Am29000/Am29027

Advanced
Micro
Devices

Floating-Point Support Strategy

By

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Floating-Point Support for the Am29K Family

Overview

The Am29000 32-bit microprocessor has advanced architectural features that provide extremely high throughput for integer computation. With a measured performance of 42,000 Dhrystones, the Am29000 easily outperforms conventional microprocessors, minicomputers, and super-minis.

In addition to providing outstanding integer performance, the Am29K family also supports high-speed floating-point computation. Floating-point-intensive applications, such as graphics, font generation, scientific computing, and signal processing, can reach new levels of performance.

By choosing among several options for floating-point support, the implementor can tailor the floating-point performance—and the overall system cost—to the application. These options are fully supported by Am29K hardware and software. Moreover, floating-point software written for the Am29000 today can be transported to future Am29K processors without modification.

Am29000 Floating-Point

The Am29000 instruction set includes fifteen opcodes for floating-point operations, including addition, subtraction, multiplication, division, comparison, and format conversion. These opcodes specify arithmetic operations for both single-precision (32-bit) and double-precision (64-bit) floating-point formats, and conversions between single-precision, double-precision, and integer representations.

The Am29000 floating-point instructions are implemented as traps. When a floating-point opcode is encountered in the instruction stream, the Am29000 executes the appropriate trap handler routine. Trapping on floating-point operations allows the implementor to tailor floating-point performance to the needs of the target system. For applications that require modest floating-point throughput, the opcodes can trap to software emulation routines; for higher-performance applications, the trap handler can drive a hardware arithmetic accelerator. For very high performance systems, traps can be dispensed with entirely, by executing code that communicates with an arithmetic accelerator directly. Even higher performance can be expected from future Am29K processors, which will directly execute Am29000 floating-point opcodes.

Floating-Point Options

The Am29K family provides both hardware and software solutions to floating-point acceleration.

Hardware Floating-Point Acceleration

Applications that are computation-intensive will benefit from the Am29027 Arithmetic Accelerator. The Am29027 is a high-speed computation unit that performs both floating-point and integer calculations, and that can improve the arithmetic throughput of an Am29000 system by an order of magnitude or more. Its features include:

- an arithmetic-logic unit (ALU) that performs a large repertoire of single-precision and double-precision floating-point and integer operations, including addition, subtraction, multiplication, comparison, and format conversion. Because the ALU uses combinatorial logic, rather than the multi-cycle serial/parallel logic found in most conventional coprocessors, it offers very low operation latency. The ALU can be configured in a completely combinatorial flow-through mode, or can be pipelined, at the user's option, to support vector operations.

- an 8-word-by-64-bit register file, for the storage of intermediate results.

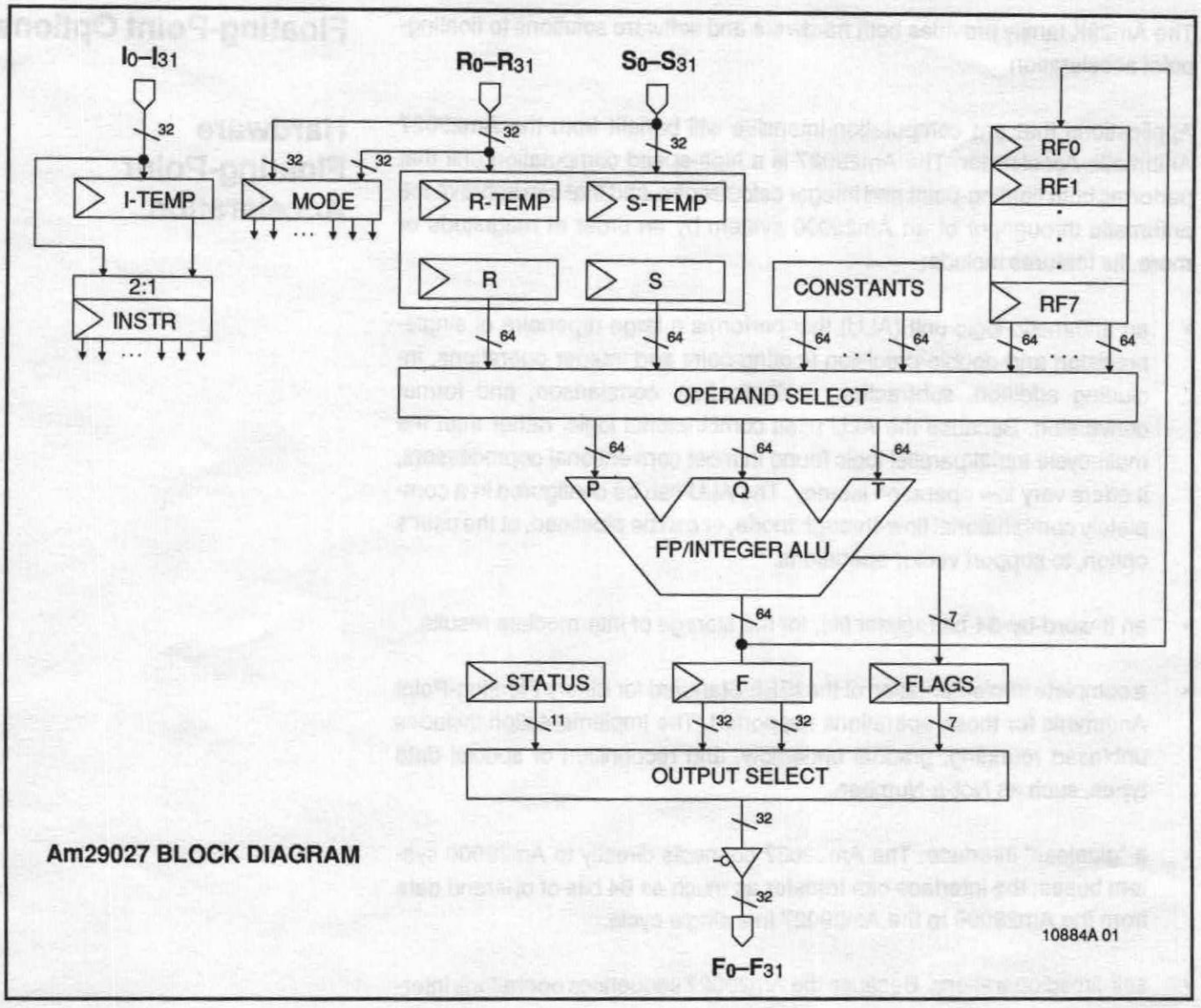
- a complete implementation of the IEEE Standard for Binary Floating-Point Arithmetic for those operations supported. The implementation includes unbiased rounding, gradual underflow, and recognition of special data types, such as Not-a-Number.

- a "glueless" interface. The Am29027 connects directly to Am29000 system buses; the interface can transfer as much as 64 bits of operand data from the Am29000 to the Am29027 in a single cycle.

- self-timed operations. Because the Am29027 sequences operations internally, the Am29000 is free to perform its own operations in parallel with accelerator operations. Self-timing also serves as an interlock mechanism, ensuring the correct handling of data dependencies.

- double-buffered input registers. Each Am29027 input register is preceded by a temporary holding register, permitting the specification of a new accelerator operation while another operation is in progress.

- extensive exception-handling support. Several options permit the implementor to accommodate anomalous conditions, such as overflow and underflow. If desired, failed operations can be completely reconstructed by recovering the state of the accelerator at the time the exception occurred.



Am29027 BLOCK DIAGRAM

- state save and restore. In flow-through mode, the entire accelerator state can be saved and restored, thus facilitating task switching and interrupt handling.

Traditional floating-point coprocessors offer operation times in the microsecond range. The high-speed combinatorial logic of the Am29027 produces results in less than a quarter of a microsecond for most basic arithmetic operations.The Am29027 has two primary modes of operation: flow-through mode, in which the ALU is completely combinatorial, and pipeline

Table 1: Am29027 Flow-through Mode Performance

Operation	time (ns)
floating-point addition (single or double-precision)	240
floating-point multiplication (single or double-precision)	240
floating-point multiplication-accumulation (A*B+C) (single or double-precision)	360
integer multiply (64b ← 32b * 32b)	240

Note: Times for register-to-register operations within the Am29027, clock frequency = 25MHz.

10884A 02

mode, in which the ALU is divided into two or more pipeline stages.Flow-through mode performance for the Am29027 is summarized in table 1.

In pipeline mode, a new operation -of any type- may be started every 120 ns. Pipeline mode is particularly useful for performing vector and matrix operations, such as those found in graphics and scientific applications. For example, the Am29027 can multiply a 4-by-4 matrix by a 4-by-1 matrix—a compound operation requiring 16 multiplications and 12 additions—in 3.6 us.

Floating-Point Emulation

For applications with more modest computation requirements, the Am29000 can emulate floating-point operations in software. Owing to its ability to perform a wide variety of single-cycle integer operations—such as addition, subtraction, shifting, and masking—the Am29000 is ideally suited for efficient floating-point emulation.To assist designers who choose to implement floating-point in software, AMD offers a complete package of emulation routines. This package provides IEEE-compatible emulation for all Am29000 floating-point instructions, and can be easily integrated with application software that is developed on Am29K compilers and assemblers.Am29000 floating-point emulation performance is summarized in table 2.

Table 2: Software Emulation Performance

Operation	time (us)
single-precision:	
floating-point addition/subtraction	4.8
floating-point multiplication	5.7
floating-point division	5.9
double-precision:	
floating-point addition/subtraction	6.7
floating-point multiplication	11.9
floating-point division	29.3

Note: Clock frequency = 25MHz.

10884A 03

Software Support for Floating-Point

Both the hardware acceleration and software emulation options for floating-point arithmetic are fully supported by Am29K family software, including compilers, assemblers, floating-point libraries, and trap handlers.

Compilers

AMD and third-party vendors offer C, FORTRAN, and Pascal compilers that support floating-point operations. The user has the option of producing compiled code containing Am29000 floating-point opcodes that trap to the appropriate handler, or generating in-line code that communicates with the Am29027 directly.

Assemblers

AM29K assemblers fully support access to the Am29027. A special set of accelerator macros allows the programmer to easily specify transactions between the Am29000 and Am29027, and to specify and execute all Am29027 instructions.

Floating-Point Libraries

AMD provides an optimized floating-point library that supports the following special math functions:

- absolute value
- field extraction
- square root, remainder
- ceiling and floor
- trigonometric (e.g., sin, cos, tan)
- logarithms, exponentials

The library functions can be called from C, FORTRAN, or Pascal source code. The library is available in two versions—one containing Am29000 floating-point opcodes that trap to the appropriate handler, and one containing in-line code that communicates directly with the Am29027.

Trap Handlers

AMD provides two software options for applications requiring floating-point trap handlers. For systems that contain a hardware floating-point accelerator, AMD provides trap handlers that transparently dispatch floating-point instructions to the Am29027. For systems that do not have an Am29027, AMD offers trap handlers that emulate all Am29000 floating-point instructions in software.

Typical System Configurations

System 1 Software Emulation

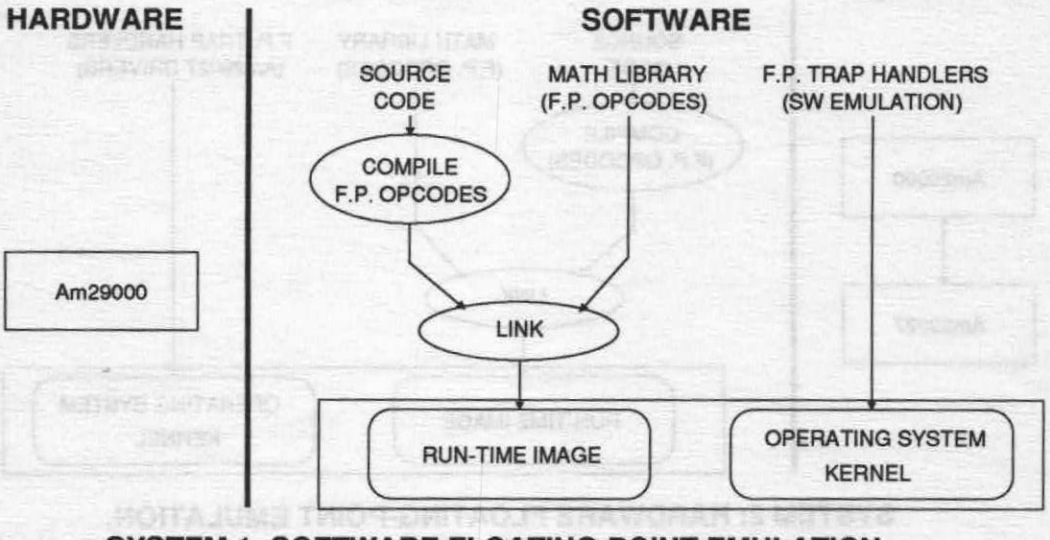
Although the implementor is free to tailor floating-point performance to application requirements, most Am29000 floating-point systems will fall into three general categories.

Systems that do not contain an Am29027 can perform floating-point operations by trapping to the appropriate software emulation routine whenever an Am29000 floating-point opcode is encountered in the instruction stream. This option has the advantages of low cost, good performance, and binary and source code compatibility with systems containing an Am29027 accelerator; it is also fully supported by AMD and third-party software tools. Executable code is prepared by:

- compiling source code with an Am29K compiler configured to issue Am29000 floating-point opcodes

- linking the resultant object code with the version of the floating point math library containing floating-point opcodes (in systems using shared libraries, this link is performed at run-time).

Trap routines that perform software emulation of floating-point operations are installed by the operating system at boot-up. In systems for which all instruction memory is ROM, these software emulation routines become part of the ROM image. Because the binary code produced during the compile and link process is unaware of trap handler internals, it can be transported between systems that have an Am29027 and those that do not.



SYSTEM 1: SOFTWARE FLOATING-POINT EMULATION

10884A 04

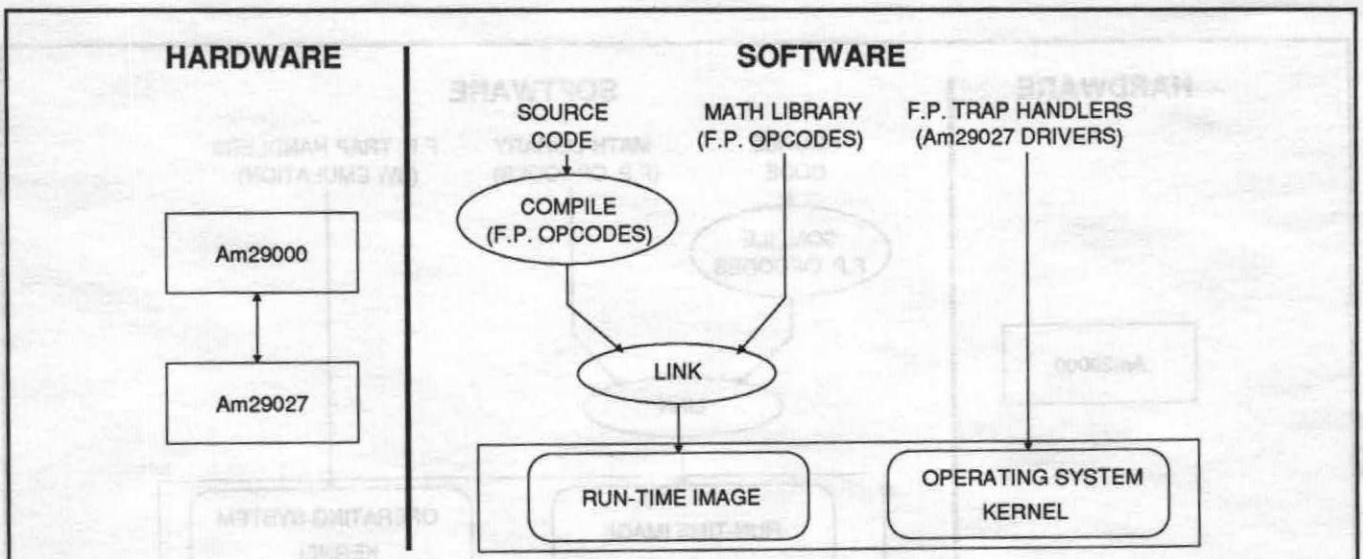
System 2 Hardware Acceleration, Trapped Operation

Systems that have an Am29027 can perform floating-point operations by trapping to the appropriate Am29027 driver routine whenever an Am29000 floating-point opcode is encountered in the instruction stream. This option has the advantages of moderate cost, very good performance, and binary and source code compatibility with systems that do not contain an Am29027; it is also fully supported by AMD and third-party software tools. Executable code is prepared by:

- compiling source code with an Am29K compiler configured to issue Am29000 floating-point opcodes
- linking the resultant object code with the version of the floating-point math library containing floating-point opcodes (in systems using shared libraries, this link is performed at run-time).

Trap routines that dispatch floating-point operations to the Am29027 are installed by the operating system at boot-up. In systems for which all instruction memory is ROM, these Am29027 driver routines become part of the ROM image.

Because the binary code produced during the compile and link process is unaware of trap handler internals, it can be transported between systems that have an Am29027 and those that do not.



SYSTEM 2: HARDWARE FLOATING-POINT EMULATION, TRAPPED OPERATION

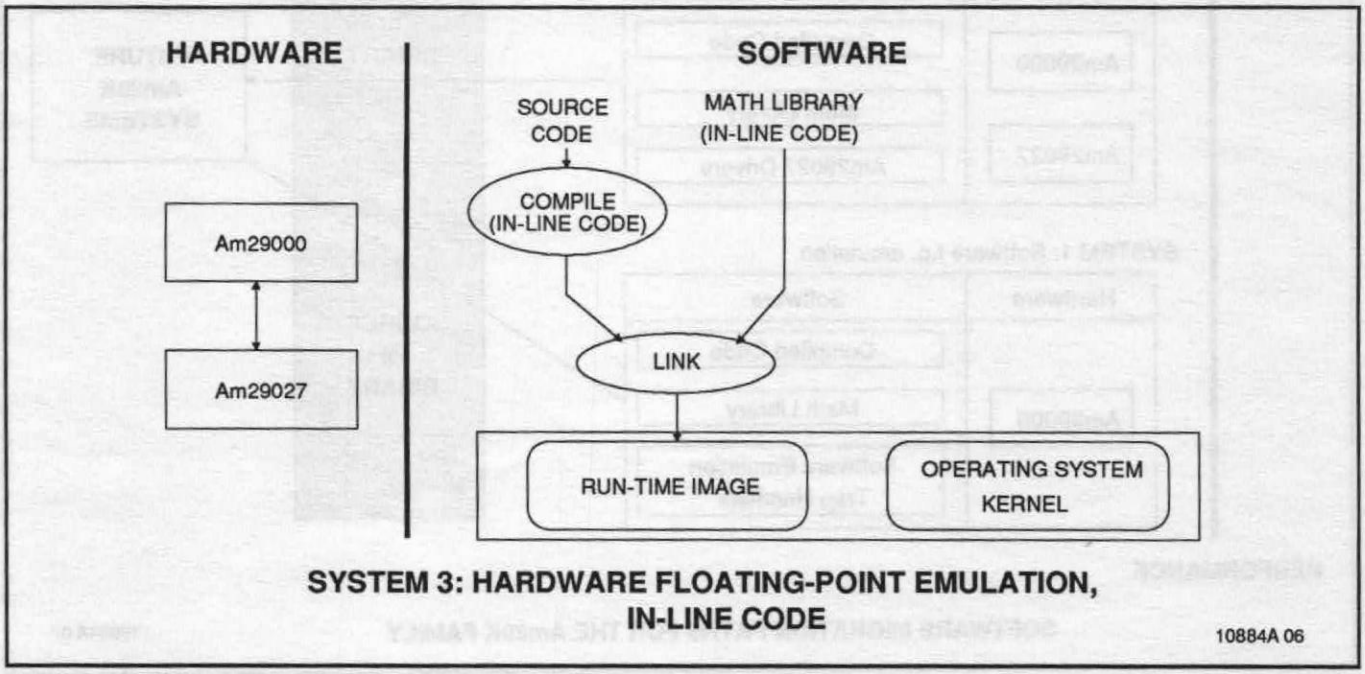
10884A 05

System 3 Hardware Acceleration, In-Line Code

Systems requiring the very highest floating-point throughput can perform floating-point operations by executing in-line code that drives the Am29027 directly. Using such code not only eliminates trap overhead, but also makes the best use of Am29027 resources. This option has the advantages of moderate cost, excellent performance, and source code compatibility with systems that do not contain an Am29027; it is also fully supported by AMD and third-party software tools. Executable code is prepared by:

- compiling source code with an Am29K compiler configured to issue in-line code that communicates with the Am29027 directly
- linking the resultant object code with the version of the floating-point math library containing in-line floating-point code that communicates with the Am29027 directly (in systems using shared libraries, this link is performed at run-time).

This approach does not require trap handlers.



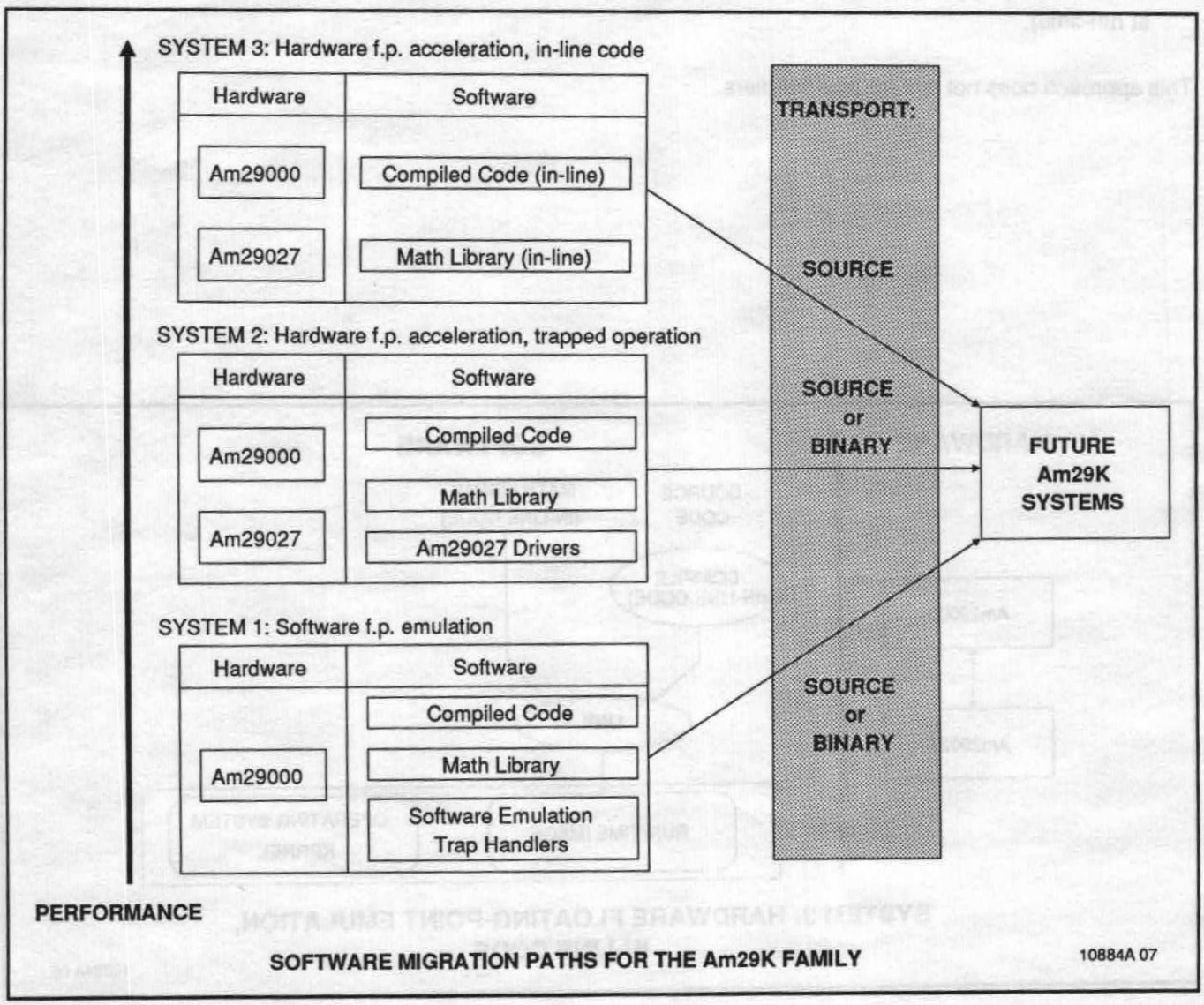
SYSTEM 3: HARDWARE FLOATING-POINT EMULATION, IN-LINE CODE

10884A 06

Future Compatibility

The Am29K floating-point strategy is designed to support not only today's needs, but tomorrow's. Software developed for any of the three system configurations previously described can be transported to future Am29K processors.

Software developers using Am29000 floating-point trapped operation (systems 1 and 2) will be able to transport either binary or source code to future Am29K Family systems; developers who choose to generate in-line code for the Am29027 (system 3) will be able to transport source code. Regardless of the option chosen, code transported to future processors will run at significantly higher speeds.



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