Improve product form and function with sleek custom touch displays

To meet rigorous user experience expectations for devices, first-rate physical design has become a higher priority than ever before. For products that incorporate touch displays, customization can improve both aesthetics and functionality. This white paper addresses some key design requirements related to custom touch displays as well as materials and practices that can help you satisfy those requirements.

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If you're designing a device with a touch display interface, it will be judged according to high standards, alongside formidable peers. End users have become accustomed to the sleek, design-forward styles of modern smartphones and tablets. Clunky designs are simply not good enough anymore, and a sharp presentation has become a first-order requirement for devices to showcase your intellectual property.

The physical design of devices has become important enough to commercial success that it may rival functional aspects such as user interface and application functionality. Design engineers must rise to the challenge, to create devices that are both functional and attractive, which often necessitates custom touch displays; doing so requires meeting an interconnected set of challenges through design tasks that include the following:

- **Design the cover lens**. As the most prominent customer-facing element, the cover lens must be aesthetically appealing as well as practical and durable, including appropriate materials and customization.
- **Optimize mechanical robustness**. Even in non-rugged settings, displays must be designed to hold up to everyday use as well as the natural elements and the occasional spill.
- **Develop flexible printed circuits**. Customizable and flexible shapes provide connectivity between the touch display and the controller within space-constrained housings that have unique shapes.

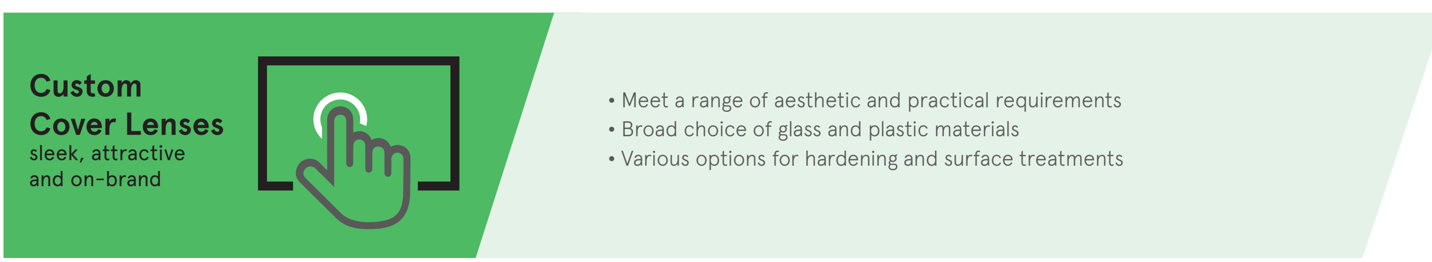
Taking each of these topics in turn, this white paper discusses materials and design approaches that can help ensure that your next product will be well received in the marketplace.

Meeting design challenges for custom touch displays...

...with custom cover lenses... ...and mechanical robustness... ...and custom flexible printed circuits.

DESIGN THE COVER LENS

Because users interact directly with the cover lens over a touch display, you should regard it as a uniquely important selling and user-experience factor. Aesthetically, it should be attractive and incorporate logos and other branding as needed. Functionality begins with your choice of material—among various types of glass or plastic—to meet durability, usability and manufacturing requirements. You can also use a variety of treatments to enhance the user experience by mitigating glare, reflections, fingerprints and microbial contamination, among other enhancements.



SELECTING AMONG TYPES OF GLASS

Glass is the predominant material used for cover lenses over touch displays, largely because of its hardness. Plain soda-lime glass may be used, which is the same material as common window glass. Glass manufacturers designate the so-called "technical glass" used for device displays by sorting to identify the soda-lime glass that has superior optical quality. That base substrate may also be treated before use through chemical, thermal or mechanical means to achieve greater durability or other characteristics.

Chemically or thermally strengthened glass

Durability and safety considerations typically require the glass to be strengthened (hardened), using either chemical or thermal processes. Chemical hardening is possible with all glass, while thermal hardening is typically only available for thicknesses over about three millimeters.

Of the two approaches, chemical hardening can make surfaces more scratch resistant, but it only affects the outer surfaces. Thermal hardening, on the other hand, hardens the material throughout, including below the surface. From a safety perspective, thermally strengthened (tempered) glass shatters into smaller pieces with less-sharp edges than untreated or chemically strengthened glass. The type of strengthening used on the glass also affects the types of inks that can be used to print on it.

- **Chemically hardened glass: organic inks are typical**, which offer a wider choice of hues compared to ceramic color but less ultraviolet resistance.
- **Thermally hardened glass: requires ceramic color**, which is superior in terms of scratch resistance, but because printing is done on the back side of the cover lens, that resistance is only relevant during manufacturing.

Note: While thermal tempering typically requires a minimum thickness of ~3mm, specialized processes enable Avnet to be one of the few suppliers that can offer ceramic colors on glass with thicknesses down to 1.8mm.

Ion-exchange strengthened glass

An option if your device needs a particularly robust cover lens, ion-exchange strengthened (alumino-silicate) glass is created using a chemical process that exchanges the native sodium ions in soda-lime glass for larger potassium ions. The result of that process is denser and more durable glass than other options, enabling lightweight, slim device form factors, especially with bezel-less designs.

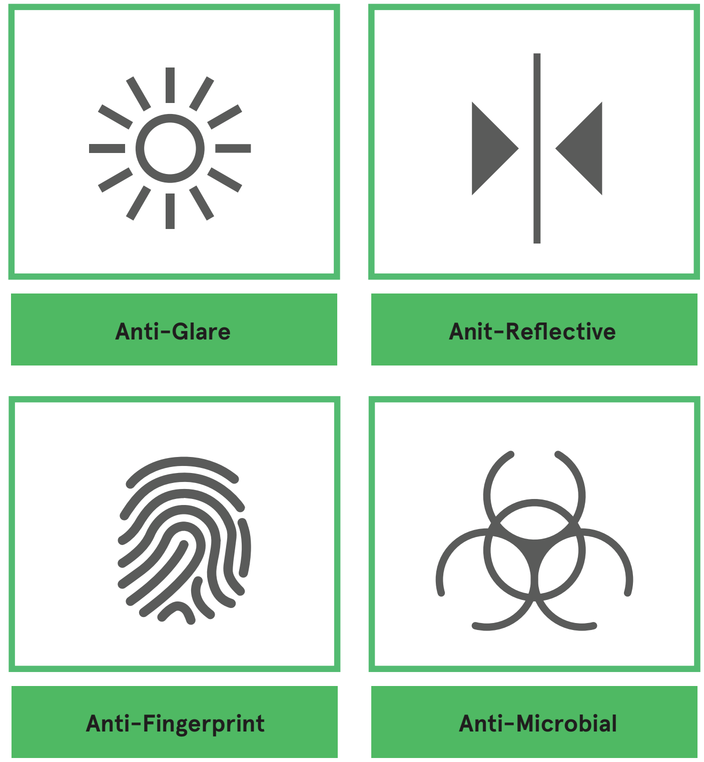
This is the technology behind commercial offerings such as Gorilla Glass (made by Corning), Dragontail (made by Asahi) and Xensation (made by Schott). Relatively high cost and minimum order quantity (MOQ) associated with alumino-silicate glass, as well as a maximum thickness of 3mm, have made it less broadly used in the industry than other options for cover lenses.

SPECIFYING SURFACE TREATMENTS FOR GLASS

To increase the usability of a cover lens under different circumstances, you can take advantage of a range of surface treatments to minimize the effects of glare, reflections, fingerprints and microbial contamination of the surface.

Note: Some device designers choose to use tinted glass or plastic for cover lenses, even to the extent that the tinting is dark enough so that it appears the same as the printed passe-partout (visually similar to a mat used in picture framing) on the lens when the device is powered off. One downside is that tinted glass requires a brighter backlight to compensate, which can have a negative effect on both bill of materials (BOM) costs and battery life. Tinted glass also places higher demands on the TFT backlight, and making it work harder can shorten its lifespan.

A range of surface treatments increases usability of the touch display



Anti-glare glass surfaces

A matte surface produced through micro-etching, anti-glare (AG) is the most common surface treatment (typically on just one side) for the glass used in cover lenses, especially for indoor applications. AG-treated glass is assigned a gloss value that indicates the fineness of the etching; typical values are between 60 and 95. Lower values correspond to rougher etching and a more matte effect.

AG-treated glass inherently reduces contrast in the display, which can create fuzziness, and the etching also decreases the impact resistance of the cover lens. In addition, poor-quality AG treatment can cause sparkling effects. To ensure a crisp and vivid image, minimize the distance between the surface (polarizer) of the display and the AG-etched side of the glass. This factor is more important with lower gloss values. Finally, the AG polarizers that many industrial TFTs are equipped with can interfere with the functionality of an AG-treated cover lens.

Note: The AG-etched side of the lens must be on the outside, toward the user.

Anti-reflective glass surfaces

The anti-reflective (AR) surface treatment used for cover lenses is a coating, identical to that used on eyeglasses to reduce reflections. Shortcomings of AR should make you shy away from it for touch applications. Chiefly, the coatings must be applied to the front side of the cover lens, where it comes into direct contact with the user's touch; the lack of durability in AR coatings can cause them to wear off over time. In addition, fingerprints tend to be more visible on AR-treated surfaces, which are also more difficult to clean.

Anti-fingerprint glass surfaces

Not commonly used for touch applications, an anti-fingerprint (AF) surface somewhat reduces the appearance of fingerprints, but chiefly makes the surface easier to clean, including in applications where it is combined with AR treatment. In addition, AF coatings tend to make fluids on the display surface disperse into smaller droplets, which can more effectively be addressed by water filtering algorithms, improving usability in wet conditions.

Anti-microbial glass surfaces

By incorporating silver into the material through an ion-exchange process, anti-microbial (AB) glass treatments reduce or eliminate bacteria on the surface of the glass that can cause illness, stain or odor. Because AB-treated glass does not add a coating, it has no effect on scratch resistance. Like other ion-exchanged glasses, AB-treated glass has high MOQ, making it best suited for high-volume projects, often in food or medical environments.

SELECTING A PLASTIC COVER LENS

Because you can form it relatively easily into novel shapes, plastic is preferable to glass for some specialized applications. Glass remains the dominant material used for cover lenses for a number of reasons, however. Plastic tends to accumulate fine scratches during normal use, which can blur the display over time. Hard coatings add to material costs but do not approach the hardness of simple glass.

Tooling costs are substantial for any plastic forms that cannot be cut directly from a planar mother sheet, which confines the use of plastic cover lenses for the most part to consumer devices that you plan to manufacture in large volumes. Manufacturing processes for plastic do not allow for tight tolerances; as those tolerances accumulate in a complex stack such as a touch-display module, they can create substantial imperfection and variation among individual devices. Moreover, plastic parts can warp after manufacturing, detracting further from a sleek design.

You must take special care when selecting sensor glue for devices with plastic cover lenses to ensure that the adhesive is compatible with both the sensor material and the cover lens. Plastic has wide variation in characteristics such as surface energy compared to glass, making experimentation with various materials and adhesives necessary.

EXAMINING THE IMPACT OF A COVER LENS ON USABILITY

The type of cover lens and how it is bonded with the sensor are primary factors to the usability of your device. The relative permittivity (ε_r) of a lens material is a measure of how easily a touch signal can penetrate it, with higher values corresponding to easier penetration by the touch signal. For example, when redesigning a device that has a 3mm acrylic glass cover lens (ε_r = ~3-4), substituting glass (ε_r = ~5-7) would make it possible for you to make that cover lens about 1.7 times thicker, to acquire the same signal strength.

Various design considerations can lead you to leave separation between the sensor and the cover glass; examples include providing ventilation, enhancing serviceability or addressing problems with adhesion. This clearance is typically filled with air (ε_r = ~1), which is quite difficult for a touch signal to penetrate. For example, a stack of 1mm air plus 3mm plastic is equivalent to a glass thickness of ~8mm, before accounting for an air gap (if present) between the sensor and LCD.

Note: The permittivity of a perfect vacuum is defined as ε_r = 1, a difference from air of less than .1 percent.

To help sense the weakened signals associated with an air layer between the touch sensor and the cover lens, you could boost the touch controller's analog/digital conversion through a massive damping stack. Unfortunately, this measure also increases noise, placing an additional burden on the controller to filter it out and potentially increasing processing times, with the effect of output latency and/or lowered EMI immunity.

Pressing the cover lens and touch sensor together to minimize or eliminate the air gap carries a risk of interference caused by the Newton's rings phenomenon. Where clearance is necessary or inevitable, you should keep it as small as possible, without encroaching on the range where optical problems occur. That distance is highly variable, depending on factors such as the wavelength of light and the rigidity of the cover lens, and you must establish it through direct testing.

OPTIMIZE MECHANICAL ROBUSTNESS

The durability of your product in use begins as mechanical robustness during its design and manufacture. With regard to the touch display, the cover lens plays a significant role, as do the suspension and bonding techniques used. If your product will be subject to outdoor use, you must also consider the negative effects of ultraviolet (UV) infrared (IR) light on your product and its components.

Mechanical Robustness
stands up to usage and the elements

- Help ensure durability, as well as safety in case of breakage
- Choose suspension technique to balance cost and utility
- Prepare for temperature extremes, ultra-violet and infrared light

MECHANICAL ASPECTS OF THE COVER LENS

The impact resistance of the cover lens is a primary consideration for your device's overall durability, and it depends primarily on the type and thickness of the cover lens material. While suppliers may provide guidance in terms of the impact class (IK class) for a given material, that information is not a direct indication of the impact resistance of the final assembly, which depends on the design as a whole.

The optimal thickness for the cover lens is a function of factors that include the other dimensions of the cover lens, as well as the application itself. For example, while a .55mm thick cover lens may be appropriate for a small touch display, a cover lens of that same thickness may bend or even break if used for a larger display. A rim or ground edge on the cover lens is also desirable, to counter the tendency for sharp glass edges to chip.

> **Note:** Even if the cover lens is sufficiently durable, especially hard touch events may generate difficult-to-interpret touch signals.

Some specialized applications—notably in the healthcare and food industries—have safety considerations that cannot be addressed by a simple, single-pane cover lens. One approach is to cover the glass with an anti-splintering foil, but the relatively soft, chemically sensitive surface can be undesirable. Likewise, a separate plastic cover can lead to loss of display clarity because of scratching.

SUSPENSION AND BONDING TECHNIQUES

The approach you take to bonding the touch sensor to the display panel plays a major role in the impact resistance as well as the overall rigidity of the touch display assembly. It is desirable for the suspension to absorb and disperse as much of the impact energy from a touch event as possible.

Air gap bonding

The most economical option when choosing a suspension technique (and also the most prevalent) involves bonding the sensor to the display with spacers and double-sided tape such as the very high bond (VHB) line of products from 3M. Characteristics such as the tape's thickness, width and placement all effect the IK test results for the finished assembly.

Optical bonding

Superior to air gap bonding but more complex and expensive, optical bonding is based on optical clear resin, a silicone or acrylic-based adhesive that mounts the touch sensor directly to the display, without an air gap. Using this approach, you can create a more durable, rigid assembly that also spreads the touch impact all over the display panel and bezel. In addition, optical bonding helps reduce internal reflections in bright sunlight conditions.

You may also find value to optical bonding in satisfying certain safety considerations. Regulations in some industries restrict the use of air gap bonding, which creates space where explosive gases can collect, for example. In addition, the resin used in optical bonding can help contain fragments from a shattered cover lens, behaving somewhat like safety glass. One consideration when using optical clear resin is its tendency to fumigate due to IR exposure. In addition, when optical clear resin is used with sensors that contain indium tin oxide (ITO), UV can increase the resistance of the ITO until the sensor becomes unresponsive.

EFFECTS OF ULTRAVIOLET, INFRARED AND OTHER FACTORS

If you are designing with outdoor usages in mind, you need to consider the effects of UV and IR light and mitigate them appropriately in your touch display design.

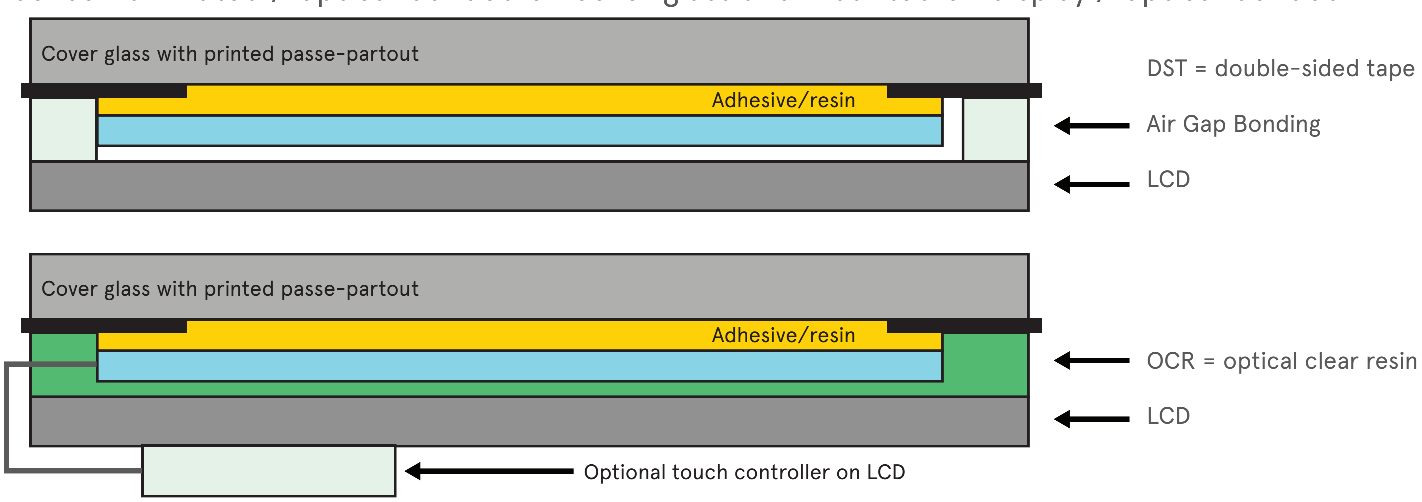
Ultraviolet light

Core components of a thin-film transistor (TFT) display may erode and eventually fail because of UV exposure. Transparent conductive tracks based on ITO within the display are particularly vulnerable. While more sophisticated materials such as some nano silver alloys are not susceptible to that deterioration, other elements of the TFT are still affected. You can use UV filters to protect display components; a less expensive option is to use optical clear resin that has built-in filtering qualities.

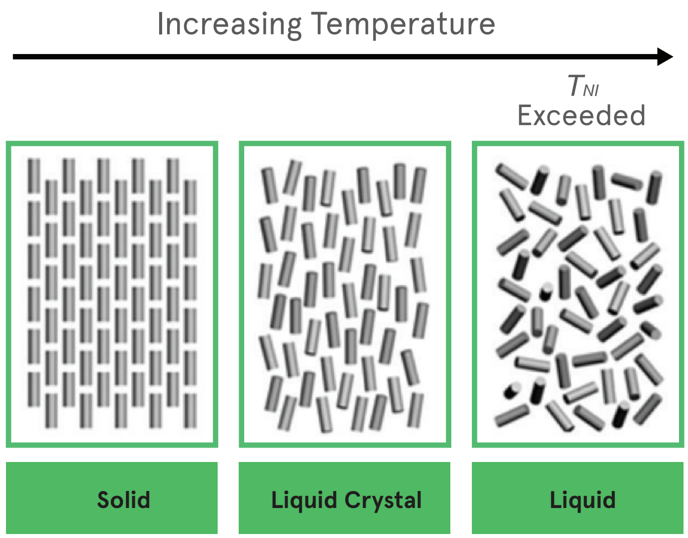
Infrared light

Heat transported into the system by IR in sunny conditions can easily cause a display or touchscreen to exceed its design operating temperatures (typically in the range of about -20 to 70 degrees Celsius). As the temperature increases above a critical point, the crystals in an LCD display shift from mesophase to an isotropic phase, in which the crystals lack positional and orientation order, resulting in a partial or complete blackout of the display. High temperatures or humidity can also adversely affect the reliable operation of the touch sensor.

Sensor laminated / optical bonded on cover glass and mounted on display / optical bonded



That critical temperature for a specific liquid crystal material is expressed as the temperature of nematic-isotropic phase transition (T_{NI}). To avoid blackout effects, you should choose panels with high minimum T_{NI} values; while 85 degrees is a common T_{NI} for standard panels, liquid crystal materials have recently been developed with T_{NI} ratings as high as 190. Unfortunately, these ratings are not commonly specified by manufacturers, especially for small and medium-sized panels.



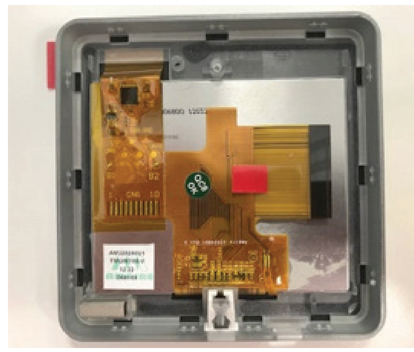
CREATE FLEXIBLE PRINTED CIRCUITS

Flexible printed circuits (FPCs) are cabling elements (sometimes referred to as "tails") that provide data connectivity to touchscreens. They typically incorporate anisotropic conductive film (ACF) and are bonded to the sensor pads at the sensor exit, and multiple FPCs may be used in a single assembly. Two primary types exist:

- **Passive FPCs** do not incorporate controller components, meaning that they require external touch controllers; they typically include blank contacts that are intended for use with external connectors.
- **Active FPCs** incorporate the controller components needed to output touch coordinates, commonly making them more compact and less expensive than the combination of a passive FPC and external controller.

TYPICAL USES FOR CUSTOM FLEXIBLE PRINTED CIRCUITS

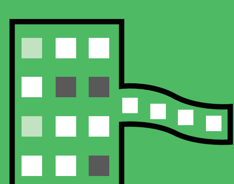
Custom FPCs may be valuable to you in cases where off-the-shelf FPCs are not suitable, due to design requirements such as specific dimensions or interfaces. In addition, product redesign may be simplified by the use of a custom FPC that emulates the size, shape and functionality of the FPC in the legacy design. You may also use custom FPCs to combine the functionality of multiple existing FPCs, which may simplify the design, reduce space requirements or improve thermal characteristics of the finished device.



Combining a touch FPC and TFT FPC into a single custom FPC.

The cost of a custom FPC may be significantly lower than the cost to develop a completely new sensor design, including non-recurring engineering and tooling costs. These factors typically make custom FPCs available at lower MOQs than custom sensors, making them more suited to devices that will be produced at low volume. Thus, a custom FPC can be a low-cost means of "customizing" a sensor. Nevertheless, fully custom sensors are often required in cases where factors such as the FPC exit position, aspect ratio, resolution or size of the active area must be changed, as well as in cases where custom 1D capacitive keys or dedicated sliders are required.

Custom Flexible Printed Circuits
tailored to specialized, space-constrained housings

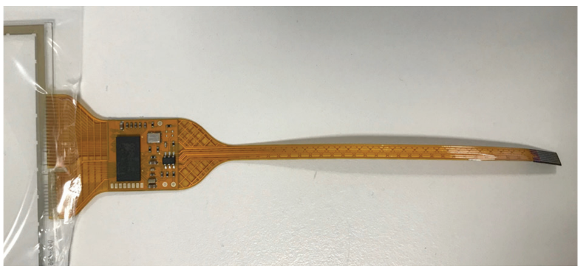


- Variable shape and flexibility to meet unique housing requirements
- Often a cost-effective touch-sensor customization approach
- Choose between active and passive flexible printed circuits

DESIGN CONSIDERATIONS FOR CUSTOM FLEXIBLE PRINTED CIRCUITS

The size and shape of custom FPCs are often key motivations for their creation. For example, you may want to extend the length of an FPC to reach the host port without expensive modifications to the rest of the system, such as moving components around on the main board. In addition, custom FPCs can accommodate nearly unlimited variations in shape, such as being L-shaped, providing clearance around other components or fitting inside specific enclosures.

> **Note:** Custom FPCs should have an appropriate shielding layer. In addition, FPCs should be as short as possible to minimize the collection of external noise, because longer FPCs are more subject to the "antenna effect."



FPC with single-chip touch controller solution.

While FPCs can theoretically be folded without damaging them at moderate temperature, cross-talking issues may make a custom FPC the more desirable solution. A custom FPC may also be preferred to solve the challenge where the touchscreen does not natively support the desired interface provided by the touch controller or its electrical characteristics. In still other applications, high shock and vibration may require ruggedized connections.

CONCLUSION

Your customers have come to expect a top-tier user experience from products like yours. Both the aesthetic appearance and the functional operation of the devices you depend on to deliver your IP must be of the highest order you can muster, or you may lose the customer loyalty you strive for every day. Touch displays are an excellent way to provide intuitive and powerful human-machine interfaces, and customization of those displays gives you greater control over the design of sleek, highly usable devices.

Partnering with Avnet can provide you with a smoother path and faster time to market for top-quality products with custom touch displays. We can provide you with the engineering expertise, guidance and testing you need at every stage of the lifecycle, to make decisions around designing devices and selecting components. Avnet also provides full manufacturing, customization and assembly services, as well as pre-engineered, fully tested display solutions.

As your partner of choice and trusted solution provider, we can deliver display solutions that enable you to build sleeker and more robust devices, faster, at lower cost.

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