

Smart Metering Technology Promotes Energy Efficiency for a Greener World

By Austin Harney

INTRODUCTION

We're all familiar with the electricity meter hidden away in the garage, basement, or other out-of-view location. We may even have looked at it once or twice to phone an up-to-date reading to the utility company in place of an estimate. Thanks to technology, a quiet revolution is taking place inside this innocuous looking meter.

Figure 1 shows an example of a traditional *electromechanical meter*—first developed in the late 19th century—that has a spinning disc and a mechanical counter display. This type of meter operates by counting the revolutions of a metal disc that rotates at a speed proportional to the power drawn through the main fuse box. Nearby coils spin the disc by inducing eddy currents and a force proportional to the instantaneous current and voltage. A permanent magnet exerts a damping force on the disc, stopping its spin after power has been removed.



Figure 1. Electromechanical energy meter.

The first step in meter evolution was the replacement of electromechanical meters with *solid-state electronic meters*. Electronic meters measure energy using highly integrated components, such as the [ADE516x](#),¹ [ADE556x](#),² [ADE716x](#),³ [ADE756x](#),⁴ and [ADE77xx](#)⁵ families of [energy-measurement ICs](#).⁶ These devices digitize the instantaneous voltage and current via a high-resolution sigma-delta ADC. Computing the product of the voltage and current gives the *instantaneous power* in watts. Integration over time gives energy used, which is usually measured in kilowatt hours (kWh). The energy data is displayed on a liquid-crystal display (LCD), as shown in Figure 2.

Electronic meters offer several benefits. In addition to measuring instantaneous power, they can measure other parameters such as *power factor* and *reactive power*. Data can be measured and stored at specific intervals, allowing the utility to offer price plans based on time-of-day of usage. This allows savvy consumers to save money by running major appliances, such as washers and dryers, during lower-cost, off-peak periods; and utility companies can avoid building new power plants because less capacity is required during peak periods. Electronic meters are not influenced by external magnets or orientation of the meter itself, so they are more tamper-proof than electromechanical meters. Electronic meters are also highly reliable.

Analog Devices has been a key player in the transition from electromechanical meters to electronic ones, shipping more

than 225 million energy measurement ICs to date. According to IMS Research, 75% of all energy meters shipped in 2007 were electronic rather than electromechanical.⁷



Figure 2. Solid-state electronic energy meter.

Electronic Meter Opens Up New Possibilities

Once meter data is available in electronic form, it becomes feasible to add communications to the meter, allowing the meter to use *automatic meter reading* (AMR) to access data remotely via the communication link. Meter manufacturers have developed different system architectures for remote reading, broadly classified as walk-by, drive-by, or networked systems. A drive-by system is shown in Figure 3. In this case, the utility company sends out a van with an on-board wireless data collector. The van drives through the neighborhood efficiently collecting meter data. A drive-by system improves the number of meters a utility employee can read in a day fivefold compared to walk-by systems and over tenfold compared to manual meter reading. In a networked system, meter data is fed to a fixed data collector, which is typically located on a pole at the end of the street or neighborhood. The data is fed back to the utility via a broadband or cellular backbone.

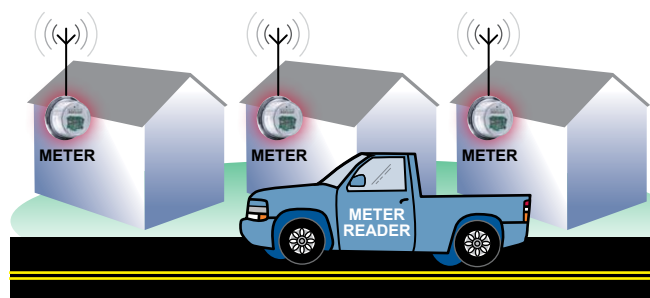


Figure 3. Drive-by meter reader.

AMR to AMI

Initially, replacing manual reading with AMR systems was seen simply as a way to reduce labor costs, but this is changing as the industry recognizes that AMR allows utility companies to conveniently provide higher order benefits and services, such as real-time pricing to promote better energy efficiency, instant reporting of fault detection, and more accurate data for profiling usage within the network. AMR is sometimes replaced with *Advanced Metering Infrastructure* (AMI) to highlight the evolution from simple remote meter reading. AMI networked metering systems can be implemented using technologies ranging from satellites to low-cost radios. The two dominant emerging technologies are RF—using the unlicensed industrial, scientific, and medical (ISM) band—and power line carrier (PLC).

RF technology uses low-power, low-cost radios to wirelessly transmit the meter information, whereas PLC uses the power line itself. Analog Devices has developed solutions for both of these technologies, with the ADF7xxx family of [short-range transceivers](#)⁸ addressing the ISM band RF segment and the SALEM® family based on the popular [Blackfin® processor](#)⁹ addressing the PLC segment. Each of these technologies has its pros and cons. For

water and gas meters in particular, RF technology is becoming the dominant choice due to the safety concerns of having power mains near water or gas. Water meters also have the added complication of often being buried underground. With electricity meters, a combination of both approaches is looking most likely, with North America favoring RF and Europe favoring power line. In the U.S., a small number of houses are typically tied to a single transformer, making PLC less economical. In some implementations, utility companies are deploying AMI using a blend, with power line used to communicate from the data collector to the electricity meter and RF used between the electricity meter and other in-home meters or devices. An interesting Google Maps page highlighting [worldwide AMR/AMI deployments](#)¹⁰ and field-trials shows up-to-date information.

Designing the RF Piece of an AMR/AMI-Enabled Utility Meter

Utility meters are often located in or around homes that have an ever-increasing number of wireless devices, so ensuring reliable radio communication is a challenge. High performance from the RF circuitry is required to reject large unwanted signals from devices such as a wireless LAN while decoding the wanted signal that might be as low as fractions of a microvolt at the input to the radio.

Good radio sensitivity is also required because this translates into longer signal transmission ranges. Remember that the meter can be located in a basement or, even worse, underground—yet it needs to communicate with a radio on a pole some blocks away or with a utility van on the street. The lower the sensitivity, the closer the receiving radio needs to be to decode the messages correctly. For a mobile drive-by system, this simply means the van must drive closer to your house, but fixed network infrastructure must use smaller cells and a corresponding larger number of data collectors. High sensitivity will thus minimize network infrastructure costs.

Low power consumption is critical in battery-powered gas and water meters. Meter vendors often try to reduce power consumption in an energy meter because this allows them to port the same design to a water or gas meter. Also, in order to operate in the unlicensed portion of the spectrum, the communication protocol used by the meter and reader must comply with the radio emissions regulations in the country of operation. Several unlicensed bands exist worldwide, the most common ones being at 900 MHz, 2.4 GHz, and 5.8 GHz.

A majority of meter manufacturers have chosen radios in the 900 MHz bands for the links between meters, and between meter and data collector. Radios at these frequencies offer better communication range for a given power budget than competing 2.4-GHz technologies and, thus, allow much wider cell coverage for a given base station or data collector. From the utility's perspective, however, a drawback of using this frequency band has been the lack of available standards. The sub-GHz bands are clearly the best technology choice for battery-powered gas and water meters, inspiring increasing demand for standardization to allow interoperability between different manufacturers' systems. Wireless M-Bus, which has grown out of the wired M-Bus users group, is one example of a standard for communication between meters, and between meter and data collector. [M-Bus](#)¹¹ is now part of the EN European Normative standard detailed in EN 13757. The Wireless M-Bus protocol is detailed in the EN 13757-4 variant. Other standardization efforts at 900 MHz are also underway.

The [ADF7020](#)¹² and the soon-to-be-released ADF7023 transceivers are examples of 900-MHz radios that are designed with metering in mind. Both devices are also suitable for systems that must comply with the Wireless M-Bus standard. A block diagram of the ADF7020 is shown in Figure 4.

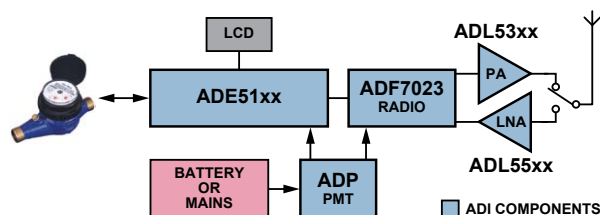


Figure 5. AMR-enabled utility meter.

The ADF7020 fully integrated, low-power radio transceiver operates in the license-free ISM bands at 433 MHz in China, 868 MHz in Europe, and 915 MHz in North America. It integrates the full *transmit* and *receive* RF sections as well as analog and digital basebands. Implementing a radio card for an [AMR-enabled utility meter](#)¹³ typically requires the ADF7020, an antenna, a small number of external passives, and a simple microcontroller to run the communication protocol, as shown in Figure 5. The ADF7020 significantly eases the burden of the external microcontroller by integrating an ultralow-power, 8-bit RISC core to run some of the lower-level communication functions. This can eliminate the

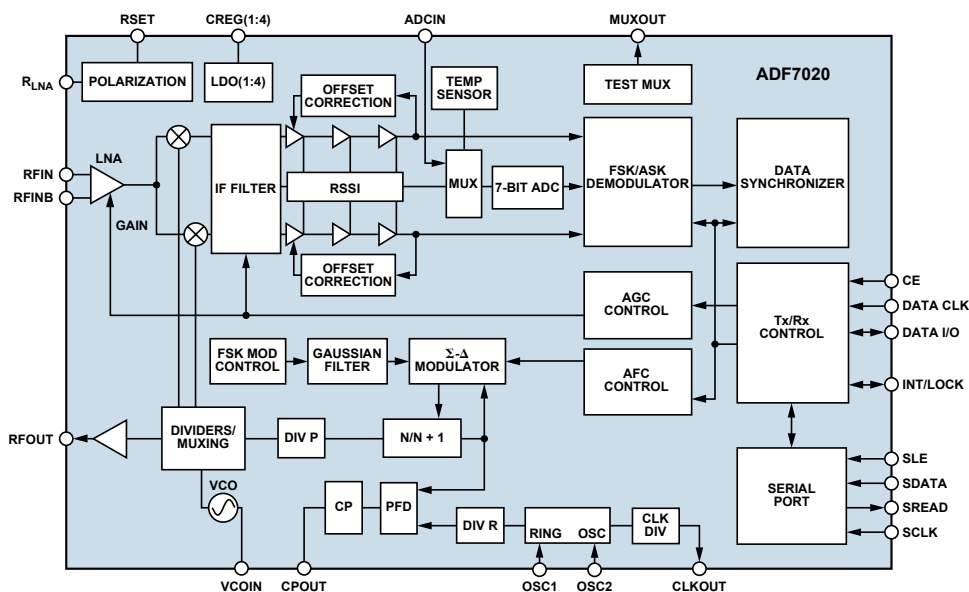


Figure 4. Functional block diagram of the ADF7020.

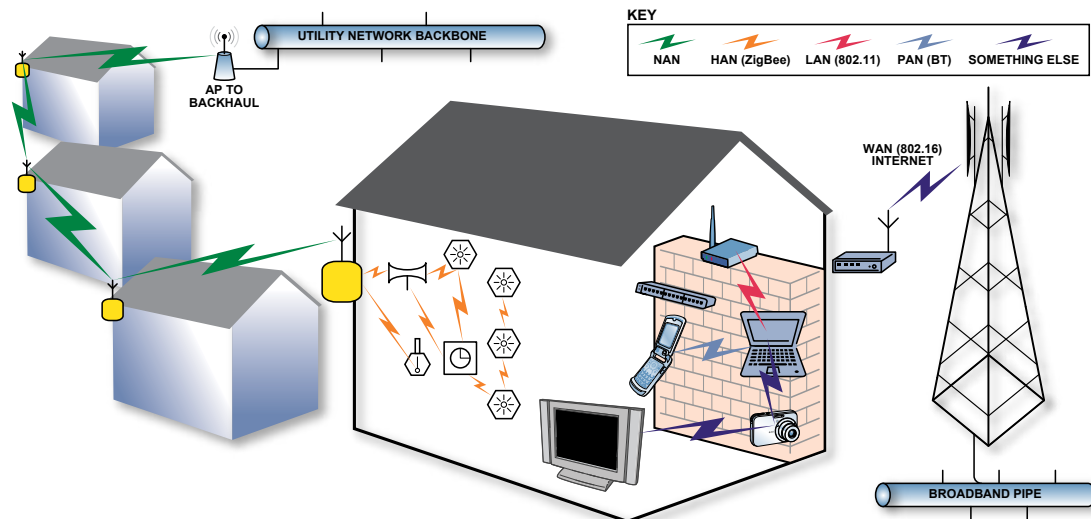


Figure 6. Home area network.

need for a separate communications-specific microcontroller in many cases. Meter manufacturers are also choosing the ADF702x family over competitive parts because their radios offer best-in-class sensitivity and blocking performance, resulting in better range between meter and data collector. The ADF7020 offers blocking performance in excess of 70 dB, meaning that the wanted signal can be detected and decoded correctly even when an unwanted out-of-band signal is up to 70 dB higher than the wanted signal. Adjacent-channel rejection is approximately 40 dB, and sensitivity can be as low as -120 dBm depending on the data-rate. This is more than 20 dB lower than the best performing ZigBee® solutions.¹⁴

HAN Network

With a communications-enabled meter soon to be available in many homes, utility companies and energy regulators are looking to the future to see how they can leverage the technology to improve energy conservation and awareness. Using this concept, sometimes called the *smart grid*, utility companies can use networks that will extend all the way into customers' homes to actively manage the transmission load. One such service could provide real-time price information, allowing the consumer to modulate energy usage. At times of peak load, during a heat wave for example, the utility company could send a message to the house, telling home owners that prices would be going up for the next hour and encouraging them to switch off appliances. This would require an in-home display where such a message could be shown. Going one step further, the utility company could communicate to the devices in your home via the meter, turning up the thermostat or turning off a pool pump, for example. This system would require communication between the meter and the home appliances and is sometimes termed the *home area network* (HAN). 900-MHz radios such as the ADF702x and ZigBee radios are both finding favor here.

Most industry participants recognize that a fully working home area network linked with the advanced meter infrastructure is a number of years away, yet the benefits of such a system mean that many companies are actively involved in developing solutions for home area networks today. A graphical depiction of the home area network is given in Figure 6.

CONCLUSION

Analog Devices is focused on supplying leading-edge technology including RF transceivers, energy measurement chipsets, RF amplifiers, isolation products, and power line control into

the metering market. The ADF702x high performance, fully integrated transceiver is suitable for communications-enabled or AMI-ready meters and allows a compact, robust, low-cost solution for meter manufacturers worldwide.

AMI and the smart grid are seen as key potential technologies to improve energy efficiency, ultimately helping in the goal to reduce carbon emissions. Analog Devices is committed to providing innovative and energy efficient devices to enable this market and to doing its part in improving energy efficiency and promoting energy conservation in the years ahead.

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