In-mold electronics dramatically increases durability. Printed electronics and components are encapsulated in resin to protect them from the environment.

IME: The New Kid on the Printing and Product Development Block

What you need to know and key considerations for success with in-mold electronics.

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Printed intelligent devices may sound like they should exist only within the realm of science fiction, but they're already populating the world today thanks to in-mold electronics (IME). Known as the perfect union of form and function, IME is becoming more widely used over other switch technologies by user interface manufacturers in a wide range of industries, such as home appliances, automotive, medical device, retail, consumer electronics, defense, industrial, and aerospace.

For those new to IME, think of it as a combination of screen printing with functional (also known as conductive) inks and in-mold decorating (IMD). The result is a cost-effective part with integrated circuitry that offers myriad benefits to manufacturers and consumers alike — and printers play a leading role in the IME creation and production process.

IME Advantages Abound

Freedom is one of the most appealing benefits IME offers to designers. Think of a washing machine backsplash for example. Regardless of machine brand, nearly all backsplashes are flat because every button, dial, and light is mechanically connected to a printed circuit board directly behind it, which is flat. There's no changing that. With IME, a backsplash can be designed as a curvaceous 3D shape with, for instance, indents for buttons, or raised areas for dials, because they don't have to be mechanically connected to a flat circuit board. Design flexibility like this empowers manufacturers to differentiate their products ▸

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like never before.

Reduced weight is another key IME benefit. When most of the mechanical switches, buttons, and knobs are pulled off a circuit board and replaced with printed capacitive touch buttons and sliders on the label, a part's thickness and weight is greatly reduced — a boon for manufacturers who strive for minimalism in functional parts. Automakers, for instance, continually search for methods to increase interior cabin space. By integrating the controls for air conditioning and audio systems into an existing structural plastic part, the complexity and weight of that assembly is decreased and, potentially, more space in the cabin can be created.

Many OEMs are also drawn to IME's ability to greatly increase a button's longevity because there are no moving parts that can fail over time. What's more, since the inks are encapsulated in resin, both the aesthetics and the electronics are protected from the environment and less likely to be damaged by exposure to moisture or chemicals. This protection, combined with no moving components, enables an IME part to be activated millions of times without wearing away the ink or degrading electronic functionality.

Additionally, the customer-facing side of an IME part can be a continuous surface, so products that require regular, thorough cleaning or disinfecting are also fully protected from dirt, bacteria, and other contaminants that can hide within cracks and crevices around mechanical switches or buttons. And, despite long-standing stereotypes that capacitive touch functions erratically when exposed to water, liquid rejection can now be offered through programming so that the user experiences no false activations when cleaning the product; nor will the product activate or "misfire" in outdoor environments.

Yet another benefit that IME offers manufacturers is the simplification of the production process itself, as well as the warehousing of parts. Going back to the washing machine backsplash example: When manufacturing multiple machines with different controls and different layouts, each would require a unique front panel, a unique printed circuit board, and maybe unique mechanical switches. With IME, the only part that needs to change is the front panel.

IME increases design freedom. Inks and substrates can conform into complex, thin shapes allowing for more 3D design latitude.

Best Uses for IME

From touch screens and near field communication, to pressure sensors, inductive coupling, and more, IME applications are, potentially, limited only by a designer's imagination

Some technologies currently leveraging IME include:

Capacitive touch membrane switches for user interface with electronic devices such as home appliances, medical equipment, and vehicle dashboard controls. These switches have fewer layers and are easier to manufacture than traditional membrane switches using dome actuators. And, because users don't experience physical movement when pressing a capacitive touch button, haptics can be added to enhance user interface as needed. A buzzing vibration or the physical sensation and sound of a click are great examples of haptics at work in an IME part.

In addition to user interface applications, IME is leveraged to carry an electronic signal from one area to another, which is especially advantageous in products that require thin heating elements such as LED headlights or defrosting elements. A case in point: A resistive heating element can be integrated into a plastic snowplow lens by inserting a label printed with conductive silver ink into an injection molding tool, so it bonds with the lens. As a result, snowplow headlights that are illuminated with low heat producing LEDs still stay free of snow and ice.

Speaking of LEDs, adding them to IME parts can produce attractive, uniform backlighting to differentiate products from the competition. When printed with transparent ink, for example, an icon can look like it's glowing. The look is accomplished with the use of side firing LEDs and manipulating the resin system to work as a light guide.

Because IME components offer a solid-state replacement alternative to mechanical switches, they are ideal for use in devices that require a maximum amount of weather resistance, such as the user interface on outdoor products and equipment. What's more, substrates used in controller applications can be tailored to meet specific requirements like UV, impact, or chemical protection.

IME can also be used in combination with printed antennae to create a smart surface. The antenna can be used to transfer information or even power between products. Alternatively, a phone can be used to light up LEDs in a smart surface.

Smart surfaces used by one fast food operation contain tiny RFID antennae and a small amount of information, including the online ordering URL and a table number, all which feed part of a larger technology platform designed to reduce the time between when an order is ready and when it arrives at the customer's table. The system works when a customer scans a mobile device over the smart label and orders their food. Once the order is placed, staff behind the scenes not only see the food order, they also see the table number so they know exactly where to deliver it. This process is now starting to be applied in wayfinding systems as well.

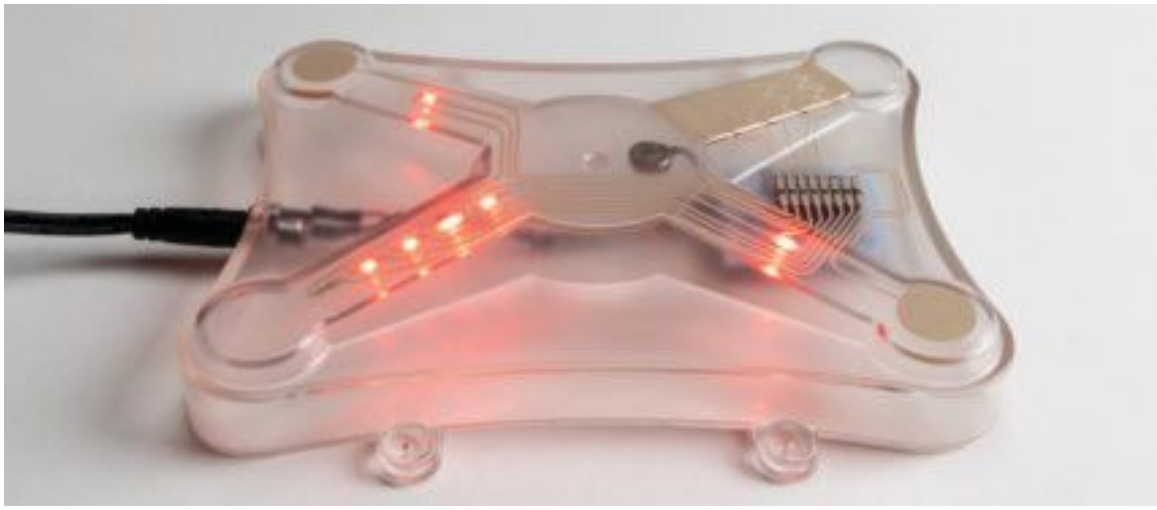
Products that require thin heating elements such as LED headlights or defrosting for appliances can take advantage by adding resistive heating elements into the formed plastic part.

The IME Process Briefly Explained

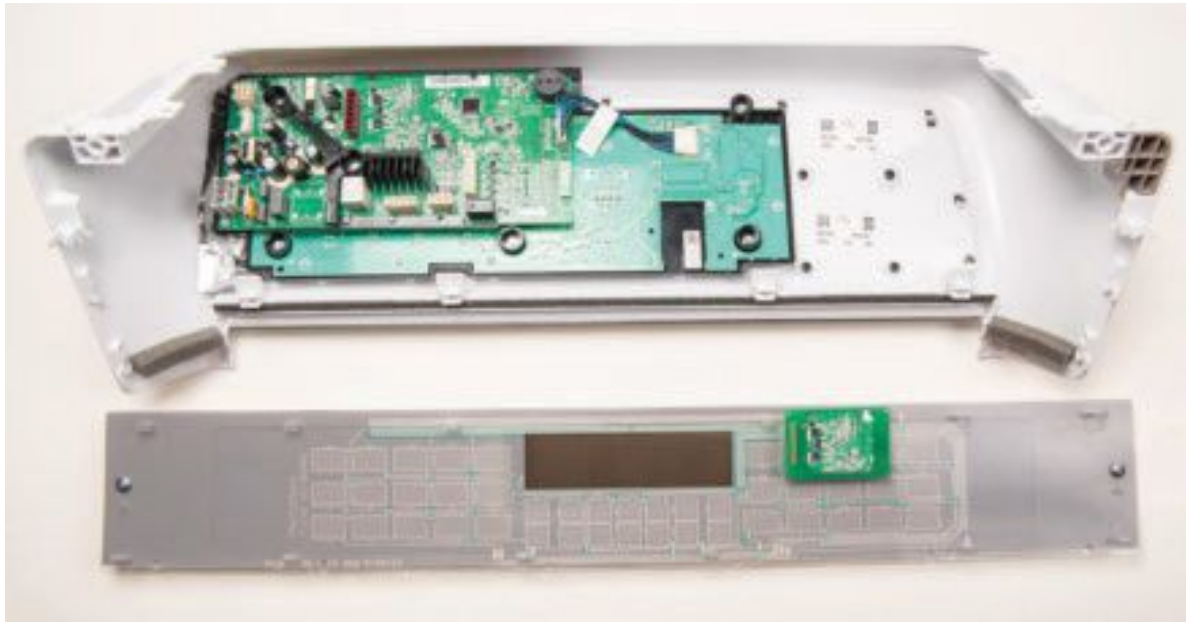
There are three main types of IME construction; which one is used in the manufacturing process is determined by customer requirements.

• **Back molding:** Back molding is a process in which a label graphic and conductive inks are printed on the subsurface of a substrate (usually clear polycarbonate or polyester). The label is placed into a mold, and resin is injected into the mold behind the label, which encapsulates the inks. A small surface mount header is placed on the other side of the mold tool to make an embedded electronic connection between the circuit and the control board.

• **Over molding:** In this process, resin is molded in front of a label containing graphics and electronics, leaving the inks exposed. Connection to a circuit can be made post-molding as a secondary operation. Over molding is a good option if a part requires a gloss finish because it eliminates the possibility ▸



Embedded LED indicators allow for smooth icon backlighting. Single point and diffused LED lighting are also available in an IME construction.



A printed circuit board can be significantly smaller since it doesn't have to be behind all the switches and lights.

Reduced BOM and increased ease of manufacturing are among the benefits of IME.

of leaving witness marks on the customer-facing surface.

• **Dual label:** Just like it sounds, in the dual label process, a traditional IMD label (graphics only) is printed and placed in one side of the mold and a second circuit label is added to the other side. Molding resin is injected between the two. The dual label process allows for more substrate options on the first surface (e.g., gloss material) and eliminates any telegraphing through to the first surface.

Key Factors for IME Success

Regardless of which process is used, there are important considerations to take into account before embarking on any IME project. First and foremost, to achieve the best possible outcome, designers should engage with an experienced IME partner early in the design process — preferably at the concept stage — and design for manufacture based on the IME partner's guidelines. When a customer's design is finalized before bringing in an IME partner, the risk greatly increases that it will be difficult, if not impossible, to incorporate IME.

Other key, practical considerations that can help guide any IME project include:

• **Form factor compared to manufacturing capabilities:** Can the part's geometry be formed using standard forming processes? Can the substrate and ink systems hold up during forming?

• **Substrate selection:** Is there an available substrate that will meet the project's environmental and chemical requirements, and work with the part's geometry?

• **Connection method:** How the in-molded circuit is connected to the control circuitry is critical for a successful IME part.

• **Tooling design:** How many gates are there? One gate is best to minimize the potential for wrinkling. It's also important to keep gate locations away from graphics and components, if possible.

• **Time:** Be sure to allow enough time to achieve the goal. Circuit design and validation, distortion to graphics, and testing printed samples can add 10-12 weeks prior to starting mold tool design.

When following the appropriate guidelines, manufacturers can take advantage of IME to create and develop products that offer consumers increased simplicity, enhanced performance, and jaw-dropping beauty — while incurring less expensive production and inventory cost. Next-generation product development will never be the same, and that bodes well for the future of screen printers who dare to think outside the box. ■

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