A SINGLE-CHIP 4-BIT MICROCOMPUTER: MN1500 SERIES

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Abstract
In recent years single-chip microcomputers have been increasingly applied to consumer product controllers and various machine controllers. In this paper, a high performance single-chip 4-bit microcomputer is described which mainly processes 4-bit data and has some instructions processing 8-bit data.

Introduction
Advancements of semiconductor technology is leading to the development of microcomputers with higher level of integration and performance. Single-chip 4-bit microcomputers are most widely applied to various products as controllers.

Conventional single-chip 4-bit microcomputers have architectural characteristics, because they are originally developed for control LSI of desktop/hand-held calculators and electronic cash registers. That is, the architecture is designed for the convenience of key-scanning and display control, therefore they are often not suitable for general purpose controllers.

The 4-bit microcomputers have often complex internal structure, because the main functional blocks, a program counter, an instruction register, and an accumulator, have different bits width and they include complex instructions for purpose of the efficient use of ROM. But the capability of the 4-bit microcomputer which processes mainly BCD data is of importance from view point of a man machine interface. This paper introduces high performance single-chip 4-bit microcomputers, MN1500 series, which are developed to bridge 4-bit and 8-bit applications for use in general purpose controllers and have bus oriented architecture.

Device Technology
The MN1500 series is fabricated using a N-channel LOCOS silicongate E/D MOS technology with the 4 µm design rule. This process technology is adopted for the reason that the MN1500 series requires high integration and high speed operation, and moreover it is necessary to transfer this series to the commercial base production quickly. The process is in substance the same one which is applied to the MN1400 series single-chip 4 bit microcomputers developed in 1977. The MN1500 series is TTL/CMOS compatible and requires a single +5 volts power supply.

Process
For the Source-Drain diffusion, As ion implantation method is used. To solve many kinds of problems deriving from shrinking of device size, new techniques such as thin oxide, low step and dry etching are adopted.

Pattern Designing
New pattern designing method has been employed so that high speed and high integration are achieved. For example, comparing an RAM cell for the MN1500 series with the MN1400 series, the former is about 33% of the latter in cell size. Figures 1(a) and 1(b) show RAM call layout of MN1500 series and MN1400 series. Concerning the operating speed, the requirement is very severe. Since it is necessary to change bus data every one clock cycle, the delay time of clock cycle timing was minimized, and bus circuit design and read/write amplifier of RAM were improved. Applying these new technologies to the MN1500 series, the MN1544, a version of the MN1500 series, contains approximately 50,000 transistors in an area of 5.4 x 5.16 mm², and a machine cycle time of 2 µs was achieved.

Architecture
The MN1500 series implements functions with logic complexity almost comparable to the high performance single chip 8-bit microcomputer.

Figure 2 shows the block diagram of the MN1500 series.

The MN1500 series includes four versions:
- MN1542 : ROM 2Kx8-bit, RAM 152x4-bit, 40-pin
- MN1544 : ROM 4Kx8-bit, RAM 256x4-bit, 40-pin
- MN1562 : ROM 2Kx8-bit, RAM 152x4-bit, 64-pin
- MN1564 : ROM 4Kx8-bit, RAM 256x4-bit, 64-pin

The major architectural features of the functional blocks are described as follows.

Internal Data Bus
The internal data buses are organized in two 4-bit data buses, because the device can do 4-bit arithmetical and logical operations and 8-bit data transfer in one machine cycle. Figure 3 shows the structure of the internal data buses.
Clock and Timing

The basic internal timing diagram is illustrated in Figure 4.

An external frequency source of 4 MHz is required. This can be a crystal, ceramic filter, or can be driven using external active components.

An instruction cycle contains one or two machine cycles. One machine cycle consists of four clock cycles. One clock cycle, typically 500 nsec, overlaps next machine cycle. It is possible to read and write RAM in one machine cycle.

ROM, Program Counter

The program counter (PC) consists of an 8-bit binary counter (lower order of PC) and a 4-bit register (higher order of PC). This implies that the MN1500 series is a page machine. The maximum size of ROM is 4096x8-bit.

RAM

RAM, contained in the microcomputer, is organized in 8-bit units. This aims to handle 8-bit data of the RAM in one machine cycle. It is possible to nest to sixteen-level subroutines and internal four registers can be stored in the RAM stack area.

The RAM has three addressing modes below:
- Register (XY) indirect addressing mode
- Register (SP) indirect addressing mode
- Direct addressing

The power supply for the RAM is independent of other parts of a microcomputer. A control pin, used to retain the RAM data, is provided.

Registers, Flags

Four 4-bit registers (E, A, X, Y) and one 8-bit register (SP) are contained.

The uses of these registers are:
A: accumulator
E: accumulator extension
X: RAM higher address register
Y: RAM lower address register
SP: Stack pointer

Each register can be used as a general purpose register. It is possible to handle 8-bit data by using A and E registers. The zero flag and the carry flag are contained and are affected by the result of operation and transfer.

Input and Output

The input and output circuits have quasibidirectional structure with output latches. The input instructions can handle 4-/8-bit data and have mask capability in the case of 4-bit input instructions. The output instructions can handle 1-/4-/8-bit data and issue strobe signals. The pulse output instruction is provided.

Interrupt Control

The two external and two internal interrupts are provided. The external interrupts are maskable and nonmaskable interrupts. The internal interrupts consist of timer/counter and serial interface interrupts. A hardware priority encoder is implemented to generate different starting address for each interrupt.

Timer Counter

The timer/counter consists of 8-bit control register, buffer register, binary counter and 7-bit prescaler and has three fundamental functions, i.e. internal timer mode, external counter mode, and pulse width measurement mode.

Serial Interface

The MN1500 series communicates with external peripherals through the serial interface. Its operation has two modes, i.e. internal and external clock modes. By using of internal clock mode, 8-bit data can be transferred to external devices within 16 usec.

Instruction Set

The MN1500 series contains powerful 124 instructions, which are divided into four categories:
- Data transfer instructions
- Input and Output instructions
- Arithmetical and Logical instructions
- Control transfer instructions

Each instruction requires one or two bytes of ROM. One byte instructions consist of one or two machine cycles. Every two bytes instructions require two machine cycles. The complex instructions which are often expressed by a combination of simple instructions are provided for a saving of the program area.

Figure 5 shows a photomicrograph of the MN1544.

Conclusion

Single-chip 4-bit microcomputer, MN1500 series, designed to be used for complex machine controllers and featuring unique architectural design has been developed with the use of new circuit design and process technology.

The organization of the multi-microcomputer which is loosely connected to each other can be realized with a few pins by employing serial interface. As a result, the MN1500 series is applicable to complex machine controllers which can not use a 4-bit microcomputer so far.
Figure 1(a). RAM Cell Layout of MN1500 Series

Figure 1(b). RAM Cell Layout of MN1400 Series

Figure 2. Block Diagram
Figure 3. Internal Bus Structure

Figure 4. Basic Instruction Timing

Figure 5. Microphotograph of the MN1544