Digital Power Factor Correction Controller With Accurate AC Power Metering

Preliminary Technical Data

ADP1047

FEATURES

- **Flexible, single phase, digital power factor correction (PFC) controller**
- **True rms ac power metering**
- **Enhanced dynamic response**
- **Optimized light load efficiency performance**
  - **Output voltage adjustment**
  - **Frequency reduction**
- **Inrush control**
- **Switching frequency spread spectrum for improved EMI**
- **External frequency synchronization**
- **PMBus compliant**
  - **Programmable ac line fault detection and protection**
  - **Programmable output fault detection and protection**
- **Extensive fault protection for high reliability systems**
- **Frequency range from 30 kHz to 400 kHz**
- **8 kB EEPROM**
- **Programming via easy-to-use graphical user interface (GUI)**

APPLICATIONS

- **AC/DC power supplies for applications including**
  - **Computing server and storage**
  - **Network and communication infrastructure**
  - **Industrial and medical**

GENERAL DESCRIPTION

The ADP1047 is a digital power factor correction controller providing accurate input power metering capability and inrush control targeting ac/dc systems.

The digital PFC function is based on a conventional boost PFC with multiplication of the output voltage feedback combined with the input current and voltage to provide optimum harmonic correction and power factor for ac/dc systems. All signals are converted into the digital domain to provide maximum flexibility—all key parameters can be reported and adjusted via the PMBus interface. This allows users to optimize system performance, maximize efficiency across the load range, and reduce design time to market.

The ADP1047 provides accurate, rms measurement of input voltage, current and power. This information can be reported to the secondary of the power supply via the PMBus interface.

The combination of a flexible, digitally controlled PFC engine and accurate input power metering facilitate the adoption of intelligent power management systems capable of making decisions to improve end user system efficiency. The device targets further efficiency improvements through programmable frequency reduction at light load and the capability to reduce the output voltage at low loads.

The ADP1047 provides enhanced integrated features and functions; the Inrush and soft start control functions provide significant component count reduction with easy design optimization.

The device targets high reliability, redundant power supply applications and has extensive and robust protection circuitry: independent overvoltage protection, overcurrent (ILIM), ground continuity metering, and ac sensing. Internal overtemperature is provided and external temperature can be recorded via an external sensing device.

The internal 8 kB EEPROM stores all the programmed values and allows standalone control without a microcontroller. All parametric reporting and adjustments are programmed via an easy-to-use GUI—no complex programming is required.

The ADP1047 operates from a single 3.3 V supply. The device is available in a 24-lead QSOP package specified over ambient temperature range −40°C to +85°C.

Rev. PrA

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FUNCTIONAL BLOCK DIAGRAM

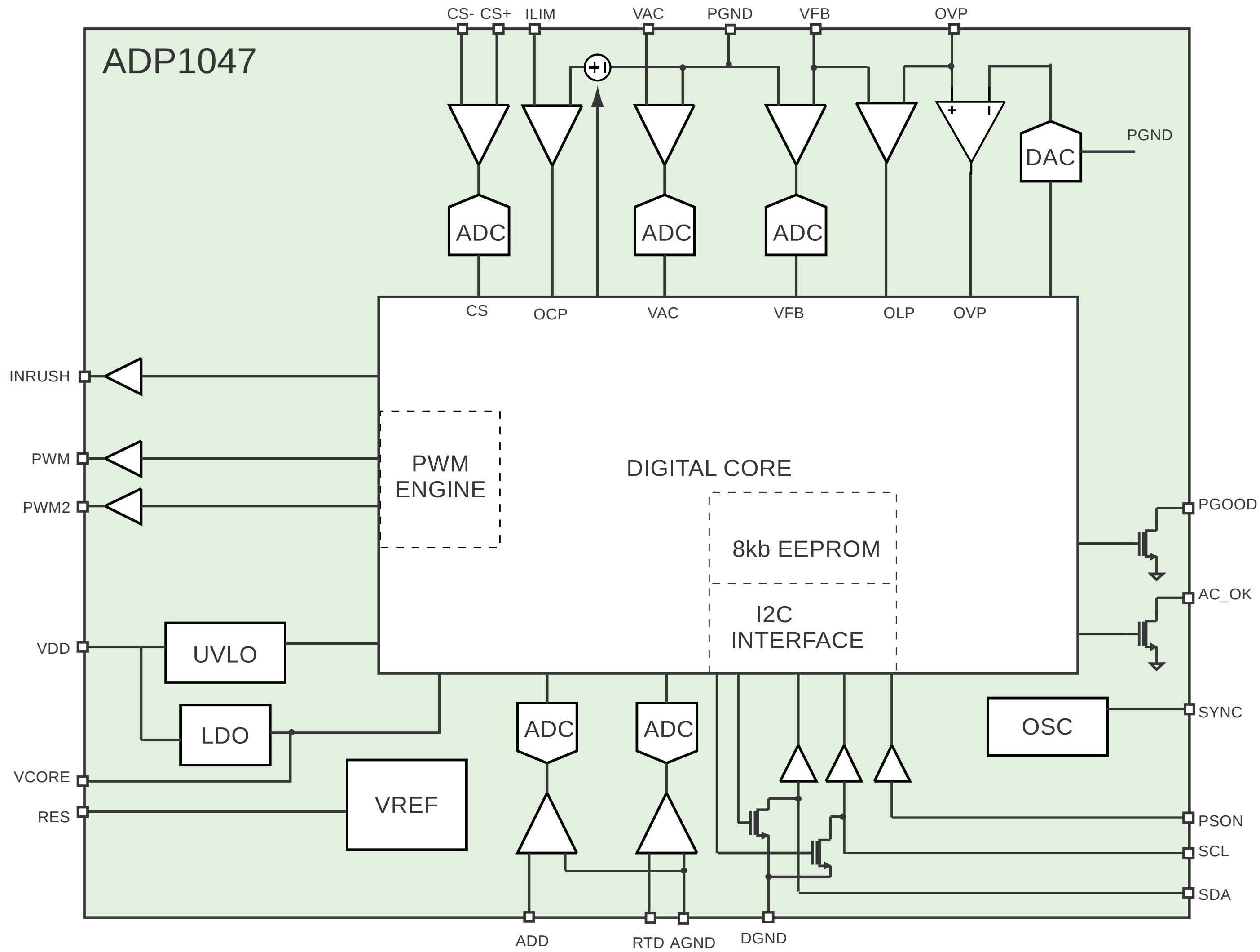


Figure 1.

SPECIFICATIONS

VDD = 3.3 V T_A = -40°C to +85°C, unless otherwise noted.

Table 1.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Units
POWER SUPPLY						
Operating Supply Voltage	V_{DD}		3.0	3.3	3.6	V
Supply Current	I_{DD}	Normal operation (PSON high)		17		mA
Peak Supply Current	I_{DD_PK}	During EEPROM programming (10 ms)		27	37	mA
POWER-ON RESET						
POWER ON RESET		V_{DD} rising	1.8		2.95	V
UVLO		V_{DD} falling	2.80	2.85	2.90	V
OVLO			3.7	3.9	4.1	V
VAC PIN LEAKAGE CURRENT						µA
OVLO Debouncing (VDD and V_{CORE})		Programmable	2		500	µs
VCORE						
Output Voltage		Temperature = 25°C	2.3	2.5	2.7	V
PWM OUTPUT						
Output Voltage						
Low	V_{PWMOL}	Sink current = 10 mA			0.4	V
High	V_{PWMOH}	Source current = 10 mA	VDD – 0.4 V			V
Rise Time		C_{LOAD} = 50 pF		3.5		ns
Fall Time		C_{LOAD} = 50 pF		1.5		ns
DUTY CYCLE						
Minimum Off Time		Programmable	40		1200	ns
Minimum On Time		Programmable	0		1200	ns
VOLTAGE SENSE INPUT RANGE						
VAC						
Input Voltage			0		1.6	V
VFB						
Input Voltage			0		1.6	V
RTD						
Input Voltage			0		1.6	V
SWITCHING FREQUENCY						
Frequency Range		Programmable (see Table TBD)	30		400	kHz
Accuracy			−3%		+3%	
OSCILLATOR, CLOCK AND PLL						
Oscillator Frequency			1.51	1.56	1.61	MHz
Digital Clock Frequency				200		MHz
PLL Frequency				200		MHz
RES						
Output Voltage		Temperature = 25°C – RES = 50 kΩ	0.98	1.0	1.02	V
Temperature Stability				320		ppm/°C
CURRENT SENSE ADC						
Input Voltage Range Low Line		Programmable		750		mV
Input Voltage Range High Line		Programmable		500		mV
Current Source High Line		10 kΩ level shift resistor, $V_{CS+} - V_{CS-} = 0$ V		75		µA
Current Source Low Line		10 kΩ level shift resistor, $V_{CS+} - V_{CS-} = 0$ V		62.5		µA
Current Source Accuracy				±0.03		%
PWM						
Output Low Level					0.8	V
Output High Level			2.0			V

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Units
PGOOD/AC_OK						
Output Low Level					0.8	V
Output High Level			2.0			V
Debounce (High to Low and Low to High)		Programmable	0		600	ms
FAST OVERCURRENT PROTECTION						
Fast OCP Threshold						
Positive Signal			1470	1500	1530	mV
Negative Signal			490	500	510	mV
Current Source						
Positive Signal		Programmable in four steps	20		80	µA
Negative Signal		Programmable in four steps	60		120	µA
Current Source Accuracy				±3.2		%
Propagation Delay		From threshold trip to PWM disabled			160	ns
Blanking Time		Programmable in eight steps	40		800	ns
Debouncing Time		Programmable in four steps	40		240	ns
RMS OVERCURRENT PROTECTION						
RMS OCP Threshold		Fully Programmable (0x5B)				
RMS Accuracy			−2		+2	%
Propagation Delay		AC line frequency is 50 Hz		12		ms
FAST OVERVOLTAGE PROTECTION						
OVP Threshold						
Rising		Fully programmable between 1 V and 1.5 V (0xFE2F) with seven bits	1		1.5	V
Falling		Fully Programmable between 1 V and 1.5 V (0xFE30) with seven bits	1		1.5	V
Minimum Step				3.9		mV
Accuracy				4		%
Propagation Delay (Latency)		Does not include blanking/debouncing			160	ns
Debouncing Time		Programmable in four steps	120		680	ns
Blanking Time		Blanking after threshold reprogramming		10		µs
ACCURATE OVERVOLTAGE PROTECTION						
OVP Threshold		Fully programmable (0x5B)				
Accuracy			−2		+2	%
Propagation Delay		AC line frequency is 50 Hz		10		ms
OPEN-LOOP PROTECTION						
VFB Error Threshold	ΔVFB		±80	±100	±120	mV
Propagation Delay				200		ns
Debouncing Time		Programmable(shared with fast OVP)	120		680	ns
Common Mode			−0.2		+1.6	V
SDA/SCL		V_{DD} = 3.3 V				
Input Voltage						
Low					0.8	V
High			2.2			V
Output Voltage Low					0.4	V
Pull-Up Current			100		350	µA
Leakage Current			−5		+5	µA
SERIAL BUS TIMING						
Clock Frequency					400	kHz
Glitch Immunity	t_{SW}				50	ns
Bus Free Time	t_{BUF}		4.7			µs
Start Setup Time	$t_{SU;STA}$		4.7			µs
Start Hold Time	$t_{HD;STA}$		4			µs

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Units
SCL Low Time	t_{LOW}		4.7			µs
SCL High Time	t_{HIGH}		4			µs
SCL, SDA Rise Time	t_R				1000	ns
SCL, SDA Fall Time	t_F				300	ns
Data Setup Time	$t_{SU;DAT}$		250			ns
Data Hold Time	$t_{HD;DAT}$		300			ns
EEPROM RELIABILITY						
Endurance			10			k cycles
Data Retention		Temperature = 85°C	10			Years

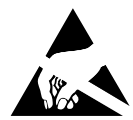
ABSOLUTE MAXIMUM RATINGS

Table 2.

Parameter	Rating
Supply Voltage (Continuous) VDD	3.8 V
Digital core supply voltage VCORE	2.7 V
Digital Pins	−0.3 V to (V_{DD} + 0.3 V)
Analog Pins	
AGND to DGND	−0.3 V to +0.3 V
Operating Temperature Range	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Maximum Junction Temperature	150°C
Peak Solder Reflow Temperature	
SnPb Assemblies (10 sec to 30 sec)	240°C
RoHS Compliant Assemblies (20 sec to 40 sec)	260°C

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ESD CAUTION



ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

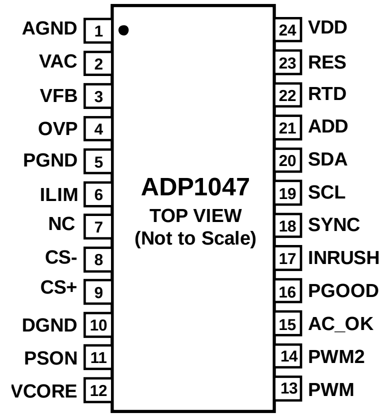


Figure 2. Pin Configuration

Table 3. Pin Function Descriptions

Pin No.	Name	Description
1	AGND	Analog Ground. Connect this pin directly to DGND. This is an analog voltage input to the ADC.
2	VAC	Input Line Voltage Sense. This signal is referred to PGND.
3	VFB	Feedback Voltage Sense. This signal is referred to PGND. This is the feedback signal for PFC power circuit regulation. This pin is used as the analog voltage input to the ADC.
4	OVP	Overvoltage Protection. This signal is referred to PGND. This signal is used as redundant OVP protection.
5	PGND	Power Ground. This is the connection for the ground line of the power rail. Place a low impedance path between this pin and AGND.
6	ILIM	Current Limiting. Peak current limiting. This signal is referred to PGND.
7	NC	No Connect. Do not connect to this pin.
8	CS−	Differential Current Sense Negative Input. This signal is used for current measurement, metering, and protection.
9	CS+	Differential Current Sense Positive Input. This signal is used for current measurement, metering, and protection.
10	DGND	Digital Ground. Ensure a low ohmic contact between this pin and AGND.
11	PSON	Power Supply Enable Signal. This signal is used to enable/disable the PFC controller. This signal is referred to DGND.
12	VCORE	Output of 2.5 V Regulator. Connect a 100 nF capacitor from this point to DGND.
13	PWM	Pulse-Width Modulation Output for PFC Regulation. This signal is referred to DGND.
14	PWM2	Auxiliary PWM (ADP1047) or Interleaved PWM Output (ADP1048). This signal is referred to DGND.
15	AC_OK	Open Drain Output. User configurable signal from a combination of flags. This signal is referred to DGND.
16	PGOOD	Open Drain Output. User configurable signal from a combination of flags. This signal is referred to DGND.
17	INRUSH	Inrush Control Signal. This is the inrush control signal to an external inrush driver; open drain referenced to DGND.
18	SYNC	Controller Synchronization. This pin allows paralleled PFC controllers to synchronize to reduce interference. This signal is referred to DGND.
19	SCL	I^2C Serial Clock Input. This signal is referred to DGND.
20	SDA	I^2C Serial Data Input and Output (Open Drain). This signal is referred to DGND.
21	ADD	Address Select Input. Connect a resistor from this pin to AGND.
22	RTD	Thermistor Input. A thermistor is placed from this pin to AGND. This signal is referred to AGND.
23	RES	Internal Voltage Reference. Connect a 50 kΩ resistor from RES to AGND.
24	VDD	Positive Supply Input for the IC. Range from 3.0 V to 3.6 V. This signal is referred to AGND.

THEORY OF OPERATION

ADP1047 is a PFC controller with AC power metering. In addition to the more conventional features like voltage sense and current sense, the part generates a programmable PWM output for control.

An extensive set of protection is offered that includes over-voltage protection (OVP), overcurrent protection (OCP), undervoltage protection (UVP), ground continuity metering, and ac sensing.

All these features are programmable through the I^{2}C bus interface. This bus interface is also used to calibrate the power supply. Other information, such as input voltage, input current, input power, and fault flags are also available through the digital bus interface.

The control loop is implemented in the digital domain allowing easy programming of filter characteristics, which is of great value in customizing and debugging designs.

The built-in EEPROM is used to store programmed values and instructions. Reliability is improved through a built-in checksum and redundancy of critical circuits. In the event of a system fault, the EEPROM can be configured to capture the first instance of failure. This feature can be used to improve overall system reliability and reduce failure mode analysis time.

ADP1047 comes with a free downloadable software GUI, which provides all the necessary software to program it.

The ADP1047 operates from a single 3.3 V supply and is specified from −40°C to +85°C.

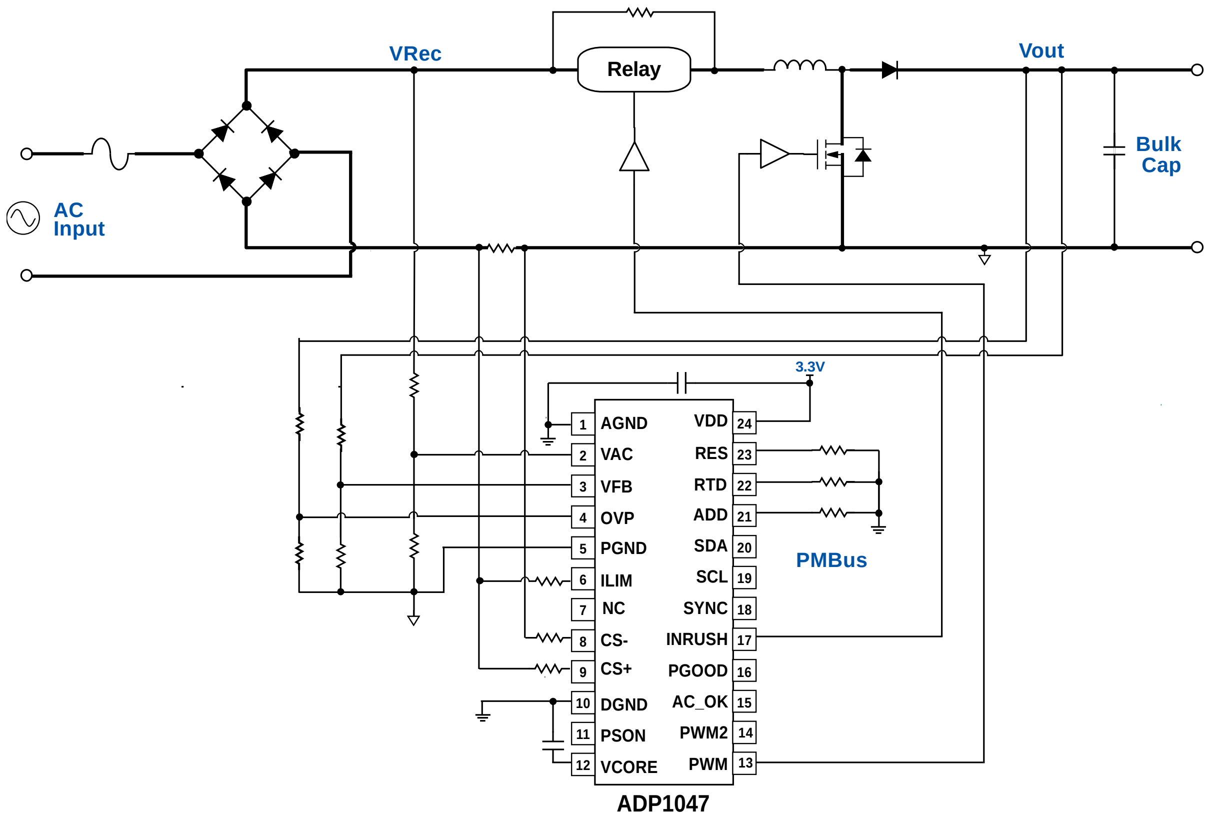


Figure 3. Typical Application Circuit

OUTLINE DIMENSIONS

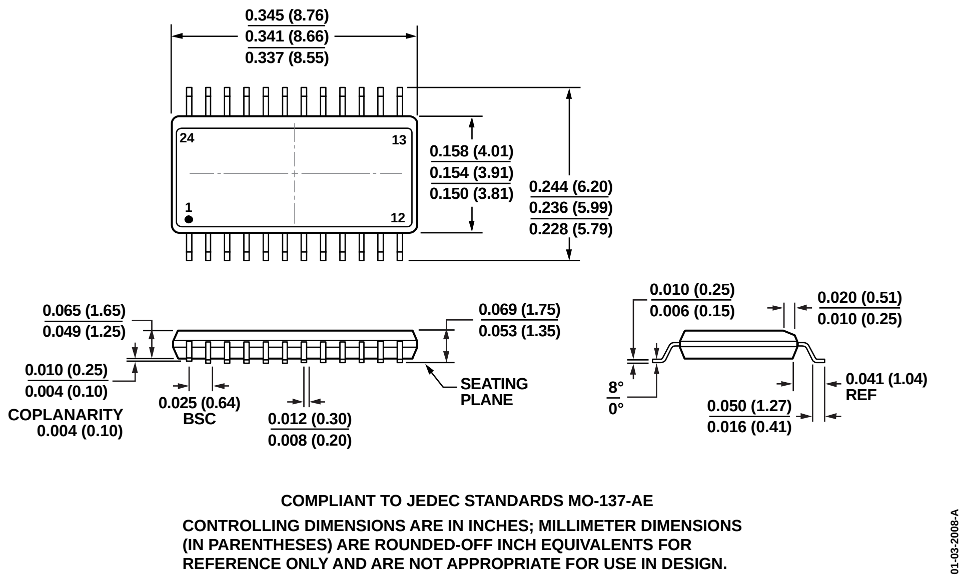


Figure 4. 24-Lead Shrink Small Outline Package [QSOP]
(RQ-24)
Dimensions shown in inches

NOTES

NOTES

I²C refers to a communications protocol originally developed by Philips Semiconductors (now NXP Semiconductors).