XYMOX TECHNOLOGIES, INC.
ENABLING THE POWER OF TOUCH

FINDING THE BEST TOUCH SENSOR

For Your Application

CONTACT

ADDRESS

XYMOX Technologies, Inc
9099 West Dean Road
Milwaukee, Wisconsin 53224
United States

PHONE, FAX, WEBSITE

Toll Free: 1.800.869.9669
Phone: 414.362.9000
Fax: 414.362.9090
Website: **xymox.com**

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Section 01

WHO THIS E-BOOK IS FOR

If you are designing or supporting an electrical device that humans interface with, you will benefit from this E-Book.

"The more that you read, the more things you will know. The more that you learn, the more places you'll go."

- Dr. Seuss

More specifically, though, this document is not targeted for designers of mass-market devices like mobile phones, tablets, laptops, or huge-volume kiosks. **Rather, engineers supporting medical devices, industrial control panels, commercial device manufacturers or food processing equipment will benefit greatly from the concepts presented.** These applications (and many others) share several common factors: smaller display screens, medium production volumes (more on that later), and often challenging application environments. If the display and touch screen itself is the main part of the product (as in a mobile phone), then this book may not be right for you. However, if the touch display is important to control the main product, then this E-Book may be exactly what you need to read today!

Section 02

WHY TOUCH SENSORS MATTER

How your customers touch your products is a critical factor in your success.

Customer satisfaction is driven by their user interface experience: touch matters!

You likely have many touch sensors in your consumer life - many kitchen appliances, washer/dryer, some automobile HVAC and radio controls, etc. When they work correctly, they are awesome. When the touch interface doesn't work right, however, the user experience colors the entire device. At Xymox, we have one teammate who goes on and on about a $3,500 oven/range with a lousy PCAP touch sensor. Due to the false touches, the interface to set basic temperatures and controls has compromised his satisfaction with the entire unit because the OEM purchased a cheap touch sensor that doesn't deliver. As a product designer or product manager, you want to avoid this with your customers.

Design choices

There are two main choices for how to proceed with incorporating a touch sensor into your device:

1. Buy off-the-shelf: The standard option touch sensor

There is an overwhelming array of stock, off-the-shelf touch screens available. Often listed as an option, display manufacturers offer touch sensors laminated directly onto the display and shipped as a single unit. This is a great solution if it works for you!

2. Specify a custom solution just for your application

If your needs are not met by a stock touch sensor, then you may be a great candidate for a custom solution. Don't be afraid - a custom solution may actually lower your overall costs and improve your end-user experience.

This E-Book will outline some factors that can help you determine which approach is right for you.

Main Factors

There are four main factors to consider when you are deciding whether to use an off-the-shelf solution or a custom approach:

Customer User Experience

Design Compromises

Supply Chain Realities

Part Availability

Section 03

CUSTOMER USER EXPERIENCE

Your customers want to have a great experience using your product.

A key aspect to that great experience is the performance of the capacitive touch sensor responding only when touched. From a touch sensor standpoint, this means that the sensitivity to a touch needs to be just right, just like Goldilocks would have it. If the sensitivity is too high or too low, your customer will likely get frustrated. And if your customer is frustrated with their touch / user-experience, they will be frustrated with your product overall – regardless of how well the rest of your device works.

If:

- **people were identical**
- **the environment never changed**
- **manufacturing could produce absolutely identical units**

Then:

a poor user experience would never happen as the system could be tuned to function perfectly with unchanging conditions.

Unfortunately, people are not the same, conditions do vary, and assembly requires some tolerance. Combined, it is very difficult to tune the device to function in all conditions.

Example:

A person with calloused, dry fingers will look electrically very different to the touch screen than a person with sweaty hands. The dry hands are less sensitive, and the touch screen should be tuned with increased sensitivity to properly work for that person. However, if the touch screen is too sensitive, the person with sweaty hands could trigger a false touch when a touch was not intended (when a sweaty finger gets close to the touch screen but doesn't actually touch it.) A compromise must be made so that the touch interface works with both types of users. Another great example is a touch panel that might be used outdoors. In the summer, users will have bare fingers to touch the panel, however in the winter they don't want to take off their gloves. Will your touch interface panel work in both situations?

Here are some commonly reported problems when an application suffers from sensor sensitivity issues:

- ☑ Product returns for inconsistent touch screen performance
- ☑ Product returns state that the touch screen does not work, but it tests OK when analyzed
- ☑ Product appears to work for some people and not for others
- ☑ Product suffers from false touches when moisture is present or when unit is splashed
- ☑ Product to product comparison shows variation in touch response
- ☑ Product returned for false touches
- ☑ Product returned for touch surfaces that are too sensitive and others that are not sensitive enough
- ☑ Product returned because it does not work well with gloves
- ☑ Product returned for not working well with cleaning sprays, bodily fluids (medical applications), or dirty environments

An application specific touch system including a custom capacitive sensor will maximize the user experience and overall customer product satisfaction.

Section 04

UNCOMPROMISED DESIGN

A stock touch sensor can be a great answer but it usually comes with some compromises.

A compromised design means that your engineering department made accommodations in the design of your unit to use the stock capacitive sensor.

Those compromises could include:

- requiring additional components
- additional assembly steps
- more expensive assembly processes
- more complicated software development
- longer development period
- removal of product features
- compromised look/feel
- more complicated rework/repair procedures

There will always be compromises between product management, engineering, purchasing, and manufacturing. The goal is to minimize the compromises.

Here are commonly reported problems when an application suffers from design compromises:

- ☑ Engineering did not design the unit exactly how it was envisioned
- ☑ Extra parts were needed to accommodate the sensor tail location and/or length
- ☑ Unit does not meet engineering's requirements as originally outlined
- ☑ Unit does not function/perform as intended in all required conditions
- ☑ Unit is not assembled in the most efficient manner, or there are work-arounds in assembly to accommodate the sensor
- ☑ People assembling the unit think it could be designed differently to reduce manufacturing costs or improve product performance
- ☑ Unit cannot be repaired easily in the field and needs to come back to the factory
- ☑ Repairs cannot be made cost effectively or are more complicated than desired
- ☑ Product features were removed or reduced against product manager's wishes

A custom designed sensor may help avoid some of these problems seen with stock sensors.

Section 05

SUPPLY CHAIN REALITIES

Supply problems are challenges faced by purchasing because of the supplier.

Most often it includes minimum order quantities and how easy (or difficult) it is to do business with the supplier. Every industry has its expected way of doing business, your purchasing department will need to deal with those differences if your company is in a different industry.

Here are some commonly reported problems resulting from the supplier:

- ☑ MOQ's are higher than purchasing normally requires
- ☑ Poor customer service. Responses take a long time. The communication process is inefficient
- ☑ Poor engineering support. Not timely or efficient
- ☑ Lead-times are unacceptable
- ☑ Purchasing has to purchase additional components due to less efficient design
- ☑ Other components are required from suppliers currently not approved

Working with suppliers who know your industry can minimize these issues.

Section 06

LONGEVITY OF SUPPLY

The life cycle of electronic parts is short - often a year or two.

Most industrial products, however, are designed to last a long time, like 5 to 20 years. What is the cost to the customer if a component is no longer available? This can be the sensor, controller, or the display. Often, a stock item is available because of large volume customers driving manufacturing economies of scale. In that case, the manufacturer will make that component available to smaller volume purchasers since they are already making large quantities. When the driving customers' demand changes, the effect can be dramatic on smaller purchasers.

Here are commonly reported problems with the long term supply of standard option sensors:

- ☑ The optional sensor is no longer available
- ☑ The display, which includes the sensor and controller, is no longer available
- ☑ The supplier of the sensor changes
- ☑ The sensor design changes

Sensors designed specifically for your application will be available for the life of the product.

Section 07

STOCK OR CUSTOM?

That is the question.

Incorporating capacitive touch capabilities into a device using the standard option sensor can be cost effective if it meets all specifications and requirements for engineering, manufacturing, purchasing, and quality.

If it works, it's a good deal and hard to beat with a custom approach. So how do you know whether you are better served by an off-the-shelf touch sensor solution or a custom solution made just for your application?

Some key attributes of your application can help you decide which approach is right for you:

Custom Sensor		Stock Touch Sensor
1000 – 100k / year	Annual Volume	>100k – millions / year
High Risk: Life could depend on it	Critical Use- Risk of False Touch	Low Risk: Just a butt dial
Long: 5-20 years	Life of Your Product	Short: 1-2 years
Must be Repairable	Product Maintenance	Product is Disposable
Low: less than once/day	Device Use Frequency	High: >50 times per day
Low: 1-20 touches / use	Touch Frequency	High: hundreds of touches / use
Basic: tap, swipe	Gestures	Complex: pinch/zoom, multi-touch
Yes, needs to work with both	With and Without Gloves	Not Important
Water, Ice, Salt, Debris	Harsh Environment?	No, mostly clean conditions
Not Critical: simple GUI and Text	Perfect Display	Display Quality is essential to your product
Custom Quantities, changing ship dates	Order Placement	Simple, steady, high MOQ's are OK

If your product characteristics indicate that you can be well served with a standard, off-the-shelf touch sensor that is supplied with the display, this is the right choice to make for lowest component cost.

If your application contains:

- functionality that cannot suffer the consequence of a false touch
- needs to last a long time (many years)
- has modest unit volume (under 100,000 units per year)
- has other attributes only available from a custom solution

then you should consider a custom touch sensor.

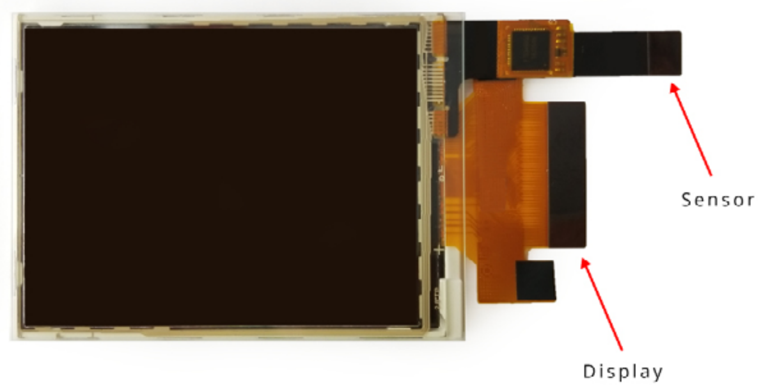
Section 08

THE STANDARD OPTION CAPACITIVE SENSOR

The development of the HMI (Human Machine Interface) for medical and industrial equipment often starts with selecting a display, as it serves as a focal point of the device and is typically expensive.

By contrast, little consideration will be given to an available touch sensor associated with the display.

Display
with Sensor and Controller



Typical characteristics of a standard, off-the-shelf touch sensor:

Technology: ITO (Indium Tin Oxide) laminated with OCA (Optically Clear Adhesive)

Controller: No option

Tuning of the controller: No option

Sensor design: No option

Tail length and location: No option

Many believe all capacitive sensors and touch screens look like this because they do not know cost effective custom sensors exist; a custom sensor that can actually reduce the cost of the final product by eliminating some of the compromises required to use a stock sensor. A custom sensor can also increase the value of your product because of a better user experience.

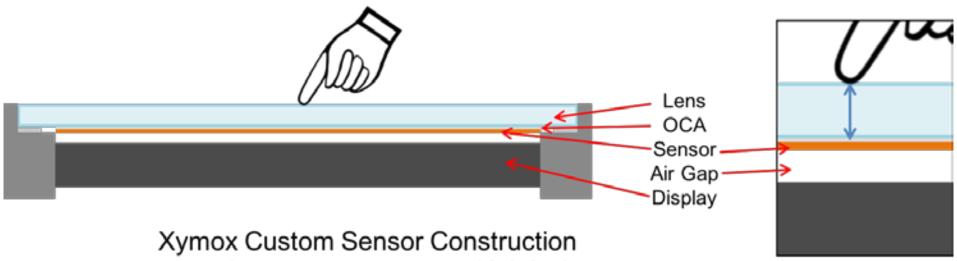
Section 09

TECHNICAL DETAILS

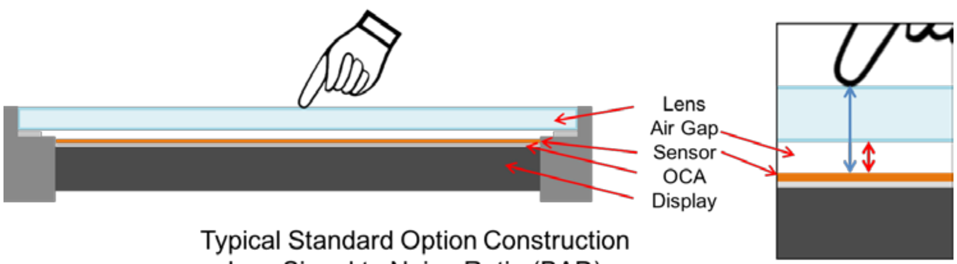
The Relationship Between Lenses and Sensors

With a standard option, the sensor is laminated to the display. With a custom solution, the sensor is typically laminated to the lens. This may seem insignificant, but to the touch controller and overall performance of the touch system, this difference is huge for two reasons:

1. The sensor is closer to the user's finger
2. The air gap is moved to isolate the sensor from the display



Xymox Custom Sensor Construction
High Signal to Noise Ratio (GOOD)



Typical Standard Option Construction
Low Signal to Noise Ratio (BAD)

Touch controllers function best when the electrical impact of the finger touching the lens is easily noticed by the controller and, at the same time, surrounding electrical noise is minimal. This is often referred to as the Signal to Noise Ratio (SNR). In simple terms, the signal is the impact of the finger coming near the sensor electrode on the electrical readings of the controller. The closer the finger gets to the electrode, the bigger the impact on the signal. The noise is the impact on the electrical readings of the controller when the display and other surrounding electronics are turned on. So, we want a lot of impact from the finger touching the lens and very little impact from surrounding electronics; high signal and low noise equate to great performance. The above illustration shows how moving a sensor to the lens helps provide the best environment for the touch system.

Section 10

WHAT CHOICES EXIST FOR A CUSTOM TOUCH SENSOR?

Answer - a lot!

When you consider creating a custom sensor, you have options for how that sensor operates to achieve the functionality that is just right for your application. There are five different aspects of the sensor to consider:

Sensor Pattern

Sensor Material

Sensor Size and Shape

Sensor Tail Location and Length

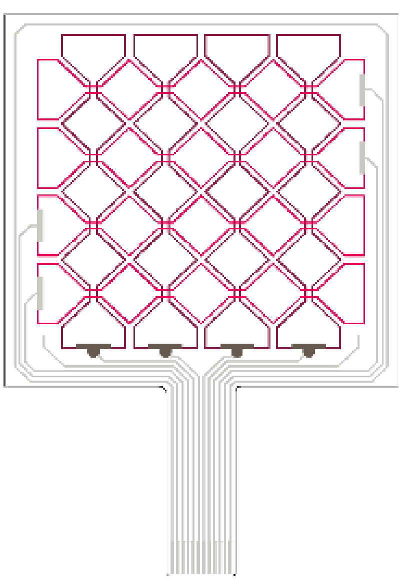
Integrated Tail or Flexible Printed Circuit with Integrated Controller

Sensor Pattern

Even though a touch sensor is transparent, there are clear conductive layers on that sensor that are patterned to form the electrodes which interact with the user.

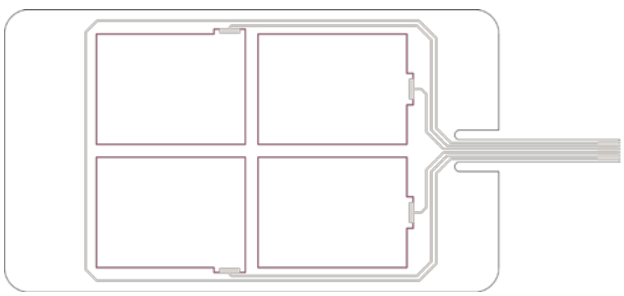
This is the material that senses where the sensor has specifically been touched. With a custom sensor, we can choose the electrode pattern that senses the touch. This choice is driven by the end-use application and requirements of the controller.

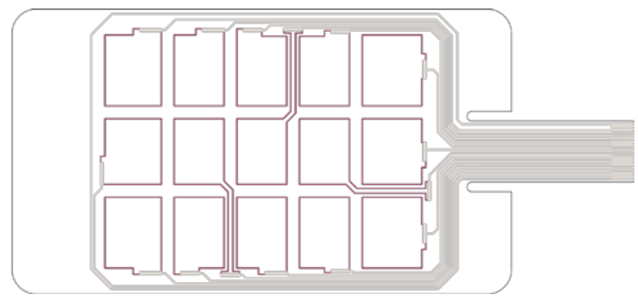
Matrix Style Sensor



These are traditional touch screen sensors most familiar to people. Xymox uses an industry standard double diamond pattern. These allow for touch points anywhere on the sensor. If gestures are important, this is most likely the sensor pattern required. These patterns require double sided (two sided or two layered) sensors and vias (a via is a tiny hole through the polyester sensor that allows circuits to be on both sides of the sensor). Materials and production costs for this type of sensor are higher than some other styles.

Discrete Style Sensor



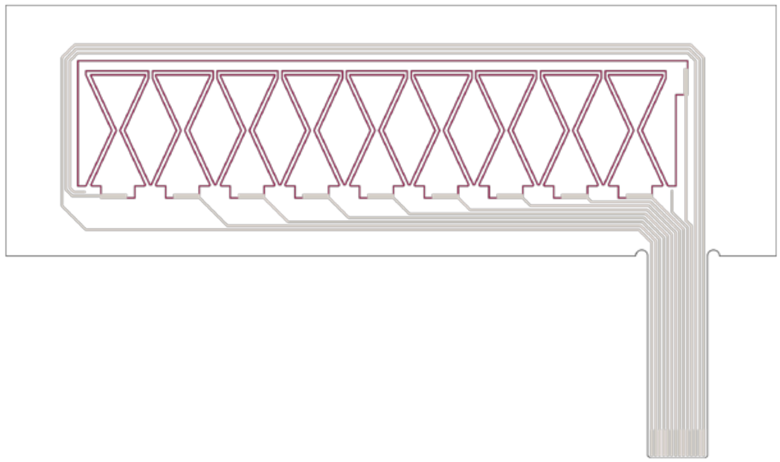


Discrete sensors provide an economical and sometimes more robust alternative to the matrix style sensor. In most medical and industrial applications, a cost effective discrete touch point sensor will better handle harsh user environment, prevent false touches, require less development time and be more cost effective than a matrix style sensor. For these reasons, discrete style sensors are becoming more popular.

Discrete Sensor Advantages:

1. More consistent and reliable
2. Less expensive sensor
3. Less development time
4. Easier programming of software

Slider Style Sensor



A slider sensor combines the cost effectiveness of the discrete style sensor with the ability to touch at any point in the X direction and perform some degree of gestures including swipe. Depending on the end use, this can be a very effective design for allowing a user to slide along the screen for a variable selection, or to swipe between menus of icons. More than one slider can be stacked on the display if the application is a good fit. For many industrial and appliance applications, a short and wide display can be useful – and a slider sensor can be a great solution.

Slider Sensor Advantages:

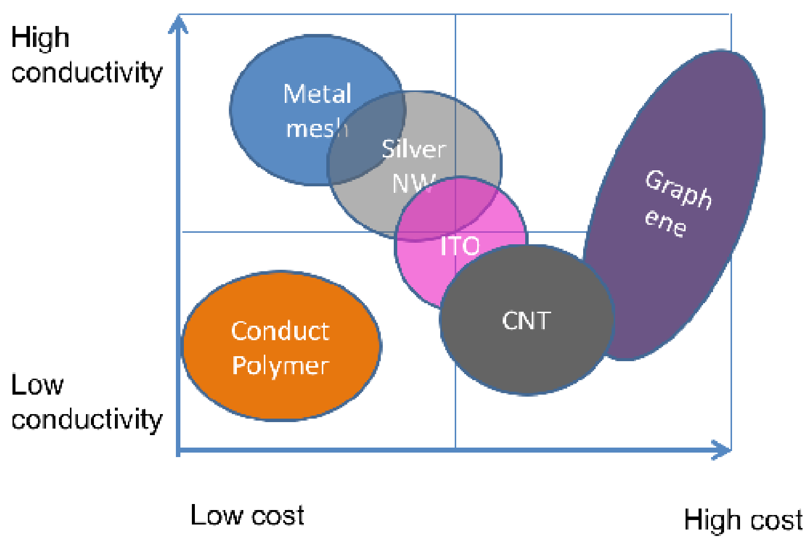
1. Less expensive sensor
2. Supports gestures such as swipe
3. Well suited for long narrow displays
4. Good compromise between Matrix style and Discrete

Sensor Material

There are two main sensor materials that are transparent and also electrically conductive.

Most touch sensors (stock sensors) are made with ITO – Indium Tin Oxide. This is a great material, though it is manufactured in a capital intensive environment, which means that short custom runs are impractical. Further, ITO is very brittle and therefore unusable in curved applications.

Many custom sensors, including those manufactured at Xymox Technologies, are made using a conductive polymer abbreviated as PEDOT. The conductive properties are slightly different than ITO, so it is not a pure drop-in substitute. As a polymer, PEDOT is flexible, making it able to be used for curved sensors.



Source: Touch Display Research, ITO-replacement report

Xymox uses two different types of application methods: we can screen print PEDOT onto a normal polyester substrate, or we can process polyester that has been coated with PEDOT into a touch sensor. Screen printed PEDOT is slightly translucent, and therefore inappropriate for a touch sensor used directly over a display. Since it is translucent, screened PEDOT is awesome for a backlit area that is intended to be touch sensitive.

For transparent sensors, Xymox uses Kodak HCF film as a raw material, then we process it into custom touch sensors. Some advantages we have is the material is flexible, has extremely high light transmission, and is easy to process.

Why does Xymox use Kodak HCF film?

As discussed above, there are several ways to get the conductive PEDOT layer applied to polyester film. Kodak has phenomenal polyester processing capabilities from their years producing photographic film, and they are able to use that technology to coat an amazingly clear layer of PEDOT on film. After Xymox processes the HCF film into a touch sensor, that incredible clarity and transparency remains. This combination of Kodak's polyester and coating capabilities with Xymox's core processes results in an incredibly clear, high light transmission touch sensor.

Sensor Size and Shape

Today's popular display sizes are based on consumer electronics (4.3", 5.0", 7.0", 10.4", etc) and typically offer a touch sensor as a standard option. However, most industrial and commercial applications are not designed around that size or shape display and have different requirements. It may seem obvious, but you should select the display best suited for the application and how the end user is expected to interact with the device. If you expect the user to watch videos, then select a display designed for videos. If the end user is expected to change the temperature of an oven, select the appropriate display. After the proper display is selected, then the proper capacitive sensor can be fit to the display.

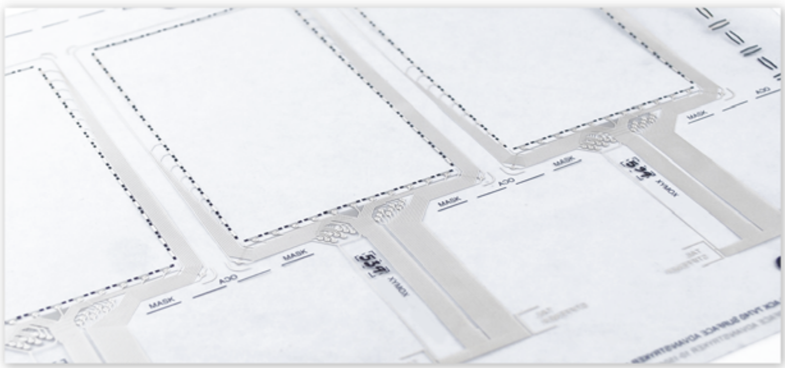
A common question is, "How large of a display can our sensors fit?" The answer for a custom sensor depends on the application. For a traditional matrix style sensor, sensors larger than 10" provide surface resistance challenges – the distances are pushing the limits of the matrix pattern and controller. In contrast, a discrete style sensor is often a much better option for improved end user experience, and these sensor configurations can be used on larger displays.

Tail Location and Length

The tail is the part of the sensor that connects to the electronics of the overall sensor assembly. The length of the tail can make a significant difference in the cost of the overall part, both through material costs and physical dimensions pertaining to manufacturing configuration. By positioning the tail in the optimal location, cost can be optimized and integration with the circuitry can happen in the best manner. Further, the assembly process can be streamlined to minimize labor and maximize throughput in your factory.

Sensor Integrated Tail or FPC with IC

There are two main ways to create the tail. An integrated tail is made by printing conductive traces on the same polyester sheet that the sensor is made from - it's just an extension of the sensor itself.



Integrated tails provide the most reliable connection to the sensor. Kodak HCF film with PEDOT allows for an extremely tight bend radius for final assembly - meaning the finished assembly is very durable.

Another option is to use a tail made from a different flex circuit and bonded to the sensor. This is the standard configuration for ITO sensors. You typically see the orange colored polyimide tail connected to the transparent sensor using conductive bonding materials to make the electrical connections. One advantage of this style is the ability to include the controller for the sensor on the tail itself (called chip-on-flex or COF.) The disadvantage is generally high cost. ITO sensors require this type of tail since ITO is not flexible and would crack.

It is most economical to have the controller be part of the main control board. Placing the controller directly on the tail is only economical when space on the main board is limited. Space is typically not a concern with our customers.

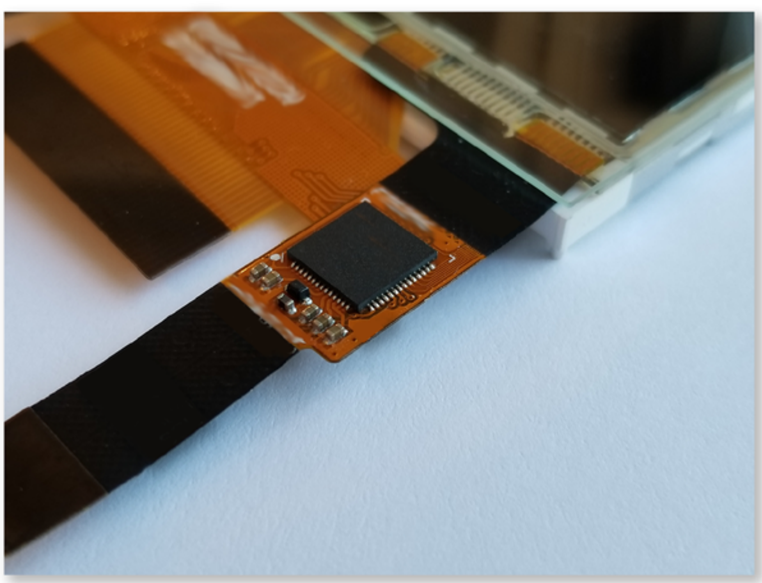
Integrated tails remove the potential reliability concern associated with bonded tails.

Controller

A functional touch sensor requires two things: a sensor and a controller. The touch controller is the brains of the operation.

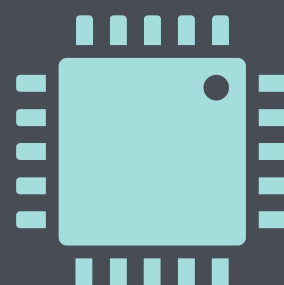
The capacitive sensor detects changes in capacitance, and the electronic controller chip is required to interpret those changes in capacitance. There are many types of controllers available, and you need the right pairing with the sensor to get it to work right. Xymox sensors can work with virtually any controller, though matching a sensor to a controller does require some programming to "tune" the sensitivity of the two components.

The standard option sensor most likely will come with a controller on a flex circuit bonded to the sensor. Ask yourself if this is the best controller for the application? Are the settings in the controller optimal for the application? Unfortunately, these settings are not configurable when using the standard sensor option. Most likely they are tuned for consumer applications – not designed for gloves, wet applications, etc.



Xymox has relationships with two controller manufacturers which operate well for the type of sensor applications we are discussing:

- Azoteq for matrix style sensors
- Alsentis for discrete style sensors



Azoteq controllers are cost effective, simple to implement and include all the common gestures expected.

Alsentis technology is based on recognizing the electronic touch signature that happens as a finger approaches and retreats from the sensor. The controller reacts to that signature rather than the traditional threshold capacitance approach. Alsentis technology translates to touch systems that work consistently over a wider range of environment conditions, user differences and manufacturing variances.

Xymox can support and work with any type of controller. We also can offer good recommendations to get you the sensor-controller pairing that works best for your application.

Lens Materials

For a custom designed user interface, a designer can choose the material for the lens – a critical choice since that is the surface that your customer touches. There are a wide range of materials, including:

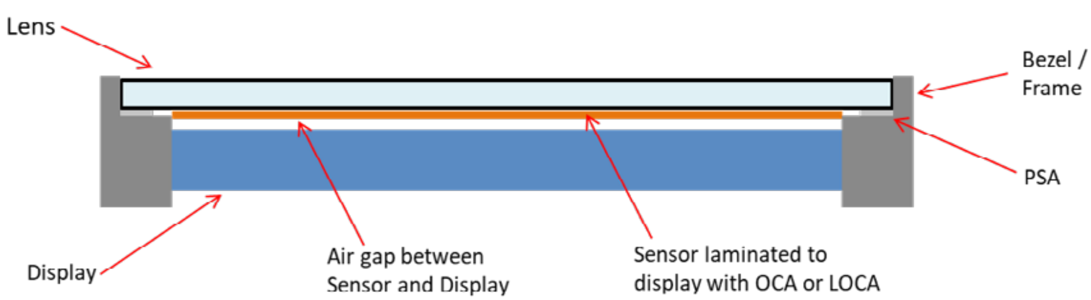
- **Acrylic**: available in standard thicknesses including 0.06" (1.5mm) and 0.118" (3.0mm), acrylic is a durable polymer material. Xymox uses only hard coated, scratch resistant acrylic for best performance.
- **Chemically Strengthened Glas**s: including popular trade names such as Gorilla Glass®, this material provides an excellent touch surface and looks great.
- **Polycarbonate**: a key advantage of polycarbonate is impact resistance, but the trade-off is a softer surface that can be scratched more easily. While scratch resistant coatings are very helpful, the overall surface is not as hard as acrylic or glass.

Xymox laminates touch sensors to all types of lenses using optically clear adhesives in our clean room environment.

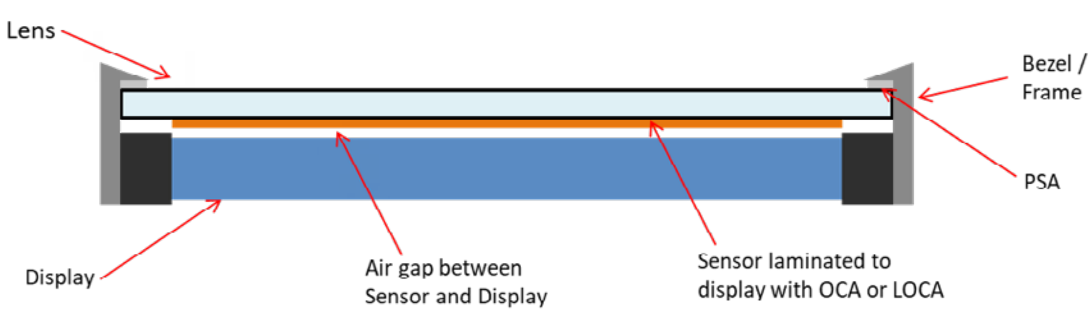
Assembly Options and Features

One of the key drivers to factory economics is the assembly operation. The primary components of the touch screen (lens, sensor and controller) can be delivered as a single assembly, partial assemblies, as individual components or attached to other components. How, where and when everything goes together greatly influences the quality of the unit, the rate of assembly and ultimately the cost of the device. Selecting a standard option sensor may force the assembly line to use additional components and perform operations with lower yields or longer than expected times.

The finished look of the assembly will be driven by Product Management and a big part of that will come from how the lens assembles to the bezel.



Top Mount



Bottom Mount

The performance of the touch sensor should not be impacted by this decision and, correspondingly, the decision on how the system is assembled and looks should not be impacted by the selection of the touch system. The selection of the touch system must always be subordinate to the requirements of device and the manufacturing department.

A custom touch sensor assembly can include features that actually improve overall quality and rate of assembly, resulting in lower overall cost. These features typically include:

- Specialized gaskets
- Specialized materials
- Antennas, such as NFC antennas
- Additional or specialized circuitry

The point is that you can get a full range of assembled components to reduce the cost of implementation.

Trust your touch sensor display expert to solve your problems

Section 11

A WORD ABOUT COSTS

Actually, there are a number of words about costs:

When designing a touch interface for your product, there are many costs you need to consider – as they all may affect your particular situation differently, depending on the application. For example, a touch sensor application will have different total cost drivers for a kitchen range, a medical defibrillator, or an industrial control panel.

- **Design Costs / Solution Engineering –** How much work will your team need to do to develop the total solution that will deliver the best user experience and total cost for your project? Do you have the expertise in pulling together the display, sensor, user requirements, controller sensitivity needs, lens choices, tail location, etc.? What will the total investment of engineering and design time be if you do this all yourself?

- **Unit cost –** This seems like the easiest part – how much do the components cost per unit? However, it is difficult to get an apples to apples comparison of alternatives when the total set of components is still being designed and formalized. It is important to consider the cost of the display, touch sensor, controller, cables, bezel, lens, etc.

- **Assembly cost –** This is the line cost in your facility to assemble the final device. There are many options in how a component assembly is designed that can reduce the complexity of assembly operations and thus cost. If you have low assembly costs, you are best off purchasing just the parts to fit your capabilities.

→ **Procurement cost –** How much time and energy will you expend sourcing products, managing MOQ's, managing lead times, and adapting to changed delivery schedules for each potential source of components? Many companies have re-shored production because the hassle of a long supply chain distance has outweighed lower part costs from other parts of the world. Is there a distributor between you and the manufacturer of your components, and do they add value to the process? The procurement cost will be influenced by these factors, among others:

1. Number of components
2. Manufacturing location of components
3. Sales channel for components
4. Flexible inventory options for customer

→ **Solution programming cost –** A discrete button sensor should be easier to program solutions than a matrix style sensor. If you are choosing a stock supplied sensor that is a matrix-style, consider whether you need this approach. While you can program a matrix sensor to work with discrete touch points, it's like buying a super car but never exceeding 55 miles per hour. The simpler the needs of the end user, the more important this difference in solution programming can be.

→ **Incoming QA cost –** As you start a new project, what is your cost of incoming quality? What will it cost if you have significant fallout in this regard? In this industry, it is not uncommon for a poorly supplied product to have 20-35% reject rate on incoming inspection and performance. What is your supplier's reputation for flawless project startup and execution? What will a flawed supplier cost per part purchased?

- **Product Field Failure Risk/Cost –** Have you ever had a field failure of your product and calculated what it cost? In a recent medical application, a competitor's field failures cost their customer about 2.5 times the purchase cost of their touch interface due to irregular performance in the field. After that experience, the customer was all too happy to pay an extra dollar for a touch interface solution that works every time. These costs didn't account for lost market share, lost customer goodwill, and overall market image. Since your success is largely dependent on your customer's touch experience with your product, be sure you are accounting for the cost of a poor field experience.

- **Repair cost –** This will be directly related to the complexity of the assembly. If we can provide a drop-in solution that requires only a lens change in the field, it could be less expensive than changing an entire display, which could require having the device shipped back to your service center for repairs.

- **End of Life costs for Components –** Stock touch sensors are often based on a very large customer driving manufacturing efficiency. For example, when a particular mobile phone screen size is in production, the manufacturer will offer that size screen to other smaller customers taking advantage of the huge production of the driving design (the phone.) Once that mobile phone is obsolete, in a year or two, the secondary customer either needs to change to match up with a new phone design driving new demand, or has to pay much more for the existing design. If the life of your product is long (often our customers have a 10-20 year life in production and service), you are vulnerable to the fast-changing world of displays and touch sensors for those displays.

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XYMOX Technologies, Inc
9099 West Dean Road
Milwaukee, Wisconsin 53224
United States

PHONE, FAX, WEBSITE

Toll Free: 1.800.869.9669
Phone: 414.362.9000
Fax: 414.362.9090
Website: **xymox.com**