February 2018
Volume 124
Issue 1979
£5.90

www.electronicsworld.co.uk

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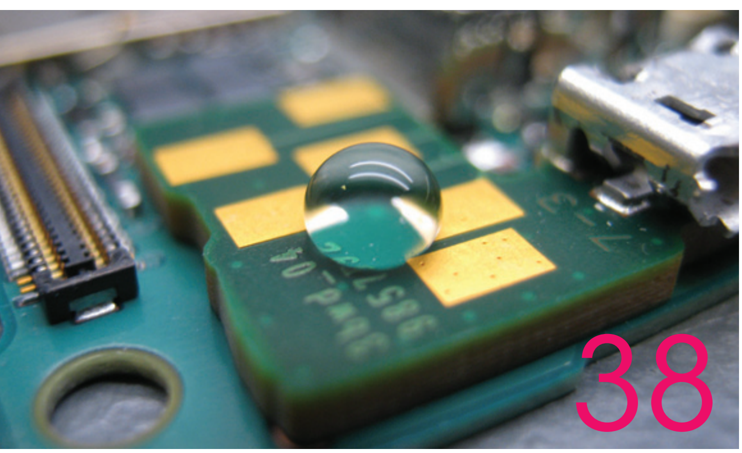

5G IS SET TO DISRUPT TEST PROCESSES

The 5G technology signifies a generational transformation that will impact the world, promising faster data rates, shorter network response times and capacity for even more devices. Unlike 4G, 5G will expand beyond our mobile devices and into all facets of our lives, enabling many of the trends discussed here.

5G features technologies such as massive MIMO and mmWave that use multiple antennas and beamforming are a huge departure on previous wireless architectures. The standards are far more complex too. Test and measurement solutions are the key to commercialisation, but test systems must expand beyond the physical layer to efficiently test these new, multi-antenna technologies.

Three Mandates

These days it's relatively straightforward to extract business benefits from small-scale Industrial Internet of Things (IIoT) pilot projects for predictive maintenance and connected smart-machine control. Attention is now shifting toward the next challenge: scaling to large IIoT deployments. Companies wishing to reap the benefits of IIoT need to take three actions:

1) Implement a reliable remote-systems management solution that can address provisioning, configuration, diagnostics and edge-device administration;
2) Simplify software management to ensure that assets run the latest software to increase performance, security and reliability and help integrate systems from multiple vendors;
3) Introduce a comprehensive data management infrastructure to handle the terabytes of data generated by IIoT systems.

We're seeing a shift, as best-in-class companies look more toward the management of their distributed systems, and avoid the risk of late adopters who can lose market share and incur unnecessary costs.

Breaking Moore's Law

Semiconductor processing has stayed close to Moore's observation for decades, but this "free" scaling is becoming harder to achieve. Engineers have a history of overcoming scaling hurdles, and some proposed alternatives to pure semiconductor scaling paint an interesting future.

The evolution of FPGAs, from a simple array of logic gates to high-performance systems with processors, DSPs, memory and data interfaces on a single chip, demonstrates this. The key to creating mixed-processing architectures is flexible software tools that help users design devices that leverage diverse computing elements.

> "Test systems must expand beyond the physical layer to efficiently test these new multi-antenna technologies

Disrupting The Automotive Industry and Beyond

Regulations limiting combustion engines are now in place around the world, so the growth of electric vehicles is vital.

But it isn't only the engine that is being electrified, it applies just as significantly to vehicle subsystems. Now, engineers need to understand the broader impact of electric vehicles on the energy grid to make them viable.

The automotive industry has an important stake in the future of the grid, which in turn will require smarter control systems. Getting to market quickly will require an increased reliance on real-time production tests, but also on ecosystem partners who can quickly build tools that become part of an industry-leading, flexible and open platform.

Automated Engineering Insights With Machine Learning

The growth of intelligent nodes across manufacturing and test systems is providing essential data to build better products and make better decisions. Many manufacturing companies have databases of maintenance and operational data for their industrial assets that contain huge amount of data and exacerbate the Big Analog Data challenge.

Today, engineers manually work with this data, but future machine-learning algorithms will process it to detect anomalies and alert maintenance personnel for troubleshooting. This analysis can then be done at the edge too, speeding up critical decisions. This will advance the tools on the market as machine learning is incorporated into the Cloud, providing engineers with pre-curated technology.

These trends are happening now, and the engineers who are aware and adopt the new technologies and processes will be the ones designing our future. ●

By Charlotte Nicolaou, Software Marketing Engineer at National Instruments (www.ni.com)

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DESIGN: **Tania King**

PUBLISHER: Wayne Darroch

ISSN: 1365-4675

PRINTER: Buxton Press Ltd

SJP business media

2nd Floor,
52-54 Gracechurch Street,
London, EC3V 0EH

SUBSCRIPTIONS:
Subscription rates:
UK - 1 year digital only £53.00+VAT
UK - 1 year print and digital sub £68.00
UK - 2 year print and digital sub £109.00
UK - 3 year print and digital sub £143.00
International - 1 year digital only £53.00
International - 1 year print and digital sub £164.00
International - 2 year print and digital sub £290.00
International - 3 year print and digital sub £409.00
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'TWISTED' LIGHT COULD MAKE FIBRE-OPTICS OBSOLETE IN WIRELESS COMMUNICATIONS

Scientists have taken a major step toward using 'twisted' light as a form of wireless, high-capacity data transmission that could make fibre optics obsolete.

An international team of physicists 'twisted' photons by passing them through a type of hologram, a process known as optical angular momentum (OAM). While conventional digital communications use photons as ones and zeros to carry information, the large number of intertwined twists in the photons allows them to carry additional data, akin to adding letters alongside the ones and zeros. Carrying additional information means that optical angular momentum has the potential to create much higher-bandwidth communications technology.

OAM techniques have already been used to transmit data over cables, but transmitting twisted light across open spaces has proven a lot more challenging. For example, even the smallest change in atmospheric pressure across open spaces can scatter light beams and cause the spin information to be lost.

The researchers tested the effects on both phase and intensity of OAM carrying light over a real link in an urban environment to assess the viability of these modes of quantum information transfer. The link was built in Erlangen, Germany, 1.6km in length, passing over fields and streets and close to high-rise buildings to accurately represent an urban environment and atmospheric turbulence that could potentially disrupt information transfer. The tests uncovered challenges that will need to be addressed to create commercial setups.

"A complete, working optical angular momentum communications system capable of transmitting data wirelessly across free space has the potential to transform online access for developing countries, defence systems and cities around the world. This is a solution that can potentially give us the bandwidth of fibre, but without the requirement for physical cabling," said Dr Martin Lavery, head of the Structured Photonics Research Group at University of Glasgow.

"Our study takes vital steps forward in the journey towards high-dimensional free-space optics as a cheaper, more accessible alternative to buried fibre optics connections," he added.

MICROPHONES EMBEDDED INTO HELMETS WILL HELP SOLDERS IN THE FIELD

A joint project between Nottingham Trent University and the Advanced Textiles Research Group (ATRG) of the School of Art & Design is developing new technology to measure and record the levels of noise soldiers experience in the field, to prevent hearing damage.

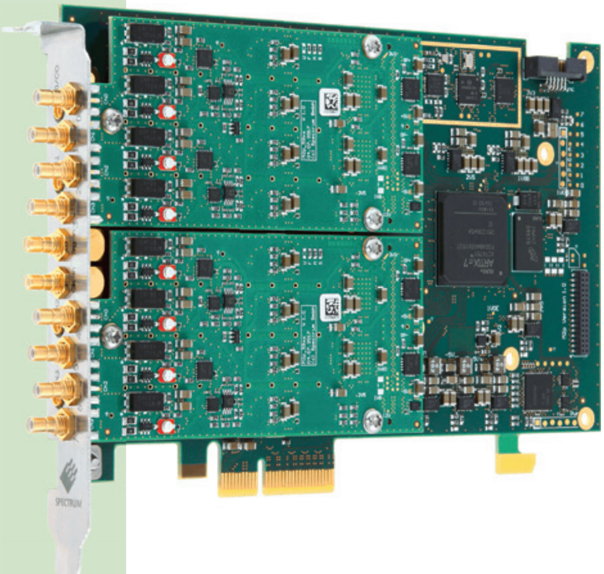
Tiny microphones, almost invisible to the naked eye, are knitted into the fabric-covering army helmets to reduce the risk of soldiers developing hearing injuries. Professor Tilak Dias and research fellow Dr Theodore Hughes-Riley (pictured) are using microelectromechanical system microphones (MEMS) to measure the level of noise the wearer is exposed to over time.

"By integrating a low-cost and discrete dosemeter directly into a textile such as a helmet cover, the noise exposure of personnel will be monitored and stored, providing the data necessary to take preventative action in the future," said Professor Dias.

A microphone will be positioned above each ear, which is vital since acoustic injury is more likely to be asymmetric, with one ear affected more than the other.

Even short exposure to sound levels exceeding 140dB can cause permanent hearing damage; a single gunshot produces sound in the range of 140-170dB.

"Hearing loss affects speech comprehension and the individual's ability to communicate with others, impairing their quality of life, so it's important that soldiers are given the best protection possible to prevent them from experiencing noise levels that can cause injury."



Introduction to modular waveform digitizers

BY **OLIVER ROVINI** AND **GREG TATE**, SPECTRUM INSTRUMENTATION

A digitizer is an electronic device that acquires analogue waveforms, processes them through analogue-to-digital converters (ADCs) and sends the digitized samples to a buffer or storage before being processed by a computer.

Modern digitizers date from the 1950s and 60s, when the need to rapidly acquire, store and process multiple channels of data first arose. Most early digitizers were built on NIM (Nuclear Instrumentation Module) or CAMAC (Computer Automated Measurement And Control) interfaces, which are bus and modular crate standards for data acquisition and control used in nuclear and particle physics experiments.

The creation of a standard instrument interface bus (GPIB/IEEE 488) in the 1970s laid the foundation for multi-instrument test and measurement systems. Concurrently, the development of personal computers (PCs) led to many standard computer interfaces such as PCI (Peripheral Component Interconnect) and VMEbus (Versa Modular Eurocard bus), providing a standard interface to interconnect peripheral devices with a PC. These computer buses were adapted to support modular instruments through interface buses such as PXI (PCI eXtensions for Instrumentation) and VXI (VME eXtensions for Instrumentation). The increasing need to reduce test time and boost data throughput resulted in the development of the LXI (LAN eXtensions for Instrumentation) standard for test system integration.

Today's modular digitizers share a common historical architecture, augmented by new, high-speed, serial-interface standards such as PCI Express (PCIe).

Choosing Your Digitizer

Selecting a digitizer requires matching application needs to the digitizer specifications. Here are some common rules of thumb to aid the selection:

Bandwidth

The required bandwidth of a digitizer depends on the nature of the waveforms measured. For sine waves, a bandwidth of greater than twice the maximum frequency is generally adequate. If the waveform is pulse-like with fast transitions, it is preferable to use a bandwidth that is five times the frequency of the pulse waveform to capture up to the fifth harmonic; see Figure 1.

Sample rate

The sampling theorem states that, to avoid aliasing, the sample rate of a digitizer needs to be at least twice the highest-frequency component in the signal being acquired, although this may not be enough to accurately reproduce fast edges in time-domain signals. Accurate digitizing of a signal requires the digitizer sample rate to be at least three to four times the required bandwidth.

Resolution and dynamic range

Resolution determines the dynamic range of the digitizer, which is the ratio of highest to lowest signal level a digitizer can handle. Applications that involve dynamic signals (signals with both large and small voltage components) need a high-resolution instrument. As a first order estimate of the required dynamic range, divide the highest signal level by the smallest signal level that is expected. As an example, consider a full-scale range of 1V and the desired minimum detectable signal level of 100uV. The ratio is 10,000:1, or 80dB. With 6dB per bit, this requires 13.3 bits of resolution in an ideal case with no additive noise, so a 14-bit digitizer would be required.

Resolution/sample rate is an area of major engineering tradeoffs. Resolution comes at the price of lower maximum sample rate. It is possible to increase the maximum sample rate by interleaving multiple ADCs, but this usually results in a decreased effective number of bits (ENOB) because of noise from the imperfect matching of gains, offsets and linearities. When comparing digitizer resolution and maximum sample rate make sure you know if the digitizers use single or multiple interleaved ADCs.

Acquisition memory length

Acquisition memory length determines the longest record length a digitizer can accommodate in a single acquisition; it also affects the sample rate on any given record duration. Record length is equal to the sample period multiplied by the acquisition memory length. For a given digitizer record length, the greater the memory length, the higher the sample rate that can be used without overflowing the memory.

Triggering

Triggers synchronize data acquisition with external events. Effective use of a digitizer requires great flexibility in device triggering. Simple edge triggers based on the slope and signal level are standard on most digitizers; many offer window-triggering, as well.

Trigger sources include the acquisition channels and multiple external trigger inputs. For maximum trigger flexibility, these inputs, along with a re-arm capability, can be combined logically to produce advanced trigger states.

Number of channels and synchronization

Each modular digitizer has a specific number of channels per card, so using multiple cards can increase the total number of channels. To maintain synchronization, multiple cards need to be synchronized, so that they share common triggers and a common clock.

Acquisition modes

Digitizers generally offer several different acquisition modes, such as ring buffer mode (like oscilloscope operation), FIFO or streaming mode, multiple recording (segment mode), gated sampling and a multiple time base (ABA mode), which combines slow continuous recording with fast acquisition on trigger events. These multiple acquisition modes feature a fast re-arm time – as short as 40 sample periods (i.e. 80ns at 500MS/s).

Form factor

Modern digitizers come in many form factors and standards, of which most popular is PCIe, typically used when size is critical. When building large automated testing systems with several different test instruments, choosing a common form-factor generally makes the integration easier.

Drivers And Software

The digitizers typically include drivers for Windows (XP, Vista, Windows 7 and Windows 8, 32-bit and 64-bit respectively) and Linux, along with programming examples and drivers for third-party software like LabVIEW or MATLAB.

While most digitizers are controlled by user-written software, it is very important to have a manufacturer-supplied software tool for direct control of the hardware for system integration and hardware verification.

Digitizers Versus Digital Oscilloscopes

Digitizers share many attributes with digital oscilloscopes, so it’s logical to ask: “Which instrument is best suited to my measurement application?” There are five main questions to ask when deciding which one to choose:

1. Will you be troubleshooting a circuit, device or process, or making measurements that may require analysis and processing?

The digitizer is the best tool for measuring, analysing or processing data. The intimate tie-in of digitizer and computer makes them instruments of choice where a large amount of data is to be processed. On the other hand, troubleshooting requires the interactive viewing capability of an oscilloscope.

2. Do you need multiple channels in a small form-factor, with minimal power?

This is the modern modular digitizer’s forte, where multiple channels per card and multiple cards per system are all fully synchronized. Modular platforms can extend the number of analogue or digital channels, and analogue and pattern waveform generation capabilities.

3. Do you need high measurement throughput?

This is another area where modular digitizers excel. Multi-lane PCIe-based modular digitizers can stream data at speeds up to 3.4GB/s, allowing easy and fast processing within the computer.

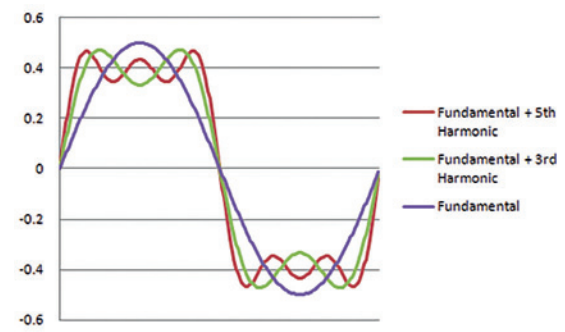
4. Will the data acquired be processed by either commercial or custom analysis software?

The high throughput and large buffer memories make digitizers a great resource for integrating a measurement system with processing software.

5. Do you need low cost of ownership?

Digitizers offer the lowest cost per acquisition channel, with ease of use, speed of integration and reliability. ●

Figure 1: The fifth harmonic is required to approximate a square wave



FREE BOOKS

This article is adapted from *“The Digitizer Handbook – Precision and Performance in PC Instrumentation”* by Spectrum Instrumentation.

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Get nPB out of your workplace

BY **MIKE JONES**, VICE PRESIDENT, MICROCARE

Cleaning is critical for PCB makers, as smaller, more densely populated circuit boards become the norm in electronics. Better cleaning enables engineers to specify stronger, more active fluxes, resulting in improved solder joints. Inadequate soldering causes a huge percentage of PCB failures, so using good fluxes and then cleaning them properly is a shortcut to success.

Each new product generation must outperform its predecessors, and as PCB size continues to decrease while power, functionality and heat output increase, the need for better cleaning rises.

Normal Propyl Bromide

A particle's size can govern just how tough it is to remove, so a choice of chemistry that covers all bases should be adopted. Before using new cleaning methods, thorough testing should be undertaken to assure consistent and cost-effective cleaning, as well as eliminating the risk of surprises during conversion.

Normal propyl bromide (nPB) is a great defluxer and makes better, stronger, more reliable PCBs. Originally, the toxicity level for nPB (also known as "TLV", "AEL" or "PEL") was set at 100 parts-per-million (ppm), safely used in aerosols. Many used it for benchtop cleaning during rework and repair, and even more for spray-degreasing precision parts.

However, recent health studies have found that nPB damages the nervous system, alters human DNA, impairs fertility and can cause cancer. Based on these reports, the European Chemicals Agency (ECHA) listed nPB as a "Substance of Very High Concern" in December 2012. In July 2017, the Ontario, Canada, Ministry of Labour enacted new worker-safety rules that restrict the use of this widely-used chemical.

Other governmental agencies across the world have followed suit: in the US several government agencies recommended 10ppm as nPB exposure limit, with California going a step further and adopting a 5ppm limit. An independent safety agency, the American Conference of Governmental Industrial Hygienists (ACGIH), lowered their recommended exposure rating to just 0.1ppm. But at these exposure levels, there is no way to safely use nPB in an aerosol package.

In an odd legal loophole, the chemical can still be packaged into an aerosol. This means many people may still be buying nPB aerosols without being aware of the risks. Because of its toxicity and impending regulatory restrictions, it's important to find an alternative.

Safer Products

When selecting a new cleaning fluid, it is important to identify a formulation that best suits the application. For example, cleaning lead-free fluxes from PCBs is different from cleaning hydraulic fluid from components or precision cleaning of micromechanical parts.

Companies are introducing non-toxic, environmentally-acceptable cleaning options that outperform older fluids. Modern, non-flammable solvent cleaning can make a substantial contribution to the performance, reliability and longevity of electronic devices.

There are now products that have the desired chemical traits, including low surface tension and viscosity and high Kb values (Kauri-butanol value is an international standardised measure of solvent power for a hydrocarbon solvent, governed by an ASTM standardised test, ASTM D1133). These characteristics allow effective defluxing of PCBs, even under tight-standoff components, and ensure that all finished-product surfaces are effectively cleaned, with no residues.

Newest are HFO solvents, which are based on hydrofluoro-olefin (HFO) technology, available from several providers. They clean very well, are safe, with exceptional environmental characteristics.

Not only do these new products work better, but they stand up to the evolving regulatory requirements imposed by governing bodies around the world. Formulations are now cleaner, greener and safer.

New advances in solvent technology mean not only impressive cleaning results but better economics, too. These solutions offer a new answer for design engineers in the electronics industry, enabling critical cleaning process that ensure that PCB contamination does not cause failures.

The future for cleaning chemistries containing nPB is no longer in doubt: It's time to change. It is important to act now – so, do your research and find suitable alternatives. ●

There's a whole catalogue of newer, safer and highly affordable cleaners that can replace nPBaning

Replacements for nPB in aerosol packages should be non-flammable, fast-drying and affordable, and deliver near-same level of cleaning

High-pressure aerosols are messy and expensive, and expose workers to fumes and overspray

On the vampire hunt

BY **LUCIO DI JASIO**, MICROCHIP TECHNOLOGY

In my youth, in my hometown in Italy, the first of November was a day dedicated to remembering the dead and, aside from the fact that it was a school holiday, it was not a happy time. There was a mandatory mass and a lengthier-than-usual sermon.

On the other hand, Halloween was a more mysterious festivity that I heard about from US movies, even though no one at home knew anything about it.

That was a long time ago, and the tradition of Halloween – or at least the commercial aspect of it – appears to have spread across the entire western world and now includes my family, too. For my son, October 31st is a festivity like Carnival used to be for me, and 'trick-or-treating' is a 'verb' he knows how to conjugate in three different languages.

For the last couple of years, on the eve of the 31st of October, I have been on duty following my son dressed as a vampire and a wild gang of his friends as they went knocking on each door in the neighbourhood. This year I was determined to 'geek' up the Halloween experience and create a portable *Vampire Detector*!

Let me explain...

Vampire Sensors

It so happens that recently I have been working with several different sensors and interfacing them (using a variety of peripherals) to an Xpress evaluation board. A little 8-bit microcontroller converted the various physical quantities (pressure, distance, humidity, temperature, light and so on) into ones and zeros, pushed those bits up a serial stream to a USB port of my Mac (or PC), which I then graphed out 'live' on screen with a simple (portable) Python script; see Figure 1.

As you might have guessed, I used some of the MikroElektronika 350 (plus) sensors that come conveniently pre-arranged on tiny (Click) boards.

I had picked out a dozen, almost at random, from the online catalogue but, since I used extensively the MPLAB Code Configurator (MCC), the exercise turned out to be so quick that I ploughed through them all in one weekend.

Coming from different vendors, each sensor presented a somewhat unique challenge, yet the code was easy to adapt for each case with only a few lines of C code on top of the templated peripheral drivers produced by MCC.

Remote Temperature Sensing

Among the little batch, an inexpensive infrared (IR) thermometer, based on the MLX90614 sensor (Figure 2), was the most pleasing to work with. Despite the minimalistic look, it comes in an unassuming four-terminal metal package (reminding me of the ancient transistors) with an integrated thermopile sensing element, a high-resolution ADC and a digital signal processor. This makes it capable of reading the temperature of a remote object without contact, converting it to a calibrated 16-bit digital value and presenting it in a register accessible on the System Management Bus (SMBus).

In fact, the IR thermometer contains two sensing elements, one detecting the temperature of an object in front of its small window, and a second sensing the temperature of the environment (or rather the case) of the device.

From an interface point of view, accessing the SMBus to retrieve the two measured values is a piece of cake; the protocol is built on top of good old I2C bus. Given the (7-bit) device address (0x5A), you select a register by writing its number (a single byte) to the device first. Any following reading operation from the device will return the unsigned (16-bit) value representing the (absolute) temperature in degrees Kelvin (with a resolution of 0.02° per lsb). Register 6 will select the ambient temperature, while register 7 will select the remote-object temperature.

In A Few Clicks

With a few mouse clicks, I put together a quick test project. I used the MPLAB X IDE, although the online version (MPLAB XPRESS) would have worked just as well.

I created a new project for the PIC16F18855, the device featured on the XPRESS evaluation board, and immediately activated the MPLAB

Figure 1: Oscilloscope view

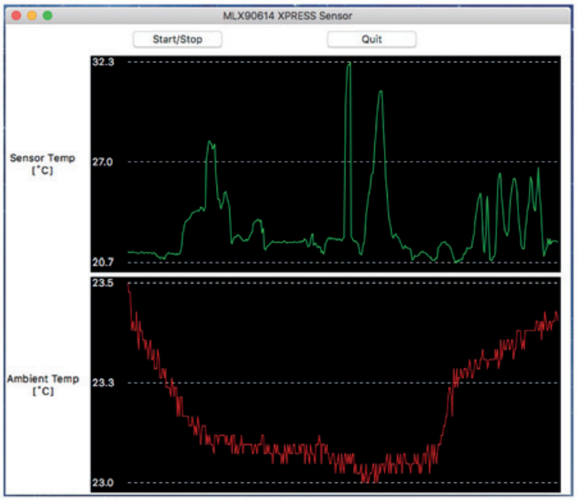


Figure 2: IRThermo click

Code Configurator. I selected the MSSP1 module (which is the I2C and SPI peripheral in PIC lingo) from the list of resources, and configured it for Master I2C mode and a 100kHz clock; see Figure 3.

I also selected the EUSART (the serial port), configured it for 9600 baud, and made it the standard output (STDIO) to *printf* to a terminal for testing/debugging purposes; see Figure 4.

With a couple more clicks in the Pin Grid window, I arranged the connections to the appropriate pins to connect the sensor (in the mikroBUS slot) and the USB-to-serial interface; see Figure 5.

Finally, I formed the SMBus sequence (register write transaction, followed by data word read-back transaction), and packaged it in a convenient IR_readSensor() function; see Listing 1.

```
#define IR_THERMO_ADDRESS 0x5A
#define AMB_TEMP 0x06
#define OBJ_TEMP 0x07

bool IR_SensorRead(uint8_t reg, float * pTemp)
{
 int16_t data;
 I2C1_MESSAGE_STATUS status = I2C1_MESSAGE_
PENDING;
 static I2C1_TRANSACTION_REQUEST_BLOCK trb[2];

 I2C1_MasterWriteTRBBuild(&trb[0], &reg, 1, IR_
THERMO_ADDRESS);
 I2C1_MasterReadTRBBuild(&trb[1], (uint8_t*)&data, 2,
IR_THERMO_ADDRESS);
 I2C1_MasterTRBInsert(2, &trb[0], &status);

 while(status == I2C1_MESSAGE_PENDING); // blocking
 *pTemp = ((float)(data) * 0.02) - 273.15; // convert to deg C

 return (status == I2C1_MESSAGE_COMPLETE);
}
```

Listing 1. IR_readSensor() function

And The 10 Lines Of Code

I added a few lines of code in the main loop (MCC created the main.c file for me) to read both temperatures, ambient and remote-object, and to output them to the terminal (Listing 2).

```
void main(void)
{
 SYSTEM_Initialize();

 INTERRUPT_GlobalInterruptEnable();
 INTERRUPT_PeripheralInterruptEnable();

 while (1)
 {
 LED3_Toggle();
 float temp1, temp2;
 IR_SensorRead(OBJ_TEMP, &temp1);
 IR_SensorRead(AMB_TEMP, &temp2);
 printf("Obj: %2.1f \t Amb: %2.1f\n", temp1, temp2);
 __delay_ms(1000);
 }
}
```

Listing 2: The main() function

Testing

As it turns out, the ambient-temperature reading comes in handy when testing the sensor, as it gives an immediate reference value that can be checked against any thermometer in the room; see Figure 6.

The object (remote) temperature reading is where the fun is, though. Put your hand in front of it and you will quickly see the temperature reading shoot to around 30°C. Point the little sensor window to your mouth (or ears) and you will get a reading close to the internal body temperature, somewhere around 36°C (hopefully!).

Figure 3: MSSP1 configuration

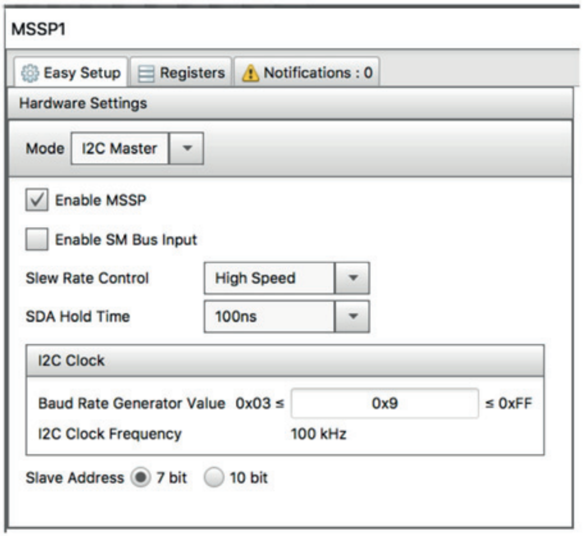
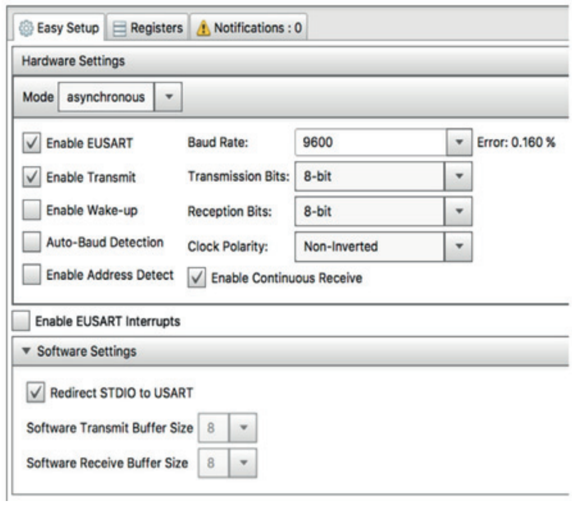


Figure 4: EUSART configuration



Foundation Services Library

Now, since I was well ahead of my schedule to deliver the greatest Vampire detector, I decided to take a little detour. As you may have noticed, I had to enable the device's global and peripheral interrupt mechanism, because the default I2C driver produced by MCC is based on a simple state machine that operates around the I2C interrupts. This is a great feature, since 'asynchronous' operation is very trendy these days, but for simple applications such as this project, it is overkill. In fact, an alternate set of I2C drivers that don't use the interrupt mechanism can be generated by MCC if the Foundation Services are selected instead.

The Foundation Services are a collection of drivers (optional download) that abstract from the details of the individual microcontroller model peripherals and create useful services commonly required by many applications. For example, instead of providing a Timer driver that presents all the knobs and switches of the hardware timers found in a specific PIC, the foundation services library offers a 'Timeout service' that abstracts the particular function (providing a time limit event) from the underlying physical implementation.

Similarly, rather than offering an MSSP driver, the Foundation Services library provides separate services for an I2C-master or I2C-slave function. The result is a simplification, but also increased flexibility. Particularly when selecting the I2C-SIMPLE service, we essentially get an abstract SMBus device. As a further benefit, the use of interrupts becomes optional; in fact, the services can operate equally well with or without them.

Alternative Clicks

In a second project instance, I selected the Foundation Library I2C-Simple service; see Figure 7.

This in turn automatically brought the I2C-Master service in my project, and as soon as I selected the serial module (there are two MSSP in the PIC16F18855 to choose from), the MSSP1 peripheral was configured automatically for me; see Figure 8.

Less Code

The main() function is in this case even shorter and easier to write. The SMBus transaction needed to retrieve the contents of a register is provided by the i2c_read2BytesRegister() function, part of the I2C-SIMPLE service API; see Listing 3.

```
#define IR_THERMO_ADDRESS 0x5A
#define AMB_TEMP 0x06
#define OBJ_TEMP 0x07

bool IR_SensorRead(uint8_t reg, float *pTemp){
 uint16_t data = i2c_read2ByteRegister(IR_
THERMO_ADDRESS, reg);
 *pTemp = ((float)(data) * 0.02) - 273.15; // convert to
deg C
 return true;
}
void main(void)
{
 SYSTEM_Initialize();

 while (1)
 {

 LED3_Toggle();
 float temp1, temp2;
 IR_SensorRead(OBJ_TEMP, &temp1);
 IR_SensorRead(AMB_TEMP, &temp2);
 printf("Obj: %2.1f \t Amb: %2.1f\n", temp1, temp2);
 __delay_ms(1000);
 }
}
```

Listing 3: Main using the foundation services

Figure 5: Pin Grid – pin assignment

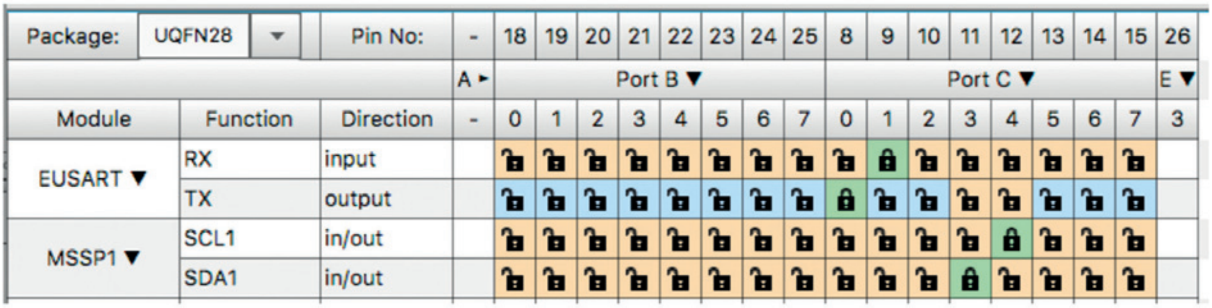


Figure 6: The terminal output

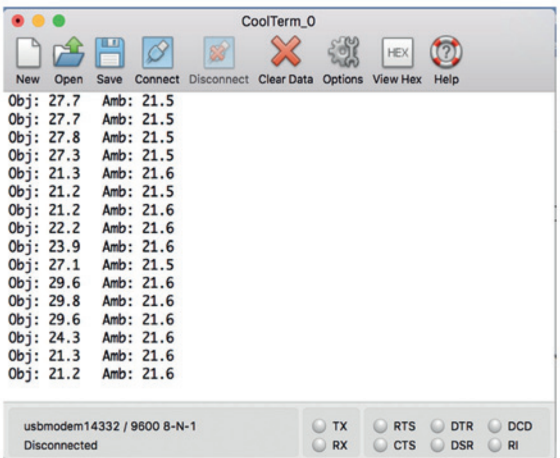


Figure 7: Adding the I2CSIMPLE Foundation Service

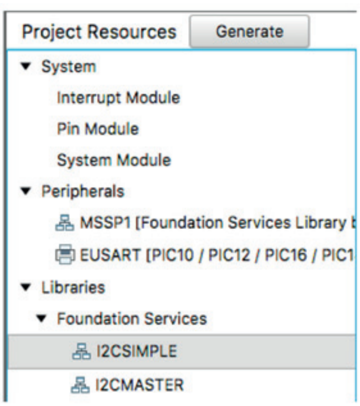
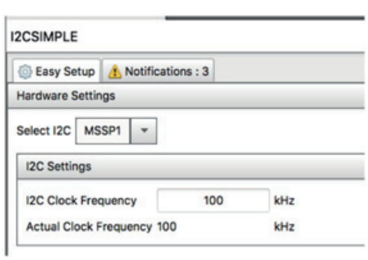


Figure 8: I2C-Simple and MSSP1



Little Vampires Hunting

Now that we have the sensor connected, we can start implementing the Vampire detection algorithm. The idea is to use the IR thermometer to scan the surroundings on a typical cold (and moonless) Halloween night. Although my little vampire wears a dark cloak, he is certain to radiate a small amount of heat. (Beware that this actually might fail with true – as in "dead!" – vampires.)

This radiation is invisible to the eye but detectable at a certain distance by the sensor. A small temperature difference of a few degrees above the freezing ambient reading should suffice to identify the little trickster, even when hiding behind a fence.

Now I only need to remove the terminal connection and replace it with a PWM driving a small speaker. Or better, using a Numerically Controlled Oscillator (NCO) I can make the beeping sound change (linearly) in pitch as the detected temperature difference increases and the vampire gets closer to my neck! (see Listing 4).

I then disconnect the Xpress board from the Mac and plug it into a USB battery pack, ready to go hunting! ●

```
void main(void)
{
 SYSTEM_Initialize();

 while (1)
 {
 LED3_Toggle();
 float temp1, temp2;
 IR_SensorRead(OBJ_TEMP, &temp1);
 IR_SensorRead(AMB_TEMP, &temp2);

 int16_t delta = (int16_t) ((temp1-temp2)*100);
 if (delta > 10){
 NCO1INCH = delta>>8; NCO1INCL = delta;
 }
 __delay_ms(100);

 NCO1INCH = 0; NCO1INCL = 0;
 __delay_ms(400);
 }
}
```

Listing 4: Sounding the alarm when a vampire is near

Remote robot control with the Raspberry Pi Zero W

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

The Raspberry Pi is a low-cost, single-board computer (SBC) running the Linux operating system on an ARM-type processor. The operating system is on a micro-SD card, and an 8GB card is more than enough to store the operating system, data and applications programs.

The Raspberry Pi has been around for several years and there are many models; see Figure 1. The latest model, Raspberry Pi 3, includes a faster processor and more memory compared to earlier versions. One thing in common for all, however, is to have GPIO ports for interfacing to external devices.

Raspberry Pi is an ideal choice for many wireless, robotics, control, monitoring and automation projects and for practising and learning the Linux operating system and Python programming language.

Raspberry Pi Zero W

The Raspberry Pi Zero W (the "W" stands for wireless) is a popular member of the family, incorporating Wi-Fi and Bluetooth capabilities. This is a small board costing around £10, with a fully-functional Linux operating system and many pre-installed applications, such as Internet Explorer, word and picture processing, spreadsheet, Python interpreter, games, and more. Its power requirements are very modest; a simple standard 5V phone charger with a micro-USB plug can be used to power it.

The Raspberry Pi Zero W has the following features:

- Single-core BCM2835 processor;
- 1GHz clock;
- 512MB RAM;
- Mini HDMI port;
- micro-B USB data port;
- micro-B USB power port;
- CSI camera connector;
- 802.11n Wireless LAN;
- Bluetooth 4.0;
- Micro-SD card socket (for the operating system);
- 2 x 20-pin GPIO interface;
- Size: 65mm x 30mm x 5mm.

The GPIO interface is accessed through a 40-way header, which provides signals for general-purpose digital input-output, SPI bus, I2C bus and UART communications. Figure 2 shows the system board with its components. At the top is the 40-pin header for the GPIO ports and at the bottom are the HDMI socket and two micro USB ports (one for power, one for USB). On the left is the micro SD card socket, and on the right the camera interface. As with all

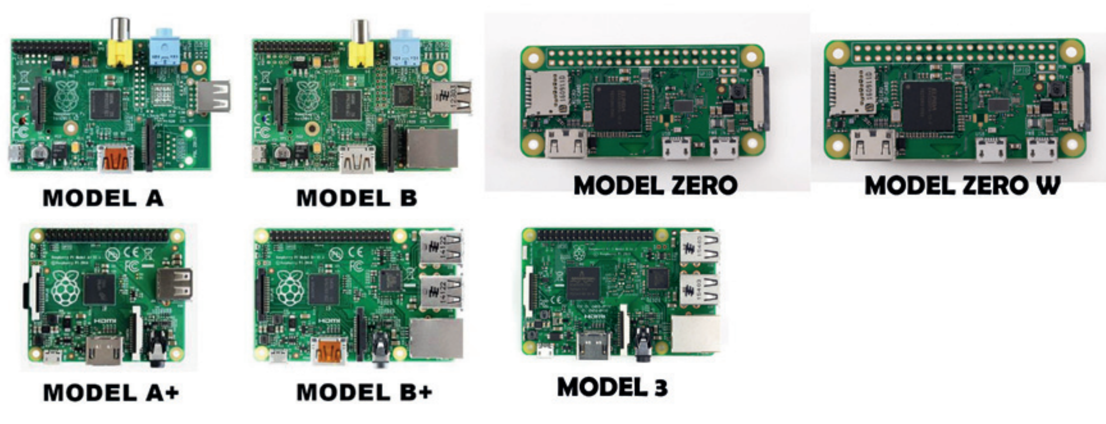


Figure 1: The Raspberry Pi family

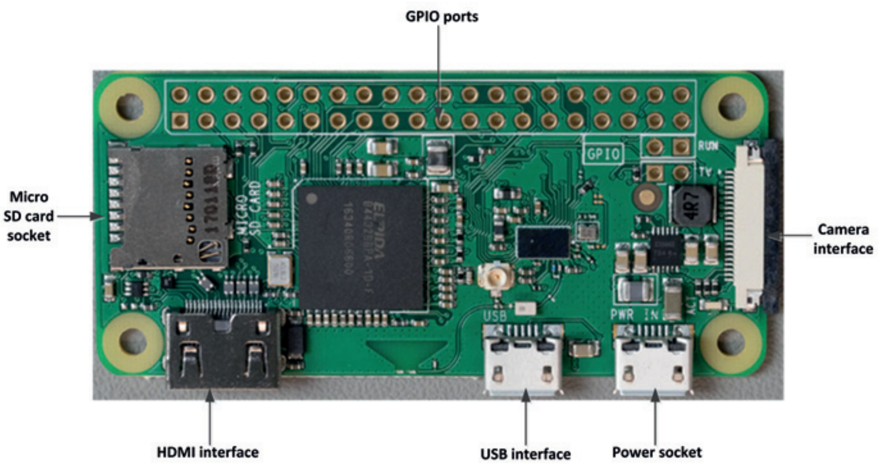


Figure 2: Raspberry Pi Zero W with its components

Raspberry Pi boards, a power supply, keyboard, mouse (or other input device) and screen must be provided to initially configure and use the Raspberry Pi Zero W.

After initial configuration, the system can be controlled remotely from a desktop computer or laptop over a suitable Wi-Fi link, using the SSH protocol with a terminal emulator software (e.g. Putty).

Raspberry Pi Zero W supports both Python 2.7 and 3.0. Applications can either be developed in command mode using a plain-text editor such as the nano or gedit, or the Python IDLE interactive programming interface can be used in the Raspberry Pi Desktop GUI mode to create and run Python programs. The latter has the advantage that the editor automatically inserts the required indentation correctly as the program lines are typed in. In addition, the IDLE interface supports graphical programming and animation interfaces where the programmer can create user-friendly interactive programs, graphics-intensive game programs, or draw various two- or three-dimensional graphics. The standard IDLE uses Python 2.7, while IDLE 3 uses Python 3.0. Although IDLE 3 has a few more functions, IDLE is still more popular due to the continued popularity of Python 2.7.

The Project

Here we present a project that shows how to use the Raspberry Pi Zero W computer aboard a mobile robot in a Wi-Fi-based application. The on-board Wi-Fi is used to communicate with an Arduino mobile phone to control the movements through simple commands using standard UDP packets; the robot's wheel motors are controlled individually to move the robot as desired.

Figure 3 shows the setup. A Wi-Fi network router provides communication between the mobile phone and the Zero W. The robot's movements are controlled by small DC motors, one for each wheel.

The output ports of the Zero W cannot provide enough current to drive the robot wheel motors directly, so an L293-type dual DC motor driver chip is used.

The project's circuit diagram is shown in Figure 4. The Raspberry Pi Zero W is powered from a standard 5V portable mobile-phone charger, mounted on the robot. Power to the wheel motors is provided by external batteries, also mounted on the robot.

The robot is controlled by sending the following simple UDP packets:

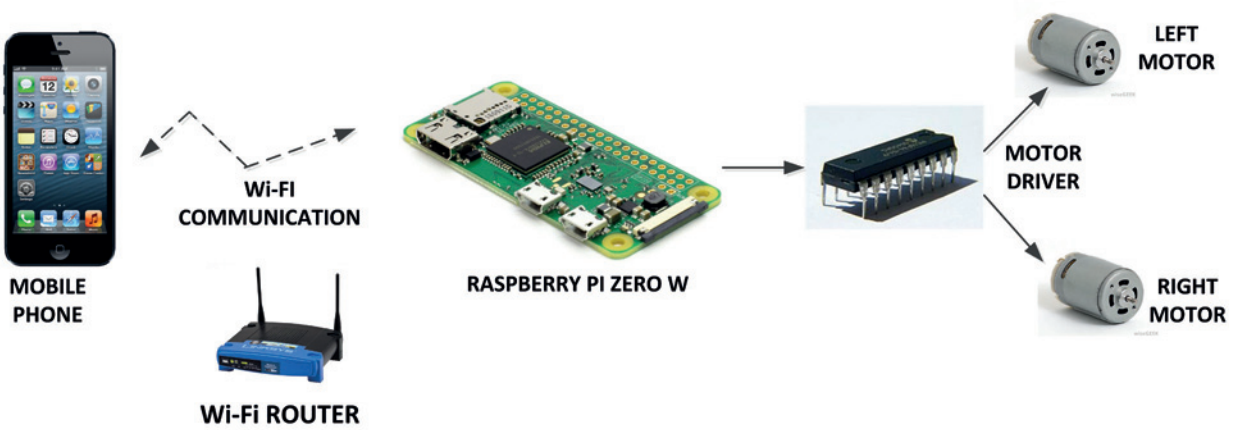
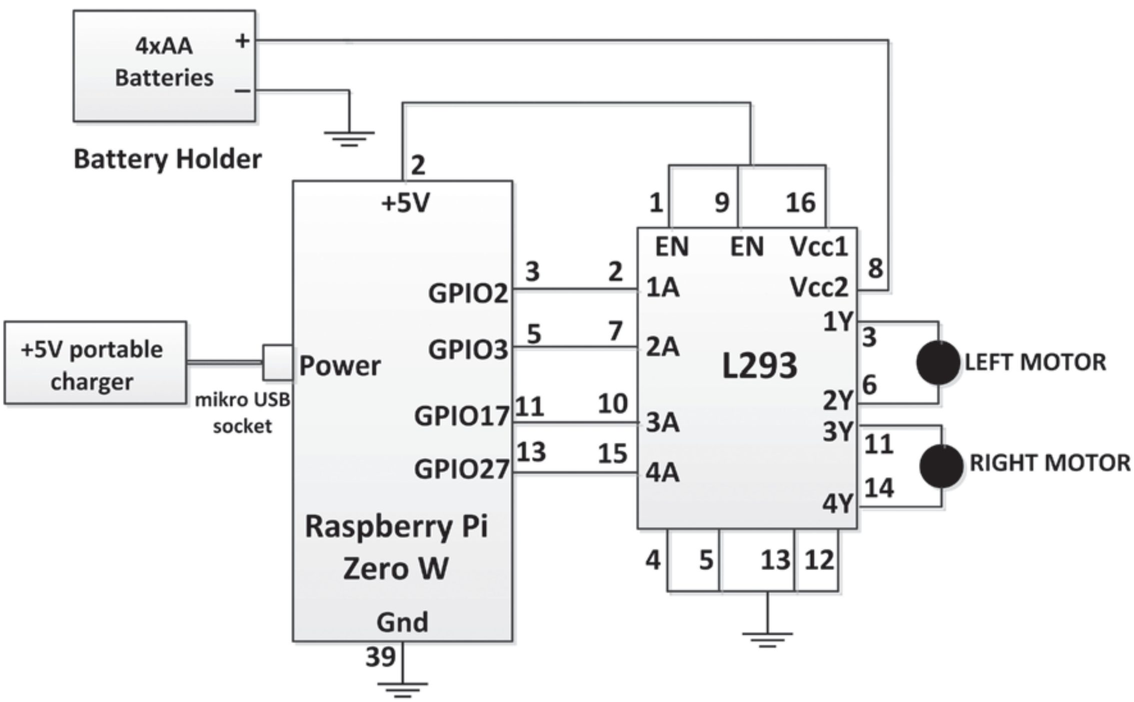


Figure 3: Project setup

Figure 4: Project diagram



Fn, Move robot in forward direction for n seconds;
Bn, Move robot in reverse direction for n seconds;
Ln, Turn robot left for n seconds;
Rn, Turn robot right for n seconds;
where n is an integer number. For example, the command #F12 will move the robot forward for 12 seconds, and the command #R2 will rotate it right for two seconds.

For forward movement, both wheels rotate in the same clockwise direction; for reverse, the wheels rotate anticlockwise. For right turning, the robot's right wheel rotates anticlockwise, while the left motor rotates clockwise; and so on.

> The GPIO interface is accessed through a 40-way header, which provides signals for digital input-output, SPI bus, I2C bus and UART communications

The Program

The program was written using Python. Because Python is an interpreter, it was necessary to load the program into the Zero W startup file so the program starts automatically after a reboot. There are several ways this can be done; in this project, the program path and name were included in system file */etc/rc.local* to ensure that the program starts automatically.

Listing 1 shows the complete program. At its beginning, the RPi, time and socket library modules are imported, and the input-output pins configured to use the BCM (business communications manager) configuration. The program then assigns names to the L293 chip pins, where L1A and L2A are the left-wheel-motor control ports, and R3A and R4A the right; all ports are configured as outputs.

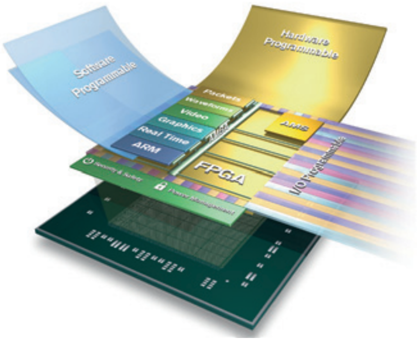
In addition to forward, reverse, left and right movements, there's also a command to stop each motor; the other four functions have a time parameter that controls their duration.

The program loop starts with a *while* statement. Inside this loop, UDP packets are received from the mobile phone on port 5000; the packets are decoded and the wheel motors controlled accordingly.

There are several UDP application programs available free of charge in the Google Store (e.g. UDP RECEIVE and SEND by Wezzi Studios) that can be used to send UDP packets to the Raspberry Pi Zero W. >

```
#---------------------------------------------------------
# REMOTE MOBILE ROBOT CONTROL VIA
WI-FI
# ================================
#
# In this project the Raspberry Pi Zero W is
mounted on the robot chassis
# together with the L293 motor driver IC.
The movements of the robot
# are controlled by sending messages from
an Android mobile phone
#
----------------------------------------------------------
import RPi.GPIO as GPIO
import time
import socket
GPIO.setmode(GPIO.BCM)

#
# L293 control pins
#
L1A = 2                          # GPIO2
L2A = 3                          # GPIO3
R3A = 17                                 # GPIO17
R4A = 27                                 # GPIO2

global data

#
# Configure L293 control pins as outputs
#
GPIO.setup(L1A, GPIO.OUT)
GPIO.setup(L2A, GPIO.OUT)
GPIO.setup(R3A, GPIO.OUT)
GPIO.setup(R4A, GPIO.OUT)

#
# Stop the motor
#
def StopMotor():
 GPIO.output(L1A, 0)
 GPIO.output(L2A, 0)
 GPIO.output(R3A, 0)
 GPIO.output(R4A, 0)
 return

#
# Set forward movement
#
def FORWARD(tim):
 GPIO.output(L1A, 0)
 GPIO.output(L2A, 1)
 GPIO.output(R3A, 0)
 GPIO.output(R4A, 1)
 time.sleep(tim)
 StopMotor()
 return

#
# Set reverse movement
#
def REVERSE(tim):
 GPIO.output(L1A, 1)
 GPIO.output(L2A, 0)
 GPIO.output(R3A, 1)
 GPIO.output(R4A, 0)
 StopMotor()
 return

#
# Turn left
#
def LEFT(tim):
 GPIO.output(L1A, 1)
 GPIO.output(L2A, 0)
 GPIO.output(R3A, 0)
 GPIO.output(R4A, 1)
 time.sleep(tim)
 StopMotor()
 return

#
# Turn right
#
def RIGHT(tim):
 GPIO.output(L1A, 0)
 GPIO.output(L2A, 1)
 GPIO.output(R3A, 1)
 GPIO.output(R4A, 0)
 time.sleep(tim)
 StopMotor()
 return

#
# This function extracts the
delay in seconds
#
def GetDelay():
 global data
 No = int(data[1:])
 return No

#
# Start of the main program loop.
Get a command from the mobile
# phone, decode the command, and
implement the required action
#
# Stop the motors at the beginning
of the program. Define the UDP
# port number and the IP address of
the Raspberry Pi Zero W
#
StopMotor()
PORT = 5000
IP = "192.168.1.161"
sock = socket.socket(socket.AF_
INET, socket.SOCK_DGRAM)
sock.bind((IP, PORT))
#
# Start of the program loop
where a command is received and
implemented
#
while True:
 data, addr = sock.recvfrom(10)
#
# Decode and implement the
command. First index of data[0] is
the command
# itself (F,B,R,L)
#
 if data[0] == 'F':
 DelayTime = GetDelay()
 FORWARD(DelayTime)
 elif data[0] == 'B':
 DelayTime = GetDelay()
 REVERSE(DelayTime)
 elif data[0] == 'L':
 DelayTime = GetDelay()
 LEFT(DelayTime)
 elif data[0] == 'R':
 DelayTime = GetDelay()
 RIGHT(DelayTime)
```

Listing 1: The program



Securing embedded vision systems against malicious attackers

BY **GILES PECKHAM** AND **ADAM TAYLOR**, XILINX

In this increasingly interconnected world, there are malicious attackers who wish to exploit vulnerabilities in embedded vision systems for nefarious purposes. Their success, depending on the application, could have serious results such as release of sensitive information or even loss of life. Should an embedded system be compromised, the security breach could have a significant impact, ranging from reputational damage to legal and regulatory repercussions.

To protect against malicious attackers, an embedded vision system should undergo a threat analysis early in the design cycle, prior to starting the detailed design.

Threat Analysis

Threat analysis considers different elements of the design, its data sensitivity and the methods by which the system can be attacked.

An embedded vision system's sensitivity and data will vary depending on its application; for example, a military system will be more sensitive than a commercial surveillance one.

So, threat analysis will consider:

- Application – Is the application mission- or life-critical? What is the end effect if device security is compromised?
- Data – How sensitive is the information stored within the system?
- Deployment – Is the system remotely deployed or used within a controlled environment?
- Access, both physical and remote – Does the system allow remote access remotely for control, maintenance and updates? If so, how is the access authorised?
- Communication interfaces – Is information transmitted to or from the system critical? Is there concern about eavesdropping and snooping? Does the equipment have to protect against advanced attacks, for example reply attacks?
- Reverse engineering – Does the embedded system contain intellectual property or other sensitive design techniques that must be protected?

The results of such threat analyses are used to implement strategies within the design to address identified threats.

At a high level, addressing the identified threats can be categorised into one of the following approaches:

- Information assurance – Ensuring the security of information stored within the system and its communications. This will need to address identity assurance that ensures access to the unit is only from a trusted source, such as when communicating and controlling its operation or updating application software in the field.
- Anti-tamper – Ensures the system can protect itself from external attacks.
- Run time – Ensures the system is protected while running.

Parameter	Zynq 7000	Zynq UltraScale+ MPSoC
Secure Boot	AES, HMAC, RSA 2048	AES, SHA3, RSA 4096
Anti Tamper	XADC	Sysmon, Secure Processor, Built in Self Test of Memories
Key Storage	eFuse and BBRAM	eFuse, BBRAM, Obfuscated Keys, Key Rolling to protect against differential power attack

Table 1: Security features built into Zynq-7000 SoC and Zynq UltraScale+ MPSoC devices

Operating System	PS only	PS with PL acceleration	Reduction
Standalone	28574	7102	75%
FreeRTOS	28368	7104	75%
Linux	36662	16544	54.8%

Table 2: AES performance (processor clock cycles) for each operating system when accelerated

Encryption

Typically, information assurance requires encryption to protect both its stored data and communications. Commonly-used encryption algorithms include the Advanced Encryption Standard (AES), a block cypher that encrypts blocks of 128 bytes, with key sizes of 128, 192 or 256 bits. There are alternatives to AES for different applications, for example Simon and Speck, developed by the National Security Agency for low-power, computationally-limited Internet of Things (IoT) applications.

Cryptography can also be used to digitally sign information. This enables the receiving system to verify the identity of the sender or ensure encrypted messages have not been changed.

Digital signatures are created with public-key encryption like RSA and hashing algorithms like SHA3. The first step is to create a fixed-length hash value for an input of arbitrary length. The resultant hash is encrypted using the private key of the sender, and communicated or appended as signature. The receiving entity generates a hash of the information received using the same algorithm and encrypts it with the sender's public key. If both the calculated and received signatures agree, that confirms who sent or created the information and that it has not been modified. As such, a digital signature is very important to verify the integrity of software during both configuration operations and field updates for embedded systems.

Tests And Anti-Tamper

Along with encryption to create a more secure IA solution, access ports such as the JTAG test port must also be protected once the system is in use, to limit the ability of attackers to read back or modify data and programs if they gain physical access to the unit.

Preventing physical access and therefore modification of the system is where the anti-tamper solution is applied. Anti-tamper techniques are used to protect many parameters of the embedded vision system. While each system and its threats are different, a common anti-tamper approach will monitor system voltage rails and temperatures to ensure an attacker can't manipulate the temperature or apply out-of-specification voltages. Such approaches have been used by third parties to cause unwelcome behaviour in embedded systems with security vulnerabilities.

Implementing Security

To achieve the secure electronic architecture for an embedded vision system, both the Xilinx Zynq-7000 SoC and Zynq UltraScale+ MPSoC provide the necessary building blocks for a secure system. Often these devices are used in conjunction with the reVISION acceleration stack to enable the use of high-level development frameworks such as OpenCV and Caffe.

> "Using a system optimising compiler such as SDSoC enables the developer to specify the algorithm using a high-level language

These built-in features of the silicon and configuration stages enable the implementation of anti-tamper functions and security, addressing the information assurance and anti-tamper requirements.

The remaining security solutions are implemented at run-time and are used to protect data in memories, peripherals and system-level control registers, protecting them from illegal access, configuration changes and malware injection. Protection mechanisms include encryption, functional isolation, Trustzones and hypervisors, while the application can implement permissions-based user accounts and secure tokens.

Many encryption algorithms can be accelerated within the programmable logic of the Zynq-7000 or Zynq UltraScale+ MPSoC. However, implementing these algorithms using hardware description language increases development time.

Using a system optimising compiler such as SDSoC enables the developer to specify the algorithm using a high-level language like C or C++, developing security at a higher level and accelerating bottleneck functions into the programmable logic.

AES is a symmetrical algorithm, using the same key for both encryption and decryption. The AES algorithm can be computationally-intensive, requiring substitutions with a defined S Box, Matrix Multiplications and several shift operations. As such, implementing AES encryption or decryption in a CPU can become a processing bottleneck.

Implementing AES encryption using SDSoC enables a significant acceleration in performance when accelerated into the programmable logic for each of the supported operating systems. ●

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CMOS clocks in extreme environments

BY **ROB RUTKOWSKI**, BLILEY TECHNOLOGIES

This is the final installment of the CMOS clock series. So far, we've discussed CMOS clocks, their basics and how they differ from LVCMOS.

If you haven't seen the previous articles in this series, I recommend checking those before continuing. In this column you will learn about CMOS clocks in extreme environments.

Key Technology

CMOS clocks are a key technology that enables everything to function, from laptops and smartphones to satellites and spacecraft.

But what exactly do these devices do, and how do they cope with extreme environments and demanding applications?

CMOS clocks are basically crystal oscillators that do not include an oven- or other method of temperature compensation. They regulate the timing functions within a system. They are part of the devices' CPU, regulating their internal clocks, making sure that commands are sent to their system at the right time.

In The Extreme

For military and navigation systems and space applications, CMOS clocks are designed to withstand extreme temperatures and high levels of g-force and vibration. As you can imagine, military applications, both ground and air, experience high levels of vibration and g-forces, not to mention the intense journies through the Earth's atmosphere and space that satellites go through.

There are many ways to optimise CMOS clocks for extreme environments, mostly through the crystal's cut, its mounting and placement within the structure, and its feedback loops.

Specifying a high-quality crystal from a trusted and experienced manufacturer is the first and possibly most critical step when optimising a CMOS clock for shock and vibration. Without a high-performance crystal, external attempts to compensate for vibrations and g-forces will not be nearly as effective. The crystal's cut can determine the impact of vibration and g-forces on the clock. An SC crystal is usually well suited in applications where high vibration and g-sensitive environments are a concern.

Next, the way the crystal is mounted can either make or break the oscillator's ability to withstand such extreme environments and maintain its desired frequency. Suspension mounts and isolator are commonly used to help absorb any shock or vibrations before they reach the crystal itself.

Important Techniques

Implementing feedback loops in the clock circuit can also lower the impact of rough environments. Feedback loops enable systems to adjust their performance to meet a desired output response. In extreme applications, feedback loops adjust system performance based on fluctuations in the output frequency.

Techniques like radiation hardening are also used to make CMOS clocks more resistant to radioactive degradation, which can be a significant challenge, especially in space-based applications.

Advanced timing capabilities enabled by CMOS clocks will continue to play a significant role in the rapid advancements of device and system technologies in the next few years. ●

FIVE KEY QUESTIONS FOR DISPLAY SPECIFICATION

BY **MIKE LOGAN**, DISPLAY AND INPUT TECHNOLOGY MANAGER, ANDERS DX

The display is the first thing a user sees and the last thing a designer thinks about. A sweeping generalisation, but so often true.

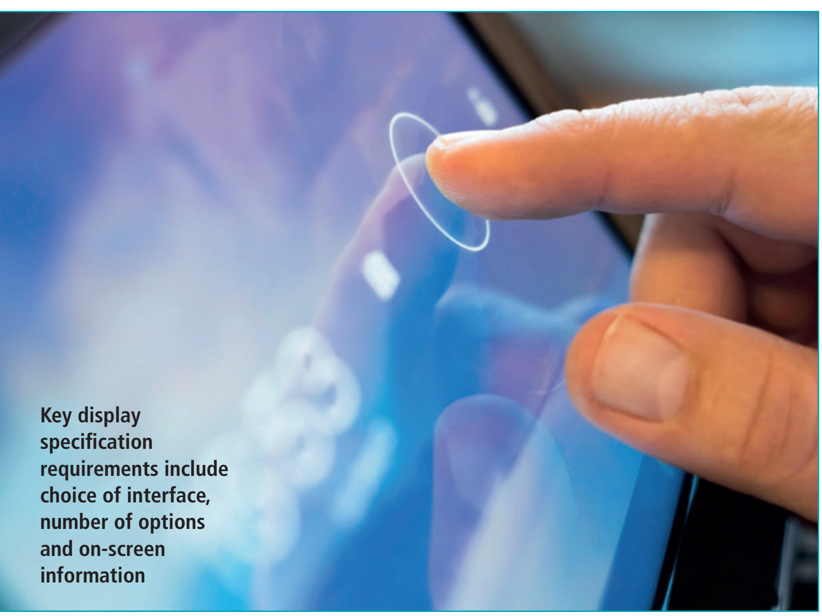
User perception of a system will be completely based on the information it provides and how it is presented. Yet system designers typically choose the display late in the design process; their focus is often on the choice of processor, operating system and software.

Thinking about how the system will be presented to its user at the start will allow greater flexibility. Let's explore five specific questions designers should ask when selecting a display for their system:

Question 1: How Big?

Firstly, don't be constrained by the relatively limited catalogue options offered by major display manufacturers. Start from a blank piece of paper and decide the size you need; the right supplier will have the exact size you require at the right price.

Whilst a standard product may appear best value for money, a customised display is often a better and more cost-effective option.



Key display specification requirements include choice of interface, number of options and on-screen information

For example, in many cases a display can be cut to size, which will avoid having to increase the case size or compromise how information is presented to fit a smaller-than-ideal screen. A display that's too large can bring hidden costs in terms of a bigger case, which can cost more to buy, ship and store, and likely uses more power.

It is also possible to remove unwanted elements from a customised display. Specifically, the number of backlight LEDs can be selected, saving money and reducing power consumption. A simpler and cheaper graphics IC can be specified, along with added or removed performance enhancement films and other parameters, to create a screen that delivers exactly what the application requires – no more, no less.

So, my first advice is not so much to dream big, as to be specific and demanding. Figure out the size that works for your system, then find a supplier with the flexibility to deliver it.

Question 2: What Resolution?

Display resolution depends on the information to be presented. Is it text, icons or graphical? Will it include video? Does it need a touch interface and, if so, how many options will be offered the user at one time, and how much information needs to be presented to help with their choice?

It's extremely hard to visualise screen appearance in the abstract; the best way is to obtain samples of the target displays and load up the interface. Platforms like DX from Anders offer pre-integrated motherboards and displays that are shipped with popular operating systems and processors. Loading an application onto these platforms is quick and simple, with easy changes, and you can even try different screen sizes for a more informed decision.

Question 3: What's The Viewing Angle?

Having chosen the display size and resolution, we move on to ergonomics – how will the system be used? Will the user stand in front of the display or look at the screen from an oblique angle?

Although display datasheets give a figure for viewing angle, this can be quite subjective. Whether or not a display can be read from a given angle can depend on light levels, the size of text or graphics being viewed and operator eyesight. With a handheld unit, generally the operator will move the instrument to clearly read the display. With a bench unit, they may be forced to view the display from an awkward angle, from above or the side. A good manufacturer will work closely with customers to understand how the equipment will be used and where the operator will be sitting.

One of the best technologies for achieving wide viewing angles is IPS (In Plane Switching). These displays offer viewing angles of over 85˚ in all directions, allowing them to be used in either landscape or portrait orientation without penalty. IPS technology offers a lot of other advantages too – better contrast, deeper black and a very sharp image.

If you're committed to a standard TN, there are still several things you can do to improve the viewing angle. A recently-introduced technology is an optical film that redirects light, adding 10 degrees of viewability in any direction, at the price of a slight loss in image sharpness. Adding 'moth-eye' films into the cavity between display and cover lens reduces reflections which can improve viewability, especially from oblique angles.

Question 4: In What Environment Will The Display Be Used?

Having considered the user, we need to think about the environment in which the display will be used; the design should accommodate the worst case.

An instrument may work well indoors or in low light, but users won't thank you if they can't read the screen in bright sunlight. In fact, sunlight is a very long way from being the display-designer's friend, as anyone who has ever strained to read an ATM screen on a sunny day will know.

The single best measure to improve readability of a display in sunlight (or any other environment) is to use optical bonding between the cover glass and the display. This eliminates internal reflection between the glass layers of the display by using optically clear adhesive that matches the indices of reflection of the glass layers it bonds, replacing the air in the gap between them. Thus, display contrast is increased so it can be read more easily even in bright conditions. Even when switched off, an optically-bonded display will appear black rather than a murky grey. Eliminating internal reflections between layers of the display tremendously improves readability.

There are other things that can be done; for example increasing the brightness of the backlight. This comes with a penalty, though, since the backlight draws more power, which reduces battery life and increases the heat generated by the display.

Question 5: Will It Be Exposed To Extreme Temperatures?

Not only are displays hard to read in bright light, but sunlight also causes extra heating. Fitting a UV-resistant overlay and using UV adhesives are always helpful, but these are just the starting point of design for a sunny environment.

Thermal management needs to be carefully considered for a display that is likely to catch the sun. A system for use outdoors usually needs to be sealed, which precludes the use of forced cooling like fans, as well as the provision of apertures for convection cooling. The only solution is to fit a heat sink, which will increase system size and weight.

Unless the heat sink is massive, some degree of heating is inevitable, so components need to be specified to handle the anticipated maximum temperature. Two items that are particularly affected are the polarisers and the liquid crystal (LC) fluid itself. Standard polarisers have a temperature range of -20°C to +70°C, but extended temperature ranges of -30°C to +85°C are available.

With the LC fluid, the specification to look out for is the 'clearing point'. When the fluid gets too hot, it loses the ability to manipulate light, causing the screen to go black. You may have seen this phenomenon on your smartphone; it reverses itself when you return to a cooler environment. Standard LC fluids have a clearing point of 70°C, but for displays where heat is an issue, materials with higher clearing points are available and advisable.

Early Decisions

Choosing the display early in the design cycle is crucial. Chosen early, along with the processor, your options will be wide open.

I have worked on many projects where the wrong display was selected at the outset, leading to display life shorter than that of the system. It is usually possible to resolve these situations, but invariably there is a penalty in cost and time.

The decision is never an easy one and it does help to involve a display partner. ●

The single best measure to improve readability of a display in bright conditions such as sunlight is to use optical bonding

BATTLE OF THE DISPLAYS

BY **THOMAS TUXEN**, PRODUCT MANAGER FOR DISPLAYS, REVIEW DISPLAY SYSTEMS

Finding the right display for an application is crucial to the success of a product, and it can be a real headache to research and decide who manufactures the best solution and, ultimately, put your product ahead of the competition.

The choice is almost always governed by the application and the environment it will operate in. These play a huge part in defining the requirements of the display panel, so, by asking a series of simple questions, such as "where", "when" and "what", you can rapidly focus on the important criteria.

Where: will the product be used; will it be a harsh or high-vibration environment; are there operating and storage temperature requirements; the ambient light conditions required; does it need to be sunlight-readable; does it need to be waterproof; how will the unit be powered?

What: is the required size; what resolution is needed; what angle should the unit be viewed from; how can the panel be tailored to reduce cost and increase performance; the type of application – industrial or commercial?

When: will production start; when will viewing stop; when will the display be made obsolete – it is becoming increasingly important to understand how long a display will be produced, especially if the application requires regulatory approvals?

Passive LCDs

Passive LCDs have been superseded by TFTs for small graphic modules; in fact, a small 3.5" QVGA TFT is now cheaper than a similar passive mono-module. However, the simple icon- and numeric-LCD options are still in demand for low-cost applications, such as desktop calculators, simple thermometers, blood pressure measuring devices, and so on.

TFT Displays

When choosing a colour display, there are two main technologies, TFT (thin film transistor) and OLED (organic light-emitting diode).

TFT displays are an 'active matrix' type, made of arrays of transistors fabricated on glass, each transistor corresponding to a pixel on the LCD. TFT displays consist of several layers of silicon, dielectric material and metal over a backlight panel. The backlight is usually made of white LEDs, polarising filters, a glass substrate and electrodes. TFT and LED technology are used together, with the latter for backlighting. Being the active-matrix type, TFTs control individual pixel updates on the screen several times per second, updating the image relative to the content source.

The pixel pitch of a TFT is related to the distance between pixels, which is typically of fixed value and set by the overall

Figure 1: In-Plane Switching (IPS) vs Twisted Nematic (TN) technology

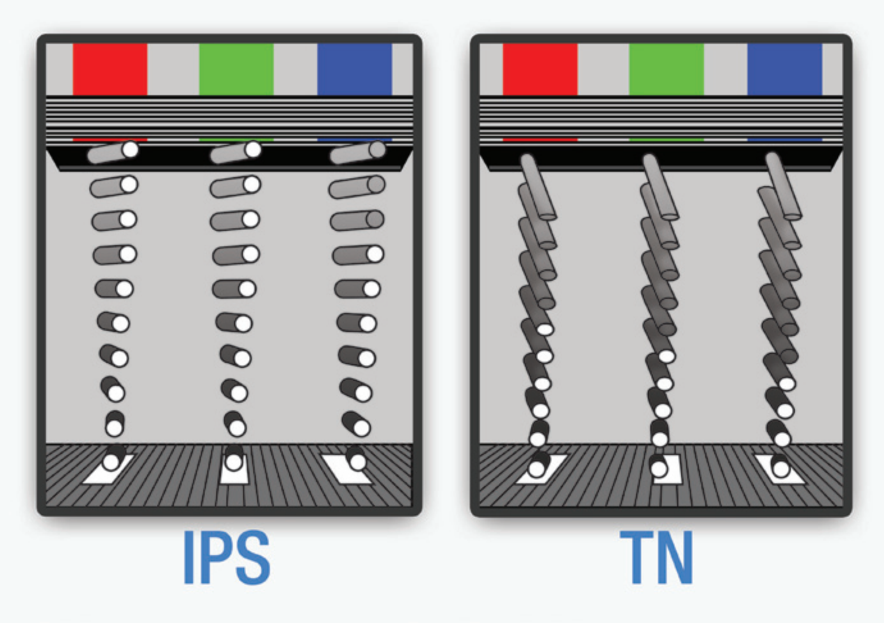
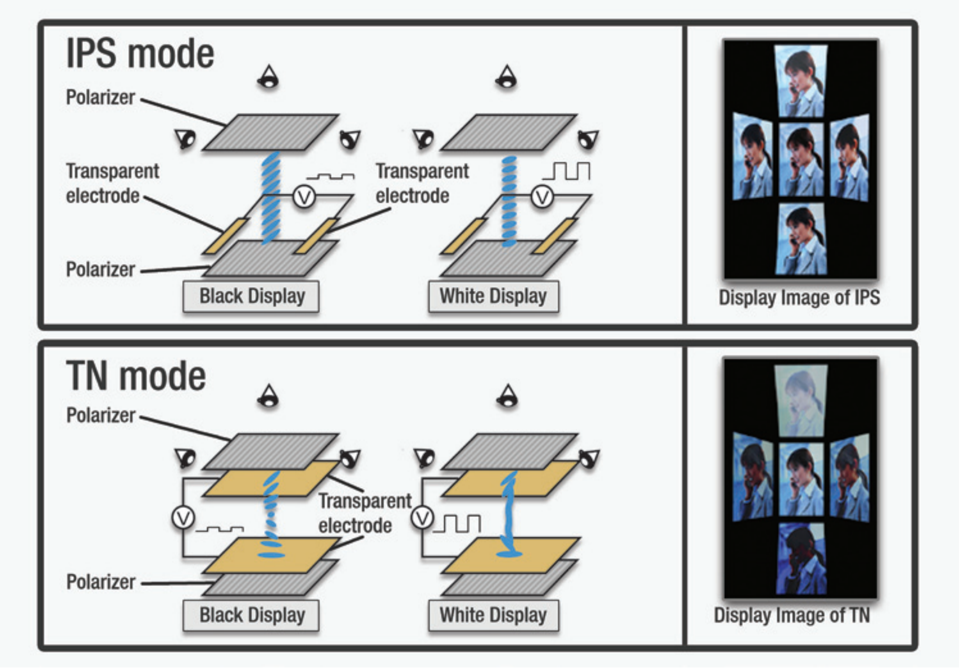


Figure 2: The construction and operation of In-Plane Switching (IPS) and Twisted Nematic (TN) displays



size of the screen and its resolution. The tighter the pixel pitch the sharper the image will be. Manufacturers are constantly looking at producing higher-resolution, sharper and clearer images through fitting more pixels onto a screen without increasing its size.

However, higher resolution also means higher cost. There are a few factors that follow that point: take a typical 8.4" VGA TFT 640 x 480 (921k pixels) and an 8.4" XGA 1024 x 768 (2.36m pixels), where there's enormous difference in the number of TFT transistor arrays and colour filters. Plus, the relative active area in high-resolution displays is smaller than those of lower resolution. So, for a higher resolution display, the backlight needs to be 2-3 times brighter.

TN vs IPS

When selecting a TFT, an important consideration is the technology of the LCD panel, of which there are basically two variations:

1) Normal TN – Twisted Nematic Liquid Crystal Fluid, where the fluid twists the light 90 degrees;

2) IPS – In-Plane Switching.

There are other variations of the IPS technology, relating to manufacturer-specific processes, including:

- VA – Vertical alignment;
- ASV – Advanced Super View;
- AFFS – Advanced Fringe Field Switching;
- SFT – Super-Fine TFT.

Normal TN is used in the majority of TFTs and is the cheaper solution. One hurdle for TN is the existence of poor viewing direction, typically downside or upside. This may not be an issue for a desk display with only one viewing angle. There are however, some wide-view film solutions to improve this.

The transmission rate of TN is better than IPS, so TN can keep the cost of the backlight unit down.

IPS has nearly unlimited viewing angles and is 100% symmetrical in all four viewing directions, typically better than 85 degrees all the way round. This makes it ideal for handheld applications where the display may be seen from any angle, including in portrait mode.

IPS has a lower transmission rate than TN, but the contrast and colour gamut are higher. So, where true colour reproduction is needed, IPS displays have the advantage.

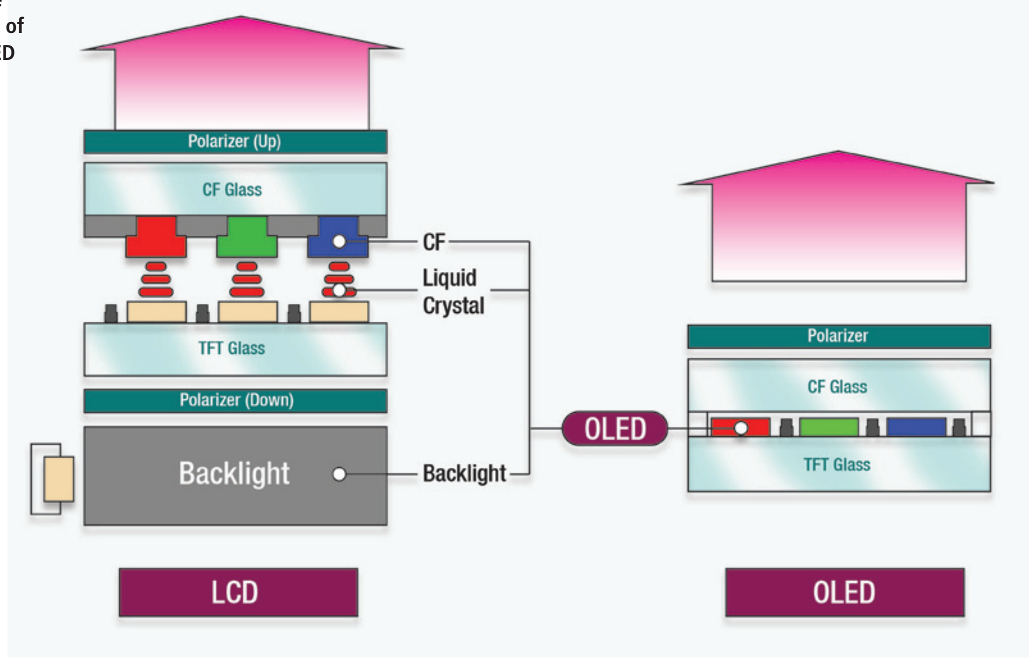
Also, TN is 2-3 times faster than IPS, making it suitable for gaming monitors.

The Interface

There are three standards of displays in the market:

- **Parallel RGB**: Mainly used for small-sized TFTs for handheld applications and where the processor is a simple microcontroller running on simple firmware.
- **LVDS**: 7" TFTs and resolutions higher than VGA are the turning point for the interface to be LVDS. Typical processors are now ARM-based or complete single-board computers (SBCs). Most SBCs come with a direct LVDS interface option, so there's no longer need for an expensive, separate, driver board.
- **eDP** (embedded Display Port): With the upcoming 4k and higher resolution displays, there is a requirement for faster interface systems, which is why SBCs are changing to eDP over LVDS to support these new displays.

Figure 3: The construction of LCD and OLED displays



One point to look out for is that both parallel RGB and LVDS interfaces may need additional voltage, which is not supported from the SBC or other processor boards. This is fine if you make your own PCB, but a bit more complicated if you build your system based on readily-available SBCs and displays. Choosing a TFT with all voltages controlled on-board eliminates the need for separate boards.

OLED Displays

In contrast to TFT displays, OLED displays are relatively new. They are solid-state devices composed of thin layers of organic molecules that emit light when under current. They are organic because they are made from carbon and hydrogen – a green technology, and since they emit light themselves, they don't require backlighting, making them ideal for mobile applications.

There are two types of OLEDs: AMOLED, an active matrix type, and PMOLED, a passive matrix. The AMOLED active matrix consists of organic OLED pixels integrated into a TFT array, which acts as an array of switches to control the current that flows to each pixel. Controlled current is essential for OLEDs over 1.8", to keep the display uniform and the current stable.

A PMOLED display uses a simple control scheme in which each row is controlled sequentially. As PMOLEDs don't contain a storage capacitor, the pixels in each line are off most of the time. To compensate for this, more voltage is required to make them brighter and, as a result, PMOLEDs are best suited to displays smaller than 50-80mm diagonally or less than 100 rows.

TFT And OLED Advantages

TFTs have been made for a while and are now an integral part of the display market. They are low in cost, have a long operating life, come in many sizes – from sub-1" to over 100", and are available in industry standards from 3.5-19".

On the other hand, OLEDs operate at temperatures as low as -40°C and as high as 85°C. They have higher contrast, low power consumption and faster response time, and are thinner. But, OLED displays have limited production capacity, are not suitable for industrial applications and are only available for mobile phones and TVs of 55" or so, with no other sizes in between.

TFT is a mature display technology, but is continously being improved to achieve wider viewing angles and colour gamut, brighter displays and improved sunlight readability, among other specifications. Being mature also means a stable supply chain, standard formats and long-term availability.

TFTs are not going to disappear from the industrial market any time soon, since at this point there are no real alternatives. OLED is a new, promising technology which still has a few issues to overcome, such as production yield, lifetime, brightness, burn-in and true colour control. Although huge investments are being made in OLED production facilities, most of the output is still used by mobile phones, where some of the longevity issues discussed here are of less importance since users change their mobile phones frequently.

Without colour filters and polarisers, OLEDs can be used for super-thin, flexible displays that will expand the way they are mounted and used – some curved OLEDs have already found their way into the mobile phone market. The possibilities for different applications in the future are exciting. ●

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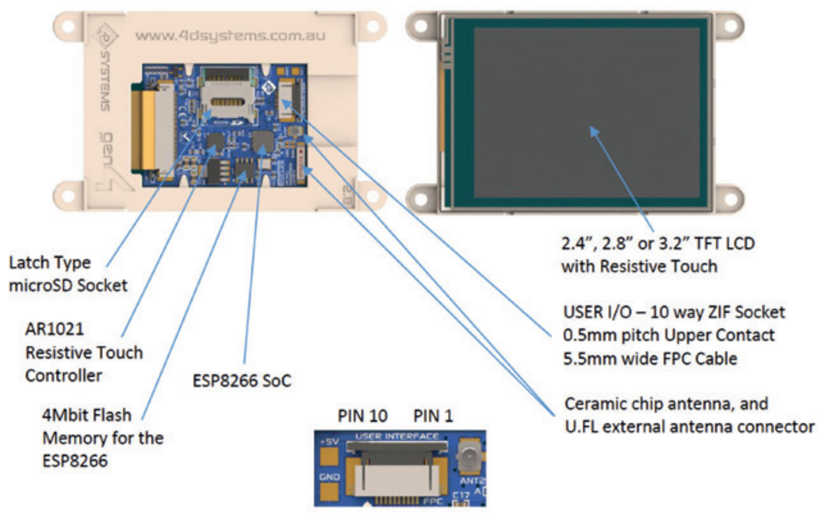
DISPLAYS FOR THE IOT

BY **MARKKU RIIHONEN**, PRODUCTS AND BUSINESS DEVELOPMENT MANAGER, 4D SYSTEMS

Figure 1: gen4 Internet of Displays module



As the Internet of Things (IoT) rapidly gains traction, there is a clear need for Internet-connected sensors with simple display functions. The ability to locally display functions such as updates from the Cloud or sensor status is just as important as being controlled by the Cloud.

The topology of many IoT setups includes gateway devices that provide two-way communication with the Cloud, batching of data collected from local sensors, and some control functions. For most IoT applications, sensors and actuators will operate wirelessly using either Wi-Fi or Bluetooth. While Wi-Fi is a lot more power-hungry than Bluetooth – especially the Bluetooth Low Energy profile (BLE) – it offers communication over greater distances with a higher data transfer rate.

Adding Local Displays

There are several compact embedded single-board computers with Wi-Fi connectivity, and adding a display can be simple enough, either through a pre-assembled display module or discrete design. Recent developments include a complete Wi-Fi-connected embedded platform that incorporates a touch-sensitive display.

An example of such a platform is the gen4 Internet of Displays (IoD) series from 4D Systems. Based on the Expressif ESP8266 Wi-Fi microcontroller, the module offers a resistive-touch 320x240-pixel TFT, with 65,000-colour display sizes of 2.4, 2.8 or 3.2 inches; see Figure 1.

In addition to a micro SD socket for data logging and image file applications, the module has 512kB of flash memory for user application code and 128kB of SRAM, of which 80kB is free.

Measuring just 78.4 x 44.8 x 7.2 mm (the 2.4-inch model), the modules can easily be programmed using the popular Arduino IDE. A comprehensive GFX4d library enables fast development of graphics-based applications through extensive primitive graphics functions, available for download from the 4D Systems GitHub page.

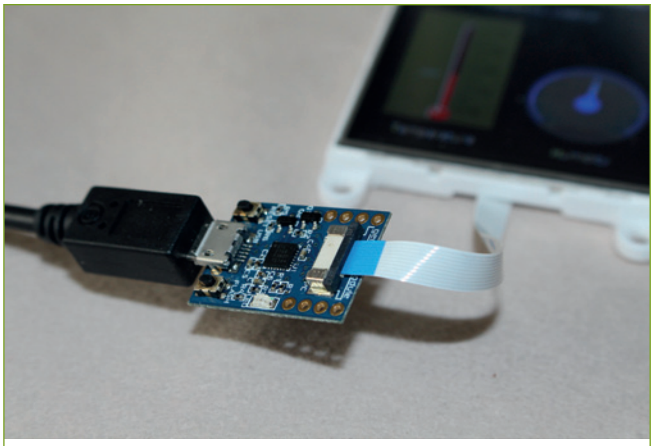


Figure 2: gen4 IoD programmer board

The Workshop4 environment, also available free from the 4D Systems website, provides a more integrated and extremely straightforward approach to graphics-based application development.

A 10-pin FPC cable connects the 4D IoD to a 4D gen4 IoD programmer (Figure 2) that provides all connectivity to the module and power, programmability and test. The ESP8266 is an extremely popular and capable wireless microcontroller, widely supported within the Arduino community, and included in many open-source projects that show its Wi-Fi capabilities. The 4D IoD series connects to free data sources, such as Weather Underground for example, to display information including ambient temperature or humidity for a given location.

Main Tasks

Pulling together this application involves downloading the Weather Underground API to gather data, and designing the graphic presentation of the information.

To start the project, install the Arduino IDE and ESP8266 community board manager files and the GFX4d library and Workshop4 IDE. Full instructions and necessary files are provided in the gen4 IoD datasheet and on the 4D Systems GitHub page.

Having downloaded and installed the latest version, to tackle the GUI using Workshop4 requires opening a new project and selecting the gen4 IoD display from the comprehensive list of available displays. There are two main window frames (Figure 3), with the Arduino code on the left and the screen of a virtual 4D module on the right.

For this project we've opted to drag a thermometer widget to the initially blank virtual 4D screen to display the temperature in degrees C, and a 'cool gauge' to display the humidity as a percentage. The screen frame shows the widget properties, which can be amended as required. We set the thermometer range zero to 40°C. Title captions can also be entered at this stage.

Once you have arranged the image widgets, select Compile to generate the Arduino skeletal code, shown in the left-hand panel of Figure 3. This process also asks to copy the two screen-layout files it generates for the micro SD card. In this example they are called WEATHE~1.DAT and WEATHE~1.GCI.

You can opt to integrate the rest of the required code for Wi-Fi communication within Workshop4, or simply copy the generated code to the Arduino IDE. Note that if you opt for Workshop4, the Arduino IDE needs to be working on the computer, since Workshop4 makes background calls to it for compiling and uploading the code. Another file ending in *const.h* is also generated and needs to be added to the Arduino IDE sketch file.

Obtaining The API

The next task is to obtain an API from Weather Underground. Keep a safe copy of the generated API, because it will be needed for the Arduino sketch; see Figure 4.

There are several options for the API, depending on how frequently you want the information updated. There is a free option that's ideal for the purposes of our example, but note that when developing the code you should not call the API more than this option allows.

The next step is to pull together the program to run on the

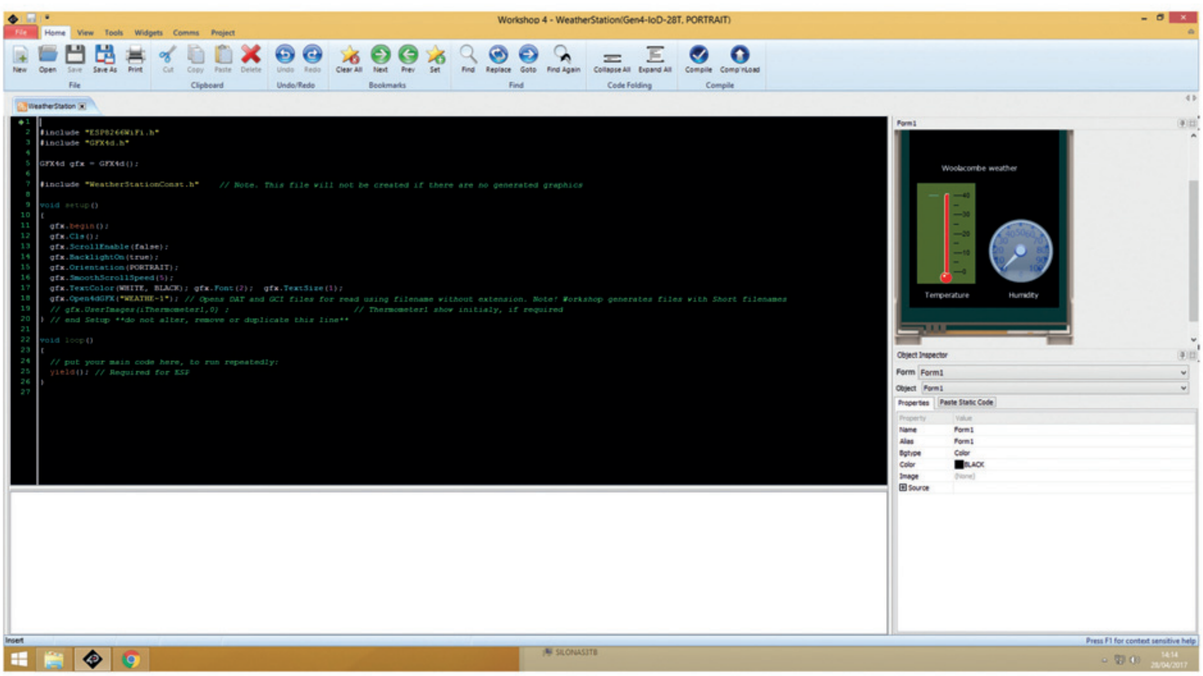


Figure 3: Workshop4 IDE

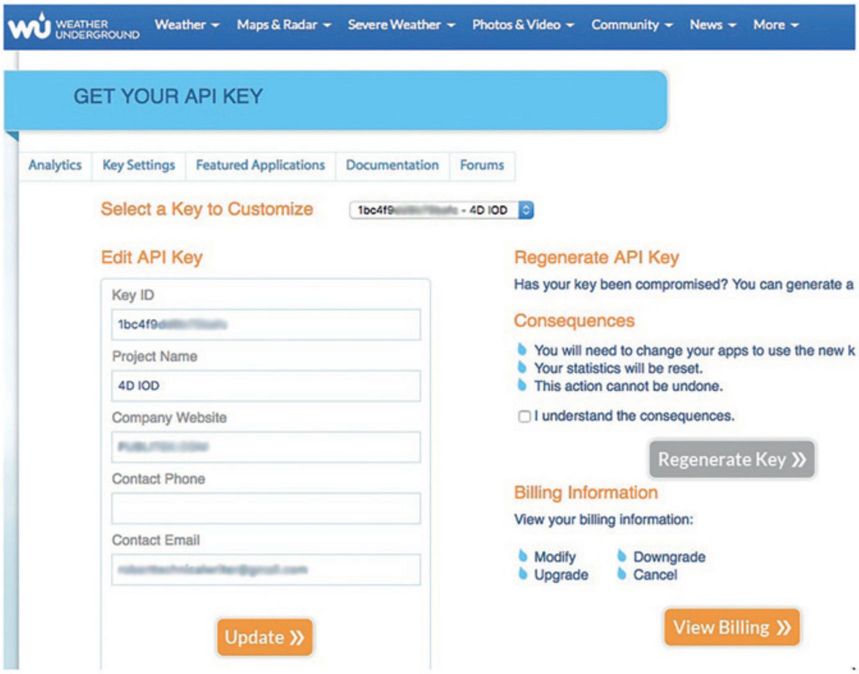


Figure 4: Generating your Weather Underground API

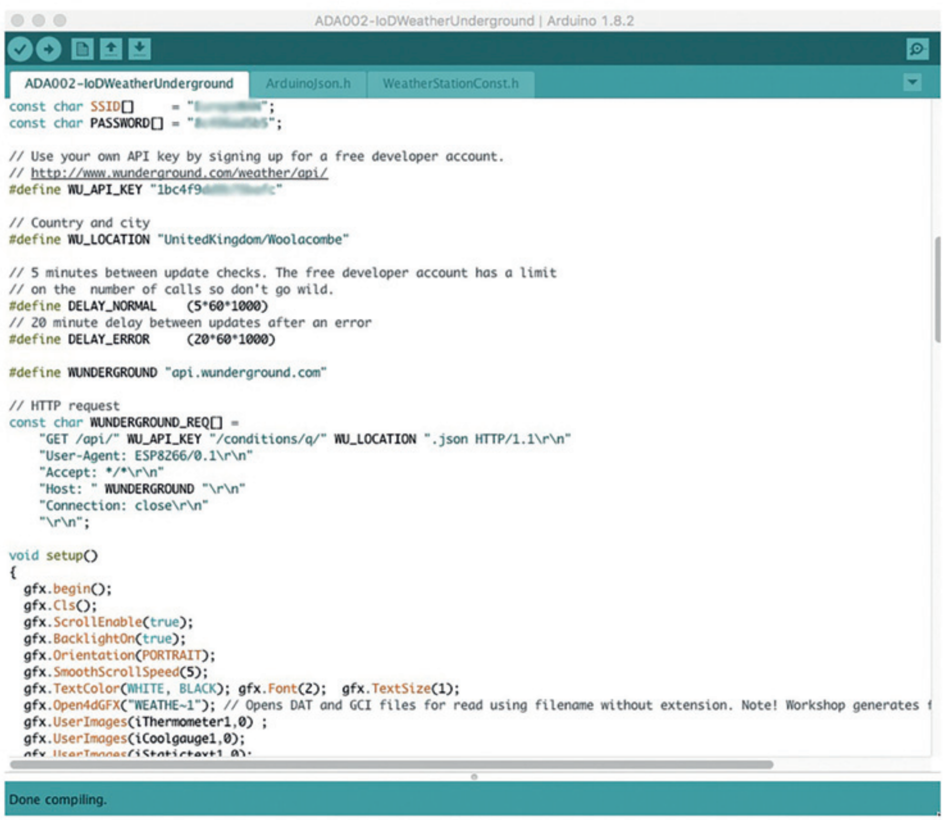


Figure 5: Code snippets

ESP8266. This task is made considerably easier by an open-source example found on the GitHub page, which provides the ideal template from which to add necessary sections from the Workshop4-generated code. In addition to incorporating the gen4 IoD graphic functions, most of the main sketch functions also are copied to the Arduino IDE's serial monitor.

Figure 5 shows the initial section of the code. Enter the SSID and password of your Wi-Fi access point, your Weather Underground API and the location for which you wish to receive weather information. There is a specific syntax for the country and location, so check the format used at the Weather Underground site.

Toward the bottom of Figure 5 you'll see how the sketch is linked to the Workshop4-generated files with the *gfx.Open4dGFX* function call. Likewise, the *gfx.UserImages(iThermometer1,0)* and *gfx.UserImages(iCoolgauge1,0)* display the initial images with a zero value. Captions under each gauge are also displayed in this way. Within the code, observed temperature is stored in the floating-point variable *otemp*, and humidity in the *ohumidity* integer. Values are displayed as:

```
gfx.UserImages(iThermometer1,otemp);
gfx.UserImages(iCoolgauge1,ohumidity)
```

Figure 6 shows the application running on the gen4 IoD module. ●

Figure 6: gen4 Internet of Displays module showing the Weather Underground weather observations

DESIGNING A BATTERYLESS FUTURE FOR INDUSTRIAL AND IOT DEVICES

BY **SCOTT SOONG**, CEO, PERVASIVE DISPLAYS

The Internet of Things (IoT) is facing something of a predicament. Its applications demand large networks of interconnected devices, implemented in areas not necessarily accessible to mains power, which means they rely on low, limited power from batteries. The snag lies in the batteries having to be regularly re-charged or replaced, as well as monitored to avoid device downtime.

So, what if there is a way to power an IoT device continuously? An everlasting IoT node may sound too good to be true, but energy-harvesting techniques now exist, which draw on solar, thermal and RF energy to power applications. Japanese-based global company Toppan Printing has recently developed a product that uses near-field communication (NFC) energy harvesting to update radio-frequency identification (RFID) data, as well as recharge low-power e-paper displays.

The right harvesting technique coupled with a suitable device design heralds a batteryless future of near-perpetual operation. Being able to say goodbye to batteries creates benefits for end users too, with an end to the cost and troublesome logistics of maintaining battery-powered devices.

Battery Trade-Off

Where wireless devices have become all-pervasive, batteries have followed, with our most commonly used devices – smartphones and laptops – depending on them. So customary is our use of these consumer electronic devices that their periodic re-charging is a minor trade-off for the convenience of untethered wireless connectivity. But, scale up this mildly annoying yet necessary habit to an industrial level and the challenges become clear. In changing the landscape of consumer electronics, wireless connectivity has, at the same time, transformed industrial devices and paved the way for the Internet of Things. It allows industrial IoT devices to be implemented in vast numbers and in remote locations, without the need for cables and networks.

Such large-scale industrial IoT operations may often provide mission-critical functionalities where loss of connectivity is far more serious than interrupting social media for a couple of hours. To maintain uptime in an industrial setting, therefore, requires that battery life be monitored closely in all battery-powered IoT devices, and carefully maintained through consistent charging and replacement. In an average factory setting, an IoT implementation involves hundreds of devices, which makes managing their battery life an even bigger headache.

Batteryless Ideal

Energy harvesting promises a bright future, but selecting the appropriate application is key to realising the batteryless ideal. Whilst solar and thermal might top the list for many uses, deriving constant energy from these sources can be problematic; the perfect power source should be continuously available for the device in operation.

However, choosing the right energy-harvesting source is only half the equation. Low-power design is also crucial, if ultimately a device is to operate within a certain power budget.

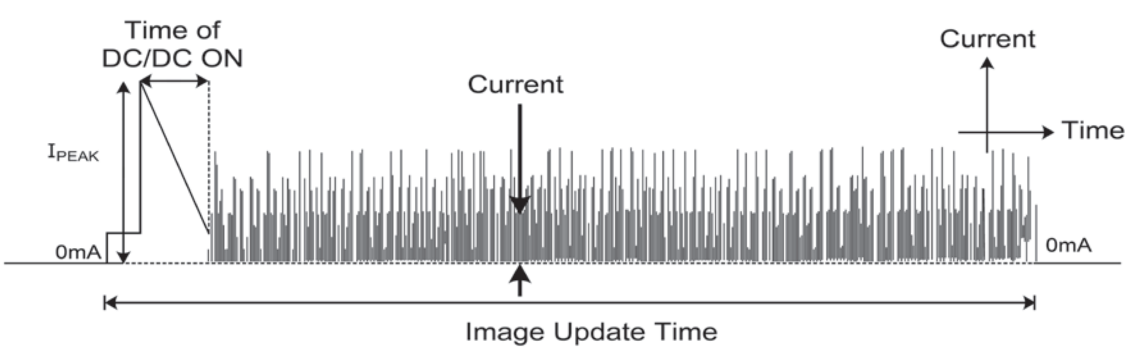


Figure 1: Electrical current used when updating an e-paper display

RF-based contactless smartcards are the perfect example of an ideal batteryless device, having a simple memory chip and antenna for energy harvesting and communication. Most of the time the device is off, consuming zero energy, but when the card is placed in range of an active RF-reader/writer, it is energised by the RF field, resulting in wireless read/write.

For this application, RF-based energy harvesting is the appropriate energy source since the smartcard only requires power during the read/write functions. By employing RFID or NFC methods, the smartcard can anticipate a certain guaranteed power budget, which simplifies device design.

The potential uses for RF energy harvesting go far beyond contactless payment and authentication, with future applications including batteryless sensors, thermometers and other forms of displaying data.

Low-Power Display Tech

E-paper, that well-known technology behind e-book readers like Kindle, is a very low-power technology using electrophoretically-charged ink particles to form an image. It is thus a perfect candidate for a batteryless design, and particularly suitable for energy harvesting.

Unlike traditional active-matrix LCD displays that require backlight to be visible, e-paper is reflective and depends on ambient lighting. To maintain an image, LCD displays require continuous screen refresh, consuming power each time. In contrast, e-paper is bistable, which means it requires zero power to maintain an image; it only uses energy at image update time.

E-paper uses minimal energy for a display to remain visible, with power consumption during screen updates remaining low. Modern displays from e-display designer and manufacturer Pervasive Displays draw as little as 2mA during a refresh, and the device can remain in use even when power is absent. This extremely low power consumption, together with its unique bistable optical characteristics, make e-paper perfect for energy harvesting using solar, thermal or RF energy sources.

> “Japanese global company Toppan Printing has recently developed a product that uses near-field communication (NFC) energy harvesting to update radio-frequency identification (RFID) data, as well as recharge low-power e-paper displays

Complex Applications

Although energy harvesting has power limitations, which means it's not the right fit for every device, it has the capacity to power some remarkably complex applications. Tokyo-based Toppan Printing's recently-developed batteryless e-paper display with integrated RFID tag, mentioned earlier, is a perfect example of this; see Figure 2. It works as a conventional, machine-readable RFID tag, as well as a user display.

Figure 2: Batteryless EPD

As expected, Toppan's zero-power device has no battery, instead operating entirely from RF energy harvested from an NFC reader/writer. At less than 7mm thick, it comes in display sizes between 1.44” and 2.70” and, together with 884 bytes of RFID data, its memory can hold three separate images for update onto its e-paper display. Both display and RFID data are updated via the interaction through its NFC reader/writer device.

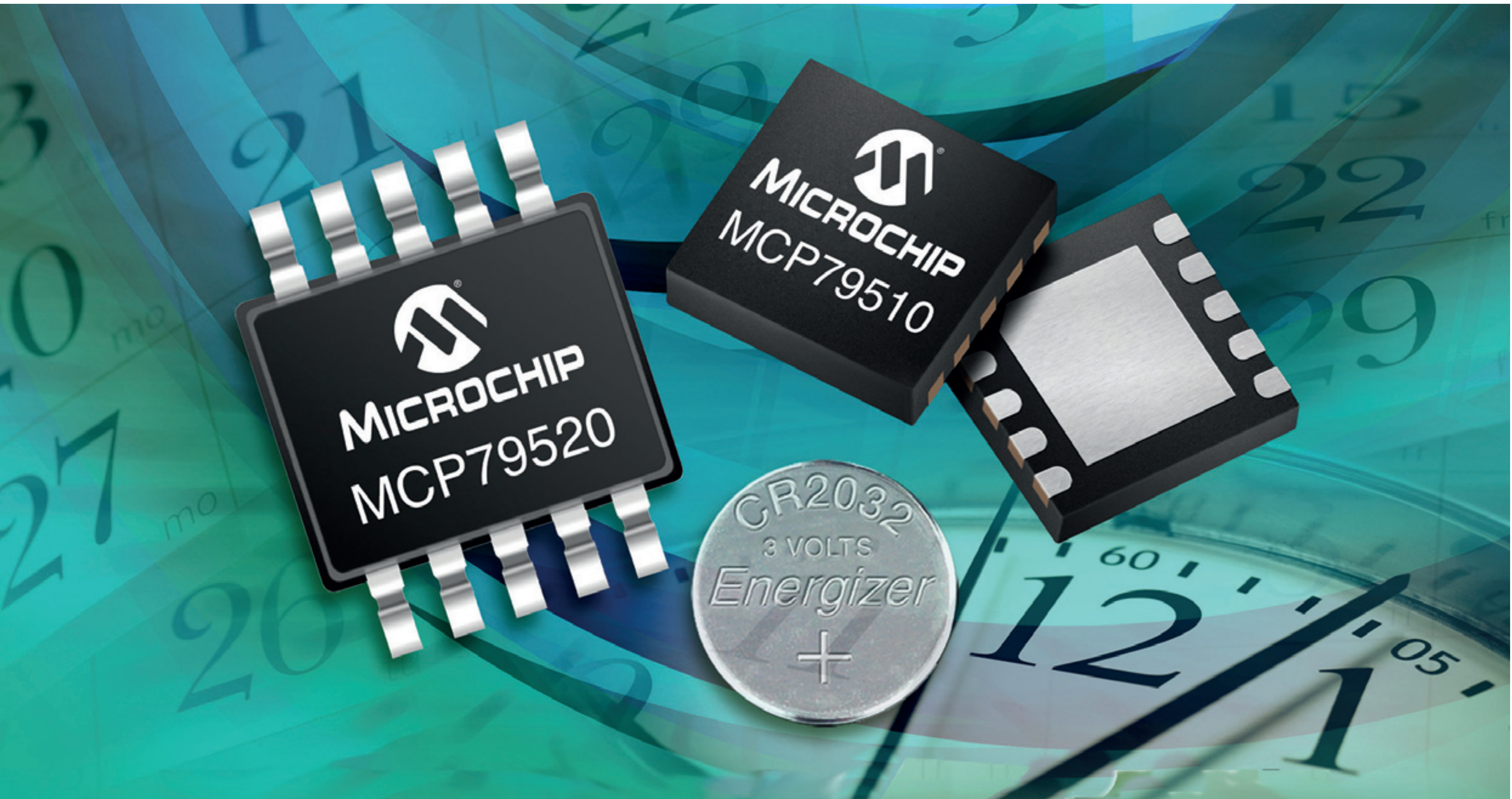
Created with logistics and warehousing applications in mind, the Toppan device replaces traditional paper labels used in asset and inventory management and manufacturing. However, unlike its plain-paper equivalents, its RFID capability ensures the device is machine-readable, for automatic tracking of goods. Its most significant capability is that it can be used at scale, due largely to its batteryless operation. For battery life and maintenance, zero battery equals zero worry.

Batteryless IoT

Batteries may be a fact of life where consumer electronics are concerned, but their use doesn't always translate in an industrial setting or for IoT applications, where there are many devices, used in remote or difficult environments where battery maintenance can be challenging.

However, innovation in energy-harvesting techniques together with reductions in power consumption for sensors, actuators and e-displays are enabling ever-greater numbers of devices to be powered from solar, thermal or RF energy sources.

With its low-power consumption and bistable optical display features, e-paper presents a new frontier for designers, opening the door to a whole raft of new devices for human interaction in industrial settings, free from the restraints of the humble battery. ●



KEEPING TIME

ALEXANDRU VALEANU FROM MICROCHIP TECHNOLOGY EXPLAINS HOW TO USE A REAL-TIME CLOCK AND CALENDAR TO IMPLEMENT AN ELECTRONIC WATCH WHERE TIME AND DATE CAN BE SET USING TWO BUTTONS

An electronic watch with a display where time and date can be set using two pushbuttons can be built using a real-time clock and calendar (RTCC), incorporating EEPROM, SRAM, unique ID time-stamp, watchdog timer and event-detect module.

One such device is the MCP795WXX SPI RTCC from Microchip. The project can be performed on a PIC18 Explorer demonstration board using its on-board resources such as LCD, accessed through the SPI bus and pushbuttons.

Figure 1 shows the schematic, including a PIC18 Explorer and the AC164147 SPI RTCC PICtail daughterboard.

To access the LCD through a minimum number of pins, the SPI on the MSSP1 module is used with a 16-bit IO expander with SPI interface (MCP23S17). The two on-board pushbuttons, S1 and S2, are connected to RB0 and RA5 GPIOs. The SPI RTCC is part of the PICtail evaluation board and is directly connected to the MSSP1 module of the MCU.

Another necessary connection is between the CLKOUT signal of the RTCC and RA4 (T0CKI), the clock input of TMR0. The RTCC is programmed to output a 1Hz square wave on CLKOUT. The TMR0 is programmed as a counter and is initialised at 0xFFFF to give a software interrupt every second.

The SPI connections between the SPI RTCC and the MCU are not open-drain and, accordingly, do not use pull-up resistors. Secondary connections are open-drain outputs or inputs and need pull-up resistors. The CLKOUT signal goes to RA4/T0CKI without a pull-up resistor and can be programmed to output 1Hz, 4kHz, 16kHz and 32kHz signals.

The 8F87J11 MCU is mounted on the PIC18 Explorer. The driver and main function codes can be written in C, using MPLAB X v2.10 and the XC8 compiler v1.34. This can implement an electronic watch displaying the six basic time and date variables on the on-board LCD, including year, month, date, hour, minutes and seconds. There's a setup sequence that sets the six variables using the two pushbuttons on the evaluation board – S1 is the menu and S2 the increment key. At the same time the code shows the user how to configure and use the time-keeping registers.

Operation

The MCP795WXX is an SPI slave device connected to the MCU's SPI bus. The RTCC chip select is controlled by the GPO pin; it is selected by pulling CS low, then the 8-bit read instruction is transmitted to the MCP795WXX, followed by the 8-bit address. After the correct read instruction and address are sent, data stored in memory at the selected address is shifted out on the SO pin. Data stored in memory at the next address can be read sequentially by continuing to provide clock pulses. The internal address pointer is automatically incremented to the next higher address, after each byte of data is shifted out.

Since the RTCC registers are separate from the SRAM array, when reading the RTCC registers set, the address will wrap back to the start of the RTCC registers. Also, when an address within the SRAM array is loaded, the internal address pointer will wrap back to the start of the SRAM array. The read instruction can be used to read the arrays indefinitely by continuing to clock the device. The read operation is terminated by raising the CS pin. The spread sequence is shown in Figure 2.

For writes, since the RTCC and SRAM registers do not require the WREN sequence like the EEPROM, the user may proceed by setting the CS low, issuing the write instruction followed by the address and then the data to be written. As no write cycle is required for the RTCC and SRAM registers, the entire array can be written in a single command.

For data to be written to the array, the CS must be brought high after a whole byte has been clocked in. If CS is brought high at any other time, the last byte will not be written. Figure 3 shown a more detailed illustration of the write sequence.

The two main functions of the electronic watch are displaying the six time and date variables using microcontroller interrupts, and setting up the variables using the two on-board pushbuttons.

The display operation is performed on the on-board LCD in a 24-hour format. Real-time display of the variables continues as long as the menu key is not pressed. The action of the increment key has no effect on the watch continuously displaying time and date.

Pressing the menu key will start the setup menu, disabling the interrupts. The menu is covered once in the order year, month, date, hour, minutes and seconds. Going from one variable to the next is performed through the menu key, and incrementing a variable is performed through the increment key. The last action of the menu key exits the setup menu.

Entering the setup menu will not stop the oscillator of the RTCC. At the end of the setup, the time and date variables are updated. If the user enters the time-setup mode, all variables are written to the RTCC in the end of the sequence, even if no variables are changed. In this case, when exiting the menu, the watch will resume counting from the point where the setup was entered.

Delays And Drivers

Since the LCD controller needs some delays to process commands, a few auxiliary delays were created. Longer delays are used for keyboard debounce or as general-purpose delays. LCD drivers handle data, commands and strings when entered into the LCD. High-level LCD functions initialise or print the date and time to the LCD. The library also includes time and date global variables.

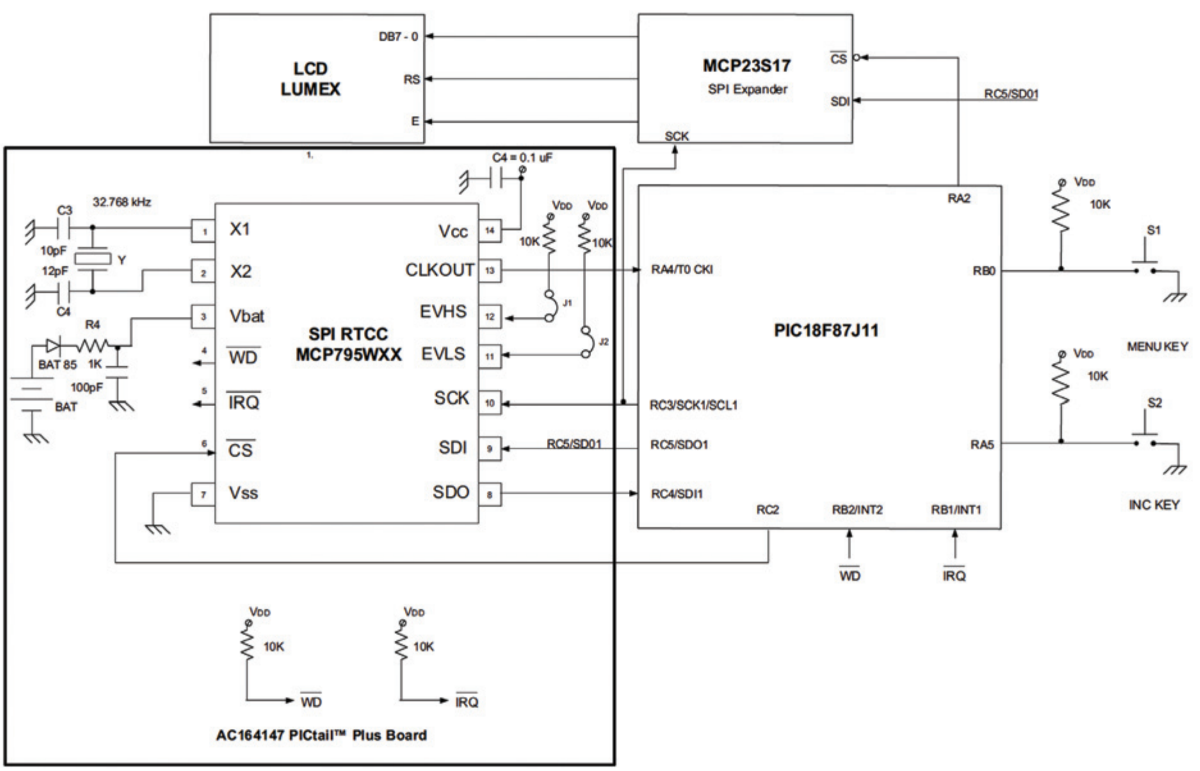


Figure 1: Schematic including a PIC18 Explorer and the AC164147 SPI RTCC PICtail daughterboard

RTCC drivers represent medium-level communications between the MSSP1 module of the PIC18 and the SPI RTCC. The related functions call the SPI drivers. Moreover, the library defines all necessary constants as registers, addresses and masks. The SPI drivers provide the low-level SPI communications with the RTCC and its functions are called by the SPI RTCC drivers.

The set of keyboard drivers has only one function. It awaits the selection of one of the two on-board switches: menu or increment key. After the selection is made, the firmware updates the code of the pressed key. Upon exiting the function, a value is returned, and the function performs a key debounce of 100ms twice. The function will exit only after the pressed key is released.

Interrupts are generated by the TMR0 overflow, which is initialised at 0xFFFF as a counter. Timer 0 is incremented once per second by the CLKOUT signal coming from the RTCC. The interrupt function calls the display time function, which reads the six related registers of the RTCC and puts them in the six global variables (year, month, date, hour, minute and seconds). The random byte access mode is used, since some versions of the application can use only a subset of the variables.

In the end, the interrupt function displays these six variables on the on-board LCD.

Configuration

The configuration of the RTCC includes two stages: RTCC initialisation and setting up the time-keeping registers. To initialise the SPI RTCC, the SPT RTCC drivers' header includes two initialisation functions: The first enables the battery through the VBATEN bit in the day register and sets the control register to disable the alarms and configure the MFP pin as a 1Hz square-wave. The second function tests the OSCON bit (day register). If the oscillator has already started, no action is taken. If the oscillator is not running, the time and date are set arbitrarily and the oscillator is started.

For setting up the time-keeping registers, the sequence can be found at the end of the main function; it updates the six time and date registers through the six time and date variables.

The use of time-keeping registers consists of reading and displaying them on the LCD. These two operations are performed by the display time function once per second in interrupts.

There are two basic functions for accessing the RTCC registers, one for writes and one for reads. Both use register addresses inside the SRAM zone of the SPI RTCC. According to these addresses, in the basic read and write functions only the register's address will differ. Reads are used in the interrupt function; writes are used in the initialisation function and the setup sequence. ●

Figure 2: Spread sequence

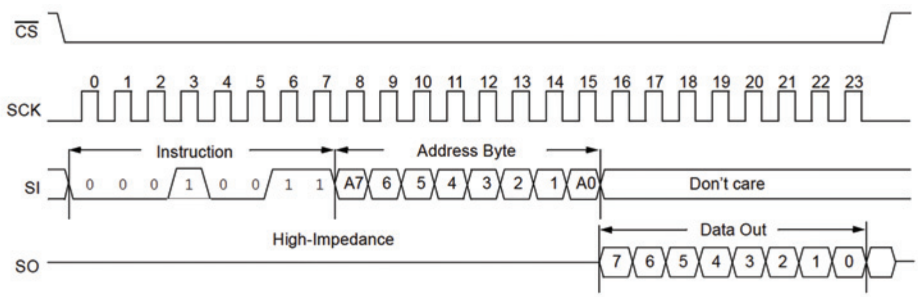
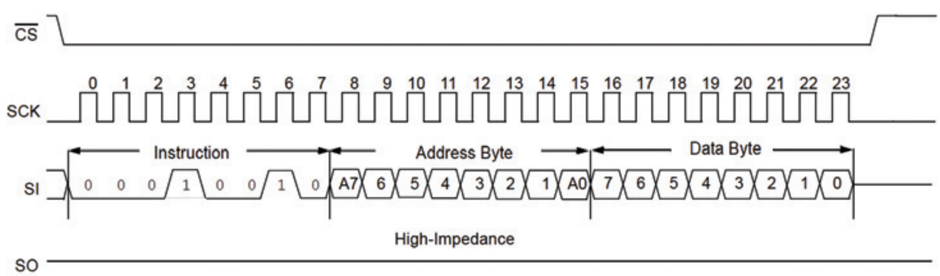


Figure 3: SPI write sequence



WATER RESISTANCE WILL DEMOCRATISE THE MOBILE PHONE INDUSTRY

BY **DR STEPHEN COULSON**, CTO, P2I

The hype surrounding the launch of iPhone 8 is a very good example of the attention a handful of devices can attract. Such mostly high-end devices are constantly the subject of discussion and speculation, but their new, industry-leading features will take years to filter down to the lower end of the market. Yet that section of the market holds the vast majority of models available to consumers today.

But why is this so? It's understandable that brand-new features take time and resources to develop, but they shouldn't be reserved for high-end devices alone. Water resistance is one such feature. Although it's been on the market for several years, it is yet to make its way into most of the mid- to low-tier models.

Figure 1: Corroded vs uncorroded (nano-coated) circuit board

Changing Expectations

Things are changing, however. As consumer awareness grows, demand for water resistance beyond premium products grows too. Clearly there's a need to protect devices from water – a leading cause of handset damage.

The demand for this feature is seen in consumer trends; recent research from market analysis firm IDC showed that the total number of devices shipped featuring water resistance increased 76% year on year in the first nine months of 2016, compared to 2015. Nevertheless, until recently, most manufacturers have not embraced innovation to help solve this problem. The mechanical options available to protect from water ingress are very expensive, and yet the technology already exists to unlock this feature for the rest of the market.

Barriers To Democratisation

There are several barriers to using technology that protects smartphones against water ingress in the lower tiers of the market. One is that they are mostly made of plastic, compared to high-end models. Water-proofing methods such as an O-ring within the phone require high-strength materials to make the phone as rigid and effective as it needs to be, and plastic lacks that. More expensive devices have a more suitable metal frame, with the rigidity to create a watertight seal. In addition, this approach limits device aesthetics, affecting its desirability, further reducing the novelty and differentiation factors.

Another barrier is the time it takes to add water-resistance technology to a device. Typically, implementing a water-resistant solution can add 1-2 months to the testing cycle and, if it fails the tests, even longer, which is not acceptable to manufacturers of mid-to-low-tier devices.

Finally, there's the associated cost due to the increased engineering, hardware and design a mechanical solutions may require. Unfortunately, mechanical solution like gaskets and seals just aren't an affordable solution for most of the market, so they are replaced with something else for the mid- to low tiers.

Driver Of Change

Device reliability and its guarantee of quality are universal values for manufacturers and consumers alike. And it is not just high-end phone consumers who demand quality, one facet of which is water resistance. This is where non-mechanical, nano-coating solutions can help. They can be applied to all types of devices, easily integrated into various manufacturing processes. Nano-coating not only protects the whole device regardless of the materials used, but as the process is refined, the time needed to coat devices decreases. Higher volumes drive the economies of scale, and savings can be passed on to the rest of the market, making these solutions more attractive to the lower tiers.

Trickling Down Trends

We can find a similar evolutionary story in Internet access from mobile phones. Just ten years ago only a small number of devices had this feature, leveraging the then-available 3G networks and advanced wireless network capabilities. Blackberry handsets, for example, had email functionality as standard before any other, but the market soon matured to the state we now recognise as the norm, with email and Internet browsers pervasive across all types of smartphones.

The story of water resistance is comparable. Memorable milestones include Motorola advertising the water resistance of its Droid Razr models as long ago as 2011, and, since then, more manufacturers have jumped on board. Once the likes of Apple and Samsung launched their top-end water-resistant range, interest grew industry-wide and the ball started rolling.

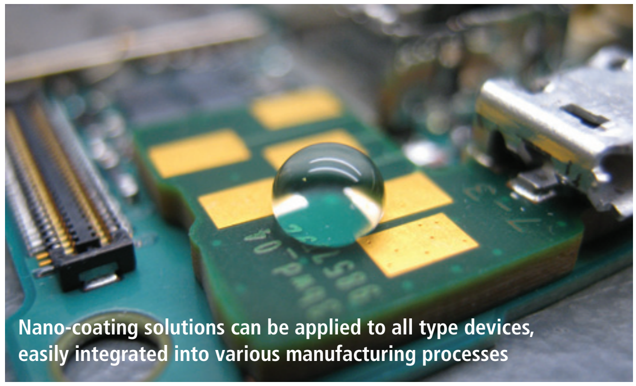
This demand is becoming just as prevalent in emerging markets such as Southeast Asia and South America as in Europe and the US, influenced by factors such as humidity in the climate of these regions, making improved water resistance crucial. Here, manufacturers will need to find ways to bring cost-effective solutions to consumers, and consider that devices will need to be protected against all kinds of liquids. Sweat, for instance, is significantly more corrosive than water and can cause long-term damage to a device, so it must be accounted for.

> "Nano-coating offers many benefits to OEMs, alongside being an inexpensive solution at multiple price-points

As consumer wealth grows in countries such as India and Brazil, low-cost water resistance technologies are being rapidly adopted.

Looking Ahead

In an age where consumers are perpetually switched on and increasingly reliant on mobile Internet access for work and their personal lives, smartphones must meet that demand. The growth of IoT technologies and the imminence of 5G networks means there will undoubtedly be a natural evolution of all products and features within the smartphone industry. Water resistance will be one, becoming widely adopted across the industry.


Nano-coating solutions can be applied to all type devices, easily integrated into various manufacturing processes


Nanocoating helps prevent water damage

Nano-coating offers many benefits to OEMs, as an inexpensive solution that provides a strong ROI at multiple price-points, and one that can be applied to an entire range of devices. These coatings can democratise the industry in terms of water resistance, and can provide the mass market with this highly-needed feature, as well as reduce the cost to the network and therefore the sector as a whole.

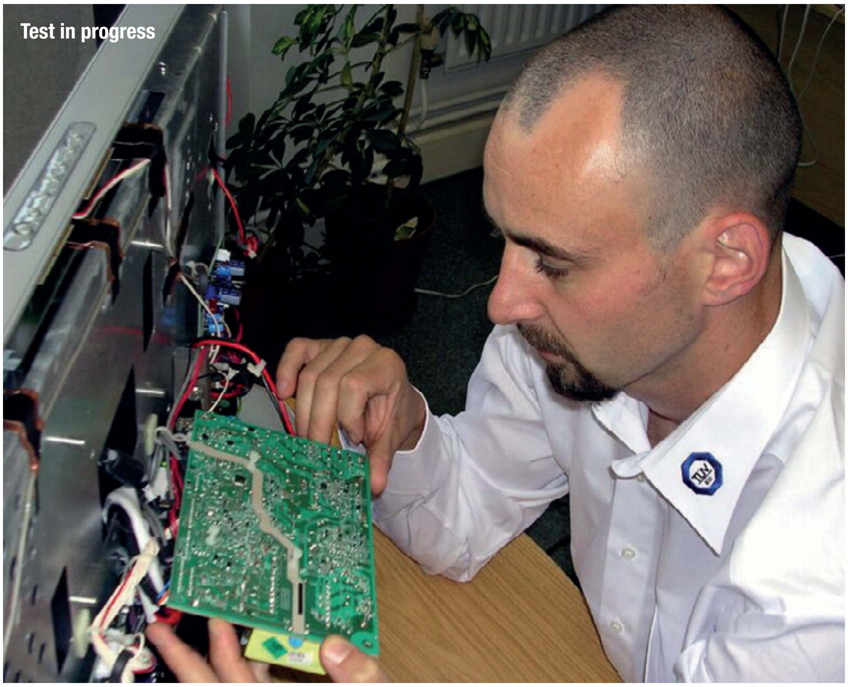
We have reached a stage where smartphones are no longer aesthetically varied, so features become an increasingly important differentiator for their makers. Water resistance should be and will be an essential part of a smartphone's DNA, to last for decades to come. ●

REDUCING RISK IN PRODUCT DESIGN AND DEVELOPMENT

BY **JEAN-LOUIS EVANS**, MANAGING DIRECTOR OF TÜV SÜD PRODUCT SERVICE, A GLOBAL PRODUCT TESTING AND CERTIFICATION ORGANISATION, AND ITS SISTER COMPANY, TÜV SÜD BABT, RADIO AND TELECOMMUNICATIONS CERTIFICATION BODY

While technology evolves rapidly, traditionally, test standards develop much more slowly. Incorporating risk management in the design and production process aims to reduce this disconnect, and all European product directives (Radio Equipment, EMC, Low Voltage, etc.) and the conformity assessment process now require risk management.

Nevertheless, most designers and manufacturers are confused about the subject, and many see costs rather than product improvements associated with it. This is further exacerbated by the fact that there's no explicit description of the risk assessment process within the standards, but is instead referenced in the European Union's (EU) New Legislative Framework (NFL).


Test in progress

NFL

The NFL was created to improve the conditions in the European market through better market surveillance and quality of conformity assessments, and clarification of the use of the CE marking. According to the European Commission (EC), the NFL:

- Sets clear and transparent rules for the accreditation of conformity assessment bodies;
- Boosts the quality of and confidence in the conformity assessment of products through stronger and clearer rules on the notification of conformity assessment bodies;
- Clarifies the meaning of CE marking and enhances its credibility;
- Establishes a common legal framework for industrial products in the form of a toolbox of measures for use in future legislation. This includes definitions of terms commonly used in product legislation and procedures to allow future sectorial legislation to become more consistent and easier to implement.

The EC's Blue Guide on the implementation of EU product rules is a useful reference to understand all the directives, regulations and decisions combined within the NFL.

Risk Analysis

Risk assessment can be presented in any format, but it is important to remember to keep it simple, so that the focus remains on showing equipment compliance. However, there is a minimum amount of information that should be included for a risk assessment to be considered adequate. It should primarily concern the intended use of the product as outlined in its instructions, and its reasonably foreseeable use. "Foreseeable use" is quite subjective, so a reasonable consideration should be made according to the product type, its intended environment and end user.

The risk management process must be used throughout the design process and product realisation to determine whether a certain requirement is applicable or not, whether an alternative requirement can be substituted, and if it can be satisfied with alternative test criteria or procedures. It is essential that any new product risk is first assessed and then tested to meet the standard.

An adequate risk analysis and assessment should cover:

- Product definition – identify functions and features, together with labelling information and instructions for use. Associated accessories or components should also be identified;

- Risk identification – identify the hazards and the subjects at risk;
- How the hazard may harm those subjects;
- The potential harm;
- The likely severity of harm – the foreseeable level of harm to the subject and probability must be assessed to determine the level of risk;
- Risk reduction/mitigation – demonstrate how the individual risks are controlled;
- Controlled risk evaluation – once risks have been reduced, re-evaluate the risk level.

Assessing Risk

Risk is a combination of the probability of occurrence of harm and the severity of that harm. A commonly-used approach to determine risk level is to issue a number as a weighting for each probability risk and then multiply that by the possible severity. However, it is important to remember that this is not just a simple multiplication, since multiplying the numbers is not always reliable and a certain amount of common sense should be used. It is therefore important not to just accept the final risk level, but review its likelihood as part of the risk management process, and adjust for it if necessary.

For existing products, as part of the risk management process it is worth using historical user data such as failure and accident rates, customer complaints and warranty returns. For a new product similar to one already on the market, ideally the new data should be benchmarked against the old.

The risk analysis and assessment should include the identification of applicable essential requirements and the selection of appropriate harmonised standards, or other specifications as risk-reduction measures. The assessment should also include a conclusive statement that confirms the product's overall compliance.

Continuing Process

Risk assessment should be instigated at the start of the conformity assessment process, not at the end, as manufacturers may have done previously. Compliance risk management must be a continuing process and the manufacturer must re-assess the risks with every product modification. Where compliance is shown to be affected, the subsequent risk controls should be established and documented in the technical file before updating the declaration of conformity and/or EU-type examination certification, as appropriate.

While individual standards do not contain explicit descriptions of the appropriate risk assessment process, two useful reference documents exist as a guide: *'ISO 31000:2009 – Risk Management Principles & Guideline'* is the 'bible' of risk assessment since it details best practice, while *'EN 31010:2010 – Risk Assessment Techniques'* delivers a detailed overview of what methods can be applied in a risk-assessment scenario.

Buyer Loyalty

Not only does the risk assessment process ensure that products meet regulatory requirements, it reduces the potential for costly non-compliance, requiring product re-designs and re-testing and cause significant time-to-market delays for new and upgraded products.

If a buyer is loyal to a brand, it means they will always go back to it, or at least consider it first. Provided the service and product quality are maintained, it is unlikely that brand-loyal customers will consider alternative suppliers.

The features and characteristics of a product determine its desirability, and if they do not degrade and the product continues to fulfil its purpose when exposed to a range of adverse conditions, a lasting belief is formed in the product's quality. Risk assessments can therefore help strengthen a brand's competitive position in the market due to improved product performance and reliability, by reducing the chance of failures. Thus, the two key drivers, brand loyalty and product quality, are both beneficially influenced by such an approach.

While risk assessment is a vital part of product development, every risk and associated risk-reduction measure are not always adequately documented. Along with compliance with CE marking requirements under the NFL, effective risk assessment enables designers and manufacturers to quickly foresee any potential problems early in the product development process. Implementing such risk-reduction measures is a key part of ensuring that products are both reliable and safe to use. ●

Testing a power supply

NEW ITX BOARDS WITH INTEL'S APOLLO LAKE PROCESSORS

congatec has introduced the new conga-PA5 Pico-ITX single board computer (SBC) and the conga-IA5 Thin Mini-ITX motherboard, two industrial-grade computing platforms featuring the latest Intel Atom, Celeron and Pentium processors, codenamed Apollo Lake.

System engineers can immediately use these boards to upgrade existing Pico-ITX and Mini-ITX designs and benefit from approximately 30% more processing power and 45% more graphics performance compared to previous generations. With improved performance, they are suitble for small-sized handheld devices, box PCs and IoT gateways, industrial-grade Thin Clients, slim HMIs and low-power GUIs, among others. Markets can be found in smart homes and smart cities, digital signage and retail, medical technology, gaming and industrial automation, as well as in shop floor and logistic systems.

The new conga-PA5 Pico-ITX SBCs and conga-IA5 Mini-ITX motherboards feature impressive security enhancements and improved real-time computing capabilities.

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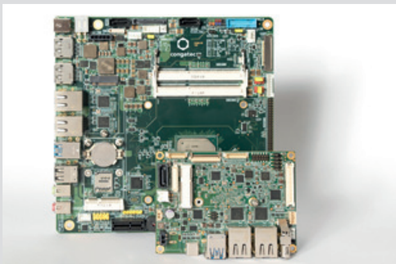

A NEW PACKAGE FOR THE TWO-WIRE, ZERO SPEED DIFFERENTIAL WHEEL SPEED SENSOR IC

Allegro MicroSystems Europe has announced a new package offering for the wheel speed sensor product family. The package includes an optimised Hall-effect integrated circuit (IC), rare-earth pellet, and high-temperature ceramic capacitor in a single overmoulded package. The fully-integrated solution reduces the need for external EMC protection and integration of a magnetic circuit, reducing manufacturing complexity.

Allegro's ATS688LSN provides a user-friendly solution for true zero-speed digital gear tooth sensing in two-wire applications, such as automotive or two-wheeler braking systems. The single integrated circuit and magnet combination incorporates a dual element Hall-effect sensor IC and signal processing circuitry that switches in response to differential magnetic signals created by a rotating ferromagnetic target. The device contains a sophisticated compensating circuit to eliminate magnetic and system offsets. Digital tracking of the analogue signal is used to achieve true zero-speed operation.

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