September 2018
Volume 124
Issue 1986
£5.90

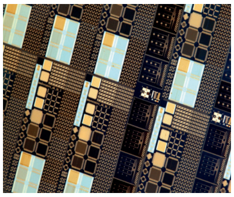
www.electronicsworld.co.uk

Electronics WORLD

THE ESSENTIAL ELECTRONICS ENGINEERING MAGAZINE

Embedded Design
Special Report

INSIDE THIS ISSUE



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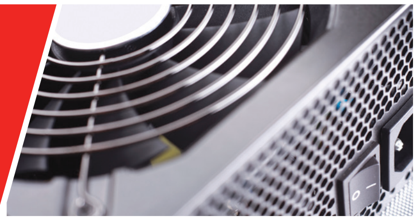
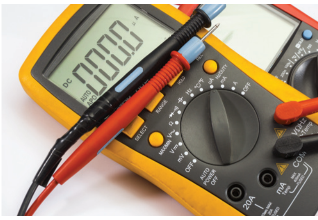
Microchip's Free Software for Circuit Design





MPLAB® Mindi™ Analog Simulator reduces circuit design time and design risk by simulating analog circuits prior to hardware prototyping. The simulation tool uses a SIMetrix/SIMPLIS simulation environment, with options to use SPICE or piecewise linear modeling, that can cover a very wide set of possible simulation needs. This capable simulation interface is paired with proprietary model files from Microchip, to model specific Microchip analog components, in addition to generic circuit devices. Finally, this simulation tool installs and runs locally, on your own PC. Once downloaded, no internet connection is required, and the simulation run time is not dependent on a remotely located server. The result is fast, accurate analog circuit simulations.

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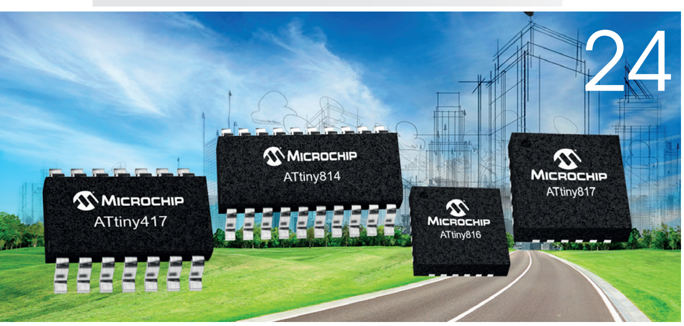

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THE ROLE OF WOMEN IN ENGINEERING

According to the Women's Engineering Society (WES), less than 10% of engineering professionals in the UK are women, the lowest figure in Europe. Latvia, Bulgaria and Cyprus are leading the way, with female engineers making up almost 30% of the workforce.

Introducing Women

In 1914, the National Council of Women was created with the aim of getting women into work to aid in the war effort as men joined the armed forces. These women, highly praised for their skills and expertise, changed the face of engineering forever.

Unfortunately, in 1919 the Restoration of Pre-War Practices Act forced women to give up their jobs to the returning men. Women's representation within engineering has never recovered.

Electrical Energy

The impact of women on engineering stems from well before World War I. Edith Clarke, born in 1883, had a long relationship with engineering, beginning work as a "computer" at AT&T in 1912. Clarke went on to become the first woman to earn an M.S. in electrical engineering from the Massachusetts Institute of Technology (MIT).

Her most remembered achievement is the invention of the Clarke calculator, a graphical equation-solving device, which she produced in her spare time. The Clarke calculator allowed the investigation of electrical characteristics of long lines used to transmit electrical energy, a system she rightly believed would become quite common. Without her calculator, long distance electrical transmission and its benefits would have become less widespread. Since electricity was one of the driving factors of the second industrial revolution, industry would have been severely hampered without this calculator. Even today companies rely on the mechanisms invented by Clarke, especially in the design of resistors.

Off-Screen Shine

Actress Hedy Lamarr, a film star from the late 1930s to the 1950s, helped develop a radio guidance system for allied torpedoes during World War II.

The spread-spectrum technology used early frequency-hopping technology to defend against the threat of jamming and was later used on US Navy ships. Even today, the principles involved in the technology are incorporated into Wi-Fi and Bluetooth. These technologies are used within various industries, including manufacturing and transport. More recently, the manufacturing industry has made the most of these digital technologies to aid the adoption of Industry 4.0.

A Pioneer

Let's not forget one of the pioneering women of engineering, Ada Lovelace, who wrote the first complete computer program, published in 1843.

Having studied mathematics and science from an early age, Lovelace theorised a method allowing Charles Babbage's analytical engine to perform "looping" – the repetition of a set of instructions, still in use in computer programs today.

Lovelace is known as the first person to recognise that a general-purpose computer could have more uses than calculations, suggesting it could create music and art.

Next Generation

The contributions of women to engineering are unsurprisingly broad and no doubt provide inspiration for women across the world who hold careers in engineering.

The question of how to inspire more women to choose careers in engineering is being asked worldwide. The answer isn't simple, and the responsibility falls to many – from engineering companies to schools.

Actress Hedy Lamarr, a film star from the late 1930s to the 1950s, helped develop a radio guidance system for allied torpedoes during World War II

These brilliant women, amongst many in their sector, will continue to inspire the next generation of engineers, who may go on to produce something just as brilliant, regardless of their gender.

International Women in Engineering day takes place each year on June 23. The day focuses on the achievements and inspiring careers accomplished by women in engineering and technical roles. Supported across the industry by movements such as the Institution of Engineering and Technology's *'Nine Percent is not Enough'* campaign, it presents an opportunity to celebrate the pioneering and influential women who have and continue to push boundaries within engineering.

The Women's Engineering Society (https://www.wes.org.uk) offers more on this subject and helps get involved. ●

Helen Marston, engineer at resistor manufacturer Cressall (www.cressall.com)

***EDITOR:* Svetlana Josifovska**
Tel: +44 (0)1732 883392
Email: svetlanaj@electronicsworld.co.uk

***SALES:* Suzie Pipe**
Tel: +44 (0)20 8306 0564
Mobile: +44 (0)7799 063311
Email: suziep@electronicsworld.co.uk

***DESIGN:* Tania King**

***PUBLISHER:* Wayne Darroch**

SJP business media

2nd floor,
St Mary Abchurch House,
123 Cannon Street,
London,
EC4N 5AU

ISSN: 1365-4675
PRINTER: Buxton Press Ltd

SUBSCRIPTIONS:
Subscription rates:
UK - 1 year digital only £53.00+VAT
UK - 1 year print and digital sub £68.00
UK - 2 year print and digital sub £109.00
UK - 3 year print and digital sub £143.00
International - 1 year digital only £53.00
International - 1 year print and digital sub £164.00
International - 2 year print and digital sub £290.00
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UNIVERSITY OF SOUTHAMPTON DEVELOPS ELECTRONICS TECHNOLOGY THAT CAN LEARN ‘BIOLOGICALLY’

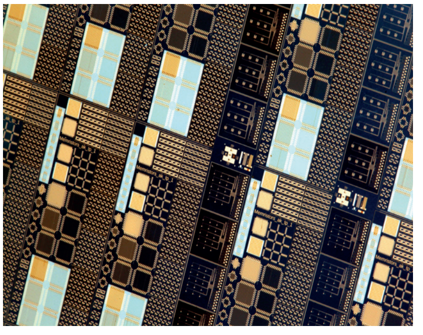
A team from the University of Southampton is approaching the design of electronic systems in a new way in the effort to make super-chips capable of fast biological-style learning.

The team’s work builds on previous developments of memristive technologies undertaken at the University of Southampton, which includes a new memristor technology that packs unprecedented amounts of data per device, almost four times more than previously reported.

“Memristors have gathered a lot of interest as a next-generation memory technology by being smaller, more power-efficient and yet able to support more memory states when compared to the existing technologies used in smartphones and computers,” said Professor Themis Prodromakis, Head of the Electronic Materials and Devices Research Group at Southampton’s Zepler Institute.

Traditionally, data processing in electronics relies on ICs containing a huge number of transistors. Here memory is an expensive resource used as sparingly as possible. Until now, performance improvements were achieved by reducing transistor size and packing more of them on a chip. However, with transistors now reaching their physical scaling limits, further improvements using the old techniques have become increasingly challenging.

Memristor chip



The projected performance gains and power savings from using memristor-based analogue devices suggest that this research could one day lead to hardware with true intelligence without the help of a cloud-based supercomputer, and yet fits in the palm of a hand. A direct result could be the creation of ultra-efficient artificial intelligence (AI) hardware, which naturally lends itself to analogue implementation more readily than to the current digital-based techniques used in today’s smartphones and the cloud. The resulting proliferation of intelligent agents can disrupt every level of social and economic activity and fundamentally change the daily environment around us.

“We soon realised that there is much more to be earned by employing this memristor technology beyond its obvious memory applications, and have previously demonstrated how memristors can be used to emulate biological learning,” added Prodromakis.

The team’s approach of combining the computational power of the analogue world with the energy benefits of digital techniques promises to shape the next generation of electronics.

“Over the last five decades we have processed digital signals and have computed using digital techniques, which has taken us very far. However, if we are truly to compute at the limits of energy efficiency the laws of physics allow, it would seem imperative that we move toward analogue computation techniques whilst being much savvier about how to mix analogue and digital signals for maximum effect,” said Dr Alexantrou Serb, lead author of the paper at the University of Southampton.

MOLECULAR SWITCHES WILL SET THE SCENE FOR PIONEERING ELECTRO-OPTICAL DEVICES

An international research team led by physicists at the Technical University of Munich (TUM) has developed molecules that can be switched between two structurally-different states. Such nano-switches can form the basis for a pioneering class of devices that could replace silicon-based components with organic molecules.

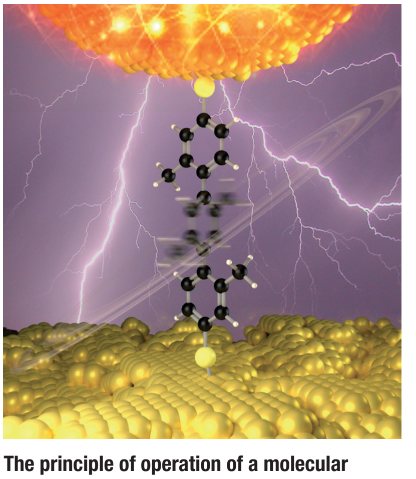
The team successfully deployed a single molecule as a switching element for light signals.

“Switching with just a single molecule brings future electronics one step closer to the ultimate limit of miniaturisation,” says scientist Joachim Reichert from the Physics Department at TUM.

At a potential difference of around one volt, the molecule changes its structure, becoming flat and conductive and able to scatter light. This optical behaviour, which differs depending on the molecule’s structure, is exciting to researchers since the scattering activity – Raman scattering, in this case – can be both observed and, also, switched on and off.

The molecules are arranged on a metal surface and contacted using the corner of a glass fragment with a very thin metal coating as a tip, which serves as electrical contact, light source and light collector in one. The fragment was used to direct laser light to the molecule and measure tiny spectroscopic signals that vary with voltage.

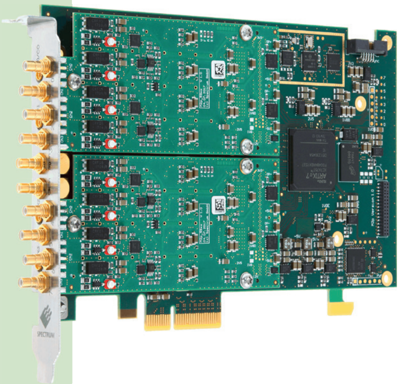
A goal of molecular electronics is to develop novel devices to replace traditional silicon-based components using integrated and directly-



The principle of operation of a molecular switch

controllable molecules.

Thanks to its tiny dimensions, this nano-system is suitable for applications in optoelectronics, in which light is switched using variations in electrical potential.



Software support for modular digitisers

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

Although modular digitisers can be considered computer hardware, they require suitable firmware and software to be integrated into the host computer system. Digitisers use embedded software and require device drivers, maintenance software and operational applications to control, view and transfer data.

Device Drivers

A device driver is the most basic software requirement and is normally supplied by the digitiser manufacturer. It is a type of software that allows interaction with hardware devices, interfacing the operating system and applications for communications, commands and data transfer. None of the modern operating systems allow access to the hardware without a dedicated, low-level kernel driver! For Windows 64-bit OS, it is even necessary to have a dedicated kernel driver signed by an authorised company.

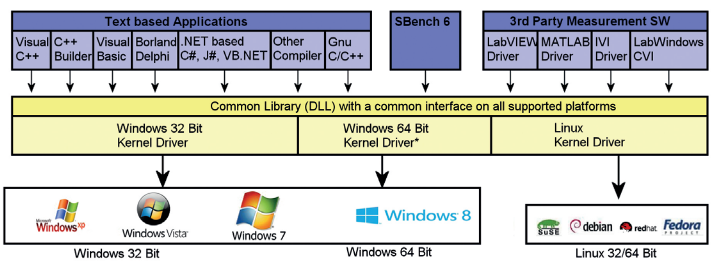


Figure 1: The digitiser device driver supports commonly-used operating systems while providing a common interface for universally-used programming languages and third-party analysis and control software

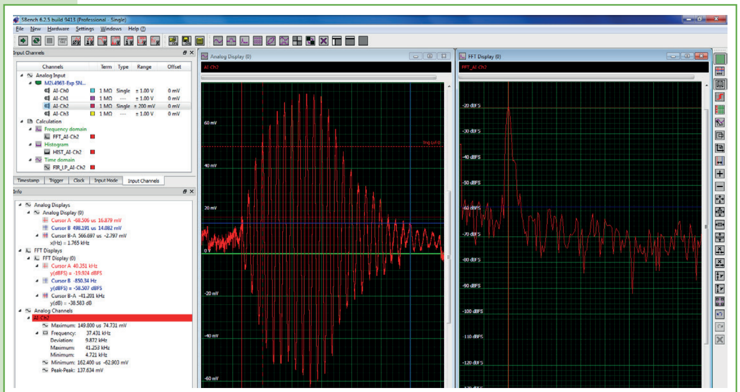


Figure 2: Example of an operational software package allowing immediate control, viewing and analysis of the digitiser's acquired data

Figure 1 shows a conceptual block diagram for a device driver.

The drivers offer a common and fast application peripheral interface (API) for using the digitiser's hardware. The driver API is the same for all supported operating systems; in this case, 32- or 64-bit versions of both Windows and Linux. Based on this driver, the user can write their own programs in commonly-used programming languages and analysis and control programs such as SBench 6, LabVIEW and MATLAB.

It's worth noting that the same core driver operates with multiple types of digitisers, supporting multiple operating systems, programming languages and third-party applications, an ideal to aspire to when selecting a digitiser, since it provides great flexibility in measurement operations.

Operating Software

Most of the larger suppliers offer some form of operating software to control the digitiser and allow viewing and transferring data; see Figure 2. It enables control of all the digitiser functions, acquires and displays data, performs measurements on acquired data and manages data transfers.

In this example, we have an acquired ultrasound burst, its Fast Fourier Transform (FFT) and measurements of amplitude, burst duration and frequency. Analysis functions include FFT, averaging, filtering and histograms. Measurements can be made with cursors or built-in measurement parameters. Here, the cursors measure the pulse burst duration, and measurement parameters are used for frequency, maximum, minimum and peak-to-peak amplitude.

Operating software of this type easily confirms the correct working of the digitiser, but also the functional setups and acquisition modes. Once verified, they can be transferred into the desired programming environment.

The software also helps review previously-acquired data for verification and additional measurements and analysis.

Third-Party-Software Support

Many digitiser users prefer to use the tools available with third-party analysis and control program applications, either because they understand the tool well or need its special capability. Most digitiser manufacturers support these programs in a variety of ways, such as support for the most common third-party programs, including LabVIEW, LabWindows/CVI and MATLAB.

LabVIEW from National Instruments is the most common graphical programming language for measurements, and is typically supported by a dedicated LabVIEW driver, which combines different digitiser functions into functional blocks and makes them available via LabVIEW. The LabVIEW driver package consists of several libraries and some open-example virtual instruments (VIs) showing the use of the driver. In addition to these libraries, all driver functions can also be directly called.

Figure 3 shows the digitiser card's analogue channels used as a simple oscilloscope. It shows the virtual front panel of an oscilloscope that allows single or multiple acquisitions of data on as many as four channels.

All clock settings, trigger modes, sources and input channel settings can be set up and changed in the interface. The example works for all acquisitions cards with up to four channels, independent of the digitiser's analogue resolution and maximum sampling speed of the digitiser.

LabWindows/CVI (which stands for C for Virtual Instrument-ation) is a C programming environment for test and measure-ment developed by National Instruments. It uses the same libraries and data acquisition modules as the company's better-known LabVIEW product, with which it is highly compatible.

MATLAB is a math analysis application from The MathWorks for Windows and Linux.

In addition to these common software applications, an IVI driver can be used, which supports the IVI class drivers, IVI digitiser and IVI scope. The IVI driver allows users to access instruments of one function class with a common software interface, independent of the hardware manufacturer. This makes it possible to use software based on an IVI instrument driver, with many of the different digitisers or scopes available on the market.

Support for Custom Programs

Drivers for digitisers should also support commonly used text-based programming languages such as C, C++, C#, J#, Visual Basic, Python and Delphi.

The digitiser user manuals should provide detailed descriptions of all the necessary commands for controlling the card and returning data to the computer. Commands are software register-based, as described in Figure 4.

Custom programming offers the greatest flexibility in operating the digitiser, especially in a system environment where multiple instruments and signal sources are involved.

Software examples for a particular programming language will allow a head start. With some additional work, having a simple-to-learn, easily-integrated yet powerful API will allow easy access to the hardware with other programming languages. Again, it's worth asking your supplier if they can help. They may have professional software engineers who can just add a starting example for your preferred programming language, for free. ●

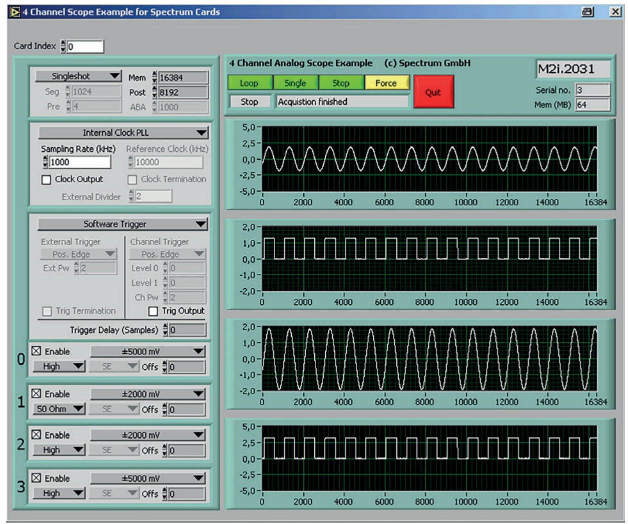


Figure 3: The virtual front panel of a LabVIEW example using the digitiser's analogue acquisition channels as a four-channel oscilloscope

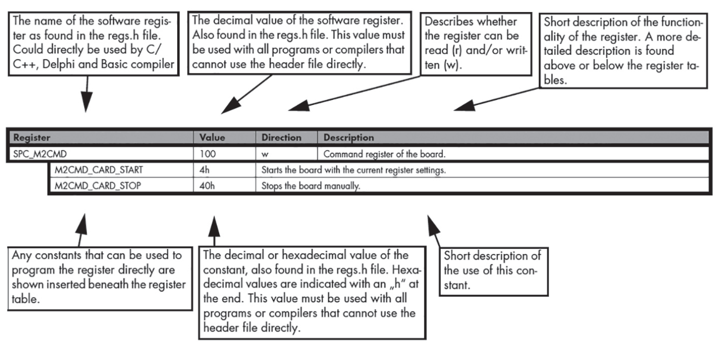
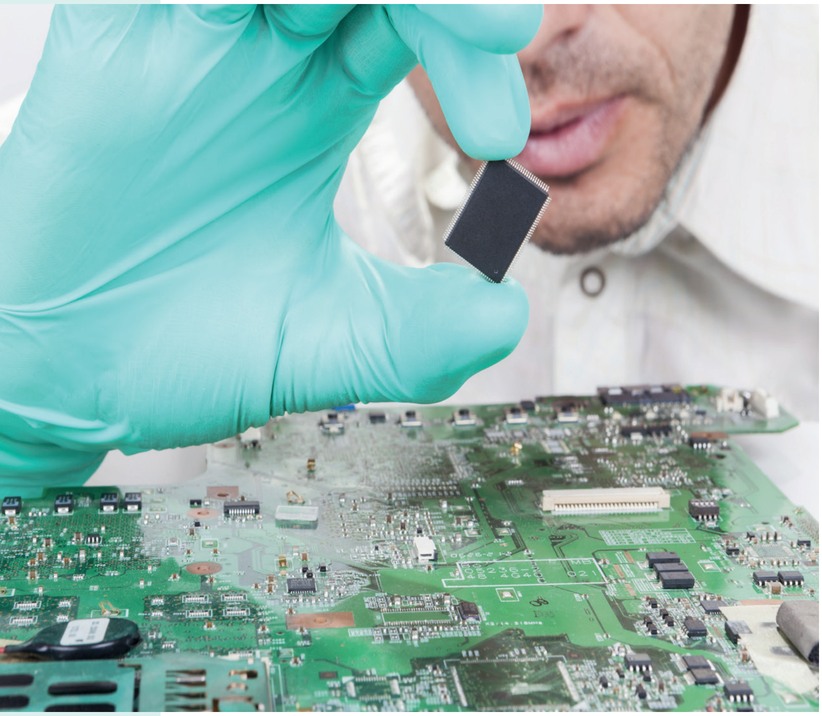


Figure 4: Programming digitiser boards that are completely software register-based

FREE BOOKS

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

To receive a free copy, go to https://spectrum-instrumentation.com/en/contact-us and tick the box marked "Please send me a copy of the Digitizer Handbook" , adding "EW" in the Comment section.



The meaning of Kb value in PCB cleaning

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

The cleaning strength of a PCB cleaner is frequently measured by an industry benchmark called the Kauri Butanol (Kb) value. A higher Kb value is usually better, and means the cleaner is more aggressive. But there are tradeoffs – stronger solvents can have compatibility problems with plastics, coatings, inks and other components. Smart engineers will examine the Kb value of their cleaning products to avoid expensive surprises.

Effective Cleaning

Contamination-related failure within the electronics industry is growing. With smaller, more densely-populated circuit boards becoming the norm, the issue of managing faults and guaranteeing the quality of the devices is important.

An effective cleaning process is critical to the longevity of electrical components, but it can be highly challenging. Many manufacturers are opting for solvent cleaning, finding it more effective, flexible and less expensive than other methods like aqueous cleaning. Before deciding which solvent to use, it is important to study the Kb values, since they are a good benchmark and starting point for analysis.

The cleaning strength of solvent cleaners is calculated by the Kauri-Butanol (Kb) test, standardised by the International Association for Testing Materials (ASTM). This is a simple process that's undertaken using a standardised test material called butanol – a thick, rubbery gum. This is immersed in the solvent for a set time under controlled conditions (temperature, pressure, etc.), and measurements are then taken of the remaining butanol to determine the quantity of material dissolved by the solvent. A value of 10 is very mild, while anything over 70 is aggressive solvent. This index is used to judge the relative cleaning power of solvents and is useful when choosing a solution for use on PCBs.

Kb values can be found on the solvent's technical data sheet, figures that'll help gauge the cleaner's strength and suitability for the contaminant requiring removal. Solvents with lower Kb values will dissolve greases but may not handle ionics and fluxes. Solvents with higher Kb values may be speedy and effective cleaners but attack plastic components. For this reason it is important to consider the components to be cleaned and the materials they house. Dependent on the contamination, make sure the solvent has the "horsepower" to dissolve the contamination and clean effectively, while not affecting the component itself.

Kb Values	
Vertrel™ XF (HCFC 43-10)	11
Vertrel(TM) MCA	20
CFC-113	31
Vertrel(TM) SMT	38
Mineral Spirits	39
MicroCare(TM) Heavy Duty Degreaser	48
Vertrel(TM) SFR	101
Tergo(TM) Metal Cleaning Fluid (MCF)	108
1,1,1-Trichloroethane (111)	124
Bromothane(TM) S (nPB)	125
Trichloroethylene (TCE)	130

Table 1: Kb values chart

Other Factors to Consider

Although Kb values are a good indicator of the cleaning solvent's strength, there are other factors to consider. The Kb test itself has some limitations. For example, it must be performed at 25°C (77°F) and within one atmosphere pressure; testing under other conditions yields different results.

It is important to use cleaning solvents from a trusted supplier to ensure testing under standardised and regulated conditions. There are some solvents that cannot be evaluated using the Kb method since they dissolve the butanol gum almost instantly.

Selecting a cleaner with optimal Kb value is a balancing act, with a number of factors affecting cleaning performance. Technicians must also look at surface tension and density, toxicity and flammability, and the cost per part cleaned. There are also environmental and safety implications, and regulations imposed on solvents. Your choice needs to be sustainable without compromising on cleaning performance.

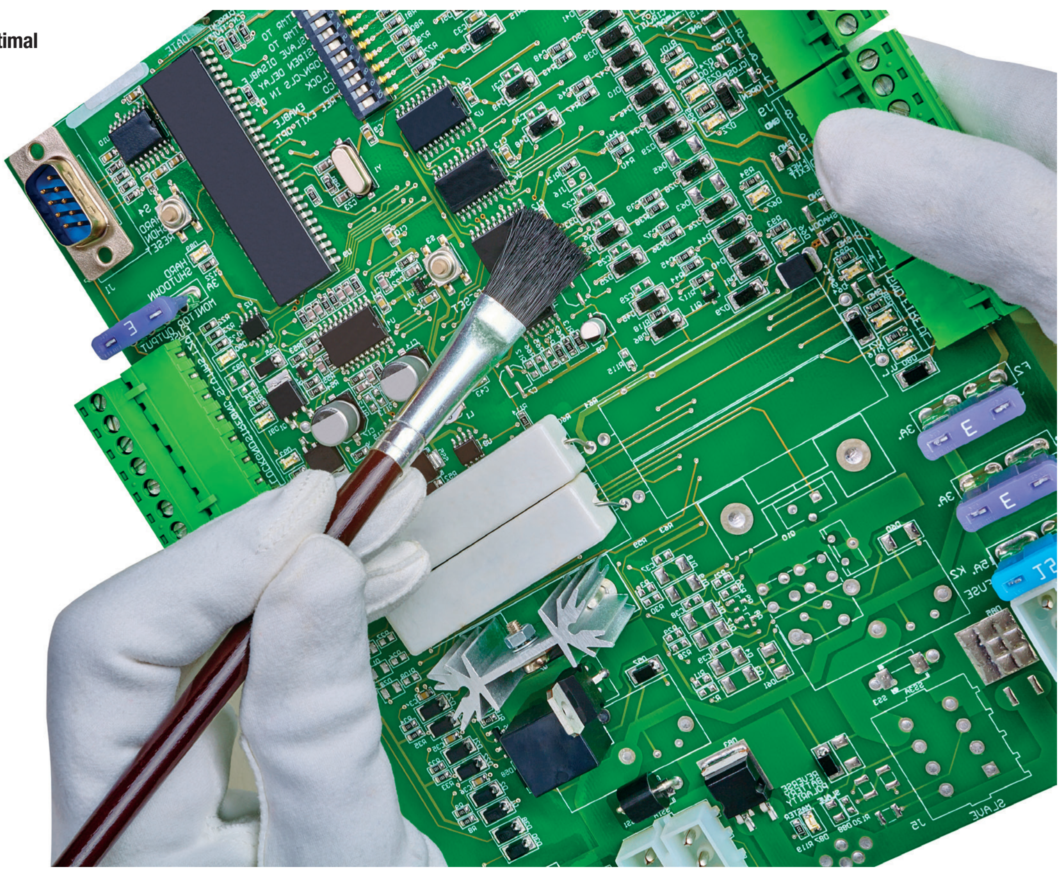
Many engineers today will not only look at the Kb value but are also substituting systematic testing procedures, rigorously testing solvents on their components, contamination and cleaning processes to deliver real-world conditions. It is difficult to predict the cleaning effectiveness of a fluid without tests. The results of a cleaning process can vary by contamination, selected solvent, application, cleaning system and physical shape of the parts being cleaned.

Reliable suppliers of cleaning solvents should offer cleaning trials. Here, tests will be undertaken to select the correct cleaning fluid for the component and the contamination. Results are analysed to select the correct critical cleaning solvent and process required, weighing all the elements to find the perfect cleaning solution for the job. Often the results are unexpected: some mild solvents may clean as well as or even better than those with much higher Kb values, maintaining excellent materials compatibility. Importantly, solvents can be tailored to have a wide range of Kb values, leading to a very versatile cleaning performance.

> **An effective cleaning process is critical to the longevity of electrical components, but it can be highly challenging**

When considering the Kb value, remember to look at the whole picture and seek professional advice for your critical cleaning requirements. ●

Selecting a cleaner with optimal Kb value is a balancing act



BY **DR MURAT UZAM**, ACADEMIC AND TECHNICAL AUTHOR, TURKEY

0-5V analogue input module 1

Following on from last issue's article in this series, Figure 1 shows the schematic diagram of the 0-5V analogue input module 1, to be used with the ADC input of a 5V microcontroller. Figure 2 shows the connection of this module to the analogue input of a 5V microcontroller.

For this design, it is assumed that the input voltage range (V_{IN}) = 0-6.26V. When $0.00V \leq V_{IN} \leq 5.00V$, $V_{OUT} = V_{IN}$. When $5.01V \leq V_{IN} \leq 6.26V$, V_{OUT} will be somewhere from 5.01V to 5.07V, due to the electrical characteristics of the LM358P-A used.

The relationship between V_{OUT} and V_{IN} is shown in Figure 3. It can be seen that input voltage values up to 6.26V are easily sustained without damage and sent out of the circuit as 5.01V to 5.07V.

The analogue voltage input signal V_{IN} can be subject to

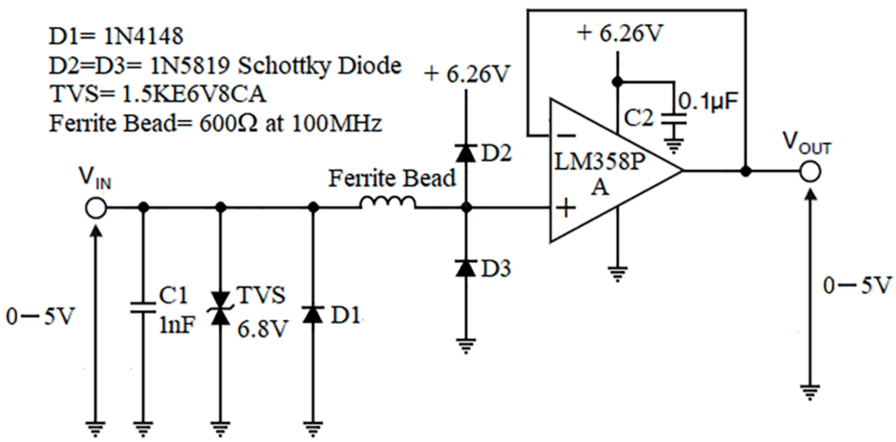


Figure 1: Schematic 0-5V analogue input module 1 to be used with an ADC input of a 5V microcontroller

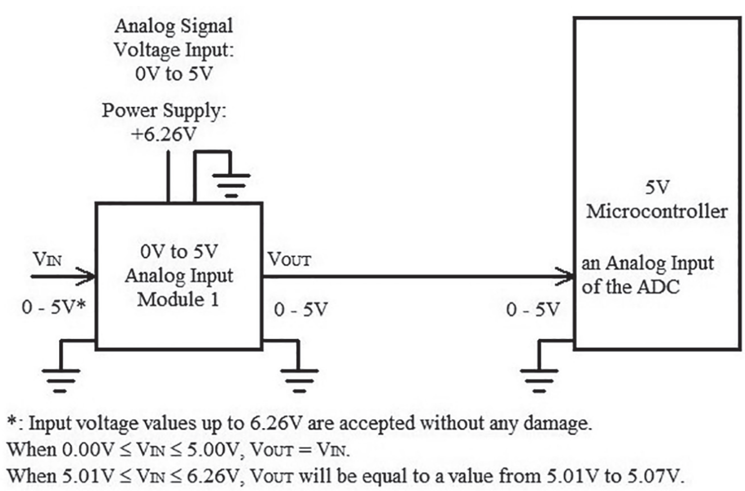


Figure 2: The 0-5V analogue input module 1 connection to the analogue input of a 5V microcontroller

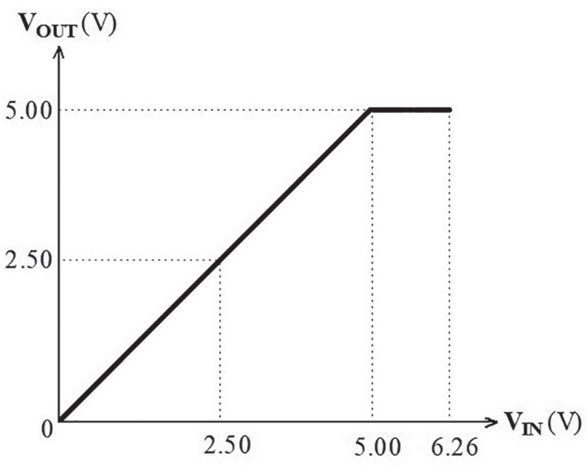


Figure 3: V_{OUT} vs V_{IN} for the 0-5V analogue input module 1 of Figure 1

electric surge or electrostatic discharge on the external terminal connections, but the TVS (transient voltage suppressor) shown in the circuit provides highly effective protection against such discharges.

D1 is used to protect the circuit from accidental reverse polarity of V_{IN}. A ferrite bead is connected in series with the input path to add isolation and decoupling from high-frequency transient noises. External Schottky diodes generally protect the operational amplifier. Even when internal ESD protection diodes are provided, the use of external diodes lowers noise and offsets errors.

Two Schottky barrier diodes D2 and D3 divert any overcurrent to the power supply or ground. The operational amplifier LM358P-A, with a +6.26V supply voltage, acts as a voltage limiter, provides a high input impedance and is connected as a buffer amplifier (a voltage follower). V_{OUT} is obtained from the output of the LM358P-A.

Table 1 shows example input- and output-voltage values for the 0-5V analogue input module 1. Top and bottom side views of the prototype circuit board of the 0-5V analogue input module 1 are shown in Figure 4. ●

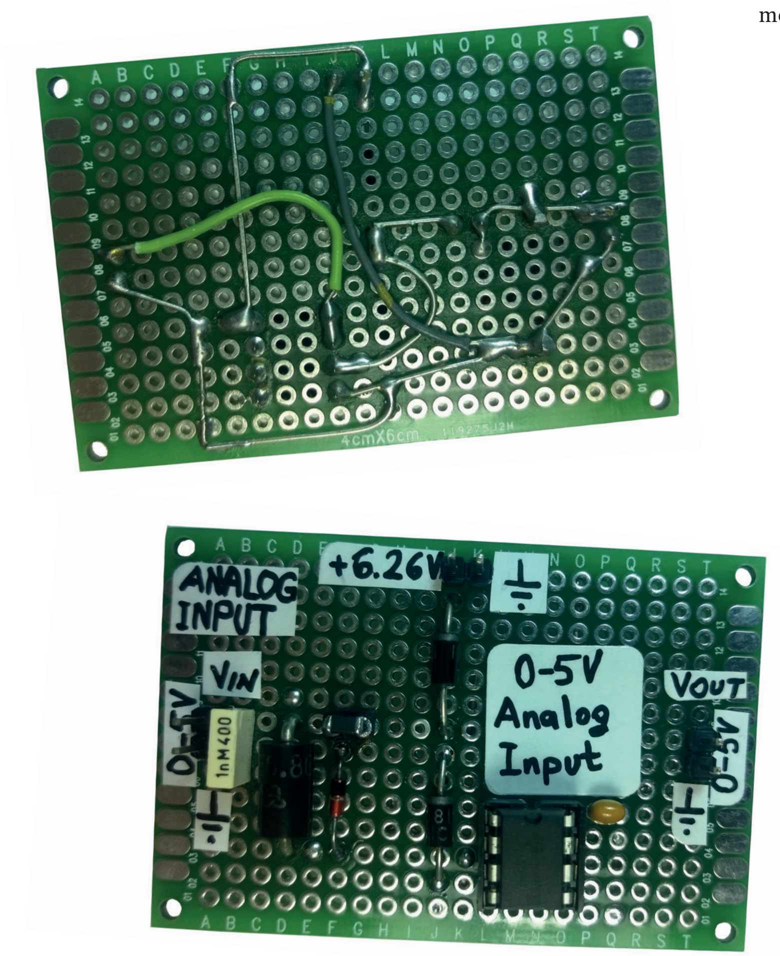


Figure 4: Top and bottom side views of the prototype circuit board of the 0-5V analogue input module 1

V_{IN}(V)	V_{OUT}(V)
6.26	5.0X
..	5.0X
6.00	5.0X
..	5.0X
5.00	5.00
..	..
4.00	4.00
..	..
3.00	3.00
..	..
2.50	2.50
..	..
2.00	2.00
..	..
1.00	1.00
..	..
0.00	0.00

Table 1: Example input and output voltage values for the 0-5V analogue input module 1

This series continues in the next issue

Ultra-low-power processor consumes too much power

QUESTION:

Why is my processor consuming more power than its data sheet suggests?

ANSWER:

Although seemingly counter-intuitive, there are times when a device consumes too little power. This is rare but possible, and it can run the design into trouble. The more common situation, of course, is parts consuming more power than their data sheet states.

For example; a little while ago a customer walked into our office with his processor board, claiming it was consuming too much power and draining the battery. Since our company proudly claims that processor to be an ultra-low power device, we had to investigate. Typically, cutting the power off to different devices on the board helps find the real offender.

Since LEDs can frequently die for various reasons (for instance, if one is hanging loosely between the supply rail and ground without an accompanying current-limiting resistor), I set out to look for one burning too-bright somewhere on the board. That wasn't it, however.

The customer also specified that the board's power consumption and battery life were at the expected levels in the lab but draining off quicker in the field. These problems are the toughest to debug, since they are difficult to reproduce.

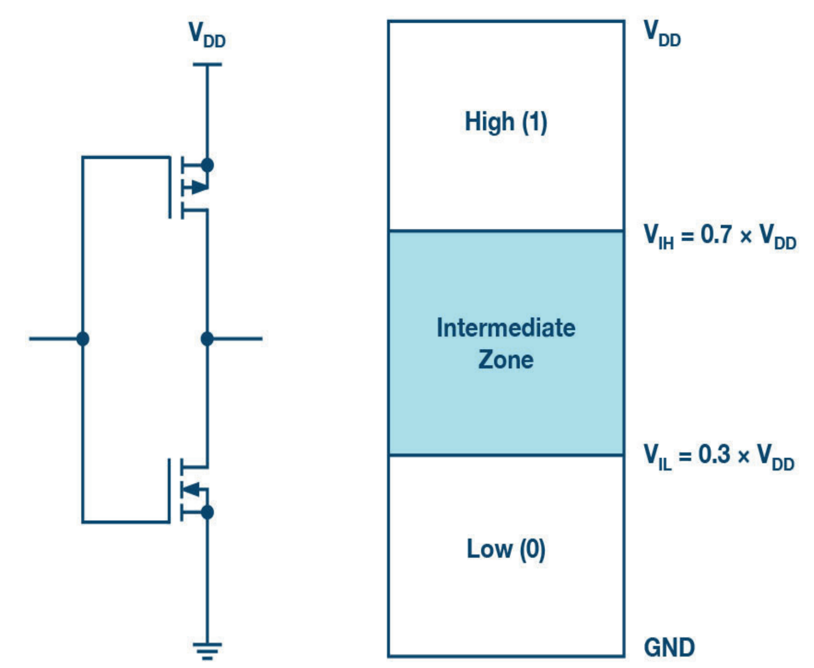


Figure 1: Typical CMOS input circuit (left) and CMOS level logics (right)

On to the Processor

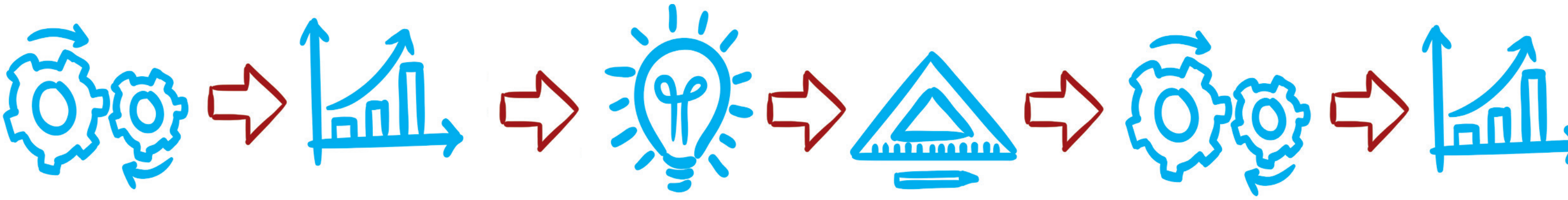
In simple terms, there are two main areas where a processor consumes power – its core and I/O. When it comes to keeping core power in check, look to things such as the PLL configuration/clock-speed, the core supply rail, and the amount of computation activity the core is busy with.

In simple terms, there are two main areas where a processor consumes power – its core and I/O

There are ways to minimise the core power consumption; for example, by reducing its clock speed or executing certain instructions that force the core to stop or go to sleep or into hibernation. However, if it's the I/O, I'll check their supply, the frequency at which they are switching and the loads they are driving.

The customer also said the processor was used purely for computation with minimal I/O activity, which rang alarm bells. The I/O pins were not needed, so the customer hadn't connected them, which led to my Eureka moment.

Let me explain: A typical CMOS digital input looks like Figure 1. When this input is driven at the recommended high (1) or low (0) level, the PMOS and NMOS FETs are turned on one at a time, but never together. There's a zone of uncertainty in the input drive voltage called the threshold region, where both PMOS and NMOS can turn on partially at the same time, creating a leakage path between the supply rail



BY ABHINAY PATIL, FIELD APPLICATIONS ENGINEER, ANALOG DEVICES

and ground; see Figure 2. This is likely to happen when the input is left floating and picks up stray noise. That's why there was high power consumption on the customer's board, and why it happened randomly.

In some cases, this could lead to a latch-up, where the device continues to draw excessive current and burns out.

An Obvious Solution

Discovering the root of the problem led me to an obvious solution, which is to drive all the unused inputs to a valid logic level, high or low. However, there's the fine print to watch out for. Let's look at a few more scenarios where improperly-handled CMOS inputs can land a design into trouble. We will broaden the scope to include not only inputs that are totally open/floating, but also those that are seemingly connected to a proper logic level.

If you simply just tie the pin to a supply rail or ground, choose the right size pull-up or pull-down resistor. This, in conjunction with the source/sink current of the pin, could shift the actual voltage level seen by the pin to an undesirable level. In other words, you need to ensure that the pull-up or pull-down is strong enough.

If you choose to drive the pin actively, always ensure that the drive strength is correct for the CMOS load. If not, noise around the circuit can be strong enough to override the driving signal and force the pin into an unwanted state.

Let's examine a couple of scenarios:

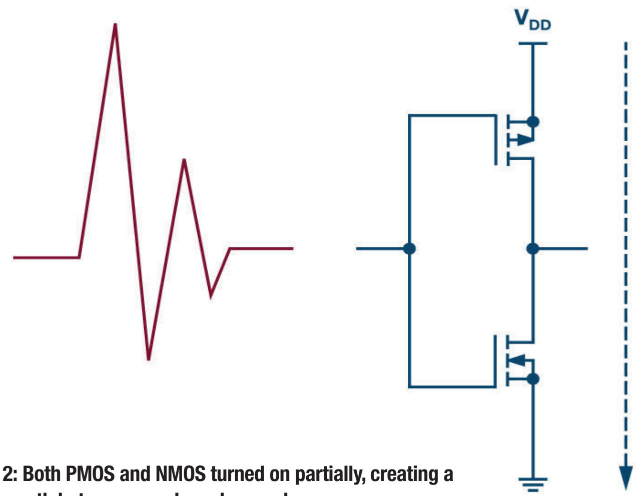


Figure 2: Both PMOS and NMOS turned on partially, creating a leakage path between supply and ground

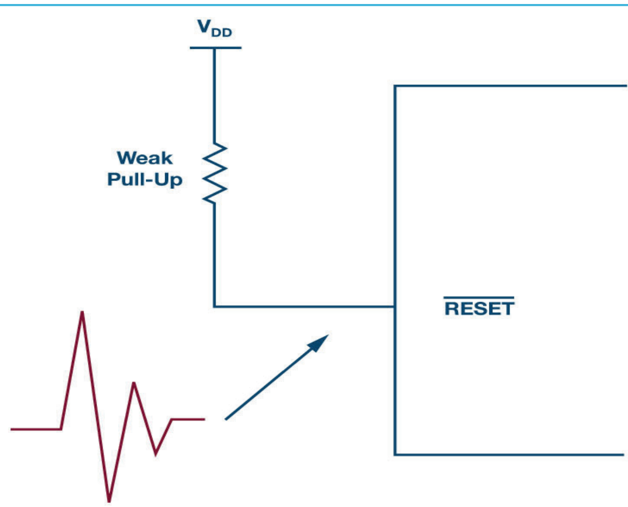


Figure 3: Noise coupled into the pin with a weak pull-up can cause the processor to reboot

1. A processor working fine in the lab started rebooting for no apparent reason in the field, because noise coupled into a RESET line that didn't have a strong enough pull-up; see Figure 3.
2. You can imagine the situation if the CMOS input belongs to a gate driver controlling a high-power MOSFET/IGBT, which could inadvertently turn on when it's not supposed to! Grim tidings indeed.

Another related (but not so obvious) problem scenario is when the driving signals have very slow rise/fall times. In this case, the input can dwell on an intermediate voltage level for too long, causing all kinds of trouble.

Despite all this, a few devices handle such problems by design. For example, parts with Schmitt-trigger inputs are inherently better at handling noisy or slow-edge signals, like those in Figures 4 and 5, respectively.

Some of ADI's latest processors also take notice of this and have special precautions in the design or explicit guidelines in place to ensure that things work smoothly. For example, the ADSP-SC58x/ADSP-2158x data sheet clearly highlights the pins with internal termination or other logic to ensure the pin is never floating; see Table 1.

In the end, as they say, it's a good idea to tie up all loose ends, especially CMOS inputs. ●

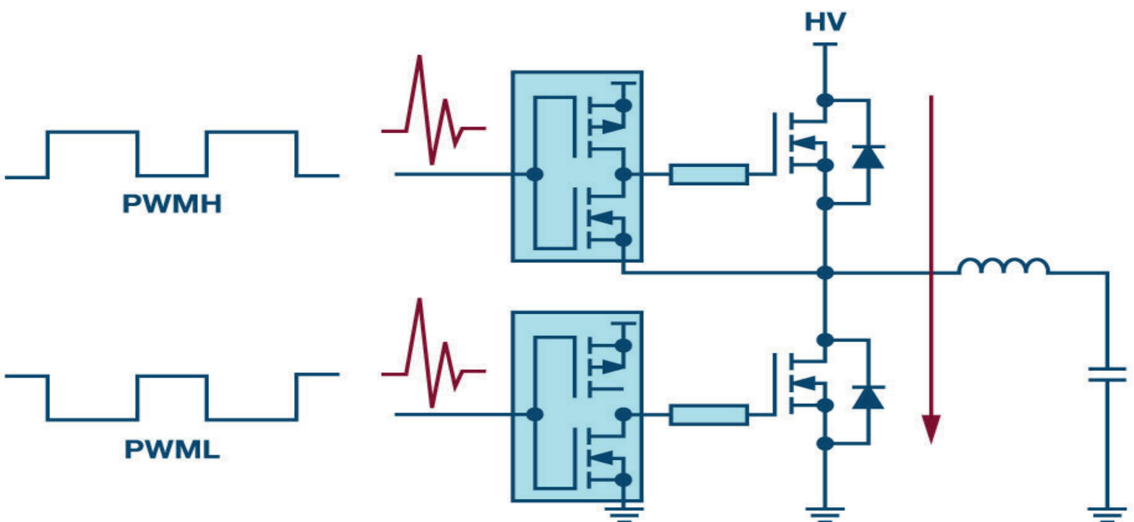


Figure 4: Noise overriding a weakly-driven CMOS input gate driver causing a short circuit on the high-voltage bus

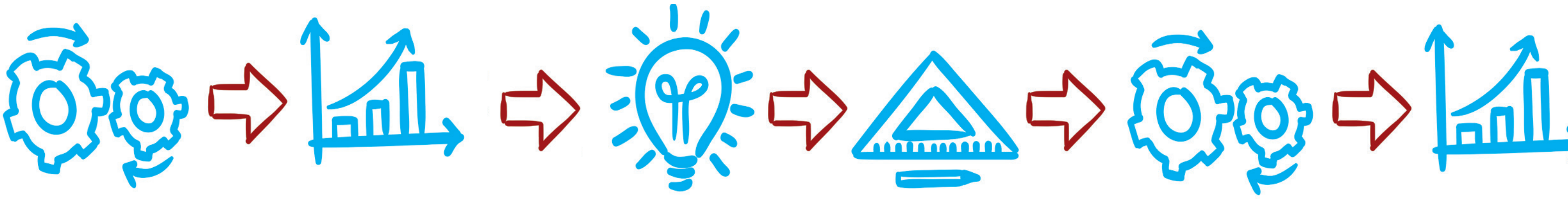
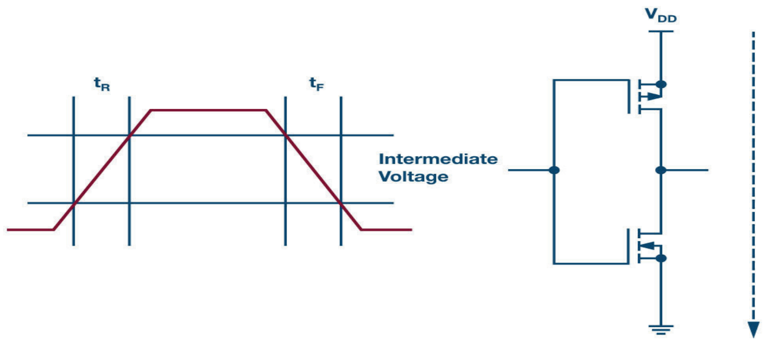


Figure 5: Slow rise and fall times on CMOS inputs creating a momentary short circuit in the transition period

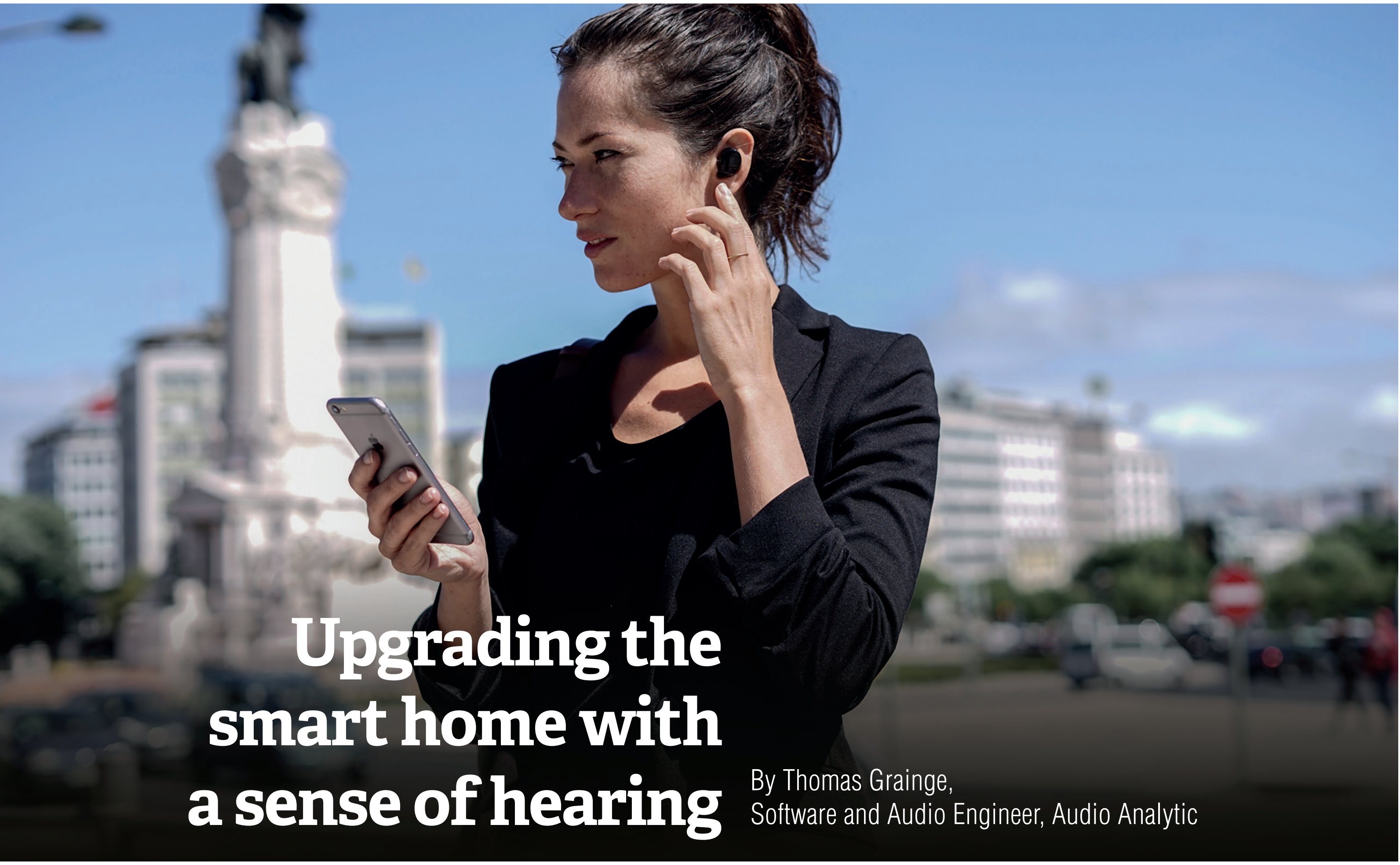


ADSP-SC582/SC583/SC584/SC587/SC589/ADSP-21583/21584/21587

Table 27. ADSP-SC58x/ADSP-2158x Designer Quick Reference

Signal Name	Type	Driver Type	Int Term	Reset Term	Reset Drive	Power Domain	Description and Notes
JTG_TCK	Input		PullUp	none	none	VDD_EXT	Desc: JTAG Clock Notes: No notes
$\overline{\text{JTG\_TRST}}$	Input		PullDown	none	none	VDD_EXT	Desc: JTAG Serial Data In Notes: No notes
MLB0_CLKN	Input	NA	Internal logic ensures that input signal does not float	none	none	VDD_EXT	Desc: MLB0 Differential Clock (-) Notes: No notes

Table 1: ADSP-SC58x/ADSP-2158x data sheet quick reference



Upgrading the smart home with a sense of hearing

By Thomas Grainge,
Software and Audio Engineer, Audio Analytic

Smart home technology is buoyant right now, with speech, music and visual recognition making giant strides that also include cutting-edge artificial intelligence (AI).

With Amazon, Apple, Google and others introducing voice-activated smart-home assistants, smart speakers are expected to sell over 40 million this year alone.

Recognising Sound

Most smart-home devices require human interaction to perform tasks, but to be capable of reacting to an audio event without manual involvement, these devices need improved contextual awareness. Sounds give key contextual cues, difficult to obtain otherwise. For example, the sound of a breaking window can be recognised easily without seeing it. So, just like the human brain, if the smart home is to be truly intelligent it must be able to recognise and respond to audible events it can't see. Augmenting voice recognition with sound recognition is a natural route to deliver contextual intelligence in the home, and the technology can be applied to many other devices containing microphones.

How to Teach Tech to Hear?

Audio Analytic has developed an AI technology that can be taught to recognise sounds beyond speech and music. Unlike voice recognition, a mature technology, for sound recognition no suitable dataset or tools exist to enable training a machine learning (ML) system at the desired sensitivity and accuracy. As a result, a new audio-specific dataset had to be built from scratch, along with the ML tools needed to extract, model and analyse sounds.

To do so, the company set itself the task of collecting real-world sounds to expose to the ML technology. Data continues to be collected from thousands of fresh audio recordings, to build and continually enrich the data platform and expand the range of sounds held within the rapidly-growing taxonomy. The company's aim is to give technology a true sense of hearing by teaching it to identify a wide range of sounds in the home, car or out and about. To support this vision, the company recently opened a dedicated Sound Lab facility in Cambridge, UK.

For machine learning to be able to process sound data systematically, the data must be described and organised. A key difference between sound recognition and speech recognition is that speech is limited by the type of sounds the human mouth can produce and follows a set structure that makes it mappable. These pre-defined rules and characteristics of speech make it easier to process in the structured, repeatable fashion that CPUs are designed for.

Similarly, music mostly results from physical resonance and conditioned by the rules of various musical genres, so it has boundaries within which it is readily analysed.

Sound is different; it is much more diverse, unbounded and unstructured than speech or music. Think about a window being smashed and the numerous ways glass shards can hit the floor, without order or pattern. Understanding the full extent of sound variability is a prerequisite for mapping its characteristics so that a machine can process it next time is encountered. To overcome this challenge, Audio Analytic had to develop a "language" of ideophones that describe an idea in sound or sensory perception.

The ML framework developed extracts of hundreds of ideophonic features from each sound. Audio Analytic's ideophonic feature extractor is made of a set of audio signal descriptors computed from the incoming audio signal, which can be combined to approximate an ideophone or a number thereof. Through encoding, decoding and introspection, the feature extractor can isolate hundreds of characteristics from sounds and describe sound profiles that uniquely identify each sound. These individual profiles are embeddable in the software sound-sensor platform, called ai3 (Figure 1), which can be integrated into almost any device equipped with a microphone.

Cloudless, Connectionless Intelligence

The ubiquity of microphones spurred by the spread of speech recognition means there is a huge opportunity to add intelligence to products through sound recognition, dramatically expanding the range of possibilities for AI-enabled devices. Home security is an obvious example, since 'wake' words do not exist in real life situations: a burglar would never announce himself when breaking in! Similarly, smoke alarms simply beep, not play a wake word, so would be ignored by the first generation of voice-activated smart-home assistants.

Embedding the sound sensor as software means that all sound identification, analysis and decision-making is done locally and instantly, providing definitive detection of target sounds by a device, triggering an immediate response. Independence from the cloud makes the technology reliable in a wider range of situations than if it required Internet connectivity. The compactness of Audio Analytic's sound profiles means they can be sent to devices over the air (OTA), expanding their capabilities. In addition, this edge intelligence means that streaming sound to cloud analysis resources is not required, simplifying designs and reducing power needs and costs.

Eliminating the need to stream audio to the cloud also helps address consumer concerns over the privacy implications of devices with always-on microphones.

Microphone-to-Processor Pathways

Gaining access to a device's microphone is the start in integrating sound detection. Initially though, obtaining quality audio from these microphones can be difficult, although this can be helped by minor alterations in mic positioning, port design and audio processing.

Managing audio processing without creating conflicts with other device functions requires thought, since the signal path can dramatically affect product performance and the quality of its listening.

Smart products need to execute multiple tasks to be useful. Inappropriate or excessive demands by a single function significantly degrades the user experience. Increasingly, equipment designers are seeking ways to transform low-power, single-purpose devices into low-power, multi-purpose devices, connected to the rest of the smart home ecosystem.

Consumers expect traditionally "dumb" unconnected devices, such as smoke alarms, to be smarter without

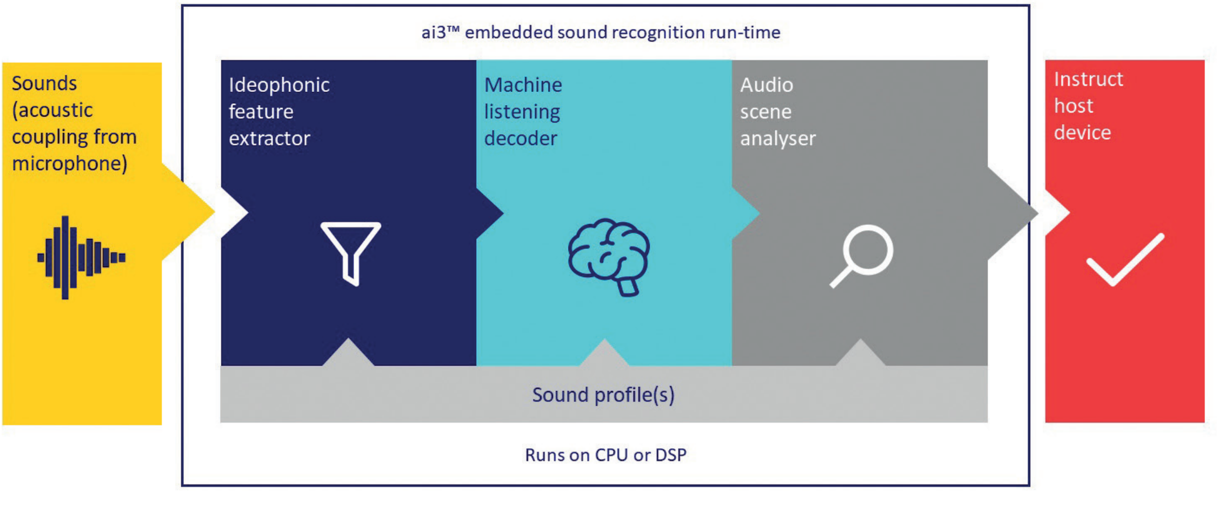


Figure 1: Block diagram of the ai3 sound recognition engine

The Hive Hub 360 uses Audio Analytic technology to detect and react to important sounds around the home

the additional costs of connected versions. Using sound recognition to deliver such extended functionality requires the embeddable software to be lightweight enough to allow the device to perform other functions, rather than be consumed by this process. Additionally, the software design must include a flexible audio path that converts audio as desired, but which also gives multiple device functions access to the audio stream.

Many of the currently-available consumer devices run Linux-based operating systems. There are a host of advantages to Linux systems for engineering teams; however, Linux audio interfacing is currently limited to a small set of tools. Achieving the necessary control over the signal path can become an issue in these conditions, so choosing the right approach is critical.

The main tool options for passing audio data from audio hardware to application processor are ALSA (Advanced Linux Sound Architecture) and PulseAudio, which offer similar functionalities but operate differently.

Of the two, PulseAudio is the easiest to understand and grapple with at first, but its configuration to gain control of the signal path can be problematic.

Despite its complex user interface, ALSA tends to be more reliable than PulseAudio in providing audio to all applications on a smart device, without taking it over completely. While it is more intuitive, PulseAudio is typically difficult to adjust to achieve a precise setup, whereas ALSA allows every setting to be configured manually, making it a more flexible tool.

The code snippet in Listing 1 is an example recording setup using ALSA, which can provide audio to multiple applications simultaneously. This approach makes possible different conversions of the same stream from the same microphone input.

Solving the challenge of giving devices the sense of hearing is complex, but cracking it is necessary to reach the next frontier of artificial intelligence in mainstream devices. ●

```
pcm_slave.hw_input {
pcm "hw:0,1" # use card 1 and device 1
channels 2 # set the number of channels channel
rate 48000 # set the native rate of the hardware
 buffer_size 4096 # This is optional
}

pcm.input_share {
type dsnoop
hint {
description "interface for sharing hardware to
multiple clients"
 }
 ipc_key 345271 # unique plugin identifier
 ipc_key_add_uid yes
 slave hw_input # use the hardware input as slave
 bindings.0 0
```

```
 bindings.1 1
}

pcm.input_left {
 type plug
 hint {
 description "left input plug, uses shared input"
 }
 slave.pcm input_share
 rate_converter samplerate_best # define which rate
converter

 route_policy copy
 # route only audio from c0 to c0
 # ttable.in.out gain
 ttable.0.0 1
 ttable.1.0 0
}

pcm.input_right {
 type plug
 hint {
 description "right input plug, uses shared input"
 }
 slave.pcm input_share
 rate_converter samplerate_best # define which rate
converter

 route_policy copy
 # only route audio from channel 1 to channel 0
 # ttable.in.out gain
 ttable.0.0 0
 ttable.1.0 1
}

pcm.input_stereo {
 type plug
 hint {
 description "flexible input plug"
 }
 slave.pcm input_share # Use the shared input device
as slave
 rate_converter samplerate_best
}
```

Listing 1: Example ALSA device configuration to provide audio simultaneously to multiple applications

Bragi devices incorporate sound recognition

Op-amp recommendations for high-fidelity headphone driver applications

By David Guo, Product Applications Engineer, Analog Devices

High fidelity describes audio equipment with ideal total harmonic distortion plus noise (THD + N) performance and accurate frequency response, resulting in excellent subjective test results.

Portable high-fidelity equipment brings a higher-quality music-listening experience. Compared to mobile phones, however, portable high-fidelity equipment is inconveniently large. Suitably, technical advances are now making possible high-fidelity performance from the thinnest mobile phones.

Typical audio digital-to-analogue converters (DACs) are not good at driving low-impedance headphones. For high-quality performance, operational amplifiers (op-amps) are used with audio DACs for signal conditioning, including current-to-voltage (I to V) conversion, filtering, attenuation and differential-to-single-ended conversion. Op-amps must have low noise, low distortion and strong drive capability, as well as perform well in subjective testing by customers.

Signal Chain

In this type of application, high-performance and low-power audio DACs can deliver dynamic range (DNR) of up to 127dB and THD + N of -120dB. Some high-performance audio DACs can be configured for either voltage or current output, configurable for better DNR and THD + N.

For a voltage-output configuration, the conditioning circuit is a differential amplifier, which converts the differential signals from right (R) and left (L) channels to single-ended; see Figure 1.

For current-output configuration, an I-to-V circuit is implemented to convert differential current signals from R and L channels to a differential voltage signal, followed by a differential amplifier circuit; see Figure 2.

I-to-V Stage

An ideal I-to-V converter for a current-output DAC is resistor-to-ground. However, most DACs do not operate linearly with voltage at the output. It is standard practice to operate an op-amp as an I-to-V converter, creating a virtual ground at the inverting input. Normally, the op-amp's output stage absorbs clock energy and current steps. However, Figure 3 shows the C_F capacitor shunts high-frequency energy to ground while correctly reproducing the desired output with extremely low THD and intermodulation distortion (IMD).

There are four components in the circuit:

- R_F is the feedback resistor. For lowest noise, the gain should be maximised in the first stage (I to V). However, distortion is related to the op-amp's open-loop gain (A_{OL}); the higher the A_{OL}, the less distortion. Normally, A_{OL} is specified within certain output voltages.
- C_F is the feedback capacitor in parallel with R_F, and together they form a pole in the transfer function. So, the cutoff frequency (f_C) of the low-pass filter is:

$$f_C = \frac{1}{2\pi R_F C_F}$$

Assuming f_C is 100kHz:

$$C_F = \frac{1}{2\pi R_F f_C} = \frac{1}{2\pi \times 4\ \text{k}\Omega \times 100\ \text{k}\Omega} \approx 390\ \text{pF}$$

- R_S is the resistor in series with C_F. Typically, R_S = 100Ω for better stability and THD + N performance.
- V_{BIAS} is the bias voltage. Typically, audio DACs generate a DC offset current. To maximise the effective output signal, adding V_{BIAS} at the non-inverting input terminal will cancel the DC voltage by the DAC DC offset current.

Op-Amp Recommendations for the I-to-V Stage in Mobile Phones

The key specifications of op-amps as the I-to-V stage in headphone drivers include the power supply, quiescent current I_Q, voltage and current noise, THD + N, common-mode rejection ratio (CMRR), power supply rejection ratio (PSRR), open look gain A_{OL} and slew rate.

To determine the maximum output without THD + N degradation, THD + N vs V_{OUT} should be measured.

Typically, an audio DAC's current output acts as a resistor in series with a voltage source. That is, the I-to-V circuit can be considered an inverting amplifier circuit. For simplicity, gain is set at -1 to determine the THD + N performance of op-amps. The following details outline the procedure to measure THD + N vs V_{OUT}, using Audio Precision's SYS-2712 audio analyser:

- The power supply is ±5V.
- The SYS-2712 analyser generates a 1kHz sine wave for the input of the amplifier circuit. The output of the amplifier circuit feeds into the SYS-2712, which generates THD + N data.
- Bandwidth of the SYS-2712 analyser is set at 22kHz.
- To find THD + N at the output range with the SYS-2712 evaluating software, the analyser input is configured as auto-range, which means the input stage gain of the analyser is increased automatically by the different input signals, including 40mV, 160mV, 300mV, 600mV, 1.2V, 2.5V and 5V. Typically, the larger the gain, the worse the noise level and THD + N of the analyser.

Headphone Basics

The characteristics of the load (here, headphones) determines the output stage. Headphones have two key specifications: impedance and sensitivity.

Impedance is typically measured at 1kHz. Low-impedance headphones are in the range of 8Ω to 32Ω, and high-impedance headphones from about 100Ω to 600Ω. As the impedance increases, more voltage (at a given current) is required to drive it, resulting in decreasing loudness of the headphones for a given voltage.

In recent years, the impedance of newer headphones has generally decreased to accommodate the lower voltages available on

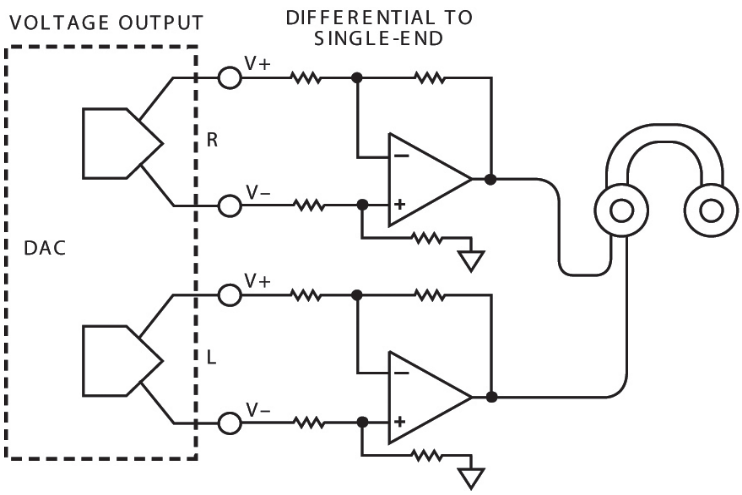


Figure 1: Voltage output configuration

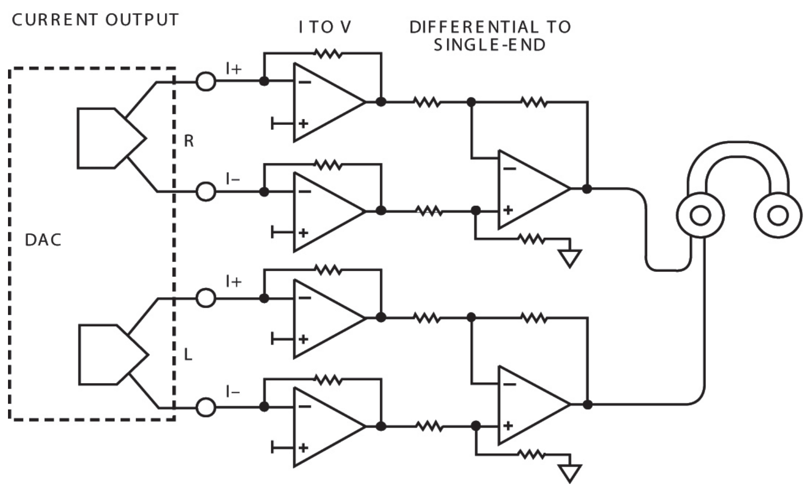


Figure 2: Current output configuration

Manufacturer	Model	Sensitivity (dB/mW)	Impedance (Ω)	Frequency (Hz)	Average Power (mW)	Peak Power (mW)	Peak Voltage (V)	Peak Current (mA)
Sony	XBA-4	108	8	3 to 28000	0.158	15.849	0.356	44.510
Audio-Technica	ATH-CHX7	100	16	15 to 22000	1.000	100.000	1.265	79.057
Shure	SE215	107	20	22 to 17500	0.200	19.953	0.632	31.585
Apple	Earpod	109	23	5 to 21000	0.126	12.589	0.538	23.396
Grado	Alice M1	100	32	20 to 22000	1.000	100.000	1.789	55.902
Creative	AURVANA Air	102	32	20 to 20000	0.631	63.096	1.421	44.404
Koss	PP	101	60	10 to 25000	0.794	79.433	2.183	36.385
Sennheiser	HD650	98	300	10 to 39500	1.585	158.489	6.895	22.985
Beyer Dynamic	DT880	96	600	5 to 35000	2.512	251.189	12.277	20.461

Table 1: Comparing the specs of a range of headphones

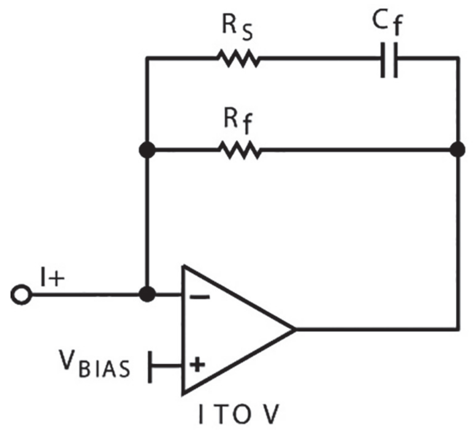


Figure 3: I-to-V stage

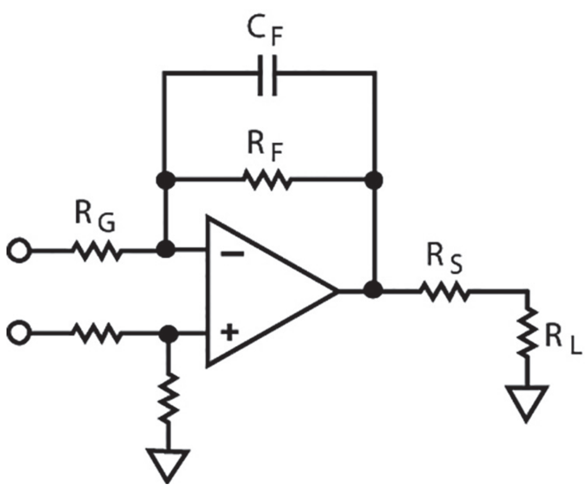


Figure 4: Differential single-ended circuit

battery-powered portable devices like mobile phones. Lower impedance means more work for the op-amp, requiring them to have larger current drive capabilities without distortion.

Sensitivity is a measure of how loud the headphones are for a given drive level. It can be measured in decibels of sound pressure level (SPL) per milliwatt (dB/mW) or decibels of SPL per volt (dB/V).

The maximum SPL can reach 120dB, with the average SPL of a recording less than 100dB. The required peak power can be found using the following formula:

$$P = 10\left(\frac{Required\ SPL - Sensitivity}{10}\right)$$

Table 1 shows the key specifications of popular headphones. The required average power is less than 2mW. To reproduce the effect of live recording, the headphone driver must maximise peak power; see Table 1.

For low-impedance headphones, the required peak current can reach 80mA without degrading THD + N.

For high-impedance headphones, the output voltage must be high. For example, the DT880 from Beyer Dynamic (600Ω) requires an op-amp output of 12V, impossible in a ±5V system. If the product targets high-impedance headphones, the power supply of the amplifier circuit must be improved.

Output Stage (First-Order Low-Pass Filter)

The output stage converts a differential voltage signal to a single-ended voltage signal; Figure 4 shows a common differential amplifier, also known as a subtractor circuit.

R_G and R_F determine the gain of the circuit, which is normally below 1. The resistors' value must be small, typically 1kΩ, to avoid inducing more noise. R_S determines the output impedance or damping factor of the headphone driver. A high damping factor (R_L/R_S) improves the control the source (headphone driver) has over the load (headphone). The impedance of the headphone isn't a pure resistance and varies by frequency. A higher R_S can induce more distortion (especially at low frequency) because of the frequency-varying impedance. From a performance perspective, R_S must be low. Generally, the damping factor remains above one.

> **Compared to mobile phones, portable high-fidelity audio equipment is inconveniently large**

From a safety perspective, higher R_S can attenuate power to protect headphones from damaging, whilst also protecting the amplifier in case the output shorts to ground, which can happen when hot-plugging headphones.

Output Stage (Second-Order Low-Pass Filter)

Compared to the first-order low-pass filter, the second-order low-pass filter has steeper roll-off, removing more noise from the specified band.

The two-pole low-pass filter with differential input is easily designed using equations for single-ended input, multiple-feedback, low-pass filters; see Figure 5. Normally, the filter gives a Bessel response, with linear phase.

Op-Amp Recommendations for the Output Stage

The key specifications for the output stage op-amp are similar to the I-to-V stage; the output stage op-amp must typically have < -100dB THD + N at 32Ω load. Analog Devices ADA4841-2, ADA4807-2 and AD8397 op-amps are recommended for the output stage of headphone drivers in

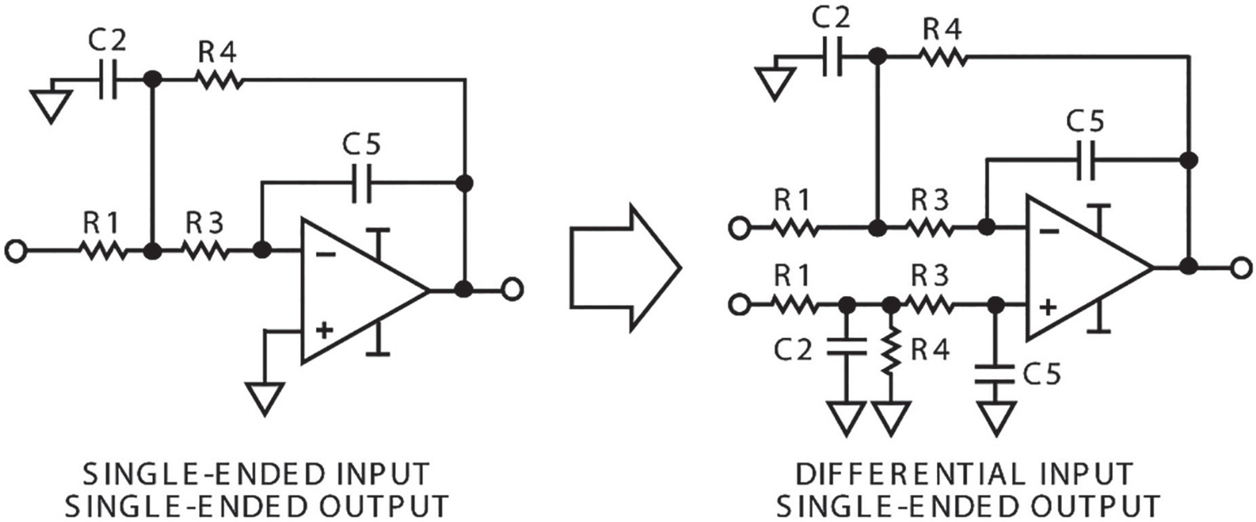


Figure 5: Second-order multiple feedback (mfb) filter

mobile phones. There are four points to consider:

- All these op-amps are low-noise, low-power, small-package devices.
- ADA4807-2 achieves low noise and RRIO (rail-to-rail input and output) by lowest I_Q. It also integrates a disable function, to further decrease power consumption.
- AD8397 subjectively tests well. The disadvantage is the AD8397's higher I_Q, at about 12mA.

THD + N VS V_{OUT}/I_{OUT} Measurement

Figure 6 shows the circuit used to find THD + N at a heavy load, with the following details:

- The power supply is ±3.3V and the gain of the subtractor is about 0.243.
- The SYS-2712 generates a 1kHz sine wave at the input of the amplifier circuit. The amplifier output is fed into the SYS-2712 analyser to determine THD + N.
- Bandwidth of the SYS-2712 analyser should be configured to 22kHz.
- To measure THD+N vs V_{OUT}/I_{OUT}, SYS-2712 is configured to produce a signal in the range 100mV_{rms} to 4V_{rms}.

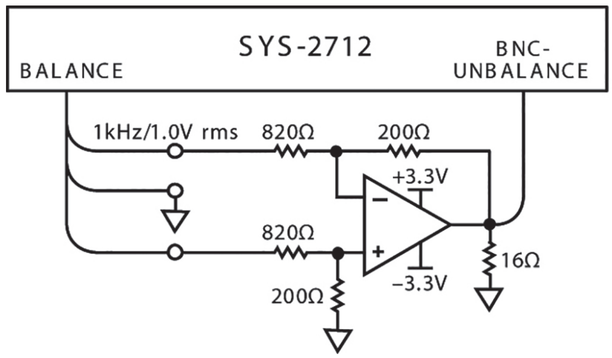


Figure 6: THD + N test with 16Ω load

Design Guidelines

In most cases, 2mW output power is enough to drive headphones.

Resistance measured at 1kΩ induces 4nV/√Hz noise, which is more than the voltage noise of most op-amps. Thus the resistor resistance in the circuit must be chosen carefully, without exceeding 1kΩ.

Shielding is very important in mobile phones. To reach < -100dB THD + N specifications, the smallest interference can degrade THD + N performance, particularly when listening to music and browsing the Internet at the same time. Metal shielding can help prevent performance degradation.

For better heat dissipation, the exposed pad of an LFCSP package should be soldered to the board pad and connected by vias to a big solid-copper plane at the opposite side of the board. The copper plane can be either ground or the board's power plane; the data sheets will specify which plane to use.

A low dropout (LDO) regulator should be used in the power supply of op-amps, with the decoupling capacitors (0.1μF and 4.7μF) near the op-amp power pins.

The capacitors in the audio path must be an NP0 ceramic type for better distortion performance. Thin-film resistors offer optimum THD performance. Metal film resistors are also suitable but cost more. ●

By Gregor Sunderdiek,
Business Development Manager
MCU8 EMEA,
Microchip Technology

Autonomous peripherals for low power in real time

Core-independent peripherals (CIPs) are autonomous, interconnected and intelligent. With CIPs, the microcontroller doesn't need to interact with the central processing unit (CPU) to execute tasks, which brings many advantages to an application.

First, the CPU is not needed for communication between peripherals. The core can sleep, and the software flow doesn't need to be interrupted, reducing the application's current consumption. Since the CPU is the microcontroller's part with highest current consumption, using CIPs reduces the power used.

Second, CIPs do not cause interrupts, which overall allows for a faster communication. If the CPU core is running software and it has to be interrupted by a peripheral to accomplish a specific task, that requires a lot of time. The interrupt needs three clock cycles with an added two for the relative jump, and might use several more cycles for the context switch to save data in the stack registers depending on the application.

Third, using CIPs means faster time-to-market. Less software has to be written since the hardware can do the task on its own. Since this reduces the risk of software errors and less software validation is needed, the development time of the product is shorter than without CIPs.

In AVR microcontrollers (MCUs), all CIPs are connected via the event system, where a multiplexer connects the event generator and the event user. There are synchronous and asynchronous events; asynchronous events need less than one clock cycle and synchronous events need two.

Many peripherals can be connected to the event system to be CIPs, including timers, real-time counters (RTCs), periodic interrupt timers (PITs), custom configurable logic (CCL), analogue comparators (ACs), analogue-to-digital converters (ADCs), universal synchronous/asynchronous receiver/transmitters (USARTs) and general-purpose input/outputs (GPIOs).

Using CIPs

CIPs must be configured before their first use. The CPU executes instructions to do the required initialisation of the event system and the peripherals.

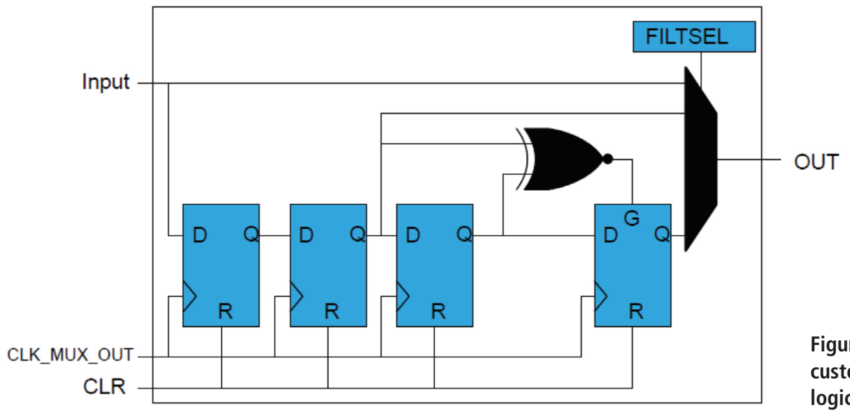


Figure 1: Filter of a custom configurable logic (CCL)

Delay/Debouncing

Several applications nowadays still use a pushbutton as an input. For each one, debounce logic or software is needed to get a non-toggling signal.

For the AVR MCU, it is easy to do the debouncing as software, using delays and/or logic in the software program. The software is not complicated, but it uses CPU resources. Whether the button has been pressed or not can be checked either by polling or via an interrupt from the GPIO controller. Both need time and CPU cycles to do the complete debouncing task.

Debouncing/Delay with the Filter of the CCL

With CIPs, completing the debouncing task can be done without additional CPU overhead; all that's needed is the custom configurable logic (CCL). The GPIO, where the button is connected, is configured as an asynchronous event generator. The CCL will be the event user. The signal from the GPIO pin to the CCL input transfers with no delay. The truth table in the CCL is configured so the output is equal to the input. The output of the truth table is routed to the filter; see Figure 1.

It is possible to remove glitches from the input signal, and the filter delay can be set from two to five clock-cycles (peripheral clock or an alternative clock) for the output signal. Using a slow clock of 32kHz, there'll be a delay of 1.5ms. It is also possible to extend the delay with a different clock or timer.

Delay with a Timer

For example, Timer/Counter B (TCB) is set up in "single-shot" mode. If the timer gets an event signal, it starts counting until it reaches its programmed maximum value and stops. The output of the TCB is connected to the CCL, where the desired combination of the delay signal can be done, allowing for a very flexible time-delay. Every new event to the TCB timer starts the counting again.

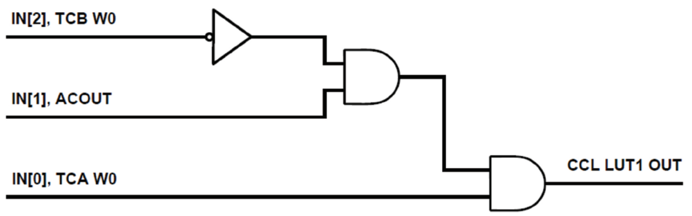


Figure 2: CCL LUT0 dead-time generation

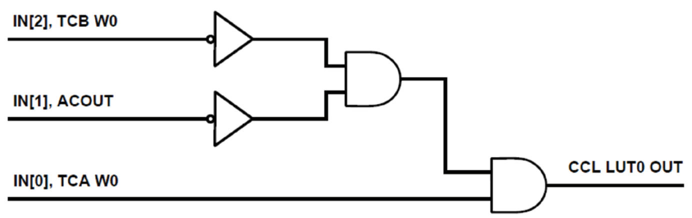


Figure 3: CCL LUT1 dead-time generation

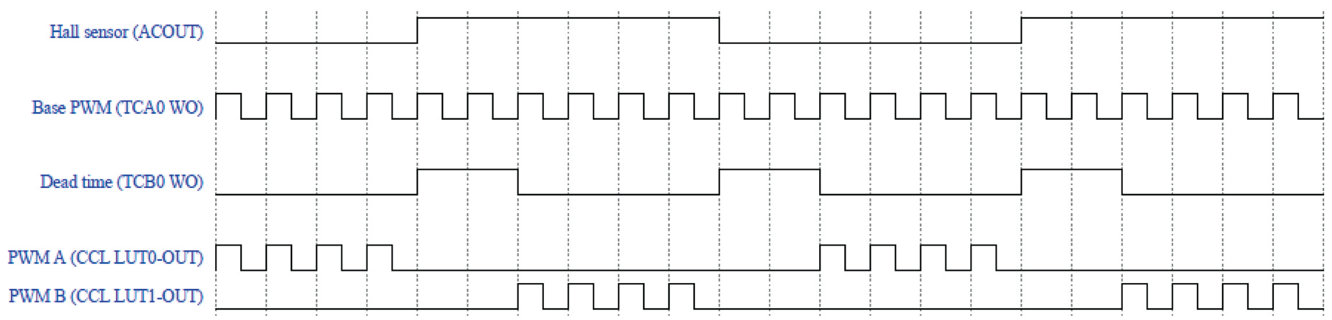


Figure 4: Dead-time generation timing diagram

Dead-Time Generation

Dead time is used in applications where switches (transistors, FETs or IGBTs) are in series between power and ground. If both are activated at the same time, there is a short. An example is an H-bridge configuration commonly used for motor control. Depending on the application, the dead time will either be between commutations or between the pulse-width modulation (PWM) pulses.

Dead time between PWM pulses is needed, for example, in sinusoidal drive and between commutations in 1-pole brushless DC (BLDC) motors. Dead time between PWM pulses can be generated with the timer's time code display (TCD).

To generate dead time between commutations, two timers are needed: the CCL and the analogue comparator (AC). Figures 2 and 3 show the logic of the CCL's truth table. The timer TCA generates the base PWM signal for the motor control. The AC is externally connected to the Hall sensor of the motor, and internally connected via the event system to timer TCB, which generates the dead time signal, if it gets a signal from the AC. The CCL combines the TCA (PWM), TCB (dead time) and the AC signal. The input signals can be selected directly in the CCL configuration, and don't need to use the event system. There are hardwired connections between these modules. The CCL then generates two PWMs (Figure 4), which drive the switches for the motor. Thus the motor runs without any CPU involvement.

Automatic Shut-off PWM Signal

Many applications need to monitor current consumption, so it doesn't exceed a maximum level. This can be done easily with the analogue comparator (AC), which measures the voltage across a shunt resistor. If it exceeds a previous configured threshold, then the PWM signal stops immediately. Both of the following examples use CIPs. The PWM output signal can thus be stopped when overcurrent is detected, without CPU interaction.

Example of LED Lighting with TCA and CCL

The timer/counter A0 generates the PWM for the LED. The AC is used to detect the overcurrent and the CCL to combine these signals, so that if there is an overcurrent detected, the PWM is automatically stopped. The AC and the TCA0 are connected via the event system to the CCL. The AC output signal and the PWM are configured in the truth table of the CCL; see Figure 5. The PWM signal is fed through if the AC event signal is zero. If overcurrent is detected, the AC event signal is one and the output is zero, as long as there is an overcurrent.

AC	TCA0 – PWM	OUT
0	1	1
0	0	0
1	x	0

Figure 5: CCL truth-table for fault-handling

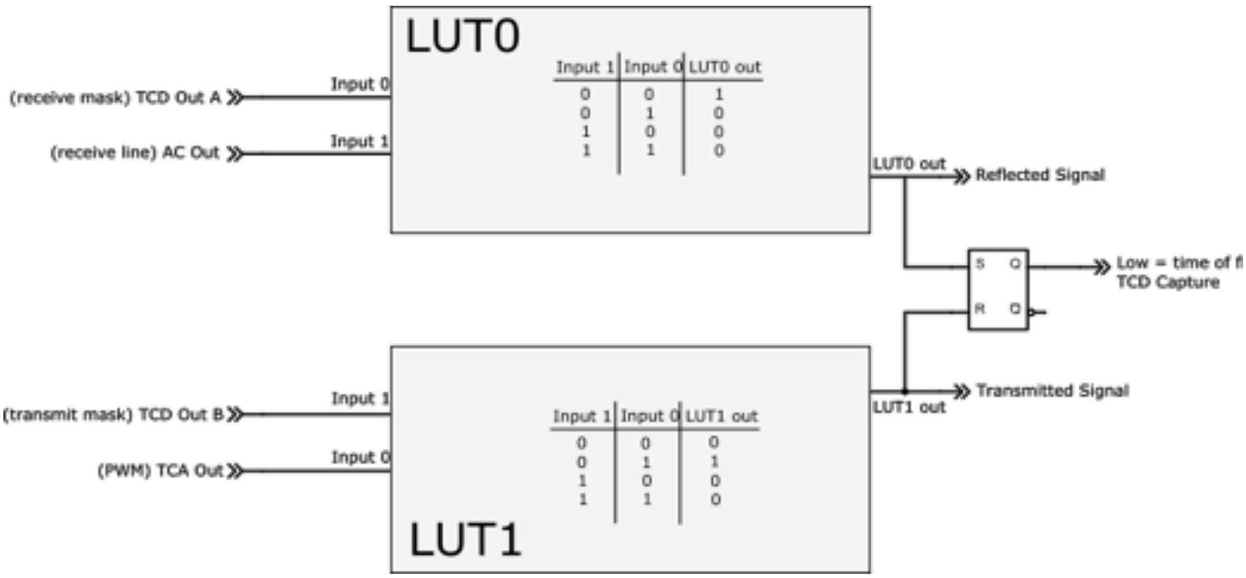


Figure 6: Measuring an ultrasonic signal's time-of-flight

Example of Motor Control with the TCD

A BLDC motor is controlled by the TCD timer that generates the two channels and two complementary channels' PWM signals to drive the four MOSFETs in an H-bridge. The AC is used to detect the overcurrent in the motor with its shunt between the motor and GND. It is connected via the event system to the Timer/Counter D0 (TCD).

The TCD features include fault-handling. If the threshold of the AC is exceeded (overcurrent detected), then an event is signalled to the TCD and the PWMs are stopped automatically.

Measuring Time-Of-Flight

Time-of-flight measures the distance of a signal. It starts when the signal leaves the transceiver and stops when it's detected by the receiver. With the time and known speed (m/s) of the signal, the distance can be calculated.

To measure the distance with an ultrasonic signal, we need the CIPs TCA0, TCB0, TCS0, AC and 2x CCL, and can determine the time-of-flight without CPU usage.

Figure 6 shows the look-up Table 1 (LUT1) with the generated transmitted signal. TCA-Out generates the PWM signal and TCD-Out-B is the transmit mask. The inverted transmit mask and the PWM are logic AND combined and then generate the transmit signal, which is shown by the LUT1 truth table.

LUT0 generates the reflected signal. AC-Out gives the activity on the receive line and TCD-Out-A is the receive mask. The inverted receive mask and the "receive line" are logic AND combined generate the reflected signal, shown by the LUT0 truth-table.

The SR latch is reset with the first transmitted signal and starts the counter in TCD. From the reflected signal and when the SR latch is set, the TCD counter is stopped. The time-of-flight is now stored in the counter of the TCD without CPU involvement. The CPU is only needed for the distance calculation, where the time-of-flight is calculated using the speed of the signal. ●

Sfera Labs's Strato Pi module

Flexible technology for a real shine

By Mark Patrick, Mouser Electronics

Open-source software, such as Linux, has been responsible for the success of many major global enterprises, including Red Hat, SUSE and Canonical. Until recently though, such software had to run on commercial motherboards from mainstream suppliers.

A new generation of hardware controllers from firms like Arduino now offers both boards for prototyping and the schematics for their mass production as open-source hardware. These boards have now added built-in wireless connectivity with the open-source drivers that developers need. With 3D printing becoming increasingly popular and the schematics readily available for a wide range of boards, this combination of open-source hardware and software is a go-to option for developers.

Viable Business Opportunities

The challenge is turning a prototype into a viable business, and there are several ways forward. The emergence of the Internet of Things (IoT) – connecting devices easily to network infrastructure – provides a significant opportunity for building a business using these open-source elements.

The Raspberry Pi Foundation launched its first low-cost credit-card-sized board in 2009, shipping millions of units, initially for hobbyist and schools. It now offers a range of options, with the Pi 3 adding wireless connectivity and the Pi Zero presenting a smaller footprint. Over time a tech community has developed, with third-party companies producing peripheral boards designed to work with this hardware. As a result, the Pi family is being adopted into a wide range of projects, most based around a variant of Debian Linux called Raspian. These projects include an infrared night-vision IoT-connected camera, a networked thermal printer, an AirPlay speaker and even a foam-cutting machine.

Raspberry Pi is just one of several boards that are available with their full schematics. Arduino has been offering its boards and schematics to developers too, and third parties have built an extensive array of add-on shields that work with the main boards. Similarly, UDOO offers its Neo board and schematics on its website.

BeagleBoard started back in 2008 as a platform for the Sitara ARM-based chips from Texas Instruments, but has also gone open-source to encourage a wider ecosystem of developers. It now includes an open-source USB-keyfob computer called PocketBeagle, centred around a 1GHz ARM processor from Octavo Systems. The Linux-based system includes 512MB of DDR3 RAM and integrated power management in a 21mm x 21mm system-in-package. It has 72 expansion pin headers with power and battery I/Os, high-speed USB, eight analogue inputs, 44 digital I/Os and numerous digital interface peripherals.

Fuelling Business in Accessories

Open-source hardware has fuelled the business in accessories and peripherals, from shields to custom I/O boards for protocols such as CAN, as well as custom cases. Sfera Labs, for example, developed the Strato Pi module that connects a Pi to a CAN network for industrial networking. This provides a galvanically-isolated RS-485 port, supporting Modbus and other communication protocols, as well as CAN where the power supply may be higher than 28V – possibly 48V or more. The board allows designers to reliably power the Raspberry Pi from 9V up to 65V for industrial applications.

Sfera has also developed Iono Pi, an I/O module that offers several digital and analogue input lines, power relay outputs and support for standard interfaces like 1-Wire and Wiegand used by modern PLC industrial controllers. Iono Pi uses the 1.2GHz quad-core ARM Cortex-A53 64-bit processor suitable for home and building automation, access control, environmental monitoring, hotel room applications, and others. Importantly, the software development is compatible with the increasing number of standard and proprietary software frameworks available for the Raspberry Pi.

3D printing has also been pivotal in creating opportunities to turn a custom project into a commercial business. For example, in 2008, the Taiwanese board and system maker VIA Technology released an open-source design for a laptop case using its x86 board that could be modified by users; sadly, it didn't catch on. Now there are vast libraries of open-source 3D-printed designs that developers can use in a project.

OS and Security

The differences with an open-source approach can show up later in the design cycle. Operating systems (OS) are no longer static and need to be updated regularly to patch security vulnerabilities. These can impact device drivers, and the new combinations of OS and drivers need to be tested to ensure they work well together and under all circumstances. This level of software testing is not usually part of open-source activity.

Security has been regarded by some as the weak point of open-source designs, but that has now been disproven. There is security software available as part of the open-source community, which looks closely at the vulnerabilities of the whole ecosystem. Instead of one or two relatively small teams focused on testing a proprietary product, there are thousands of engineers looking at the constituent open-source software, highlighting potential problems long before they show up.

Volume Manufacturing

There is, of course, a long way to go from having a prototype or even a product to setting up a viable business. While the prototype may get significant traction on crowdfunding websites, there are subsequent cost and production issues to consider. A third-party supplier may be able to produce several boards, but if the product takes off commercially, the transition to volume production is not without challenges.

Having the schematics is a good start, but there are numerous manufacturing issues, from component sourcing to tolerances and quality. The new company then also must handle certification for different global markets, which takes time and money, putting the newly-made board through test houses, particularly with wireless on the board.

The boards also use external power supplies that need to be sourced and certified safe and compliant for markets around the world, increasing the complexity of ramping up to a volume business. Furthermore, 3D printing is not cost-effective at high volume levels, so a supplier is needed to develop the right tooling with the desired quality and cost. In the worst-case scenario, the product may be impossible to manufacture in volume at all.

All this is a long way from selecting a cool design from an open-source website, and is one reason companies focus on peripheral boards for existing platforms rather than full products such as IoT gateways or sensor nodes. Then, if the product is aimed at the IoT, there is the issue of software updating. Over-the-air (OTA) updates must be handled carefully to avoid causing problems in the end units – in some case this can turn a product into a 'brick', making it all but unusable.

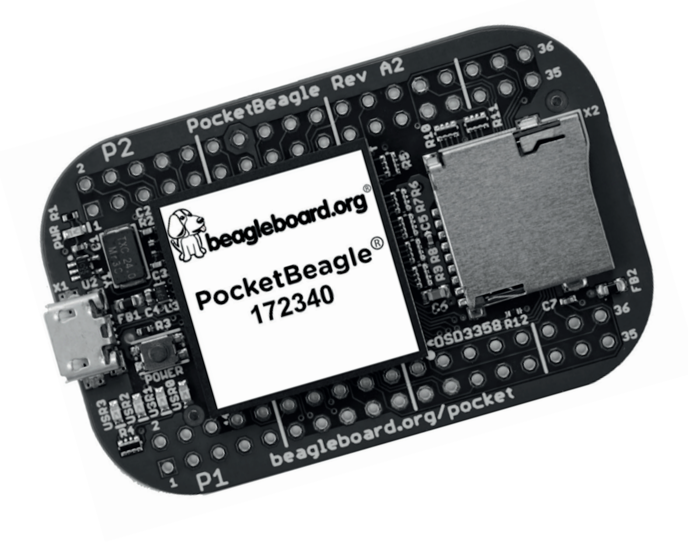
The ethos of the open-source community also requires that developments made using the software and hardware are offered back to the community

Once the product is successfully deployed, there may be further licensing or commercialisation requirements. The Raspberry Pi Foundation merely insists on 'Powered by Raspberry Pi' on the documentation, but other open-source suppliers have commercial agreements that may include support for the kind of issues highlighted here.

The ethos of the open source community also requires that developments made using the software and hardware are offered back to the community. This can have an impact on the ownership of the intellectual property rights and the value future investors may see in the business.

Going Forward

While open-source hardware and software with 3D printing can dramatically speed up the development of a prototype, there is still a significant gap when turning that prototype into a business. Nevertheless, that prototype can be shown to prospective investors as a working demonstration, greatly boosting the chances of securing financial backing. With significant investment to attract skilled manufacturing, software and test engineers, the idea can move from concept to reality, with volume deployment following from that. Feeding back the technology into the open-source community can then stimulate more innovation from a new generation of ambitious entrepreneurs. ●



The PocketBeagle board

Selecting the right mains filter for your application

By Keith Armstrong, Principal EMC Consultant and Director of Cherry Clough Consultants

Choosing a filter can seem a bit like black art – although it definitely it is not! It is fair to say that, in many applications, even when all the best efforts have been made using guidelines, it may be necessary to try several filters to find the best one; but, guidelines do help avoid unpleasant experiences at a later project stage.

Calculating Filter Specifications

To estimate a filter's performance for the control of emissions, compare the anticipated spectrum of emissions from the (unfiltered) product with the limits of the relevant EMC emissions standard. See *'Do-It-Yourself EMC Testing'*, available on the EMC Standards's website, for easy conducted noise measurements.

For immunity, compare the external electrical noises with the susceptibility of the circuits in the product and the desired level of performance during interference. Commercial/industrial EMC standards are based on economic compromises, so to avoid EMI in real-life operation (to keep warranty costs down and customers satisfied), it is best to assess the electromagnetic environment the product will work in and compare it with the normal EMC standards.

Impedance Problems

All filters work on the principle of providing a large discontinuity in the characteristic impedance seen by a radio frequency (RF) wave travelling along a conductor, with the intention of reflecting most of the energy in the waves associated with the unwanted noises back to the source.

Filters are often specified by tests done with 50Ω source and load impedances, which unfortunately means that filter specifications are not necessarily a good indication of real-life performance.

Typically, a mains filter fits between the AC supply and a product's AC-DC power converter. The impedance of the AC supply varies from 2Ω to 2,000Ω during the day, depending on the connected load and measured frequency. The RF characteristic impedance of the mains lead to the product is about 150Ω, and the impedance of an AC-DC power converter looks like a short circuit when its rectifiers are turned on, and an open circuit at all other times.

The inductors and capacitors in mains filters make them resonant circuits, so their performance can depend critically on their source and load impedances.

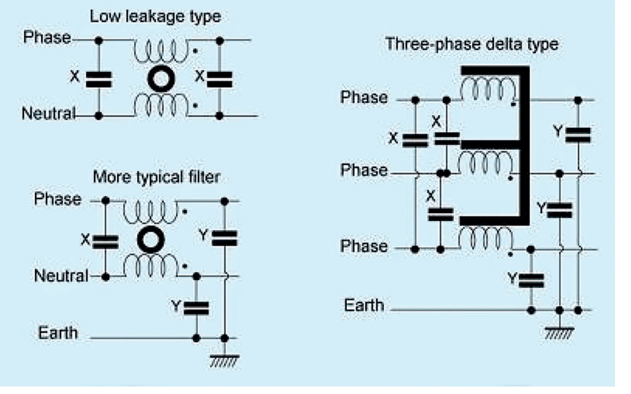


Figure 1: Some typical single-stage mains filters

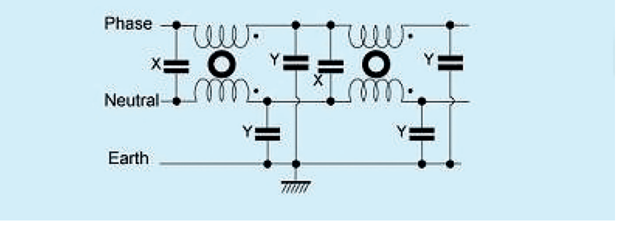


Figure 2: A typical two-stage mains filter

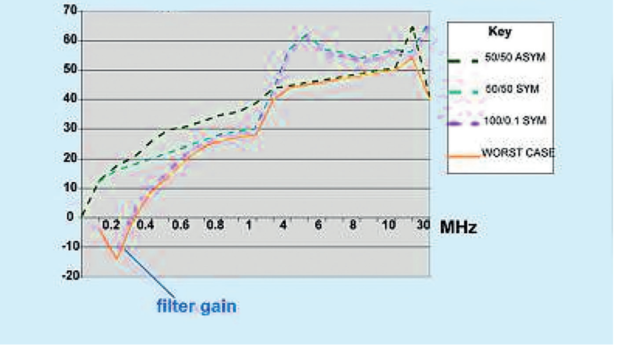


Figure 3: Deriving a reliable filter attenuation curve from manufacturer's data

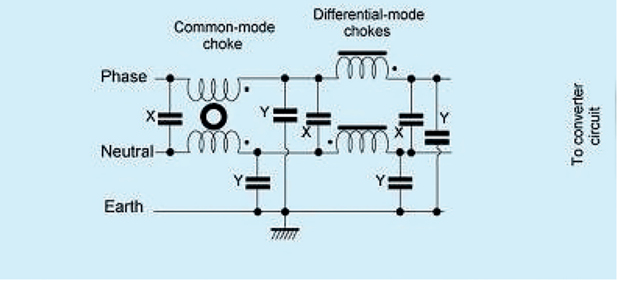


Figure 4: Example of mains filter for a switching power converter

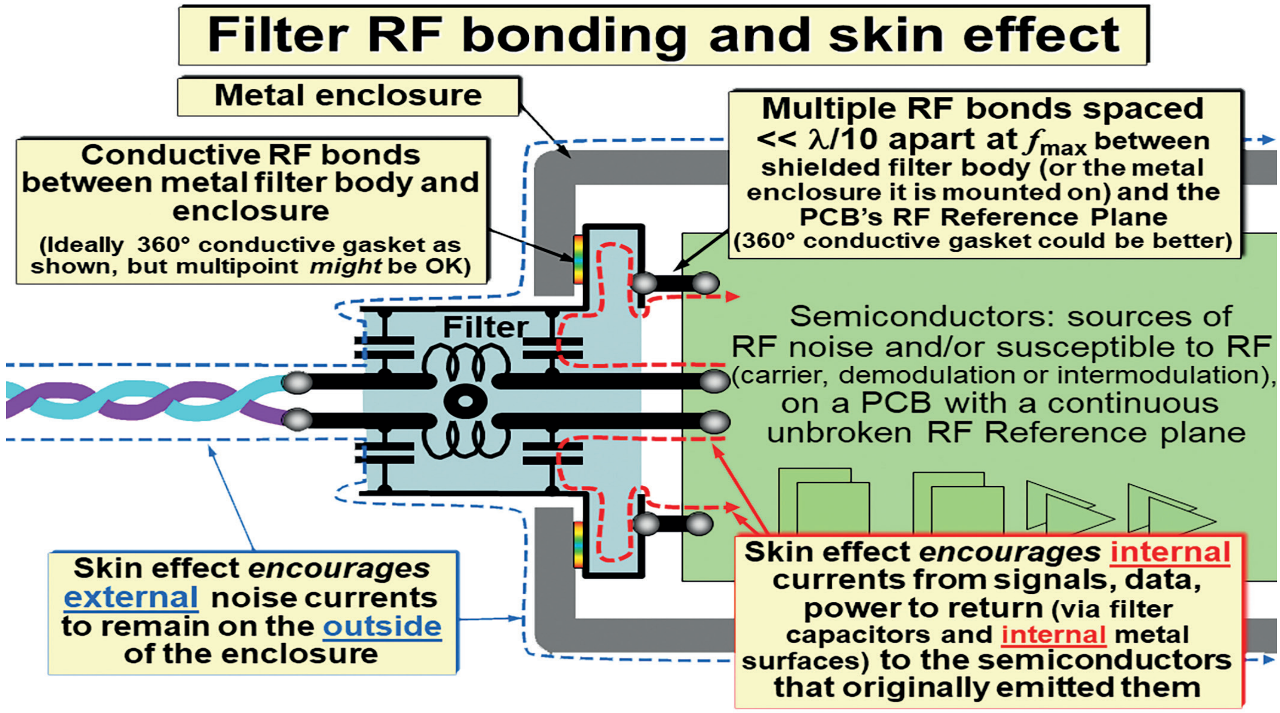


Figure 5: Keeping internal currents inside and external ones outside

Mains filters with a single stage (Figure 1) are very sensitive to source and load impedances and can easily provide gain, rather than attenuation, when operated with source and load impedances other than their specification. This gain usually pops up in the 150kHz to 4MHz region and is typically between 10 and 20dB, leading to the possibility that fitting a single-stage mains filter can increase emissions and/or worsen susceptibility in that frequency range.

Filters with two or more stages (Figure 2) are able to maintain an internal node at an impedance which doesn't depend very much on source and load impedances, hence provide an attenuation performance closer to their 50/50Ω specifications.

To deal with this impedance problem, it is best to only purchase filters for which the manufacturer has specified both common-mode (CM, 'asymmetrical') and differential-mode (DM, 'symmetrical') performances, with both matched 50/50Ω and mismatched sources and loads according to the methods described in CISPR 17. Mismatched measurements are made using a 0.1Ω source and 100Ω load (and vice-versa).

When filters are chosen by taking an attenuation-versus-frequency curve that follows worst-case figures from all six attenuation curves provided (assuming that this resultant curve represents the filter's actual performance), their performance in real life is usually as good or better than expected. Figure 3 shows an example of this procedure.

Most mains filters achieve attenuation of CM noises by using CM chokes, plus low-value Y capacitors between phases and ground. For DM noise attenuation they rely on X capacitors connected between phases, plus the leakage inductances of the CM chokes.

Low-frequency noise from switch-mode converters, phase angle power controllers, motor drives and the like, often need more DM attenuation than can be achieved by the means discussed here and may need to use DM chokes as shown in Figure 4. Magnetic saturation of the choke core makes this difficult, so these filters tend to be larger and more expensive.

Most mains filters use Y capacitors connected between phases and ground, with values around a few nF as so not to exceed the ground leakage limits imposed by the relevant safety standard. In general, the Y capacitors are connected to the side of the filter that has the highest levels of noise, for example the Y capacitors would be fitted to a filter's mains input when filtering a linear power supply for a low-frequency analogue product but would be fitted to the filter's mains output when filtering a switching converter and/or a product that contains any digital processing or RF analogue circuits.

For medical apparatus, the ground-leakage currents may be limited to such low levels that the use of reasonably-sized Y capacitors is impossible, and it is necessary to achieve more attenuation from their CM chokes and/or by using more stages.

In systems, the ground leakages from the small Y capacitors in a number of items of equipment can add up to create unsafe levels of ground leakage currents. This buildup of ground leakages can cause ground voltage differences that impose hum and high levels of transients on cables between equipment. Modern, EMC practices call for three-dimensionally meshed ground system bonding (see IEC 61000-5-2), but many older installations do not use this, so products intended for large systems can benefit from filters with small or even non-existent Y capacitors, even though such filters may be larger and costlier.

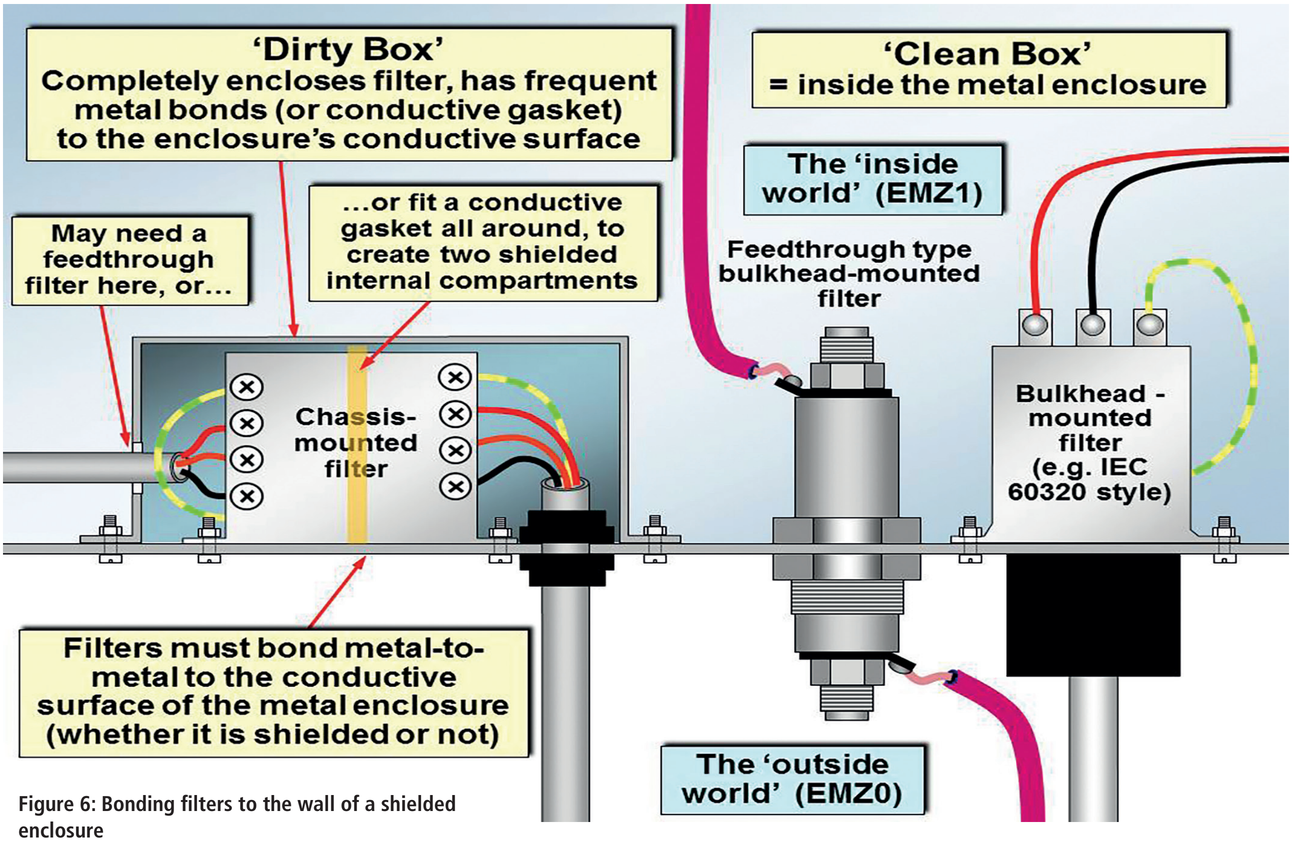


Figure 6: Bonding filters to the wall of a shielded enclosure

Mains filter performance varies with temperature and current, and *'EMC Performance of Drive Application Under Real Load Condition'* (F Beck, J Sroka, 1999) shows that varying the mains voltage, load current and ambient temperature within the rated ranges reduces the attenuation of a mains filter by up to 20dB, compared with its performance during normal emissions testing. So, to ensure acceptable performance in real life it may be better to select a mains filter that achieves significantly more attenuation than is required, merely to pass the usual EMC tests at the usual ambient temperature.

Synergy of Filters and Shielding

For successful RF performance, filtering and shielding must be considered together. Incorrect filter design, construction or mounting can easily compromise radiated emissions, and inadequate shielding can compromise conducted emissions.

Filter performance is easily compromised by field couplings (leakages) between the conductors on their unfiltered and filtered sides, so their inputs and outputs should be kept as far apart as possible. Other conductors should not cross the filtered boundary without being adequately filtered, shielded or directly bonded to the RF reference, potentially needing shielding techniques to control any remaining leakages.

Since RF current always flows on the surfaces of metal objects due to 'skin effect', and there is a 1:1 relationship between the surface currents and the electric (E) and magnetic (H) fields that impinge on the metal surface, for good EMC shielding and/or filtering, it must be ensured that the internal surface currents (i.e. the internal fields) remain inside and the external surface currents (i.e. the external fields) outside; see Figure 5 for the principles of correct filter assembly.

All currents, even stray CM ones, always flow in lowest overall-impedance closed loops.

Where an external cable to be filtered connects to an unshielded PCB, the filter should employ the PCB's 0V plane as its RF reference and be directly bonded to it with very low inductance.

Where an external cable to be filtered enters a shielded enclosure, the filter should be directly bonded to the shielding surface at the point where the cable penetrates the enclosure. Ideally, the filter's metal body is bonded to the shielding surface all around the aperture it fits in. Some filters are provided with multiple ground bonding points for this purpose, or a conductive gasket may be used instead. Bulkhead-mounted, or feedthrough, filters are the best.

An IEC 60320 inlet filter with a metal body installed in a shielded enclosure can achieve good attenuation at frequencies above 30MHz if its metal body has seamless construction with a very low inductance connection directly to the shielding surface; see Figure 6.

For high power, most filters use spade or screw-terminal connections, making bulkhead mounting impossible. Figure 6 shows a screw-terminal filter mounted using the 'dirty-box' method, which encloses it in an additional shielded enclosure within the main shielded enclosure. Even though the input and output cables in the 'dirty box' are kept very short and far away from each other, high frequencies may still leak between them, and a high-frequency feedthrough filter might be needed at the point where one of the cables penetrates the wall of the 'dirty box'.

Another approach is to use a conductive gasket inside the 'dirty box', to help shield the input and output wires from each other. ●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The Ribbon was created by lighting artist Min Sang Cho, and combines OLED technology with 3D printing techniques, finished with 24-carat gold leaf

Flexible technology for a real shine

By Ian Drinkwater, Managing Director of trade lighting supplier Applelec

OLED (organic light-emitting diode) technology is still relatively unexplored as far as lighting is concerned; however, its versatility and the soft, natural light it produces make it ideal for a wide range of applications.

In fact, many of us are already carrying OLED technology in our pocket or bag. Mobile phones and electronic devices feature OLED screens; Samsung has used them since introducing its Galaxy range several years ago, although the Apple iPhone X is the first to have an OLED screen. As far as handheld technology goes, OLED screens create a more vivid and realistic picture than liquid crystal displays (LCDs).

The use of OLEDs in televisions, computer screens and gaming devices is also relatively widespread, thanks to benefits such as enhanced picture quality and a larger viewing angle of around 160 degrees, without colours darkening or disappearing. For gaming in particular, OLEDs respond up to 200 times faster than LCDs, enabling pictures to move faster than ever.

OLED Operation

Unlike regular LEDs, OLED modules use a series of thin light-emitting films composed of hydrocarbon chains rather than semiconductors laden with metals.

A typical LED consists of two electrodes, a cathode and an anode, that produce light when powered. Colour is determined by the semiconductor used. By contrast, an OLED comprises layers of an organic compound sandwiched between the cathode and anode and placed on a surface such as rigid glass or flexible plastic.

Since OLEDs need no backlight, they are also significantly thinner than their LED counterparts, in some cases up to ten times thinner.

A further OLED benefit is energy efficiency. The backlight of an LED is never actually turned off, but rather is blocked, producing the colour black when the pixel shutter is fully closed. An OLED has no backlight and simply turns each pixel off to produce black, consuming no power.

Lighting Designer's Dream

In theory, OLEDs are a lighting or architectural specifier's dream thanks to their simplicity. Slim, flat, flexible, cool to the touch and virtually glare-free, these modular light panels can be incorporated into fixtures or embedded in furniture, walls and even textiles.

The relatively high cost of OLED panels may have limited their use in general lighting schemes; however, the creative possibilities are wide-ranging. While as a lighting option OLED is still regarded as something of an emerging technology, its aesthetic potential as tiles or soft panels is huge.

OLEDs can even be utilised with 3D printing techniques – thanks to their slender and flexible nature, it's possible to create stunning sculptural light installations. One such example is The Ribbon (see images left and below), created by London-based lighting artist Min Sang Cho and showcased at the 2016 London Design Festival. Applelec supplied materials for the piece, which combines OLED technology with 3D printing techniques to illustrate both the artistic and technological possibilities presented by OLED.

The Ribbon was 3D-printed in its basic form before being manipulated and finished by hand, when 24-carat gold leaf was delicately applied to each piece of ribbon to emphasise the soft, ambient reflections from the OLEDs. The organic nature of the light produced is eye-catching yet without obtrusive glare.

It is possible to customise the installation in size and shape, with each segment measuring 1.2m when straightened, while within the installation the individual sections are 4m in length and 1m deep.

One segment features three flexible 400mm x 50mm OLED panels on one side while the other side is hand-painted with gold leaf. Power consumption is impressively low, with the installation drawing just 9W per unit.

After being unveiled at the design festival, The Ribbon was transported to its permanent home in the VIP reception area of the Genting Highland Casino in Malaysia.

'O' for Organic

One key feature of the light emitted by an OLED module is that it is softer and more akin to natural daylight than that produced by bulbs; in fact, with the exception of old-style incandescent lamps, the relaxed, diffused light an OLED produces is the closest light source to natural light. This makes it ideal for a wide range of applications where the benefits of natural light – or something close to it – have been identified. Researchers and architectural designers alike have noted the positive effect of daylight on human health, specifically an increase in productivity and employee comfort when introduced in the workplace.

As OLED can be used to recreate daylight without either increased glare or energy consumption, health centres can reap benefits from its use, as well as facilities such as sensory rooms that help adults and children with learning difficulties.

Indeed, the arguments for replicating natural light in a healthcare setting in particular are irrefutable, with research showing various outcomes, including shorter hospital stays, faster post-operative recovery, reduced pain-relief requirements and a quicker recovery time from depressive conditions.

Studies have also shown the benefits of natural light in office spaces, educational establishments, museums and even shops – light which can, of course, be recreated with OLEDs. The fact that they are incorporated into thin panels offers impressive space-saving potential, allowing more room for the displays themselves.

Its ability to create illumination across a surface as opposed to a specific point, along with the low levels of heat produced, makes OLED the ideal choice to light potentially fragile or sensitive artefacts.

On a smaller scale, being slim, flexible and energy-efficient, OLED is perfect for use in task lamps. Unlike regular luminaires, OLED is free from blue light and, consequently, the associated risks, such as eye strain and possible retinal damage.

Lighting is a frequently used tool to create mood within a retail environment, doing far more than highlighting certain products. Bright lighting is understood to represent honesty, energy and positivity, triggering a high level of calm and relaxation.

OLED displays can be used to enhance open or public areas, engaging, entertaining and informing visitors. Its flexibility makes OLED ideal for use on curved, arched, concave and convex surfaces, while flat panels can be used on ceilings, walls or even floors. Video walls, curved areas and in-glass wallpaper displays are among the other possibilities.

Emerging Energy-Efficient Technology

At present, OLED technology is relatively young and continues to develop, along with its potential for further energy efficiency. Moves are being made to prolong the lifetime of OLED modules, with some already capable of reaching 10,000 hours or more.

The technology can be seen in all its glory at Applelec's recently-expanded London showroom. Situated in the Business Design Centre in Islington, it features a spectacular lighting display incorporating almost 100 OLED modules in both a track-mounted and pendant form.

The display is proving a draw for specifiers and product purchasers keen to explore the flexibility and versatility of this technology. ●

The Ribbon by lighting artist Min Sang Cho uses OLEDs

UVC LEDs and nanomaterials promise to transform many applications, starting with water disinfection

By John Cafferkey, Marketing Manager, Cambridge Nanotherm

Disinfecting water with UVC radiation has a long history. First used in 1910 in France for municipal water disinfection, unreliable equipment made the initial foray into UVC rather short-lived. It wasn't until the 1950s that the technology was mature enough to be rolled out and adopted in various countries. By the mid-1980s, some 1,500 UV water disinfection plants were operating across Europe.

However, UV disinfection has remained the preserve of large-scale municipal, industrial and maritime applications. These systems use mercury vapour discharge lamps to generate the UVC radiation required – essentially a fluorescent lamp without the phosphor-coating, to allow the UVC radiation out.

UVC Use

UVC has a wavelength of 200-280nm in the electromagnetic spectrum – known as the germicidal range. In the right dose, UVC radiation penetrates the cell walls of micro-organisms and stops them from reproducing by disrupting their DNA. By this mechanism, water exposed to UVC light can be disinfected, making it safe.

The reliance on mercury vapour lamps as the source of UVC radiation has limited the range of applications. These lamps are large and fragile, so they are only suited to applications where they are safe from damage, since they contain mercury and present a health risk if broken. These factors have made the development of small form-factor, rugged and portable applications impractical.

The dominance of mercury vapour lamps is now being challenged by developments in UV LED technology. New materials and manufacturing techniques are ushering in a variety of LEDs that operate in the UV spectrum. Long-wave (UVA) LEDs have been commercially available for several years, and now short-wave (UVC) LEDs are emerging with the potential to revolutionise the market and open a whole host of new sterilisation and disinfection applications. Such is the potential of UVC LED technology that market analyst firm Yole Développement predicts that the nascent $7m UVC LED market will explode to $610m by 2021.

New Possibilities

LED technology is unlikely to replace mercury vapour lamps for large-scale applications, such as municipal-scale water treatment because LEDs simply cannot compete on power output. However, it's precisely this low power niche that creates opportunities for small form-factor applications.

LEDs are small, robust and low-power enough to be battery-operated. They can be power-cycled on and off instantly without damage, and their spectral output can be tightly controlled to deliver exactly the wavelength required. These features make UVC LEDs ideal for small, portable applications where they can be embedded directly into devices. Water bottles could incorporate UVC LEDs to disinfect water at the push of a button. This kind of technology could enable walkers, travellers and campers to fill their water bottles from a river and have safe drinking water in an instant.

Travelling applications aside, the technology has the potential to revolutionise the way we access clean water in our homes. The water dispenser in the fridge could be embedded with UVC LED technology that activates when pouring a glass of water. Taps and showers could be embedded with UVC LED technology to disinfect water at the point of use. Several companies already make innovative in-home water disinfection products based around UVC LEDs. UVC LED technology could also be valuable in the workplace, in water coolers.

On a more critical level, the technology has the potential to save lives in humanitarian disasters where there is no access to clean water. A simple, rapid, portable method of disinfecting standing water could help stop the spread of water-borne pathogens, a significant threat in disaster zones.

The Thermal Issue in UVC LEDs

However, to fully realise the benefits of small form-factor UVC LED devices, there are some significant technical barriers to overcome. One of these is thermal management.

Like any electronic component, LEDs are extremely sensitive to heat. If the LED junction exceeds its maximum operating temperature, its life can be significantly reduced, its light quality degraded and its life ultimately shortened.

UVC LEDs are inefficient – visible-light LEDs run at around 40% efficiency, but moving up the electromagnetic spectrum, efficiency decreases. UVC LEDs are only around 5% efficient, which means that in practice they only convert around 5% of their power into light, the remaining 95% being heat that needs to be removed.

The surface area of the LED is extremely small, so cooling by convection is not an option. Also, when operating safely, the LED is not hot enough to radiate heat away, so the only way to remove it is through its back, mounted on a thermally-conductive PCB. The objective is to get the heat from the LED junction, through the chip package, down into the PCB, and out to the ambient atmosphere via a heatsink as efficiently as possible.

Most visible-light high-power LED modules rely on metal-clad PCBs (MCPCBs) for thermal management. These are manufactured from a sheet of metal, usually aluminium, with the copper circuit layer attached, using a layer of thermally-conductive but electrically-insulating dielectric. Commonly, this material is epoxy-filled with ceramic powder to boost thermal conductivity.

However, there's a catch. UV radiation degrades organic material, and since the epoxy used for the dielectric layer on MCPCBs is organic, it is unsuited to UVC applications, limiting options for PCB materials to electronics-grade ceramics. Aluminium nitride (AIN) is more than thermally capable of cooling LEDs (thermal conductivity 140-170W/Mk), but is expensive, which makes meeting the overall budget difficult. Aluminium oxide (Al2O3), or alumina, whilst much cheaper, has a much lower thermal performance at 20-30W/mK, insufficient to meet the demanding cooling requirements of UVC LEDs. What's more, both materials are very brittle and easily breakable; they can snap if screw-mounted and are unsuitable for more rugged applications.

Nanomaterials to the Rescue

There is one product that addresses all these challenges and has thermal conductivity of 150W/mK, well within the range required to ensure UVC LEDs run at an appropriate temperature.

Using a patented electro-chemical oxidation (ECO) process, this approach from Cambridge Nanotherm transforms the surface of an aluminium board into a very thin layer of nanograin alumina ceramic, just tens of microns thick. The nanograin alumina layer acts as the dielectric between the copper circuit and the aluminium board. Because the layer produced by the ECO process is a true nanomaterial, it has uncommon properties, such as high dielectric strength. Accordingly, it can be quite thin, so heat can easily pass through, giving the substrate its exceptional thermal conductivity.

The ECO process is followed by thin-film processing (sputtering) to fabricate the copper circuit layer directly on the nanoceramic dielectric, further improving the PCB's thermal efficiency. And because no organic epoxy is used at any stage of the process, there is nothing for UV radiation to degrade.

The whole approach results in an MCPCB with a thermal performance that rivals AlN but without any of the problems associated with poor manufacturability or brittleness.

Effective Thermal Management

Effective thermal management is a critical element to consider in any high-power LED design, and with UVC LEDs the issue is magnified. Unless both the thermal and mechanical problems are addressed, the range of applications open to UVC LEDs will be limited.

Nanoceramic substrates have been successfully applied to UVA LEDs as a more robust, cost-effective and machinable solution than AlN. With the UVC LED market for water disinfection on the cusp of rapid growth, the issues around the viability of ceramics as a robust substrate for more rugged UVC applications need addressing.

As designers get ever more creative with UVC applications, the need for an alternative to ceramic substrates will become increasingly pressing. Nanomaterials such as nanoceramic offer the ideal solution for designers – the perfect balance of thermal performance, manufacturability, ruggedness and price. The potential for UVC applications is large, from lifestyle-changing to lifesaving, and nanoceramics will be at the core of many of these applications. ●

UVC LEDS AND THEIR EXTERNAL QUANTUM EFFICENCY

Whilst LEDs are far more energy-efficent than incandescent bulbs, they are far from perfect converters of power to light.

The efficiency of LEDs is measured by external quantum efficiency (EQE). Three factors contribute to a device's EQE: its light extraction efficiency (LEE), electron injection efficiency (EIE) and internal quantum efficiency (IQE). The output is a percentage of how much power is converted into light. Any power that isn't converted to light becomes heat.

The EQE of LEDs plummets when moving up the electro-magnetic spectrum. At a wavelength of 380nm (UVA) the EQE is at best 40%.

There are various projects underway to improve the EQE of UVC LEDs, from new technologies and different manufacturing approaches to growing different substrate materials for the LED die. However, for the foreseeable future the low EQE of UVC LEDs means thermal management will remain a critical challenge.

ETAL GROUP CELEBRATES 50 YEARS OF SUCCESS

ETAL Group, a manufacturer of magnetic components for the telecom, power technology, automotive and defence industries, this year celebrates 50 years in business. At the same time, it celebrates ten years of manufacturing at its recently-expanded Ratmalana, Sri Lanka facility.

Originally founded in 1968 as EGMTC (Elektronik Gruppen Magnetic Technology Components), the company develops high-performance magnetic components, primarily transformers and inductors, most of which custom-made. The business was renamed ETAL in 2008 when Profec Technologies, a Finnish manufacturer of inductive components was acquired and merged with EGMTC.

ETAL Group recently added a new UK R&D centre with a fast turnaround, prototyping and small-batch facility. The announcement followed the acquisition by ETAL of Sussex-based transformer and wound component specialist Grandchain.

www.etalgroup.com

DATA AND WORKFLOWS FOR INDUSTRY 4.0

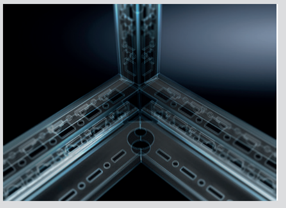
The new Rittal VX25 large enclosure system supports the control and switchgear engineering industry on the path to Industry 4.0.

The new system combines a physical enclosure with its digital twin, ensuring it will meet all future digital needs – from online configuration and engineering to assembly, automation and tracking.

Rittal has created a system capable of merging real and physical workflows, delivering significant improvements in efficiency for panel builders and switchgear manufacturers.

The VX25 ensures 3D data is available in consistent maximum quality. The digital element supports control and switchgear manufacturers across every process along their value chain. This means electrical planning, mechanical design, purchasing, cost calculation and manufacturing, as well as every other area of switchgear construction, can always access complete, high-quality data, opening new ways for end users to digitise their processes in accordance with Industry 4.0.

www.rittal.co.uk

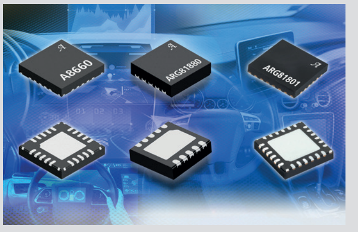


LOW EMI DC/DC BUCK REGULATORS FROM ALLEGRO

Allegro MicroSystems Europe announced the latest additions to its regulators portfolio, the A8660, ARG81880 and ARG81801. These devices reduce EMI through switching frequency dithering and allow system noise management though external clock synchronisation.

The devices are AEC-Q100 automotive qualified, designed to operate over a wide input voltage range to withstand automotive stop/start, cold crank and load dump conditions, and are also capable of switching at 2.2MHz for reduction in component size and cost. The devices cover a wide output current range (from sub-1A to 10A), provide tightly-regulated supply rails across temperatures, and are targeted at automotive and industrial applications such as ADAS, HUD, telematics, infotainment, clusters, camera recorders, ECUs, smart appliances, industrial automation/robotics, IoT and others.

www.allegromicro.com



TOSHIBA LAUNCHES HIGH-CURRENT PHOTORELAYS IN DIP4 PACKAGE

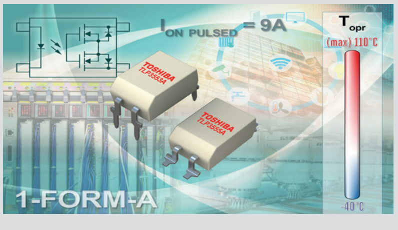
Toshiba Electronics Europe launched two new high-current photorelays fabricated with its latest U-MOS IX semiconductor process.

The new TLP3553A and TLP3555A devices feature off-state output terminal voltage ratings of 30V and 60V, and on-state continuous current ratings of 4A and 3A – higher than previous-generation products. When operated in pulsed mode, the current ratings increase to 9A for both devices.

Common applications for these devices include industrial equipment (PLCs, I/O interface, sensor controls), building automation systems (heating, ventilation and air conditioning, or HVAC), security equipment and the replacement of mechanical relays in legacy systems.

The TLP3553A features a low on-state resistance of just 50mΩ (max.), which is less than a typical mechanical relay (about 100mΩ).

www.toshiba.semicon-storage.com



FIRST CONGATEC SMARC 2.0 MODULE WITH NXP I.MX8 PROCESSOR

Congatec announces the conga-SMX8, the company's first SMARC 2.0 Computer-on-Module based on the 64-bit NXP i.MX8 multi-core ARM processor family.

The ARM Cortex A53/A72-based conga-SMX8 represents the new flagship module for ultra-low-power embedded designs, offering the recent best-in-class ARM processor with excellent performance, flexible graphics and numerous embedded features for all types of IIoT applications. It provides high-performance multi-core computing along with extended graphics capabilities for up to three independent 1080p displays or a single 4K screen.

Further benefits include hardware-based real-time and hypervisor support, along with broad scalability, resistance against harsh environments and extended temperature ranges. The SMARC 2.0 module meets the needs for low-power embedded, industrial and IoT applications and the mobility sector.

www.congatec.com

ONE-STOP-SHOP FAN IMPLEMENTATION SERVICE FROM INELCO HUNTER

In conjunction with EBM Papst, Inelco Hunter now offers a one-stop-shop fan implementation service for easier, streamlined implementation of complete fan assemblies. The potential benefits include shorter supply chain and lower cost of acquisition.

This innovative new concept is called Higher Level Assembly, or HLA. The proposition is simple and compelling: why buy a fan when you can source a complete, bespoke service? And why spend time, money and resources managing multiple suppliers when you can choose a comprehensive service from a single supplier with proven manufacturing quality?

As its name suggests, HLA is the assembly of any number of component parts into a complete or near-complete system, finished product or sub-level assembly. It frees design engineers and engineering buyers from the time-consuming expense of sourcing, buying, storing and assembling many different components.

www.inelcohunter.co.uk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