

# On-Line JOURNAL

## Next Generation Smart Control Panels Take User Interfaces to a New Level

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### Useful Links in this Article:

**AT91SAM9RL64** The AT91SAM9R/RL is an ARM9-based microcontroller focused on applications that support smart control panels. Its ARM926EJ-S processor, achieving 210 MIPS at 190 MHz, gives it the power required for intelligent user interfaces, and its double-buffered LCD controller with virtual screen support gives high-resolution, flicker-free displays. Its 64K bytes of on-chip SRAM gives it sufficient capacity for code execute-in-place and screen buffering. It has an External Bus Interface for access to a wide range of off-chip memories.

<http://www.embeddeddeveloper.com/processors/2426/Atmel/AT91SAM9RL64.htm>

### SUMMARY

*The continuous decrease in cost and size of solid-state memories enables a large amount of content to be stored in many products such as portable media players or smart phones. At the same time, the deployment of the Internet and the ability to connect to the net virtually anywhere gives products access to almost unlimited content. Another example is set-top boxes, which are connected to cable networks or satellites and provide access to hundreds of TV programs and movies in parallel. Without giving the user the ability to navigate through the content and find the right information in the shortest possible time and an easy way to connect to the network, these products are worthless. Altogether the user interface determines the ultimate user experience of the device.*

### A NEW GENERATION OF USER INTERFACES

A revolution is under way in how users interact with products or systems. Mechanical buttons are replaced by touch screens and capacitive sensors; segment displays are replaced by color LCDs and beepers are replaced by voice messages.

These changes enable users to improve control and simplify navigation through content. Recently introduced multi-media products have proved that consumers are willing to pay a higher price for systems with a smart user interface. Refrigerators or cookers with Internet access to look-up recipes or shop on-line are gaining market share. Radios with internet access or intelligent remote controls to explore the massive content provided via cable or satellite are other examples of applications that face the challenge to assist the user in finding the information or program that he or she is looking for.

The technology underlying a great user experience is based on continuous innovations in hardware and software, the reduction of cost and the tight integration of both hardware and software. Strong relationships between companies developing content and the products rendering it are as important as the technology behind the product itself. It will determine if the content can be exploited by the user. As examples, an audio file compressed in WMA cannot run on an MP3-only player, or the size of images and video need to be adapted to the screen size of the device rendering them.

### USING HIGH SPEED USB FOR INTERCONNECT

Most microcontrollers used in today's user interfaces are low cost, very limited in performance and unable to deal with networking. An I<sup>2</sup>C or SPI connects the user interface to the host processing platform, running at several 100k bps. A higher performance class of microcontrollers and a user interface co-processor and the host is required for the new generation of user interfaces. For example, a 320x240 pixel, 24-bit color/pixel, 60Hz QVGA screen requires a data transmission rate of 6.75M Byte/s. Parallel wiring provides the bandwidth but significantly increases the system costs, adds substantial wiring complexity and creates EMC issues. A high speed USB 2.0 interface can transfer data at up to 24M Byte/s in isochronous mode as one high speed USB endpoint can transport 3x10<sup>24</sup> bytes per frame in 125µs. High Speed USB offers a robust, EMC compatible and cost effective alternative to parallel wires.

400MHz plus embedded MPUs optimized for portable multi-media players and mobile phones running Linux, Symbian or WinCE offer access to great multi-media players able to display user manuals and video animation on top of a navigator, but they require substantial memories, adding unacceptable costs to many systems. The required high clock frequency raises the EMC complexity. Multimedia modules, such as those for mobile phone, media player or PDA, featuring MPEG4/H.264/DivX, 3D engine, or MP3/AAC/OGG codec can be managed by the host processor instead of the control panel microcontroller itself, keeping it a cost effective part. A low cost embedded MPU running an RTOS and a good Graphical User Interface (GUI) middleware package, able to navigate through the content like a portable multi-media player, and a USB High Speed connection to the host is an excellent compromise between cost and improved user experience.

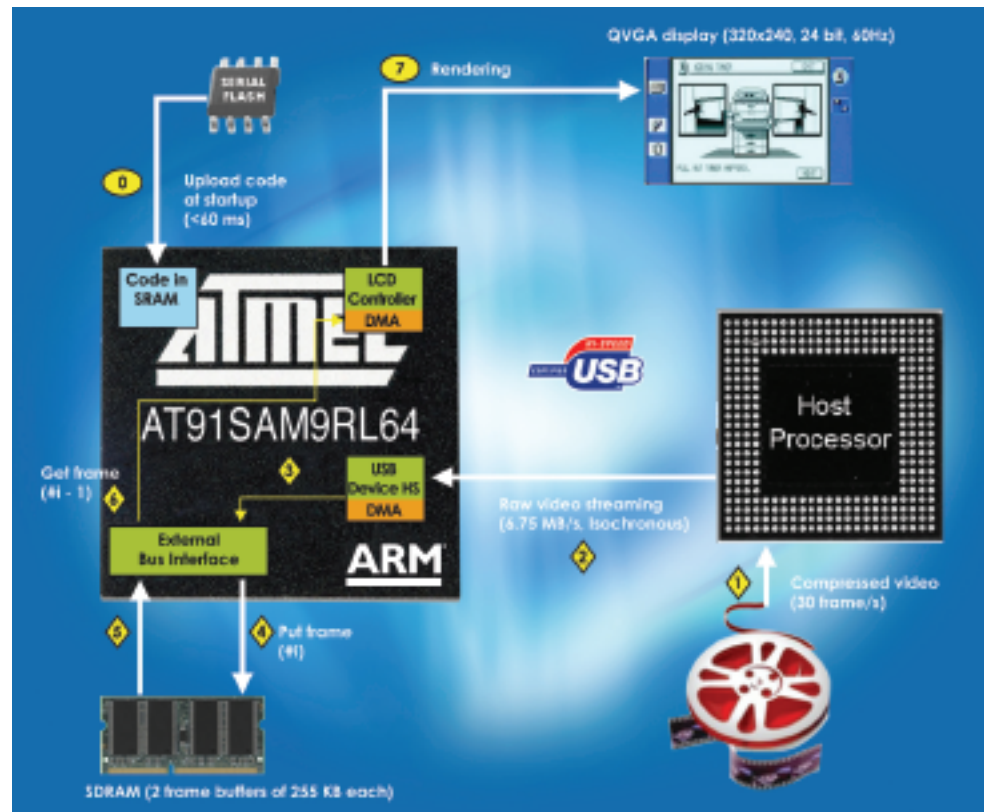


Figure 1: AT91SAM9RL64 video rendering process

Designers should take care to ensure that the microcontroller has sufficient on-chip bandwidth to move the data between the USB port, the external memories and the peripherals without too much CPU involvement.

If the microcontroller does not have the internal bandwidth to support video streaming, then the display quality will have a tendency to flicker. If the video quality is too poor, its utility for the enduser is diminished.

Atmel has addressed this issue by implementing a 6-layer AHB with DMA controller on its AT91SAM9RL64 embedded microprocessor that connects 6 masters (2xCPU, PDC, USB Device, DMA controller, LCD controller) to 6 slaves (Internal SRAM and ROM, USB device, LCD controller, External Bus Interface, Peripheral bridge) via parallel paths. All masters may concurrently access any slave at a maximum theoretical speed of 19.2G bit/s at 190 MHz, meaning for example that there is no contention on the internal bus when the microcontroller is receiving new frames from USB while sending previous ones to the LCD for rendering, and leaves the CPU 100% free to do application processing. If multiple masters wish to access the same slave, arbitration is automatically performed thanks to a built-in round-robin mechanism.

Once pre-processed, the raw video stream can be delivered to the

smart control panel and displayed without any modification. This type of system works as follows. The smart control panel's MCU uploads its program from external flash to its on-chip SRAM, using a boot loader. Once the program is uploaded, the microcontroller, initializes the external bus interface, USB controller, LCD controller and other internal peripherals, and then waits for a user interaction.

At such time as a user requires a video display, the remote host processor begins converting the compressed 30 frame per second (fps) QVGA (320x240 pixels) movie to a raw video stream ready to be displayed on the LCD display. The host processor decompresses and scales the video input according to the size and resolution of the screen. The microcontroller on the smart control panel has a DMA controller on the USB Device port, so it can push the video stream to the frame buffer located in the external SDRAM through the EBI, without stealing any cycles from the CPU. In this example, one frame can be stored in a 900K Byte buffer on the SDRAM.

The microcontroller can take care of the flickering issue (i.e. bad synchronization between image data refresh and visual refresh), by asking the LCD DMA controller to display the frames in sequence by using the double-buffering technique - two interchangeable buffers in the video memory. While one buffer is showing a frame, you draw the next frame of animation into the other buffer. Then tell the video controller to switch the buffer it is showing; a very fast operation that

requires no copying and is done during the screen refresh interval so it produces no flicker at all.

### TIGHT COOPERATION BETWEEN HARDWARE, SOFTWARE AND CONTENT PROVIDERS

Finally, the LCD controller needs to deliver the frames to the screen to render the streaming video.

Since more than 80% of the job is done by the different DMA controllers, the CPU uses a marginal number of MIPS, leaving it free to monitor the different sensors, check the battery life, and poll the keyboard for user activity.

This brings us to another challenge, which is the screen size. For cost and portability reasons, screen sizes are kept small. Content management or Internet navigation programs cannot rely on large screens like on a PC or a TV set; but more likely the screen size of a mobile phone or smaller. Only a relatively small part of information can be shown to the user at any time. The user does not want a simple list anymore, but he wants icons that represent the content instead of text and they need to move smoothly, beat or fade.

The next generation of control panels will be smart. The mechanical parts of the interface will almost disappear. A typical control panel will have programmable buttons on a touch screen interface or capacitive sensors, like those on the smart mobile phones recently introduced into the market by Apple, Nokia or HTC. They will be able to tell their users how to use them with integrated electronic user guides that will replace the impossible-to-find “printed version”. If a printer needs a new cartridge, or a washing machine needs its filter cleaned or a patient needs to connect a medical logger without the assistance of a qualified person, the equipment will be able to tell the user what to do and how to do it. It may even show the user still images as examples or a streaming video on the LCD screen. These control panels will be vocal too; text and beeps will be replaced by synthesized voice messages guiding the user through the process. They will also be multi-tasking, serving as a control panel, manage the communication channel and control the system. They will be entertaining, able to play streaming video, MP3 and RSS (Really Simple Syndication) feeds.

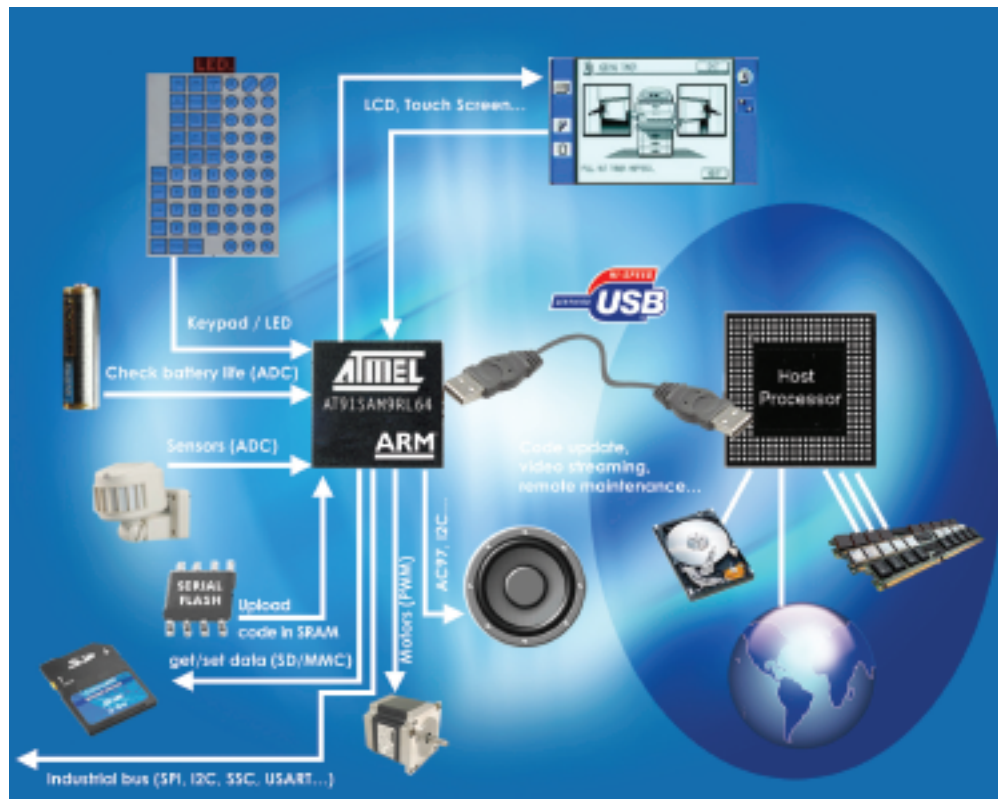


Figure 2: Smart Control Panel Functional Diagram

These smart control panels will improve the user experience of security systems, medical data logging, heating/cooling control, computer assisted manufacturing, computer peripherals, vehicle cruise control and navigation, banking terminals, white goods and home lighting applications, to name a few.

### EMBEDDED PROCESSOR REQUIREMENTS

All these features will require a lot of bandwidth; they will need high-speed interfaces and easy-to-customize graphical user interface software, and multiple sensors and actuators. The embedded processors will need to be able to move massive amounts of data around the chip without compromising CPU computation performance. Alternatively, DSP algorithms for audio and video decoding, or image scaling can be executed on a remote host processor connected via a high speed USB or WLAN. High speed USB has the advantage of better EMC immunity, robustness and 2 to 4 times lower cost than unshielded parallel cables. USB's “Plug and Play” capability facilitates the system design and it also provides an easy connection to maintenance stations and analyzers for diagnostic and repair functions. WLAN allows the user interface to be portable allowing the user interface to be detached and operate as a remote control.

The functional diagram of such a Smart Control Panel looks like the figure 2 above.

For all of these reasons, microcontrollers for smart control panel applications require multiple peripheral controllers including: LCD, keypad interface (touch sensitive and mechanical), DMA for both peripherals and memories, AC97 or I2S for sound, 480 Mbps high speed USB 2.0 device for global data transfers such as program upload or raw video streaming sent by the remote host processor. They will also need a real-time clock (RTC) and an optional memory protection or management unit to run multiple applications safely. Analog-to-digital converters (ADCs) to get sensor data or check the battery life and control the touch screen and pulse width modulators (PWMs) to drive motors, LCD displays and its backlight control.

Ideally, the control panel microcontroller has some fast on-chip SRAM that has been uploaded with real-time constrained algorithms like an MP3 audio decoder, thereby securing a high quality audio playback when the LCD display is being refreshed. The application can be stored in a serial Flash memory connected via a high speed SPI bus and shadowed when required within tens of seconds into the on-chip SRAM (an SPI running at 25Mbs with a dedicated DMA can transfer 64KBytes in about 20 ms). To achieve the determinism required for such applications (particularly audio decoding, video streaming, anti-flickering...), the internal SRAM should be tightly connected to the CPU, through a highspeed bus such as tightly coupled memory (TCM) or a multi layered advanced highspeed bus (AHB) as defined by ARM.

Finally, since control panels are likely to be USB self-powered, the microcontroller should consume no more than 100 mA, and should have a built-in voltage regulator.

Video rendering is a complex, computationally intensive task, better managed by a host processor located outside the smart control panel, with sufficient computational resources to support the execution of video decompression and scaling.

The exceptional computational requirements and intricate connections between the Smart Control Panel, its peripherals, memories and external host processors, mandate careful evaluation of the microcontroller to be used. A device with an ARM9 processor is generally mandated because of the high computational throughput required for streaming video and to control all the sensor and actuators. Designers should take care that the controller also has tightly coupled memories, a multi-layer bus, and DMA on all peripherals to ensure adequate on-chip bandwidth. For any control panel that will utilize streaming video in its user-interface, sufficient on-chip SRAM is required to run real-time critical software routines in parallel to massive data transfers. A USB High Speed Device provides the connection to the main processor decompressing the video streams and controlling the network connection.