



Low Cost Power/Energy IC with Pulse Output

Features

- Single Chip; Power Measurement Solution
- Energy Data Linearity: $\pm 0.1\%$ of Reading over 1000:1 Dynamic Range
- On-Chip functions: Measures Energy and Performs Energy-to-Pulse Conversions
- Meets Accuracy Spec for IEC 687/1036
- High Pass Filter Option
- Four Input Ranges for Current Channel
- On-Chip 2.5 V Reference (25 ppm/ $^{\circ}\text{C}$ typ)
- Pulse Outputs for Stepper Motor or Mechanical Counter
- On-Chip Energy Direction Indicator
- Ground Referenced Input Signals with Single Supply
- High Frequency Output for Calibration
- On-Chip Power-on Reset
- Power Supply Configurations:
 $VA+ = +5\text{ V}$; $AGND = 0\text{ V}$; $VD+ = +3.3\text{ V to }5\text{ V}$

Description

The CS5466 is a low cost power meter solution combining two $\Delta\Sigma$ Analog-to-Digital Converters (ADC)'s, an energy-to-frequency converter, and energy pulse outputs on a single chip. It is designed to accurately measure and calculate energy for single phase 2- or 3-wire power metering applications with minimal external components.

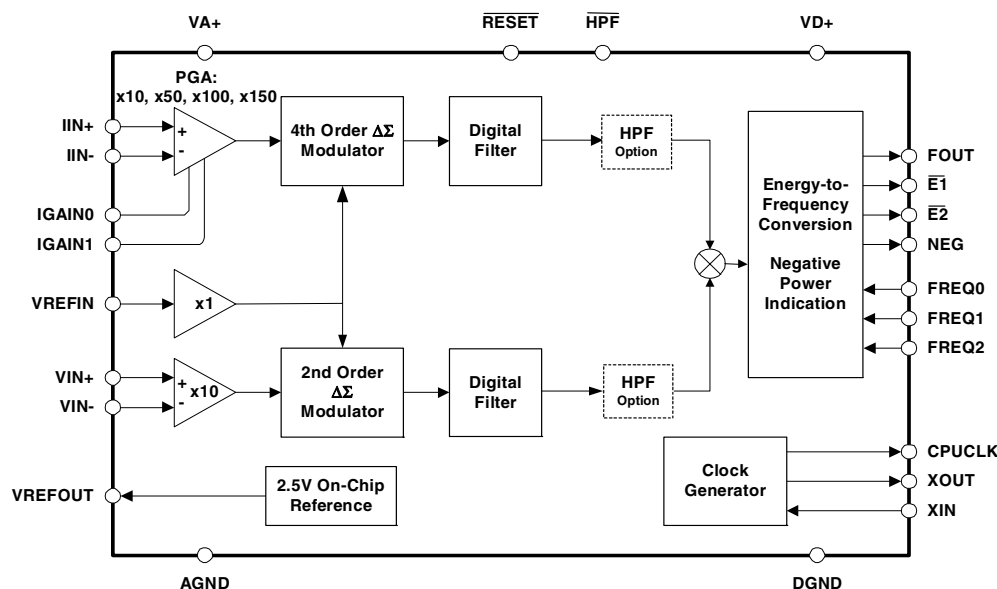
Low frequency energy outputs, $\overline{E1}$ and $\overline{E2}$, supply average real power and can be used to drive a stepper motor or a mechanical counter; the high frequency energy output FOUT can be used for calibration; and NEG indicates negative power.

The CS5466 has configuration pins which allow for direct configuration of pulse output frequency, current channel input range, and high pass filter enable option.

The CS5466 also has a power-on reset function which holds the part in reset until the supply reaches an operable level.

ORDERING INFORMATION

CS5466-ISZ -40° to 85° C 24-pin SSOP Lead Free



Preliminary Product Information

This document contains information for a new product. Cirrus Logic reserves the right to modify this product without notice.

TABLE OF CONTENTS

1. GENERAL DESCRIPTION	3
2. PIN DESCRIPTION	4
3. CHARACTERISTICS/SPECIFICATIONS	5
RECOMMENDED OPERATING CONDITIONS	5
ANALOG CHARACTERISTICS	5
VREFOUT REFERENCE OUTPUT VOLTAGE	6
DIGITAL CHARACTERISTICS	7
SWITCHING CHARACTERISTICS	8
ABSOLUTE MAXIMUM RATINGS	9
4. THEORY OF OPERATION	10
4.1 Digital Filters	10
4.2 Average Real Power Computation	10
5. FUNCTIONAL DESCRIPTION	11
5.1 Analog Inputs	11
5.1.1 Voltage Channel	11
5.1.2 Current Channel	11
5.2 High-Pass Filter	11
5.3 Energy Pulse Outputs	11
5.3.1 Pulse Output Format.	11
5.3.2 Selecting Frequency of $\overline{E1}$ and $\overline{E2}$	11
5.3.3 Selecting Frequency of FOUT	12
5.3.4 Absolute Max Frequency on $\overline{E1}$ and $\overline{E2}$	12
5.3.5 $\overline{E1}$ and $\overline{E2}$ Frequency Calculation	12
5.4 Energy Direction Indicator	13
5.5 Power-on Reset	13
5.6 Oscillator Characteristics	13
5.7 Basic Application Circuit	13
6. PACKAGE DIMENSIONS	15
7. REVISIONS	16

LIST OF FIGURES

Figure 1. Timing Diagram for $\overline{E1}$, $\overline{E2}$ and FOUT	8
Figure 2. Data Flow	10
Figure 3. Oscillator Connection	13
Figure 4. Typical Connection Diagram	14

LIST OF TABLES

Table 1. Current Channel PGA Setting	11
Table 2. Maximum Frequency for $\overline{E1}$, $\overline{E2}$ and FOUT	12
Table 3. Absolute Max Frequency on $\overline{E1}$ and $\overline{E2}$	12

1. GENERAL DESCRIPTION

The CS5466 is a CMOS monolithic power measurement device with an energy computation engine. The CS5466 combines a programmable gain amplifier, two $\Delta\Sigma$ ADC's and energy-to-frequency conversion circuitry on a single chip.

The CS5466 is designed for energy measurement applications and is optimized to interface to a shunt or current transformer for current measurement, and to a resistive divider or transformer for voltage measurement. The current channel has a programmable gain amplifier (PGA) which provides four full-scale input options. With a single +5 V supply on VA+/AGND, both of the CS5466's input channels accommodate common mode + signal levels between (AGND - 0.25 V) and VA+.

The CS5466 has three pulse output pins: $\overline{E1}$, $\overline{E2}$ and FOUT. $\overline{E1}$ and $\overline{E2}$ can be used to directly drive a mechanical counter or stepper motor, or interface to a micro controller. The FOUT pin conveys average real power at a pulse frequency many times higher than that of the $\overline{E1}$ or $\overline{E2}$ pulse frequency, allowing for high speed calibration.

2. PIN DESCRIPTION

Crystal Out	XOUT	□ 1 ●	24 □	XIN	Crystal In
CPU Clock Output	CPUCLK	□ 2	23 □	FREQ0	Frequency Select 0
Positive Power Supply	VD+	□ 3	22 □	$\overline{E1}$	Energy Output 1
Digital Ground	DGND	□ 4	21 □	$\overline{E2}$	Energy Output 2
Gain Select 0	IGAIN0	□ 5	20 □	FREQ1	Frequency Select 1
Negative Energy Indicator	NEG	□ 6	19 □	RESET	Reset
Gain Select 1	IGAIN1	□ 7	18 □	FOUT	High Frequency Output
High Pass Filter Enable	\overline{HPF}	□ 8	17 □	FREQ2	Frequency Select 2
Differential Voltage Input	VIN+	□ 9	16 □	IIN+	Differential Current Input
Differential Voltage Input	VIN-	□ 10	15 □	IIN-	Differential Current Input
Voltage Reference Output	VREFOUT	□ 11	14 □	VA+	Positive Analog Supply
Voltage Reference Input	VREFIN	□ 12	13 □	AGND	Analog Ground

Clock Generator

Crystal Out	1, 24	XOUT, XIN - A single stage amplifier inside the chip is connected to these pins and can be used with a crystal to provide the system clock for the device. Alternatively, an external clock can be supplied to the XIN pin to provide the system clock for the device.
Crystal In		
CPU Clock Output	2	CPUCLK - Output of on-chip oscillator which can drive one standard CMOS load.

Control Pins

Gain Select	5, 7	IGAIN1, IGAIN0 - Used to select the current channel input gain range.
Frequency Select	17, 20, 23	FREQ2, FREQ1, FREQ0 - Used to select max pulse output frequency for $\overline{E1}$, $\overline{E2}$, and FOUT.
High Pass Filter Enable	8	\overline{HPF} - High disables the HPF. Low activates HPF on Voltage channel. Connecting \overline{HPF} pin to FOUT pin activates HPF on Current channel.
Reset	19	RESET - Low activates Reset.

Energy Pulse Outputs

Energy Output	21, 22	$\overline{E1}$, $\overline{E2}$ - Active low alternating pulses with an output frequency that is proportional to the average real power.
High Freq Output	18	FOUT - Outputs energy pulses at a frequency higher than $\overline{E1}$ and $\overline{E2}$ outputs. Used for calibration purposes.
Neg Energy Indicator	6	NEG - High indicates negative energy.

Analog Inputs/Outputs

Differential Voltage Inputs	9, 10	VIN+, VIN- - Differential analog input pins for voltage channel.
Voltage Reference Output	11	VREFOUT - The on-chip voltage reference output pin. The voltage reference has a nominal magnitude of 2.5 V and is referenced to the AGND pin on the converter.
Voltage Reference Input	12	VREFIN - Voltage input to this pin establishes the voltage reference for the on-chip modulators.
Differential Current Inputs	16, 15	IIN+, IIN- - Differential analog input pins for current channel.

Power Supply Connections

Positive Digital Supply	3	VD+ - The positive digital supply.
Digital Ground	4*	DGND - Digital Ground.
Analog Ground	13	AGND - Analog Ground.
Positive Analog Supply	14	VA+ - The positive analog supply.

3. CHARACTERISTICS/SPECIFICATIONS

RECOMMENDED OPERATING CONDITIONS

Parameter	Symbol	Min	Typ	Max	Unit
Positive Digital Power Supply	VD+	3.135	5.0	5.25	V
Positive Analog Power Supply	VA+	4.75	5.0	5.25	V
Voltage Reference	VREFIN	-	2.5	-	V
Specified Temperature Range	T _A	-40	-	+85	°C

ANALOG CHARACTERISTICS

- Min / Max characteristics and specifications are guaranteed over all Operating Conditions.
- Typical characteristics and specifications are measured at nominal supply voltages and T_A = 25 °C.
- VA+ = VD+ = 5 V ±5%; AGND = DGND = 0 V; VREFIN = +2.5 V. All voltages with respect to 0 V.
- MCLK = 4.096 MHz

Parameter	Symbol	Min	Typ	Max	Unit	
Analog Inputs (Current Channel)						
Differential Input Range {(I _{IN+})-(I _{IN-})}	I _{IN}	(Gain = 10)	-	±250	-	mV
		(Gain = 50)	-	±50	-	mV
		(Gain = 100)	-	±25	-	mV
		(Gain = 150)	-	±16.7	-	mV
Input Capacitance (All Gain Ranges)	C _{inI}	-	25	-	pF	
Effective Input Impedance (All Gain Ranges)	Z _{inI}	30	-	-	kΩ	
Analog Inputs (Voltage Channel)						
Differential Input Range {(V _{IN+})-(V _{IN-})}	V _{IN}	-	-	±250	mV	
Input Capacitance	C _{inV}	-	0.2	-	pF	
Effective Input Impedance	Z _{inV}	2	-	-	MΩ	
Accuracy (Energy Outputs)						
Full-Scale Error (Note 1)	FSE	-	0.1	-	%F.S.	

Notes: 1. Applies after system calibration.

ANALOG CHARACTERISTICS (Continued)

Parameter	Symbol	Min	Typ	Max	Unit	
Power Supplies						
Power Supply Currents	I_{A+}	-	1.3	-	mA	
	I_{D+} (VA+ = VD+ = 5 V)	-	2.9	-	mA	
	I_{D+} (VA+ = 5 V, VD+ = 3.3 V)	-	1.7	-	mA	
Power Consumption	(VA+ = VD+ = 5 V)	-	21	25	mW	
(Note 2)	(VA+ = 5 V, VD+ = 3.3 V)	-	11.6	-	mW	
Power Supply Rejection Ratio	(50, 60 Hz)	-	-	-	-	
(Note 3)	Voltage Channel (Gain = 10)	PSRR	45	55	-	dB
	Current Channel (Gain = 10)		75	-	-	dB
	(Gain = 50)		56	75	-	dB
	(Gain = 100)		56	75	-	dB
	(Gain = 150)		56	75	-	dB

- Notes: 2. All outputs unloaded. All inputs CMOS level.
3. Definition for PSRR: VREFIN tied to VREFOUT, VA+ = VD+ = 5 V, a 150 mV zero-to-peak sine wave (frequency = 60 Hz) is imposed onto the +5 V supply voltage at VA+ and VD+ pins. The “+” and “-” input pins of both input channels are shorted to VA-. Then the CS5466 is put into an internal test mode and digital output data is collected for the channel under test. The zero-peak value of the digital sinusoidal output signal is determined, and this value is converted into the zero-peak value of the sinusoidal voltage that would need to be applied at the channel’s inputs, in order to cause the same digital sinusoidal output. This voltage is then defined as V_{eq} . PSRR is then (in dB):

$$PSRR = 20 \cdot \log \left\{ \frac{0.150V}{V_{eq}} \right\}$$

VREFOUT REFERENCE OUTPUT VOLTAGE

Parameter	Symbol	Min	Typ	Max	Unit
Reference Output					
Output Voltage	REFOUT	+2.4	+2.5	+2.6	V
VREFOUT Temperature Coefficient	(Note 4) TC_{VREF}		25	60	ppm/°C
Load Regulation	(Note 5) ΔV_R		6	10	mV
Reference Input					
Input Voltage Range	VREFIN	+2.4	+2.5	+2.6	V
Input Capacitance		-	4	-	pF
Input CVF Current		-	25	-	nA

- Notes: 4. The voltage at VREFOUT is measured across the temperature range. From these measurements the following formula is used to calculate the VREFOUT Temperature Coefficient:.

$$TC_{VREF} = \left(\frac{VREFOUT_{MAX} - VREFOUT_{MIN}}{VREFOUT_{AVG}} \right) \left(\frac{1}{T_{A_{MAX}} - T_{A_{MIN}}} \right) \left(1.0 \times 10^6 \right)$$

5. Specified at maximum recommended output current of 1 μ A, source or sink.

DIGITAL CHARACTERISTICS (Note 6)

- Min / Max characteristics and specifications are guaranteed over all Operating Conditions.
- Typical characteristics and specifications are measured at nominal supply voltages and TA = 25 °C.
- VA+ = VD+ = 5V ±5%; AGND = DGND = 0 V. All voltages with respect to 0 V.
- MCLK = 4.096 MHz

Parameter	Symbol	Min	Typ	Max	Unit
Master Clock Characteristics					
Master Clock Frequency Internal Gate Oscillator	MCLK	3	4.096	5	MHz
Master Clock Duty Cycle		40	-	60	%
CPUCLK Duty Cycle (Note 7 and 8)		40		60	%
Filter Characteristics					
High Pass Filter Corner Frequency -3 dB		-	0.125	-	Hz
Input/Output Characteristics					
High-Level Input Voltage	V_{IH}	(VD+) - 0.5 0.8 VD+	- -	- -	V V
	\overline{XIN} \overline{RESET}				
Low-Level Input Voltage (VD = 5 V)	V_{IL}	- -	- -	1.5 0.2 VD+	V V
	\overline{XIN} \overline{RESET}				
Low-Level Input Voltage (VD = 3.3 V)	V_{IL}	- -	- -	0.3 0.2 VD+	V V
	\overline{XIN} \overline{RESET}				
High-Level Output Voltage (except XOUT) I _{out} = +5 mA	V _{OH}	(VD+) - 1.0	-	-	V
Low-Level Output Voltage (except XOUT) I _{out} = -5 mA	V _{OL}	-	-	0.4	V
Input Leakage Current	I _{in}	-	±1	±10	µA
Digital Output Pin Capacitance	C _{out}	-	5	-	pF
Drive Current FOUT, E1, E2, NEG (Note 9)	I _{DR}		90		mA

- Notes:
6. All measurements performed under static conditions.
 7. If external MCLK is used, then the duty cycle must be between 45% and 55% to maintain this specification.
 8. The frequency of CPUCLK is equal to MCLK.
 9. V_{OL} and V_{OH} are not specified under this condition.

SWITCHING CHARACTERISTICS

- Min / Max characteristics and specifications are guaranteed over all Operating Conditions.
- Typical characteristics and specifications are measured at nominal supply voltages and $T_A = 25\text{ }^\circ\text{C}$.
- $V_{A+} = 5\text{ V} \pm 5\%$ $V_{D+} = 3.3\text{ V} \pm 5\%$ or $5\text{ V} \pm 5\%$; $AGND = DGND = 0\text{ V}$. All voltages with respect to 0 V.
- Logic Levels: Logic 0 = 0 V, Logic 1 = V_{D+} .

Parameter	Symbol	Min	Typ	Max	Unit	
Rise Times (Note 10)	Any Digital Input	-	-	1.0	μs	
	Any Digital Output	-	50	-	ns	
Fall Times (Note 10)	Any Digital Input	-	-	1.0	μs	
	Any Digital Output	-	50	-	ns	
Start-up						
Oscillator Start-Up Time	XTAL = 4.096 MHz (Note 11)	t_{ost}	-	60	-	ms
$\overline{E1}$ and $\overline{E2}$ Timing (Note 12 and 13)						
Period		t_1	500	-	-	ms
Pulse Width		t_2	250	-	-	ms
Rising Edge to Falling Edge		t_3	250			ms
$\overline{E1}$ Falling Edge to $\overline{E2}$ Falling Edge		t_4	250	-	-	ms
FOUT Timing (Note 12 and 13)						
Period		t_5	0.10	$1 / f_{\text{FOUT}}$		ms
Pulse Width	(Note 14)	t_6	-	$0.5 \cdot t_5$	90	ms
FOUT low		t_7	-	$0.5 \cdot t_5$	-	ms

- Notes: 10. Specified using 10% and 90% points on wave-form of interest. Output loaded with 50 pF.
11. Oscillator start-up time varies with crystal parameters. This specification does not apply when using an external clock source.
12. Pulse output timing is specified at $MCLK = 4.096\text{ MHz}$. Current and voltage signals are at unity power factor. Refer to Section 5.3 for more information on pulse output pins.
13. Timing is proportional to the frequency of $MCLK$.
14. When $FREQ2 = 0$, $FREQ1 = 1$ and $FREQ0 = 1$, $FOUT$ will have a typical pulse width of 20 μs at $MCLK = 4.096\text{ MHz}$.

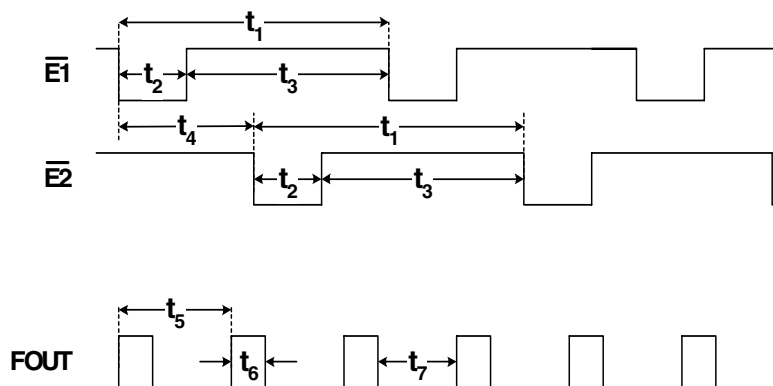


Figure 1. Timing Diagram for $\overline{E1}$, $\overline{E2}$ and $FOUT$

ABSOLUTE MAXIMUM RATINGS

WARNING: Operation at or beyond these limits may result in permanent damage to the device.

Normal operation is not guaranteed at these extremes.

Parameter	Symbol	Min	Typ	Max	Unit	
DC Power Supplies (Notes 15 and 16)	Positive Digital	VD+	-0.3	-	+6.0	V
	Positive Analog	VA+	-0.3	-	+6.0	V
Input Current, Any Pin Except Supplies (Notes 17, 18, 19)	I _{IN}	-	-	±10	mA	
Output Current, Any Pin Except VREFOUT	I _{OUT}	-	-	100	mA	
Power Dissipation (Note 20)	P _D	-	-	500	mW	
Analog Input Voltage All Analog Pins	V _{INA}	- 0.3	-	(VA+) + 0.3	V	
Digital Input Voltage All Digital Pins	V _{IND}	-0.3	-	(VD+) + 0.3	V	
Ambient Operating Temperature	T _A	-40	-	85	°C	
Storage Temperature	T _{stg}	-65	-	150	°C	

- Notes:
15. VA+ and AGND must satisfy $\{(VA+) - (AGND)\} \leq + 6.0 V$.
 16. VD+ and AGND must satisfy $\{(VD+) - (AGND)\} \leq + 6.0 V$.
 17. Applies to all pins including continuous over-voltage conditions at the analog input pins.
 18. Transient current of up to 100 mA will not cause SCR latch-up.
 19. Maximum DC input current for a power supply pin is ±50 mA.
 20. Total power dissipation, including all input currents and output currents.

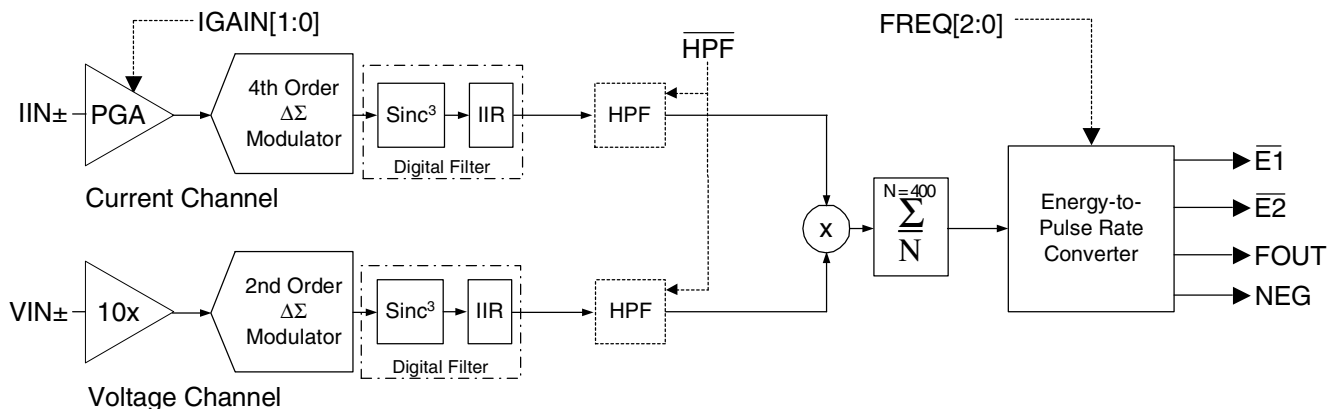


Figure 2. Data Flow

4. THEORY OF OPERATION

The CS5466 is a dual channel Analog-to-Digital Converter (ADC) followed by a computation engine that performs an energy-to-pulse conversion. The flow diagram for the two data paths is depicted in Figure 2. The analog inputs are structured with two dedicated channels, voltage and current, then optimized to simplify interfacing to sensing elements.

The voltage sensing element introduces a voltage waveform on the voltage channel input VIN_{\pm} and is subject to a fixed 10x gain amplifier. A second order delta-sigma modulator samples the amplified signal for digitization.

Simultaneously, the current sensing element introduces a voltage waveform on the current channel input IIN_{\pm} and is subject to the four selectable gains of the Programmable Gain Amplifier (PGA). The amplified signal is sampled by a fourth order delta-sigma modulator for digitization. Both converters sample at a rate of $(MCLK)/8$, the over-sampling provides a wide dynamic range and simplified anti-alias filter design.

4.1 Digital Filters

The decimating digital filters on both channels are $Sinc^3$ filters followed by 4th-order IIR filters. The single bit data is passed to the low pass decimation filter and output at

a fixed word rate. The output word is passed to the IIR filter to compensate for the magnitude roll-off of the low-pass filtering operation.

An optional digital High-Pass Filter (HPF in Figure 2) removes any dc component from the selected signal path. By removing the dc component from the voltage or current channel, any dc content will also be removed from the calculated average real power as well.

4.2 Average Real Power Computation

The instantaneous voltage and current data samples are multiplied together to obtain the instantaneous power. The product is then averaged over 400 conversions to compute the average real power value used to drive pulse outputs $\overline{E1}$, $\overline{E2}$ and FOUT. Output pulse rate of $\overline{E1}$ and $\overline{E2}$ can be set to one of four frequencies to directly drive a stepper motor or a electromechanical counter or interface to a microcontroller or infrared LED. The alternating output pulses of $\overline{E1}$ and $\overline{E2}$ allows for use with low cost electromechanical counters.

Output FOUT provides a uniform pulse stream that is proportional to the average real power and is designed for system calibration. The FREQ2:0 inputs set the output pulse rate of $\overline{E1}$, $\overline{E2}$ and FOUT. See Section 5.3 for more details.

5. FUNCTIONAL DESCRIPTION

5.1 Analog Inputs

The CS5466 is equipped with two fully differential input channels. The inputs $V_{IN\pm}$ and $I_{IN\pm}$ are designated as the voltage and current channel inputs, respectively. The full-scale differential input voltage for the current and voltage channel is $\pm 250\text{ mV}_P$.

5.1.1 Voltage Channel

The output of the line voltage resistive divider or transformer is connected to the V_{IN+} and V_{IN-} input pins of the CS5466. The voltage channel is equipped with a 10x fixed gain amplifier. The full-scale signal level that can be applied to the voltage channel is $\pm 250\text{ mV}$. If the input signal is a sine wave the maximum RMS voltage is:

$$\frac{250\text{mV}_P}{\sqrt{2}} \cong 176.78\text{mV}_{RMS}$$

which is approximately 70.7% of maximum peak voltage.

5.1.2 Current Channel

The output of the current sense resistor or transformer is connected to the I_{IN+} and I_{IN-} input pins of the CS5466. To accommodate different current sensing devices the current channel incorporates a Programmable Gain Amplifier (PGA) that can be set to one of four input ranges. Input pins $IGAIN1$ and $IGAIN0$ (See Table 1) define the PGA's four gain selections and corresponding maximum input signal level.

$IGAIN1$	$IGAIN0$	Maximum Input Range	
0	0	$\pm 250\text{mV}$	10x
0	1	$\pm 50\text{mV}$	50x
1	0	$\pm 25\text{mV}$	100x
1	1	$\pm 16.67\text{mV}$	150x

Table 1. Current Channel PGA Setting

For example if $IGAIN1=IGAIN0=0$, the current channel's PGA gain is set to 10x. If the input signals are pure sinusoids with zero phase shift, the maximum peak differential signal on the current or voltage channel is $\pm 250\text{ mV}_P$. The input signal levels are approximately 70.7% of maximum peak voltage producing a full scale energy pulse registration equal to 50% of absolute maximum energy pulse registration. This will be discussed further in Section 5.3.

5.2 High-Pass Filter

By removing the offset from either channel, no error component will be generated at dc when computing the average real power. Input pin HPF defines the three options;

- High-Pass Filter (HPF) is disabled when pin HPF is connected high.
- HPF is enabled in the voltage channel when pin HPF is connected low.
- HPF is enabled in the current channel when pin HPF is connected to pin FOUT.

5.3 Energy Pulse Outputs

The CS5466 provides three output pins for energy registration. The $\overline{E1}$ and $\overline{E2}$ pins provide a simple interface from which energy can be registered. These pins are designed to directly connect to a stepper motor or electromechanical counter. The pulse rate on the $\overline{E1}$ and $\overline{E2}$ pins are in the range of 0 to 4 Hz and all frequency settings are optimized to be used with standard meter constants. The FOUT pin is designated for system calibration, the pulse rate can be selected to reach a frequency of 8000 Hz.

5.3.1 Pulse Output Format.

The CS5466 produces alternating pulses on $\overline{E1}$ and $\overline{E2}$. This pulse format is designed to drive a stepper motor. Each pin produces active low pulses with a minimum pulse width of 250 ms when $MCLK = 4.096\text{ MHz}$. Refer to CS5466 Switching Characteristics on page 8 for timing parameters.

The FOUT pin issues active high pulses. The pulse width is equal to 90 ms (typical), unless the period falls below 180 ms. At this time the pulses will be equal to half the period. In mode 3 ($FREQ2:0 = 3$), the pulse width of all FOUT pulses is typically 20 μs regardless of the pulse rate ($MCLK = 4.096\text{ MHz}$).

5.3.2 Selecting Frequency of $\overline{E1}$ and $\overline{E2}$

The pulse rate on $\overline{E1}$ and $\overline{E2}$ can be set to one of four frequency ranges. Input pins $FREQ1$ and $FREQ0$ (See Table 2) determine the maximum frequency on $\overline{E1}$ and $\overline{E2}$ for pure sinusoidal inputs with zero phase shift. As shown in Figure 1 on page 8, the frequency of $\overline{E2}$ is equal to the frequency of $\overline{E1}$ with active low alternating pulses.

As discussed in Section 5.1.2, the maximum frequency on the $\overline{E1}$ and $\overline{E2}$ output pins is equal to the selected frequency in Table 2 if the maximum peak differential signal applied to both channels is a sine wave with zero phase shift.

Table 2. Maximum Frequency for $\overline{E1}$, $\overline{E2}$ and FOUT

Frequency Select			Maximum Frequency for a Sine Wave (Notes 1, 2 and 3)			
FREQ2	FREQ1	FREQ0	$\overline{E1}$ or $\overline{E2}$	$\overline{E1+E2}$	FOUT	
0	0	0	0.125 Hz	0.25 Hz	$64x(\overline{E1+E2})$	16 Hz
0	0	1	0.25 Hz	0.5 Hz	$32x(\overline{E1+E2})$	16 Hz
0	1	0	0.5 Hz	1.0 Hz	$16x(\overline{E1+E2})$	16 Hz
0	1	1	1.0 Hz	2.0 Hz	$2048x(\overline{E1+E2})$	4,096 Hz
1	0	0	0.125 Hz	0.25 Hz	$128x(\overline{E1+E2})$	32 Hz
1	0	1	0.25 Hz	0.5 Hz	$64x(\overline{E1+E2})$	32 Hz
1	1	0	0.5 Hz	1.0 Hz	$32x(\overline{E1+E2})$	32 Hz
1	1	1	1.0 Hz	2.0 Hz	$16x(\overline{E1+E2})$	32 Hz

Notes: 1 A pure sinusoidal input with zero phase shift is applied to the voltage and current channel.
 2 MCLK = 4.096 MHz
 3 See Figure 1 on page 8 for $\overline{E1}$ and $\overline{E2}$ timing diagram.

5.3.3 Selecting Frequency of FOUT

The pulse output FOUT is designed to assist with meter calibration. Using the FREQ2:0 pins, FOUT can be set to frequencies higher than that of $\overline{E1}$ and $\overline{E2}$. The FOUT frequency is directly proportional to the $\overline{E1}$ and $\overline{E2}$ frequencies. Table 2 defines the maximum frequencies for FOUT and the dependency of FOUT on $\overline{E1}$ and $\overline{E2}$.

5.3.4 Absolute Max Frequency on $\overline{E1}$ and $\overline{E2}$

The CS5466 supports input signals on the voltage and current channel that may not be a sine wave. A typical situation of achieving the absolute maximum frequency on $\overline{E1}$ and $\overline{E2}$ would be if a 250 mV dc signal is applied to the VIN and IIN input pins. The digital high-pass filter should be disengaged by selecting HPF = 1.

The absolute maximum pulse rate observed on $\overline{E1}$ and $\overline{E2}$, determined by the FREQ2:0 selection is defined below in Table 3.

Frequency Select			Absolute Max Frequency	
FREQ2	FREQ1	FREQ0	$\overline{E1}$ or $\overline{E2}$	$\overline{E1+E2}$
x	0	0	0.25 Hz	0.5 Hz
x	0	1	0.5 Hz	1.0 Hz

Table 3. Absolute Max Frequency on $\overline{E1}$ and $\overline{E2}$

Frequency Select			Absolute Max Frequency	
FREQ2	FREQ1	FREQ0	$\overline{E1}$ or $\overline{E2}$	$\overline{E1+E2}$
x	1	0	1.0 Hz	2.0 Hz
x	1	1	2.0 Hz	4.0 Hz

Table 3. Absolute Max Frequency on $\overline{E1}$ and $\overline{E2}$

5.3.5 $\overline{E1}$ and $\overline{E2}$ Frequency Calculation

The pulse output frequency of $\overline{E1}$ and $\overline{E2}$ is directly proportional to the average power calculated from the input signals. To calculate the output frequency on $\overline{E1}$ and $\overline{E2}$, use the following transfer function:

$$FREQ_{E1,E2} = \frac{VIN * 10 * IIN * IGAIN * FREQ_{max}}{VREFIN^2}$$

$FREQ_{E1,E2}$ = Actual frequency of $\overline{E1}$ and $\overline{E2}$ pulses [Hz]
 VIN = rms voltage across VIN+ and VIN- [V]
 IIN = rms voltage across IIN+ and IIN- [V]
 IGAIN = Current channel gain selection (10, 50, 100, 150)
 FREQ_{max} = Absolute Max Frequency for $\overline{E1}$ and $\overline{E2}$ [Hz]
 VREFIN = Voltage at VREFIN pin [V]

Example:

For a given application, assuming a 50 Hz line frequency and a purely resistive load (unity power factor), the following configuration is used:

- $FREQ2:0 = 3 \therefore FREQ_{max} = 2 \text{ Hz}$
- $IGAIN1:0 = 2 \therefore IGAIN = 100$
- $VREFIN = VREFOUT = 2.5 \text{ V}$

In this configuration the maximum sine wave that can be applied is 250 mVp on the voltage channel and 25 mVp on the current channel. Using the above formula, the output frequency of E1 or E2 is calculated:

$$\frac{.25V_p * 10 * .025V_p * 100 * 2Hz}{\sqrt{2} * \sqrt{2} * 2.5V^2} = 1Hz$$

With maximum pure sinusoidal input signals, the frequency of $\overline{E1}$ or $\overline{E2}$ is half the absolute maximum frequency set with $FREQ2:0$.

To calculate the frequency of $FOUT$ for the example above, assume $FREQ2 = 0$.

$$FOUT = 2048 * (\overline{E1} + \overline{E2}) = 2048 * (2Hz) = 4096Hz$$

5.4 Energy Direction Indicator

The NEG pin indicates the sign of the calculated average power. If negative average power is detected the NEG output pin will become active high and will remain active high until positive average power is detected. The NEG pin is valid at least 250ns prior to any assertion of E1 or E2, and FOUT, to indicate the sign of a given energy output. The NEG pin is updated at a rate of 10 Hz at $MCLK = 4.096 \text{ MHz}$.

5.5 Power-on Reset

Upon powering up, the digital circuitry is held in reset until the analog voltage reaches 4.0 V. At that time, an eight XIN clock period delay is enabled to allow the oscillator to stabilize. The CS5466 will then initialize. The device reads the control pins $IGAIN1:0$, $FREQ2:0$ and HPF , and begins performing energy measurements.

5.6 Oscillator Characteristics

XIN and XOUT are the input and output of an inverting amplifier which can provide oscillation and can be configured as an on-chip oscillator, as shown in Figure 3. The oscillator circuit is designed to work with a quartz crystal. To reduce circuit cost, two load capacitors C1

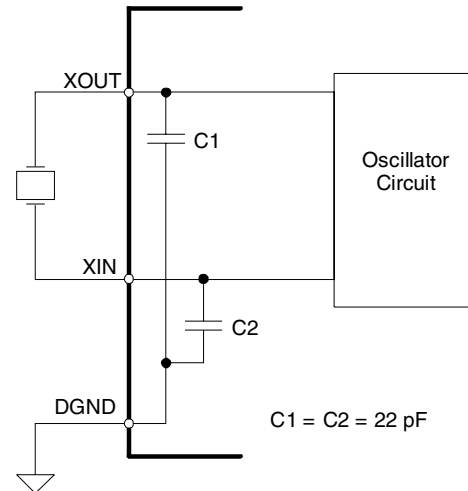


Figure 3. Oscillator Connection

and C2 are integrated in the device, one between XIN and DGND, one between XOUT and DGND. Lead lengths should be minimized to reduce stray capacitance. To drive the device from an external clock source, XOUT should be left unconnected while XIN is driven by the external circuitry. There is an amplifier between XIN and the digital section which provides CMOS level signals. This amplifier works with sinusoidal inputs so there are no problems with slow edge times.

5.7 Basic Application Circuit

Figure 4 shows the CS5466 configured to measure power in a single-phase 2-wire system while operating in a single supply configuration. In this diagram, a shunt resistor is used to sense the line current and a voltage divider is used to sense the line voltage. In this type of shunt resistor configuration, the common-mode level of the CS5466 must be referenced to the line side of the power line. This means that the common-mode potential of the CS5466 will track the high voltage levels, as well as low voltage levels, with respect to earth ground potential.

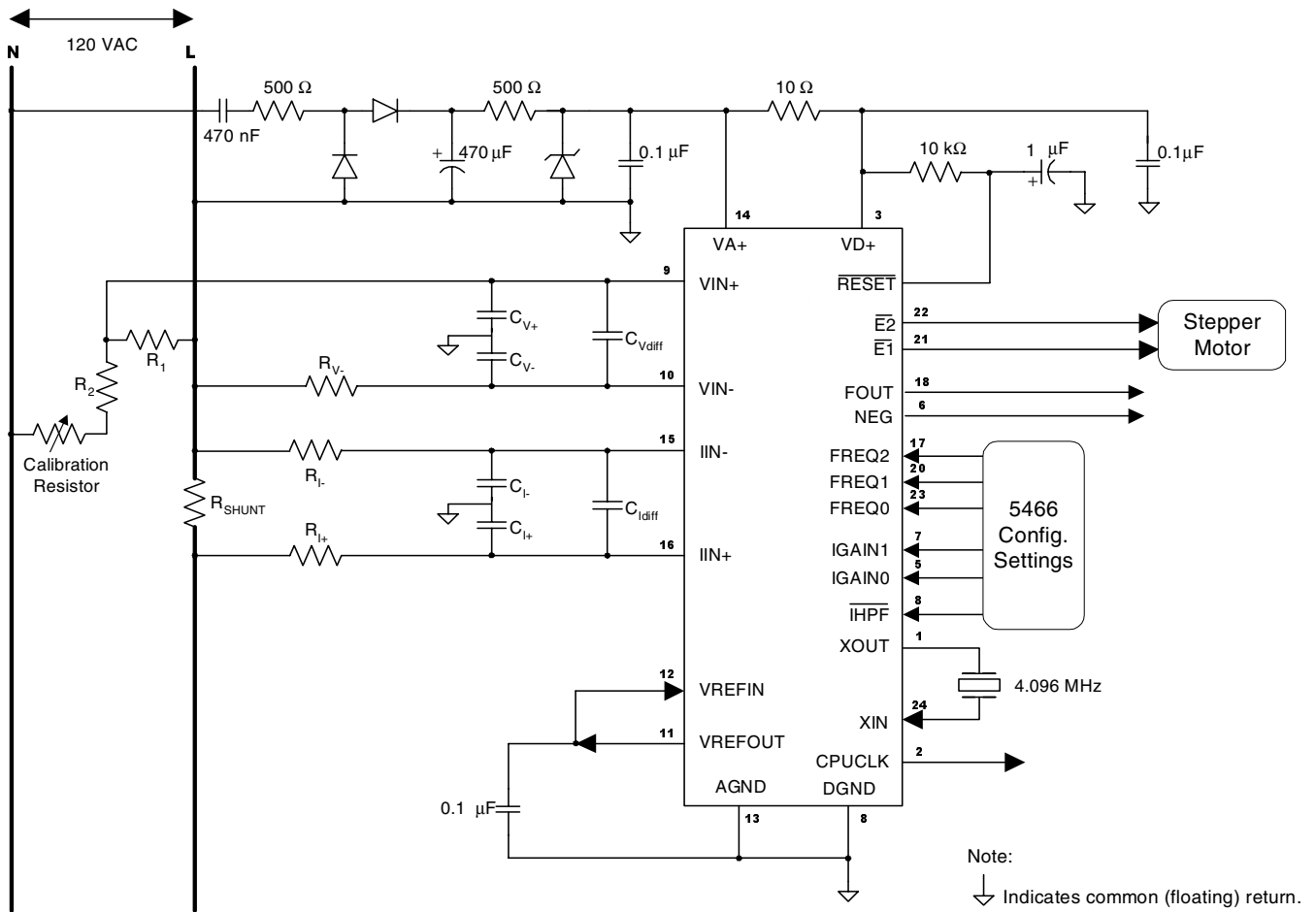
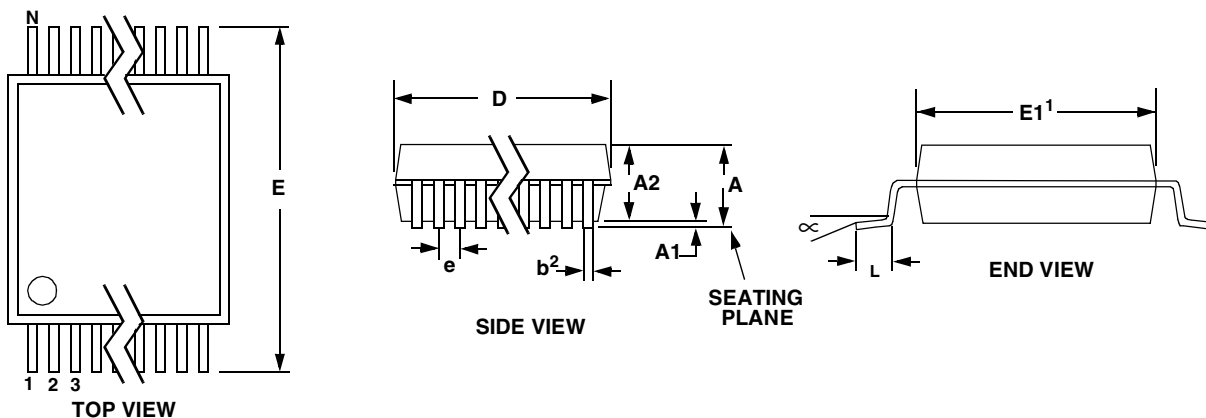


Figure 4. Typical Connection Diagram

6. PACKAGE DIMENSIONS
24L SSOP PACKAGE DRAWING


DIM	INCHES			MILLIMETERS			NOTE
	MIN	NOM	MAX	MIN	NOM	MAX	
A	--	--	0.084	--	--	2.13	
A1	0.002	0.006	0.010	0.05	0.13	0.25	
A2	0.064	0.068	0.074	1.62	1.73	1.88	
b	0.009	--	0.015	0.22	--	0.38	2,3
D	0.311	0.323	0.335	7.90	8.20	8.50	1
E	0.291	0.307	0.323	7.40	7.80	8.20	
E1	0.197	0.209	0.220	5.00	5.30	5.60	1
e	0.022	0.026	0.030	0.55	0.65	0.75	
L	0.025	0.03	0.041	0.63	0.75	1.03	
∞	0°	4°	8°	0°	4°	8°	

JEDEC #: MO-150

Controlling Dimension is Millimeters.

- Notes:
1. "D" and "E1" are reference datums and do not include mold flash or protrusions, but do include mold mismatch and are measured at the parting line, mold flash or protrusions shall not exceed 0.20 mm per side.
 2. Dimension "b" does not include dambar protrusion/intrusion. Allowable dambar protrusion shall be 0.13 mm total in excess of "b" dimension at maximum material condition. Dambar intrusion shall not reduce dimension "b" by more than 0.07 mm at least material condition.
 3. These dimensions apply to the flat section of the lead between 0.10 and 0.25 mm from lead tips.

7. REVISIONS

Revision	Date	Changes
PP1	September 2004	Initial Release

Contacting Cirrus Logic Support

For all product questions and inquiries contact a Cirrus Logic Sales Representative.

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