LUMISSIL Microsystems
A Division of ISSI

Capacitive Touch Matrix Sensing for Appliance HMI Design

For appliance Human-Machine-Interface with high key count, enabling sleek and sophisticated design, high electrical sensing performance and easy integration with LED indicators enables a high-end look and functionality.

Sleek and sophisticated Human-Machine-Interface panel is an important part of modern appliance design. Today's home appliances have more value-added features than ever before. Capacitive touch technology enable appliance designers flexibility in electrical and functional design to support rich functionality. This is done while continuing to make a product that is aesthetically pleasing and easy for consumers to use.

Household appliances have multiple selection options for enabling different features. Cap-Touch sensors can be used for buttons, sliders, rings, touchless proximity and gesture sensing, etc. The ability to design human interface with no moving parts on an elegant flat surface of any shape and different material and integrated with other HMI elements like LEDs, create excellent design options for an attractive product.

ELECTRONIC DEVICES USER INTERFACE

Traditionally, appliances with Human-Machine-Interface (HMI) has been mechanically based; requiring users to select the desired function by physically turning a knob or pushing buttons. With the introduction of the microcontroller (MCU), the range of function selections and operating options have increased to a complex level. A simple mechanical interface cannot keep up with the demands of increasingly automated functions such as sensing, process control and cycle times.

The mechanical knobs and switches are being replaced with MCU based capacitive sensing inputs which have no movable or raised parts, resulting in an easy to clean interface with no mechanical wear and tear. In addition, a greater number of LEDs are being incorporated in the user interface to provide visual feedback for the appliance operating status.

A well-designed user interface simplifies the management of this massive amount of control information found in today's appliances. A typical Appliance HMI consists of touch buttons, LCD seven segment displays, LED indicators and backlighting with audio and haptic feedback. An HMI not only allows the user to configure the appliance operation, but also displays the operating status.

The design engineer would use the onboard MCU to read finger touch sensors and drive these LEDs. However, using main device MCU for these functions may consume valuable CPU cycles and negatively affect the performance of sensors with unreliable display refresh, depending on the firmware and bandwidth of the MCU. For this reason, Figure 1 shows an approach for application-specific Cap-Touch controller with standard code that doesn't require programing. Designers of complex control panels can turn to Cap-Touch controllers and programmable LED drivers to offload the MCU, resulting in simplified firmware and a stable performance.

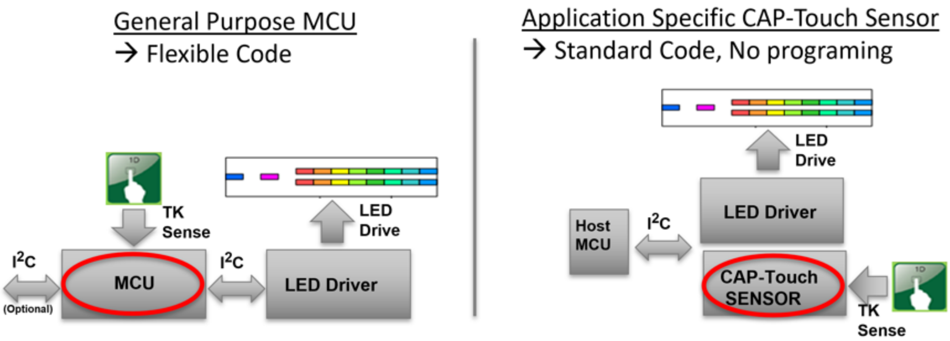

FIGURE 1 - MCU VS. CAP-TOUCH SENSOR DESIGNS

TRADITIONAL CAPACITIVE TOUCH SENSORS DESIGN

For standard self-sensing capacitive touch controller, MCU's GPIO outputs can be configured as the input of a sensor. The sensing technology incorporated into the MCU would typically be TK3 - Sigma Delta (Differential dual-slope charge sharing) or TK2-(Charge transfer).

In any case, the architecture determines that maximum number of sensors is determined by number of available GPIOs and hence determining the size of the MCU and its relative cost. The functionality of the device is limited by number of sensors and GPIOs, and adding sensing functionalities like proximity sense, shield driver, buzzer output, etc. will further reduce the available sensors.

In addition, other system functions that the MCU can perform such as driving LEDs, controlling LED Drivers and actuating electro-mechanical elements of the system is again limited by same number of I/Os.

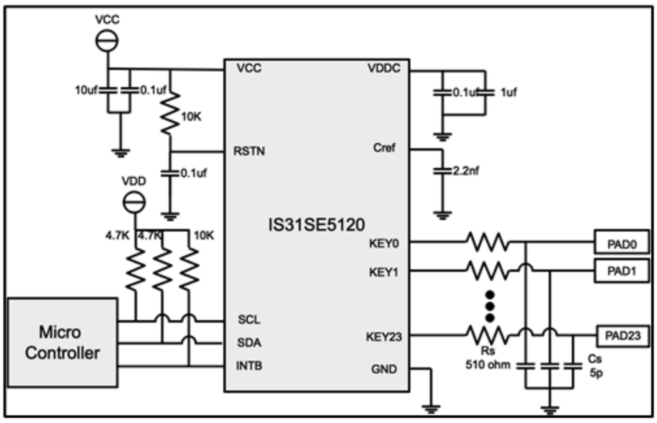

FIGURE 2 - TRADITIONAL CAPACITIVE TOUCH SENSOR – IS31SE5120

Figure 2 shows the IS31SE5120 which is the standard-code sensor implementation of IS31CS8977 – 27 I/Os – 24 self-sensing Cap-sense and 3 for I2C communication.

CAPACITIVE TOUCH MATRIX SENSING

An alternative approach is to use an Array of X transmitters and Y receivers, each of those is an I/O of the MCU. Then each Cap-Touch sensor includes 2 electrodes of transmit and received signal. The MCU is measuring the disruption of signal when the finger is touching or approaching the electrodes, depending on the application.

Figure 3 below shows how the IS31CS8977 can use 10 I/O channels to create a matrix of 3 transmitters and 7 receivers for a total of 21 Capacitive-Sense sensors. This can be further increased up to 5 transmitters and flexible number of receivers, limited by the MCU core processing power. For example, if a design matrix of 5 transmitters and 7 receivers, then it can create 35 sensor matrix – that is larger than the 27 I/Os maximum channels available on the device, and only 12 I/O's (i.e. 5+7) out of 27 are used for Cap-Touch sensors and up to15 more are left for other MCU functions, including communication, signal drivers and control, etc.

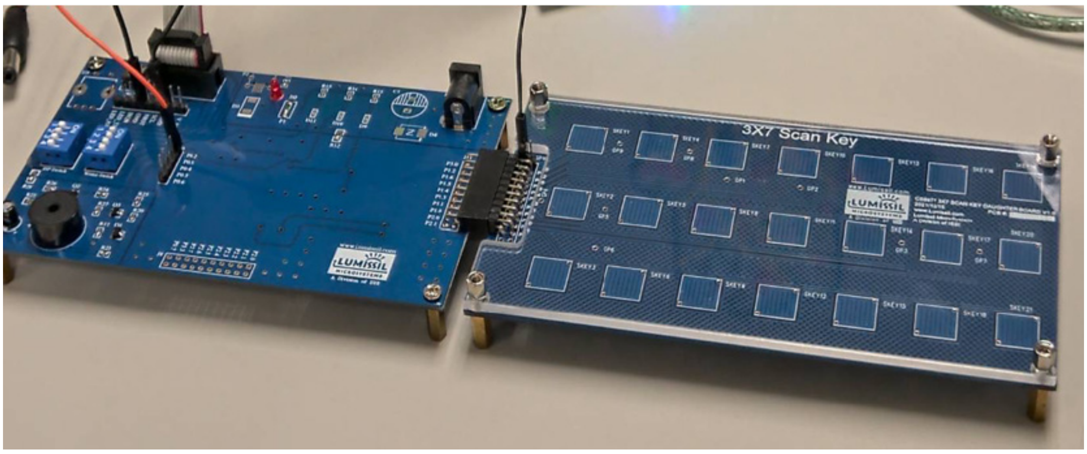

FIGURE 3 - MATRIX CAPACITIVE TOUCH SENSING

MATRIX DESIGN ADVANTAGES

Smaller number of MCU pins - Using an X-Y I/O interface between MCU and sensors practically means that less MCU I/Os control more sensing points. This practically means that either a smaller MCU can be selected for a set number of sensors, or that larger numbers of sensor and richer functionality can be achieved with a given size MCU.

Shorter traces - Lower number of traces and routing of traces between sensors (along "X line" or "Y column") makes it easier to design and protect from external and cross-talk radiated noise. This would further improve "real life SNR" and even more applicable in large appliance HMIs with large PCBs and long traces.

Connection interface - Utilizing 2 X and Y electrodes for implementation of the Cap-Touch button enables the designer to easily integrate into and around sensor visual LED light elements for indication and illumination.

Ultra Low power – "Wake on touch" technology allows for keeping the MCU at a few microampere average current and that whole controlled device at extremely low standby power consumption. While power consumption is most critical for battery-powered devices, the "wake on touch" function allows appliance design to incorporate features like activation of elements or displays with hand touch or proximity sensing while maintaining low power consumption.

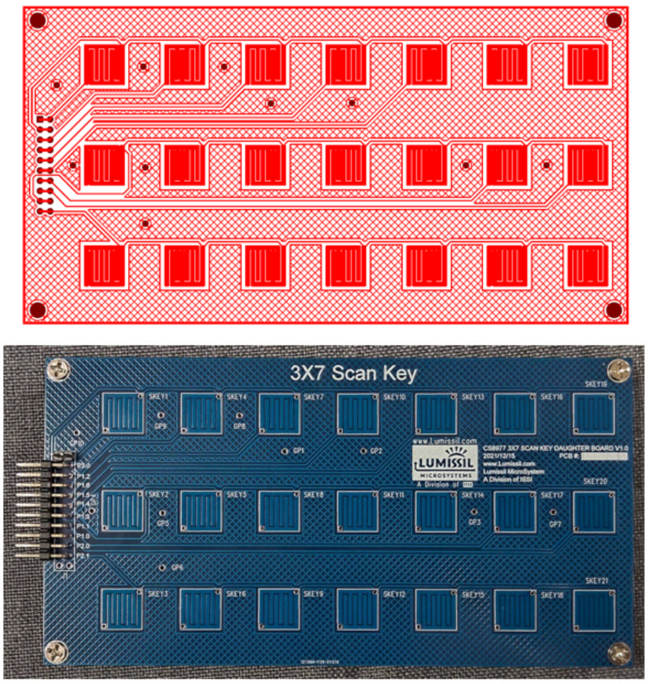

FIGURE 4 - CAPACITIVE TOUCH SENSORS ARRANGEMENT IN ARRAY

MATRIX TOUCH SENSOR OPERATION

In a matrix array configuration, sensors are typically arranged in rows and columns (though exceptions are possible), resulting in a scanning architecture which is the most efficient for larger number of sensors. The basic concept is that each Capacitive sensor and its associated register can be sensed and addressed by its row/column location in the array.

Sensor function and layout on PCB are shown in Figure 5. It is set in a manner that combine 2 electrodes (X and Y) so that maximum radiated signal can be transmitted between them (For example - 2 combs meshed together). The finger approaching or touching the button will interfere with the electromagnetic lines and the change in signal will be sensed by receiver electrode.

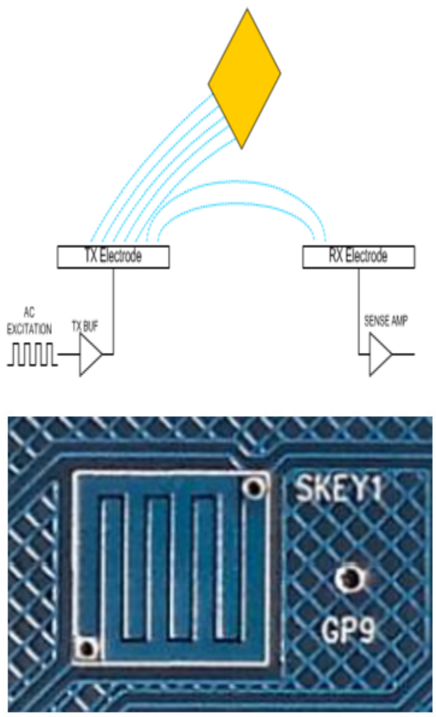

FIGURE 5 - CAP TOUCH BUTTON FINGER SENSING – MUTUAL SENSE

An internal state machine sequentially cycles through each of the X-Y combination, transmitting a signal in the X lines and reading received signal on the Y-line. The sampling of each sensor is averaged to achieve required SNR. The sampling rate is impacted by the MCU processor performance and impact sensitivity and response time of the implemented device.

MATRIX CAP-TOUCH SENSOR DESIGN PERFORMANCE

We are measuring signal to noise for a range of sampling frequencies (250Khz to 2Mhz) and different measurement distances from a finger (2mm, 3mm). For example, the Figure 6 graph shows a measurement of the 21 sensors signal and noise at 250Khz frequency and 3mm touch distance. Testing demonstrates very good performance. Averaged measurement results shown in Figure 7 show in fact better SNR than the Sigma Delta technology used in standard Cap-Touch sensors. This opens the door for a variety of application and implementations for large scale sensor matrices, touchless sensing and other applications that require high SNR performance to accurately sense material location, existence, motion, etc.

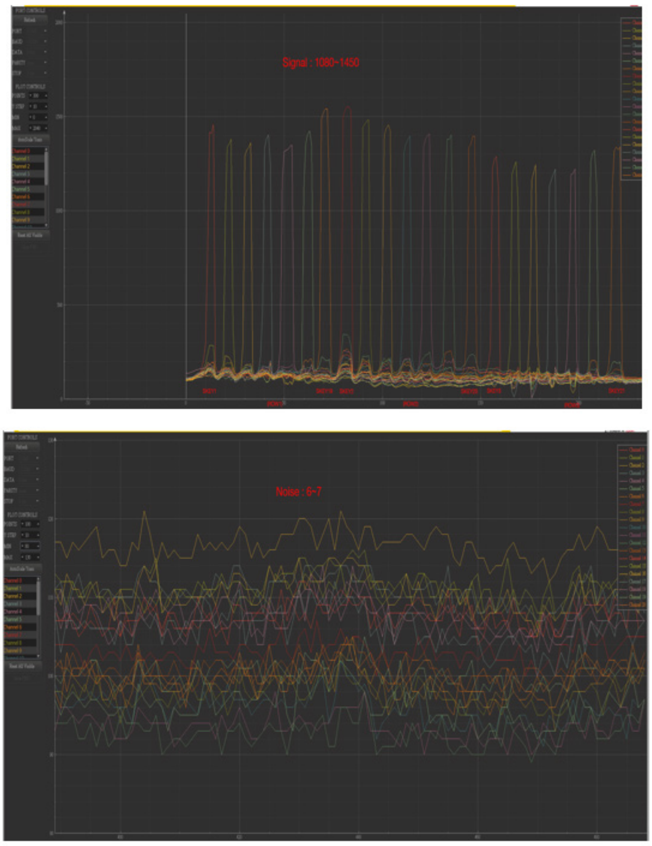

FIGURE 6 - SCAN SIGNAL AND NOISE MEASUREMENTS – 250Khz, 3mm DISTANCE MEASUREMENT

- 2MHz, 2mm: ~(8500/180) = 47.2
- 2MHz, 3mm: ~(4500/180) = 25.0

- 1MHz, 2mm: ~(3400/20) = 170.0
- 1MHz, 3mm: ~(3800/40) = 95.0

- 500KHz, 2mm: ~(2700/15) = 180.0
- 500KHz, 3mm: ~(2600/15) = 173.3

- 250KHz, 2mm: ~(1100/6.5) = 169.2
- 250KHz, 3mm: ~(1200/6.5) = 184.6

FIGURE 7 - SNR ESTIMATION (BY MEDIAN VALUE) – PER FREQUENCY AND MEASURE DISTANCE

SUMMARY

Appliances with intuitive interfaces are a must have feature to compete in today's market. Creating an eye-catching interface requires modern look, reliable and easy to clean touch interface, as well as color animation with LED lighting. Lumissil Microsystems offers a family of innovative capacitive touch IC solutions and LED drivers to help HMI designers create appliance interfaces with reliable control, informative feedback and attractive looking surfaces.

Visit our website, www.lumissil.com to download datasheets, application notes, example code and reference designs.

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