Criteria for ARM Migration as the Industry Standard MCU

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Synopsis:
In the past decade, the ARM® architecture has become one of the most pervasive processor architectures in the industry. In 2004 alone, over 1.2 billion ARM processor-based products were shipped. This success has elevated ARM to the position of the world's most successful IP company. Already the ARM architecture has made great headway as the leading processor IP for ASIC and custom SoC applications. Most recently it has become a emerging architecture in standard off-the shelf microcontroller (MCU) products. Several major MCU solution providers are offering portfolios of standard off-the-shelf general purpose as well as application specific ARM MCUs. And the list of suppliers is rapidly increasing.

This article reviews available tools as well as design advantages and challenges engineers will need to consider when designing MCUs based on the ARM architecture.

The newfound popularity of ARM MCUs has led some to dub ARM MCUs as the "8051 of this generation". For ARM to live up to this reputation, and to show that ARM has become the standard choice for both custom and standard products, a number of criteria need to be met.

Firstly, they need to have a strong infrastructure. This has already been addressed. The infrastructure of support built around the ARM architecture is very robust. With over one hundred licensees and countless third parties there are a broad range of highly specialized vendors providing support for every aspect of development based on the ARM platform. This includes support for silicon solutions, application software, RTOS, and software development tools.

Due to the large user base and every increasing business potential, many of the top industry suppliers offer services and products to ARM developers. As an example, most of the top software development tool vendors, such as Green Hills, IAR and Keil (a recent acquisition of ARM) offer tools for the ARM architecture. This broad array of vendors ensures a high level of quality and competitive prices.

Secondly, there has to be a high level of compatability and transferability. Again ARM already addresses this as well. Another reason for ARM's success has been the proven roadmap of Instruction Set Architecture (ISA) compatible cores encompassing entry-level 32-bit ARM7 family all the way up to high performance ARM10 and ARM11 processors.

An embedded system developer can rest assure that when using ARM, they can rely on the same underlying architecture for multiple projects requiring different price, performance and features.

For example, a developer can develop a MCU product based on the entry level ARM7TDMI™. Then the next generation of his product may require higher performance, so the developer simply moves to an ARM9 processor-based MCU that offers higher performance and added features. Also, since ARM does not allow any deviation in its ISA by its licensees, developers can be sure that a steady supply of processor compatible ARM MCUs are available to them from multiple vendors. In addition, the same software development tools, when carefully picked, will support any of the ARM proccessors chosen. Using the same tools across multiple platforms can reduce development cost and time. When choosing the software development tools, the developer needs to be aware that although the ISA is the same across different ARM proccessors, certain cores have built in extensions to give them added advantages. To take full advantage of the processor's capabilities, the software development tools chosen must have support for the particular core being used. For example, ARM946E proccessor have built in DSP extensions for MAC intensive applications. Although, software compiled for an ARM9TDMI proccessor will readily execute on the ARM946E processors, to take full advantage of the processor features, the software development tools utilized should have native support for the ARM9E proccessors.

The fact that ARM cores are synthesizable means that developers can develop an end-product using an existing standard off the shelf MCU, and should demand for their end product increase, they can cost optimize by moving to a custom MCU which integrates more functions into a single ARM SoC.

The wide industry acceptance of ARM processors has created a beneficial environment for developers interested in using

ARM. The large user base translates into large business potential which fuels a steady flow of innovative and competitive solutions. The competition between various vendors is lowering costs for chips as well as tools. It also is producing a growing pool of developers that are familiar with the processors and can provide more innovative solutions based on this architecture.

Finally, there has to be a broad range of tools supporting the architecture. As recent industry surveys indicate, the most critical factor in deciding which MCU to use is the availability, cost and quality of development tools. Development tools include software compilation and debug tools as well as readily available development boards for the particular MCU in mind.

In ARM's case there are a number of tools to choose from and more appearing on the market everyday. These range from freely available GNU tools to full featured, fully supported tools from major industry players.

When choosing the right tool, there are a number of factors to consider. These factors are cost, vendor support, features and ease of use of the tools. The cost of the tool is driven by the other three factors. When considering the cost of the tools, one must consider the entire cost of the project.

An initial higher cost for the tools can save money down the road in a number of ways. For example, the most expensive item on the silicon side continues to be memory. Through optimization, software development tools can improve code density and lower the need for large memory or increase performance at no premium. Also, a full-featured tool with an easy to use GUI and feature-full debugger, can reduce cost by speeding up the code development and debug process and therefore reducing project cost. Also, a fully supported tool means direct technical support from the vendor. Since software development is one of the most labor intensive and costly parts of the project, this results in direct savings in cost as well as time-to-market.

As an example, GNU tool-chain is a stable and freely distributed tool-chain that supports both ARM as well as the ARM Thumb® instruction sets. Note that an ARM compiler is really two compilers, one for ARM 32-bit instructions and one for Thumb 16-bit instructions that are supported by most ARM processors. Other tools available range in price from a few thousand to over ten thousand U.S. dollars. Although GNU is free, it has low optimization, and it does not have direct technical support unless support is purchased. GNU tool-chain does not have user friendly IDE (Integrated Development Environment) which increases the startup learning curve, and it has questionable debug support that may prolong software debugging and therefore increase development time and cost.

The continuing reduction in the cost of silicon means that 32-bit ARM SoCs are being manufactured and sold to the market at lower costs. ARM-based MCUs can be purchased at below $5 price ranges today. This price point is approaching and at times beating the price of traditional 8- and 16-bit MCUs. Designers migrating to ARM will find that they can utilize the benefits of 32-bit performance and increased features at low or no price premiums.

In addition to Software development tools, it is critical to have a stable development board with the desired MCU early on to start evaluation and software design. The ideal development board should be low cost, stable, expandable through interface connectors, easy to use and have the basic interfaces frequently required such as RS232 DB9s and standard JTAG connector.

No matter how you slice it, ARM is well positioned to become the standard MCU architecture.

Case Study

Let's examine the validity of ARM's market expansion in a case study. In this case, Oki Semiconductor, a long time ARM licensee and an ARM solution provider is used as an example.

Oki has been designing and manufacturing MCUs since the 1980s. Oki manufactures 4-, 8-, and 16-bit Oki-original proprietary processor architectures as well as 8051-based MCUs. In the mid 1990s, Oki's customer base was requiring higher performance 32-bit custom MCUs. A number of solutions were evaluated and, ARM7TDMI was chosen as the processor of choice. This decision was based on the fact that ARM offered a promising roadmap of ISA compatible cores with efficiency and

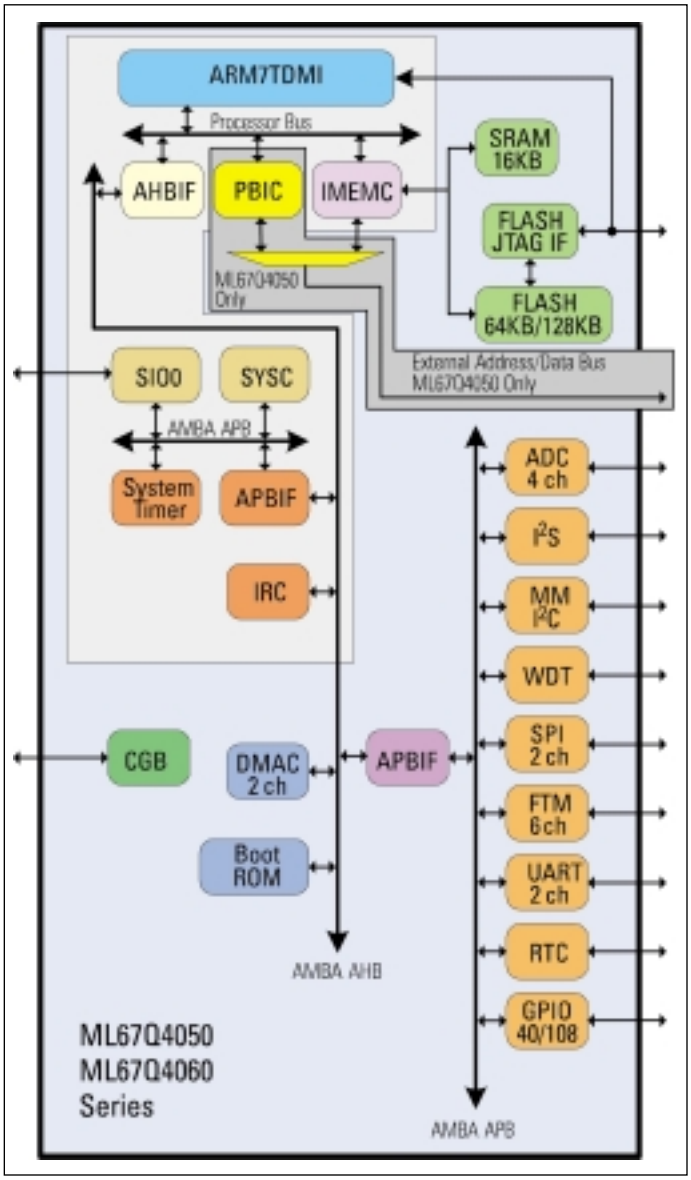

Figure 1: Oki's Standard MCUs are designed using a platform approach based around the ARM core and AMBA bus

good performance, synthesizable IPs and an extensive tools support infrastructure. The ARM as an ASIC library proved to be a success for Oki. By 1999 Oki decided to apply this success in to the standard off-the shelf MCU market. Oki's experience in marketing 8051-based MCUs, showed that a de-facto standard processor is generally more successful in the market. This resulted in a family of standard off the-shelf MCUs based on the ARM7TDMI processor .

One of the enabling factors in producing different flavors of ARM MCUs is the platform approach to SoC design. Early on, ARM developed the Advanced Microcontroller Bus Architecture (AMBA) standard. AMBA is an open architecture that was developed to standardize busses that connect to the processor core, thus enabling the development of AMBA compatible IPs that can interface as peripherals to the bus. Using this technique, an MCU requiring a processor core plus memory and several peripherals can be quickly assembled in a short period of time at lower risk of failure arising from design errors. In addition, availability of a large data bank of AMBA compatible IPs allows for easy procurement of desired peripherals. This approach to design enables development of various flavors of ARM MCUs built with different memory configurations and different peripherals sets geared towards particular application.

As shown in Figure 1 (see page 21), Oki's standard ARM MCUs are designed based on this type of platform approach. In the case illustrated, and ARM7TDMI is interfaced to the standard AMBA bus, and numerous peripherals from Oki's library of AMBA compatible IPs are used as "Lego blocks" to create an MCU with the right mix of functionalities.

Today, Oki offers a growing portfolio of standard off-the shelf ARM MCUs based on ARM7TDMI as well as ARM946E processor cores. In addition, Oki licenses other cores for ASIC and custom solutions.

Oki has the "World's Smallest ARM" which is based on ML67Q4060 series MCUs that are available in a 5 mm x 5 mm 64-pin WCSP package. This small package is ideal for space constrained applications such as mobile consumer products. Given that tools are an important deciding factor, this MCU series is supported by the industry's lowest cost, full-featured ARM MCU development kit dubbed the AME-51 which directly supports the growth of the 32-bit ARM processor in the former 8- and 16-bit MCU market. The AME-51 Kit comes complete with IAR software development suite, Oki ARM evaluation board, JTAG hardware and everything needed to start developing right out of the box for a low price of $249. The low cost of this tool kit attracts 8- and 16-bit MCU developers who were up to now intimidated by the costs associated with 32-bit processors.

Oki's expanded 32-bit processor strategy based on the ARM architecture has been very successful in the low and mid-end embedded markets. Oki continues to design ASICS as well as standard products based on ARM processor and licenses new cores from ARM to meet the requirements of its customer base. ARM's steady stream of new innovative technologies and high performance cores have proven to be sufficient to meet the needs of many of the current and upcoming embedded applications.

Conclusion

ARM processors are widely used in ASICs, custom SoCs and now as standard off-the-shelf MCUs. The emergence of ARM as the processor of choice has been fueled by the vast support infrastructure facilitated by the numerous ARM partners and licensees. A growing user base and an increasing number of tool vendors offering everything from chips to innovative application solutions insure a healthy competition that will keep quality high and drive costs lower. Designers migrating to ARM, will find a whole host of benefits that will aide them in quickly building cost effective systems. A robust roadmap of cores and innovative new technologies insure that for the foreseeable future, ARM architecture continues to dominate the embedded MCU market and has truly earned the title of "8051 of the this generation".