APPLE COMPUTER CO.

NEWTON --- "A MIND FOREVER VOYAGING THROUGH STRANGE SEAS OF THOUGHT --- ALONE."

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:	15734 Hz
Frame Rate:	60.05 Hz
Format:	40 characters/line, 24 lines; with automatic scrolling
Display Memory:	Dynamic shift registers (1K x 7)
Character Matrix:	5 x 7
RAM MEMORY:	16-pin, 4K Dynamic, type 4096 (2104)
On-board RAM Capacity:	8K bytes (4K supplied)
POWER SUPPLIES:	+5 Volts @ 3 amps, +/- 12 Volts @0.5 amp and -5 Volts @ 0.5 amps
Input Power Requirements:	8 to 10 Volts AC (RMS) @ 3 amps, 26 to 28 Volts AC (RMS) Center-Tapped, 1A.
Recommended Transformers:	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 micro-ocessor system, consisting of a Mos Technology)2 microprocessor and support hardware, in-gral 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

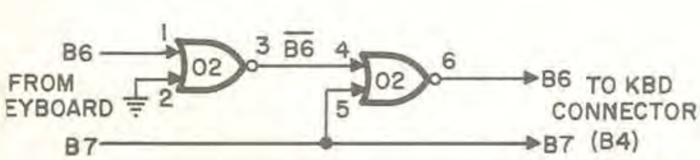
The Apple Computer is fully assembled, tested, and burned in. The only external devices necessary for operation of the system are: An ASCII encoded keyboard, a video display monitor, and AC power sources of 8 to 10 Volts (RMS) @3 amps and 28Volts (RMS) @1 amp. The following three articles describe the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

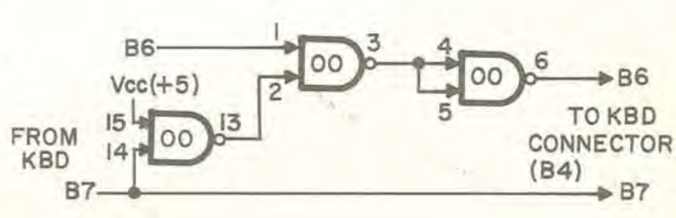
Keyboard:

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 upper-case alpha (A-F, R).

It is therefore convenient, though it's not essential, to have a keyboard equipped with upper-case 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 +5 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: 8 to 10 VAC (RMS) at 3 amps, and 28 VAC (RMS) Center-Tapped at 1 amp. These AC supplies enter the system at the Molex connector, J1. The 8 to 10 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 +5V supply, while the regulator is capable of supplying 3 amps. The remaining 1.5 amps DC from the +5V 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 b Ø b AA b 2Ø b EF b FF b E8 b 8A b 4C b 2 b Ø (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 PROGRAM AND RETURN TO THE SYSTEM MONITOR, HIT THE "RESET" BUTTON. TO RUN AGAIN, TYPE : R (RET).

```
FFØØ  D8          RESET       CLD              Clear decimal arithmetic mode.
FFØ1  58                      CLI
FFØ2  AØ 7F                   LDY #$7F         Mask for DSP data direction register.
FFØ4  8C 12 DØ                STY DSP          Set it up.
FFØ7  A9 A7                   LDA #$A7         KBD and DSP control register mask.
FFØ9  8D 11 DØ                STA KBD CR       Enable interrupts, set CA1, CB1, for
FFØC  8D 13 DØ                STA DSP CR        positive edge sense/output mode.
FFØF  C9 DF       NOTCR       CMP #$DF         "←"?
FF11  FØ 13                   BEQ BACKSPACE    Yes.
FF13  C9 9B                   CMP #$9B         ESC?
FF15  FØ 03                   BEQ ESCAPE       Yes.
FF17  C8                      INY              Advance text index.
FF18  1Ø ØF                   BPL NEXTCHAR     Auto ESC if >127.
FF1A  A9 DC       ESCAPE      LDA #$DC         "\".
FF1C  20 EF FF                JSR ECHO         Output it.
FF1F  A9 8D       GETLINE     LDA #$8D         CR.
FF21  2Ø EF FF                JSR ECHO         Output it.
FF24  AØ Ø1                   LDY #$Ø1         Initiallize text index.
FF26  88          BACKSPACE   DEY              Back up text index.
FF27  3Ø F6                   BMI GETLINE      Beyond start of line, reinitialize.
FF29  AD 11 DØ    NEXTCHAR    LDA KBD CR       Key ready?
FF2C  1Ø FB                   BPL NEXTCHAR     Loop until ready.
FF2E  AD 1Ø DØ                LDA KBD          Load character. B7 should be '1'.
FF31  99 ØØ Ø2                STA IN, Y        Add to text buffer.
FF34  2Ø EF FF                JSR ECHO         Display character.
FF37  C9 8D                   CMP #$8D         CR?
FF39  DØ D4                   BNE NOTCR        No.
FF3B  AØ FF                   LDY #$FF         Reset text index.
FF3D  A9 ØØ                   LDA #$ØØ         For XAM mode.
FF3F  AA                      TAX              Ø→X.
FF4Ø  ØA          SETSTOR     ASL              Leaves $7B if setting STOR mode.
FF41  85 2B       SETMODE     STA MODE         $ØØ = XAM, $7B = STOR, $AE = BLOK XAM.
FF43  C8          BLSKIP      INY              Advance text index.
FF44  B9 ØØ Ø2    NEXT ITEM   LDA IN, Y        Get character.
FF47  C9 8D                   CMP #$8D         CR?
FF49  FØ D4                   BEQ GETLINE      Yes, done this line.
FF4B  C9 AE                   CMP #$AE         "."?
FF4D  9Ø F4                   BCC BLSKIP       Skip delimiter.
FF4F  FØ FØ                   BEQ SETMODE      Set BLOCK XAM mode.
FF51  C9 BA                   CMP #$BA         ":"?
FF53  FØ EB                   BEQ SETSTOR      Yes, set STOR mode.
FF55  C9 D2                   CMP #$D2         "R"?
FF57  FØ 3B                   BEQ RUN          Yes, run user program.
FF59  86 28                   STX L            $ØØ→L.
FF5B  86 29                   STX H             and H.
FF5D  84 2A                   STY YSAV         Save Y for comparison.
FF5F  B9 ØØ Ø2    NEXTHEX     LDA IN, Y        Get character for hex test.
FF62  49 BØ                   EOR #$BØ         Map digits to $Ø-9.
FF64  C9 ØA                   CMP #$ØA         Digit?
FF66  9Ø Ø6                   BCC DIG          Yes.
FF68  69 88                   ADC #$88         Map letter "A"-"F" to $FA-FF.
FF6A  C9 FA                   CMP #$FA         Hex letter?
FF6C  9Ø 11                   BCC NOTHEX       No, character not hex.
FF6E  ØA          DIG         ASL
FF6F  ØA                      ASL              Hex digit to MSD of A.
FF7Ø  ØA                      ASL
FF71  ØA                      ASL
FF72  A2 Ø4                   LDX #$Ø4         Shift count.
FF74  ØA          HEXSHIFT    ASL              Hex digit left, MSB to carry.
```

```
FF75   26 28                    ROL L              Rotate into LSD.
FF77   26 29                    ROL H              Rotate into MSD's.
FF79   CA                       DEX                Done 4 shifts?
FF7A   DØ F8                    BNE HEXSHIFT       No, loop.
FF7C   C8                       INY                Advence text index.
FF7D   DØ EØ                    BNE NEXTHEX        Always taken. Check next character for hex.
FF7F   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 = Ø for STOR, 1 for XAM and BLOCK XAM
FF87   A5 28                    LDA L              LSD's of hex data.
FF89   81 26                    STA (STL, X)       Store at current 'store index'.
FF8B   E6 26                    INC STL            Increment store index.
FF8D   DØ B5                    BNE NEXTITEM       Get next item. (no carry).
FF8F   E6 27                    INC STH            Add carry to 'store index' high order.
FF91   4C 44 FF   TONEXTITEM    JMP NEXTITEM       Get next command item.
FF94   6C 24 ØØ   RUN           JMP (XAML)         Run at current XAM index.
FF97   3Ø 2B      NOTSTOR       BMI XAMNEXT        B7 = Ø for XAM, 1 for BLOCK XAM.
FF99   A2 Ø2                    LDX #$Ø2           Byte count.
FF9B   B5 27      SETADR        LDA L-1, X         Copy hex data to
FF9D   95 25                    STA STL-1, X        'store index'.
FF9F   95 23                    STA XAML-1, X      And to 'XAM index'.
FFA1   CA                       DEX                Next of 2 bytes.
FFA2   DØ F7                    BNE SETADR         Loop unless X = Ø.
FFA4   DØ 14      NXTPRNT       BNE PRDATA         NE means no address to print.
FFA6   A9 8D                    LDA #$8D           CR.
FFA8   2Ø EF FF                 JSR ECHO           Output it.
FFAB   A5 25                    LDA XAMH           'Examine index' high-order byte.
FFAD   2Ø DC FF                 JSR PRBYTE         Output it in hex format.
FFBØ   A5 24                    LDA XAML           Low-order 'examine index' byte.
FFB2   2Ø DC FF                 JSR PRBYTE         Output it in hex format.
FFB5   A9 BA                    LDA #$BA           ":".
FFB7   2Ø EF FF                 JSR ECHO           Output it.
FFBA   A9 AØ      PRDATA        LDA #$AØ           Blank.
FFBC   2Ø EF FF                 JSR ECHO           Output it.
FFBF   A1 24                    LDA (XAML, X)      Get data byte at 'examine index'.
FFC1   2Ø DC FF                 JSR PRBYTE         Output it in hex format.
FFC4   86 2B      XAMNEXT       STX MODE           Ø→ MODE (XAM mode).
FFC7   A5 24                    LDA XAML
FFC8   C5 28                    CMP L              Compare 'examine index' to hex data.
FFCA   A5 25                    LDA XAMH
FFCC   E5 29                    SBC H
FFCE   BØ C1                    BCS TONEXTITEM     Not less, so no more data to output.
FFDØ   E6 24                    INC XAML
FFD2   DØ Ø2                    BNE MOD8CHK        Increment 'examine index'.
FFD4   E6 25                    INC XAMH
FFD6   A5 24      MOD8CHK       LDA XAML           Check low-order 'examine index' byte
FFD8   29 Ø7                    AND #$Ø7            For MOD 8 = Ø
FFDA   1Ø C8                    BPL NXTPRNT        Always taken.
FFDC   48         PRBYTE        PHA                Save A for LSD.
FFDD   4A                       LSR
FFDE   4A                       LSR
FFDF   4A                       LSR                MSD to LSD position.
FFEØ   4A                       LSR
FFE1   2Ø E5 FF                 JSR PRHEX          Output hex digit.
FFE4   68                       PLA                Restore A.
FFE5   29 ØF      PRHEX         AND #$ØF           Mask LSD for hex print.
FFE7   Ø9 BØ                    ORA #$BØ           Add "Ø".
FFE9   C9 BA                    CMP #$BA           Digit?
```

65Ø2 HEX MONITOR LISTING (continued)

```
FFEB  9Ø Ø2                    BCC ECHO     Yes, output it.
FFED  69 Ø6                    ADC #$Ø6     Add offset for letter.
FFEF  2C 12 DØ      ECHO       BIT DSP      DA bit (B7) cleared yet?
FFF2  3Ø FB                    BMI ECHO     No, wait for display.
FFF4  8D 12 DØ                 STA DSP      Output character.  Sets DA.
FFF7  6Ø                       RTS          Return.
FFF8  ØØ ØØ (unused)
FFFA  ØØ ØF (NMI)
FFFC  ØØ FF (RESET)
FFFE  ØØ ØØ (IRQ)
```

HARDWARE NOTES

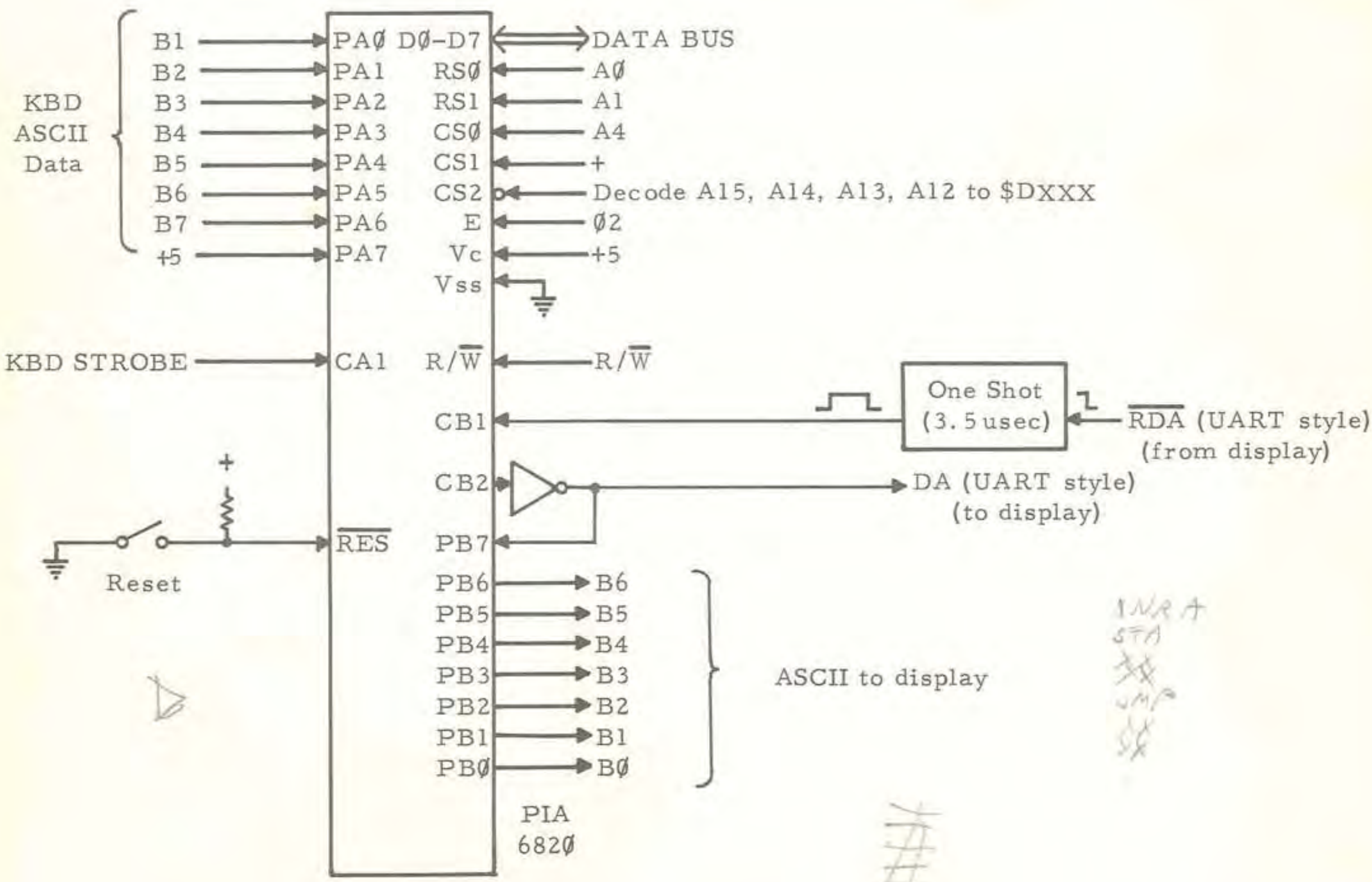
Page Ø Variables

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

Other Variables

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

KBD/DSP Interface



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 "on-board" 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 Ø1), $\overline{RF}$ goes low, and remains low for one clock cycle. Ø2 is inhibited during a refresh cycle, and the processor is held in Ø1 (it's inactive state). Dynamic memories, which must clock during refresh cycles, should derive their clock from Ø0, which is equivalent to Ø2, 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 Ø2 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 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:

```
    LDA KBD CR (DØ11)
    BPL
    LDA KBD DATA (DØ1Ø)
```

Output to Display:

```
    BIT DSP (DØ12)
    BPL
    STA DSP (DØ12)
```

PIA Internal Registers:

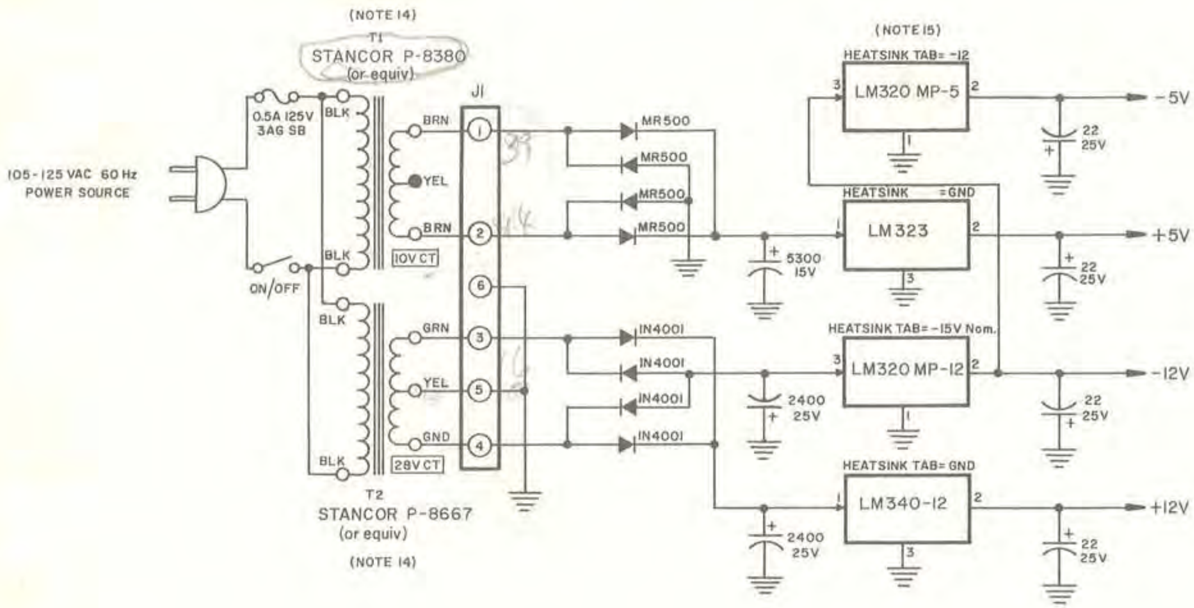
KBD Data — DØ1Ø
High order bit equals 1.

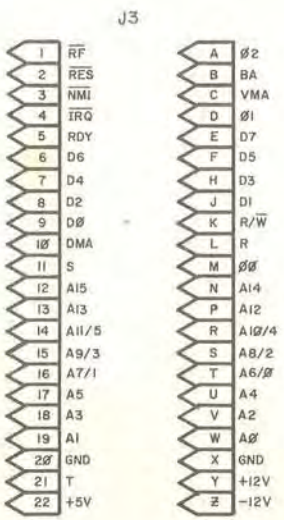
KBD Control Reg. — DØ11
High order bit indicates "key ready". Reading key clears flag. Rising edge of KBD sets flag.

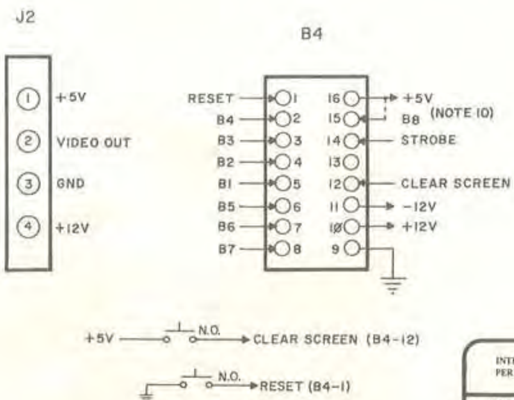
DSP DATA — DØ12
Lower seven bits are data output, high order bit is "display ready" input (1 equals ready, Ø equals busy)

DSP Control Reg. — DØ13

REVISIONS				
SYM	DESCRIPTION	INITIALS and DATE		
		DRFTG.	CHECK	ENGRG.
A				







NOTES: (continued from sheet 2/3)

14. T1 EQUIVALENT TRANSFORMER SHALL BE 8 TO 10 VOLT SECONDARY, WITH 3 AMP MINIMUM CURRENT RATING. T2 EQUIVALENT TRANSFORMER SHALL BE 28 VOLT SECONDARY, CENTER-TAPPED, WITH 1 AMP MINIMUM RATING.

15. CASE OF REGULATOR, LM323, AND HEAT SINK TABS OF REMAINING THREE REGULATORS ARE ALL AT DIFFERENT ELECTRICAL POTENTIALS. CAUTION SHOULD BE EXERCISED TO INSURE AGAINST DIRECT ELECTRICAL CONTACT BETWEEN THESE POINTS. THEY MUST NOT BE SHORTED TOGETHER, NOR TO THE HEATSINK OF THE LM323.

-REF-	00100
NEXT ASSY	USED ON
APPLICATION	

INTERPRET THIS DRAWING PER USASI Y14.5

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON:
FRACTIONS = ±1/16 .x = ±.1
ANGLES = ±1° .xx = ± .03
SURFACE FINISH .xxx = ± .010

MATERIAL:

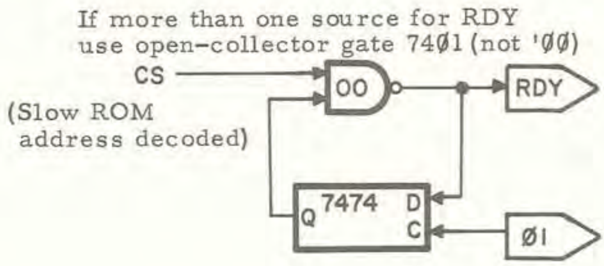
		DATE
DRAWN BY	R. WAYNE	4-2-76
CHECKED		
DESIGN ENGINEER	S. WOZNIAK	3-10-76
PROJECT ENGINEER	S. JOBS	3-10-76
DOCUMENT CONTROL		
APPROVED		

APPLE COMPUTER COMPANY

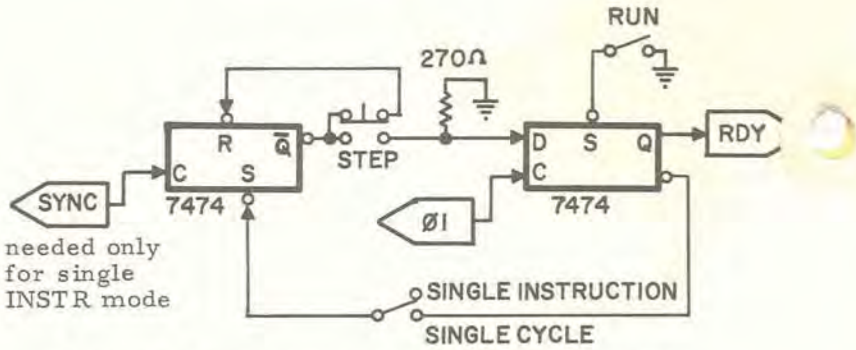
TITLE: SCHEMATIC DIAGRAM
APPLE-1
POWER SUPPLY

SIZE: C | DRAWING NO. 00101 | REV: A
SCALE | SHEET 3 OF 3

DRAWING NO. 00101 | SHEET 3/3 | REV A



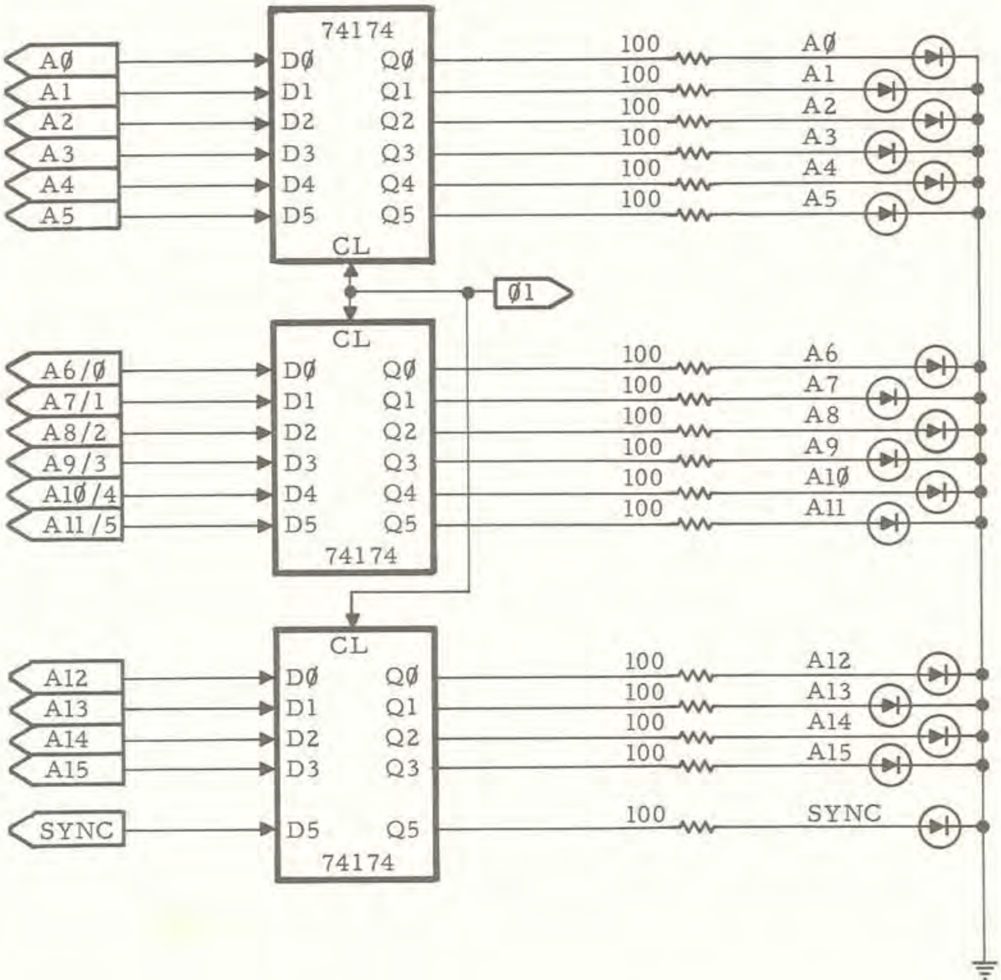
SLOW ROM



(NOTE: Features not needed may be omitted)

SINGLE STEP FOR 6502

ADDRESS DISPLAY



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The responsibility for the failure of any Apple Computer product, or component thereof, which, at the discretion of the Apple Computer Company, shall have resulted either directly or indirectly from accident, abuse, or misapplication of the product, shall be assumed by the customer, and the Apple Computer Company shall assume no liability as a consequence of such events under the terms of this warranty.

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