Building robust HMIs for rugged and harsh applications

Sponsored by: Boyd in partnership with 3M

Heavy duty industries and equipment are increasingly pivoting to smart, networked technologies to take full advantage of the Internet of Things (IoT) and Artificial Intelligence (AI). Due to the incorporation of smart technologies, human machine interfaces (HMIs) have become essential components in countless products and applications, thanks to their ability to offer control and merge physical and digital data in a user-friendly display.

Engineers face various material challenges in the design and manufacturing of HMIs destined for harsh locations. This is most notable for films, foams, tapes and adhesives that are just as important as the processors and software underlying each HMI. Boyd is at the forefront of the solutions that ruggedized HMIs, thanks to its expertise and ability to convert resilient materials into nearly endless shapes, sizes and form factors.

Figure 1. HMIs used in smart agriculture environments have thermal management considerations where critical internal components need to be maintained below a specific temperature to function properly. Source: Boyd

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A look at HMIs in harsh environments

HMIs can vary quite a bit between manufacturers, applications and user markets. Inputs range from capacitive or resistive digital buttons to physical buttons and voice control. Displays might be high-definition, high-resolution TFT LCD or high-performance OLED. Applications differ from next-gen automobiles for infotainment, in a high-tech tractor to monitor GPS position, or in a construction vehicle to monitor instruments.

Be it a field harvester, crane, skid steer, excavator or any type of agricultural or forestry equipment, HMIs in these applications have recurring as well as application-specific design challenges.

HMIs must have high brightness, contrast and glare or reflection control for readability in any environment or time of day. Extreme temperatures cause materials to expand, contract, dry out, swell or outgas over time; all of which affect HMI longevity. Add to the mix ingress contaminants, such as dirt, dust and water, and it's clear there are numerous weatherability challenges for HMI adhesives and sealing materials.

The various electronics and electrical components within the HMI have two unique operating challenges. First, they must withstand road conditions and vibration through everyday operations. These environmental factors are considerable for heavy machinery. They must also exhaust heat from internal electronics and the display module, which can compromise performance. To deliver the aesthetics and user experience consumers expect from phone and tablet displays, the HMI must also be thin, lightweight and immersive, which means unusual sizes and contoured screens to fit within dashboards, mirrors or control panels.

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There is also the issue of electromagnetic interference (EMI), radio frequency interference (RFI) and electromagnetic compatibility (EMC). New and more electronics networked into heavy industries increases the chances for signal interference or electronic crosstalk. Ensuring the right data is received and processed is key to the task at hand.

This is where foams, tapes and other materials with high-performance compression and electrical characteristics play an important role. These materials can ensure thermal and electrical contacts remain consistently connected, potential damage due to overheating is prevented, and HMIs are protected from short circuiting, contaminant ingress or mechanical failure from vibration.

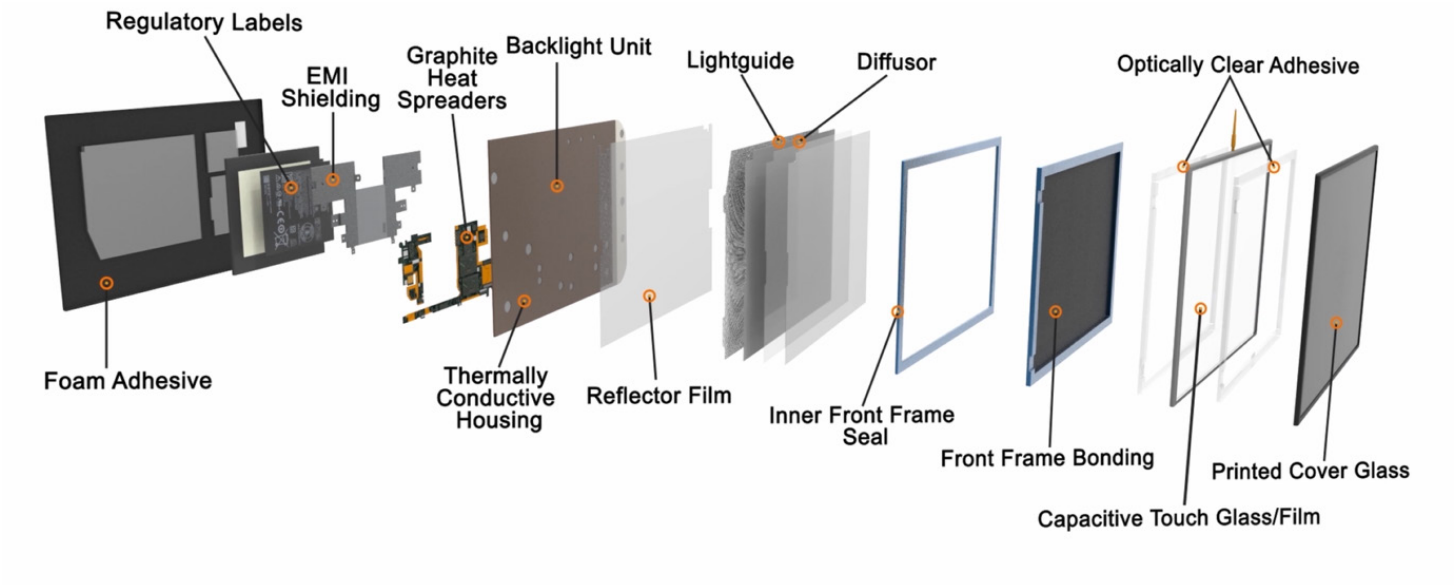

Figure 2. A comprehensive breakdown of each Boyd solution in a ruggedized display. Source: Boyd.

Materials solutions for ruggedization

Bonding is increasingly complex for modern HMIs. HMI assemblies feature a variety of layers bonded together. These bonds are critical to display utility and functionality. Different surfaces interact with bonding adhesives based on their properties and surface energy.

Display layer bonds must have appropriate peel adhesion, shear strength and impact resistance. Impact resistance prevents the bond from failing due to vibration or shock. Ensuring display bonds provide long term performance with minimal failures requires an understanding of surface energy compatibility, temperature range, conformability, adhesive strength and more.

Although the primary engineering challenges include extreme temperature cycling and harsh vibration, the quality of the bond is important. To create an attractive “frameless” aesthetic, bond lines must be precise and narrow.

Older models with standard display panels followed straight design lines that were relatively easy to bond. Next-generation HMIs in harsh environment applications feature multiple displays, unusual shapes or a large, curved display.

Vibration and shock dampers, gaskets and seals are inherent components to HMI enclosure design. Thin and lightweight foams are highly effective at absorbing vibration and shock, while also being flexible enough to fit into predefined enclosure dimensions and accommodate temperature cycle swelling and contraction. A variety of open or closed cell foams can exhibit low compression set, high durability, waterproofing, oil resistance, dust proofing and mechanical resiliency, among other characteristics, across wide operating temperatures. Protective coatings add additional protection for high-touch surfaces with built-in scratch, abrasion and chemical resistance. 3M™ VHB™ Tapes enable an impact resistant bond through a viscoelastic foam core and adhesive skin with good energy absorbing capabilities for strong holding power and drop shock performance in an IPx8 rated seal to prevent water intrusion.

Figure 3. Bonds in rugged HMI applications are subjected to both mechanical and electrical strains. The right bonding tapes must be properly installed for robust and visually appealing solutions. Source: Boyd

Thermal management in HMIs

Thermal management is a critical aspect to improve HMI durability. Modern displays feature increasing power densities in thinner enclosures — all of which increase thermal density. Traditional air-cooled heat sink technologies are no longer feasible due to low profile design configurations and thermal load.

The ability to conduct and spread thermal energy across a wider surface area to dissipate heat is especially critical in rugged heavy-duty applications, which often times are already in warm climates. Excessive heat buildup will cause a display to overheat, potentially resulting in slow response time, malfunction or complete shutdown. Continuous exposure to heat also increases wear and tear and reduces the display lifespan.

Deploying special heat spreaders and thermal interface materials (TIM) is a reliable way to transfer heat from an HMI. Most commonly, heat is dissipated away from critical components to the display enclosure where heat is transferred to the ambient environment. For example, to dissipate heat from sensors or embedded processors, certain thermally conductive adhesives, graphite films, vapor chambers or TIMs can be highly effective solutions. 3M's portfolio of silicone and acrylic thermal gap pads and tapes are laden with thermally conductive filler materials, making them useful solutions for managing heat. Supplying these to HMI integrators in precut forms saves critical manufacturing time and hassle.

Addressing EMI for HMIs

Embedded compute modules, sensors and the wide variety of electronic controls within smart and autonomous technologies cause electrical and signal noise that can interfere with sensitive electronics if not properly managed. Signal crosstalk can lead to faulty display performance, slower response times, unreceived remote instructions and slower data transfers. Unmanaged EMI can prevent operators from receiving accurate info or lead to underperformance or equipment downtime, all of which are serious risks for large construction, mining, industrial and agricultural enterprises. EMI is a serious HMI design challenge whenever wireless connectivity and high-speed digital interfaces are leveraged to communicate between subsystems within the vehicle.

Meeting EMC standards and ensuring the display has a high degree of signal integrity requires not only thoughtful design, but also materials that shield sensitive components and protect signal integrity. Blocking and absorbing EMI with grounding and shielding tapes, foams, polymers and fabrics are common solutions. Conductive tapes are composed of a conductive matrix carrier, such as nickel/copper-coated conductive fabrics, and backed with a conductive pressure sensitive adhesive. These tapes create an electrical connection between ground signals on the PCB and display panel to generate a grounding area that shields and protects internal components from EMI. 3M also offers a portfolio of Electrically Conductive Adhesive Transfer Tapes (ECATTs), which are filled with conductive particles to help maximize EMI performance.

EMI absorbers like AB5000HF, AB6000HF and AB7000HF, on the other hand, use a magnetic sheet with high permeability to absorb high frequency signals. These function like ferrite cores, but instead of being placed in series/parallel to the circuit, EMI absorbers can be cut into specific shapes and assembled with EMI reflective shielding solutions like conductive tapes to minimize EMI noise leakage while fitting into low-profile HMI designs. The combination of shielding and absorbing EMI materials both direct electrical noise away from critical components while also absorbing near-field EMI within the enclosed shielded space.

For EMI tapes, installers must apply appropriate pressure to the bond line after assembly to ensure optimal adhesion that engages conductive particles between the substrates to make electrical connection. Without appropriate surface contact and conductivity, adhesion, grounding resistance and shielding performance may degrade quickly. Boyd's comprehensive EMI and RFI shielding solutions ensure designers solve EMI challenges in a cost-effective and efficient way. For instance, Boyd can combine EMI tapes with other materials like gaskets or seals to create a two-for-one noise, vibration and harshness solution with EMI performance, saving on assembly time and cost.

Designing for user experience

If the HMI cannot be easily seen and read in a variety of lighting scenarios, it won't serve the user. To enhance HMI display brightness, clarity and visibility, specialized films and adhesives are employed to minimize glare and reflection, create a vivid and high contrast screen and improve general readability. Backlit switches, branding and nameplates are also key to providing a rich and safe user environment. Printed capacitive switches can also integrate with backlit technologies to provide backlit touch sensing to an HMI.

Optically clear adhesives (OCAs) maximize light transmission by filling in air gaps and optimizing the refractive index between the cover lens and display panel to improve readability and contrast. Advanced light control films constrain light exiting the HMI and other potential light sources to minimize reflections on surfaces around the display, like the windshield or side windows. 3M's BEF and DBEF films can help increase the amount of light displayed in a device, leading to better device readability.

Boyd leverages display enhancement films, anti-shatter and reinforcement materials, light control guides, OCAs and display protection films to help HMI manufacturers build the best, brightest and most robust HMIs possible for harsh agricultural and construction applications.

Badging and branding

Custom and application-specific materials for HMIs are a vital enabler for another aspect — badging and branding. Manufacturers often seek to emulate a certain appearance and tactile feel for today's progressive technologies. In addition, interior and exterior nameplates, logos, metal trim and accents go a long way to creating lasting brand identity and together, these create distinctive brand style. Boyd offers a broad range of materials, printing techniques and custom decorative finishes that help brands fully integrate an immersive HMI brand experience to differentiate a more tailored look and feel.

Figure 4. Various films and adhesives can be used to optimize the brightness, clarity, and visibility of HMIs to dramatically improve the user experience. Source: Boyd

Why Boyd?

Boyd has more than two decades of precision converting experience and has helped HMI designers solve critical engineering challenges with advanced materials. They have shipped more than one billion display components worldwide. In-house experts and operations can design and fabricate advanced materials solutions in class 100 clean rooms for contaminant-free, optically pure display and HMI components that help equipment designers differentiate their brand and user experience.

Visit the Boyd website for more information.

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Boyd is a world-leading innovator of technologies in material science, engineered material, and thermal management that seal, protect, interface with, and cool our customers' most critical applications. We embrace science to solve ambitious performance targets. Boyd architects material innovation, combining technologies in novel ways to redefine the possible. Continually redefining the possible has driven over 90 years of innovation and customer success.

The Internet of Things (IoT) has proliferated advanced compute technology across all industries with applications exponentially becoming more complex. Users want devices smaller, faster, lighter, and more intuitive with greater functionality. More smart functionality operating faster in tighter spaces with more sophisticated interfaces mean greater power density and more heat, electrical, and mechanical challenges. Adding further complexity, devices are used in unpredictable environments with harsh conditions and must be contaminant and waterproof, insulated against temperature extremes, and ruggedized.