AoT-News

Under the Microscope
Review Service

Tech-Corner
An overview of ARM family of processors and the Art of Technology Software-Framework

Speed-Dating à la AoT
with Andreas Dätwyler

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Under the Microscope

Review Service

A simple but very effective way to improve the quality and accelerate the progress of development projects is the Review Service from Art of Technology.

Very different things can be verified in a review such as a new concept, a design, schematics or source code; the basic approach is always very similar.

One or more reviewers examine conduct the review on the basis of a checklist with irregularities being documented in a report. Corrections are then implemented on the basis of this report. Quite often during this remedial process other errors are discovered and rectified.

A clearly defined review process ensures that all issues found will be remedied. As each reviewer has a different perspective, a high quality review can be achieved using a diverse review team comprising different specialists. The time invested in a review leads to significantly reduced corrective actions being necessary at later stages of a project, resulting in a product with significantly improved quality and fewer errors.

We would be happy to provide you with an experienced reviewer, or a review team, to support you with your review process.

If you would like to take advantage of our review service, contact:
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Tech-Corner (Part 1)

The ARM Processor Family

Attila Dogan, Klaus Ruzicka

Over the past few years, ARM processors have acquired a wide market share and have gained a leading role in many areas. The following article provides an overview of the ARM7, ARM9, ARM11, ARM Cortex-M3, ARM Cortex-A8/A9 and the ARM Cortex-R with their respective advantages and disadvantages.

ARM7

Probably the best known and most widely used member of the ARM Family is the ARM7. It is the workhorse of the embedded electronics industry and has replaced the revered 68HC11 as the micro-processor of choice for virtually every application. Unlike Motorola with the 68HC11, ARM does not produce the processors themselves, but rather license the design to other chip manufacturers, who add the peripherals (timer, UART, ADC, DAC, CAN bus interface…) and integrate the CPU core together with peripherals and memory (Flash and RAM) on a chip to form a complete solution for specific applications. The wide distribution of the ARM7 has led to the availability of ARM7-CPU based microcontrollers for almost every conceivable application. These microcontrollers are used in low-cost low-power electronics to supervise and control the surrounding electronics. As a 32-bit microcontroller, the ARM7 equipped with ample memory simplifies and accelerates software development cycles in comparison to 16-bit and even more so compared to 8-bit microcontrollers.

The modern ARM7 microcontrollers have sophisticated power management systems which can switch specific parts of the microcontroller on or off as required, as well as send the microcontroller to sleep and wake it with an external signal. This makes it possible to develop small, lightweight mobile devices that still have a long battery life.

There is a generous selection of integrated peripherals for the ARM7. There is virtually no application for which there isn't a microcontroller with the right peripherals. Beside the obligatory RAM (usually between 2 kB and 128 kB) and Flash (usually between 8 kB and 512 kB) memories, most microcontrollers also include a timer/counter unit and a reset controller. I2C, SPI and UART interfaces for external components are almost always available. These days many microcontrollers also feature an integrated USB controller and for the more demanding communications, where USB, RS-232 and RS-485 aren't sufficient, there are microcontrollers with integrated CAN bus or Ethernet controllers as well as PWM generators, LCD controllers and encryption/decryption accelerators (AES, 3DES).

ARM9

The ARM9 is an enhancement of the ARM7 architecture. Due to the integrated memory management unit (MMU) and structural changes that allow an increased clock rate up to 1GHz, the ARM9 is used almost exclusively in systems with fully-fledged operating systems (i.e. Android, Linux, Windows CE etc.) or systems with high performance demands. Current applications include systems with complex user interfaces which have become more and more common with the increased popularity of smart phones and has led to ARM9 variants that include a DSP core (like the Integra Family from TI). Because of these higher demands, the RAM and Flash memory are not normally integrated on the chip but rather connected as external components.

ARM11

The ARM11 is a further enhancement of the ARM9 to achieve even higher clock rates at lower power consumption. The first single instruction multiple data (SIMD) instructions (like MMX and SSE) were added to support the emerging multimedia applications. Furthermore, the cache structure of the ARM9 was simplified and made faster.

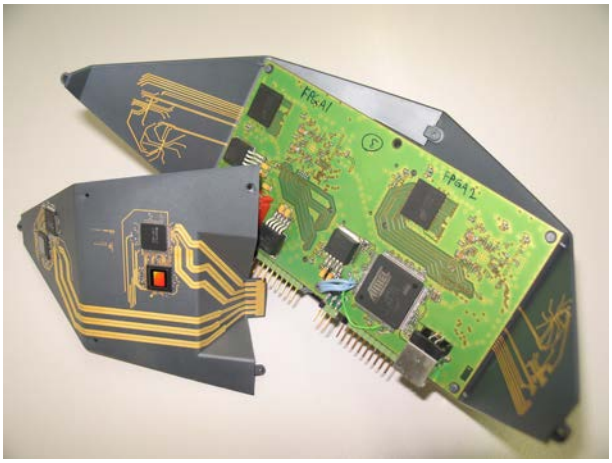
ARM Cortex-A, -M and -R

In a reorientation of the ARM product portfolio various classes of applications were identified, each with different demands on the processor. Due to the partly contradicting requirements ARM decided to offer three classes of processor:

- a cost optimized embedded processor line (Cortex-M) which ususllay runs without or with a small real time operating system
- a high performance application processor line (Cortex-A) for demanding applications that use a high-end operating systems (i.e. Linux, Symbian, Android or Windows CE)
- a real time processor line (Cortex-R) for real time and security critical applications where higher processing power is required (eg. autombile industry)

ARM Cortex-M3

As part of the rejuvenation of the ARM7 architecture, that had become a bit long in the tooth, ARM decided also to address a few non-technical issues. Specifications were refined and expanded, while some system components which were previously left to the manufacturers were more precisely defined (e.g. single memory map or SysTick timer and power management). This makes it possible to migrate, to a certain extent, software that was written for the processors of one manufacturer, with a manageable cost, to processors of a different manufacturer.



Camera system with Atmel SAM3U as controlling system und USB User Interface

The main advantages of the Cortex-M3 compared to the ARM7 are the higher processing power per mW and the improved power management system, which generally lead to lower power consumption. Due to the high compatibility between the ARM7 and the Cortex-M3 core, the entire periphery can be used unmodified. Many manufacturers have seized the opportunity to revise the peripherals to meet the increased needs of their customers. In particular, the higher clock rates and processing power enable the handling of higher data rates. It is now possible to fully exploit the available data rate of 100 Mbit/s Ethernet links and the use of High-Speed USB is now a valid option.

ARM Cortex-A8/A9

The Cortex-A8 and its multi-core brother the Cortex-A9 are the successors of the ARM9 and ARM11 families and are designed primarily for high performance computing and multimedia tasks. New features include a multi-issue superscalar pipeline to ensure better performance per MHz than the ARM9 and ARM11 and the expansion of the ARM11-SIMD instructions for multimedia applications. With these changes the Cortex-A8

and even more so the Cortex-A9, achieve performance levels that were previously reserved for desktop processors, and all that with a power consumption that is still only a few Watts.

ARM Cortex-R

Although the Cortex-A family delivers high computational power they do not, due to their architecture (multi-issue pipeline, caches, etc.), allow exactly definable reaction times. This is problematic for applications with high real-time requirements since a low response time to interrupts cannot be guaranteed. The Cortex-R, with its different pipeline structure and memory architecture, forms a link between the Cortex-A and Cortex-M offering similar computing power to the Cortex-A, but with a predictable response time. These processors are mainly used in control systems where high data rates and low reaction times are required, such as hard disks or management systems for internal combustion engines.

Summary

The different ARM processors cover a wide range of applications. Each processor family was designed for a field of application where it can develop its full potential. Art of Technology has accrued extensive experience using various ARM processors in a variety of applications ranging from consumer products and systems with data encryption to medical implants.

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Art of Technology

Tech-Corner (Part 2)

Software for the ARM7 / Cortex-M3 Processors

Attila Dogan, Klaus Ruzicka

The selection of a processor for an embedded system involves much more than just hardware costs and maximum processing power. Important for an optimal, cost effective and an overall stable system is the use of power saving (i.e. disabling unnecessary features, reduction of processor clock...) especially for battery-powered devices and the ideal utilization of the integrated peripherals.

Especially the integrated control of the processor peripherals (e.g. PIO's, Interrupts, interfaces and bus-systems like UART, SPI, I2C/TWI, OWI, CAN, LIN, USB, Ethernet as well as ADC, DAC, PWM and Timer, Watchdog) represents a significant portion of total software development effort. Concepts and control details are different for each manufacturer.

The Software Framework from Art of Technology

The Art of Technology prefers to use, among others, the ARM7/Cortex-M3 series from Atmel. The SAM3[1] has the same periphery concept as the SAM7[2]; as such the C code can be used with or without minor modifications on both processor families.

In search of a reliable basis for the development of hardware-related software Art of Technology has evaluated several existing operating systems, libraries and frameworks from well-known manufacturers, only to find to again and again, that they contained mostly only the simplest functions (and in some cases even incorrect). Above all they were not particularly suited to reliable error handling as safety-related parts. Frequently, these libraries and operating systems had no (adequate) functions for power management, which is especially important for battery-powered devices.

Module	Description	Medical
Clock	Control of the clock speed (RC, Quarz, PLL) with automatic flash wait state adoption, RTC control, blocking und non-blocking waits (clock speed change invariant), measure time, immediate software timer.	Yes
Power	Up to 32 modules are allowed to request a power mode. Automatically the lowest possible is used	Yes
Watchdog	Internal Watchdog (0...16s). Function calls for manual, request reason for last reset.	Yes
Error Handling	All modules provide (wherever useful) an uniform Error Handling. Thus allowing error logging (down to HAL level) at application level.	Yes
Trace	Standard Interface or reduced Version to minimize memory requirements. May turn off for the whole project by use of a compile switch.	Yes
Debug	Using the Trace module, debugging can be controlled for each module in up to 4 levels	Normally disabled in production version by compile switch
Ringbuffer	First In – First Out buffer with overflow detection	Yes
Crc	CRC 16 /32 memory consumption	Yes
Timer	Configurable amount of software timers in 125ms (MID) or 1s (SLOW) granularity, clock speed change invariant.	Yes
Hal-Timer	Precise Hardware Timer	Yes
PIO PIO-Irq	Inputs / Outputs / Peripheral function on all IO-banks, allows control of PullUp, OpenCollector, Interrupts on Inputs	Yes
Key	Handling mechanical contacts as switches, buttons, buttons used as switches, connectors	Yes
ADC	8bit/10bit, Software/Extern/Hal-Timer triggered (repeated) single shot measurements, averaging (mean/moving average). Infinite or limited sampling ring buffer.	Yes
PWM	Pulse width modulation with base frequency control in 1024 steps.	Yes
SPI	Hardware, Hardware with Software CS control, Interrupt support and software implementation (via PIO's). Use of several HW/SW SPI's in parallel possible.	Yes
TWI /I2C	Master/Slave Interface with 8/16 bit wide data, several busses possible.	No
OWI	Dallas One Wire Interface. Software Implementation, as no HW support. Uses PIO's, PIO-Interrupts, Hal-Timer, blocking waits and clock tasks to minimize blocking time. Several parts on one bus upon request.	Yes
UART	Serial Interface	Yes
USB	Virtual Com Port, Full-Speed measured up to 5.5Mbit/s. (High-Speed in preparation for SAM3). Implementation passes Chapter-9 conformance tests. Supports USB isolation hardware (5kV as used for medical products) *No* special drivers required on PC side, .inf files available for Windows 2k/XP/Vista/7	Yes
	Mass Storage Device upon request	No
Flash	Program new application via Bootloader, Persistent Parameter Storage. Supports Flash Page Lock/Unlock. Restriction: Only first Flash-Controller supported (up to SAM7x256)	Yes
Memory Card	Simplified (only Root Directory, DOS 8.3 file names), but fully compatible FAT16 or FAT32 files system for MMC, SD and SD-HC cards via SPI Interface from 129MB to 32GB	Yes

Table 1: Art of Technology Atmel SAM 3/7 Software Framework on internal peripherals / generic use functions

[1] Atmel AR / Cortex-M3 Processor

[2] Atmel ARN7 Processor

For this reason Art of Technology designed and re-programmed more and more critical parts, resulting over time in a complete software framework for the ARM family of processors, which are mainly used in medical devices (including Implants). As such the code has been well documented (SDS[3]) and tested (SIT[4] where useful, otherwise SAT[5]) and has been subjected to at least on review. An overview is given in Table 1.

The modules controlling clock, power, timer and error handling provide an operating system-like environment, while allowing full control over the power management.

Atmel SAM7X in a battery powered charging and control system for a human medical implant
Art of Technology AG for Sequana Medical AG (formerly NovaShunt AG)

Table 2 provides a brief overview of other modules used for the control of displays, external ADC's, pressure and temperature sensors as well as battery charge and monitor chips and GPS, etc., based on the low-level interfaces mentioned.

Apart the framework itself, a boot-loader requiring only 16 kB memory (via USB or UART) is available to enable easy application updates in the field. A failed update operation (e.g. power failure, application error, etc) does not impair the function of the boot-loader. The conditions for the activation of the boot-loader can be programmed and configured.

Module	Description	Interface	Medical
AoT_Prot	Generic Protocol handler	USB/Serial	No
AT45DB	External Data Flash	SPI	No
BQ24103	Li Battery Charger with Stepper	PIO's	Yes
DS2401	Silicon Serial Number	Dallas1W	No
DS2762	Li Battery Monitor with Alerts and Battery disconnect	Dallas1W	Yes
LTC244x	ADC, 17...24bit	SPI	No
MS5607	Pressure and Temperature Sensor	SPI	Yes
MT9P001	Image Sensor (Configuration interface)	I2C	No
NAND	Nand-Flash interface	PIO's	No
SCA8X0	Acceleration Sensor	SPI	No
SCA3000	Acceleration Sensor	SPI	No
SCP1000	Pressure Sensor	SPI	No
SHTxx	Humidity and Temperature Sensor	I2C	No
UBX	u-Blox GPS	Serial	No
WX12864	Graphical display	SPI	No

Table 2: Art of Technology Atmel SAM 3/7 Software Framework for external peripherals

Our boot-loader and framework for the Atmel SAM3/7 family of processors enables Art of Technology to develop good code-quality applications for our customers quickly and cost effectively, covering simple consumer products to active implants for medical applications.

For further information contact:
Etienne Hirt: etienne.hirt@aotag.ch or Klaus Ruzicka: klaus.ruzicka@aotag.ch

[3] Software Design Specification
[4] Software Integration Test
[5] Software Acceptance Test

Table 1

Art of Technology Atmel SAM 3/7 Software Framework for internal peripherals / generic use functions

Module	Description	Medical
Clock	Control of the clock speed (RC, Quarz, PLL) with automatic flash wait state adoption, RTC control, blocking und non-blocking waits (clock speed change invariant), measure time, immediate software timer	Yes
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Trace	Standard Interface or reduced Version to minimize memory requirements. May turn off for the whole project by use of a compile switch.	Normally disabled in production version by compile switch
Debug	Using the Trace module, debugging can be controlled for each module in up to 4 levels	
Ringbuffer	First In – First Out buffer with overflow detection	Yes
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[6] Hardware Abstraction Layer

Module	Description	Medical
	Mass Storage Device upon request	No
Flash	Program new application via Bootloader, Persistent Parameter Storage. Supports Flash Page Lock/Unlock. Restriction: Only first Flash-Controller supported (up to SAM7x256)	Yes
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SCA3000	Acceleration Sensor	SPI	No
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SHTxx	Humidity and Temperature Sensor	I2C	No
UBX	u-Blox GPS	Serial	No
WX12864	Graphical display	SPI	No

Speed-Dating à la AoT

with Andreas Dätwyler

I've heard that you have a special hobby?
Over 10 years ago I started modelling. Together with two colleagues I've built a helicopter and developed a camera platform which can rotate around all three axes.

The helicopter weighs about 6kg and can fly for about 7 minutes. My two colleagues are the pilots and I'm the photographer.

Age	33
Profession	Senior HW/SW-Engineer
At AoT	since 2002
Zodiac sign	Lion

What do you photograph?
Houses: for example Photographs of construction sites to document the building progress. We even had an order from a cantonal Building Authority (see www.helipics.ch).

What would you spend a lot of money on?
Traveling is also one of my hobbies; 4 years ago I was in Papua New Guinea and repaired electronic devices for a relief organization that operates a nationwide radio network used to alert emergency medical service so that a plane can be directed to the bush airfield. Otherwise in case of an emergency, it would take up to a week to walk or two days by car - if the car can get through at all.

What would you never spend money on?
A luxury cruise or tour, or a week in a 5-star hotel.

What one thing do you definitely want to do in Life?
Already done; I got married last year.

You're invited to a Costume Party; how would you disguise yourself?
As a British Second World War pilot; I'm not fan of war itself but I find these planes fascinating.

If you were an animal, which animal would you be?
A weasel: small and inconspicuous, but agile.

Describe yourself in 5 Adjectives?
Agile, Adventurous, Balanced, Social with many interests.

What is your best characteristic?
Endurance, hanging in there!

What should your Epitaph say?
He lived what he believed.