The EBM2000 System Architecture

Simply Powerful, Secure but Open – the Future of Electronic Books and Advanced Pocketable Consumer Computing

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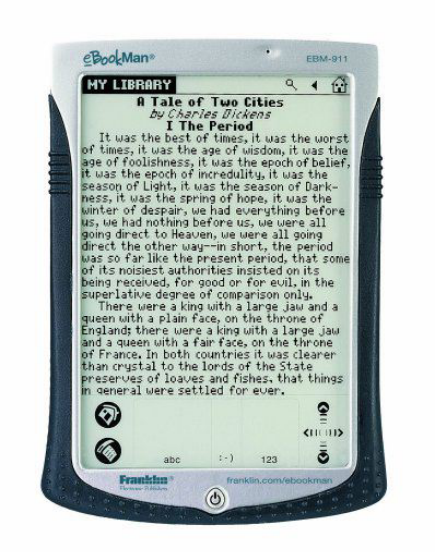
August 24, 2000

Abstract

We give an overview of the hardware/software architecture for hand-held computing behind the eBookMan product line from Franklin Electronic Publishers.

The primary contributions of this architecture and its implementation in eBookMan are the idea of "secure but open" computing, and the best overall price-performance thus far for a multimedia-capable hand-held eBook/computer.



1 Introduction and Vision

Welcome to the world of EBM2000 – the next step in the transition of electronic books and advanced computing to a truly portable and mainstream consumer experience. The eBookMan products are the first pocketable computers based on EBM2000 that set new standards for price-performance while introducing the notion of "secure but open computing."

The earliest hand-held computing devices were single-purpose, including calculators and "closed" ebooks such as spellers, dictionaries, and language translation devices. Franklin first established its leadership in this category with its introduction of the first mass-marketed dedicated eBooks in the late 1980's. Since then it has sold over 21,000,000 of these devices, and they are available today on over 45,000 retail shelves and on the internet. They have become true "appliances."

Next came PDAs. Their focus on personal organization tasks made them instant successes in the marketplace – compounded by their "open" nature that allowed thousands of independent developers to contribute software applications. PDA functionality is now so important that it is moving into other hand-held devices such as cellular telephones.

Because almost everyone is a consumer of media (print and audio), eBooks represent the next important step in the growth of hand-held computing. EBM2000 targets eBook functionality using a Franklin technology base that allows it to reach truly consumer prices. In our view an eBook differs from a PDA in three ways: i) there is more focus on maximizing the screen display, ii) there is an emphasis on multimedia, and iii) there is more emphasis on security and digital rights management (DRM).

Our vision is that future pocketable computers and telephones will fall into three rough categories: i) those with absolutely minimal screens, ii) those with enough screen to handle PDA tasks, iii) those with screen's large enough for eBook functionality and other general-purpose computational tasks. This final category is the focus of EBM2000. While downsized versions of desktop PCs will continue to play an important role in the market, their size, weight, and price will limit their market. Furthermore, ubiquity of wireless connectivity that enables email and Internet access from pocketable computers will decrease the importance of the downsized desktop.

1.1 Interactive Content

Our vision for eBook content is that it spans the spectrum from passive traditional media, to pure interactive content at the other extreme. Reading

a print book, as-is, is an example of passive content. A video game or math quiz program is an example of largely interactive content. In between are wonderful possibilities that represent an exciting dimension of the EBM2000 vision. Beyond the dictionaries and language devices Franklin has already pioneered, we see, for example, textbooks that have been made interactive in a meaningful way to enhance student learning and teacher productivity.

From its first eBooks, Franklin has taken pride in going beyond facsimile publication – adding spelling correction and indexing to every product and amazing search features to books such as the Bible. This is a Franklin tradition that EBM2000 expands into the world of open eBooks by allowing publishers and developers to create exciting interactive content that can reach a world-wide audience thanks to eBookMan's low price. Because EBM2000 is the first platform of its kind that can reach retail prices affordable by just about any school, we hope our work has a positive impact on education.

1.2 Open but secure architecture

An important contribution of the EBM2000 architecture is its introduction of the idea of "open but secure" computing. The earliest hand-held machines, as well as the first generation eBooks, were secure but closed systems. PDAs are open but not secure. eBookMan achieves the best of both – open AND secure. So publisher and developer intellectual property can be protected and licensed using almost any licensing model, while users can enjoy applications and content created and available world-wide.

In EBM2000, the security starts with an authenticated operating system which is protected against virus-infection. The secure operating system, in turn, protects the security of all programs: one program cannot access or interfere with the operation of another, and all data are secure even when written to external storage or synchronized with a PC. Every software publisher has their own secure "sand-box" in which to play freely but privately.

The most apparent aspect of security is safeguarding intellectual property. But security has another important implication. It safeguards the proper operation of the operating system and installed software. Our vision is that this is a necessary step to achieve "appliance" status for hand-held, or for that matter any computing device.

1.3 Technology as a Package

Lastly, an important part of EBM2000 is the extent of its vertical integration. It starts with a formal (Verilog/VHDL) specification for the processor

itself, associated MMU and other circuits, and extends upward through a modern multitasking microkernel, interface middle-ware, and a suite of application libraries. Finally, at the highest level, EBM2000 includes software applications from partners to provide key applications bundled in every device. Franklin is in a unique position within its industry to produce such an integrated design – and as hand-held eBooks and computing transitions to truly consumer prices, this level of integration represents an important competitive and strategic advantage. In addition to the many innovations of EBM2000, it represents an important component of Franklin's value proposition to its customers.

2 The EBM2000 Hardware

The creation of EBM2000 was guided by a quest for computational power in the context of minimalism – in order to allow EBM2000 implementations to reach extremely low retail prices and multiple simple small form factors.

ASIC Chip The EBM2000 design begins with a single custom ASIC chip manufactured to Franklin's specification. The centerpiece of this chip is a modern 32-bit RISC processor, code-named the SNK, designed in Franklin's engineering center. Clocked at 24MHz, it is several times faster than the most popular processor used in today's PDAs and features highly compact object code. Using the popular Dhrystone 1.1 and 2.1 benchmarks eBookMan's SNK processor delivers 4821/3846 Dhrystones per second respectively – corresponding to 2.7/2.2 VAX MIPS respectively.

Privileged mode Hardware support for security begins with a special privileged processor mode which is only available to the operating system. An integral MMU supports virtual memory so that each application receives its own secure gigabyte address space. Because all low-level hardware details are hidden by the privileged mode, EBM2000 can evolve its hardware heart without obsoleting applications. To give a complete picture of EBM2000 and its initial eBookMan implementations we now describe some of its low-level details even though many are hidden by operating system abstractions.

Memory Main memory consists of an SDRAM chip under control of the ASIC. Sophisticated prefetching and timing coordination provide a *surrogate* cache and contribute to the processor's speed. The initial

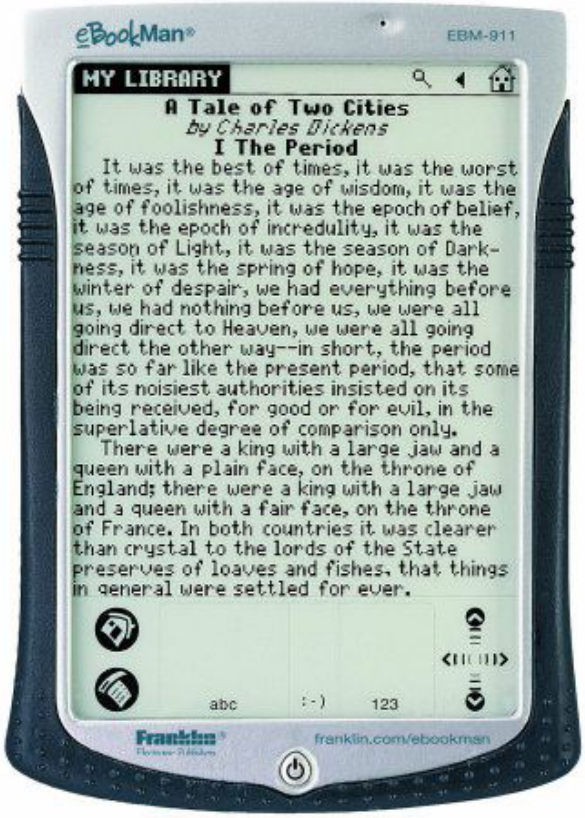


Figure 1: Franklin's eBookMan – introduced in 2000 – a new pocketable media device and computer. It introduces the idea of "secure but open" computing, and establishes the best overall price-performance thus far for a multimedia-capable hand-held eBook/computer.

eBookMan implementations of EBM2000 provide either 8MB or 16MB of RAM memory, but the design scales to larger values. A special scratch-pad RAM on the ASIC is used by privileged applications to further accelerate critical code segments. Nonvolatile memory and bootstrap operation are provided by a single external flash memory device.

Display The ASIC features an LCD display control circuit that generates 16 resolved gray levels by using special nonlinear coding techniques, and reduces display artifacts using a pseudorandomization technique. Initial EBM2000 devices include a 240x200 pixel display that displays 87% more information than the 160x160 size that has become standard for PDAs. Such screen size is just big enough to generate an acceptable reading experience, while allowing implementations to remain pocketable and low-cost.

Selected models include advanced polarizer technology for advanced contrast and viewing angle. An electroluminescent backlight is provided on selected initial models along with a software image "flip" feature to counter the black/white inversion that takes place when backlighting and advanced polarization are combined under low lighting levels.

Power Consumption Electrical power minimization is a first-order design objective of EBM2000 and despite their computational power, the eBookMan products operate with only two AAA batteries.

Touch-panel EBM2000 includes touch-panel operation and software drivers for handwriting recognition from any region of the screen. Initial EBM2000 implementations use a standard resistive touch-panel and passive stylus. Below the active screen area there is also a special marked handwriting area with separate regions for alphabetic, punctuation, and numeric characters. This 3-way approach enhances accuracy and simplifies the expression of punctuation – a common complaint with many of today's hand-held devices. There are also two special icons, and a unique "scratch-scroll" region described in the following section.

Expansion Expansion is provided through a standard plug-in multimedia card (MMC) that may hold either flash (R/W) or ROM storage – up to 64MB with today's MMC devices. The MMC interface circuits are included in the ASIC.

Connectivity Connectivity is provided via a USB interface that may function in either host, device, or in a special RS232(Asynchronous) mode. On initial models Internet connectivity is provided by external USB modems (conventional and wireless). A special USB cable can be provided to connect an eBookMan to an automobile power adaptor. Another cable allows eBookMan to connect to a PC using RS232(Asynchronous) rather than its default USB. A simple external cradle mechanically houses the unit on a desktop. It includes no electrical components other than a cable, which is integrated into the housing. While cradled eBookMan draws power from its host – not from its internal batteries.

Audio The audio subsystem consists of a 13-bit DAC that operates at up to approximately 24KHz, along with a 10-bit ADC. All units include a small speaker (not intended for public audio output), a headphone jack, and a microphone.

Clock All system clocks are derived from a single 32KHz crystal, which also provides the real-time clock.

Buttons The EBM2000 design requires a single button, the power button, which also controls the backlight if depressed continuously. The eBookMan also includes a separate multi-position actuator, offering two "forward" and two "reverse" positions, resting at center position. It may be depressed to generate "Click" events. The function of this switch is context sensitive and controls page-up/down in books, LCD contrast, Audio volume, and any other controls determined by the application. A small recessed reset button provides emergency system reboot.

3 The EBM2000 Software

The EBM2000 operating system provides a modern, uniform, "big-system" environment that abstracts away all hardware details and features a gigabyte virtual memory space for every application. It is built on a state-of-the-art microkernel that provides preemptive multitasking, multiple threads per process, and interprocess communication.

Launcher The user interacts with the system through a Launcher that allows applications to be selected via the touch panel. A feature of EBM2000 is that users may return later to continue using an application, rather than restarting it as is common with many current PDAs.

Handwriting takes place either in a special touch-pad region below the LCD, or anywhere on the screen under program control. Touch-pad icons below the LCD are used to immediately return to the launcher, or to activate a menu of options. A pop-up keyboard provides an alternative to handwritten input.

Scrolling A unique "scratch-scroll" area of the touch-pad allows the user to move up and down, or pan left and right, using simple gestures. This alternative to scroll bars eliminates the difficulty of precise continued positioning which is required by most handhelds in order to perform these operations.

Initial Bundled Applications The initial core set of eBookMan applications include eBook readers, a music player, an audio book player, an organizational suite, and a voice memo recorder. Many others will become available through a growing community of independent developers, and Franklin's own targeted development. The eBookMan software environment includes a PC application that supports synchronization with personal information managers, downloading and transcoding of various media types, and transparent backup of eBookMan's entire memory while maintaining the security of all protected information.

Security The eBookMan secure publishing software components are used by Franklin and its publishing partners to create secure content for distribution on the Web and otherwise. The description of Franklin security and digital rights management infrastructure appears in a companion document.

SDK The eBookMan developer's tool kit (SDK) can be used under Linux, or within the 'CYGWIN' environment under Windows. Compilation and debugging are provided by Franklin adaptations of the well-known gcc/gdb tools. An integrated emulation environment allows applications to be developed and tested prior to running them in actual eBookMan hardware.

Developers access the system through libraries that include:

- STANDARD: "Standard Libraries" familiar to C/C++ programmers providing memory allocation, math and string functions, and many others.

- GUI: "Graphical User Interface" providing a complete selection of drawing elements and widgets.
- EVENT: "Event Manager" providing input events from the touch-pad and all other sources, in addition to operating system signals.
- DATABASE: "Database Object" providing a simple abstraction for RAM-based record/field oriented databases similar to those employed by PDA programming environments.
- MEMORY: "Memory Object" providing a low-level abstraction for shared and secure memory objects associated with the program. These fill the role of "files" in the system.

Additional libraries exist, and more will be created as EBM2000 matures. The associated documentation is available in print and hyper-linked online forms.

4 EBM2000 and the Future of Entry-Level eBooks

The core elements of EBM2000 will power the world's next generation of dedicated eBooks, reaching markets that do not require full-scale open-system functionality. For the first time developer's world-wide will be able to create low-cost dedicated consumer eBooks within a modern development environment for applications that range from education, to travel, to vertical industrial markets. Franklin's introduction of the world's first products of this kind, such as spellers, dictionaries, and Bibles in the 1980's fired the imagination of developers everywhere, and spawned the creation of a small industry. Now, down-sized implementations of EBM2000 will unleash this imagination, for the first time at the level of individual creative developers and organizations who are close to their markets and can best recognize and express dedicated product designs.