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THE DEVELOPMENT SYSTEMS COMPANY

Ashling Product Brief APB168

Smart Card Application Development, Debugging and Verification & Validation using Ashling's Smart Card tools

1 Introduction

Smart Cards represent one of the physically smallest, yet most widely used, applications for Embedded Microprocessors. Within a few square millimeters of silicon, Smart Cards contain a complete microprocessor system, including a processor (and often a coprocessor), volatile and non-volatile memories, and input/output.

Despite their small size, Smart Cards also represent one of the most security-critical of all embedded applications. Hundreds of millions of these tiny embedded systems are in use today in applications such as Subscriber Identity for mobile telephone handsets, banking, fare systems for public transport, and physical and network access systems [Ref. 1].

Accordingly, development of software for Smart Card systems must deliver secure, safe and reliable code. In particular, the system-design, development, debug and Verification & Validation process for on-chip Smart Card code must be carefully chosen: The cost of software coding errors is high. Errors in Smart Card software could potentially cause loss of service to millions of subscribers to a cellular network, or bring transport fare collection to a halt throughout a city, or compromise the security of a campus of buildings or a worldwide computer network.

With the objective of selecting a secure and reliable development methodology for Smart Cards, this brief paper outlines the stages in the development of on-chip and system code, and identifies the specialized tools from vendors such as Ashling that can be applied at each stage.

2 Smart Card development flow

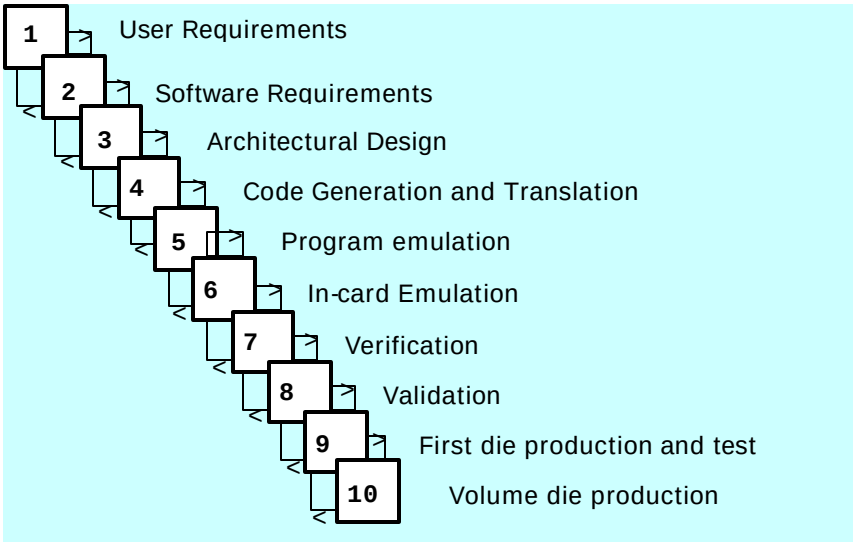

Figure 1: The Smart Card development process

The Smart Card development process flow is illustrated in *Figure 1*, and tabulated below:

1. **User requirements:**
   Capture and define the top-level (application) requirements for the Smart Card system, to serve as the overall Requirements-Specification and the basis for the Validation Plan.
2. **Software requirements:**
   Translate the top-level user-requirements into a set of software requirements.
3. **Architectural design:**
   Define the hardware and software architecture, and partition the User requirements between software and hardware.
4. **Code Generation and Translation:**
   Compile and Assemble source code into executable Smart Card microprocessor object code.
5. **Program Emulation:**
   Download the executable object code to the Smart Card In-Circuit Emulator; execute each code unit or module in real-time on the Emulator, while debugging code execution.
6. **In-card Emulation:**
   Connect the In-Circuit Emulator to the application-system's Card Reader using an ISO7816-format (Smart Card format) probe adapter; download the executable code to the emulator, and execute the entire Smart Card system, including the Smart Card processor and memory (represented by the Emulator), the Smart Card contact pads (represented by the ISO7816-format probe adapter), the Card Reader and the back-end application to which the Card Reader connects.
7. **Verification:**
   Test the execution of the Smart Card program in its application.
   Measure the Code Coverage (the percentage of the entire Smart Card code that has been executed at least once during the test procedure).
   Performance Analysis: Measure the execution-time of all C functions in the Smart Card on-card program; compare with the requirements specification [Ref. 3].
8. **Validation:**
   Application-test the Smart Card code using the Smart Card Emulator, ISO7816-format probe adapter), the Card Reader and the back-end application [Ref. 1]
9. **First die production and test:**
   Submit the verified and validated Smart Card ROM code image to the Smart Card silicon vendor for fabrication, and request one or more packaged die samples in return. Insert the die sample(s) in one or more ISO7816-format probe adapters, and again test and validate the application using the sample Smart Card die.
10. **Volume die production:**
    Commence volume production of Smart Card die at the silicon vendor; and submit the die to the Smart Card vendor to be embedded and embossed in a plastic card, with ISO7816-format Smart Card contacts.

3 Use of Ashling tools in the Smart Card development flow

Ashling Microsystems, the leading vendor of Emulator, Debug, Code Coverage and Performance Analysis tools for Smart Card and Contactless-card development, supplies a range of tools that may be applied during the Smart Card development process. Typical tools required at each stage of the process are:

1. **User requirements:**
   Manual or semi-automated document-management tools are generally used.
2. **Software requirements:**
   Manual or semi-automated document-management tools are generally used.
3. **Architectural design:**
   May use manual or semi-automated document-management tools; sometimes uses design-capture CASE tools.
4. **Code Generation and Translation:**
   For 80C51-core Smart Cards: Keil CA51 Compiler, Assembler and Linker.
   For SmartMX-core Smart Cards: Keil PK51 Compiler, Assembler and Linker.
   For SmartMIPS-core Smart Cards: Ashling AsIDE-MIPS Integrated Development Environment and GNU GCC MIPS Compiler, Assembler and Linker.
5. **Program Emulation:**
   For 80C51-core and SmartMX-core Smart Cards: Ashling Ultra-51 series Smart Card Emulator and PathFinder-51 Source Debugger.
   For SmartMIPS-core Smart Cards: Ashling Vitra-MIPS or Opella-MIPS Smart Card Emulator and PathFinder-MIPS Source Debugger.
6. **In-card Emulation:**
   Ashling Smart Card Emulator and PathFinder Source Debugger, with Ashling ISO7816-format Probe Adapter
7. **Verification:**
   Code Coverage Measurement: **For 80C51-core and SmartMX-core Smart Cards:**
   Ashling Ultra-51 series Smart Card Emulator and Ashling CodeScan-51 Code Coverage Measurement System
   Code Coverage Measurement: **For SmartMIPS-core Smart Cards:**
   Ashling Ultra-51 series Smart Card Emulator and Ashling CodeScan-51 Code Coverage Measurement System
   Performance Analysis: **For 80C51-core and SmartMX-core Smart Cards:**
   Ashling Ultra-51 series Smart Card Emulator and Ashling STARS-51 Performance Analysis System
   Performance Analysis: **For SmartMIPS-core Smart Cards:**
   Ashling Vitra-MIPS or Opella-MIPS Smart Card Emulator and PathFinder-MIPS Source Debugger.
   Ashling Vitra-MIPS Smart Card Emulator with Trace and PathFinder-MIPS Source Debugger
8. **Validation:**
   Ashling Smart Card Emulator and PathFinder Source Debugger, with Ashling ISO7816-format Probe Adapter
9. **First die production and test:**
   Ashling ISO7816-format Probe Adapter, with user's sample packaged die fitted
10. **Volume die production.**

4 Secure Development Environment

Ashling's range of development tools provides a comprehensive and powerful environment for all stages of development for Philips' Smart Cards and Contact/Contactless (dual-Interface) cards. Working in co-

operation with Philips, Ashling's products and procedures ensure the security and reliability of Smart Card programs.

5 Summary of Ashling Smart Card tools for 80C51 and SmartMX cores

5.1 Compiler

Ashling supplies and supports the Keil CA51 Keil CA51 Compiler, Assembler and Linker, which is the recommended software platform for 80C51-core Smart Cards.

For SmartMX-core Smart Cards, Ashling supplies and supports the Keil PK51 Compiler, Assembler and Linker, the recommended software platform for 80C51-core Smart Cards.

Full information on these Compilers is available at www.ashling.com/compilers/keil.html

5.2 Emulator

Ashling's Ultra-51 series Emulators provide real-time In-Circuit Emulation for Philips Semiconductors P8WE5xxx and P8WE6xxx Smart Cards, P8RF5xxx and P8RF6xxx Contact/Contactless Dual-interface cards, and P5CTxxx SmartMX Triple Interface cards.
Features of the Ultra Emulator include:

- Uniform, upgradeable platform for all Smart Card families (Contact and Contactless)
- 32K frames x 96-bit trace, expandable to 512K
- Time-Stamp on all traced frames
- On-the-fly breakpoints, trigger, trace, variables display
- Fully software-configurable; FPGA hardware allows easy upgrades

5.3 Source Debugger

Ashling's PathFinder-51 Source Debugger provides the user-interface for the Ultra Emulators. Controlled by button-bar, menus, mouse or automated script files, PathFinder supports all Philips Semiconductors Contact and Dual-interface Smart Cards.

5.4 Code Coverage Measurement

Ashling's "CodeScan" Code Coverage Measurement option for the Ultra Smart Card Development System identifies all tested, untested and unreachable code in a Smart Card program. This allows you to implement a repeatable, step-by-step program test procedure, to ensure that every byte of code has been tested, and to keep a formal record of test completeness.

5.5 STARS Performance Analyzer

Ashling's STARS (Software Test, Analysis and Reporting System) Performance Analyzer option for the Ultra-51 series Smart card Emulators measures the maximum, minimum and total execution time of every function in the program code, in real-time. You can measure and optimize the execution time of your Smart Card program, identify untested program paths, and verify conformance to an execution-time specification.

6 Summary of Ashling Smart Card tools for SmartMIPS cores

6.1 Compiler

Ashling's AsIDE-MIPS Integrated Development Environment installs and drives the GNU GCC MIPS Compiler for SmartMIPS cores. AsIDE-MIPS supports all Philips Semiconductors Contact and Dual-interface Smart Cards.

6.2 Emulator

Ashling's Vitra-MIPS Networked Emulator with Trace and Opella-MIPS compact EJTAG Emulator provide real-time In- Emulation for Philips Semiconductors SmartMIPS Smart Cards.

Features of the Ashling Emulators include:

- Uniform, upgradeable platform for all SmartMX-core Smart Card families
- 64K frames x 128-bit trace, expandable to 512K frames (Vitra-MIPS)
- Time-Stamp on all traced frames

- On-the-fly breakpoints, trigger, trace, variables display
- Fully software-configurable; FPGA hardware allows easy upgrades

6.3 Source Debugger

Ashling's PathFinder-MIPS Source Debugger provides the user-interface for the Vitra and Opella Emulators. Controlled by button-bar, menus, mouse or automated script files, PathFinder supports all SmartMIPS-core Smart Cards.

6.4 Performance Analysis and Code Coverage Measurement

Ashling's PathFinder-MIPS Source Debugger, when used with the Vitra-MIPS Networked Emulator and Trace, can be used to measure and optimize the execution time of your Smart Card program, identify untested program paths, and verify conformance to an execution-time specification.

PathFinder-MIPS and Vitra-MIPS can also be used to identify all tested, untested and unreachable code in a Smart Card program. This allows you to implement a repeatable, step-by-step program test procedure, to ensure that every byte of code has been tested, and to keep a formal record of test completeness.

7 Contactless Smart Card development process

The development process described above applies to both Smart Cards and Contact/Contactless (dual-Interface) cards, with some minor changes for Contactless cards:

- The Architectural design phase must include an important decision: to use either the "built-in" Contactless operating-system kernel for the Contactless communication function; or to create all Contactless functions *ab-initio*.
- During the In-card Emulation, Verification, Validation and First die production and test phases, the Ashling ISO7816-format Probe Adapter (which contains both ISO-7816 format Smart Card contacts, and a Contactless Antenna) is configured as a Contactless Antenna.

8 References

1. "Smart Card Handbook, Second Edition", W. Rankl and W. Effing, ©2000, Wiley, ISBN 0-471-98875-8, Chp. 10.
2. "Smart Cards: A guide to building and managing smart card applications", Henry Dreifus and J. Thomas Monk, ©1997, Wiley, ISBN 0-471-15748-1, Chp. 11.
3. "Tools for Software Quality Assurance in Embedded Systems", APB167, Ashling Microsystems, Inc.
4. "Smart Card Emulators, Probes and Adapters", APB164, Ashling Microsystems, Inc.

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