Smart Devices Enabled to Efficiently Communicate, Sense, Hear, Act and Interact with User

The latest advancements in embedded systems and communication and sensing technology have led to the increasing development of smart applications. This has been a continuously evolving process, involving either the creation of completely new solutions or the rapid transformation of existing ones into corresponding highly smart environments. The main driving forces of the smart transformation have been advancements in processing, communication and storage capabilities of embedded system devices, which can be combined into small form factors and boost power efficiency. The latest generation of smart devices are portable and feature continuous operation lifetimes, resulting in their increased ubiquity in different environments.

Design Trends

Small portable devices such as sport watches, medical, smart home, industry automation and security system devices, like mobile POS, and smart consoles such as E-bike consoles, have driven increasing levels of innovation. The data speaks for itself. Based on the latest Data Bridge Market Research reports, a Compound Annual Growth Rate (CAGR) of 18.8% for the wearable devices market, 22.8% for the smart home market and 29.3% for the broader market of Internet of Things (IoT) is expected through 2029.

Three design trends seem to determine the design of such smart devices:

- Smart devices are incorporating more and more sensing and processing capabilities in order to implement a broad, high-quality set of functionality, thereby broadening end-product features and capabilities.

- More and more smart devices require wireless connectivity. That connectivity mostly targets connection with a smart phone or similar device, enabling additional functionality, advanced data storage and device monitoring capabilities, as well as the ability to quickly and easily update the device.

- Finally, someone could be wondering: “Is the device really smart if it is not like a smartphone?” The use of smartphones has determined the way we interact with technology. We would prefer all devices to have a display in addition to connectivity options. Supporting high resolution images and smooth animations, voice commands and touch interface brings the user experience closer to that of a smartphone.

So, what does it take to consider a portable device smart? A typical smart device based on a microcontroller-based architecture is presented in Figure 1. The device primarily needs to have three kinds of abilities:

- closely sense and interact with the environment;
- quickly and efficiently process commands and user interactions;
- present, via an easy-to-use interface and/or display, the results of the processed commands.

Of course, apart from sensor elements, a microcontroller unit (MCU) for processing, driving peripherals and controlling signals using General Purpose I/O (GPIO), a radio enabling wireless communication and finally some output and input user interface for interacting with the user, there are many more electronics and general functionality that need to converge within a typically small form factor device, leading to conflicting design constraints with respect to size, cost and power consumption.

Manufacturers of such devices face multiple design challenges. The more effectively they deal with them and succeed in differentiating their products, the more chances they have to gain market share.

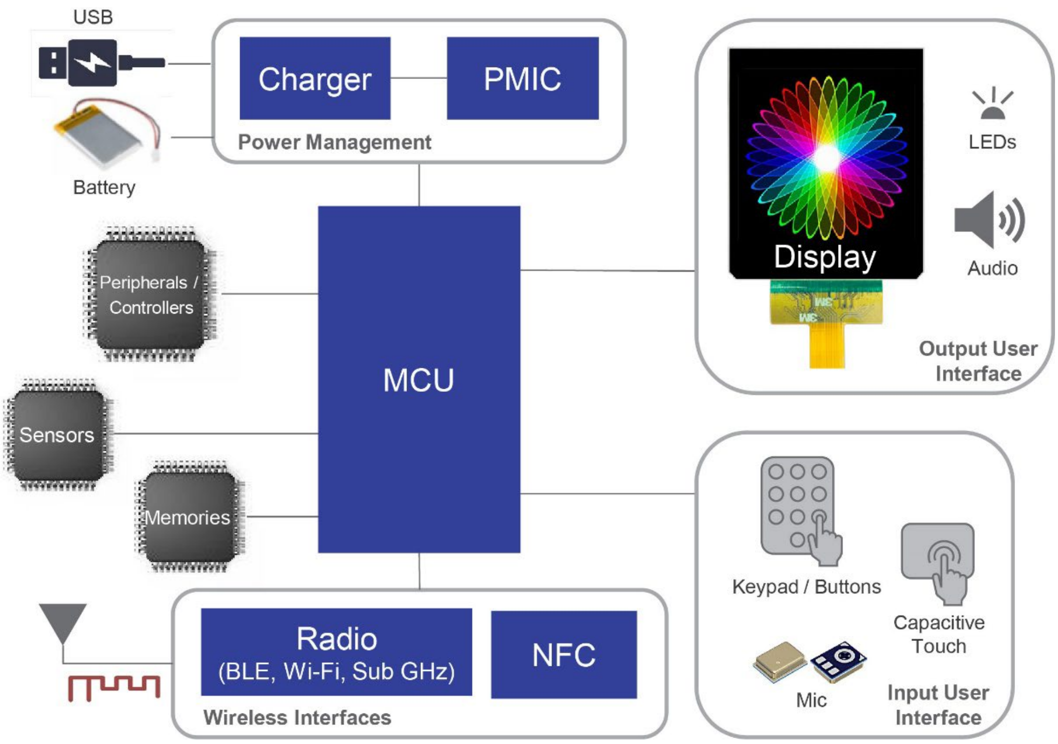

Figure 1: Typical microcontroller-based architecture of portable smart device

Execute efficiently by adapting processing speed and operating voltage

When a system performs operations involving increased processing activity under real time restrictions (e.g. graphics operations), there is always demand for maximum processing power and an MCU supporting high system clock frequencies, while in instances of low processing activity (e.g. transactions with sensors), operating at maximum processing speed results in unnecessarily increased power consumption. A critical aspect to this balancing act is the operating voltage of the core system and peripherals, with the use of lower voltage levels leading to power savings. If the system could leverage processing speed and operating voltage based on the kind of operations it executes, the portable smart device would deliver a combination of quality in implemented functionality and battery lifetime.

Continuously and efficiently sense and hear to detect stimuli (i.e. gesture, voice)

In their normal operation mode, portable smart devices mainly stay in a state where sensors/peripherals are periodically accessed by the MCU, continuously gathering data regarding their operation status and the environment, and waiting for any stimuli to be detected before switching to a more power hungry mode (e.g. switch on display). This mode plays a critical role in the device's total energy consumption footprint, and it must be efficient. The integration of special hardware state machines or more advanced solutions employing a low power CPU are ideal for a smart device design. They essentially implement a low power "always on" autonomous subsystem, able to control sensors/peripherals and wake up the power-hungry main system only when needed.

Accelerate graphics for better user experience

Consumer expectations for a smartphone-like experience on smart devices impose a challenge in delivering vivid, functionality rich user interface graphics in a highly constrained system environment. Having a CPU performing all graphics operations, such as fetching resources from a slow memory module and creating display screens by gradually processing and merging those resources, would exhaust most of its available processing bandwidth. The use of hardware accelerators (e.g. GPU, DMA) specialized to handle those operations in a more efficient way than the general-purpose CPU is the only way to deal with this challenge. This specialized hardware, fine-tuned to execute in one cycle what requires several cycles on the CPU, can significantly offload the main CPU, and boost graphics performance with less power.

Communicate in a standard way, using low power and be up to date

From the user's perspective, connectivity is taken for granted in a smart device. The same holds for end-product manufacturers, since products can be enriched with more functionality and can be easily updated, speeding up production time. An important requirement is to support a standard, widely accepted wireless technology. There are plenty of them, but the options are limited when interoperability (e.g., smartphones) is considered. On top of that, the selected technology must demonstrate strong low power characteristics to support extended battery lifetimes in portable smart devices. Finally, as wireless technology standards evolve by adding more features or resolving vulnerabilities, it is important that the connectivity in the end-products is always up to date.

Be flexible on memory storage

The increasing firmware size and the amount of data stored locally and manipulated in smart devices have challenged their memory architecture, with designers trying to meet application memory requirements on density, performance and cost. The use of external memories has become a must and the varying attributes of size, data throughput, reliability and cost can address corresponding requirements ranging from a simple smart home device up to the complicated design of a smart watch. NOR, NAND and eMMC flashes can increase system non-volatile memory for storing application firmware images, configuration parameters and data/resources (especially graphics), while PSRAM can be used for storing framebuffers, caching data fetched from non-volatile memory, and generally extending internal MCU RAM space. If the system can leverage memory space extension in terms of the number, type and interface of the external memories to the host MCU, then application requirements will be met more efficiently, at a lower cost.

Secure application and data

As users interact with their smart devices in varying environments, emerging concerns appear regarding device security and data privacy regarding sensitive data. For example, personal data maintained in medical devices must not be exposed, information communicated by a mobile POS must be secure, all while the application firmware running on a device must also be secure and authenticated, just to name some cases. Designers need to take measures against threats and assure consumers that their end products fully meet security requirements, while at the same time protecting their assets (i.e., application firmware). This can be achieved by adopting solutions which enable rich security features in both the device and communication level, such as secure firmware execution, code/data encryption and secure connectivity.

Renesas' Solution

All the above challenges need to be tackled one by one by designers to make their end products distinguished in the market, while simultaneously needing to address the constant requirements of reducing bill of material (BOM) costs and lowering power consumption. A dilemma is presented to designers and manufacturers, whether to move towards a design with increased component modularity or more integration. The first approach provides more flexibility, allowing for selecting the best modules with respect to the requirements of the end-product, while the second leads to self-contained system designs with less reliability risks, decreased cost, small size and less power consumption, as shown in Figure 2.

Renesas adopts the "more integration" approach with its DA1470x Family SoC solution. Its unique features make it a perfect fit for portable smart devices, comprising a means to address all the trends and challenges presented above. Along with its main CPU, based on ARM Cortex M33 and operating at up to 160MHz, it integrates a power management unit, a JEITA compliant battery charger, a hardware voice activity detector (VAD), a Sensor Node Controller (SNC), a Graphics Processing Unit (GPU), Bluetooth LE connectivity, audio streaming and many more capabilities, all in a single chip, with functions traditionally performed by multiple MCUs. The block diagram of DA1470x is shown in Figure 3, while its key features are summarized in Figure 4.

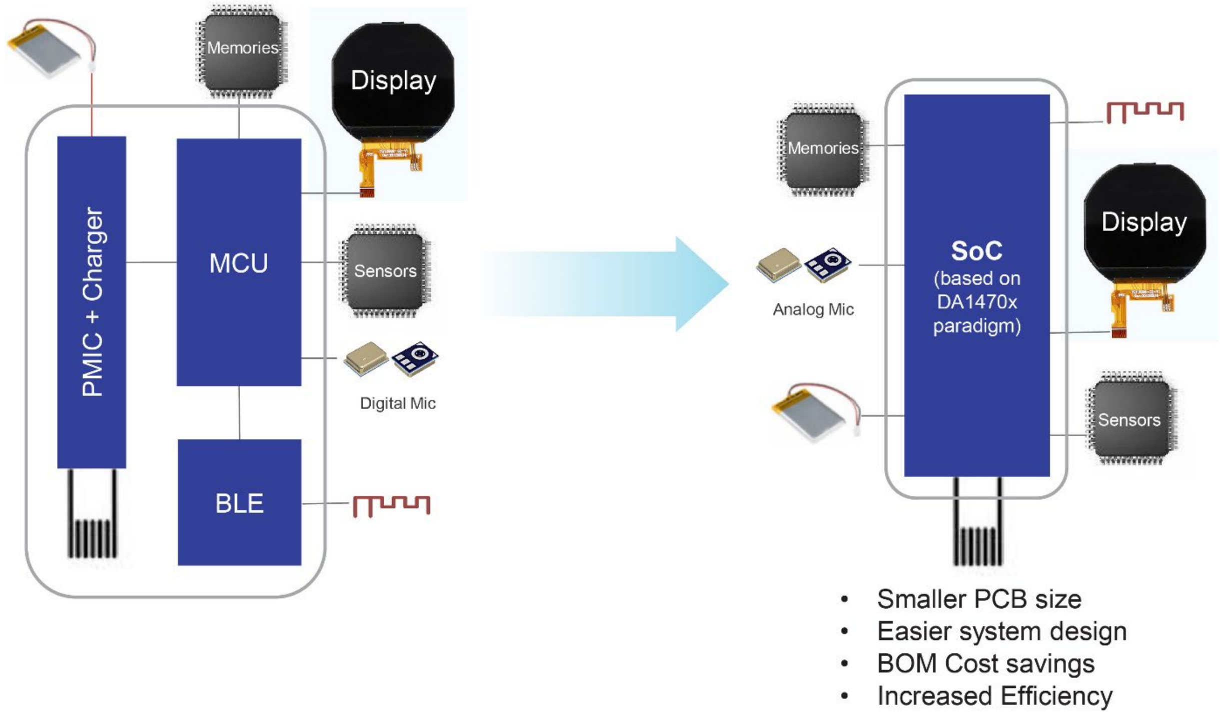

Figure 2: More integration against more modularity in a wearable design

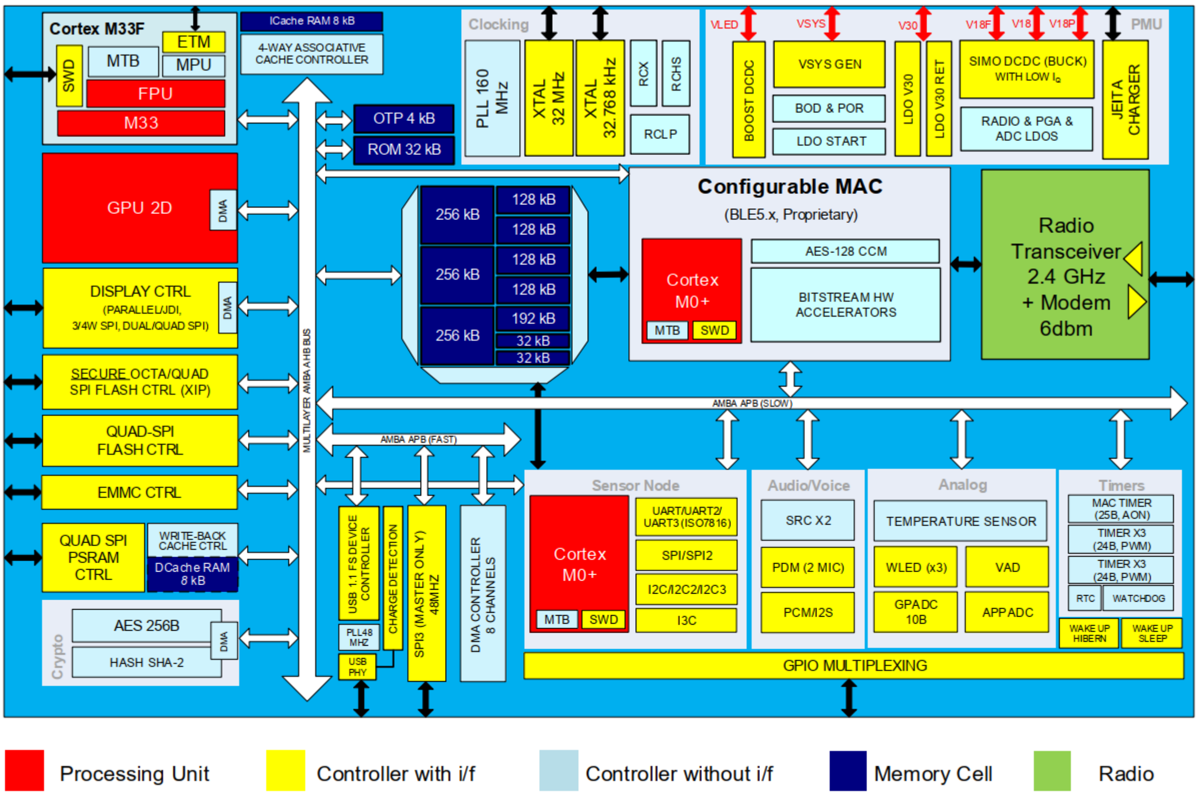

Figure 3: The DA1470x SoC architecture

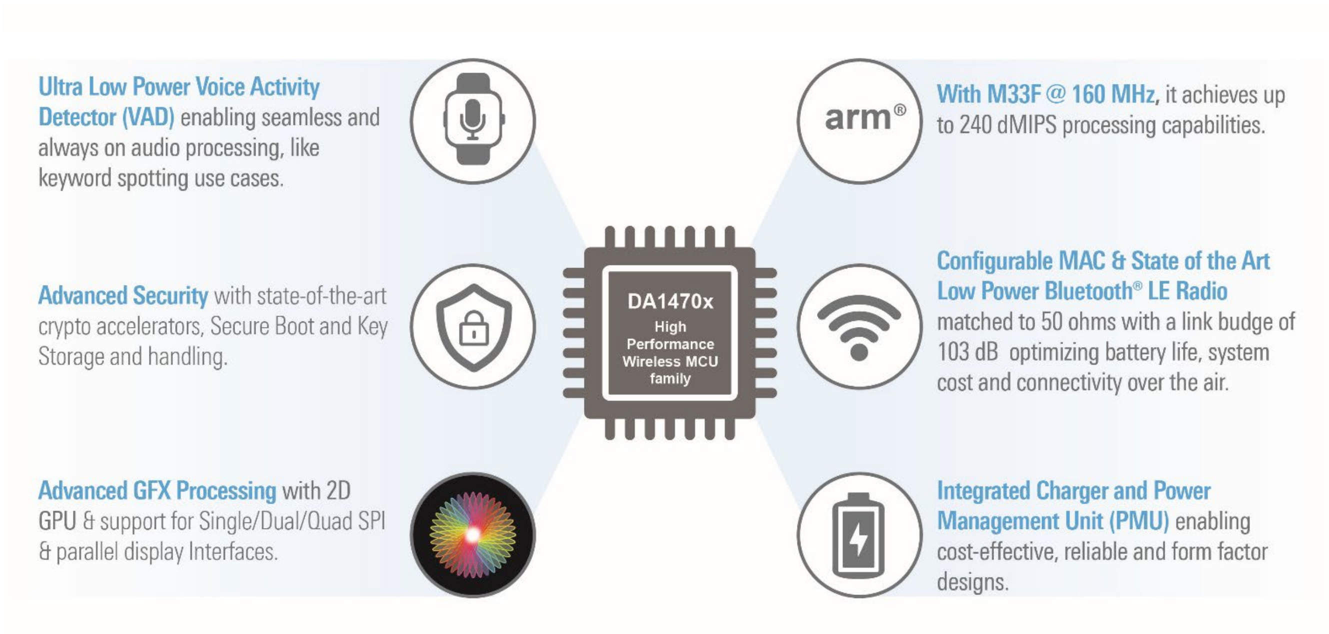

Figure 4: DA1470x SoC key features

DA1470x enables efficient and complete power and clock management with its integrated PMU and well-structured clock tree. Processing speed and power consumption can be adapted based on application needs, by leveraging the frequency of the system clock and operating voltage level (up to 32MHz @0.9V and up to 160MHz @1.2V). By grouping well matched sets of functionalities (i.e., processing, sensing, connectivity, audio) into several different power domains, it enables maximum flexibility in controlling which part of the system will be turned off, boosting energy efficiency in support of different application features. Flexibility is also provided in powering external peripherals through power rails of different voltage supply levels as outputs of highly efficient DCDC converters (1.2V / 1.8V at 100mA, 4.5V to 5.0V at 150mA) and LDOs (3.0V at max. 160mA - enabled also in sleep). Regarding system sleep, there are different power modes which support longer battery lifetime, achieving 0.4uA at 3.0V in the shipping/hibernation mode.

Targeting the total energy consumption footprint of a portable smart device with respect to sensing and hearing, DA1470x employs a low power Sensor Node Controller (SNC) and a voice activity detector (VAD). The SNC has enough processing power provided by its ARM Cortex M0+ processor (max. 32MHz) to implement sensor hub operations. It resides in a separate power domain and operates autonomously, having concurrent access to multiple communication interfaces to which sensors and peripherals are connected, thus allowing for the rest of the system to go to sleep. It executes in parallel and offloads the main CPU, providing either raw or high-level sophisticated information based on continuously acquired sensing data, and implementing a stimuli detection and notification mechanism towards the main CPU. For detecting voice activity, the system employs the integrated VAD block, which enables seamless audio processing with system-on current <26uA. The VAD front end is continuously sampling the output of an external analog microphone and generates an interrupt towards a system CPU to further configure the system for audio sampling as soon as an audible peak is detected.

To enable rich graphical experiences in smart IoT devices, DA1470x integrates a 2D GPU and a display controller. The GPU resides in a separate power domain, has access to both the internal RAM and external memories for manipulating graphics resources, and operates at the same clock frequency as the main CPU (max 160MHz), allowing for significant processing bandwidth savings in the main CPU when graphics processing is performed. It supports most common graphics primitives (e.g., BLIT, box, circle etc.) and several attributes for them (e.g., anti-aliasing, blend modes, edge blur etc.), as well as a range of input/output color formats, while it can execute either synchronously with the main CPU or completely asynchronously, achieving the best system performance. To efficiently drive a wide range of high-resolution displays at high frame rates, the integrated display controller supports data transfers in 2 layers with alpha blending, dithering and gamma correction over single/double/quad SPI, DPI-2, DBI-B and JDI parallel interfaces and different input/output color formats. Based on a representative Renesas wearable UI demo application on DA1470x, which uses LVGL graphics framework and a 390x390 QSPI display to demonstrate fast and smooth screen sliding and update of a typical wearable UI, a graphics performance of >35 fps can be consistently achieved.

Regarding connectivity, DA1470x integrates a separate power domain for a 2.4GHz radio and an ARM Cortex-M0+ supporting BLE 5.2. BLE 5 is a standard, widely adopted low power wireless technology, able to leverage data throughput (max 2Mbps) and transmission range with a low power consumption footprint, thus perfectly matching the varying connectivity requirements required by smart applications. Transmission range and connectivity reliability are further improved in DA1470x with the configurable transceiver output power reaching up to +6dBm, while the support of a single wire antenna and the fact that no RF matching or RX/TX switching is required, enabling optimized connectivity at a lower system cost. With the mature implementation of a BLE 5 stack having already been adopted in millions of end-products, DA1470x has a proven quality of service in supporting BLE wireless connectivity, while it allows for future-proof design investment, since the stack is software programmable. This means that end-products can be protected against emerging wireless technology vulnerabilities over time but can also be upgraded with more connectivity features as the BLE stack is continuously evolving.

In order to address the challenges of memory architecture imposed by the varying storage needs of smart applications, DA1470x provides a set of different interfaces for connecting external memories, allowing for supporting storage options ranging in data transfer speed, size, reliability, endurance and cost. There is an Octa/Quad SPI interface for executing on-the-fly with the main CPU the application FW residing in a non-volatile NOR Flash, two dedicated QSPI interfaces for PSRAM and NOR or NAND storage flashes, respectively, allowing for extending system RAM and storing the graphics resources or persistent application data, and finally an eMMC interface (up to 48MHz SDR mode) for extending the size of data/resources being stored at a lower cost. Such flexibility plays a large part in meeting application requirements for memory storage in the most cost-effective way.

Finally, as requirements evolve regarding device security and data privacy in such constrained designs, DA1470x also provides advanced security features. There is a secure boot mechanism, support for firmware execution and decryption on-the-fly at the same time from an external flash memory, and a key storage and handling mechanism, providing complete protection and authentication of the application firmware and stored data. On top of that, there is a cryptographic engine with state-of-the art crypto accelerators (AES, MD5, SHA) which accelerate any application security operations, as well as a True Random Number Generator (TRNG) for secure key generation. Security at the communication level is supported by the implemented mature BLE stack which supports all security-related features defined in the BLE 5 specification.

Summary

In summary, Renesas' advanced SoC DA1470x provides unique features in increased level of integration, making it a perfectly matched solution for tackling the emerging challenges imposed by the smart transformation taking place in several application domains.

More information about the DA1470x SoC family, as well as Renesas winning combinations of a wearable activity tracker and an Instrument Panel for Light EVs and eBikes can be found at www.renesas.com/da14706.

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu, Koto-ku, Tokyo 135-0061, Japan

https://www.renesas.com

Contact Information

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