HOW TO BUY A MINICOMPUTER

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INTRODUCTION

We wrote this book for two reasons. First, we wanted to give prospective buyers some help in comparing minicomputers. So we made Section I of the book a series of pertinent questions and answers about buying minicomputers. Should you buy a minicomputer from an OEM, a systems house, or direct from the computer manufacturer? Should you consider the new semiconductor memories? What comes as "standard equipment" with a minicomputer? What kind of service arrangements are available? What software and peripherals are available with minicomputers?

We think we're well qualified to provide the answers to these questions. In the three years since we introduced the Nova computer, we've become the number 2 company in the minicomputer business. We've built a reputation as the industry's leading technical innovator. Data General was first to introduce a 16-bit multi-accumulator minicomputer

first to take advantage of large and medium scale integration, first to use more reliable large-scale printed circuit boards, and first to introduce semiconductor memory to minicomputers. At the same time, we've become a broad-based supplier of a comprehensive line of minicomputer mainframes, peripheral equipment, and software.

We know what we're talking about, and we have some very strong opinions about what minicomputers should be, and the things a minicomputer company should do for its customers.

Inevitably, our opinions are reflected in the questions and answers in Section I of this book. It's no coincidence, for example, that, in discussing minicomputer architecture, we favor the multiple accumulator approach. We spent a lot of time thinking about architecture before we built our first computer, and we came to the conclusion that this approach was best. So we build our computers that way, and in this book we've presented our opinions that way. Not because it's convenient for us to say that, but because that's what we really believe.

Our second reason for writing the book was selfish. The more people know about minicomputers, the more they'll buy minicomputers. And since a significant share of the minicomputers sold all over the world are ours, that should be good for us. We also think that we offer the best computers, software, peripherals, and overall support on the market. So, Section II of the book contains a concise discussion of Data General Corporation's products and capabilities, with point-by-point references to the questions asked in Section I.

We're confident that prospective buyers, armed with this sort of information, are more likely to buy our products. That's how Data General plans to become the number one minicomputer company.

SECTION I

1. WHAT KIND OF ARCHITECTURE DO MINICOMPUTERS USE?

Minicomputers have word lengths from 8 to 24 bits. A machine with a longer word costs more, but, because each word stores more data or more instructions, it is faster and more powerful. The shorter word length requires more memory to store data and programs, so any cost advantage may be lost in anything but the simplest applications. There is an inherent advantage in buying a minicomputer with a word-length that is a multiple of 8, since this is the basic unit around which most industry-wide standards have been established.

With the ready availability of MSI and LSI circuitry in recent years, it has become economical to build minicomputers with multiple accumulators. The accumulators provide locations in the CPU in which an operand can be temporarily stored, and then retrieved quickly when it's needed. Several operations can progress at once; data flow within the com-

puter is easier, and programming is much more convenient than in a single-accumulator machine. You should be most concerned whether the machine has a single accumulator or multiple accumulators, not precisely how many accumulators it has.

A minicomputer's word length is essentially short; thus, to directly address all but a few memory locations is impractical, since few bits would be left over for instructions or data. Therefore, most locations are reached by non-direct means. If index registers are used, the effective address is the given address as modified by the contents of the index register. If indirect addressing is used, the program first must go to an intermediate address to find the location of the effective address. The use of multiple word instructions allows more bits for direct addressing. Relative addressing allows a movable block of locations some distance ahead and behind the location of the instruction to be addressed directly. You should look for machines that use some flexible combination of these techniques.

A commonly used definition of a computer's architecture is the relationship between major subsystems. One method of connecting the pieces of a minicomputer is for the central processor to talk to the memory over a memory bus, and to all external devices over an I/O bus. Some minicomputers treat the memory as an external device and talk to it over the same I/O bus, just like a paper tape reader or a CRT display.

The apparent advantage of putting the memory on the I/O bus is simplicity and modularity. On the other hand, this allows any malfunctioning I/O device to tie up, not only other I/O devices, but all memory/CPU functions as well. In addition, the presence of memory signals on the I/O bus considerably complicates the I/O bus function. The advantage of using separate I/O and memory buses is that the critical, high-density

memory/CPU traffic is assigned to its own set of optimized data paths, while the less predictable I/O traffic is handled over a general purpose I/O bus.

In considering minicomputer architecture, be careful to distinguish between architecture and implementation. In theory, a computer can incorporate certain specific features that optimize that machine for a particular class of applications. In practice, however, real improvements in performance have been the results of advances in general purpose architecture (e.g., the use of multiple accumulators).

In general, there are a number of alternatives available in terms of minicomputer architecture, but, in practical terms, recent trends have been toward 16-bit, multi-accumulator machines employing a variety of addressing schemes and two somewhat different I/O bus schemes.

2. WHAT SORT OF INSTRUCTION SETS DO MINICOMPUTERS HAVE?

In evaluating instruction sets for minicomputers, you should make a decision about the complexity of the instructions you want to work with.

A very complex instruction includes more than one function and uses more than one word. Using these macro-instructions, you can write programs using a minimum of code. Macro-instructions that are customized for a particular class of applications can be very effective in the selected application. However, in most other situations they are relatively inefficient. Because they are more than one word long, macro-instructions require a relatively long time to execute and use more memory than single-word instructions.

At the other end of the spectrum, micro-instructions are extremely simple and can be executed very quickly. They occupy less than a single word, so several bits are available for

addressing. They make it possible to write very economical, precise programs. However, their extremely abstract nature presents a formidable obstacle to all but the most accomplished programmers, and, because many instructions must be used, they use a great deal of memory.

Between macro and micro there is a wide area called general-purpose instruction sets. A general-purpose instruction fits into a single word (as opposed to a multi-word macro-instruction) and contains a complete operation (e.g., a full 16-bit add is accomplished by one instruction).

3. HOW FAST IS A MINICOMPUTER?

First, look at memory cycle time. Machines currently available specify memory cycle times ranging from under .5 microsecond to 2 or 3 microseconds.

Be careful to make the distinction between memory access time and full memory cycle time. Using core memories, access time is the time it takes to read the data at a specific core location. Cycle time is the time required to read and restore the data, and is typically double access time.

Cycle time, however, is only the beginning. How many cycles does the central processor take to *do* anything? One machine might take 2 or more memory cycles to execute an ADD instruction, while another does it in one cycle. You should look at the actual execution times for the computer's various instructions.

Finally, you can look at benchmark programs for applications similar to yours. Compare the total execution time and the number of instructions required for each computer. This is a good test of the computer's speed and the effectiveness of its instruction set for a specific type of application. But benchmarks can be misleading. To be useful, your benchmark program (or combination of benchmarks) should be long enough to

test the computer in a variety of situations: probably at least 100 words of code. Then make sure that the benchmark is designed to suit your application, not a particular machine. Any manufacturer can design benchmarks that make him look good. On the other hand, a manufacturer may be able to alter your benchmark to take advantage of the strengths of his machine without affecting the usefulness of the program. This is a realistic approach and should be allowed.

4. WHEN IS COMPATIBILITY IMPORTANT?

Compatibility within a family of minicomputer main-frames is important to anyone developing systems for volume resale. An original equipment manufacturer (OEM) has a large investment in equipment and software other than the minicomputer. It's unrealistic for him to build in the newest, fastest minicomputer if it means that he has to totally rebuild the rest of his system. However, if he can simply substitute a faster, compatible computer without modifying any other hardware or software, he can in turn offer his customers a compatible line of products at different price/performance levels.

For the end-user buying a single minicomputer for long term use, compatibility within a family of main frames might be less critical, but not if he plans to buy more computers in the future. Then, if he buys truly compatible computers, most of his older system can be used with the new computer. Even if he doesn't currently plan to buy more computers, the insurance of a compatible line is of considerable value.

End-users as well as OEMs benefit if the computers they buy are compatible with the complete line of peripherals and software available for the manufacturer's product line. Just because a manufacturer offers a certain set of peripherals and software for one model, there is no guarantee that he will ever offer it for a new model. In many cases, the effort required

to rewrite a complex piece of software or design a new interface to suit a different central processor architecture is considered impractical.

5. WHAT'S "STANDARD" AND WHAT'S "EXTRA"?

In spite of the highly competitive pricing in the minicomputer industry, there are marked differences in what hardware you get in a "basic" minicomputer configuration at an advertised price. You should expect to get a chassis, a central processor, a memory module, input/output facility, power supply, and an operator console with a complete set of status indicators and control switches.

There are also "less than basic" machines available, usually with minimum memory, no operator console, and no expansion capability. Generally, these machines are no less expensive than stripped-down versions of standard models.

A basic minicomputer usually includes one 4096-word memory module. But don't forget to consider word length; 4096 8-bit words store a lot less data than 4096 16-bit words.

An interface to a teletypewriter terminal is essential for almost every application. You should know whether it's standard or an extra cost option.

A Direct Memory Access (DMA) data channel is a requirement for most systems with any high-speed I/O requirements. It is standard on some minicomputers, but can cost as much as $1,000 for others.

A number of other common features can be standard equipment or options. Some to be alert for are: power fail protect and automatic restart, hardware multiply/divide, automatic program load, and automatic interrupt source identification. You should also be aware of exactly how much room is available in the standard chassis for adding memory and interfaces. If it's inadequate, expansion hardware is usually an

expensive option.

6. HOW IMPORTANT ARE THE NEW MEMORY TECHNOLOGIES?

In the majority of cases, you'll only be concerned with core memories, at least for now. The price of core memory has continued to come down and performance has improved steadily with new product technology. However, the rate of improvement of price/performance for cores has now slowed considerably. Cores smaller than 18 mils (500 to 600 nanoseconds cycle time) don't appear practical for minicomputers.

Semiconductor memories will eventually achieve higher performance at costs at least comparable to today's cores. The bipolar technology currently available to the minicomputer field yields very high performance, but is still quite expensive in terms of both price and power consumption. MOS devices are simpler and less expensive than bipolar devices, but currently do not offer any significant speed advantage over core. However, dramatic price/performance improvements in both technologies seem inevitable.

Even today, the chances are steadily improving that your application is one in which semiconductor memory is the right choice. For cycle times less than 800 nanoseconds, semiconductor memory is about three times as fast as core memory, but is only twice as expensive. You should consider which minicomputers are compatible with semiconductor memory, and look at the possibility of mixing core with semiconductor memory. The use of small blocks of very fast semiconductor memory to store critical, frequently used subroutines or loops can yield substantial improvements in overall system performance.

The manufacturers who have had extensive practical experience with this new technology offer their customers

substantial advantages even today. In the future, they should be able to phase-in the new memory technology without significant disruption of their product lines.

7. WHAT SOFTWARE COMES WITH A MINICOMPUTER?

Some minicomputers come with only the barest essentials (assembler, editor, loader), while others offer a compatible selection of the same sort of software that is available on large machines, and in some cases packaged applications software is available. Minicomputers are almost completely "bundled," so, in effect, the software is free, and the computer that comes with the most, the best, or precisely the right software offers a major advantage. In a few situations, software is priced separately, so you will have to evaluate those costs on top of the price of hardware.

If you can write your own application programs, you should be most interested in the availability and quality of the developmental software offered. You need assemblers, editors, loaders, and a complete set of arithmetic and utility programs (availability of floating point software is often important). The assembler should take no more than two passes. In comparing assemblers, you should consider memory requirement, throughput speed, size of the symbol table, input format flexibility, and features such as pseudo commands, relocatability, and inter-program communication. The editor should provide the programmer with the maximum tools for manipulating his programs. Look for character-editing features (in addition to line editing), string search capability, and the availability of pointers.

If you plan to do a great deal of development programming, consider which computers offer cross assemblers. A cross assembler will speed the development process consider-

ably, and keep the minicomputer free for production work. It allows you to assemble source code for the minicomputer on a large-scale computer, taking advantage of the high speed and large memory capacity of the bigger machines.

For general purpose programming, higher level tools, principally compilers, are most important. Some manufacturers offer several compilers, including FORTRAN, ALGOL, and BASIC, while others have none.

The quality of the compilers available varies widely. You should examine the amount of memory required and the features offered. Many minicomputer compilers are very limited versions of standard software, while others include the standard language features, as well as powerful extensions. The smaller versions usually occupy much less memory, but they are also less useful by a wide margin.

If your system requires mass storage and multiple peripherals, a Disc Operating System provides an orderly means of managing data files and peripheral devices. A good operating system should also include extensive diagnostic and debugging capabilities. Similarly, for real-time applications, a Real-Time Operating System can save a great deal of programming effort.

Thorough diagnostics should be provided for the computer (including individual tests for all subsystems) and for each peripheral. The diagnostics should be capable of pinpointing a problem to a specific component, not just a function.

In a few instances, minicomputer manufacturers supply software packages for specific applications. These are usually turn-key systems for unsophisticated users in well-defined applications. These systems must be evaluated in terms of cost, memory requirements, specific application-oriented features, and the level of customizing required. Very often an application package must be modified to fit the precise

equipment configuration it controls (e.g., a specific combination of machine tool and controller in a machine tool tape preparation system).

If the minicomputer manufacturer does not supply the software you need, you must write it yourself or buy it from a software house.

8. WHAT PERIPHERALS ARE AVAILABLE WITH MINICOMPUTERS?

Practically every sort of device that can be used with a computer can be connected to a minicomputer. Of course, in most situations, the only peripherals you should be concerned with are the ones you think you need: any others are irrelevant. However, requirements change and computer systems tend to expand. The broader the line of peripherals offered by the manufacturer, the easier it is to meet new requirements with minimum design compromises.

No manufacturer can offer every peripheral, but there are some critical areas in which lack of support can be a real problem. The manufacturer you buy from should offer a line of paper tape products, several models of teletypewriter terminals, and a variety of alternative methods of mass storage, including industry-compatible magnetic tape and disc units. Off-the-shelf multiplexors, modems, and multi-line controllers are essential in communications applications, and a complete set of analog-to-digital and digital-to-analog devices is required in real-time applications. Some manufacturers offer a very useful direct interface to an IBM System 360 computer. CRT units, card punch equipment, plotters, line printers, and other peripherals are also available.

Some of these units (small line printers for instance) have been designed primarily for use with minicomputers, while others are standard, industry-compatible products.

While the peripheral need not be a special mini model, be sure that it's a reasonable match for the computer you pick.

In some cases, the minicomputer manufacturer simply resells equipment he buys from the peripheral manufacturer; in other cases, he builds the peripheral himself, either totally or in large part. Either approach can work well, but the buyer should make sure that he understands the level of support to which the minicomputer manufacturer will commit himself for a particular peripheral device. If the minicomputer manufacturer does not support the complete system, including peripherals and interfaces, the user may have a very difficult time solving any problems that develop.

9. HOW DO I INTERFACE TO THE MINICOMPUTER?

If the minicomputer manufacturer has off-the-shelf interfaces, at reasonable prices, for the devices you will use, your problem is solved. Or, if the peripheral manufacturer has gone to the trouble of building a standard interface between his device and the minicomputer you're considering, your problem should be equally well solved; and you can be fairly confident that the computer must be relatively easy to interface, or the peripheral manufacturer wouldn't have gone to the considerable effort and expense of developing the interface.

A good interface is simple in the sense that the I/O bus signal lines have well defined, independent meanings and no complex sequencing of signals is required. The more parallel and direct the interface is, the easier it will be for the user to build and debug his logic.

A standard I/O interface should mount in the mainframe chassis without the addition of an extender chassis. In fact, you should be able to add several interfaces before you need an additional chassis. The interface should be physically simple and preferably mounted on a single printed circuit

board. Ideally, it will simply plug into the chassis through some very reliable type of connector. If any wiring is necessary, the wiring locations should be easy to reach and clearly designated.

The manufacturer should also offer clear, complete documentation including logic diagrams and diagnostic programs for each standard interface.

The minicomputer manufacturer should provide a variety of general purpose interface products on which custom interfaces can be developed, tested, and implemented. The mainframe chassis should provide for mounting custom interfaces as conveniently as standard products.

If the minicomputer manufacturer doesn't have precisely the interfaces you want, but does offer a wide variety of reasonably priced interfaces for standard devices, it indicates that the computer is basically easy to interface. A custom-built interface meeting your specific requirements should be practical.

10. HOW CAN I EVALUATE INPUT/OUTPUT CAPABILITY?

Minicomputers interface to more different kinds of peripherals than other computers. There's absolutely no need to sacrifice speed or flexibility in the I/O department.

The computer's data transfer rates should meet the speeds of the I/O devices in the system. The I/O facility must be capable of handling the number of I/O lines you need. The I/O word length (usually the same as the machine's basic memory word length) should be a good match for the data word lengths of the I/O devices. If it's shorter, multiple words are required for each word of data transferred.

The minicomputer you choose should have facilities for both of the two types of data transfer typically used: program-controlled data transfer through the I/O bus, and direct mem-

ory transfer.

Program controlled data transfer is typically used to service relatively low-speed peripheral devices (teletype-writers, paper-tape readers, card readers). Because data flows through a register in the central processor, one word at a time, this type of data transfer is relatively slow (up to 30K words/second). It is also inexpensive, since interface hardware can be kept quite simple. An I/O bus facility is offered as standard equipment by all major manufacturers.

Data transfer across a Direct Memory Access (DMA) channel is used to service high-speed devices, such as disc memories or CRT displays. Data is transferred directly between main memory and the peripheral device in blocks at rates up to one word each memory cycle (one million words/second for a machine with a basic memory cycle time of 1.0 microseconds). DMA is available as an extra-cost option on most minicomputers, but on some it is standard equipment.

11. WHAT PRIORITY INTERRUPT SCHEME IS BEST?

Priorities can be established using hardware interrupts or programmed interrupts. In general, hardware interrupts are faster, but they are more complex to implement, require more memory, and are less flexible than programmed interrupts. The number of priority levels available varies from single-level, in which the device nearest the processor on the I/O bus is serviced first, to dozen of levels. The single-level scheme may be inadequate in a complex system, but more than 16 levels are often irrelevant. Even in complex communications networks, there are rarely more than a few significantly different levels of priority. Flexibility is really more significant than multiplicity. For example, if a system includes a device that is highly critical, but requests service infrequently, the interrupt scheme should be flexible enough to give that device high

priority when it makes a request, but to ignore it otherwise.

12. HOW MUCH CAN A MINICOMPUTER BE EXPANDED?

Most minicomputers have a maximum memory capacity of 32K words, and can be interfaced to several peripheral devices at once. However, in many cases no more than 8 or 12K of memory and one or two interfaces can be built into the box the computer comes in. If the user requires more memory or interfaces, he must pay for an expansion chassis and all the clumsy connections between it and the CPU chassis. On the other hand, some minicomputers comfortably accommodate a full 32K of memory and interfaces to multiple peripherals within a single chassis.

Memory modules, peripheral interfaces, and CPU options should be mechanically simple, easy to plug in, and require minimum wiring. Modules that fit on single printed circuit boards and plug into the mainframe directly, with no wiring, are the simplest.

13. HOW CAN I JUDGE HARDWARE RELIABILITY?

You can start by looking at the manufacturer's figures for mean-time-between-failures (MTBF). Comparing these figures from one manufacturer to another can be very difficult – chances are you'll be mixing apples and oranges. At any rate, it's a start.

The more medium-scale and large-scale integrated circuitry (MSI and LSI) a minicomputer uses, the higher its inherent reliability. Using this advanced circuitry, a specific function can be implemented using fewer components. Thus there are fewer sources of potential failure associated with that function. Because MSI and LSI components are at least as reliable, on an individual basis, as the less advanced circuits

they replace, the net result is higher inherent reliability for the specific function. The same is true when a number of functions are combined in a major subsystem assembly, such as a central processor. There is an additional gain in reliability due to the overall reduction in packaging required: there are fewer integrated circuits, fewer connections, and fewer printed circuit boards.

The simplicity of the overall mechanical package also has a good deal to do with the reliability of the system. If major subsystems can be contained on single boards, there is a minimum of internal wiring and the fewest possible connections of all sorts. Simple organization also means easy access for maintenance. If major subsystems are contained on single boards, a malfunction can be isolated very quickly.

14. WHAT TYPES OF FIELD SERVICE ARE AVAILABLE?

Field service contracts of several types are available, ranging from straight time and materials arrangements to 24-hour on-site coverage. Each user must establish his own requirements and evaluate in those terms: if he doesn't require in-depth field service support, its availability shouldn't be important. On the other hand, if a manufacturer can not offer a real range of field service, there is considerable doubt that he can be depended upon to supply even a little timely support when it's critical.

You should know how fast the field service engineer is going to get to you when you need him. No matter how big or small the overall organization, or how far away the nearest service center, you must evaluate the level of service that your specific installation is likely to enjoy.

If you're going to operate a computer at a remote site, you should probably buy a complete set of spare parts and make sure that someone at the installation can handle mainte-

nance. In this case, reliability, ease of maintenance, and good documentation and diagnostic programs are much more important than the size of the manufacturer's field service organization.

Good documentation can eliminate many service problems before they become problems. The minicomputer manufacturer should supply a complete set of system drawings, logic diagrams, and maintenance manuals. A thorough set of diagnostics for both mainframes and peripherals is another essential. Preferably, diagnostic programs should make gate-by-gate logic checks, rather than simply functional checks.

15. WHAT TRAINING SHOULD I RECEIVE?

You're at a disadvantage if the minicomputer you buy does not come with adequate factory training.

For those with previous minicomputer experience, these courses are a useful review of the details of a specific machine. For anyone with a general computer background but little knowledge of minicomputers, the courses are an absolutely necessary introduction to the special characteristics of small computers.

For the unsophisticated, training is obviously very important, but the courses offered may be too advanced. It can be more productive to take some introductory computer courses before going into the manufacturer's course, or to delay taking the courses until after the computer has been installed and running for some time.

Typically, minicomputer manufacturers include with each machine a programming course and hardware course, each one man/week long. Additional courses can be bought. Usually the courses are held at the manufacturer's plant, and the customer pays his expenses.

The best way to evaluate the courses available is to

read a course description. The software course should include a thorough grounding in the practical features of the software that are most important in a new installation: loaders, diagnostics, utility programs, debuggers, arithmetic routines, and assemblers. An understanding of this software will make it relatively simple to use higher level compilers and applications software.

The hardware course should also concentrate on the basics: installation, interfacing peripherals, troubleshooting, and typical service routines.

16. SHOULD I BUY FROM AN OEM, A SYSTEMS HOUSE, OR A MINICOMPUTER MANUFACTURER?

The original equipment manufacturer, or OEM, sells a minicomputer as a plug-in to the equipment he manufactures. In many cases the final buyer is not even aware of the computer within the system. Often the computerized model is the most sophisticated, most expensive system the OEM sells.

The OEM can be the best vendor to deal with in a situation in which the real requirement is for a computerized whatsit. The OEM is a whatsit manufacturer who builds the computer right into a package. He should have a good understanding of the problems involved, and, if he sells lots of computerized whatsits, he should be able to offer the best support and price for the whole system.

If you don't feel that you can handle an overall system development project yourself, and an OEM doesn't offer a packaged solution, you might go to a systems house — a company that specializes in putting together hardware, software, and interfaces to solve a specific problem, usually on a one-shot basis. Some systems houses concentrate on one type of application, e.g., medical systems, communications systems, power plant control systems. The major advantage of the sys-

tems house is that it can devote a full-time, professional effort to a specific problem until it is solved. Once the problem is solved, you stop paying for it.

If you are confident that you can match a computer, peripherals, and software to your specific problem, you should buy directly from the manufacturer. He should be able to offer the best price and the best support for the computer and any peripherals and software he provides. In an increasing number of cases, the manufacturer can also provide systems interfaces and application-oriented software.

17. HOW RELIABLE ARE THE MINICOMPUTER MANUFACTURERS?

Many companies in the minicomputer business are simply not capable of providing the level of support appropriate to a product of this complexity and cost. The simplest way to judge the reliability of a particular manufacturer is to look at his track record: how many computers have been installed? If the numbers are substantial, you can be fairly confident that the manufacturer is reliable. On the other hand, every successful new company has its first customer.

Many support-related functions are unimportant to a particular minicomputer user. For example, a variety of standard peripherals is of little interest to an OEM who buries a stripped-down minicomputer inside his own hardware. On the other hand, the manufacturer's overall reliability can best be judged as the sum of a series of factors, some of which are of no interest in a specific case. These factors include compatibility within a family of central processors, a broad line of compatible peripherals and software, in-depth field service, good documentation, and a responsive sales effort. Considering these factors together should give a reasonable evaluation of the company's general commitment to customer support.

SECTION II

In the fall of 1968, when we announced our first product, the Nova, Data General made a commitment to a design philosophy based on innovative, aggressive use of the most advanced technology available. When the industry leader was sticking to 12-bit machines, we introduced a 16-bit computer. We were the first minicomputer company to make substantial use of medium scale integrated circuitry, and the first to introduce semiconductor memory. The Nova was the first minicomputer built around the same sort of architectural design previously used in large systems. The resulting multiple accumulator, 16-bit organization has since become the standard for minicomputers. The Nova's mechanical organization, using large printed circuit boards and a single large back panel for all interconnections, has likewise become the accepted approach for advanced minicomputers.

At the same time, we also committed ourselves to becoming a broad-based minicomputer company with a full line of products. Based on that commitment, we immediately embarked on a highly successful program to develop software, peripherals, interfaces, service, customer support, and a range of truly compatible products.

The opinions expressed in this book reflect our commitments to the constant improvement of both technology and customer service. The objective proof of these commitments is our products: Data General's computers are what we think minicomputers should be. The market acceptance of our products seems to be substantial proof that knowledgeable people agree with us. Three years after we demonstrated our first machine, over 2,000 Nova-line computers were installed, and Data General has become the number 2 minicomputer company in the world.

The following paragraphs describe briefly the Nova-

line minicomputers in terms of the questions in Section I.

1. ARCHITECTURE

The Nova-line computers offer variations in memory cycle time, I/O data transfer rates, and instruction execution times, but they all use the same 16-bit, multi-accumulator architecture and instruction set. They have an I/O bus to handle communications between central processor and peripheral devices, a memory bus for CPU/memory communications, and a Direct Memory Access (DMA) channel for direct high speed communications between memory and peripheral devices. They use a relative addressing scheme, combined with indexed addressing and multiple level indirect addressing. In addition, the first 256 locations in memory can always be addressed directly.

This 16-bit, multi-accumulator architecture, which Data General introduced first for minicomputers, has become the standard for minicomputer design. As implemented in the Nova-line, the multi-accumulator architecture results in large advantages in terms of speed, efficient use of memory, and ease of programming. It cuts down on the number of instructions necessary to execute a program, reduces the amount of data movement in the machine, and makes programming significantly easier. The use of available accumulators as index registers allows a very flexible addressing structure.

2. INSTRUCTION SET

All the Nova-line computers use the same general-purpose instruction set. Each instruction fits in a single 16-bit word, and the maximum possible number of functions has been built into each instruction. For example, a single input/output instruction can transfer a word between an accumulator and a device and at the same time control the operation of

the device.

The arithmetic and logical instructions are arranged so that each bit has its own function; thus it is unnecessary to decode most portions of the instruction word. The same instruction that adds or subtracts can also shift the result or swap its halves, test the result and/or carry for a skip and specify whether or not the result shall actually be retained.

This combination of general-purpose flexibility and maximum functional density is extremely effective for both novice and sophisticated programmers.

3. SPEED

The Nova line offers a series of very fast minicomputers. The Nova 1200, Nova 1210, and Nova 1220 have a full memory cycle of 1.2 microseconds, and can execute any of their arithmetic or logical instructions in 1.35 microseconds. Nova 800 and Nova 820 have a full memory cycle of 0.8 microseconds, and execute arithmetic and logical instructions in a single cycle. Using core memory, Supernova has a full memory cycle of 0.8 microseconds and executes arithmetic and logical instructions in one cycle. Using semiconductor memory, which can be interchanged with core, the Supernova SC executes arithmetic or logical instructions in 0.3 microseconds.

The basic speed of the hardware, combined with the power of the instruction set and the economy of the architecture used, make the Nova computers the fastest line of compatible minicomputers on the market.

4. COMPATIBILITY

Data General's computers all use the same interfaces to the same peripherals. They use the same software, and the same instruction set. In some cases, Nova-line computers are interchangeable. For example, a Nova 1220 can be upgraded to

the same level of performance as the faster Nova 820 simply by sliding the Nova 1220 central processor board and core memory boards out of the chassis and replacing them with the faster Nova 820 boards. The change can be made in seconds, and no modification of software, peripherals, or interfaces is required.

5. STANDARD EQUIPMENT

In a standard configuration, a Nova-line computer comes with central processor, programmer's console, power supply, 4096 16-bit words of core memory, Direct Memory Access (DMA) channel, interface for a teletypewriter, automatic interrupt source identification, and slide mounts or tabletop enclosure. Automatic program load, power monitor and auto restart, and hardware multiply/divide are central processor options and require no additional printed circuit boards. A low-cost turnkey console can be substituted for the programmer's console in applications that don't require a full complement of switches and status indicators.

6. NEW MEMORY TECHNOLOGIES

Data General was the first company to offer semiconductor memory in a minicomputer. Supernova SC comes with semiconductor memory with a full cycle time of 300 nanoseconds, making it the fastest minicomputer on the market. The semiconductor memory is completely compatible with Supernova core memory, which has a full cycle time of 800 nanoseconds. Semiconductor and core memories can be mixed in the same machine, with the faster semiconductor memory being used to execute repetitive subroutines or loops. The bipolar technology used in the Supernova SC memory yields the highest level of performance currently available for minicomputer memories.

7. SOFTWARE

Data General provides the most extensive software package available with any 16-bit computer. There are two types of minicomputer software: essential operating software that requires minimum investment in memory, and more fully developed software that requires more memory, but which also offers the standard features and extensions necessary in implementing a total system.

For minimum system configurations, in which economy of memory usage is critical, Data General's standard assembler, editor, loader, and debug comprise a powerful, compact software package.

For systems requiring extended programming capability, Data General's developmental software package includes standard and relocatable editors, assemblers, cross assemblers, diagnostics, and utility programs.

Three compilers are available: Extended FORTRAN IV, Extended ALGOL, and single-user and timesharing BASIC. Each of these languages includes all of the standard features of the language, plus powerful extensions.

A device, independent Disc Operating System, provides a comprehensive file management system. DOS supports an extensive software library, including the relocatable assembler, editor, linking loader, and ALGOL and FORTRAN compilers. A Real-Time Operating System and a Stand-Alone Operating System are also available.

Datapoint is a program for the preparation of paper tapes for numerical control of machine tools.

8. STANDARD PERIPHERALS

Data General offers peripheral devices in every major category. The list of standard Data General peripherals includes industry-compatible magnetic tape units, a variety of

compact and large-scale industry-compatible disc storage systems, communications hardware, a wide range of analog-to-digital and digital-to-analog converters, line-printers, interfaces to IBM System 360 computers, plotters, card readers, and paper-tape equipment.

Many of these devices are manufactured wholly or in part by Data General. Others are sold substantially as they are built by major peripheral manufacturers. In any case, any peripheral device sold by Data General Corporation is completely interfaced and supported by Data General.

9. INTERFACING

Standard interfaces are available for all peripheral devices offered by Data General, and are compatible with any of the Nova-line minicomputers. Interfaces are extremely simple to install. One or more interfaces are mounted on a standard 15-inch square printed circuit board, which slides into the Nova-line chassis and plugs into the back-panel through a highly reliable finger connector.

Non-standard interfaces can be built on a variety of general-purpose wiring frames and printed circuit boards. The general-purpose hardware has the same 15-inch square format and back panel connectors as the standard interfaces and plugs into the same chassis.

10. INPUT/OUTPUT FACILITY

Program-controlled data transfer is made through the I/O bus, and high speed data transfer is made through the Direct Memory Access (DMA) channel, which is standard equipment on all the Nova computers. The maximum data transfer rate is 1.25 million words per second using DMA. Up to 62 external devices can be addressed, and the I/O word length is 16 bits.

11. PRIORITY INTERRUPT SYSTEM

Sixteen levels of priority interrupt are available for the Nova-line computers.

12. EXPANSION

The Nova-line minicomputers can be expanded to 32K 16-bit words of memory and can address up to 62 external devices. The modular packaging of the Nova-line computers makes it possible to offer several hardware/software compatible computers with different memory and interface capacities. Standard chassis are available with from four to 17 slots for mounting printed circuit subassembly boards carrying central processor, memory, and interfaces. In several of the Nova-line computers, a full 32K of core memory can be installed, in addition to multiple interfaces to peripheral devices.

13. HARDWARE RELIABILITY

The use of the maximum possible amount of MSI/LSI circuitry and the simplest, most modular overall mechanical design make the Nova-line minicomputers the most reliable on the market. For example, in a 4K configuration, a complete Nova 1210 uses fewer IC packages than most minicomputers use in their central processors alone. The entire Nova 1210 central processor fits on a single printed circuit board. The resulting minimization of interconnections of all sorts means a minimum of potential failures. Data General's published MTBF figures are among the best available for minicomputers.

14. FIELD SERVICE

Data General field offices are located in major cities all over the United States, Canada, and Europe. A variety of

field service arrangements are available, including an on-call service contract. Under that contract all service is performed on a top priority, rapid-turnaround basis at the customer's site. There is a monthly contract charge and no additional charges for time or material. Under the Warranty Extension plan, labor and parts are free for equipment returned to the factory by the customer.

The mechanical design of the Nova line offers distinct advantages from a service point of view. The Nova-line computers are extremely easy to troubleshoot; there are few printed circuit boards involved, so a fault can be isolated very quickly. Because it is extremely easy to exchange boards, the suspected board can be replaced temporarily, allowing the system to keep running while the fault is corrected. The board then can be serviced in the field, or it can be mailed to the Data General factory for service.

15. TRAINING

Data General supplies two one-week training courses with each Nova-line computer: a programming course and a hardware maintenance course. The courses are run on a regular, frequent schedule at Data General's manufacturing headquarters in Southboro, Mass. These courses are designed to provide the user with a practical working knowledge of the system features that are most important in implementing a new computer system. Hands-on instruction is emphasized. A knowledge of computer fundamentals is assumed.

16. OEM/SYSTEMS HOUSE/MANUFACTURER

Data General Corporation is a full-line minicomputer manufacturer, supplying a broad, compatible line of mainframes, peripherals, software, interfaces, and support services which is as complete as any available to the end user.

For the OEM, the Nova line offers a broad range of completely compatible mainframes and very favorable price/performance ratios at each level. The complete compatibility of the Nova line allows the OEM to develop his system using a large configuration, implement the system at the lowest price possible, offer his customers a range of system prices and performance levels, and guarantee them considerable flexibility for expansion and modification. Data General's comprehensive software encourages the rapid development of effective special-purpose software by the OEM.

When Data General went into business three years ago, minicomputer discount schedules were designed to offer maximum advantage to OEM purchasers of 100 or 200 computers – an unrealistically large number. Data General's discount scheme offers very attractive advantages to purchasers of 10 to 20 units, and has now become the standard of the minicomputer business.

For the systems house, whose concerns are usually more akin to those of the end user, the Nova line offers compatibility, reliability, easy expansion, and a broad line of software and peripherals. Data General's developmental software is particularly useful in creating special-purpose systems.

17. MANUFACTURER'S RELIABILITY

Three years after we demonstrated our first machine, over 2,000 Nova-line computers were installed all over the world. No other minicomputer manufacturer has ever achieved such rapid acceptance. This rapid growth to the number 2 position in our field has been due in large part to our commitment to providing the complete range and quality of products and services expected of a large, reliable manufacturer. We have consistently demonstrated our ability to deliver products that perform as promised, on schedule.

	Nova 1200	Nova 1210	Nova 1220	Nova 800	Nova 820	Supernova SC
Word Length	16 bits	16 bits	16 bits	16 bits	16 bits	16 bits
Core Memory Cycle Time	1.2 μsecs	1.2 μsecs	1.2 μsecs	0.8 μsecs	0.8 μsecs	0.8 μsecs
Semiconductor Memory Cycle Time						0.3 μsecs
Memory Capacity (16-bit words)	32K	24K	32K	32K	32K	32K
Core Memory Increments (16-bit words)	1, 2, 4 or 8K	1, 2, 4 or 8K	1, 2, 4 or 8K	1, 2, 4 or 8K	1, 2, 4 or 8K	2, 4 or 8K
Semiconductor Memory Increments (16-bit words)						256, 512, 1024
Semiconductor ROM Increments (16-bit words)	256, 512, 1024	256, 512, 1024	256, 512, 1024	256, 512, 1024	256, 512, 1024	256, 512, 1024
Memory Capacity in Basic Chassis (16-bit words)	32K	24K	32K	32K	32K	32K
Hardware Accumulators	4	4	4	4	4	4
Index Registers	2 hardware; 16 memory	2 hardware; 16 memory	2 hardware; 16 memory	2 hardware; 16 memory	2 hardware; 16 memory	2 hardware; 16 memory
I/O Word Length	16 bits	16 bits	16 bits	16 bits	16 bits	16 bits
Direct Memory Access Channel	standard	standard	standard	standard	standard	standard
Max. Word Transfer Rate (DMA)	833.3 KHz	833.3 KHz	833.3 KHz	1.25 MHz	1.25 MHz	1.25 MHz
Priority Interrupt Levels	16	16	16	16	16	16
Response Time to Interrupt	17.8 μsecs	17.8 μsecs	17.8 μsecs	11.0 μsecs	11.0 μsecs	9.8 μsecs
Maximum Number of I/O Devices Addressable	62	62	62	62	62	62
Total Subassembly Slots	7, 17*	4	10	7, 17*	10	11**
Power Required	——— 47-63 Hz, single phase, 15 amperes, 115 or 230 volts ±20% ———					115 or 230 volts ±10%
Power Dissipation	300 watts typical	300 watts typical	300 watts typical	300 watts typical	300 watts typical	600 watts typical
I/O Bus Levels	Ground and +3	Ground and +3	Ground and +3	Ground and +3	Ground and +3	Ground and +3
Operating Temperature	0 to +55°C	0 to +55°C	0 to +55°C	0 to +55°C	0 to +55°C	0 to +55°C
Relative Humidity	to 90%	to 90%	to 90%	to 90%	to 90%	to 90%
Weight	50 lbs.	40 lbs.	50 lbs.	50 lbs.	50 lbs.	60 lbs.
Height	5¼ in. 10½ in.*	5¼ in.	10½ in.	5¼ in. 10½ in.*	10½ in.	10½ in.**
Width	19 in.	19 in.	19 in.	19 in.	19 in.	19 in.
Depth	23 in.	20 in.	20 in.	23 in.	20 in.	22 in.

*Jumbo chassis **With semiconductor memory expansion chassis

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