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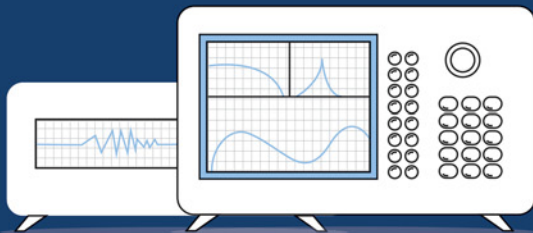
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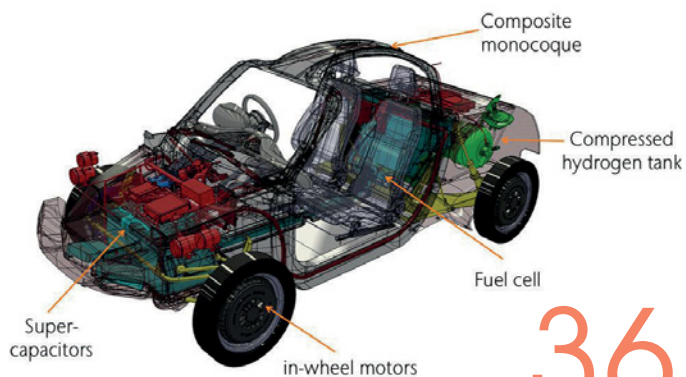
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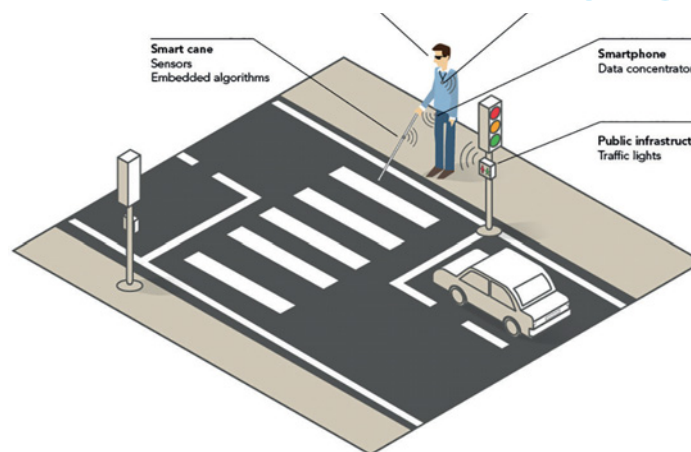
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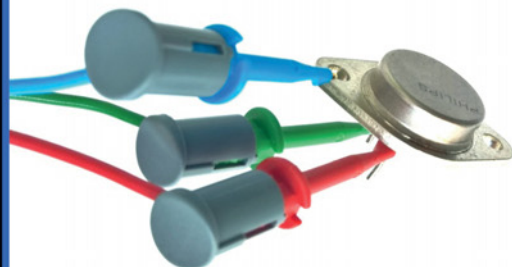


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Current gain $h_{FE}=67$ +	Current gain $h_{FE}=117$ +	Diode protection between C-E +	Gate Threshold $V_{GS}=3.47V$ +	RED GREEN BLUE Anod Cath +
Test current $I_C=2.50mA$ +	Test current $I_C=2.50mA$ +	Current gain $h_{FE}=9124$ +	Test current $I_D=2.50mA$ +	Forward voltage D1 $V_F=1.983V$ +
Base-Emitter V $V_{BE}=0.293V$ +	Base-Emitter V $V_{BE}=0.711V$ +	Test current $I_C=2.50mA$ +	Diode or diode junction(s) +	Test current D1 $I_F=3.223mA$ +
Test current $I_B=4.981mA$ +	Test current $I_B=4.583mA$ +	Base-Emitter V $V_{BE}=1.321V$ +	RED GREEN BLUE Anod Cath +	Pinout for D2 +
Leakage current $I_C=0.027mA$ +	Leakage current $I_C=0.000mA$ +	Test current $I_B=3.720mA$ +	Forward voltage $V_F=0.694V$ +	RED GREEN BLUE Anod Cath +
		Leakage current $I_C=0.000mA$ +	Test current $I_F=4.663mA$ +	Forward voltage D2 $V_F=1.927V$ +
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PLASTIC ELECTRONICS INNOVATIONS ARE GETTING COMMERCIAL

Imagine an ultra-thin smartphone that can wrap around the wrist, or a bio-tattoo that monitors vital statistics and alerts medical professionals when they deviate from normal. Following a comprehensive study, InnovationDB, the world's largest licensable-IP technology database, has concluded that these innovations are on the brink of entering the commercial stage.

Plastic or organic electronics use organic semiconducting materials as opposed to the inorganic materials found in conventional electronic devices. Plastic electronics enable circuits to be deposited or printed onto almost any surface – rigid or flexible, substrate or plastic.

Organic semiconductors are broadly divided into two groups based on their molecular weight: small-molecule and polymer. Semiconducting small molecules are polycyclic aromatic compounds, including pentacene and rubrene. Polymers are molecular chains with a regularly repeating structure, including polyacetylene, poly (p-phenylene vinylene) (PPV) and its derivatives. Semiconducting polymers form thin films with large surface areas, giving this group a wider range of potential applications, while small molecules offer superior control over charge transport.

Plastic electronics excel over conventional electronics in offering low-cost, low-waste, low-energy-consumption manufacturing, with novel physical properties and sustainability. Although they don't have a "killer" application they help generate new, innovative products and improve a myriad of existing goods, explaining the demand across many sectors. They will not replace conventional silicon electronics, but rather supplement and complement existing efforts to expand product functionality in areas where conventional devices have failed to secure market traction, creating new market opportunities.

Research house IDTechEx estimates the total market for plastic electronics will grow from \$26.5bn in 2016 to \$69bn in 2026 with application areas such as:

- **Organic Light-Emitting Diodes (OLEDs):** The most established sector in the plastics electronics industry, OLEDs use organic semiconductors to create a thin light-emitting panel. OLEDs generate light via electroluminescence, removing the need for a backlight, increasing energy efficiency over conventional LEDs. OLEDs have appeared commercially in some smartphone screens and TVs since 2013. Other uses include:
- **Wearable devices:** Lightweight and high definition, OLEDs are an ideal

“ Spray-on solar paint using OPV technology has hit the market with Mercedes-Benz using a multi-voltaic silver paint

candidate for micro-displays in virtual reality headsets. Fraunhofer FEP has integrated image sensor capabilities into micro-displays monitoring eye movements, potentially allowing patients with degenerative diseases to use eye movements to convert pre-composed text to speech.

- **Smart contact lenses impregnated with OLEDs:** Google, Samsung and Sony are investing in this technology for applications including blood glucose level monitoring, augmented reality and vision correction/enhancement.
- **Organic Thin-Film Transistors (OTFTs):** Most organic transistors are OTFTs. These devices are easier to fabricate than traditional silicon-based transistors, since OTFTs can be printed on plastic or flexible substrates at room temperature.
- **Biomedical sensors and electronic skin:** Ultra-stretchy and ultra-thin material, mimicking the flexibility of skin and capable of self-healing under heat application. Special coating keeps out oxygen and water vapour so it can work for several days, as opposed to the hour-long lives of previous e-skin attempts.
- **Organic PhotoVoltaic (OPV) or Organic Solar Cells:** OPVs could vastly improve solar cells due to their flexibility, large-area coverage and low-cost manufacturing techniques.
- **Organic solar cars:** Entire cars coated in solar cells are not yet available commercially, but spray-on solar paint using OPV technology has hit the market, with Mercedes-Benz using a multi-voltaic silver paint on its G-Code concept car.
- **Wearable organic solar cells:** Flexible organic solar cells woven into fabric developed by scientists in China in 2014 enabled the possibility of plugging smartphones into coats to charge.

The plastic electronics sector faces many economic, social, technological, legal and environmental challenges. However, the industry's cautious approach in changing manufacture, design and implementation will enable the industry to survive and futureproof itself. Ultimately, plastic electronic devices are an inevitable outcome in our future.

By Gerald Law, CEO of Innovation DB (www.innovationdb.com)

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LETI PROJECT WILL ADAPT AUTONOMOUS-CAR OBSTACLE-DETECTION TECHNOLOGY FOR PERSONAL USE

Leti, a technology research institute in France, is working on developing a multisensor and low-power spatial-exploration and obstacle-detection system for personal wearers, with further uses in robotics, drones and smart manufacturing.

Obstacle-detection technology is typically used in autonomous cars but Leti plans to make it portable and wearable for the visually-impaired and blind.

Called INSPEX, it will be used for real-time, 3D detection, location and warning of obstacles in all

weather and visibility conditions, such as smoke, dust, fog, heavy rain/snow and darkness, and in indoor and outdoor environments with unknown stationary and mobile obstacles.

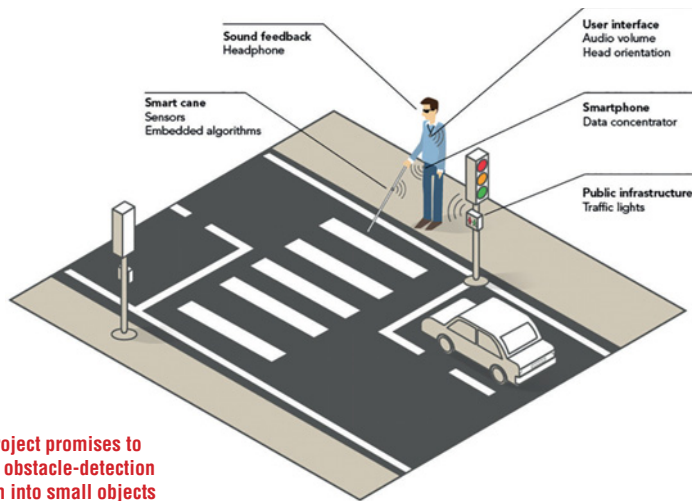
The system will be based on state-of-the-art sensors including LiDAR, UWB radar and MEMS ultrasound. It will miniaturize and reduce the power consumption of these sensors, and then integrate them with an inertial measurement unit, environmental sensing, wireless communications, signal-and-data processing, power-

efficient data fusion and user interface, to operate in wider smart- and Internet-of-Things environments.

In addition, the INSPEX system is planned for human mobility – first responders, or disabled persons; instrumentation – distance-measuring tools; smart homes and factories – assembly machines; and security surveillance systems.

Initially, the INSPEX demonstrator will integrate the mobile detection device into a white cane for the visually-impaired. For this application, an augmented reality (AR) audio Interface will be integrated to provide spatial 3D sound feedback using extra-auricular earphones. This feedback will take into account head attitude, tracked by an AHRS in the headset, to provide 3D spatial sound feedback of an obstacle's real-time direction and range. The context-aware communications will integrate the user with wider smart environments, such as smart traffic lights, navigation beacons and ID tags associated with IoT objects. The user's mobile device will allow integration with apps, such as mapping, for example.

The project is also supported by other European universities and organisations. "It is a strong example of European innovation to bring leading-edge technology to a broader segment of users," said Suzanne Leseq, project coordinator at Leti.



Leti project promises to install obstacle-detection system into small objects such as a walking cane

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THE WORLD'S THINNEST WALL CHARGER CLOSER TO COMPLETION THANKS TO \$1.2M FUNDING

Israeli start-up Kado, which is developing a new ultra-thin charging technology, has raised \$1.2m to help it complete development of the world's thinnest wall charger.

Kado has unveiled two ultra-thin chargers: one for smartphones and tablets, and one for laptops, which is also the world's first ever foldable charger.

According to research data, smartphone

users own an average of two chargers per person, which are largely bulky and cumbersome. Kado's entrepreneurs have developed a power-conversion technology with high levels of power density and utilisation that they claim sets a new standard for compact and extremely-thin chargers and transformers, suited for today's mobile lifestyle.

"Kado's vision is to release users from the vicious cycle of the inverse relationship in which smartphones and tablets need faster charging to increase their mobility, which ironically leads chargers to be more cumbersome and less mobile," said Itay Hasid, Kado co-CEO.

Kado Wallet, the company's ultra-thin charger for smartphones, is just 5mm thin, and can be carried in a wallet, a purse or a pocket. It also includes a unique cable mechanism.

The 21-gram Kado Wallet supplies up to 10W and can also charge different devices, including tablets, cameras, wireless speakers and headphones.

Kado Sleeve for laptops, the world's first ever foldable charger, weighs only 97 grams and provides up to 70W. It has two USB ports for simultaneously charging a laptop and a smaller device.

Kado is developing additional products and peripherals, such as dedicated cables, covers and other modular items to complete its unique charging portfolio. Its products will be launched first in the US, then Japan and Europe.

The world's thinnest wall charger can be carried in a wallet or a purse



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HDO-A Oscilloscopes

Teleadyne LeCroy introduces the HDO4000A, HDO6000A, HDO8000A, and MDA800A analog and mixed-signal oscilloscopes. These four high-definition oscilloscope product lines range from 200 MHz – 1 GHz bandwidth and utilize 12-bit HD4096 technology on up to 8 analog channels. This technology arrived in 2012 and remains unique in the market place. Today's announcement takes these ground-breaking products to new levels of measurement capability. HDO-A oscilloscopes feature Enhanced Sample Rate technology that automatically ensures optimal display of acquired waveforms to the instruments' full rated bandwidth. Additionally, the next-generation MAUI® with OneTouch user interface makes measurement setup insanely easy and provides users dramatically faster time to insight when debugging complex signal abnormalities. Lastly, the updated PC systems with faster processors, more CPU memory, and solid-state drives add even more value. With the HDO-A introduction, the world's highest definition oscilloscopes become even more powerful and productive with 10x oversampling up to 10 GS/s on all models, the most efficient and intuitive user interface, and a supercharged PC system..

HDO4000A, HDO6000A, HDO8000A, and MDA800A Provide Application Excellence

All HDOs are ideal for debugging and troubleshooting power electronics, automotive electronics, and embedded/mechatronic designs with high-resolution sensor signals. They are the favored oscilloscopes in automotive, digital power management, power integrity, physics, and military/aero applications. The eight channels provided by the HDO8000A series are ideal for high

power and/or three-phase power conversion testing and digital power management validation. MDA800A Motor Drive Analyzers, which are built on the HDO8000A platform, also perform three-phase electrical and mechanical power calculations with unique static and dynamic power views as well as complete control system validation.

HDOs owe their high performance to bandwidths up to 1 GHz, acquisition memory of up to 250 Mpt/ch, and 12-bit vertical resolution. There are also mixed-signal oscilloscope (MSO) options/models. All HDOs offer an extensive array of serial trigger, decode, measure/graph, and eye diagram (TDME) options. All of the above, coupled with many other general-purpose and application-specific probes and software options, have made the HDOs an industry favorite.

HD4096 12-Bit Technology

HD4096 High Definition Technology finds its roots in high-sample-rate 12-bit ADCs, high signal-to-noise ratio amplifiers, and low-noise system architecture. This technology enables HDO-A oscilloscopes to capture and display signals of up to 1 GHz at 16 times more resolution than other oscilloscopes. In the HDO-A oscilloscopes, HD4096 technology is augmented by Enhanced Sample Rate technology, which automatically ensures optimal display of acquired waveforms to the instruments' full rated bandwidth.

16x More Resolution Combined with High Sample Rate and Long Memory

12-bits of vertical resolution provides sixteen times more resolution than 8-bits. The 4096 discrete levels reduce the



quantization error. Signals captured with lower resolution oscilloscopes have a higher level of quantization error resulting in less accurate waveforms on the display. Signals captured on an oscilloscope with 12-bit HD4096 technology are accurately displayed with minimal quantization error.

With up to 250 Mpts of memory the HDO-A High Definition Oscilloscopes can capture large amounts of data with more precision than other oscilloscopes. The 10 GS/s, 250 Mpts architecture provides the ability to capture a fast transient or a long acquisition.

- A** Clean, Crisp Waveforms - When compared to waveforms captured and displayed by 8-bit oscilloscopes, waveforms captured with HD4096 technology are dramatically crisper and cleaner. Oscilloscopes with HD4096 acquire waveforms at high resolution, high sample rate and low noise to display the most accurate waveforms.
- B** More Signal Details - Signal details often lost in the noise are clearly visible and easy to distinguish when captured on oscilloscopes with HD4096. Details which were previously difficult to even see can now be easily seen and measured. Using the oscilloscope zoom capabilities gives an even closer look at the details for unparalleled insight to the signals on screen.
- C** Unmatched Measurement Precision - Precise measurements are critical for effective debug and analysis. HD4096 enables oscilloscopes to deliver unmatched measurement precision to improve testing capabilities and provide better results.

MAUI with OneTouch Gesture Control

All HDO-A oscilloscopes feature MAUI with OneTouch, which extends Teledyne LeCroy's long tradition of user-interface innovation. MAUI with OneTouch optimizes convenience and efficiency by enabling all common operations with a single touch of the display. This user interface has revolutionary drag-and-drop actions to copy and set up channels, math functions, and measurement parameters without lifting a finger. Common gestures such as drag, drop, pinch, and flick facilitate instinctive interaction with the oscilloscope. The "Add New" button quickly enables a new channel, math, or measurement while traces and parameters turn off with a flick of a finger. In sum, MAUI with OneTouch delivers a unique set of touchscreen gestures that simplifies measurement setup and brings unsurpassed efficiency and intuitiveness to oscilloscope operation.

Exceptional Serial Data Analysis

Teledyne LeCroy offers a broad variety of optional software packages to equip HDO-A oscilloscopes for all serial data test requirements ranging from automated standards compliance packages to flexible debugging toolkits. A suite of protocol-specific measurement and eye diagram packages provides unparalleled insight into serial data anomalies. These unique packages complement the industry's most powerful trigger/decode software providing the ability to extract decoded data and plot over time, perform bus timing measurements, and create eye diagrams for testing against standard or custom

masks. The 16 digital lines in mixed-signal models can be used for trigger, decode, and measurements for analyzing timing irregularities or for general-purpose debug of digital designs. This allows analog channels to be reserved for observing physical layer defects.

Very Powerful, Deep Toolbox

The standard collection of math, measurement, debug, and documentation tools provides unsurpassed analysis capabilities. Application-specific packages enable streamlined debugging for common design/validation scenarios. The advanced customization option enables user-defined parameters and math functions providing unique and limitless analysis capability.

Teledyne LeCroy's 50+ year heritage has its origins in the high-speed collection of data in the field of high-energy physics, and the processing of long records to extract meaningful information. We didn't invent the oscilloscope, but we did invent the digital oscilloscope, which can take full advantage of advanced digital signal processing and waveshape analysis tools to provide unparalleled insight.

Teledyne LeCroy provides more powerful, more unique, and more standard tools than any other oscilloscope company, and much of what is now "standard" in competitive products originated at Teledyne LeCroy. Our tools and operating philosophy are standardized across much of our product line for a consistent user experience from 200 MHz to 100 GHz. Our MAUI advanced user interface makes the tools easy to access, use, and combine in powerful ways to solve unique problems.

Advanced Customization

With the XDEV option, third party programs can be completely integrated into the oscilloscope's processing stream. Create customized math functions and parameters using C/C++, MATLAB, Excel, JScript or Visual Basic without leaving the oscilloscope application - and view the results directly on the oscilloscope, in real-time.

teledynelecroy.com

HDO A oscilloscopes now combines Serial Bus Trigger, Decode, Measure/Graph, and Eye Diagrams





In 1kB of RAM

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

These days, when programming on a desktop computer, even when targeting a mobile platform, it is easy to assume that memory is simply unlimited. Our mind is otherwise unable to process the immensity of a resource that is measured in gigabytes. I am not talking about mass-storage; I refer instead to the random access memory (RAM) available to load and run an application.

The quest for huge RAM devices has been among the greatest forces driving the semiconductor industry. RAM chips have literally been driving the development of the most extreme CMOS geometries, with multi-billion-dollar investments in new factories around the world.

As we often claim, though, in the embedded world things are different! Flash and RAM memory development have to be balanced by reasonable constraints in power consumption, operating voltages and I/O drive capabilities.

Why Is RAM Expensive?

I won't go into historical details trying to explain the origin of the acronym RAM, but we need to distinguish between the two fundamental types of RAM memory cells available today: dynamic RAM (DRAM) and static RAM (SRAM). The distinction lies in the particular logic circuit used to implement each single bit in a memory cell.

In SRAM, the cell is implemented using six MOSFET transistors; see Figure 1. This is essentially a flip-flop circuit and its state (Q) is what holds the data bit.

In DRAM, each memory cell is implemented using a much simpler circuit that requires a single MOSFET transistor, as shown in Figure 2. A single MOSFET transistor is used for each memory cell, and the capacitive element is obtained from the (parasitic) gate capacitance of a normal MOSFET transistor, shown in grey in Figure 2. The actual information bit is stored as charge in that capacitor.

The 'D' in the DRAM acronym is an attempt to put a positive spin on what is in reality the greatest drawback of this type of RAM circuit: it's volatile. Unless the memory contents are refreshed, they disappear after a few milliseconds. This particular feature makes DRAM highly unsuitable for most embedded control applications where a periodic refresh of the memory contents is incompatible with the real-time nature of the application and/or limited power budgets. So SRAM is preferred at the cost of the much larger silicon area required to implement each bit and the accordingly higher price tag. As a result, a RAM array is often the single largest/most-expensive module present in a modern microcontroller die.

At this point, it is interesting to note that even flash memory is implemented using a somewhat similar charge-storage mechanism, although that requires higher voltages and a custom CMOS process, including numerous additional layers to provide the necessary isolation.

Effects Of RAM Scarcity

Many cite RAM scarcity as a key factor in adopting modern programming languages in the embedded space; some say that RAM scarcity was holding back even the adoption of C compilers until only a few years ago.

Today, the same arguments are applied to the relatively slow adoption of C++, and even slower adoption of other object-oriented and/or functional programming languages that are readily used in the mainstream computing world. In fact, languages such as Java, Javascript, Go, Python and Lua rely on an abundance of RAM. They generalize their systems treating every variable as an object; maintain type information

“ The quest for huge RAM devices has been among the greatest forces driving the semiconductor industry **”**

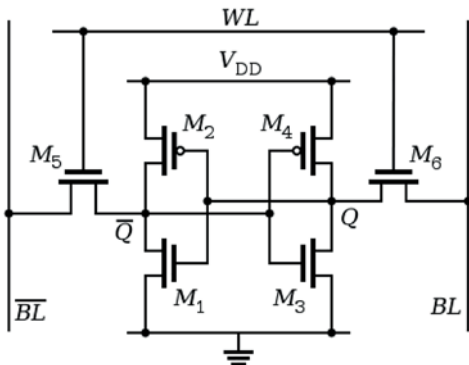


Figure 1: SRAM Cell

at run-time to allow introspection and dynamic typing; and extensively use dynamic memory management with automatic garbage collection. In reality, all of them have already been ported and demonstrated on modern microcontrollers; however, their application has been limited to the largest architectures and the available microcontroller models. It's a pity, because the productivity and superior versatility of those languages could have a great impact on the entire embedded industry.

Doing More With Less

Since most high-volume applications can't justify the waste of large amounts of RAM, embedded control designers are constantly challenged to make the most of what they have. Fortunately, in many applications the actual minimum amount of RAM required can be much smaller than what's used in reference (desktop) applications, where RAM scarcity never applies. A bit of ingenuity and the willingness to dig deeper are two important traits of a successful designer who attempts to port mainstream code to the constrained world of microcontrollers.

Audio Playback In Less Than 1kb RAM

Going back to a project I introduced in a previous instalment of this series, I will make an example out of the (smallest) SD-card audio (WAV) player project. Whereas previously I focused on the code size reduction challenge, here I will describe the reasoning that allowed a dramatic reduction of RAM usage.

As you may know, data on an SD card (or any hard disk for that matter) is split into chunks known as sectors, each 512 bytes large. This is an archaic rule that goes back to the early days of eight-inch floppy disks, and holds true today across all operating and file systems.

Any application expected to play back audio files has to rely on a file system which, in turn, allocates at least one buffer of that size. In fact, most file I/O libraries make use of two such buffers: one for the actual data read/write and one for

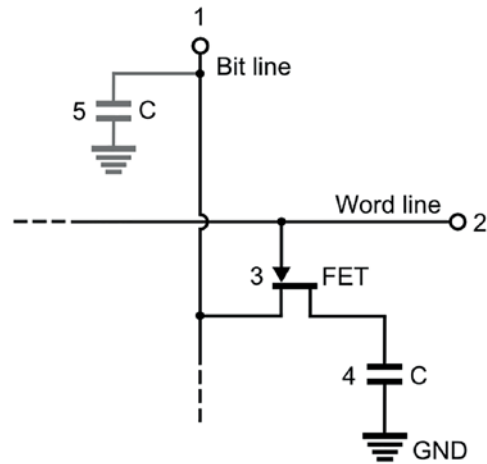


Figure 2: DRAM cell

access and caching of the file allocation tables (FATs). Files are fragmented and scattered in a non-sequential order throughout a typical mass-storage device. FATs, or similar structures, are required to maintain a linked-list of the sectors composing each data file.

But there's more: Since retrieving data from a mass-storage device is not guaranteed to happen in a fixed and deterministic time, it is common to use an additional buffering mechanism to play back the audio without introducing noticeable artifacts, such as gaps and clicks. As an example, if a single-sector read from the above-mentioned SD card requires a maximum of T_{reads} (ms), a sufficient number of audio samples must be buffered to maintain continuous play for at least two such read operations.

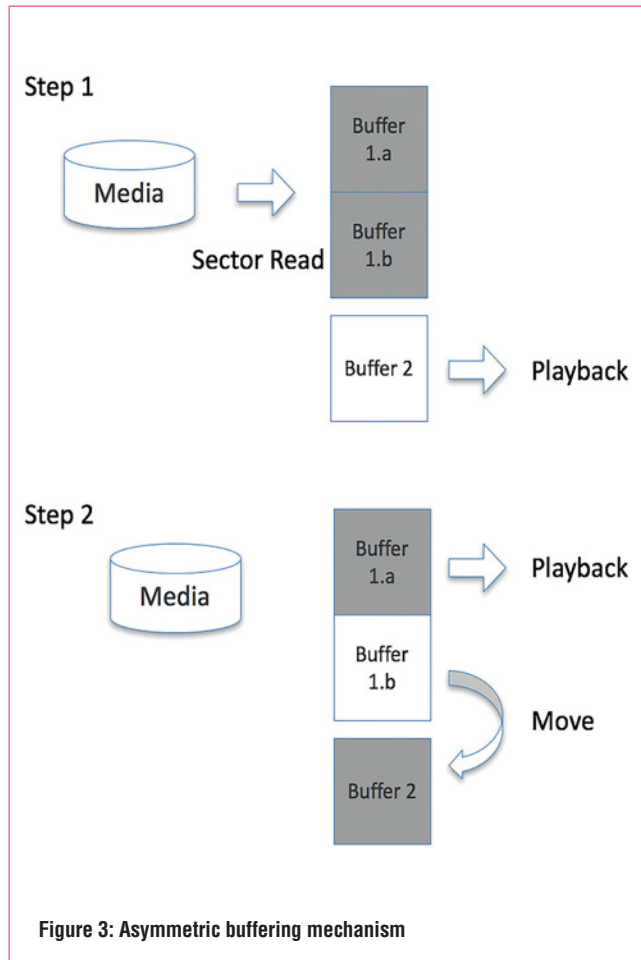
Even assuming a well-optimized embedded file system and a fast SD card access mechanism (SPI interface of sufficient clock speed), we'll end up using a grand total of at least four 512-byte buffers or 2kB of RAM.

Achieving The Impossible

If 1kB of RAM is all we have available in a chosen microcontroller model, such as a PIC16F1619 in the specific project example, including all the application stacks and global and local memory space, the proposition would seem impossible.

But, if we re-evaluate some of the assumptions hidden in the previous presentation of the problem, we can see how the impossible can be achieved.

- 1) File system libraries are designed for most generic uses, where data can be retrieved from a file, possibly a single byte at a time. The audio player application, though, is a very special case: We can – and should – always attempt to retrieve entire sectors at once. Not only does



this dispense with much of the logic required to keep track of the location of data within a sector, but it can altogether eliminate the file system data buffer. Instead of copying from media to a (file system) buffer, and then to the application buffer, we can and should simply move data directly from the media into the application-provided (audio) buffer.

- 2) The second assumption – made during the design of a file system – is that the greatest possible (average) access speed is desirable. Once more, in an audio playback application this is simply not true. Receiving data on time is important, but receiving data early is actually of no benefit. Audio playback is based on the steady consumption of samples over time. In other words, once we are assured that the worst-case scenario is satisfied – including retrieving a sector from the FAT before each sector of data – we realize that we can give up on caching the FAT altogether. While on average this will produce more work than necessary, if the calculations are correct audio playback will not be affected.
- 3) The third assumption is about the size of the audio-playback buffers themselves. The actual size of the buffers

required to keep the audio flowing smoothly is not necessarily a multiple of a sector size; it could in fact be only a fraction – a half or a quarter of a sector will suffice.

A little bit of mathematics can help verify how small those buffers can actually be, based on the data consumption rate. For example, we have the following for an 8-bit, mono, PCM-encoded, uncompressed audio WAV file:

Samples Size: 1 byte
 Number of channels: 1
 Sample rate: 44.100smps

Data rate = Sample rate x Number of channels x Sample size

In this case, the data rate translates directly from samples to bytes per second. We are especially interested in its inverse:

$$T_{\text{sample}} = 1 / \text{Data rate} = 22.6\mu\text{s (microseconds)}$$

Given a maximum record access time (T_{read}) of ~ 2ms, obtained by adding the actual SD-card-vendor specifications (T_{seek}), and the shortest time required by the microcontroller to transfer back a sector's worth of data using the SPI peripheral, we can verify that the number of bytes consumed during the data retrieval of a new sector is:

$$N = 2 \times T_{\text{read}} / T_{\text{sample}} = 176 \text{ bytes}$$

Any pair of buffers greater than N will then be sufficient for our purposes, but 256, at half the size of a sector, is a nice round choice.

- 4) Thus far we have been able to reduce the memory usage from 2kB (4 x 512 bytes) to just 1kB (512 + 2 x 256), but we must do better if we want to reserve some space for the application stack and variables, too. We can reduce memory usage further by allowing for an overlap between the record buffer and at least one of the two audio buffers. This is possible by having two different-size buffers. The first will be as large as a media sector (512 bytes), whereas the second will be only as large as an audio buffer (256 bytes).

First, an entire sector is read directly to the first (large) buffer. Audio playback can start immediately from the first half of the buffer, but we simultaneously start moving its second half into the second (small) audio buffer.

When playback of the first (half) buffer is complete, we continue playback from the second (small) audio buffer. At this point the first buffer is completely available to us to re-fill with new data from the next media record. Rinse and repeat. See Figure 3. ●



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Non-contact temperature measurement in embedded applications

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

A

ll objects emit energy as thermal radiation. Non-contact temperature sensors work by measuring the intensity of this emitted energy, converting it to a meaningful temperature reading.

In most temperature measurement applications the sensor is in contact with the object, liquid or gas whose temperature is to be measured. There are some important situations, however, where measuring the object's temperature is done without touching it, including:

- **Fast response is required:** Temperature measurements by contact sensors are slow, since the probes take time to sense the temperature of the object they touch. Non-contact temperature sensors on the other hand have very fast response times.
- **The target is moving or vibrating:** It is difficult to measure the temperature of a moving or vibrating object with a contact sensor.
- **The target is inaccessible:** In some temperature measurement applications the target may be located in a place that's difficult to reach.
- **The target cannot be touched:** The target may contain a corrosive, toxic or dangerous chemical, making contact measurement impossible.
- **No cleaning is required:** In contact temperature measurements it may be necessary to clean the probe after measurement, for example if the probe was in contact with an oily surface.
- **Size of the target:** The target may be too small or difficult to reliably touch with a probe.
- **High temperature range:** Non-contact temperature sensors allow very high temperatures (e.g. over 1300°C) to be measured easily, beyond the range of most contact probes.

On the flip side, non-contact sensors, also known as infrared (or IR) temperature sensors, suffer from some disadvantages, including:

- The target must be optically visible to the sensor;
- Non-contact sensors measure only the surface temperature;
- The air between sensor and target must be clean and free from any dust or smoke;
- The reflectivity of the target must be considered, since highly reflective targets can give rise to errors.

Accuracy Of Non-Contact Measurements

Several factors affect the accuracy of non-contact temperature measurements, including:

● Target reflectivity

Most objects are reflective, and some more than others. For example, shiny metal reflects more infrared energy than a matt surface.

Emissivity is the opposite of reflectivity, and materials such as paper, wood, rubber and matt-painted surfaces have high emissivities.

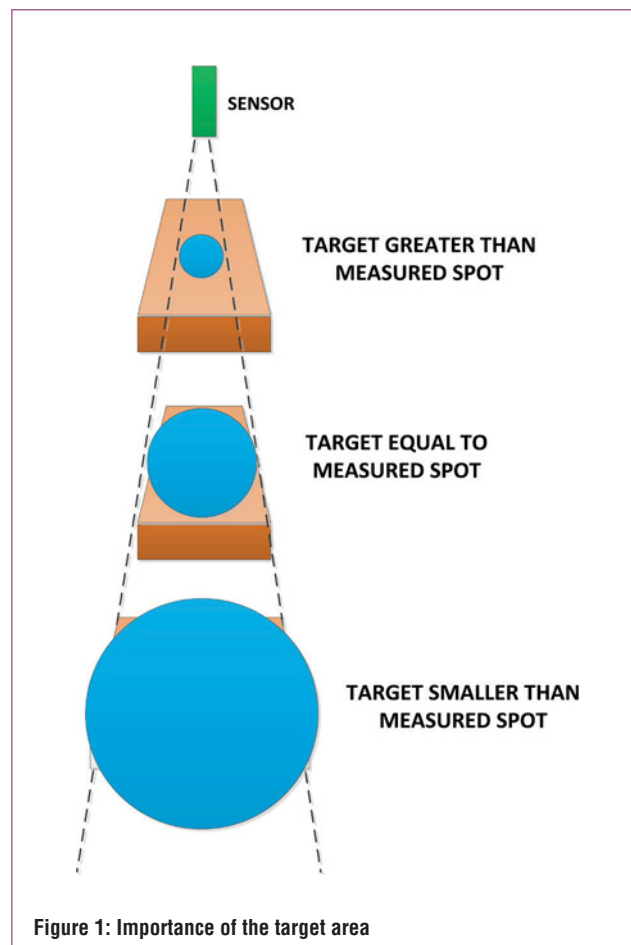


Figure 1: Importance of the target area

In general, it is easy to measure the temperature of high-emissivity materials accurately using non-contact sensors. To achieve accurate readings from highly reflective surfaces it may be necessary to make the surface non-reflective, e.g. by painting or coating it with a low-reflectivity material.

● Ambient temperature

In a non-contact sensor there is air between the sensor and the target and therefore it is important to ensure that the air temperature is within the operating temperature limits of the sensor.

● Line of sight

Any material such as dust or smoke in the air and between sensor and target can give rise to measurement errors. The cleaner the air, the more accurate the measurement will be.

● Target area

The target area is important in non-contact temperature measurements. Manufacturers of sensors recommend that for accurate measurements the target area should exceed the sensor's field of view by 50%. As shown in Figure 1, if the target area is smaller than the sensor's field of view then objects in the background will affect the accuracy of the measurement. If the target area is equal to that field of view then good results can be obtained. For best results, the target area should be larger than the field of view of the sensor.

● Optical Resolution

The optical ratio is defined as ratio of the distance between sensor and target to the diameter of the point on the target to be measured. For example, if the distance between sensor and target is 10cm and the diameter of the point to be measured on the target is 1cm then the optical resolution is 10:1. The higher the optical resolution, the more accurate the measurement. Higher resolution sensors are in general more expensive, and the choice depends on the dimensions of the target and the distance to it. Manufacturers usually provide charts of optical resolution. The many infrared sensors on the market have optical resolutions ranging from 2:1 to more than 400:1.

● Focal Point

More expensive sensors are available with fixed or variable focus lenses.

Popular Non-Contact Sensors

There are many different non-contact temperature sensors available on the market:

The Melexis MLX90614 is a small non-contact infrared thermometer chip (Figure 2) with an internal 17-bit ADC and DSP, and a wide temperature range, from -40°C to 85°C for ambient temperature, and -70°C to 382.2°C for object temperature. The device operates in two modes: PWM and SMBus. The PWM output is 10-bits and provides a resolution of 0.14°C, while the SMBus interface has a resolution of 0.02°C.

Amphenol's ZTP-315 is a small, low-cost, non-contact temperature sensor chip (Figure 3) with integrated IR filter and a thermistor for temperature compensation. The temperature range



Figure 2: Melexis MLX90614 infrared thermometer chip



Figure 3: Amphenol ZTP-315 temperature sensor

of the device is +20°C to +380°C, having a response time of 0.3-0.6s.

The Grove infrared temperature module (Figure 4) is a very low-cost, non-contact sensor module consisting of 116 thermocouple elements in series on a floating micro membrane. The module measures temperature from -10°C to +100°C, with accuracy of ±2°C. Operating voltage is 3-5V.

Non-Contact Thermometer Design

A view of the design is shown in Figure 5.

● **IrThermo 2 Click:** This is a small click board that contains the Texas Instruments TMP007 infrared thermopile temperature sensor chip with an integrated math engine. The sensor absorbs infrared radiation emitted by the target object within its field of view and the integrated math engine calculates the temperature by comparing it with that of the die. The measurement range of the TMP007 sensor is -40°C to +125°C. Its internal ADC is 16-bit with digital resolution of 14-bits. An internal EEPROM is provided to store the calibration coefficients. The board is designed to use either 3.3V or a 5V. The IrThermo 2 board is interfaced to external world via the I2C bus. There are two on-

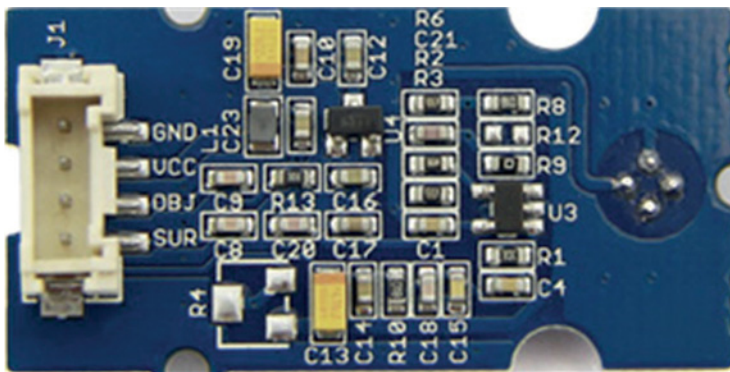


Figure 4: Grove infrared temperature module

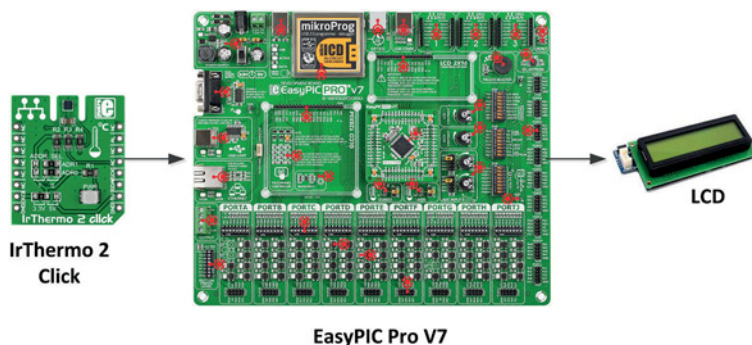


Figure 5: Block diagram of the designed system

board I2C pull-up resistors for convenience.

- **The MikroElektronika EasyPIC Pro V7:** This is a full-capacity PIC microcontroller development board, offering three mikroBUS sockets. The IrThermo 2 click board is plugged into mikroBUS socket 1 of the development board. EasyPIC Pro V7 operates with an external 8MHz crystal. It also has a PIC18F87K22 microcontroller, 128KB program memory, 3862 bytes of RAM, 69 LEDs, push-button switches, mikroProg ICD debugger with programmer, and so on.

- **LCD:** A 16-character by two-row LCD displays the temperature reading.

The design's circuit diagram is shown in Figure 6. The TMP007 sensor is connected to the PIC microcontroller I2C lines, and the LCD to its PORTB.

Operation

Operation of this non-contact thermometer system is simple; it is described in Listing 1 as a PDL. The program operates in an endless loop where the temperature is read through the I2C bus, converted to °C and displayed on the LCD every second.

BEGIN

Define the LCD interface

Initialize I2C bus

DO FOREVER

Read temperature

Convert temperature into °C

Display temperature

Wait two seconds

ENDDO

END

Listing 1: System operation

The Software

The project software is shown in Listing 2. At the beginning of the project, the interface between the LCD and the microcontroller is defined using sbit statements and the I2C address of the sensor is set. The I2C bus is initialised by calling to function I2C_Init. The remainder of the program is executed in an endless loop.

Inside this loop, function ReadTemperature is called to read the temperature from the TMP007 sensor chip using the built-in I2C library routines. The temperature is returned as a floating point number. The chip I2C address is set to 0x80 by default. As described in the sensor data sheet, the following operations must be performed to convert the 16-bit temperature data into degrees Centigrade:

- Read the temperature as a 16-bit data;
- The data is in 2's complement format;
- Shift right the data by 2 bits;
- Multiply by the LSB value (0.03125) to convert into °C.
- The temperature is now available as a positive or negative floating point value.
- Table 1 shows the 2's complement output of the sensor for different temperature values.

Temperature (°C)	Digital Output (2's complement)
150	0100 1011 0000 0000
100	0011 0010 0000 0000
50	0001 1001 0000 0000
0.03125	0000 0000 0000 0100
0	0000 0000 0000 0000
-25	1111 0011 0111 0000
-40	1110 1011 1111 1100
-55	1110 0100 0111 1100

Table 1: 2's complement output of the sensor

After converting the temperature into °C, it is converted into a string by calling to function FloatToStr; any leading spaces are removed by the Ltrim function and then displayed on the two-row LCD in the following format:

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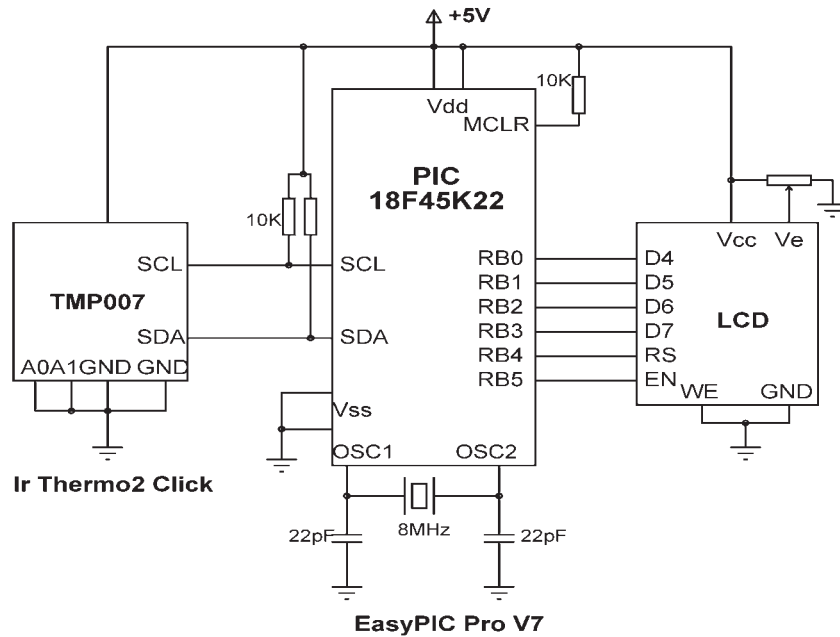


Figure 6: Circuit diagram of the design

Row 1: Temperature

Row 2: <floating point temperature>

This process is repeated endlessly at two-second intervals. ●

```
#define TMP007_Address 0x80
```

```
sbit LCD_RS at RB4_bit;
```

```
sbit LCD_EN at RB5_bit;
```

```
sbit LCD_D4 at RB0_bit;
```

```
sbit LCD_D5 at RB1_bit;
```

```
sbit LCD_D6 at RB2_bit;
```

```
sbit LCD_D7 at RB3_bit;
```

```
sbit LCD_RS_Direction at TRISB4_bit;
```

```
sbit LCD_EN_Direction at TRISB5_bit;
```

```
sbit LCD_D4_Direction at TRISB0_bit;
```

```
sbit LCD_D5_Direction at TRISB1_bit;
```

```
sbit LCD_D6_Direction at TRISB2_bit;
```

```
sbit LCD_D7_Direction at TRISB3_bit;
```

```
float Temperature;
```

```
void ReadTemperature()
```

```
{
```

```
char temp[2];
```

```
int Rawtemp;
```

```
I2C1_Start();
```

```
I2C1_Wr(TMP007_Address);
```

```
I2C1_Wr(0x03);
```

```
I2C1_Repeated_Start();
```

```
I2C1_Wr(TMP007_Address+1);
```

```
temp[0] = I2C1_Rd(1);
```

```
temp[1] = I2C1_Rd(I2C_NACK);
```

```
I2C1_Stop();
```

```
RawTemp = ((temp[0] << 8) | (temp[1])) >> 2;
```

```
if(RawTemp & 0x2000)
```

```
RawTemp |= 0xC000;
```

```
Temperature = (float)RawTemp * 0.03125;
```

```
}
```

```
void main()
```

```
{
```

```
unsigned char Txt[14];
```

```
ANSELB = 0;
```

```
ANSELC = 0;
```

```
LCD_Init();
```

```
I2C1_Init(100000);
```

```
Delay_Ms(200);
```

```
while(1)
```

```
{
```

```
ReadTemperature();
```

```
Lcd_Cmd(_LCD_CLEAR);
```

```
Lcd_Out(1,1,"Temperature");
```

```
FloatToStr(Temperature, Txt);
```

```
Ltrim(Txt);
```

```
Lcd_Out(2,1,Txt);
```

```
Delay_Ms(2000);
```

```
}
```

Listing 2: Project software

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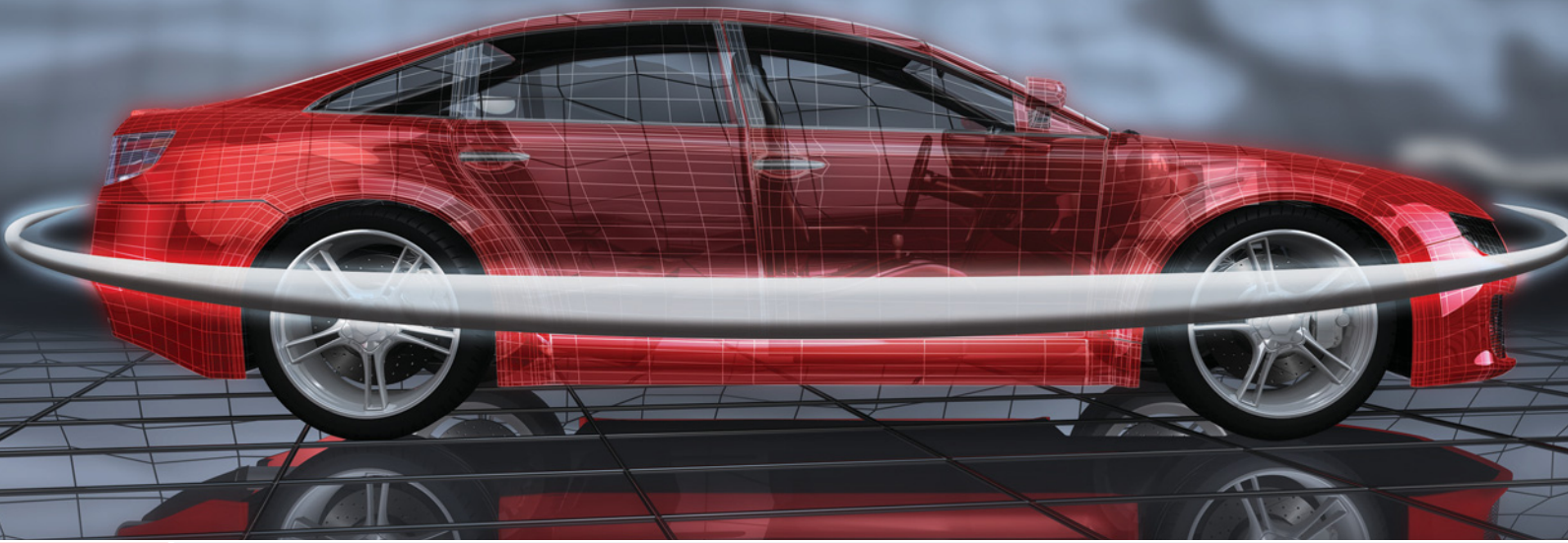
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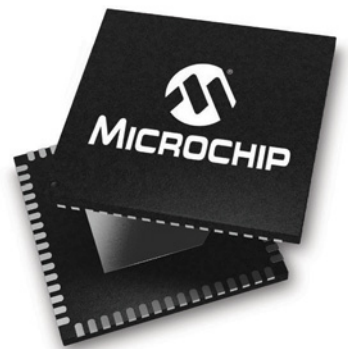
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Application Examples

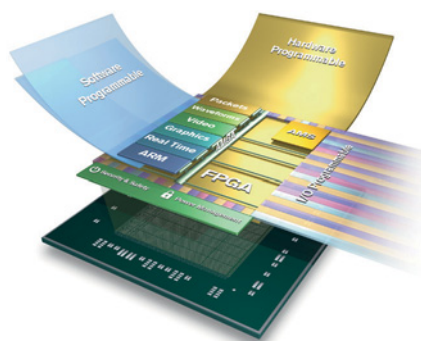
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Behind the screen

BY AARON BEHMAN AND ADAM TAYLOR OF XILINX

The first two articles in this series discussed image-sensor selection and basic signal-processing challenges encountered when designing embedded vision systems. Considering the signal chain in detail, it can be seen to contain a number of common elements for capturing, conditioning, analysing and storing or displaying the images detected by the sensor. From a high-level system perspective, these can be thought of as three functional groups.

Interface To The Image Sensor

Depending on the type of sensor, this interface must provide the required clocking, biases and configuration signals, as well as receiving the sensor data, decoding if necessary, and formatting before passing it to the image-processing chain.

Image-Processing Chain

The image-processing chain then performs operations such as colour filter array interpolation and colour-space conversion; such as colour to grayscale, for example.

Any algorithmic manipulation needed is also applied within the

image-processing chain. This may range from simple algorithms, such as noise reduction or edge enhancement, to more complex algorithms like object recognition or optical flow.

It is common to call algorithm implementation the upstream section of the image processing chain. The complexity of this section depends on the application. The output formatting, which converts the processed image data into the correct format to be output to either a display or a communication interface, is referred to as the downstream section.

System Supervision And Control

This is separate from the sensor-interfacing and image-processing functions, and focuses on two aspects. The first configures the image processing chain, analyses the image and provides updates as required during algorithm execution. The second aspect is control and management of the wider embedded vision system, which involves:

- Power management and sequencing of image device power rails;
- Self-test and other system management functions;
- Network-enabled or point-to-point communication;
- Configuration of the image device over an I2C or SPI link prior to the first imaging operations.

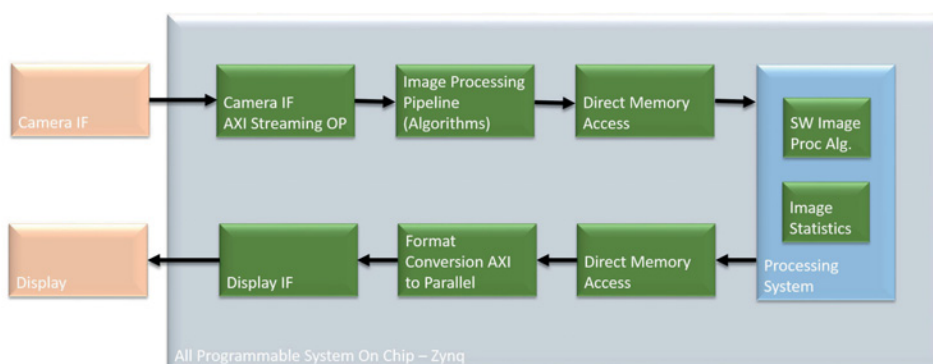


Figure 1: The Zynq programmable SoC combines key system functions on a single chip

Some applications may also allow the system supervision to access a frame store and execute algorithms on the frames within. In this case system supervision becomes part of the image-processing chain.

Implementation Challenges

The sensor interface, image-processing chain and display or memory interface all must handle high data bandwidths. System supervision and control, on the other hand, processes and responds to commands received by the communications interface, and support external communications. If the system supervision is also to form part of the image-processing chain, then a high-performance processor is required.

To meet such demands, embedded vision systems can be implemented using a combination of a main processor and companion FPGA, or a programmable system-on-chip (SoC) such as a Xilinx Zynq device that closely integrates a high-performance processor with FPGA fabric; see Figure 1. Challenges within each of the three high-level areas influence the individual functions needed.

Device Interface

Most embedded vision applications use CMOS Imaging Sensors (CIS), which may have either a CMOS parallel output bus with status flags or high-speed serialised communications to support faster frame rates than are possible using a parallel interface. This can simplify system interfacing, at the expense of a more complex FPGA implementation.

To facilitate synchronisation, commonly data channels with the image and other data words are coupled with a synchronisation channel with code words defining the data channel content. Along with data and synchronisation lanes there is also a clock lane, since the interface is source-synchronous. These high-speed serialised lanes are normally implemented as LVDS or Reduced Swing LVDS to reduce system noise and power.

Regardless of the interface, the sensor usually must be configured before any image can be obtained. This is typically done via a general-purpose interface such as I2C or SPI. Implementing this interface in an FPGA not only ensures the high signal bandwidth required, but also allows for easier integration with the image-processing chain.

The I2C or SPI sensor-configuration interface may be implemented by either the FPGA or by the system supervision and control processor.

Image-Processing Chain

The image-processing chain consists of both upstream and downstream elements, and interfaces with the pixel data output by the device interface. However, the pixels received may not be in the correct format to display an image. Image

correction may also be needed, particularly if a colour sensor is used.

To maintain throughput at the required data rates, image-processing chains are often implemented in FPGAs to exploit their parallel nature and allow tasks to be pipelined for high frame rates.

It is also vital to consider latency in applications like Advanced Driver Assistance Systems (ADAS). Basing the image processing cores on a common protocol simplifies interconnection of the processing IP and establishes an efficient image-processing chain.

There are several widely used protocols; AXI is one of the most common, due to its flexible nature; it supports both memory-mapped and streamed interfaces.

Typical processing stages within the image-processing chain are:

- Colour Filter Array: Generation of each pixel's colour which results from the sensor's Bayer pattern;
- Colour Space Conversion: Conversion from RGB to YUV used in many image-processing algorithms and output schemes;
- Chroma Re-sampling: Conversion of YUV pixels to a more efficient pixel encoding scheme.
- Image Correction Algorithms: such as colour or gamma correction, or image enhancement and noise reduction.
- On the downstream side the video output timing can be configured and converted back to native parallel-output format before it is sent to the required driver.

Some systems also use external DDR memory as a frame store. Often, this is also available to the processor on the SoC, enabling the system supervisor to transfer data over networks like Gigabit Ethernet or USB if required, extend the image-processing chain.

System Supervision

System supervision is traditionally implemented in the processor, for configuring the image-processing chain to the application. To receive and process such commands, system supervision must be capable of supporting several communications interfaces, from simple RS232, Gigabit Ethernet, USB and PCIe to more specialised interfaces such as CAN.

If the architecture of the embedded vision system permits, the processor can be used to generate image overlay information which maybe superimposed on the output image. Access to image data also allows the processor to handle other tasks.

In The Next Issue

The next article in this series will describe how to build a working vision system using readily-available tools, with an off-the-shelf kit containing a Zynq 7020 programmable SoC and a commercial image-sensing module. ●



Temperature – no longer a problem

BY TOMMY REED, VP OF TECHNOLOGY AT BLILEY TECHNOLOGIES

The temperature compensated crystal oscillator (TCXO or Xtal oscillator) is used where a precision frequency source is required within a small space and at reasonable cost.

By applying temperature compensation in the crystal oscillator module, it is possible to considerably improve the basic performance of the oscillator.

In view of their usefulness, a wide range of TCXOs is available from many suppliers in a variety of packages, from surface-mount to through-hole, some of which are compatible with the dual-in-line (DIP) format used in many ICs.

The Effects Of Temperature

Although crystal oscillators are highly stable, they are affected by temperature. The cut of the actual crystal element does help minimize these effects, but only to some extent. For a crystal with the AT cut, temperature drift can be minimized around normal ambient temperature, but drift increases above and below it; see Figure 1.

The effects of temperature are, to a large extent, repeatable and definable, making it possible to compensate for many of them with a temperature-compensated crystal oscillator, TCXO.

A TCXO adjusts the oscillator frequency to compensate for changes resulting from temperature variations. To achieve this, the main element within a TCXO is a voltage controlled crystal oscillator (VCXO), connected to a circuit that senses the temperature and applies a small correction voltage to the oscillator; see Figure 2.

Main TCXO Elements

Five different elements comprise the temperature-controlled oscillator:

1. **Compensation network:** This is key to the operation of the whole system. An approximate curve for the temperature frequency response of the oscillator is shown in Figure 1. The compensation curve can be expressed approximately as a third-order polynomial expression, although a more accurate representation accounts for some non-linearities and works out

closer to a fifth-order polynomial. The compensation network needs to sense the temperature and produce a voltage that is the inverse of this.

Early designs used analogue circuitry and a network of capacitors, resistors and thermistors to directly control the frequency of oscillation. This type of circuit included both blocks on the diagram of the compensation network and the crystal frequency pulling block.

Current technologies typically use an indirect approach, where temperature is sensed in the compensation network and a voltage is generated to provide a frequency-change inverse of the temperature curve. This can be achieved with analogue components, but current technologies often incorporate some form of digital signal processing for a far more accurate response, with the possibility of linearising units separately by programming a ROM with the response of the particular oscillator. The DSP circuitry is often contained within a special ASIC to tailor it to suit the application without draining too much current.

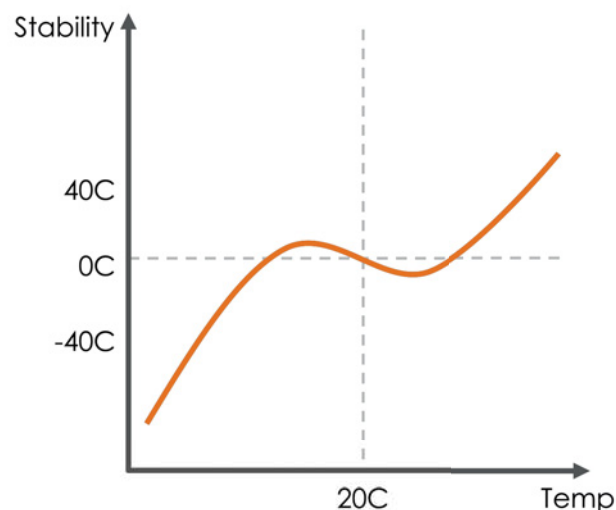
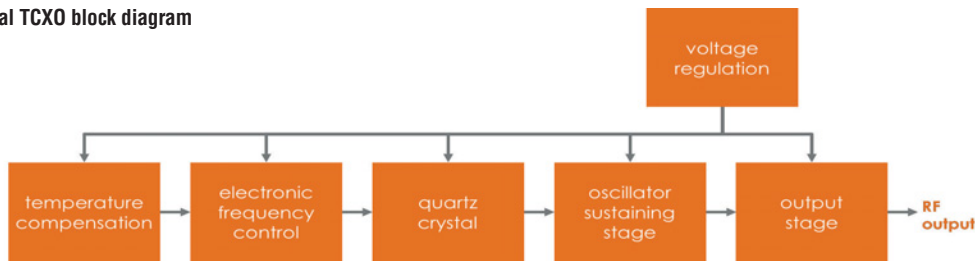


Figure 1: Typical crystal frequency versus temperature

Figure 2: Typical TCXO block diagram



2. **Oscillator pulling circuit:** Once the voltage has been generated, it's applied to a circuit that pulls the frequency of the crystal oscillator. This typically incorporates a varactor diode and some low-pass filtering.
3. **Crystal oscillator:** The oscillator circuit is standard, designed to provide the crystal with ideal drive levels.
4. **Voltage regulator:** To prevent external voltage changes from introducing unwanted frequency shifts, the overall TCXO should incorporate a voltage regulator, which itself must not introduce unwanted temperature effects.
5. **Buffer amplifier:** A buffer amplifier is required to adjust the output level and isolate the crystal oscillator from any external load changes.

TCXOs normally have an external adjustment to periodically reset the frequency, helping remove the effects of crystal ageing. The period between calibration adjustments will depend on the accuracy required, but may be six months to a year. Shorter intervals may be used for very high levels of accuracy. ●

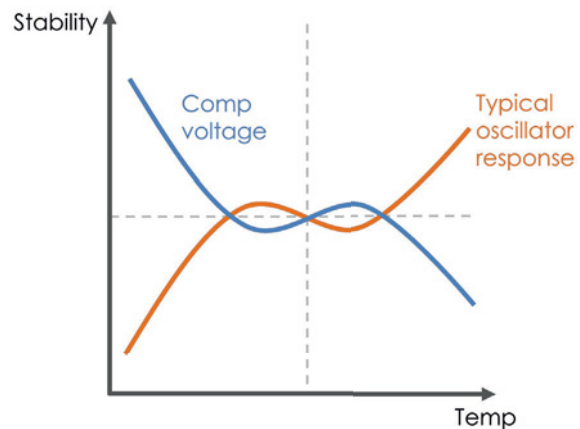


Figure 3: Compensation voltage versus temperature response



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R&S APN62	Syn Function Generator 1Hz-260KHz	£195
Fluke/Philips PM3092	Oscilloscope 2+2 Channel 200MHz Delay etc	£250
HP3325A	Synthesised Function Generator	£195
HP3561A	Dynamic Signal Analyser	£650
HP6032A	PSU 0-60V 0-50A 1000W	£750
HP6622A	PSU 0-20V 4A Twice or 0-50V 2A Twice	£350
HP6624A	PSU 4 Outputs	£350
HP6632B	PSU 0-20V 0-5A	£195
HP6644A	PSU 0-60V 3.5A	£400
HP6654A	PSU 0-60V 0-9A	£500
HP8341A	Synthesised Sweep Generator 10MHz-20GHz	£2,000
HP83731A	Synthesised Signal Generator 1-20GHz	£1,800
HP8484A	Power Sensor 0.01-18GHz 3nW-10uW	£75
HP8560A	Spectrum Analyser Synthesised 50Hz - 2.9GHz	£1,250
HP8560E	Spectrum Analyser Synthesised 30Hz - 2.9GHz	£1,750
HP8563A	Spectrum Analyser Synthesised 9KHz-22GHz	£2,250
HP8566B	Spectrum Analyser 100Hz-22GHz	£1,200
HP8662A	RF Generator 10KHz - 1280MHz	£750
Marconi 2022E	Synthesised AM/FM Signal Generator 10KHz-1.01GHz	£325
Marconi 2024	Synthesised Signal Generator 9KHz-2.4GHz	£800
Marconi 2030	Synthesised Signal Generator 10KHz-1.35GHz	£750
Marconi 2305	Modulation Meter	£250
Marconi 2440	Counter 20GHz	£295
Marconi 2945	Communications Test Set Various Options	£2,500
Marconi 2955	Radio Communications Test Set	£595
Marconi 2955A	Radio Communications Test Set	£725
Marconi 6200	Microwave Test Set	£1,500
Marconi 6200A	Microwave Test Set 10MHz-20GHz	£1,950
Marconi 6200B	Microwave Test Set	£2,300
Marconi 6960B with	6910 Power Meter	£295



MARCONI 2955B Radio Communications Test Set



FLUKE/PHILIPS PM3092 Oscilloscope 2+2 Channel 200MHz Delay TB, Autoset etc

Tektronix TDS3012	Oscilloscope 2 Channel 100MHz 1.25GS/S	£450
Tektronix 2430A	Oscilloscope Dual Trace 150MHz 100MS/S	£350
Tektronix 2465B	Oscilloscope 4 Channel 400MHz	£600
Cirrus CL254	Sound Level Meter with Calibrator	£40
Farnell AP60/50	PSU 0-60V 0-50A 1KW Switch Mode	£195
Farnell H60/50	PSU 0-60V 0-50A	£500
Farnell B30/10	PSU 30V 10A Variable No Meters	£45
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Farnell XA35/2T	PSU 0-35V 0-2A Twice Digital	£75
Farnell LF1	Sine/sq Oscillator 10Hz-1MHz	£45
Racal 1991	Counter/Timer 160MHz 9 Digit	£150
Racal 2101	Counter 20GHz LED	£295
Racal 9300	True RMS Millivoltmeter 5Hz-20MHz etc	£45
Racal 9300B	As 9300	£75
Black Star Orion	Colour Bar Generator RGB & Video	£30
Black Star 1325	Counter Timer 1.3GHz	£60
Ferrograph RTS2	Test Set	£50
Fluke 97	Scopemeter 2 Channel 50MHz 25MS/S	£75
Fluke 99B	Scopemeter 2 Channel 100MHz 5GS/S	£125
Gigatronix 7100	Synthesised Signal Generator 10MHz-20GHz	£1,950
Panasonic VP7705A	Wow & Flutter Meter	£60
Panasonic VP8401B	TV Signal Generator Multi Outputs	£75
Pendulum CNT90	Timer Counter Analyser 20GHz	£750
Seaward Nova	PAT Tester	£95
Solartron 7150	6 1/2 Digit DMM True RMS IEEE	£65
Solartron 7150 Plus	as 7150 plus Temp Measurement	£75
Solartron 7075	DMM 7 1/2 Digit	£60
Solartron 1253	Gain Phase Analyser 1mHz-20KHz	£600
Tasakago TM035-2	PSU 0-35V 0-2A 2 Meters	£30
Thurby PL320QMD	PSU 0-30V 0-2A Twice	£160-£200
Thurby TG210	Function Generator 0.002-2MHz TTL etc Kenwood Badged	£65

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LED TECHNOLOGY ADVANCES AUTOMOTIVE ADAPTIVE FRONT-LIGHTING SYSTEMS

BY **MARK PATRICK** OF MOUSER ELECTRONICS



The Adaptive Front-lighting System (AFS) is a recent lighting technology for automotive needs, promising driving safety for passengers and oncoming traffic too. Cars can adjust their headlights' angle and intensity based on speed and direction of travel, to reduce high-beam dazzle, improve visibility around curves and increase general night-time visibility.

Until now, AFS has mainly relied on mechanical means to adjust light beams created by traditional halogen or HID bulbs, but recent improvements in LED technology now enable AFSs to work using purely solid-state technology.

First seen on Audi's 2014 top-of-the-line A8 model, LED matrix headlights have an array of individually-dimmable LEDs. By adjusting the LED lighting pattern, the headlight module can create a variety of adaptive lighting effects while minimising the use of mechanical actuators. With fewer moving parts, faster activation and dimming capability, these LED-based AFSs are not only more reliable but create high-speed, precise, lighting pattern changes not possible with traditional mechanically-actuated adaptive lighting.

Improving Night-Time Visibility

Driving at night is dangerous; statistics show that fatal accidents happen three times more often at night than during the day. Improved night-time visibility can make a huge difference, enabling better awareness of the road and other road users, as well as earlier detection of hazards.

In recent years, a number of OEMs have introduced AFSs, and some of the more sophisticated versions also adjust the beam shape to suit road conditions. An example is the Mercedes Intelligent Light System, which uses a rotating drum with contours to adjust the beam formation. As the drum rotates, it changes the projection of the headlight, forming different beam shapes to suit varying road conditions. For instance, a wider beam is used for better lateral visibility on country roads, whereas a tighter beam with longer throw would be used on high-speed motorways.

Lighting has made a tremendous leap forward in automotive applications, where interest has moved away from illuminating automotive interiors to becoming a key component in exterior lighting. The compact, energy-efficient and fast-activating solid-state lighting of LEDs has improved almost every lighting system, from brake lights to tail lights and headlights. Could LEDs transform AFSs as well?

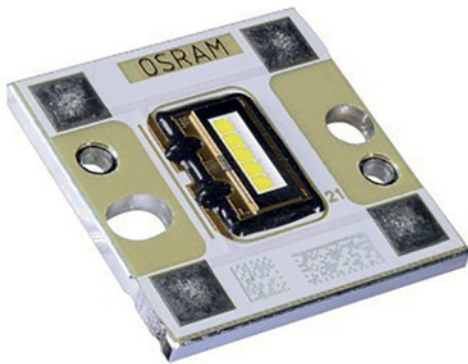


Figure 1: Advances in LED technology like Chip-On-Board and ThinGaN allow a single, compact, LED module such as this Osram OSTAR headlamp to power a low beam



Figure 2: Used in the Mercedes CLS multibeam headlight, the Olson Compact LED from Osram is an example of an LED designed for AFS systems

Improving Automotive Lighting

LEDs are a natural fit for automotive lighting, with superior service life, vibration resistance and energy efficiency compared to traditional incandescent bulbs. In brake lights, the faster activation of LEDs gave cars at the rear additional reaction time. As headlights, LEDs provide higher colour temperature, close to daylight, and since they are a surface emitter, much more of the light LEDs generate hits the road, whereas halogen or HID bulbs lose a lot of lighting efficiency by projecting light in all directions, including away from the target area.

LEDs have been used in interior and signal lighting since the '90s, but despite all their benefits, they weren't used in headlights until 2008. The first full-LED headlamp appeared on the Audi R8 as an expensive €3,590 option, and the 2008 Lexus LS600H also featured LED headlamps, albeit only for its low beams. Unlike interior and signal lighting, headlights require high-intensity white light, which was difficult to achieve at the time.

However, advances in high-brightness LED technology quickly followed, making LED headlamps much more affordable. Today, LED headlights are on everything from high-end Mercedes models to the Toyota Corolla ZR. And now, LEDs are also being adopted for the next-generation AFSs.

The newest generation of adaptive front lighting systems use compact LEDs arranged in an array. LEDs are smaller than traditional bulb lighting, they turn on and off faster and can be dimmed, allowing for a variety of AFS effects.

LED-matrix-style headlight technology debuted in 2014 on Audi's A8 model, and has also been adopted by BMW and Mercedes. LED matrix headlights use compact LEDs arranged in a grid pattern. The illumination originally provided by a single halogen or HID bulb is instead the output of multiple LEDs. The more LEDs, the greater the resolution of the beam and thus the more precisely it can be adjusted.

Dazzle-Free High Beams

The headline feature of LED-based AFS systems is their ability to produce high beams that don't dazzle oncoming drivers. Cameras mounted on the windshield detect oncoming vehicles by their headlight pattern. The oncoming vehicle is tracked and the corresponding LEDs on the headlight array darkened, with the area dynamically adjusting to the oncoming vehicle's position as it passes by.

The significance of dazzle-free high-beam technology can't be overstated. High beams significantly increase night-time visibility range, but traditional high beams often have to be turned off to avoid blinding oncoming drivers.

Dazzle-free high beams let drivers keep their high beams on without threat to other road users, to see deep into the night at all times.

Precision Light Control

While bright, HID bulbs can't be dimmed and take time to warm up. Halogen bulbs start faster but not as fast as LEDs, and dimming them greatly shortens their service life. The ability to be quickly activated and deactivated, or dimmed to a pre-specified level, sets LEDs apart from traditional bulb-based AFSs, leading to much more precise lighting control.

Modern matrix lighting systems, built around automotive-grade high-current LED drivers, such as ON Semiconductor's NCV78763, can potentially offer over 1000 brightness gradients, controllable at the individual LED level.

This level of precision enables LED-based AFS to create sophisticated effects such as eliminating back-glare caused by wet roads, fog or traffic signs by detecting the area of glare and dimming the corresponding LEDs.

Curve Lighting

LED-based AFS technology also steer the beam to increase visibility around turns. Besides detecting steering wheel direction and vehicle yaw rate, predictive curve lighting can also use camera detection or even the GPS navigation system. When a bend in the road is encountered, the emphasis of the beam shifts toward the direction of the curve, increasing visibility while turning and permitting earlier detection of obstacles.

The advantages AFSs bring to automotive forward-lighting systems are indeed revolutionary. ●

In recent years, a number of OEMs have introduced AFSs, and some of the more sophisticated versions also adjust the beam shape to suit road conditions



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DEMOCRATIZATION OF 3D IN THE CAR

BY MICHAEL GRABOWSKI, RENESAS ELECTRONICS EUROPE



Figure 1: Modern automotive instrument cluster

The concept vehicles of today's car makers show a clear trend toward a so-called "digital living space", where the interior becomes a data-processing centre, providing information to the driver more than ever before. This in turn calls for larger high-resolution displays and panels, rendering the traditional pointer-based instrument cluster obsolete; thanks to the iPhone, tomorrow's dashboard is going to look more like the face of a smartphone. Modern displays are already seen in luxury models, but also in some cost-sensitive middle- and small-class vehicles.

Post-Smartphone Era

When Otto Schulze patented the first eddy current tachometer for a car at the Imperial Patent Office in Berlin in 1902, he could have hardly imagined how this display would develop in the coming years.

When digital speed sensors first replaced mechanical transmission shafts, the vehicle's information pointers were mounted on the stepper motors. In 1986, the first full-scale LCD instrument cluster appeared in the Volkswagen Golf II GTI, leaving motorists amazed. This effect didn't last long however, thanks to the so-called "smartphone effect", and nowadays motorists are underwhelmed by their in-car displays, disliking most of them – from the appearance of the graphics to the small text size and generic old-fashioned looks.

Premium Class Vehicle Luxury

Automotive trade shows have for ages been platforms for car manufacturers to show off their new designs and features, and lately these are interior and exterior lighting; larger, multiple displays in the cockpit; and new-age infotainment applications. Modern luxury vehicles have put old pointer-instruments almost entirely out of service; instead, the dashboard sports elaborate 3D-type applications, such as rotating car images and camera tracking of the car's sides and top, as well as tyre pressure monitors and destination pointers.

However, these big, high-resolution, 3D animations have a

problem: they are very expensive! They may be acceptable in a luxury car, but are certainly beyond the scope of middle- to small-class models. And, the costs are pushed up not only by the display, but also by the controller, its peripherals and power supply.

Car makers of today have a balancing act ahead: how to offer cutting-edge displays the buyer will pay for.

As with other technologies, the display features can find their way into the middle and small class segments only through evolution: HD video resolution, a 3D OpenGL hardware and H.264 decoder IP. But, to keep things informative rather than distracting during driving, legislatures and regulatory bodies are issuing special regulations for the instrument cluster; 'wow-factor' effects are only a second priority.

The Hybrid R-Car D1

The new R-Car D1 series from Renesas consists of automotive system-on-chip (SoC) devices specialised for 3D instrument-cluster systems. These are hybrid products that combine the RH850/D1x series' extensive 2D scalability with the high-performance visual functions of the R-Car family. Therefore, the R-Car D1 is regarded both as a smaller representative of the R-Car family and the highest-performance representative in the RH850/D1x series.

The RH850/D1x series has 11 products based on RH850 CPU architecture, but with significantly better performance and faster internal bus architecture. To enhance this series' capabilities, such as HD resolution, 3D GPU and H.264, the R-Car family's higher-performance architecture is required.

This family also supports complex operating systems such as Linux, QNX and Integrity. Up to two ARM Cortex-A7 CPUs (3 million DMIPS) form the basis for an SGX540 GPU (5.3 MFLOP) from Imagination Technologies – the same architecture Apple has used in the iPhone and the iPad.

A 32-bit DDR3-L memory interface is integrated to process large volumes of image data. To ensure design continuity for customers of the RH850/D1x series when moving to R-Car D1,

the same 2D GPU, functional safety IPs and HMI (Human Machine Interface) tool have remained.

Once the step to R-Car D1 is taken, further performance enhancements are then possible. For example, the latest third-generation R-Car derivative offers up to eight 64-bit dual-core CPUs on the big.LITTLE ARM architecture (47 million DMIPS), a dual-core lockstep real-time CPU and a PowerVR GX6650 (340 GFLOP) from IMG. Also, Renesas decided to offer a complete solution for the R-Car D1, a system controller and a software package to avoid redundancies and reduce the development NRE of the instrument cluster.

System Solution

With the R-Car D1, Renesas has created a system solution together with the smallest representative of the RH850/D1x series, the RH850/D1L1. Together with the R-Car D1, the RH850/D1L1 takes over functional safety, access security through its SHE-compliant IP, and power management. It can also take over the AUTOSAR-compliant network communication via the CAN-I/F and serve as a serial boot flash for starting the R-Car D1.

Thanks to the integrated security IP, the RH850/D1L1 can exchange and check the access key with the R-Car D1 and determine if the necessary access rights are available for security-relevant queries. The RH850/D1L1 has been developed entirely according to ISO26262, so it can also evaluate data from the video-out checker and thus detect software errors during video output.

Since a SoC does not possess any significant internal memory, it must copy its data from an external ROM at the start. This external ROM can be connected via its fast 8-bit interface, but a part of the RH850/D1L1 flash can also be used for this purpose.

Often, during booting, a multi-stage concept is used: A first system check can be executed using the RH850/D1L1 program code. Then, a start screen is displayed, read from an external flash via the 8-bit I/F, and finally all the rest can be loaded from a large, cost-effective, Raw-NAND memory.

Although considered trivial by some, the package also significantly impacts the costs of the printed circuit board. R-Car D1 series' 543-pin BGA package with a contact spacing of 1mm is cost-saving. Because of this relatively large spacing, the board can be laid out easily and produced inexpensively, while still ensuring a long and reliable lifetime.

Everything Will Be Alike

To use the entire D-series immediately, Renesas also provides the appropriate graphics drivers. The Renesas Graphic Library (RGL) provides an easy-to-use API to facilitate usage of all graphics features. The software quality is so high that it can be used directly in the series product; leading ECU and HMI tool manufacturers already use it.

For the 2D GPU, Renesas provides a self-developed, highly-optimised API; the 3D GPU is controlled by drivers according to



Figure 2: The modern dashboard will show multiple information

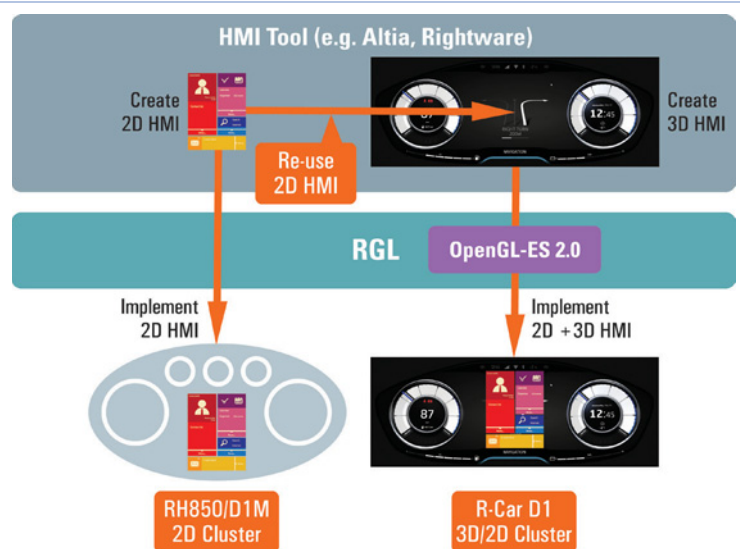


Figure 3: Renesas R-Car D1 application

the OpenGL ES 2.0 standard. These are also included in the RGL. As a result, the customer receives the complete graphics driver package from a single source, ensuring seamless and stress-free integration of all graphics functions.

Which leads to the next topic. Thanks to these cross-platform graphics drivers with the included HMI tools, manufacturers can adapt their operating concepts very easily to the 2D and 3D GPUs of the entire D-Series. A consistent working concept is created, from the RH850/D1L to the R-Car D1, providing the largest range of automotive display controllers with a common IP platform.

In the end the question, therefore, remains: Who benefits from the R-Car D1 series?

It is useful for all developers whose goal is a comprehensive portfolio of instrument clusters and a high degree of reusability, with the same HMI tools and the same graphics drivers. That way, expenses for hardware and software development can be distributed over a broad product spectrum without having to reinvent the wheel with every new development. Also, development quality can be improved continually over all projects, since know-how gained from one benefits all the others. ●

IMPROVING NAVIGATIONAL DATA WITH NEW ALGORITHMS AND SYSTEMS

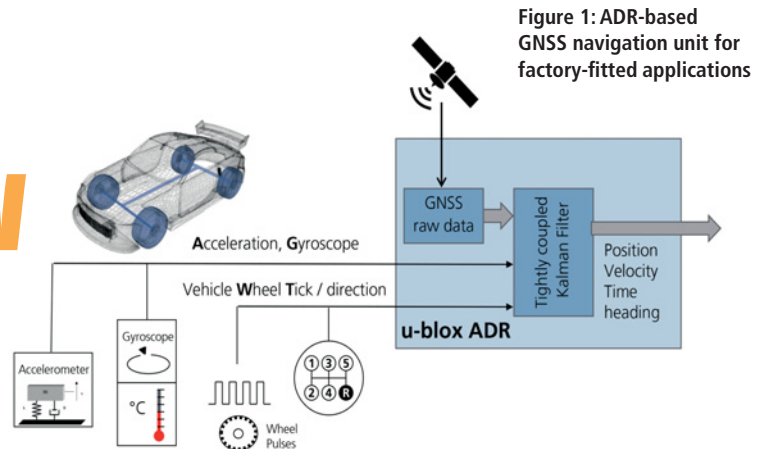


Figure 1: ADR-based GNSS navigation unit for factory-fitted applications

BY **NICK ROBINS**, TECHNICAL DIRECTOR AT ALPHA MICRO COMPONENTS



We all have stories to tell about our satellite navigation experiences, one of which has to be the getting in and out of multi-story car parks. Driving into one of these is usually straightforward enough, but leaving them can be a different experience. Navigating out of a carpark

whilst shielded from radio signals by multiple levels of concrete – underground or above ground – can leave us holding up the traffic until our Global Navigation Satellite System (GNSS) unit “finds” itself.

Typically, new car models are fitted with a GNSS-complementing 3D Automatic Dead Reckoning (ADR) system (Figure 1), which calculates the car’s current position by using a previously-determined position, its speed, direction and acceleration. Tightly integrated into the vehicle’s own network, wheel “tick” distance data and direction come from sensor pulses, while a gyroscope and accelerometer measure direction, speed and distance.

Combining data from the GNSS and the dead-reckoning approach through a Kalman filter produces a reliable and precise method of knowing a vehicle’s position. So, for example, as a vehicle enters a tunnel and the GNSS signal drops off, dead-reckoning data continues to estimate the vehicle’s actual location.

Challenges

However, car parks and tunnels are not the only challenges to GNSS reception. The so-called “urban canyon” effect experienced in densely-packed city centres, where tall buildings not only significantly attenuate GNSS signal strengths but also cause multiple path reflections, presents a challenge in just the place where precise and reliable navigation is needed the most.

The Kalman filter algorithm (named after Rudolf Kálmán, who developed the algorithm), also known as linear quadratic estimation, uses a series of measurements taken over time that cancel out their inherent statistical noise to produce a position estimate more

accurate than a single measurement.

While the development of 3D ADR technologies are a significant step forward for new factory-fitted vehicle platforms, there are many more uses for ADR systems, including road tolling, fleet tracking and management, and pay-as-you-drive insurance policies, among others.

Untethered Dead Reckoning

There’s another, similar, approach to GNSS for ADR that is also gaining in popularity; it’s called Untethered Dead Reckoning (UDR) because there’s no physical connection to the vehicle network or systems apart from power.

Instead of sensing wheel ticks and using separate accelerometers and gyroscopes, a single module does everything completely independent of any electrical connections to a vehicle. One such module is NEO-M8U from u-blox (Figure 2), which features a 72-channel receiver that can concurrently operate with multiple GNSS constellations such as GPS, GLONASS, Galileo and BeiDou. Also integrated – and the key components for the dead reckoning calculations – are a MEMS accelerometer and gyroscope. Measuring just 12.2mm x 16.0mm x 2.4mm and packaged in a 24-pin leadless chip carrier, the NEO-M8U delivers a navigational update at up to 20Hz.

Figure 3 shows the positional accuracy and reliability UDR can bring to automotive navigation. Figure 3 (left) shows the navigation of a vehicle around the central part of Singapore using GNSS alone. Note the random and sudden changes in positional information, clearly not reliable enough for navigating around the city. However, with UDR, the results are much better – see Figure 3 (right).

A Kalman Filter At The Heart

It is worth noting that the u-blox module uses a single Kalman filter tightly coupled with GNSS. An alternative competitive approach uses multiple Kalman filters; however, this can feed more errors into the positional data.

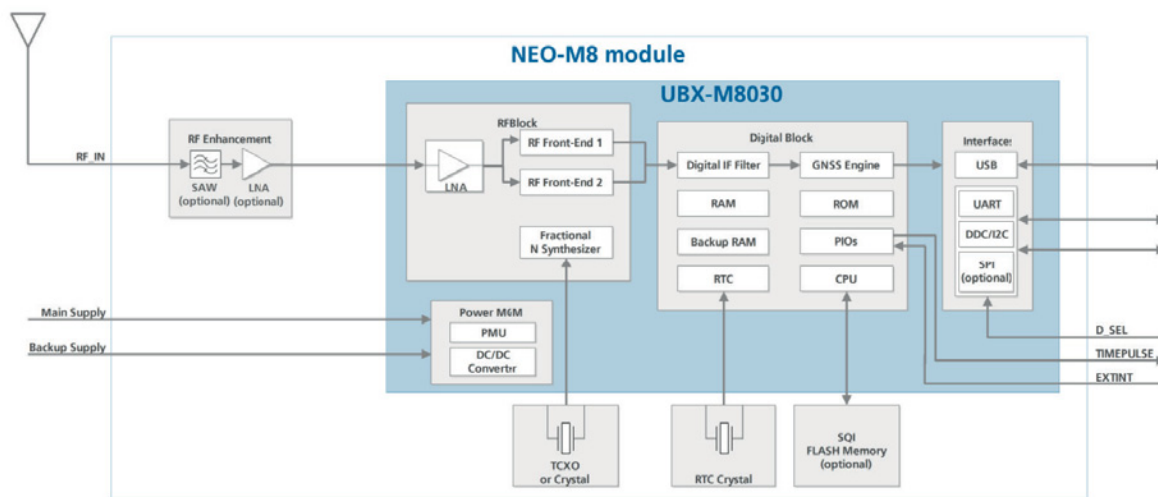


Figure 2: The NEO-M8U module from u-blox

Figure 4 (left) shows a vehicle going around a corner with the NEO-M8U providing updates every 50ms (20Hz). This compares to Figure 4 (right) where the GNSS system provides position updates every 100ms (10Hz).

Being able to provide location data from the sensors with little latency not only improves the navigation but also, should the application require it, allows near-real-time accurate positional data. This would be of great use in accident investigations for example, or for much more precise navigation through complex multi-lane motorway intersections.

Also, the module can detect GNSS signal jamming, and has a save-on-shutdown feature that saves the current location and satellite orbit information into external flash memory.

Data from the module is available in the NMEA and RTCM industry standard protocols, and communication, control and configuration are achieved using u-blox's UBX receiver description and UBX protocol.

Setting Up The Testing

When contemplating a new navigation-based design, engineers should carefully research the development tools available for their chosen module. The u-blox EVK-M8U provides an evaluation platform for the NEO-M8U module. This comprehensive board offers a complete breakout of the M8U module in addition to current and voltage measurement capabilities, SPI/I2C interfaces and running on USB power. Evaluation software allows configuration of

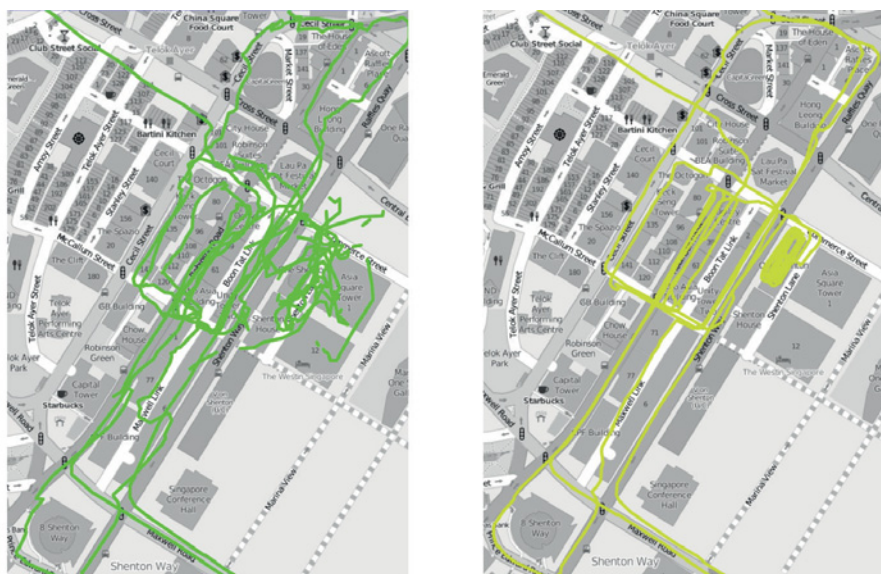


Figure 3: Navigation using GNSS only (left) and with UDR (right)

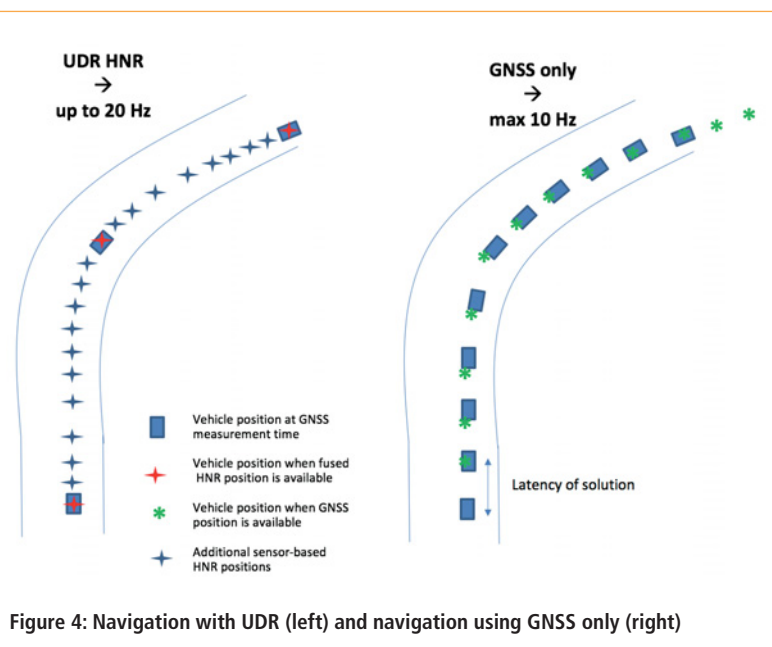


Figure 4: Navigation with UDR (left) and navigation using GNSS only (right)

the module, displaying data from the gyroscope, accelerometer and GNSS receiver.

Initial operation starts with calibration of the module, after which it is ready for navigation. This initialisation process estimates all

unknown parameters required for sensor data fusion, for which the test vehicle platform needs to be stationary in an area of good GNSS reception.

Figure 5 shows the status panel of the evaluation software after the initialisation phase; the module has entered navigation mode and is starting to compute a combined GNSS and dead-reckoning fix. Once the EVK-M8U has been initialised and calibrated it is ready for testing.

A variety of routes are recommended for the test drives, such as city centres, urban landscapes, routes through tunnels, and other similar districts where the GNSS signal is heavily attenuated and/or reflected by tall buildings or trees. The software has a record function that stores data for subsequent analysis.

Understanding the power consumption profile of the end design and matching it with an adequately-rated battery can make the difference in gaining customer respect and, ultimately, a successful product.

Going Forth With UDR

UDR removes the uncertainty associated with GNSS navigation in poor signal areas. Interruptions in satellite navigation can be a huge inconvenience, especially in built-up urban areas. UDR promises not only to improve a driver's experience with GNSS, but also looks set to launch many new applications. ●

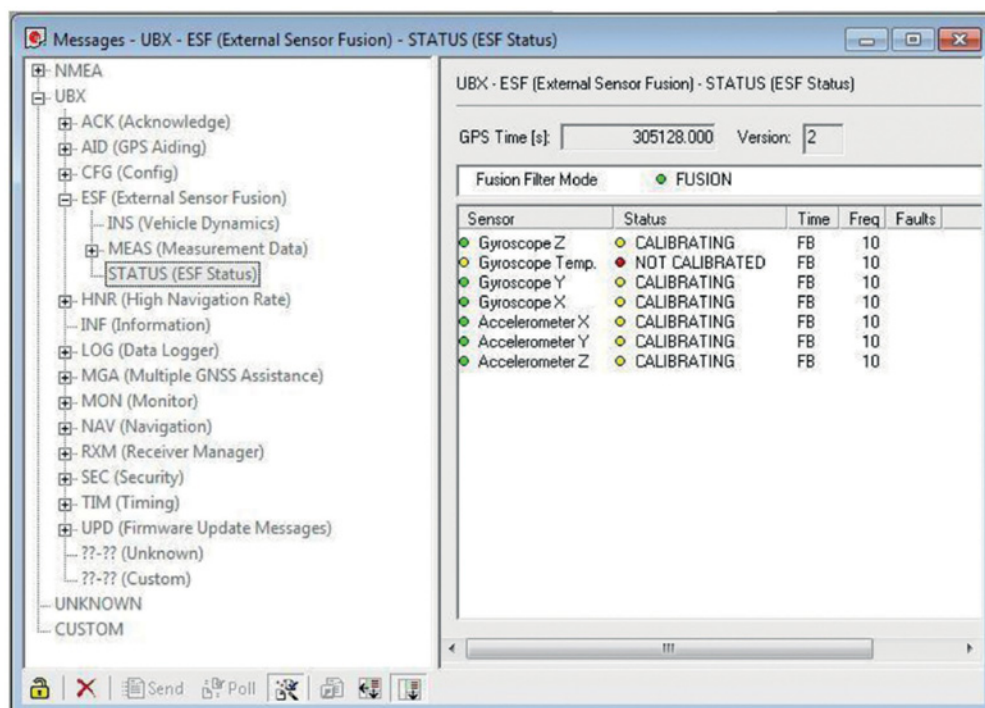


Figure 5: Screenshot of evaluation board software, u-center, showing the fusion mode

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**Model PLV60-USB 5V USB Hub**

This charge only model has 10 output ports which are switchable for 10 x 1A or 5 x 2.4A 5V outputs. Integral power supply will operate from a 90-264VAC universal AC input.

**Model PLV120-USB 5V USB Hub**

This 10 port, charge only, model is available with 10 independent 5V 2.4A outputs. Features smart charging IC and can charge any device using USB charging technology. Integral power supply operates from 90-264VAC input.

**Model PSUSB-0824 5V charge & sync hub**

Provides 8 output ports with up to 5V 1.5A (CDP mode) or 5V 2.4A (DCP mode) Supports iOS and Android devices. Supports high speed 480 Mbps, full speed 12 Mbps and low speed 1.5 Mbps operation. Up to 8 units can be cascaded to increase output ports to 64. Housed in compact aluminium case measuring 170 x 80 x 30mm. Powered by external 120W power supply with 90-264VAC input.

**Models PSUSB-1024 & PSUSB-2024 10 & 20 port
charge & sync hubs**

Provides up to 1.5A (CDP mode) or 2.4A (DCP mode) Supports iOS and Android devices. Features Green Energy mode switch. The 10 & 20 Port hubs can be cascaded with another unit to double the number of ports. Supports high speed 480 Mbps, full speed 12 Mbps and low speed 1.5 Mbps operation. These models feature integral fan cooling via temperature controlled fans and will shutdown with over temperature. Compact metal housing measures 268 x 102 x 40mm Powered by external 150W (10 ports) or 288W (20 ports) power supply with 90-264VAC input.

**Model PSUSB-20CH charge & sync hub**

Charges and syncs up to 20 devices. Charge current 1.1A per port in charge mode. Supports high speed 480 Mbps, full speed 12 Mbps and low speed 1.5 Mbps operation. Compatible with all USB compliant devices. 2 x 20 port hubs can be connected in cascade mode increasing number of ports to 40. Housed in metal enclosure which measures 268 x 102 x 40mm Powered by external 150W power supply with 90-264VAC input.



ANALYSIS OF EMI NOISE IN HYBRID ELECTRIC VEHICLES

BY **HEMENG PENG** FROM THE CHONGQING CEPREI INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTE IN CHONGQING, CHINA



With the growing number of electronic systems in vehicles as well as the trend for electric and hybrid cars, electromagnetic compatibility (EMC) has grown in importance here too. High-power electronic equipment can be found on both electric (EVs) and hybrid electric vehicles (HEVs), and their switching elements' on/off operation have large di/dt , injecting interference spikes into a wide frequency range.

So, to make power equipment EM compatible, the first thing to do is measure the electromagnetic interference (EMI). Accurate analysis of interference currents' propagation paths and their parameters, such as impedance, leads to accurate EMI prediction models and the consequent EMI suppression solutions.

This article will focus on measuring the conducted interference current on the DC main lines in a typical HEV (moderate hybrid). We will determine the different values of interference in different operating modes.

The High-Power Section

A typical hybrid car's electrical system is shown in Figure 1. Generally, this system consists of low-voltage and high-voltage sections. The HEV's high-voltage part is very different from that of a traditional vehicle, comprising a high-voltage traction battery, DC/DC converter, DC/AC motor driver, AC motor and a cable jumper, while the low-voltage system is powered by a 12V or 24V lead-acid battery.

Major components in the high-voltage system of a tandem HEV are:

- NI-MH traction battery: its output voltage range is 96-190VDC, with output voltage rated 144VDC, current capacity of 6A and peak power of 18kW.
- DC-DC converter: input voltage range is 96-190VDC, and output range 9-18VDC. The working voltage is rated 13.5V or 14.5V, with 18kW peak power output. It replaces the generator of traditional vehicles, changes the voltage from high to low, and powers the low-voltage equipment.
- DC/AC converter (bi-directional): input voltage range is 96-190VDC, with three-phase AC output peak power of 18kW. DC is transformed into three-phase AC to drive the motor and charge the traction battery.
- AC Permanent Magnet Synchronous Motor (PMSM): its rated power is 13kW and rated moment of torsion 56Nm, to make the vehicle go.

Test And Measurement

The HEV's motor-driven part has several working states: start-up, idling, electric assist and charging, each with its own induced interference.

For our test setup, the DC/DC converter is considered the test object; a current probe and spectrum analyzer are used to measure the conducted interference current spectrum on the converter's input power line, and an oscilloscope with a high-voltage passive probe is used to measure the interference voltage signal in the time domain.

The experimental setup consists of the spectrum analyzer

(a) Locations of the main power sections in a typical hybrid vehicle

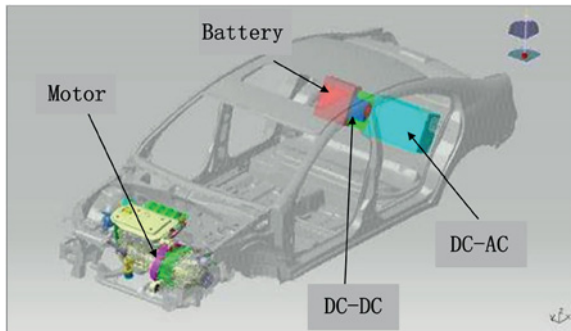
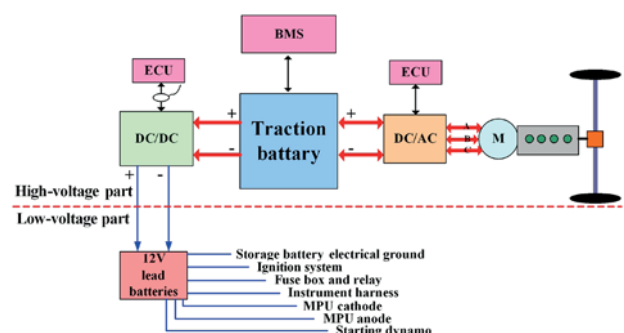
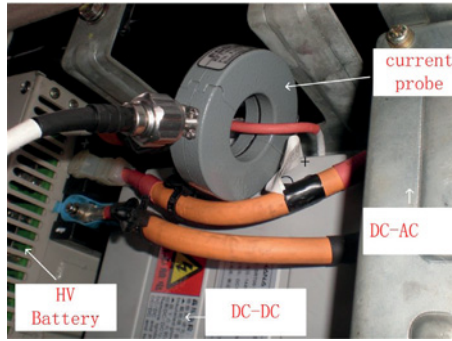


Figure 1: Electrical system structure in a hybrid electric vehicle (HEV)

(b) Wiring map of the main electrical system



a) Test setup



(b) Spectrum acquired from the measurement

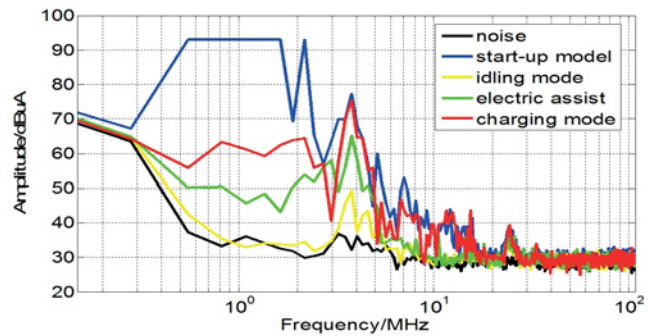


Figure 2: Measurement of conducted interference current on the DC/DC power line (positive pole)

(frequency range 0-3GHz), FCC current probe (frequency range 10kHz-250MHz), oscilloscope and high-voltage probe. The current measurement arrangement is shown in Figure 2a; the frequency range measured is 9kHz-108MHz. The FCC current probe measures the conducted interference current spectrum of the positive pole of the DC/DC power line in its four working states; see Figure 2b.

From this figure it can also be concluded that in the conducted frequency range (apart from several frequency points at around 2MHz), in startup and charging modes there's higher interference current than that in idling and electric assist modes.

By comparison, Figure 3a shows that in startup and charging modes, above 3MHz the values of interference are nearly the same, but below 3MHz in startup mode the value of interference current is far larger than in charging mode.

Figure 3b shows that in the range 500kHz-5MHz, the interference current on the positive pole of the DC/DC power line in electric-assist mode is larger than in idling mode; interference is around 15dB, and above 5MHz both interference values are approximately the same and close to the environmental noise.

Propagation Paths

When the HEV is started by the hybrid-vehicle control unit (HCU), the low-voltage system is powered by the traction battery through the DC/DC converter; see the interference propagation mechanism

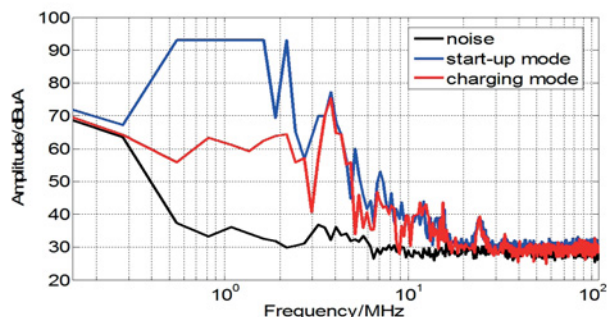
in Figure 4. Regardless of the vehicle's working state, the DC/DC converter will continuously operate in DC buck state (turning 144VDC into 12VDC), so the level of interference to the converter produced by the switching elements should be constant, and the interference signal will propagate to the converter's input and output lines.

In practice however, the level of interference on the DC/DC power line is entirely different in the four operating modes, as shown in Figure 2b. This indicates that the measured interference on the DC/DC power line is not entirely produced by the main circuit, but some part comes from the main circuit of the DC/AC converter itself, propagated to the DC/DC power line through the traction battery.

After comparing the interference spectrums of the DC/DC and DC/AC power lines, we conclude that their characteristics are similar in idling and electric-assist modes. Additionally, when the frequency is above 4MHz, interference levels in the four operating modes are nearly the same, which shows that one part of the interference on the positive pole of the DC/DC power line is produced by the DC/AC power line, coupled by the traction battery – i.e., the traction battery is the conduction path. A way to calculate this coupling interference is shown in Figure 5.

In Figure 5, the interference current, which propagates from the DC/AC converter to the DC/DC converter along the power line paths ① and ②, is influenced by distance and frequency.

(a) Comparison of interference current spectrum for startup and charging modes



(b) Comparison of interference current frequency spectrum for idling and electric assist

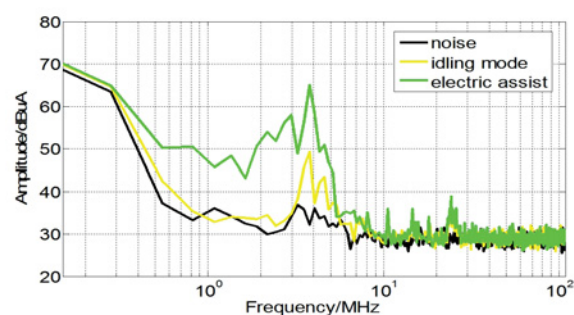


Figure 3: Frequency spectrum of the interference current on the positive pole of the DC/DC power line

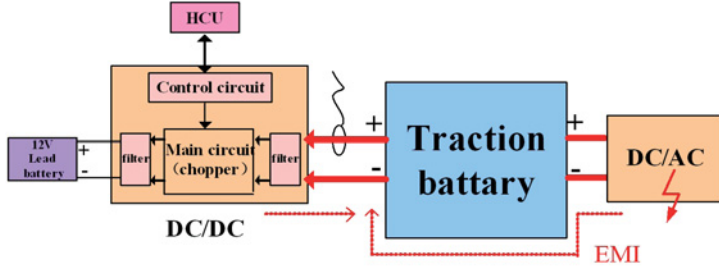


Figure 4: Map of the DC/DC interference path

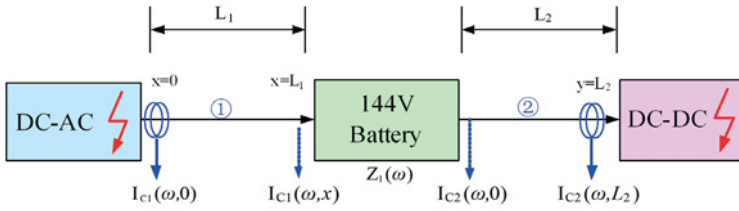


Figure 5: Calculation model of EMI coupling

Therefore, the interference characteristics can be represented by functions $D_1(\omega, x)$ and $D_1(\omega, y)$ respectively, where $\omega = 2\pi f$, x changes from 0 to L_1 , and y changes from 0 to L_2 , as shown in Figure 5.

The interference current produced by the DC/AC converter is $I_{C1}(\omega, 0)$, measured at the DC/AC port ($x=0$). The interference current $I_{C1}(\omega, x)$ that propagates down the line from the DC/AC converter to the 144V battery (see Figure 5) can be calculated by a transfer function such as:

$$I_{C1}(\omega, x) = I_{C1}(\omega, 0)D_1(\omega, x) \quad (1)$$

At the battery input port, where $x=L_1$, the interference current $I_{C1}(\omega, L_1)$ is:

$$I_{C1}(\omega, L_1) = I_{C1}(\omega, 0)D_1(\omega, L_1) \quad (2)$$

When the interference current propagates from the battery input port ($x=L_1$) to the output port ($y=0$), the battery output port's

current $I_{C2}(\omega, 0)$ is then:

$$I_{C2}(\omega, 0) = I_{C1}(\omega, L_1)D_1(\omega) \quad (3)$$

where $D_1(\omega)$ is the propagation characteristic of the 144V battery in Figure 5. Combining Equations 2 and 3, we can express the $I_{C2}(\omega, 0)$ as:

$$I_{C2}(\omega, 0) = I_{C1}(\omega, 0) \cdot D_1(\omega, L_1) \cdot D_1(\omega) \quad (4)$$

When the interference current propagates from the battery's output port ($y=0$) to the DC/DC converter, the interference current $I_{C2}(\omega, y)$ on the power line path ② can be calculated by a transfer function method such as:

$$I_{C2}(\omega, y) = I_{C2}(\omega, 0)D_1(\omega, y) \quad (5)$$

Combining Equations 4 and 5, $I_{C2}(\omega, y)$ can be expressed as:

$$I_{C2}(\omega, y) = I_{C1}(\omega, 0) \cdot D_1(\omega, L_1) \cdot D_1(\omega) \cdot D_1(\omega, y) \quad (6)$$

When $y=L_2$, at the input port of the DC/DC converter ($y=L_2$), the interference current $I_{C2}(\omega, L_2)$ can be calculated as:

$$I_{C2}(\omega, L_2) = I_{C1}(\omega, 0) \cdot D_1(\omega, L_1) \cdot D_1(\omega) \cdot D_1(\omega, L_2) \quad (7)$$

So, the interference current's relationship between the DC/AC converter $I_{C1}(\omega, 0)$ and the DC/DC converter $I_{C2}(\omega, L_2)$ is obvious.

Interference Currents

Interference comparisons on the input and output lines of the DC/DC converter are shown in Figures 2 and 6. If the interference produced by the low-voltage part of the system is ignored, the interference on the output line of the DC/DC converter can be thought of as interference produced by operation of the switching elements.

The variation trend and amplitude of interference current in the four working states are more or less the same in Figure 6, which agrees with the theoretical analysis that a constant interference is produced by the DC/DC converter, regardless of the vehicle's operating mode.

On the whole, the interference level of the DC/DC converter's output line is less than the level of interference on its power line, which also proves our analysis's conclusion that the interference on the DC/DC power line not only comes from its main circuit, but from the DC/AC converter too.

Similar analysis of interference current on the negative pole of the DC/DC power line agrees with our analysis for the positive power line. So, we conclude that the electromagnetic environment is worst when vehicles are starting up or charging. At those times, the switching power supply is under heavy load, so the interference becomes relatively large. In addition, interference on the power line of the DC/DC converter comes partly from the coupling with the motor driver, with the traction battery acting as a coupling path. ●

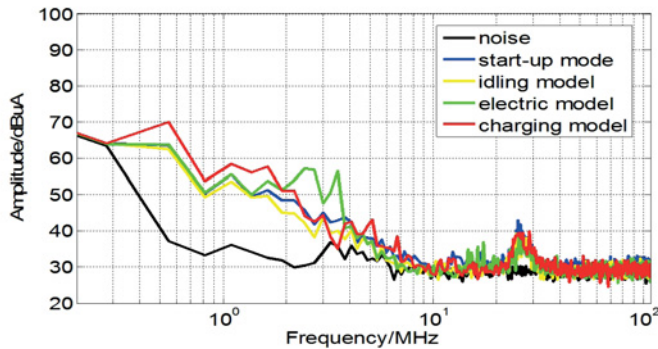
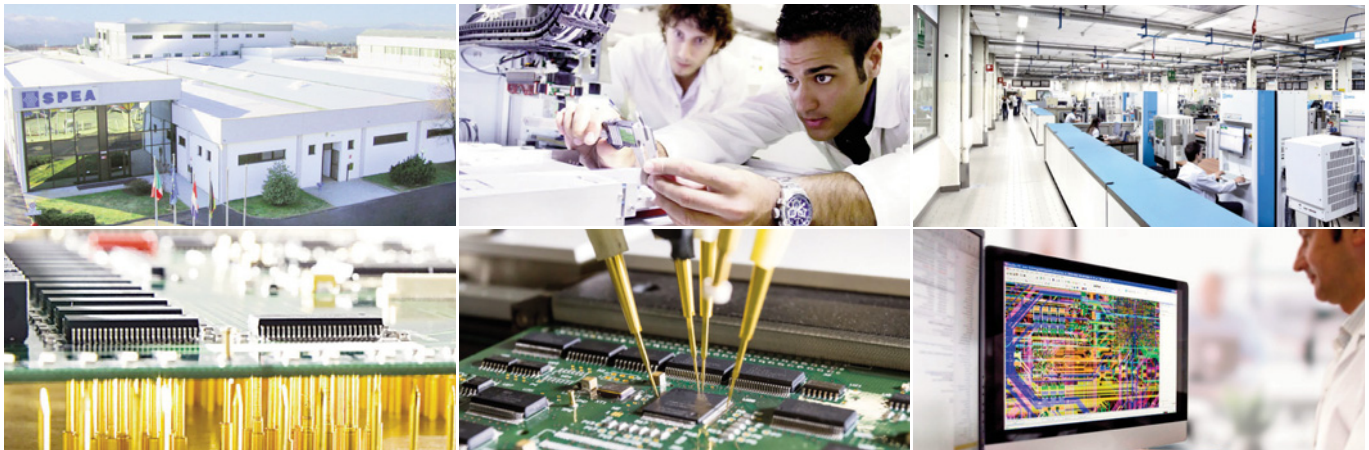


Figure 6: Interference spectrum of DC/DC output positive pole in four states



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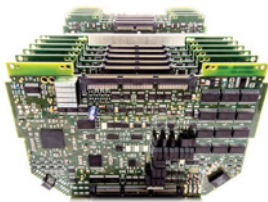
SPEA



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**Data
Bank**



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Customers	Global semiconductor and electronics industries
Founded	1976
Employees	Approx. 600
Location	Volpiano, Italy. Offices worldwide.
Web site	www.spea.com

VEHICLE CLEAN SLATE: HYDROGEN FUEL CELLS

BY **DOUGLAS PONSFORD**, SOFTWARE AND SYSTEMS ARCHITECT AT RIVERSIMPLE



It is said that nothing is certain except death and taxes. As the world's industrialisation continues apace, and the use of cars for personal transport continues to be an aspiration for generations to come, another certainty is increasingly obvious – eventually, we will run out of oil!

Although huge strides have been made in raising the efficiency of the internal combustion engine (ICE), there is still an upper limit to the calorific value of fossil fuel converted into kinetic energy, which is roughly 25-30%. Even in top-level motorsports, where turbocharged F1 engines take advantage of kinetic and heat energy recovery, overall unit efficiency still struggles to exceed 40%.

Petrol is wonderful stuff, but as any automotive engineer will tell you, utilising less than half the potential energy is a very poor yield.

Electrifying Solution

Electric vehicles are meant to help; all major car makers now offer models based on partly- and fully-electric propulsion systems, most using Li-ion batteries. This technology, while solving some of the issues with the ICE, brings new problems, such as large and heavy batteries that also take a long time to charge. Hybrid vehicles, where petrol or diesel is used to keep the battery system topped up, are only a stop-gap solution, as fossil fuel is still the primary energy source.

A mix of fuels and powertrains is required in the future to make the most of vehicle efficiencies and reduce emissions. Such mixes will be different, catering to different needs; the characteristics of battery electric vehicles (BEVs) and hydrogen fuel cell vehicles (HFCVs) are different and yet we need both, for different roles.

Fuel cells do not store energy, and unlike Lithium-based batteries they only provide electrical energy while the active chemicals are supplied to the electrodes (see Figure 1). The most common fuel cells use hydrogen as fuel and oxygen as oxidant, with outputs of heat, water and current.

Although often compared to batteries, since both use a chemical reaction to make power, fuel cells produce electricity only as long as hydrogen is supplied, never losing their charge.

Meet Rasa

Powys-based Riversimple is currently developing a car called Rasa, from the Latin phrase 'Tabula Rasa', meaning 'clean slate'. Figure 2 shows the Rasa in its home-town of Llandrindod Wells, the UK.

The Rasa's hydrogen storage system (see Figure 3) uses a 350-bar hydrogen tank, also considering the availability of hydrogen refuelling stations. This version is the standard for all commercial uses; the 700-bar tank is primarily for passenger vehicles with more constrained fuel tank space.

The core of any good driving experience is a vehicle's powertrain. Rasa's powertrain is based on a small hydrogen fuel cell which charges a bank of high-performance super-capacitors, which in turn provide the electrical energy to accelerate the vehicle via four in-wheel DC motors. The super-caps only provide acceleration; at constant cruising speed forward motion is maintained only by the fuel cell.

The four motor-generator units also replenish reserves of electrical energy during braking, by acting as generators. Regenerative braking is applied from the Rasa's maximum speed of 60mph down to 8mph, where friction braking takes over to bring the Rasa to a stop. From 60mph, up to 70% of the car's kinetic energy is recovered as electrical energy in a single braking event, compared to 10% for a Prius.

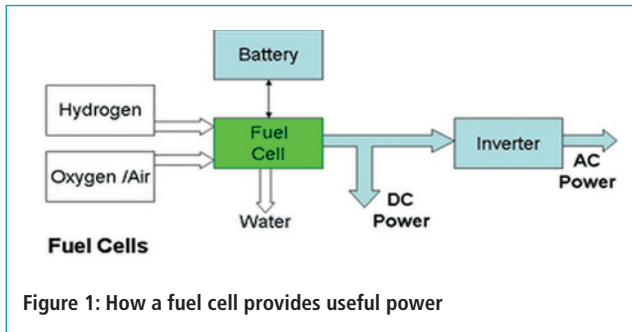
Electronic Control Units And Software

The powertrain, chassis and body of the Rasa are run by a distributed control system, built on 32-bit microcontroller ECU hardware, running complex, real-time embedded software. The initial prototyping hardware was based on New Eagle Motohawk hardware, built around the Freescale MPC5554 microcontroller platform.

Each of the development ECUs in the Rasa prototype can run up to three CAN bus links, complemented by a mix of digital and analogue inputs and outputs (I/O).

These commercially-available, automotive-specification ECUs are used for the primary control system within the vehicle's electrical architecture, which also provides driver controls and runs the display system:

- High Voltage Controller (HVC) controls the power output of the fuel cell via the DC-DC converter to charge the super-caps to the required level;
- Vehicle System Controller controls the torque applied to each wheel by issuing commands to the four inverters, one for each wheel;
- Body Controller (BC) is for the driver interface functions, reading



control inputs (indicators, drive selection, wipers, etc.) and the dash displays.

- Axle Guardian (AG) monitors and oversees the operational status of the vehicle and also individual components, to ensure continuous safe operation. The AG is designed primarily to help accomplish the safety integrity objectives of the overall control system and, second, to provide a controlled and repeatable vehicle start-up and shutdown sequence. AG will ensure that a drive cycle cannot start unless a system-wide checklist is passed. It also forces all system shutdown processes to be completed safely at the end of each drive cycle, thus providing end-to-end, ignition-on to ignition-off system safety supervision.

The control system software was entirely implemented using model-based development, with MATLAB and Simulink as the basis for all application-layer software development, simulation and unit test.

Each ECU is provided with a low-level operating system containing the specific hardware device drivers, thus providing a level of abstraction for the application layer development and potential porting to a different hardware solution for production.

Safety Considerations

Functional safety cannot be bought off-the-shelf, but rather is designed into the overall control system from the start; it is a key issue facing future automotive development. New functionalities in areas such as driver assistance, autonomous driving, propulsion, vehicle dynamics and active and passive safety systems increasingly touch the domain of system safety engineering.

With increasing technological complexity, software, mechanical and electronic implementation, there are increasing risks from systemic and random hardware failures. Guidance from the ISO-26262 development standard helps avoid these risks by providing appropriate requirements and processes.

Originally adapted from IEC-61508 to comply with the specific needs of electrical and/or electronic systems within road vehicles, ISO-26262 applies to all activities undertaken during the lifecycle of safety-related systems comprised of electrical, electronic and software components.

System safety is usually implemented via a mixture of technologies – mechanical, hydraulic, pneumatic, electrical, electronic and software – and whilst ISO-26262 is primarily concerned with the functional safety of electrical/electronic systems,



Figure 2: The Riversimple Rasa

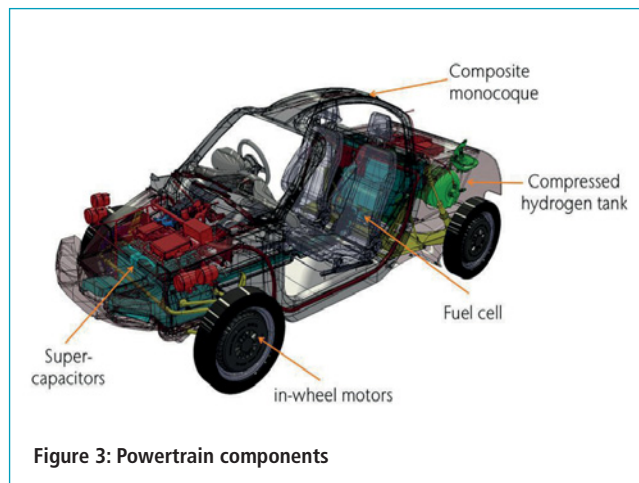


Figure 3: Powertrain components

it provides a framework under which safety-related systems based on other technologies can be developed, an approach taken by Riversimple.

To ensure continued safe operation of the Rasa, the electrical architecture implements Axle Guardian (AG), a system supervisory strategy that monitors control data flows on the vehicle network to determine whether the control system and its components are operating within safe limits. The development standards and processes applied to the HVC, VSC and BC controllers are fully aligned with the ISO-26262 standard, and implementation of the AG oversight strategy ensures that the requisite Automotive Safety Integrity Level (ASIL) is achieved. This removes the cost and complexity of developing any part of the system to the highest ASIL, because the ASIL is an emergent property of the entire electrical architecture.

Power Delivery And Performance

The Rasa is very light – it weighs only 580kg, and embodies these key features:

- A low-powered PEM (polymer electrolyte membrane) hydrogen fuel cell, capable of developing up to 8.5kW;

- A bank of 120 lithium hybrid super-capacitors, charged by the output of the fuel cell, controlled to a floating voltage of 66-114V and providing up to 1.9MJ of available energy;
- Four electric motors, one in each wheel, spinning at up to 840rpm, each developing up to 160Nm of torque. Each motor is a direct drive to the wheel and supports regenerative braking, recovering up to 70% of kinetic energy;
- Each 3-phase motor-inverter can drive up to 14kW into each wheel-motor;
- A hydrogen storage system of 350-bar, with a capacity for holding 1.5kg of fuel;
- The monocoque structure is constructed from lightweight composites, weighing only 39.6kg;
- Lightweight seat frames, trimmed in recycled PET fabric, weighing only 10.8kg per seat.

The synthesis of these technologies delivers ground-breaking efficiency and range, many times better than inserting fuel cells into conventional, heavy, vehicles. The production prototype achieves the equivalent of ~ 250mpg, with a range of 300 miles and a cruising speed of 60mph, reached within 10 seconds.

Tailpipe emissions are zero, and ~ 40g CO₂/km well-to-wheel – even if the hydrogen comes from natural gas. Refuelling takes around five minutes, comparable with the time it takes to fill the tank of a diesel or petrol car.

Electricity derived from the fuel cell flows to the motors in each wheel. These motors are small and lightweight, and give the car four-wheel drive. They also carry out a braking function; the motor acts as a generator during braking, capturing much of the kinetic energy as electrical energy, while also slowing the vehicle.

Although there is some heat loss in this regenerative braking function, it is small in comparison to the 100% heat loss from traditional friction brakes. As the car decelerates, this regenerated electricity flows into the car's bank of super-capacitors. Unlike a battery, these capacitors can accept a huge charge very quickly, but they don't store a lot of energy. The energy they take in is sent back to the motors again, and used to accelerate; see Figure 4.

The energy is networked around the car; it can flow in any direction on any path except back into the fuel cell. This innovative network design means the fuel cell is only required to be large

RIVERSIMPLE

Riversimple was founded by Hugo Spowers, who is also its chief engineer. An Oxford-University-educated engineer and entrepreneur, Spowers founded OScar Automotive in 2001, which became Riversimple in 2007.

The first fuel-cell car to emerge was the LIFEcar, developed by a consortium Spowers brought together with the Morgan Motor Company and presented at the Geneva Motorshow in 2008.

Riversimple is currently crowdfunding to build 20 Rasa prototype cars for its beta test later this year. Investments start from £50 (www.riversimple.com).

CLEAN ENERGY

More than 85% of the world's hydrogen is generated from methane, not electricity. Generation of electricity from natural gas is considered the cleanest form of fossil-derived electricity, and in the UK's grid it is 49% efficient, whereas steam reformation of natural gas to create hydrogen is 75% efficient.

Simulations evaluating vehicle efficiency suggest that a more efficient hydrogen vehicle can be built for any range over roughly 100 miles (though it is also possible to build inefficient hydrogen vehicles). For a vehicle of the familiar range of around 300+ miles, there is no solution on the horizon remotely as efficient as a hydrogen car; see Figure 5.

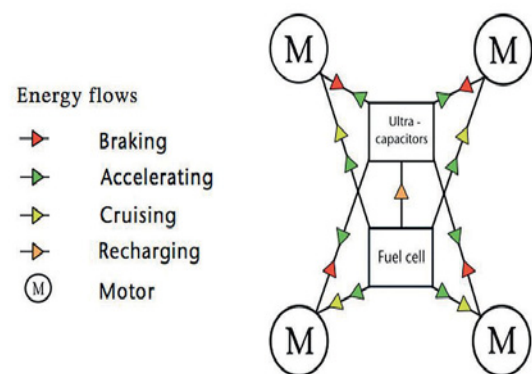


Figure 4: Energy flow in the Rasa

Energy efficiency

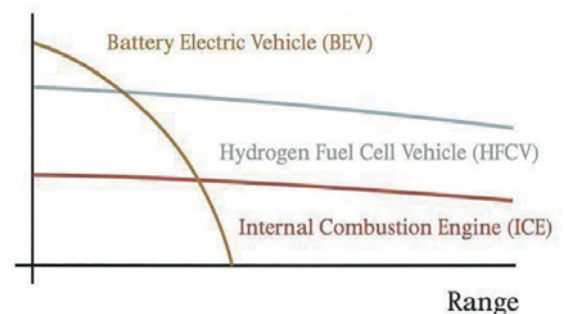


Figure 5: Relationship between energy efficiency and design range for different vehicle energy sources

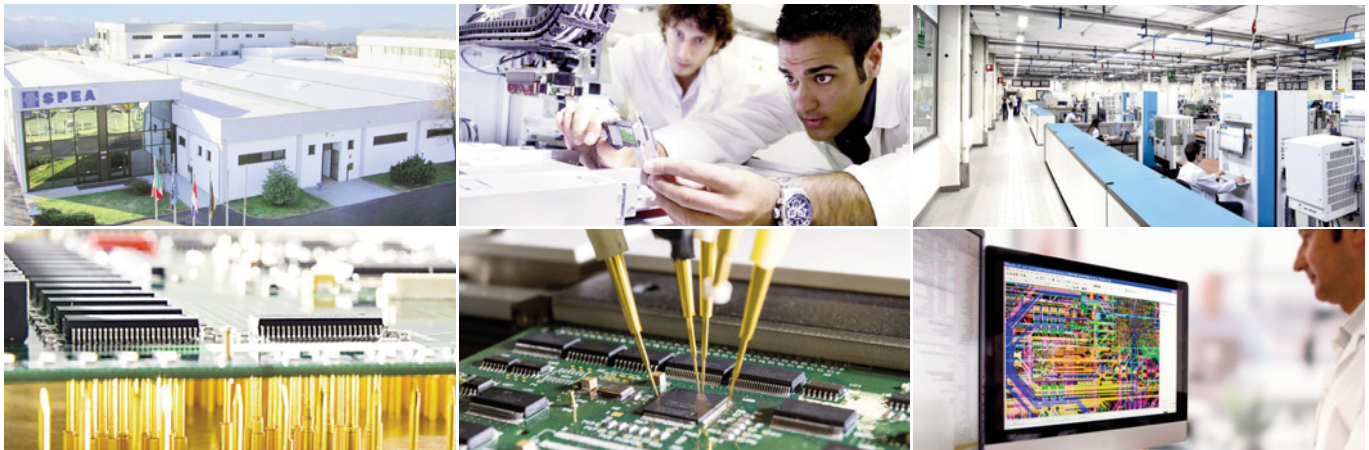
enough to provide cruising power, rather than acceleration.

The amount of electrical energy harvested during braking depends on vehicle speed and the amount of applied braking, but can be more than 50%. This recovered energy is stored in the super-caps, which then provide 80% of the energy for acceleration. ●



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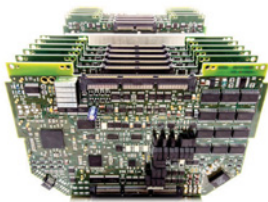
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Employees	Approx. 600
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Web site	www.spea.com

SWITCH CONTROL OF ELECTRIC VEHICLE'S PERMANENT MAGNET SYNCHRONOUS MOTOR

BY HUANG SONG, ZHANG LI AND FANG SHAN-SHAN FROM CHONGQING UNIVERSITY IN CHINA

Its high efficiency, high power-density and low vibration and noise have made the permanent-magnet synchronous motor (PMSM), which relies on permanent magnets instead of windings in the rotor, first choice for use in electric vehicles. But, for reliable operation in electric vehicles, the PMSM must meet two key requirements: low speed at constant torque and high speed at constant power. Since the conventional permanent magnet motor is excited by the low permeability of its material, its main magnetic field is difficult to adjust, making it near impossible to reach the right balance between these two states.

To solve this problem, academics have developed various solutions, such as adding a DC/DC converter module between the DC bus and the inverter, adopting variable-flux or mixed-excitation structures, and others. All of which, unfortunately, have proven either too low in efficiency, too complicated in structure, or too high in cost.

Here, we will focus on solving the impact current and torque have on the PMSM's switching process between series and parallel modes, and we will suggest suitable switching schemes.

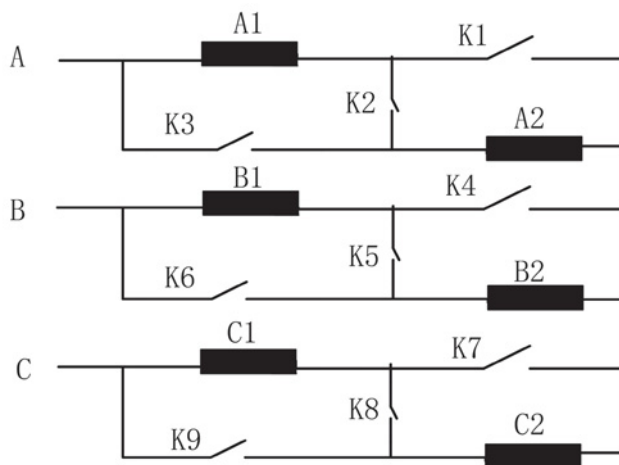


Figure 1: Structure of a series-parallel switching circuit for two sets of windings in the star configuration

Winding Structure Operation

For our winding structure, we used a series-to-parallel switching circuit, (Figure 1), where A1, B1, C1 and A2, B2, C2 are sets of windings; A, B, C are the windings' split phases; and K1 through K9 are switches.

When the electric vehicle runs at low speed, K1, K3, K4, K6, K7 and K9 open, and K2, K5 and K8 close, putting the two sets of windings in series. With more turns per phase, the back electromotive force (EMF) and required DC bus voltage increase too, and the current through the windings decreases, producing the same torque as with only one set of windings operational.

When the speed of the electric vehicle is high, then K1, K3, K4, K6, K7 and K9 close, K2, K5 and K8 open, and the two sets of windings operate in parallel. With the smaller number of turns per phase, there is a corresponding reduction in the motor's back EMF, the breakover speed (at which the two states swap) increases, the magnetic field weakens and demagnetization current decreases.

Obviously, if the windings' operation changes from series to parallel, the back EMF will halve, proportionate to the number of turns, and the resistance and inductance fall to a quarter of the original. When the applied voltage doesn't change, to maintain voltage balance, the transition process makes a greater transient impact. The maximum current impact is nearly six times the RMS in steady-series state, which will inevitably damage the system.

When the windings' operation changes from parallel to series, the switches act suddenly, the equivalent windings- and back-EMF double, and the resistance and inductance quadruple. Under constant applied voltage, to maintain the voltage balance there will be a great transient impact on the transition process, with the current maximum over 2.5 times the RMS in steady-series state.

Control Scheme

Here we recommend a control scheme to minimize the large impacts of current and torque transients when they exceed the parameters of what the motor can bear, and therefore damage it; see Figure 2.

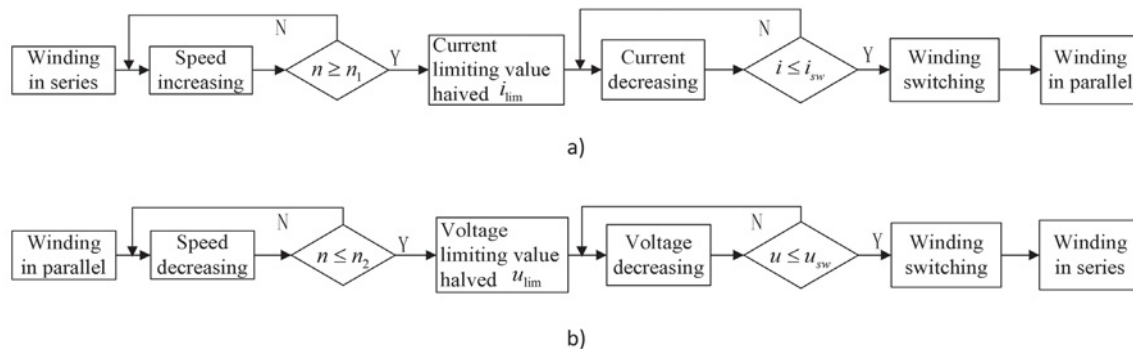


Figure 2: Flow chart of the switching scheme

When the windings' operation changes from series to parallel, the current cannot mutate, so there will be a large transient-current impact, which reduces the inverter's current (its current capacity must be larger for safe operation of the motor). So when the speed reaches the switching threshold, the control unit of the simulation circuit (Figure 3) decreases the (current limited) winding current and changes the in-series winding to in-parallel. At that point, the winding current cannot mutate, thus the terminal voltage doubles, but the actual voltage may not meet the requirements, so when the speed reaches the switching threshold, the controller's voltage-limited value halves.

When the terminal voltage decreases to a certain point, i.e. $u \leq u_{sw}$, the in-series windings begin operating in parallel.

In Figure 2, n_1 is the speed-switching condition when the

The brush DC motor uses an internal power supply with stationary magnets, whereas the brushless ones use rotation permanent magnets

windings change from series to parallel operation, and $n_1 = n + \Delta n$. n_2 is the speed-switching condition when the windings' change operating from parallel to series, with $n_2 = n - \Delta n$, n being the best switching speed, where the value of current when in series and parallel is close to that of semi-load conditions (in our study, the load is half the rated maximum).

The symbol Δn is the speed-switching threshold, used to adjust the switching process. Its value should be carefully considered: if too small, there will be repeated changeover when the speed increases or decreases; but if too large, no changeover occurs.

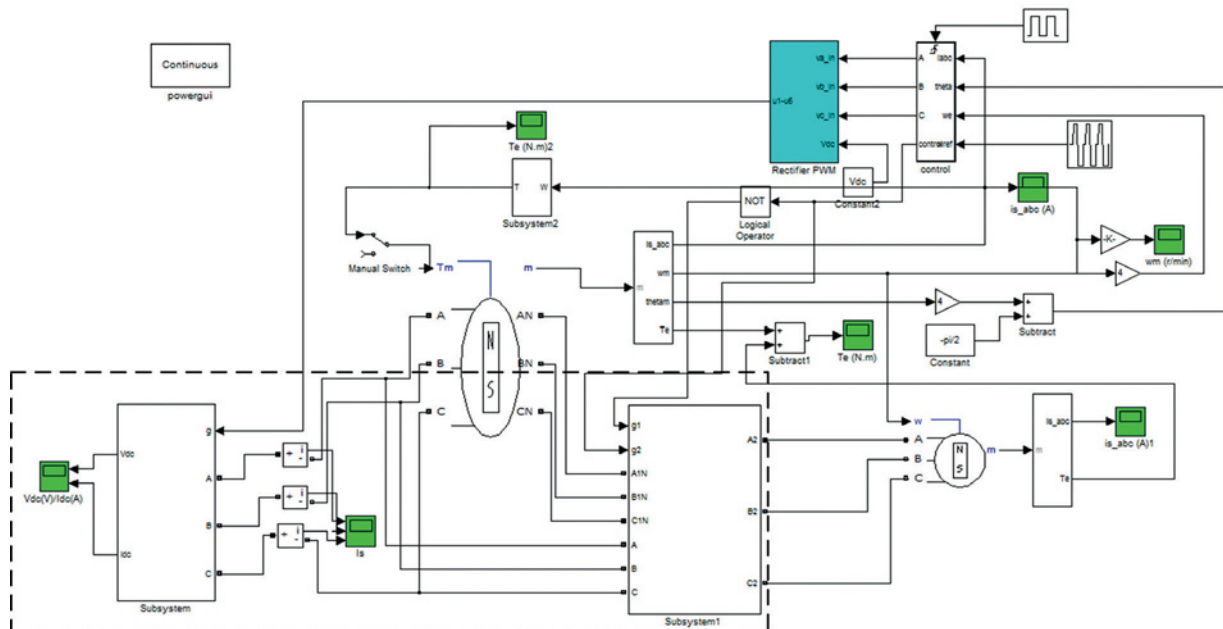


Figure 3: Simulation circuit of a variable-winding type PMSM

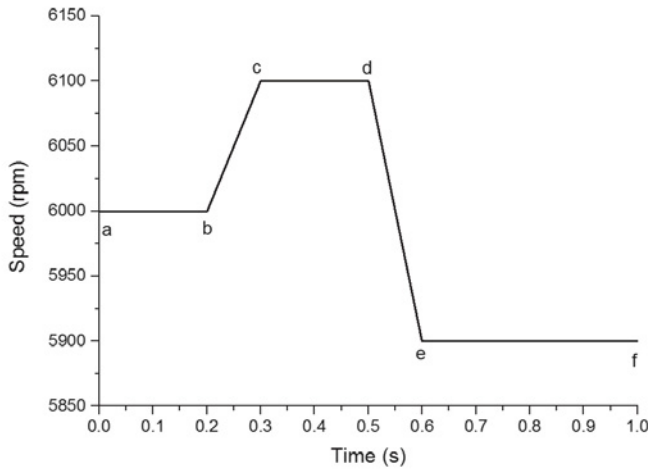


Figure 4: Curve of the given speed

Symbols i_{sw} and u_{sw} are the current- and voltage-switching conditions for each phase winding; i_{lim} and u_{lim} are current and voltage limited values of the inverter

u_{sw} is $V_{dc} * 0.98 / 2 / \sqrt{2/3} / 2 = 315V$ (phase value),

u_{lim} is $V_{dc} * 0.98 / 2 / \sqrt{2/3} = 630V$ (phase value),

i_{lim} is 610A, i_{sw} is 320A.

Adopting constant power conversion, the current limited value i_{lim} is $610 * \sqrt{2/3} = 498A$, and the i_{sw} current switching condition is $320 * \sqrt{2/3} = 261A$.

Figure 2a shows the moment the windings change from series to parallel. At first, they are in series, but when the speed reaches the switching speed n_1 , the current limited value of controller i_{lim} halves, and the current through the windings lowers.

When the current through the windings reaches the changeover condition $i \leq i_{sw}$, the switches K1, K3, K4, K6, K7, K9 turn off and K2, K5, K8 turn on, and the process of changing from series to parallel is completed.

Figure 2b shows the switchover operation from parallel to series. The windings are in parallel at first, but when the speed drops to the switching speed n_2 , u_{lim} , the voltage limit value of the controller halves and the voltage across the windings reduces. When the switching condition $u \leq u_{sw}$ is reached, switches K1, K3, K4, K6, K7, K9 turn off; K2, K5 and K8 turn on; and switchover process completes.

Simulation

To verify the feasibility and effectiveness of the changeover schemes outlined here, we built a simulation Simulink model (see Figure 3) to check if the transient impacts behave as predicted during the transition process.

The motor prototype parameters are shown in Table 1.

parameters	value	parameters	value
Rated power kW	350	Rated voltage V	633
Rated speed rpm	3000	Rated torque N.m	1114.08
Max speed rpm	9000	Max back-EMF V	1400

Table 1: Motor parameters

The number of stator-winding-turns in a single set is 15. The motor runs at low speed; two sets of windings are in series, making the effective turns number for each phase 30. In high-speed operation, the two sets of windings are in parallel, so the effective number of turns per phase is 15.

When the prototype operates in semi-load conditions and the speed is 6000rpm, currents through the windings are similar when in series or parallel. The line back-EMFs when the motor is running at 6000rpm in series and 9000rpm in parallel don't exceed the inverter's 1400V, therefore the optimal switching speed is 6000rpm, and Δn is 100rpm, so $n_1 = 6100\text{rpm}$ and $n_2 = 5900\text{rpm}$.

In Figure 3, I is the PWM module (on the right side of the control unit), II is the inverter module, IV is the switch module consisting of nine IGBTs, and III and V are two identical PMSMs.

Ignoring the influence of saturation, switching of the two winding-sets can be achieved by switching two identical PMSMs.

The PWM wave generated by I module controls the inverter's output, while the DC link current is converted into AC to supply the PMSM. Because III and V simulate the two sets of windings in a motor, they should have the same speed; in our study we've made the output speed of III the input signal of V.

Simulation Setup And Results

The speed observed in the simulation is shown in Figure 4.

The operation's stages, are as follows:

- (1) ab (0.0-0.2s) shows the initial state of switching. The motor runs in series at 6000rpm, at 175KW.
- (2) bcd (0.2-0.3-0.5s). The motor accelerates in the bc segment; the controller increases the motor's speed from 6000rpm, and when it reaches 6100rpm, the motor switches from series to parallel operation, as shown in Figure 2a. It then continues to run in parallel in the cd segment (0.3-0.5s).
- (3) def (0.5-0.6-1s). The controller reduces the motor's speed in the de part (0.5-0.6s). When its speed reaches 5900rpm, it switches from parallel into series mode, as shown in Figure 2b. It continues to run in series in the ef part (0.6-1.0s). The simulation results of this process are shown in Figure 5.

In Figure 5a, the motor's speed increases from point b at 6000rpm to point c at 6100rpm, at constant pace. From Figures 6b-e we see that the winding current holds around 280A, the torque is around 310Nm with 900V terminal voltage.

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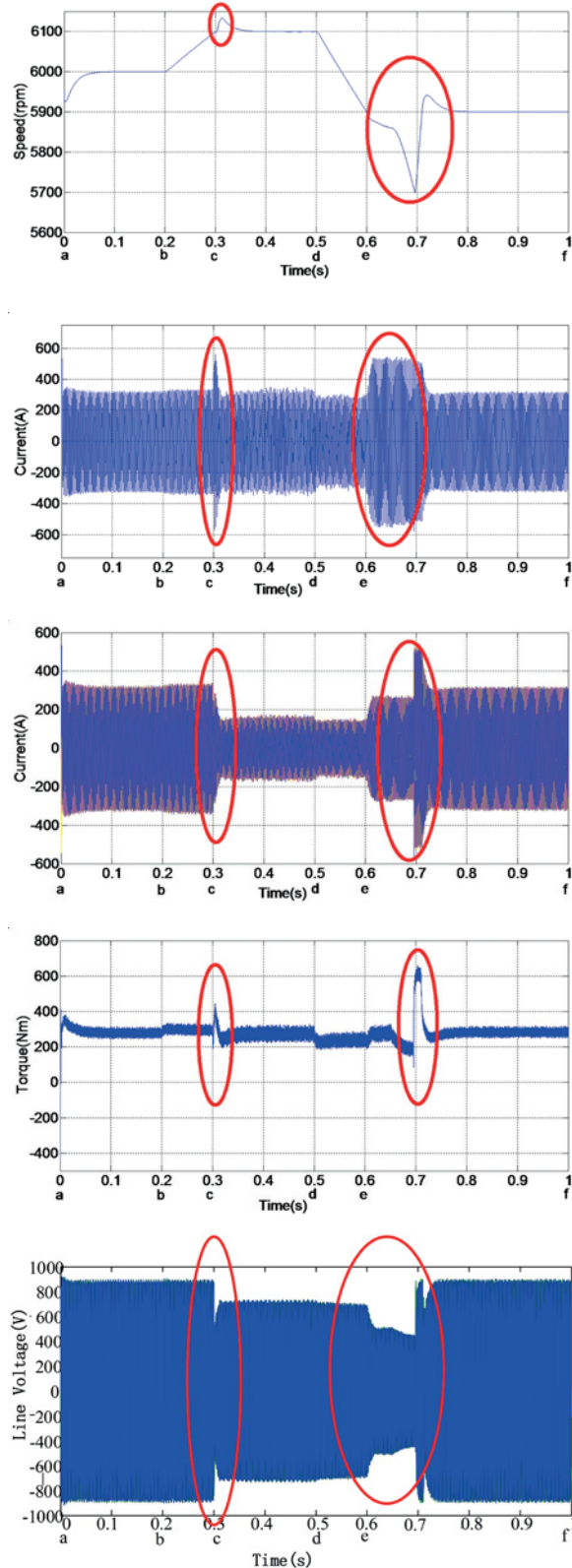


Figure 5: Speed and current waveforms of the switching process

To keep the speed steady in the cd section, a feedback loop takes effect, lowering the electromagnetic torque from 310Nm – its value at point c. Because at this point motor speed reaches the switching condition of 6100rpm, the windings switch from series to parallel and the number of turns halves. The current through a single set of windings cannot mutate, so at the switching moment the current doubles to 560A (point c of Figure 5b) and the terminal voltage halves to 450V. To keep voltage balance, the demagnetization current i_d decreases and cross-axis current i_q increases, to the torque at point c of Figure 5d. The terminal voltage rises to a stable value of 700V.

As motor speed decreases from 6100rpm at point d to 5900rpm at point e, the windings' current and torque become constant. To keep motor speed unchanged at 5900rpm in the ef stage, the torque increases from 300Nm, its value at point e, but still lower than the load torque, so motor speed continues to slow. Because its speed reaches the switching condition of 5900rpm at point e, the voltage limited value halves (to 315V) and the switches don't engage, so the windings continue to run in parallel.

To maintain a voltage balance, the demagnetization current i_d is increased, so the current through a single set of windings increases too, with the windings' current doubling. As shown at e in Figure 5b, when the voltage decreases to 500V, this meets the power requirements of the load. If it continued to decrease to the switching threshold, the power would not meet the load requirements, so the voltage would be out of control. To prevent this, the motor begins to weaken the magnetic link, and the demagnetization current i_d increases. Because inverter current is limited, the cross-axis current i_q decreases along with the torque, and the motor's speed drops dramatically to 5700rpm.

When the voltage reaches the switching condition at 420V, the windings change operation from parallel to series, and the current limited value doubles (to 610A). When the speed loop acts, torque rises to 670Nm, motor speed rises to 5930rpm and the current through a single set of windings increases to 530A. Because the number of turns doubles, the voltage increases and the speed loop begins to act, so the motor's speed, torque and current decrease, eventually reaching stable values.

The above results show that these switching schemes can indeed inhibit the impact of large torque and current transients on a permanent-magnet synchronous motor during switchover. Thus, these approaches become part of a solid foundation for the development of high-performance, economic electric cars. ●

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MILITARY CONNECTORS FOR RUGGED APPLICATIONS

BY **MATTHIAS OETTL**, DIVISION MANAGER AT HEILIND ELECTRONICS MIL/AERO

The rise of cyber-physical systems such as robots and autonomous vehicles is leading to a demand for rugged, resilient connectors that can cope with harsh environments. These systems need to withstand not just moisture and dirt, but corrosive contaminants as well.

Many connectors are supported by data claiming them to be reliable and suited for demanding applications; but, do they perform outside the narrow range of conditions specified in the documentation?

More important to connector design is an understanding of the different construction techniques that have been proven in harsh environments, through decades of experience and work in highly demanding applications. That is why, when it comes to rugged connectors, it is worth looking at military connectors for non-military applications.

The major advantage of military standard connectors is that the designs have been refined and battle-tested over time – and so have the requirements. The evolution of military standards and the connectors that follow them, closely match the demanding requirements of ruggedised systems, and provide a number of options to support different needs. If a connector application does not need the full complement of ruggedisation, other options are available that may cost less. The key is to match the requirements of the application to the connector type. This need not to be as challenging as it first appears since there are specialists who can help, with specific technical skills and many years of experience in this demanding industry.

Circular Connector Design

In contrast to the connectors used on office computers and similar products, military designers long ago opted for a circular architecture that has become a staple of rugged connectors ever since. The shape is important. Whether the interface is Ethernet, USB, parallel bus or a custom mix of signal pins, the same circular shape is a consistent feature of military-grade rugged connectors because of its excellent performance.

The circular shape provides the basis for higher mechanical strength, particularly if the connector is subject to shocks or high forces perpendicular to the signal flow. There are no sharp angles or corners often found in commercial-grade connectors that focus such stress into small portions of the connector body.

The MIL-DTL-28840 standard took the circular connector concept into shipboard systems, using corrosion-resistant materials and seals to protect against sea water and chemicals. The MIL-DTL-38999 standard provided a high-density connector for increasingly complex electronic systems, following the trend towards subminiature connectors in the commercial IT space.

The longevity of the core connector shape has led to a design that maximises usability and robustness in real-world use. Damage caused by misaligned connectors needs to be minimised, since obviously a system cannot be rendered unusable in active service conditions. Connections may have to be made under fire, so the connector design needs to be implemented in such a way that mismatching and damage cannot occur.

Keyways

Military connectors employ keyways, not only to ensure the two halves align correctly as they are brought together, but also to prevent damage to fragile pins in high-density designs. Usually there is a master keyway providing primary alignment between shells. On this is superimposed a set of minor keyways to allow the orientation of the respective inserts to be altered relative to the master key. This is achieved by slightly altering the angle of the inserts in the shells. For instance, the pin insert may be placed some degrees clockwise relative to the master, while sockets are moved anticlockwise in the same manner. Thus, different pin arrangements are catered for without compromising the protection against mismatching.

Although the use of keyways prevents most of the potential for damage when mating connectors, there is still the danger of socket hardware damaging the pins of a high density plug with which it's to be mated. This occurs at the moment of insertion or withdrawal. The pin insert is surrounded by a cylindrical metal shield that projects well beyond the delicate pin inserts. On bringing the two halves of the connector together, this shield engages and aligns them before the pins are mated. This scoop-free design prevents damage by attempts to engage the connectors when the halves are not in line.

Once the connectors are mated, they lock together with coupling. A common choice is between threaded, bayonet and breech-lock designs. In all cases, the aim is to add extra compression to the joint before positive locking occurs, to ensure excellent contact between the two

halves of the connector. The MIL-DTL-38999 connector and similar designs have evolved to employ a triple-start threading mechanism for the double benefits of high protection against vibration, and faster mating and unmating without missed connection.

Using The Right Materials

The choices of material and design for connector contacts have been instrumental in the long-term stability of the military connector standards, making them highly suitable for any application that requires ruggedness. Connectors are precision mechanical devices whose interfaces are critical and subject to mechanical wear, more so than most electrical components. If not catered for, the effects of oxidation and sulphide formation will reduce the connector's reliability.

Connectors may be required to have contacts made and broken repeatedly and in conditions that encourage corrosion as well as mechanical wear. Industrial applications, as well as military, often subject the connector assembly to vibration or repeated physical force, which contributes to fatigue or abrasion of the contact materials.

These life stresses cause degradation of electrical conductivity, and in inferior designs can result in open, intermittent contact or excessive resistance. In some installations, mechanical strain can also adversely affect the integrity of the securing apparatus. Among the materials found in lower-cost connectors are metal alloys >

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suitable for casting, such as those zinc based. The contact materials for military circular connectors tend to be metals and alloys with higher endurance.

Beryllium copper is commonly used by leading manufacturers of circular connectors. Copper has the key advantage of being an excellent conductor but is a relatively soft metal. Alloying copper with beryllium, however, dramatically changes its physical performance, and the resulting alloy of beryllium with copper has the further benefit of being comparatively lightweight.

Small changes in the beryllium content, which is typically between 0.15% and 2% by weight, produces alloys with widely differing physical properties. All retain an elastic modulus of around 20 million psi, about 10-20% higher than other copper alloys.

For the shell around the connector body, there are a number of material choices. One is aluminium that is plated or anodised for corrosion protection. A variety of plating materials can be used. Traditionally, cadmium was a high-quality choice for corrosion resistance but the introduction of environmental restrictions, such as the RoHS and REACH directives, mean less toxic materials must be used in most applications. Experience has shown that zinc alloyed with nickel provides high salt-spray resistance, comparable to that of cadmium plating. This performance is achieved without compromising electrical continuity. Higher continuity, though with less resistance to salt spray, is available using nickel over aluminium.

Stainless steel provides another option for shell construction. Along with its excellent corrosion resistance, it is generally one of the best choices for situations requiring operation in sterile conditions – suiting it to food and medical applications. Plating of stainless steel is generally nickel or a passivation layer.

The Connector's Internal Structure

Internal contacts generally need to be protected from moisture ingress, possibly to the level of a hermetic seal. Examination of the internal structure of the typical circular connectors reveals how well-suited to this the design is. There are often a number of layers of insulating material packing the space between the connector body and the contacts.

Looking into the front of the male connector, a user will see the interfacial seal, but behind that will be an insulator layer, a retention disc and, finally, a grommet that extends to the rear of the connector body. The female connector provides a deep insulating layer on top of another retention disc and the grommet. As well as enhancing in the sealing ability of the connector, the retention discs help ensure firm contact between electrically important mating parts.

The insulating materials are carefully chosen. Dielectric materials in low-cost commercial connectors may include polyethylene and polystyrene, possibly glass-filled for high voltage breakdown performance. Circular connector manufacturers will often specify FEP fluorocarbon or polytetrafluoroethylene (PTFE). For connectors with a sealed interface, the gasket material is typically silicone rubber.

A careful choice of insulating materials and contacts ensures high

THE AS50515 CONNECTOR DESIGN

Developed more than 70 years ago, the AS50515 connector (see below) is well known as a cost-effective solution for high reliability, waterproof and heavy vibration requirements in many military and industrial applications. Its structure offers easy engagement and disengagement, the ability to house a wide variety of contact types and excellent mechanical and electrical performance under harsh conditions.

Nevertheless, the AS50515 standard has limitations, which led to the development of a number of variants (e.g. reverse bayonet) that optimise contact size for high-density interconnection, as well as providing support for features such as multi-key polarisation. This means that in a connector based on the core AS50515 design, the metal shell has a number of keyways to correspond to the mating connector, depending on the application.

AS50515 is widely applied in powertrain applications in transportation, and industrial robotics where high power-handling capability is essential. It also meets the European MIL-standards (VG-standard).



Unmated AS50515 connector

performance in electrically-demanding applications, such as high-frequency signal interfaces. These connectors will provide consistent electrical performance and mechanical reliability. Also, basing connector choice around a known and well-supported standard such as MIL 38999, ensures uniform performance among products from different vendors. For example, such a standard will demand gold plating levels to a specified minimum level to guarantee conductivity.

A further advantage of materials specified for military use lies in the operational temperature range of the connectors. They can be used across a wide range of temperatures, often down to -65°C and up to +200°C, depending on the model.

For operation in hazardous, fire-prone environments, another option is fibre-optic connections. Because of the high signal-integrity of photonic transmissions, there are many options for fibre-optic connectors in military product ranges – as well as pertinent standards, such as MIL-PRF-29504 termination.

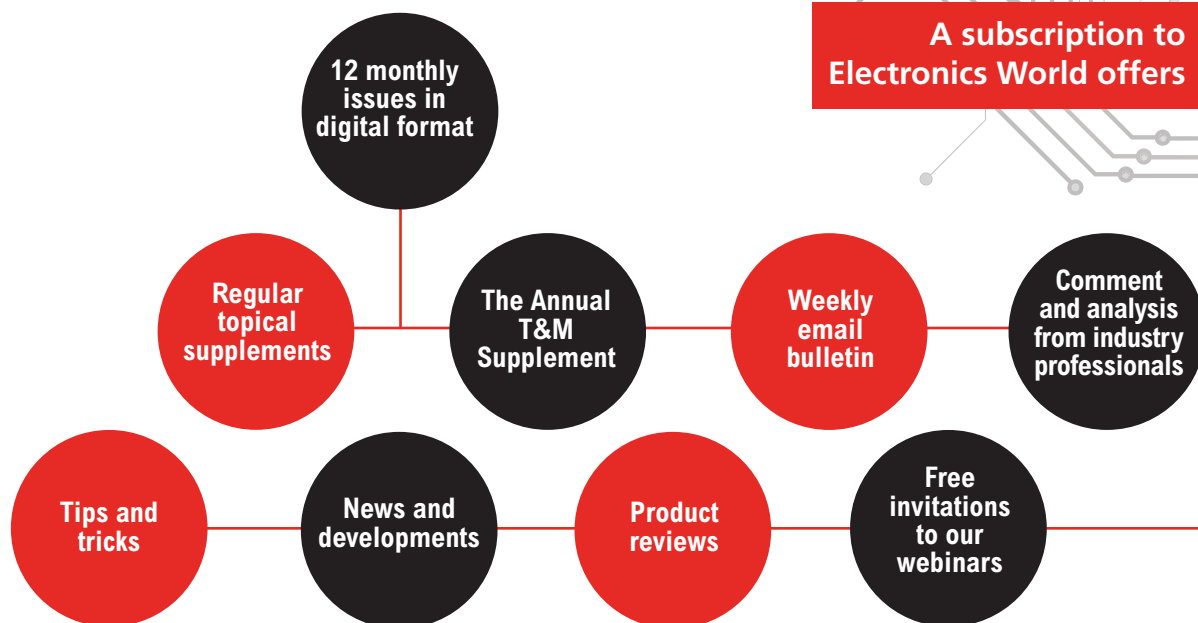
Designed to fit MIL-DTL-28840, MIL-DTL-38999 and similar connectors, the MIL-PRF-29504 standard determines performance criteria for fibre-optic termination to ensure clean mating. Because of the need to preserve optical continuity under shock and vibration, fibre-optic standards are more stringent in this respect and ensure that reliable performance is maintained in compliant products.

A combination of experience and clear standardisation that maximises interoperability and resilience makes the military circular a smart choice for a wide range of industrial applications bound for harsh environment applications with stringent performance requirements. ●

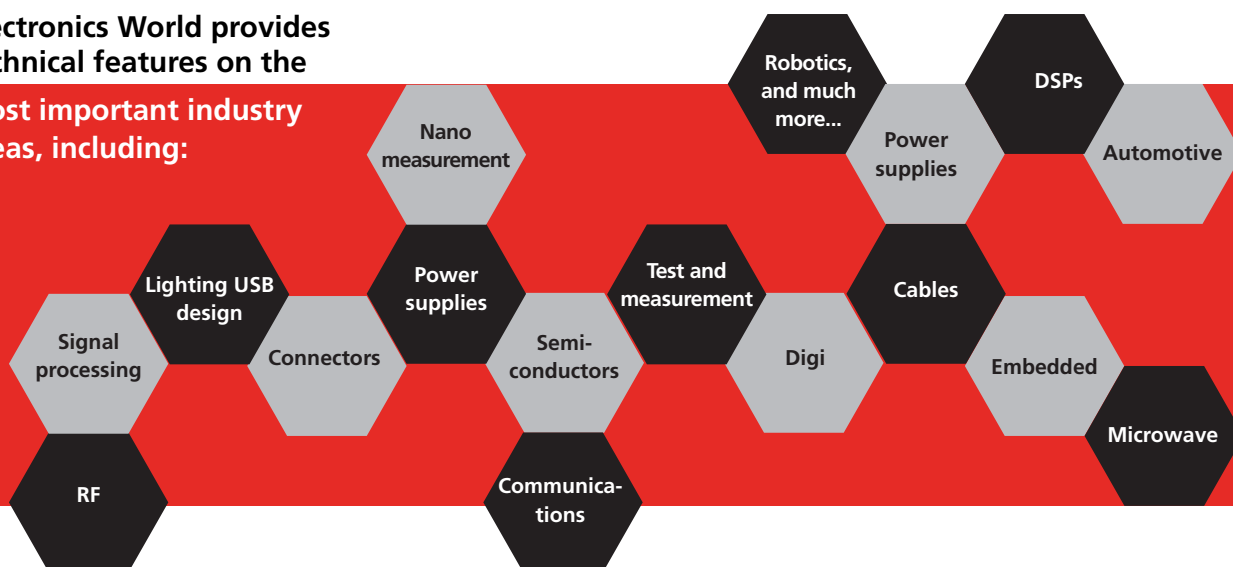
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As Apacer's next generation SSD, the PM110-M280 (M.2 2280) uses the PCIe Gen3 x4 interface and is compliant with the latest NVMe 1.2 specifications. At 4K, the SSD achieves random read and write speeds of up to 293,000 IOPS and 194,000 IOPS respectively, demonstrating remarkable computing performance. Its slim and lightweight forms allow the M.2 2280 to offer more flexible applications.

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USB 3.0 OSCILLOSCOPE PACKED WITH TECHNOLOGY

TiePie engineering launched Handyscope HS6 DIFF, a USB 3.0 oscilloscope packed with technology. This new four-channel, high-resolution oscilloscope has differential inputs and is available with sampling rates from 50MS/s to 1GS/s. The scope also features TiePie engineering's unique SafeGround technology, which allows safe switching of differential inputs to single ended.

Differential inputs offer the advantage of not having connections between the channels and the ground of the computer, avoiding short circuits. When SafeGround is active and accidentally a wrong connection is made which causes a short circuit, the technology disconnects the ground of the input channel without damaging the scope or the PC.

Also unique is the standard CMI interface on the Handyscope HS6 DIFF, which allows connecting more scopes together to create an instrument with multiple measuring channels with the same sample frequency (0ppm deviation).

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The rugged CE-certified 19-inch expandable human machine interface supports up to 32GB system memory of dual-channel DDR4-2133 to deliver high computing capability. The rich I/O interfaces include three RS-232 ports, one RS-232/422/485 port, four USB 3.0 ports, two USB 2.0 ports, two Gigabit Ethernet ports, and so on.

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Allegro MicroSystems Europe announced a new N-channel power MOSFET driver capable of isolating a three-phase load by controlling the in-phase isolation MOSFETS. It is intended for automotive systems that must meet Automotive Safety Integrity Level (ASIL) requirements. This new device was designed for EPS (Electronic Power Steering) systems, electric braking and three-phase relay driver applications and is supplied with detailed safety documentation.

In safety-critical applications, motor isolation is an essential requirement, currently addressed with discrete circuitry or relays in most competitive solutions. The A6862 three-phase isolation driver is intended to replace a relay driven motor disconnect in automotive safety-critical systems. It also provides the drive for reverse battery protection and battery isolation.

www.allegromicro.com



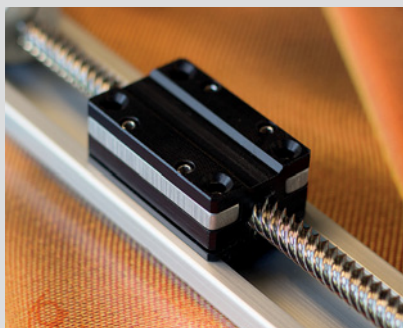
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Small, light and flat, when used in combination with the dryspin high-helix threads, the linear axis not only carries out simple handling tasks, by implementing a stepper or DC motor, it can also handle high-speed sensor adjustments.

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MACOM Technology Solutions confirmed the production-ready MAOP-L284CN, a 100G CWD4M transmitter L-PIC (Lasers integrated with a Silicon Photonic Integrated Circuit), and supporting driver and controller IC chipset.

To meet the bandwidth demands, resiliency and data redundancy requirements of today's Cloud data centres, optical interconnects are transitioning from 100G to 400G, driving a surge in demand for high-speed optical links.

MACOM's demonstration shows the platform's PAM-4 CWD4M capability of uncooled operation at 400G at distances up to two kilometers on single mode fibre. These devices leverage key MACOM technologies optimised for high port-density applications. The demonstration will transmit 100G PAM-4 over a single lambda with the L-PIC platform at OFC 2017.

MACOM's L-PIC device combines four high-performance distributed feedback (DFB) laser diodes using MACOM's patented Etched Facet Technology (EFT), four 28G Mach-Zehnder optical modulators and so on.

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