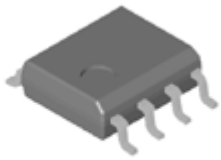
RED4201

RED4201 Boost PFC Controller

Features

- High power factor & low THD
- Wide input voltage range
- No noise during startup/load switching
- Enhanced Error Amplifier with excellent dynamic performance
- Strong driving capability (±1A)
- Integrates chip enable pin, low standby power consumption
- Supports CRM and DCM, stable output voltage under light load
- High internal reference voltage accuracy: ±2%
- Protection modes:
  - Output over-voltage protection
  - FB short circuit protection
  - Cycle-by-cycle over-current protection
  - Over-temperature protection
  - VCC UVLO / clamp



Small SO8 package

Applications

- Active PFC applications
- LED drivers
- Switched-mode power supplies

Order code

Part Number	Package	Packaging
RED4201AD-TR13	SO8	Tape and reel

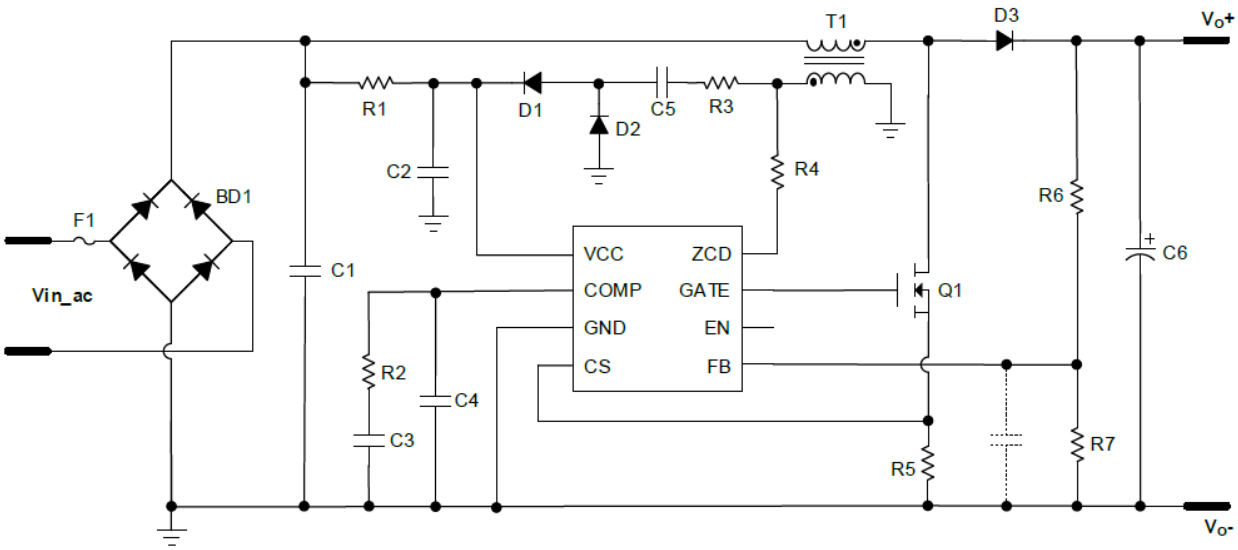


Figure 1: Typical application circuit

Device Pins

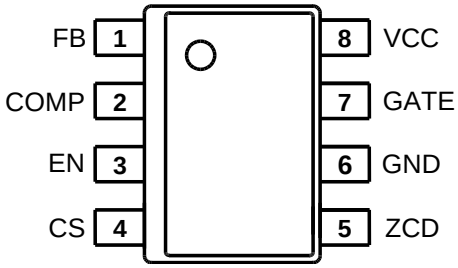


Figure 2: SO8 pin connections (top view)

Pin Functions

Pin #	Name	Function
1	FB	Output voltage feedback pin.
2	COMP	Voltage loop compensation pin.
3	EN	Chip enable pin.
4	CS	Current sense pin.
5	ZCD	Zero-crossing detection pin.
6	GND	Chip ground.
7	GATE	Gate drive of external power MOSFET.
8	VCC	IC Power Supply pin.

Features

RED4201 is a high PF, low THD, PFC controller, which is mainly applied in medium or high- power LED lighting applications.

The chip integrates THD compensation function, gets excellent PF and THD at light load; and also embedded various protections to ensure the system stability and reliability.

Startup

During startup, the capacitor at VCC pin is charged by the startup resistor. When VCC reaches startup voltage V_{CLP}, EN pin voltage is larger than V_{EN} and $V_{FB} > V_{FB_EN}$, the internal control logic starts to work, COMP pin voltage rises rapidly to above VBURST, then chip starts to output.

Constant Output Voltage Setting

RED4201 samples the output voltage through FB pin, and adopts a closed-loop feedback mechanism to realize high-precision output constant voltage control. The output voltage can be calculated as:

$$Vout = Vref \times \left(\frac{R6}{R7} + 1\right)$$

Where:

Vref is the internal reference voltage;
R6 is the FB pin pull-up resistor;
R7 is the FB pin pull-down resistor.

Zero-crossing Detection

RED4201 detects the zero-crossing state of the inductor current through ZCD pin. When GATE is turned off and the freewheeling diode stops freewheeling, the voltage on load winding begins to drop, resulting in ZCD voltage drop. When it is lower than the demagnetization detection threshold, demagnetization ends and next conduction cycle begins.

THD Compensation

When GATE is high, the auxiliary winding voltage becomes negative, and ZCD sources current to its current limit resistor. RED4201 detects the input voltage by sensing this current, and perform s THD compensation and ON time control.

CS minimum peak voltage, V_{CS_MIN} varies with the input voltage. When input voltage is low, the chip increases system ON time, t_{ON} by setting V_{CS_MIN}, to reduce the conduction dead time of the rectifier bridge, thereby improving THD.

Operating Modes

Under heavy load, RED4201 works in CRM with low conduction loss and good EMI performance. As the load becomes lighter, t_{ON} decreases gradually, the operating frequency increases, and both system efficiency and EMI deteriorates. However, due to the t_{ON_MIN} limit, t_{ON} cannot reduce infinitely. If continues working in CRM, the output voltage will rise and even trigger OVP.

To solve the above problems, the system enters DCM during light load. The time and depth of entering DCM are determined by detecting the COMP voltage.

If $V_{COMP} < V_{DCM}$ when inductor demagnetization is completed, the chip does not turn on MOS immediately to enter the next cycle, but increases the waiting time to enter DCM. The lower the COMP pin voltage, the longer the waiting time and the deeper in DCM.

As the load becomes further lighter, COMP pin voltage also drops When $V_{COMP} < V_{BURST}$, the system enters the Burst mode and stops switching immediately, then the output voltage begins to drop. Due to the internal compensation loop, COMP pin voltage rises above V_{BURST} again, the chip starts to switch again, and the output voltage rises. This hiccup mechanism effectively avoids outputting high voltage at light load and no load.

Chip Enable

RED4201 integrates chip enable pin, EN, which can be controlled by the external MCU.

When EN pin voltage is larger than V_{EN} for t_{LEB_EN}, the chip works normally.

If EN pin voltage is lower than V_{DIS} for t_{DIS_HYS}, the system enters standby mode, where the power consumption is extremely low.

If it is set to floating, EN pin will be automatically pulled up to high internally.

Enhanced Error Amplifier (EA)

RED4201 uses an enhanced error amplifier (EA) to achieve good dynamic performance. The pull-up and pull-down resistors are internally connected to COMP pin.

When V_{FB} > V_{FB_UVP2}, the pull-down resistor accelerates the discharge of COMP pin voltage; as FB pin voltage drops to V_{FB_UVP2}, it is disconnected.

When V_{FB} < V_{FB_UVP2}, COMP pin is internally pulled up to VCC to speed up the loop response; as FB pin voltage rises to V_{FB_UVP2} < V_{FB} < V_{FB_UVP1}, the pull-up resistor increases; increases; when V_{FB} > V_{FB_UVP1}, the pull-up resistor is disconnected automatically.

Enhanced EA helps to prevent the output voltage from overshooting or plunging when load changes abruptly. This mechanism reduces the stress on devices and greatly enhances system reliability.

Output Over-Voltage Protection

Once V_{FB} > V_{FB_UVP1}, the chip stops switching immediately and resumes when FB pin voltage drops by 60 mV.

When V_{FB} > V_{FB_UVP2}, the internal enhancement EA accelerates the discharge of COMP pin voltage. When V_{COMP} < V_{BURST}, the chip stops switching.

As load becomes lighter, COMP pin voltage decreases gradually. Once V_{COMP} < V_{BURST}, the chip immediately stops switching and the output voltage begins to drop. Due to the compensation loop, COMP pin voltage rises above V_{BURST} again, the chip resumes switching, and the output voltage rises. This hiccup mechanism effectively avoids outputting high voltage at light load and no load.

FB Short-circuit Protection

When V_{FB} < V_{FB_DIS}, the chip stops working immediately and resumes when FB pin rises to the enable threshold V_{FB_EN}.

Cycle-by-cycle Over-current Protection

RED4201 detects CS pin voltage cycle-by-cycle, and compares it with the internal threshold. When it reaches the threshold, turns off MOS. The peak current of inductor is calculated as:

$$Ipeak = \frac{Vocp1}{R5}$$

Where, Vocp1 is the cycle-by-cycle over-current limit threshold, R5 is the current sense resistor at CS pin.

This cycle-by-cycle current limiting mechanism protects related power devices, such as power MOSFETs, inductors, etc.

Over Temperature Protection

Once the chip junction temperature exceeds T_{OTP}, the chip immediately stops output to reduce the temperature rise, and restarts to work when the junction temperature drops to T_{OTP_HYS}.

PCB Layout Considerations

1. Reduce the power loop area, (the loop composed of bus capacitor, power inductor, MOS and the loop composed of bus capacitor, power inductor, freewheeling diode, and output electrolytic capacitor) to ensure better EMI characteristics. In addition, placing the chip outside the power loop can reduce interference.

2. The wire of power ground should be as short and thick as possible, especially the ground of the rectified CBB capacitor, the ground of CS resistor, and the ground of output electrolytic capacitor.

3. GATE pin trace should be as short as possible.

4. First connect the signal ground (such as the ground of VCC, COMP, FB, auxiliary winding) and the chip ground together, and then connect them to the power ground. Besides, the signal ground and the power ground should be as close as possible to ensure output voltage accuracy.

5. The VCC capacitor and CS filter capacitor should be as close as possible to the VCC and GND pins.

6. The resistors at ZCD and FB pins should be as close as possible to the chip and far away from the moving point of the system to reduce interference. Connecting a parallel ceramic capacitor with the pull-down resistor of FB pin can effectively reduce noise interference.

7. The heat dissipator is generally connected with the power component, the dissipator needs to be connected to the ground.

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
VCC pin voltage	V_{CC}		-0.3	30	V
GATE pin voltage	V_{GATE}		-0.3	30	V
Supply current	I_{DD}		0	20	mA
Input/output voltages (EN/CS/FB/COMP/ZCD pin)	V_{IO}		-0.3	5.5	V
Power dissipation	P_{DMAX}			1	W
Junction temperature	T_J		-40	+150	°C
Storage temperature	T_P		-55	+150	°C
Lead temperature	T_L	Soldering, 10s		260	°C

ELECTRICAL CHARACTERISTICS

Unless otherwise specified, V_{CC} =20V, T_A =25°C.

VCC Pin

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Clamp voltage	V_{CLP}	I_{CC}=1mA	23	25	27	V
UVLO threshold	V_{UVLO}	VCC voltage ramps down	7.3	8.3	9.3	V
Startup voltage	V_{STP}	VCC voltage ramps up	9.3	10.3	11.3	V

Supply current

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Startup current	I_{STP}	V_{CC} = V_{STP} – 1V			75	μA
Standby current 0	I_{STB0}	V_{EN} = 0V			20	μA
Standby current 1	I_{STB1}	V_{FB} = 0V, EN pin voltage larger than V_{EN}			80	μA
VCC Quiescent operating current	I_Q	No switching			500	μA

COMP Pin

Parameter	Symbol	Condition	Min	Typ	Max	Unit
EA transconductance	G_m			64		μA / V
Burst voltage	V_{BURST}	To enter burst mode		0.5		V
EA current capability	I_{COMP}	V_{FB} = 0V		8		μA
DCM voltage	V_{DCM}	To enter DCM		1.3		V

EN Pin

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Chip enable voltage	V_{EN}				1.8	V
Chip disable voltage	V_{DIS}		0.5			V
Chip disable delay time	t_{DIS_HYS}			45		ms
Blanking time	t_{LEB_EN}			900		ns

CS Pin

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Cycle-by-cycle over-current limit threshold	V_{OCP1}			1.1		V
Leading edge blanking time	t_{LEB_CS}			200		ns
Over-current protection threshold	V_{OCP2}			2.4		V
CS minimum peak voltage	V_{CS_MIN}			50		mV

Zero-Crossing Detection(ZCD) Pin

Parameter	Symbol	Condition	Min	Typ	Max	Unit
ZCD falling edge threshold	V_{ZCD_TH}			0.5		V
ZCD detection threshold hysteresis	V_{ZCD_HYS}			0.2		V

Gate Driver(GATE) Pin

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Maximum pull-up current	I_{SOURCE}	V_{GATE} = 0V		1000		mA
Maximum pull-down current	I_{SINK}	V_{GATE} = V_{CC}		1000		mA

Voltage Feedback(FB) Pin

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Internal reference voltage	V_{FB_REF}		2.45	2.5	2.55	V
OVP threshold 1	V_{FB_OVP1}	FB pin voltage rising	2.57	2.69	2.81	V
Fast OVP threshold 2	V_{FB_OVP2}	FB pin voltage rising		2.63		V
Fast UVP threshold 1	V_{FB_UVP1}	FB pin voltage falling		2.3		V
Fast UVP threshold 2	V_{FB_UVP2}	FB pin voltage falling		2.27		V
FB detection enable threshold	V_{FB_EN}	FB pin voltage rising	0.45	0.5	0.55	V
FB detection enable voltage	V_{FB_DIS}	FB pin voltage falling	0.4	0.46	0.52	V

Over-Temperature Protection (OTP)

Parameter	Symbol	Condition	Min	Typ	Max	Unit
OTP threshold	T_{OTP}			145		°C
OTP Hysteresis	T_{OTP_HYS}			25		°C

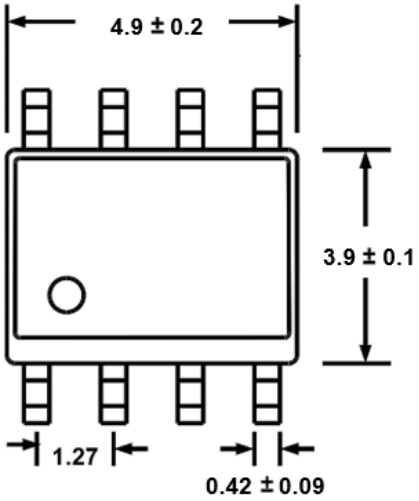
Control Loop

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Maximum switching frequency	f_{SW_MAX}			450		kHz
Demagnetization detection blanking time	t_{DEM_BLK}			1		µs
Minimum ON time	t_{ON_MIN}			200		ns
Maximum ON time	t_{ON_MAX}			30		µs
Minimum OFF time	t_{OFF_MIN}			1		µs
Maximum OFF time 1	t_{OFF_MAX1}	V_{FB} < 2.3V		25		µs
Maximum OFF time 2	t_{OFF_MAX2}	V_{FB} > 2.3V		50		µs
Maximum OFF time 3	t_{OFF_MAX3}			500		µs

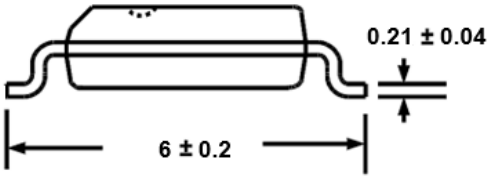
PACKAGE INFORMATION

Package Dimensions

SO8N package dimensions are shown below. All units are in mm.



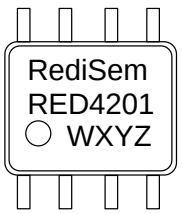




Available packages

Package type	Part number	Moisture Sensitivity Level (MSL)	Packaging	Thermal Resistances		
SO8	RED4201AD-TR13	3 (JEDEC J-STD-020)	Tape and reel 4000pcs/13" reel	Junction - Case	θ_{JC}	90°C/W
				Junction - Ambient	θ_{J}	128°C/W

Package Marking



SO8 top-side marking for RED4201

RED4201= 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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