

THE M68HC16 AND M68300 FAMILIES OF MODULAR MICROCONTROLLERS



the
ADVANCED MICROCONTROLLER
Family



MOTOROLA
Semiconductor Products Sector



A FAMILY TRADITION THE M68HC16 AND M68300 MODULAR MICROCONTROLLERS

Generation after generation, Motorola continues to build on its long tradition of superior microcontroller design. You'll find this heritage in the M68HC16 and M68300 modular microcontroller families.

THE M68HC16 FAMILY

The 16-bit M68HC16 modular microcontroller family offers Motorola customers a versatility unsurpassed by any other supplier. In addition to a CPU featuring faster multiply, divide and integrated DSP functions, as well as speeds running eight times faster than standard 68HC11 microcontrollers, the M68HC16 Family also boasts an extensive list of standard features and modular peripherals that make this highly integrated family the perfect choice for a wide range of embedded control applications.

THE M68300 FAMILY

The M68300 is a powerful 32-bit modular microcontroller family with a CPU based on the 68000 instruction set. It combines high performance data manipulation capabilities with a group of peripheral subsystems. Because the family is built with standard modules that interface through a common Intermodule Bus (IMB), the time it takes to develop new customer-specific derivatives is greatly reduced.

The modular design concept, as well as features of both the M68HC16 and M68300 modular microcontroller families are reviewed on the following pages, including:

- Core features
- Typical applications
- Peripherals
- Hardware and software tool support

Come meet the members of the M68HC16 and M68300 Families.

THE MODULAR DESIGN CONCEPT

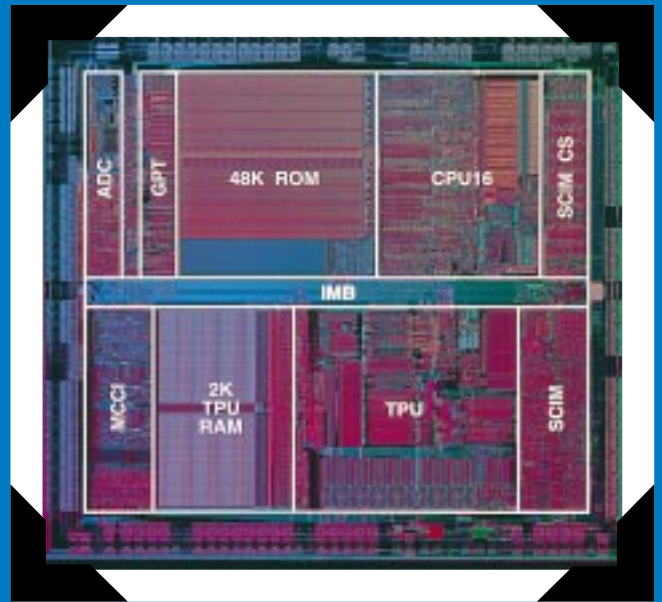
A hardware or software system has “modular architecture” when each component, or module, can be replaced independently of all other modules.

Motorola’s modular design methodology assures customers that proven on-chip peripherals may be combined to meet specific market and application needs. For example, the M68HC16 and M68300 Families use Motorola’s standard Intermodule Bus (IMB). The primary advantage of using a common bus is that devices can share common modular on-chip peripherals. This feature not only makes the best use of modules that are known performers, proven and tested in thousands of applications; it also allows driver code written in C for the M68HC16 devices to simply be recompiled and run on an M68300 Family member without changes.

AT THE CORE OF THE M68HC16

The CPU of the M68HC16 is a true 16-bit high speed processor. Because CPU16 was designed with a rich, orthogonal instruction set and memory-mapped I/O, the microcontroller is very easy to program. The instruction set supports high-level languages and is optimized for compiler performance. A key feature is the System Integration Module (SIM). It contains chip select logic that eliminates external glue logic, which other microcontrollers need to interface with external memory. In all, the SIM reduces chip count, decreases the size and cost of an implementation, and simplifies and quickens development of M68HC16 Family applications. CPU16 is upward source-code compatible with our 8-bit industry-standard M68HC11 microcontrollers. Other features in the fully static design include:

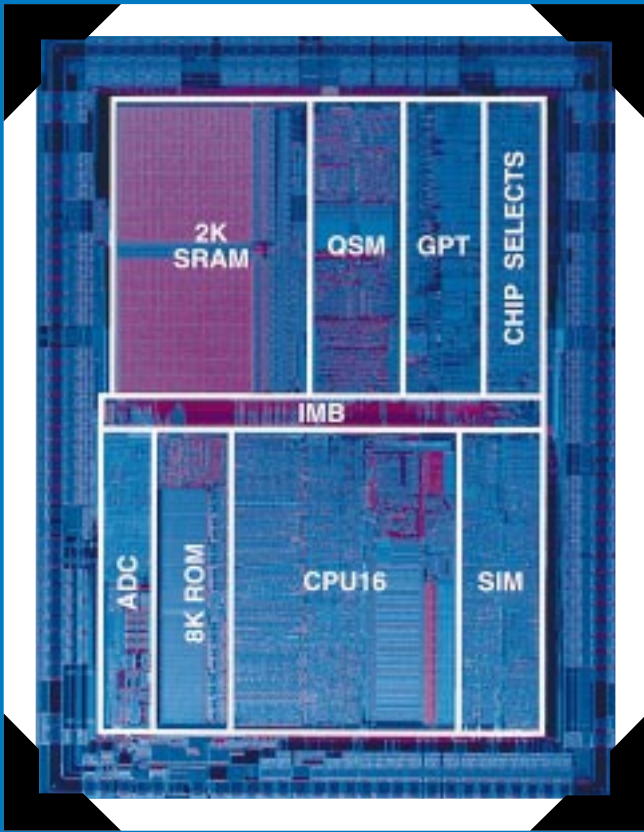
- Enhanced 16-bit implementation of the 68HC11 CPU
- Digital Signal Processing (DSP) functions
- Background Debug™ Mode
- High-level language support
- 1 Mbyte data space
- 1 Mbyte program space
- Two 16-bit general purpose accumulators
- Three 16-bit index registers



The 68HC16Y1 incorporates a true 16-bit CPU, SCIM, 10-bit ADC, a MCCI, GPT, TPU, 2 Kbyte standby RAM module and a 48 Kbyte masked ROM module.

- Dynamic 8- or 16-bit bus sizing
- Fast interrupt response time
- 16 MHz, 20 MHz, and 25 MHz versions
- 2.7 V to 3.6 V, as well as 5.0 V versions

The M68HC16 Family is continually being expanded to meet new embedded control requirements with a growing selection of on-chip peripherals including A/D converters, timers, serial I/O, RAM, ROM, and non-volatile flash EEPROM memory.



The 68HC16Z2 incorporates 12 chip selects, a synthesized clock, a true 16-bit CPU with integrated DSP, 8 Kbytes ROM, 2 Kbytes SRAM, 10-bit ADC, QSPI, and GPT.

M68HC16 MICROCONTROLLER FAMILY APPLICATIONS

The unique modular approach of the M68HC16 microcontroller family combines a standardized central processor, the CPU16, and an Intermodule Bus (IMB), that provide a basic framework on which existing peripheral modules can be easily integrated to meet market demands for a wide range of embedded control applications. Additionally, the M68HC16 microcontroller family runs eight times faster than standard members of the 8-bit

M68HC11 Family, making it an optimal microcontroller for a wide range of embedded control applications, including:

- Automotive management systems
 - Active suspension
 - Anti-lock Braking Systems (ABS)
 - Engine and transmission control
- Telecommunications equipment
 - Digital and analog cellular phones
 - Telephone switching
 - Hand-held radios
- High-end consumer electronics
 - Cable TV boxes
 - Camcorders and cameras
 - Digital audio systems
- Office automation equipment
 - Fax machines
 - Modems
 - Plain paper copiers
- Computer subsystems
 - Hard disk drives
 - Tape drives
 - Magneto-optical disk drives
- Industrial control and instrumentation
 - ATM machines
 - Card readers
 - Bar code readers
 - Medical equipment
 - Robotics

AT THE CORE OF THE M68300

Along with sharing a common product development history, including Motorola's standard Intermodule Bus (IMB), the M68300 Family uses the same on-chip peripherals, external bus interface and development systems as the M68HC16 Family – allowing easy migration from 16- to 32-bit applications.

Based on the Motorola 68000 instruction set, the performance improvements include instructions developed for Motorola's 68010 and 68020 microprocessors as well as additional instructions for embedded control and data movement. CPU32 features include:

- M68000 Opcode Compatibility

- Selected M68010 Enhancements (Virtual Memory, Vector Base Register, Loop Mode)
- Selected M68020 Enhancements (Addressing Modes, Instructions)
- Background Debug Mode
- High level language support
- 16 Mbyte program space
- Dynamic 8- or 16-bit bus sizing
- Fast interrupt response time
- 16 MHz, 20 MHz, and 25 MHz versions
- 2.7 V to 3.6 V, as well as 5.0 V versions
- Low Power Stop (LPSTOP) instruction
- Table Look-Up and Interpolate (TABL) instruction
- Advanced debug support (Opcode Tracking, BDM, Breakpoint Pin)

In all, the M68300 Family of microcontrollers combines a powerful 32-bit architecture with many popular peripherals to create a wide range of unique solutions where cost, integration and performance are vital.



M68300 MICROCONTROLLER FAMILY APPLICATIONS

The M68300 is well-suited for high performance applications such as:

- Automotive
 - Engine and transmission control
 - Intelligent Transportation System (ITS)
 - Global positioning
- Consumer electronics
 - VCRs
 - Home video game systems
 - Compact Disc Interactive (CD-I) players
- Communications equipment
 - Digital and analog cellular phones
 - Telephone switching
 - Satellite communications
 - Line cards
- Office automation equipment
 - Laser printers
 - Plotters
 - Pocket secretaries or Personal Digital Assistants (PDAs)
 - Fax machines

- Bubble jet printers and plotters
- Industrial control and instrumentation
 - Bar code readers
 - Factory automation (manufacturing, asset tracking)
 - Test and measurement (Logic Analyzers, Emulators)
 - Medical equipment
 - Robotics

The M68300 microcontroller family is perfectly matched for applications needing 32-bit performance with demanding timing functions, and for control-intensive applications requiring high volume data movement.



IN-CIRCUIT DEBUGGING

BACKGROUND DEBUG MODE

Microprocessor debugging programs are generally implemented with external software. The CPU16 and CPU32 Background Debug Mode provides a debugger implemented in CPU microcode. Background Debug Mode is present on all M68HC16 and M68300 Family members.

Background Debug Mode incorporates a full set of debug options: registers can be viewed and altered, memory can be read or written, and test features can be invoked.

Background Debug Mode simplifies in-circuit emulation by providing much of the needed intelligence as part of the CPU itself, without the use of other MCU resources. Typical emulator hardware replaces the target system processor, and communication



THE 68HC16Z1, WITH ON-CHIP DSP CAPABILITIES, POWERS SPECTRAPHYSICS' HAND-HELD BARCODE SCANNER.

with the target system can take place via a complex serial interface. By contrast, Background Debug Mode uses a simple serial interface that can be implemented with minimal external logic. This results in lower cost, more reliable development tools that provide complete system emulation.



INTELLIGENT INTERMODULE BUS (IMB) PERIPHERALS

The IMB connects the CPU16 and CPU32 to the on-chip “intelligent” peripherals including the System Integration Module (SIM), which allows designers to minimize external glue logic. Other peripheral modules available for M68HC16 and M68300 derivatives include:

TIME PROCESSOR UNIT (TPU)

The TPU is a powerful on-chip peripheral device used in the M68300 and M68HC16 Families of modular microcontrollers. It is a semi-autonomous co-processor dedicated to performing complex, high speed timing tasks without interrupting the CPU.

Major TPU features include:

- Sixteen channels, each associated with an I/O pin, an input capture register, and an output compare register with comparator
- Two free-running 16-bit counters with programmable prescalers used for timing control of channel events
- A task-switched microengine that interfaces to each of the channels and executes microcode programs to control those channels
- A control store (micro-ROM) that contains programs the microengine executes
- A dual-port RAM for communication between the TPU and the host CPU
- Pre-programmed motion control and other functions

More than 20 different timing functions are available in the TPU library, most of which are in two standard microcoded ROMs. This library gives you the ability to access additional timing functions that can be loaded into TPURAM to upgrade and differentiate your application.

The Time Processor Unit 2 (TPU2) is available for M68HC16 and M68300-based applications with complex timing requirements. It provides an expanded control-store (microROM) for programs up to 4 Kbytes and also supports a higher system clock resolution.

GENERAL PURPOSE TIMER (GPT)

The GPT is a simple, yet flexible 11-channel timer, well-suited for systems requiring a moderate degree of timing control.

The GPT features:

- Nine-stage prescaler (independent prescaler taps for capture/compare unit and the PWM unit)
- One 16-bit free-running counter for capture/compare unit
 - Three input capture pins
 - Four output compare pins
 - One input capture/output compare pin
- Second 16-bit free-running counter for two-channel PWM (Pulse Width Modulation) unit
 - Programmable period and duty cycle
 - 8-bit resolution
- An 8-bit Pulse accumulator/event counter input
- Independent clock source input pin

CONFIGURABLE TIMER MODULE (CTM)

The CTM takes modularity one step further. This timer increases flexibility by defining its function in terms of individual submodules, allowing each configuration to match an application’s requirements. And the CTM is easily configurable for different kinds of applications.

CTM features include:

- Counter submodules
 - Clock prescaler
 - 16-bit free-running counter
 - 16-bit modulus counter
- Action submodules



MOTOROLA'S INTERNATIONAL 8200 MAKES EXCELLENT USE OF THE HIGH INTEGRATION AND LOW POWER CONSUMPTION OF THE 68332. THIS PHONE IS A LIGHT PORTABLE DIGITAL CELLULAR PHONE TARGETED TO THE GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS (GSM) MARKETPLACE.

- Programmed I/O
- Single action input capture/output compare channels
- Double action input capture/output compare channels, with PWM mode
- PWM channels
- Real time clock and battery backed data RAM and external clock source
- I/O pin for each input capture/output compare
- Output-only pin for each PWM channel
- External clock input capability
- Interrupt capability on all capture/compare/PWM channels and on counter overflow conditions
- Two, three or four time base buses, allowing greater flexibility in time bases

SYSTEM INTEGRATION MODULE (SIM)

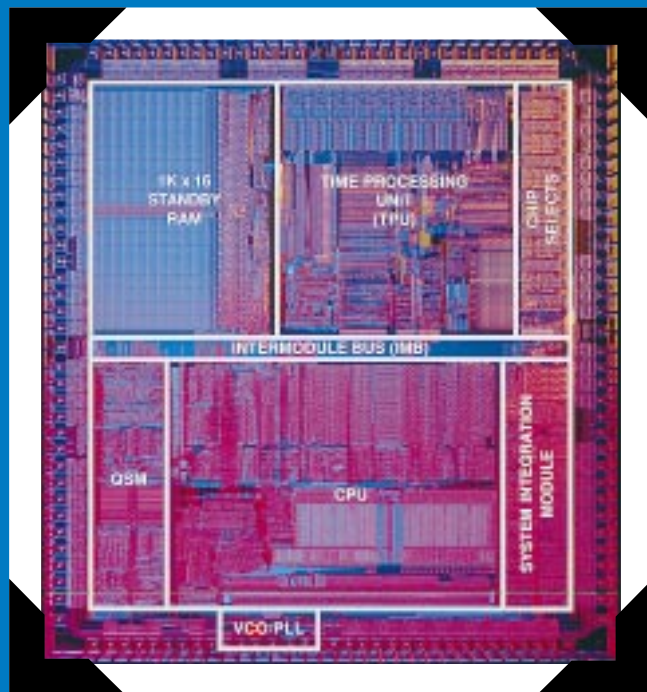
The SIM provides an external bus interface and system failure protection mechanisms including:

- Twelve programmable chip selects with programmable wait states
- External bus supporting dynamic bus sizing
- Watchdog timer
- Seven external IRQ pins configurable between edge and level sensitivity
- Interrupt response monitor (clock and bus monitoring)
- Phase-Locked Loop (PLL) clock system
- Periodic Interrupt Timer (PIT)

SINGLE-CHIP INTEGRATION MODULE (SCIM)

With all of the same features as the SIM, except as noted, the SCIM supports operation in expanded-bus or single-chip modes. Features include:

- Three operational modes
 - Fully expanded (SIM functionality or Single Chip Emulation with nine chip selects)
 - 8-bit Data Bus with Port H as an I/O port
 - Single chip; Ports A, B, E, F, G, and H as I/O ports; Port C as output only
- Watchdog systems
 - Hardware: Bus response time monitor
 - Software: 15.6 milliseconds to 1 second range



The 68332 incorporates a 32-bit CPU, SIM, TPU, QSM, and a 2 Kbyte static RAM module with TPU emulation capability (TPURAM).

An enhanced version of the Single Chip Integration Module, SCIM2, is also available for M68HC16 and M68300 microcontrollers.

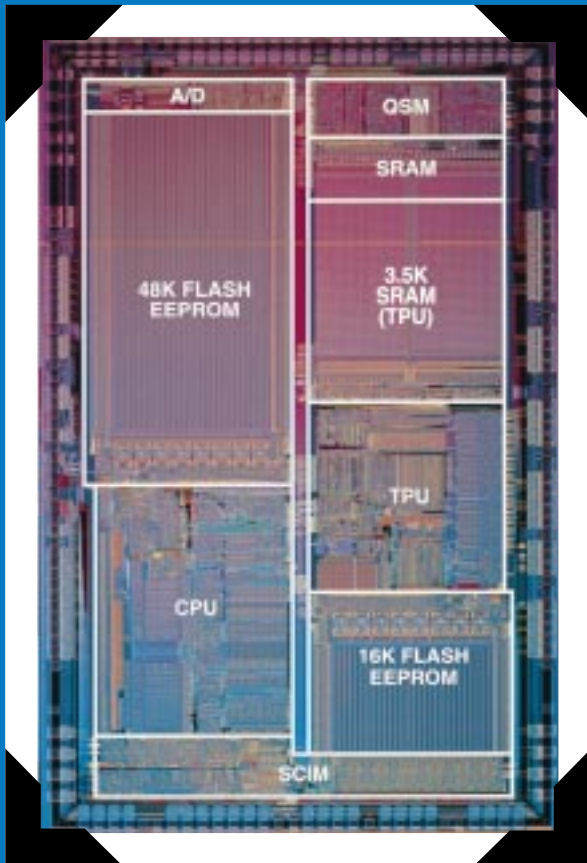
SCIM2 has the same features as the SCIM but also includes:

- Improved re-set controller
- More flexible clock source selection

STREAMLINE INTEGRATION MODULE (SLIM)

- Low pin-count package integration module
 - Minimum of 31 pins, supports full testing
- Phase-Locked Loop clock system or external clock

- PLL driven from 32 KHz, 2-8 MHz crystal or 20 MHz external source
- 16 address pins minimum
 - Optionally supports up to 24, if pins available
- Multiple operational modes
 - Single Chip, Ports A, B, C, D, E, F, G, H as I/O Ports
 - Master Mode - non-multiplexed or multiplexed 8- or 16-bit data bus
 - Peripheral Mode - non-multiplexed 16-bit data bus
- Software watchdog system
- Real-Time Clock
 - Periodic interrupt timer
 - Can be chained with software watchdog for long timeouts



The 68F333 incorporates CPU32, 64 Kbytes Flash, 4 Kbytes static RAM module with TPU emulation capability (TPURAM), SCIM, QSM, and 10-bit analog-to-digital converter.

CONTROLLER AREA NETWORK INTERFACE MODULE (TOUCAN™ MODULE)

The TouCAN module implements the Controller Area Network (CAN) protocol, an asynchronous communications protocol used in automotive and industrial control systems. CAN's high-speed (1 Mbit/sec), short distance, priority-based protocol runs over a variety of mediums, supporting both standard and extended identification message formats.

Our TouCAN module offers full implementation of CAN protocol specification, version 2.0A/B with both standard data and remote frames (up to 109 bits long) and extended data and remote frames (up to 127 bits long). It also allows for 0 to 8 bytes data length and a programmable bit rate up to 1 Mbit/sec. Other features are:

- 16 receive/transmit message buffers of 0 to 8 bytes data length
- No read/write semaphores
- Three programmable mask registers: global, for message buffers 0 through 12; special, for message buffer 14; and special, for message buffer 15
- Programmable loop-back for self test operation
- Global network time, synchronized by specific message
- Low power sleep mode with programmable wake up on bus activity

QUEUED SERIAL MODULE (QSM)

The Queued Serial Module (QSM) contains two serial ports:

- Serial Peripheral Interface (SPI) with enhanced queued RAM and full-duplex, synchronous three-line bus
- Serial Communications Interface (SCI) provides standard asynchronous NRZ format with speeds up to 524K baud
- Four serial chip selects for flexible SPI peripheral addressing
- One 8-bit general purpose I/O port

MULTI-CHANNEL COMMUNICATIONS INTERFACE (MCCI)

The MCCI contains three serial interfaces: a Serial Peripheral Interface (SPI) and two Serial Communication Interfaces (SCI).

- Two independent SCI ports provide standard asynchronous NRZ format at baud rates up to 524K baud
- One standard SPI allows easy system expansion to peripherals



CANON'S BJC-600C COLOR BUBBLE-JET PRINTER UTILIZES THE 68334, WITH ON-CHIP TPU, TO ENABLE THE HIGH-SPEED COMPLEX CALCULATIONS AND EXECUTION REQUIRED OF MOST PRINTER ENGINES.

via a full-duplex synchronous three-line bus

- Master and slave-mode operation

DIRECT MEMORY ACCESS (DMA)

The DMA provides for low-latency transfers to external peripherals or memory, and for memory-to-memory data exchange. Two fully programmable independent channels provide additional flexibility.

DUAL UNIVERSAL ASYNCHRONOUS/SYNCHRONOUS RECEIVER TRANSMITTER (DUART)

This DUART peripheral offers:

- Direct support of RTS and CTS signals
- Optional baud clock external input pins
- Dual NRZ Serial RS-232 channels
- Double buffered transmit operations, and quadruple buffered receive operations
- Independently programmable TxD and RxD baud rates
- RxD baud rates for each channel up to 76.8K baud

ANALOG-TO-DIGITAL CONVERTER (ADC)

Eight channels, eight result registers and eight automated conversion

modes begin this peripheral's list of features. It also provides:

- 10-bit resolution
- Programmable sample and hold times
- Three result alignment modes
- 8-bit conversion in 8 microseconds; 10-bit conversion in 9 microseconds

QUEUED ANALOG-TO-DIGITAL CONVERTER (QADC)

The QADC matches the offerings of the ADC and adds:

- Two independent queues controlling 32 result registers with three result alignment formats
- 16 analog input channels, or up to 44 when multiplexed externally
- Alternate voltage reference, and programmable sample and hold times
- The Queues' conversions can be set to continuous modes; or they may be started by either software commands, the QADC module periodic interval timer, or by an external trigger

FLASH ELECTRICALLY ERASABLE PROGRAMMABLE READ-ONLY MEMORY (FLASH EEPROM)

The Flash EEPROM features include:

- Support for byte, word, and long-word operations
- Fast termination (2 clock) access speed
- Word programmable, bulk erasable, non-volatile 16-bit wide memory
- Offered in 8 Kbyte increments from 8K to 100K
- Requires an external 12 volt programming/erasure voltage source
- 2 Kbyte Block Erasable EEPROM (BEFlash) modules that provide byte/word programming with a 12 volt external input, and eight independently-erasable various-sized blocks

STANDBY RAM MODULE (SRAM)

Portable, low-power applications are supported with a Standby RAM mode during microcontroller power-downs.

Supporting byte, word and long-word operations, Static Random Access Memory (SRAM) is available in 1, 1.5, 2, 3.5 and 4 Kbyte blocks, and provides fast termination (2 clock) access speeds.

Additionally, the Fast Static RAM can be maintained by just 3 volts on the standby voltage pin.

STATIC RAM MODULE WITH TPU EMULATION CAPABILITY (TPURAM)

The TPURAM facilitates the use of custom or substitute TPU functions. When the TPU enters emulation mode, this SRAM module becomes dedicated to the TPU and replaces the TPU control store ROM. Different TPU functions may be downloaded to the TPURAM for execution by the TPU. Most microcontrollers currently available with a TPU have 2 Kbytes of TPURAM, allowing complete emulation of the TPU module.

READ ONLY MEMORY (ROM)

Also supporting byte, word and long-word operations, the ROM is available in 4 Kbyte increments from 4 to 64 Kbytes, and provides fast termination (2 clock) access speed. The ROM's 16-bit wide memory contents are masked on a custom basis.



DEVELOPMENT SUPPORT

Motorola provides hardware and software support for our rapidly-growing M68HC16 and M68300 microcontroller families. With evaluation boards, in-circuit emulators, register initialization software, a real-time kernel, C compilers, and debuggers, Motorola delivers all you need to successfully design, debug and evaluate your Motorola microcontroller-based application.

In addition to Motorola's development tools, more than 65 independent development tool suppliers provide support with: emulators, logic analyzers, programmers, evaluation boards, simulators, C compilers, real-time operating systems, assemblers, and debuggers – all allowing you to develop, monitor, test and debug your code to get your applications up and running fast.



THE MEVB1632 MODULAR EVALUATION BOARD (MEVB)

The MEVB aids hardware and software evaluation by providing essential microcontroller timing and I/O port replacement circuitry. It supports devices from the M68HC16 and M68300 Families. The MEVB's flexibility, ease-of-use and features make it a fast and economical tool for prototyping your application.

The MEVB's features include:

- Jumper-selectable support for multiple memory devices (Flash EEPROM, EPROM and RAM) and sizes from 32 to 512 Kbytes
- Seven software breakpoints
- Logic analyzer connection for all MCU pins
- On-board Flash EEPROM programming support
- On-board wire-wrap area
- Integrated development environment for assembling, editing, evaluating, programming and source-level debugging (IASM16/32, ICD16/32, PROG16/32)
- On-board programming voltage circuitry eliminates the need for a separate programming voltage power supply
- PC host interface connection through Background Debug Mode and serial I/O expansion via RS-232C

THE MMDS1632 MODULAR DEVELOPMENT SYSTEM

Providing high-speed, real-time hardware and software emulation for target systems based on Motorola's M68HC16 and M68300 microcontroller families, the MMDS1632 can emulate various microcontroller devices. It includes a Station Module (SM) which houses a control board, internal power supply, and easy-access active probe connections, as well as host software to support target system emulation and bus analysis, and complete documentation.

Additionally, the MMDS1632 Modular Development System's features include:

- Real-time, in-circuit emulation
- Four hardware breakpoints

**THE 68HC16Z2, USED IN ENGINE CONTROL MODULES
OF CHRYSLER'S CIRRUS AUTOMOBILES,
HAS ON-CHIP MEMORY, AND MANY OTHER
FEATURES, MAKING IT A COST-EFFECTIVE
SOLUTION WITHIN THE M68HC16 FAMILY.**

- More than 1 Mbyte built-in emulation memory with 4 Kbytes of real-time read/write memory
- Ninety-six channels real-time bus analysis, 52 Kbytes deep
- Sixteen logic chips for individual signal selection and analysis
- Built-in self-test

SDI™ SERIAL DEBUG INTERFACE

The SDI Serial Debug Interface is a serial in-circuit debugging tool that utilizes the Background Debug Mode on M68HC16 and M68300 microcontrollers to quickly update and verify application code. When used with compatible debug software such as the MCUdebug debugger, developers can view and modify their application in real time. The SDI tool is available in 5 volt only and low voltage (2.7 - 5.5 V) versions.

MCUinit™ RAPID INITIALIZATION SOFTWARE

The MCUinit development tool simplifies and accelerates initialization of M68HC16 and M68300 microcontrollers. It includes a graphical user interface, on-line context-sensitive help, automatic code generation and rule checking, and debugging support when used with the MMDS1632.

MCUinit software currently supports the 68HC16Y1, 68HC916Y1, 68HC16Z1, 68HC16Z2, 68331, 68332, 68F333, 68334, and 68360 microcontroller derivatives.

On-chip IMB peripheral modules supported include the QSM, MCCI, TPU, GPT, SIM, SCIM, ADC, and various types of memory, such as SRAM, ROM, and Flash EEPROM. Clicking on a particular IMB peripheral button opens configuration panels for the module. Users enter settings for the module, such as the clock rate, address range, timer functions, and baud rate by clicking a button or filling in a text box. Once selections are made, the MCUinit tool generates the initialization code in C or in assembly language. The code is fully commented for maintenance purposes, and users may add their own comments.

RTEK™ REAL TIME EMBEDDED KERNEL

The RTEK kernel offers a robust real-time operating system framework for a broad range of embedded software applications. This fully-functional kernel provides more than 180 kernel services

providing task, memory and interrupt management, event synchronization, data movement, and exclusive accesses. Plus there are three separate scheduling methods supported: pre-emptive, time-sliced, and round robin. The RTEK kernel utilizes an easy-to-use C language interface and supports both static and dynamic kernel objects, providing extensive flexibility for designers of microcontroller-based products. It also supports five Motorola microcontroller families, including the M68HC16 and M68300 Families. This broad usage capability allows a great advantage for users who migrate their applications from one architecture to another.

MCUasm™ ASSEMBLY LANGUAGE TOOLSET

The MCUasm assembler is a full-featured toolset for CPU16 with nearly a dozen different code-building tools, including a project manager, linkers, S-record generator, assembler, disassembler and assembly language converter. This integrated toolset gives users the flexibility to control assembly listings, select case-sensitive labels, and alter symbol tables to shorten download times. Its syntax and language extensions are common to most Motorola microcontroller families, making it easy for users to migrate upward without sacrificing speed or efficiency. The MCUasm tool is optimized to handle large and complex input, allows nested include files, and supports the Common Object File Format (COFF) and P&E Microcomputer's Map files.




THE M68HC16 AND THE M68300 – FAMILY STYLE

Each successive Motorola microcontroller generation gives you more power and performance while building on Motorola's legendary strengths. The M68HC16 and the M68300 continue this family tradition.

Find out more about how the M68HC16 and the M68300 Families can work for your next application. For additional information or more literature, call your local Motorola sales office or call (800)765-7795, ext. 906; or fax (800)765-9753; or write us at P.O. Box 13026, Austin, Texas 78711-3026. Additional information can be found on our World Wide Web site, at: <http://freeware.aus.sps.mot.com/amcu/home.html>

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WWW: <http://freeware.aus.sps.mot.com/amcu/home.html>

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