Microcontroller-Based Energy Metering using the AD7755

by John Markow

As the energy metering industry converts from electromechanical meters to more-accurate solid-state meters, power-system designers have a chance to incorporate new features that weren't previously possible. In demand now are solid-state meters that measure energy more accurately than electromechanical meters, incorporate multiple-rate billing, and are capable of being read remotely by the utility company. This article describes how the AD7755 Energy Meter[1] integrated circuit could be used in three-phase energy metering with power outage detection and measurement backup, and remote, automated, multiple-rate metering.

The AD7755 is an accurate (to 0.1%) single-phase energy-measurement IC. It accepts a pair of voltage inputs that represent the voltage and current of a power line. Internally, these signals are converted to the digital domain with oversampling A/D converters. A fixed-function digital signal processor continuously multiplies the two signals; their product is proportional to instantaneous power. After being low-pass filtered, the digital signal is then converted to a frequency—scaled according to selectable settings—to generate frequency outputs at terminals F1, F2, and CF. The signals at F1 and F2 can be used to drive an electromechanical counter (typically at full-scale rates from 0.5 to 5 Hz), while the higher-frequency CF signal is suitable for calibration. The *frequency* (or rate) of the pulse outputs is proportional to the instantaneous *real power* being monitored by the meter. Accordingly, in a given interval, the total *number* of pulses generated at these outputs is proportional to the *energy* transferred to the load. A reverse-polarity logic signal indicates when the measured instantaneous power goes negative (i.e., the load is returning net power to the line).
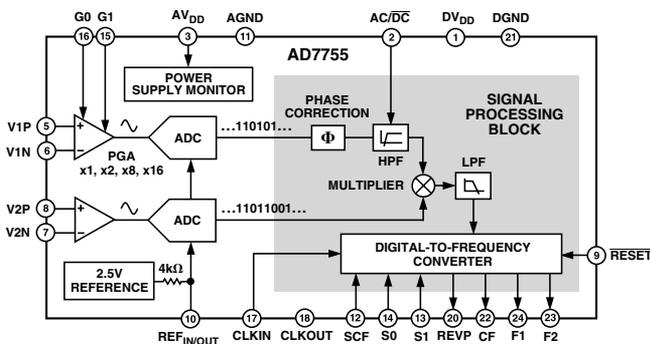

Figure 1. Block Diagram of the AD7755

The CF frequency output is a pulse train proportional to the F1,F2 outputs, with full-scale output rates of 21.76 Hz, 43.52 Hz, and 5.57 kHz, for ac inputs. It is well suited to interfacing to a microcontroller that performs calculations and makes decisions.

[1]www.analog.com

[2]www.microchip.com

Figure 2 shows how three AD7755s-one for each phase-are used with a microcontroller to make a three-phase energy meter.
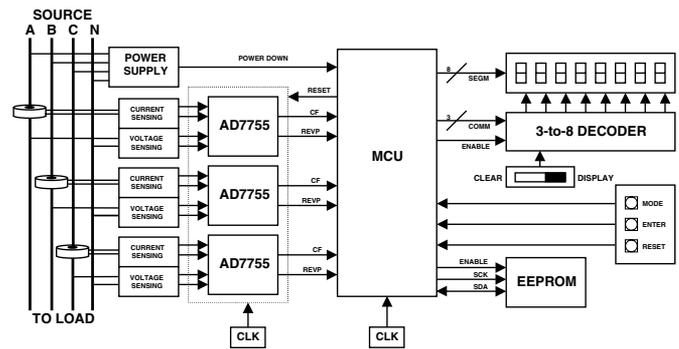

Figure 2. Functional block diagram of a three-phase microcontroller-based energy meter

The microcontroller serves as the "brains" of the system, performing all the required housekeeping tasks and interacting with the other components—the energy meter ICs, the power supply, the EEPROM, the display, and buttons to operate the meter—to view energy or power, calibrate the phases, or clear the reading. Besides low cost, the basic microcontroller requirements are:

* *Sufficient I/O to drive the display.* If an LCD display is used a driver is required. If one is not incorporated into the MCU, an LED display can easily be controlled with a 3-to-8 decoder.

* *Interrupts.* To avoid missing any energy-indicating pulses, the system can be configured to trigger interrupts in the MCU. A power supply monitor can generate an MCU interrupt when it has detected a brownout condition and initiate an emergency energy measurement backup.

* *EEPROM Serial Interface.* A simple serial interface can be created using only two or three I/O lines. An MCU with a built-in serial interface makes the design even easier.

* *Timers.* There are two main time intervals that need to be maintained. First, a display update rate must be set at about 2 seconds. Also, if an LED display is used, a timer must cycle through the digits at a sufficient rate to minimize on flicker. Additionally, the calibration routine must be carefully timed, but can be implemented with interrupt postscalers.

As an added feature, a second serial interface could be used to communicate with a host system for remote/automated metering. Also, either an external or internal clock could be used to implement multi-rate metering.

Reference Design: A three-phase energy-meter reference design (Figure 2) has been implemented to demonstrate how multiple AD7755s can be interfaced to a microcontroller. It uses a Microchip PIC16C67 microcontroller[2], serial EEPROM, an 8-digit LED display, current transformers for current sensing, and resistor dividers for voltage sensing. Power is furnished by a transformer-based supply incorporating power-loss detection.

The analog interface to the AD7755s is instrumented with voltage divider resistors for the voltage channels and current transformers

for the current channels. The current transformers provide a degree of electrical isolation and eliminate the need for current-sensing shunts within the meter. The microcontroller code is written in the C programming language and has been programmed into the PIC16C67. The particular compiler that was used also includes a set of instructions to interface to a Microchip serial EEPROM, which stores energy measurement digits and the calculation limits obtained in calibration mode. The display consists of 8 LED digits multiplexed by a 3-to-8 decoder. The power supply uses three transformers, a rectifier, and a regulator to convert 220-V, 3-phase ac to a dc voltage capable of powering the meter even if one phase goes out. A reference design data sheet/application note is available[3].

Since the meter determines the cost of energy to the user, the most important requirements of an energy meter are reliability and accuracy over time. The energy is measured in a fairly simple way—by pulse-limit comparison. In this method, the microcontroller counts the number of pulses on a phase until the total reaches a calibrated limit. At this point, the energy reading is incremented by the smallest unit within the range of the display (in this case, 0.01 kWh). This technique implies that the display register need only be updated when necessary and also avoids complex numerical operations that could make the meter operate inefficiently.

The maximum output frequency at CF in the slow mode is 43.52 Hz, or 156,672 pulses/h. Allowing for headroom, a 220-volt, 60-ampere system could be calibrated so that 0.01 kWh of measured energy produces approximately 100 pulses on CF. Calibration is done in the high-frequency mode, in which the maximum frequency on CF is 128 times faster, or 5.57 kHz. During calibration, a fixed power is set on the line at a value that yields 1/128 kWh over the calibration interval. Because of the scaling factor of 128, the number of pulses counted during the calibration time is equivalent to 1 kWh when the AD7755 is returned to the low-frequency mode.

Suppose 10287 pulses had been counted during this interval. Then the display would have to be incremented by 0.01 kWh every 102.87 pulses, rather than every 100 pulses. This fractional-N count could be accomplished in several ways. For example, during the time required to advance the display by 100 increments (i.e., to accumulate 1.00 kWh in 0.01 kWH steps), 13 of those steps could be produced by a count of 102 pulses, and the other 87 steps would require a count of 103 pulses. An alternative that has been in use is, starting with 102 pulses per step, to add 8 pulses on every 10th step, and 7 more pulses on every 100th step.

The high frequency setting on the AD7755s yields better results in a shorter calibration time (about 30 seconds). Due to possible variations in the system, and to historical practices, each phase of a three-phase meter is calibrated independently.

Conclusion: A basic solid-state meter design like that described above will most likely be more accurate, more reliable, and cheaper than electromechanical meters, and will allow for added features that benefit both the customer and utility company. In the near future, the utility company will monitor your energy consumption remotely and bill you according to peak- and off-cycle usage—or even (in the Motorola[4] system) allow you to keep track of your usage. Not only will the measurement be more accurate, but, implemented over an entire electrical network, solid-state metering allows for more efficient energy management.

References

Three-Phase Energy Meter reference design data sheet (REF-AD7755-3). Analog Devices.

AD7755 Energy Meter IC with Pulse Output data sheet. Analog Devices.

Daigle, Paul. "All Electronic Power and Energy Meters," *Analog Dialogue*. Volume 33, Number 2, February, 1999.

[3]www.analog.com/industry/energymeter/index.html

[4]www.mot.com/GSS/SSTG/ISSPD/URM/index.html