# RED1502

## LLC Controller for SMPS

## Features

- Advanced LLC controller for use in combination with PPFC or APFC
- Current Mode control for improved stability & transient response
- Low Audio noise in standby, burst mode
- 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

- Passive PFC CV drivers up to 80W
- Active PFC CV drivers up to 200W
- audio supplies, adaptors, TV power

## Order code

| Part Number | Package | Packaging |
|---|---|---|
| RED1502AL-TR7 | SOT23-6 | Tape and reel |

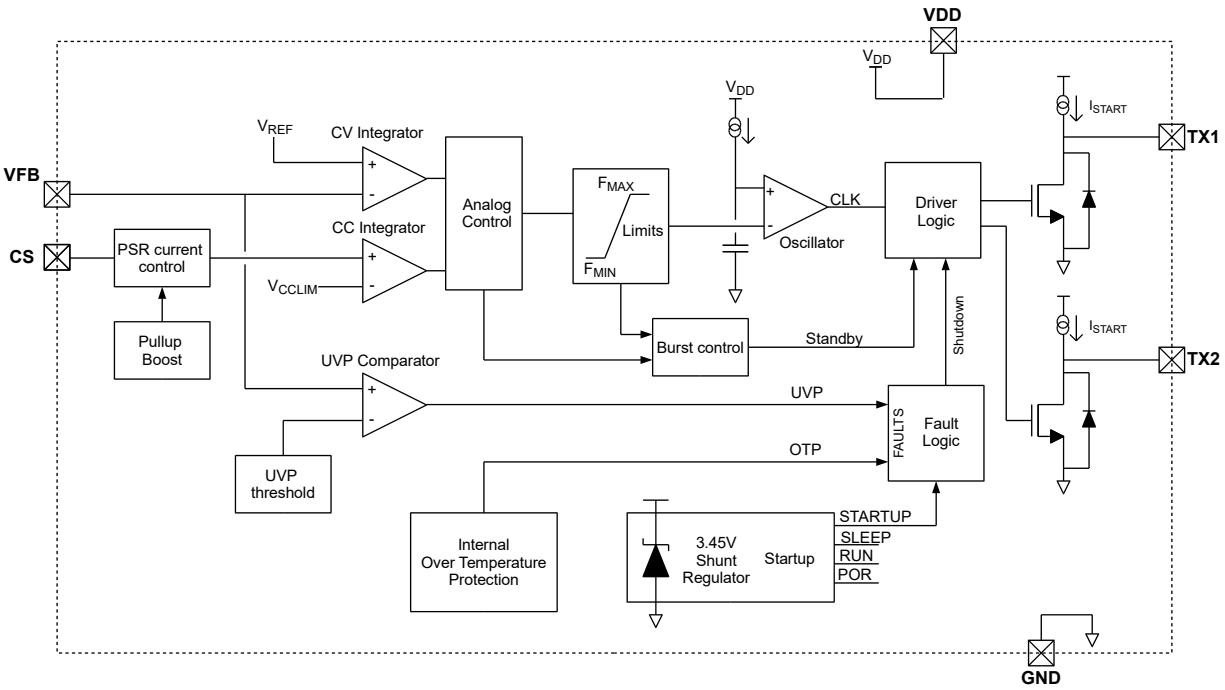



*Figure 1: Block diagram*

## Device Pins

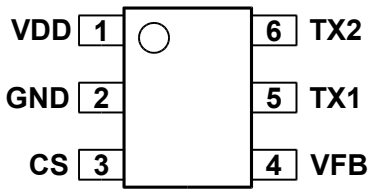



*Figure 2: SOT23-6 pin connections (top view)*

## 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

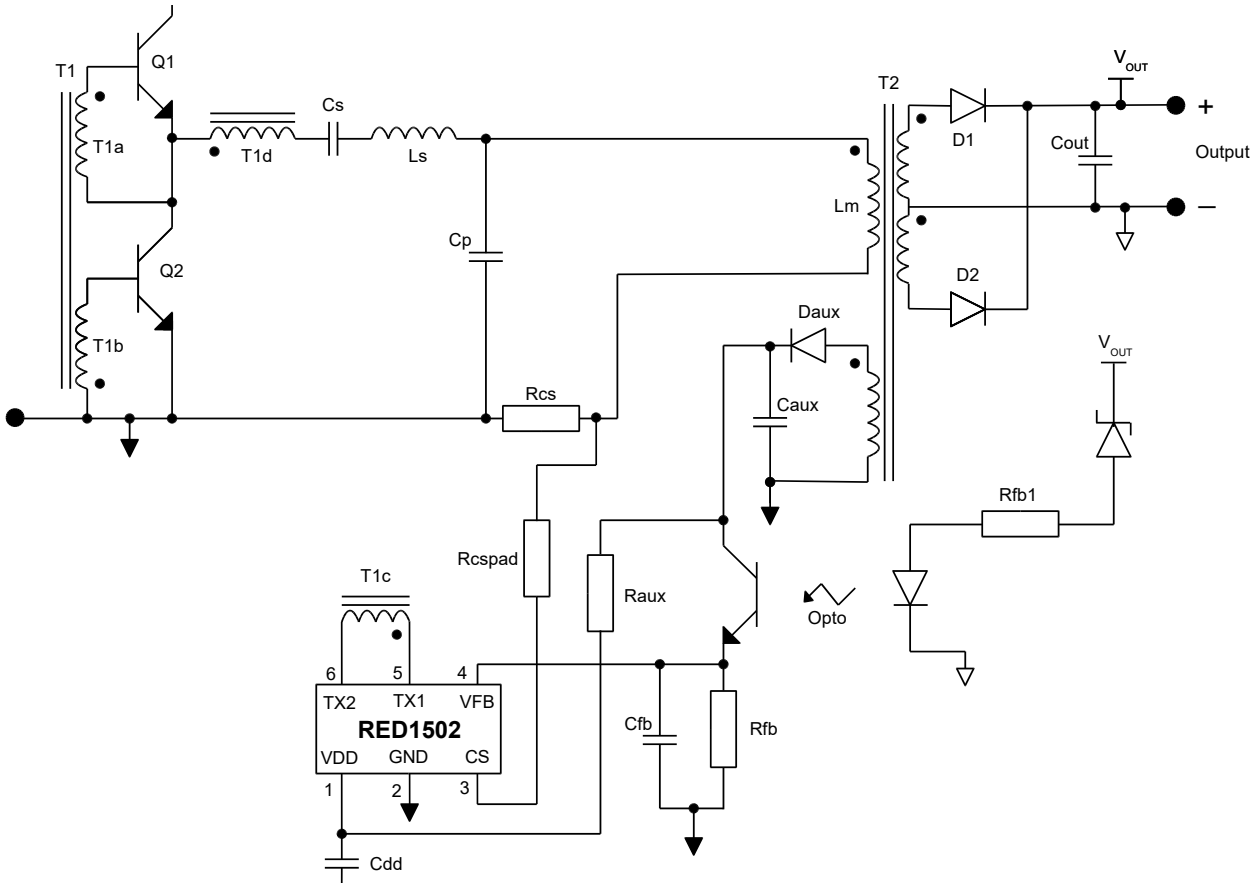



*Figure 3: Typical Application Schematic: LLC converter with RED1502 CV controller*

# Features

RED1502 is a controller specifically intended for resonant half-bridge topology. Output voltage and current regulation are obtained by modulating the frequency.

RED1502 uses the CSOC (Controlled Self-Oscillating Converter) scheme to drive two low-cost bipolar transistors in a half-bridge configuration. RED1502 based LLC converters are able to achieve much higher efficiencies than similar flyback designs.

The RED1502 PSR scheme regulates the 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 RED1502. The bipolar switching transistors are turned on correctly through the self-oscillation of the converter and turned off by RED1502. This greatly simplifies the design process and improves the robustness of the LLC converter.

### *Capacitive Mode Protection*

RED1502 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 RED1502. 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.

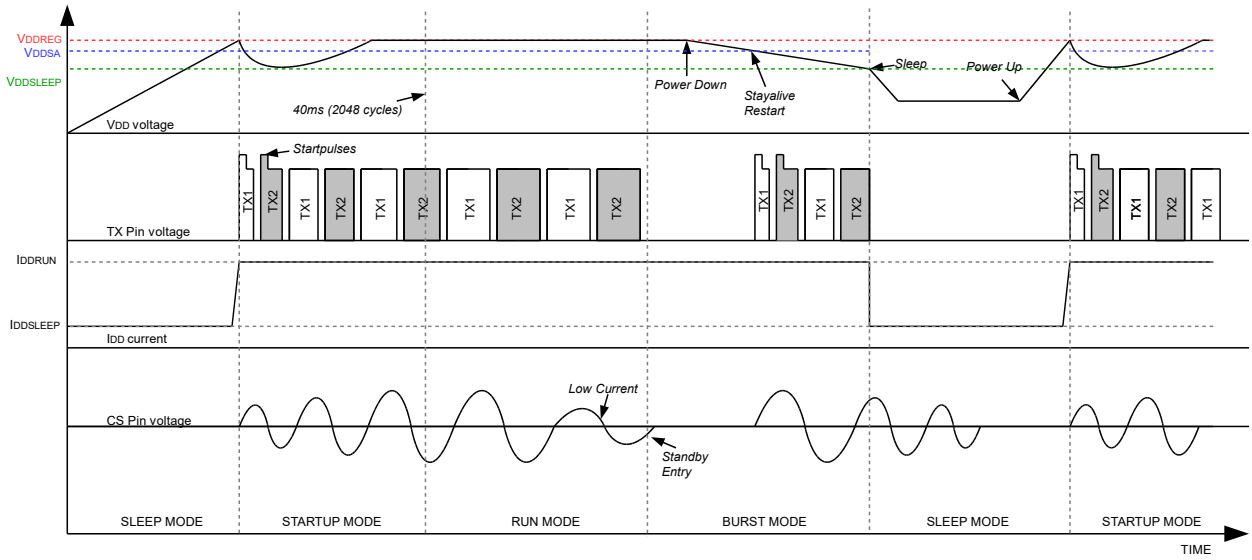



*Figure 4: IC Start-up waveforms*

### *Output stage*

A diagram of the output stage can be seen in Figure 5. To start the converter oscillating the RED1502 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.

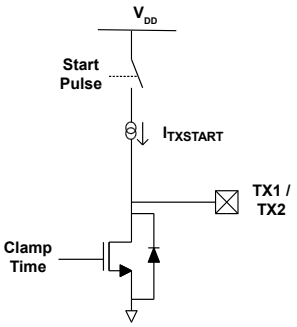



*Figure 5: Output Stage*

## 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.

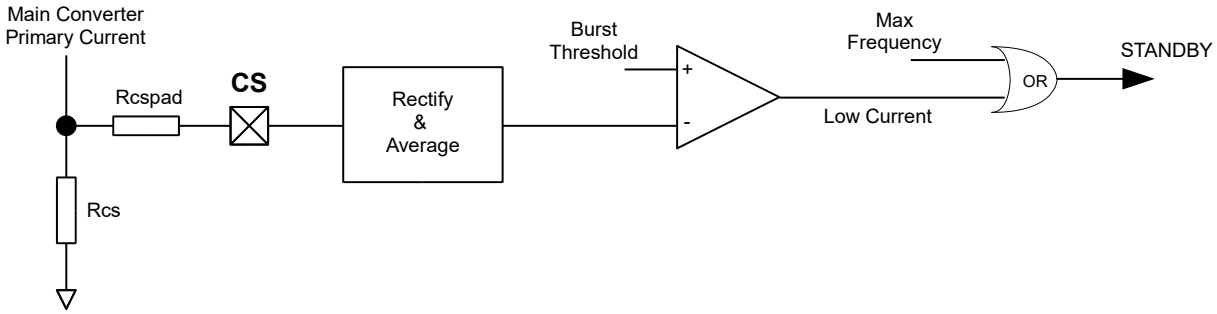



*Figure 6: Standby Entry Circuit*

## 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

RED1502 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

### 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 RED1502 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 RED1502 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 600mV ($V_{OCPTHR}$) 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)

An internal Over-Temperature Protection shuts down the controller if the IC temperature exceeds 125°C. The IC will restart 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 |

### *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)**

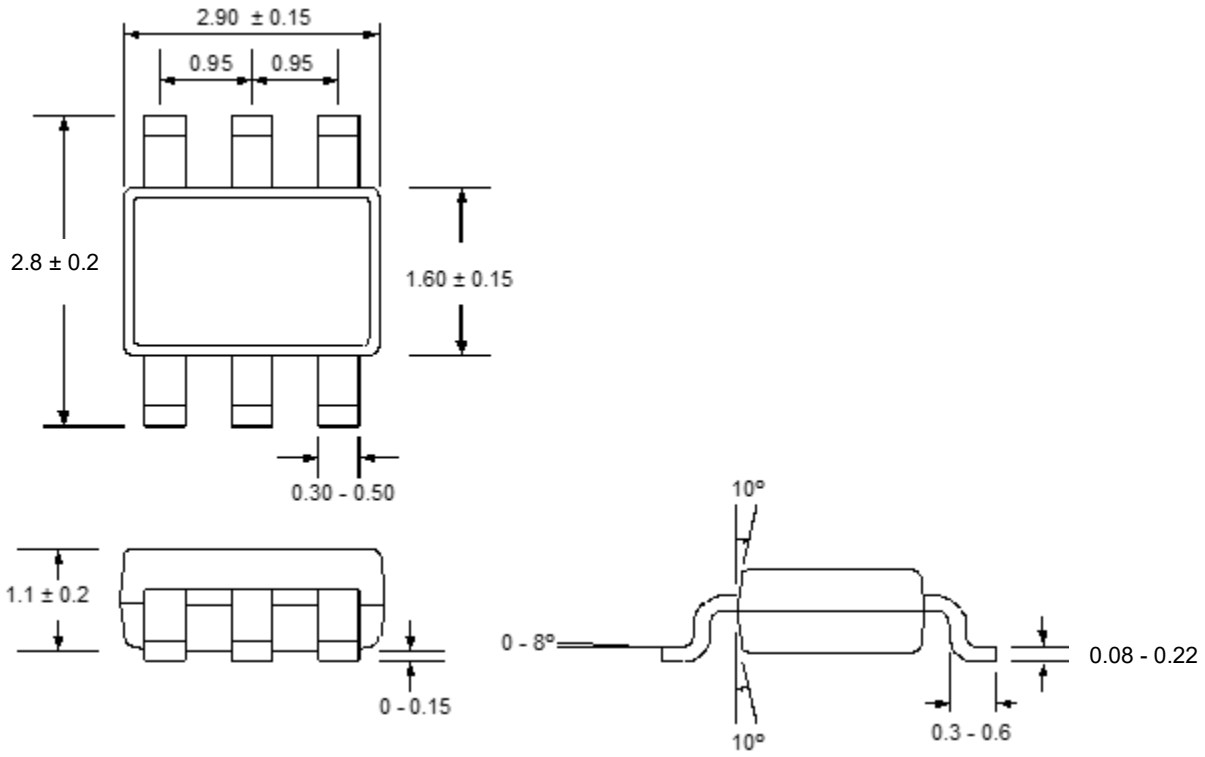
| Parameter | Symbol | Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Over-Temperature Protection threshold | $T_{OTPS}$ | At silicon junction | 115 | 125 | 135 | °C |
| Over-Temperature Protection reset hysteresis | $T_{OTP_HYS}$ | At silicon junction | | 8 | | °C |

**: not tested in production*

# PACKAGE INFORMATION

## *Package Dimensions*

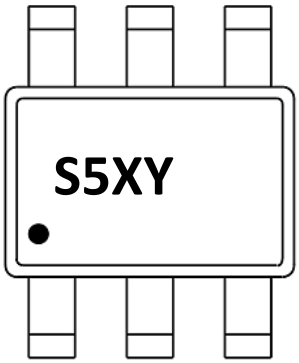
SOT23-6 package dimensions are shown below. All units are in mm.




## *Available packages*

| Package type | Part number | Moisture Sensitivity Level (MSL) | Packaging |
|---|---|---|---|
| SOT23-6 | RED1502AL-TR7 | 3 (JEDEC J-STD-020) | Tape and reel<br>3000 / 7" reel |

## *Package Marking*




**SOT23-6 top side marking for RED1502**

S5XY:

S5 = RED1502

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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