Application Note

CS5480/84/90 Measurement Accuracy vs. IEC Standards

1. Introduction

Cirrus Logic's CS5480, CS5484, and CS5490 energy measurement ICs benefit from on-chip, high-performance, 24-bit ADC converters in conjunction with its digital calibration and compensation algorithms. This application note presents accuracy results from testing the CS5480. The CS5484 and CS5490 uses the same core technology as the CS5480. Testing results of the CS5484 and CS5490 show nearly identical results.

The CS5480 has world-leading accuracy over an extensive, dynamic range. This application note cites measurements of active energy, reactive energy, and I_{RMS} load performance acquired from the CS5480 using three different types of current sensor: Rogowski coil, current transformer (CT), and shunt. A comparison between the CS5480 measurements and the IEC 62053 standards is presented. This comparison shows that the CS5480 meets IEC 62053-22 class 0,2S standards for active energy and IEC 62053-23 class 2 standards for reactive energy. Comparison with the ANSI C12.20 standard is not included in this application note because the ANSI standard is less stringent than the IEC 62053 standard, so it is implied that the CS5480 meets it.

2. Test Setup

The following diagram illustrates the connections between the PPS400.3 power source, PRS400.3 power reference, current sensor, CDB5480U board (+3.3V DC power supply), and a host PC.

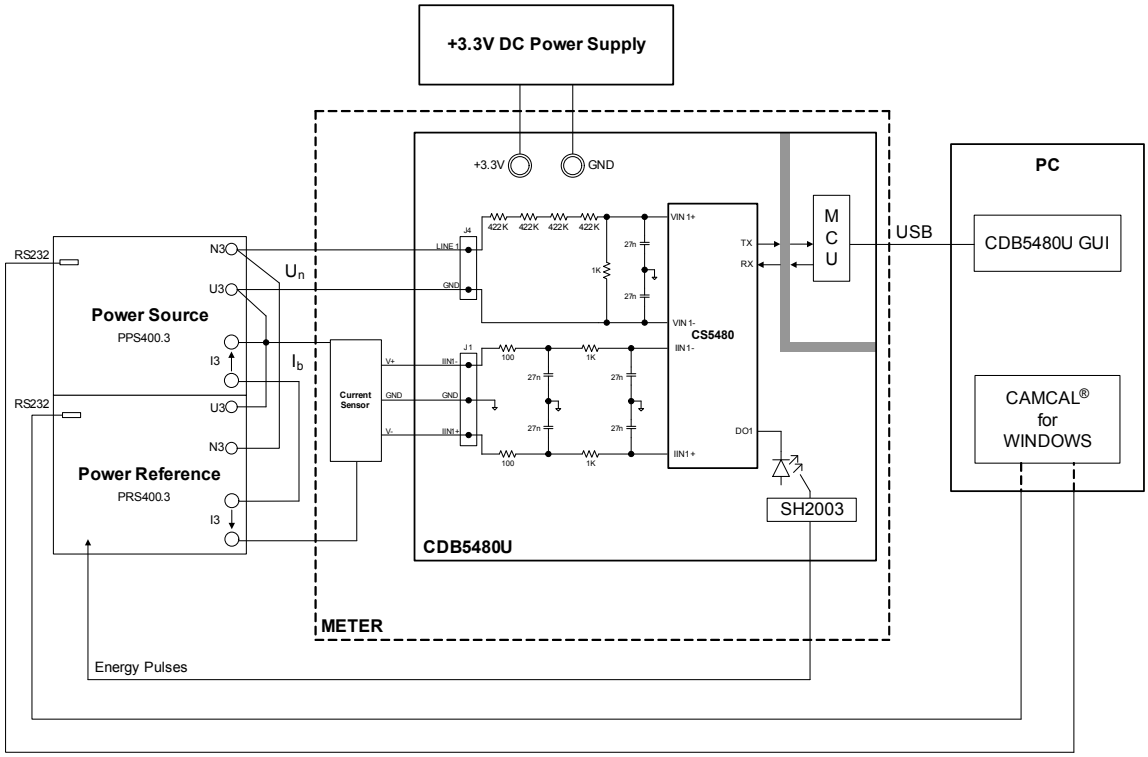

Figure 1. Test Setup Connection Diagram

The Cirrus Logic CDB5480U demonstration board and current sensor form a single-phase, two-wire energy meter. The CDB5480U software is installed on a host PC and used to configure, calibrate, and control the meter using the USB port. The software collects the measurement results from the CS5480 registers once per second. CAMCAL® for WINDOWS software controls the MTE Meter Test Equipment AG PPS400.3 power source and PRS400.3 power reference using two COM ports. CAMCAL performs the active and reactive accuracy test procedure automatically.

The active or reactive energy pulses provided by the CS5480 drive the on-board LED using energy pulse output DO1. The energy pulses are sensed by photoelectric scanning head SH2003 and directed back into PRS400.3. The accuracy of the active and reactive energy is then measured by PRS400.3 and sent to the CAMCAL software. The meter constant is 2000 impulses/kWh, or 2000 impulses/kVarh.

I_{RMS} accuracy is manually calculated and based on a 10-second average using the I_{RMS} register values. The I_{RMS} register is read once per second using the CDB5480U software.

2.1 Calibrations and Meter Types

Prior to the accuracy test, the following calibrations and compensations were performed:

- Gain calibration
- AC offset calibration
- Phase compensation
- Active and reactive power offset correction

Using the CDB5480U board with different current sensors forms different types of meters. To test the accuracy of the CS5480, the following meters were formed:

- Rogowski coil meter, where U_n = 240 V and $I_{b(max)}$ = 2 (80 A) at 50 Hz
- Current transformer (CT) meter, where U_n = 240 V and $I_{b(max)}$ = 2.5 (100 A) at 50 Hz
- Shunt meter, where U_n = 240 V and $I_{b(max)}$ = 2.5 (100 A) at 50 Hz

All accuracy tests were conducted at room temperature. Influences from ambient temperature and self-heating are not included.

Refer to Application Note 366, entitled *CS5480/84/90 Power Meter Calibration*, for more information about calibrations and compensations.

Refer to the CDB5480U data sheet, entitled *CDB5480U Engineering Board and GUI Software*, for more information about the CDB5480U board.

Refer to the CS5480 data sheet, entitled *Three Channel Energy Measurement IC*, for more information about the CS5480.

3. Accuracy Test with Rogowski Coil, U_n = 240 V and $I_{b(max)}$ = 2 (80 A) at 50 Hz

Pulse PA3202NL is used as the current sensor. The secondary output voltage of PA3203NL is 416 µV/A at 50 Hz. When the meter is applied with the maximum load current, I_{max} = 80 A, the Rogowski coil secondary output is approximately 33 mV_{RMS}, which is below the CS5480 maximum I-channel input range when setting the PGA for current channel 1 (I1) to 50x.

High-pass filter (HPF) is enabled on the voltage channel: V1FLT[1:0] = '01'

Integrator is enabled on the current channel: I1FLT[1:0] = '11'

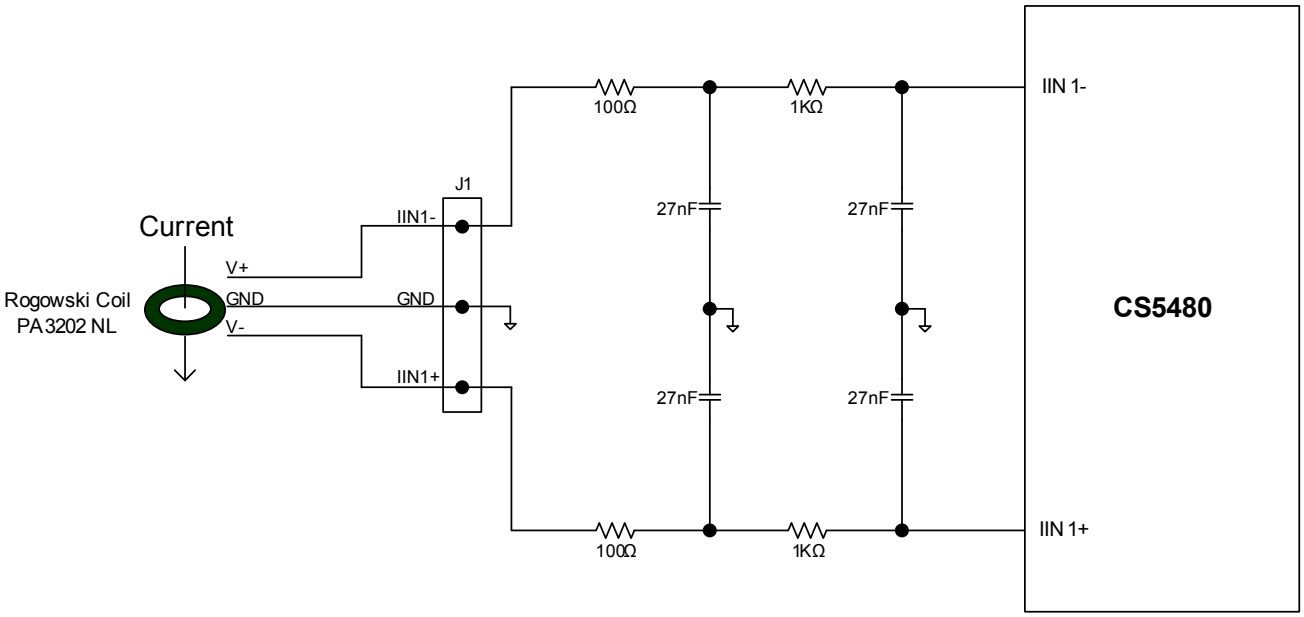

Figure 2. Connection between Rogowski Coil and CS5480

3.1 Accuracy Results for Active Energy Load Performance

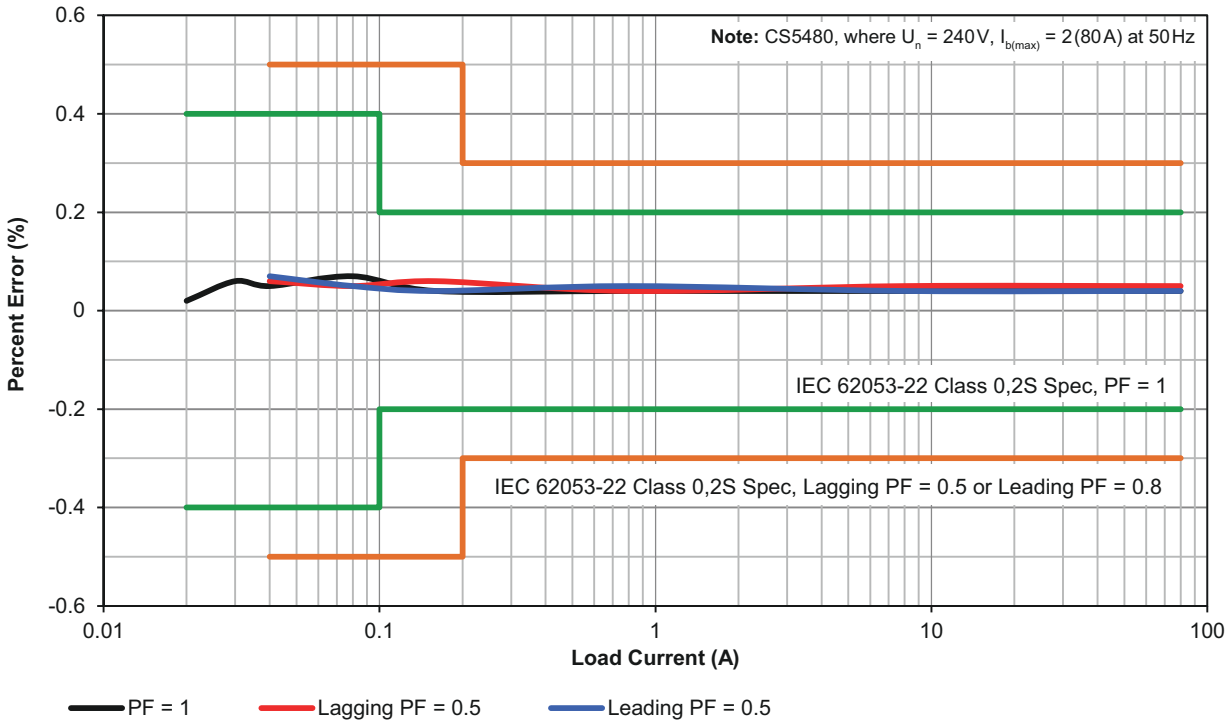

Figure 3. Active Energy Load Performance vs. IEC 62053-22 Class 0,2S Standard

Power Factor	Load Current (A)	Current Dynamic Range (x:1)	Error
PF = 1	80	1	0.04%
	8	10	0.04%
	0.8	100	0.04%
	0.16	500	0.04%
	0.08	1000	0.07%
	0.04	2000	0.05%
	0.03	3333	0.06%
	0.02	4000	0.02%
Lagging PF = 0.5	80	1	0.05%
	8	10	0.05%
	0.8	100	0.04%
	0.16	500	0.06%
	0.08	1000	0.05%
	0.04	2000	0.06%
Leading PF = 0.5	80	1	0.04%
	8	10	0.04%
	0.8	100	0.05%
	0.16	500	0.04%
	0.08	1000	0.05%
	0.04	2000	0.07%

Table 1. Active Energy Load Performance

3.2 Accuracy Results for Reactive Energy Load Performance

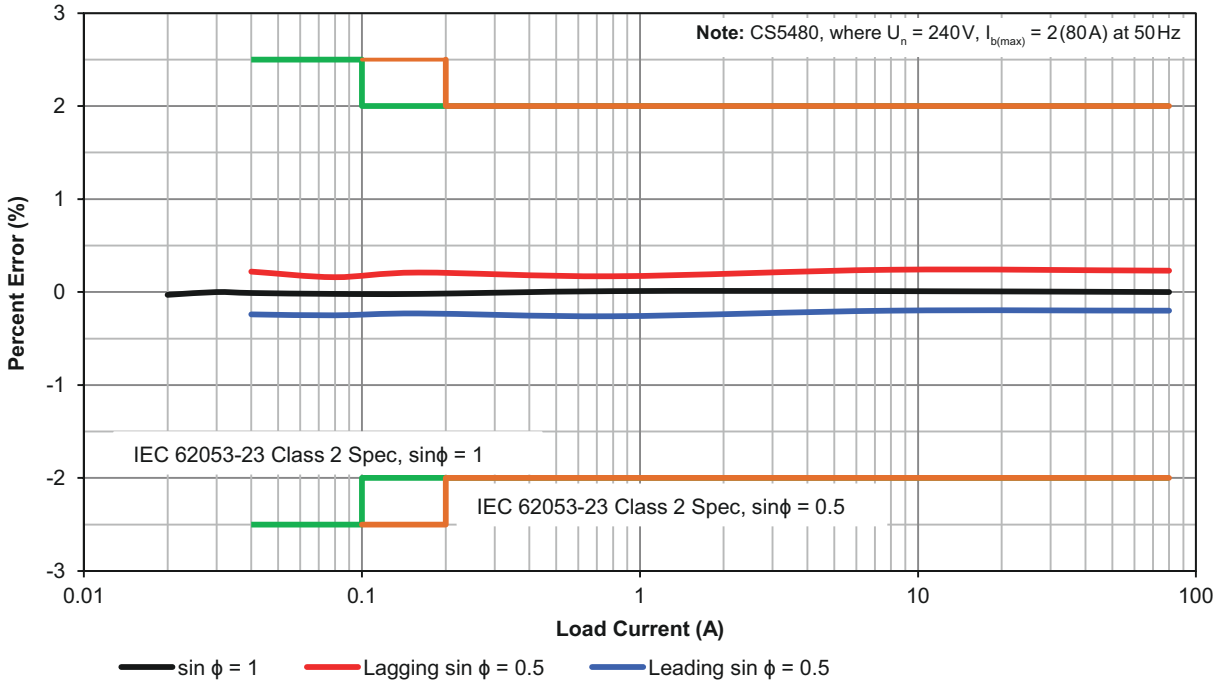

Figure 4. Reactive Energy Load Performance vs IEC 62053-23 Class 2 Standard

Power Factor	Load Current (A)	Current Dynamic Range (x:1)	Error
sinϕ = 1	80	1	0.00%
	8	10	0.01%
	0.8	100	0.01%
	0.16	500	-0.02%
	0.08	1000	-0.02%
	0.04	2000	-0.01%
	0.03	3333	0.00%
	0.02	4000	-0.03%
Lagging sinϕ = 0.5	80	1	0.23%
	8	10	0.24%
	0.8	100	0.17%
	0.16	500	0.21%
	0.08	1000	0.16%
	0.04	2000	0.22%
Leading sinϕ = 0.5	80	1	-0.20%
	8	10	-0.20%
	0.8	100	-0.26%
	0.16	500	-0.23%
	0.08	1000	-0.25%
	0.04	2000	-0.24%

Table 2. Reactive Energy Load Performance

3.3 Accuracy Results for I_{RMS} Load Current Performance

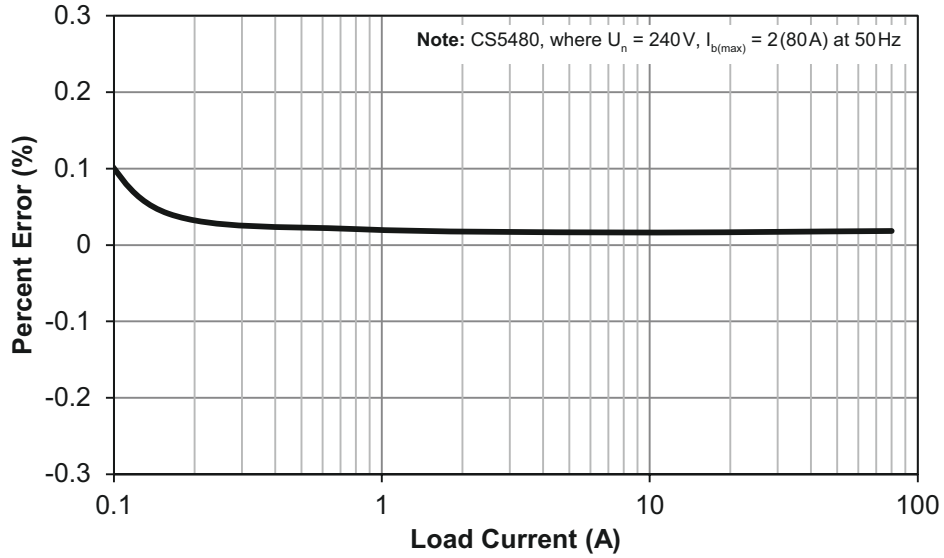

Figure 5. I_{RMS} Load Current Performance

Load Current (A)	Current Dynamic Range (x:1)	I_{RMS} Register Value (10-Second Average)	I_{RMS} Error
80	1	0.60011034	0.02%
8	10	0.06009873	0.02%
0.8	100	0.006001252	0.02%
0.16	500	0.001200491	0.04%
0.08	1000	0.000600857	0.14%

Table 3. I_{RMS} Load Current Performance

4. Accuracy Test with Current Transformer CT, U_n = 240 V and $I_{b(max)}$ = 2.5 (100 A) at 50 Hz

Taehwatrans TZ76V is used as the current sensor. The CT has the turn's ratio of 2500:1. Use 4 Ω as the load resistor. When the meter is applied with the maximum load current, I_{max} = 100 A, the secondary output voltage is (100/2500) × 4 = 0.16 V_{RMS}, which is below the maximum I-channel input range when setting the PGA for current channel 1 (I1) to 10x.

High-pass filter (HPF) is enabled on the voltage channel: V1FLT[1:0] = '01'

High-pass filter (HPF) is enabled on the current channel: I1FLT[1:0] = '01'

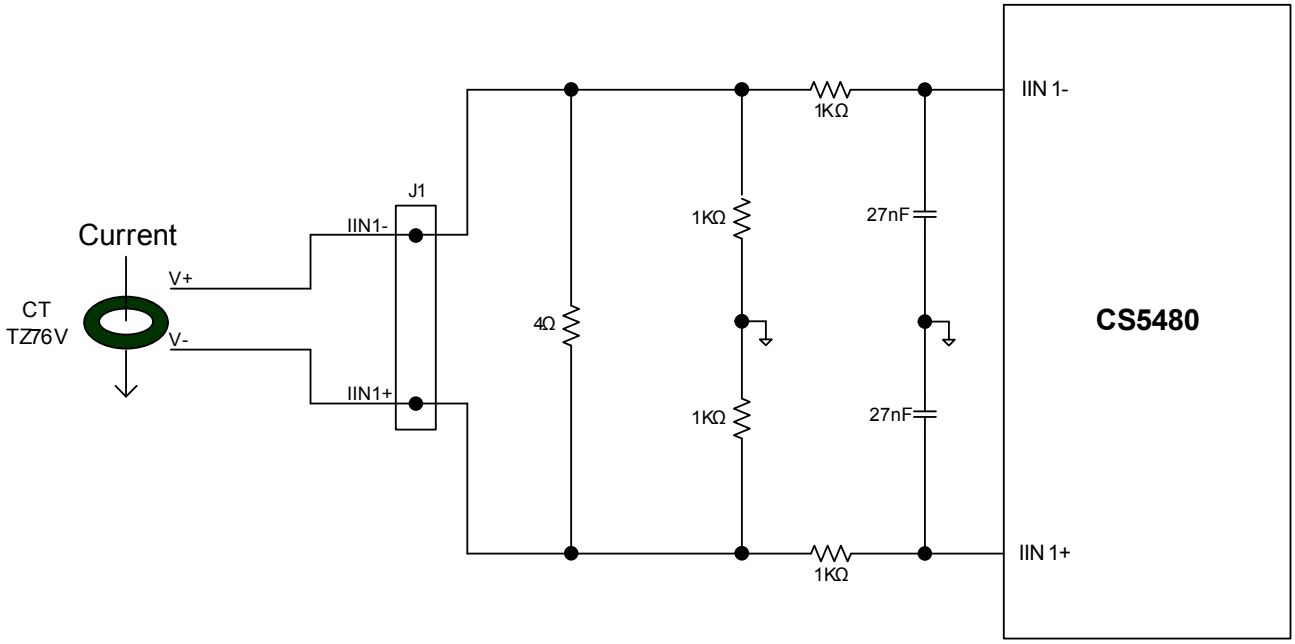

Figure 6. Connection between Current Transformer CT and CS5480

4.1 Accuracy Results for Active Energy Load Performance

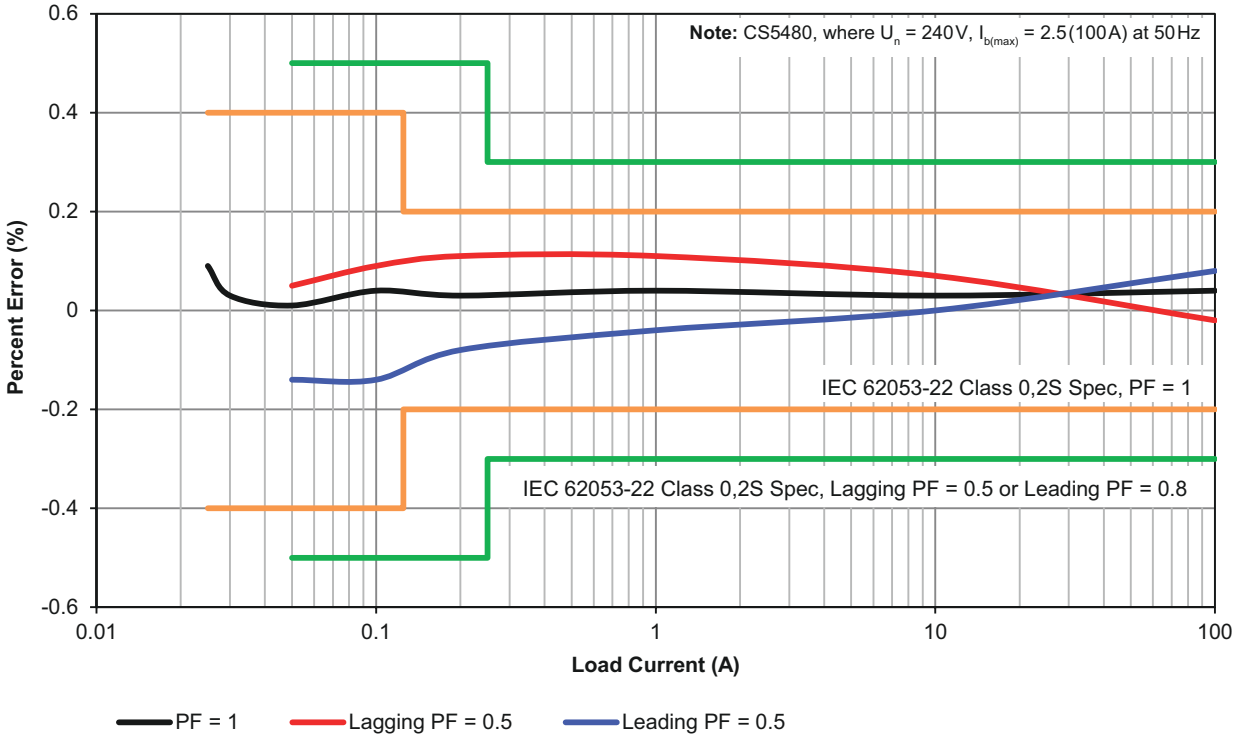

Figure 7. Active Energy Load Performance vs IEC 62053-22 Class 0,2S Standard

Power Factor	Load Current (A)	Current Dynamic Range (x:1)	Error
PF = 1	100	1	0.04%
	10	10	0.03%
	1	100	0.04%
	0.2	500	0.03%
	0.1	1000	0.04%
	0.05	2000	0.01%
	0.03	3333	0.03%
	0.025	4000	0.09%
Lagging PF = 0.5	100	1	-0.02%
	10	10	0.07%
	1	100	0.11%
	0.2	500	0.11%
	0.1	1000	0.09%
	0.05	2000	0.05%
Leading PF = 0.5	100	1	0.08%
	10	10	0.00%
	1	100	-0.04%
	0.2	500	-0.08%
	0.1	1000	-0.14%
	0.05	2000	-0.14%

Table 4. Active Energy Load Performance

4.2 Accuracy Results for Reactive Energy Load Performance

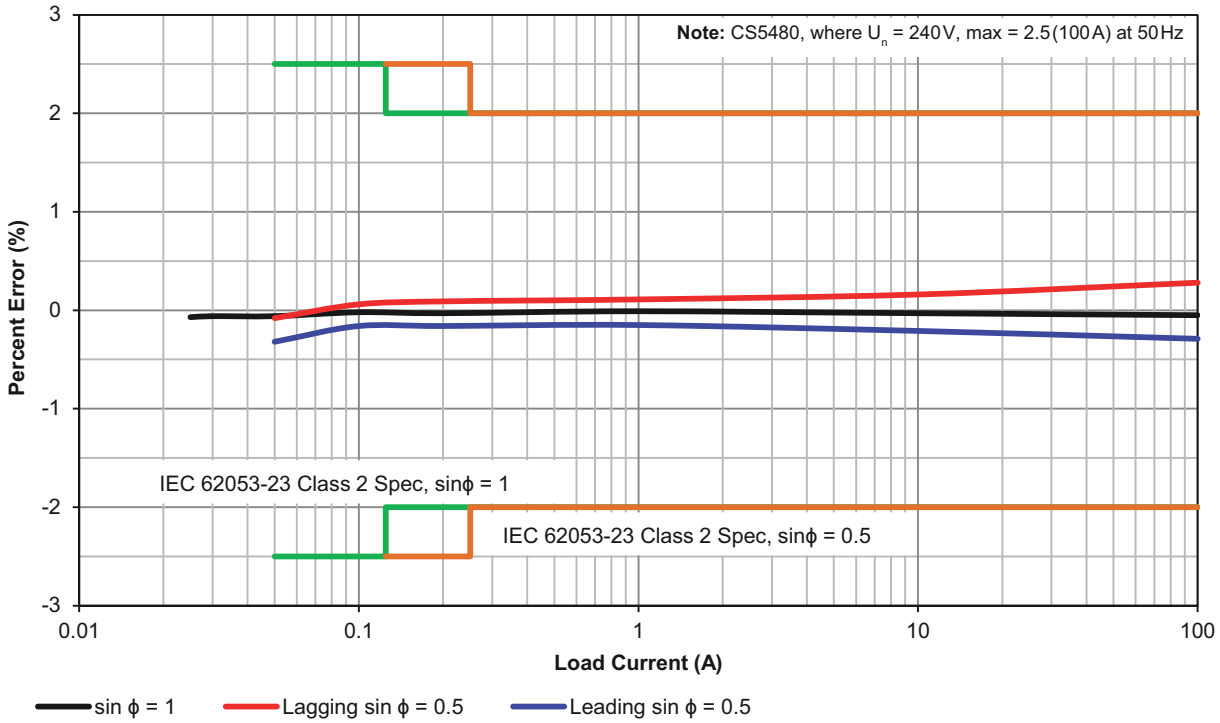

Figure 8. Reactive Energy Load Performance vs IEC 62053-23 Class 2 Standard

Power Factor	Load Current (A)	Current Dynamic Range (x:1)	Error
sinϕ = 1	100	1	-0.05%
	10	10	-0.03%
	1	100	-0.01%
	0.2	500	-0.03%
	0.1	1000	-0.02%
	0.05	2000	-0.06%
	0.03	3333	-0.06%
	0.025	4000	-0.07%
Lagging sinϕ = 0.5	100	1	0.28%
	10	10	0.16%
	1	100	0.11%
	0.2	500	0.09%
	0.1	1000	0.06%
	0.05	2000	-0.08%
Leading sinϕ = 0.5	100	1	-0.29%
	10	10	-0.21%
	1	100	-0.15%
	0.2	500	-0.16%
	0.1	1000	-0.16%
	0.05	2000	-0.32%

Table 5. Reactive Energy Load Performance

4.3 Accuracy Results for I_{RMS} Load Current Performance

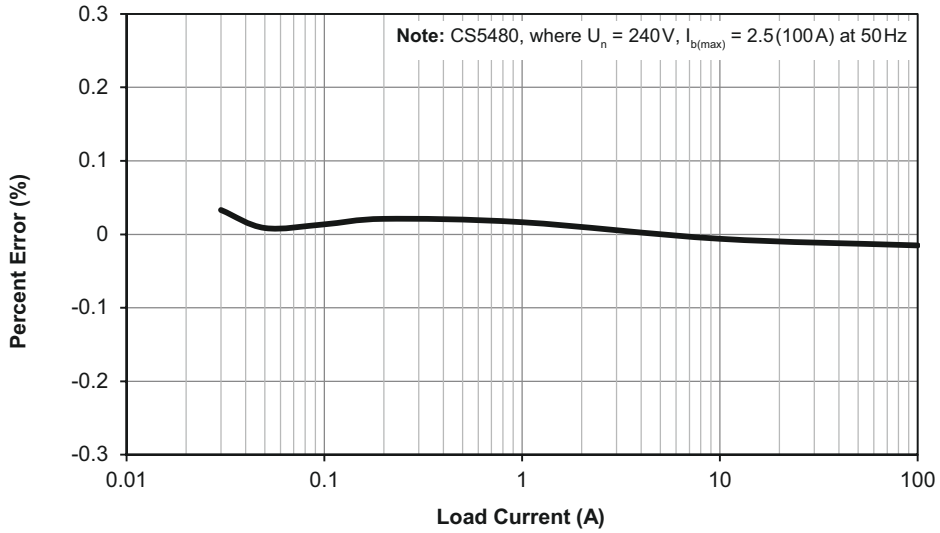

Figure 9. I_{RMS} Load Current Performance

Load Current (A)	Current Dynamic Range (x:1)	I_{RMS} Register Value (10-Second Average)	I_{RMS} Error
100	1	0.59990938	-0.02%
10	10	0.059996352	-0.01%
1	100	0.00600099	0.02%
0.2	500	0.001200253	0.02%
0.1	1000	0.000600082	0.01%
0.05	2000	0.000300026	0.01%
0.03	3333	0.00018006	0.03%

Table 6. I_{RMS} Load Current Performance

5. Accuracy Test with Shunt, U_n = 240V and $I_{b(max)}$ = 2.5(100A) at 50Hz

A 100µΩ shunt is used as the current sensor. When the meter is applied with the maximum load current, I_{max} = 100A, the voltage output from the shunt is 10mV_{RMS}, which is below the maximum I-channel input range when setting the PGA for current channel 1 (I1) to 50x.

High-pass filter (HPF) is enabled on the voltage channel: V1FLT[1:0] = '01'

High-pass filter (HPF) is enabled on the current channel: I1FLT[1:0] = '01'

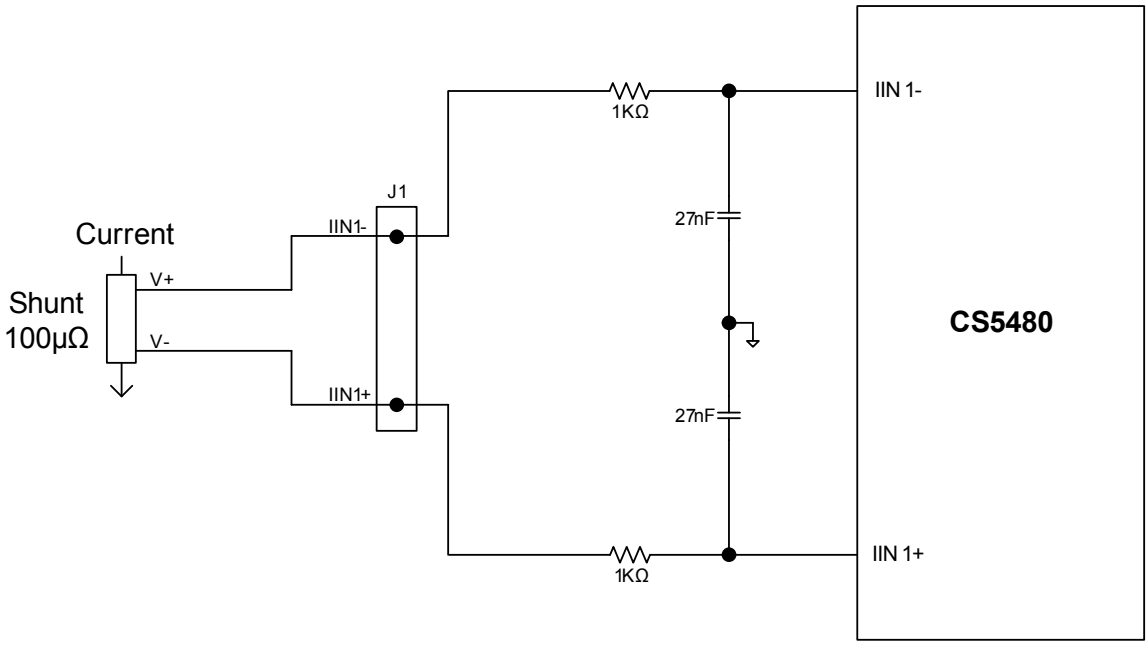

Figure 10. Connection between Shunt and CS5480

5.1 Accuracy Results for Active Energy Load Performance

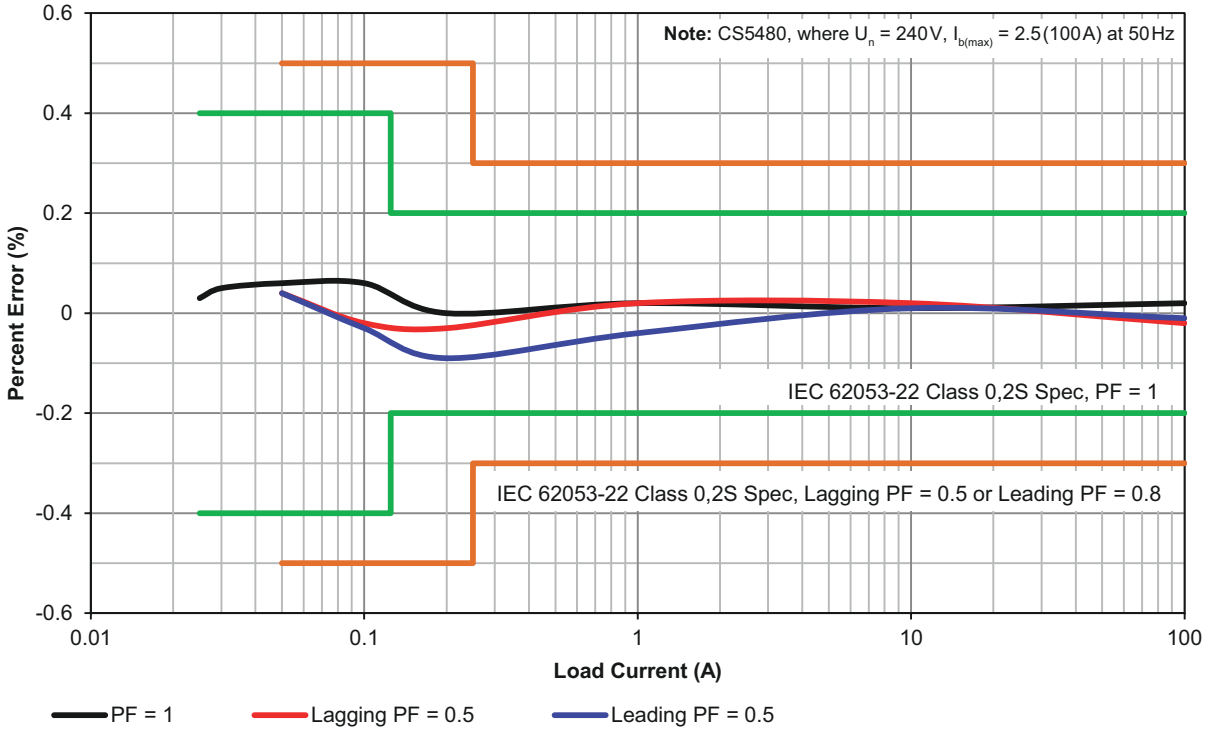

Figure 11. Active Energy Load Performance vs IEC 62053-22 Class 0,2S Standard

Power Factor	Load Current (A)	Current Dynamic Range (x:1)	Error
PF = 1	100	1	0.02%
	10	10	0.01%
	1	100	0.02%
	0.2	500	0.00%
	0.1	1000	0.06%
	0.05	2000	0.06%
	0.03	3333	0.05%
	0.025	4000	0.03%
Lagging PF = 0.5	100	1	-0.02%
	10	10	0.02%
	1	100	0.02%
	0.2	500	-0.03%
	0.1	1000	-0.02%
	0.05	2000	0.04%
Leading PF = 0.5	100	1	-0.01%
	10	10	0.01%
	1	100	-0.04%
	0.2	500	-0.09%
	0.1	1000	-0.03%
	0.05	2000	0.04%

Table 7. Active Energy Load Performance

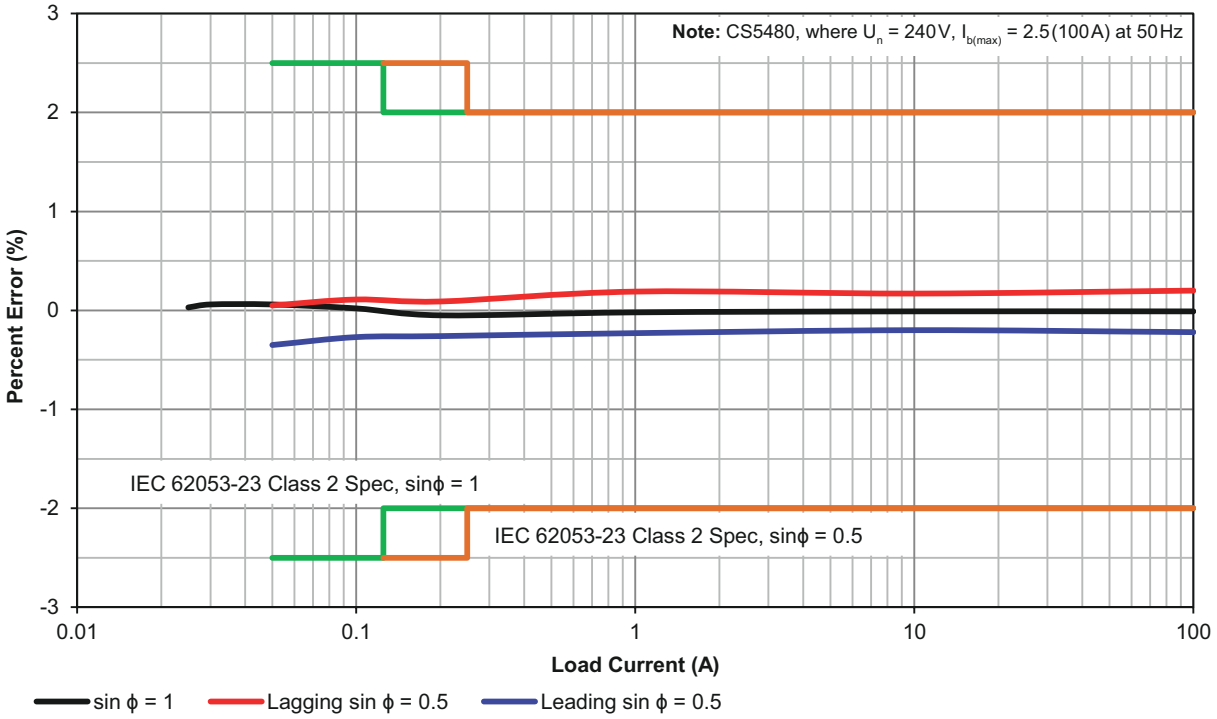

Figure 12. Reactive Energy Load Performance vs IEC 62053-23 Class 2 Standard

Power Factor	Load Current (A)	Current Dynamic Range (x:1)	Error
sinϕ = 1	100	1	-0.01%
	10	10	-0.01%
	1	100	-0.02%
	0.2	500	-0.05%
	0.1	1000	0.02%
	0.05	2000	0.06%
	0.03	3333	0.06%
	0.025	4000	0.03%
Lagging sinϕ = 0.5	100	1	0.20%
	10	10	0.17%
	1	100	0.19%
	0.2	500	0.09%
	0.1	1000	0.11%
	0.05	2000	0.05%
Leading sinϕ = 0.5	100	1	-0.22%
	10	10	-0.20%
	1	100	-0.23%
	0.2	500	-0.26%
	0.1	1000	-0.27%
	0.05	2000	-0.35%

Table 8. Reactive Energy Load Performance

5.2 Accuracy Results for I_{RMS} Load Current Performance

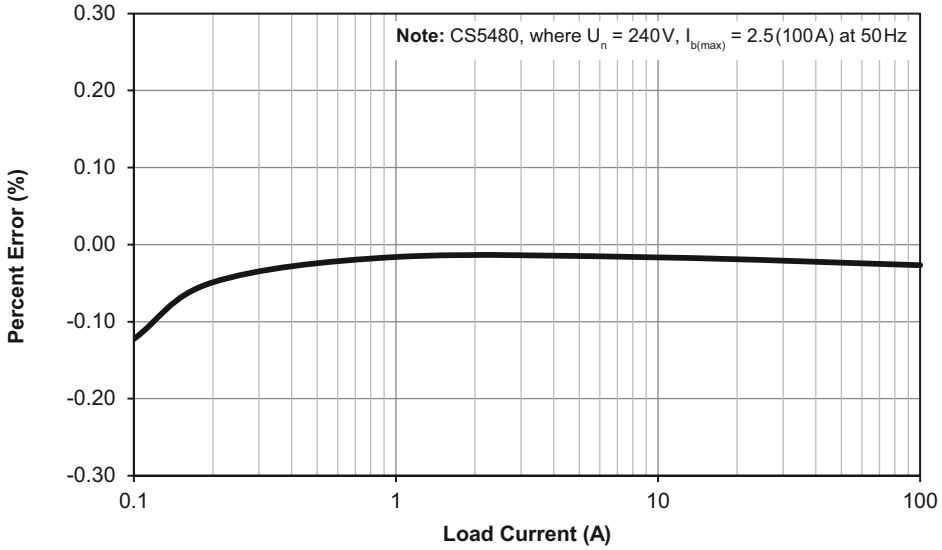

Figure 13. I_{RMS} Load Current Performance

Load Current (A)	Current Dynamic Range (x:1)	I_{RMS} Register Value (10-Second Average)	I_{RMS} Error
100	1	0.599839375	-0.03%
10	10	0.059990012	-0.02%
1	100	0.00599035	-0.02%
0.2	500	0.001199412	-0.05%
0.1	1000	0.000599265	-0.12%

Table 9. I_{RMS} Load Current Performance

6. Summary

The CS5480 supports three current sensors: Rogowski coil, current transformer, and shunt. It achieves 0.1% accuracy over 4000:1 dynamic range at PF = 1 for active energy and $\sin\varphi = 1$ for reactive energy. The active and reactive energy load performance exceeds IEC 62053-22 class 0,2S specifications and IEC 62053-23 class 2 specifications, respectively. The CS5480 is the best-in-class analog front-end device for high-accuracy electricity meters with extensive load range: $I_{max} / I_b \geq 40$.

7. Revision History

Revision	Date	Changes
REV1	MAR 2012	Initial Release.

Contacting Cirrus Logic Support

For all product questions and inquiries contact a Cirrus Logic Sales Representative.
To find one nearest you go to http://www.cirrus.com