RED1544

RED1544 LLC CV Controller

Features

- High power LLC controller
- High Efficiency using rugged Bipolar power transistors
- Extra Low Standby power, burst mode
- Current Mode control for improved stability & transient response
- Protection modes:
  - Overload output including short-circuit
  - No-Load output
  - Capacitive mode protection
  - Over-Temperature
  - External NTC pin
- SO8 IC package



SO8

Applications

- Passive PFC LLC SMPS up to 400W
- Active PFC LLC SMPS up to 650W
- Ebike chargers, audio supplies, adaptors, TV power

Order code

Part Number	Package	Packaging
RED1544AD-TR13	SO8	Tape and reel

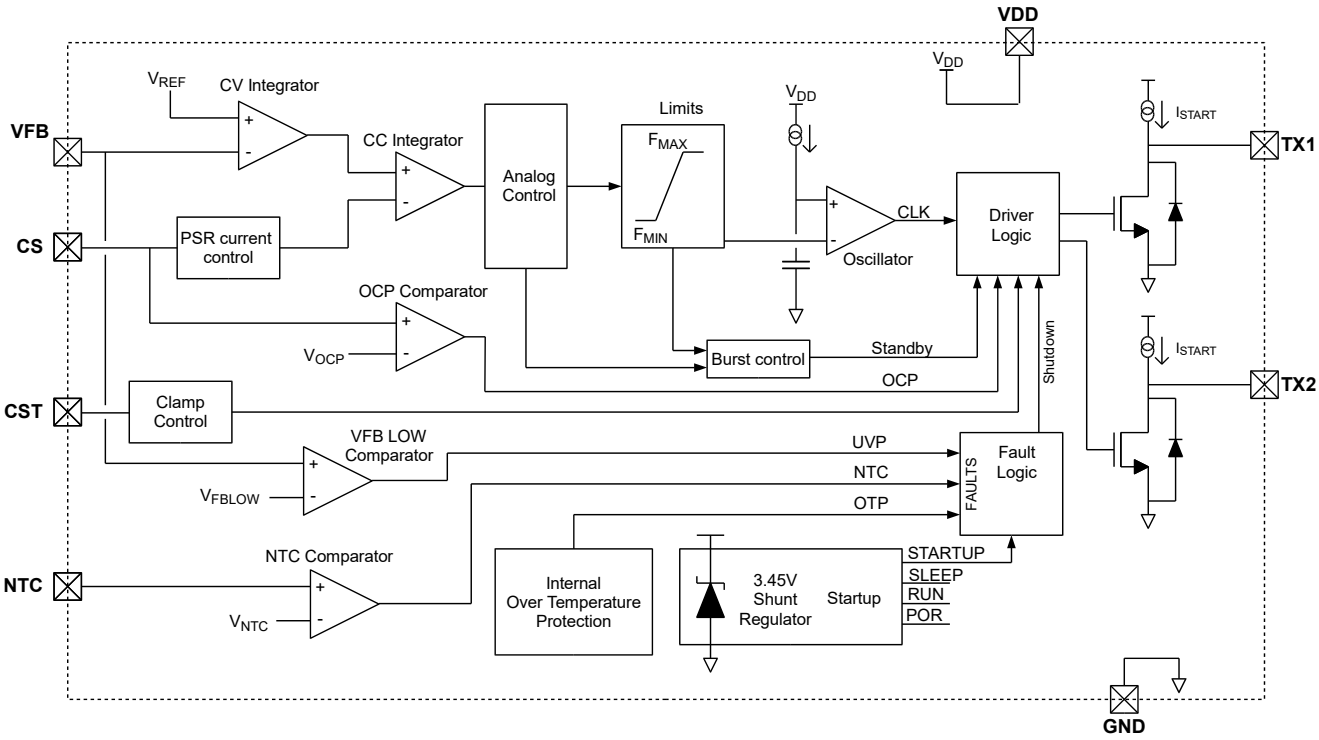


Figure 1: IC Block diagram

Device Pins

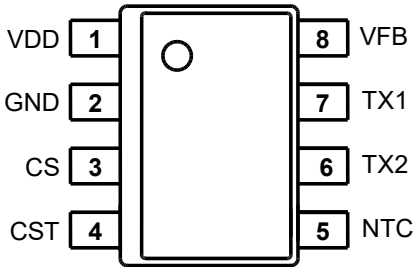


Figure 2: SO8 pin connections (top view)

Pin Functions

Pin #	Name	Function
1	VDD	IC Power Supply pin
2	GND	IC 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	CST	Total Primary current detection
5	NTC	External over-temperature sense
6	TX2	Output to control transformer
7	TX1	Output to control transformer
8	VFB	Feedback sensing for output voltage regulation

Typical Application

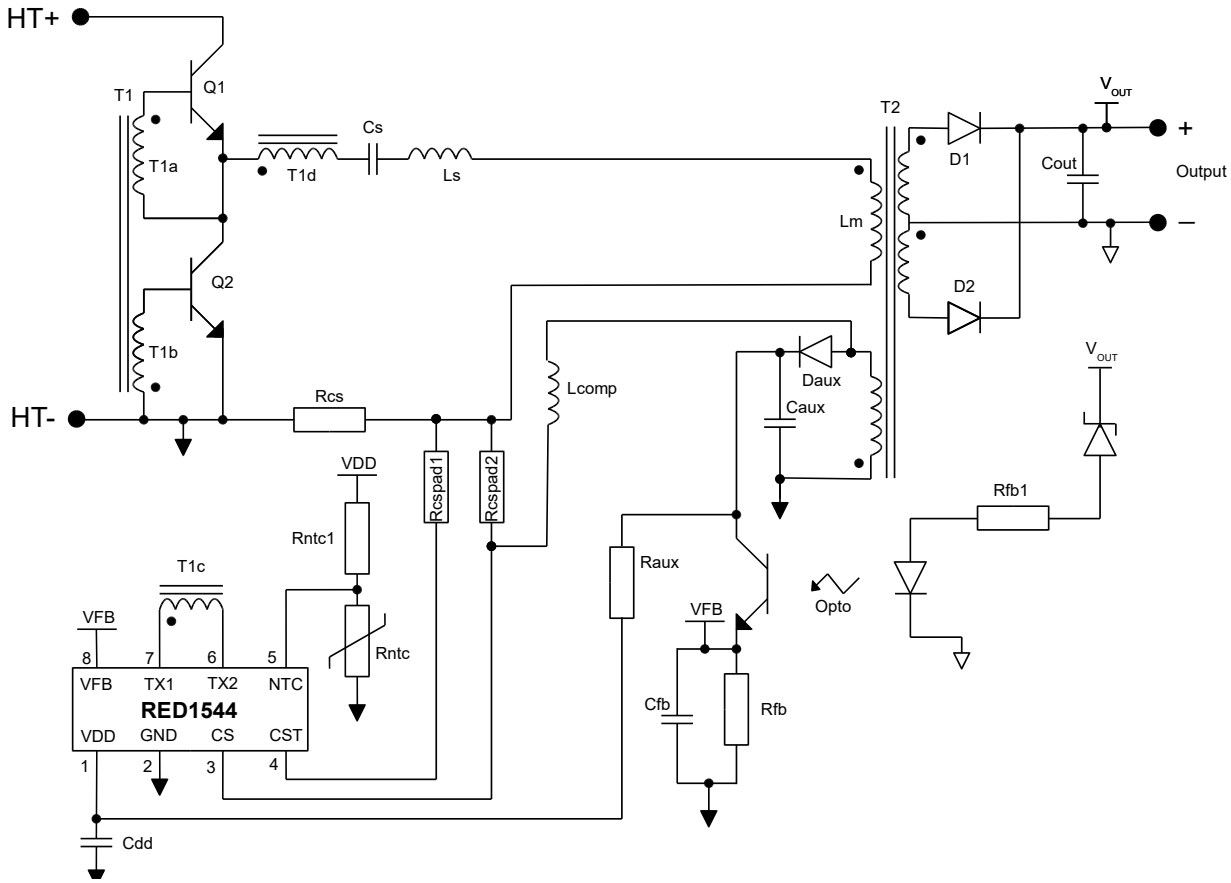


Figure 3: Typical Application Schematic: LLC converter with RED1544 CV controller

Features

The RED1544 is a controller specifically intended for resonant half-bridge topology. Output voltage and current regulation are obtained by modulating the frequency.

RED1544 uses the CSOC (Controlled Self-Oscillating Converter) scheme to drive two low-cost bipolar transistors in a half-bridge configuration. RED1544 based LLC converters are able to achieve much higher efficiencies than similar flyback designs.

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 average primary-side current.

A current sense input, CS, provides constant current (CC) operation by varying the frequency. The CC level is pre-set to value derived from the average primary-side current. The pin also includes instantaneous cycle-by-cycle overcurrent protection (OCP). The OCP threshold is pre-set to a value derived from the peak primary-side current.

An internal over-temperature protection (OTP) feature shuts down the controller if the IC temperature exceeds the pre-set threshold. The NTC pin also provides external temperature sensing and overtemperature shutdown.

Feedback control is via the VFB pin, which also includes protection by shutting down the controller if the feedback signal is lost. This pin can also be used for sensing an output overvoltage or undervoltage.

IC Operation

Start-up, Shutdown and Re-start

Figure 4 shows typical start-up waveforms for RED1544. 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 165uA (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 back to 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.

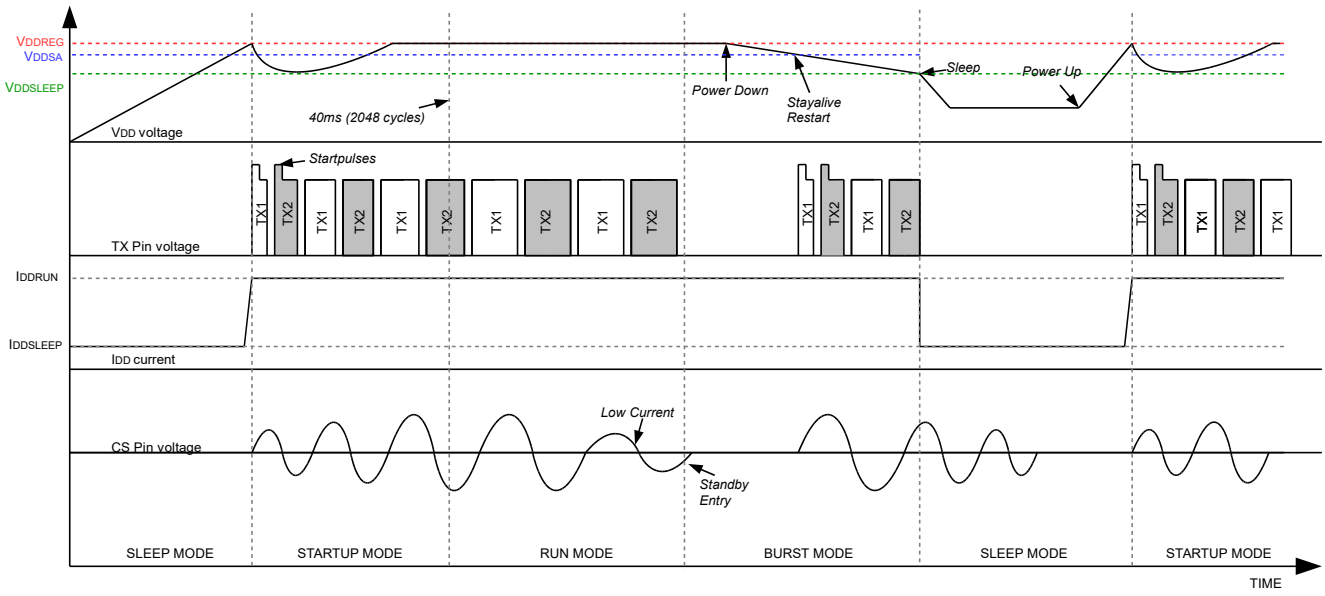


Figure 4: IC Start-up waveforms

Output stage

A diagram of the output stage can be seen in Figure 5. To start the converter oscillating the RED1544 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 on to pull TX pin low, which switches off the corresponding bipolar transistor in the power converter half-bridge.

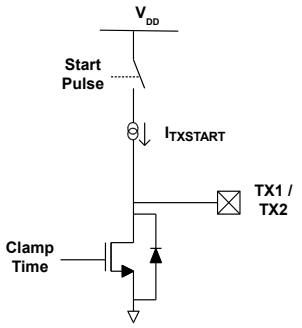


Figure 5: Output Stage

Constant Voltage control (CV mode)

The IC regulates the output voltage on VFB pin. The internal feedback network defines the loop gain and phase for the voltage control loop. This network should be configured to form an integrator with lead compensation and some high-frequency noise suppression. The VFB input senses the output voltage through a simple external control loop using a secondary side reference (e.g. TL431) and an optocoupler. This signal is compared to a fixed voltage reference of 1.2V (V_{REF}) inside the IC. The IC regulates the output voltage by controlling the operating frequency.

Current Mode control (CC mode)

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 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.

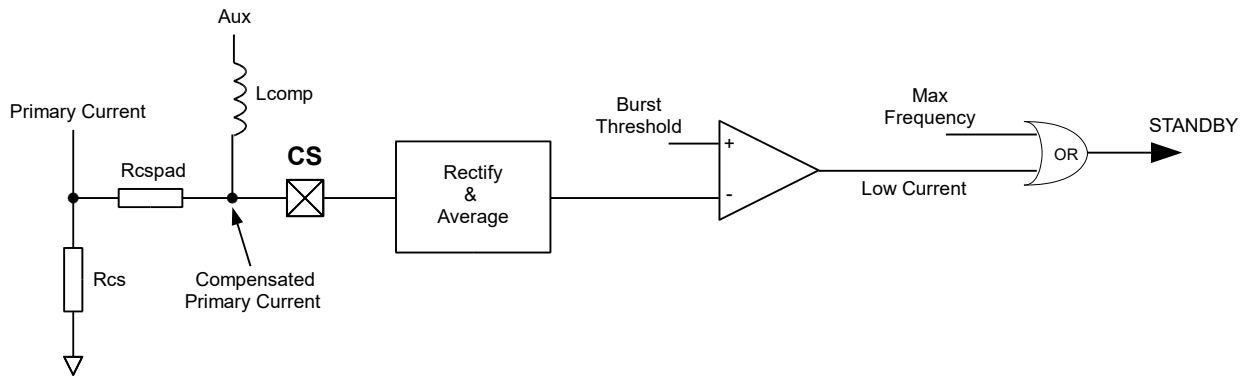


Figure 6: Standby Entry Circuit

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 internally set to approximately 10% of rated load current. 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

RED1544 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, with the converter off, 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.

Constant Current Regulation on CS pin

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

Oscillator

The RED1544 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.

Clamp control

The RED1544 senses primary current through CST pin to control TXs clamping release during zero current crossing to optimize the switching loss on BJTs.

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 RED1544. The bipolar switching transistors are turned on correctly through the self-oscillation of the converter and turned off by RED1544. This greatly simplifies the design process and improves the robustness of the LLC converter.

Inherent Capacitive Mode Protection

The self-oscillating converter is inherently unable to sustain oscillation in capacitive switching mode and is therefore simpler to design than comparable MOSFET-based solutions. The RED1544 includes TXs capacitive mode protection feature which prevents the converter from entering capacitive switching mode on a cycle-by-cycle basis by limiting TXs pulse width.

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.

VFB Low Protection

During output under voltage condition, primary VFB drop below 300mV(V_{FBLOW}). The RED1544 detects the VFB low faults and shutdown TXs pulses and reset the chip.

Over-Temperature Protection & NTC

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. NTC pin is also offered for external over-temperature sensing.

External NTC sensing

RED1544 features an NTC pin to interface with an external over-temperature circuit as shown in figure 7. The NTC pin is biased by an external R_{NTC1} and R_{NTC} featuring a Negative Temperature Coefficient resistor (NTC). An internal comparator determines the NTC pin trip point.

The external NTC circuit should be filtered with decoupling capacitor C_{FILTER} and biased so that under normal operation, the voltage V_{NTC} on the NTC pin is above the trip-point where $V_{NTC} = VDD * R_{NTC}/(R_{NTC1}+R_{NTC})$. The NTC pin is blanked for approximately 500us at IC start-up to avoid any spurious triggering while the external NTC circuit is settling. When the converter heats up, the NTC resistance decreases. After the NTC pin voltage drops below the trip-point V_{NTC}, the IC will shut the converter down and restart provided that the converter has cooled down and the NTC pin voltage has increased.

With the appropriate selection and placement of the NTC circuit, it is possible to achieve accurate over-temperature shutdown anywhere on the converter PCB.

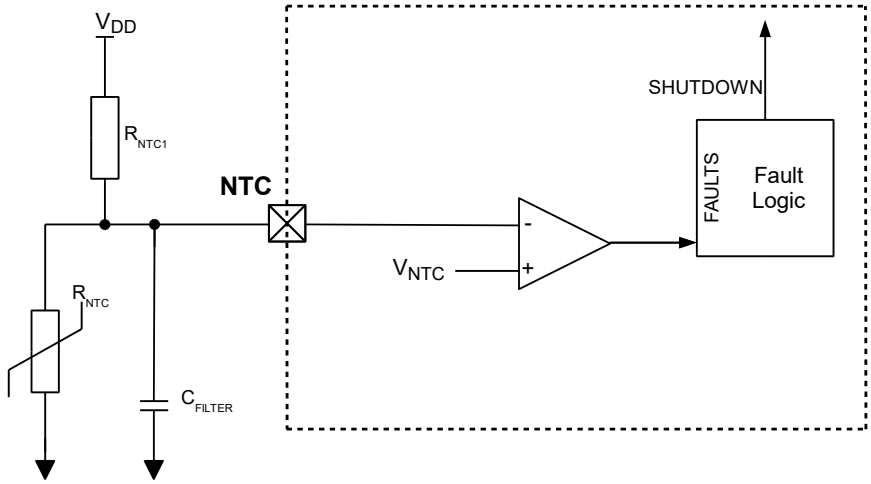


Figure 7: RED1544 NTC pin circuit

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}		210			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	165	210	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
VFB low threshold voltage	V_{FBLOW}	T_J= 0°C to 85°C, V_{DD}=3.45V		0.3		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_{OCP}*			600		mV

CST Pin

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Tx pin clamp release threshold	V_{CLAMP}			±45		mV

Oscillator

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Min oscillator frequency	F_{MIN}			52		kHz
Max oscillator frequency	F_{MAX}			160		kHz

TX1, TX2 Pins

Parameter	Symbol	Condition	Min	Typ	Max	Unit
On-state resistance	R_{TXON}			0.5	1	Ω
TX pin clamp current	$I_{TXCLAMP}$*	TX pin frequency >30kHz			1600	mA
Start-pulse output current	$I_{TXSTART}$	TX pin voltage 2V		34		mA
Start-pulse width	$T_{TXSTART}$			800		ns

NTC Pin

Parameter	Symbol	Condition	Min	Typ	Max	Unit
NTC Threshold	V_{NTC}	High to low transition		450		mV
Hysteresis	V_{HYS}			35		mV

*Over-Temperature Protection (OTP)**

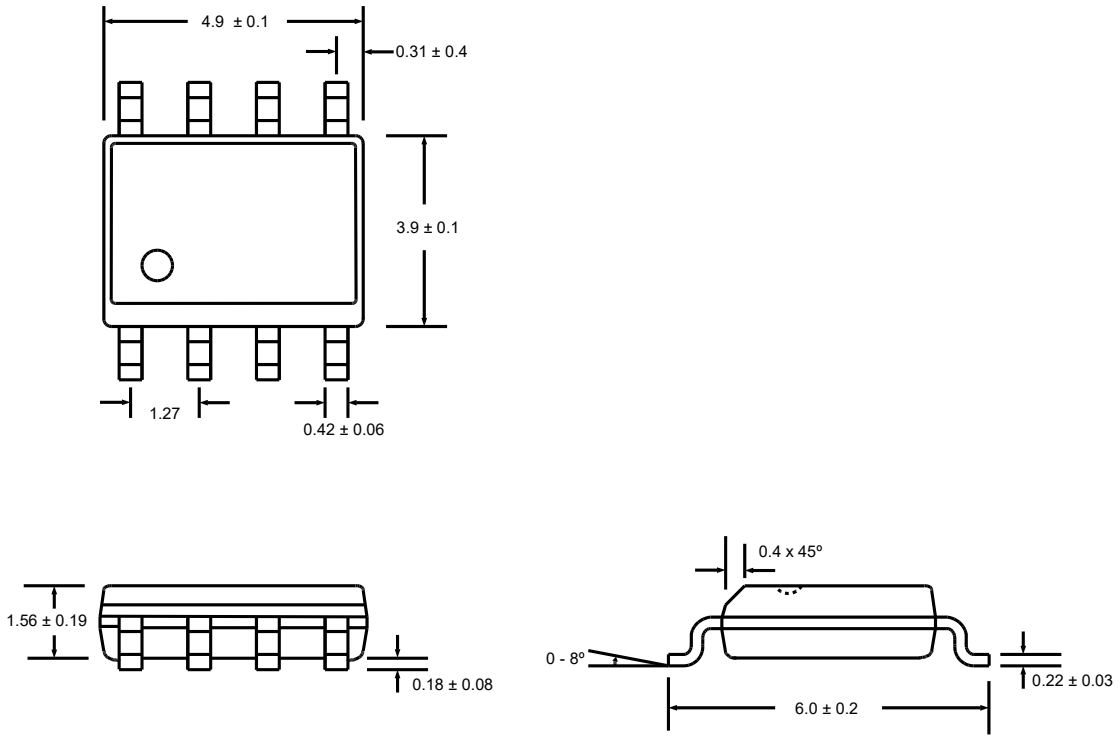
Parameter	Symbol	Condition	Min	Typ	Max	Unit
Over-Temperature Protection threshold	T_{OTPS}	At silicon junction	115	125	135	°C
Over-Temperature Protection reset hysteresis	T_{OTP_HYS}	At silicon junction		8		°C

**: not tested in production*

PACKAGE INFORMATION

Package Dimensions

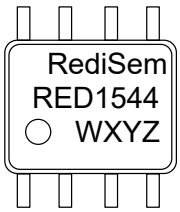
SO8 package dimensions are shown below. All units are in mm.



Available packages

Package type	Part number	Moisture Sensitivity Level (MSL)	Packaging
SO8	RED1544AD-TR13	3 (JEDEC J-STD-020)	Tape and reel 2500 / 13” reel

Package Marking



SO8 top-side marking for RED1544

RED1544= Part Number

WXYZ= Lot Code, e.g. AAAA, AAAB

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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