Woz

APPLE II®
REFERENCE MANUAL

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Apple II Reference Manual

A REFERENCE MANUAL
FOR THE APPLE II
AND THE APPLE II PLUS
PERSONAL COMPUTERS

TABLE OF CONTENTS

CHAPTER 1
APPROACHING YOUR APPLE

CHAPTER 2
CONVERSATION WITH APPLES

CHAPTER 3
THE SYSTEM MONITOR

CHAPTER 4
MEMORY ORGANIZATION

CHAPTER 5
INPUT/OUTPUT STRUCTURE

CHAPTER 6
HARDWARE CONFIGURATION

INDEX

INTRODUCTION

This is the User Reference Manual for the Apple II and Apple II Plus personal computers. Like the Apple itself, this book is a tool. As with all tools, you should know a little about it before you start to use it.

This book will not teach you how to program. It is a book of facts, not methods. If you have just unpacked your Apple, or you do not know how to program in any of the languages available for it, then before you continue with this book, read one of the other manuals accompanying your Apple. Depending upon which variety of Apple you have purchased, you should have received one of the following:

Apple II BASIC Programming Manual
(part number A2L0005)

The Applesoft Tutorial
(part number A2L0018)

These are tutorial manuals for versions of the BASIC language available on the Apple. They also include complete instructions on setting up your Apple. The Bibliography at the end of this manual lists other books which may interest you.

There are a few different varieties of Apples, and this manual applies to all of them. It is possible that some of the features noted in this manual will not be available on your particular Apple. In places where this manual mentions features which are not universal to all Apples, it will use a footnote to warn you of these differences.

This manual describes the Apple II computer and its parts and procedures. There are sections on the System Monitor, the input/output devices and their operation, the internal organization of memory and input/output devices, and the actual electronic design of the Apple itself. For information on any other Apple hardware or software product, please refer to the manual accompanying that product.

CHAPTER 1
APPROACHING YOUR APPLE

For detailed information on setting up your Apple, refer to Chapter 1 of either the **Apple BASIC Programming Manual** or **The Applesoft Tutorial.**

In this manual, all directional instructions will refer to this orientation: with the Apple's typewriter-like keyboard facing you, "front" and "down" are towards the keyboard, "back" and "up" are away. Remove the lid of the Apple by prying up the back edge until it "pops", then pull straight back on the lid and lift it off.

This is what you will see:

Photo 1. The Apple II.

THE POWER SUPPLY

The metal box on the left side of the interior is the Power Supply. It supplies four voltages: +5v, −5.2v, +11.8v, and −12.0v. It is a high-frequency "switching"-type power supply, with many protective features to ensure that there can be no imbalances between the different supplies. The main power cord for the computer plugs directly into the back of the power supply. The power-on switch is also on the power supply itself, to protect you and your fingers from accidentally becoming part of the high-voltage power supply circuit.

110 volt model

110/220 volt model

Photo 2. The back of the Apple Power Supply.

THE MAIN BOARD

The large green printed circuit board which takes up most of the bottom of the case is the computer itself. There are two slightly different models of the Apple II main board: the original (Revision Ø) and the Revision 1 board. The slight differences between the two lie in the electronics on the board. These differences are discussed throughout this book. A summary of the differences appears in the section "Varieties of Apples" on page 25.

On this board there are about eighty integrated circuits and a handful of other components. In the center of the board, just in front of the eight gold-toothed edge connectors ("slots") at the rear of the board, is an integrated circuit larger than all others. This is the brain of your Apple. It is a Synertek/MOS Technology 65Ø2 microprocessor. In the Apple, it runs at a rate of 1,023,000 machine cycles per second and can do over five hundred thousand addition or subtraction operations in one second. It has an addressing range of 65,536 eight-bit bytes. Its repertory includes 56 instructions with 13 addressing modes. This microprocessor and other versions of it are used in many computers systems, as well as other types of electronic equipment.

Just below the microprocessor are six sockets which may be filled with from one to six slightly smaller integrated circuits. These ICs are the Read-Only Memory (ROM) "chips" for the Apple. They contain programs for the Apple which are available the moment you turn on the power. Many programs are available in ROM, including the Apple System Monitor, the Apple Autostart Monitor, Apple Integer BASIC and Applesoft II BASIC, and the Apple *Programmer's Aid # 1* utility subroutine package. The number and contents of your Apple's ROMs depend upon which type of Apple you have, and the accessories you have purchased.

Right below the ROMs and the central mounting nut is an area marked by a white square on the board which encloses twenty-four sockets for integrated circuits. Some or all of these may be filled with ICs. These are the main Random Access Memory (RAM) "chips" for your Apple. An Apple can hold 4,096 to 49,152 bytes of RAM memory in these three rows of components.* Each row can hold eight ICs of either the 4K or 16K variety. A row must hold eight of the same

* You can extend your RAM memory to 64K by purchasing the Apple Language Card, part of the Apple Language System (part number A2B0006).

type of memory components, but the two types can both be used in various combinations on different rows to give nine different memory sizes.* The RAM memory is used to hold all of the programs and data which you are using at any particular time. The information stored in RAM disappears when the power is turned off.

The other components on the Apple II board have various functions: they control the flow of information from one part of the computer to another, gather data from the outside world, or send information to you by displaying it on a television screen or making a noise on a speaker.

The eight long peripheral slots on the back edge of the Apple's board can each hold a peripheral card to allow you to extend your RAM or ROM memory, or to connect your Apple to a printer or other input/output device. These slots are sometimes called the Apple's "backplane" or "mother board".

TALKING TO YOUR APPLE

Your link to your Apple is at your fingertips. Most programs and languages that are used with the Apple expect you to talk to them through the Apple's keyboard. It looks like a normal typewriter keyboard, except for some minor rearrangement and a few special keys. For a quick review on the keyboard, see pages 6 through 12 in the **Apple II BASIC Programming Manual** or pages 5 through 11 in **The Applesoft Tutorial**.

Since you're talking with your fingers, you might as well be hearing with your eyes. The Apple will tell you what it is doing by displaying letters, numbers, symbols, and sometimes colored blocks and lines on a black-and-white or color television set.

* The Apple II is designed to use both the 16K and the less expensive 4K RAMs. However, due to the greater availability and reduced cost of the 16K chips, Apple now supplies only the 16K RAMs.

THE KEYBOARD

The Apple Keyboard

Number of Keys:	52
Coding:	Upper Case ASCII
Number of codes:	91
Output:	Seven bits, plus strobe
Power requirements:	+5v at 120mA −12v at 50mA
Rollover:	2 key
Special keys:	CTRL ESC RESET REPT ← →

Memory mapped locations:

	Hex	Decimal	
Data	$C000	49152	-16384
Clear	$C010	49168	-16368

The Apple II has a built-in 52-key typewriter-like keyboard which communicates using the American Standard Code for Information Interchange (ASCII)*. Ninety-one of the 96 upper-case ASCII characters can be generated directly by the keyboard. Table 2 shows the keys on the keyboard and their associated ASCII codes. "Photo" 3 is a diagram of the keyboard.

The keyboard is electrically connected to the main circuit board by a 16-conductor cable with plugs at each end that plug into standard integrated circuit sockets. One end of this cable is connected to the keyboard; the other end plugs into the Apple board's keyboard connector, near the very front edge of the board, under the keyboard itself. The electrical specifications for this connector are given on page 102.

Most languages on the Apple have commands or statements which allow your program to accept input from the keyboard quickly and easily (for example, the INPUT and GET statements in BASIC). However, your programs can also read the keyboard directly.

* All ASCII codes used by the Apple normally have their high bit set. This is the same as standard mark-parity ASCII.

"Photo" 3. The Apple Keyboard.

READING THE KEYBOARD

The keyboard sends seven bits of information which together form one character. These seven bits, along with another signal which indicates when a key has been pressed, are available to most programs as the contents of a memory location. Programs can read the current state of the keyboard by reading the contents of this location. When you press a key on the keyboard, the value in this location becomes 128 or greater, and the particular value it assumes is the numeric code for the character which was typed. Table 3 on page 8 shows the ASCII characters and their associated numeric codes. The location will hold this one value until you press another key, or until your program tells the memory location to forget the character it's holding.

Once your program has accepted and understood a keypress, it should tell the keyboard's memory location to "release" the character it is holding and prepare to receive a new one. Your program can do this by referencing another memory location. When you reference this other location, the value contained in the first location will drop below 128. This value will stay low until you press another key. This action is called "clearing the keyboard strobe". Your program can either read or write to the special memory location; the data which are written to or read from that location are irrelevant. It is the mere *reference* to the location which clears the keyboard strobe. Once you have cleared the keyboard strobe, you can still recover the code for the key which was last pressed by adding 128 (hexadecimal \$8Ø) to the value in the keyboard location.

These are the special memory locations used by the keyboard:

Table 1: Keyboard Special Locations

Location: Hex	Decimal		Description
\$CØØØ	49152	-16384	Keyboard Data
\$CØ1Ø	49168	-16368	Clear Keyboard Strobe

The **RESET** key at the upper right-hand corner does not generate an ASCII code, but instead is directly connected to the microprocessor. When this key is pressed, all processing stops. When the key is released, the computer starts a reset cycle. See page 36 for a description of the RESET function.

The CTRL and SHIFT keys generate no codes by themselves, but only alter the codes produced by other keys.

The REPT key, if pressed alone, produces a duplicate of the last code that was generated. If you press and hold down the REPT key while you are holding down a character key, it will act as if you were pressing that key repeatedly at a rate of 10 presses each second. This repetition will cease when you release either the character key or REPT.

The POWER light at the lower left-hand corner is an indicator lamp to show when the power to the Apple is on.

Table 2: Keys and Their Associated ASCII Codes

Key	Alone	CTRL	SHIFT	Both	Key	Alone	CTRL	SHIFT	Both
space	$AØ	$AØ	$AØ	$AØ	RETURN	$8D	$8D	$8D	$8D
Ø	$BØ	$BØ	$BØ	$BØ	G	$C7	$87	$C7	$87
1!	$B1	$B1	$A1	$A1	H	$C8	$88	$C8	$88
2"	$B2	$B2	$A2	$A2	I	$C9	$89	$C9	$89
3#	$B3	$B3	$A3	$A3	J	$CA	$8A	$CA	$8A
4$	$B4	$B4	$A4	$A4	K	$CB	$8B	$CB	$8B
5%	$B5	$B5	$A5	$A5	L	$CC	$8C	$CC	$8C
6&	$B6	$B6	$A6	$A6	M	$CD	$8D	$DD	$9D
7'	$B7	$B7	$A7	$A7	N^	$CE	$8E	$DE	$9E
8(	$B8	$B8	$A8	$A8	O	$CF	$8F	$CF	$8F
9)	$B9	$B9	$A9	$A9	P@	$DØ	$9Ø	$CØ	$8Ø
:*	$BA	$BA	$AA	$AA	Q	$D1	$91	$D1	$91
;+	$BB	$BB	$AB	$AB	R	$D2	$92	$D2	$92
,<	$AC	$AC	$BC	$BC	S	$D3	$93	$D3	$93
-=	$AD	$AD	$BD	$BD	T	$D4	$94	$D4	$94
.>	$AE	$AE	$BE	$BE	U	$D5	$95	$D5	$95
/?	$AF	$AF	$BF	$BF	V	$D6	$96	$D6	$96
A	$C1	$81	$C1	$81	W	$D7	$97	$D7	$97
B	$C2	$82	$C2	$82	X	$D8	$98	$D8	$98
C	$C3	$83	$C3	$83	Y	$D9	$99	$D9	$99
D	$C4	$84	$C4	$84	Z	$DA	$9A	$DA	$9A
E	$C5	$85	$C5	$85	→	$88	$88	$88	$88
F	$C6	$86	$C6	$86	←	$95	$95	$95	$95
					ESC	$9B	$9B	$9B	$9B

All codes are given in hexadecimal. To find the decimal equivalents, use Table 3.

Table 3: The ASCII Character Set

Decimal:		128	144	160	176	192	208	224	240
	Hex:	$80	$90	$A0	$B0	$C0	$D0	$E0	$F0
0	$0	nul	dle		0	@	P		p
1	$1	soh	dc1	!	1	A	Q	a	q
2	$2	stx	dc2	"	2	B	R	b	r
3	$3	etx	dc3	#	3	C	S	c	s
4	$4	eot	dc4	$	4	D	T	d	t
5	$5	enq	nak	%	5	E	U	e	u
6	$6	ack	syn	&	6	F	V	f	v
7	$7	bel	etb	'	7	G	W	g	w
8	$8	bs	can	(	8	H	X	h	x
9	$9	ht	em	)	9	I	Y	i	y
10	$A	lf	sub	*	:	J	Z	j	z
11	$B	vt	esc	+	;	K	[	k	{
12	$C	ff	fs	,	<	L	\	l	|
13	$D	cr	gs	—	=	M	]	m	}
14	$E	so	rs	.	>	N	^	n	~
15	$F	si	us	/	?	O	_	o	rub

Groups of two and three lower case letters are abbreviations for standard ASCII control characters.

Not all the characters listed in this table can be generated by the keyboard. Specifically, the characters in the two rightmost columns (the lower case letters), the symbols [(left square bracket), \ (backslash), _ (underscore), and the control characters "fs", "us", and "rub", are not available on the Apple keyboard.

The decimal or hexadecimal value for any character in the above table is the sum of the decimal or hexadecimal numbers appearing at the top of the column and the left side of the row in which the character appears.

THE APPLE VIDEO DISPLAY

The Apple Video Display

Display type:	Memory mapped into system RAM
Display modes:	Text, Low-Resolution Graphics, High-Resolution Graphics
Text capacity:	960 characters (24 lines, 40 columns)
Character type:	5 × 7 dot matrix
Character set:	Upper case ASCII, 64 characters
Character modes:	Normal, Inverse, Flashing
Graphics capacity:	1,920 blocks (Low-Resolution) in a 40 by 48 array 53,760 dots (High-Resolution) in a 280 by 192 array
Number of colors:	16 (Low-Resolution Graphics) 6 (High-Resolution Graphics)

THE VIDEO CONNECTOR

In the right rear corner of the Apple II board, there is a metal connector marked "VIDEO". This connector allows you to attach a cable between the Apple and a closed-circuit video monitor. One end of the connecting cable should have a male RCA phono jack to plug into the Apple, and the other end should have a connector compatible with the particular device you are using. The signal that comes out of this connector on the Apple is similar to an Electronic Industries Association (EIA)-standard, National Television Standards Committee (NTSC)-compatible, positive composite color video signal. The level of this signal can be adjusted from zero to 1 volt peak by the small round potentiometer on the right edge of the board about three inches from the back of the board.

A non-adjustable, 2 volts peak version of the same video signal is available in two other places: on a single wire-wrap pin* on the left side of the board about two inches from the back of the board, and on one pin of a group of four similar pins also on the left edge near the back of the board. The other three pins in this group are connected to −5 volts, +12 volts, and ground. See page 97 for a full description of this auxiliary video connector.

* This pin is not present in Apple II systems with the Revision 0 board.

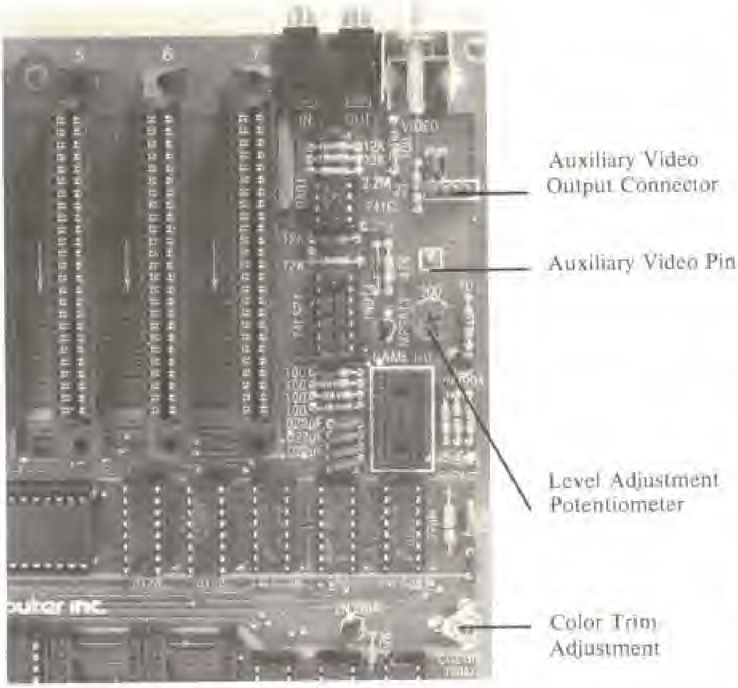


Photo 4. The Video Connectors and Potentiometer.

EURAPPLE (50 HZ) MODIFICATION

Your Apple can be modified to generate a video signal compatible with the CCIR standard used in many European countries. To make this modification, just cut the two X-shaped pads on the right edge of the board about nine inches from the back of the board, and solder together the three O-shaped pads in the same locations (see photo 5). You can then connect the video connector of your Apple to a European standard closed-circuit black-and-white or color video monitor. If you wish, you can obtain a "Eurocolor" encoder to convert the video signal into a PAL or SECAM standard color television signal suitable for use with any European television receiver. The encoder is a small printed circuit board which plugs into the rightmost peripheral slot (slot 7) in your Apple and connects to the single auxiliary video output pin.

> WARNING: This modification will void the warranty on your Apple and requires the installation of a different main crystal. This modification is not for beginners.

SCREEN FORMAT

Three different kinds of information can be shown on the video display to which your Apple is connected:

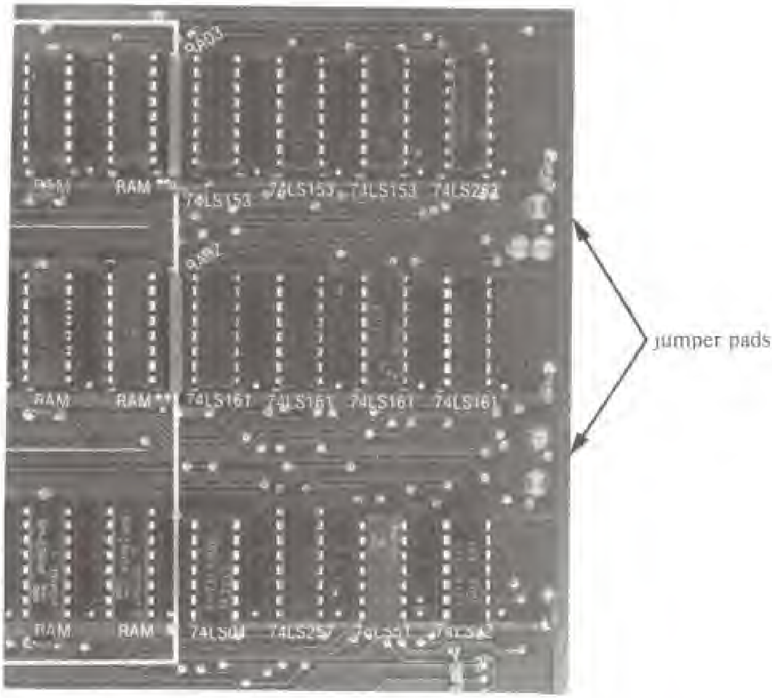


Photo 5. Eurapple (50 hz) Jumper Pads.

1) **Text**. The Apple can display 24 lines of numbers, special symbols, and upper-case letters with 40 of these characters on each line. These characters are formed in a dot matrix 7 dots high and 5 dots wide. There is a one-dot wide space on either side of the character and a one-dot high space above each line.

2) **Low-Resolution Graphics**. The Apple can present 1,920 colored squares in an array 40 blocks wide and 48 blocks high. The color of each block can be selected from a set of sixteen different colors. There is no space between blocks, so that any two adjacent blocks of the same color look like a single, larger block.

3) **High-Resolution Graphics**. The Apple can also display colored dots on a matrix 280 dots wide and 192 dots high. The dots are the same size as the dots which make up the Text characters. There are six colors available in the High-Resolution Graphics mode: black, white, red, blue, green, and violet.* Each dot on the screen can be either black, white, or a color, although not all colors are available for every dot.

When the Apple is displaying a particular type of information on the screen, it is said to be in that particular "mode". Thus, if you see words and numbers on the screen, you can reasonably be assured that your Apple is in Text mode. Similarly, if you see a screen full of multicolored blocks, your computer is probably in Low-Resolution Graphics mode. You can also have a four-line "caption" of text at the bottom of either type of graphics screen. These four lines replace

* For Apples with Revision Ø boards, there are four colors: black, white, green, and violet.

the lower 8 rows of blocks in Low-Resolution Graphics, leaving a 40 by 40 array. In High-Resolution Graphics, they replace the bottom 32 rows of dots, leaving a 280 by 160 matrix. You can use these "mixed modes" to display text and graphics simultaneously, but there is no way to display both graphics modes at the same time.

SCREEN MEMORY

The video display uses information in the system's RAM memory to generate its display. The value of a single memory location controls the appearance of a certain, fixed object on the screen. This object can be a character, two stacked colored blocks, or a line of seven dots. In Text and Low-Resolution Graphics mode, an area of memory containing 1,024 locations is used as the source of the screen information. Text and Low-Resolution Graphics share this memory area. In High-Resolution Graphics mode, a separate, larger area (8,192 locations) is needed because of the greater amount of information which is being displayed. These areas of memory are usually called "pages". The area reserved for High-Resolution Graphics is sometimes called the "picture buffer" because it is commonly used to store a picture or drawing.

SCREEN PAGES

There are actually *two* areas from which each mode can draw its information. The first area is called the "primary page" or "Page 1". The second area is called the "secondary page" or "Page 2" and is an area of the same size immediately following the first area. The secondary page is useful for storing pictures or text which you want to be able to display instantly. A program can use the two pages to perform animation by drawing on one page while displaying the other and suddenly flipping pages.

Text and Low-Resolution Graphics share the same memory range for the secondary page, just as they share the same range for the primary page. Both mixed modes which were described above are also available on the secondary page, but there is no way to mix the two pages on the same screen.

Table 4: Video Display Memory Ranges

Screen	Page	Begins at: Hex	Begins at: Decimal	Ends at: Hex	Ends at: Decimal
Text/Lo-Res	Primary	$400	1024	$7FF	2047
	Secondary	$800	2048	$BFF	3071
Hi-Res	Primary	$2000	8192	$3FFF	16383
	Secondary	$4000	16384	$5FFF	24575

SCREEN SWITCHES

The devices which decide between the various modes, pages, and mixes are called "soft switches". They are switches because they have two positions (for example: on or off, text or graphics) and they are called "soft" because they are controlled by the software of the computer.

A program can "throw" a switch by referencing the special memory location for that switch. The data which are read from or written to the location are irrelevant; it is the *reference to the address* of the location which throws the switch.

There are eight special memory locations which control the setting of the soft switches for the screen. They are set up in pairs; when you reference one location of the pair you turn its corresponding mode "on" and its companion mode "off". The pairs are:

Table 5: Screen Soft Switches

Location: Hex	Decimal		Description:
$C050	49232	-16304	Display a GRAPHICS mode.
$C051	49233	-16303	Display TEXT mode.
$C052	49234	-16302	Display all TEXT or GRAPHICS.
$C053	49235	-16301	Mix TEXT and a GRAPHICS mode.*
$C054	49236	-16300	Display the Primary page (Page 1).
$C055	49237	-16299	Display the Secondary page (Page 2).
$C056	49238	-16298	Display LO-RES GRAPHICS mode.*
$C057	49239	-16297	Display HI-RES GRAPHICS mode.*

There are ten distinct combinations of these switches:

Table 6: Screen Mode Combinations

Primary Page			Secondary Page		
Screen	Switches		Screen	Switches	
All Text	$C054	$C051	All Text	$C055	$C051
All Lo-Res Graphics	$C054 $C052	$C056 $C050	All Lo-Res Graphics	$C055 $C052	$C056 $C050
All Hi-Res Graphics	$C054 $C052	$C057 $C050	All Hi-Res Graphics	$C055 $C052	$C057 $C050
Mixed Text and Lo-Res	$C054 $C053	$C056 $C050	Mixed Text and Lo-Res	$C055 $C053	$C056 $C050
Mixed Text and Hi-Res	$C054 $C053	$C057 $C050	Mixed Text and Hi-Res	$C055 $C053	$C057 $C050

(Those of you who are learned in the ways of binary will immediately cry out, "Where's the other six?!", knowing full well that with 4 two-way switches there are indeed *sixteen* possible combinations. The answer to the mystery of the six missing modes lies in the TEXT/GRAPHICS switch. When the computer is in Text mode, it can also be in one of six combinations of the Lo-Res/Hi-Res graphics mode, "mix" mode, or page selection. But since the Apple is displaying text, these different graphics modes are invisible.)

To set the Apple into one of these modes, a program needs only to refer to the addresses of the memory locations which correspond to the switches that set that mode. Machine language programs should use the hexadecimal addresses given above; BASIC programs should PEEK or POKE their decimal equivalents (given in Table 5, "Screen Soft Switches", above). The switches may be thrown in any order; however, when switching into one of the Graphics modes, it is helpful to throw the TEXT/GRAPHICS switch last. All the other changes in mode will then take place invisibly behind the text, so that when the Graphics mode is set, the finished graphics

* These modes are only visible if the "Display GRAPHICS" switch is "on".

screen appears all at once.

THE TEXT MODE

In the Text mode, the Apple can display 24 lines of characters with up to 40 characters on each line. Each character on the screen represents the contents of one memory location from the memory range of the page being displayed. The character set includes the 26 upper-case letters, the 10 digits, and 28 special characters for a total of 64 characters. The characters are formed in a dot matrix 5 dots wide and 7 dots high. There is a one-dot wide space on both sides of each character to separate adjacent characters and a one-dot high space above each line of characters to separate adjacent lines. The characters are normally formed with white dots on a dark background; however, each character on the screen can also be displayed using dark dots on a white background or alternating between the two to produce a flashing character. When the Video Display is in Text mode, the video circuitry in the Apple turns off the color burst signal to the television monitor, giving you a clearer black-and-white display.*

The area of memory which is used for the primary text page starts at location number 1024 and extends to location number 2047. The secondary screen begins at location number 2048 and extends up to location 3071. In machine language, the primary page is from hexadecimal address \$400 to address \$7FF; the secondary page is from \$800 to \$BFF. Each of these pages is 1,024 bytes long. Those of you intrepid enough to do the multiplication will realize that there are only 960 characters displayed on the screen. The remaining 64 bytes in each page which are not displayed on the screen are used as temporary storage locations by programs stored in PROM on Apple Intelligent Interface® peripheral boards (see page 82).

Photo 6 shows the sixty-four characters available on the Apple's screen.

Photo 6. The Apple Character Set.

Table 7 gives the decimal and hexadecimal codes for the 64 characters in normal, inverse, and flashing display modes.

* This feature is not present on the Revision 0 board.

Table 7: ASCII Screen Characters

	Inverse				Flashing				Normal							
									(Control)						(Lowercase)	
Decimal	Ø	16	32	48	64	8Ø	96	112	128	144	16Ø	176	192	2Ø8	224	24Ø
Hex	$ØØ	$1Ø	$2Ø	$3Ø	$4Ø	$5Ø	$6Ø	$7Ø	$8Ø	$9Ø	$AØ	$BØ	$CØ	$DØ	$EØ	$FØ
Ø $Ø	@	P		Ø	@	P		Ø	@	P		Ø	@	P		Ø
1 $1	A	Q	!	1	A	Q	!	1	A	Q	!	1	A	Q	!	1
2 $2	B	R	"	2	B	R	"	2	B	R	"	2	B	R	"	2
3 $3	C	S	#	3	C	S	#	3	C	S	#	3	C	S	#	3
4 $4	D	T	$	4	D	T	$	4	D	T	$	4	D	T	$	4
5 $5	E	U	%	5	E	U	%	5	E	U	%	5	E	U	%	5
6 $6	F	V	&	6	F	V	&	6	F	V	&	6	F	V	&	6
7 $7	G	W	'	7	G	W	'	7	G	W	'	7	G	W	'	7
8 $8	H	X	(	8	H	X	(	8	H	X	(	8	H	X	(	8
9 $9	I	Y	)	9	I	Y	)	9	I	Y	)	9	I	Y	)	9
1Ø $A	J	Z	*	:	J	Z	*	:	J	Z	*	:	J	Z	*	:
11 $B	K	[	+	;	K	[	+	;	K	[	+	;	K	[	+	;
12 $C	L	\	,	<	L	\	,	<	L	\	,	<	L	\	,	<
13 $D	M	]	—	=	M	]	—	=	M	]	—	=	M	]	—	=
14 $E	N	^	.	>	N	^	.	>	N	^	.	>	N	^	.	>
15 $F	O	_	/	?	O	_	/	?	O	_	/	?	O	_	/	?

Table 7. ASCII Screen Character Set

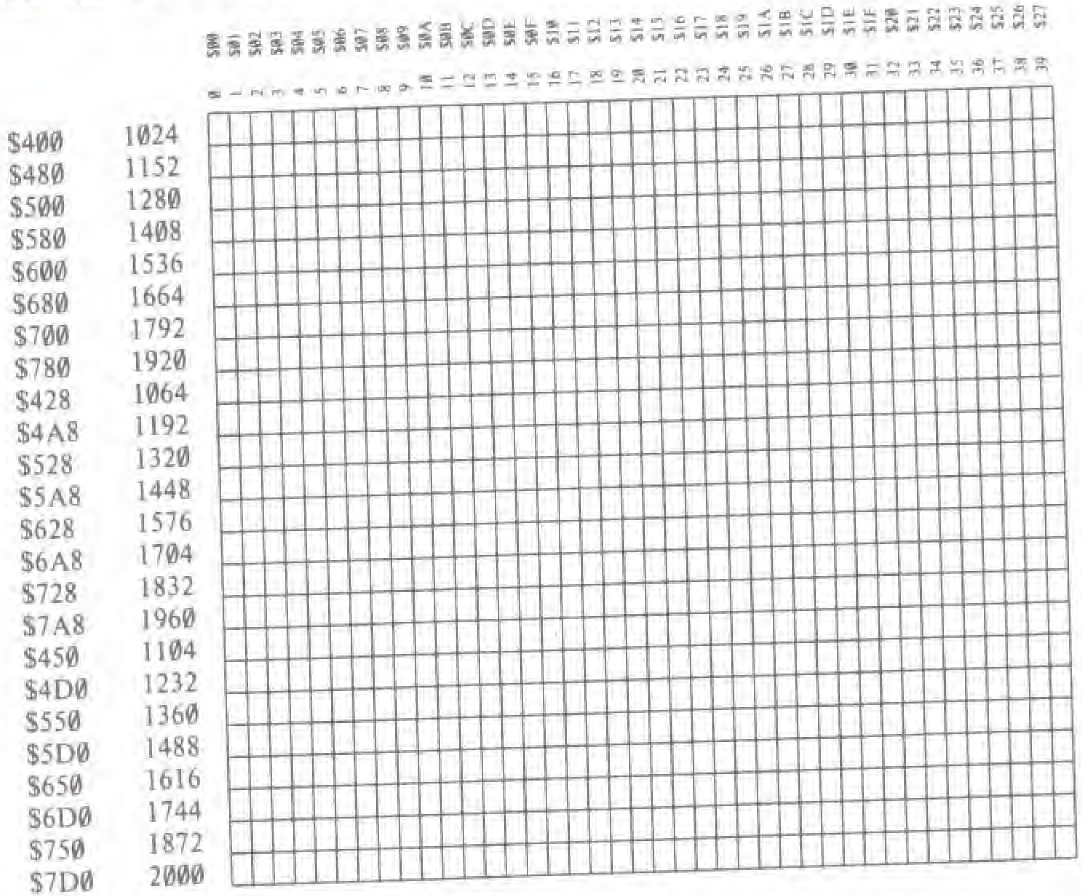


Figure 1. Map of the Text Screen

Figure 1 is a map of the Apple's display in Text mode, with the memory location addresses for each character position on the screen.

THE LOW-RESOLUTION GRAPHICS (LO-RES) MODE

In the Low-Resolution Graphics mode, the Apple presents the contents of the same 1,024 locations of memory as is in the Text mode, but in a different format. In this mode, each byte of memory is displayed not as an ASCII character, but as two colored blocks, stacked one atop the other. The screen can show an array of blocks 40 wide and 48 high. Each block can be any of sixteen colors. On a black-and-white television set, the colors appear as patterns of grey and white dots.

Since each byte in the page of memory for Low-Resolution Graphics represents two blocks on the screen, stacked vertically, each byte is divided into two equal sections, called (appropriately enough) "nybbles". Each nybble can hold a value from zero to 15. The value which is in the lower nybble of the byte determines the color for the upper block of that byte on the screen, and the value which is in the upper nybble determines the color for the lower block on the screen. The colors are numbered zero to 15, thus:

Table 8: Low-Resolution Graphics Colors

Decimal	Hex	Color	Decimal	Hex	Color
0	$0	Black	8	$8	Brown
1	$1	Magenta	9	$9	Orange
2	$2	Dark Blue	10	$A	Grey 2
3	$3	Purple	11	$B	Pink
4	$4	Dark Green	12	$C	Light Green
5	$5	Grey 1	13	$D	Yellow
6	$6	Medium Blue	14	$E	Aquamarine
7	$7	Light Blue	15	$F	White

(Colors may vary from television to television, particularly on those without hue controls. You can adjust the tint of the colors by adjusting the COLOR TRIM control on the right edge of the Apple board.)

So, a byte containing the hexadecimal value $D8 would appear on the screen as a brown block on top of a yellow block. Using decimal arithmetic, the color of the lower block is determined by the quotient of the value of the byte divided by 16; the color of the upper block is determined by the remainder.

Figure 2 is a map of the Apple's display in Low-Resolution Graphics mode, with the memory location addresses for each block on the screen.

Since the Low-Resolution Graphics screen displays the same area in memory as is used for the Text screen, interesting things happen if you switch between the Text and Low-Resolution Graphics modes. For example, if the screen is in the Low-Resolution Graphics mode and is full of colored blocks, and then the TEXT/GRAPHICS screen switch is thrown to the Text mode, the screen will be filled with seemingly random text characters, sometimes inverse or flashing. Similarly, a screen full of text when viewed in Low-Resolution Graphics mode appears as long horizontal grey, pink, green or yellow bars separated by randomly colored blocks.

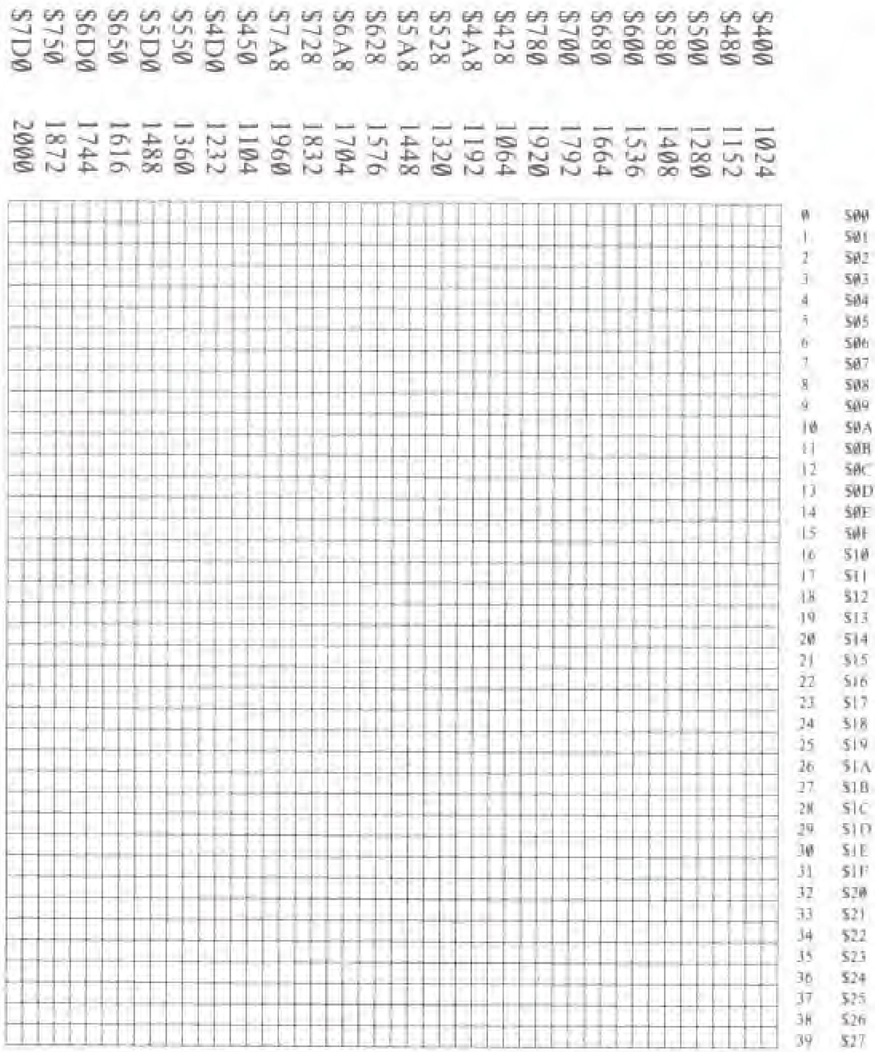


Figure 2. Map of the Low-Resolution Graphics Mode

THE HIGH-RESOLUTION GRAPHICS (HI-RES) MODE

The Apple has a second type of graphic display, called High-Resolution Graphics (or sometimes "Hi-res"). When your Apple is in the High-Resolution Graphics mode, it can display 53,760 dots in a matrix 280 dots wide and 192 dots high. The screen can display black, white, violet, green, red, and blue dots, although there are some limitations concerning the color of individual dots.

The High-Resolution Graphics mode takes its data from an 8,192-byte area of memory, usually called a "picture buffer". There are two separate picture buffers: one for the primary page and one for the secondary page. Both of these buffers are independent of and separate from the memory areas used for Text and Low-Resolution Graphics. The primary page picture buffer for the High-Resolution Graphics mode begins at memory location number 8192 and extends up to location number 16383; the secondary page picture buffer follows on the heels of the first at memory location number 16384, extending up to location number 24575. For those of you with sixteen fingers, the primary page resides from $2ØØØ to $3FFF and the secondary page follows in succession at $4ØØØ to $5FFF. If your Apple is equipped with 16K (16,384 bytes) or less of memory, then the secondary page is inaccessible to you; if its memory size is less than 16K, then the entire High-Resolution Graphics mode is unavailable to you.

Each dot on the screen represents one bit from the picture buffer. Seven of the eight bits in each byte are displayed on the screen, with the remaining bit used to select the colors of the dots in that byte. Forty bytes are displayed on each line of the screen. The least significant bit (first bit) of the first byte in the line is displayed on the left edge of the screen, followed by the second bit, then the third, etc. The most significant (eighth) bit is not displayed. Then follows the first bit of the next byte, and so on. A total of 280 dots are displayed on each of the 192 lines of the screen.

On a black-and-white monitor or TV set, the dots whose corresponding bits are "on" (or equal to 1) appear white; the dots whose corresponding bits are "off" or (equal to Ø) appear black. On a color monitor or TV, it is not so simple. If a bit is "off", its corresponding dot will always be black. If a bit is "on", however, its color will depend upon the *position* of that dot on the screen. If the dot is in the leftmost column on the screen, called "column Ø", or in any even-numbered column, then it will appear violet. If the dot is in the rightmost column (column 279) or any odd-numbered column, then it will appear green. If two dots are placed side-by-side, they will both appear white. If the undisplayed bit of a byte is turned on, then the colors blue and red are substituted for violet and green, respectively.* Thus, there are six colors available in the High-Resolution Graphics mode, subject to the following limitations:

1) Dots in even columns must be black, violet, or blue.

2) Dots in odd columns must be black, green, or red.

3) Each byte must be either a violet/green byte or a blue/red byte. It is not possible to mix green and blue, green and red, violet and blue, or violet and red in the same byte.

* On Revision Ø Apple boards, the colors red and blue are unavailable and the setting of the eighth bit is irrelevant.

4) Two colored dots side by side always appear white, even if they are in different bytes.

5) On European-modified Apples, these rules apply but the colors generated in the High-Resolution Graphics mode may differ.

Figure 3 shows the Apple's display screen in High-Resolution Graphics mode with the memory addresses of each line on the screen.

OTHER INPUT/OUTPUT FEATURES

Apple Input/Output Features

Inputs:	Cassette Input Three One-bit Digital Inputs Four Analog Inputs
Outputs:	Cassette Output Built-In Speaker Four "Annunciator" Outputs Utility Strobe Output

THE SPEAKER

Inside the Apple's case, on the left side under the keyboard, is a small 8 ohm speaker. It is connected to the internal electronics of the Apple so that a program can cause it to make various sounds.

The speaker is controlled by a soft switch. The switch can put the paper cone of the speaker in two positions: "in" and "out". This soft switch is not like the soft switches controlling the various video modes, but is instead a *toggle* switch. Each time a program references the memory address associated with the speaker switch, the speaker will change state: change from "in" to "out" or vice-versa. Each time the state is changed, the speaker produces a tiny "click". By referencing the address of the speaker switch frequently and continuously, a program can generate a steady tone from the speaker.

The soft switch for the speaker is associated with memory location number 49200. Any reference to this address (or the equivalent addresses -16336 or hexadecimal $C030) will cause the speaker to emit a click.

A program can "reference" the address of the special location for the speaker by performing a "read" or "write" operation to that address. The data which are read or written are irrelevant, as it is the *address* which throws the switch. Note that a "write" operation on the Apple's 6502 microprocessor actually performs a "read" before the "write", so that if you use a "write" operation to flip any soft switch, you will actually throw that switch *twice*. For toggle-type soft switches, such as the speaker switch, this means that a "write" operation to the special location

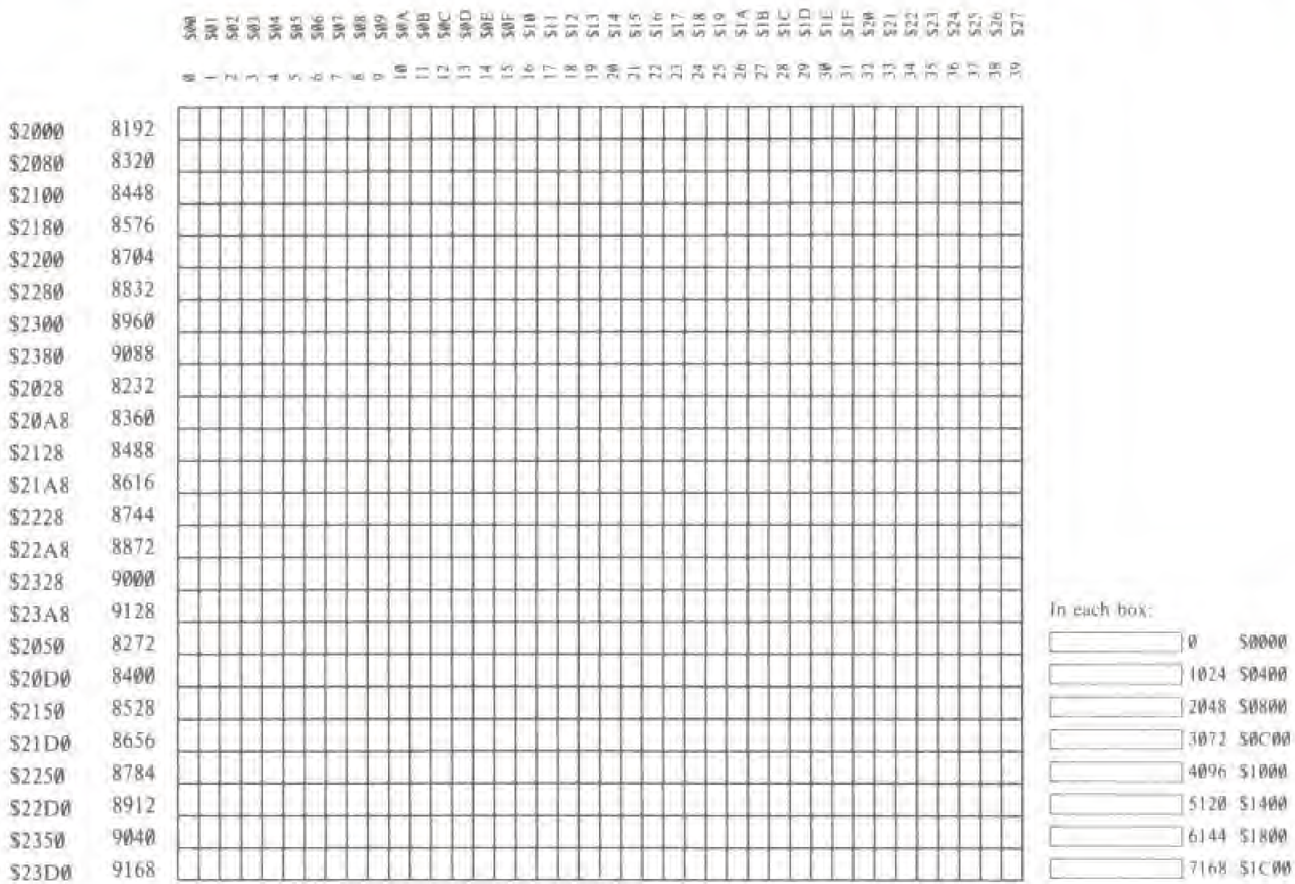


Figure 3. Map of the High-Resolution Graphics Screen

To obtain the address for any byte, add the addresses for that byte's box row, box column, and position in box.

controlling the switch will leave the switch in the same state it was in before the operation was performed.

THE CASSETTE INTERFACE

On the back edge of the Apple's main board, on the right side next to the VIDEO connector, are two small black packages labelled "IN" and "OUT". These are miniature phone jacks into which you can plug a cable which has a pair of miniature phono plugs on each end. The other end of this cable can be connected to a standard cassette tape recorder so that your Apple can save information on audio cassette tape and read it back again.

The connector marked "OUT" is wired to yet another soft switch on the Apple board. This is another toggle switch, like the speaker switch (see above). The soft switch for the cassette output plug can be toggled by referencing memory location number 49184 (or the equivalent -16352 or hexadecimal $C020). Referencing this location will make the voltage on the OUT connector swing from zero to 25 millivolts (one fortieth of a volt), or return from 25 millivolts back to zero. If the other end of the cable is plugged into the MICROPHONE input of a cassette tape recorder which is recording onto a tape, this will produce a tiny "click" on the recording. By referencing the memory location associated with the cassette output soft switch repeatedly and frequently, a program can produce a tone on the recording. By varying the pitch and duration of this tone, information may be encoded on a tape and saved for later use. Such a program to encode data on a tape is included in the System Monitor and is described on page 46.

Be forewarned that if you attempt to flip the soft switch for the cassette output by writing to its special location, you will actually generate *two* "clicks" on the recording. The reason for this is mentioned in the description of the speaker (above). You should only use "read" operations when toggling the cassette output soft switch.

The other connector, marked "IN", can be used to "listen" to a cassette tape recording. Its main purpose is to provide a means of listening to tones on the tape, decoding them into data, and storing them in memory. Thus, a program or data set which was stored on cassette tape may be read back in and used again.

The input circuit takes a 1 volt (peak-to-peak) signal from the cassette recorder's EARPHONE jack and converts it into a string of ones and zeroes. Each time the signal applied to the input circuit swings from positive to negative, or vice-versa, the input circuit changes state: if it was sending ones, it will start sending zeroes, and vice versa. A program can inspect the state of the cassette input circuit by looking at memory location number 49248 or the equivalents -16288 or hexadecimal $C060. If the value which is read from this location is greater than or equal to 128, then the state is a "one"; if the value in the memory location is less than 128, then the state is a "zero". Although BASIC programs can read the state of the cassette input circuit, the speed of a BASIC program is usually much too slow to be able to make any sense out of what it reads. There is, however, a program in the System Monitor which will read the tones on a cassette tape and decode them. This is described on page 47.

THE GAME I/O CONNECTOR

The purpose of the Game I/O connector is to allow you to connect special input and output devices to heighten the effect of programs in general, and specifically, game programs. This connector allows you to connect three one-bit inputs, four one-bit outputs, a data strobe, and four analog inputs to the Apple, all of which can be controlled by your programs. Supplied with your Apple is a pair of Game Controllers which are connected to cables which plug into the Game I/O connector. The two rotary dials on the Controllers are connected to two analog inputs on the Connector; the two pushbuttons are connected to two of the one-bit inputs.

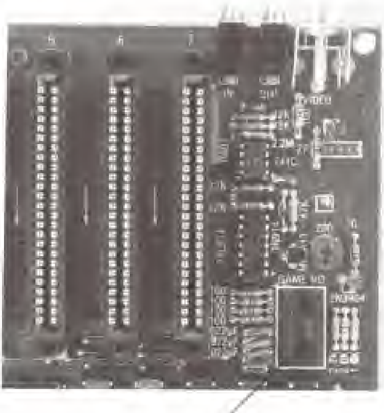


Photo 7. The Game I/O Connector.

ANNUNCIATOR OUTPUTS

The four one-bit outputs are called "annunciators". Each annunciator output can be used as an input to some other electronic device, or the annunciator outputs can be connected to circuits to drive lamps, relays, speakers, etc.

Each annunciator is controlled by a soft switch. The addresses of the soft switches for the annunciators are arranged into four pairs, one pair for each annunciator. If you reference the first address in a pair, you turn the output of its corresponding annunciator "off"; if you reference the second address in the pair, you turn the annunciator's output "on". When an annunciator is "off", the voltage on its pin on the Game I/O Connector is near 0 volts; when an annunciator is "on", the voltage is near 5 volts. There are no inherent means to determine the current setting of an annunciator bit. The annunciator soft switches are:

Table 9: Annunciator Special Locations

Ann.	State	Address: Decimal		Hex
0	off	49240	-16296	$C058
	on	49241	-16295	$C059
1	off	49242	-16294	$C05A
	on	49243	-16293	$C05B
2	off	49244	-16292	$C05C
	on	49245	-16291	$C05D
3	off	49246	-16290	$C05E
	on	49247	-16289	$C05F

ONE-BIT INPUTS

The three one-bit inputs can each be connected to either another electronic device or to a push-button. You can read the state of any of the one-bit inputs from a machine language or BASIC program in the same manner as you read the Cassette Input, above. The locations for the three one-bit inputs have the addresses 49249 through 49251 (-16287 through -16285 or hexadecimal $C061 through $C063).

ANALOG INPUTS

The four analog inputs can be connected to 150K Ohm variable resistors or potentiometers. The variable resistance between each input and the +5 volt supply is used in a one-shot timing circuit. As the resistance on an input varies, the timing characteristics of its corresponding timing circuit change accordingly. Machine language programs can sense the changes in the timing loops and obtain a numerical value corresponding to the position of the potentiometer.

Before a program can start to read the setting of a potentiometer, it must first reset the timing circuits. Location number 49264 (-16272 or hexadecimal $C070) does just this. When you reset the timing circuits, the values contained in the four locations 49252 through 49255 (-16284 through -16281 or $C064 through $C067) become greater than 128 (their high bits are set). Within 3.060 milliseconds, the values contained in these four locations should drop below 128. The exact time it takes for each location to drop in value is directly proportional to the setting of the game paddle associated with that location. If the potentiometers connected to the analog inputs have a greater resistance than 150K Ohms, or there are no potentiometers connected, then the values in the game controller locations may never drop to zero.

STROBE OUTPUT

There is an additional output, called $\overline{\text{C040 STROBE}}$, which is normally +5 volts but will drop to zero volts for a duration of one-half microsecond under the control of a machine language or BASIC program. You can trigger this "strobe" by referring to location number 49216 (-16320 or $C04F). Be aware that if you perform a "write" operation to this location, you will trigger the strobe *twice* (see a description of this phenomenon in the section on the Speaker).

Table 10: Input/Output Special Locations

Function:	Address: Decimal		Hex	Read/Write
Speaker	49200	-16336	$C030	R
Cassette Out Cassette In	49184 49256	-16352 -16288	$C020 $C060	R R
Annunciators*	49240 through 49247	-16296 through -16289	$C058 through $C05F	R/W
Flag inputs	49249 49250 49251	-16287 -16286 -16285	$C061 $C062 $C063	R R R
Analog Inputs	49252 49253 49254 49255	-16284 -16283 -16282 -16281	$C064 $C065 $C066 $C067	R
Analog Clear	49264	-16272	$C070	R/W
Utility Strobe	49216	-16320	$C040	R

VARIETIES OF APPLES

There are a few variations on the basic Apple II computer. Some of the variations are revisions or modifications of the computer itself; others are changes to its operating software. These are the basic variations:

AUTOSTART ROM / MONITOR ROM

All Apple II Plus Systems include the Autostart Monitor ROM. All other Apple systems do not contain the Autostart ROM, but instead have the Apple System Monitor ROM. This version of the ROM lacks some of the features present in the Autostart ROM, but also has some features which are not present in that ROM. The main differences in the two ROMs are listed on the following pages.

* See the previous table.

- **Editing Controls**. The ESC-I, J, K, and M sequences, which move the cursor up, left, right, and down, respectively, are not available in the Old Monitor ROM.

- **Stop-List**. The Stop-List feature (invoked by a [CTRL S]), which allows you to introduce a pause into the output of most BASIC or machine language programs or listings, is not available in the Old Monitor ROM.

- **The RESET cycle**. When you first turn on your Apple or press [RESET], the Old Monitor ROM will send you directly into the Apple System Monitor, instead of initiating a warm or cold start as described in "The RESET Cycle" on page 36.

The Old Monitor ROM does, however, support the STEP and TRACE debugging features of the System Monitor, described on page 51. The Autostart ROM does not recognize these Monitor commands.

REVISION Ø / REVISION 1 BOARD

The Revision Ø Apple II board lacks a few features found on the current Revision 1 version of the Apple II main board. To determine which version of the main board is in your Apple, open the case and look at the upper right-hand corner of the board. Compare what you see to Photo 4 on page 10. If your Apple does not have the single metal video connector pin between the four-pin video connector and the video adjustment potentiometer, then you have a Revision Ø Apple.

The differences between the Revision Ø and Revision 1 Apples are summarized below.

- **Color Killer.** When the Apple's Video Display is in Text mode, the Revision Ø Apple board leaves the color burst signal active on the video output circuit. This causes text characters to appear tinted or with colored fringes.

- **Power-on RESET.** Revision Ø Apple boards have no circuit to automatically initiate a RESET cycle when you turn the power on. Instead, you must press [RESET] once to start using your Apple.

  Also, when you turn on the power to an Apple with a Revision Ø board, the keyboard will become active, as if you had typed a random character. When the Apple starts looking for input, it will accept this random character as if you had typed it. In order to erase this character, you should press [CTRL X] after you [RESET] your Apple when you turn on its power.

- **Colors in High-Resolution Graphics.** Apples with Revision Ø boards can generate only four colors in the High-Resolution Graphics mode: black, white, violet, and green. The high bit of each byte displayed on the Hi-Res screen (see page 19) is ignored.

- **24K Memory Map problem.** Systems with a Revision Ø Apple II board which contain 20K or 24K bytes of RAM memory appear to BASIC to have more memory than they actually do. See "Memory Organization", page 72, for a description of this problem.

- **50 Hz Apples.** The Revision Ø Apple II board does not have the pads and jumpers which you can cut and solder to convert the VIDEO OUT signal of your Apple to conform to the European PAL/SECAM television standard. It also lacks the third VIDEO connector, the single metal pin in front of the four-pin video connector.

- **Speaker and Cassette Interference.** On Apples with Revision Ø boards, any sound generated by the internal speaker will also appear as a signal on the Cassette Interface's OUT connector. If you leave the tape recorder in RECORD mode, then any sound generated by the internal speaker will also appear on the tape recording.

- **Cassette Input.** The input circuit for the Cassette Interface has been modified so that it will respond with more accuracy to a weaker input signal.

POWER SUPPLY CHANGES

In addition, some Apples have a version of the Apple Power Supply which will accept only a 110 volt power line input. These are are not equipped with the voltage selector switch on the back of the supply.

THE APPLE II PLUS

The **Apple II Plus** is a standard Apple II computer with a Revision 1 board, an Autostart Monitor ROM, and the Applesoft II BASIC language in ROM in lieu of Apple Integer BASIC. European models of the Apple II Plus are equipped with a 110/220 volt power supply. The Apple Mini-Assembler, the Floating-Point Package, and the SWEET-16 interpreter, stored in the Integer BASIC ROMs, are not available on the Apple II Plus.

CHAPTER 2
CONVERSATION WITH APPLES

Almost every program and language on the Apple needs some sort of input from the keyboard, and some way to print information on the screen. There is a set of subroutines stored in the Apple's ROM memory which handle most of the standard input and output from all programs and languages on the Apple.

The subroutines in the Apple's ROM which perform these input and output functions are called by various names. These names were given to the subroutines by their authors when they were written. The Apple itself does not recognize or remember the names of its own machine language subroutines, but it's convenient for us to call these subroutines by their given names.

STANDARD OUTPUT

The standard output subroutine is called COUT. COUT will display upper-case letters, numbers, and symbols on the screen in either Normal or Inverse mode. It will ignore control characters except RETURN, the bell character, the line feed character, and the backspace character.

The COUT subroutine maintains its own invisible "output cursor"* (the position at which the next character is to be placed). Each time COUT is called, it places one character on the screen at the current cursor position, replacing whatever character was there, and moves the cursor one space to the right. If the cursor is bumped off the right edge of the screen, then COUT shifts the cursor down to the first position on the next line. If the cursor passes the bottom line of the screen, the screen "scrolls" up one line and the cursor is set to the first position on the newly blank bottom line.

When a RETURN character is sent to COUT, it moves the cursor to the first position of the next line. If the cursor falls off the bottom of the screen, the screen scrolls as described above.

THE STOP-LIST FEATURE

When any program or language sends a RETURN code to COUT, COUT will take a quick peek at the keyboard. If you have typed a CTRL S since the last time COUT looked at the keyboard, then it will stop and wait for you to press another key. This is called the *Stop-List* feature.** When you press another key, COUT will then output the RETURN code and proceed with normal output. The code of the key which you press to end the Stop-List mode is ignored unless it is a CTRL C. If it is, then COUT passes this character code back to the program or language which is sending output. This allows you to terminate a BASIC program or listing by typing CTRL C while you are in Stop-List mode.

A line feed character causes COUT to move its mythical output cursor down one line without any horizontal motion at all. As always, moving beyond the bottom of the screen causes the screen to scroll and the cursor remains at its same position on a fresh bottom line.

A backspace character moves the imaginary cursor one space to the left. If the cursor is bumped off the left edge, it is reset to the rightmost position on the previous line. If there is no previous line (if the cursor was at the top of the screen), the screen does *not* scroll downwards, but instead

* From latin *cursus*, "runner"

** The Stop-list feature is not present on Apples without the Autostart ROM.

the cursor is placed again at the rightmost position on the top line of the screen.

When COUT is sent a "bell" character (CTRL G), it does not change the screen at all, but instead produces a tone from the speaker. The tone has a frequency of 100Hz and lasts for 1/10th of a second. The output cursor does not move for a bell character.

BUT SOFT, WHAT LIGHT THROUGH YONDER WINDOW BREAKS!

(OR, THE TEXT WINDOW)

In the above discussions of the various motions of the output cursor, the words "right", "left", "top", and "bottom" mean the physical right, left, top, and bottom of the standard 40-character wide by 24-line tall screen. There is, however, a way to tell the COUT subroutine that you want it to use only a section of the screen, and not the entire 960-character display. This segregated section of the text screen is called a "window". A program or language can set the positions of the top, bottom, left side, and width of the text window by storing those positions in four locations in memory. When this is done, the COUT subroutine will use the new positions to calculate the size of the screen. It will never print any text outside of this window, and when it must scroll the screen, it will only scroll the text within the window. This gives programs the power to control the placement of text, and to protect areas of the screen from being overwritten with new text.

Location number 32 (hexadecimal $20) in memory holds the column position of the leftmost column in the window. This position is normally position 0 for the extreme left side of the screen. This number should never exceed 39 (hexadecimal $27), the leftmost column on the text screen. Location number 33 (hexadecimal $21) holds the width, in columns, of the cursor window. This number is normally 40 (hexadecimal $28) for a full 40-character screen. Be careful that the sum of the window width and the leftmost window position does not exceed 40! If it does, it is possible for COUT to place characters in memory locations not on the screen, endangering your programs and data.

Location 34 (hexadecimal $22) contains the number of the top line of the text window. This is also normally 0, indicating the topmost line of the display. Location 35 (hexadecimal $23) holds the number of the bottom line of the screen (plus one), thus normally 24 (hexadecimal $18) for the bottommost line of the screen. When you change the text window, you should take care that you know the whereabouts of the output cursor, and that it will be inside the new window.

Table 11: Text Window Special Locations

Function:	Location: Decimal	Hex	Minimum/Normal/Maximum Value Decimal	Hex
Left Edge	32	$20	0/0/39	$0/$0/$17
Width	33	$21	0/40/40	$0/$28/$28
Top Edge	34	$22	0/0/24	$0/$0/$18
Bottom Edge	35	$23	0/24/24	$0/$18/$18

SEEING IT ALL IN BLACK AND WHITE

The COUT subroutine has the power to print what's sent to it in either Normal or Inverse text modes (see page 14). The particular form of its output is determined by the contents of location number 5Ø (hexadecimal $32). If this location contains the value 255 (hexadecimal $FF), then COUT will print characters in Normal mode; if the value is 63 (hexadecial $3F), then COUT will present its display in Inverse mode. Note that this mode change only affects the characters printed after the change has been made. Other values, when stored in location 5Ø, do unusual things: the value 127 prints letters in Flashing mode, but all other characters in Inverse; any other value in location 5Ø will cause COUT to ignore some or all of its normal character set.

Table 12: Normal/Inverse Control Values

Value: Decimal	Hex	Effect:
255	$FF	COUT will display characters in Normal mode.
63	$3F	COUT will display characters in Inverse mode.
127	$7F	COUT will display letters in Flashing mode, all other characters in Inverse mode.

The Normal/Inverse "mask" location, as it is called, works by performing a logical "AND" between the bits contained in location 5Ø and the bits in each outgoing character code. Every bit in location 5Ø which is a logical "zero" will force the corresponding bit in the character code to become "zero" also, regardless of its former setting. Thus, when location 5Ø contains 63 (hexadecimal $3F or binary ØØ111111), the top two bits of every output character code will be turned "off". This will place characters on the screen whose codes are all between 0 and 63. As you can see from the ASCII Screen Character Code table (Table 7 on page 15), all of these characters are in Inverse mode.

STANDARD INPUT

There are actually two subroutines which are concerned with the gathering of standard input: RDKEY, which fetches a single keystroke from the keyboard, and GETLN, which accumulates a number of keystrokes into a chunk of information called an *input line.*

RDKEY

The primary function of the RDKEY subroutine is to wait for the user to press a key on the keyboard, and then report back to the program which called it with the code for the key which was pressed. But while it does this, RDKEY also performs two other helpful tasks:

1). *Input Prompting.* When RDKEY is activated, the first thing it does is make visible the hidden output cursor. This accomplishes two things: it reminds the user that the Apple is waiting for a key to be pressed, and it also associates the input it wants with a particular place on the screen. In most cases, the input prompt appears near a word or phrase describing what is being requested by the particular program or language currently in use. The input cursor itself is a flashing representation of whatever character was at the position of the output cursor. Usually this is the blank character, so the input cursor most often appears to be a flashing square.

When the user presses a key, RDKEY dutifully removes the input cursor and returns the value of the key which was pressed to the program which requested it. Remember that the output cursor is just a position on the screen, but the input cursor is a flashing character on the screen. They usually move in tandem and are rarely separated from each other, but when the input cursor disappears, the output cursor is still active.

2). *Random Number Seeding.* While it waits for the user to press a key, RDKEY is continually adding 1 to a pair of numbers in memory. When a key is finally pressed, these two locations together represent a number from Ø to 65,535, the exact value of which is quite unpredictable. Many programs and languages use this number as the base of a random number generator. The two locations which are randomized during RDKEY are numbers 78 and 79 (hexadecimal $4E and $4F).

GETLN

The vast majority of input to the Apple is gathered into chunks called *input lines.* The subroutine in the Apple's ROM called GETLN requests an input line from the keyboard, and after getting one, returns to the program which called it. GETLN has many features and nuances, and it is good to be familiar with the services it offers.

When called, GETLN first prints a *prompting character*, or "prompt". The prompt helps you to identify which program has called GETLN requesting input. A prompt character of an asterisk (*) represents the System Monitor, a right caret (>) indicates Apple Integer BASIC, a right bracket (]) is the prompt for Applesoft II BASIC, and an exclamation point (!) is the hallmark of the Apple Mini-Assembler. In addition, the question-mark prompt (?) is used by many programs and languages to indicate that a user program is requesting input. From your (the user's) point of view, the Apple simply prints a prompt and displays an input cursor. As you type, the characters you type are printed on the screen and the cursor moves accordingly. When you press **RETURN**, the entire line is sent off to the program or language you are talking to, and you get another prompt.

Actually, what really happens is that after the prompt is printed, GETLN calls RDKEY, which displays an input cursor. When RDKEY returns with a keycode, GETLN stores that keycode in an *input buffer* and prints it on the screen where the input cursor was. It then calls RDKEY again. This continues until the user presses **RETURN**. When GETLN receives a RETURN code from the keyboard, it sticks the RETURN code at the end of the input buffer, clears the remainder of the screen line the input cursor was on, and sends the RETURN code to COUT (see above). GETLN then returns to the program which called it. The program or language which requested input may now look at the entire line, all at once, as saved in the input buffer.

At any time while you are typing a line, you can type a **CTRL X** and cancel that entire line. GETLN will simply forget everything you have typed, print a backslash (\), skip to a new line, and display another prompt, allowing you to retype the line. Also, GETLN can handle a maximum of 255 characters in a line. If you exceed this limit, GETLN will cancel the entire line and you must start over. To warn you that you are approaching the limit, GETLN will sound a tone every keypress starting with the 249th character.

GETLN also allows you to edit and modify the line you are typing in order to correct simple typographical errors. A quick introduction to the standard editing functions and the use of the two arrow keys, ← and →, appears on pages 28-29 and 53-55 of the **Apple II BASIC Programming Manual**, or on pages 27-28, 52-53 and Appendix C of **The Applesoft Tutorial**, at least one of which you should have received. Here is a short description of GETLN's editing features:

THE BACKSPACE (←) KEY

Each press of the backspace key makes GETLN "forget" one previous character in the input line. It also sends a backspace character to COUT (see above), making the cursor move back to the character which was deleted. At this point, a character typed on the keyboard will replace the deleted character both on the screen and in the input line. Multiple backspaces will delete successive characters; however, if you backspace over more characters than you have typed, GETLN will forget the entire line and issue another prompt.

THE RETYPE (→) KEY

Pressing the retype key has exactly the same effect as typing the character which is under the cursor. This is extremly useful for re-entering the remainder of a line which you have backspaced over to correct a typographical error. In conjunction with *pure cursor moves* (which follow), it is also useful for recopying and editing data which is already on the screen.

ESCAPE CODES

When you press the key marked ESC on the keyboard, the Apple's input subroutines go into *escape mode*. In this mode, eleven keys have separate meanings, called "escape codes". When you press one of these eleven keys, the Apple will perform the function associated with that key. After it has performed the function, the Apple will either continue or terminate escape mode, depending upon which escape code was performed. If you press any key in escape mode which is not an escape code, then that keypress will be ignored and escape mode will be terminated.

The Apple recognizes eleven escape codes, eight of which are *pure cursor moves*, which simply move the cursor without altering the screen or the input line, and three of which are *screen clear codes*, which simply blank part or all of the screen. All of the screen clear codes and the first four pure cursor moves (escape codes @, A, B, C, D, E, and F) terminate the escape mode after operating. The final four escape codes (I, K, M, and J) complete their functions with escape mode active.*

ESC A — A press of the ESC key followed by a press of the A key will move the cursor one space to the right without changing the input line. This is useful for skipping over unwanted characters in an input line: simply backspace back over the unwanted characters, press ESC A to skip each offending symbol, and use the retype key to re-enter the remainder of the line.

ESC B — Pressing ESC followed by B moves the cursor back one space, also without disturbing the input line. This may be used to enter something twice on the same line without retyping it: just type it once, press ESC B repeatedly to get back to the beginning of the phrase, and use the retype key to enter it again.

* These four escape codes are not available on Apples without the Autostart Monitor ROM.

ESC C The key sequence ESC C moves the cursor one line directly down, with no horizontal movement. If the cursor reaches the bottom of the text window, then the cursor remains on the bottom line and the text in the window scrolls up one line. The input line is not modified by the ESC C sequence. This, and ESC D (below), are useful for positioning the cursor at the beginning of another line on the screen, so that it may be re-entered with the retype key.

ESC D The ESC D sequence moves the cursor directly up one line, again without any horizontal movement. If the cursor reaches the top of the window, it stays there. The input line remains unmodified. This sequence is useful for moving the cursor to a previous line on the screen so that it may be re-entered with the retype key.

ESC E The ESC E sequence is called "clear to end of line". When COUT detects this sequence of keypresses, it clears the remainder of the screen line (*not* the input line!) from the cursor position to the right edge of the text window. The cursor remains where it is, and the input line is unmodified. ESC E always clears the rest of the line to blank spaces, regardless of the setting of the Normal/Inverse mode location (see above).

ESC F This sequence is called "clear to end of screen". It does just that: it clears everything in the window below or to the right of the cursor. As before, the cursor does not move and the input line is not modified. This is useful for erasing random garbage on a cluttered screen after a lot of cursor moves and editing.

ESC @ The ESC @ sequence is called "home and clear". It clears the entire window and places the cursor in the upper left-hand corner. The screen is cleared to blank spaces, regardless of the setting of the Normal/Inverse location, and the input line is not changed (note that "@" is SHIFT P).

ESC K
ESC J
ESC M
ESC I

These four escape codes are synonyms for the four pure cursor moves given above. When these four escape codes finish their respective functions, they do *not* turn off the escape mode: you can continue typing these escape codes and moving the cursor around the screen until you press any key other than another escape code. These four keys are placed in a "directional keypad" arrangement, so that the direction of each key from the center of the keypad corresponds to the direction which that escape code moves the cursor.

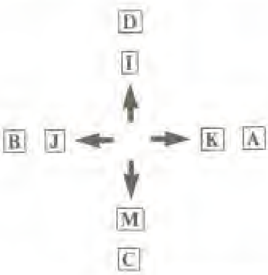


Figure 4. Cursor-moving Escape Codes.

THE RESET CYCLE

When you turn your Apple's power switch on* or press and release the [RESET] key, the Apple's 65Ø2 microprocessor initiates a RESET cycle. It begins by jumping into a subroutine in the Apple's Monitor ROM. In the two different versions of this ROM, the Monitor ROM and the Autostart ROM, the RESET cycle does very different things.

AUTOSTART ROM RESET

Apples with the Autostart ROM begin their RESET cycles by flipping the soft switches which control the video screen to display the full primary page of Text mode, with Low-Resolution Graphics mixed mode lurking behind the veil of text. It then opens the text window to its full size, drops the output cursor to the bottom of the screen, and sets Normal video mode. Then it sets the COUT and KEYIN switches to use the Apple's internal keyboard and video display as the standard input and output devices. It flips annunciators Ø and 1 ON and annunciators 2 and 3 OFF on the Game I/O connector, clears the keyboard strobe, turns off any active I/O Expansion ROM (see page 84), and sounds a "beep!".

These actions are performed every time you press and release the [RESET] key on your Apple. At this point, the Autostart ROM peeks into two special locations in memory to see if it's been RESET before or if the Apple has just been powered up (these special locations are described below). If the Apple has just been turned on, then the Autostart ROM performs a "cold start"; otherwise, it does a "warm start".

1) **Cold Start**. On a freshly activated Apple, the RESET cycle continues by clearing the screen and displaying "APPLE II" top and center. It then sets up the special locations in memory to tell itself that it's been powered up and RESET. Then it starts looking through the rightmost seven slots in your Apple's backplane, looking for a Disk II Controller Card. It starts the search with Slot 7 and continues down to Slot 1. If it finds a disk controller card, then it proceeds to bootstrap the Apple Disk Operating System (DOS) from the diskette in the disk drive attached to the controller card it discovered. You can find a description of the disk bootstrapping procedure in **Do's and Don'ts of DOS**, Apple part number A2L0012, page 11.

   If the Autostart ROM cannot find a Disk II controller card, or you press [RESET] again before the disk booting procedure has completed, then the RESET cycle will continue with a "lukewarm start". It will initialize and jump into the language which is installed in ROM on your Apple. For a Revision Ø Apple, either without an Applesoft II Firmware card or with such a card with its controlling switch in the DOWN position, the Autostart ROM will start Apple Integer BASIC. For Apple II-Plus systems, or Revision Ø Apple IIs with the Applesoft II Firmware card with the switch in the UP position, the Autostart ROM will begin Applesoft II Floating-Point BASIC.

2) **Warm Start**. If you have an Autostart ROM which has already performed a cold start cycle, then each time you press and release the [RESET] key, you will be returned to the language you were using, with your program and variables intact.

---

* Power-on RESET cycles occur only on Revision 1 Apples or Revision Ø Apples with at least one Disk II controller card.

AUTOSTART ROM SPECIAL LOCATIONS

The three "special locations" used by the Autostart ROM all reside in an area of RAM memory reserved for such system functions. Following is a table of the special locations used by the Autostart ROM:

Table 13: Autostart ROM Special Locations

Location: Decimal	Hex	Contents:
1010 1011	$3F2 $3F3	Soft Entry Vector. These two locations contain the address of the reentry point for whatever language is in use. Normally contains $E003.
1012	$3F4	Power-Up Byte. Normally contains $45. See below.
64367 (-1169)	$FB6F	This is the beginning of a machine language subroutine which sets up the power-up location.

When the Apple is powered up, the Autostart ROM places a special value in the power-up location. This value is the Exclusive-OR of the value contained in location 1011 with the constant value 165. For example, if location 1011 contains 224 (its normal value), then the power-up value will be:

	Decimal	Hex	Binary
Location 1011	224	$E0	11100000
Constant	165	$A5	10100101
Power-Up Value	69	$45	01000101

Your programs can change the soft entry vector, so that when you press RESET you will go to some program other than a language. If you change this soft entry vector, however, you should make sure that you set the value of the power-up byte to the Exclusive-OR of the high part of your new soft entry vector with the constant decimal 165 (hexadecimal $A5). If you do not set this power-up value, then the next time you press RESET the Autostart ROM will believe that the Apple has just been turned on and it will do another cold start.

For example, you can change the soft entry vector to point to the Apple System Monitor, so that when you press RESET you will be placed into the Monitor. To make this change, you must place the address of the beginning of the Monitor into the two soft entry vector locations. The Monitor begins at location $FF69, or decimal 65385. Put the last two hexadecimal digits of this address ($69) into location $3F2 and the first two digits ($FF) into location $3F3. If you are working in decimal, put 105 (which is the remainder of 65385/256) into location 1010 and the value 255 (which is the integer quotient of 65385/256) into location 1011.

Now you must set up the power-up location. There is a machine-language subroutine in the Autostart ROM which wil automatically set the value of this location to the Exclusive-OR mentioned above. Al you need to do is to execute a JSR (Jump to SubRoutine) instruction to the address $FB6F. If you are working in BASIC, you should perform a CALL -1169. Now everything is set, and the next time you press RESET, you will enter the System Monitor.

To make the RESET key work in its usual way, just restore the values in the soft entry vector to their former values ($E003, or decimal 57347) and again call the subroutine described above.

"OLD MONITOR" ROM RESET

A RESET cycle in the Apple II Monitor ROM begins by setting Normal video mode, a full screen of Primary Page text with the Color Graphics mixed mode behind it, a fully-opened text window, and the Apple's standard keyboard and video screen as the standard input and output devices. It sounds a "beep!", the cursor leaps to the bottom line of the uncleared text screen, and you find yourself facing an asterisk (*) prompt and talking to the Apple System Monitor.

CHAPTER 3
THE SYSTEM MONITOR

Buried deep within the recesses of the Apple's ROM is a masterful program called the System Monitor. It acts as both a supervisor of the system and a slave to it; it controls all programs and all programs use it. You can use the powerful features of the System Monitor to discover the hidden secrets in all 65,536 memory locations. From the Monitor, you may look at one, some, or all locations; you may change the contents of any location; you can write programs in Machine and Assembly languages to be executed directly by the Apple's microprocessor; you can save vast quantities of data and programs onto cassette tape and read them back in again; you can move and compare thousands of bytes of memory with a single command; and you can leave the Monitor and enter any other program or language on the Apple.

ENTERING THE MONITOR

The Apple System Monitor program begins at location number $FF69 (decimal 65385 or −151) in memory. To enter the Monitor, you or your BASIC program can CALL this location. The Monitor's prompt (an asterisk [*]) will appear on the left edge of the screen, with a flashing cursor to its right. The Monitor accepts standard input lines (see page 32) just like any other system or language on the Apple. It will not take any action until you press RETURN. Your input lines to the Monitor may be up to 255 characters in length. When you have finished your stay in the Monitor, you can return to the language you were previously using by typing CTRL C RETURN (or, with the Apple DOS, 3 D Ø G RETURN), or simply press RESET.*

ADDRESSES AND DATA

Talking to the Monitor is somewhat like talking to any other program or language on the Apple: you type a line on the keyboard, followed by a RETURN, and the Monitor will digest what you typed and act according to those instructions. You will be giving the Monitor three types of information: *addresses, values,* and *commands.* Addresses and values are given to the Monitor in hexadecimal notation. Hexadecimal notation uses the ten decimal digits (Ø-9) to represent themselves and the first six letters (A-F) to represent the numbers 10 through 15. A single hexadecimal digit can, therefore, have one of sixteen values from 0 to 15. A pair of hex digits can assume any value from 0 to 255, and a group of four hex digits can denote any number from 0 to 65,536. It so happens that any address in the Apple can be represented by four hex digits, and any value by two hex digits. This is how you tell the Monitor about addresses and values. When the Monitor is looking for an address, it will take any group of hex digits. If there are fewer than four digits in the group, it will prepend leading zeroes; if there are more than four hex digits, the Monitor will truncate the group and use only the last four hex digits. It follows the same procedure when looking for two-digit data values.

The Monitor recognizes 22 different command characters. Some of these are punctuation marks, others are upper-case letters or control characters. In the following sections, the full name of a command will appear in capital letters. The Monitor needs only the first letter of the command name. Some commands are invoked with control characters. You should note that although the Monitor recognizes and interprets these characters, a control character typed on an input line will *not* appear on the screen.

* This does not work on Apples without the Autostart ROM.

The Monitor remembers the addresses of up to five locations. Two of these are special: they are the addresses of the last location whose value you inquired about, and the location which is next to have its value changed. These are called the *last opened location* and the *next changeable location*. The usefulness of these two addresses will be revealed shortly.

EXAMINING THE CONTENTS OF MEMORY

When you type the address of a location in memory alone on an input line to the Monitor, it will reply* with the address you typed, a dash, a space, and the value** contained in that location, thus:

```
*E000

E000- 20
*300

0300- 99
*
```

Each time the Monitor displays the value contained in a location, it remembers that location as the *last opened location*. For technical reasons, it also considers that location as the *next changeable location*.

EXAMINING SOME MORE MEMORY

If you type a period (.) on an input line to the Monitor, followed by an address, the Monitor will display a *memory dump*: the values contained in all locations from the last opened location to the location whose address you typed following the period. The Monitor then considers the last location displayed to be both the last opened location and the next changeable location.

---

* In the examples, your queries are in normal type and the Apple replies in **boldface**.

** The values printed in these examples may differ from the values displayed by your Apple for the same instructions.

```
*2Ø

ØØ2Ø- ØØ
*.2B

ØØ21- 28 ØØ 18 ØF ØC ØØ ØØ
ØØ28- A8 Ø6 DØ Ø7
*3ØØ

Ø3ØØ- 99
*.315

Ø3Ø1- B9 ØØ Ø8 ØA ØA ØA 99
Ø3Ø8- ØØ Ø8 C8 DØ F4 A6 2B A9
Ø31Ø- Ø9 85 27 AD CC Ø3
*.32A

Ø316- 85 41
Ø318- 84 4Ø 8A 4A 4A 4A 4A Ø9
Ø32Ø- CØ 85 3F A9 5D 85 3E 2Ø
Ø328- 43 Ø3 2Ø
*
```

You should notice several things about the format of a memory dump. First, the first line in the dump begins with the address of the location *following* the last opened location; second, all other lines begin with addresses which end alternately in zeroes and eights; and third, there are never more than eight values displayed on a single line in a memory dump. When the Monitor does a memory dump, it starts by displaying the address and value of the location following the last opened location. It then proceeds to the next successive location in memory. If the address of that location ends in an 8 or a Ø, the Monitor will "cut" to a new line and display the address of that location and continue displaying values. After it has displayed the value of the location whose address you specified, it stops the memory dump and sets the address of both the last opened and the next changeable location to be the address of the last location in the dump. If the address specified on the input line is less than the address of the last opened location, the Monitor will display the address and value of only the location following the last opened location.

You can combine the two commands (opening and dumping) into one operation by concatenating the second to the first; that is, type the first address, followed by a period and the second address. This two-addresses-separated-by-a-period form is called a *memory range*.

```
*3ØØ.32F

Ø3ØØ- 99 B9 ØØ Ø8 ØA ØA ØA 99
Ø3Ø8- ØØ Ø8 C8 DØ F4 A6 2B A9
Ø31Ø- Ø9 85 27 AD CC Ø3 85 41
Ø318- 84 4Ø 8A 4A 4A 4A 4A Ø9
Ø32Ø- CØ 85 3F A9 5D 85 3E 2Ø
Ø328- 43 Ø3 2Ø 46 Ø3 A5 3D 4D
*3Ø.4Ø

ØØ3Ø- AA ØØ FF AA Ø5 C2 Ø5 C2
ØØ38- 1B FD DØ Ø3 3C ØØ 4Ø ØØ
ØØ4Ø- 3Ø
*EØ15.EØ25
```

```
E015- 4C ED FD
E018- A9 20 C5 24 B0 0C A9 8D
E020- A0 07 20 ED FD A9
*
```

EXAMINING STILL MORE MEMORY

A single press of the [RETURN] key will cause the Monitor to respond with one line of a memory dump; that is, a memory dump from the location following the last opened location to the next eight-location "cut". Once again, the last location displayed is considered the last opened and next changeable location.

```
*5

0005- 00
*[RETURN]
 00 00
*[RETURN]

0008- 00 00 00 00 00 00 00 00
*32

0032- FF
*[RETURN]
 AA 00 C2 05 C2
*[RETURN]

0038- 1B FD D0 03 3C 00 3F 00
*
```

CHANGING THE CONTENTS OF A LOCATION

You've heard all about the "next changeable location"; now you're going to use it. Type a colon followed by a value.

```
*0

0000- 00
*:5F
```

Presto! The contents of the next changeable location have just been changed to the value you typed. Check this by examining that location again:

```
*0

0000- 5F
```

```
*
```

You can also combine opening and changing into one operation:

```
*302:42

*302

0302- 42
*
```

When you change the contents of a location, the old value which was contained in that location disappears, never to be seen again. The new value will stick around until it is replaced by another hexadecimal value.

CHANGING THE CONTENTS OF CONSECUTIVE LOCATIONS

You *don't* have to type an address, a colon, a value, and press [RETURN] for each and every location you wish to change. The Monitor will allow you to change the values of up to eighty-five locations at a time by typing only the initial address and colon, and then all the values separated by spaces. The Monitor will duly file the consecutive values in consecutive locations, starting at the next changeable location. After it has processed the string of values, it will assume that the location following the last changed location is the next changeable location. Thus, you can continue changing consecutive locations without breaking stride on the next input line by typing another colon and more values.

```
*300:69 01 20 ED FD 4C 0 3

*300

0300- 69
*[RETURN]
 01 20 ED FD 4C 00 03
*10:0 1 2 3

*:4 5 6 7

*10.17

0010- 00 01 02 03 04 05 06 07
*
```

MOVING A RANGE OF MEMORY

You can treat a range of memory (specified by two addresses separated by a period) as an entity unto itself and move it from one place to another in memory by using the Monitor's MOVE command. In order to move a range of memory from one place to another, the Monitor must be told both where the range is situated in memory and where it is to be moved. You give this information to the Monitor in three parts: the address of the destination of the range, the address of the first location in the range proper, and the address of the last location in the range. You specify the starting and ending addresses of the range in the normal fashion, by separating them with a period. You indicate that this range is to be placed somewhere else by separating the range and the destination address with a left caret (<). Finally, you tell the Monitor that you want to move the range to the destination by typing the letter M, for "MOVE". The final command looks like this:

```
{destination} < {start} . {end} M
```

When you type this line to the Monitor, of course, the words in curly brackets should be replaced by hexadecimal addresses and the spaces should be omitted. Here are some real examples of memory moves:

```
*Ø.F

ØØØØ- 5F ØØ Ø5 Ø7 ØØ ØØ ØØ ØØ
ØØØ8- ØØ ØØ ØØ ØØ ØØ ØØ ØØ ØØ
*3ØØ:A9 8D 2Ø ED FD A9 45 2Ø DA FD 4C ØØ Ø3

*3ØØ.3ØC

Ø3ØØ- A9 8D 2Ø ED FD A9 45 2Ø
Ø3Ø8- DA FD 4C ØØ Ø3
*Ø<3ØØ.3ØCM

*Ø.C

ØØØØ- A9 8D 2Ø ED FD A9 45 2Ø
ØØØ8- DA FD 4C ØØ Ø3
*31Ø<8.AM

*31Ø.312

Ø31Ø- DA FD 4C
*2<7.9M

*Ø.C

ØØØØ- A9 8D 2Ø DA FD A9 45 2Ø
ØØØ8- DA FD 4C ØØ Ø3
*
```

The Monitor simply makes a copy of the indicated range and moves it to the specified destination. The original range is left undisturbed. The Monitor remembers the last location in the original range as the last opened location, and the first location in the original range as the next changeable location. If the second address in the range specification is less than the first, then only one value (that of the first location in the range) will be moved.

If the destination address of the MOVE command is inside the original range, then strange and (sometimes) wonderful things happen: the locations between the beginning of the range and the destination are treated as a sub-range and the values in this sub-range are replicated throughout the original range. See "Special Tricks", page 55, for an interesting application of this feature.

COMPARING TWO RANGES OF MEMORY

You can use the Monitor to compare two ranges of memory using much the same format as you use to move a range of memory from one place to another. In fact, the VERIFY command can be used immediately after a MOVE to make sure that the move was successful.

The VERIFY command, like the MOVE command, needs a range and a destination. In shorthand:

```
{destination} < {start} . {end} V
```

The Monitor compares the range specified with the range beginning at the destination address. If there is any discrepancy, the Monitor displays the address at which the difference was found and the two offending values.

```
*0:D7 F2 E9 F4 F4 E5 EE A0 E2 F9 A0 C3 C4 C5

*300<0.DM

*300<0.DV

*6:E4

*300<0.DV

0006-E4 (EE)
*
```

Notice that the VERIFY command, if it finds a discrepancy, displays the address of the location in the original range whose value differs from its counterpart in the destination range. If there is no discrepancy, VERIFY displays nothing. It leaves both ranges unchanged. The last opened and next changeable locations are set just as in the MOVE command. As before, if the ending address of the range is less than the starting address, the values of only the first locations in the ranges will be compared. VERIFY also does unusual things if the destination is within the original range; see "Special Tricks", page 55.

SAVING A RANGE OF MEMORY ON TAPE

The Monitor has two special commands which allow you to save a range of memory onto cassette tape and recall it again for later use. The first of these two commands, WRITE, lets you save the contents of one to 65,536 memory locations on standard cassette tape.

To save a range of memory to tape, give the Monitor the starting and ending addresses of the range, followed by the letter W (for WRITE):

{start} . {end} W

To get an accurate recording, you should put the tape recorder in *record* mode before you press [RETURN] on the input line. Let the tape run a few seconds, then press [RETURN]. The Monitor will write a ten-second "leader" tone onto the tape, followed by the data. When the Monitor is finished, it will sound a "beep" and give you another prompt. You should then rewind the tape, and label the tape with something intelligible about the memory range that's on the tape and what it's supposed to be.

```
*Ø: FF FF AD 3Ø CØ 88 DØ Ø4 C6 Ø1 FØ Ø8 C
A DØ F6 A6 ØØ 4C Ø2 ØØ 6Ø

*Ø.14

ØØØØ- FF FF AD 3Ø CØ 88 DØ Ø4
ØØØ8- C6 Ø1 FØ Ø8 CA DØ F6 A6
ØØ1Ø- ØØ 4C Ø2 ØØ 6Ø
*Ø.14W

*
```

It takes about 35 seconds total to save the values of 4,096 memory locations preceded by the ten-second leader onto tape. This works out to a speed of about 1,350 bits per second, average. The WRITE command writes one extra value on the tape after it has written the values in the memory range. This extra value is the *checksum*. It is the partial sum of all values in the range. The READ subroutine uses this value to determine if a READ has been successful (see below).

READING A RANGE FROM TAPE

Once you've saved a memory range onto tape with the Monitor's WRITE command, you can read that memory range back into the Apple by using the Monitor's READ command. The data values which you've stored on the tape need not be read back into the same memory range from whence they came; you can tell the Monitor to put those values into any similarly sized memory range in the Apple's memory.

The format of the READ command is the same as that of the WRITE command, except that the command letter is R, not W.

{start} . {end} R

Once again, after typing the command, don't press [RETURN]. Instead, start the tape recorder in PLAY mode and wait for the tape's nonmagnetic leader to pass by. Although the WRITE command puts a ten-second leader tone on the beginning of the tape, the READ command needs only three seconds of this leader in order to lock on to the frequency. So you should let a few seconds of tape go by before you press [RETURN], to allow the tape recorder's output to settle down to a steady tone.

```
*Ø:Ø Ø Ø Ø Ø Ø Ø Ø Ø Ø Ø Ø Ø Ø Ø Ø Ø Ø Ø
 Ø Ø

*Ø.14
```

```
0000- 00 00 00 00 00 00 00 00
0008- 00 00 00 00 00 00 00 00
0010- 00 00 00 00 00
*0.14R

*0.14

0000- FF FF AD 30 C0 88 D0 04
0008- C6 01 F0 08 CA D0 F6 A6
0010- 00 4C 02 00 60
*
```

After the Monitor has read in and stored all the values on the tape, it reads in the extra checksum value. It compares the checksum on the tape to its own checksum, and if the two differ, the Monitor beeps the speaker and displays "ERR". This warns you that there was a problem during the READ and that the values stored in memory aren't the values which were recorded on the tape. If, however, the two checksums match, the Monitor will give you another prompt.

CREATING AND RUNNING MACHINE LANGUAGE PROGRAMS

Machine language is certainly the most efficient language on the Apple, albeit the least pleasant in which to code. The Monitor has special facilities for those of you who are determined to use machine language to simplify creating, writing, and debugging machine language programs.

You can write a machine language program, take the hexadecimal values for the opcodes and operands, and store them in memory using the commands covered above. You can get a hexadecimal dump of your program, move it around in memory, or save it to tape and recall it again simply by using the commands you've already learned. The most important command, however, when dealing with machine language programs is the GO command. When you open a location from the Monitor and type the letter G, the Monitor will cause the 6502 microprocessor to start executing the machine language program which begins at the last opened location. The Monitor treats this program as a subroutine: when it's finished, all it need do is execute an RTS (return from subroutine) instruction and control will be transferred back to the Monitor.

Your machine language programs can call many subroutines in the Monitor to do various things. Here is an example of loading and running a machine language program to display the letters A through Z:

```
*300:A9 C1 20 ED FD 18 69 1 C9 DB D0 F6 60

*300.30C

0300- A9 C1 20 ED FD 18 69 01
0308- C9 DB D0 F6 60
*300G
ABCDEFGHIJKLMNOPQRSTUVWXYZ
*
```

(The instruction set of the Apple's 6502 microprocessor is listed in Appendix A of this manual.)

Now, straight hexadecimal code isn't the easiest thing in the world to read or debug. With this in mind, the creators of the Apple's Monitor neatly included a command to list machine language programs in *assembly language* form. This means that instead of having one, two, or three bytes of unformatted hexadecimal gibberish per instruction you now have a three-letter mnemonic and some formatted hexadecimal gibberish to comprehend for each instruction. The LIST command to the Monitor will start at the specified location and display a screenfull (20 lines) of instructions.

```
*300L

0300-   A9 C1       LDA   #$C1
0302-   20 ED FD    JSR   $FDED
0305-   18          CLC
0306-   69 01       ADC   #$01
0308-   C9 DB       CMP   #$DB
030A-   D0 F6       BNE   $0302
030C-   60          RTS
030D-   00          BRK
030E-   00          BRK
030F-   00          BRK
0310-   00          BRK
0311-   00          BRK
0312-   00          BRK
0313-   00          BRK
0314-   00          BRK
0315-   00          BRK
0316-   00          BRK
0317-   00          BRK
0318-   00          BRK
0319-   00          BRK
*
```

Recognize those first few lines? They're the assembly language form of the program you typed in a page or so ago. The rest of the lines (the BRK instructions) are just there to fill up the screen. The address that you specify is remembered by the Monitor, but not in one of the ways explained before. It's put in the *Program Counter*, which is used solely to point to locations within programs. After a LIST command, the Program Counter is set to point to the location immediately following the last location displayed on the screen, so that if you do another LIST command it will continue with another screenfull of instructions, starting where the first screen left off.

THE MINI-ASSEMBLER

There is another program within the Monitor* which allows you to type programs into the Apple in the same assembly format which the LIST command displays. This program is called the Apple Mini-Assembler. It is a "mini"-assembler because it cannot understand symbolic labels, something that a full-blown assembler must do. To run the Mini-Assembler, type:

---

* The Mini-Assembler does not actually reside in the Monitor ROM, but is part of the Integer BASIC ROM set. Thus, it is not available on Apple II Plus systems or while Firmware Applesoft II is in use.

```
*F666G

!
```

You are now in the Mini-Assembler. The exclamation point (!) is the prompt character. During your stay in the Mini-Assembler, you can execute any Monitor command by preceding it with a dollar sign ($). Aside from that, the Mini-Assembler has an instruction set and syntax all its own.

The Mini-Assembler remembers one address, that of the Program Counter. Before you start to enter a program, you must set the Program Counter to point to the location where you want your program to go. Do this by typing the address followed by a colon. Follow this with the mnemonic for the first instruction in your program, followed by a space. Now type the operand of the instruction (Formats for operands are listed on page 66). Now press [RETURN]. The Mini-Assembler converts the line you typed into hexadecimal, stores it in memory beginning at the location of the Program Counter, and then disassembles it again and displays the disassembled line on top of your input line. It then poses another prompt on the next line. Now it's ready to accept the second instruction in your program. To tell it that you want the next instruction to follow the first, don't type an address or a colon, but only a space, followed by the next instruction's mnemonic and operand. Press [RETURN]. It assembles that line and waits for another.

If the line you type has an error in it, the Mini-Assembler will beep loudly and display a circumflex (^) under or near the offending character in the input line. Most common errors are the result of typographical mistakes: misspelled mnemonics, missing parentheses, etc. The Mini-Assembler also will reject the input line if you forget the space before or after a mnemonic or include an extraneous character in a hexadecimal value or address. If the destination address of a branch instruction is out of the range of the branch (more than 127 locations distant from the address of the instruction), the Mini-Assembler will also flag this as an error.

```
!300 LDX #02

0300-    A2 02        LDX   #$02
! LDA $0,X

0302-    B5 00        LDA   $00,X
! STA $10,X

0304-    95 10        STA   $10,X
! DEX

0306-    CA           DEX
! STA $C030

0307-    8D 30 C0     STA   $C030
! BPL $302

030A-    10 F6        BPL   $0302
! BRK

030C-    00           BRK
!
```

To exit the Mini-Assembler and re-enter the Monitor, either press [RESET] or type the Monitor command (preceded by a dollar sign) FF69G:

```
!$FF69G

*
```

Your assembly language program is stored in memory. You can look at it again with the LIST command:

```
*300L

0300-    A2 02         LDX    #$02
0302-    B5 00         LDA    $00,X
0304-    95 10         STA    $10,X
0306-    CA            DEX
0307-    8D 30 C0      STA    $C030
030A-    10 F6         BPL    $0302
030C-    00            BRK
030D-    00            BRK
030E-    00            BRK
030F-    00            BRK
0310-    00            BRK
0311-    00            BRK
0312-    00            BRK
0313-    00            BRK
0314-    00            BRK
0315-    00            BRK
0316-    00            BRK
0317-    00            BRK
0318-    00            BRK
0319-    00            BRK
*
```

DEBUGGING PROGRAMS

As put so concisely by Lubarsky*, "There's always one more bug." Don't worry, the Monitor provides facilities for stepping through ornery programs to find that one last bug. The Monitor's STEP** command decodes, displays, and executes one instruction at a time, and the TRACE** command steps quickly through a program, stopping when a BRK instruction is executed.

Each STEP command causes the Monitor to execute the instruction in memory pointed to by the Program Counter. The instruction is displayed in its disassembled form, then executed. The contents of the 6502's internal registers are displayed after the instruction is executed. After execution, the Program Counter is bumped up to point to the next instruction in the program.

Here's what happens when you STEP through the program you entered using the Mini-Assembler, above:

---

* In *Murphy's Law, and Other Reasons why Things Go Wrong,* edited by Arthur Bloch. Price/Stern/Sloane 1977.

** The STEP and TRACE commands are not available on Apples with the Autostart ROM.

```
*300S

0300-    A2 02        LDX   #$02
 A=0A X=02 Y=D8 P=30 S=F8
*S

0302-    B5 00        LDA   $00,X
 A=0C X=02 Y=D8 P=30 S=F8
*S

0304-    95 10        STA   $10,X
 A=0C X=02 Y=D8 P=30 S=F8
*12

0012- 0C
*S

0306-    CA           DEX
 A=0C X=01 Y=D8 P=30 S=F8
*S

0307-    8D 30 C0     STA   $C030
 A=0C X=01 Y=D8 P=30 S=F8
*S

030A-    10 F6        BPL   $0302
 A=0C X=01 Y=D8 P=30 S=F8
*S

0302-    B5 00        LDA   $00,X
 A=0B X=01 Y=D8 P=30 S=F8
*S

0304-    95 10        STA   $10,X
 A=0B X=01 Y=D8 P=30 S=F8
*
```

Notice that after the third instruction was executed, we examined the contents of location 12. They were as we expected, and so we continued stepping. The Monitor keeps the Program Counter and the last opened address separate from one another, so that you can examine or change the contents of memory while you are stepping through your program.

The TRACE command is just an infinite STEPper. It will stop TRACEing the execution of a program only when you push RESET or it encounters a BRK instruction in the program. If the TRACE encounters the end of a program which returns to the Monitor via an RTS instruction, the TRACEing will run off into never-never land and must be stopped with the RESET button.

```
*T

0306-    CA           DEX
 A=0B X=00 Y=D8 P=32 S=F8
0307-    8D 30 C0     STA   $C030
 A=0B X=00 Y=D8 P=32 S=F8
030A-    10 F6        BPL   $0302
```

```
 A=ØB X=ØØ Y=D8 P=32 S=F8
Ø3Ø2-    B5 ØØ          LDA    $ØØ,X
 A=ØA X=ØØ Y=D8 P=3Ø S=F8
Ø3Ø4-    95 1Ø          STA    $1Ø,X
 A=ØA X=ØØ Y=D8 P=3Ø S=F8
Ø3Ø6-    CA             DEX
 A=ØA X=FF Y=D8 P=BØ S=F8
Ø3Ø7-    8D 3Ø CØ       STA    $CØ3Ø
 A=ØA X=FF Y=D8 P=BØ S=F8
Ø3ØA-    1Ø F6          BPL    $Ø3Ø2
 A=ØA X=FF Y=D8 P=BØ S=F8
Ø3ØC-    ØØ             BRK
Ø3ØC-      A=ØA X=FF Y=D8 P=BØ S=F8
*
```

EXAMINING AND CHANGING REGISTERS

As you saw above, the STEP and TRACE commands displayed the contents of the 65Ø2's internal registers after each instruction. You can examine these registers at will or pre-set them when you TRACE, STEP, or GO a machine language program.

The Monitor reserves five locations in memory for the five 65Ø2 registers: A, X, Y, P (processor status register), and S (stack pointer). The Monitor's EXAMINE command, invoked by a CTRL E, tells the Monitor to display the contents of these locations on the screen, and lets the location which holds the 65Ø2's A-register be the next changeable location. If you want to change the values in these locations, just type a colon and the values separated by spaces. Next time you give the Monitor a GO, STEP, or TRACE command, the Monitor will load these five locations into their proper registers inside the 65Ø2 before it executes the first instruction in your program.

```
*CTRL E

 A=ØA X=FF Y=D8 P=BØ S=F8
*:BØ Ø2

*CTRL E

 A=BØ X=Ø2 Y=D8 P=BØ S=F8
*3Ø6S

Ø3Ø6-    CA             DEX
 A=BØ X=Ø1 Y=D8 P=3Ø S=F8
*S

Ø3Ø7-    8D 3Ø CØ       STA    $CØ3Ø
 A=BØ X=Ø1 Y=D8 P=3Ø S=F8
*S

Ø3ØA-    1Ø F6          BPL    $Ø3Ø2
 A=BØ X=Ø1 Y=D8 P=3Ø S=F8

*
```

MISCELLANEOUS MONITOR COMMANDS

You can control the setting of the Inverse/Normal location used by the COUT subroutine (see page 32) from the Monitor so that all of the Monitor's output will be in Inverse video. The INVERSE command does this nicely. Input lines are still displayed in Normal mode, however. To return the Monitor's output to Normal mode, use the NORMAL command.

```
*Ø.F

ØØØØ- ØA ØB ØC ØD ØE ØF DØ Ø4
ØØØ8- C6 Ø1 FØ Ø8 CA DØ F6 A6
*I

*Ø.F

ØØØØ- ØA ØB ØC ØD ØE ØF DØ Ø4
ØØØ8- C6 Ø1 FØ Ø8 CA DØ F6 A6
*N

*Ø.F

ØØØØ- ØA ØB ØC ØD ØE ØF DØ Ø4
ØØØ8- C6 Ø1 FØ Ø8 CA DØ F6 A6
*
```

The BASIC command, invoked by a [CTRL B], lets you leave the Monitor and enter the language installed in ROM on your Apple, usually either Apple Integer or Applesoft II BASIC. Any program or variables that you had previously in BASIC will be lost. If you've left BASIC for the Monitor and you want to re-enter BASIC with your program and variables intact, use the [CTRL C] (CONTINUE BASIC) command. If you have the Apple Disk Operating System (DOS) active, the '3DØG' command will return you to the language you were using, with your program and variables intact.

The PRINTER command, activated by a [CTRL P], diverts all output normally destined for the screen to an Apple Intelligent Interface® in a given slot in the Apple's backplane. The slot number should be from 1 to 7, and there should be an interface card in the given slot, or you will lose control of your Apple and your program and variables may be lost. The format for the command is:

{slot number} [CTRL P]

A PRINTER command to slot number Ø will reset the flow of printed output back to the Apple's video screen.

The KEYBOARD command similarly substitutes the device in a given backplane slot for the Apple's keyboard. For details on how these commands and their BASIC counterparts PR# and IN# work, please refer to "CSW and KSW Switches", page 83. The format for the KEYBOARD command is:

{slot number} [CTRL K]

A slot number of Ø for the KEYBOARD command will force the Monitor to listen for input from the Apple's built-in keyboard.

The Monitor will also perform simple hexadecimal addition and subtraction. Just type a line in the format:

{value} + {value}
{value} − {value}

The Apple will perform the arithmetic and display the result:

```
*2Ø+13
=33
*4A-C
=3E
*FF+4
=Ø3
*3-4
=FF
*
```

SPECIAL TRICKS WITH THE MONITOR

You can put as many Monitor commands on a single line as you like, as long as you separate them with spaces and the total number of characters in the line is less than 254. You can intermix any and all commands freely, except the STORE (:) command. Since the Monitor takes all values following a colon and places them in consecutive memory locations, the last value in a STORE must be followed by a letter command before another address is encountered. The NORMAL command makes a good separator; it usually has no effect and can be used anywhere.

```
*3ØØ.3Ø7 3ØØ:18 69 1 N 3ØØ.3Ø2 3ØØS S

Ø3ØØ- ØØ ØØ ØØ ØØ ØØ ØØ ØØ ØØ
Ø3ØØ- 18 69 Ø1
Ø3ØØ-    18           CLC
 A=Ø4 X=Ø1 Y=D8 P=3Ø S=F8
Ø3Ø1-    69 Ø1        ADC    #$Ø1
 A=Ø5 X=Ø1 Y=D8 P=3Ø S=F8
*
```

Single-letter commands such as L, S, I, and N need not be separated by spaces.

If the Monitor encounters a character in the input line which it does not recognize as either a hexadecimal digit or a valid command character, it will execute all commands on the input line up to that character, and then grind to a halt with a noisy beep, ignoring the remainder of the input line.

The MOVE command can be used to replicate a pattern of values throughout a range in memory.

To do this, first store the pattern in its first position in the range:

```
*300:11 22 33

*
```

Remember the number of values in the pattern: in this case, 3. Then use this special arrangement of the MOVE command:

{start+number} < {start} . {end−number} M

This MOVE command will first replicate the pattern at the locations immediately following the original pattern, then re-replicate that pattern following itself, and so on until it fills the entire range.

```
*303<300.32DM

*300.32F

0300- 11 22 33 11 22 33 11 22
0308- 33 11 22 33 11 22 33 11
0310- 22 33 11 22 33 11 22 33
0318- 11 22 33 11 22 33 11 22
0320- 33 11 22 33 11 22 33 11
0328- 22 33 11 22 33 11 22 33
*
```

A similar trick can be done with the VERIFY command to check whether a pattern repeats itself through memory. This is especially useful to verify that a given range of memory locations all contain the same value:

```
*300:0

*301<300.31FM

*301<300.31FV

*304:02

*301<300.31FV

0303-00 (02)
0304-02 (00)
*
```

You can create a command line which will repeat all or part of itself indefinitely by beginning the part of the command line which is to be repeated with a letter command, such as **N**, and ending it with the sequence 34:*n*, where *n* is a hexadecimal number specifying the character position of the command which begins the loop; for the first character in the line, *n*=0. The value for *n* must be followed with a space in order for the loop to work properly.

```
*N 300 302 34:0

0300- 11
```

```
0302- 33
0300- 11
0302- 33
0300- 11
0302- 33
0300- 11
0302- 33
0300- 11
0302- 33
0300- 11
0302- 33
030
*
```

The only way to stop a loop like this is to press [RESET].

CREATING YOUR OWN COMMANDS

The USER ([CTRL Y]) command, when encountered in the input line, forces the Monitor to jump to location number $3F8 in memory. You can put your own JMP instruction in this location which will jump to your own program. Your program can then either examine the Monitor's registers and pointers or the input line itself. For example, here is a program which will make the [CTRL Y] command act as a "comment" indicator: everything on the input line following the [CTRL Y] will be displayed and ignored.

```
*F666G

!300:LDY $34

0300-    A4 34       LDY   $34
! LDA 200,Y

0302-    B9 00 02    LDA   $0200,Y
! JSR FDED

0305-    20 ED FD    JSR   $FDED
! INY

0308-    C8          INY
! CMP #$8D

0309-    C9 8D       CMP   #$8D
! BNE 302

030B-    D0 F5       BNE   $0302
! JMP $FF69

030D-    4C 69 FF    JMP   $FF69
!3F8:JMP $300

03F8-    4C 00 03    JMP   $0300
```

```
!SFF69G

*[CTRL Y] THIS IS A TEST.
THIS IS A TEST.

*
```

SUMMARY OF MONITOR COMMANDS

Summary of Monitor Commands.

Examining Memory.	
{adrs}	Examines the value contained in one location.
{adrs1}.{adrs2}	Displays the values contained in all locations between {adrs1} and {adrs2}.
RETURN	Displays the values in up to eight locations following the last opened location.
Changing the Contents of Memory.	
{adrs}:{val} {val} ...	Stores the values in consecutive memory locations starting at {adrs}.
:{val} {val} ...	Stores values in memory starting at the next changeable location.
Moving and Comparing.	
{dest}<{start}.{end}M	Copies the values in the range {start}.{end} into the range beginning at {dest}.
{dest}<{start}.{end}V	Compares the values in the range {start}.{end} to those in the range beginning at {dest}.
Saving and Loading via Tape.	
{start}.{end}W	Writes the values in the memory range {start}.{end} onto tape, preceded by a ten-second leader.
{start}.{end}R	Reads values from tape, storing them in memory beginning at {start} and stopping at {end}. Prints "ERR" if an error occurs.
Running and Listing Programs.	
{adrs}G	Transfers control to the machine language program beginning at {adrs}.
{adrs}L	Disassembles and displays 20 instructions, starting at {adrs}. Subsequent L's will display 20 more instructions each.

The Mini-Assembler

F666G	Invoke the Mini-Assembler.*
$\{command\}	Execute a Monitor command from the Mini-Assembler.
$FF69G	Leave the Mini-Assembler.
{adrs} S	Disassemble, display, and execute the instruction at {adrs}, and display the contents of the 6502's internal registers. Subsequent S's will display and execute successive instructions.**
{adrs} T	Step infinitely. The TRACE command stops only when it executes a BRK instruction or when you press RESET.**
CTRL E	Display the contents of the 6502's registers.

Miscellaneous.

I	Set Inverse display mode.
N	Set Normal display mode.
CTRL B	Enter the language currently installed in the Apple's ROM.
CTRL C	Reenter the language currently installed in the Apple's ROM.
{val}+{val}	Add the two values and print the result.
{val}−{val}	Subtract the second value from the first and print the result.
{slot} CTRL P	Divert output to the device whose interface card is in slot number {slot}. If {slot}=0, then route output to the Apple's screen.
{slot} CTRL K	Accept input from the device whose interface card is in slot number {slot}. If {slot}=0, then accept input from the Apple's keyboard.
CTRL Y	Jump to the machine language subroutine at location $3F8.

* Not available in the Apple II Plus.
** Not available in the Autostart ROM.

SOME USEFUL MONITOR SUBROUTINES

Here is a list of some useful subroutines in the Apple's Monitor and Autostart ROMs. To use these subroutines from machine language programs, load the proper memory locations or 65Ø2 registers as required by the subroutine and execute a JSR to the subroutine's starting address. It will perform the function and return with the 65Ø2's registers set as described.

$FDED COUT Output a character

COUT is the standard character output subroutine. The character to be output should be in the accumulator. COUT calls the current character output subroutine whose address is stored in CSW (locations $36 and $37), usually COUT1 (see below).

$FDFØ COUT1 Output to screen

COUT1 displays the character in the accumulator on the Apple's screen at the current output cursor position and advances the output cursor. It places the character using the setting of the Normal/Inverse location. It handles the control characters RETURN, linefeed, and bell. It returns with all registers intact.

$FE8Ø SETINV Set Inverse mode

Sets Inverse video mode for COUT1. All output characters will be displayed as black dots on a white background. The Y register is set to $3F, all others are unchanged.

$FE84 SETNORM Set Normal mode

Sets Normal video mode for COUT1. All output characters wwill be displayed as white dots on a black background. The Y register is set to $FF, all others are unchanged.

$FD8E CROUT Generate a RETURN

CROUT sends a RETURN character to the current output device.

$FD8B CROUT1 RETURN with clear

CROUT1 clears the screen from the current cursor position to the edge of the text window, then calls CROUT.

$FDDA PRBYTE Print a hexadecimal byte

This subroutine outputs the contents of the accumulator in hexadecimal on the current output device. The contents of the accumulator are scrambled.

$FDE3 PRHEX Print a hexadecimal digit

This subroutine outputs the lower nybble of the accumulator as a single hexadecimal digit. The contents of the accumulator are scrambled.

$F941 PRNTAX Print A and X in hexadecimal

This outputs the contents of the A and X reisters as a four-digit hexadecimal value. The accumulator contains the first byte output, the X register contains the second. The contents of the accumulator are usually scrambled.

$F948 PRBLNK Print 3 spaces

Outputs three blank spaces to the standard output device. Upon exit, the accumulator usually contains $AØ, the X register contains Ø.

$F94A PRBL2 Print many blank spaces

This subroutine outputs from 1 to 256 blanks to the standard output device. Upon entry, the X register should contain the number of blanks to be output. If X=$ØØ, then PRBL2 will output 256 blanks.

$FF3A BELL Output a "bell" character

This subroutine sends a bell (CTRL G) character to the current output device. It leaves the accumulator holding $87.

$FBDD BELL1 Beep the Apple's speaker

This subroutine beeps the Apple's speaker for .1 second at 1KHz. It scrambles the A and X registers.

$FDØC RDKEY Get an input character

This is the standard character input subroutine. It places a flashing input cursor on the screen at the position of the output cursor and jumps to the current input subroutine whose address is stored in KSW (locations $38 and $39), usually KEYIN (see below).

$FD35 RDCHAR Get an input character or ESC code

RDCHAR is an alternate input subroutine which gets characters from the standard input, but also interprets the eleven escape codes (see page 34).

$FD1B KEYIN Read the Apple's keyboard

This is the keyboard input subroutine. It reads the Apple's keyboard, waits for a keypress, and randomizes the random number seed (see page 32). When it gets a keypress, it removes the flashing cursor and returns with the keycode in the accumulator.

$FD6A GETLN Get an input line with prompt

GETLN is the subroutine which gathers input lines (see page 33). Your programs can call GETLN with the proper prompt character in location $33; GETLN will return with the input line in the input buffer (beginning at location $2ØØ) and the X register holding the length of the input line.

$FD67 GETLNZ Get an input line

GETLNZ is an alternate entry point for GETLN which issues a carriage return to the standard output before falling into GETLN (see above).

$FD6F GETLN1 Get an input line, no prompt

GETLN1 is an alternate entry point for GETLN which does not issue a prompt before it gathers the input line. If, however, the user cancels the input line, either with too many backspaces or with a CTRL X, then GETLN1 will issue the contents of location $33 as a prompt when it gets another line.

$FCA8 WAIT Delay

This subroutine delays for a specific amount of time, then returns to the program which called it. The amount of delay is specified by the contents of the accumulator. With A the contents of the accumulator, the delay is $\frac{1}{2}(26+27A+5A^2)$ μseconds. WAIT returns with the A register zeroed and the X and Y registers undisturbed.

$F864 SETCOL Set Low-Res Graphics color

This subroutine sets the color used for plotting on the Low-Res screen to the color passed in the accumulator. See page 17 for a table of Low-Res colors.

$F85F NEXTCOL Increment color by 3

This adds 3 to the current color used for Low-Res Graphics.

$F800 PLOT Plot a block on the Low-Res screen

This subroutine plots a single block on the Low-Res screen of the prespecified color. The block's vertical position is passed in the accumulator, its horizontal position in the Y register. PLOT returns with the accumulator scrambled, but X and Y unmolested.

$F819 HLINE Draw a horizontal line of blocks

This subroutine draws a horizontal line of blocks of the predetermined color on the Low-Res screen. You should call HLINE with the vertical coordinate of the line in the accumulator, the leftmost horizontal coordinate in the Y register, and the rightmost horizontal coordinate in location $2C. HLINE returns with A and Y scrambled, X intact.

$F828 VLINE Draw a vertical line of blocks

This subroutine draws a vertical line of blocks of the predetermined color on the Low-Res screen. You should call VLINE with the horizontal coordinate of the line in the Y register, the top vertical coordinate in the accumulator, and the bottom vertical coordinate in location $2D. VLINE will return with the accumulator scrambled.

$F832 CLRSCR Clear the entire Low-Res screen

CLRSCR clears the entire Low-resolution Graphics screen. If you call CLRSCR while the video display is in Text mode, it will fill the screen with inverse-mode "@" characters. CLRSCR destroys the contents of A and Y.

$F836 CLRTOP Clear the top of the Low-Res screen

CLRTOP is the same as CLRSCR (above), except that it clears only the top 40 rows of the screen.

$F871 SCRN Read the Low-Res screen

This subroutine returns the color of a single block on the Low-Res screen. Call it as you would call PLOT (above). The color of the block will be returned in the accumulator. No other registers are changed.

$FB1E PREAD Read a Game Controller

PREAD will return a number which represents the position of a game controller. You should pass the number of the game controller (Ø to 3) in the X register. If this number is not valid, strange things may happen. PREAD returns with a number from $ØØ to $FF in the Y register. The accumulator is scrambled.

$FF2D PRERR Print "ERR"

Sends the word "ERR", followed by a bell character, to the standard output device. The accumulator is scrambled.

$FF4A IOSAVE Save all registers

The contents of the 65Ø2's internal registers are saved in locations $45 through $49 in the order A-X-Y-P-S. The contents of A and X are changed; the decimal mode is cleared.

$FF3F IOREST Restore all registers

The contents of the 65Ø2's internal registers are loaded from locations $45 through $49.

MONITOR SPECIAL LOCATIONS

Table 14: Page Three Monitor Locations			
Address: Decimal	Hex	Use: Monitor ROM	Autostart ROM
1008 1009	\$3F0 \$3F1	None.	Holds the address of the subroutine which handles machine language "BRK" requests (normally \$FA59).
1010 1011	\$3F2 \$3F3	None.	Soft Entry Vector.
1012	\$3F4	None.	Power-up Byte.
1013 1014 1015	\$3F5 \$3F6 \$3F7	Holds a "JuMP" instruction to the subroutine which handles Applesoft II "&" commands.* Normally \$4C \$58 \$FF.	
1016 1017 1018	\$3F8 \$3F9 \$3FA	Holds a "JuMP" instruction to the subroutine which handles "USER" (CTRL Y) commands.	
1019 1020 1021	\$3FB \$3FC \$3FD	Holds a "JuMP" instruction to the subroutine which handles Non-Maskable Interrupts.	
1022 1023	\$3FE \$3FF	Holds the address of the subroutine which handles Interrupt ReQuests.	

* See page 123 in the **Applesoft II BASIC Reference Manual**

MINI-ASSEMBLER INSTRUCTION FORMATS

The Apple Mini-Assembler recognizes 56 mnemonics and 13 addressing formats used in 65Ø2 Assembly language programming. The mnemonics are standard, as used in the **MOS Technology/Synertek 6500 Programming Manual** (Apple part number A2L0003), but the addressing formats are different. Here are the Apple standard address mode formats for 65Ø2 Assembly Language:

Table 15: Mini-Assembler Address Formats	
Mode:	Format:
Accumulator	None.
Immediate	#${value}
Absolute	${address}
Zero Page	${address}
Indexed Zero Page	${address},X ${address},Y
Indexed Absolute	${address},X ${address},Y
Implied	None.
Relative	${address}
Indexed Indirect	(${address},X)
Indirect Indexed	(${address}),Y
Absolute Indirect	(${address})

An {address} consists of one or more hexadecimal digits. The Mini-Assembler interprets addresses in the same manner that the Monitor does: if an address has fewer than four digits, it adds leading zeroes; if it has more than four digits, then it uses only the last four.

All dollar signs ($), signifying that the addresses are in hexadecimal notation, are ignored by the Mini-Assembler and may be omitted.

There is no syntactical distinction between the Absolute and Zero Page addressing modes. If you give an instruction to the Mini-Assembler which can be used in both Absolute and Zero-Page mode, then the Mini-Assembler will assemble that instruction in Absolute mode if the operand for that instruction is greater than $FF, and it will assemble that instruction in Zero Page mode if the operand for that instruction is less than $Ø1ØØ.

Instructions with the Accumulator and Implied addressing modes need no operand.

Branch instructions, which use the Relative addressing mode, require the *target address* of the branch. The Mini-Assembler will automatically figure out the relative distance to use in the instruction. If the target address is more than 127 locations distant from the instruction, then the Mini-Assembler wil sound a "beep", place a circumflex (^) under the target address, and ignore the line.

If you give the Mini-Assembler the mnemonic for an instruction and an operand, and the addressing mode of the operand cannot be used with the instruction you entered, then the Mini-Assembler will not accept the line.

CHAPTER 4
MEMORY ORGANIZATION

The Apple's 65Ø2 microprocessor can directly reference a total of 65,536 distinct memory locations. You can think of the Apple's memory as a book with 256 "pages", with 256 memory locations on each page. For example, "page $3Ø" is the 256 memory locations beginning at location $3ØØØ and ending at location $3ØFF. Since the 65Ø2 uses two eight-bit bytes to form the address of any memory location, you can think of one of the bytes as the *page number* and the other as the *location within the page*.

The Apple's 256 pages of memory fall into three categories: Random Access Memory (RAM), Read-Only Memory (ROM), and Input/Output locations (I/O). Different areas of memory are dedicated to different functions. The Apple's basic memory map looks like this:

System Memory Map		
Page Number: Decimal	Hex	
Ø	$ØØ	RAM (48K)
1	$Ø1	
2	$Ø2	
.	.	
.	.	
.	.	
19Ø	$BE	
191	$BF	
192	$CØ	I/O (2K)
193	$C1	
.	.	
.	.	
.	.	
198	$C6	
199	$C7	
2ØØ	$C8	I/O ROM (2K)
2Ø1	$C9	
.	.	
.	.	
.	.	
2Ø6	$CE	
2Ø7	$CF	
2Ø8	$DØ	ROM (12K)
2Ø9	$D1	
.	.	
.	.	
.	.	
254	$FE	
255	$FF	

Figure 5. System Memory Map

RAM STORAGE

The area in the Apple's memory map which is allocated for RAM memory begins at the bottom of Page Zero and extends up to the end of Page 191. The Apple has the capacity to house from 4K (4,096 bytes) to 48K (49,152 bytes) of RAM on its main circuit board. In addition, you can expand the RAM memory of your Apple all the way up to 64K (65,536 bytes) by installing an Apple Language Card (part number A2B0006). This extra 16K of RAM takes the place of the Apple's ROM memory, with two 4K segments of RAM sharing the 4K range from $D000 to $DFFF.

Most of your Apple's RAM memory is available to you for the storage of programs and data. The Apple, however, does reserve some locations in RAM for use of the System Monitor, various languages, and other system functions. Here is a map of the available areas in RAM memory:

Table 16: RAM Organization and Usage

Page Number: Decimal	Hex	Used For:	
0	$00	System Programs	
1	$01	System Stack	
2	$02	GETLN Input Buffer	
3	$03	Monitor Vector Locations	
4 5 6 7	$04 $05 $06 $07	Text and Lo-Res Graphics Primary Page Storage	
8 9 10 11	$08 $09 $0A $0B	Text and Lo-Res Graphics Secondary Page Storage	FREE RAM
12 through 31	$0C $1F		
32 through 63	$20 $3F	Hi-Res Graphics Primary Page Storage	
64 through 95	$40 $5F	Hi-Res Graphics Secondary Page Storage	
96 through 191	$60 $BF		

Following is a breakdown of which ranges are assigned to which functions:

Zero Page. Due to the construction of the Apple's 6502 microprocessor, the lowermost page in the Apple's memory is prime real estate for machine language programs. The System Monitor uses about 20 locations on Page Zero; Apple Integer BASIC uses a few more; and Applesoft II BASIC and the Apple Disk Operating System use the rest. Tables 18, 19, 20, and 21 show the locations on zero page which are used by these system functions.

Page One. The Apple's 6502 microprocessor reserves all 256 bytes of Page 1 for use as a "stack". Even though the Apple usually uses less than half of this page at any one time, it is not easy to determine just what is being used and what is lying fallow, so you shouldn't try to use

Page 1 to store any data.

Page Two. The GETLN subroutine, which is used to get input lines by most programs and languages, uses Page 2 as its input buffer. If you're sure that you won't be typing any long input lines, then you can (somewhat) safely store temporary data in the upper regions of Page 2.

Page Three. The Apple's Monitor ROM (both the Autostart and the original) use the upper sixteen locations in Page Three, from location $3FØ to $3FF (decimal 1ØØ8 to 1Ø23). The Monitor's use of these locations is outlined on page 62.

Pages Four through Seven. This 1,024-byte range of memory locations is used for the Text and Low-Resolution Graphics Primary Page display, and is therefore unusable for storage purposes. There are 64 locations in this range which are not displayed on the screen. These 64 locations are reserved for use by the peripheral cards (see page 82).

RAM CONFIGURATION BLOCKS

The Apple's RAM memory is composed of eight to 24 integrated circuits. These IC's reside in three rows of sockets on the Apple board. Each row can hold eight chips of either the 4,096-bit (4K) or 16,384-bit (16K) variety. The 4K RAM chips are of the Mostek "4096" family, and may be marked "MK4096" or "MCM6604". The 16K chips are of the "4116" type, and may have the denomination "MK4116" or "UPD4160". Each row must have eight of the same type of chip, although different rows may hold different types.

A row of eight 16K IC's represents 16,384 eight-bit bytes of RAM. The leftmost IC in a row represents the lowermost (least significant) bit of every byte in that range, and the rightmost IC in a row represents the uppermost (most significant) bit of every byte. The row of RAM IC's which is frontmost on the Apple board holds the RAM memory which begins at location Ø in the memory map; the next row back continues where the first left off.

You can tell the Apple how much memory it has, and of what type it is, by plugging *Memory Configuration Blocks* into three IC sockets on the left side of the Apple board. These configuration blocks are three 14-legged critters which look like big, boxy integrated circuits. But there are no chips inside of them; only three jumper wires in each. The jumper wires "strap" each row of RAM chips into a specific place in the Apple's memory map. All three configuration blocks should be strapped the same way. Apple supplies several types of standard configuration blocks for the most common system sizes. A set of these was installed in your Apple when it was built, and you get a new set each time you purchase additional memory for your Apple. If, however, you want to expand your Apple's memory with some RAM chips that you did not purchase from Apple, you may have to construct your own configuration blocks (or modify the ones already in your Apple).

There are nine different RAM memory configurations possible in your Apple. These nine memory sizes are made up from various combinations of 4K and 16K RAM chips in the three rows of sockets in your Apple. The nine memory configurations are:

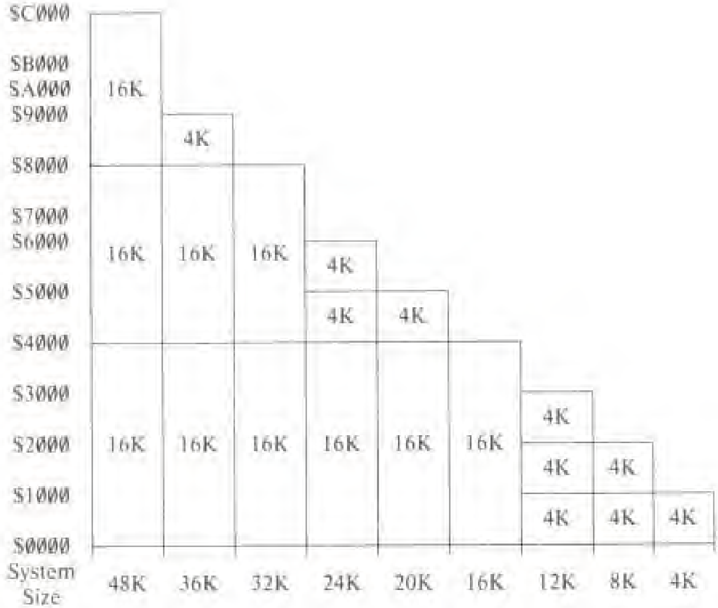


Figure 6. Memory Configurations

Of the fourteen "legs" on each controller block, the three in the upper-right corner (looking at it from above) represent the three rows of RAM chips on the Apple's main board. There should be a wire jumper from each one of these pins to another pin in the configuration block. The "other pin" corresponds to a place in the Apple's memory map where you want the RAM chips in each row to reside. The pins on the configuration block are represented thus:

4K range \$0000-\$0FFF	*1* ○	*14*	Frontmost row ("C")
4K range \$1000-\$1FFF	*2*	*13*	Middle row ("D")
4K range \$2000-\$2FFF	*3*	*12*	Backmost row ("E")
4K range \$3000-\$3FFF	*4*	*11*	No connection.
4K range \$4000-\$4FFF	*5*	*10*	16K range \$0000-\$3FFF
4K range \$5000-\$5FFF	*6*	*9*	16K range \$4000-\$7FFF
4K range \$8000-\$8FFF	*7*	*8*	16K range \$8000-\$BFFF

Figure 7. Memory Configuration Block Pinouts

If a row contains eight chips of the 16K variety, then you should connect a jumper wire from the pin corresponding to that row to a pin corresponding to a 16K range of memory. Similarly, if a row contains eight 4K chips, you should connect a jumper wire from the pin for that row to a pin corresponding to a 4K range of memory. You should *never* put 4K chips in a row strapped for 16K, or vice versa. It is also not advisable to leave a row unstrapped, or to strap two rows into the same range of memory.

You should always make sure that there is some kind of memory beginning at location 0. Your Apple's memory should be in one contiguous block, but it does not need to be. For example, if you have only three sets of 4K chips, but you want to use the primary page of the High-

Resolution Graphics mode, then you would strap one row of 4K chips to the beginning of memory (4K range $0000 through $0FFF), and strap the other two rows to the memory range used by the High-Resolution Graphics primary page (4K ranges $2000 through $2FFF and $3000 through $3FFF). This will give you 4K bytes of RAM memory to work with, and 8K bytes of RAM to be used as a picture buffer.

Notice that the configuration blocks are installed into the Apple with their front edges (the edge with the white dot, representing pin 1) towards the front of the Apple.

There is a problem in Apples with Revision 0 boards and 20K or 24K of RAM. In these systems, the 8K range of the memory map from $4000 to $5FFF is duplicated in the memory range $6000 to $7FFF, regardless of whether it contains RAM or not. So systems with only 20K or 24K of RAM would appear to have 24K or 36K, but this extra RAM would be only imaginary. This has been changed in the Revision 1 Apple boards.

ROM STORAGE

The Apple, in its natural state, can hold from 2K (2,048 bytes) to 12K (12,288 bytes) of Read-Only memory on its main board. This ROM memory can include the System Monitor, a couple of dialects of the BASIC language, various system and utility programs, or pre-packaged subroutines such as are included in Apple's *Programmer's Aid #1* ROM.

The Apple's ROM memory resides in the top 12K (48 pages) of the memory map, beginning at location $D000. For proper operation of the Apple, there must be some kind of ROM in the upppermost locations of memory. When you turn on the Apple's power supply, the microprocessor must have some program to execute. It goes to the top locations in the memory map for the address of this program. In the Apple, this address is stored in ROM, and is the address of a program within the same ROM. This program initializes the Apple and lets you start to use it. (For a description of the startup cycle, see "The RESET Cycle", page 36.)

Here is a map of the Apple's ROM memory, and of the programs and packages that Apple currently supports in ROM:

<table>
<tr><th colspan="4">Table 17: ROM Organization and Usage</th></tr>
<tr><th colspan="2">Page Number:</th><th colspan="2" rowspan="2">Used By:</th></tr>
<tr><th>Decimal</th><th>Hex</th></tr>
<tr><td>208</td><td>$D0</td><td rowspan="2">Programmer's Aid #1</td><td rowspan="10">Applesoft
II
BASIC</td></tr>
<tr><td>212</td><td>$D4</td></tr>
<tr><td>216</td><td>$D8</td><td rowspan="2"></td></tr>
<tr><td>220</td><td>$DC</td></tr>
<tr><td>224</td><td>$E0</td><td rowspan="5">Integer BASIC</td></tr>
<tr><td>228</td><td>$E4</td></tr>
<tr><td>232</td><td>$E8</td></tr>
<tr><td>236</td><td>$EC</td></tr>
<tr><td>240</td><td>$F0</td></tr>
<tr><td>244</td><td>$F4</td><td>Utility Subroutines</td></tr>
<tr><td>248</td><td>$F8</td><td rowspan="2">Monitor ROM</td><td rowspan="2">Autostart ROM</td></tr>
<tr><td>252</td><td>$FC</td></tr>
</table>

Six 24-pin IC sockets on the Apple's board hold the ROM integrated circuits. Each socket can hold one of a type 9316B 2,048-byte by 8-bit Read-Only Memory. The leftmost ROM in the Apple's board holds the upper 2K of ROM in the Apple's memory map; the rightmost ROM IC holds the ROM memory beginning at page $DØ in the memory map. If a ROM is not present in a given socket, then the values contained in the memory range corresponding to that socket will be unpredictable.

The Apple Firmware card can disable some or all of the ROMs on the Apple board, and substitute its own ROMs in their place. When you have an Apple Firmware card installed in any slot in the Apple's board, you can disable the Apple's on-board ROMs by flipping the card's controller switch to its UP position and pressing and releasing the RESET button, or by referencing location $CØ8Ø (decimal 4928Ø or -16256). To enable the Apple's on-board ROMs again, flip the controller switch to the DOWN position and press RESET, or reference location $CØ81 (decimal 49281 or -16255). For more information, see Appendix A of the **Applesoft II BASIC Programming Reference Manual**.

I/O LOCATIONS

4,096 memory locations (16 pages) of the Apple's memory map are dedicated to input and output functions. This 4K range begins at location $CØØØ (decimal 49152 or -16384) and extends on up to location $CFFF (decimal 53247 or -12289). Since these functions are somewhat intricate, they have been given a chapter all to themselves. Please see Chapter 5 for information on the allocation of Input/Output locations.

ZERO PAGE MEMORY MAPS

Table 18: Monitor Zero Page Usage

Decimal	Hex	Ø $Ø	1 $1	2 $2	3 $3	4 $4	5 $5	6 $6	7 $7	8 $8	9 $9	1Ø $A	11 $B	12 $C	13 $D	14 $E	15 $F
Ø	$ØØ																
16	$1Ø																
32	$2Ø	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
48	$3Ø	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
64	$4Ø	•	•	•	•	•	•	•	•	•	•					•	•
8Ø	$5Ø	•	•	•	•	•	•										
96	$6Ø																
112	$7Ø																
128	$8Ø																
144	$9Ø																
16Ø	$AØ																
176	$BØ																
192	$CØ																
2Ø8	$DØ																
224	$EØ																
24Ø	$FØ																

Table 19: Applesoft II BASIC Zero Page Usage

Decimal	Hex	Ø $Ø	1 $1	2 $2	3 $3	4 $4	5 $5	6 $6	7 $7	8 $8	9 $9	1Ø $A	11 $B	12 $C	13 $D	14 $E	15 $F
Ø	$ØØ	•	•	•	•	•	•					•	•	•	•	•	•
16	$1Ø	•	•	•	•	•	•	•	•	•							
32	$2Ø																
48	$3Ø																
64	$4Ø																
8Ø	$5Ø	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
96	$6Ø	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
112	$7Ø	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
128	$8Ø	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
144	$9Ø	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
16Ø	$AØ	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
176	$BØ	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
192	$CØ	•	•	•	•	•	•	•	•	•	•	•	•	•	•		
2Ø8	$DØ	•	•	•	•	•	•			•	•	•	•	•	•	•	•
224	$EØ	•	•	•		•	•	•	•	•	•	•					
24Ø	$FØ	•	•	•	•	•	•	•	•	•							

Table 20: Apple DOS 3.2 Zero Page Usage																	
Decimal		Ø	1	2	3	4	5	6	7	8	9	1Ø	11	12	13	14	15
	Hex	$Ø	$1	$2	$3	$4	$5	$6	$7	$8	$9	$A	$B	$C	$D	$E	$F
Ø	$ØØ																
16	$1Ø																
32	$2Ø							●	●			●	●	●	●	●	●
48	$3Ø						●	●	●	●	●					●	●
64	$4Ø	●	●	●	●	●	●	●	●	●		●	●	●	●		
8Ø	$5Ø																
96	$6Ø								●	●	●	●					●
112	$7Ø	●															
128	$8Ø																
144	$9Ø																
16Ø	$AØ																●
176	$BØ	●															
192	$CØ											●	●	●	●		
2Ø8	$DØ									●							
224	$EØ																
24Ø	$FØ																

Table 21: Integer BASIC Zero Page Usage																	
Decimal		Ø	1	2	3	4	5	6	7	8	9	1Ø	11	12	13	14	15
	Hex	$Ø	$1	$2	$3	$4	$5	$6	$7	$8	$9	$A	$B	$C	$D	$E	$F
Ø	$ØØ																
16	$1Ø																
32	$2Ø																
48	$3Ø																
64	$4Ø											●	●	●	●		
8Ø	$5Ø						●	●	●	●	●	●	●	●	●	●	●
96	$6Ø	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
112	$7Ø	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
128	$8Ø	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
144	$9Ø	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
16Ø	$AØ	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
176	$BØ	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
192	$CØ	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
2Ø8	$DØ	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
224	$EØ																
24Ø	$FØ																

CHAPTER 5
INPUT/OUTPUT STRUCTURE

The Apple's Input and Output functions fall into two basic categories: those functions which are performed on the Apple's board itself, and those functions which are performed by peripheral interface cards plugged into the Apple's eight peripheral "slots". Both of these functions communicate to the microprocessor and your programs via 4,096 locations in the Apple's memory map. This chapter describes the memory mapping and operation of the various input and output controls and functions; the hardware which executes these functions is described in the next chapter.

BUILT-IN I/O

Most of the Apple's inherent I/O facilities are described briefly in Chapter 1, "Approaching your Apple". For a short description of these facilities, please see that chapter.

The Apple's on-board I/O functions are controlled by 128 memory locations in the Apple's memory map, beginning at location $C000 and extending up through location $C07F (decimal 49152 through 49279, or -16384 through -16257). Twenty-seven different functions share these 128 locations. Obviously, some functions are affected by more than one location: in some instances, as many as sixteen different locations all can perform exactly the same function. These 128 locations fall into five types: Data Inputs, Strobes, Soft Switches, Toggle Switches, and Flag Inputs.

Data Inputs. The only Data Input on the Apple board is a location whose value represents the current state of the Apple's built-in keyboard. The uppermost bit of this input is akin to the Flag Inputs (see below); the lower seven bits are the ASCII code of the key which was most recently pressed on the keyboard.

Flag Inputs. Most built-in input locations on the Apple are single-bit 'flags'. These flags appear in the highest (eighth) bit position in their respective memory locations. Flags have only two values: 'on' and 'off'. The setting of a flag can be tested easily from any language. A higher-level language can use a "PEEK" or similar command to read the value of a flag location: if the PEEKed value is greater than or equal to 128, then the flag is on; if the value is less than 128, the flag is off. Machine language programs can load the contents of a flag location into one of the 6502's internal registers (or use the BIT instruction) and branch depending upon the setting of the N (sign) flag. A BMI instruction will cause a branch if the flag is on, and a BPL instruction will cause a branch if the flag is off.

The Single-Bit (Pushbutton) inputs, the Cassette input, the Keyboard Strobe, and the Game Controller inputs are all of this type.

Strobe Outputs. The Utility Strobe, the Clear Keyboard Strobe, and the Game Controller Strobe are all controlled by memory locations. If your program reads the contents of one of these locations, then the function associated with that location will be activated. In the case of the Utility Strobe, pin 5 on the Game I/O connector will drop from +5 volts to 0 volts for a period of .98 microseconds, then rise back to +5 again; in the case of the Keyboard Strobe, the Keyboard's flag input (see above) will be turned off; and in the case of the Game Controller Strobe, all of the flag inputs of the Game Controllers will be turned off and their timing loops restarted.

Your program can also trigger the Keyboard and Game Controller Strobes by *writing* to their controlling locations, but you should not write to the Utility Strobe location. If you do, you will produce *two* .98 microsecond pulses, about 24.43 nanoseconds apart. This is due to the method in which the 6502 writes to a memory location: first it reads the contents of that location, then it writes over them. This double pulse will go unnoticed for the Keyboard and Game Controller Strobes, but may cause problems if it appears on the Utility Strobe.

Toggle Switches. Two other strobe outputs are connected internally to two-state "flip-flops". Each time you read from the location associated with the strobe, its flip-flop will "toggle" to its other state. These toggle switches drive the Cassette Output and the internal Speaker. There is no practical way to determine the setting of an internal toggle switch. Because of the nature of the toggle switches, you should only read from their controlling locations, and not write to them (see Strobe Outputs, above).

Soft Switches. Soft Switches are two-position switches in which each side of the switch is controlled by an individual memory location. If you reference the location for one side of the switch, it will throw the switch that way; if you reference the location for the other side, it will throw the switch the other way. It sets the switch without regard to its former setting, and there is no way to determine the position a soft switch is in. You can safely write to soft switch controlling locations: two pulses are as good as one (see Strobe Outputs, above). The Annunciator outputs and all of the Video mode selections are controlled by soft switches.

The special memory locations which control the built-in Input and Output functions are arranged thus:

Table 22: Built-In I/O Locations

	$Ø	$1	$2	$3	$4	$5	$6	$7	$8	$9	$A	$B	$C	$D	$E	$F
$CØØØ	Keyboard Data Input															
$CØ1Ø	Clear Keyboard Strobe															
$CØ2Ø	Cassette Output Toggle															
$CØ3Ø	Speaker Toggle															
$CØ4Ø	Utility Strobe															
$CØ5Ø	gr	tx	nomix	mix	pri	sec	lores	hires	anØ		an1		an2		an3	
$CØ6Ø	cin	pb1	pb2	pb3	gcØ	gc1	gc2	gc3	repeat $CØ6Ø-$CØ67							
$CØ7Ø	Game Controller Strobe															

Key to abbreviations:

gr	Set GRAPHICS mode	tx	Set TEXT mode
nomix	Set all text or graphics	mix	Mix text and graphics
pri	Display primary page	sec	Display secondary page
lores	Display Low-Res Graphics	hires	Display Hi-Res Graphics
an	Annunciator outputs	pb	Pushbutton inputs
gc	Game Controller inputs	cin	Cassette Input

PERIPHERAL BOARD I/O

Along the back of the Apple's main board is a row of eight long "slots", or Peripheral Connectors. Into seven of these eight slots, you can plug any of many Peripheral Interface boards designed especially for the Apple. In order to make the peripheral cards simpler and more versatile, the Apple's circuitry has allocated a total of 280 byte locations in the memory map for each of seven slots. There is also a 2K byte "common area", which all peripheral cards in your Apple can share.

Each slot on the board is individually numbered, with the leftmost slot called "Slot Ø" and the rightmost called "Slot 7". Slot Ø is special: it is meant for RAM, ROM, or Interface expansion. All other slots (1 through 7) have special control lines going to them which are active at different times for different slots.

PERIPHERAL CARD I/O SPACE

Each slot is given sixteen locations beginning at location $CØ8Ø for general input and output purposes. For slot Ø, these sixteen locations fall in the memory range $CØ8Ø through $CØ8F; for slot 1, they're in the range $CØ9Ø through $CØ9F, *et cetera*. Each peripheral card can use these locations as it pleases. Each peripheral card can determine when it is being selected by listening to pin 41 (called $\overline{\text{DEVICE SELECT}}$) on its peripheral connector. Whenever the voltage on this pin drops to 0 volts, the address which the microprocessor is calling is somewhere in that peripheral card's 16-byte allocation. The peripheral card can then look at the bottom four address lines to determine which of its sixteen addresses is being called.

Table 23: Peripheral Card I/O Locations

	$Ø–$F	Slot
$CØ8Ø	Input/Output for slot number	Ø
$CØ9Ø		1
$CØAØ		2
$CØBØ		3
$CØCØ		4
$CØDØ		5
$CØEØ		6
$CØFØ		7

Column headings printed: $Ø $1 $2 $3 $4 $5 $6 $7 $8 $9 $A $B $C $D $E $F

PERIPHERAL CARD ROM SPACE

Each peripheral slot also has reserved for it one 256-byte page of memory. This page is usually used to house 256 bytes of ROM or Programmable ROM (PROM) memory, which contains driving programs or subroutines for the peripheral card. In this way, the peripheral interface cards can be "intelligent": they contain their own driving software; you do not need to load separate programs in order to use the interface cards.

The page of memory reserved for each peripheral slot has the page number $C*n*, where *n* is the slot number. Slot Ø does not have a page reserved for it, so you cannot use most Apple interface cards in that slot. The signal on Pin 1 (called $\overline{\text{I/O SELECT}}$) of each peripheral slot will become active (drop from +5 volts to ground) when the microprocessor is referencing an address within that slot's reserved page. Peripheral cards can use this signal to enable their PROMs, and use the lower eight address lines to address each byte in the PROM.

Table 24: Peripheral Card PROM Locations

	$00	$10	$20	$30	$40	$50	$60	$70	$80	$90	$A0	$B0	$C0	$D0	$E0	$F0
$C100										1						
$C200										2						
$C300										3						
$C400					PROM space for slot number					4						
$C500										5						
$C600										6						
$C700										7						

I/O PROGRAMMING SUGGESTIONS

The programs in peripheral card PROMs should be portable; that is, they should be able to function correctly regardless of where they are placed in the Apple's memory map. They should contain no absolute references to themselves. They should perform all JuMPs with conditional or forced branches.

Of course, you can fill a peripheral card PROM with subroutines which are *not* portable, and your only loss would be that the peripheral card would be slot-dependent. If you're cramped for space in a peripheral card PROM, you can save many bytes by making the subroutines slot-dependent.

The first thing that a subroutine in a peripheral card PROM should do is to save the values of *all* of the 6502's internal registers. There is a subroutine called IOSAVE in the Apple's Monitor ROM which does just this. It saves the contents of all internal registers in memory locations $45 through $49, in the order A-X-Y-P-S. This subroutine starts at location $FF4A. A companion subroutine, called IORESTORE, restores *all* of the internal registers from these storage locations. You should call this subroutine, located at $FF3F, before your PROM subroutine finishes.

Most single-character input and output is passed in the 6502's Accumulator. During output, the character to be displayed is in the Accumulator, with its high bit set. During input, your subroutine should pass the character received from the input device in the Accumulator, also with its high bit set.

A program in a peripheral card's PROM can determine which slot the card is plugged into by executing this sequence of instructions:

```
0300-    20 4A FF     JSR    $FF4A
0303-    78           SEI
0304-    20 58 FF     JSR    $FF58
0307-    BA           TSX
0308-    BD 00 01     LDA    $0100,X
030B-    8D F8 07     STA    $07F8
030E-    29 0F        AND    #$0F
0310-    A8           TAY
```

After a program executes these steps, the slot number which its card is in will be stored in the 6502's Y index register in the format $0*n*, where *n* is the slot number. A program in the ROM can further process this value by shifting it four bits to the left, to obtain $*n*0.

```
0311-    98           TYA
```

```
0312-    0A        ASL
0313-    0A        ASL
0314-    0A        ASL
0315-    0A        ASL
0316-    AA        TAX
```

A program can use this number in the X index register with the 6502's indexed addressing mode to refer to the sixteen I/O locations reserved for each card. For example, the instruction

```
0317-    BD 80 C0    LDA    $C080,X
```

will load the 6502's accumulator with the contents of the first I/O location used by the peripheral card. The address $C080 is the *base address* for the first location used by all eight peripheral slots. The address $C081 is the base address for the second I/O location, and so on. Here are the base addresses for all sixteen I/O locations on each card:

Table 25: I/O Location Base Addresses

Base Address	Slot 0	1	2	3	4	5	6	7
$C080	$C080	$C090	$C0A0	$C0B0	$C0C0	$C0D0	$C0E0	$C0F0
$C081	$C081	$C091	$C0A1	$C0B1	$C0C1	$C0D1	$C0E1	$C0F1
$C082	$C082	$C092	$C0A2	$C0B2	$C0C2	$C0D2	$C0E2	$C0F2
$C083	$C083	$C093	$C0A3	$C0B3	$C0C3	$C0D3	$C0E3	$C0F3
$C084	$C084	$C094	$C0A4	$C0B4	$C0C4	$C0D4	$C0E4	$C0F4
$C085	$C085	$C095	$C0A5	$C0B5	$C0C5	$C0D5	$C0E5	$C0F5
$C086	$C086	$C096	$C0A6	$C0B6	$C0C6	$C0D6	$C0E6	$C0F6
$C087	$C087	$C097	$C0A7	$C0B7	$C0C7	$C0D7	$C0E7	$C0F7
$C088	$C088	$C098	$C0A8	$C0B8	$C0C8	$C0D8	$C0E8	$C0F8
$C089	$C089	$C099	$C0A9	$C0B9	$C0C9	$C0D9	$C0E9	$C0F9
$C08A	$C08A	$C09A	$C0AA	$C0BA	$C0CA	$C0DA	$C0EA	$C0FA
$C08B	$C08B	$C09B	$C0AB	$C0BB	$C0CB	$C0DB	$C0EB	$C0FB
$C08C	$C08C	$C09C	$C0AC	$C0BC	$C0CC	$C0DC	$C0EC	$C0FC
$C08D	$C08D	$C09D	$C0AD	$C0BD	$C0CD	$C0DD	$C0ED	$C0FD
$C08E	$C08E	$C09E	$C0AE	$C0BE	$C0CE	$C0DE	$C0EE	$C0FE
$C08F	$C08F	$C09F	$C0AF	$C0BF	$C0CF	$C0DF	$C0EF	$C0FF
	I/O Locations							

PERIPHERAL SLOT SCRATCHPAD RAM

Each of the eight peripheral slots has reserved for it 8 locations in the Apple's RAM memory. These 64 locations are actually in memory pages $04 through $07, inside the area reserved for the Text and Low-Resolution Graphics video display. The contents of these locations, however, are *not* displayed on the screen, and their contents are not changed by normal screen operations.* The peripheral cards can use these locations for temporary storage of data while the cards are in operation. These "scratchpad" locations have the following addresses:

* See "But Soft...", page 31

Table 26: I/O Scratchpad RAM Addresses							
Base	Slot Number						
Address	1	2	3	4	5	6	7
$0478	$0479	$047A	$047B	$047C	$047D	$047E	$047F
$04F8	$04F9	$04FA	$04FB	$04FC	$04FD	$04FE	$04FF
$0578	$0579	$057A	$057B	$057C	$057D	$057E	$057F
$05F8	$05F9	$05FA	$05FB	$05FC	$05FD	$05FE	$05FF
$0678	$0679	$067A	$067B	$067C	$067D	$067E	$067F
$06F8	$06F9	$06FA	$06FB	$06FC	$06FD	$06FE	$06FF
$0778	$0779	$077A	$077B	$077C	$077D	$077E	$077F
$07F8	$07F9	$07FA	$07FB	$07FC	$07FD	$07FE	$07FF

Slot 0 does not have any scratchpad RAM addresses reserved for it. The Base Address locations are used by Apple DOS 3.2 and are also shared by all peripheral cards. Some of these locations have dedicated functions: location $7F8 holds the slot number (in the format $C*n*) of the peripheral card which is currently active, and location $5F8 holds the slot number of the disk controller card from which any active DOS was booted.

By using the slot number $0*n*, derived in the program example above, a subroutine can directly reference any of its eight scratchpad locations:

```
031A-    B9 78 04     LDA   $0478,Y
031D-    99 F8 04     STA   $04F8,Y
0320-    B9 78 05     LDA   $0578,Y
0323-    99 F8 05     STA   $05F8,Y
0326-    B9 78 06     LDA   $0678,Y
0329-    99 F8 06     STA   $06F8,Y
032C-    B9 78 07     LDA   $0778,Y
032F-    99 F8 07     STA   $07F8,Y
```

THE CSW/KSW SWITCHES

The pair of locations $36 and $37 (decimal 54 and 55) is called CSW, for "Character output SWitch". Individually, location $36 is called CSWL (CSW Low) and location $37 is called CSWH (CSW High). This pair of locations holds the address of the subroutine which the Apple is currently using for single-character output. This address is normally $FDF0, the address of the COUT subroutine (see page 30). The Monitor's PRINTER (CTRL P) command, and the BASIC command PR#, can change this address to be the address of a subroutine in a PROM on a peripheral card. Both of these commands put the address $C*n*00 into this pair of locations, where *n* is the slot number given in the command. This is the address of the first location in whatever PROM happens to be on the peripheral card plugged into that slot. The Apple will then call this subroutine every time it wishes to output one character. This subroutine can use the instruction sequences given above to find its slot number and use the I/O and RAM scratchpad locations for its slot. When it is finished, it can either execute an RTS (ReTurn from Subroutine) instruction, to return to the program or language which is sending the output, or it can jump to the COUT subroutine at location $FDF0, to display the character on the screen and then return to the program which is producing output.

Similarly, locations $38 and 39 (decimal 56 and 57), called KSWL and KSWH separately or KSW

(Keyboard input SWitch) together, hold the address of the subroutine the Apple is currently using for single-character input. This address is normally $FD1B, the address of the KEYIN subroutine. The Monitor's KEYBOARD command (CTRL K) and the BASIC command IN# both change this address to $C*n*00, again with *n* the slot number given in the command. The Apple will call the subroutine at the beginning of the PROM on the peripheral card in this slot whenever it wishes to get a single character from the input device. The subroutine should place the input character into the 6502's accumulator and ReTurn from Subroutine (RTS). The subroutine should set the high bit of the character before it returns.

The subroutines in a peripheral card's PROM can change the addresses in the CSW and KSW switches to point to places in the PROM other than the very beginning. For example, a certain PROM could begin with a segment of code to determine what slot it is in and do some initialization, and then jump in to the actual character handling subroutine. As part of its initialization sequence, it could change KSW or CSW (whichever is applicable) to point directly to the beginning of the character handling subroutine. Then the next time the Apple asks for input or output from that card, the handling subroutines will skip the already-done initialization sequence and go right in to the task at hand. This can save time in speed-sensitive situations.

A peripheral card can be used for both input and output if its PROM has seperate subroutines for the separate functions and changes CSW and KSW accordingly. The initialization sequence in a peripheral card PROM can determine if it is being called for input or output by looking at the high parts of the CSW and KSW switches. Whichever switch contains $C*n* is currently calling that card to perform its function. If both switches contain $C*n*, then your subroutine should assume that it is being called for output.

EXPANSION ROM

The 2K memory range from location $C800 to $CFFF is reserved for a 2K ROM or PROM on a peripheral card, to hold large programs or driving subroutines. The expansion ROM space also has the advantage of being absolutely located in the Apple's memory map, which gives you more freedom in writing your interface programs.

This PROM space is available to all peripheral slots, and more than one card in your Apple can have an expansion ROM. However, only one expansion ROM can be active at one time.

Each peripheral card's expansion ROM should have a flip-flop to enable it. This flip-flop should be turned "on" by the $\overline{\text{DEVICE SELECT}}$ signal (the one which enables the 256-byte PROM). This means that the expansion ROM on any card will be partially enabled after you first reference the card it is on. The other enable to the expansion ROM should be the $\overline{\text{I/O STROBE}}$ line, pin 20 on each peripheral connector. This line becomes active whenever the Apple's microprocessor is referencing a location inside the expansion ROM's domain. When this line becomes active, and the aforementioned flip-flop has been turned "on", then the Apple is referencing the expansion ROM on this particular board (see figure 8).

A peripheral card's 256-byte PROM can gain sole access to the expansion ROM space by referring to location $CFFF in its initialization subroutine. This location is a special location, and all peripheral cards should recognize it as a signal to turn their flip-flops "off" and disable their expansion ROMs. Of course, this will also disable the expansion ROM on the card which is trying to grab the ROM space, but the ROM will be enabled again when the microprocessor gets another instruction from the 256-byte driving PROM. Now the expansion ROM is enabled, and its space is clear. The driving subroutines can then jump directly into the programs in the ROM, where

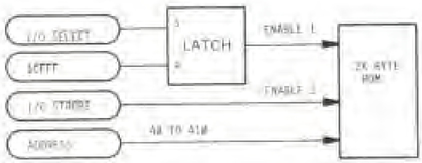


Figure 8. Expansion ROM Enable Circuit

they can enjoy the 2K of unobstructed, absolutely located memory space:

```
0332-    2C FF CF    BIT    $CFFF
0335-    4C 00 C8    JMP    $C800
```

It is possible to save circuitry (at the expense of ROM space) on the peripheral card by not fully decoding the special location address, $CFFF. In fact, if you can afford to lose the last 256 bytes of your ROM space, the following simple circuit will do just fine:

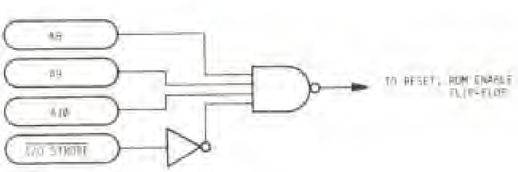


Figure 9. $CFXX Decoding

CHAPTER 6
HARDWARE CONFIGURATION

THE MICROPROCESSOR

The 65Ø2 Microprocessor

Model:	MCS65Ø2/SY65Ø2
Manufactured by:	MOS Technology, Inc. Synertek Rockwell
Number of instructions:	56
Addressing modes:	13
Accumulators:	1 (A)
Index registers:	2 (X,Y)
Other registers:	Stack pointer (S) Processor status (P)
Stack:	256 bytes, fixed
Status flags:	N (sign) C (carry) V (overflow)
Other flags:	I (Interrupt disable) D (Decimal arithmetic) B (Break)
Interrupts:	2 (IRQ, NMI)
Resets:	1 (RES)
Addressing range:	2^{16} (64K) locations
Address bus:	16 bits, parallel
Data bus:	8 bits, parallel Bidirectional
Voltages:	+5 volts
Power dissipation:	.25 watt
Clock frequency:	1.023MHz

The microprocessor gets its main timing signals, Φ0 and Φ1, from the timing circuits described below. These are complimentary 1.023MHz clock signals. Various manuals, including the MOS

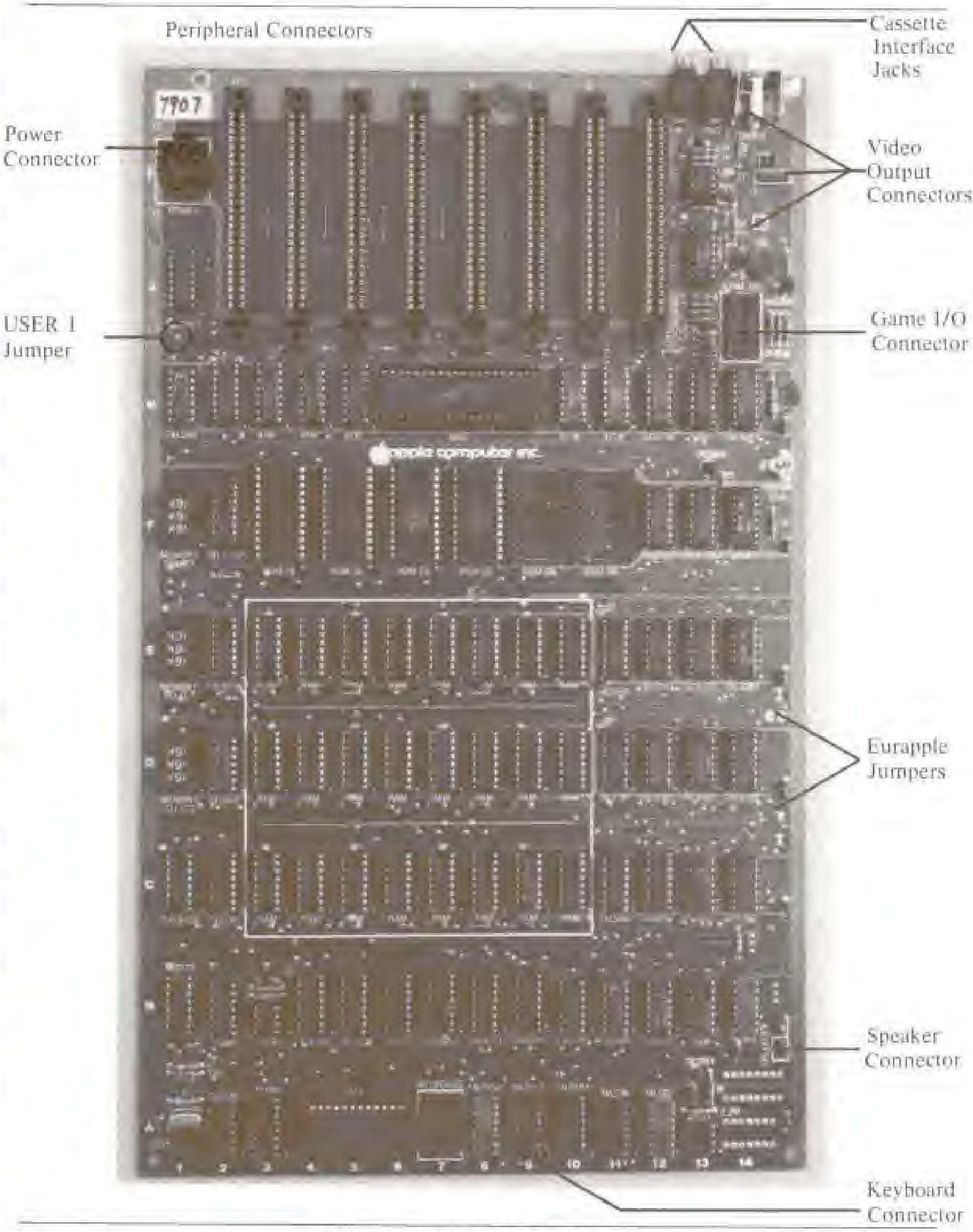


Figure 10. The Apple Main Board

Technology Hardware manual, use the designation Φ2 for the Apple's Φ0 clock.

The microprocessor uses its address and data buses only during the time period when Φ0 is active. When Φ0 is low, the microprocessor is doing internal operations and does not need the data and address buses.

The microprocessor has a 16-bit address bus and an 8-bit bidirectional data bus. The Address bus lines are buffered by three 8T97 three-state buffers at board locations H3, H4, and H5. The address lines are held open only during a DMA cycle, and are active at all other times. The address on the address bus becomes valid about 300ns after Φ1 goes high and remains valid through all of Φ0.

The data bus is buffered through two 8T28 bidirectional three-state buffers at board locations H10 and H11. Data from the microprocessor is put onto the bus about 300ns after Φ1 and the READ/WRITE signal (R/$\overline{W}$) both drop to zero. At all other times, the microprocessor is either listening to or ignoring the data bus.

The RDY, $\overline{RES}$, $\overline{IRQ}$, and $\overline{NMI}$ lines to the microprocessor are all held high by 3.3K Ohm resistors to +5v. These lines also appear on the peripheral connectors (see page 105).

The SET OVERFLOW (SO) line to the microprocessor is permanently tied to ground.

SYSTEM TIMING

Table 27: Timing Signal Descriptions

14M:	Master Oscillator output, 14.318 MHz. All timing signals are derived from this signal.
7M:	Intermediate timing signal, 7.159 MHz.
COLOR REF:	Color reference frequency, 3.580MHz. Used by the video generation circuitry.
Φ0 (Φ2) :	Phase 0 system clock, 1.023MHz, compliment to Φ1.
Φ1:	Phase 1 system clock, 1.023 MHz, compliment to Φ0.
Q3:	A general-purpose timing signal, twice the frequency of the system clocks, but asymmetrical.

All peripheral connectors get the timing signals 7M, Φ0, Φ1, and Q3. The timing signals 14M and COLOR REF are not available on the peripheral connectors.

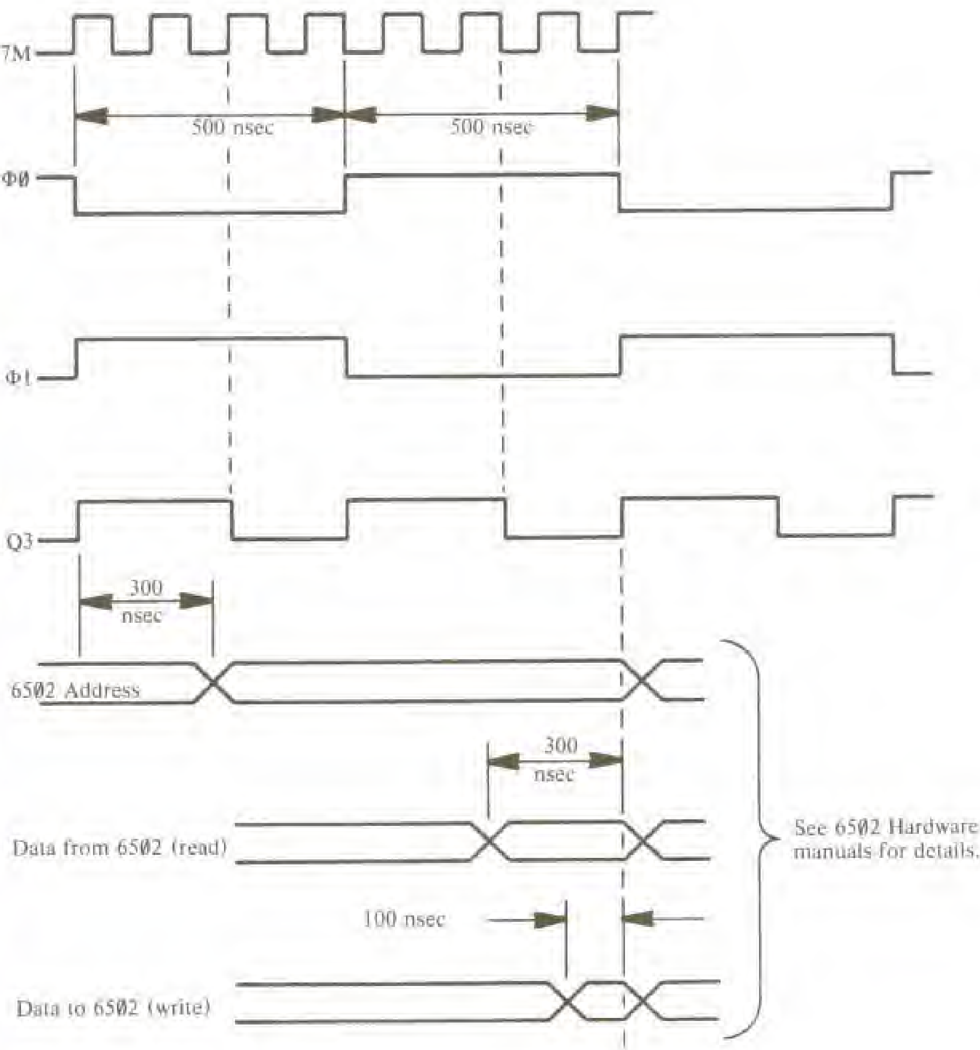


Figure 11. Timing Signals and Relationships

POWER SUPPLY

The Apple Power Supply (U. S. Patent #4,130,862)

Input voltage:	107 VAC to 132 VAC, or 214 VAC to 264 VAC (switch selectable*)
Supply voltages:	+5.0 +11.8 −12.0 −5.2
Power Consumption:	60 watts max. (full load) 79 watts max. (intermittent**)
Full load power output:	+5v: 2.5 amp −5v: 250ma +12v: 1.5 amp (~ 2.5 amp intermittent**) −12v: 250ma
Operating temperature:	55c (131° Farenheit)

The Apple Power Supply is a high-voltage "switching" power supply. While most other power supplies use a large transformer with many windings to convert the input voltage into many lesser voltages and then rectify and regulate these lesser voltages, the Apple power supply first converts the AC line voltage into a DC voltage, and then uses this DC voltage to drive a high-frequency oscillator. The output of this oscillator is fed into a small transformer with many windings. The voltages on the secondary windings are then regulated to become the output voltages.

The +5 volt output voltage is compared to a reference voltage, and the difference error is fed back into the oscillator circuit. When the power supply's output starts to move out of its tolerances, the frequency of the oscillator is altered and the voltages return to their normal levels.

If by chance one of the output voltages of the power supply is short-circuited, a feedback circuit in the power supply stops the oscillator and cuts all output circuits. The power supply then pauses for about ½ second and then attempts to restart the oscillations. If the output is still shorted, it will stop and wait again. It will continue this cycle until the short circuit is removed or the power is turned off.

If the output connector of the power supply is disconnected from the Apple board, the power supply will notice this "no load" condition and effectively short-circuit itself. This activates the protection circuits described above, and cuts all power output. This prevents damage to the power supply's internals.

* The voltage selector switch is not present on some Apples.

** The power supply can run 20 minutes with an intermittent load if followed by 10 minutes at normal load without damage.

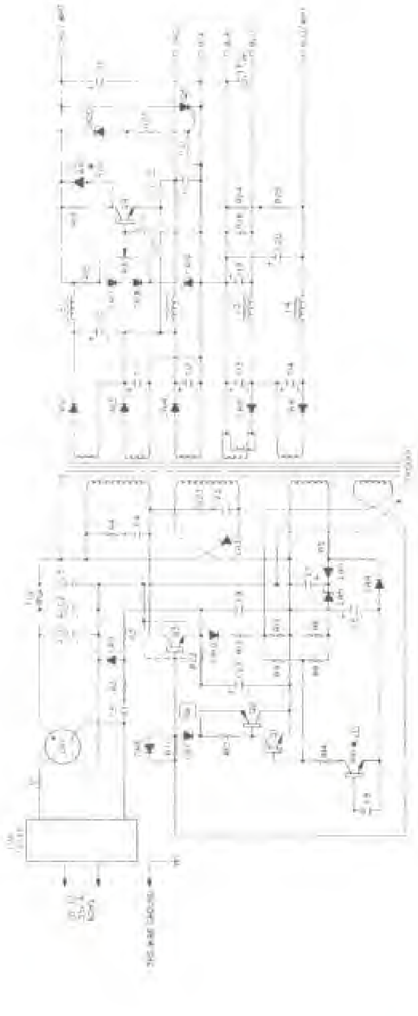


Figure 12. Power Supply Schematic Drawing

If one of the output voltages leaves its tolerance range, due to any problem either within or external to the power supply, it will again shut itself down to prevent damage to the components on the Apple board. This insures that all voltages will either be correct and in proportion, or they will be shut off.

When one of the above fault conditions occurs, the internal protection circuits will stop the oscillations which drive the transformer. After a short while, the power supply will perform a restart cycle, and attempt to oscillate again. If the fault condition has not been removed, the supply will again shut down. This cycle can continue infinitely without damage to the power supply. Each time the oscillator shuts down and restarts, its frequency passes through the audible range and you can hear the power supply squeal and squeak. Thus, when a fault occurs, you will hear a steady "click click click" emanating from the power supply. This is your warning that something is wrong with one of the voltage outputs.

Under no circumstances should you apply more than 140 VAC to the input of the transformer (or more than 280 VAC when the supply's switch is in the 220V position). Permanent damage to the supply will result.

You should connect your Apple's power supply to a properly grounded 3-wire outlet. It is very important that the Apple be connected to a good earth ground.

CAUTION: There are dangerous high voltages inside the power supply's case. Much of the internal circuitry is *not* isolated from the power line, and special equipment is needed for service. **DO NOT ATTEMPT TO REPAIR YOUR POWER SUPPLY!** Send it to your Apple dealer for service.

ROM MEMORY

The Apple can support up to six 2K by 8 mask programmed Read-Only Memory ICs. One of these six ROMs is enabled by a 74LS138 at location F12 on the Apple's board whenever the microprocessor's address bus holds an address between $DØØØ and $FFFF. The eight Data outputs of all ROMs are connected to the microprocessor's data line buffers, and the ROM's address lines are connected to the buffers driving the microprocessor's address lines AØ through A1Ø.

The ROMs have three "chip select" lines to enable them. CS1 and CS3, both active low, are connected together to the 74LS138 at location F12 which selects the individual ROMs. CS2, which is active high, is common to all ROMs and is connected to the $\overline{\text{INH}}$ (ROM Inhibit) line on the peripheral connectors. If a card in any peripheral slot pulls this line low, all ROMs on the Apple board will be disabled.

The ROMs are similar to type 2316 and 2716 programmable ROMs. However, the chip selects on most of these PROMs are of a different polarity, and they cannot be plugged directly into the Apple board.

A7	1	24	+5v
A6	2	23	A8
A5	3	22	A9
A4	4	21	$\overline{CS3}$
A3	5	20	$\overline{CS1}$
A2	6	19	A1Ø
A1	7	18	CS2
AØ	8	17	D7
DØ	9	16	D6
D1	10	15	D5
D2	11	14	D4
Gnd	12	13	D3

Figure 13. 9316B ROM Pinout.

RAM MEMORY

The Apple uses 4K and 16K dynamic RAMs for its main RAM storage. This RAM memory is used by both the microprocessor and the video display circuitry. The microprocessor and the video display interleave their use of RAM: the microprocessor reads from or writes to RAM only during ΦØ, and the video display refreshes its screen from RAM memory during Φ1.

The three 74LS153s at E11, E12, and E13, the 74LS283 at E14, and half of the 74LS257 at C12 make up the address multiplexer for the RAM memory. They take the addresses generated by the microprocessor and the video generator and multiplex them onto six RAM address lines. The other RAM addressing signals, $\overline{RAS}$ and $\overline{CAS}$, and the signal which is address line 6 for 16K RAMs and $\overline{CS}$ for 4K RAMs, are generated by the RAM select circuit. This circuit is made up of two 74LS139s at E2 and F2, half of a 74LS153 at location C1, one and a half 74LS257s at C12 and J1, and the three Memory Configuration blocks at D1, E1, and F1. This circuit routes signals to each row of RAM, depending upon what type of RAM (4K or 16K) is in that row.

The dynamic RAMs are refreshed automatically during Φ1 by the video generator circuitry. Since the video screen is always displaying at least a 1K range of memory, it needs to cycle through every location in that 1K range sixty times a second. It so happens that this action automatically refreshes every bit in all 48K bytes of RAM. This, in conjunction with the interleaving of the video and microprocessor access cycles, lets the video display, the microprocessor, and the RAM refresh run at full speed, without interfering with each other.

The data inputs to the RAMs are drawn directly off of the system's data bus. The data outputs of the RAMs are latched by two 74LS174s at board locations B5 and B8, and are multiplexed with the seven bits of data from the Apple's keyboard. These latched RAM outputs are fed directly to the video generator's character, color, and dot generators, and also back onto the system data bus by two 74LS257s at board locations B6 and B7.

−5v	1 ○	16	Gnd
Data In	2	15	$\overline{\text{CAS}}$
R/$\overline{\text{W}}$	3	14	Data Out
$\overline{\text{RAS}}$	4	13	$\overline{\text{CS}}$
A5	5	12	A2
A4	6	11	A1
A3	7	10	AØ
+12v	8	9	+5v

4096 4K RAM
Pinout

−5v	1 ○	16	Gnd
Data In	2	15	$\overline{\text{CAS}}$
R/$\overline{\text{W}}$	3	14	Data Out
$\overline{\text{RAS}}$	4	13	A6
A5	5	12	A2
A4	6	11	A1
A3	7	10	AØ
+12v	8	9	+5v

4116 16K RAM
Pinout

Figure 14. RAM Pinouts

THE VIDEO GENERATOR

There are 192 scan lines on the video screen, grouped in 24 lines of eight scan lines each. Each scan line displays some or all of the contents of forty bytes of memory.

The video generation circuitry derives its synchronization and timing signals from a chain of 74LS161 counters at board locations D11 through D14. These counters generate fifteen synchronization signals:

HØ H1 H2 H3 H4 H5
VØ V1 V2 V3 V4
VA VB VC

The "H" family of signals is the horizontal byte position on the screen, from ØØØØØØ to binary 1ØØ111 (decimal 39). The signals VØ through V4 are the vertical line position on the screen, from binary ØØØØØ to binary 1Ø111 (decimal 23). The VA, VB, and VC signals are the vertical scan line position within the vertical screen line, from binary ØØØ to 111 (decimal 7).

These signals are sent to the RAM address multiplexer, which turns them into the address of a single RAM location, dependent upon the setting of the video display mode soft switches (see below). The RAM multiplexer then sends this address to the array of RAM memory during Φ1. The latches which hold the RAM data sent by the RAM array reroute it to the video generation circuit. The 74LS283 at location rearranges the memory addresses so that the memory mapping on the screen is scrambled.

If the current area on the screen is to be a text character, then the video generator will route the lower six bits of the data to a type 2513 character generator at location A5. The seven rows in each character are scanned by the VA, VB, and VC signals, and the output of the character generator is serialized into a stream of dots by a 74166 at location A3. This bit stream is routed to an exclusive-OR gate, where it is inverted if the high bit of the data byte is off and either the sixth bit is low or the 555 timer at location B3 is high. This produces inverse and flashing characters. The text bit stream is then sent to the video selector/multiplexer (below).

If the Apple's video screen is in a graphics mode, then the data from RAM is sent to two 74LS194 shift registers at board locations B4 and B9. Here each nybble is turned into a serial data stream. These two data streams are also sent to the video selector/multiplexer.

The 74LS257 multiplexer at board position A8 selects between Color and High-Resolution graphics displays. The serialized Hi-res dot stream is delayed one-half clock cycle by the 74LS74 at location A11 if the high bit of the byte is set. This produces the alternate color set in High-Resolution graphics mode.

The video selector/multiplexer mixes the two data streams from the above sources according to the setting of the video screen soft switches. The 74LS194 at location A10 and the 74LS151 at A9 select one of the serial bit streams for text, color graphics, or high-resolution graphics depending upon the screen mode. The final serial output is mixed with the composite synchronization signal and the color burst signal generated by the video sync circuits, and sent to the video output connectors.

The video display soft switches, which control the video modes, are decoded as part of the Apple's on-board I/O functions. Logic gates in board locations B12, B13, B11, A12, and A11 are used to control the various video modes.

The color burst signal is created by logic gates at B12, B13, and C13 and is conditioned by R5, coil L1, C2, and trimmer capacitor C3. This trimmer capacitor can be tuned to vary the tint of colors produced by the video display. Transistor Q6 and its companion resistor R27 disable the color burst signal when the Apple is displaying text.

VIDEO OUTPUT JACKS

The video signal generated by the aforementioned circuitry is an NTSC compatible, similar to an EIA standard, positive composite video signal which can be fed to any standard closed-circuit or studio video monitor. This signal is available in three places on the Apple board:

RCA Jack. On the back of the Apple board, near the right edge, is a standard RCA phono jack. The sleeve of this jack is connected to the Apple's common ground and the tip is connected to the video output signal through a 200 Ohm potentiometer. This potentiometer can adjust the voltage on this connector from 0 to 1 volt peak.

Auxiliary Video Connector. On the right side of the Apple board near the back is a Molex KK100 series connector with four square pins, .25" tall, on .10" centers. This connector supplies the composite video output and two power supply voltages. This connector is illustrated in figure 15.

Table 28: Auxiliary Video Output Connector Signal Descriptions

Pin	Name	Description
1	GROUND	System common ground; 0 volts.
2	VIDEO	NTSC compatible positive composite video. Black level is about .75 volt, white level about 2.0 volt, sync tip level is 0 volts. Output level is not adjustable. This is not protected against short circuits.
3	+12v	+12 volt power supply.
4	−5v	−5 volt line from power supply.

Auxiliary Video Pin. This single metal wire-wrap pin below the Auxiliary Video Output Connector supplies the same video signal available on that connector. It is meant to be a connection point for Eurapple PAL/SECAM encoder boards.

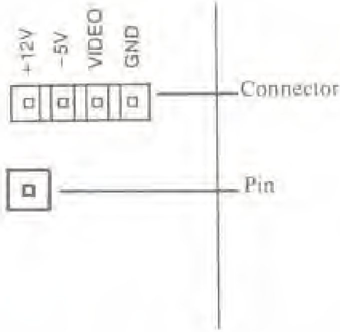


Figure 15. Auxiliary Video Output Connector and Pin.

BUILT-IN I/O

The Apple's built-in I/O functions are mapped into 128 memory locations beginning at $CØØØ. On the Apple board, a 74LS138 at location F13 called the I/O selector decodes these 128 special addresses and enables the various functions.

The 74LS138 is enabled by another '138 at location H12 whenever the Apple's address bus contains an address between $CØØØ and $CØFF. The I/O selector divides this 256-byte range into eight sixteen-byte ranges, ignoring the range $CØ8Ø through $CØFF. Each output line of the '138 becomes active (low) when its associated 16-byte range is being referenced.

The "Ø" line from the I/O selector gates the data from the keyboard connector into the RAM data multiplexer.

The "1" line from the I/O selector resets the 74LS74 flip-flop at B10, which is the keyboard flag.

The "2" line toggles one half of a 74LS74 at location K13. The output of this flip-flop is connected through a resistor network to the tip of the cassette output jack.

The "3" line toggles the other half of the 74LS74 at K13. The output of this flip-flop is connected through a capacitor and Darlington amplifier circuit to the Apple's speaker connector on the right edge of the board under the keyboard.

The "4" line is connected directly to pin 5 of the Game I/O connector. This pin is the utility $\overline{\text{CØ4Ø STROBE}}$.

The "5" line is used to enable the 74LS259 at location F14. This IC contains the soft switches for the video display and the Game I/O connector annunciator outputs. The switches are selected by the address lines 1 through 3 and the setting of each switch is controlled by address line Ø.

The "6" line is used to enable a 74LS251 eight-bit multiplexer at location H14. This multiplexer, when enabled, connects one of its eight input lines to the high order bit (bit 7) of the three-state system data bus. The bottom three address lines control which of the eight inputs the multiplexer chooses. Four of the mux's inputs come from a 553 quad timer at location H13. The inputs to this timer are the game controller pins on the Game I/O connector. Three other inputs to the multiplexer come from the single-bit (pushbutton) inputs on the Game I/O connector. The last multiplexer input comes from a 741 operational amplifier at location K13. The input to this op amp comes from the cassette input jack.

The "7" line from the I/O selector resets all four timers in the 553 quad timer at location H13. The four inputs to this timer come from an RC network made up of four 0.022μF capacitors, four 100 Ohm resistors, and the variable resistors in the game controllers attached to the Game I/O connector. The total resistance in each of the four timing circuits determines the timing characteristics of that circuit.

"USER 1" JUMPER

There is an unlabeled pair of solder pads on the Apple board, to the left of slot Ø, called the "User 1" jumper. This jumper is illustrated in Photo 8. If you connect a wire between these two pads, then the USER 1 line on each peripheral connectors becomes active. If any peripheral card pulls this line low, *all* internal I/O decoding is disabled. The $\overline{\text{I/O SELECT}}$ and the $\overline{\text{DEVICE SELECT}}$ lines all go high and will remain high while USER 1 is low, regardless of the address on the address bus.

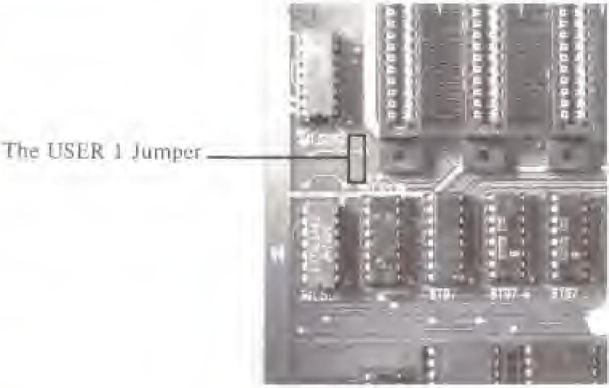


Photo 8. The USER 1 Jumper.

THE GAME I/O CONNECTOR

+5v	1 ○	16	NC
PBØ	2	15	ANØ
PB1	3	14	AN1
PB2	4	13	AN2
$\overline{\text{CØ4Ø STROBE}}$	5	12	AN3
GCØ	6	11	GC3
GC2	7	10	GC1
Gnd	8	9	NC

Figure 16.
Game I/O Connector Pinouts

Table 29: Game I/O Connector Signal Descriptions

Pin:	Name:	Description:
1	+5v	+5 volt power supply. Total current drain on this pin must be less than 100mA.
2-4	PBØ-PB2	Single-bit (Pushbutton) inputs. These are standard 74LS series TTL inputs.
5	$\overline{\text{CØ4Ø}}$ $\overline{\text{STROBE}}$	A general-purpose strobe. This line, normally high, goes low during ΦØ of a read or write cycle to any address from $CØ4Ø through $CØ4F. This is a standard 74LS TTL output.
6,7,10,11	GCØ-GC3	Game controller inputs. These should each be connected through a 150K Ohm variable resistor to +5v.
8	Gnd	System electrical ground.
12-15	ANØ-AN3	Annunciator outputs. These are standard 74LS series TTL outputs and must be buffered if used to drive other than TTL inputs.
9,16	NC	No internal connection.

THE KEYBOARD

The Apple's built-in keyboard is built around a MM5740 monolithic keyboard decoder ROM. The inputs to this ROM, on pins 4 through 12 and 22 through 31, are connected to the matrix of keyswitches on the keyboard. The outputs of this ROM are buffered by a 7404 and are connected to the Apple's Keyboard Connector (see below).

The keyboard decoder rapidly scans through the array of keys on the keyboard, looking for one which is pressed. This scanning action is controlled by the free-running oscillator made up of three sections of a 7400 at keyboard location U4. The speed of this oscillation is controlled by C6, R6, and R7 on the keyboard's printed-circuit board.

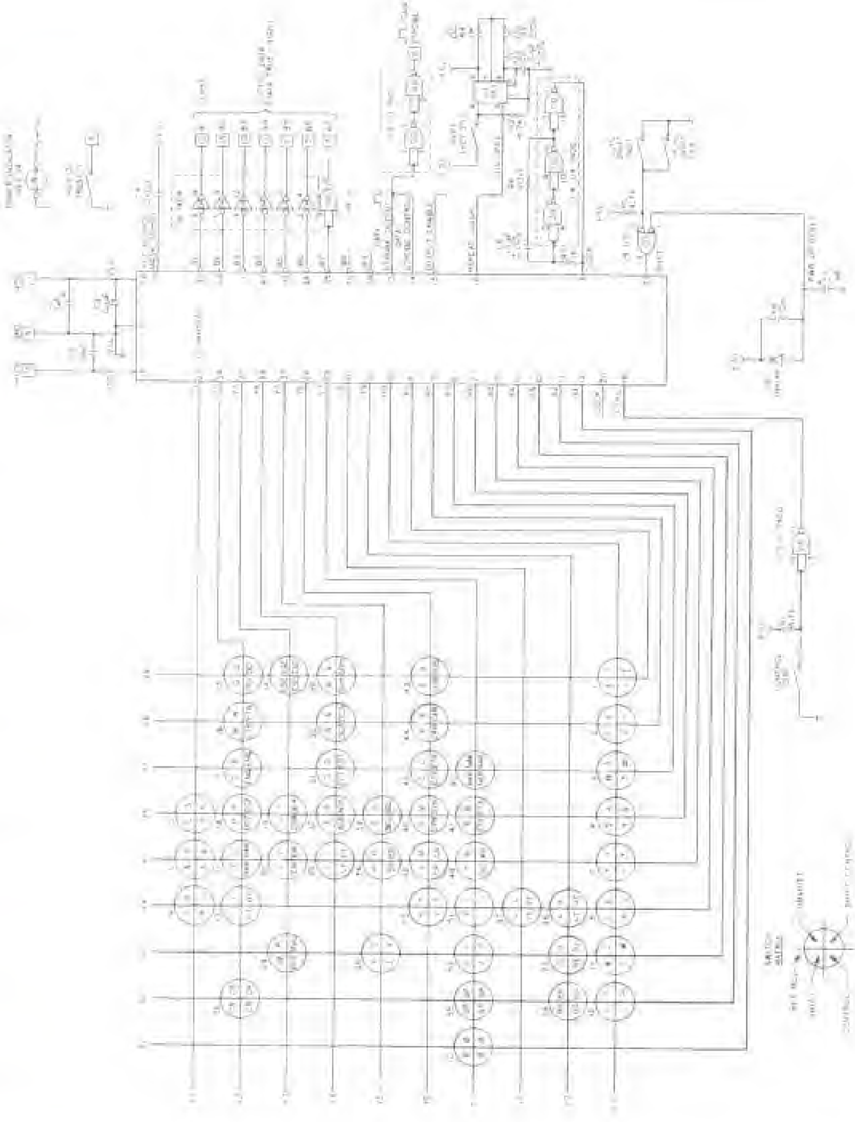


Figure 17. Schematic of the Apple Keyboard

The [REPT] key on the keyboard is connected to a 555 timer circuit at board location U3 on the keyboard. This chip and the capacitor and three resistors around it generate the 10Hz "REPeaT" signal. If the 220K Ohm resistor R3 is replaced with a resistor of a lower value, then the [REPT] key will repeat characters at a faster rate.

See Figure 17 for a schematic diagram of the Apple Keyboard.

KEYBOARD CONNECTOR

The data from the Apple's keyboard goes directly to the RAM data multiplexers and latches, the two 74LS257s at locations B6 and B7. The STROBE line on the keyboard connector sets a 74LS74 flip-flop at location B10. When the I/O selector activates its "Ø" line, the data which is on the seven inputs on the keyboard connector, and the state of the strobe flip-flop, are multiplexed onto the Apple's data bus.

Table 30: Keyboard Connector Signal Descriptions

Pin:	Name:	Description:
1	+5v	+5 volt power supply. Total current drain on this pin must be less than 120mA.
2	STROBE	Strobe output from keyboard. This line should be given a pulse at least 10μs long each time a key is pressed on the keyboard. The strobe can be of either polarity.
3	$\overline{\text{RESET}}$	Microprocessor's $\overline{\text{RESET}}$ line. Normally high, this line should be pulled low when the [RESET] button is pressed.
4,9,16	NC	No connection.
5-7, 10-13	Data	Seven bit ASCII keyboard data input.
8	Gnd	System electrical ground.
15	−12v	−12 volt power supply. Keyboard should draw less than 50mA.

+5v	*1*	*16*	NC
STROBE	*2*	*15*	−12v
RESET	*3*	*14*	NC
NC	*4*	*13*	Data 1
Data 5	*5*	*12*	Data Ø
Data 4	*6*	*11*	Data 3
Data 6	*7*	*10*	Data 2
Gnd	*8*	*9*	NC

Figure 18.
Keyboard Connector Pinouts

CASSETTE INTERFACE JACKS

The two female miniature phone jacks on the back of the Apple II board can connect your Apple to a normal home cassette tape recorder.

Cassette Input Jack: This jack is designed to be connected to the "Earphone" or "Monitor" output jacks on most tape recorders. The input voltage should be 1 volt peak-to-peak (nominal). The input impedance is 12K Ohms.

Cassette Output Jack: This jack is designed to be connected to the "Microphone" input on most tape recorders. The output voltage is 25mv into a 100 Ohm impedance load.

POWER CONNECTOR

This connector mates with the cable from the Apple Power Supply. This is an AMP #9-35028-1 six-pin male connector.

Table 31: Power Connector Pin Descriptions		
Pin:	Name:	Description:
1,2	Ground	Common electrical ground for Apple board.
3	+5v	+5.0 volts from power supply. An Apple with 48K of RAM and no peripherals draws ~1.5 amp from this supply.
4	+12v	+12.0 volts from power supply. An Apple with 48K of RAM and no peripherals draws ~400ma from this supply.
5	−12v	−12.0 volts from power supply. An Apple with 48K of RAM and no peripherals draws ~12.5ma from this supply.
6	−5v	−5.0 volts from power supply. An Apple with 48K of RAM and no peripherals draws ~0.0ma from this supply.

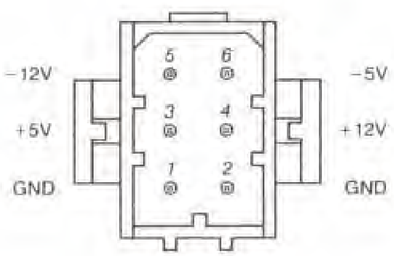


Figure 19. Power Connector

SPEAKER

The Apple's internal speaker is driven by half of a 74LS74 flip-flop through a Darlington amplifier circuit. The speaker connector is a Molex KK100 series connector, with two square pins, .25" tall, on .10" centers.

Table 32: Speaker Connector Signal Descriptions

Pin:	Name:	Description:
1	SPKR	Speaker signal. This line will deliver about .5 watt into an 8 Ohm load.
2	+5v	+5 volt power supply.

Figure 20. Speaker Connector

PERIPHERAL CONNECTORS

The eight peripheral connectors along the back edge of the Apple's board are Winchester #2HW25C0-111 50-pin PC card edge connectors with pins on .10" centers. The pinout for these connectors is given in Figure 21, and the signal descriptions are given on the following pages.

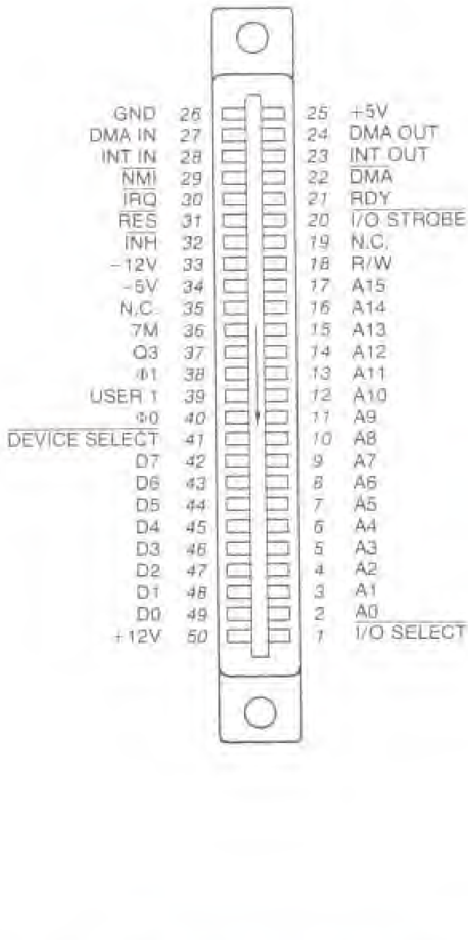


Figure 21. Peripheral Connector Pinout

Pin:	Name:	Description:
1	I/O SELECT	This line, normally high, will become low when the microprocessor references page $C*n*, where *n* is the individual slot number. This signal becomes active during Φ0 and will drive 10 LSTTL loads*. This signal is not present on peripheral connector 0.
2-17	A0-A15	The buffered address bus. The address on these lines becomes valid during Φ1 and remains valid through Φ0. These lines will each drive 5 LSTTL loads*.
18	R/$\overline{\mathrm{W}}$	Buffered Read/$\overline{\mathrm{Write}}$ signal. This becomes valid at the same time the address bus does, and goes high during a read cycle and low during a write. This line can drive up to 2 LSTTL loads*.
19	SYNC	On peripheral connector 7 *only*, this pin is connected to the video timing generator's SYNC signal.
20	$\overline{\mathrm{I/O\ STROBE}}$	This line goes low during Φ0 when the address bus contains an address between $C800 and $CFFF. This line will drive 4 LSTTL loads*.
21	RDY	The 6502's RDY input. Pulling this line low during Φ1 will halt the microprocessor, with the address bus holding the address of the current location being fetched.
22	$\overline{\mathrm{DMA}}$	Pulling this line low disables the 6502's address bus and halts the microprocessor. This line is held high by a 3KΩ resistor to +5v.
23	INT OUT	Daisy-chained interrupt output to lower priority devices. This pin is usually connected to pin 28 (INT IN).
24	DMA OUT	Daisy-chained DMA output to lower priority devices. This pin is usually connected to pin 22 (DMA IN).
25	+5v	+5 volt power supply. 500mA current is available for *all* peripheral cards.
26	GND	System electrical ground.

Table 33: Peripheral Connector Signal Description

* Loading limits are for each peripheral card.

Table 33 (cont'd): Peripheral Connector Signal Description		
Pin:	Name:	Description:
27	DMA IN	Daisy-chained DMA input from higher priority devices. Usually connected to pin 24 (DMA OUT).
28	INT IN	Daisy-chained interrupt input from higher priority devices. Usually connected to pin 23 (INT OUT).
29	$\overline{\text{NMI}}$	Non-Maskable Interrupt. When this line is pulled low the Apple begins an interrupt cycle and jumps to the interrupt handling routine at location $3FB.
30	$\overline{\text{IRQ}}$	Interrupt ReQuest. When this line is pulled low the Apple begins an interrupt cycle only if the 65Ø2's I (Interrupt disable) flag is not set. If so, the 65Ø2 will jump to the interrupt handling subroutine whose address is stored in locations $3FE and $3FF.
31	$\overline{\text{RES}}$	When this line is pulled low the microprocessor begins a RESET cycle (see page 36).
32	$\overline{\text{INH}}$	When this line is pulled low, all ROMs on the Apple board are disabled. This line is held high by a 3KΩ resistor to +5v.
33	−12v	−12 volt power supply. Maxmum current is 200mA for all peripheral boards.
34	−5v	−5 volt power supply. Maximum current is 200mA for all peripheral boards.
35	COLOR REF	On peripheral connector 7 *only*, this pin is connected to the 3.5MHz COLOR REFerence signal of the video generator.
36	7M	7MHz clock. This line will drive 2 LSTTL loads*.
37	Q3	2MHz asymmetrical clock. This line will drive 2 LSTTL loads*.
38	Φ1	Microprocessor's phase one clock. This line will drive 2 LSTTL loads*.
39	USER 1	This line, when pulled low, disables *all* internal I/O address decoding**.

* Loading limits are for each peripheral card.
** See page 99.

Table 33 (cont'd): Peripheral Connector Signal Description		
Pin:	Name:	Description:
40	Φ0	Microprocessor's phase zero clock. This line will drive 2 LSTTL loads*.
41	$\overline{\text{DEVICE SELECT}}$	This line becomes active (low) on each peripheral connector when the address bus is holding an address between \$C0*n*0 and \$C0*n*F, where *n* is the slot number plus \$8. This line will drive 10 LSTTL loads*.
42-49	D0-D7	Buffered bidirectional data bus. The data on this line becomes valid 300nS into Φ0 on a write cycle, and should be stable no less than 100ns before the end of Φ0 on a read cycle. Each data line can drive one LSTTL load.
50	+12v	+12 volt power supply. This can supply up to 250mA total for all peripheral cards.

* Loading limits are for each peripheral card.

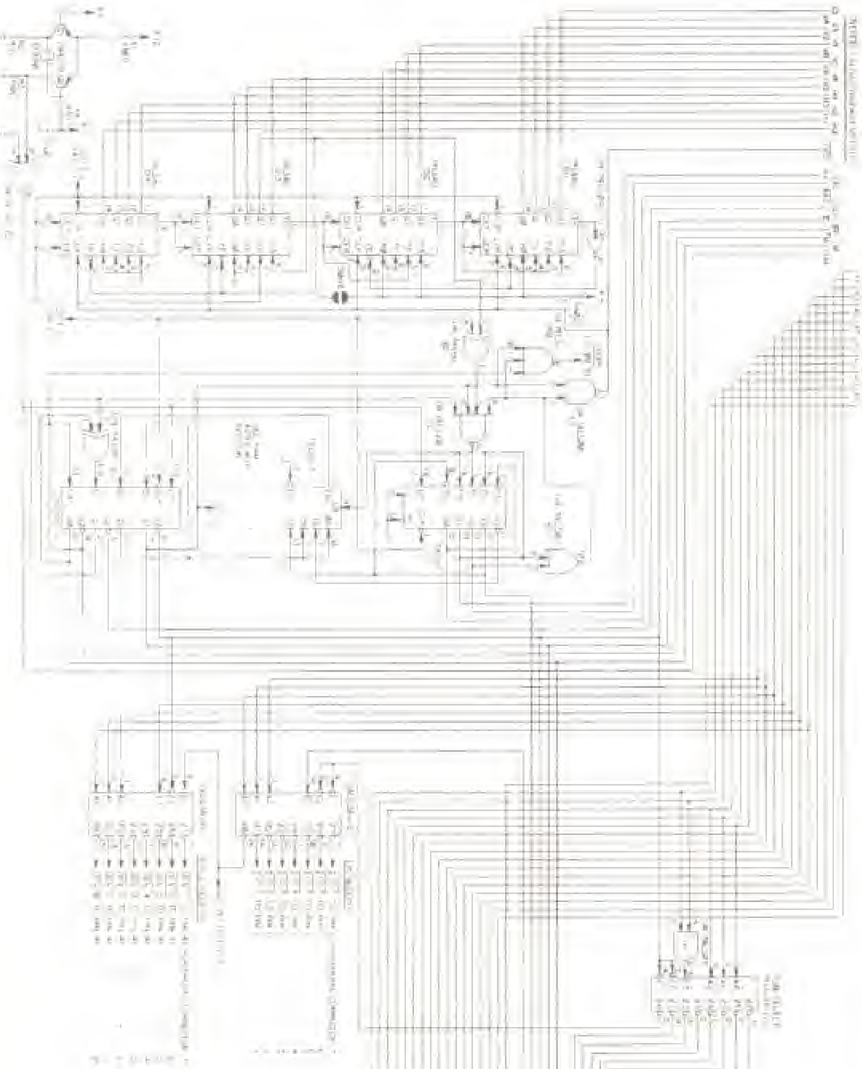


Figure 22-1. Schematic Diagram of the Apple II

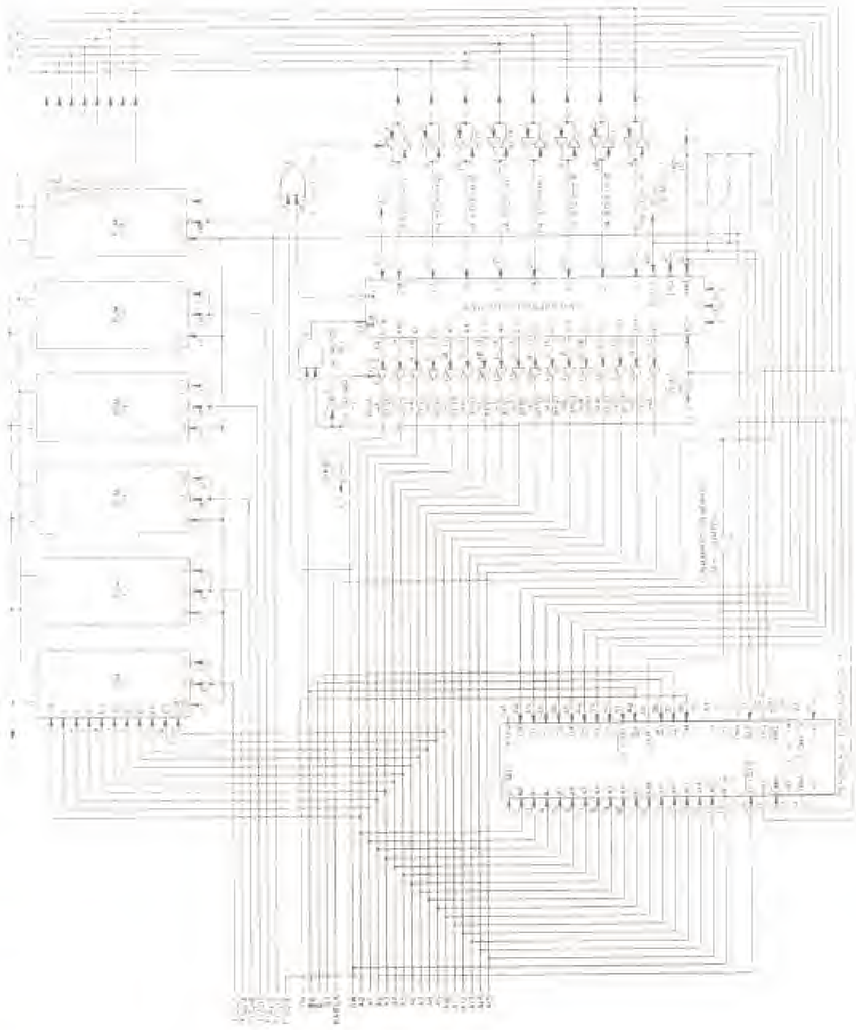


Figure 22-2. Schematic Diagram of the Apple II

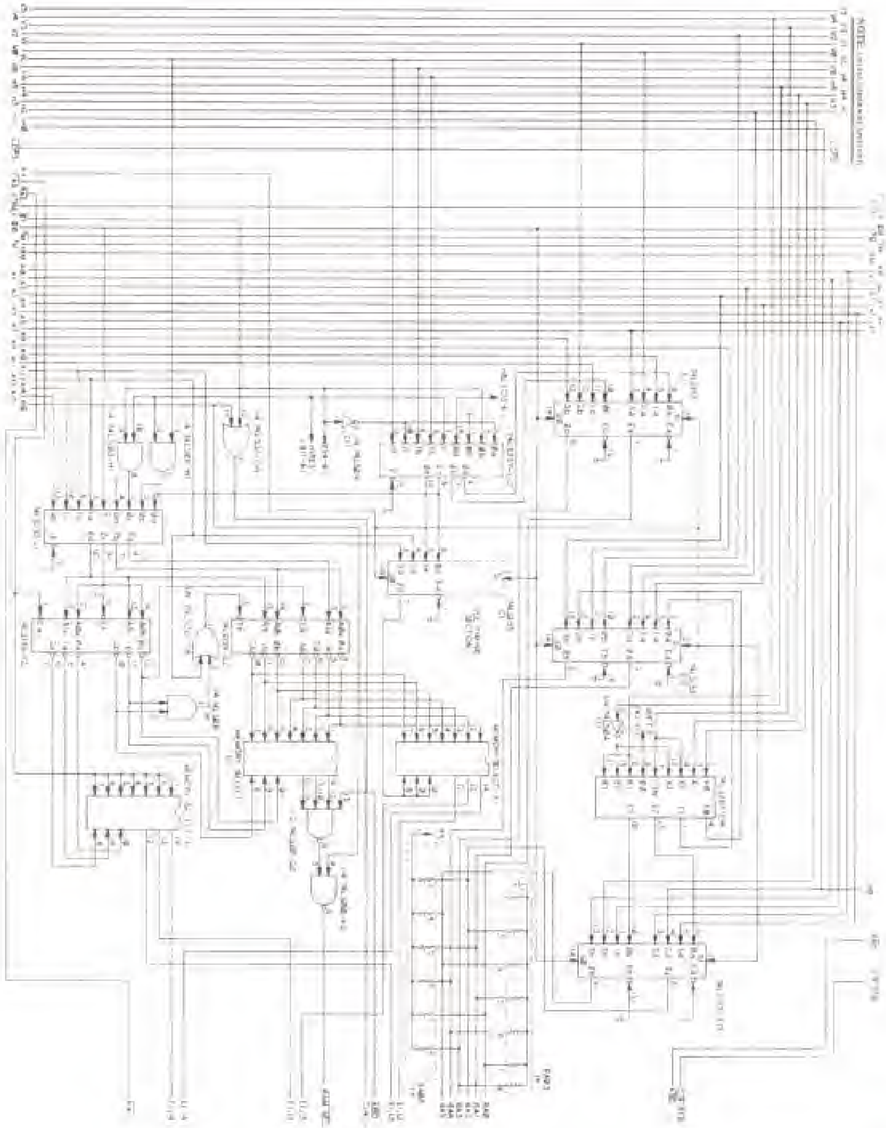


Figure 22-3. Schematic Diagram of the Apple II

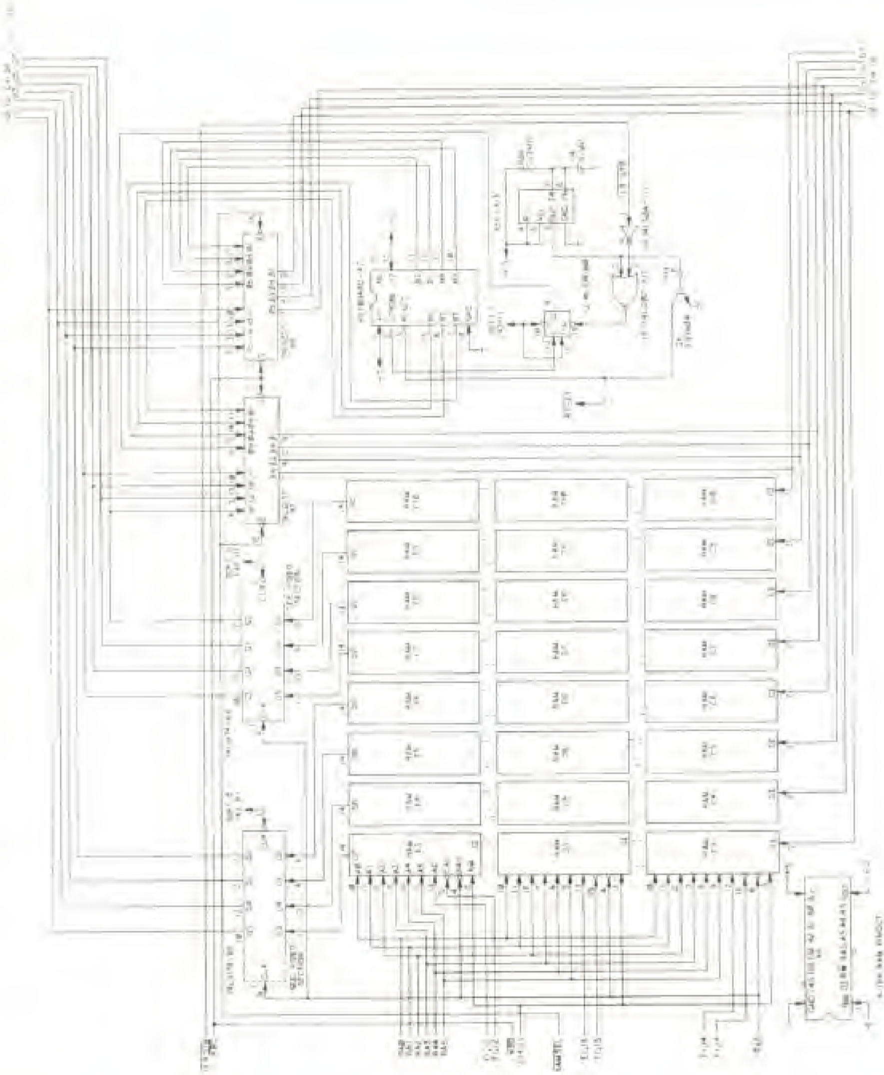


Figure 22-4. Schematic Diagram of the Apple II

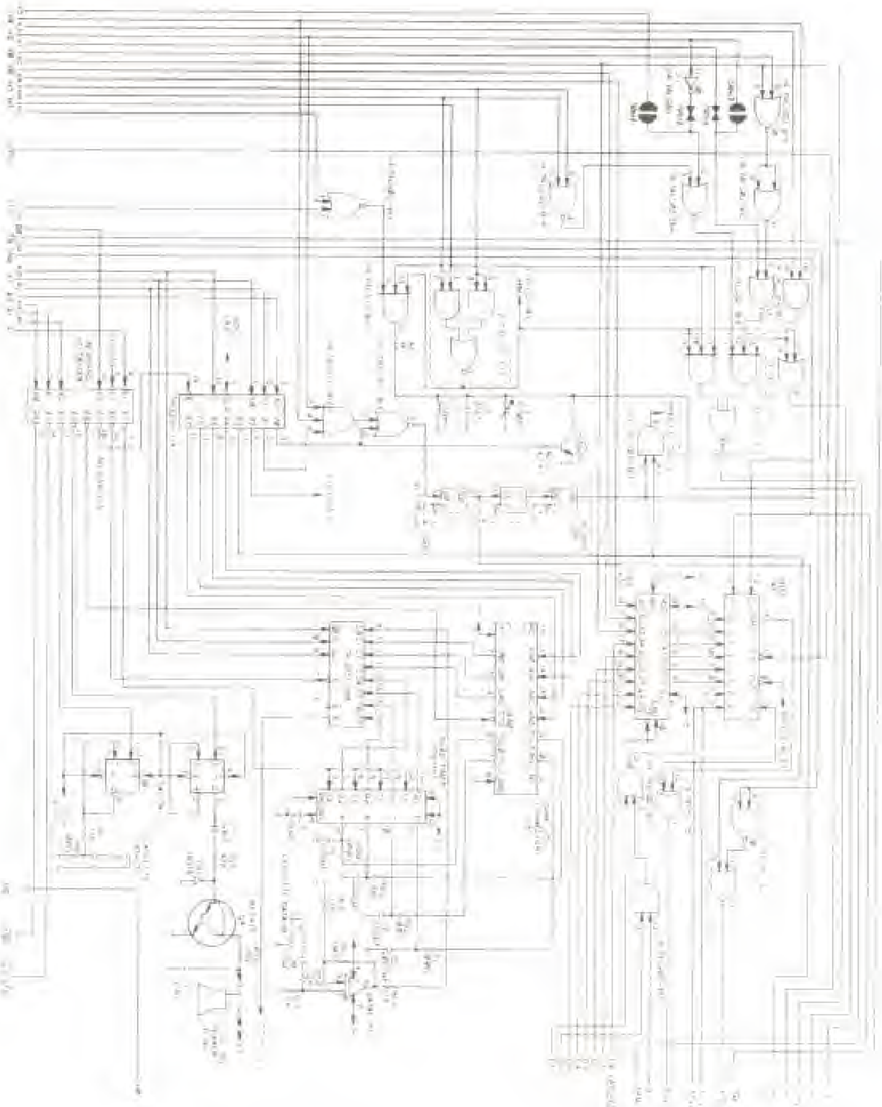


Figure 22-5. Schematic Diagram of the Apple II

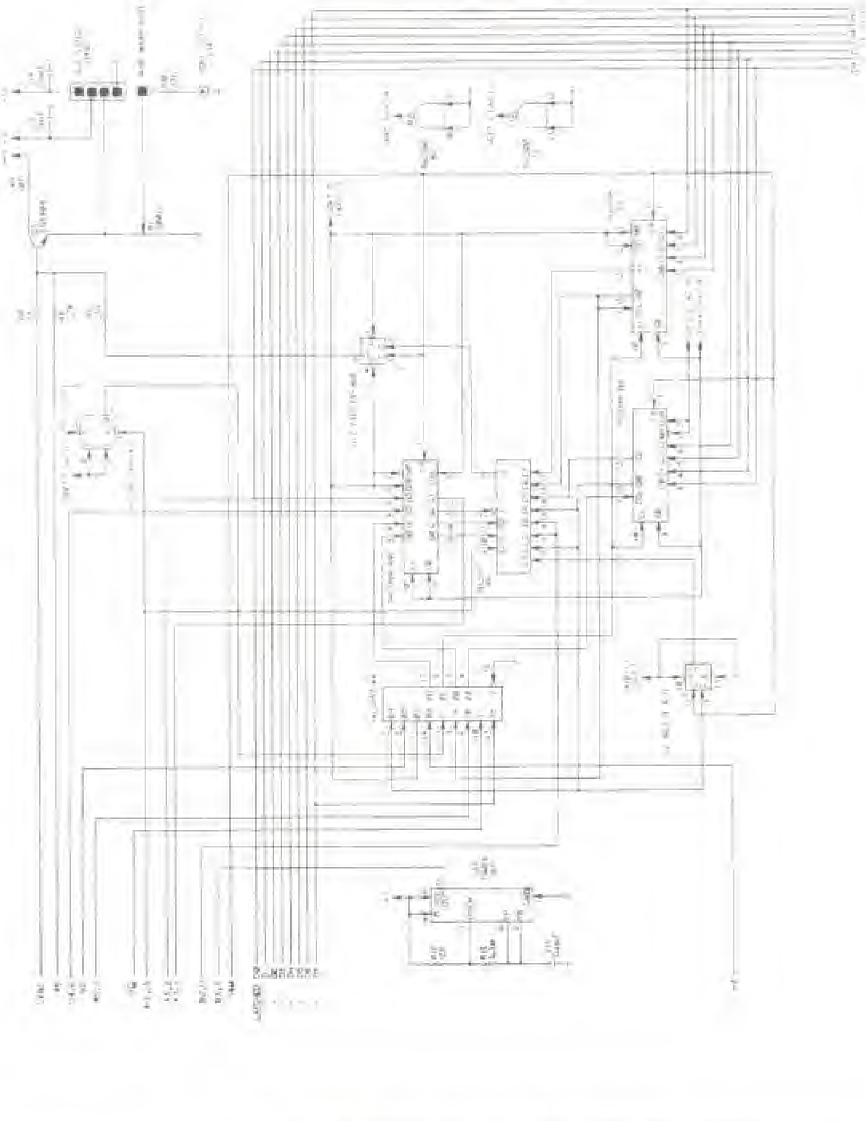


Figure 22-6. Schematic Diagram of the Apple II

APPENDIX A
THE 65Ø2 INSTRUCTION SET

6502 MICROPROCESSOR INSTRUCTIONS

ADC	Add Memory to Accumulator with Carry
AND	"AND" Memory with Accumulator
ASL	Shift Left One Bit (Memory or Accumulator)
BCC	Branch on Carry Clear
BCS	Branch on Carry Set
BEQ	Branch on Result Zero
BIT	Test Bits in Memory with Accumulator
BMI	Branch on Result Minus
BNE	Branch on Result not Zero
BPL	Branch on Result Plus
BRK	Force Break
BVC	Branch on Overflow Clear
BVS	Branch on Overflow Set
CLC	Clear Carry Flag
CLD	Clear Decimal Mode
CLI	Clear Interrupt Disable Bit
CLV	Clear Overflow Flag
CMP	Compare Memory and Accumulator
CPX	Compare Memory and Index X
CPY	Compare Memory and Index Y
DEC	Decrement Memory by One
DEX	Decrement Index X by One
DEY	Decrement Index Y by One
EOR	"Exclusive-Or" Memory with Accumulator
INC	Increment Memory by One
INX	Increment Index X by One
INY	Increment Index Y by One
JMP	Jump to New Location
JSR	Jump to New Location Saving Return Address
LDA	Load Accumulator with Memory
LDX	Load Index X with Memory
LDY	Load Index Y with Memory
LSR	Shift Right one Bit (Memory or Accumulator)
NOP	No Operation
ORA	"OR" Memory with Accumulator
PHA	Push Accumulator on Stack
PHP	Push Processor Status on Stack
PLA	Pull Accumulator from Stack
PLP	Pull Processor Status from Stack
ROL	Rotate One Bit Left (Memory or Accumulator)
ROR	Rotate One Bit Right (Memory or Accumulator)
RTI	Return from Interrupt
RTS	Return from Subroutine
SBC	Subtract Memory from Accumulator with Borrow
SEC	Set Carry Flag
SED	Set Decimal Mode
SEI	Set Interrupt Disable Status
STA	Store Accumulator in Memory
STX	Store Index X in Memory
STY	Store Index Y in Memory
TAX	Transfer Accumulator to Index X
TAY	Transfer Accumulator to Index Y
TSX	Transfer Stack Pointer to Index X
TXA	Transfer Index X to Accumulator
TXS	Transfer Index X to Stack Pointer
TYA	Transfer Index Y to Accumulator

THE FOLLOWING NOTATION APPLIES TO THIS SUMMARY:

A	Accumulator
X, Y	Index Registers
M	Memory
$\bar{C}$	Borrow
P	Processor Status Register
S	Stack Pointer
✓	Change
—	No Change
+	Add
$\wedge$	Logical AND
-	Subtract
$\veebar$	Logical Exclusive Or
↑	Transfer From Stack
↓	Transfer To Stack
→	Transfer To
←	Transfer To
$\vee$	Logical OR
PC	Program Counter
PCH	Program Counter High
PCL	Program Counter Low
OPER	Operand
#	Immediate Addressing Mode

FIGURE 1 ASL-SHIFT LEFT ONE BIT OPERATION

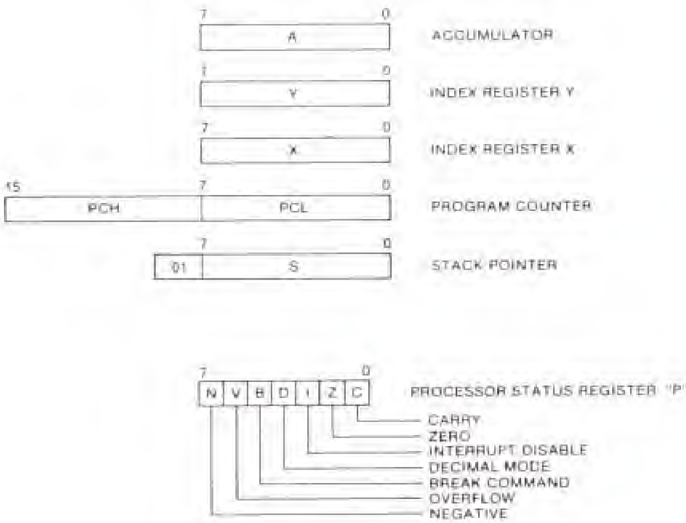
FIGURE 2 ROTATE ONE BIT LEFT (MEMORY OR ACCUMULATOR)

FIGURE 3

NOTE 1: BIT — TEST BITS

Bit 6 and 7 are transferred to the status register. If the result of A $\wedge$ M is zero then Z=1, otherwise Z=0

PROGRAMMING MODEL



INSTRUCTION CODES

Name Description	Operation	Addressing Mode	Assembly Language Form	HEX OP Code	No. Bytes	"P" Status Reg. N Z C I D V
ADC Add memory to accumulator with carry	A+M+C → A,C	Immediate	ADC #Oper	69	2	√√√- - -√
		Zero Page	ADC Oper	65	2	
		Zero Page,X	ADC Oper,X	75	2	
		Absolute	ADC Oper	6D	3	
		Absolute,X	ADC Oper,X	7D	3	
		Absolute,Y	ADC Oper,Y	79	3	
		(Indirect,X)	ADC (Oper,X)	61	2	
		(Indirect),Y	ADC (Oper),Y	71	2	
AND "AND" memory with accumulator	A∧M → A	Immediate	AND #Oper	29	2	√√- - - -
		Zero Page	AND Oper	25	2	
		Zero Page,X	AND Oper,X	35	2	
		Absolute	AND Oper	2D	3	
		Absolute,X	AND Oper,X	3D	3	
		Absolute,Y	AND Oper,Y	39	3	
		(Indirect,X)	AND (Oper,X)	21	2	
		(Indirect),Y	AND (Oper),Y	31	2	
ASL Shift left one bit (Memory or Accumulator)	(See Figure 1)	Accumulator	ASL A	0A	1	√√√- - -
		Zero Page	ASL Oper	06	2	
		Zero Page,X	ASL Oper,X	16	2	
		Absolute	ASL Oper	0E	3	
		Absolute,X	ASL Oper,X	1E	3	
BCC Branch on carry clear	Branch on C=0	Relative	BCC Oper	90	2	- - - - - -
BCS Branch on carry set	Branch on C=1	Relative	BCS Oper	B0	2	- - - - - -
BEQ Branch on result zero	Branch on Z=1	Relative	BEQ Oper	F0	2	- - - - - -
BIT Test bits in memory with accumulator	A∧M, M_7 → N, M_6 → V	Zero Page	BIT* Oper	24	2	M_7√- - - - M_6
		Absolute	BIT* Oper	2C	3	
BMI Branch on result minus	Branch on N=1	Relative	BMI Oper	30	2	- - - - - -
BNE Branch on result not zero	Branch on Z=0	Relative	BNE Oper	D0	2	- - - - - -
BPL Branch on result plus	Branch on N=0	Relative	BPL oper	10	2	- - - - - -
BRK Force Break	Forced Interrupt PC+2 ↓ P ↓	Implied	BRK*	00	1	- - -1- -
BVC Branch on overflow clear	Branch on V=0	Relative	BVC Oper	50	2	- - - - - -

[illegible]

[illegible]

Name Description	Operation	Addressing Mode	Assembly Language Form	HEX OP Code	No. Bytes	"P" Status Reg. N Z C I D V
BVS Branch on overflow set	Branch on V = 1	Relative	BVS Oper	70	2	
CLC Clear carry flag	$0 \rightarrow C$	Implied	CLC	18	1	- - 0 - - -
CLD Clear decimal mode	$0 \rightarrow D$	Implied	CLD	D8	1	- - - - 0 -
CLI	$0 \rightarrow I$	Implied	CLI	58	1	- - - 0 - -
CLV Clear overflow flag	$0 \rightarrow V$	Implied	CLV	B8	1	- - - - - 0

CMP
Compare memory and accumulator
	$A - M$	Immediate
		Zero Page
		Zero Page, X
		Absolute
		Absolute, X
		Absolute, Y
		(Indirect, X)
		(Indirect), Y
			CMP #Oper
			CMP Oper
			CMP Oper, X
			CMP Oper
			CMP Oper, X
			CMP Oper, Y
			CMP (Oper, X)
			CMP (Oper), Y
				C9
				C5
				D5
				CD
				DD
				D9
				C1
				D1
					2
					2
					2
					3
					3
					3
					2
					2
						√√√- - -

CPX Compare memory and index X	$X - M$	Immediate Zero Page Absolute	CPX #Oper CPX Oper CPX Oper	E0 E4 EC	2 2 3	√√√- - -
CPY Compare memory and index Y	$Y - M$	Immediate Zero Page Absolute	CPY #Oper CPY Oper CPY Oper	C0 C4 CC	2 2 3	√√√- - -
DEC Decrement memory by one	$M - 1 \rightarrow M$	Zero Page Zero Page, X Absolute Absolute, X	DEC Oper DEC Oper, X DEC Oper DEC Oper, X	C6 D6 CE DE	2 2 3 3	√√- - - -
DEX Decrement index X by one	$X - 1 \rightarrow X$	Implied	DEX	CA	1	√√- - - -
DEY Decrement index Y by one	$Y - 1 \rightarrow Y$	Implied	DEY	88	1	√√- - - -

Name Description	Operation	Addressing Mode	Assembly Language Form	HEX OP Code	No. Bytes	"P" Status Reg. N Z C I D V
EOR "Exclusive-Or" memory with accumulator	A ⊻ M → A	Immediate	EOR #Oper	49	2	√√----
		Zero Page	EOR Oper	45	2	
		Zero Page,X	EOR Oper,X	55	2	
		Absolute	EOR Oper	4D	3	
		Absolute,X	EOR Oper,X	5D	3	
		Absolute,Y	EOR Oper,Y	59	3	
		(Indirect,X)	EOR (Oper,X)	41	2	
		(Indirect),Y	EOR (Oper),Y	51	2	
INC Increment memory by one	M + 1 → M	Zero Page	INC Oper	E6	2	√√----
		Zero Page,X	INC Oper,X	F6	2	
		Absolute	INC Oper	EE	3	
		Absolute,X	INC Oper,X	FE	3	
INX Increment index X by one	X + 1 → X	Implied	INX	E8	1	√√----
INY Increment index Y by one	Y + 1 → Y	Implied	INY	C8	1	√√----
JMP Jump to new location	(PC+1) → PCL	Absolute	JMP Oper	4C	3	------
	(PC+2) → PCH	Indirect	JMP (Oper)	6C	3	
JSR Jump to new location saving return address	PC+2 ↓ (PC+1) → PCL (PC+2) → PCH	Absolute	JSR Oper	20	3	------
LDA Load accumulator with memory	M → A	Immediate	LDA #Oper	A9	2	√√----
		Zero Page	LDA Oper	A5	2	
		Zero Page,X	LDA Oper,X	B5	2	
		Absolute	LDA Oper	AD	3	
		Absolute,X	LDA Oper,X	BD	3	
		Absolute,Y	LDA Oper,Y	B9	3	
		(Indirect,X)	LDA (Oper,X)	A1	2	
		(Indirect),Y	LDA (Oper),Y	B1	2	
LDX Load index X with memory	M → X	Immediate	LDX #Oper	A2	2	√√----
		Zero Page	LDX Oper	A6	2	
		Zero Page,Y	LDX Oper,Y	B6	2	
		Absolute	LDX Oper	AE	3	
		Absolute,Y	LDX Oper,Y	BE	3	
LDY Load index Y with memory	M → Y	Immediate	LDY #Oper	A0	2	√√----
		Zero Page	LDY Oper	A4	2	
		Zero Page,X	LDY Oper,X	B4	2	
		Absolute	LDY Oper	AC	3	
		Absolute,X	LDY Oper,X	BC	3	

Name Description	Operation	Addressing Mode	Assembly Language Form	HEX OP Code	No. Bytes	"P" Status Reg. N Z C I D V
LSR Shift right one bit (memory or accumulator)	(See Figure 1)	Accumulator	LSR A	4A	1	0√√---
		Zero Page	LSR Oper	46	2	
		Zero Page,X	LSR Oper,X	56	2	
		Absolute	LSR Oper	4E	3	
		Absolute,X	LSR Oper,X	5E	3	
NOP No operation	No Operation	Implied	NOP	EA	1	------
ORA "OR" memory with accumulator	A V M → A	Immediate	ORA #Oper	09	2	√√----
		Zero Page	ORA Oper	05	2	
		Zero Page,X	ORA Oper,X	15	2	
		Absolute	ORA Oper	0D	3	
		Absolute,X	ORA Oper,X	1D	3	
		Absolute,Y	ORA Oper,Y	19	3	
		(Indirect,X)	ORA (Oper,X)	01	2	
		(Indirect),Y	ORA (Oper),Y	11	2	
PHA Push accumulator on stack	A ↓	Implied	PHA	48	1	------
PHP Push processor status on stack	P ↓	Implied	PHP	08	1	------
PLA Pull accumulator from stack	A ↑	Implied	PLA	68	1	√√----
PLP Pull processor status from stack	P ↑	Implied	PLP	28	1	From Stack
ROL Rotate one bit left (memory or accumulator)	(See Figure 2)	Accumulator	ROL A	2A	1	√√√---
		Zero Page	ROL Oper	26	2	
		Zero Page,X	ROL Oper,X	36	2	
		Absolute	ROL Oper	2E	3	
		Absolute,X	ROL Oper,X	3E	3	
ROR Rotate one bit right (memory or accumulator)	(See Figure 3)	Accumulator	ROR A	6A	1	√√√---
		Zero Page	ROR Oper	66	2	
		Zero Page,X	ROR Oper,X	76	2	
		Absolute	ROR Oper	6E	3	
		Absolute,X	ROR Oper,X	7E	3	

Name Description	Operation	Addressing Mode	Assembly Language Form	HEX OP Code	No. Bytes	"P" Status Reg. N Z C I D V
RTI Return from interrupt	P↑ PC↑	Implied	RTI	40	1	From Stack
RTS Return from subroutine	PC↑, PC+1 → PC	Implied	RTS	60	1	------
SBC Subtract memory from accumulator with borrow	$A - M - \overline{C} \rightarrow A$	Immediate	SBC #Oper	E9	2	√√√--√
		Zero Page	SBC Oper	E5	2	
		Zero Page,X	SBC Oper,X	F5	2	
		Absolute	SBC Oper	ED	3	
		Absolute,X	SBC Oper,X	FD	3	
		Absolute,Y	SBC Oper,Y	F9	3	
		(Indirect,X)	SBC (Oper,X)	E1	2	
		(Indirect),Y	SBC (Oper),Y	F1	2	
SEC Set carry flag	1 → C	Implied	SEC	38	1	--1---
SED Set decimal mode	1 → D	Implied	SED	F8	1	----1-
SEI Set interrupt disable status	1 → I	Implied	SEI	78	1	---1--
STA Store accumulator in memory	A → M	Zero Page	STA Oper	85	2	------
		Zero Page,X	STA Oper,X	95	2	
		Absolute	STA Oper	8D	3	
		Absolute,X	STA Oper,X	9D	3	
		Absolute,Y	STA Oper,Y	99	3	
		(Indirect,X)	STA (Oper,X)	81	2	
		(Indirect),Y	STA (Oper),Y	91	2	
STX Store index X in memory	X → M	Zero Page	STX Oper	86	2	------
		Zero Page,Y	STX Oper,Y	96	2	
		Absolute	STX Oper	8E	3	
STY Store index Y in memory	Y → M	Zero Page	STY Oper	84	2	------
		Zero Page,X	STY Oper,X	94	2	
		Absolute	STY Oper	8C	3	
TAX Transfer accumulator to index X	A → X	Implied	TAX	AA	1	√√----
TAY Transfer accumulator to index Y	A → Y	Implied	TAY	A8	1	√√----
TSX Transfer stack pointer to index X	S → X	Implied	TSX	BA	1	√√----

Name Description	Operation	Addressing Mode	Assembly Language Form	HEX OP Code	No. Bytes	"P" Status Reg. N Z C I D V
TXA Transfer index X to accumulator	X → A	Implied	TXA	8A	1	√ √ - - - -
TXS Transfer index X to stack pointer	X → S	Implied	TXS	9A	1	- - - - - -
TYA Transfer index Y to accumulator	Y → A	Implied	TYA	98	1	√ √ - - - -

HEX OPERATION CODES

00 — BRK
01 — ORA — (Indirect, X)
02 — NOP
03 — NOP
04 — NOP
05 — ORA — Zero Page
06 — ASL — Zero Page
07 — NOP
08 — PHP
09 — ORA — Immediate
0A — ASL — Accumulator
0B — NOP
0C — NOP
0D — ORA — Absolute
0E — ASL — Absolute
0F — NOP
10 — BPL
11 — ORA — (Indirect), Y
12 — NOP
13 — NOP
14 — NOP
15 — ORA — Zero Page, X
16 — ASL — Zero Page, X
17 — NOP
18 — CLC
19 — ORA — Absolute, Y
1A — NOP
1B — NOP
1C — NOP
1D — ORA — Absolute, X
1E — ASL — Absolute, X
1F — NOP
20 — JSR
21 — AND — (Indirect, X)
22 — NOP
23 — NOP
24 — BIT — Zero Page
25 — AND — Zero Page
26 — ROL — Zero Page
27 — NOP
28 — PLP
29 — AND — Immediate
2A — ROL — Accumulator
2B — NOP
2C — BIT — Absolute
2D — AND — Absolute
2E — ROL — Absolute
2F — NOP
30 — BMI
31 — AND — (Indirect), Y
32 — NOP
33 — NOP
34 — NOP
35 — AND — Zero Page, X
36 — ROL — Zero Page, X
37 — NOP
38 — SEC
39 — AND — Absolute, Y
3A — NOP
3B — NOP
3C — NOP
3D — AND — Absolute, X
3E — ROL — Absolute, X
3F — NOP
40 — RTI
41 — EOR — (Indirect, X)
42 — NOP
43 — NOP
44 — NOP
45 — EOR — Zero Page
46 — LSR — Zero Page
47 — NOP
48 — PHA
49 — EOR — Immediate
4A — LSR — Accumulator
4B — NOP
4C — JMP — Absolute
4D — EOR — Absolute
4E — LSR — Absolute
4F — NOP
50 — BVC
51 — EOR (Indirect), Y
52 — NOP
53 — NOP
54 — NOP
55 — EOR — Zero Page, X
56 — LSR — Zero Page, X
57 — NOP
58 — CLI
59 — EOR — Absolute, Y
5A — NOP
5B — NOP
5C — NOP
5D — EOR — Absolute, X
5E — LSR — Absolute, X
5F — NOP
60 — RTS
61 — ADC — (Indirect, X)
62 — NOP
63 — NOP
64 — NOP
65 — ADC — Zero Page
66 — ROR — Zero Page
67 — NOP
68 — PLA
69 — ADC — Immediate
6A — ROR — Accumulator
6B — NOP
6C — JMP — Indirect
6D — ADC — Absolute
6E — ROR — Absolute
6F — NOP
70 — BVS
71 — ADC — (Indirect), Y
72 — NOP
73 — NOP
74 — NOP
75 — ADC — Zero Page, X
76 — ROR — Zero Page, X
77 — NOP
78 — SEI
79 — ADC — Absolute, Y
7A — NOP
7B — NOP
7C — NOP
7D — ADC — Absolute, X NOP
7E — ROR — Absolute, X NOP
7F — NOP
80 — NOP
81 — STA — (Indirect, X)
82 — NOP
83 — NOP
84 —STY — Zero Page
85 — STA — Zero Page
86 — STX — Zero Page
87 — NOP
88 — DEY
89 — NOP
8A — TXA
8B — NOP
8C — STY — Absolute

8D — STA — Absolute
8E — STX — Absolute
8F — NOP
90 — BCC
91 — STA — (Indirect), Y
92 — NOP
93 — NOP
94 — STY — Zero Page, X
95 — STA — Zero Page, X
96 — STX — Zero Page, Y
97 — NOP
98 — TYA
99 — STA — Absolute, Y
9A — TXS
9B — NOP
9C — NOP
9D — STA — Absolute, X
9E — NOP
9F — NOP
A0 — LDY — Immediate
A1 — LDA — (Indirect, X)
A2 — LDX — Immediate
A3 — NOP
A4 — LDY — Zero Page
A5 — LDA — Zero Page
A6 — LDX — Zero Page
A7 — NOP
A8 — TAY
A9 — LDA — Immediate
AA — TAX
AB — NOP
AC — LDY — Absolute
AD — Absolute
AE — LDX — Absolute
AF — NOP
B0 — BCS
B1 — LDA — (Indirect), Y
B2 — NOP
B3 — NOP
B4 — LDY — Zero Page, X
B5 — LDA — Zero Page, X
B6 — LDX — Zero Page, Y
B7 — NOP
B8 — CLV
B9 — LDA — Absolute, Y
BA — TSX
BB — NOP
BC — LDY — Absolute, X
BD — LDA — Absolute, X
BE — LDX — Absolute, Y
BF — NOP
C0 — CPY — Immediate
C1 — CMP — (Indirect, X)
C2 — NOP
C3 — NOP
C4 — CPY — Zero Page
C5 — CMP — Zero Page
C6 — DEC — Zero Page
C7 — NOP
C8 — INY
C9 — CMP — Immediate
CA — DEX
CB — NOP
CC — CPY — Absolute
CD — CMP — Absolute
CE — DEC — Absolute
CF — NOP
D0 — BNE
D1 — CMP — (Indirect), Y
D2 — NOP
D3 — NOP
D4 — NOP
D5 — CMP — Zero Page, X
D6 — DEC — Zero Page, X
D7 — NOP
D8 — CLD
D9 — CMP — Absolute, Y
DA — NOP
DB — NOP
DC — NOP
DD — CMP — Absolute, X
DE — DEC — Absolute, X
DF — NOP
E0 — CPX — Immediate
E1 — SBC — (Indirect, X)
E2 — NOP
E3 — NOP
E4 — CPX — Zero Page
E5 — SBC — Zero Page
E6 — INC — Zero Page
E7 — NOP
E8 — INX
E9 — SBC — Immediate
EA — NOP
EB — NOP
EC — CPX — Absolute
ED — SBC — Absolute
EE — INC — Absolute
EF — NOP
F0 — BEQ
F1 — SBC — (Indirect), Y
F2 — NOP
F3 — NOP
F4 — NOP
F5 — SBC — Zero Page, X
F6 — INC — Zero Page, X
F7 — NOP
F8 — SED
F9 — SBC — Absolute, Y
FA — NOP
FB — NOP
FC — NOP
FD — SBC — Absolute, X
FE — INC — Absolute, X
FF — NOP

APPENDIX B
SPECIAL LOCATIONS

Table 1: Keyboard Special Locations			
Location: Hex	Decimal		Description:
$C000	49152	-16384	Keyboard Data
$C010	49168	-16368	Clear Keyboard Strobe

Table 4: Video Display Memory Ranges					
Screen	Page	Begins at: Hex	Decimal	Ends at: Hex	Decimal
Text/Lo-Res	Primary	$400	1024	$7FF	2047
	Secondary	$800	2048	$BFF	3071
Hi-Res	Primary	$2000	8192	$3FFF	16383
	Secondary	$4000	16384	$5FFF	24575

Table 5: Screen Soft Switches			
Location: Hex	Decimal		Description:
$C050	49232	-16304	Display a GRAPHICS mode.
$C051	49233	-16303	Display TEXT mode.
$C052	49234	-16302	Display all TEXT or GRAPHICS.
$C053	49235	-16301	Mix TEXT and a GRAPHICS mode.
$C054	49236	-16300	Display the Primary page (Page 1).
$C055	49237	-16299	Display the Secondary page (Page 2).
$C056	49238	-16298	Display LO-RES GRAPHICS mode.
$C057	49239	-16297	Display HI-RES GRAPHICS mode.

Table 9: Annunciator Special Locations				
Ann.	State	Address: Decimal		Hex
0	off	49240	-16296	$C058
	on	49241	-16295	$C059
1	off	49242	-16294	$C05A
	on	49243	-16293	$C05B
2	off	49244	-16292	$C05C
	on	49245	-16291	$C05D
3	off	49246	-16290	$C05E
	on	49247	-16289	$C05F

Table 10: Input/Output Special Locations				
Function	Address: Decimal		Hex	Read/Write
Speaker	49200	-16336	$C030	R
Cassette Out Cassette In	49184 49256	-16352 -16288	$C020 $C060	R R
Annunciators	49240 through 49247	-16296 through -16289	$C058 through $C05F	R/W
Flag inputs	49249 49250 49251	-16287 -16286 -16285	$C061 $C062 $C063	R R R
Analog Inputs	49252 49253 49254 49255	-16284 -16283 -16282 -16281	$C064 $C065 $C066 $C067	R
Analog Clear	49264	-16272	$C070	R/W
Utility Strobe	49216	-16320	$C040	R

Table 11: Text Window Special Locations				
Function	Location: Decimal	Hex	Minimum/Normal/Maximum Value Decimal	Hex
Left Edge	32	$20	0/0/39	$0/$0/$17
Width	33	$21	0/40/40	$0/$28/$28
Top Edge	34	$22	0/0/24	$0/$0/$18
Bottom Edge	35	$23	0/24/24	$0/$18/$18

Table 12: Normal/Inverse Control Values		
Value: Decimal	Hex	Effect:
255	$FF	COUT will display characters in Normal mode.
63	$3F	COUT will display characters in Inverse mode.
127	$7F	COUT will display letters in Flashing mode; all other characters in Inverse mode.

Table 13: Autostart ROM Special Locations		
Location: Decimal	Hex	Contents:
1010 1011	$3F2 $3F3	Soft Entry Vector. These two locations contain the address of the reentry point for whatever language is in use. Normally contains $E003.
1012	$3F4	Power-Up Byte. Normally contains $45.
64367 (-1169)	$FB6F	This is the beginning of a machine language subroutine which sets up the power-up location.

Table 14: Page Three Monitor Locations

Address: Decimal	Hex	Use: Monitor ROM	Autostart ROM
1008 1009	$3F0 $3F1	None.	Holds the address of the subroutine which handles machine language "BRK" requests (normaly $FA59).
1010 1011	$3F2 $3F3	None.	Soft Entry Vector.
1012	$3F4	None.	Power-up byte.
1013 1014 1015	$3F5 $3F6 $3F7	Holds a "JuMP" instruction to the subroutine which handles Applesoft II "&" commands. Normaly $4C $58 $FF.	
1016 1017 1018	$3F8 $3F9 $3FA	Holds a "JuMP" instruction to the subroutine which handles "User" (CTRL Y) commands.	
1019 1020 1021	$3FB $3FC $3FD	Holds a "JuMP" instruction to the subroutine which handles Non-Maskable Interrupts.	
1022 1023	$3FE $3FF	Holds the address of the subroutine which handles Interrupt ReQuests.	

Table 22: Built-In I/O Locations

	$0	$1	$2	$3	$4	$5	$6	$7	$8	$9	$A	$B	$C	$D	$E	$F
$C000	Keyboard Data Input															
$C010	Clear Keyboard Strobe															
$C020	Cassette Output Toggle															
$C030	Speaker Toggle															
$C040	Utility Strobe															
$C050	gr	tx	nomix	mix	pri	sec	lores	hires	an0		an1		an2		an3	
$C060	cin	pb1	pb2	pb3	gc0	gc1	gc2	gc3	repeat $C060-$C067							
$C070	Game Controller Strobe															

Key to abbreviations:

gr	Set GRAPHICS mode	tx	Set TEXT mode
nomix	Set all text or graphics	mix	Mix text and graphics
pri	Display primary page	sec	Display secondary page
lores	Display Low-Res Graphics	hires	Display Hi-Res Graphics
an	Annunciator outputs	pb	Pushbutton inputs
gc	Game Controller inputs	cin	Cassette Input

Table 23: Peripheral Card I/O Locations

	$Ø	$1	$2	$3	$4	$5	$6	$7	$8	$9	$A	$B	$C	$D	$E	$F
$CØ8Ø										Ø						
$CØ9Ø										1						
$CØAØ										2						
$CØBØ						Input/Output for slot number				3						
$CØCØ										4						
$CØDØ										5						
$CØEØ										6						
$CØFØ										7						

Table 24: Peripheral Card PROM Locations

	$ØØ	$1Ø	$2Ø	$3Ø	$4Ø	$5Ø	$6Ø	$7Ø	$8Ø	$9Ø	$AØ	$BØ	$CØ	$DØ	$EØ	$FØ
$C1ØØ										1						
$C2ØØ										2						
$C3ØØ										3						
$C4ØØ						PROM space for slot number				4						
$C5ØØ										5						
$C6ØØ										6						
$C7ØØ										7						

Table 25: I/O Location Base Addresses

Base Address	Slot Ø	1	2	3	4	5	6	7
$CØ8Ø	$CØ8Ø	$CØ9Ø	$CØAØ	$CØBØ	$CØCØ	$CØDØ	$CØEØ	$CØFØ
$CØ81	$CØ81	$CØ91	$CØA1	$CØB1	$CØC1	$CØD1	$CØE1	$CØF1
$CØ82	$CØ82	$CØ92	$CØA2	$CØB2	$CØC2	$CØD2	$CØE2	$CØF2
$CØ83	$CØ83	$CØ93	$CØA3	$CØB3	$CØC3	$CØD3	$CØE3	$CØF3
$CØ84	$CØ84	$CØ94	$CØA4	$CØB4	$CØC4	$CØD4	$CØE4	$CØF4
$CØ85	$CØ85	$CØ95	$CØA5	$CØB5	$CØC5	$CØD5	$CØE5	$CØF5
$CØ86	$CØ86	$CØ96	$CØA6	$CØB6	$CØC6	$CØD6	$CØE6	$CØF6
$CØ87	$CØ87	$CØ97	$CØA7	$CØB7	$CØC7	$CØD7	$CØE7	$CØF7
$CØ88	$CØ88	$CØ98	$CØA8	$CØB8	$CØC8	$CØD8	$CØE8	$CØF8
$CØ89	$CØ89	$CØ99	$CØA9	$CØB9	$CØC9	$CØD9	$CØE9	$CØF9
$CØ8A	$CØ8A	$CØ9A	$CØAA	$CØBA	$CØCA	$CØDA	$CØEA	$CØFA
$CØ8B	$CØ8B	$CØ9B	$CØAB	$CØBB	$CØCB	$CØDB	$CØEB	$CØFB
$CØ8C	$CØ8C	$CØ9C	$CØAC	$CØBC	$CØCC	$CØDC	$CØEC	$CØFC
$CØ8D	$CØ8D	$CØ9D	$CØAD	$CØBD	$CØCD	$CØDD	$CØED	$CØFD
$CØ8E	$CØ8E	$CØ9E	$CØAE	$CØBE	$CØCE	$CØDE	$CØEE	$CØFE
$CØ8F	$CØ8F	$CØ9F	$CØAF	$CØBF	$CØCF	$CØDF	$CØEF	$CØFF
	I/O Locations							

Table 26: I/O Scratchpad RAM Addresses							
Base Address	Slot Number						
	1	2	3	4	5	6	7
$0478	$0479	$047A	$047B	$047C	$047D	$047E	$047F
$04F8	$04F9	$04FA	$04FB	$04FC	$04FD	$04FE	$04FF
$0578	$0579	$057A	$057B	$057C	$057D	$057E	$057F
$05F8	$05F9	$05FA	$05FB	$05FC	$05FD	$05FE	$05FF
$0678	$0679	$067A	$067B	$067C	$067D	$067E	$067F
$06F8	$06F9	$06FA	$06FB	$06FC	$06FD	$06FE	$06FF
$0778	$0779	$077A	$077B	$077C	$077D	$077E	$077F
$07F8	$07F9	$07FA	$07FB	$07FC	$07FD	$07FE	$07FF

APPENDIX C
ROM LISTINGS

AUTOSTART ROM LISTING

```
0000:            ********************************
0000:            *
0000:            * APPLE II
0000:            * MONITOR II
0000:            *
0000:            * COPYRIGHT 1978 BY
0000:            * APPLE COMPUTER, INC.
0000:            *
0000:            * ALL RIGHTS RESERVED
0000:            *
0000:            * STEVE WOZNIAK
0000:            *
0000:            ********************************
0000:            *
0000:            * MODIFIED NOV 1978
0000:            * BY JOHN A
0000:            *
0000:            ********************************
F800:                     ORG $F800
F800:                     OBJ $2000
F800:            ********************************
F800:            LOC0     EQU $00
F800:            LOC1     EQU $01
F800:            WNDLFT   EQU $20
F800:            WNDWDTH  EQU $21
F800:            WNDTOP   EQU $22
F800:            WNDBTM   EQU $23
F800:            CH       EQU $24
F800:            CV       EQU $25
F800:            GBASL    EQU $26
F800:            GBASH    EQU $27
F800:            BASL     EQU $28
F800:            BASH     EQU $29
F800:            BAS2L    EQU $2A
F800:            BAS2H    EQU $2B
F800:            H2       EQU $2C
F800:            LMNEM    EQU $2C
F800:            V2       EQU $2D
F800:            RMNEM    EQU $2D
F800:            MASK     EQU $2E
F800:            CHKSUM   EQU $2E
F800:            FORMAT   EQU $2E
F800:            LASTIN   EQU $2F
F800:            LENGTH   EQU $2F
F800:            SIGN     EQU $2F
F800:            COLOR    EQU $30
F800:            MODE     EQU $31
F800:            INVFLG   EQU $32
F800:            PROMPT   EQU $33
F800:            YSAV     EQU $34
F800:            YSAV1    EQU $35
F800:            CSWL     EQU $36
F800:            CSWH     EQU $37
F800:            KSWL     EQU $38
F800:            KSWH     EQU $39
F800:            PCL      EQU $3A
F800:            PCH      EQU $3B
F800:            A1L      EQU $3C
F800:            A1H      EQU $3D
F800:            A2L      EQU $3E
F800:            A2H      EQU $3F
F800:            A3L      EQU $40
F800:            A3H      EQU $41
F800:            A4L      EQU $42
F800:            A4H      EQU $43
F800:            A5L      EQU $44
F800:            A5H      EQU $45
```

```
F800               ACC      EQU $45      ; NOTE OVERLAP WITH A5H!
F800               XREG     EQU $46
F800               YREG     EQU $47
F800               STATUS   EQU $48
F800               SPNT     EQU $49
F800               RNDL     EQU $4E
F800               RNDH     EQU $4F
F800               PICK     EQU $95
F800               IN       EQU $0200
F800               BRKV     EQU $3F0     ; NEW VECTOR FOR BRK
F800               SOFTEV   EQU $3F2     ; VECTOR FOR WARM START
F800               PWREDUP  EQU $3F4     ; THIS MUST = EOR #$A5 OF SOFTEV+1
F800               AMPERV   EQU $3F5     ; APPLESOFT & EXIT VECTOR
F800               USRADR   EQU $03F8
F800               NMI      EQU $03FB
F800               IRQLOC   EQU $3FE
F800               LINE1    EQU $400
F800               MSLOT    EQU $07F8
F800               IOADR    EQU $C000
F800               KBD      EQU $C000
F800               KBDSTRB  EQU $C010
F800               TAPEOUT  EQU $C020
F800               SPKR     EQU $C030
F800               TXTCLR   EQU $C050
F800               TXTSET   EQU $C051
F800               MIXCLR   EQU $C052
F800               MIXSET   EQU $C053
F800               LOWSCR   EQU $C054
F800               HISCR    EQU $C055
F800               LORES    EQU $C056
F800               HIRES    EQU $C057
F800               SETAN0   EQU $C058
F800               CLRAN0   EQU $C059
F800               SETAN1   EQU $C05A
F800               CLRAN1   EQU $C05B
F800               SETAN2   EQU $C05C
F800               CLRAN2   EQU $C05D
F800               SETAN3   EQU $C05E
F800               CLRAN3   EQU $C05F
F800               TAPEIN   EQU $C060
F800               PADDL0   EQU $C064
F800               PTRIG    EQU $C070
F800               CLRROM   EQU $CFFF
F800               BASIC    EQU $E000
F800               BASIC2   EQU $E003
F800                        PAGE
F800: 4A           PLOT     LSR A
F801: 08                    PHP
F802: 20 47 F8              JSR GBASCALC
F805: 28                    PLP
F806: A9 0F                 LDA #$0F
F808: 90 02                 BCC RTMASK
F80A: 69 E0                 ADC #$E0
F80C: 85 2E        RTMASK   STA MASK
F80E: B1 26        PLOT1    LDA (GBASL),Y
F810: 45 30                 EOR COLOR
F812: 25 2E                 AND MASK
F814: 51 26                 EOR (GBASL),Y
F816: 91 26                 STA (GBASL),Y
F818: 60                    RTS
F819: 20 00 F8     HLINE    JSR PLOT
F81C: C4 2C        HLINE1   CPY H2
F81E: B0 11                 BCS RTS1
F820: C8                    INY
F821: 20 0E F8              JSR PLOT1
F824: 90 F6                 BCC HLINE1
F826: 69 01        VLINEZ   ADC #$01
F828: 48           VLINE    PHA
F829: 20 00 F8              JSR PLOT
F82C: 68                    PLA
F82D: C5 2D                 CMP V2
F82F: 90 F5                 BCC VLINEZ
F831: 60           RTS1     RTS
```

```
F832:  A0 2F         CLRSCR   LDY #$2F
F834:  D0 02                  BNE CLRSC2
F836:  A0 27         CLRTOP   LDY #$27
F838:  84 2D         CLRSC2   STY V2
F83A:  A0 27                  LDY #$27
F83C:  A9 00         CLRSC3   LDA #$00
F83E:  85 30                  STA COLOR
F840:  20 28 F8               JSR VLINE
F843:  88                     DEY
F844:  10 F6                  BPL CLRSC3
F846:  60                     RTS
F847:                         PAGE
F847:  48            GBASCALC PHA
F848:  4A                     LSR A
F849:  29 03                  AND #$03
F84B:  09 04                  ORA #$04
F84D:  85 27                  STA GBASH
F84F:  68                     PLA
F850:  29 18                  AND #$18
F852:  90 02                  BCC GBCALC
F854:  69 7F                  ADC #$7F
F856:  85 26         GBCALC   STA GBASL
F858:  0A                     ASL A
F859:  0A                     ASL A
F85A:  05 26                  ORA GBASL
F85C:  85 26                  STA GBASL
F85E:  60                     RTS
F85F:  A5 30                  LDA COLOR
F861:  18                     CLC
F862:  69 03                  ADC #$03
F864:  29 0F         SETCOL   AND #$0F
F866:  85 30                  STA COLOR
F868:  0A                     ASL A
F869:  0A                     ASL A
F86A:  0A                     ASL A
F86B:  0A                     ASL A
F86C:  05 30                  ORA COLOR
F86E:  85 30                  STA COLOR
F870:  60                     RTS
F871:  4A            SCRN     LSR A
F872:  08                     PHP
F873:  20 47 F8               JSR GBASCALC
F876:  B1 26                  LDA (GBASL),Y
F878:  28                     PLP
F879:  90 04         SCRN2    BCC RTMSKZ
F87B:  4A                     LSR A
F87C:  4A                     LSR A
F87D:  4A                     LSR A
F87E:  4A                     LSR A
F87F:  29 0F         RTMSKZ   AND #$0F
F881:  60                     RTS
F882:                         PAGE
F882:  A6 3A         INSDS1   LDX PCL
F884:  A4 3B                  LDY PCH
F886:  20 96 FD               JSR PRYX2
F889:  20 48 F9               JSR PRBLNK
F88C:  A1 3A         INSDS2   LDA (PCL,X)
F88E:  A8                     TAY
F88F:  4A                     LSR A
F890:  90 09                  BCC IEVEN
F892:  6A                     ROR A
F893:  B0 10                  BCS ERR
F895:  C9 A2                  CMP #$A2
F897:  F0 0C                  BEQ ERR
F899:  29 87                  AND #$87
F89B:  4A            IEVEN    LSR A
F89C:  AA                     TAX
F89D:  BD 62 F9               LDA FMT1,X
F8A0:  20 79 F8               JSR SCRN2
F8A3:  D0 04                  BNE GETFMT
F8A5:  A0 80         ERR      LDY #$80
F8A7:  A9 00                  LDA #$00
F8A9:  AA            GETFMT   TAX
```

```
F8AA  BD A6 F9            LDA FMT2,X
F8AD  85 2E               STA FORMAT
F8AF  29 03               AND #$03
F8B1  85 2F               STA LENGTH
F8B3  98                  TYA
F8B4  29 8F               AND #$8F
F8B6  AA                  TAX
F8B7  98                  TYA
F8B8  A0 03               LDY #$03
F8BA  E0 8A               CPX #$8A
F8BC  F0 0B               BEQ MNNDX3
F8BE  4A        MNNDX1    LSR A
F8BF  90 08               BCC MNNDX3
F8C1  4A                  LSR A
F8C2  4A        MNNDX2    LSR A
F8C3  09 20               ORA #$20
F8C5  88                  DEY
F8C6  D0 FA               BNE MNNDX2
F8C8  C8                  INY
F8C9  88        MNNDX3    DEY
F8CA  D0 F2               BNE MNNDX1
F8CC  60                  RTS
F8CD  FF FF FF            DFB $FF,$FF,$FF
F8D0                      PAGE
F8D0  20 82 F8  INSTDSP   JSR INSDS1
F8D3  48                  PHA
F8D4  B1 3A     PRNTOP    LDA (PCL),Y
F8D6  20 DA FD            JSR PRBYTE
F8D9  A2 01               LDX #$01
F8DB  20 4A F9  PRNTBL    JSR PRBL2
F8DE  C4 2F               CPY LENGTH
F8E0  C8                  INY
F8E1  90 F1               BCC PRNTOP
F8E3  A2 03               LDX #$03
F8E5  C0 04               CPY #$04
F8E7  90 F2               BCC PRNTBL
F8E9  68                  PLA
F8EA  A8                  TAY
F8EB  B9 C0 F9            LDA MNEML,Y
F8EE  85 2C               STA LMNEM
F8F0  B9 00 FA            LDA MNEMR,Y
F8F3  85 2D               STA RMNEM
F8F5  A9 00     NXTCOL    LDA #$00
F8F7  A0 05               LDY #$05
F8F9  06 2D     PRMN2     ASL RMNEM
F8FB  26 2C               ROL LMNEM
F8FD  2A                  ROL A
F8FE  88                  DEY
F8FF  D0 F8               BNE PRMN2
F901  69 BF               ADC #$BF
F903  20 ED FD            JSR COUT
F906  CA                  DEX
F907  D0 EC               BNE NXTCOL
F909  20 48 F9            JSR PRBLNK
F90C  A4 2F               LDY LENGTH
F90E  A2 06               LDX #$06
F910  E0 03     PRADR1    CPX #$03
F912  F0 1C               BEQ PRADR5
F914  06 2E     PRADR2    ASL FORMAT
F916  90 0E               BCC PRADR3
F918  BD B3 F9            LDA CHAR1-1,X
F91B  20 ED FD            JSR COUT
F91E  BD B9 F9            LDA CHAR2-1,X
F921  F0 03               BEQ PRADR3
F923  20 ED FD            JSR COUT
F926  CA        PRADR3    DEX
F927  D0 E7               BNE PRADR1
F929  60                  RTS
F92A  88        PRADR4    DEY
F92B  30 E7               BMI PRADR2
F92D  20 DA FD            JSR PRBYTE
F930  A5 2E     PRADR5    LDA FORMAT
F932  C9 E8               CMP #$E8
```

```
F934  B1 3A              LDA (PCL),Y
F936  90 F2              BCC PRADR4
F938                     PAGE
F938  20 56 F9  RELADR   JSR PCADJ3
F93B  AA                 TAX
F93C  E8                 INX
F93D  D0 01              BNE PRNTYX
F93F  C8                 INY
F940  98        PRNTYX   TYA
F941  20 DA FD  PRNTAX   JSR PRBYTE
F944  8A        PRNTX    TXA
F945  4C DA FD           JMP PRBYTE
F948  A2 03     PRBLNK   LDX #$03
F94A  A9 A0     PRBL2    LDA #$A0
F94C  20 ED FD  PRBL3    JSR COUT
F94F  CA                 DEX
F950  D0 F8              BNE PRBL2
F952  60                 RTS
F953  38        PCADJ    SEC
F954  A5 2F     PCADJ2   LDA LENGTH
F956  A4 3B     PCADJ3   LDY PCH
F958  AA                 TAX
F959  10 01              BPL PCADJ4
F95B  88                 DEY
F95C  65 3A     PCADJ4   ADC PCL
F95E  90 01              BCC RTS2
F960  C8                 INY
F961  60        RTS2     RTS
F962  04        FMT1     DFB $04
F963  20                 DFB $20
F964  54                 DFB $54
F965  30                 DFB $30
F966  0D                 DFB $0D
F967  80                 DFB $80
F968  04                 DFB $04
F969  90                 DFB $90
F96A  03                 DFB $03
F96B  22                 DFB $22
F96C  54                 DFB $54
F96D  33                 DFB $33
F96E  0D                 DFB $0D
F96F  80                 DFB $80
F970  04                 DFB $04
F971  90                 DFB $90
F972  04                 DFB $04
F973  20                 DFB $20
F974  54                 DFB $54
F975  33                 DFB $33
F976  0D                 DFB $0D
F977  80                 DFB $80
F978  04                 DFB $04
F979  90                 DFB $90
F97A  04                 DFB $04
F97B  20                 DFB $20
F97C  54                 DFB $54
F97D  3B                 DFB $3B
F97E  0D                 DFB $0D
F97F  80                 DFB $80
F980  04                 DFB $04
F981  90                 DFB $90
F982  00                 DFB $00
F983  22                 DFB $22
F984  44                 DFB $44
F985  33                 DFB $33
F986  0D                 DFB $0D
F987  C8                 DFB $C8
F988  44                 DFB $44
F989  00                 DFB $00
F98A  11                 DFB $11
F98B  22                 DFB $22
F98C  44                 DFB $44
F98D  33                 DFB $33
F98E  0D                 DFB $0D
```

```
F98F  C8          DFB $C8
F990  44          DFB $44
F991  A9          DFB $A9
F992  01          DFB $01
F993  22          DFB $22
F994  44          DFB $44
F995  33          DFB $33
F996  0D          DFB $0D
F997  80          DFB $80
F998  04          DFB $04
F999  90          DFB $90
F99A  01          DFB $01
F99B  22          DFB $22
F99C  44          DFB $44
F99D  33          DFB $33
F99E  0D          DFB $0D
F99F  80          DFB $80
F9A0  04          DFB $04
F9A1  90          DFB $90
F9A2  26          DFB $26
F9A3  31          DFB $31
F9A4  87          DFB $87
F9A5  9A          DFB $9A
F9A6  00    FMT2  DFB $00
F9A7  21          DFB $21
F9A8  81          DFB $81
F9A9  82          DFB $82
F9AA  00          DFB $00
F9AB  00          DFB $00
F9AC  59          DFB $59
F9AD  4D          DFB $4D
F9AE  91          DFB $91
F9AF  92          DFB $92
F9B0  86          DFB $86
F9B1  4A          DFB $4A
F9B2  85          DFB $85
F9B3  9D          DFB $9D
F9B4  AC    CHAR1 DFB $AC
F9B5  A9          DFB $A9
F9B6  AC          DFB $AC
F9B7  A3          DFB $A3
F9B8  A8          DFB $A8
F9B9  A4          DFB $A4
F9BA  D9    CHAR2 DFB $D9
F9BB  00          DFB $00
F9BC  D8          DFB $D8
F9BD  A4          DFB $A4
F9BE  A4          DFB $A4
F9BF  00          DFB $00
F9C0  1C    MNEML DFB $1C
F9C1  8A          DFB $8A
F9C2  1C          DFB $1C
F9C3  23          DFB $23
F9C4  5D          DFB $5D
F9C5  8B          DFB $8B
F9C6  1B          DFB $1B
F9C7  A1          DFB $A1
F9C8  9D          DFB $9D
F9C9  8A          DFB $8A
F9CA  1D          DFB $1D
F9CB  23          DFB $23
F9CC  9D          DFB $9D
F9CD  8B          DFB $8B
F9CE  1D          DFB $1D
F9CF  A1          DFB $A1
F9D0  00          DFB $00
F9D1  29          DFB $29
F9D2  19          DFB $19
F9D3  AE          DFB $AE
F9D4  69          DFB $69
F9D5  A8          DFB $A8
F9D6  19          DFB $19
F9D7  23          DFB $23
```

```
F9D8:  24                  DFB $24
F9D9:  53                  DFB $53
F9DA:  1B                  DFB $1B
F9DB:  23                  DFB $23
F9DC:  24                  DFB $24
F9DD:  53                  DFB $53
F9DE:  19                  DFB $19
F9DF:  A1                  DFB $A1
F9E0:  00                  DFB $00
F9E1:  1A                  DFB $1A
F9E2:  5B                  DFB $5B
F9E3:  5B                  DFB $5B
F9E4:  A5                  DFB $A5
F9E5:  69                  DFB $69
F9E6:  24                  DFB $24
F9E7:  24                  DFB $24
F9E8:  AE                  DFB $AE
F9E9:  AE                  DFB $AE
F9EA:  A8                  DFB $A8
F9EB:  AD                  DFB $AD
F9EC:  29                  DFB $29
F9ED:  00                  DFB $00
F9EE:  7C                  DFB $7C
F9EF:  00                  DFB $00
F9F0:  15                  DFB $15
F9F1:  9C                  DFB $9C
F9F2:  6D                  DFB $6D
F9F3:  9C                  DFB $9C
F9F4:  A5                  DFB $A5
F9F5:  69                  DFB $69
F9F6:  29                  DFB $29
F9F7:  53                  DFB $53
F9F8:  84                  DFB $84
F9F9:  13                  DFB $13
F9FA:  34                  DFB $34
F9FB:  11                  DFB $11
F9FC:  A5                  DFB $A5
F9FD:  69                  DFB $69
F9FE:  23                  DFB $23
F9FF:  A0                  DFB $A0
FA00:  D8         MNEMR    DFB $D8
FA01:  62                  DFB $62
FA02:  5A                  DFB $5A
FA03:  48                  DFB $48
FA04:  26                  DFB $26
FA05:  62                  DFB $62
FA06:  94                  DFB $94
FA07:  88                  DFB $88
FA08:  54                  DFB $54
FA09:  44                  DFB $44
FA0A:  C8                  DFB $C8
FA0B:  54                  DFB $54
FA0C:  68                  DFB $68
FA0D:  44                  DFB $44
FA0E:  E8                  DFB $E8
FA0F:  94                  DFB $94
FA10:  00                  DFB $00
FA11:  B4                  DFB $B4
FA12:  08                  DFB $08
FA13:  84                  DFB $84
FA14:  74                  DFB $74
FA15:  B4                  DFB $B4
FA16:  28                  DFB $28
FA17:  6E                  DFB $6E
FA18:  74                  DFB $74
FA19:  F4                  DFB $F4
FA1A:  CC                  DFB $CC
FA1B:  4A                  DFB $4A
FA1C:  72                  DFB $72
FA1D:  F2                  DFB $F2
FA1E:  A4                  DFB $A4
FA1F:  8A                  DFB $8A
FA20:  00                  DFB $00
```

```
FA21  AA                    DFB $AA
FA22  A2                    DFB $A2
FA23  A2                    DFB $A2
FA24  74                    DFB $74
FA25  74                    DFB $74
FA26  74                    DFB $74
FA27  72                    DFB $72
FA28  44                    DFB $44
FA29  68                    DFB $68
FA2A  B2                    DFB $B2
FA2B  32                    DFB $32
FA2C  B2                    DFB $B2
FA2D  00                    DFB $00
FA2E  22                    DFB $22
FA2F  00                    DFB $00
FA30  1A                    DFB $1A
FA31  1A                    DFB $1A
FA32  26                    DFB $26
FA33  26                    DFB $26
FA34  72                    DFB $72
FA35  72                    DFB $72
FA36  88                    DFB $88
FA37  C8                    DFB $C8
FA38  C4                    DFB $C4
FA39  CA                    DFB $CA
FA3A  26                    DFB $26
FA3B  48                    DFB $48
FA3C  44                    DFB $44
FA3D  44                    DFB $44
FA3E  A2                    DFB $A2
FA3F  C8                    DFB $C8
FA40                        PAGE
FA40  85 45        IRQ      STA ACC
FA42  68                    PLA
FA43  48                    PHA
FA44  0A                    ASL A
FA45  0A                    ASL A
FA46  0A                    ASL A
FA47  30 03                 BMI BREAK
FA49  6C FE 03              JMP (IRQLOC)
FA4C  28           BREAK    PLP
FA4D  20 4C FF              JSR SAV1
FA50  68                    PLA
FA51  85 3A                 STA PCL
FA53  68                    PLA
FA54  85 3B                 STA PCH
FA56  6C F0 03              JMP (BRKV) ;BRKV WRITTEN OVER BY DISK BOOT
FA59  20 82 F8     OLDBRK   JSR INSDS1
FA5C  20 DA FA              JSR RGDSP1
FA5F  4C 65 FF              JMP MON
FA62  D8           RESET    CLD         ; DO THIS FIRST THIS TIME
FA63  20 84 FE              JSR SETNORM
FA66  20 2F FB              JSR INIT
FA69  20 93 FE              JSR SETVID
FA6C  20 89 FE              JSR SETKBD
FA6F  AD 58 C0     INITAN   LDA SETAN0 ; AN0 = TTL HI
FA72  AD 5A C0              LDA SETAN1 ; AN1 = TTL HI
FA75  AD 5D C0              LDA CLRAN2 ; AN2 = TTL LO
FA78  AD 5F C0              LDA CLRAN3 ; AN3 = TTL LO
FA7B  AD FF CF              LDA CLRROM ; TURN OFF EXTNSN ROM
FA7E  2C 10 C0              BIT KBDSTRB ; CLEAR KEYBOARD
FA81  D8           NEWMON   CLD
FA82  20 3A FF              JSR BELL   ; CAUSES DELAY IF KEY BOUNCES
FA85  AD F3 03              LDA SOFTEV+1 ;IS RESET HI
FA88  49 A5                 EOR #$A5   ;A FUNNY COMPLEMENT OF THE
FA8A  CD F4 03              CMP PWREDUP ; PWR UP BYTE ???
FA8D  D0 17                 BNE PWRUP  ; NO SO PWRUP
FA8F  AD F2 03              LDA SOFTEV ; YES SEE IF COLD START
FA92  D0 0F                 BNE NOFIX  ; HAS BEEN DONE YET?
FA94  A9 E0                 LDA #$E0   ; ??
FA96  CD F3 03              CMP SOFTEV+1 ; ??
FA99  D0 08                 BNE NOFIX  ; YES SO REENTER SYSTEM
FA9B  A0 03        FIXSEV   LDY #3     ; NO SO POINT AT WARM START
```

```
FA9D  8C F2 03          STY SOFTEV  ; FOR NEXT RESET
FAA0  4C 00 E0          JMP BASIC   ; AND DO THE COLD START
FAA3  6C F2 03  NOFIX   JMP (SOFTEV) ; SOFT ENTRY VECTOR
FAA6                *********************************
FAA6  20 60 FB  PWRUP   JSR APPLEII
FAA9            SETPG3  EQU *       ; SET PAGE 3 VECTORS
FAA9  A2 05             LDX #5
FAAB  BD FC FA  SETPLP  LDA PWRCON-1,X ; WITH CNTRL B ADRS
FAAE  9D EF 03          STA BRKV-1,X ; OF CURRENT BASIC
FAB1  CA                DEX
FAB2  D0 F7             BNE SETPLP
FAB4  A9 C8             LDA #$C8    ; LOAD HI SLOT +1
FAB6  86 00             STX LOC0    ; SETPG3 MUST RETURN X=0
FAB8  85 01             STA LOC1    ; SET PTR H
FABA  A0 07     SLOOP   LDY #7      ; Y IS BYTE PTR
FABC  C6 01             DEC LOC1
FABE  A5 01             LDA LOC1
FAC0  C9 C0             CMP #$C0    ; AT LAST SLOT YET?
FAC2  F0 D7             BEQ FIXSEV  ; YES AND IT CANT BE A DISK
FAC4  8D F8 07          STA MSLOT
FAC7  B1 00     NXTBYT  LDA (LOC0),Y ; FETCH A SLOT BYTE
FAC9  D9 01 FB          CMP DISKID-1,Y ; IS IT A DISK ??
FACC  D0 EC             BNE SLOOP   ; NO SO NEXT SLOT DOWN
FACE  88                DEY
FACF  88                DEY         ; YES SO CHECK NEXT BYTE
FAD0  10 F5             BPL NXTBYT  ; UNTIL 4 CHECKED
FAD2  6C 00 00          JMP (LOC0)
FAD5  EA                NOP
FAD6  EA                NOP
FAD7                * REGDSP MUST ORG $FAD7
FAD7  20 8E FD  REGDSP  JSR CROUT
FADA  A9 45     RGDSP1  LDA #$45
FADC  85 40             STA A3L
FADE  A9 00             LDA #$00
FAE0  85 41             STA A3H
FAE2  A2 FB             LDX #$FB
FAE4  A9 A0     RDSP1   LDA #$A0
FAE6  20 ED FD          JSR COUT
FAE9  BD 1E FA          LDA RTBL-251,X
FAEC  20 ED FD          JSR COUT
FAEF  A9 BD             LDA #$BD
FAF1  20 ED FD          JSR COUT
FAF4                * LDA ACC+5,X
FAF4  B5 4A             DFB $B5,$4A
FAF6  20 DA FD          JSR PRBYTE
FAF9  E8                INX
FAFA  30 E8             BMI RDSP1
FAFC  60                RTS
FAFD  59 FA     PWRCON  DW  OLDBRK
FAFF  00 E0 45          DFB $00,$E0,$45
FB02  20 FF 00
FB05  FF        DISKID  DFB $20,$FF,$00,$FF
FB06  03 FF 3C          DFB $03,$FF,$3C
FB09  C1 D0 D0  TITLE   DFB $C1,$D0,$D0
FB0C  CC C5 A0          DFB $CC,$C5,$A0
FB0F  DD DB             DFB $DD,$DB
FB11            XLTBL   EQU *
FB11  C4 C2 C1          DFB $C4,$C2,$C1
FB14  FF C3             DFB $FF,$C3
FB16  FF FF FF          DFB $FF,$FF,$FF
FB19                *   MUST ORG $FB19
FB19  C1 D8 D9  RTBL    DFB $C1,$D8,$D9
FB1C  D0 D3             DFB $D0,$D3
FB1E  AD 70 C0  PREAD   LDA PTRIG
FB21                    LST ON
FB21  A0 00             LDY #$00
FB23  EA                NOP
FB24  EA                NOP
FB25  BD 64 C0  PREAD2  LDA PADDL0,X
FB28  10 04             BPL RTS2D
FB2A  C8                INY
FB2B  D0 F8             BNE PREAD2
FB2D  88                DEY
```

```
FB2E  60           RTS2B    RTS
FB2F  A9 00        INIT     LDA #$00
FB31  85 48                 STA STATUS
FB33  AD 56 C0              LDA LORES
FB36  AD 54 C0              LDA LOWSCR
FB39  AD 51 C0     SETTXT   LDA TXTSET
FB3C  A9 00                 LDA #$00
FB3E  F0 0B                 BEQ SETWND
FB40  AD 50 C0     SETGR    LDA TXTCLR
FB43  AD 53 C0              LDA MIXSET
FB46  20 36 F8              JSR CLRTOP
FB49  A9 14                 LDA #$14
FB4B  85 22        SETWND   STA WNDTOP
FB4D  A9 00                 LDA #$00
FB4F  85 20                 STA WNDLFT
FB51  A9 28                 LDA #$28
FB53  85 21                 STA WNDWDTH
FB55  A9 18                 LDA #$18
FB57  85 23                 STA WNDBTM
FB59  A9 17                 LDA #$17
FB5B  85 25        TABV     STA CV
FB5D  4C 22 FC              JMP VTAB
FB60  20 58 FC     APPLEII  JSR HOME     ; CLEAR THE SCRN
FB63  A0 08                 LDY #8
FB65  B9 08 FB     STITLE   LDA TITLE-1,Y ; GET A CHAR
FB68  99 0E 04              STA LINE1+14,Y
FB6B  88                    DEY
FB6C  D0 F7                 BNE STITLE
FB6E  60                    RTS
FB6F  AD F3 03     SETPWRC  LDA SOFTEV+1
FB72  49 A5                 EOR #$A5
FB74  8D F4 03              STA PWREDUP
FB77  60                    RTS
FB78               VIDWAIT  EQU *        ; CHECK FOR A PAUSE
FB78  C9 8D                 CMP #$8D     ; ONLY WHEN I HAVE A CR
FB7A  D0 18                 BNE NOWAIT   ; NOT SO, DO REGULAR
FB7C  AC 00 C0              LDY KBD      ; IS KEY PRESSED?
FB7F  10 13                 BPL NOWAIT   ; NO
FB81  C0 93                 CPY #$93     ; IS IT CTL S ?
FB83  D0 0F                 BNE NOWAIT   ; NO SO IGNORE
FB85  2C 10 C0              BIT KBDSTRB  ; CLEAR STROBE
FB88  AC 00 C0     KBDWAIT  LDY KBD      ; WAIT TILL NEXT KEY TO RESUME
FB8B  10 FB                 BPL KBDWAIT  ; WAIT FOR KEYPRESS
FB8D  C0 83                 CPY #$83     ; IS IT CONTROL C ?
FB8F  F0 03                 BEQ NOWAIT   ; YES SO LEAVE IT
FB91  2C 10 C0              BIT KBDSTRB  ; CLR STROBE
FB94  4C FD FB     NOWAIT   JMP VIDOUT   ; DO AS BEFORE
FB97                        PAGE
FB97  38           ESCOLD   SEC          ; INSURE CARRY SET
FB98  4C 2C FC              JMP ESC1
FB9B  A8           ESCNOW   TAY          ; USE CHAR AS INDEX
FB9C  B9 48 FA              LDA XLTBL-$C9,Y ; XLATE IJKM TO CBAD
FB9F  20 97 FB              JSR ESCOLD   ; DO THIS CURSOR MOTION
FBA2  20 0C FD              JSR RDKEY    ; AND GET NEXT
FBA5  C9 CE        ESCNEW   CMP #$CE     ; IS THIS AN N ?
FBA7  B0 EE                 BCS ESCOLD   ; N OR GREATER DO IT
FBA9  C9 C9                 CMP #$C9     ; LESS THAN I ?
FBAB  90 EA                 BCC ESCOLD   ; YES SO OLD WAY
FBAD  C9 CC                 CMP #$CC     ; IS IT A L ?
FBAF  F0 E6                 BEQ ESCOLD   ; DO NORMAL
FBB1  D0 E8                 BNE ESCNOW   ; GO DO IT
FBB3  EA                    NOP
FBB4  EA                    NOP
FBB5  EA                    NOP
FBB6  EA                    NOP
FBB7  EA                    NOP
FBB8  EA                    NOP
FBB9  EA                    NOP
FBBA  EA                    NOP
```

```
FBBB  EA              NOP
FBBC  EA              NOP
FBBD  EA              NOP
FBBE  EA              NOP
FBBF  EA              NOP
FBC0  EA              NOP
FBC1              *     MUST ORG $FBC1
FBC1: 48          BASCALC PHA
FBC2: 4A              LSR A
FBC3: 29 03           AND #$03
FBC5: 09 04           ORA #$04
FBC7: 85 29           STA BASH
FBC9: 68              PLA
FBCA: 29 18           AND #$18
FBCC: 90 02           BCC BASCLC2
FBCE: 69 7F           ADC #$7F
FBD0: 85 28       BASCLC2 STA BASL
FBD2: 0A              ASL A
FBD3: 0A              ASL A
FBD4: 05 28           ORA BASL
FBD6: 85 28           STA BASL
FBD8: 60              RTS
FBD9: C9 87       BELL1   CMP #$87
FBDB: D0 12           BNE RTS2B
FBDD: A9 40           LDA #$40
FBDF: 20 A8 FC        JSR WAIT
FBE2: A0 C0           LDY #$C0
FBE4: A9 0C       BELL2   LDA #$0C
FBE6: 20 A8 FC        JSR WAIT
FBE9: AD 30 C0        LDA SPKR
FBEC: 88              DEY
FBED: D0 F5           BNE BELL2
FBEF: 60          RTS2B   RTS
FBF0                  PAGE
FBF0: A4 24       STORADV LDY CH
FBF2: 91 28           STA (BASL),Y
FBF4: E6 24       ADVANCE INC CH
FBF6: A5 24           LDA CH
FBF8: C5 21           CMP WNDWDTH
FBFA: B0 66           BCS CR
FBFC: 60          RTS3    RTS
FBFD: C9 A0       VIDOUT  CMP #$A0
FBFF: B0 EF           BCS STORADV
FC01: A8              TAY
FC02: 10 EC           BPL STORADV
FC04: C9 8D           CMP #$8D
FC06: F0 5A           BEQ CR
FC08: C9 8A           CMP #$8A
FC0A: F0 5A           BEQ LF
FC0C: C9 88           CMP #$88
FC0E: D0 C9           BNE BELL1
FC10: C6 24       BS      DEC CH
FC12: 10 E8           BPL RTS3
FC14: A5 21           LDA WNDWDTH
FC16: 85 24           STA CH
FC18: C6 24           DEC CH
FC1A: A5 22       UP      LDA WNDTOP
FC1C: C5 25           CMP CV
FC1E: B0 0B           BCS RTS4
FC20: C6 25           DEC CV
FC22: A5 25       VTAB    LDA CV
FC24: 20 C1 FB    VTABZ   JSR BASCALC
FC27: 65 20           ADC WNDLFT
FC29: 85 28           STA BASL
FC2B: 60          RTS4    RTS
FC2C: 49 C0       ESC1    EOR #$C0      ; ESC @ ?
FC2E: F0 28           BEQ HOME      ; IF SO DO HOME AND CLEAR
FC30: 69 FD           ADC #$FD      ; ESC-A OR B CHECK
FC32: 90 C0           BCC ADVANCE   ; A, ADVANCE
FC34: F0 DA           BEQ BS        ; B, BACKSPACE
FC36: 69 FD           ADC #$FD      ; ESC-C OR D CHECK
FC38: 90 2C           BCC LF        ; C, DOWN
FC3A: F0 DE           BEQ UP        ; D, GO UP
```

```
FC3C: 69 FD             ADC #$FD      ; ESC-E OR F CKECK
FC3E: 90 5C             BCC CLREOL    ; E, CLEAR TO END OF LINE
FC40: D0 E9             BNE RTS4      ; ELSE NOT F, RETURN
FC42: A4 24    CLREOP   LDY CH        ; ESC F IS CLR TO END OF PAGE
FC44: A5 25             LDA CV
FC46: 48       CLEOP1   PHA
FC47: 20 24 FC          JSR VTABZ
FC4A: 20 9E FC          JSR CLEOLZ
FC4D: A0 00             LDY #$00
FC4F: 68                PLA
FC50: 69 00             ADC #$00
FC52: C5 23             CMP WNDBTM
FC54: 90 F0             BCC CLEOP1
FC56: B0 CA             BCS VTAB
FC58: A5 22    HOME     LDA WNDTOP
FC5A: 85 25             STA CV
FC5C: A0 00             LDY #$00
FC5E: 84 24             STY CH
FC60: F0 E4             BEQ CLEOP1
FC62                    PAGE
FC62: A9 00    CR       LDA #$00
FC64: 85 24             STA CH
FC66: E6 25    LF       INC CV
FC68: A5 25             LDA CV
FC6A: C5 23             CMP WNDBTM
FC6C: 90 B6             BCC VTABZ
FC6E: C6 25             DEC CV
FC70: A5 22    SCROLL   LDA WNDTOP
FC72: 48                PHA
FC73: 20 24 FC          JSR VTABZ
FC76: A5 28    SCRL1    LDA BASL
FC78: 85 2A             STA BAS2L
FC7A: A5 29             LDA BASH
FC7C: 85 2B             STA BAS2H
FC7E: A4 21             LDY WNDWDTH
FC80: 88                DEY
FC81: 68                PLA
FC82: 69 01             ADC #$01
FC84: C5 23             CMP WNDBTM
FC86: B0 0D             BCS SCRL3
FC88: 48                PHA
FC89: 20 24 FC          JSR VTABZ
FC8C: B1 28    SCRL2    LDA (BASL),Y
FC8E: 91 2A             STA (BAS2L),Y
FC90: 88                DEY
FC91: 10 F9             BPL SCRL2
FC93: 30 E1             BMI SCRL1
FC95: A0 00    SCRL3    LDY #$00
FC97: 20 9E FC          JSR CLEOLZ
FC9A: B0 86             BCS VTAB
FC9C: A4 24    CLREOL   LDY CH
FC9E: A9 A0    CLEOLZ   LDA #$A0
FCA0: 91 28    CLEOL2   STA (BASL),Y
FCA2: C8                INY
FCA3: C4 21             CPY WNDWDTH
FCA5: 90 F9             BCC CLEOL2
FCA7: 60                RTS
FCA8: 38       WAIT     SEC
FCA9: 48       WAIT2    PHA
FCAA: E9 01    WAIT3    SBC #$01
FCAC: D0 FC             BNE WAIT3
FCAE: 68                PLA
FCAF: E9 01             SBC #$01
FCB1: D0 F6             BNE WAIT2
FCB3: 60                RTS
FCB4: E6 42    NXTA4    INC A4L
FCB6: D0 02             BNE NXTA1
FCB8: E6 43             INC A4H
FCBA: A5 3C    NXTA1    LDA A1L
FCBC: C5 3E             CMP A2L
FCBE: A5 3D             LDA A1H
FCC0: E5 3F             SBC A2H
FCC2: E6 3C             INC A1L
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FCC4  D0 02              BNE RTS4B
FCC6  E6 3D              INC A1H
FCC8  60        RTS4B    RTS
FCC9                     PAGE
FCC9  A0 4B     HEADR    LDY #$4B
FCCB  20 DB FC           JSR ZERDLY
FCCE  D0 F9              BNE HEADR
FCD0  69 FE              ADC #$FE
FCD2  B0 F5              BCS HEADR
FCD4  A0 21              LDY #$21
FCD6  20 DB FC  WRBIT    JSR ZERDLY
FCD9  C8                 INY
FCDA  C8                 INY
FCDB  88        ZERDLY   DEY
FCDC  D0 FD              BNE ZERDLY
FCDE  90 05              BCC WRTAPE
FCE0  A0 32              LDY #$32
FCE2  88        ONEDLY   DEY
FCE3  D0 FD              BNE ONEDLY
FCE5  AC 20 C0  WRTAPE   LDY TAPEOUT
FCE8  A0 2C              LDY #$2C
FCEA  CA                 DEX
FCEB  60                 RTS
FCEC  A2 08     RDBYTE   LDX #$08
FCEE  48        RDBYT2   PHA
FCEF  20 FA FC           JSR RD2BIT
FCF2  68                 PLA
FCF3  2A                 ROL A
FCF4  A0 3A              LDY #$3A
FCF6  CA                 DEX
FCF7  D0 F5              BNE RDBYT2
FCF9  60                 RTS
FCFA  20 FD FC  RD2BIT   JSR RDBIT
FCFD  88        RDBIT    DEY
FCFE  AD 60 C0           LDA TAPEIN
FD01  45 2F              EOR LASTIN
FD03  10 F8              BPL RDBIT
FD05  45 2F              EOR LASTIN
FD07  85 2F              STA LASTIN
FD09  C0 80              CPY #$80
FD0B  60                 RTS
FD0C  A4 24     RDKEY    LDY CH
FD0E  B1 28              LDA (BASL),Y
FD10  48                 PHA
FD11  29 3F              AND #$3F
FD13  09 40              ORA #$40
FD15  91 28              STA (BASL),Y
FD17  68                 PLA
FD18  6C 38 00           JMP (KSWL)
FD1B  E6 4E     KEYIN    INC RNDL
FD1D  D0 02              BNE KEYIN2
FD1F  E6 4F              INC RNDH
FD21  2C 00 C0  KEYIN2   BIT KBD       ; READ KEYBOARD
FD24  10 F5              BPL KEYIN
FD26  91 28              STA (BASL),Y
FD28  AD 00 C0           LDA KBD
FD2B  2C 10 C0           BIT KBDSTRB
FD2E  60                 RTS
FD2F  20 0C FD  ESC      JSR RDKEY
FD32  20 A5 FB           JSR ESCNEW
FD35  20 0C FD  RDCHAR   JSR RDKEY
FD38  C9 9B              CMP #$9B
FD3A  F0 F3              BEQ ESC
FD3C  60                 RTS
FD3D                     PAGE
FD3D  A5 32     NOTCR    LDA INVFLG
FD3F  48                 PHA
FD40  A9 FF              LDA #$FF
FD42  85 32              STA INVFLG
FD44  BD 00 02           LDA IN,X
FD47  20 ED FD           JSR COUT
FD4A  68                 PLA
FD4B  85 32              STA INVFLG
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```
FD4D: BD 00 02            LDA IN,X
FD50: C9 88               CMP #$88
FD52: F0 1D               BEQ BCKSPC
FD54: C9 98               CMP #$98
FD56: F0 0A               BEQ CANCEL
FD58: E0 F8               CPX #$F8
FD5A: 90 03               BCC NOTCR1
FD5C: 20 3A FF            JSR BELL
FD5F: E8         NOTCR1   INX
FD60: D0 13               BNE NXTCHAR
FD62: A9 DC      CANCEL   LDA #$DC
FD64: 20 ED FD            JSR COUT
FD67: 20 8E FD   GETLNZ   JSR CROUT
FD6A: A5 33      GETLN    LDA PROMPT
FD6C: 20 ED FD            JSR COUT
FD6F: A2 01               LDX #$01
FD71: 8A         BCKSPC   TXA
FD72: F0 F3               BEQ GETLNZ
FD74: CA                  DEX
FD75: 20 35 FD   NXTCHAR  JSR RDCHAR
FD78: C9 95               CMP #$95
FD7A: D0 02               BNE CAPTST
FD7C: B1 28               LDA (BASL),Y
FD7E: C9 E0      CAPTST   CMP #$E0
FD80: 90 02               BCC ADDINP
FD82: 29 DF               AND #$DF      ; SHIFT TO UPPER CASE
FD84: 9D 00 02   ADDINP   STA IN,X
FD87: C9 8D               CMP #$8D
FD89: D0 B2               BNE NOTCR
FD8B: 20 9C FC            JSR CLREOL
FD8E: A9 8D      CROUT    LDA #$8D
FD90: D0 5B               BNE COUT
FD92: A4 3D      PRA1     LDY A1H
FD94: A6 3C               LDX A1L
FD96: 20 8E FD   PRYX2    JSR CROUT
FD99: 20 40 F9            JSR PRNTYX
FD9C: A0 00               LDY #$00
FD9E: A9 AD               LDA #$AD
FDA0: 4C ED FD            JMP COUT
FDA3:                     PAGE
FDA3: A5 3C      XAM8     LDA A1L
FDA5: 09 07               ORA #$07
FDA7: 85 3E               STA A2L
FDA9: A5 3D               LDA A1H
FDAB: 85 3F               STA A2H
FDAD: A5 3C      MOD8CHK  LDA A1L
FDAF: 29 07               AND #$07
FDB1: D0 03               BNE DATAOUT
FDB3: 20 92 FD   XAM      JSR PRA1
FDB6: A9 A0      DATAOUT  LDA #$A0
FDB8: 20 ED FD            JSR COUT
FDBB: B1 3C               LDA (A1L),Y
FDBD: 20 DA FD            JSR PRBYTE
FDC0: 20 BA FC            JSR NXTA1
FDC3: 90 E8               BCC MOD8CHK
FDC5: 60         RTS4C    RTS
FDC6: 4A         XAMPM    LSR A
FDC7: 90 EA               BCC XAM
FDC9: 4A                  LSR A
FDCA: 4A                  LSR A
FDCB: A5 3E               LDA A2L
FDCD: 90 02               BCC ADD
FDCF: 49 FF               EOR #$FF
FDD1: 65 3C      ADD      ADC A1L
FDD3: 48                  PHA
FDD4: A9 BD               LDA #$BD
FDD6: 20 ED FD            JSR COUT
FDD9: 68                  PLA
FDDA: 48         PRBYTE   PHA
FDDB: 4A                  LSR A
FDDC: 4A                  LSR A
FDDD: 4A                  LSR A
FDDE: 4A                  LSR A
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FDDF:  20 E5 FD          JSR PRHEXZ
FDE2:  68                PLA
FDE3:  29 0F    PRHEX    AND #$0F
FDE5:  09 B0    PRHEXZ   ORA #$B0
FDE7:  C9 BA             CMP #$BA
FDE9:  90 02             BCC COUT
FDEB:  69 06             ADC #$06
FDED:  6C 36 00 COUT     JMP (CSWL)
FDF0:  C9 A0    COUT1    CMP #$A0
FDF2:  90 02             BCC COUTZ
FDF4:  25 32             AND INVFLG
FDF6:  84 35    COUTZ    STY YSAV1
FDF8:  48                PHA
FDF9:  20 78 FB          JSR VIDWAIT ; GO CHECK FOR PAUSE
FDFC:  68                PLA
FDFD:  A4 35             LDY YSAV1
FDFF:  60                RTS
FE00                     PAGE
FE00:  C6 34    BL1      DEC YSAV
FE02:  F0 9F             BEQ XAM8
FE04:  CA       BLANK    DEX
FE05:  D0 16             BNE SETMDZ
FE07:  C9 BA             CMP #$BA
FE09:  D0 BB             BNE XAMPM
FE0B:  85 31    STOR     STA MODE
FE0D:  A5 3E             LDA A2L
FE0F:  91 40             STA (A3L),Y
FE11:  E6 40             INC A3L
FE13:  D0 02             BNE RTS5
FE15:  E6 41             INC A3H
FE17:  60       RTS5     RTS
FE18:  A4 34    SETMODE  LDY YSAV
FE1A:  B9 FF 01          LDA IN-1,Y
FE1D:  85 31    SETMDZ   STA MODE
FE1F:  60                RTS
FE20:  A2 01    LT       LDX #$01
FE22:  B5 3E    LT2      LDA A2L,X
FE24:  95 42             STA A4L,X
FE26:  95 44             STA A5L,X
FE28:  CA                DEX
FE29:  10 F7             BPL LT2
FE2B:  60                RTS
FE2C:  B1 3C    MOVE     LDA (A1L),Y
FE2E:  91 42             STA (A4L),Y
FE30:  20 B4 FC          JSR NXTA4
FE33:  90 F7             BCC MOVE
FE35:  60                RTS
FE36:  B1 3C    VFY      LDA (A1L),Y
FE38:  D1 42             CMP (A4L),Y
FE3A:  F0 1C             BEQ VFYOK
FE3C:  20 92 FD          JSR PRA1
FE3F:  B1 3C             LDA (A1L),Y
FE41:  20 DA FD          JSR PRBYTE
FE44:  A9 A0             LDA #$A0
FE46:  20 ED FD          JSR COUT
FE49:  A9 A8             LDA #$A8
FE4B:  20 ED FD          JSR COUT
FE4E:  B1 42             LDA (A4L),Y
FE50:  20 DA FD          JSR PRBYTE
FE53:  A9 A9             LDA #$A9
FE55:  20 ED FD          JSR COUT
FE58:  20 B4 FC VFYOK    JSR NXTA4
FE5B:  90 D9             BCC VFY
FE5D:  60                RTS
FE5E:  20 75 FE LIST     JSR A1PC
FE61:  A9 14             LDA #$14
FE63:  48       LIST2    PHA
FE64:  20 D0 F8          JSR INSTDSP
FE67:  20 53 F9          JSR PCADJ
FE6A:  85 3A             STA PCL
FE6C:  84 3B             STY PCH
FE6E:  68                PLA
FE6F:  38                SEC
```

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FE70:  E9 01             SBC #$01
FE72:  D0 EF             BNE LIST2
FE74:  60                RTS
FE75:                    PAGE
FE75:  8A       A1PC     TXA
FE76:  F0 07             BEQ A1PCRTS
FE78:  B5 3C    A1PCLP   LDA A1L,X
FE7A:  95 3A             STA PCL,X
FE7C:  CA                DEX
FE7D:  10 F9             BPL A1PCLP
FE7F:  60       A1PCRTS  RTS
FE80:  A0 3F    SETINV   LDY #$3F
FE82:  D0 02             BNE SETIFLG
FE84:  A0 FF    SETNORM  LDY #$FF
FE86:  84 32    SETIFLG  STY INVFLG
FE88:  60                RTS
FE89:  A9 00    SETKBD   LDA #$00
FE8B:  85 3E    INPORT   STA A2L
FE8D:  A2 38    INPRT    LDX #KSWL
FE8F:  A0 1B             LDY #KEYIN
FE91:  D0 08             BNE IOPRT
FE93:  A9 00    SETVID   LDA #$00
FE95:  85 3E    OUTPORT  STA A2L
FE97:  A2 36    OUTPRT   LDX #CSWL
FE99:  A0 F0             LDY #COUT1
FE9B:  A5 3E    IOPRT    LDA A2L
FE9D:  29 0F             AND #$0F
FE9F:  F0 06             BEQ IOPRT1
FEA1:  09 C0             ORA #IOADR/256
FEA3:  A0 00             LDY #$00
FEA5:  F0 02             BEQ IOPRT2
FEA7:  A9 FD    IOPRT1   LDA #COUT1/256
FEA9:           IOPRT2   EQU *
FEA9:  94 00             STY LOC0,X  ; $94,$00
FEAB:  95 01             STA LOC1,X  ; $95,$01
FEAD:  60                RTS
FEAE:  EA                NOP
FEAF:  EA                NOP
FEB0:  4C 00 E0 XBASIC   JMP BASIC
FEB3:  4C 03 E0 BASCONT  JMP BASIC2
FEB6:  20 75 FE GO       JSR A1PC
FEB9:  20 3F FF          JSR RESTORE
FEBC:  6C 3A 00          JMP (PCL)
FEBF:  4C D7 FA REGZ     JMP REGDSP
FEC2:  60       TRACE    RTS
FEC3:           * TRACE IS GONE
FEC3:  EA                NOP
FEC4:  60       STEPZ    RTS         ; STEP IS GONE
FEC5:  EA                NOP
FEC6:  EA                NOP
FEC7:  EA                NOP
FEC8:  EA                NOP
FEC9:  EA                NOP
FECA:  4C F8 03 USR      JMP USRADR
FECD:                    PAGE
FECD:  A9 40    WRITE    LDA #$40
FECF:  20 C9 FC          JSR HEADR
FED2:  A0 27             LDY #$27
FED4:  A2 00    WR1      LDX #$00
FED6:  41 3C             EOR (A1L,X)
FED8:  48                PHA
FED9:  A1 3C             LDA (A1L,X)
FEDB:  20 ED FE          JSR WRBYTE
FEDE:  20 BA FC          JSR NXTA1
FEE1:  A0 1D             LDY #$1D
FEE3:  68                PLA
FEE4:  90 EE             BCC WR1
FEE6:  A0 22             LDY #$22
FEE8:  20 ED FE          JSR WRBYTE
FEEB:  F0 4D             BEQ BELL
FEED:  A2 10    WRBYTE   LDX #$10
FEEF:  0A       WRBYT2   ASL A
FEF0:  20 D6 FC          JSR WRBIT
```

```
FEF3  D0 FA       508           BNE WRBYT2
FEF5  60          509           RTS
FEF6  20 00 FE    510 CRMON     JSR BL1
FEF9  68          511           PLA
FEFA  68          512           PLA
FEFB  D0 6C       513           BNE MONZ
FEFD  20 FA FC    514 READ      JSR RD2BIT
FF00  A9 16       515           LDA #$16
FF02  20 C9 FC    516           JSR HEADR
FF05  85 2E       517           STA CHKSUM
FF07  20 FA FC    518           JSR RD2BIT
FF0A  A0 24       519 RD2       LDY #$24
FF0C  20 FD FC    520           JSR RDBIT
FF0F  B0 F9       521           BCS RD2
FF11  20 FD FC    522           JSR RDBIT
FF14  A0 3B       523           LDY #$3B
FF16  20 EC FC    524 RD3       JSR RDBYTE
FF19  81 3C       525           STA (A1L,X)
FF1B  45 2E       526           EOR CHKSUM
FF1D  85 2E       527           STA CHKSUM
FF1F  20 BA FC    528           JSR NXTA1
FF22  A0 35       529           LDY #$35
FF24  90 F0       530           BCC RD3
FF26  20 EC FC    531           JSR RDBYTE
FF29  C5 2E       532           CMP CHKSUM
FF2B  F0 0D       533           BEQ BELL
FF2D  A9 C5       534 PRERR     LDA #$C5
FF2F  20 ED FD    535           JSR COUT
FF32  A9 D2       536           LDA #$D2
FF34  20 ED FD    537           JSR COUT
FF37  20 ED FD    538           JSR COUT
FF3A  A9 87       539 BELL      LDA #$87
FF3C  4C ED FD    540           JMP COUT
FF3F              541           PAGE
FF3F  A5 48       542 RESTORE   LDA STATUS
FF41  48          543           PHA
FF42  A5 45       544           LDA A5H
FF44  A6 46       545 RESTR1    LDX XREG
FF46  A4 47       546           LDY YREG
FF48  28          547           PLP
FF49  60          548           RTS
FF4A  85 45       549 SAVE      STA A5H
FF4C  86 46       550 SAV1      STX XREG
FF4E  84 47       551           STY YREG
FF50  08          552           PHP
FF51  68          553           PLA
FF52  85 48       554           STA STATUS
FF54  BA          555           TSX
FF55  86 49       556           STX SPNT
FF57  D8          557           CLD
FF58  60          558           RTS
FF59  20 84 FE    559 OLDRST    JSR SETNORM
FF5C  20 2F FB    560           JSR INIT
FF5F  20 93 FE    561           JSR SETVID
FF62  20 89 FE    562           JSR SETKBD
FF65              563           PAGE
FF65  D8          564 MON       CLD
FF66  20 3A FF    565           JSR BELL
FF69  A9 AA       566 MONZ      LDA #$AA
FF6B  85 33       567           STA PROMPT
FF6D  20 67 FD    568           JSR GETLNZ
FF70  20 C7 FF    569           JSR ZMODE
FF73  20 A7 FF    570 NXTITM    JSR GETNUM
FF76  84 34       571           STY YSAV
FF78  A0 17       572           LDY #$17
FF7A  88          573 CHRSRCH   DEY
FF7B  30 E8       574           BMI MON
FF7D  D9 CC FF    575           CMP CHRTBL,Y
FF80  D0 F8       576           BNE CHRSRCH
FF82  20 BE FF    577           JSR TOSUB
FF85  A4 34       578           LDY YSAV
FF87  4C 73 FF    579           JMP NXTITM
FF8A  A2 03       580 DIG       LDX #$03
```

```
FF8C:  0A                  ASL A
FF8D:  0A                  ASL A
FF8E:  0A                  ASL A
FF8F:  0A                  ASL A
FF90:  0A        NXTBIT    ASL A
FF91:  26 3E               ROL A2L
FF93:  26 3F               ROL A2H
FF95:  CA                  DEX
FF96:  10 F8               BPL NXTBIT
FF98:  A5 31     NXTBAS    LDA MODE
FF9A:  D0 06               BNE NXTBS2
FF9C:            *
FF9C:  B5 3F               LDA A2H,X
FF9E:            *
FF9E:  95 3D               STA A1H,X
FFA0:            *
FFA0:  95 41               STA A3H,X
FFA2:  E8        NXTBS2    INX
FFA3:  F0 F3               BEQ NXTBAS
FFA5:  D0 06               BNE NXTCHR
FFA7:  A2 00     GETNUM    LDX #$00
FFA9:  86 3E               STX A2L
FFAB:  86 3F               STX A2H
FFAD:  B9 00 02  NXTCHR    LDA IN,Y
FFB0:  C8                  INY
FFB1:  49 B0               EOR #$B0
FFB3:  C9 0A               CMP #$0A
FFB5:  90 D3               BCC DIG
FFB7:  69 88               ADC #$88
FFB9:  C9 FA               CMP #$FA
FFBB:  B0 CD               BCS DIG
FFBD:  60                  RTS
FFBE:  A9 FE     TOSUB     LDA #GO/256
FFC0:  48                  PHA
FFC1:  B9 E3 FF            LDA SUBTBL,Y
FFC4:  48                  PHA
FFC5:  A5 31               LDA MODE
FFC7:  A0 00     ZMODE     LDY #$00
FFC9:  84 31               STY MODE
FFCB:  60                  RTS
FFCC:                      PAGE
FFCC:  BC        CHRTBL    DFB $BC
FFCD:  B2                  DFB $B2
FFCE:  BE                  DFB $BE
FFCF:  B2                  DFB $B2        ; T CMD NOW LIKE USR
FFD0:  EF                  DFB $EF
FFD1:  C4                  DFB $C4
FFD2:  B2                  DFB $B2        ; S CMD NOW LIKE USR
FFD3:  A9                  DFB $A9
FFD4:  BB                  DFB $BB
FFD5:  A6                  DFB $A6
FFD6:  A4                  DFB $A4
FFD7:  06                  DFB $06
FFD8:  95                  DFB $95
FFD9:  07                  DFB $07
FFDA:  02                  DFB $02
FFDB:  05                  DFB $05
FFDC:  F0                  DFB $F0
FFDD:  00                  DFB $00
FFDE:  EB                  DFB $EB
FFDF:  93                  DFB $93
FFE0:  A7                  DFB $A7
FFE1:  C6                  DFB $C6
FFE2:  99                  DFB $99
FFE3:  B2        SUBTBL    DFB $B2
FFE4:  C9                  DFB $C9
FFE5:  BE                  DFB $BE
FFE6:  C1                  DFB $C1
FFE7:  35                  DFB $35
FFE8:  8C                  DFB $8C
FFE9:  C4                  DFB $C4
FFEA:  96                  DFB $96
FFEB:  AF                  DFB $AF
```

```
FFEC: 17        DFB $17
FFED: 17        DFB $17
FFEE  2B        DFB $2B
FFEF  1F        DFB $1F
FFF0  83        DFB $83
FFF1  7F        DFB $7F
FFF2  5D        DFB $5D
FFF3: CC        DFB $CC
FFF4  B5        DFB $B5
FFF5: FC        DFB $FC
FFF6  17        DFB $17
FFF7  17        DFB $17
FFF8  F5        DFB $F5
FFF9  03        DFB $03
FFFA  FB 03     DW  NMI
FFFC  62 FA     DW  RESET
FFFE  40 FA     DW  IRQ

ENDASM
```

MONITOR ROM LISTING

```
*****************************
*                           *
*         APPLE II          *
*      SYSTEM MONITOR       *
*                           *
*    COPYRIGHT 1977 BY      *
*   APPLE COMPUTER, INC.    *
*                           *
*   ALL RIGHTS RESERVED     *
*                           *
*        S. WOZNIAK         *
*         A. BAUM           *
*                           *
*****************************
            TITLE           "APPLE II SYSTEM MONITOR"
LOC0        EPZ  $00
LOC1        EPZ  $01
WNDLFT      EPZ  $20
WNDWDTH     EPZ  $21
WNDTOP      EPZ  $22
WNDBTM      EPZ  $23
CH          EPZ  $24
CV          EPZ  $25
GBASL       EPZ  $26
GBASH       EPZ  $27
BASL        EPZ  $28
BASH        EPZ  $29
BAS2L       EPZ  $2A
BAS2H       EPZ  $2B
H2          EPZ  $2C
LMNEM       EPZ  $2C
RTNL        EPZ  $2C
V2          EPZ  $2D
RMNEM       EPZ  $2D
RTNH        EPZ  $2D
MASK        EPZ  $2E
CHKSUM      EPZ  $2E
FORMAT      EPZ  $2E
LASTIN      EPZ  $2F
LENGTH      EPZ  $2F
SIGN        EPZ  $2F
COLOR       EPZ  $30
MODE        EPZ  $31
INVFLG      EPZ  $32
PROMPT      EPZ  $33
YSAV        EPZ  $34
YSAV1       EPZ  $35
CSWL        EPZ  $36
CSWH        EPZ  $37
KSWL        EPZ  $38
KSWH        EPZ  $39
PCL         EPZ  $3A
PCH         EPZ  $3B
XQT         EPZ  $3C
A1L         EPZ  $3C
A1H         EPZ  $3D
A2L         EPZ  $3E
A2H         EPZ  $3F
A3L         EPZ  $40
A3H         EPZ  $41
A4L         EPZ  $42
A4H         EPZ  $43
A5L         EPZ  $44
A5H         EPZ  $45
ACC         EPZ  $45
XREG        EPZ  $46
YREG        EPZ  $47
STATUS      EPZ  $48
```

```
                SPNT      EPZ  $49
                RNDL      EPZ  $4E
                RNDH      EPZ  $4F
                ACL       EPZ  $50
                ACH       EPZ  $51
                XTNDL     EPZ  $52
                XTNDH     EPZ  $53
                AUXL      EPZ  $54
                AUXH      EPZ  $55
                PICK      EPZ  $95
                IN        EQU  $0200
                USRADR    EQU  $03F8
                NMI       EQU  $03FB
                IRQLOC    EQU  $03FE
                IOADR     EQU  $C000
                KBD       EQU  $C000
                KBDSTRB   EQU  $C010
                TAPEOUT   EQU  $C020
                SPKR      EQU  $C030
                TXTCLR    EQU  $C050
                TXTSET    EQU  $C051
                MIXCLR    EQU  $C052
                MIXSET    EQU  $C053
                LOWSCR    EQU  $C054
                HISCR     EQU  $C055
                LORES     EQU  $C056
                HIRES     EQU  $C057
                TAPEIN    EQU  $C060
                PADDL0    EQU  $C064
                PTRIG     EQU  $C070
                BASIC     EQU  $E000
                BASIC2    EQU  $E003
                          ORG  $F800         ROM START ADDRESS
F800:  4A       PLOT      LSR  A             Y-COORD/2
F801:  08                 PHP                SAVE LSB IN CARRY
F802:  20 47 F8           JSR  GBASCALC      CALC BASE ADR IN GBASL,H
F805:  28                 PLP                RESTORE LSB FROM CARRY
F806:  A9 0F              LDA  #$0F          MASK $0F IF EVEN
F808:  90 02              BCC  RTMASK
F80A:  69 E0              ADC  #$E0          MASK $F0 IF ODD
F80C:  85 2E    RTMASK    STA  MASK
F80E:  B1 26    PLOT1     LDA  (GBASL),Y     DATA
F810:  45 30              EOR  COLOR          XOR  COLOR
F812:  25 2E              AND  MASK            AND MASK
F814:  51 26              EOR  (GBASL),Y         XOR DATA
F816:  91 26              STA  (GBASL),Y          TO DATA
F818:  60                 RTS
F819:  20 00 F8 HLINE     JSR  PLOT          PLOT SQUARE
F81C:  C4 2C    HLINE1    CPY  H2            DONE?
F81E:  B0 11              BCS  RTS1           YES, RETURN
F820:  C8                 INY                 NO, INCR INDEX (X-COORD)
F821:  20 0E F8           JSR  PLOT1         PLOT NEXT SQUARE
F824:  90 F6              BCC  HLINE1        ALWAYS TAKEN
F826:  69 01    VLINEZ    ADC  #$01          NEXT Y-COORD
F828:  48       VLINE     PHA                 SAVE ON STACK
F829:  20 00 F8           JSR  PLOT           PLOT SQUARE
F82C:  68                 PLA
F82D:  C5 2D              CMP  V2            DONE?
F82F:  90 F5              BCC  VLINEZ         NO,LOOP.
F831:  60       RTS1      RTS
F832:  A0 2F    CLRSCR    LDY  #$2F          MAX Y, FULL SCRN CLR
F834:  D0 02              BNE  CLRSC2        ALWAYS TAKEN
F836:  A0 27    CLRTOP    LDY  #$27          MAX Y, TOP SCRN CLR
F838:  84 2D    CLRSC2    STY  V2            STORE AS BOTTOM COORD
                *                        FOR VLINE CALLS
F83A:  A0 27              LDY  #$27          RIGHTMOST X-COORD (COLUMN)
F83C:  A9 00    CLRSC3    LDA  #$0           TOP COORD FOR VLINE CALLS
F83E:  85 30              STA  COLOR         CLEAR COLOR (BLACK)
F840:  20 28 F8           JSR  VLINE         DRAW VLINE
F843:  88                 DEY                NEXT LEFTMOST X-COORD
F844:  10 F6              BPL  CLRSC3        LOOP UNTIL DONE.
F846:  60                 RTS
F847:  48       GBASCALC  PHA                FOR INPUT 000DEFGH
F848:  4A                 LSR  A
```

```
F849:  29 03              AND  #$03        GENERATE GBASH=000001FG
F84B:  09 04              ORA  #$04
F84D:  85 27              STA  GBASH       AND GBASL=HDEDE000
F84F:  68                 PLA
F850:  29 18              AND  #$18
F852:  90 02              BCC  GBCALC
F854:  69 7F              ADC  #$7F
F856:  85 26     GBCALC   STA  GBASL
F858:  0A                 ASL  A
F859:  0A                 ASL  A
F85A:  05 26              ORA  GBASL
F85C:  85 26              STA  GBASL
F85E:  60                 RTS
F85F:  A5 30     NXTCOL   LDA  COLOR       INCREMENT COLOR BY 3
F861:  18                 CLC
F862:  69 03              ADC  #$03
F864:  29 0F     SETCOL   AND  #$0F        SETS COLOR=17*A MOD 16
F866:  85 30              STA  COLOR
F868:  0A                 ASL  A           BOTH HALF BYTES OF COLOR EQUAL
F869:  0A                 ASL  A
F86A:  0A                 ASL  A
F86B:  0A                 ASL  A
F86C:  05 30              ORA  COLOR
F86E:  85 30              STA  COLOR
F870:  60                 RTS
F871:  4A        SCRN     LSR  A           READ SCREEN Y-COORD/2
F872:  08                 PHP              SAVE LSB (CARRY)
F873:  20 47 F8           JSR  GBASCALC    CALC BASE ADDRESS
F876:  B1 26              LDA  (GBASL),Y   GET BYTE
F878:  28                 PLP              RESTORE LSB FROM CARRY
F879:  90 04     SCRN2    BCC  RTMSKZ      IF EVEN, USE LO H
F87B:  4A                 LSR  A
F87C:  4A                 LSR  A
F87D:  4A                 LSR  A           SHIFT HIGH HALF BYTE DOWN
F87E:  4A                 LSR  A
F87F:  29 0F     RTMSKZ   AND  #$0F        MASK 4-BITS
F881:  60                 RTS
F882:  A6 3A     INSDS1   LDX  PCL         PRINT PCL,H
F884:  A4 3B              LDY  PCH
F886:  20 96 FD           JSR  PRYX2
F889:  20 48 F9           JSR  PRBLNK      FOLLOWED BY A BLANK
F88C:  A1 3A              LDA  (PCL,X)     GET OP CODE
F88E:  A8        INSDS2   TAY
F88F:  4A                 LSR  A           EVEN/ODD TEST
F890:  90 09              BCC  IEVEN
F892:  6A                 ROR  A           BIT 1 TEST
F893:  B0 10              BCS  ERR         XXXXXX11 INVALID OP
F895:  C9 A2              CMP  #$A2
F897:  F0 0C              BEQ  ERR         OPCODE $89 INVALID
F899:  29 87              AND  #$87        MASK BITS
F89B:  4A        IEVEN    LSR  A           LSB INTO CARRY FOR L/R TEST
F89C:  AA                 TAX
F89D:  BD 62 F9           LDA  FMT1,X      GET FORMAT INDEX BYTE
F8A0:  20 79 F8           JSR  SCRN2       R/L H-BYTE ON CARRY
F8A3:  D0 04              BNE  GETFMT
F8A5:  A0 80     ERR      LDY  #$80        SUBSTITUTE $80 FOR INVALID OPS
F8A7:  A9 00              LDA  #$0         SET PRINT FORMAT INDEX TO 0
F8A9:  AA        GETFMT   TAX
F8AA:  BD A6 F9           LDA  FMT2,X      INDEX INTO PRINT FORMAT TABLE
F8AD:  85 2E              STA  FORMAT      SAVE FOR ADR FIELD FORMATTING
F8AF:  29 03              AND  #$03        MASK FOR 2-BIT LENGTH
                 *         (P=1 BYTE, 1=2 BYTE, 2=3 BYTE)
F8B1:  85 2F              STA  LENGTH
F8B3:  98                 TYA              OPCODE
F8B4:  29 8F              AND  #$8F        MASK FOR 1XXX1010 TEST
F8B6:  AA                 TAX               SAVE IT
F8B7:  98                 TYA              OPCODE TO A AGAIN
F8B8:  A0 03              LDY  #$03
F8BA:  E0 8A              CPX  #$8A
F8BC:  F0 0B              BEQ  MNNDX3
F8BE:  4A        MNNDX1   LSR  A
F8BF:  90 08              BCC  MNNDX3      FORM INDEX INTO MNEMONIC TABLE
F8C1:  4A                 LSR  A
```

```
F8C2: 4A          MNNDX2   LSR   A          1) 1XXX1010=>00101XXX
F8C3: 09 20                ORA   #$20       2) XXXYYY01=>00111XXX
F8C5: 88                   DEY                3) XXXYYY10=>00110XXX
F8C6: D0 FA                BNE   MNNDX2     4) XXXYY100=>00100XXX
F8C8: C8                   INY                5) XXXXX000=>000XXXXX
F8C9: 88          MNNDX3   DEY
F8CA: D0 F2                BNE   MNNDX1
F8CC: 60                   RTS
F8CD: FF FF FF             DFB   $FF,$FF,$FF
F8D0: 20 82 F8    INSTDSP  JSR   INSDS1     GEN FMT, LEN BYTES
F8D3: 48                   PHA              SAVE MNEMONIC TABLE INDEX
F8D4: B1 3A       PRNTOP   LDA   (PCL),Y
F8D6: 20 DA FD             JSR   PRBYTE
F8D9: A2 01                LDX   #$01       PRINT 2 BLANKS
F8DB: 20 4A F9    PRNTBL   JSR   PRBL2
F8DE: C4 2F                CPY   LENGTH     PRINT INST (1-3 BYTES)
F8E0: C8                   INY              IN A 12 CHR FIELD
F8E1: 90 F1                BCC   PRNTOP
F8E3: A2 03                LDX   #$03       CHAR COUNT FOR MNEMONIC PRINT
F8E5: C0 04                CPY   #$04
F8E7: 90 F2                BCC   PRNTBL
F8E9: 68                   PLA              RECOVER MNEMONIC INDEX
F8EA: A8                   TAY
F8EB: B9 C0 F9             LDA   MNEML,Y
F8EE: 85 2C                STA   LMNEM      FETCH 3-CHAR MNEMONIC
F8F0: B9 00 FA             LDA   MNEMR,Y      (PACKED IN 2-BYTES)
F8F3: 85 2D                STA   RMNEM
F8F5: A9 00       PRMN1    LDA   #$00
F8F7: A0 05                LDY   #$05
F8F9: 06 2D       PRMN2    ASL   RMNEM      SHIFT 5 BITS OF
F8FB: 26 2C                ROL   LMNEM        CHARACTER INTO A
F8FD: 2A                   ROL   A              (CLEARS CARRY)
F8FE: 88                   DEY
F8FF: D0 F8                BNE   PRMN2
F901: 69 BF                ADC   #$BF       ADD "?" OFFSET
F903: 20 ED FD             JSR   COUT       OUTPUT A CHAR OF MNEM
F906: CA                   DEX
F907: D0 EC                BNE   PRMN1
F909: 20 48 F9             JSR   PRBLNK     OUTPUT 3 BLANKS
F90C: A4 2F                LDY   LENGTH
F90E: A2 06                LDX   #$06       CNT FOR 6 FORMAT BITS
F910: E0 03       PRADR1   CPX   #$03
F912: F0 1C                BEQ   PRADR5     IF X=3 THEN ADDR.
F914: 06 2E       PRADR2   ASL   FORMAT
F916: 90 0E                BCC   PRADR3
F918: BD B3 F9             LDA   CHAR1-1,X
F91B: 20 ED FD             JSR   COUT
F91E: BD B9 F9             LDA   CHAR2-1,X
F921: F0 03                BEQ   PRADR3
F923: 20 ED FD             JSR   COUT
F926: CA          PRADR3   DEX
F927: D0 E7                BNE   PRADR1
F929: 60                   RTS
F92A: 88          PRADR4   DEY
F92B: 30 E7                BMI   PRADR2
F92D: 20 DA FD             JSR   PRBYTE
F930: A5 2E       PRADR5   LDA   FORMAT
F932: C9 E8                CMP   #$E8       HANDLE REL ADR MODE
F934: B1 3A                LDA   (PCL),Y    SPECIAL (PRINT TARGET,
F936: 90 F2                BCC   PRADR4       NOT OFFSET)
F938: 20 56 F9    RELADR   JSR   PCADJ3
F93B: AA                   TAX              PCL,PCH+OFFSET+1 TO A,Y
F93C: E8                   INX
F93D: D0 01                BNE   PRNTYX     +1 TO Y,X
F93F: C8                   INY
F940: 98          PRNTYX   TYA
F941: 20 DA FD    PRNTAX   JSR   PRBYTE     OUTPUT TARGET ADR
F944: 8A          PRNTX    TXA                OF BRANCH AND RETURN
F945: 4C DA FD             JMP   PRBYTE
F948: A2 03       PRBLNK   LDX   #$03       BLANK COUNT
F94A: A9 A0       PRBL2    LDA   #$A0       LOAD A SPACE
F94C: 20 ED FD    PRBL3    JSR   COUT       OUTPUT A BLANK
F94F: CA                   DEX
```

```
F950:  D0 F8               BNE  PRBL2        LOOP UNTIL COUNT=0
F952:  60                  RTS
F953:  38       PCADJ      SEC               0=1-BYTE, 1=2-BYTE,
F954:  A5 2F    PCADJ2     LDA  LENGTH         2=3-BYTE
F956:  A4 3B    PCADJ3     LDY  PCH
F958:  AA                  TAX               TEST DISPLACEMENT SIGN
F959:  10 01               BPL  PCADJ4         (FOR REL BRANCH)
F95B:  88                  DEY               EXTEND NEG BY DECR PCH
F95C:  65 3A    PCADJ4     ADC  PCL
F95E:  90 01               BCC  RTS2         PCL+LENGTH(OR DISPL)+1 TO A
F960:  C8                  INY                 CARRY INTO Y (PCH)
F961:  60       RTS2       RTS
                *          FMT1 BYTES:          XXXXXXY0 INSTRS
                *          IF Y=0               THEN LEFT HALF BYTE
                *          IF Y=1               THEN RIGHT HALF BYTE
                *                                    (X=INDEX)
F962:  04 20 54
F965:  30 0D    FMT1       DFB  $04,$20,$54,$
F967:  80 04 90
F96A:  03 22               DFB  $80,$04,$90,$
F96C:  54 33 0D
F96F:  80 04               DFB  $54,$33,$0D,$
F971:  90 04 20
F974:  54 33               DFB  $90,$04,$20,$
F976:  0D 80 04
F979:  90 04               DFB  $0D,$80,$04,$
F97B:  20 54 3B
F97E:  0D 80               DFB  $20,$54,$3B,$
F980:  04 90 00
F983:  22 44               DFB  $04,$90,$00,$
F985:  33 0D C8
F988:  44 00               DFB  $33,$0D,$C8,$
F98A:  11 22 44
F98D:  33 0D               DFB  $11,$22,$44,$
F98F:  C8 44 A9
F992:  01 22               DFB  $C8,$44,$A9,$
F994:  44 33 0D
F997:  80 04               DFB  $44,$33,$0D,$
F999:  90 01 22
F99C:  44 33               DFB  $90,$01,$22,$
F99E:  0D 80 04
F9A1:  90                  DFB  $0D,$80,$04,$
F9A2:  26 31 87
F9A5:  9A                  DFB  $26,$31,$87,$ZZXXXY01 INSTR'S
F9A6:  00       FMT2       DFB  $00             ERR
F9A7:  21                  DFB  $21             IMM
F9A8:  81                  DFB  $81             Z-PAGE
F9A9:  82                  DFB  $82             ABS
F9AA:  00                  DFB  $00             IMPLIED
F9AB:  00                  DFB  $00             ACCUMULATOR
F9AC:  59                  DFB  $59             (ZPAG,X)
F9AD:  4D                  DFB  $4D             (ZPAG),Y
F9AE:  91                  DFB  $91             ZPAG,X
F9AF:  92                  DFB  $92             ABS,X
F9B0:  86                  DFB  $86             ABS,Y
F9B1:  4A                  DFB  $4A             (ABS)
F9B2:  85                  DFB  $85             ZPAG,Y
F9B3:  9D                  DFB  $9D             RELATIVE
F9B4:  AC A9 AC
F9B7:  A3 A8 A4 CHAR1      ASC  ",),#($"
F9BA:  D9 00 D8
F9BD:  A4 A4 00 CHAR2      DFB  $D9,$00,$D8,$
                *CHAR2:    "Y",0,"X$$",0
                *          MNEML          IS OF FORM:
                *          (A)  XXXXX000
                *          (B)  XXXYY100
                *          (C)  1XXX1010
                *          (D)  XXXYYY10
                *          (E)  XXXYYY01
                *               (X=INDEX)
F9C0:  1C 8A 1C
F9C3:  23 5D 8B MNEML      DFB  $1C,$8A,$1C,$
F9C6:  1B A1 9D
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F9C9:  8A 1D 23 344           DFB  $1B,$A1,$9D,$
F9CC:  9D 8B 1D
F9CF:  A1 00 29 345           DFB  $9D,$8B,$1D,$
F9D2:  19 AE 69
F9D5:  A8 19 23 346           DFB  $19,$AE,$69,$
F9D8:  24 53 1B
F9DB:  23 24 53 347           DFB  $24,$53,$1B,$
F9DE:  19 A1    348           DFB  $19,$A1        (A) FORMAT ABOVE
F9E0:  00 1A 5B
F9E3:  5B A5 69 349           DFB  $00,$1A,$5B,$
F9E6:  24 24    350           DFB  $24,$24        (B) FORMAT
F9E8:  AE AE A8
F9EB:  AD 29 00 351           DFB  $AE,$AE,$A8,$
F9EE:  7C 00    352           DFB  $7C,$00        (C) FORMAT
F9F0:  15 9C 6D
F9F3:  9C A5 69 353           DFB  $15,$9C,$6D,$
F9F6:  29 53    354           DFB  $29,$53        (D) FORMAT
F9F8:  84 13 34
F9FB:  11 A5 69 355           DFB  $84,$13,$34,$
F9FE:  23 A0    356           DFB  $23,$A0        (E) FORMAT
FA00:  D8 62 5A
FA03:  48 26 62 357  MNEMR    DFB  $D8,$62,$5A,$
FA06:  94 88 54
FA09:  44 C8 54 358           DFB  $94,$88,$54,$
FA0C:  68 44 E8
FA0F:  94 00 B4 359           DFB  $68,$44,$E8,$
FA12:  08 84 74
FA15:  B4 28 6E 360           DFB  $08,$84,$74,$
FA18:  74 F4 CC
FA1B:  4A 72 F2 361           DFB  $74,$F4,$CC,$
FA1E:  A4 8A    362           DFB  $A4,$8A        (A) FORMAT
FA20:  00 AA A2
FA23:  A2 74 74 363           DFB  $00,$AA,$A2,$
FA26:  74 72    364           DFB  $74,$72        (B) FORMAT
FA28:  44 68 B2
FA2B:  32 B2 00 365           DFB  $44,$68,$B2,$
FA2E:  22 00    366           DFB  $22,$00        (C) FORMAT
FA30:  1A 1A 26
FA33:  26 72 72 367           DFB  $1A,$1A,$26,$
FA36:  88 C8    368           DFB  $88,$C8        (D) FORMAT
FA38:  C4 CA 26
FA3B:  48 44 44 369           DFB  $C4,$CA,$26,$
FA3E:  A2 C8    370           DFB  $A2,$C8        (E) FORMAT
FA40:  FF FF FF 371           DFB  $FF,$FF,$FF
FA43:  20 D0 F8 372  STEP     JSR  INSTDSP        DISASSEMBLE ONE INST
FA46:  68       373           PLA                   AT (PCL,H)
FA47:  85 2C    374           STA  RTNL           ADJUST TO USER
FA49:  68       375           PLA                   STACK. SAVE
FA4A:  85 2D    376           STA  RTNH             RTN ADR.
FA4C:  A2 08    377           LDX  #$08
FA4E:  BD 10 FB 378  XQINIT   LDA  INITBL-1,X     INIT XEQ AREA
FA51:  95 3C    379           STA  XQT,X
FA53:  CA       380           DEX
FA54:  D0 F8    381           BNE  XQINIT
FA56:  A1 3A    382           LDA  (PCL,X)        USER OPCODE BYTE
FA58:  F0 42    383           BEQ  XBRK           SPECIAL IF BREAK
FA5A:  A4 2F    384           LDY  LENGTH         LEN FROM DISASSEMBLY
FA5C:  C9 20    385           CMP  #$20
FA5E:  F0 59    386           BEQ  XJSR           HANDLE JSR, RTS, JMP,
FA60:  C9 60    387           CMP  #$60             JMP ( ), RTI SPECIAL
FA62:  F0 45    388           BEQ  XRTS
FA64:  C9 4C    389           CMP  #$4C
FA66:  F0 5C    390           BEQ  XJMP
FA68:  C9 6C    391           CMP  #$6C
FA6A:  F0 59    392           BEQ  XJMPAT
FA6C:  C9 40    393           CMP  #$40
FA6E:  F0 35    394           BEQ  XRTI
FA70:  29 1F    395           AND  #$1F
FA72:  49 14    396           EOR  #$14
FA74:  C9 04    397           CMP  #$04           COPY USER INST TO XEQ AREA
FA76:  F0 02    398           BEQ  XQ2              WITH TRAILING NOPS
FA78:  B1 3A    399  XQ1      LDA  (PCL),Y        CHANGE REL BRANCH
FA7A:  99 3C 00 400  XQ2      STA  XQTNZ,Y          DISP TO 4 FOR
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FA7D:  88                        DEY                   JMP TO BRANCH OR
FA7E:  10 F8                     BPL   XQ1             NBRANCH FROM XEQ.
FA80:  20 3F FF                  JSR   RESTORE       RESTORE USER REG CONTENTS.
FA83:  4C 3C 00                  JMP   XQTNZ         XEQ USER OP FROM RAM
FA86:  85 45          IRQ        STA   ACC             (RETURN TO NBRANCH)
FA88:  68                        PLA
FA89:  48                        PHA                 **IRQ HANDLER
FA8A:  0A                        ASL   A
FA8B:  0A                        ASL   A
FA8C:  0A                        ASL   A
FA8D:  30 03                     BMI   BREAK         TEST FOR BREAK
FA8F:  6C FE 03                  JMP   (IRQLOC)      USER ROUTINE VECTOR IN RAM
FA92:  28             BREAK      PLP
FA93:  20 4C FF                  JSR   SAV1          SAVE REG'S ON BREAK
FA96:  68                        PLA                   INCLUDING PC
FA97:  85 3A                     STA   PCL
FA99:  68                        PLA
FA9A:  85 3B                     STA   PCH
FA9C:  20 82 F8       XBRK       JSR   INSDS1        PRINT USER PC.
FA9F:  20 DA FA                  JSR   RGDSP1          AND REG'S
FAA2:  4C 65 FF                  JMP   MON           GO TO MONITOR
FAA5:  18             XRTI       CLC
FAA6:  68                        PLA                 SIMULATE RTI BY EXPECTING
FAA7:  85 48                     STA   STATUS          STATUS FROM STACK, THEN RTS
FAA9:  68             XRTS       PLA                 RTS SIMULATION
FAAA:  85 3A                     STA   PCL             EXTRACT PC FROM STACK
FAAC:  68                        PLA                   AND UPDATE PC BY 1 (LEN=0)
FAAD:  85 3B          PCINC2     STA   PCH
FAAF:  A5 2F          PCINC3     LDA   LENGTH        UPDATE PC BY LEN
FAB1:  20 56 F9                  JSR   PCADJ3
FAB4:  84 3B                     STY   PCH
FAB6:  18                        CLC
FAB7:  90 14                     BCC   NEWPCL
FAB9:  18             XJSR       CLC
FABA:  20 54 F9                  JSR   PCADJ2        UPDATE PC AND PUSH
FABD:  AA                        TAX                   ONTO STACK FOR
FABE:  98                        TYA                   JSR SIMULATE
FABF:  48                        PHA
FAC0:  8A                        TXA
FAC1:  48                        PHA
FAC2:  A0 02                     LDY   #$02
FAC4:  18             XJMP       CLC
FAC5:  B1 3A          XJMPAT     LDA   (PCL),Y
FAC7:  AA                        TAX                 LOAD PC FOR JMP,
FAC8:  88                        DEY                   (JMP) SIMULATE.
FAC9:  B1 3A                     LDA   (PCL),Y
FACB:  86 3B                     STX   PCH
FACD:  85 3A          NEWPCL     STA   PCL
FACF:  B0 F3                     BCS   XJMP
FAD1:  A5 2D          RTNJMP     LDA   RTNH
FAD3:  48                        PHA
FAD4:  A5 2C                     LDA   RTNL
FAD6:  48                        PHA
FAD7:  20 8E FD       REGDSP     JSR   CROUT         DISPLAY USER REG
FADA:  A9 45          RGDSP1     LDA   #ACC            CONTENTS WITH
FADC:  85 40                     STA   A3L             LABELS
FADE:  A9 00                     LDA   #ACC/256
FAE0:  85 41                     STA   A3H
FAE2:  A2 FB                     LDX   #$FB
FAE4:  A9 A0          RDSP1      LDA   #$A0
FAE6:  20 ED FD                  JSR   COUT
FAE9:  BD 1E FA                  LDA   RTBL-$FB,X
FAEC:  20 ED FD                  JSR   COUT
FAEF:  A9 BD                     LDA   #$BD
FAF1:  20 ED FD                  JSR   COUT
FAF4:  B5 4A                     LDA   ACC+5,X
FAF6:  20 DA FD                  JSR   PRBYTE
FAF9:  E8                        INX
FAFA:  30 E8                     BMI   RDSP1
FAFC:  60                        RTS
FAFD:  18             BRANCH     CLC                 BRANCH TAKEN,
FAFE:  A0 01                     LDY   #$01            ADD LEN+2 TO PC
FB00:  B1 3A                     LDA   (PCL),Y
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```
FB02:  20 56 F9          JSR  PCADJ3
FB05:  85 3A             STA  PCL
FB07:  98                TYA
FB08:  38                SEC
FB09:  B0 A2             BCS  PCINC2
FB0B:  20 4A FF  NBRNCH  JSR  SAVE       NORMAL RETURN AFTER
FB0E:  38                SEC               XEQ USER OF
FB0F:  B0 9E             BCS  PCINC3     GO UPDATE PC
FB11:  EA        INITBL  NOP
FB12:  EA                NOP             DUMMY FILL FOR
FB13:  4C 0B FB          JMP  NBRNCH       XEQ AREA
FB16:  4C FD FA          JMP  BRANCH
FB19:  C1        RTBL    DFB  $C1
FB1A:  D8                DFB  $D8
FB1B:  D9                DFB  $D9
FB1C:  D0                DFB  $D0
FB1D:  D3                DFB  $D3
FB1E:  AD 70 C0  PREAD   LDA  PTRIG      TRIGGER PADDLES
FB21:  A0 00             LDY  #$00       INIT COUNT
FB23:  EA                NOP             COMPENSATE FOR 1ST COUNT
FB24:  EA                NOP
FB25:  BD 64 C0  PREAD2  LDA  PADDL0,X   COUNT Y-REG EVERY
FB28:  10 04             BPL  RTS2D        12 USEC
FB2A:  C8                INY
FB2B:  D0 F8             BNE  PREAD2       EXIT AT 255 MAX
FB2D:  88                DEY
FB2E:  60        RTS2D   RTS
FB2F:  A9 00     INIT    LDA  #$00       CLR STATUS FOR DEBUG
FB31:  85 48             STA  STATUS       SOFTWARE
FB33:  AD 56 C0          LDA  LORES
FB36:  AD 54 C0          LDA  LOWSCR     INIT VIDEO MODE
FB39:  AD 51 C0  SETTXT  LDA  TXTSET     SET FOR TEXT MODE
FB3C:  A9 00             LDA  #$00         FULL SCREEN WINDOW
FB3E:  F0 0B             BEQ  SETWND
FB40:  AD 50 C0  SETGR   LDA  TXTCLR     SET FOR GRAPHICS MODE
FB43:  AD 53 C0          LDA  MIXSET       LOWER 4 LINES AS
FB46:  20 36 F8          JSR  CLRTOP       TEXT WINDOW
FB49:  A9 14             LDA  #$14
FB4B:  85 22     SETWND  STA  WNDTOP     SET FOR 40 COL WINDOW
FB4D:  A9 00             LDA  #$00         TOP IN A-REG,
FB4F:  85 20             STA  WNDLFT       BTTM AT LINE 24
FB51:  A9 28             LDA  #$28
FB53:  85 21             STA  WNDWDTH
FB55:  A9 18             LDA  #$18
FB57:  85 23             STA  WNDBTM       VTAB TO ROW 23
FB59:  A9 17             LDA  #$17
FB5B:  85 25     TABV    STA  CV         VTABS TO ROW IN A-REG
FB5D:  4C 22 FC          JMP  VTAB
FB60:  20 A4 FB  MULPM   JSR  MD1        ABS VAL OF AC AUX
FB63:  A0 10     MUL     LDY  #$10       INDEX FOR 16 BITS
FB65:  A5 50     MUL2    LDA  ACL        ACX * AUX + XTND
FB67:  4A                LSR  A            TO AC, XTND
FB68:  90 0C             BCC  MUL4       IF NO CARRY,
FB6A:  18                CLC               NO PARTIAL PROD.
FB6B:  A2 FE             LDX  #$FE
FB6D:  B5 54     MUL3    LDA  XTNDL+2,X  ADD MPLCND (AUX)
FB6F:  75 56             ADC  AUXL+2,X    TO PARTIAL PROD
FB71:  95 54             STA  XTNDL+2,X      (XTND).
FB73:  E8                INX
FB74:  D0 F7             BNE  MUL3
FB76:  A2 03     MUL4    LDX  #$03
FB78:  76        MUL5    DFB  #$76
FB79:  50                DFB  #$50
FB7A:  CA                DEX
FB7B:  10 FB             BPL  MUL5
FB7D:  88                DEY
FB7E:  D0 E5             BNE  MUL2
FB80:  60                RTS
FB81:  20 A4 FB  DIVPM   JSR  MD1        ABS VAL OF AC, AUX.
FB84:  A0 10     DIV     LDY  #$10       INDEX FOR 16 BITS
FB86:  06 50     DIV2    ASL  ACL
FB88:  26 51             ROL  ACH
FB8A:  26 52             ROL  XTNDL      XTND/AUX
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FB8C:  26 53              ROL   XTNDH        TO AC.
FB8E:  38                 SEC
FB8F:  A5 52              LDA   XTNDL
FB91:  E5 54              SBC   AUXL        MOD TO XTND.
FB93:  AA                 TAX
FB94:  A5 53              LDA   XTNDH
FB96:  E5 55              SBC   AUXH
FB98:  90 06              BCC   DIV3
FB9A:  86 52              STX   XTNDL
FB9C:  85 53              STA   XTNDH
FB9E:  E6 50              INC   ACL
FBA0:  88        DIV3     DEY
FBA1:  D0 E3              BNE   DIV2
FBA3:  60                 RTS
FBA4:  A0 00     MD1      LDY   #$00        ABS VAL OF AC, AUX
FBA6:  84 2F              STY   SIGN          WITH RESULT SIGN
FBA8:  A2 54              LDX   #AUXL         IN LSB OF SIGN.
FBAA:  20 AF FB           JSR   MD2
FBAD:  A2 50              LDX   #ACL
FBAF:  B5 01     MD2      LDA   LOC1,X      X SPECIFIES AC OR AUX
FBB1:  10 0D              BPL   MDRTS
FBB3:  38                 SEC
FBB4:  98        MD3      TYA
FBB5:  F5 00              SBC   LOC0,X      COMPL SPECIFIED REG
FBB7:  95 00              STA   LOC0,X        IF NEG.
FBB9:  98                 TYA
FBBA:  F5 01              SBC   LOC1,X
FBBC:  95 01              STA   LOC1,X
FBBE:  E6 2F              INC   SIGN
FBC0:  60        MDRTS    RTS
FBC1:  48        BASCALC  PHA               CALC BASE ADR IN BASL,H
FBC2:  4A                 LSR   A             FOR GIVEN LINE NO.
FBC3:  29 03              AND   #$03          0<=LINE NO.<=$17
FBC5:  09 04              ORA   #$04        ARG=000ABCDE, GENERATE
FBC7:  85 29              STA   BASH          BASH=000001CD
FBC9:  68                 PLA                 AND
FBCA:  29 18              AND   #$18          BASL=EABAB000
FBCC:  90 02              BCC   BSCLC2
FBCE:  69 7F              ADC   #$7F
FBD0:  85 28     BSCLC2   STA   BASL
FBD2:  0A                 ASL   A
FBD3:  0A                 ASL   A
FBD4:  05 28              ORA   BASL
FBD6:  85 28              STA   BASL
FBD8:  60                 RTS
FBD9:  C9 87     BELL1    CMP   #$87        BELL CHAR? (CNTRL-G)
FBDB:  D0 12              BNE   RTS2B         NO,RETURN
FBDD:  A9 40              LDA   #$40        DELAY .01 SECONDS
FBDF:  20 A8 FC           JSR   WAIT
FBE2:  A0 C0              LDY   #$C0
FBE4:  A9 0C     BELL2    LDA   #$0C        TOGGLE SPEAKER AT
FBE6:  20 A8 FC           JSR   WAIT          1 KHZ FOR .1 SEC.
FBE9:  AD 30 C0           LDA   SPKR
FBEC:  88                 DEY
FBED:  D0 F5              BNE   BELL2
FBEF:  60        RTS2B    RTS
FBF0:  A4 24     STOADV   LDY   CH          CURSER H INDEX TO Y-REG
FBF2:  91 28              STA   (BASL),Y    STOR CHAR IN LINE
FBF4:  E6 24     ADVANCE  INC   CH          INCREMENT CURSER H INDEX
FBF6:  A5 24              LDA   CH            (MOVE RIGHT)
FBF8:  C5 21              CMP   WNDWDTH     BEYOND WINDOW WIDTH?
FBFA:  B0 66              BCS   CR            YES CR TO NEXT LINE
FBFC:  60        RTS3     RTS                 NO,RETURN
FBFD:  C9 A0     VIDOUT   CMP   #$A0        CONTROL CHAR?
FBFF:  B0 EF              BCS   STOADV        NO,OUTPUT IT.
FC01:  A8                 TAY               INVERSE VIDEO?
FC02:  10 EC              BPL   STOADV        YES, OUTPUT IT.
FC04:  C9 8D              CMP   #$8D        CR?
FC06:  F0 5A              BEQ   CR            YES.
FC08:  C9 8A              CMP   #$8A        LINE FEED?
FC0A:  F0 5A              BEQ   LF            IF SO, DO IT.
FC0C:  C9 88              CMP   #$88        BACK SPACE? (CNTRL-H)
FC0E:  D0 C9              BNE   BELL1         NO, CHECK FOR BELL.
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FC10:  C6 24          BS       DEC  CH          DECREMENT CURSER H INDEX
FC12:  10 E8                   BPL  RTS3        IF POS, OK. ELSE MOVE UP
FC14:  A5 21                   LDA  WNDWDTH     SET CH TO WNDWDTH-1
FC16:  85 24                   STA  CH
FC18:  C6 24                   DEC  CH          (RIGHTMOST SCREEN POS)
FC1A:  A5 22          UP       LDA  WNDTOP      CURSER V INDEX
FC1C:  C5 25                   CMP  CV
FC1E:  B0 0B                   BCS  RTS4        IF TOP LINE THEN RETURN
FC20:  C6 25                   DEC  CV          DECR CURSER V-INDEX
FC22:  A5 25          VTAB     LDA  CV          GET CURSER V-INDEX
FC24:  20 C1 FB       VTABZ    JSR  BASCALC     GENERATE BASE ADDR
FC27:  65 20                   ADC  WNDLFT      ADD WINDOW LEFT INDEX
FC29:  85 28                   STA  BASL        TO BASL
FC2B:  60             RTS4     RTS
FC2C:  49 C0          ESC1     EOR  #$C0        ESC?
FC2E:  F0 28                   BEQ  HOME          IF SO, DO HOME AND CLEAR
FC30:  69 FD                   ADC  #$FD        ESC-A OR B CHECK
FC32:  90 C0                   BCC  ADVANCE       A, ADVANCE
FC34:  F0 DA                   BEQ  BS            B, BACKSPACE
FC36:  69 FD                   ADC  #$FD        ESC-C OR D CHECK
FC38:  90 2C                   BCC  LF            C,DOWN
FC3A:  F0 DE                   BEQ  UP            D, GO UP
FC3C:  69 FD                   ADC  #$FD        ESC-E OR F CHECK
FC3E:  90 5C                   BCC  CLREOL        E, CLEAR TO END OF LINE
FC40:  D0 E9                   BNE  RTS4          NOT F, RETURN
FC42:  A4 24          CLREOP   LDY  CH          CURSOR H TO Y INDEX
FC44:  A5 25                   LDA  CV          CURSOR V TO A-REGISTER
FC46:  48             CLEOP1   PHA              SAVE CURRENT LINE ON STK
FC47:  20 24 FC                JSR  VTABZ       CALC BASE ADDRESS
FC4A:  20 9E FC                JSR  CLEOLZ      CLEAR TO EOL, SET CARRY
FC4D:  A0 00                   LDY  #$00        CLEAR FROM H INDEX=0 FOR REST
FC4F:  68                      PLA              INCREMENT CURRENT LINE
FC50:  69 00                   ADC  #$00        (CARRY IS SET)
FC52:  C5 23                   CMP  WNDBTM      DONE TO BOTTOM OF WINDOW?
FC54:  90 F0                   BCC  CLEOP1        NO, KEEP CLEARING LINES
FC56:  B0 CA                   BCS  VTAB          YES, TAB TO CURRENT LINE
FC58:  A5 22          HOME     LDA  WNDTOP      INIT CURSOR V
FC5A:  85 25                   STA  CV            AND H-INDICES
FC5C:  A0 00                   LDY  #$00
FC5E:  84 24                   STY  CH          THEN CLEAR TO END OF PAGE
FC60:  F0 E4                   BEQ  CLEOP1
FC62:  A9 00          CR       LDA  #$00        CURSOR TO LEFT OF INDEX
FC64:  85 24                   STA  CH          (RET CURSOR H=0)
FC66:  E6 25          LF       INC  CV          INCR CURSOR V(DOWN 1 LINE)
FC68:  A5 25                   LDA  CV
FC6A:  C5 23                   CMP  WNDBTM      OFF SCREEN?
FC6C:  90 B6                   BCC  VTABZ         NO, SET BASE ADDR
FC6E:  C6 25                   DEC  CV          DECR CURSOR V(BACK TO BOTTOM)
FC70:  A5 22          SCROLL   LDA  WNDTOP      START AT TOP OF SCRL WNDW
FC72:  48                      PHA
FC73:  20 24 FC                JSR  VTABZ       GENERATE BASE ADDRESS
FC76:  A5 28          SCRL1    LDA  BASL        COPY BASL,H
FC78:  85 2A                   STA  BAS2L         TO BAS2L,H
FC7A:  A5 29                   LDA  BASH
FC7C:  85 2B                   STA  BAS2H
FC7E:  A4 21                   LDY  WNDWDTH     INIT Y TO RIGHTMOST INDEX
FC80:  88                      DEY                OF SCROLLING WINDOW
FC81:  68                      PLA
FC82:  69 01                   ADC  #$01        INCR LINE NUMBER
FC84:  C5 23                   CMP  WNDBTM      DONE?
FC86:  B0 0D                   BCS  SCRL3         YES, FINISH
FC88:  48                      PHA
FC89:  20 24 FC                JSR  VTABZ       FORM BASL,H (BASE ADDR)
FC8C:  B1 28          SCRL2    LDA  (BASL),Y    MOVE A CHR UP ON LINE
FC8E:  91 2A                   STA  (BAS2L),Y
FC90:  88                      DEY              NEXT CHAR OF LINE
FC91:  10 F9                   BPL  SCRL2
FC93:  30 E1                   BMI  SCRL1       NEXT LINE
FC95:  A0 00          SCRL3    LDY  #$00        CLEAR BOTTOM LINE
FC97:  20 9E FC                JSR  CLEOLZ      GET BASE ADDR FOR BOTTOM LINE
FC9A:  B0 86                   BCS  VTAB        CARRY IS SET
FC9C:  A4 24          CLREOL   LDY  CH          CURSOR H INDEX
FC9E:  A9 A0          CLEOLZ   LDA  #$A0
```

```
FCA0:  91 28     CLEOL2   STA  (BASL),Y    STORE BLANKS FROM 'HERE'
FCA2:  C8                 INY                TO END OF LINES (WNDWDTH)
FCA3:  C4 21              CPY  WNDWDTH
FCA5:  90 F9              BCC  CLEOL2
FCA7:  60                 RTS
FCA8:  38        WAIT     SEC
FCA9:  48        WAIT2    PHA
FCAA:  E9 01     WAIT3    SBC  #$01
FCAC:  D0 FC              BNE  WAIT3       1.0204 USEC
FCAE:  68                 PLA              (13+2712*A+512*A*A)
FCAF:  E9 01              SBC  #$01
FCB1:  D0 F6              BNE  WAIT2
FCB3:  60                 RTS
FCB4:  E6 42     NXTA4    INC  A4L         INCR 2-BYTE A4
FCB6:  D0 02              BNE  NXTA1         AND A1
FCB8:  E6 43              INC  A4H
FCBA:  A5 3C     NXTA1    LDA  A1L         INCR 2-BYTE A1.
FCBC:  C5 3E              CMP  A2L
FCBE:  A5 3D              LDA  A1H           AND COMPARE TO A2
FCC0:  E5 3F              SBC  A2H
FCC2:  E6 3C              INC  A1L           (CARRY SET IF >=)
FCC4:  D0 02              BNE  RTS4B
FCC6:  E6 3D              INC  A1H
FCC8:  60        RTS4B    RTS
FCC9:  A0 4B     HEADR    LDY  #$4B        WRITE A*256 'LONG 1'
FCCB:  20 DB FC           JSR  ZERDLY        HALF CYCLES
FCCE:  D0 F9              BNE  HEADR         (650 USEC EACH )
FCD0:  69 FE              ADC  #$FE
FCD2:  B0 F5              BCS  HEADR       THEN A 'SHORT 0'
FCD4:  A0 21              LDY  #$21          (400 USEC)
FCD6:  20 DB FC  WRBIT    JSR  ZERDLY      WRITE TWO HALF CYCLES
FCD9:  C8                 INY                OF 250 USEC ('0')
FCDA:  C8                 INY                OR 500 USEC ('1')
FCDB:  88        ZERDLY   DEY
FCDC:  D0 FD              BNE  ZERDLY
FCDE:  90 05              BCC  WRTAPE      Y IS COUNT FOR
FCE0:  A0 32              LDY  #$32          TIMING LOOP
FCE2:  88        ONEDLY   DEY
FCE3:  D0 FD              BNE  ONEDLY
FCE5:  AC 20 C0  WRTAPE   LDY  TAPEOUT
FCE8:  A0 2C              LDY  #$2C
FCEA:  CA                 DEX
FCEB:  60                 RTS
FCEC:  A2 08     RDBYTE   LDX  #$08        8 BITS TO READ
FCEE:  48        RDBYT2   PHA              READ TWO TRANSITIONS
FCEF:  20 FA FC           JSR  RD2BIT        (FIND EDGE)
FCF2:  68                 PLA
FCF3:  2A                 ROL  A           NEXT BIT
FCF4:  A0 3A              LDY  #$3A        COUNT FOR SAMPLES
FCF6:  CA                 DEX
FCF7:  D0 F5              BNE  RDBYT2
FCF9:  60                 RTS
FCFA:  20 FD FC  RD2BIT   JSR  RDBIT
FCFD:  88        RDBIT    DEY              DECR Y UNTIL
FCFE:  AD 60 C0           LDA  TAPEIN        TAPE TRANSITION
FD01:  45 2F              EOR  LASTIN
FD03:  10 F8              BPL  RDBIT
FD05:  45 2F              EOR  LASTIN
FD07:  85 2F              STA  LASTIN
FD09:  C0 80              CPY  #$80        SET CARRY ON Y-REG.
FD0B:  60                 RTS
FD0C:  A4 24     RDKEY    LDY  CH
FD0E:  B1 28              LDA  (BASL),Y    SET SCREEN TO FLASH
FD10:  48                 PHA
FD11:  29 3F              AND  #$3F
FD13:  09 40              ORA  #$40
FD15:  91 28              STA  (BASL),Y
FD17:  68                 PLA
FD18:  6C 38 00           JMP  (KSWL)      GO TO USER KEY-IN
FD1B:  E6 4E     KEYIN    INC  RNDL
FD1D:  D0 02              BNE  KEYIN2      INCR RND NUMBER
FD1F:  E6 4F              INC  RNDH
FD21:  2C 00 C0  KEYIN2   BIT  KBD         KEY DOWN?
```

```
FD24:  10 F3              BPL   KEYIN       LOOP
FD26:  91 28              STA   (BASL),Y    REPLACE FLASHING SCREEN
FD28:  AD 00 C0           LDA   KBD         GET KEYCODE
FD2B:  2C 10 C0           BIT   KBDSTRB     CLR KEY STROBE
FD2E:  60                 RTS
FD2F:  20 0C FD  ESC      JSR   RDKEY       GET KEYCODE
FD32:  20 2C FC           JSR   ESC1          HANDLE ESC FUNC.
FD35:  20 0C FD  RDCHAR   JSR   RDKEY       READ KEY
FD38:  C9 9B              CMP   #$9B        ESC?
FD3A:  F0 F3              BEQ   ESC           YES, DON'T RETURN
FD3C:  60                 RTS
FD3D:  A5 32     NOTCR    LDA   INVFLG
FD3F:  48                 PHA
FD40:  A9 FF              LDA   #$FF
FD42:  85 32              STA   INVFLG      ECHO USER LINE
FD44:  BD 00 02           LDA   IN,X          NON INVERSE
FD47:  20 ED FD           JSR   COUT
FD4A:  68                 PLA
FD4B:  85 32              STA   INVFLG
FD4D:  BD 00 02           LDA   IN,X
FD50:  C9 88              CMP   #$88        CHECK FOR EDIT KEYS
FD52:  F0 1D              BEQ   BCKSPC        BS, CTRL-X.
FD54:  C9 98              CMP   #$98
FD56:  F0 0A              BEQ   CANCEL
FD58:  E0 F8              CPX   #$F8        MARGIN?
FD5A:  90 03              BCC   NOTCR1
FD5C:  20 3A FF           JSR   BELL          YES, SOUND BELL
FD5F:  E8        NOTCR1   INX               ADVANCE INPUT INDEX
FD60:  D0 13              BNE   NXTCHAR
FD62:  A9 DC     CANCEL   LDA   #$DC        BACKSLASH AFTER CANCELLED LIN
FD64:  20 ED FD           JSR   COUT
FD67:  20 8E FD  GETLNZ   JSR   CROUT       OUTPUT CR
FD6A:  A5 33     GETLN    LDA   PROMPT
FD6C:  20 ED FD           JSR   COUT        OUTPUT PROMPT CHAR
FD6F:  A2 01              LDX   #$01        INIT INPUT INDEX
FD71:  8A        BCKSPC   TXA                 WILL BACKSPACE TO 0
FD72:  F0 F3              BEQ   GETLNZ
FD74:  CA                 DEX
FD75:  20 35 FD  NXTCHAR  JSR   RDCHAR
FD78:  C9 95              CMP   #PICK       USE SCREEN CHAR
FD7A:  D0 02              BNE   CAPTST        FOR CTRL-U
FD7C:  B1 28              LDA   (BASL),Y
FD7E:  C9 E0     CAPTST   CMP   #$E0
FD80:  90 02              BCC   ADDINP      CONVERT TO CAPS
FD82:  29 DF              AND   #$DF
FD84:  9D 00 02  ADDINP   STA   IN,X        ADD TO INPUT BUF
FD87:  C9 8D              CMP   #$8D
FD89:  D0 B2              BNE   NOTCR
FD8B:  20 9C FC           JSR   CLREOL      CLR TO EOL IF CR
FD8E:  A9 8D     CROUT    LDA   #$8D
FD90:  D0 5B              BNE   COUT
FD92:  A4 3D     PRA1     LDY   A1H         PRINT CR,A1 IN HEX
FD94:  A6 3C              LDX   A1L
FD96:  20 8E FD  PRYX2    JSR   CROUT
FD99:  20 40 F9           JSR   PRNTYX
FD9C:  A0 00              LDY   #$00
FD9E:  A9 AD              LDA   #$AD        PRINT '-'
FDA0:  4C ED FD           JMP   COUT
FDA3:  A5 3C     XAM8     LDA   A1L
FDA5:  09 07              ORA   #$07        SET TO FINISH AT
FDA7:  85 3E              STA   A2L           MOD 8=7
FDA9:  A5 3D              LDA   A1H
FDAB:  85 3F              STA   A2H
FDAD:  A5 3C     MOD8CHK  LDA   A1L
FDAF:  29 07              AND   #$07
FDB1:  D0 03              BNE   DATAOUT
FDB3:  20 92 FD  XAM      JSR   PRA1
FDB6:  A9 A0     DATAOUT  LDA   #$A0
FDB8:  20 ED FD           JSR   COUT        OUTPUT BLANK
FDBB:  B1 3C              LDA   (A1L),Y
FDBD:  20 DA FD           JSR   PRBYTE      OUTPUT BYTE IN HEX
FDC0:  20 BA FC           JSR   NXTA1
```

```
FDC3:  90 E6            BCC  MOD8CHK     CHECK IF TIME TO,
FDC5:  60       RTS4C   RTS                PRINT ADDR
FDC6:  4A       XAMPM   LSR  A           DETERMINE IF MON
FDC7:  90 EA            BCC  XAM           MODE IS XAM
FDC9:  4A               LSR  A             ADD, OR SUB
FDCA:  4A               LSR  A
FDCB:  A5 3E            LDA  A2L
FDCD:  90 02            BCC  ADD
FDCF:  49 FF            EOR  #$FF        SUB: FORM 2'S COMPLEMENT
FDD1:  65 3C    ADD     ADC  A1L
FDD3:  48               PHA
FDD4:  A9 BD            LDA  #$BD
FDD6:  20 ED FD         JSR  COUT        PRINT '=', THEN RESULT
FDD9:  68               PLA
FDDA:  48       PRBYTE  PHA              PRINT BYTE AS 2 HEX
FDDB:  4A               LSR  A             DIGITS, DESTROYS A-REG
FDDC:  4A               LSR  A
FDDD:  4A               LSR  A
FDDE:  4A               LSR  A
FDDF:  20 E5 FD         JSR  PRHEXZ
FDE2:  68               PLA
FDE3:  29 0F    PRHEX   AND  #$0F        PRINT HEX DIG IN A-REG
FDE5:  09 B0    PRHEXZ  ORA  #$B0          LSB'S
FDE7:  C9 BA            CMP  #$BA
FDE9:  90 02            BCC  COUT
FDEB:  69 06            ADC  #$06
FDED:  6C 36 00 COUT    JMP  (CSWL)      VECTOR TO USER OUTPUT ROUTINE
FDF0:  C9 A0    COUT1   CMP  #$A0
FDF2:  90 02            BCC  COUTZ       DON'T OUTPUT CTRL'S INVERSE
FDF4:  25 32            AND  INVFLG      MASK WITH INVERSE FLAG
FDF6:  84 35    COUTZ   STY  YSAV1       SAV Y-REG
FDF8:  48               PHA              SAV A-REG
FDF9:  20 FD FB         JSR  VIDOUT      OUTPUT A-REG AS ASCII
FDFC:  68               PLA              RESTORE A-REG
FDFD:  A4 35            LDY  YSAV1         AND Y-REG
FDFF:  60               RTS                THEN RETURN
FE00:  C6 34    BL1     DEC  YSAV
FE02:  F0 9F            BEQ  XAM8
FE04:  CA       BLANK   DEX              BLANK TO MON
FE05:  D0 16            BNE  SETMDZ      AFTER BLANK
FE07:  C9 BA            CMP  #$BA        DATA STORE MODE?
FE09:  D0 BB            BNE  XAMPM         NO, XAM, ADD OR SUB
FE0B:  85 31    STOR    STA  MODE        KEEP IN STORE MODE
FE0D:  A5 3E            LDA  A2L
FE0F:  91 40            STA  (A3L),Y     STORE AS LOW BYTE AS (A3)
FE11:  E6 40            INC  A3L
FE13:  D0 02            BNE  RTS5        INCR A3, RETURN
FE15:  E6 41            INC  A3H
FE17:  60       RTS5    RTS
FE18:  A4 34    SETMODE LDY  YSAV        SAVE CONVERTED ':', '+',
FE1A:  B9 FF 01         LDA  IN-1,Y        '-', '.' AS MODE.
FE1D:  85 31    SETMDZ  STA  MODE
FE1F:  60               RTS
FE20:  A2 01    LT      LDX  #$01
FE22:  B5 3E    LT2     LDA  A2L,X       COPY A2 (2 BYTES) TO
FE24:  95 42            STA  A4L,X         A4 AND A5
FE26:  95 44            STA  A5L,X
FE28:  CA               DEX
FE29:  10 F7            BPL  LT2
FE2B:  60               RTS
FE2C:  B1 3C    MOVE    LDA  (A1L),Y     MOVE (A1 TO A2) TO
FE2E:  91 42            STA  (A4L),Y       (A4)
FE30:  20 B4 FC         JSR  NXTA4
FE33:  90 F7            BCC  MOVE
FE35:  60               RTS
FE36:  B1 3C    VFY     LDA  (A1L),Y     VERIFY (A1 TO A2) WITH
FE38:  D1 42            CMP  (A4L),Y       (A4)
FE3A:  F0 1C            BEQ  VFYOK
FE3C:  20 92 FD         JSR  PRA1
FE3F:  B1 3C            LDA  (A1L),Y
FE41:  20 DA FD         JSR  PRBYTE
FE44:  A9 A0            LDA  #$A0
FE46:  20 ED FD         JSR  COUT
```

```
FE49:  A9 A0                    LDA  #$A0
FE4B:  20 ED FD                 JSR  COUT
FE4E:  B1 42                    LDA  (A4L),Y
FE50:  20 DA FD                 JSR  PRBYTE
FE53:  A9 A9                    LDA  #$A9
FE55:  20 ED FD                 JSR  COUT
FE58:  20 B4 FC    VFYOK        JSR  NXTA4
FE5B:  90 D9                    BCC  VFY
FE5D:  60                       RTS
FE5E:  20 75 FE    LIST         JSR  A1PC        MOVE A1 (2 BYTES) TO
FE61:  A9 14                    LDA  #$14          PC IF SPEC'D AND
FE63:  48          LIST2        PHA                DISSEMBLE 20 INSTRS
FE64:  20 D0 F8                 JSR  INSTDSP
FE67:  20 53 F9                 JSR  PCADJ       ADJUST PC EACH INSTR
FE6A:  85 3A                    STA  PCL
FE6C:  84 3B                    STY  PCH
FE6E:  68                       PLA
FE6F:  38                       SEC
FE70:  E9 01                    SBC  #$01        NEXT OF 20 INSTRS
FE72:  D0 EF                    BNE  LIST2
FE74:  60                       RTS
FE75:  8A          A1PC         TXA              IF USER SPEC'D ADR
FE76:  F0 07                    BEQ  A1PCRTS       COPY FROM A1 TO PC
FE78:  B5 3C       A1PCLP       LDA  A1L,X
FE7A:  95 3A                    STA  PCL,X
FE7C:  CA                       DEX
FE7D:  10 F9                    BPL  A1PCLP
FE7F:  60          A1PCRTS      RTS
FE80:  A0 3F       SETINV       LDY  #$3F        SET FOR INVERSE VID
FE82:  D0 02                    BNE  SETIFLG       VIA COUT1
FE84:  A0 FF       SETNORM      LDY  #$FF        SET FOR NORMAL VID
FE86:  84 32       SETIFLG      STY  INVFLG
FE88:  60                       RTS
FE89:  A9 00       SETKBD       LDA  #$00        SIMULATE PORT #0 INPUT
FE8B:  85 3E       INPORT       STA  A2L           SPECIFIED (KEYIN ROUTINE)
FE8D:  A2 38       INPRT        LDX  #KSWL
FE8F:  A0 1B                    LDY  #KEYIN
FE91:  D0 08                    BNE  IOPRT
FE93:  A9 00       SETVID       LDA  #$00        SIMULATE PORT #0 OUTPUT
FE95:  85 3E       OUTPORT      STA  A2L           SPECIFIED (COUT1 ROUTINE)
FE97:  A2 36       OUTPRT       LDX  #CSWL
FE99:  A0 F0                    LDY  #COUT1
FE9B:  A5 3E       IOPRT        LDA  A2L         SET RAM IN/OUT VECTORS
FE9D:  29 0F                    AND  #$0F
FE9F:  F0 06                    BEQ  IOPRT1
FEA1:  09 C0                    ORA  #IOADR/256
FEA3:  A0 00                    LDY  #$00
FEA5:  F0 02                    BEQ  IOPRT2
FEA7:  A9 FD       IOPRT1       LDA  #COUT1/256
FEA9:  94 00       IOPRT2       STY  LOC0,X
FEAB:  95 01                    STA  LOC1,X
FEAD:  60                       RTS
FEAE:  EA                       NOP
FEAF:  EA                       NOP
FEB0:  4C 00 E0    XBASIC       JMP  BASIC       TO BASIC WITH SCRATCH
FEB3:  4C 03 E0    BASCONT      JMP  BASIC2      CONTINUE BASIC
FEB6:  20 75 FE    GO           JSR  A1PC        ADR TO PC IF SPEC'D
FEB9:  20 3F FF                 JSR  RESTORE     RESTORE META REGS
FEBC:  6C 3A 00                 JMP  (PCL)       GO TO USER SUBR
FEBF:  4C D7 FA    REGZ         JMP  REGDSP      TO REG DISPLAY
FEC2:  C6 34       TRACE        DEC  YSAV
FEC4:  20 75 FE    STEPZ        JSR  A1PC        ADR TO PC IF SPEC'D
FEC7:  4C 43 FA                 JMP  STEP        TAKE ONE STEP
FECA:  4C F8 03    USR          JMP  USRADR      TO USR SUBR AT USRADR
FECD:  A9 40       WRITE        LDA  #$40
FECF:  20 C9 FC                 JSR  HEADR       WRITE 10-SEC HEADER
FED2:  A0 27                    LDY  #$27
FED4:  A2 00       WR1          LDX  #$00
FED6:  41 3C                    EOR  (A1L,X)
FED8:  48                       PHA
FED9:  A1 3C                    LDA  (A1L,X)
```

```
FEDB:  20 ED FE                JSR   WRBYTE
FEDE:  20 BA FC                JSR   NXTA1
FEE1:  A0 1D                   LDY   #$1D
FEE3:  68                      PLA
FEE4:  90 EE                   BCC   WR1
FEE6:  A0 22                   LDY   #$22
FEE8:  20 ED FE                JSR   WRBYTE
FEEB:  F0 4D                   BEQ   BELL
FEED:  A2 10        WRBYTE     LDX   #$10
FEEF:  0A           WRBYT2     ASL   A
FEF0:  20 D6 FC                JSR   WRBIT
FEF3:  D0 FA                   BNE   WRBYT2
FEF5:  60                      RTS
FEF6:  20 00 FE     CRMON      JSR   BL1          HANDLE CR AS BLANK
FEF9:  68                      PLA                  THEN POP STACK
FEFA:  68                      PLA                  AND RTN TO MON
FEFB:  D0 6C                   BNE   MONZ
FEFD:  20 FA FC     READ       JSR   RD2BIT       FIND TAPEIN EDGE
FF00:  A9 16                   LDA   #$16
FF02:  20 C9 FC                JSR   HEADR        DELAY 3.5 SECONDS
FF05:  85 2E                   STA   CHKSUM       INIT CHKSUM=$FF
FF07:  20 FA FC                JSR   RD2BIT       FIND TAPEIN EDGE
FF0A:  A0 24        RD2        LDY   #$24         LOOK FOR SYNC BIT
FF0C:  20 FD FC                JSR   RDBIT          (SHORT 0)
FF0F:  B0 F9                   BCS   RD2            LOOP UNTIL FOUND
FF11:  20 FD FC                JSR   RDBIT        SKIP SECOND SYNC H-CYCLE
FF14:  A0 3B                   LDY   #$3B         INDEX FOR 0/1 TEST
FF16:  20 EC FC     RD3        JSR   RDBYTE       READ A BYTE
FF19:  81 3C                   STA   (A1L,X)      STORE AT (A1)
FF1B:  45 2E                   EOR   CHKSUM
FF1D:  85 2E                   STA   CHKSUM       UPDATE RUNNING CHKSUM
FF1F:  20 BA FC                JSR   NXTA1        INCR A1, COMPARE TO A2
FF22:  A0 35                   LDY   #$35         COMPENSATE 0/1 INDEX
FF24:  90 F0                   BCC   RD3          LOOP UNTIL DONE
FF26:  20 EC FC                JSR   RDBYTE       READ CHKSUM BYTE
FF29:  C5 2E                   CMP   CHKSUM
FF2B:  F0 0D                   BEQ   BELL         GOOD, SOUND BELL AND RETURN
FF2D:  A9 C5        PRERR      LDA   #$C5
FF2F:  20 ED FD                JSR   COUT         PRINT "ERR", THEN BELL
FF32:  A9 D2                   LDA   #$D2
FF34:  20 ED FD                JSR   COUT
FF37:  20 ED FD                JSR   COUT
FF3A:  A9 87        BELL       LDA   #$87         OUTPUT BELL AND RETURN
FF3C:  4C ED FD                JMP   COUT
FF3F:  A5 48        RESTORE    LDA   STATUS       RESTORE 6502 REG CONTENTS
FF41:  48                      PHA                  USED BY DEBUG SOFTWARE
FF42:  A5 45                   LDA   ACC
FF44:  A6 46        RESTR1     LDX   XREG
FF46:  A4 47                   LDY   YREG
FF48:  28                      PLP
FF49:  60                      RTS
FF4A:  85 45        SAVE       STA   ACC          SAVE 6502 REG CONTENTS
FF4C:  86 46        SAV1       STX   XREG
FF4E:  84 47                   STY   YREG
FF50:  08                      PHP
FF51:  68                      PLA
FF52:  85 48                   STA   STATUS
FF54:  BA                      TSX
FF55:  86 49                   STX   SPNT
FF57:  D8                      CLD
FF58:  60                      RTS
FF59:  20 84 FE     RESET      JSR   SETNORM      SET SCREEN MODE
FF5C:  20 2F FB                JSR   INIT           AND INIT KBD/SCREEN
FF5F:  20 93 FE                JSR   SETVID         AS I/O DEV'S
FF62:  20 89 FE                JSR   SETKBD
FF65:  D8           MON        CLD                MUST SET HEX MODE!
FF66:  20 3A FF                JSR   BELL
FF69:  A9 AA        MONZ       LDA   #$AA         '*' PROMPT FOR MON
FF6B:  85 33                   STA   PROMPT
FF6D:  20 67 FD                JSR   GETLNZ       READ A LINE
FF70:  20 C7 FF                JSR   ZMODE        CLEAR MON MODE, SCAN IDX
FF73:  20 A7 FF     NXTITM     JSR   GETNUM       GET ITEM, NON-HEX
FF76:  84 34                   STY   YSAV           CHAR IN A-REG
```

```
FF78:  A0 17                LDY  #$17        X-REG=0 IF NO HEX INPUT
FF7A:  88        CHRSRCH    DEY
FF7B:  30 E8                BMI  MON         NOT FOUND, GO TO MON
FF7D:  D9 CC FF             CMP  CHRTBL,Y    FIND CMND CHAR IN TBL
FF80:  D0 F8                BNE  CHRSRCH
FF82:  20 BE FF             JSR  TOSUB       FOUND, CALL CORRESPONDING
FF85:  A4 34                LDY  YSAV          SUBROUTINE
FF87:  4C 73 FF             JMP  NXTITM
FF8A:  A2 03     DIG        LDX  #$03
FF8C:  0A                   ASL  A
FF8D:  0A                   ASL  A           GOT HEX DIG,
FF8E:  0A                   ASL  A             SHIFT INTO A2
FF8F:  0A                   ASL  A
FF90:  0A        NXTBIT     ASL  A
FF91:  26 3E                ROL  A2L
FF93:  26 3F                ROL  A2H
FF95:  CA                   DEX              LEAVE X=$FF IF DIG
FF96:  10 F8                BPL  NXTBIT
FF98:  A5 31     NXTBAS     LDA  MODE
FF9A:  D0 06                BNE  NXTBS2      IF MODE IS ZERO
FF9C:  B5 3F                LDA  A2H,X         THEN COPY A2 TO
FF9E:  95 3D                STA  A1H,X         A1 AND A3
FFA0:  95 41                STA  A3H,X
FFA2:  E8        NXTBS2     INX
FFA3:  F0 F3                BEQ  NXTBAS
FFA5:  D0 06                BNE  NXTCHR
FFA7:  A2 00     GETNUM     LDX  #$00        CLEAR A2
FFA9:  86 3E                STX  A2L
FFAB:  86 3F                STX  A2H
FFAD:  B9 00 02  NXTCHR     LDA  IN,Y        GET CHAR
FFB0:  C8                   INY
FFB1:  49 B0                EOR  #$B0
FFB3:  C9 0A                CMP  #$0A
FFB5:  90 D3                BCC  DIG         IF HEX DIG, THEN
FFB7:  69 88                ADC  #$88
FFB9:  C9 FA                CMP  #$FA
FFBB:  B0 CD                BCS  DIG
FFBD:  60                   RTS
FFBE:  A9 FE     TOSUB      LDA  #GO/256     PUSH HIGH-ORDER
FFC0:  48                   PHA                SUBR ADR ON STK
FFC1:  B9 E3 FF             LDA  SUBTBL,Y    PUSH LOW ORDER
FFC4:  48                   PHA                SUBR ADR ON STK
FFC5:  A5 31                LDA  MODE
FFC7:  A0 00     ZMODE      LDY  #$00        CLR MODE, OLD MODE
FFC9:  84 31                STY  MODE          TO A-REG
FFCB:  60                   RTS              GO TO SUBR VIA RTS
FFCC:  BC        CHRTBL     DFB  $BC         F("CTRL-C")
FFCD:  B2                   DFB  $B2         F("CTRL-Y")
FFCE:  BE                   DFB  $BE         F("CTRL-E")
FFCF:  ED                   DFB  $ED         F("T")
FFD0:  EF                   DFB  $EF         F("V")
FFD1:  C4                   DFB  $C4         F("CTRL-K")
FFD2:  EC                   DFB  $EC         F("S")
FFD3:  A9                   DFB  $A9         F("CTRL-P")
FFD4:  BB                   DFB  $BB         F("CTRL-B")
FFD5:  A6                   DFB  $A6         F("-")
FFD6:  A4                   DFB  $A4         F("+")
FFD7:  06                   DFB  $06         F("M")  (F=EX-OR $B0+$89)
FFD8:  95                   DFB  $95         F("<")
FFD9:  07                   DFB  $07         F("N")
FFDA:  02                   DFB  $02         F("I")
FFDB:  05                   DFB  $05         F("L")
FFDC:  F0                   DFB  $F0         F("W")
FFDD:  00                   DFB  $00         F("G")
FFDE:  EB                   DFB  $EB         F("R")
FFDF:  93                   DFB  $93         F(":")
FFE0:  A7                   DFB  $A7         F(".")
FFE1:  C6                   DFB  $C6         F("CR")
FFE2:  99                   DFB  $99         F(BLANK)
FFE3:  B2        SUBTBL     DFB  #BASCONT-1
FFE4:  C9                   DFB  #USR-1
FFE5:  BE                   DFB  #REGZ-1
```

```
FFE6:  C1          DFB  #TRACE-1
FFE7:  B5          DFB  #VFY-1
FFE8:  6C          DFB  #INPRT-1
FFE9:  C1          DFB  #STEPZ-1
FFEA:  96          DFB  #OUTPRT-1
FFEB:  AF          DFB  #XBASIC-1
FFEC:  17          DFB  #SETMODE-1
FFED:  17          DFB  #SETMODE-1
FFEE:  2B          DFB  #MOVE-1
FFEF:  1F          DFB  #LT-1
FFF0:  83          DFB  #SETNORM-1
FFF1:  7F          DFB  #SETINV-1
FFF2:  5D          DFB  #LIST-1
FFF3:  CC          DFB  #WRITE-1
FFF4:  B5          DFB  #GO-1
FFF5:  FC          DFB  #READ-1
FFF6:  17          DFB  #SETMODE-1
FFF7:  17          DFB  #SETMODE-1
FFF8:  F5          DFB  #CRMON-1
FFF9:  03          DFB  #BLANK-1
FFFA:  FB          DFB  #NMI          NMI VECTOR
FFFB:  03          DFB  #NMI/256
FFFC:  59          DFB  #RESET        RESET VECTOR
FFFD:  FF          DFB  #RESET/256
FFFE:  86          DFB  #IRQ          IRQ VECTOR
FFFF:  FA          DFB  #IRQ/256
            XQTNZ  EQU  $3C
```

SYMBOL TABLE
(NUMERICAL ORDER)

0000	LOC0
0022	WNDTOP
0026	GBASL
002A	BAS2L
002D	V2
002E	FORMAT
0030	COLOR
0034	YSAV
0038	KSWL
003C	A1L
0040	A3L
0044	A5L
0047	YREG
004F	RNDH
03F2	SOFTEV
03FB	NMI
C000	IOADR
C030	SPKR
C053	MIXSET
C057	HIRES
C05B	CLRAN1
C05F	CLRAN3
CFFF	CLRROM
F80C	RTMASK
F826	VLINEZ
F836	CLRTOP
F856	GBCALC
F87F	RTMSKZ
F8A5	ERR
F8C9	MNNDX3
F8F5	NXTCOL
F926	PRADR3
F940	PRNTYX
F94A	PRBL2
F956	PCADJ3
F9A6	FMT2
FA00	MNEMR
FA62	RESET
FAA3	NOFIX
FABA	SLOOP
FAE4	RDSP1
FB11	XLTBL
FB2E	RTS2D
FB4B	SETWND
FB6F	SETPWRC
FB97	ESCOLD
FBD0	BASCLC2
FBF0	STORADV
FC10	BS
FC2B	RTS4
FC58	HOME
FC76	SCRL1
FC9E	CLEOLZ
FCAA	WAIT3
FCC9	HEADR
FCE5	WRTAPE
FCFD	RDBIT
FD2F	ESC
FD62	CANCEL
0001	LOC1
0023	WNDBTM
0027	GBASH
002B	BAS2H
002D	RMNEM
002F	LASTIN
0031	MODE
0035	YSAV1
0039	KSWH
003D	A1H
0041	A3H
0045	A5H
0048	STATUS
0095	PICK
03F4	PWREDUP
03FE	IRQLOC
C000	KBD
C050	TXTCLR
C054	LOWSCR
C058	SETAN0
C05C	SETAN2
C060	TAPEIN
E000	BASIC
F80E	PLOT1
F828	VLINE
F838	CLRSC2
F864	SETCOL
F882	INSDS1
F8A9	GETFMT
F8D0	INSTDSP
F8F9	PRMN2
F92A	PRADR4
F941	PRNTAX
F94C	PRBL3
F95C	PCADJ4
F9B4	CHAR1
FA40	IRQ
FA6F	INITAN
FAA6	PWRUP
FAC7	NXTBYT
FAFD	PWRCON
FB19	RTBL
FB2F	INIT
FB5B	TABV
FB78	VIDWAIT
FB9B	ESCNOW
FBD9	BELL1
FBF4	ADVANCE
FC1A	UP
FC2C	ESC1
FC62	CR
FC8C	SCRL2
FCA0	CLEOL2
FCB4	NXTA4
FCD6	WRBIT
FCEC	RDBYTE
FD0C	RDKEY
FD35	RDCHAR
FD67	GETLNZ
0020	WNDLFT
0024	CH
0028	BASL
002C	H2
002E	MASK
002F	LENGTH
0032	INVFLG
0036	CSWL
003A	PCL
003E	A2L
0042	A4L
0045	ACC
0049	SPNT
0200	IN
03F5	AMPERV
0400	LINE1
C010	KBDSTRB
C051	TXTSET
C055	HISCR
C059	CLRAN0
C05D	CLRAN2
C064	PADDL0
E003	BASIC2
F819	HLINE
F831	RTS1
F83C	CLRSC3
F871	SCRN
F88C	INSDS2
F8BE	MNNDX1
F8D4	PRNTOP
F910	PRADR1
F930	PRADR5
F944	PRNTX
F953	PCADJ
F961	RTS2

F9BA CHAR2
FA4C BREAK
FA81 NEWMON
FAA9 SETPG3
FAD7 REGDSP
FB02 DISKID
FB1E PREAD
FB39 SETTXT
FB60 APPLEII
FB88 KBDWAIT
FBA5 ESCNEW
FBE4 BELL2
FBFC RTS3
FC22 VTAB
FC42 CLREOP
FC66 LF
FC95 SCRL3
FCA8 WAIT
FCBA NXTA1
FCDB ZERDLY
FCEE RDBYT2
FD1B KEYIN
FD3D NOTCR
FD6A GETLN
0021 WNDWDTH
0025 CV
0029 BASH
002C LMNEM
002E CHKSUM
002F SIGN
0033 PROMPT
0037 CSWH
003B PCH
003F A2H
0043 A4H
0046 XREG
004E RNDL
03F0 BRKV
03F8 USRADR
07F8 MSLOT
C020 TAPEOUT
C052 MIXCLR
C056 LORES
C05A SETAN1
C05E SETAN3
C070 PTRIG
F800 PLOT
F81C HLINE1
F832 CLRSCR
F847 GBASCALC
F879 SCRN2
F89B IEVEN
F8C2 MNNDX2
F8DB PRNTBL

F914 PRADR2
F938 RELADR
F948 PRBLNK
F954 PCADJ2
F962 FMT1
F9C0 MNEML
FA59 OLDBRK
FA9B FIXSEV
FAAB SETPLP
FADA RGDSP1
FB09 TITLE
FB25 PREAD2
FB40 SETGR
FB65 STITLE
FB94 NOWAIT
FBC1 BASCALC
FBEF RTS2B
FBFD VIDOUT
FC24 VTABZ
FC46 CLEOP1
FC70 SCROLL
FC9C CLREOL
FCA9 WAIT2
FCC8 RTS4B
FCE2 ONEDLY
FCFA RD2BIT
FD21 KEYIN2
FD5F NOTCR1
FD71 BCKSPC
FD75 NXTCHAR
FD92 PRA1
FDB3 XAM
FDD1 ADD
FDED COUT
FE04 BLANK
FE1D SETMDZ
FE36 VFY
FE75 A1PC
FE84 SETNORM
FE8D INPRT
FE9B IOPRT
FEB3 BASCONT
FEC4 STEPZ
FEED WRBYTE
FF0A RD2
FF3F RESTORE
FF59 OLDRST
FF7A CHRSRCH
FFA2 NXTBS2
FFC7 ZMODE
FD7E CAPTST
FD96 PRYX2
FDB6 DATAOUT
FDDA PRBYTE

FDF0 COUT1
FE0B STOR
FE20 LT
FE58 VFYOK
FE78 A1PCLP
FE86 SETIFLG
FE93 SETVID
FEA7 IOPRT1
FEB6 GO
FECA USR
FEEF WRBYT2
FF16 RD3
FF44 RESTR1
FF65 MON
FF8A DIG
FFA7 GETNUM
FFCC CHRTBL
FD84 ADDINP
FDA3 XAM8
FDC5 RTS4C
FDE3 PRHEX
FDF6 COUTZ
FE17 RTS5
FE22 LT2
FE5E LIST
FE7F A1PCRTS
FE89 SETKBD
FE95 OUTPORT
FEA9 IOPRT2
FEBF REGZ
FECD WRITE
FEF6 CRMON
FF2D PRERR
FF4A SAVE
FF69 MONZ
FF90 NXTBIT
FFAD NXTCHR
FFE3 SUBTBL
FD8E CROUT
FDAD MOD8CHK
FDC6 XAMPM
FDE5 PRHEXZ
FE00 BL1
FE18 SETMODE
FE2C MOVE
FE63 LIST2
FE80 SETINV
FE8B INPORT
FE97 OUTPRT
FEB0 XBASIC
FEC2 TRACE
FED4 WR1
FEFD READ
FF3A BELL

```
FF4C SAV1
FF73 NXTITM
FF98 NXTBAS
FFBE TOSUB
```

SYMBOL TABLE
(ALPHABETICAL ORDER)

```
003D A1H
FE7F A1PCRTS
0040 A3L
0044 A5L
FBF4 ADVANCE
002A BAS2L
0029 BASH
FD71 BCKSPC
FE00 BL1
FC10 BS
F9BA CHAR2
0024 CH
C059 CLRAN0
FC9C CLREOL
FB3C CLRSC3
FDED COUT
FC62 CR
0025 CV
FBA5 ERR
FB97 ESCOLD
F9A6 FMT2
0026 GBASL
FD6A GETLN
FCC9 HEADR
FB19 HLINE
0200 IN
FB82 INSDS1
C000 IOADR
03FE IRQLOC
C000 KBD
0038 KSWL
0400 LINE1
0000 LOC0
FE22 LT2
C053 MIXSET
F8C2 MNNDX2
FF69 MONZ
FA81 NEWMON
FD5F NOTCR1
FF98 NXTBAS
FD75 NXTCHAR
FA59 OLDBRK
FE97 OUTPRT
F956 PCADJ3
0095 PICK
F910 PRADR1
F930 PRADR5
FDDA PRBYTE
FDE3 PRHEX
F8DB PRNTBL
0033 PROMPT
03F4 PWREDUP
FF16 RD3
FD35 RDCHAR
FAD7 REGDSP
FF3F RESTORE
004F RNDH
F87F RTMSKZ
F961 RTS2
003C A1L
003F A2H
0043 A4H
0045 ACC
03F5 AMPERV
FBC1 BASCALC
E000 BASIC
FBD9 BELL1
FE04 BLANK
FD62 CANCEL
002E CHKSUM
FCA0 CLEOL2
C058 CLRAN1
FC42 CLREOP
F832 CLRSCR
FDF0 COUT1
FEF6 CRMON
FDB6 DATAOUT
FC2C ESC1
FD2F ESC
002E FORMAT
F856 GBCALC
FFA7 GETNUM
C057 HIRES
FC58 HOME
FB2F INIT
F88C INSDS2
FEA7 IOPRT1
FA40 IRQ
FD1B KEYIN
002F LASTIN
FE5E LIST
0001 LOC1
FE20 LT
F9C0 MNEML
F8C9 MNNDX3
FF65 MON
03FB NMI
FB94 NOWAIT
FF90 NXTBIT
FFAD NXTCHR
FF59 OLDRST
C064 PADDL0
F95C PCADJ4
F80E PLOT1
F914 PRADR2
F94A PRBL2
FB1E PREAD
FDE5 PRHEXZ
F8D4 PRNTOP
FD96 PRYX2
FAA6 PWRUP
FCFD RDBIT
FD0C RDKEY
FEBF REGZ
FF44 RESTR1
004E RNDL
F831 RTS1
FBFC RTS3
FE78 A1PCLP
003E A2L
0042 A4L
FD84 ADDINP
FB60 APPLEII
FBD0 BASCLC2
E003 BASIC2
FBE4 BELL2
FA4C BREAK
FD7E CAPTST
FF7A CHRSRCH
```

FC9E CLEOLZ
C05D CLRAN2
CFFF CLRROM
F836 CLRTOP
FDF6 COUTZ
0037 CSWH
FFBA DIG
FBA5 ESCNEW
FA9B FIXSEV
FB47 GBASCALC
FBA9 GETFMT
FEB6 GO
C055 HISCR
F89B IEVEN
FEBB INPORT
FBD0 INSTDSP
FEA9 IOPRT2
C010 KBDSTRB
FD21 KEYIN2
002F LENGTH
FE63 LIST2
C056 LORES
002E MASK
FA00 MNEMR
FDAD MOD8CHK
FE2C MOVE
FAA3 NOFIX
FCBA NXTA1
FFA2 NXTBS2
F8F5 NXTCOL
FCE2 ONEDLY
F954 PCADJ2
003B PCH
F800 PLOT
F926 PRADR3
F94C PRBL3
FB25 PREAD2
F8F9 PRMN2
F944 PRNTX
C070 PTRIG
FCFA RD2BIT
FCEE RDBYT2
FAE4 RDSP1
F938 RELADR
FADA RGDSP1
FB19 RTBL
F8EF RTS2B
FCC8 RTS4B
FE75 A1PC
0041 A3H
0045 A5H
FDD1 ADD
002B BAS2H
FEB3 BASCONT
0028 BASL

FF3A BELL
03F0 BRKV
F9B4 CHAR1
FFCC CHRTBL
FC46 CLEOP1
C05F CLRAN3
F838 CLRSC2
0030 COLOR
FD8E CROUT
0036 CSWL
FB02 DISKID
FB9B ESCNOW
F962 FMT1
0027 GBASH
FD67 GETLNZ
002C H2
F81C HLINE1
FA6F INITAN
FEBD INPRT
0032 INVFLG
FE9B IOPRT
FB88 KBDWAIT
0039 KSWH
FC66 LF
002C LMNEM
C054 LOWSCR
C052 MIXCLR
F8BE MNNDX1
0031 MODE
07F8 MSLOT
FD3D NOTCR
FCB4 NXTA4
FAC7 NXTBYT
FF73 NXTITM
FE95 OUTPORT
F953 PCADJ
003A PCL
FD92 PRA1
F92A PRADR4
F94B PRBLNK
FF2D PRERR
F941 PRNTAX
F940 PRNTYX
FAFD PWRCON
FF0A RD2
FCEC RDBYTE
FEFD READ
FA62 RESET
002D RMNEM
F80C RTMASK
F82E RTS2D
FDC5 RTS4C
FE17 RTS5
FC2B RTS4
FC76 SCRL1
F879 SCRN2

C05C SETAN2
FE86 SETIFLG
FE18 SETMODE
FB6F SETPWRC
002F SIGN
0049 SPNT
FE0B STOR
C060 TAPEIN
FEC2 TRACE
FECA USR
FE58 VFYOK
F828 VLINE
FCA8 WAIT
0022 WNDTOP
FEEF WRBYT2
FDA3 XAMB
F811 XLTBL
0034 YSAV
FCBC SCRL2
FC70 SCROLL
C05E SETAN3
FE80 SETINV
FE84 SETNORM
FB39 SETTXT
FABA SLOOP
0048 STATUS
FBF0 STORADV
C020 TAPEOUT
C050 TXTCLR
03F8 USRADR
FBFD VIDOUT
FC24 VTABZ
FCAA WAIT3
0021 WNDWDTH
FEED WRBYTE
FDC6 XAMPM
0046 XREG
FCDB ZERDLY
FF4C SAV1
FC95 SCRL3
C058 SETAN0
F864 SETCOL
FE89 SETKBD
FAA9 SETPG3
FE93 SETVID
03F2 SOFTEV
FEC4 STEPZ
FFE3 SUBTBL
FB09 TITLE
C051 TXTSET
002D V2
FB78 VIDWAIT
FC22 VTAB
0023 WNDBTM
FED4 WR1

```
FECD WRITE
FDB3 XAM
0047 YREG
FFC7 ZMODE
FF4A SAVE
F871 SCRN
C05A SETAN1
FB40 SETGR
FE1D SETMDZ
FAAB SETPLP
FB4B SETWND
C030 SPKR
FB65 STITLE
FB5B TABV
FFBE TOSUB
FC1A UP
FE36 VFY
F826 VLINEZ
FCA9 WAIT2
0020 WNDLFT
FCD6 WRBIT
FCE5 WRTAPE
FEB0 XBASIC
0035 YSAV1

SYMBOL TABLE SIZE
2589   BYTES USED
2531   BYTES REMAINING

SLIST 4A
```

GLOSSARY

65Ø2: The manufacturer's name for the microprocessor at the heart of your Apple.

Address: As a noun: the particular number associated with each memory location. On the Apple, an address is a number between Ø and 65535 (or $ØØØØ and $FFFF hexadecimal). As a verb: to refer to a particular memory location.

Address Bus: The set of wires, or the signal on those wires, which carry the binary-encoded address from the microprocessor to the rest of the computer.

Addressing mode: The Apple's 65Ø2 microprocessor has thirteen distinct ways of referring to most locations in memory. These thirteen methods of forming addresses are called **addressing modes**.

Analog: Analog measurements, as opposed to digital measurements, use an continuously variable physical quantity (such as length, voltage, or resistance) to represent values. Digital measurements use precise, limited quantities (such as presence or absence of voltages or magnetic fields) to represent values.

AND: A binary function which is "on" if and only if all of its inputs are "on".

Apple: 1. The round fleshy fruit of a Rosaceous tree (Pyrus Malus). 2. A brand of personal computer. 3) Apple Computer, Inc., manufacturer of home and personal computers.

ASCII: An acronym for the American Standard Code for Information Interchange (often called "USASCII" or misinterpreted as "ASC-II"). This standard *code* assigns a unique value from Ø to 127 to each of 128 numbers, letters, special characters, and control characters.

Assembler: 1) One who assembes electronic or mechanical equipment. 2) A program which converts the *mnemonics* and *symbols* of assembly language into the *opcodes* and *operands* of machine language.

Assembly language: A language similar in structure to machine language, but made up of *mnemonics* and *symbols*. Programs written in assembly language are slightly less difficult to write and understand than programs in machine language.

BASIC: Acronym for "Beginner's All-Purpose Symbolic Instruction Code". BASIC is a *higher-level language*, similar in structure to FORTRAN but somewhat easier to learn. It was invented by Kemney and Kurtz at Dartmouth College in 1963 and has proved to be the most popular language for personal computers.

Binary: A number system with two digits, "Ø" and "1", with each digit in a binary number representing a power of two. Most digital computers are binary, deep down inside. A binary signal is easily expressed by the presence or absence of something, such as an electrical potential or a magnetic field.

Binary Function: An operation performed by an electronic circuit which has one or more inputs and only one output. All inputs and outputs are binary signals. See *AND OR*, and *Exclusive-OR*.

Bit: A *Binary digIT*. The smallest amount of information which a computer can hold. A single bit specifies a single value: "Ø" or "1". Bits can be grouped to form larger values (see *Byte* and *Nybble*).

Board: See *Printed Circuit Board*.

Bootstrap ("boot"): To get a system running from a *cold-start.* The name comes from the machine's attempts to "pull itsef off the ground by tugging on its own bootstraps."

Buffer: A device or area of memory which is used to hold something temporarily. The "picture buffer" contains graphic information to be displayed on the video screen; the "input buffer" holds a partially formed input line.

Bug: An error. A *hardware bug* is a physical or electrical malfunction or design error. A *software* bug is an error in programming, either in the logic of the program or typographical in nature. See "feature".

Bus: A set of wires or *traces* in a computer which carry a related set of data from one place to another, or the data which is on such a bus.

Byte: A basic unit of measure of a computer's memory. A byte usualy comprises eight *bits.* Thus, it can have a value from Ø to 255. Each character in the *ASCII* can be represented in one byte. The Apple's memory locations are all one byte, and the Apple's addresses of these locations consist of two bytes.

Call: As a verb: to leave the program or subroutine which is currently executing and to begin another, usualy with the intent to return to the original program or subroutine. As a noun: an instruction which calls a subroutine.

Character: Any *graphic* symbol which has a specific meaning to people. Letters (both upper- and lower-case), numbers, and various symbols (such as punctuation marks) are all characters.

Chip: See *Integrated Circuit.*

Code: A method of representing something in terms of something else. The ASCII code represents characters as binary numbers, the BASIC language represents algorithms in terms of program statements. **Code** is also used to refer to programs, usually in *low-level languages.*

Cold-start: To begin to operate a computer which has just been turned on.

Color burst: A signal which color television sets recognize and convert to the colored dots you see on a color TV screen. Without the color burst signal, all pictures would be black-and-white.

Computer: Any device which can recieve and store a set of *instructions*, and then act upon those instructions in a predetermined and predictable fashion. The definition implies that both the instruction and the *data* upon which the instructions act can be changed. A device whose instructions cannot be changed is not a computer.

Control (CTRL) character: Characters in the *ASCII* character set which usually have no graphic representation, but are used to control various functions. For example, the RETURN control character is a signal to the Apple that you have finished typing an *input line* and you wish the computer to act upon it.

CRT: Acronym for "Cathode-Ray Tube", meaning any television screen, or a device containing such a screen.

Cursor: A special symbol which reminds you of a certain position on something. The cursor on a slide rule lets you line up numbers; the cursor on the Apple's screen reminds you of where you are when you are typing.

Data (datum): Information of any type.

Debug: To find *bugs* and eliminate them.

DIP: Acronym for "Dual In-line Package", the most common container for an Integrated Circuit. DIPs have two parallel rows of *pins*, spaced on one-tenth of an inch centers. DIPs usually come in 14-, 16-, 18-, 20-, 24-, and 40-pin configurations.

Disassembler: A program which converts the *opcodes* of *machine language* to the *mnemonics* of *assembly language*. The opposite of an *assembler*.

Display: As a noun: any sort of output device for a computer, usually a *video* screen. As a noun: to place information on such a screen.

Edge connector: A socket which mates with the edge of a *printed circuit board* in order to exchange electrical signals.

Entry point: The location used by a machine-language subroutine which contains the first executable instruction in that subroutine: consequently, often the beginning of the subroutine.

Excusive-OR: A binary function whose value is "off" only if all of its inputs are "off", or all of its inputs are "on".

Execute: To perform the intention of a command or instruction. Also, to run a program or a portion of a program.

Feature: A *bug* as described by the marketing department.

Format: As a noun: the physical form in which something appears. As a verb: to specify such a form.

Graphic: Visible as a distinct, recognizable shape or color.

Graphics: A system to display graphic items or a collection of such items.

Hardware: The physical parts of a computer.

Hexadecimal: A number system which uses the ten digits Ø through 9 and the six letters A through F to represent values in base 16. Each hexadecimal digit in a hexadecimal number represents a power of 16. In this manual, all hexadecimal numbers are preceded by a dollar sign ($).

High-level Language: A *language* which is more intelligible to humans than it is to machines.

High-order: The most important, or item with the highest vaue, of a set of similar items. The high-order bit of a byte is that which has the highest place value.

High part: The *high-order* byte of a two-byte address. In decimal, the high part of an address is the quotient of the address divided by 256. In the 65Ø2, as in many other microprocessors, the high part of an address comes last when that address is stored in memory.

Hz (Hertz): Cycles per second. A bicycle wheel which makes two revolutions in one second is running at 2Hz. The Apple's microprocessor runs at 1,023,000Hz.

I/O: See *Input/Output.*

IC: See *Integrated Circuit.*

Input: As a noun: data which flows from the outside world into the computer. As a verb: to obtain data from the outside world.

Input/Output (I/O): The software or hardware which exchanges data with the outside word.

Instruction: The smallest portion of a program that a computer can execute. In 65Ø2 machine language, an instruction comprises one, two, or three bytes; in a higher-level language, instructions may be many characters long.

Integrated circuit: A small (less than the size of a fingernail and about as thin) wafer of a glassy material (usually silicon) into which has been etched an electronic circuit. A single IC can contain from ten to ten thousand discrete electronic components. ICs are usually housed in *DIPs* (see above), and the term IC is sometimes used to refer to both the circuit and its package.

Interface: An exchange of information between one thing and another, or the mechanisms which make such an exchange possible.

Interpreter: A program, usualy written in machine language, which understands and executes a higher-level language.

Interrupt: A physical effect which causes the computer to jump to a special interrupt-handling subroutine. When the interrupt has been taken care of, the computer resumes execution of the interrupted program with no noticeable change. Interrupts are used to signal the computer that a particular device wants attention.

K: Stands for the greek prefix "Kilo", meaning one thousand. In common computer-reated usage, "K" usually represents the quantity $2^{1\emptyset}$, or 1Ø24 (hexadecimal $4ØØ).

Kilobyte: 1,024 bytes.

Language: A computer language is a code which (hopefully!) both a programmer and his computer understand. The programmer expresses what he wants to do in this code, and the computer understands the code and performs the desired actions.

Line: On a video screen, a "line" is a horizontal sequence of graphic symbols extending from one edge of the screen to the other. To the Apple, an *input line* is a sequence of up to 254 characters, terminated by the control character RETURN. In most places which do not have personal computers, a line is something you wait in to use the computer.

Low-level Language: A *language* which is more intelligible to machines than it is to humans.

Low-order: The least important, or item with the least vaue, of a set of items. The low-order bit in a byte is the bit with the least place vaue.

Low part: The *low-order* byte of a two-byte address. In decimal, the low part of an address is the remainder of the address divided by 256, also called the "address *modulo* 256." In the 65Ø2, as in many other microprocessors, the low part of an address comes first when that address is stored in memory.

Machine language: The lowest level language which a computer understands. Machine languages are usually binary in nature. Instructions in machine language are single-byte *opcodes* sometimes followed by various *operands*.

Memory address: A memory address is a two-byte value which selects a single memory location out of the *memory map*. Memory addresses in the Apple are stored with their low-order bytes first, followed by their high-order bytes.

Memory location: The smallest subdivision of the memory map to which the computer can refer. Each memory location has associated with it a unique *address* and a certain *value*. Memory locations on the Apple comprise one byte each.

Memory Map: This term is used to refer to the set of all memory locations which the microprocesor can address directly. It is also used to describe a graphic representation of a system's memory.

Microcomputer: A term used to described a computer which is based upon a microprocessor.

Microprocessor: An integrated circuit which understands and executes machine language programs.

Mnemonic: An acronym (or any other symbol) used in the place of something more difficut to remember. In *Assembly Language*, each machine language opcode is given a three letter mnemonic (for example, the opcode $60 is given the mnemonic RTS, meaning "ReTurn from Subroutine").

Mode: A condition or set of conditions under which a certain set of rules apply.

Modulo: An arithmetic function with two operands. *Modulo* takes the first operand, divides it by the second, and returns the remainder of the division.

Monitor: 1) A closed-circuit television receiver. 2) A program which allows you to use your computer at a very low level, often with the values and addresses of individual memory locations.

Multiplexer: An electronic circuit which has many data inputs, a few selector inputs, and one output. A multiplexer connects one of its many data inputs to its output. The data input it chooses to connect to the output is determined by the selector inputs.

Mux: See *Multiplexer*.

Nybble: Colloquial term for half of a byte, or four bits.

Opcode: A machine language instruction, numerical (often binary) in nature.

OR: A binary function whose value is "on" if at least one of its inputs are "on".

Output: As a noun, data generated by the computer whose destination is the real world. As a verb, the process of generating or transmitting such data.

Page: 1) A screenfull of information on a video display. 2) A quantity of memory locations, addressible with one byte. On the Apple, a "page" of memory contains 256 locations.

Pascal: A noted French scientist.

PC board: See *Printed Circuit Board*.

Peripheral: Something attached to the computer which is not part of the computer itself. Most peripherals are input and/or output devices.

Personal Computer: A computer with *memory*, *languages*, and *peripherals* which are well-suited for use in a home, office, or school.

Pinout: A description of the function of each pin on an IC, often presented in the form of a diagram.

Potentiometer: An electronic component whose resistance to the flow of electrons is proportional to the setting of a dial or knob. Also known as a "pot" or "variable resistor".

Printed Circuit Board: A sheet of fiberglass or epoxy onto which a thin layer of metal has been applied, then etched away to form *traces*. Electronic components can then be attached to the board with molten solder, and they can exchange electronic signals via the etched traces on the board. Small printed circuit boards are often called "cards", especially if they are meant to connect with *edge connectors*.

Program: A sequence of instructions which describes a process.

PROM: Acronym for "*Programmable Read-Only Memory*". A PROM is a ROM whose contents can be altered by electrical means. Information in PROMs does not disappear when the power is turned off. Some PROMs can be erased by ultraviolet light and be reprogrammed.

RAM: See *Random-Access Memory*.

Random-Access Memory (RAM): This is the main memory of a computer. The acronym RAM can be used to refer either to the integrated circuits which make up this type of memory or the memory itself. The computer can store values in distinct locations in RAM and recall them again, or alter and re-store them if it wishes. On the Apple, as with most small computers, the values which are in RAM memory are lost when the power to the computer is turned off.

Read-Only Memory (ROM): This type of memory is usually used to hold important programs or data which must be available to the computer when the power is first turned on. Information in ROMs is placed there in the process of manufacturing the ROMs and is unalterable. Information stored in ROMs does not disappear when the power is turned off.

Reference: 1) A source of information, such as this manual. 2) As a verb, the action of examining or altering the contents of a memory location. As a noun, such an action.

Return: To exit a subroutine and go back to the program which called it.

ROM: See *Read-Only Memory*.

Run: To follow the sequence of instructions which comprise a program, and to complete the process outlined by the instructions.

Scan line: A single sweep of a cathode beam across the face of a *cathode-ray tube*.

Schematic: A diagram which represents the electrical interconnections and circuitry of an electronic device.

Scroll: To move all the text on a display (usually upwards) to make room for more (usually at the bottom).

Soft switch: A two-position switch which can be "thrown" either way by the software of a computer.

Software: The *programs* which give the hardware something to do.

Stack: A reserved area in memory which can be used to store information temporarily. The information in a stack is referenced not by address, but in the order in which it was placed on the stack. The last datum which was "pushed" onto the stack will be the first one to be "popped" off it.

Strobe: A momentary signal which indicates the occurrence of a specific event.

Subroutine: A segment of a program which can be executed by a single *call*. Subroutines are used to perform the same sequence of instructions at many different places in one program.

Syntax: The structure of instructions in a given *language*. If you make a mistake in entering an instruction and garble the syntax, the computer sometimes calls this a "SYNTAX ERROR."

Text: Characters, usually letters and numbers. "Text" usually refers to large chunks of English, rather than computer, language.

Toggle switch: A two-position switch which can only flip from one position to the other and back again, and cannot be directly set either way.

Trace: An etched conductive path on a *Printed-Circuit Board* which serves to electronically connect components.

Video: 1) Anything visual. 2) Information presented on the face of a *cathode-ray tube*.

Warm-start: To restart the operation of a computer after you have lost control of its language or operating system.

Window: Something out of which you jump when the power fails and you lose a large program. Really: a reserved area on a *display* which is dedicated to some special purpose.

BIBLIOGRAPHY

Here are some other publications which you might enjoy:

Synertek/MOS Technology 6500 Programming Manual
This manual is an introduction to machine language programming for the MC65Ø2 microprocessor. It describes the machine lanuage operation of the Apple's microprocessor in meticulous detail. However, it contains no specific information about the Apple.

This book is available from Apple. Order part number A2L0003.

Synertek/MOS Technology 6500 Hardware Manual
This manual contains a detailed description of the internal operations of the Apple's 65Ø2 microprocessor. It also has much information regarding interfacing the microprocessor to external devices, some of which is pertinent to the Apple.

This book is also available from Apple. Order part number A2L0002.

The Apple II Monitor Peeled
This book contains a thorough, well-done description of the operating subroutines within the Apple's original Monitor ROM.

This is available from the author:

William E. Dougherty
14349 San Jose Street
Los Angeles, CA 91345

Programming the 65Ø2
This book, written by Rodnay Zaks, is an excellent tutorial manual on machine and assembly-language programming for the Apple's 65Ø2 microprocessor.

This manual is available from Sybex Incorporated, 2020 Milvia, Berkeley, CA 94704. It should also be available at your local computer retailer or bookstore. Order book number C202.

65Ø2 Applications
This book, also written by Rodnay Zaks, describes many applications of the Apple's 65Ø2 microprocessor.

This is also available from Sybex. Order book number D302.

System Description: The Apple II
Written by Steve Wozniak, the designer of the Apple computers, this article describes the basic construction and operation of the Apple II.

This article was originally published in the May, 1977 issue of BYTE magazine, and is available from BYTE Publications, Inc. Peterborough, NH 30458.

SWEET16: The 65Ø2 Dream Machine
Also written by Steve Wozniak, this article describes the SWEET16© interpretive machine language enclosed in the Apple's Integer BASIC ROMs.

This article appeared in the October, 1977 issue of BYTE magazine, and is available from BYTE Publications, Inc. Peterborough, NH 30458.

More Colors for your Apple
This article, written by Allen Watson III, describes in detail the Apple High-Resolution Graphics mode. Also included is a reply by Steve Wozniak, the designer of the Apple, describing a modification you can make to update your Revision Ø Apple to add the two extra colors available on the Revision 1 board.

This article appeared in the June, 1979 issue of BYTE magazine, and is available from BYTE Publications, Inc. Peterborough, NH 30458.

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This is one of the largest Apple user group newsletters. For information, write:

> Apple Puget Sound Program Library Exchange
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The Cider Press
This is another large club newsletter. For information, write:

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INDEX

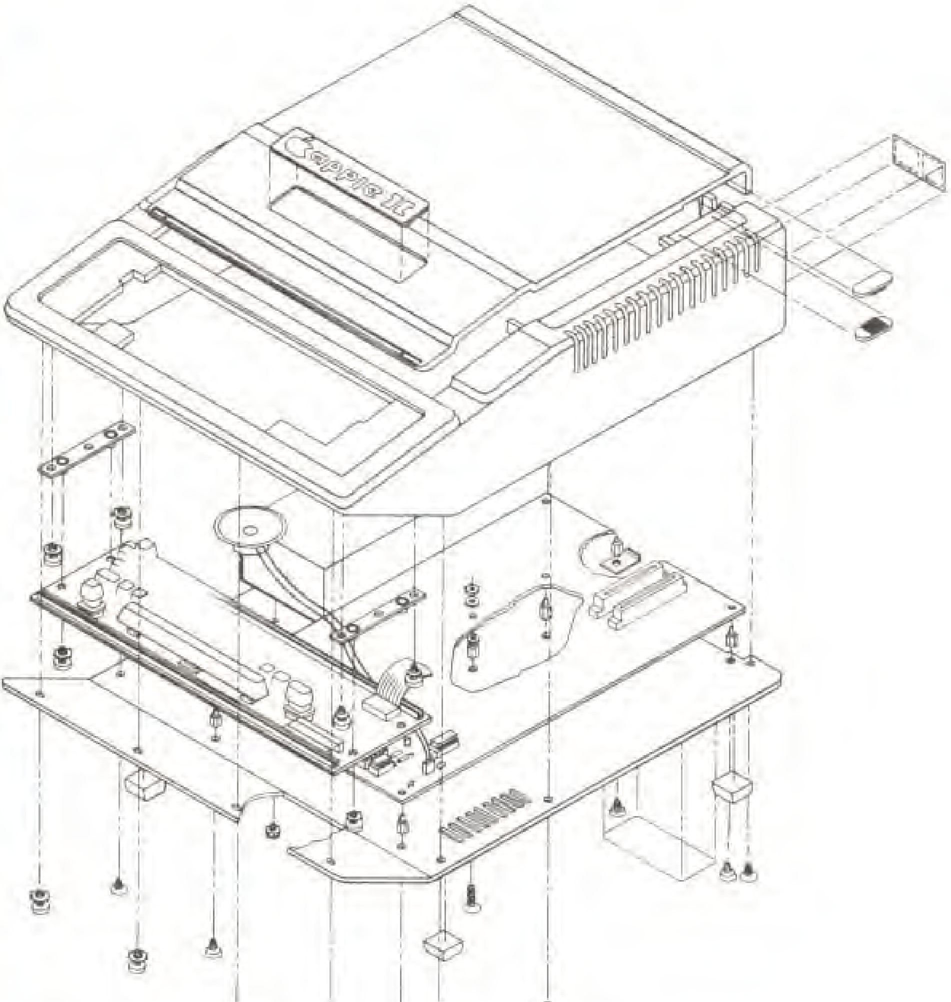
GENERAL INDEX

INDEX OF FIGURES

INDEX OF PHOTOS

INDEX OF TABLES

CAST OF CHARACTERS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