WIRE PROCESSING EXPO ISSUE

APPLIANCE & HVAC REPORT

Reaching Design Engineers at the OEM Level

March/April 2020 VOLUME 2 ➢ NUMBER 2



9 FEATURES COVERING

SENSORS
JOINT INTEGRITY
CONTRACTS
MATERIALS
SAFETY

Current Sensing

The challenges of advanced embedded systems

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AK STEEL
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NEW PRODUCTS

BACHARACH
CINCINNATI TEST SYSTEMS
REGAL BELOIT CORPORATION

Welcome to Our 2nd Issue of 2020



By the time you have read this our presidential election is barely 7 months away. Perhaps the most important accomplishment, for good or ill, of President Trump was his legislation reducing income taxes.

Some view this as a good thing, others not so much. So it was interesting to see a quote on it from the CEO of Whirlpool.

In a recent issue of ***The Wall Street Journal***, Marc Bitzer was quoted: "On the whole it was positive, in that it helped the broader consumer, but on the effective tax rate for us it was a lot less than you'd think". Bitzer went on to say Whirlpool didn't see a meaningful change in its taxes. Nor did they boost their US hiring or capital investment as a result of the law.

Sounds like on a scale of 1-10 he's giving it a 5 or 6.

OK…who likes numbers? I do. And while I believe it was Mark Twain who said "***there are lies, damn lies and statistics***" this humble publisher would differ with that view. A former boss of mine, the late A. William (Bill) Reynolds taught me "***You can't manage it if you can't measure it***".

This brand you have in your hands, or on your computer or your phone is dedicated to the designing of products in the appliance and HVAC sectors. And of course design leads to manufacturing. So I thought it be interesting to look at the manufacturing market in the US over the last 10 years, ***based on employment***. The numbers are interesting and are from the Bureau of Labor Statistics.

From 2008 to 2018 the number of people employed in this country grew from 149.3 million to 161.0 million, an average annual rate of .8%. Not sure if that's good or bad.

In 2018, manufacturing was the sixth biggest sector of the workforce. Guess what? Same as 2008. But the number of manufacturing jobs decreased by .5% per year during that ten-year period.

Here are the Top 5 sectors for employment for 2018 and 2008 and the annual growth rate for each:

	2018	2008	Growth Rate
Professional and business services	21.0 million	17.8 million	1.7%
Health care and social assistance	19.9 million	16.2 million	2.1%
State and local government	19.7 million	19.7 million	0.0%
Leisure and hospitality	16.3 million	13.4 million	2.0%
Retail trade	125.8 million	15.3 million	0.4%

Bottom line? Three of the five largest employment sectors have grown faster than the overall employed labor face. Four of the five have a positive growth rate and only one, state and local government, stayed flat (and I get that surprises lots of people…it did me)

But manufacturing, while still important, has fallen further behind its peers.

We're very happy to provide you with the Appliance & HVAC Report. Hopefully the technical information, industry news and product releases are informative and are meeting your needs. But we know we can always do better. Feel free to email me anytime with suggestions on how to do it!

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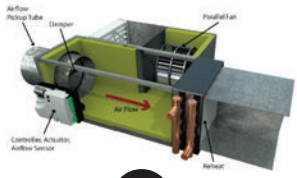
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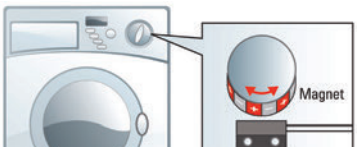
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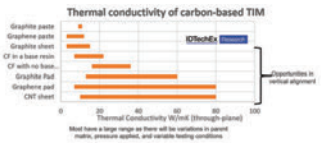
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Inserts are available in a variety of shapes and sizes. The key is choosing an Insert that meets performance and assembly requirements.



How to Maintain Joint Integrity

When Converting From Metal to Plastic

BY CHRISTIE JONES

The weakest sections of many plastic part designs are the joints and assembly points. During screw assembly of mating components, the screw has to be tightened with sufficient torque to produce the recommended axial tension load between the host component and the threads of the screw in order to prevent loosening. A common problem with bolted joints is that plastics are susceptible to creep or stress relaxation. Under loads well below the elastic limit, plastics will lose their ability to maintain a load. When this occurs, the threaded connection becomes loose.

Metal threaded Inserts significantly improve joint strength in plastic parts and are not themselves susceptible to creep. The larger body diameter and body design of the Insert allow the appropriate installation torque to be applied to the

screw. These joints do not become loose over time since the brass provides permanent creep resistance for the entire load path of the thread. Additionally, the Inserts enable unlimited assembly/ disassembly of the components without compromising the integrity of the threads. Ultimately, it is often the metal Insert that allows designers to replace cast or machined metal components with less expensive plastic without sacrificing performance.

Typical performance requirements for assemblies using Inserts involve tensile strength, rotational torque, and pull- through strength. Tensile strength, or pull-out, is the axial force required to pull the Insert out of the plastic material. Torque is the rotational force required to rotate the Insert in the plastic material. Finally, pull-through is a combination of rotational torque and tensile force applied opposite the head of the Insert (see Figure 1).

The following factors affect Insert performance:

- Insert type, design, and quality of Insert features.
- Plastic specifications.
- Design and quality of the plastic components, including hole tolerance consistency.
- The installation process.

Start with the performance requirements of the assembly, and then select the appropriate Insert. The objective is to choose an Insert with sufficient torque resistance to accommodate the tightening torque necessary to achieve sufficient axial tension load on the threaded joint to keep it together and prevent loosening, while also achieving pull-out values necessary for the load conditions that the Insert will be exposed to while in service.

In general, resistance to torque is a function of Insert diameter, and resistance to pull-out is a function of Insert length.

How They Are Insalled

There are many different styles of Inserts designed to accommodate various performance requirements and installation methods. The installation method must be considered, as this will affect the type of Insert that can be used as well as the overall cost of the assembly. The two primary types of Inserts are those that are molded in and those installed after the molding process (post-mold).

Molded-in Inserts usually yield the highest performance, yet this form of installation is by far the most expensive. In addition, you run the risk of damaging the mold if the Insert is not properly positioned during the molding process. That can result in tens of thousands of dollars in lost profit.

Inserts installed with heat or ultrasonics after molding yield good performance at a fraction of the assembled cost of the molded-in Inserts. Post-mold installation is very efficient and eliminates the requirement of properly loading

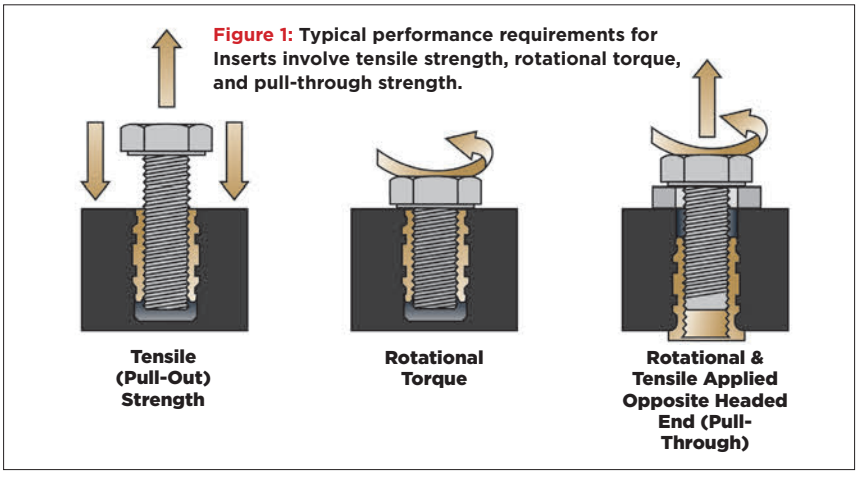


Figure 1: Typical performance requirements for Inserts involve tensile strength, rotational torque, and pull-through strength.

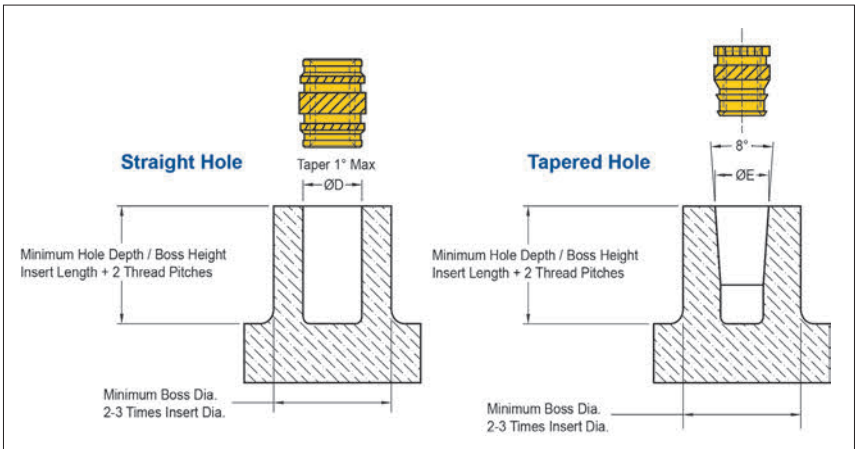


Figure 2: Molded holes are preferable to drilled holes because of the strong, denser surface of the molded hole. For straight holes, the taper should not exceed a 1° included angle, and tapered holes should have an 8° included angle.

Inserts into a mold during the mold cycle. Typically, Inserts installed with heat yield the best combination of overall performance and lowest installed cost.

Self-tapping Inserts provide the best pull-out resistance for a post-mold Insert, yet the assembler has to be very careful about installing the Insert so that it is perfectly square to the hole or it will not mate well with the screw.

Expansion Inserts are designed for non-critical applications where ease of installation is the primary design criterion, not torque and pull-out resistance. Another low-cost option is press-in Inserts that are designed to reduce installation cost at a sacrifice of torque and pull-out performance.

Hole Design Guidelines

Correct hole size is critical. Larger holes decrease performance, while smaller holes induce undesirable stresses and potential cracks in the plastic. Undersized holes may also result in flash at the hole edge. The Insert manufacturer's recommended hole size for the Insert must be adjusted if fillers are used in the plastic. If the filler content is 15% or more, it is suggested to widen the hole by 0.08mm (.003"), and if filler content is 35% or more, the suggested hole diameter increase is 1.5mm (.006").

Holes for post-mold Inserts should always be deeper than the length of the Insert. For self-tapping Inserts, use a minimum depth of 1.2 times the Insert length. For other Inserts, the recommended depth is the Insert length plus two thread pitches. The assembly screw should never bottom out on the hole, as jack-out would result.

Tapered holes reduce installation time and ensure proper alignment of the Insert to the hole. Easier release from the core pin is an additional benefit. Only tapered Inserts should be used in tapered holes. The disadvantage is that tapered Inserts are not symmetrical, and therefore must be oriented prior to installation.

Insert performance is affected by the plastic boss diameter and/or wall thickness. Generally, the optimum wall thickness or boss diameter is two to three times the Insert diameter, with the relative multiple decreasing as the Insert diameter increases. The plastic wall thickness has to be large enough to avoid bulging during installation and strong enough for the recommended assembly screw installation torque. Poor knit lines in the vicinity of the Insert will cause failures and reduced Insert performance.

Post-mold Inserts that are cold-pressed into the hole require larger boss diameters and/or wall thickness to withstand the greater stresses induced during installation. Installing the Inserts while the plastic is still warm after molding generally avoids problems.

Mating Components

The diameter of the clearance hole in the mating component is very important. The Insert and not the plastic must carry the load. The hole in the mating component must be larger than the outside diameter of the assembly screw but smaller than the pilot or face diameter of the Insert in order to prevent jack-out. If a larger hole in the mating component is required for alignment purposes, a headed Insert should be considered. Inserts should be installed flush (or no more than 0.13mm (.005") above the hole).

If the mating component is also plastic, the use of a Compression Limiter should be considered to maintain the preload of the threaded joint. In order for the Compression Limiter to work properly, it should abut the Insert so that the Insert, and not the plastic, carries the load.

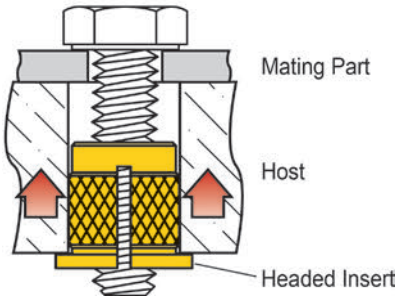


Figure 3: In high-load applications, consider locating the head of the Insert opposite the load to increase pull-out strength. Tapered Inserts should not be used in pull-through applications.

Inserts with heads provide a larger bearing surface and a conductive surface if needed. High-load applications can benefit from locating the head opposite the load in a pull-through configuration (see Figure 3). Tapered Inserts should not be used in pull-through applications or in thin-walled bosses as this will cause cracking of the plastic. ●



Christie Jones *is a market Development Manager SPIROL International Corp. www.spirol.com*



Advancing Electrical Safety in Global Appliance Markets

BY PIERRE PEREZ

Safety and quality are paramount for appliance manufacturers striving to deliver a positive customer experience while successfully competing in global markets. Electrical products designed for consumers, however, come with inherent risks. Human error and misuse of appliances, short circuits and wiring account for many of these dangers. In order to mitigate some of them, the reliability of electrical components housed in appliances is a high priority for industry leaders.

Home Appliance Safety: An Industry Priority

Resistance to heat and fire is one of the primary safety issues in appliance design. Although global fire death rates have fallen over the past several decades, a majority of fires (about 60 percent) and most fire casualties, occur in the home, according to a report by the Austrian Standards Institute. Electrical appliances are often an underlying factor. For example, unattended equipment was the number one source of home fires in the U.S. from 2012 through 2016, while electrical failures or malfunctions were the second leading source, according a 2019 report by the National Fire Protection Association.

Manufacturers strive to take swift action to protect consumers when a potentially harmful or dangerous product defect becomes known. At any given time, due to known safety concerns, millions of gas and electric ranges, refrigerators, dishwashers, clothes dryers and washers, and small appliances are on recall lists. This causes several problems. First, recalls are not only exorbitantly costly for manufacturers but also can have a lasting negative impact on a brand's reputation. Additionally, consumers must be aware and proactive in

registering products and taking recommended actions when notified of recalls, behavior that manufacturers cannot rely on.

As a result, the appliance industry strongly supports the development and strengthening of standards to improve product and consumer safety. Most appliance safety standards and certifications evolved through extensive testing, data and collaboration within the industry yet remain largely voluntary. Manufacturers have a vested interest in protecting consumers by delivering high-quality products that meet or exceed UL, Glow Wire and/or NiChrome testing certifications.

COMPARE AND CONTRAST TABLE
HOME APPLIANCE STANDARD TESTS

UL-94	Glow Wire	NiChrome
Evaluates flammability of polymeric (plastic) materials and their tendencies to extinguish	Measures ignition resistance of plastic or resin material	Is a heat contact test that simulates the effect of overheated electrical connections
For components used in devices and appliances	For components used in home appliances	For components used in home appliances
Uses open flame or radiant heat source to which the part is exposed (direct flame)	Uses a heated Glow Glow Wire element that is pressed into the connector (indirect flame)	Uses a heat source up to 1000˚C (higher than other tests) to make contact with component
Tests done on component level	Tests done on material and component level	Tests done with appliances

Underwriters Laboratories (UL) Standards

An independent organization based in the United States, Underwriters Laboratories provides safety-related certification, validation, inspection and testing services for product materials, including those commonly used in appliance wiring systems and connectors. The UL 94 Standard for Flammability of Plastic Materials for Parts in Devices and Appliances includes small-scale tests to evaluate the flammability of polymeric (plastic) materials in response to a small, open-flame or radiant-heat source under controlled laboratory conditions.

The UL 94 standard provides a method for rating the ignition characteristics of plastic materials used in devices and appliances. A range of burn tests specify the flammability of the materials on a scaled rating system (HB, V-0, V-1, V-2). While UL ratings may be used to prequalify or confirm the general burn rate of a material, it is important to understand that flame resistance and safety may vary widely in appliances and other applications. Also, materials that are UL rated V-0 or V-2, for example, do not necessarily meet NiChrome or Glow Wire requirements, which entails additional testing.

Glow Wire Testing

The International Electrical Commission (IEC) developed Glow Wire standards to test the potential effects of an overloaded circuit or overheated component in a home appliance. Most of the industry now demands Glow Wire testing compliance for connectors and other components intended for use in appliances. The Glow Wire testing methodology can be found in the IEC 60695-2 series.

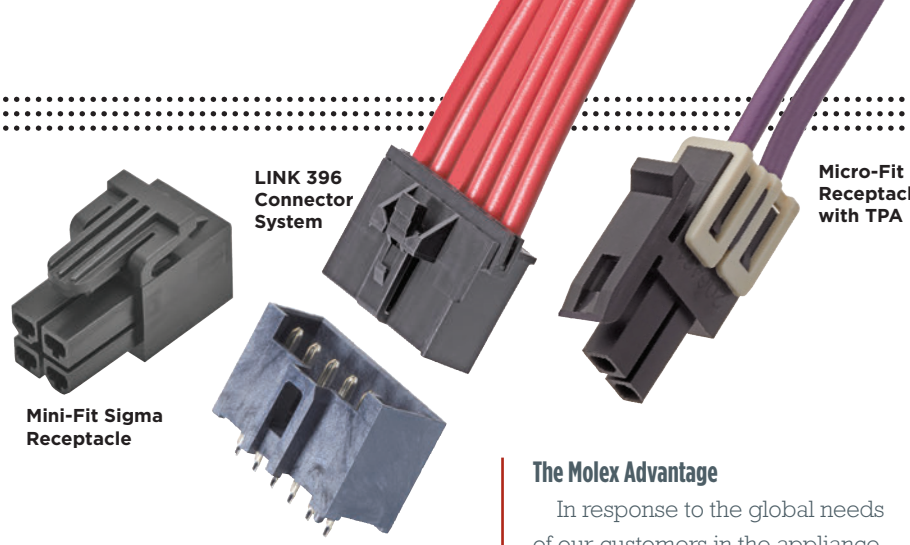
Glow Wire requirements for unattended appliances are more stringent than those for attended appliances. The standard requires that insulation materials, including the connector housing, conductor insulation and printed circuit boards in all circuits carrying more than 0.20A, be able to resist ignition in the event of Glow Wire overload. The requirements are lower for attended appliances and unattended appliances with currents lower than 0.20A.

Designed to identify the tendency of the connector material to melt and/or catch fire when wires are overloaded, Glow Wire testing specifically measures ignition resistance of the plastic or resin connector material. Glow Wire testing utilizes an indirect flame, which differs from the direct-flame methods outlined in the UL specification. In order to pass the Glow Wire tests, connectors must be molded in materials that can specifically conform to the IEC Glow Wire Ignition Temperature (GWIT) and the IEC Glow Wire Flammability Index (GWFI) standards.

NiChrome Wire Component Bench Tests

NiChrome wire testing is performed with heat contact at the appliance level, simulating the effect of an overheated electrical connection, with temperatures ranging up to 1000˚C (1800˚F), which is higher than the temperatures of other testing methods.

NiChrome wire testing is included in multiple UL Major Appliance standards, and there is a continuous effort to improve the test and extend it to IEC standards. In fact, UL and IEC are collaborating to establish a NiChrome wire bench testing protocol.



Major appliance manufacturers typically burn entire units in the process of doing this appliance-level testing. They may burn as many as 25 to 35 test units for a new appliance design. To help contain testing costs, Molex conducts NiChrome filtration-system procedures at the component level. Then, based on both those test results and our past experience, we will recommend those components that most likely won't propagate fire to other parts of the appliance and, therefore, can help them pass the test.

Comparing Flammability Tests

Glow Wire and NiChrome are the specific electrical standard tests, and the UL conducts these tests and others, including tests for UL 94 compliance. Below is a table that compares and contrasts these common home appliance standards.

Global manufacturers are seeking cost-effective, standardized solutions that conform to a wider range of specifications and requirements, to ensure the safety of their products and customers around the world. For example, though the U.S. doesn't require Glow Wire testing for appliances sold domestically, American manufacturers often sell their products in Europe and must comply with Glow Wire testing requirements as a result. Therefore, standardized testing and Glow Wire-compliant connectors are needed in most regions — and are preferred by leading manufacturers around the world.

The Molex Advantage

In response to the global needs of our customers in the appliance industry, Molex offers a portfolio of components that are UL 94 V0 and Glow Wire compliant. We also have begun to design connectors, such as the Mini-Fit Sigma Connector System, that uses a resin that, in our internal screen tests and in most of the end-use cases analyzed, passed the NiChrome test in end applications.

Molex Glow Wire capable connectors come in many popular styles to meet all safety and environmental requirements mandated by the home appliance industry and many of them are also UL 94V0 compliant. In fact, numerous Molex wire-to-wire and wire-to-board connector housings, in a range of styles and configurations are available in both UL 94- and Glow Wire-compatible materials. In addition to strengthening electrical safety, many of these connectors also provide premium features in appliance applications. ●



Pierre Perez *started his career at Molex in 2015 as a Product Engineer. In 2017 he transitioned to an Associate Product Manager under the Power and Signal Business Unit. In 2018 Pierre was promoted to a Global Product Manager with primary focus on New Product Development and the Home Appliance Industry.*





Modern current sensing technologies are available for a wide range of applications – from EV cars and ADAS systems to home appliances, telecommunications and server farms.

Current Sensing Rises to the Challenges of Advanced Embedded Systems

BY KHAGENDRA THAPA

The embedded electronics development community is currently experiencing the biggest changes in our industry since the creation of the integrated circuit. From new software-oriented solutions like Artificial Intelligence, to new hardware topologies, to new semiconductor materials, we are in the middle of a disruptive period of demanding growth.

Much of these advances are related to user functionality, like Cloud-based Internet of Things (IoT) solutions that rely on next-generation RF technologies. Other rapidly emerging current sensing applications include Electric Vehicles (EV) and their Advance Driver-Assistance Systems (ADAS) and Autonomous Driving needs, to wide-bandgap power switches based on Silicon Carbide (SiC) and/or Gallium Nitride (GaN) semiconductors. Some of the most important advances in these spaces have been in performance and efficiency, enabling the next generation of electronic solutions to address the challenges and demands of users and the marketplace.

The latest trends in personal electronics put a lot of pressure on the designers of embedded systems. When it comes to consumer and medical wearables, advanced personal electronics, and the internet of things, the smaller, more functional, and longer lasting, the better. Similarly, industrial and automotive applications are pushing boundaries to achieve smaller, more efficient, reliable, and robust solutions. Significant improvement in all of these include reducing parts count, simplifying circuitry, and increasing operational efficiency.

Current-sensing technologies are key to creating the small precision control and protection electronic circuits needed to make the devices of tomorrow serve applications in an efficient and cost-effective manner. There is no precision without feedback, and current sensing can provide the critical performance information an embedded intelligent system needs to manage itself. The size, accuracy and speed of your current-sensing solution will directly impact all of these aspects.

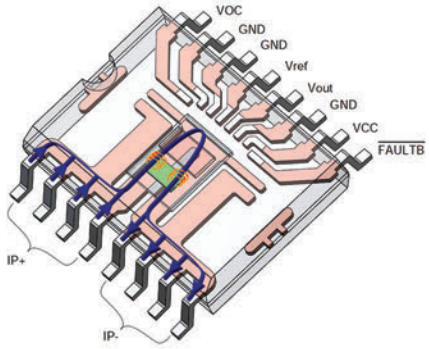
AMR Current Sensing

A single-chip solution, the ACEINNA Anisotropic Magnetoresistive (AMR) technology based, isolated current sensor does not require additional components other than a decoupling capacitor. Compared to the other methods of current sensing, an AMR sensor provides a compact and high-performance solution. For example, the problem with using a shunt resistor is that it is inherently not isolated. A current transformer is

COMPARISON **Advantages of AMR based Current Sensing versus other types of current sensing technologies**

Desired Feature	Aceinna AMR	Hall IC / Hall IC based Modules	Current Transformer	Sense Resistor
Accuracy	✓	✗	✓/✗*	✓/✗*
DC - >1MHz 3dB BW	✓	✗	✗	✓
Isolated	✓	✓	✓	✗
Small Size	✓	✓/✗**	✗	✗

*Current Transformer and Sense Resistor applications require design trade-offs regarding complexity and customization. Accuracy will depend upon the components selected and the quality of the design.
**Hall Effect IC based sensor modules (such as those with Ferrite cores) are not small.



ACEINNA Current Sensors use a U-bend with two AMR sensors to cancel out external fields

bulkier than an AMR based current sensor and it only works with AC. Compared to using a Hall-effect sensor, AMR technology offers a bandwidth of 1.5 megahertz, and has a lower offset and noise.

Delivering better performance than a shunt register or transformer, AMR technology can respond to both DC and AC bi-directional current, with a bandwidth of 1.5 megahertz and a lower offset and less noise than Hall-effect-based solutions. Offering better accuracy, higher bandwidth with lower phase shift, and a very fast output step response, an AMR based current sensor is an accurate and compact solution for very critical measurements to protect and control power systems.

Within the sensor, the current flows through a U-bend in the lead frame, where it generates a forward or reverse field measured by two current sensors in the device. By measuring the field from both current directions, the device cancels out the external fields and magnetic anomalies which might be present. This allows a horizontally-sensing AMR chip to ignore external fields generated from other nearby components on the board.

Electric Vehicles

There is a tremendous amount of attention being paid to EVs right now. Much of the focus is on improving the efficiency of the powertrain, motors and On-board/Off-board charging systems as well as the performance of the battery pack, as they are all directly related to vehicle range and charging efficiency. The proper



application of current-sensing technology in these application areas can deliver significant advantages.

Since the motors are where the power is being spent, any improvement there will cascade benefits throughout the system, from increasing EV range to reducing thermal management needs. When it comes to driving motors, the switching frequencies and control mechanisms are critical.

Effective motor control requires accurate performance measurement, and for that you need effective current sensors. For condition monitoring of motors for predictive maintenance, fast current sensors help to measure and monitor motor ripple currents to determine lifetime and performance parameters. On the protection side, the current sensor helps support safety by improving the control, accuracy, and reliability of a motor drive.

Many EV power electronics and charging systems are migrating to advanced wide-bandgap semiconductors like Silicon Carbide (SiC) and Gallium Nitride (GaN), as the benefits provided include higher efficiency and the ability to increase the switching frequency. A significant benefit of faster switching is the ability to shrink the size of the passives and magnetics in a circuit, with direct size and weight benefits.

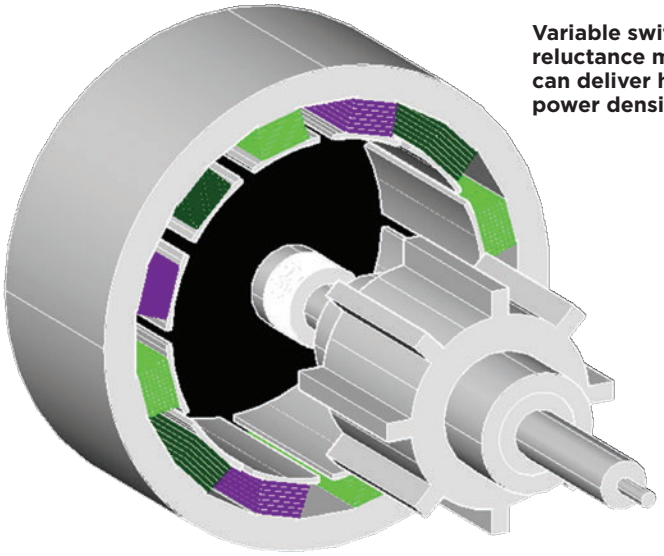
However, when a circuit is switching faster, the ability to measure the performance parameters must be able to keep up, demanding real-time information from a fast and accurate current sensor. Monitoring the circuit in real-time enables advanced functionality like dynamic control of the power switching and motor drive frequency, as well as reliable and fast fault detection.

In the related area of electric trains, industrial machines, traction and robotics, we are starting to see the use of reluctance motors, a winding-free design that generates torque through magnetic reluctance. Available in synchronous, variable, switched and variable-stepping configurations, reluctance motors can deliver high power density at low cost.

The problems with reluctance motors include high torque ripple at low speed, and the resulting noise. In addition, because of the extremely high temperatures involved, reluctance motors are usually deployed with a separate harness and control system. Advanced solutions using wide-bandgap SiC semiconductors and high bandwidth AMR sensors can take more heat, enabling size, weight, and complexity reductions of the overall system, providing cascading benefits.

Constructed without copper coils in the rotor, reluctance motors can be lighter than comparable electric motors. However, the required control system is very complex, because if you don't accurately control the current, which is related to torque, you'll get a torque ripple and that generates noise issues. Advanced fast current sensing improves control of the ripple current, which provides lower noise and a more reliable solution.

It's important to bring up the protection side again because in high-power systems, you might want to switch the whole power stage off in 1.5 microseconds. If you look at that shutdown time budget, your step response needs to be less than 500 nanoseconds, and that's going to become more stringent as we migrate into higher power and frequency levels.



Variable switched reluctance motors can deliver high power density

Power Factor Correction

Used to reduce the lagging power factor in inductive loads, Power Factor Correction (PFC) compensates for the phase difference between voltage and current, for when the power factor drops, the system becomes less efficient.

To get 1 kW of real power at a 0.2 power factor, 5 kVA of apparent power needs to be transferred (1 kW ÷ 0.2 = 5 kVA). This obviously can severely impact the performance in the case of inductive loads such as motors, refrigerators and HVAC systems, Inverters, uninterruptible power supplies (UPS), and similar application spaces.

Fast turn-on and -off time, fast reverse recovery and lower ON resistance of wide bandgap SiC

and GaN based power switches are allowing effective use of Totem Pole architecture to improve efficiency of PFC and reduce the number of components used. These benefits help power systems to achieve higher efficiency 80+ Gold and Titanium certifications.

For example, when it comes to ripple currents in the PFC in a Totem Pole, to measure current cycle-by-cycle to calculate the pulse-width modulation (PWM) duty ratio, you need to have a high bandwidth for the ability to match the circuit's switching frequency. Let's say if your PFC switching frequency is being pushed to 65, 140, 200, 300 kilohertz, you ideally want 10 times the bandwidth of the switching frequency for the current sensor.

Smart Manufacturing

When it comes to smart manufacturing and the smart factory, it's really about automation and data exchange. In a system where powered devices are connected to an intelligent infrastructure and the internet, you'll also need power conversion. Power monitoring and management are critical to the optimal operation of a smart assembly process, with everything being measured in real-time.

There are various locations in an automated system where an AMR current sensor can be deployed to take advantage of its accuracy, bandwidth, and step response. If you have a highly accurate sensor, then you can optimize your process and increase efficiency and productivity.

This performance advantage can be further leveraged by using AMR current sensing to determine how much the processor is being used, especially for applications involving AI, the Cloud, and data storage. AMR current sensors can also enable the use of power tracking for performance monitoring's sake, optimization of processor loading and thermal management.

Looking Forward

Whether it is for advanced EVs, entire smart factories, UPS, inverters or motor drive, efficient and cost-effective power management is key to optimal performance. In applications from driving motors or powering 5G telecom, you want to be operating much faster and more effectively. Advanced current sensing enables a higher level of control, with a higher efficiency, at higher frequencies and temperatures.

The next generation of embedded devices must be able to serve the latest application spaces in the most efficient and cost-effective manner. Using AMR-based current sensing solutions to ensure that the electronics are performing at their best will pay off in cascading benefits throughout the entire system.

There is no precision without feedback. Precise fast current feedback enables the highest levels of efficient and safe operation in an advanced powered circuit. ●



***Khagendra Thapa**, VP of Business Development of ACEINNA's Current Sensing Business, has over 22 years of business management and leadership experience in the electronics equipment and semiconductor industry. For more information about ACEINNA Current Sensing, visit www.aceinna.com/current-sensors*



Piezoresistive or Advanced Thermal Sensor Technology:

Which one to choose for HVAC applications

BY DR. OLEG GRUDIN AND PAUL SITTARD

Introduction

Heating, ventilation, and air conditioning (HVAC) equipment designers are facing mounting challenges to create much more accurate systems that consume far less energy. These pressures are most acute in the commercial market where air handling systems play a major role in HVAC design.

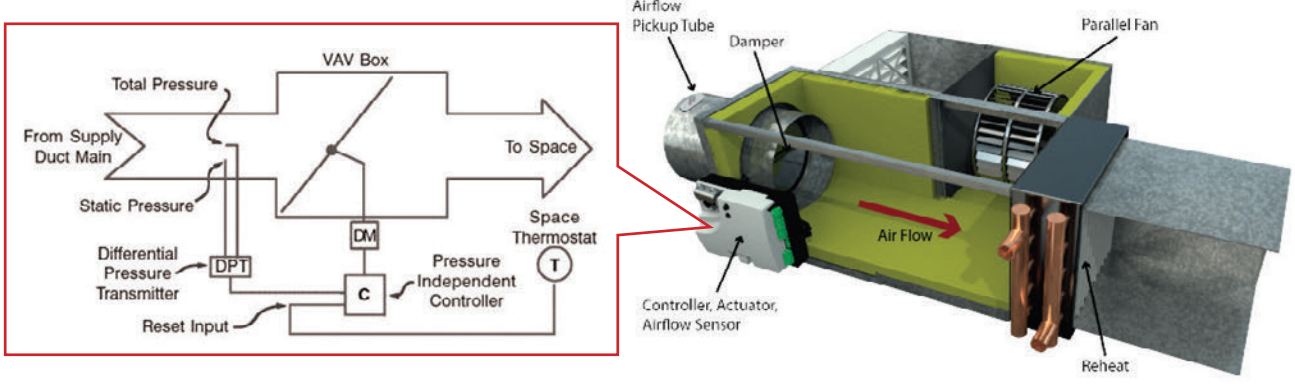
Variable air volume (VAV) systems are the industry standard for distributing heated and cooled air to office and commercial spaces. This equipment employs differential pressure sensors that control the air volume through the HVAC system, plus measure pressure in the flow duct.

In HVAC environments, pressure is an important physical value and its measurement is a critical task. The electronic sensors that perform the measurement work are extremely accurate and reliable even in the smallest pressure ranges. These differential pressure sensors operate at only a few millibars (few inches of water column) to measure volumetric air flow. Unlike relative and absolute pressure sensors, differential pressure sensors measure the delta between two pressures — and therefore have two separate pressure connections.

Sensors make HVAC systems more efficient by measuring air flow and pressure for effective air distribution. Their critical role means selecting the correct sensor is essential to ensure maximum HVAC system performance and occupant comfort.

This paper focuses on the two technologies that have proven their worth for differential pressure measurement in HVAC applications: piezoresistive (diaphragm-based) sensors and thermal (flow-based) sensors Both technologies have strengths and weaknesses.

Flow Duct and VAV Box



The Sensor's Role in VAV Systems

VAV systems are the most frequent HVAC sensor applications. These systems provide design engineers with a way to zone large areas of workspace in commercial buildings for heating and cooling occupants. A VAV system consists of a sheet metal box with a damper and controls. A thermostat connects to the box's controller, which positions the damper based on programmed inputs and variables such as air flow and temperature. The air that is supplied to the VAV box is provided by a large air handler and central ductwork. When the VAV box is in cooling mode, the damper will modulate to a fully open position since air conditioning requires higher air flow. Heating requires less air flow so the damper will modulate to a minimum position.

The air handler's blower fan must modulate to vary the air flow depending on demand. The VAV box has a sensor inside to measure air flow. The air flow and temperature variables control damper position based on temperature and cubic-feet-per-minute (CFM) demands. An additional sensor inside the main supply duct measures air pressure. There is a pressure set point inside the control program for the air handler. The air handler's controls will ramp the blower up and down depending on the duct pressure to maintain the set point in the program.

Two Technologies, One Choice

As mentioned, there are two technologies commonly applied in HVAC equipment: piezoresistive (diaphragm-based) sensors and thermal (flow-based) sensors. In addition, an advanced version of thermal technology is available that eliminates most of the traditional flow-based sensor's drawbacks. Selecting the appropriate sensor technology requires an understanding of their advantages and disadvantages.

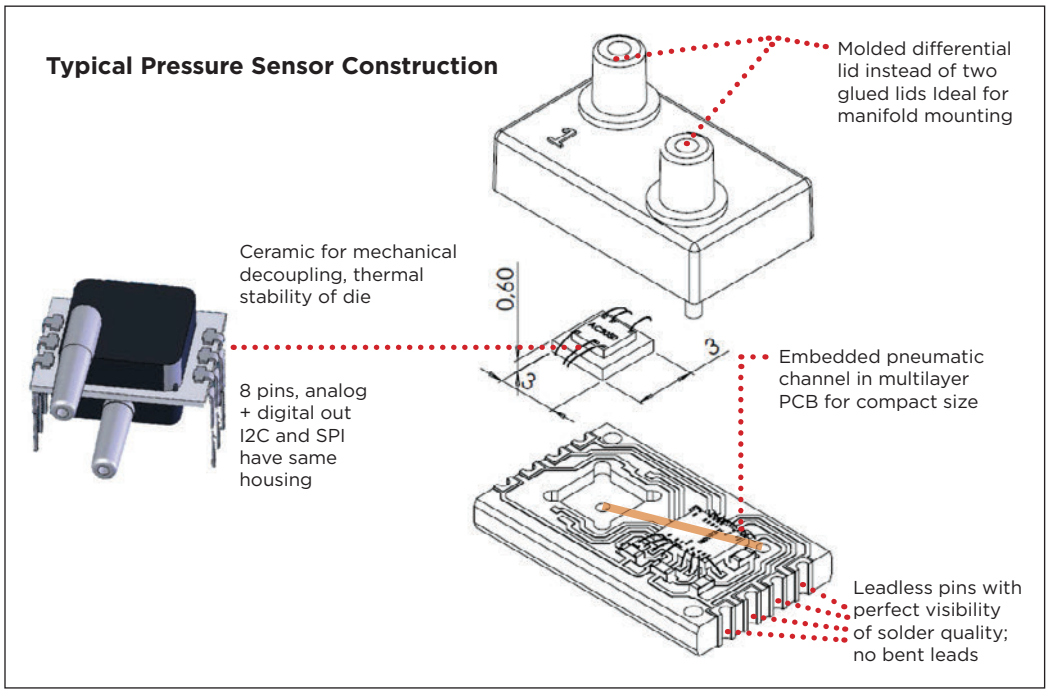
There are several criteria that the design engineer must consider when choosing the optimal sensor. The first decision concerns pressure range. Many HVAC applications require sensors that detect very low pressures that range down to 0.25 millibars (less than 0.5 inches of water). You must be sure that the sensor can accurately measure at the desired pressure level.

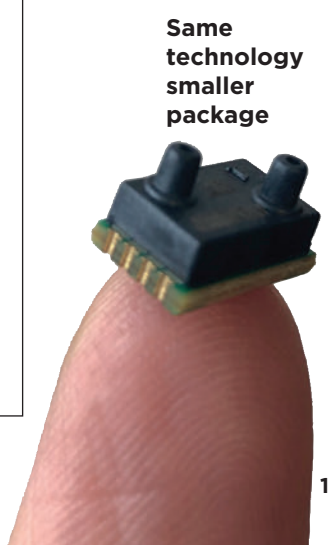
Other selection criteria include the sensor's sensitivity, long-term accuracy, robustness, dust resistance, and stability (the sensor must operate for many years without calibration).

Piezoresistive (Diaphragm-Based) Technology: When High Linearity Is Essential

Piezoresistive differential pressure sensors consist of thin silicon diaphragms in which resistors are embedded as a Wheatstone bridge. If there are differences in pressure, the diaphragm pushes through and distortion occurs. The semiconductor resistors arranged in the measuring bridge react to these mechanical stresses with the so-called piezoresistive effect. In other words, the resistances of the resistors change, the electrical voltages change, and a pressureproportional measuring signal is triggered.

For years, piezoresistive sensor technology has been perceived as the





low-risk option for HVAC applications. Air handling systems are dusty places. The piezoresistive sensor does not have a flow channel, so dust will not hinder its performance. While the technology has high sensitivity (few millibars), its measurement range of 1 millibar (0.5 inches of water column) to 10 bar will not be acceptable for measuring very low pressures. Piezoresistive sensors have high linear signal-pressure characteristics and excellent overall accuracy. They come in very small sizes for compact applications.

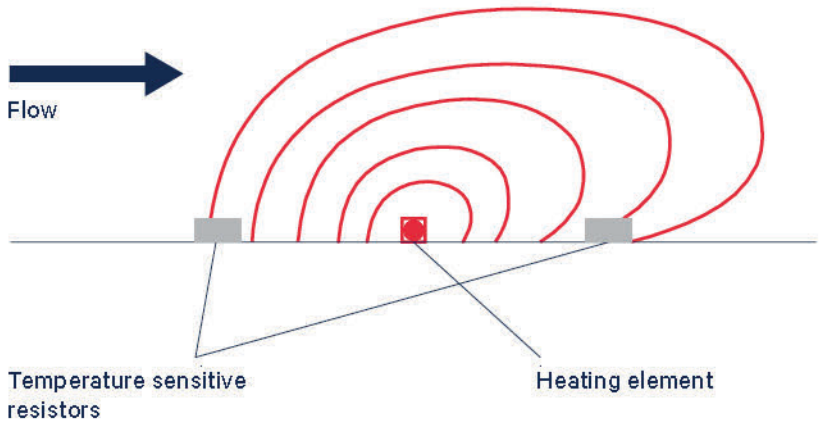
Traditional Thermal (Flow-Based) Technology

Traditional thermal differential pressure sensors incorporate a heating element positioned between two temperature-sensitive resistors (one upstream, one downstream). If there is a pressure difference (differential pressure) between the two sensor connections, gas flows through the sensor and the temperature profile moves in the direction of the downstream resistor. This results in a temperature difference between the two resistors, which in turn triggers an output signal proportional to the gas flow: the measure of the underlying differential pressure.

To measure volumetric flow, the flow-based sensor must be connected to the main flow channel e.g. via tubes. Sometimes, additional filters are used in the bypass channel to protect the sensor against dust, humidity, or bacterial contamination. However, any pneumatic element between the main flow channel and the bypass represents additional flow resistance that leads to a pressure drop. The pressure sensor will therefore measure a differential pressure which is lower than the one caused by the flow-restricting element in the main channel. The result is an inaccurate measurement of the volumetric flow rate in the main flow channel. The higher the flow impedance of the connecting tubes and additional filters compared to the sensor, the more dominant is this effect.

For conventional flow-based differential pressure sensors, a maximum allowed tube length to the sensor is recommended, or respectively, a correction formula is given to compensate for the pressure drop in the bypass. Traditionally, tube lengths were kept short to prevent adding pneumatic impedance that would alter the sensor's calibration and cause it to return an incorrect value.

Principle of Thermal Mass Flow Measurement



In the past, these issues have caused concern among OEM designers about the construction of thermal flow-through technology. However, an advanced generation of thermal sensors is quickly alleviating those concerns.

Advanced Thermal Technology: The Ideal Choice for Ultra-Low-Pressure Measurement

Advanced thermal differential pressure sensors are based on a silicon chip only about 4 mm2 (0.006 in2) in size. The sensors incorporate innovative MEMS technology that integrates a micro-flow channel within the silicon sensor chip. Advanced thermal sensors can measure ultra-low air or gas pressures from 0.25 millibar (0.1 inches of water column) full scale (FS).

Advanced thermal technology features high dynamic ranges and high sensitivities for very low pressures, especially around zero. The sensors offer digital signal conditioning for calibration, temperature compensation, and amplification. They can be optimized to different application requirements depending on whether a high sensitivity, high dynamic range, or linear output signal is needed.

Probably the most significant advantage of advanced thermal technology over piezoresistive is its zero-offset accuracy.

Typically, differential pressure is created in the system by an air velocity probe that converts air velocity into delta-P. These probes use the physical principle of a classic Pitot tube. The probe may be constructed in the shape of a stick with multiple orifices or as a bent metal tube distributed across the duct cross section (also with multiple orifices). In this case, delta-P is close the square function of air velocity (or flow). Therefore, if flow drops from its maximum value to 10% of maximum,

the delta-P drops by a factor of 100. Note that the offset accuracy/stability of piezoresistive technology is about 1% FS. This means it is not accurate in the lower 10% of operating flow. It also adds long-term offset drift. Thermal sensors have much better (0.1% FS) offset accuracy and long-term stability.

The integration of the miniaturized flow channel with the sensor chip enables the advanced thermal pressure sensor to achieve very high pneumatic impedances up to 20,000 to 50,000 Pa/(ml/s). This performance is up to 100 times higher than comparable sensors. The miniaturized flow channel reduces the gas flow through the sensor to an absolute minimum and offers unique application advantages in dusty and humid environments as well as when using long connection tubes or filters.

With advanced thermal technology, the bypass flow is almost exclusively determined by the very high flow impedance of the sensor device. The influences of additional components with resistance to flow can be neglected. That means advanced thermal differential pressure sensors can be used with long tubing, filters, or other pneumatic elements without losing their calibration. Even if these elements change their resistance over time, there will be no negative influence on the measurement accuracy. This capability gives the engineer more flexibility in designing the air handling system.

HVAC SENSOR COMPARISON

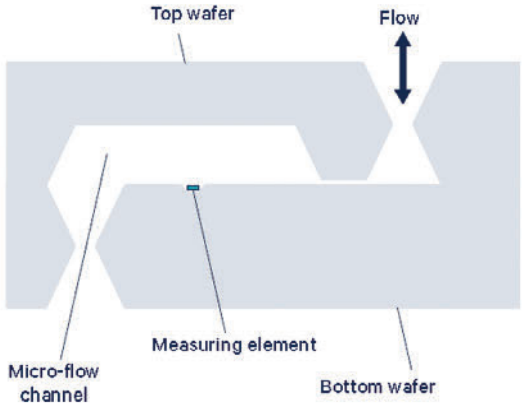
PROPERTIES	PIEZORESISTIVE SENSOR	ADVANCED THERMAL SENSOR
Sensitivity (measurement ranges of a few millibars)	High	High
Measurement Range	1 millibar (100 Pa) to 10 bar	0.25 millibar (25 Pa) and up
Overall Accuracy	High	High
Zero-Point stability	Marginal	High
Long-Term Stability	Marginal (due to offset drift)	High
Hysteresis Effects	Low	Low
Linear Signal-Pressure Characteristics	High	Good
Interfaces	Analog & Digital	Analog & Digital
Size	Very Small	Very Small
Calibrated & Temperature Compensated	Yes	Yes

The Problem of Dust

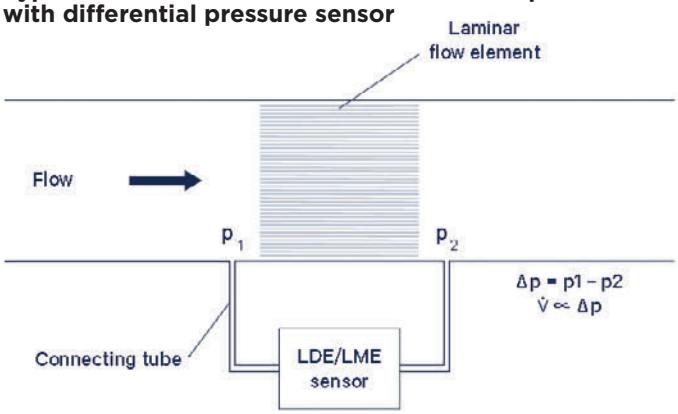
In the past, when traditional thermal pressure sensors were used for volumetric flow measurement in dirty HVAC environments, dust particles might reach the inside of the sensor and the walls of the inner flow channel. This condition would increase the sensor's pneumatic impedance, decrease the output signal, and cause a loss of calibration. In a worst-case scenario, the flow channel might be completely blocked, resulting in sensor failure.

Advanced thermal pressure sensors are highly immune to applications in dusty environments. Due to the very high pneumatic impedance, the air flow through the sensor is extremely small. This means that the total amount of dust-laden gas that streams through the bypass channel for volumetric flow measurement is reduced to an

Principle Construction of Differential Pressure Sensors (cross section)



Typical volumetric flow measurement set-up with differential pressure sensor



absolute minimum compared to traditional thermal pressure sensors. Additionally, the flow velocity is greatly reduced so the remaining dust quantity will settle in the bypass before it reaches the sensor input. As a result, the sensor does not require a dust filter. Its ability to eliminate the ingress of dust ensures highly accurate measurements and very long sensor lifetimes.

Avoiding the "Chimney Effect"

Traditional thermal sensors must be installed in a specific orientation to stop the ''chimney effect.'' Advanced thermal sensors eliminate this problem of position dependency by allowing device installation in any desired orientation. Now, the air handling system designer can place the device in any position, greatly improving design flexibility. The advanced thermal sensor also enhances design flexibility through the accuracy of its flow channel. In traditional thermal sensors, the flow channel and gas flow are determined by the geometry of their plastic housings. These housings are not manufactured as accurately as semiconductor technology, resulting in lower stability. In contrast, the advanced sensor's micro-flow channel is defined at the die level. This permits construction of the sensor housing for high design flexibility, extremely low production tolerances, much smaller and more stable packaging, and reduced manufacturing costs.

Conclusion

In selecting a differential pressure sensor, the decision comes down to the application's requirements. One sensor may have to function under changing temperatures, another will be exposed to strong vibration, while a third must cope with dusty air. No matter how demanding the conditions, there is always a pressure sensor that will perform with accuracy and reliability over a long period of time. Both sensor technologies behave quite similarly in practice due to their high degree of sensitivity and accuracy. Each technology has its own strengths and advantages. The piezoresistive sensor is impressive thanks to its high linearity. The advanced thermal sensor eliminates the drawbacks of traditional flow technology and reacts particularly sensitively around the zero point of the measurement. Choosing the correct technology will result in an HVAC air handling system that delivers maximum occupant comfort at the lowest possible energy cost. ●



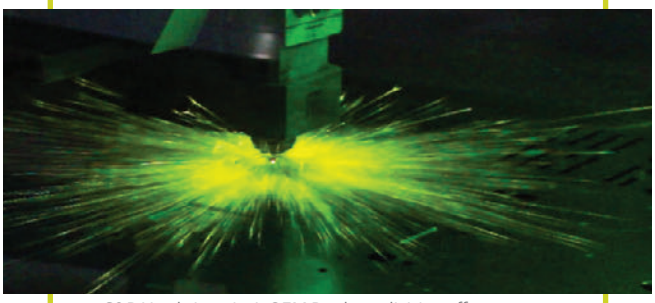
Dr. Oleg Grudin *is technical director at First Sensor. He has 30 years of experience in semiconductors physics, MEMS thermal sensors, and sensor-based instrumentation system.*



Paul Sittard*, sales manager, has over 30 years' experience working for analog/mixed-signal semiconductor and sensor companies in various technical, marketing, sales, and management roles.*

For more information visit us@first-sensor.com / www.first-sensor.com

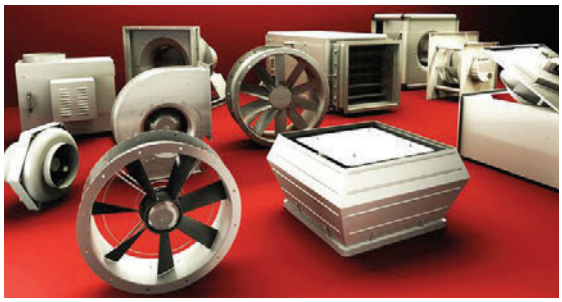
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Rosenberg curved and axial fans with Gen 3 EC motors offer more power, greater efficiency, ModBus RTU, plus preventive maintenance and reliability features.

They integrate easily into Building Management Systems. Applications include data centers, rooftop units, HVAC/R, clean rooms, schools, and hospitals

Ecofit constant pressure and constant airflow blowers automatically adjust to maintain optimum performance levels in changing conditions.

Rosenberg forward curved blowers provide up to 8800 CFM cooling capacity within a space-saving design, perfect for wall-mount air conditioning from 1.5-ton to 15-ton capacity.

ECFanGrid™ is a highly efficient, cost-effective air movement solution for new AHUs or retrofit projects replacing large radial fans.

A series of EC backward curved fans operating in parallel, ECFanGrid™ is easy to install, provides higher volume and more uniform airflow, less noise.



EpoxySet offers the EO-31FL, a flexible, silver filled electrically conductive epoxy. This creamy paste has an easy 1:1 mix ratio and can be applied by stencil, pneumatic dispensing and by hand. Curing can be done at room temperature or with mild heat. It has a 3 hour working time, with a one year shelf life.

The EO-31FL produces a good bond to a wide variety of substrates including metals, ceramic, glass and many engineered plastics. With the room temperature cure, it has an excellent volume resistivity of 10-3 ohm-cm. This high performance, adhesive has been used down to cryogenic temperatures without causing structural or electronic failures.



Optronics International, a leading manufacturer and supplier of heavy-duty LED vehicle lighting, announced that it has completed its acquisition of Texas-based USA Harness, Inc. USA Harness serves the global transportation industry with its USA-PLUS Sealed Modular Wiring Harness System and its patented USA-PLUS Modular Connection System. With its unique O-ring-style seal and secondary lock pin design, the USA-PLUS Modular Connection System has been tested and proven to perform at three times the industry standard. The acquisition makes Optronics the newest of only a few manufacturers capable of fully serving the light-, medium- and heavy-duty commercial vehicle industry.



Regal Beloit Corporation, a leading manufacturer of electric motors, electrical motion controls, power generation and power transmission components, has merged three websites into one. Customers who used to visit regalpts.com, grovegear.com or hubcityinc.com for bearings, gearing, couplings, conveying and mechanical power transmission products will now find product content, enhanced product CAD information, industry solutions and availability in one place on www.regalbeloit.com. This move brings additional tools and ease of use to customers in one mobile-friendly site. This consolidation of product offerings brings robust functionalities to distributors, original equipment manufacturers (OEMs) and end users, who can now save time while browsing a new and improved product catalog interface.

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Saki Corporation, an innovator in the field of automated optical and X-ray inspection and measurement equipment, announces that it has been chosen by **Infineon Technologies AG**, one of the largest suppliers worldwide of power semiconductors, to receive its Supplier Award 2019 in the High Power Semiconductor (HPS) Equipment category. Saki's automated X-ray inspection (AXI) system is used by Infineon to inspect its insulated gate bipolar transistor (IGBT) power modules. The award is given annually to the supplier who has best demonstrated extraordinary accomplishments in operational performance and roadmap fitness, with exceptional quality and logistics performance.

We are honored to receive Infineon's award for our equipment and customer service in the power semiconductor industry," said Eddie Ichiyama, General Manager of Saki Europe GmbH, who accepted the award at a ceremony held in K.L in Malaysia. "IGBTs are widely used in EV inverters for hybrid and electric vehicles. The quality assurance of these products is essential. We are happy to contribute to Infineon's quality assurance process with our highly accurate and powerful IGBT X-Ray inspection machine. This award recognizes our commitment to helping our customers produce the highest quality products."



AK Steel Holding Corp. has entered an agreement with Cleveland-based **Cleveland-Cliffs Inc.** estimated to be worth about $3 billion.

The combined firm would be led by Cliffs chairman, president and CEO Lourenco Goncalves. AK Steel CEO Roger Newport would retire as CEO and a director of AK Steel upon completion of the deal, while three AK Steel board members would join the combined board as two Cliffs members exit.

AK Steel would retain its branding and corporate identity following the merger as it would become a wholly owned subsidiary of Cliffs. Cliffs would maintain a significant presence at AK Steel's current headquarters office in West Chester along with its Research and Innovation Center in Middletown.

Under the agreement, AK Steel shareholders would receive 0.4 shares of Cliffs common stock for each share that they own, which would result in Cliffs shareholders owning 68% of the combined company and AK Steel shareholders owning 32%.

Cliffs is North America's largest producer of iron ore pellets and AK Steel is a leading producer of flat-rolled carbon, stainless and electrical steel products. The combined company would provide iron ore and steel products for customers across North America.

"By combining the best-in-class quality of AK Steel's assets and its enviable product mix with Cliffs' debt profile and proven management team, we are creating a premier North American company, self-sufficient in iron ore pellets and geared toward high value-added steel products," Goncalves said in a statement.

He said the firm would pursue growth opportunities, including the possibility of reopening AK Steel's recently shuttered Ashland Works plant that resulted in the layoff of 260 employees. He said the plant could be used to produce merchant pig iron, "an opportunity neither company could pursue on a standalone basis."

"We believe this transaction is a compelling opportunity for AK Steel shareholders to participate in the substantial upside potential of what will be a premier vertically integrated producer of value-added iron ore and steel products with significant scale and diversification.

SK Capital has agreed to acquire the performance products and solutions business (PPB) of **PolyOne Corporation** for approximately $775 million.

PPB is comprised of Geon Performance Materials, a maker of polyvinyl chloride (PVC) compounds; and Producer Services, a maker of a range of formulated polypropylene and thermoplastic polyolefin products, and a provider of contract manufacturing services. PPB has twelve manufacturing locations across North America and Asia and has approximately 1,100 employees. PPB has annual sales of approximately $700 million and its products are sold to companies that are active in the construction and automotive end markets.

Geon dates back to 1927 when BFGoodrich discovered and produced the first usable vinyl polymer. In 1948 the company created a vinyl plastic division based on this technology and later, in 1993, spun off the division through a public offering creating Geon.







DSS Switch, a manufacturer of HVAC hardware recognized the high efficiency of Mini Split AC systems (aka Ductless AC). After researching 120V & 240V Mini Split AC systems, it was discovered that a 1-ton unit typically draws no more than 5 AMPS. Further testing was done with a 700-WATT generator easily powering a 1-ton unit. This translates to 3-ton systems easily running on 25-AMPS or less. Like unitary systems, Mini Splits also require a disconnect switch in close proximity to the condenser. DSS Switch designed a disconnect switch with a generator port. Using the exact same wiring as a standard disconnect switch, the contractor can now offer the system ''Generator Ready''. Big upsell, no extra work!



Cincinnati Test Systems, the expert in leak detection equipment, has added the Sentinel 3520 Series to its portfolio of leak and flow test instruments, providing manufacturers with the data-driven control they need for challenging test scenarios.

Previously available through Sciemetric as the 3520 Series, this product has proven itself over the past several years with automotive and off-highway OEMs and manufacturers of other industrial equipment.

Manufacturers often struggle to balance leak test accuracy, cycle time and Gage R when faced with large part volumes, variable volumes, parts with multiple cavities, and other complex requirements. The patented Sentinel 3520 Series delivers the precise balance of pressure control, flow range, and fill rate these scenarios require to deliver an accurate reading within the required cycle time.

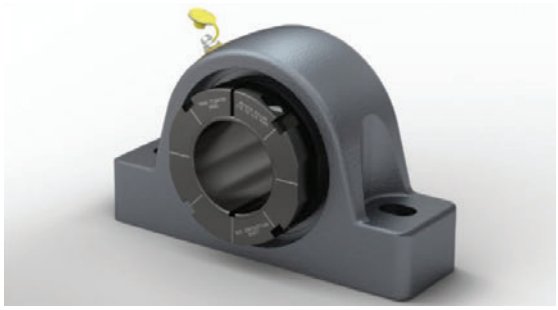
This is achieved through a powerful combination of precision electronics and hardware, and by pairing the 3520 instrument with a sigPOD controller and its process signature verification (PSV) software.

"We are focused on providing the most complete leak test portfolio to our customers," said CTS President Kevin Hansell. "The Sentinel 3520 is a perfect addition to a lineup that has the versatility, flexibility, and data-driven accuracy to tackle anything from the most stringent of micro-leak requirements to the largest and most complex part volumes. At CTS, we help manufacturers achieve a higher standard of quality and efficiency that resonates across the entire production line."

Powerful performance driven by unique features:

- Fast Fill: Pneumatics separated from the controller and placed close to the part under test reduce hose and systems volume for ultra-fast fill rates, especially for large parts.
- Enhanced Control: Greater precision to adjust for environmental factors, like temperature and air pressure.
- Extreme Accuracy: Pressure control resolution down to 30.000,01 psi. Flexible PSV software captures and visualizes thousands of data points.
- Increased Insight: Digital process signatures give insight into every millisecond of each test cycle.
- Vast Range: Test parts from 1 cc to 1 million cc in volume.

Additional analysis for continuous improvement of the leak test can be achieved by connecting one or more 3520 systems (and other CTS instruments) to the QualityWorX CTS DataHub. Leak test data can be further consolidated and analyzed with other production and plant data using Industry 4.0 data analytics platforms QualityWorX and Sciemetric Studio.



Regal Beloit Corporation , a leading manufacturer of electric motors, electrical motion controls, power generation and power transmission components, announces the release of the new Klamploc adapter lock for Sealmaster mounted unitized spherical roller bearings (USRB).

The Klamploc adapter lock was designed to simplify the installation process while improving shaft lock reliability. It accomplishes these goals with two unique design features.

The first feature includes key installation steps that are written on the lock collar. Regal always recommends fully reading the installation instructions prior to attempting an installation. Often, after bearings are removed from their boxes prior to installation, the boxes and the installation sheets get discarded by users. Or, the sheets might be reviewed ahead of time, but the installation specifications do not get memorized or are unavailable when needed at a job site. Because the Klamploc adapter has installation steps clearly marked on its collar, the installer can simply read the specs from the bearing itself.

The second key design feature is a split collar with a cap screw to close the split. With the Klamploc adapter, there are neither parts to remove and then install nor parts to bend on the bearing. Other market options require one or more parts to be removed before installation. This not only introduces additional non-value-added steps, but it also creates a situation where these parts, often small, can be lost.

"Other market options require a tab to be bent down to achieve the final lock, but bent tabs can be subjective," said Jason Annes, Sr. Product Manager, Regal Beloit. "With the Klamploc adapter, the final lock of the collar is achieved by simply tightening the screw to the specified torque, eliminating the competition's several steps."

In addition to offering simplified final locking, the split Klamploc collar has a benefit unique to the industry. When tightening the collar cap screw, the split collar compresses and grips the adapter sleeve, which can provide additional clamp force to the shaft when combined with the properly set adapter lock.

Sealmaster USRB bearings with the Klamploc adapter lock have launched in bore sizes of 5 inches and below. Sizes above 5 inches will be launched in 2020.



Bacharach, an industry expert in gas detection and analysis instrumentation, introduces the Monoxor XR (extended range) hand-held exhaust gas analyzer for measuring CO (carbon monoxide) in ambient air or directly from the exhaust pipe of forklifts, floor burnishers or other equipment burning propane, gasoline, diesel, or CNG (compressed natural gas). The Monoxor XR is the ideal instrument for verifying worker safety and achieving compliance with OSHA air quality regulations.

It can also be used for engine tuning and diagnostics, resulting in improved equipment efficiency and fuel savings. The Monoxor XR provides visual and audible alarming for instant alerting of personnel to dangerous CO levels. The expanded measuring range of 80,000 ppm allows technicians to test even the most poorly maintained equipment without risking damage to the gas sensor. Bacharach's Combustion mobile app allows the user to quickly and easily create and send customizable emissions reports from their smartphones or tablets. A specialized exhaust probe kit is available for direct connection to various exhaust pipe designs, and a magnetic rubber boot is available to provide a non-slip, secure grip for hands-free testing.
The Monoxor XR employs Bacharach's B-SMART® sensor technology for pre-calibrated sensor replacement in the field - minimizing downtime, maintenance costs, and overall cost of ownership.

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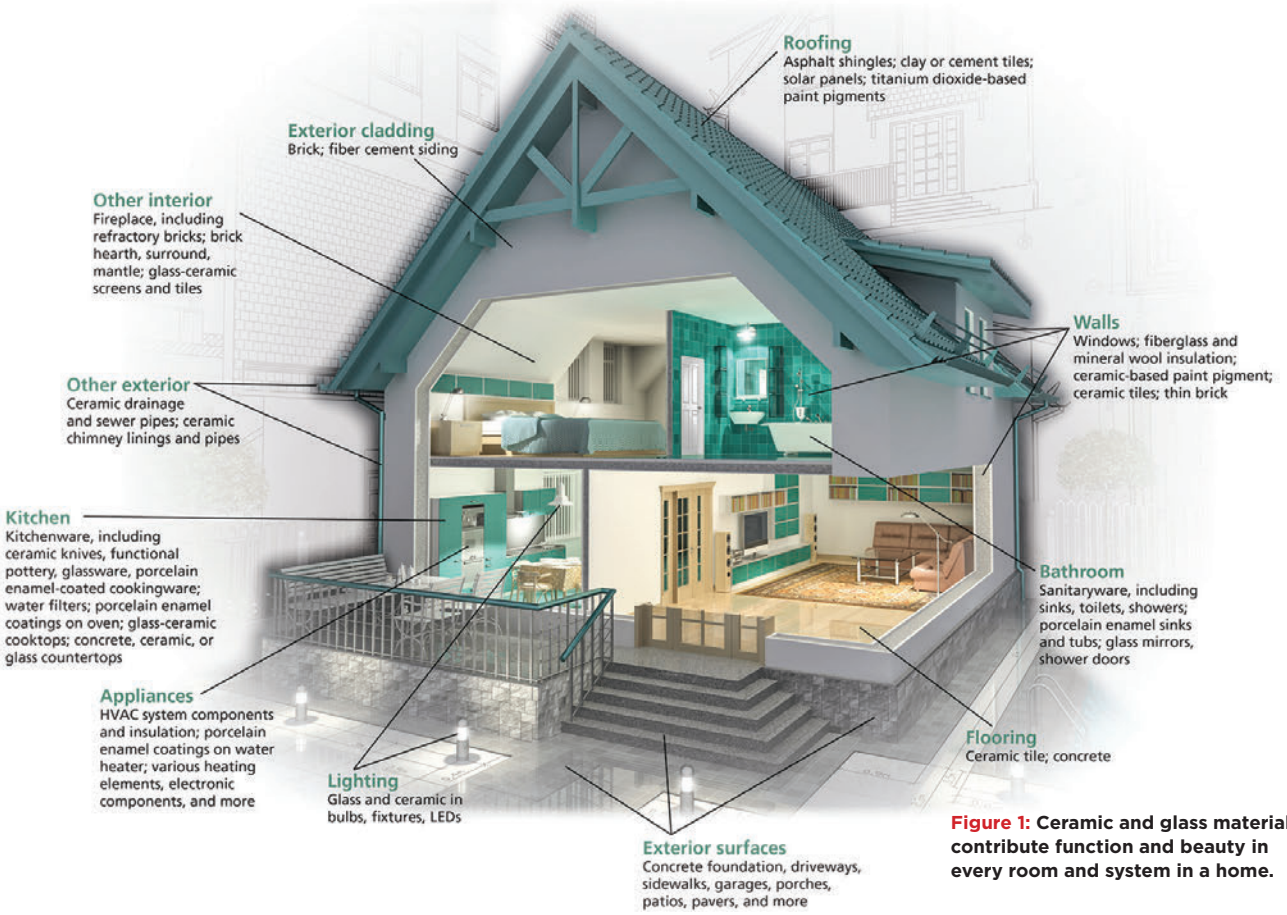


Figure 1: Ceramic and glass materials contribute function and beauty in every room and system in a home.

PART 1

How Ceramics and Glass Contribute to the $4.17T Residential Building Market

BY APRIL GOCHA & LISA MCDONALD

Across the globe, 230 billion m2 in new construction is expected to be built over the next 40 years. For scale, that unprecedented rate is the equivalent of building Paris every week for the next four decades.[1]

In part, this is because of growing global population—approaching eight billion people—each of whom needs a place to live. Urban areas are growing at a rate of 200,000 people per day,[2] causing many cities to feel the pressure under struggling infrastructures, skyrocketing housing prices, and rising homelessness.

So it is no surprise that residential housing represents a sizeable portion of the globe's total future construction. The global market for residential building construction, including new builds, renovation, and remodeling, was worth nearly $4.17 trillion in 2017 and is predicted to reach nearly $6.80 trillion by 2022, growing at a healthy compound annual growth rate (CAGR) of 10.3%. The Asia Pacific region, driven by growth in China, constitutes 58.1% of that market, followed by North America (19.4%) and western Europe (11.5%).[3]

Construction has a significant impact on global economies as well. The residential building construction market comprised an estimated 5.8% of global gross domestic product (GDP) in 2019 and is expected to reach 6.9% by 2022. Also considering both residential investment and consumption spent on housing services, which includes things like rent and utilities, housing contributes an average 15–18% GDP.[4]

"At the national level, the impact is broad-based, as jobs are generated in the industries that produce lumber, concrete, lighting fixtures, heating equipment, and other products that go into a home or remodeling project," according to the National Association of Home Builders report.[5] "Other jobs are generated in the process of transporting, storing, and selling these projects. Still others are generated for professionals

such as architects, engineers, real estate agents, lawyers, and accountants who provide services to home builders, home buyers, and remodelers.''

In total, construction of each new single-family home in the U.S. contributes an estimated 2.97 jobs to the economy and $280,433 in combined wages and profits.[6] In other words, the construction industry is large, it is significant, and its impact extends wide.

Energy Efficiency

In addition to having a significant impact on global economies and markets, buildings and construction together account for about a third of global energy use and energy-related CO2 emissions—making construction a prime target for efforts to reduce energy consumption.

''If there's a defining theme for the building sector in 2019, it's energy codes,'' according to a New Buildings Institute article.[7] ''Actions to update the rules that cities and states set to determine how effectively new residential and commercial buildings use energy are progressing on several fronts across the U.S.''

Regulations and initiatives nudge toward increased energy efficiency across the globe, nudging companies and industries to act to reduce their use of energy, water, and resources as well as their total negative impact on the environment.

In the U.S., a national model for energy use standards called the International Energy Conservation Code (IECC) forms a precedent for more local adoption of energy-use standards by U.S. states and cities. Updated every three years, IECC codes target building envelopes as well as mechanical, lighting, and power systems for opportunities to increase energy efficiency.

In Europe, the European Energy Performance in Buildings Directive mandates that all new buildings achieve nearly zero-energy status by 2020—meaning that the buildings must use low amounts of energy sourced mostly from renewables.

Materials Offer Solution

Considering that the construction industry uses over 400 million tons of material every year,[8] materials provide vast potential to improve building energy efficiency.

For instance, producing an annual estimated 76 million tons of finished concrete for U.S. construction generates 9.8 million tons of CO2.[8] However, efforts to reduce concrete use can only go so far, so changes to reduce the negative environmental impact of producing and using concrete become important for future sustainability.

Advancements in the materials themselves as well as improvements to their production, use, and disposal are all important considerations to reduce overall energy use and mitigate negative environmental impacts.

Advanced materials offer broad advantages, such as increased recyclability, reduced construction time, and higher quality, versatility, and durability and are already changing residential construction, according to a BCC market report.[3]

''Fluor, a U.S.-based construction company, is using 50%-faster-curing concrete in its construction projects. Other advanced construction materials in the market include super-lightweight ceramic sidings, organically coated steel, self-healing concrete, rain-absorbing roof-mats, and micro-encapsulated phase-change material.''

In other words, materials offer solutions.

These solutions represent substantial industries for diverse building products, which, due to the size and scope of the construction industry, significantly influence supply chains, R&D, and manufacturing of the even more diverse materials they incorporate.

''The European Commission estimates that 70% of product innovation across all industries is derived from new or improved materials,'' according to a World Economic Forum report on the future of construction.[2] ''With approximately one-third of construction cost attributed to building materials, the scope for applying advanced building materials is considerable.''

Enabled by Ceramics and Glass

In the U.S., the median size of a new single-family home sold in 2018 was 2,435 ft2 (median price: $281,200).[9] However, that size varies significantly across the developed world, with an average for all homes closer to 1,200 ft2.[10] The variation gets even wider if you consider all the dwellings called home across the entire globe.

Each of those dwellings contain a host of materials, which themselves vary widely based on the region, climate, availability, preference, and local practice.

What most people call home, however, includes ceramic and glass materials on the interior and exterior surfaces, within walls and spaces, and affixed throughout—top and bottom, inside and out. Ceramic and glass materials are integral to both building homes and making homes functional buildings to inhabit.

This article provides a snapshot into use of ceramics and glass in and around a home and the markets they drive. While the full extent of these applications is beyond the scope of this article, Figure 1 shows some examples of specific applications and places where ceramic and glass materials can be found in residential homes.

Further, the materials and the

TABLE 1
SELECT COMPANIES THAT MANUFACTURE CERAMIC & GLASS BUILDING PRODUCTS

Company (location)	Annual Revenue (Millions)	Website	Role in Value Chain
Saint-Gobain (Courbevoie, France)	$46,670	www.saint-gobain.com	Various diverse products, including building glass, roofing, insulation pigment materials for tiles
*CertainTeed, subsidiary of Saint-Gobain (Malvern, Pa.)	$4,000 ‡	www.certainteed.com	Roofing, insulation, siding, various building and construction products
LIXIL Group Corp. (Tokyo, Japan)	$16,900	www.lixil.com	Sanitaryware, as well as various other building materials and construction products
Mohawk Industries Inc. (Calhoun, Ga.)	$9,984	www.mohawkind.com	Flooring (including ceramic tile), countertops
*Dal-Tile, subsidiary of Mohawk (Dallas,Texas	$5.7 ‡	www.daltile.com	Ceramic tile, countertops
Kohler Co. (Kohler, Wisc.)	$7,727 ‡	www.kohlercompany.com	Sanitaryware; also manufactures diverse other products
Owens Corning (Toledo, Ohio)	$6,384 †	www.owenscorning.com	Roofing, insulation
Boral (Sydney, Australia)	$5,869	www.boral.com	Various building products, including roof tiles, windows, drywall
Toto (Kitakyushu, Japan)	$5,407	www.toto.com	Sanitaryware
Carlisle (Scottsdale, Ariz.)	$4,600 ‡	www.carlisle.com	Various diverse products including roofing, insulation, other construction materials
Johns Manville (Denver, Colo.)	$3,100 ‡	www.jm.com	Roofing, insulation
GAF Materials (Parsippany, N.J.)	$3,000	www.gaf.com	Roofing
Schott AG (Mainz, Germany)	$2,325	www.schott.com	Various diverse products including flat glass, ceramics for various home applications
*Schott North America Inc. (Elmsford, N.Y.)	$56 †	www.us.schott.com	Various diverse products including flat glass, ceramics, and glass-ceramics for various home applications
Roca (Barcelona, Spain)	$2,009	www.roca.como	Sanitaryware, ceramic tile
Ferro Corp. (Mayfield Heights, Ohio)	$1,612	www.ferro.com	Various products in diverse industries, including porcelain enamel
IKO Industries (Calgary, Alberta, Canada)	$1,188 ‡	www.iko.com	Roofing, insulation
Acme Brick Co. (Fort Worth, Texas)	$758 †	www.brick.com	Brick
Knauf Insulation (Abu Dhabi, United Arab Emirates)	$406 ‡	www.knaufinsilation.com	Insulation
SCG Ceramics (Bangkok, Thailand)	$381	www.scgceramics.com	Ceramic tile, sanitaryware
Mansfield Plumbing LLC (Perrysville, Ohio)	$181 †	www.mansfieldplumbing.com	Plumbingware

* Conversions per Google as of October 19, 2019. All financial data obtained from company reports unless otherwie noted.
† Data obtained from NAICS codes. ‡ Private company or data not available; revenue estimated from owler.com or hoovers.com.

products they enable represent significant industries that contribute to the global economy. Table 1 provides a sampling of companies that manufacture ceramic and glass materials, or products tied to the construction industry and a glimpse of the commerce involved.

Raise the Roof

Globally, roofing sales are expected to hit $120 billion by 2022, with bituminous products, the category that includes asphalt shingles, the most popular choice for roofing in 2017 with 34% of global sales. Concrete and clay tiles accounted for 30% of the market in terms of area of roofing, although they account for the largest fraction of sales due to the products' higher price. The rest of the roofing market divides between metal (11%), fiber cement (6%), rubber (4%), and plastic materials (5%) ("other" materials account for the remaining 10%). Demand for all types of roofing globally is expected to rise 2.4% annually through 2022.[11]

It is no surprise that the roofing market itself is heavily influenced by weather. Weather-related reroofing alone accounts for about a third of U.S. demand for residential roofing per year.[12]

"With storms becoming more powerful and more frequent, roofing must boast increased durability and impact resistance," says Lucas J. Hamilton, manager of applied building science for Saint-Gobain Corp. (Malvern, Pa.).

Storm-resistant roofing is predicted to account for a growing portion of the market, especially as insurers require installation of these products

as a term of coverage and building codes increasingly demand them. These include wind-resistant, impact-resistant, and UV-resistant products, as well as those that withstand extreme temperatures or prolonged moisture.[12]

Modern laminated asphalt shingles have been engineered to withstand wind gusts of up to 140 mph, have impact resistance to intense hail and windborne debris, or better reflect solar radiation to improve homes' energy efficiency. These properties are significant developments from the first iterations of asphalt shingles, which were often composed of organic matter such as cotton rags, paper, and wood pulp, coated with asphalt, and topped with crushed slate, oyster shells, or other rock-like materials.

"In the 1970s, there was a big transformation in the industry to use fiberglass mat to serve as the backbone or the structure of shingles," says Carmen LaTorre, senior R&D leader for shingle innovation at Owens Corning. Fiberglass mats themselves not only provide modern asphalt shingles with much more durability, but they have also allowed shingles to get thinner and lighter, allowing multilayer designs that further improve strength and durability.

The other major improvement in modern shingles, LaTorre says, is that modern asphalt shingles are topped with engineered ceramic-coated granules instead of crushed rocks. The ceramic coatings can contain different additives, ingredients, and pigments to achieve various performance functions or desired colors. Granules can even receive multiple coatings, each applied as a slurry and kiln-fired onto the granules, to achieve a desired combination of performance or processing benefits. For example, by mixing together granules with different pigments and



Figure 2: Ceramic-coated granules can be manufactured in an array of colors and functionalities to provide dimensional effects and performance to asphalt shingles.

shades of pigments, manufacturers can fabricate shingles with rich dimensional effects that mimic other types of roofs but have the enhanced performance of asphalt shingles (Figure 2).

Pigmented ceramic-coated granules are not just for looks, however—they also can be designed with specific functional features, such as better light reflectivity. Roofs that better reflect the sun's radiation, commonly called "cool roofs," help buildings reduce energy use by preventing radiation from being absorbed into buildings as heat. Whereas standard asphalt roofs reflect less than 20% of sunlight, cool roofs reflect an average 67% of direct sunlight.[13]

In the U.S., regulations in California have been particularly influential in driving demand for roofing materials with enhanced reflectivity to increase the energy efficiency of buildings and reduce urban heat island effects. The state's CalGreen standards—the first statewide set of mandatory green building codes in the U.S.—specify that buildings must adhere to various practices spanning planning and design, energy efficiency, water conservation, material conservation and resource efficiency, and environmental quality.

For roofing materials in particular, CalGreen codes include standards for solar reflectance index, which measures a material's ability to reflect solar heat.

"Roofing is being influenced by energy efficiency requirements, and the industry must meet these requirements by being nimble and efficient despite the ongoing labor shortage," Hamilton says.

While California's regulations drive development of cool roofs, industry is watching this market segment and technology closely. "The industry is monitoring this and coming up with higher reflective coatings or granules" LaTorre says. "Even today, discussion continues around what those standards are and whether they will be even more stringent in the future."

If codes do become more stringent, roofing materials will undoubtedly evolve alongside. But designing and testing new roofing materials is a difficult task, partly because the existing materials today already have such high performance.

"For any new material, you must have a really rigorous protocol to show that it can withstand the cold, the hot, the cycling temperatures," LaTorre says. "So that's one of the biggest challenges to product developers—you've got a great track record with existing materials, so how do you make sure that you evaluate that the next generation of materials can have that same durability?"

Better With Brick

For thousands of years, human civilizations have inhabited brick structures—many of which, impressively, still stand today.

While the clay-based materials in brick changed relatively little across thousands of years, the manufacturing processes shifted dramatically.

"On the operations side, there's been a lot of innovations to try to make product as efficiently and cost effectively as possible," says Stephen Sears, chief operating officer and vice president of marketing for the Brick Industry Association (Reston, Va.).

In addition to automation, modern brickmaking plants also adopted extensive innovations in the kilns and dryers—including variable speed drives to electronically control fan speed and pulsed firing technology to improve firing efficiency—that significantly improved the industry's energy efficiency. "These methods have really enhanced the industry's fuel efficiency per unit of production," according to Garth Tayler, an expert with more than 50 years of experience in the brick industry and retired technical director for Acme Brick (Fort Worth, Texas).

The U.S. clay brick and product manufacturing industry—which includes clay brick, ceramic tiles, and refractory products—is estimated to reach $7 billion in total revenue in 2019, representing an annual 2.3% growth from 2014–2019.[14]

Despite this incremental growth, the brick industry is still recovering from the 2008–2009 Great Recession. "Our total manufacturing net sales, what's called value product shipments, was about $1.2 billion total in 2018. We were up to $2.2 billion at some point in the 2000s but we got hit really hard in 2011," Sears adds.

And although he says the brick industry recovered from that trough, it is still not yet back up to pre-recession levels.

Part of that is due to the reduced number of new homes starts since the Great Recession hit its hardest. While numbers have been steadily increasing year over year, the number of new single-family homes built in the U.S. in 2018 was nearly 50% of that in 2005 (Figure 3). That change of pace was felt across the construction industry.

In 2018, 21% of new single-family homes had exteriors clad in brick, a percentage that remained relatively stable in the U.S. over the past several decades.[15]

Today, homeowners and builders have more choices than ever for exterior cladding, and that is one of the biggest current challenges for brick. "We are under incredible competition," Sears says. "And there are some really strong competitors."

Perhaps the strongest competition comes from fiber cement siding, a durable composite siding product composed of cement reinforced with cellulose fibers, often wood pulp. Fiber cement represents the fastest growing exterior material category, expected to increase 3.6% annually through 2022.[16] While fiber cement clad the exterior of just 9% of new single-family homes in the U.S. in 2005, that share jumped to 20% in 2018—just behind brick's 21%.[15]

While other cladding materials offer lower cost than brick, none comes close to its strength and durability.

"Brick is by far the most durable and requires the least amount of maintenance," says John Hewitt, assistant plant manager of Interstate Brick (West Jordan, Utah). After considering the cost of maintenance and replacement, which can become significant with other materials, he says, brick comes out on top.

Research at the National Brick Research Center (NBRC; Anderson, S.C.) measures and quantifies brick properties, which demonstrate that brick as a cladding material is unsurpassed in terms of thermal performance and impact resistance.

"The way energy codes work right now, is all based on R-value," says John Sanders, director of NBRC and research associate professor of materials science and engineering at Clemson University. "It's an artificial sort of temperature measurement that doesn't simulate the real world. And it completely neglects materials like brick that have a significant amount of thermal mass."

The R-value reflects the ability of a material or system to resist heat transfer through conduction. A higher R-value indicates greater insulating ability because the material or system prevents more heat transfer.

To more accurately test and

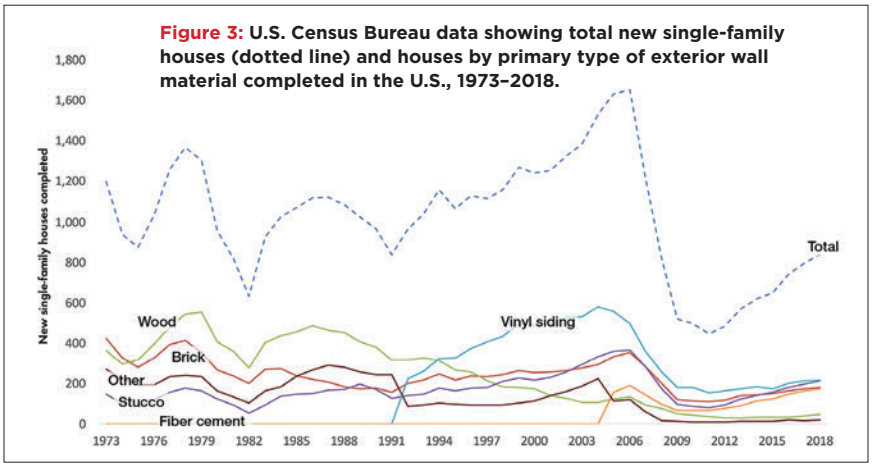


Figure 3: U.S. Census Bureau data showing total new single-family houses (dotted line) and houses by primary type of exterior wall material completed in the U.S., 1973–2018.

demonstrate the real-world performance of brick walls, NBRC specially built hot boxes to quantify the thermal performance of entire 6-foot by 8-foot wall panels. ''When we subject brick wall panels to real-world temperature cycles, what we find is that energy use is up to 50% less than what R-value would tell you,'' Sanders explains.

Based on these results, Sanders says brick likely performs even better than its R-value indicates. However, current codes do not reflect these new data because the codes are based on the assumption that convection is the major contributor to heat flow for brick walls. ''What we've been able to prove is that it's actually radiation in that air space that is the dominant means of air flow, and convection is a very minor contributor,'' he adds.

Using these kinds of data, NBRC is researching how to further improve the performance of brick wall systems, such as incorporating radiant barriers in the wall and optimizing the size and coring of brick.

A recent innovation in the brick industry is thin brick. Thin brick, just 0.5–1.5-inch thick instead of the typical 3-5/8-inch thickness of standard brick, offers versatility. In addition to both interior and exterior applications, it can go places where a full brick is space or weight prohibitive. Installation is faster and easier, and thin brick can be added in renovations and installed on accent walls and backsplashes, for example.

Demand for thin brick is high, and companies are certainly investing in them. Whereas many companies simply manufacture standard brick and saw the faces off to fabricate thin bricks, Interstate Brick recently invested in a separate extrusion line specifically designed to fabricate thin brick, Hewitt says. ''In general, the industry is currently faced with the challenge of how to make enough of these without additional manufacturing steps, particularly saw cutting full-sized brick down into thin-brick slices.''

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The IBEX solid-state microwave/convection oven by ITW.

Smart Microwave Oven Designs

BY BY THOMAS FORRISTER

What makes an electronic device "smart"? Connectivity, certainly, is a large factor, and it is now commonplace to seamlessly switch from a phone or tablet to a computer using Bluetooth, wireless internet, or 4G LTE and 5G protocols. Another sign that earns the smart (and sometimes artificial intelligence) label is a device's computing capabilities, which help us more easily perform everyday tasks. Take the smart home concept, for example. Thanks to the broader software capabilities of many devices, consumers are now able to automate their lives and save energy costs by using robot vacuum cleaners and adjusting lighting and heating settings on a timer.

Inside the kitchen, appliances such as refrigerators, dishwashers, and microwave ovens with smart features are becoming part of daily life. Smart appliances also have a place in professional kitchens. By designing cutting-edge smart appliances for these professional spaces, Illinois Tool Works (ITW) Food Equipment Group, the world's largest commercial food equipment company, is revolutionizing the way chefs cook, manage their time during service, and build menus.

Generating Microwaves with Solid-State Technology

ITW provides industrial appliance products ranging from drink service refrigeration to hot holding equipment, and uses the COMSOL Multiphysics® software to build and distribute simulation applications, improving manufacturing processes and designs. One of their latest commercial offerings, IBEX, is a microwave and convection oven that is designed for the professional kitchen. The IBEX product includes a number of smart features and changes the way food is cooked by heating food differently than other smart combination ovens.

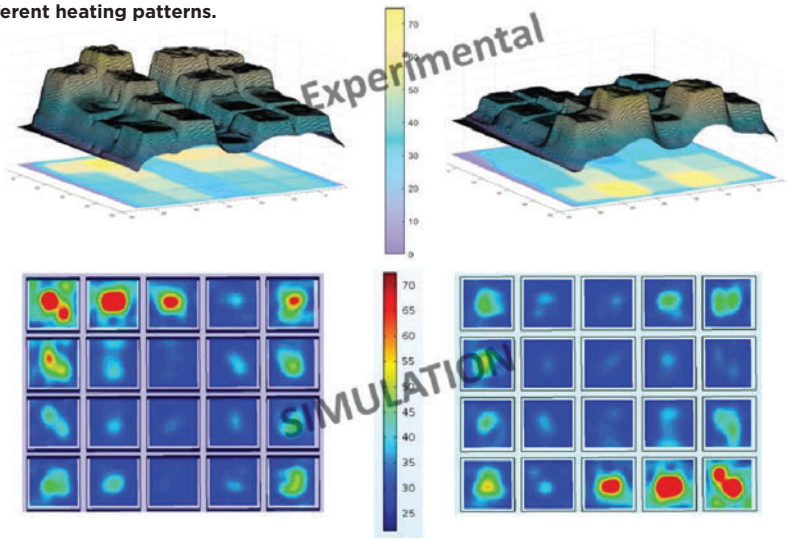
RF technology provides consistent performance during the varied load conditions required for cooking. Engineers at ITW are harnessing the power of RF energy with a solid-state RF power amplifier and receiver, which directs the energy in a smarter, more uniform, and more efficient way than with a traditional magnetron — depending on the type of food or how much food it is heating. This technology achieves the quality of a combination oven, but with a rapid-cook oven time.

The targeted heating capabilities help automate tasks for chefs and other kitchen staff. Aside from the efficiency of solid-state heating, the IBEX oven is able to use algorithms to help professionals program recipes and custom menus, as well as perform common functions as they go about their work. No smart device would be complete without the connectivity factor: The IBEX has a USB port to easily expand menus via upload or transfer.

Adding smart features helps kitchen professionals, but what about tools that aid in designing the equipment? "When trying to optimize food heating with microwave/RF energy, simulations can be used to gain an approximate understanding of what to expect," says Christopher Hopper, sr. RF systems engineer at ITW. "Using simulation to get an idea of the heating patterns available in a solid-state oven allows for a more informed experimental setup."

He adds that the team also saves on food and labor costs, because there are virtually no trial-and-error runs of an experiment — they can do it all ahead of time to find the optimal design for both the appliance and the related experiments.

The improved uniformity when combining different heating patterns.



Working Smart with a Combination of Simulation and Experiments

Setting up experiments by first using the COMSOL® software and add-on RF Module helps Hopper and his team study varying loads, uniformity, hot spots in the food, and more. Then they take advantage of LiveLink™ for MATLAB® to reduce computational time by combining parametric sweeps with complex postprocessing. Hopper finds this interfacing capability especially beneficial, as he uses the MATLAB® software extensively.

One of their important experiments considers the efficiency of the solid-state RF IBEX design. Hopper and his team were interested in how well the oven can maintain a high efficiency for different food containers that have varied volumes and load distribution, so they used simulation to help them test the containers and identify where there was room for uniformity improvement. A cubic arrangement of thin layers and an array of cylinder-shaped loads were compared. For each type of container, the solid-state oven could maintain highly efficient energy delivery to the load.

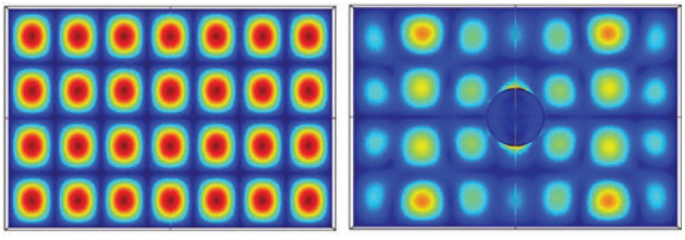
Current rapid-cook ovens on the market are unable to adjust parameters such as phase, frequency, and output power, which leads to large swings in efficiency when the load volume, distribution, and number of items change. Alternatively, the effectiveness of convection or combi ovens depends on the surface area of the load, so increasing the number of items does not necessarily lead to an increase in time required for cooking or reheating. In contrast, the IBEX oven's efficiency stays high for a multitude of load configurations, thus combining the quality of a combi/convection oven with the speed of commercial rapid-cook ovens.

However, simply having the ability to control frequency, phase, and output power is not enough to maintain highly efficient energy delivery. Instead, they relied on the closed-loop feedback system to evaluate opportunities for improving cooking configurations. Closed-loops, as opposed to open-loop-type ovens, allow the device to learn the initial conditions, apply specialized heating configurations, and adapt to the changing physical properties of the load during cooking. By using closed loops as a form of control, engineers can feed the system's generated output back into the system. By comparing the actual output with the desired output, they can design this type of system to automatically sense and monitor the difference in output via an error signal, and thus change the loads, food properties, and other conditions to improve the cooking process.

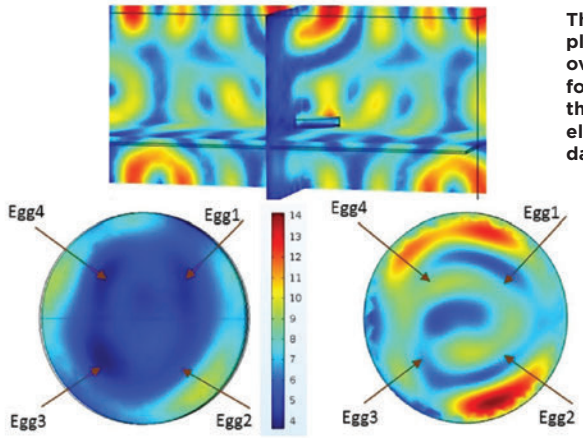
Using feedback from the cavity/load system, they are able to run tests to see that cooking configurations can be combined to improve uniformity and consistent energy delivery while using less nominal power to achieve the same result.

From there, the team can continue to refine tests and confirm and understand the simulation results. "COMSOL Multiphysics® allows our team to perform accurate coupled electromagnetics and thermal simulations of food materials, or loads," says Hopper. "The properties of these loads change with temperature and frequency, and we have found that the software can account for these changes and provide good approximations for the heating pattern, electromagnetic field magnitude, and power loss density."

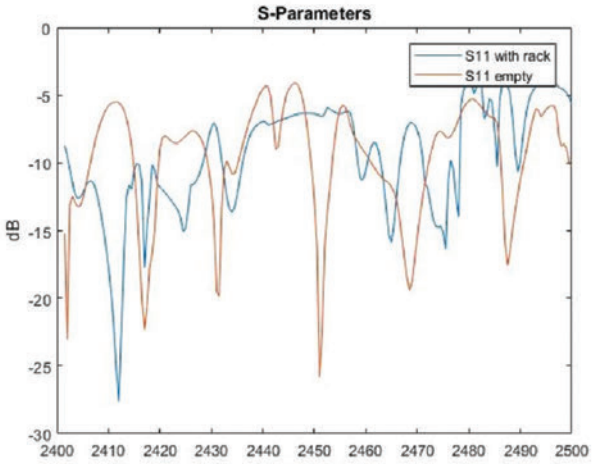
For example, when they create simulations of loaded and unloaded cavity modes, the team can see where hot spots are most likely to be located. Evaluating likely heating patterns and potential cavity and cookware absorption using simulation can assist them in structuring their experiments



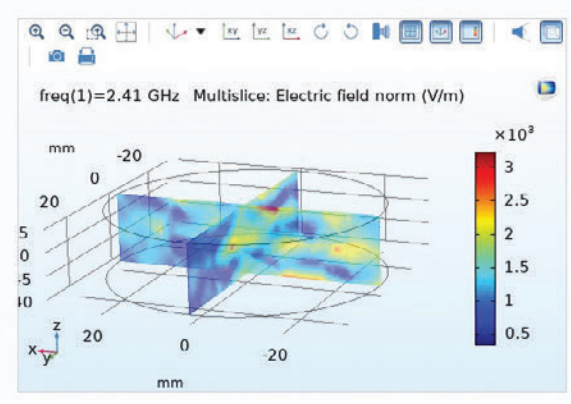
Electric field pattern comparison for loaded and unloaded cavity modes within a microwave oven.

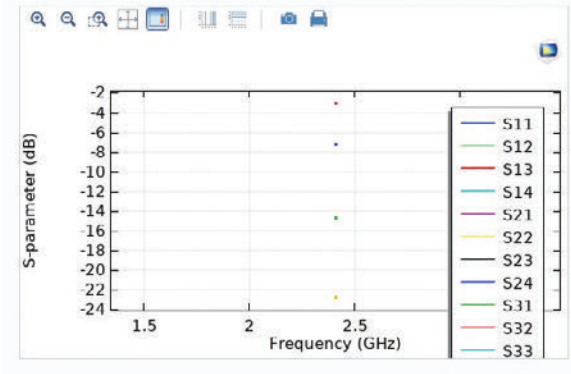


The probe placement in the oven and eggs for collecting thermal and electromagnetic data.



S-parameters for an oven with and without a rack.





User interface for an IBEX oven simulation application.

in which thermal and electromagnetic data will be collected using multiple frequencies. Furthermore, they can be sure that the simulation results are accurate by creating an intentional temperature difference between foods like bread and eggs.

The More Cooks in the Smart Appliance Design Kitchen, the Better

In addition to more complex simulations, Hopper creates simulation applications so that colleagues are able to interact with the design by changing parameters such as frequency or phase response, temperature and time (in terms of recipe creation), sample size and location effects, dielectric properties, and more.

There are many advantages to deploying applications within an organization. "When working in a diverse team with different skill levels and backgrounds, I have found that tailoring applications to a person's interests and job duties lightens the workload on the simulation experts," says Hopper.

He also sees building simulation applications as an opportunity to educate others. In fact, some of the applications of the IBEX oven have been created specifically to introduce new team members and interns to the basics of wave interference, dielectric and loss factor dependencies, and RF heating.

Solid-state cooking devices present many promising advancements in the culinary arts, with targeted food heating being just one of them. By continuing to use important ingredients like simulation, applications, and postprocessing tools, engineers and manufacturers in the food equipment industry can design more efficient and reliable smart appliances for both professional and home kitchens.



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Custom Magnetic Sensor Guide For Appliance Applications

How to find digital and analog sensors that drive efficient, reliable white goods designs

BY RYAN SHEAHEN

The demand for energy efficiency and convenience is driving the application of sensor technology in the home appliance and white goods market. Within this industry, sensors are used for detecting and controlling temperature, position, proximity, level and speed. As more sensors are integrated into appliance designs, engineers must identify advanced sensing solutions that deliver the improved accuracy, reliability and efficiency demanded by consumers.

When an off-the-shelf sensing solution will not meet the unique requirements of an appliance application, the design engineer must specify a custom sensor. To find the best custom sensor for an appliance design, the engineer should consider the full magnetic circuit as well as the environmental, mechanical, electrical and magnetic parameters of the application. When all key factors are known, the engineer can recommend a custom magnetic circuit design with a robust sensing technology.

This article will discuss how to select digital and analog sensors for appliance designs that utilize magnetic sensing technology. In addition to defining and describing the benefits of Hall effect sensors and reed switches, it will provide examples of appliance designs that incorporate these sensors.

Analog Sensors for Superior Accuracy and Stability

Analog sensing applications allow the end user to collect instantaneous feedback on the magnet's position. Analog Hall effect sensors deliver a high-accuracy, high-resolution ratiometric output signal in large and small appliances. Unlike mechanical switches, these sensors can be hidden behind the appliance walls, increasing the appliance's aesthetic appeal. Since analog Hall effect devices utilize noncontact magnetic sensing, they do not exhibit the mechanical wear associated with lever arm or push-button technologies.

Recent design advancements in analog Hall effect technology have enabled the Hall effect chip to measure the angle of the flux field instead of the traditional amplitude. This improvement makes it much less susceptible to temperature changes, allowing the sensor to deliver a more stable analog output signal across a large temperature range.

Rotary Hall Effect Sensor

The following section provides details on two types of Hall effect sensors that can be selected for analog appliance applications.

Combining a Hall effect sensing element with electrical circuitry, this semiconductor-based sensor provides an analog output signal that corresponds to the change in a rotating magnetic field.

Rotary Hall effect sensors offer two output options: analog or pulse-width modulation (PWM). The engineer can program the sensor to associate a specific output voltage or PWM

output value with a precise degree of rotation. Multiple programming points are available up to 360 degrees of rotation. Each programming point represents a voltage or PWM output value that corresponds to a given angle of the magnetic field. This results in a ratiometric output signal relative to the degree of rotation.

Benefits: Unlike a mechanical rotary or resistive film rotary device, the rotary Hall effect sensor does not experience mechanical wear or changing resistance values. In addition, it is very stable over normal operating temperatures up to +105°C. Units are accurate from 0–360 degrees rotation with 0.5 V–4.5 VDC output or 10–90% duty cycle for PWM.

Appliance Applications: Rotary Hall effect sensors can be used to detect the dial position in washing machines, clothes dryers, stoves/ranges and blenders. For consumers who prefer the detent/clicking sound and feel of a mechanical rotary dial, the design engineer can add these mechanical features to the external packaging that encapsulates the noncontact rotary Hall effect sensor. Thus, the end user gets the mechanical experience while still enjoying the high reliability of a Hall effect sensor.

Linear Hall Effect Sensor

Instead of measuring rotation like the rotary Hall effect sensor, the linear Hall effect sensor measures the linear movement of a magnetic field. The Hall effect sensor is programmable for a set output voltage that is ratiometric for a given travel distance. Its output options are the same as the rotary Hall effect sensor. The sensor measures the linear movement and relative flux angle of a magnetic actuator up to 30 mm of travel distance with a single Hall effect chip. This results in a ratiometric output signal relative to the precise movement of the sensor.

Benefits: Before programming the output voltage (or PWM value) to correspond to the relative magnetic field value of the actuation magnet, the sensor and actuator can be placed in their final mounting area within the application, considering all magnetic influences from the nearby surroundings. This allows the engineer to optimize the application's output since any shunting, mechanical tolerances or stack-up tolerances of the magnetic field will be included within the programming environment.

Appliance Applications: Linear Hall effect sensors are often used to monitor fluid levels in refrigerator ice makers, dishwashers, washing machines and coffee makers.

Digital Sensors for Precise, High-Reliability Applications

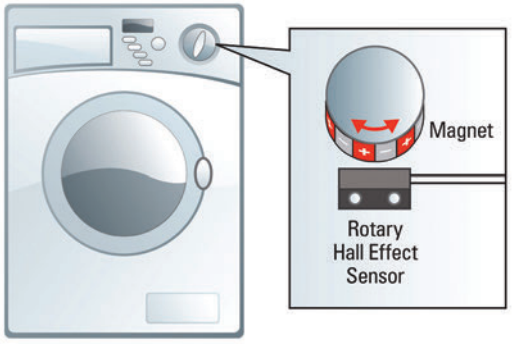
Most white goods applications demand digital output to verify that an object is in its proper position. The use of microprocessor-based sensing and control systems in appliances require low-voltage, low-current switching devices such as reed switches and Hall effect sensors. The following noncontact sensors provide outstanding reliability and durability in digital appliance applications:

Reed Switch

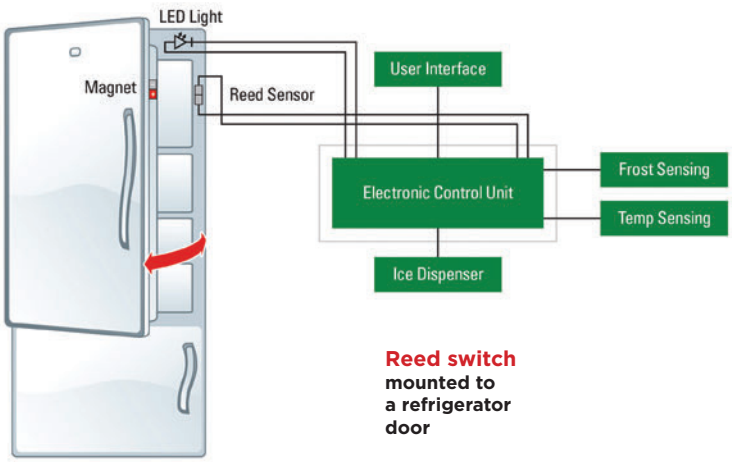
The reed switch is an electrical switch that does not require power to operate like an integrated circuit. Its electrical contacts are hermetically sealed within a glass tube with precious metal contact material.

Benefits: This sealed switch is highly reliable because it is unaffected by moisture and other environmental elements. Because its electrical contacts will not oxidize, the reed switch can deliver reliable operation for millions of cycles with logic-level loads.

Appliance Applications: Since reed sensors are very reliable with logic-level loads, they are useful for digital on/off operations. For example, they can be used to detect door/lid closure in refrigerators, dishwashers, washing machines, clothes dryers,



Rotary Hall effect sensor used in the dial of a washing machine or dryer



Reed switch mounted to a refrigerator door

stoves/ranges, coffee makers and food processors.

In a refrigerator, the magnet is mounted to the door while the reed sensor is attached to the fixed frame hidden behind the external wall of the refrigerator. When the door is open, the magnetic field cannot be sensed by the reed sensor, causing the LED bulb to turn on. When the door is closed, the sensor detects the proper magnetic field and the LED turns off. In this application, a microcontroller within the appliance receives the signal from the reed sensor. Then, the control unit activates or deactivates the LED.

Digital Hall Effect Sensor

Combining a Hall effect sensing element with electrical circuitry, this semiconductor-based device varies the output voltage relative to a change in the magnetic field. The digital Hall effect sensor provides a digital on/off output signal that corresponds to a change in the magnetic field. Since the Hall effect sensor is a contactless component with no moving parts, its operational lifetime is significantly longer than a mechanical switch. The active circuitry within the Hall effect device draws a small amount of current at all times. This sensor can only be used in applications characterized by low DC voltage and current.

Benefits: Digital Hall effect sensors offer high reliability and can be programmed to activate at a given magnetic field tolerance for precise sensing requirements.

Appliance Applications: Digital Hall effect sensors are used in speed-sensing applications such as washing machines, clothes dryers and blenders.

In a washing machine, a rotating 16-pole ring magnet activates the Hall effect chip with each passing red (north pole) segment. It deactivates the chip with each passing white (south pole) segment. This process produces a very accurate high-speed signal.

Conclusion

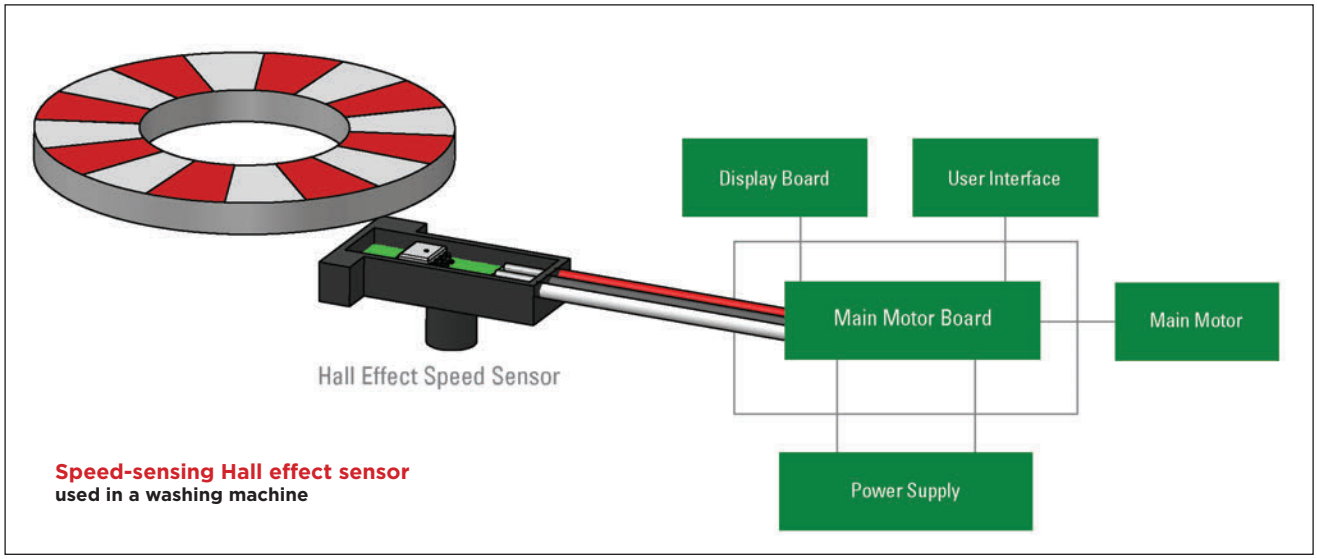
The need for energy-efficient, conveniently designed appliances has triggered a demand for advanced sensors. When design engineers must address custom sensing requirements, reed switches and Hall effect sensors can be used in complex appliance designs. Analog applications benefit from the stability and accuracy of rotary and linear Hall effect sensors. On the other hand, reed switches and digital Hall effect sensors provide exceptional precision and reliability in digitally-driven white goods applications. Building a magnetic circuit that incorporates all known parameters and a robust custom sensor will result in a highly reliable, efficient appliance design. ●



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Learn more about Magnetic Sensors and Reed Switches: ***Littelfuse.com/magnetic***

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Speed-sensing Hall effect sensor
used in a washing machine

Thermal Interface Applications

Competition is Heating Up *for* Material Manufacturers

BY DR. RICHARD COLLINS

Thermal interface materials (TIM) play a crucial role in numerous sectors, from lithium-ion batteries to 5G base stations, LEDs, consumer electronics and more. Heat dissipation is often on the limiting factors as many industries look to increase power and reduce the size.

Efficiently and uniformly transferring the heat generated from a device to a heat sink is typically aided by some form of interface material. TIM can take numerous forms (and names), from gap pads/fillers to conductive adhesives, thermal greases, and beyond. There are a variety of property considerations for a TIM given its specific applications this includes the adhesiveness, viscosity, coefficient of thermal expansion (CTE), bond line thickness, reworkability, and longevity. However, the most significant is the through-plane conductivity and the thermal contact resistance (the interface of the interface material).

IDTechEx has conducted an extensive analysis of this industry and have a leading market report on the industry: ''Thermal Interface Materials 2020-2030: Forecasts, Technologies, Opportunities''. This includes a detailed review of numerous industries and a review of the key players and material considerations.

Enhanced through-plane conductivity is becoming a key market pull in numerous sectors. Traditional materials and designs are not providing sufficient performance which opens the way for new material adoption and market entrants. For many industries this is progressing to above 10 W/mk, but for certain industries the key will be getting far beyond 25 W/mk.

The incumbent materials, such as ceramic filled silicone resins, still have markets to expand into (the most notable of which being lithium-ion batteries for electric vehicles) but are also under threat in more demanding areas. A previous article discussed the diversifying and growing markets.

This article will highlight some of the advanced materials being explored or adopted. In addition, it is important to consider routes to manipulating the alignment of conductive fillers. Alignment, particularly for anisotropic additives, can either provide a cost saving by using less material for same performance or improve the performance for the same filler content. This should also be considered in conjunction with the mechanical performance the matrix material provides. Achieving alignment can be done in multiple routes: mechanical, magnetic, electrical, dielectrophoresis, or in how the conductive fillers are grown.

Advanced Carbons

Many are turning to advanced carbon for higher conductivity either as a conductive filler in a polymer matrix or standalone. This includes graphite, pitch-based carbon fiber, carbon nanotubes, and graphene.

As shown in the figure below, achieving vertical alignment gives the potential for high conductivity up to ca. 80 W/mk.

One of the most notable examples is the adoption of carbon fiber in the Samsung Galaxy Note9. IDTechEx has been informed that carbon fiber based TIM is also in use for power

electronic devices in electric vehicles, a variety of military applications, high performance computing and more.

Graphite through to graphene as sheets, pastes or vertically aligned in pads have all received a significant amount of attention. All report significant conductivity improvements and show current and future promise in LEDs, consumer electronics, base stations and more.

Carbon nanotubes have been known since the early 1990s and have been explored as a conductive filler, but more notable is the extensive research in vertically aligned forests/ arrays (VACNT). There are still notable challenges, from how the VACNT are transferred after growth through to how they achieve uniform contact resistance. However, significant collaborations and announcements from many of the leading players in China and Japan indicate that this a promising future area.

One of the challenges of using advanced carbons is that they are electrically conductive; this means the device must be designed accordingly. Ceramics are preferred for this amongst other reasons. There are trends to more spherical or flake like particles where appropriate, but concerning emerging material there is more interest around boron nitride nanostructures. Boron nitride nanotubes (BNNT) or nanosheets (BNNS) are both starting to become commercial.

BNNTs have a wide variation in property and cost with still a limited number of players, but many are progressing from the lab to pilot plants and even full-scale production. Most cite TIM as a key target market with already some promising results and interest from significant industries.

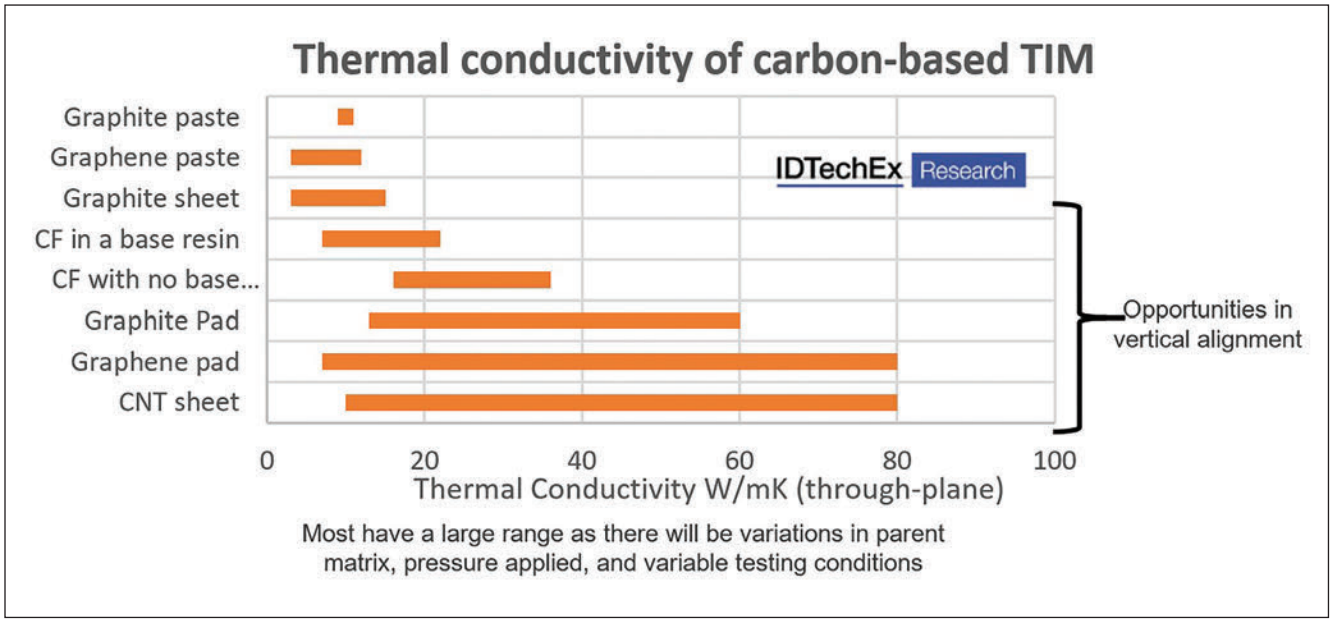
Through extensive primary interviews and detailed analysis. The market report provides a view of all these advanced materials as well as incumbents such as phase change materials (PCM), thermal greases and more. The report gives 50 forecast lines on key sectors, providing a comprehensive overview and outlook for this industry.

To connect with others on this topic, join us at The IDTechEx Show! Europe 2020, 13 - 14 May, Estrel Convention Center, Berlin, Germany. Presenting the latest emerging technologies at one event, with seven concurrent conferences and a single exhibition covering Electric Vehicles, Energy Storage, Graphene, Internet of Things, Printed Electronics, Sensors and Wearable Technology. Please visit www.IDTechEx.com/Europe to find out more.

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***Richard Collins, PhD**, is a Principal Analyst at IDTechEx with specialist knowledge in advanced materials, electric vehicles, structural electronics, and energy harvesting. He has provided keynote presentations at conferences and technical masterclasses in 4-continents.*



Benchmarking study of different carbon materials used as TIM in different forms. Source: "Thermal Interface Materials 2020-2030: Forecasts, Technologies, Opportunities"

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Contracts That Help or Hurt

BY KENNETH ROSS

What Every Engineer Should Know

When it comes to contracts, what terms and conditions are most important, and how can engineers support their company's efforts to evaluate and minimize risks?

The supply chain for many products can be complex, especially for electrical products that include component parts comprised of many subcomponents. On the manufacturing side, we talk about Tier 1, 2, 3, 4 and sometimes Tier 5 suppliers. On the distribution side, we can have importers, distributors, dealers, manufacturer's representatives and retailers. All of these relationships are governed by implied or express contracts. As a result, contracts can have a significant impact on the liability of all entities in the chain of production and distribution.

Every entity that buys a component, raw material, finished product or service is a buyer and needs to consider the risks it is willing to assume and what obligations and risks it wants to impose on the seller. However, every buyer is also a seller and, when they are a seller, they have different interests.

In addition, the buyer and seller in a particular purchase have a somewhat adverse relationship with each other and there may not be a meeting of the minds as to the duties and obligations involving this purchase/sale. It is hard enough for courts to interpret clear contracts to which both sides have agreed. However, when there is a "battle of the forms" and arguably no clear agreement, it is impossible to know whose contract clearly governs the purchase. In that situation, the courts have a much more difficult time.

Therefore, the surest way to understand the deal is to have a contract that has been signed by both parties. Unfortunately, this is not realistic for many companies and probably happens infrequently. Either one entity issues a purchase order and the seller just agrees to it, or the seller sends their terms and conditions and the buyer agrees to it by paying the invoice.

This article will discuss the terms and conditions that buyers and sellers should be interested in obtaining, how a contract should be entered into, and what role engineers can play in helping their company evaluate and minimize risks.

Purchasing

Before a manufacturer produces its product, it buys raw materials, component parts and maybe subassemblies, typically from entities outside their company. Each of these purchases is governed by some kind of contract. Sometimes the contract is express and signed by both parties. Sometimes it is nonexistent and the law must supply the terms of an implied contract. Or, sometimes each party to the transaction sends a document with terms and conditions that they would like to govern the deal. In all of these situations, a contract is most likely formed and the terms and conditions that result could affect potential liability if the product causes injury, damage or loss.

When a manufacturer buys raw materials, component parts and services, it wants the strongest warranty from the seller and the least exclusions, limitations and disclaimers. For example, if the manufacturer provides a 1-year warranty with its product, it should try to buy critical component parts that have at least a 1-year warranty.

It should try to get the supplier to warrant that the product meets specifications and all applicable laws and regulations, agree to repair or replace any defective or non-compliant product, and agree to pay for all costs of recalling or repairing the product, including labor if that is required.

The manufacturer wants to protect itself from a supplier who sells them a component that is defective and causes harm to the ultimate user or requires them to recall the product. One way to do this is to include an indemnification clause in the purchase order where the supplier agrees to indemnify the manufacturer for all product liability costs and consequential damages to the extent that defects in the components caused the injury, damage or loss.

One example of a contentious issue involves who pays for recall costs and what costs are reimbursable. If I am an OEM and buy components, I would want to be protected in case a defective component requires me or someone else down the chain to recall the product. And I would want the supplier to pay for all recall costs, including any administrative costs for implementing the recall. The trouble is that most suppliers would balk at such a requirement or could not pay for it if it occurred. So, they might agree with it on the assumption that the OEM would never try to get them to pay for it or they can blame someone else if a recall occurs because of a defect.

In some industries, OEMs are big and powerful, and they require their Tier 1 suppliers to agree to pay for all recall costs. Then the Tier 2 and lower suppliers who manufacture small and cheap components, most likely will not agree to be responsible for all such costs if their component is defective and causes a recall. The result is that the Tier 1 supplier will have to pay for the recall even if the recall was totally caused by the Tier 2 or lower supplier's component. While this sounds unfair, it makes sense given that the maker of a low-cost component part can't make enough of a profit to potentially be responsible for the full cost of a recall.

So, if you are a Tier 1 supplier in such a situation, what do you do? You can try to buy recall insurance, but that coverage can be expensive and somewhat limited. And the insurance company may take into account that you are responsible for problems you didn't cause. This might significantly raise the price of purchasing such coverage. You can also seek out a Tier 2 or lower supplier that will agree to pay for all recall costs. But that may raise the price significantly, and, if a problem occurs, the supplier may not have the financial ability to meet its obligations.

A better approach is to identify safety critical parts that will go into your product (this should be done during a typical risk assessment) and take additional measures to ensure that these critical components you are purchasing have been designed correctly, meet specifications, and work correctly in the product into which it is installed. Minimizing the risk of a recall is the best way to protect the OEM and all suppliers.

This is where the engineer can be helpful. The purchasing department can't be expected to evaluate the risks that occur from agreeing to a contract with a supplier and to identify adequate measures that should be taken to minimize future risks. Design and manufacturing engineers need to provide input on whether the risks are acceptable or not and need to consider the cost and difficulty of employing additional quality and reliability testing and inspections or at least requiring the supplier to provide evidence of their testing and inspection procedures. The phrase, ''trust but verify,'' comes to mind in this situation.

The same philosophy can apply to any purchaser down the chain – a dealer, distributor, retailer, etc. How can they purchase a product and hold the manufacturer responsible for any harm arising from the manufacturer's acts or omissions? They usually do this by having the manufacturer agree to an indemnification agreement. In this case, the dealer wants as broad an indemnification as possible against the manufacturer and the manufacturer wants a narrow one. The goal is to apportion the risk consistent with the desires of the parties. Unfortunately, both parties want something that is a little different.

For example, a retailer may want to be fully indemnified by the

manufacturer against product liability. However, the way the provision is written, it may also protect the retailer even if they are negligent when selling the product and this negligence causes harm.

Next, the purchaser may ask the seller to name them as an additional insured under the seller's insurance policy, so that any claim or lawsuit can be sent directly to that company for handling, no questions asked.

So, when the manufacturer or supplier negotiates the purchase of components or a finished product, they need to evaluate their own potential liability and what is a fair apportionment between the parties. This will not always work, especially if the more powerful party wants more than they should get.

Sales

The tables are turned when you are the seller of a component or final product. The seller wants to limit its warranty, disclaim all implied warranties, limit its remedies and disclaim all indirect and consequential damages such as recall costs. It may also want to be indemnified for injury, damage or loss that is caused by someone else down the supply chain.

However, if the buyer such as an OEM has more market power than the Tier 1 supplier, they won't agree to such provisions. They want to be protected from all problems no matter who caused them, even themselves. The result is that it is impossible to accommodate everyone's goals and each side should negotiate a contract which allocates the level of risk that the parties are willing to accept.

However, there is one other provision that a seller of a finished product should be interested in obtaining. It is a clause whereby the buyer agrees that the seller's terms and conditions will be passed through and not altered in the buyer's contract with their customer. So, let's say that the seller disclaims all consequential damages such as recall costs and the buyer agrees to it. But then the buyer sells their product to a purchaser and does not obtain a similar agreement from their customer to disclaim consequential damages. Then the product fails. Both the manufacturer and their supplier could be liable for consequential damages even if the component seller's contract had such a provision.

An example arises from my time as an in-house lawyer at a large electrical manufacturer. This manufacturer sold small electrical components and devices through distributors. The contract between the manufacturer and the distributor limited and disclaimed all the damages that have been discussed above. And the distributor agreed to them. However, the distributor sold the electrical product using a contract that protected them from extra damages but not the manufacturer.

A similar result can occur if a Tier 2 supplier doesn't protect itself in its contract with the Tier 1 supplier and the Tier 1 supplier's contract with the OEM protects the Tier 1 supplier but no suppliers below them.

A manufacturer's contract with its distributors should require that the distributor sell the manufacturer's products using terms and conditions that are consistent with those agreed to by the manufacturer and distributor. By doing that, the manufacturer and the distributor's liability would be consistent and both parties would be protected in case of a problem.

Entering into Contracts

In reality, most purchases and sales are made pursuant to what is known as the "battle of the forms." What that means is the purchaser and seller send paper back and forth, each with its own terms and conditions on the back and, at the end of the process, no one knows with certainty what terms and conditions govern the contract.

An example will be helpful. ABC Company sends a Request for Proposal to XYZ Company and on the back are terms and conditions and a statement on the front that these terms and conditions will govern the purchase. XYZ sends a proposal and on the back are their terms and conditions and the proposal makes it clear that these govern the sale.

ABC sends a purchase order to XYZ for the goods with their terms and conditions on the back. XYZ acknowledges the purchase order with their own acknowledgment form with their terms and conditions. Finally, XYZ ships the goods and sends an invoice with their terms and conditions. Whose terms and conditions govern the deal?

It can be said with great certainty that no one really knows for sure, not the parties, not the lawyers for both parties, and not even the courts. The area of law governing the "battle of the forms" is one of the most confusing and vague provisions in the law. The only way we would really know for sure is for a judge to rule on the question. The reality is that the parties never really agreed on the terms and conditions, but the court will not say that there is no contract because the product was already delivered and paid for. So, the court has to guess and to "fill in" the relevant provisions of a contract that were not agreed to by the parties.

This situation should be avoided if possible. While many purchases are not made with a contract signed by both sides, it is very easy to have a master set of terms and conditions and then send purchase orders based on the master agreement. Even if the purchase order has terms and

conditions on the back, the terms of the master agreement should apply.

So, each entity needs to evaluate their own situation in this chain of production and distribution, determine how much risk they are willing to assume and how much to spread elsewhere, and establish contracting procedures that match this determination.

Contracts are usually only needed when something goes wrong. And, good relations between contracting parties can go bad when that happens. So, it is dangerous to have a fuzzy contract or, worse, sell products or buy products "on a handshake" and rely on your prior good faith dealings to solve any problems that arise.

Dealers, Distributors and Retailers

Agreements between a dealer or distributor and a manufacturer are a little different than the normal sale. Dealers or distributors have rights and responsibilities that go well beyond those of a normal entity in the chain of distribution. For example, they may agree to provide warranty service, to give safety orientations and training to purchasers, to provide normal maintenance, and to provide repair services outside of the warranty.

They have divided loyalties because they are an advocate for their customer to the manufacturer but also a representative of the manufacturer. Again, as before, the contracts should reflect the rights and responsibilities of both sides and clearly allocate the risks between the parties.

The goal is for the party at fault to pay for the loss and protect the party that was not at fault. Many times, there may be shared responsibilities or there may be no one at fault. In that case, each of the parties may need to defend themselves.

Over the years, I have had problems with retailers who want to be indemnified and held harmless for all product liability claims and litigation, even if the retailer's personnel did something that made the product unsafe, thus causing an accident. This is unfair and should be avoided if possible. However, many retailers are aggressive and basically say that if you want us to buy your product, you will agree to our terms.

In addition, I have been having issues recently on recalls where the retailer is demanding a large reimbursement even if the retailer decides to do a more expansive recall than what the government requires. This can occur in communicating to the consumer, if their identity is known and to provide a remedy in excess of what the government thinks is appropriate. And, provisions in the retailer's terms and conditions are usually very broadly drawn and have no limits. It is a potential minefield for any manufacturer who sells to a large retailer. The seller should evaluate what the retailer expects of them in case of a recall so it can evaluate risk and take any protective measures to reduce the financial ramifications if a problem arises.

Without contracts describing the rights and responsibilities of each party to the contract, everyone is left to wonder what they have to do and what happens if a loss occurs. Some type of contract that sets forth basic guidelines at least gives each party an idea of the parameters of the relationship.

Conclusion

Despite the view of contracts as legal boilerplate and usually unimportant, they are important when something bad happens. Then you will wish you had clear contracts that reflect your acceptance of risk.

Also, while the contract does contain some legal terminology that engineers may find hard to understand, they should understand what the contract provides and be sure they agree with the terms, whether the terms are theirs or the party on the other side.

The legal language in the contract should clearly represent what both sides believe are the rights and responsibilities in the deal. You do not want to litigate the meaning of a contract – you have the opportunity to have a true meeting of the minds before you sign the deal or ship the products.

And, lastly, even if you have a good contract that protects you, don't fully rely on it. You still want to prevent problems from occurring. Relying on a contract or indemnification clause or purchaser's insurance policy to protect you may work, but still could cost your company a great deal of money and time to enforce and permanently hamper your relationship with your customer.

The bottom line is that every company should perform a contract audit so that they understand what they are agreeing to for purchases and sales. While lawyers would take the lead on that, engineers have an integral role in identifying, evaluating and minimizing risks. ●



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