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Microprocessors

Summary

There are a number of ways to design microprocessors into products, and each design method is briefly considered, along with the factors affecting the choice. Considerations governing which microprocessors to use for any particular application are looked at, with some examples of the many hundreds of design problems which may readily be solved with microprocessors. Reference is made to the exciting new field that now exists for equipment designers to solve complex circuitry requirements with very compact, reliable designs. Finally, the support activities connected with the use of microprocessors are outlined showing how these vary with the level of activity being undertaken.

Introduction

A significant new integrated circuit known as the microprocessor has recently been added to the design engineer's range of electronic components. When treated with respect it is a powerful device enabling a range of problems to be effectively solved.

It is easy to be misled by claims that it can be used to solve almost any design problem, in fact it is an addition to the number of possible solutions available at the system design stage. The sort of designs now including a microprocessor range from units such as message preparation terminals, small data gathering systems and data entry units to quite complex systems involving the use of more than one microprocessor such as data switching systems. Figure 1 shows a typical microprocessor chip whilst figure 2 is a photograph of the same chip embodied in a design containing memory circuits and interface logic.

Microprocessors are very complex large-scale integration (LSI) chips which require care in design, production and test. One particular feature is their ability to be programmed, a factor which is often played down in the initial considerations, only to become a major factor later on. However, programming can be successfully tackled if care is taken and sound engineering disciplines followed.

Microprocessor chips are made up of many hundreds of microcircuits which include transistors, resistors, etc., all constructed in such a way as to form a complex logic array of circuits. The chip thus replaces many hundreds of simple integrated circuits (gates) and contains circuits which perform all the functions of a conventional processor such as control, arithmetic and microprogram units, complete with the necessary interfaces for external connections.

The decision to use a microprocessor must be based on sound reasoning and logical deduction. Once the question has been decided, then the most suitable type must be selected, and finally the right support facilities made available. If all these factors have been fully considered then a satisfactory product design will follow.

The designer's choice

The engineer, when setting out to design a new product against a specification, must choose one of four basic design paths.

The conventional approach using random logic and discrete circuits is still an effective method. A wide range of medium scale integration (MSI) and general logic circuits are available. This method is often used where fast operation is required.

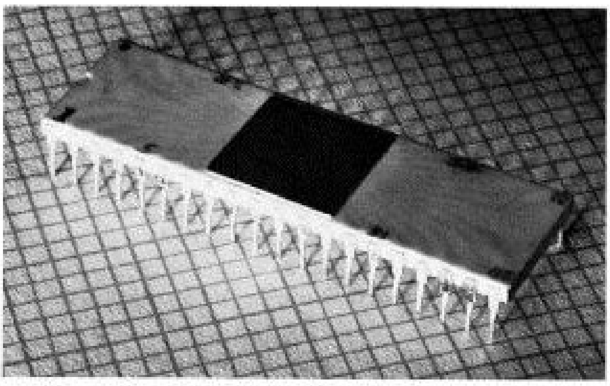

Figure 1. Typical microprocessor chip

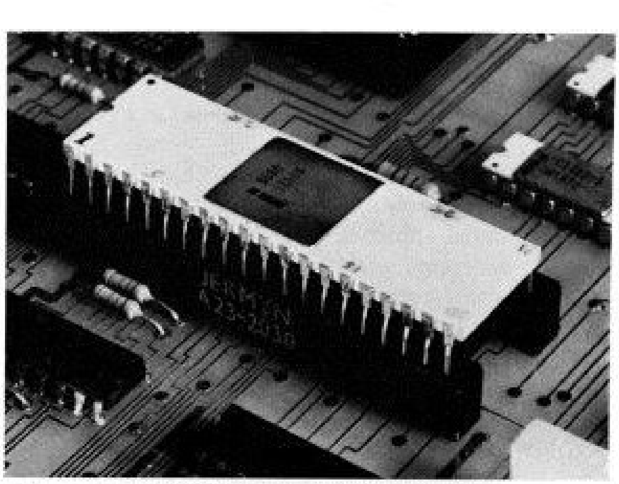

Figure 2. Example of microprocessor chip in use with memory circuits and interface logic

Another approach is to use 'custom designed large scale integration'. In this case one or more chips are designed specifically to meet a requirement and for a large production run each component will be much cheaper than an equivalent logic array.

The microprocessor approach can be tackled in one of two ways. The first method is to combine the microprocessor and its associated LSI chips together with discrete circuits and general logic to form a special-to-purpose design. This method is most applicable to the smaller units, particularly if cost is a key factor, but there must be a sufficient production quantity to cover the development costs.

The second method is to select modules from a standard range and combine them with special modules as required. This approach is best suited to the larger units and tends to take a form similar to a conventional minicomputer.

Factors affecting the designer's choice

The factors affecting the choice of design approach are numerous and interactive. It is therefore essential that as many facts as possible are gathered together, sifted, and sorted before the final decision is taken.

The estimated production quantities will affect both development and unit cost; microprocessors and their associated memory chips tend to be much cheaper in quantity.

The product specification may call for features which determine the choice of design concept. If flexibility, options and ability to change quickly are required then a microprocessor might be the best selection. The ability to change during the design phase or afterwards may well limit the freedom of choice, and whilst it is hoped that customers and product planners can finalize a specification before design commences, it is often not the case.

The speed at which the system has to operate and process information is a major factor. In some cases it may well rule out certain options. Because processors require a number of instructions to carry out a function, they are slower than a general logic array.

The time-scale of a project is not wholly determined by technical considerations, and may be affected by marketing and customer requirements. A requirement for short time-scales may rule out extensive special-purpose designs.

An organization tends to have a certain level of expertise readily available, and this is bound to affect the initial approach to a design problem. It is not easy to redeploy, recruit or invest on a grand scale just because a new technique looks promising.

Finally, the necessary support facilities may not be readily available as, for example, software for microprocessors while custom LSI requires excellent computer-aided design (CAD) facilities.

Which microprocessor?

Full consideration of the above points may lead the designer to decide on a microprocessor-based solution. If this is the case, then the next stage is to choose which microprocessor is the most suitable.

The construction of an LSI chip is a basic factor affecting overall performance. Microprocessors come in four types, complementary metal oxide silicon (CMOS), N-channel metal oxide silicon (NMOS), P-channel metal oxide silicon (PMOS) and bipolar. NMOS and PMOS are the oldest and most popular, whereas CMOS has the advantage of low power and bipolar is much faster. Both CMOS and bipolar are available to cover military temperature ranges.

Another consideration is the number of bits in a processor word, as this affects both speed of operation and precision of calculation. There are 4, 8, 12 and 16-bit processors, the most usual is 8 bits which readily finds application in systems involving character handling.

Once construction and word size have been selected, there is not much choice in speed of operation, most devices get the best speed out of the available technology.

Apart from these considerations, processing power is also affected by what is known as the architecture or system design framework of microprocessors which covers such things as instruction set, addressing mode, interrupt system, etc. However, most microprocessors have acceptable architectures, and so are capable of giving the required performance.

A feature of many bipolar microprocessors is the ability to program the micro-instructions, a facility which can be useful in certain replacement types of application.

Other matters include delivery times, price, software support available, and the range of associated LSI chips, e.g memory interfaces, clock, etc.

Consideration should also be given to the type of memory required, ferrite core, semiconductor or both, and whether a read only memory (ROM) is necessary. A very wide range of semiconductor memory types, speeds and sizes is available. A recent addition is the erasable programmable ROM which besides having the advantages of ROM also allows the user to re-program the device and for this reason is particularly useful.

The majority of applications are satisfied using an 8 bit NMOS/PMOS microprocessor, particularly in communications which involves character handling. Marconi Communications Systems (MCSL) has chosen the INTEL 8080 for its first applications since it is readily available, has all the necessary facilities including a large family of associated chips, and has already been reliably produced in large quantities.

Typical applications

There are three general microprocessor application areas; special-to-purpose, modular and distributed systems. The examples listed below only serve to illustrate the hundreds of possible applications in many different spheres.

Some examples in the special-to-purpose area where a microprocessor is built into a design (see figure 3) are automatic vehicle location, traffic-light control and data terminals.

In the modular area where one or more standard modules or printed-circuit boards (PCBs) e.g processor, memory, input/output are combined with special-to-purpose modules (as shown in figure 4) examples are found in message preparation terminals, point-of-sale terminals, satellite communication terminals and automatic test equipment.

Finally, there is the distributed processing system where the system is divided into a number of similar units (see figure 5). The units are interconnected in an array with each having the capacity to perform a particular function and would be built up either of special-to-purpose designs or standard modules. This system arrangement has considerable advantages in economic growth and reliability factors. Some examples are message switching, telephony switching, telex switching and satellite ground station control.

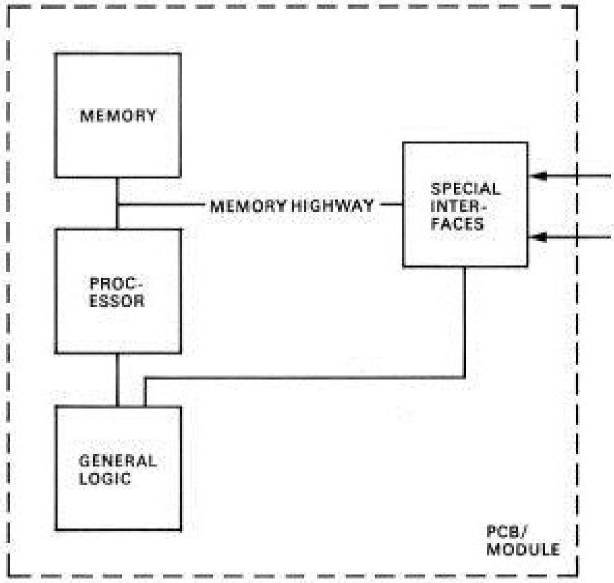

Figure 3. Special to purpose design

Design concept

When a microprocessor is built into a product, it will have a computer-like structure with a central processing unit (CPU), memory, peripherals and some general-purpose logic.

The CPU may be one LSI chip or multiple LSI chips depending on the type selected. The memory is used to contain the program and its associated data, its size ranging from a few hundred words to many thousands of words. A system must have at least one input and one output channel in order to function, and units connected to these channels are called peripherals. In addition general circuits such as a clock, reset and interfaces could be required.

These circuits may be on one special printed-circuit board or a number of boards and in either case the system must be programmed. There are two choices, either machine code or a program language. In the first case the actual binary code which the processor acts upon is written down and fed directly into the processor. This is only satisfactory for very small programs since the result is not easily understood or changed.

Although programming languages have been developed to overcome the serious disadvantages of machine code, some sort of software support system is needed to convert the language into machine code. This usually takes the form of an assembler for use with assembly code or a compiler for use with a high level language.

It is important to ensure that the software support system and the equipment design concept are compatible. This can be achieved either by following the manufacturer's instructions and using the support services available with the processor or by developing a multipurpose structure and providing general purpose support. If the latter course is taken, different microprocessors may be used in the same structure with full support and a measure of manufacturer independence achieved. The MCSL design achieves this by defining the basic memory interface which may be contained within a printed-circuit board (see figure 3) or as an interconnection system between boards (see figure 4).

Support

Having the right tools enables the designer to work efficiently. However, the provision of these tools depends to some extent on their cost, the number of

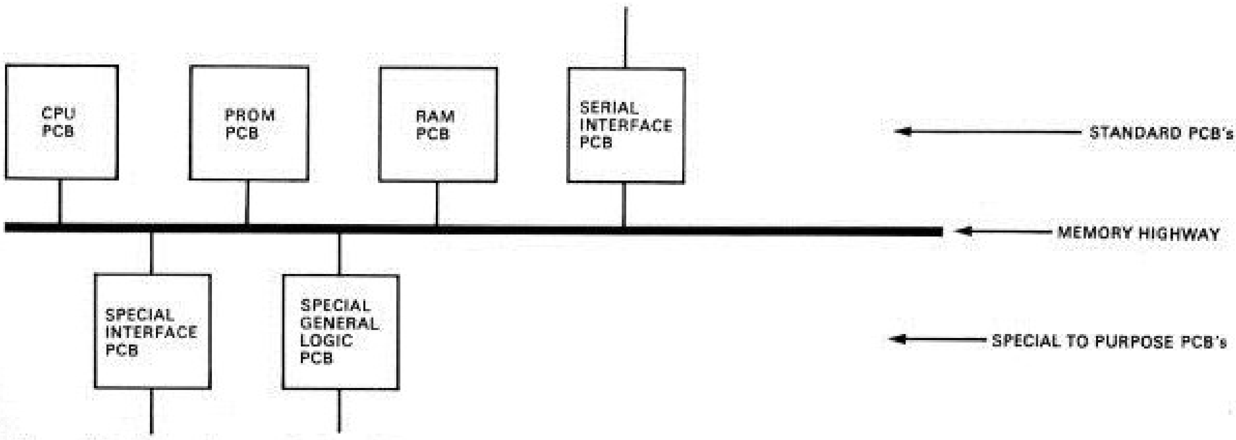

Figure 4. Design using standard modules

applications involved, the size of projects and the timescales.

It is possible to program in machine code, load the data into a programmable read only memory (PROM) and test the unit on-line. In this case the only tool is a PROM programmer, which can be hired. Program faults would be found by on-line trial and error.

Considerable time may have to be spent re-programming the PROMs. This can be resolved by using read write memory, a loader and paper tape reader, which enables fast loading during the test stages.

Working in machine code means that large parts of the program will need rewriting when a change is made, since insertion of a new instruction will alter the address of all subsequent instructions. This problem can be solved by writing the program in an assembly code. The program must then be processed using an assembler, which itself must be run on a computer, which could be a microprocessor system.

It is likely to take a long time to fault-find a program on-line if no test access facilities are available, since a number of problems could lead to erroneous operations and widespread data corruptions with no obvious clue to the fault. A diagnostic panel helps in this task by enabling the tester to control the program. However, when using a panel, it is not easy to access the working registers in a microprocessor, or keep track of changes and record data automatically. A more satisfactory solution is to test a program under control of a simulator running on a general purpose computer and only carry out final testing on-line.

A test-aid simulation system which incorporates such features as tracing, data display, batch working, data recording, memory protection and ability to change data, leads to efficient program testing which can be readily repeated.

Finally, to reduce documentation, improve program accuracy, reduce writing time and ease changing, a high-level language such as Coral 66 which allows the use of assembly code for sensitive areas, should be considered. However, an efficient compiler and a suitable computer system is then required.

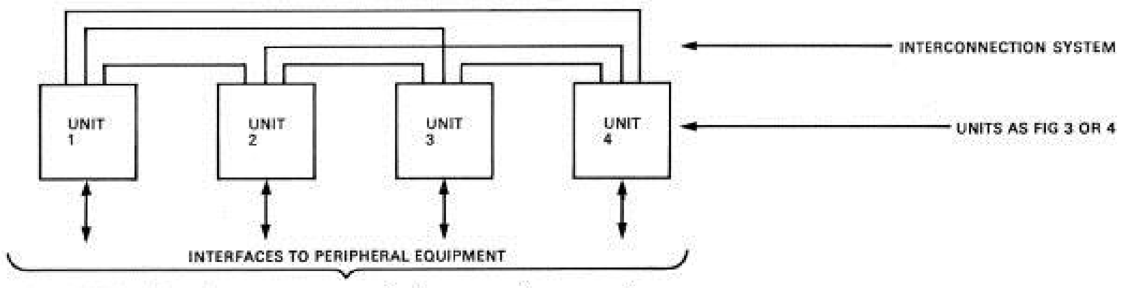

Figure 5. Distributed processor system showing array interconnections

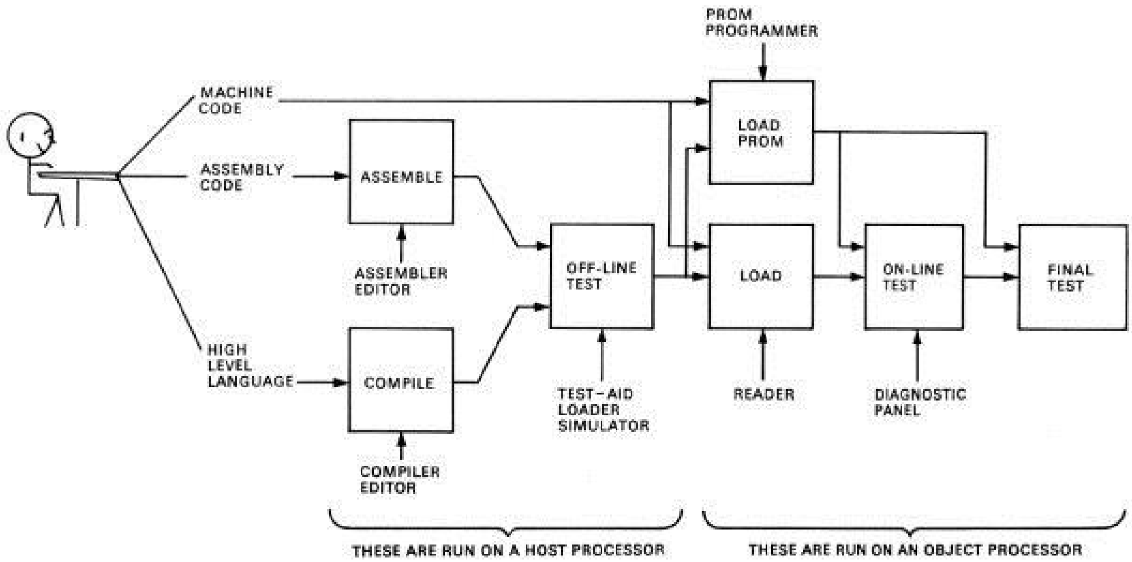

Figure 6. Support system showing the associated services

The manufacturers of microprocessors provide some of the above facilities; access is gained by use of a terminal connected to a large computer-bureau system. In designing one small system these facilities will probably be adequate, though bureau systems tend to be expensive if used extensively. Also a change to a new microprocessor involves considerable re-training and re-equipping.

In MCSL there is a support system which in concept is independent of manufacturer and bureau or host-computer system, giving designers considerable freedom of choice. Figure 6 shows the whole series of support services, which must be designed to be fully compatible with each other.

Conclusion

This article illustrates that microprocessors are complex components, and in order that they may be applied correctly and used effectively, careful consideration of all the design details along the lines indicated is very necessary.

However, once the potential user has fully familiarized himself with the factors involved, the design process will then be no more difficult than other methods, so long as full engineering disciplines are applied to both the equipment and software design.

There is no doubt that the use of microprocessors produces cost effective designs and in our experience enables problems to be solved which could not have been undertaken by other methods.