The IoT is Changing the Way Sensor-Based Systems are Designed and Implemented

The push to eliminate fossil fuels can make one think of salmon swimming upstream. Economic reasons—such as cost-prohibitive solar panels, charge controllers and batteries—have deterred many from going off grid, or at least reducing their carbon footprints as much as possible. However, technology may soon make fighting the opposing current less strenuous. The use of grid-tied inverters for example, allows a solar panel to put energy back into the grid without the need for batteries, charge controllers, or a rewiring of a facility. What is more, the Internet of Things (IoT) has come along to let you monitor solar-panel performance from anywhere in the world.

This article looks at how the IoT is changing the way sensors and systems that rely on sensors are designed and implemented. The ability to deploy and share low-cost and distributed sensors allows a finer layer of control, and may be part of a societal solution for increased energy efficiency. All technologies and parts referenced in the article can be found online on Digi-Key's website.

Cloud connectivity

For countless decades, energy producers and distributors have had closed systems for status and control. Through dedicated wireless links, telephone lines, or inter-facility cabling, nerve centers as well as remote switching or sensing stations were closed systems or networks. On the positive side, any tampering and hacking had to be done locally by physically tapping into or interrupting hard-run cabling or communications links.

However, IoT and cloud connectivity are changing all of this and rather quickly. Petroleum, liquid and natural gas refineries, storage facilities, transfer systems, and switching stations (as well as their safety monitoring and control functions) are all moving to complete connectivity through a cloud-type of environment. Similarly, in-the-home cloud-based systems can offer advantages such as remote control. Here, through the use of a smartphone or tablet, access to key home or facility systems can be allowed to read sensor information, save energy, prepare for occupancy, or shut off services when not needed.

The most noteworthy example is the remote-controlled thermostat. A simple temperature sensor linked to a microcontroller and communication network has the potential to reduce energy expended on heating and air conditioning, which are among the most power-hungry home systems.

While learning algorithms can try to anticipate settings to create more autonomous operation, the real benefit comes when you can control temperature from anywhere. For example, the learned behavior may indicate that on this weekday at this time, the heat should be raised from 50 to 70 degrees in anticipation of occupancy; but if you know you won't be there, a simple override command can keep the temperature set at 50 degrees saving more energy in one night than all the CCFL bulbs in your house.

A design solution example

One of the biggest advantages of IoT-style connectivity is the ability to link redundant or dissimilar sensors and systems to share functionality. For example, security systems may use pyroelectric infrared sensors (PIR) and/or microwave-based motion detectors to trip an alarm if motion is detected. Typically, the alarm system is a closed loop and an island unto itself (Figure 1).

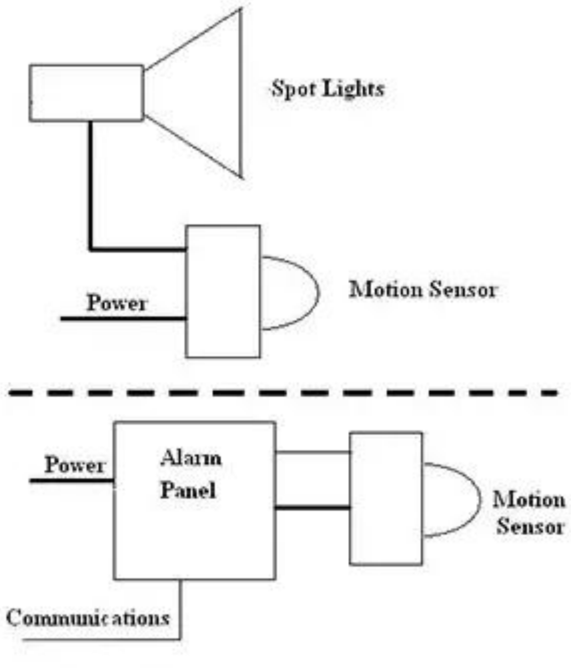

Figure 1: Independent systems provide limited functionality and often carry with them the added cost burden of redundant hardware.

However, when key sensors can be shared through the use of connectivity with other systems that may have a completely different primary function, a higher level of autonomy and energy savings can take place without the sacrifice of performance or functionality. Two (or more) independent systems can share a sensor eliminating redundancy and reducing cost. As an example, let's look at a system that allows a single sensor to share functionality with other systems (Figure 2).

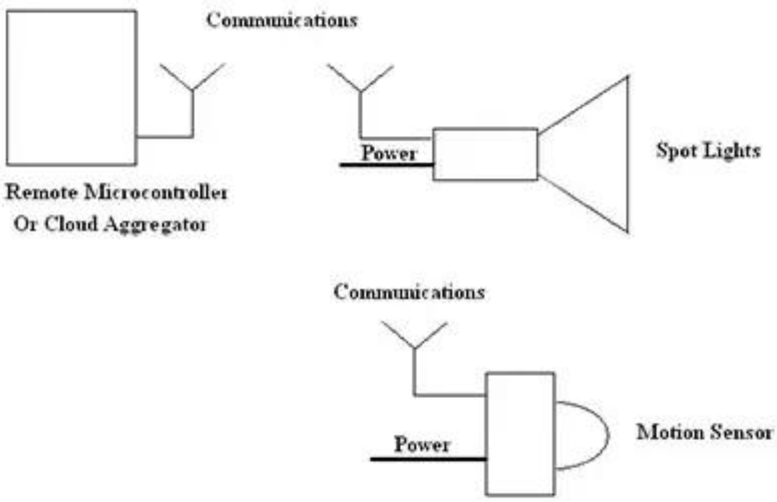

Figure 2: Connectivity between unrelated systems provides a new layer of capabilities neither system could achieve previously. This can change the architectural approach to IoT-distributed sensor and control designs.

In our example, the motion detector for a security light no longer drives and controls the security light. Instead, its actions are monitored by a microcontroller. The on/off link of the floodlights is no longer just on and off. The lights are driven by a microcontroller-based dimmer.

An artificial-intelligence-style algorithmic programming technique ties together the functions of this solution. As part of a higher level of awareness, the facility "knows" certain things. It knows if it is daytime or nighttime. It knows if its environment is light or dark. It knows if the room is occupied or empty. Two other states are important: the house knows if it is in secure mode or not (i.e., if the alarm is armed), and it knows if people are awake or asleep.

A truth-table-like problem-solving approach can determine what actions to take (Figure 3). This prevents the inefficient burning of energy during the daytime; but, it also saves energy in other ways.

Daytime Nighttime	Light Dark	Home Away	Non-Secure Secure	Awake Asleep	Light Action	Alarm Action
0	0	0	0	0	No Action	No Action
0	0	0	0	1	No Action	No Action
0	0	0	1	0	No Action	Send Alert
0	0	0	1	1	No Action	Heightened Alert
0	0	1	0	0	No Action	No Action
0	0	1	0	1	No Action	No Action
0	0	1	1	0	No Action	Send Alarm
0	0	1	1	1	No Action	Send Alarm
0	1	0	0	0	Light on 50%	No Action
0	1	0	0	1	Light on 30%	No Action
0	1	0	1	0	Light on 50%	Send Alert
0	1	0	1	1	Light on 70%	Heightened Alert
0	1	1	0	0	Light on 50%	Send Alert
0	1	1	0	1	Light on 70%	Send Alert
0	1	1	1	0	Light on 100%	Send Alarm
0	1	1	1	1	Light on 100%	Send Alarm
1	0	0	0	0	No Action	No Action
1	0	0	0	1	No Action	No Action
1	0	0	1	0	No Action	Send Alert
1	0	0	1	1	No Action	Heightened Alert
1	0	1	0	0	No Action	No Action
1	0	1	0	1	No Action	No Action
1	0	1	1	0	No Action	Send Alarm

1	0	1	1	1	No Action	Send Alarm
1	1	0	0	0	Light on 50%	No Action
1	1	0	0	1	Light on 30%	No Action
1	1	0	1	0	Light on 50%	Send Alert
1	1	0	1	1	Light on 70%	Heightened Alert
1	1	1	0	0	Light on 50%	Send Alert
1	1	1	0	1	Light on 70%	Send Alert
1	1	1	1	0	Light on 100%	Send Alarm
1	1	1	1	1	Light on 100%	Send Alarm

Figure 3: Like a logic design problem, the multi-output solution to a shared and distributed sensor array can be reduced to truth-table-like functionality. A system may know day times and night times as part of a programmed algorithm, so rule-based assertions may not need specific day or night information to act appropriately.

Just because a security light can burn 150 watts does not mean it has to. Operating at 30 percent intensity, for example, the light can still illuminate an area well enough for safety. If in secure mode, the switch to 60 percent intensity lets a would-be intruder know they have been detected. It also can place the alarm system into a heightened state and maybe turn on a video DVR for a period of time. The sharing of sensor data allows a cumulative energy savings as well as the ability to enhance the performance of other systems.

This is important when it comes to IoT and cloud connectivity. It allows a system to "think" at a higher level and only interrupt you if there is something real to address. This approach also allows a resident to interact with their environment at a higher level, while letting the encapsulated technology reduce overall energy demands.

It is interesting to note that intuitive expectation may be overridden by sensor data. For example, just because a building knows the sunrise and sunset times as part of a programmed day/night algorithm doesn't mean it can use that data to save energy most efficiently. Instead,ambient light sensors like the Avago APDS-9008-020 can more finely pick a threshold of darkness to avoid burning lights until they are really needed. Combined with PIR preamps like the ROHM BD9251FV-E2 and PIR Controller Chips like the ON Semiconductor NCS36000DRG, virtually any low-cost RF microcontroller such as TI's CC3200R1M1RGCR can provide an ideal solution for the next generation of IoT-based energy-management sensors.

Like factories, homes and apartments one day may operate with incentives to never exceed peak demand loads. This allows utilities that generate and distribute power to have more predictable loading since customers take on the responsibility of real-time load control; when industrial facilities, civic building, or even homes use more power at any one point in time than a pre-determined threshold, the energy rates increase.

The ability to access key information such as real-time current draw can allow controls to switch loads and work with other systems to save energy without sacrificing services or performance. As this article has shown, the design methodology, sensors, and communications technology are all readily available to engineers.