% of rated load current on the application. Below this point, the IC enters a controlled burst-mode operation at light load, by switching in and out of STANDBY, thereby minimising the converter's input power consumption.

Standby Entry

RED2545 will enter standby when either the IC reaches its maximum allowable operating frequency or when a low load condition is detected. When the IC detects this condition, it goes into standby. This can be seen in Figure 6. In standby mode, the converter is held in the off condition, with the IC waiting for a standby exit signal.

Standby Exit

During standby, the output voltage will fall slightly. The control loop then demands more power by turning the optocoupler off slightly, thereby lowering the voltage on the VFB pin. When the IC senses this, the controller will exit out of standby and begin the start sequence. The converter will again deliver power to the load and the IC will remain out of standby for a while until the load falls again, when the IC re-enters standby.

If VDD falls below 3V (V_{DDSA}) whilst in standby, it will force an exit out of standby. While VDD remains below 3V, standby will not be allowed. When VDD rises above 3V, standby is again allowed when standby entry is requested.

PSR Current Control

Current regulation is used during pullup and during overload conditions. There are two current control methods used in the converter:

1. constant current (CC) regulation.
2. an instantaneous peak current limit (OCP).

PSR Average Current Estimation

The signal from the CS pin is divided into two different paths. The bottom path provides peak instantaneous Over-Current Protection (OCP) while the PSR Average Current Estimation block provides the current regulation (CC) information. The voltage on the CS pin is an AC signal biased around GND. Inside the PSR block this signal is processed to provide a voltage proportional to the average converter output current.

Starting pullup capacity

The RED2545 includes an increased ability to pull up capacitive and constant power loads by temporarily increasing the constant-current level by 15%. With increased pullup capacity, take care to check the series resonant inductor flux density and current & voltage rating of components during start-up.

Constant Current Regulation

CC operation is defined by an internally compensated control loop. The average current regulation point, V_{CCREG} is pre-set to 165mV, referred to the CS pin.

Oscillator

The RED2545 includes an internal oscillator which is used to control the switching frequency of the converter. The maximum and minimum frequency limits are pre-set inside the IC and have been chosen to suit a low power CSOC converter. The oscillator ramp is compared to an internal control voltage to produce the correct frequency required to regulate the converter.

Over Current Protection

Over-Current Protection (OCP) is an instantaneous termination of the current oscillator cycle and the transistor on-time. When a peak voltage greater than **Error! Reference source not found.**mV (V_{OCPTHR}) is sensed on the CS pin the OCP comparator terminates the current oscillator on-time cycle. The oscillator is reset and the off-time begins resulting in the bipolar transistors turning off and the half-bridge commutating. This is repeated in subsequent cycles whenever the CS voltage exceeds the threshold. However, in a correctly designed converter it should not be possible to trip OCP in normal operation.

Over-Temperature Protection(OTP) Threshold Selection

It is possible to select the over-Temperature protection triggering threshold on RED2545. Typically, a capacitor value of 470pF or less for Cfb on the VFB pin, T_{OTPS1} is selected. With a capacitor of 1.5nF or greater, T_{OTPS2} is selected. An internal Over-Temperature Protection shuts down the controller if the IC temperature exceeds T_{OTPS1} or T_{OTPS2}. Hysteresis ensures the IC restarts the converter when the IC temperature drops by 8°C.

ABSOLUTE MAXIMUM RATINGS

CAUTION: Permanent damage may result if a device is subjected to operating conditions at or in excess of absolute maximum ratings.

Parameter	Symbol	Condition	Min	Max	Unit
Supply voltage	V_{DD}	SLEEP mode: self-limited by IC start-up ($V_{DDSTART}$)	-0.5	4.5	V
Supply voltage	V_{DD}	RUN mode: Self-limited by internal shunt regulator	-0.5	4.0	V
Supply current	I_{DD}		0	2	mA
Input/output voltages	V_{IO}		-0.5	V_{DD} + 0.5	V
Input/output currents	I_{IO}		-10	10	mA
Junction temperature	T_J	T_{J_MAX} limited by OTP (T_{OTPS_MAX})	-20	+135	°C
Storage temperature	T_P		-20	+125	°C
Lead temperature	T_L	Soldering, 10 s		260	°C
ESD withstand		Human body model, JESD22-A114		2	kV
		Capacitive Discharge Model		500	V

NORMAL OPERATING CONDITIONS

Unless otherwise stated, electrical characteristics are defined over the range of normal operating conditions. Functionality and performance are not defined when a device is subjected to conditions outside this range and device reliability may be compromised.

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Minimum supply current	I_{DDMIN}		200			µA
Junction temperature	T_J		-20	25	125	°C

ELECTRICAL CHARACTERISTICS

Unless otherwise stated:

- Min and Max electrical characteristics apply over normal operating conditions.
- Typical electrical characteristics apply at T_J = 25°C and I_{DD} = $I_{DDREG(TYP)}$.
- The chip is operating in RUN mode.
- Voltages are specified relative to the GND pin.

VDD Pin

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Supply voltage	V_{DDREG}	I_{DD}< $I_{DDSHUNT}$	3.4	3.45	3.5	V
	V_{DDSA}	To enter Stayalive mode		3		V
	$V_{DDSLEEP}$	To enter SLEEP mode	2.65	2.75	2.85	V
Supply current	I_{DDREG}	In RUN mode, VDD<VDD_{REG}	130	155	200	µA
	$I_{DDSLEEP}$	In SLEEP mode	17	20	23	µA
	$I_{DDSHUNT}$	VDD shunt regulator max current			2	mA

VFB Pin

Parameter	Symbol	Condition	Min	Typ	Max	Unit
VFB threshold voltage	V_{REF}	T_J= 0°C to 85°C, V_{DD}=3.45V		1.20		V
OTP selection threshold	V_{OTP}			0.5		V

CS Pin

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Constant current regulation	V_{CCREG}	DC CS signal. T_J= 0°C to 85°C	162	165	168	mV
Instantaneous over-current protection threshold	V_{OCPTHR}			600		mV

Oscillator

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Min oscillator frequency	F_{MIN}		37.5	40	43.5	kHz
Max oscillator frequency	F_{MAX}		145.5	150	154.5	kHz

TX1, TX2 Pins

Parameter	Symbol	Condition	Min	Typ	Max	Unit
On-state resistance	R_{TXON}			1	1.5	Ω
TX pin clamp current	$I_{TXCLAMP}$*	TX pin frequency >30kHz			800	mA
Start-pulse output current	$I_{TXSTART}$	TX pin voltage 2V		17		mA
Start-pulse width	$T_{TXSTART}$			800		ns

*Over-Temperature Protection (OTP)**

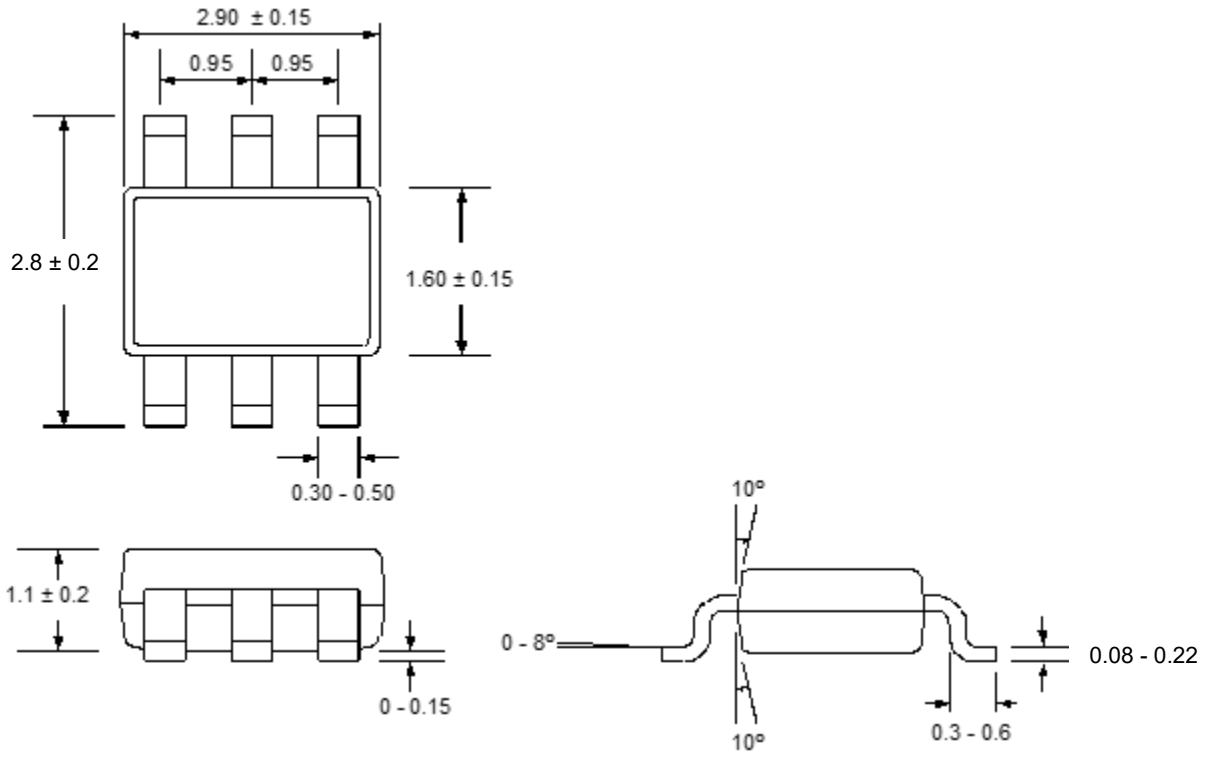
Parameter	Symbol	Condition	Min	Typ	Max	Unit
Over-Temperature Protection threshold 1	T_{OTPS1}	At silicon junction, VFB>0.5V at startup	95	105	115	°C
Over-Temperature Protection threshold 2	T_{OTPS2}	At silicon junction, VFB=<0.5V at startup	115	125	135	°C
Over-Temperature Protection reset hysteresis	T_{OTP_HYS}	At silicon junction		8		°C

*****: not tested in production*

PACKAGE INFORMATION

Package Dimensions

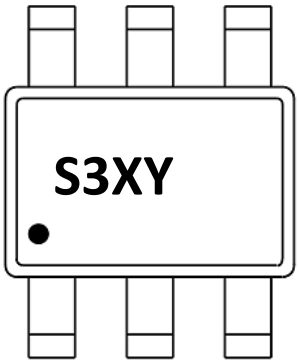
SOT23-6 package dimensions are shown below. All units are in mm.



Available packages

Package type	Part number	Moisture Sensitivity Level (MSL)	Packaging
SOT23-6	RED2545AL-TR7	3 (JEDEC J-STD-020)	Tape and reel 3000 / 7" reel

Package Marking



SOT23-6 top side marking for RED2545

S3XY:

S3 = RED2545

XY= Lot Code starting with AA, then AB, AC etc.

Status

The status of this Datasheet is shown in the footer.

Datasheet Status	Product Status	Definition
Preview	In development	The Datasheet contains target specifications relating to design and development of the described IC product.
Preliminary	In qualification	The Datasheet contains preliminary specifications relating to functionality and performance of the described IC product.
Production	In production	The Datasheet contains specifications relating to functionality and performance of the described IC product which are supported by testing during development and production.

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