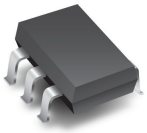
RED2101

Controller IC for Bipolar Transistor CFLs

Features

- Long lamp life >15,000 hours
- Low-cost bipolar transistor CFL circuit
- Controlled preheat current
- <1s preheat time
- Controlled ignition ramp
- Lamp power limit at high mains
- Capacitive mode detection
- Automatic dead-time control
- Reduced lamp component size and cost
- Micropower operating current (0.5mA)
- Ultra-small SOT23-6 package



SOT23-6

Applications

- Long-life Compact Fluorescent Lamps
- Power up to 25W with TO92 transistors

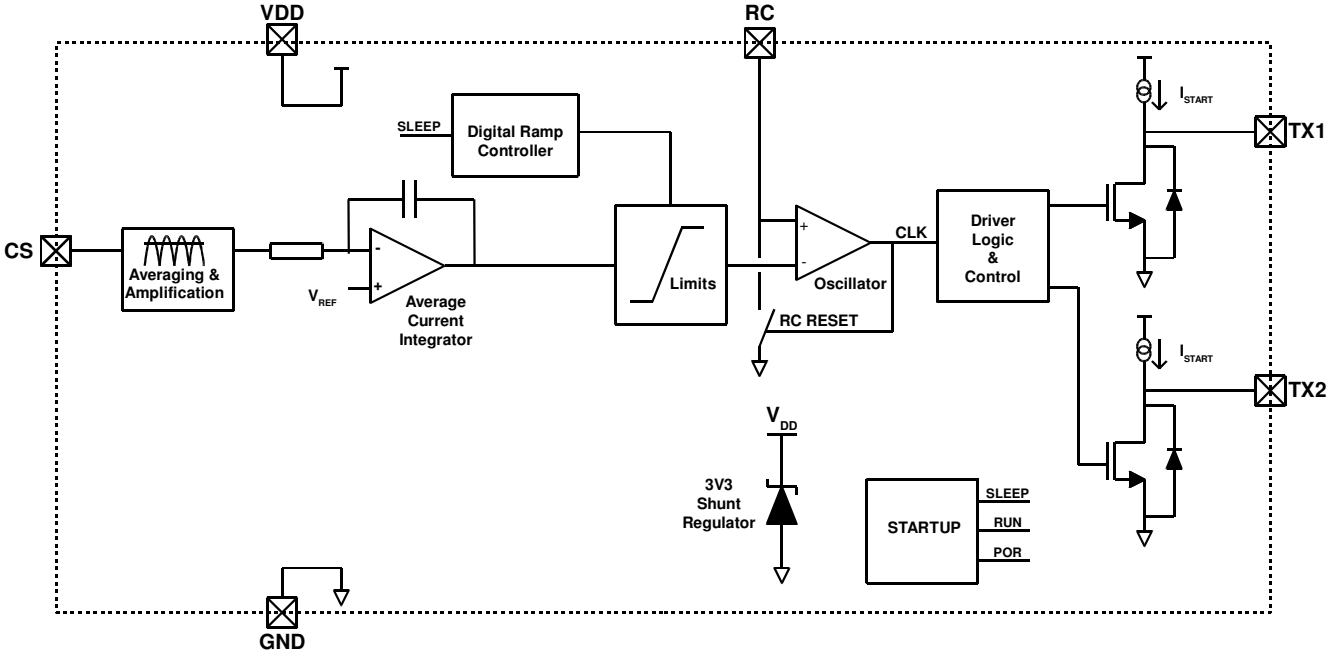


Figure 1: Block Diagram

RED2101 Device Pins

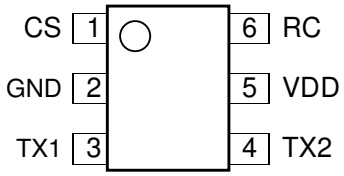


Figure 2: SOT23-6 pin connections (top view)

RED2101 Pin Functions

Pin #	Name	Function
1	CS	Current sense input for preheat current control and protection features
2	GND	Chip ground.
3	TX1	Output to base drive transformer
4	TX2	Output to base drive transformer
5	VDD	This pin provides power to the IC. Connect a 470nF capacitor between VDD and GND (pin 2)
6	RC	External RC network sets the minimum switching frequency. 30k, 330p = 40kHz

RED2101 Application Overview

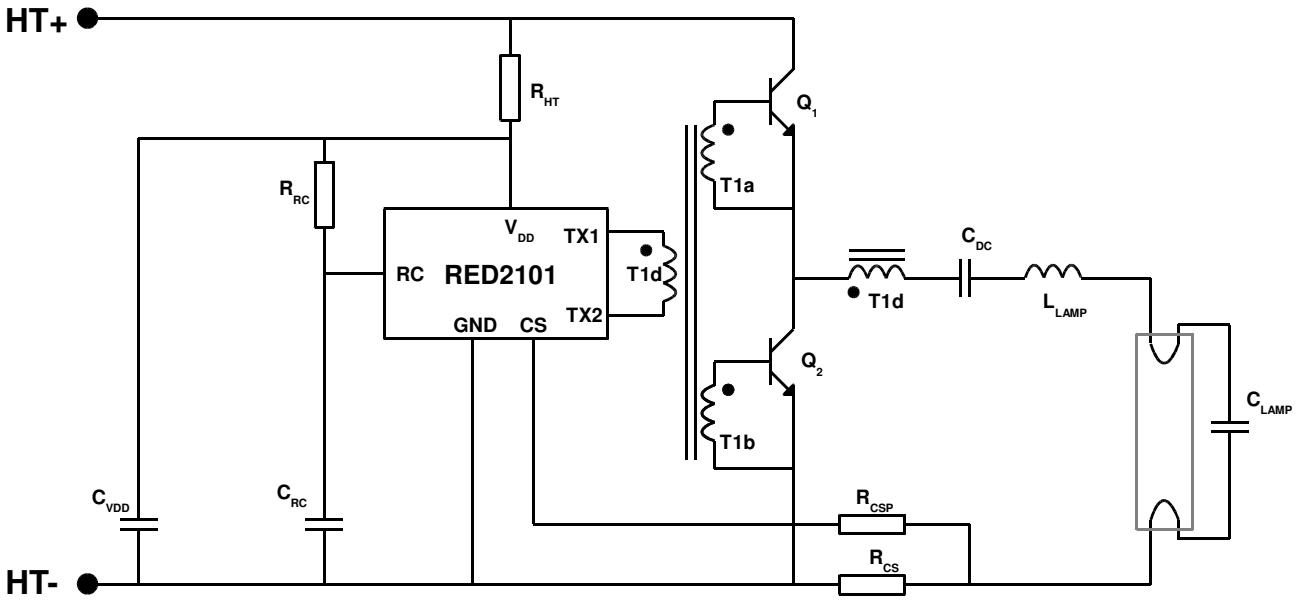


Figure 3: RED2101 Application diagram

The RED2101 is a controller IC specific for compact fluorescent lamps (CFLs) with integrated ballast. Unlike other controller ICs RED2101 has been designed to work in a standard low-cost CFL circuit with bipolar transistors lamps using patented CSOC (Controlled Self-Oscillating Converter) topology.
The lamp operating modes (start, preheat, ignition, run) are all controlled by the IC. The lamp current is controlled by modulating the operating frequency of the half-bridge.
More than 15,000hrs of CFL life can be achieved with RED2101 through accurately preheating and igniting the lamp. At high mains voltages the lamp power is limited to protect the lamp and preserve lamp life.

CSOC base drive technology
RED2101 uses patented CSOC (Controlled Self Oscillating Converter) technology to drive bipolar transistors in a standard half-bridge series LC converter used for fluorescent lamps. This type of ballast circuit uses robust low cost bipolar transistors along with a simple base drive transformer that provides the bulk of the base drive to turn the transistors on. The converter naturally self-commutates and the IC used to force the end of each commutation cycle to control the frequency.
CSOC technology does not suffer from many of the problems associated with MOSFET ballasts, such as dead-time and capacitive switching as these are automatically controlled by the IC.
CSOC drive technology allows smaller bipolar transistors to be used. For a 20W spiral CFL small 1A TO92 13002 transistor types are sufficient.

RED2101 Operation

IC Startup & Power Supply

The startup and operating current of the RED2101 is supplied through R_{HT}. Figure 5 shows typical waveforms for the IC at startup. In SLEEP mode the IC and transistors are off and an I_{DD} of 0.5mA ($I_{DDSLEEP}$) is required to pull the V_{DD} pin voltage up to 3.6V ($V_{DDSTART}$). The IC then starts and a controlled zener clamp inside the IC regulates the V_{DD} voltage down to 3.3V (V_{DDREG}). The IC operating current is nominally 0.5mA (I_{DDRUN}) plus any excess current that is required to clamp V_{DD} to 3.3V. If power is removed from the CFL and V_{DD} falls below 2.7V ($V_{DDSLEEP}$), the IC enters SLEEP mode and will only restart if sufficient $I_{DDSLEEP}$ is supplied to reach $V_{DDSTART}$.

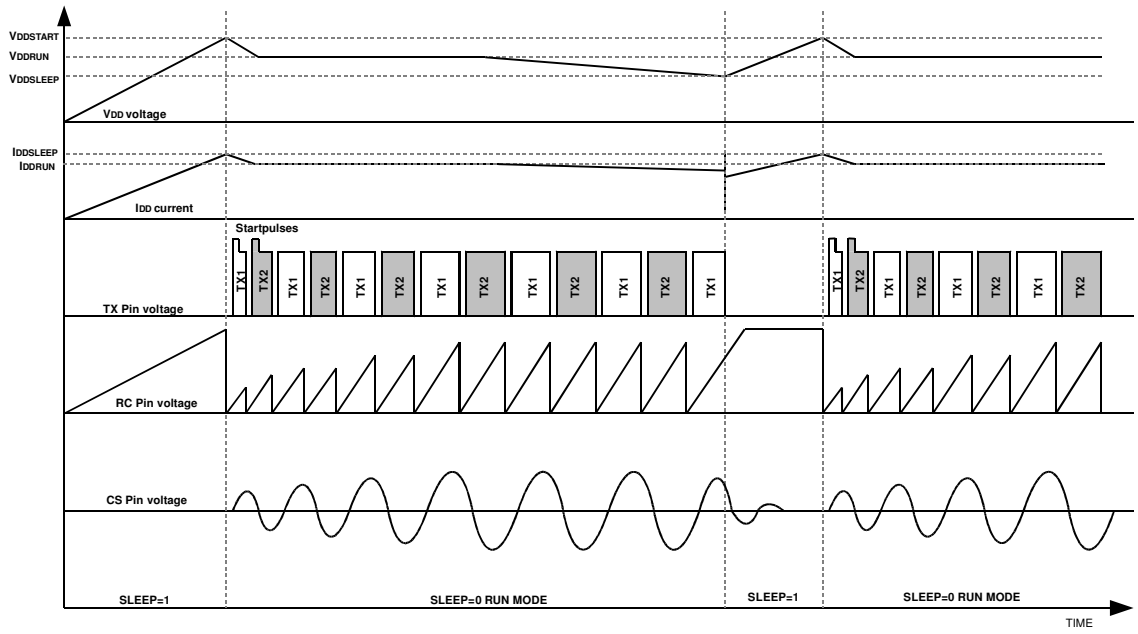


Figure 4: RED2101 Startup waveforms

Start Ramp

When RED2101 turns on it issues start current pulses via the base drive transformer T1 to switch the bipolar transistors Q1 & Q2 on and off. The initial operating frequency (F_{START}) is high (about 85kHz) to allow time for the series resonant tank components to settle down. In Start mode the switching frequency is ramped down for approximately 50ms until the average voltage on the CS pin reaches its control value V_{CSPH} (200mV).

If during start mode the half-bridge stops oscillating, the IC will automatically re-start the oscillations by re-issuing start pulses. During this time the frequency is continually reduced along the start ramp. This ensures that the lamp is always reliably started.

Preheat

At the end of the start-ramp RED22011 goes into Preheat mode and controls the lamp filament current. Preheat current is controlled by varying the switching frequency. The IC senses the voltage at the CS pin and adjusts the half-bridge frequency to control the average current. The current control circuit is inside the IC, the only component required to set the preheat current is resistor R_{cs}. The following equation shows how to choose R_{cs} (Ω).

$$R_{CS} = \frac{0.22}{I_{PH}}$$

Where I_{PH} is the required RMS preheat current of the lamp. R_{cs} will typically vary from 2 Ω for a small lamp down to 0.3 Ω for two large lamps. During preheat the minimum switching frequency is limited to 55kHz (V_{RCPH_MAX}=1.65V) to avoid early ignition.

The current averaging circuit, control loop and compensation components are all internal to RED2101. The preheat time is set inside RED2101 by a timer that counts the number of oscillator cycles from IC start-up. When the preheat timer overflows the Ignition mode is started. In preheat the switching frequency

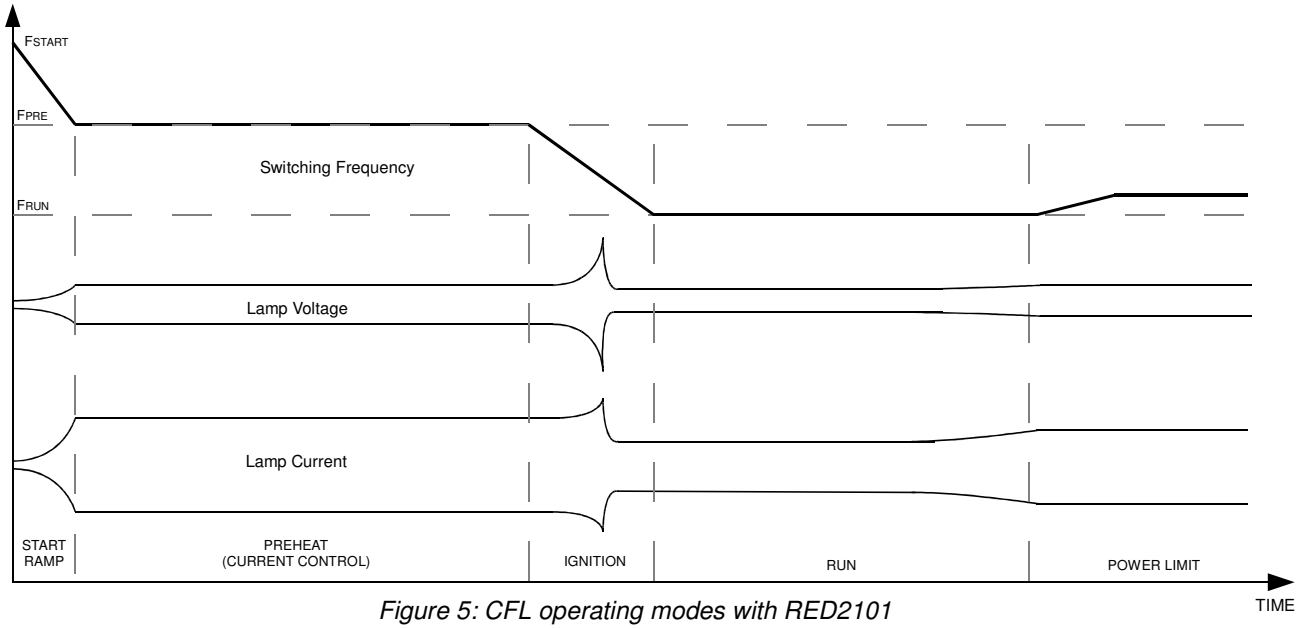


Figure 5: CFL operating modes with RED2101

Ignition

At the beginning of the ignition ramp frequency is slowly reduced at a fixed rate, which increases the voltage across the lamp. When the voltage across the lamp is sufficiently high it is ignited and starts to burn. The switching frequency continues ramping down to a minimum frequency F_{MIN}.

RED2101 automatically adjusts the bipolar transistor drive circuit to make sure that even with heavily saturated lamp inductors the half-bridge keeps switching and the lamp is reliably ignited. This feature enables very small inductors to be used as saturation during lamp ignition is not an issue for a RED2101 based CFL. Heavily saturated inductors normally damage MOSFETs in conventional circuits.

Run

Once F_{MIN} is reached RED2101 is in Run mode. The minimal operating frequency of the CFL is programmed by C_{RC} and R_{RC} connected to the RC oscillator pin. The run frequency F_{MIN} can be calculated as follows:

$$F_{MIN} = \frac{1}{(2.4 \times R_{RC} \times C_{RC} + 0.8us)}$$

The resonant tank components L_{lamp} and C_{lamp} need to be chosen appropriately to ensure the correct lamp voltage in preheat and run modes. It is recommended that a 330pF, 5% COG capacitor is used for C_{RC}. For 40 kHz operation choose R_{RC} to be 30 kΩ.

Lamp Power limit

The average current control circuit is activated in RUN mode. This enables the user to set a maximum lamp current, which is useful to limit maximum lamp power and temperature for safer lamp designs. Once the maximum lamp current level has been reached, for example due to an ageing lamp or high mains voltages, RED2101 will automatically adjust the half-bridge frequency to keep the average lamp current at this level. Resistor R_{CSP} (Ω) sets this maximum RUN current and can be calculated using the equation:

$$R_{CSP} = (7.6 \times I_{RUN\_max} \times R_{CS}) - 1100$$

where I_{RUN_max} is the desired maximum RMS lamp current in mA, R_{CS} is the current sense resistor previously calculated for preheat current control. The recommended range for R_{CSP} is 47 Ω to 1kΩ. All RUN current control components and loop compensation are internal to RED2101.

Capacitive Mode Protection

RED2101 features adaptive capacitive mode protection that automatically increases the operating frequency away from capacitive mode operation. This feature allows CFLs to operate down to low mains voltages, when capacitive mode operation occurs, or can significantly reduce bulk capacitor size for a given operating voltage range.

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}		-0.5	4.0	V
Supply current	I_{DD}		-10	10	mA
Input/output voltage	V_{IO}		-0.5	V_{DD} + 0.5	V
Input/output current	I_{IO}		-10	10	mA
Junction temperature	T_J		-25	150	℃
Storage temperature	T_P		-40	150	℃
Lead temperature	T_L	Soldering 10 s		260	℃

NORMAL OPERATING CONDITIONS

Unless otherwise stated, electrical characteristics are defined over the range of normal operating conditions. Functionality and performance is 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
Supply current	I_{DD}	V_{DD} shuntreg off (V_{DD} < V_{DDREG})	0.5	0.6	0.8	mA
Full-Power (minimum) switching frequency	F_{NOM}	R_{RC} = 30k; C_{RC}=330p		40		kHz
Junction temperature	T_J			25		℃

ELECTRICAL CHARACTERISTICS

Unless otherwise stated:

- Min and Max electrical characteristics apply over normal operating conditions.
- Typical electrical characteristics apply at $T_J = T_{J(TYP)}$ 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_{DDRUN}	To enter RUN mode	3.2	3.6	4.0	V
	V_{DDREG}	In RUN mode	3.1	3.3	3.5	V
	$\Delta V_{DDSLEEP}$	To enter SLEEP mode (measured relative to V_{DDREG})		-600		mV
Supply current	I_{DDREG}	In RUN mode, $V_{DD} < V_{DDREG}$	0.5		0.8	mA
	$I_{DDSLEEP}$	In SLEEP mode	0.3		0.6	mA

CS Pin

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Average current regulation threshold voltage - preheat	V_{CSPH}	CS pin series resistor 47R, squarewave	240	265	290	mV
Average current regulation threshold voltage - run	V_{CSRUN}	Variable level set by resistor R_{CSP}	160		300	mV
CS input leakage current	I_{CSBIAS}	$V_{DD} > V_{CS} > (V_{GND} - 0.2\ V)$			10	µA

RC Pin

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Start Frequency	F_{START}	C_{RC}=330pF, R_{RC}=30kΩ	100	110	120	kHz
Start Frequency down ramp*	dF/dt_{start}	C_{RC}=330pF, R_{RC}=30kΩ		0.3		kHz/ms
Start ramp time	T_{ST}	C_{RC}=330pF, R_{RC}=30kΩ, f_{PH}=55kHz		50		ms
Ignition Frequency down ramp	dF/dt_{ign}	C_{RC}=330pF, R_{RC}=30kΩ		0.2		kHz/ms
Run Frequency	F_{RUN}	C_{RC}=330pF, R_{RC}=30kΩ .		40		kHz
Preheat Frequency Range	F_{PHX}	C_{RC}=330pF, R_{RC}=30kΩ .	55		120	kHz

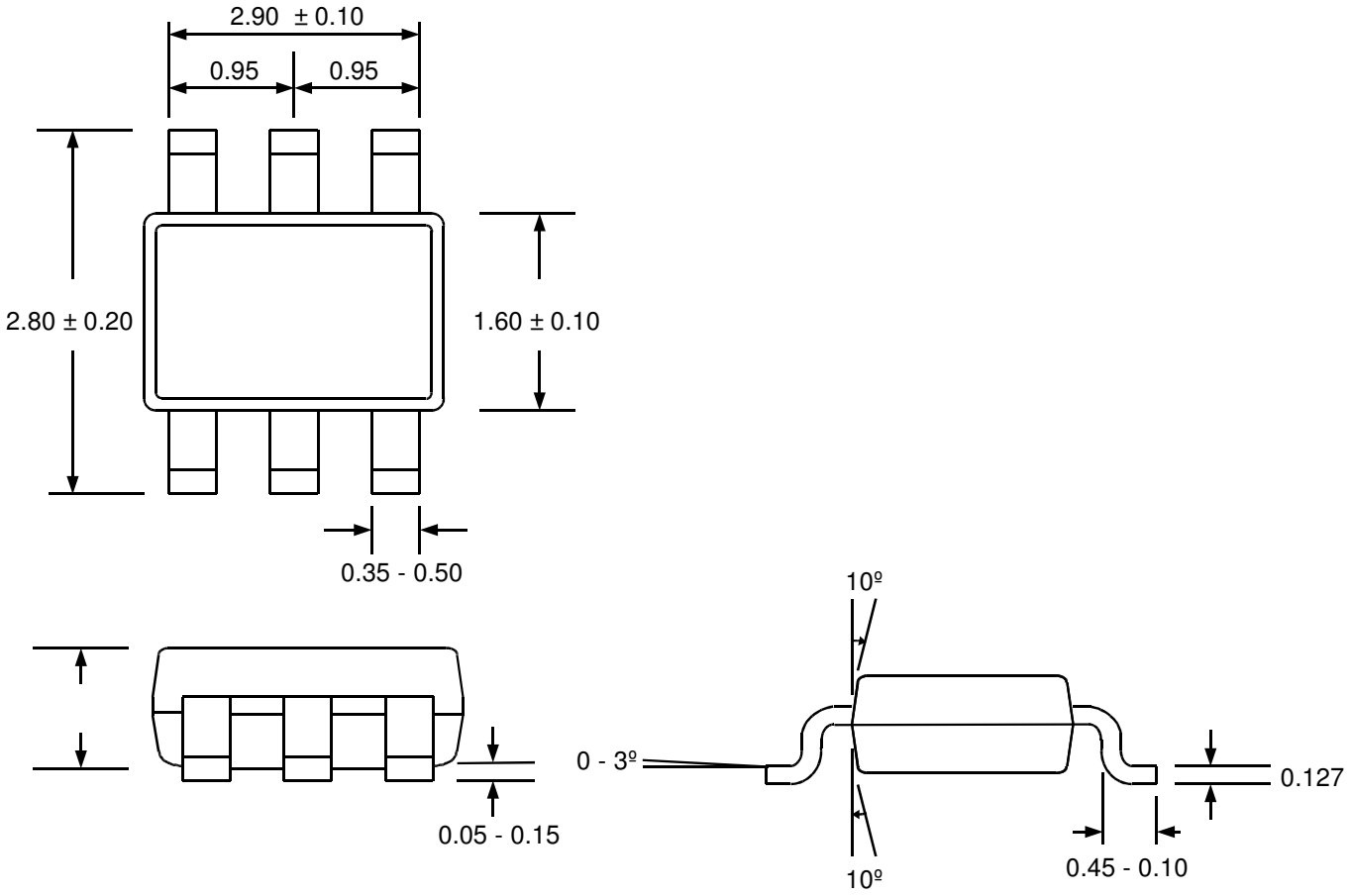
TX1, TX2 Pins

Parameter	Symbol	Condition	Min	Typ	Max	Unit
On-state resistance	R_{TXON}				5	Ω
Off-state current	I_{TXOFF}	$V_{DD} > V_{TX} > V_{GND}$			10	µA

PACKAGE INFORMATION

Package Dimensions

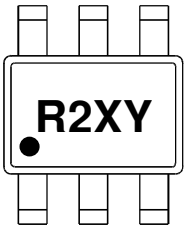
SOT23-6 package dimensions are shown below. All units are in mm.



Available packages

Package type	Part number	Moisture Sensitivity Level (MSL)	Packaging
SOT23-6	RED2101AL-TR7	3 (JEDECJ-STD-020)	Tape and reel 3000 / 7" reel

Package Marking



Part numbering for RED2101

R2AA:
R2 = RED2101
XY= Lot Code, e.g. AA, AB

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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