

AN1057

Selecting the Right Microcontroller Unit

Introduction

Selecting the proper microcontroller unit (MCU) for your application is one of the critical decisions which control the success or failure of your project. There are numerous criteria to consider when choosing an MCU and this application note will enumerate most of them. It presents an outline of the thought process guiding this decision.

The reader must attach their own grading scale to the selection criteria presented and then evaluate the total to make the correct personal decision.

Purpose

The main goal is to select the least expensive MCU that minimizes the overall cost of the system while still fulfilling the system specification, for example, performance, reliability, environmental, etc.

The overall cost of the system includes everything, such as engineering research and development (R&D), manufacturing (parts and labor), warranty repairs, updates, field service, upward compatibility, ease of use, etc.

Selection Process

To start the selection process, the designer must first ask, "What does the MCU need to do in my system?" The answer to this one simple question dictates the required MCU features for the system and, thus, is the controlling agency in the selection process.

The second step is to conduct a search for MCUs which meet all of the system requirements. This usually involves searching the literature — primarily data books, data sheets, and technical trade journals — but also includes peer consultations. These days, recent trade journals seem to contain the most up-to-date information for the newer MCUs. If the fit is good enough, a single-chip MCU solution has been found; otherwise, a second search must be conducted to find an MCU which best fits the requirements with a minimum of extra circuitry, including considerations of cost and board space. Obviously, a single-chip solution is preferred for cost as well as reliability reasons. Of course, if there is a company policy dictating which MCU manufacturer to use, this will narrow your search considerably.

The last step has several parts, all of which attempt to reduce the list of acceptable MCUs to a single choice. These parts include pricing, availability, development tools, manufacturer support, stability, and sole-sourcing. The whole process may need to be iterated several times to arrive at the optimum decision.

Selection Criteria

The general outline of the main criteria in selecting a microcontroller is listed here in the order of importance. Each criteria is explained in greater detail later in this application note.

1. Suitability for the application system — For example, can it be done with a single-chip MCU or at most a few additional chips?
 - a. Does it have the required number of I/O (input/output) pins/ports? — For example, too few = can't do the job, and too many = excessive cost

- b. Does it have all the other required peripherals, such as serial I/O, random-access memory (RAM), read-only memory (ROM), analog-to-digital (A/D), digital-to-analog (D/A), etc.?
 - c. Does it have other peripherals that are not needed?
 - d. Does the CPU (central processor unit) core have the correct throughput? — For example, computer power, to handle the system requirements over the life of the system for the chosen implementation language? Too much is wasteful, and too little will never work.
 - e. Is the MCU affordable? — Does the project budget allocate enough funds to permit using this MCU? A budgeting quotation from the manufacturer is usually required to answer this question. If the MCU is not affordable for the project, all the other questions become irrelevant and you must start looking for another MCU.
2. Availability?
 - a. Is the device available in sufficient quantities?
 - b. Is the device in production today?
 - c. What about the future?
 3. Is development support available?
 - a. Assemblers
 - b. Compilers
 - c. Debugging tools
 - Evaluation module (EVM)
 - In-circuit emulators
 - Logic analyzer pods
 - Debug monitors
 - Source-level debug monitors

- d. On-line bulletin board service (BBS)
 - Real-time executives
 - Application examples
 - Bug reports
 - Utility software, including "free" assemblers
 - Sample source code
 - e. Applications support
 - Specific group who does nothing but applications support?
 - Application engineers, technicians, or marketers?
 - How knowledgeable are the support personnel? Are they truly interested in helping you with your problem?
 - Telephone and/or fax support?
4. Manufacturer's history and track record
- a. Demonstrated competence in design
 - b. Reliability of silicon; for example, manufacturing excellence
 - c. On-time delivery performance
 - d. Years in business
 - e. Financial report

System Requirements

Applying system analysis to the current project will determine the MCU requirements for the system. Here are some questions to ask and answer.

- What peripheral devices are required?
- Is the application to be bit manipulating or number crunching?
- Once data is received, how much manipulation is required? Is the system to be driven by interrupt, polled, or human responses?

- How many devices/bits (I/O pins) need to be controlled? Among the many possible types of I/O devices to be controlled/monitored are RS-232C terminals, switches, relays, keypads, sensors (temperature, pressure, light, voltage, etc.), audible alarms, visual indicators (LCD displays, LEDs), analog-to-digital (A/D), and digital-to-analog (D/A).
- Is a single or multiple voltage power supply required for the system?
- What is the power supply tolerance?
- Is the device characterized for operation at your system supply voltage?
- Are the voltages to be held to a small fixed percent variation or are they to operate over a wider range?
- What is the operating current?
- Is the product to be ac or battery operated? If battery operated, should rechargeables be used, and if so, what is the operational time required before recharging and the required time for recharging?
- Are there size and weight restrictions or aesthetic considerations such as shape and/or color?
- Is there anything special about the operating environment, such as military specifications, temperature, humidity, atmosphere (explosive, corrosive, particulates, etc.), pressure/altitude?
- Is the application to be disk-based or ROM-based?
- Is it a real-time application, and if so, are you going to build or purchase a real-time kernel program or maybe a public domain version will suffice?
- Does your schedule contain enough time and personnel to develop your own application?
- What about royalty payments and bug support?

Much more investigation is required for real-time applications to evaluate their special requirements.

**General MCU
Attributes**

MCUs generally can be classified into 8-bit, 16-bit, and 32-bit groups based upon the size of their arithmetic and index register(s), although some designers argue that bus access size determines the 8-, 16-, 32-bit architecture. For instance:

- Is a lower-cost 8-bit MCU able to handle the requirements of the system, or is a higher-cost 16-bit or 32-bit MCU required?
- Can 8-bit software simulation of features found on the 16-bit or 32-bit MCUs permit using the lower-cost 8-bit MCU by sacrificing some code size and speed? For example, can an 8-bit MCU be used with software macros to implement 16-bit accumulator and indexing operations? The choice of implementation language (high-level) versus assembler) can greatly affect system throughput, which can then dictate the choice of 8-, 16-, and 32-bit architectures, but system cost restraints may override this.

Clock speed, or more accurately bus speed, determines how much processing can be accomplished in a given amount of time by the MCU. Some MCUs have a narrow clock speed range, whereas others can operate down to zero. Sometimes a specific clock frequency is chosen to generate another clock required in the system, for example, for serial baud rates. In general, computational power, power consumption, and system cost increase with higher clock frequencies. System costs increase with frequency because not only does the MCU cost more, but so do all the support chips required, such as RAMs, ROMs, PLDs (programmable logic device), and bus drivers.

Consider also the processing technology of the MPU: N-channel metal-oxide semiconductor (NMOS) versus high-density complementary metal-oxide semiconductor (HCMOS).

In HCMOS, signals drive from rail-to-rail, unlike earlier NMOS processors. Since these criteria can significantly affect noise issues in system design, HCMOS uses less power and thus generates less heat. The design geometries in HCMOS are smaller, which permit denser designs for a given size and thus allow higher bus speeds. The denser designs also allow lower cost, for more units can be processed on the same sized silicon wafer. For these reasons, most MCUs today are produced using HCMOS technology.

MCU Resources

By definition, all MCUs have on-chip resources to achieve a higher level of integration and reliability at a lower cost. An on-chip resource is a block of circuitry built into the MCU which performs some useful function under control of the MCU. Built-in resources increase reliability because they do not require any external circuitry to be working for the resource to function. They are pre-tested by the manufacturer and conserve board space by integrating the circuitry into the MCU.

Some of the more popular on-chip resources are memory devices, timers, system clock/oscillator, and I/O. Memory devices include read/write memory (RAM), read-only memory (ROM), erasable programmable ROM (EPROM), electrically erasable programmable ROM (EEPROM), and electrically erasable memory (EEM). The term EEM actually refers to an engineering development version of an MCU where EEPROM is substituted for the ROM to reduce development time. Timers include both real-time clocks and periodic interrupt timers. Be sure to consider the range and resolution of the timer as well as any subfunctions, such as timer compare and/or input capture lines. I/O includes serial communication ports, parallel ports (I/O lines), analog-to-digital (A/D) converters, digital-to-analog (D/A) converters, liquid crystal display drivers (LCD), and vacuum fluorescent display drivers (VFD).

The less common built-in resources are internal/external bus capability, computer operating properly (COP) watchdog system, clock operating properly detection, selectable memory configurations, and system integration module (SIM). The SIM replaces the external "glue" logic usually required to interface to external devices via chip select pins.

On most MCUs with on-chip resources, a configuration register block is included to control these resources. Sometimes the configuration register block itself can be set up to appear at a different location in the memory map. Sometimes a user and/or factor test register is present, which indicates concern for quality by the manufacturer.

With configuration registers also comes the possibility of errant code altering the desired configuration, so check for "lock-out" mechanisms. For example, before a register can be changed, a bit in another register must first be altered in a certain sequence. Although configuration registers can at first be very confusing and intimidating because of their complexity, they are extremely valuable because of the flexibility they offer at a low cost so that a single MCU can serve many applications.

MCU Instruction Set

The instruction set and registers of each MCU should be considered carefully, as they play critical roles in the capability of the system. Have software engineers study the indexed addressing modes versus the anticipated needs of your system: Have them ask and answer:

- Are there any specialty instructions available which could be used in your system, such as multiply, divide, and table lookup/interpolate?
- Are there any low-power modes for battery conservation, such as stop, low-power stop, and/or wait?
- Are there any bit manipulation instructions (bit set, bit clear, bit test, bit change, branch on bit set, branch on bit clear) to allow easier implementation of controller applications?
- How about big field instructions?

Be dubious of fancy instructions which seem to do a lot in one instruction. The real measure of performance is how many clock cycles it takes to accomplish the task at hand, not how many instructions were executed. A fair comparison is to code the same routine and compare the total number of clock cycles executed and bytes used. For instance, ask:

- Are there any unimplemented instructions in the opcode map, and what happens if they are accidentally executed?
- Does the system handle this gracefully with an exception handler or does the system crash?

MCU Interrupts

Examining the interrupt structure is a necessity when constructing a real-time system. For instance, you should look at:

- How many interrupt lines or levels are there versus how many does your system require?
- Is there an interrupt level mask?
- Once an interrupt level is acknowledged, are there individual vectors to the interrupt handler routines or must each possible interrupt source be polled to determine the source of the interrupt

In speed critical applications, such as controlling a printer, the interrupt response time, for example, the time from the start of the interrupt (worst case phasing relative to the MCU clock) until the first instruction in the appropriate interrupt handler is executed, can be the selection criterion in determining the right MCU.

Company Attributes

Examine the assets of your own company with a little truthful introspection.

- Does your company have a significant investment in knowledge/training of existing personnel with a particular MCU manufacturer and in the development tools for those MCUs?
- Does your company own enough development tools or will you have to buy or rent more?
- If a new MCU is under construction, are there development tools available, such as high-level language compilers, assembler/linkers, evaluation modules, and debuggers/emulators?
- Are your present development tools easily expandable for new MCUs?
- Will additional personnel have to be hired and trained for this project?
- Can you hire an expert to train/lead the rest of your team?
- Does your budget permit hiring additional permanent staff and/or contractors?
- Is your company satisfied with your current MCU manufacturer's product line and services?

Supplier Attributes

The third step is pruning the list of technically acceptable MCUs by examining the MCU manufacturer and supplier, for instance, the company with which you plan to enter into a long-term relationship for mutual benefit. A supplier can either be the MCU manufacturer itself or it can be a full-service dealer who is the authorized representative for several manufacturers.

A supplier with a broader range of products and a reputation for quality, reliability, service, and on-time deliverability at a fair price can best serve your needs. Additionally, the more products you purchase from one supplier, the more leverage you obtain for pricing, service and support.

Always keep in mind that although your dollar volume may seem high to you, it is always a relative amount to the total business of the supplier. Suppliers who can furnish not only MCUs, but memories (RAM and ROM), discrete devices (transistors, diodes, etc.), standard digital logic devices (7400, 74HC00, etc.), speciality chips, customer-specific devices (CSIC), application-specific devices (AS(C), and programmable logic devices (PLDs) will be better suited to serve your growing needs.

Also ask if the manufacturer and/or supplier has won any awards for quality, reliability, service, and/or deliverability. Be suspicious of self-bestowed awards.

Manufacturer Attributes

Other criteria to consider in selecting the MCU manufacturer/supplier are stability, sole-supplier status, literature, and support. Stability can best be ascertained by considering the number of years in business and obtaining a Dunn & Bradstreet rating plus copies of past annual and quarterly financial reports. Your company's purchasing and credit departments can greatly assist you in these areas.

Listing on a major stock exchange is another sign of stability. A local stock broker can assist you in obtaining up-to-date information for those manufacturers listed on stock exchanges, or you can visit your local library to check the periodical guide for pertinent information. The Wall Street Journal is another excellent source of up-to-date financial news.

Sole-supplier status is, unfortunately, usually the norm, as most MCU manufacturers do not often cross license their products to other manufacturers. If the manufacturer has a good track record for supply, delivery, and pricing, sole-supplier status should not be a problem.

Manufacturer Support

Direct manufacturer support includes marketing/sales, field application engineers (FAEs), and application engineering. Be sure and ask:

- Are the FAEs near your site?
- When telephoning for support, can you reach the support person directly, or do you play telephone tag?
- Are calls returned promptly?
- Is there a toll-free number?
- Is there a fax number?
- How many phone lines are available?
- Are the phone lines always busy?
- Do they have an individual voice mail answering system or does a secretary in another office take message which must be physically relayed to the support person? Voice mail is a state-of-the-art computer-controlled answering system whereby each user effectively has their own password-protected answering machine with enhanced capabilities, such as message forwarding.
- What hours do the support personnel work?
- Do they have other duties and/or responsibilities besides support?
- How many support personnel are there?
- Are factory personnel — such as product engineers, manufacturing engineers, quality engineers, hardware engineers, and software engineers — readily available to assist the support personnel?
- Are the factory people on-site with the support personnel?
- Are the support personnel knowledgeable, have a helpful attitude, and do they follow through in a timely manner when they promise to do something, such as research your problem or send you something?
- Does it come via regular mail, UPS, or Overnight Express? Were you charged for fast delivery?

- Does the manufacturer have an electronic bulletin board service (BBS) where information such as application programs, product news, software updates, source code, bug lists, electronic mail, and conferencing are available?
- What baud rates are supported?
- How many phone lines are available?
- What are the hours of operation?
- Do you need any special brand of computer and/or modem or accessory?
- Is there a system operator (sysop) assigned to manager it?

Literature Support

Literature covers a wide selection of printed material which can assist you in the selection process. This includes items from the manufacturer, such as data sheets, data books, and application notes, as well as items available at the local book store and/or library. Book store and library items indicate not only the popularity of the manufacturers and MCUs under consideration, but they also offer unbiased opinions when written by non-manufacturer-related authors.

Finalizing the Selection

As a final step to help in the selection process, built a table listing each MCU under consideration on one axis and the important attributes on the other axis. Then fill in the blanks from the manufacturer's data sheets to obtain a fair side-by-side comparison. Some manufacturers have premade comparison sheets of their MCU product line which makes this task much easier, but as with all data sheets, be sure they are up-to-date with current production units.

Among the possible attributes are:

- Price — For the anticipated production volume, including predictions for future pricing, for instance, will the price be decreasing as you move into production?
- RAM, ROM, EPROM, and EEPROM
- Timer(s)

- A/D and D/A
- Serial ports and parallel ports (I/O control lines)
- Bus speed (minimum/maximum?)
- Special instructions (multiply, divide, etc.)
- Number of available interrupts, interrupt response time (time from start of interrupt to execution of the first interrupt handler instruction)
- Package size/type (ceramic DIP (dual in-line package) or LCC, plastic 0.3-inch DIP or 0.6-inch DIP, shrink DIP (.071-inch pin spacing), PLCC (plastic-leaded chip carrier), PQFP (plastic quad flat pack), EIAJQFP, SOIC (small outline integrated circuit), some involve surface mount technology)
- Power supply requirements
- Any other items important to your system design

The tables at the end of this application note detail the attributes of Motorola's MCU product line.

If, after all this, you still have more than one MCU on your list, consider expandability and value. For instance, consider:

- What expansions in the system requirements can you predict that will be needed in possible future iterations of this product?
- And lastly, consider value, for if two MCUs cost the same but one offers a few more features which are not required today but would make future expansion easier for no additional cost, chose that MCU.

Custom MCU Solution

If there is no commercially available single-chip MCU that meets your system requirements and your anticipated production volume is high enough, consider using a custom CSIC MCU. In a custom CSIC MCU, you choose the core processor type and the exact peripherals needed for your system from a list of standard cells available. This gives you the benefits of a single-chip solution for slightly more cost, so the production volume must be high enough to justify it.

Additionally, some manufacturers will not even start production unless the order volume is around 1 million units. However, if your production volume can be combined with others to reach the 1 million level, production could be started. Or, if the desired unit is judged to have a broad enough market appeal, the manufacturer may proceed with production anyway because they plan to offer it as a standard product.

As the design initiator, you may be able to obtain an exclusivity clause whereby you have sole rights to the CSIC MCU for a specific period. Then the manufacturer can start marketing it to everyone.

Teamwork

Finally, as project leader, you can do all this investigative work yourself, or you can start involving your team by assigning investigative tasks to them, such as having the software engineers evaluate the instruction sets of each MPU under consideration.

By involving your team early in the decision process, you not only build team spirit, but gain individual commitment to the project via active participation. This approach undoubtedly generates some conflict, as everyone has their own opinion, but your job as project leader is to be a mediator. After listening to all opinions, it is still your choice as project leader. As in political elections, once the inner of the primary has emerged, all party members are expected to fully support the winner, and so should all project team members support the decisions of the project leader to help ensure a successful project.

Conclusion

In conclusion, selecting the right MCU for your project is not an easy decision, as MCUs have been more complex devices since on-chip resources were added. And since the trend is toward more on-chip integration of off-chip resources to reduce system costs, the decision will become increasingly complex with time.

This application note is not intended to make the choice for the designer, but to serve as a thought-provoking guideline as to all the possible selection criteria that should be considered in this important decision process.

Motorola Microcontroller Comparison Guide

Freescale maintains a comparison guide on our most popular M68HC05, M68HC11, and M68300 Families of microcontrollers (MCUs). For a copy, please contact the Freescale Literature Distribution Center nearest you and request the current *Microcontroller (MCU) Quarterly Update Folder*, Freescale part number SG148/D.

Freescale 8-Bit M68HC05 Microcontroller Family

Programming Model

The M68HC05 Family of MCUs has five central processor (CPU) registers available to the programmer as shown in [Figure 1](#).

Freescale 9-Bit M68HC11 Microcontroller Family

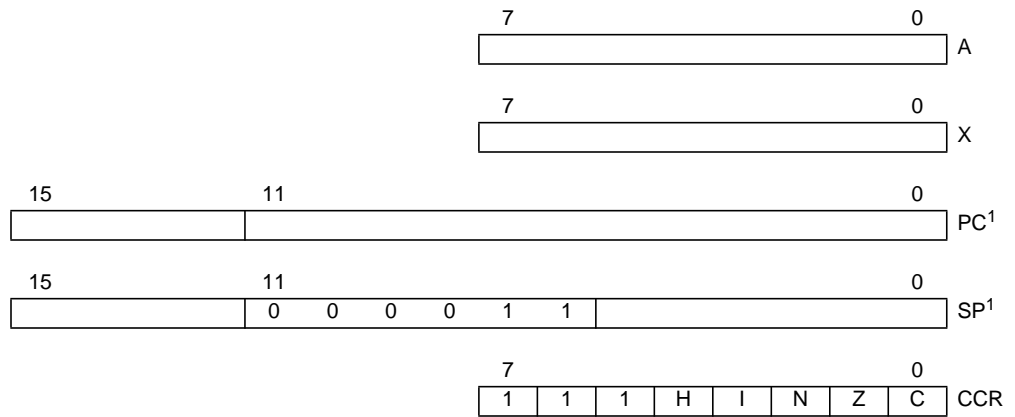
Programming Model

The M68HC11 Family of MCUs has eight central processor unit (CPU) registers available to the programmer as shown in [Figure 2](#).

Freescale 16-and 32-Bit M68300 Microcontroller Family

Programming Model

The M68300 Family of MCUs has 23 central processor unit (CPU) registers available to the programmer as shown in [Figure 3](#) and [Figure 4](#), organized into user and supervisor models.



1. Length depends on the address/memory size of the individual M68HC05, for instance, a 2-K memory map requires an 11-bit program counter and stack pointer as shown. Current length ranges from 11 to 14 bits (2 K to 16 K).

Figure 1. M68HC05 Programming Model

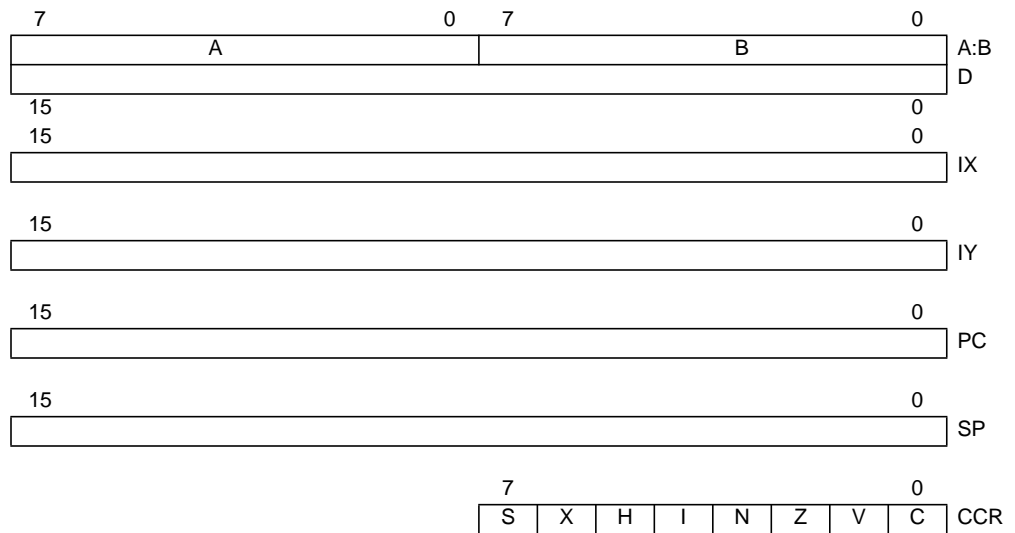


Figure 2. M68HC11 Programming Model

For most up-to-date information, contact the Motorola Literature Distribution Center nearest you and request the *MCU Freeware* brochure, Motorola part number BR568/D.

Motorola Literature Distribution Centers

Motorola has several Literature Distribution Centers (LDCs) worldwide with the main one located in Phoenix, AZ, U.S.A. They carry all Motorola literature, including data books, data reference manuals, user manuals, application notes, brochures, books on Motorola products, etc. Contact your local Motorola representative or the LDC office nearest you and they will be most happy to serve you. The LDC addresses are listed on the back cover of this application note. The phone numbers are listed here or consult your local telephone director books.

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About Motorola

Motorola was founded in 1928 by Paul V. Galvin and has continuously been in the electronics business since then. Motorola moved up to number 48 on the 1989 Fortune 500 list of the largest U.S. industrial corporations with \$9.62 billion in sales and is the number 3 in electronics in the U.S., behind General Electric and Westinghouse Electric. In terms of semiconductor market share, Motorola is number 1 in North America and number 4 in the world. Motorola's Microcontroller Division is the world's number 1 supplier of 8-bit MCUs, with more than 500 million in use around the globe. Motorola was ranked number 3 by Fortune Magazine's poll of America's most admired cooperations.

Application Note

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