INJECTION MOLDED STRUCTURAL ELECTRONICS (IMSE™) FOR SIMPLIFIED, ELEGANT HOME APPLIANCE HUMAN-MACHINE INTERFACES (HMI)

Case Study

Introduction

The Human Machine Interface (HMI) in home appliances is used to communicate essential information to the user and to provide the user with means of controlling key appliance functions. A cost-effective, appealing, and intuitive HMI helps brands to stand out from their competition. In this case study we explain IMSE benefits for home appliance HMIs, illustrate TactoTek's IMSE technology industrialization process, and provide an overview of IMSE design and manufacturing methods. In the appendix we present a conceptual design example for a refrigerator HMI.

Conventional Electro-Mechanical Structure has Challenges

The Human-Machine Interface (HMI) is one of the most important points of contact between the customer and the product. At its best, an HMI provides intuitive and responsive controls for the user while also contributing to the design language of the product. With home appliances, differentiating between brands cost efficiently can be difficult, however, advances in HMI functionality and design are powerful tools in setting your designs apart. *[1, 2]*

Conventional electronics create conventional interfaces. Design and integration possibilities are limited by the multi-layer structure including a separate cosmetic surface, a typically rigid full-sized printed circuit board assembly (PCBa), and other structural components. For example, with conventional electronics creating illumination features requires a certain structural installation depth (15-30mm). What's more, changes to illumination for different variants requires costly and time-consuming tool modifications. When used, capacitive buttons are often made with large metal sensors which forces them into layouts in a row on a flat surface—monotonous and makes operating the appliance complex.

Touch screens can deliver an aesthetically pleasing experience, but their appeal is diminished by the high initial cost of the panel, requirement for complex control electronics, limited form factors and large openings in appliance insulating layers. When turned off, a black screen does not increase the beauty of the product and while turned on, displays require energy to operate. Additionally, the pursuit of aesthetics may lead to counter-intuitive logic in the operation of the HMI that frustrates users *[3]*. Creating technically advanced, simply operated HMIs for users without adding to the cost of manufacturing and operation is a challenge that cannot be solved with either conventional HMIs or touch screens.

Providing the consumer with more effective connectivity is one method of increasing the usability of household appliances, and at the same time provides the OEMs and brands a possibility to collect data during the lifetime of the appliance. Increasingly appliances are part of the Smart Home ecosystem and connectivity between household appliances, smart phones and the internet is the norm [Source1]. Efficient placement of antennas is difficult with conventional electronics assemblies due to the installation depth of the control electronics, the required space and the presence of materials that disrupt antenna radiation patterns.

The issues presented above—design limitations, technology constraints and cost structure limit HMI innovation for home appliances. TactoTek offers a revolutionary solution for solving these challenges with Injection Molded Structural Electronics (IMSE™) technology.

IMSE in Nutshell

TactoTek® in-mold structural electronics (IMSE™) solutions integrate printed electronics and standard electronic components within durable 3D injection-molded plastics. Because IMSE parts are thin (typically 2-4mm) and able to conform to complex 3D shapes, designers have the freedom to add electronic functions where they choose and in shapes and styling that support their design vision and natural user interactions.

Industrialized IMSE Platforms and Building Blocks for Customer Applications

To make IMSE adoption easy and straightforward TactoTek is dedicated to developing, industrializing, and commercializing IMSE technology. TactoTek's industrialization process provides our customers with verified material platforms that are reliably mass-produced and withstand a lifetime of use.

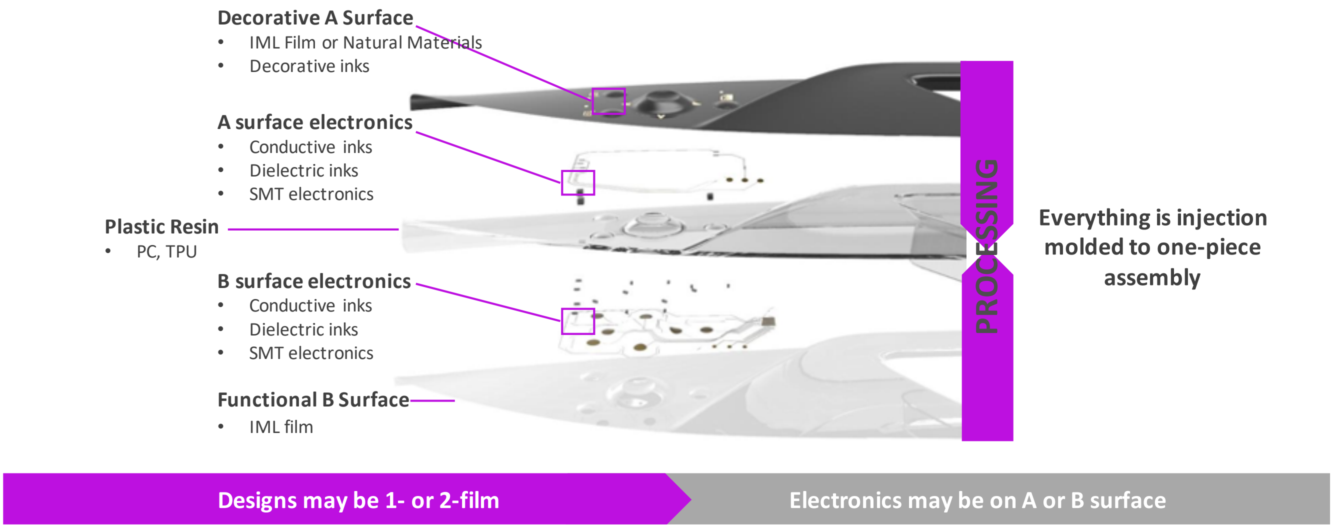

Figure 1. IMSE platforms are verified material combinations ready for mass-production

All IMSE platforms undergo an extensive verification process where both individual materials and components are verified, and ultimately the entire material stack is verified for both manufacturability and lifetime performance.

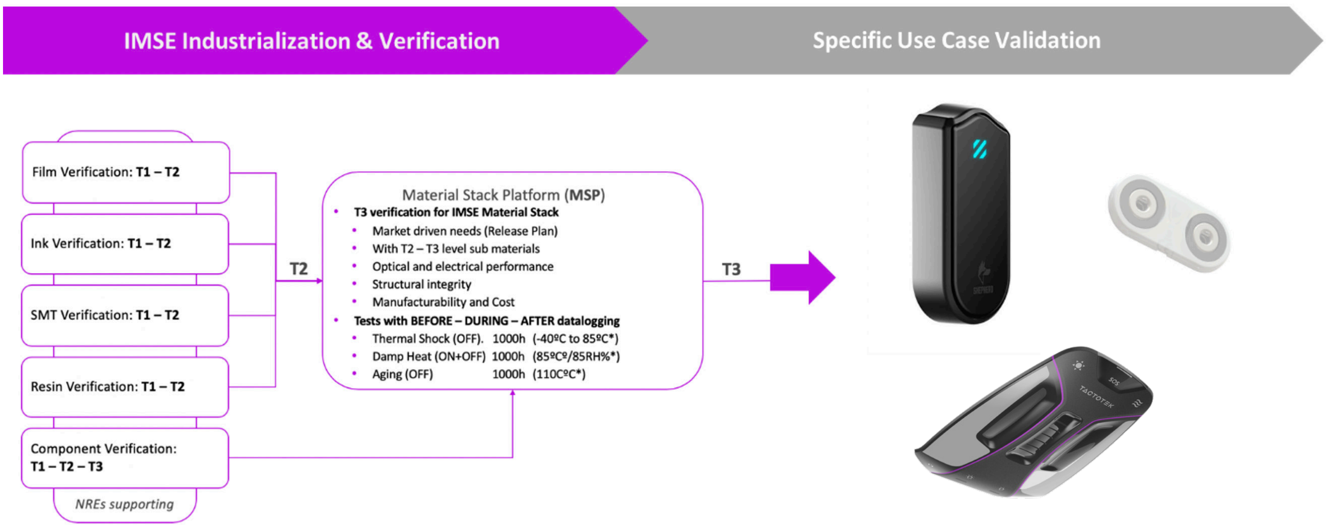

Figure 2. IMSE Verification & Industrialization

Functional features – IMSE building blocks – are designed into a product according to its functional requirements. TactoTek maintains a library of reference designs that are proven solutions for creating different functionality with IMSE parts. These IMSE building blocks are a combination of material and design knowledge that are combined into real functional parts—again verified by TactoTek. TactoTek-tested materials, components and designs are the solid core around which a new breed of electronics can be created; repeatedly and with a high manufacturing yield.

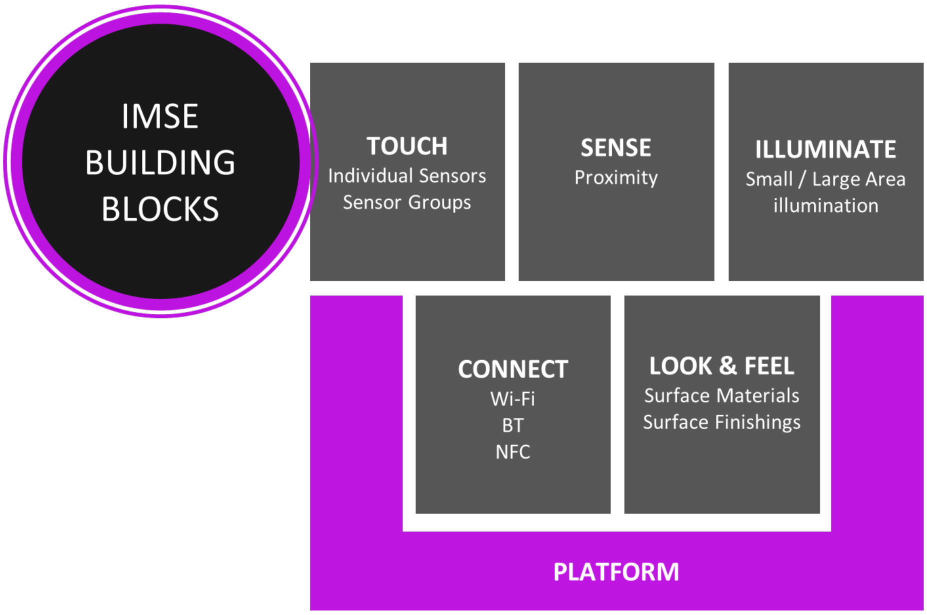

Figure 3. IMSE building blocks are functional features built on top of IMSE platforms

IMSE Design and Manufacturing Process

The IMSE design process begins with setting the design objectives. TactoTek does not do industrial design, however we do help OEMs and brands realize their design vision with IMSE technology as well as engineer and manufacture IMSE parts. As with any product, the needs of the end-user are the biggest factor in specifying the functions, usability and other expectations of the part. These requirements are then converted into specific functions, performance of these functions, operating conditions and quality requirements.

With the list of requirements ready, an IMSE design concept is created by combining TactoTek verified IMSE platforms and proven IMSE building blocks, thus enabling rapid turnaround times.

Example items that affect the selection of IMSE platforms and building blocks:

- Operating conditions
- Curvature of the part
- Number of functions and size of the part
- Illumination requirements for styling, icons and indicators, including size, distance, brightness, uniformity, single color or RGB, static or dynamic
- Distance between capacitive sensors and sensor groups
- Price target

IMSE design is a holistic process – all design disciplines are seamlessly integrated as is the part structure itself. By combining cosmetics, structure and function into a single injection molded

IMSE part, we significantly reduce the assembly and integration challenges typical of conventional electronics. Simulating IMSE part behaviour during and after manufacturing for illumination, mechanical, electric and antenna properties, significantly reduces the time to production-ready parts. IMSE design disciplines include:

- Mechanics & Tooling Design
- Illumination Design
- Electronics, Antenna & Embedded SW Design
- Print & Graphics Design

The IMSE manufacturing process is straight-forward. IMSE manufacturing starts with printing. Decoration, if desired, is printed on film insert molding (FIM) material, followed by printing electronics including conductive circuitry, touch controls, antennas and proximity sensors. Second, electronic components are mounted using standard high-speed pick-and-place (SMT) equipment. Components are attached to the FIM substrate using conductive and structural adhesives. Third, thermoforming transforms the flat electronics film into its 3D shape. TactoTek design rules and verified material stacks maintain mechanical and electrical system integrity through the forming process. Fourth, the formed electronics film is used as an insert for injection molding, resulting in a single piece structure with electronics encapsulated within injection molded plastics. Typical molding materials include high pressure, high temperature plastics such as polycarbonate and thermoplastic polyurethane (PC and TPU). Efficient functional testing in production is ensured with IMSE optimized test systems and equipment. This removes the need for producing product specific test equipment and their controls from scratch.

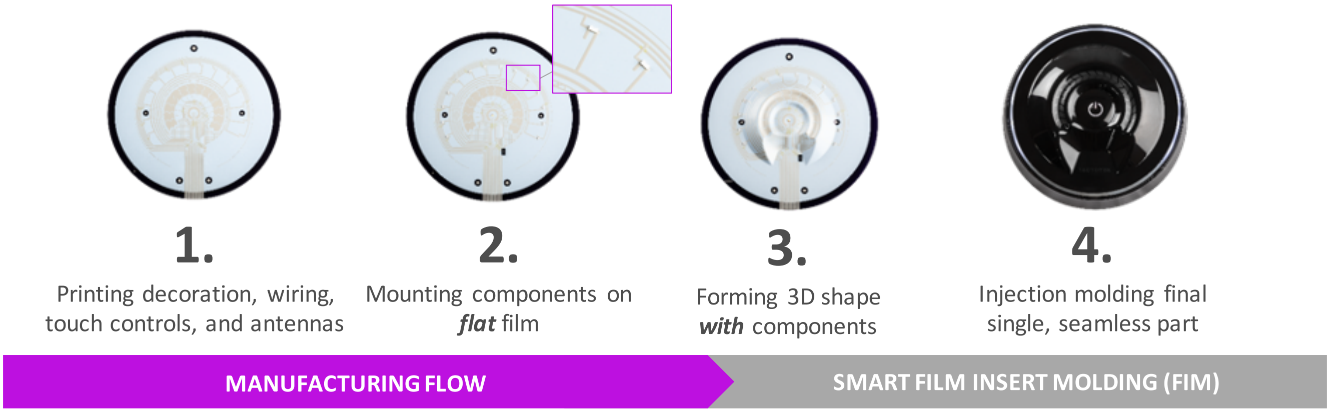

Figure 4. IMSE manufacturing process is realized with standard high-speed equipment

Solving the Appliance HMI Challenges with IMSE

Brand Differentiation by Design

The HMI provides direct information exchange between the end user and the product. It should be intuitive and simply operated. IMSE technology enables OEMs and brands to use the HMI to create and emphasize their unique brand language.

With attractive and informative illumination, high performance capacitive touch controls, proximity sensors and antennas, IMSE technology presents sophisticated electronic functionality, simply. IMSE HMIs are seamless 3D designs that guide user interactions as well as visual appeal.

Seamless and easy-to-clean while using the 3D geometry for design aesthetics, a slim (2-4mm) IMSE HMI panel can be mounted in many locations, including ones not feasible for conventional electronics. The control panel below wraps around the edge of an appliance making it easy to assemble and minimizing openings for the surrounding mechanics.

Figure 5. IMSE parts are 3D seamless

IMSE eliminates entry points for dirt and other contaminants by eliminating all crevasses created by mechanical buttons and illumination outcoupling points. Cleaning an IMSE HMI panel is as simple as wiping it clean with a damp cloth. TactoTek verified material platforms are compatible with most household chemicals and are durable in operating conditions common to appliances.

Consumers are living in a home of connected devices, and appliances are increasingly part of their smart home systems. Antennas, including wi-fi, Bluetooth and NFC perform extremely well in IMSE solutions, in part because the antennas are located within the molded part structure and away from many sources of interference. In IMSE parts antennas are printed at the same time as circuitry and other printed electronics features. With IMSE, every appliance can have an effective connectivity feature.

Reduced Complexity for Total Cost Efficiency

Conventional HMIs in most home appliances consist of separate assemblies for each button, light guide, and mechanical casing(s). IMSE combines cosmetics, structure and function into a single

injection molded part.
The total cost of ownership (TCO) is a combination of direct and indirect costs that accumulate around a product. IMSE reduces the costs around many common TCO elements:

- part and tool design (fewer sub-parts to be designed, less tools to be designed)
- tooling investment (IMSE requires one tool set: one injection mold, and related forming and trimming tools)
- sub-part manufacturing
- inventory management (less sub-parts and components)
- assembly (significantly reduced assembly steps in production)
- supply chain management (IMSE parts are vertically integrated, no separate electronics and mechanics)
- shipping and logistics (up to 90% less thickness and weight)

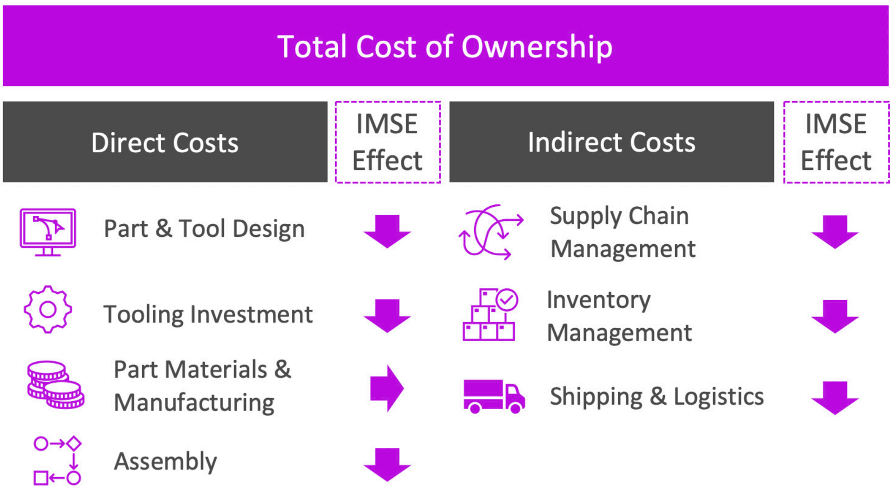

Figure 6. IMSE for total cost efficiency

As mentioned above, a particularly important feature of IMSE technology for appliances is fast, low cost versioning for product variants, face-lifts and localization. Both cosmetics and electrical functions of IMSE parts can be modified with printing processes and neither require tooling changes. In fact, different variants can be including in the same thermoforming and injection molding production runs.

This benefit is multiplied when the same shape of IMSE part is utilized in multiple product categories. A cleverly designed part of the same shape can be used in appliances ranging from dishwashers to laundry machines drastically reducing the tooling investment required throughout the complete product portfolio.

As IMSE parts are very thin (2-4mm), they can also be mounted onto the surface of surrounding mechanics, which makes it easy to adjust HMI position without compromising surrounding mechanics.

In addition to total cost efficiency IMSE comes with a single electro-mechanical interface. Meanwhile, all IMSE HMI electronics are encapsulated in plastics protecting them from harsh environmental conditions, including moisture.

IMSE—Your Competitive Edge

Today's consumers demand sophisticated electronic functionality. IMSE technology enables home appliance HMIs that are beautiful outside and where technology is skin deep. IMSE supports intuitive user experiences and delivers a palette for using HMI to support and differentiate brand identity, cost effectively.

Appendix 1 – Refrigerator HMI Design Example

Refrigerator HMI Panel

In our design example, the HMI is integrated seamlessly into the overall product design. We set our targets to create conceptual designs for two different scenarios: 1) replacing a more conventional type of HMI panel for combined refrigerator-freezer, 2) creating an HMI panel that is not following anything traditional other than the functions. We selected the following functionalities for both conceptual designs:

- Proximity sensor for waking up the HMI
- Powering on / off the appliance
- Temperature adjustment (for both refrigerator and freezer)
- Alarm functions for a) too low temperature and b) door left open

For the traditional style HMI panel, we wanted to keep the surface of the part flat, but bring geometry to the side of the part, and use IMSE capability for creating ambient large area illumination as sign for an alarm. For the more futuristic HMI panel we wanted to demonstrate a dual usage for the part with the same geometry and tool set.

Figure 7. Initial ideas for IMSE HMI locations

IMSE Design Example – Traditional Style

Our first design example illustrates a more traditional HMI with numeric symbols for temperature adjustment. Surface of the HMI is flat, but the part curves around the refrigerator door, and curved side of the part is equipped with ambient illumination for indicating an alarm-status. All symbols are printed and visible during HMI sleep mode.

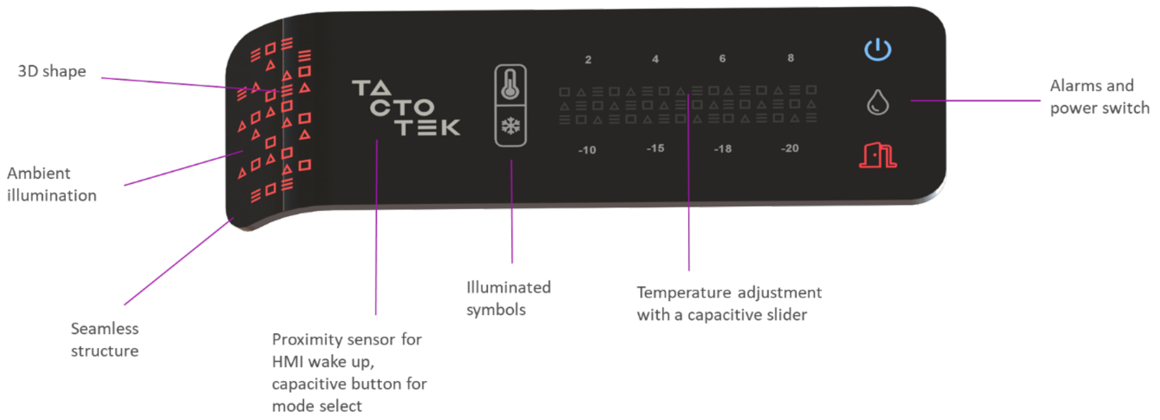

Figure 8. IMSE design example 1 functions

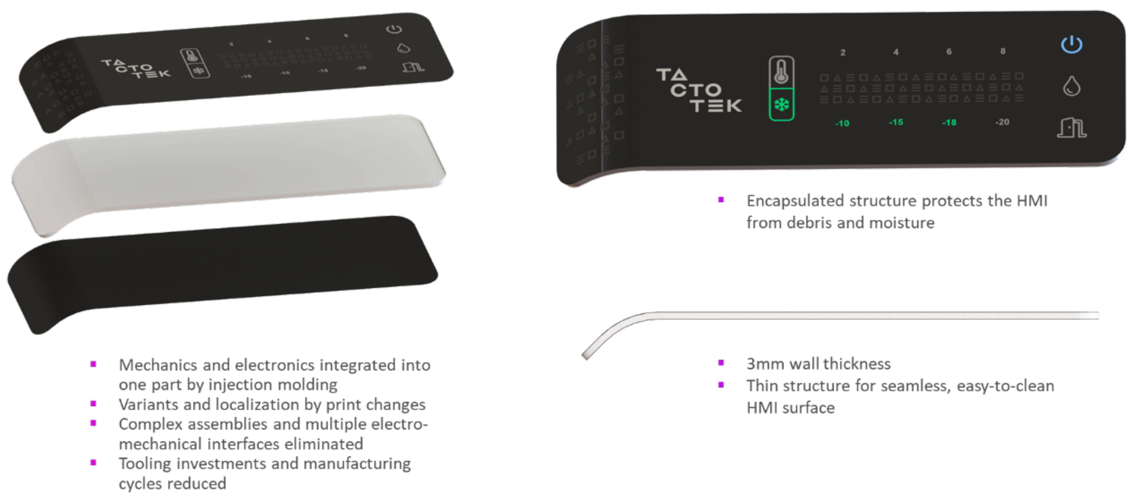

Figure 9. IMSE design example 1 structure and details

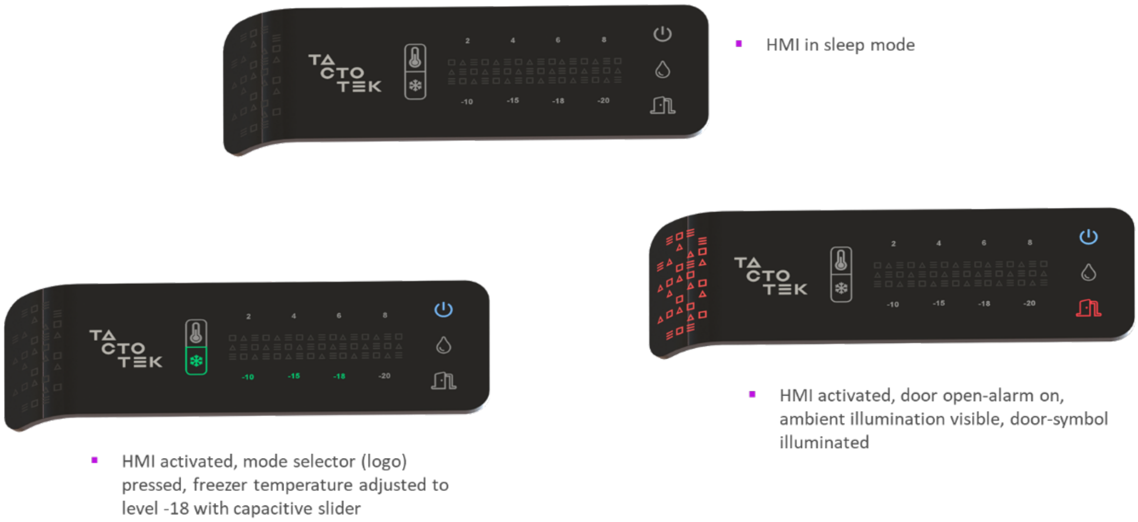

Figure 10. IMSE design example 1 operating mode examples

IMSE Design Example – More 3D

Our second design example illustrates the same functionalities, but with a different design. Part has both overall curvature and 3D functions in the form of recessed capacitive slider and raised power switch. Symbols are hidden-til-lit, which means that they are not visible when the HMI is in sleep mode.

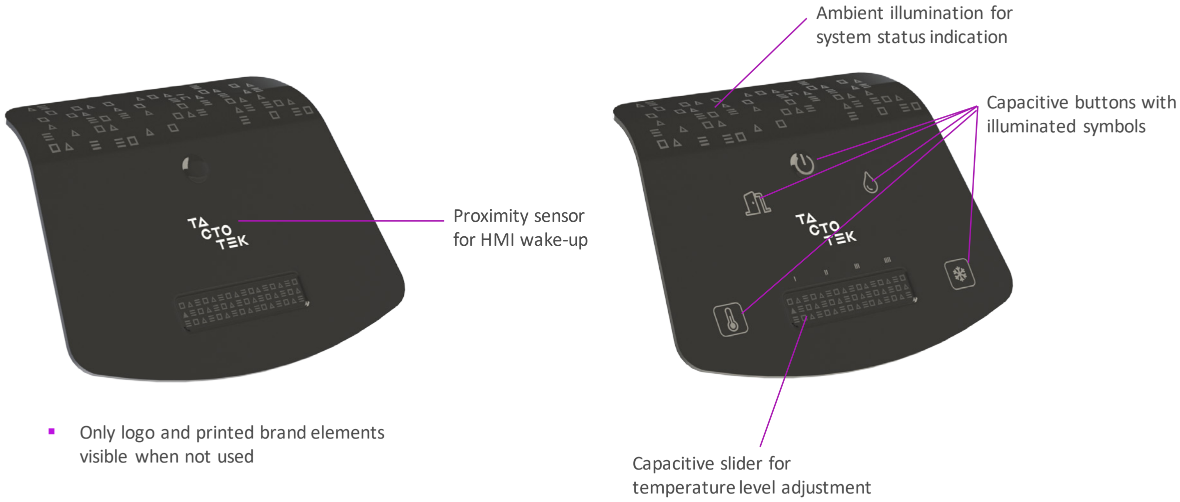

Figure 11. IMSE design example 2 functions

Figure 12. IMSE design example 2 structure and details

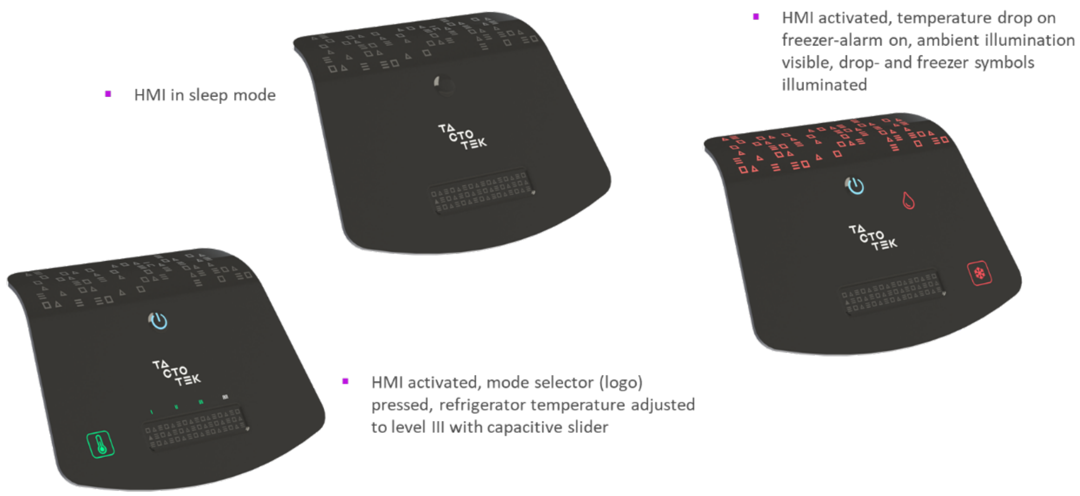

Figure 13. IMSE design example 2 operating mode examples

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