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# **APPLE-1**

# OPERATION MANUAL

APPLE COMPUTER COMPANY 770 Welch Road Palo Alto, Calif. 94304

# SPECIFICATIONS

MICROPROCESSOR:	MOS TECHNOLOGY 6502		
Microprocessor Clock Frequency:	1.023 MHz		
Effective Cycle Frequency: (Including Refresh Waits)	0.960 MHz		
VIDEO OUTPUT:	Composite positive video, 75 ohms, level adjustable between zero and +5Vpp.		

Line Rate:

Frame Rate:

Format:

Display Memory:

Character Matrix:

RAM MEMORY:

On-board RAM Capacity:

POWER SUPPLIES:

Input Power Requirements:

Recommended Transformers:

15734 Hz

60.05 Hz

40 characters/line, 24 lines; with automatic scrolling

Dynamic shift registers (1K x 7)

 $5 \ge 7$ 

16-pin, 4K Dynamic, type 4096 (2104)

8K bytes (4K supplied)

+5 Volts @ 3 amps, +/- 12 Volts @0.5 amp and -5 Volts @ 0.5 amps

8 to 10 Volts AC (RMS) @ 3 amps, 26 to 28 Volts AC (RMS) Center-Tapped, 1A.

Stancor # P-8380 or Triad F31-X Stancor # P-8667 or Triad F40-X

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# INTRODUCTION

The Apple Computer is a complete microocessor system, consisting of a Mos Technology )2 microprocessor and support hardware, ingral video display electronics, dynamic memory and refresh hardware, and fully regulated power supplies. It contains resident system monitor software, enabling the user, via the keyboard and display, to write, examine, debug, and run programs efficiently; thus being an educational tool for the learning of microprocessor programming, and an aid in the development of software.

The integral video display section and the keyboard interface renders unnecessary the need for an external teletype. The display section contains its own memory, leaving all of RAM for user programs, and the output format is 40 characters/ line, 24 lines/page, with auto scrolling. Almost any ASCII encoded keyboard will interface directly with the Apple system.

The board has sockets for upto 8K bytes of the 16 pin, 4K type, RAM, and the system is fully expandable to 65K via the edge connector. The system uses dynamic memory (4K bytes supplied), although static memory may also be used. All refreshing of dynamic memory, including all "off-board" expansion memory, is done automatically. The entire system timing, including the microprocessor clock and all video signals, originates in a single crystal oscillator.

Further, the printed circuit board contains a "breadboard area", in which the user can add additional "on-board" hardware (for example, extra PIA's, ACIA's, EROM's, and so on).

This manual is divided into three Sections:

Section I GETTING THE SYSTEM RUNNING. Section II USING THE SYSTEM MONITOR. (listing included) Section III EXPANDING THE SYSTEM.

Please read Section I thoroughly, before attempting to "power-up" your system, and study Section III carefully before attempting to expand your system. In addition to this manual, Apple "Tech Notes" are available which contain examples of expansion hardware and techniques.

# SECTION I GETTING THE SYSTEM RUNNING

The Apple Computer is fully assembled, tested, and burned in. The only external devices necessary for operation of the system are: An ASCII encoded keyboard, a video display monitor, and AC power sources of 8 to 10 Volts (RMS) @3 amps and 28Volts (RMS) @1 amp. The following three articles describe the attachment of these devices in detail.

#### Keyboard:

Any ASCII encoded keyboard, with positive DATA outputs, interfaces directly with the Apple system via a "DIP" connector. If your keyboard has negative logic DATA outputs (rare), you can install inverters (7404) in the breadboard area. The strobe can be either positive or negative, of long or short duration. The "DIP" keyboard connector (B4) has inputs for seven DATA lines, one STROBE line, and two normally-open pushbutton switches, used for RESET (enter monitor), and CLEAR SCREEN (see schematic diagram, sheet 3 of 3, for exact circuitry). This keyboard connector also supplies three voltages, (+5V, +12V, and-12V) of which one or more may be necessary to operate the keyboard. Pin 15 of the keyboard connector (B4) must be tied to +5V (pin 16) for normal operation.

NOTE: The system monitor accepts only uppercase alpha (A-F, R).

It is therefore convenient, though it's not essential, to have a keyboard equipped with uppercase alpha lock (usually in the electronics). Either of the following suggested circuits may be used to provide alpha lock capability, if needed, and can be built in the breadboard area.



#### Display:

The Apple Computer outputs a composite video signal (composite of sync and video information) which can be applied to any standard raster-scan type video display monitor. The output level is adjustable with the potentiometer located near the video output Molex connector, J2. The additional two outside pins on the Molex connector supply 45 and +12 volts, to be used in future Apple accessories. The composite video signal can also be modulated at the proper RF frequency, with an inexpensive commercially available device, and applied to the antenna terminals of a home television receiver. Since the character format is 40 characters / line, all television receivers will have the necessary bandwidth to display the entire 40 characters. Two large manufacturers of video display monitors, which connect directly with the Apple Computer, are Motorola and Ball. The mating four-pin Molex connector is provided.

#### AC Power Sources:

Two incoming AC power sources are required for operation: 8to10 VAC (RMS) at 3 amps, and 28 VAC (RMS) Center-Tapped at lamp. These AC supplies enter the system at the Molex connector, J1. The 8to10 volts AC provides the raw AC for the +5 volt supply, while the 28 VCT supplies the raw AC for the +12 and -12 volt supplies, and the -5V supply is derived from the -12V regulated output.

The board, as supplied, requires no more than 1.5 amps DC from the 45V supply, while the regulator is capable of supplying 3 amps. The remaining 1.5 amps DC from the 45V supply is available for user hardware expansion (provided suitable transformer ratings are employed).

A suitable source of the raw AC voltages required, are two commercially available transformers; Stancor P/N P-8380 or equivalent (8 to 10 volts at 3 amps), and Stancor P/N P-8667 or equivalent (28VCT at 1 amp). Simply wire the secondaries to the mating six-pin Molex connector supplied, and wire the primaries in parallel, as shown in the schematic diagram (power supp section, Dwg.No. 00101, sheet 3 of 3.

# TEST PROGRAM

After attaching the keyboard, display, and AC power sources, you can try a simple program to test if your system and the attachments are functioning together properly. While it does not test many possible areas of the microprocessor system, the test program will test for the correct attachment of the keyboard, display, and power supplies.

#### FIRST:

Hit the RESET button to enter the system monitor. A backslash should be displayed, and the cursor should drop to the next line.

#### SECOND:

Type- Ø: A9 bØ bAA b 2Ø b EF b FF b E8 b 8A b 4C b 2 bØ (RET) (Ø is a zero, NOT an alpha "O"; b means blank or space; and (RET) hit the "return" key on the keyboard)

#### THIRD:

Type- Ø. A (RET) (This should print out, on the display, the program you have just entered.)

#### FOURTH:

Type- R (RET) (R means run the program.)

THE PROGRAM SHOULD THEN PRINT OUT ON THE DISPLAY A CONTINUOUS STREAM OF ASCII CHARACTERS. TO STOP THE PRO-GRAM AND RETURN TO THE SYSTEM MONITOR, HIT THE "RESET" BUTTON, TO RUN AGAIN, TYPE : R (RET).

# 6502 HEX MONITOR LISTING

RESET

NOTCR

ESCAPE

GETLINE

BACKSPACE

NEXTCHAR

SETSTOR

SETMODE

NEXT ITEM

NEXTHEX

DIG

HEXSHIFT

BLSKIP

FFØØ	77.8
FFØ1	58
FFØ2	AØ 7F
	0C 12 Dd
FFØ4	8C 12 DØ
FFØ7	A9 A7
FFØ9	8D 11 DØ
	8D 13 DØ
FFØF	C9 DF
	FØ 13
<b>FF13</b>	C9 9B
FF15	FØ 03
FF17	
FF18	10 ØF
EF1A	A9 DC
	20 EF FF
FFIF	A9 8D
	20 EF FF
FF24	AØØ1
FF26	88
	3Ø F6
<b>FF29</b>	AD 11 DØ
FF2C	10 FB
TROP	AD 10 DØ
FF31	99 ØØ Ø2
<b>FF34</b>	20 EF FF
	C9 8D
FF 39	DØ D4
FF3B	AØ FF
FF3D	A9 ØØ
FF3F	AA
FF4Ø	ØA
I I I IV	or on
	85 2B
FF43	C8
FF44	B9 ØØ Ø2
1111	D7 44 45
FF47	C9 8D
FF49	FØ D4
FF4B	C9 AE
	9Ø F4
FF4F	FØFØ
FF51	C9 BA
FF53	FØEB
FF55	C9 D2
FF57	FØ 3B
FF59	86 28
FF5B	86 29
FF5D	84 2A
	B9 ØØ Ø2
FF5F	
FF62	49 BØ
FF64	C9 ØA
FF66	90 06
FF68	69 88
FF6A	C9 FA
FF6C	90 11
FF6E	ØA
FF6F	ØA
FF7Ø	ØA
FF71	ØA
FF72	A2 Ø4
FF74	ØA
1000 1000	Sector Contraction of the sector of the sect

CLD CLI LDY #\$7F STY DSP LDA #\$A7 STA KBD CR STA DSP CR CMP #\$DF BEQ BACKSPACE CMP #\$9B BEQ ESCAPE INY BPL NEXTCHAR LDA #\$DC JSR ECHO LDA #\$8D JSR ECHO LDY #\$Ø1 DEY BMI GETLINE LDA KBD CR BPL NEXTCHAR LDA KBD STA IN, Y JSR ECHO CMP #\$8D BNE NOTCR LDY #\$FF LDA #\$ØØ TAX ASL STA MODE INY . LDA IN, Y CMP #\$8D BEQ GETLINE CMP #\$AE BCC BLSKIP BEQ SETMODE CMP #\$BA BEQ SETSTOR CMP #\$D2 BEQ RUN STX L STX H STY YSAV LDA IN, Y EOR #\$BØ CMP #\$ØA BCC DIG ADC #\$88 CMP #\$FA BCC NOTHEX ASL ASL ASL ASL LDX #\$Ø4 ASL

Clear decimal arithmetic mode. Mask for DSP data direction register. Set it up. KBD and DSP control register mask. Enable interrupts, set CA1, CB1, for positive edge sense/output mode. 11-11? Yes. ESC? Yes. Advance text index. Auto ESC if >127. 11 \ 11 Output it. CR. Output it. Initiallize text index. Back up text index. Beyond start of line, reinitialize. Key ready? Loop until ready. Load character. B7 should be '1'. Add to text buffer. Display character. CR? No. Reset text index. For XAM mode. Ø-►X. Leaves \$7B if setting STOR mode. \$ØØ = XAM, \$7B = STOR, \$AE = BLOK XAM. Advance text index. Get character. CR? Yes, done this line. 11.11? Skip delimiter. Set BLOCK XAM mode. 11.11 ? Yes, set STOR mode. "R"? Yes, run user program. \$00→L. and H. Save Y for comparison. Get character for hex test. Map digits to \$∅-9. Digit? Yes. Map letter "A"-"F" to \$FA-FF. Hex letter? No, character not hex. Hex digit to MSD of A.

Shift count. Hex digit left, MSB to carry.

# 6502 HEX MONITOR LISTING (continued)

		0502	HEX MONITOR LIST	tio (continued)
<b>FF75</b>	26 28		ROL L	Rotate into LSD.
FF77	26 29		ROL H	Rotate into MSD's.
FF79	CA		DEX	Done 4 shifts?
FF7A	DØF8		BNE HEXSHIFT	No, loop.
FF7C			INY	Advence text index.
	DØ EØ		BNE NEXTHEX	Always taken. Check next character for hex.
	C4 2A	NOTHEX	CPY YSAV	Check if L, H empty (no hex digits).
FF81	FØ 97		BEQ ESCAPE	Yes, generate ESC sequence.
FF83	24 2B		BIT MODE	Test MODE byte.
FF85	5Ø 1Ø		BVC NOTSTOR	B6 = $\emptyset$ for STOR, 1 for XAM and BLOCK XAM
	A5 28		LDA L	LSD's of hex data.
FF89	81 26		STA (STL, X)	Store at current 'store index'.
	E6 26		INC STL	Increment store index.
	DØ B5		BNE NEXTITEM	Get next item. (no carry).
	E6 27		INC STH	Add carry to 'store index' high order.
FF91	4C 44 FF	TONEXTITEM	JMP NEXTITEM	Get next command item.
	6C 24 ØØ	RUN	JMP (XAML)	Run at current XAM index.
FF97	3Ø 2B	NOTSTOR	BMI XAMNEXT	B7 = $\emptyset$ for XAM, 1 for BLOCK XAM.
FF99	A2 Ø2		LDX #\$Ø2	Byte count.
	B5 27	SETADR	LDA L-1, X	Copy hex data to
	95 25		STA STL-1, X	'store index'.
FF9F	95 23		STA XAML-1, X	And to 'XAM index'.
	CA		DEX	Next of 2 bytes.
	DØF7		BNE SETADR	Loop unless $X = \emptyset$ .
	DØ 14	NXTPRNT	BNE PRDATA	NE means no address to print.
	A9 8D		LDA #\$8D	CR.
	20 EF FF		JSR ECHO	Output it.
	A5 25		LDA XAMH	'Examine index' high-order byte.
	20 DC FF		JSR PRBYTE	Output it in hex format.
	A5 24		LDA XAML	Low-order 'examine index' byte.
	20 DC FF		JSR PRBYTE	Output it in hex format.
	A9 BA		LDA #\$BA	":".
FFB7	20 EF FF A9 A0	PRDATA	JSR ECHO	Output it. Blank,
		PRDATA	LDA #\$AØ JSR ECHO	
	2Ø EF FF Al 24			Output it.
FFC1	20 DC FF		LDA (XAML, X) JSR PRBYTE	Get data byte at 'examine index'. Output it in hex format.
FFC4	86 2B	XAMNEXT	STX MODE	Ø MODE (XAM mode).
	A5 24		LDA XAML	¢ ♥ MODE (MMM mode).
	C5 28		CMP L	Compare 'examine index' to hex data.
	A5 25		LDA XAMH	compare examine index to nex data.
	E5 29		SBC H	
	BØ C1		BCS TONEXTITEM	Not less, so no more data to output.
	E6 24		INC XAML	Not 1053, 50 no more data to output.
	DØ Ø2		BNE MOD8CHK	Increment 'examine index'.
	E6 25		INC XAMH	Inc. outon of the start of the
	A5 24	MOD8CHK	LDA XAML	Check low-order 'examine index' byte
	29 Ø7	IN DOUTE	AND #\$Ø7	For MOD 8= Ø
	1Ø C8		BPL NXTPRNT	Always taken.
FFDC		PRBYTE	PHA	Save A for LSD.
FFDD			LSR	
FFDE	100740		LSR	
FFDF			LSR	MSD to LSD position.
FFEØ			LSR	
FFE1	20 E5 FF		JSR PRHEX	Output hex digit.
FFE4			PLA	Restore A.
	29 ØF	PRHEX	AND #\$ØF	Mask LSD for hex print.
	Ø9 BØ		ORA #\$BØ	Add "Ø".
	C9 BA		CMP #\$BA	Digit?
			10 St 5	0

A

\*

# 6502 HEX MONITOR LISTING (continued)

FFEB	90 02
FFED	69 Ø6
FFEF	2C 12 DØ ECHO
FFF2	3Ø FB
FFF4	8D 12 DØ
FFF7	6Ø
FFF8	ØØ ØØ (unused)
FFFA	ØØ ØF (NMI)
FFFC	ØØ FF (RESET)
FFFE	00 00 (IRO)

BCC ECHO ADC #\$Ø6 BIT DSP BMI ECHO STA DSP RTS Yes, output it. Add offset for letter. DA bit (B7) cleared yet? No, wait for display. Output character. Sets DA. Return.

# HARDWARE NOTES

Page Ø Variables			
XAML	24		
XAMH	25		
STL	26		
STH	27		
L	28		
H	29		
YSAV	2A		
MODE	2B		

IN	2ØØ-27F	_
KBD	DØ1Ø	)
KBD CR	DØ11	PIA
DSP	DØ12	
DSP CR	DØ13	)

KBD/DSP Interface



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# SECTION III HOW TO EXPAND THE APPLE SYSTEM

The Apple system can be expanded to include more memory and IO devices, via a 44-pin edge connector. The system is fully expandable to 65K, with the entire data and address busses, clocks, control signals (i. e. IRQ, NMI, DMA, RDY, etc.), and power sources available at the connector. All address lines are TTL buffered, and data lines can drive ten equivalent capacitive loads (one TTL load and 130pf) without external buffers. All clock signals are TTL. The Apple system runs at approximately 1 MHz (see spec sheet) and is fully compatible with 6800/6500 style timing.

Three power sources are available at the edge connector: +5 volts regulated, and raw DC (approximately +/- 14V) for the +12V, -12V, and -5V supplies. If +12V, -12V, or -5V supplies are required, EXTERNAL REGULATORS MUST BE USED. An excess of 1.5 amps from the "onboard" regulated +5V supply is available for expansion (assuming suitable transformer ratings are employed). Exercise great care in the handling of the raw DC, as no short-circuit protection is provided.

# REFRESH:

Four out of every 65 clock cycles is dedicated to memory refresh. At the start of a refresh cycle (150 ns after leading edge of  $\emptyset$ 1),  $\overline{\text{RF}}$ goes low, and remains low for one clock cycle.  $\emptyset$ 2 is inhibited during a refresh cycle, and the processor is held in  $\emptyset$ 1 (it's inactive state). Dynamic memories, which must clock during refresh cycles, should derive their clock from  $\emptyset$ 0, which is equivalent to  $\emptyset$ 2, except that it continues during a refresh cycle. Devices, such as PIA's, will not be affected by a refresh cycle, since they react to  $\emptyset$ 2 only. Refer to Apple "Tech Notes" for a variety of interfacing examples.

# DMA:

The Apple system has full DMA capabil: For DMA, the DMA control line tri-states i address buss, thus allowing external devices to control the buss. Consult MOS TECHNOLOGY 6502 Hardware Manual for details. (For DMA use, the solder jumper on the board, marked "DMA", must be broken.)

For the 6502 microprocessor, the RDY line is used to halt the processor for single stepping, or slow ROM applications. Refer to Apple "Tech Notes" for examples.

#### SOFTWARE CONSIDERATIONS:

The sequences listed below are the routines used to read the keyboard or output to the display.

Read Key from KBD: <sup>LDA</sup> KBD CR (DØ11) BPL LDA KBD DATA (DØ10)

Output to Display: (DØ12) BPL STA DSP (DØ12) (DØ12)

PIA Internal Registers: KBD Data DØ1Ø High order bit equals 1.

> KBD Control Reg. DØ11 High order bit indicates "key ready". Reading key clears flag. Rising edge of KBD sets flag.

> DSP DATA DØ12 Lower seven bits are data output, high order bit is "display ready" input (lequals ready, Ø equals busy)

DSP Control Reg. DØ13





SLOW ROM

(NOTE: Features not needed may be omitted)

SINGLE STEP FOR 6502

# ADDRESS DISPLAY



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