White Paper

Bring Fast, Accurate Multitouch User Interfaces to Your Designs

December 2020

Abstract

Years of experience with smartphones has taught us that the best way to interact with complex equipment is through a fluid and intuitive user interface enabled by a touchscreen. As a result, capacitive touch user interfaces are spreading to a wide range of other equipment, from kitchen cooktops to industrial control panels.

The challenge for designers in what may be lower-margin markets such as consumer product, home appliance, and industrial equipment, is that the smartphone experience has taught us to expect very high-performance touch user interfaces. Nothing is more likely to break a user's trust in a device than a touch interface whose response lags their input by too long, or which cannot react consistently to multiple touches, or which gets confused by the presence of water on the overlay. Users carry these expectations forward even to lower-cost markets such as the Internet of Things (IoT), where something like a humble home thermostat now has a cloud connection and a full-color, touchscreen interface.

Microcontroller (MCU) makers are responding to this challenge by developing cost-effective MCUs that also include the sophisticated hardware and software support necessary to implement effective capacitive touch solutions in low-cost contexts. Renesas, for example, has introduced its RA2L1 Group of low-energy, general purpose MCUs which include a 48MHz Arm Cortex M23 CPU that will remain active at operating currents down to 64 Amps per megahertz of operating clock rate, and which draws just 250nA in standby. The part also includes hardware support for AES encryption, true random number generation, and a unique ID for each device. There are also hardware features to support IEC/UL 60730 certification, which helps ensure the functional safety of home appliances.

The RA2L1 MCUs also include other features to reduce the overall bill of materials for designs built with these parts, such as an internal oscillator accurate to +/–1.0% high current-drive and 5V-tolerant I/O ports, and a wide operating voltage range from 1.6 to 5.5V. Memory options include 128Kbyte and 256Kbyte of flash, and 32Kbyte of RAM.

What sets the RA2L1 Group of MCUs apart, though, is its hardware implementation of the second generation of Renesas' capacitive touch sensing unit technology, known as CTSU2. This includes circuitry to improve the noise immunity and sensor accuracy of touch interfaces built with the technology. CTSU2 also adds the ability to do fast parallel scanning of a touch interface to enable touchpad, 3D gesture-recognition and high-precision applications. The gesture recognition facilities are expected to enable a new generation of no-touch user interfaces, important for public applications where hygiene is a priority.

The hardware facilities of the RA2L1 Group of MCUs are supported through Renesas' own e² studio IDE, E2 and E2 Lite on-chip debugging emulator, and by accessing the Arm development ecosystem.

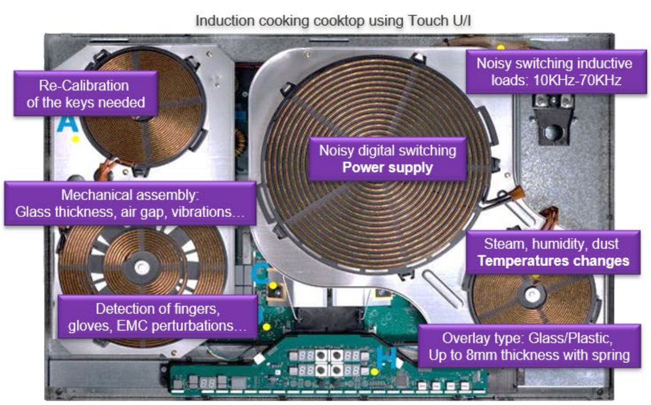
Application Examples

The advanced facilities of the RA2L1's CTSU2 enable support for several types of advanced user interfaces. The unit's fast-scanning facilities make it possible to build touch interfaces that can successfully sense and distinguish multiple touches, as well as making it possible to recognize gestures in three-dimensional space.

The high accuracy of the CTSU2 makes it possible to implement applications such as water-flow and water-level measurements, as well as paper-type and paper-thickness sensing. The CTSU2's circuit design also makes it useful in applications that are sensitive to the kind of electrical noise, as well as resisting mis-readings in situations in which an overlay is wet or has iced over.

Improving Noise Immunity Through Multifrequency Scanning

Touch user interfaces now have to operate in environments in which they are subject to complex forms of electromagnetic interference. Figure 1 (below) shows an example of this as it applies to a domestic induction cooktop that uses a touch user interface. In this application, the touch buttons are likely to be affected by conducted switching noise from the power supply, as well as radiated RF noise and magnetic circuit noise generated by switching the large inductive loads of the cooktops themselves. Other issues that designers will have to consider include temperature changes as the cooktop's glass cover heats up, physical vibrations caused by the induction coils, and issues such as the impact of the mechanical assembly and the choice of materials in the cooktop.



Renesas' RA MCU integrates multiple noise counter measures in hardware

Type	Frequency Band	Noise Source	CTSU2 Hardware Noise Filtering
Switching	1KHz – 1MHz	Inductive Circuit Noise	OK
		Magnetic Circuit Noise	OK
		Power Supply Noise	OK
RF	100KHz – 900 MHz	AM Wave Noise	OK OK

Figure 1: Multiple noise sources challenge the effective implementation of a capacitive touch interface in a domestic induction cooktop

Renesas has responded to the challenge of effectively implementing a capacitive touch solution in electromagnetically noisy environments by taking a more sophisticated approach to the way in which the touch sensors are sensed. Figure 2 (below) shows that in the original CTSU approach, the sensing points were sampled at a fixed frequency, creating an opportunity for synchronous noise at similar frequencies to affect the reading.

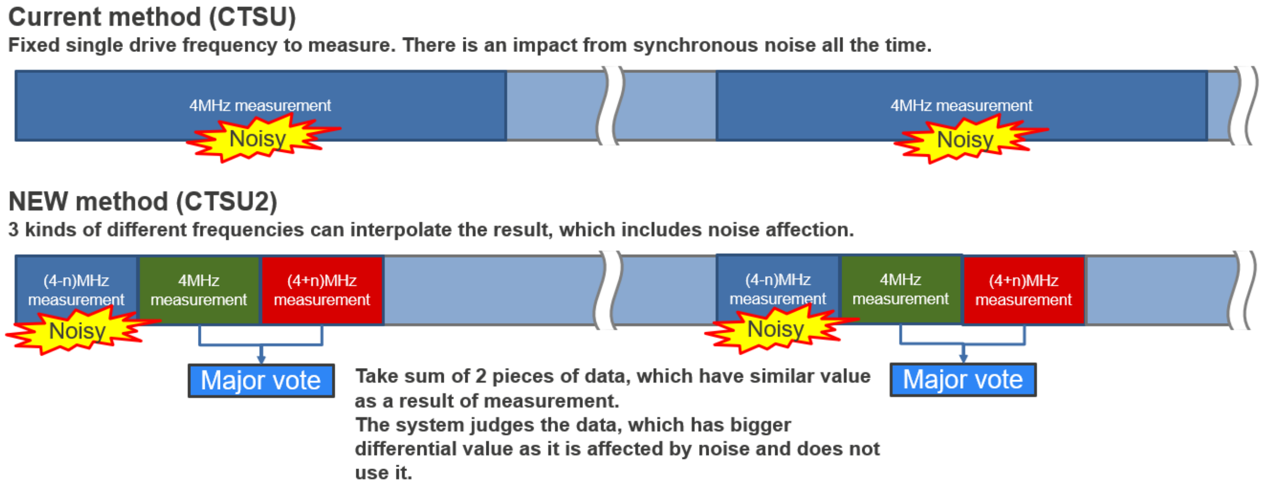


Figure 2: Scanning at multiple frequencies enables the MCU to reject noise by 'voting' on the correct readings

In the new CTSU2 approach, the sensing points are sampled at three different frequencies. These can be automatically derived from the main sampling frequency. The CTSU2 then uses the three measurements to come to a majority vote about which readings are correct, making it much easier to reject spurious measurements caused by conducted or radiated noise. This helps touch interfaces built with the CTSU2 technology to meet the requirements of the IEC EN 61000-4-3 level 4 radiated-noise immunity standard, and the EN 61000-4-6 level 3 conducted-noise immunity standard.

Along with the ability to automatically derive the secondary scanning frequencies from the main sensor-drive pulse frequency, it's also possible to adjust the gap between the main and the two secondary frequencies independently. This makes it possible to make the touch interface more robust against electromagnetic interference, as well as opening up the opportunity to tune the sampling frequencies of a touch user interface on the production line. To take the example of our induction cooktop support example, this would make it possible to mitigate the effect of a particular noise mode being produced by induction coils from a single production batch, or to consider the effects of a particular combination of materials and adhesives used to mount the touch interface.

Improving Touch Sensitivity

The CTSU2 also includes technology to improve the touch sensitivity by improving the way in which they are shielded.

Figure 3 shows the advantage of adding shielding to a touchpad layout. In the first scenario (at left), the touchpad electrodes are open to parasitic coupling from below, making it easy to couple electrical noise directly into the touchpad signal. Adding a ground plane below the electrodes (as in the center diagram) reduces this effect, at the cost of increased parasitic capacitance between the pad and the ground plane, which may in turn reduce the touch interface's sensitivity. The third scenario (at right) shows the advantages of implementing a shield electrode for the electrode pads: It helps reduce the amount of noise coupling into the pad and the parasitic capacitance between the shield and the pad.

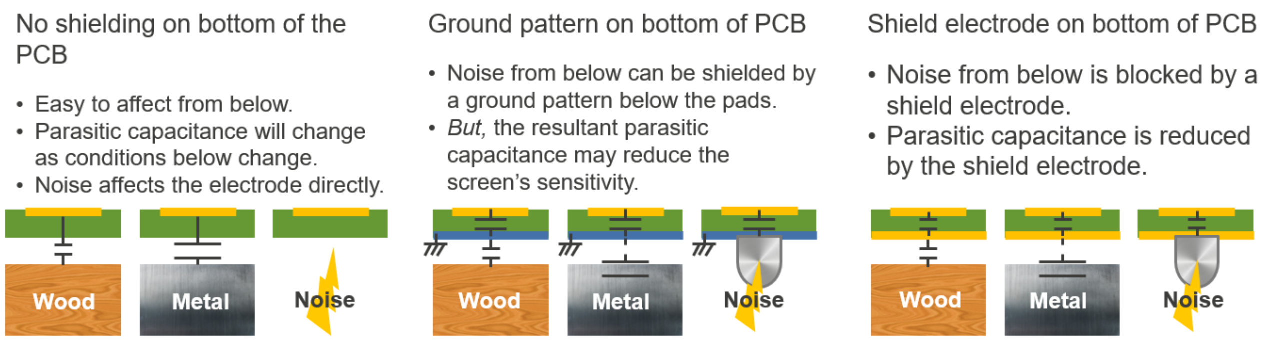


Figure 3: Three approaches to suppressing coupled noise and parasitic capacitances in touchscreens

Figure 4 (below) shows one of the enhancements that has been made in the evolution of the Renesas capacitive touch solution from CTSU to CTSU2. In the CTSU implementation, each touch electrode defined in the PCB pattern needed a separate shield electrode and each shield electrode needed its own current driver. In the CTSU2 approach, multiple pads can share a shield electrode and that electrode can be directly driven by the RA2L1 MCU.

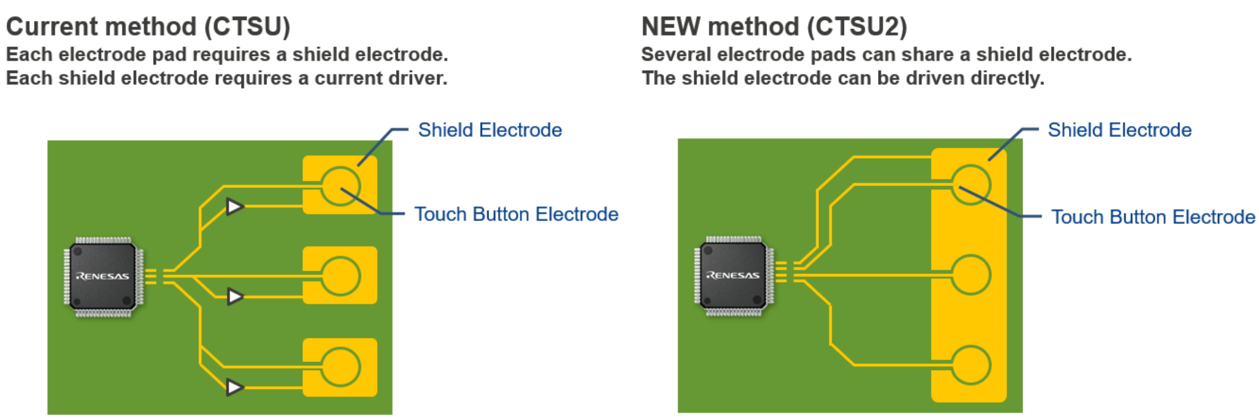


Figure 4: Two approaches to shielding touchpad electrodes

The shield electrode can be set in a self-capacitance mode. The electrode signal is a buffered version of the sensor-switching signal, with the same amplitude, frequency, and phase. Multiple electrode pads can share a common shield electrode pattern. Using this method, electrode pads can be shielded from noise impinging from either side, and from below. This helps to reduce parasitic capacitances and is more tolerant of the effect of liquid droplets, reducing the likelihood of false user interactions.

Other upgrades that affect accuracy include the integration of current-drive oscillator correction circuits, upgraded sensor-drive pulse circuits with frequency-locked loops, and better current-mirror circuits that boost the CTSU2 current measurement range.

Fast Scanning Enables Accurate Multipoint Touch Interfaces

As suggested in the introduction to this article, users expect increasingly sophisticated interfaces, and this creates demand for capacitive touch interfaces that can sense and correctly interpret multiple touchpoints.

The CTSU2 in the RA2L1 MCUs has been updated to enable much faster scanning by enabling parallel readouts. In the CTSU implementation, the way in which the capacitance of a finger touch changed the frequency of the sensing signal was measured sequentially. If, for example, a touch pad was defined by a grid of seven horizontal and seven vertical touch zones, reading out its state would take 49 sequential measurements.

In the CTSU2 approach, up to 20 measurements can be made at once, and so the 7x7 matrix discussed above could be read out in just seven steps. This mutual simultaneous scanning, using capacitance-to-frequency conversion, enables high-speed parallel scanning for multitouch interface.

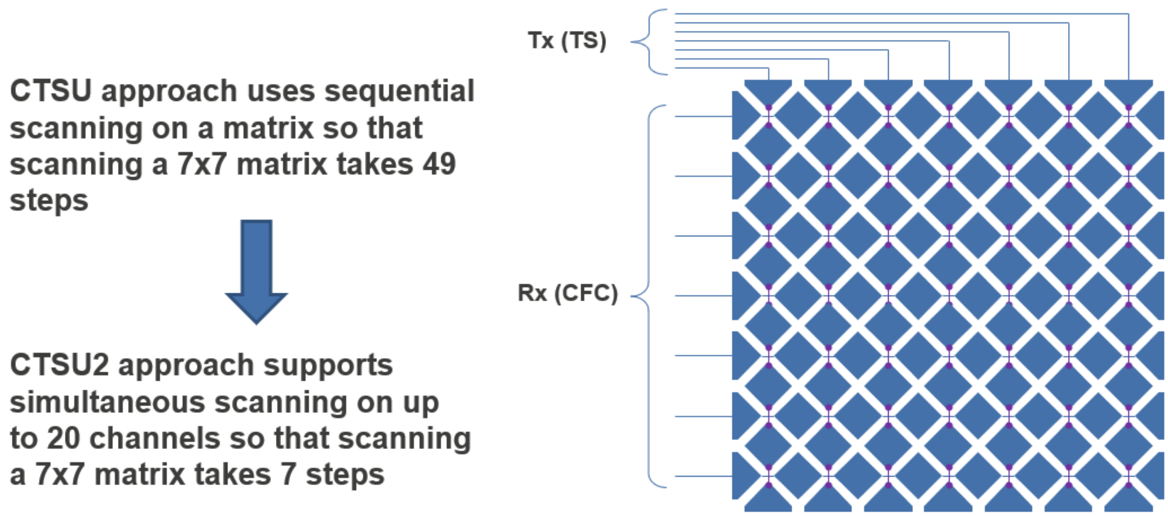


Figure 5: Parallel scanning enables multitouch interfaces

The CTSU2 circuitry also supports a slower frequency scan by expanding the lower frequency range of the sensor-drive pulse. This enhanced range of scan speed options will enable users to make trade-offs between the speeds at which their interfaces are scanned, the resultant accuracy (especially in multitouch applications).

Conclusion

Although the principles of the CTSU2 are straightforward, implementing them in a real design involves setting and adjusting multiple parameters in order to achieve the required touchscreen performance.

Renesas developed its FSP Touch Driver Software to enable designers to manipulate the key parameters of the CTSU2. It is now possible to adjust the signal to noise ratio of the touch measurements through the driver software. Although this involves a trade-off with the time it takes to make a measurement, the result is a signal with a better S/N ratio and therefore a more accurate measurement.

Renesas has also implemented a feature to reduce the amount of ROM or RAM used to run the driver software, potentially enabling developers to choose lower-footprint devices for the production phase of their projects. The driver software has been optimized to reduce the number of API subroutines from 21 to 14, to make it easier to integrate them with other peripheral software. Key functions such as UARTs and timers can be controlled from API routines in the Touch Driver software.

Other development help for users of the Renesas RA2L1 and its CTSU2 touch interface include a Solution Starter Kit, the RA2L1 Touch RSSK.

Renesas has also updated its QE for Capacitive Touch development support tool to the QE for Capacitive Touch (RA) version. Among the additions to this version are support for the latest version of its Flexible Software Package.

Renesas is also offering support through its e² studio integrated design environment (IDE), and access to the tools and services available in the Arm ecosystem.

Learn More

1. RA2L1 Product Page
2. RA2L1 RSSK Cap Touch Kit
3. RA Partner Ecosystem
4. RA Family of MCUs