



8237A HIGH PERFORMANCE PROGRAMMABLE DMA CONTROLLER (8237A-5)

- Enable/Disable Control of Individual DMA Requests
- Four Independent DMA Channels
- Independent Autoinitialization of All Channels
- Memory-to-Memory Transfers
- Memory Block Initialization
- Address Increment or Decrement
- High Performance: Transfers up to 1.6M Bytes/Second with 5 MHz 8237A-5
- Directly Expandable to Any Number of Channels
- End of Process Input for Terminating Transfers
- Software DMA Requests
- Independent Polarity Control for DREQ and DACK Signals
- Available in EXPRESS — Standard Temperature Range
- Available in 40-Lead Cerdip and Plastic Packages

(See Packaging Spec, Order # 231369)

The 8237A Multimode Direct Memory Access (DMA) Controller is a peripheral interface circuit for microprocessor systems. It is designed to improve system performance by allowing external devices to directly transfer information from the system memory. Memory-to-memory transfer capability is also provided. The 8237A offers a wide variety of programmable control features to enhance data throughput and system optimization and to allow dynamic reconfiguration under program control.

The 8237A is designed to be used in conjunction with an external 8-bit address latch. It contains four independent channels and may be expanded to any number of channels by cascading additional controller chips. The three basic transfer modes allow programmability of the types of DMA service by the user. Each channel can be individually programmed to Autoinitialize to its original condition following an End of Process (EOP). Each channel has a full 64K address and word count capability.

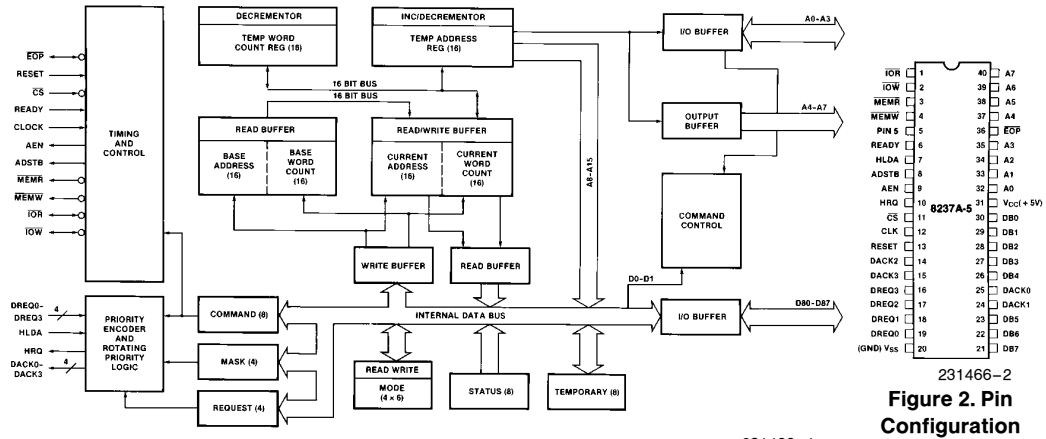


Figure 1. Block Diagram

231466-2
Figure 2. Pin Configuration

231466-1

Table 1. Pin Description

| Symbol | Type | Name and Function |
|------------------|------|--|
| V _{CC} | | POWER: +5V supply. |
| V _{SS} | | GROUND: Ground. |
| CLK | I | CLOCK INPUT: Clock Input controls the internal operations of the 8237A and its rate of data transfers. The input may be driven at up to 5 MHz for the 8237A-5. |
| \overline{CS} | I | CHIP SELECT: Chip Select is an active low input used to select the 8237A as an I/O device during the Idle cycle. This allows CPU communication on the data bus. |
| RESET | I | RESET: Reset is an active high input which clears the Command, Status, Request and Temporary registers. It also clears the first/last flip/flop and sets the Mask register. Following a Reset the device is in the Idle cycle. |
| READY | I | READY: Ready is an input used to extend the memory read and write pulses from the 8237A to accommodate slow memories or I/O peripheral devices. Ready must not make transitions during its specified setup/hold time. |
| HLDA | I | HOLD ACKNOWLEDGE: The active high Hold Acknowledge from the CPU indicates that it has relinquished control of the system busses. |
| DREQ0–DREQ3 | I | DMA REQUEST: The DMA Request lines are individual asynchronous channel request inputs used by peripheral circuits to obtain DMA service. In fixed Priority, DREQ0 has the highest priority and DREQ3 has the lowest priority. A request is generated by activating the DREQ line of a channel. DACK will acknowledge the recognition of DREQ signal. Polarity of DREQ is programmable. Reset initializes these lines to active high. DREQ must be maintained until the corresponding DACK goes active. |
| DB0–DB7 | I/O | DATA BUS: The Data Bus lines are bidirectional three-state signals connected to the system data bus. The outputs are enabled in the Program condition during the I/O Read to output the contents of an Address register, a Status register, the Temporary register or a Word Count register to the CPU. The outputs are disabled and the inputs are read during an I/O Write cycle when the CPU is programming the 8237A control registers. During DMA cycles the most significant 8 bits of the address are output onto the data bus to be strobed into an external latch by ADSTB. In memory-to-memory operations, data from the memory comes into the 8237A on the data bus during the read-from-memory transfer. In the write-to-memory transfer, the data bus outputs place the data into the new memory location. |
| \overline{IOR} | I/O | I/O READ: I/O Read is a bidirectional active low three-state line. In the Idle cycle, it is an input control signal used by the CPU to read the control registers. In the Active cycle, it is an output control signal used by the 8237A to access data from a peripheral during a DMA Write transfer. |
| \overline{IOW} | I/O | I/O WRITE: I/O Write is a bidirectional active low three-state line. In the Idle cycle, it is an input control signal used by the CPU to load information into the 8237A. In the Active cycle, it is an output control signal used by the 8237A to load data to the peripheral during a DMA Read transfer. |

Table 1. Pin Description (Continued)

| Symbol | Type | Name and Function |
|--------------------------|------|--|
| $\overline{\text{EOP}}$ | I/O | END OF PROCESS: End of Process is an active low bidirectional signal. Information concerning the completion of DMA services is available at the bidirectional $\overline{\text{EOP}}$ pin. The 8237A allows an external signal to terminate an active DMA service. This is accomplished by pulling the $\overline{\text{EOP}}$ input low with an external $\overline{\text{EOP}}$ signal. The 8237A also generates a pulse when the terminal count (TC) for any channel is reached. This generates an $\overline{\text{EOP}}$ signal which is output through the $\overline{\text{EOP}}$ line. The reception of $\overline{\text{EOP}}$, either internal or external, will cause the 8237A to terminate the service, reset the request, and, if Autoinitialize is enabled, to write the base registers to the current registers of that channel. The mask bit and TC bit in the status word will be set for the currently active channel by $\overline{\text{EOP}}$ unless the channel is programmed for Autoinitialize. In that case, the mask bit remains unchanged. During memory-to-memory transfers, $\overline{\text{EOP}}$ will be output when the TC for channel 1 occurs. $\overline{\text{EOP}}$ should be tied high with a pull-up resistor if it is not used to prevent erroneous end of process inputs. |
| A0–A3 | I/O | ADDRESS: The four least significant address lines are bidirectional three-state signals. In the Idle cycle they are inputs and are used by the CPU to address the register to be loaded or read. In the Active cycle they are outputs and provide the lower 4 bits of the output address. |
| A4–A7 | O | ADDRESS: The four most significant address lines are three-state outputs and provide 4 bits of address. These lines are enabled only during the DMA service. |
| HRQ | O | HOLD REQUEST: This is the Hold Request to the CPU and is used to request control of the system bus. If the corresponding mask bit is clear, the presence of any valid DREQ causes 8237A to issue the HRQ. |
| DACK0–DACK3 | O | DMA ACKNOWLEDGE: DMA Acknowledge is used to notify the individual peripherals when one has been granted a DMA cycle. The sense of these lines is programmable. Reset initializes them to active low. |
| AEN | O | ADDRESS ENABLE: Address Enable enables the 8-bit latch containing the upper 8 address bits onto the system address bus. AEN can also be used to disable other system bus drivers during DMA transfers. AEN is active HIGH. |
| ADSTB | O | ADDRESS STROBE: The active high, Address Strobe is used to strobe the upper address byte into an external latch. |
| $\overline{\text{MEMR}}$ | O | MEMORY READ: The Memory Read signal is an active low three-state output used to access data from the selected memory location during a DMA Read or a memory-to-memory transfer. |
| $\overline{\text{MEMW}}$ | O | MEMORY WRITE: The Memory Write is an active low three-state output used to write data to the selected memory location during a DMA Write or a memory-to-memory transfer. |
| PIN5 | I | PIN5: This pin should always be at a logic HIGH level. An internal pull-up resistor will establish a logic high when the pin is left floating. It is recommended however, that PIN5 be connected to V_{CC} . |

FUNCTIONAL DESCRIPTION

The 8237A block diagram includes the major logic blocks and all of the internal registers. The data interconnection paths are also shown. Not shown are the various control signals between the blocks. The 8237A contains 344 bits of internal memory in the form of registers. Figure 3 lists these registers by name and shows the size of each. A detailed description of the registers and their functions can be found under Register Description.

| Name | Size | Number |
|-------------------------------|---------|--------|
| Base Address Registers | 16 bits | 4 |
| Base Word Count Registers | 16 bits | 4 |
| Current Address Registers | 16 bits | 4 |
| Current Word Count Registers | 16 bits | 4 |
| Temporary Address Register | 16 bits | 1 |
| Temporary Word Count Register | 16 bits | 1 |
| Status Register | 8 bits | 1 |
| Command Register | 8 bits | 1 |
| Temporary Register | 8 bits | 1 |
| Mode Registers | 6 bits | 4 |
| Mask Register | 4 bits | 1 |
| Request Register | 4 bits | 1 |

Figure 3. 8237A Internal Registers

The 8237A contains three basic blocks of control logic. The Timing Control block generates internal timing and external control signals for the 8237A. The Program Command Control block decodes the various commands given to the 8237A by the microprocessor prior to servicing a DMA Request. It also decodes the Mode Control word used to select the type of DMA during the servicing. The Priority Encoder block resolves priority contention between DMA channels requesting service simultaneously.

The Timing Control block derives internal timing from the clock input. In 8237A systems, this input will usually be the $\phi 2$ TTL clock from an 8224 or CLK from an 8085AH or 8284A. 33% duty cycle clock generators, however, may not meet the clock high time requirement of the 8237A of the same frequency. For example, 82C84A-5 CLK output violates the clock high time requirement of 8237A-5. In this case 82C84A CLK can simply be inverted to meet 8237A-5 clock high and low time requirements. For 8085AH-2 systems above 3.9 MHz, the 8085 CLK(OUT) does not satisfy 8237A-5 clock LOW and HIGH time requirements. In this case, an external clock should be used to drive the 8237A-5.

DMA OPERATION

The 8237A is designed to operate in two major cycles. These are called Idle and Active cycles. Each device cycle is made up of a number of states. The 8237A can assume seven separate states, each composed of one full clock period. State I (SI) is the inactive state. It is entered when the 8237A has no

valid DMA requests pending. While in SI, the DMA controller is inactive but may be in the Program Condition, being programmed by the processor. State S0 (S0) is the first state of a DMA service. The 8237A has requested a hold but the processor has not yet returned an acknowledge. The 8237A may still be programmed until it receives HLDA from the CPU. An acknowledge from the CPU will signal that DMA transfers may begin. S1, S2, S3 and S4 are the working states of the DMA service. If more time is needed to complete a transfer than is available with normal timing, wait states (SW) can be inserted between S2 or S3 and S4 by the use of the Ready line on the 8237A. Note that the data is transferred directly from the I/O device to memory (or vice versa) with IOR and MEMW (or MEMR and IOW) being active at the same time. The data is not read into or driven out of the 8237A in I/O-to-memory or memory-to-I/O DMA transfers.

Memory-to-memory transfers require a read-from and a write-to-memory to complete each transfer. The states, which resemble the normal working states, use two digit numbers for identification. Eight states are required for a single transfer. The first four states (S11, S12, S13, S14) are used for the read-from-memory half and the last four states (S21, S22, S23, S24) for the write-to-memory half of the transfer.

IDLE CYCLE

When no channel is requesting service, the 8237A will enter the Idle cycle and perform "SI" states. In this cycle the 8237A will sample the DREQ lines every clock cycle to determine if any channel is requesting a DMA service. The device will also sample CS, looking for an attempt by the microprocessor to write or read the internal registers of the 8237A. When CS is low and HLDA is low, the 8237A enters the Program Condition. The CPU can now establish, change or inspect the internal definition of the part by reading from or writing to the internal registers. Address lines A0-A3 are inputs to the device and select which registers will be read or written. The IOR and IOW lines are used to select and time reads or writes. Due to the number and size of the internal registers, an internal flip-flop is used to generate an additional bit of address. This bit is used to determine the upper or lower byte of the 16-bit Address and Word Count registers. The flip-flop is reset by Master Clear or Reset. A separate software command can also reset this flip-flop.

Special software commands can be executed by the 8237A in the Program Condition. These commands are decoded as sets of addresses with the CS and IOW. The commands do not make use of the data bus. Instructions include Clear First/Last Flip-Flop and Master Clear.

ACTIVE CYCLE

When the 8237A is in the Idle cycle and a non-masked channel requests a DMA service, the device will output an HRQ to the microprocessor and enter the Active cycle. It is in this cycle that the DMA service will take place, in one of four modes:

Single Transfer Mode—In Single Transfer mode the device is programmed to make one transfer only. The word count will be decremented and the address decremented or incremented following each transfer. When the word count “rolls over” from zero to FFFFH, a Terminal Count (TC) will cause an Auto-initialize if the channel has been programmed to do so.

DREQ must be held active until DACK becomes active in order to be recognized. If DREQ is held active throughout the single transfer, HRQ will go inactive and release the bus to the system. It will again go active and, upon receipt of a new HLDA, another single transfer will be performed. In 8080A, 8085AH, 8088, or 8086 system, this will ensure one full machine cycle execution between DMA transfers. Details of timing between the 8237A and other bus control protocols will depend upon the characteristics of the microprocessor involved.

Block Transfer Mode—In Block Transfer mode the device is activated by DREQ to continue making transfers during the service until a TC, caused by word count going to FFFFH, or an external End of

Process (\overline{EOP}) is encountered. DREQ need only be held active until DACK becomes active. Again, an Autoinitialization will occur at the end of the service if the channel has been programmed for it.

Demand Transfer Mode—In Demand Transfer mode the device is programmed to continue making transfers until a TC or external \overline{EOP} is encountered or until DREQ goes inactive. Thus transfers may continue until the I/O device has exhausted its data capacity. After the I/O device has had a chance to catch up, the DMA service is re-established by means of a DREQ. During the time between services when the microprocessor is allowed to operate, the intermediate values of address and word count are stored in the 8237A Current Address and Current Word Count registers. Only an \overline{EOP} can cause an Autoinitialize at the end of the service. \overline{EOP} is generated either by TC or by an external signal. DREQ has to be low before S4 to prevent another Transfer.

Cascade Mode—This mode is used to cascade more than one 8237A together for simple system expansion. The HRQ and HLDA signals from the additional 8237A are connected to the DREQ and DACK signals of a channel of the initial 8237A. This allows the DMA requests of the additional device to propagate through the priority network circuitry of the preceding device. The priority chain is preserved and the new device must wait for its turn to acknowledge requests. Since the cascade channel of the initial 8237A is used only for prioritizing the additional device, it does not output any address or control

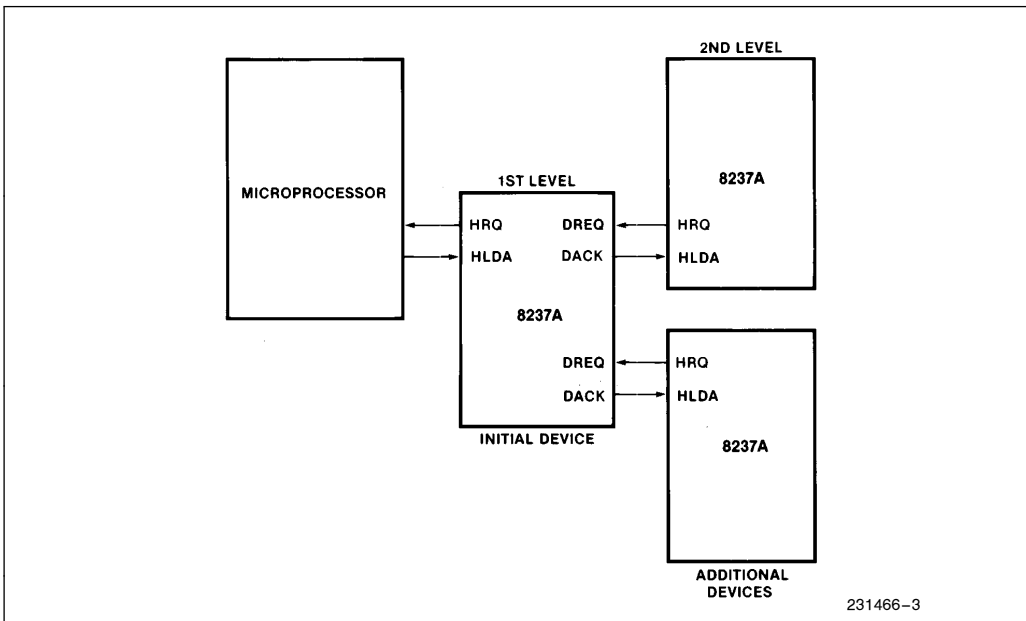


Figure 4. Cascaded 8237As

signals of its own. These could conflict with the outputs of the active channel in the added device. The 8237A will respond to DREQ and DACK but all other outputs except HRQ will be disabled. The ready input is ignored.

Figure 4 shows two additional devices cascaded into an initial device using two of the previous channels. This forms a two level DMA system. More 8237As could be added at the second level by using the remaining channels of the first level. Additional devices can also be added by cascading into the channels of the second level device, forming a third level.

TRANSFER TYPES

Each of the three active transfer modes can perform three different types of transfers. These are Read, Write and Verify. Write transfers move data from an I/O device to the memory by activating \overline{MEMW} and $\overline{I\overline{O}R}$. Read transfers move data from memory to an I/O device by activating \overline{MEMR} and $\overline{I\overline{O}W}$. Verify transfers are pseudo transfers. The 8237A operates as in Read or Write transfers generating addresses, and responding to EOP, etc. However, the memory and I/O control lines all remain inactive. The ready input is ignored in verify mode.

Memory-to-Memory—To perform block moves of data from one memory address space to another with a minimum of program effort and time, the 8237A includes a memory-to-memory transfer feature. Programming a bit in the Command register selects channels 0 and 1 to operate as memory-to-memory transfer channels. The transfer is initiated by setting the software DREQ for channel 0. The 8237A requests a DMA service in the normal manner. After HLDA is true, the device, using four state transfers in Block Transfer mode, reads data from the memory. The channel 0 Current Address register is the source for the address used and is decremented or incremented in the normal manner. The data byte read from the memory is stored in the 8237A internal Temporary register. Channel 1 then performs a four-state transfer of the data from the Temporary register to memory using the address in its Current Address register and incrementing or decrementing it in the normal manner. The channel 1 current Word Count is decremented. When the word count of channel 1 goes to FFFFH, a TC is generated causing an \overline{EOP} output terminating the service.

Channel 0 may be programmed to retain the same address for all transfers. This allows a single word to be written to a block of memory.

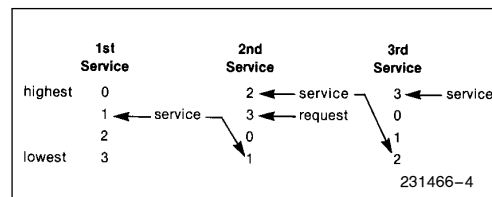
The 8237A will respond to external \overline{EOP} signals during memory-to-memory transfers. Data comparators in block search schemes may use this input to terminate the service when a match is found. The timing of memory-to-memory transfers is found in Figure 12. Memory-to-memory operations can be detected as an active AEN with no DACK outputs.

Autoinitialize—By programming a bit in the Mode register, a channel may be set up as an Autoinitialize channel. During Autoinitialize initialization, the original values of the Current Address and Current Word Count registers are automatically restored from the Base Address and Base Word count registers of that channel following \overline{EOP} . The base registers are loaded simultaneously with the current registers by the microprocessor and remain unchanged throughout the DMA service. The mask bit is not altered when the channel is in Autoinitialize. Following Autoinitialize the channel is ready to perform another DMA service, without CPU intervention, as soon as a valid DREQ is detected. In order to Autoinitialize both channels in a memory-to-memory transfer, both word counts should be programmed identically. If interrupted externally, \overline{EOP} pulses should be applied in both bus cycles.

Priority—The 8237A has two types of priority encoding available as software selectable options. The first is Fixed Priority which fixes the channels in priority order based upon the descending value of their number. The channel with the lowest priority is 3 followed by 2, 1 and the highest priority channel, 0. After the recognition of any one channel for service, the other channels are prevented from interfering with that service until it is completed.

After completion of a service, HRQ will go inactive and the 8237A will wait for HLDA to go low before activating HRQ to service another channel.

The second scheme is Rotating Priority. The last channel to get service becomes the lowest priority channel with the others rotating accordingly.



With Rotating Priority in a single chip DMA system, any device requesting service is guaranteed to be recognized after no more than three higher priority services have occurred. This prevents any one channel from monopolizing the system.

Compressed Timing—In order to achieve even greater throughput where system characteristics permit, the 8237A can compress the transfer time to two clock cycles. From Figure 11 it can be seen that state S3 is used to extend the access time of the read pulse. By removing state S3, the read pulse width is made equal to the write pulse width and a transfer consists only of state S2 to change the address and state S4 to perform the read/write. S1 states will still occur when A8–A15 need updating (see Address Generation). Timing for compressed transfers is found in Figure 14.

Address Generation—In order to reduce pin count, the 8237A multiplexes the eight higher order address bits on the data lines. State S1 is used to output the higher order address bits to an external latch from which they may be placed on the address bus. The falling edge of Address Strobe (ADSTB) is used to load these bits from the data lines to the latch. Address Enable (AEN) is used to enable the bits onto the address bus through a three-state enable. The lower order address bits are output by the 8237A directly. Lines A0–A7 should be connected to the address bus. Figure 11 shows the time relationships between CLK, AEN, ADSTB, DB0–DB7 and A0–A7.

During Block and Demand Transfer mode services, which include multiple transfers, the addresses generated will be sequential. For many transfers the data held in the external address latch will remain the same. This data need only change when a carry or borrow from A7 to A8 takes place in the normal sequence of addresses. To save time and speed transfers, the 8237A executes S1 states only when updating of A8–A15 in the latch is necessary. This means for long services, S1 states and Address Strobes may occur only once every 256 transfers, a savings of 255 clock cycles for each 256 transfers.

REGISTER DESCRIPTION

Current Address Register—Each channel has a 16-bit Current Address register. This register holds the value of the address used during DMA transfers. The address is automatically incremented or decremented after each transfer and the intermediate values of the address are stored in the Current Address register during the transfer. This register is written or read by the microprocessor in successive 8-bit bytes. It may also be reinitialized by an Autoinitialize back to its original value. Autoinitialize takes place only after an \overline{EOP} .

Current Word Register—Each channel has a 16-bit Current Word Count register. This register determines the number of transfers to be performed. The actual number of transfers will be one more than the number programmed in the Current Word Count register (i.e., programming a count of 100 will result in 101 transfers). The word count is decremented after each transfer. The intermediate value of the word count is stored in the register during the transfer. When the value in the register goes from zero to FFFFH, a TC will be generated. This register is loaded or read in successive 8-bit bytes by the microprocessor in the Program Condition. Following the end of a DMA service it may also be reinitialized by an Autoinitialize back to its original value. Autoinitialize can occur only when an \overline{EOP} occurs. If it is not Autoinitialized, this register will have a count of FFFFH after TC.

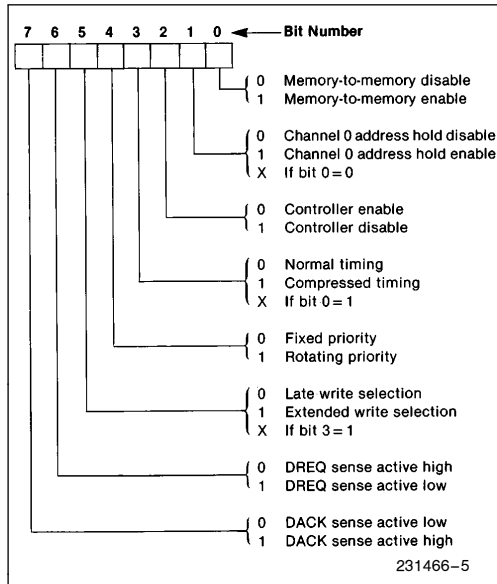
Base Address and Base Word Count Registers—Each channel has a pair of Base Address and Base Word Count registers. These 16-bit registers store the original value of their associated current registers. During Autoinitialize these values are used to restore the current registers to their original values. The base registers are written simultaneously with their corresponding current register in 8-bit bytes in the Program Condition by the microprocessor. These registers cannot be read by the microprocessor.

Command Register—This 8-bit register controls the operation of the 8237A. It is programmed by the microprocessor in the Program Condition and is cleared by Reset or a Master Clear instruction. The following table lists the function of the command bits. See Figure 6 for address coding.

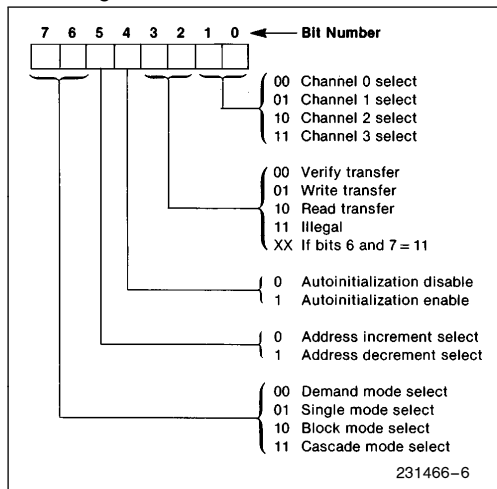
Mode Register—Each channel has a 6-bit Mode register associated with it. When the register is being written to by the microprocessor in the Program Condition, bits 0 and 1 determine which channel Mode register is to be written.

Request Register—The 8237A can respond to requests for DMA service which are initiated by software as well as by a DREQ. Each channel has a request bit associated with it in the 4-bit Request register. These are non-maskable and subject to prioritization by the Priority Encoder network. Each register bit is set or reset separately under software control or is cleared upon generation of a TC or external \overline{EOP} . The entire register is cleared by a Reset. To set or reset a bit, the software loads the proper form of the data word. See Figure 5 for register address coding. In order to make a software request, the channel must be in Block Mode.

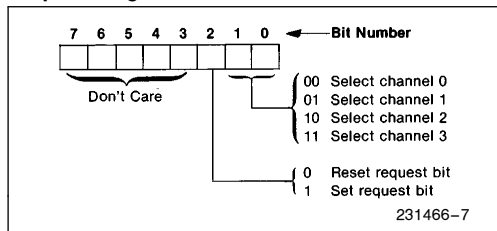
Command Register



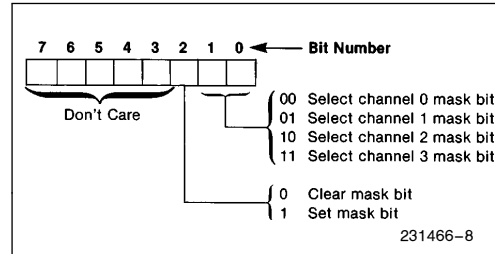
Mode Register



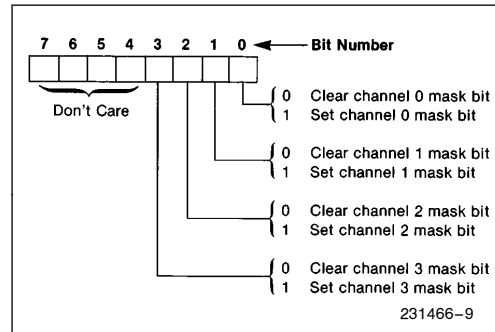
Request Register



Mask Register—Each channel has associated with it a mask bit which can be set to disable the incoming DREQ. Each mask bit is set when its associated channel produces an EOP if the channel is not programmed for Autoinitialize. Each bit of the 4-bit Mask register may also be set or cleared separately under software control. The entire register is also set by a Reset. This disables all DMA requests until a clear Mask register instruction allows them to occur. The instruction to separately set or clear the mask bits is similar in form to that used with the Request register. See Figure 5 for instruction addressing.



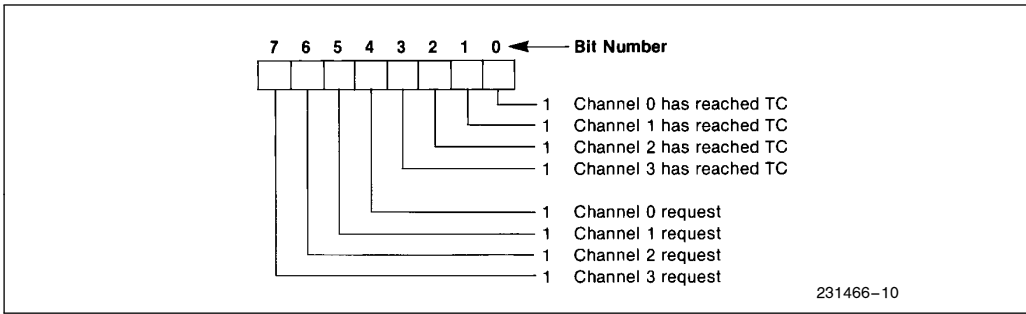
All four bits of the Mask register may also be written with a single command.



| Register | Operation | Signals | | | | | |
|-----------|-----------|---------|-----|-----|----|----|-------|
| | | CS | IOR | IOW | A3 | A2 | A1 A0 |
| Command | Write | 0 | 1 | 0 | 1 | 0 | 0 0 |
| Mode | Write | 0 | 1 | 0 | 1 | 0 | 1 1 |
| Request | Write | 0 | 1 | 0 | 1 | 0 | 0 1 |
| Mask | Set/Reset | 0 | 1 | 0 | 1 | 0 | 1 0 |
| Mask | Write | 0 | 1 | 0 | 1 | 1 | 1 1 |
| Temporary | Read | 0 | 0 | 1 | 1 | 1 | 0 1 |
| Status | Read | 0 | 0 | 1 | 1 | 0 | 0 0 |

Figure 5. Definition of Register Codes

Status Register—The Status register is available to be read out of the 8237A by the microprocessor. It contains information about the status of the devices at this point. This information includes which channels have reached a terminal count and which chan-



nels have pending DMA requests. Bits 0–3 are set every time a TC is reached by that channel or an external EOP is applied. These bits are cleared upon Reset and on each Status Read. Bits 4–7 are set whenever their corresponding channel is requesting service.

Temporary Register—The Temporary register is used to hold data during memory-to-memory transfers. Following the completion of the transfers, the last word moved can be read by the microprocessor in the Program Condition. The Temporary register always contains the last byte transferred in the previous memory-to-memory operation, unless cleared by a Reset.

Software Commands—These are additional special software commands which can be executed in the Program Condition. They do not depend on any specific bit pattern on the data bus. The three software commands are:

Clear First/Last Flip-Flop: This command must be executed prior to writing or reading new address or word count information to the 8237A. This initializes the flip-flop to a known state so that subsequent accesses to register contents by the microprocessor will address upper and lower bytes in the correct sequence.

Master Clear: This software instruction has the same effect as the hardware Reset. The Command, Status, Request, Temporary, and Internal First/Last Flip-Flop registers are cleared and the Mask register is set. The 8237A will enter the Idle cycle.

Clear Mask Register: This command clears the mask bits of all four channels, enabling them to accept DMA requests.

Figure 6 lists the address codes for the software commands.

| Signals | | | | | | Operation |
|---------|----|----|----|-----|-----|--------------------------------|
| A3 | A2 | A1 | A0 | IOR | IOW | |
| 1 | 0 | 0 | 0 | 0 | 1 | Read Status Register |
| 1 | 0 | 0 | 0 | 1 | 0 | Write Command Register |
| 1 | 0 | 0 | 1 | 0 | 1 | Illegal |
| 1 | 0 | 0 | 1 | 1 | 0 | Write Request Register |
| 1 | 0 | 1 | 0 | 0 | 1 | Illegal |
| 1 | 0 | 1 | 0 | 1 | 0 | Write Single Mask Register Bit |
| 1 | 0 | 1 | 1 | 0 | 1 | Illegal |
| 1 | 0 | 1 | 1 | 1 | 0 | Write Mode Register |
| 1 | 1 | 0 | 0 | 0 | 1 | Illegal |
| 1 | 1 | 0 | 0 | 1 | 0 | Clear Byte Pointer Flip/Flop |
| 1 | 1 | 0 | 1 | 0 | 1 | Read Temporary Register |
| 1 | 1 | 0 | 1 | 1 | 0 | Master Clear |
| 1 | 1 | 1 | 0 | 0 | 1 | Illegal |
| 1 | 1 | 1 | 0 | 1 | 0 | Clear Mask Register |
| 1 | 1 | 1 | 1 | 0 | 1 | Illegal |
| 1 | 1 | 1 | 1 | 1 | 0 | Write All Mask Register Bits |

Figure 6. Software Command Codes

| Channel | Register | Operation | Signals | | | | | | | Internal Flip-Flop | Data Bus DB0-DB7 | |
|---------|-----------------------------|-----------|---------|-----|-----|----|----|----|----|--------------------|------------------|--------|
| | | | CS | IOR | IOW | A3 | A2 | A1 | A0 | | | |
| 0 | Base and Current Address | Write | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | A0-A7 |
| | | | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | A8-A15 |
| | Current Address | Read | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | A0-A7 |
| | | | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | A8-A15 |
| | Base and Current Word Count | Write | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | W0-W7 |
| | | | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | W8-W15 |
| | Current Word Count | Read | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | W0-W7 |
| | | | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | W8-W15 |
| 1 | Base and Current Address | Write | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | A0-A7 |
| | | | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | A8-A15 |
| | Current Address | Read | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | A0-A7 |
| | | | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | A8-A15 |
| | Base and Current Word Count | Write | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | W0-W7 |
| | | | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | W8-W15 |
| | Current Word Count | Read | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | W0-W7 |
| | | | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | W8-W15 |
| 2 | Base and Current Address | Write | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | A0-A7 |
| | | | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | A8-A15 |
| | Current Address | Read | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | A0-A7 |
| | | | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | A8-A15 |
| | Base and Current Word Count | Write | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | W0-W7 |
| | | | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | W8-W15 |
| | Current Word Count | Read | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | W0-W7 |
| | | | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | W8-W15 |
| 3 | Base and Current Address | Write | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | A0-A7 |
| | | | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | A8-A15 |
| | Current Address | Read | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | A0-A7 |
| | | | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | A8-A15 |
| | Base and Current Word Count | Write | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | W0-W7 |
| | | | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | W8-W15 |
| | Current Word Count | Read | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | W0-W7 |
| | | | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | W8-W15 |

Figure 7. Word Count and Address Register Command Codes

PROGRAMMING

The 8237A will accept programming from the host processor any time that HLDA is inactive; this is true even if HRQ is active. The responsibility of the host is to assure that programming and HLDA are mutually exclusive. Note that a problem can occur if a DMA request occurs, on an unmasked channel while the 8237A is being programmed. For instance, the CPU may be starting to reprogram the two byte Address register of channel 1 when channel 1 receives a DMA request. If the 8237A is enabled (bit 2 in the command register is 0) and channel 1 is unmasked, a DMA service will occur after only one byte of the Address register has been reprogrammed. This can be avoided by disabling the controller (setting bit 2 in the command register) or masking the channel before programming any other registers. Once the programming is complete, the controller can be enabled/unmasked.

After power-up it is suggested that all internal locations, especially the Mode registers, be loaded with some valid value. This should be done even if some

channels are unused. An invalid mode may force all control signals to go active at the same time.

APPLICATION INFORMATION (Note 1)

Figure 8 shows a convenient method for configuring a DMA system with the 8237A controller and an 8080A/8085AH microprocessor system. The multi-mode DMA controller issues a HRQ to the processor whenever there is at least one valid DMA request from a peripheral device. When the processor replies with a HLDA signal, the 8237A takes control of the address bus, the data bus and the control bus. The address for the first transfer operation comes out in two bytes—the least significant 8 bits on the eight address outputs and the most significant 8 bits on the data bus. The contents of the data bus are then latched into an 8-bit latch to complete the full 16 bits of the address bus. The 8282 is a high speed, 8-bit, three-state latch in a 20-pin package. After the initial transfer takes place, the latch is updated only after a carry or borrow is generated in the least significant address byte. Four DMA channels are provided when one 8237A is used.

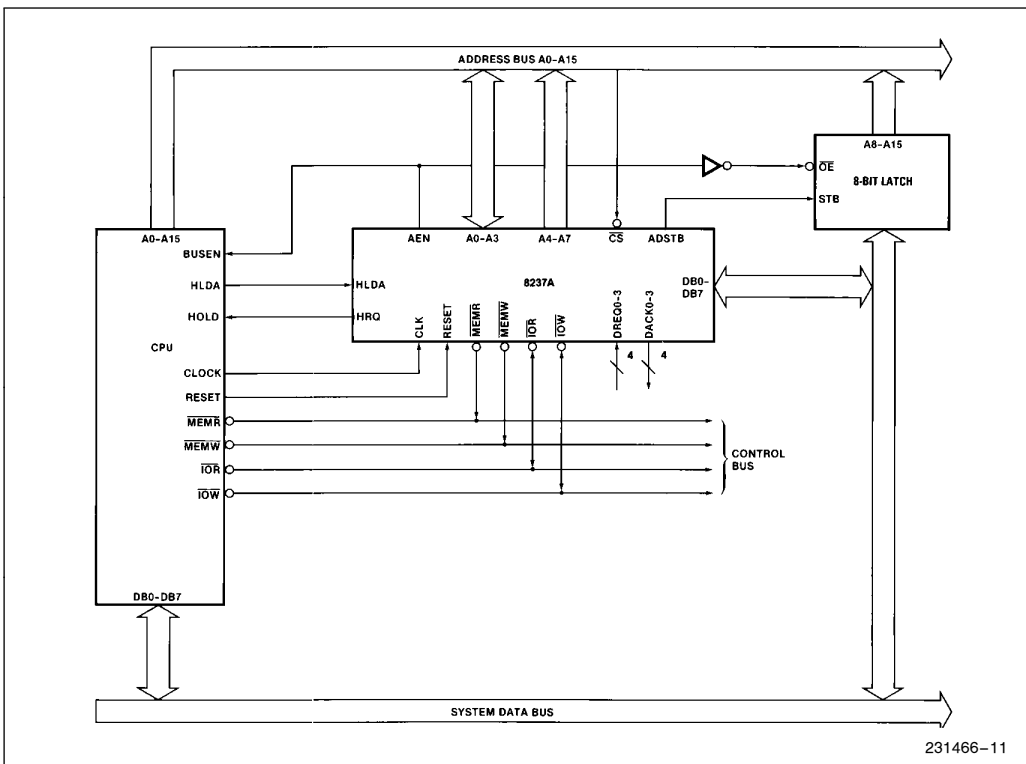


Figure 8. 8237A System Interface

NOTE:

1. See Application Note AP-67 for 8086 design information.

ABSOLUTE MAXIMUM RATINGS*

Ambient Temperature under Bias 0°C to 70°C
Case Temperature 0°C to +75°C
Storage Temperature -65°C to +150°C
Voltage on Any Pin with
Respect to Ground -0.5V to +7V
Power Dissipation 1.5 Watt

NOTICE: This is a production data sheet. The specifications are subject to change without notice.

**WARNING: Stressing the device beyond the "Absolute Maximum Ratings" may cause permanent damage. These are stress ratings only. Operation beyond the "Operating Conditions" is not recommended and extended exposure beyond the "Operating Conditions" may affect device reliability.*

D.C. CHARACTERISTICS

$T_A = 0^\circ\text{C}$ to 70°C , $T_{\text{CASE}} = 0^\circ\text{C}$ to 75°C , $V_{\text{CC}} = +5.0\text{V} \pm 5\%$, $\text{GND} = 0\text{V}$

| Symbol | Parameter | Min | Typ (Note 1) | Max | Unit | Test Conditions |
|-----------------|--------------------------------|------|-----------------|-----------------------|---------------|---|
| V _{OH} | Output High Voltage | 2.4 | | | V | I _{OH} = -200 μA |
| | | 3.3 | | | V | I _{OH} = -100 μA (HRQ Only) |
| V _{OL} | Output LOW Voltage | | | 0.40 | V | I _{OL} = 3.2 mA |
| V _{IH} | Input HIGH Voltage | 2.0 | | V _{CC} + 0.5 | V | |
| V _{IL} | Input LOW Voltage | -0.5 | | 0.8 | V | |
| I _{LI} | Input Load Current | | | ± 10 | μA | $0\text{V} \leq V_{\text{IN}} \leq V_{\text{CC}}$ |
| I _{LO} | Output Leakage Current | | | ± 10 | μA | $0.45\text{V} \leq V_{\text{OUT}} \leq V_{\text{CC}}$ |
| I _{CC} | V _{CC} Supply Current | | 110 | 130 | mA | T _A = +25°C |
| | | | 130 | 150 | mA | T _A = 0°C |
| C _O | Output Capacitance | | 4 | 8 | pF | f _c = 1.0 MHz, Inputs = 0V |
| C _I | Input Capacitance | | 8 | 15 | pF | |
| C _{IO} | I/O Capacitance | | 10 | 18 | pF | |

NOTE:

1. Typical values are for T_A = 25°C, nominal supply voltage and nominal processing parameters.

A.C. CHARACTERISTICS—DMA (MASTER) MODE
 $T_A = 0^\circ\text{C to } 70^\circ\text{C}$, $T_{\text{CASE}} = 0^\circ\text{C to } 75^\circ\text{C}$, $V_{\text{CC}} = +5\text{V} \pm 5\%$, $\text{GND} = 0\text{V}$

| Symbol | Parameter | 8237A-5 | | Unit |
|--------|--|---------|-----|------|
| | | Min | Max | |
| TAEL | AEN HIGH from CLK LOW (S1) Delay Time | | 200 | ns |
| TAET | AEN LOW from CLK HIGH (S1) Delay Time | | 130 | ns |
| TAFAB | ADR Active to Float Delay from CLK HIGH | | 90 | ns |
| TAFC | $\overline{\text{READ}}$ or $\overline{\text{WRITE}}$ Float from CLK HIGH | | 120 | ns |
| TAFDB | DB Active to Float Delay from CLK HIGH | | 170 | ns |
| TAHR | ADR from $\overline{\text{READ}}$ HIGH Hold Time | TCY-100 | | ns |
| TAHS | DB from ADSTB LOW Hold Time | 30 | | ns |
| TAHW | ADR from $\overline{\text{WRITE}}$ HIGH Hold Time | TCY-50 | | ns |
| TAK | DACK Valid from CLK LOW Delay Time (Note 1)220 | | 170 | ns |
| | $\overline{\text{EOP}}$ HIGH from CLK HIGH Delay Time (Note 2) | | 170 | ns |
| | $\overline{\text{EOP}}$ LOW from CLK HIGH Delay Time | | 170 | ns |
| TASM | ADR Stable from CLK HIGH | | 170 | ns |
| TASS | DB to ADSTB LOW Setup Time | 100 | | ns |
| TCH | Clock High Time (Transitions ≤ 10 ns) | 80 | | ns |
| TCL | Clock LOW Time (Transitions ≤ 10 ns) | 68 | | ns |
| TCY | CLK Cycle Time | 200 | | ns |
| TDCL | CLK HIGH to $\overline{\text{READ}}$ or $\overline{\text{WRITE}}$ LOW Delay (Note 3) | | 190 | ns |
| TDCTR | $\overline{\text{READ}}$ HIGH from CLK HIGH (S4) Delay Time (Note 3) | | 190 | ns |
| TDCTW | $\overline{\text{WRITE}}$ HIGH from CLK HIGH (S4) Delay Time (Note 3) | | 130 | ns |
| TDQ1 | HRQ Valid from CLK HIGH Delay Time (Note 4) | | 120 | ns |
| TDQ2 | | | 120 | ns |
| TEPS | $\overline{\text{EOP}}$ LOW from CLK LOW Setup Time | 40 | | ns |
| TEPW | $\overline{\text{EOP}}$ Pulse Width | 220 | | ns |
| TFAAB | ADR Float to Active Delay from CLK HIGH | | 170 | ns |
| TFAC | $\overline{\text{READ}}$ or $\overline{\text{WRITE}}$ Active from CLK HIGH | | 150 | ns |
| TFADB | DB Float to Active Delay from CLK HIGH | | 200 | ns |
| THS | HLDA Valid to CLK HIGH Setup Time | 75 | | ns |
| TIDH | Input Data from $\overline{\text{MEMR}}$ HIGH Hold Time | 0 | | ns |
| TIDS | Input Data to $\overline{\text{MEMR}}$ HIGH Setup Time | 170 | | ns |
| TODH | Output Data from $\overline{\text{MEMW}}$ HIGH Hold Time | 10 | | ns |
| TODV | Output Data Valid to $\overline{\text{MEMW}}$ HIGH | 125 | | ns |
| TQS | DREQ to CLK LOW (S1, S4) Setup Time (Note 1) | 0 | | ns |
| TRH | CLK to READY LOW Hold Time | 20 | | ns |
| TRS | READY to CLK LOW Setup Time | 60 | | ns |
| TSTL | ADSTB HIGH from CLK HIGH Delay Time | | 130 | ns |
| TSTT | ADSTB LOW from CLK HIGH Delay Time | | 90 | ns |

A.C. CHARACTERISTICS—PERIPHERAL (SLAVE) MODE

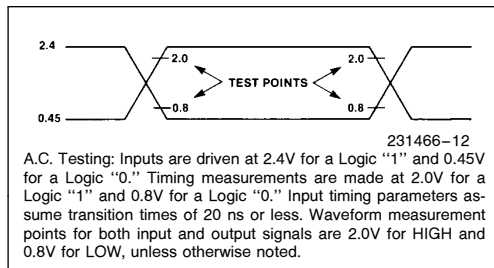
$T_A = 0^\circ\text{C}$ to 70°C , $T_{\text{CASE}} = 0^\circ\text{C}$ to 75°C , $V_{\text{CC}} = +5\text{V} \pm 5\%$, $\text{GND} = 0\text{V}$

| Symbol | Parameter | 8237A-5 | | Unit |
|--------|---|---------|-----|------|
| | | Min | Max | |
| TAR | ADR Valid or $\overline{\text{CS}}$ LOW to $\overline{\text{READ}}$ LOW | 50 | | ns |
| TAW | ADR Valid to $\overline{\text{WRITE}}$ HIGH Setup Time | 130 | | ns |
| TCW | CS LOW to $\overline{\text{WRITE}}$ HIGH Setup Time | 130 | | ns |
| TDW | Data Valid to $\overline{\text{WRITE}}$ HIGH Setup Time | 130 | | ns |
| TRA | ADR or CS Hold from $\overline{\text{READ}}$ HIGH | 0 | | ns |
| TRDE | Data Access from $\overline{\text{READ}}$ LOW (Note 5) | | 140 | ns |
| TRDF | DB Float Delay from $\overline{\text{READ}}$ HIGH | 0 | 70 | ns |
| TRSTD | Power Supply HIGH to RESET LOW Setup Time | 500 | | ns |
| TRSTS | RESET to First $\overline{\text{IOWR}}$ | 2TCY | | ns |
| TRSTW | RESET Pulse Width | 300 | | ns |
| TRW | $\overline{\text{READ}}$ Width | 200 | | ns |
| TWA | ADR from $\overline{\text{WRITE}}$ HIGH Hold Time | 20 | | ns |
| TWC | CS HIGH from $\overline{\text{WRITE}}$ HIGH Hold Time | 20 | | ns |
| TWD | Data from $\overline{\text{WRITE}}$ HIGH Hold Time | 30 | | ns |
| TWWS | Write Width | 160 | | ns |
| TWR | End of Write to End of Read in DMA Transfer | 0 | | ns |

NOTES:

- DREQ and DACK signals may be active high or active low. Timing diagrams assume the active high mode.
- EOP is an open collector output. This parameter assumes the presence of a 2.2K pullup to V_{CC} .
- The net $\overline{\text{IOW}}$ or $\overline{\text{MEMW}}$ Pulse width for normal write will be $\text{TCY} - 100$ ns and for extended write will be $2\text{TCY} - 100$ ns. The net $\overline{\text{IOF}}$ or $\overline{\text{MEMR}}$ pulse width for normal read will be $2\text{TCY} - 50$ ns and for compressed read will be $\text{TCY} - 50$ ns.
- TDQ is specified for two different output HIGH levels. TDQ1 is measured at 2.0V. TDQ2 is measured at 3.3V. The value for TDQ2 assumes an external 3.3 K Ω pull-up resistor connected from HRQ to V_{CC} .
- Output Loading on the Data Bus is 1 TTL Gate plus 100 pF capacitance.

A.C. TESTING INPUT/OUTPUT WAVEFORM



WAVEFORMS

SLAVE MODE WRITE TIMING

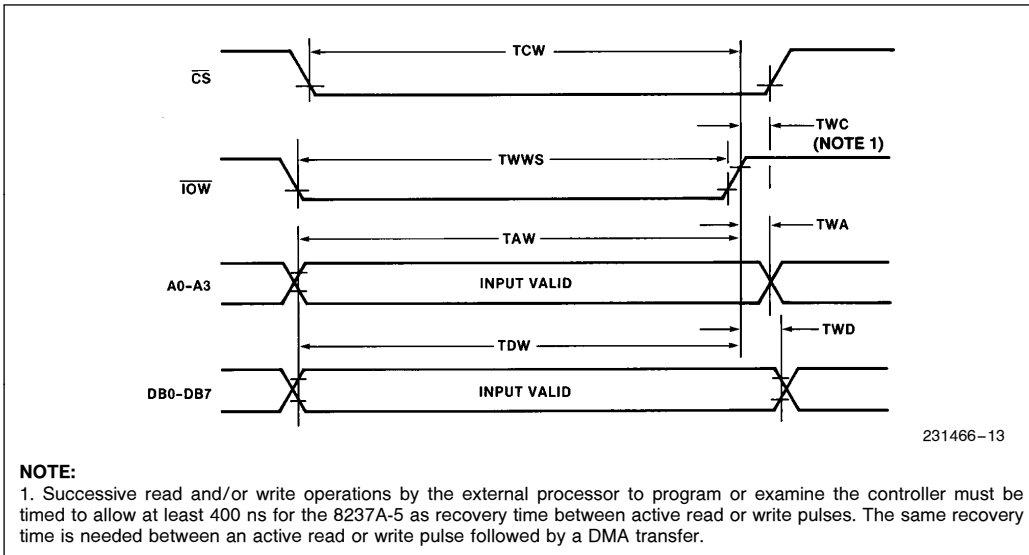


Figure 9. Slave Mode Write

SLAVE MODE READ TIMING

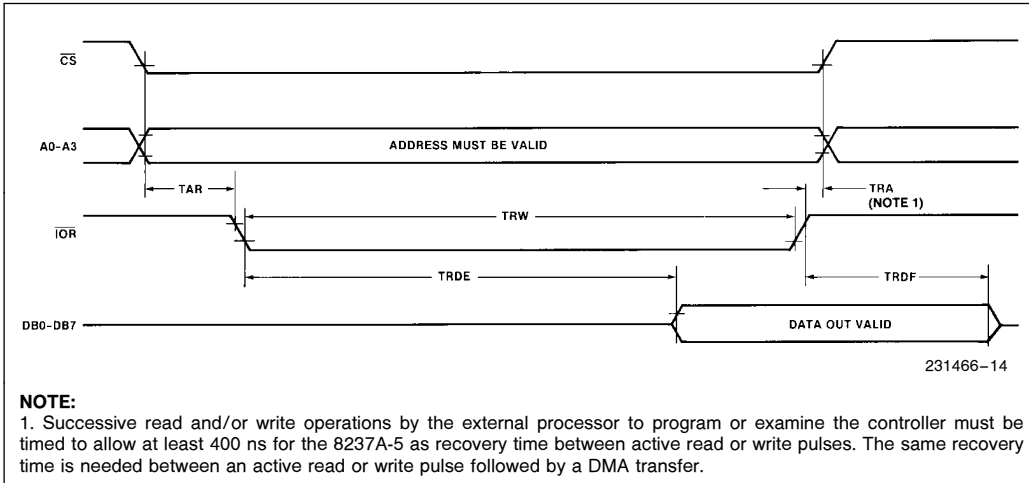


Figure 10. Slave Mode Read

WAVEFORMS (Continued)

MEMORY-TO-MEMORY TRANSFER TIMING

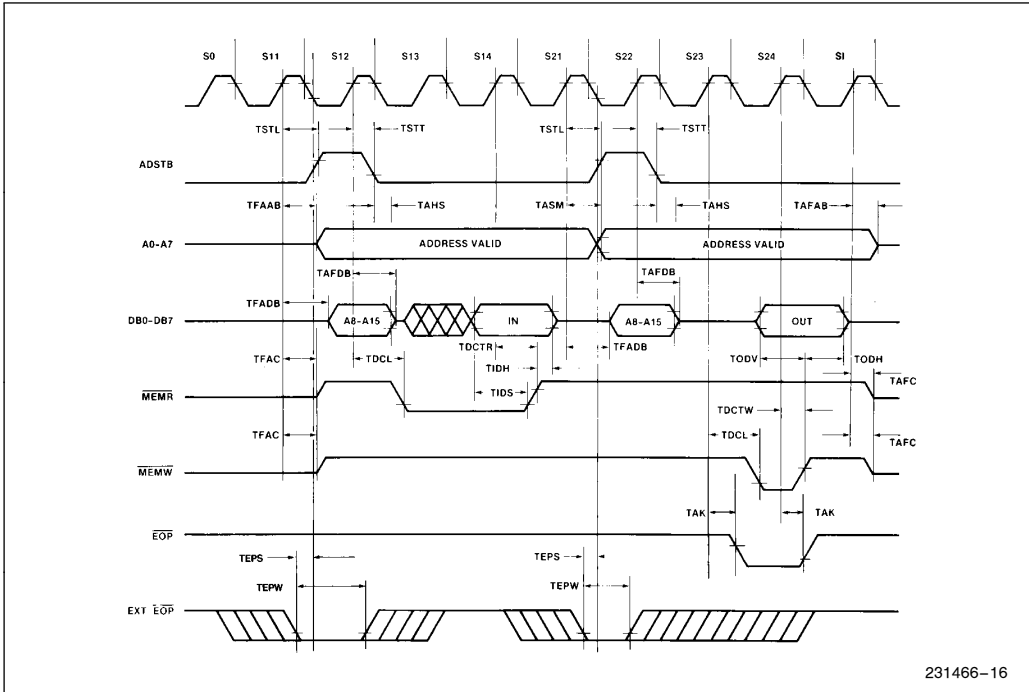


Figure 12. Memory-to-Memory Transfer

READY TIMING

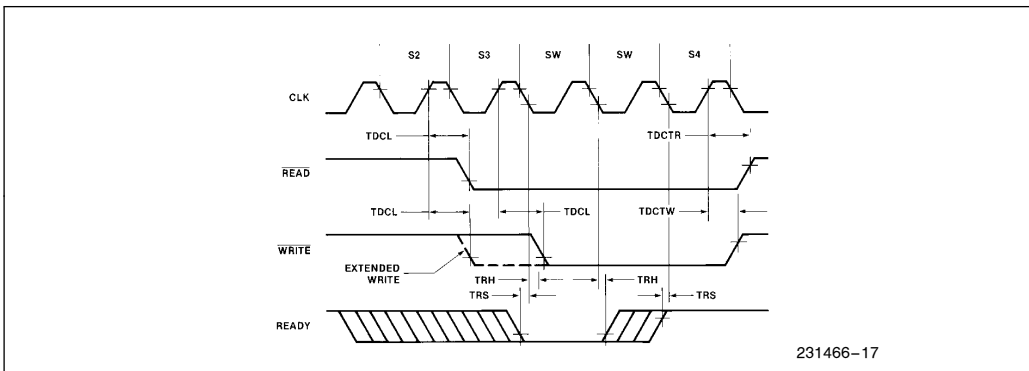


Figure 13. Ready



WAVEFORMS (Continued)

COMPRESSED TRANSFER TIMING

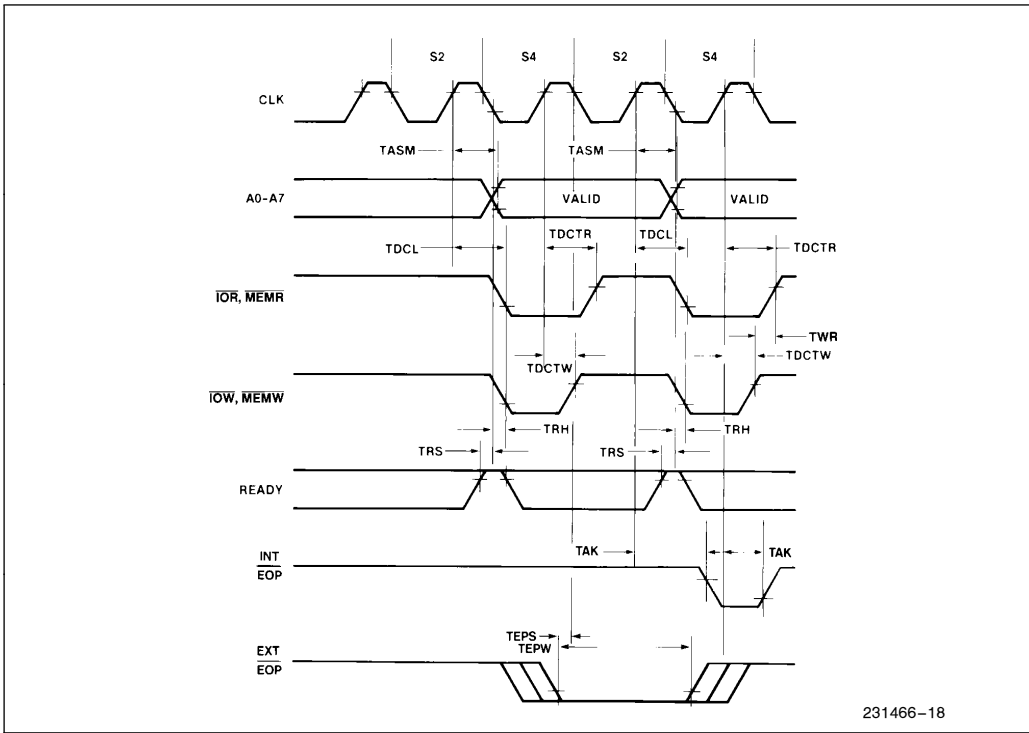


Figure 14. Compressed Transfer

RESET TIMING

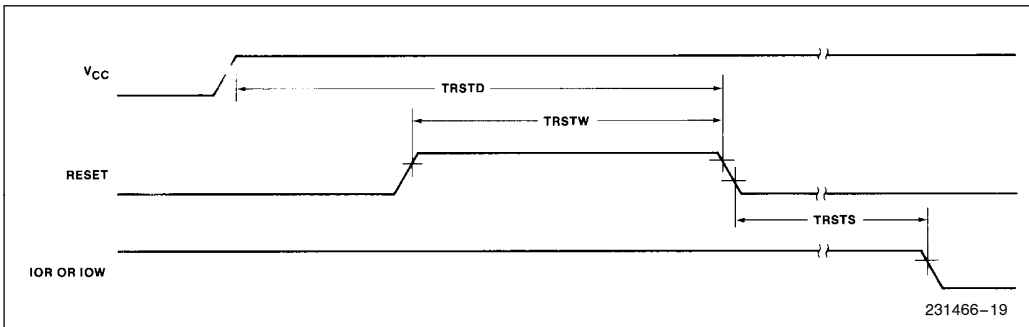


Figure 15. Reset

DESIGN CONSIDERATIONS

1. **Cascading from channel zero.** When using multiple 8237s, always start cascading with channel zero. Channel zero of the 8237 will operate incorrectly if one or more of channels 1, 2, or 3 are used in the cascade mode while channel zero is used in a mode other than cascade.
2. **Do not treat the DREQ signal as an asynchronous input while the channel is in the “demand” or “cascade” modes.** If DREQ becomes inactive at any time during state S4, an illegal state may occur causing the 8237 to operate improperly.
3. **HRQ must remain active until HLDA becomes active.** If HRQ goes inactive before HLDA is received the 8237 can enter an illegal state causing it to operate improperly.
4. **Make sure the MEMR# line has 50 pF loading capacitance on it.** When doing memory to memory transfers, the 8237 requires at least 50 pF loading capacitance on the MEMR# signal for proper operation. In most cases board capacitance is sufficient.
5. **Treat the READY input as a synchronous input.** If a transition occurs during the setup/hold window, erratic operation may result.
6. **Any channel in cascade mode should have an active DREQ before a HRQ.**

DATA SHEET REVISION REVIEW

The following list represents key differences between this and the -003 data sheet. Please review this summary carefully.

1. Item 6 was added to the “Design Considerations” section.

REVISION SUMMARY

The following list represents the key differences between rev. 004 and rev. 005 of the 1994 8237A Data Sheet.

1. References to and specifications for the 8237A and 8237A-4 are removed. Only the 8237A-5 5 MHz device remains in production.