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Energy Meter Design Operates Accurately Over Wide Current Range

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The current specification is an important parameter for energy meters as it signifies a meter's ability to accurately measure the power consumed by a user's electrical load. There are generally two parts to this specification: the basic current (I_b) for direct-connected meters or the rated current I_n for transformer-operated meters , and the maximum current I_{max}. Of these current ratings, you will typically see the current specification defined in terms of I_b with the I_{max} value shown in parentheses. For example, some common values for the energy meter current specification include 5 (20) A and 5 (30) A.

These values are important because regulatory agencies have established various requirements for the current specification. For example, IEC standard IEC62052-11 recommends that the maximum current shall be 4 times or more the value of the basic current for direct-connect type meters, while the State Grid Corporation of China Enterprise Standard Q/GDW 364-2009 stipulates that the current specification for direct-connect type meters should be chosen from either 5 (60) A or 10 (100) A.

The maximum current rating is particularly significant. Consider that the life of an energy meter is over ten years, sometime twenty years. During this time, the energy load can change dramatically. For example, in residential applications, the electricity demand may grow substantially just a few years after meter installation. This is especially true during the annual peak period when the maximum electricity load could be close to or even exceed the maximum current of the energy meter. This represents a dangerous situation that must be avoided. So, for electrical safety, utilities may have to replace a large number of energy meters, which are still in the early or mid-life phase of their operational life. Naturally, this results in a substantial waste of resources.

Generally, the current specification range of an energy meter is related to the dynamic range of its A/D sampling, which is determined by the energy metering IC used in the meter. Limited by the dynamic range of the existing metering ICs, utilities have had to define many different current specifications for energy meters to suit a range of demands for electricity usage. With so many current specifications, utilities and manufacturers have had to increase the resources they devote to building and stocking energy meters. Their inventories have grown to include multiple energy-meter models along with the additional test equipment and spare parts required to support the various models. This trend has greatly hampered efforts by utilities and meter manufacturers to standardize their equipment.

Also, with the wide application of renewable sources such as solar and wind energy generation to the power grid, the new smart meter should have a bi-directional measuring function, both for the tens of kilowatts consumed during peak load hours, and for the several watts of power generated from renewable sources during off-peak hours.

Ultimately, both utilities and energy meter manufacturers would like to develop a single current specification that would meet the electricity demands of all users. This is a challenge that R&D teams—those in the utility and metering industries as well as IC design houses—have been working for years to solve.

To that end, IDT developed the 90E24 metering IC. This device enables the design of a single-phase energy meter with a current specification of 1 (100) A, while maintaining a measurement accuracy of better than 0.2% from 20 mA to 100 A. That equates to a current measurement dynamic range of 5000:1. Over temperature, the accuracy of current measurement is maintained with a temperature coefficient of less than 150 ppm/°C.

With its 1 (100) A current specification and high accuracy, this energy meter design can merge existing requirements for current specifications of 5 (20) A, 10 (40) A, 15 (60) A, 20 (80) A, 30 (100) A and even 1.5 (6) A. In other words, the wide-span meter design enables utilities to purchase one meter model that meets the electricity demands of many different users, which then reduces the inventory of energy meters, and simplifies requirements for test equipment and spare parts for both the utility and the meter manufacturer.

In this article, we'll describe the design of a 1 (100) A wide-span energy meter. We'll discuss the key points of hardware design, describe calibration procedures and metering features, and then present test data to verify metering performance.

Overview

The 90E24 is a high-performance wide-span energy metering IC. Its features are in full compliance with the requirements of the IEC62052-11, IEC62053-21 and IEC62053-23 standards. The 90E24 is applicable in class 1 or class 2 single-phase watt-hour meters or class 2 single-phase var-hour meters. The IC features an accuracy of 0.1% for active energy and 0.2% for reactive energy over a dynamic range of 5000:1.

The 90E24 block diagram is shown in Fig. 1.

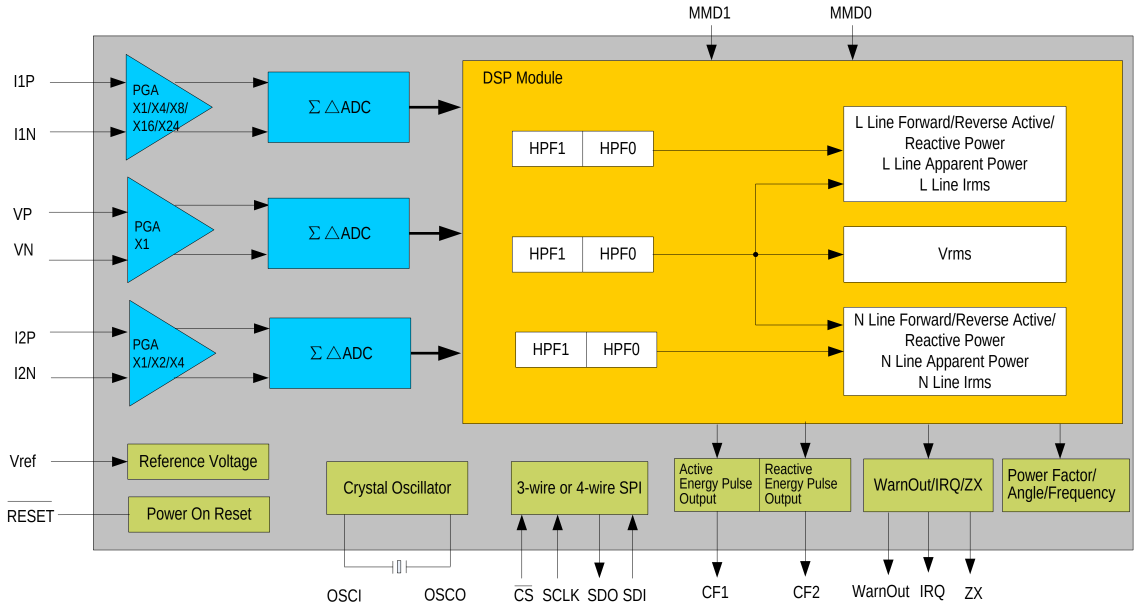

Fig. 1 90E24 block diagram.

Wide-Span Meter Design

Hardware Design

The meter consists of the 90E24 metering IC, an MCU and peripheral components. The metering part of the reference design is shown in Fig. 2.

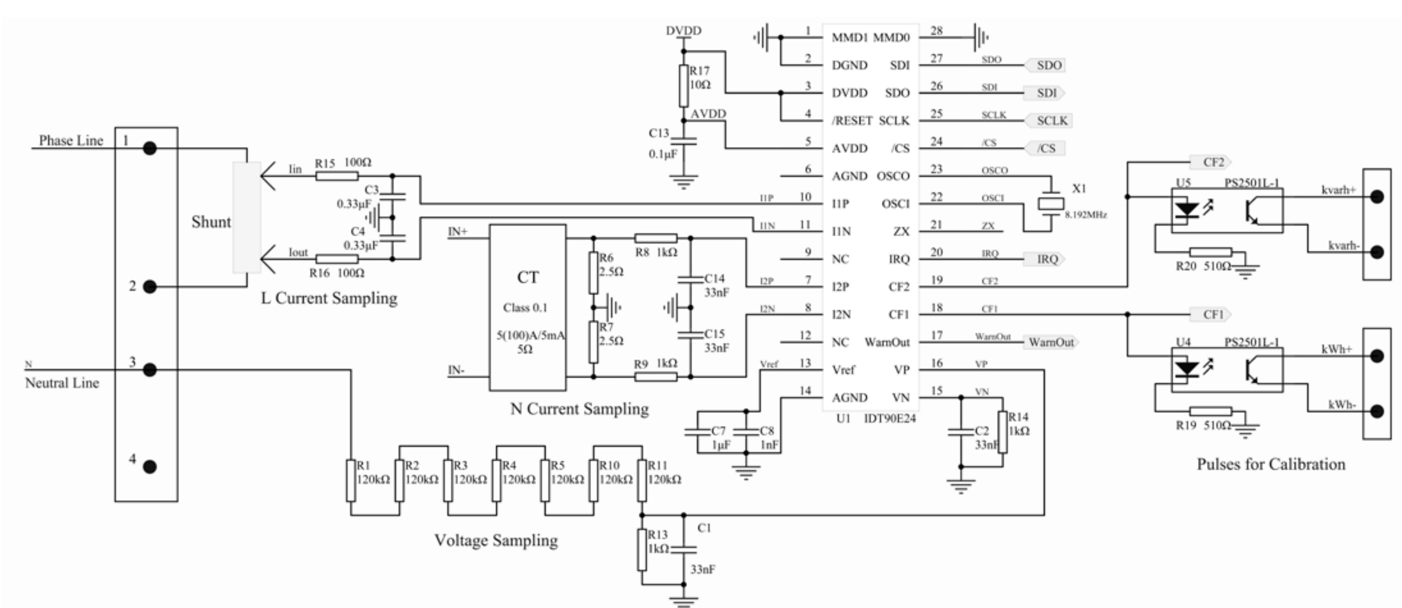

Fig. 2. Hardware design.

The 90E24 has three ADC-input channels, one for voltage sampling and two for phase line (L line) and neutral line (N line) current sampling.

The ADC range for the voltage-input channel is 120 µVrms to 600 mVrms. A resistor divider network is used for voltage sampling. The divider rate is 1 kΩ:840 kΩ, so the typical input to ADC is 261.593 mVrms at 220 Vac.

The ADC range for the L-line input channel is 5 µVrms to approx. 25 mVrms (when gain is '24'). A 150-µΩ shunt resistor is used for L-line current sampling. The maximum input to the ADC is 15 mVrms at 100 A.

The ADC range for the N-line input channel is 120 µVrms to 600 mVrms (when gain is '1'). A current transformer (CT) is used for N-line current sampling. The parameters for CT are 5 A (100 A)/5 mA, 5 Ω, and the maximum input to the ADC is 500 mVrms at 100 A. The CT can also isolate the L line and N line.

The 90E24 has a built-in 1.2-V reference voltage, which requires a 1-µF and a 1-nF SMT capacitor to connect to the Vref pin. The temperature coefficient is 15 ppm/°C. The 90E24 also has built-in 10-pF capacitors for the crystal oscillator, so no external capacitors are needed. The external crystal shall be 8.192 MHz. The design uses a Microchip core 8-bit RISC MCU FM2307, integrating EEPROM and an LCD driver. It communicates with the 90E24 through an SPI interface.

As this discussion illustrates, the 90E24-based metering employs common components, ensuring low BOM cost.

Calibration

Calibration Method

The meter can be calibrated at a single point over the dynamic range.

However, due to the very small signal in L-line current-sampling circuits, any external interference may cause perceptible metering error, especially in a low-current state. For this nearly constant external interference, the 90E24 provides power-offset compensation.

The L line and N line need to be calibrated sequentially. Reactive energy does not need to be calibrated once the active energy has been calibrated.

Calibration Steps

A single-point calibration of the L line requires the following four steps:

1. Enter Small Power mode, set U = 220 V and I = 0 A to eliminate active/reactive power offset.
2. Set U = 220 V, I = 5 A and PF = 1.0 to calibrate L-line gain.
3. Set U = 220 V, I = 5 A, PF = 0.5 L and Freq = 50 Hz to compensate L-line phase angle.
4. Set U = 220 V, I = 5 A to calibrate Urms and Irms.

The N-line calibration is similar to that of the L line.

For more details about 90E24 calibration, refer to the IDT application note AN-641 (Single-Phase Energy Metering IC Application Note).

Features Of The Meter Design

The meter can measure active and reactive energy and display that information on an LCD display. The active and reactive energy are captured and accumulated from the energy-pulse output pins CF1 and CF2 of the 90E24.

The design can meter both the L and N lines, and can be configured in anti-tampering mode.

The meter can also measure electricity parameters such as Vrms, Irms, mean active/reactive/apparent power, frequency, power factor and phase angle. The MCU can read these parameters from the 90E24 through the SPI interface and display them on the LCD.

The meter provides two communication ports to the external system: RS-485 and infrared. The RS-485 port is also used for meter calibration.

For the meter prototype described in this article, the operating parameters are as follows:

1. Reference voltage: 220 Vac
2. Current specification: 1 (100) A
3. Reference frequency: 50 Hz
4. Meter constant: 3200 imp/kWh, 3200 imp/kvarh
5. Startup current: 0.4% I_b, which is 4 mA

Test Data

Metering Dynamic Range Test

The whole meter can achieve a metering accuracy of 0.2% for active energy and 0.4% for reactive energy over the dynamic range of 5000:1.

The active-energy error test result for L line is shown in Table 1. The active-energy error test result for N line is similar to that of L line.

Table 1. Metering dynamic range test.

Current(A)	L Line Actual kWh Error (%) (PF=1.0)		
	Meter #1	Meter #2	Meter #3
0.02	-0.0373	0.0259	0.1566
0.05	-0.0319	0.0142	0.0373
0.1	-0.0263	-0.0170	0.0362
0.25	-0.0142	-0.0337	0.0195
0.5	-0.0071	-0.0337	0.0124
1	-0.0177	-0.0355	0.0000
2.5	-0.0177	-0.0355	-0.0177
5	0.0177	-0.0355	0.0177
10	-0.0355	-0.0710	-0.0355
20	0.0000	-0.0888	0.0000
30	-0.0592	-0.0592	-0.0592
40	-0.0444	-0.0444	-0.0444
60	-0.0592	-0.0888	-0.0592
80	-0.0444	-0.0444	-0.0444
100	-0.0444	-0.0444	-0.0444

Current(A)	L Line Actual kWh Error (%) (PF=0.5L)		
	Meter #1	Meter #2	Meter #3
0.02	-0.1235	0.0668	0.1938
0.05	-0.0518	-0.0003	0.1238
0.1	-0.0170	-0.0223	0.0583
0.25	-0.0177	-0.0177	0.0337
0.5	0.0088	-0.0142	0.0160
1A	0.0142	-0.0142	0.0284
2.5	-0.0177	-0.0355	-0.0177
5	-0.0355	-0.0533	-0.0355
10	0.0355	-0.0355	0.0000
20	-0.0888	0.0000	0.0888
30	0.0000	-0.0444	0.0000
40	-0.0444	-0.0444	-0.0444
60	-0.0444	-0.0444	-0.0444
80	-0.0444	-0.0444	-0.0444
100	-0.0444	-0.0444	-0.0444

Temperature Influence Test

The temperature influence test result for L line is shown in Table 2. The test result for N line is similar to that of L line.

Table 2. Temperature influence test.

Temp.	Influence (ppm/°C) (PF=1.0)				
	80 A	20 A	5 A	1 A	0.5 A
-40°C	-96.42	-96.32	-84.77	-85.91	-88.14
-10°C	-89.26	-101.94	-86.74	-78.51	-77.51
25°C	--	--	--	--	--
55°C	-73.93	-59.13	-76.93	-66.27	-68.63

Temp.	Influence (ppm/°C) (PF=0.5L)				
	80 A	20 A	5 A	1 A	0.5 A
-40°C	-102.86	-82.18	-84.82	-88.26	-68.15
-10°C	-88.83	-101.54	-71.03	-71.03	-72.54
25°C	--	--	--	--	--
55°C	-88.33	-88.33	-88.37	-70.73	-69.57

The temperature influence of the whole meter is better than 150 ppm/°C.

Conclusion

As the test results indicate, the 90E24 can fully achieve the design requirement of a single-phase 1 (100) A energy meter. The complete meter design can achieve an active energy accuracy of better than 0.2% and a temperature influence of less than 150 ppm/°C while employing inexpensive peripheral components and requiring only single-point calibration.

References

1. IEC Standard: IEC62052-11 Electricity metering equipment (AC) - General requirements, tests and test conditions - Part 11: Metering equipment

2. IEC Standard: IEC62053-21 Electricity metering equipment (AC) - Particular requirements - Part 21: Static meters for active energy (classes 1 and 2)

3. IEC Standard: IEC62053-22 Electricity metering equipment (AC) - Particular requirements - Part 23: Static meters for reactive energy (classes 2 and 3)

4. Single-Phase High-Performance Wide-Span Energy Metering IC 90E21/22/23/24 data sheet.

5. AN-641: Single-Phase Energy Metering IC Application Note.

6. Reference Design Calibration Software User's Guide.

About The Authors

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