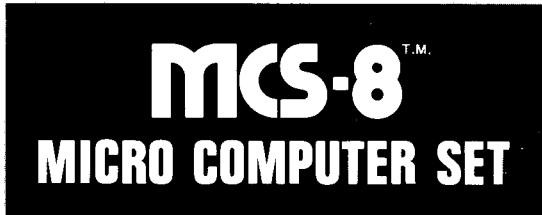




INTEL CORP. 3065 Bowers Avenue, Santa Clara, California 95051 • (408) 246-7501

8008 8-BIT PARALLEL CENTRAL PROCESSOR UNIT



USERS MANUAL

INCLUDES the 8008-1,
SIM8-01-MP7-03,
and the Bootstrap Loader

NOV. 1972

REV. 2

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For MCS-8^{T.M.} systems

- 1. Prototyping board**, SIM8-01. Forms operational micro-programmed computer with Intel's erasable PROMs in place of mask-programmed ROMs. Holds up to 16K bits of PROM and 8K bits of RAM.
- 2. PROM programmer**, MP7-03. Intel erasable PROMs plug into this board for programming using a teletypewriter.
- 3. SIM8 hardware assembler**. Eight PROMs plug into SIM8 board, enabling the prototype to assemble its own programs.
- 4. System interface and control module** interconnects all other support hardware and a TTY for program assembly, simulation, PROM programming, prototype operation and debugging. Intel MCB8-10.
- 5. TTY transmit/receive test program** on PROM which plugs into prototyping board. Intel AO-800.
- 6. Chip-select and I/O test program** on PROM which plugs into prototyping board. Intel AO-801.
- 7. RAM test program** on PROM that plugs into prototyping board. Intel AO-802.
- 8. Bootstrap loader** enables you to enter data or a program into the RAMs from a teletypewriter paper tape or keyboard, and execute the program from the RAMs. Consists of three PROMs (AO-860, 861 and 862) that plug into the prototyping board.
- 9. Fortran IV assembler** gives you the assistance of any general-purpose computer in developing MCS-8 programs.
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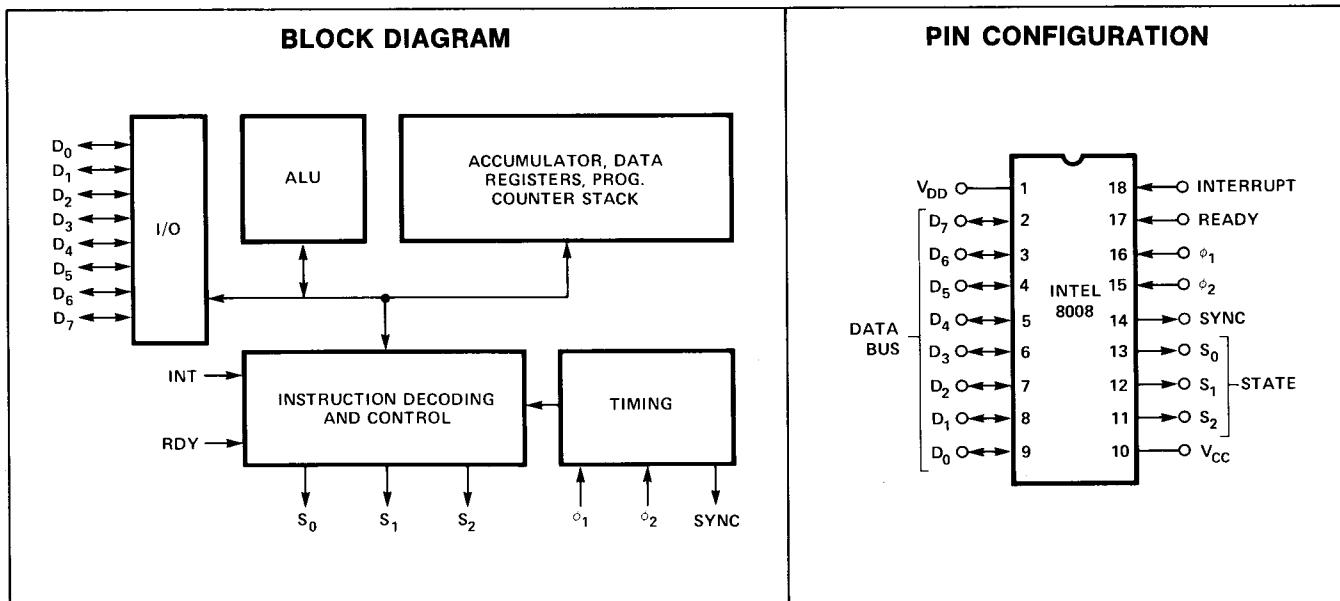
8008

8 Bit Parallel Central Processor Unit

The 8008 is a complete computer system central processor unit which may be interfaced with memories having capacities up to 16K bytes. The processor communicates over an 8-bit data and address bus and uses two leads for internal control and four leads for external control. The CPU contains an 8-bit parallel arithmetic unit, a dynamic RAM (seven 8-bit data registers and an 8x14 stack), and complete instruction decoding and control logic.

Features

- 8-Bit Parallel CPU on a Single Chip
- 48 Instructions, Data Oriented
- Complete Instruction Decoding and Control Included
- Instruction Cycle Time — 12.5 μ s with 8008-1 or 20 μ s with 8008
- TTL Compatible (Inputs, Outputs and Clocks)
- Can be used with any type or speed semiconductor memory in any combination
- Directly addresses 16K x 8 bits of memory (RAM, ROM, or S.R.)
- Memory capacity can be indefinitely expanded through bank switching using I/O instructions
- Address stack contains eight 14-bit registers (including program counter) which permit nesting of subroutines up to seven levels
- Contains seven 8-bit registers
- Interrupt Capability
- Packaged in 18-Pin DIP



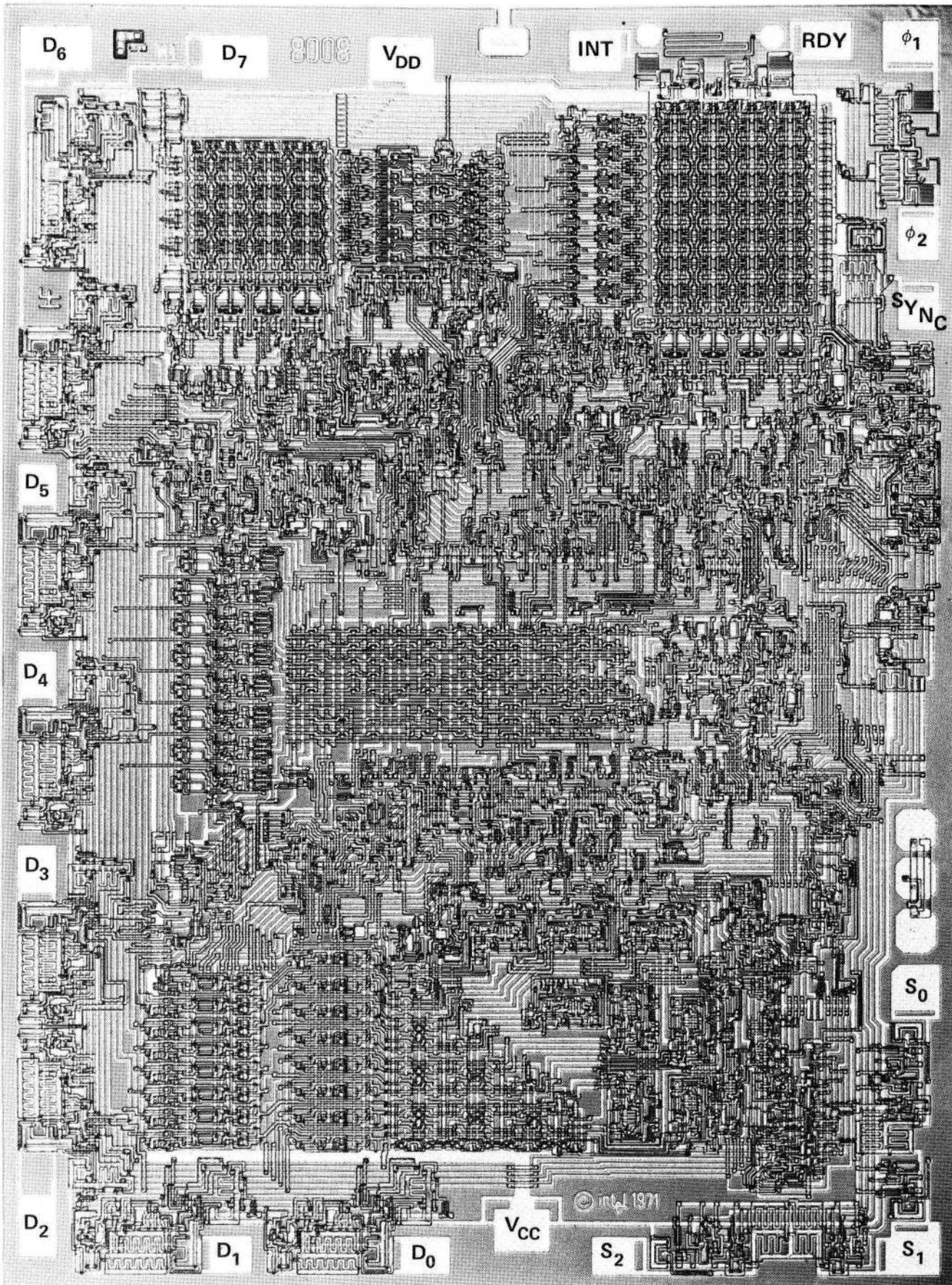
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8008 Photomicrograph With Pin Designations

I. INTRODUCTION

The 8008 is a single chip MOS 8-bit parallel central processor unit for the MCS-8 micro computer system. A micro computer system is formed when the 8008 is interfaced with any type or speed standard semiconductor memory up to 16K 8-bit words. Examples are INTEL's 1101, 1103, 2102 (RAMs), 1301, 1601, 1701 (ROMs), 1404, 2401 (Shift Registers).

The processor communicates over an 8-bit data and address bus (D_0 through D_7) and uses two input leads (READY and INTERRUPT) and four output leads (S_0 , S_1 , S_2 and Sync) for control. Time multiplexing of the data bus allows control information, 14 bit addresses, and data to be transmitted between the CPU and external memory.

This CPU contains six 8-bit data registers, an 8-bit accumulator, two 8-bit temporary registers, four flag bits, and an 8-bit parallel binary arithmetic unit which implements addition, subtraction, and logical operations. A memory stack containing a 14-bit program counter and seven 14-bit words is used internally to store program and subroutine addresses. The 14-bit address permits the direct addressing of 16K words of memory (any mix of RAM, ROM or S.R.).

The control portion of the chip contains logic to implement a variety of register transfer, arithmetic control, and logical instructions. Most instructions are coded in one byte (8 bits); data immediate instructions use two bytes; jump instructions utilize three bytes. Presently operating with a 500 kHz clock, the CPU executes non-memory referencing instructions in 20 microseconds.

All inputs (including clocks) are TTL compatible and all outputs are low-power TTL compatible.

The instruction set of the 8008 consists of 48 instructions including data manipulation, binary arithmetic, and jump to subroutine.

The normal program flow of the 8008 may be interrupted through the use of the "INTERRUPT" control line. This allows the servicing of slow I/O peripheral devices while also executing the main program.

The "READY" command line synchronizes the 8008 to the memory cycle allowing any type or speed of semiconductor memory to be used.

STATE and SYNC outputs indicate the state of the processor at any time in the instruction cycle.

II. PROCESSOR TIMING

The 8008 is a complete central processing unit intended for use in any arithmetic, control, or decision-making system. The internal organization is centered around an 8-bit internal data bus. All communication within the processor and with external components occurs on this bus in the form of 8-bit bytes of address, instruction or data. (Refer to the accompanying block diagram for the relationship of all of the internal elements of the processor to each other and to the data bus.) For the MCS-8 a logic "1" is defined as a high level and a logic "0" is defined as a low level.

A. State Control Coding

The processor controls the use of the data bus and determines whether it will be sending or receiving data. State signals S_0 , S_1 , and S_2 , along with SYNC inform the peripheral circuitry of the state of the processor. A table of the binary state codes and the designated state names is shown below.

| S_0 | S_1 | S_2 | STATE |
|-------|-------|-------|---------|
| 0 | 1 | 0 | T1 |
| 0 | 1 | 1 | T1I |
| 0 | 0 | 1 | T2 |
| 0 | 0 | 0 | WAIT |
| 1 | 0 | 0 | T3 |
| 1 | 1 | 0 | STOPPED |
| 1 | 1 | 1 | T4 |
| 1 | 0 | 1 | T5 |

B. Timing

Typically, a machine cycle consists of five states, two states in which an address is sent to memory (T1 and T2), one for the instruction or data fetch (T3), and two states for the execution of the instruction (T4 and T5). If the processor is used with slow memories, the READY line synchronizes the processor with the memories. When the memories are not available for either sending or receiving data, the processor goes into the WAIT state. The accompanying diagram illustrates the processor activity during a single cycle.

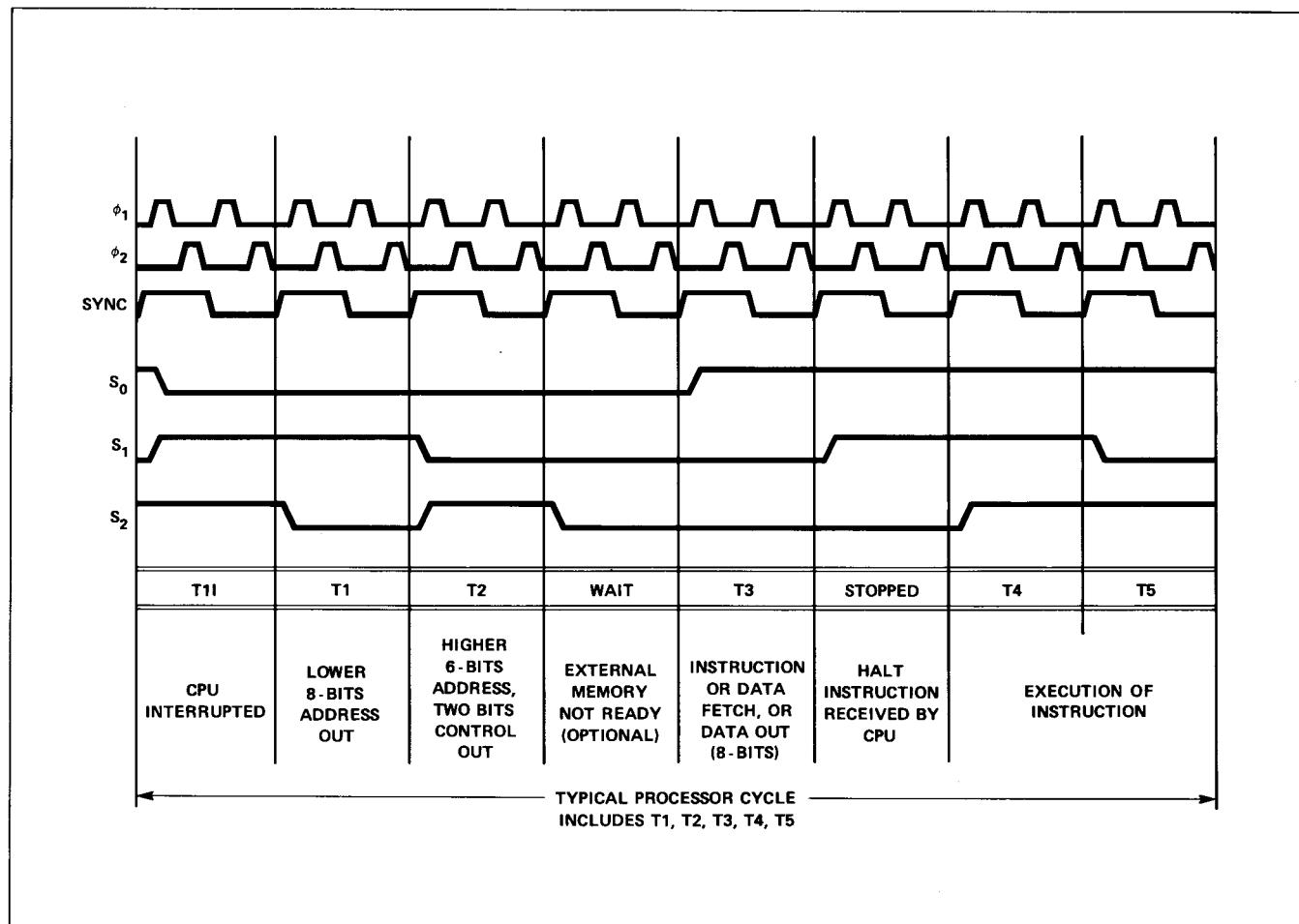


Figure 1. Basic 8008 Instruction Cycle

The receipt of an INTERRUPT is acknowledged by the T1I. When the processor has been interrupted, this state replaces T1. A READY is acknowledged by T3. The STOPPED state acknowledges the receipt of a HALT instruction.

Many of the instructions for the 8008 are multi-cycle and do not require the two execution states, T4 and T5. As a result, these states are omitted when they are not needed and the 8008 operates asynchronously with respect to the cycle length. The external state transition is shown below. Note that the WAIT state and the STOPPED may be indefinite in length (each of these states will be 2^n clock periods). The use of READY and INTERRUPT with regard to these states will be explained later.

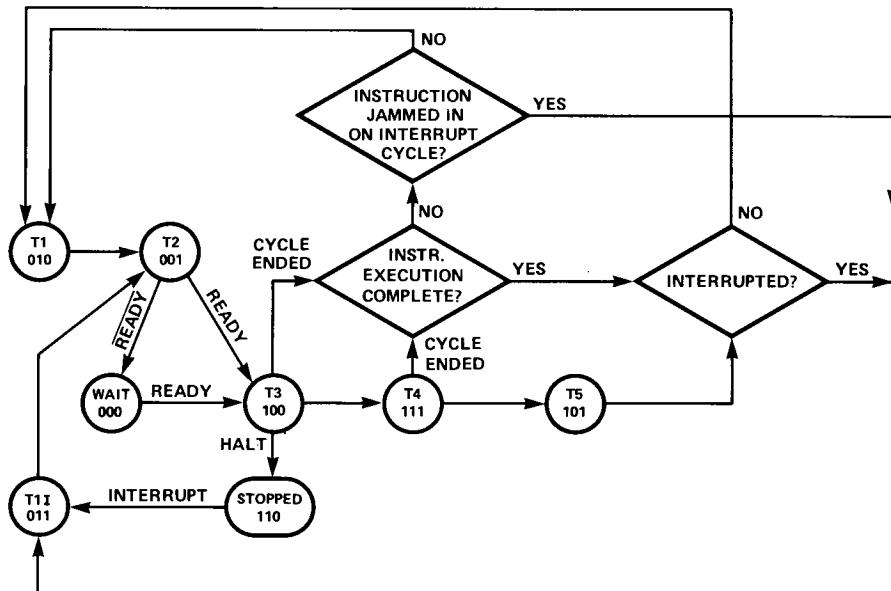


Figure 2. CPU State Transition Diagram

C. Cycle Control Coding

As previously noted, instructions for the 8008 require one, two, or three machine cycles for complete execution. The first cycle is always an instruction fetch cycle (PCI). The second and third cycles are for data reading (PCR), data writing (PCW), or I/O operations (PCC).

The cycle types are coded with two bits, D₆ and D₇, and are only present on the data bus during T2.

| D ₆ | D ₇ | CYCLE | FUNCTION |
|----------------|----------------|-------|---|
| 0 | 0 | PCI | Designates the address is for a memory read (first byte of instruction). |
| 0 | 1 | PCR | Designates the address is for a memory read data (additional bytes of instruction or data). |
| 1 | 0 | PCC | Designates the data as a command I/O operation. |
| 1 | 1 | PCW | Designates the address is for a memory write data. |

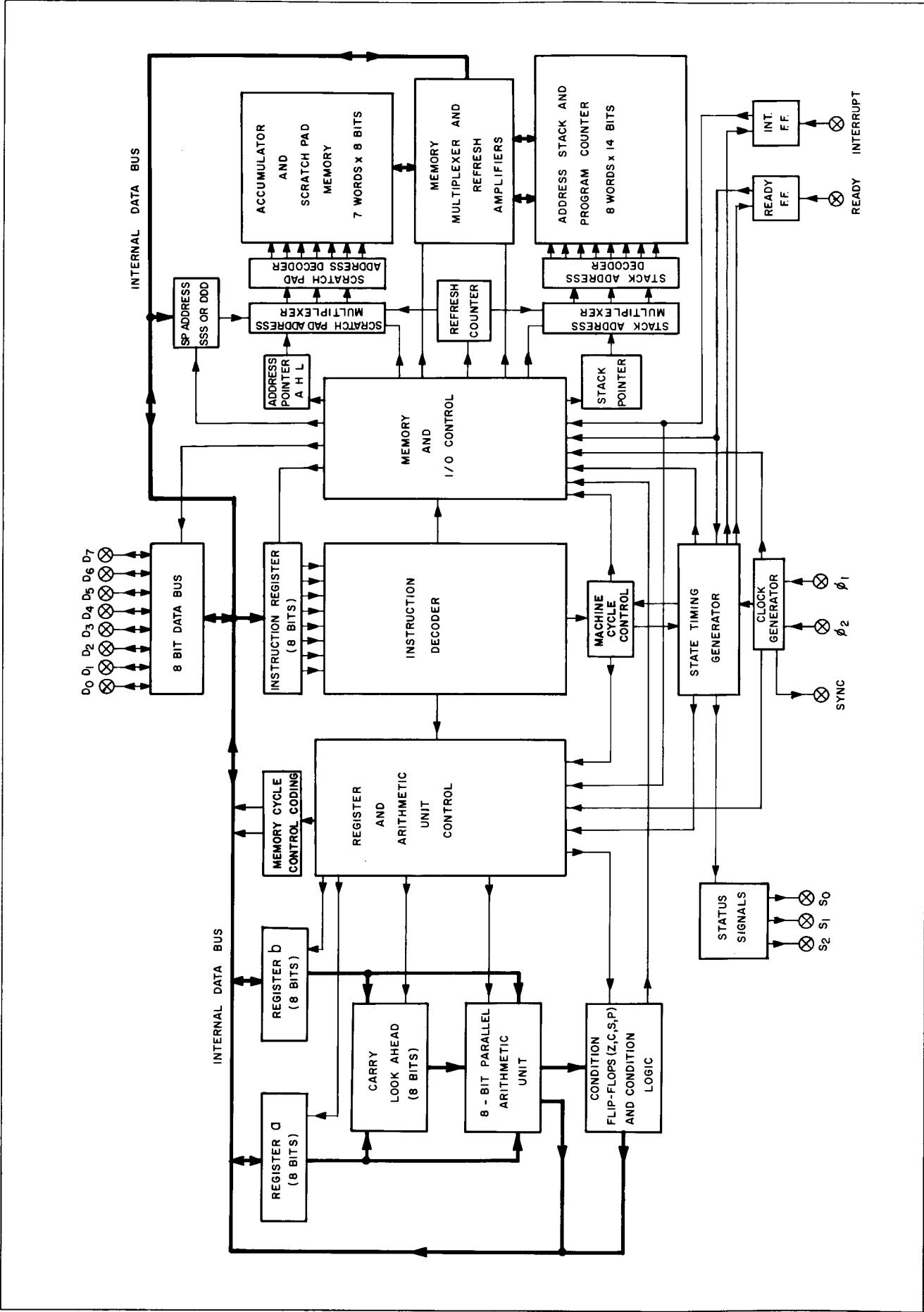


Figure 3. 8008 Block Diagram

III. BASIC FUNCTIONAL BLOCKS

The four basic functional blocks of this Intel processor are the instruction register, memory, arithmetic-logic unit, and I/O buffers. They communicate with each other over the internal 8-bit data bus.

A. Instruction Register and Control

The instruction register is the heart of all processor control. Instructions are fetched from memory, stored in the instruction register, and decoded for control of both the memories and the ALU. Since instruction executions do not all require the same number of states, the instruction decoder also controls the state transitions.

B. Memory

Two separate dynamic memories are used in the 8008, the pushdown address stack and a scratch pad. These internal memories are automatically refreshed by each WAIT, T3, and STOPPED state. In the worst case the memories are completely refreshed every eighty clock periods.

1. Address Stack

The address stack contains eight 14-bit registers providing storage for eight lower and six higher order address bits in each register. One register is used as the program counter (storing the effective address) and the other seven permit address storage for nesting of subroutines up to seven levels.

The stack automatically stores the content of the program counter upon the execution of a CALL instruction and automatically restores the program counter upon the execution of a RETURN. The CALLs may be nested and the registers of the stack are used as last in/first out pushdown stack.

A three-bit address pointer is used to designate the present location of the program counter. When the capacity of the stack is exceeded the address pointer recycles and the content of the lowest level register is destroyed. The program counter is incremented immediately after the lower order address bits are sent out. The higher order address bits are sent out at T2 and then incremented if a carry resulted from T1. The 14-bit program counter provides direct addressing of 16K bytes of memory. Through the use of an I/O instruction for bank switching, memory may be indefinitely expanded.

2. Scratch Pad Memory or Index Registers

The scratch pad contains the accumulator (A register) and six additional 8-bit registers (B, C, D, E, H, L). All arithmetic operations use the accumulator as one of the operands. All registers are independent and may be used for temporary storage. In the case of instructions which require operations with a register in external memory, scratch pad registers H & L provide indirect addressing capability; register L contains the eight lower order bits of address and register H contains the six higher order bits of address (in this case bit 6 and bit 7 are "don't cares").

C. Arithmetic/Logic Unit (ALU)

All arithmetic and logical operations (ADD, ADD with carry, SUBTRACT, SUBTRACT with borrow, AND, EXCLUSIVE OR, OR, COMPARE, INCREMENT, DECREMENT) are carried out in the 8-bit parallel arithmetic unit which includes carry-look-ahead logic. Two temporary registers, register "a" and register "b", are used to store the accumulator and operand for ALU operations. In addition, they are used for temporary address and data storage during intra-processor transfers. Four control bits, carry flip-flop (c), zero flip-flop (z), sign flip-flop (s), and parity flip-flop (p), are set as the result of each arithmetic and logical operation. These bits provide conditional branching capability through CALL, JUMP, or RETURN on condition instructions. In addition, the carry bit provides the ability to do multiple precision binary arithmetic.

D. I/O Buffer

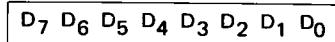
This buffer is the only link between the processor and the rest of the system. Each of the eight buffers is bi-directional and is under control of the instruction register and state timing. Each of the buffers is low power TTL compatible on the output and TTL compatible on the input.

IV. BASIC INSTRUCTION SET

The following section presents the basic instruction set of the 8008. For a detailed description of the execution of each instruction, refer to Appendix I.

Data and Instruction Formats

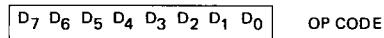
Data in the 8008 is stored in the form of 8-bit binary integers. All data transfers to the system data bus will be in the same format.



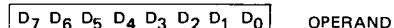
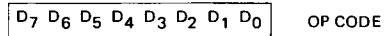
DATA WORD

The program instructions may be one, two, or three bytes in length. Multiple byte instructions must be stored in successive words in program memory. The instruction formats then depend on the particular operation executed.

One Byte Instructions



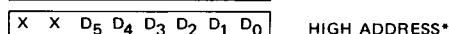
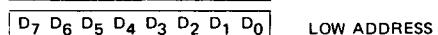
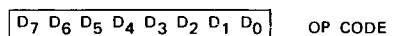
Two Byte Instructions



TYPICAL INSTRUCTIONS

Register to register, memory reference,
I/O arithmetic or logical, rotate or
return instructions

Three Byte Instructions



Immediate mode instructions

JUMP or CALL instructions

*For the third byte of this instruction, D₆ and D₇ are "don't care" bits.

For the MCS-8 a logic "1" is defined as a high level and a logic "0" is defined as a low level.

Index Register Instructions

The load instructions do not affect the flag flip-flops. The increment and decrement instructions affect all flip-flops except the carry.

| MNEMONIC | MINIMUM STATES REQUIRED | INSTRUCTION CODE D ₇ D ₆ D ₅ D ₄ D ₃ D ₂ D ₁ D ₀ | DESCRIPTION OF OPERATION |
|-----------------------------------|-------------------------|---|--|
| (1)Lr ₁ r ₂ | (5) | 1 1 D D D S S S | Load index register r ₁ with the content of index register r ₂ . |
| (2)LrM | (8) | 1 1 D D D 1 1 1 | Load index register r with the content of memory register M. |
| LMr | (7) | 1 1 1 1 1 S S S | Load memory register M with the content of index register r. |
| (3)LrI | (8) | 0 0 D D D 1 1 0 B B B B B B B B | Load index register r with data B . . . B. |
| LMI | (9) | 0 0 1 1 1 1 1 0 B B B B B B B B | Load memory register M with data B . . . B. |
| INr | (5) | 0 0 D D D 0 0 0 | Increment the content of index register r (r ≠ A). |
| DCr | (5) | 0 0 D D D 0 0 1 | Decrement the content of index register r (r ≠ A). |

Accumulator Group Instructions

The result of the ALU instructions affect all of the flag flip-flops. The rotate instructions affect only the carry flip-flop.

| | | | |
|-----|-----|------------------------------------|--|
| ADr | (5) | 1 0 0 0 0 S S S | Add the content of index register r, memory register M, or data B . . . B to the accumulator. An overflow (carry) sets the carry flip-flop. |
| ADM | (8) | 1 0 0 0 0 1 1 1 | |
| ADI | (8) | 0 0 0 0 0 1 0 0 B B B B B B B B | |
| ACr | (5) | 1 0 0 0 1 S S S | Add the content of index register r, memory register M, or data B . . . B from the accumulator with carry. An overflow (carry) sets the carry flip-flop. |
| ACM | (8) | 1 0 0 0 1 1 1 1 | |
| ACI | (8) | 0 0 0 0 1 1 0 0 B B B B B B B B | Subtract the content of index register r, memory register M, or data B . . . B from the accumulator. An underflow (borrow) sets the carry flip-flop. |
| SUr | (5) | 1 0 0 1 0 S S S | Subtract the content of index register r, memory register M, or data B . . . B from the accumulator with borrow. An underflow (borrow) sets the carry flip-flop. |
| SUM | (8) | 1 0 0 1 0 1 1 1 | |
| SUI | (8) | 0 0 0 1 0 1 0 0 B B B B B B B B | |
| SBr | (5) | 1 0 0 1 1 S S S | Subtract the content of index register r, memory register M, or data B . . . B from the accumulator with borrow. An underflow (borrow) sets the carry flip-flop. |
| SBM | (8) | 1 0 0 1 1 1 1 1 | |
| SBI | (8) | 0 0 0 1 1 1 0 0 B B B B B B B B | |

| MNEMONIC | MINIMUM STATES REQUIRED | INSTRUCTION CODE | DESCRIPTION OF OPERATION |
|----------|-------------------------|---|--|
| | | D ₇ D ₆ D ₅ D ₄ D ₃ D ₂ D ₁ D ₀ | |
| NDr | (5) | 1 0 1 0 0 S S S | |
| NDM | (8) | 1 0 1 0 0 1 1 1 | |
| NDI | (8) | 0 0 1 0 0 1 0 0 B B B B B B B B | Compute the logical AND of the content of index register r, memory register M, or data B . . . B with the accumulator. |
| XRr | (5) | 1 0 1 0 1 S S S | |
| XRM | (8) | 1 0 1 0 1 1 1 1 | |
| XRI | (8) | 0 0 1 0 1 1 0 0 B B B B B B B B | Compute the EXCLUSIVE OR of the content of index register r, memory register M, or data B . . . B with the accumulator. |
| ORr | (5) | 1 0 1 1 0 S S S | |
| ORM | (8) | 1 0 1 1 0 1 1 1 | |
| ORI | (8) | 0 0 1 1 0 1 0 0 B B B B B B B B | Compute the INCLUSIVE OR of the content of index register r, memory register m, or data B . . . B with the accumulator. |
| CPr | (5) | 1 0 1 1 1 S S S | |
| CPM | (8) | 1 0 1 1 1 1 1 1 | |
| CPI | (8) | 0 0 1 1 1 1 0 0 B B B B B B B B | Compare the content of index register r, memory register M, or data B . . . B with the accumulator. The content of the accumulator is unchanged. |
| RLC | (5) | 0 0 0 0 0 0 1 0 | Rotate the content of the accumulator left. |
| RRC | (5) | 0 0 0 0 1 0 1 0 | Rotate the content of the accumulator right. |
| RAL | (5) | 0 0 0 1 0 0 1 0 | Rotate the content of the accumulator left through the carry. |
| RAR | (5) | 0 0 0 1 1 0 1 0 | Rotate the content of the accumulator right through the carry. |

Program Counter and Stack Control Instructions

| | | | |
|---------|-----------|---|---|
| (4) JMP | (11) | 0 1 X X X 1 0 0 B ₂ B ₂ B ₂ B ₂ B ₂ B ₂ X X B ₃ B ₃ B ₃ B ₃ B ₃ B ₃ | Unconditionally jump to memory address B ₃ . . . B ₃ B ₂ . . . B ₂ . |
| (5) JFc | (9 or 11) | 0 1 0 C ₄ C ₃ 0 0 0 B ₂ B ₂ B ₂ B ₂ B ₂ B ₂ X X B ₃ B ₃ B ₃ B ₃ B ₃ B ₃ | Jump to memory address B ₃ . . . B ₃ B ₂ . . . B ₂ if the condition flip-flop c is false. Otherwise, execute the next instruction in sequence. |
| JTc | (9 or 11) | 0 1 1 C ₄ C ₃ 0 0 0 B ₂ B ₂ B ₂ B ₂ B ₂ B ₂ X X B ₃ B ₃ B ₃ B ₃ B ₃ B ₃ | Jump to memory address B ₃ . . . B ₃ B ₂ . . . B ₂ if the condition flip-flop c is true. Otherwise, execute the next instruction in sequence. |
| CAL | (11) | 0 1 X X X 1 1 0 B ₂ B ₂ B ₂ B ₂ B ₂ B ₂ X X B ₃ B ₃ B ₃ B ₃ B ₃ B ₃ | Unconditionally call the subroutine at memory address B ₃ . . . B ₃ B ₂ . . . B ₂ . Save the current address (up one level in the stack). |
| CFc | (9 or 11) | 0 1 0 C ₄ C ₃ 0 1 0 B ₂ B ₂ B ₂ B ₂ B ₂ B ₂ X X B ₃ B ₃ B ₃ B ₃ B ₃ B ₃ | Call the subroutine at memory address B ₃ . . . B ₃ B ₂ . . . B ₂ if the condition flip-flop c is false, and save the current address (up one level in the stack.) Otherwise, execute the next instruction in sequence. |
| CTc | (9 or 11) | 0 1 1 C ₄ C ₃ 0 1 0 B ₂ B ₂ B ₂ B ₂ B ₂ B ₂ X X B ₃ B ₃ B ₃ B ₃ B ₃ B ₃ | Call the subroutine at memory address B ₃ . . . B ₃ B ₂ . . . B ₂ if the condition flip-flop c is true, and save the current address (up one level in the stack). Otherwise, execute the next instruction in sequence. |
| RET | (5) | 0 0 X X X 1 1 1 | Unconditionally return (down one level in the stack). |
| RFc | (3 or 5) | 0 0 0 C ₄ C ₃ 0 1 1 | Return (down one level in the stack) if the condition flip-flop c is false. Otherwise, execute the next instruction in sequence. |
| RTc | (3 or 5) | 0 0 1 C ₄ C ₃ 0 1 1 | Return (down one level in the stack) if the condition flip-flop c is true. Otherwise, execute the next instruction in sequence. |
| RST | (5) | 0 0 A A A 1 0 1 | Call the subroutine at memory address AAA000 (up one level in the stack). |

Input/Output Instructions

| | | | |
|-----|-----|-----------------|---|
| INP | (8) | 0 1 0 0 M M M 1 | Read the content of the selected input port (MMM) into the accumulator. |
| OUT | (6) | 0 1 R R M M M 1 | Write the content of the accumulator into the selected output port (RRMM, RR ≠ 00). |

Machine Instruction

| | | | |
|-----|-----|-----------------|---|
| HLT | (4) | 0 0 0 0 0 0 0 X | Enter the STOPPED state and remain there until interrupted. |
| HLT | (4) | 1 1 1 1 1 1 1 1 | Enter the STOPPED state and remain there until interrupted. |

NOTES:

- (1) SSS = Source Index Register DDD = Destination Index Register These registers, r_i , are designated A(accumulator-000), B(001), C(010), D(011), E(100), H(101), L(110).
- (2) Memory registers are addressed by the contents of registers H & L.
- (3) Additional bytes of instruction are designated by BBBBBBBB.
- (4) X = "Don't Care".
- (5) Flag flip-flops are defined by C₄C₃: carry (00-overflow or underflow), zero (01-result is zero), sign (10-MSB of result is "1"), parity (11-parity is even).

V. PROCESSOR CONTROL SIGNALS

A. Interrupt Signal (INT)

1) INTERRUPT REQUEST

If the interrupt line is enabled (Logic "1"), the CPU recognizes an interrupt request at the next instruction fetch (PCI) cycle by outputting $S_0 S_1 S_2 = 011$ at T1I time. The lower and higher order address bytes of the program counter are sent out, but the program counter is not advanced. A successive instruction fetch cycle can be used to insert an arbitrary instruction into the instruction register in the CPU. (If a multi-cycle or multi-byte instruction is inserted, an interrupt need only be inserted for the first cycle.)

When the processor is interrupted, the system INTERRUPT signal must be synchronized with the leading edge of the ϕ_1 or ϕ_2 clock. To assure proper operation of the system, the interrupt line to the CPU must not be allowed to change within 200ns of the falling edge of ϕ_1 . An example of a synchronizing circuit is shown on the schematic for the SIM8-01 (Section VII). This is a new circuit recently added to the SIM8-01 board.

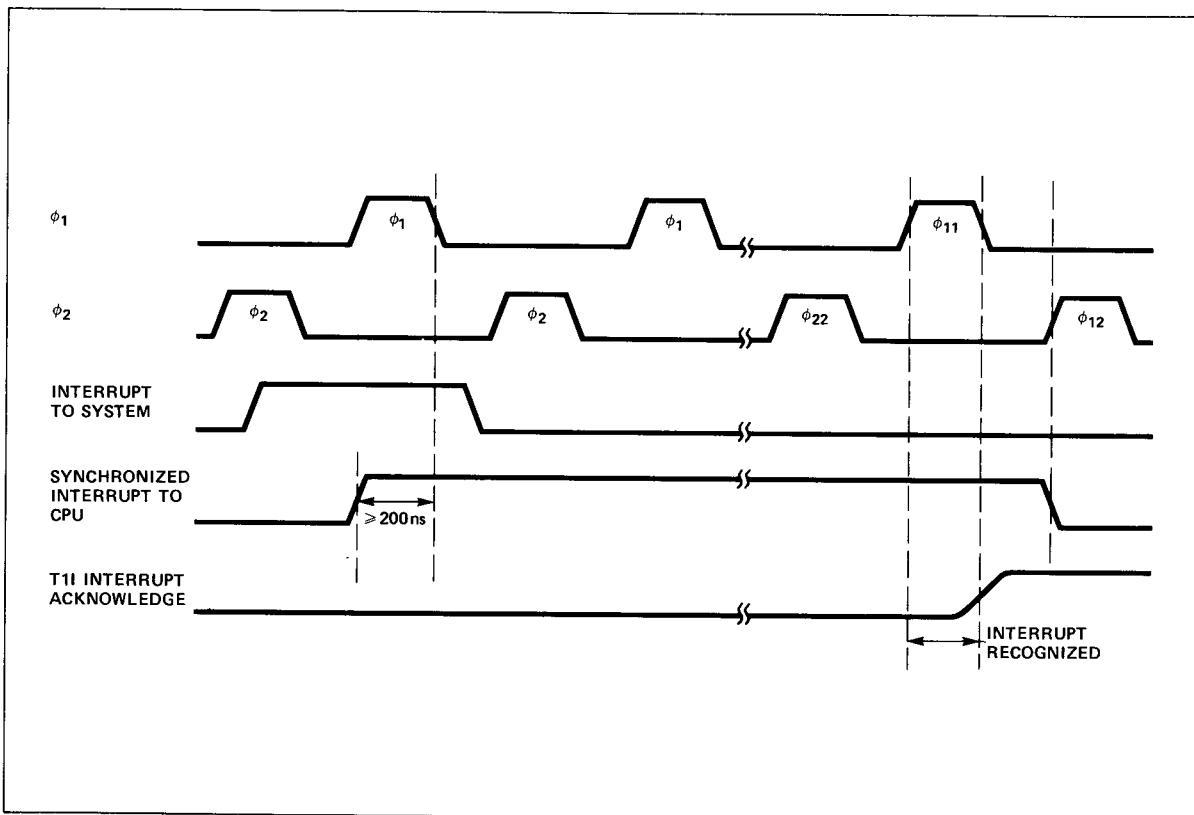


Figure 4. Recognition of Interrupt

If a HALT is inserted, the CPU enters a STOPPED state; if a NOP is inserted, the CPU continues; if a "JUMP to 0" is inserted, the processor executes program from location 0, etc. The RESTART instruction is particularly useful for handling interrupt routines since it is a one byte call.

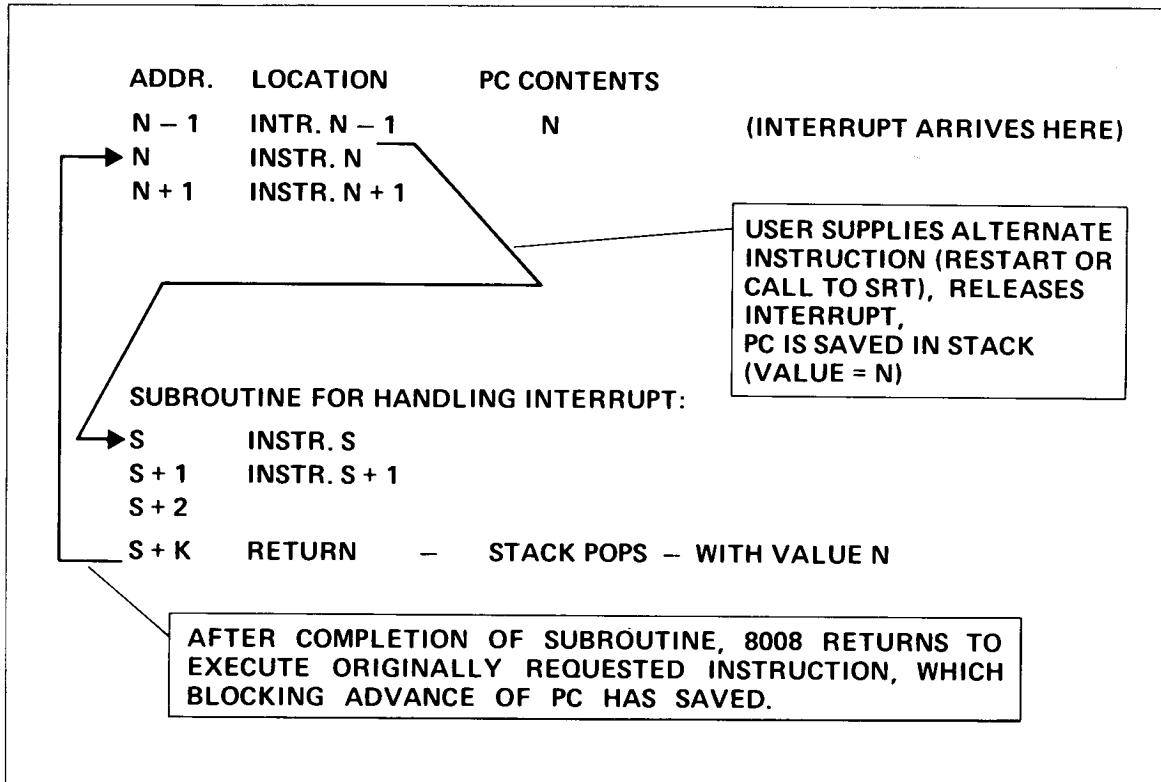


Figure 5. 8008 Interrupt

2) START-UP OF THE 8008

When power (V_{DD}) and clocks (ϕ_1, ϕ_2) are first turned on, a flip-flop internal to the 8008 is set by sensing the rise of V_{DD} . This internal signal forces a HALT (00000000) into the instruction register and the 8008 is then in the STOPPED state. The following sixteen clock periods after entering the STOPPED state are required to clear (logic "0") memories (accumulator, scratch pad, program counter, and stack). During this time the interrupt line has been at logic "0". Any time after the memories are cleared, the 8008 is ready for normal operation.

To reset the flip-flop and also escape from the stopped state, the interrupt line must go to a logic "1"; It should be returned to logic "0" by decoding the state T1I at some time later than ϕ_{11} . Note that whenever the 8008 is in a T1I state, the program counter is not incremented. As a result, the same address is sent out on two successive cycles.

Three possible sequences for starting the 8008 are shown on the following page. The RESTART instruction is effectively a one cycle call instruction, and it is convenient to use this instruction to call an initiation subroutine. Note that it is not necessary to start the 8008 with a RESTART instruction.

The selection of initiation technique to use depends on the sophistication of the system using the 8008. If the interrupt feature is used only for the start-up of the 8008 use the ROM directly, no additional external logic associated with instructions from source other than the ROM program need be considered. If the interrupt feature is used to jam instructions into the 8008, it would then be consistent to use it to jam the initial instruction.

The timing for the interrupt with the start-up timing is shown on an accompanying sheet. The jamming of an instruction and the suppression of the program counter update are handled the same for all interrupts.

EXAMPLE 1:

Shown below are two start-up alternatives where an instruction is not forced into the 8008 during the interrupt cycle. The normal program flow starts the 8008.

| a. | 8008 ADDRESS OUT | INSTRUCTION IN ROM | |
|----|------------------|--------------------|--------------------|
| | 0 0 0 0 0 0 | 0 0 0 0 0 0 0 0 0 | NOP |
| | 0 0 0 0 0 0 | 0 0 0 0 0 0 0 0 0 | NOP |
| | 0 0 0 0 0 0 | 0 0 0 0 0 0 0 0 1 | INSTR ₁ |
| | 0 0 0 0 0 0 | 0 0 0 0 0 0 0 1 0 | INSTR ₂ |

| b. | 8008 ADDRESS OUT | INSTRUCTION IN ROM | |
|----|------------------|--------------------|-----------------------------|
| | 0 0 0 0 0 0 | 0 0 0 0 0 0 0 0 0 | RST (RST = 00 XYZ 101) |
| | 0 0 0 0 0 0 | 0 0 X Y Z 0 0 0 | INSTR ₁ |
| | 0 0 0 0 0 0 | 0 0 X Y Z 0 0 1 | INSTR ₂ |

EXAMPLE 2:

A RESTART instruction is jammed in and first instruction in ROM initially ignored.

| | 8008 ADDRESS OUT | INSTRUCTION IN ROM | |
|--|------------------|--------------------|--|
| | 0 0 0 0 0 0 | 0 0 0 0 0 0 0 0 0 | INSTR ₁ (RST = 00 XYZ 101) |
| | 0 0 0 0 0 0 | 0 0 X Y Z 0 0 0 | INSTR _a |
| | 0 0 0 0 0 0 | 0 0 X Y Z 0 0 1 | INSTR _b |
| | . | . | Start-up Routine |
| | . | . | |
| | 0 0 0 0 0 0 | 0 0 n n n n n n | RETURN |
| | 0 0 0 0 0 0 | 0 0 0 0 0 0 0 0 | INSTR ₁ (INSTR ₁ executed now) Main Program |
| | 0 0 0 0 0 0 | 0 0 0 0 0 0 0 1 | INSTR ₂ |
| | . | . | |
| | . | . | |

Note that during the interrupt cycle the flow of the instruction to the 8008 either from ROM or another source must be controlled by hardware external to 8008.

START-UP OF THE 8008

B. Ready (RDY)

The 8008 is designed to operate with any type or speed of semiconductor memory. This flexibility is provided by the READY command line. A high-speed memory will always be ready with data (tie READY line to V_{CC}) almost immediately after the second byte of the address has been sent out. As a result the 8008 will never be required to wait for the memory. On the other hand, with slow ROMs, RAMs or shift registers, the data will not be immediately available; the 8008 must wait until the READY command indicates that the valid memory data is available. As a result any type or any combination of memory types may be used. The READY command line synchronizes the 8008 to the memory cycle. When a program is being developed, the READY signal provides a means of stepping through the program, one cycle at a time.

VI. ELECTRICAL SPECIFICATION

The following pages provide the electrical characteristics for the 8008. All of the inputs are TTL compatible, but input pull-up resistors are recommended to insure proper V_{IH} levels. All outputs are low-power TTL compatible. The transfer of data to and from the data bus is controlled by the CPU. During both the WAIT and STOPPED states the data bus output buffers are disabled and the data bus is floating.

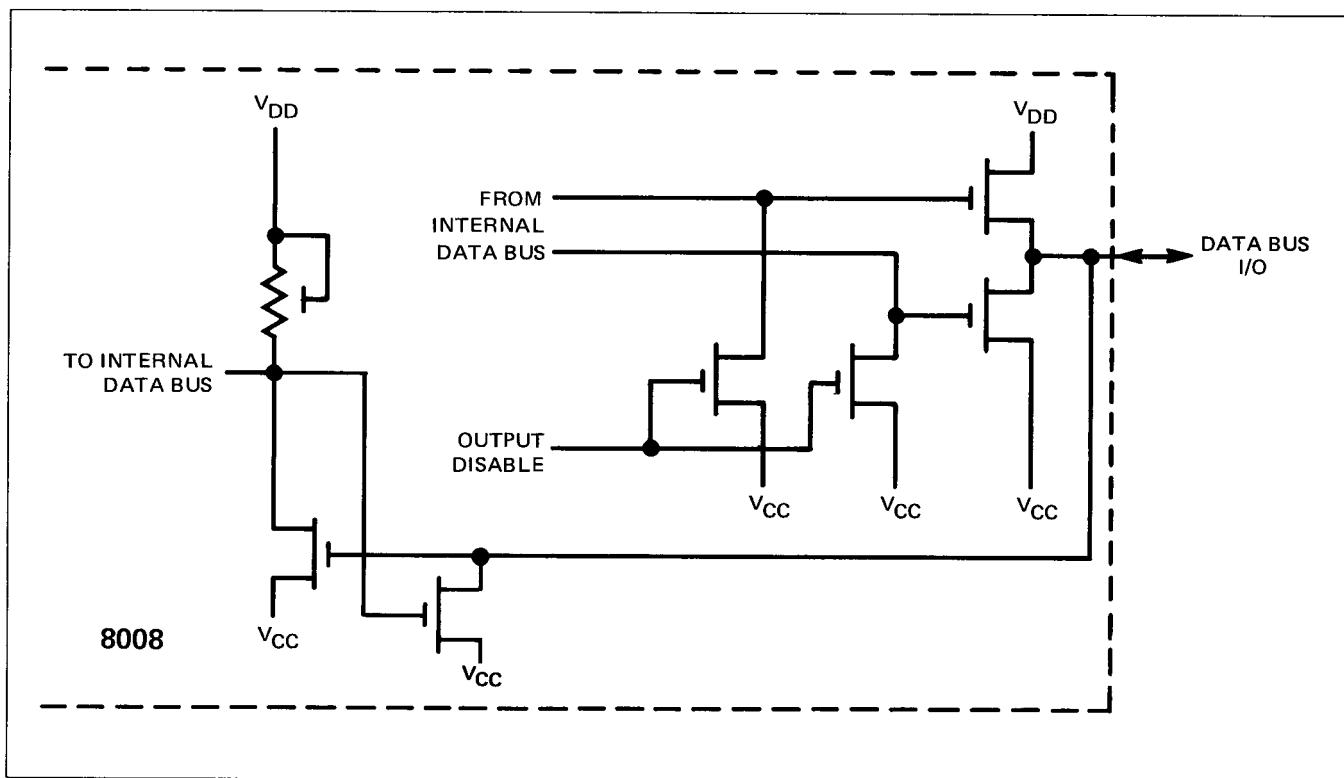


Figure 6. Data Bus I/O Buffer

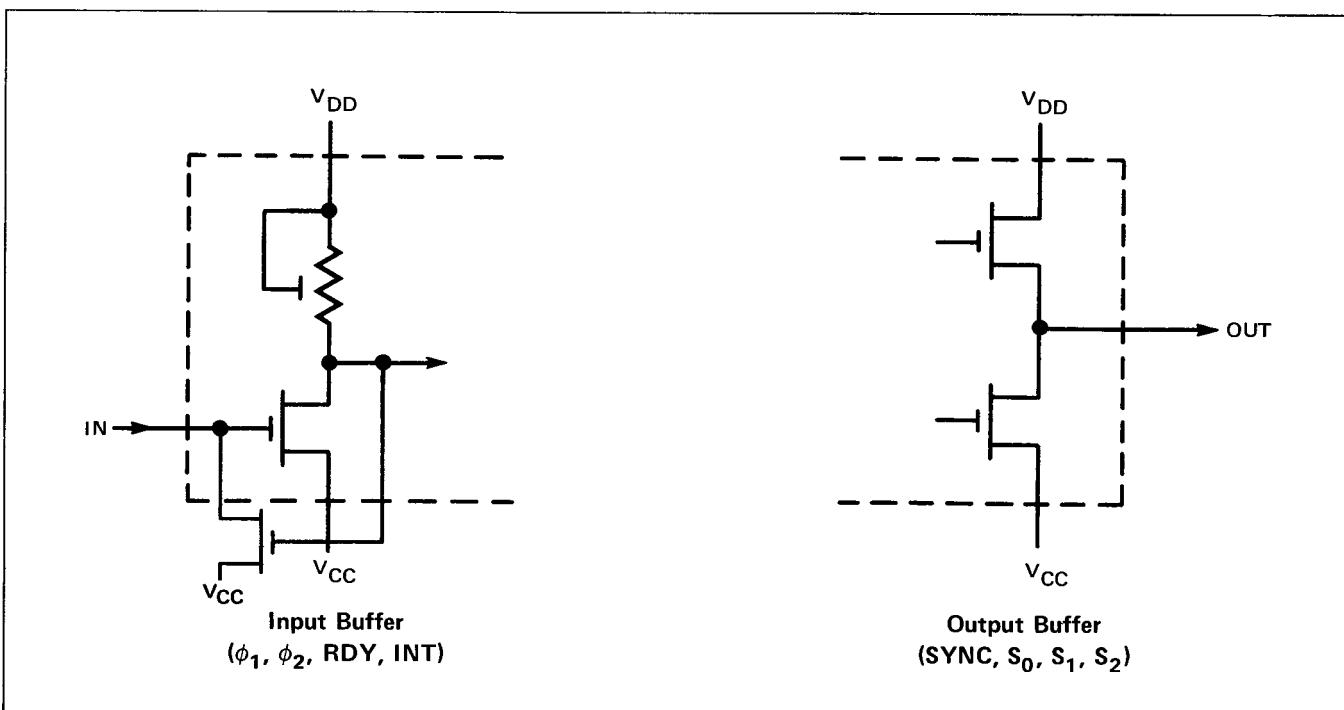


Figure 7. I/O Circuitry

ABSOLUTE MAXIMUM RATINGS*

| | |
|--|-----------------|
| Ambient Temperature Under Bias | 0°C to +70°C |
| Storage Temperature | -55°C to +150°C |
| Input Voltages and Supply Voltage With Respect to V_{CC} | +0.5 to -20V |
| Power Dissipation | 1.0 W @ 25°C |

*COMMENT

Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other condition above those indicated in the operational sections of this specification is not implied.

D.C. AND OPERATING CHARACTERISTICS

$T_A = 0^\circ\text{C}$ to 70°C , $V_{CC} = +5\text{V} \pm 5\%$, $V_{DD} = -9\text{V} \pm 5\%$ unless otherwise specified. Logic "1" is defined as the more positive level (V_{IH} , V_{OH}). Logic "0" is defined as the more negative level (V_{IL} , V_{OL}).

| SYMBOL | PARAMETER | LIMITS | | | UNIT | TEST CONDITIONS |
|----------|--|----------------|------|----------------|---------------|---|
| | | MIN. | TYP. | MAX. | | |
| I_{DD} | AVERAGE SUPPLY CURRENT-OUTPUTS LOADED* | | 30 | 60 | mA | $T_A = 25^\circ\text{C}$ |
| I_{LI} | INPUT LEAKAGE CURRENT | | | 10 | μA | $V_{IN} = 0\text{V}$ |
| V_{IL} | INPUT LOW VOLTAGE (INCLUDING CLOCKS) | V_{DD} | | $V_{CC} - 4.2$ | V | |
| V_{IH} | INPUT HIGH VOLTAGE (INCLUDING CLOCKS) | $V_{CC} - 1.5$ | | $V_{CC} + 0.3$ | V | |
| V_{OL} | OUTPUT LOW VOLTAGE | | | 0.4 | V | $I_{OL} = 0.44\text{mA}$ $C_L = 200\text{ pF}$ |
| V_{OH} | OUTPUT HIGH VOLTAGE | $V_{CC} - 1.5$ | | | V | $I_{OH} = 0.2\text{mA}$ |

*Measurements are made while the 8008 is executing a typical sequence of instructions. The test load is selected such that at $V_{OL} = 0.4\text{V}$, $I_{OL} = 0.44\text{mA}$ on each output.

A.C. CHARACTERISTICS

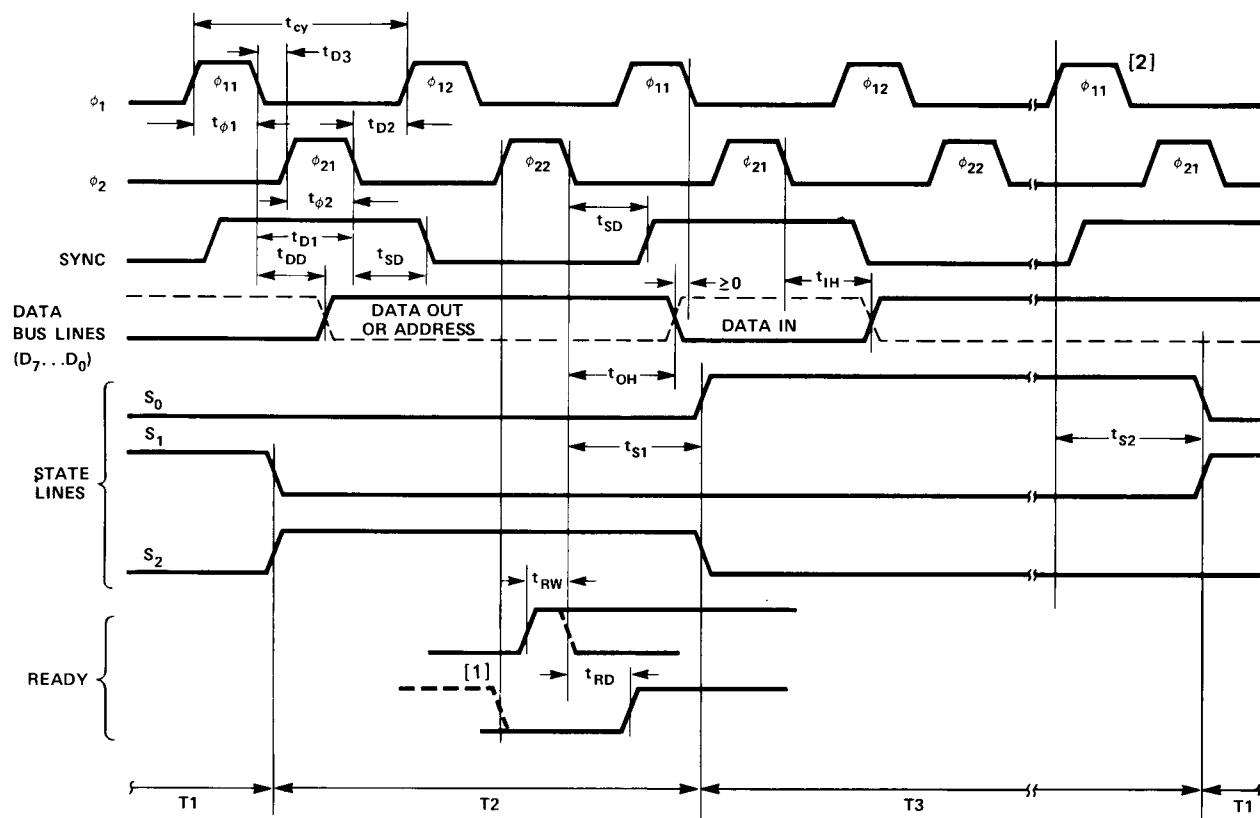
$T_A = 0^\circ\text{C}$ to 70°C ; $V_{CC} = +5\text{V} \pm 5\%$, $V_{DD} = -9\text{V} \pm 5\%$. All measurements are referenced to 1.5V levels.

| SYMBOL | PARAMETER | 8008 | | 8008-1 | | UNIT | TEST CONDITIONS | | |
|--------------|---|--------|------|--------|------|---------------|--------------------------|--|--|
| | | LIMITS | | LIMITS | | | | | |
| | | MIN. | MAX. | MIN. | MAX. | | | | |
| t_{CY} | CLOCK PERIOD | 2 | 3 | 1.25 | 3 | μs | $t_R, t_F = 50\text{ns}$ | | |
| t_{R,t_F} | CLOCK RISE AND FALL TIMES | | 50 | | 50 | ns | | | |
| t_{ϕ_1} | PULSE WIDTH OF ϕ_1 | .70 | | .35 | | μs | | | |
| t_{ϕ_2} | PULSE WIDTH OF ϕ_2 | .55 | | .35 | | μs | | | |
| t_{D1} | CLOCK DELAY FROM FALLING EDGE OF ϕ_1 TO FALLING EDGE OF ϕ_2 | .90 | 1.1 | | 1.1 | μs | | | |
| t_{D2} | CLOCK DELAY FROM ϕ_2 TO ϕ_1 | .40 | | .35 | | μs | | | |
| t_{D3} | CLOCK DELAY FROM ϕ_1 TO ϕ_2 | .20 | | .20 | | μs | | | |
| t_{DD} | DATA OUT DELAY | | 1.0 | | 1.0 | μs | $C_L = 100\text{pF}$ | | |
| t_{OH} | HOLD TIME FOR DATA OUT | .10 | | .10 | | μs | | | |
| t_{IH} | HOLD TIME FOR DATA IN | [1] | | [1] | | μs | | | |
| t_{SD} | SYNC OUT DELAY | | .70 | | .70 | μs | $C_L = 100\text{pF}$ | | |
| t_{S1} | STATE OUT DELAY (ALL STATES EXCEPT T1 AND T1I) ^[2] | | 1.1 | | 1.1 | μs | $C_L = 100\text{pF}$ | | |
| t_{S2} | STATE OUT DELAY (STATES T1 AND T1I) | | 1.0 | | 1.0 | μs | $C_L = 100\text{pF}$ | | |
| t_{RW} | PULSE WIDTH OF READY DURING ϕ_{22} TO ENTER T3 STATE | .35 | | .35 | | μs | | | |
| t_{RD} | READY DELAY TO ENTER WAIT STATE | .20 | | .20 | | μs | | | |

[1] $t_{IH} \text{ MIN} \geq t_{SD}$

[2] If the INTERRUPT is not used, all states have the same output delay, t_{S1} .

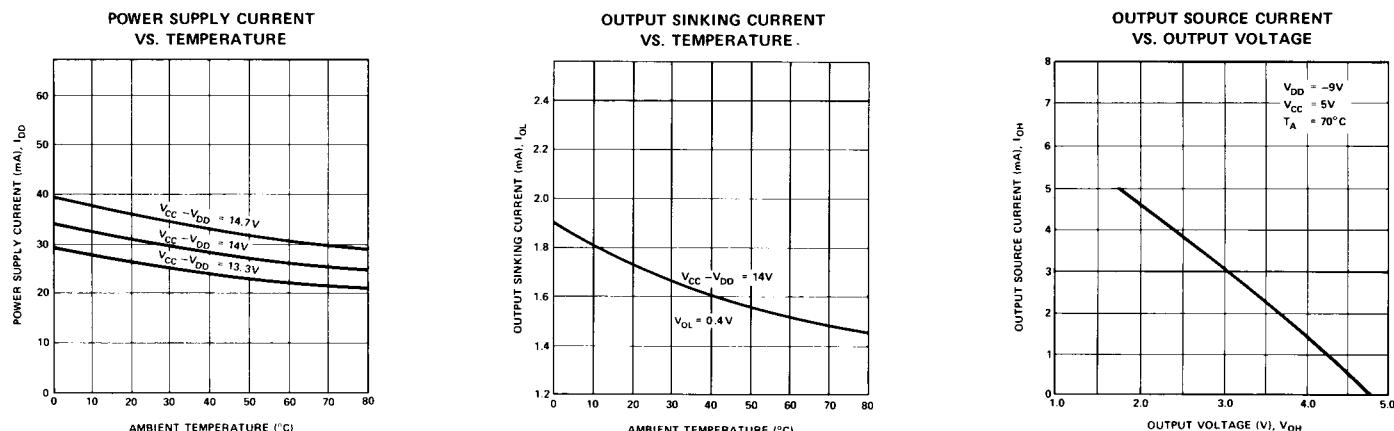
TIMING DIAGRAM



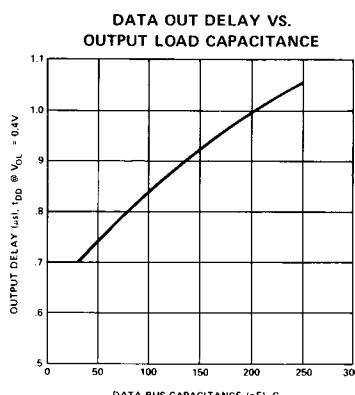
[1] READY line must be at "0" prior to ϕ_{22} of T2 to guarantee entry into the WAIT state.

[2] INTERRUPT line must not change levels within 200ns (max.) of the falling edge of ϕ_1 .

TYPICAL D.C. CHARACTERISTICS



TYPICAL A.C. CHARACTERISTICS



CAPACITANCE $f = 1MHz$; $T_A = 25^\circ C$; Unmeasured Pins Grounded

| SYMBOL | TEST | LIMIT (pF) | |
|-----------|--------------------------|------------|------|
| | | TYP. | MAX. |
| C_{IN} | INPUT CAPACITANCE | 5 | 10 |
| C_{DB} | DATA BUS I/O CAPACITANCE | 5 | 10 |
| C_{OUT} | OUTPUT CAPACITANCE | 5 | 10 |

VII THE SIM8-01 — AN MCS-8^{T.M.} MICRO COMPUTER

During the development phase of systems using the 8008, Intel's single chip 8-bit parallel central processor unit, both hardware and software must be designed. Since many systems will require similar memory and I/O interface to the 8008, Intel has developed a prototyping system, the SIM8-01. Through the use of this system and Intel's programmable and erasable ROMs (1702), MCS-8 systems can be completely developed and checked-out before committing to mask programmed ROMs (1301).

The SIM8-01 is a complete byte-oriented computing system including the processor (8008), 1K x 8 memory (1101), six I/O ports (two in and four out), and a two-phase clock generator. Sockets are provided for 2K x 8 of ROM or PROM memory for the system microprogram. The SIM8-01 may be used with either the 8008 or 8008-1. To operate at clock frequencies greater than 500kHz, former SIM8-01 boards must be modified as detailed in the schematic and the following system description. Note that all Intel-developed 8008 programs interface with TTY and require system operation at 500kHz. Currently, the SIM8-01 is supplied with the 8008-1 CPU and the system clock preset to 500kHz.

The following block diagram shows the basic configuration of the SIM8-01. All interface logic for the 8008 to operate with standard ROM and RAM memory is included on the board. The following pages present the SIM8-01 schematic and detailed system description.

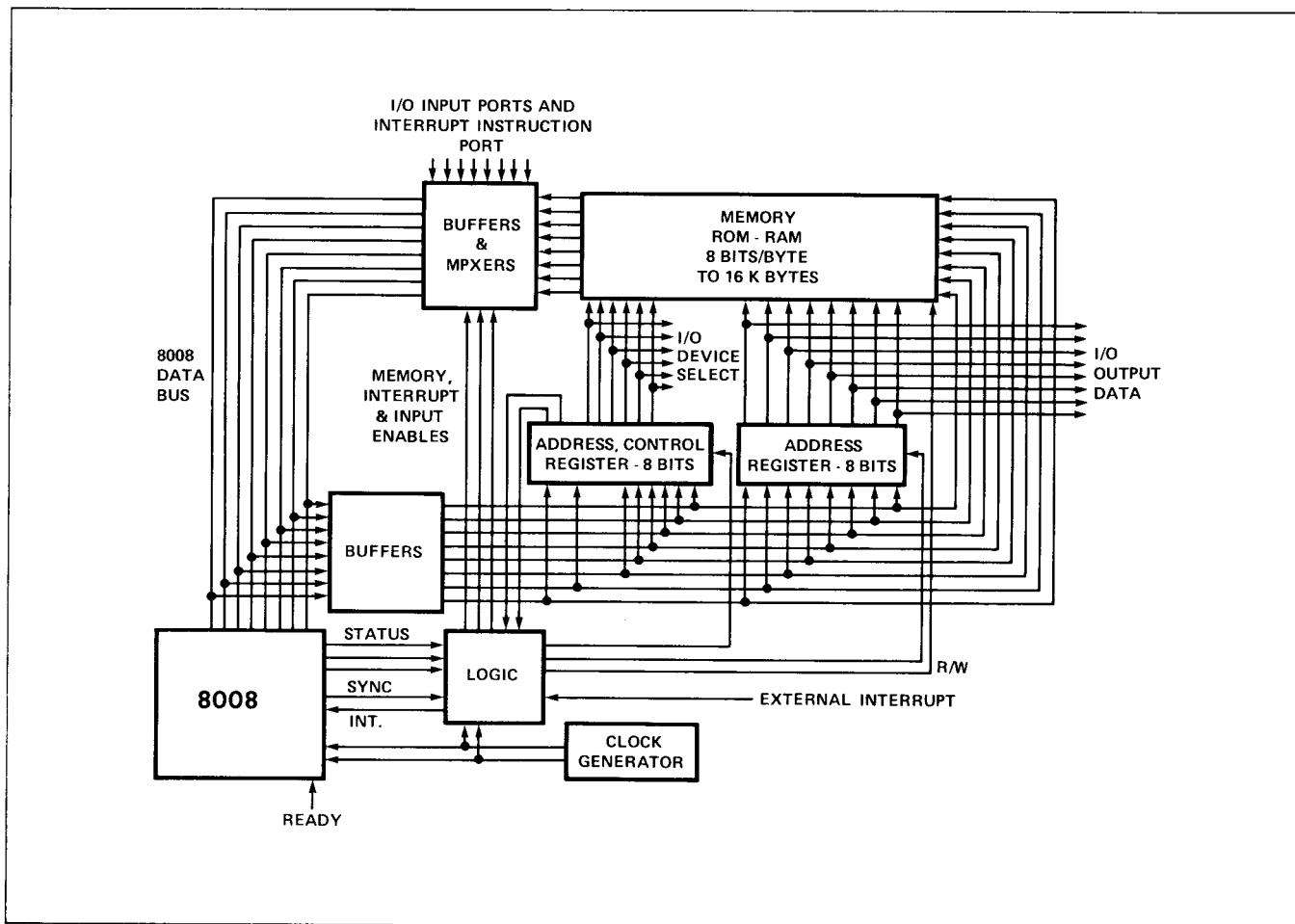


Figure 8. MCS-8 Basic System

SIM8-01 SPECIFICATIONS

Card Dimensions:

- 11.5 inches high
- 9.5 inches deep

System Components Included on Board:

- 8008-1
- Complete TTL interface to memory
- 1K x 8 RAM memory
- Sockets for 2K x 8 PROM memory
- TTY interface cks.
- Two input and four output ports
- Two phase clock generator

Maximum Memory Configuration:

- 1K x 8 RAM
- 2K x 8 PROM
- All control lines are provided for memory expansion

Operating Speed

- 2 μ s clock period
- 20 μ s typical instruction cycle

D.C. Power Requirement:

• Voltage:

$$V_{CC} = 5V \pm 5\%$$

$$\text{TTL GRD} = 0V$$

$$V_{DD} = -9V \pm 5\%$$

• Current:

Eight ROMs

| | Typical | Maximum |
|--|---------|---------|
|--|---------|---------|

$$I_{CC} = 2.5 \text{ amps}$$

$$I_{DD} = 1.0 \text{ amps}$$

$$I_{CC} = 4.0 \text{ amps.}$$

$$I_{DD} = 1.5 \text{ amps.}$$

Connector:

- Wire wrap type Amphenol 86 pin connector P/N 261-10043-2

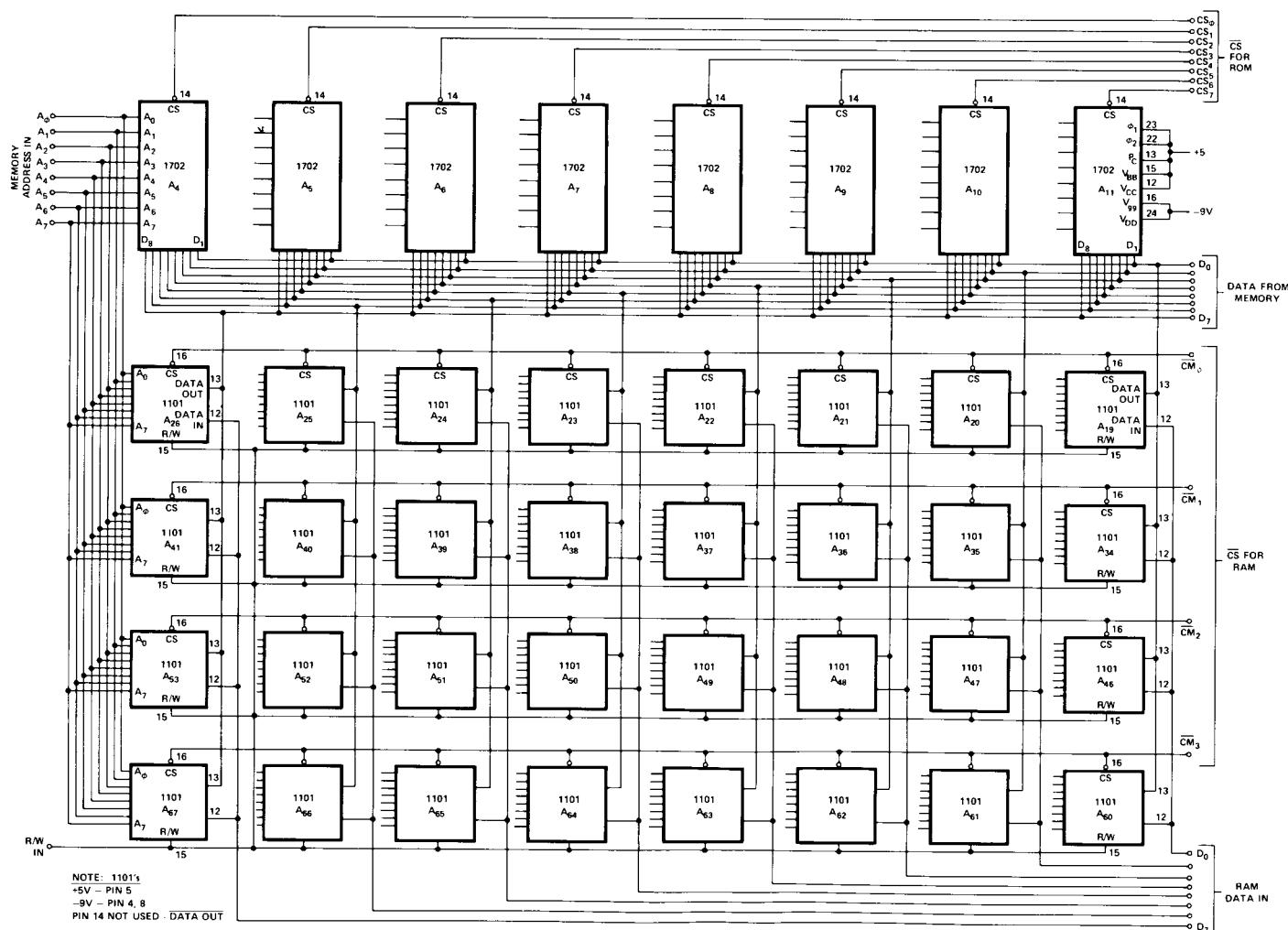


Figure 9. MCS-8 Memory System

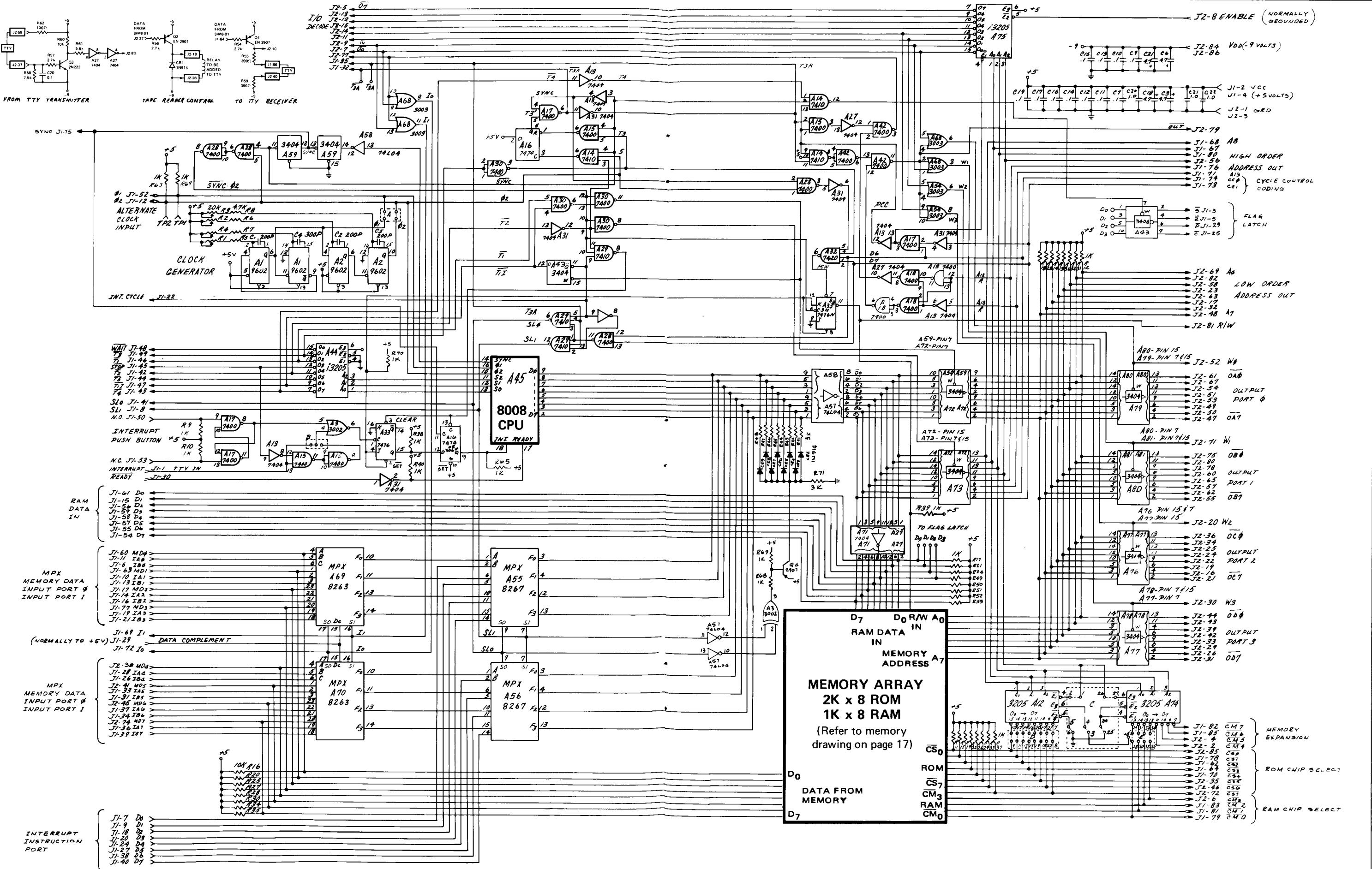


Figure 10. Complete SIM8-01 Schematic

SYSTEM DESCRIPTION

The 8008 processor communicates over an 8-bit data bus (D_0 through D_7) and uses two input lines (READY and INTERRUPT) and four output lines (S_0 , S_1 , S_2 , and SYNC) for control. Time multiplexing of the data bus allows control information, 14-bit addresses, and data to be transmitted between the CPU, memory, and I/O. All inputs, outputs, and control lines for the SIM8-01 are positive-logic TTL compatible.

Two Phase Clock Generator

The basic system timing for the SIM8-01 is provided by two non-overlapping clock phases generated by 9602 single shot multivibrators (A_1 , A_2). The clocks are factory adjusted as shown in the timing diagram below. Note that this is the maximum specified operating frequency of the 8008. An option is provided on the board for using external clocks. If the jumper wires in box A are removed, external clocks may be connected at pins J1-52 and J1-12 (Normally these pins are the output of the clock generators on the board). The clock generator may be adjusted for operation up to 800kHz when using the 8008-1.

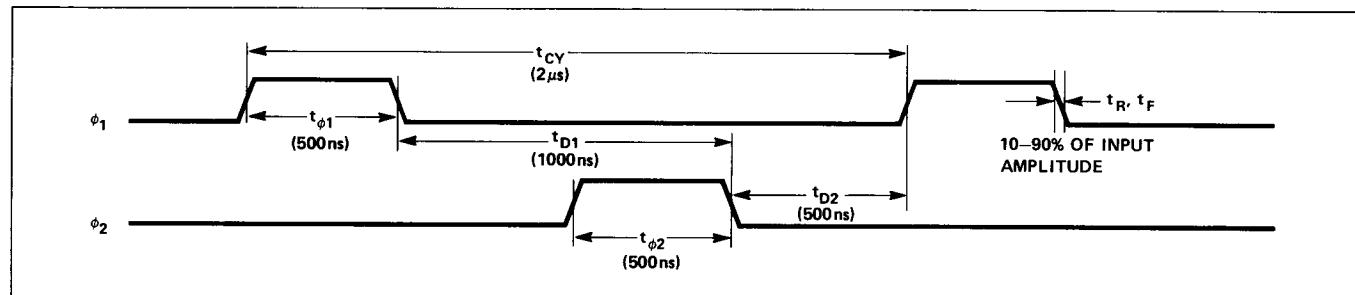


Figure 11. SIM8-01 Timing Diagram

Memory Organization

The SIM8-01 has capacity for $2K \times 8$ of ROM or PROM and $1K \times 8$ of RAM. The memory can easily be expanded to $16K \times 8$ using the address and chip select control lines provided. Further memory expansion may be accomplished by dedicating an output port to the control of memory bank switching.

In an MCS-8 system, it is possible to use any combination of memory elements. The SIM8-01 is shipped from the factory with the ROM memory designated from address 0 → 2047, RAM memory from 2048 → 3071, and memory expansion for all addresses 3072 and above. Jumper wires provided on the board (boxes C, D, E) allow complete flexibility of the memory organization. They may be rearranged to meet any requirement. the Intel 3205 data sheet provides a complete description of the one of eight decoder used in this system. the 3205 truth table is shown below.

| ADDRESS | | | ENABLE | | | OUTPUTS | | | | | | | |
|---------|-------|-------|--------|-------|-------|---------|---|---|---|---|---|---|---|
| A_0 | A_1 | A_2 | E_1 | E_2 | E_3 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| L | L | L | L | L | H | L | H | H | H | H | H | H | H |
| H | L | L | L | L | H | H | L | H | H | H | H | H | H |
| L | H | L | L | L | H | H | H | L | H | H | H | H | H |
| H | H | L | L | L | H | H | H | H | L | H | H | H | H |
| L | L | H | L | L | H | H | H | H | H | L | H | H | H |
| H | L | H | L | L | H | H | H | H | H | H | L | H | H |
| L | H | H | L | L | H | H | H | H | H | H | H | L | H |
| H | H | H | L | L | H | H | H | H | H | H | H | H | L |
| X | X | X | L | L | L | H | H | H | H | H | H | H | H |
| X | X | X | H | L | L | H | H | H | H | H | H | H | H |
| X | X | X | L | H | L | H | H | H | H | H | H | H | H |
| X | X | X | H | H | L | H | H | H | H | H | H | H | H |
| X | X | X | H | L | H | H | H | H | H | H | H | H | H |
| X | X | X | L | H | H | H | H | H | H | H | H | H | H |
| X | X | X | H | H | H | H | H | H | H | H | H | H | H |

CONTROL LINES

- **Interrupt**

The interrupt control line is directly available as an input to the board. For manual control, a normally open push-button switch may be connected to terminals J1-50 and J1-53. The interrupt may be inserted

under system control on pin J1-1. An external flip-flop (A33) latches the interrupt and is reset by T11 when the CPU recognizes the interrupt. Instructions inserted under interrupt control may be set up automatically or by toggle switches at the interrupt input port as shown on the schematic. Use the interrupt line and interrupt input port to start up the 8008.

Note that the interrupt line has two different connections to the input to the board (box B). The path from J1-1 directly to pin 4 of package A3 is the normal interrupt path (**the board is shipped from the factory with this connection**). If the connection from pin 8 of package A15 to pin 4 of package A3 is made instead, the processor will recognize an interrupt only when it is in the STOPPED state. This is used to recognize the "start character" when entering data from TTY.

● Ready

The ready line on the 8008 provides the flexibility for operation with any type of semiconductor memory. On the SIM8-01 board, the ready line is buffered; and at the connector (J1-30), the READY line is active low. During program development, the READY line may be used to step the system through a program.

NORMAL OPERATION OF SYSTEM

The 8008 CPU exercises control over the entire system using its state lines (S_0 , S_1 , S_2) and two control bits (CC0, CC1) which are sent onto the data bus with the address. The state lines are decoded by a 3205 (A44) and gated with appropriate clock and SYNC signals. The two control bits form part of the control for the multiplexers to the data bus (A55, A56), the memory read/write line (A33) and the I/O line (A17).

In normal operation, the lower order address is sent out of the CPU at state T1, stored in 3404 latches (A59, A72) and provided to all memories. The high order address is sent out at a state T2 and stored in 3404 latches (A72, A73). These lines are decoded as the chip selects to the memory. The two highest order bits (CC0, CC1) are decoded for control.

To guarantee that instructions and data are available to the CPU at the proper time, the T3 state is anticipated by setting a D-type flip-flop (A16) at the end of each T2 state. This line controls the multiplexing of data to the 8008. This flip-flop is reset at the end of each T3 state. In addition, switched pull-up resistors are used on the data-bus to minimize data bus loading and increase bus response. **The use of switched resistors on the data bus is mandatory when using the 8008-1. SIM8-01 boards built prior to October, 1972 must be modified in order to operate with the 8008-1 at clock frequencies greater than 500kHz.**

Normally, the 8008 executes instructions and has no interaction with the rest of the system during states T4 and T5. In the case of the INP instruction, the content of the flag flip-flops internal to the 8008 is sent out at state T4 and stored in a 3404 latch (A43).

Instructions and data are multiplexed onto the 8008 data bus through four multiplexers (A55, A56, A69, A70). **In normal operation, line J1-29 should be at +5V in order for "true" data to reach the 8008 data bus.**

System I/O

The SIM8-01 communicates with other systems or peripherals through two input ports and four output ports. All control and I/O selection decoding lines are provided for expansion to the full complement of eight input ports and twenty-four output ports. To expand the number of input ports, break the trace at the output of Device A68, pin 11, and generate input port decoding external to the SIM8-01. Control the input multiplexer through pin J1-69. The output ports latch data and remain unchanged until referenced again under software control. **Note that all output ports complement data.** When power is first applied to the board, the output ports should be cleared under software control to guarantee a known output state. **To enable the I/O device decoder, pin J2-8 should be at ground.**

Teletype Interface

The 8008 is designed to operate with all types of terminal devices. A typical example of peripheral interface is the teletype (ASR-33). The SIM8-01 contains the three simple transistor TTY interface circuits shown on the following page. One transistor is used for receiving serial data from the teletype, one for transmitting data back to the teletype, and the third for tape reader control.

The teletype must be operating in the full duplex mode. Refer to your teletype operating manual for making connections within the TTY itself. Many models include a nine terminal barrier strip in the rear of

the machine. It is at this point where the connections are made for full duplex operation. The interconnections to the SIM8-01 for transmit and receive are made at this same point. (See Figure 12)

A micro computer bulletin describing the interconnection of Intel micro computers and the ASR-33 teletype is available on request.

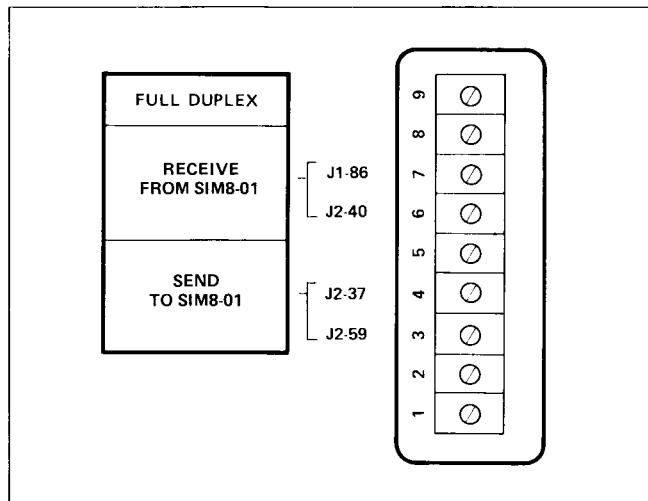


Figure 12. Teletype Terminal Strip

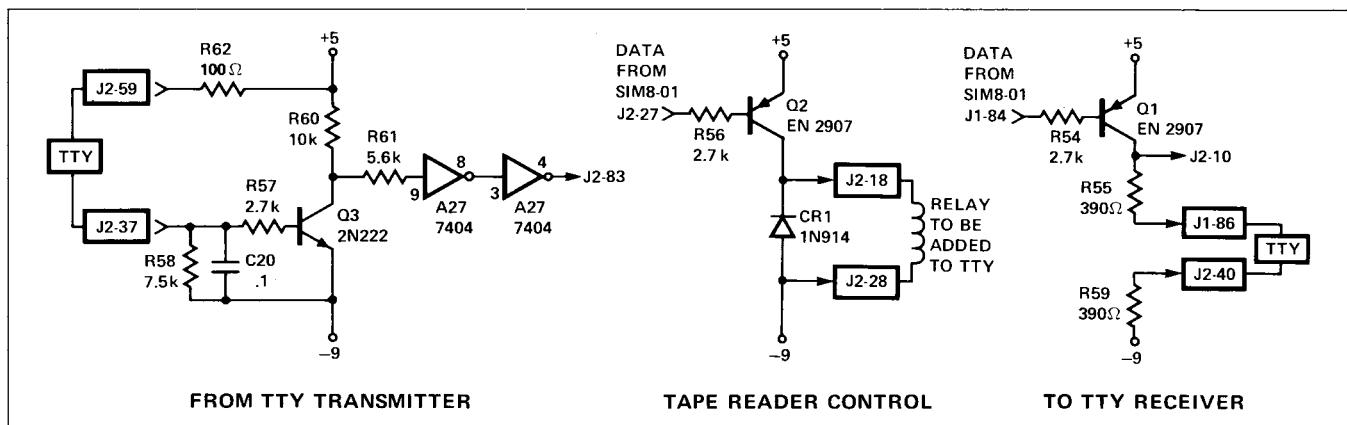


Figure 13. SIM8-01 Teletype Interface Circuitry

To use the teletype tape reader with the SIM8-01, the machine must contain a reader power pack. The contacts of a 10V dc relay must be connected in series with the TTY automatic reader (refer to TTY manual) and the coil is connected to the SIM8-01 tape reader control as shown.

For all Intel developed TTY programs for the SIM8-01, the following I/O port assignments have been made:

1. DATA IN -- INPUT PORT 0, BIT 0 (J2-83 connected to J1-11)
2. DATA OUT -- OUTPUT PORT 2, BIT 0 (J1-84 connected to J2-36)
3. READER CONTROL -- OUTPUT PORT 3, BIT 0 (J2-27 connected to J2-44)

Note that the SIM8-01 clock generator must remain set at 500kHz. All Intel developed TTY programs are synchronized to operate with the SIM8-01 at 500kHz.

In order to sense the start character, data in is also sensed at the interrupt input (J2-83 connected to J1-11) and the interrupt jumper (box B) must be between pin 8 of A15 and pin 4 of A3. It requires approximately 110ms for the teletype to transmit or receive eight serial data bits plus three control bits. The first and last bits are idling bits, the second is the start bit, and the following eight bits are data. Each bit stays 9.09ms. While waiting for data to be transmitted, the 8008 is in the STOPPED state; when the start character is received, the processor is interrupted and forced to call the TTY processing routine. Under software control, the processor can determine the duration of each bit and strobe the character at the proper time.

A listing of a teletype control program is shown in Appendix III.

SIM8-01 MICRO COMPUTER BOARD PIN DESCRIPTION

| Pin No. | Connector | Symbol | Description |
|---------|-----------|-----------------|----------------------------|
| 2, 4 | J1 | +5V | +5VDC POWER SUPPLY |
| 84 & 86 | J2 | -9V | -9VDC POWER SUPPLY |
| 1, 3 | J2 | GND | GROUND |
| 60 | J1 | MD ₀ | DATA FROM MEMORY # BIT # |
| 63 | J1 | MD ₁ | DATA FROM MEMORY 1 BIT 1 |
| 17 | J1 | MD ₂ | DATA FROM MEMORY 2 BIT 2 |
| 77 | J1 | MD ₃ | DATA FROM MEMORY 3 BIT 3 |
| 38 | J2 | MD ₄ | DATA FROM MEMORY 4 BIT 4 |
| 41 | J2 | MD ₅ | DATA FROM MEMORY 5 BIT 5 |
| 45 | J2 | MD ₆ | DATA FROM MEMORY 6 BIT 6 |
| 74 | J2 | MD ₇ | DATA FROM MEMORY 7 BIT 7 |
| 11 | J1 | IA ₀ | DATA INPUT PORT # BIT # |
| 10 | J1 | IA ₁ | DATA INPUT PORT # BIT 1 |
| 14 | J1 | IA ₂ | DATA INPUT PORT # BIT 2 |
| 19 | J1 | IA ₃ | DATA INPUT PORT # BIT 3 |
| 28 | J1 | IA ₄ | DATA INPUT PORT # BIT 4 |
| 33 | J1 | IA ₅ | DATA INPUT PORT # BIT 5 |
| 37 | J1 | IA ₆ | DATA INPUT PORT # BIT 6 |
| 36 | J1 | IA ₇ | DATA INPUT PORT # BIT 7 |
| 6 | J1 | IB ₀ | DATA INPUT PORT 1 BIT # |
| 13 | J1 | IB ₁ | DATA INPUT PORT 1 BIT 1 |
| 16 | J1 | IB ₂ | DATA INPUT PORT 1 BIT 2 |
| 21 | J1 | IB ₃ | DATA INPUT PORT 1 BIT 3 |
| 26 | J1 | IB ₄ | DATA INPUT PORT 1 BIT 4 |
| 31 | J1 | IB ₅ | DATA INPUT PORT 1 BIT 5 |
| 34 | J1 | IB ₆ | DATA INPUT PORT 1 BIT 6 |
| 39 | J1 | IB ₇ | DATA INPUT PORT 1 BIT 7 |
| 61 | J2 | JA _g | OUTPUT PORT # BIT # |
| 67 | J2 | JA ₁ | OUTPUT PORT # BIT 1 |
| 54 | J2 | JA ₂ | OUTPUT PORT # .IT# 2 |
| 51 | J2 | JA ₃ | OUTPUT PORT # BIT 3 |
| 53 | J2 | JA ₄ | OUTPUT PORT # BIT 4 |
| 49 | J2 | JA ₅ | OUTPUT PORT # BIT 5 |
| 50 | J2 | JA ₆ | OUTPUT PORT # BIT 6 |
| 47 | J2 | JA ₇ | OUTPUT PORT # BIT 7 |
| 75 | J2 | OB _g | OUTPUT PORT 1 BIT # |
| 80 | J2 | OB ₁ | OUTPUT PORT 1 BIT 1 |
| 78 | J2 | OB ₂ | OUTPUT PORT 1 BIT 2 |
| 60 | J2 | OB ₃ | OUTPUT PORT 1 BIT 3 |
| 65 | J2 | OB ₄ | OUTPUT PORT 1 BIT 4 |
| 57 | J2 | OB ₅ | OUTPUT PORT 1 BIT 5 |
| 62 | J2 | OB ₆ | OUTPUT PORT 1 BIT 6 |
| 55 | J2 | OB ₇ | OUTPUT PORT 1 BIT 7 |
| 36 | J2 | OC _g | OUTPUT PORT 2 BIT # |
| 34 | J2 | OC ₁ | OUTPUT PORT 2 BIT 1 |
| 25 | J2 | OC ₂ | OUTPUT PORT 2 BIT 2 |
| 24 | J2 | OC ₃ | OUTPUT PORT 2 BIT 3 |
| 22 | J2 | OC ₄ | OUTPUT PORT 2 BIT 4 |
| 19 | J2 | OC ₅ | OUTPUT PORT 2 BIT 5 |
| 16 | J2 | OC ₆ | OUTPUT PORT 2 BIT 6 |
| 21 | J2 | OC ₇ | OUTPUT PORT 2 BIT 7 |
| 44 | J2 | OD _g | OUTPUT PORT 3 BIT # |
| 43 | J2 | OD ₁ | OUTPUT PORT 3 BIT 1 |
| 39 | J2 | OD ₂ | OUTPUT PORT 3 BIT 2 |
| 42 | J2 | OD ₃ | OUTPUT PORT 3 BIT 3 |
| 33 | J2 | OD ₄ | OUTPUT PORT 3 BIT 4 |
| 29 | J2 | OD ₅ | OUTPUT PORT 3 BIT 5 |
| 26 | J2 | OD ₆ | OUTPUT PORT 3 BIT 6 |
| 31 | J2 | OD ₇ | OUTPUT PORT 3 BIT 7 |
| 69 | J2 | A _g | LOW ORDER ADDRESS OUT |
| 82 | J2 | A ₁ | LOW ORDER ADDRESS OUT |
| 58 | J2 | A ₂ | LOW ORDER ADDRESS OUT |
| 23 | J2 | A ₃ | LOW ORDLR ADDRESS OUT |
| 63 | J2 | A ₄ | LOW ORDER ADDRESS OUT |
| 17 | J2 | A ₅ | LOW ORDER ADDRESS OUT |
| 32 | J2 | A ₆ | LOW ORDER ADDRESS OUT |
| 48 | J2 | A ₇ | LOW ORDER ADDRESS OUT |
| 68 | J1 | A ₈ | HIGH ORDER ADDRESS OUT |
| 67 | J1 | A ₉ | HIGH ORDER ADDRESS OUT |
| 80 | J1 | A ₁₀ | HIGH ORDER ADDRESS OUT |
| 56 | J2 | A ₁₁ | HIGH ORDER ADDRESS OUT |
| 76 | J1 | A ₁₂ | HIGH ORDER ADDRESS OUT |
| 71 | J1 | A ₁₃ | HIGH ORDER ADDRESS OUT |
| 74 | J1 | CC _g | CYCLE CONTROL CODING |
| 73 | J1 | CC ₁ | CYCLE CONTROL CODING |
| 61 | J1 | D _g | RAM DATA IN D _g |
| 15 | J1 | D ₁ | RAM DATA IN D ₁ |
| 56 | J1 | D ₂ | RAM DATA IN D ₂ |
| 59 | J1 | D ₃ | RAM DATA IN D ₃ |
| 58 | J1 | D ₄ | RAM DATA IN D ₄ |

| Pin No. | Connector | Symbol | Description |
|---------|-----------|----------------------------------|--|
| 57 | J1 | D ₅ | RAM DATA IN D ₅ |
| 55 | J1 | D ₆ | RAM DATA IN D ₆ |
| 54 | J1 | D ₇ | RAM DATA IN D ₇ |
| 48 | J1 | WAIT | STATE COUNTER |
| 49 | J1 | T ₃ | STATE COUNTER |
| 46 | J1 | T ₁ | STATE COUNTER |
| 45 | J1 | STOP | STATE COUNTER |
| 42 | J1 | T ₂ | STATE COUNTER |
| 44 | J1 | T ₅ | STATE COUNTER |
| 47 | J1 | T ₁ | STATE COUNTER |
| 43 | J1 | T ₄ | STATE COUNTER |
| 79 | J1 | CM _g | RAM CHIP SELECT # |
| 81 | J1 | CM ₁ | RAM CHIP SELECT 1 |
| 83 | J1 | CM ₂ | RAM CHIP SELECT 2 |
| 6 | J2 | CM ₃ | RAM CHIP SELECT 3 |
| 2 | J2 | CM ₄ | RAM CHIP SELECT 4 |
| 4 | J2 | CM ₅ | RAM CHIP SELECT 5 |
| 85 | J1 | CM ₆ | RAM CHIP SELECT 6 |
| 82 | J1 | CM ₇ | RAM CHIP SELECT 7 |
| 85 | J2 | CS _g | ROM CHIP SELECT # |
| 78 | J1 | CS ₁ | ROM CHIP SELECT 1 |
| 62 | J1 | CS ₂ | ROM CHIP SELECT 2 |
| 64 | J1 | CS ₃ | ROM CHIP SELECT 3 |
| 70 | J1 | CS ₄ | ROM CHIP SELECT 4 |
| 35 | J2 | CS ₅ | ROM CHIP SELECT 5 |
| 46 | J2 | CS ₆ | ROM CHIP SELECT 6 |
| 72 | J2 | CS ₇ | ROM CHIP SELECT 7 |
| 5 | J2 | O ₇ | I/O DECODE OUT O ₇ |
| 13 | J2 | O ₆ | I/O DECODE OUT O ₆ |
| 12 | J2 | O ₅ | I/O DECODE OUT O ₅ |
| 15 | J2 | O ₄ | I/O DECODE OUT O ₄ |
| 14 | J2 | O ₃ | I/O DECODE OUT O ₃ |
| 11 | J2 | O ₂ | I/O DECODE OUT O ₂ |
| 9 | J2 | O ₁ | I/O DECODE OUT O ₁ |
| 7 | J2 | O ₀ | I/O DECODE OUT O ₀ |
| 3 | J1 | S | FLAG FLIP FLOP-Sign |
| 5 | J1 | Z | FLAG FLIP FLOP-Zero |
| 23 | J1 | P | FLAG FLIP FLOP-Parity |
| 25 | J1 | C | FLAG FLIP FLOP-Carry |
| 7 | J1 | D ₀ | INTERRUPT INSTRUCTION INPUT # |
| 9 | J1 | D ₁ | INTERRUPT INSTRUCTION INPUT 1 |
| 18 | J1 | D ₂ | INTERRUPT INSTRUCTION INPUT 2 |
| 20 | J1 | D ₃ | INTERRUPT INSTRUCTION INPUT 3 |
| 24 | J1 | D ₄ | INTERRUPT INSTRUCTION INPUT 4 |
| 27 | J1 | D ₅ | INTERRUPT INSTRUCTION INPUT 5 |
| 38 | J1 | D ₆ | INTERRUPT INSTRUCTION INPUT 6 |
| 40 | J1 | D ₇ | INTERRUPT INSTRUCTION INPUT 7 |
| 59 | J2 | FROM TTY TRANSMITTER IN } | FROM TTY TRANSMITTER IN } TTY BUFFER |
| 37 | J2 | FROM TTY TRANSMITTER OUT | FROM TTY TRANSMITTER OUT } TTY BUFFER |
| 83 | J2 | DATA FROM TTY TRANSMITTER BUFFER | |
| 27 | J2 | TAPE READER CONTROL IN | |
| 18 | J2 | TAPE READER CONTROL OUT | |
| 28 | J2 | TAPE READER CONTROL (-9VDC) | |
| 84 | J1 | DATA TO TTY RECEIVER BUFFER | |
| 10 | J2 | TO TTY RECEIVER OUT | |
| 86 | J1 | TO TTY RECEIVER OUT | |
| 40 | J2 | TO TTY RECEIVER OUT | |
| 81 | J2 | READY/WRITER | |
| 72 | J1 | I _g | MULTIPLEXER CONTROL LINES N8263 |
| 41 | J1 | SLI _g | MULTIPLEXER CONTROL LINES N8267 |
| 69 | J1 | II | MULTIPLEXER CONTROL LINES N8263 |
| 8 | J1 | SLL | MULTIPLEXER CONTROL LINES N8267 |
| 29 | J1 | DATA COMPLEMENT | |
| 52 | J1 | B ₁ | B ₁ CLOCK (alternate clock) |
| 12 | J1 | B ₂ | B ₂ CLOCK (alternate clock) |
| 75 | J1 | SYNC | SYNC OUT |
| 30 | J1 | READY | READY IN |
| 1 | J1 | INTERRUPT | INTERRUPT IN |
| 8 | J2 | I/O ENABLE | ENABLE OF I/O DEVICE DECODER |
| 79 | J2 | OUT | SYSTEM OUTPUT CONTROL |
| 77 | J2 | IN | SYSTEM INPUT CONTROL |
| 50 | J1 | N.O. | PUSH BUTTON SWITCH } INTERRUPT |
| 53 | J1 | N.C. | PUSH BUTTON SWITCH } INTERRUPT |
| 52 | J2 | W _g | OUTPUT LATCH STROBE PORT # |
| 71 | J2 | W ₁ | OUTPUT LATCH STROBE PORT 1 |
| 20 | J2 | W ₂ | OUTPUT LATCH STROBE PORT 2 |
| 30 | J2 | W ₃ | OUTPUT LATCH STROBE PORT 3 |
| 22 | J1 | INT CYCLE | INTERRUPT CYCLE INDICATOR |
| 32 | J1 | T ₃ A | ANTICIPATED T ₃ OUTPUT |
| 35 | J1 | T ₃ A | ANTICIPATED T ₃ OUTPUT |

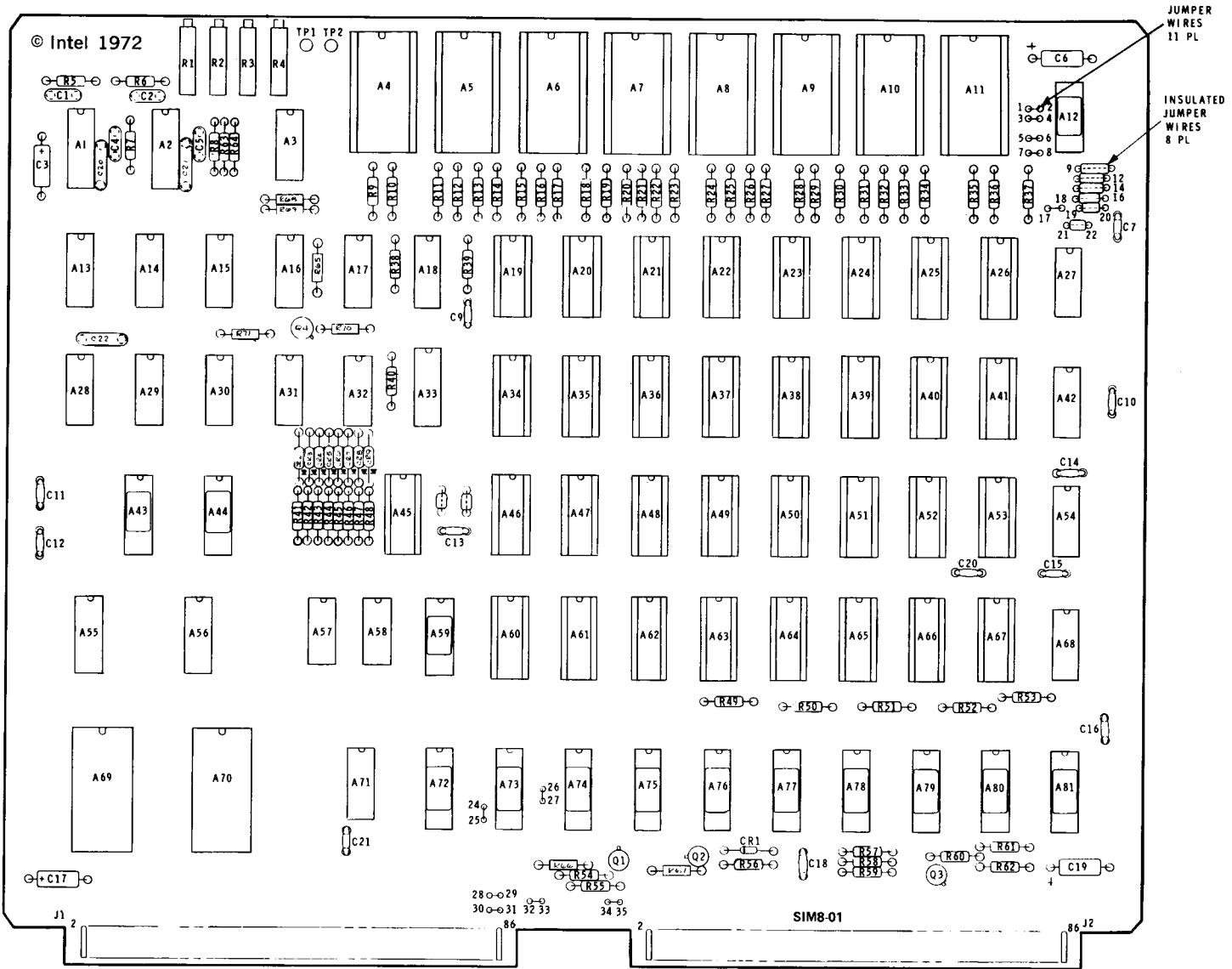


Figure 14. SIM8-01 Assembly Diagram

VIII. PROM PROGRAMMING SYSTEM

A. General System Description and Operating Instructions

Intel has developed a low-cost micro computer programming system for its electrically programmable ROMs. Using Intel's eight bit micro computer system and a standard ASR 33 teletype (TTY), a complete low cost and easy to use ROM programming system may be assembled. The system features the following functions:

- 1) Memory loading
- 2) Format checking
- 3) ROM programming
- 4) Error checking
- 5) Program listing

For specifications of the Intel ROMs, refer to the Intel Data Catalog.

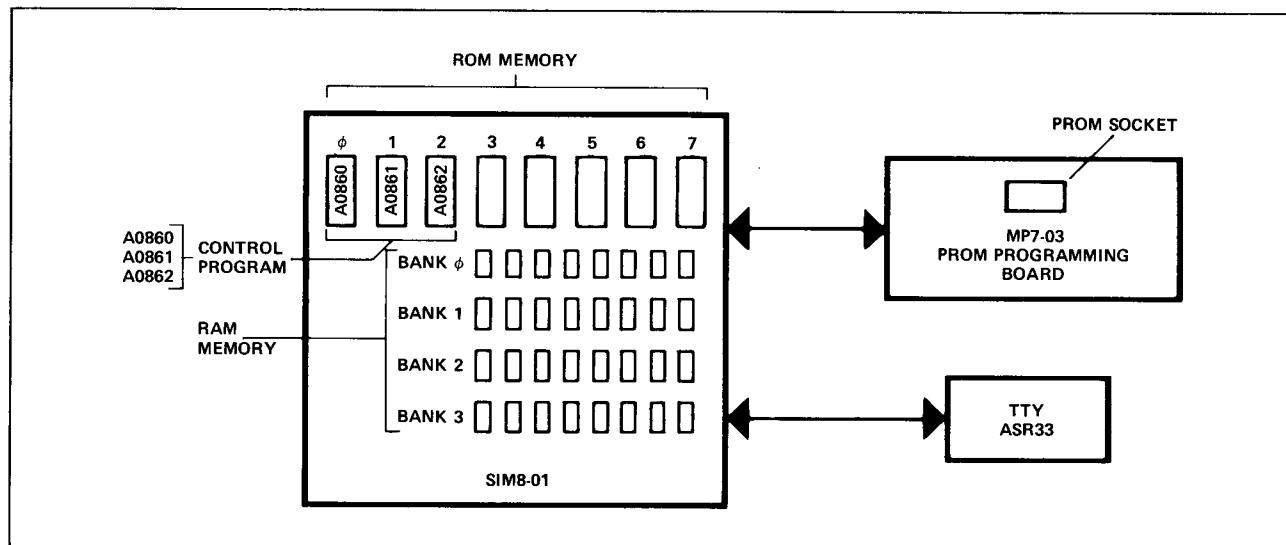


Figure 15. MCS-8 PROM Programming System

This programming system has four basic parts:

- 1) The micro computer (SIM8-01)
This is the **MCS-8** prototype board, a complete micro-computer which uses 1702 PROMs for the microprogram control. The total system is controlled by the 8008 CPU.
- 2) The control program (A0860, A0861, A0862)
These control ROMs contain the microprograms which control the bootstrap loading, programming, format and error checking, and listing functions. For high speed programming of Intel's new 1702A PROM (three minutes) use control PROM A0863 in place of A0862.
- 3) The programmer (MP7-03)
This is the programmer board which contains all of the timing and level shifting required to program the Intel ROMs. This is the successor of the MP7-02.
- 4) ASR 33 (Automatic Send Receive) Teletype
This provides both the keyboard and paper tape I/O devices for the programming system.

In addition, a short-wave ultraviolet light is required if the erasable and reprogrammable 1701's or 1702's are used.

This system has two modes of operation:

- 1) Automatic — A paper tape is used in conjunction with the tape reader on the teletype. The tape contains the program for the ROM.
- 2) Manual — The keyboard of the TTY is used to enter the data content of the word to be programmed.

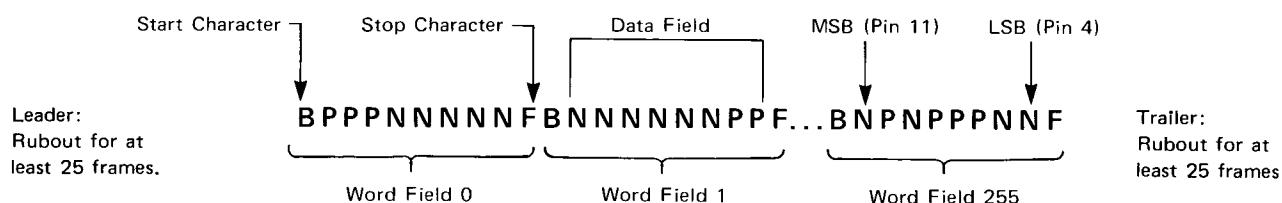
PROGRAMMING THE 1601/1701 AND 1602/1702

Information is introduced by selectively programming "1's (output high) and "0's (output low) into the proper bit locations. Note that these ROMs are defined in terms of positive logic.

Word address selection is done by the same decoding circuitry used in the READ mode. The eight output terminals are used as data inputs to determine the information pattern in the eight bits of each word. A low data input level (ground – P on tape) will leave a "1" and a high data input level (+48V – N on tape) will allow programming of "0". All eight bits of one word are programmed simultaneously by setting the desired bit information patterns on the data input terminals.

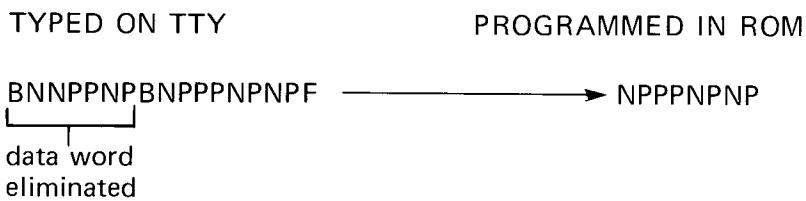
TAPE FORMAT

The tape reader used with a model 33 ASR teletype accepts 1" wide paper tape using 7 or 8 bit ASCII code. For a tape to correctly program a 1601/1701 or 1602/1702, it must follow exactly the format rules below:



The format requirements are as follows:

- 1) There must be exactly 256 word fields in consecutive sequence, starting with word field 0 (all address lines low) to program an entire ROM. If a short tape is needed to program only a portion of the ROM, the same format requirements apply.
- 2) Each word field must consist of ten consecutive characters, the first of which must be the start character B. Following that start character, there must be exactly eight data characters (P's or N's) and ending with the stop character F. NO OTHER CHARACTERS ARE ALLOWED ANYWHERE IN A WORD FIELD. If an error is made while preparing a tape and the stop character "F" has not been typed, a typed "B" will eliminate the previous characters entered. **This is a feature not available on Intel's 7600 programmer; the format shown in the 1601/1701 data sheet must be used when preparing tapes for other programming systems.** An example of this error correcting feature is shown below:

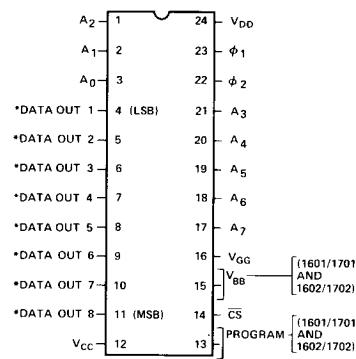


If any character other than P or N is entered, a format error is indicated. If the stop character is entered before the error is noticed, the entire word field, including the B and F, must be rubbed out. **Within the word field, a P results in a high level output, and N results in a low level output.** The first data character corresponds to the desired output for data bit 8 (pin 11), the second for data bit 7 (pin 10), etc.

- 3) Preceding the first word field and following the last word field, there must be a leader/trailer length of at least 25 characters. This should consist of rubout punches.

- 4) Between word fields, comments not containing B's or F's may be inserted. It is important that a carriage return and line feed characters be inserted (as a "comment") just before each word field or at least between every four word fields. When these carriage returns are inserted, the tape may be easily listed on the teletype for purposes of error checking. It may also be helpful to insert the word number (as a "comment") at least every four word fields.

PROM PIN CONFIGURATION



*THIS PIN IS THE DATA INPUT LEAD FOR THE 1601/1701
AND 1602/1702 DURING PROGRAMMING

IMPORTANT

It should be noted that the PROM's are described in the data sheet with respect to positive logic (high level = p-logic 1). The MCS-8 system is also defined in terms of positive logic. Consider the instruction code for LHD (one of the 48 instructions for the MCS-8).

1 1 1 0 1 0 1 1

When entering this code to the programmer it should be typed,

B P P P N P N P P F

This is the code that will be put into the 1301, Intel's mask programmed ROM, when the final system is defined.

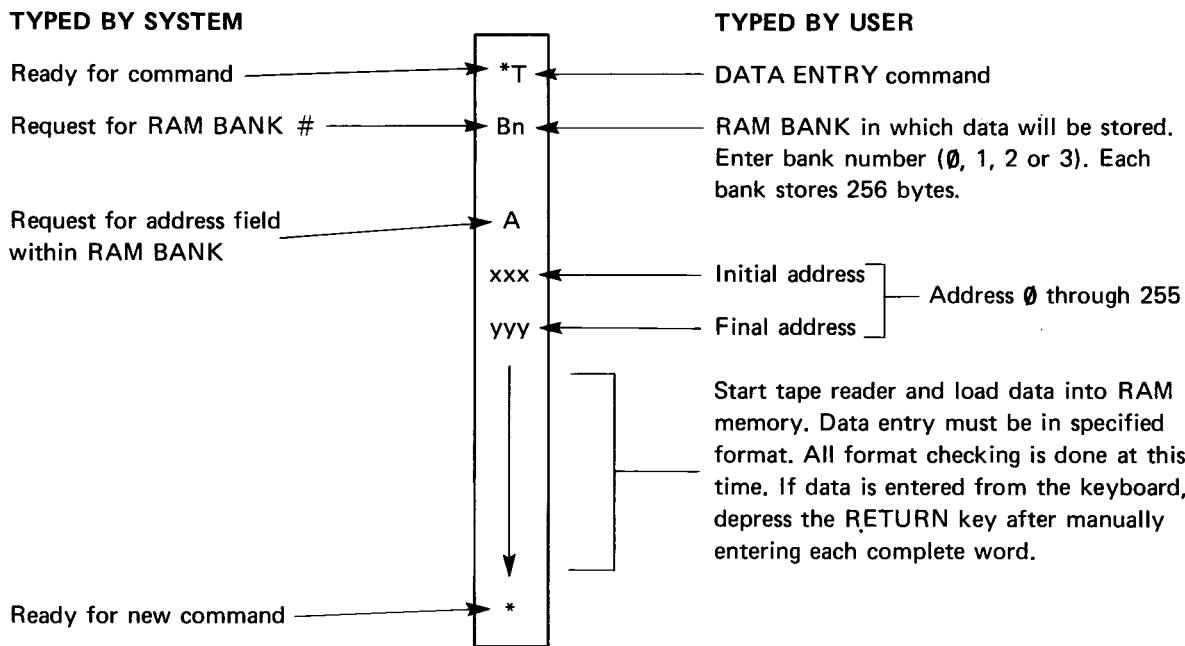
OPERATING THE PROGRAMMER

The SIM8-01 is used as the micro computer controller for the programming. The control program performs the function of a bootstrap loader of data from the TTY into the RAM memory. It then presents data and addresses to the PROM to be programmed and controls the programming pulse. The following steps must be followed when programming a PROM:

- 1) Place control ROMs in SIM8-01
- 2) Turn on system power
- 3) Turn on TTY to "line" position
- 4) Reset system with an INTERRUPT (Instr. RST = 00 000 101)
- 5) Change instruction at interrupt port to a NO OP
- 6) Start system with an INTERRUPT (Instr NO OP = 11 000 000)
- 7) Load data from TTY into micro computer memory
- 8) Insert PROM into MP7-03
- 9) Program PROM
- 10) Remove PROM from MP7-03. To prevent programming of unwanted bits, never turn power on or off while the PROM is in the MP7-03.

LOADING DATA TO THE MICRO COMPUTER (THE BOOTSTRAP LOADER)

The programming system operates in an interactive mode with the user. After resetting and starting the system with an INTERRUPT [steps 4), 5), 6)], a "*" will appear on the TTY. This is the signal that the system is ready for a command. To load a data tape, the following sequence must be followed:



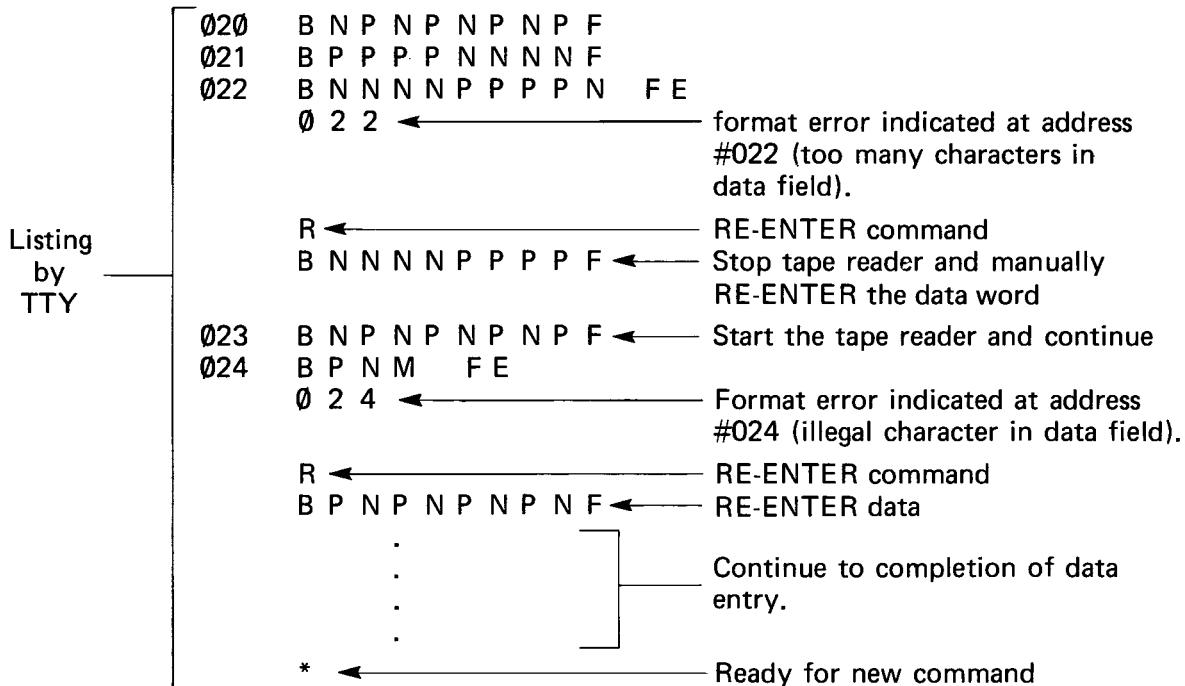
This RAM bank may be edited by re-entering blocks of data prior to programming a PROM. More than one RAM bank may be loaded in preparation for programming several different PROMs or to permit the merging of blocks of data from different banks into a single PROM. (See the explanation of the CONTINUE command in section IX.)

FORMAT CHECKING

When the system detects the first format error (data words entered either on tape or manually), it will stop loading data and it will print out the address where the format error occurred.

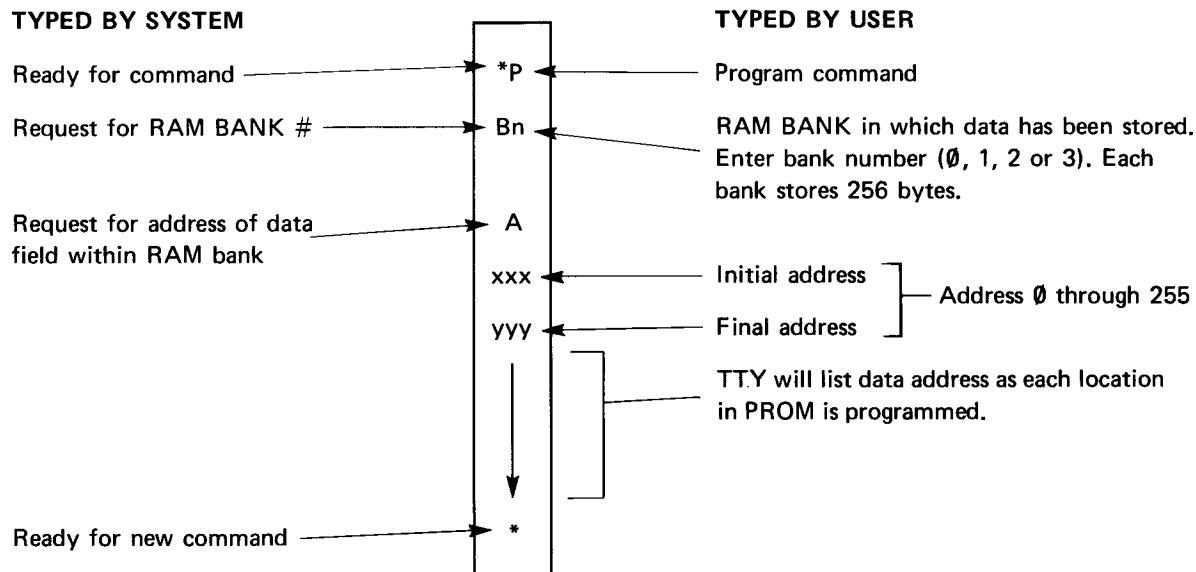
At this time, an "R" may be typed and the data can be RE-ENTERED manually. This is shown below.

EXAMPLE 1:



PROGRAMMING

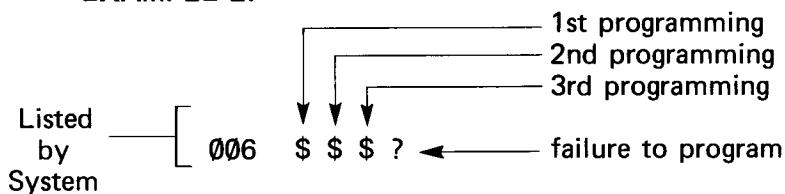
After data has been entered, the PROM may be programmed. Data from a designated address field in a designated RAM bank is programmed into corresponding addresses in the PROM. A complete PROM or any portion of a PROM may be programmed in the following manner:



ERROR CHECKING

After each location in ROM is programmed, the content of the location is read and compared against the programming data. In the event that the programming is not correct, the ROM location will be programmed again. The MCS-8 programming system allows each location of the ROM to be reprogrammed up to four times. A "\$" will be printed for each reprogramming. If a location in ROM will not accept a data word after the fourth time, the system will stop programming and a "?" will be printed. This feature of the system guarantees that the programmed ROM will be correct, and incompletely erased or defective ROMs will be identified.

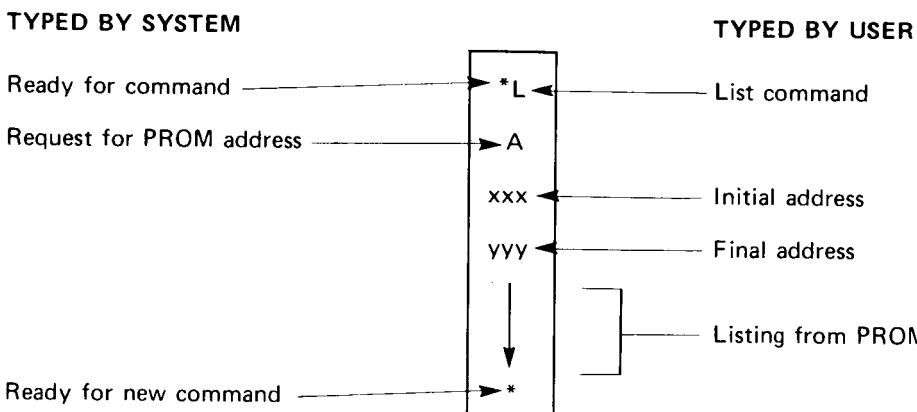
EXAMPLE 2:



If a location in the ROM will not program, a new ROM must be inserted in the programmer. The system must be reset before continuing. (If erasable ROMs are being used, the "faulty" ROM should be erased and reprogrammed).

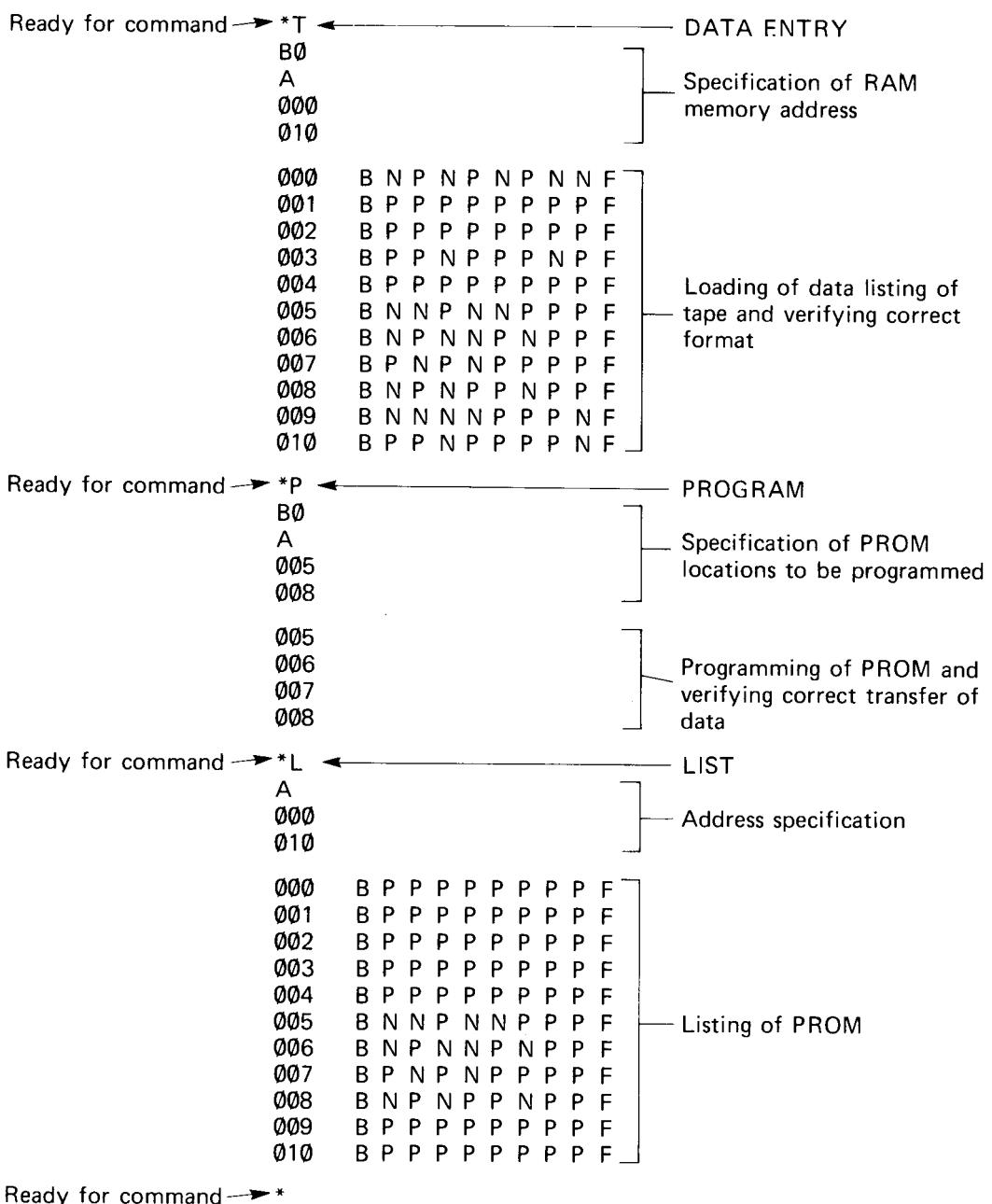
PROGRAM LISTING

Before or after the programming is finished, the complete content of the ROM, or any portion may be listed on the teletype. A duplicated programming tape may also be made using the teletype tape punch. To list the ROM:



The listing feature may also be used to verify that a 1701 or 1702 is completely erased.

EXAMPLE 3:



1701, 1702 ERASING PROCEDURE

The 1701 and 1702 may be erased by exposure to high intensity short-wave ultraviolet light at a wavelength of 2537 Å. The recommended integrated dose (i.e., UV intensity x exposure time) is 6W-sec/cm². Example of ultraviolet sources which can erase the 1701 or 1702 in 10 to 20 minutes is the Model S-52 and Model UVS-11 short-wave ultraviolet lamps manufactured by Ultra-Violet Products, Inc. (San Gabriel, California). **The lamps should be used without short-wave filters, and the 1701 or 1702 to be erased should be placed about one inch away from the lamp tubes.**

B. MP7-03 Programming System

The MP7-03 is the PROM programming board which easily interfaces with the SIM8-01. All address and data lines are completely TTL compatible. The MP7-03 requires +5VDC @ 0.8 amps, -9 VDC @ 0.1 amps, and 50 Vrms @ 1 amp. Two Stancor P8180 (or equivalent) filament transformers (25.2 Vrms @ 1 amp) with their secondaries connected in series provide the 50 Vrms.

This programmer board is the successor of the MP7-02. The MP7-03 enables programming of Intel's new 1702A, a pin-for-pin replacement for the 1702.

When the MP7-03 is used under SIM8-01 control with control ROM A0862 replaced by A0863, the 1702A may be programmed an order of magnitude faster than the 1702, less than three minutes.

IMPORTANT:

Only use the A0863 control PROM when programming the new 1702A. Never use it when programming the 1702. The programming duty cycle is too high for the 1702 and it may be permanently damaged.

The MP7-03 features three data control options:

- 1) Data-in switch (Normal-Complement). If this switch is in the complement position, data into the PROM is complemented.
- 2) Data-out switch (Normal-Complement). If this switch is in the complement position, data read from the PROM is complemented.
- 3) Data-out switch (Enable-Disable). If this switch is in the enable position, data may be read from the PROM. In the disable position, the output line may float up to a high level (logic "1"). As a result, the input ports on the prototype system may be used for other functions without removing the MP7-03 card.

MP7-03 Programmer Board Specifications

Features:

- High speed programming of Intel's new 1702A (three minutes)
- Inputs and outputs TTL compatible
- Board sold complete with transformers, capacitor and connector
- Directly interfaces with SIM8-01 Board

Connector:

- a. Solder lug type/Amphenol
72 pin connector
P/N 225-23621-101
- b. Wire wrap type - Amphenol
72 pin connector
P/N 261-15636

Dimensions:

8.4 inches high

9.5 inches deep

Power Requirement:

V_{CC} = +5 @ 0.8 amps

TTL GRD = 0V

* V_{DD} = -9V @ 0.1 amps

V_P = 50Vrms @ 1 amp

*This board may be used with a -10V supply because a pair of diodes (i.e. 1N914 or equivalent) are located on the board in series with the supply. Select the appropriate pin for either -9V or -10V operation.

A micro computer bulletin which describes the modification of the MP7-02 for programming the 1602A/1702A is available on request. These modifications include complete failsafe circuitry (now on MP7-03) to protect the PROMs and the 50V power supply.

C. Programming System Interconnection

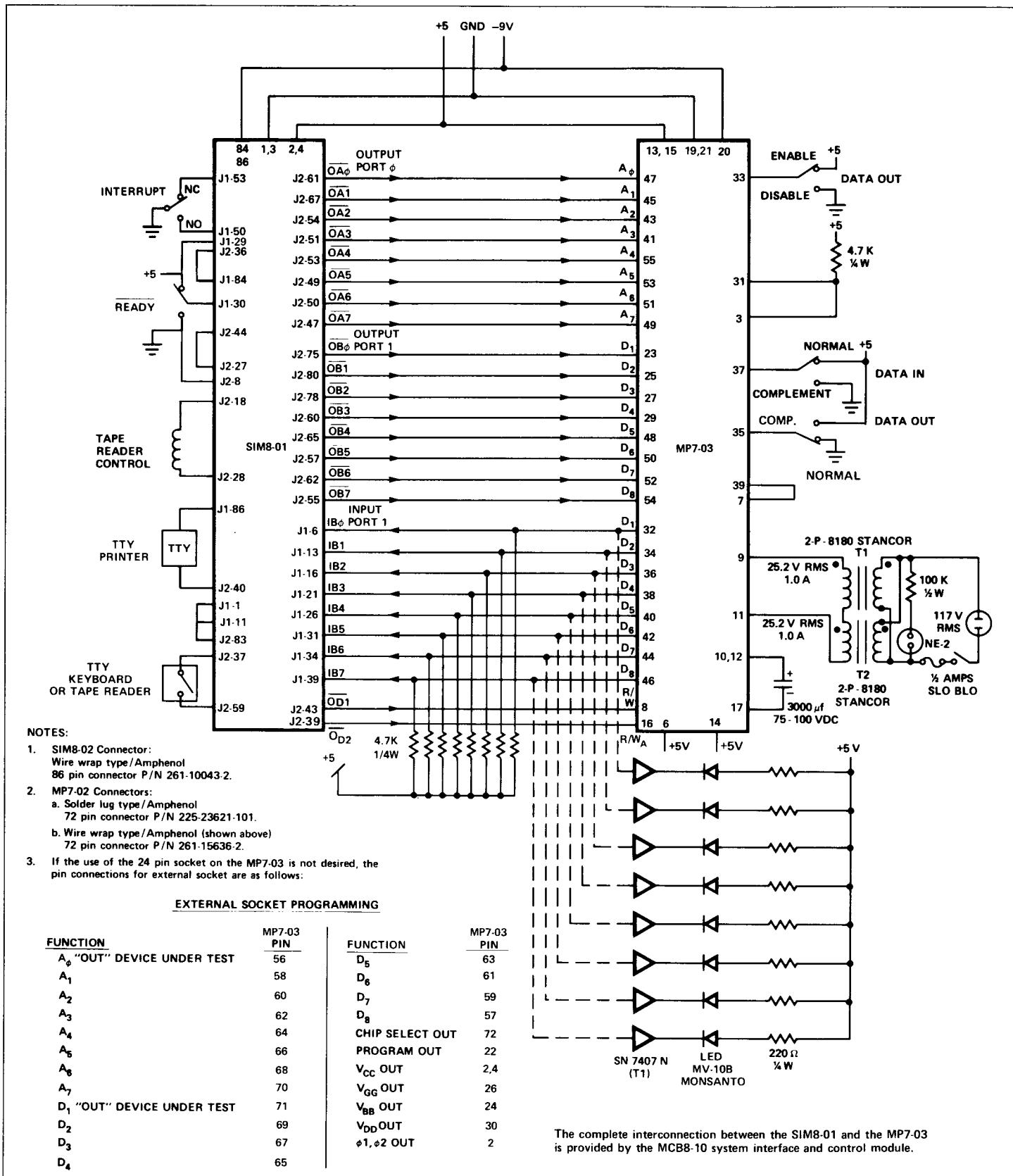


Figure 16. MP7-03/SIM8-01 PROM Programming System

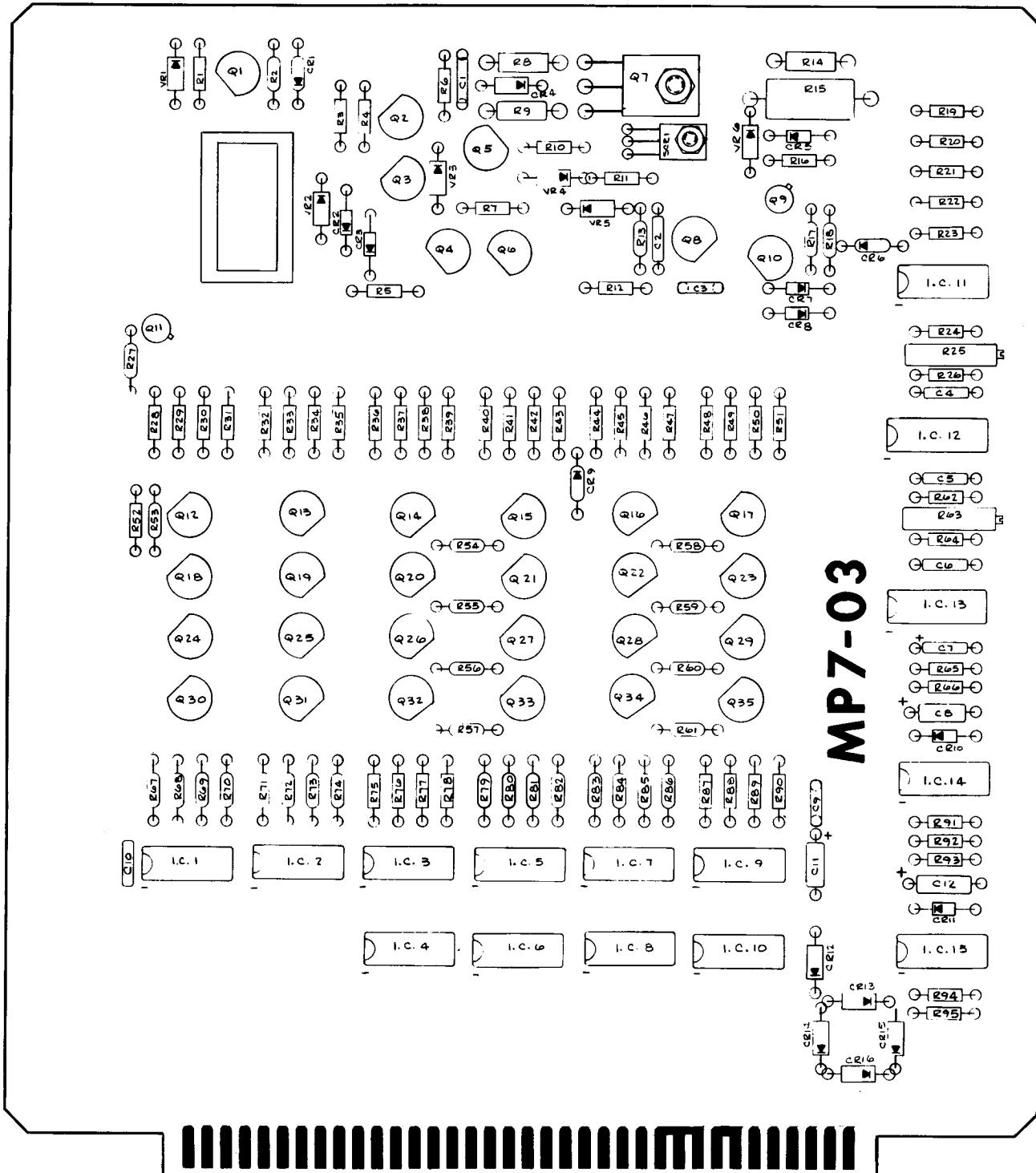


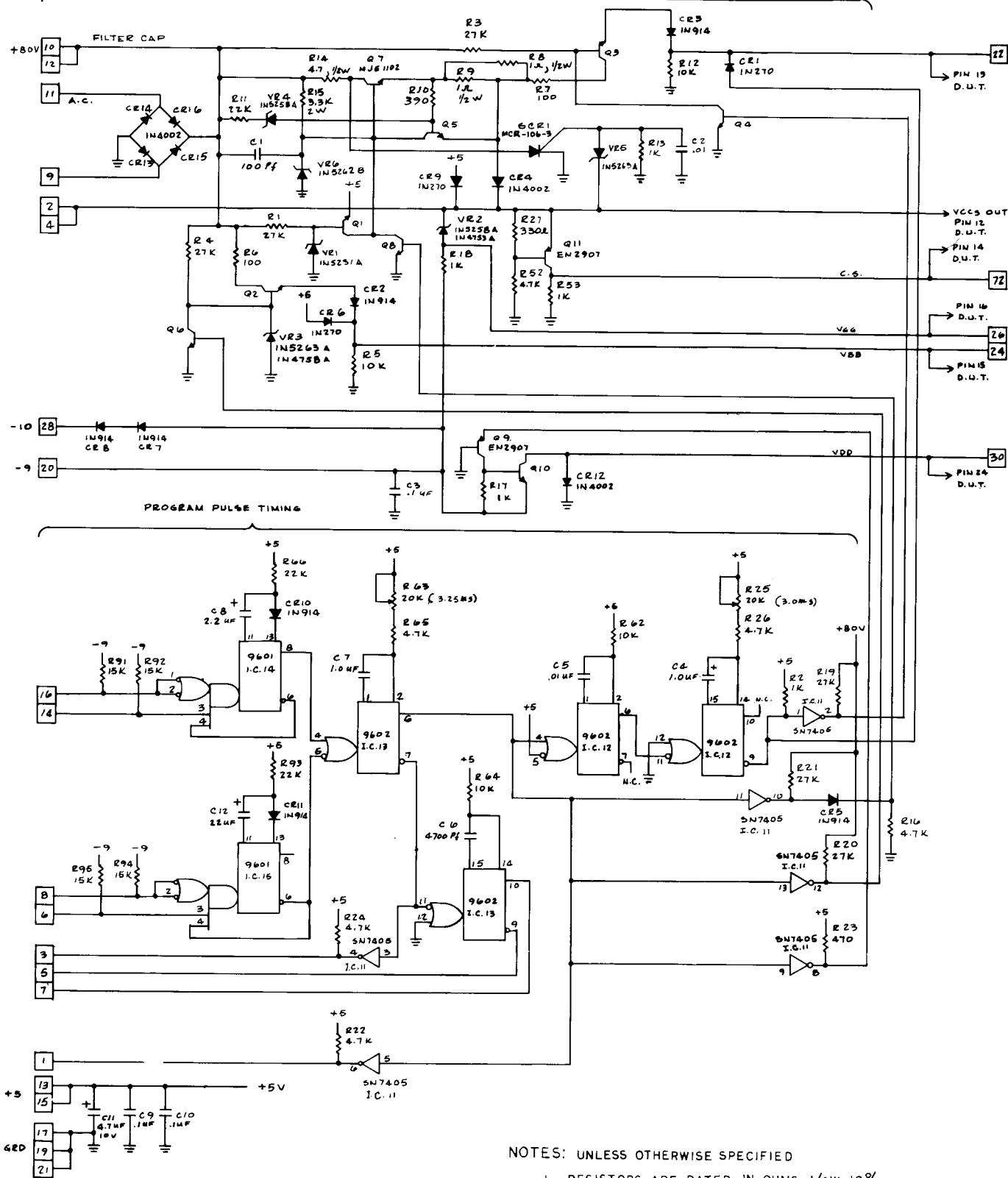
Figure 17a. Component Side of MP7-03 Card



Solder Connector P/N 225-23621-101 Wirewrap Connector P/N 261-15636-2

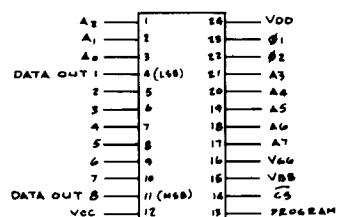
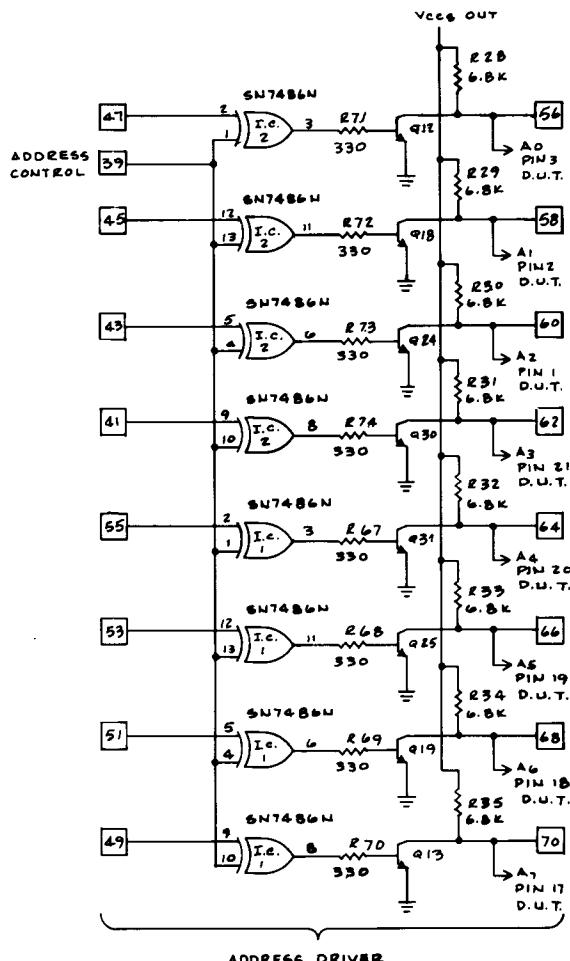
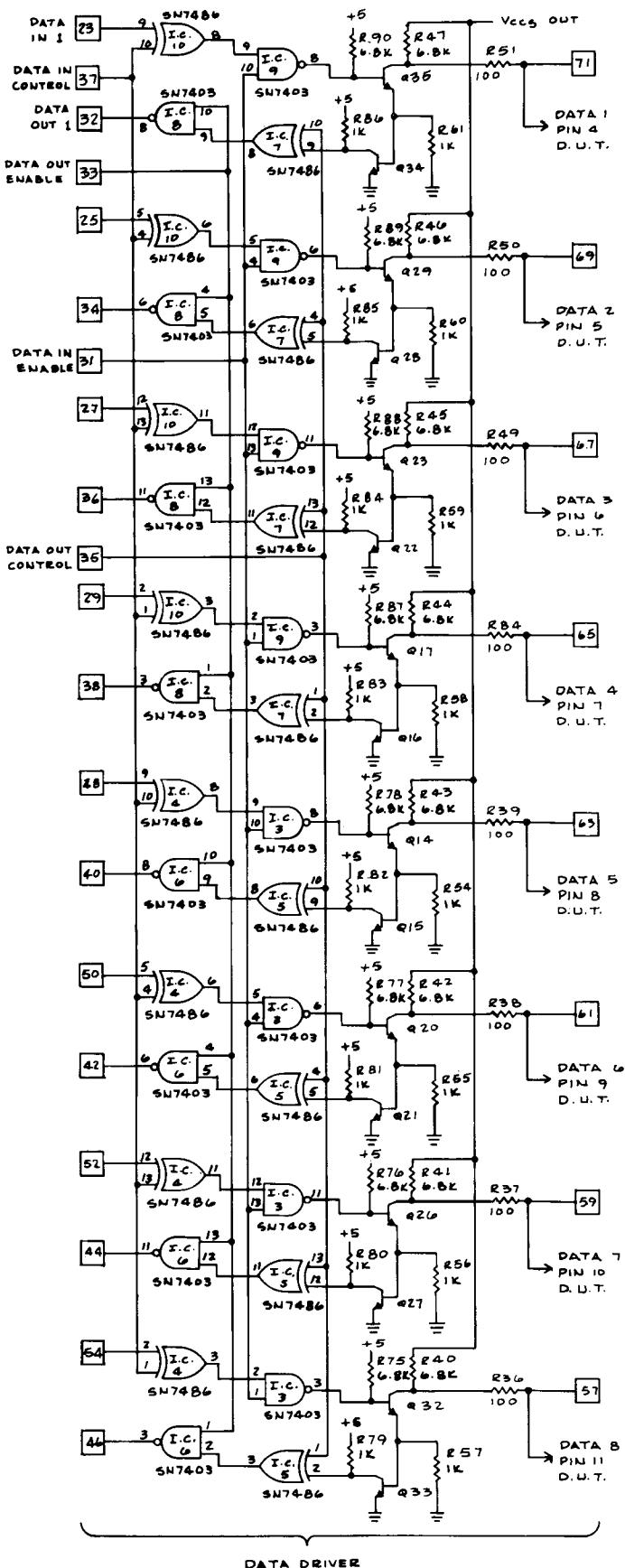
Figure 17b. Pin Definition — Reverse Side of MP7-03 Card

POWER SUPPLY REGULATOR



NOTES: UNLESS OTHERWISE SPECIFIED

- RESISTORS ARE RATED IN OHMS 1/4W, 10%.
- TRANSISTORS ARE SE6021, OR 2N3658 OR 2N3722.



DEVICE TO BE PROGRAMMED

(1702 or 1702A)

Figure 18. MP7-03 PROM Programmer Board Schematic

IX. PROGRAM ASSEMBLY AND EXECUTION

A. 8008 Assembler Software Package

The 8008 Assembler generates object programs from symbolic assembly language instructions. Programs are written in the assembly language using mnemonic symbols both for 8008 instruction and for special assembler operations. Symbolic addresses can be used in the source program; however, the assembled program will use absolute addresses.

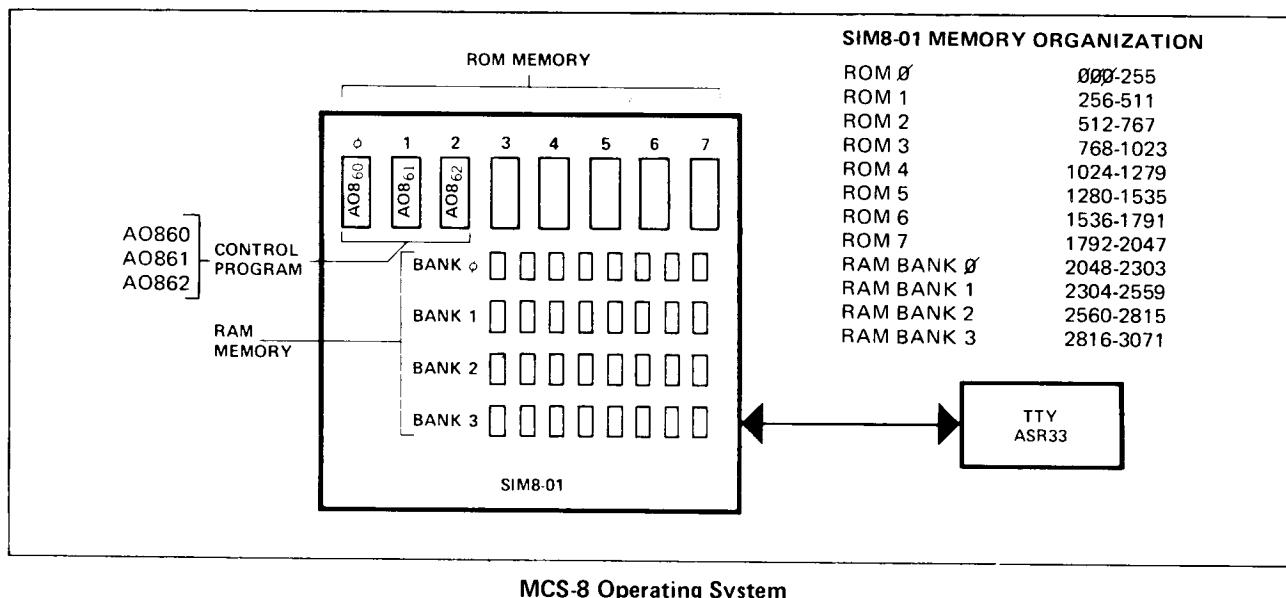
The Assembler is designed to operate from a time shared terminal with input by paper tape or directly from the terminal keyboard. The assembled program is punched out at the terminal in 8 level binary paper tape.

The Assembler is written in batch FORTRAN IV and is designed to run on an XDS 940 or on other machines having FORTRAN IV capability and a word length of 24 bits or more. Modifications to the program may be required for machines other than the XDS 940.

This program is currently available from nationwide computer timesharing services for timesharing computer users or as a software package for adaptation to another machine. Assembler software specifications are available on request.

B. Execution of Programs From RAM on SIM8-01 Using Memory Loader Control Programs.

The previous section provided a description of the preparation of tapes and the programming of PROMs for permanently storing the micro computer programs. During the system development, programs may be loaded, stored, and executed directly from RAM memory. This section explains these additional features.



The system has three basic parts

- 1) The micro computer (SIM8-01)
- 2) The bootstrap memory loader control program (AO860, AO861, AO862)
- 3) ASR 33 (Automatic Send Receive) Teletype

The control program provides the complete capability for executing programs from RAM. Two additional program commands are required; "C", the CONTINUE command for loading more than one bank of memory, and "E", the program EXECUTION command.

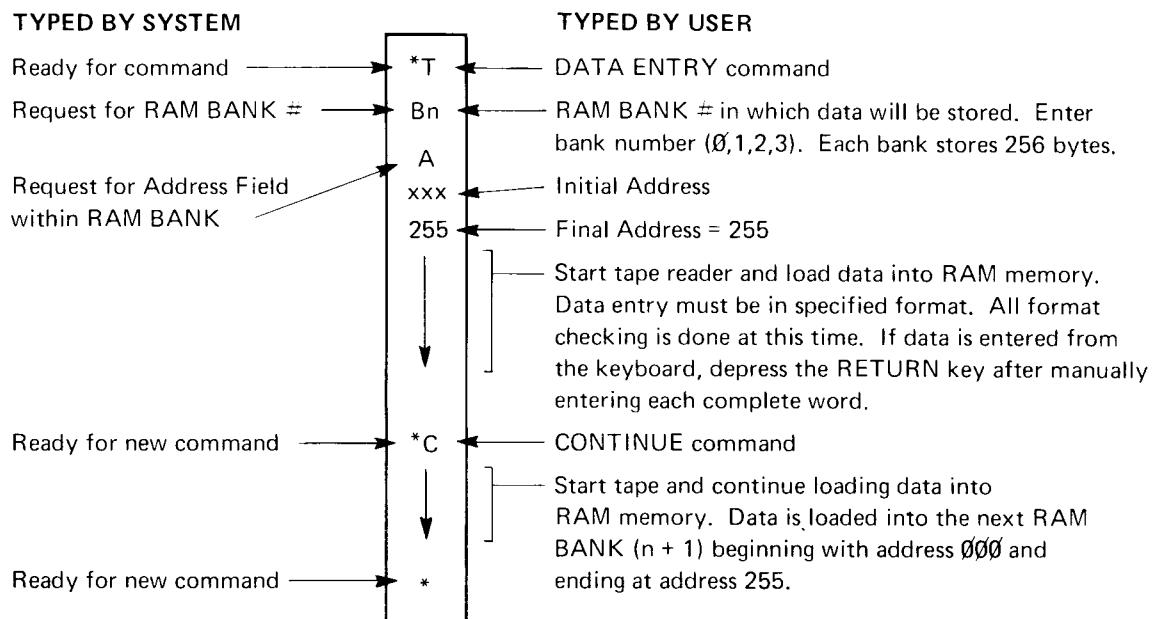
OPERATING THE MICRO COMPUTER SYSTEM

To use the SIM8-01 as the micro computer controller for the bootstrap loading of a program from the TTY into RAM memory and the execution of programs stored in RAM, the following steps must be followed:

- 1) Place control ROMs in SIM8-01
- 2) Turn on system power
- 3) Turn on TTY to "line" position
- 4) Reset system with an INTERRUPT (Instr. RST = 00 000 101)
- 5) Change instruction at interrupt port to a NO OP
- 6) Start system with an INTERRUPT (Instr. NO OP = 11 000 000)
- 7) Load data from TTY into micro computer RAM memory
- 8) Execute the program stored in RAM

LOADING OF MULTIPLE RAM BANKS

Through the use of the command "C", (CONTINUE) subsequent RAM banks may be loaded with data without entering a new data entry command and new memory bank and address designations.



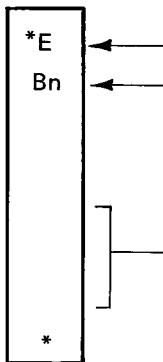
Note that the CONTINUE command should only be used when the subsequent RAM will be completely loaded with 256 bytes of data. For partial loading of RAM banks, always use the DATA ENTRY command. The content of a RAM bank may be edited by using the DATA ENTRY command and revising and re-entering sections of the bank. When a program is being stored in memory, the first instruction of the program should be located at address 000 in a RAM bank. The entire RAM memory with the exception of the last fifteen bytes of RAM bank 3 may be used for program or data storage in conjunction with the bootstrap loader.

PROGRAM EXECUTION

The program which has been loaded into RAM may be executed directly from RAM.

TYPED BY SYSTEM

Ready for command →



TYPED BY USER

Program EXECUTION command ←

Request for RAM BANK # →

RAM BANK in which the program has been stored.
The first instruction in a program must be at address 000 in a RAM bank.

Program beginning at address 000 of RAM BANK # n
will be executed by the MCS-8 system.

*To return to the bootstrap control program, the
ending statement of the program being executed
should be "JMP 462"*

Ready for command →

CAUTION: When executing a program from a single RAM bank or multiple RAM banks, care must be taken to insure that all JUMP addresses and subroutine CALL addresses are appropriately assigned within the memory storage being used.

SUMMARY OF SYSTEM COMMANDS

Using Intel's special control ROMs (AO860, AO861, AO862) the following control commands are available:

| COMMAND | EXPLANATION |
|---------|---|
| T | DATA ENTRY – Enter data from TTY into a RAM bank |
| C | CONTINUE – Continue entering 256 byte blocks of data into subsequent RAM banks |
| R | RE-ENTER – Re-enter a data word where a format error has occurred and continue entering data |
| E | EXECUTE – Execute the program stored in RAM memory |
| P | PROGRAM – Program a PROM using data stored in RAM memory |
| L | LIST – List the content of the PROM on the TTY |

Listing of Bootstrap Loader Program
 (Intel tape numbers A0860, A0861, A0862, October 2, 1972)

| | | |
|-------------------------------------|--------------------------------|---|
| BECIN LAI 1 | SUPPRESS TTY | *TYPE A AND IDENTIFY INITIAL AND FINAL LOCATION |
| OUT 12B | OUTPUT 2 | * |
| XRA | CLEAR AC | ADRESL CAL CRLF |
| OUT 13B | OUTPUT 3 - TAPE READER CONTROL | LBI 301B LOAD (A) |
| HLT | | CAL TTYOUT TYPE (A) |
| JMP START | | AD1 CAL CRLF |
| * | | LCI 253 C=253 |
| *TELETYPE TAPE READER & I/O CONTROL | | CAL TTY CALL FOR TTY KB INPUT |
| * | | INL L=L+1 |
| TAPE LAI 1 | TAPE READER ENABLE CODE | LOAD TTY KB INPUT TO M |
| OUT 13B | OUTPUT 3 - ENABLE TAPE READER | C=C+1 |
| TTY HLT | WAIT FOR TTY START PULSE | JUMP IF C IS NOT ZERO |
| LDI 194 | TTY DELAY - 4 MSEC. | RET |
| ST2 IND | | * |
| JFZ ST2 | | *DATA INPUT ROUTINE |
| XRA | TAPE READER DISABLE CODE | DATAIN CAL TAPE READ TAPE |
| OUT 13B | OUTPUT 3, DISABLE TAPE READER | LAI 102B LOAD (B) |
| OUT 12B | OUTPUT 2, OUTPUT START PULSE | CPB SEARCH FOR (B) |
| LEI 248 | TTY DATA SAMPLING COUNTER | JFZ DATAIN JUMP IF IT IS NOT (B) |
| TTYIN CAL TTYD1 | TTY DELAY - 8.7 msec. | DATA1 LHI 11 H=11 |
| INP 0B | READ TTY DATA INPUT | LLI 255 L=255 |
| XRI 255 | COMPLEMENT TTY DATA | LAI 248 DATA BIT COUNTER |
| OUT 12B | OUTPUT 2, TTY DATA OUT | CPB STORE DATA BIT CONTR |
| RAR | STORE TTY DATA | JFZ DATA1 READ TAPE |
| LAB | LOAD TTY DATA TO REG. B | LAI 250 MEMORY LOC. FOR DATA |
| RAR | | CPB LOAD (P) |
| LBA | LOAD AC TO REG. B | JTZ PDATA SEARCH FOR (P) |
| INE | E = E + 1 | LAI 120B IF (P) STORE (1) |
| JFZ TTYIN | JUMP IF ZERO F/F IS NOT SET | CPB LOAD (N) |
| LAB | LOAD REG. B TO AC | JTZ NDATA SEARCH FOR (N) |
| NDI 127 | REMOVE PARITY BIT | LAI 102B IF (N) STORE (0) |
| LBA | STORE TTY INPUT DATA | CPB LOAD (B) |
| CAL TTYD1 | | JTZ DATA1 SEARCH FOR (B) |
| LAI 1 | | LAI 177B IF (B) DELETE LAST INSTRUCTION |
| OUT 12B | SUPPRESS TTY | CPB LOAD (R0) |
| RET | NOP | JFZ FMEROR SEARCH FOR RUBOUT |
| LAA | | CAL RUBOUT JUMP IF NOT RUBOUT |
| LAA | | JMP DATA2 CALL FOR RUBOUT ROUTINE |
| LAA | | |
| LAA | | FMEROR CAL FORMAT CALL FOR FORMAT ERROR ROUTINE |
| * | | JMP DATAEN |
| *TTY DELAY - 8.7 msec. | | PDATA LAI 1 REPLACE (P) WITH (1) |
| * | | RAR ROTATE RICHT |
| TTYD1 LDI 121 | 8.7 msec. DELAY | LAB ROTATE LEFT |
| ST IND | D=D+1 | |
| JFZ ST | | |
| RET | | |
| * | | |
| *BCD TO BINARY CONVERSION | | |
| * | | |
| BCDBIN LAM | LOAD LSD TO A | NDATA XRA CLEAR AC AND CARRY |
| SUI 48 | AC=AC-48 | LAM |
| LBA | LOAD A TO B | RAL ROTATE LEFT |
| DCL | L=L-1 | LMA |
| LAM | LOAD M TO A | |
| SUI 48 | A=A-48 | DATA3 LLI 255 LOAD M TO B |
| LEA | LOAD A TO E | CPB INC DATA BIT COUNTER |
| BB1 JTZ BB2 | IF A=0 JUMP | JFZ DATA2 JUMP IF B IS NOT ZERO |
| LAI 10 | AC=10 | CAL TAPE CALL FOR TAPE INPUT |
| ADB | AC=AC+B | LAI 106B LOAD (F) |
| LBA | LOAD AC TO REG. B | CPB SEARCH FOR (F) |
| DCE | E=E-1 | JTZ DATA4 STORE DATA IF IT IS (F) |
| JMP BB1 | | LAI 102B LOAD (B) |
| BB2 DCL | L=L-1 | CPB SEARCH FOR (B) |
| LAM | LOAD M TO A | JTZ DATA1 DELETE LAST INSTRUCTION IF IT IS (B) |
| SUI 48 | A=A-48 | LAI 177B LOAD (R0) |
| LEA | LOAD A TO E | CPB SEARCH FOR (R0) |
| BB3 JTZ BB4 | AC=100 | JFZ FMEROR JUMP IF IT IS NOT (R0) |
| LAI 100 | AC=AC+B | CAL RUBOUT CALL FOR (R0) ROUTINE |
| ADB | LOAD AC TO REG. B | JMP DATA2 |
| LBA | E=E-1 | |
| DCE | | |
| JMP BB3 | | |
| BB4 RET | | |
| * | | |
| *BINARY TO BCD CONVERSION | | |
| * | | |
| BINBCD LHI 11 | | RUBOUT LAA NOP |
| BNBD LLI 241 | | LAA |
| BNBD LCI 0 | CLEAR REG. C | LAA |
| BNBD LAB | | LAA |
| BD1 SUI 100 | AC=AC-100 | LAA |
| JTC BD2 | JUMP IF AC<100 | LAA |
| INC | C=C+1 | LAA |
| BD2 LBI 100 | LOAD 100 TO REC. B | FORMAT LBI 240B LOAD (SP) |
| ADB | AC=AC+B | CAL TTYOUT TYPE (SP) |
| LBA | LOAD AC TO REC. B | LBI 306B LOAD (F) |
| LAI 48 | A=A+48 | CAL TTYOUT TYPE (F) |
| ADC | A=A+C | LBI 305B LOAD (E) |
| LMA | LOAD A TO MEMORY | CAL TTYOUT TYPE (E) |
| LCI 0 | CLEAR REG. C | LISTA CAL CRLF |
| LAB | LOAD B TO A | PRINTA LLI 253 L=253 |
| | | LBM LOAD MEMORY TO B |
| | | CAL BINBCD BIN TO BCD CONV |
| | | LEI 253 E=253 |

| | | | | |
|-------------------------------|------------|--|-------------------|----------------------------|
| BD3 | SUI 10 | AC=AC-10 | DCL | L=L-1 |
| | JTC BD4 | JUMP IF AC<10 | DCL | L=L-1 |
| | INC | C=C+1 | LAM | LOAD MSD TO AC |
| | JMP BD3 | | ADI 128 | AC=AC+128 |
| BD4 | LBI 10 | B = 10 | LBA | LOAD AC TO B |
| | ADB | AC=AC+B | CAL TTYOUT | TYPE BCD LOCATION |
| | LBA | LOAD AC TO REG B | INL | L=L+1 |
| | LAI 48 | A=A+48 | INE | E=E+1 |
| | ADC | A=A+C | JFZ FM1 | JUMP IF E IS NOT 0 |
| | INL | L=L+1 | LAI 1 | FORMAT ERROR FLAG |
| | LMA | LOAD A TO M | RET | |
| | LAI 48 | A=A+48 | | |
| | ADB | A=A+B | | |
| | INL | L=L+1 | | |
| | LMA | LOAD A TO M | | |
| | RET | RETURN | | |
| * | | | * | |
| *TTY OUTPUT ROUTINE | | *ENTER ADDRESS AND CONVERT THEM INTO BINARY REP. | | |
| * | | | * | |
| TTYOUT | LCI 253 | C=253 | ENTERA LHI 11 | H=11 |
| TTYO | CAL TTYD1 | DELAY - 9.012 MSEC. | LLI 240 | L=240 |
| | INC | C=C+1 | ENTERH CAL ADRESH | ENTER BANK NO. |
| | JFZ TTYO | | ENTERL CAL ADRESL | ENTER INITIAL ADDRESS |
| | XRA | | CAL AD1 | ENTER FINAL ADDRESS |
| | OUT 12B | TTY START PULSE | CAL CRLF | |
| | LCI 248 | REG C=248 | LLI 246 | L=246 |
| TTY1 | CAL TTYD1 | TTY DELAY - 9.012 MSEC. | CAL BCDBIN | FINAL ADRES-BINARY |
| | LAB | LOAD DATA TO AC | LCB | LOAD B TO C |
| | OUT 12B | OUTPUT DATA | DCL | L=L-1 |
| | RAR | STORE DATA IN CARRY | CAL BCDBIN | INITIAL ADRES-BINARY |
| | LBA | LOAD A TO B | DCL | L=L-1 |
| | LAI 0 | AC = 0 | LAM | AC=M |
| | RAR | RESTORE DATA BIT | SUI 48 | AC=AC-48 |
| | ADB | RESTORE DATA | ADI 8 | AC=AC+8 |
| | LBA | STORE | LLI 252 | L=252 |
| | INC | C=C+1 | LMA | STORE BANK NO IN M |
| | JFZ TTY1 | JUMP IF AC IS NOT ZERO | INL | L=L+1=253 |
| | CAL TTYD1 | TTY DELAY - 9.012 MSEC. | LMB | STORE INITIAL ADRES IN M |
| | LAI 1 | A=A+1 | INL | L=L+1=254 |
| | OUT 12B | SUPPRESS TTY | LMC | STORE FINAL ADRES IN M |
| | RET | | RET | |
| * | | | * | |
| *CARRIAGE RETURN & LINE FEED | | *SET ADDRESS TO 1101 RAM | | |
| * | | | * | |
| CRLF | LBI 215B | CARRIAGE RETURN - CR | SETMA LHI 11 | H=11 |
| | CAL TTYOUT | TYPE CR | LLI 252 | L=252 |
| LF | LBI 212B | LINE FEED - LF | LDM | BANK NO TO D |
| | CAL TTYOUT | TYPE LF | INL | L=L+1=253 |
| | RET | | LAM | INIT ADR TO E |
| * | | | OUT 10B | WRITE ADDRESS TO OUT 0 |
| *ERROR SIGNAL | | | LLA | LOAD AC TO L |
| * | | | LHD | D TO H = BANK NO |
| ERROR | LBI 277B | (?) | RET | |
| | CAL TTYOUT | TYPE (?) | | |
| | RET | | | |
| * | | | | |
| *TYPE B AND IDENTIFY RAM BANK | | *ADDRESS CHECKING | | |
| * | | | * | |
| ADRESH | CAL CRLF | | ACHECK LHI 11 | H=11 |
| | LBI 302B | LOAD (B) | LLI 254 | L=254 |
| | CAL TTYOUT | TYPE (B) | LAM | LOAD FINAL ADRES. TO AC |
| | CAL TTY | CALL FOR TTY KB INPUT | DCL | L=L-1=253 |
| | LMB | STORE INPUT IN MEMORY | CPM | COMPARE:AF-AI |
| | RET | | JTZ CHECK | JUMP IF AF-AI=0 |
| * | | | LCM | LOAD AI TO AC |
| START | CAL CRLF | | INC | AI=A1+1 |
| | LBI 252B | B=252B | LMC | LOAD AI TO MEMORY |
| | CAL TTYOUT | TYPE (*) | CHECK RET | |
| | CAL TTY | CALL FOR TTY KB INPUT | * | |
| | LAI 124B | LOAD (T) TO AC | *PROGRAM BEGINS | |
| | CPB | AC-B | * | |
| | JTZ TAPEIN | JUMP IF AC-B=0 | LISTIN LHI 11 | H=11 |
| | LAI 105B | AC=105B, (E) | LLI 240 | L=240 |
| | CPB | AC-B | CAL ENTERL | ENTER INITIAL & FINAL ADR. |
| | JTZ EXECUT | JUMP IF AC-B=0 | LISTER CAL CRLF | |
| | LAI 122B | AC=122B, (R) | LLI 251 | L=251 |
| | CPB | AC-B | LAI 252 | NO. OF INSTR. PER LINE |
| | JTZ READIN | JUMP IF AC-B=0 | LMA | LOAD AC TO MEMORY |
| | LAI 103B | AC=103B, (C) | PRINTA | PRINT ADDRESS |
| | CPB | AC-B | LBI 240B | LOAD [SP] |
| | JTZ CONTIN | JUMP IF AC-B=0 | CAL TTYOUT | PRINT [SP] |
| | LAI 114B | AC=114B, (L) | LBI 302B | LOAD [B] |
| | CPB | AC-B | CAL TTYOUT | PRINT [B] |
| | JTZ LISTIN | JUMP IF AC-B=0 | LLI 253 | L=253 |
| | LAI 120B | AC=120B, (P) | LAM | LOAD AI TO AC |
| | CPB | AC-B | OUT 10B | OUTPUT AI TO OUT 0 |
| | JTZ PROGRM | JUMP IF AC-B=0 | LEI 248 | READ DELAY/DATA BIT CONTR |
| | CAL ERROR | TYPE (?) | INP 1B | READ INPUT FROM 1702 |
| | JMP START | | | |
| * | | | | |
| *LOAD DATA INPUT TO 1101 RAM | | LIST2 RAL | | |
| * | | | LLI 249 | L=249 |
| TAPEIN | CAL ENTERA | ENTER ADDRESS | LMA | SAVE INPUT DATA |
| READIN | CAL DATAIN | READ TAPE INPUT ROUTI | JTC PRINTP | PRINT [P] IF CARRY=1 |
| | RAR | CHECK FOR FE FLAG | LBI 316B | LOAD [N] |
| | JTC START | JUMP IF CARRY=1 | CAL TTYOUT | PRINT [N] |
| | | | JMP LIST3 | |
| | | | PRINTP LBI 320B | LOAD [P] |
| | | | CAL TTYOUT | PRINT [P] |
| | | | LIST3 LAM | LOAD DATA TO AC |
| | | | INE | E=E+1 |
| | | | JFZ LIST2 | JUMP IF E IS NOT 0 |
| | | | LBI 306B | LOAD [F] |
| | | | CAL TTYOUT | PRINT [F] |

| | | | |
|-----------------------|---------------------|-------------------|----------------------------|
| LLI 250 | L=250 | LBI 240B | LOAD [SP] |
| LCM | LOAD MEMORY TO C | CAL TTYOUT | PRINT [SP] |
| CAL SETMA | SET MEMORY ADDRESS | CAL ACHECK | AF - AI |
| LAC | | JTZ START | |
| OUT 11B | | LLI 251 | LOAD LINE CONTR. TO AC |
| LMA | LOAD DATA TO MEMORY | LCM | LOAD MEMORY TO C |
| CAL ACHECK | COMPARE AF AND AI | INC | C=C+1 |
| JTZ START | JUMP IF A=0 | LMC | |
| JMP READIN | READ INPUT DATA | JTZ LISTER | JUMP IF LINE CONTR.=4 |
| EXECUT LHI 11 | H=11 | JMP LIST1 | |
| LLI 240 | L=240 | * | |
| BANK0 EQU 4000B | BANK 0 LOCATION | *PROM PROGRAMMER | |
| BANK1 EQU 4400B | BANK 1 LOCATION | * | |
| BANK2 EQU 5000B | BANK 2 LOCATION | PROGRAM CAL ENTRA | ENTER MEMORY ADDRESS |
| BANK3 EQU 5400B | BANK 3 LOCATION | PG1 LLI 255 | REPROGRAM CONTR. |
| CAL ADRESH | ENTER BANK NO | LAI 253 | AC=253 |
| CAL CRLF | | LMA | LOAD AC TO MEMORY |
| LAM | LOAD MEMORY TO AC | CAL LISTA | PRINT ADDRESS |
| SUI 48 | AC=AC-48 | PG2 CAL SETMA | SET ADDRESS TO 1702 |
| ADI 8 | AC=AC+8 | LAI 255 | COMPLEMENT INPUT DATA |
| LHA | LOAD AC TO H | XRM | LOAD DATA TO AC |
| LAI 8 | AC=8 | OUT 11B | WRITE DATA TO OUT 1 |
| CPH | AC=AC-H | LAI 2 | AC=2, DELAY |
| JTZ BANK0 | JUMP, IF AC=0 | OUT 13B | PROGRAM PULSE ENABLE |
| LAI 9 | | LCI 254 | DELAY = 5 SEC. |
| CPH | | PG3 LEI 0 | E=0 |
| JTZ BANK1 | | PG4 CAL TTYD1 | DELAY - 8.7 MSEC. |
| LAI 10 | | INE | E=E+1 |
| CPH | | JFZ PG4 | JUMP IF E IS NOT 0 |
| JTZ BANK2 | | INC | C=C+1 |
| LAI 11 | | JFZ PG3 | JUMP IF D IS NOT 0 |
| CPH | | LAI 0 | AC=0 |
| JTZ BANK3 | | OUT 13B | DISABLE PROGRAM PULSE |
| CAL ERROR | | INP 1B | READ DATA FROM 1702 |
| JMP START | | CPM | COMPARE DATA |
| CONTIN LHI 11 | | JTZ PC5 | JUMP IF COMPARED |
| LLI 252 | | LBI 244B | LOAD [\$] |
| LDM | | CAL TTYOUT | PRINT[\$] |
| IND | D=D+1 | LHI 11 | |
| LMD | BANK=BANK+1 | LLI 255 | |
| INL | L=L+1 | LBM | |
| XRA | CLEAR AC | INB | |
| LMA | INITIAL ADRES=0 | LMB | LOAD B TO MEMORY |
| INL | | JFZ PG2 | |
| LAI 255 | | CAL ERROR | |
| LMA | FINAL ADRES=255 | JMP START | PRINT [?] |
| JMP READIN | | PG5 CAL ACHECK | |
| * | | JTZ START | CONTINUE PROG. NEXT INSTR. |
| *PROM LISTING ROUTINE | | JMP PG1 | |
| * | | END | |

APPENDIX I
FUNCTIONAL DEFINITION

| Symbols | Meaning | | |
|--------------|--------------------------------|---|--------------------------|
| <B2> | Second byte of the instruction | | |
| <B3> | Third byte of the instruction | | |
| r | | One of the scratch pad register references: A, B, C, D, E, H, L | |
| c | | One of the following flag flip-flop references: C, Z, S, P | |
| $C_4 C_3$ | Flag flip-flop codes | | Condition for True |
| | 00 | carry | Overflow, underflow |
| | 01 | zero | Result is zero |
| | 10 | sign | MSB of result is "1" |
| | 11 | parity | Parity of result is even |
| M | | Memory location indicated by the contents of registers H and L | |
| () | | Contents of location or register | |
| \wedge | | Logical product | |
| \vee | | Exclusive "or" | |
| \vee | | Inclusive "or" | |
| A_m | | Bit m of the A-register | |
| STACK | | Instruction counter (P) pushdown register | |
| P | | Program Counter | |
| \leftarrow | | Is transferred to | |
| XXX | | A "don't care" | |
| SSS | | Source register for data | |
| DDD | | Destination register for data | |
| | Register # | Register Name | |
| | (SSS or DDD) | | |
| | 000 | A | |
| | 001 | B | |
| | 010 | C | |
| | 011 | D | |
| | 100 | E | |
| | 101 | H | |
| | 110 | L | |

INDEX REGISTER INSTRUCTIONS

LOAD DATA TO INDEX REGISTERS – One Byte

Data may be loaded into or moved between any of the index registers, or memory registers.

| | | |
|---|------------|---|
| Lr₁r₂ (one cycle – PCI) | 11 DDD SSS | $(r_1) \leftarrow (r_2)$ Load register r_1 with the content of r_2 . The content of r_2 remains unchanged. If SSS=DDD, the instruction is a NOP (no operation). |
| LrM (two cycles – PCI/PCR) | 11 DDD 111 | $(r) \leftarrow (M)$ Load register r with the content of the memory location addressed by the contents of registers H and L. (DDD≠111 – HALT instr.) |
| LMr (two cycles – PCI/PCW) | 11 111 SSS | $(M) \leftarrow (r)$ Load the memory location addressed by the contents of registers H and L with the content of register r . (SSS≠111 – HALT instr.) |

LOAD DATA IMMEDIATE – Two Bytes

A byte of data immediately following the instruction may be loaded into the processor or into the memory

| | | |
|--|-------------------------------------|--|
| Lrl (two cycles – PCI/PCR) | 00 DDD 110 $\langle B_2 \rangle$ | $(r) \leftarrow \langle B_2 \rangle$ Load byte two of the instruction into register r . |
| LMI (three cycles – PCI/PCR/PCW) | 00 111 110 $\langle B_2 \rangle$ | $(M) \leftarrow \langle B_2 \rangle$ Load byte two of the instruction into the memory location addressed by the contents of registers H and L. |

INCREMENT INDEX REGISTER – One Byte

| | | |
|---------------------------------|------------|--|
| INr (one cycle – PCI) | 00 DDD 000 | $(r) \leftarrow (r)+1$. The content of register r is incremented by one. All of the condition flip-flops except carry are affected by the result. Note that DDD≠000 (HALT instr.) and DDD≠111 (content of memory may not be incremented). |
|---------------------------------|------------|--|

DECREMENT INDEX REGISTER – One Byte

| | | |
|---------------------------------|------------|--|
| DCr (one cycle – PCI) | 00 DDD 001 | $(r) \leftarrow (r)-1$. The content of register r is decremented by one. All of the condition flip-flops except carry are affected by the result. Note that DDD≠000 (HALT instr.) and DDD≠111 (content of memory may not be decremented). |
|---------------------------------|------------|--|

ACCUMULATOR GROUP INSTRUCTIONS

Operations are performed and the status flip-flops, C, Z, S, P, are set based on the result of the operation. Logical operations (NDr, XNr, ORr) set the carry flip-flop to zero. Rotate operations affect only the carry flip-flop. Two's complement subtraction is used.

ALU INDEX REGISTER INSTRUCTIONS – One Byte

(one cycle – PCI)

Index Register operations are carried out between the accumulator and the content of one of the index registers (SSS=000 thru SSS=110). The previous content of register SSS is unchanged by the operation.

| | | |
|------------|------------|---|
| ADr | 10 000 SSS | $(A) \leftarrow (A)+(r)$ Add the content of register r to the content of register A and place the result into register A. |
| ACr | 10 001 SSS | $(A) \leftarrow (A)+(r)+(carry)$ Add the content of register r and the contents of the carry flip-flop to the content of the A register and place the result into Register A. |
| SUr | 10 010 SSS | $(A) \leftarrow (A)-(r)$ Subtract the content of register r from the content of register A and place the result into register A. Two's complement subtraction is used. |

ACCUMULATOR GROUP INSTRUCTIONS - Cont'd.

| | | | |
|-----|--------|-----|--|
| SBr | 10 011 | SSS | $(A) \leftarrow (A) - (r) - (\text{borrow})$ Subtract the content of register r and the content of the carry flip-flop from the content of register A and place the result into register A. |
| NDr | 10 100 | SSS | $(A) \leftarrow (A) \wedge (r)$ Place the logical product of the register A and register r into register A. |
| XRr | 10 101 | SSS | $(A) \leftarrow (A) \vee (r)$ Place the "exclusive - or" of the content of register A and register r into register A. |
| ORr | 10 110 | SSS | $(A) \leftarrow (A) V (r)$ Place the "inclusive - or" of the content of register A and register r into register A. |
| CPr | 10 111 | SSS | $(A) - (r)$ Compare the content of register A with the content of register r. The content of register A remains unchanged. The flag flip-flops are set by the result of the subtraction. Equality or inequality is indicated by the zero flip-flop. Less than or greater than is indicated by the carry flip-flop. |

ALU OPERATIONS WITH MEMORY – One Byte (two cycles – PCI/PCR)

Arithmetic and logical operations are carried out between the accumulator and the byte of data addressed by the contents of registers H and L.

| | | | |
|-----|--------|-----|---|
| ADM | 10 000 | 111 | $(A) \leftarrow (A) + (M)$ ADD |
| ACM | 10 001 | 111 | $(A) \leftarrow (A) + (M) + (\text{carry})$ ADD with carry |
| SUM | 10 010 | 111 | $(A) \leftarrow (A) - (M)$ SUBTRACT |
| SBM | 10 011 | 111 | $(A) \leftarrow (A) - (M) - (\text{borrow})$ SUBTRACT with borrow |
| NDM | 10 100 | 111 | $(A) \leftarrow (A) \wedge (M)$ Logical AND |
| XRM | 10 101 | 111 | $(A) \leftarrow (A) \vee (M)$ Exclusive OR |
| ORM | 10 110 | 111 | $(A) \leftarrow (A) V (M)$ Inclusive OR |
| CPM | 10 111 | 111 | $(A) - (M)$ COMPARE |

ALU IMMEDIATE INSTRUCTIONS – Two Bytes

(two cycles –PCI/PCR)

Arithmetic and logical operations are carried out between the accumulator and the byte of data immediately following the instruction.

| | | | |
|-----|--------|------------------|--|
| ADI | 00 000 | 100 $< B_2 >$ | $(A) \leftarrow (A) + < B_2 >$ ADD |
| ACI | 00 001 | 100 $< B_2 >$ | $(A) \leftarrow (A) + < B_2 > + (\text{carry})$ ADD with carry |
| SUI | 00 010 | 100 $< B_2 >$ | $(A) \leftarrow (A) - < B_2 >$ SUBTRACT |
| SBI | 00 011 | 100 $< B_2 >$ | $(A) \leftarrow (A) - < B_2 > - (\text{borrow})$ SUBTRACT with borrow |
| NDI | 00 100 | 100 $< B_2 >$ | $(A) \leftarrow (A) \wedge < B_2 >$ Logical AND |
| XRI | 00 101 | 100 $< B_2 >$ | $(A) \leftarrow (A) \vee < B_2 >$ Exclusive OR |
| ORI | 00 110 | 100 $< B_2 >$ | $(A) \leftarrow (A) V < B_2 >$ Inclusive OR |
| CPI | 00 111 | 100 $< B_2 >$ | $(A) - < B_2 >$ COMPARE |

ROTATE INSTRUCTIONS – One Byte

(one cycle – PCI)

The accumulator content (register A) may be rotated either right or left, around the carry bit or through the carry bit. Only the carry flip-flop is affected by these instructions; the other flags are unchanged.

| | | | | |
|------------|----|-----|-----|---|
| RLC | 00 | 000 | 010 | $A_{m+1} \leftarrow A_m, A_0 \leftarrow A_7, (\text{carry}) \leftarrow A_7$ Rotate the content of register A left one bit. Rotate A_7 into A_0 and into the carry flip-flop. |
| RRC | 00 | 001 | 010 | $A_m \leftarrow A_{m+1}, A_7 \leftarrow A_0, (\text{carry}) \leftarrow A_0$ Rotate the content of register A right one bit. Rotate A_0 into A_7 and into the carry flip-flop. |
| RAL | 00 | 010 | 010 | $A_{m+1} \leftarrow A_m, A_0 \leftarrow (\text{carry}), (\text{carry}) \leftarrow A_7$ Rotate the content of Register A left one bit. Rotate the content of the carry flip-flop into A_0 . Rotate A_7 into the carry flip-flop. |
| RAR | 00 | 011 | 010 | $A_m \leftarrow A_{m+1}, A_7 \leftarrow (\text{carry}), (\text{carry}) \leftarrow A_0$ Rotate the content of register A right one bit. Rotate the content of the carry flip-flop into A_7 . Rotate A_0 into the carry flip-flop. |

PROGRAM COUNTER AND STACK CONTROL INSTRUCTIONS

JUMP INSTRUCTIONS – Three Bytes

(three cycles – PCI/PCR/PCR)

Normal flow of the microprogram may be altered by jumping to an address specified by bytes two and three of an instruction.

| | | | | |
|---|----|-----------|---------------------------|--|
| JMP (Jump Unconditionally) | 01 | XXX | 100 $<B_2>$ $<B_3>$ | $(P) \leftarrow <B_3><B_2>$ Jump unconditionally to the instruction located in memory location addressed by byte two and byte three. |
| JFc (Jump if Condition False) | 01 | $0C_4C_3$ | 000 $<B_2>$ $<B_3>$ | If $(c) = 0$, $(P) \leftarrow <B_3><B_2>$. Otherwise, $(P) = (P)+3$. If the content of flip-flop c is zero, then jump to the instruction located in memory location $<B_3><B_2>$; otherwise, execute the next instruction in sequence. |
| JTc (Jump if Condition True) | 01 | $1C_4C_3$ | 000 $<B_2>$ $<B_3>$ | If $(c) = 1$, $(P) \leftarrow <B_3><B_2>$. Otherwise, $(P) = (P)+3$. If the content of flip-flop c is one, then jump to the instruction located in memory location $<B_3><B_2>$; otherwise, execute the next instruction in sequence. |

CALL INSTRUCTIONS – Three Bytes

(three cycles – PCI/PCR/PCR)

Subroutines may be called and nested up to seven levels.

| | | | | |
|--|----|-----------|---------------------------|---|
| CAL (Call subroutine Unconditionally) | 01 | XXX | 110 $<B_2>$ $<B_3>$ | $(\text{Stack}) \leftarrow (P), (P) \leftarrow <B_3><B_2>$. Shift the content of P to the pushdown stack. Jump unconditionally to the instruction located in memory location addressed by byte two and byte three. |
| CFc (Call subroutine if Condition False) | 01 | $0C_4C_3$ | 010 $<B_2>$ $<B_3>$ | If $(c) = 0$, $(\text{Stack}) \leftarrow (P), (P) \leftarrow <B_3><B_2>$. Otherwise, $(P) = (P)+3$. If the content of flip-flop c is zero, then shift contents of P to the pushdown stack and jump to the instruction located in memory location $<B_3><B_2>$; otherwise, execute the next instruction in sequence. |
| CTc (Call subroutine if Condition True) | 01 | $1C_4C_3$ | 010 $<B_2>$ $<B_3>$ | If $(c) = 1$, $(\text{Stack}) \leftarrow (P), (P) \leftarrow <B_3><B_2>$. Otherwise, $(P) = (P)+3$. If the content of flip-flop c is one, then shift contents of P to the pushdown stack and jump to the instruction located in memory location $<B_3><B_2>$; otherwise, execute the next instruction in sequence. |

In the above JUMP and CALL instructions $<B_2>$ contains the least significant half of the address and $<B_3>$ contains the most significant half of the address. Note that D_6 and D_7 of $<B_3>$ are "don't care" bits since the CPU uses fourteen bits of address.

RETURN INSTRUCTIONS – One Byte (one cycle – PCI)

| | | | |
|---|----|------------------------------------|---|
| A return instruction may be used to exit from a subroutine; the stack is popped-up one level at a time. | | | |
| RET | 00 | XXX 111 | (P) \leftarrow (Stack). Return to the instruction in the memory location addressed by the last value shifted into the pushdown stack. The stack pops up one level. |
| RFc (Return Condition False) | 00 | 0C ₄ C ₃ 011 | If (c) = 0, (P) \leftarrow (Stack); otherwise, (P) = (P)+1. If the content of flip-flop c is zero, then return to the instruction in the memory location addressed by the last value inserted in the pushdown stack. The stack pops up one level. Otherwise, execute the next instruction in sequence. |
| RTc (Return Condition True) | 00 | 1C ₄ C ₃ 011 | If (c) = 1, (P) \leftarrow (Stack); otherwise, (P) = (P)+1. If the content of flip-flop c is one, then return to the instruction in the memory location addressed by the last value inserted in the pushdown stack. The stack pops up one level. Otherwise, execute the next instruction in sequence. |

RESTART INSTRUCTION – One Byte (one cycle – PCI)

The restart instruction acts as a one byte call on eight specified locations of page 0, the first 256 instruction words.

| | | | |
|--|--|--|--|
| INPUT/OUTPUT INSTRUCTIONS | | | |
| One Byte (two cycles – PCI/PCC) | | | |
| Eight input devices may be referenced by the input instruction | | | |

| | | | |
|--|----|---------|--|
| MACHINE INSTRUCTION | | | |
| HALT INSTRUCTION – One Byte (one cycle – PCI) | | | |
| OUT | 01 | RRM MM1 | (Output data lines) \leftarrow (A). The content of register A is made available to external equipment at state T1 and the content of the instruction register is made available to external equipment at state T2 of the PCC cycle. RRM MM1 denotes output device number (RR \neq 00). |

Twenty-four output devices may be referenced by the output instruction.

| | | | |
|--|----|-----------------------------|---|
| MACHINE INSTRUCTION | | | |
| HALT INSTRUCTION – One Byte (one cycle – PCI) | | | |
| HLT | 00 | 000 00X or 11 111 111 | On receipt of the Halt Instruction, the activity of the processor is immediately suspended in the STOPPED state. The content of all registers and memory is unchanged. The P-counter has been updated and the internal dynamic memories continue to be refreshed. |

APPENDIX II

INTERNAL PROCESSOR OPERATION

Internally the processor operates through five different states:

| | Internal State | Typical Function |
|-----------|---------------------------|--|
| T1 | NORMAL INTERRUPT | Send out lower eight bits of address and increment program counter. |
| T2 | | Send out lower eight bits of address and suppress incrementing of program counter. |
| T3 | WAIT NORMAL STOPPED | Send out six higher order bits of address and two control bits, D_6 and D_7 . Increment program counter if there has been a carry from T1. Wait for READY signal to come true. Refresh internal dynamic memories while waiting. Fetch and decode instruction; fetch data from memory; output data to memory. Refresh internal memories. |
| T4 and T5 | | Remain stopped until INTERRUPT occurs. Refresh internal memories. Execute instruction and appropriately transfer data within processor. Content of data bus transfer is available at I/O bus for convenience in testing. Some cycles do not require these states. In those cases, the states are skipped and the processor goes directly to T1. |

The 8008 is driven by two non-overlapping clocks. Two clock periods are required for each state of the processor. A SYNC signal (divide by two of ϕ_2) is sent out by the 8008. This signal distinguishes between the two clock periods of each state.

The following timing diagram shows the typical activity during each state. Note that ϕ_1 is generally used to precharge all data lines and memories and ϕ_2 controls all data transfers within the processor.

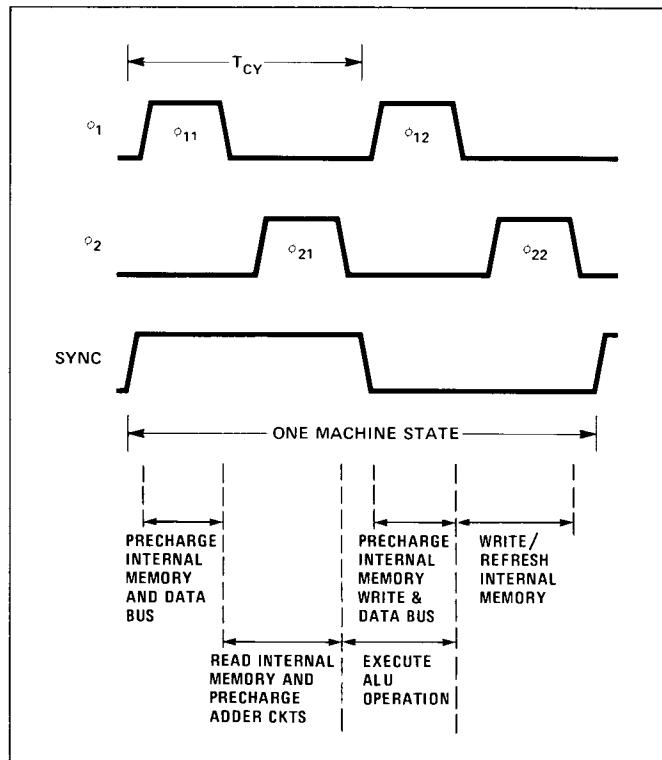


Figure 19. Internal Timing Activity Within Any State

INTERNAL PROCESSOR OPERATION

INDEX REGISTER INSTRUCTIONS

| INSTRUCTION CODING D ₇ D ₆ D ₅ D ₄ D ₃ D ₂ D ₁ D ₀ | OPERATION | #OF STATES TO EXECUTE INSTRUCTION | MEMORY CYCLE ONE (1) | | | | |
|---|-----------|---|----------------------------|---------------------|-----------------------------------|----------------------|----------------------------|
| | | | T1(2) | T2 | T3 | T4(3) | T5 |
| 1 1 D D D S S S | Lr1r2 | (5) | PC _L OUT (4) | PC _H OUT | FETCH INSTR.(5) TO IR & REG. b | SSS TO REG. b (6) | REG. b TO DDD |
| 1 1 D D D 1 1 1 | LrM | (8) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | | → (7) |
| 1 1 1 1 1 S S S | LMr | (7) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | SSS TO REG. b | → |
| 0 0 D D D 1 1 0 | LrI | (8) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | | → |
| 0 0 1 1 1 1 1 0 | LMI | (9) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | | → |
| 0 0 D D D 0 0 0 | INr | (5) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | X | ADD OP - FLAGS AFFECTED |
| 0 0 D D D 0 0 1 | DCr | (5) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | X | SUB OP - FLAGS AFFECTED |

ACCUMULATOR GROUP INSTRUCTIONS

| | | | | | | | |
|-----------------|----------|-----|---------------------|---------------------|--------------------------------|---------------|---------------------------------|
| 1 0 P P P S S S | ALU OP r | (5) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | SSS TO REG. b | ALU OP - FLAGS AFFECTED |
| 1 0 P P P 1 1 1 | ALU OP M | (8) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | | → |
| 0 0 P P P 1 0 0 | ALU OP I | (8) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | | → |
| 0 0 0 0 0 0 1 0 | RLC | (5) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | X | ROTATE REG. A CARRY AFFECTED |
| 0 0 0 0 1 0 1 0 | RRC | (5) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | X | ROTATE REG. A CARRY AFFECTED |
| 0 0 0 1 0 0 1 0 | RAL | (5) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | X | ROTATE REG. A CARRY AFFECTED |
| 0 0 0 1 1 0 1 0 | RAR | (5) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | X | ROTATE REG. A CARRY AFFECTED |

PROGRAM COUNTER AND STACK CONTROL INSTRUCTIONS

| | | | | | | | |
|-----------------|-----|-----------|---------------------|---------------------|---|-----------------------------------|---|
| 0 1 X X X 1 0 0 | JMP | (11) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | | → |
| 0 1 U C C 0 0 0 | JFc | (9 or 11) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | | → |
| 0 1 1 C C 0 0 0 | JTc | (9 or 11) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | | → |
| 0 1 X X X 1 1 0 | CAL | (11) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | | → |
| 0 1 0 C C 0 1 0 | CFc | (9 or 11) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | | → |
| 0 1 1 C C 0 1 0 | CTc | (9 or 11) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | | → |
| 0 0 X X X 1 1 1 | RET | (5) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | POP STACK | X |
| 0 0 0 C C 0 1 1 | RFc | (3 or 5) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | POP STACK (13) | X |
| 0 0 1 C C 0 1 1 | RTc | (3 or 5) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | POP STACK (13) | X |
| 0 0 A A A 1 0 1 | RST | (5) | PC _L OUT | PC _H OUT | FETCH INSTR. TO REG. b AND PUSH STACK (0 → REG. a) | REG. a TO PC _L (14) | |

I/O INSTRUCTIONS

| | | | | | | | |
|-----------------|-----|-----|---------------------|---------------------|--------------------------------|--|---|
| 0 1 0 0 M M M 1 | INP | (8) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | | → |
| 0 1 R R M M M 1 | OUT | (6) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b | | → |

MACHINE INSTRUCTIONS

| | | | | | | | |
|-----------------|-----|-----|---------------------|---------------------|---|--|--|
| 0 0 0 0 0 0 0 X | HLT | (4) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b & HALT (18) | | |
| 1 1 1 1 1 1 1 1 | HLT | (4) | PC _L OUT | PC _H OUT | FETCH INSTR. TO IR & REG. b & HALT (18) | | |

NOTES:

- The first memory cycle is always a PCI (instruction) cycle.
- Internally, states are defined as T1 through T5. In some cases more than one memory cycle is required to execute an instruction.
- Content of the internal data bus at T4 and T5 is available at the data bus. This is designed for testing purposes only.
- Lower order address bits in the program counter are denoted by PC_L and higher order bits are designated by PC_H.
- During an instruction fetch the instruction comes from memory to the instruction register and is decoded.
- Temporary registers are used internally for arithmetic operations and data transfers (Register a and Register b.)
- These states are skipped.
- PCR cycle (Memory Read Cycle).
- "X" denotes an idle state.
- PCW cycle (Memory Write Cycle).
- When the JUMP is conditional and the condition fails, states T4 and T5 are skipped and the state counter advances to the next memory cycle.

| MEMORY CYCLE TWO | | | | | MEMORY CYCLE THREE | | | | |
|-------------------------|---------------------|----------------|-------|---------------|--------------------|------------|---------------|----|----|
| T1 | T2 | T3 | T4 | T5 | T1 | T2 | T3 | T4 | T5 |
| REG. L OUT (8) | REG. H OUT | DATA TO REG. b | X (9) | REG. b TO DDD | | | | | |
| REG. L OUT (10) | REG. H OUT | REG. b TO OUT | | | | | | | |
| PC _L OUT (8) | PC _H OUT | DATA TO REG. b | X | REG. b TO DDD | | | | | |
| PC _L OUT (8) | PC _H OUT | DATA TO REG. b | | → | REG. L OUT(10) | REG. H OUT | REG. b TO OUT | | |
| | | | | | | | | | |
| | | | | | | | | | |

| | | | | | | | | | |
|-------------------------|---------------------|----------------|---|------------------------------|--|--|--|--|--|
| REG. L OUT (8) | REG. H OUT | DATA TO REG. b | X | ALU OP - FLAGS AFFECTED | | | | | |
| PC _L OUT (8) | PC _H OUT | DATA TO REG. b | X | ARITH OP - FLAGS AFFECTED | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

| | | | | | | | | |
|-------------------------|---------------------|-------------------------|---|------------------------|---------------------|----------------------------|------------------------------|------------------------------|
| PC _L OUT (8) | PC _H OUT | LOWER ADD. TO REG. b | → | PC _L OUT(8) | PC _H OUT | HIGHER ADD. REG. a | REG. a TO PC _H | REG. b TO PC _L |
| PC _L OUT (8) | PC _H OUT | LOWER ADD. TO REG. b | → | PC _L OUT(8) | PC _H OUT | HIGHER ADD. REG. a (11) | REG. a TO PC _H | REG. b TO PC _L |
| PC _L OUT (8) | PC _H OUT | LOWER ADD. TO REG. b | → | PC _L OUT(8) | PC _H OUT | HIGHER ADD. REG. a (11) | REG. a TO PC _H | REG. b TO PC _L |
| PC _L OUT (8) | PC _H OUT | LOWER ADD. TO REG. b | → | PC _L OUT(8) | PC _H OUT | HIGHER ADD. REG. a | REG. a TO PC _H | REG. b TO PC _L |
| PC _L OUT (8) | PC _H OUT | LOWER ADD. TO REG. b | → | PC _L OUT(8) | PC _H OUT | HIGHER ADD. REG. a (12) | REG. a TO PC _H | REG. b TO PC _L |
| PC _L OUT (8) | PC _H OUT | LOWER ADD. TO REG. b | → | PC _L OUT(8) | PC _H OUT | HIGHER ADD. REG. a (12) | REG. a TO PC _H | REG. b TO PC _L |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

| | | | | | | | | | |
|--------------------|---------------|----------------|-----------------|------------------|--|--|--|--|--|
| REG. A TO OUT (15) | REG. b TO OUT | DATA TO REG. b | COND ff OUT(16) | REG. b TO REG. A | | | | | |
| REG. A (15) TO OUT | REG. b TO OUT | X (17) | | | | | | | |

| | | | | | | | | | |
|--|--|--|--|--|--|--|--|--|--|
| | | | | | | | | | |
| | | | | | | | | | |

12. When the CALL is conditional and the condition fails, states T4 and T5 are skipped and the state counter advances to the next memory cycle. If the condition is true, the stack is pushed at T4, and the lower and higher order address bytes are loaded into the program counter.
13. When the RETURN condition is true, pop up the stack; otherwise, advance to next memory cycle skipping T4 and T5.
14. Bits D₃ through D₅ are loaded into PC_L and all other bits are set to zero; zeros are loaded into PC_H.
15. PCC cycle (I/O Cycle).
16. The content of the condition flip-flops is available at the data bus: S at D₀, Z at D₁, P at D₂, C at D₃.
17. A READY command must be supplied for the OUT operation to be completed. An idle T3 state is used and then the state counter advances to the next memory cycle.
18. When a HALT command occurs, the CPU internally remains in the T3 state until an INTERRUPT is recognized. Externally, the STOPPED state is indicated.

The figure below shows state transitions relative to the internal operation of the processor. As noted in the previous table, the processor skips unnecessary execution steps during any cycle. The state counter within the 8008 operates is a five bit feedback shift register with the feedback path controlled by the instruction being executed. When the processor is either waiting or stopped, it is internally cycling through the T3 state. This state is the only time in the cycle when the internal dynamic memories can be refreshed.

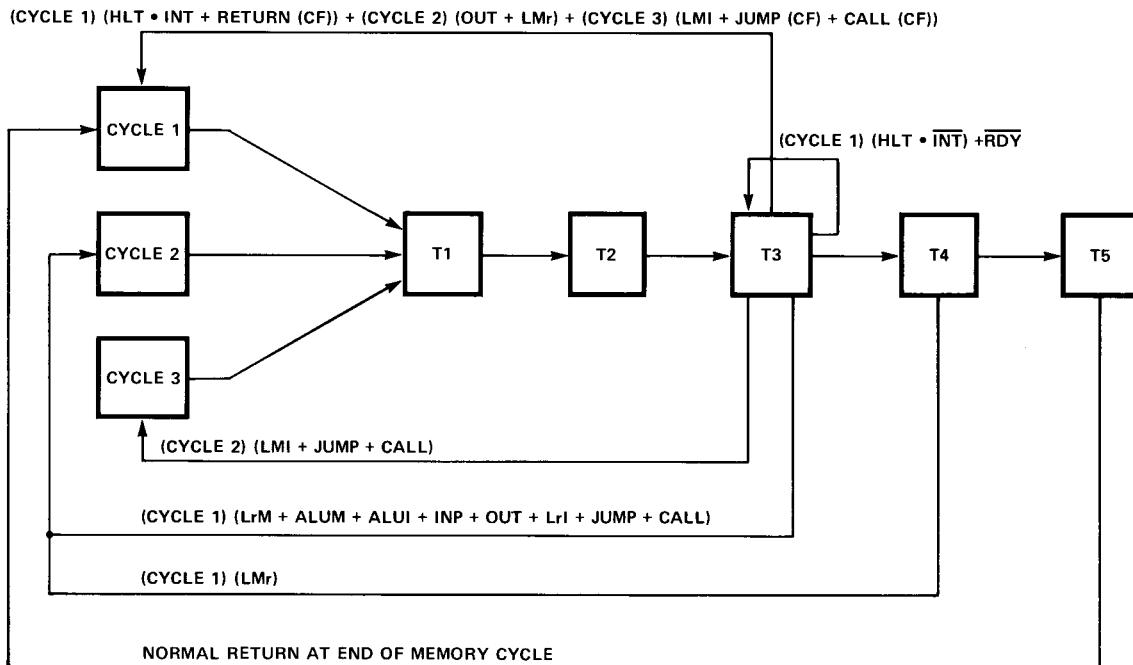


Figure 20. Transition State Diagram (Internal)

APPENDIX III

PROGRAMMING EXAMPLES

A. Sample Program to Search A String Of Characters In Memory Locations 200-219 For A Period (.)

| MNEMONIC | OPERAND | EXPLANATION | BYTES | LOCATION | ROM CODE | COMMENT |
|------------|---------|-------------------------------|-------|-------------------|----------------------------------|---------------|
| Start: LLI | 200 | Load L with 200 | 2 | 100 101 | 00110110 11001000 | (200) |
| LHI | 0 | Load H with 0 | 2 | 102 103 | 00101110 00000000 | (0) |
| Loop: LAM | | Fetch Character from Memory | 1 | 104 | 11000111 | ASC II |
| CPI | "." | Compare it with period | 2 | 105 106 | 00111100 00101110 | ASC II (.) |
| JTZ | Found | If equal go to return | 3 | 107 108 109 | 01101000 01110111 00000000 | (119) |
| CAL | INCR | Call increment H&L subroutine | 3 | 110 111 112 | 01000110 00111100 00000000 | (60) |
| LAL | | Load L to A | 1 | 113 | 11000110 | |
| CPI | 220 | Compare it with 220 | 2 | 114 115 | 00111100 11011100 | (220) |
| JFZ | Loop | If unequal go to loop | 3 | 116 117 118 | 01001000 01101000 00000000 | (104) |
| Found: RET | | Return | 1 | 119 | 00000111 | |
| INCR: INL | | Increment L | 1 | 60 | 00110000 | |
| RFZ | | Return if not zero | 1 | 61 | 00001011 | |
| INH | | Increment H | 1 | 62 | 00101000 | |
| RET | | Return | 1 | 63 | 00000111 | |

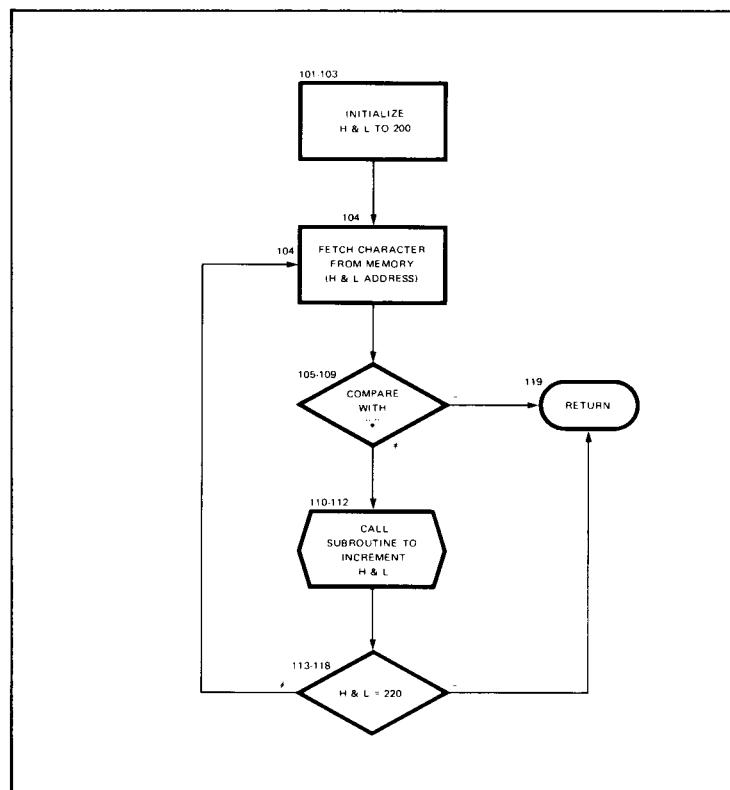


Figure 21. Subroutine to Search For Period

B. Teletype and Tape Reader Control Program (A0800)

| | | |
|-------|-----------|--------------------------------|
| BEGIN | LAI 1 | SUPPRESS TTY |
| | OUT 12B | OUTPUT 2 |
| | XRA | CLEAR AC |
| | OUT 13B | OUTPUT 3 - TAPE READER CONTROL |
| | CAL TAPE | CALL FOR TAPE READER CONT. RT. |
| | JMP BEGIN | |
| TAPE | LAI 1 | TAPE READER ENABLE CODE |
| | OUT 13B | OUTPUT 3 - ENABLE TAPE READER |
| | CAL TTYD1 | TAPE READER CONTROL DELAY |
| TTY | HLT | WAIT FOR TTY START PULSE |
| | CAL TTYD2 | TTY DELAY - 4.468 msec. |
| | XRA | TAPE READER DISABLE CODE |
| | OUT 13B | OUTPUT 3, DISABLE TAPE READER |
| | INP 0B | INPUT 0, READ START PULSE |
| | LCI 255 | COMPLEMENT TTY START PULSE |
| | XRC | EXCLUSIVE-OR REG. C |
| | OUT 12B | OUTPUT 2, OUTPUT START PULSE |
| | LEI 248 | TTY DATA SAMPLING COUNTER |
| TTYIN | CAL TTYD1 | TTY DELAY - 9.012 msec. |
| | INP 0B | READ TTY DATA INPUT |
| | LCI 255 | COMPLEMENT TTY DATA |
| | XRC | |
| | OUT 12B | OUTPUT 2, TTY DATA OUT |
| | RAR | STORE TTY DATA |
| | LAB | LOAD TTY DATA TO REC. B |
| | RAR | |
| | LBA | LOAD AC TO REG. B |
| | INE | E = E + 1 |
| | JFZ TTYIN | JUMP IF ZERO F/F IS NOT SET |
| | LAB | LOAD REG. B TO AC |
| | OUT 11B | OUTPUT 1, TTY CHARACTER |
| | SUI 128 | REMOVE PARITY BIT |
| | LBA | STORE TTY INPUT DATA |
| | CAL TTYD1 | |
| | LAI 1 | SUPPRESS TTY |
| | OUT 12B | |
| | RET | |
| TTYD1 | LDI 115 | 9.012 msec. DELAY |
| ST | IND | D = D + 1 |
| | JFZ ST | |
| | RET | |
| TTYD2 | LDI 186 | 4.468 msec. DELAY |
| ST2 | IND | D = D + 1 |
| | JFZ ST2 | |
| | RET | |
| | END | |

C. Memory Chip Select Decodes and Output Test Program (A0801)

```

BEGIN LAI 15           LOAD 15 TO AC
      OUT 10B
      OUT 11B
      OUT 12B
      OUT 13B
      OUT 14B
      OUT 15B
      OUT 16B
      OUT 17B
      CAL DELAY          DELAY 16.436 MSEC.
      CAL DELAY
      CAL DELAY
      CAL DELAY
      XRA                CLEAR AC
      OUT 10B
      OUT 11B
      OUT 12B
      OUT 13B
      OUT 14B
      OUT 15B
      OUT 16B
      OUT 17B
      LCI 240             LOAD 240 TO REG. C
      LLI 252B            LOAD 252B(OCTAL) TO REC. C
      LHI 0               LOAD 0 TO REC. H
CTEST  LAH              LOAD H TO AC
      OUT 10B
      LAL                LOAD L TO AC
      OUT 11B
      XRA                CLEAR AC
      LMA                WRITE AC TO MEMORY
      CAL DELAY
      CAL DELAY
      INH                H = H + 1
      INC                C = C + 1
      JFZ CTEST
      JMP BEGIN
DELAY   LDI 0             LOAD 0 TO REC. D
D1      IND               D = D + 1
      JFZ D1
      RET
      END

```

D. RAM Test Program (A0802)

```

BEGIN LAI 0           LOAD 0 TO AC
      OUT 10B          WRITE TO OUTPUT 0
      OUT 11B          WRITE TO OUTPUT 1
      OUT 12B          WRITE TO OUTPUT 2
      OUT 13B          WRITE TO OUTPUT 3
      LBI 8            LOAD 8 TO REC. B
      LCI 0            LOAD 0 TO REC. C
      LHI 8            LOAD 8 TO REC H
      LLI 0            LOAD 0 TO REC. L
      CLEAR AC
LM1   XRA
LM2   LMA
      INL
      CPL
      JFZ LM2          JUMP IF AC IS NOT ZERO
      INH
      LAI 12           H = H + 1
      CPH
      JFZ LM1          LOAD 12 TO AC
      LHI 8            AC-H
      REPT4 LAB         JUMP IF AC IS NOT ZERO
      OUT 10B           LOAD REC. B TO AC
      REPT3 LLC         LOAD REC. C TO L
      LAC
      OUT 13B           LOAD REC. C TO AC
      LAI 255
      LMA
      CPM
      JFZ ERROR        LOAD 255 TO AC
      REPT2 LAH         LOAD AC TO MEMORY
      OUT 10B           AC-M
      REPT5 XRA         JUMP IF AC IS NOT ZERO
      INL
      CPL
      JTZ REPT1        LOAD REC. H TO AC
      LAL
      OUT 11B           CLEAR AC
      XRA
      CPM
      JFZ ERROR        AC - L
      JMP REPT5        JUMP IF AC=0
      REPT1 INH         LOAD REC. L TO AC
      LAI 12
      CPH
      JTZ CONT
      XRA
      CPM
      JFZ ERROR
      JMP REPT2
CONT  LHB             CLEAR AC
      XRA
      INC
      CPC
      JFZ REPT3        AC-M
      INB
      LHB
      LAI 12
      CPB
      JFZ REPT4
      JMP BEGIN
ERROR LAI 240         JUMP IF AC IS NOT ZERO
      ADB
      OUT 10B           LOAD REC. P TO H
      LAL
      OUT 11B           C = C + 1
      LAM
      OUT 12B           AC - C
      LAC
      OUT 13B           B = B + 1
      HLT
      END              LOAD REC. P TO H
                           AC-B
                           LOAD 240 TO AC
                           AC=AC+B
                           LOAD REC. L TO AC
                           LOAD MEMORY TO AC
                           LOAD REC. C TO AC

```

APPENDIX IV

INTEL DEVICE SPECIFICATIONS

A. 1101A/1101A1 256-Bit Fully-Decoded Random Access Memory

- Access time below 750 ns typically, 1.0 μ sec maximum — 1101A1; 1.5 μ sec maximum — 1101A: over temperature
- Low power dissipation—typically less than 1.5 mW/bit during access
- Low power standby mode
- Directly DTL and TTL compatible
- OR-Tie capability
- Simple memory expansion—chip-select input lead
- Fully decoded—on-chip address decode and sense
- Inputs protected against static charge
- Ceramic and plastic package
- Silicon gate MOS technology

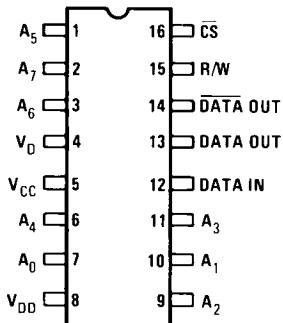
The Intel 1101A Series are 256 word by 1 bit random access memory elements using normally off P-channel MOS devices integrated on a monolithic array. Each unit uses fully dc stable (static) circuitry and therefore requires no clocks to operate.

The 1101A, an improved version of the 1101, requires only two power supplies (+5V and -9V) for operation, and is a direct pin-for-pin replacement for the 1101.

The 1101A Series is designed primarily for small buffer storage applications where high performance, low cost, and ease of interfacing with other standard logic circuits are important design objectives. The unit will directly interface with standard bipolar integrated logic circuits (TTL, DTL, etc.). The data output buffers are capable of driving TTL loads directly. A separate chip select (CS) lead allows easy selection of an individual package when outputs are OR-tied.

For applications requiring a faster access time we recommend the 1101A1 which is a selection from the 1101A and has a guaranteed maximum access time of 1.0 μ sec.

Applications. Scratch pad memories, buffer storage, data terminals, minicomputers, calculators, data multiplexers, automatic test equipment, sequential memories, table look up, program memories, buffers for line printers, card readers and pulse height analyzers.



D.C. Characteristics

($T_A = 0^\circ\text{C}$ to $+70^\circ\text{C}$, $V_{CC} = +5V \pm 5\%$, $V_0 = -9V \pm 5\%$, $V_{DD} = -9V \pm 5\%$ unless otherwise specified)

| Test | Min. | Typ. | Max. | Unit |
|---|--------------|----------------|------|------|
| Input load current (All Input Pins) | 1.0 | 500 | nA | |
| Power supply current, V_{DD} @ 25°C | 13 | 19 | mA | |
| Power supply current, V_0 @ 25°C | | 18 | mA | |
| Input "low" voltage | -10 | $V_{CC} - 4.5$ | V | |
| Input "high" voltage | $V_{CC} - 2$ | $V_{CC} + 0.3$ | V | |
| Output "low" voltage ($I_{OL} = 2$ mA) | | + .45 | V | |
| Output "high" voltage | | + 3.5 | V | |

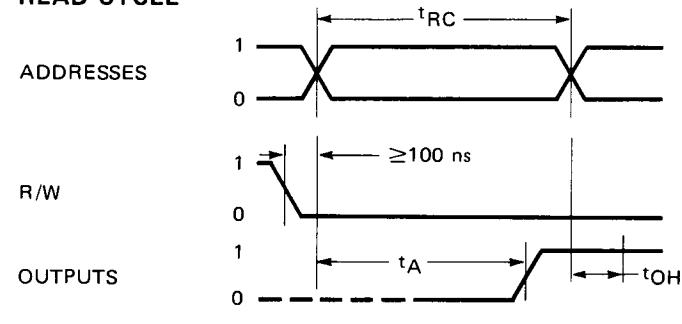
A.C. Characteristics

($T_A = 0$ to 70°C , $V_{CC} = +5V \pm 5\%$, $V_0 = -9V \pm 5\%$, $V_{DD} = -9 \pm 5\%$)

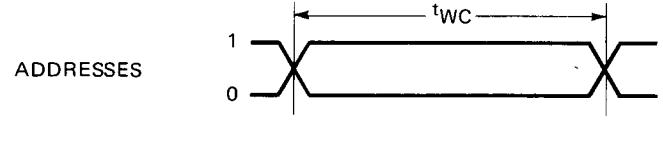
| Test | Min. | Typ. | Max. | Unit |
|---|------|------|-----------------|-----------------|
| Write cycle (t_{WC}) | 0.8 | | | μsec |
| Read cycle access time 1101A (t_A) | | 1.5 | μsec | |
| Access Time Through Chip Select Input (t_{CS}) | | 1.0 | μsec | |
| | | 0.3 | μsec | |

Timing diagram

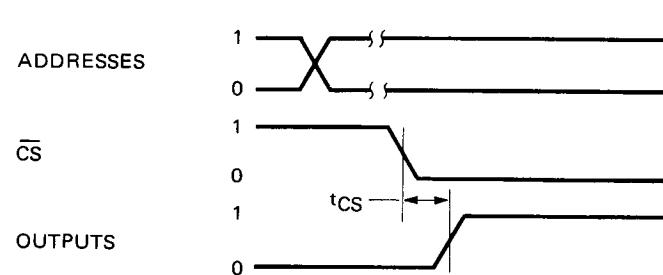
READ CYCLE



WRITE CYCLE



CHIP SELECT AND DESELECT



B. 1601/1701, 1602/1702 Electrically Programmable ROMs

The Intel 1601, 1602, 1701, and 1702 is a 256 word by 8 bit electrically programmable ROM ideally suited for uses where fast turnaround and pattern experimentation are important such as in prototype or in one of a kind systems. The 1601, 1602, 1701, and 1702 is factory reprogrammable which allows Intel to perform a complete programming and functional test on each bit position before delivery.

The four devices 1601, 1602, 1701, and 1702 use identical chips. The 1601 and 1701 is operable in both the static and dynamic mode while the 1602 and 1702 is operable in the static mode only. Also, the 1701 and 1702 has the unique feature of being completely erasable and field reprogrammable. This is accomplished by a quartz lid that allows high intensity ultraviolet light to erase the 1701 and 1702. A new pattern can then be written into the device. This procedure can be repeated as many times as required.

The 1301 is a direct replacement part which is programmed by a metal mask and is ideal for large volume and lower cost production runs of systems initially using the 1601/1701 or the static only 1602/1702.

The dynamic mode of the 1601/1701 and 1301 refers to the decoding circuitry and not to the memory cell. Dynamic operation offers higher speed and lower power dissipation than the static operation.

The 1601, 1602, 1701, and 1702 is fabricated with silicon gate technology. This low threshold technology allows the design and production of higher performance MOS circuits and provides a higher functional density on a monolithic chip than conventional MOS technologies.

D.C. Characteristics for static operation

($T_A = 0^\circ\text{C}$ to 70°C , $V_{CC} = +5V \pm 5\%$, $V_{DD} = -9V \pm 5\%$, $V_{GG} = -9V \pm 5\%$)

| Test | Min. | Max. | Unit |
|--|---------------|----------------|------|
| Standby power supply current @ 25°C | 10 | μA | |
| Power supply current @ 25°C under continuous operation | 46 | mA | |
| Input load current | 1 | μA | |
| Input "high" voltage | $V_{CC} - 2$ | $V_{CC} + .3$ | V |
| Input "low" voltage | $V_{CC} - 10$ | $V_{CC} - 4.2$ | V |
| Output "low" voltage @ $I_{OL} = 1.6 \text{ mA}$ | 0.45 | V | |
| Output "high" voltage @ $I_{OH} = -100 \mu\text{A}$ | 3.5 | V | |

A.C. Characteristics for static operation

($T_A = 0^\circ\text{C}$ to 70°C , $V_{CC} = +5V \pm 5\%$, $V_{DD} = -9V \pm 5\%$, $V_{GG} = -9V \pm 5\%$ unless otherwise noted)

1601/1701
1602/1702

| Test | Typ. | Max. | Typ. | Max. | Unit |
|-------------------------|------|------|------|------|---------------|
| Repetition Rate | 1 | | 1 | | MHz |
| Address to output delay | .700 | 1 | 550 | 1 | μs |

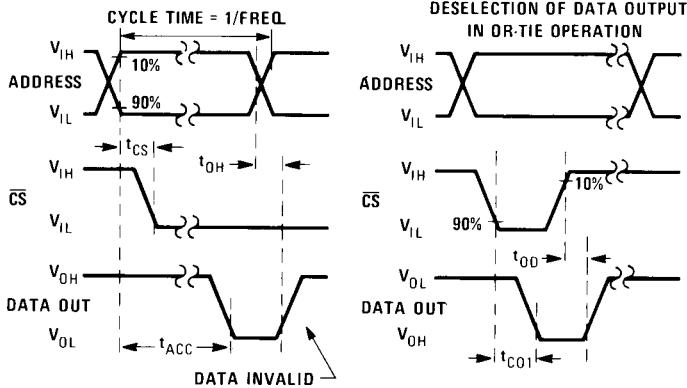
Switching Characteristics for Static Operation

Conditions of:

Input pulse amplitudes: 0 to 4V

Output load is 1 TTL gate

Normal Operation (constant V_{GG})



D.C. Characteristics for dynamic operation

($T_A = 0^\circ\text{C}$ to 70°C , $V_{CC} = V_{GG} = +5V \pm 5\%$, $V_{DD} = -9V \pm 5\%$, unless otherwise noted)

| Test | Typ. | Max. | Unit |
|--|--------------------------------|----------|------|
| Unselected average power supply current at 25°C ($\phi = \text{CS} = +5V$) | 5 | 10 | mA |
| Average power supply current @ $T_A = 25^\circ\text{C}$ | [1601/1701 1301] 30 28 | 45 40 | mA |

A.C. Characteristics for dynamic operation

($T_A = 0^\circ\text{C}$ to 70°C , $V_{CC} = +5V \pm 5\%$, $V_{DD} = -9V \pm 5\%$, unless otherwise noted)

1601/1701
1301

| Test | Min. | Typ. | Max. | Min. | Typ. | Max. | Unit |
|--------------------------|-------|------|------|------|------|------|---------------|
| 01 Clock pulse width | 0.260 | 2 | .260 | 2 | | | μs |
| 02 Clock pulse width | 0.140 | 2 | .140 | 2 | | | μs |
| 02 delay from 01 | 0.150 | 2 | .150 | 2 | | | μs |
| 01 delay from 02 | .05 | 2 | .05 | 2 | | | μs |
| Address to output access | 450 | 650 | | 450 | 650 | | ns |

Switching Characteristics for Dynamic Operation

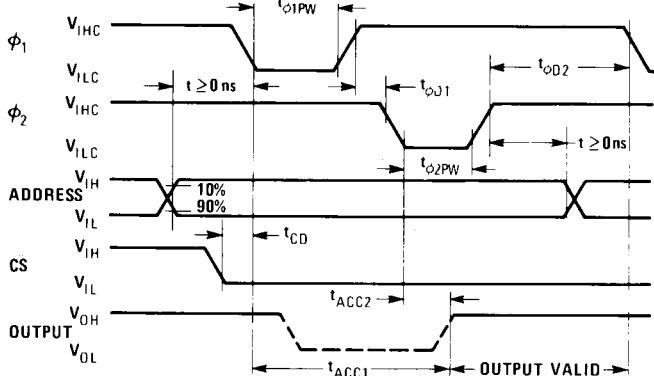
Condition of test:

Input pulse amplitude: 0 to 4V

Input rise and fall times ≤ 50 nsec

Output load is 1 TTL gate; measurements made at output of TTL gate ($t_{pd} \leq 15$ nsec)

Read timing

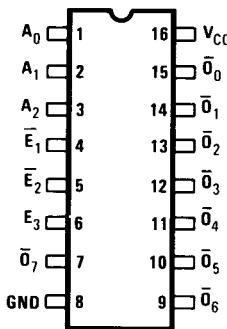


C. 3205 High-Speed 1-Out-Of-8 Binary Decoder

- Easy memory expansion—3 enable inputs
- Fast—18 nsec max. delay
- TTL/DTL compatible
- Low input load currents—0.25 mA max.
- High fan out—10 mA min. sink current
- 16 pin ceramic or plastic package

The 3205 is a high-speed 1-of-8 binary decoder designed for use with fast bipolar memory components such as the Intel 3101A and 3102.

Applications. General purpose high-speed 1-of-8 decode, bipolar memory expansion, chip-select decoder.



A.C. Characteristics

($T_A = 0^\circ\text{C}$ to 75°C , $V_{CC} = 5.0\text{V} \pm 5\%$)

| Test | Max. |
|-----------------------------------|----------------|
| Address or enable to output delay | 18 nsec |
| Input capacitance | 4 pF (typical) |

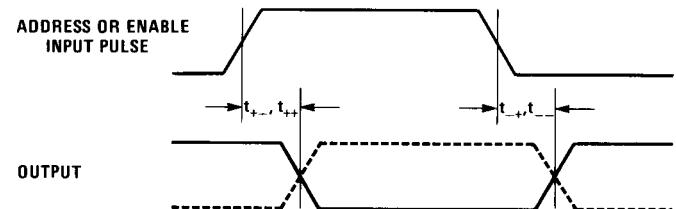
D.C. Characteristics

($T_A = 0^\circ\text{C}$ to 75°C , $V_{CC} = 5.0\text{V} \pm 5\%$)

| Test | Min. | Max. | Unit |
|--|-------|---------------|------|
| Input load current | -0.25 | mA | |
| Input Leakage current | 10 | μA | |
| Output "low" voltage ($I_{OL} = 10\text{ mA}$) | 0.45 | V | |
| Output "high" voltage | 2.4 | V | |
| Input "low" voltage | 0.85 | V | |
| Input "high" voltage | 2.0 | V | |
| Power supply current | 75 | mA | |

Timing diagram

Condition of test:
Input pulse amplitudes: 2.5V
Input rise and fall times: 5 nsec
between 1V and 2V
Measurements are made at 1.5V

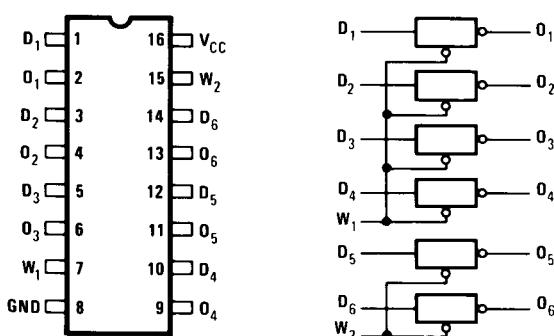


D. 3404 High-Speed 6-Bit Latch

- Memory register applications
- High speed—12 nsec max. input to output delay
- Easy to use—Independent 4-bit and 2-bit latches
- High fan out—10 mA min. output sink current
- High fan in—0.25 mA max. input load current
- TTL/DTL compatible
- Standard 16-pin DIP

The 3404 is a high-speed 6-bit latch built using Schottky bipolar technology. The circuitry consists of a 4-bit latch and an independent 2-bit latch on the same chip. The latches may be used as very high-speed inverters by applying a continuous "low" at the "write" inputs.

Applications. Memory data register, address register, inverter, high fan out buffers, "pipelined" processors.



A.C. Characteristics

($T_A = 0^\circ\text{C}$ to 75°C , $V_{CC} = 5.0\text{V} \pm 5\%$)

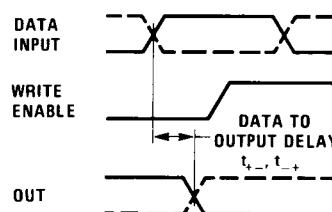
| Test | Min. | Max. | Unit |
|---------------------------------------|------|------|------|
| Data to output delay | 12 | nsec | |
| Write enable to output delay | 17 | nsec | |
| Write enable pulse width (t_{WP}) | 15 | | |

D.C. Characteristics

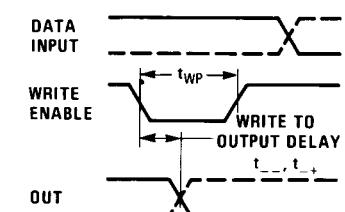
($T_A = 0^\circ\text{C}$ to 75°C , $V_{CC} = 5.0\text{V} \pm 5\%$)

| Test | Min. | Max. | Unit |
|--|-------|---------------|------|
| Data input load current | -0.25 | mA | |
| Input leakage current | 10 | μA | |
| Output "low" voltage ($I_{OL} = 10\text{ mA}$) | 0.45 | V | |
| Output "high" voltage | 2.4 | V | |

Data delay



Write enable delay



Ordering Information

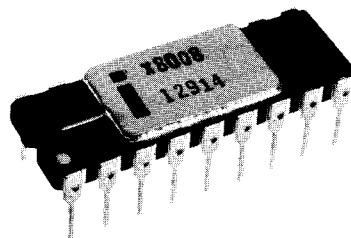
- (1) The 8008 CPU is available in ceramic only and should be ordered as C8008 or C8008-1.
- (2) **SIM8-01 Prototyping System**
This MCS-8 system for program development provides complete interface between the CPU and ROMs and RAMs. 1702 electrically programmable and erasable ROMs may be used for the program development. Each board contains one 8008 CPU, 1K x 8 RAM, and sockets for up to eight 1702's (2K x 8 PROM). This system should be ordered as SIM8-01 (the number of PROMs should also be specified).
- (3) **Memory Expansion**
Additional memory for the 8008 may be developed from individual memory components. Specify
RAM 1101 ROM 1702 SR 1404
1103 1301 2401
2102
- (4) **MP7-03 ROM Programmer**
This is the programmer board for 1702 or 1702A. The 1702 control ROMs used with the SIM8-01 for an automatic programming system are specified by pattern numbers A0860, A0861, A0862. Pattern A0863 should also be specified for programming the 1702A.
- (5) **MCB8-10 System Interface and Control Module**
The MCB8-10 is a complete chassis which provides the interconnection between the SIM8-01 and MP7-03. In addition, the MCB8-10 provides the 50 Vrms power supply for PROM programming, complete output display, and single step control capability for program development.
- (6) **Bootstrap Loader**
The same control ROM set used with the PROM programming system is used for the bootstrap loading of programs into RAM and execution of programs from RAM. Specify 1702 PROMs programmed to tapes A0860, A0861, A0862.
- (7) **MCS-8 Fortran Assembler and Fortran Simulator**
This software program converts a list of instruction

mnenomics into machine instructions and simulates the execution of instructions by the 8008. This program is written in Fortran IV and is available via time-sharing service or directly from Intel. Contact Intel for all the details.

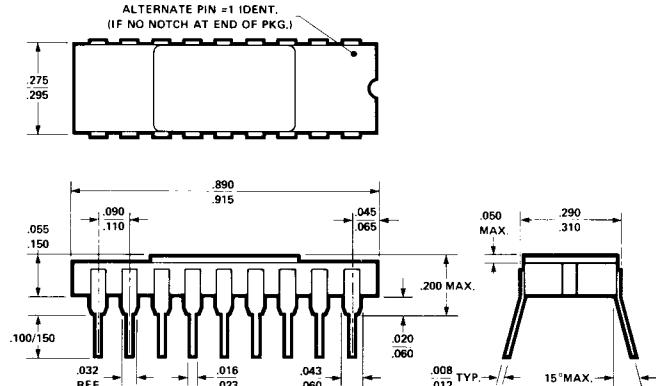
(8) **SIM8 Hardware Assembler**

Eight PROMs containing the assembly program plug into the SIM8-01 prototyping board permitting assembly of all MCS-8 software. To order, specify A0840 through A0847. The complete hardware assembler description and users' guide is available on request.

Packaging Information



CERAMIC PACKAGE OUTLINE



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Phone: 492003
Telex: 21060

MCS-8 INSTRUCTION SET

Index Register Instructions

The load instructions do not affect the flag flip-flops. The increment and decrement instructions affect all flip-flops except the carry.

| MNEMONIC | MINIMUM STATES REQUIRED | INSTRUCTION CODE | | | | | DESCRIPTION OF OPERATION | |
|-----------|-------------------------|------------------|----------------|----------------|----------------|----------------|--------------------------|--|
| | | D ₇ | D ₆ | D ₅ | D ₄ | D ₃ | | |
| (1) Lr1'2 | (5) | 1 | 1 | D | D | D | S S S | Load index register r ₁ with the content of index register r ₂ . |
| (2) LrM | (8) | 1 | 1 | D | D | D | 1 1 1 | Load index register r with the content of memory register M. |
| LMr | (7) | 1 | 1 | 1 | 1 | 1 | S S S | Load memory register M with the content of index register r. |
| (3) LrI | (8) | 0 | 0 | D | D | D | 1 1 0 | Load index register r with data B . . . B. |
| LMI | (9) | 0 | 0 | B | B | B | B B B | Load memory register M with data B . . . B. |
| INr | (5) | 0 | 0 | D | D | D | 0 0 0 | Increment the content of index register r (r ≠ A). |
| DCr | (5) | 0 | 0 | D | D | D | 0 0 1 | Decrement the content of index register r (r ≠ A). |

Accumulator Group Instructions

The result of the ALU instructions affect all of the flag flip-flops. The rotate instructions affect only the carry flip-flop.

| | | | | | | | | |
|-----|-----|---|---|---|---|---|-------|--|
| ADR | (5) | 1 | 0 | 0 | 0 | S | S S | Add the content of index register r, memory register M, or data B . . . B to the accumulator. An overflow (carry) sets the carry flip-flop. |
| ADM | (8) | 1 | 0 | 0 | 0 | 0 | 1 1 1 | |
| ADI | (8) | 0 | 0 | 0 | 0 | 1 | 0 0 | |
| ACr | (5) | 1 | 0 | 0 | 0 | 1 | S S S | Add the content of index register r, memory register M, or data B . . . B from the accumulator with carry. An overflow (carry) sets the carry flip-flop. |
| ACM | (8) | 1 | 0 | 0 | 0 | 1 | 1 1 1 | |
| ACI | (8) | 0 | 0 | 0 | 0 | 1 | 0 0 | |
| SUr | (5) | 1 | 0 | 0 | 1 | 0 | S S S | Subtract the content of index register r, memory register M, or data B . . . B from the accumulator. An underflow (borrow) sets the carry flip-flop. |
| SUM | (8) | 1 | 0 | 0 | 1 | 0 | 1 1 1 | |
| SUI | (8) | 0 | 0 | 0 | 1 | 0 | 1 0 0 | |
| SBr | (5) | 1 | 0 | 0 | 1 | 1 | S S S | Subtract the content of index register r, memory register M, or data B . . . B from the accumulator with borrow. An underflow (borrow) sets the carry flip-flop. |
| SBM | (8) | 1 | 0 | 0 | 1 | 1 | 1 1 1 | |
| SBi | (8) | 0 | 0 | 0 | 1 | 1 | 0 0 | |
| NDr | (5) | 1 | 0 | 1 | 0 | 0 | S S S | Compute the logical AND of the content of index register r, memory register M, or data B . . . B with the accumulator. |
| NDM | (8) | 1 | 0 | 1 | 0 | 0 | 1 1 1 | |
| NDI | (8) | 0 | 0 | 1 | 0 | 0 | 1 0 0 | |
| XRr | (5) | 1 | 0 | 1 | 0 | 1 | S S S | Compute the EXCLUSIVE OR of the content of index register r, memory register M, or data B . . . B with the accumulator. |
| XRM | (8) | 1 | 0 | 1 | 0 | 1 | 1 1 1 | |
| XRI | (8) | 0 | 0 | 1 | 0 | 1 | 0 0 | |
| ORr | (5) | 1 | 0 | 1 | 1 | 0 | S S S | Compute the INCLUSIVE OR of the content of index register r, memory register M, or data B . . . B with the accumulator. |
| ORM | (8) | 1 | 0 | 1 | 1 | 0 | 1 1 1 | |
| ORI | (8) | 0 | 0 | 1 | 1 | 0 | 1 0 0 | |
| CPr | (5) | 1 | 0 | 1 | 1 | 1 | S S S | Compare the content of index register r, memory register M, or data B . . . B with the accumulator. The content of the accumulator is unchanged. |
| CPM | (8) | 1 | 0 | 1 | 1 | 1 | 1 1 1 | |
| CPI | (8) | 0 | 0 | 1 | 1 | 1 | 0 0 | |
| RLC | (5) | 0 | 0 | 0 | 0 | 0 | 0 1 0 | Rotate the content of the accumulator left. |
| RRC | (5) | 0 | 0 | 0 | 0 | 1 | 0 1 0 | Rotate the content of the accumulator right. |
| RAL | (5) | 0 | 0 | 0 | 1 | 0 | 0 1 0 | Rotate the content of the accumulator left through the carry. |
| RAR | (5) | 0 | 0 | 0 | 1 | 1 | 0 1 0 | Rotate the content of the accumulator right through the carry. |

Program Counter and Stack Control Instructions

| | | | | | | | | |
|---------|-----------|---|---|----------------|----------------|----------------|-------------------------------|--|
| (4) JMP | (11) | 0 | 1 | X | X | X | 1 0 0 | Unconditionally jump to memory address B ₃ . . . B ₃ B ₂ . . . B ₂ . |
| (5) JFc | (9 or 11) | 0 | 1 | 0 | C ₄ | C ₃ | 0 0 0 | Jump to memory address B ₃ . . . B ₃ B ₂ . . . B ₂ if the condition flip-flop c is false. Otherwise, execute the next instruction in sequence. |
| JFc | (9 or 11) | 0 | 1 | B ₂ | B ₂ | B ₂ | B ₂ B ₂ | |
| JTC | (9 or 11) | 0 | 1 | B ₂ | B ₂ | B ₂ | B ₂ B ₂ | |
| CAL | (11) | 0 | 1 | X | X | X | 1 1 0 | Unconditionally call the subroutine at memory address B ₃ . . . B ₃ B ₂ . . . B ₂ . Save the current address (up one level in the stack). |
| CFc | (9 or 11) | 0 | 1 | B ₂ | B ₂ | B ₂ | B ₂ B ₂ | |
| CTc | (9 or 11) | 0 | 1 | B ₂ | B ₂ | B ₂ | B ₂ B ₂ | |
| RET | (5) | 0 | 0 | X | X | X | 1 1 1 | Unconditionally return (down one level in the stack). |
| RFc | (3 or 5) | 0 | 0 | 0 | C ₄ | C ₃ | 0 1 1 | Return (down one level in the stack) if the condition flip-flop c is false. Otherwise, execute the next instruction in sequence. |
| RTc | (3 or 5) | 0 | 0 | 1 | C ₄ | C ₃ | 0 1 1 | Return (down one level in the stack) if the condition flip-flop c is true. Otherwise, execute the next instruction in sequence. |
| RST | (5) | 0 | 0 | A | A | A | 1 0 1 | Call the subroutine at memory address AAA000 (up one level in the stack). |

Input/Output Instructions

| | | | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|--|
| INP | (8) | 0 | 1 | 0 | 0 | M | M | 1 | Read the content of the selected input port (MMM) into the accumulator. |
| OUT | (6) | 0 | 1 | R | R | M | M | 1 | Write the content of the accumulator into the selected output port (RRRMM, RR ≠ 00). |

Machine Instruction

| | | | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|---|
| HLT | (4) | 0 | 0 | 0 | 0 | 0 | 0 | X | Enter the STOPPED state and remain there until interrupted. |
| HLT | (4) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |

NOTES:

- (1) SSS = Source Index Register
- (2) DDD = Destination Index Register
- (3) Memory registers are addressed by the contents of registers H & L.
- (4) X = "Don't Care".
- (5) Flag flip-flops are defined by C₄C₃: carry (00-overflow or underflow), zero (01-result is zero), sign (10-MSB of result is "1"), parity (11-parity is even).



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