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FEATURES

REGULARS

LPWANS WILL TAKE ON CELLULAR FOR IoT APPLICATIONS

While traditional cellular networks have dominated the market for M2M connectivity, this is about to change, according to Beecham Research analysts in a report called *'Low Power Wide Area Networks for IoT Applications Market Report and Forecast'*. Offering low power, low cost and long range, Low Power Wide Area Networks (LPWANs) enable a far wider range of M2M and IoT applications than those currently constrained by budgets and distance from a power source.

Beecham Research expects that by 2020 LPWANs will provide 26% of the total IoT connectivity market with 345 million connections, marking an end to the near-monopoly of traditional cellular networks for machine connectivity.

"LPWANs represent the most dynamic and potentially game-changing development in the M2M/IoT market," said David Parker, senior analyst at Beecham Research and author of the report. "The lower speeds of LPWANs are the trade-off for longer range, offering networks optimised for machine connectivity with much lower deployment costs than traditional cellular networks. LPWANs will both compete and collaborate with cellular and other network technologies to stimulate market growth with more connectivity options for end users."

The report also warns of the hype around 'big data' applications where everything is defined in terms of the 3Vs – velocity, volume and variety.

"Our look at LPWANs highlighted that there are many applications that are not big data and not necessarily real-time, interactive or immersive," said Robin Duke-Woolley, CEO of Beecham Research. "So, from a connectivity point of view, the market will move towards 4G-5G for satisfying big data IoT, while on the other side LPWANs and equivalent networks will address the low data IoT requirement."

The Beecham Research report investigates the increasing range of LPWAN technologies, including the likes of Sigfox and companies in the LoRa Alliance, currently leading the LPWAN field in terms of network deployment, industry support, investment and customers. Most of these LPWAN solutions use the ISM (Industrial Scientific and Medical) bands better known for use by short-range wireless technologies like ZigBee, Wi-Fi and 6LoWPAN. However, recent advances have enabled LPWANs to operate using the ISM bands over longer distances, up to 50km in rural areas and 5-10km in urban areas.

> "LPWANs will provide 26% of the total IoT connectivity market with over 345 million connections by 2020

Another LPWAN technology with long-range and low-power characteristics is known as TV White Spaces (TVWS), which uses the gaps in between VHF/UHF parts of the spectrum, previously used for TV broadcasting. TVWS promises connectivity over distances of 10km and with superior in-building penetration compared to 3G or 4G.

"New entrants working in the ISM and TVWS bands are promoting overall market growth and providing a spur to action within the GSMA world," said Parker. "Developing standards for the cellular operating community is a slower process but the emergence of LTE-M and Narrowband IoT (NB-IOT) will allow cellular operators to compete with these new entrants on a level playing field of range, battery life and costs."

While the market is fast moving, Beecham Research's Duke-Woolley also raises concerns about over-optimistic forecasts.

"We have seen some staggering predictions of the number of connected devices in the next five or ten years that are simply unrealistic. The risk is that new and established companies build business plans based on these forecasts and run out of funding before they have a chance to become established and see return on their investment."

Beecham Research is a technology market research, analysis and consulting firm (www.beechamresearch.com)

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RESEARCH TEAM EXPLAINS THE AGING PROCESS IN LITHIUM ION BATTERIES

Lithium-ion batteries' aging process significantly reduces their potential storage capacity and yet scientists know very little about its causes. Until now, when researchers at Technical University of Munich (TUM) have identified two key mechanisms for loss of capacity during operation: the active lithium in the cell slowly dissipates in various side reactions and, second, decomposition of the electrolyte is accelerated by transition metals deposited on the anode that increase its conductivity.

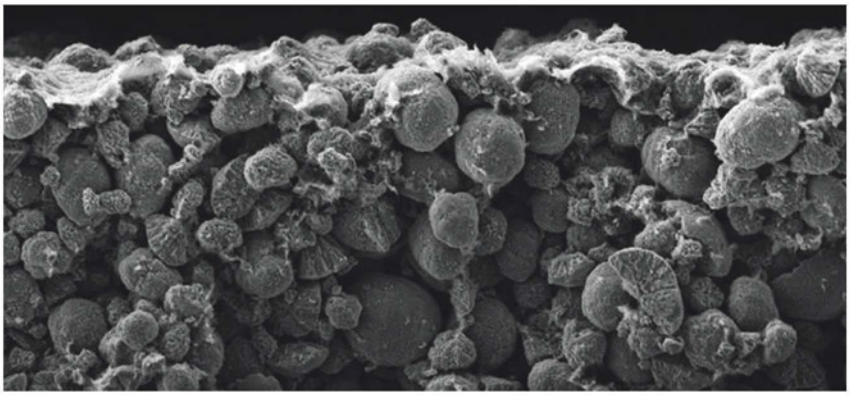
To understand the aging mechanism, TUM scientists combined electrochemical investigations with measurement methodologies as diverse as X-ray diffraction, impedance measurements and prompt gamma activation analysis (PGAA). They analyzed the behaviour of batteries with graphite anodes and nickel-manganese-cobalt cathodes, so-called NMC cells, at various temperatures. Impedance measurements were used to track the increasing resistance in the battery cells. Neutron activation analysis ultimately facilitated the accurate determination of extremely minute quantities of transition metals on the graphite electrodes.

Although by the way of trial and error battery manufacturers have already determined the optimal relationship between the electrode material and amount of lithium, there's still room for improvement, say TUM researchers.

"Using our insights, now individual processes can be improved. Possibilities include additives that improve the build-up of the pacifying layer for example, or modifications of the cathode surface," says Irmgard Buchberger, member of the TUM team working on this project.

LI-ION BATTERIES

Lithium-ion batteries with graphite anodes are a relatively new development. They were patented in 1989 and have been deployed in electrical devices since 1991. They have proven a great success, especially since they are useful in a wide range of devices, from small electrical goods to electric cars, airplanes and even locomotives. They are also promising intermediate storage facilities with capacities up to a megawatt. However, batteries with graphite anodes suffer their first significant loss of capacity – up to 10% – during the initial charging cycle, or formation step. Each additional charge-discharge cycle reduces storage capacity further, and even mere storage, especially above room temperature, decreases their capacity. That's why the TUM research is so important.



Electron microscopic image of the cathode of a Nickel-Mangan-Cobalt-battery (NMC)
Image: Irmgard Buchberger (TUM)

SCIENTISTS SHOW SOLAR PANELS CAN DOUBLE AS COMMUNICATIONS SYSTEMS

A new form of wireless data communication using solar energy has been demonstrated by a University of Edinburgh research team.

At this year's technology event TED Global in London it was demonstrated that Li-Fi – visible light communications (VLC) technology that delivers high-speed, bidirectional, mobile communications similar to Wi-Fi – can use solar panels as self-powering communications nodes. Team leader Professor Harald Haas showed how future devices – which can range from smart watches with solar cells to houses with solar panels – can absorb power and receive high-speed data at the same time.

The prototype used in the demonstration was built jointly between the University of Edinburgh's Li-Fi R&D Centre and pureLiFi, a University of Edinburgh spin-off company, both pioneers in using visible light instead of radio frequencies for wireless data communication.

"This University of Edinburgh technology combines light-based data communications, or Li-Fi, with energy harvesting to create an exciting set of applications not previously anticipated, including in rural broadband access, smart city networks and the Internet of Things," said Tom Higgison, IP Project Manager at the Edinburgh Research & Innovation (ERI) commercialisation arm of the University. "The wider opportunity is to transform global communications by speeding up the process of bringing Internet and other data communication functionality to remote and poorer regions in a way not previously thought achievable due to lack of infrastructure and investment."

ERI is now looking for industrial partners to work with the University's Li-Fi R&D Centre to develop the technology for commercial use.

"My aspiration is that this broadband solar panel receiver technology for Li-Fi will help solve the challenges of the digital divide throughout the world and catalyze the uptake of the IoT as connectivity and battery-free power supplies are essential if we want to connect a trillion objects to the Internet," added Professor Haas.

"Sell me the product!"

BY **MYK DORMER**

In a perfect world, we engineers would live happy lives of ivory tower abstraction, concerned only with the fascinating intricacies of each design and innovation that just happened into our imaginations, untroubled by commercial realities or financial strictures.

Unfortunately, *this* world – while fine in many ways – is far from perfect, and every engineering job contains, in addition to a kernel of actual technological innovation, a great deal of associated support activities, ranging from project management and resource planning to the identification and sourcing of critical components... And at that point we run into a problem.

Sourcing a part ought to be a simple task: Start with a good understanding of the required performance and key specifications needed. Add in additional limitations and considerations, such as physical size, cost and availability, and then browse through the relevant sections of favourite manufacturer and distributor catalogues until you have at least a shortlist of possibilities, if not a single obvious choice. Especially in low-power RF, individual circuit functions fall into well-defined categories (gain-blocks, mixers, filters, and so on), so the selection task ought to be simplicity itself.

It used to be, but not any more.

Something has happened to the structure of some manufacturer's catalogues, or rather the websites that have replaced the catalogues. An insidious change is underway and it's making the design engineer's job harder, rather than easier. I am referring to the grouping of products by "solution" rather than "function".

Instead of listing products by their function (grouping amplifiers with amplifiers, and mixers with mixers, and so on), the literature is re-organized to group components according to their intended application, listing together (for example) all the parts that the supplier anticipates could be used in a cellular base station in one category, and all the parts intended for use in a handset in another. In extreme cases the categorization starts with general categories such as "sub-1GHz" or "wireless infrastructure" before finally sub-grouping into actual application areas one or more layers of menu further down.

As an aid to device selection, especially for a novice engineer, this can be useful, and I suspect that this was probably the original intention. The problem I am seeing is that while some suppliers retain parallel "function" and "application" index structures, there is an increasing trend to conceal the functional index from the customer (I have heard the excuse that it is "too complicated") and only allow access to the catalogue by intended application categories.

In a simple world, where parts only had single uses and where every design followed rigid canonical techniques, a solution-based catalogue might be the best solution, but engineering is never simplistic, and good engineers improve their designs and products through innovation and the innovative application of available technology. Forcing them to select components by having to second-guess what a supplier's sales and marketing staff have decided a part should be used for, rather than by searching libraries of parts by function and specification using their own engineering judgment and design skill, is to put an unnecessary difficulty in the way of an already far-from-trivial process.

> "Forcing engineers to select components by having to second-guess what a supplier's sales and marketing staff have decided a part should be used for, rather than by searching libraries of parts by function and specification, is to put an unnecessary difficulty in the way of an already far-from-trivial process

A secondary problem raises its head when an engineer is working on a design that doesn't fall into one of the small number of sales- and marketing-identified solution groups at all, as is often the case in low-power radio design. As an example, most of the PLL chips used in high-end ISM radio modules actually originate from the cellular handset or base station sectors, and are being put to a use far from that originally intended by the suppliers.

In short, I am advocating simple "by circuit function" indexing in supplier literature and websites. This may be in parallel with the pretty-looking and superficially (to the non-engineer) easier to use structures, but it must not be replaced by them. A very large proportion of users of these catalogues are highly experienced designers, who will be aided far more by literature that concisely delivers functional-parameter-based data and which highlights novel features, than they will by structures that attempt to railroad them into unimaginative, unchallenging designs. ●

Myk Dormer, Consultant Engineer, Radiometrix Ltd
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In ten lines of code

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

Whilst preparing to write this column, a Twitter notification flashed on my screen: the Raspberry Pi team had just announced the new Raspberry Pi Zero, a $5 personal computer, heralding a wonderful time for makers, tinkerers, hobbyists, hackers and indeed us engineers who design commercial electronic products.

As I watched Eben Upton (CEO of the Raspberry Pi trading company) in a video announcement, I could not help but relate to and reminisce about those early years of the mid-80s when not many electronic things were affordable. At the time I could not afford the BBC computer or the "luxurious" Amiga, but I did spend whatever I had on buying a Sinclair ZX Spectrum. Eben's effort to make computing affordable for everyone really resonates with me, so well done!

As a further reflection, I've often wondered if it was not precisely the frugality of the Spectrum and its many limitations that taught me to dig deeper inside the machine and made me fall in love with that strange world between software and hardware that we today call "embedded".

So it won't be a surprise if I write that, whilst amazed by the new record low reached by what is, after all, just another personal computer (PC), I won't be buying one this Christmas – sorry! I have instead already purchased a CodeBug to put under the tree for my son. It does not run Linux, and instead of an HDMI display port it features a 5 x 5-matrix LED display, which I find a plus and it looks like much more fun; see Figure 1.

Little Systems On Chip

The Raspberry Pi Zero is based on a system-on-a-chip (BCM2835) that includes not only a 1GHz ARM11 core but also a video interface, several serial interfaces (USB, UART, SPI) and an external memory interface to manage the necessary huge chunk of external DDR2 RAM (512MB) and some serious mass storage (SD card) needed to run the full Linux operating system. These are impressive capabilities for a single-chip device, especially when compared to earlier generations of PCs.

When we look instead at the CodeBug, the heart of the board is a much smaller device – an 8-bit PIC18F25K50 – but its characteristics are equally impressive compared to those of earlier-generation microcontrollers. In fact, we could argue that whilst at 48MHz the processing power is much inferior to that of the Zero, the little micro is a small SoC marvel on its own.

As you would expect for a microcontroller, all the memory (RAM and Flash) is on-board the chip. The serial interfaces (USB, UART, SPI and I2C), power supply regulation and voltage supervisor circuits are also integrated. Five different oscillators are available on-chip for a greater flexibility and control of power consumption, and that includes auto-tuning circuits that allow the PIC to operate at full-speed USB without an external crystal. There are also several analog peripherals with flexible input/output multiplexers.

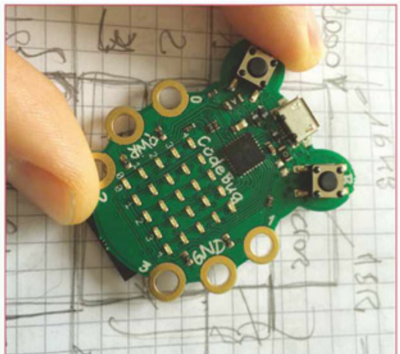


Figure 1: CodeBug – coding just became physical

A PIC is obviously the result of a very different set of design choices that favoured embedded over computing all the way through. In fact, it is no secret that when Raspberry Pi users need to interface to the real world, it is the PIC (and other 8-bit microcontrollers) that they often turn to in the form of "hats", little daughter boards that provide the necessary I/O interfaces and, often, the required voltage translation.

Keeping Complexity In Check

I don't want to draw attention to any further differences between the two worlds, but I should point out that both platforms share common concerns: "How to keep complexity under control?", "How not to scare but possibly attract novice users"? etc, making their respective solutions, once more, completely divergent.

The microcontrollers' approach traditionally consists of a standard set of free software tools: IDE, compilers, linkers, simulators, debuggers (optionally available in professional editions for a small cost), and seeding the hardware tools market with a basic set of demo and development boards. Modern-day micros' datasheets have begun to inflate with their complexity and growing number of peripherals. For example, one of my favourite new families of small PIC microcontrollers, the PIC16F161X, dedicated to small appliance applications and featuring only devices with a maximum of 20 pins and no more than 16KB of Flash (as of this writing), is documented in a datasheet that spans 650 pages!

Let The Machine Do What It Does Best

The smart way is to use smart(er) software tools such as the MPLAB Code Configurator, MCC for short. This is essentially one of a class of code generators that recently appeared in the embedded control market, which provides a huge boost to productivity. The reasons behind it are:

1. MCC is fully integrated in the IDE (it's an MPLAB X plugin) and therefore already aware of the project context (part number selection, other source files already present, etc).
2. Even the most complex peripherals, such as the Signal Measurement Timer (SMT), can be visually presented to the user as a single page/dialog, comprising only a handful of scrolling lists, check boxes and a few intuitive options; see Figure 2.
3. A templating engine takes care of translating the configuration choices made into a minuscule set of fully-customized functions, meaning there are a few functions to learn, but also consistent and intuitive naming conventions, no parameters or shortest parameters list passed, and so on; see Listing 1.
4. The output of the MCC is composed of very short (C language) source files that can be completely inspected by the user and further hand-optimized by the experts. MCC will be very careful not to undo those modifications should the user later request a new code generation pass, automatically offering a convenient merge/diff option.

In essence, what MCC does is lets the "machine" do what it does best. The repetitive and error-prone phase of peripheral configuration, often resulting in many tedious hours scouring datasheets, is gone or considerably shortened to a few, much more enjoyable and intellectually-stimulating minutes of both discovery and creation. In fact, we can learn about specific peripheral capabilities from the same dialog window, essentially bypassing the role of a datasheet altogether.

```
void SMT1_Initialize(void) {
 // CPOL rising edge; EN enabled; SPOL high/rising
edge enabled; SMT1PS 1:1 Prescaler; ...
 SMT1CON0 = 0x80;
 // SMT1MODE Counter; SMT1GO disabled;
SMT1REPEAT Single Acquisition mode;
 SMT1CON1 = 0x08;
 // SMT1CPRUP SMT1PR1 update complete; SMT1TS
not incrementing; RST SMT1TMR1 update complete
...
 SMT1STAT = 0x00;
 SMT1CLK = 0x00;                    // SMT1CSEL
FOSC;
 SMT1WIN = 0x00;            // SMT1WSEL SMTWINx;
 SMT1SIG = 0x00;            // SMT1SSEL SMTxSIG;
 SMT1PRU = 0x00;             // SMT1PR16 0x0;
 SMT1PRH = 0x00;            // SMT1PR8 0x0;
 SMT1PRL = 0x00;            // SMT1PR0 0x0;
}

void SMT1_DataAcquisitionEnable(void) {
 SMT1CON1bits.SMT1GO = 1;           // Start the SMT
module by writing to SMTxGO bit
}

void SMT1_SetPeriod(uint32_t periodVal) {
 // Write to the SMT1 Period registers
 SMT1PRU = (periodVal >> 16);
 SMT1PRH = (periodVal >> 8);
 SMT1PRL = periodVal;
}
```

Listing 1: Section of the source file (smt1.c) generated by MCC to configure the SMT peripheral

In Ten Lines Of Code

Once the (peripheral) configuration is taken care of, we can focus on the application, the more intelligent and fun part of the design, which is what lies inside the main loop as opposed to what comes before it.

The classic "Hello World" test, which in the embedded universe is invariably translated in blinking an LED, becomes again a refreshing ten (binary) lines of code exercise. ●

```
LED_Toggle();
__delay_ms(500);
```

Listing 2: The only ten (binary) lines of code needed to create an embedded "Hello World"

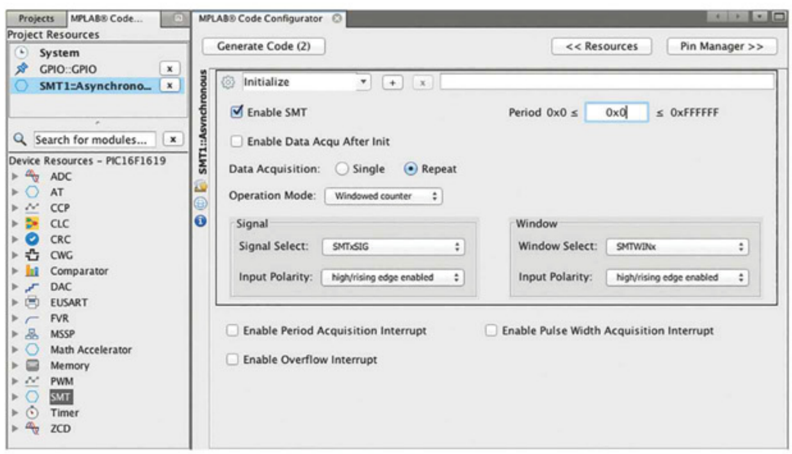
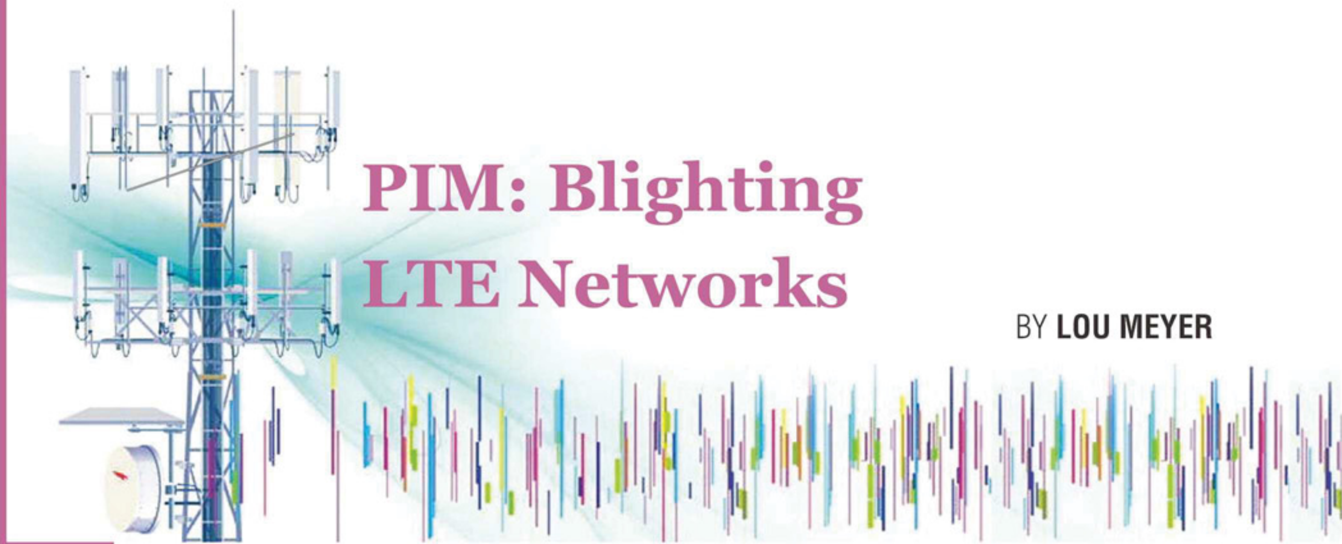


Figure 2: MPLAB code configurator: signal measurement timer dialog window



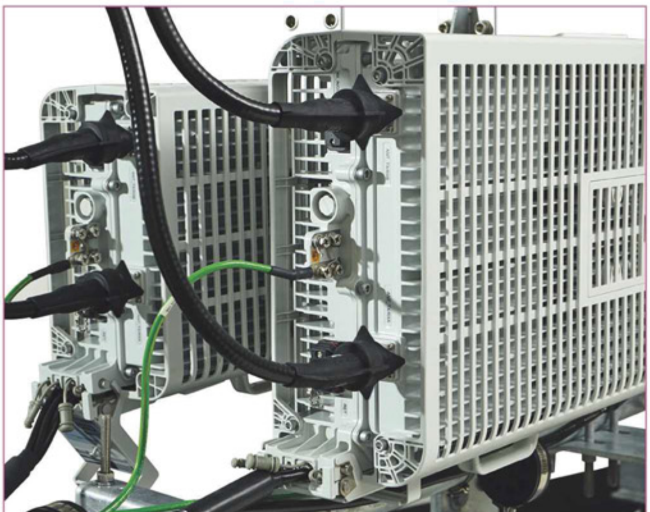
PIM: Blighting LTE Networks

BY **LOU MEYER**

In today's competitive and rapidly-growing wireless communications industry, no provider can afford to ignore pervasive and system-wide problems that impact performance – especially those that will only get worse over time as networks become more complex.

One such disruptive problem that continues to grow is passive intermodulation (PIM).

PIM results when two or more wireless signals mix together and create disruptive frequencies that cause interference or degrade signal transmission in wireless networks. This common phenomenon is well known in the industry and recognized by RF engineers as a real obstacle to network efficiency. And, since data usage is on the rise and network antennas and radios are more sensitive than ever to smaller levels of distortion, PIM incidents and their negative impact will become more prevalent. For example, even a 1dB drop in uplink sensitivity due to PIM can reduce coverage by 11%. Adding to the problem is network complexity, with each component in the RF path representing a potential source of PIM.



Sureguard's attachement to the antenna

The bottom line is PIM is a huge challenge for network operators, with the potential to impact efficiency, capacity and the bottom line.

So, since PIM is such a concern, what can we do about it? What are the specific areas, components and conditions that can cause PIM and the technical considerations to avoid it? Can tower design or even installation factors cause PIM? Most importantly, what can be done to minimize PIM in today's congested, multi-signal environment?

Passive Intermodulation Defined

PIM is generated in a circuit carrying more than one frequency whenever nonlinearity occurs. The greater the degree of nonlinearity (the curvature of the voltage/current or output power/input power characteristic), the greater the level of the PIM signal generated.

In LTE systems, PIM affects many 180kHz resource blocks, which reduces cell and neighbour capacity. PIM also increases LTE intercell interference on the affected band and complete system. Furthermore, PIM can cause the system to operate at maximum power, causing undesirable increased power dissipation in the components.

The severity of PIM generation depends on the degree of nonlinear-to-linear current flow, which in turn depends on how well metal-to-metal contact is created at the junction. The best contact is achieved by welding, soldering or brazing the two metal components. If doing this is impractical, there should be some means of creating high pressure across the contacting surfaces. Low or uneven contact pressure increases the proportion of nonlinear current flow and, correspondingly, the magnitude of generated PIM. Nonlinearity at conductor joints can also be produced by the presence of corrosion, which may form over time, especially at junctions of dissimilar metals in the presence of moisture.

Every component in the RF path has the potential to contribute to PIM. Common causes include:

- Surface oxides
- Loose metal-to-metal contacts;
- Surface contaminants, such as solder splatters;
- Contact between dissimilar metals;
- Improperly torqued connections;
- Structures or objects in close proximity to sites.

Identifying PIM and localizing the offending components can be difficult. Tell-tale symptoms can masquerade as an under-performing system:

- Increased noise floor at the base receiver;
- Mobiles increase power to overcome noise;
- Increased uplink interference;
- Degraded C/I (much lower SNR)
- Reduced service area;
- Increased rate of dropped calls;
- Decreased data throughput performance.

RF Cable Assemblies And PIM

Wireless service providers deploying LTE often must accommodate both conventional and fibre-to-the-antenna (FTTA) site architectures with multiple components. At the heart of it are assemblies – dozens of them – each having to deliver consistent and superior electrical performance. If even one assembly fails, the cost to troubleshoot and replace it can be steep.

The integrity and quality of the coaxial cable assembly technology are crucial factors in minimizing PIM. Handling and protecting the all-important connectors, especially during the installation phase, is critical to PIM prevention. Network operators should consider pre-tested, PIM-certified jumper cable assemblies as frontline defences against unwanted and potentially costly PIM. In fact, a large percentage of PIM incidents and complaints are often caused by poor-quality connector installations done in the field, often due to the lack of recommended cable preparation tools. To consistently meet system PIM performance levels, eliminate installation variables and provide long-term protection against moisture ingress and other environmental threats, consider PIM-certified cable assemblies installed by an experienced and well-equipped team.

Top-Of-The-Tower PIM Challenges

Out of the many components that can contribute to PIM, the antennas are the most difficult to test. Older antennas were not necessarily designed to prevent PIM and are often the root cause. There's a reasonable expectation that most antenna technology does address PIM, but network operators should confirm that performance specifications meet this standard.

Of course, the many components at the top of the tower can contribute to PIM, especially as they age or become increasingly degraded by metal corrosion. Connected parts and structures can become loosened through environmental exposure, wind and vibration. Simply put, time and elements can degrade connections in the RF signal path, causing PIM. The choice of PIM-certified components and careful, high-quality installation will help remediate these issues in the long term.

In the process, it's important to take a system-wide approach to solving the PIM pervasive challenge. By definition, PIM is a system issue because it takes one passive component and two or more frequencies in the RF path to create an unwanted signal. That means it's important to embrace a comprehensive and proactive strategy for addressing PIM, instead of waiting for network testing to indicate a problem. A holistic approach is required to network modernization that takes into account all the factors that may lead to PIM. ●

Lou Meyer is Director for Applications Engineering and Base Station Antennas at CommScope.
This column is an edited extract from CommScope's new eBook, 'LTE Best Practices'.

TECHNICAL TIPS FOR FIGHTING PIM

LTE is particularly sensitive to the negative effects of PIM. Possible PIM sources include poor connections, damaged cables or water infiltration into transmission equipment. PIM can also be caused by objects outside the path, such as light poles, buried conduit or site equipment. Here's how to limit the appearance of PIM in wireless networks, both outdoors and inside.

- In the design phase, ensure that no frequency bands or blocks will produce undesired PIM effects on common paths. Using band/block PIM calculators (such as one from CommScope) will help analyze the RF design.
- Train installers on PIM-related issues and ensure they have the correct tools, particularly torque wrenches. They should tighten connections to specified torque values, keep connectors clean and follow best practices for installation. Installers should be able to identify internal and external PIM sources using the latest equipment. Operators should also consider proactively testing for PIM as part of a preventative maintenance scheme.
- Use system components that are highly rated for PIM and/or dynamically PIM tested at the factory. Dynamic PIM, based on the International Electrotechnical Commission 62037 standard, is a more comprehensive measure of PIM that takes real-world conditions into account. Use structural antenna mounts designed to minimize PIM caused by multiple frame connections, loose hardware due to overloading, environmental corrosion and other factors.
- If possible, make the RF path connections in the factory. By pre-assembling and pre-testing for PIM in a quality-controlled environment, there is less scope for problems during outdoor installation.
- Indoors, transition to distributed antenna system (DAS) passive devices that are certified and can be verified for PIM performance of -160dBc. Going forward, high performing passive components will play a crucial role in the long-term success of high-end DAS solutions.

MICROPROCESSOR-BASED MICROGRID PROTECTION FROM FAULTS

BY **SOHRAB MIRSAEIDI, DALILA MAT SAID, MOHAMMAD WAZIR MUSTAFA** AND **MOHAMMAD HAFIZ HABIBUDDIN** FROM UNIVERSITI TEKNOLOGI MALAYSIA, AND **KIMIA GHAFFARI** FROM THE ISLAMIC AZAD UNIVERSITY IN IRAN

Increased concern over global warming is urging researchers to explore cleaner and more efficient energy generation. To eliminate negative influences on the environment from fossil-fuel-based electricity production, one approach is to use cleaner distributed energy resources (DERs) closer to the customer, such as wind turbines, photovoltaic systems, micro gas turbines and fuel cells.

One way of integrating a number of DERs is in microgrids – a collection of electrical/heat loads, parallel DERs and energy storage devices that can operate in grid or islanded mode (see Figure 1). A microgrid is a high reliable system in offering high-quality power to customers who need uninterruptible power supplies at lower cost.

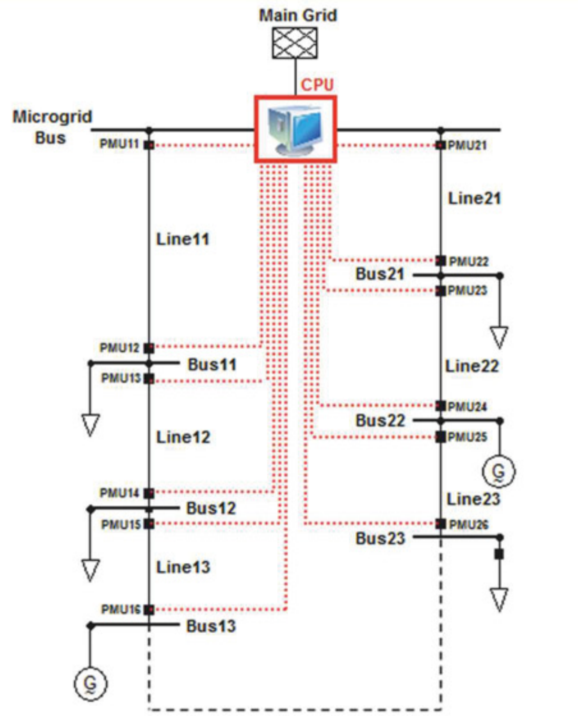


Figure 1: A typical microgrid structure

Microgrid Pros And Cons

Notwithstanding their numerous advantages, microgrids pose some technical challenges that need addressing, one of which is their protection. Protecting them cannot be fully achieved with certain methods traditionally applied to distribution networks, such as overcurrent-based protection. There should be a specific microgrid protection scheme, which will allow microgrid operation in grid-connected mode under normal circumstances, but when a fault arises disconnect it from the network and transfer it into islanded mode. The protection should take into account: (a) the bidirectional power flow in feeders; (b) the existence of looped feeders; and (c) the decreased fault current in standalone operation mode.

We developed a microgrid protection scheme based on positive-sequence components using phasor measurement units (PMUs) and a central protection unit (CPU). The proposed scheme protects both radial and looped microgrids against different types of faults, with just single-phase tripping. Furthermore, since the CPU updates its pickup values (upstream and downstream equivalent positive-sequence impedances of each line), after only one change in the microgrid configuration, it can protect the setup against subsequent faults.

Technical Challenges Of Protecting Microgrids

The majority of distribution networks are designed to operate in radial mode, where the power flows in one direction from higher voltage levels to lower ones. The protection of such networks is accomplished using simple and relatively low-cost overcurrent-based devices, such as overcurrent relays, re-closers and fuses. But when a microgrid is formed within a distribution network, the network's configuration involves a more complex, multi-source power system. Since the microgrid can operate in both grid-connected and standalone modes, it'll need protection for both.

In grid-connected mode, the microgrid experiences a large short-circuit current to the fault point, so protection can be achieved with existing protection devices within the

FAULT TYPE	POSITIVE-SEQUENCE	NEGATIVE-SEQUENCE	ZERO-SEQUENCE
SINGLE LINE TO GROUND	YES	YES	YES
LINE TO LINE	YES	YES	NO
LINE TO LINE TO GROUND	YES	YES	YES
THREE PHASE	YES	NO	NO

Table 1: Symmetrical components for different fault types

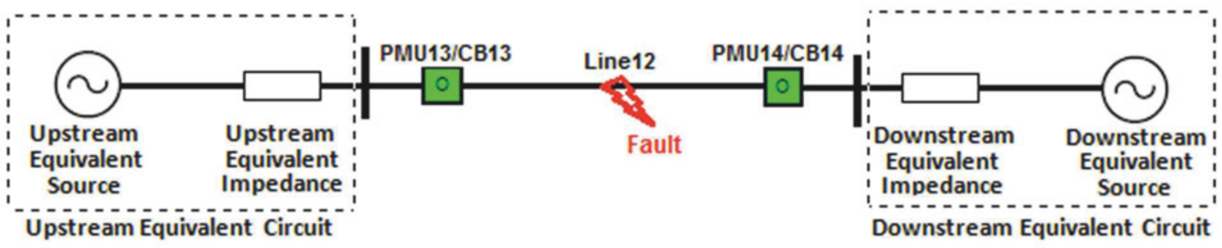


Figure 2: Upstream and downstream equivalent circuits of Figure 1's Line 12 during a fault

distribution network. However, in islanded mode, fault currents are drastically lower than those in grid-connected mode, because the Thevenin's impedance viewed from the fault point is much higher than that in grid-connected mode. So the use of traditional overcurrent-based protective devices is no longer valid, and alternative protection schemes are therefore necessary.

Proposed Protection Scheme

In our protection scheme, PMUs which are responsible for extracting voltage and current phasors (magnitudes and their respective phasor angles) based on digital sampling of waveforms are installed at both ends of each line in the microgrid. Information from each line is transferred to the CPU through a digital communication system. When a fault occurs, the information is analyzed by the CPU to establish the fault's location and phases. Subsequently, depending on the fault type proper tripping signals are issued to the relevant circuit breakers.

To detect different types of faults, our protection scheme is based on the symmetrical components approach, first developed by C. L. Fortescue, one of the most effective schemes around. It transforms a three-phase unbalanced system into three sets of symmetrical balanced phasors, namely positive-, negative- and zero-sequence components. If a fault strikes within a network, these symmetrical components are formed depending on the fault type.

Table 1 shows the symmetrical components for different types of faults. It can be seen that the positive sequence is the only component that exists for all type faults, the reason we used it in our scheme.

Determining Fault Locations

For the best protection of different configuration microgrids, microgrid feeders should be partitioned in such a way that each section (microgrid's line or bus) is protected independently of others. To achieve this, each line's upstream and downstream sections are replaced with upstream and downstream equivalent circuits respectively. Both equivalent circuits include a voltage source in series with the impedance.

Figure 2 shows the upstream and downstream equivalent circuits of Line 12 of Figure 1 during a fault, with Figure 3 showing its different symmetrical components.

By replacing the equivalent impedance of the negative- and zero-sequence networks between terminals AB of a positive-sequence network for all type faults, a generic model for analyzing different faults can be created; see Figure 4, where the impedance $Z_{eq2,o}$ in the negative- and zero-sequence networks.

Different faults have different impedance values. Equation 1 expresses the value of impedance $Z_{eq2,o}$ for different type of faults:

$$Z_{eq2,0} = \begin{cases} Z_{eq0} + Z_{eq2} \; for\ single\ line\ to\ ground\ faults \\ Z_{eq2} \; for\ line\ to\ line\ faults \\ Z_{eq0} \| Z_{eq2} \; for\ line\ to\ line\ to\ ground\ faults \\ 0 \; for\ three\ phase\ faults \end{cases} \quad (1)$$

where

$$Z_{eqo} = (Z_{Uo} + Z_{LUo}) || (Z_{Do} + Z_{LDo})$$
$$Z_{eq2} = (Z_{U2} + Z_{LU2}) || (Z_{D2} + Z_{LD2})$$

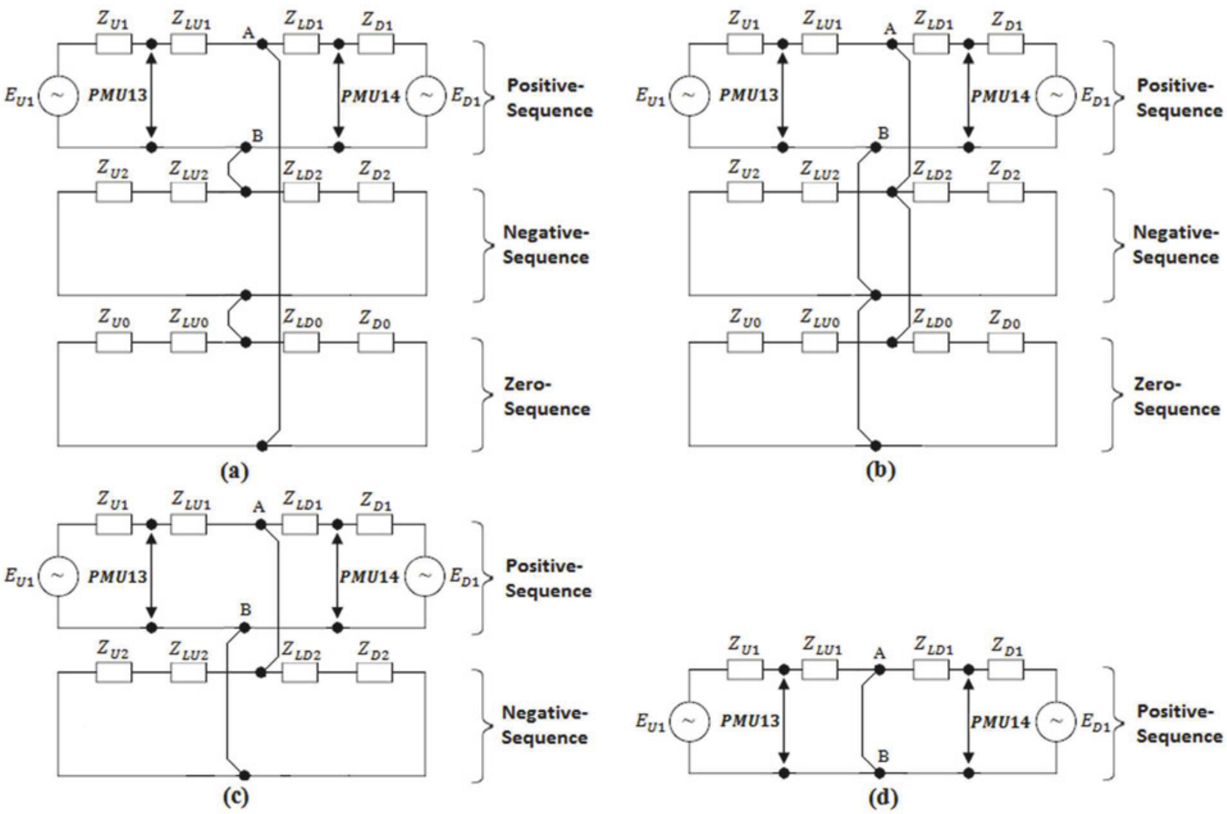


Figure 3: Equivalent circuit diagram of the system with symmetrical components, upstream and downstream for: (a) single line to ground fault; (b) line to line to ground fault; (c) line to line fault; (d) three phase fault

In the proposed protection scheme, after detection of the fault, the section is identified by the developed model of Figure 4 in such a way as to compare the value of the upstream and downstream equivalent positive-sequence impedances before and after the fault. In fact, when a fault occurs inside a line, impedance $Z_{eq2,o}$ is created between points C and D. Therefore, the values of both upstream and downstream equivalent positive-sequence impedances after the fault (Z_{U1}, Z_{D1}) remain equal to the values of those impedances before the fault ($Z_{U1\,(pre)}$, $Z_{D1\,(pre)}$), but in case a fault occurs at the upstream or downstream of a line, only the value of Z_{D1} or only the value of Z_{U1} remain constant after the fault.

Synchrophasor Data System

In our protection scheme, since the total positive-sequence impedance of each line is calculated using the positive-sequence voltage and current phasors (magnitudes and their respective phasor angles), getting time-synchronized measurements from both ends is necessary. The purpose of the synchrophasor data system is to make rapid measurements (at least 30 per second) of voltage and current phasors (magnitude and their respective phasor angles) that include precise time stamps, and make them available for CPU analysis.

Figure 5 shows the structure of the synchrophasor data system in the proposed protection scheme. As shown, the components of the synchrophasor data system include:

- **Phasor measurement unit (PMU):** It calculates voltage and current phasors based on digital sampling of AC waveforms and a precise time signal provided by a global positioning system (GPS) clock. A PMU provides output data in a standard protocol at rates of at least 30 samples per second for communication to remote locations. The block diagram of a phasor measurement unit is shown in Figure 6.
- **Communications:** A mechanism to transport digital information from the PMU to the location where the data will be used. Communication is typically provided through a private wide-area network (WAN), but it can be any digital transport system with acceptable security and availability.
- **Phasor data concentrator (PDC):** It receives and time-synchronizes phasor data from multiple PMUs to produce a real-time, time-aligned, output data stream.

Central Protection Unit Structure

To implement the proposed protection scheme, we designed a

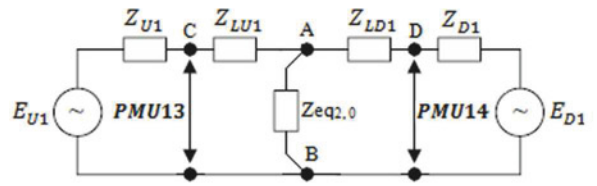


Figure 4: Generic model for analyzing different types of faults

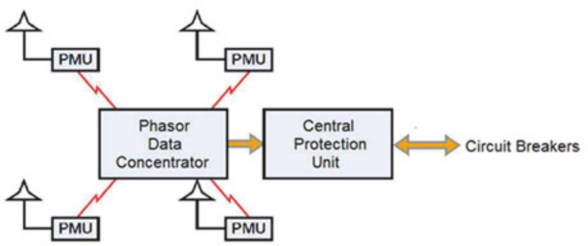


Figure 5: Structure of the synchrophasor data system in the proposed protection scheme

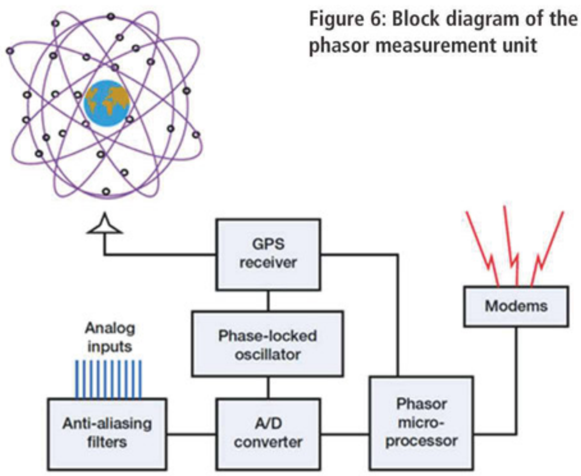


Figure 6: Block diagram of the phasor measurement unit

digital CPU; the CPU's schematic diagram for the microgrid of Figure 1 is shown in Figure 7.

As shown in the figure, there's a dedicated protection module (PM) for protecting each line and its adjacent buses. Each PM receives the voltage and current phasors from the installed PMUs at both ends of the respective line. If a fault occurs inside that line or adjacent bus, tripping signal commands are sent accordingly to the respective circuit breakers, and then the faulted section is isolated from the rest of the microgrid.

Figure 8 shows the schematic diagram of Line 12 PM for the microgrid in Figure 1. Each PM consists of four main parts: fault incident detector, fault locator, faulty-phase detector and blocking signal issue-maker.

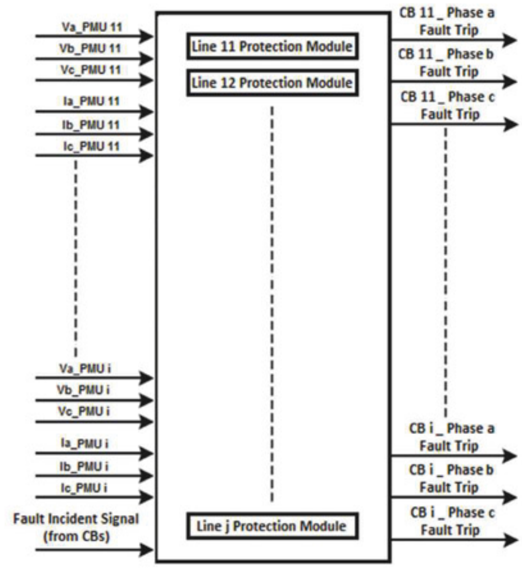


Figure 7: Architecture of the CPU for the microgrid shown in Figure 1

When a fault occurs in a microgrid section (line or bus), the positive-sequence current magnitude of that section is drastically increased; hence, the fault occurrence can be detected by comparing the magnitude before and after the fault. In the CPU this function is performed by a fault incident detector.

It should be noted that the settings of this detector should avoid any wrong operation of the PMs in case of a small change in the positive-sequence current magnitude. Moreover, since a fault in one section may increase the positive-sequence current magnitude of other sections, PMs related to non-faulted lines may issue fault trip signals mistakenly, so an additional detector (fault locator) is necessary.

Fault Locator

Prior to a fault, the fault locator of each line first calculates the values of the Thevenin equivalent positive-sequence impedances (TEPSIs) at both ends of that line, and then determines the values of the impedances $Z_{U1\,(pre)}$ and $Z_{D1\,(pre)}$. The faulted section can be recognized by comparing the values of upstream and downstream equivalent positive-sequence impedances before the fault ($Z_{U1\,(pre)}$, $Z_{D1\,(pre)}$) and after (Z_{U1}, Z_{D1}).

To determine the TEPSI of each point within the microgrid, we introduced an online methodology by using three consecutive voltage and current measurements of PMUs at different time instants. Since any change in the frequency of the microgrid system will lead to a slip between the microgrid frequency system and the PMU

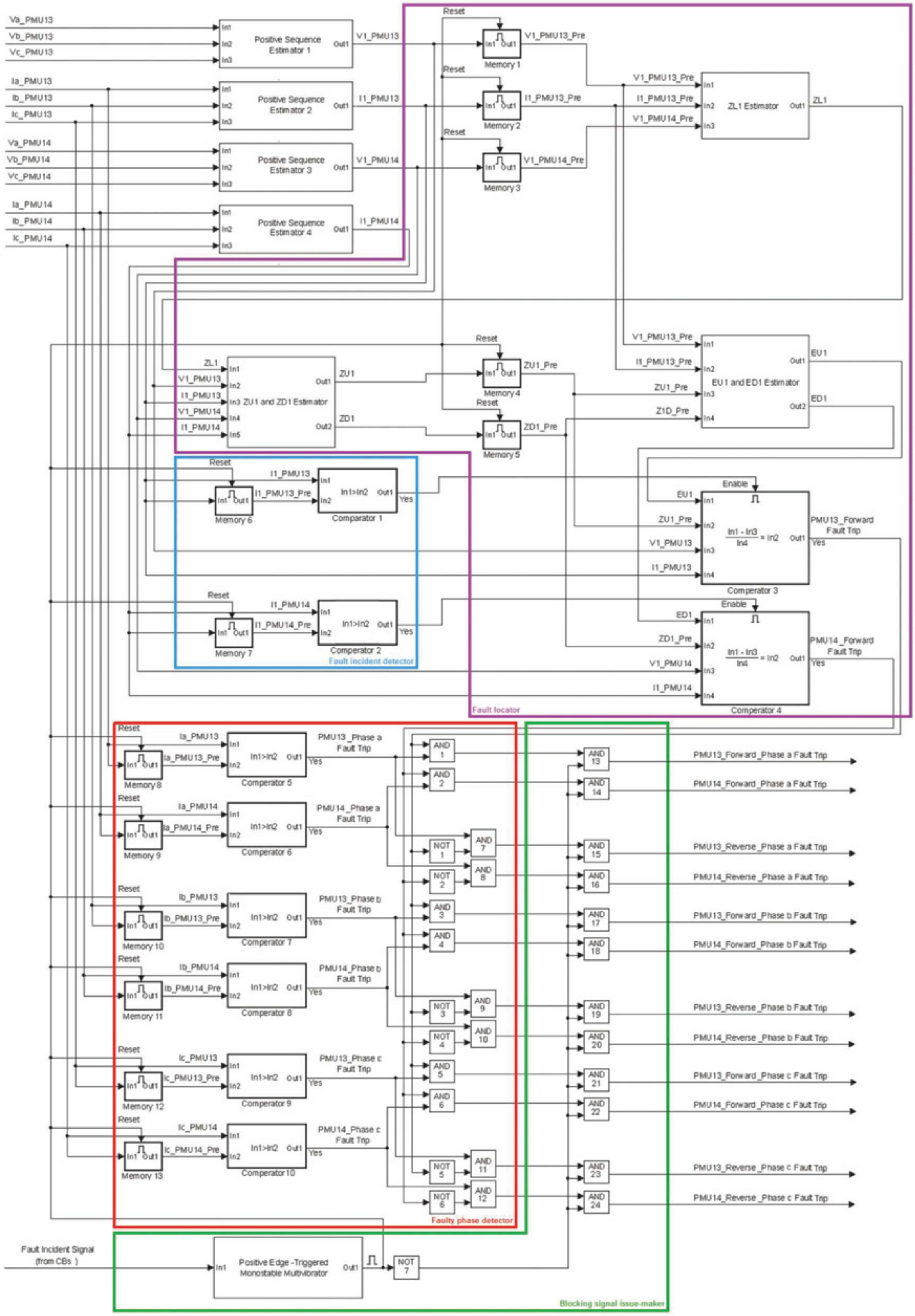


Figure 8: Schematic of Line 12 PM for the microgrid in Figure 1

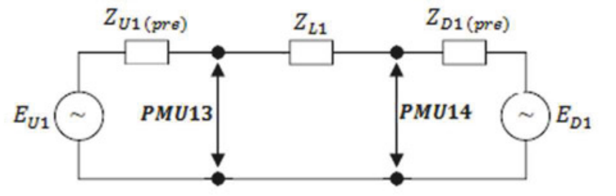


Figure 9: Equivalent circuit diagram of the positive-sequence network for Line 12 (of Figure 1) prior to a fault

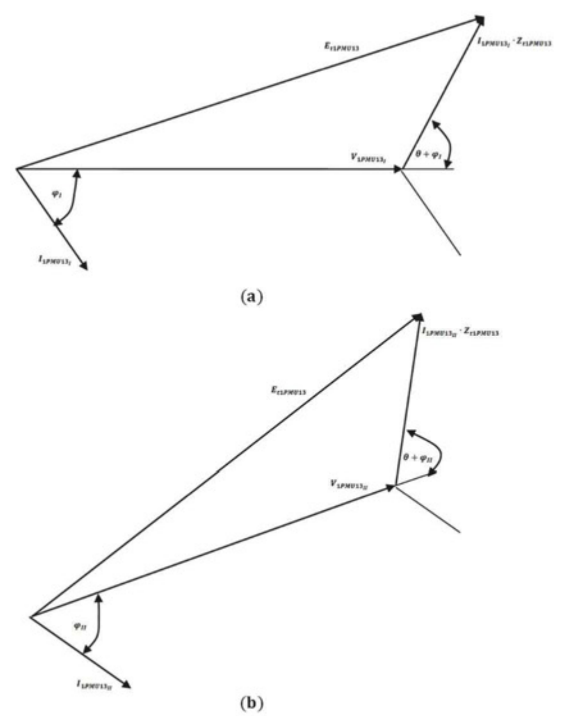


Figure 10: Positive-sequence phasor diagrams for two different measurements at PMU13 terminals: (a) first measurement; (b) second measurement

sampling frequency, the phase angles of voltage and current for these three measurements will be different.

Figure 9 shows the equivalent circuit diagram of the positive-sequence network for Line 12 (of Figure 1) prior to a fault.

Based on Thevenin's model, the node positive-sequence voltage equation is defined as:

$$V_1 = E_{t1} - Z_{t1} \cdot I_1 \tag{2}$$

According to Equation 2, the positive-sequence voltage equation for PMU13's terminals becomes:

$$V_{1PMU13} = E_{t1PMU13} - Z_{t1PMU13} \cdot I_{1PMU13} \tag{3}$$

where

$E_{t1PMU13}$ = Thevenin's equivalent positive-sequence voltage source at PMU 13's terminals;

$Z_{t1PMU13}$ = Thevenin's equivalent positive-sequence impedance at PMU 13's terminals.

The positive-sequence phasor diagrams of Equation 3 for two different measurements at PMU 13's terminals are shown in Figure 10.

Figure 11 shows the positive-sequence impedance plane including the circles obtained from three different measurements. In the diagram, the value of Thevenin's equivalent positive-sequence impedance seen from PMU 13's terminals is specified by the intersection of the three circles.

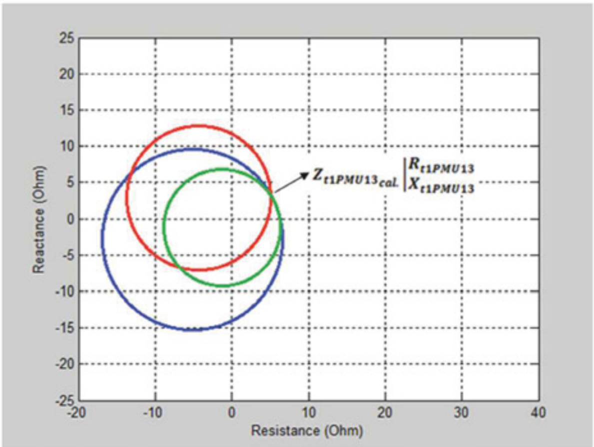


Figure 11: Positive-sequence impedance plane, including the circles obtained from three different measurements

TRANSFORMER TYPE	HV (KV)	LV (KV)	VECTOR GROUP
TR-1	69	24.9	DYN0
TR-2	24.9	0.4	YNYN0
TR-3	24.9	0.4	YNYN0
TR-4	24.9	0.4	YNYN0

Table 2: Information about the microgrid's applied transformers

NAME	PHASE A		PHASE B		PHASE C	
	KW	KVAR	KW	KVAR	KW	KVAR
LOAD 201	100	16	75	14	30	3
LOAD 301	175	22	53	18	10	2
LOAD 401	14	5	77	13	21	7
LOAD 402	93	26	24	10	18	5
LOAD 403	111	38	28	3	12	6

Table 3: Information about the microgrid's loads

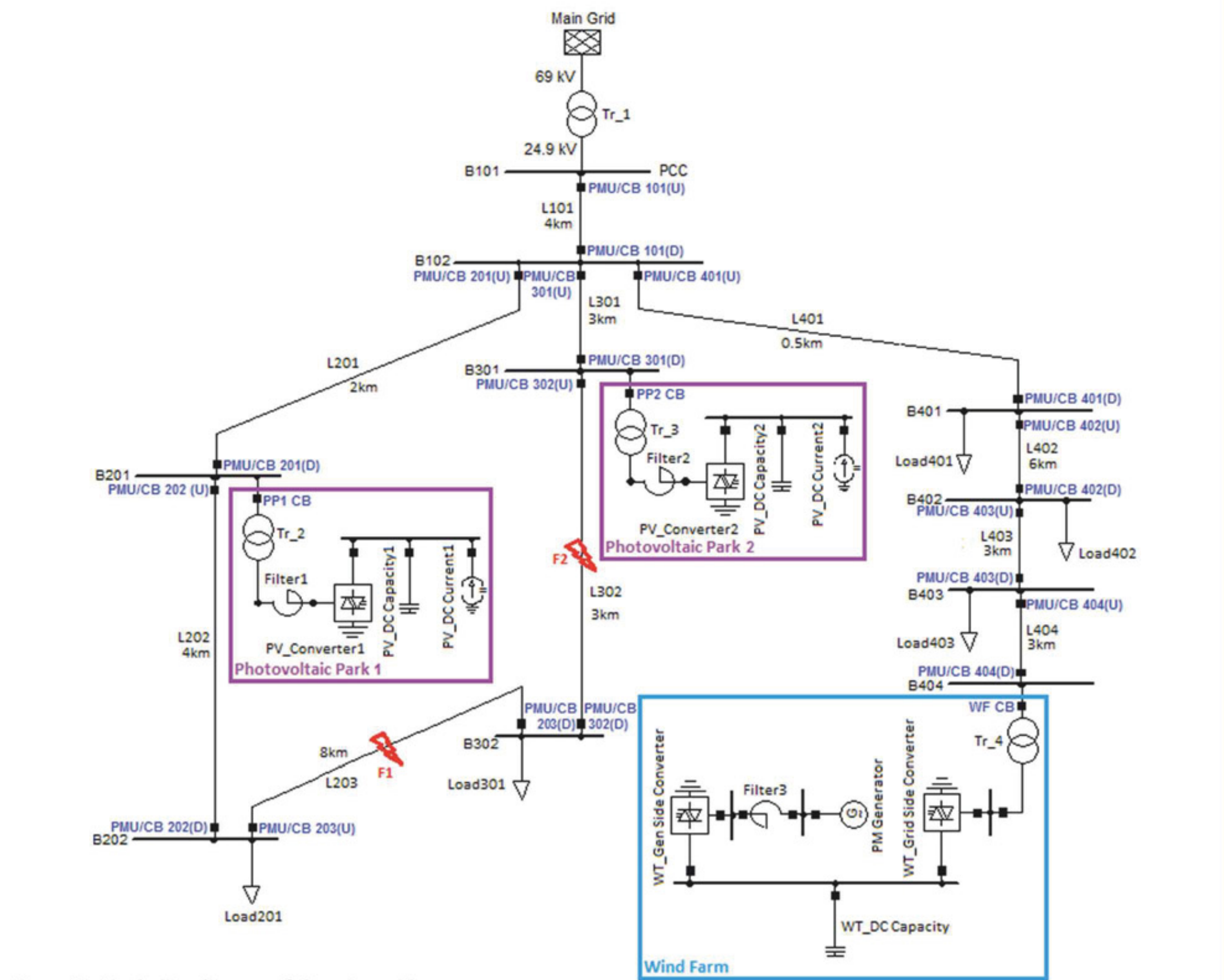


Figure 12: Single-line diagram of the microgrid

Faulty-Phase Detector

Single-phase tripping has long been regarded as an effective way of improving system security and reliability. It leads to removal of unnecessary interruptions of the unaffected phases in case the fault does not involve all three phases.

In the CPU, having detected the faulted section with the fault locator, the affected phases of that section are identified through a faulty-phase detector. This detector compares the current magnitude of each phase of the faulted section before and after the fault, and then issues disconnection signals to the relevant circuit breakers of that section.

To update the values of $Z_{U1\,(pre)}$ and $Z_{D1\,(pre)}$, as well as preclude any wrong operation of the PMs for subsequent faults, a blocking signal may be sent out by the CPU. After isolation of the first fault (inside or outside the microgrid), a 'fault incident' signal is issued from the disconnected circuit breakers to the CPU. The signal resets the memories and blocks all PM outputs until new values for $Z_{U1\,(pre)}$ and $Z_{D1\,(pre)}$ are determined, and handled by the so-called Positive Edge-Triggered Monostable Multivibrator.

Once received, the fault-incident signal generates an output pulse of duration T, which should be longer than the time needed to update the values of $Z_{U1\,(pre)}$ and $Z_{D1\,(pre)}$.

Simulation Results

To evaluate the effectiveness of the proposed scheme, several simulations were carried out using the DIgSILENT PowerFactory and MATLAB software packages.

The single-line diagram of the study microgrid is shown in Figure 12. It can be seen that the microgrid is connected to the main grid by means of a 69kV/24.9kV Dyn transformer. It also includes two photovoltaic parks (640kW each) and one wind farm (504kW), connected to the network with YNyn transformers.

Information about the applied transformers and the microgrid's loads are shown in Tables 2 and 3. ●

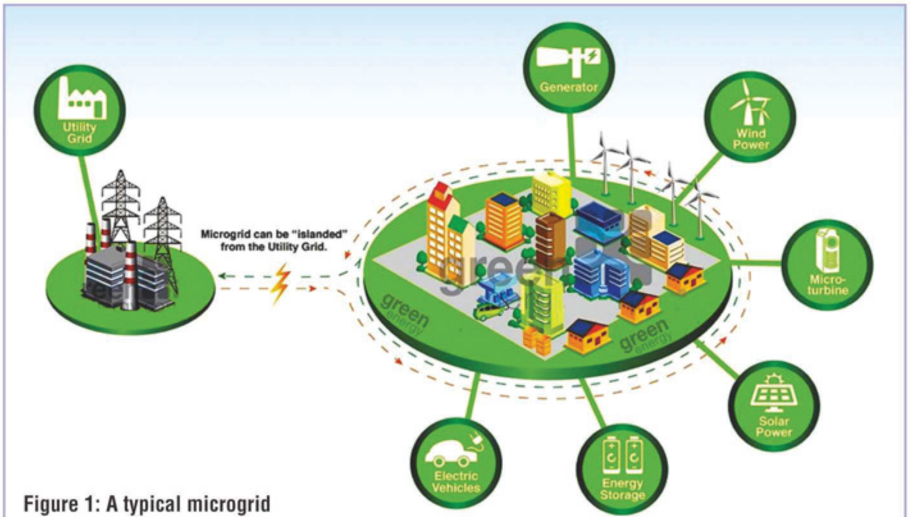


Figure 1: A typical microgrid

MOHAMMAD REZA MIVEH, **MOHD FADLI RAHMAT** AND **MOHD WAZIR MUSTAFA** FROM UNIVERSITI TEKNOLOGI MALAYSIA AND **ALI ASGHAR GHADIMI** FROM ARAK UNIVERSITY IN IRAN DISCUSS CONTROL OF AUTONOMOUS MICROGRIDS

PROGRESS IN CONTROLLING AUTONOMOUS MICROGRIDS

A typical power system consists of equipment such as massive power plants, transmission systems and distribution networks to provide electricity to end consumers. Due to their availability and ability to generate huge amounts of electricity, fossil-fuel-based technologies have been the most common choice for generating electricity in these traditional power systems. Fossil-fuel generation technologies have improved our quality of life, but the advancements have come at a very high price. Moreover, they are the main cause of environmental pollution. Hence, for economic, technical and environmental reasons, it is essential to find energy alternatives that are renewable and environmentally clean.

With the recent focus on renewable and sustainable energies, integrating small power generating units such as wind turbines and photovoltaic systems has become a priority in the distribution network. Throughout the world, policies have been developed to increase the use of green-energy technologies. For instance, the US and Germany are planning some 30% of their electricity to be generated from green sources by 2020.

Green-energy technologies in general provide numerous benefits for the power system. But, to efficiently integrate these distributed energy resources (DERs) into the low-voltage distribution networks, a number of technical and operational challenges should be addressed. Indeed, not only should the potential advantages of renewable energies be harnessed, but also the present levels of reliability and controllability in the power system must be maintained and possibly improved.

Microgrids

The recently-developed microgrid is a reasonably attractive alternative for overcoming the challenges of integrating DERs into traditional power systems.

A microgrid can be defined as a cluster of distributed generators (DGs), loads, powered electronic devices and energy storage systems, which behaves as a controllable entity, see Figure 1, capable of operating in both grid-connected and autonomous modes. Moreover, it can handle the transitions between these two modes. In grid-connected mode, any deficit can be supported by power from the utility grid, while the excess power generated within the microgrid can be transferred to the utility grid. On the other hand, the power generated in the microgrid through DERs, in autonomous mode must be in balance with the demand of local loads. The ability of the microgrid to operate in islanded mode increases the reliability, controllability and security of the system, especially in emergency situations. Furthermore, it reduces the vulnerability of the power system to external attacks or power quality events.

The types of DERs in a particular microgrid can be varied based on the operating mode, type of generation technology and topology of the system. Generally, DERs and conventional large generators differ considerably not only in scale, but also in the way they generate electricity – basically, traditional large generators are synchronous machines with a fixed frequency.

Based on their technologies DERs may be categorized into three main groups, including variable frequency (e.g. wind turbines), high-speed frequency (e.g. small gas turbines) and direct energy

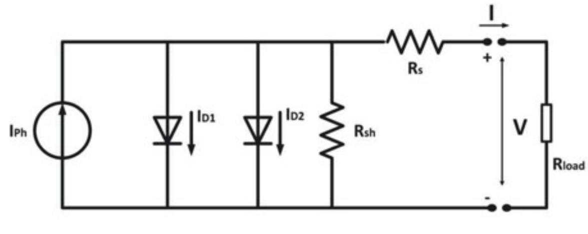


Figure 2: Electrical equivalent circuit of a two-diode PV cell

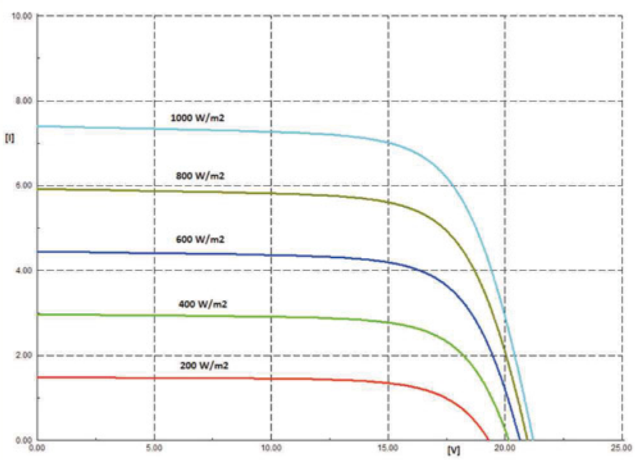


Figure 3: Electrical equivalent circuit of a two-diode PV cell

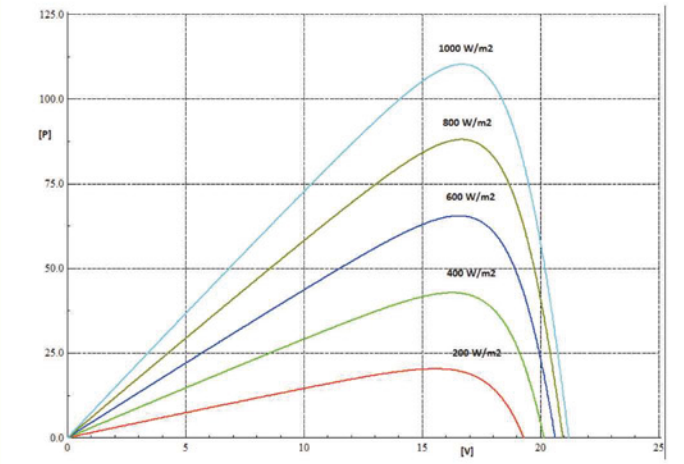


Figure 4: Output P-V characteristics with varying solar irradiation

conversion sources (e.g. photovoltaic arrays). Meanwhile, these units can be also classified based on dispatchability, containing non-dispatchable and dispatchable units. The output of non-dispatchable resources such as wind turbines and photovoltaic units is not controllable. In contrast, dispatchable units such as battery energy storage systems (BESS) can be fully controlled.

Modeling Of Solar Photovoltaic Array

For the purposes of our study, the dynamic model of a solar photovoltaic (PV) array was developed using the DIgSILENT power factory software.

The equivalent circuit model for a PV cell contains two diodes in parallel with an ideal current source, series resistance (R_s) and parallel resistance (R_{sh}) are shown in Figure 2. An ideal current source delivers current in proportion to the solar flux to which it is exposed. In a practical PV cell, a series resistance is offered by the semiconductor material, the metal grid, metal contacts and current collecting bus. These resistive losses are lumped together as series resistor (R_s). Similarly, a certain loss is associated with a small leakage of current through a resistive path in parallel with the intrinsic device. This can be represented by the parallel resistor, R_{sh}.

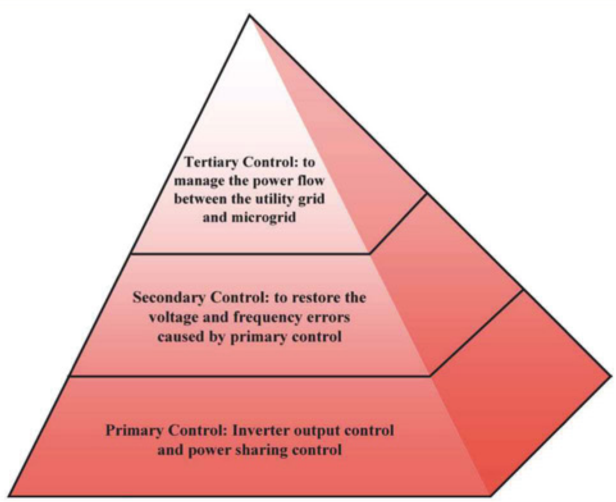


Figure 5: Hierarchical control levels of a microgrid

According to the equivalent circuit in Figure 2, the general PV panel current-voltage relationship for a specified illumination and temperature is given as:

$$I = I_{ph} - I_{s1}\left[EXP\left(\frac{V+R_S I}{N_S V_t}\right) - 1\right] - I_{s2} \left[EXP\left(\frac{V+R_S I}{2N_S V_t}\right) - 1\right] - \left(\frac{V+R_S I}{R_{Sh}}\right) \quad (1)$$

where I and V are the terminal current and voltage of the PV panel, I_{s1} is the saturation current due to the diffusion mechanism, I_{s2} is the saturation current because of carrier recombination in the space-charge region, N_s is the number of series-connected PV cells in the PV panel, R_s and R_{sh} are the series and shunt resistances, and V_t is the cell's thermal voltage.

Figures 3 and 4 show the I-V and P-V characteristics of the PV cell respectively under varying solar irradiation with constant temperature.

Islanded Operation

In autonomous mode, the microgrid operates as an independent entity. In this mode the need for a proper load sharing mechanism to balance sudden active mismatches leads to numerous operational and technical challenges. Therefore, autonomous mode is considerably more challenging than grid-connected mode.

> "The main advantage of droop control is that it eliminates the need for communication

Since frequency and voltage of islanded operation are no longer supported by the utility grid, DER units are responsible for providing suitable control. Power balance also can be achieved through local controllers or by a central controller (CC). Local controllers operate based on local measurements, whereas CCs use communication links to guarantee that all units contribute to carrying the load in a pre-specified manner.

Changing the operating method of the power system through microgrids presents a number of operational challenges. Indeed, to ensure present levels of reliability and harness the full potential

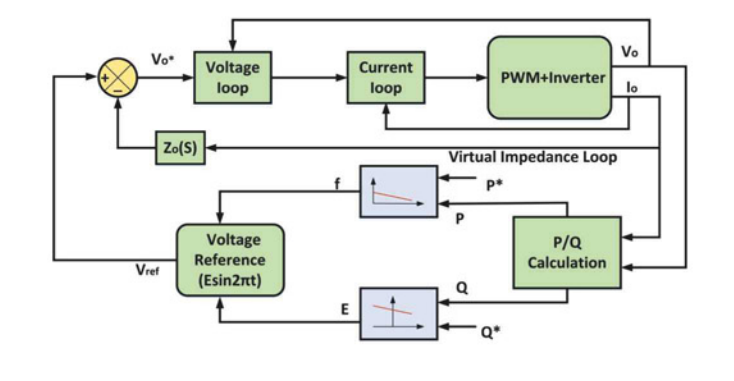


Figure 6: Primary control, including inner current and voltage loops, and droop control

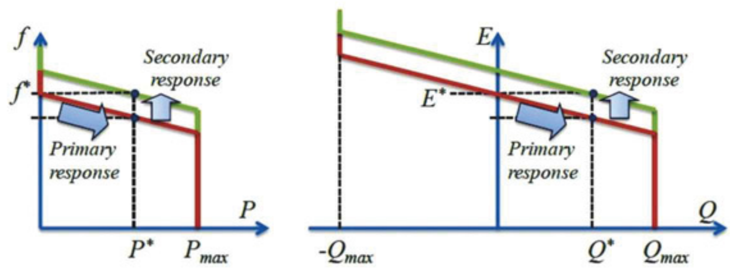


Figure 7: P_f and Q_E primary and secondary control actions

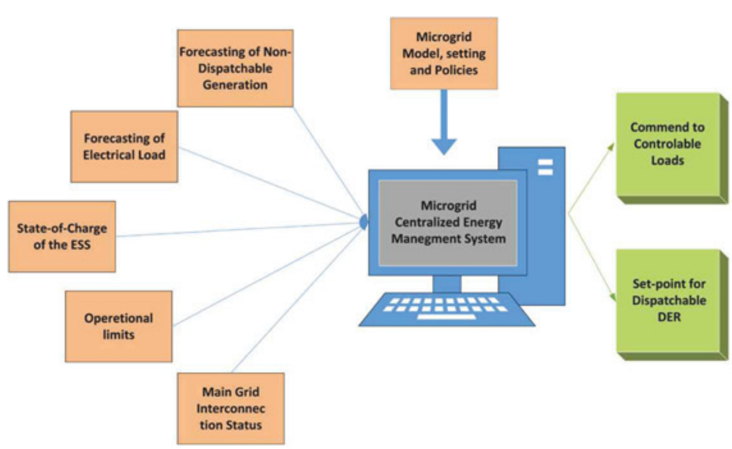


Figure 8: General structure of centralized secondary control for microgrids

advantage of DG units, some technical and operational issues in the design of a proper control system need to be considered, with the ultimate aim to ensure the reliable and economical operation of the microgrid.

Here, islanded operation is considered. Islanding operation requires adequate control and management systems to provide stable, autonomous operation. Voltage and frequency control, active and reactive power sharing, power quality control and optimizing operating costs together comprise the key principles of microgrid control structure in islanded mode. With respect to these requirements, hierarchical control can cover all these responsibilities.

Hierarchical Control Of Islanded Microgrids

In structuring a power system to accomplish these control actions, two different approaches – centralized and decentralized – can be used.

In a fully centralized technique, a CC performs the control actions for all units based on extensive communication links. On the other hand, in a fully decentralized approach, each control unit operates based on local measurements. For microgrid applications, implementing either fully centralized or fully decentralized control is impossible, due to the large number of controller units and stringent performance requirements.

A possible solution to these limitations can be achieved by introducing a hierarchical control scheme, a compromise between fully decentralized and centralized approaches, which includes three different levels. These levels, based on infrastructure requirements and speed of response, can be classified into primary, secondary and tertiary controllers; see Figure 5.

Primary control is the fastest level, responsible for inverter output control and power sharing, subsequent to the islanding process. Secondary control restores voltage and frequency deviations of islanded mode caused by the primary control. Indeed, it is responsible for mitigating the steady-state errors produced by the power-sharing unit.

At primary level, the main task of the inverter output controller is to regulate the electrical signals of the autonomous microgrid. Normally, inverter output control includes an external loop for voltage control and an inner loop for current regulation. The power-sharing controller is also used to manage active and reactive power sharing.

Typically, power sharing is done using active power-frequency and reactive power-voltage droop controllers without the need for communication links. Figure 6 shows primary level, including inner current and voltage loops, and droop control.

Secondary level is also used to correct the frequency and voltage deviations caused by the primary level. In some circumstances, the frequency or voltage of the microgrid increase, due to an unexpected reduction on the demand side. As shown in Figure 7, to match demand with generation, the frequency or voltage of an islanded microgrid must be correctly changed through at primary level.

As can be seen, the voltage or frequency in autonomous mode even after operation of the power-sharing unit is below the rated value. In such a situation, the main target of secondary control is to restore the operating point.

Researchers have recently started using multi-feedback loops in conjunction with the droop method for operating two or more voltage source inverters (VSIs) in an islanded microgrid. This comprises an outer voltage loop for voltage control and an inner current loop to generate the gate signals of the PWM (pulse width modulation).

Proper design of these control loops can be achieved using various controllers in different reference frames. Use of a proportional-integral controller in the synchronous reference frame with an additional feed-forward compensation path is a common approach, extensively used to improve performance of the regulators. Multi-variable control methods are another approach, widely used for the design of the control loops.

Power-Sharing Control

Power-sharing control is the second stage within the primary level. It can be implemented either using the droop concept or the CC. Indeed, this level can be classified into two different approaches: droop-based and non-droop-based.

Droop-based method

The concept of droop comes from the balance of power in conventional synchronous generators used in traditional electrical power systems. In this concept, whenever an imbalance between the mechanical power of the generator and its output electric active power occurs, the rotor speed will change, causing frequency deviation.

Similarly, output reactive power variations cause deviation in voltage magnitude. This concept can be artificially applied to inverter-based DG units in islanded microgrids. The main idea of this technique is to mimic the behaviour of a synchronous generator by reducing the frequency when the active power increases. The relationship between active power/frequency and reactive power/voltage can be written as:

$$\omega_o = \omega^* - K_P (P_o - P^*) \quad (2)$$

$$V_o = V^* - K_Q (Q_o - Q^*) \quad (3)$$

where ω^* and V^* correspond to the reference values for angular frequency and voltage respectively, and ω_o and V_o correspond to the measured output frequency and voltage of the DG system, respectively.

Non-droop-based methods

Non-droop-based methods use parallel converter configuration based on a communication link. Over long distances, communication links are vulnerable and expensive. Concentrated control, master/slave, instantaneous current sharing and circular chain control methods are the main examples of non-droop-based approaches.

Secondary Control In Islanded Mode

Secondary control is the highest level of hierarchical control in islanded mode. It is responsible for the reliable and economical operation of microgrids by restoring the frequency and voltage deviation caused by the primary level. Secondary control can be implemented either in centralized or decentralized way. The performance of secondary control in centralized manner significantly depends on the operation of the CC, while in decentralized approach various units can decide to interact with the microgrid.

The general structure of centralized secondary control for microgrids is shown in Figure 8. As can be seen, the CC uses information from DERs units, loads, the network and forecasting systems to provide proper set-points for dispatchable DERs and appropriate commands for controllable loads. As can be observed, the input variables may include forecasted power output of non-dispatchable energies and local loads, state of charge of the BESS, operation limits of dispatchable DGs, the utility grid interconnection status, security and reliability constraints of the microgrid and forecasting of grid energy price. The output variables of the CC are used as reference values for the next level to cope with the selected control objectives.

On the other hand, in the decentralized approach, the energy management challenges are handled by providing the highest possible autonomy for DG units and loads. Indeed, control of variables is done locally. Although decentralized secondary control has difficulty providing high levels of coordination for the microgrid, it can easily incorporate new DG units without needing to change the controller's settings.

Trends

The progress of microgrid control schemes in autonomous mode has evolved very buoyantly in numerous ways relating to the aspects discussed here.

But despite the numerous advantages of energy storage systems, such as power quality enhancement and microgrid islanded operation, they have not been fully utilized. The main cause of this limitation is the lack of proper control and management; further work needs to be done to develop control strategies for various energy-storage technologies, such as pumped hydro and compressed-air energy storage.

Even though a considerable amount of literature exists on the development of microgrid output control strategies, several questions still remain unanswered. The following areas can benefit from further research: improving robustness to topological and parametric uncertainties; improving the controllers' transient response; obviating the need for complex communication infrastructure; accounting for imbalance and harmonics; enhancing the control schemes' scalability; and developing control schemes that function for both grid-tied and islanded modes.

The main advantage of droop control is that it eliminates the need for communication. Moreover, in this approach, the control action is based on only local measurements. This gives droop control significant flexibility in that, as long as the balance between generation and demand is maintained, there is no interdependency between the local controllers.

However, the conventional droop control method has several challenges that need to be addressed: poor transient performance or instability owing to the use of average values of active and reactive power over a cycle; ignoring load dynamics that can result in failure subsequent to a large or fast load change; requiring special provisions for system restoration; poor performance when adopted for distribution networks; and unsuitability for nonlinear loads since it does not account for harmonic currents, among others. ●

A CASCADED MULTILEVEL INVERTER BASED ON VECTOR MAPPING

ZHENG LU, HONGLIN OUYANG AND **MUXUAN XIAO** FROM HUNAN UNIVERSITY IN CHINA PRESENT A NOVEL, SIMPLIFIED, SPACE VECTOR PULSE WIDTH MODULATION (SVPWM) METHOD FOR DESIGNING MULTILEVEL INVERTERS

Multilevel inverters find many applications such as in high-voltage motor drives. Typically, there are three commercial topologies of multilevel inverters: diode-clamped, flying capacitor and cascaded H-bridge. Diode-clamped and flying-capacitor inverters have unbalanced DC capacitor voltage, and the cascaded H-bridge inverter is based on a series connection of isolated power cells with a standalone DC source. This last topology needs fewer semiconductors to achieve the same output voltage than the other two configurations, and the higher the voltage level the less the harmonic content in the output voltage waveform, making it suitable for modular and scalable designs. The main drawback, however, is that it needs more standalone DC sources.

Pulse Width Modulation

There are three types of pulse width modulation (PWM) methodologies for a cascaded multilevel inverter: carrier wave modulated PWM, selected harmonic elimination PWM and space vector PWM, or SVPWM. The last modulation sheme was proposed by J. Holtz and relates to the AC motor and inverter as a whole; with it round flux trajectory with constant amplitude can be achieved for an AC motor. This approach offers small torque ripple, low noise, high utilization of the DC voltage and easy implementation with a digital signal processor (DSP).

A lot of effort has gone into researching SVPWM. Here we propose a simplified cascaded multilevel inverter SVPWM methodology that uses the mapping principle to split the reference voltage vector into a base vector and 2-level vectors,

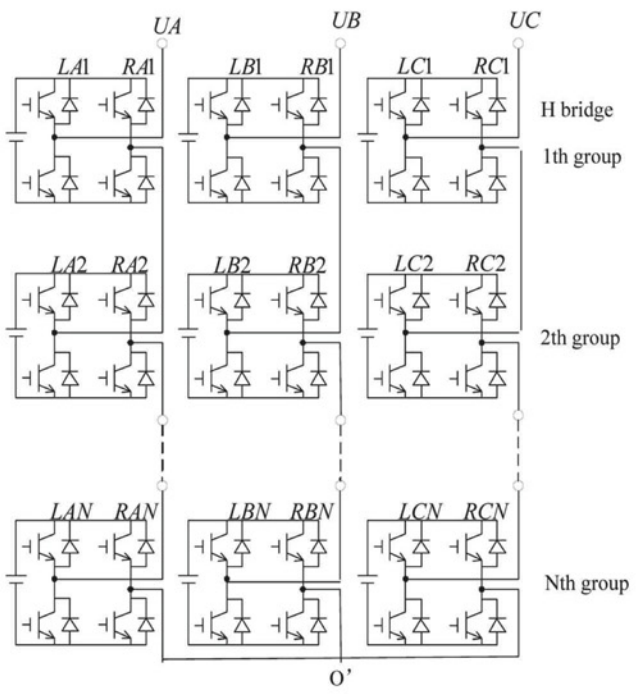


Figure 1: Cascaded H-bridge inverter topology

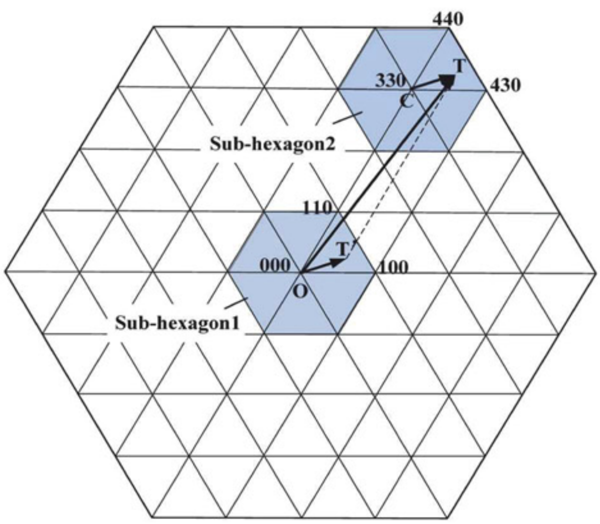


Figure 2: Mapping and reverse mapping of a 2-level inverter; the switch state of the centre vector is 000

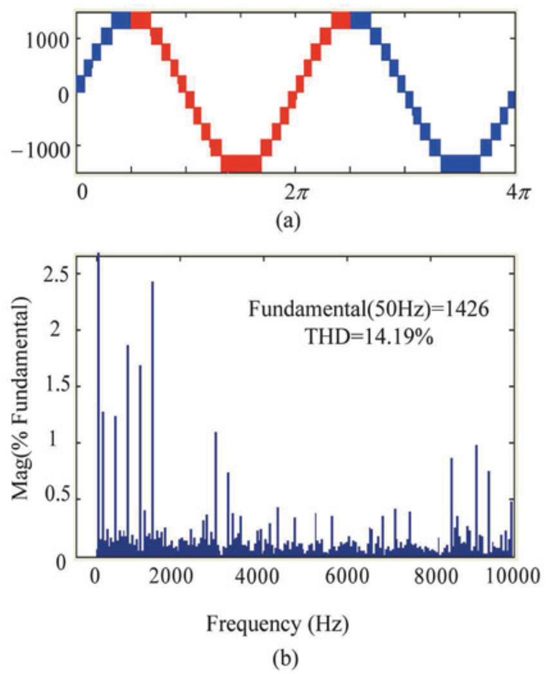


Figure 3: Phase A voltage waveform and its harmonic analysis: (a) phase A voltage waveform; (b) harmonic analysis

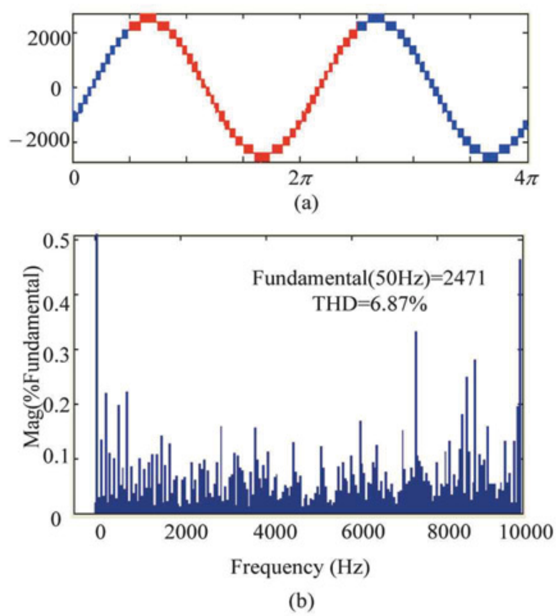


Figure 4: Line voltage waveform and its harmonic: (a) line voltage waveform; (b) harmonic analysis analysis

based on the study of Aneesh Mohamed A. S. et al. The mapping process subtracts the base vector from the reference vector and the modulation process is greatly simplified.

This methodology is suitable for any n level, independent of the number of voltage levels.

Cascaded H-Bridge Multilevel Inverter Topology

The cascaded H-bridge multilevel inverter was first created by the US-based Robicon Corporation. With it high output voltage can be realized, by connecting several power cells in series. Moreover, many problems that traditionally exist in high-voltage inverters have been solved with it, such as low input power factor, large motor torque ripple, the influence of output du/dt on motor insulation and so on.

Figure 1 shows the multilevel inverter topology based on a series connection of n H-bridge inverter cells per phase. Every H-bridge cell is powered by a constant DC voltage, rectified from AC by diodes, or provided by a constant DC source.

Every H-bridge cell is built with four semiconductors. When the PWM driving signals are applied to the semiconductors, there are three resultant output voltage levels: -E, 0, +E.

In general, the number of output voltage levels is $2N + 1$ where there are N cascaded H-bridge cells; and the number of line voltage levels is $4N - 1$. Moreover, the greater the number of voltage levels, the closer to a sinusoidal wave the output voltage waveform becomes and the lesser the harmonic content.

Proposed Strategy

Figure 2 shows the space vector diagram of a 5-level inverter. If we take point O as the centre, six small triangles (six sectors) around point O form a hexagon called sub-hexagon 1, space vector diagram.

Similarly, six sectors around point C form sub-hexagon 2, the 2-level space vector diagram containing the tip of the multilevel reference vector. The switch state of this centre vector is 330, and the tip of the reference voltage vector is located in the 0 sector of sub-hexagon 2.

Mapping is the shifting of reference vector CT to OT', without a change to its amplitude or direction. This is realized by subtracting the centre base vector 330 from each vector (440, 430, 330) of the triangle in which the tip of the reference vector CT is located, so the multilevel space vector modulation is transformed into a 2-level space vector modulation, and the choice of multilevel inverter switch vectors and their duration are greatly simplified.

Reverse mapping is the opposite process, where vector OT' is shifted to CT. The multilevel switch vectors 330, 430, 440 can be obtained by adding the base vector 330 to 2-level switch vectors 000, 100, 110.

Similarly, the reference vector with a tip located in any sub-hexagon can be derived by adding the corresponding base vector to the centre 2-level switch vectors. Therefore, the switch vector corresponding to any one sector can easily be gained with reverse mapping.

Reference Vector Mapping

The reference vector can be mapped to the centre sub-hexagon by the base vector. Once it is mapped to the centre sub-hexagon, the switch vectors form the 2-level reference vector, with its sequence and duration.

On the other hand, the base vector is added to the 2-level switch vectors simultaneously by reverse mapping, obtaining the multilevel inverter switch vectors, their sequence and duration.

The steps are summarized below:

(1) Identification of the base vector;

(2) Mapping of the multilevel reference vector to the corresponding sector of the centre sub-hexagon;

(3) Determination of the switch vectors that consist of the 2-level reference vector by using the two-level SVPWM algorithm;

(4) Reverse mapping of the switch vectors determined in step 3 and determining the switch vectors of the multilevel inverter.

Modulation And Simulation

Once the three phase-symmetrical output voltages of the inverter are measured, after adding the zero sequence voltage, we can determine the three-phase reference voltage and base vector (by reducing the integer function with the three-phase reference voltage). The corresponding 2-level vector is the difference between the reference voltage and base vector.

The reference voltage vector of the multilevel inverter can be assumed as a reference voltage of a 2-level inverter after mapping, and it can be determined with the 2-level SVPWM algorithm. The complexity of the algorithm does not increase with the voltage levels, which makes it suitable for any n-level inverter.

The simulation model of an 11-level cascaded H bridge inverter is achieved with MATLAB. Every cell of the inverter is powered with 300V DC voltage.

Figure 3 shows that the A phase voltage waveform is similar to a sinusoidal wave, and that the total harmonic distortion (THD) is 14.19%.

Figure 4 shows the waveform of the output line voltage U_{ac} and its harmonic analysis. Since the number of step waves is increased to 10, the line voltage becomes closer to a sinusoidal wave, and the THD is only 6.87%. ●

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BUILDING CLASS-D AUDIO AMPLIFIERS

IVAN SKORYK EXPLAINS HOW TO SELECT THE BEST COMPONENTS TO BUILD A CLASS-D AUDIO AMPLIFIER

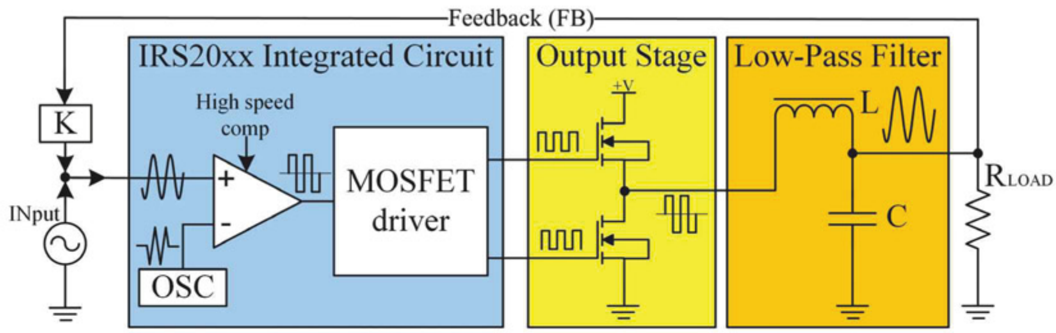


Figure 1: Block diagram of a single-channel amplifier based on IRS20xx

Over last few decades, linear amplifiers of a well-known "A", "B" and "AB" classes have been used in a vast number of commercial and industrial applications to amplify frequencies in the audio range from 20Hz-20kHz. Linear amplifiers deliver signal amplification within the audio range with low coefficient of total harmonic distortion (THD). This parameter is very important for listeners, since it partly determines the quality of the amplifier.

Although linear amplifiers have low THD, they also have relatively low electrical efficiencies (theoretical maximum for the AB class is 72%) due to their linear operation, which requires an extensive heatsink or a cooling system to keep the output-stage transistors in their optimal temperature range, preventing thermal breakdown.

As electronic technologies continue to improve, the Class-D amplifier has slowly begun to replace linear amplifiers, with competitive advantages such as higher efficiency, cost-effectiveness and compact design, as well as reduced need for cooling systems.

The name for the Class-D amplifier comes from "digital amplifier", derived from how it drives the final stage (output) transistor, even though it could be built using only analog components. This device usually amplifies signals with field effect transistors (FETs), normally used in the output stage, by switching them between the ON and OFF states rather than linearly varying the current thorough them, which makes Class-D different and quite efficient compared to linear amplifiers.

IRS20xx Topology And Operation

One main advantage of the Class-D amplifier is that its output stage transistors do not require heatsinks or special cooling components to dissipate heat when output power increases to over 500W; this is achieved through its efficient operation, which is close to 95%.

An example of Class-D amplifiers is the IRS20xx family manufactured by International Rectifier (IR), which simplifies audio amplifier designs with its need for fewer external components, making it cost-effective, flexible and compact. Figure 1 shows the block diagram of a single-channel class-D amplifier built on an IC from this family.

There are three main modules in the diagram: the triangular wave generator (OSC) with a high-speed comparator and MOSFET switching driver; final output stage transistors; and output low-pass filter LC connected to the load, R_{LOAD}. The first two modules are integrated into the IRS20xx chip, whereas the output stage transistors, low-pass filter and load are external.

> "The Class-D amplifier has slowly begun to replace linear amplifiers, with competitive advantages such as higher efficiency, cost-effectiveness and compact design, as well as reduced need for cooling systems

The "hot" rail of the load is connected to the amplifier's input through the voltage divider K providing the negative feedback (FB) necessary for stable operation of the entire design, similar to the FB in linear amplifiers.

The high-speed comparator compares the input analog signal with the triangular wave signal being generated by the internal oscillator (OSC), running at the internal clock frequency of the entire chip. The comparator produces a series of pulse-width-modulated (PWM) signals that follow the clock frequency. The duty cycle of the PWM signal is proportional to the instantaneous value of the input analogue signal. The produced PWM signal is then transferred to the MOSFET driver, which in turn drives the gates of the high-power MOSFET transistors in the output stage, producing an amplified replica of the PWM signal formed by the comparator.

The amplified PWM signal passes through the output low-pass filter, which eliminates any high-frequency switching components of the PWM signal and recovers an amplified analog signal for feeding a loudspeaker.

The high efficiency of the class-D amplifier lies in its switching technique between the ON and OFF states of the output stage transistors, as no simultaneous current and voltage drop occur across them, which would normally lead to undesirable heat generation. When a transistor is ON, the voltage drop across it is imperceptible and the current is equal to the load current. When the transistor is OFF, the voltage drop across it is equal to the supply voltage so there's no current across it, and therefore no heat produced, making it very energy-efficient. In this way the whole energy of the power source is transferred to the load without any heat losses in the output stage.

Chip Selection

To achieve the best design for an amplifier, the optimal choice of components is highly important. Two key parts are the IC and final-stage MOSFET transistors; both should be selected in light of the desired output power and specific speaker impedance.

The choice of the IRS20xx chip, for example, should be determined by the maximum supply voltage allowed and number of channels required. The ICs in the IRS20xx family, together with their main parameters and properties are shown in Table 1.

The MOSFET transistors to a large extent determine the maximum output power rate and reliability of the final design. Before choosing a particular transistor, calculations should be done to determine the maximum current across the load, which in turn is used to select the MOSFET that can sustain it without incurring damage. The commonly-used MOSFETs optimized for operation in Class-D audio applications are shown in Table 2.

Figure 2 shows a broad variety of transistors suitable for Class-D audio operation. MOSFET requirements can easily be determined using the desired root mean square (RMS) output power and required load impedance of the design. The chosen MOSFET should have drain-source breakdown voltage equal or greater than the supply voltage.

Help At Hand

Class-D amplifiers built on IRS20xx are more suitable for mobile applications than linear amplifiers at optimal output power, due to their high efficiency.

To increase the output power rate, none of the components has to be changed or redesigned; the only change needed is to place MOSFETs in parallel at the output stage, a change that is not so simple to make in linear amplifiers.

IRS90xx also has embedded adjustable overcurrent protection, which shuts down the output stage MOSFETs when excessive current is detected, preventing damage. ●

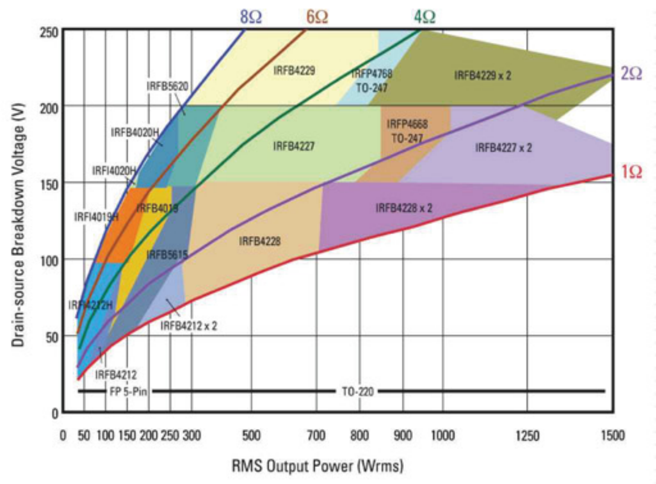


Figure 2: MOSFET drain-source breakdown voltage versus output power for different load impedances

Type	Case	Max supply voltage (V)	Number of channels
IRS20965S	16-lead SOIC narrow	100	1
IRS20957SPBF		100	1
IRS2052M	48-lead MLPQ	100	2
IRS2053M		200	3
IRS2093MPBF		200	4

Table 1: The IRS20xx family of ICs

Type	Case	V_{DS}(V)	I_D(A)
IRFB5615	TO-220AB	150	35
IRFB5620		200	25
IRF6775M	DirectFET MZ	150	4.9
IRF6785		200	3.4
IRF6643		150	6.2
IRFI4019H-117P	TO220-Full pack 5 pin	150	8.7
IRFI4020H-117P		200	9.1

Table 2: Optimized audio MOSFET for Class-D

MORE CHANGES TO THE WIDEBAND TESTING REQUIREMENTS

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

The European Telecommunications Standards Institute (ETSI) is a European standards organization, developing globally-applicable standards for information and communications technologies. These include fixed, mobile, radio, converged, broadcast and Internet technologies, with standards covering GSM, DECT, smart cards and electronic signatures, among others.

ETSI has prepared many standards for the Radio & Telecommunications Terminal Equipment Directive 1999/5/EC (R&TTE), which is a 'new approach' directive. New Approach Directives establish a regulatory framework for placing goods and services on the European market, free movement of those goods and services and their use.

The principles of the New Approach are:

- Legislative harmonization is limited to "essential requirements", which define the minimum requirements products placed on the European Community market must meet in order to benefit from free movement within the Community.
- Technical specifications of products meeting the essential requirements set out in the directives are found in Harmonized Standards.
- Application of harmonized standards remains voluntary, and the manufacturer may always apply other technical specifications to meet the essential requirements.
- Products manufactured in compliance with Harmonized Standards benefit from a presumption of conformity with the corresponding essential requirements.

The essential requirements of New Approach Directives are usually expressed in general terms, and they therefore rely on the related Harmonized Standards for the technical details.

The R&TTE Directive

In the EU it is mandatory that radio equipment meet the 'essential requirements' of the R&TTE. By adhering to harmonised standards, manufacturers and service providers can demonstrate that they have followed the essential requirements of the directive and claim 'presumption of conformity'. Consequently, this allows them to put their products and services on the market in Europe.

The R&TTE Directive will be superseded by the Radio Equipment Directive (RED) in June 2016. The essential requirements of the RED are broadly identical to those of the R&TTE Directive, so the situation regarding wireless devices will remain largely unchanged.

The essential requirements of the R&TTE Directive are:

- Protection of health and safety of the user and any other person, based on the protection requirements of the Low Voltage Directive 73/23/EEC (Article 3.1a).
- The essential requirements of the Electromagnetic Compatibility (EMC) Directive 2004/108/EC (Article 3.1b).
- Effective use of the radio spectrum/orbital resource so as to avoid harmful interference (Article 3.2).

The European Commission may invoke certain other requirements for particular classes of equipment, which may be related to:

- Correct interworking with the network (Article 3.3a).
- Avoidance of harm to the network (Article 3.3b).
- Protection of personal data and privacy (Article 3.3c).
- Avoidance of fraud (Article 3.3d).
- Ensuring access to emergency services (Article 3.3e).
- Facilitation of use by users with a disability (Article 3.3f).

Changing Scene

EN 300 328 is one of the most common standards used today to demonstrate compliance with Article 3.2 of the R&TTE Directive, which covers the effective use of spectrum. This standard also covers wideband data transmission equipment, such as Wi-Fi, Bluetooth and ZigBee devices, which operate in the unlicensed 2.4GHz ISM band, as well as other technologies such as proprietary wideband transmission systems and frequency-hopping spread-spectrum (FHSS) devices. This important standard affects millions of devices employing these commonly-used technologies.

Harmonized Standards only take effect when they are cited in the Official Journal of the European Union. During 2013 and 2014 there was a transition period, while EN 300 328 Version 1.7.1 was expiring, to be replaced by EN 300 328 Version 1.8.1. During this time, as each of these two versions of the standard were published in the EU Official Journal, both provided a presumption of conformity with the essential requirements of the R&TTE Directive.

On 31st December 2014, V1.7.1 of EN 300 328 ceased to provide a presumption of conformity and was superseded by Version 1.8.1. However, no sooner did V1.8.1 become the only harmonized standard published in the EU Official Journal, against which manufacturers could issue their Declaration of Conformity to the R&TTE Directive, than its successor was introduced. This next version – EN 300 328 V1.9.1 – is now published and available to download free of charge from the ETSI website, www.etsi.org.

> "The essential requirements of New Approach Directives are usually expressed in general terms, and they therefore rely on the related Harmonized Standards for the technical details

The R&TTE Official Journal was updated on 17th April 2015 and a new list of R&TTE Directive harmonized standards published, which included EN 300 328 V1.9.1, used to demonstrate compliance. The OJ was again updated on 10th July 2015, highlighting the constantly changing scenario where manufacturers need to keep abreast of this "moving target" of harmonized standards.

New Standard

EN 300 328 V1.8.1 and EN 300 328 V1.9.1 can be used immediately to demonstrate compliance with the R&TTE Directive without the need to involve a Notified Body in the compliance process (i.e. manufacturers can "self-declare" compliance).

However, it should be noted that a Notified Body can still be involved in the compliance process on a voluntary basis, even if the standards are published in the Official Journal. This allows the use of the Notified Body's identification number on the product and packaging, indicating that a third party has been involved in the compliance process.

"It should be noted that the RED does not allow use of the NB number on the product and packaging unless the NB has been involved in the manufacturer's production quality process," it states.

Both EN 300 328 V1.8.1 and V1.9.1 can be used to demonstrate compliance until V1.8.1 expires on 30th November 2016.

Technical Differences

If a product is compliant with version V1.8.1, then no re-testing is required and conformity with version V1.9.1 can be assumed. In such a case, applicants may update their Technical Construction File (TCF), detailing that the changes in version 1.9.1 do not affect the compliance of their products. The Declaration of Conformity (DoC) must then be updated to V1.9.1. We would also advise that an updated application form be included in the TCF (as published in Annex E of EN 300 328 V1.9.1).

For manufacturers of products with a geolocation capability, there is no test requirement. If V1.8.1 test results have been used for compliance with V1.9.1, this will need to be factored into the TCF, and will be satisfied by completion of the EN 300 328 v1.9.1 application form.

There are also changes to the application form, since EN 300 328 V1.9.1 no longer refers to the values of 'r' and 'q'. Consequently, manufacturers no longer have to contact chipset vendors for this information in cases where the values are not easily mapped to the technology under test. Also, the minimum Clear Channel Assessment (CCA) value, which a manufacturer must declare on the application form, has been reduced from 20µs to 18µs.

For frequency-hopping devices such as Bluetooth, manufacturers have the option to provide a statistical analysis to demonstrate compliance with 'Frequency Occupation' (Clause 4.3.1.3.4) in lieu of testing. In some cases, the calculation can be complicated and require input from a chipset vendor or expert in the technology field. Note that the term "Accumulated Transmit Time" is now used instead of "Dwell Time" in order to avoid confusion, since the term "Dwell Time" may have a different meaning when used in other technological fields.

Test time and costs to the applicant are also further reduced since there is no longer a requirement to test 'Transmitter Unwanted Emissions' in the out-of-band domain (Clause 5.3.9) at extreme temperatures. One other notable change is that the receiver blocking requirement (Clause 5.3.7) is reduced from -30dBm to -35dBm, a less stringent limit.

There will be additional Receiver requirements in the majority of ETSI radio standards to comply with the RED, and many standards are currently being updated by ETSI. It is likely that an updated version of EN 300 328 will be published before the RED comes into force in June 2016.

Now is the time to act in order to ensure that your products comply with the new EN 300 328 V1.9.1. ●

FIVE BENEFITS OF EARLY EMC TESTING

DUNSTAN POWER FROM BYTESNAP DESIGN, ONE OF THE FEW DESIGN CONSULTANCIES WITH A UK EMC TESTING CHAMBER, LISTS THE BENEFITS OF PRE-COMPLIANCE TESTING

You have built a great product that meets market demand. You are confident that it radiates little energy and is not susceptible to outside interference, yet when you reach the final EMC testing stage, your product fails. This is the nightmare scenario for most product designers. The cost of testing was already high, but re-testing will stretch the planned budget and slow down the entire project.

A failed compliance test means design engineers need to find out why the product failed and how to fix it.

To avoid this scenario, pre-compliance testing should not be considered an add-on at the end of a project; instead, it should be built in from day one.

In the software-testing industry, there is a movement to test earlier in the product development lifecycle. Likewise, this school of thought is taking hold in the electronics hardware industry – measuring emissions from a device during each major development stage is the best way to avoid costly re-testing and high failure rates.

Key Testing Benefits

There are a number of advantages of pre-compliance testing:

1. Early error detection speeds up project lifecycle

The earlier product deficiencies are identified in the development process, the easier it is to rectify any shortcomings. Fixing problems after compliance testing is much more expensive and time-consuming than fixing them during the design stage. Pre-compliance testing can focus on the areas identified as potential causes for concern and find early solutions for them.

The risk of a design failing is usually proportional to how long testing is delayed, so managers who leave testing to the end of a project are completely dependent on the design team's skill and experience. An apt analogy is the process of baking a cake without checking its taste at different stages, but instead throwing it all together, baking it and then finding out there wasn't enough sugar.

Early analysis of the electronics can also drive system decisions. EMC is not just about electronics – it's about the system, and mechanical changes may be required, such as adding EMI shields, coating boxes or adding EMC foam to fill any leaks or gaps in an enclosure.

2. Testing is already done to compliance standards

Using an anechoic testing chamber before formal testing can determine whether or not a design will meet relevant compliance standards. The ability to test to EN55022, EN61000 and EN61000-3-2, as well as MIL-STD-461 for emissions improves confidence in the design.

Setting pre-compliance as a milestone can help keep a project healthy by focusing the team on ensuring that the software, electronics and mechanics will meet a certain standard for the test. For example, this could mean testing the front end of a data acquisition system or processor module on its own in a mechanical enclosure that runs data processing algorithms.

3. More agile projects where testing is integrated in the development

Standalone pre-compliance testing can be expensive, especially if a product doesn't pass the first time, as subsequent rounds of testing are required after design alterations. However, when testing is integrated into the development, a testing chamber and expert advice are available during the entire project. Design engineers who offer EMC pre-compliance testing as part of their services are continuously on the lookout for areas of risk during product development. For instance, testing during development with evaluation or strip boards will provide the designer with the opportunity to add preventive measures such as signal bead filters to prevent potential issues.

> "Fixing problems after compliance testing is much more expensive and time consuming than fixing them during the design stage

4. Reduced risk of failing certification

Early EMC testing can de-risk a project by determining non-compliance prior to submission for formal testing. Along with EMC, a chamber can be used to measure comparative signal strength for low-power radios, to check performance over time or the effect of modifications. Pre-compliance testing makes certification overall a less stressful experience.

5. Changes are based on real-world feedback

Early EMC testing can save money by reducing overengineering and ensuring that a product can pass compliance tests easily. Before a product is tested it is not known where the problems might occur. This can lead to countermeasures being added where they are not needed.

Henry Ford used to send engineers to examine Ford cars in scrap yards to understand which components still had lots of life left due to overengineering. This helped his engineers to downgrade the specification on these components to achieve cost savings. The equivalent can be done with EMC testing, to optimise a project's bill of materials. ●

A remote-controlled scrolling LED display system

BY **DR DOGAN IBRAHIM**

Public addressing systems (PASs) have gone under considerable changes in the last decade. In the past, such systems were based on illuminated fixed signs, programmable sign boards, audio systems, CCTV and so on, most of which were generally hard-wired, complex in nature and difficult to expand. For example, hard connection was required to program and change a displayed sign, and this was not easy, specifically if the sign was located at an inaccessibly-remote place.

Nowadays, most PASs are based on scrolling LEDs where the message to be displayed is scrolled left, character by character, at a speed comfortable for reading from a given distance. The height of the characters and their scrolling speed are chosen based on the distance from the display and the approaching speed of the reader, if for example the reader happens to be in a moving vehicle.

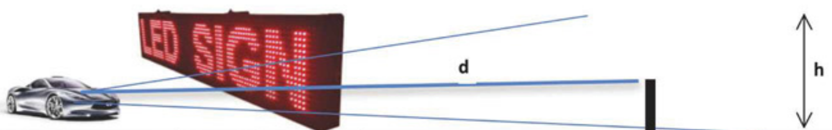
The displayed message in some types of scrolling LED displays can only be changed locally, where a PC, laptop, or a special device is connected to change the message. Such display systems have limited use, since not being able to change the notice instantly is a major disadvantage.

In other systems, a handheld remote-control unit is used to change the message. Scrolling LED sign systems where messages can be changed remotely are much more common in outdoor applications or for instant notifications.

Choice Of A Scrolling LED Display

Choosing the right scrolling LED display for the application depends on several factors, including:

- Where the display will be used (indoor or outdoor);
- Required display and character widths;
- Required display and character heights;
- Ambient light conditions;
- Colour of the display;
- Display resolution;
- Viewing angle;
- Method of changing the message;
- Text or graphics;



LED Character Size (h)	Max Viewing Distance (d)	Maximum Viewing Time (seconds)					
		5mph (8km/h)	15mph (24km/h)	25mph (40km/h)	35mph (56km/h)	55mph (89km/h)	75mph (121km/h)
51mm (2in)	30m (100ft)	13.7	4.6	2.7	1.9	1.2	0.9
152mm (6in)	91m (300ft)	41.1	13.7	8.2	5.8	3.7	2.7
229mm (9in)	137m (450ft)	61.6	20.5	12.3	8.8	5.6	4.1
330mm (13in)	198m (650ft)	89.0	29.7	17.8	12.7	8.1	5.9
457mm (18in)	274m (900ft)	123.3	41.1	24.6	17.5	11.2	8.2
610mm (24in)	366m (1200ft)	164.4	54.8	32.8	23.4	14.9	10.9
914mm (36in)	549m (1800ft)	246.6	8.22	49.2	35.1	22.3	16.4
1219mm (48in)	732m (2400ft)	328.8	109.6	65.6	46.8	29.8	21.8

Acceptable exposure times are shaded

Table 1: Maximum viewing distance [credit: www.electronicsigns.com]

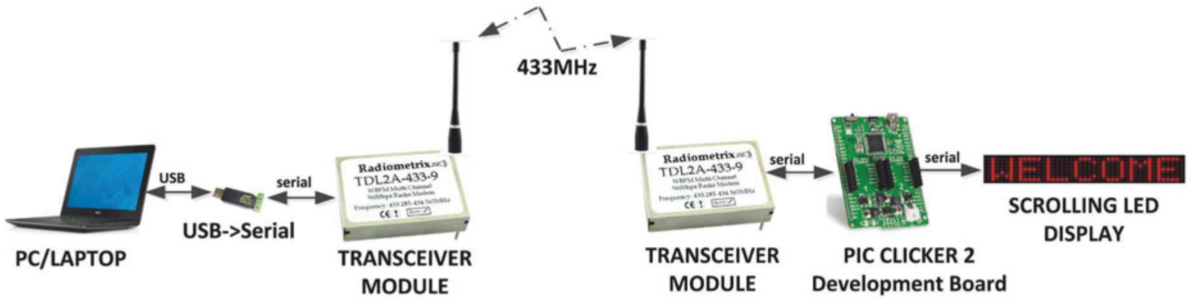


Figure 1: System layout

- Characters per line;
- Ambient temperature;
- Skill of the reader; and
- Availability of mains power.

Displays for indoor use are much easier to install and maintain than outdoor ones, because such displays operate under normal room temperatures and in controlled light conditions, and mains power is always available. The display height does not have to be very large since people usually walk around and are close to the display. There are no communications problems, since the messages in such displays are usually configured using handheld devices. Indoor displays are a lot cheaper than outdoor ones.

The use of outdoor displays requires careful consideration of many factors. For example, local mains power may not be available, and it may need to rely on renewable energy sources such as solar or wind power. The ambient light can be strong, requiring high brightness LEDs, or installation at such an angle to reduce the effects of direct sunlight. Larger characters may be required to make the display visible and readable. The display must also be robust to withstand extreme temperatures and weather conditions.

The maximum viewing distance of a display depends on many factors, but character size and the approaching speed of the reader are the main ones to consider. For a stationary reader, one inch of character size is estimated for every 50 feet of viewing distance. Thus, for example, a 3-inch display can be read from a distance of 150 feet. Things become more complicated when the reader is moving (e.g. driving), since the viewing time now also depends on the vehicle speed and display scrolling speed.

Table 1 shows the maximum viewing distance (the farthest point from which the sign is visible) of a fixed display when the reader is mobile. The shaded areas represent acceptable exposure times. For example, with an 8-inch high display and travelling at 55mph, the maximum viewing distance is 900 feet with a maximum viewing time of 11.2s.

The Hardware

Here we show how wireless UHF RF modules can be used to communicate with a display to configure the messages to be displayed, see Figure 1.

System operation is as follows: A program has been developed on a laptop or other PC to send messages to the display. A USB/serial converter module is connected to a USB port of the laptop to convert the USB data into the serial format required by the UHF RF transceiver modem module. At the other end of the system, a matching transceiver module receives the transmitted data. The scrolling display used in the design accepts serial data output from the second UART port of the PIC microcontroller.

The system's block diagram is shown in Figure 2. The USB/serial

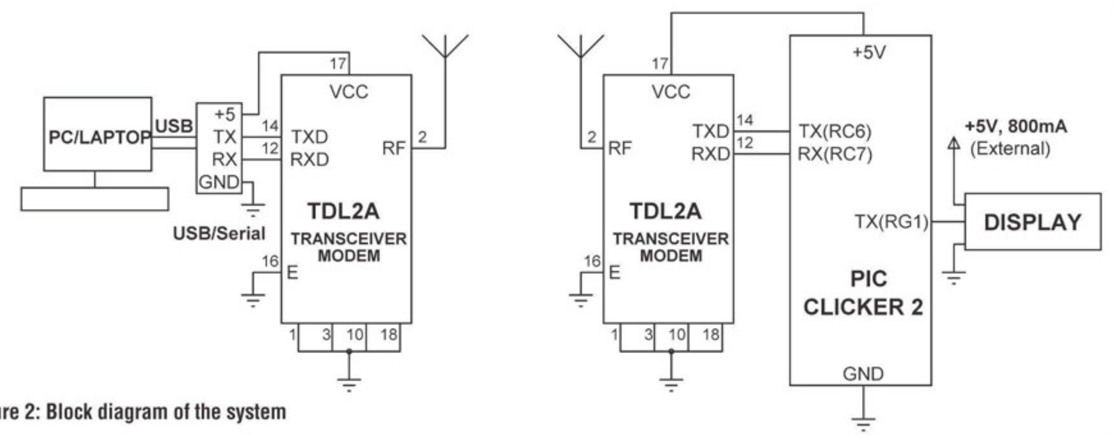


Figure 2: Block diagram of the system

Figure 3: PC program in Visual Basic form

```
Imports System.IO.Ports

Public Class Form1
        Public mySerialPort As New SerialPort
        Private Sub Form1_Load(sender As System.Object, e As
        System.EventArgs) Handles MyBase.Load
        With mySerialPort
                .PortName = "COM34"
                .BaudRate = 9600
                .DataBits = 8
                .Parity = Parity.None
                .StopBits = StopBits.None
                .Handshake = Handshake.None
                .ReadTimeout = 500
        End With
        End Sub

        Private Sub ButtonConnect_Click(sender As System.Object,
        e As System.EventArgs) Handles ButtonConnect.Click
                Dim DisplayText As String
                DisplayText = "!" & TextBox1.Text & "*"
                If Not mySerialPort.IsOpen Then
                        mySerialPort.Open()
                End If
                mySerialPort.Write(DisplayText)
                Dim incoming As String = mySerialPort.ReadLine()
                MsgBox("Displayed msg: " & Mid(incoming, 2))
        End Sub
End Class
```

Figure 4: Visual Basic program listing

```
void main()
{
        unsigned char n, Buff[20];
        UART1_Init(9600);                       // Initialize UART1 (RC6/RC7)
        UART2_Init(9600);                       // Initialize UART2 (RG1)
        Delay_Ms(1000);                         // Wait 1 second

        while(1)
        {
                if(UART1_Data_Ready() == 1)     // Data available ?
                {
                        UART1_Read_Text(Buff, "*", 20);  // Read data until "*"
                        UART2_Write_Text(Buff);          // Write to display
                        UART2_Write(0x0D);               // Send carriage-return
                        UART1_Write_Text(Buff);          // Send acknowledgement
                        UART1_Write(0x0A);               // Send line-feed
                }
        }
```

Figure 5: Microcontroller program listing

converter module (www.sunrom.com) plugs into a USB port of a computer and provides UART functionalities.

We use a TDL2A transceiver module, manufactured by Radiometrix (www.radiometrix.com), since the communication is in two directions; i.e. an acknowledgement signal is received back from the display. Radiometrix manufactures a variety of single and multi-channel radio telemetry modules, operating in the HF, VHF and UHF bands.

The TDL2A is a 433MHz ISM band, 9600 baud, multi-channel transceiver module operating at +5V. It is pin compatible with the higher power (25mW) module TDH2, suitable for designs requiring longer range.

PIC Clicker 2 (www.mikroe.com) is a low-cost PIC microcontroller development board with a PIC18F87J50 microcontroller on-board, programmed via a bootloader program. We used a low-cost (around £20) scrolled LED display for this project to demonstrate the principles of operation.

The display is manufactured by Sunrom Technologies and consists of 48 x 8 LEDs, 8 LEDs high and 48 LEDs wide, controlled by ASCII data with variable scrolling speeds.

Serial data is simply sent to the display in the following format: The "!" character identifies the beginning of the message, while the message is terminated with a carriage-return character **!message<CR>**

The Software

Two programs were developed for the system: one for the PC and one for the microcontroller.

The PC program was developed using the Visual Studio, Visual Basic language. As shown in Figure 3, the program consists of a single form where the user simply enters the message to be displayed in a textbox. An acknowledgement is sent back to the PC and shown in a message box to confirm that the message was sent to the display.

The program listing is shown in Figure 4. Notice that the COM34 serial port is assigned to the PC's USB port. Subroutine ButtonConnect_Click is activated when the user clicks the Display button to send the message to the display. String variable DisplayText stores the message after inserting character "!" at the beginning, and terminating the message with character "*", used by the microcontroller program to detect the end of the message.

After sending the message, the program waits to receive an acknowledgement from the display. The acknowledgement is a copy of the original message sent to the display, shown in a message box on the PC screen. Function ReadLine() reads lines of serial data from the serial port until a line-feed character is received.

The microcontroller program was developed using the mikroC Pro for PIC programming language and compiler. Figure 5 shows the program developed for this project. Received data (message) is stored in array Buff and is then sent to the display. This message is echoed back to the sender as acknowledgement.

The system can be improved in several ways. For instance, messages could be sent from mobile phones, encrypted or password-protected to avoid unauthorized changes. ●

SOUTHERN 15 Manufacturing & Electronics

FIVE | Farnborough | Hants | GU14 6XL

9th to 11th February 2016

A World Of Electronics At Southern Electronics 2016

Southern Manufacturing and Electronics returns to FIVE, Farnborough, from February 9th to 11th, 2016. The show continues in its popular three-day format, making it easier to plan a trip to the UK's largest and longest-running electronics exhibition.

Keeping up to date with the latest innovations in components and sub-assemblies is no easy task, but with its extensive range of suppliers in a single venue, Southern Electronics makes that job considerably easier. The proof is also in the show breaking attendance records on a yearly basis for over a decade, now considered by many the Number One electronics event in the UK.

Easy Location

Situated close to the M3 in Hampshire and well-served by public transport, the event is easily accessible, and offers free entry and free on-site car parking. The three-day opening introduced last year allows visitors more flexibility in scheduling their visits, as well as helps attract exhibitors from an ever-wider geographic area, which now includes the whole of Europe from Lithuania and Estonia to Spain and Italy.

Southern Electronics's combination of design, production and components gives the event a unique profile and atmosphere. Some 50% of the 18,000m² exhibition area is dedicated to electronics, attracting visitors from every branch of the industry.

Within the manufacturing areas, visitors will find an equally vast range of vendors providing everything from state-of-the-art machine tools and automation systems to nylon stand-offs and fixings. Engineering services range from design to box-build, and precision engineering to heavy fabrication. There're are several hundred production equipment suppliers showing their products and services, from advanced stock management systems, optical inspection and soldering to complete clean room solutions, and even anti-static flooring and industrial lighting.

Vast Range Of Exhibitors

Among its range of exhibitors are major international suppliers such as RS Components, Cosel Europe, Yamaichi Electronics, Hirose, Lemo, Molex, Midas Components, Nexus GB, Sinclair Rush and many more, to much more specialised suppliers and service providers, such as York EMC, METECC, SIC, Gem Cable and Bytesnap Design, giving visitors an opportunity to see highly-skilled companies.

The event is also the pre-eminent marketplace for subcontracting and specialist engineering services of all types. The European PCB industry is represented by firms such as Espirit Circuits, Eurocircuits, PCB Baltic and European Circuits. Firms like Blundell Production Equipment, Optris and Bondline Electronics provide production hardware, while companies such as Easby Electronics, JJS Manufacturing, CT Production, ERNI Electronics and EC Electronics showcase different types of design and build services.

Within the Manufacturing area, visitors will meet a thorough cross-section of the UK's top precision engineering firms. Other areas of advanced manufacturing will include composites, engineering plastics and additive manufacturing. Technology Trails will guide attendees around the exhibition, enabling them to best organize their time at the show. Sectors covered include aerospace, automotive, contract electronics manufacturing and medical technology.

Other specialist areas, for example the live demonstration Machinery Centre, will enable visitors eaisly locate products and services. A tiny selection of the offerings highlighted in 2016 will include CNC machine tools and machining centres, CAD/CAM tools, advanced adhesives, fasteners and joining technology, 3D printing, laser cutting, packaging solutions, labelling and marking, pressings, fabrications and enclosures, metrology and test equipment, coating and finishing, motors, drives and controls and handling and storage.

Seminars

Combined with the exhibition and demonstration areas, Southern Electronic's free seminar programme is a hugely popular draw for show attendees. Two programmes run in tandem in two theatres, focusing on engineering and electronics respectively, covering discussions on technical breakthroughs, business management, design and current commercial regulation. Access to these high-calibre engineering and business expertise is free.

The full list of seminars and the all-important pre-registration, can be seen at www.industrysouth.co.uk.

Although admission to the show is free for business visitors, registration is necessary. To register for tickets, visit www.industrysouth.co.uk.

Show visitors can keep up to date with the latest event and exhibitor news by visiting the show's official blog, http://blog.industrysouth.co.uk, by following @industry_co_uk #southmanf on Twitter or by joining the show's official group on the popular business networking site LinkedIn at http://linkedin.industrysouth.co.uk.

For more information call Phil Valentine on +44 (0)1784 880890, fax +44(0) 1784 880892, email philv@etes.co.uk or go to ***www.industrysouth.co.uk***

AWS ELECTRONICS GROUP WILL SUPPORT EMS MARKET IN FRANCE

AWS, a specialist electronics manufacturing services (EMS) provider, is now supporting French customers with the appointment of DSA Commerce as representative in this strategically-important European market.

Headed by Alfredo Desa, DSA Commerce is well established in France and especially active in key markets such as automotive, aerospace, rail, medical and nuclear.

"Many companies in France are looking for a reliable EMS partner that can provide a high-quality service on technically-challenging designs, yet keep costs competitive. AWS, with its high volume facility in Namestrovo, Slovakia, meets the needs of our customers in France perfectly," said Desa, owner and director of DSA Commerce.

AWS has six lines in Slovakia with 18 pick-and-place machines and a large area dedicated to mechatronics and box build, replicating the exact AWS systems at its European HQ.

www.awselectronicsgroup.com

ASTUTE ELECTRONICS CERTIFIED TO MIL/AERO ANTI-COUNTERFEIT STANDARD AS 6081

Astute Electronics gained certification to AS 6081, the SAE aerospace standard for counterfeit mitigation, designed to provide a very high level of protection for companies in the aerospace and defence industries.

This makes Astute the first British as well as first European company to gain this certification, and only the fourth company in the world to achieve it. Astute is also the first company worldwide to have more than one location certified – in the UK and the US.

AS 6081 standardizes practices and methods to mitigate the risks of purchasing and supplying fraudulent/counterfeit electronic parts. It covers activities such as identifying reliable sources to procure parts; assessing and controlling suspect or confirmed fraudulent/counterfeit parts; and reporting suspect and confirmed fraudulent/counterfeit parts to users and the authorities.

www.astute.co.uk

YUASA LAUNCHES NEW EUROPEAN WEBSITES

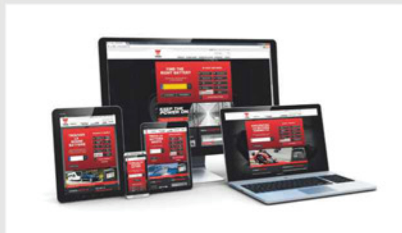
Yuasa Battery Europe has launched a series of ground-breaking new European websites for automotive, industrial and motorcycle markets.

The five new Yuasa sites were switched on at the beginning of November with the UK, Germany, France, Spain and Italy being served by their own individual sites, offering an informative and engaging resource for customers, distributors, industry professionals and retailers.

The websites are mobile-ready with easy navigation, industry-leading battery finders and in-depth information resources. There is also plenty of engaging content, including updates on Yuasa's products, in-depth technical information, news, exclusive Yuasa motorsport content and other informative guides and features.

The websites show the entire range of Yuasa products including specifications, part numbers and photographs, and include downloadable brochures, datasheets and so on.

www.yuasaeurope.com



AURORA GROUP UNVEILS 2016 CATALOGUE AT LUXLIVE

The Aurora Group, a global manufacturer of smart LED lighting solutions, has unveiled its new catalogue, 'Lighting 2016 Edition 1', at LuxLive 2015.

The catalogue reveals new products that Aurora will be releasing in the new year, and demonstrates how the company intends to deliver 'Value Beyond Illumination' going forward. For the first time, the catalogue represents the entire Aurora Group branded portfolio, including the recently rebranded retail lighting specialists, Microlights, which has over 30 years' experience in assisting customers enhance their retail sales through lighting.

The 2016 catalogue presents Aurora Group's combined expertise and products under one brand, as Richard Sells, Group Managing Director, explains: "With a consolidated approach we can offer a complete range of products to accommodate five sectors – residential, hospitality, retail, commercial and industrial."

www.auroralighting.com

GOOEE MAKES IT SEVEN OF THE BEST WITH NEW OEMS ON BOARD

Gooee is working in association with five more original equipment manufacturers (OEMs) relating to its 'Gooee Inside' technology, bringing the total number of manufacturers to seven. Gooee's partners will now be able to use the world's first 'Full-Stack' IoT platform, developed by Gooee, and connect their products to the Internet of Things.

The partnerhips will ensure lighting manufacturers can take advantage of a new trend toward intelligent lighting solutions and integrate the latest smart IoT technology into their extensive ranges.

"We are dedicated to developing the latest technologies that exceed the market's expectations," said Jan Kemeling, Gooee's Chief Commercial Officer. "That means creating high-performance smart components and software solutions that present no surprises, no disappointments and no compromises."

www.gooee.com

NEW FROM TÜV SÜD

TÜV SÜD Product Service launched this month its automated test rig service to help manufacturers and retailers enhance their brand reputation through improved product reliability and quality.

The new service will test products that have a repetitive use, for example those that incorporate switches or hinges. TÜV SÜD will build a bespoke test rig to accommodate individual products and develop a test schedule set against expected usage for the lifecycle of the product.

Manufacturing a reliable product at an attractive price point has become a key competitive differentiator as the market continues to demand value for money.

"Product reliability testing has become increasingly important as cash-strapped consumers demand a long product life and look for products with a positive brand image," said Richard Poate, Senior Manager at TÜV SÜD Product Service.

www.tuv-sud.co.uk

3M ELECTRONIC ASSEMBLY SOLUTIONS FOR THERMAL MANAGEMENT

3M is offering an extensive range of thermal management materials (TIMs), designed to provide simple, fast and effective solutions for thermal management in a wide variety of electronic design environments.

Products in this range dissipate heat while accelerating assembly time. They are also designed to reduce waste and weight, plus improve reliability due to reduced heat. A variety of flexible options suit a broad choice of applications, such as medical devices, consumer electronics, high-end automotive, batteries and lighting.

"As devices become ever smaller and more powerful, so does the pressure on every individual component – including tapes and pads – to deal with additional heat generation. 3M offers an extremely high-quality range of products that address these demands," said Terry Clark from UK-based DK Thermal Ltd, which distributes the 3M range.

www.3M.co.uk

FEMALE VERSION OF HARTING M12 SLIM DESIGN CONNECTOR

Harting has expanded its product portfolio for Gigabit Ethernet connectivity by introducing a female version of the M12 Slim Design connector. The new connector complements the existing male version, so that all the company's compact M12 variants are now available in crimp connection technology.

The new connectors have been significantly reduced both in diameter and length: the outer diameter has been slimmed down to 16.5mm, allowing a high integration density to be achieved with appropriate devices such as switches. In addition, the housing is significantly more robust, being able to withstand torques of up to 1.5Nm. The connectors with x-coding conform to IEC 61076-2-109, and comply with Cat. 6A and Performance Class EA.

The Harting Group develops, manufactures and distributes electrical and electronic connectors, network components, pre-assembled system cables, and backplane assemblies.

www.harting.co.uk

CADENCE ANNOUNCES PALLADIUM Z1 FOR DATACENTRE-CLASS EMULATION

Cadence Design Systems unveiled the Cadence Palladium Z1 enterprise emulation platform, the industry's first datacentre-class emulation system, delivering up to 5x greater emulation throughput than the previous generation, with an average 2.5x greater workload efficiency than the closest competitor. With enterprise-level reliability and scalability, the Palladium Z1 platform executes up to 2304 parallel jobs and scales up to 9.2 billion gates, addressing the growing market requirement for emulation technology that can be efficiently utilized across global design teams to verify increasingly complex systems-on-chip (SoCs).

Palladium Z1 enterprise emulation platform features rack-based blade architecture to provide enterprise-class reliability, a 92% smaller footprint and 8x better gate density than the Palladium XP II platform. It offers a unique virtual target relocation capability, and payload allocation into available resources at run time, avoiding re-compiles.

www.cadence.com

UNMANAGED SWITCH MAKES IT EASY SENDING LONG-DISTANCE DATA

Belden is now offering the SPIDER III Standard Line, unmanaged entry-level industrial Ethernet rail switches capable of bridging long distances without disruptions. The latest switches are based on the proven Hirschmann technology for high quality, cost-effective way to transfer large amounts of data. The switch has up to eight Fast Ethernet or Gigabit Ethernet ports, and two of the ports can be fibre optic.

The SPIDER III Standard Line of switches is future-proof thanks to Gigabit speed. The switches are designed for use in harsh environments and have the necessary certifications, making them ideal for the manufacturing, machine building, solar power and traffic control industries. They also work on the principle of plug-and-play that allows easy installation without compromising quality or reliability. Users can connect multiple devices without the need for a complex configuration process.

www.belden.com

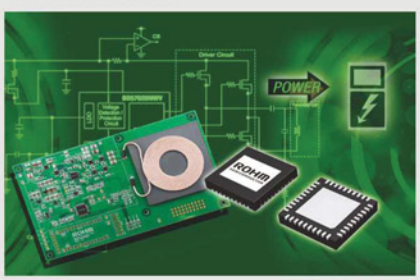
FIRST QI-CERTIFIED MEDIUM POWER TRANSMITTER REFERENCE DESIGN

ROHM has received certification from WPC (Wireless Power Consortium) for its reference design using the BD57020MWV wireless power transmitter IC. This is the first device in the world certified to be compliant with the new Qi medium power specification.

WPC's Qi standard for medium power has attracted attention as a next-generation standard for inductive power transmission that will enable wireless charging of tablet PCs while allowing smartphones and other mobile devices to be charged up to 3x faster than the existing low-power standard (5W). In addition, a Foreign Object Detection (FOD) function is included to provide greater safety by detecting foreign metallic objects before power transfer to protect against possible damage due to overheating.

ROHM also developed a reference design that will help accelerate adoption in applications that will benefit from wireless charging.

www.rohm.com/eu



THE RIGHT MASS FLOW METER FOR EVERY MEDICAL DEVICE

Swiss sensor manufacturer Sensirion adds three new products to the SFM3xxx platform for flow measurement in medical applications. For the first time, the flow sensor range now includes autoclavable mass flow meters, thus the five products in the platform now offer the right solution for all gas flow measurement applications in medical technology.

All sensors in this range share characteristics such as high precision and robustness. The fully calibrated and temperature-compensated sensors measure the flow rates of air and other non-aggressive gases bidirectionally and highly accurately. They also impress with very low pressure drop and fast response time.

The digital mass flow meter SFM3000 is particularly suitable for high-volume applications where cost is paramount. With the SFM3100, Sensirion offers an analog product that can be easily integrated into existing devices.

www.sensirion.com/gasflow

NEW RIGEL SAFETY ANALYSER SPEEDS UP MEDICAL DEVICE TESTING

Faster and safer testing of medical devices and installed equipment in hospitals and healthcare facilities is provided by the new, battery-powered, 288 Plus from Rigel Medical.

This automated safety analyser is one of the smallest around and incorporates a host of new features for enhanced performance and faster testing of electrical safety to IEC 62353, and leakage tests in accordance with IEC 61010, IEC 60601, NFPA, AAMI and AS/NZ3551.

While most conventional testers rely on mains power, the 288 Plus retains operational integrity, even without mains connection, due to standard AA battery power compatibility. This provides greater flexibility for users and makes it quicker to complete in-service testing of point-to-point leakage as well as earth continuity and insulation resistance. There's also a short boot-up times between tests.

www.rigelmedical.com

8-SWITCH MATRIX LED DIMMER SIMPLIFIES LED MATRIX DESIGNS

The LT3965 is a LED bypass switching device that enables independent dimming and diagnostics of eight individual LEDs or LED segments. The LT3965 works in conjunction with an LED driver circuit configured as a current source, and features eight individually-controlled floating 17V/330mΩ NMOS switches. Using these internal power switches and an integrated I2C serial interface, individual LEDs within the string can be turned on or off, or they can be PWM dimmed to offer unique patterns within the LED matrix.

Typical applications include automotive matrix LED headlights, industrial lighting and large LED display lighting.

The I2C serial interface enables digital programming with 256:1 dimming ratios with or without the 11-bit resolution fade transition between the dimming states. Each switch can control and monitor a single LED or a segment.

www.linear.com

HIGH-PERFORMANCE OSCILLOSCOPES OFFER 16-BIT VERTICAL RESOLUTION

Now available from Link Microtek are the latest Rohde & Schwarz RTO-series high-performance digital oscilloscopes that offer high-definition signal analysis with a vertical resolution of up to 16 bits, clear and simple touchscreen operation and the world's first real-time digital trigger system.

As part of the Rohde & Schwarz general-purpose 'Value Instruments' range, the oscilloscopes are designed to provide a precise, reliable and affordable solution for a wide variety of test-and-measurement applications.

The RTO series includes 2- and 4-channel versions with bandwidths ranging from 600MHz to 4GHz. The oscilloscopes combine high acquisition rate of one million waveforms per second with a very low inherent noise level of 1% of full scale at 1mV/div and 1GHz, enabling precise measurements to be made even at low signal amplitudes.

www.linkmicrotek.com

MOUSER NOW SHIPPING MOLEX HIGH-PERFORMANCE MEDISPEC CONNECTORS

Mouser Electronics is now stocking the MediSpec Medical Plastic Circular (MPC) interconnect system from Molex. This is an affordable, high-performance interconnect solution that combines premium performance and ease-of-use to meet the stringent standards of medical devices. In addition, the MediSpec is also recommended for use in avionics, high-use entertainment equipment, and test and measurement devices.

The Molex MediSpec MPC Interconnect System uses the Molex Low Force Helix (LFH) contact system to ensure a reliable electrical interface over thousands of insertions. MediSpec connectors offer a simple push-pull engagement with optional locking sleeve for ease-of-use. The connectors use lightweight medical-grade plastic housing on the standard male plug and panel-mount female receptacles, which can withstand medical industry sterilization processes, including autoclave, ethylene oxide (EtO), gamma and chemical.

www.mouser.com

LEMO AT BVE 2016

LEMO will show its latest products at BVE 2016 – the largest UK broadcasting and production event, taking place 23-25 February at Excel, London – including a range of HD-SDi to fibre converters, plug and plug fibre systems and the latest advancements in cable specifically developed for the broadcast market.

The LEMO SERBAL rugged range of compact HD-SDi to fibre converters allows outputs from up to four cameras to be transmitted over one industry standard LEMO 3k.93C SMPTE cable.

The LEMO SHACK is a plug-and-play system which allows fibre broadcast camera and CCUs to run on a standard duplex single-mode fibre and connectors thus removing the need to use hybrid SMPTE camera cables.

LEMO will also show its NORTHWIRE fibre broadcast camera cable manufactured to both the SMPTE and ARIB standards.

www.lemo.co.uk

RUGGED IP65 DOOR ENCLOSURES NEED NO HIDDEN EXTRAS

Hylec-APL has extended its DE range of IP65 door enclosures known for their rugged, maintenance-free and cost-effective protection in long-life applications.

All DE door enclosures are supplied with a galvanised-steel back plate, external mounting brackets and a lock and key as standard. Made from flame-retardant ABS, the enclosures feature wall thicknesses of up to 3.5mm to offer impact resistance of IK08 (protection against impacts with an energy up to 5J). Because ABS is non-corrosive, the enclosures deliver protection from continued exposure to external conditions, even in marine applications. Liquid gasket seals – a standard feature throughout the range – ensure IP65 protection is maintained, even when the doors are repeatedly opened and closed for regular access.

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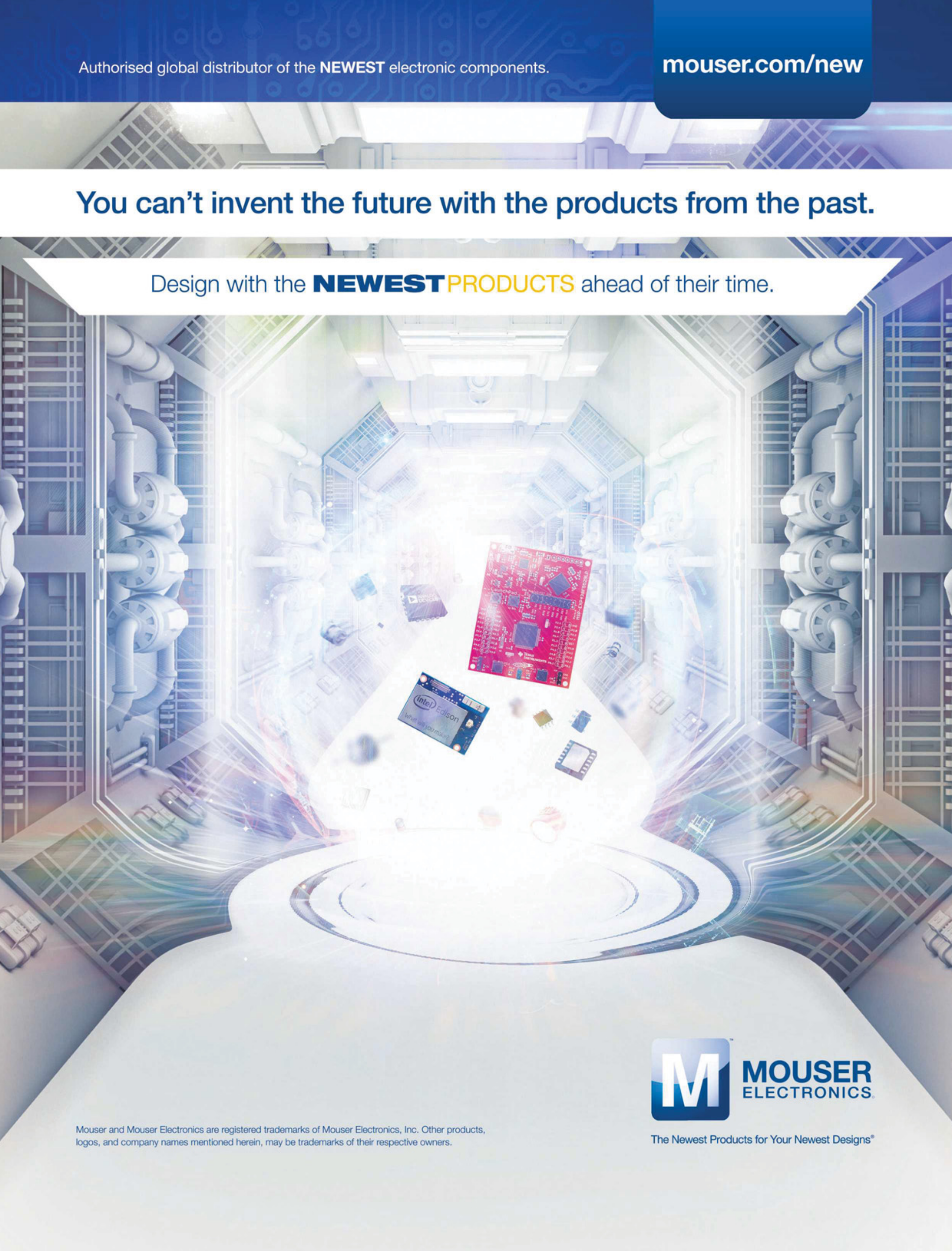
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