Integrated Woz Machine (IWM) Specification

Device Specification

[ Revision 19 ]

AUTHOR
Apple Computer Inc.

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1978 - February 1982

(This page is not part of the original document)
INTRODUCTION

What is this document?

The Integrated Woz Machine (IWM) Device Specification describes the internal operation of this single chip circuit whose purpose was to integrate the discrete logic of the Apple Disk II floppy disk drive controller into a single integrated circuit.

This device was used by the Apple IIc, Apple IIgs and Apple Macintosh computers to control attached Apple Disk II 5.25" floppy drives (capacity 143 KB) or Apple 3.5" floppy drives (capacity 800 KB).

This is specification revision 19.

"Woz" refers to Steve Wozniak, the original designer of the Apple Disk II floppy drive and its drive controller.

Revision history at the end of this document includes the initials of several people involved in the development of the IWM device:

    rhn=???  bcs=Bryan Stearns  ws=Wendall Sanders  woz=Steve Wozniak

This specification was not made public by Apple Computer, Inc.

Facts about this document

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References

US Patent 4,742,448 "Integrated Floppy Disk Drive Controller", 03 May 1988
This is the IWM patent as assigned to Wendell Sander and Robert Bailey.

US Patent 4,916,556 "Disk Drive Controller", 10 April 1990
This is the SWIM patent, the IWM's successor, as assigned to Wendell Sander and Brian Sander.

Steve Wozniak interview, "The Apple Story: Part II"
BYTE magazine, January 1985 (Part I can be found in BYTE December 1984)

BYTE: The Macintosh uses a custom chip called the IWM - Integrated Woz Machine - that does the same sort of recording. Can you tell us anything about that?

WOZNIAK: My design was basically a little sequencer, or state machine. It used a PROM and a latch and cycled through various states depending on the input data coming off the floppy disk. The IWM takes that design and adds other features like the ability to go twice as fast - it can also do IBM format, double-density recordings.

BYTE: It sounds like a fascinating part. Do you think well see Apple II owners benefit from it in any way?

WOZNIAK: Well, it's our standard disk controller now, and it's cheaper than the older design. It's used in the Apple IIC.

BYTE: Could you use it to get higher-density recording on an Apple II 5/4-inch disk?

WOZNIAK: No, because the disk drives themselves aren't certified for double-density recording. You need heads with the proper gap, and they're more expensive.

BYTE: You're a former hobbyist. Could a hobbyist guy one of these chips and a spec sheet and start playing with it?

WOZNIAK: I don't think Apple would give out the spec sheet. I totally disagree with that policy because I'm very respectful to the hobbyists. They're a tiny part of our market, but they're loyal supporters and faithful people to the company. If they had a spec sheet, they could start playing with it and figure out a lot more incredible things that we never planned it to be used for -- even using it as a communications channel from Apple to Apple, Macintosh to Macintosh. There are a lot of great tricks you could do with that little part. It's a beautiful random I/O device that has too many things that have not been taken anywhere.

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Integrated WOZ Machine (IWM)  
-----------------------------  
Device Specification  

Features  
--------  
* Backwards-compatible with 16 sector Disk ][ controller  
* Use of 7M (or 8 MHz) to minimize sampling error rate  
* Fast mode using 2 use bit cells  
* Asynchronous mode with pollable handshake registers  

General Description  
-------------------  

The IWM is an integration of the Disk II floppy disc interface. When the IWM is reset, it becomes a controller compatible with the current Disk II interface in its operation with currently supported Apple II and /// software. In addition the IWM has extensions including a status register, mode register, and multiple modes of operation. The IWM provides an asynchronous mode which relaxes the precise software/hardware timing required in synchronous mode, a fast mode with a data rate twice that of Disk II, and an optional 1 second one-shot timer to hold the enable outputs low.  

The IWM is a peripheral device that connects to a host data bus. The device generates and receives serial GCR encoded data. A programmable digital one shot is used for serial data reception. The IWM generates buffered drive enables and phase line control signals.  

Packaging and Pin Assignment  
-----------------------------  

The IWM is packaged in a standard 28-pin, 600 mil plastic DIP.  

<table>
<thead>
<tr>
<th>Pin</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHASE0</td>
<td>1</td>
</tr>
<tr>
<td>PHASE2</td>
<td>2</td>
</tr>
<tr>
<td>A0</td>
<td>3</td>
</tr>
<tr>
<td>A1</td>
<td>4</td>
</tr>
<tr>
<td>A2</td>
<td>5</td>
</tr>
<tr>
<td>A3</td>
<td>6</td>
</tr>
<tr>
<td>/DEV</td>
<td>7</td>
</tr>
<tr>
<td>WR DATA</td>
<td>8</td>
</tr>
<tr>
<td>/WR REQ</td>
<td>9</td>
</tr>
<tr>
<td>D0</td>
<td>0</td>
</tr>
<tr>
<td>D1</td>
<td>11</td>
</tr>
<tr>
<td>D2</td>
<td>12</td>
</tr>
<tr>
<td>D3</td>
<td>13</td>
</tr>
<tr>
<td>GND</td>
<td>14</td>
</tr>
</tbody>
</table>

---

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Technical Description

The primary purpose of the IWM is to allow a microprocessor to read and write serial GCR (group code) encoded data. The IWM may be controlled by setting state bits and reading or writing registers. Setting a state bit and accessing a register is done simultaneously. The registers are the mode register, the status register, the write-handshake register, the read data register, and the write data register. The modes selected by the mode register include synchronous or asynchronous mode and slow or fast mode.

The data format is an 8 bit nibble with the MSB set. The MSB of the 8 bit data nibble is shifted in or written out first. A bit is transferred every bit cell time. The bit cell time defaults to 4 μs (set to 2 μs in fast mode). Therefore the data rate is one nibble every 32 μs (16 μs in fast mode). When writing data out, a one is written as a transition on the WRDATA output at a bit cell boundary time and a zero is written as no transition.

The IWM is put into the write state by a transition from the write protect sense state to the write load state. In the synchronous mode, the time of that transition and every 8 Q3 periods (4 μs) thereafter, until L7 is cleared, marks the beginning of a write window. The duration of the write window is 4 periods of the Q3 input signal (2 μs). The data written at the last write access occurring within this write window will load the shift register with the data to be shifted out. If the next write access has not occurred 32 μs (64 Q3 periods) after a load, the write will be extended in multiples of 4 μs (8 Q3 periods) until another write access, and zeros will be shifted out.

In synchronous mode, Q3 clock input is used internally to generate the 32 and 40 μs timings, which would then be 60 and 80 of the Q3 clock input periods in duration, respectively, and the bit cell timings, 8 Q3 periods per bit cell time in slow mode.

In asynchronous mode the write shift register is buffered and, when the buffer is empty, the IWM sets the MSB of the write-handshake register to a one to indicate that the next data nibble can be written to the buffer. The buffer register may be written at any time during the write state. Only the data last written into the buffer register, before the contents of the buffer register is transferred to the write shift register, is used.

In asynchronous mode CLK is used to generate the bit cell timings. In fast mode the CLK clock is equivalent to the clock input on FCLK. In slow mode CLK is equivalent to the clock input on FCLK divided by two. Therefore, in 7M and slow mode the bit cell time will be 28 FCLK clock input periods in duration, in 8M and slow mode the cell time will be 32 periods, and in 8M and fast mode the cell time will be 16 periods. In asynchronous mode the write shift register is loaded every 8 bit cell times starting seven CLK periods after the write state begins.
An underrun occurs when data has not been written to the buffer register between the time the write-handshake bit indicates an empty buffer and the time the buffer is transferred to the write shift-register. If an underrun occurs in asynchronous mode /WRREQ will be disabled (set to a TTL high state) and the /underrun flag will be set to zero. This occurrence can be detected by reading the write-handshake register before clearing state bit L7. Clearing state bit L7 will reset the /underrun flag.

When L6 and L7 are both zero the IWM is in the read state. When reading serial data, a falling transition within a bit cell window is considered to be a one, and no falling transition within a bit cell window is considered to be a zero. The receive data input on RDDATA is synchronized internally with the CLK clock. The synchronized falling transition is then discriminated to the nearest bit cell window using the 7.8 mHz FCLK clock signal in fast mode and the FCLK signal divided by two in slow mode. A digital one-shot data recovery scheme is used. Every falling transition establishes the bit cell windows, used by the data separator in the IWM to recover the following bits, until another falling transition is received.

In the read state the data is shifted into the LSB of the shift register, and the shift register shifts data from LSB to MSB. A full data nibble is considered to be shifted in when a one is shifted into the MSB. When a full data nibble is shifted into the internal shift register, the data will be latched by the read data register and the shift register will be cleared to all zeros so that it will then be ready to shift in the next data word.

In the synchronous mode the shift register is readable in any intermediate state with this exception: when a one is shifted into the MSB, the shift register will appear, to the data bus, to be stalled for a period of two bit times plus four CLK periods. This is to allow the host processor time to poll the MSB to determine when data is valid. In asynchronous mode the data register will latch the shift register when a one is shifted into the MSB and will be cleared 14 FCLK periods (about 12 ms) after a valid data read takes place (a valid data read being defined as both /DEV being low and D7 (the msb) outputting a one from the data register for at least one FCLK period).
### Read data bit cell windows

<table>
<thead>
<tr>
<th>mode</th>
<th>Nclks</th>
<th>period</th>
<th>data</th>
<th>notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>slow</td>
<td>7M</td>
<td>7-20</td>
<td>FCLK/2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21-34</td>
<td>Ø1</td>
<td>6.0-9.71+ μS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35-48</td>
<td>ØØ1</td>
<td>10.0-13.71+ μS</td>
</tr>
<tr>
<td>slow</td>
<td>8M</td>
<td>8-23</td>
<td>FCLK/2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24-39</td>
<td>Ø1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>40-55</td>
<td>ØØ1</td>
<td></td>
</tr>
<tr>
<td>fast</td>
<td>7M</td>
<td>7-20</td>
<td>FCLK</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21-34</td>
<td>Ø1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>35-48</td>
<td>ØØ1</td>
<td></td>
</tr>
<tr>
<td>fast</td>
<td>8M</td>
<td>8-23</td>
<td>FCLK</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24-39</td>
<td>Ø1</td>
<td>3.0-4.75+ μS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40-55</td>
<td>ØØ1</td>
<td>5.0-6.875+ μS</td>
</tr>
</tbody>
</table>

The table above shows how the data separator in the IWM discriminates between ones and zeros when reading. Nclks is the number of clock periods between falling transitions of the internally synchronous version of RDDATA. The clock period is either that of the FCLK input or that of the FCLK input divided by two in slow mode. Each falling transition resets the read data windows for subsequent data to be relative to that transition. The data patterns noted above are the bit patterns that are shifted in as a result of the transitions and the absence of transitions in their respective windows.

In port operation, which is asynchronous mode true and latch mode false with /DEV held low indefinitely, read data will appear and change as if the IWM were being continually read. In port operation the IWM can be used to continuously clock data into external registers. The MSH will be cleared at least six FCLK periods before being set. Except in port operation, in asynchronous mode the latch mode bit should be set for reliability in clearing the data register after a read).

Data written to the IWM is sampled by the the zero to one transition of the logical OR of Q3 and /DEV. In asynchronous mode the Q3 input may be tied low.
Signal and Bus operation Description

1. Vcc
   +5 volt supply
   GND
   Ground reference and negative supply

2. Device Control Signals

   A1-A3
   These three inputs select one of the 8 bits in the state register to be updated.

   A0
   The data input to the state bit selected by A1-A3. The state to which the addressed
   state bit is set by an operation will select the register to be accessed by
   that operation.

   Also the /READ input. A low on this input
   enables the IWM to send the register
   selected by the state onto the data bus.

   D0-D7
   The bidirectional data bus.

   /DEV
   Active low device enable. The falling edge of /DEV latches information on A0-A3. The rising edge of
   the logical function ( Q3 OR /DEV ) qualifies write register data.

   FCLK
   Clock input for the serial data logic; either 7 or 8 MHz.

   Q3
   2.0 MHz clock input used to qualify the
   timing of the serial data being written out
   in the synchronous mode.

   /RESET
   Active low system reset input.
   When asserted, this signal places all IWM
   outputs in their inactive state, and
   sets the state and the modes to their defaults.

3. Inputs (2)

   RDDATA
   The serial data input. The falling transition of each pulse is synchronized by
   the IWM.

   SENSE
   An input to the IWM that can be polled via
   the status register.

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4. Outputs (8)

WRDATA
The serial data output. A transition occurs on this output for each one bit.

/ENBL1, /ENBL2
Programmable buffered output lines. No more than one enable may be low at any time. If an enable is low when Motor-On is true, if the 1-second on board timer is enabled then the selected one will stay low for about 1 second after it is programmed high.

/WRREQ
This signal is a programmable buffered output line.

PHASEØ-3
These are programmable output lines. A true TTL logic "1" (5.4 volts) can be maintained even while driving two darlington inputs in parallel.
Register Description

State Register

This is an 8-bit write-only pseudo-register. The bits in this register are individually addressed by A3, A2, A1. The data on A0 is latched into the addressed state bit by /DEV low. All eight state bits are reset to 0 by /RESET low.

Not only do the state bits control certain chip functions and outputs, the setting of two of the state bits L6 and L7, and Motor-On, internally select which register is to be selected and whether the operation is to be a read or a write. If an operation occurs that changes the state of one of these bits to a new state, that new state will select the register to be accessed during that operation and whether the operation is to be a read or a write.

<table>
<thead>
<tr>
<th>Address</th>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>A 1 in this bit will drive PHASE0 to a high state.</td>
</tr>
<tr>
<td>1</td>
<td>PHASE1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>PHASE2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>PHASE3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LMotor-On</td>
<td>A 1 on LMotor-On sets the enable selected below low</td>
</tr>
<tr>
<td>5</td>
<td>Drive-Sel</td>
<td>A 1 on this bit selects /ENBL2; a 0 selects /ENBL1</td>
</tr>
<tr>
<td>6</td>
<td>L6</td>
<td>(see description below)</td>
</tr>
<tr>
<td>7</td>
<td>L7</td>
<td>(see description below)</td>
</tr>
</tbody>
</table>

The state bits L7 and L6, and Motor-On, select which register is available to be read or written. Other registers are read during any operation in which A0 is a zero. A register is written when both L6 and L7 are set or are being set to 1 and A0 is a one.

The combination of L7 and Motor-On and /underrun enables /WRREQ low.

<table>
<thead>
<tr>
<th>L7 L6 Motor-On</th>
<th>register operation selected</th>
<th>State Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Φ Φ Φ</td>
<td>read all ones</td>
<td>Read</td>
</tr>
<tr>
<td>Φ Φ 1</td>
<td>read data register</td>
<td>Write-Protect Sense</td>
</tr>
<tr>
<td>Φ 1 x</td>
<td>read status register</td>
<td>Write</td>
</tr>
<tr>
<td>1 Φ x</td>
<td>read write-handshake register</td>
<td></td>
</tr>
<tr>
<td>1 1 Φ</td>
<td>write mode register</td>
<td>Mode Set</td>
</tr>
<tr>
<td>1 1 1</td>
<td>write data register</td>
<td>Write Load</td>
</tr>
</tbody>
</table>

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Mode register  
(a write only register)

--- ---

All eight mode bits are reset to Ø by /RESET low.

<table>
<thead>
<tr>
<th>bit</th>
<th>function</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSB Ø</td>
<td>1 = latch mode (should be set in asynchronous mode)</td>
</tr>
<tr>
<td>1</td>
<td>Ø = synchronous handshake protocol; 1 = asynchronous</td>
</tr>
<tr>
<td>2</td>
<td>Ø = 1-second on board timer enable; 1 = timer disable</td>
</tr>
<tr>
<td>3</td>
<td>Ø = slow mode; 1 = fast mode (2 µs bit cell timing)</td>
</tr>
<tr>
<td>4</td>
<td>Ø = 7MHz; 1 = 8MHz (7 or 8 MHz clock descriptor)</td>
</tr>
<tr>
<td>5</td>
<td>1 = test mode; Ø = normal operation</td>
</tr>
<tr>
<td>6</td>
<td>1 = MZ-reset</td>
</tr>
<tr>
<td>MSB 7</td>
<td>reserved for future expansion</td>
</tr>
</tbody>
</table>

In latch mode the msb of the read data is latched internally during /DEV low (this internally latched msb is then used for the determination of a valid data read).

If the 1-second timer bit is a zero then the enable (/ENBL1 or /ENBL2) selected by Drive-Sel will be held low for $2^{23} + 100$ FCLK periods (about 1 second) after the LMotor-On state bit is reset to zero. If the latch mode bit is set the timer is not guaranteed to count up to $2^{23}$. Motor-On is synonymous with either /ENBL1 or ENBL2 being low.

Fast mode selects a bit cell time of 2 µs instead of 1 µs. The 7/8 MHz descriptor indicates whether the input clock (FCLK) is to be divided by 7 or 8 to provide 1 µs internal timing.

When the test mode bit is a 1, device operation is unspecified, except that status register bit 5 can always be read and that the mode register can always be set.
Status register  (a read-only register)

<table>
<thead>
<tr>
<th>bit</th>
<th>function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4</td>
<td>same as mode register</td>
</tr>
<tr>
<td>5</td>
<td>1 = either /ENBL1 or /ENBL2 is currently active (low)</td>
</tr>
<tr>
<td>6</td>
<td>1 = MZ (reset to Ø by /RESET and MZ-reset)</td>
</tr>
<tr>
<td>7</td>
<td>1 = SENSE input high; Ø = SENSE input low</td>
</tr>
</tbody>
</table>

The MZ bit is reserved for compatibility with future products and should always be read as a zero.

Handshake Register  (a read only register)

<table>
<thead>
<tr>
<th>bit</th>
<th>function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>reserved for future use (currently read as ones)</td>
</tr>
<tr>
<td>6</td>
<td>1 = write state (cleared to Ø if a write underrun occurs)</td>
</tr>
<tr>
<td>7</td>
<td>1 = write data buffer register ready for data</td>
</tr>
</tbody>
</table>

Data Register

The operation of the data register depends on the setting of state bits L6 and L7 and on the synchronous mode bit. With L6 and L7 clear, the data register operates as a read data register. With L7 set the data register operates in the write state as a write data buffer.
Maximum Ratings

---

supply voltage  
-0.3 to +7.0 V
input voltage  
-0.3 to +7.0 V
storage temperature  
-35 to +125 degrees C
operating temperature  
Ø to +7Ø degrees C (ambient)

DC characteristics

sym  parameter  min  max  units  notes
Vcc  supply voltage  4.75  5.25  Volts
Icc  supply current  —  200  mA  5
Vil  Input low  —  0.8  V  3
Vih  Input high  2.0  —  V  4
Ii  input leakage  —  100  uA  1
Vol  TTL output low  —  .4  V  6
Voh  TTL output high  2.4  —  V  6
Ioh  source current at Voh  3.2  —  mA  2
Iol  sink current at Vol  3.2  —  mA  2

Notes

1. Inputs.

The inputs have static protection. All IWM inputs and bidirectional lines in the input mode are high impedance except as noted below:

WPROM and /RDDATA:
- pulled up to VCC of 10k ohms nominal
- (source current of 80 to 600 uA at 0.4 to 2.8 Volts)

2. Outputs Ioh and Iol apply to D0 thru D7 and WRDATA. The following output lines have special drive capabilities, noted below:

/ENBL1, /ENBL2:
- Sink current of at least 5.0 mA at Vol
- Source current of at least 40 uA at Voh

/WRREQ:
- Sink current of at least 10.0 mA at Voh
- Source current of at least 40 uA at Voh

PHASEB-3:
- Source current of at least 1.0 mA at Voh
- Source current of 0.5 mA when pulled down to 3.0 V.
- Sink current of at least 2.4 mA at Vol

3. TTL Vil is also referred to as a zero.

4. TTL Vih is also referred to as a one.

5. at 5.25 V over full operating temperature range.
### AC characteristics

<table>
<thead>
<tr>
<th>sym</th>
<th>parameter</th>
<th>min</th>
<th>max</th>
<th>units</th>
<th>notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>tas</td>
<td>A0-A3 to /DEV, fe</td>
<td>40</td>
<td>---</td>
<td>nS</td>
<td>setup</td>
</tr>
<tr>
<td>tah</td>
<td>/DEV, re to A0-A3 invalid</td>
<td>-1</td>
<td>---</td>
<td>nS</td>
<td>addr hold</td>
</tr>
<tr>
<td>tds</td>
<td>data to (Q3 OR /DEV), re</td>
<td>50</td>
<td>---</td>
<td>nS</td>
<td>setup</td>
</tr>
<tr>
<td>tdh</td>
<td>(Q3 OR /DEV), re to data</td>
<td>10</td>
<td>---</td>
<td>nS</td>
<td>data hold</td>
</tr>
<tr>
<td>tda</td>
<td>/DEV, fe to data out</td>
<td>---</td>
<td>200</td>
<td>nS</td>
<td>access, 1.</td>
</tr>
<tr>
<td>tds1</td>
<td>/DEV low</td>
<td>200</td>
<td>---</td>
<td>nS</td>
<td>6.</td>
</tr>
<tr>
<td>tds2</td>
<td>/DEV high</td>
<td>450</td>
<td>---</td>
<td>nS</td>
<td>6.</td>
</tr>
<tr>
<td>tde</td>
<td>/DEV to /ENBLx or /WRREQ</td>
<td>---</td>
<td>500</td>
<td>nS</td>
<td>2.</td>
</tr>
<tr>
<td>tdp</td>
<td>/DEV to PHASEx</td>
<td>---</td>
<td>500</td>
<td>nS</td>
<td>2.</td>
</tr>
<tr>
<td>trdh</td>
<td>RDDATA high time</td>
<td>300</td>
<td>---</td>
<td>nS</td>
<td>5.</td>
</tr>
<tr>
<td>tckh</td>
<td>FCLK high time</td>
<td>50</td>
<td>200</td>
<td>nS</td>
<td></td>
</tr>
<tr>
<td>tckl</td>
<td>FCLK low time</td>
<td>50</td>
<td>200</td>
<td>nS</td>
<td></td>
</tr>
<tr>
<td>tckp</td>
<td>FCLK period</td>
<td>120</td>
<td>140</td>
<td>nS</td>
<td></td>
</tr>
<tr>
<td>tckpt</td>
<td>FCLK period, no timer</td>
<td>120</td>
<td>500</td>
<td>nS</td>
<td>11.</td>
</tr>
<tr>
<td>tqd1</td>
<td>Q3, re to /DEV, fe</td>
<td>1</td>
<td>100</td>
<td>nS</td>
<td>7.</td>
</tr>
<tr>
<td>tqdsh</td>
<td>Q3, re to /DEV, re</td>
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<td>100</td>
<td>ns</td>
<td>7.</td>
</tr>
<tr>
<td>tq3h</td>
<td>Q3 high</td>
<td>260</td>
<td>300</td>
<td>nS</td>
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<tr>
<td>tq3l</td>
<td>Q3 low</td>
<td>190</td>
<td>---</td>
<td>nS</td>
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</tr>
<tr>
<td>tdmsbh</td>
<td>D0-6 valid to D7 re</td>
<td>50</td>
<td>---</td>
<td>nS</td>
<td>8.</td>
</tr>
<tr>
<td>tres</td>
<td>/RESET low time</td>
<td>500</td>
<td>---</td>
<td>nS</td>
<td>10.</td>
</tr>
<tr>
<td>trwrh</td>
<td>/RESET to /WRREQ high</td>
<td>---</td>
<td>300</td>
<td>nS</td>
<td></td>
</tr>
<tr>
<td>tsj</td>
<td>sampling jitter</td>
<td>---</td>
<td>12.5</td>
<td>nS</td>
<td>4.</td>
</tr>
<tr>
<td>tckwr</td>
<td>write clock, re to WRDATA</td>
<td>---</td>
<td>500</td>
<td>nS</td>
<td>9.</td>
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<tr>
<td>twrj</td>
<td>write data jitter</td>
<td>---</td>
<td>62.5</td>
<td>nS</td>
<td>9.</td>
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<tr>
<td>cp</td>
<td>pin capacitance</td>
<td>---</td>
<td>15</td>
<td>pF</td>
<td></td>
</tr>
</tbody>
</table>

**Notes**

1. Load = 130 pF and 8 LS TTL loads
2. Load = 1000 pF and rated maximum current
3. fe = falling edge (TTL high to low) re = rising edge
4. tsj is the uncertainty window in sampling the asynchronous input RDDATA and synchronizing it internally, with CM at any constant Vcc and temperature.
5. trdh and trd1 must be at least twice the period of CLK to be properly synchronized.
6. the time between 2 successive /DEV selects will be greater than 2 CLK periods, and in synchronous mode will be no less than 1 Q3 period. /DEV may be held low indefinitely.
7. These apply to the synchronous mode only. In other modes Q3 may be held low indefinitely.
8. If, when /DEV is low, data on D0-7 is changing to a word with D7 high, the data on D0-6 must become valid before the rising edge of D7.
9. tckwr is the time from FCLK, re, in asynchronous mode, or Q3, re, in synchronous mode, to changes in the output WRDATA, driving a load of 100 pF.
  twrj is the change in tckwr from edge to edge of WRDATA at any constant Vcc and temperature.
10. for test purposes tres must be at least 24 times tckp.
11. tckpt is max FCLK period with 3-second timer disabled.

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This specification is confidential to Apple and contains proprietary information.

Changes from earlier specs

A0-3 pinout corrected
/ENBL1 and /ENBL2 pinout corrected
tdmsbh specified
latch mode added (change to breadboard also)

Changes from rev#11 spec (4/16/82)

D0-7 pinout changed to facilitate IC layout
write jitter specified

Changes from rev#12 spec (5/5/82)

Address setup time changed to 40 nS

Changes from rev#14 spec (6/4/82)

LMotor-On different from Motor-On
Phase lines sink 2.4 mA
tres test condition added
underrun and other nomenclature cleared up

Changes from rev#17 spec (8/17/82)

read data stall time changed to 7 CLKS
relaxed AC and DC characteristics

rhn Ø2/Ø5/82
bc/s Ø1/11/82
ws 10/20/81
woz 1978,79