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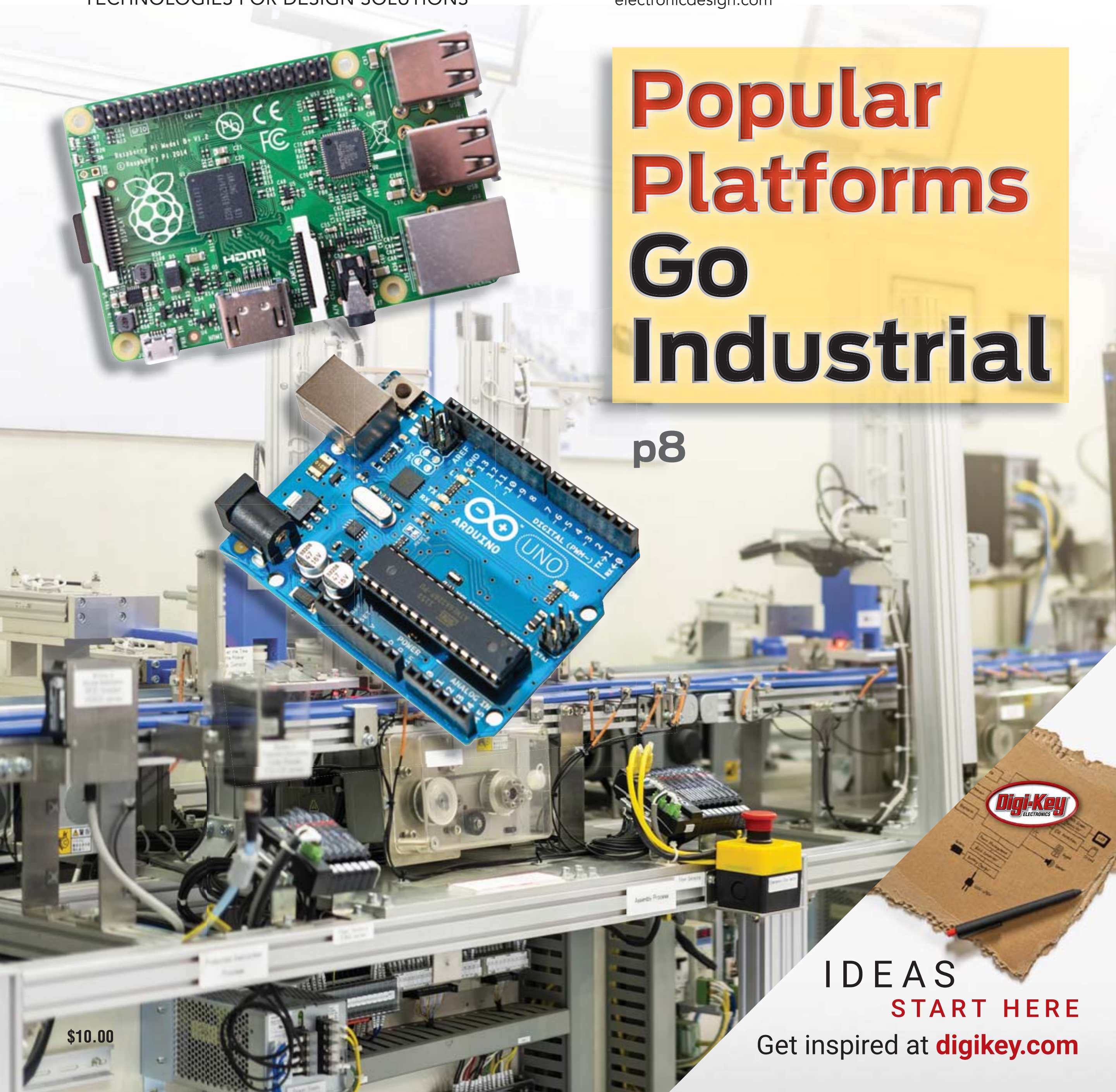

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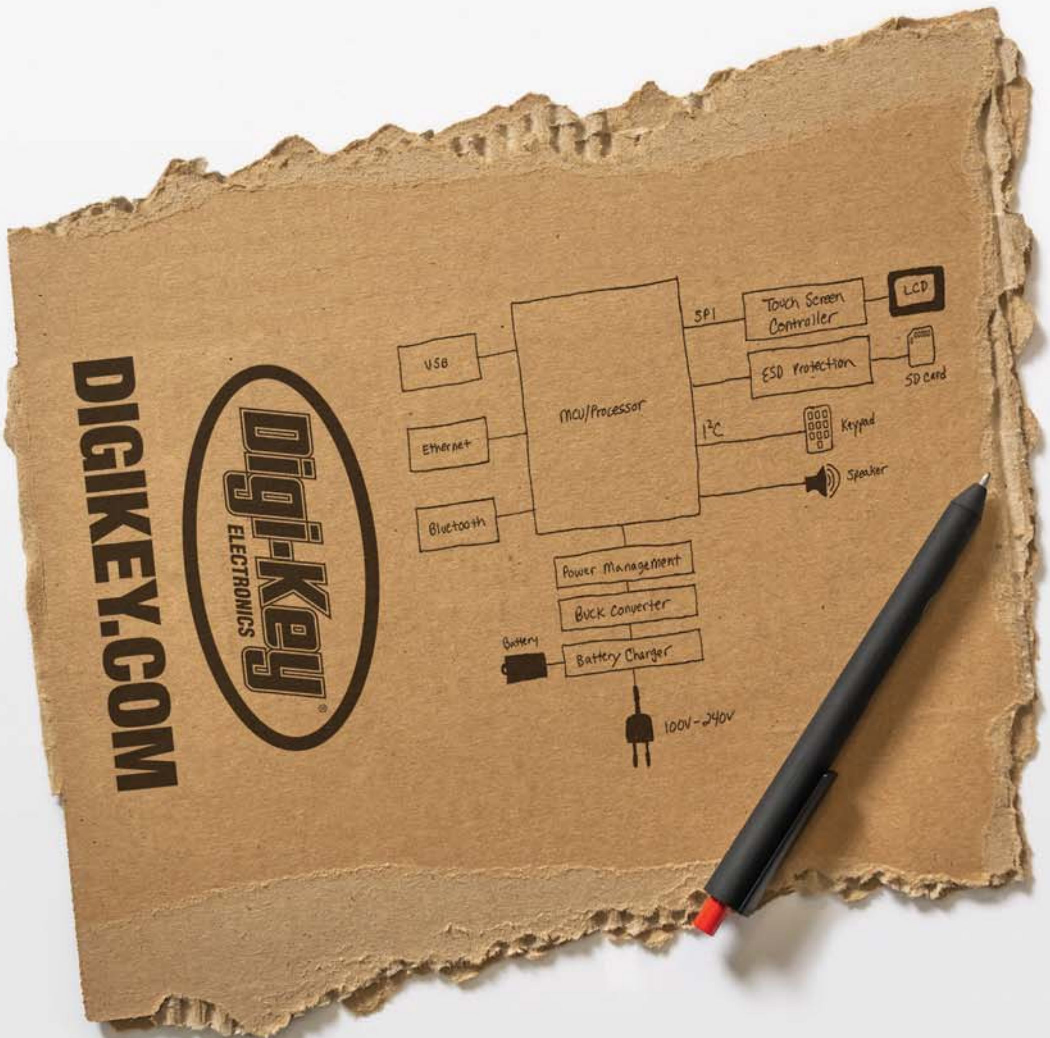

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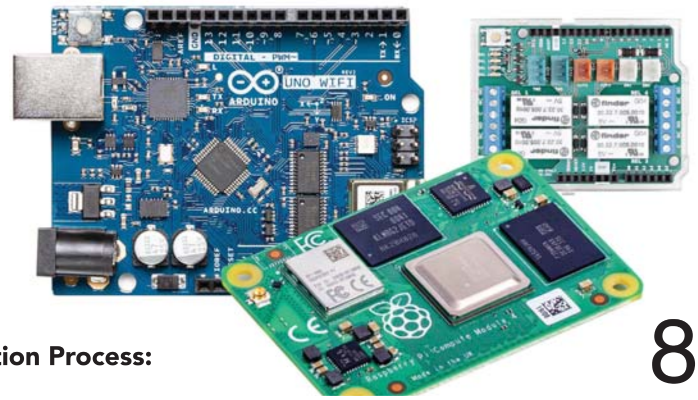

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ElectronicDesign 70 YEARS

Editorial

WILLIAM WONG | Senior Content Director
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Paying Tribute to a Great Educator

1. Lou Frenzel has been a regular technology editor with *Electronic Design* for decades.

Lou Frenzel has decided to put down the pencil. For decades, he's been a steady source of information in education and at *Electronic Design*.

IF YOU'RE A REGULAR *Electronic Design* reader, you have probably read a host of articles from Contributing Technology Editor Lou Frenzel *(Fig. 1)*. He's been a full-time editor as well as a contributing editor over the years and has finally decided to take it easy. We wish him well.

I write a lot, but I think Lou has me beat on the book side of things. As a budding electrical engineer, you may have used a copy of his *Principles of Electronic Communication Systems (Fig. 2)*. This hefty tome has been updated four times, with the fifth edition being released this year. You can also check out one of his many articles on *Electronic Design* like "10 Tips for Writing Your First Technical Book."

Having written almost two dozen books, he's an authority on writing as well as technology. His Communiqué blog has informed and entertained over the years and will be sorely missed.

Lou's career hasn't just centered around being an editor at *Electronic Design*. He held Vice President-level positions with Heathkit, Longman Crown, McGraw Hill, and Technovate. And he taught communication and electronics college classes for nine years.

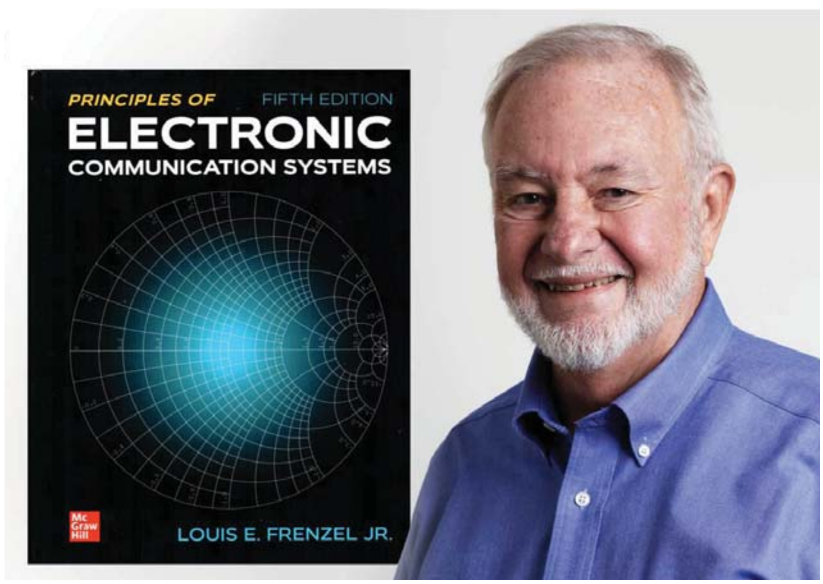
Lou started with a bachelor's degree from the University of Houston and picked up a master's degree from the University of Maryland. He's a longtime amateur radio operator (W5LEF) and electronic hobbyist.

We both started full time at *Electronic Design* in 2000, covering different technology areas. I focused on test, processors, and software, and Lou covered communications. This was back when print was king and a six-page article was considered small. Video was merely a glimmer from Hollywood.

These days, we record regular TechXchange Talks with engineers and CTOs. It's a much different arena now, and Lou adapted to the technology as usual, providing insights, entertainment, and education along the way.

As a budding electrical engineer, you may have used a copy of his ***Principles of Electronic Communication Systems.*** *This hefty tome has been updated four times, with the fifth edition being released this year.*

Lou now lives in Bulverde, TX with his wife Joan. You can still check out his latest projects on his website, *www.loufrenzel.com*. We will stay in touch, but I will miss his regular contributions to *Electronic Design*. ed



2. *"The Principles of Electronic Communication Systems"* by Lou Frenzel is now in its fifth iteration. (McGraw Hill)

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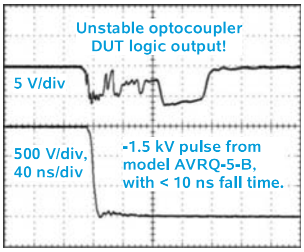

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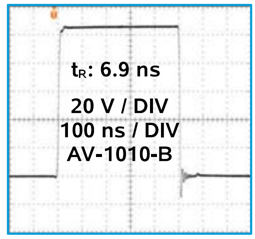

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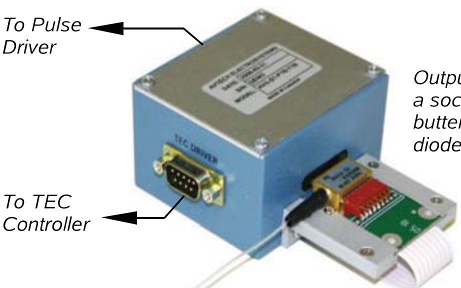
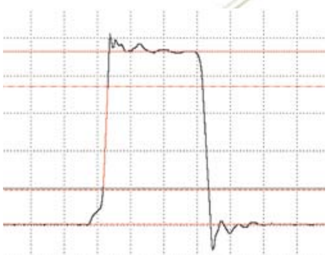


Output module with a socket-mounted butterfly-packaged diode installed.



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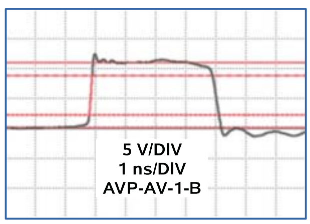

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20 V	200 ps	10 MHz	AVMR-2D-B
40 V	150 ps	1 MHz	AVP-AV-HV3-B
50 V	500 ps	1 MHz	AVR-E5-B
100 V	500 ps	100 kHz	AVR-E3-B
100 V	300 ps	20 kHz	AVI-V-HV2A-B
200 V	1 ns	50 kHz	AVIR-1-B
200 V	2 ns	20 kHz	AVIR-4D-B
400 V	2.5 ns	2 kHz	AVL-5-B-TR

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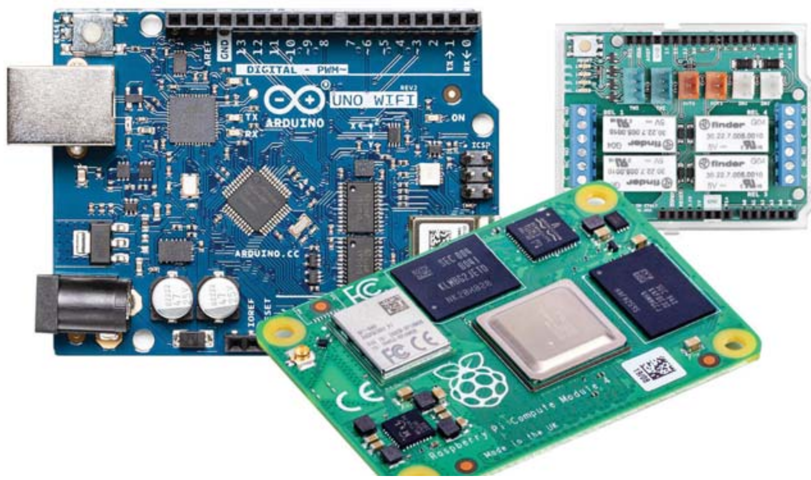
WILLIAM G. WONG | Senior Content Director

Using Popular Platforms in Industrial Settings

This article examines the rise of platforms like Raspberry Pi and Arduino in industrial solutions, including COM and SOM versions.



If you've looked at a development kit lately, it may be compatible with one of the popular hobbyist/maker platforms like Raspberry Pi or Arduino *(Fig. 1)*. It's not surprising given the ecosystems that have grown up around these popular platforms. This is partially due to the software infrastructure and available tools and applications, but it really comes down to the hardware compatibility.

Expansion boards like the Arduino 4 Relays Shield *(Fig. 2)* is why these platforms have become so popular. It's allowed third parties to give developers access to peripherals from wireless communication to gas sensors. The original platforms had standard interfaces such as USB, but they typically lacked features like wireless communication. Though later versions of these platforms included more features along these lines, there was no way a single board could address the needs of all users or vendors.

The Raspberry Pi's 40-pin, dual inline header has 3- and 5-V power plus digital I/O pins that include dedicated pins for a serial port, SPI, and I^{2}C in addition to pulse-width-modulation (PWM) signals.

The standard Arduino has multiple headers that make board layout interesting. Single inline connectors reside on both sides of the main board; the Arduino Uno has two 6-pin, dual inline headers as well. The single inline headers include a 28-pin set on one side and 7-pin + 8-pin set on the other side. Like the Raspberry Pi, digital I/O pins have dedicated pins for a serial port, SPI, and I^{2}C along with PWM signals.

Analog signals are available on both platforms depending on the host microcontroller. Most pins have more than one function associated with them, although only one can be active at a time. This makes for an intriguing tradeoff when attempting to deal with a stack of interface cards.

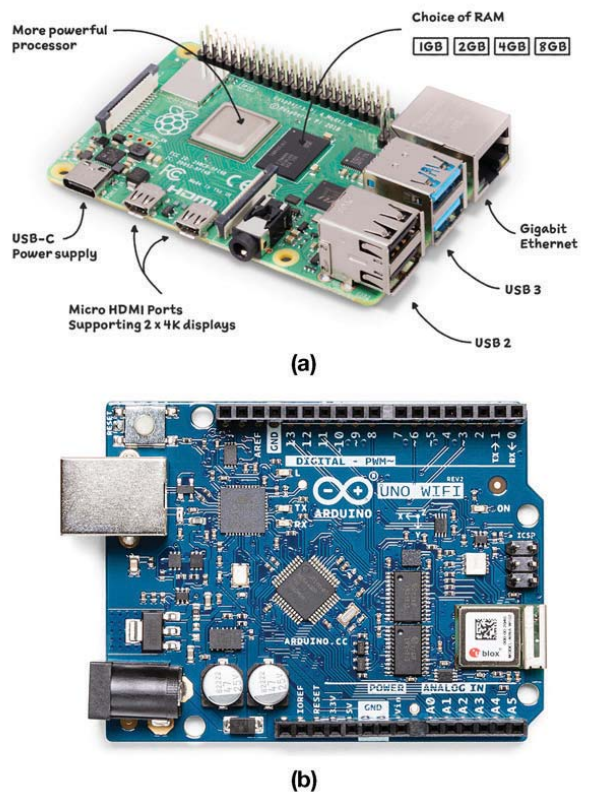
Not all cards are stackable, and conflicts abound as interfaces like SPI can't be shared by default. Multidrop interfaces like I^{2}C can handle multiple devices, but only if there are no address conflicts, which is often the case with the peripheral adapters. Having fixed addresses makes programming easier, at least for the provider of an adapter. However, that means two boards of the same type could not be used at the same time.

Rugged Design Issues

Some development boards are designed for ease of use, but they ignore things like mounting holes that are needed to provide consistent and reliable connections in industrial applications. Many peripheral boards simply rely on the interface headers to provide the electrical connection as well as physical stability. This tends to be a non-issue when using the system on a workbench, but it can lead to major problems in the field. For instance, when using prototypes in the field, shock, vibration, dust, and so on may become problematic.

Other issues designers will need to contend with are I/O protection and isolation, since these platforms often have limited support in this area. This includes considerations regarding connectors. Many I/O ports will use lower frequencies easily handled by even the headers employed on these systems. However, high-speed interfaces like USB and HDMI require better connectors and board designs.

Power and power sources are areas that will need to be examined when moving a design to production. Particular points of attention include power to the main board and power distribution to peripherals.



1. Raspberry Pi (a) and Arduino (b) are two of the most popular developer platforms that are often turned into industrial products. *(Credit Raspberry Pi Foundation and Arduino—a and b, respectively)*

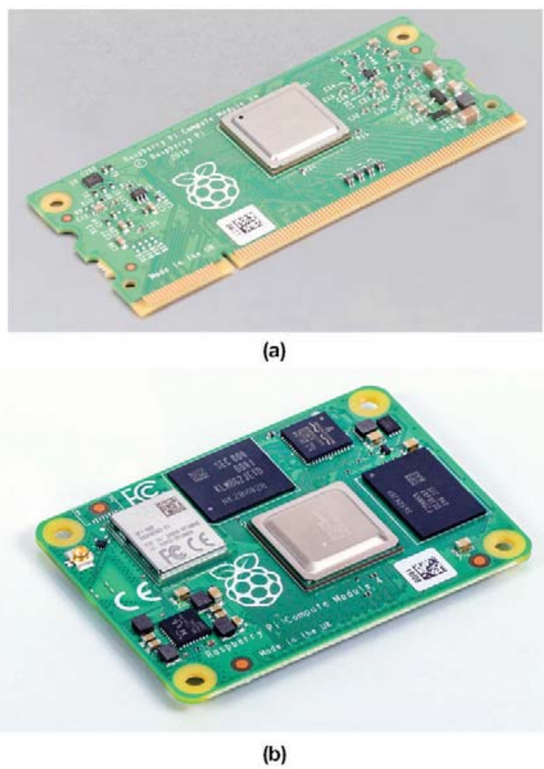
2. The Arduino 4 Relays Shield is an example of a peripheral card that can handle industrial interfaces. *(Credit: Arduino)*

Transitioning to Products

These days, designers are more cognizant of semiconductor availability. The general availability issues arise with Arduino-based solutions. However, a range of similar chips often can be used when building a new solution from scratch. The board schematics for these platforms are readily available and distributed as open-source hardware. Thus, they could be used as the basis for a customized printed circuit board (PCB).

Creating a custom PCB is a reasonable approach for Arduino platforms at the chip level, but not necessarily for Raspberry Pi platforms. The reason is that system-on-chip (SoC) processors used on the Raspberry Pi aren't generally available to companies that don't crank out tens of thousands or millions of products. It's possible to get similar chips, but additional hardware and software changes would be required, and they could be significant.

One alternative is to utilize a Raspberry Pi Compute Module. This computer-on-module (COM) uses the same processors but lacks the connections, thus requiring a standard socket instead *(Fig. 3)*. The Compute Module 3+ and Compute Module 4 are currently available in two different form factors. The former plugs into an SODIMM socket and has two mounting holes to keep things stable.



3. The Raspberry Pi Compute 3+ (a) and Compute 4 (b) are COM systems designed for industrial carrier boards.

Underneath the smaller-form-factor Compute Module 4 is a pair of high-density sockets. The inclusion of a wireless module simplifies the design for some applications. The module measures only 40 × 55 mm while providing more capacity, performance, and features.

Arduino has recognized that providing a more rugged solution is useful for both production as well as prototyping. The Arduino Portenta family is an industrial-grade system-on-module (SOM) that comes with Linux already installed in flash *(Fig. 4)*.

These industrial-grade modules come with industrial-grade prices as expected. There's no such thing as a free lunch, but the advantage is that the hard design aspects of these modules have been handled and the support and documentation are worth the additional cost.

4. The Arduino Portenta platform is an example of an Arduino platform design for industrial applications.

Designing carrier boards for these COMs is usually much easier than designing a custom PCB that would host the SOM. It may be as simple as a board that provides the necessary connectors, or it may add peripherals that might have been on peripheral boards in a prototype system. The carrier board often is simpler, with fewer layers than the COM PCB, since the carrier PCB usually isn't as dense as the COM.

Designer Issues

Designers must consider their own background and expertise when turning a prototype into a production solution. Though not a new issue, it's possible to generate a working prototype with these platforms very quickly. The assumption might be that a product could be created just as quickly. It's not out of the question, but infrequent.

If a module approach like the Raspberry Pi Compute Module is chosen, it can streamline the design process. However, other considerations should not be overlooked. For instance, the designers' backgrounds often determine how well these issues are addressed.

Analog, power, and communications tend to be the major issues when transitioning from a prototype to production. Analog interfaces can be some of the most difficult to contend with unless you have

These industrial-grade modules come with industrial-grade prices as expected. There's no such thing as a free lunch, but the advantage is that the hard design aspects of these modules have been handled and the support and documentation are worth the additional cost.

a background in this area. Noise, interconnects, and the operation of the analog interfaces can cause reliability and accuracy issues that may not have shown up in a prototype.

The same is true for power. Providing headroom from a single power source may be sufficient for some applications. However, everything from power surges to noise can be an issue when it comes to a production solution.

Communications also covers a lot of ground, especially for wireless communication. Industrial and even office and home environments can be electrically noisy. Though testing in different environments with different problems may be costly, it's necessary to provide a product that works and doesn't require significant support.

Finally, don't forget to design for production as well as design for serviceability. Usually, solutions based on platforms like Raspberry Pi or Arduino are simple and oriented around the software added to the system, with a few peripherals and minimal space constraints. In these cases, production and serviceability aren't significant issues. On the other hand, trying to pack a solution within a tiny footprint or having something with long-term support requirements may warrant design changes.

For example, Sfera Labs' Iono Pi Max is based on a Raspberry Pi Compute Module. One feature is dual SDcard sockets, as they use this type of flash memory for the operating system and data. They also add a watchdog microcontroller. The MCU can select which card the system boots from to manage field updates with a rollback option should an update fail to work properly. This wouldn't be found in a stock platform used for a prototype.

Reducing time to market has always been a goal for developers. Platforms and development kits are one way to speed the design process. Addressing the limitations and issues of moving from a prototype platform to production can help as well.

ANDREY SOLOVEV | Chief Technology Officer, Integra Sources

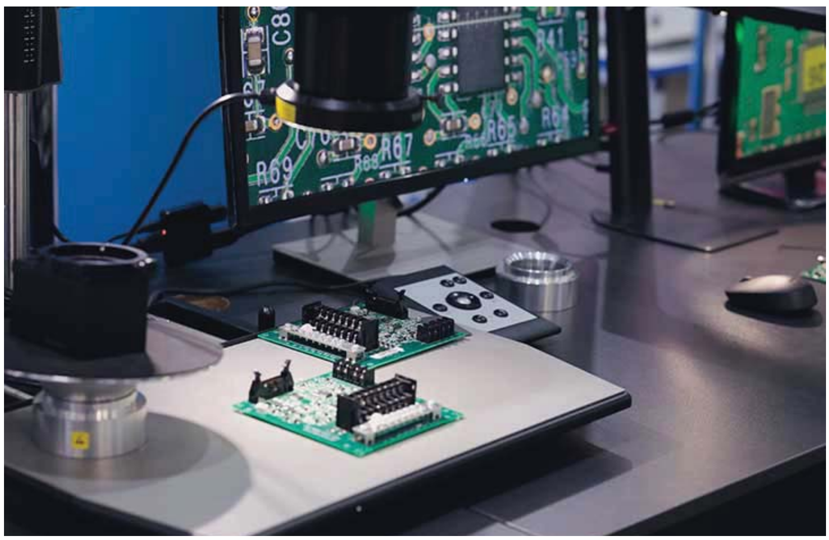
PCB Testing Throughout the Production Process: Matter and Methods

This article, devoted to the importance of PCB checks, shines a light on the most popular PCB testing methods and their application in circuit-board design and production.

Testing is a key element of printed-circuit-board (PCB) design. If PCB testing is used at all stages of the production process, manufacturers can save resources and increase productivity by ensuring the quality of their products.

PCB designers pay attention to the board's checks, as they want to be confident that indicators of PCB functionality are within allowed values, and the PCB is carefully made. Lots of quality checks are involved to make sure that the designed product can be produced at scale.

Such PCB tests can be applied to prototypes and small batches. They check boards for open short circuits and defect solder joints, as well as test their performance *(Fig. 1)*. The same goals are pursued by testing in mass production.



1. An inspection system with a digital microscope is used to check the quality of PCB soldering. *Credit: Genkur, iStock*

Manufacturers use different methods for PCB and PCB assembly (PCBA) examination. The choice of testing approach is associated with the production scale, product characteristics, and novelty.

Let's take a look at the most used and well-known procedures.

Manual Vision Inspection

Manual visual inspection (MVI), the oldest method of PCB inspection, doesn't require the use of expensive equipment *(Fig. 2)*. Examination by a specialist can identify such visible defects as bad solder, lack of details or their wrong position, cracked joints, and interrupted traces.

MVI isn't a highly effective method for mass production due to human mistakes and the increasing complexity of boards with hidden joints. However, this approach works well in PCB design and small batch production.

Automated Optical Inspection

Automated optical inspection (AOI) is more suitable for large-scale production. An AOI machine compares the photo of the tested circuit board taken by a single 2D camera or two 3D cameras to the given example. This equipment may be placed at the end of the production line for timely flaw detection.

The AOI system can be effective as the first stage of PCBA testing. This method is more accurate than MVI, but AOI equipment needs a substantial amount of time to install and program for every PCB design change. That's why it's not a good option for prototyping.

AOI can be used together with other methods of PCB testing—e.g., with flying probes, in-circuit testing (ICT), or functional testing—for a more accurate and complete examination.

Automated X-Ray Inspection

Automated X-ray inspection (AXI) is a unique testing tool as it uses X-rays *(Fig. 3)*. AXI creates 2D or 3D images of the hidden solder joints and can detect solder voids and open connections.

Being a rather costly and time-consuming technology, it's best suited for mass PCB production and checking complex boards. It also can be rather useful for prototype design and small-batch testing, because it's able to inspect the chip elements with pads that are out of sight.

In-Circuit Testing

In-circuit testing (ICT), or a "bed of nails," is a highly accurate type of electronics check. This is a fully automated and expensive appliance, so ICT is preferable as a final testing stage of high-scale products with a design that doesn't have to be changed.

ICT powers up each component of the board and provides their automatic verification one by one for open short circuits and incorrect orientation, and checks resistance and capacitance, providing more than 90% fault coverage.

ICT equipment uses fixed probes ("nails"), which are set in correspondence with the PCB access points. Nails examine the integrity of solder joints and verify the undamaged connection. ICT test jig fixtures, which can be either mechanical or pneumatic, are very efficient for mass-production testing.

Another ICT advantage is that it can examine ball-grid-array (BGA) assemblies, FPGAs, and power up, as well as try out LEDs.

Flying Probe Testing

Flying probe electronics testing (FPT) is a more budgetary alternative to ICT—it doesn't need a PCB test fixture and long programming time. However, testing PCBs with FPT is 15 times slower than ICT.

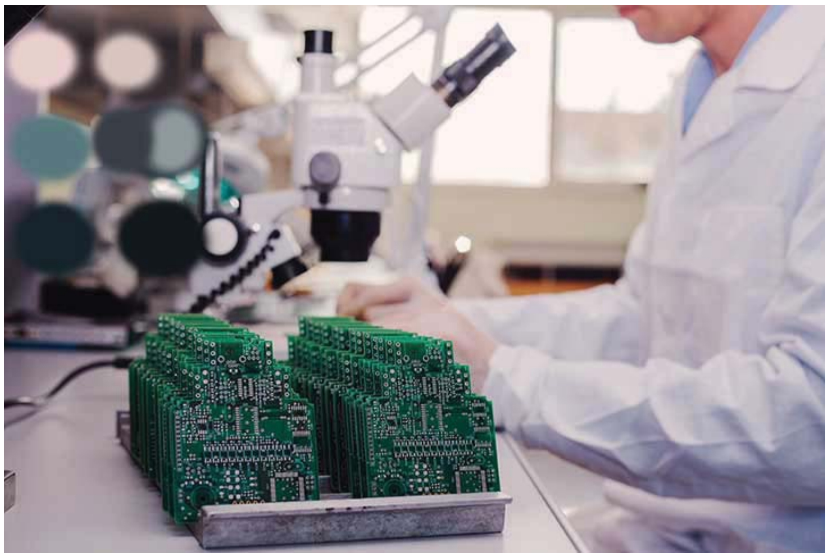
The FPT appliance inspects a PCB with the help of probes; some of them are static (they're under a tested PCB), others are movable (they 'fly" over the board) *(Fig. 4)*. The probes ("needles") are programmed to check all components of the PCB.

This method is more suitable for prototypes and not large batch production. It doesn't need much space and much time for installation and provides a high percent of coverage, but is a bit slow in testing.

Stress Tests

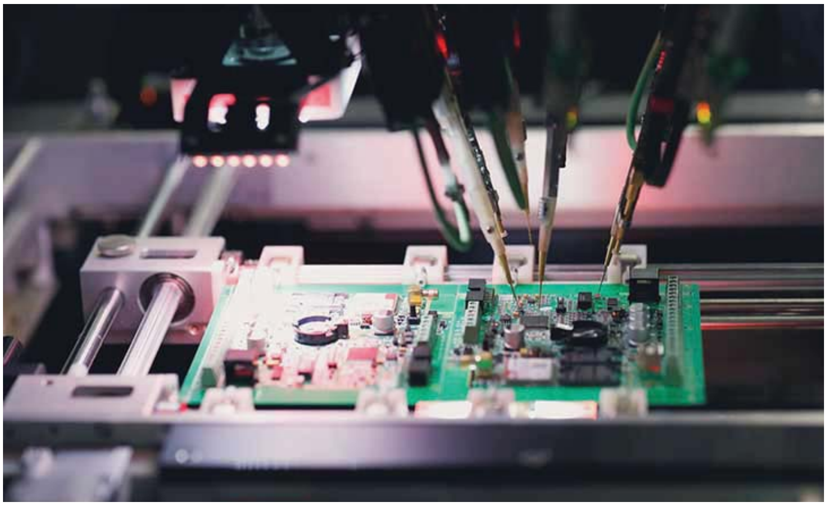
Stress tests may be needed to evaluate the ability of circuit boards to endure maximum loads and parameter changes. The functioning conditions examined can involve temperature, current, operating frequency, or other significant parameters. These tests are specific and therefore can be used for certain types of PCBs.

Burn-in testing is a way to examine designed templates and PCBs for mass



2. Manual vision inspection uses microscopes to examine printed circuit boards. *Credit: Franz12, iStock*

3. The automated X-ray inspection leverages X-rays to check system details. *Credit: Genkur, iStock*



4. A flying probe testing machine connects to PCB elements with the help of probes to conduct tests. *Credit: Genkur, iStock*

manufacturing. Burn-in testing supplies power to the PCB, typically at its maximum-specified capacity for two to seven days. It aims to disclose any problems or defects of the board by using it in extreme or prolonged working conditions.

Stress tests are in the HALT/HASS (Highly Accelerated Life Testing/Highly Accelerated Stress Screening) group of methods. Their purpose is to determine and get rid of faults as well as guarantee the product's quality at the development (HALT) phase or production (HASS) phase. They're most often performed for printed boards used in specific applications—medical and industrial equipment, aerospace, and automotive vehicles. Stress tests can be done for newly launched products to ensure that they're structurally and functionally reliable.

Functional Testing

The PCB Functional Test (FCT) examines the correctness of electronics performance. These tests are usually carried out at the end of the manufacturing process to verify the functionality of the PCB and its compliance with the specifications.

Depending on the PCB design complexity, and consumer's needs, tests may involve simply checking whether the board can be turned on or not, or a comprehensive full study.

PCB Laboratory Tests and Certification

Specially equipped laboratories can thoroughly examine circuit boards, using such appliances as an x-ray inner-layer registration tester, plating thick tester, impedance tester, copper adhesion tester, UV spectrophotometer, and many others.

Labs can confirm that the PCB meets all required requirements and specifications.

PCB Simulations

It's often too expensive to test certain design elements. Simulation tools enable designers to get the needed data without going through physical PCB tests. By using simulation, engineers can achieve economical goals and obtain appropriate results if testing equipment and other investigation aspects are too costly.

All elements of the PCB can be studied. PCB simulation software uses mathematical models to foresee PCB behavior.

Now let's take a look at some simulation tools in more detail.

Spice Simulation

Simulation Program with Integrated Circuit Emphasis (Spice) is a widely used simulation tool. Different Spice software packages may have various functions, but almost all of them can do certain types of basic PCB analyses.

DC Operating Point Analysis works with static dc characteristics. It can calculate all dc performance in the datasheet.

The transient analysis works with the time response. It calculates the voltage and current for each period.

AC Analysis works with frequency characteristics. It calculates the small-signal response of a circuit board and gives simulation results such as gain and phase characteristics versus frequency.

Other Spice tools, such as Temperature Sweep Analysis, Fourier Analysis, Noise Analysis, and Worst Case Analysis, also can be employed for a comprehensive investigation of PCB behavior.

IBIS Simulation

Input/Output Buffer Information Specification (IBIS), which simulates an integrated circuit's input/output buffers, is kind of an alternative to Spice simulation. It can be up to 100 times faster than Spice, but sometimes it's less accurate. IBIS calculates the board's behavior and can be used in PCB design at both schematic and layout steps.

The key element of the IBIS model includes a table with current, voltage, and timing characteristics. The IBIS model doesn't contain transistor-level data about the PCB, so vendors are assured about the safety of their intellectual property. Most IBIS models are easy to use and can be taken without restraint.

Conclusion

Testing is an essential stage of PCB design and production. Designers and manufacturers can choose and use appropriate investigation methods on their own or entrust them to special laboratories. Tests should guarantee the security and correct functionality of the PCB.

On that front, Integra Sources works with trusted and reputable manufacturers that conduct all required PCB tests. Our engineers pay a lot of attention to verifying all components of projects, running both hardware- and software-related tests.

To see the article in its entirety, go to www.electronicdesign.com.

YUVAL BOGER | Chief Marketing Officer, Classiq Technologies

What's New in Quantum Computing?

Many businesses are already working on various ways to create large, stable qubits that will power the quantum future. But how close are we to this, and what do we need to do to get there?

Quantum computers offer tantalizing competitive advantages to those companies that master their use. Governments, academic institutions, and private companies alike are investing in a quantum future.

As a reminder, quantum computers work with qubits—quantum bits—similar to transistors or classical bits. These qubits are operated on by quantum gates, just like logical gates in classical computers. The number of qubits in a quantum computer is a good first approximation to the power of the computer. The fidelity, or error rate, of the gates also is an important parameter.

Multiple vendors are working on various ways—often called modalities—of creating a large number of stable qubits. Some of these qubit modalities include ion trap (IonQ), superconducting (IBM), photonic (PsiQuantum and Xanadu), cold atoms (ColdQuanta and Atom Computing), and topological (Microsoft). Among the recent announcements are IBM reaching 127 qubits, Microsoft achieving a major milestone in topological qubits, and IonQ reporting increased fidelity of its qubits.

While these are just interim waypoints, they drive us closer to being able to deliver true business value from quantum computers. Though many advances are still needed in the hardware, some are predicting that just 420 qubits would be enough to outperform supercomputers capable of 1018 floating-point operations per second.

Another important implication is that a chasm is starting to form between quantum computers and classical computers. Generally speaking, any software that can be written for a 50-qubit quantum computer can be simulated on a classical computer. But as we get to 100, 200 qubits and beyond, such simulation is no longer possible.

We are entering uncharted territory with regard to what can be done with quantum computers, as well as with practical issues such as how to debug a program that you can't simulate, how to test that algorithms scale up correctly with the number of qubits, and more.

Why are Quantum Computers Considered a Strategic Technology?

The prospects of developing new compounds and better EV batteries, optimizing the supply chain to achieve substantial cost reductions, obtaining more accurate risk analysis, or gleaning new insights from quantum machine learning are exciting to business managers and CTOs alike.

The same is true not just for companies, but also for countries. Many governments see quantum computing as a strategic, enabling technology and have started national quantum programs. As of the beginning of this year, governments across the world have invested over $25 billion in quantum technology, with China ($15B) and the European Union ($7B) leading the pack.

Adm. Michael Rogers (USN, Ret.), former Director of the National Security Agency, says "Many nations around the world, particularly the most industrialized or the most developed [ones], have identified quantum as a technology that once perfected has both significant economic as well as national security impact and that there will be advantage to be gained by having those sets of capabilities. Particularly if you're able to do it earlier than some of your competition, whether that competition be from an economic perspective, from a national security perspective, or from an espionage perspective."

Realizing the potential of quantum, several companies are adopting a strategy of exploring quantum as an insurance policy. Just like in a regular insurance policy, one pays a small amount relative to the potential cost of an adverse event.

Thus, companies are exploring proof of concepts and training their people. They believe that such relatively modest investments can help them avoid situations where they're hopelessly behind competitors, where they're struggling to find qualified people, or where they're at some terrible disadvantage.

Can You Really Crack RSA Encryption with a Quantum Computer? Do These Computers Have Other Cybersecurity-Related Uses?

Yes, quantum computers have the potential to break the RSA encryption that secures most financial transactions around the world. RSA encryption uses two large prime numbers, known only to the sender and recipient. The product of these two numbers is made public, but RSA designers were confident that no machine would be capable of factoring it without spending several billions of years.

But quantum computers have unique properties, called superposition, entanglement, and interference. Algorithm developers utilize these properties to create algorithms that dramatically outperform their classical counterparts. One such algorithm, called Shor's algorithm, is a method for finding prime factors of a number much more efficiently than a classical computer, and thus break the RSA code.

We expect that sufficiently large quantum computers would require only a few minutes to break RSA, whereas a classical computer might take billions of years. However, such computers are still years away, giving companies some time to prepare for this change.

Indeed, companies have been working on communication methods called "quantum-resistant," meaning that they could not be broken by quantum computers. For example, Ciena, J.P. Morgan Chase, and Toshiba successfully ran a proof of concept for quantum key distribution, which is a mathematically proven defense against a quantum-computing cybersecurity attack. It's important to respect the power of quantum computing, but don't lose sleep over Shor's algorithm breaking our financial systems overnight.

How Soon Before One Can Own a Quantum Computer?

Most quantum computers today are hosted in the cloud. And, since the rate of hardware change is so big, it makes sense to keep it this way. Though some new advances make it possible for smaller quantum computers to run at room temperature, we're quite far from the time of personal quantum computers.

Cloud-based quantum computers make it easy to experiment with quantum technology without spending large amounts of money to purchase them. Indeed, many companies now look at quantum as an operating expense, as opposed to a capital expense.

Hosting on the cloud makes it easier to run what's known as hybrid algorithms. They utilize both quantum- and classical-computing methods to combine the advantages of each technology

How Soon Would Quantum Computers Deliver True Business Value, and in What Areas is this Expected?

Although the truly groundbreaking impact of quantum computing is predicted within the decade, a broad range of industries are exploring plenty of use cases. Some companies are taking the first steps of implementations.

One sector that's embracing quantum computing is the financial arena. J.P. Morgan Chase & Co., for instance, is integrating its framework with quantum technology for portfolio optimization and pricing financial options. NTT Data has explored credit risk analysis. Goldman Sachs has a large team of quantum experts. Some organizations, such as insurance giant AXA, understood the promise of quantum and are taking the long view—performing proof of concepts, building support inside the organization, and educating multiple busines units.

In the automotive industry, companies like Volkswagen are building internal quantum competencies. It did this after successful proof of concepts showed that using logistic optimization and quantum machine learning can minimize production costs and predict traffic patterns for autonomous vehicles. Volkswagen also used quantum computing for successful optimization of its paint shop scheduling. BMW recently completed a quantum challenge focused on multiple areas including sensor placement, configuration management, and more.

The power of quantum computing also can be seen when simulating interactions between molecules. This type of research can help scientists better understand the nature of this world, discovering new molecules for more efficient and powerful EV batteries or for pharmaceutical use, cutting down on time spent in early phases of trials searching for possible substances. In addition, energy and logistics companies have found quantum to be an intriguing way to optimize the supply chain.

The time when quantum computers outperform their classical counterparts doesn't rely strictly on qubit count. We also need these systems to be scalable and enduring.

Today's quantum computers are noisy, meaning that the fidelity of their calculation can easily be impacted by slight imperfections or small environmental changes. As a result, many quantum-computing experiments use hybrid quantum/classical algorithms. There's much to gain in using quantum computers for a small portion of the calculations and letting classical computers handle the rest.

There's widespread expectation that every month, quantum companies are improving their quantum computers: more qubits, less noise, greater fidelity.

There's widespread expectation that every month, quantum companies are improving their quantum computers: more qubits, less noise, greater fidelity. While the time to true quantum utility is still unknown, it's mostly a question of when, not if.

Though the quantum computer for everyday people is still a dream of the future, some investments are already paying off.

What are Key Challenges in Creating and Working with Nex-Gen Quantum Computers?

The most evident challenge in getting to the point of quantum computing producing massive, real-world changes is the scalability of hardware. Real, powerful use can only be achieved with larger, more complex systems. And there's much to do to grow these systems while reducing errors and noise.

Quantum physicists are hard at work engineering new solutions as more problems arise. They're creating more stable qubits, more accurate quantum gates, and more compact and scalable physical systems.

It's not easy to build larger systems—more qubits means more particles to tend to. Each addition to the system may affect the qubits' abilities to interact with each other productively or could introduce all sorts of errors.

There's also the need for larger and more efficient cryogenic systems for those hardware vendors dealing with close to absolute-zero temperatures. More qubits means more wires and equipment that needs to be stored in these cold chambers, which are not easy or cheap to make.

And as these systems scale up, the process of creating the software for larger computers becomes more difficult. Today, most software is designed by explicitly specifying the connections of qubits to quantum gates, or by cobbling together pre-written code blocks. As systems become larger, this manual process becomes difficult and will soon turn into being nearly impossible.

If we think about analogies from other disciplines, this progression isn't surprising. It's not difficult to write a few lines of code in assembly language, but you wouldn't want to write a mathematical simulation this way. It's relatively easy to connect together a few digital AND, OR, and NOR gates, but this isn't how companies design high-end CPUs. The process of writing software will need to evolve.

What Concepts in Electronic Design Might be Applicable to Quantum Computing?

When learning about digital electronic circuits, hands-on gate-based design is crucial to develop a basic understanding of digital concepts. However, once the basics are learned, very few people design large, meaningful systems by connecting discrete logic gates.

Instead, real solutions are implemented by specifying high-level functional models, while computer-aided design solutions (such as those from Cadence or Synopsys) handle the heavy lifting of synthesizing such a system from the functional design. A computer can do a much better job at finding appropriate implementations to the functional model, minimizing the number of gates, or fulfilling other design constraints that are important to the human designer.

Companies like Classiq are starting to apply this method to quantum computing, synthesizing sophisticated gate-level quantum circuits from high-level functional models. They apply similar methods to turn models into circuits while meeting a set of constraints (such as the number of qubits or type of gates being used) and optimizing the circuit to the hardware platform of choice.

Without the right software, quantum computers might be useless, so it's good to see that the ability to write sophisticated software progresses alongside hardware improvements.

Quantum computing is a game-changing technology for those that harness it. Don't wait to get started. ed

ADAM KIMMEL | Technical Content Writer, Mouser Electronics

EV Battery Chemistry and Its Impact on the Electronics Industry

The industry wants to know when electric cars will be available for everyone, but it's essential to understand the limiting component to answer that question.

Electric vehicles (EVs) are surging ahead, with new startups like Byton, Canoo, and Rivian entering the arena each year to follow Tesla's lead. In the meantime, automotive bluebloods GM and Ford have committed $7B and $11B (respectively) to defend their market-leading positions. Moreover, Europe and China paced the global markets with over one million new registrations in 2020. On top of that, the cost of EVs, long said by EV opponents to be a deal-breaking challenge, is coming down as supply ramps up. Nonetheless, significant technical and commercial challenges remain.

The industry wants to know when electric cars will be available for everyone. It's essential to understand the limiting component to answer that question, both from an economic and a technology perspective. The battery pack is the most expensive component in an EV, consuming 30% of the total cost to battery electric vehicle (BEV) and plug-in hybrid electric vehicle (PHEV) consumers.

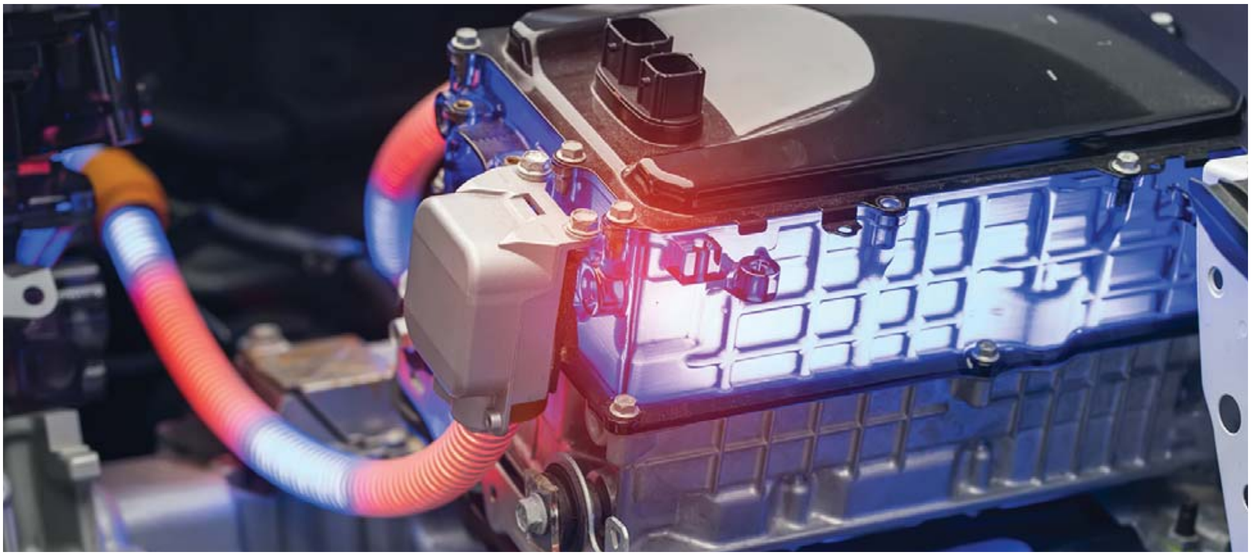
Still, with vehicle demand exponentially increasing, the cost per kilowatt-hour (kWh) is exponentially decreasing, down to $137/kWh at the end of 2020. BloombergNEF estimates that at $100/kWh, electric cars will soon be at cost parity with gasoline-powered vehicles.

Now that battery cost is on the decline, the key problems to solve are charging time and total range. Drivers expect a refueling time of around five minutes or less, which becomes the unofficial benchmark for EV charging. The battery chemistry and charging infrastructure will dictate how quickly a driver can charge an EV.

There's no clear choice for the best battery technology within the battery segment. Lithium-ion (Li-ion) dominates the market, but market alternatives offer exciting value propositions, including some technically superior to Li-ion.

But if the automotive industry genuinely shifts toward electric cars, the sharp increase in battery production will create unprecedented demand for minerals to make the batteries. Because many existing battery chemistries overlap with consumer electronics, it also will significantly impact that market. As a result, there will be tension in the supply chain for competing priorities over mineral supply between the two industries at the highest level.

The "winning" EV battery chemistry would ideally de-risk mineral supply while providing the technical and environmental benefits that EVs can deliver. What follows is a review of how the leading battery alternatives affect electronics.



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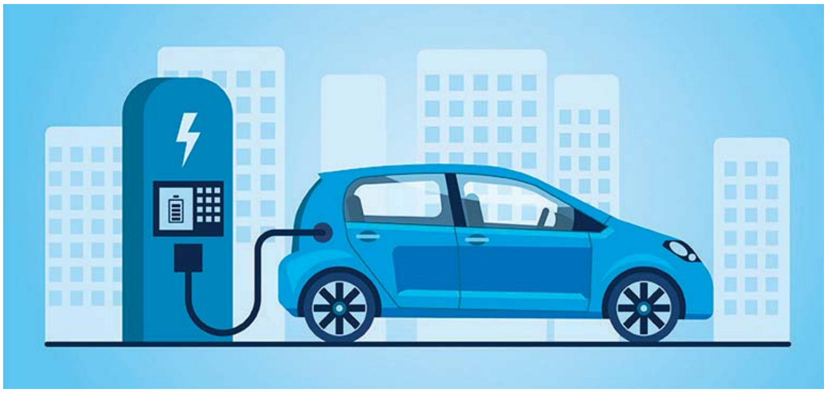


Top Battery Alternatives

The overwhelming majority of EV batteries are Li-ion-based. Li-ion's liquid-state technology works by employing lithium to carry the electric charge between the electrodes. To put the scale of EV batteries into perspective, they use 10,000X the amount of lithium of mobile phones, ramping up the demand for lithium and driving up its commodity price.

However, Li-ion is not without its challenges. Thus, battery manufacturers are developing alternatives, paced by nickel metal hydride (NMH), lead-acid, ultracapacitors, and solid-state batteries.

Li-Ion

One of the biggest reasons electric-vehicle manufacturers prefer lithium-ion battery technology is its high power-to-mass ratio. Heavy components are the enemy of range, as the battery uses too much energy starting and stopping a heavier vehicle instead of traveling a further distance per charge.

In addition, Li-ion batteries have high energy density and better performance than their alternatives at elevated temperatures. Li-ion's use in the consumer electronics industry is partly responsible for the high energy density.

The decreasing size of electronics and the desire for longer operating hours per charge spurred innovation in this parameter. As a result, Li-ion's energy density is more than 2.5X greater than both NMH and lead-acid batteries. In addition, Li-ion batteries are recyclable, making them a good choice for environmentally focused consumers.

Lithium batteries consist of:

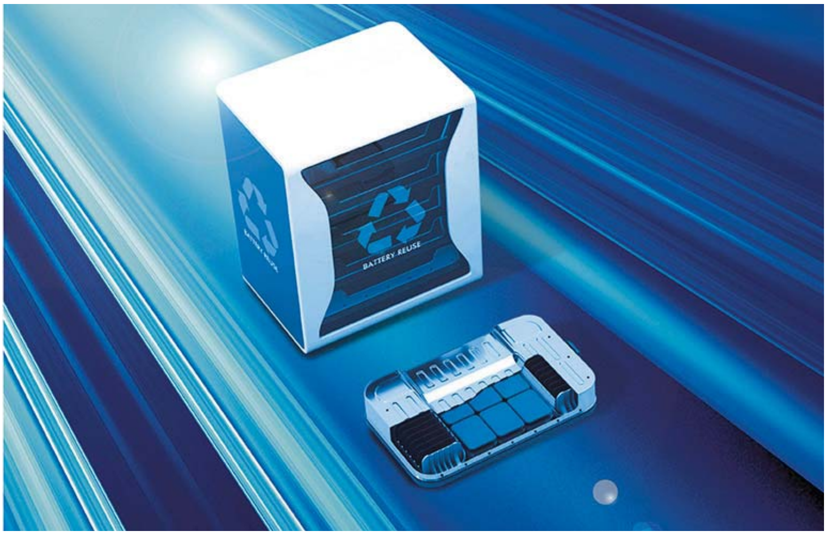
- A cathode (source of lithium-oxide ions) that determines the capacity and voltage of the battery.
- An anode (releases lithium ions) that enables electric current to flow through to an external circuit.
- An electrolyte (comprised of salts, solvents, and additives), a medium that enables the movement of ions between cathode and anode. It's what gives the name to the battery type ("Li-ion" means lithium carries the ions).
- A separator to prevent direct contact between the anode and the cathode.

These benefits are why Li-ion is the preferred technology for consumer electronics. However, automotive applications demand specific energy (expressed in W-h/kg). These demands are substantially more severe than for consumer electronics, prompting the U.S. Advanced Battery Consortium (USABC) to develop energy targets. These targets and the plateauing progress in improving energy density indicate that scientists may need to create or consider new materials to meet the energy demand.

Changing or modifying the Li-ion battery chemistry for EVs may affect the cost, supply chain, and availability of the new materials for non-automotive applications.

Nickel Metal Hydride (NMH)

While Li-ion is the standard for all-electric vehicles (AEVs), NMH is better



suited for hybrid electric (HEVs) and plug-in hybrid electric vehicles (PHEVs). Though NMH has a better lifecycle than Li-ion or lead-acid, the chemistry brings its share of tradeoffs.

NMH batteries are less expensive than Li-ion but experience higher self-discharge rates when not in use. They also generate substantial heat at the hotter end of the operating range. Rejecting excess heat reduces range and shortens product life cycles. This technology also risks undesired hydrogen loss that manufacturers and consumers must monitor and control.

Though seemingly unlikely, an uptick in NMH demand for EVs would affect cell phones, computers, and similar electronic devices. In addition, power tools often use NMH batteries, so a shift in demand or availability of minerals could significantly impact the construction industry.

Solid-State Electrolytes

The clear winner for liquid-state electrolytes is Li-ion, especially with the percentage of BEVs likely to substantially increase in the coming years. But Li-ion is sensitive to cost swings due to market movement and reshuffling, along with skyrocketing demand.

In addition, there's an opportunity to improve the top safety concern of flammable liquid catching fire. Safety is one of the most critical success criteria for EVs to inspire public confidence, so industry and safety regulators would likely welcome an opportunity to step up the safety features.

Solid-state batteries (comprised of lithium metal) address the most pressing safety challenges of Li-ion, using essentially the same chemistry. Solid-state technology utilizes a solid disc electrolyte, whereas Li-ion employs a liquid. Long thought by many engineers and materials scientists to be the long-term solution for EVs, devices like pacemakers, radio-frequency identification (RFID), and wearables already use solid-state technology.

Solid-state batteries are more stable, have a higher energy density than the already high-density Li-ion, come from readily available materials, offer lower flammability and faster charging, and improve and extend the performance range of EV batteries. For these reasons, solid-state batteries seem like the future.

Barriers to Wide-Scale Adoption

Solid-state looks to be the future of EV batteries, but developers must solve some of the challenges to widescale adoption. Solid-state batteries will carry a higher development cost due to a lack of capital to produce mass quantities. It's crucial to get this cost down to encourage consumers to purchase cars with these kinds of batteries.

Gaps in the solid Li electrolyte material degrade battery performance and service life when implemented into BEVs. In addition, solid-state batteries are prone to cracking and like to charge at 60°C for optimal performance.

Another challenge was that a condition of high electrical resistance existed between the positive electrode and the electrolyte. Researchers learned that annealing (heating at a specific temperature over a particular amount of time) in combination with preventing exposing the electrolyte to water vapor brought the resistance back in line.

As with any development material, it will be critical for the manufacturing process to be efficient. There hasn't been a mass-produced solid-state battery for electric vehicles to date. As a result, manufacturing challenges through lack of experience with the solid electrolyte material would substantially delay wide-scale adoption. A manufacturing issue also could cause the EV battery plant to shut down, delaying the majority of the public's first interaction with the new battery and affecting consumer confidence.

The need to anneal and shield the solid material from water vapor may influence how engineers apply this technology. The extra steps to condition the electrolyte could enable the design for mass production. Still, it may add lead times to components using the material and add conditioned storage costs to avoid exposure to water vapor.

Conclusion and Takeaway

EVs are changing the way we think about batteries. Engineers are challenging previous realities like specific energy limits and materials of construction. The extra demand for EV charging, safety requirements, and efficiency goals may disrupt the electronics industry, closely tied to electric vehicles, through their battery technology. Understanding how EVs' economic and technical developments influence electronics and other related markets is essential for seamless implementation. ed

BOB ZOLLO | Solution Architect for Battery Testing, Electronic Industrial Solutions Group

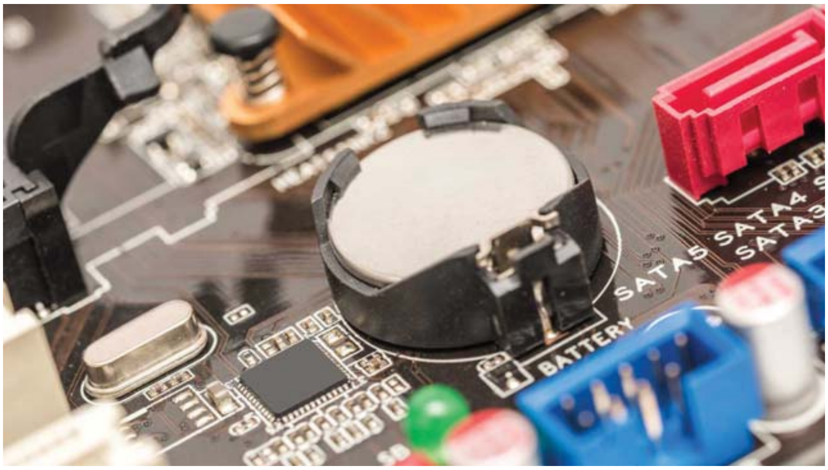
How to Prepare for Battery-Cell Discharge Testing to Low Voltage

What challenges emerge when performing low-voltage-discharge testing? This article discusses those issues and presents solutions, as well as recommends the proper equipment to use during such tests.

When discharging battery cells, it's sometimes desirable to discharge the cells to a low voltage. Under normal operation, care must be taken to prevent discharging the cell below the safe operating voltage of the cell. However, when testing cells, the purpose of the test may be to characterize cell behavior when pushed below normal operating voltages. In this article, I will focus on lithium-ion cells whenever I use examples of voltage thresholds, but the challenges and solutions to low-voltage testing are the same—independent of the cell chemistry.

Referring to my example of a lithium-ion cell, the minimum discharge voltage is when the open-circuit voltage (OCV) of the cell hits the voltage associated with 0% state of charge (SoC). While the minimum OCV of each lithium-ion chemical formulation, such as iron phosphate or nickel manganese cobalt, is different, this number is typically in the 2.5-V range. Some chemistries can go down to 2 V or even lower.

Depending on the nature of the test, you may want to keep within the safe operating voltage or drive the cell down lower in voltage. For example, if you're performing a cell cycle-life test, the goal is to properly cycle the cell between charged and discharged states. This determines how long the cell will survive before it loses its ability to adequately hold a charge.



For this test, you will want to keep the cell within its normal operating OCV range to prevent damaging the cell because of over-discharging or over-charging. By contrast, for safety testing, you may want to deliberately discharge the cell beyond its minimum OCV to characterize its behavior and determine when the cell becomes damaged or even dangerous.

Low-Voltage-Discharge Test Equipment Choices

To conduct these tests, you will need test equipment capable of discharging cells to a low voltage. In a cell characterization lab, such as found in an electric-vehicle OEM, you will be testing many cells and have many tests to perform, so dedicated turnkey cell test equipment is warranted.

For some users, such as the design team of a small IoT device, cell testing may be just a small part of their overall design task. For this lab, a dedicated turnkey cell tester may not be worthwhile. Instead, standard benchtop power supplies and electronic loads may be utilized for the occasional cell test. *Table 1 (page 24)* describes various types of test equipment that can be used.

From *Table 1*, you can see that there are two cases for test equipment *(Table 2)*.

For case 2, what is the cause of this limitation on low-voltage operation? Why can the more expensive equipment for case 1 operate down to 0 V but not for case 2? The answer is related to how power electronics operate to produce negative current to discharge cells.

How Does an Electronic Load Work?

Fundamentally, an electronic load or a cell-discharge circuit in the battery test system must present a load on the cell to pull current out of the cell. In its simplest form, that load is a resistor. Due to Ohm's Law, the current through the load resistor would be a function of the voltage across the resistor. So, as the cell discharges, the cell voltage would drop and the current through the resistor would drop, resulting in a non-constant current load condition.

Therefore, in practice, no cell test equipment company would propose to use a resistor, as they're not programmable, and they cannot produce a constant current load on the cell.

Instead, in its simplest form, test equipment uses a transistor, typically a field-effect transistor (FET), to discharge the cell.* The FET looks like a resistor that can be varied by a control voltage. The current through the FET is measured using a current-sense resistor (i.e., a current shunt). The measured current is provided as a feedback signal to the discharge control circuit so that the current can be regulated to a fixed constant-current value.

The discharge control circuit adjusts the resistance of the FET to maintain the required constant current out of the cell independent of the cell's voltage, creating a variable resistor that's controlled to draw regulated constant current from the cell during a test. The power drawn from the cell is the product of the voltage of the cell times the current drawn from the cell.

For some test systems that are either lower in power or less sophisticated, the power being drawn from the cell is dissipated as heat. In more sophisticated sys-

Case	Equipment Type	Voltage range	Intended purpose	Considerations
1	Dedicated battery test system	5 V to 0 V with +/- current	Full cell characterization within normal operating OCV and beyond.	The wide operating range of this tester requires the most sophisticated system design, increasing equipment size and cost.
2	Dedicated basic battery cycler	4.5 V to 2 V with +/- current	Cell cycle-life testing restricted to operation within normal OCV range of the cell.	The limited operating range of this cycler reduces equipment cost and complexity, but also limits the ability of the equipment to just cycling as its operating range doesn't support full wide-range cell characterization.
1	4-quadrant power supply, often referred to as an SMU (Source-Measure Unit)	+5 V to -5 V with +/- current	Not specifically intended for cell testing, but the ability to generate any +/- voltage along with +/- current means it can charge cells (+ voltage, + current) and discharge cells (+ voltage and – current). Since it can operate down at low voltage, it can perform cell characterization within normal operating OCV and beyond.	SMUs are often expensive and generally not available above 50 W of output power. However, if you're only testing a small number of low-power cells, the total flexibility of the SMU for cell testing and other general electronic testing tasks make it an excellent choice in a small laboratory.
1	2-quadrant power supply	+5 V to near 0 V with +/- current	Not specifically intended for cell testing, but the ability to generate voltage down to near 0 V along with +/- current means it can charge cells (+ voltage, + current) and discharge cells (+ voltage and – current). Since it can operate down at low voltage, it can perform cell characterization within normal operating OCV and beyond.	2-quadrant power supplies can be expensive but are available up to 20,000 W of output power. Testing very large cells under high-current conditions is possible with these supplies. Again, if you're only testing a small number of cells, the flexibility of a 2-quadrant supply for cell testing and other general electronic testing tasks make it an excellent choice in a small laboratory.
2	Electronic Load	4.5 V to 2 V with - current only	Electronic loads can be used to discharge cells but not charge cells, as electronic loads only pull current from the cell. When using electronic loads to discharge cells, the minimum operating voltage of the load (typically 2 V) means the electronic load cannot be used for full cell characterization that requires low-voltage operation.	Electronic loads are available at various price points and power levels. While a cost-effective option when testing a small number of cells in a small laboratory, an electronic load will need to be combined with a power supply if charging is required.

Table 1

Case 1	Discharge to low voltage to 2 V or less.	In a large cell-testing lab, for the highest flexibility to enable low-voltage discharge testing, dedicated high-performance cell testers are needed. Alternatively, for a small laboratory, a more costly SMU or 2-quadrant power supplies can be used.
Case 2	Discharge to normal cell minimum voltage of 2 V or greater.	In a large cell-testing lab, for testing that's limited in voltage range, a basic cycler can be used if low-voltage discharge testing is not required. Alternatively, for a small laboratory, a general-purpose electronic load can be used for cell testing, but it cannot perform low-voltage testing and will need to be coupled with a power supply for charge testing.

Table 2

tems, the power is captured and regenerated back to the ac line.

Limitations and Solutions for Low-Voltage-Discharge Testing

While this FET load method has worked quite well for years, it suffers from a limitation. As the discharge control circuit wants to draw more current, it programs the FET to have lower and lower resistance. Eventually, the FET's resistance cannot be "turned down" any further—it has reached its minimum resistance, known as the full-on resistance of the FET.

Once the FET reaches this minimum resistance, it just operates as a fixed, very low resistance. As the voltage of the cell goes toward 0 V, the maximum current that can be drawn drops linearly because of Ohm's Law:

Max_Available_Load_Current = Cell_Voltage / FET_Full-on_Resistance

This behavior is visible in the discharge characteristic of the cycler channel or electronic load.*

If you need to go below 2 V with a basic cycler or an electronic load, there's a solution. It's possible to put a boost supply in series with the output of the cell.* This boost supply adds the required voltage to keep the input voltage to the cycler or electronic load above this minimum operating voltage such that the discharge control circuit never has to push the FET to its full-on resistance state.

The boost supply can be complex to configure and adds extra cost to the test setup. But if you must test at low voltage and you're limited to the equipment you have available, this may be a viable choice. In a future article, I will cover how to configure a boost supply to allow for low-voltage operation.

For case 1, where the test equipment can go to 0 V or even negative voltage, the boost supply is effectively built into the tester architecture. Therefore, the cell test channel or SMU can, by design, achieve low-voltage operation without the external boost supply, thanks to its internal boost supply. While this gives you the greatest flexibility, it does mean the testers are more complex and will carry a higher cost.

Summary

If low-voltage-discharge testing is required by your test protocol, it's recommended to buy test equipment that supports low-voltage-discharge testing below 2 V. For cycle-life testing, where your test protocol never requires low-voltage-discharge testing, savings is possible by selecting equipment that doesn't support operation below 2 V and doesn't have a built-in boost supply. ed

**For accompanying images, please see the online version of the article at www.electronicdesign.com.*

ElectronicDesign 70 YEARS
Design Feature
BENJAMIN REISS | Field Applications Engineer, Analog Devices

A Better Way to Optimize Signal Chains: Use a CTSD Converter

Thanks to their resistive inputs and inherent filter properties, CTSD ADCs can simplify and optimize numerous signal-chain designs.

The CTSD topology offers possibilities for optimizing signal chains beyond traditional architectures. Many of today's applications require smaller form factors but still demand the same performance. Developers are often faced with the question of how to realize this and frequently make do with compromises.

For example, it's possible to reduce the form factor by sacrificing noise performance or accuracy. This article explores using a continuous-time sigma-delta (CTSD) converter as a new way to optimize the design and reduce bill-of-materials (BOM) costs and form factor.

Optimizing the Design

To achieve an optimal yield of the desired sensor or signal, all elements in the signal chain must be perfectly coordinated. Several discrete components are usually used, from the sensor to the analog-to-digital converter (ADC). Apart from the sensor and the ADC, oftentimes there are instrumentation amplifiers, ADC drivers, reference buffers, and filters. The selection of an appropriate ADC driver and the filter design, in particular, represent sources of error that are repeatedly underestimated.

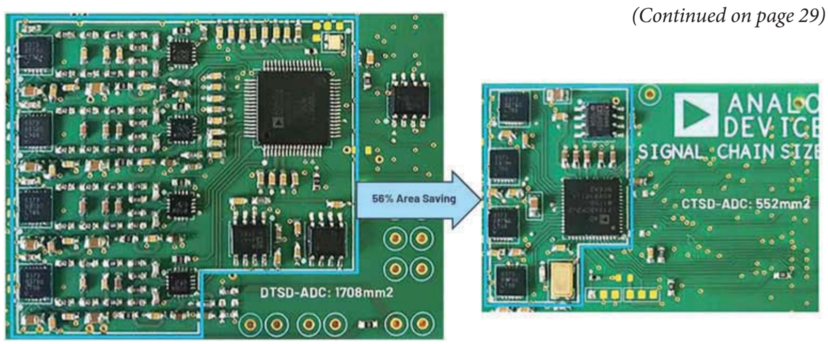
One way to optimize the design and reduce BOM costs as well as form factor is to use μModule devices. These devices are highly integrated solutions containing the converter as well as buffers and passive components. With this new CTSD technology, it's possible to drive the ADC directly without having to use an amplifier as a buffer. In addition, the new topology allows for simplification of the filter design.

DT-ADCs vs. CTSD Converters

Figure 1 shows the difference between the traditional discrete-time ADCs (DT-ADCs) and CTSD converters. Compared with the traditional design, the CTSD design allows for a reduction in form factor of up to 68%.

Traditional DT-ADCs, such as SAR ADCs or sigma-delta ADCs, use the switched capacitor topology. This is found on the ADC and reference inputs. Differentiation is made between the two phases "sample" and "hold." They correspond to charging and discharging of the "hold" capacitor. Hence, there must be enough current supplied for charging and discharging as well as charge absorp-

(Continued on page 29)



1. A comparison of DTSD and CTSD form factors, showing clear savings through CTSD ADCs.

JAMES MORRA | Senior Editor

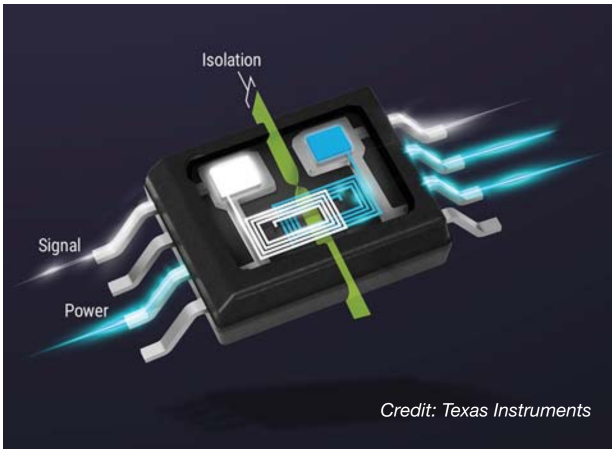
High-Voltage Batteries Ahead! Proceed with Isolation!

TI is trying to transform the tightly wound cylindrical coils and mechanical switches of traditional relays into components that can fit inside a standard IC package.

Texas Instruments introduced a family of solid-state relays that uniquely integrates power and signal transfer in a single chip with robust isolation that is becoming standard in electric vehicles (EVs).

The chips include the TPSI3050-Q1 isolated driver IC with an integrated 10-V gate supply and the TPSI2140-Q1 1,400-V isolated switch that delivers "industry-leading reliability" in a smaller envelope while reducing costs.

Jeff Morroni, head of power management R&D at TI, said car manufacturers are building batteries into EVs that have close to 10X the voltages of most vehicles on the road. As a result, they are also investing in "isolation" technologies to help keep everyone and everything inside safe from high-voltage hazards.



Credit: Texas Instruments

Danger! High-Voltage!

Electronic isolation prevents the flow of dc and excess ac between various building blocks of a high-voltage system while still allowing signals and power to flow between them. The purpose of isolation in electric vehicles is to prevent high-voltage spikes that can deliver a deadly shock or damage the electronics inside.

It is valuable when ferrying power between low- and high-side devices that must never be connected for safety purposes. Insufficient isolation also opens the door to noise and electromagnetic interference (EMI).

"Anywhere you have high voltages, safety is critical, and high voltage is critical anywhere you have to transfer power more efficiently and cost-effectively," said Morroni, adding that in battery management and other systems in EVs, "we need to ensure the high voltages don't make it to the chassis to prevent shock."

Today, most electric cars have internal architectures that can handle 400 V of energy from a battery pack, a step up from the 12- and 48-V systems that dominate cars today. But now, 800-V batteries are becoming standard to increase EV range and reduce charging times.

Every system in the EV is connected to the high-voltage battery pack. But the delicate electronics—such as the microcontrollers (MCUs) and other chips that control the systems in the EV—require only several volts.

TI is investing more in isolated power supplies and other automobile-grade chips such as the TPSI3050-Q1 and TPSI2140-Q1. These types of devices help electronics safely sip from the torrent of energy flowing on the main power bus and communicate with electric motors and other high-voltage, fast-transient systems.

Isolation-on-a-Chip

Designing for high reliability in high-voltage EVs typically requires the use of bulky, heavy, and thus, costly, components such as transformers and relays to control hazardous voltages and currents.

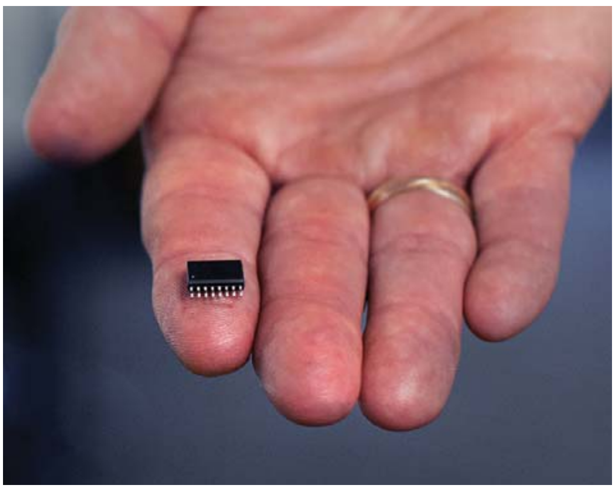
But as systems in electric cars get more compact, the components inside them must also sit closer together. That presents new design challenges for isolation, said TI's Troy Coleman, VP and GM of power switches.

TI is trying to transform the heavy coils of wiring winding in transformers and the tightly wound cylindrical coils and mechanical switches of relays into components that can fit inside a standard IC package while maintaining safety.

TI rolled out in 2020 a proprietary integrated transformer technology that brings high-density, isolated dc-dc power conversion into a single package, replacing transformers—one of the stalwarts in the world of isolation, used for safety purposes and to keep transients and harmonics in check. To help reduce costs in electric vehicles, TI is integrating the technology into more of its high-reliability automotive power supplies.

The solid-state relays are the latest in TI's growing portfolio of ICs for isolating signals and power in cars. The company said they are the first in a solid-state relay family that will include industrial-grade devices.

Protecting against high-voltage spikes is vital in industrial-grade power supplies, such as solar and other renewable-powered grid inverters, in addition to robotics and motor-control systems. Eliminating disruptive ground loops in power rails with large ground-potential differences (GPDs) is important. Preserving data during common-mode transients and keeping high-side devices safely isolated also are priorities.



TI said that its integrated transformer technology shrinks power solution size by up to 80%. *(Credit: TI)*

Reinforced Isolation

The TPSI3050-Q1 is TI's automotive-grade switch driver with reinforced isolation that can be paired with a single dc power switch or dual back-to-back ac power switches to create a complete solid-state relay. TI said the chip integrates power and signal transfer across a single "isolation barrier" that separates the low- from the high-voltage side (the battery side) of the power rail to better protect against high-voltage spikes.

The integrated 10-V gate supply voltage means there's no need for an isolated secondary supply bias. The TPSI3050-Q1 can also serve as an isolated dc-dc power supply that delivers 50 mW to auxiliary ICs.

TI said the highlights of the TPSI3050-Q1 are robustness and reliability. The reinforced isolation offers up to 5 kV_{RMS} of protection. According to TI, the switch driver, which can handle a harsh temperature range of –40 to 125°C, has a 10X longer lifespan in a smaller package than electromechanical relays, which can break down through constant use. The chip fits inside a 7.50- × 5.85-mm SOIC package.

For safety purposes, many industry standards require parts with "basic" isolation, which according to TI offers a single layer of isolation against shock and other hazards in cars. But that means if the isolation barrier is breached, any additional protection is gone. For "reinforced" isolation, the components must be able to prove electrical strength, reliability, and shock protection equal to twice the basic isolation rating.

The high level of integration in the chip displaces at least three components, reducing the footprint up to 90% by integrating the functions of an isolated power supply, digital isolator, and gate driver in a single chip.

The new solid-state relays can disconnect and connect loads through a single isolation barrier in a fraction of the time of electromechanical relays, allowing for safer operation of high-voltage automotive systems.

With an integrated gate-drive voltage of 10 V with 1.5/3.0-A peak source and sink current, TI said that its customers can pair it with a wide range of external power switches in systems such as onboard chargers.

50% Off Isolation

The TPSI2140-Q1 is a 1400-V, 50-mA isolated switch that also integrates power and signal transmission in a single chip, saving up to 50% of space compared to other non-mechanical devices called photorelays.

Basic isolation protection is 3.75 kV_{RMS}, giving it 4X greater durability against dielectric breakdown than alternatives. The chip tolerates up to 2 mA of avalanche current—3X more than existing solutions to bolster safety and slow down degradation. TI also offers the TPSI2140T-Q1, equipped with its Thermal Avalanche Protection (TAP) feature, which can contain avalanche currents up to 5 mA, adding further robustness.

The component, housed in a 10.3- × 7.5-mm SOIC package with wide pins for improved thermal dissipation, runs on a primary side supply current of 7.5 mA in the "on" state and 6 μA in the "off" state.

A wide range of other protection features are being brought into the fold with the TPSI2140-Q1, which uses the company's capacitive isolation technology to protect against high-voltage spikes in electric cars. The switch withstands a peak voltage surge—also called V_{IOSM}—of up to 6,000 V. Furthermore, it has an estimated useful lifespan of more than 25 years under high voltages of 1,000 V_{RMS}.

TI said that it is ideal for battery-management systems at the heart of EVs to detect faults in the insulation enveloping high-voltage batteries faster and with higher reliability than optoelectronics-based photorelays.

The TPSI3050- and TPSI2140-Q1 are in pre-production. Pricing is $1.99 and $2.75, respectively, in 1,000-unit quantities.

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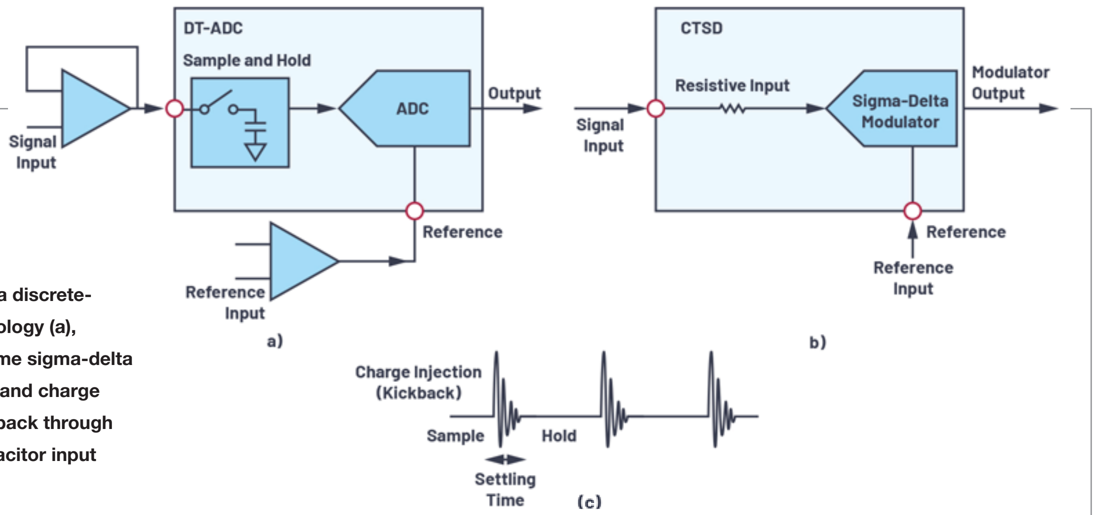

2. Shown are a discrete-time ADC topology (a), continuous-time sigma-delta converter (b), and charge injection kickback through switched capacitor input stage (c).

tion due to parasitic properties (charge injection kickback) *(Fig. 2)*.

Many sensors are unable to supply such high currents and hence require buffering. Apart from this function, the driver must be fast enough (short settling time, high slew rate) for the output at the end of the "sample" phase *(Fig. 2c)* to be settled so that no additional errors are introduced into the desired signal. Thus, the demands placed on the ADC driver are very high.

A CTSD converter has a resistive input and can be driven directly by the sensor. If the sensor can't drive the ADC (for example, if the sensor has a very high impedance), a simple amplifier can be interposed for impedance transformation.

A further advantage of the CTSD is the inherent antialiasing filter (low-pass filter) property. With traditional topologies, low-pass filters are needed at the inputs to filter unwanted high-frequency signals.

The reason for this is the Nyquist criterion, which states that the sampling rate must be at least twice as high as the frequency of the desired signal. If the sampling rate is too low, aliasing may occur and undesired noise may fold over into the signal. One explanation for the inherent antialiasing filter properties of CTSD converters is that the sampling doesn't occur right at the modulator input, but rather after the loop filter.

Conclusion

The CTSD topology offers a further, new possibility besides the traditional architectures for optimizing signal chains. If the time to market, BOM, or form factor plays an important role as well, ADCs such as the AD4134 represent good alternatives. Thanks to their resistive inputs and inherent filter properties, numerous designs can be simplified and optimized with them. In many applications, ADC drivers, passive components for the filter design, and reference buffers can be eliminated. ed

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ALIX PAULTRE | Editor-at-Large

Oscilloscopes Evolve from Humble Displays to Powerful Tools

From the early CRT-based tools to the latest multifunctional powerhouses, the venerable oscilloscope has long been a mainstay of electronic design.

Able to graphically display a range of electronic circuit performance information as a two-dimensional plot over time, oscilloscopes produce waveforms too fast and transient to be perceived by the human eye alone. Not only is it a primary tool for the electronic design engineer, the oscilloscope also can be found in mil/aero, science, medicine, and telecom, among other spaces.

Waveform analysis of properties such as amplitude, frequency, rise time, time interval, distortion, and other aspects is a significant force-multiplier in the design process. In the beginning, the calculation of these values required manually measuring the waveform against scales built into the screen of the instrument.

Genesis of the Oscilloscope

Early high-speed visualizations of electrical voltages were made with an electromechanical oscillograph *(see opening image, left)*. These were eventually replaced by oscilloscopes based on cathode-ray-tube (CRT) tech to display results. Once referred to as cathode-ray oscilloscopes, CROs were overtaken by digital storage oscilloscopes (DSOs) with thin LCD panel displays, fast analog-to-digital converters (ADCs), and digital signal processors (DSPs).

The electromagnetic oscillograph, invented by William Duddell, measured variations of electric current going through a magnetic coil, which induces momentum in the coil that can be directly measured. Some models used a mirror to reflect a beam of light to allow for measurement of minute movements of the coil. Others had a pointer, often fitted with a pen, to record values. A modern oscilloscope may have an integrated display, or it can be an electronic module that plugs into a computer or laptop to process, display, and record waveforms.

The first CRO was created by German physicist Ferdinand Braun, and V. K. Zworykin developed a sealed, high-vacuum CRT with a thermionic emitter in 1931, enabling General Radio to manufacture an oscilloscope that was usable outside a laboratory.

The first dual-beam oscilloscope came in the late 1930s from a British company called A.C. Cossor, which was later acquired by Raytheon. Widely used during WWII for working on radar equipment, the CRT in the uncalibrated device did not produce a true double beam, but rather a split beam made by an additional plate between the vertical deflection plates.

Early oscilloscopes had a synchronized sawtooth waveform generator to provide the time axis. Charging a capacitor with a constant current creates a rising voltage, which is then fed to the horizontal deflection plates to create the sweep. When the capacitor reached a certain point, it would be discharged; the trace would return to the left to start another traverse. The charging current could be adjusted so that the sawtooth generator would have a longer period than a multiple of the vertical axis signal.

The First Real-Time Digital Oscilloscope

Providing a digital solution with analog driveability, the 9400 Dual 175-MHz oscilloscope challenged the industry with a display that shows both the real-time input signal in the upper trace and its computed Fourier spectrum in the lower trace. Released in 1971, the display used a standard mass-produced television CRT.

The 9400 was notable for leveraging LeCroy's long acquisition memory technology for practical long-memory analysis capabilities at a time when other solutions focused on recreating the viewing experience of an analog oscilloscope.

A few years later, LeCroy came out with the WD 2000 Waveform Digitizer *(see opening image, upper right)*. With a real-time ADC, memory, and display in one box, the device captured real-time single-shot events. It didn't have much memory depth—only 20 samples—and it didn't provide any input signal conditioning (50-Ω;, 1-V full-scale only), and it sold for about $20,000. However, it boasted all of the basic features of a digital oscilloscope, and it was fast. Those 20 samples were 1-ns apart in real-time.

Sampling (or "equivalent time") oscilloscopes had been around for a while, offering much higher sampling rates for repetitive signals only, but the WD 2000 was a real-time scope with a small CRT. It achieved its speed through a current-sampling technique derived from the company's particle physics ADCs, known as "Wilkinson Run-Down" ADCs. They were quite slow, but very accurate, and there were 20 of them compared to more modern designs based on a single "flash" type of ADC.

An interesting note involves Mike Bedesem, the President of LeCroy Research Systems (the company's name at the time), who was said to have painted the text on the front panels of the WD 2000s by hand. The WD2000 was a harbinger of the company's 9400 digital oscilloscope, in the sense that it was a convergence of High Energy Physics technology applied to viewing a signal. It, too, like the 9400, introduced in 1984, was a physicist's oscilloscope.

Pursuing Performance

The electronics industry has always been about developing more and better solutions, and the world of oscilloscopes must stay ahead of the pack. The Infiniium UXR developed by Keysight Technologies was the first series of real-time oscilloscopes to offer high-performance data acquisition with 10 bits of resolution. The solution offers four simultaneous channels with 5 to 110 GHz of real-time analog bandwidth, each concurrently sampling at 256 Gsamples/s.

Providing advanced performance, ultra-low noise, and high signal fidelity, the Infiniium UXR enabled engineers to capture and examine very fast phenomena. The one-, two-, and four-channel models feature a 10-bit ADC and deep memory of up to 2 Gpoints per channel.

Claiming the highest effective number of bits (ENOB) at full bandwidth, the Infiniium UXR has a noise floor of less than 1 mVrms of vertical noise at 110 GHz. The device also ensures accuracy in its measurements with a jitter of less than 25 fs (rms) of intrinsic jitter and less than 10 fs (rms) of inter-channel jitter. Furthermore, the solution enables precise operation with available self-calibration modules.

On top of that, there's a measurement-acceleration ASIC and memory controller capable of 5 trillion integer operations per second (IOPS). That's made possible with Keysight's indium-phosphide ASIC technology for low noise and high signal integrity through full bandwidth time-interleaved sampling. The oscilloscope's 16 GB of RAM plus a 3.0-GHz quad-core processor and hardware acceleration enable fast processing. And a 15.4-in. capacitive touchscreen brings to light the Infiniium UXR's ability to measure edges as fast as 2.8 ps.

A Multifaceted Tool

Convergence and integration have been major drivers in the electronics industry, and the test and measurement space is no stranger to that force. The latest oscilloscopes are more than just display mechanisms—they're full-blown powerful development tools with multiple functions.

For instance, the latest solution from Tektronix, the 2 Series mixed-signal oscilloscope (MSO), is not only powerful, fast, and accurate, it's also a sleek, lightweight design that includes a high-resolution 10.1-in. touchscreen display *(see opening image, lower right)*.

Measuring 1.5 in. thick and weighing less than 4 lb., the scope can fit into a laptop bag. It's available in battery-powered configurations, enabling engineers to use the same instrument on the bench or in the field. An entry-level scope with a common tablet-like user interface, the 2 Series MSO is an approachable device for seasoned and novice scope users. With a bandwidth of up to 500 MHz, it claims the widest bandwidth in its category.

An ecosystem of ready-to-use software includes TekScope PC, TekDrive, and VNC. With TekScope PC, visualization and analysis capabilities can expand beyond the oscilloscope to the PC and analysis of waveforms can be performed anywhere and anytime. A collaborative data cloud workspace makes it possible to upload, store, organize, search, download, and share any file type from any connected device, and a built-in VNC server enables the remote connect, control, and viewing of the 2 Series MSO from anywhere, on any device.

The 2 Series MSO features up to four analog channels with a 500-MHz bandwidth, 2.5-Gsample/s rate, 16 channels, 50-MHz AFG, 4-bit digital pattern generator, advanced triggers, protocol decode, DVM, and frequency counter. The capacitive touchscreen and intuitive user interface make it easy to use. An offering of compatible probes and accessories makes the 2 Series MSO capable and versatile to address a variety of applications.

Looking Forward

Oscilloscopes have come a long way, from electromechanical display mechanisms to advanced digital products with a wide bandwidth, fast capture, and high fidelity. From their early iterations that couldn't even store their data for later analysis, to the latest multi-tool solutions, oscilloscopes have become an even more vital tool for electronic design. The next generation of devices over the horizon promises to be even more powerful, functional, and useful. ed

WILLIAM G. WONG | Senior Content Director

Getting Started with Fast Embeddable AI Hardware

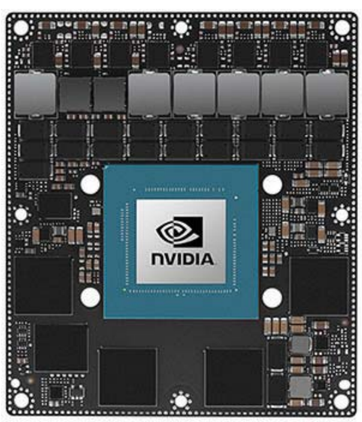
NVIDIA's software is what makes the Jetson AGX Orin development kit so compelling.

NVIDIA's Jetson AGX Orin Development Kit is a great embedded platform for delivering 275 TOPS of raw performance. It targets applications like robotics, but works equally well for any embedded application that needs artificial intelligence (AI) and machine learning (ML) support in the field.

The Jetson AGX Orin module *(see figure)* is built around a dozen, 64-bit Arm Cortex-A78AE v8.2 cores that have access to a 3-MB L2 and 6-MB L3 cache as well as a GPU based on NVIDIA's new Ampere architecture. This includes 2,048 NVIDIA CUDA cores and 64 Tensor cores plus a pair of NVIDIA Deep Learning Accelerators (NDLAs) v2.0 for AI/ML applications. The Programmable Vision Accelerator (PVA) streamlines video processing of multiple video streams, which is a common task for the platform.

The hardware is impressive, but it's the encompassing NVIDIA software that really makes the difference. The Jetson Jetpack SDK is built on Ubuntu Linux, including UEFI-based bootloader support and OP-TEE as the Trusted Execution Environment. The dev kit comes with everything installed, which makes getting started much easier. It includes support for the underlying CUDA, CuDNN, TensorRT, and DeepStream tools.

Two items that stand out in the latest kit are the NVIDIA Train-Adapt-Optimize (TAO) and NVIDIA RIVA. The latter targets speech AI, while TAO builds on pre-trained models from NVIDIA. These can be customized in Microsoft's Azure cloud. ed



The high end of the Jetson family includes the Jetson AGX Orin (left) and the Jetson Orin (right).

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