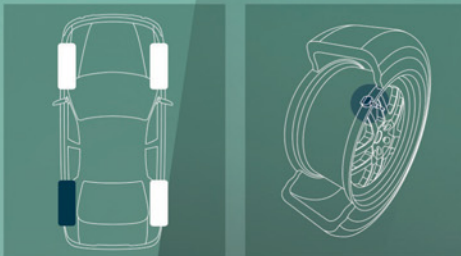


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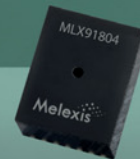
SPECIAL REPORT SENSORS

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MELEXIS TPMS SENSOR IC

MLX91804



Melexis



Technology

Engineered 'sand' may help cool electronic devices



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Tackling modern-day and future semiconductor challenges

HMC6352

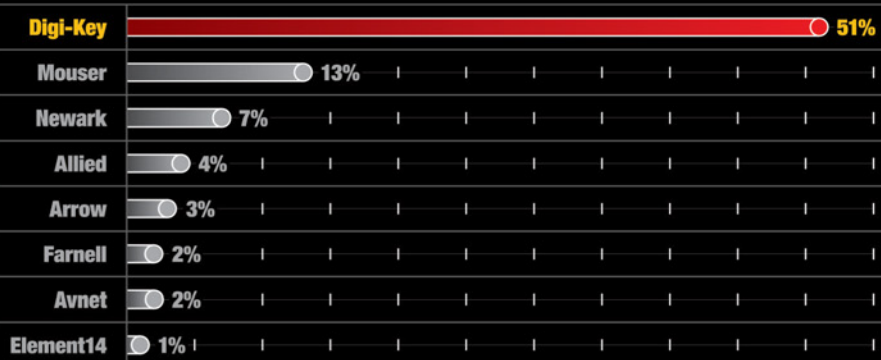


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*AspenCore's 11th Design Engineer and Supplier Interface Study gathered information from engineers regarding their need for product information and other services, as well as how and when they interface with suppliers and how they see the quality and value of that interface. 1,750 U.S. engineers participated in this year's web-based survey. The results represent those surveys completed by April 2016.

When asked "Best in Class: Parts in stock available for immediate delivery?" The chart above shows the results among the industry's electronic component distributors.

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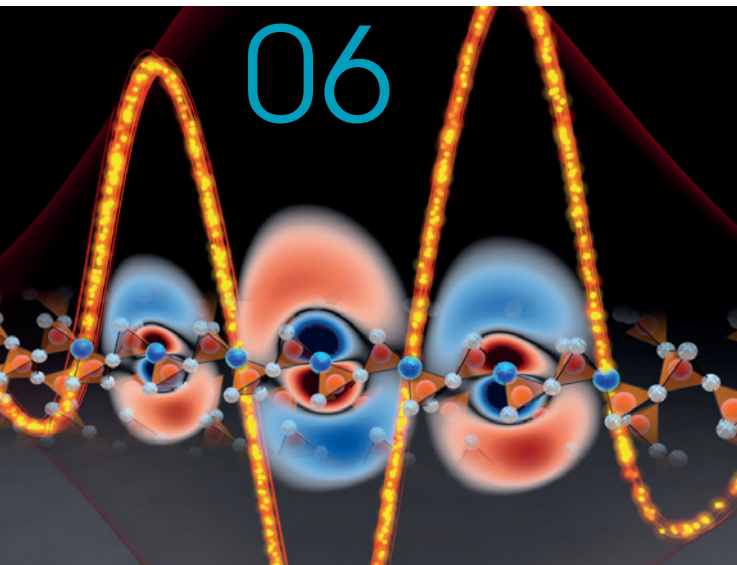
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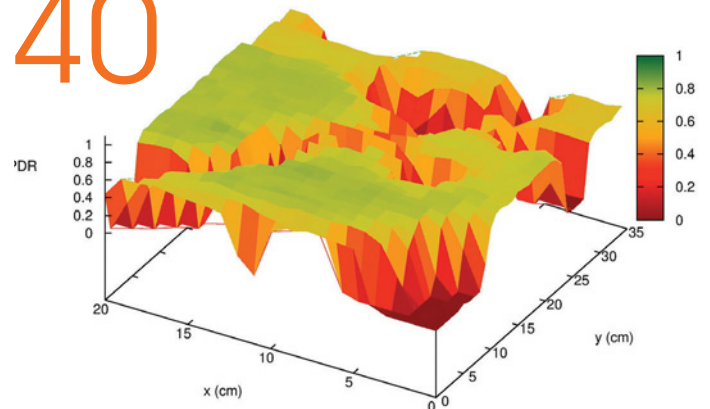


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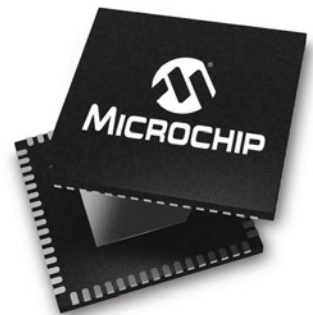
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LOOKING UPSTREAM: PROTECTION FROM DDoS ATTACKS

Distributed Denial of Service (DDoS) attacks are one of the most prevalent types of cyber-attack on the Internet. While once the sole preserve of bad hackers coding in their bedrooms looking to cause mischief, DDoS-for-hire botnets now allow just about anyone to launch a crippling attack for just a few dollars – with no coding skills required.

Since they first emerged in the early 2000s, we've seen attacks evolve from rudimentary volumetric attacks designed to knock sites offline, into far more complex and malicious threats, where the attacks are more sophisticated, deceptive and frequent. In many cases these attacks are merely a smokescreen, designed not to deny service but to distract from the real motive – usually data theft and network infiltration.

Given that the DDoS problem has changed so dramatically, it's time to re-evaluate our response. How can network and security teams stay ahead of these chronic attacks and respond appropriately? The responsibility in many cases lies with host providers and ISPs.

If a host provider doesn't have effective DDoS mitigation as part of its service, useless and potentially harmful traffic could be sent across customers' networks.

It's difficult to visualize traffic flowing across networks, and analyzing it is a far too big a job to handle. Whether it's a sub-saturation attack designed to explore or weaken certain parts of a network, or a huge flood attempting to knock the whole place offline, customers aren't able to hold providers to account, despite the second-rate service they may be getting.

The legacy solution for host providers was to black-hole traffic, i.e. if a suspected DDoS attack was taking place, traffic would be sent to a non-existent IP location. However, this also sends the good traffic there too, meaning legitimate users can't visit the site or service they were hoping to, costing the business money and customers. This is doing the attackers' work for them, with the site out of use due to a DDoS attack, even after the attack itself has subsided.

Fast-forward to today and the technology has not only caught up with the hackers, but has altogether surpassed their capabilities. There are now technological innovations that use real-time mitigation tools

Such innovations mean providers are better positioned than ever to offer effective protection to their customers, so that sites and applications can stay up and running, uninterrupted and unimpeded

installed directly in-line with the peering point, so customer traffic can be protected as it travels across an organization's network. Such innovations mean providers are better positioned than ever to offer effective protection to their customers, so that sites and applications can stay up and running, uninterrupted and unimpeded.

Fortunately, host providers are starting to deploy this technology as part of their service packages to protect their customers, and the latest solutions are scalable and automated. This maximizes efficiency and minimizes the need for human intervention.

Providers can tune these systems so customers only get good traffic, helping their sites run far more efficiently. It's a win-win for both sides, as providers' services become more streamlined and reliable, protecting their reputations and attracting more customers. The upside for customers is that they are no longer paying for poorly-filtered traffic.

If purpose-built technology is laid out at ISP peering points, DDoS traffic is halted before it can enter their networks. This effectively shuts the door on DDoS traffic, whilst leaving a window open for the legitimate user traffic.

When shopping around for a hosting provider, watch for the companies that don't provide security as part of their offering, since they may end up charging for traffic you didn't ask for and shouldn't be paying for.

If you opt for a company that does offer security as a service, you'll save a lot of the expensive call-outs, downtime and loss of customers that go hand in hand with DDoS attacks, which negligent providers allow to run their course.

Dave Larson is Chief Operating Officer of Corero Network Security (www.corero.com)

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ENGINEERED 'SAND' MAY HELP COOL ELECTRONIC DEVICES

Silicon dioxide nanoparticles have been coated with high-dielectric constant polymer to form so-called "cooling sand" that promises inexpensive, improved heat removal for increasingly power-hungry electronic devices. The unique surface properties of the coated nanoscale material help conduct heat at potentially higher efficiencies than existing heat-sink materials. The theoretical physics behind the phenomenon involves nanoscale electromagnetic effects created on the surface of silicon dioxide particles acting together.

"We have shown for the first time that a packed nanoparticle bed that typically acts as an insulator can turn into a conductor," said Baratunde Cola, an associate professor at the Georgia Institute of Technology. "Using the collective surface electromagnetic effect of the nanoparticles, the thermal conductivity can increase 20-fold, allowing it to dissipate heat."

Research papers have long predicted the ability of surface phonon polaritons (quantum quasiparticles produced by strong coupling of electromagnetic waves with electric or magnetic excitation) to



"Cooling sand" promises to inexpensively provide improved heat removal in ICs

increase thermal conduction in nanomaterials made from silicon dioxide for example. In the specific case of surface phonon polaritons, the electromagnetic waves are coupled to a certain frequency and polarization of vibrating atoms, known as optical phonons, occurs in the material. With particles smaller than 100nm, their surface properties allow phonons of heat to flow from particle to particle in the closely packed bed with the assistance of the coupled electromagnetic waves.

"When these particles are close enough together, their modes are coupled, which allows the energy to transport," added Cola.

Further testing is needed to ensure long-term efficiency and reliability of electronic devices cooled with this technique. The research could create a new class of high thermal-conductivity materials useful for heat dissipation from power electronics, LEDs and other applications with high heat fluxes.

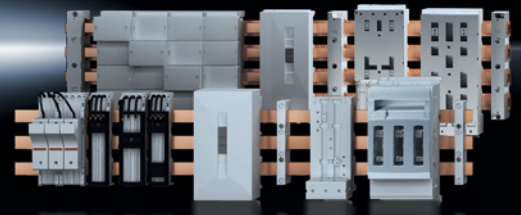
"You could basically take an electronic device, pack these ethylene glycol-coated nanoparticles in the air space as a heat dissipation material that at the same time won't conduct electricity," said Cola. "The material has the potential to be very inexpensive and easy to work with."

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LIGHT WAVE ELECTRONICS MAY PAVE THE WAY FOR SUPERFAST TRANSISTORS

Light waves could be the technology of choice to drive future transistors, making them 100,000 times faster than current digital electronics. So say researchers from the Laboratory for Attosecond Physics (LAP) at the Max Planck Institute of Quantum Optics, the Ludwig-Maximilians University Munich, Technical University of Munich and the University of Tsukuba, who are jointly working on the project.

State-of-the-art electronic circuits have reached clock rates of several billion switching cycles per second, but are limited by the heat accumulated during the switching processes. Now, researchers are looking into other technologies to overcome such barriers.

Light waves oscillate at petahertz frequencies (10^{15} Hz). The electric field of light changes its direction some trillion times per second, and is able to move electrons in solids at this speed.

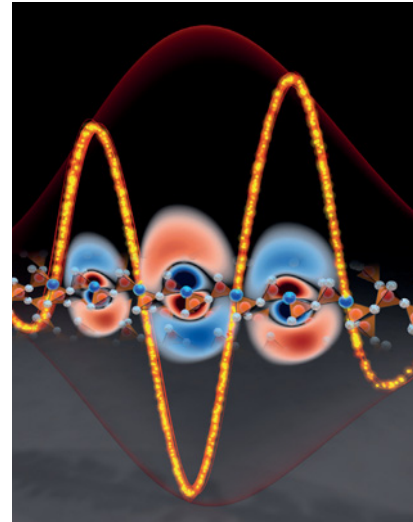
LAP physicists already have the ability to manipulate the electronic properties of matter at optical frequencies. They fired extremely strong, femtosecond-laser pulses onto thin silicon dioxide glass. The light pulse lasted only a single strong field oscillation cycle, so the electrons moved left and right only once. The full temporal characterization of the

light field after transmission through a thin glass plate for the first time provides direct insight into attosecond electron dynamics, induced by the light pulse in the solid. Measurement reveals that electrons react with a delay of only ten attoseconds to the incoming light, which determines the energy transferred between light and matter.

Since it is now possible to measure this energy exchange within one light cycle, the parameters of the light-matter interaction can be better understood and optimized to reach the ultimate speed for signal processing. The more reversible the exchange and the less residual energy left in the medium after the light pulse has passed, the brighter the future light-field-driven electronics.

The researchers also succeeded in optimizing energy consumption by varying the light field's amplitude. At certain field strengths, energy is transferred from the field to the solid during the first half of the pulse cycle and is almost completely emitted back in the second half.

These findings verify that a potential switching medium for future light-driven electronics need not overheat. Thus the 'cool relationship' between



A yellow light-wave and silicon's electrons (blue-red) come into swing, taking on the energy of the light, and moving it on

[Credit: Christian Hackenberger/MPQ]

glass and light might provide an opportunity for dramatically accelerated electronic signals and data processing.



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ONGOING PROGRESSION OF TPMS TECHNOLOGY - TIRES ARE ABOUT TO GET A WHOLE LOT SMARTER

By Mark Holdaway & Ivan Zagan, Melexis

Tires play a fundamental role in shaping the car driver's experience. Ideally they provide both the fast and safe acceleration and deceleration that help make driving the pleasure it is. But they also must meet the demand for continually increasing fuel economy and long service life.

It's a tough job and yet most of us remain unaware of the radical developments taking place in the interface between drive train and the road ahead. Disruptive trends and innovations are leading to a connected, smart tire revolution.

Extreme numbers

Tires comprise an assembly of up to 100 individual components. On regular cars, the tires are subjected to >2000 g acceleration and operating temperatures up to and beyond 100 °C. You need to get inflation pressure right, as a 0.3 bar (30 kPa) reduction in tire pressure results in a 1.5% increase in fuel consumption and CO2 emissions to say nothing of elevated tire wear. Data also shows that 40% of blowouts are caused by under inflation. It is in this context that in US since 2008 and in Europe since 2014, tire pressure measurement systems (TPMS) have been mandated as standard fitment to all new cars.

The global market for TPMS hardware is thus growing substantially, with 356 million sensors forecasted to be shipped annually by 2022, according to projections from automotive research specialists Strategy Analytics. The installation rate of TPMS in new cars has steadily climbed globally over the last few years and is now edging close to 1 in every 2 cars with rapidly increasing demand in Asia (in particular from China) being witnessed right now.

Let's be direct

Two flavors of TPMS exist. The simplest being indirect TPMS (iTPMS) which makes use of individual wheel speed data fed from the car's anti-lock brake (ABS) system to identify differences of wheel radius thus inferring tire pressure change. A faster spinning wheel is a certain tell-tale of under inflation. Today, clever algorithms can determine far more than simply tire pressure by this approach. Little more than some extra on-board processing is needed to implement iTPMS. In practice though, the system requires calibration throughout the car's operating lifetime. Making this system deliver consistent and reliable warnings combined with general user confusion, means the user experience with sensor-less iTPMS systems has been mixed. Thus, it is no surprise that iTPMS is losing ground to direct sensing. Currently iTPMS represents less than 15% of global installations and is on a downward trend.

Direct TPMS however places an intelligent sensor in each wheel embedded within the stem of a modified tire valve. As the name implies, the individual sensors provide a direct

measurement of tire inflation and temperature allowing measurement accuracy down to around 4 kPa (or 0.04 bar). Data from each wheel's sensor is provided via a low power RF link to a central ECU invariably connected to the car's CAN bus.

Power dictates

Available energy budget for each TPMS sensor is strictly limited. Ideally, energy harvesting might provide a continuous supply of energy whilst driving, but aside from their practical cost and size limitations, a need to monitor conditions even statically (consider the spare tire) mean that battery derived power dominates nowadays. Standard CR2032 lithium cells are the power source of choice today. Of course, this choice already dominates the current limits of a TPMS sensor's dimensions.

A TPMS sensor module has several key component parts as seen in figure 1. It will consist of a pressure sensor and an extra temperature sensor aids pressure measurement accuracy. Normally the sensor will be teamed with a low power MCU and a short range RF transceiver. Additional, valuable information comes with the inclusion of an acceleration sensor which can be used to extract helpful data about tire grip and road surface conditions.

Usually these parts are mounted on a PCB along with associated passive components, a battery, plus a simple antenna optimised for the specific RF link budget. This is mounted into some form of protective enclosure - which is then usually attached to the wheel mounted valve. The sensor device, depending on its level of sophistication will either incorporate, or alternatively be accompanied by a wireless transmitter. This will communicate data to an electronic control unit (ECU) within the vehicle's chassis, providing updated pressure data on a regular basis.

Driving into the future

Whilst the TPMS market may appear to be largely stable and commoditised, there are a number of automotive mega trends that extends to the tires and the installed TPMS electronics. Among these are:

- **Autonomous vehicles (AVs)** - Delivering a fully autonomous driving experience requires the fusion of data from a wide array of on and off-board sensor sources in real time.
- **Car sharing** - Shared or part time ownership anticipates a changed model that might benefit from the future availability of AVs. But even now there are options across the US and Europe where vehicles can be acquired on a shared or short term basis. These dynamics are already impacting decision making within automotive OEMs and changing the landscape for the whole supply chain. Unsurprisingly they will lead to considerable changes in how TPMS technology is implemented - particularly in relation to the following:
 - **TPMS functionality extensions** - New features like wheel

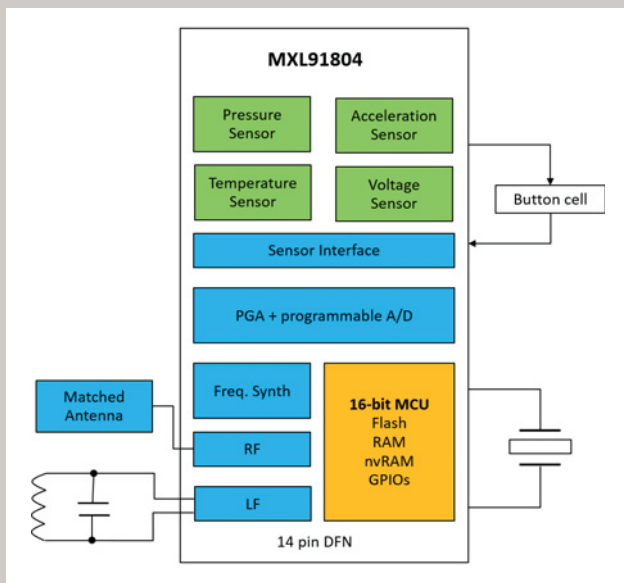


Figure 1: Functional block diagram for the MLX91804 from Melexis

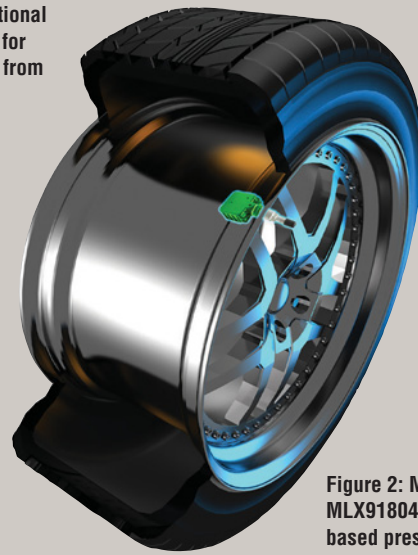


Figure 2: Melexis' MLX91804 MEMS-based pressure sensor placed in situ

sensor auto-location (identifying exact wheel position on the chassis) to ease manufacturing and improve after-sales fitment simplicity; tire inflation assistance, tire wear and loading are all emerging needs driven primarily by the previously mentioned shifting car ownership models. As shared ownership concepts appear along with AVs, it will be critically important to deliver more comprehensive tire data.

Migration to tire mounted sensors (TMS) - Soon, it is envisaged that TMS modules will be attached to the inner liner of the tire enabling new safety related features to be implemented and simplifying the tire supply chain. Smart tires allow car OEMs and tire vendors alike to optimise the vehicle system (in terms of dynamics, safety and economics).

Slimming down the sensor module's size and weight sits at the forefront of responding to this set of dynamics. It is perhaps not immediately obvious why this might be a design goal. After all, the tire inner is essentially air under pressure and there's space to spare. But the real issue is weight. Consider a 20g sensor module embedded in the tire wall exposed to 2000g acceleration. The module will exert 20kg deforming force on the tire wall. Clearly then, small wheel weight imperfections can cause noticeable performance modifications and accelerated tire wear. It is this exact factor that puts even the latest semiconductor development efforts at the very edge of what is practical for TMS systems to be practically realised.

As the battery is the biggest and heaviest component within the module, the focus becomes one of power consumption. However, the autonomous lifetime of the sensor module is set to 10 years and cannot be compromised upon. Therefore, increasingly, electronic design effort targets reducing the power consumed to support more functionality whilst aiming for lower overall size and weight. By curbing the power consumption both in sleep mode and when operational - it will be possible to enable the desired downsizing of the batteries.

The Melexis MLX91804 presents engineers with just such a next generation option and in doing so, establishes new industry benchmarks. It combines a high degree of integration with minimal number of external passive components required.

Industry-leading power consumption is demonstrated (at least 3 times lower standby current than competing devices), while the part still delivers excellent sensor accuracy down to 0.04 bar and resolution down to 0.002 bar. On power alone, Melexis have already shown that it is possible to migrate to a smaller CR1632 cell – shaving off 1.2 g (or 40 %) from the battery weight and 35% lowering battery volume, whilst still meeting a long operational lifetime. Delivering this low power advantage comes from years of experience in designing ultra-low drain circuitry and a fastidious attention given to the optimal sensor, processing and RF interaction rates.

The MLX91804 features a high precision MEMS-based pressure sensing element and a cutting-edge 16-bit microcontroller unit (MCU). The 315/433 MHz frequency wireless transmitter embedded into the IC is capable of dealing with data rates of up to 150kbits/s. A large 16 kB of program memory is included for the storing of custom application data/libraries. In addition, there is a built-in single or dual axis high-g range accelerometer to deliver enhanced telematics including tire traction data.

The most notable aspect of the MLX91804 is its brand new, 14-pin DFN wettable flank package, measuring just 5mm x 4mm. This gives a footprint 60% smaller than the smallest alternative sensor currently available. Its size and robustness will help the automotive business to get closer to the goal of proliferation of TMS technology in the near future.

With the arrival of ultra-compact, nano-Watt sensor solutions like the MLX91804, the concept of smart tires are just around the corner. Time will tell how the emergence of electronics embedded within the tire wall will further enhance the driving experience and general road safety.

One future use case would be mapping in real-time, tire traction statistics combined with GPS data to provide fore-warnings to autonomous driving systems of slippery road conditions ahead. However, this information gets integrated into our future transportation concepts; one thing is certain, these changes will cause disruption to this important part of the automotive supply chain and create new business opportunities.



SMBus sensors in the Cloud

BY **LUCIO DI JASIO**, MCU8 BUSINESS DEVELOPMENT MANAGER AT MICROCHIP TECHNOLOGY

The Inter-Integrated Circuit (or I2C) bus was originally developed by Philips Semiconductors more than 30 years ago to solve the problem of connecting multiple sensors and low-bandwidth peripherals across the short distances of a (single) application PCB using minimal resources. The original standard defined a simple synchronous bus consisting of just two wires: a bi-directional data line and clock line (initially limited to a maximum frequency of 100kHz).

The I2C bus turned out to be a huge success. Most semiconductor manufacturers ended up licensing the technology, and an enormous number of embedded devices are today using the original protocol or one of its many descendants.

In fact, the I2C bus was soon extended to support higher clock speeds (400kHz, 1MHz, etc.) as serial EEPROM (SEE, 24LCxx series) devices started proliferating and offering ever-larger memory sizes.

Eventually I2C became the foundation for many more specialized protocols among which:

- SMBus, defined by Intel, used to connect fans and sensors on (PC) motherboards and PCI cards;
- PMBus, further specialized to control power supplies;
- DDC2, used on VGA connectors to identify monitor resolutions and capabilities;
- SPD, or Serial Presence Detect, to identify SDRAM module's capabilities.

It is important to note that these examples mostly represent subsets of the original I2C bus electrical specifications and the standard communication protocol. The new specifications are typically designed to impose more stringent constraints on peripheral devices (limiting leakage and power consumption, reducing tolerances) and eventually simplifying or formalizing the data exchange protocols used. As a result, any microcontroller that has a minimally flexible I2C peripheral module can be used to communicate with any these protocols/devices with minimum effort.

In the following I will explore some of the features of a high precision temperature sensor (EMC1001), conveniently found on the inexpensive Xpress evaluation board, to demonstrate how to quickly configure the I2C module of a modern PIC microcontroller (PIC16F18855) using the MPLAB Xpress Cloud-based toolchain.

EMC1001

The EMC1001 is a 1.5°C-accurate temperature sensor device conforming to Intel SMBus 2.0 specifications. It is typically offered in a minuscule SOT23-6 package and often found on desktop and laptop motherboards. Beside the two pins required for the bus (SMB/I2C) interface, two additional (open drain) output pins can be configured to indicate alarm conditions (passing specific temperature thresholds). Interestingly, one of the two output pins (ADDR/THERM) is also used to select the device address. In fact, the pull-up resistor (required) is sensed and used to discriminate among four possible SMBus address values.

Aside from that, configuring and reading the device status is simply a matter of accessing a few 8-bit registers (occasionally paired to form 10-bit values), as listed in the device datasheet

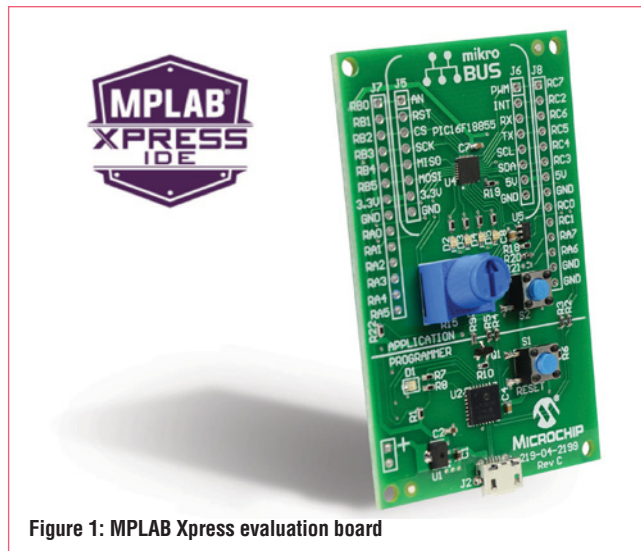


Figure 1: MPLAB Xpress evaluation board

(Register Map). For clarity, in the following code listings I will use a set of constants defined in Listing 1.

```
// EMC1001 registers
#define EMC_TEMP_HI 0x00 // temperature value high
byte
#define EMC_STATUS 0x01 // Status register
#define EMC_TEMP_LO 0x02 // low byte containing 1/4
°C fraction
#define EMC_CONFIG 0x03 // configuration register
#define EMC_LIMIT 0x20 // THERM limit temperature
(->ALARM1)
#define EMC_HIST 0x21 // THERM hysteresis
#define EMC_PROD_ID 0xFD // Product ID
#define EMC_MANUF_ID 0xFE // Manufacturer ID
#define EMC_REVISION 0xFF // Revision
```

Listing 1: EMC1001 registers

The Xpress evaluation board connects the EMC1001 to the PIC16F18855 microcontroller pins RC3 and RC4 that correspond to the default (preferred) I2C pads of the device. Note that, we could have connected the EMC1001 to any other pair of I/O pins, using the Peripheral Pin Select (PPS) feature to re-route the signals internally to the correct peripheral (MSSP). The two specific pins chosen though have special driver pads that are tuned to match the I2C electrical specifications and are to be preferred when maximum level of compatibility is needed.

If you have the MPLAB X IDE and the entire PIC toolchain already installed on your computer, you can fire it up. In case this is your first experiment with a PIC microcontroller or another device, you will be able to follow along by using the complete cloud toolchain from your favourite browser: just select the URL <https://mplabxpress.microchip.com> and enter the IDE (click on the MPLAB Xpress badge icon).

Note that to access the MPLAB Code Configurator tool used here, you will need to log into a myMicrochip account.

New Project

Let's create a project using the New Project Wizard. Select a PIC16F18855 device and choose the most recent version of the XC8 compiler (free). When asked to choose a debugging tool, select the Simulator for now.

When facing the newly-created empty project window, we will immediately activate the MPLAB Code Configurator tool, from the 'Tools > Embedded' menu. This tool helps create very quickly all the necessary drivers and to configure all the peripherals needed for immediate use.

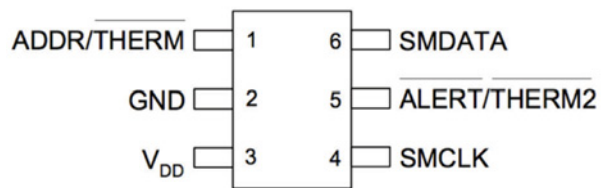


Figure 2: EMC1001 temperature sensor

Once inside, the list of available peripheral modules can be found on the left of the screen. PIC architectural legacy requires the two synchronous interfaces (I2C and SPI) to be supported via the same peripheral module called MSSP (Master Synchronous Serial Port). Double-clicking on the MSSP2 module brings up the configuration screen with details of the peripheral.

Select the mode to be "I2C Master", enable "SMBus input" and set the I2C clock divider to the value of "4" to produce a bus clock of 50kHz (assuming the default system oscillator setting is 1MHz), as shown in Figure 2.

Since in this project we intend to use the serial port as well, let's also select from the list of available peripherals the EUSART. We'll configure it for a standard 9,600 baud rate; see Figure 3.

Enabling the "Redirection of STDIO to USART" will allow us to use the standard I/O library (stdio.h) to send formatted strings directly to the serial port.

To complete the configuration we will select the Pin Module, found in the top left pane of the MCC project window, and we will proceed to make the UART TX pin an output assigned to the RCO pin so to connect to the serial-to-USB interface of the Xpress evaluation board.

Ensuring that the pin is going to "Start High" (as shown in Figure 5) will avoid spurious reception errors, when launching the program for the first time or after resetting the board.

Now we are ready to generate all the required peripheral drivers and configuration files at the click of a button, aptly called "Generate".

The previously empty project window will now be populated automatically with a main.c file and a folder named "MCC Generated Files", containing a few more source files including i2c.c, eusart.c, mcc.c, interrupt.c and pin_manager.c.

Implementing The SMB Register Read Protocol

While in previous projects we have already examined the serial drivers (eusart.c/h) and pin-handling macros (pin_manager.c/h), this will be a great opportunity to look at the I2C drivers (i2c.c/h) generated by MCC (v3.15).

The I2C master drivers are significantly different from most other peripheral drivers produced by MPLAB Code Configurator. Perhaps the most important difference is that they are designed as autonomous-state machines, driven by the interrupt events produced by the MSSP peripheral. Each transaction on the I2C

“The I2C bus turned out to be a huge success; most semiconductor manufacturers ended up licensing the technology”

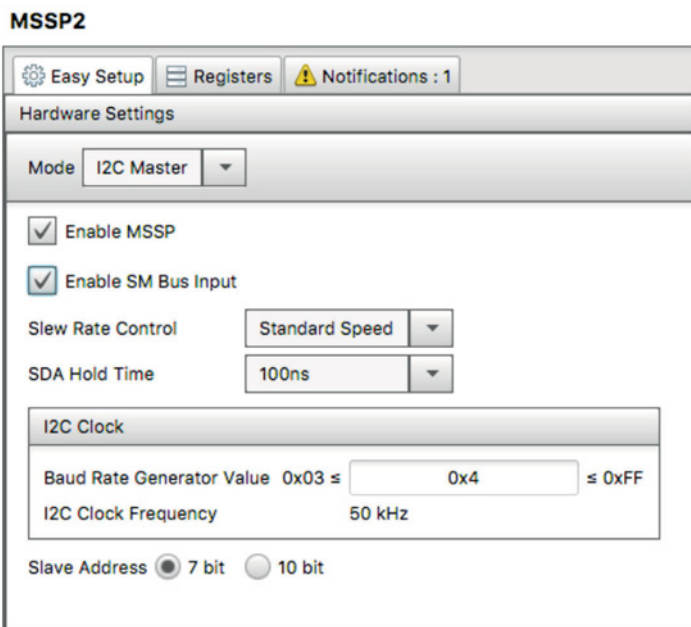


Figure 3: MCC I2C Module (MSSP2) configuration

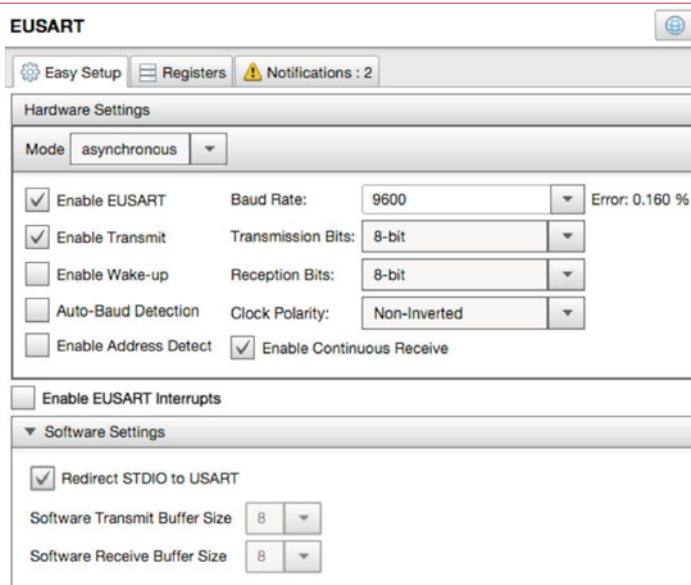


Figure 4: USART configuration

bus is assembled by combining elementary steps such as Start, Send Address, Send Byte, Read Byte and Stop. Macro blocks to read and write *n* bytes of data at a time are available to be further combined in a list (an array is actually used) of transactions, eventually fed to the state machine for execution.

Accessing a register of the EMC1001 temperature sensor according to the SMBus protocol requires two such macro blocks:

- A Write macro block to select the specific register (single byte write);

- A Read macro block to extract the register contents (single byte read).

The EMC1001 (register) read sequence is therefore declared as an array of two transaction request blocks (`trb[2]`).

Each transaction block is initialized by calling the respective `MasterWriteTRBBuild()` or `MasterReadTRBBuild()` function, taking care to pass:

- the device address;
- the number of bytes to be transferred; and
- a pointer to a buffer where the data will be read-from/written-to.

Eventually, the transaction list is “inserted” in the state machine for immediate execution, passing along a pointer to the status variable that will be used to monitor progress, as shown in Listing 2.

```
bool EMC1001_Read(uint8_t reg, uint8_t *pData)
{
    I2C2_MESSAGE_STATUS status = I2C2_MESSAGE_PENDING;
    static I2C2_TRANSACTION_REQUEST_BLOCK trb[2];

    I2C2_MasterWriteTRBBuild(&trb[0], &reg, 1, EMC1001_ADDRESS);
    I2C2_MasterReadTRBBuild(&trb[1], pData, 1, EMC1001_ADDRESS);
    I2C2_MasterTRBInsert(2, &trb[0], &status); // 2 transactions [W + R]

    while(status == I2C2_MESSAGE_PENDING); // blocking

    return (status == I2C2_MESSAGE_COMPLETE);
}
```

Listing 2: SMB reading a register value

The application can then periodically poll the status variable to verify if/when the transaction has completed successfully or in error.

For maximum simplicity, in Listing 2 we simply wait for the state machine sequence to complete (in a blocking loop). Any more complex application would benefit from a proper asynchronous implementation.

In 10 Lines Of Code

We are now ready to focus on the main part of our application.

Since the I2C (driver) state machine is based on interrupts generated by the MSSP peripheral, it is important to enable the global and peripheral interrupts after the usual call to `SYSTEM_Initialize()`, by uncommenting a pair of functions (`INTERRUPT_xxx_Enable()`) in the `main.c` template produced by MCC.

In the main loop we are going to read the contents of the `TEMP_HI` and `TEMP_LO` registers of the EMC1001 sensor. The first register will return the temperature integer value (expressed in degrees Celsius), whilst the second will provide the first two bits of the fractional part of the temperature, giving four possible decimal pairs

(.00, .25, .50, .75) to be added to or subtracted from the integer value, depending on whether the value is plus or minus.

Listing 3 shows the whole loop now requires less than 10 lines of code.

```
void main(void)
{
    int8_t temp;
    uint8_t templo;

    SYSTEM_Initialize();
    INTERRUPT_GlobalInterruptEnable();
    INTERRUPT_PeripheralInterruptEnable();

    while (1) {
        puts("Temperature Sensor Demo\n");
        if (EMC1001_Read(EMC_TEMP_HI, (uint8_t*)&temp))
        {
            EMC1001_Read(EMC_TEMP_LO, &templo); // get lsb
            templo = templo >> 6;
            // complement to 1 if T negative
            if (temp < 0) templo = 3-templo;
            printf("\nThe temperature is: %.%d C\n", temp,
                templo*25);
        }

        __delay_ms(1000);
    }
}
```

Listing 3: Periodic temperature reading

We can build the project (from the online IDE in a browser on the desktop) and download the resulting hex file directly to the Xpress evaluation board (drive).

To test the code, launch a terminal application and connect it to the Xpress virtual serial port. Simply breathing on the small board will be sufficient to produce detectable variation of the temperature reading.

Controlling The ALARM1/2 Outputs

Whereas periodic polling of the temperature is sufficient for some applications, the EMC1001 sensor's ability to directly activate an output at a specific temperature threshold can help protect critical equipment with a faster and more reliable mechanism.

Note that the EMC1001 offers two separate types of outputs, of which the first is connected to the ADDR/THERM pin (marked ALARM1 on the XPRESS evaluation board) and connected to the RA7 pin of the PIC microcontroller. Its operation is enabled by default on the EMC1001, controlled by a single temperature threshold set by the LIMIT register (85 degrees Celsius by default). When this threshold is passed, the output (open drain) is pulled low and remains such until the temperature descends below the

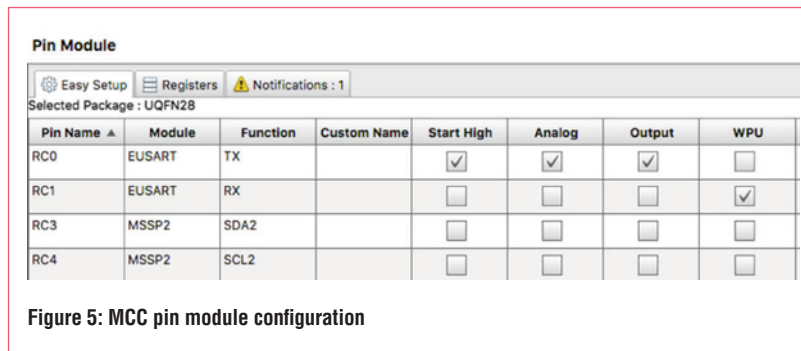


Figure 5: MCC pin module configuration

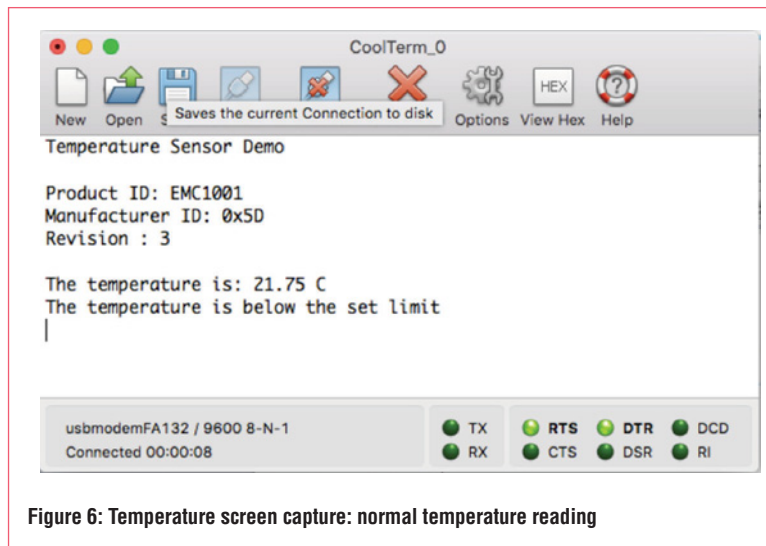


Figure 6: Temperature screen capture: normal temperature reading

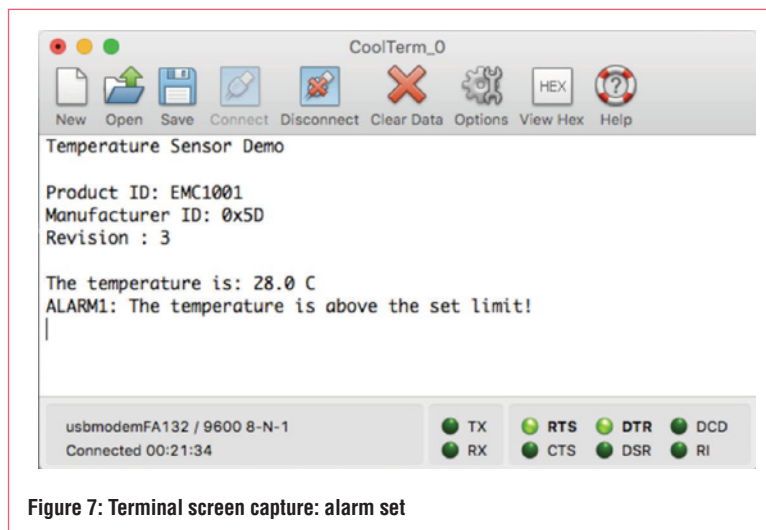


Figure 7: Terminal screen capture: alarm set

(LIMIT) threshold minus a further amount controlled by the HYST register (10 degrees Celsius by default).

The second, independent output pin, marked ALARM2 on the XPRESS evaluation board, is disabled by default and is controlled by an independent mechanism based on two (10-bit) registers: HIGH_LIMIT and LOW_LIMIT. Any time the detected

temperature is outside the range defined by those two thresholds, the (open drain) output is driven low.

Note that on the Xpress evaluation board the pull-up resistor for the ALARM2 pin is not mounted. You will need to solder one (R21) or more, then simply enable the internal pull-up of the RA6 pin of the PIC microcontroller.

To demonstrate the ALARM1 functionality we'll need to modify the THERM limit/threshold, or we will be hard pressed to apply 85°C to the board. Writing a new value to a sensor register will require assembling a new sequence of I2C commands. Listing 4 shows how to accomplish this by creating a simple transaction list composed of a single write block where both the register index and the new value are placed sequentially in the same buffer.

```
bool EMC1001_Write(uint8_t reg, uint8_t data)
{
    uint8_t buffer[2];
    buffer[0] = reg; buffer[1] = data;
    I2C2_MESSAGE_STATUS status = I2C2_
MESSAGE_PENDING;
    static I2C2_TRANSACTION_REQUEST_BLOCK
trb;

    I2C2_MasterWriteTRBBuild(&trb, buffer, 2,
EMC1001_ADDRESS);
    I2C2_MasterTRBInsert(1, &trb, &status); // 1
transaction W

    while(status == I2C2_MESSAGE_PENDING); //
blocking

    return (status == I2C2_MESSAGE_COMPLETE);
}
```

Listing 4: Writing to an SMB device register

Now that new values can be written to the device registers, might as well modify the hysteresis register value to define a more easily observable range.

```
EMC1001_Write(EMC_LIMIT, 28); // set the
THERM limit
EMC1001_Write(EMC_HIST, 2); // reduce the
hysteresis
```

Listing 5: Setting the temperature limit and hysteresis range

Two additional lines of code can be inserted in Listing 5 before the main loop is entered.

If we build the project and re-program the Xpress evaluation board, we will be able to observe the ALARM1 output change by connecting a voltmeter to the RA7 pin available on the outer row (connector J8) of the board.

```
if (EMC1001_Read(EMC_STATUS, (uint8_t*)&temp)) {
    if (temp > 1)
        puts("ALARM1: The temperature is above the set limit!");
    else
        puts("The temperature is below the set limit");
}
```

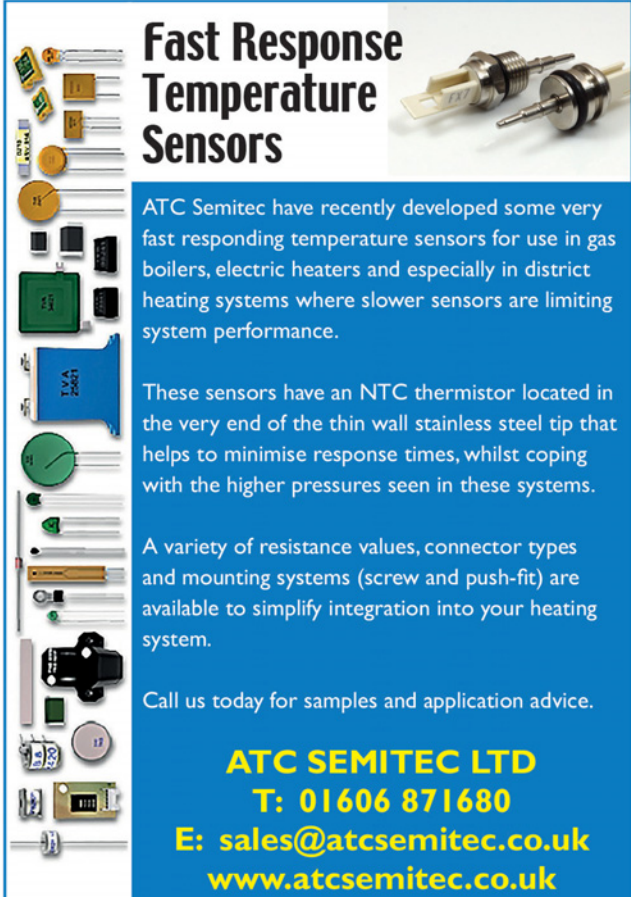
Listing 6: Testing for the THERM limit

Alternatively, we can add a couple more lines to the main loop itself to test the THERM/ALARM1 output through the STATUS register (bit 0), as shown in Listing 6.

See Figures 6 and 7 for the resulting messages captured on the terminal screen.

In Closing

The I2C bus and its derivative SMBus can appear intimidating at first. The MSSP peripheral, controlling all synchronous serial interfaces of the PIC microcontroller looks more complex than most other peripherals on the device datasheet, but the MPLAB Code Configurator makes their use extremely simple. Either using the MPLAB Xpress cloud IDE or the MPLAB X desktop version, a few clicks of the mouse will produce a well designed and flexible set of drivers to access the little but accurate EMC1001 temperature sensor in less than 10 lines of code. ●



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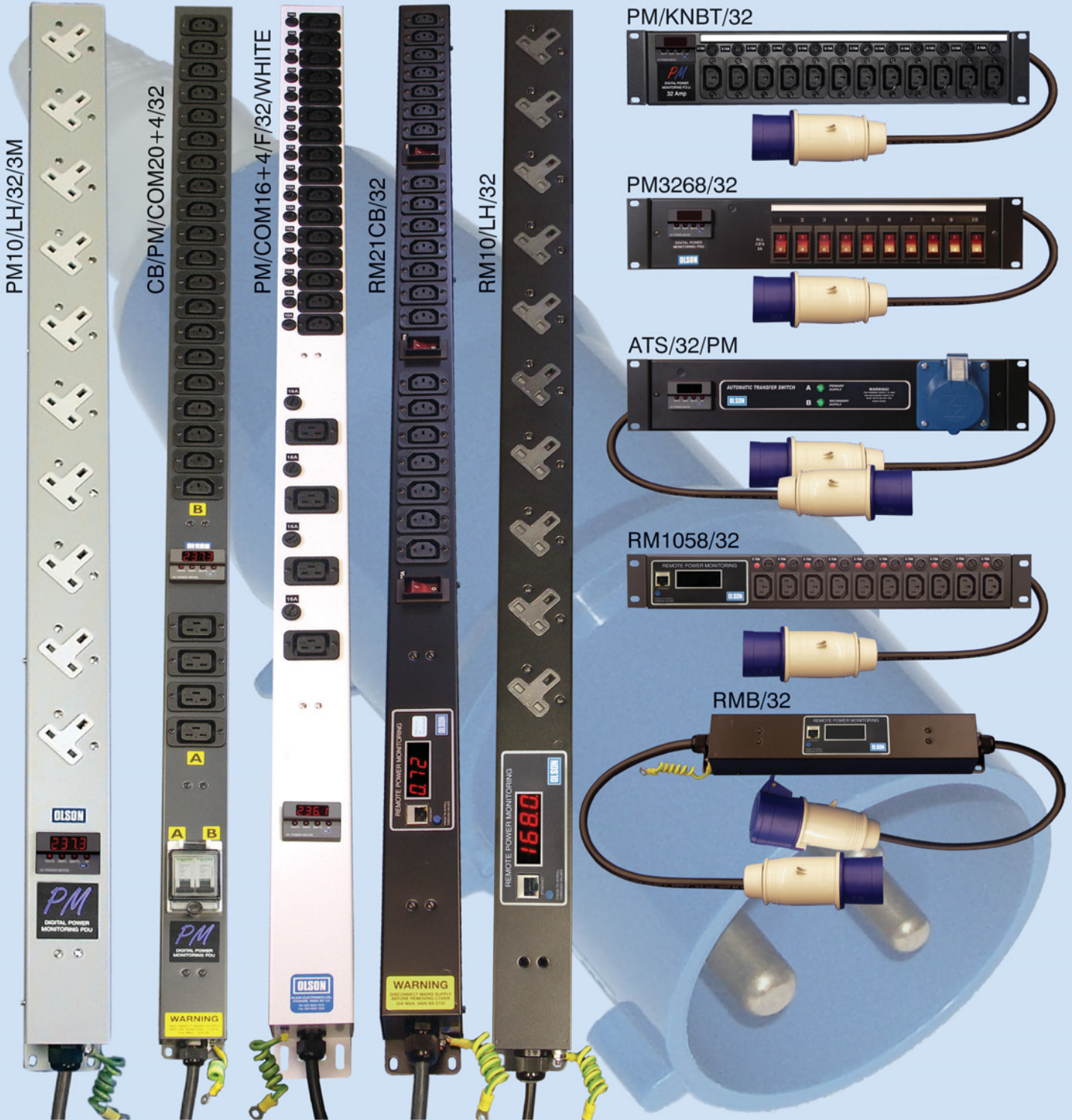
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Digital compasses in embedded applications

BY **DR DOGAN IBRAHIM**, PROFESSOR AT THE NEAR EAST UNIVERSITY, CYPRUS

Simple magnetic compasses have been used for finding directions for millennia. These devices have a needle pointing at Earth's magnetic north, and even though they may not be very accurate, without them our world would not be the same.

Earth's magnetic field is very weak – around $50\mu\text{T}$. It can basically be thought of as a magnetic dipole tilted about 11° with respect to Earth's rotational axis. The actual direction of the magnetic north pole varies slightly, depending on time and our position on Earth.

Modern Compass Applications

Navigation is an important part of most mobile robotic applications, since it helps know the orientation of a robot at any given time, but also for controlling its movements, typically achieved with a digital compass. The compass measures the robot's orientation and provides angular direction information to the user. A GPS device may be used where it is required to know the physical coordinates (latitude, longitude, altitude, speed) and the time, in addition to the basic compass heading.

Most compass modules use a magnetometer (also called

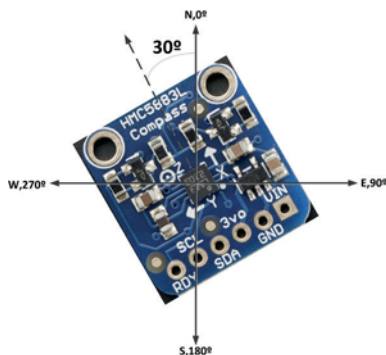


Figure 1: The HMC5883 compass module



Figure 2: The HMC6352 compass module

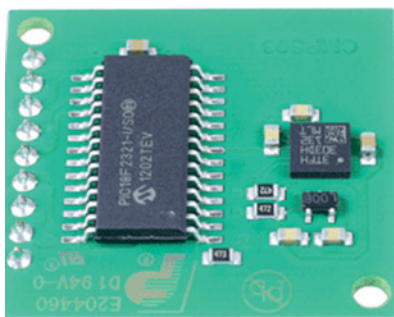


Figure 3: The Daventech CMPS03 compass module

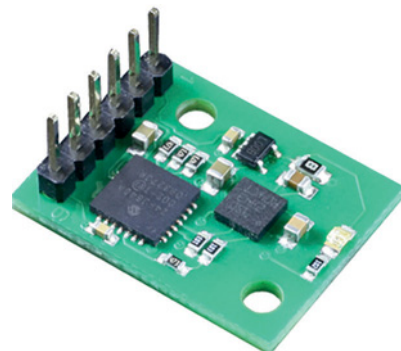


Figure 4: The CMPS11 tilt compensated compass

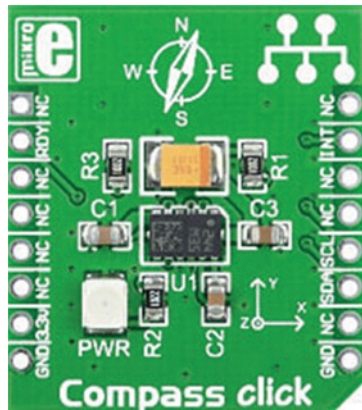


Figure 5: The Compass Click module

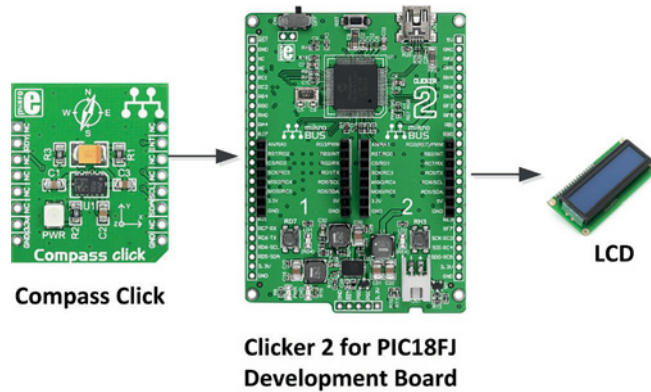


Figure 6: A view of the designed system

a Gaussmeter) which detects the strength and direction of a magnetic field along three perpendicular axes, and outputs digital data proportional to the direction of the measured field.

There are basically two types of magnetometer measurements: vector magnetometers are used to measure the vector components of a magnetic field, for example measuring the heading in relation to the magnetic north; scalar magnetometers measure the magnitude of a magnetic field.

Initially, digital compass modules were developed and used almost exclusively in navigation and tracking applications, mainly in military and aerospace equipment. In the last decade, and since their price dropped sharply, modules have been used in consumer devices, including smart phones, tablets and electronic games.

Compasses In Embedded Applications

The output of a digital compass is normally calibrated in degrees where north is 0° , east 90° , south 180° and west 270° .

Digital compasses for embedded applications can be either chips or modules; essentially, modules are chips mounted on small boards with connectors for power and interface signals. The advantages of modules are that they are easier to handle and to interface in embedded applications.

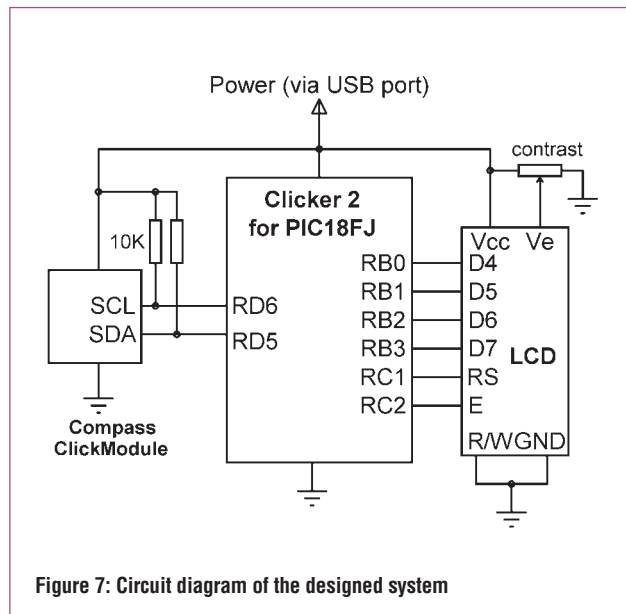
There are many digital compass modules that can be used in embedded applications. Some are very basic and provide only eight directions with 45° between each direction, whilst some are professional grade, accurate to 1° or better. Here are some examples of popular digital compass modules:

- The Honeywell HMC5883 is a surface mount chip based on the magneto-resistive principle. A high-resolution ADC is provided on-chip that offers 1° to 2° heading accuracy as

a digital compass. Some basic features of this compass chip include low-voltage (2.16-3.6V) operation, on-chip 12-bit ADC, I2C interface to most microcontrollers, low operating current (100 μ A working, 2 μ A idle) and a small footprint.

The HMC5883 chip is also available as a module (see Figure 1), where the x axis gives the direction with respect to north.

- The Honeywell HMC6352 compass module (Figure 2) offers 0.5° resolution and operates with a supply voltage of 2.7-5.2V. As with the HMC5883, it uses the I2C interface for connection to a microcontroller. The operating current is 1mA @3V.
- The Daventech CMPS03 compass module (Figure 3) is based on the Philips KMZ51 magnetic sensor, providing 0.1° resolution with accuracy of 3-4 degrees. The output is either in form of a byte, giving 0-255 $^\circ$, or as an unsigned integer, giving 0-3599, which corresponds to 0-359.9 $^\circ$. The module outputs the heading via PWM or I2C interface and operates from a 5V supply, requiring 20mA current.
- The CMPS11 by Daventech is a tilt compensated compass module offering a resolution of 0.1° . It contains a 3-axis magnetometer, 3-axis gyro and a 3-axis accelerometer. A Kalman filter algorithm is used to remove errors caused by tilting the board. Bearing is calculated using a magnetic field sensor with pitch and roll sensing. The operating voltage is 3.6-5V and the module is interfaced to a microcontroller via its I2C interface or a serial UART.
- The mikroElektronika Compass Click module (Figure 5) is based on the high-performance LSM303DLHC chip that measures both linear acceleration and compass heading. A 16-bit output data in 2s complement form is provided through its I2C interface. The module operates from 3.3V and is compatible with the mikroBUS layout. The orientation of each axis is marked on the board.



Designing A Microcontroller-Based Compass Device

The design of a microcontroller-based digital compass is described in this section to show how a digital compass module can be used in an embedded application.

Figure 6 shows the designed system, which is based on the Compass Click module shown in Figure 5.

The Clicker 2 for PIC18FJ microcontroller development board, also by mikroElektronika, is used in this design for simplicity. The Compass Click module is connected to mikroBUS socket 1 of the board. A 16x2-character LCD display shows the heading. The LCD is operated in 4-bit mode to simplify the design and to minimize the I/O pin count. The development board carries a PIC18F87J50-type medium-performance microcontroller operated at 3.3V, with an external 8MHz crystal. In addition, the board includes 128kbytes of flash program memory and 3904 bytes of RAM.

Other microcontroller development boards could also be used; the only requirement is an I2C bus interface and at least six general-purpose output ports to connect to the LCD (a serial LCD requiring only one output pin can be used, too). Also, the Compass Click module I/O signals are 3.3V compatible, so level-shifting circuits may be required if the chosen microcontroller operating voltage is 5V.

The system circuit diagram is shown in Figure 7. The LCD is connected to PORTB (RB0-RB3) and PORTC (RC1-RC2) of the microcontroller. Power to the development board is supplied from the USB port of a PC, converted to 3.3V by the development board. The Compass Click module is powered from the development board via its mikroBUS socket.

The PIC18F87J50 microcontroller has two built-in I2C bus interfaces. In this example, the interface at PORTD (I2C2) is used. The connections between the Compass Click module and the PIC18F87J50 microcontroller are as follows:

Compass click module	PIC18F87J50
SCL	RD6
SDA	RD5

Two 10K pull-up resistors are used at the SCL and SDA lines as required by the I2C bus specifications.

The Software

To program this design we used the popular mikroC Pro for PIC programming language and IDE. The PIC18F87J50 microcontroller on the development board is factory pre-loaded with a bootloader program. The developed user program is compiled on a PC and uploaded into the target microcontroller via a compatible bootloader program on the PC.

Listing 1 shows the complete program of the system. First, the control register addresses the LSM303DHL compass chip and the LCD interface signals are defined. The main program configures all ports as general purpose digital ports. The LCD is then initialized and the text 'Compass' displays for one second; the I2C bus and the compass module are now initialized too. This requires both the accelerometer and the magnetic sensor on the board to be enabled and configured for continuous operation. mikroC Pro for PIC I2C library functions are used to read and write to the compass module over the selected I2C bus.

The rest of the program is executed in an endless loop, where function getCompass() reads the compass data, and getHeading() calculates the heading as a floating-point number between 0° and 359° and stores it in variable heading. This variable is then converted into a string and displayed on the first row of the LCD. The process is repeated after a one-second delay.

Notice that it is important to read all six magnetic data bytes from the LSM303DHL chip, otherwise communication to chip will be halted. Also, it may be necessary to calibrate the compass module for accurate results. The calibration procedure can be found in STMicroelectronics Application Note AN3192. ●

```
#define Pi 3.14159
// LSM303 registers
#define CTRL_REG1_A 0x20
#define CTRL_REG4_A 0x23
#define CRA_REG_M 0x00
#define MR_REG_M 0x02
#define OUT_X_H_M 0x03
#define LSM303_MAG 0x3C
#define LSM303_ACCEL 0x32
// LCD interface
sbit LCD_RS at RC1_bit;
sbit LCD_EN at RC2_bit;
sbit LCD_D4 at RB0_bit;
sbit LCD_D5 at RB1_bit;
```

continued on p20>

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```

sbit LCD_D6 at RB2_bit;
sbit LCD_D7 at RB3_bit;

sbit LCD_RS_Direction at TRISC1_bit;
sbit LCD_EN_Direction at TRISC2_bit;
sbit LCD_D4_Direction at TRISB0_bit;
sbit LCD_D5_Direction at TRISB1_bit;
sbit LCD_D6_Direction at TRISB2_bit;
sbit LCD_D7_Direction at TRISB3_bit;
// End LCD interface

unsigned char Txt[14];
int Mx, My, Mz, mag[6];
float heading;
//
// Get compass reading
//
void getCompass()
{
    I2C2_Start();
    I2C2_Wr(LSM303_MAG);
    I2C2_Wr(OUT_X_H_M);
    I2C2_Repeated_Start();
    I2C2_Wr(LSM303_MAG+1);
    mag[0] = I2C2_Rd(1);
    mag[1] = I2C2_Rd(1);
    mag[2] = I2C2_Rd(1);
    mag[3] = I2C2_Rd(1);
    mag[4] = I2C2_Rd(1);
    mag[5] = I2C2_Rd(0);
    I2C2_Stop();
    Mx = (int) (mag[0] << 8) + mag[1];
    My = (int) (mag[2] << 8) + mag[3];
    Mz = (int) (mag[4] << 8) + mag[5];
}

void LSM303_write(char device, char dat, char
address)
{
    I2C2_Start();
    I2C2_Wr(device);
    I2C2_Wr(address);
    I2C2_Wr(dat);
    I2C2_Stop();
}

//
// Get compass heading in degrees
//
void getHeading()
{
    if(Mx == 0 && My > 0)heading = 90;
    else if(Mx == 0 && My < 0)heading = 270;
    else heading = 180*atan2(My, Mx)/Pi;
    if(heading < 0)heading += 360;
}
//
// Initialise the accelerometer and compass for
continuous operation
//
void initCompass()
{
    LSM303_write(LSM303_ACCEL,0x27, CTRL_
REG1_A);
    LSM303_write(LSM303_ACCEL,0x40, CTRL_
REG4_A);
    LSM303_write(LSM303_MAG, 0x14, CRA_
REG_M);
    LSM303_write(LSM303_MAG, 0x00, MR_
REG_M);
}

void main()
{
    ANCON0 = 0xFF; //
Configure ports as digital
    ANCON1 = 0xFF; //
Configure ports as digital
    LCD_Init(); // Initialise LCD
    LCD_Out(1,1,"Compass"); // Display
"Compass"
    Delay_Ms(1000); // Wait 1
second
    I2C2_Init(50000); // Initialise I2C
    initCompass(); // Initialise
compass

    while(1) // Do forever
    {
        getCompass(); // Get compass
data
        getHeading(); // Get heading
        FloatToStr(heading,Txt); // Convert into
string
        Lcd_Cmd(_LCD_CLEAR); // Clear LCD
        Lcd_Out(1,1,Txt); // Display heading
in degrees
        Delay_Ms(1000); // Wait 1 second
    }
}

```

Listing 1: The program

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Die Optimisation

BY **OLIVER KING**, CHIEF TECHNOLOGY OFFICER OF MOORTEC

Since the semiconductor industry's early days, for increased device performance and functionality we've relied on the trend of doubling transistor count per unit area every 18 months. But, when the process node reached 28nm, this law broke down. So, now, designers need to find new ways to continue increasing performance.

Using the analogy of the internal combustion engine, for decades it was fine to have the fuel consumption and emissions that came with it, as innovation was limited. Improvements to cars focused around adding features and functionalities; people bought new cars because they wanted the latest features. But, when oil prices started to rise and the impact vehicles made on the environment became more pronounced, innovation was channelled to improving engine efficiency. The results were quite astounding, as the modern car engine now delivers more power whilst consuming less fuel and emitting less harmful gasses.

Similarly, the semiconductor industry is now in the position where it has to do the same. We can no longer rely on adding more transistors to make a better, faster, chip, even though customers still expect their new computers, phones or tablets to be faster and have more storage than their old ones.

Device Optimisation

One technique used to improve semiconductors is device optimisation. By being aware of the device's thermal and voltage environment and understanding where it fits within the ever-increasing sphere of variations, helps the system architects and circuit designers get more from their silicon. With advancing nodes processes and their rising costs, it becomes even more important to ensure that every last drop of performance is extracted from a die. However, this is not an issue solely for semiconductors; it becomes a far-reaching one.

With the growth of the IoT market, we will see an explosion in the number of wireless devices, a majority of which will use older process nodes. These devices will typically be battery-powered and sensitive to power consumption, which will drive improvements in product efficiency rather than improved

performance (essentially, these are different names for the same problem). By understanding where a given die is with respect to process, voltage and temperature (PVT), a more optimum solution can be found, regardless of how it's being measured – by performance or by efficiency.

We also have to consider another big growth area of semiconductors – automotive. With the rise of Advanced Driver Assistance Systems (ADAS) and infotainment applications we will see more advanced nodes being used, certainly down to 28nm in the near future. Ideally, some of these products should be on more advanced nodes, but these processes have not been qualified for automotive applications, leading to available technologies being squeezed by designers to get the extra level of performance and efficiency. In addition, the environment is harsh in automotive applications. So, when putting all these together, it becomes clear that there's room for die optimisation and basic parameter-monitoring, if not purely for safety and reliability reasons.

Accurate Monitoring

Accurate PVT monitors are key to implementing die optimisation; the relationship between power consumption and supply voltage of CMOS logic is only too well-known to designers. Being able to reduce the supply voltage by even a few percent per process point will result in worthwhile power savings. The same is true with performance; a given clock speed can be met with a lower voltage supply, resulting in power savings. But neither is possible if the monitors are not accurate.

PVT monitors are not new; they have been used in the industry for a long time, although perhaps not in what I call “mission-critical” roles. Once we start looking at optimisation and potentially putting PVT monitors into dynamic control systems – where we now see the latest generation being used – then reliability and testability are critical.

Having features within PVT monitors to ensure they can be tested easily in production is a minimum entry requirement but, in addition to that, knowing the data from these monitors can be trusted is fundamental. As such, having in-field fault detection and reporting built into the monitors is important.



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Let us consider the situation where a chip within a smartphone or tablet contains a temperature monitor which fails, where this failure tells the system its temperature is 0°C when actually it is 50°C, and because of this the system decides it can run with higher clock rates, pushing the die temperature up even further. The result could be very serious indeed. It is cases like these that highlight the need for robust operation of PVT monitors.

The Future Of On-Chip Monitoring

On-chip PVT monitoring is here to stay. The costs of advanced node technologies are continuing to increase and there's also fragmentation, where the very advanced nodes become more niche for those devices which really need the performance. For those nodes, optimisation will be part of the architecture to ensure costs are minimised.

As the rest of the industry moves to smaller nodes, they will look to differentiate their products from their competitor's, and good die optimisation will play a big part in that. ●



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MAIN FACTORS DRIVING THE APPLICATION OF SENSORS IN APPLIANCE DESIGNS

BY **GWENN GMEINDER**, BUSINESS DEVELOPMENT MANAGER AT LITTELFUSE

Smart technology is an integral part of many consumer electronic devices. Within the home appliance market, a growing number of smart appliances are incorporating sensors to enable advanced sensing and control. Sensor technologies for position, proximity, level, flow and speed controls are used across a broad array of appliances to deliver improved accuracy, reliability and efficiency. Modern smart appliance designs require multiple sensors in each unit as shown in Figure 1.

Appliance Sensor Applications

There are four main factors that drive the design of smart home appliances, including:

- The demand for consumer convenience and home automation. As modern homes become more dependent on smart technology, smart appliances with advanced sensors will be in the best position to support future smart home infrastructures, enabling synchronized communication and control.
- Demand for smart appliances is truly global.
- Soaring energy prices and government regulations demand energy-efficient appliances. The use of sensors in multiple applications, including smart power grids, smart buildings and smart industrial process control, help enable a more efficient use of resources and a reduction in greenhouse gas emissions. Modern appliances with built-in efficiencies from advanced sensors dramatically reduce the required levels of energy/water and minimize the amount of waste fluids for disposal.

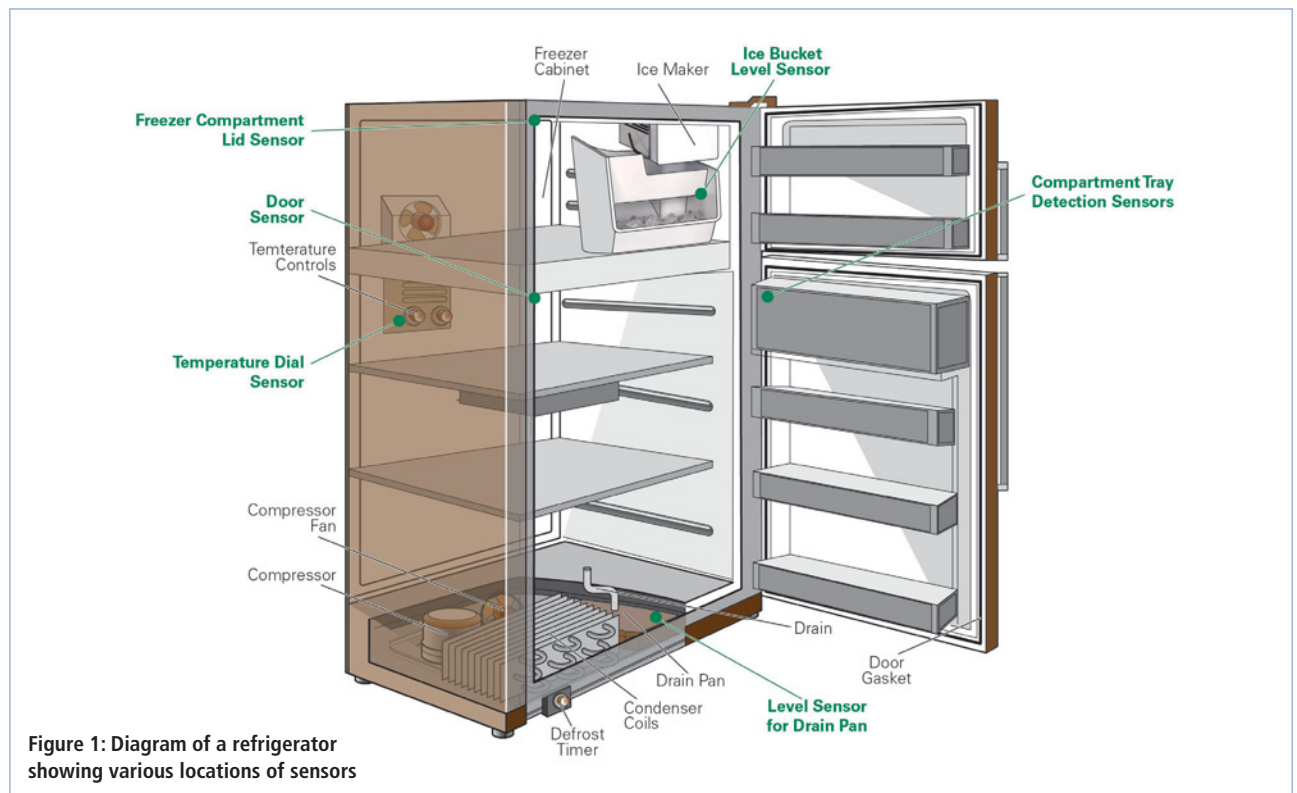


Figure 1: Diagram of a refrigerator showing various locations of sensors

- The use of microprocessor control systems has reduced the need for large mechanical contactors/relays and switching technologies that traditionally switched several amps and incandescent light bulbs. Today's smart appliances require low-voltage and low-current switching/sensing devices, and non-contact sensing devices are ideal for replacing the mechanical units.

Reed Switch And Hall Effect Sensors

Reed switches and Hall effect sensors are non-contact sensing technologies with a life of millions of operating cycles. They are considered non-contact because the activating device does not have to make physical contact with the sensor to change its output.

A reed switch is an electrical switch operated by an applied magnetic field. As a passive component it requires no power to operate.

The switch consists of two or three thin metal pieces called reeds with plated contacts at their tips, spaced a small distance apart. The reeds are usually enclosed in a sealed glass tube filled with inert gas.

Because of its simplicity and reliable performance, the reed switch is ideal for low-power applications such as home appliances.

Reed sensors are often

used in refrigerators or ovens to detect whether a door is open or closed. The sensor sends a signal to a control unit to promptly activate or deactivate an LED or other circuitry in the appliance.

The magnetic sensitivity switchpoints of reed switches are more precise than solid-state digital switches. High accuracy is especially vital when designing the system to function under all operating conditions.

Reed switch contacts are hermetically sealed, so they are protected from extreme temperatures, humidity and moisture found in many appliances without impacting their contact stability or operating life.

Hall Effect Sensors

Hall effect sensors are semiconductor-based transducers that vary their output voltage in response to changes in the magnetic field. These sensors combine a Hall-effect sensing element with circuitry to provide a digital on/off or analogue output signal that corresponds to a change in the magnetic field without involving moving parts. Unlike a reed switch, a Hall effect device contains active circuitry that draws a minute amount of current at all times.

Hall effect sensors are programmable and can be used in a variety of ways to obtain multiple outputs, including digital, analogue and speed sensing.

Hall effect sensors are quite popular in washing machine speed sensor applications. The rotational speed of the machine tub is monitored by a multipole magnet (16 or 32 poles) attached to the

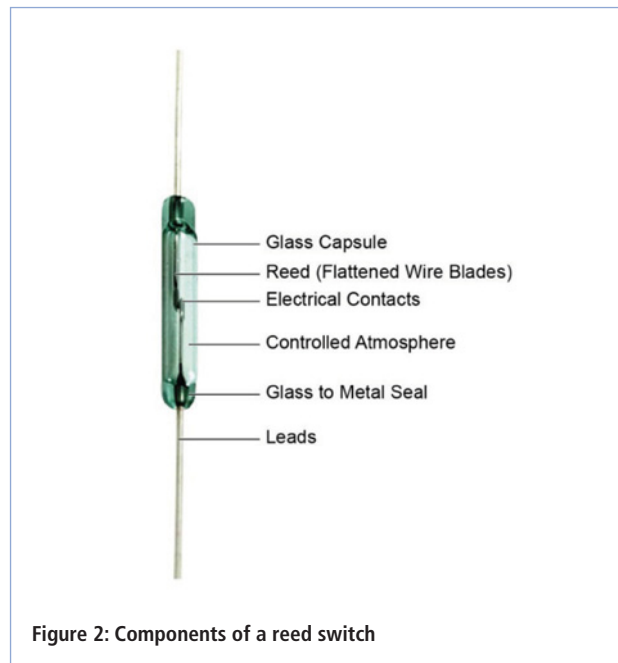


Figure 2: Components of a reed switch

motor shaft. The magnet rotates over a Hall effect sensor with excellent speed measurement capabilities. This digital speed signal is sent to a control unit that internally controls the motor speed for the various speed cycles.

Non-Contact Sensor Benefits

To compete in today's smart appliance market designers must take advantage of every technology at their disposal, including non-contact sensors. These sensors will enhance the performance and appearance of the appliance design, leading to increased consumer satisfaction and demand. In addition to the energy savings associated with microprocessor controls, other benefits include enhanced reliability and reduced maintenance costs compared to mechanical devices.

Output signal options for non-contact sensors include digital signals for position sensing and ratiometric output values for linear or rotational sensing. These signals deliver instantaneous values, which enable tighter controls and better resolution for enhanced sensing accuracy.

With non-contact sensing technologies, appliance designs are much more flexible for applications requiring tight tolerances. This is especially important in confined areas where the space available for mounting sensors is very limited.

Non-contact sensors deliver improved reliability and durability over the life of the appliance because they are unaffected by mechanical wear or oxidation build-up on contacts. In addition, they are impervious to changes in temperature or moisture typically found in many household appliances.

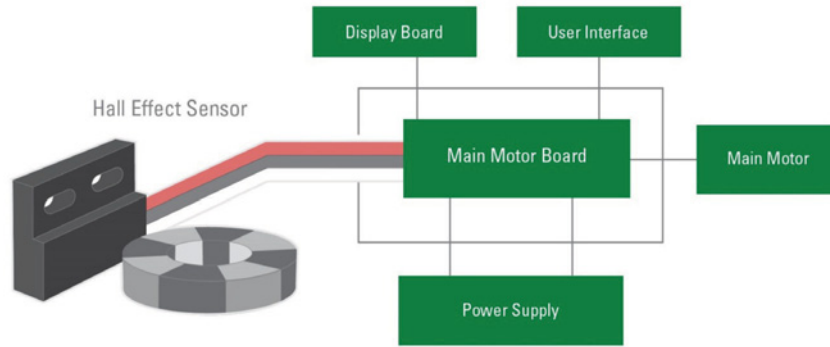


Figure 3: Washing machine drum speed Hall effect sensor with ring magnet

Improved Energy Efficiency

Non-contact sensing solutions help deliver energy efficiencies needed for household appliances to earn the Energy Star rating. Increased use of Energy Star appliances has led to a positive effect on the environment, including:

- Energy Star products prevent over 150 million metric tons of greenhouse gas emissions each year, according to the US Environmental Protection Agency (EPA).
- These products save more than 200 billion kilowatt-hours of electricity per year, equal to 15% of residential use in the US.

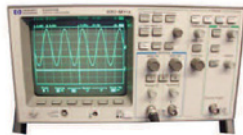
- The Energy Star program has resulted in energy usage savings worth billions of dollars since its inception in 1992 (source: www.energystar.gov).

Enhanced Aesthetic Appeal

Unlike mechanical devices, non-contact sensors have no visible levers or push-buttons, since they are hidden behind appliance panels, resulting in sleeker and more attractive designs that modern customers like, in addition to their more reliable and durable functionalities. ●



HP 34401A Digital Multimeter 6 1/2 Digit



HP 54600B Oscilloscope Analogue/Digital Dual Trace 100MHZ



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Marconi 2955A	Radio Communications Test Set	£725
Marconi 6200	Microwave Test Set	£1,500
Marconi 6200A	Microwave Test Set 10MHZ-20GHZ	£1,950
Marconi 6200B	Microwave Test Set	£2,300
Marconi 6960B with	6910 Power Meter	£295

Tektronix TDS3012	Oscilloscope 2 Channel 100MHZ 1.25GS/S	£450
Tektronix 2430A	Oscilloscope Dual Trace 150MHZ 100MS/S	£350
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Cirrus CL254	Sound Level Meter with Calibrator	£40
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Farnell B30/10	PSU 30V 10A Variable No Meters	£45
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Farnell XA35/2T	PSU 0-35V 0-2A Twice Digital	£75
Farnell LF1	Sine/sq Oscillator 10HZ-1MHZ	£45
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Racal 9300B	As 9300	£75
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Solartron 7150 Plus	as 7150 plus Temp Measurement	£75
Solartron 7075	DMM 7 1/2 Digit	£60
Solartron 1253	Gain Phase Analyser 1mHZ-20KHZ	£600
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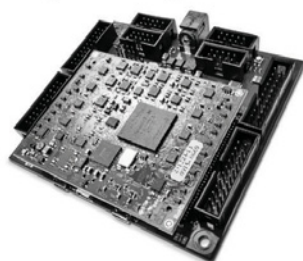
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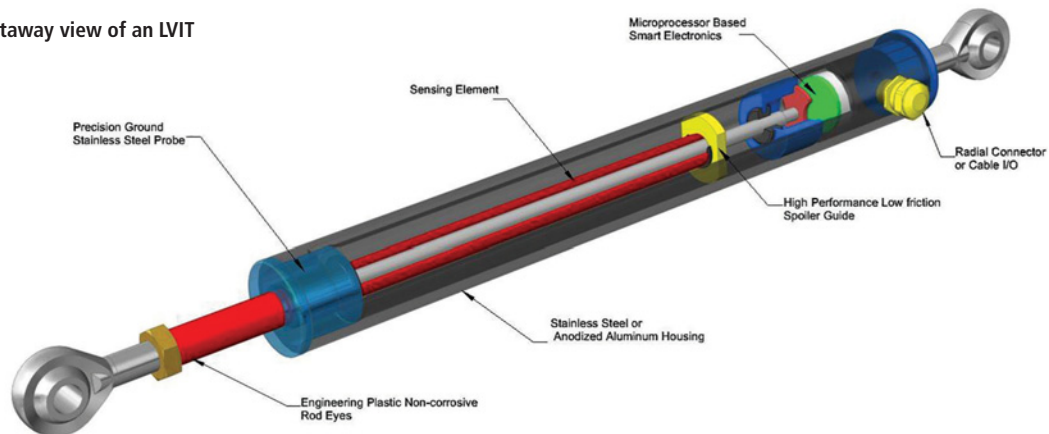


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Figure 1: Cutaway view of an LVIT



THE ROLE OF LVIT TECHNOLOGY IN THE WORLD OF SENSORS

BY **JOHN MATLACK**, VP OF SALES AND MARKETING AT THE US-BASED ALLIANCE SENSORS GROUP

Linear variable inductive transducers (LVITs) have been around for over 30 years but have recently grown in popularity because of their low cost, flexibility and variety of packaging formats.

LVITs (Figure 1) are contactless position-sensing devices that use eddy currents formed by an inductor on the surface of a conductive movable element to vary the resonant frequency of an L-C tank circuit. The most common form of an LVIT uses a small-diameter inductive probe surrounded by a conductive tube called a “spoiler” that is mechanically coupled to the moving object.

Typical LVITs have full ranges from fractions of an inch to over 30 inches. Modern electronics using microprocessors and small component sizes make outstanding performance possible, achieving linearity errors of less than $\pm 0.1\%$ and temperature coefficients of 50ppm/ $^{\circ}\text{F}$, along with either analogue or digital outputs.

The range of housing sizes for LVITs can be seen in Figure 2.

Applications

LVITs are found in a wide variety of applications that require position information or feedback. Typical applications include mobile hydraulics, subsea hardware, civil engineering testing, power generation and energy development, and factory automation.

In mobile hydraulics the LVIT is commonly used to measure hydraulic or pneumatic cylinder positions. Usually the sensor has a pressure-sealed head and a probe long enough to insert

into a gun-drilled hole in the cylinder’s ram. The ID of this hole in the ram then acts as the spoiler. The sensor head can either be port-mounted or embedded in the end cap of the cylinder. A typical in-cylinder LVIT installation is shown in Figure 3.

This packaging works for many different applications in mobile hydraulics, such as bulldozer shovel or snowplow positioning, boom positioning on hydraulic cranes and manlifts, and in a variety of agricultural vehicle accessory position feedback requirements.

For subsea cylinder applications involving pumps, chokes, blowout preventers and remotely-operated-vehicle (ROV)-based actuators, the LVIT is designed to withstand the internal and/or external pressures of a PBOF (pressure balanced, oil-filled) system.

Other technologies commonly used to satisfy these applications require additional hardware like a ring magnet to operate, which adds cost to the machining of the cylinder ram and complexity to the installation. Typical subsea LVITs are shown in Figure 4.

Civil engineering applications include measuring bridge expansion and contraction due to seasonal heating and cooling and related shifts in trunnions, and roller support mechanisms. This problem of expansion and contraction is compounded with railway bridges and trackage, where the expansion of a mile-long section of rail can be as much as four feet over a change of temperature in some climates of more than 100 degrees F. This can lead to rail buckling, known in the industry as “sun kink”, and the derailment of a train.

In this type of application, instead of having a bare probe

protruding from the sensor head, the LVIT's probe coil, spoiler and electronics are packaged inside cylindrical housing for heavy-duty protection, allowing the sensor to be exposed to its environment. The LVITs are connected to the pier and deck of the bridge to measure the relative position of the two, or directly to the rails to measure rail buckling.

LVIT technology is extremely robust and so can withstand seasonal weather conditions such as heat, cold, rain and snow. An installation of heavy-duty LVITs under a bridge is shown in Figure 5.

Factory And Energy Uses

LVITs are used in many factory automation applications, including packaging and material-handling equipment, die platen positioning in plastic molding machines, roller positioning and web tension controls in paper mills or converting facilities, and robotic spray painting systems. Being contactless, the basic measurement mechanism of an LVIT does not wear out over time. LVITs also do not have the higher installed cost associated

with other contactless technologies.

LVITs are also found throughout the energy sector. In power generation applications, LVITs are used for valve position feedback, and to measure feedwater pump displacement and generator shell movement. In oil fields, LVITs are used in hydraulically-operated pumps that replace Lufkin-style pump jacks, and to measure the poppet position inside check valves.

Alliance Sensors Group's LVIT product lines are offered with its proprietary SenSet field programmable scaling, which allows a user to adjust for mechanical variations after installation in the application simply by pushing a button or grounding a terminal. This SenSet feature reduces setup time and cost of ownership. For example, SenSet allows a rising stem valve that opens 9.5in to be coupled to a 10in range LVIT and get full scale output over the 9.5in by scaling the sensor's output after installation.

LVITs represent a valuable and cost-effective position measuring technology for a broad range of applications. ●



Figure 2: A range of housing sizes for LVITs



Figure 3: A typical in-cylinder LVIT installation

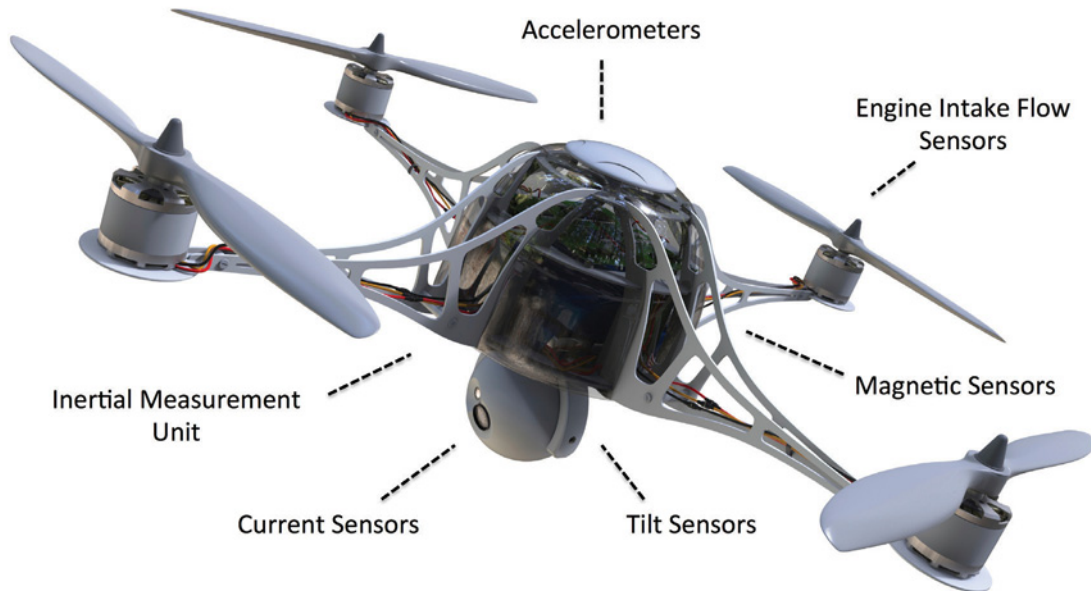


Figure 4: Typical subsea LVITs



Figure 5: Heavy duty LVITs under a bridge

Figure 1: MEMSIC sensor technologies used in drones



SENSORS PLAY CRITICAL ROLES IN ENABLING INNOVATION IN DRONES

IN TODAY'S FAST-GROWING DRONE MARKET SEGMENT, SENSORS ARE OFTEN THE UNHERALDED KEY COMPONENT INSIDE. IN THIS ARTICLE, **CHRIS WINKLER**, SENIOR EXECUTIVE FOR STRATEGIC PRODUCT LINES AND CORPORATE STRATEGY AT MEMSIC, DISCUSSES THE TECHNOLOGIES THAT EMPOWER THEM

A

utonomous industrial drones are a fast-growing industry sector. Market research firm Tractica estimates that annual worldwide shipments of commercial drones will increase from the current 80,000 units to approximately 2.7 million units in 2025, with services enabled by them generating annual revenues of \$8.2bn.

In the past, innovations in drone technology almost exclusively focused on military applications. However, recently the trend has started to shift toward commercial applications, including cargo transport and delivery, surveying, agriculture, law enforcement, filmmaking and healthcare, among others.

Accelerometers

Accelerometers are used to determine position and orientation of the drone in flight. Just like their importance to the operation of a Nintendo Wii controller or an iPhone screen, these small silicon-based sensors play a key role in maintaining flight control.

MEMS-based accelerometers sense movement in several ways. One type senses micro movements of very small structures embedded in an integrated circuit (IC). The movements change the amount of electrical current passing through the structures, indicating change of position relative to gravity. Because of the accelerometers' small size and low power consumption, they can be included in multiple parts of a drone, to better inform the control system. And because of their sensitivity, they play an important role in stabilizing on-board cameras, vital in capturing video.

Another technology used in accelerometers is thermal sensing, which offers several distinct advantages, perfect for drone applications because of thermal sensors' robustness and immunity to vibrations. Because they are more immune to vibrations than other technologies, thermal MEMS sensors are perfect in drone applications to minimize problems from increased vibration generated by moving propulsion fans and propellers.

This technology is unique to MEMSIC, which integrates MEMS inertial sensors and signal processing circuitry on a standard monolithic CMOS wafer.

The thermal MEMS accelerometer is based on the principle of convection of heated gas molecules within a sealed cavity. Highly accurate temperature sensors can detect changes in temperature resulting from very small changes in acceleration (or inclination). This technology has a number of unique properties and benefits:

1. There are no moving parts. The “proof mass” in this accelerometer consists of heated gas molecules; see Figure 3. This means there is no detectable resonance, which makes these sensors virtually immune to out-of-band vibration and shock, which is particularly important in drones, with their significant vibrations from high RPM rotors.
2. These devices are extremely robust and reliable, providing shock tolerance of 50,000G (nearly an order of magnitude greater than many competing devices). Also, there is no possibility of “stiction” as in sensor types measuring capacitance between mechanical beams.
3. Thermal accelerometers have exceptionally good zero-g offset stability with time and temperature, and have virtually undetectable thermal hysteresis (an effect commonly experienced with many other accelerometer types that limits the ability to measure small accelerations or tilt angles).

Inertial Measurement Units

Inertial measurement units (IMUs) combined with global positioning systems (GPS) are critical for maintaining direction and flight paths. As drones become more autonomous, such devices are essential to maintain adherence to flight rules and air traffic control.

In addition to their accelerometers, IMUs utilize multi-axis magnetometers that are, in essence, small, accurate compasses. IMUs sense changes in direction and feed data into a central processor, which ultimately indicates direction, orientation and speed.

MEMS technology has fostered an amazing reduction in size and cost. Where once such units cost tens of thousands of dollars and were large boxes, modern IMUs are just a fraction of the size and cost of IMUs of the 1990s, leveraging improvements in drone technology. Without the availability of highly accurate, low cost and small size IMUs, none of the potential drone applications would be imaginable.

Inertial Sensors And Systems

Some inertial systems – such as those from MEMSIC, for example – incorporate an extended Kalman filter (EKF) algorithm that provides on-the-fly calibration of the angular rate sensors and linear accelerometers. The EKF algorithm uses feedback from the accelerometers, rate sensors,

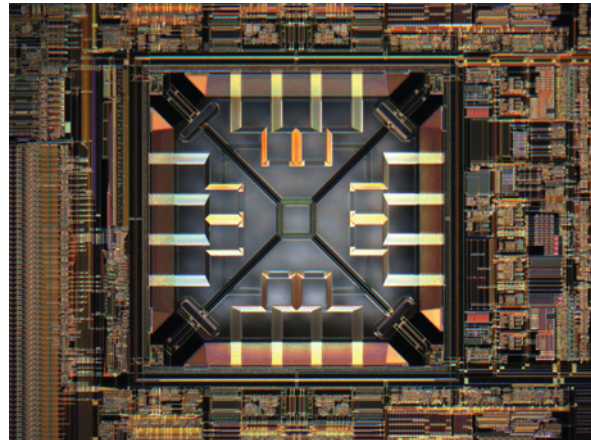


Figure 2: MEMSIC's sensor integrated into CMOS technology

magnetometers and GPS (or air speed) to estimate corrections to the trajectory state and inertial sensor errors. The ability to accurately and effectively estimate these corrections and errors allows the inertial systems to offer unparalleled performance and affordability.

The Kalman filter attitude correction approach achieves improved system performance through its ability to estimate attitude errors and gyro bias states. The advantage of this approach is that an absolute attitude error estimate is provided to the trajectory to correct any errors due to physical noise disturbances and gyro errors, as well as a characterization and tracking of the gyro biases, which in effect provides an online rate sensor calibration.

MEMSIC offers a wide range of inertial products based on the combination of MEMS acceleration and angular rate sensor technologies. The more highly integrated MEMSIC systems incorporate reference data from sources such as a three-axis magnetometer, GPS receiver and/or an air data computer to enhance overall performance. However, all of MEMSIC's inertial systems are designed to operate without the need for external components.

Accurate attitude sensing is accomplished by measuring acceleration in three orthogonal axes and the angular rate about each of these axes to compute roll and pitch angles relative to the gravity vector. Heading is calculated by computing the yaw angle about the z-axis relative to the Earth's magnetic field. The integration of GPS and/or airspeed (from air data computer) provides additional information to the Kalman filter, permitting better attitude corrections, as well as the ability to estimate further accelerometer and magnetometer sensor errors including bias, scale factor and misalignment.

Tilt Sensors

Tilt sensors, combined with gyros and accelerometers, provide input to the flight control system to maintain level flight. This is extremely important for applications where

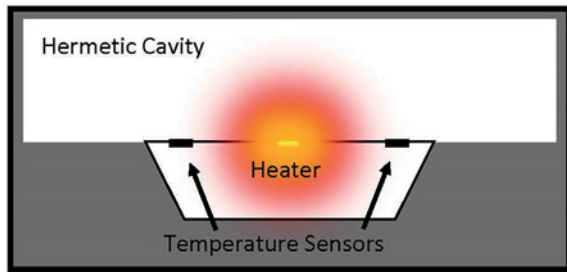


Figure 3: Thermal accelerometer uses heated gas as 'proof mass'

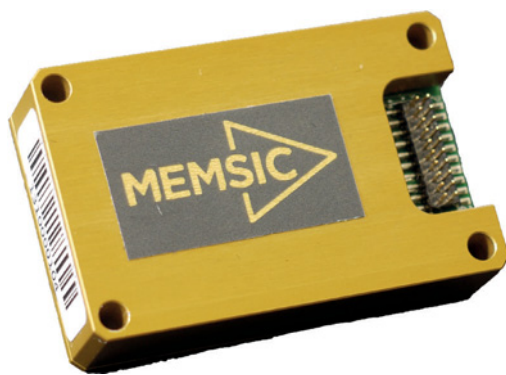


Figure 4: MEMSIC's IMU380

stability is paramount, from surveillance to delivery of fragile goods. These types of sensors combine accelerometers with gyroscopes, allowing detection of small variations of movement. It is gyroscope compensation that allows these tilt sensors to be used in moving applications like motor vehicles or drones.

“Vibration has caused problems for tilt sensors for years, forcing customers to either sacrifice response time by heavily filtering the output of a static inclinometer or to buy more expensive IMU solutions with more capability than they need,” said James Fennelly, MEMSIC Product Marketing Manager.

Current Sensors

Power consumption and use are important, particularly in smaller drones that are battery powered. Current sensors can be used to monitor and optimize power drain, safe charging of internal batteries, and to detect fault conditions with motors or other parts of the system. Current sensors work by measuring electrical current and ideally provide electrical isolation to reduce power loss and eliminate opportunity for electrical shock or damage to the user or systems.

Current sensors with fast response time and high accuracy optimize the battery life and performance of drones. This allows smaller, electrically-powered drones to fly longer.

Magnetic Sensors

In drones, electronic compasses provide critical directional information to inertial navigation and guidance systems. Anisotropic magnetoresistive (AMR) permalloy sensors have superior accuracy and response time, while consuming significantly less power than alternative technologies, so they are well suited to drone applications. Turnkey solutions provide drone manufacturers with quality data sensing in a very rugged and compact package.

Engine Intake Flow Sensors

MEMS thermal mass flow sensors have been explored extensively for their simple structure and implementation. MEMS technology is amenable to creating micro-heaters and thermal sensors with no moving parts, simplifying fabrication and operational requirements. Other advantages of thermal mass flow sensors are their small size, short response time, low power consumption, and higher sensitivity to low flow rates.

A thermal mass flow sensor typically consists of upstream and downstream temperature sensors (thermopiles) and a heater located between the two temperature sensors. The sensor chip consists of a central heater source (micro heater) and two temperature sensors (thermopiles), placed symmetrically around the micro-heater, upstream and downstream. If no gas flows over the sensor surface, the symmetric thermopiles measure the same rise in temperature, resulting in the same output voltage of the two thermopiles. With a non-zero gas flow from the inlet to the outlet of the meter, the velocity of a fully-developed laminar air flow unbalances the temperature profile around the heater and heat is transferred from the upstream thermopiles to the downstream ones, causing a change in their voltages. Larger gas flow rates result in larger asymmetry in the temperature profile.

Ideally, sensors are thermally isolated so that only flow-related heat transfer can occur. Other heat transfer pathways, such as through substrate or electrical leads, can result in thermal losses that degrade sensor performance and need to be minimized in the device design.

Flow sensors can be used to effectively monitor air flow into small gas engines used to power some drones. These help the engine CPU determine the proper fuel-to-air ratio for a given engine speed, leading to improved power and efficiency and reduced emissions.

Many gas engine mass flow sensors employ a calorimetric principle with a heated element and at least one temperature sensor to quantify mass flow. MEMS thermal mass air flow sensors also use the calorimetric principle but on a micro scale, making them highly suitable for applications where reduced weight is critical. Such applications include digital pitot tubes to determine airspeed. ●

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NEXT-GENERATION SEMICONDUCTOR COMPONENTS BENEFIT UAVs

BY **NICOLAS CHANTIER, SÉBASTIEN FRASSE-SOMBET AND ANDREW GLASCOTT-JONES**
FROM E2V SEMICONDUCTORS, BASED IN FRANCE

The global market for unmanned aerial vehicles (UAVs) has grown substantially in the past decade, primarily driven by US military demand.

UAVs are typically considered military equipment, but their use in non-military applications is also growing, with a large increase in volume expected in the near future.

Industries such as public safety, land/crop surveying and oil/gas are seen as key markets that can benefit from UAVs for monitoring and surveillance, and also as unmanned cargo carriers.

Due to UAVs' small size and limited fuel capacity, size weight and power (SWaP) is an important factor behind the choice of components for these systems.

Typically, UAV sub-systems include sensors, communications, data processing and data fusion, mission and UAV control systems; see Table 1 for their different characteristics.

Sensors

There are various sensors used in UAVs, including:

- Passive microwave and millimeter wave meteorology for atmospheric profiles, including atmospheric water and ozone content; hydrology for soil moisture; oceanography for mapping sea ice, currents and surface winds, as well as detection of pollutants, such as oil slicks; and ground monitoring for vegetation conditions, snow cover, traffic control on land and at sea, and sensing road conditions.
- Synthetic aperture radar (SAR) and radar topographic mapping, geology and mining, oil spill monitoring, sea ice monitoring,

oceanography, agricultural classification and assessment and land use monitoring.

- Visible spectrum and infra-red cameras for image transfer to tactical ground stations.
- Electronic warfare payloads that monitor electromagnetic activity and for surveillance purposes. In this case a very wide bandwidth ADC is often found to be the best choice since this allows a wide input spectrum to be monitored. In addition, a high sample rate is necessary to ensure that the maximum size of the Nyquist zones.

The EV10AS152 by e2v Semiconductors is often used for these applications since it has an input bandwidth of 5GHz, and a sample rate of 3GSps gives Nyquist zones of 1.5GHz (see Figure 2). This part also has an extremely low latency of five clock cycles, which is very attractive where a fast response is required.

New developments include a 12-bit 5.4GSps ADC with input analogue bandwidth of greater than 3GHz and a latency of 26 clock cycles.

Synthetic Array Radar

One of the most promising UAV radar sensors is SAR, which is a method of synthesizing a large antenna from smaller ones.

SAR is a good way to take topographical data, including determining the contours of the earth or oceans, the composition of materials on the earth's surface or underground – with the great advantage of being able to work at night or through clouds.

A SAR system uses ADCs or DACs for transmission and receive in its elements. Performance parameters for these systems are bandwidth (since resolution depends on bandwidth) and SFDR

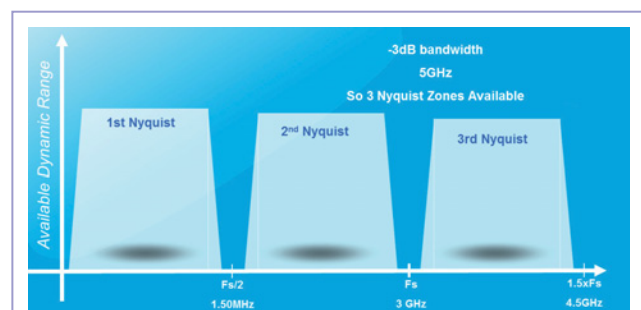
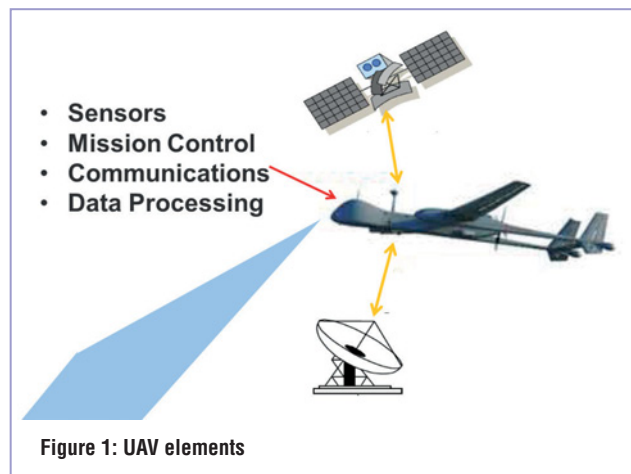


Table 1: UAV subs-systems and their characteristics

Data processing and sensor fusion

Combining information from different sensors for use on board the vehicle. On-board computation on the data received to reduce data link overload or to increase response time.

Communications

Handling communication and coordination between multiple agents in the presence of incomplete and imperfect information.

Mission Control

Determining an optimal path for vehicle to follow while meeting certain objectives and mission constraints, such as obstacles or fuel requirements. In addition in the military arena, threats need to be assessed and treated.

Sensors

For gathering of information that can be remotely sensed. Up to now this has been the main application for UAVs. The multiple sensor types and their applications are described in this article.

(Spurious-Free Dynamic Range, which is the ratio of the signal to the strongest spurious signal in the output).

Note that for a radar system, the resolution is a function of the signal's bandwidth:

$$\Delta R = \frac{c}{2.B}$$

where c is the speed of light, B the useful bandwidth and ΔR is the resolution.

Lidar

Light detection and ranging (lidar) systems consist of a laser and a high-speed, low-noise receiver for reflected-signal analysis. The range of the reflecting object can be determined with a 'time of flight' (TOF) analysis, although more advanced systems use radar processing techniques. Lidar applications include industrial range-finding and measurement, and airborne anti-collision devices.

Control Systems

UAV control systems provide a great degree of autonomous operation, even when being flown remotely by ground-based operators. As a result, autonomy is considered an extension of the control environment.

Systems requiring autonomous control within the UAV are:

Engine Control

The e2v Semiconductors PC5674 has an increased temperature range of -55°C to +150°C, making it attractive for high-temperature environments such as aircraft engines. The part contains embedded flash for program storage and 256kbyte of SRAM. Other features suitable for engine control include a programmable timer interface, CAN bus interface and internal 12-bit ADCs.

Communications Control

For more computationally-intensive control operations, such as communications control and navigation, higher-performing

integrated processors are ideal. e2v Semiconductors's P8548E and P2041 processors contain DDR memory interface, PCIx, Ethernet and GPIO, as well as powerful encryption engines supporting many different algorithms.

Avionics Data Bus ARINC

Common standard for data transfer on avionics platforms is ARINC 429 – a self-clocking, self-synchronizing, differential bus that transfers data at up to 100kbit/s. The TS68C429 ARINC controller from e2v Semiconductors provides the interface between bus and microprocessor.

Data Fusion, Analysis and Mission Control

Combining of data from different on-board sensors can be a computationally-intensive operation. In particular, image processing from optical and radar sensors requires large amounts of processing power.

Using high-performance processors on board a UAV allows optimization of data-link resources, eases the mission control task and also means that the response time can be dramatically improved.

e2v Semiconductors's PC7448 is a best seller in the avionics industry and used extensively in flight computers. This high-

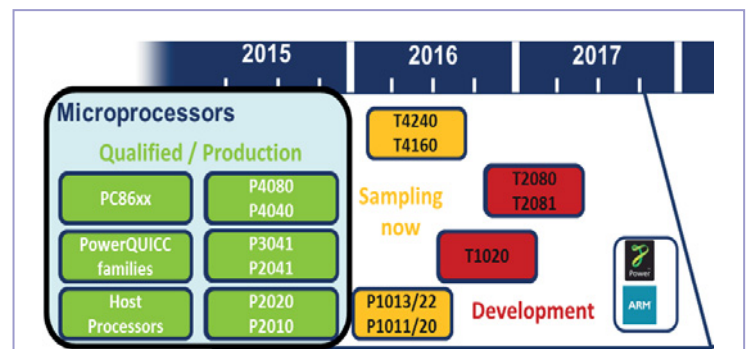


Figure 3: The e2v Semiconductors high-performance microprocessors

performance, superscalar microprocessor can provide performance up to 3000 Dhrystone MIPS and has integrated L1 and L2 cache.

More advanced multicore processors such as the P and T series make it possible to segment tasks within a particular core. Communication between tasks and cores is handled by dedicated on-chip hardware, which means that separate tasks can interact more rapidly than when managed by separate processors.

The e2v Semiconductors product portfolio is shown in Figure 3.

The P or T series processors are fully integrated and have multiple embedded interfaces including PCIx, Ethernet, DDR3 memory control, GPIO, RapidIO and others. Depending on the model, the device may also benefit from data-path hardware acceleration whereby incoming packets are routed to a particular core without software intervention.

The e2v Semiconductors/Micron and ISSSI partnership offers an extended temperature range DDR memory for high reliability requirements.

Note the T and P series parts offer an anti-tamper trust architecture which permits locking the devices' configuration, giving greater security.

Communications

A UAV communications system comprises an uplink control data, downlink information transfer and health status data of the vehicle, as well as navigation data link (e.g. a global positioning system – GPS).

In general, the communications system of a UAV will include a link to a tactical ground station which can control the UAV when it is close enough. After this, the UAV may pass into autopilot mode where it moves based on its inertial sensors. In addition, satellite communications can be employed for control and data transfer. There

are also air traffic control aspects to consider.

Safety is a top priority in the operation of UAVs, particularly as it relates to secure and reliable command-and-control links. Therefore, the communications network in which the UAV operates plays an essential role in meeting security requirements. Advanced encryption is required, and many of the Power PC processors described here have advanced encryption hardware incorporated: for example DES, 3DES, MD-5, SHA-1/2, AES, RSA, RNG, Kasumi F8/F9 and ARC-4 encryption algorithms.

Software Defined Radio

The ideal software defined radio (SDR) is one that has transceivers that perform up-conversion and down-conversion between baseband and the RF carrier exclusively in the digital domain.

The data converters produced by e2v Semiconductors have excellent performance at high input frequencies, for example the EV12AS200 12-bit 1.5GSps ADC has flat performance up to 1.5GHz and the EV12DS130A has output bandwidth greater than 6GHz. These components can be used in a direct-conversion SDR.

The advantages of the SDR approach include software-based channelization, which means greater flexibility; component drift is eliminated; and there are a reduced number of components, which improves cost and reliability. In addition, the need to design a mixing chip with a specific frequency plan is eliminated.

Other advantages include the possibility of high hop rates, since local oscillator PLL settling is eliminated. Also, since the functionality is software-defined, field updates become possible.

Using the DAC EV12DS130A in particular means that extra frequency-hopping encryption can be employed, which greatly improving the security of the link. ●

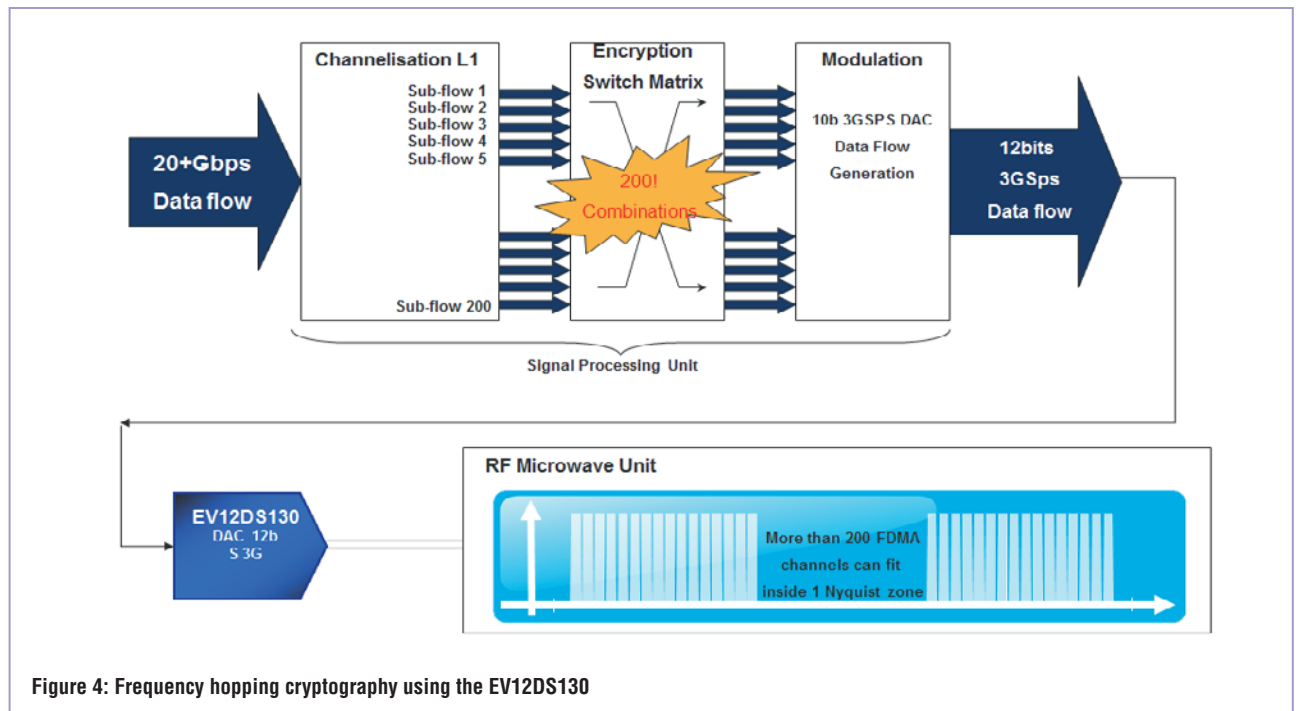
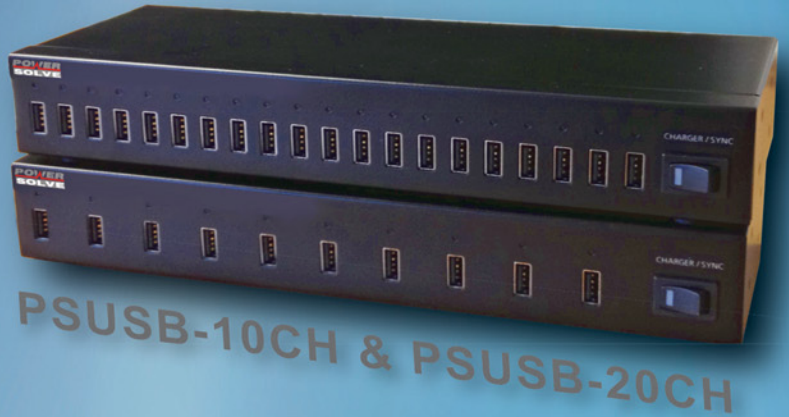


Figure 4: Frequency hopping cryptography using the EV12DS130

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- Output ports, 10 x 5V 2.4A
- Will charge any device powered by standard USB charging technology, with smart charging IC
- EMC to EN55022'B', CISPR22 'B' & FCC 'B'
- Full International Safety Approvals & CE marked
- Compact Desk Top Enclosure with On/Off switch
- Meets ROHS requirements

Features

- Universal 90-264VAC Input
- IEC320 C8 2 pin AC Input Connector (UK power cord included)
- Outputs switchable from 10 x 5V 1A or 5 x 5V 2.4A
- Will charge most devices powered by standard USB 5VDC chargers
- EMC to EN55022'B', CISPR22 'B' & FCC 'B'
- Full International Safety Approvals & CE marked
- Compact Desk Top Enclosure
- Meets ROHS requirements



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USING BCG SENSORS FOR SLEEP ANALYSIS

BY **SAMI M. NURMI**, TEST DESIGN ENGINEER; **JOONAS MAKKONEN**, PRODUCT MANAGER; **ULF MERIHEIN**, SENIOR MEMS APPLICATION SPECIALIST; AND **MARIKA JUPPO**, BUSINESS DEVELOPMENT MANAGER, ALL AT MURATA ELECTRONICS

Sleep disorders are a modern day blight, with a negative impact on health and quality of life. Whilst many sleep problems can be easily identified or are temporary, there are cases where detailed sleep analysis is necessary to properly investigate the root cause.

The established method for such sleep analysis is polysomnography (PSG), which takes place overnight in a specialist laboratory environment, with multiple sensors placed on the patient's body, with trained staff then monitoring and analysing the data. The whole process is expensive, as well as intrusive and unpleasant for the patient.

Alternative Analysis Methods

Over the past few years a less intrusive and lower cost alternative to PSG has been developed. Ballistocardiography (BCG) works by measuring the mechanical forces originating from the body whilst the patient sleeps.

The technique is suitable for long-term use, BCG data is collected through an accelerometer that is not physically attached to the patient. Recent clinical tests conducted by the Aalto University School of Electrical Engineering in collaboration with the University of Turku, Finland, sought to validate that the data gathered via BCG

sensor matches the standard PSG data closely enough to be used as a sleep analysis tool in a home environment. The overnight tests were conducted in a clinical sleep laboratory with a sample of 20 people.

A Murata SCA11H BCG sensor node was taped to the bed mattress to gather BCG measurements; see Figure 1a. Figure 1b shows the much more invasive PSG measurement sensors.

Two BCG sensor nodes were used during the tests; one provided processed vital signs data and the other raw accelerometer signals. The total measurement data included 18 sensors, six of which for electroencephalography (EEG) brain activity, measurement of eye movements with electro-oculography (EOG), measurement of muscle tension with electromyography (EMG) and measurement of respiratory rate with thorax belt and nasal prongs.

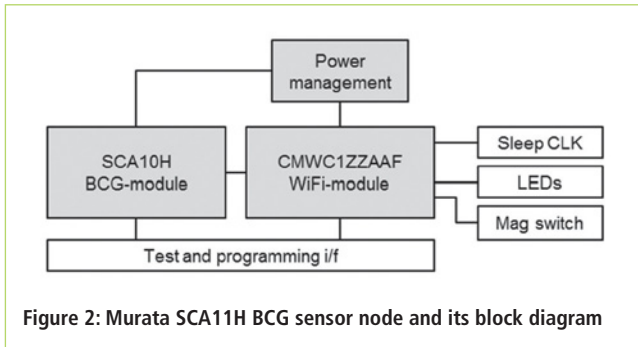
In PSG mode, cardio function was also measured by electrocardiography (ECG). The key indicators of heart rate (HR) and respiratory rate (RR) were calculated from the ECG and thorax belt readings, respectively.

BCG Sensor

The contactless Murata SCA11H BCG sensor consists of a Murata SCA10H BCG sensor module, including a 1-axis accelerometer, an IEEE 802.11b/g/n-compliant Wi-Fi communication module and a



Figure 1: (a) BCG and (b) PSG clinical test setups



host microprocessor; see Figure 2. The accelerometer operates with a 1kHz sampling frequency and has 90 μ g detection resolution. Using a proprietary Murata algorithm, the detected signal can be processed to report multiple parameters every second. These include HR, RR, relative cardiac stroke volume (SV) and heart rate variability (HRV). In addition, several other non-clinical values were reported such as bed occupancy status, signal strength and time-stamp.

The results of the tests concluded that the BCG results were accurate and correlated well with the PSG results. An example of one night's HR and RR data can be seen in Figure 3. It was established that BCG was a reliable approach for sleep analysis.

From Figure 3 it can be seen that the HR was typically at a high level during wakefulness and REM sleep compared to deep and light sleep. HRV was highest in deep sleep and lowest during wakefulness and REM sleep. There was no clear difference between RR for different sleep stages, and respiratory rate variability (RRV) was typically at its lowest level during deep sleep and increased during REM and wakefulness.

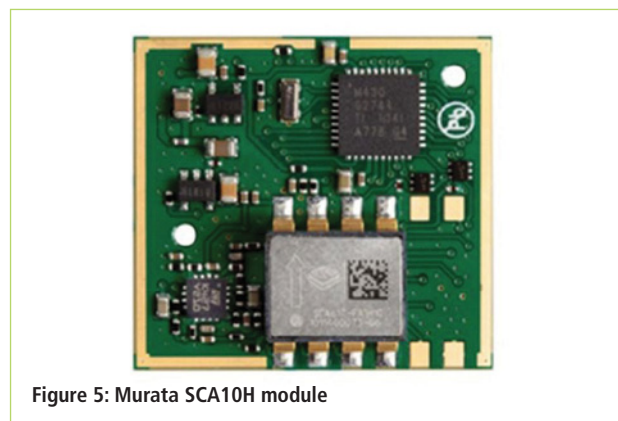
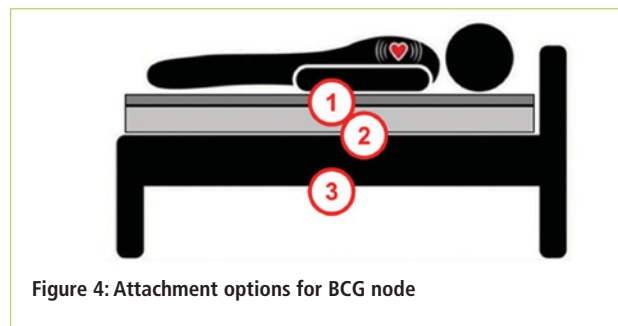
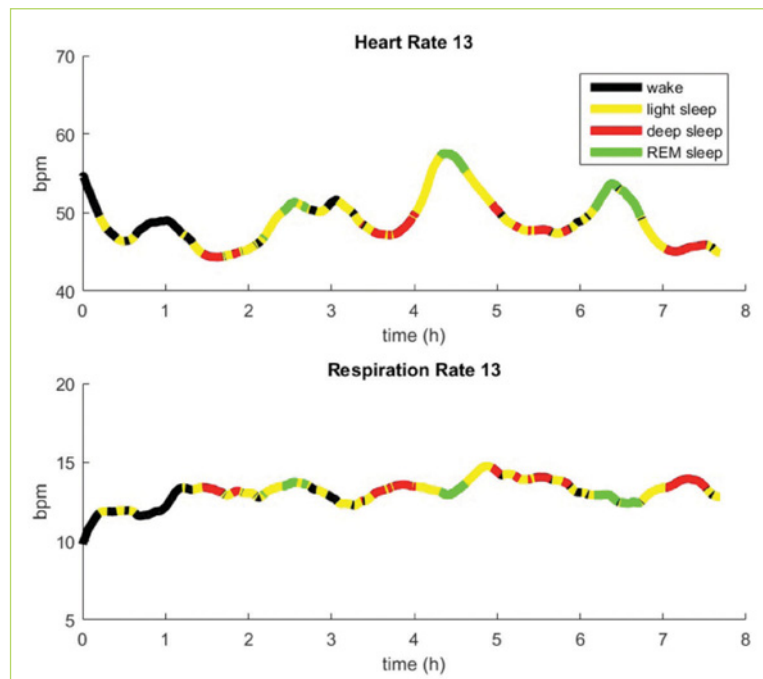
The BCG sensor was also able to record movement of the person during the measurement process, something the PSG approach does only by visual observation. These sleep stages were scored from the recorded PSG data and categorized according to the American Academy of Sleep Medicine (AASM) criteria.

Measuring just 83.7 x 40.7 x 17.6mm, the SCA11H node is housed in an IP55 waterproof plastic enclosure from a nominal 9VDC supply. The firmware can be remotely upgraded over-the-air (OTA). The node can be accessed locally via TCP/IP or it can be configured to send data directly to customer's cloud service.

Figure 4 illustrates the recommended attachment locations for the BCG sensor node. Position 1 is underneath the mattress, perhaps between a mattress and a topper. Position 2 indicates the top part of the bed frame and Position 3 the side of the bed frame.

MEMS Module

The Murata SCA10H accelerometer module contains a single-axis MEMS accelerometer. Communication with the MEMS module is via a standard UART interface. A detailed binary protocol specification document highlights the data and message-frame-formats the module uses for UART communication. Both SCA11H node and SCA10H module are already available. SCA11H is targeted for system manufacturers, whereas the main interest in the SCA10H module product is mainly from various device manufacturers.



The comparative clinical tests between PSG and BCG heart measurement methods concluded that using a BCG-based approach for conducting sleep analysis was an inexpensive and unobtrusive way to measure sleep over multiple nights, which can even be done at home. According to the results, the HR and HRV parameters measured by BCG were accurate and correlated with the PSG data, confirming that Murata's BCG products are reliable enough for sleep analysis. ●

DEALING WITH WIRELESS SENSOR NETWORK CONSTRAINTS

BY **ROSS YU**, PRODUCT MARKETING MANAGER AT DUST NETWORKS PRODUCT GROUP, PART OF LINEAR TECHNOLOGY

One of the biggest promises of the Industrial Internet of Things (IIoT) is to leverage real-world data gathered through wireless sensor networks (WSNs) to drive higher efficiencies and streamline business practices.

The demands on WSNs are diverse, with sensors placed throughout buildings, city streets, industrial plants, tunnels and bridges, moving vehicles or in remote locations, such as along pipelines or at weather stations. A common requirement across such applications for the IIoT is for WSNs to deliver both power economy and wire-like reliability across a broad spectrum of network configurations, sizes and data rates.

Wireless mesh networks have become increasingly popular due to their ability to cover large areas using relatively low-power radios that relay messages from node to node, and maintain high reliability by using alternate pathways and channels to overcome interference.

One technique in particular, called Time Synchronized Channel Hopping (TSCH) mesh networking, pioneered by Linear Technology's Dust Networks and incorporated into the WirelessHART industrial standard, is field-proven to deliver the performance needed by the IIoT. TSCH networks typically experience better than 99.999% data reliability, and all wireless nodes, even routing ones, enjoy multi-year battery life from small lithium batteries. However, many mesh networks use similar sounding networking techniques, such as "frequency agility" vs "channel hopping," "sleepy" vs "time synchronized" meshes, and yet yield drastically different performance levels. These wireless networking

details determine how such protocol level choices greatly impact a WSN's performance and the network's overall suitability for an application.

Wireless Sensor Network Challenges

Since wireless is unreliable by nature, it is important to understand the sources of unreliability to be able to account for them in a communications system. Unlike wired communications – where the signal is shielded from the outside world by cabling – RF propagates in the open air and interacts with the surrounding environment. Thus, there is the possibility for other RF transmission sources to cause active interference.

However, a much more common effect is multipath fading, where the RF message may be attenuated by its own signal reflected from surrounding surfaces along the signal path and arriving out of phase (Figure 1). Mobile phone users experience multipath fading every day when their phones seemingly have poor signal strength in one spot, which improves by moving just a few centimeters. The effects of multipath change over time, as nearby reflective surfaces (e.g., people, cars, doors) move. The net result is that any RF channel will experience significant variation in signal quality over time.

Further adding to the challenge is the fact that multipath fading is unpredictable. By definition, a network must be actively transmitting on a channel to experience – hence measure – the channel's performance in the face of multipath fading. Therefore, while using a simple passive receive signal strength measurement (RSSI) of an unused channel may be helpful to detect active interferers, it cannot predict that channel's suitability in the face of multipath fading.

Fortunately, since multipath fading affects each RF channel differently over time, frequency diversity using channel hopping minimizes the negative effects of multipath fading.

Common Approaches Seen In WSNs

To understand how different WSNs perform in the face of these constraints, let us examine techniques often used in wireless mesh networks to address frequency diversity and conserve low power.

- **Single Channel WSNs and Channel Agility** – A common approach in simple wireless mesh networks is to have all nodes operate on a single channel. Since only one RF channel is used, by definition only one device can transmit at a time. Network stack developers often still choose single-channel operation due to its relative simplicity, resulting in a WSN with no frequency diversity.

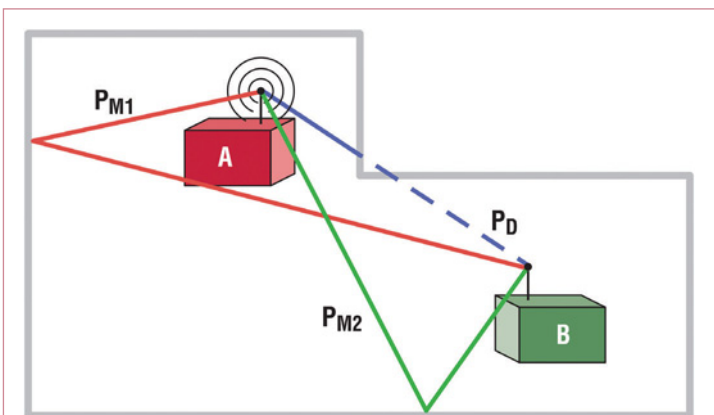


Figure 1: Multipath fading – A radio signal's strength at the receiver (B) is affected not only by the direct path (P_D), but also by reflections (P_{M1} and P_{M2}) which may arrive out of phase and cause significant fading

- **Duty Cycling by Network-Wide Sleeping** – For low-power operation, wireless sensor networks perform some form of duty cycling to minimize the time spent in active operation (e.g. transmit and receive, which typically draw milliamps of power) and maximize the time spent in a low-power sleep mode (typically using 1mA or less). Some networks incorporate a network-wide sleep scheme (sometimes called a “sleepy” mesh), in which all nodes in the network go into a low-power sleep state for an extended period and wake up at approximately the same time to send/receive/forward network traffic. In such sleep schemes, the network is completely unavailable for communications during the inactive period. For example, if a WSN only wakes once an hour for communications, then the network is unable to send an alarm message during that hour, nor can it receive a message from a controller to light up an attached warning indicator. It is also important to consider how the use of network-wide sleep affects the WSN’s ability to cope with real-world operating conditions. During the extended sleep periods, the surrounding RF environment remains dynamic and changing. Any signal pathways that become unusable during network sleep can only be repaired when the

network awakens. Even more troublesome is the fact that sleepy networks tend to be single-channel networks, placing further stress on the network during its active period, increasing the risk of communications instability.

“Since wireless is unreliable by nature, it is important to understand the sources of unreliability to be able to account for them in a communications system”

Another result of using network-wide sleep is that the approach forces a user to settle for a slower data rate than called for by the application. This is an unfortunate trade-off, since the main purpose of a WSN is to convey data reliably and to use that information to enable deeper insight into the user’s systems by showing operational trends and inefficiencies, such as deteriorating performance in aging motors, or increased cyclic power draw of old refrigeration equipment in a retail store.

TSCH Mesh Networks

TSCH mesh networks use tight time-synchronization across a multi-hop network to closely coordinate communications and frequency channel usage. In a TSCH network, each node shares a common sense of time that is accurate across the network to within a few tens of microseconds. Each node exchanges timing offset information with its neighbours to maintain time synchronization.

Network communication is organized into time slots in which individual packet transmit/receive opportunities are scheduled. That is, each time slot is long enough (e.g., 7.5ms) for a transmitting node to wake up, transmit a packet and receive its link-layer acknowledgment from the receiving node.

Network traffic in a TSCH can be dynamically scheduled, which

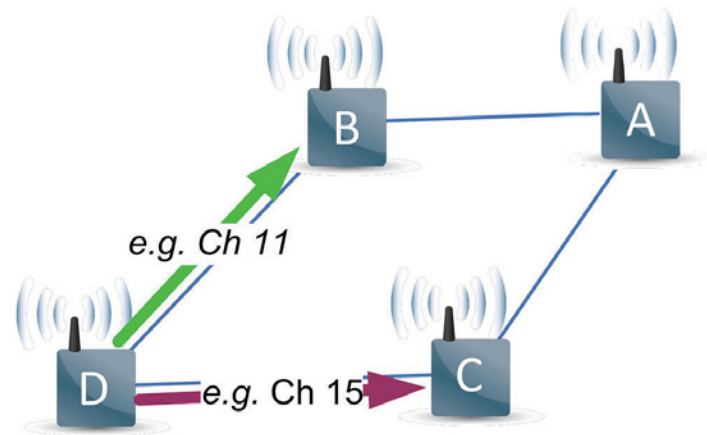


Figure 2: Path and frequency diversity – If communication fails on the green arrow, node D retries on the purple arrow using another channel and pathway

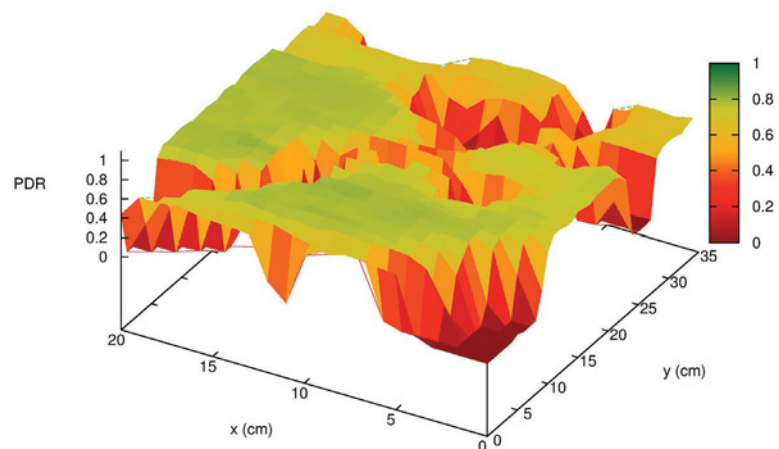


Figure 3: Multipath fading causes the quality of a link to vary dramatically, even when moving the receiver by only a couple of centimeters

enables pair-wise channel hopping, full path and frequency diversity, low-power packet exchange and high-availability duty cycling.

- **Pair-Wise Channel Hopping** – Time synchronization enables channel hopping on every transmitter-receiver pair for frequency diversity. In a TSCH network, every packet-exchange channel hops to avoid inevitable RF interference and fading. In addition, multiple transmissions between different device pairs can occur simultaneously on different channels, increasing network bandwidth. For example, there are fifteen usable channels available in the IEEE 802.15.4 2.4GHz radio specification, a popular choice for WSN implementations due to the global availability of this ISM band. This represents up to fifteen times the available bandwidth

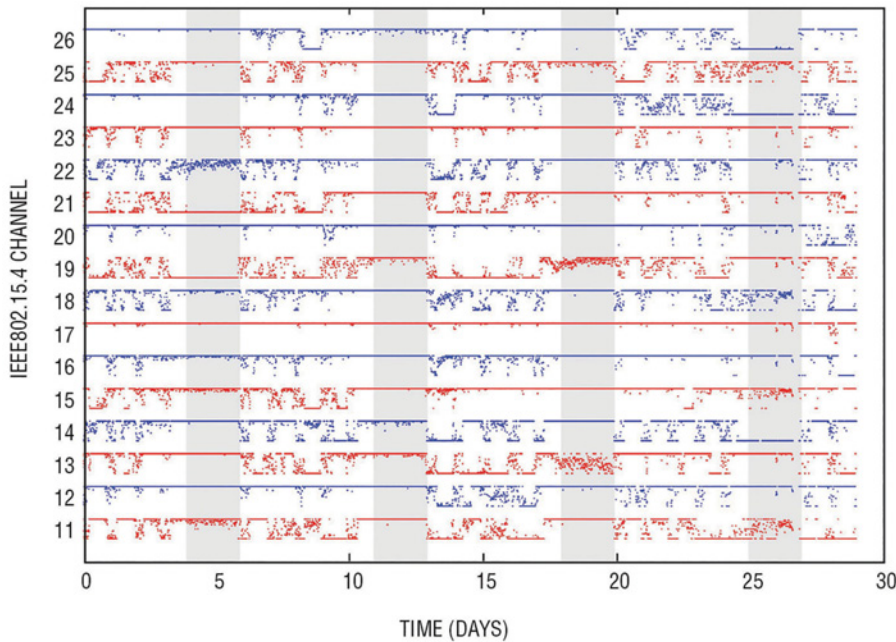


Figure 4: The packet delivery ratio of a wireless link varies over time

for a TSCH network, compared to that of a single-channel 802.15.4 WSN.

- Full Path and Frequency Diversity – Each device has redundant paths to overcome communications interruptions due to interference, physical obstruction or multipath fading. If a packet transmission fails on one path, a mote will automatically retry on the next available path and a different RF channel (see Figure 2). By exercising path diversity and frequency diversity each time (time diversity), the probability of success on each retry is higher than with a single-channel system.

System Approach To Low Power

By taking a somewhat holistic view of how energy is spent in a wireless sensor network, we see that power consumption can be thought of as a function of data traffic, as well as the energy required to send a packet and the number of retries needed to successfully send a packet from one node to another:

$$\text{Average Energy} = f\left(\left(\frac{\text{Num Packets}}{\text{Period of Time}}\right) \times \left(\frac{\text{Energy}}{\text{per Packet}}\right) \times \left(\frac{\text{Num Retries}}{\text{to Successfully Send A Packet}}\right)\right)$$

By focusing on energy per packet and using a networking protocol that exercises time, path, frequency diversity on every retry (thereby reducing the average number of retries required to send a packet), low current consumption can be achieved by improving efficiency throughout the system rather than making sacrifices on the application layer. The communication schedules in a TSCH network are highly configurable, with communications timeslots automatically allocated based on application needs.

A TSCH network can be configured for slow data rates to minimize power required, and potentially enable the use of energy harvesting. That same TSCH network can be configured to support heterogeneous report rates, as is commonly done in industrial plants,

which have slow-changing variables (e.g., tank level) and faster changing variables (flow in a pipe).

A TSCH network will automatically allocate the required timeslots to the portions of a network that need it. Instead of forcing users to tailor their applications to meet the needs of the network, a TSCH network can be tailored to meet the needs of a wide variety of applications.

Multipath Fading Effects

Multipath fading depends on the position and nature of every object in the environment, and is unpredictable in any practical setup. One good property is that the topography depicted in Figure 3 changes with the frequency. That is, if a packet is not received because of multipath fading, retransmitting on a different frequency has a high probability of success.

Because objects in the environment are not static, multipath effect change over time. For example, cars

drive by and doors open and close; Figure 4 shows the packet delivery ratio on a single wireless path between two industrial sensors over 26 days and for each of the 16 channels used by the system. There are weekly cycles where workdays and weekends are clearly visible. At any given time, some channels are good (high delivery), some poor and some highly variable.

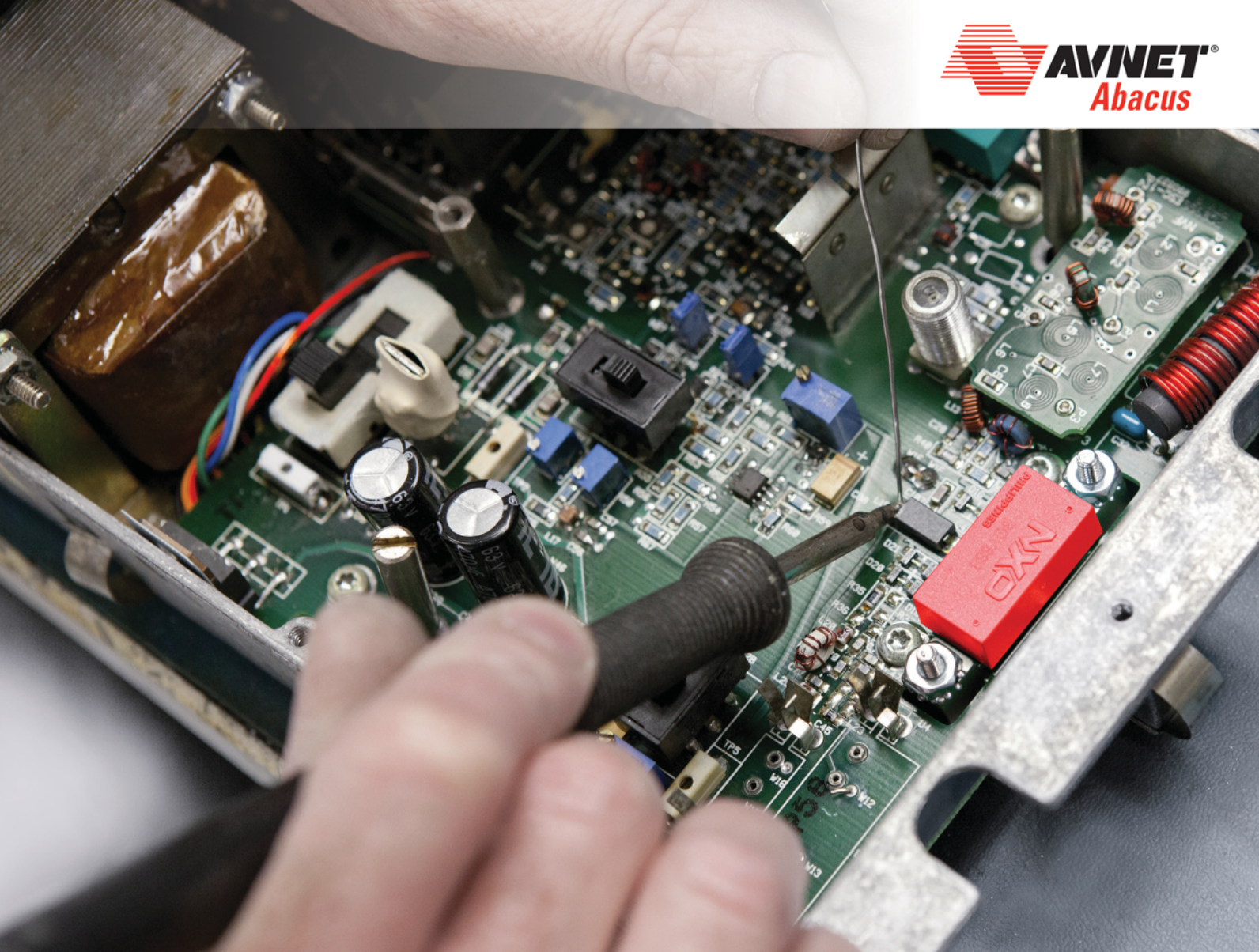
Channel 17, whilst generally good, has at least one period of zero delivery. Each path in the network shows qualitatively similar behaviour, but unique channel performance, and there is never any one channel viable everywhere in the network.

Because of interference and multipath fading, the key to building a reliable wireless system is to exploit both channel and path diversity. ●

TSCH WITH LOW POWER HARDWARE

The operating currents for 802.15.4 transceivers for general operations, such as transmit, receive and sleep have steadily decreased over the past decade. For example, the LTC5800-IPM from Linear Technology draws 9.5mA for +8dBm transmit power and 4.5mA for receive, which is 3-5 times lower than prior generation 802.15.4 transceivers.

Reducing peak current draws is a good start, but the energy required to send a packet is a function of the amount of charge drawn over a period of time. If current draw is measured on an oscilloscope and plotted over time, then the energy required to send a packet is shown as the area under the curve and affected not only by peak currents, but also by the length of each operation. Products such as the LTC5800-IPM deliver precisely optimized packet exchanges with a successful packet transmission/acknowledgement for a mere 54.5µC charge at 3.6V supply voltage (or 196.2µJ of energy).



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THE INTERNET OF THINGS: AN ARCHITECTURAL OVERVIEW

BY **DR DOGAN IBRAHIM** OF THE NEAR EAST UNIVERSITY IN CYPRUS

Internet of Things (IoT) is a new concept in intelligent automation and monitoring using the Internet as a communications medium. The word “things” in IoT usually refers to devices that have unique identifiers, connected to the Internet to exchange information with each other in real time.

Such devices usually have sensors and/or actuators that can be used to collect data about their environments and to monitor and control those environments as required. The collected data can be processed locally or, alternatively, it can be sent to centralized servers or the cloud for remote storage and processing.

IOT Apps

The use of the IoT spans a wide range of applications, including homes, offices, factories, cities, industry, environment,

agriculture, health, retail, transportation and more.

Some home applications include wireless-enabled and Internet-connected smart appliances that can be turned on and off remotely using, say, a mobile phone or a tablet. For example, a small device the size of a matchbox can be used to collect data about temperature, humidity and atmospheric pressure inside the house. This data is then sent and stored remotely in the cloud, so anyone with an app-enabled device can access and monitor it at any time and from anywhere, provided there is Internet connectivity. The user can then remotely adjust the controls for that environment (central heating, lighting etc).

Smart refrigerators can keep track of items stored and place orders automatically through the Internet with little interaction from their owners. Smart televisions can learn their owners’ watching habits and inform them when a show of possible

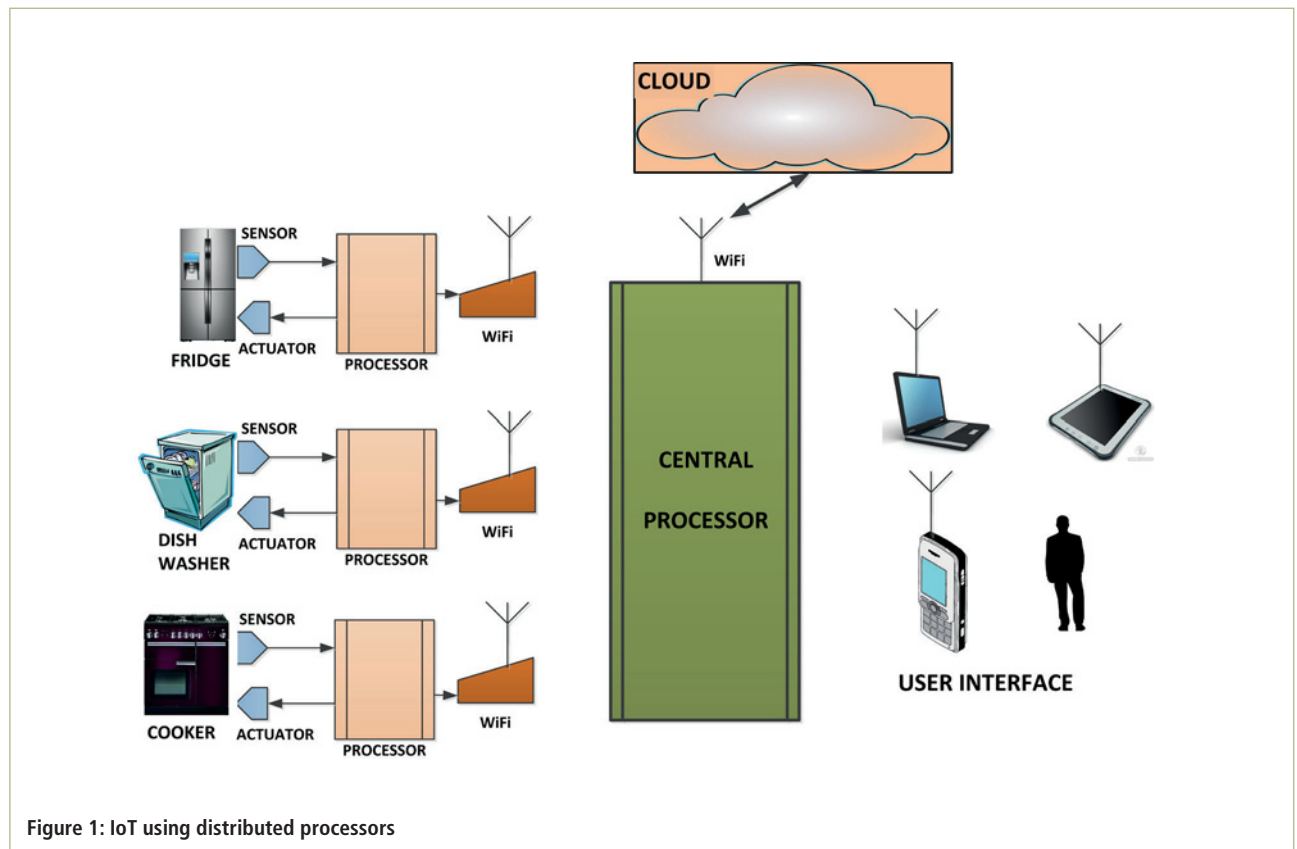


Figure 1: IoT using distributed processors

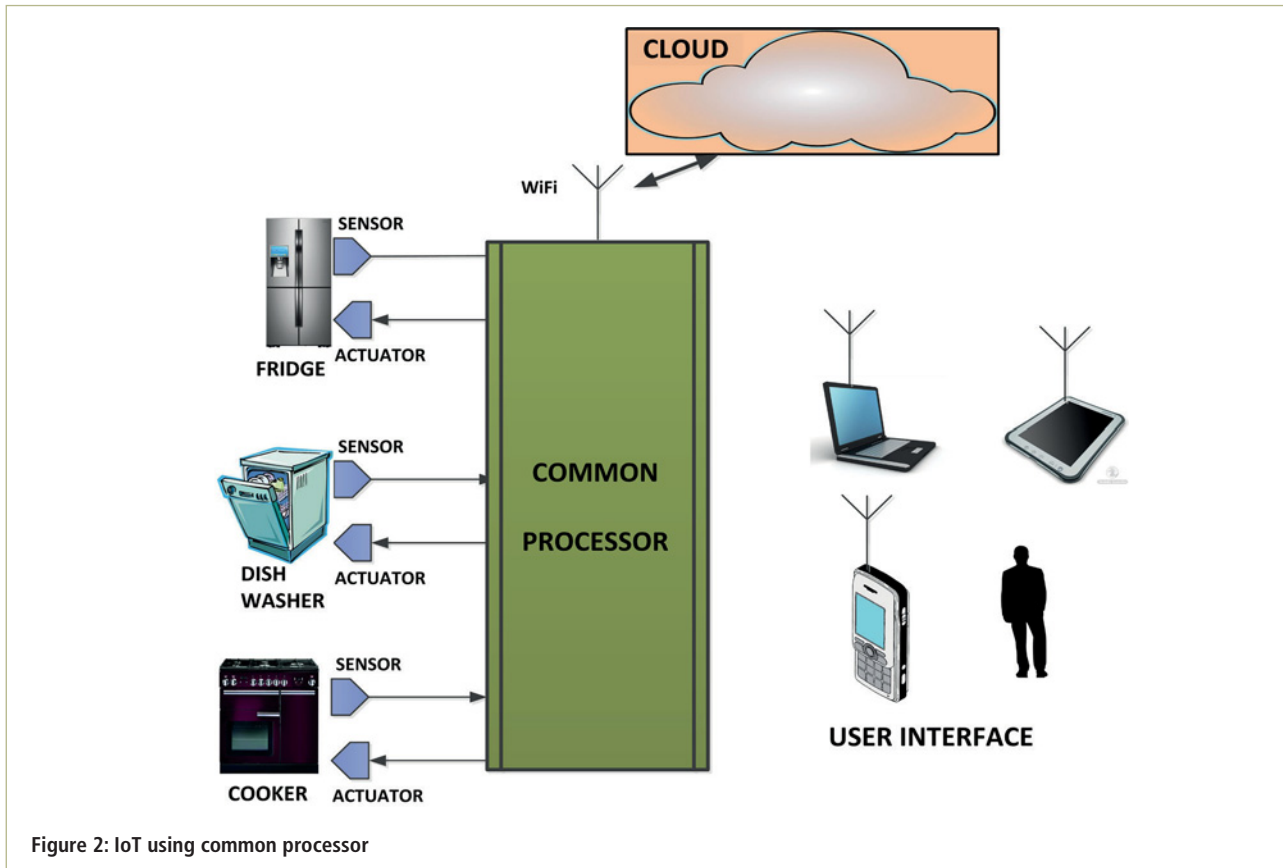


Figure 2: IoT using common processor

interest is on the air. Wireless-enabled burglar alarm systems can be activated automatically to warn home owners of any intrusion. Smart home-lighting systems can turn on and off automatically and can change light intensities to adapt to the environment. For example, the light intensity can be reduced automatically in the day to save energy. Lights can also be controlled automatically by sensing human movements. Smart smoke detectors can raise alarms in a friendly human voice, describing where the problem is and what actions to take.

IOT And The City

There are many applications of the IoT in big cities. For example, smart carparks can recognize drivers looking for a space to park and inform them of availability nearby. Smart roads can send messages of bad weather conditions to drivers via SMS or voice alerts. Details of traffic congestion, accidents and road works can be sent to drivers in real time to make driving safer. Weather conditions can be sensed and the data analyzed, informing the authorities to prepare for possible hazards, such as floods, storms, wind gusts and so on.

Health centres can automatically be informed if a serious condition such as a heart attack is detected, wherever the patient may be

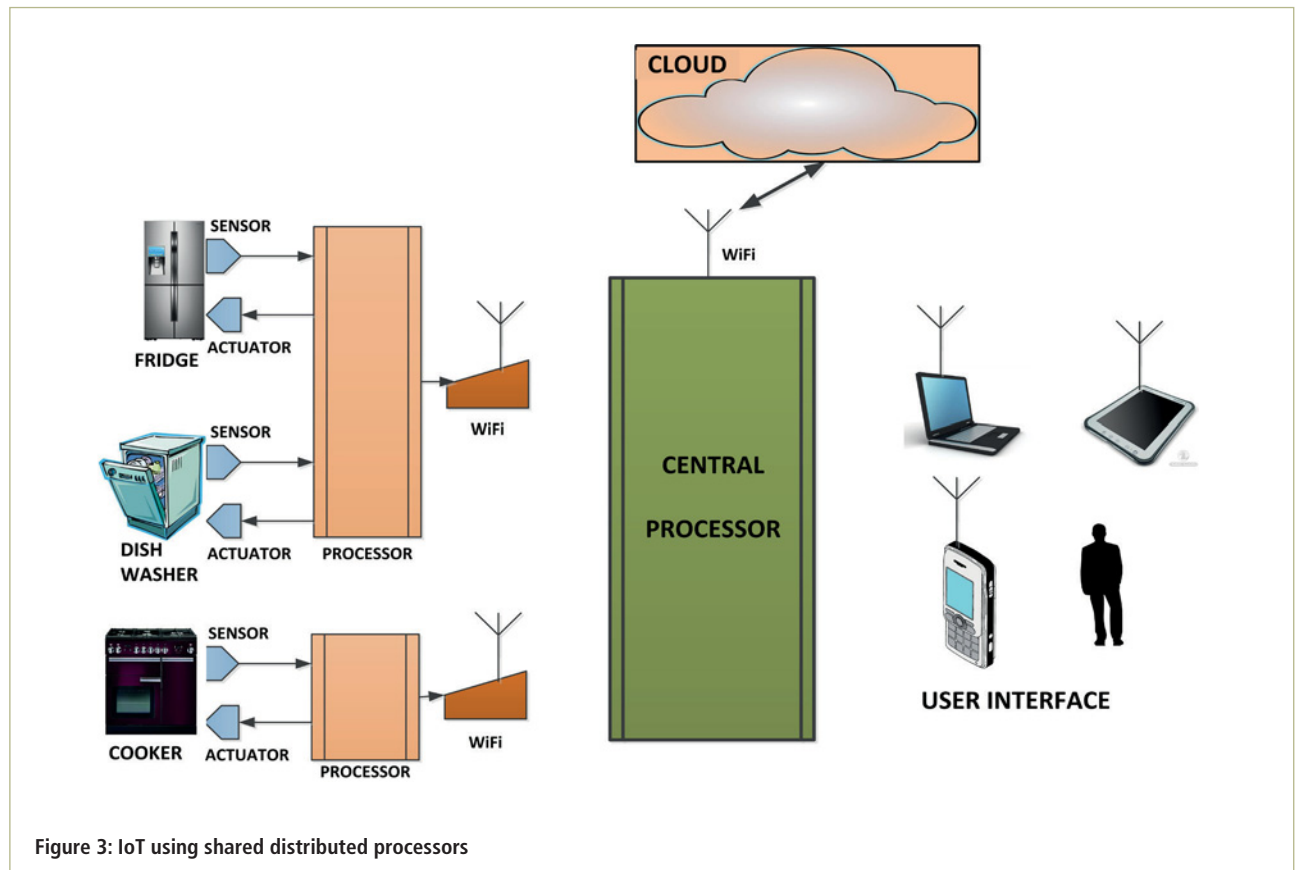
Smart environmental IoT systems can measure pollution levels, dangerous gas leakage and possible water contamination. Data collected by these systems can be analyzed and any life-threatening conditions sent to residents via the Internet so the affected areas can be avoided.

IoT can be used by emergency services to save lives and improve the environment. For example, gas leakage details can be sent automatically to gas service departments to prevent explosions or poisoning. Similarly, water leakage can be detected by sensors and the relevant authorities informed to rectify the problem. Emergency services can be given priority at traffic lights to speed their access. Forest fires can be detected early and appropriate actions taken to avoid large-scale damage to the environment. Similarly, river floods can be detected early and IoT-based flood monitoring systems used to raise alerts when water levels rise sharply.

Widespread IOT

There are also many applications of the IoT in the retail industry. Purchasing habits of users can be stored by systems which then inform them of special offers and discounts nearby.

IoT systems can also be used in vehicles. For example, the state of a vehicle engine can be sent to a maintenance centre by an IoT-based remote vehicle diagnostics application. Owners are then informed of faults in their vehicles at an early stage.



Repair appointments could also be made automatically with the maintenance centres, who may know the availability of the owners and service centres, and also the car's faults.

IoT systems can be used at airports to inform passengers of flight delays. Flight tickets and hotel rooms can be booked by simple voice commands, with payments automatically made from stored credit cards.

IoT systems can be used in healthcare to save lives. For example, wearable IoT devices allow continuous monitoring of health statistics such as blood pressure, ECG, body temperature and so on. Health centres can automatically be informed if a serious condition such as a heart attack is detected, wherever the patient may be.

IoT Architectures

There is no single IoT architecture. The application can use any accessible medium to read the sensors and send control data back to the actuators.

Distributed processors are used when each device has a local processor (e.g. a microcontroller) allocated to it (see Figure 1).

There are several variations of the basic distributed processor architecture. For example, devices may be allowed to communicate with each other to exchange data, or communicate directly with the user. In addition, local processors may be configured to send and receive data directly from the cloud.

An alternative of Figure 1 is that each local processor can communicate with others and/or with the central processor using other communication technologies, such as Bluetooth, ZigBee, RF and RFID.

However, disadvantages include high cost and that each processor requires power that may not be easy or convenient to supply. In addition, system component count is high, resulting in higher failure rates and in that each local processor needs to be programmed. This configuration is suitable if all equipment is placed within a small perimeter. But, the advantage of this architecture is that devices can easily communicate with each other.

Common Processor

In common-processor architecture, sensors and actuators are all connected to a common processor (e.g. a microcontroller) through their input and output ports, so there's no direct communication between items of equipment.

The common processor stores the states of equipment on the cloud using WiFi. Users normally send commands to the cloud when they wish to monitor or control individual equipment, and the common processor normally receives its commands from the cloud and activates the required actuator connected to its output port.

Figure 2 shows an IoT system using a common processor.

This architecture has the advantage of low cost and that the power supply requirement is minimal. In addition, there

	Bluetooth	Wi-Fi	ZigBee	Raw RF (UHF)	Raw RF (VHF)
Range	50-100m	100m	75m	500m	5-10km
Data Rate	24Mbps	54Mbps	250kbps	various	Various
Security	128-bit encryption	various	128-bit encryption	various	Various
Band	2.4GHz	2.4GHz	2.4GHz (+868MHz UK)	433, 866, 915MHz and others	150, 169, 173MHz and others
Power Consumption	High	High	Low	Low - medium	Low-medium

Table 1: Low power radio (LPR) communication technologies

is only one processor to be programmed, lowering the cost as well as the maintenance. Disadvantages include a lot of wiring, especially for wide-spread equipment, and that there is no direct communications link between devices.

Using Shared Distributed Processors

This architecture is similar to the distributed processor architecture but here a number of devices are connected and share a local processor. The advantage of this architecture is mainly its simplicity and low cost.

The number of devices to be connected to a processor depends on the application, the distance between them and the availability of suitable power sources. The disadvantage of this architecture is that the software cost and maintenance are higher since more than

one processor needs to be programmed.

Figure 3 shows an IoT system based on this architecture.

Communication

Communication between IoT devices, local processors and the central processor, between the central processor and the cloud, and between users and the cloud are important parts of any IoT system. Low Power Radio (LPR) products can be used to establish communication in an IoT network.

A developer has a large choice of LPR devices, including Bluetooth enabled, Wi-Fi based, ZigBee based, Raw RF and RFID. The first three use well-known and established protocols, employing high-level encryption algorithms. A brief description and comparison of these methods is given in Table 1. ●

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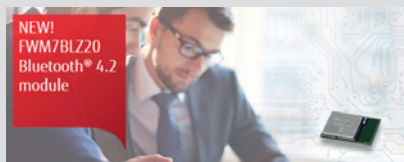
FUJITSU RELEASES THE FWM7BLZ20 SMART MODULE

Fujitsu Components launched the small, high-quality and powerful FWM7BLZ20 series Bluetooth 4.2 low energy module.

The FWM7BLZ20 is based on the Nordic Semiconductor's Bluetooth v4.2 SoC, which comes with integrated antenna and is certified. Compared to other Fujitsu modules, it achieves half of the power consumption (5.4mA actual measured value) and double the transmission distance at a receiving sensitivity of -94dBm (actual measured value).

The embedded nRF52832 QFN-package SoC has been designed around a 32-bit ARM Cortex-M4F CPU with 512kB flash and 64kB RAM. Its size is just 15.7 x 9.8 x 1.7mm, same as the MBH7BLZ02-series, with integrated 32MHz and 32.768kHz crystal oscillators required for low power and great accuracy.

www.fujitsu.com/uk/components

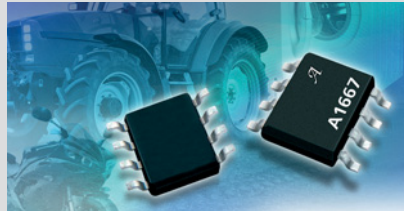


THREE-WIRE TRUE ZERO-SPEED MAGNETIC SPEED SENSOR IC

In response to requests for a PCB-mounted speed sensor IC featuring an advanced sensing algorithm, Allegro MicroSystems has released the A1667 in a surface-mount SOIC-8 package. The device provides a user-friendly solution for highly compact ring magnet applications using PCB mounting, ideal for applications such as automotive transmissions and industrial equipment.

The A1667 incorporates a dual-element Hall IC that switches in response to differential magnetic signals created by a ring magnet. The IC contains a sophisticated compensating circuit designed to eliminate the detrimental effects of magnet and system offsets. Digital processing of the analogue signal provides zero-speed performance independent of air gap, as well as dynamic adaptation of device performance to the typical operating conditions found in automotive applications, including reduced vibration sensitivity. The open-drain output is configured for three-wire applications.

www.allegromicro.com



CONGATEC INTRODUCES HIGHLY FLEXIBLE IOT GATEWAY SYSTEM

congatec has introduced its flexible IoT gateway solution. This new, highly flexible IoT gateway system is application ready and easily customizable for rapid field deployment.

The congatec IoT gateway offers extreme levels of flexibility in terms of processing performance and software integration, able to host up to eight wireless antennas that can be connected to three mini PCI Express slots and six internal USB-based slots for wireless and wired connectivity modules. Customized system designs are also available on request.

OEMs utilizing the conga IoT gateway system benefit from a pre-configured, pre-certified IoT gateway that can easily connect a wide range of heterogeneous sensors and systems to cloud-based services. Target uses include Industrial Internet of Things (IIoT) applications such as smart cities, smart agriculture, connected homes and vehicles, and others.

www.congatec.com



NORTHERN MANUFACTURING & ELECTRONICS BRINGS ENGINEERS TO MANCHESTER

The Northern Manufacturing & Electronics Show returns to Manchester's EventCity on September 28th and 29th.

The number and variety of vendors participating gives the show a tremendously wide appeal; this includes PCB makers, component distributors, enclosure specialists, CEMS, test equipment manufacturers, designers and even industrial finance specialists amidst others. Among the electronics component vendors for 2016 are Easby Electronics, Fischer Connectors, Lemo UK and Variohm Eurosensor. Alongside the electronic parts suppliers, there's a wide variety of mechanical component suppliers, such as Lee Spring and Rencol Components, and

manufacturers of labels and nameplates, such as Mockridge, The London Nameplate Company and GSM Graphic Arts.

Among the many other parts and components represented are enclosures from Phoenix Mecano, motor controllers from Zikodrive Motor Controllers and specialist foam materials from MSA Foams.

Northern Manufacturing is also a vital marketplace for the electronics industry's subcontract services. Assembly and PCB manufacture are well represented, with firms such as LCL Electronics, European Circuits, Datalink Electronics, Cornelius Electronics and JJS Manufacturing among others. All of the exhibitors

can be found at www.industrynorth.co.uk.

Over the two days of the show, there is also a free seminar programme, designed to attract a wide variety of industrial professionals from all sections of manufacturing, engineering design and production. Alistair Williamson returns with his popular session looking at the innovation process, from identifying an opening, feasibility studies, brand strategy and market research through to successful prototyping and design for trouble-free manufacturing.

The event's location is close to the heart of Manchester, and allows for easy access by public transport, plus 3,000 free car-parking spaces. www.industry.co.uk



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Geyer Electronic eK was founded in 1964, selling electronic components from a small office in central Munich. 50 years on and Geyer is now well known as a manufacturer and supplier of high quality Frequency Control Products for the Automotive, Telecom, Medical and Security, Consumer/Multimedia and Industrial Electronics. With an international network of Sales Offices and distributors, factories in Taiwan, Japan and S Korean, and a Design and Test Center at its Headquarters in Germany, Geyer Electronic is able to offer dedicated support to their clients from design stage, through to volume production, manufacturing around 75 million parts per month to ISO9001, ISO 14001 and TS15949/AEC-Q200 standards

Geyer eK moved to their Headquarters in Gräfelfing, in the west of Munich, in 2002 where they were able to benefit from the access offered by the Autobahn routes, and opened a Design and Test Center in 2011 to develop the crystal products and to work with clients on custom-designed solutions for their applications. Since that time, the Design Center has been expanded and now offers a comprehensive consultation service from our team of five Application Engineers, providing design validation, custom samples and prototype devices, and 3D models of our components to help customers' engineers during

the design stages. We also offer the unique Y-Quartz App to help Design Engineers select the optimum crystal specifications to work in their system, supported by advice from our Application Engineers if requested.

Geyer Electronic UK Ltd, based at their office in Romsey Hampshire, supports customers in the UK and Ireland by working closely with their R&D teams, using the Munich sales support and Design Centre to help identify the optimum crystal, oscillator, SAW filter or resonator for their projects and supplying samples for evaluation and prototype builds.

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Electroquartz

Euroquartz is the sole remaining UK quartz crystal manufacturer of high specification HC49U, UM1 and UM5 crystals, as well as a range of military clock oscillators and crystal filters.

Manufacturing, engineering and sales are situated in a custom-built modern facility in Crewkerne, Somerset, UK from where a comprehensive range of frequency control products is also offered. The recently upgraded facility enables Euroquartz to perform full military screening tests and qualification testing on all other products in the company's portfolio.

The test capabilities of the facility include accurate frequency measurement, temperature cycling, acceleration testing, gross leak, fine leak, filter characteristic testing as well as active burn-in routines. Custom crystal selection testing is also offered from the Euroquartz test facility.

Founded in 1982, the company has a wealth of experience and technical knowledge making it a leading specialist in the field of frequency products. Customer service and quality are the main driving forces behind the business, a fact clearly demonstrated by the company's AS9100 quality

certification awarded in 2015.

As a long-standing and well respected manufacturer in its own right, Euroquartz has access to many very specialised sources of supply that are not available from many of their competitors.

Euroquartz is a privately owned British-company providing a flexible and quality service unrivalled in the frequency control field.

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In the UK, ODU is probably best known for its miniature military push-pull connectors.

Notably, since 2002, ODU has supplied more than 100,000 helmet connectors for use on the UK Bowman military communications programme, without a single reported connector failure.

The AMC (Advanced Military Connector) series was originally developed to meet the ever-demanding needs of the many international 'Future Soldier' programmes, intended to equip the average ground-based combat soldier with an integrated set of high-technology systems, linked to an array of battlefield information resources.

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ODU will be at several exhibitions this year so, if you are faced with a connector or packaging problem, then why not come and talk to its representatives, or get in touch now:

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With an optimistic view on the flash market and as a response to the changes in the memory industry, Apacer developed its industrial memory line in the early years of 2000.

Today, Apacer offers a large portfolio of innovative Solid State Drive Solutions (SATA, PATA, Flash Cards and USB) and DRAM Solutions (desktop, notebook and server) for the industrial and embedded markets. More recently, Apacer developed a range of data security technologies by launching data security enhanced products and unique value added features.

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