Implications of passive stylus on large capacitive touchscreens

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Manufacturers of mobile devices want to differentiate themselves through advanced features that meet consumer demand for a natural user interface with the ease of pen and paper, combined with the flexibility of a PC. A small tip, passive stylus with palm rejection would give manufacturers the ability to deliver a low cost solution that enables writing, editing, signature capture, precise navigation, and other new applications. However, implementing such capabilities introduces several challenges for passive stylus developers to meet the necessary performance requirements using capacitive sensing technology on larger touchscreens. Specifically, advanced algorithms and sensing methods are required that are able to detect a very small signal of interest from the stylus while rejecting the large, unwanted signal from the user’s hand. Devices also must be able to dynamically switch back and forth between stylus and multitouch input while maintaining the speed, precision and responsiveness required for a desirable user experience.

As capacitive touch screen sizes grow, it becomes more intuitive to use a writing device similar to paper and pen. The most common ways for manufacturers to enable pen capabilities are through an active or passive stylus. An active stylus includes electric components, requires a power source, and transmits a signal to the host device. This allows for advanced features such as hovering above the display, pressure sensing, button support, and eraser functionality. A passive stylus is a piece of conductive material that is essentially an extension of the user. The capacitive coupling from the individual’s hand enables a signal to be sent when the stylus touches the screen. There is no active communication between the pen and the host platform, so it can be difficult to differentiate between a finger and a passive stylus.

In many cases, the features that can be implemented using either type of stylus are not worth the added cost to the system. The additional components and power requirements for an active stylus make it a tough sell, and the poor performance and/or large tip of a passive stylus make for an unnatural writing experience. This said, the user experience for a passive stylus can be improved if the stylus can have a small tip on the order of 1-2 mm, support the user resting his or her palm on the screen while writing, and maintaining sufficient speed and accuracy so that “ink” deposits directly under the contact point.

To create a viable implementation that supports a finger plus a small tip passive stylus, many use cases must be considered. For example, developers need to consider how fast the system needs to be able to switch between detecting fingers and writing with stylus. Similarly, they must define how the system should react if the stylus touches before the finger or palm, after the finger or palm, or simultaneously. Other important details include configuring how close the stylus can be to a hand before the stylus signal is no longer detected. Figure 1 shows example state machine progressions of stylus use cases.
The Stylus Paradox

Passive stylus detection is a complex problem for touch engineers, with the root of the problem being the stylus paradox. The stylus paradox is that the signal profile for a passive stylus is several times smaller than that of a normal touch input, but the fine point of the stylus makes the user believe that it will be more accurate.

Accuracy and linearity are proportionally related to the signal to noise ratio of the system. Since the noise floor generally will not change relative to the input, a reduction in signal greatly affects SNR. A rough approximation for the signal level of a capacitive touch screen is the area of coverage for the touch input. This means that a 2 mm passive stylus will have 25 times lower signal strength than a typical 10 mm touch. It is this signal gap that causes so many problems for the touch engineer. The firmware must be able to detect the small stylus signal, even in the presence of the larger touch signal. This will often require separate sensor scanning modes at the expense of noise immunity and refresh rate. Additionally, the most natural fit for a passive stylus is a large touch pad, which already has lower refresh rates or larger pitch sensors, each of which lower system performance metrics.

Fundamentally, there are two issues related to managing the signal gap. The stylus must first be detected despite its very low signal. Once it is detected, the stylus must be accurately reported. Both of these issues present their own difficulties. Conceptually, the most common sense approach to detecting the stylus is maximizing the sensor signal. This is often accomplished by minimizing the dynamic range of the sensor to signal levels that are very near the expected levels, or even through software multiplication and filtering. However, high gain systems are easily saturated by larger inputs such as normal finger touches. So care must be made to accommodate both normal touches and small stylus signals. One common method is to perform two separate scans at each expected signal level to decipher normal touches from stylus inputs.
Managing the Dead Zone

This mode switching is vulnerable to false detections, which must be filtered out. One classic example is an approaching or departing finger. As a finger approaches, its signal level is quite low (in the passive stylus region), which is also true when the finger departs. Therefore, other qualifiers must be used to verify any detected stylus inputs.

Managing the Dead Zone

Once detected, the stylus must be accurately reported. Unlike a typical finger touch, the fine point of the passive stylus allows the user to see exactly where it is placed relative to the LCD screen. Therefore, there is a higher expectation of accuracy despite a greatly lower signal to noise ratio. Linearity is also a critical factor because a common usage of the stylus is for writing. The critical issue with a passive stylus as it relates to accuracy and linearity is the dead zone.

The dead zone is an area within the touch screen where the report signal levels do not change even though the input stimulus has moved to a new location. For example, a 2 mm passive stylus tip can be completely surrounded by a typical 5 mm sensor on the touch screen.

Small movements of the stylus within the center of the sensor are difficult to detect, but as far as the
sensors are concerned, inputs are always quantized to the center of their elements. So, as the stylus moves within sensor, it is reported as being in a fixed position, hence the dead zone.

A generalized approach to solving this problem is to look at all surrounding sensors and use them to create indices into a look-up-table, which are used to correct the reported position to better approximate the actual position. Thus, passive stylus accuracy and linearity problems boil down to creative ways to generate these indices or more complicated look-up-tables, because the dead zone is a physical problem that generally cannot be overcome and therefore must be corrected for.

The Necessity of Touch Rejection

Early passive stylus implementations allowed only a single input type at a time, and normal finger touches were a higher priority. These systems would not work if a normal touch was present on the screen, which included gripping the edges of the phone or tablet while writing, or when resting a palm on the screen while using the stylus. However, these are two very common use cases for a stylus on a larger screen. For ease of use, rejecting these types of touches while a stylus is on the screen is paramount for user satisfaction. The reason a touch on the screen affects stylus performance, again, depends upon the signal gap.

A touch on the screen spreads its signal to several sensors, and the periphery sensors are generally in the stylus region of signal level. The signal level of a normal touch is also much higher than that of the stylus. It is like having two flashlights in a dark room where one is very bright and one is very dim. The brighter flashlight makes it very difficult to see the dim flashlight. Additionally, common noise is injected through normal touches. So, if a noisy touch shares a common sensor receiver with the stylus, the stylus may be undetectable.

These common mode noise issues are a whole other class of problems. In general, they are solved for a passive stylus by isolation of the desired signal by only scanning particular sensors of interest. This presumes the stylus can initially be detected and then tracked as it moves on the screen, which makes the first touch down of the stylus the most vulnerable. However, once the stylus is tracked by a sensor subset, most unwanted touch issues are no longer a problem.

While most of these issues seem very difficult to overcome, advances in today’s touch controllers make it possible to have a device that is sensitive enough to detect a small tip passive stylus but also smart enough to reject noise and unwanted objects on the screen. From a user perspective, an intelligent touch controller is able to handle many of the input related issues with detecting and tracking a touch object. The key to success from a system level will be developing applications that enable the user to consume, create and manipulate programs on their device in ways that increase productivity and feel natural.

Also see:

- Aggressively combat noise in capacitive touch applications
- Noise wars: Projected capacitance strikes back against internal noise
- Capacitive sensing—integrating multiple interfaces—Part I, Part II
- Choosing a touch technology for handheld-system applications
- Determining the right switch technology for consumer, industrial interfaces