

# ***SERVICE MANUAL***

## **C-128/C128D COMPUTER**

**NOVEMBER 1987**

**PN-314001-08**

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# COMMODORE 128

# PERSONAL COMPUTER

## GENERAL FEATURES

- Advanced Styling • 100% Compatible with Commodore 64
- Built-in, Easy to Use DOS support • RAM Expandable up to 512K RAM Using RAM Disk Option • Upper and Lower Case Character Set
- Built-in BASIC • 3 Separate Modes of Operation

## 64 MODE

- 8502 Microprocessor (6502/6510 Compatible) • 6581 Sound Interface Chip • 64K RAM • 16K ROM • BASIC 2.0 • 40 x 25 Lines (320 x 200 resolution) • 16 Colors + 8 Sprites

## 128 MODE

- 8502 Microprocessor (6502/6510 Compatible)
- 6581 Sound Interface Chip • 128K RAM (Expandable to 512K Using RAM Disk Option) • 48K ROM + 16K ROM for DOS Support
- BASIC 7.0 • Machine Language Monitor • 40 x 25 Lines (320 x 200 resolution) • 80 x 25 Lines (640 x 200 resolution) • 16 Colors + 8 Sprites (40 Column Only)

## CP/M MODE

- Z80 Microprocessor • CP/M™ Plus Version 3.0
- 128K RAM (Expandable to 512K Using RAM Disk Option)
- 40 x 25 Lines (320 x 200 resolution) • 80 x 25 Lines (640 x 200 resolution) • 16 Colors

## KEYBOARD

- Full Size Typewriter Style • 92 Keys • 14 Key Numeric Keypad
- 8 Programmable Function Keys • 6 Cursor Keys • Help Key
- 40/80 Column Key • No Scroll • Line Feed • Escape • Tab
- Cap Lock • Alt (Not all accessible in 64 Mode)

## INPUTS/OUTPUTS

- User Port
- Cassette Port
- RF/TV Port
- Audio Input
- Composite Video
- Serial Port
- 2 Game Ports
- Cartridge Port
- Audio Output
- Digital RGBI Video

## RECOMMENDED PERIPHERALS

- MPS 802, MPS 803, MPS 1000 Printers
- 1541, 1571 Single Disk Drive
- 1901 Monochrome Monitor • 1902 Digital RGBI Color Monitor
- 1660 and 1670 Modems • Fully Compatible with Commodore 64 Software and Accessories in 64 Mode

## POWER REQUIREMENTS

- 117 Volts AC, 60 Hz, 15 Watts

†Specifications subject to change without notice

\*CP/M is a registered trademark of Digital Research, Inc.

# PARTS LIST

## C-128

**PLEASE NOTE: Commodore part numbers are provided for reference only and do not indicate the availability of parts from Commodore. Industry standard parts (Resistors, Capacitors, Connectors) should be secured locally. Approved cross-references for TTL chips, Transistors, etc. are available in manual form through the Service Department. Unique or non-standard parts will be stocked by Commodore and are indicated on the parts list by a "C".**

### TOP CASE ASSY

|                 |             |
|-----------------|-------------|
| Top Case        | C 251987-01 |
| Keyboard        | C 310401-01 |
| Nameplate       | C 310400-01 |
| Lamp Holder Set | C 252013-01 |
| LED Assembly    | C 250754-01 |

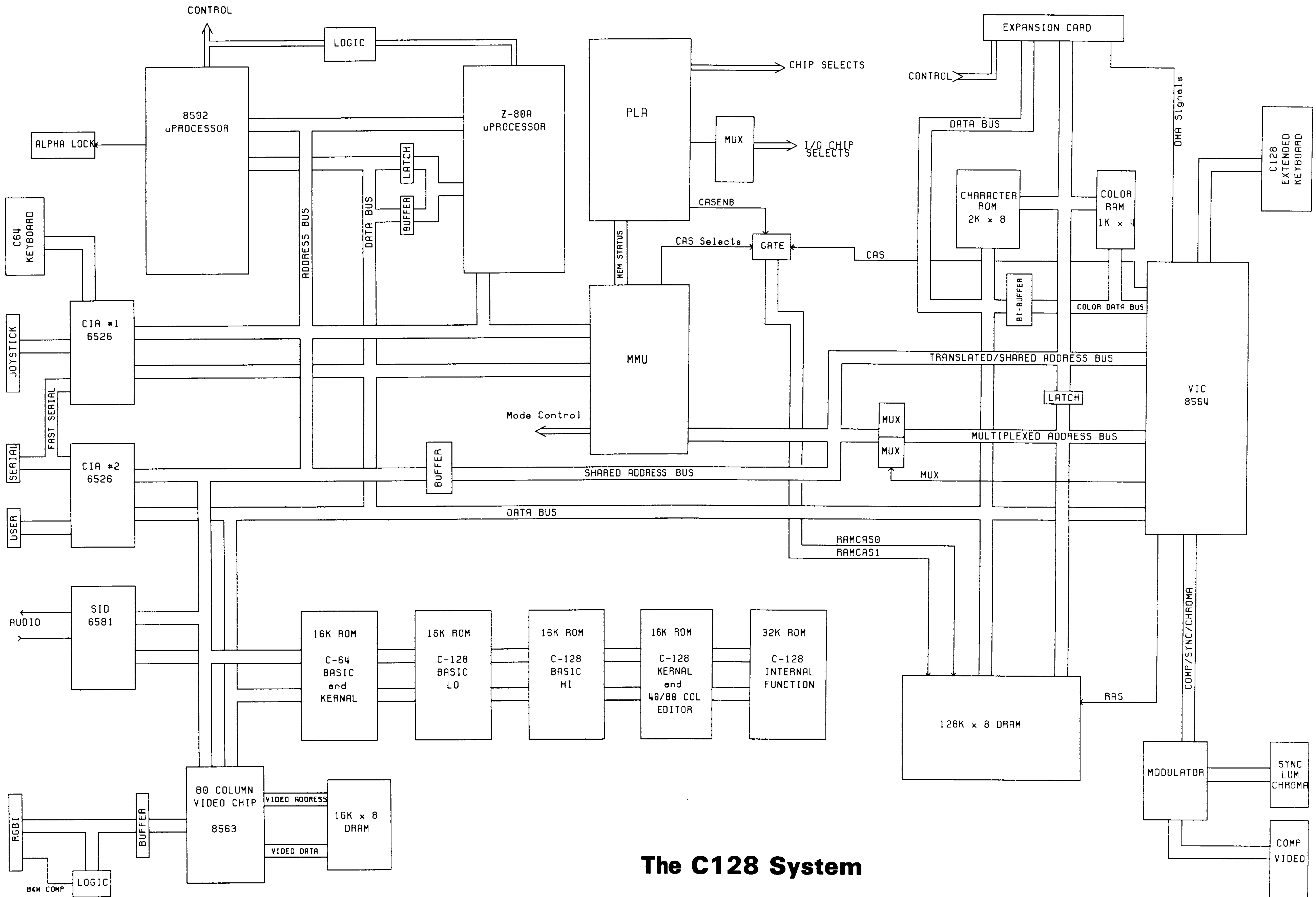
### BOTTOM CASE ASSY

|                      |             |
|----------------------|-------------|
| Bottom Case          | C 251988-01 |
| Foot, Self-Adhesive  | C 251993-01 |
| PCB Top Shield       | C 252015-01 |
| PCB Bottom Shield    | C 252016-01 |
| PCB Insulation Sheet | C 252017-01 |

### ACCESSORIES

|                    |             |
|--------------------|-------------|
| Users Manuals      |             |
| Introductory Guide | C 319773-01 |
| System Guide       | C 310638-01 |
| Power Supply       | C 310416-01 |
| RF Cable           | C 326189-01 |
| Switch Box         | C 904778-01 |
| Tutorial Diskette  | C 317667-01 |
| CP/M Diskette # 1  | C 317430-01 |
| CP/M Diskette # 2  | C 317431-01 |

# BLOCK DIAGRAM



**The C128 System**

# BUS ARCHITECTURE

**FOLD OUT SCHEMATIC PAGES 73-76 FOR EASY REFERENCE.**

## **The Processor Bus**

The **Processor Bus** is the data and address buses that are directly connected to the 8502 processor. These buses are designated D<sub>0</sub> - D<sub>7</sub> for the eight bit data bus and A<sub>0</sub> - A<sub>15</sub> for the sixteen bit address bus. These buses tie the processor to most of the system ROM and I/O devices, including at least part of all System ROM, all built-in Function ROM, the MMU, the PLA, the 8563 Video Processor, the SID, and both CIA chips.

The Processor Bus is in direct communication with the Z-80 co-processor as well. All address lines are shared directly by both processors. In order to allow the Z-80 to operate on a 6502 family bus, it is necessary to latch data going into the Z-80 and gate the data leaving the Z-80. Thus, the Z-80 has a small local data bus, designated ZD<sub>0</sub> - ZD<sub>7</sub>. During a write cycle, when AEC is high, Z-80 data is gated to the Processor Bus. During a read cycle, Processor Bus data is gated to the Z-80 data bus. This read data is transparently latched by the 1 MHz system clock.

The read and write cycles referred to are, unless otherwise specified, 8502 type bus cycles. The Z-80 Read Enable and Write Enable outputs are conditioned using logic to interface with an 8502 bus cycle, so no distinction is made as to the differences between cycles of the different processors.

As mentioned above, the Z-80 is not in direct communication with the Processor Data Bus, due to the necessity of adapting the Z-80 to 8502 bus protocol. Note, however, that every other device and the translated bus (except two that will be explained later) shares the Processor Data Bus as a common data bus.

## **The Translated Address Bus**

Another C128 system bus is the **Translated Address Bus**, which is produced by the MMU during AEC high. This bus consists of only high order addressing lines, designated TA<sub>8</sub> - TA<sub>15</sub>. These lines reflect the action of the MMU on the normal high order address lines, which may or may not include some sort of translation. The MMU can translate the address of page zero or page one in normal operation, and it translates the Z-80 address from \$0000 thru \$0FFF in order to direct it to read the Z-80 BIOS. A more complete description of MMU translations can be found in the MMU section. Normally the Translated Address Bus indirectly drives the DRAMs and the VIC chip by driving the Multiplexed Address Buses. It directly drives System ROM 4 address line 12 to allow the Z-80 ROM relocation. Finally, this bus becomes address lines 8 thru 15 of the C64 compatible expansion port.

During a VIC cycle or a DMA, the MMU pulls TA<sub>12</sub> - TA<sub>15</sub> high, while TA<sub>8</sub> - TA<sub>11</sub> are tri-stated. This allows the VIC chip to drive TA<sub>8</sub> - TA<sub>11</sub> as VIC addresses VA<sub>8</sub> - VA<sub>11</sub>.

## **The Multiplexed Address Bus**

This section actually describes two related address buses, the **Multiplexed Address Bus** and the **VIC Multiplexed Address Bus**, known respectively as MA<sub>0</sub> - MA<sub>7</sub> and VMA<sub>0</sub> - VMA<sub>7</sub>. The VIC Multiplexed Address Bus is created during AEC high by multiplexing the high order Translated Address Bus (TA<sub>8</sub> - TA<sub>15</sub>) with the low order Processor Address Bus (A<sub>0</sub> - A<sub>7</sub>), controlled via the MUX signal. This bus, driven through series resistors, is called the Multiplexed Address bus. The VIC Multiplexed Address Bus is used in addressing the VIC chip registers while the Multiplexed Address Bus is the processor's DRAM address for both 64K banks of DRAM.

## **BUS ARCHITECTURE (Continued)**

During a VIC cycle, AEC low, the VIC chip address lines must be asserted. There is no completely separate address bus for the VIC addresses, so it shares the VMA<sub>0</sub> - VMA<sub>7</sub> and TA<sub>8</sub> - TA<sub>11</sub> address lines that are otherwise tri-stated during AEC low. Most of the VIC addresses come out of the VIC chip already multiplexed, but two of them, VA<sub>6</sub> and VA<sub>7</sub>. They do not supply column information, as the VIC chip supplies only fourteen bits of addressing. The higher order address bits VA<sub>14</sub> and VA<sub>15</sub> come from CIA 2, as in the C64. Thus, the VIC supplies complete VMA<sub>0</sub> - VMA<sub>7</sub> for a VIC DRAM access or DRAM refresh. The TA<sub>8</sub> - TA<sub>11</sub> supplied by VIC are used in conjunction with another addressing bus for non-multiplexed VIC cycle addresses, such as Character ROM and Color RAM accesses.

### **The Shared Address Bus**

The **Shared Address Bus** is a non-multiplexed address bus used by both the processor and the VIC chip. This is necessary to communicate with common resources, namely the Character ROM and Color RAM. During AEC high, the Shared Address Bus, designated SA<sub>0</sub> - SA<sub>7</sub>, is driven by A<sub>0</sub> - A<sub>7</sub>, the lower order Processor Address bits. The higher order bits needed are supplied by the Translated Address Bus, which is also a shared address bus. Thus, the processor is able to access both shared items.

During AEC low, the VIC addresses VA<sub>0</sub> - VA<sub>7</sub> (VMA<sub>0</sub> - VMA<sub>7</sub>) must come onto the Shared Address Bus. Since VA<sub>0</sub> - VA<sub>6</sub> are actually multiplexed, the row address only must be sent to the Shared Address Bus. Thus, the Multiplexed VIC addresses are transparently gated when either  $\overline{\text{RAS}}$  or MUX are low, but latched when both are high, which would indicate that a column address is about to be presented. The high order address bits, as well, are supplied by the shared Translated Address Bus. Note that the Shared Address Bus provides the lower eight bits of the expansion port address, allowing VIC access to cartridges and some additional drive capability by way of the TTL chips used to drive the Shared Address Bus.

### **The Color Data Bus**

The Color RAM is written to or read from by a nybble data bus called the **Color Data Bus**. During AEC high, the Color Data Bus is connected to the lower half of the Processor Data Bus via an analog switch, allowing the Processor full access to the Color RAM. During AEC low, that switch is opened, effectively isolating the Color Data Bus from the Processor Data Bus. In this state, it is driven by the VIC extended data bus D<sub>8</sub> - D<sub>11</sub>.

### **The Display Bus**

The Display Bus is a bus local to the 8563 Video Controller VIC chip, consisting of the **Display Address**, DA<sub>0</sub> - DA<sub>7</sub>, and the **Bus Display Data Bus**, DD<sub>0</sub> - DD<sub>7</sub>. This local bus supports the 8563 display RAM, which is completely isolated from the rest of the C128 system. The Display Address Bus is a multiplexed address bus providing addressing to the display DRAM. The Display Data Bus provides communication between this DRAM and the 8563. The 8563 also provides row and column strobes and dynamic refresh to this DRAM.

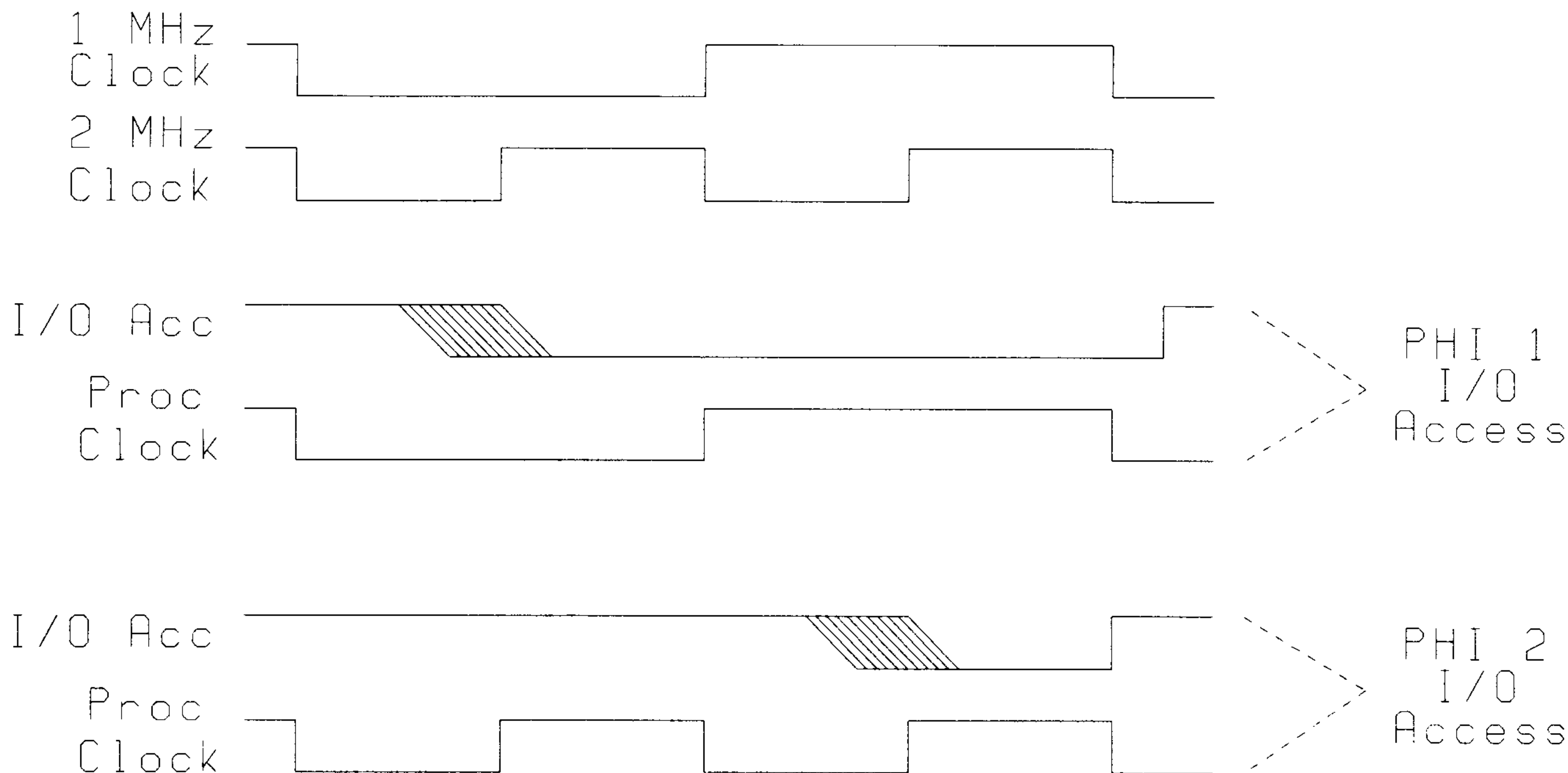
# THE 8502 MICROPROCESSOR

**FOLD OUT SCHEMATIC SHEET 2, PAGE 74, FOR EASY REFERENCE.**

The 8502 is an HMOSII Technology microprocessor similar to the 6510/6502. It is the normal operating processor and is used in the C64 and the C128 modes. Fully software compatible with the 6510, hence the 6502, the 8502 also features a zero page port used in memory management and cassette implementations. The 8502 is also specified for operation at 2 MHz. The 2 MHz operation is made possible by removing the VIC from the system. The VIC chip is never completely removed from the C128 system, as it continues to function as clock generator and bus arbitrator. However, the VIC is removed as a display chip and co-processor, thus the full clock cycle can be devoted to processor functioning instead of sharing the cycle with the VIC. The task of video display processor is then taken over by the 8563, which can function without the need for bus sharing that the VIC required. Since the I/O devices, SID, etc., are rated at 1 MHz only, stretching of the 2 MHz clock is used to allow these parts to be directly accessed by the 2 MHz processor, and still keep throughput to a maximum. The I/O devices are not affected by the 2 MHz operation as they are still driven by a 1 MHz source (and as such, all timer operations remain unchanged), and clock stretching is only used to synchronize the 2 MHz machine cycle to the 1 MHz  $\phi_0$  high time. The clock sources and clock stretching capabilities are generated by the VIC chip.

## CLOCK STRETCHING

When running in 2 MHz mode, the processor clock sometimes must be stretched. This is handled by the VIC chip, the processor, and the PLA working together. When an I/O operation is decoded during a 2 MHz cycle, the phase relationship between the 2 MHz and the 1 MHz clocks must be considered. If the 2 MHz access occurs during 1 MHz  $\phi_1$ , the access to a clocked I/O chip would be out of synchronization with the 1 MHz clock that drives all I/O chips. Thus, during this phase relationship, IOACC, from the PLA, signals the VIC chip to extend the 2 MHz clock. Should the 2 MHz cycles take place during the 1 MHz  $\phi_2$  cycle, no special attention is necessary.



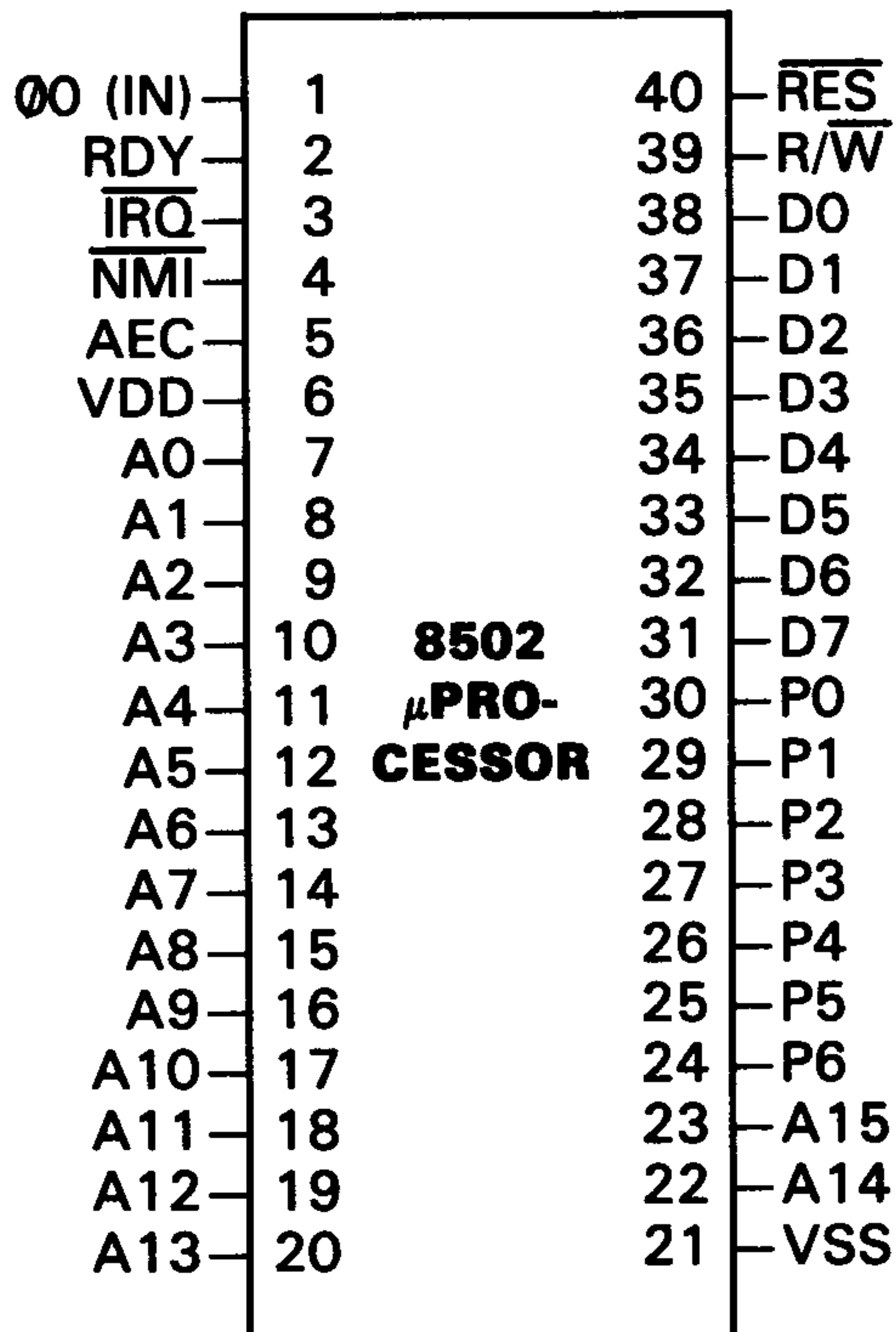
**Clock Stretching in 2 MHz Mode**

Please take note to consider the speed implications of this. In 2 MHz mode, half of the I/O accesses given will occur at an effective speed of 1 MHz. For time critical operations, then, accesses to I/O chips are kept at a minimum.



# THE 8502 MICROPROCESSOR (Continued)

## 315020 8502 MICROPROCESSOR



|       |        |   |
|-------|--------|---|
| 1     | ∅0     | Phase 0 clock input. This is the dual speed system clock for the 128.   |
| 2     | RDY    | Ready. TTL level input, used to DMA the 8502. The processor operates normally while RDY is high. When RDY makes a transition to the low state, the processor will finish the operation it is on, and any subsequent operation if it is a write cycle. On the next occurrence of read cycle the processor will halt, making it possible to tri-state the processor to gain complete access to the system bus.  |
| 3     | IRQ    | The Interrupt Request input is a request that the processor initiate an interrupt sequence. The processor will complete execution of the current instruction before recognizing the request. At that time, the interrupt mask in the Status Code Register will be examined. If the interrupt mask is not set, the processor will begin an interrupt sequence. The Program Counter and the Processor status register will be stored on the stack and the interrupt disable flag is set so that no other interrupts can occur. The processor will then load the program counter from the memory location \$FFFE and \$FFFF.   |
| 4     | NMI    | The Non-Maskable Interrupt Request is a negative-edge sensitive request that the processor initiate an interrupt sequence. The processor will complete execution of the current instruction before recognizing the request. The Program Counter and the processor status register will be stored on the stack. The processor will then load the program counter from the memory locations \$FFFA and \$FFFB.  |
| 5     | AEC    | The Address Enable Control. The Address Bus is only valid when the AEC line is high. When low, the address bus is in a high impedance state. This allows DMA's for dual processor systems.  |
| 6     | VDD    | 5VDC input.   |
| 7-20  | A0-A15 | Address bus outputs. Unidirectional bus used to address memory and I/O devices. The address bus can be disabled by controlling the AEC input.   |
| 21    | VSS    | DC ground.  |
| 24-30 | P0-P6  | Bidirectional I/O port used for transferring data to and from the processor directly. The Data Register is located at location \$0001 and the Data Direction Register is located at location \$0000.  |
| 31-38 | D0-D7  | Bi-directional bus for transferring data to and from the device and the peripherals.  |
| 39    | R/W    | The read/write line is a TTL level output from the processor to control the direction of data transfer between the processor and memory, peripherals, etc. This line is high for reading memory and low for writing.  |
| 40    | RES    | The Reset input is used to reset or start the $\mu$ processor from a power down condition. During the time that this line is held low, writing to or from the $\mu$ processor is inhibited. When a positive edge is detected on the input, the $\mu$ processor will immediately begin the reset sequence. After a system initialization time of 6 cycles, the mask interrupt flag will be set and the processor will load the program counter from the contents of the memory locations \$FFFC and \$FFFD. This is the start location for program control. After VCC reaches 4.75 volts in a power up routine, reset must be held low for at least 2 cycles. At this time the R/W line will become valid. |

# THE Z-80 MICROPROCESSOR

**FOLD OUT SCHEMATIC SHEET 2, PAGE 74, FOR EASY REFERENCE.**

The Z-80 microprocessor is used as a secondary processor in the C128 to run CP/M based programs. The Z-80 is interfaced to the 8502 bus and can access all of the devices that the 8502 can access.

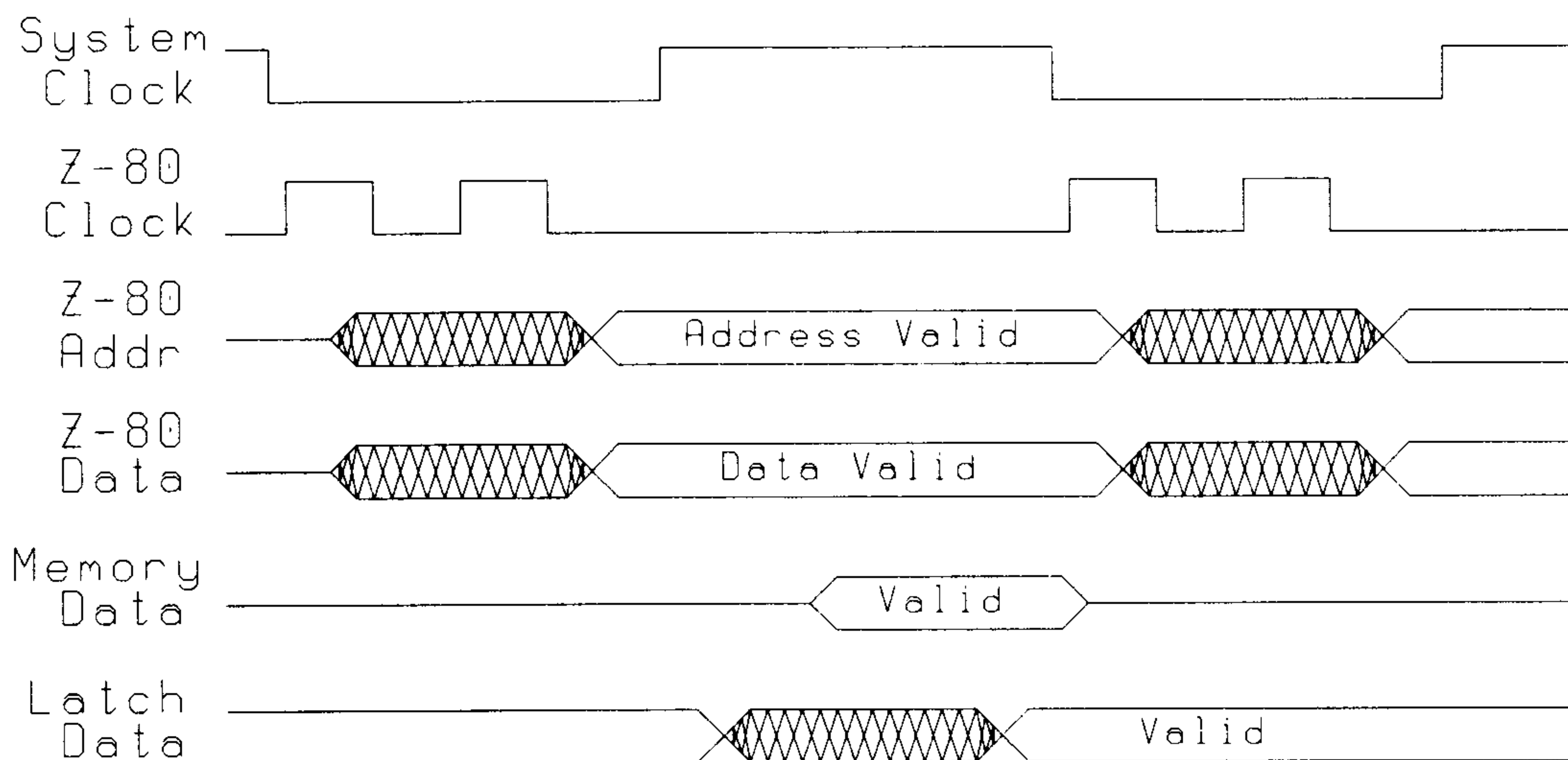
## Bus Interface

Since a Z-80 bus cycle is much different than a 65xx family bus cycle, a certain amount of interfacing is required for a Z-80 to control a 65xx type bus. Since the Z-80 has built-in bus arbitration control lines, it is possible to isolate the Z-80 by tri-stating its address line. Thus, the Z-80 and 8502 both share common address lines.

The data lines do not interface quite as easily. Due to the shared nature of the bus during Z-80 mode, it is necessary to isolate the Z-80 from the bus during AEC low. Thus, a tri-stable buffer must drive the Processor bus during Z-80 data writes. The reverse problem occurs during a Z-80 read — the Z-80 must not read things that are going on during AEC low. It must latch the data that was present during AEC high. Thus, a transparent latch drives the data input to the Z-80. It is gated by the Z-80 Read Enable output, and latched when the 1 MHz clock is low. It will be seen that the Z-80 actually runs during AEC low, but that the data bus interfaces with it only during AEC high.

## Control Interface

The Z-80 control interfacing must provide useful clock pulses to the Z-80 and must tailor the Z-80 Read and Write Enable signals for the 8502 type bus protocol. The Z-80 clock is provided by the VIC chip, and is basically a 4 MHz clock that only occurs during  $\phi_0$  low, as seen in the Z-80 bus timing diagram. This insures that the Z-80 is only clocked when it is actively on the bus. One additional problem that arises in clocking the Z-80 is that while all of the 8502 levels, and most of the Z-80 levels, are TTL compatible, the Z-80 clock input expects levels very close to five volts. For that reason, the output from the VIC chip is processed by a transistor switching circuit to give a full amplitude clock. This circuit uses the nine volt supply, thus, the nine volt circuit must be operational for the Z-80 to function.



**Z-80 Bus Timing**

## THE Z-80 MICROPROCESSOR (Continued)

The Z-80 is designed to have explicit Read, Write and I/O cycles, where an I/O cycle is distinct from a memory cycle. The 65xx family uses only memory mapped I/O and thus, for a 65xx bus, all I/O devices appear as memory locations, and all non-write cycles appear as read cycles. The Z-80 communicates cycle information via two control lines, the Read Enable and Write Enable lines. The C128 uses the Read Enable line of the Z-80 to gate the Processor Bus data to the Z-80 data bus. The Write Enable interfacing is somewhat more complicated.

The Write Enable Circuitry consists of a rising-edge triggered D-Type flip-flop and an SR flip-flop. The D-flop is triggered by the rising-edge of the 1 MHz clock. The positive output of the SR drives the D-input, and the Q output gated with AEC drives an open collector inverter, which in turn drives the R/W line of the 8502 bus. The  $\overline{S}$  input is driven by the Z-80  $\overline{WE}$ , and the  $\overline{R}$  input is driven by the Q output of the D-flop. Normally the D-input is low, resulting in an 8502 read cycle. When the Z-80  $\overline{WE}$  signal falls, it sets the SR flop, causing the D-input to rise. This line remains high, even if the Z-80  $\overline{WE}$  should rise again. When the 1 MHz clock rises, this high level is clocked, causing an 8502 write cycle that will last one complete 1 MHz cycle. When the Write signal is passed by the D-flop, the  $\overline{Q}$  output will reset the SR flop. If no more  $\overline{WE}$  signals come, the D-flop will once again set 8502 Read mode.

### Processor Switching

It is important in normal operation for the Z-80 and 8502 to operate as co-processors, communicating between each other. This is, however, only serial co-processing, not to be considered parallel co-processing or multiprocessing. Only one processor may have the bus at any one time. This is important in several ways. First, the C128 system must power up with the Z-80 as the master processor. This is because the Z-80 will not power up cleanly, and may accidentally access the bus when powering up. Thus, it is made master on powerup and can do anything it likes to the bus. Also, the Z-80 can start up certain C64 applications that would cause the 8502 to crash, thus again it is the logical choice for startup processor. After some initializations, the Z-80 will start up the 8502 in either C128 or C64 mode, depending upon if a cartridge is present.

The second reason for processor switching is to allow the Z-80 to access 8502 Kernal routines. For standardized programs, or for any I/O operation not supported in the Z-80 BIOS, the Z-80 can pass on the task of I/O to the 8502. Since the Z-80 sees BIOS ROM where the 8502 sees its pages 0 through F, the Z-80 can operate without fear of disrupting any 8502 pointers or the stack in RAM Bank 0.

The Z-80 can receive a bus grant request from the MMU, via  $\overline{Z80EN}$ , or from the VIC chip, via BA. Since the VIC control line is used for DMAs, that is not of immediate concern. The  $\overline{Z80EN}$  action, however, is, since it is the mechanism by which processors swap control. When the  $\overline{Z80EN}$  line goes high, it triggers a Z-80  $\overline{BUSRQ}$ . The Z-80 will relinquish the bus by pulling  $\overline{BUSACK}$  low. This action drives the 8502 AEC high and, providing VIC does not request a DMA, will also drive the 8502 RDY line high, enabling the 8502. To switch back, a low on the Z-80  $\overline{BUSRQ}$  will result in Z-80  $\overline{BUSACK}$  going high, tri-stating and halting the 8502.

# THE Z-80 MICROPROCESSOR (Continued)

## 906150 Z-80 MICROPROCESSOR

|                     |    |    |                    |    |        |   |
|---------------------|----|----|--------------------|----|--------|---|
| A11                 | 1  | 40 | A10                | 18 | HALT   | Halt State. Active low output indicating that the Z-80 has executed a HALT instruction and is awaiting some kind of interrupt before execution can continue. While in the HALT state, the CPU continuously executes NOPs to continue refresh activity.  |
| A12                 | 2  | 39 | A9                 | 19 | MEMREQ | Memory Request. Active low, tri-state output that indicates that the address bus holds a valid address for a memory read or write operation.  |
| A13                 | 3  | 38 | A8                 | 20 | IORQ   | Input/Output Request. Active low, tri-state output. The $\overline{IORQ}$ signal indicates that the lower half of the address bus holds a valid address for an I/O read or write operation. An $\overline{IORQ}$ signal is also generated with an $\overline{M1}$ signal when an interrupt is being acknowledged to indicate that an interrupt response vector can be placed on the data bus. An interrupt can be acknowledged during $\overline{M1}$ ; I/O operations never occur during $\overline{M1}$ . |
| A14                 | 4  | 37 | A7                 | 21 | RD     | Memory Read. Active low, tri-state output. $\overline{RD}$ indicates that the CPU wants to read data from memory or from an I/O device. This signal is generally used to gate read data onto the data bus.  |
| A15                 | 5  | 36 | A6                 | 22 | WR     | Memory Write. Active low, tri-state output. $\overline{WR}$ indicates that the data bus holds valid data to be processed by memory or by an I/O device.   |
| PHI                 | 6  | 35 | A5                 | 23 | BUSAK  | Bus Acknowledge. Active low output, used to indicate to any device taking over the bus that the Z-80 has gone into tri-state and the bus has been granted. While in this mode it cannot refresh dynamic memory.   |
| D4                  | 7  | 34 | A4                 | 24 | WAIT   | Wait. Active low input, used to drive the Z-80 into wait states. As long as this signal is low, the Z-80 will execute wait states, allowing this signal to be used to access slow memory and I/O devices. While the Z-80 is in a WAIT state, it cannot refresh dynamic memory.  |
| D3                  | 8  | 33 | A3                 | 25 | BUSRQ  | Bus Request. Active low input that is used to request the CPU address, data, tri-statable output control signals to all go tri-state for bus sharing and DMAs. The lines go tri-state upon termination of the current machine cycle.  |
| D5                  | 9  | 32 | A2                 | 26 | RESET  | Reset. Active low input which forces the program counter to zero and initializes the Z-80, which will set interrupt mode 0, disable interrupts, and set registers I and R to zero. During RESET, address and data buses tri-state and all other signals go inactive.  |
| D6                  | 10 | 31 | A1                 | 27 | M1     | Machine Cycle One. Output, active low. This signal indicates that the current machine cycle is the OP code fetch of an instruction execution. During execution of a two byte op-code, $\overline{M1}$ is generated as each byte is fetched. $\overline{M1}$ also occurs with $\overline{IORQ}$ to indicate an interrupt acknowledge cycle.  |
| VCC                 | 11 | 30 | A0                 | 28 | RFSH   | Refresh. Active low output used to indicate that the address bus holds a refresh address in its lower seven bits. Thus, the current $\overline{MREQ}$ signal should be used to do a refresh read to all dynamic memories not refreshed from an alternate source. A7 is set to zero and the upper eight bits contain the I register at this time.  |
| D2                  | 12 | 29 | VSS                | 29 | VSS    | Ground.   |
| D7                  | 13 | 28 | $\overline{RFSH}$  |    |        |   |
| D0                  | 14 | 27 | $\overline{M1}$    |    |        |   |
| D1                  | 15 | 26 | $\overline{RESET}$ |    |        |   |
| $\overline{INT}$    | 16 | 25 | $\overline{BUSRQ}$ |    |        |   |
| $\overline{NMI}$    | 17 | 24 | $\overline{WAIT}$  |    |        |   |
| $\overline{HALT}$   | 18 | 23 | $\overline{BUSAK}$ |    |        |   |
| $\overline{MEMREQ}$ | 19 | 22 | $\overline{WR}$    |    |        |   |
| $\overline{TORQ}$   | 20 | 21 | $\overline{RD}$    |    |        |   |

1-5, 30-40 A0-A15 16 Bit tri-stating Address Bus. Used for 16 bit memory address during memory cycles, used for 8 bit I/O address during I/O cycles. This allows up to 256 input or 256 output ports. During refresh time, the lower 7 bits contain a valid refresh address.

6 PHI Single phase system clock.

7-10, 12-15 D0-D7 Input/Output Data Bus, capable of tri-stating, used for 8-bit data exchanges with memory and I/O devices.

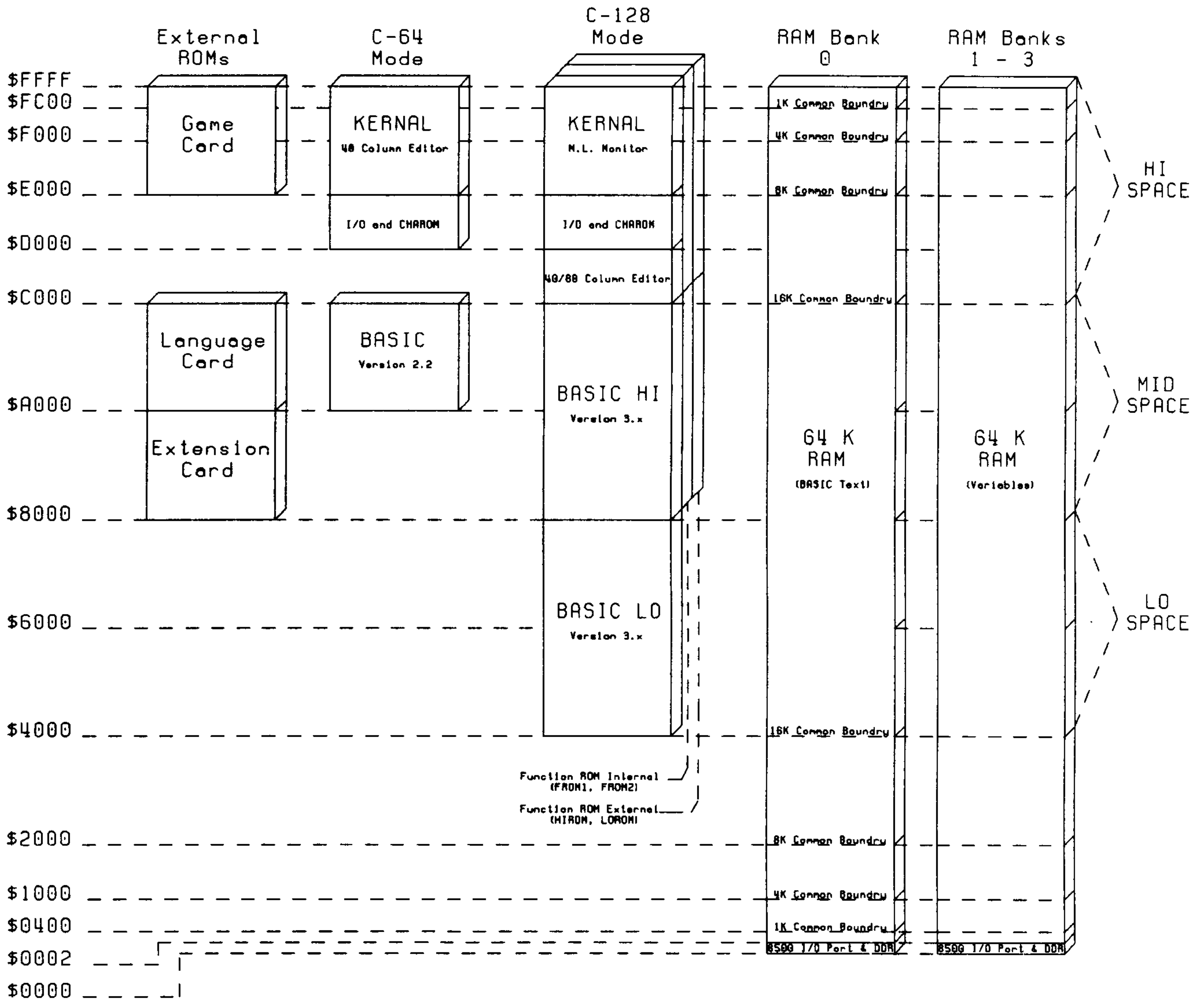
11 VCC 5VDC input.

16 INT Interrupt Request. Active low input, driven by external devices. If the interrupt flag IFF is enabled, and the  $\overline{BUSRQ}$  line is not active, the processor will honor the requested interrupt at the end of the current instruction. When the Z-80 acknowledges an interrupt, it generates an interrupt acknowledge signal ( $\overline{IORQ}$  during  $\overline{M1}$ ) at the beginning of the next instruction cycle. There are three different modes of response to a given interrupt.

17 NMI Non-Maskable Interrupt. Active low input. This interrupt is edge triggered and cannot be masked against. It is always recognized at the end of the current instruction, forcing the Z-80 to take a restart at location \$0066. The program counter is automatically saved in the stack to allow a return from the interrupted program. Note that continuous WAIT cycles can delay an NMI by preventing the end of the current cycle, and that  $\overline{BUSRQ}$  will override NMI.

# MEMORY ARCHITECTURE

**FOLD OUT SCHEMATIC PAGES 73-76 FOR EASY REFERENCE.**



**C128 Memory Map**

## C128 ROM Memory Organization

The memory map is an important consideration in maintaining C64 compatibility. The standard map is shown for the C64 mode. The C128 basically becomes a C64 when in C64 mode.

## MEMORY ARCHITECTURE (Continued)

C128 mode is achieved at system reset, and is controlled by a bit in the MMU configuration register (See MMU Circuit Theory, page 20). In C128 mode, the MMU asserts itself in the C128 memory map at \$FF00 and in the I/O space starting at \$D500. Use of MMU registers, located at \$FF00, allows memory management without actually having the I/O block banked in at the time and with a minimum loss of contiguous RAM. The MMU is removed from the memory map in C64 mode but is still used by hardware to manage memory.

The ROMs in C64 mode, both internally and externally, look just like C64 ROMs. The internal BASIC and KERNAL provide the C64 mode with the normal C64 operating system in ROM. This ROM actually duplicates some of the ROM used in C128 mode, but is necessary, as it is not accessible from C128 mode. In C128 mode, up to 48K of Operating System is present, with the exact amount being set by software control. This allows quicker access to underlying RAM by turning off unneeded sections of the Operating System.

The External ROMs represented on the memory map are those used in the C64 mode, and obey the C64 rules for mapping, i.e., cartridges assert themselves in hardware via the  $\overline{\text{EXROM}}$  and  $\overline{\text{GAME}}$  lines. External ROMs in C128 mode are mapped as banked ROMs, such that when the system is initialized, all ROM slots are polled for the existence of a ROM and the ROM's priority if one exists. This allows much more flexibility than the hardware ROM substitution method, since the Kernal and Basic ROMs can be swapped out for an application program, swapped out for external program control, or turned off all together. This banking manipulation is accomplished by writing to the Configuration Register at location \$D500 or \$FF00, in the MMU.

The hardware also features the ability to store preset values for the configuration and force a load of the Configuration Register by writing to one of the LCR (Load Configuration Register) registers.

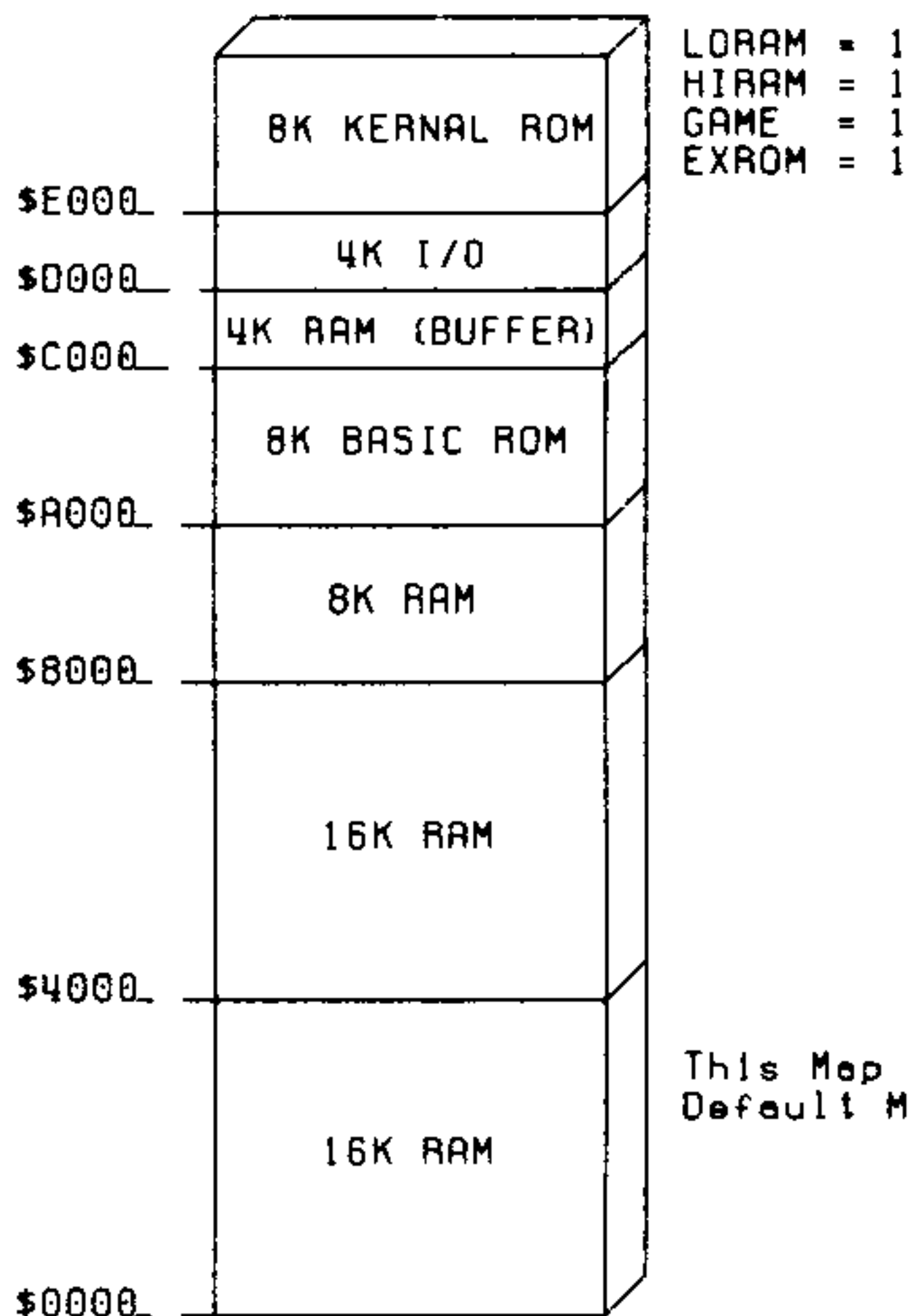
### C128 RAM Memory Organization

Refer again to the **C128 Memory Map**. The RAM present in the system is actually composed of two 64K by 8 bytes of contiguous DRAM. The RAM is accessed by selecting one of the two banks of 64K according to the RAM banking rules set in the RAM Configuration Register of the MMU. The area shown as RAM is representative of what the  $\mu$ Processor would see if all ROM were disabled. Bank switching can be accomplished in one of two ways.

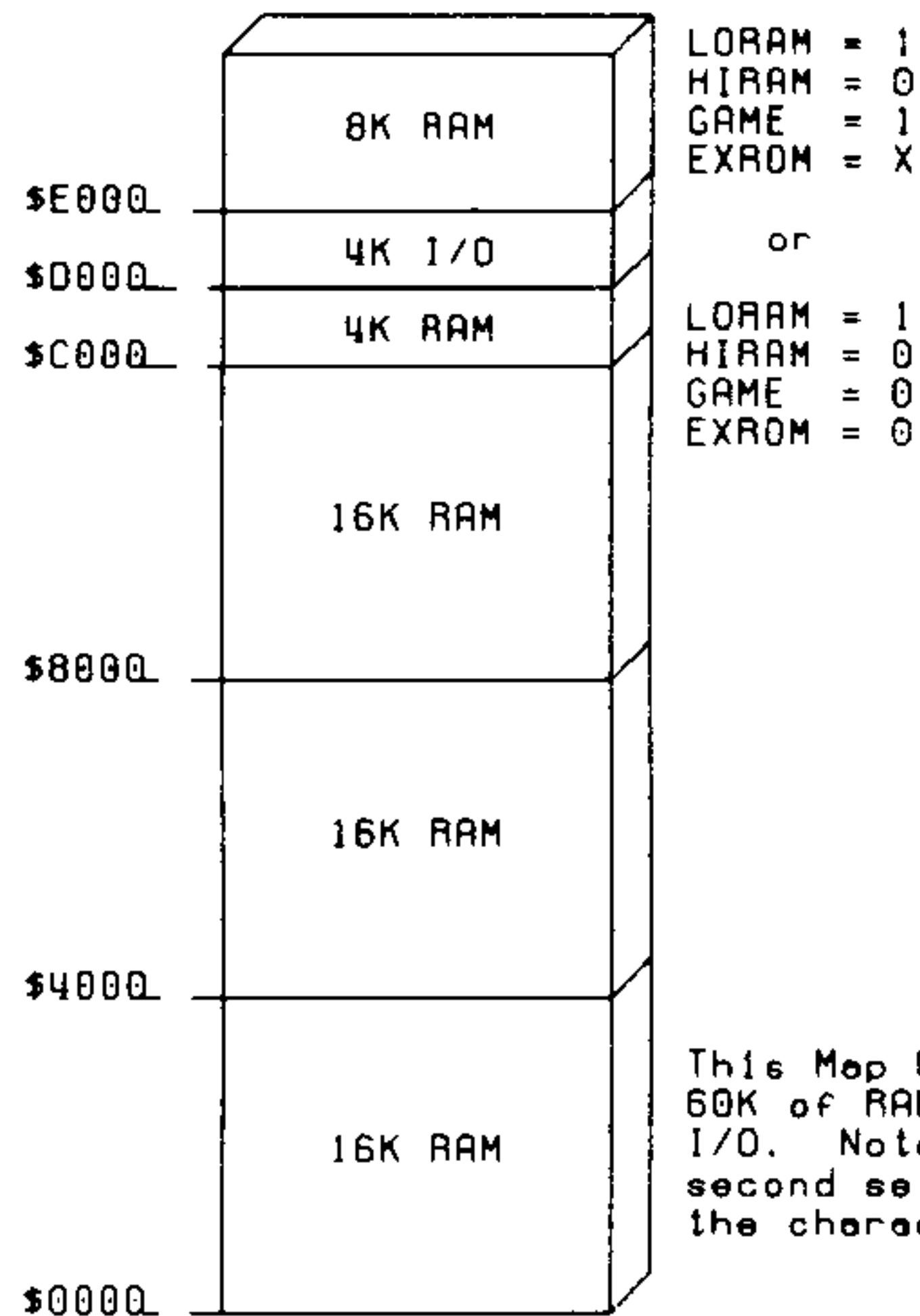
The bank in use is a function of the value stored in the Configuration Register. A store to this register will always take effect immediately. An indirect store to this register, using preprogrammed bank configuration values, can be accomplished by writing to one of the **indirect load** registers, known as LCRs (Load Configuration Register), located in the \$FF00 region of memory. By writing to an LCR the contents of its corresponding PCR (PreConfiguration Register) will be latched into the configuration register. Refer to the MMU section on page 20 and the Alternate Memory Configurations on the following page.

When dealing with 64K banks of memory at once, it may be desirable to bank in bank 1 but still retain the system RAM (Stack, Zeropage, Screen, etc.). The MMU has provisions for what is referred to as **common RAM**. This is the RAM that does not bank, and is programmable in size and as to whether it appears at the top, bottom, or both in the memory map. The size is set by bits 0 and 1 in the **RAM Configuration Register (RCR)**. If the value of the bits is zero, 1K will be common. Values of one, two, and three produce common areas of 4K, 8K, and 16K respectively. If bit 2 of the RCR is set, bottom memory is held common, if bit 3 is set, then top memory is common. In all cases, common RAM is physically located in bank 0.

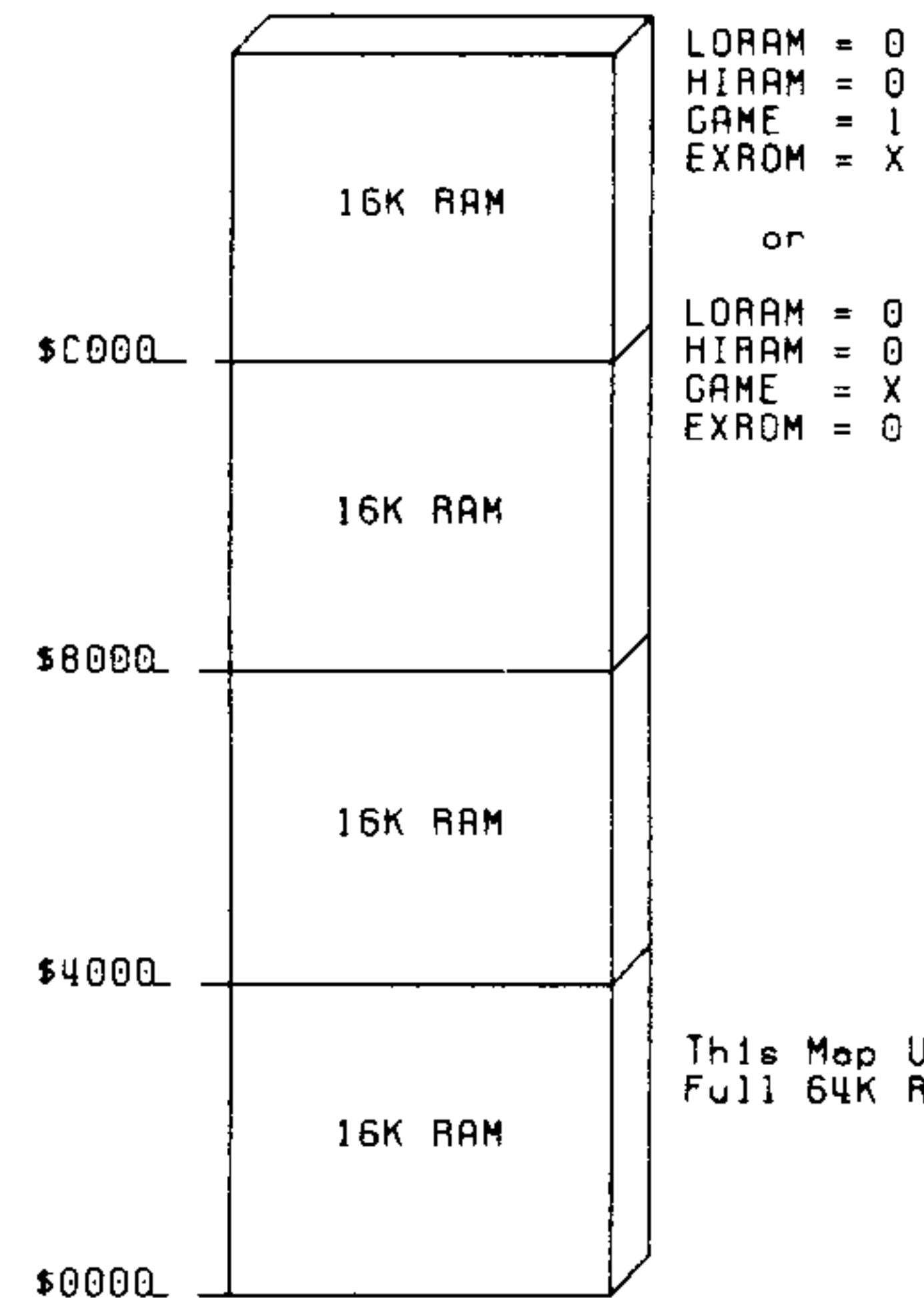
## MEMORY ARCHITECTURE (Continued)



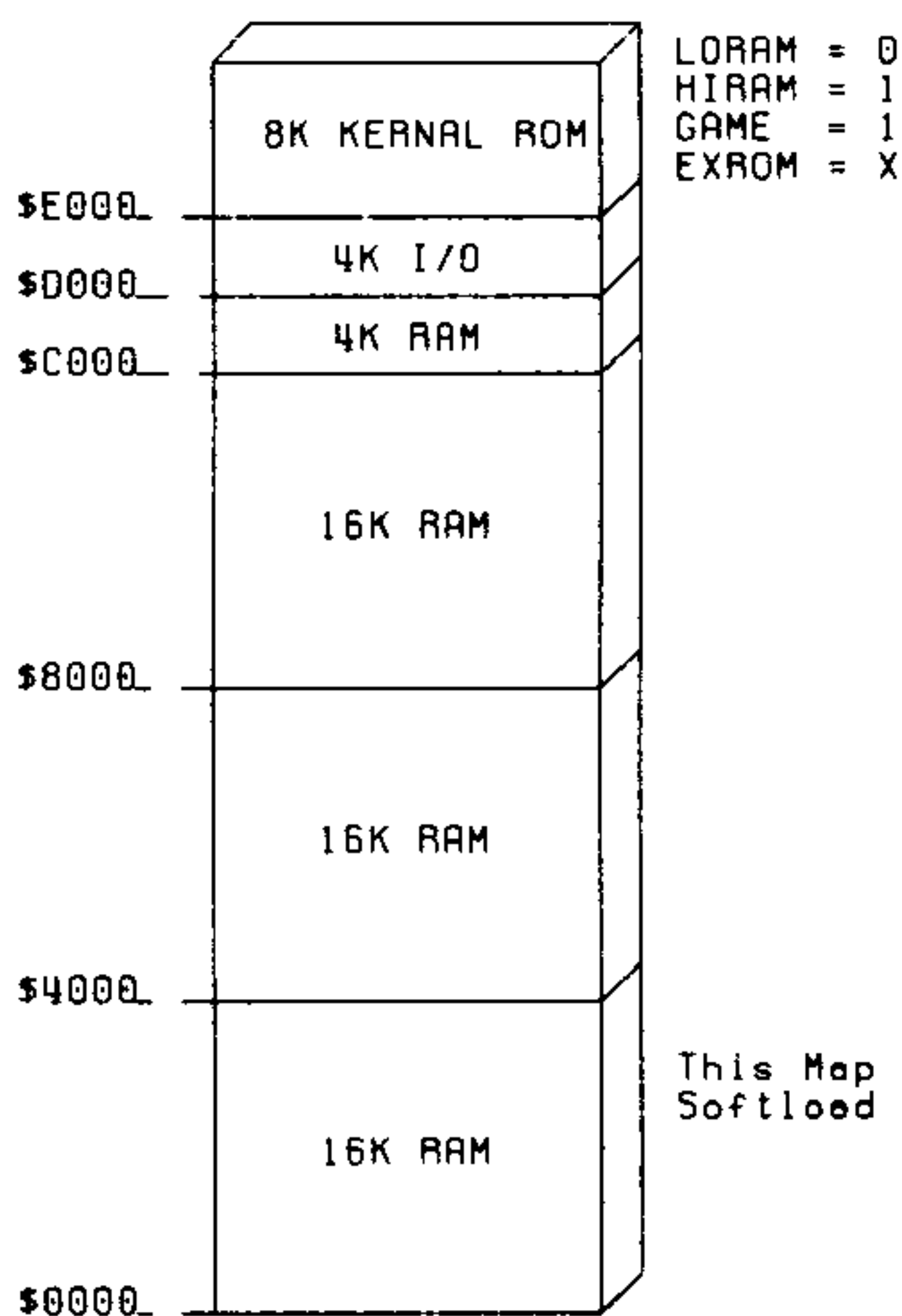
This Map is the Default Memory Map



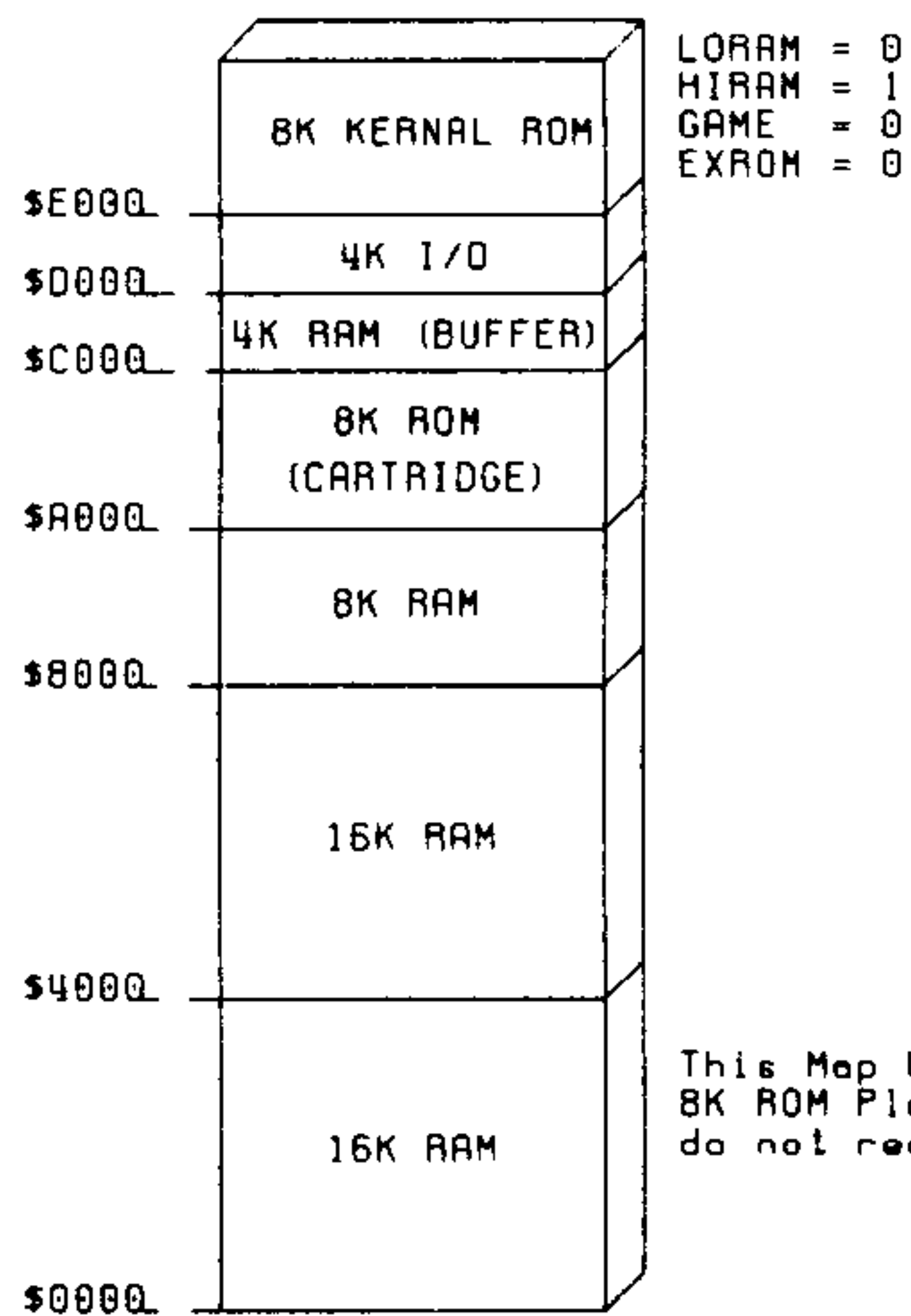
This Map Used For 60K of RAM and I/O. Note that the second setup removes the character ROM.



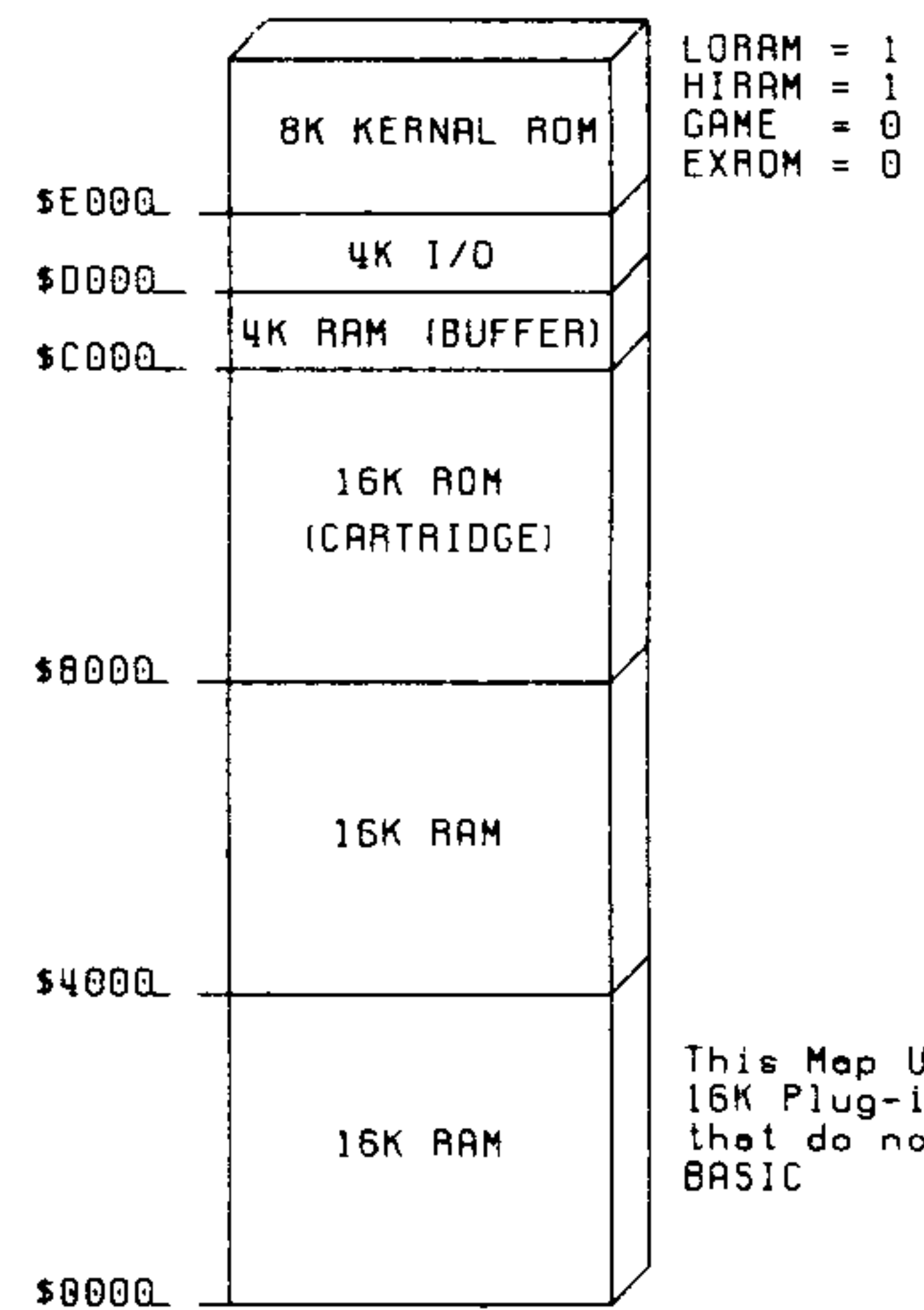
This Map Used For Full 64K RAM Access



This Map Used For Softloaded Languages



This Map Used For 8K ROM Plug-ins that do not require BASIC



This Map Used For 16K Plug-in ROMs that do not require BASIC

### C64 Alternate Memory Configurations

Zero page and page one can be located (or relocated) independently of the RCR. When the processor accesses an address that falls within zeropage or page one, the MMU adds to the high order  $\mu$ Processor address, the contents of the P0 register pair or the P1 register pair, respectively, and puts this new address on the bus, including the extended addressing bit A<sub>16</sub>. RAM banking will occur as appropriate to access the new address. Writes to the P0 and P1 registers will be stored in a pre-latch, until a write to the respective P<sub>X</sub>L register occurs. This prevents a P<sub>X</sub>H register from affecting the translated address until both high and low bytes have been written.

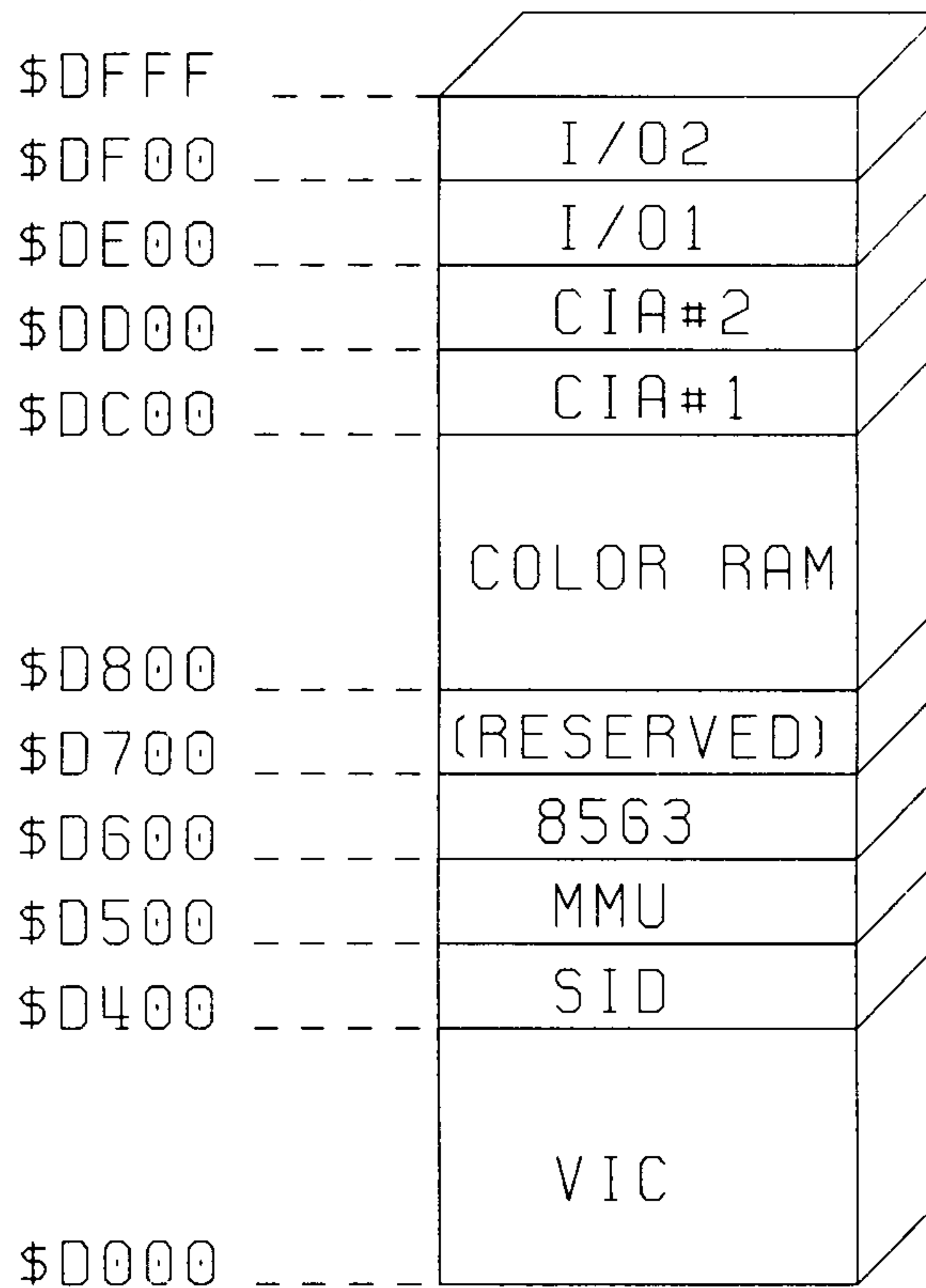
At the same time, the contents of the P0 and P1 registers are applied to a digital comparator, and a reverse substitution occurs if the address from the 8502 falls within the page pointed to by the register. This results in not just relocating the zero or one page but swapping the zero or one page with the memory that it replaced. Swapping only occurs if the swapped area is defined as RAM, i.e., System or Function ROM must always be at their assigned addresses and thus should not be back-substituted. Note that upon system reset, the pointers are set to true zero and true one page.

For VIC chip access, one bit in the MMU status register is substituted for extended address line A<sub>16</sub>, selecting the proper CAS enable to make it possible to steer the VIC to anywhere in the 128K range. Note that AEC is the mechanism that the MMU uses to steer a VIC space address, i.e., when AEC is low a VIC access is assumed. This results in the VIC bank being selected as well for an outside DMA, since this too will pull the AEC line low.

## MEMORY ARCHITECTURE (Continued)

### MMU and I/O Memory Organization

The block of memory represented by the **I/O Block** is an expanded view of the memory block entitled **I/O + CHAROM**, as shown in the C128 memory map. When the I/O block exists, access to VIC, SID, and I/O, as well as the addition of the MMU can be accomplished. All I/O functions remain as they were previously on the C64 with the exception that the MMU and the 80 Column chip have been added. With the exception of four registers that are asserted in the zero page in C128 mode, all new MMU registers appear in an unused slot in the I/O Memory block, though they will only appear in C128 mode. Detailed descriptions of the MMU registers can be found in the MMU section on page 20.



**I/O Block**



# READ ONLY MEMORY

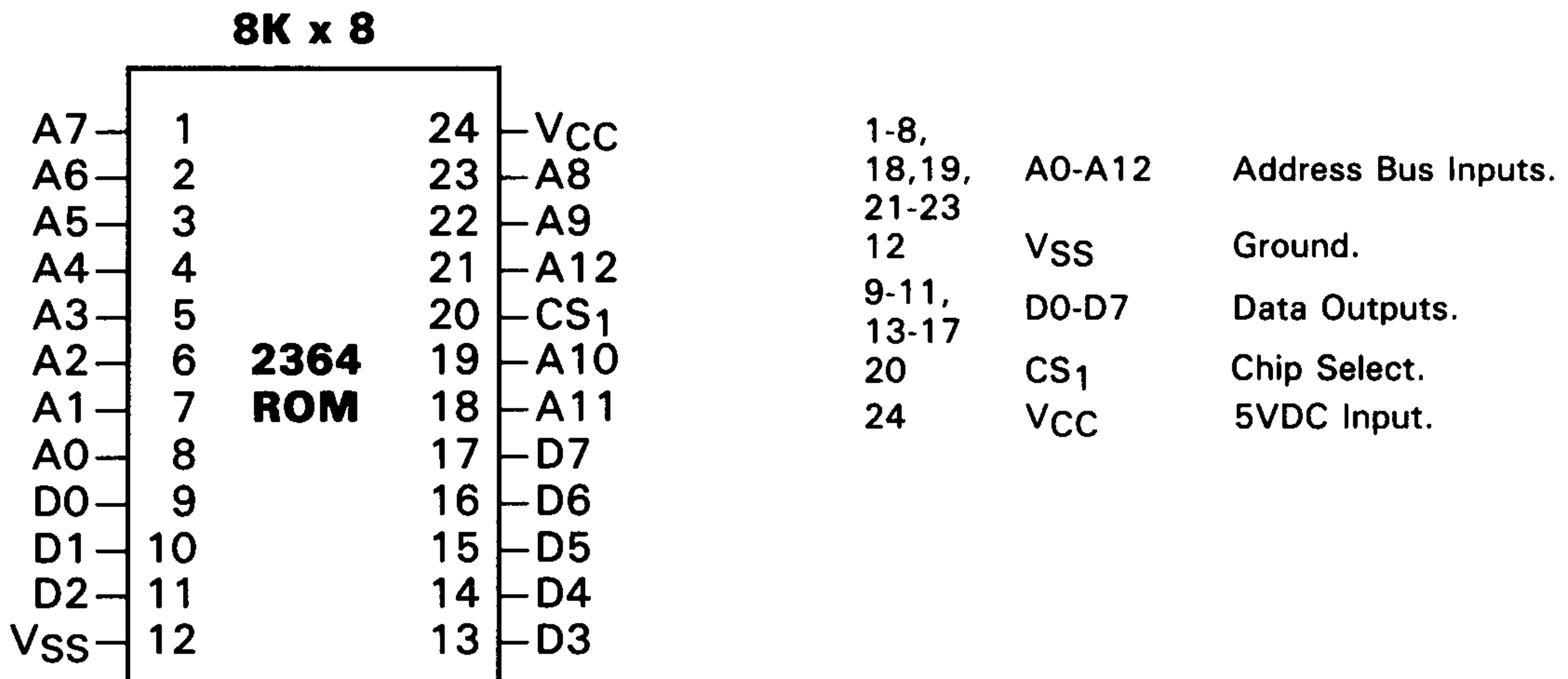
**FOLD OUT SCHEMATIC SHEETS 3 AND 4, PAGES 75 AND 76, FOR EASY REFERENCE.**

In C64 mode, the operating system resides in 16K of ROM, which includes approximately 8K for Kernal and 8K for Basic. In C128 mode, the operating system resides in 48K of ROM and includes advanced Kernal and Basic features. The Kernal, by definition, is the general operating system of the computer, with fixed entry points into usable subroutines. The entry table for the Kernal is located in memory at addresses \$FF40 - \$FFF9, excluding of course the MMU registers at \$FF00 - \$FF04. There is also a CHARACTER ROM, 8K x 8, which resides on the Shared Bus, shared by the VIC chip and the processor. The C64 OS ROM is wired so as to appear as two chunks of non-contiguous ROM, copying the actual C64 ROM memory map. Provision is included to handle system ROM as either four 16K x 8 ROMs or as two 32K x 8 ROMs. All internal C128 function ROMs will be the 32K x 8 variety.

## Rom Banking

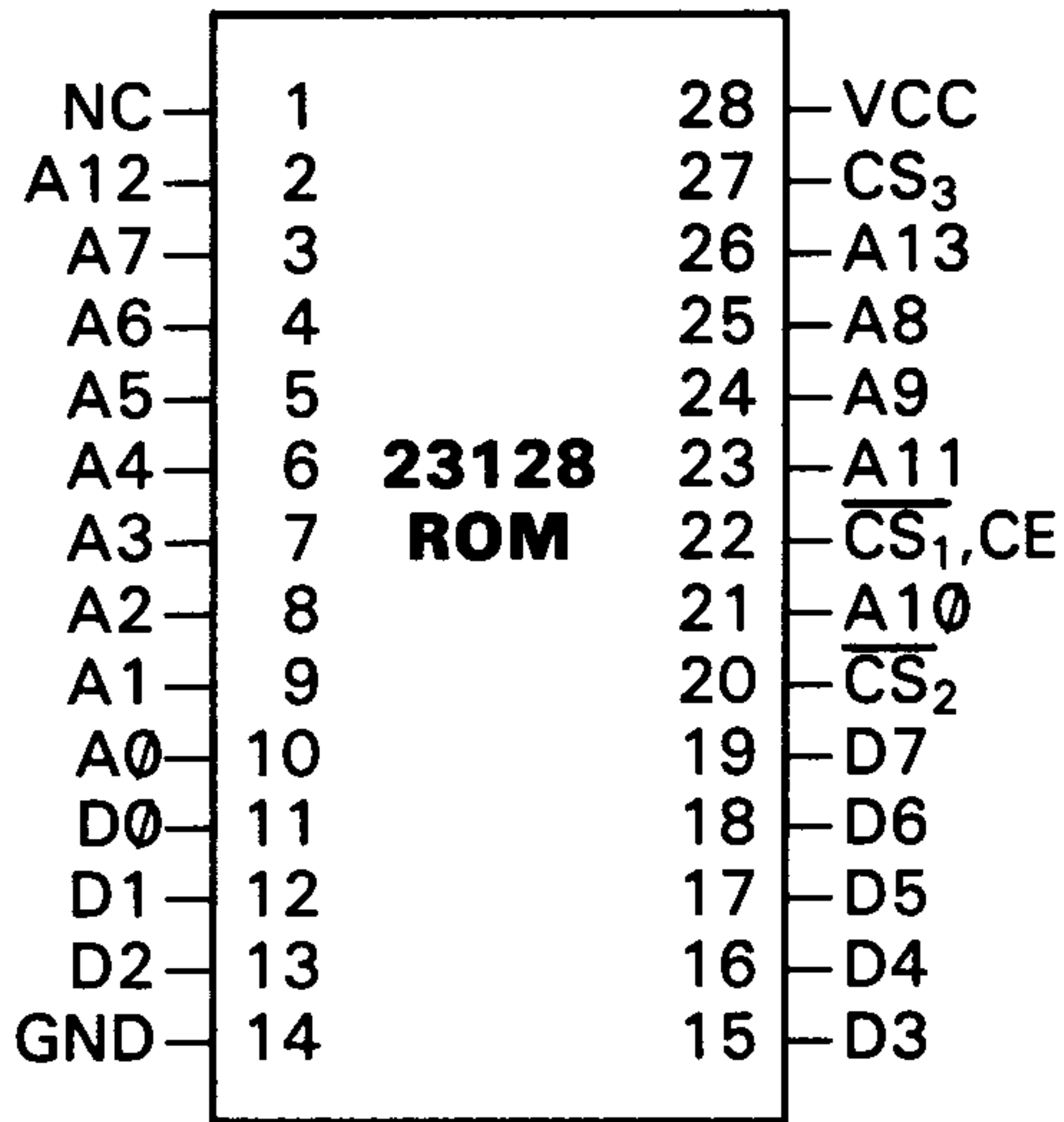
Refer to the **MMU Register Map** on page 20. Note that the Configuration Register (CR) controls the type of ROM or RAM seen in a given address location. Dependent on the contents of the CR, ROM may be enabled and disabled to attain the most useful configuration for the application at hand. ROM is enabled in three memory areas in C128 mode, each consisting of 16K of address space. The lower ROM may be defined as RAM or System ROM, the upper two ROMs may be System ROM, Function ROM, Cartridge ROM, or RAM. In C64 mode the C64 memory mapping rules apply, which are primitive compared to those used in C128 mode. C64 ROM is banked as two 8K sections, BASIC and KERNAL, according to the page zero port and the cartridge in place at the time. No free banking can take place when a cartridge is in place.

In the C128, if an address falls into the range of an enabled ROM, the MMU will communicate the status of ROM to the PLA decoder via the Memory Status lines. Essentially, the MMU looks up in the Configuration Register which ROM or RAM is set. The various combinations possible are shown on the **C128 Memory Map** found on page 11. The banking scheme, the way it is implemented, allows up to 32K of internal, bankable ROM for use such as Function Key Applications programs, and will support 32K of external bankable ROM. Various combinations of ROM are possible, and can be noted by studying the configurations for the Configuration Register.



**READ ONLY MEMORY (Continued)**

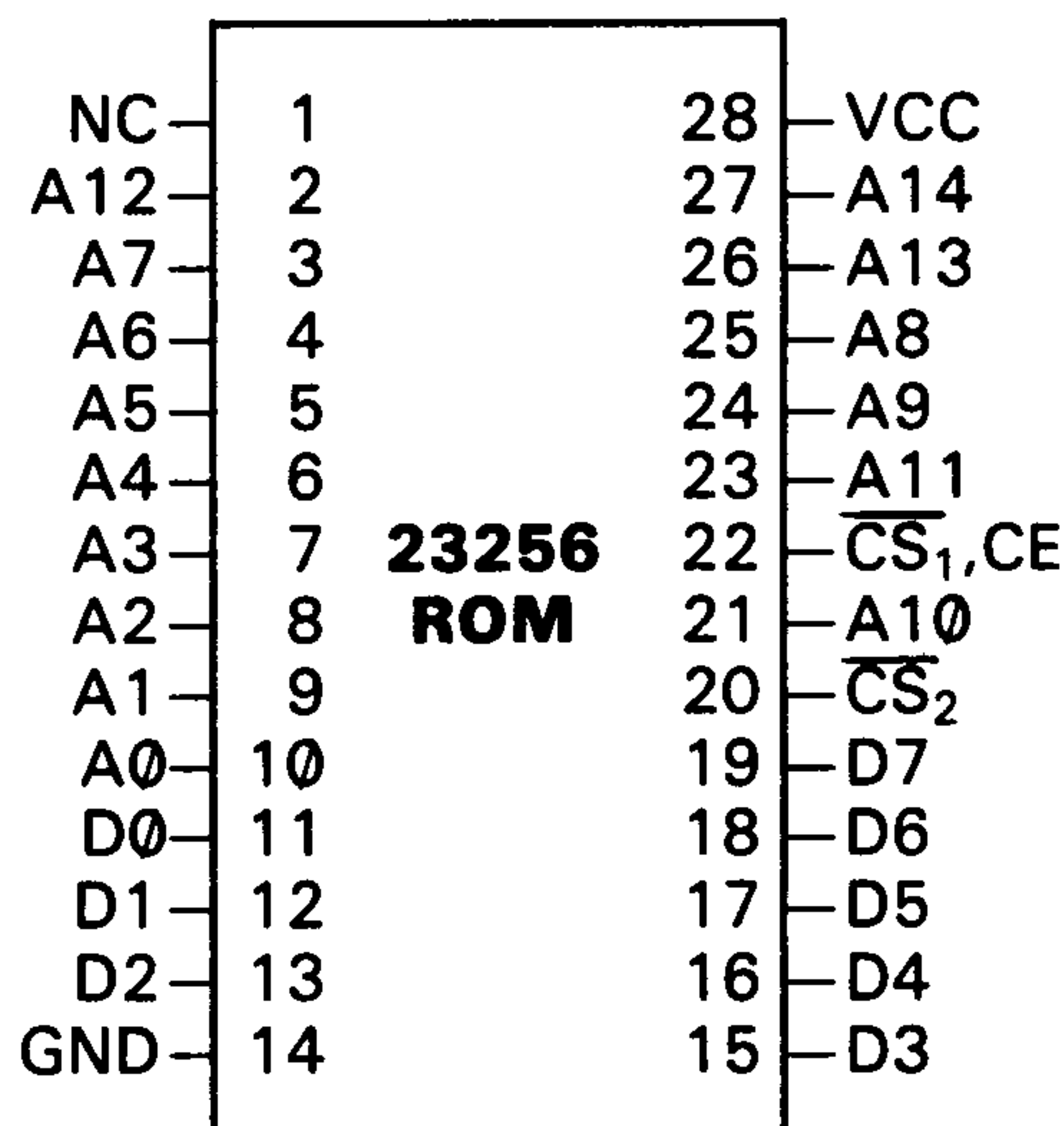
**PIN CONFIGURATION**



**16K x 8 ROM**

|                       |                      |                     |
|-----------------------|----------------------|---------------------|
| 1                     | NC                   | Not Connected.      |
| 2-10,<br>21,<br>23-26 | A0-A13               | Address Bus Inputs. |
| 11-13,<br>15-19       | D0-D7                | Data Outputs.       |
| 14                    | GND                  | Ground.             |
| 20                    | CS <sub>2</sub>      | Chip Select.        |
| 22                    | CS <sub>1</sub> , CE | Output Enable.      |
| 27                    | CS <sub>3</sub>      | Program Enable.     |
| 28                    | VCC                  | 5VDC Input.         |

**PIN CONFIGURATION**



**32K x 8 ROM**

|                       |                      |                     |
|-----------------------|----------------------|---------------------|
| 1                     | NC                   | Not Connected.      |
| 2-10,<br>21,<br>23-27 | A0-A14               | Address Bus Inputs. |
| 11-13,<br>15-19       | D0-D7                | Data Outputs.       |
| 14                    | GND                  | Ground.             |
| 20                    | CS <sub>2</sub>      | Chip Select.        |
| 22                    | CS <sub>1</sub> , CE | Output Enable.      |
| 28                    | VCC                  | 5VDC Input.         |

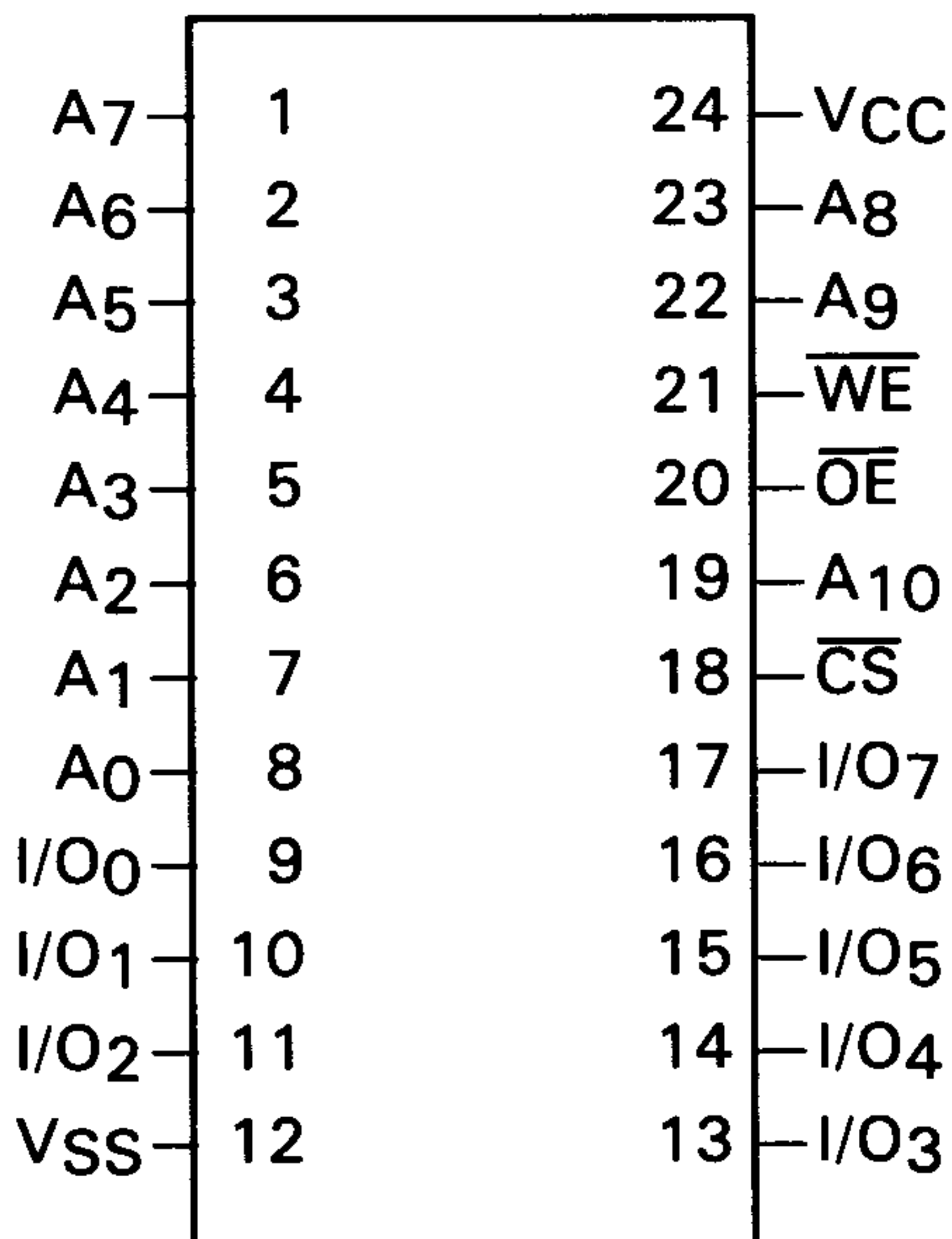
# RANDOM ACCESS MEMORY

**FOLD OUT SCHEMATIC SHEETS 3 AND 4, PAGES 75 AND 76, FOR EASY REFERENCE.**

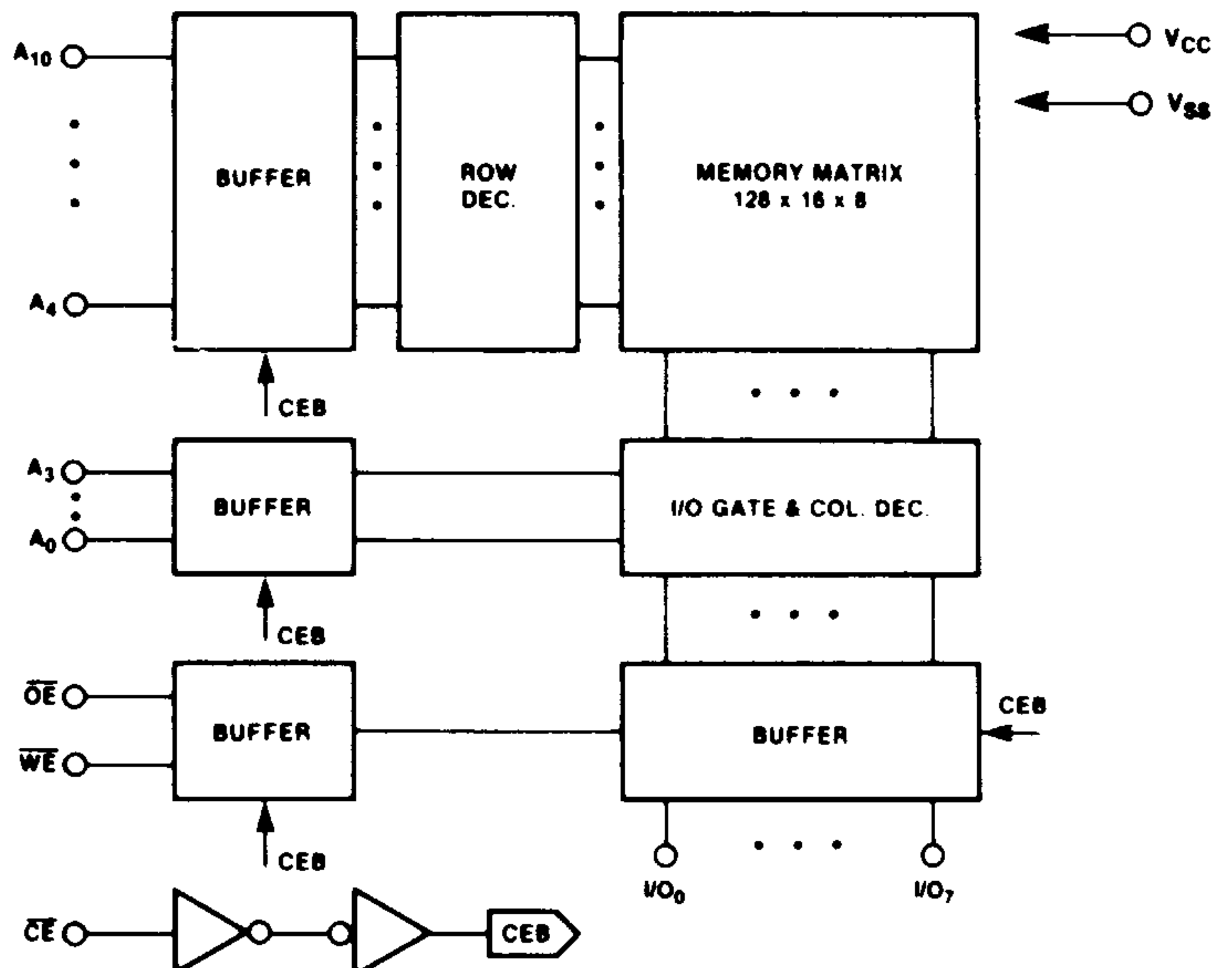
The C128 System contains 128K of processor-addressable 4164 DRAMs in the 64K x 1 configuration, organized into two individual 64K banks. Additionally, the system contains 16K of video display 4416 DRAMs (16K x 4) local to the 8563 CRT Controller, and 8K of STATIC RAM used as VIC COLOR RAM.

RAM banking, described in detail in the MMU section, is controlled by several MMU registers: the Configuration Register, the RAM Configuration Register, and the Page Zero and Page One Pointers. Simply put, the Configuration register controls which 64K bank of RAM is selected, the RAM Configuration Register controls if and how much RAM is kept in common between banks, and the Pointer registers redirect the zero and one pages to any page in memory, overriding the effect of the two configuration registers. In the system, RAM bank select is achieved via gated CAS control.

## 2016 2K x 8 STATIC RAM



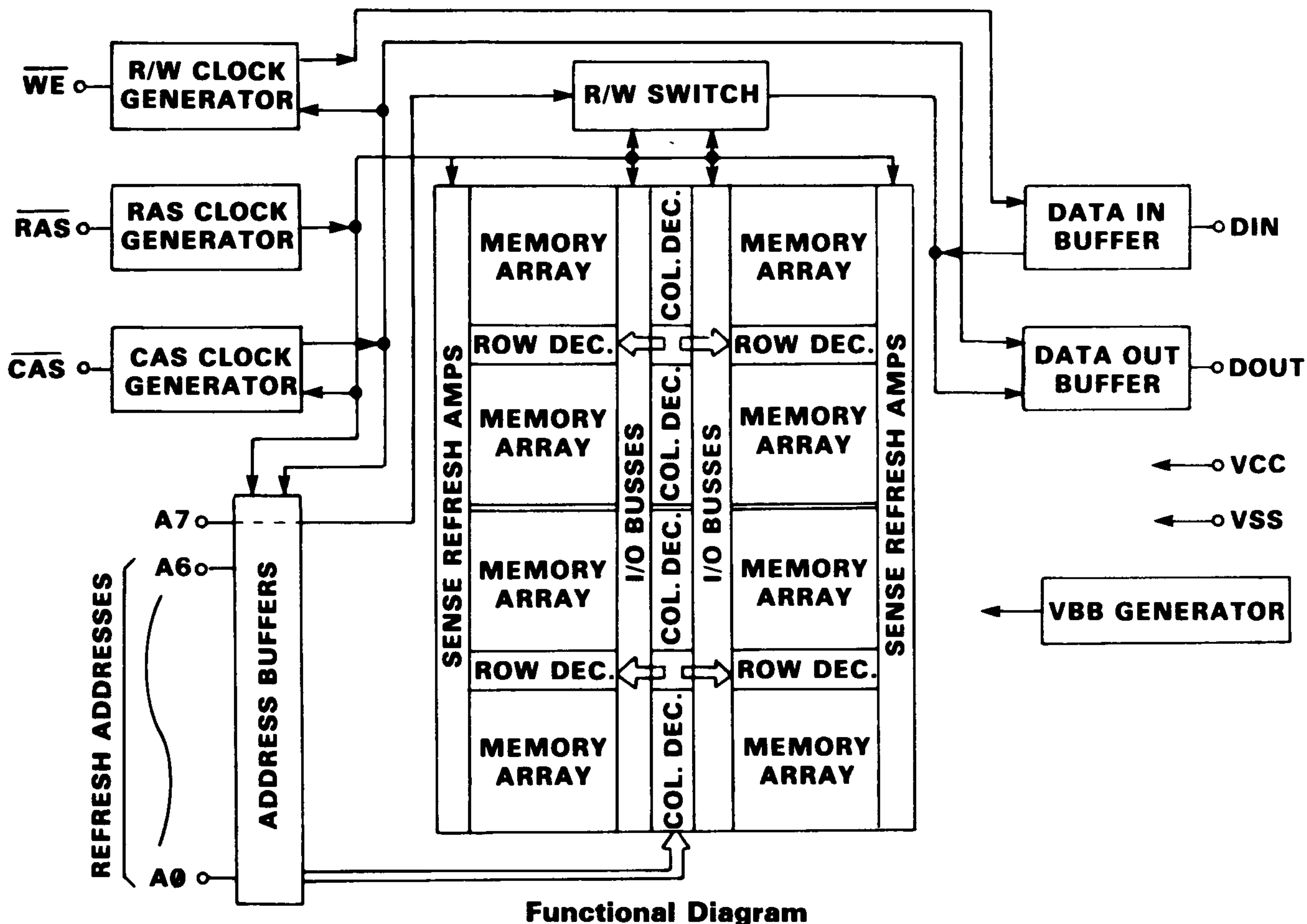
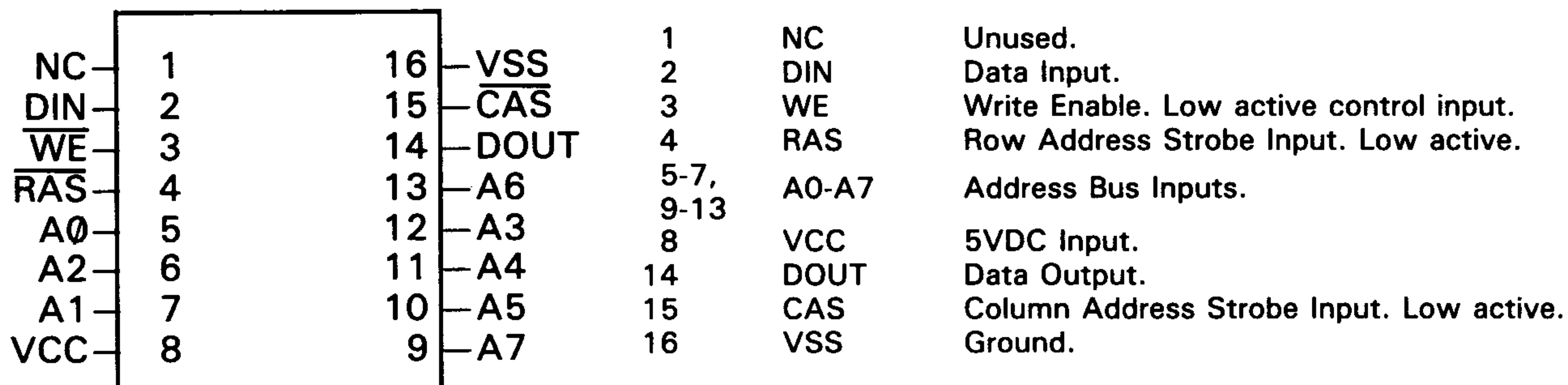
- 1-8, 19, 22 A0-A10 Address Bus Inputs.
- 23
- 9-11, I/O0-I/O7 Common Data Input/Output Lines.
- 13-17
- 12 VSS Ground.
- 18 CS Chip Select Enable, Low Active.
- 20 OE Output Enable, Low Active.
- 21 WE Write (Input) Enable, Low Active.
- 24 VCC 5VDC Input.



**Functional Diagram**

# RANDOM ACCESS MEMORY (Continued)

## 4164 64K x 1 DYNAMIC RAM

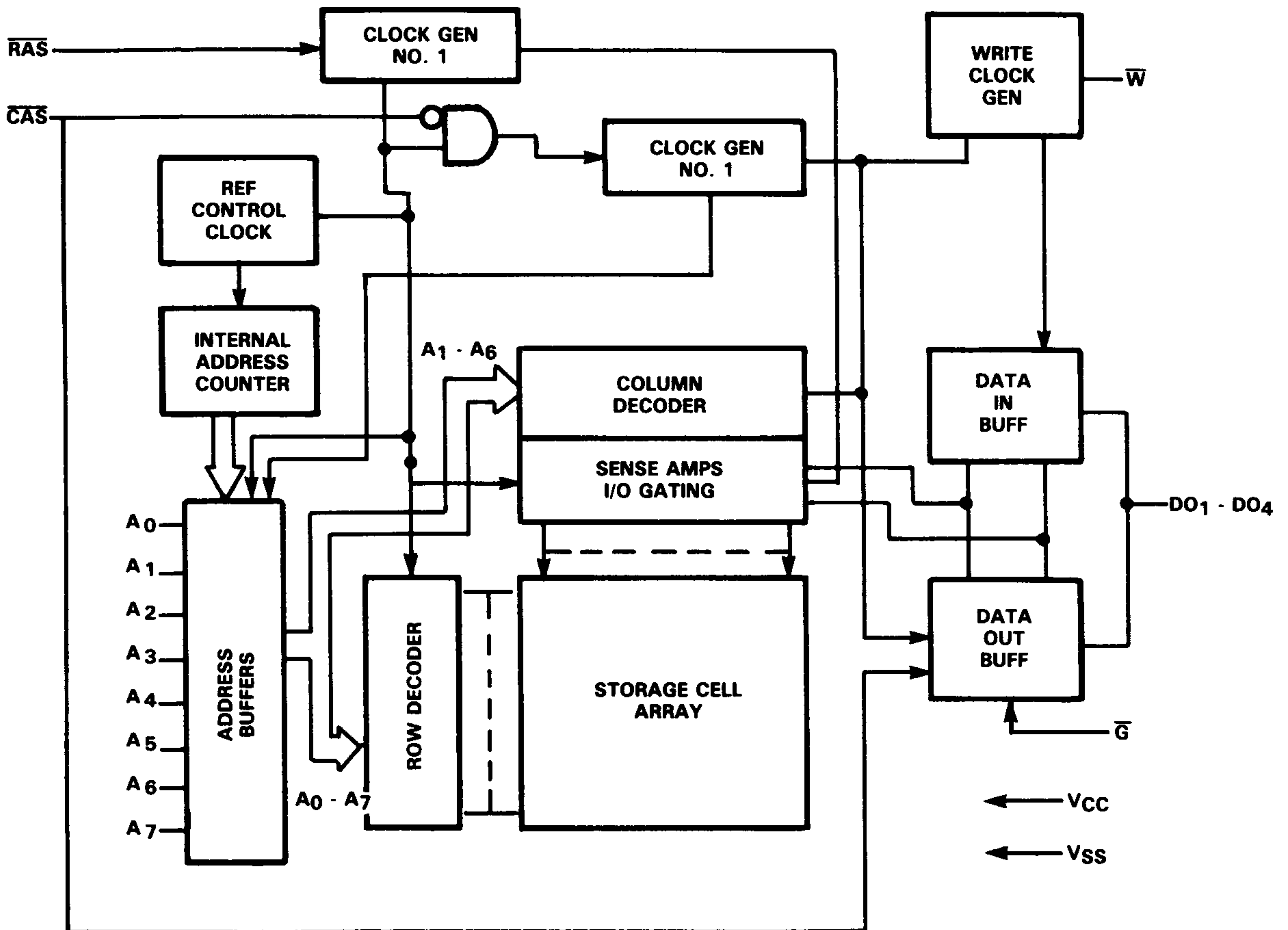


Functional Diagram

# RANDOM ACCESS MEMORY (Continued)

## 4416 16K x 4 DYNAMIC RAM

|        |   |    |     |           |        |                                    |
|--------|---|----|-----|-----------|--------|------------------------------------|
| ENABLE | 1 | 18 | VSS | 1         | ENABLE | Output Enable ( $\bar{G}$ ).       |
| D0     | 2 | 17 | D3  | 2,3,15,17 | D0-D3  | Common Data Input/Output Lines.    |
| D1     | 3 | 16 | CAS | 4         | WE     | Write (Input) Enable. Low Active.  |
| WE     | 4 | 15 | D2  | 5         | RAS    | Refresh Address. Low Active.       |
| RAS    | 5 | 14 | A0  | 6-8,10-14 | A0-A7  | Address Bus Inputs.                |
| A6     | 6 | 13 | A1  | 9         | VDD    | 5VDC Input.                        |
| A5     | 7 | 12 | A2  | 16        | CAS    | Column Address Strobe. Low Active. |
| A4     | 8 | 11 | A3  | 18        | VSS    | Ground.                            |
| VDD    | 9 | 10 | A7  |           |        |                                    |



Functional Diagram

# THE MEMORY MANAGEMENT UNIT

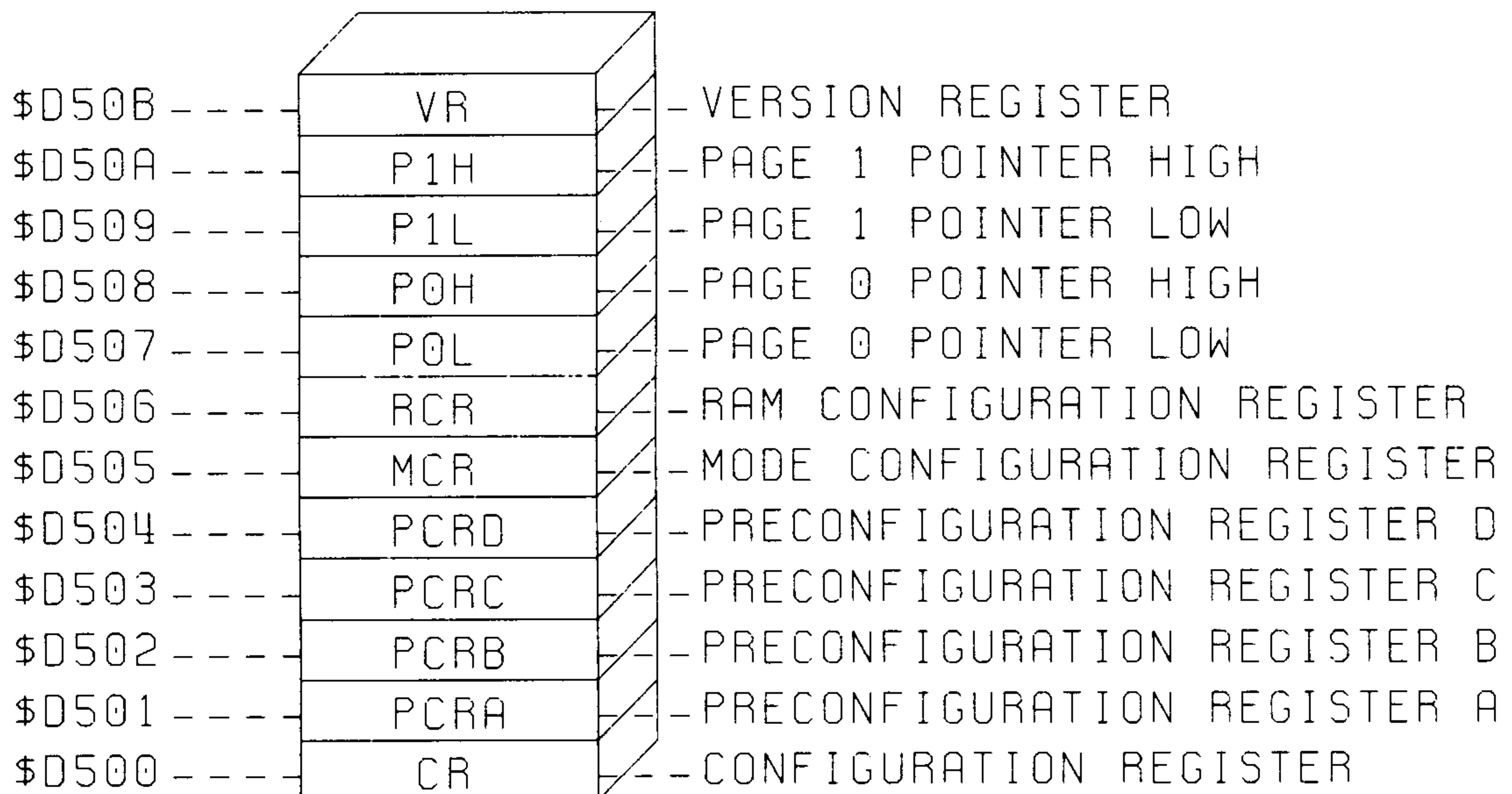
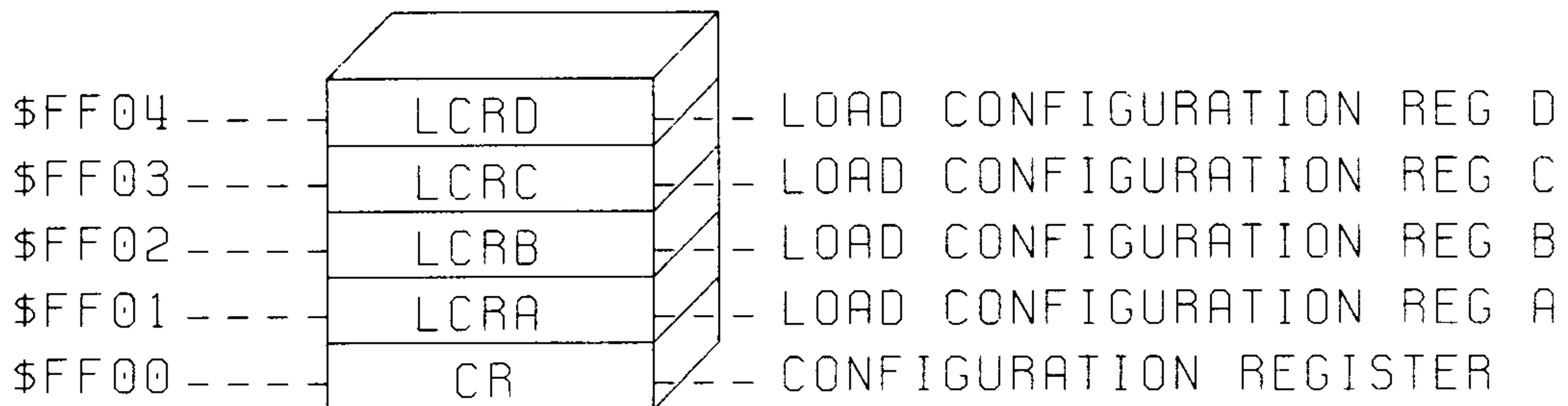
**FOLD OUT SCHEMATIC SHEET 2, PAGE 74, FOR EASY REFERENCE.**

The MMU is designed to allow complex control of the C128 system memory resources. It handles all of the standard **C64 modes of operation** in a fashion as to be completely compatible with the C64. Additionally, it controls the management of particular C128 modes including the Z-80 mode.

Summary of MMU functions:

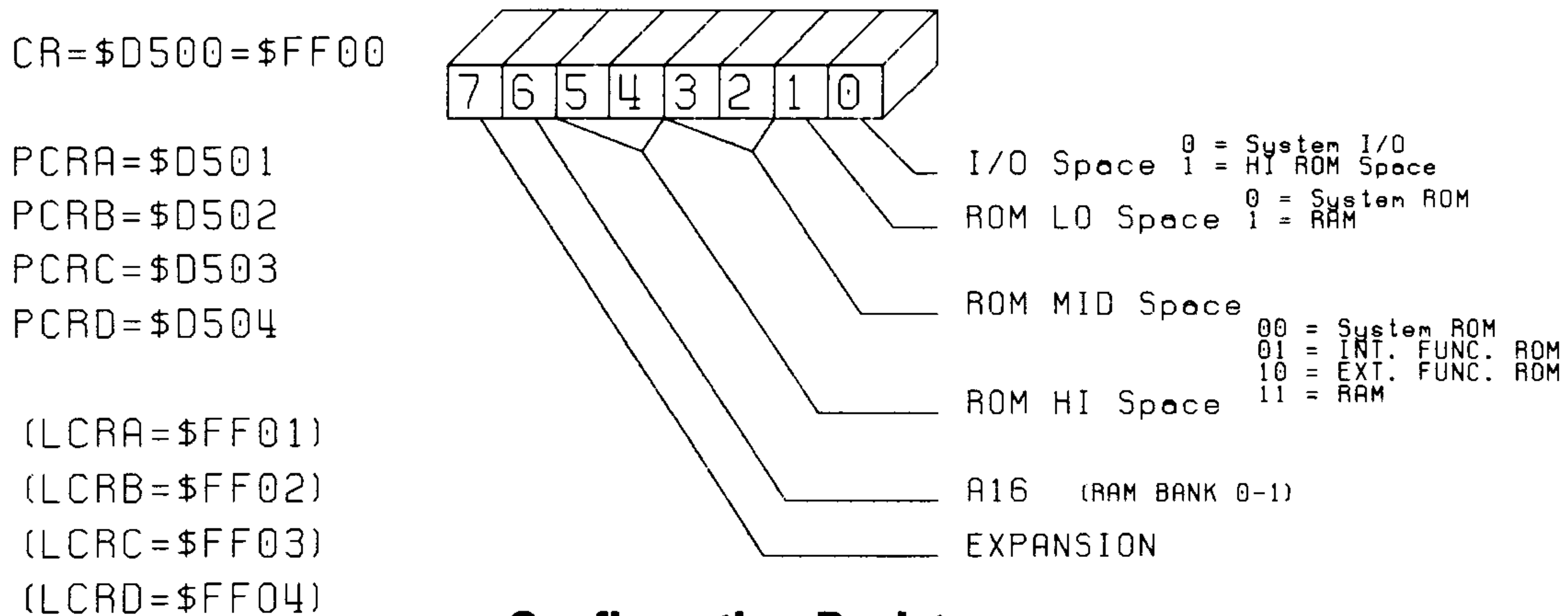
- Generation of Translated Address Bus, TA<sub>8</sub> – TA<sub>15</sub>.
- Generation of control signals for different processor modes – C128, C64, Z-80.
- Generation of CAS select lines for RAM banking.
- Generation of ROMBANK (MS<sub>0</sub>, MS<sub>1</sub>) lines for ROM banking.

The MMU is the mechanism by which the various memory modes shown in the C128 Memory Map are chosen. Additionally, the MMU provides for Z-80 mode, which was not shown on that diagram. Following is a description of the MMU register types. Note that in C64 mode the MMU completely disappears from the system's memory map. Note that the data out of the MMU is valid **only** on AEC high. This is necessary to avoid bus contention during a VIC cycle.



**MMU Register Map**

## THE MEMORY MANAGEMENT UNIT (Continued)



**Configuration Register  
Preconfiguration Register**

### The Configuration Register

The **Configuration Register**, CR, controls the ROM, RAM, and I/O configuration of the C128 system. It is located at \$D500 in I/O space and at \$FF00 in system space. Some of the bits in this register are at times reflected by hardware lines MS<sub>0</sub> and MS<sub>1</sub> in C128 mode, depending upon how RAM and ROM have been set. These MS lines are used to inform the PLA about the type of memory in a particular address range. In C64 mode, MS<sub>0</sub> and MS<sub>1</sub> are always high, and the selection of RAM and ROM is done by the PLA using standard C64 banking methods. The MS lines are alternately referred to as ROMBANK lines. They will be referred to as MS lines in this section in the interest of simplicity.

In C128 mode, bit 0 controls whether an I/O space, \$D000 — \$DFFF, or a ROM/RAM access occurs. A low will select I/O, a high will enable some kind of ROM/RAM access, the nature of which is controlled by other bits in this register. The value of this bit is stored in a pre-latch, until the fall of the clock, in order to prevent its changing in an unstable situation. Note that when not I/O space, the ROM/RAM access is controlled by the defined ROM Hi configuration bits, which are described later. This bit resets to 0. When the I/O bit is low, MMU registers \$D500 to \$D50B will assert themselves. When the bit is high, these registers disappear from the memory map. MMU registers \$FF00 to \$FF04 are always available in C128 mode. The hardware line I/OSE always reflects the polarity of this bit when in C128 mode. In C64 mode the I/OSE line, the hardware line driven by this bit, is completely ignored by the PLA, and the MMU is never asserted, even when C64 I/O is enabled. The C64 method of selecting I/O via HIROM and CHAREN takes over here. The I/O hardware line remains in its set state when in C128 mode, even though it has no effect in this mode.

Bit number 1 controls processor access to ROM low space, \$4000 — \$7FFF, in C128 mode. If the bit is high, the area will appear as RAM, and a RAM access, CAS enable, will be generated to the appropriate RAM bank, which is determined by other bits in this register. If low, system ROM will be located in the space. This bit affects the memory status lines MS<sub>0</sub> and MS<sub>1</sub> which are decoded by the PLA to generate ROM chip selects. Selecting ROM here will drive both memory status lines low when the processor address falls within the specified low space range. This bit resets low to include the C128 Basic Low ROM. Of course in C64 mode, this bit is ignored.

The next two bits, bits 2 and 3, determine for C128 mode the type of memory that will be located in the mid space, \$8000 — \$BFFF. If they are both low, system ROM will be located here. If bit 2 alone is high, internal function ROM is located here. External function ROM appears for bit 3 being alone high, and RAM appears, along with the proper CAS generation, for both bits set high. These bits also affect the hardware memory access lines. When in the aforementioned mid block address range, MS<sub>0</sub> will reflect the status of bit 3, and MS<sub>1</sub> will reflect the status of bit 2. These bits both reset low to start out with Basic Hi. C64 mode ignores these bits.

## THE MEMORY MANAGEMENT UNIT (Continued)

Bits 4 and 5 determine the contents of the Hi block, \$C000 — \$FFFF, for C128 mode, and have no effect on C64 mode. As with the mid space, both bits zero will set up system ROM, bit 4 high will set up internal function ROM, bit 5 high will set up external function ROM, and both bits high will set up RAM. Note that the I/O configuration bit, when set for I/O space, will leave the area from \$D000 to \$DFFF as I/O space, regardless of the values of these bits. If not set for I/O space, \$D000 to \$DFFF will contain the character ROM if the ROM chosen is System ROM. As with the other ROM selection bits, these bits are reflected by the memory status lines when this region of address is accessed. Bit 5 corresponds to MS<sub>0</sub> and bit 4 to MS<sub>1</sub>. Both of these bits reset to low to permit Kernal and Character ROM to power up in this address space. Note that there is always a hole in high ROM during C128 mode for the MMU registers at \$FF00 to \$FF04. This hole is brought about by holding both MS lines high and both CAS enable lines high. These bits are ignored in C64 mode.

Finally, bit 6 controls the RAM bank selection. When low, it will select bank 0 by dropping CAS<sub>0</sub>. When high, it will select bank 1 by dropping CAS<sub>1</sub>. Bit 7 is unassigned at the present, left for future expansion. Note that a RAM share status that is non-zero will override the normal CAS enable generation to provide CAS<sub>0</sub> for all shared memory. Also, note that when the proper CAS enable is generated, any area of memory, even if that area does not have its ROM bank bits set for RAM, is accessed. It is up to the PLA to block CAS for a read from ROM. This allows RAM bleed through on a write to ROM. For any access to the MMU registers from \$FF00 to \$FF04, in any C128 mode configuration, both CAS enable lines and both MS lines will be high. Note that in C64 mode, the bank used follows the same rules as in C128 mode, though of course banks cannot be changed once in C64 mode.

### The Preconfiguration Mechanism

The Preconfiguration Mechanism is a feature of the MMU that allows the Configuration Register to be loaded with one of several memory configurations, with a minimum of time and memory on the part of the user. The scheme makes use of two sets of registers, the **Preconfiguration Registers** and the **Load Configuration Registers**.

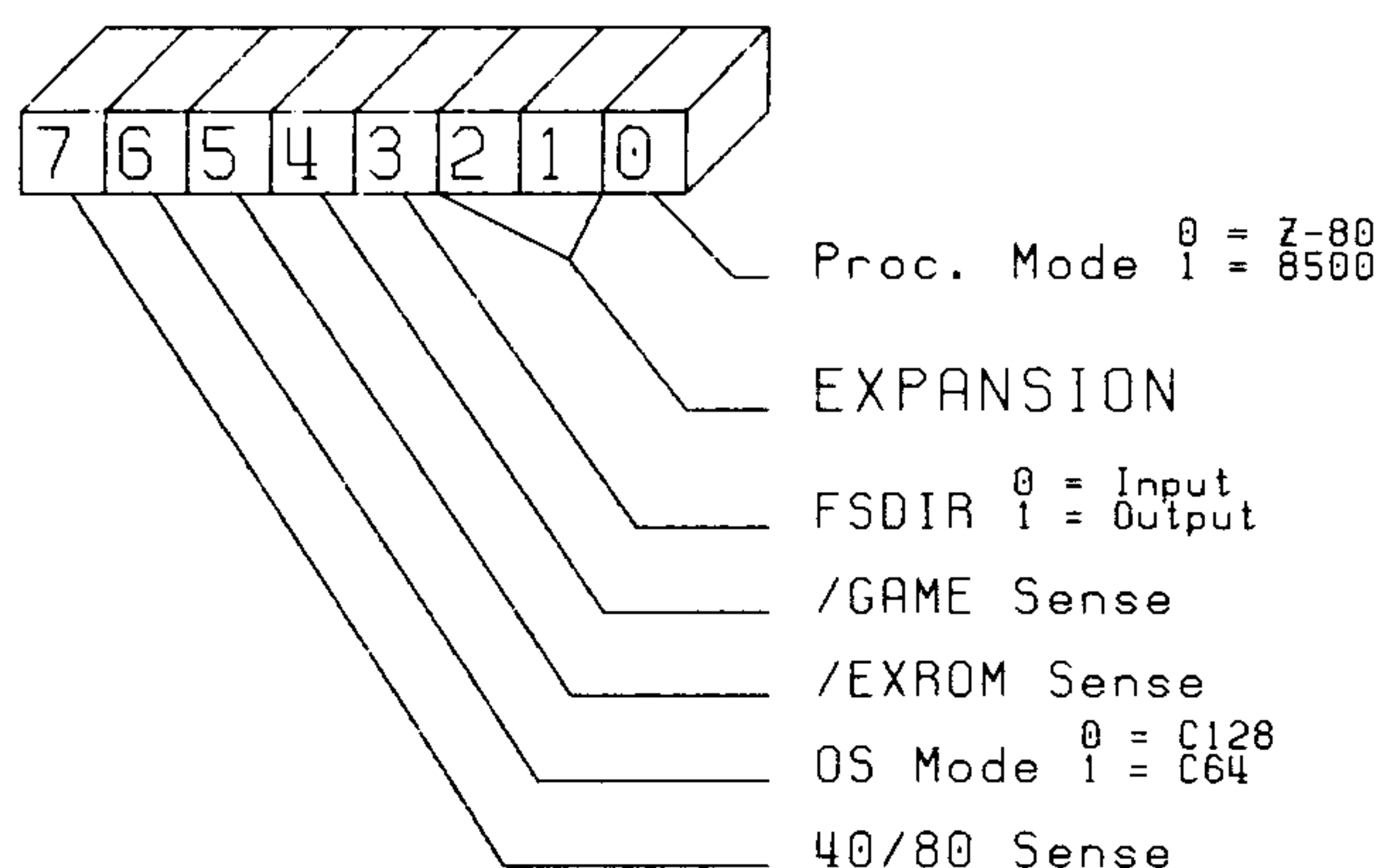
The Preconfiguration Registers (PCRA — PCRD) are used to store several different memory configurations that may be accessed with a single store instruction. The format of each preconfiguration register is the same as for the Configuration Register but, when a value is stored to a preconfiguration register, no immediate effect takes place. They occupy I/O space from \$D501 to \$D504. These registers always reset to all zeros.

Load Configuration Registers (LCRA — LCRD) directly correspond with the preconfiguration registers on a one-to-one basis. A write to a Load Configuration Register causes the contents of the corresponding Preconfiguration Register to be transferred to the Configuration Register. A read of any Load Configuration Register returns the value of its corresponding Preconfiguration Register. Load Configuration Registers are located in system space from \$FF01 to \$FF04. Neither the Load Configuration Registers nor the Preconfiguration Registers have any effect in C64 mode. These registers reset to all zeros. Note that these, and the configuration register at \$FF00, will **always** be available, completely independent of the ROM, RAM, or bank configuration defined for Hi ROM space. Any address in this range will cause the MMU to force both memory status lines and both CAS enable lines high.



## THE MEMORY MANAGEMENT UNIT (Continued)

MCR=\$D505



### Mode Configuration Register

#### The Mode Configuration Register

The control of the current system mode is governed by the **Mode Configuration Register, MCR**. It controls which processor, 8502 or Z-80, and which operating system mode, C64 or C128, is currently in operation, and handles other overhead of the different operating modes. This register is located in the I/O space at \$D505.

Several of the bits in this register function as bidirectional ports, including the FSDIR, GAME, EX-ROM, and 40/80 bits. This type of port functions like an output port. If a value is written to the port, its hardware line will reflect that value written, and a read will return that value. The only exception to this is if an external source is pulling down the corresponding port line. When pulled down, a read of the port will return a low. Once the external source has been removed, a read will return the value previously stored. Thus, as an input, the port can be driven low, but not high, by an external source. Under each bit description, both the input and output functions of each port bit will be described in detail.

The first bit, bit 0, controls which processor is enabled. It is reflected by the output line **Z80EN**. When low, it indicates that the processor is the Z-80. This is the reset configuration, and will cause the Z-80 processor to be active and all accesses to memory to follow the Z-80 mapping rules. In Z-80 mode, any address to RAM bank 0 in the range from \$0000 to \$0FFF will be translated to the corresponding address in the range from \$D000 to \$DFFF, where the Z-80 CP/M BIOS physically exists in System ROM. Additionally, the memory status lines MS<sub>0</sub> and MS<sub>1</sub>, will reflect system ROM (both low) for accesses in the range of the BIOS, and the page zero and page one offset pointers will be disabled. RAM can still be banked by the CR A<sub>16</sub> bit, which controls CAS<sub>0</sub> and CAS<sub>1</sub>. When in bank one, the BIOS ROM disappears, allowing the RAM from \$0000 to \$FFFF to be used by the system, and enabling the page zero and one offset pointers.

A change to this processor select bit is held in pre-latch until a clock transition, in order to prevent processor changing in the midst of an instruction execution. Bringing this bit high will cause the Z-80 to be disabled and the 8502 to take over. Upon system power up, the Z-80 will turn itself off and bring up C128 mode by setting this bit and allowing the 8502 to take over.

Bits 1 and 2 are unused, but are reserved for future expansion as possible port lines. Currently, they will return high if read, and cannot be written to.

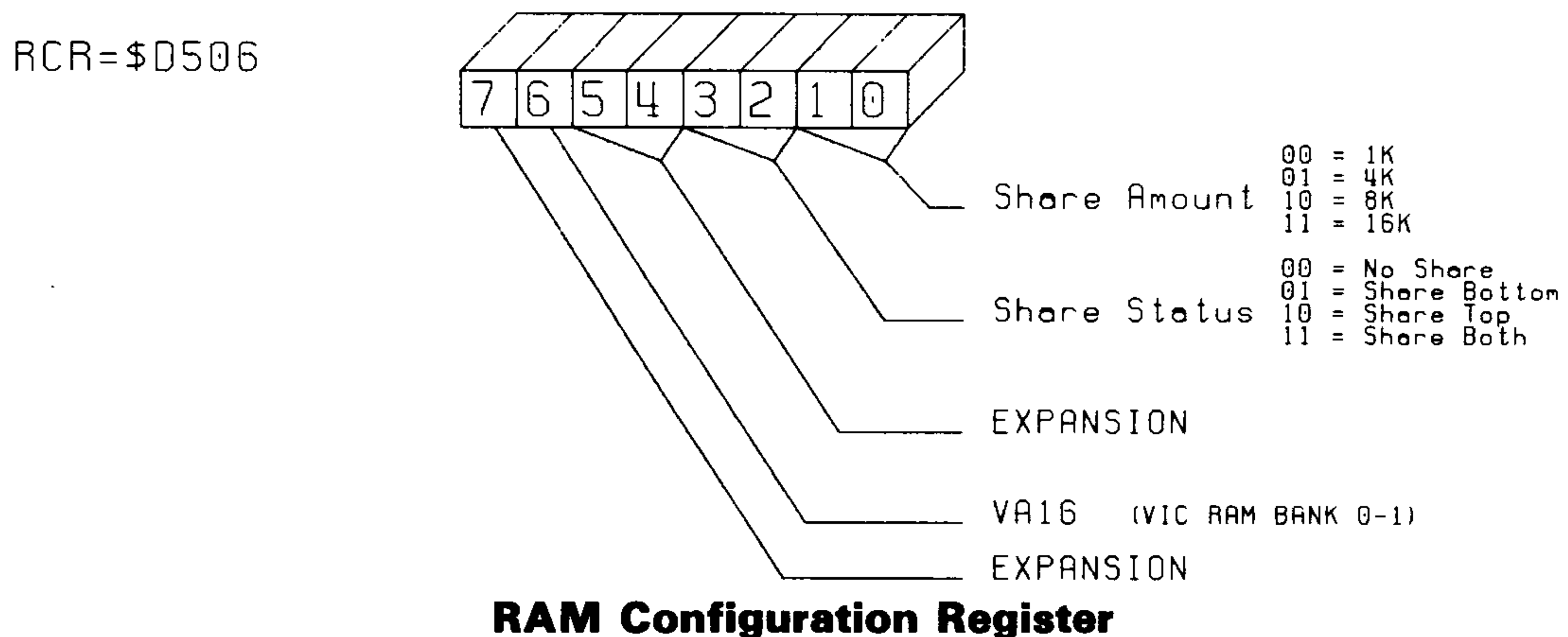
Bit 3 is the **FSDIR** control bit. It is used as an output to control the fast serial disk data direction buffer hardware, and as an input to sense a fast disk enable signal. This bit is a bidirectional port bit as explained above, and its hardware line is called **FSDIR**.

## THE MEMORY MANAGEMENT UNIT (Continued)

Bits 4 and 5 are the  $\overline{\text{GAME}}$  and  $\overline{\text{EXROM}}$  sense bits, respectively, which are implemented as bidirectional ports as explained above. As inputs, they directly reflect the hardware cartridge control lines  $\overline{\text{GAME}}$  and  $\overline{\text{EXROM}}$  as used in C64 mode. C128 cartridges do not use  $\overline{\text{EXROM}}$  and  $\overline{\text{GAME}}$ , so if they are detected in C128 mode, a C64 cartridge is present and C64 mode should be asserted. They have no dedicated C128 function.

The operating system mode is set by bit 6. This bit is cleared to zero upon reset and its presence enables all MMU registers and other C128 features, as well as asserting the C128 control line in hardware. Setting this bit removes the MMU from the memory map and sets the system up in C64 mode. Note that the C128 MS3 hardware line reflects a logical inversion of the level of this bit.

Bit 7 is used to detect the status of the screen mode switch, as presented in hardware to the Sense40 column pin. If this bit is high, the 40/80 column switch is open, if low, the switch is closed. The display mode will be set according to a software interpretation of this bit. This bit is a bidirectional port bit, but its output function is undedicated at this time.



### The RAM Configuration Register

The **RAM Configuration Register** sets up the RAM segmenting parameters for both the processor and the block pointer for the VIC chip. This register is located in the I/O space at \$D506.

Bits 0 and 1 function together to determine the size of the RAM to be shared between banks, assuming that sharing is enabled. With common RAM, the RAM bank bits of the configuration register are basically overridden, as the selected bank of RAM will be used for the non-common areas, while bank 0 will be used for the specified common areas. ROM and I/O block configuration bits, however, are still important. If the value of the bits together is 0, then 1K of RAM is held common. If the value is 1, then 4K; 2, then 8K; 3, then 16K. These bits have no effect in C64 mode, and the reset value of both bits is defined to be zero.

Bits 2 and 3 function to determine how and if RAM is kept common. If both are low, no sharing takes place. If bit 2 is set, the bottom RAM is shared. If bit 3 is set, the top RAM is shared. Both may be set at the same time for sharing both top and bottom memory. The reset configuration sets both of these bits zero, such that no common memory is present.

The next two bits, numbers 4 and 5, are not used in this MMU. They are available for possible future expansion. They read low, and cannot be written to.

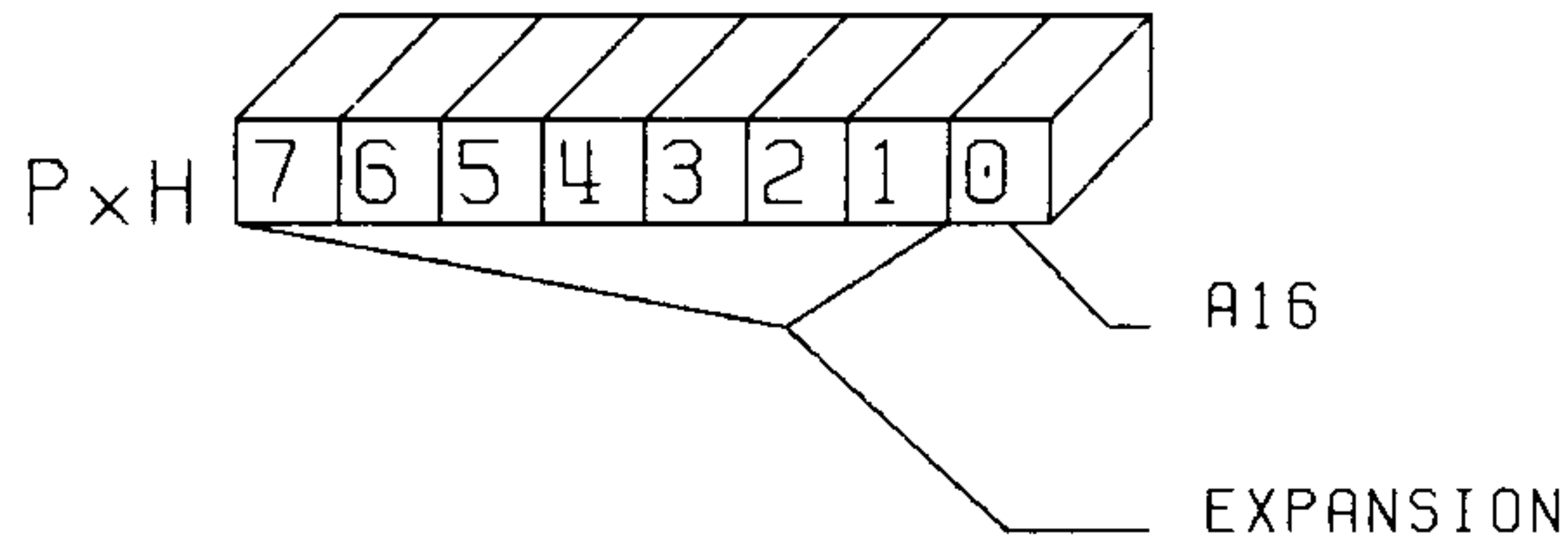
## THE MEMORY MANAGEMENT UNIT (Continued)

Bit 6 functions as a RAM bank pointer for VIC. It is used to drive CAS<sub>0</sub> low when set low or CAS<sub>1</sub> low when set high, thus selecting either RAM bank 0 or RAM bank 1 for the VIC, independently from the processor bank. When in 2 MHz mode the 80-column chip takes over, causing the VIC to be disabled. This disabling is affected by the VIC chip itself holding AEC constantly high, and thus is not directly effected by actions of the MMU. Note that since a VIC cycle is detected by AEC low, that any DMA will put the MMU into VIC configuration, as it too brings AEC low. This allows independent bank selection for DMAs in 80 column mode.

Bit 7 is currently unused.

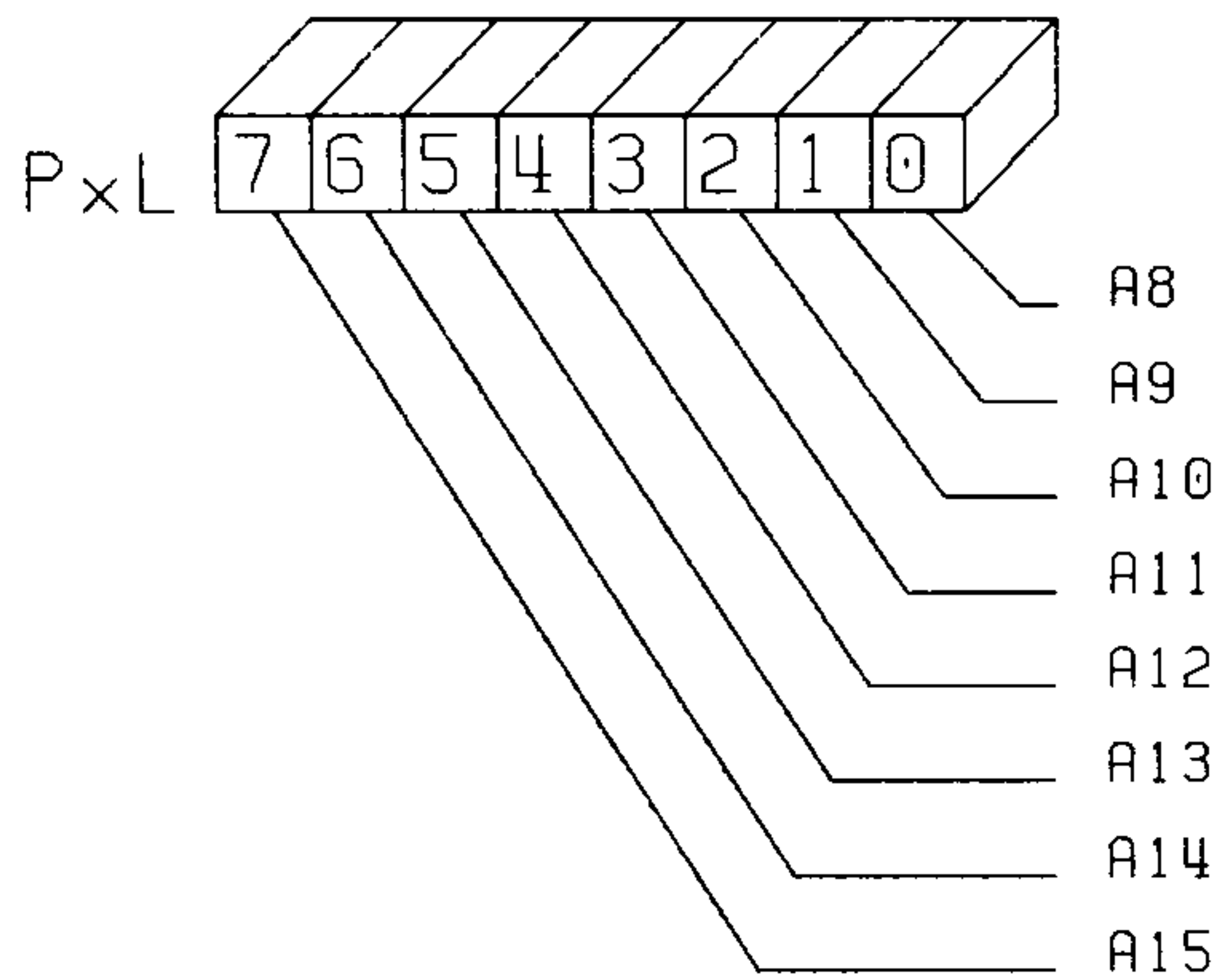
P0H=\$D508

P1H=\$D50A



P0L=\$D507

P1L=\$D509



**Page Pointer**

### The Page Pointers

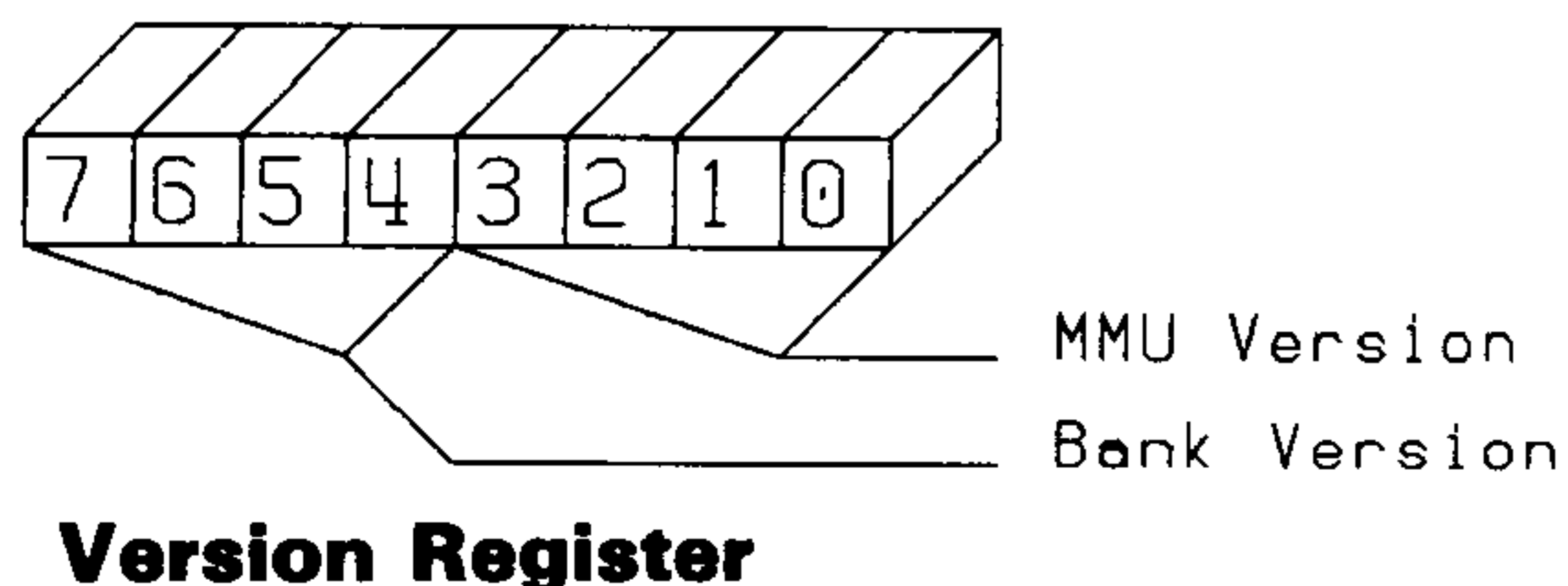
The page pointers are four registers that allow independent relocation of pages zero and one, when running under either processor. These are especially useful when running under the 8502 as they help to remove some of the zero page and stack size limitations normally associated with 6502 family processors.

For zero page relocation, the MMU provides the **Page Zero Pointer High (P0H)** and **Page Zero Pointer Low (P0L)** registers. Bit 0 of the P0H register corresponds to translated addresses TA<sub>16</sub> for any zero page access, \$0000 — \$00FF, controlling the generation of CAS<sub>0</sub> or CAS<sub>1</sub> depending on whether it is low or high. The remaining bits are currently unused, and will always return zero. These bits override the RAM bank bits, the ROM block, and the I/O block bits to determine which physical page appears as zero page for all zero page accesses. A write to the P0H register is stored in pre-latch until a write to the P0L register occurs. Bits 0 to 7 of the P0L correspond to Translated Addresses TA<sub>8</sub> to TA<sub>15</sub> for any zero page access, thus relocating the zero page. Any access to the area that has become the relocated zero page will be switched back to the original zero page if that area is mapped as RAM. If mapped as ROM, then the reverse mapping is not done, allowing access to the ROM. A write to this register sets up the zero page transfer, which can occur as soon as the next low clock cycle. Register P0L is located in the I/O space at \$D507, while register P0H is located at \$D508.

## THE MEMORY MANAGEMENT UNIT (Continued)

The registers for page one relocation, the **Page One Pointer High** (P1<sub>H</sub>) and the **Page One Pointer Low** (P1<sub>L</sub>) do for page one essentially what P0<sub>H</sub> and P0<sub>L</sub> do for the zero page. The functions and bit correspondences are exactly the same. P1<sub>L</sub> is located in the I/O space at \$D509 and P1<sub>H</sub> at \$D50A. Note that both register pairs are initialized upon reset to reflect true page zero and true page one access for the 8502 processor. Note that these registers continue to take effect in Z-80 mode, as well as in 8502 mode, when set to bank one. When set to bank zero, they are disabled to provide true Z-80 BIOS access.

VR=\$D50B

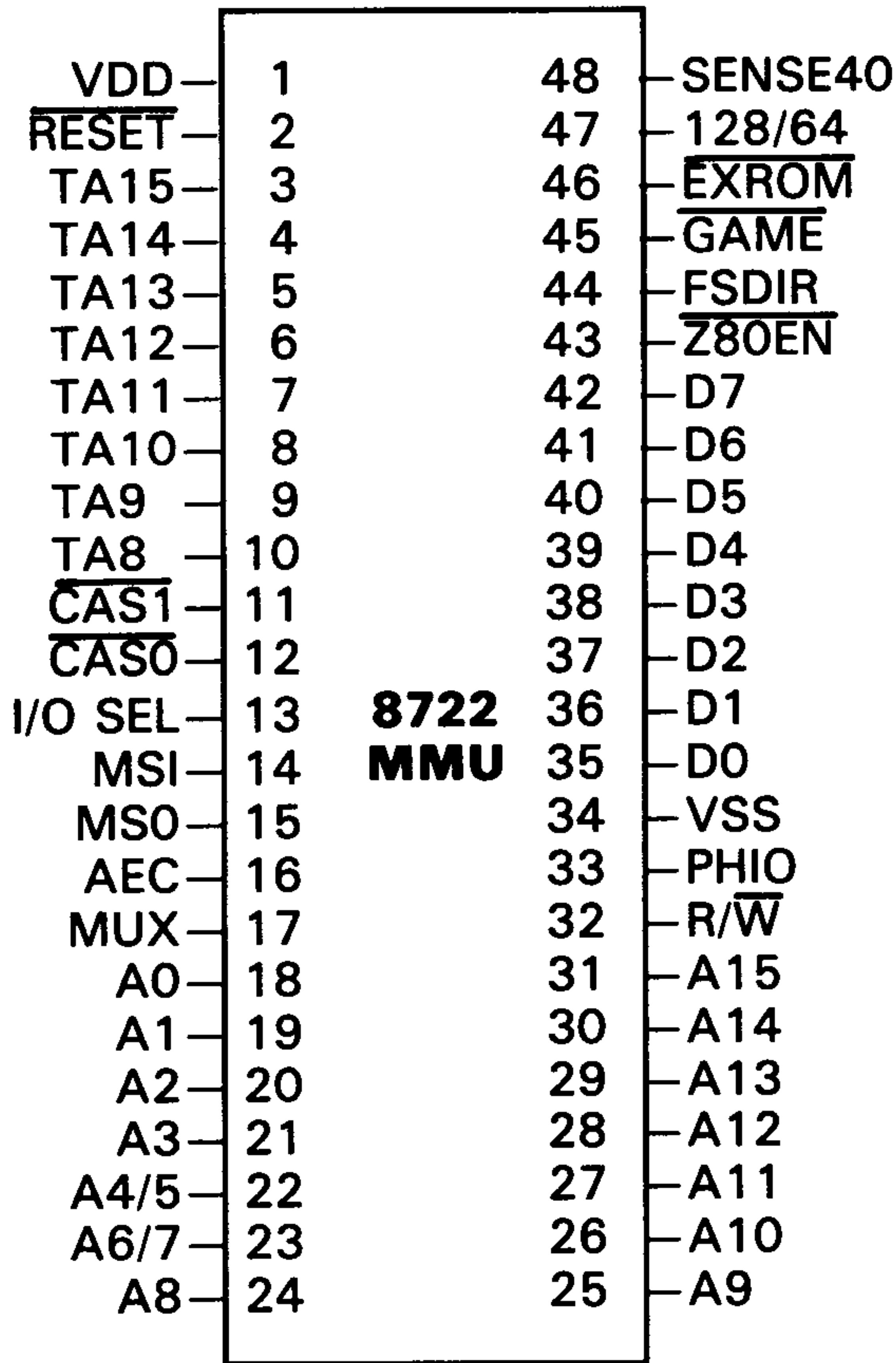


### System Version Register

The final register is the **System Version Register**, which is located at \$D50B in the I/O block. This register is a read-only register that returns a code containing the version of the MMU and the size and capability of the system's memory. The lower nybble, bits 0 through 3, contain the version of the MMU in the system. The upper nybble, bits 4 through 7, contains a code relating the number of memory blocks available in the system. This allows software to compensate for any later systems with more available memory, and should make it quite simple for the current C128 to remain compatible with any software written in the future for an expanded C256, etc. system. The initial C128 will read a 2 here, indicating two 64K blocks are available. A zero in this nybble would indicate sixteen 64K blocks.

# THE MEMORY MANAGEMENT UNIT (Continued)

## 310389 8722 MEMORY MANAGEMENT UNIT



|       |                                     |  |
|-------|-------------------------------------|--|
| 1     | VDD                                 | 5VDC input.  |
| 2     | RESET                               | System Reset. This input initializes internal registers on a power up or hardware reset.   |
| 3-10  | TA8-TA15                            | Translated Address outputs. Tri-stated for VIC cycles during AEC, provides translated physical address for use on the Multiplexed Address Bus and the Shared Static Bus. TA <sub>12</sub> to TA <sub>15</sub> are each defined to have an internal, depletion mode pullup with an equivalent resistance of 3.3KΩ. TA <sub>8</sub> to TA <sub>11</sub> each go tristate during VIC time (AEC low). Column Address Strobe. The CAS output lines control DRAM banking. CAS <sub>0</sub> enables the first bank of 64K, CAS <sub>1</sub> enables the second bank of 64K.                           |
| 11,12 | CAS <sub>0</sub> , CAS <sub>1</sub> |  |
| 13    | I/O SEL, MS <sub>2</sub>            | I/O Select, Memory Status 2. This output is identified by both identifiers. It is used to select memory mapped I/O in C128 mode and is also known as MS <sub>2</sub> . In C128 mode, this line always reflects the polarity of the I/O bit. It is ignored by the PLA in C64 mode, and remains high throughout C64 mode.  |
| 14,15 | MS <sub>0</sub> , MS <sub>1</sub>   | Memory Status 0, 1. Also called ROMBANK <sub>0</sub> and ROMBANK <sub>1</sub> , these outputs control ROM banking for all ROM slots. These lines are used to decode ROM bank selection for any ROM access in C128 mode. If they are both low, a system ROM has been selected. If MS <sub>1</sub> is high alone, then a built in function ROM has been selected. If MS <sub>0</sub> is alone high, then an external function ROM has been selected. Finally, if both are high, the RAM that occupies the particular slot has been selected. In C64 mode the PLA completely ignores these lines. |
| 16    | AEC                                 | The Address Enable Control indicates whether the 8502 processor or the VIC has access to the shared bus. When low, VIC or an external DMA has the bus and VA <sub>16</sub> and VA <sub>17</sub> have the processor bus, and no pointer or BIOS translation takes place.  |
| 17    | MUX                                 | The Memory Multiplex signal, used to clock various sections of the MMU.  |
| 18-31 | A0-A15                              | A0 - A3, A8 - A15: Addresses from the microprocessor. Used to derive chip selects as well as multiplexed address lines.<br>A4/5, A6/7: Combined addresses from the microprocessor. Used along with simple addresses, combined in this fashion to lower the pin count of the MMU.   |
| 32    | R/W                                 | R/W: System Read/Write control line. This input is high for a processor read, low for a processor write.   |
| 33    | PHIO                                | Presystem clock. Used for early transition of gated signals on write operations. Processor address is valid on the rising edge and data is valid on the falling edge.  |
| 34    | VSS                                 | System Ground.   |
| 35-42 | D0-D7                               | Data inputs from the microprocessor. Used for writing to internal registers.   |
| 43    | Z80EN                               | This output is used to enable the Z80 processor and disable the normal operation of the 8502 processor. It goes low to indicate Z-80 mode, high for all other modes.   |
| 44    | FSDIR                               | Fast Serial Direction. This port is a bidirectional line that in output mode controls the data direction of the fast serial disk interface.  |
| 45    | GAME                                | Game ROM Enable. This signal is used to sense the GAME line on the expansion connector in C64 mode and as the color RAM bank control line in C128 mode.  |
| 46    | EXROM                               | External ROM Enable. This signal is used to sense the EXROM line on the expansion connector in C64 mode and as an expansion control line in C128 mode.   |
| 47    | 128/64, MS <sub>3</sub>             | This output directs the system to act in either C128 or C64 mode. It goes low to indicate C64 mode, high for C128 mode.  |
| 48    | 40/80                               | Sense 40/80. This bidirectional port is used in input mode to sense the 40/80 column switch. It detects whether or not the switch is closed. The output mode is not used at this time.   |

# THE PROGRAMMED LOGIC ARRAY

**FOLD OUT SCHEMATIC SHEET 2, PAGE 74, FOR EASY REFERENCE.**

The 8721 C128 PLA is a programmed version of the Commodore 48 Pin Programmable Logic Array. It provides all of the chip selects and other decoded signals that were necessary for the C64, along with a number of such signals new in the C128 system.

Summary of PLA functions:

- Control all ROM selects (KERNAL, BASIC, FUNCTION, EXTERNAL) in all operating modes.
- VIC chip select.
- Color RAM chip select.
- Character RAM chip select.
- Gated write enable to color RAM.
- Latched write enable to DRAMs.
- Z-80 select decoding.
- Z-80, I/O decoding, for Z-80 I/O cycle and Z-80 memory mapping.
- Data bus direction signal.
- I/O group chip select (includes I/O-1, I/O-2, CIA-1, CIA-2, SID, 8563).
- I/O access signal indicating an I/O operation is occurring.
- Column Address Strobe Enable for DRAM.

## Chip Select Generation

The PLA device is responsible for defining the banking rules for ROM and RAM that the system will follow. The chip generates chip selects for all ROM and the VIC chip. It generates an enable for any other I/O device in the map, and can enable or disable CAS based upon what else is enabled. In C128 mode, decisions are made using the processor addresses and the four mode status lines: ROMBANKLO, ROMBANKHI, I/O SELECT, and C128/64. The C128 mode banking scheme is quite straightforward and simple. In Z-80 mode, the selection mechanism becomes even simpler, thanks to the I/O cycle of the Z-80 processor.

C64 chip selects account for the bulk of the PLA font. The C64 selects I/O, RAM, and ROM based upon the internal control lines BA, HIRAM, LORAM, and CHAREN. The status of these lines, and the decoded addresses, determine for any given time which, if any, chip is selected. When a cartridge is inserted, two additional control lines come into play — EXROM and GAME. Various combinations of these lines cause different memory maps to be asserted, all based upon the PLA font.

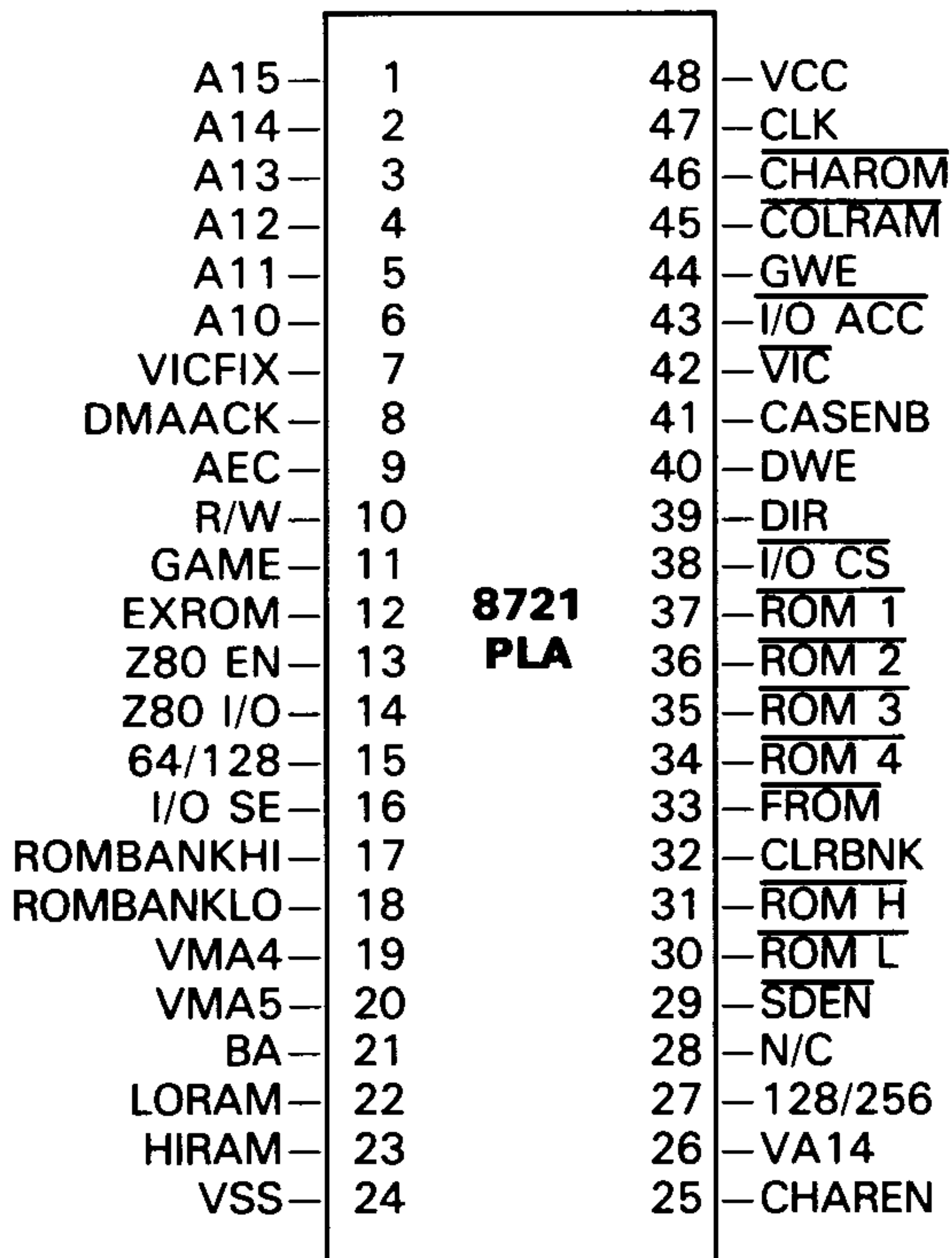
## Other PLA Functions

The PLA performs a variety of functions other than chip selects. It creates the write enable strobes for both DRAM and Color RAM. In C128 mode, the C64 control lines HIRAM, LORAM, and CHAREN are not needed, since the MMU controls the more sophisticated C128 method of banking. Thus, these lines are used to extend the functionality of the C128 at little or no additional cost in hardware. The CHAREN line is used in C128 mode to turn the Character ROM on and off in VIC address space. In the C64, the presence of this ROM was a function of the VIC bank selected. In C128 mode, the ROM can appear or disappear in any VIC bank.

The second of the new functions uses LORAM and HIRAM to select one of two Color RAM banks. The level of LORAM selects the bank that will be seen during processor time, the level of HIRAM selects the bank that will be seen during VIC time. Thus, a program can swap between two full color pictures very clearly, or the processor can modify one full color picture while displaying another.

# PROGRAMMED LOGIC ARRAY (Continued)

## 315012-01 PROGRAMMABLE LOGIC ARRAY



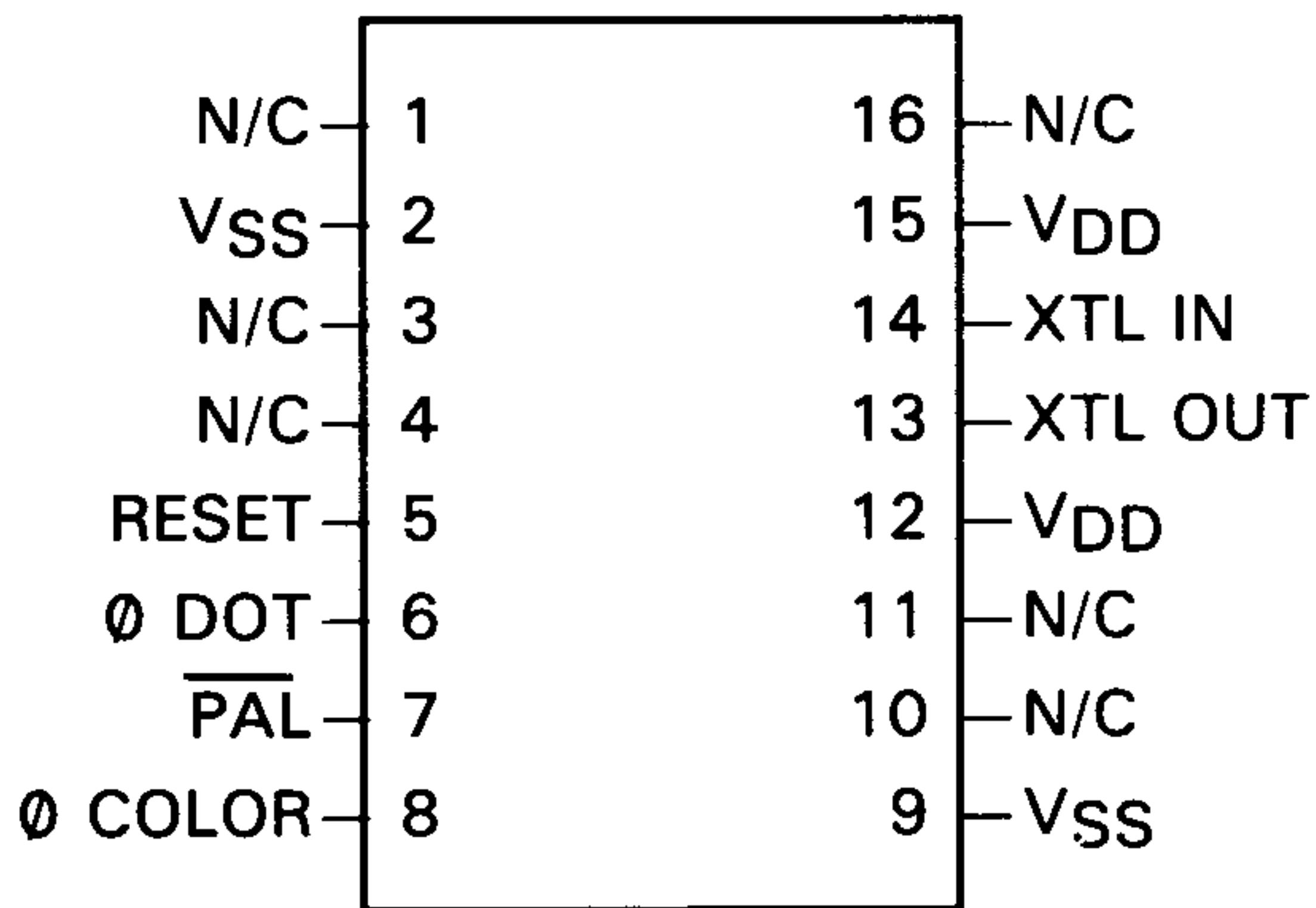
**8721  
PLA**

|       |                        |  |
|-------|------------------------|--|
| 1-6   | A10-A15                | Address input from 8502 microprocessor.  |
| 7     | VICFIX                 | Input to modify CASENB latching for VIC timing.  |
| 8     | DMAACK                 | DMA Acknowledge input pulled high in C128 system.  |
| 9     | AEC                    | Address Enable Control input from VIC.   |
| 10    | R/W                    | Read/Write input from 8502 microprocessor.   |
| 11    | GAME                   | Input from the expansion port indicating an external ROM in C64 mode. Unused in C128 mode.                                 |
| 12    | EXROM                  | Input from the expansion port indicating an external ROM in C64 mode. Unused in C128 mode.                                 |
| 13    | Z80EN                  | Input from the Z80 BUSACK line indicating the Z-80 relinquishes the bus.   |
| 14    | Z80 I/O                | Z80 input requesting I/O.  |
| 15    | 64/128                 | High input sets C128 mode.   |
| 16    | I/O SE                 | I/O select input from MMU.   |
| 17,18 | ROMBANKLO<br>ROMBANKHI | Input from MMU to indicate ROM bank status.  |
| 19,20 | VMA4,VMA5              | Input from VIC multiplexed address.  |
| 21    | BA                     | Bus Available Input from VIC.  |
| 22,   | LORAM                  | Memory configuration signals input from the 8502 port. They are used for C64 mode memory mapping and C128 mode extensions. |
| 23,   | HIRAM                  |  |
| 25    | CHAREN                 |  |
| 24    | VSS                    | Ground   |
| 26    | VA14                   | VIC address 14 input from the 6526. Selects video map in C64 mode.   |
| 27    | 128/256                | Input line to indicate whether 128K or 256K ROMs are installed in the system. High for 128K, low for 256K.                 |
| 28    | N/C                    | No connection.   |
| 29    | SDEN                   | SD enable output used to enable the buffer between the data bus and the S DATA bus.  |
| 30,31 | ROM L, ROM H           | Active low outputs. They are the chip selects for expansion ROMs.  |
| 32    | CLRBK                  | Output for color RAM bank select.  |
| 33    | FROM                   | Function ROM chip select output. Active low.   |
| 34-37 | ROM 1-4                | ROM chip selects for operating system ROM. Active low output.  |
| 38    | I/O CAS                | Active low output used as I/O chip select. Enables external decoder for CIA1 and 2, I/O 1 and SID and 8563.                |
| 39    | DIR                    | Data Bus Direction control output for the Data to S Data buffer.   |
| 40    | DWE                    | Active low output for DRAM write enable. MUX latches the output in the PLA.  |
| 41    | CASENB                 | RAM Column Address Strobe Enable. Used to gate CAS outputs from MMU. The active low output is latched by MUX in the PLA.   |
| 42    | VIC                    | Active low output to select the VIC chip.  |
| 43    | I/O ACC                | Indicates access to a 1 MHz part, typically an I/O part. Used by the VIC to stretch the 2 MHz clock.                       |
| 44    | GWE                    | Active low output used as write enable for color RAM.  |
| 45    | COLRAM                 | Color RAM chip select, valid for MPU and VIC.  |
| 46    | CHAROM                 | Character ROM chip select, valid for MPU and VIC.  |
| 47    | CLK                    | Common clock input from VIC.   |
| 48    | VCC                    | 5VDC input.  |

# 8701 CLOCK GENERATOR

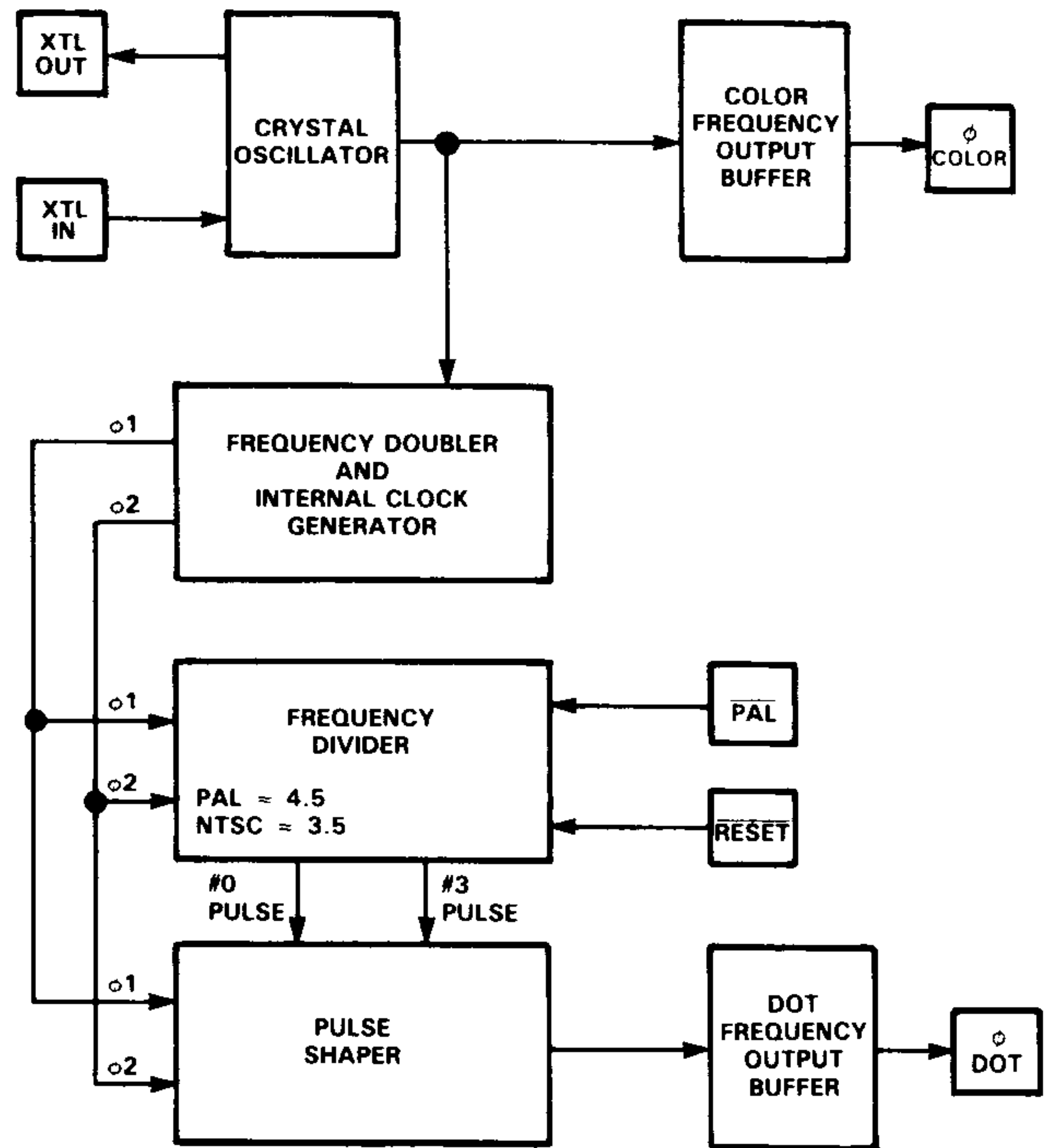
**FOLD OUT SCHEMATIC SHEET 3, PAGE 75, FOR EASY REFERENCE.**

## PIN ASSIGNMENT



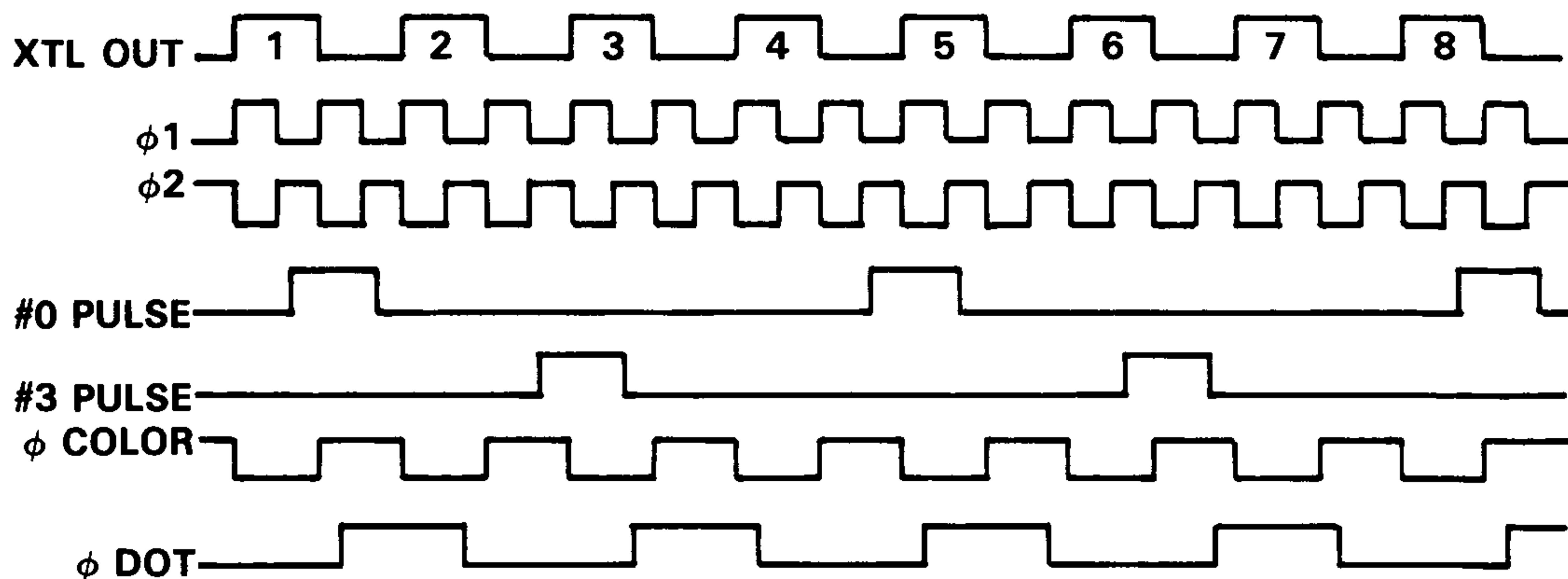
## OUTPUTS

|       |             |               |
|-------|-------------|---------------|
| Pin 6 | Dot Clock   | 8.1818 MHz.   |
| Pin 8 | Color Clock | 14.31818 MHz. |



**Block Diagram**

The oscillator circuit uses an external crystal to generate a precise frequency, compatible with either **PAL** or **NTSC** video systems. This frequency can be fine-adjusted using an external trimmer capacitor. The output of this oscillator is buffered and becomes the color clock output. It also goes to the frequency doubler circuit. From there, a pair of non-overlapping clocks are generated (PHI1 and PHI2). These go to the frequency divider which in turn generate a pair of signals, #0 pulse and #3 pulse. Their frequency is determined by the state of the PAL/NTSC input pin. These two pulses go through some digital delays, and with the help of PHI1 and PHI2 are re-combined to form the dot clock frequency. This signal is then buffered and sent out via the dot clock pin.



**NTSC Clock Timing Diagram**



# THE VIDEO INTERFACE

**FOLD OUT SCHEMATIC SHEET 3, PAGE 75, FOR EASY REFERENCE.**

The C128 VIC video interface hardware allows the connection of a standard commercial television and/or a color monitor. The monitor may accept either a composite video signal or separate chroma and luminance/sync signals in addition to an audio signal. This output is very similar to the output of the 8 pin video C64 units.

The C128 also provides 80 column video interfacing. The available 80 column display is RGBI and monochrome, able to interface to most RGBI TYPE I monitors and most 80 column compatible monochrome monitors.

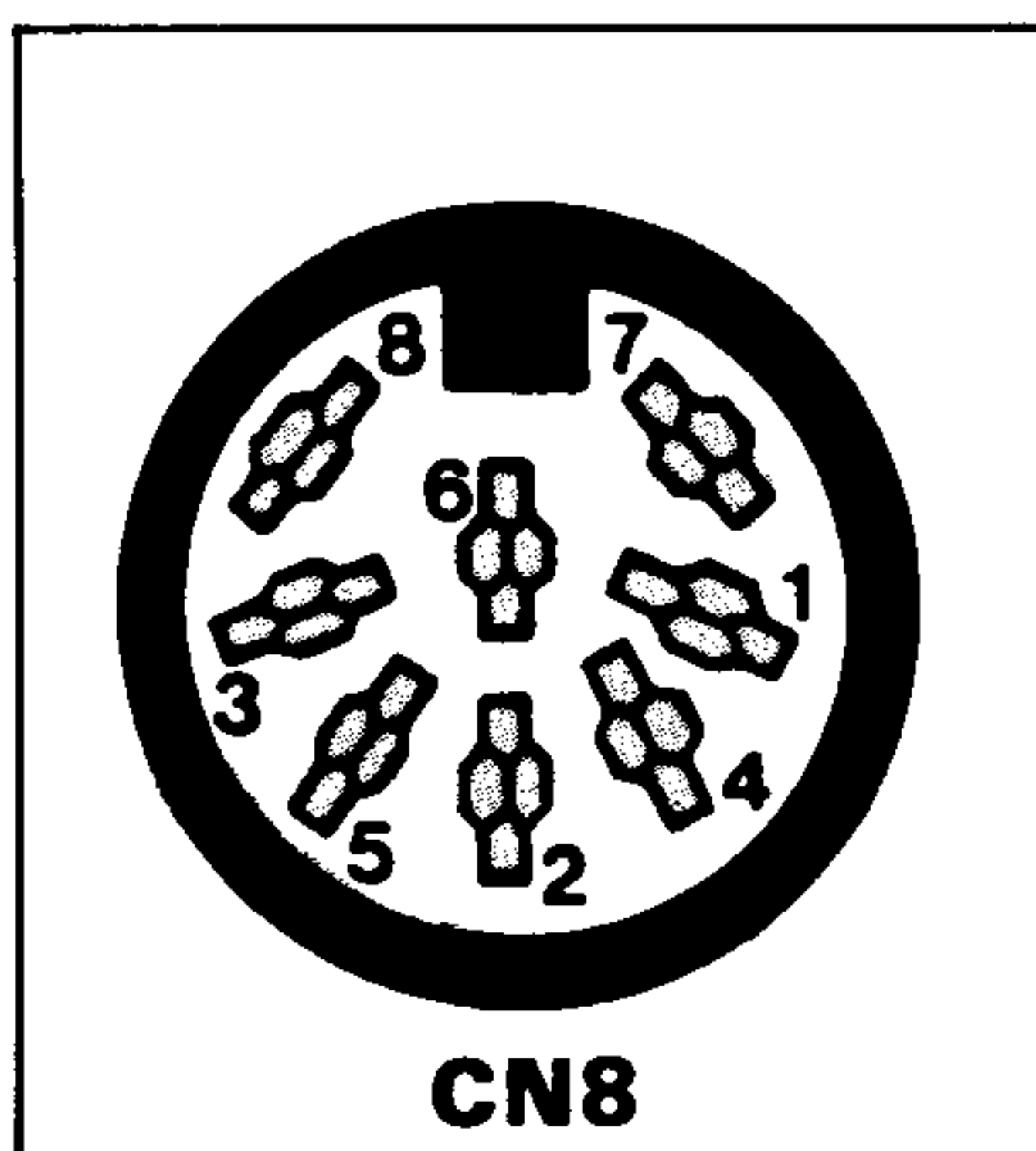
## The VIC Video Interface

The VIC video interface supplies a 40 column display in sixteen colors. The VIC signal is available at RF levels at the RF modulator output and at analog levels at the 8 pin DIN monitor connector.

## RF Modulator

The modulator provides a broadcast type RF signal carrying the VIC composite video and audio signals. The NTSC modulator is switchable between channels 3 and 4 to help minimize local broadcast interference. The signal generated by the RF modulator complies with FCC ruling concerning FCC Class B, TV interface devices. The RF output is accessible via a standard RCA type phone/video jack.

## Monitor Output



| Pin | Signal    | Description             |
|-----|-----------|-------------------------|
| 1   | LUM/SYNC  | Luminance/SYNC Output   |
| 2   | GND       |                         |
| 3   | AUDIO OUT |                         |
| 4   | VIDEO OUT | Composite signal output |
| 5   | AUDIO IN  |                         |
| 6   | COLOR OUT | Chroma signal output    |
| 7   | NC        | No connection           |
| 8   | NC        | No connection           |

The VIC video output provides the following signals:

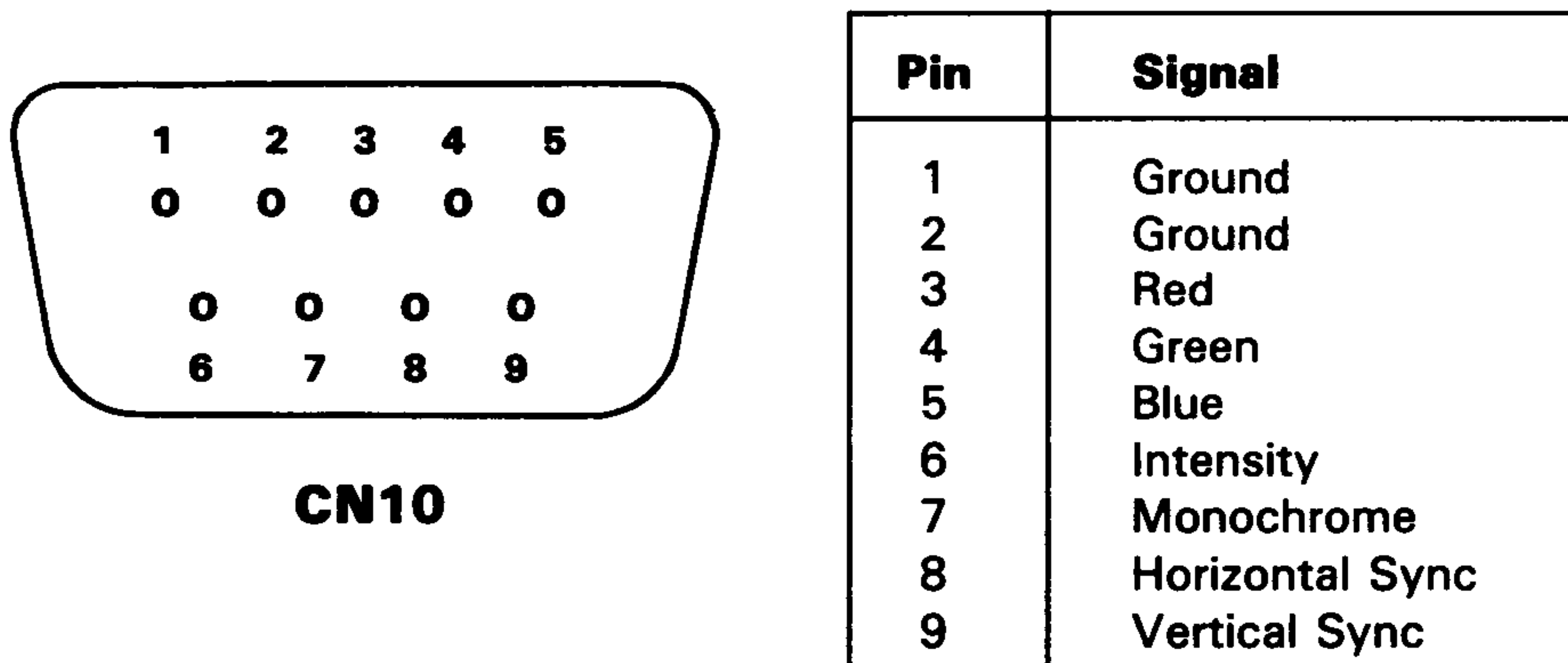
| Signal         | Level   | Impedance   | DC Offset |
|----------------|---------|-------------|-----------|
| Luminance/Sync | 1 V p-p | 75 $\Omega$ | 0.5 V     |
| Chroma         | 1 V p-p | 75 $\Omega$ | 0.5 V     |
| Composite      | 1 V p-p | 75 $\Omega$ | 0.5 V     |
| Audio          | 1 V p-p | 1K          |           |

## THE VIDEO INTERFACE (Continued)

### The RGBI Video Interface

The 8563 video interface signal, for 80 column display in sixteen colors, is available at digital levels for RGBI and at a three-level derived analog for black and white composite video.

### Monitor Output



The 8563 output provides the following signals:

| Signal         | Level | Impedance |
|----------------|-------|-----------|
| Red            | TTL   | TTL       |
| Green          | TTL   | TTL       |
| Blue           | TTL   | TTL       |
| Intensity      | TTL   | TTL       |
| HSync          | TTL   | TTL       |
| VSync          | TTL   | TTL       |
| Composite      |       | 75Ω       |
| Full Intensity | 2.0V  |           |
| Half Intensity | 1.5V  |           |
| Sync           | 0.5V  |           |

# THE 8564 VIDEO INTERFACE CHIP

**FOLD OUT SCHEMATIC SHEET 3, PAGE 75, FOR EASY REFERENCE.**

The 8564 VIC chip used in the C128 is an updated version of the VIC chip used in current C64 systems. It contains all of the video capabilities of the earlier 6567 VIC chip, including high resolution bit mapped graphics and movable image blocks. It also supports new features used by the C128 system, including extended keyboard scanning. Its register map is upward compatible with the old VIC, allowing compatibility in C64 mode. It is powered by a single 5V DC source, instead of the two sources required by the old VIC chip.

Summary of functions that remain the same as the 6567 VIC:

- Standard Color Character Display Mode
- Multicolor Character Display Mode
- Extended Color Character Display Mode
- Standard Bit Map Mode
- Multicolor Bit Map Mode
- Movable Image Blocks
- Movable Image Block Magnification
- Movable Image Block Priority
- Movable Image Block Collision Detection
- Screen Blanking
- Row/Column Display Select
- Smooth Scrolling
- Light Pen
- Raster Compare Interrupt

As these functions exist in the previous VIC, their description is purposely kept to a minimum. The new functions, however, are described in detail below. Additional Functions of 8564 VIC:

## Extended Keyboard Scanning

The 8564 contains a register called the **Keyboard Control Register**. This register allows scanning of three additional keyboard control lines on the C128 keyboard. Thus, the C128 keyboard can have advanced additional keys in C128 mode, while still retaining complete C64 keyboard compatibility in C64 mode. In this register, register 47, bits 0-2 are directly reflected in output lines K<sub>0</sub> to K<sub>2</sub>, while bits 3-7 are unused, returning high when read.

## 2 MHz Operation

The VIC chip contains a register which allows the C128 system to operate at 2 MHz instead of the standard 1 MHz of the C64. This operating speed, however, disallows the use of the VIC chip as a display processor. This bit is bit zero in register 48, and setting this bit enables 2 MHz mode. During 2 MHz operation, the VIC is disabled as a video processor. The  $\mu$ Processor spends the cycle full time on the bus, while VIC is responsible only for dynamic RAM refresh and DMA arbitration. Clearing this bit will bring back 1 MHz operation and allow the use of the VIC as a video display chip. During refresh and I/O access, the system clock is forced to 1 MHz regardless of the setting of this bit.

Bit one of this register contains a chip testing facility. For normal operation this bit must be clear. None of the other bits in this register are connected.

## **THE 8564 VIDEO INTERFACE CHIP (Continued)**

### **System Clock Control**

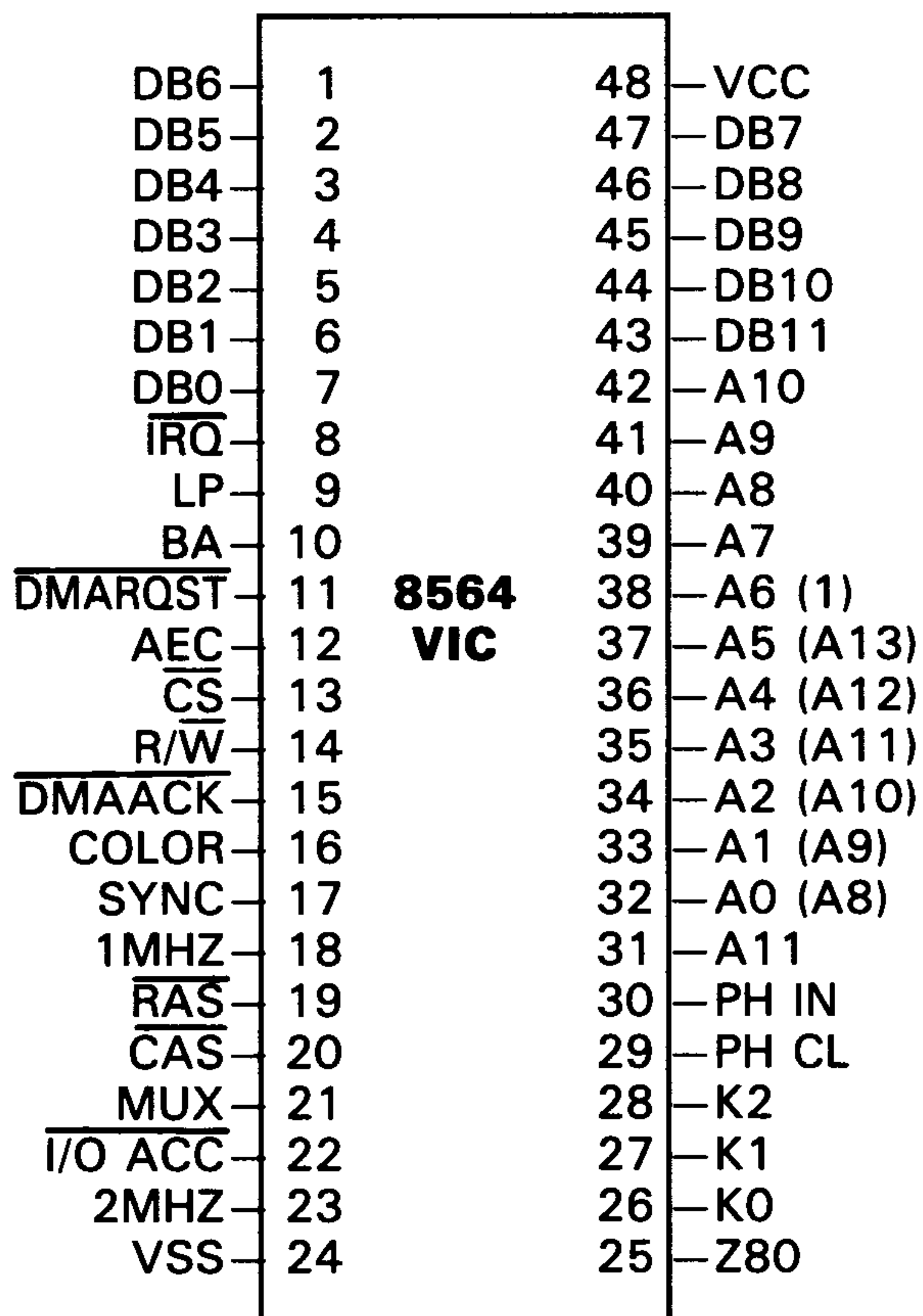
The new VIC chip generates several clocks used by the C128 system. The main clock is the 1 MHz clock, which operates at approximately 1 MHz at all times. Most bus operations and all I/O operations take place in reference to this clock. The next clock to consider is the 2 MHz clock. This clock clocks selected system components, such as the processor, at 2 MHz when in 2 MHz mode. The VIC chip monitors the  $\overline{\text{IOACC}}$  input, which indicates the access of an I/O chip, and when asserted, will stretch the 2 MHz clock to synchronize all 2 MHz parts with the 1 MHz I/O parts. Finally, the last clock is the Z-80 clock, which is a 4 MHz clock that only takes place during the low half of the 1 MHz clock. One final note is that since I/O parts look only at the 1 MHz clock, all I/O timings remain the same no matter what the 2 MHz clock is doing.

### **DMA and Bus Arbitration**

True DMA of the internal processor can now be accomplished by requesting the DMA through VIC. The VIC will shut down the processor in an orderly fashion, instead of a suicidal fashion. A DMA source requests a DMA via the DMARQST input. VIC will respond to that request with a DMAACK after shutting down the processor. The DMA source must listen to the DMAACK line and be prepared to itself be shut down in the event that VIC decides to do its own DMA. Thus, the VIC chip has the highest DMA priority. The C128 system does not use this DMA arbitration scheme, but a fatal DMA scheme similar to that of the C64.

# THE 8564 VIDEO INTERFACE CHIP (Continued)

## 315009 8564 VIDEO INTERFACE CHIP



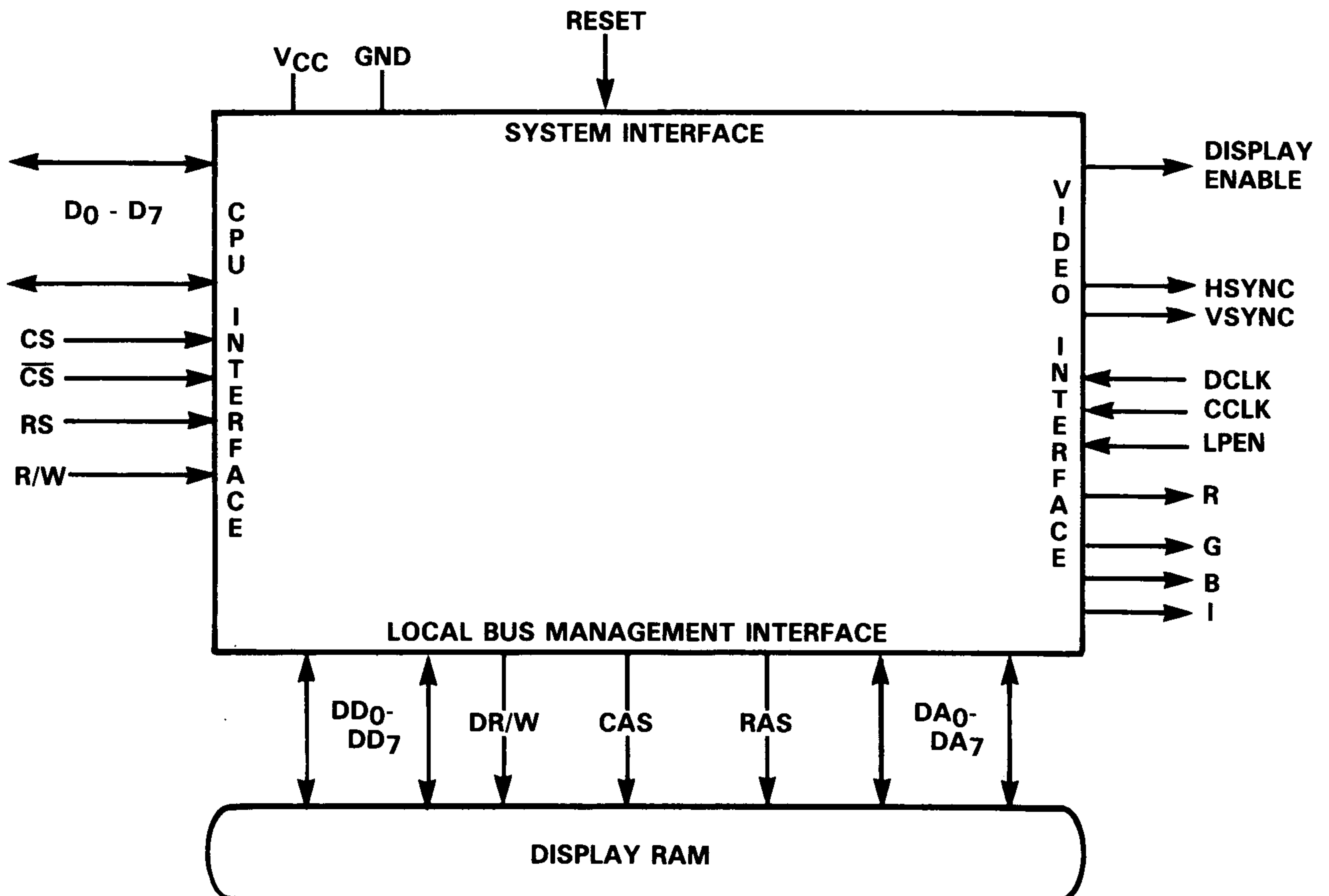
**8564  
VIC**

|           |          |  |
|-----------|----------|--|
| 1-7,47    | DB0-DB7  | These are the bidirectional Data Bus signals. They are for communication between the VIC and the processor, and can only be accessed during AEC high.  |
| 8         | IRQ      | Interrupt output. Generates a low interrupt signal.  |
| 9         | LP       | Light Pen. Edge triggered latch for light pen input.   |
| 10        | BA       | Bus Available output. Used to DMA the processor.   |
| 11        | DMARQST  | External DMA request input. Pulled high on the C128.   |
| 12        | AEC      | Address Enable Control output. Goes high for processor enable on the shared bus, low for VIC cycle and VIC or external DMA.  |
| 13        | CS       | Chip select input. A low signal selects the VIC chip.  |
| 14        | R/W      | Standard 8502 bus Read/Write for interface between the processor and the various VIC registers.  |
| 15        | DMAACK   | External DMA Acknowledge. Not used in the C128 design.   |
| 16        | COLOR    | Output containing all color based video information: chrominance, color reference burst, and color of display data.  |
| 17        | SYNC     | Output containing composite sync information, video data, and luminance information.   |
| 18        | 1MHZ     | The 1MHz system clock. All system bus activity is referenced to this clock.  |
| 19        | RAS      | Row Address Strobe output for DRAMS.   |
| 20        | CAS      | Column Address Strobe output for DRAMS.  |
| 21        | MUX      | Address Multiplexing control output for DRAMS.   |
| 22        | I/O ACC  | Input from the PLA, indicating an I/O chip access for clock stretching.  |
| 23        | 2MHZ     | This is the changing system clock, which will be either 1MHz or 2MHz. If the 2MHz bit is clear, no VIC or external DMA is taking place, and no I/O operation is occurring, the clock will be 2MHz. It will be 1MHz otherwise.  |
| 24        | VSS      | Ground.  |
| 25        | Z80 PHI  | The special 4MHz Z-80 clock.   |
| 26-28     | K0-K2    | Extended keyboard strobe bits.   |
| 29        | PH CL    | The Color Clock input, used to derive the chroma signal, 14.31818 MHz NTSC.  |
| 30        | PH IN    | The fundamental shift rate clock input, also called the DOT clock. Used as the reference for all system clocks. Determines the dot transfer rate to the display.   |
| 31        | A11      | See A8-A11 below.  |
| 32-37     | A0-A5    | Multiplexed Address Lines. During row address time, A0 - A5 are driven on A0 - A5. During column address time, A8 - A13 are driven on A0 - A5 and A6 is held at one. During a processor write or read, A0 - A5 serve as address inputs which latch on the low edge of RAS. |
| 38, 39    | A6, A7   | Used as VIC address lines.   |
| 31, 40-42 | A8-A11   | Static Address lines. These address lines are used for non-multiplexed VIC memory accesses, such as to Character ROM and Color RAM.  |
| 43-46     | DB8-DB11 | These are the extended data bus signals. They are used for VIC communication with the Color RAM.   |
| 47        | DB7      | See Pins 1-7, 47, DB0-DB7.   |
| 48        | VCC      | 5VDC input.  |

# THE 8563 VIDEO CONTROLLER

**FOLD OUT SCHEMATIC SHEET 3, PAGE 75, FOR EASY REFERENCE.**

The 8563 is a HMOSII technology, custom, 80 column, color video display controller. The 8563 supplies all necessary signals to directly interface to 16K of DRAM, including refresh, and generates RGBI for use with an external RGBI monitor.



There are many different signals involved with the 8563 chip, but they can generally be divided into three categories. The CPU Interface signals serve as an interface to the 8502 bus. The Local Bus Management signals serve to maintain the local memory bus. Finally, the Video Interface signals are those signals that are necessary to provide an RGBI image on an RGBI monitor.

The 8563 chip interfaces directly to the 8502 bus using a minimum of signals. This is due mainly to the local memory used by the 8563.

The Local Bus Management Interface is a group of signals generated by the 8563 for the management of local video DRAM. This local DRAM both simplifies the addition of an 80 column video display to the system and enables it to support an 80 column display without taxing its memory resources.

The final set of 8563 signals are the Video Interface signals. These signals are directly related to the displayed video image.

## THE 8563 VIDEO CONTROLLER (Continued)

### External Registers

The 8563, which sits at \$D600 in the C128, appears to the user as a device consisting of only two registers. These two registers are indirect registers which must be programmed to access the internal set of thirty-seven programming registers. The first register, located at \$D600, is called the Address/Status register. When written to, the five least significant bits convey the address of an internal register to be accessed in some way. On a read of this register, a status byte is returned. Bit 7 of this register is low while display memory is being updated, and goes high when ready for the next operation. The 6th bit will return low for a light pen register invalid condition and high for a valid light pen address. The final register indicates with a low that the scan is not in vertical blanking, high that it is in vertical blanking.

The other register is the data register. It can be read and written to. Its purpose is to write data to the internal register selected by the Address register. All internal registers can be read and written to through this register, though not all of them are a full eight bits wide.

### Internal Registers

There are thirty-seven internal registers in the 8563, used for a variety of operations. They fall into two basic groups — setup registers and display registers. Setup registers are used to define internal counts for proper video display.

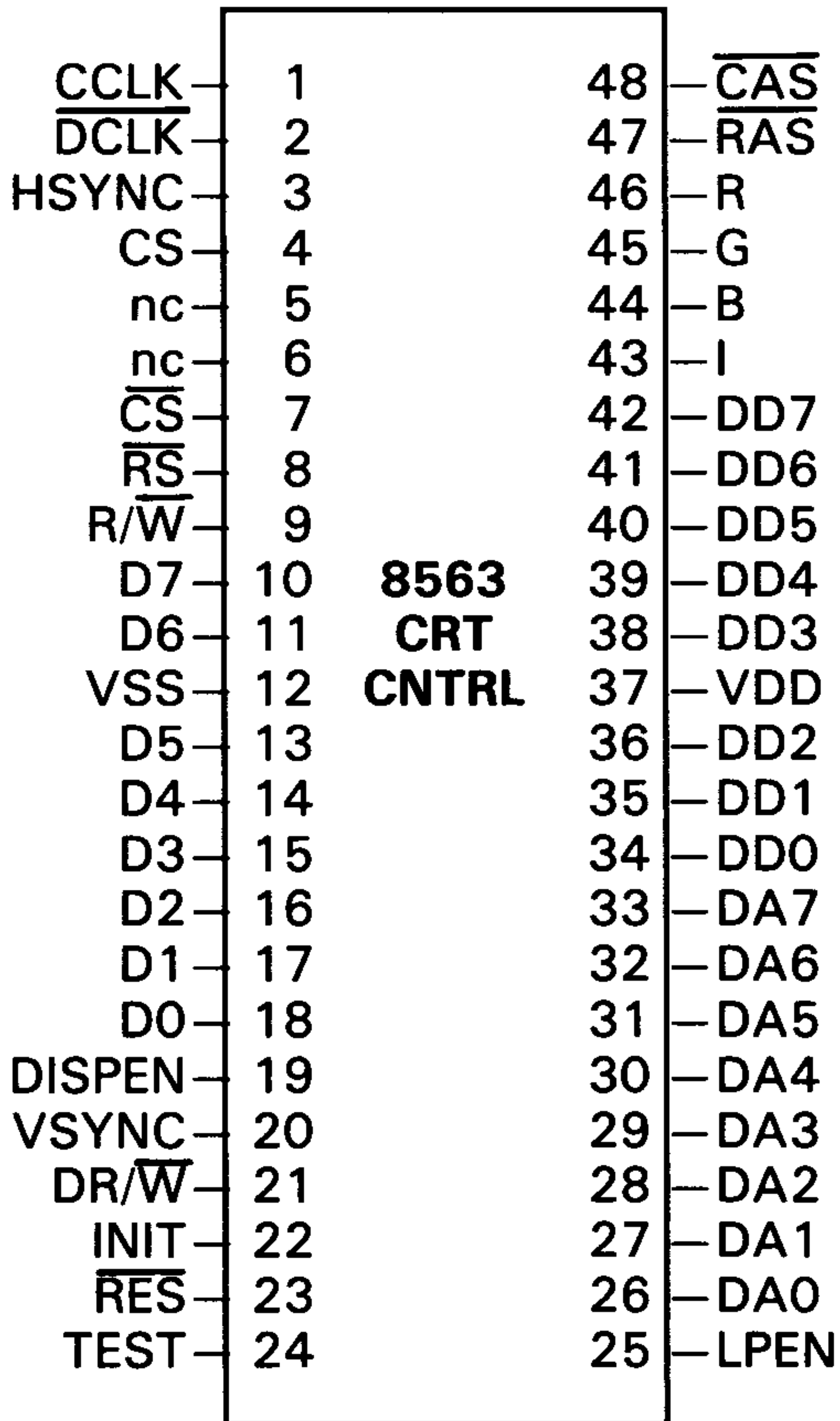
The display registers are used to define and manipulate characters on the screen. Once a character set has been downloaded to the chip, it is possible to display 80 column text in 4-bit digital color. There are also block movement commands that remove the time overhead needed to load large amounts of data to the chip through the two levels of indirection. Below is a display of the 8563 internal register map.

|     | Bit 7                            | Bit 6      | Bit 5      | Bit 4                  | Bit 3                          | Bit 2 | Bit 1 | Bit 0 |
|-----|----------------------------------|------------|------------|------------------------|--------------------------------|-------|-------|-------|
| R00 | Horizontal Total                 |            |            |                        |                                |       |       |       |
| R01 | Horizontal Displayed             |            |            |                        |                                |       |       |       |
| R02 | Horizontal Sync Position         |            |            |                        |                                |       |       |       |
| R03 | Vertical Sync Width              |            |            |                        | Horizontal Sync Width          |       |       |       |
| R04 | Vertical Total                   |            |            |                        |                                |       |       |       |
| R05 | Vertical Total Adjust            |            |            |                        |                                |       |       |       |
| R06 | Vertical Displayed               |            |            |                        |                                |       |       |       |
| R07 | Vertical Sync Position           |            |            |                        |                                |       |       |       |
| R08 | Interlace Mode                   |            |            |                        |                                |       |       |       |
| R09 | Character Total Vertical         |            |            |                        |                                |       |       |       |
| R10 | Cursor Mode                      |            |            |                        | Cursor Start Scan Line         |       |       |       |
| R11 | Cursor End Scan Line             |            |            |                        |                                |       |       |       |
| R12 | Display Start Address (High)     |            |            |                        |                                |       |       |       |
| R13 | Display Start Address (Low)      |            |            |                        |                                |       |       |       |
| R14 | Cursor Position (High)           |            |            |                        |                                |       |       |       |
| R15 | Cursor Position (Low)            |            |            |                        |                                |       |       |       |
| R16 | Light Pen Vertical               |            |            |                        |                                |       |       |       |
| R17 | Light Pen Horizontal             |            |            |                        |                                |       |       |       |
| R18 | Update Location (High)           |            |            |                        |                                |       |       |       |
| R19 | Update Location (Low)            |            |            |                        |                                |       |       |       |
| R20 | Attribute Start Address (High)   |            |            |                        |                                |       |       |       |
| R21 | Attribute Start Address (Low)    |            |            |                        |                                |       |       |       |
| R22 | Character Total-Horizontal       |            |            |                        | Character Displayed-Horizontal |       |       |       |
| R23 | Character Displayed-Vertical     |            |            |                        |                                |       |       |       |
| R24 | Copy/Fill                        | Rev Screen | Blink Rate | Vertical Smooth Scroll |                                |       |       |       |
| R25 | Graph/Text                       | Attrb Enb  | Semigraph  | Pix Dbf                | Horizontal Smooth Scroll       |       |       |       |
| R26 | Foreground Color                 |            |            |                        | Background Color               |       |       |       |
| R27 | Address Increment per Row        |            |            |                        |                                |       |       |       |
| R28 | Character Set Address            |            |            |                        | 4164/4416                      |       |       |       |
| R29 | Underline Scan Line              |            |            |                        |                                |       |       |       |
| R30 | Word Count (count-1)             |            |            |                        |                                |       |       |       |
| R31 | CPU Read/Write Data              |            |            |                        |                                |       |       |       |
| R32 | Block Copy Source Address (High) |            |            |                        |                                |       |       |       |
| R33 | Block Copy Source Address (Low)  |            |            |                        |                                |       |       |       |
| R34 | Display Enable Begin             |            |            |                        |                                |       |       |       |
| R35 | Display Enable End               |            |            |                        |                                |       |       |       |
| R36 | DRAM Refresh per Scan Line       |            |            |                        |                                |       |       |       |

### 8563 REGISTER MAP

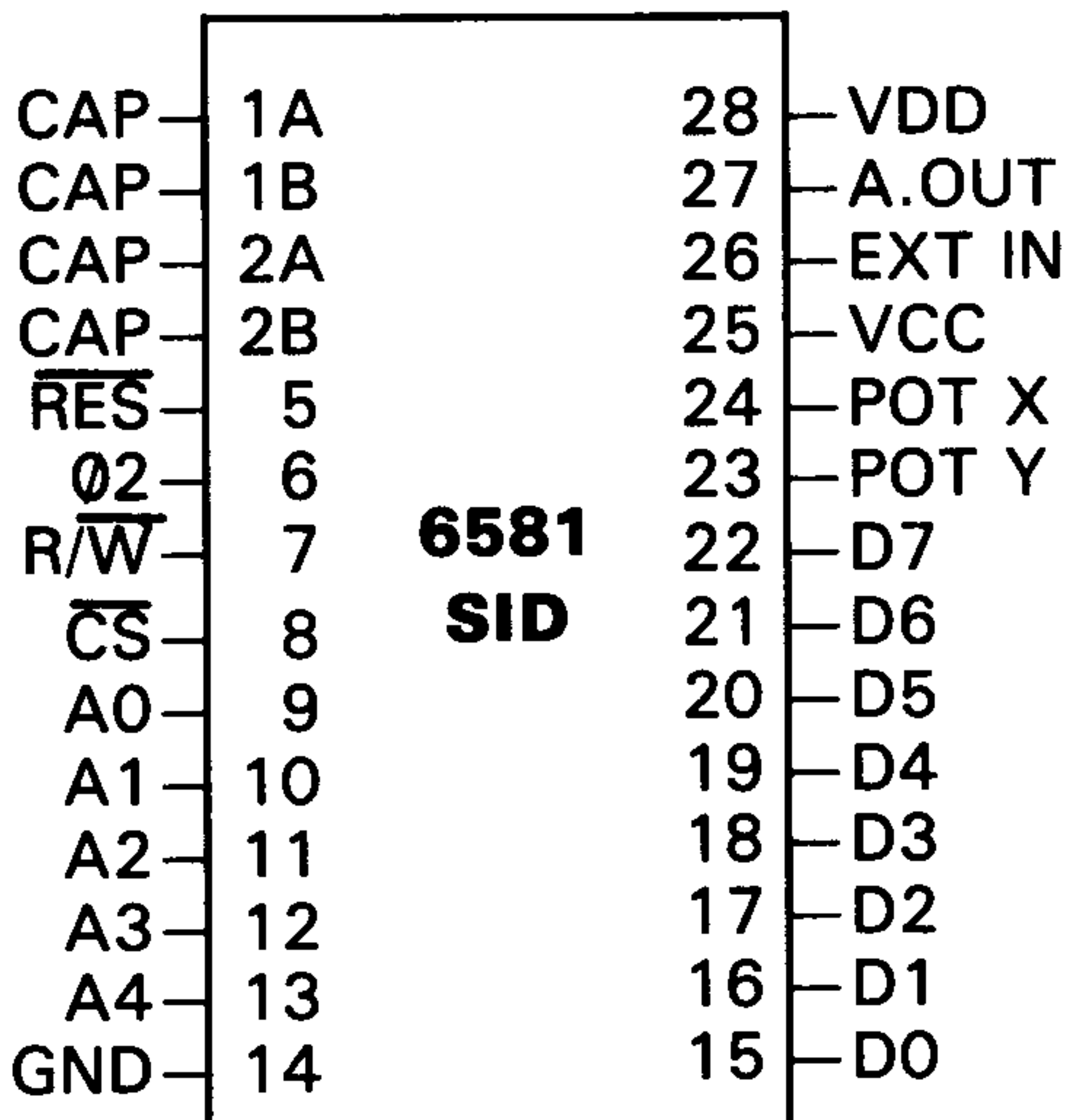
## 8563 VIDEO CONTROLLER (Continued)

### 315014 8563 CRT VIDEO CONTROLLER



|             |         |  |
|-------------|---------|--|
| 1           | CCLK    | Character Clock output.  |
| 2           | DCLK    | Video Dot Clock D.   |
| 3           | HSYNC   | Horizontal Sync Signal.  |
| 4           | CS      | Chip Select input, active high.  |
| 5,6         | NC      | No Connection.   |
| 7           | CS      | Chip Select input, active low.   |
| 8           | RS      | Register Select input. A high allows reads & writes to the selected data register. A low allows reads of the Status register and writes to the Address register.                 |
| 9           | R/W     | The read/write line controls the data direction for the data bus. Read is active high, write is active low.  |
| 10,11,13-18 | DD0-D7  | Bi-directional data bus.   |
| 12          | VSS     | Ground.  |
| 19          | DISPEN  | Display Enable output.   |
| 20          | VSYNC   | Vertical Sync signal.  |
| 21          | DR/W    | Local Display DRAM Read/Write.   |
| 22          | INIT    | Active low input for clearing internal control latches.  |
| 23          | RES     | Reset input that initializes all internal scan counters, but not control registers.  |
| 24          | TEST    | Used for testing only — tied to ground.  |
| 25          | LPEN    | Input for Light Pen. A positive going transition on this input latches the vertical and horizontal position of the character being displayed at that time.                       |
| 26-33,      | DA0-DA7 | Local display DRAM address bus.  |
| 34-36,      | DD0-DD7 | Bidirectional local display DRAM data bus.   |
| 38-42       |         |  |
| 37          | VCC     | 5VDC input.  |
| 43-46       | R,G,B,I | Pixel Data Outputs. A four-bit code is formed, associated with each pixel, containing color/intensity information, allowing a total of 16 colors on grey shades to be displayed. |
| 47          | RAS     | Row Address Strobe for local DRAM.   |
| 48          | CAS     | Column Address Strobe for local DRAM.  |

### 906112 6581 SOUND INTERFACE DEVICE (SID)



|         |                   |   |
|---------|-------------------|---|
| 1,2,3,4 | CAP1A,1B<br>2A,2B | Capacitor filter connections.   |
| 5       | RES               | Reset input. A low pulse initializes the SID.   |
| 6       | $\emptyset 2$     | Processor phase 2 clock input.  |
| 7       | R/W               | Processor read/write input.   |
| 8       | CS                | Chip select input.  |
| 9-13    | A0-A4             | Address lines from processor.   |
| 14      | GND               | Dc ground connection.   |
| 15-22   | DD0-D7            | Data Bus connections.   |
| 23      | POT Y             | Input to a A/D converter used to detect the value of a variable resistor. Commonly connected to game paddles. |
| 24      | POT X             | Same as POT Y.  |
| 25      | VCC               | 5VDC input.   |
| 26      | EXT IN            | External audio input.   |
| 27      | Audio out         | Audio output, AC coupled to audio amp.  |
| 28      | VDD               | 12VDC input.  |



# IC 8568

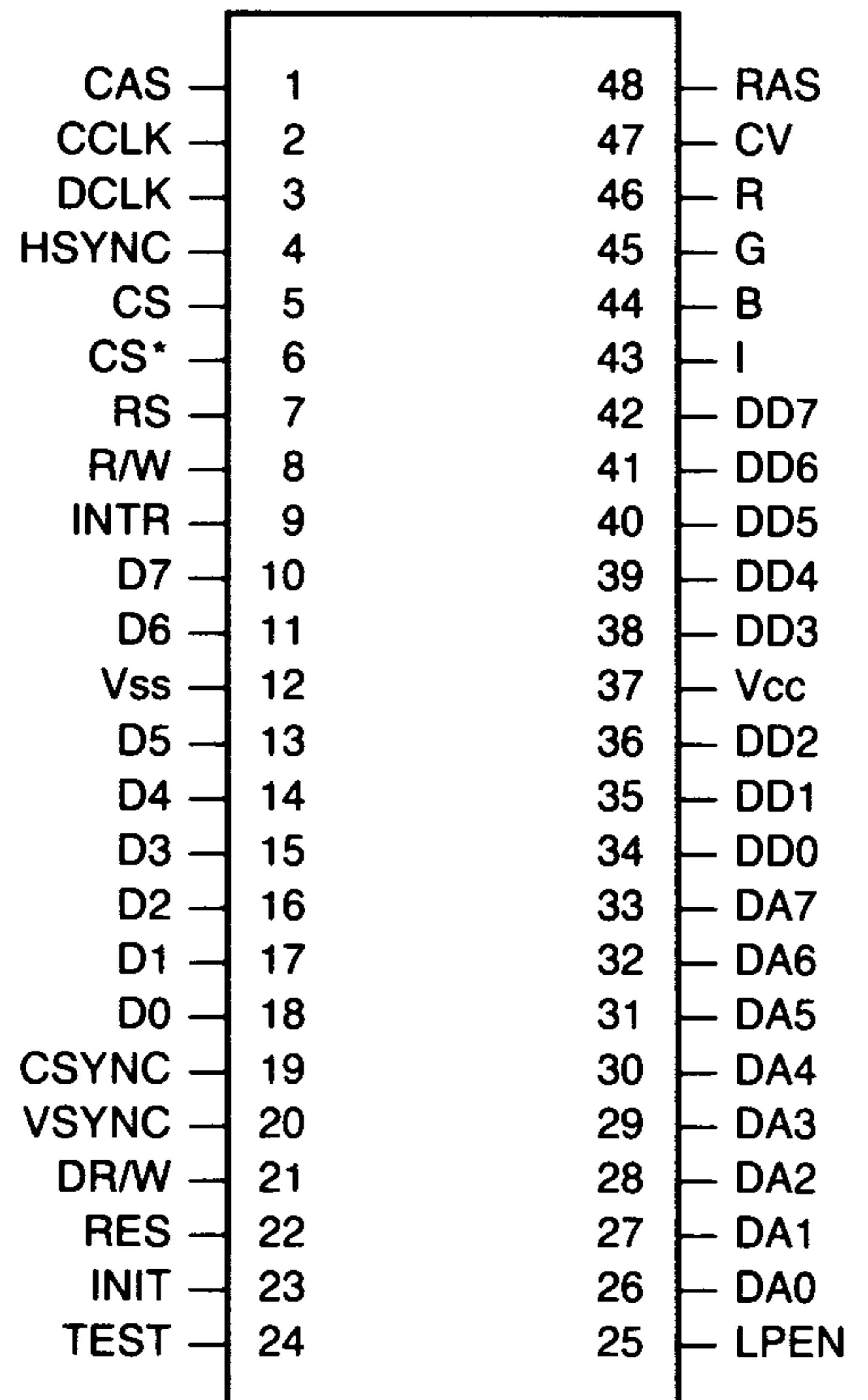
## 80 COLUMN CRT CONTROLLER

PN #315092-01

This Circuit implements the features of the 6545E CRT Controller with additional features to increase system integration.

### Features

- Single +5 volt power supply.
- Interlaced or non-interlaced display.
- NTSC or PAL operation.
- Shared RAM for Character Data, Pointers and Attributes.
- Cursor and Attributes decoded on-chip.
- R, G, B, I pixel outputs.
- Separate programmable Horizontal and Vertical Sync outputs.
- Character Clock generated on-chip.
- Interfaces to DRAMs with on-chip RAS/CAS timing.
- Programmable character fonts.
- Programmable frame height, width and rate.
- Directly interfaces to 4164 or 4416 DRAMs.



The device is a highly integrated text display chip designed to reduce the parts count of an 80-column display system. The CRT Controller contains the high-speed pixel frequency logic, requiring only a buffer to drive low impedance loads. The CRT Controller is capable of addressing 64K of DRAM memory for Character Data (character fonts), Character Pointers and Attributes. In addition, the DRAM signals RAS, CAS, Read/Write, Data and Multiplexed Addresses are generated on-chip and require no external logic to interface to the DRAMs. The DRAM multiplexed Addresses can be configured via a programmable register bit to interface directly to either 4164 or 4416 Type DRAMs

The device contains an internal 80-column double line buffer. This buffer is loaded with Character Pointers and Attributes during the Horizontal-Blanking interval (and any blank scan lines). These Pointers and Attributes are loaded during one displayed character row for use in the next character row. This device is equivalent to a 2568 or 8568.

The -01 version of the part is intended for use in systems with a TTL level Dclk signal. The -02 version is for systems with a CMOS level Dclk.

# PIN DESCRIPTION

## **CPU INTERFACE**

|       |  |
|-------|--|
| D0-D7 | Bidirectional Data Bus interface to the CPU.   |
| CS    | Chip Select input (active high).   |
| CS*   | Chip Select input (active low).  |
| RS    | Register select input. A high allows reads and writes of the selected data register. A low allows reads of the Status Register and writes of the Address Register.   |
| R/W   | Read/write input to control D0-D7 data direction. A high allows the CPU to read data supplied by the CRT Controller. A low allows the CRT Controller to accept data written by the CPU.  |
| INTR  | Interrupt request output. An open-drain output that is driven low when the Update Ready status bit makes a 'zero' to 'one' transition. This output goes high-impedance when either the Update Ready status bit is a 'zero' or the CPU reads the status register. |

## **VIDEO INTERFACE**

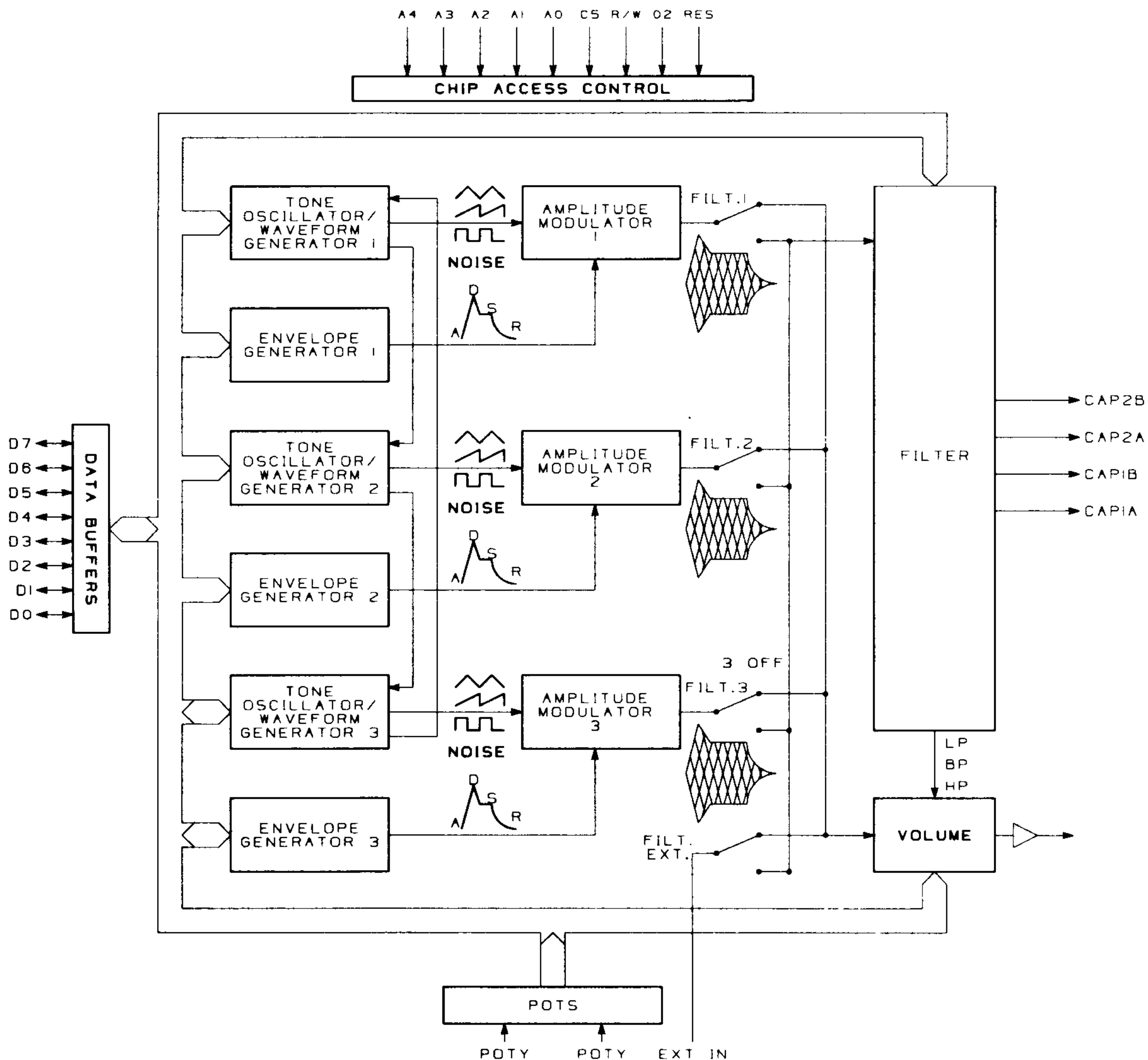
|            |  |
|------------|--|
| Vcc        | 5 VDC $\pm 5\%$  |
| Vss        | 0 VDC  |
| RES        | Reset input to initialize all internal scan counter circuits. The control registers are not affected. RES can be used to synchronize the display frame to an externally generated signal. This signal should not be confused with the INIT input.  |
| LPEN       | Light pen input. A low-to-high transition of the LPEN input loads the internal light pen registers with the vertical and horizontal character positions.   |
| DCLK       | Dot clock input. Determines the pixel width, DCLK is divided internally to generate the internal character clock and DRAM signals.   |
| HSYNC      | Horizontal sync output. HSYNC polarity, position and duration are fully programmable.  |
| VSYNC      | Vertical sync output. VSYNC polarity, position and duration are fully programmable.  |
| CSYNC      | Composite SYNC output. This is the logical exclusive-nor of internal active-high HSYNC and VSYNC signals.  |
| R, G, B, I | Red, Green, Blue and Intensity outputs. These output a four-bit code associated with each pixel. A total of 16 colors (or shades of gray) may be displayed.  |
| CV         | Composite Video output. This is the logical OR of the R, G, and B outputs.   |
| DR/W       | Video Display RAM read/write output signal.  |
| DD0-DD7    | Video Display RAM bidirectional Data Bus.  |
| DA0-DA7    | Video Display RAM multiplexed Address Bus outputs.   |
| RAS        | Row Address Strobe output for the multiplexed addresses.   |
| CAS        | Column address strobe output for the multiplexed addresses.  |
| CCLK       | Character clock output (for unspecified uses).   |
| INIT       | Initialization input pin (active low). Clears internal control latches, allowing the CRT Controller to begin proper operation following power-on initialization. The INIT pin should be held low for at least 16 DCLK cycles during system initialization, and held high during operation. |
| TEST       | This pin reconfigures the part to simplify automatic testing. In normal use this pin should be connected to Vss.   |

# 8580 SID

Part #318013-01

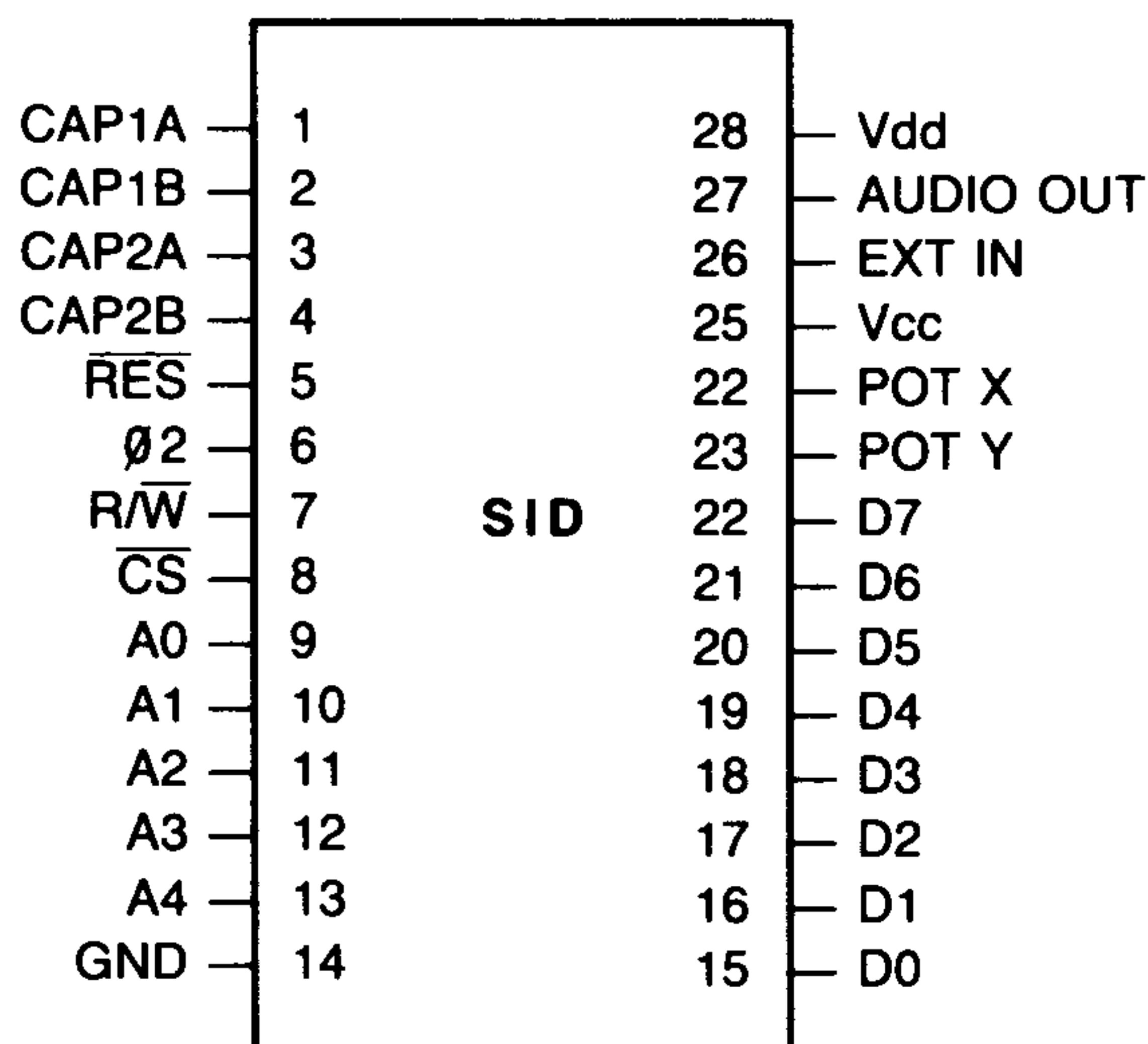
The SID consists of three synthesizer "voices" which can be used independently or in conjunction with each other (or external audio sources) to create complex sounds. Each voice consists of a Tone Oscillator/Waveform Generator, and an Envelope Generator and an Amplitude Modulator. The Tone Oscillator controls the pitch of the voice over a wide range. The Oscillator produces four waveforms at the selected frequency, with the unique harmonic content of each waveform providing simple control of tone color. The volume dynamics of the oscillator are controlled by the Amplitude Modulator under the direction of the Envelope Generator. When triggered, the Envelope Generator creates an amplitude envelope with programmable rates of increasing and decreasing volume. In addition to the three voices, a programmable Filter is provided for generating complex, dynamic tone colors via subtractive synthesis.

SID allows the microprocessor to read the changing output of the third Oscillator and third Envelope Generator. These outputs can be used as a source of modulation information for creating vibrato, frequency/filter sweeps and similar effects. The third oscillator can also act as a random number generator for games. Two A/D converters are provided for inter-facing SID with potentiometers. These can be used for "paddles" in a game environment or as front panel controls in a music synthesizer. SID can process external audio signals, allowing multiple SID chips to be daisy-chained or mixed in complex polyphonic systems.



**SID BLOCK DIAGRAM**

## SID PIN DESCRIPTION



### CAP1A, CAP1B (Pins 1,2)/CAP2A, CAP2B (Pins 3,4)

These pins are used to connect the two integrating capacitors required by the programmable Filter. C1 connects between pins 1 and 2, C2 between pins 3 and 4. Both capacitors should be the same value. Normal operation of the Filter over the audio range (approximately 30Hz-12KHz) is accomplished with a value of 6800 pF for C1 and C2. Polystyrene capacitors are preferred. The frequency range of the Filter can be tailored to specific applications by the choice of capacitor values. For example, a low-cost game may not require full high-frequency response. In this case, larger values for C1 and C2 could be chosen to provide more control over the bass frequencies of the Filter. The approximate maximum Cutoff Frequency of the Filter is given by:  $FC_{max} = 8.2E - 5/C$

Where C is the capacitor value. The range of the Filter extends approximately 9 octaves below the maximum Cutoff Frequency.

### Res (Pin 5)

This TTL-level input is the reset control for SID. When brought low for at least ten 02 cycles, all internal registers are reset to zero and the audio output is silenced. This pin is normally connected to the reset line of the microprocessor or a power-on-clear circuit.

### 02 (Pin 6)

This TTL-level input is the master clock for SID. All oscillator frequencies and envelope rates are referenced to this clock. 02 also controls data transfers between the SID and the microprocessor. Data can only be transferred when 02 is high. Essentially, 02 acts as a high-active chip select as far as data transfers are concerned. This pin is normally connected to the system clock, with a normal operating frequency of 1.0MHz.

### R/W (Pin 7)

This TTL-level input controls the direction of data transfers between SID and the microprocessor. If the chip select conditions have been met, a high on this line allows the microprocessor to Read data from the selected SID register and a low allows the microprocessor to Write data into the selected SID register. This pin is normally connected to the system Read/Write line.

### CS (Pin 8)

This TTL-level input is a low active chip select which controls data transfers between SID and the microprocessor CS must be low for any transfer. A Read from the selected SID register can only occur if CS is low, 02 is high and R/W is low. This pin is normally connected to address decoding circuitry, allowing SID to reside in the memory map of a system.

## SID PIN DESCRIPTION *(Continued)*

### **A0-A4 (Pins 9-13)**

These TTL-level inputs are used to select one of the 29 SID registers. Although enough addresses are provided to select 1 of 32 registers, the remaining three register locations are not used. A Write to any of these three locations is ignored and a Read returns invalid data. These pins are normally connected to the corresponding address lines of the microprocessor so that SID may be addressed in the same manner as memory.

### **GND (Pin 14)**

For best results, the ground line between SID and the power supply should be separate from the ground lines to other digital noise at the audio output.

### **D0-D7 (Pins 15-22)**

These bidirectional lines are used to transfer data between SID and the microprocessor. They are TTL compatible in the output mode and capable of driving 2 TTL loads in the output mode. The data buffers are usually in the high-impedance off state. During a Write operation, the data buffers remain in the off (input) state and the microprocessor supplies data to SID over these lines. During a Read operation, the data buffers turn on and SID supplies data to the microprocessor over these lines. The pins are normally connected to the corresponding data lines of the microprocessor.

### **POTX, POTY (Pins 24, 23)**

These pins are inputs to the A/D converters used to digitize the position of potentiometers. The conversion process is based on the time constant of a capacitor tied from the POT pin to ground, charged by a potentiometer tied from the POT pin to +5 volts. The component values are determined by:  
 $RC = 1.04E-3$

Where R is the maximum resistance of the pot and C is the capacitor. The larger the capacitor, the smaller the POT value jitter. The recommended values for R and C are 470K Ohms and 2200 pF. Note that a separate pot and cap are required for each POT pin.

### **Vcc (Pin 25)**

As with the GND line, separate +5 VDC line should be run between SID Vcc and the power supply in order to minimize noise. A bypass capacitor should be located close to the pin.

### **Ext In (Pin 26)**

This analog input allows external audio signals to be mixed with the audio output of SID or processed through the Filter. Typical sources include voice, guitar and organ. The input impedance of this pin is in the order of 100K Ohms. External input amplitude should not exceed 3 volts p-p.

Due to the DC level at the external input pin, external signals should be AC-coupled to EXT IN by an electrolytic capacitor in capacitor in the 1-10 $\mu$ F range. As the direct audio path (FILTEX = 0) has unity gain, EXT IN can be used to mix outputs of many SID chips by daisy-chaining. The number of chips that can be chained in this manner is determined by the amount of noise and distortion allowable at the final output. Note that the output Volume control will affect not only the three SID voices, but also any external inputs.

### **Audio Out (Pin 27)**

This open-source buffer is the final audio output of SID, composed of the three SID voices, the Filter and any external input. The output level is set by the output Volume control and reaches a maximum of approximately 3 volts p-p at a 4.75 VDC level.

The output of SID rides on a 4.75 level, it should be AC-coupled to any audio amplifier with an electrolytic capacitor in the 1-10 $\mu$ F range.

### **Vdd (Pin 28)**

As with Vcc, a separate +9 VDC line should be run to SID Vdd and a bypass capacitor should be used.

# EQUAL-TEMPERED MUSICAL SCALE VALUES

The following table lists the numerical values which must be stored in the SID Oscillator frequency control registers to produce the notes of the equal-tempered musical scale. The equal-tempered scale consists of an octave containing 12 semitones (notes): C, D, E, F, G, A, B and C\*, D\*, F\*, G\*, A\*. The frequency of each semitone is exactly the 12th root of 2 ( $12\sqrt[12]{2}$ ) times the frequency of the previous semitone. The table is based on a  $\text{O2} = \text{clock}$  of 1.0 MHz. Refer to the equation given in the Register Description for use of other master clock frequencies. The scale selected is concert pitch, in which A4=440 Hz. Transpositions of this scale and scales other than the equal-tempered scale are also possible.

| Musical Note | Freq. (Hz) | Osc. Fn. (Decimal) | Osc. Fn. (Hex) | Musical Note | Freq. (Hz) | Osc. Fn. (Decimal) | Osc. Fn. (Hex) |
|--------------|------------|--------------------|----------------|--------------|------------|--------------------|----------------|
| 0 C0         | 16.35      | 274                | 0112           | 48 C4        | 261.63     | 4389               | 1125           |
| 1 C0\$       | 17.32      | 291                | 0123           | 49 C4\$      | 277.18     | 4650               | 122A           |
| 2 D0         | 18.35      | 308                | 0134           | 50 D4        | 293.66     | 4927               | 133F           |
| 3 D0\$       | 19.44      | 326                | 0146           | 51 D4\$      | 311.13     | 5220               | 1464           |
| 4 E0         | 20.60      | 346                | 015A           | 52 E4        | 329.63     | 5530               | 159A           |
| 5 F0         | 21.83      | 366                | 016E           | 53 F4        | 349.23     | 5859               | 16E3           |
| 6 F0\$       | 23.12      | 388                | 0184           | 54 F4\$      | 370.00     | 6207               | 183F           |
| 7 G0         | 24.50      | 411                | 018B           | 55 G4        | 392.00     | 6577               | 1981           |
| 8 G0\$       | 25.96      | 435                | 01B3           | 56 G4\$      | 415.30     | 6968               | 1B38           |
| 9 A0         | 27.50      | 461                | 01CD           | 57 A4        | 440.00     | 7382               | 1CD6           |
| 10 A0\$      | 29.14      | 489                | 01E9           | 58 A4\$      | 466.16     | 7821               | 1E80           |
| 11 B0        | 30.87      | 518                | 0206           | 59 B4        | 493.88     | 8286               | 205E           |
| 12 C1        | 32.70      | 549                | 0225           | 60 C5        | 523.25     | 8779               | 224B           |
| 13 C1\$      | 34.65      | 581                | 0245           | 61 C5\$      | 554.37     | 9301               | 2455           |
| 14 D1        | 36.71      | 616                | 0268           | 62 D5        | 587.33     | 9854               | 267E           |
| 15 D1\$      | 38.89      | 652                | 028C           | 63 D5\$      | 622.25     | 10440              | 28C8           |
| 16 E1        | 41.20      | 691                | 02B3           | 64 E5        | 659.25     | 11060              | 2B34           |
| 17 F1        | 43.65      | 732                | 02DC           | 65 F5        | 698.46     | 11718              | 2DC6           |
| 18 F1\$      | 46.25      | 776                | 0308           | 66 F5\$      | 740.00     | 12415              | 307F           |
| 19 G1        | 49.00      | 822                | 0336           | 67 G5        | 783.99     | 13153              | 3361           |
| 20 G1\$      | 51.91      | 871                | 0367           | 68 G5\$      | 830.61     | 13935              | 366F           |
| 21 A1        | 55.00      | 923                | 039B           | 69 A5        | 880.00     | 14764              | 39AC           |
| 22 A1\$      | 58.27      | 978                | 03D2           | 70 A5\$      | 932.33     | 15642              | 3D1A           |
| 23 B1        | 61.74      | 1036               | 040C           | 71 B5        | 987.77     | 16572              | 40BC           |
| 24 C2        | 65.41      | 1097               | 0449           | 72 C6        | 1046.50    | 17557              | 4495           |
| 25 C2\$      | 69.30      | 1163               | 048B           | 73 C6\$      | 1108.73    | 18601              | 48A9           |
| 26 D2        | 73.42      | 1232               | 04D0           | 74 D6        | 1174.66    | 19709              | 4CFC           |
| 27 D2\$      | 77.78      | 1305               | 0519           | 75 D6\$      | 1244.51    | 20897              | 518F           |
| 28 E2        | 82.41      | 1383               | 0567           | 76 E6        | 1318.51    | 22121              | 5669           |
| 29 F2        | 87.31      | 1465               | 05B9           | 77 F6        | 1396.91    | 23436              | 5B8C           |
| 30 F2\$      | 92.50      | 1552               | 0610           | 78 F6\$      | 1479.98    | 24830              | 60FE           |
| 31 G2        | 98.00      | 1644               | 066C           | 79 G6        | 1567.98    | 26306              | 6602           |
| 32 G2\$      | 103.83     | 1742               | 06CE           | 80 G6\$      | 1661.22    | 27871              | 6CDF           |
| 33 A2        | 110.00     | 1845               | 0735           | 81 A6        | 1760.00    | 29528              | 7358           |
| 34 A2\$      | 116.54     | 1955               | 07A3           | 82 A6\$      | 1864.65    | 31234              | 7A34           |
| 35 B2        | 123.47     | 2071               | 0817           | 83 B6        | 1975.53    | 33144              | 8178           |
| 36 C3        | 130.81     | 2195               | 0893           | 84 C7        | 2093.00    | 35115              | 892B           |
| 37 C3\$      | 138.59     | 2325               | 0915           | 85 C7\$      | 2217.46    | 37203              | 9153           |
| 38 D3        | 146.83     | 2463               | 099F           | 86 D7        | 2349.32    | 39415              | 99F7           |
| 39 D3\$      | 155.56     | 2610               | 0A32           | 87 D7\$      | 2489.01    | 41759              | A31F           |
| 40 E3        | 164.81     | 2765               | 0ACD           | 88 E7        | 2637.02    | 44242              | ACD2           |
| 41 F3        | 174.61     | 2930               | 0B72           | 89 F7        | 2793.83    | 46873              | B719           |
| 42 F3\$      | 185.00     | 3104               | 0C20           | 90 F7\$      | 2959.95    | 49660              | C1FC           |
| 43 G3        | 196.00     | 3288               | 0C08           | 91 G7        | 3135.96    | 52613              | CO85           |
| 44 G3\$      | 207.65     | 3484               | 0D9C           | 92 G7\$      | 3322.44    | 55741              | O98O           |
| 45 A3        | 220.00     | 3691               | 0E6B           | 93 A7        | 3520.00    | 59056              | E6B0           |
| 46 A3\$      | 233.08     | 3910               | 0F46           | 94 A7\$      | 3729.31    | 62567              | F467           |
| 47 B3        | 246.94     | 4143               | 102F           | 95 B7        | 3951.06    | 66288              | 1F2F0          |

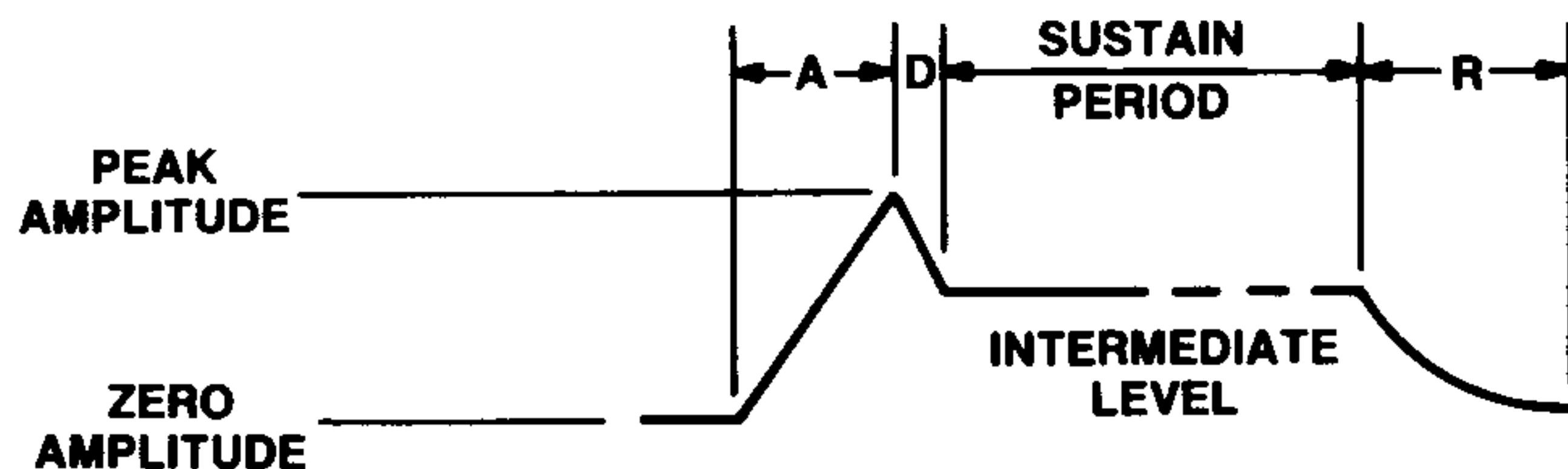
Although the table above provides a simple and quick method for generating the equal-tempered scale, it is very memory inefficient as it requires 192 bytes for the table alone. Memory efficiency can be improved by determining the note value algorithmically. Using the fact that each note in an octave is exactly half the frequency of that note in the next octave, the note look-up table can be reduced from 96 entries to 12 entries, as there are 12 notes per octave. If the 12 entries

(24 bytes) consist of the 16-bit values for the eighth octave (C7 through B7), then notes in lower octaves can be derived by choosing the appropriate note in the eighth octave and dividing the 16-bit value by two for each octave of difference. As division by two is nothing more than a right-shift of the value, the calculation can easily be accomplished by a simple software routine. Although note B7 is beyond the range of the Oscillators, this value should still be included in the

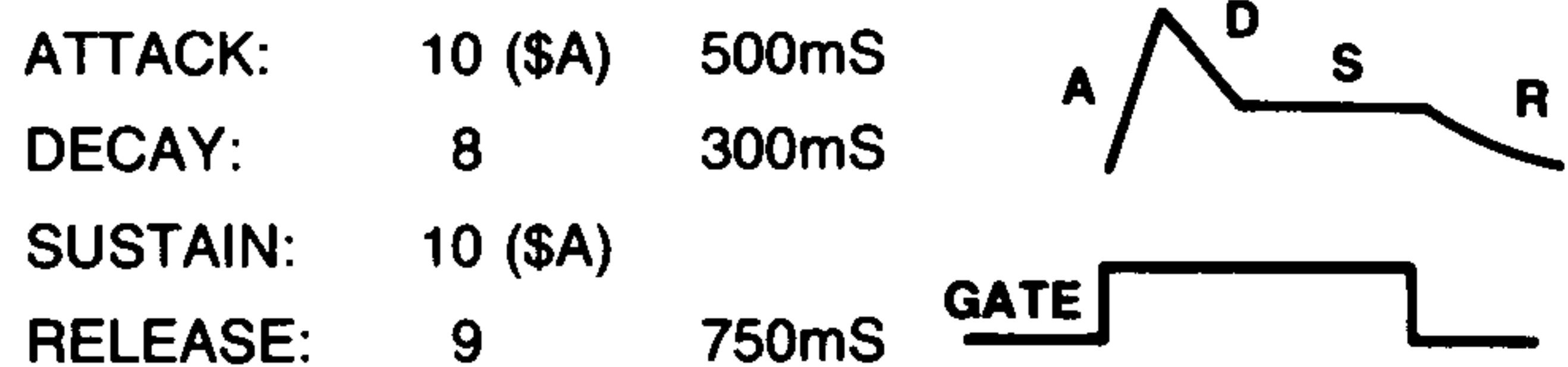
table for calculation purposes (the MSB of B7 would require a special software case, such as generating this bit in the CARRY before shifting). Each note must be specified in a form which indicates which of the 12 semitones is desired, and which of the eight octaves the semitone is in. Since four bits are necessary to select 1 of 12 semitones and three bits are necessary to select 1 of 8 octaves, the information can fit in one byte, with the lower nybble selecting the semitone (by addressing the look-up table) and the upper nybble being used by the division routine to determine how many times the table value must be right-shifted.

## SID ENVELOPE GENERATORS

The four-part ADSR (ATTACK, DECAY, SUSTAIN, RELEASE) envelope generator has been proven in electronic music to provide the optimum trade-off between flexibility and ease of amplitude control. Appropriate selection of envelope parameters allows the simulation of a wide range of percussion and sustained instruments. The violin is a good example of a sustained instrument. The violinist controls the volume by bowing the instrument. Typically, the volume builds slowly, reaches a peak, then drops to an intermediate level. The violinist can maintain this level for as long as desired, then the volume is allowed to slowly die away. A "snapshot" of this envelope is shown below:



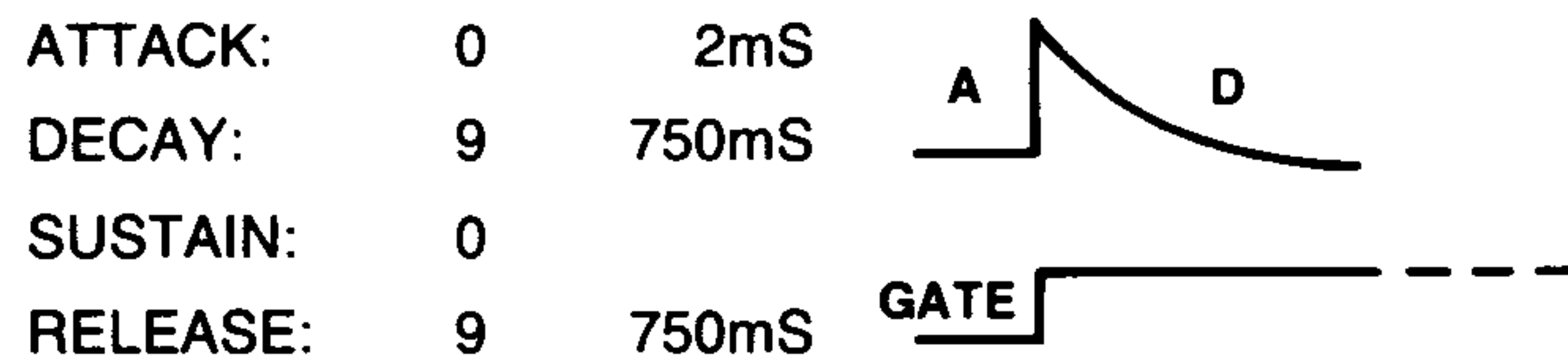
This volume envelope can be easily reproduced by the ADSR as shown below, with typical envelope rates:



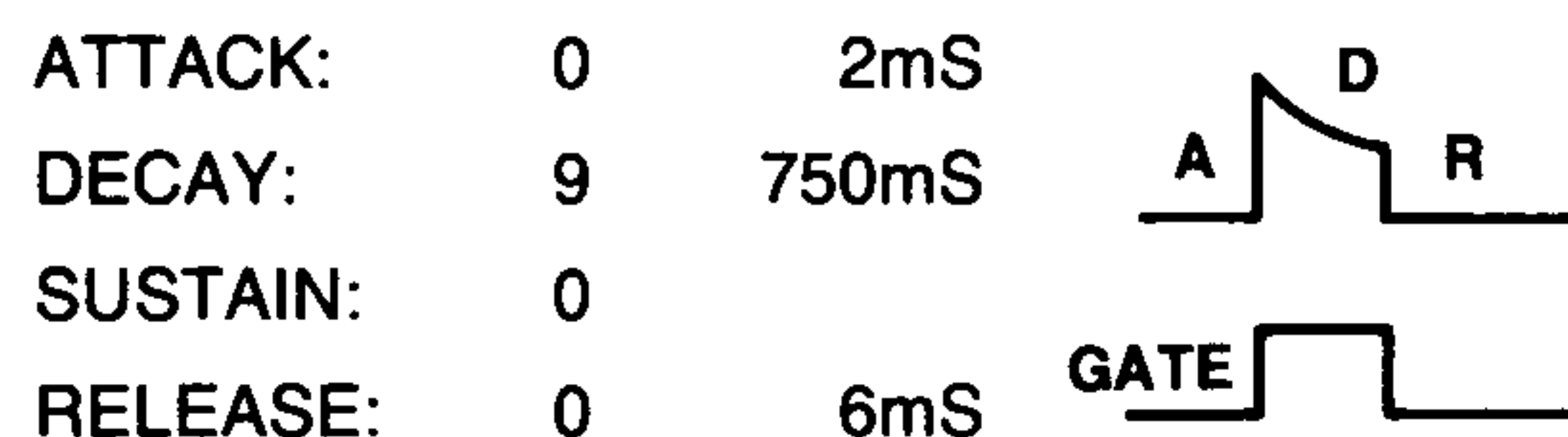
Note that the tone can be held at the intermediate SUSTAIN level for as long as desired. The tone will not begin to die away until GATE is cleared. With minor alterations, this basic envelope can be used for brass and woodwinds as well as strings.

An entirely different form of envelope is produced by percussion instruments such as drums, cymbals and gongs, as well as certain keyboards such as pianos and harpsichords. The percussion envelope is characterized by a nearly instantaneous attack, immediately followed by a decay to zero volume. Percussion instruments cannot be sustained at a constant amplitude. For example, the instant a drum is struck, the sound reaches full volume and decays rapidly regardless

of how it was struck. A typical cymbal envelope is shown below:

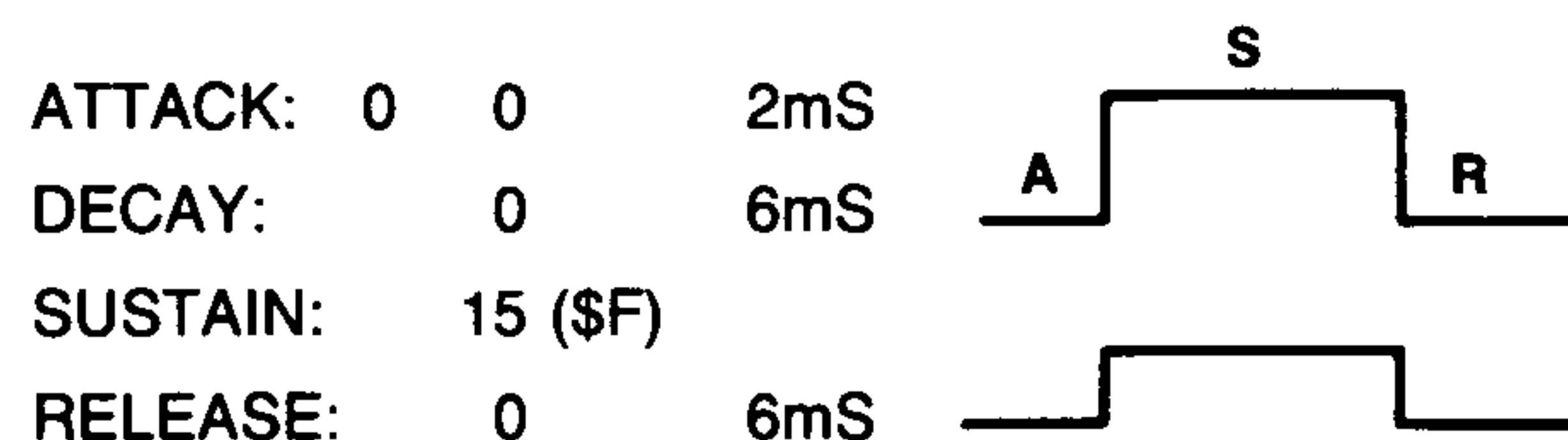


Note that the tone immediately begins to decay to zero amplitude after the peak is reached, regardless of when GATE is cleared. The amplitude envelope of pianos and harpsichords is somewhat more complicated, but can be generated quite easily with the ADSR. These instruments reach full volume when a key is first struck. The amplitude immediately begins to die away slowly as long as the key remains depressed. If the key is released before the sound has fully died away, the amplitude will immediately drop to zero. This envelope is shown below:

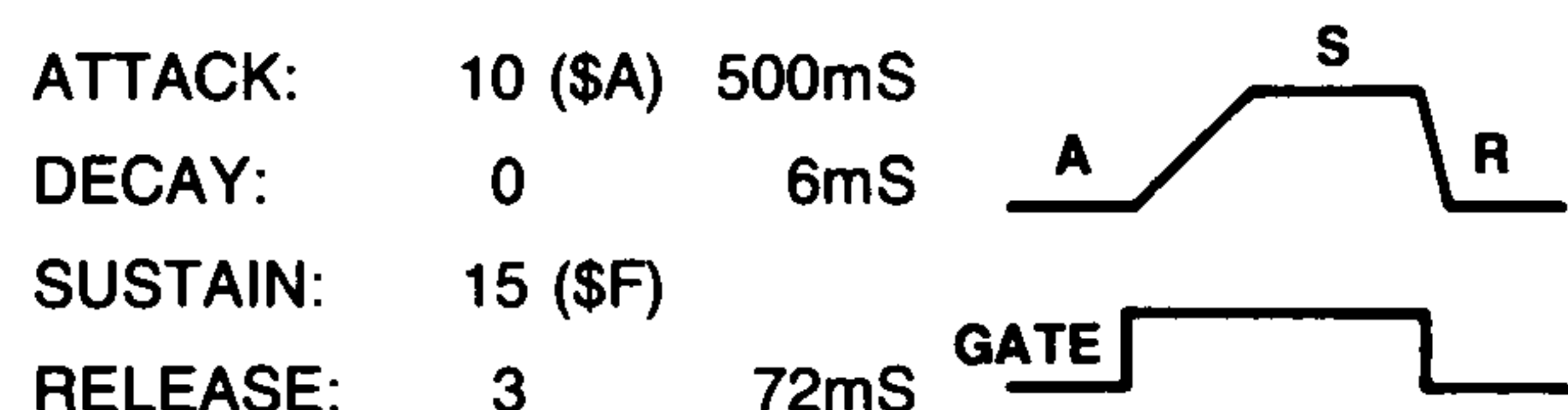


Note that the tone decays slowly until GATE is cleared, at which point the amplitude drops rapidly to zero.

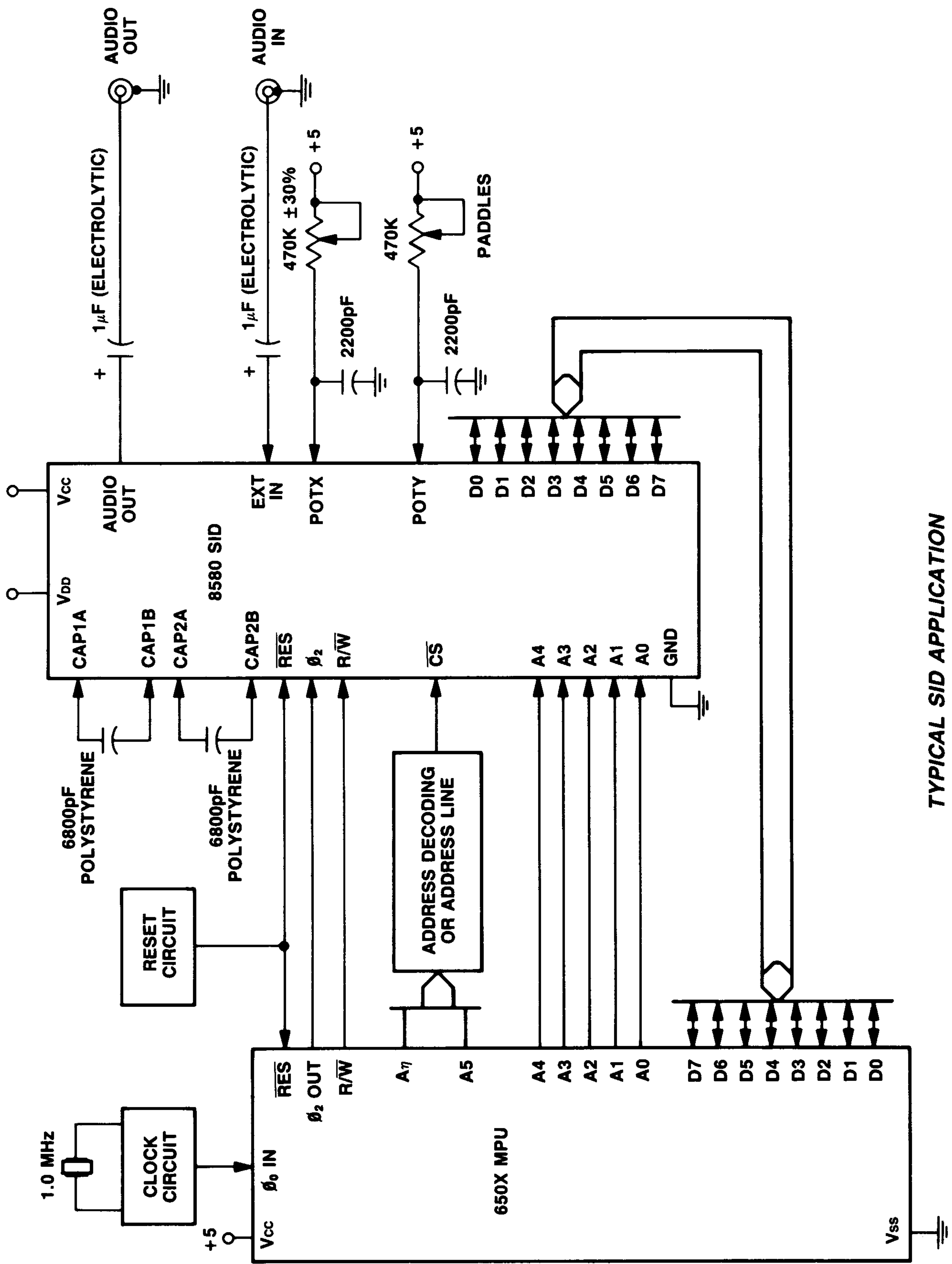
The most simple envelope is that of the organ. When a key is pressed, the tone immediately reaches full volume and remains there. When the key is released, the tone drops immediately to zero volume. This envelope is shown below:



The real power of SID lies in the ability to create original sounds rather than simulations of acoustic instruments. The ADSR is capable of creating envelopes which do not correspond to any "real" instruments. A good example would be the "backwards" envelope. This envelope is characterized by a slow attack and rapid decay which sounds very much like an instrument that has been recorded on tape then played backwards. This envelope is shown below:



Many unique sounds can be created by applying the amplitude envelope of one instrument to the harmonic structure of another. This produces sounds similar to familiar acoustic instruments, yet notably different. In general, sound is quite subjective and experimentation with various envelope rates and harmonic contents will be necessary in order to achieve the desired sound.



TYPICAL SID APPLICATION



# FLOPPY DISK DRIVE READ/WRITE AMPLIFIER

*Part #252308-01*

## FUNCTIONS

This is an integrated circuit designed for Read/Write of Floppy Disk Drive (FDD)

This IC offers the following features:

1. Including Head SW Matrix for selecting Read/Write.
2. The voltage gain of Pre-Amplifier can be selected to 100 or 200 by connecting the external capacitor.
3. Peak Shift is less than 1% over Pre-Amplifier input range of 0.25 mVp-p to 10 mVp-p without adjustment.
4. Time Domain Filter contains retriggerable monostable multivibrator which has internal timing capacitor allowing to be used only external resistor.
5. Common, Write and Erase drivers have large current capacities to satisfy versatile FDD's conditions.
6. Write current can be determined by external resistors and is virtually independent against a change of temperature and power supply voltage.
7. Write current may be selected to two different values by Digital Input signal, if Write current compensation is required on inner tracks of the disk.
8. WRITE GATE and ERASE GATE input timings can be set independently.
9. Power Monitor circuit with Schmitt-Trigger function inhibits illegal writing against power supply voltage fluctuation including power ON/OFF transients.
10. The number of external components is greatly reduced by this one-chip Read/Write IC.

### Absolute Maximum Ratings (Ta = 25°C)

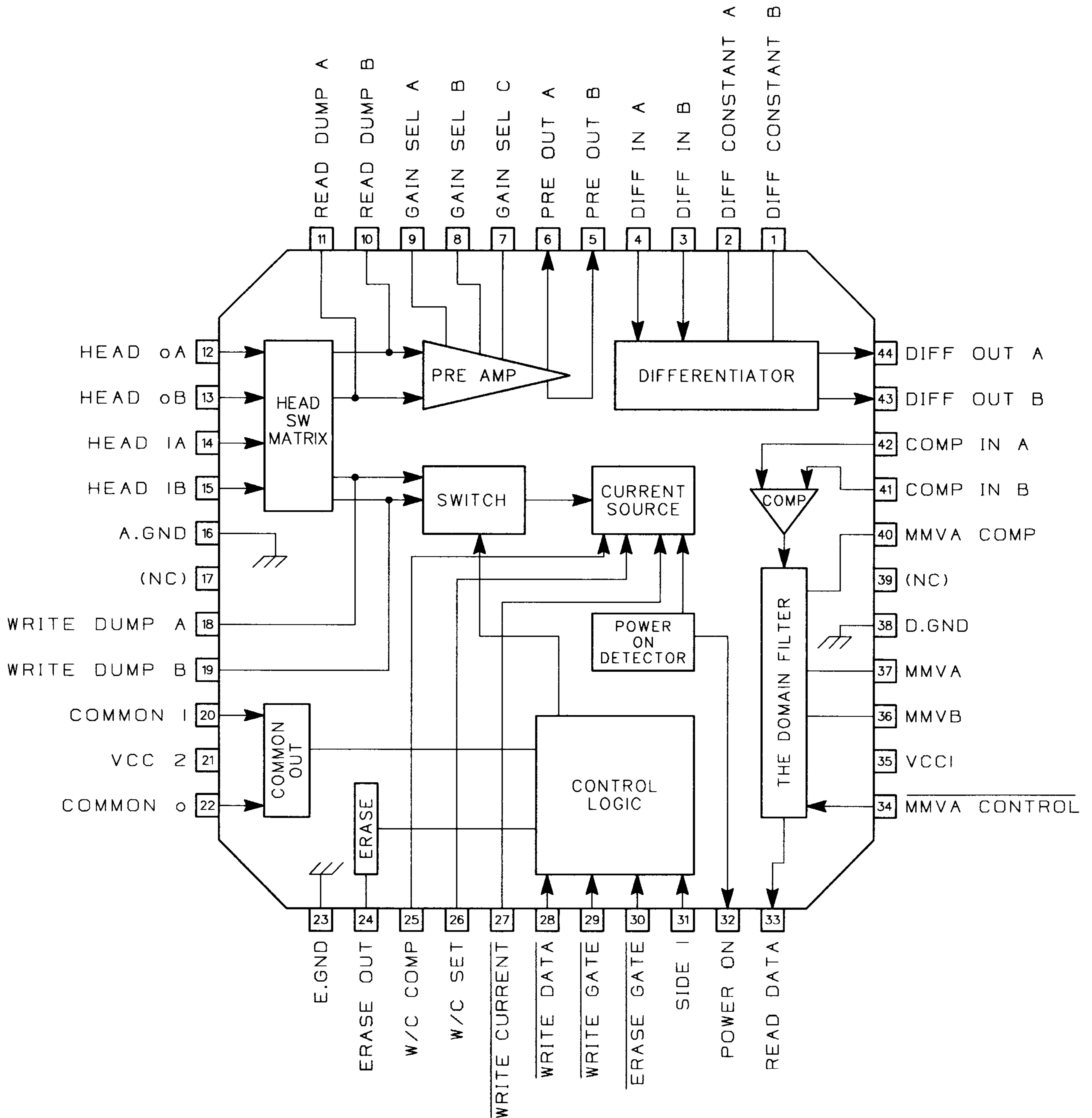
|   |                   |
|---|-------------------|
| • Power Supply Voltage Vcc:                       | 17V               |
| • Power Supply Voltage Vcc:                       | 7V                |
| • Digital Signal Inputs (NOTE 1) Input Voltage    | -0.5 — +5.5V      |
| • POWER ON OUTPUT Voltage Applied                 | 15V               |
| • ERASE OUTPUT Voltage Applied                    | 20V               |
| • COMMON 0, COMMON 1, SOURCE Currents             | 150mA             |
| • POWER ON OUTPUT SINK Current                    | 20mA              |
| • ERASE OUTPUT SINK Current                       | 150mA             |
| • HEAD 0A and 0B. HEAD 1A and 1B. Voltage Applied | 23V               |
| • Operating Ambient Temperature                   | Topr -20 — +75°C  |
| • Operating Junction Temperature                  | Tj + 150°C        |
| • Storage Temperature                             | Tstg -65 — +150°C |

NOTE 1: These inputs are WRITE CURRENT, WRITE DATA, WRITE GATE, ERASE GATE, SIDE 1, and MMVA CONTROL.

# PIN DESCRIPTION

| PIN   | DESCRIPTION          | FUNCTION  |   |
|-------|----------------------|---|---|
| 1     | DIFF CONSTANT B      | Connect external components to set the differential constant.   |   |
| 2     | DIFF CONSTANT A      |   |   |
| 3     | DIFF IN B            |   |   |
| 4     | DIFF IN A            |   |   |
| 5     | PRE OUT B            |   |   |
| 6     | PRE OUT A            |   |   |
| 7,8,9 | GAIN SEL A.B.C.      |   |   |
| 10    | READ DUMP B          |   | Connect the head dumping resistor for Read. |
| 11    | READ DUMP A          |   |   |
| 12    | HEAD <sub>0</sub> A  | Input and output terminals for Read/Write head on Side 0.   |   |
| 13    | HEAD <sub>0</sub> B  |   |   |
| 14    | HEAD <sub>1</sub> A  | Input and output terminals for Read/Write head on Side 1.   |   |
| 15    | HEAD <sub>1</sub> B  |   |   |
| 16    | A. GND               | Analog circuit Ground.  |   |
| 18    | WRITE DUMP A         | Connect the head dumping resistor for Write.  |   |
| 19    | WRITE DUMP B         |   |   |
| 20    | COMMON1              | Connect the center tap of Read/Write head on Side 1.  |   |
| 21    | VCC2                 | 12V Power supply terminal.  |   |
| 22    | COMMON <sub>0</sub>  | Connect the center tap of Read/Write head on Side 0.  |   |
| 23    | E. GND               | Erase circuit Ground.   |   |
| 24    | ERASE OUT            | Open Collector Erase current output.  |   |
| 25    | W/C COMP             | Connect a resistor for Write current compensation.  |   |
| 26    | W/C SET              | Connect a resistor to determine Write current.  |   |
| 27    | <u>WRITE CURRENT</u> | Digital input pin. When <u>WRITE CURRENT</u> is set to "L", Write current is increased.                                     |   |
| 28    | <u>WRITE DATA</u>    | Digital input pin with Schmitt-Trigged function. When <u>WRITE DATA</u> is set from "H" to "L". Write current is switched.  |   |
| 29    | <u>WRITE GATE</u>    | Digital input pin. When <u>WRITE GATE</u> is set to "L", Write circuit block becomes Active causing Write current to be ON. |   |
| 30    | <u>ERASE GATE</u>    | Digital input pin. When <u>ERASE GATE</u> is set to "L", Erase circuit becomes Active, causing Erase current to be ON.      |   |
| 31    | <u>SIDE 1</u>        | Digital input pin. When <u>SIDE 1</u> is set to "L", Read/Write head on Side 1 becomes Active.                              |   |
| 32    | POWER ON             | Open Collector output. When Power Monitor circuit detects the power supply voltage drop. POWER ON output is ON.             |   |
| 33    | <u>READ DATA</u>     | Read Data output (Totem-Pole output).   |   |
| 34    | <u>MMVA CONT</u>     | Digital input pin. When <u>MMVA CONT</u> is set to "L", the pulse width of Time Domain Filter's mono-multi is decreased.    |   |
| 35    | VCC1                 | 5V Power supply terminal.   |   |
| 36    | MMVS                 | Connect a resistor to determine the pulse width of Read Data output.  |   |
| 37    | MMVA                 | Connect a resistor to determine the pulse width of Time Domain Filter's mono-multi.   |   |
| 38    | D. GND               | Digital circuit Ground.   |   |
| 40    | MMVA COMP            | Connect a resistor for the pulse width compensation of Time Domain Filter's mono-multi.                                     |   |
| 41    | COMP IN B            | Comparator input.   |   |
| 42    | COMP IN A            |   |   |
| 43    | DIFF OUT B           | Differentiator output.  |   |
| 44    | DIFF OUT A           |   |   |

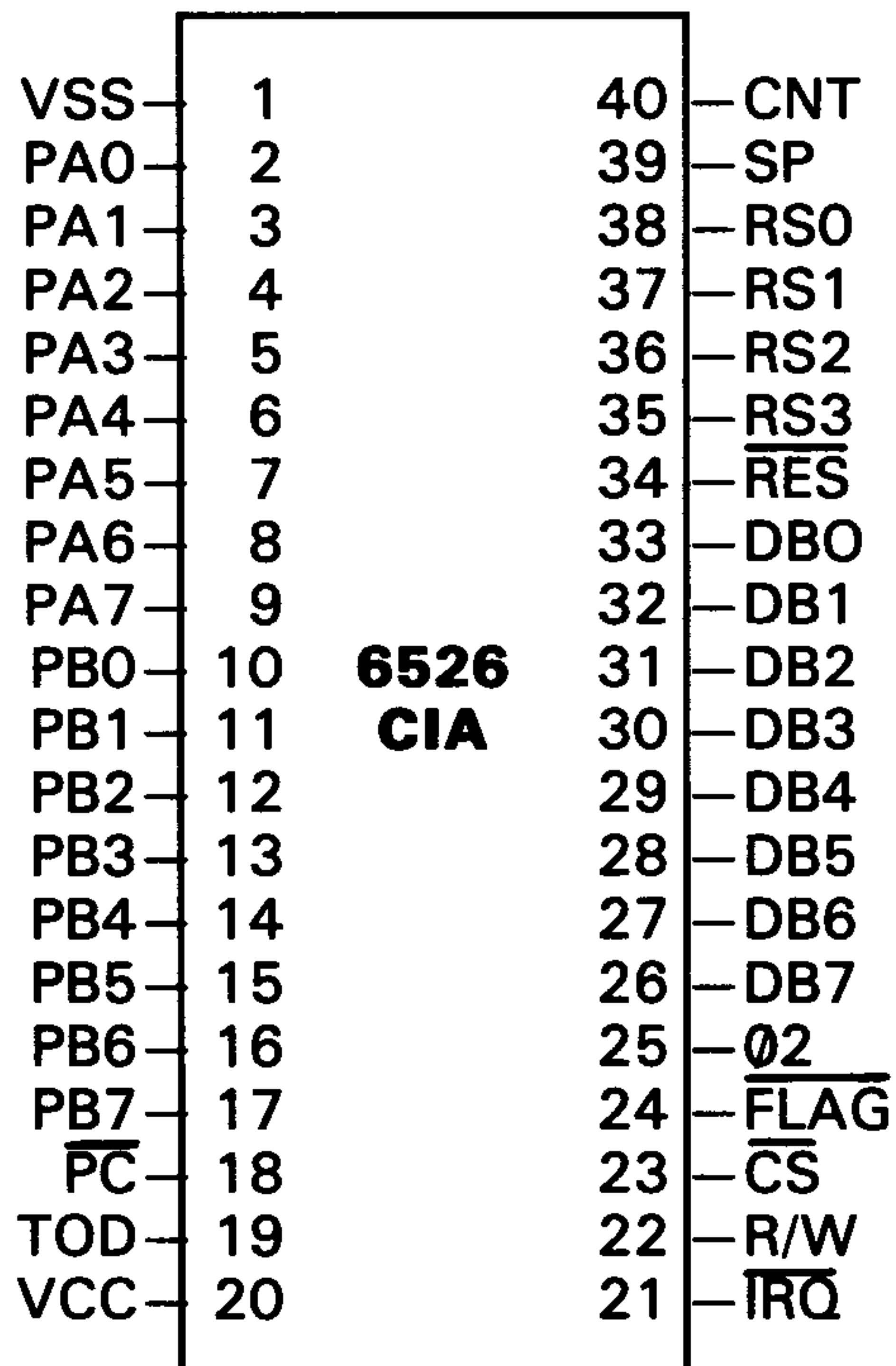
**PIN CONFIGURATION**



# I/O – INPUT/OUTPUT CIRCUITS

**FOLD OUT SCHEMATIC SHEET 1, PAGE 73, FOR EASY REFERENCE.**

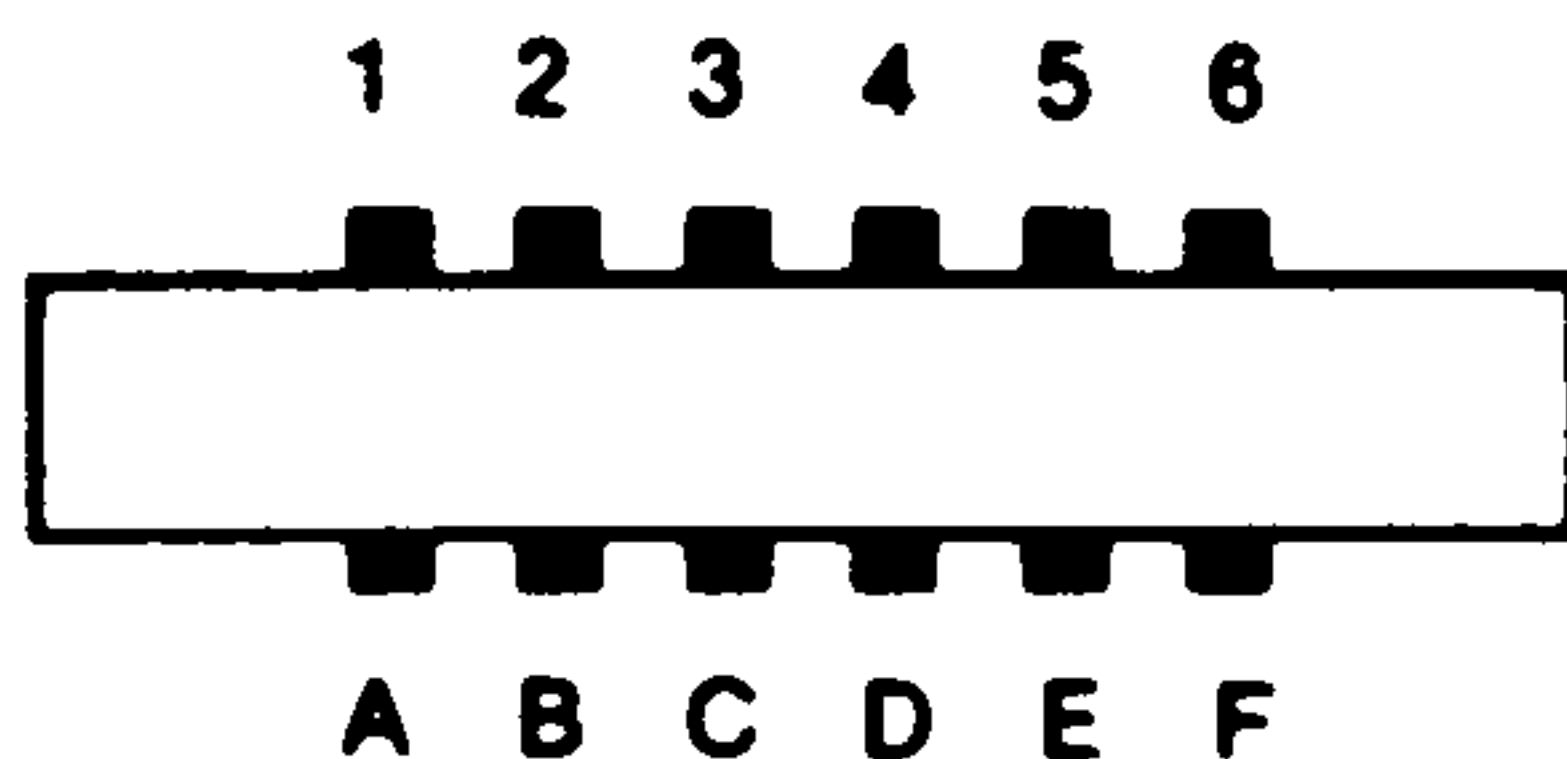
## 906108 6526 COMPLEX INTERFACE ADAPTER



|       |         |  |
|-------|---------|--|
| 1     | VSS     | Ground Connection.   |
| 2-9   | PA0-PA7 | Parallel port A signals. Bidirectional parallel port.  |
| 10-17 | PB0-PB7 | Parallel port B signals. Bidirectional parallel port.  |
| 18    | PC      | Handshake output. A low pulse is generated after a read or write on port B.  |
| 19    | TOD     | Time of day clock input. Programmable 50hz or 60hz input.  |
| 20    | VCC     | 5VDC input.  |
| 21    | IRQ     | Interrupt output to microprocessor.  |
| 22    | R/W     | READ/WRITE input from microprocessor's R/W output.   |
| 23    | CS      | Chip select input. A low pulse will activate CIA.  |
| 24    | FLAG    | Negative-edge sensitive interrupt input. Can be used as a handshake line for either parallel port.   |
| 25    | Ø2      | Ø2 clock input.  |
| 26-33 | DB0-DB7 | Bidirectional data bus.  |
| 34    | RES     | Low active reset input. Initializes CIA.   |
| 35-38 | RS0-RS3 | Register select inputs. Used to select all internal registers for communications with the parallel ports, time of day clock, and serial port (SP). |
| 39    | SP      | Serial Port bidirectional connection. An internal shift register converts microprocessor parallel data into serial data, and visa-versa.           |
| 40    | CNT     | Count input. Internal timers can count pulses applied to this input. Can be used for frequency dependent operations.                               |

## CASSETTE INTERFACE

### PIN CONFIGURATION

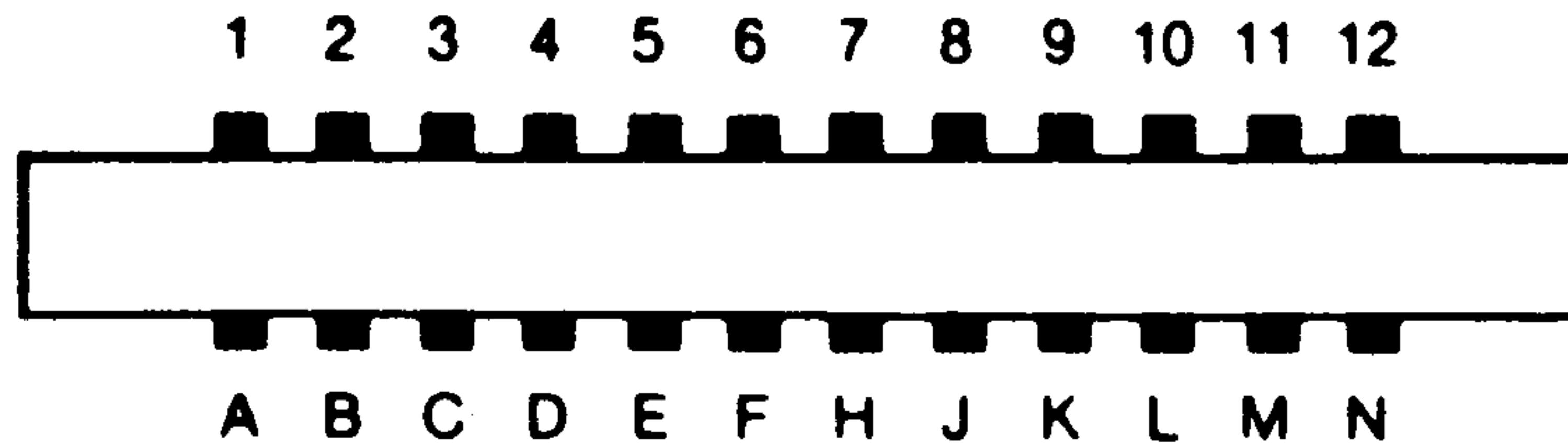


| Pin | Signal         |
|-----|----------------|
| A-1 | GND            |
| B-2 | +5V            |
| C-3 | CASSETTE MOTOR |
| D-4 | CASSETTE READ  |
| E-5 | CASSETTE WRITE |
| F-6 | CASSETTE SENSE |

The Cassette interface is controlled by the 8502 microprocessor. One of the features of the 8502 is a built-in parallel I/O port (P0-P5). P3 - P5 control most of the cassette interface circuitry. P3, pin 27 of U6, outputs the write data signal to connector CN2 on pins E and 5. P4 is an input that senses the play switch depressed on the cassette deck. P5 is an output that controls the cassette motor. When P5 goes "low", pin 12 of the inverter U30 goes "high", Q3 is biased on and current is passed through the cassette motor coil. U1 is a Complex Interface Adapter (CIA). Parallel ports, serial outputs, and Timers are standard features of the CIA. Read data enters on pins D, 4 of CN2. U1 accepts the read data signal on the FLAG input pin 24.

# THE USER PORT

## PIN CONFIGURATION\*

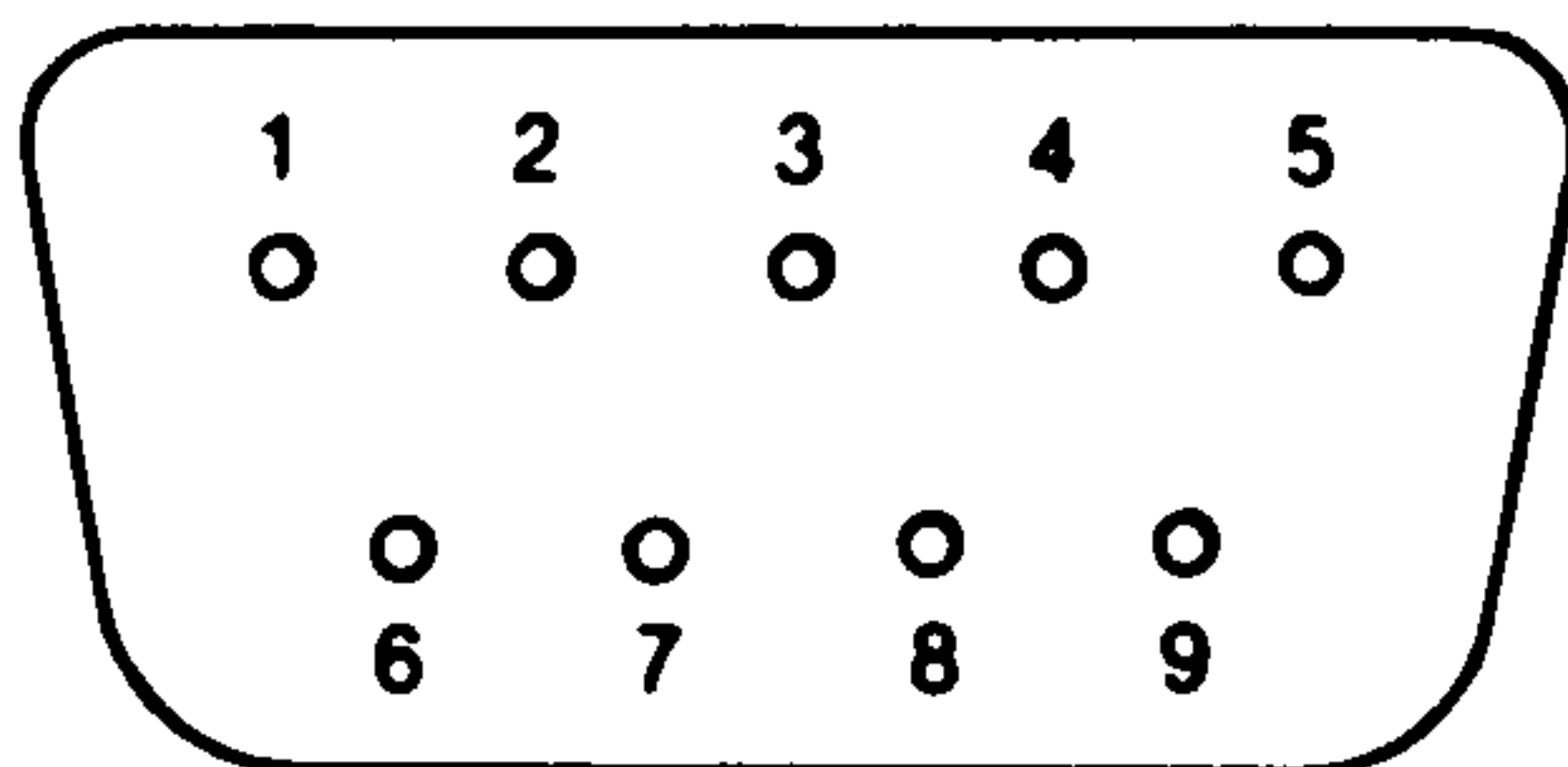


\* See Sheet 1 of Schematic for line definitions.

Parallel port B of the 6526 CIA device at U4 (PB0-PB7) is made available on the user port. Parallel data transfers with external devices are made very easily through this parallel port. SP1 and SP2 are bi-directional serial ports. CNT1 and CNT2 are bi-directional synchronizing clock signals for each serial port.

# THE CONTROL PORTS

## PIN CONFIGURATIONS



Control Port 1

| Pin | Type        | Note      |
|-----|-------------|-----------|
| 1   | JOYA0       |           |
| 2   | JOYA1       |           |
| 3   | JOYA2       |           |
| 4   | JOYA3       |           |
| 5   | POT AY      |           |
| 6   | BUTTON A/LP |           |
| 7   | +5V         | MAX. 50mA |
| 8   | GND         |           |
| 9   | POT AX      |           |

Control Port 2

| Pin | Type     | Note      |
|-----|----------|-----------|
| 1   | JOYB0    |           |
| 2   | JOYB1    |           |
| 3   | JOYB2    |           |
| 4   | JOYB3    |           |
| 5   | POT BY   |           |
| 6   | BUTTON B |           |
| 7   | +5V      | MAX. 50mA |
| 8   | GND      |           |
| 9   | POT BX   |           |

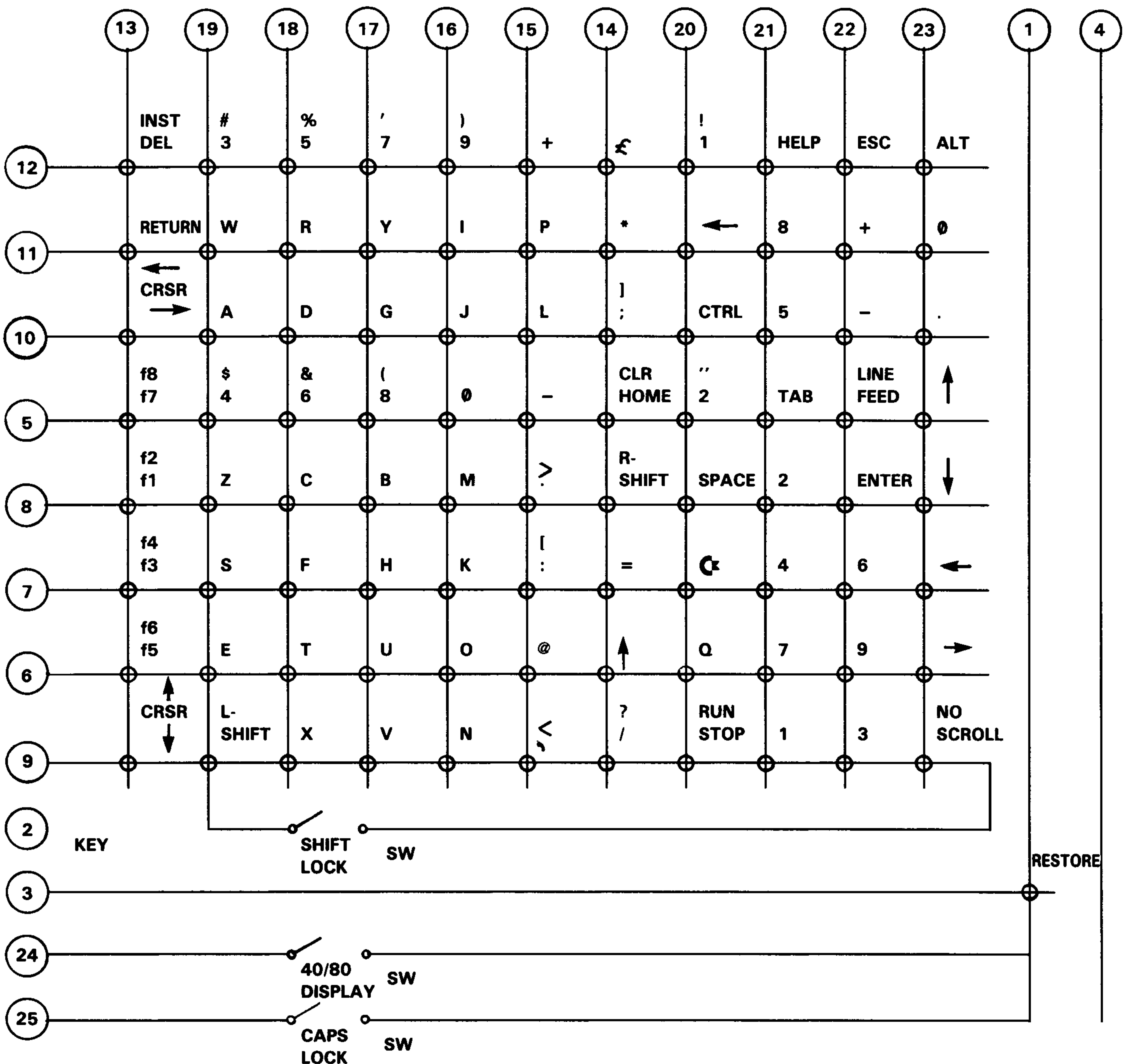
There are two Control ports, numbered 1 and 2. Each Controller port can accept a joystick or game controller paddle. A light pen can be plugged only into port 1, CN3. The control port signals are tied to keyboard inputs and handled by the 6526 CIA device at U1.

# THE KEYBOARD

The C128 keyboard is an advance over the standard C64 keyboard. In 64 mode, only the standard 66 keys are accessible.

In 128 mode, 24 extra keys are available. They are the separate CURSOR keys, the HELP key, additional FUNCTION keys, an ALPHA-LOCK key, the 40/80 key and a NUMERIC KEYPAD. These additional keys are strobed by the VIC chip or are tied to dedicated 8502 or MMU I/O lines.

Keyboard operations are controlled by the 6526 I/O device at location U1.

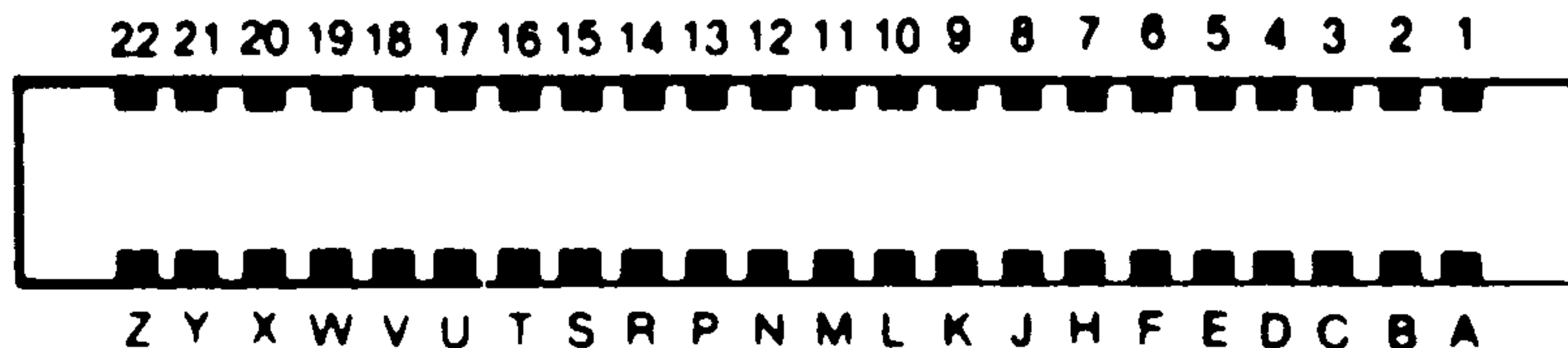


KEYBOARD MATRIX

# THE EXPANSION BUS

The expansion bus available at CN1, is a parallel port that is used to connect program or game cartridges as well as special interfaces.

## PIN CONFIGURATION\*



**\*See Sheet 1 of Schematic for line definitions.**

The C128 Expansion Bus is compatible with the C64 Expansion Bus, while at the same time allowing extended capabilities in C128 mode.

## CARTRIDGE ADDITION

The C128 can use larger and more sophisticated cartridges than the C64 can. One of the main reasons for this is the new banking scheme used in the C128 for external cartridges. The C64 uses two hardware control lines,  $\overline{\text{EXROM}}$  and  $\overline{\text{GAME}}$ , to control banking out of internal facilities and banking in of cartridge facilities. The C128 uses a software polling method, where, upon power-up, it polls the cartridge, according to a defined protocol, to determine if such a cartridge exists, and if so, its software priority. Since the C128 is always free to bank between cartridges and built-in ROM, an external application can take advantage of internal routines and naturally become an extended part of the C128, as opposed to becoming a replacement application.

The elimination of  $\overline{\text{EXROM}}$  and  $\overline{\text{GAME}}$  as hardware control lines for cartridge identification, in C128 mode, has freed up both of these lines for extended functioning. Both of the lines appear as bits in the MMU mode configuration register, and are both input and output ports. Neither has a dedicated function other than general cartridge function expansion and lend themselves to act as latched banking lines or input sense lines.

## DMA Capability

The C128 expansion bus supports DMAs in a fashion similar to that of the C64. A C64 DMA is achieved by pulling the  $\overline{\text{DMA}}$  pin on the expansion bus low. Immediately after this happens, the RDY and AEC lines of the processor are brought low. This can cause problems, depending on what the processor is doing at the time. The RDY input of a 65xx series processor, when brought low, will halt the processor on the next  $\phi_1$  cycle, leaving the processor's address lines reflecting the current address being fetched. However, if the processor is in a write cycle when RDY is brought low, it will ignore RDY until the next read cycle. Thus, in the C64, a  $\overline{\text{DMA}}$  input occurring during a write cycle will tri-state the processor's address and data bus, but not stop it until up to three cycles later when the next read cycle occurs. The write cycles following the  $\overline{\text{DMA}}$  input do not actually write, causing memory corruption and often processor fatality when the  $\overline{\text{DMA}}$  line is released. Any  $\overline{\text{DMA}}$  input during  $\phi_2$  is a potentially fatal DMA.

## THE EXPANSION BUS (Continued)

If a proper  $\overline{\text{DMA}}$  is asserted, the C64 tri-states and shuts down, allowing the DMA source complete access to the processor bus. Such a DMA source must monitor the  $\phi_2$  and BA outputs, as it must tri-state when the VIC is on the bus, and it must completely DMA when a VIC DMA is called for. The VIC chip always has the highest DMA priority. When on the bus, the DMA source has access to RAM, ROM, and I/O in the C64 DMA scheme. A proper DMA shutdown is usually achieved via some C64 software handshaking with the DMA source.

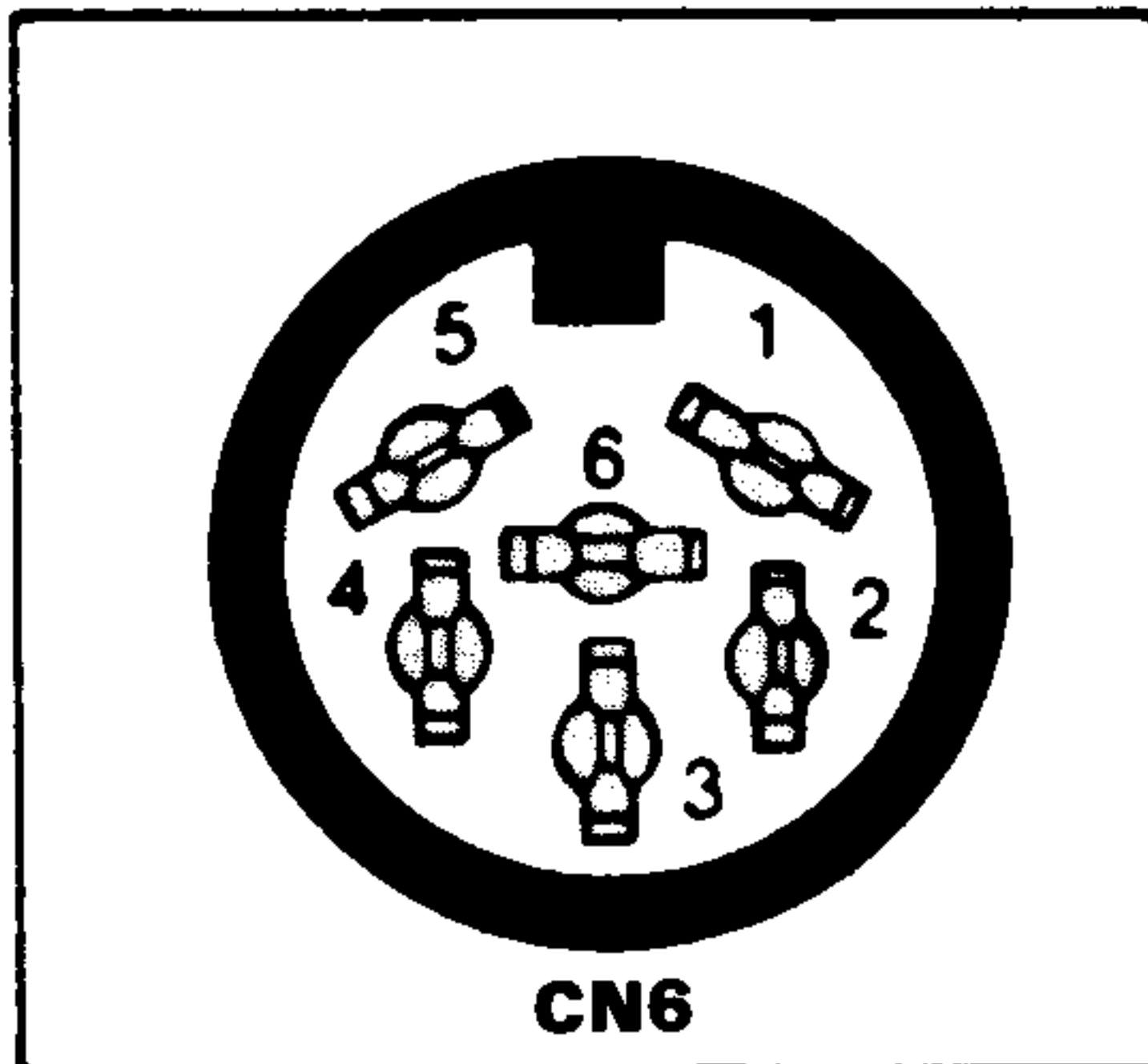
The C128 mode uses a similar DMA scheme. When the  $\overline{\text{DMA}}$  input goes low, the RDY input to the 8502, the AEC input to the 8502, and the  $\overline{\text{BUSRQST}}$  input to the Z-80, immediately go low. Additionally, the gated AEC signal, GAEC, goes low, causing the MMU to go immediately to its VIC cycle mode, and the Z-80 data-out buffer to tri-state. The DMA causes the Address to Shared Address buffer to reverse direction, and the Translated Address to Address buffer to be enabled, giving the external DMA source complete access to the processor Address Bus. The PLA is still looking at ungated AEC and, as such, will allow access to I/O devices, RAM, and ROM. There can be no access to the MMU. Thus, for C128 memory mapping, the memory map must be set up before being DMAed. For C64 mode, memory mapping is done by the 8502 processor port lines and by the external  $\overline{\text{EXROM}}$  and  $\overline{\text{GAME}}$ . Since the 8502 ports will be inaccessible by a DMA source, only C64 map changes based upon  $\overline{\text{EXROM}}$  and  $\overline{\text{GAME}}$  can be made during a DMA. This is the same as is true in a C64 unit. All DMA sources, as with the C64, must yield to the VIC during  $\phi_0$  or BA low. In order to use DMAs, the DMA source will most likely have to cooperate with a C128 mode program that allows the C128 to shake hands in software with a DMA source to effect DMA non-destructively. A DMA source may also be able to monitor  $\phi_0$  and R/W to achieve a non-destructive DMA, since unlike the C64, the C128 does not tri-state the R/W line during VIC time. The R/W line will, of course, tri-state during a DMA to allow the DMA source to drive it, and care must be taken to look at the R/W line for this only after it becomes valid. In any case,  $\phi_0$  and BA must be constantly monitored to allow the VIC chip to function.



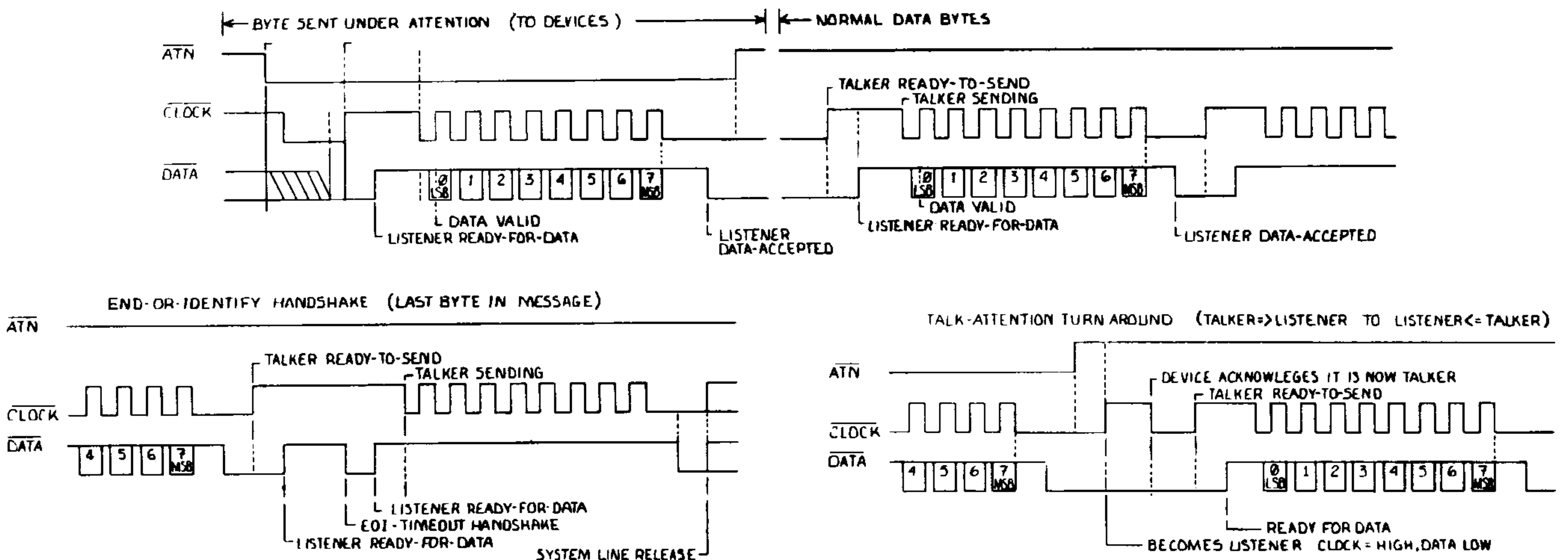
# THE SERIAL BUS

The C128 Serial Bus is an improved version of the C64/VIC 20 serial bus. The C128 improves this bus by allowing communication at much greater speeds with specially designed peripherals, the most important being the disk drive, while still maintaining capability with older, slower peripherals used by the VIC 20 and the C64.

Serial Interface Connector



| Pin No. | Signal      | Description  |
|---------|-------------|--|
| 1       | SERIAL SRQ  | The slow serial bus does not use the SERVICE REQUEST line. The fast serial bus uses it as a fast bidirectional clock line. |
| 2       | GND         | Chassis ground.  |
| 3       | SERIAL ATN  | The ATTENTION line is a low active handshake used to address a device on the bus.  |
| 4       | SERIAL CLK  | This is the slow serial CLOCK. It is used by slow serial devices to clock data transmitted on the serial bus.              |
| 5       | SERIAL DATA | The bidirectional serial DATA line is used by both slow and fast devices to transmit data in sync with a clock signal.     |
| 6       | RES         | The RESET line is used to reset all peripherals when the host resets.  |



## Bus Operations

There are three basic bus operations that take place on the serial bus, in both fast and slow modes. The first of these is called **Control**. The C128 is the **controller** in most circumstances. The **controller** of the bus is always the device that initiates protocol on the bus, requesting peripheral devices to do one of the two other serial operations, either **Talk** or **Listen**.

All serial bus devices can listen. A **Listener** is a device that has been ordered by the **Controller** to receive data. Some devices, such as disk drives, can talk. A **Talker** can send data to the **Controller**. Both hardware and software drive this bus protocol.

## **THE SERIAL BUS (Continued)**

### **The Standard (Slow) Serial Bus**

The slow serial bus uses the port lines of the 6526 at U4, C1A 2, to drive ATN, CLK and DATA. The operation is the same as that of the C64 and when in C64 mode, slow to fast interference is automatically removed.

### **The Fast Serial Bus**

In order to talk as a fast talker, the Controller must be addressing a fast device. When addressing any device, the C128 sends a fast byte, toggling the SRQ line eight times, with the ATN line low. If the device is a fast device, it will record the fact that a fast Controller accessed it and respond with a fast acknowledge. If the device is a slow device, no response is delivered and the C128 then assumes it is talking with a slow device. The status of the fast or slow is retained until the device is requested to untalk, unlisten, or if an error or system reset occurs.

The fast serial bus, in order to achieve its speed increase, uses different hardware than that of the slow serial bus. The fast serial method is to use the serial port lines of the 6526 U1, CIA 1, pin 39, to actually transfer the serial data. This increases the transfer rate dramatically.

The  $\overline{\text{FSDIR}}$  bidirectional control line signals the MMU at U7, pin 44, that a fast device is present. The MMU then outputs control signals to the data direction buffer hardware for fast serial operation.

## COMMON LINE DEFINITIONS

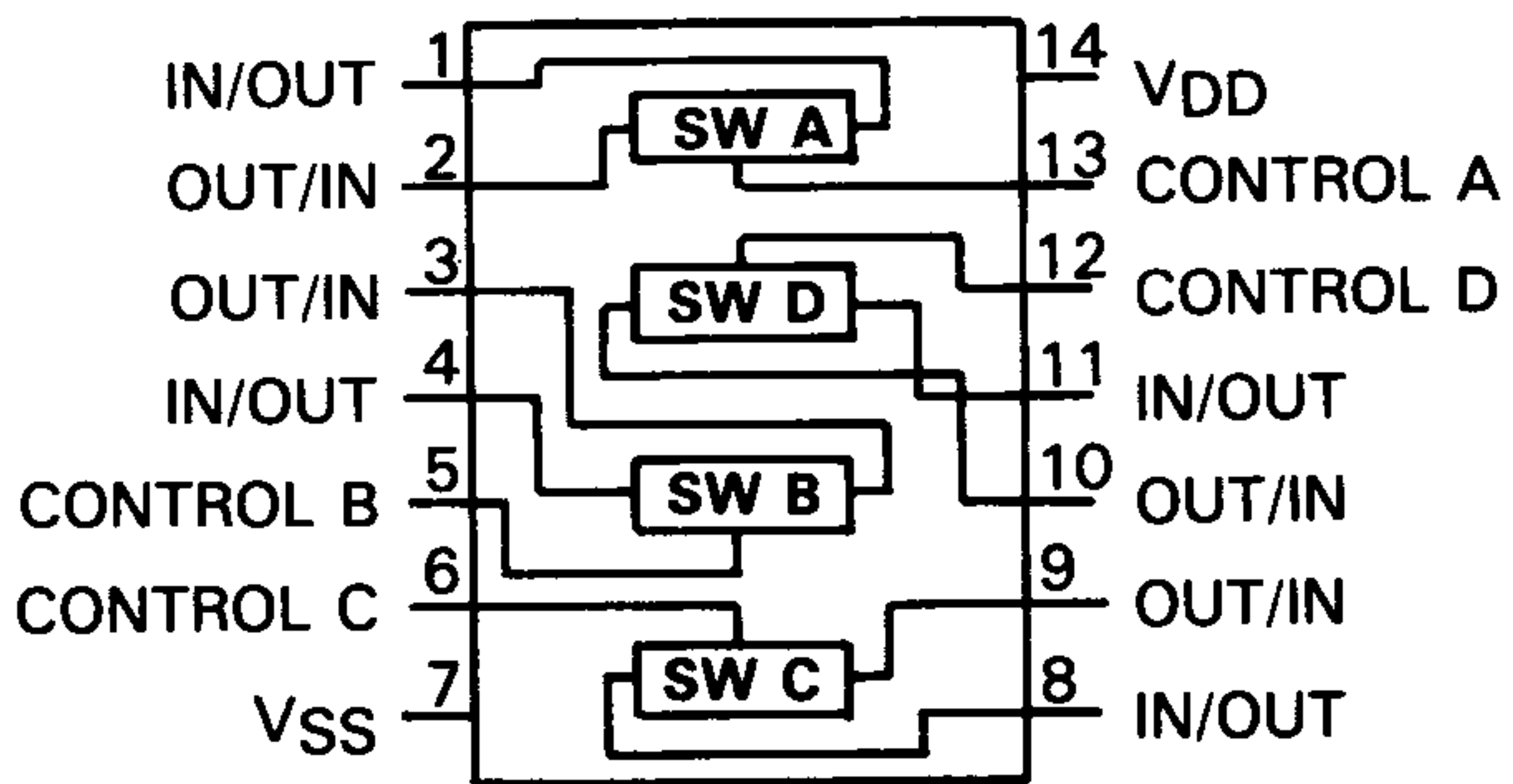
|  |  |   |  |
|--|--|---|--|
| A0-A7<br>AEC<br>ATN  | PROCESSOR ADDRESS BUS<br>ADDRESS ENABLE CONTROL<br>ATTENTION LINE  | LCR<br>LP   | LOAD CONFIGURATION REGISTER<br>LIGHT PEN INPUT   |
| BA   | BUS AVAILABLE  | MA0-MA11<br>MMU<br>MS 0-4   | MULTIPLEXED ADDRESS BUS<br>MEMORY MANAGEMENT UNIT<br>MEMORY STATUS, ALSO IDENTIFIED AS<br>ROMBANK  |
| C128/64<br>CAP LK<br>CAS<br>CASENB<br>CASS SENSE<br>CASS WRT<br>CASS MTR<br>CHAROM<br>CIA<br>CLR BNK<br>CNT<br>COLORAM | C128 OR C64 MODE<br>CAPITAL LOCK<br>DRAM COLUMN ADDRESS STROBE<br>RAM COLUMN ADDRESS STROBE ENABLE<br>CASSETTE SENSE<br>CASSETTE WRITE<br>CASSETTE MOTOR<br>CHARACTER ROM SELECT<br>COMPLEX INTERFACE ADAPTOR<br>COLOR RAM BANK SELECT<br>COUNT INPUT<br>COLOR RAM CHIP SELECT | MUX<br><br>NMI<br><br>PHI 0<br>POT X,Y  | ADDRESS MULTIPLEX CONTROL<br>MEMORY MULTIPLEX<br><br>NON-MASKABLE INTERRUPT<br><br>2 MHZ 0 CLOCK<br>JOYSTICK PORT INPUTS   |
| D0-D7<br>DA0-DA7<br>DD0-DD7<br>DMA<br>DOT CLK<br>DRAM<br>DRESET<br>DWE   | DATA BUS<br>DISPLAY ADDRESS<br>DISPLAY DATA BUS<br>DIRECT MEMORY ACCESS<br>8.18 MHZ VIDEO DOT CLOCK<br>DYNAMIC RAM<br>DYNAMIC RAM RESET<br>DRAM WRITE ENABLE   | RCR<br>RESET<br>ROM 1-4<br><br>ROM H,L<br>ROMBANK<br>0,1<br>RS<br>RSTR<br>R/W | RAM CONFIGURATION REGISTER<br>SYSTEM RESET<br>ROM CHIP SELECTS FOR OPERATING<br>SYSTEM<br>CHIP SELECTS FOR EXPANSION ROMS<br><br>MEMORY STATUS SELECT<br>REGISTER SELECT<br>RESTORE<br>READ/WRITE LINE |
| EXROM<br>EXTRES  | EXTERNAL ROM ENABLE<br>EXTERNAL RESET  | SA0-SA7<br><br>TA8-TA15<br>TOD  | SHARED ADDRESS BUS<br><br>TRANSLATED ADDRESS BUS<br>TIME OF DAY  |
| FROM<br>FSDIR  | FUNCTION ROM<br>FAST SERIAL DIRECTION  | VA 14,15<br>VIC<br>VMA0-VMA7  | VIC ADDRESSES<br>VERSATILE INTERFACE CHIP<br>VIC MULTIPLEXED ADDRESS BUS   |
| GAME<br>GWE  | GAME ROM ENABLE<br>COLOR RAM WRITE ENABLE  | Z80EN<br>Z80 PHI<br>ZD0-ZD7   | Z-80 ENABLE<br>Z-80 CLOCK<br>Z-80 DATA BUS   |
| I/O<br>IOACC<br>IRQ  | I/O SELECT<br>I/O ACCESS<br>INTERRUPT REQUEST  | 1 MHZ<br>40/80 SENSE  | MASTER CLOCK $\phi$ IN<br>40/80 COLUMN STATUS SENSE  |

# COMMON I.C.'S PIN ASSIGNMENTS AND LOGIC

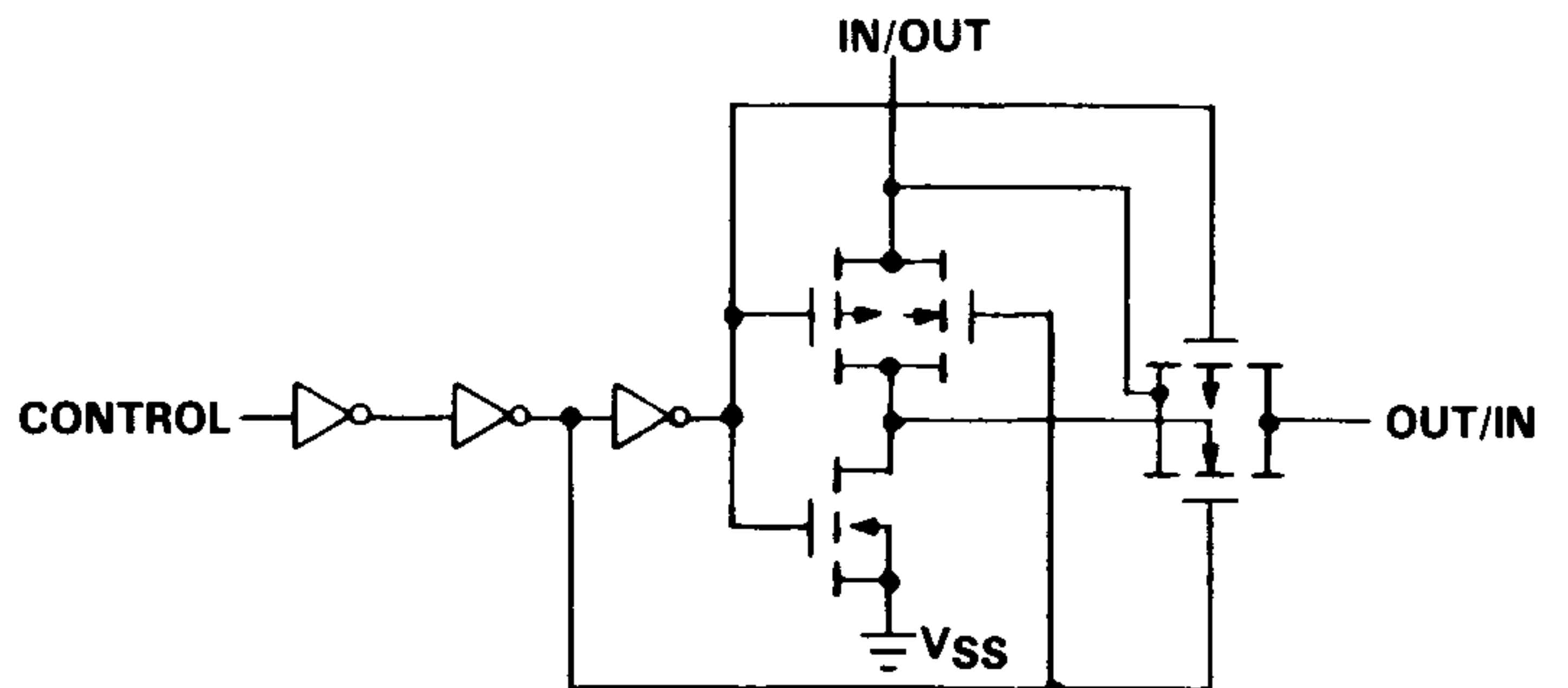
## 4066 QUAD BILATERAL SWITCH

### PIN ASSIGNMENTS

#### DUAL-IN-LINE PACKAGE

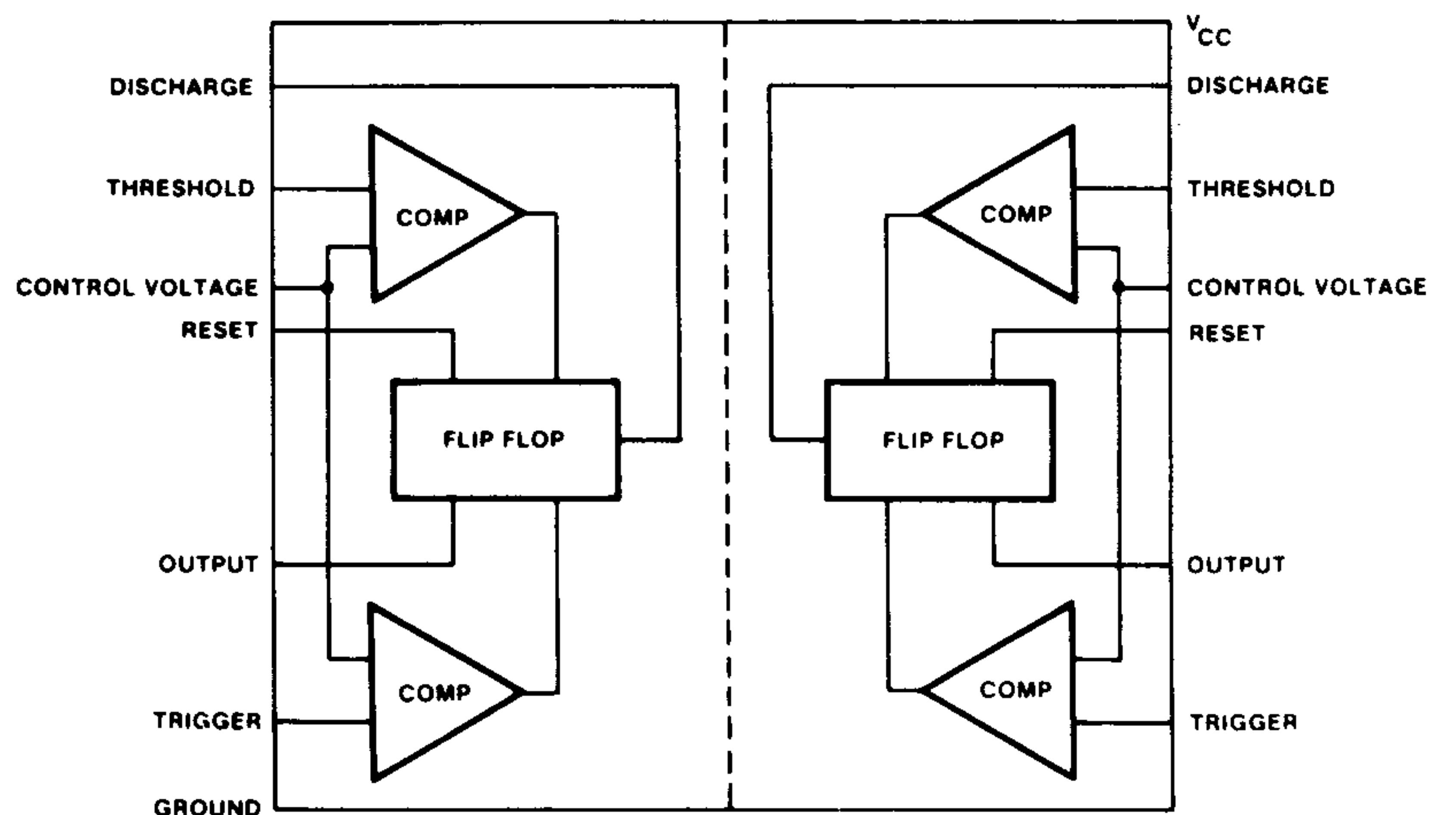
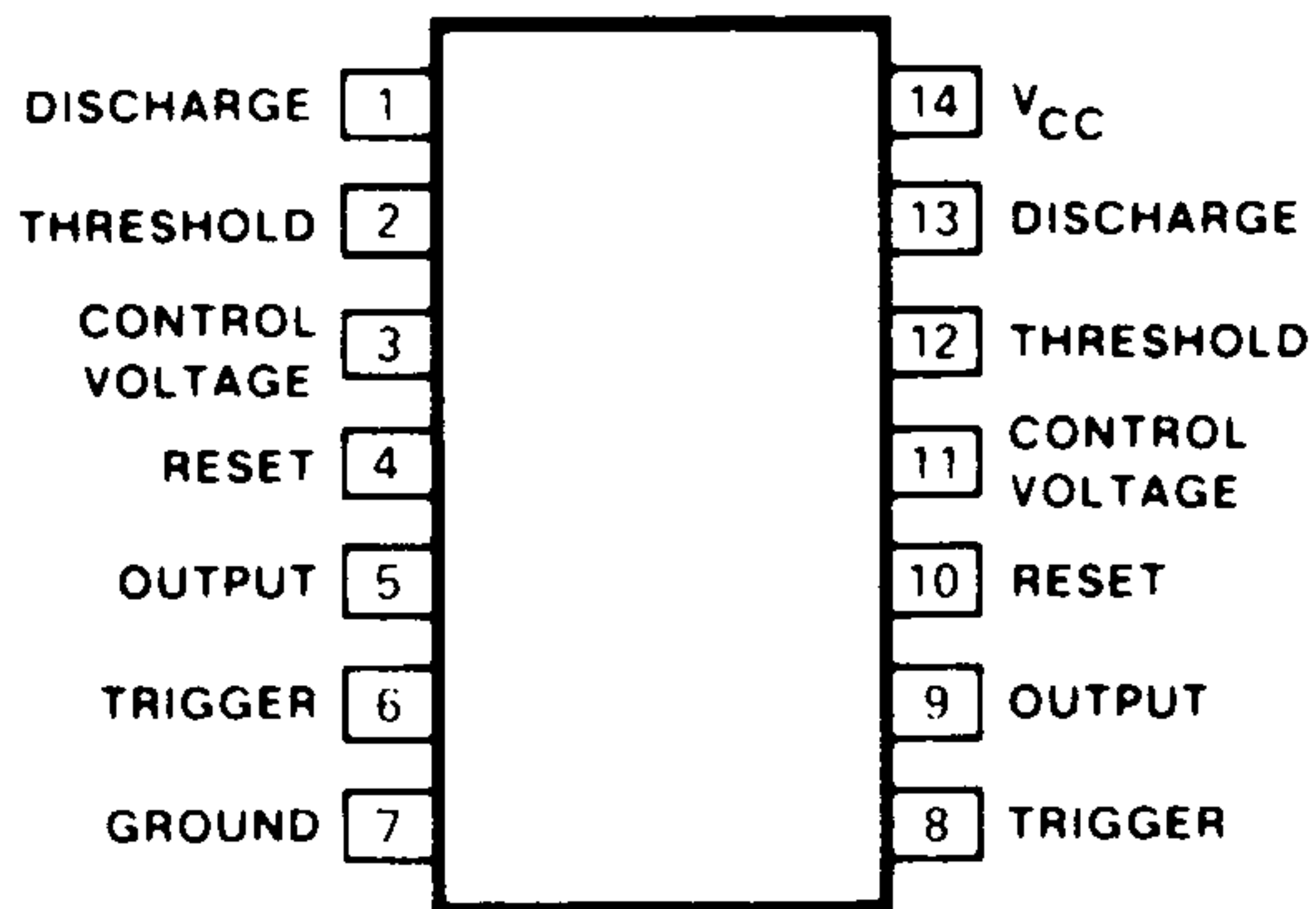


### INTERNAL DIAGRAM (EACH SWITCH)



## 556 DUAL TIMER

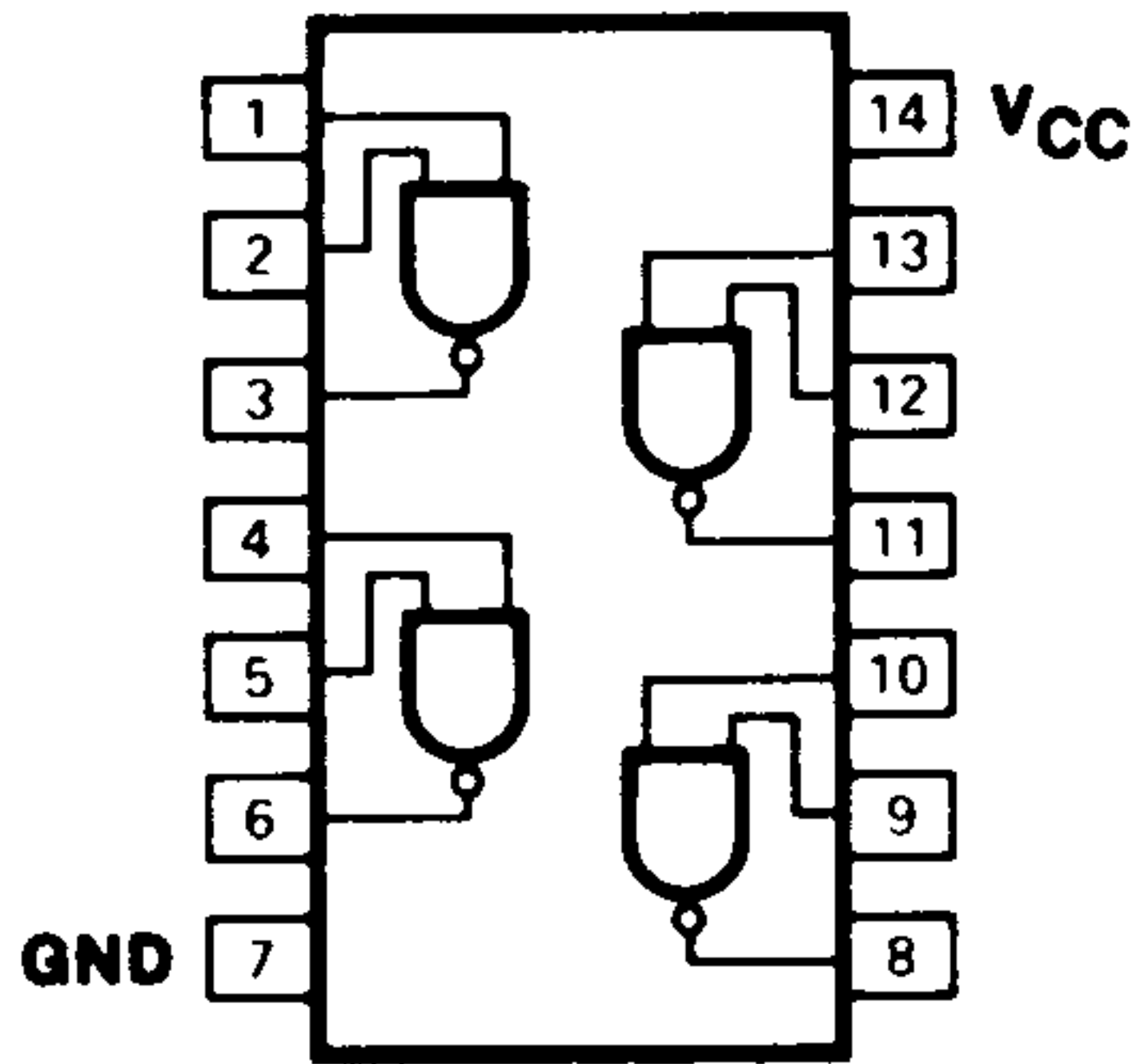
### PIN ASSIGNMENTS



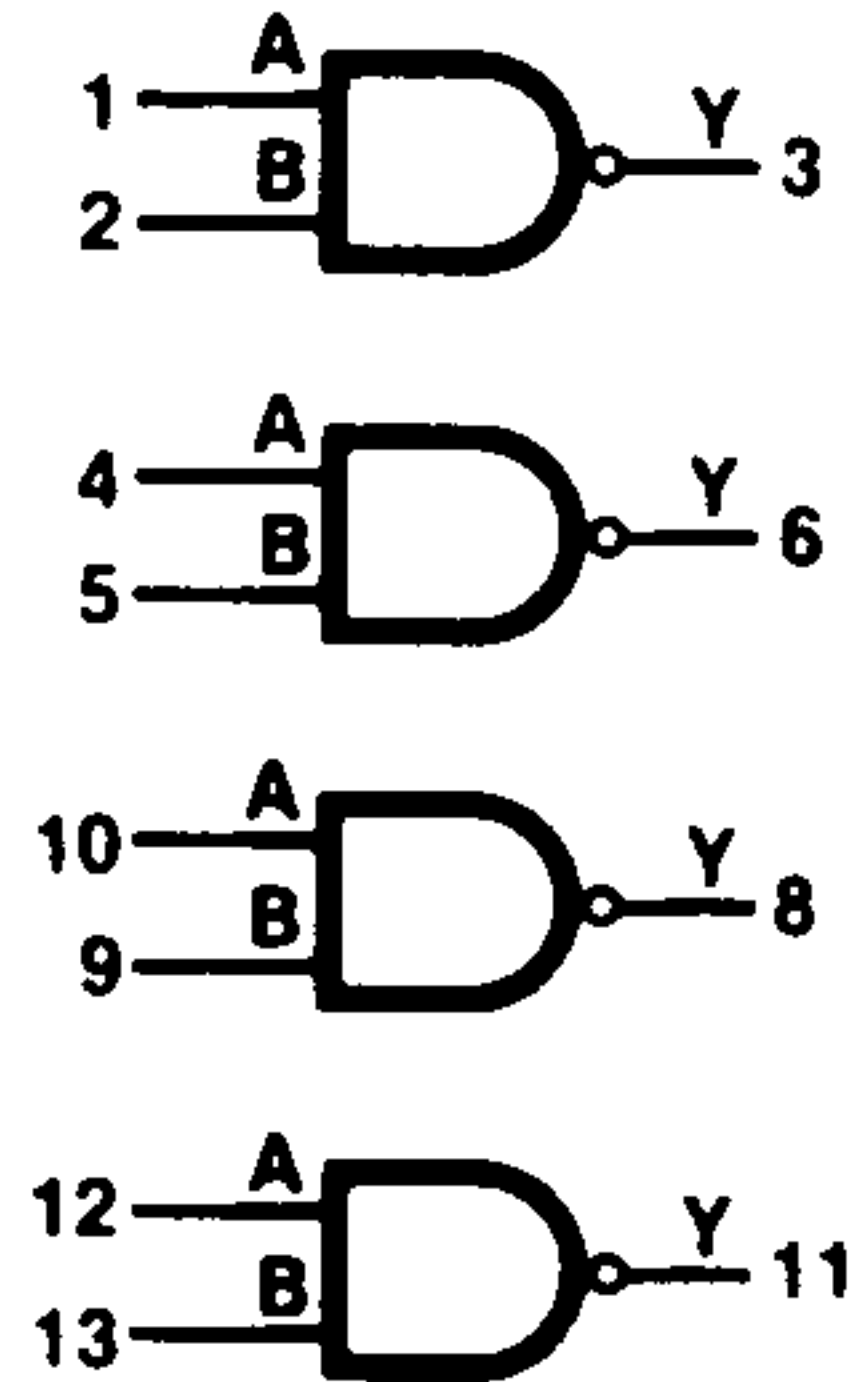
## COMMON I.C.'S (Continued)

### 7400 • 74S00 • 74LS00 QUAD 2-INPUT NAND GATE

#### PIN ASSIGNMENT



#### LOGIC DIAGRAM



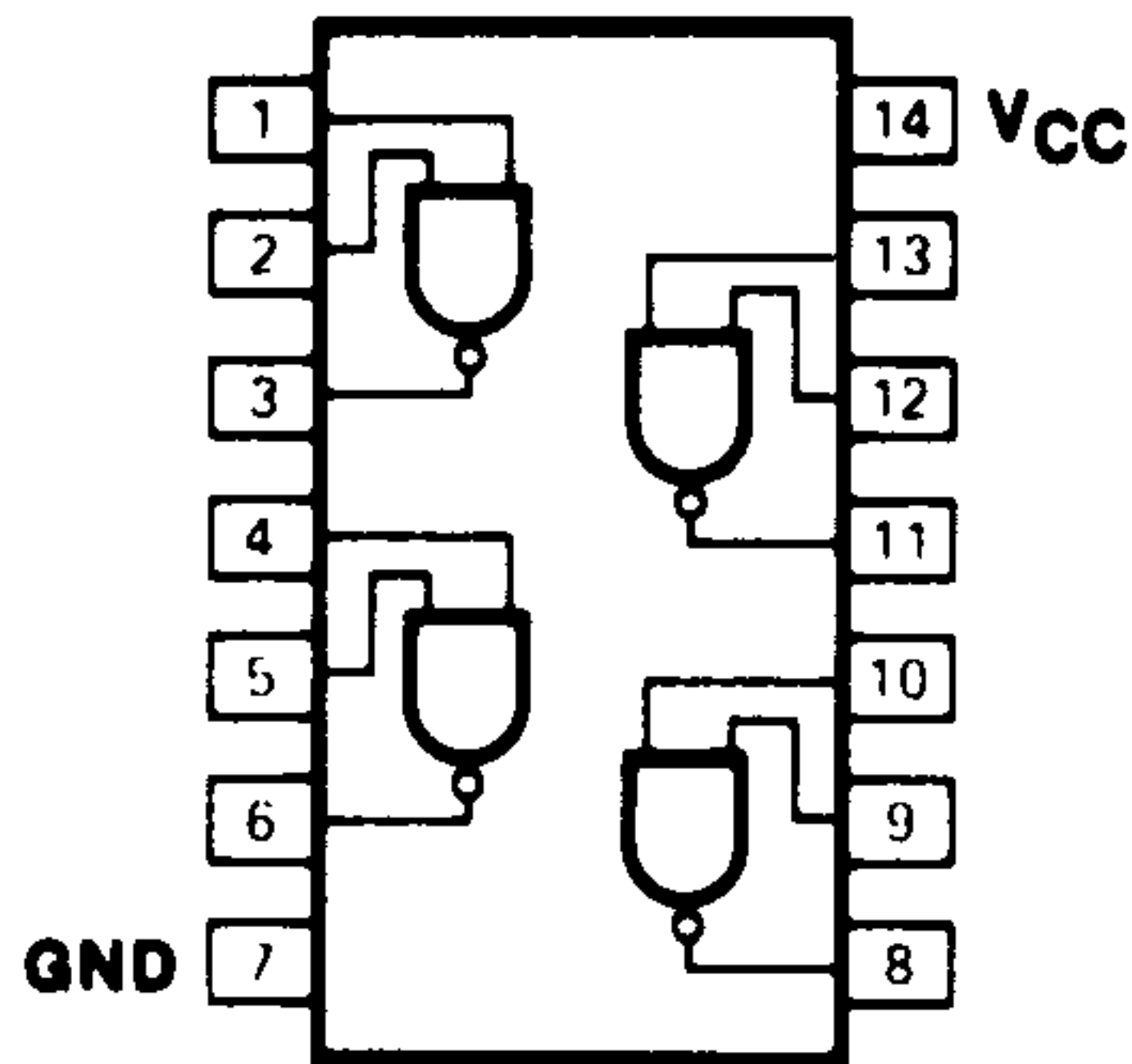
#### TRUTH TABLE

| INPUTS |   | OUTPUT |
|--------|---|--------|
| A      | B | Y      |
| L      | L | H      |
| L      | H | H      |
| H      | L | H      |
| H      | H | L      |

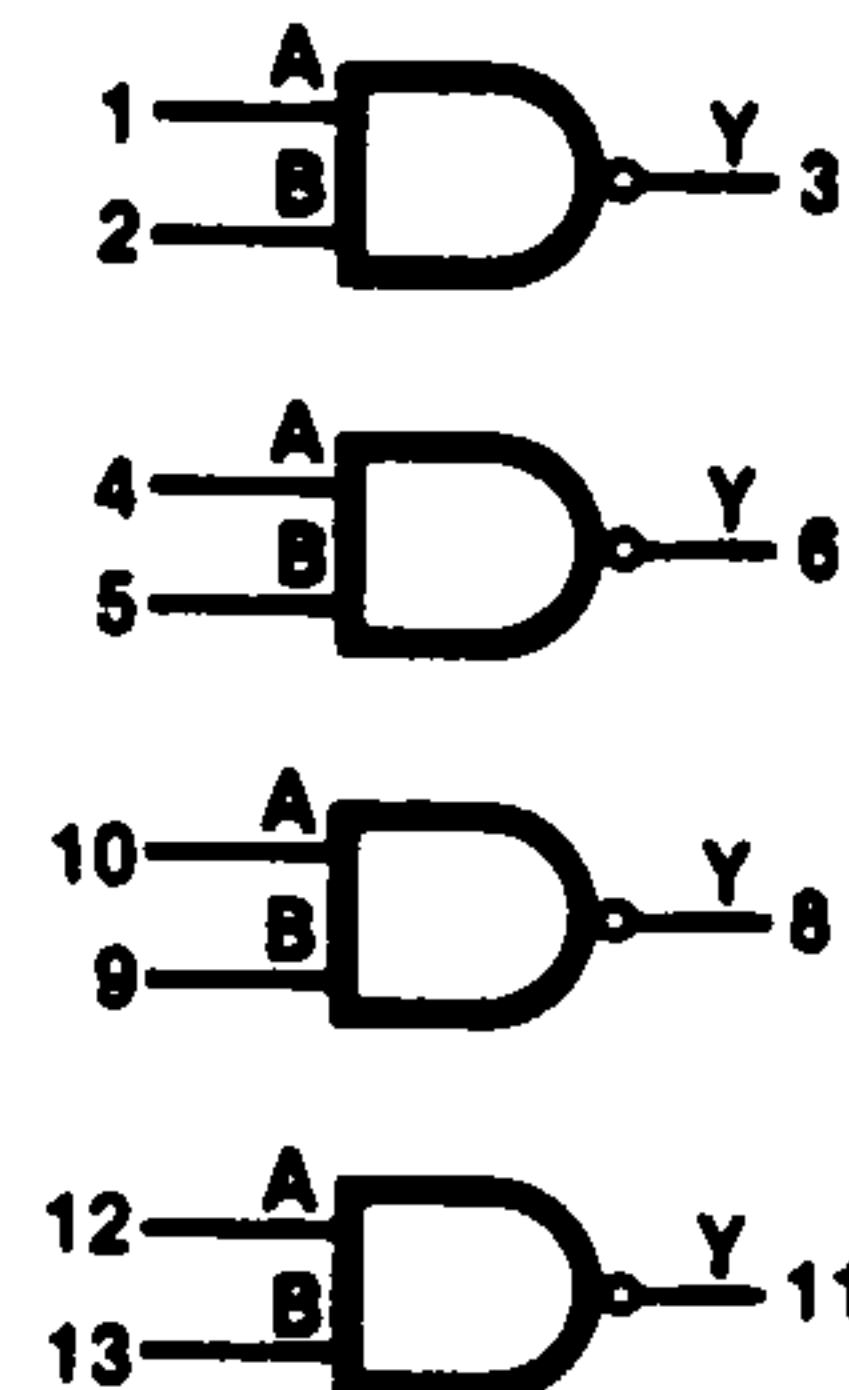
H = HIGH voltage level  
L = LOW voltage level

### 74LS03 QUAD 2-INPUT NAND GATE (OPEN COLLECTOR)

#### PIN ASSIGNMENT



#### LOGIC DIAGRAM



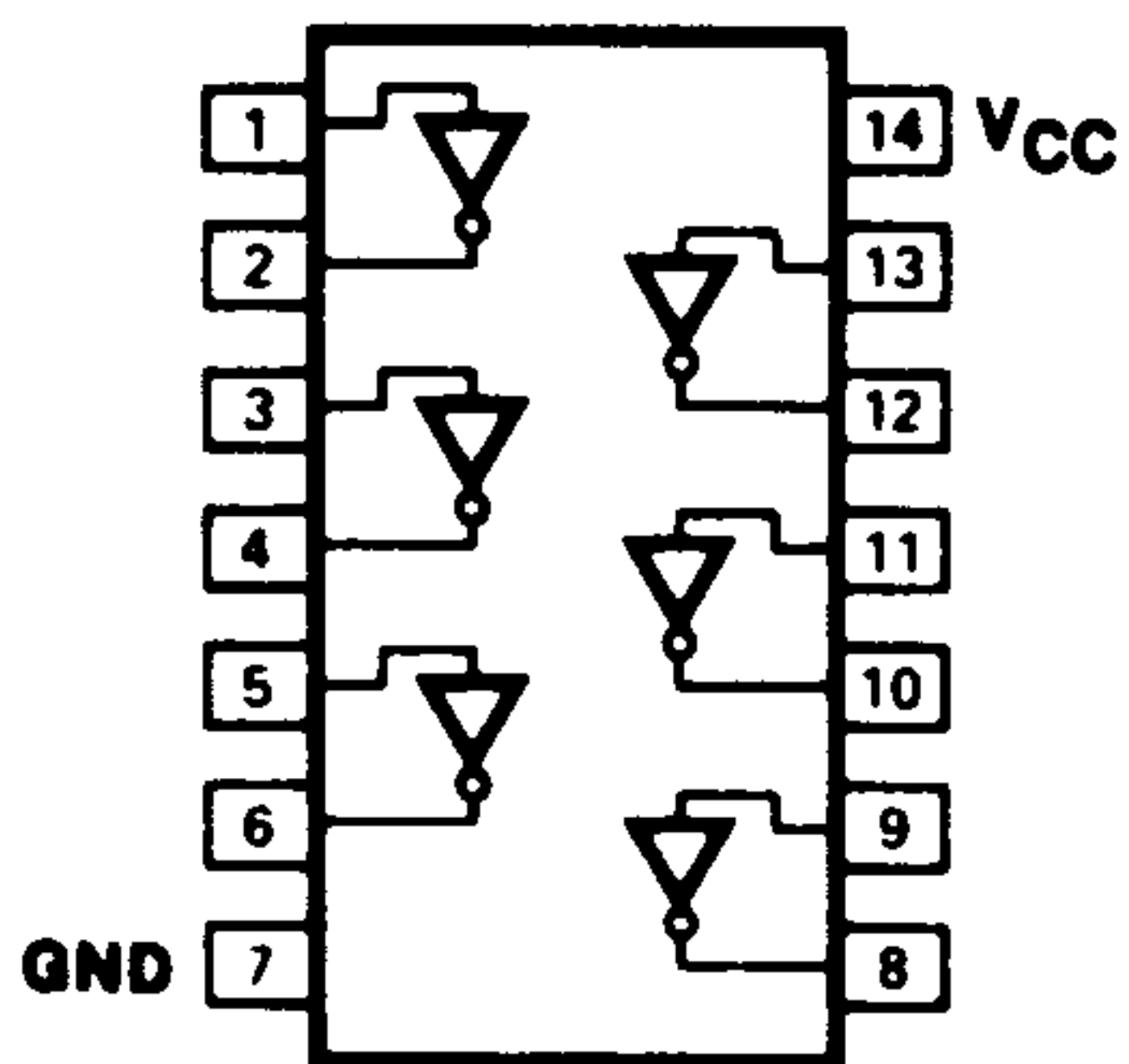
#### TRUTH TABLE

| INPUTS |   | OUTPUT |
|--------|---|--------|
| A      | B | Y      |
| L      | L | H      |
| L      | H | H      |
| H      | L | H      |
| H      | H | L      |

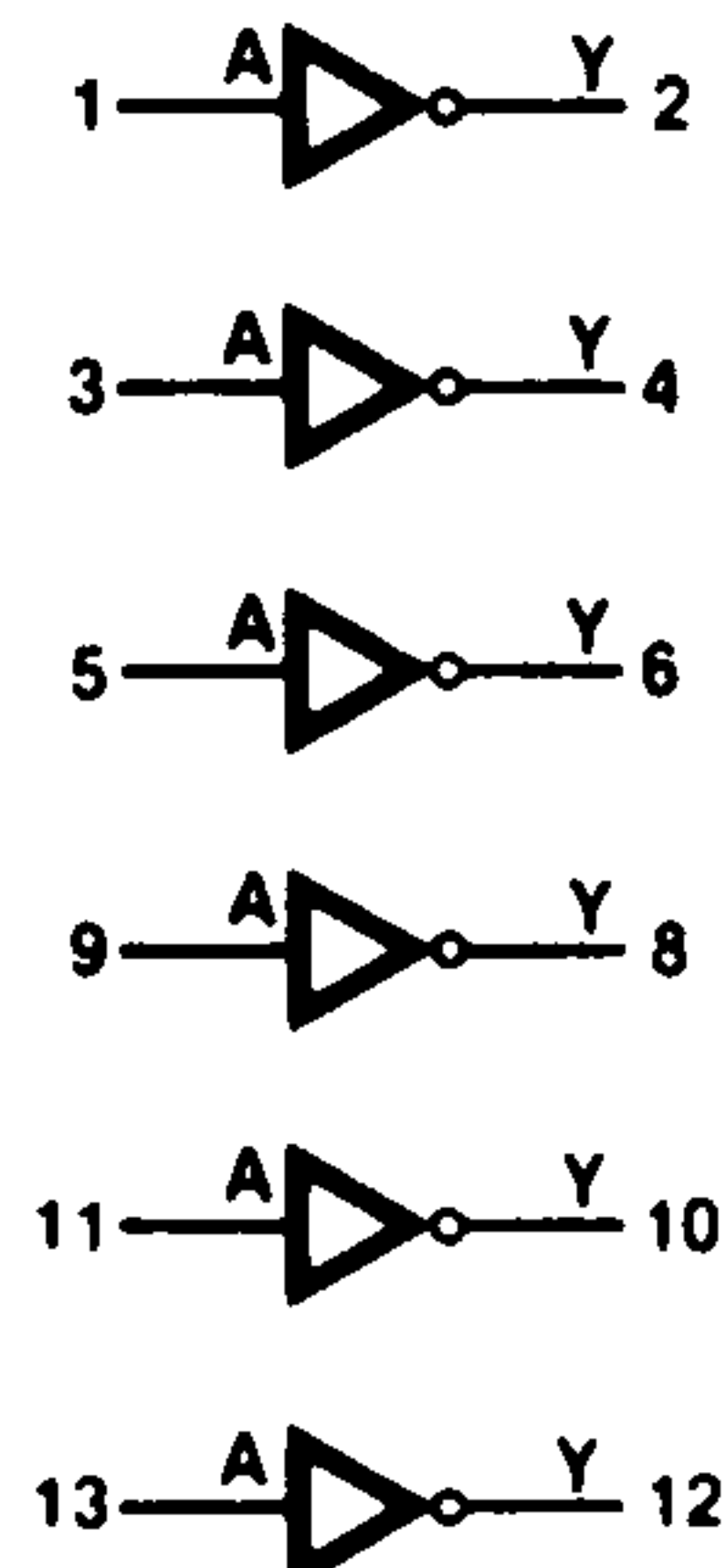
H = HIGH voltage level  
L = LOW voltage level

### 7406 HEX INVERTER BUFFER/DRIVER (OPEN COLLECTOR)

#### PIN ASSIGNMENT



#### LOGIC DIAGRAM



#### TRUTH TABLE

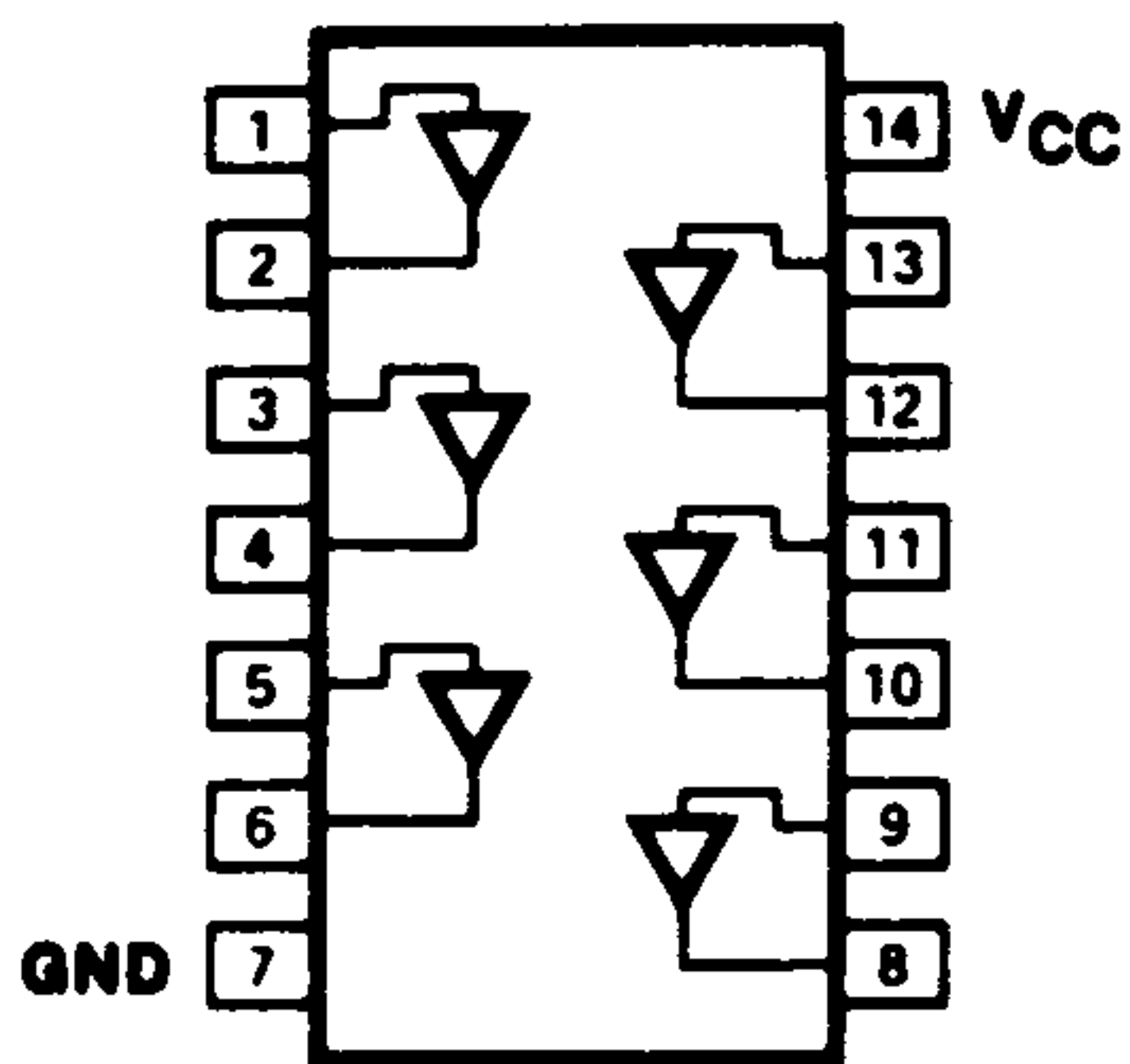
| INPUT | OUTPUT |
|-------|--------|
| A     | Y      |
| H     | L      |
| L     | H      |

H = HIGH voltage level  
L = LOW voltage level

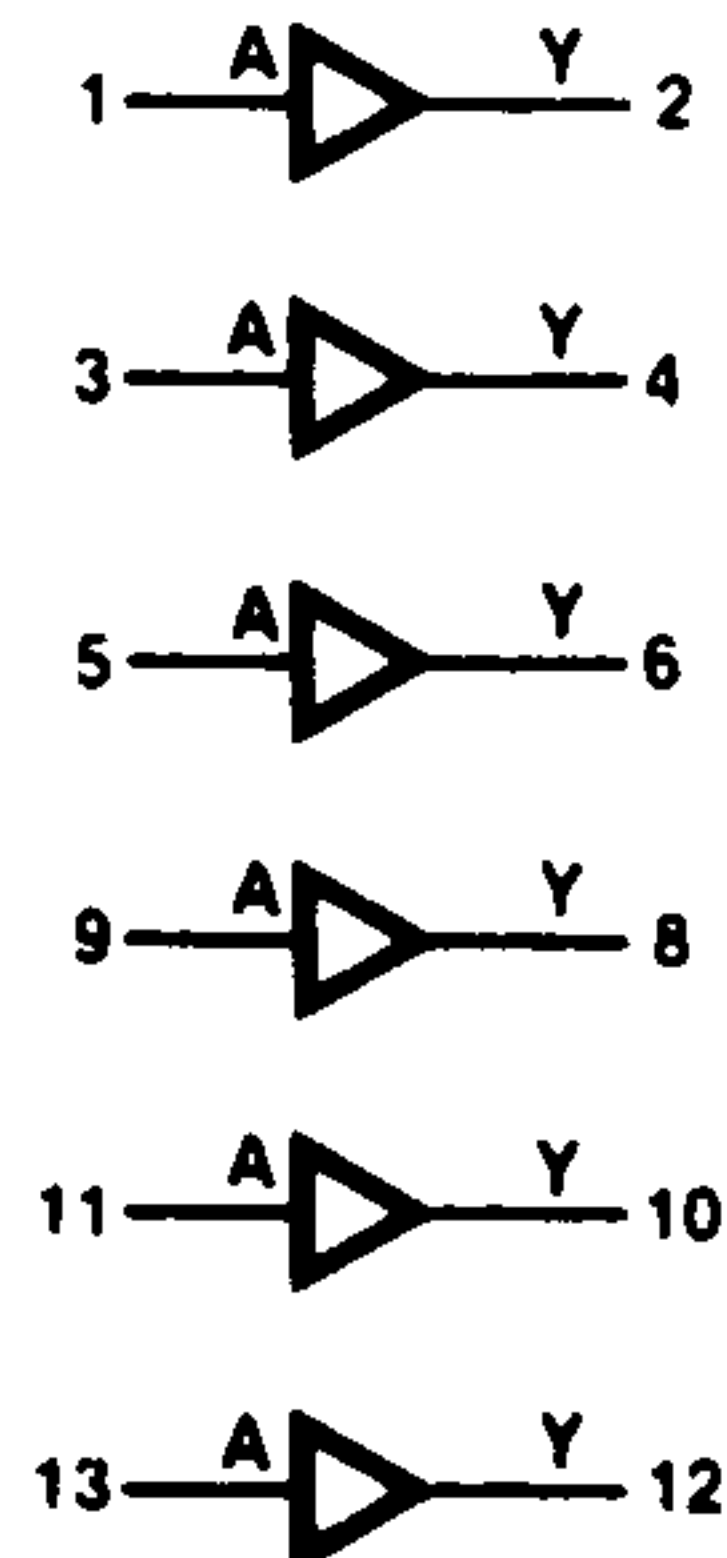
# COMMON I.C.'S (Continued)

## 7407 HEX BUFFER/DRIVER (OPEN COLLECTOR)

### PIN ASSIGNMENT



### LOGIC DIAGRAM



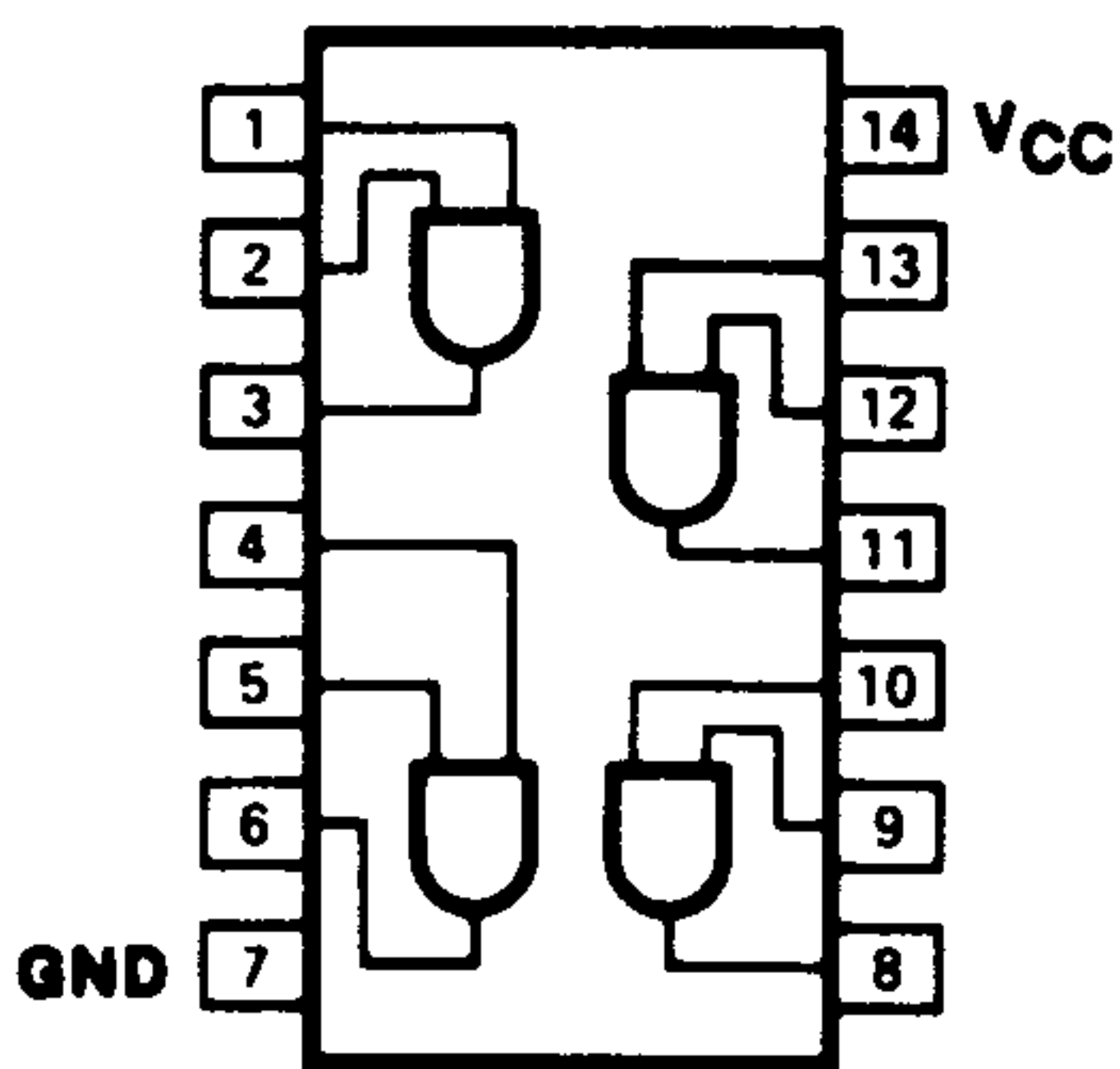
### TRUTH TABLE

| INPUT | OUTPUT |
|-------|--------|
| A     | Y      |
| H     | H      |
| L     | L      |

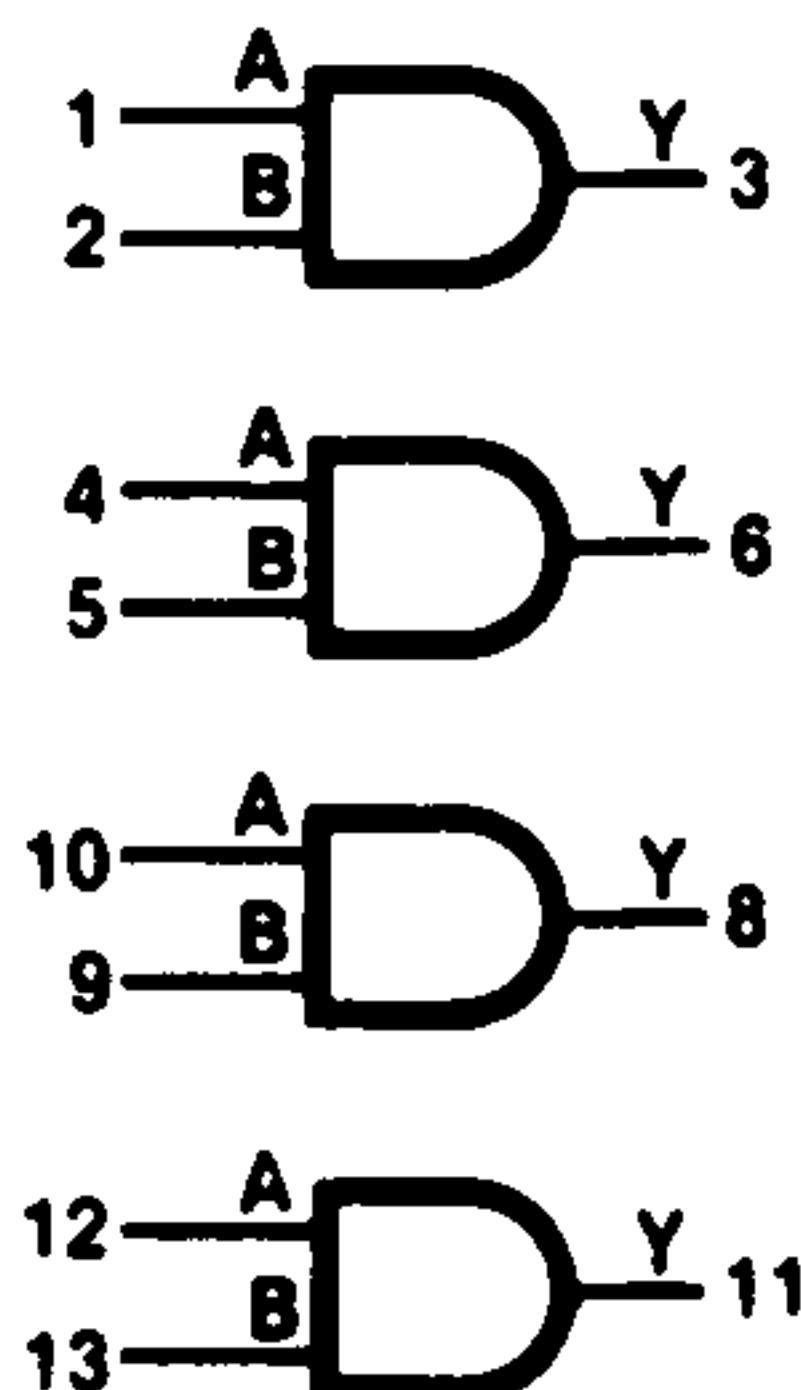
H = HIGH voltage level  
L = LOW voltage level

## 7408 • 74S08 • 74LS08 QUAD 2-INPUT AND GATE

### PIN ASSIGNMENT



### LOGIC DIAGRAM



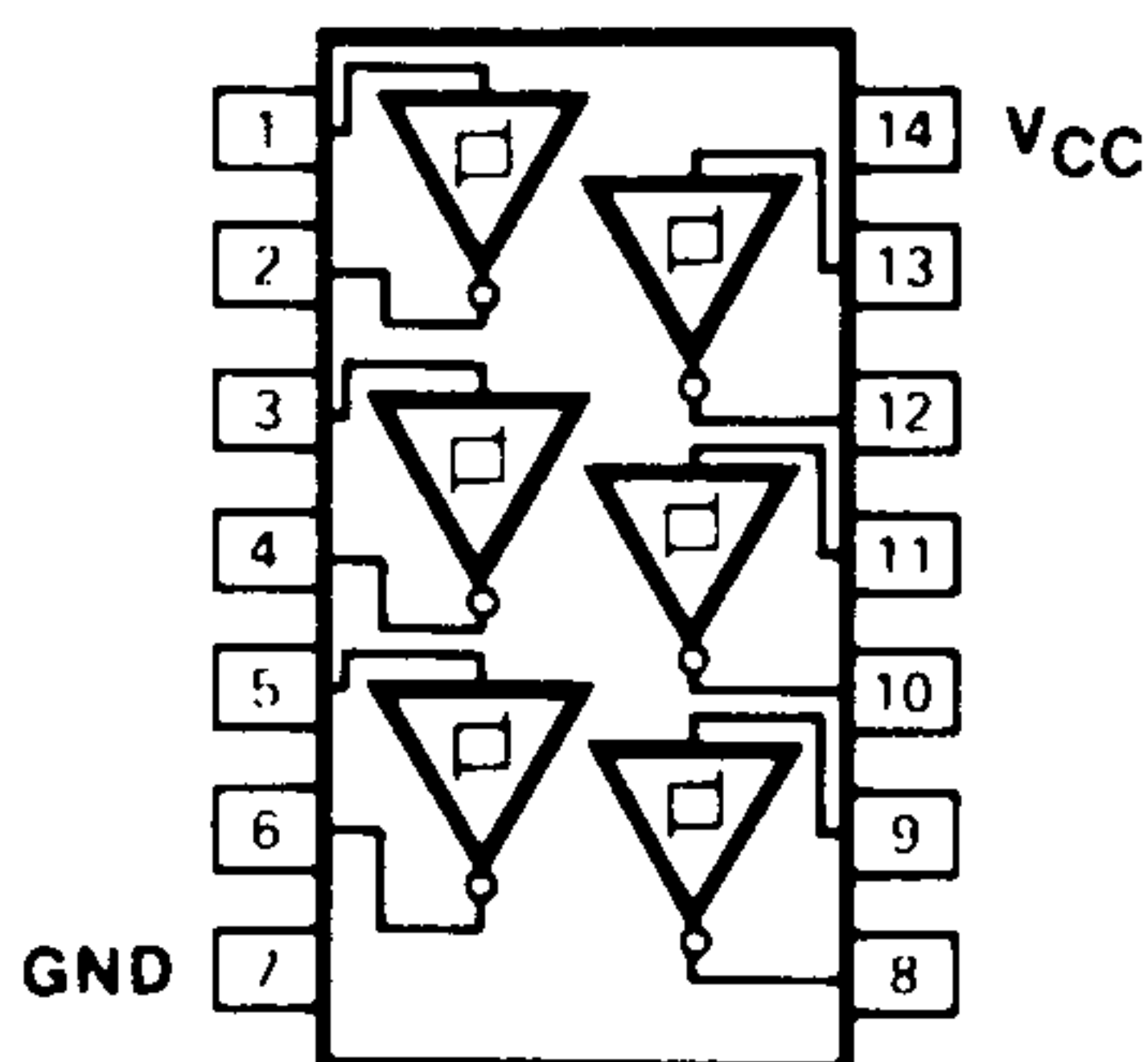
### TRUTH TABLE

| INPUTS |   | OUTPUT |
|--------|---|--------|
| A      | B | Y      |
| L      | L | L      |
| L      | H | L      |
| H      | L | L      |
| H      | H | H      |

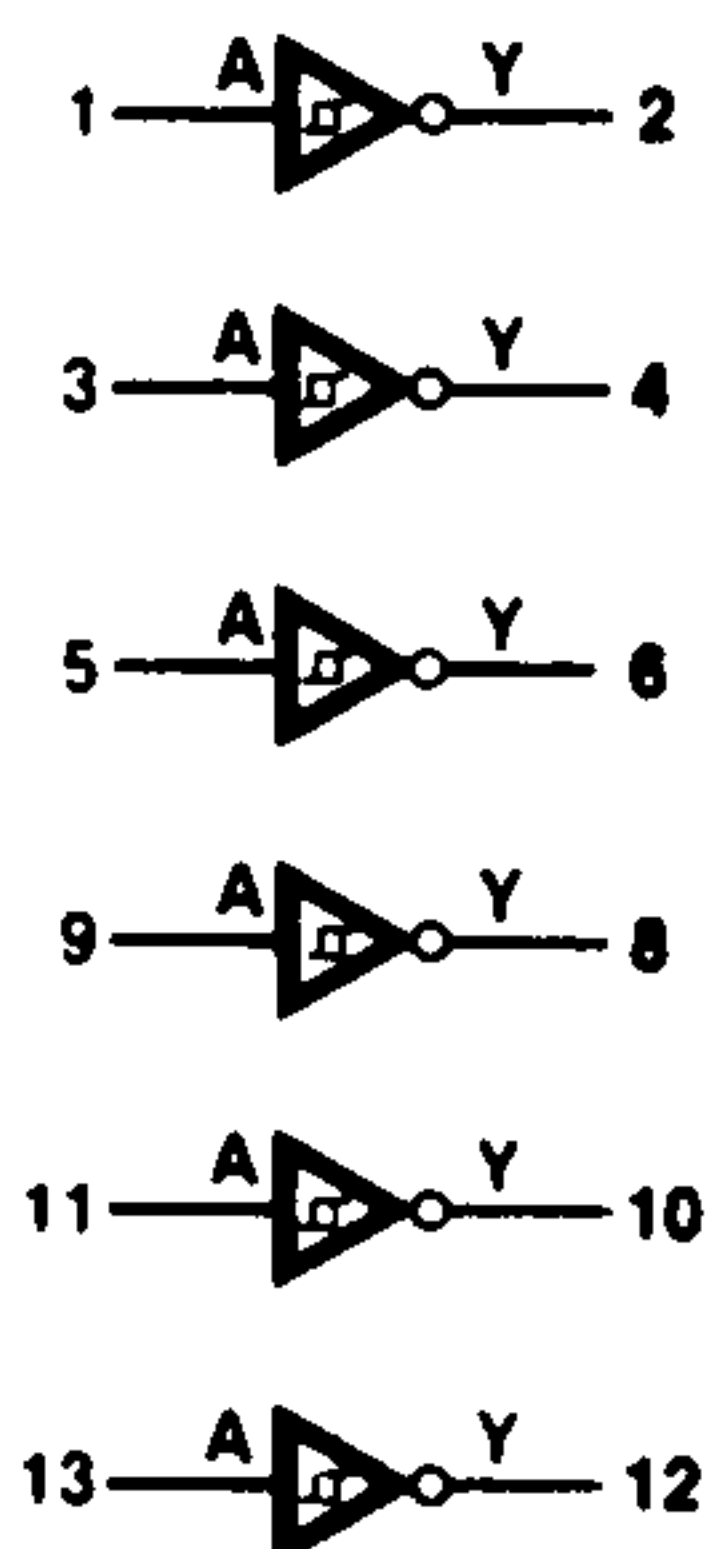
H = HIGH voltage level  
L = LOW voltage level

## 7414 • 74LS14 HEX INVERTER SCHMITT TRIGGER

### PIN ASSIGNMENT



### LOGIC DIAGRAM



### TRUTH TABLE

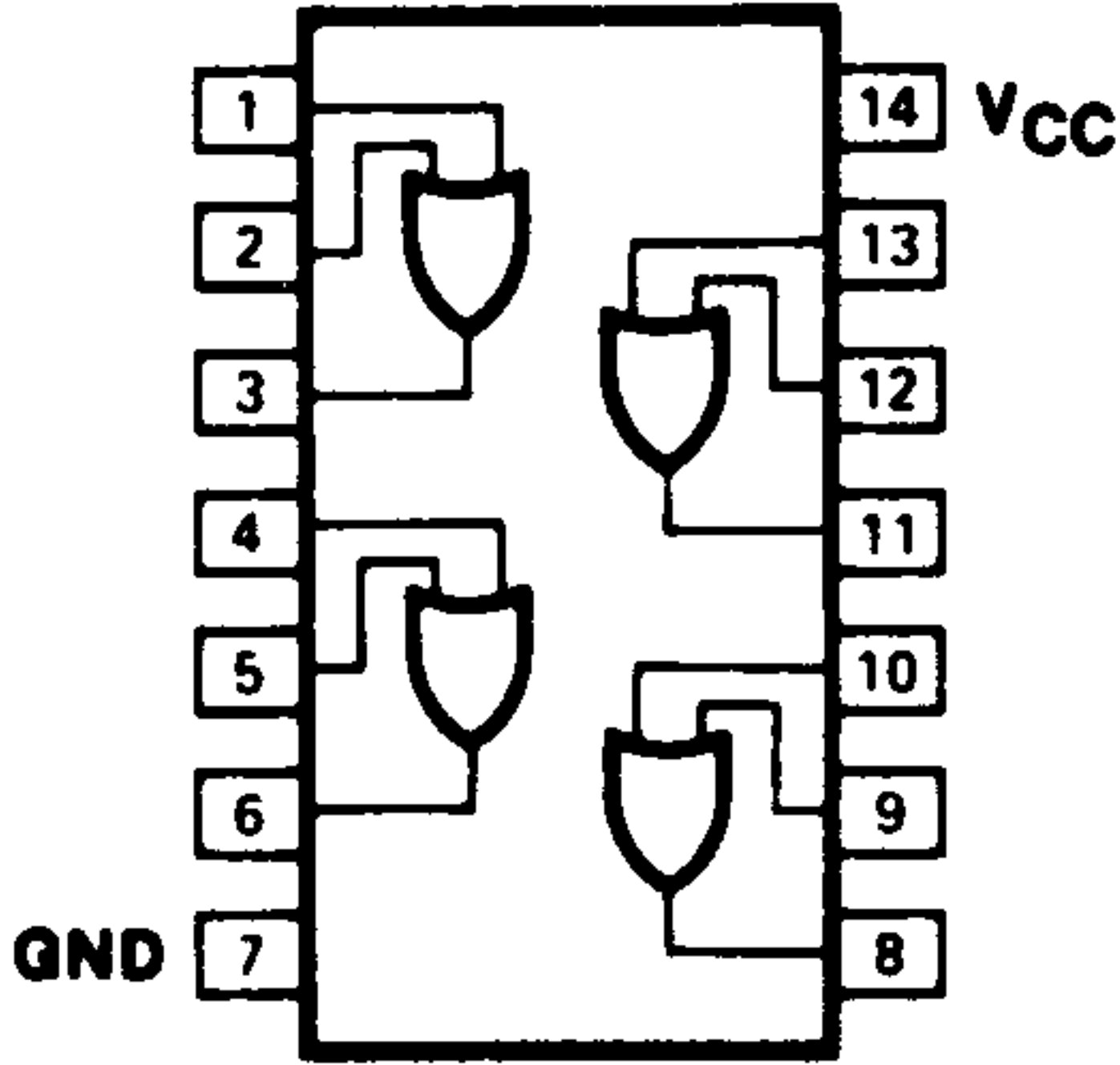
| INPUT | OUTPUT |
|-------|--------|
| A     | Y      |
| 0     | 1      |
| 1     | 0      |

H = HIGH voltage level  
L = LOW voltage level

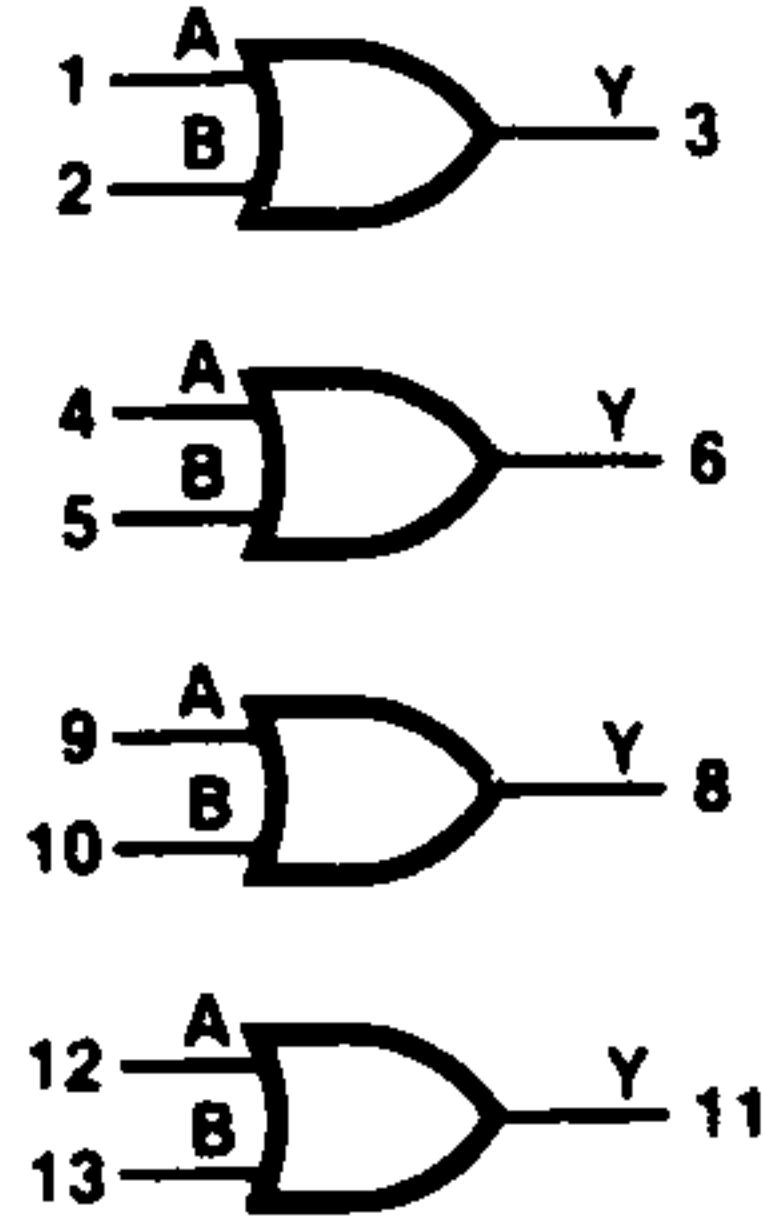
# COMMON I.C.'S (Continued)

## 7432 • 74S32 • 74LS32 • 74F32 QUAD 2-INPUT OR GATE

### PIN ASSIGNMENT



### LOGIC DIAGRAM



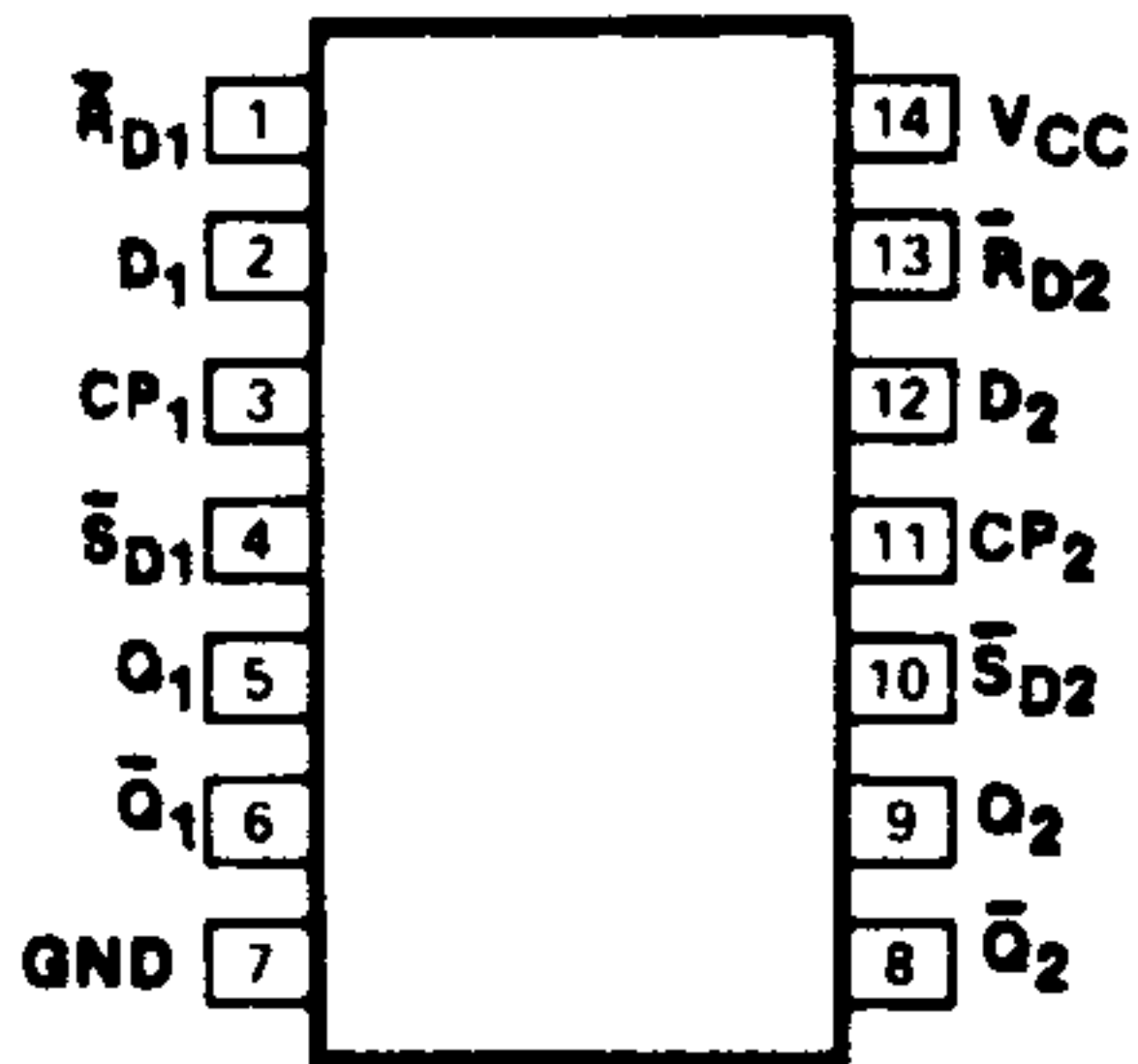
### TRUTH TABLE

| INPUTS |   | OUTPUT |
|--------|---|--------|
| A      | B | Y      |
| L      | L | L      |
| L      | H | H      |
| H      | L | H      |
| H      | H | H      |

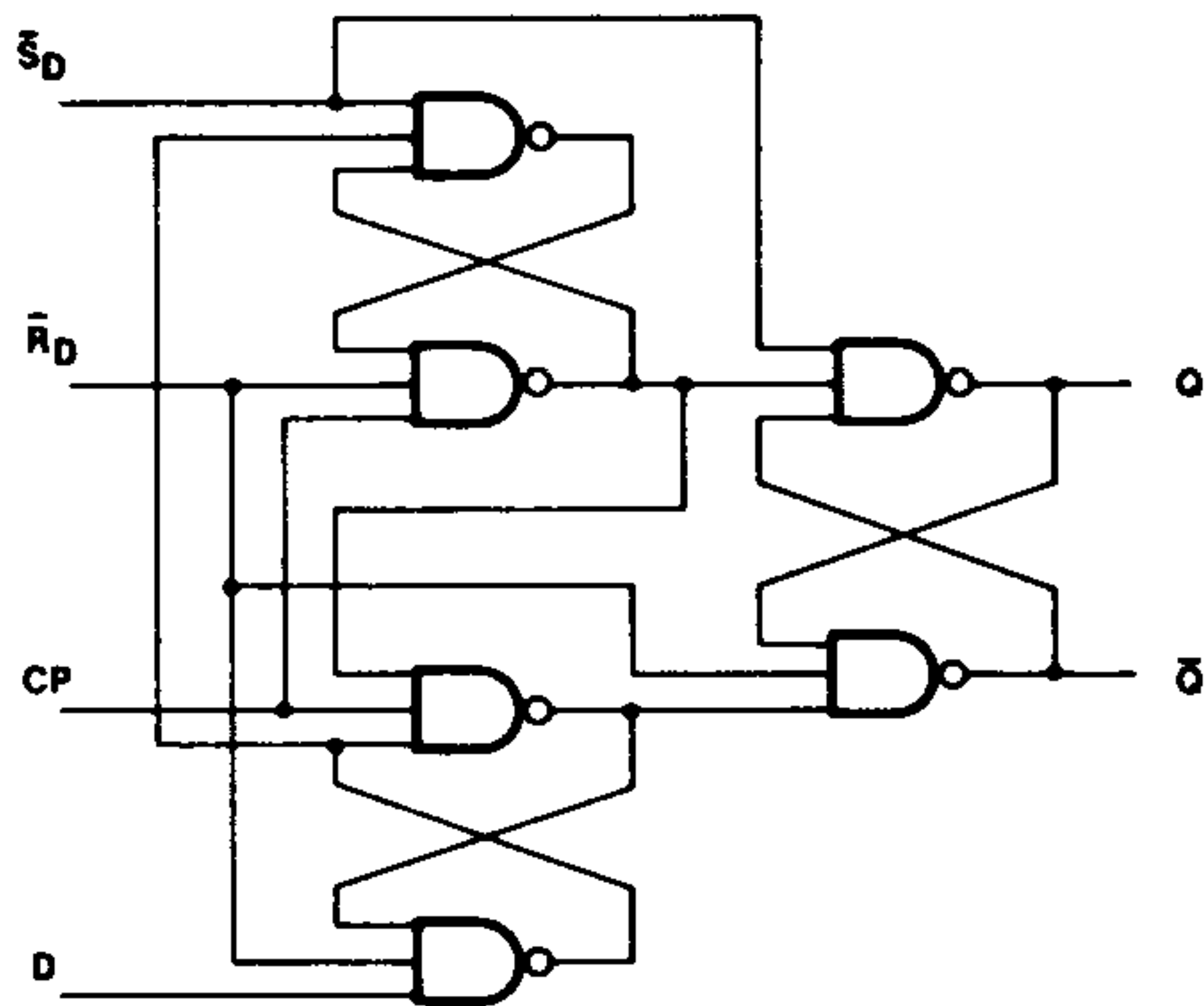
H = HIGH voltage level  
L = LOW voltage level

## 7474 • 74S74 • 74LS74 DUAL D-TYPE FLIP FLOP (POSITIVE EDGE TRIGGERED)

### PIN ASSIGNMENT



### LOGIC DIAGRAM



### TRUTH TABLE

| OPERATING MODE              | INPUTS      |             |    | OUTPUTS |   |           |
|-----------------------------|-------------|-------------|----|---------|---|-----------|
|                             | $\bar{S}_D$ | $\bar{R}_D$ | CP | D       | Q | $\bar{Q}$ |
| Asynchronous Set            | L           | H           | X  | X       | H | L         |
| Asynchronous Reset (Clear)  | H           | L           | X  | X       | L | H         |
| Undetermined <sup>(a)</sup> | L           | L           | X  | X       | H | H         |
| Load "1" (Set)              | H           | H           | ↑  | h       | H | L         |
| Load "0" (Reset)            | H           | H           | ↑  | l       | L | H         |

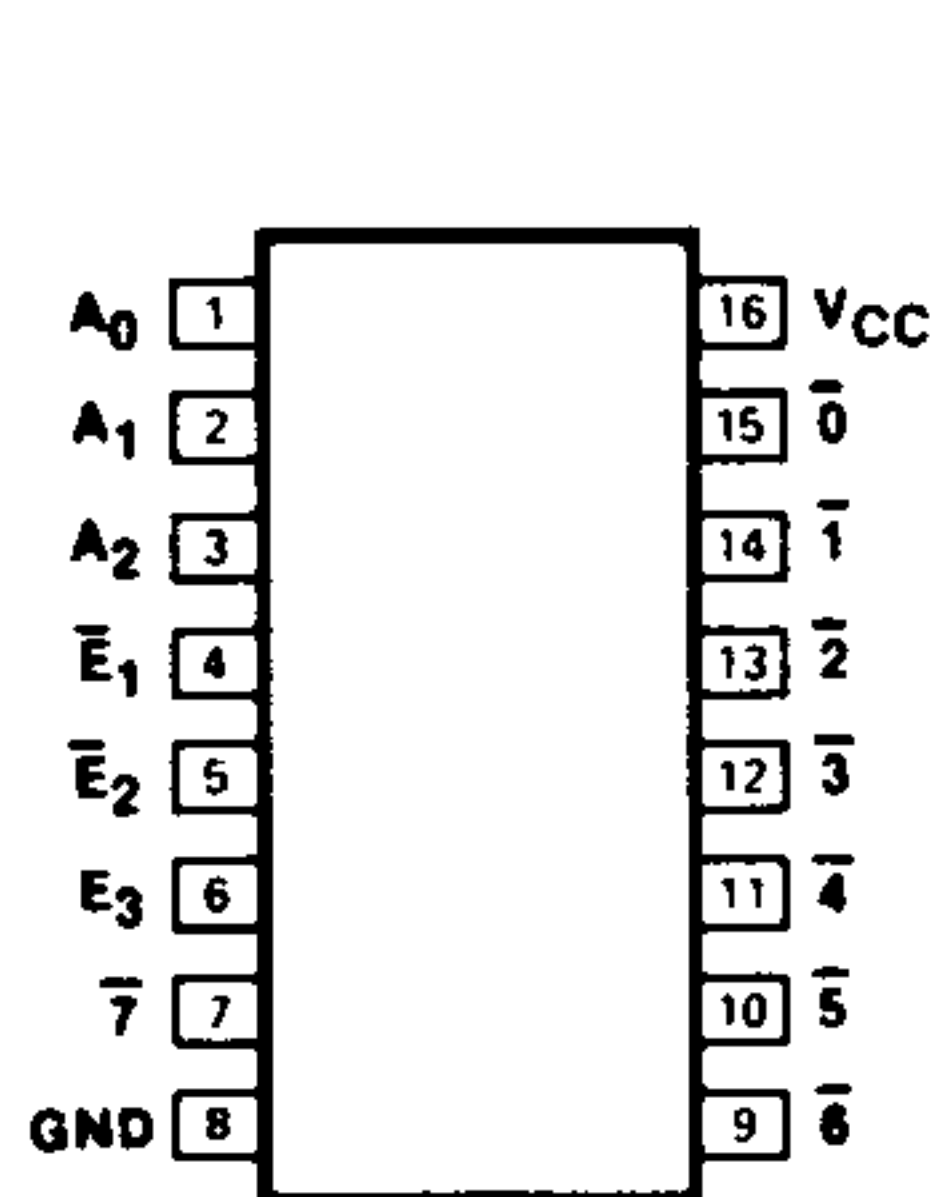
H = HIGH voltage level steady state.  
h = HIGH voltage level one setup time prior to the LOW-to-HIGH clock transition.  
L = LOW voltage level steady state.  
l = LOW voltage level one setup time prior to the LOW-to-HIGH clock transition.  
X = Don't care.  
↑ = LOW-to-HIGH clock transition.

#### NOTE

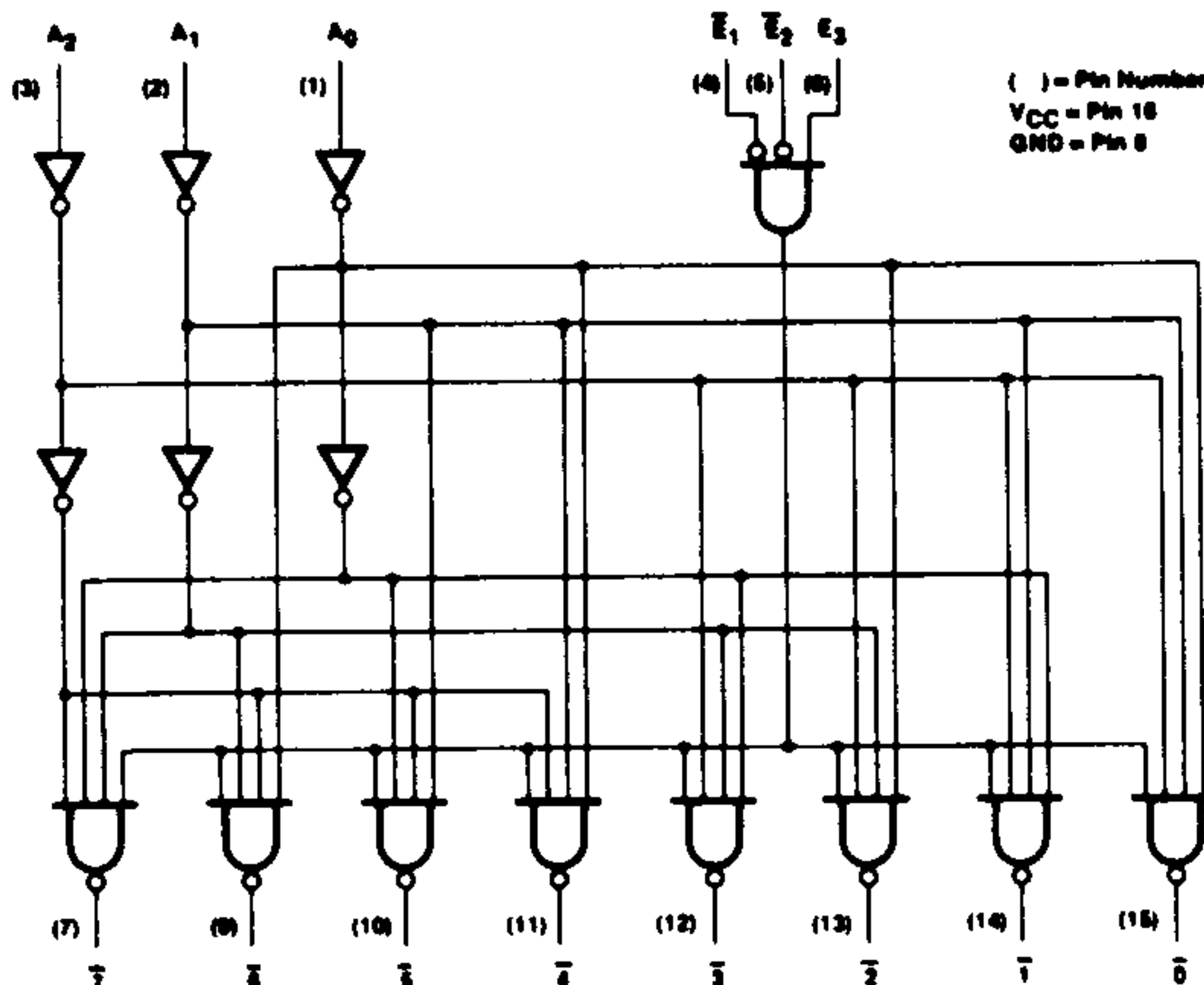
(a) Both outputs will be HIGH while both  $\bar{S}_D$  and  $\bar{R}_D$  are LOW, but the output states are unpredictable if  $\bar{S}_D$  and  $\bar{R}_D$  go HIGH simultaneously.

## 74S138 • 74LS138 DECODER/DEMULTIPLEXER

### PIN ASSIGNMENT



### LOGIC DIAGRAM



### TRUTH TABLE

| INPUTS      |             |             |                |                |                | OUTPUTS |    |    |    |    |    |    |    |
|-------------|-------------|-------------|----------------|----------------|----------------|---------|----|----|----|----|----|----|----|
| $\bar{E}_1$ | $\bar{E}_2$ | $\bar{E}_3$ | A <sub>0</sub> | A <sub>1</sub> | A <sub>2</sub> | 0̄      | 1̄ | 2̄ | 3̄ | 4̄ | 5̄ | 6̄ | 7̄ |
| H           | X           | X           | X              | X              | X              | H       | H  | H  | H  | H  | H  | H  | H  |
| X           | H           | X           | X              | X              | X              | H       | H  | H  | H  | H  | H  | H  | H  |
| X           | X           | L           | X              | X              | X              | H       | H  | H  | H  | H  | H  | H  | H  |
| L           | L           | H           | L              | L              | L              | L       | L  | L  | L  | L  | L  | L  | L  |
| L           | L           | H           | L              | L              | L              | L       | L  | L  | L  | L  | L  | L  | L  |
| L           | L           | H           | L              | L              | L              | L       | L  | L  | L  | L  | L  | L  | L  |
| L           | L           | H           | L              | L              | L              | L       | L  | L  | L  | L  | L  | L  | L  |
| L           | L           | H           | L              | L              | L              | L       | L  | L  | L  | L  | L  | L  | L  |
| L           | L           | H           | L              | L              | L              | L       | L  | L  | L  | L  | L  | L  | L  |
| L           | L           | H           | L              | L              | L              | L       | L  | L  | L  | L  | L  | L  | L  |
| L           | L           | H           | L              | L              | L              | L       | L  | L  | L  | L  | L  | L  | L  |
| L           | L           | H           | L              | L              | L              | L       | L  | L  | L  | L  | L  | L  | L  |
| L           | L           | H           | L              | L              | L              | L       | L  | L  | L  | L  | L  | L  | L  |
| L           | L           | H           | L              | L              | L              | L       | L  | L  | L  | L  | L  | L  | L  |
| L           | L           | H           | L              | L              | L              | L       | L  | L  | L  | L  | L  | L  | L  |

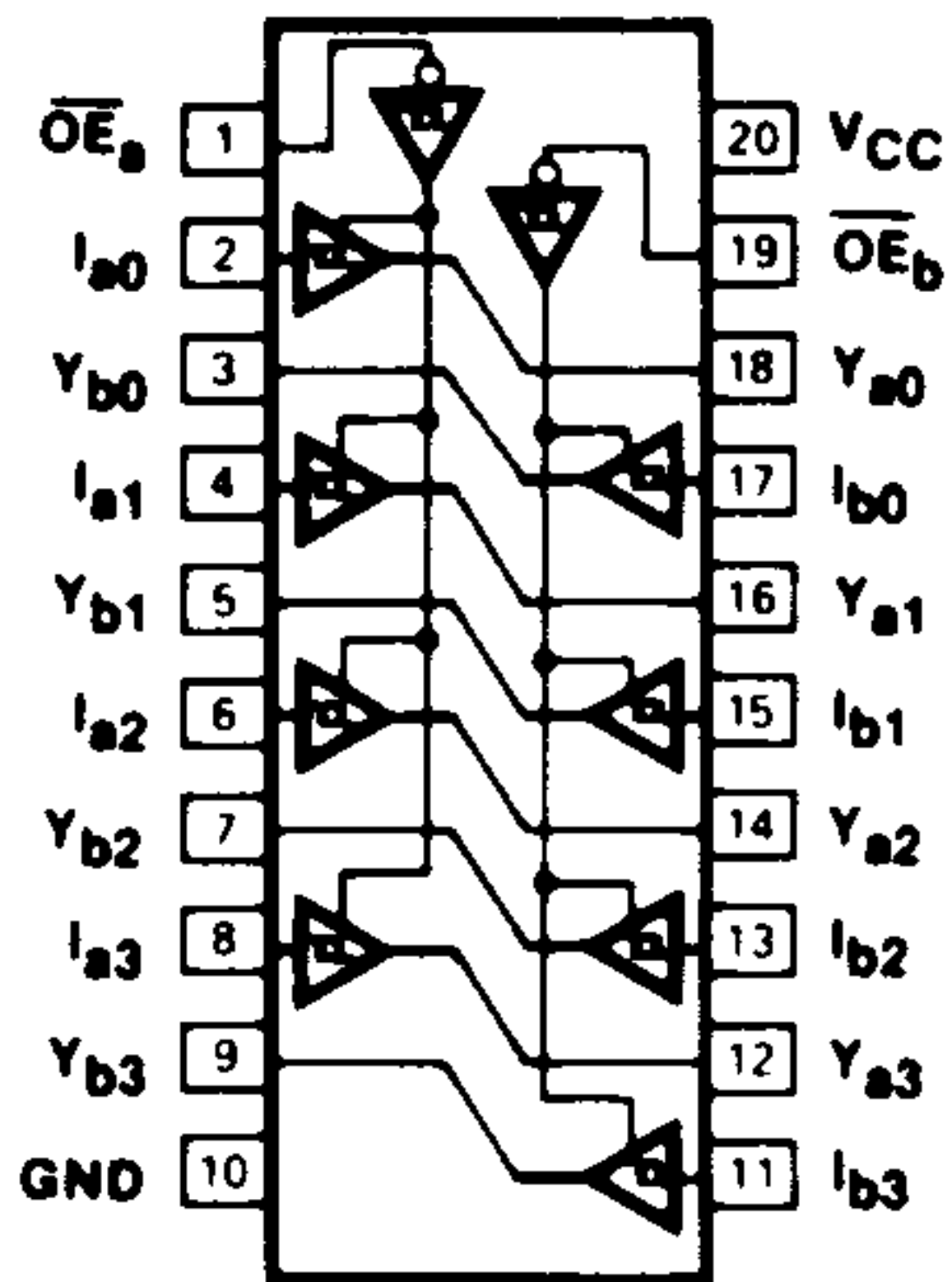
#### NOTES

H = HIGH voltage level  
L = LOW voltage level  
X = Don't care

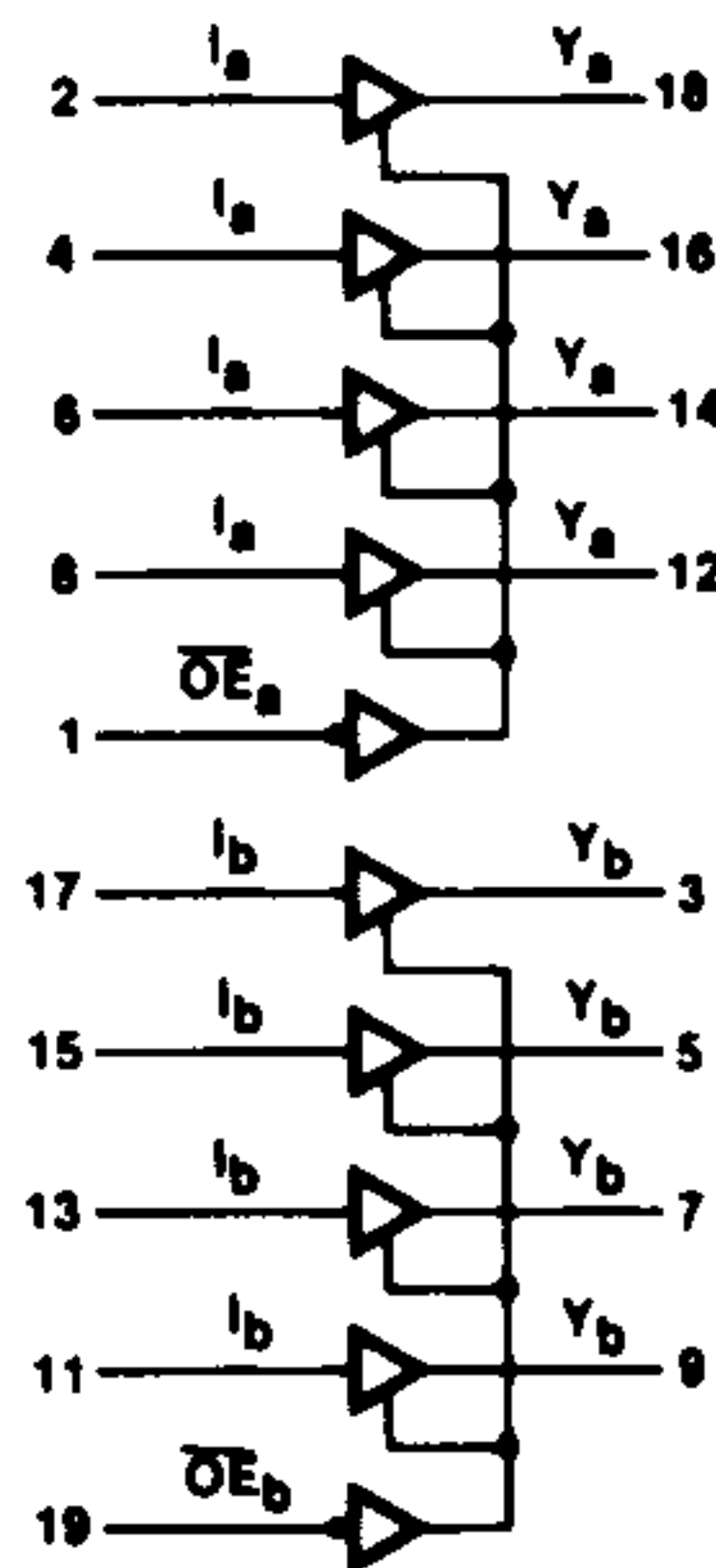
# COMMON I.C.'S (Continued)

## 74S244 • 74LS244 OCTAL 3-STATE BUFFER

### PIN ASSIGNMENT



### LOGIC DIAGRAM



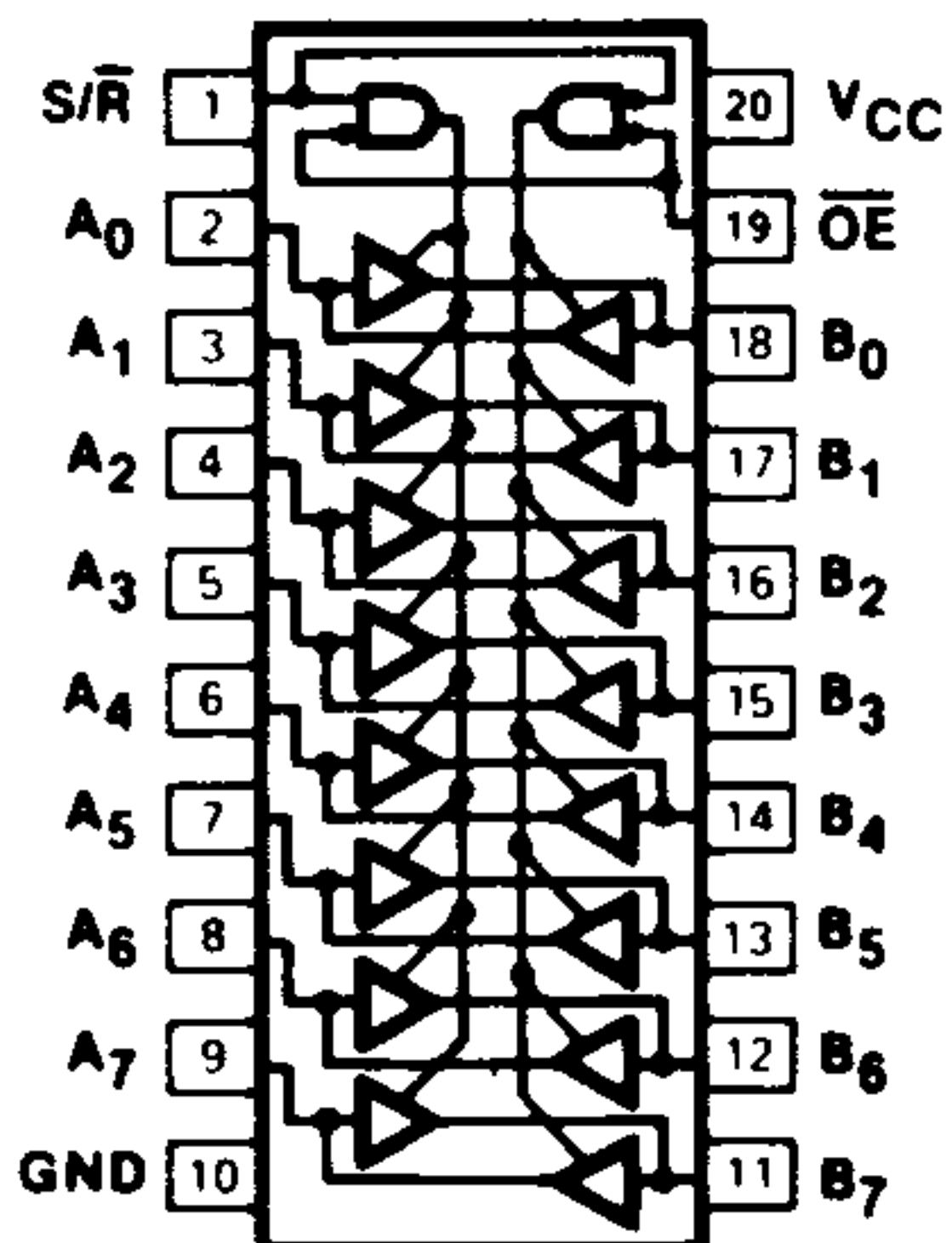
### TRUTH TABLE

| INPUTS            |       |                   |       | OUTPUT |       |
|-------------------|-------|-------------------|-------|--------|-------|
| $\overline{OE}_a$ | $I_a$ | $\overline{OE}_b$ | $I_b$ | $Y_a$  | $Y_b$ |
| L                 | L     | L                 | L     | L      | L     |
| L                 | H     | L                 | H     | H      | H     |
| H                 | X     | H                 | X     | (Z)    | (Z)   |

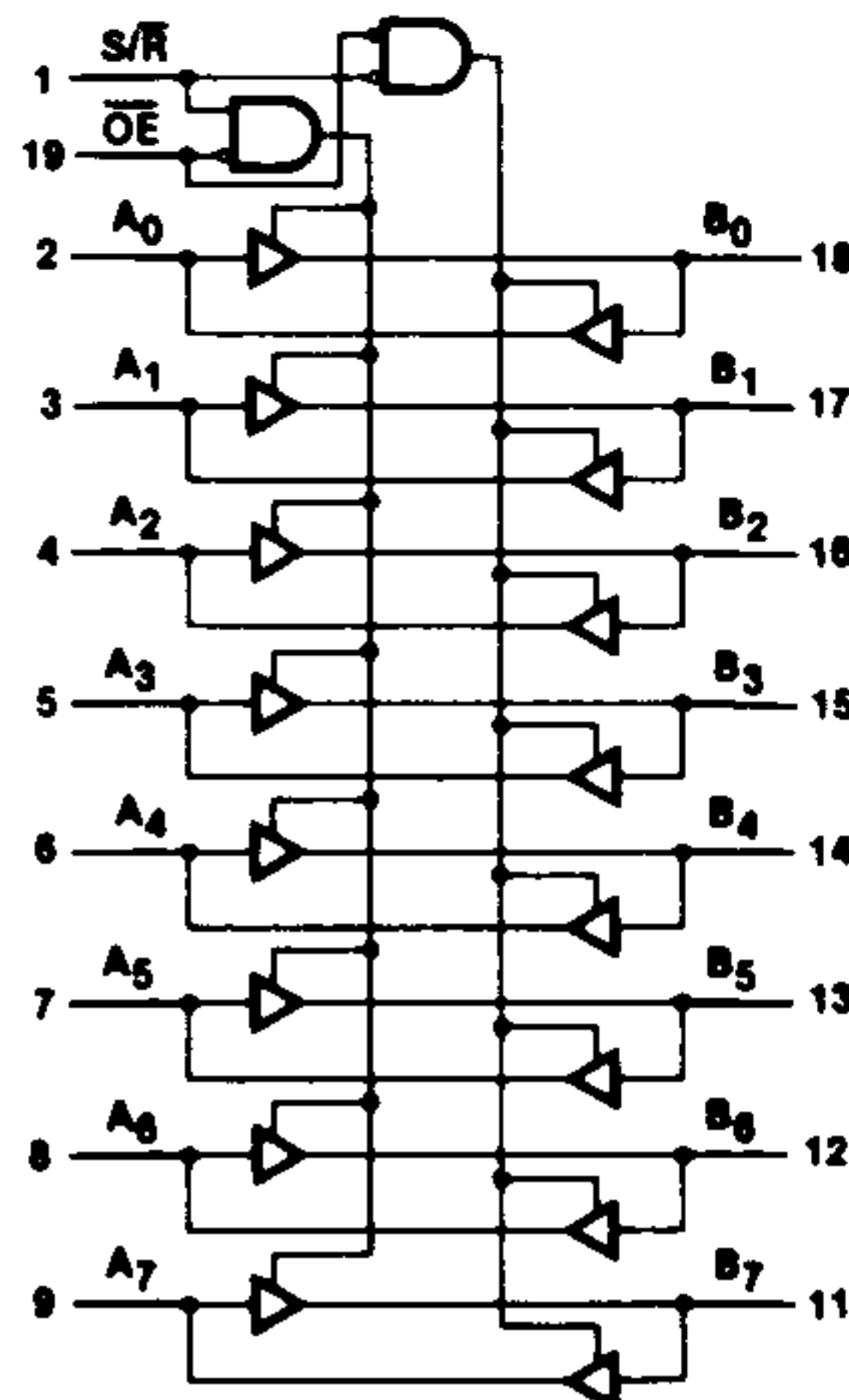
H = HIGH voltage level  
L = LOW voltage level  
X = Don't care  
Z = HIGH impedance "off" state

## 74LS245 • 74F245 OCTAL BUS TRANSCEIVER

### PIN ASSIGNMENT



### LOGIC DIAGRAM



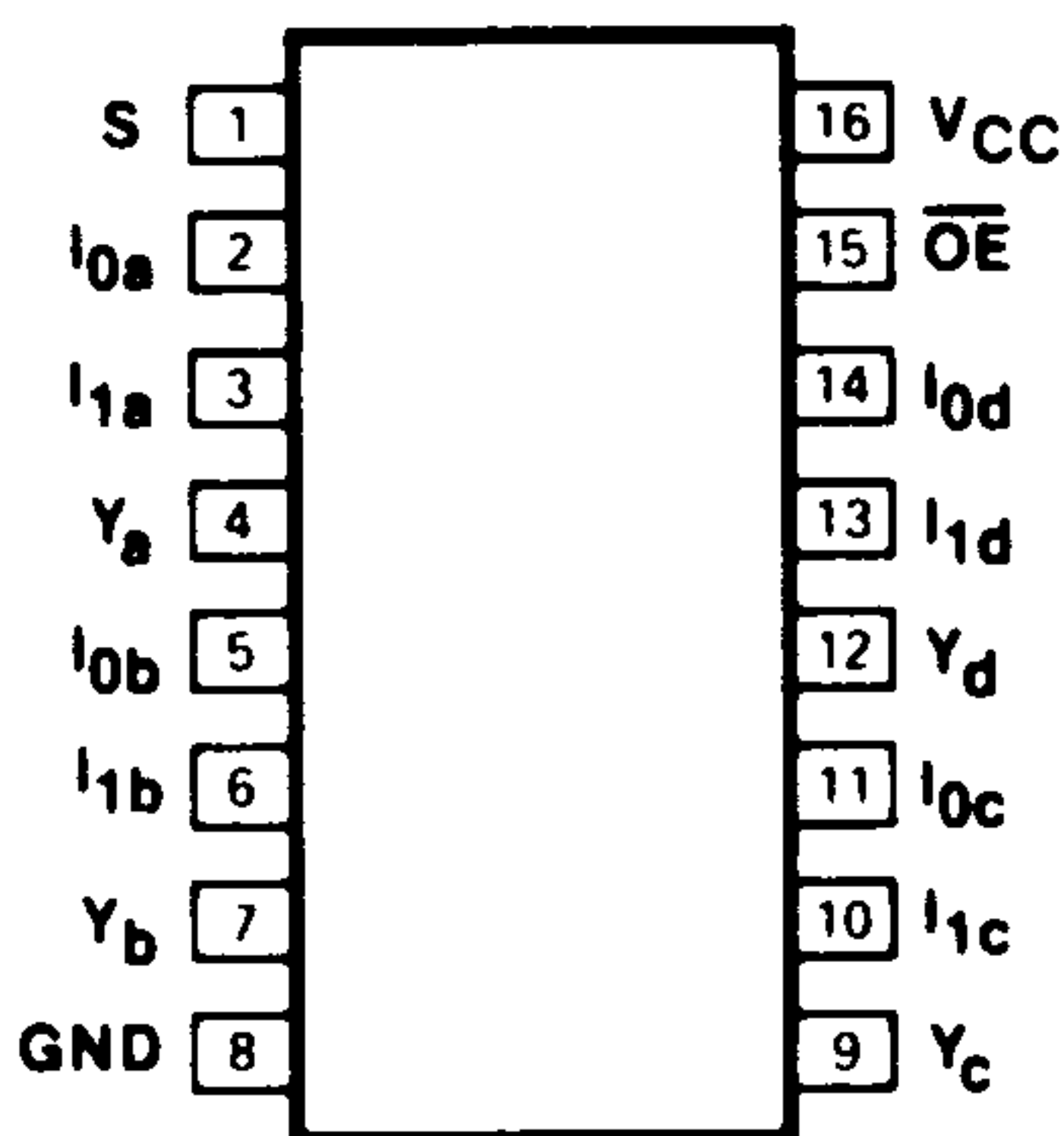
### TRUTH TABLE

| INPUTS          |     | INPUTS/OUTPUTS |         |
|-----------------|-----|----------------|---------|
| $\overline{OE}$ | S/R | $A_n$          | $B_n$   |
| L               | L   | $A = B$        | INPUTS  |
| L               | H   | INPUT          | $B = A$ |
| H               | X   | (Z)            | (Z)     |

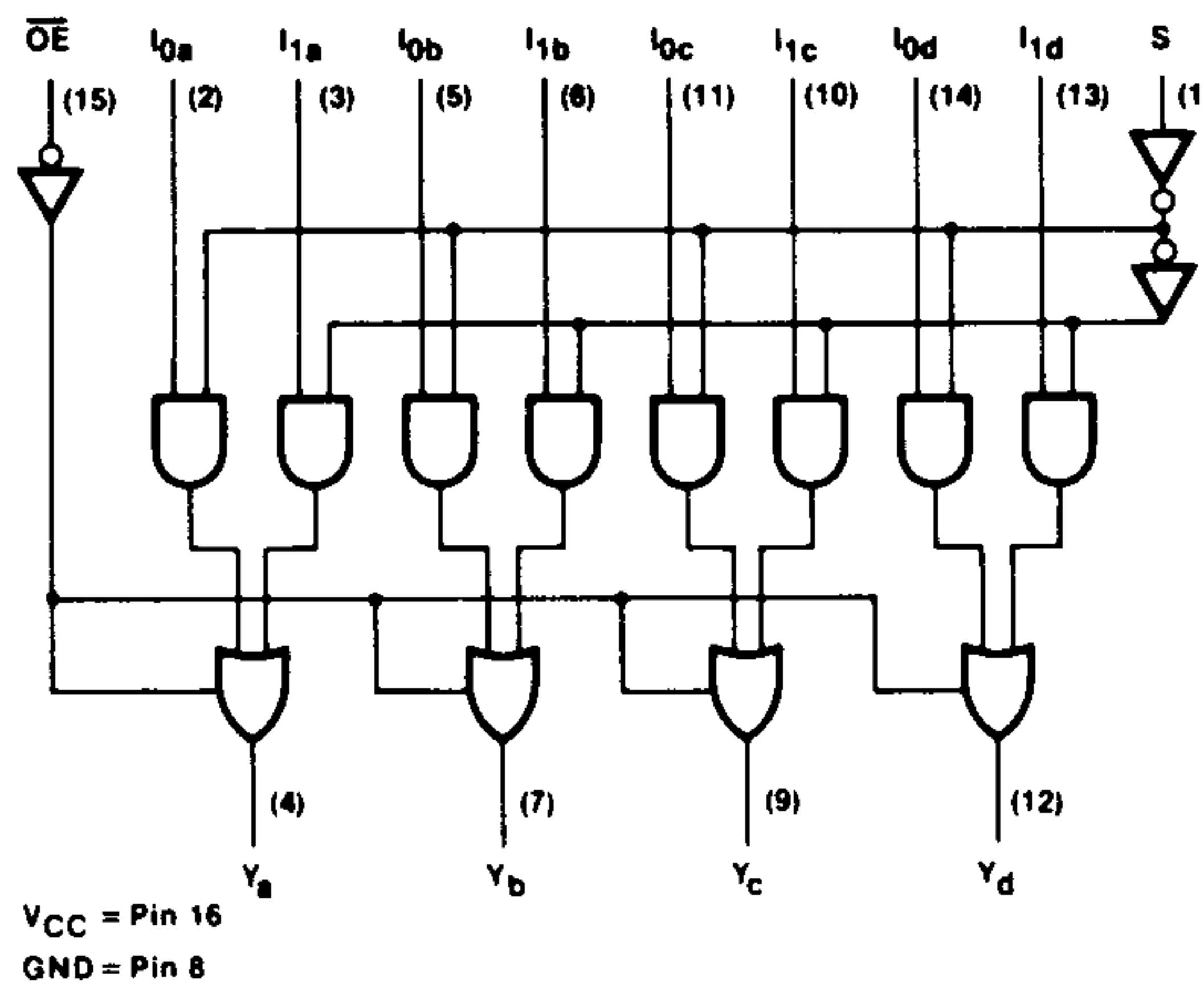
H = HIGH voltage level  
L = LOW voltage level  
X = Don't care  
(Z) = HIGH impedance "off" state

## 72S257 • 74LS257

### PIN ASSIGNMENT



### LOGIC DIAGRAM



### TRUTH TABLE

| ENABLE          |   | SELECT INPUT |       |
|-----------------|---|--------------|-------|
| $\overline{OE}$ | S | $I_0$        | $I_1$ |
| H               | X | (Z)          | (Z)   |
| L               | H | L            | L     |
| L               | L | H            | H     |
| L               | X | L            | L     |
| L               | H | H            | H     |

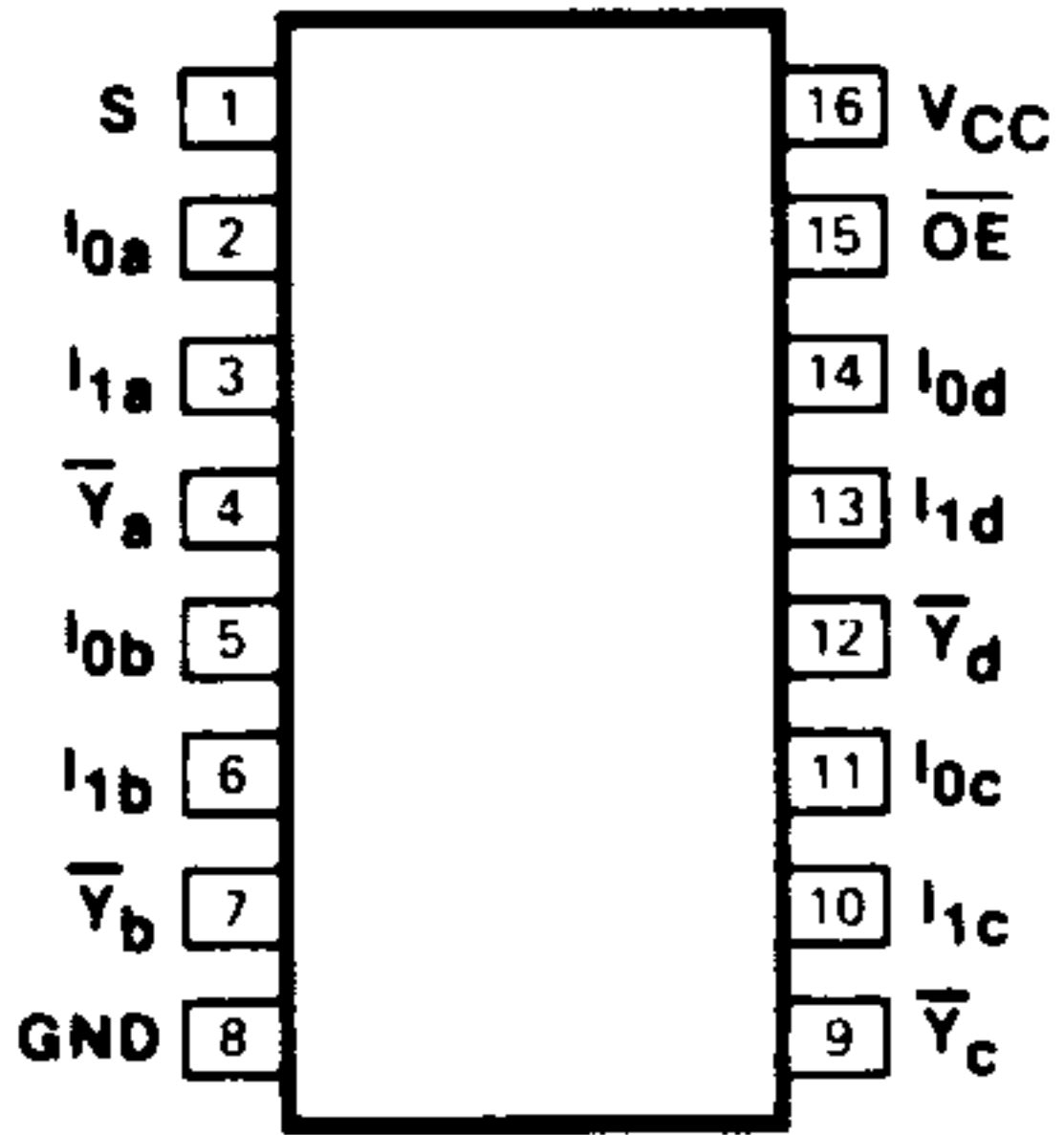
H = HIGH voltage level  
L = LOW voltage level  
X = Don't care  
(Z) = HIGH impedance (off) state



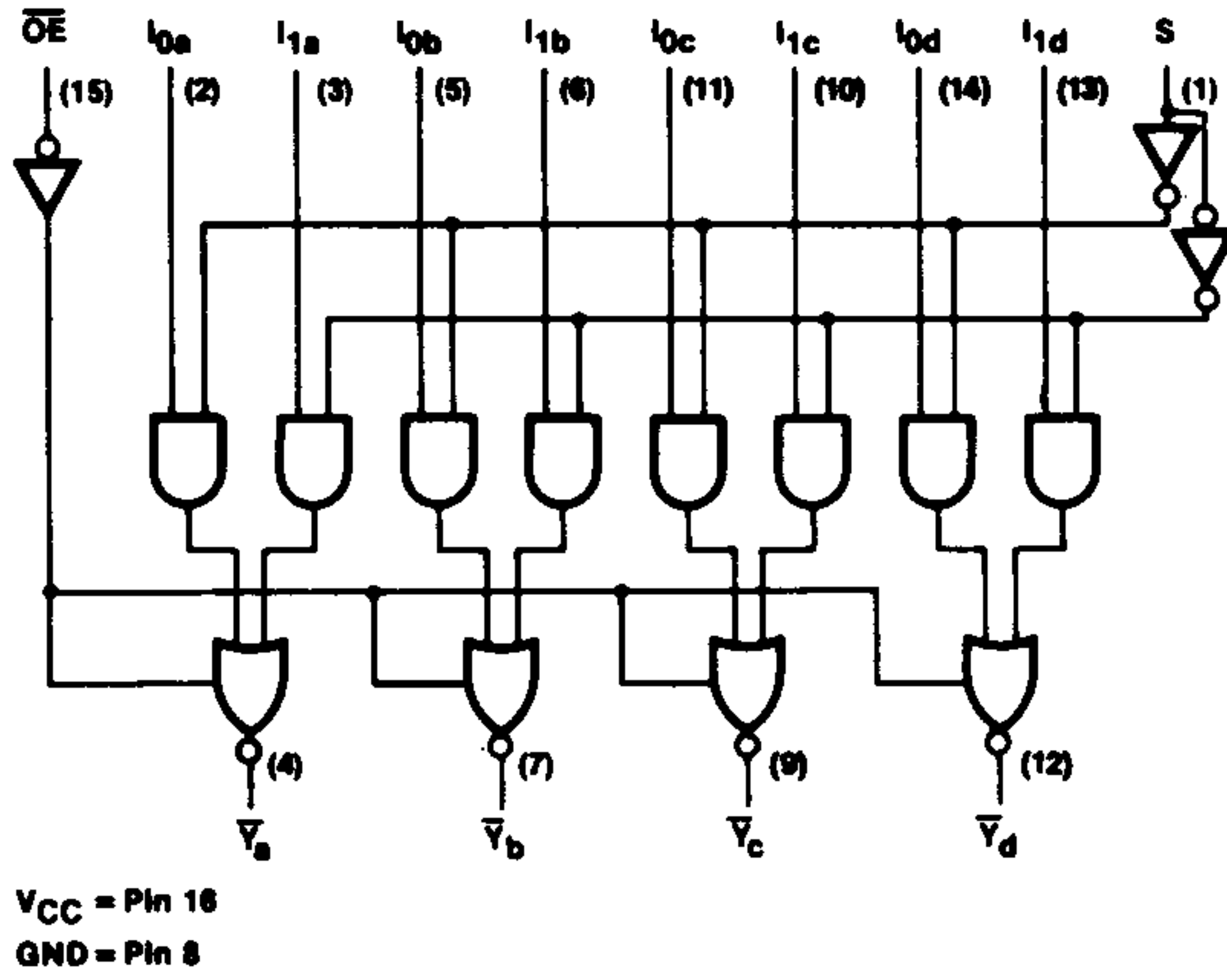
# COMMON I.C.'S (Continued)

## 72S258 • 74LS258A QUAD 2:1 MULTIPLEXER (3-STATE)

### PIN ASSIGNMENT



### LOGIC DIAGRAM



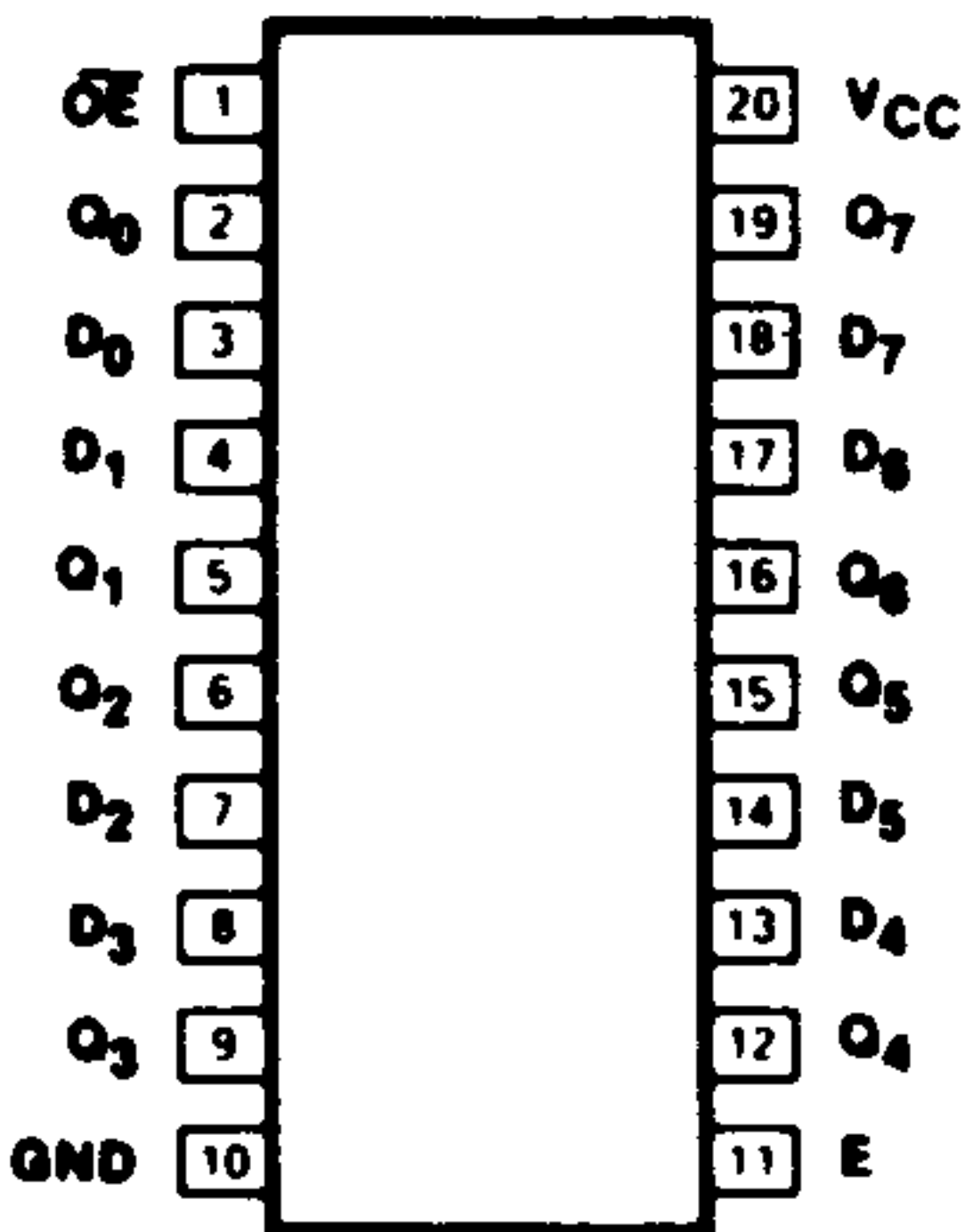
### TRUTH TABLE

| OUTPUT ENABLE | SELECT INPUT | DATA INPUTS    |                | OUTPUTS |
|---------------|--------------|----------------|----------------|---------|
|               |              | I <sub>0</sub> | I <sub>1</sub> |         |
| H             | X            | X              | X              | (Z)     |
| L             | H            | X              | L              | H       |
| L             | H            | X              | H              | L       |
| L             | L            | L              | X              | H       |
| L             | L            | H              | X              | L       |

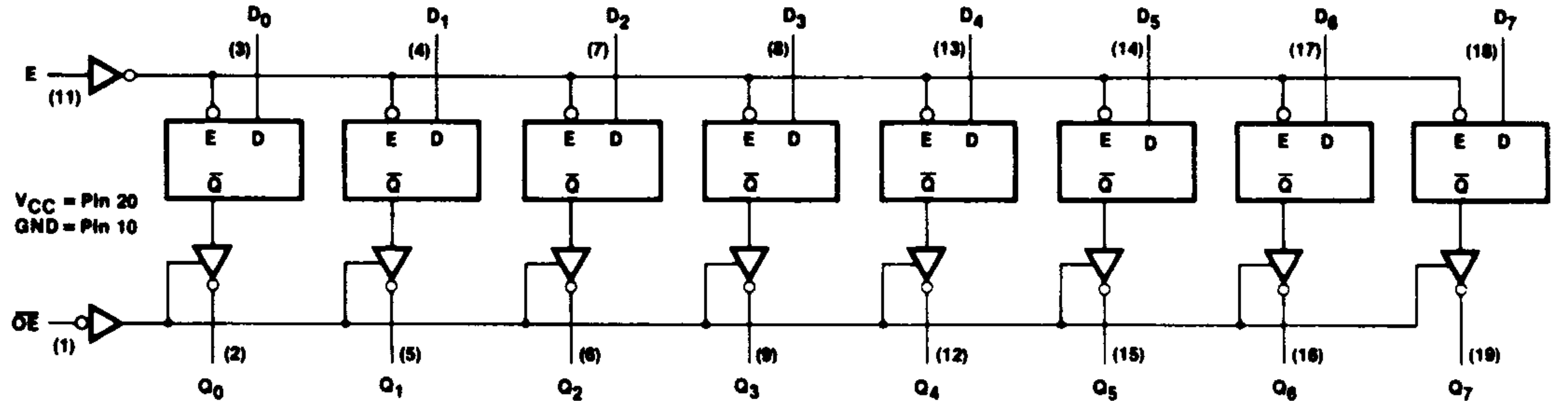
H = HIGH voltage level  
L = LOW voltage level  
X = Don't care  
(Z) = HIGH impedance (off) state

## 74S373 • 74LS373 OCTAL LATCH (3-STATE)

### PIN ASSIGNMENT



### LOGIC DIAGRAM

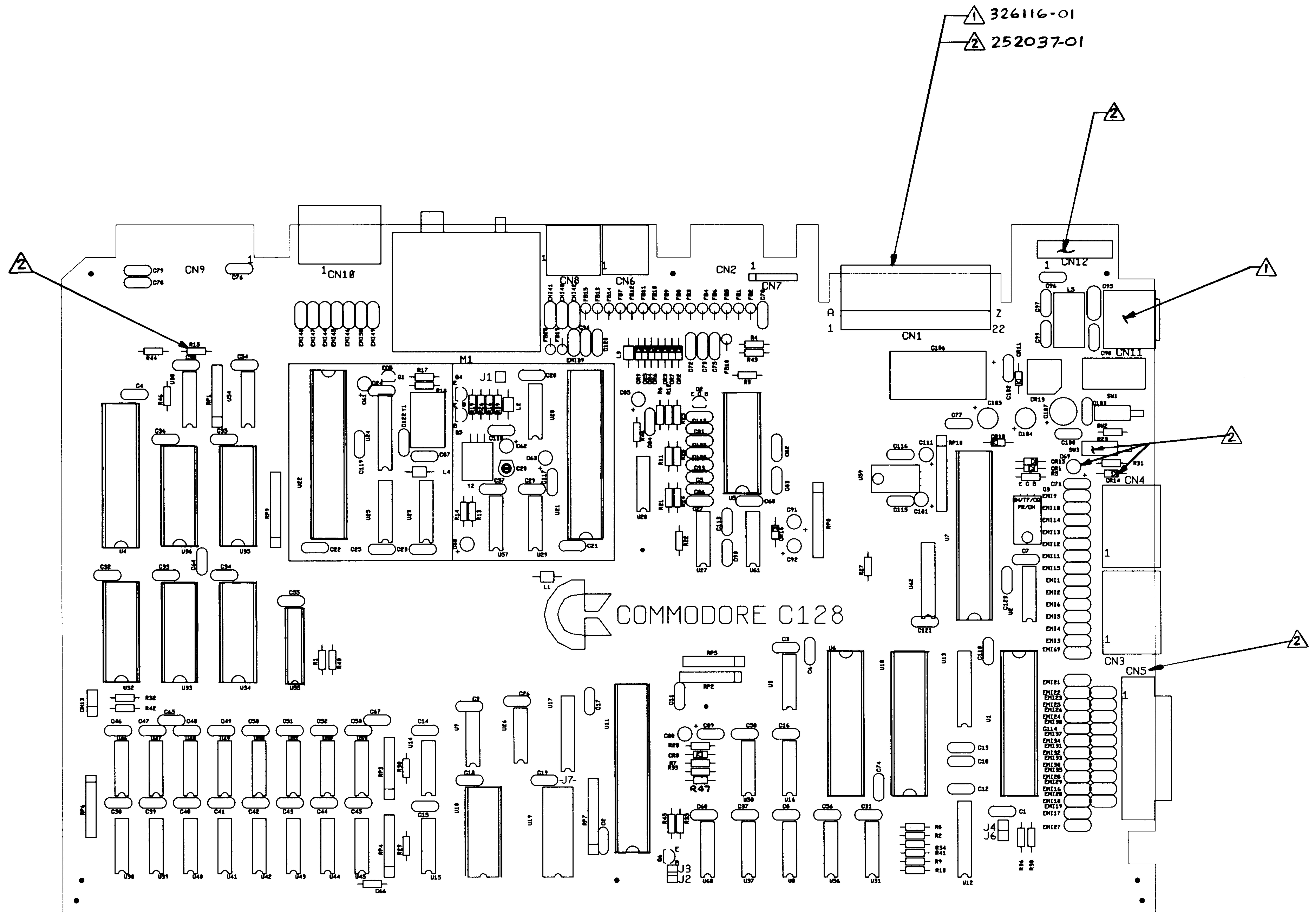


### TRUTH TABLE

| OPERATING MODES                    | INPUTS |   |                | INTERNAL REGISTER | OUTPUTS<br>Q <sub>0</sub> -Q <sub>7</sub> |
|------------------------------------|--------|---|----------------|-------------------|---|
|                                    | OE     | E | D <sub>n</sub> |                   |   |
| Enable and read register           | L      | H | L              | L                 | L   |
|                                    | L      | H | H              | H                 | H   |
| Latch and read register            | L      | L | l              | L                 | L   |
|                                    | L      | L | h              | H                 | H   |
| Latch register and disable outputs | H      | L | l              | L                 | (Z)                                       |
|                                    | H      | L | h              | H                 | (Z)                                       |

H = HIGH voltage level  
h = HIGH voltage level one setup time prior to the LOW-to-HIGH clock transition or HIGH-to-LOW OE transition  
L = LOW voltage level

l = LOW voltage level one setup time prior to the LOW-to-HIGH clock transition or HIGH-to-LOW OE transition  
(Z) = HIGH impedance "off" state  
↑ = LOW-to-HIGH clock transition



**NOTE :**  
 ▲ LOW END ONLY  
 ▲ HIGH END ONLY

**BOARD LAYOUT**  
**PCB ASSY #310379 Revision 6**  
**IDENTIFYING FACTOR: On solder side of board**  
**at the EXPANSION BUS, CN1, the artwork**  
**#310381 REV. 6 appears.**

# PARTS LIST

## PCB ASSEMBLY #310379

### REV. 6

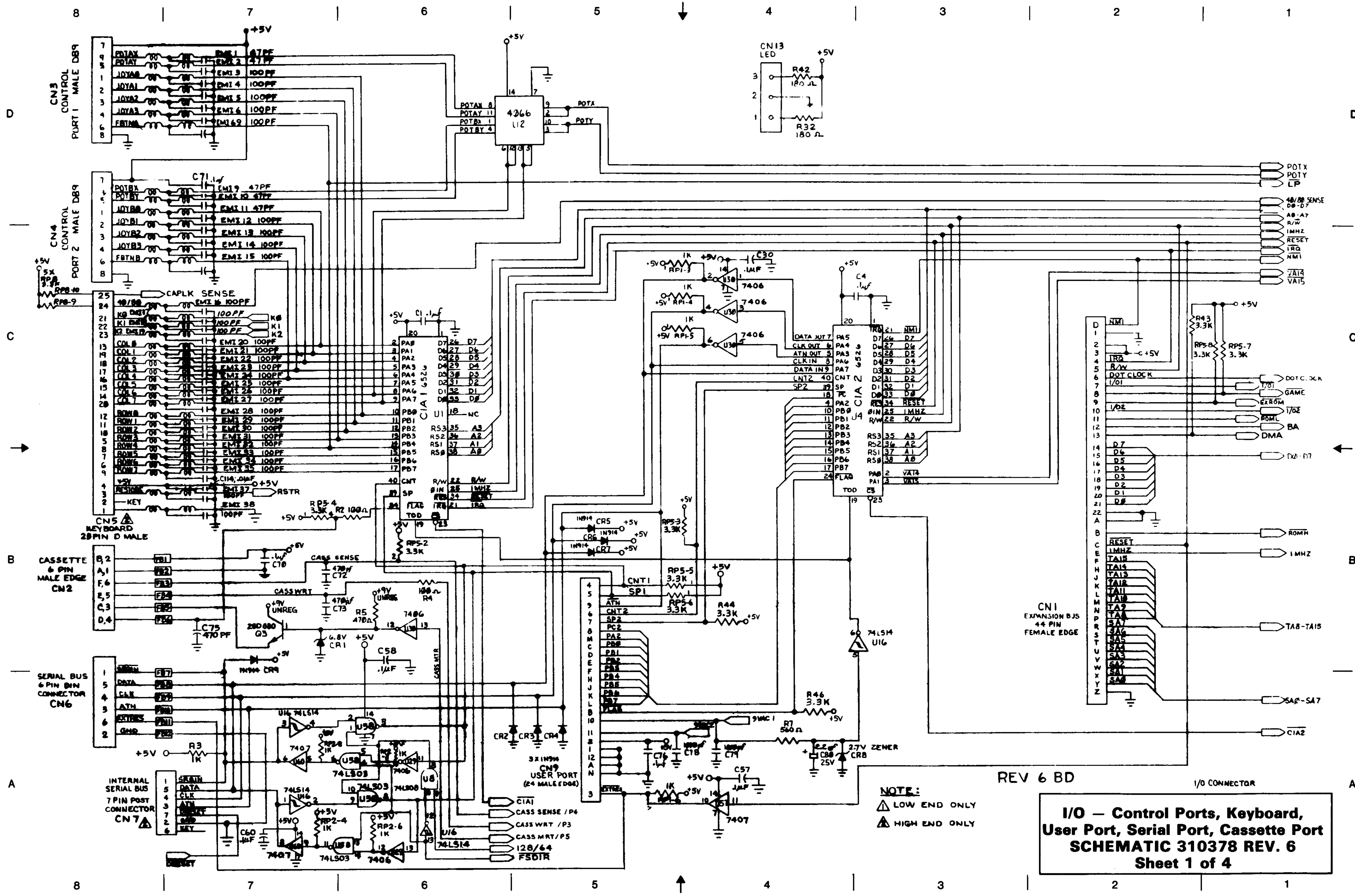
| INTEGRATED CIRCUITS |                                 |                  | DIODES (Continued)  |                     |                        |
|---------------------|---------------------------------|------------------|---|---------------------|------------------------|
| U1                  | 6526 CIA                        | 906108-01        | CR13  | Bridge Rect 100V 2A | 251026-01              |
| U2                  | 4066                            |                  | CR15,16   | 1N914               |                        |
| U3                  | 74LS138                         |                  | CR100,101   | 1N914               |                        |
| U4                  | 6526 CIA                        | 906108-01        | <b>RESISTORS</b> — All values in ohms, 1/4W, 5% unless noted otherwise. |                     |                        |
| U5                  | 6581 SID                        | 906112-01        | R1  | 68                  |                        |
| U6                  | 8502 Microprocessor             | 315020-01        | R2  | 100                 |                        |
| U7                  | 8722-R1 MMU                     | 310389-01        | R3  | 1K                  |                        |
| U8                  | 74LS08                          |                  | R4  | 100                 |                        |
| U9                  | 74LS32                          |                  | R5  | 470                 |                        |
| U10                 | Z80B Microprocessor 6 MHz       | 906150-02        | R6  | 47K                 |                        |
| U11                 | 8721-R3 PLA                     | 315012-01        | R7  | 560                 |                        |
| U12                 | 74LS373                         |                  | R8  | 3.3K                |                        |
| U13                 | 74LS244                         |                  | R9  | 10K                 |                        |
| U14,15              | 74LS257A                        |                  | R10   | 3.3K                |                        |
| U16                 | 74LS14                          |                  | R11,12  | 1K                  |                        |
| U17                 | 74ALS373                        |                  | R13,14  | 330 1W 5%           |                        |
| U18                 | ROM 64K 128 Char                | 390059-01        | R16   | 120                 |                        |
| U19                 | 2016 16K RAM — 200ns            |                  | R17   | 47                  |                        |
| U20                 | 4066                            |                  | R18   | 82                  |                        |
| U21                 | 8564-R4 VIC                     | 315009-01        | R19   | 330 1W 5%           |                        |
| U22                 | 8563-R7 CRT Cntrl               | 315014-01        | R20   | 10K                 |                        |
| U23                 | 4416 Dynamic RAM — 150ns        |                  | R21   | 470K                |                        |
| U24                 | 74LS244                         |                  | R22   | 47K                 |                        |
| U25                 | 4416 Dynamic RAM — 150ns        |                  | R23   | 100K                |                        |
| U26                 | 74LS257A                        |                  | R24   | 47K                 |                        |
| U27                 | 556                             |                  | R25   | 100K                |                        |
| U28                 | 8701 Clock Generator            | 251527-01        | R26   | 100                 |                        |
| U29,30              | 7406                            |                  | R27   | 4.7K                |                        |
| U31                 | 74LS00                          |                  | R28   | 10K                 |                        |
| U32                 | ROM 1 — C64 Kern & Basic        | 251913-01        | R29,30  | 68                  |                        |
| U33                 | ROM 2 — Basic \$4000            | 318018-02        | R31   | 100                 |                        |
| U34                 | ROM 3 — Basic \$8000            | 318019-02        | R32   | 180                 |                        |
| U35                 | ROM 4 — Kernal \$C000           | 318020-03        | R33,34  | 10K                 |                        |
| U36                 | ROM Mem Function                | Blank            | R35   | 100                 |                        |
| U37                 | 7406                            |                  | R36   | 10K                 |                        |
| U38-53              | 4164 Dynamic RAM — 200ns        |                  | R38   | 10K                 |                        |
| U54                 | 74LS32                          |                  | R39   | 120                 |                        |
| U55                 | 74LS245                         |                  | R40   | 180                 |                        |
| U56                 | 74LS74                          |                  | R41   | 680                 |                        |
| U57                 | 7407                            |                  | R42   | 180                 |                        |
| U58                 | 74LS03                          |                  | R43,44  | 3.3K                |                        |
| U59                 | 7812 Regulator 12V, To-220 Case |                  | R45   | 1.2K                |                        |
| U60                 | 7407                            |                  | R46   | 3.3K                |                        |
| U61                 | 74LS08                          |                  | R47   | 1K                  |                        |
| U62                 | 74LS244                         |                  | R48   | 10K                 |                        |
| <b>TRANSISTORS</b>  |                                 |                  | R100,101  | 1K                  |                        |
| Q1,2                | 2SC1815                         |                  | R102  | 47K                 |                        |
| Q3                  | 2SD880                          |                  | R103,04   | 1K                  |                        |
| Q4,5,6              | 2SC1815                         |                  | R105  | 470                 |                        |
| Q100                | 2N4403                          |                  | R106  | 1K                  |                        |
| Q101                | 2SC1815                         |                  | <b>RESISTOR PACKS</b>   |                     |                        |
| Q102                | 2N4403                          |                  | RP1   | 1K +/-2%            | 8 Pin, SIP, Pin 1 Com  |
| <b>DIODES</b>       |                                 |                  | RP2   | 1K 1/8W +/-10%      | 9 Pin, SIP, Pin 1 Com  |
| CR1                 | RD6.8EB                         | Zener 6.8V 400MW | RP3,4   | 33 +/-2%            | 8 Pin, SIP, Isolated   |
| CR2-7               | 1N914                           | Sub: IN4148      | RP5   | 3.3K +/-10%         | 8 Pin, SIP, Pin 1 Com  |
| CR8                 | 1N4371                          | Zener 2.7V 500MW | RP6   | 1K 1/8W +/-10%      | 9 Pin, SIP, Pin 1 Com  |
| CR9                 | 1N914                           | Sub: IN4148      | RP7,8   | 3.3K                | 10 Pin, SIP, Pin 1 Com |
| CR10,11             | 1N4001                          | Rect 50V 1A      | RP9,10  | 10K                 | 10 Pin, SIP, Pin 1 Com |

**PART LIST PCB ASSEMBLY 310379 REV. 6**

| <b>CAPACITORS</b> — All caps are 25v, + 80%,<br>- 20% unless noted otherwise. |            |                                 | <b>CAPACITORS (Continued)</b> |                             |                           |
|---|------------|---------------------------------|-------------------------------|-----------------------------|---------------------------|
| C1  | Cer        | .1 $\mu$ F                      | C105                          | Elect                       | 330 $\mu$ F, 50V, +/- 20% |
| C2  | Cer        | 10000pF                         | C106                          | Elect                       | 1000 $\mu$ F, 25V         |
| C3-5  | Cer        | .1F                             | C107                          | Elect                       | 100 $\mu$ F, 16V          |
| C6  | Cer        | .22 $\mu$ F                     | C108,9                        | Cer                         | 1800pF, 50V 10%           |
| C7-19   | Cer        | .1 $\mu$ F                      | C110                          | Cer                         | 10000pF                   |
| C20   | Trim       | 4-40pF                          | C111                          | Elect Alum                  | 10 $\mu$ F, 16V           |
| C21   | Cer        | .22 $\mu$ F                     | C112                          | Cer                         | 470pF, 50V, 10%           |
| C22   | Cer        | .1 $\mu$ F                      | C113,14                       | Cer                         | 10000pF                   |
| C23   | Cer        | .22 $\mu$ F                     | C115,16                       | Cer                         | .1 $\mu$ F                |
| C24   | Cer        | .1 $\mu$ F                      | C117-23                       | Cer                         | 10000pF                   |
| C25   | Cer        | .22 $\mu$ F                     | C124                          | Cer                         | .1 $\mu$ F, 16V           |
| C26,27  | Cer        | .1 $\mu$ F                      | <b>MISCELLANEOUS</b>          |                             |                           |
| C28   | Cer        | .22 $\mu$ F                     | Y1                            | 16 MHz Clock Oscillator     | 325566-01                 |
| C29-37  | Cer        | .1 $\mu$ F                      | Y2                            | 14.31818 Crystal            | 251467-01                 |
| C38-53  | Cer        | .22 $\mu$ F                     | L1-4                          | Inductor 2.2 $\mu$ H        |                           |
| C54-58  | Cer        | .1 $\mu$ F                      | L5                            | Line Filter Assy            | 251878-01                 |
| C60   | Cer        | .1 $\mu$ F                      | FB1-15,<br>18-20              | Ferrite Beads               |                           |
| C61-63  | Elect Alum | 10 $\mu$ F, 16V                 | EMI1,2                        | EMI Filter                  | 47pF                      |
| C64,65  | Cer        | 10000pF                         | EMI3-6                        | EMI Filter                  | 100pF                     |
| C66   | Mylar      | .01 $\mu$ F, 250V, +/- 20%      | EMI9-11                       | EMI Filter                  | 47pF                      |
| C67   | Cer        | 10000 $\mu$ F                   | EMI12-35,<br>37,38            | EMI Filter                  | 100pF                     |
| C68   | Cer        | .1 $\mu$ F                      | EMI39                         | EMI Filter                  | 270pF                     |
| C69   | Elect Alum | 10 $\mu$ F, 16V                 | EMI40-42                      | EMI Filter                  | 100pF                     |
| C70,71  | Cer        | .1 $\mu$ F                      | EMI44-50                      | Ferrite Bead                |                           |
| C72,73  | Cer        | 470pF, 50V, 10%                 | EMI69                         | EMI Filter                  | 100pF                     |
| C74   | Cer        | 10000pF                         | M1                            | Modulator                   | 251917-01                 |
| C75   | Cer        | 470pF, 50V, 10%                 | SW1                           | Rocker Switch               | 252182-01                 |
| C76   | Cer        | .1 $\mu$ F                      | SW2                           | Push BT SPDT                | 251260-01                 |
| C77   | Cer        | 10000pF                         | CN1                           | RT Angle Card Edge          | 906100-02                 |
| C78,C79   | Cer        | 1000pF, 50V, 10%                | CN3,4                         | Mini D Cnnct Joy1,2         | 251057-01                 |
| C80   | Elect      | 2.2 $\mu$ F, 25V                | CN6,7                         | 6 Pin Din Serial Cnnct Shld | 252166-01                 |
| C81   | Cer        | 1000pF, 50V, 10%                | CN8                           | 8 Pin Din Video Cnnct Shld  | 252168-01                 |
| C82,83  | Cer        | 470pF, 50V, 10%                 | CN10                          | D Cnnct 9 Pin Fem Rgbi      | 252024-01                 |
| C84   | Cer        | 220pF, 50V, 10%                 | CN11                          | 5 Pin Square Din Shielded   | 252167-01                 |
| C85   | Elect Alum | 10 $\mu$ F, 16V                 | CN13                          | 3 Pin Header .1 Center      |                           |
| C86   | Cer        | .1 $\mu$ F                      |                               | Shield Box                  | 326265-02                 |
| C87   | Cer        | .22 $\mu$ F                     |                               | Shield Cap                  | 310407-01                 |
| C88   | Elect Alum | 10 $\mu$ F, 16V                 |                               |                             |                           |
| C89   | Cer        | 51pF, 50V, +/- 5%               |                               |                             |                           |
| C90   | Cer        | 360pF, 50V, +/- 5%              |                               |                             |                           |
| C91   | Elect      | 1 $\mu$ F, 16V                  |                               |                             |                           |
| C92   | Elect Alum | 10 $\mu$ F, 16V                 |                               |                             |                           |
| C93   | Cer        | .1 $\mu$ F                      |                               |                             |                           |
| C94   | Cer        | .22 $\mu$ F                     |                               |                             |                           |
| C95   | Cer Mono   | .22 $\mu$ F, 100V, + 80%, - 20% |                               |                             |                           |
| C96-99  | Cer        | .22 $\mu$ F, 50V                |                               |                             |                           |
| C100  | Cer        | .1 $\mu$ F                      |                               |                             |                           |
| C101  | Elect      | 10 $\mu$ F, 35V, +/- 20%        |                               |                             |                           |
| C102  | Cer        | .1 $\mu$ F                      |                               |                             |                           |
| C103  | Cer        | 10000pF                         |                               |                             |                           |
| C104  | Elect      | 220 $\mu$ F, 50V                |                               |                             |                           |

### QUICK REFERENCE

| TITLE            | PAGE |
|------------------|------|
| 4066             | 57   |
| 6526             | 49   |
| 74XXX            | 58   |
| BUS ARCHITECTURE | 4    |
| CASSETTE PORT    | 49   |
| CONTROL PORTS    | 50   |
| EXPANSION BUS    | 52   |
| KEYBOARD         |      |
| Test             | 51   |
| Matrix           | 51   |
| LINE DEFINITIONS | 56   |
| SERIAL BUS       | 54   |
| USER PORT        | 50   |



**NOTE:**  
 ▲ LOW END ONLY  
 ▲ HIGH END ONLY

**I/O - Control Ports, Keyboard, User Port, Serial Port, Cassette Port**  
**SCHEMATIC 310378 REV. 6**  
 Sheet 1 of 4

### QUICK REFERENCE

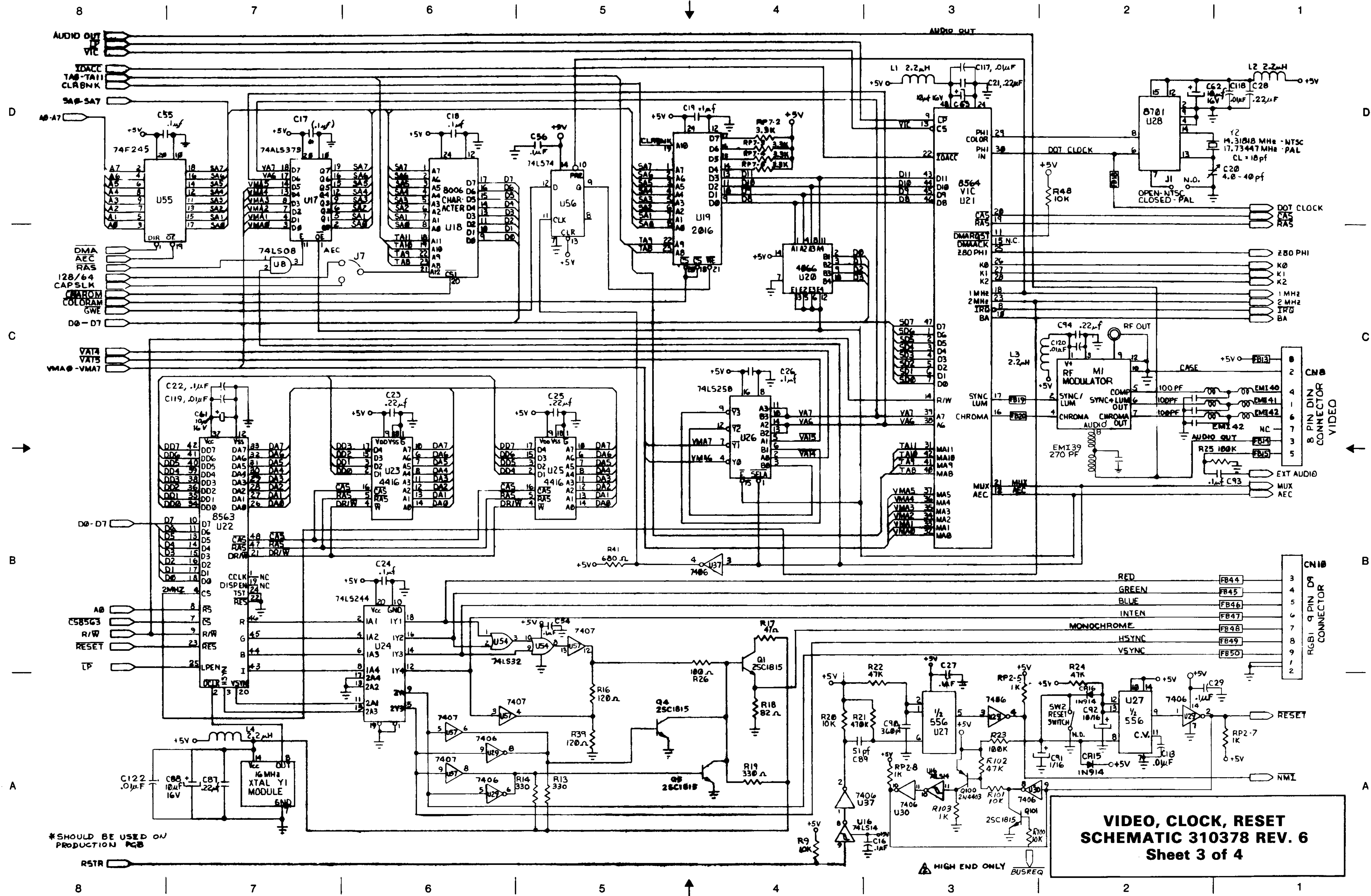
| TITLE               | PAGE |
|---------------------|------|
| 6581                | 38   |
| 74XXX               | 58   |
| 8502                | 6    |
| 8721                | 29   |
| 8722                | 27   |
| BUS ARCHITECTURE    | 4    |
| LINE DEFINITIONS    | 56   |
| MEMORY ARCHITECTURE | 11   |
| MMU                 |      |
| Text                | 20   |
| Pin Configuration   | 27   |
| PLA                 |      |
| Text                | 28   |
| Pin Configuration   | 29   |
| SID                 | 38   |
| Z80                 |      |
| Text                | 8    |
| Pin Configuration   | 10   |





## QUICK REFERENCE

| TITLE               | PAGE |
|---------------------|------|
| 2016                | 17   |
| 4066                | 57   |
| 4416                | 19   |
| 556                 | 57   |
| 74XXX               | 58   |
| 8563                | 38   |
| 8564                | 35   |
| 8701                | 30   |
| BUS ARCHITECTURE    | 4    |
| CLOCK               | 30   |
| LINE DEFINITIONS    | 56   |
| MEMORY ARCHITECTURE | 11   |
| MODULATOR           | 77   |
| RAM                 | 17   |
| ROM                 | 15   |
| VIC                 |      |
| Text                | 33   |
| Pin Configuration   | 35   |
| VIDEO CONTROLLER    |      |
| Text                | 36   |
| Pin Configuration   | 38   |
| VIDEO INTERFACE     | 33   |



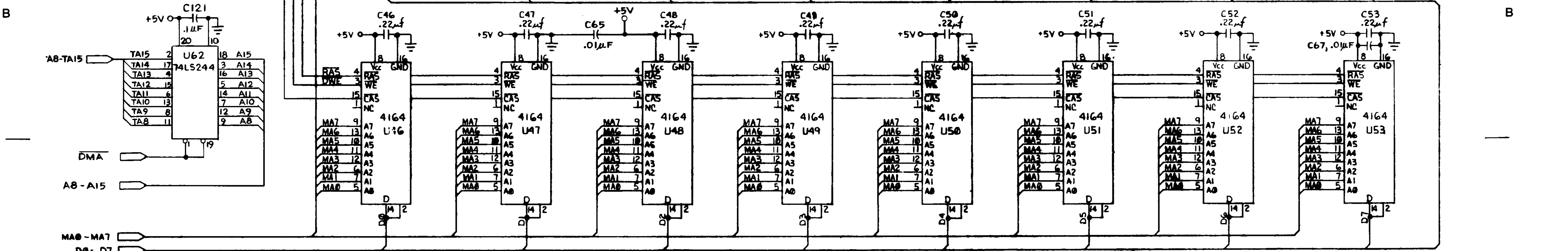
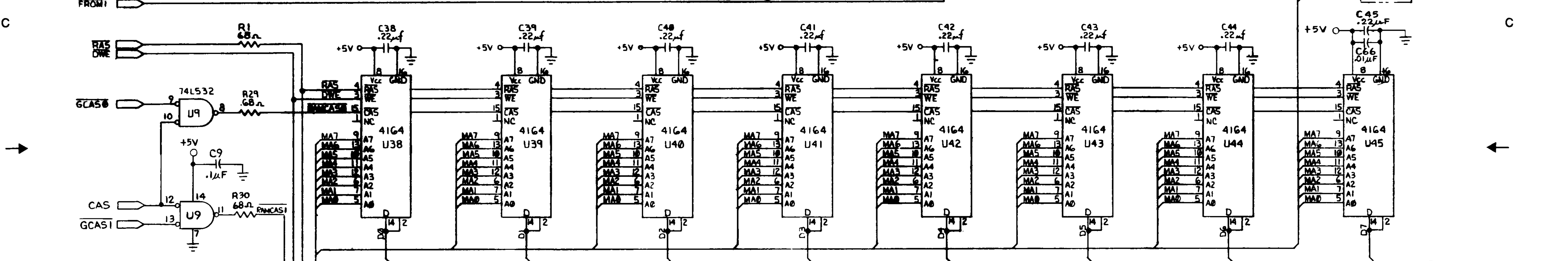
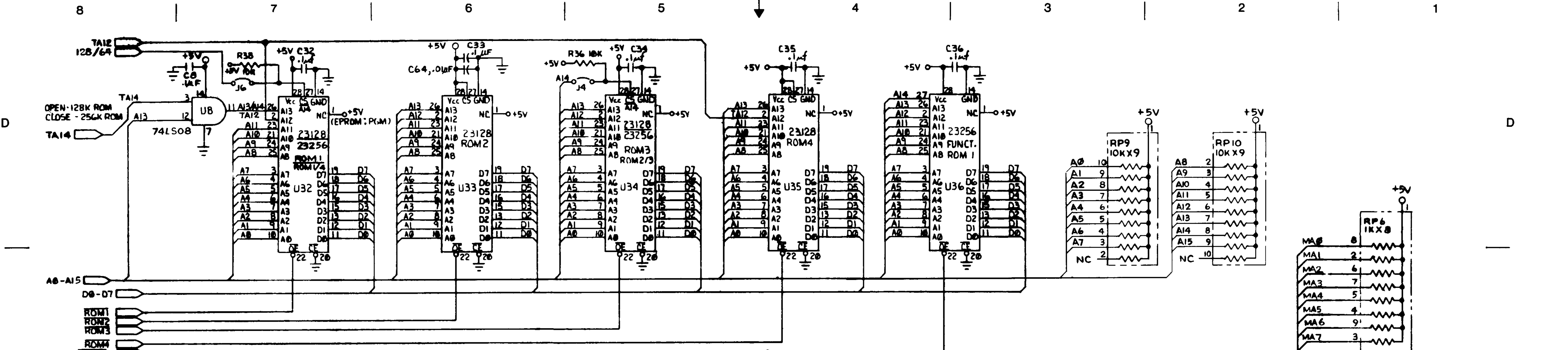
\*SHOULD BE USED ON PRODUCTION PCB

**VIDEO, CLOCK, RESET SCHEMATIC 310378 REV. 6**  
Sheet 3 of 4

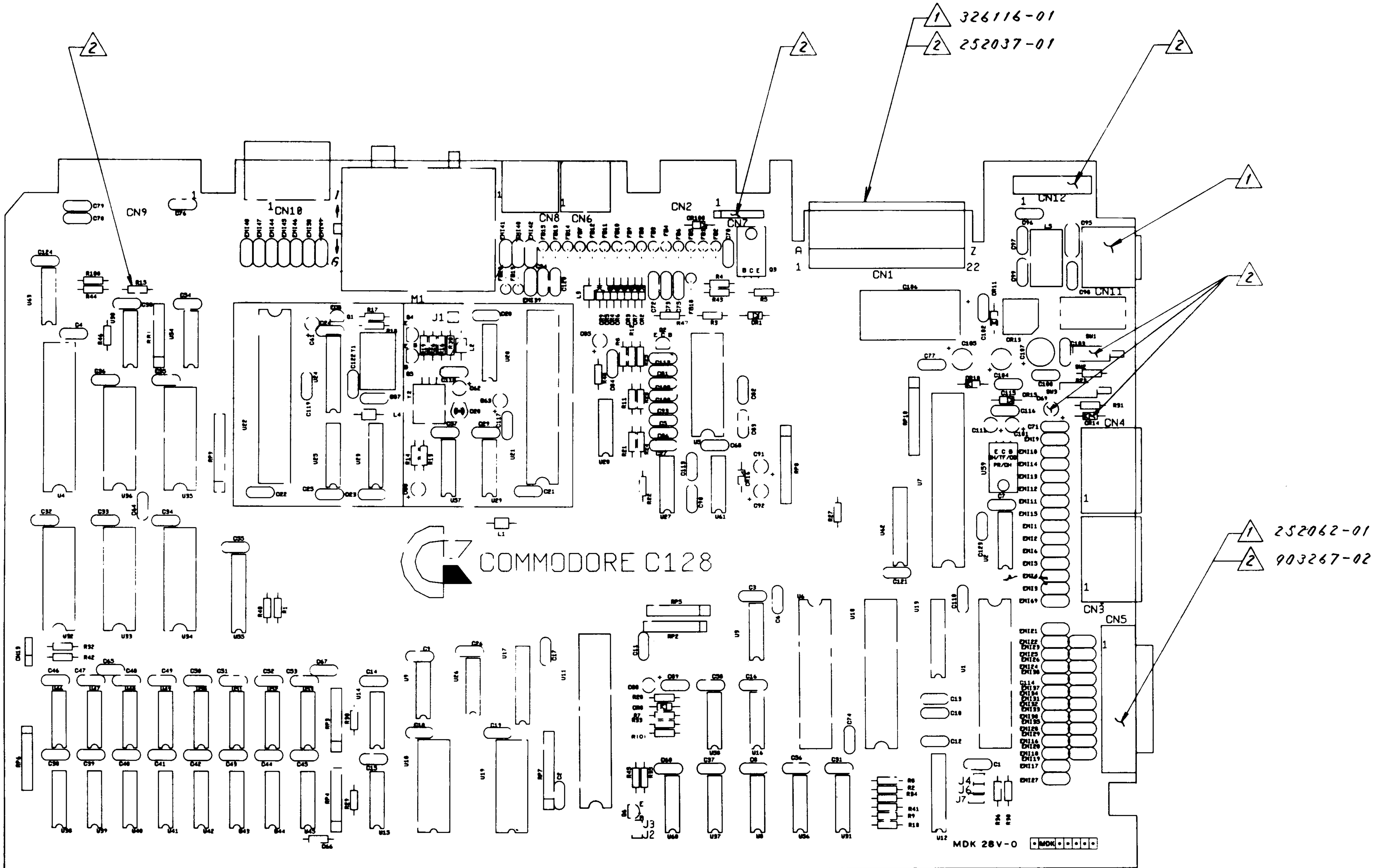
HIGH END ONLY

### **QUICK REFERENCE**

| <b>TITLE</b>               | <b>PAGE</b> |
|----------------------------|-------------|
| <b>23128</b>               | <b>16</b>   |
| <b>4164</b>                | <b>18</b>   |
| <b>74XXX</b>               | <b>58</b>   |
| <b>BUS ARCHITECTURE</b>    | <b>4</b>    |
| <b>LINE DEFINITIONS</b>    | <b>56</b>   |
| <b>MEMORY ARCHITECTURE</b> | <b>11</b>   |
| <b>RAM</b>                 | <b>17</b>   |
| <b>ROM</b>                 | <b>15</b>   |



**RAM, ROM  
SCHEMATIC 310378 REV. 6  
Sheet 4 of 4**



NOTE :

- △ 1 : LOW END ONLY
- △ 2 : HIGH END ONLY

**BOARD LAYOUT**  
**PCB ASSY #310379 Revision 7**  
**IDENTIFYING FACTOR: On solder side of board**  
**at the EXPANSION BUS, CN1, the artwork**  
**#310381 REV. 7 appears.**

# PARTS LIST

## PCB ASSEMBLY #310379

### REV. 7

| INTEGRATED CIRCUITS |                                 |                  | DIODES (Continued)   |                     |                        |
|---------------------|---------------------------------|------------------|--|---------------------|------------------------|
| U1                  | 6526 CIA                        | 906108-01        | CR13   | Bridge Rect 100V 2A | 251026-01              |
| U2                  | 4066                            |                  | CR15,16  | 1N914               | Sub: IN4148            |
| U3                  | 74LS138                         |                  | CR100  | 1N914               | Sub: IN4148            |
| U4                  | 6526 CIA                        | 906108-01        | <b>RESISTORS</b> — All values in ohms, 1/4W,<br>5% unless noted otherwise. |                     |                        |
| U5                  | 6581 SID                        | 906112-01        |  |                     |                        |
| U6                  | 8502 Microprocessor             | 315020-01        | R1   | 68                  |                        |
| U7                  | 8722-R1 MMU                     | 310389-01        | R2   | 100                 |                        |
| U8                  | 74LS08                          |                  | R3   | 1K                  |                        |
| U9                  | 74F32                           |                  | R4   | 100                 |                        |
| U10                 | Z80B Microprocessor 6 MHz       | 906150-02        | R5   | 470                 |                        |
| U11                 | 8721-R3 PLA                     | 315012-01        | R6   | 47K                 |                        |
| U12                 | 74LS373                         |                  | R7   | 560                 |                        |
| U13                 | 74LS244                         |                  | R8   | 3.3K                |                        |
| U14,15              | 74LS257A                        |                  | R9   | 10K                 |                        |
| U16                 | 74LS14                          |                  | R10  | 3.3K                |                        |
| U17                 | 74ALS373                        |                  | R11,12   | 1K                  |                        |
| U18                 | ROM 64K 128 Char                | 390059-01        | R13,14   | 330 1W 5%           |                        |
| U19                 | 2016 16K RAM — 200ns            |                  | R16  | 120                 |                        |
| U20                 | 4066                            |                  | R17  | 47                  |                        |
| U21                 | 8564-R4 VIC                     | 315009-01        | R18  | 82                  |                        |
| U22                 | 8563-R7 CRT Cntrl               | 315014-01        | R19  | 330 1W 5%           |                        |
| U23                 | 4416 Dynamic RAM — 150ns        |                  | R20  | 10K                 |                        |
| U24                 | 74LS244                         |                  | R21  | 470K                |                        |
| U25                 | 4416 Dynamic RAM — 150ns        |                  | R22  | 47K                 |                        |
| U26                 | 74LS257A                        |                  | R23  | 100K                |                        |
| U27                 | 556                             |                  | R24  | 47K                 |                        |
| U28                 | 8701C Clock Generator           | 251527-03        | R25  | 100K                |                        |
| U29,30              | 7406                            |                  | R26  | 100                 |                        |
| U31                 | 74LS00                          |                  | R27  | 4.7K                |                        |
| U32                 | ROM 1 — C64 Kern & Basic        | 251913-01        | R28  | 10K                 |                        |
| U33                 | ROM 2 — Basic \$4000            | 318018-02        | R29,30   | 68                  |                        |
| U34                 | ROM 3 — Basic \$8000            | 318019-02        | R31  | 100                 |                        |
| U35                 | ROM 4 — Kernal \$C000           | 318020-03        | R32  | 180                 |                        |
| U36                 | ROM Mem Function                | Blank            | R33,34   | 10K                 |                        |
| U37                 | 7406                            |                  | R35  | 100                 |                        |
| U38-53              | 4164 Dynamic RAM — 150ns        |                  | R36  | 10K                 |                        |
| U54                 | 74LS32                          |                  | R38  | 10K                 |                        |
| U55                 | 74F245                          |                  | R39  | 120                 |                        |
| U56                 | 74LS74                          |                  | R40  | 180                 |                        |
| U57                 | 7407                            |                  | R41  | 680                 |                        |
| U58                 | 74LS03                          |                  | R42  | 180                 |                        |
| U59                 | 7812 Regulator 12V, TO-220 CASE |                  | R43,44   | 3.3K                |                        |
| U60                 | 7407                            |                  | R45  | 1.2K                |                        |
| U61                 | 74LS08                          |                  | R46  | 3.3K                |                        |
| U62                 | 74LS244                         |                  | R47  | 1K                  |                        |
| U63                 | 7406                            |                  | R48  | 10K                 |                        |
| <b>TRANSISTORS</b>  |                                 |                  | R100,101   | 1K                  |                        |
| Q1,2                | 2SC1815                         |                  | R102   | 68                  |                        |
| Q3                  | 2SD880                          |                  | <b>RESISTOR PACKS</b>  |                     |                        |
| Q4,5,6              | 2SC1815                         |                  | RP1  | 1K +/-2%            | 8 Pin, SIP, Pin 1 Com  |
| <b>DIODES</b>       |                                 |                  | RP2  | 1K 1/8W +/-10%      | 9 Pin, SIP, Pin 1 Com  |
| CR1                 | RD6.8EB                         | Zener 6.8V 400MW | RP3,4  | 33 +/-2%            | 8 Pin, SIP, Isolated   |
| CR2-7               | 1N914                           | Sub: IN4148      | RP5  | 3.3K +/-10%         | 8 Pin, SIP, Pin 1 Com  |
| CR8                 | 1N4371                          | Zener 2.7V 500MW | RP6  | 1K 1/8W +/-10%      | 9 Pin, SIP, Pin 1 Com  |
| CR9                 | 1N914                           | Sub: IN4148      | RP7,8  | 3.3K                | 10 Pin, SIP, Pin 1 Com |
| CR10,11             | 1N4001                          | Rect 50V 1A      | RP9,10   | 10K                 | 10 Pin, SIP, Pin 1 Com |

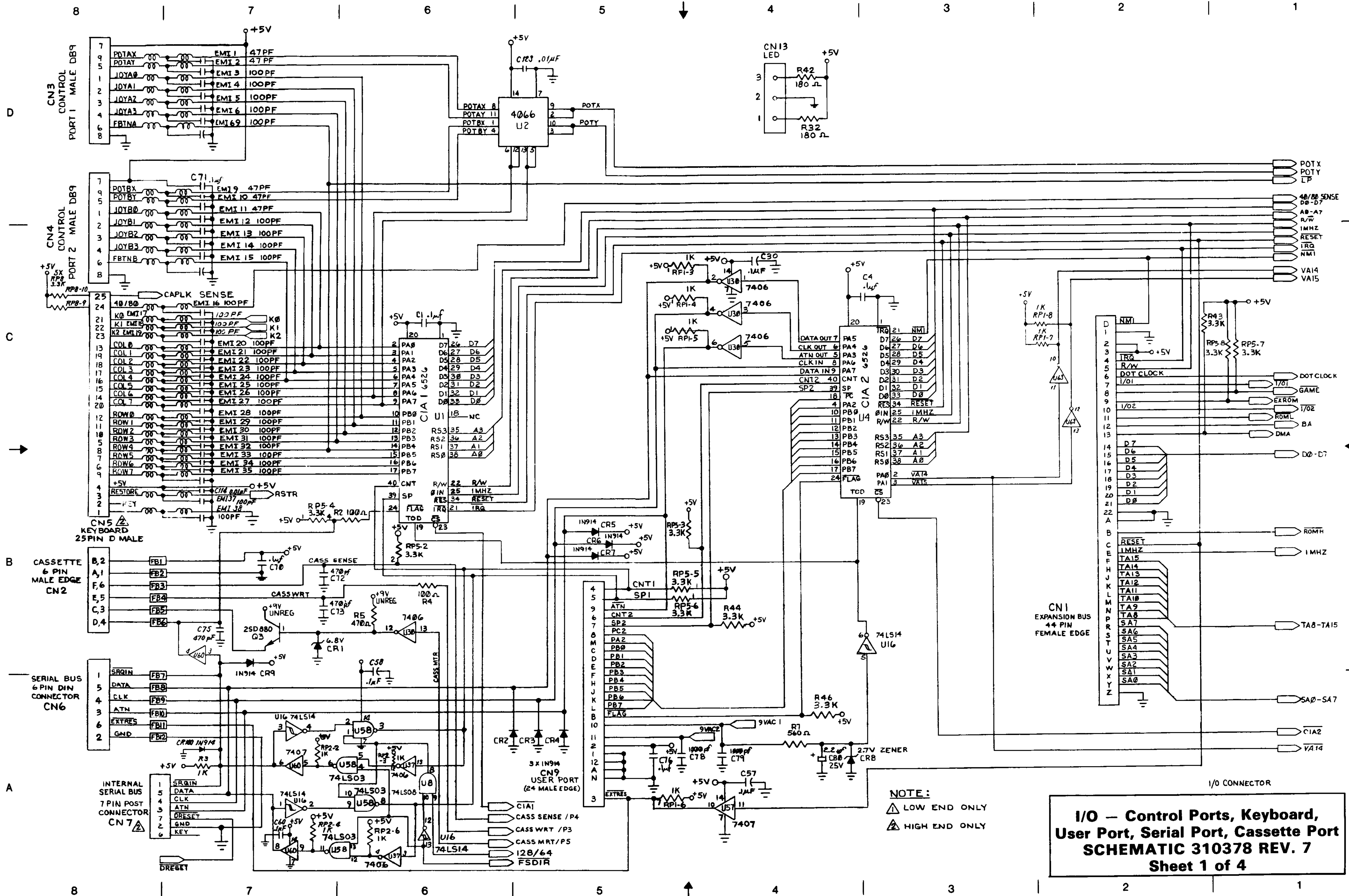
**PART LIST PCB ASSEMBLY 310379 REV. 7**

| <b>CAPACITORS</b> — All caps are 25v, +80%,<br>-20% unless noted otherwise. |            |              |            | <b>CAPACITORS (Continued)</b> |                             |             |           |
|---|------------|--------------|------------|-------------------------------|-----------------------------|-------------|-----------|
| C1  | Cer        | .1μF         |            | C105                          | Elect                       | 330μF, 50V, | +/-20%    |
| C2  | Cer        | .01μF        |            | C106                          | Elect                       | 1000μF, 25V |           |
| C3-5  | Cer        | .1F          |            | C107                          | Elect                       | 100μF, 16V  |           |
| C6  | Cer        | .22μF        |            | C108,9                        | Cer                         | .01μF       |           |
| C7-19   | Cer        | .1μF         |            | C110                          | Cer                         | .01μF       |           |
| C20   | Trim       | 4-40pF       |            | C111                          | Elect Alum                  | 10μF, 16V   |           |
| C21   | Cer        | .22μF        |            | C112                          | Cer                         | 470pF, 50V, | 10%       |
| C22   | Cer        | .1μF         |            | C113,14                       | Cer                         | .01μF       |           |
| C23   | Cer        | .22μF        |            | C115,16                       | Cer                         | .1μF        |           |
| C24   | Cer        | .1μF         |            | C117-23                       | Cer                         | .01μF       |           |
| C25   | Cer        | .22μF        |            | C124                          | Cer                         | .1μF, 16V   |           |
| C26,27  | Cer        | .1μF         |            | C125,126                      | Cer                         | .01μF       |           |
| C28   | Cer        | .22μF        |            | <b>MISCELLANEOUS</b>          |                             |             |           |
| C29-37  | Cer        | .1μF         |            | Y1                            | 16 MHz Clock Oscillator     |             | 325566-01 |
| C38-53  | Cer        | .22μF        |            | Y2                            | 14.31818 Crystal            |             | 251467-01 |
| C54-58  | Cer        | .1μF         |            | L1-4                          | Inductor 2.2μH              |             |           |
| C50   | Cer        | .1μF         |            | L5                            | Line Filter Assy            |             | 251878-01 |
| C61-62  | Elect Alum | 10μF, 16V    |            | FB1-15,<br>18-20              | Ferrite Beads               |             |           |
| C63   | Elect Alum | 100μF, 6.3V  |            | EMI1,2                        | EMI Filter                  |             | 47pF      |
| C64,65  | Cer        | .01μF        |            | EMI3-6                        | EMI Filter                  |             | 100pF     |
| C66   | Cer        | .01μF, 25V   | A          | EMI9-11                       | EMI Filter                  |             | 47pF      |
| C67   | Cer        | .01μF        |            | EMI12-35,<br>37,38            | EMI Filter                  |             | 100pF     |
| C68   | Cer        | .1μF         |            | EMI39                         | EMI Filter                  |             | 270pF     |
| C70,71  | Cer        | .1μF         |            | EMI40-42                      | EMI Filter                  |             | 100pF     |
| C72,73  | Cer        | 470pF, 50V,  | 10%        | EMI44-50                      | Ferrite Bead                |             |           |
| C74   | Cer        | .01μF        |            | EMI69                         | EMI Filter                  |             | 100pF     |
| C75   | Cer        | 470pF, 50V,  | 10%        | M1                            | Modulator                   |             | 251917-01 |
| C76   | Cer        | .1μF         |            | SW1                           | Rocker Switch               |             | 252182-01 |
| C77   | Cer        | .01μF        |            | SW2                           | Push BT SPDT                |             | 251260-01 |
| C78,C79   | Cer        | 1000pF, 50V, | 10%        | CN1                           | RT Angle Card Edge          |             | 906100-02 |
| C80   | Elect      | 2.2μF, 25V   |            | CN3,4                         | Mini D Cnnct Joy1,2         |             | 251057-01 |
| C81   | Cer        | 1000pF, 50V, | 10%        | CN5                           | Keybd Cnnct                 |             | 252062-01 |
| C82,83  | Cer        | 470pF, 50V,  | 10%        | CN6                           | 6 Pin Din Serial Cnnct Shld |             | 252166-01 |
| C84   | Cer        | 220pF, 50V,  | 10%        | CN8                           | 8 Pin Din Video Cnnct Shld  |             | 252168-01 |
| C85   | Elect Alum | 10μF, 16V    |            | CN10                          | D Cnnct 9 Pin Fem Rgbi      |             | 252024-01 |
| C86   | Cer        | .1μF         |            | CN11                          | 5 Pin Square Din Shielded   |             | 252167-01 |
| C87   | Cer        | .22μF        |            | CN13                          | 3 Pin Header .1 Center      |             |           |
| C88   | Elect Alum | 10μF, 16V    |            |                               | Shield Box                  |             | 326265-02 |
| C89   | Cer        | 51pF, 50V,   | +/-5%      |                               | Shield Cap                  |             | 310407-01 |
| C90   | Cer        | 360pF, 50V,  | +/-5%      |                               |                             |             |           |
| C91   | Elect      | 1μF, 50V     |            |                               |                             |             |           |
| C92   | Elect Alum | 10μF, 16V    |            |                               |                             |             |           |
| C93   | Cer        | .1μF         |            |                               |                             |             |           |
| C94   | Cer        | .22μF        |            |                               |                             |             |           |
| C95   | Cer Mono   | .22μF, 100V, | +80%, -20% |                               |                             |             |           |
| C96-99  | Cer        | .1μF, 16V    |            |                               |                             |             |           |
| C100  | Cer        | .1μF         |            |                               |                             |             |           |
| C101  | Elect      | 10μF, 35V,   | +/-20%     |                               |                             |             |           |
| C102  | Cer        | .1μF         |            |                               |                             |             |           |
| C103  | Cer        | .01μF        |            |                               |                             |             |           |
| C104  | Elect      | 220μF, 50V   |            |                               |                             |             |           |

### QUICK REFERENCE

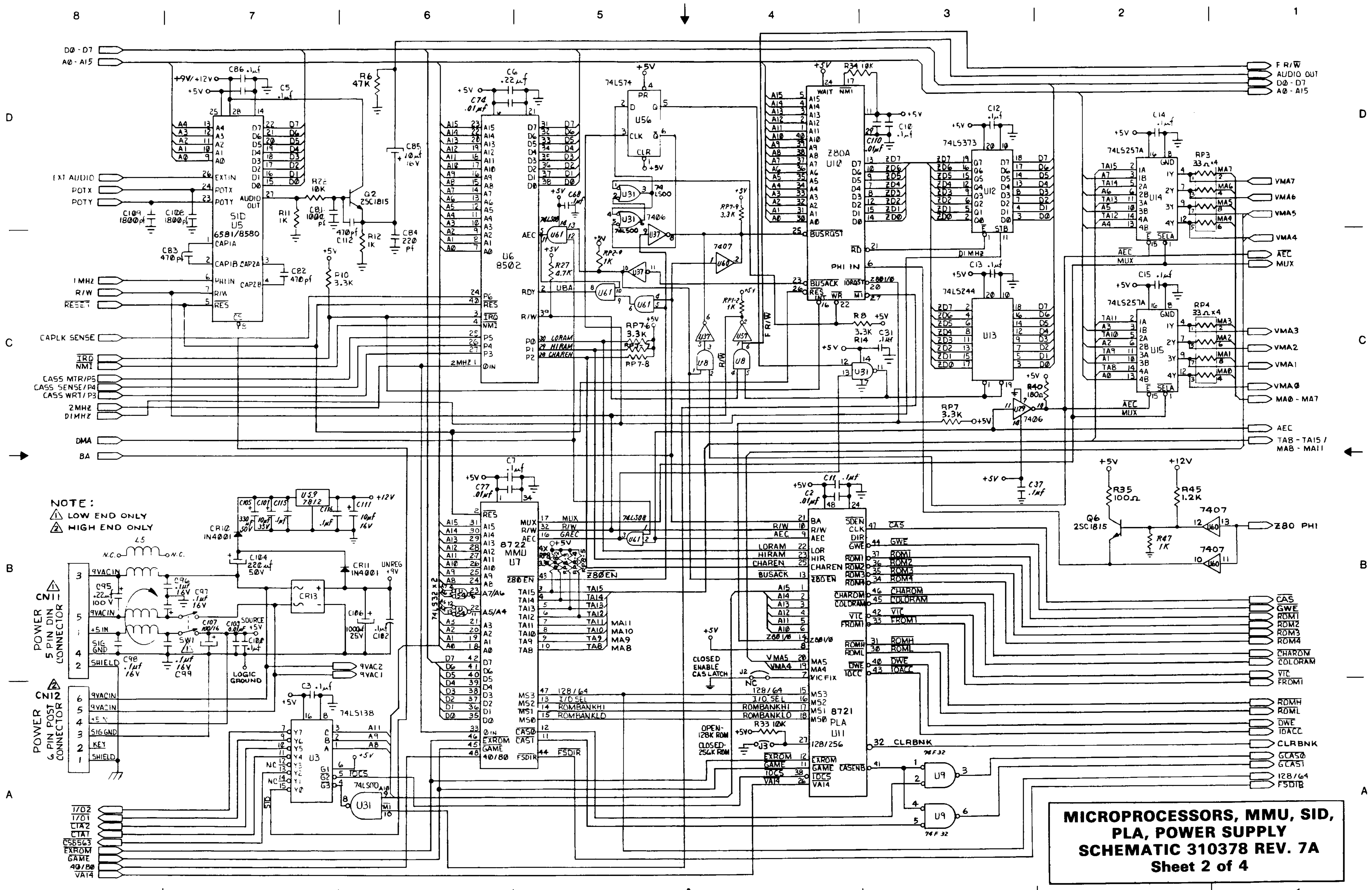
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|------------------|------|
| 4066             | 57   |
| 6526             | 49   |
| 74XXX            | 58   |
| BUS ARCHITECTURE | 4    |
| CASSETTE PORT    | 49   |
| CONTROL PORTS    | 50   |
| EXPANSION BUS    | 52   |
| KEYBOARD         |      |
| Test             | 51   |
| Matrix           | 51   |
| LINE DEFINITIONS | 56   |
| SERIAL BUS       | 54   |
| USER PORT        | 50   |





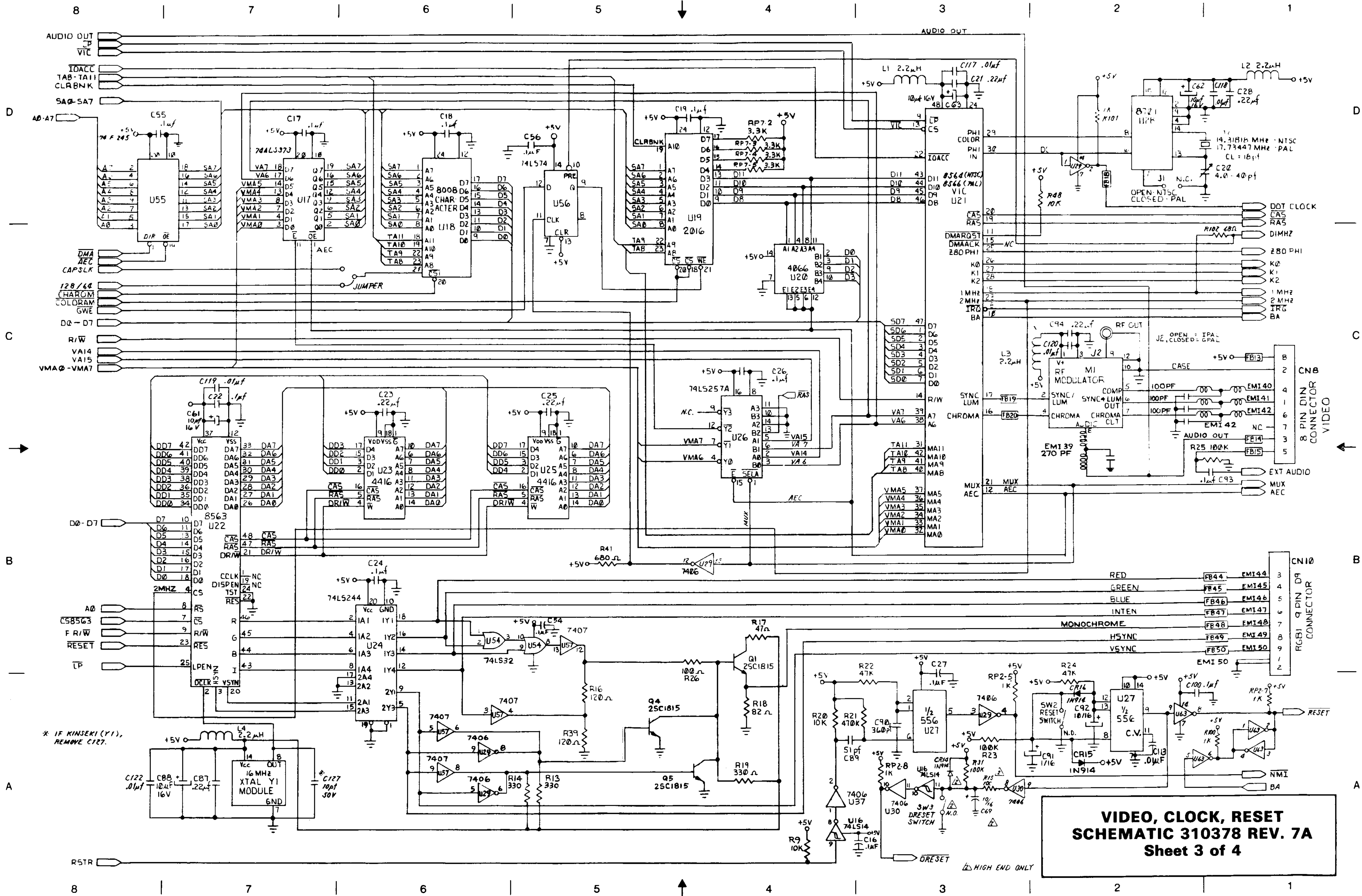
## QUICK REFERENCE

| TITLE                      | PAGE      |
|----------------------------|-----------|
| <b>6581</b>                | <b>38</b> |
| <b>74XXX</b>               | <b>58</b> |
| <b>8502</b>                | <b>6</b>  |
| <b>8721</b>                | <b>29</b> |
| <b>8722</b>                | <b>27</b> |
| <b>BUS ARCHITECTURE</b>    | <b>4</b>  |
| <b>LINE DEFINITIONS</b>    | <b>56</b> |
| <b>MEMORY ARCHITECTURE</b> | <b>11</b> |
| <b>MMU</b>                 |           |
| Text                       | <b>20</b> |
| Pin Configuration          | <b>27</b> |
| <b>PLA</b>                 |           |
| Text                       | <b>28</b> |
| Pin Configuration          | <b>29</b> |
| <b>SID</b>                 | <b>38</b> |
| <b>Z80</b>                 |           |
| Text                       | <b>8</b>  |
| Pin Configuration          | <b>10</b> |



## QUICK REFERENCE

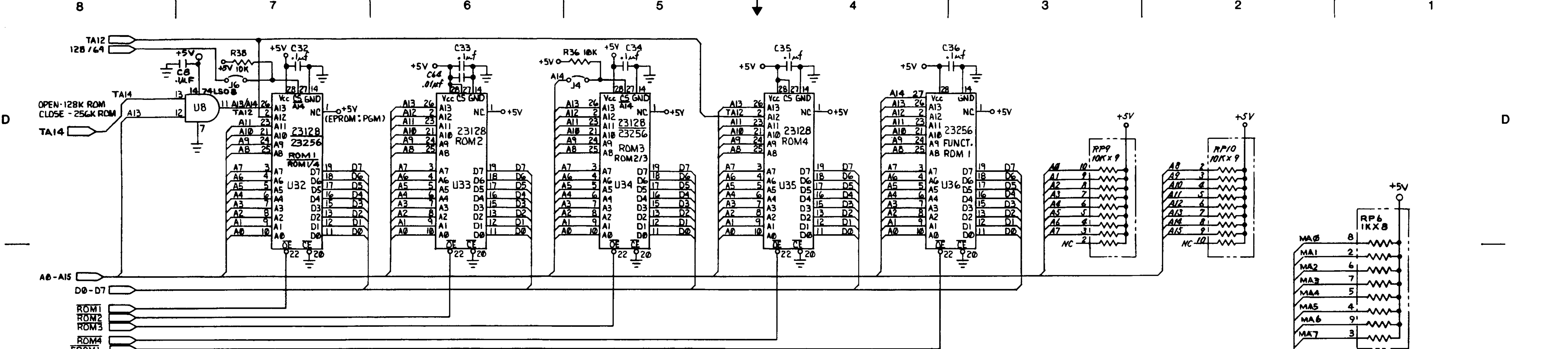
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|---------------------|------|
| 2016                | 17   |
| 4066                | 57   |
| 4416                | 19   |
| 556                 | 57   |
| 74XXX               | 58   |
| 8563                | 38   |
| 8564                | 35   |
| 8701                | 30   |
| BUS ARCHITECTURE    | 4    |
| CLOCK               | 30   |
| LINE DEFINITIONS    | 56   |
| MEMORY ARCHITECTURE | 11   |
| MODULATOR           | 77   |
| RAM                 | 17   |
| ROM                 | 15   |
| VIC                 |      |
| Text                | 33   |
| Pin Configuration   | 35   |
| VIDEO CONTROLLER    |      |
| Text                | 36   |
| Pin Configuration   | 38   |
| VIDEO INTERFACE     | 33   |



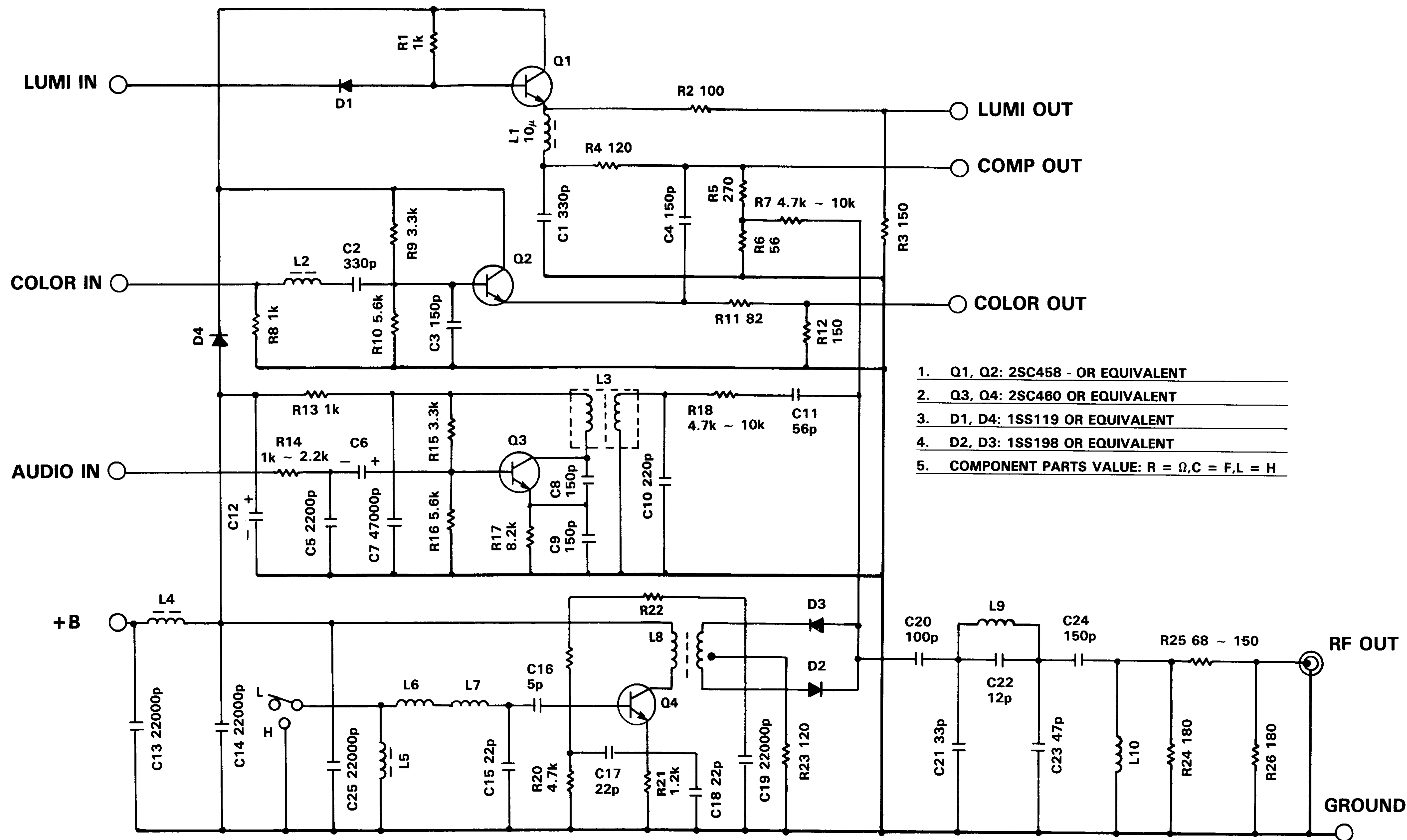
**VIDEO, CLOCK, RESET  
SCHEMATIC 310378 REV. 7A  
Sheet 3 of 4**

### **QUICK REFERENCE**

| <b>TITLE</b>               | <b>PAGE</b> |
|----------------------------|-------------|
| <b>23128</b>               | <b>16</b>   |
| <b>4164</b>                | <b>18</b>   |
| <b>74XXX</b>               | <b>58</b>   |
| <b>BUS ARCHITECTURE</b>    | <b>4</b>    |
| <b>LINE DEFINITIONS</b>    | <b>56</b>   |
| <b>MEMORY ARCHITECTURE</b> | <b>11</b>   |
| <b>RAM</b>                 | <b>17</b>   |
| <b>ROM</b>                 | <b>15</b>   |



# RF MODULATOR









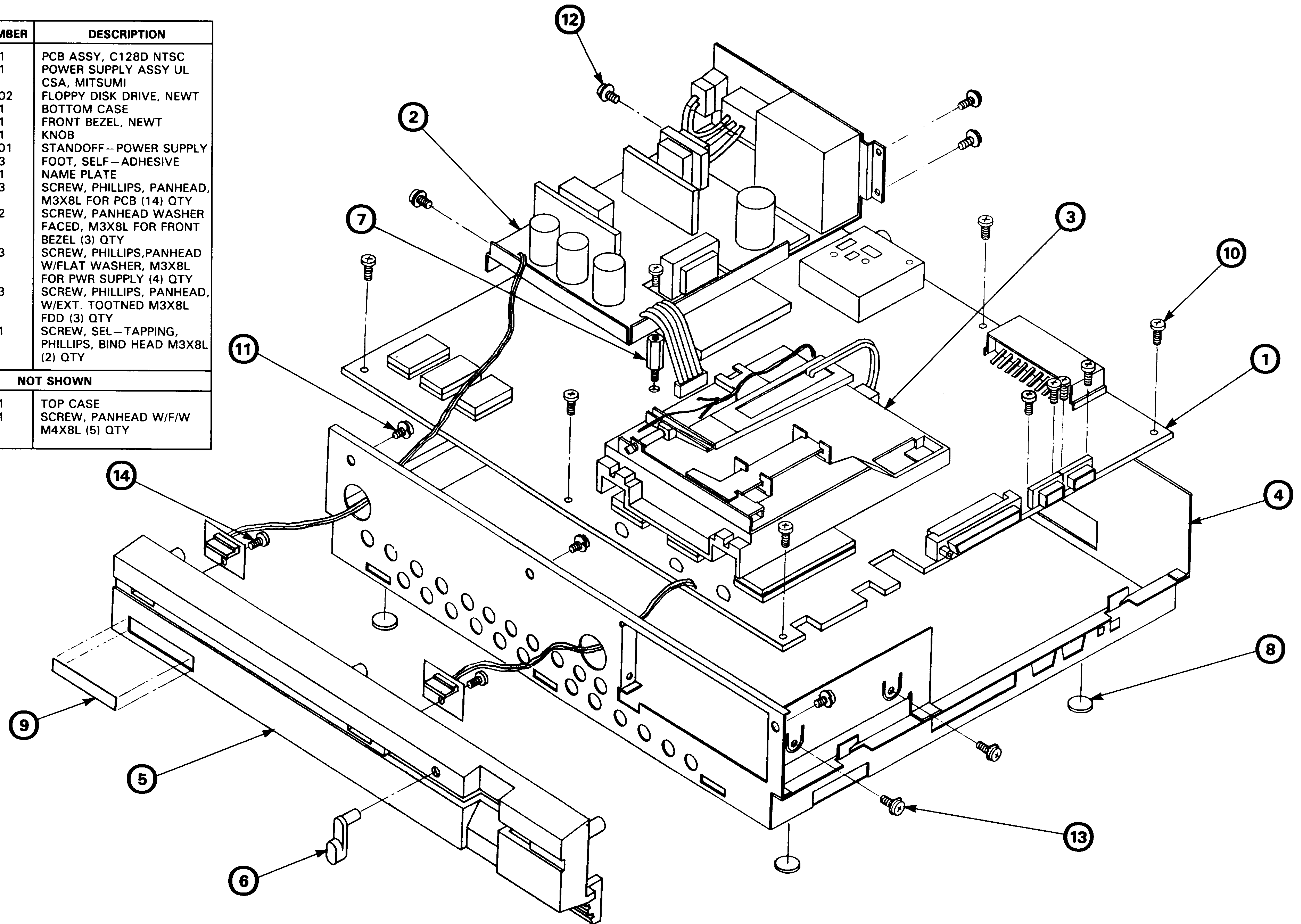
# MAJOR PARTS LIST

|   |            |
|---|------------|
| PCB ASSY C128D NTSC                           | C250477-01 |
| MANUAL — USERS                                | C354114-01 |
| KEYBOARD ASSY NTSC                            | C250735-02 |
| CASE TOP                                      | C252454-01 |
| CASE BOTTOM                                   | C252455-01 |
| BEZEL, FRONT NEWT                             | C252457-01 |
| KNOB  | C252050-01 |
| DRIVE ASSY — NEWT                             | C252083-02 |
| STAND-OFF                                     | C252461-01 |
| FOOT, SELF-ADHESIVE                           | C950150-01 |
| NAMEPLATE                                     | C251889-01 |
| POWER SUPPLY ASSY UL, CSA MITSUMI             | C252449-01 |
| POWER SUPPLY ASSY UL, CAS DEE-VAN SUB FOR -01 | 252449-03  |
| RF MODULATOR, PAL                             | 252404-01  |
| CARTRIDGE GUIDE                               | C326116-01 |
| SHIELD BOX                                    | C326265-01 |
| SHIELD CAP ASSY                               | C310407-01 |
| DISKETTE DEMO 1571                            | C252093-01 |
| MANUAL — SERVICE                              | C314980-01 |

**C - Indicates Commodore Stocked Part Number**

# SERVICE PARTS REFERENCE DIAGRAM

| ITEM             | PART NUMBER | DESCRIPTION  |
|------------------|-------------|--|
| 1                | 250477-01   | PCB ASSY, C128D NTSC   |
| 2                | 252449-01   | POWER SUPPLY ASSY UL<br>CSA, MITSUMI                                       |
| 3                | 2522083-02  | FLOPPY DISK DRIVE, NEWT  |
| 4                | 252455-01   | BOTTOM CASE  |
| 5                | 252457-01   | FRONT BEZEL, NEWT  |
| 6                | 252050-01   | KNOB   |
| 7                | 2522461-01  | STANDOFF—POWER SUPPLY  |
| 8                | 950150-03   | FOOT, SELF-ADHESIVE  |
| 9                | 251889-01   | NAME PLATE   |
| 10               | 906800-03   | SCREW, PHILLIPS, PANHEAD,<br>M3X8L FOR PCB (14) QTY                        |
| 11               | 906801-02   | SCREW, PANHEAD WASHER<br>FACED, M3X8L FOR FRONT<br>BEZEL (3) QTY           |
| 12               | 325544-03   | SCREW, PHILLIPS, PANHEAD<br>W/FLAT WASHER, M3X8L<br>FOR PWR SUPPLY (4) QTY |
| 13               | 325541-03   | SCREW, PHILLIPS, PANHEAD,<br>W/EXT. TOOTHED M3X8L<br>FDD (3) QTY           |
| 14               | 906883-01   | SCREW, SEL-TAPPING,<br>PHILLIPS, BIND HEAD M3X8L<br>(2) QTY                |
| <b>NOT SHOWN</b> |             |  |
|                  | 252454-01   | TOP CASE   |
|                  | 350108-01   | SCREW, PANHEAD W/F/W<br>M4X8L (5) QTY                                      |

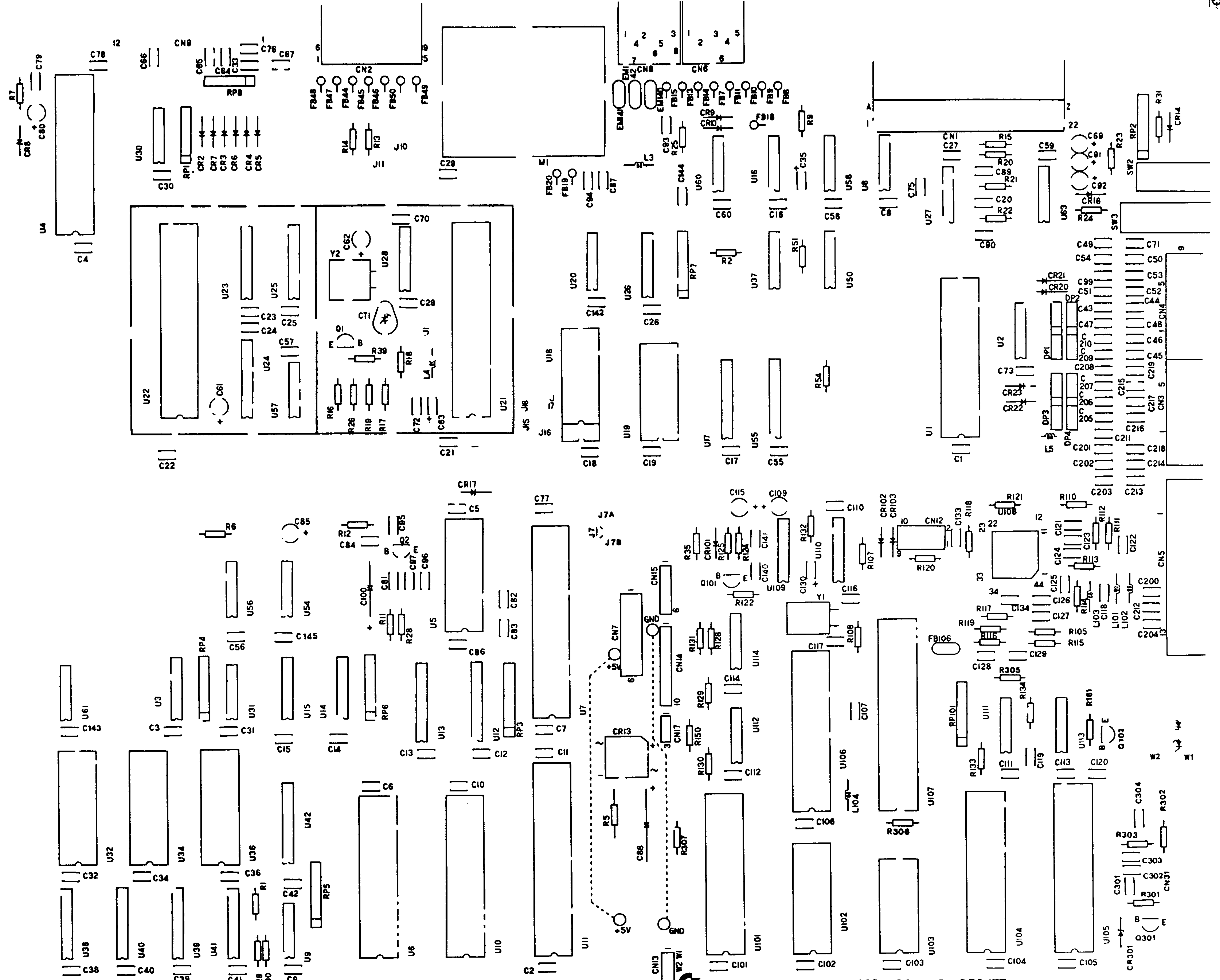


# COMPONENTS PARTS LIST

*PCB ASSEMBLY #250477*

|                |                              |            |
|----------------|------------------------------|------------|
| U41            | IC 64K X 4 DRAM              | 390083-02  |
| U5             | IC SID 8580                  | C318013-01 |
| U21            | IC VIC 8564 NTSC             | C315009-01 |
| U11            | IC PAL 8721                  | C315012-01 |
| U7             | IC MMU 8722                  | C310389-01 |
| U10            | IC Z80 B 6MHZ                | 906150-02  |
| U18            | IC CHAR ROM                  | C315079-01 |
| U27            | IC NE556                     | 901523-03  |
| U19, 103       | IC 2016 20LB 2K X 8          | 251637-05  |
| U18            | IC 8006 C128/C64 CHAR ROM    | C390059-01 |
| U2, 20         | IC 4066                      | 901502-01  |
| U23, 25, 38-40 | IC 64K X 4 DRAM 150NS        | 390083-02  |
| U1, 4          | IC 6526                      | C906108-01 |
| U28            | IC 8701                      | C251527-07 |
| U6             | IC 8502 MPU                  | C315020-01 |
| U22            | IC 8568 80 COL CRT CNTRL     | C315092-01 |
| U32            | C128 ROM 2/3 (UK)            | 318023-02  |
| U34            | C128 ROM 1/4                 | C318022-02 |
| U17            | IC 74ALS373                  | 390058-01  |
| U55            | 74F245                       | 252208-01  |
| U9             | 74F32                        | 390077-01  |
| U107           | FDC 5710                     | C252371-01 |
| U104, 106      | VIA 6522A 2MHZ               | C901437-02 |
| U104, 106 Sub. | IC 65SC22A 1MHZ              | 310653-01  |
| U102           | EP-ROM 27256 300NS           | C252372-01 |
| U108           | FDD R/W AMP SONY CX20185     | C252308-01 |
| U108 Sub.      | FDD R/W AMP MOTOROLA MC28719 | 252308-02  |
| U108 Sub.      | FDD R/W AMP SANYO LA8200     | 252308-03  |
| U109           | UPA2003C NEC                 | C251871-01 |
| U109 Sub.      | IC IR2C19 SHARP              | 251871-02  |
| Q101           | TRANS 2SA683                 | 252400-01  |
| Q301           | TRANS 2SD880                 | 902694-01  |
| Q101 Sub.      | TRANS MPSU51                 | 310657-01  |
| Q1, 2          | TRANS 2SC1815                | 902693-01  |
| DP1, 3         | DIODE ARRAY 7 PIN            | C252333-01 |
| DP2, 4         | DIODE ARRAY 7 PIN            | C252333-02 |
| CR301          | DIODE ZENER RD 6.8 EB        | 900927-01  |
| M1             | RF MODULATOR NTSC            | C252405-01 |
| CT1            | TRIMMER CAP 6.5 - 40P        | C251029-02 |
| SW1, 2         | RESET BUTTON                 | C251260-01 |
| CN5            | CONNECTOR MALE 25 PIN        | C359002-02 |

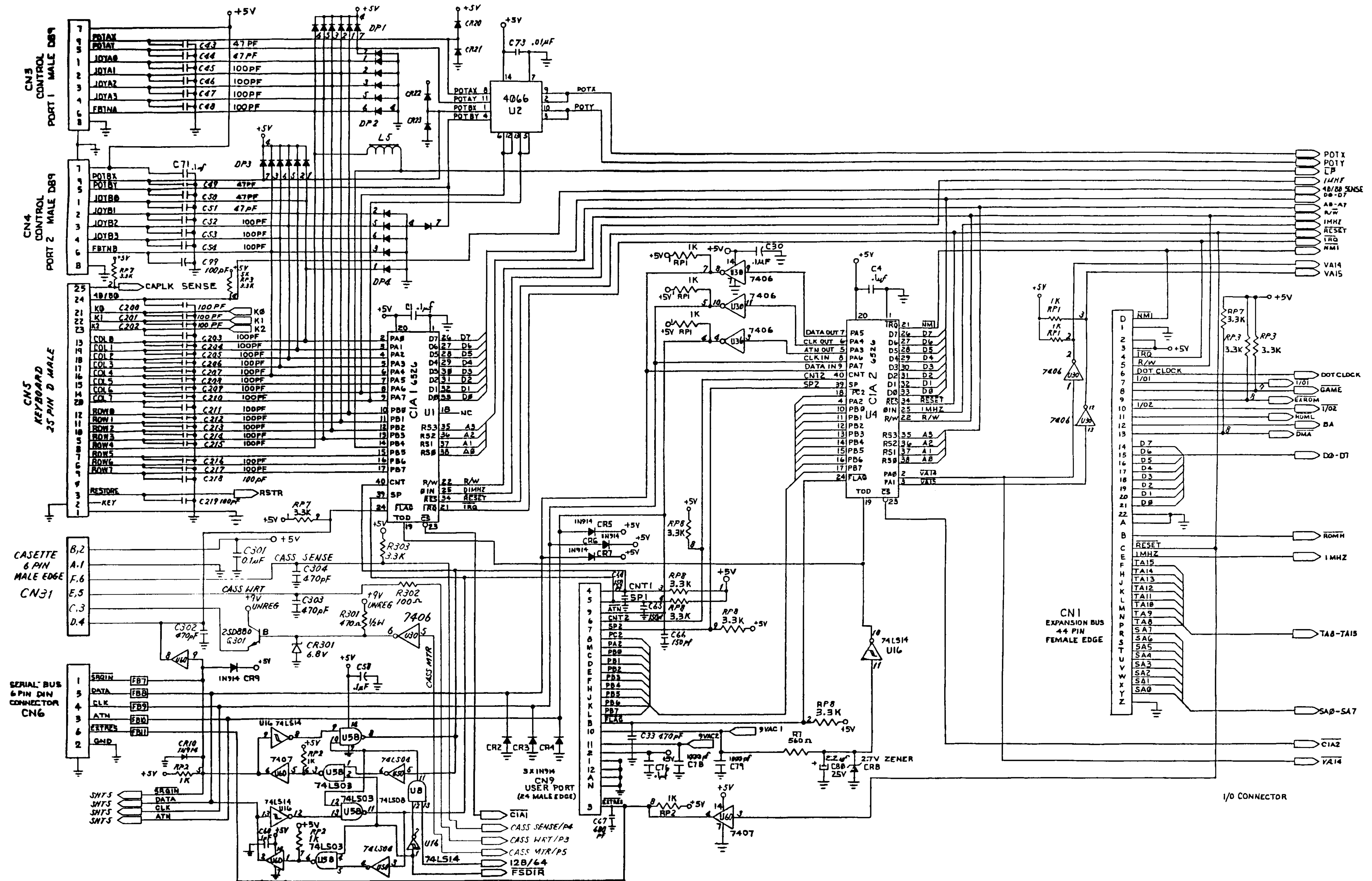
**C-Indicates CBM Stocked Part Number**

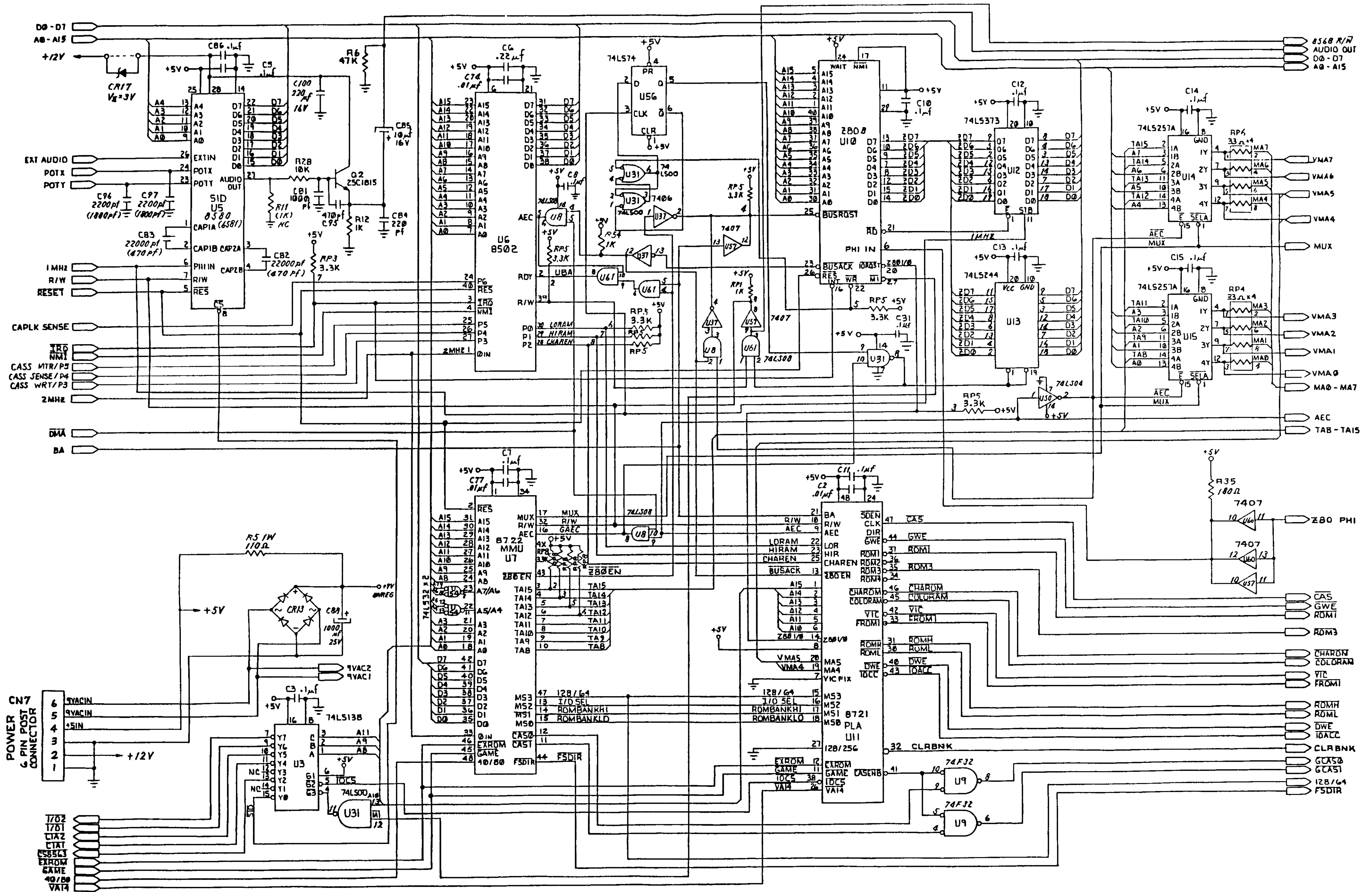


GX-211 VO 8730 94V-0

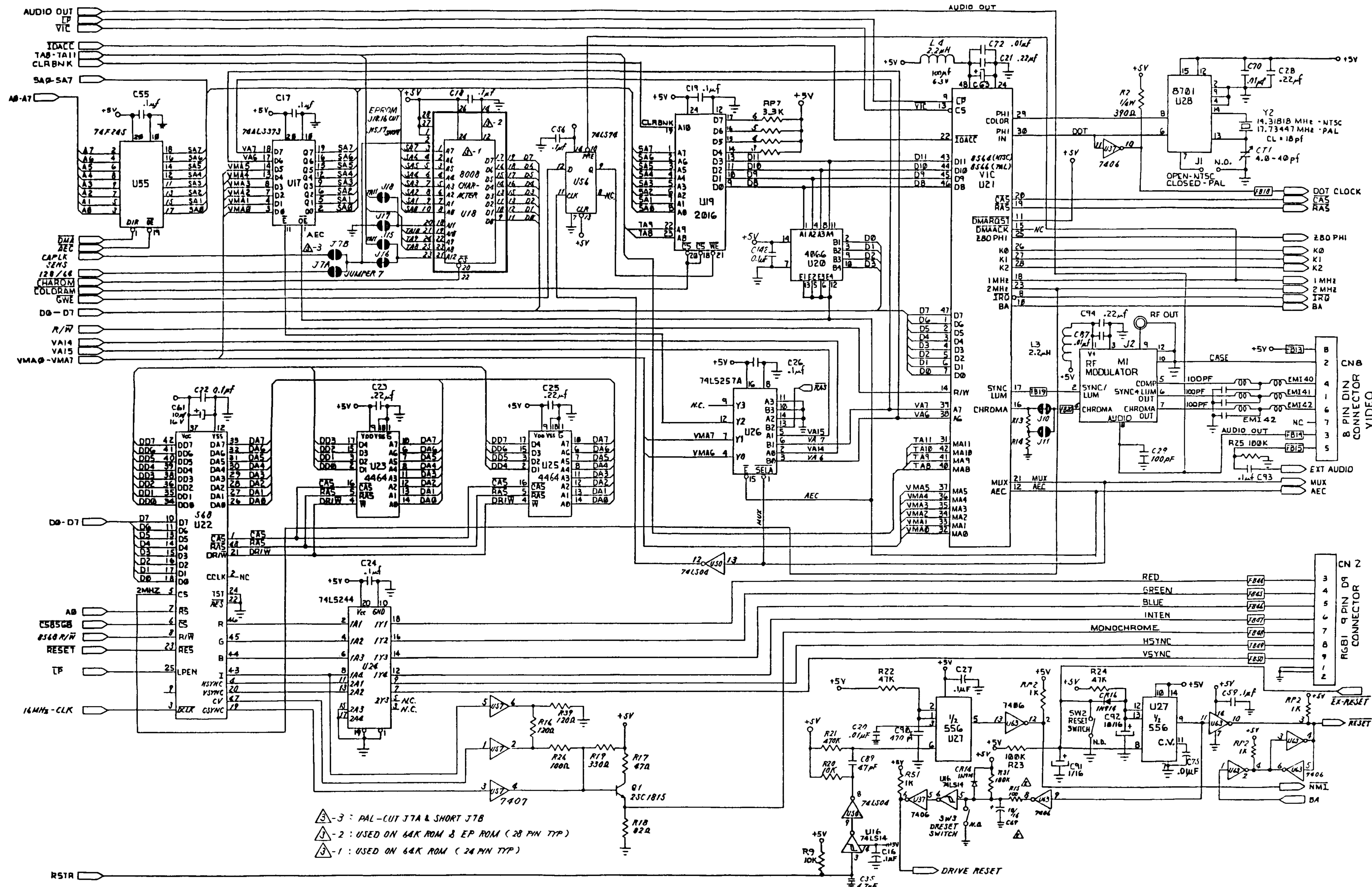
COMMODORE C128DCR PCB ASSY NO. 250477



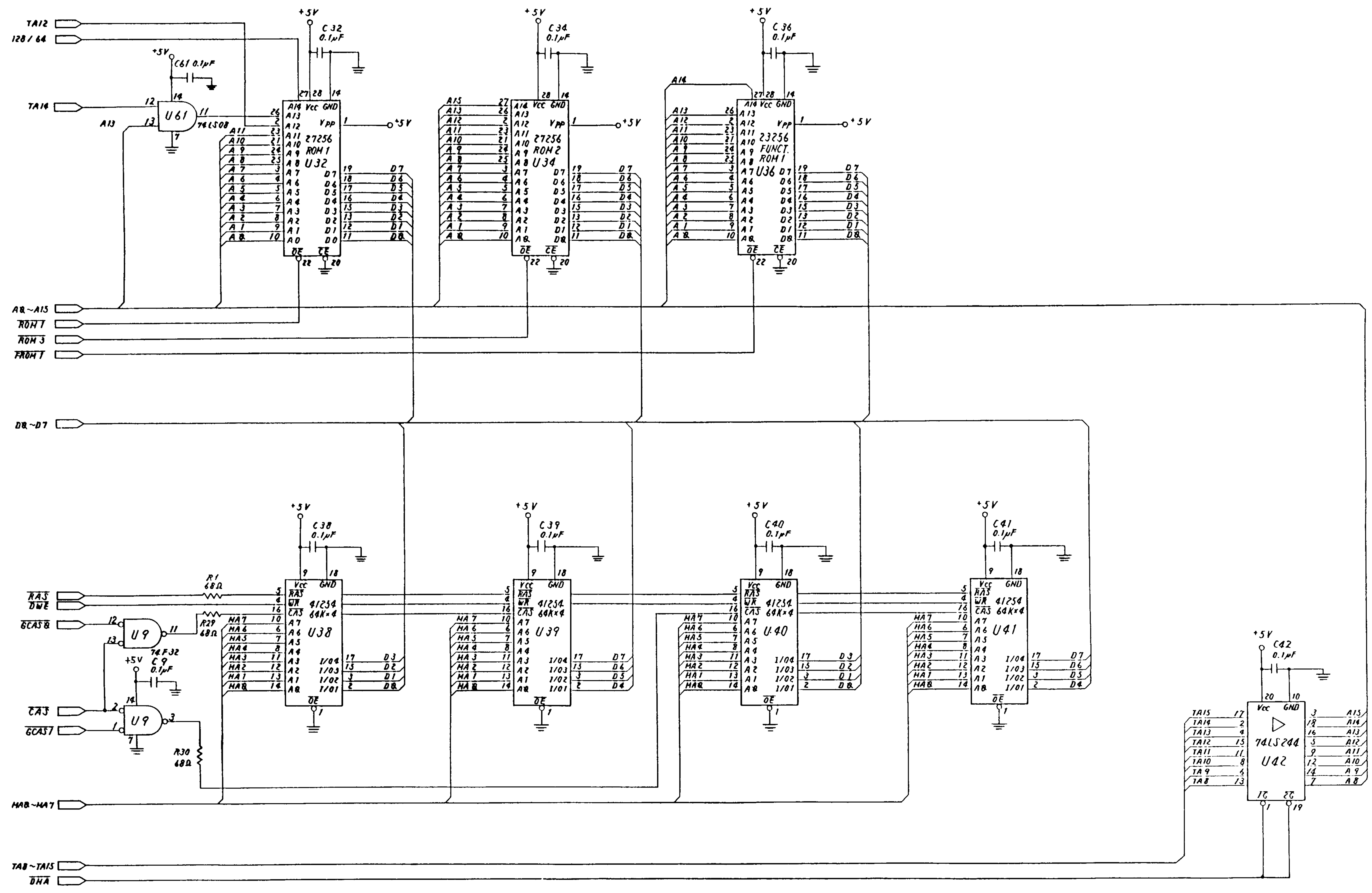


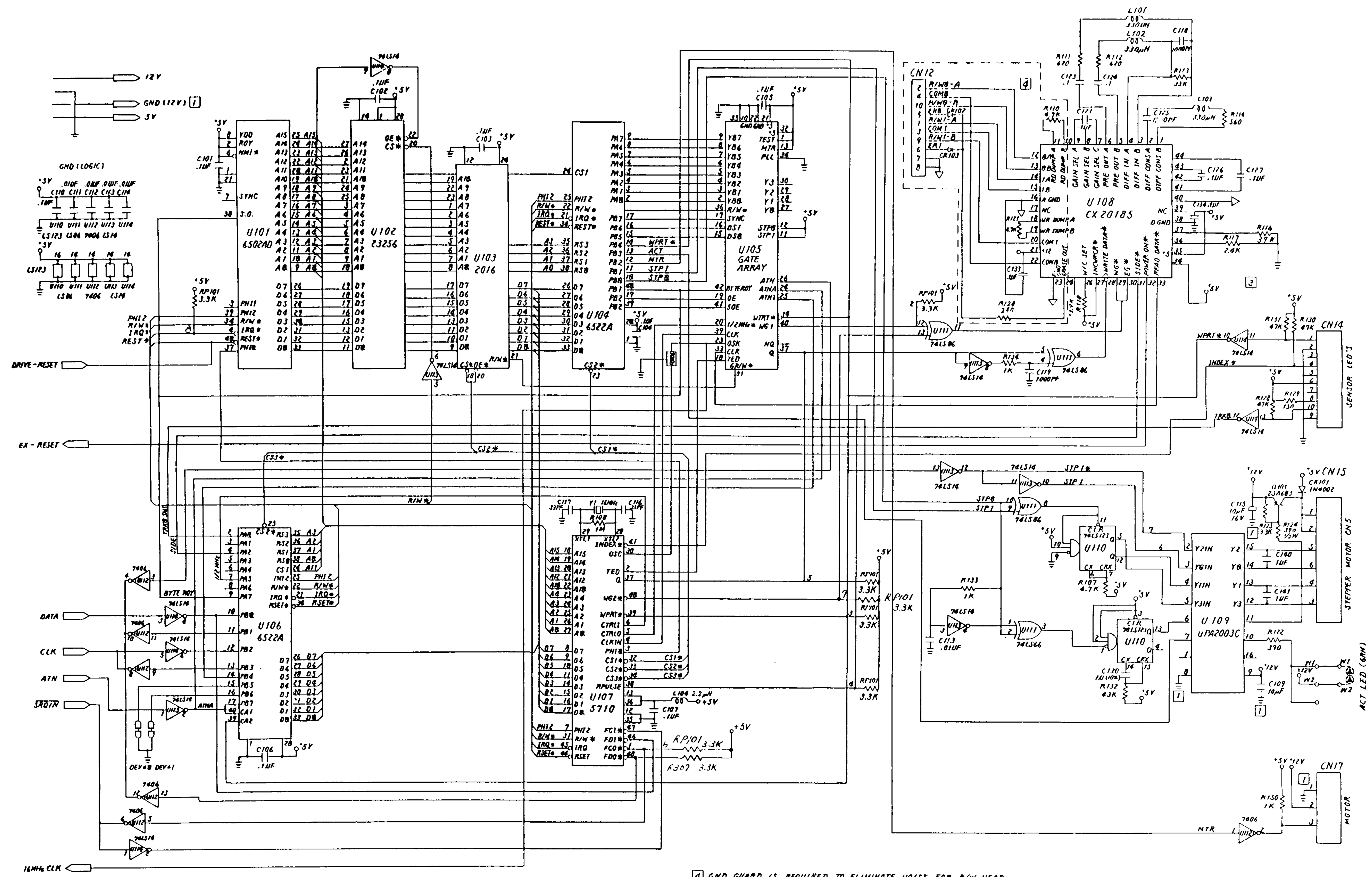






△-3 : PAL-CUT J7A & SHORT J7B  
 △-2 : USED ON 64K ROM & EP ROM (28 PIN TYP)  
 △-1 : USED ON 64K ROM (24 PIN TYP)





FDD CONTROL

- 1 GND GUARD IS REQUIRED TO ELIMINATE NOISE FOR R/W HEAD.
  - 2 XMF & XK VALUE WILL MEET FUJITSU R/W IC. / OPTION.
  - 3 THIS SCHEMATIC MEETS NEMTRONICS DS02 DISK DRIVE.
  - 4 STEPPER GND: LOW IMPEDANCE GND CONNECTION IS REQUIRED BETWEEN EACH POINT TO ELIMINATE NOISE.
- NOTES-UNLESS OTHERWISE SPECIFIED: