White Paper

Transformative Technologies in the Building Automation and Control Industry

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Abstract

The drive to optimize every aspect of the modern commercial and industrial building is not new. Mechanical thermostats have been replaced with comprehensive environmental monitoring systems, networked and connected to IT-style backends and much more. We are still at the beginning of these changes: the need to create an energy/materials-efficient, productive, enjoyable, and safe environment is an incredible challenge, demanding truly transformative technology ingredients integrated into a complex connected system. In this white paper, geared toward engineering managers and design engineers building products for the building automation and control industry, we will explore major challenges and the transformative technologies addressing focus areas such as operator enhancing interfaces, cloud and mesh connected devices, and enhanced controls such as e-AI (embedded Artificial Intelligence).

Challenges Facing the Building Automation and Control Industry

The building automation and control industry is currently undergoing a radical transformation. In a report from November 2017, the market research firm, IHS Markit, projected that building automation and control equipment would reach over $6.2 billion globally in 2021. This rapid growth is pushing businesses to reevaluate not just the products that they are offering their customers, but also the technologies behind these products and services. There are three primary challenges that the industry is currently facing:

- Outstanding environmental control
- Increasingly complex safety and security
- Lower operating cost, higher resource & operational efficiency

Let's briefly examine each of these challenges; later in this paper, we will tie specific technologies to solutions that can be leveraged to address them.

First, delivering an outstanding environment control experience is critical to building automation in the modern era. In today's buildings, it's no longer adequate to simply have a mechanical thermostat on the wall. The value in automating a building is not only the convenience of immediacy, but a more rewarding total consumer experience and more cost effective and efficient building management. In today's world, buildings don't only need to manage temperature, but also need to monitor air quality, detect security and safety issues, and direct occupants in an emergency. Customers are used to walking around with powerful computers in their pockets with high-resolution displays that provide them with near instantaneous information and experiences. Customers accustomed to that level of technology don't want to switch from a rich HMI environment to pushing buttons, turning knobs, and looking at bulb indicators; or even worse, having to continuously get up to adjust a room setting. They are looking for a seamless, high-technology experience that provides them with the ability to automatically adjust a room's environmental setting when a meeting is scheduled or provide them with seamless entry into a building.

Second, building managers need to deal with the ever-increasing complexity of building safety and security. A modern building may go into a lockdown mode under a security threat, and the ability to do so seamlessly with the push of a button can ensure that its occupants remain safe. Another example is where building monitors, consoles, and lighting can direct occupants where to go in an emergency, whether there is a fire or other urgent situation. This is often referred to as occupant notification and routing. Buildings need to be able to detect and suppress fires and manage occupant movement through balancing elevator operations and escalators. On top of these complex issues, there are also other areas that need to be managed such as power distribution, building IT infrastructure, and tenant control of the environment.

Finally, it's critical that a building be operated as efficiently as possible while minimizing costs. How many times do occupants leave the heat or air on in a room that isn't being occupied that results in not only wasted energy, but also additional wear and tear on the HVAC equipment? Integrating all these pieces together is a major challenge that is affecting how building automation and control equipment are designed and integrated. These three challenges are shaping the way that building automation and control equipment will be made. To address these challenges, there are three transformative technologies that businesses can leverage in order to effectively deal with them.

Three Transformative Technologies

There are three transformative technologies that businesses can leverage in order to address building automation and control service challenges that significantly affect their business outcomes. These transformative technologies include:

- Human Machine Interfaces (HMI)
- Communications
- Controls

Human Machine Interfaces (HMI)

Human machine interfaces in embedded systems have traditionally been very basic. Many industrial products and similar applications today still use simple 2x16 character displays, LEDs, and a few buttons for human interaction. In the age of connected devices and the prevalence of smart phones with high-resolution images and videos, operators expect that same level of simplicity and efficiency on everything they encounter. As soon as a system has a graphic/touch display on it, it can dramatically transform what can be done with the product. For example, add a graphic/touch display to a conference room's environmental controls and suddenly, you don't just have a way to adjust room temperature, but also the ability to interact with the user to provide them with important information such as how long a conference room is booked, air quality status, lighting controls, and building incident status. The HMI suddenly takes on a life of its own and can dramatically increase product value.

HMIs for building automation and control can be broken up into two key areas: tenant facing and infrastructure. Tenant facing HMIs are graphical interfaces and touch screens in public areas that control various features such as:

- Access control
- Emergency routing and instructions
- Environment control
- Multimedia content for advertising and notification

For example, these panels may allow a user to present a badge that provides access to a location or that displays whether that location is available or not.

Infrastructure HMIs are graphic and touch screens that you would find on major equipment and control systems such as HVAC, chiller, etc. These provide immediate, local, and efficient operator interaction and have the potential to be used as multimedia content hubs where training and safety videos can be provided on-demand when the user needs to understand how to operate the piece of equipment or requires additional direction.

The goal of HMI in building automation and control is to provide better tenant experience, improved safety and security, and a more efficient infrastructure operation.

Communications

Adding communication interfaces to building automation and control products can radically transform how and what can be done with the product. Imagine adding Wi-Fi or Bluetooth to chillers, HVAC systems, or security panels. Suddenly that connectivity adds a plethora of capabilities and ways that the product can be used for:

- Collecting run-time and performance data
- Performing predictive maintenance analytics
- Adapting to user consumption and interactions to minimize waste
- Managing device wear and tear to maximize lifetime
- Over-the-air firmware upgrades for maintenance, security, and features enhancements

These are just a few examples of the nearly endless possibilities for how a company can use communication interfaces to not just provide new capabilities to their clients, but also to revolutionize the way that their business model works.

In the building automation and control industry, we can examine communication needs in three main categories:

- Cloud
- In-premise
- Inter-Device

From a cloud perspective, we have technologies such as 4G NB-IoT / Cat-M1, which can be used to avoid in-premise connectivity and security concerns. These technologies bypass any local communications network and use the low-cost IoT portion of the well-proven cellular LTE network. There is also the option to use Ethernet or Wi-Fi, provided it can be securely integrated into in-premise architectures.

In-premise communication technologies such as Ethernet and Wi-Fi can be used; however, these are not the only technologies available. Two very interesting technologies in this area include Bluetooth® 5 and 802.15.4 Thread Mesh. Mesh networking could be used to connect multiple panels, sensors, pieces of equipment, or other devices together so that they can all communicate with each other. Imagine what could be done with sensor data from thousands of devices throughout a building. There are even times when one would want one machine to talk to another, such as when sequencing an emergency access path throughout the building or to efficiently direct air throughout the building. This connectivity can also minimize uplink complexity to the Cloud – only one device needs to be the gateway since it can aggregate all the other connected-devices' traffic.

Inter-Device communications could use Ethernet or USB where high bandwidth is needed for fast media deployment, but it's important to realize that these solutions can be expensive to add to a design. An alternative to low-bandwidth, flexible, highly reliable and cost-constrained applications is to use RS-485, Power Line Communication (PLC) or CAN-wired technology. While it might take longer for media, content, and firmware to be forwarded from the edge gateway to the various subsystems (i.e., via a nightly update cycle), the cost benefits of PLC, CAN and RS-485 are significant when multiplied by all the different endpoints in commercial and enterprise infrastructure.

The result of adding communication interfaces to building automation and control are fewer proprietary networks, more use of TCP/IP, data encryption, increased security, lower costs, and better integration.

Controls

A critical component in every embedded system is how it controls and interacts with its environment. When we hear the word "controls," we often imagine old-school, big, failure-prone mechanical/mechatronic input sensors and output controls/actuators, but digital sensors, digital controls, solid state relays, optical switches and much more are revolutionizing the way electronics are interacting with the outside world. They're smaller, less expensive, and increasingly "instrumented," meaning they don't just perform their assigned input/output function, but have data and statistics (blown LED, stuck switch, overcurrent relay, etc.) built-in for preventative maintenance and systems operational efficiency. Control applications can now use these inexpensive and instrumented sensors and leverage their connections through communications and HMIs to provide ways to interact with the environment that were not available previously.

Behind control technology is the dramatic increase in processing power, miniaturization of sensors, and even artificial intelligence. Together, these three are allowing businesses to put in place the sensors and communication scaffolding that allow for predictive maintenance. Diagnostics is an area where lots of innovation is currently ongoing. It used to be that OEM design teams would search for the cheapest parts they could get, but now they are considering instrumentation of equipment to detect faults and issues before they occur to decrease downstream costs and increase uptime. For example, a machine could indicate that a relay has gone bad. An indication such as this results in down time while the machine is being serviced. This is not acceptable. On the other hand, if we can detect that the relay is showing signs of failure through increased current draw or additional mechanical jitter on the contact, we can proactively schedule replacement in a way that minimally impacts occupants.

The use of these advanced controls results in an optimized infrastructure operator and tenant experience, improved safety and security, energy usage, redundancy, automation, and uptime with predictive failure analysis.

The only question now is how do we implement these technologies?

Three Levels of Technology Integration

There are three different levels of technology integration businesses can use to achieve their desired outcomes through transformative technologies. It's important to realize that there is not a 'one size fits all' solution -- your specific path will depend on the end application, business resources, and desired degree of customization. These three levels of integration are:

- Modules: Serious Integrated
- Silicon and tools: Renesas RZ MPUs
- Silicon and software: Renesas Synergy™ Platform MCUs

We will now examine each of these and explore their advantages and drawbacks.

Modules: Serious Integrated

Complete turn-key modules have the highest level of integration and can combine all three technologies into a solution with a minimal amount of engineering. The benefits to using an off-the-shelf intelligent module include:

- Scalable with one-system architecture
- Fully integrated out-of-the-box hardware, software, and tools, pre-ported/pre-licensed
- Fastest time to market, lowest cost of development, and sustainability

Example HMI modules include the Serious Integrated HMI Modules (SIMs) from Serious Integrated. These modules are designed to act as an intelligent, self-contained HMI peripheral with a single scalable architecture. Leading-edge HMI capability and extremely fast time to market with minimal coding and sustaining engineering makes system integration far easier than any other silicon type solution. UL197 and UL60950 options are specifically available for food service environments where LCD breakage is a concern. All drivers, software, BSPs, and firmware are built in, and the (free!) professional GUI tool, SHIPTide, makes GUI development fast and easy to maintain.

In a low-level design, design teams must build up and maintain an entire software/firmware infrastructure themselves. Adopting Linux, for example, implies a sustaining engineering burden of up to 20 million lines of community-only supported code with a myriad of tricky license agreements. Leveraging a full module solution means there is no driver design, no low-level code, and only a high-level graphic design using SHIPTide. SHIPTide can produce a fully functional HMI with graphics and fonts in typically 1,000 lines of code or less. A typical C solution requires tens of thousands of lines of code. That's 10 to 100 times less code in magnitude, meaning much less debugging and testing, which dramatically saves time and cost.

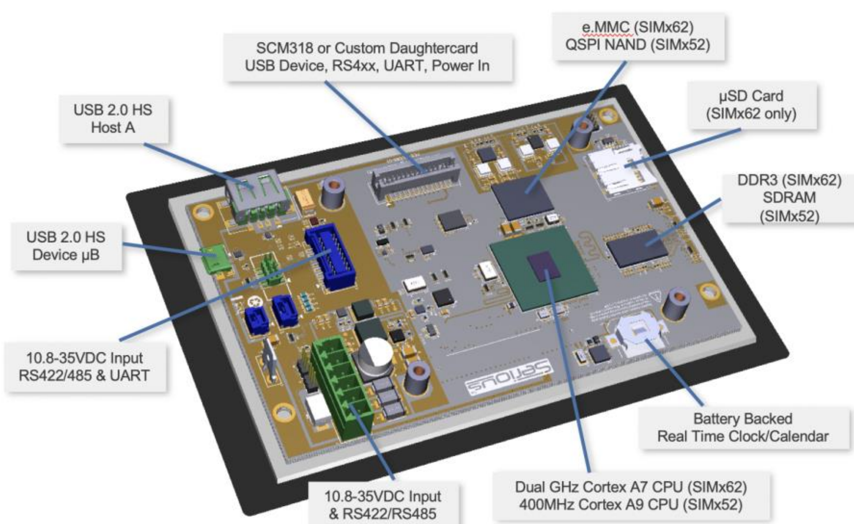

Figure 1 *– A breakdown of the Serious Integrated HMI module (SIM)*

A scalable, off-the-shelf HMI platform will have numerous features, which can be seen in Figure 1. These features include:

- A scalable 3.5" to 10.1" LCD architecture
- Capacitive, resistive, and no-touch options with indoor or outdoor LCDs
- RS-422/485, UART, and USB device interfaces
- USB host/microSD card for upgrades, file transfer, and diagnostics
- I^2S interface for audio output
- Connections via micro USB, industrial connector, 16-pin harness or 30-pin header
- 10.8-35 VDC powered, -40C to 85C operating temperature

Different modules will also have different capabilities based on the need for the end application. For example, businesses looking for a cost-effective modern HMI might use the SIMx52 Series powered by a Renesas RZ/A1L 400 MHz Arm® Cortex®-A9 Microprocessor (MPU) with 128 MB SPI NAND and 16 MB+ SDRAM. Businesses who want a performance HMI with the ability to create video playback would use the SIMx62 powered by a Renesas RZ/G1E dual-core 1 GHz Arm Cortex-A7 MPU with 128 MB DDR3 and 4 GB eMMC.

For communications and control, there are also plenty of modules that fit the bill for the building automation market. An all-in-one module that we are going to look at is the Serious Integrated SCM318 comms/control module that can be seen in Figure 2.

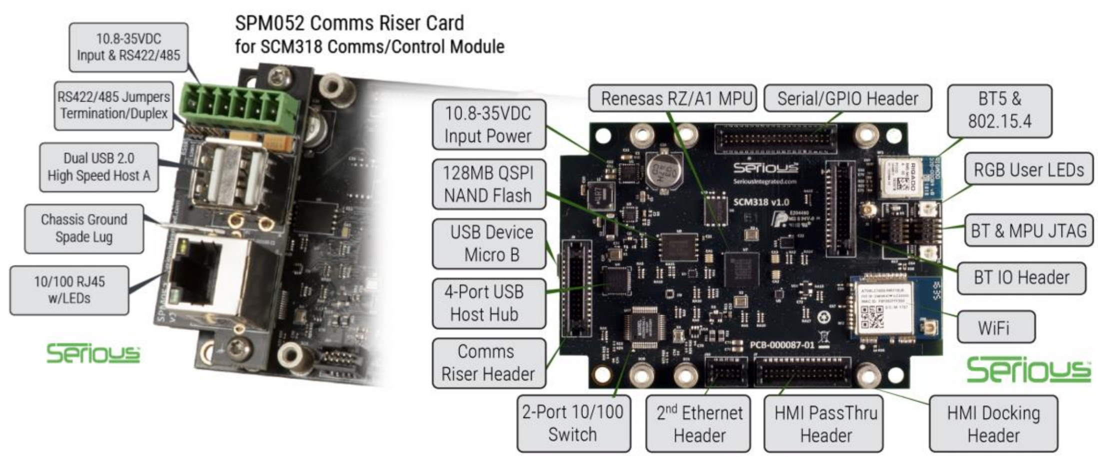

***Figure 2** – SCM318 Comms/Control Module*

The SCM318 is an all-in-one comms, control hub, and edge gateway, providing broad and secure connectivity to WAN, PAN, M2M, and intra-chassis networks. The module is based on a powerful Renesas RZ/A1L MPU with 400 MHz Arm Cortex-A9 processor. The module can be used with or without an HMI and is "app ready" with pre-licensed SHIPWare software frameworks and a comprehensive Segger Suite. SHIPWare contains everything a developer needs to develop their full product quickly and easily and customize as they see fit. The software that comes with the module and its capabilities include:

- SHIPWare: Frameworks, Drivers, Protocols, OS, Stacks, BSP, and more
- Frameworks: Messaging, Serial Stream, Bootloader, Upgrader
- Drivers: I^2C, SPI, UART, Wi-Fi, Storage, USB host/device, Ethernet, etc.
- SHIPBridge protocol for Serious HMI module integration
- Segger Commercial OS and Stack Suite (TCP/IP, USB, File System, Crypto)
    - Pre-licensed, pre-ported, fully supported binaries
    - Source upgrades available
- Dev kit comes with Segger Embedded Studio industrial-grade C IDE

When considering a product design using modules, it's easy to imagine a design where modules are used to dramatically accelerate development time. Figure 3 shows how using Serious Integrated modules can be applied to different areas within building automation and control. On the left, there is a SIM552 with a 7" display for conference room and office control along with a tenant-facing SIM862 10.2" display. An SCM318 comms/control module contains control I/O, as well as the edge gateway with cloud connectivity via Wi-Fi, Ethernet, or Bluetooth 5 and mesh networks. The HMIs connect into the SCM318 via USB, RS-485, or RS-422. On the right, there is a SCM318 Comms/Control module that can be used by building infrastructure to sense and control the environment that can then be connected to a SPM916 4G NB-IoT and LTE-M for monitoring and control, but also for communication with local and wide area networks. There is also a SIM552 7" HMI module that can be used in infrastructure equipment such as HVAC equipment that can connect to a SCM318 for Comms/Control.

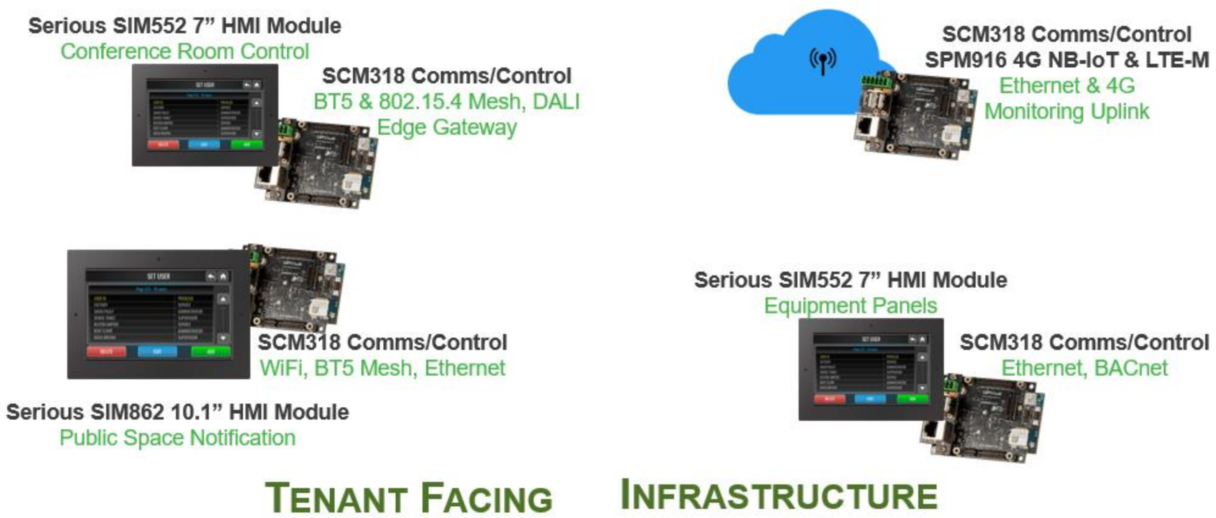

Figure 3 *– Example modules and display panels that can be used in building automation and control designs; design teams can leverage these transformative technologies to get a cost-effective and scalable locker to market quickly and cost effectively.*

Choosing the Right Renesas Processor for HMI

Selecting the right microprocessor (MPU) or microcontroller (MCU) for the application is a good place to start. While there are many features to consider such as raw performance needs, embedded RAM and flash sizes, and peripherals, the best starting point is to determine the display resolution required. The chart in Figure 4 compares processors by MCU and MPU family.

***Figure 4** – Selecting the Device by Display Resolution*

For example, Serious uses the RZ/G1 MPU Series for higher performance 800x480 through 1080p graphics for some modules and RZ/A1L MPUs for smaller, less demanding, 320x240 through 800x480 GUI applications. While this paper will not discuss the Renesas RL78 Series, we will now dive deeper into the Renesas RZ and Renesas Synergy™ families for those design teams that have the engineering resources to do their own hardware and software development.

Silicon and Tools: RZ MPUs

If a complete module-level solution cannot work for your design, the ultimate flexibility and cost control at the BOM level is still the traditional embedded systems approach of silicon on a custom PCB with custom software incorporating vendor and third-party components and tools. The big tradeoff between this path and the module path is the cost and time to develop and sustain the product. For building automation equipment, businesses should be looking for silicon and tools that include:

- High-performance and cost-effective 32-bit MPUs
- Full integration for key HMI, communications, and control capabilities
- Excellent tools and third-party software tools support

Figure 5 shows the Renesas RZ Family of MPUs that are particularly well suited for building automation and control equipment. This is exactly why Serious Integrated used these parts as the foundation for developing their new generation of SIM and SCM modules. For example, the Serious SIMx62 Series, with high-resolution HMI and video playback, is powered by the RZ/G1E dual-core processor. The Serious SIMx52 Series, for cost-effective low-to-midrange resolutions, is powered by the RZ/A1L MPU. Finally, the Serious SCM318 communications module is powered by the RZ/A1L and RZ/A1LC MPUs.

HMI, comms, and controls solutions on the RZ/A1 Series can be developed using an RTOS (FreeRTOS™, ThreadX®, Unison) or in bare metal. Development tools supported include Eclipse-based e² studio IDE, as well as commercial tools from IAR.

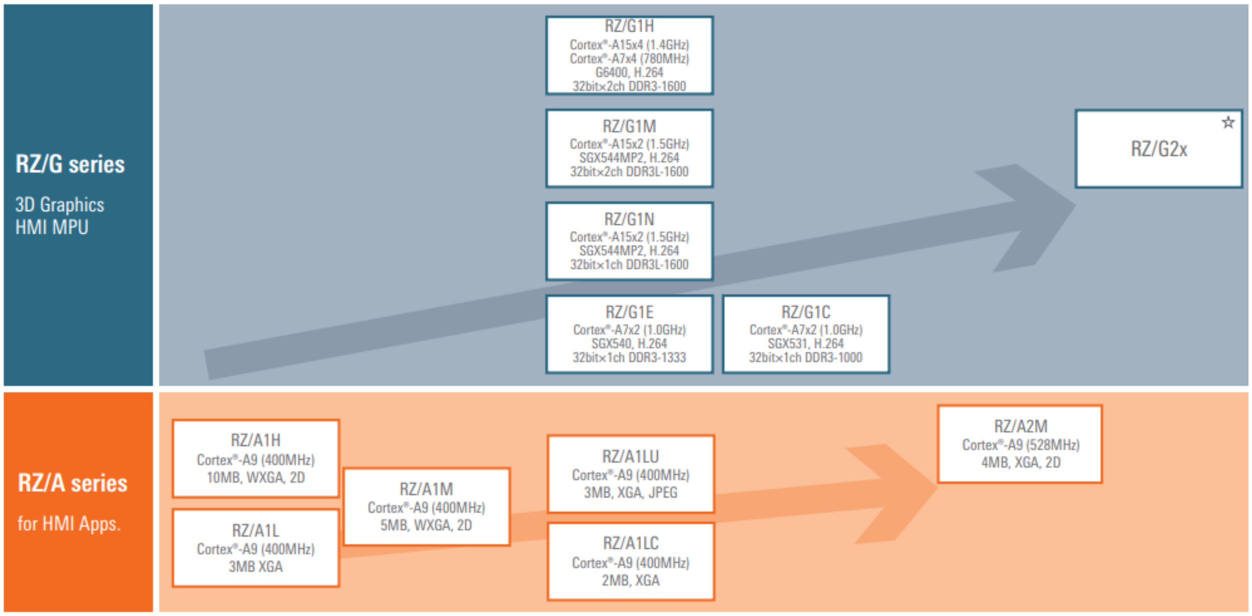

***Figure 5** – The RZ/G and RZ/A Series of MPUs provide high-performance and standard-performance graphics processing for modern building automation and control equipment.*

For engineers who prefer to develop solutions using the powerful Open Source Linux Operating System, the Renesas RZ/G Series offers over 10 years of community support on the Linux kernel since Renesas adopted the CIP Linux Kernel for the RZ/G family. This extended Linux kernel support is especially useful in the building automation and control industry where products tend to have a long life and require Linux kernel and security support/patches over several years.

CIVIL INFRASTRUCTURE PLATFORM

***Figure 6** – CIP Linux Kernel on the Renesas RZ/G MPUs is supported for over 10 years by the Linux Foundation*

Another key feature of Renesas Linux enablement: Renesas fully tests and delivers a Verified Linux Platform that includes CIP Linux kernel and middleware verified to run on Renesas RZ/G processors. This verification eliminates the arduous integration and testing effort involved with using open source software components on industrial grade equipment.

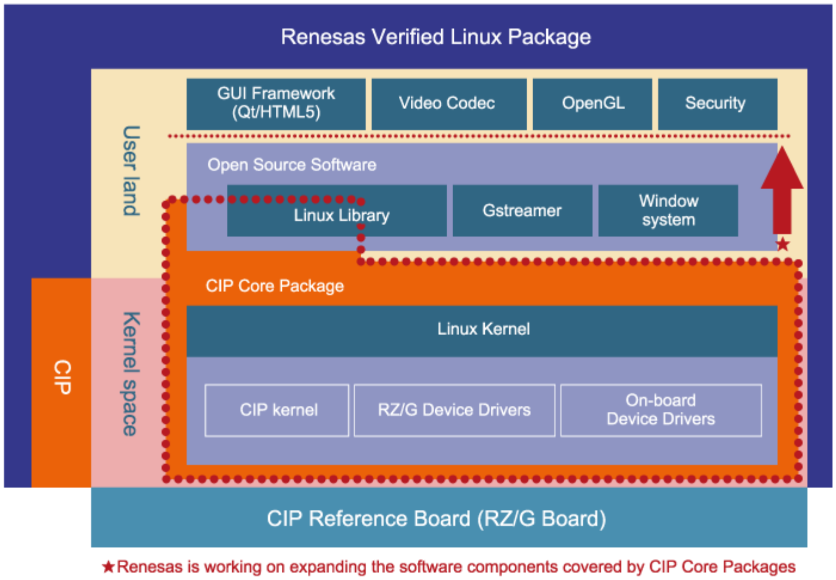

***Figure 7** – Renesas Verified Linux Package – offers full integration and testing of open source components*

Silicon and Software: Renesas Synergy Platform MCUs

The last, and perhaps newest, approach to technology integration is to leverage a microcontroller platform such as the Renesas Synergy™ Platform. Like the traditional silicon+tools approach, the OEM design team still needs to develop and validate their specific hardware platform incorporating the MCU and software. MCUs in the Renesas Synergy Platform are high performance 32-bit Arm Cortex-M cores surrounded by outstanding peripherals well suited for a wide variety of building automation applications from comms and control to HMI.

Although, instead of assembling a mix of vendor and third-party software infrastructure and then developing the custom embedded application(s), each Synergy MCU comes with the Synergy Software Package (SSP) -- a complete, pre-licensed, and tested suite of commercial embedded OS, stacks, and infrastructure. This suite includes Express Logic's commercial and robust ThreadX® RTOS and supporting middleware. Also, pre-licensed and included in the Platform are two world-class IDEs: the professional Renesas IAR Embedded Workbench® for Renesas Synergy and the Eclipse-based Renesas e^2 studio. Both of these IDEs, along with the SSP, elevate the software development process with high level configuration and construction of the infrastructure upon which embedded applications can quickly be constructed.

The Synergy Platform provides two MCU Groups that fit well with building automation applications: the S7G2 and the S5D9. The S7G2 MCU Group fits well for integrated solutions that require HMI, comms, and control, while the S5D9 MCU Group is suitable for control and communication applications. Figure 8 shows a snapshot of some of the capabilities that are applicable for building automation. Each provides a capacitive touch capability that excels in harsh conditions like water and frost. The capacitive touch can also be used to create metal buttons that won't wear out over time, which makes it easier to clean when used in proximity detection or touchless applications.

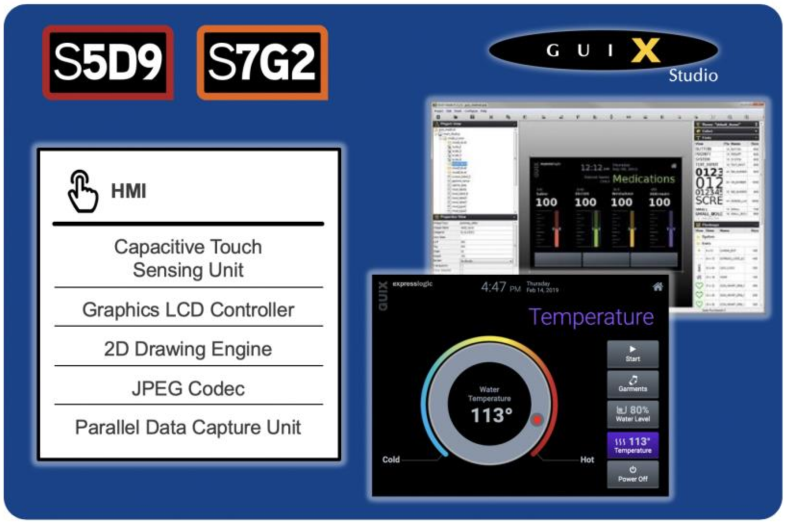

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Figure 8 – *A snapshot overview of the Renesas Synergy Platform HMI capabilities.*

The S7G2 and S5D9 also have extensive peripheral capabilities to meet connectivity challenges such as:

- RS232/RS422/RS485
- Ethernet
- USB
- CAN

The Platform also supports many protocols and busses to connect to sensors and external wireless modules like Wi-Fi, Bluetooth®, LoRA, and cellular through interfaces like:

- SPI
- I^2C
- UART

There is also support for an external memory interface to log onboard activities and perform remote debugging and maintenance through a SD card or eMMC.

There are several ready-made application and product example kits with Synergy microcontrollers:

Figure 9: *Renesas Synergy Platform Kits*

Like the Serious Integrated module approach, one of the major strengths of the Renesas Synergy Platform is the no-cost commercial and robust IDEs, software infrastructure, OS, middleware, and stacks. This reduces your time to market, reduces your sustaining engineering costs, and gives you access to fully supported software infrastructure out of the box.

Conclusions

The dramatic growth in the building automation and controls industry is challenging businesses to deliver a great tenant experience, improve safety and security, and lower operating costs while improving operational efficiency. As we have presented in this paper, these challenges can be addressed through three transformative technologies: HMI, communications, and controls. Design teams can evaluate the tradeoffs between three levels of technology ingredients -- modules, silicon and tools, and silicon and software – to access these transformative technologies to meet their design and business objectives, including flexibility, development cost, sustaining engineering cost, scalability, and product cost. The results will include a more comfortable experience for tenants, decreased operational costs and required resources, and improved safety along with reduced liability.

The only decision to make now is the level of integration for transforming your next building automation and control industry equipment design.

Additional Resources

- Arrow transformative HMI technologies (http://bit.ly/arrow-hmi)
- Serious Integrated (https://www.seriousintegrated.com/)
- Renesas home appliance solutions (https://www.renesas.com/us/en/solutions/building-automation.html)
- Renesas RZ microprocessor family (http://bit.ly/renesas-rz)
- Renesas Synergy microcontroller platform (http://bit.ly/renesas-synergy)