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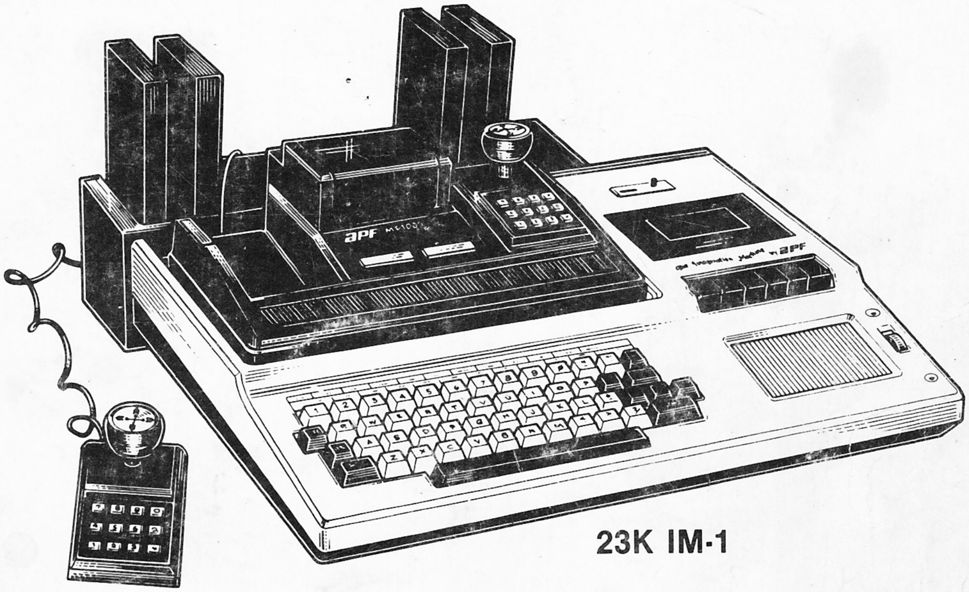

PROGRAMMING AND TECHNICAL ASSISTANCE MANUAL

- HIGH RESOLUTION GRAPHICS
- MACHINE LANGUAGE
- MEMORY MAPS
- SCHEMATICS AND PARTS LIST

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INTRODUCTION

This APF Imagination Machine Technical Reference Manual is written for those of you who would like to "know" more about the inner workings of the Imagination Machine. It assumes the reader is a technical person who has some general understanding of microcomputers (hardware, software, or both).

Chapters 1-2 and Appendix C supply all of the available electrical schematics. Also, a brief operations description is given. The rest of the manual goes into areas such as memory maps, details of machine language programming, and high resolution graphics mode.

The book is filled with details of information. Read through it all or just the sections that interest you, and then get ready to experiment with your imagination.

Note: Please do not infer from this manual that APF can or will make available design engineers for your circuits or ideas. We present this information so you can enhance your uses and fun of the Imagination Machine. Once you open the cabinets you void the warranties and are on your own.

All information presented in this manual is believed to be accurate and correct.

CHAPTER 1

THE MP1000 DESCRIPTION

Figure 1-2 shows a block diagram of the MP1000. The MP1000 contains the following sections:

1. The Microprocessor Unit (The MPU)
2. The Video Display Generator (The VDG)
3. The T.V. Driver (The MC1372)
4. The Internal ROM
5. The Peripheral Interface Driver (PIA)
6. The IK Read Write Memory for Screen Image
7. Power Supply

THE MPU

The brains of the system is the microprocessing unit (MPU). The MP1000 uses an 8 bit microprocessor - the MC6800. Fuller details of this are available from several semiconductor suppliers. The MPU gets its instructions from the Read Only Memory, processes these instructions and data, stores codes in the read write memory for the VDG to interpret and put out screen patterns, and sends and reads codes from the PIA.

All data is transferred over an 8 bit bidirectional data bus. Addresses are sent out from the MPU on a 16 bit bus (65,536 unique addresses).

The rate at which instructions are executed and data is transferred is set by a biphase clock input to the CPU. These are ø1, and ø2. The MP1000 has a clock rate of 894886 KHZ or a cycle time of 1.1174605 microseconds. This clock is derived by dividing the 3.579545 mhz xtal frequency by 4

MP1000 CLOCK TIMING

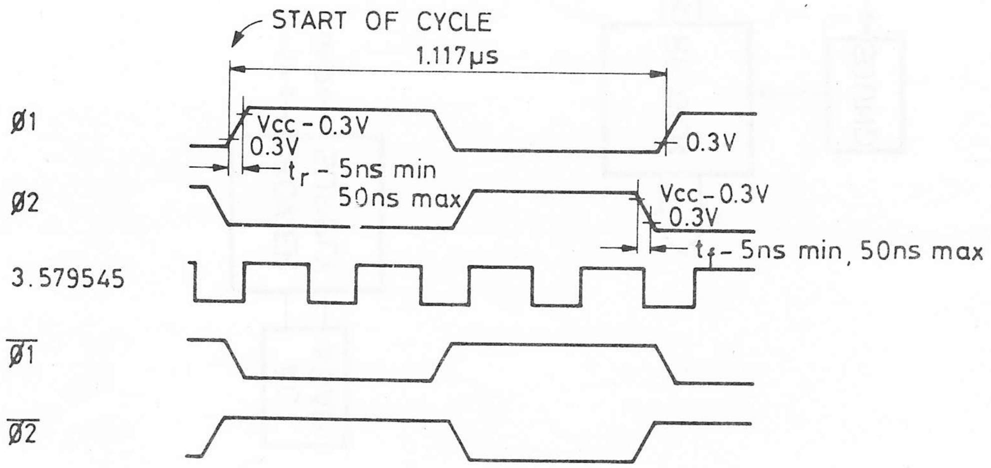


Figure 1-1

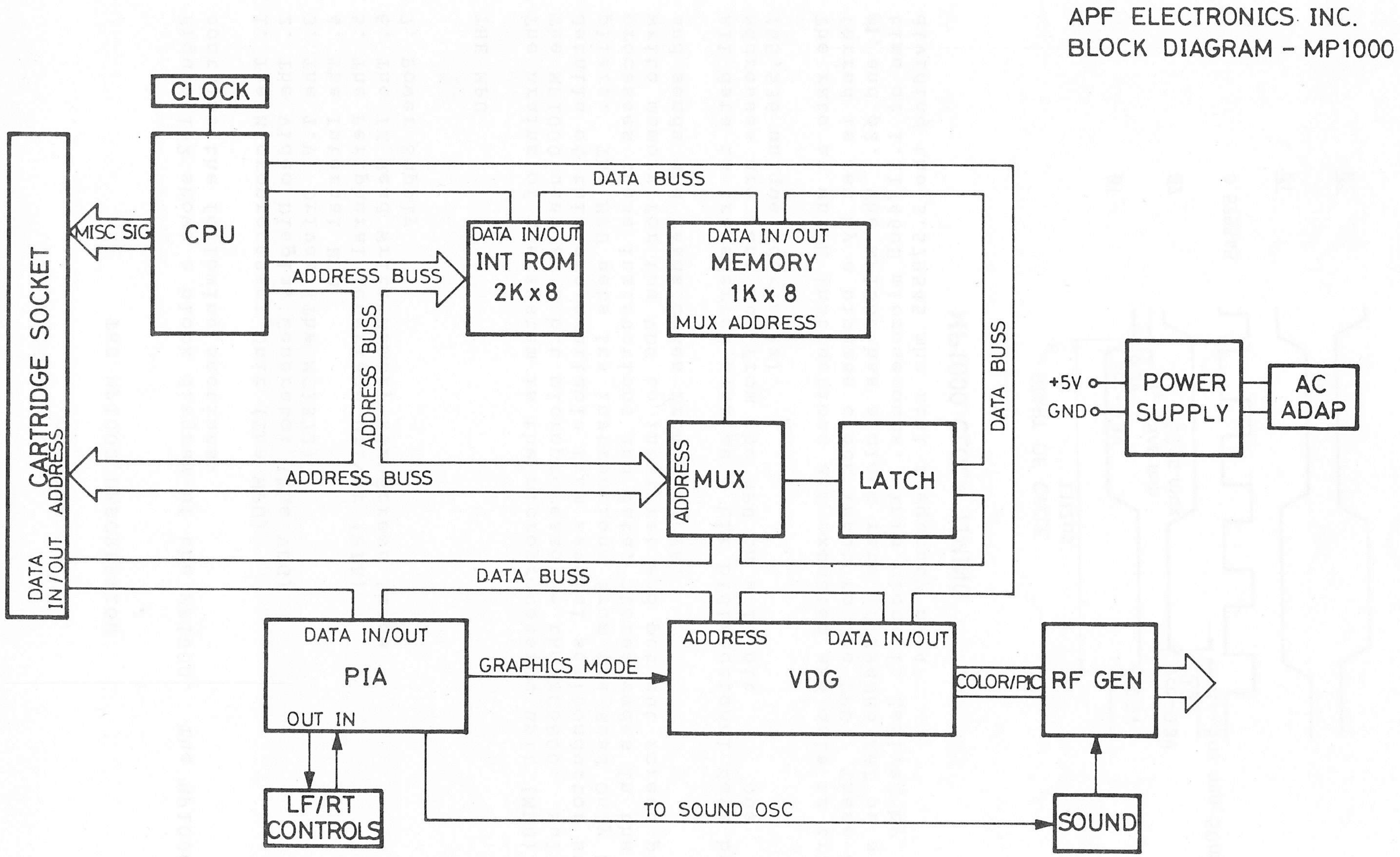


Figure I-2
MP1000 Block Diagram

During operation of the MPU, instructions are fetched from memory, executed, and the next instruction is fetched. The sequence of which instructions are fetched is determined by the program flow. There are 2 exceptions to this -

Power Up or Reset

Whenever power is turned on or the Reset button is depressed, PIN 40 of the MPU receives a signal which directs it to start a reset or initialization sequence. The starting address of this sequence is stored in ROM memory at locations Hex FFFF and FFFE. The MPU always goes to these locations to find its reset program starting address.

Interrupts

The other time the sequence of instructions can be changed is if an interrupt request is granted. The MPU stops what it is doing and finds the address of the interrupt routines which is stored at Hex FFF8 and FFF9.

VIDEO DISPLAY GENERATOR (VDG)

The VDG is a large scale integrated circuit that scans memory to produce a composite video signal and generates alphanumeric or graphics displays. It always scans memory during Phase 1 so as to not interfere with the MPU. Although the VDG can have up to 14 modes of operation, it is implemented in the MP1000 to have a maximum capability with minimum parts count. A description of the input/output signals is:

Address Output Lines (DA0-DA12) - Thirteen address lines are used by the VDG to scan the display memory. The starting address of the display memory corresponds to the upper left corner of the display screen. As the television signal sweeps from the left to right and top to bottom, the VDG increments the RAM display address.

Data Inputs (DD0-DD7) - Eight data lines are used to input data from RAM to be processed by the VDG. The data is interpreted and transformed into luminance Y (PIN 28) and color outputs ØA and ØB (PIN 11 and PIN 10).

Power Inputs - V_{CC} requires +5 volts. V_{SS} requires zero volts and is grounded.

Video Outputs (ØA, ØB, Y, CHB) - These four analog outputs are used to transfer luminance and color information to a standard NTSC color television receiver via the MC1372 RF modulator.

LUMINANCE (Y) - This six level analog output contains composite sync., blanking and four levels of video luminance.

ØA - This three level analog output is used in combination with ØB and Y outputs to specify one of eight colors.

ø B - This four level analog output is used in combination with øA and Y outputs to specify one of eight colors. Additionally, one analog level is used to specify the time of the color burst reference signal.

CHROMA BIAS (CHB) - This pin is an analog output and provides a D.C. reference corresponding to the quiescent value of øA and øB. CHB is used to quarantee good thermal tracking and minimize the variation between 1372 and 6847.

Synchronizing Inputs ($\overline{MS}$,CLK)

Three-State Control - ($\overline{MS}$) is a TTL compatible input which, when low, forces the VDG address lines into a high impedance state.

Clock (CLK) - The VDG clock input (CLK) uses a 3.579545 MHz (standard) TV crystal frequency square wave. The duty cycle of this clock must be between 45 and 55 percent since it controls the width of alternate dots on the television screen. The MC1372 RF modulator supplies the 3.579545 MHz clock and has provisions for a duty cycle adjustment.

Synchronizing Outputs ($\overline{FS}$,$\overline{HS}$,$\overline{RP}$) - Three TTL compatible outputs provide circuits, exterior to the VDG, with timing references to the following internal VDG states:

> FIELD SYNC - ($\overline{FS}$) - The high to low transition of the $\overline{FS}$ output coincides with the end of active display area. During this time interval an MPU may have total access to the display RAM without causing undesired flicker on the screen. The Low to High transition of $\overline{FS}$ coincides with the trailing edge of the vertical synchronization pulse.
>
> HORIZONTAL SYNC - ($\overline{HS}$) - The $\overline{HS}$ pulse coincides with the horizontal synchronization pulse furnished to the television receiver by the VDG. The high to low transition of the $\overline{HS}$ outputs coincides with the leading edge of the horizontal synchronization pulse.
>
> ROW PRESET - ($\overline{RP}$) - An external character generator ROM may be used with the VDG. An external four bit counter must be added to supply row selection. The counter is clocked by the $\overline{HS}$ signal and cleared by the $\overline{RP}$ signal.

Mode Control Lines (Input) ($\overline{A}$/G,$\overline{A}$/S,$\overline{INT}$/EXT,GM0,GM1,GM2,CSS, INV) - Eight TTL compatible inputs are used to control the operating mode of the VDG. CSS and INV are changed on a character by character basis. The CSS pin is used to select between two possible alphanumeric colors; when the VDG is in the alphanumeric mode and between two color sets when the VDG is in and full Graphic mode.

PB4 PB5
PB7 D7 GND D6 +5 +5 PB6
35 34 31 32 27 29 30

TABLE OF MODE CONTROL LINES (INPUTS)

$\overline{A}$/G	$\overline{A}$/S	$\overline{INT}$/EXT	INV	GM2	GM1	GM0	ALPHA/GRAPHIC MODE SELECTION
0	0	0	0	X	X	X	Internal Alphanumerics
0	0	0	1	X	X	X	Internal Alphanumerics Inverted
0	0	1	0	X	X	X	External Alphanumerics (not used)
0	0	1	1	X	X	X	External Alphanumerics Inverted (not used)
0	1	0	X	X	X	X	Semigraphics 4
0	1	1	X	X	X	X	Semigraphics 6 (not used)
1	X	X	X	0	0	0	64 x 64 Color Graphics (not used)
1	X	X	X	0	0	1	128 x 64 Graphics (not used)
1	X	X	X	0	1	0	128 x 64 Color Graphics (not used)
1	X	X	X	0	1	1	128 x 96 Graphics (not used)
1	X	X	X	1	0	0	128 x 96 Color Graphics (not used)
1	X	X	X	1	0	1	128 x 192 Graphics (not used)
1	X	X	X	1	1	0	128 x 192 Color Graphics
1	X	X	X	1	1	1	256 x 192 Graphics

X = DON't CARE

Basically, the MPU places 8 bit codes into the screen memory area. As the VDG outputs the composite video signal, it fetches from memory the appropriate 8 bit code for where it is up to on outputting to the screen (like an X,Y coordinate) and interprets the code based upon the selected VDG mode.

The details of each mode as implemented in the MP1000 are as follows:

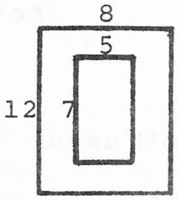
Major Mode 1

Alphanumeric/Semigraphics Mode

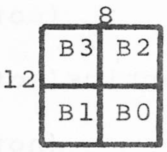
These modes always occupy an 8 x 12 dot character matrix box, and there are 32 x 16 character boxes per TV frame. This mode is entered by changing $\overline{A}$/G to alphamode. Then all submodes are selectable on a character by character basis.

Alphanumeric - internal ROM of VDG generates one of 64 ASCII displays characters in a 5 x 7 box. One of two colors can be selected with an inverse mode.

Semigraphics - 8 x 12 dot box is broken into 4 small boxes, each of which are 4 dots wide by 6 dots high. The 8 x 12 box is given a color and each of the 4 small boxes can be on (luminance) or off (no luminance) with that color.



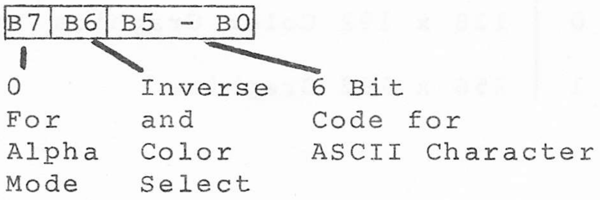
Alphanumeric Box - 5 x 7 ASCII character in an 8 x 12 box.



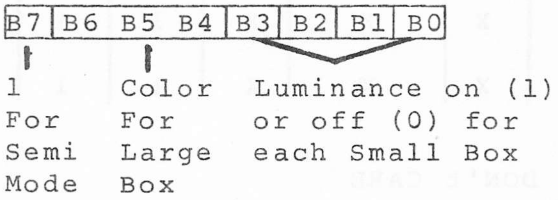
Semigraphics Box - 4 small boxes (B0-B3), each 4 dots by 6 dots.

Interpretation of 8 Bit Screen Map Word in Alphanumeric/ Semigraphics Mode

Alphanumeric



Semigraphic



Color Codes for Semigraphics

B6	B5	B4	Color
0	0	0	Dark Green
0	0	1	Yellow
0	1	0	Blue
0	1	1	Red
1	0	0	White
1	0	1	Cyan
1	1	0	Purple
1	1	1	Orange

Major Mode 2

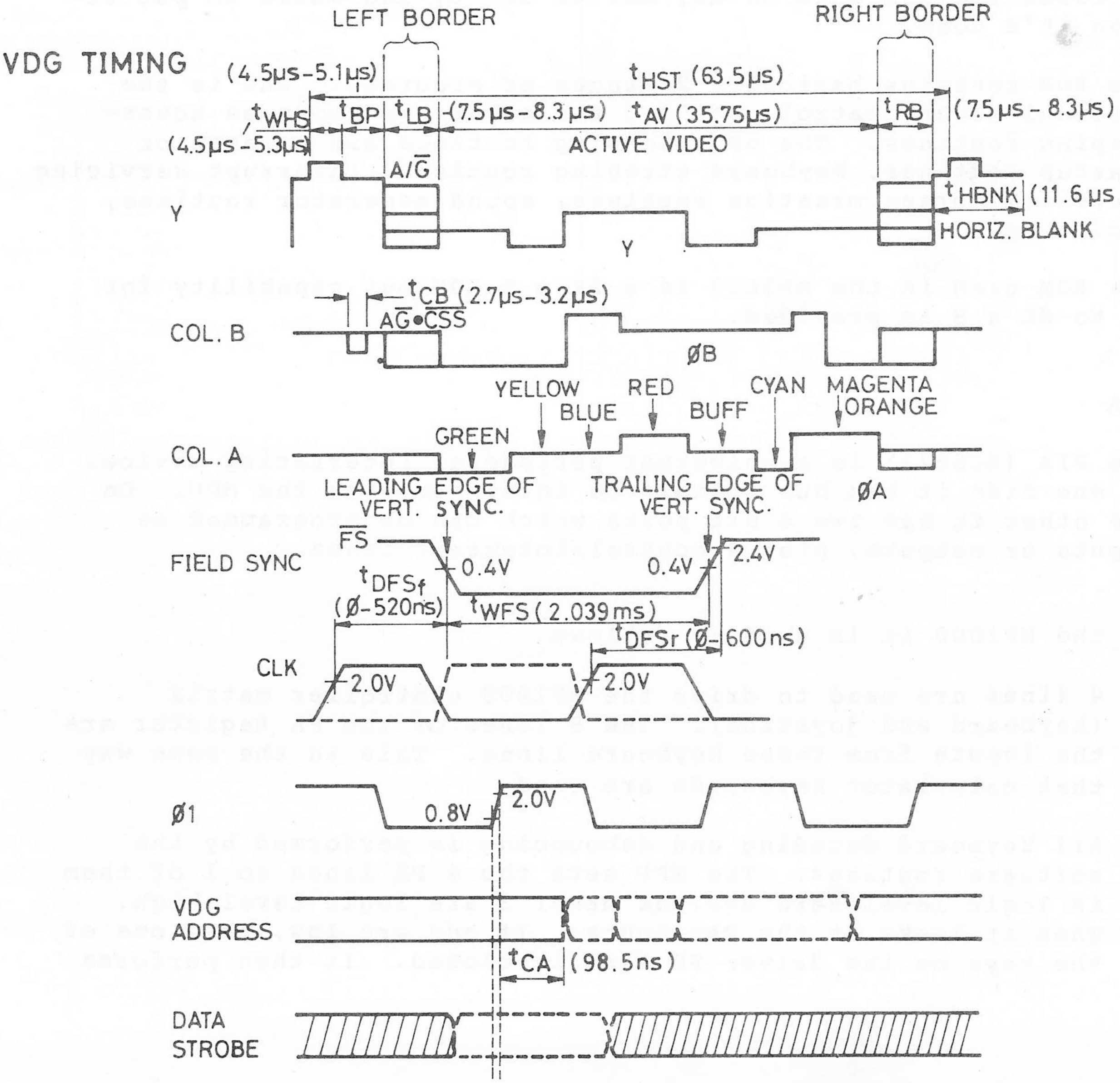
High Resolution Graphics (128 x 192 or 256 x 192)

This mode is implemented similar to the alphanumeric mode except the character shapes are not predefined in ROM like the ASCII characters are. Instead they are defined in RAM by the program. The screen is mapped to have 32 x 12 character boxes. Each box is 8 dots or 4 dots wide by 16 dots high.

The object shapes are defined in one section of memory, and the image map in another.

The system is forced to do 2 fetches from memory before sending data to the VDG for interpretation. The first fetch gets the object number, and the second gets the details of the particular row of the object.

For more details in programming in this mode, see Chapter VIII.


VDG TIMING

MC1372

The MC1372 color TV video modulator is used to generate an RF TV signal from baseband color-difference and luminance signal supplied by the VDG.

The MC1372 also supplies the system 3.579545 MHz clock. The device contains a chroma subcarrier oscillator, lead and lag networks, suppressed carrier DSB chroma modulator; and RF oscillator and modulator.

In the MP1000 the luminance, chroma and sound carrier signals are inputted to the MC1372. The output is a modulated RF signal whose carrier frequency is set by the LC tank circuit.

ROM

The ROM contains sequences of MC6800 instruction codes and data. It tells the MPU what to do, how to do it, and where to put it when it's done.

The ROM contains basically 2 groups of programs. One is the internal rocket patrol game and the other are known as housekeeping routines. The housekeeping routines are a reset or startup routines, keyboard strobing routines, interrupt servicing routines, screen creation routines, sound generator routines, etc.

The ROM used in the MP1000 is a 2K x 8 ROM but capability for up to 8K x 8 is provided.

PIA

The PIA (MC6821) is a universal peripheral interfacing device. On one side it has bus signals to interface with the MPU. On the other it has two 8 bit ports which can be programmed as inputs or outputs, plus 4 control/interrupt lines.

In the MP1000 it is used as follows

1) 4 lines are used to drive the MP1000 controller matrix (keyboard and joystick). The 8 lines of the PA Register are the inputs from these keyboard lines. This is the same way that calculator keyboards are read.

   All keyboard decoding and debouncing is performed by the software routines. The MPU sets the 4 PB lines so 1 of them is logic level zero and the other 3 are logic level high. Then it looks at the PA inputs. If any are low, then one of the keys on the driver PB line is closed. It then performs decoding and debouncing of that key. If not, it changes the 4 PB lines so the next one is low with the other 3 high and, again, looks at the PA inputs.

2) PB6 - drives the GMO input of the VDG.

3) PB7 - selects alphanumeric or graphics mode.

4) CA2 - controls the object latch register.

5) CB2 - generates a sound oscillator

6) CB1 - inputs field sync from the VDG and passes it to the MPU as an interrupt signal.

Register control of the PIA is given in Table 1-1.

MEMORY AND ADDRESS MULTIPLEXING

The screen memory consists of 1K x 8 bytes. It is comprised of 2 x 2114 (1K x 4) memory chips. Access time on these parts is 200 NS which is very critical.

Only the MPU can write data to memory, but there are 4 possible addressing modes for reading. These are

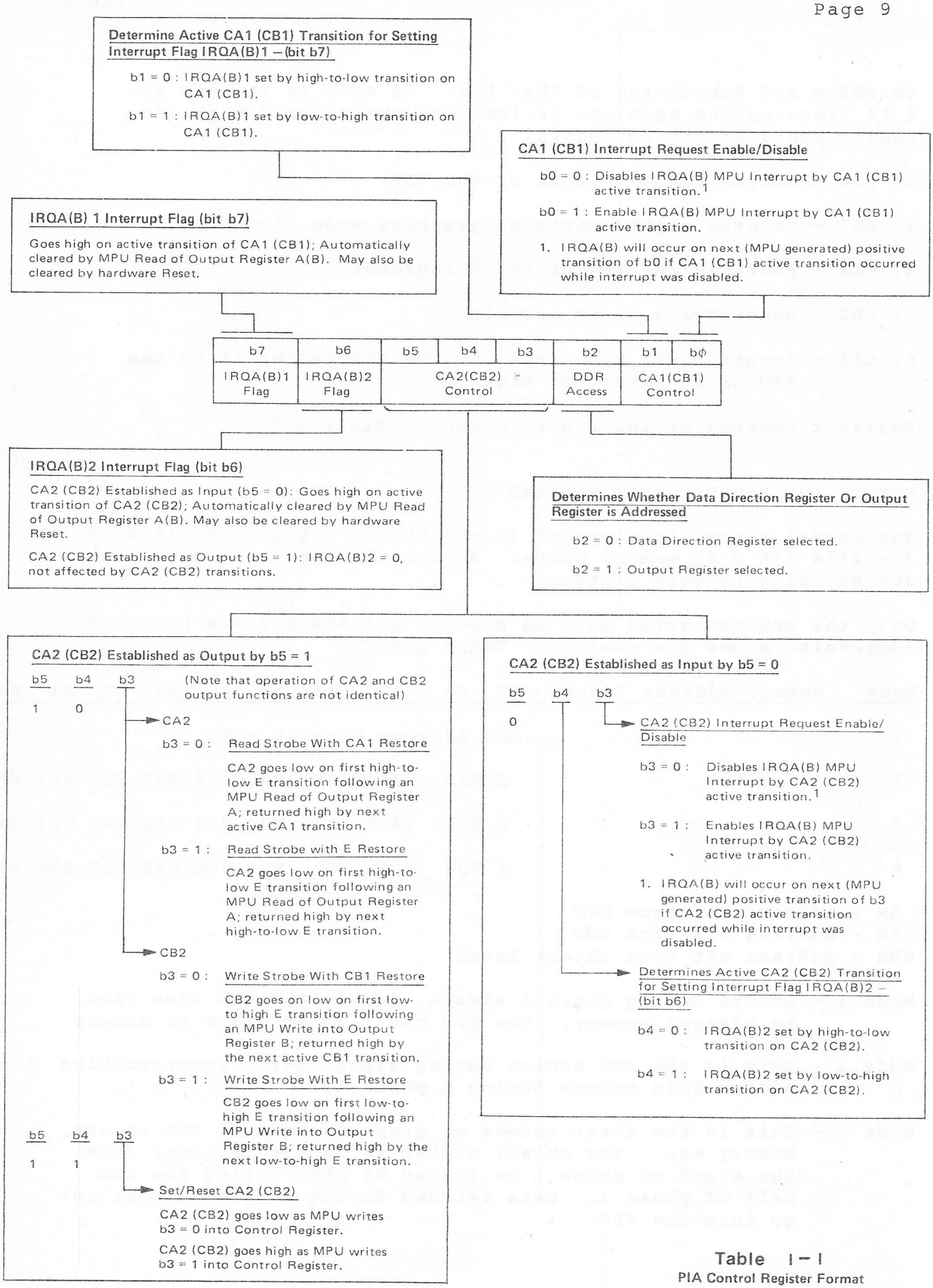
Mode	Memory Address Input → A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
1	MPU Address Bits A9 - A0									
2	1	VA8	VA7	VA6	VA5	VA4	VA3	VA2	VA1	VA0
3	0	VA12	VA11	VA10	VA9	VA4	VA3	VA2	VA1	VA0
4	1	VD4	VD3	VD2	VD1	VD0	VA8	VA7	VA6	VA5

AN - Address bit from CPU
VAN - Address bit from VDG
VDN - Address bit from object latch

Mode 1 - Occurs during phase 2 always, and is the MPU time slot to address memory. The CPU can read or write to memory.

Mode 2 - This is the VDG access during alphanumerics/semigraphics mode. This occurs during a phase 1.

Mode 3 - This is the first access on graphics mode of the screen memory map. The object number is latched halfway from the start of phase 1 so it can be used during the 2nd half of phase 1. Data fetched during this mode does not go into the VDG.



b7	b6	b5	b4	b3	b2	b1	bφ
IRQA(B)1 Flag	IRQA(B)2 Flag	CA2(CB2) Control			DDR Access	CA1(CB1) Control	

Determine Active CA1 (CB1) Transition for Setting Interrupt Flag IRQA(B)1 – (bit b7)

b1 = 0 : IRQA(B)1 set by high-to-low transition on CA1 (CB1).

b1 = 1 : IRQA(B)1 set by low-to-high transition on CA1 (CB1).

CA1 (CB1) Interrupt Request Enable/Disable

b0 = 0 : Disables IRQA(B) MPU Interrupt by CA1 (CB1) active transition.[1]

b0 = 1 : Enable IRQA(B) MPU Interrupt by CA1 (CB1) active transition.

1. IRQA(B) will occur on next (MPU generated) positive transition of b0 if CA1 (CB1) active transition occurred while interrupt was disabled.

IRQA(B) 1 Interrupt Flag (bit b7)

Goes high on active transition of CA1 (CB1); Automatically cleared by MPU Read of Output Register A(B). May also be cleared by hardware Reset.

IRQA(B)2 Interrupt Flag (bit b6)

CA2 (CB2) Established as Input (b5 = 0): Goes high on active transition of CA2 (CB2); Automatically cleared by MPU Read of Output Register A(B). May also be cleared by hardware Reset.

CA2 (CB2) Established as Output (b5 = 1): IRQA(B)2 = 0, not affected by CA2 (CB2) transitions.

Determines Whether Data Direction Register Or Output Register is Addressed

b2 = 0 : Data Direction Register selected.

b2 = 1 : Output Register selected.

CA2 (CB2) Established as Output by b5 = 1

b5 b4 b3
1 0

(Note that operation of CA2 and CB2 output functions are not identical)

CA2

b3 = 0 : Read Strobe With CA1 Restore

CA2 goes low on first high-to-low E transition following an MPU Read of Output Register A; returned high by next active CA1 transition.

b3 = 1 : Read Strobe with E Restore

CA2 goes low on first high-to-low E transition following an MPU Read of Output Register A; returned high by next high-to-low E transition.

CB2

b3 = 0 : Write Strobe With CB1 Restore

CB2 goes on low on first low-to high E transition following an MPU Write into Output Register B; returned high by the next active CB1 transition.

b3 = 1 : Write Strobe With E Restore

CB2 goes low on first low-to-high E transition following an MPU Write into Output Register B; returned high by the next low-to-high E transition.

b5 b4 b3
1 1

Set/Reset CA2 (CB2)

CA2 (CB2) goes low as MPU writes b3 = 0 into Control Register.

CA2 (CB2) goes high as MPU writes b3 = 1 into Control Register.

CA2 (CB2) Established as Input by b5 = 0

b5 b4 b3
0

CA2 (CB2) Interrupt Request Enable/Disable

b3 = 0 : Disables IRQA(B) MPU Interrupt by CA2 (CB2) active transition.[1]

b3 = 1 : Enables IRQA(B) MPU Interrupt by CA2 (CB2) active transition.

1. IRQA(B) will occur on next (MPU generated) positive transition of b3 if CA2 (CB2) active transition occurred while interrupt was disabled.

Determines Active CA2 (CB2) Transition for Setting Interrupt Flag IRQA(B)2 – (bit b6)

b4 = 0 : IRQA(B)2 set by high-to-low transition on CA2 (CB2).

b4 = 1 : IRQA(B)2 set by low-to-high transition on CA2 (CB2).

Table I – I
PIA Control Register Format

Mode 4 - This is the 2nd access in graphics mode. The row number is determined by VA5-VA8 (1 of 16) and the object # (from the latch) are sent to memory. The resulting data is clocked into the VDG. This mode occurs during the 2nd half of phase 1 during graphics mode.

MODE SELECTION

Depending upon whether the VDG is in graphics or alphanumerics mode, the memory is mapped differently. The two maps are shown in figure 3-2 in Chapter 3.

POWER SUPPLY

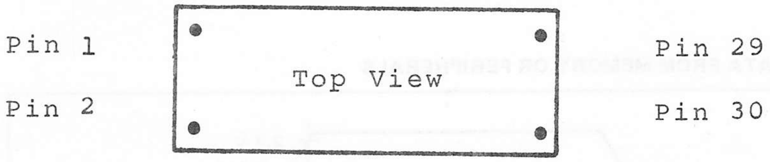
The power supply consists of an external A.C. adaptor and internal circuits.

The A.C. input (approximately 9.6 volts) is rectified, filtered and regulated to provide a D.C. voltage of 5 volts +/- 5%. This is used to supply all of the semiconductors in the MP1000. Maximum current capability is approximately 1 amp.

CARTRIDGE SOCKET

The cartridge socket provides all of the signals to the outside world.

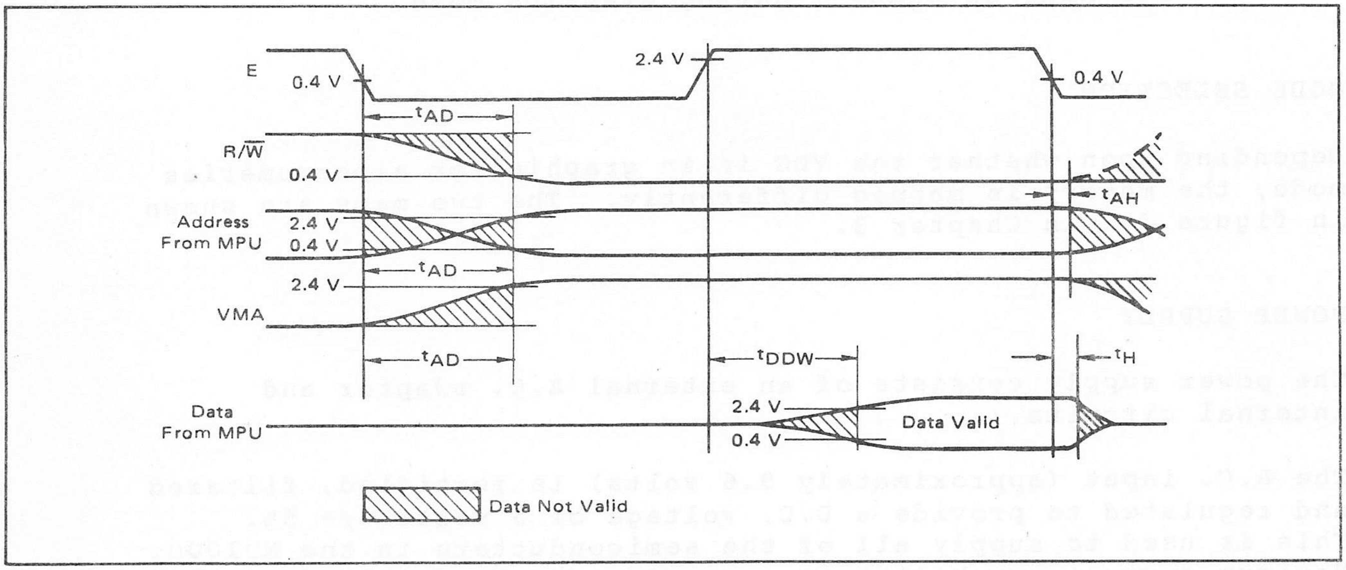
These pinouts are as follows



Pin	Signal	Pin	Signal
1	D0	16	A7
2	A0	17	D3
3	D1	18	A15
4	A1	19	Read/Write
5	D2	20	A8
6	A2	21	Phase 2
7	Ground	22	A14
8	A3	23	EN $\overline{89}$
9	D7	24	A9
10	A4	25	VMA
11	D6	26	A13
12	A5	27	+5 Volts
13	D5	28	A10
14	A6	29	A11
15	D4	30	A12

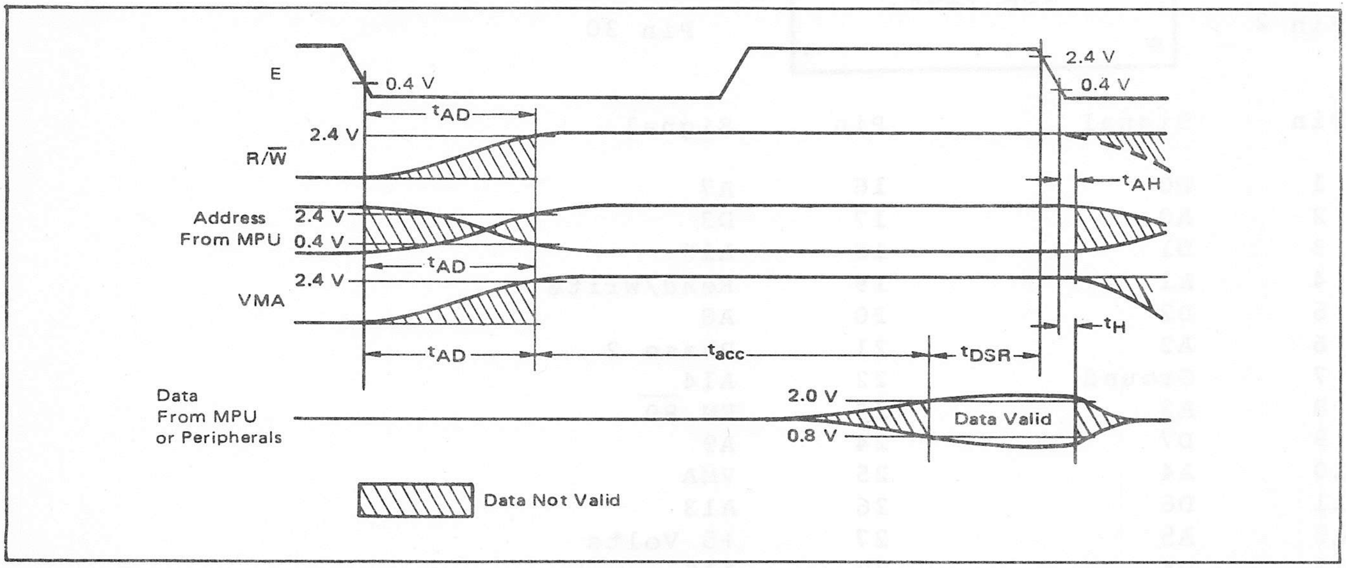
SYSTEM TIMING

WRITE DATA IN MEMORY OR PERIPHERALS



tAD = 270 ns maximum
tacc = 530 ns maximum
tDSR = 100 ns maximum
tAH = 20 ns maximum
tH = 20 ns maximum
tDDW = 165 ns maximum

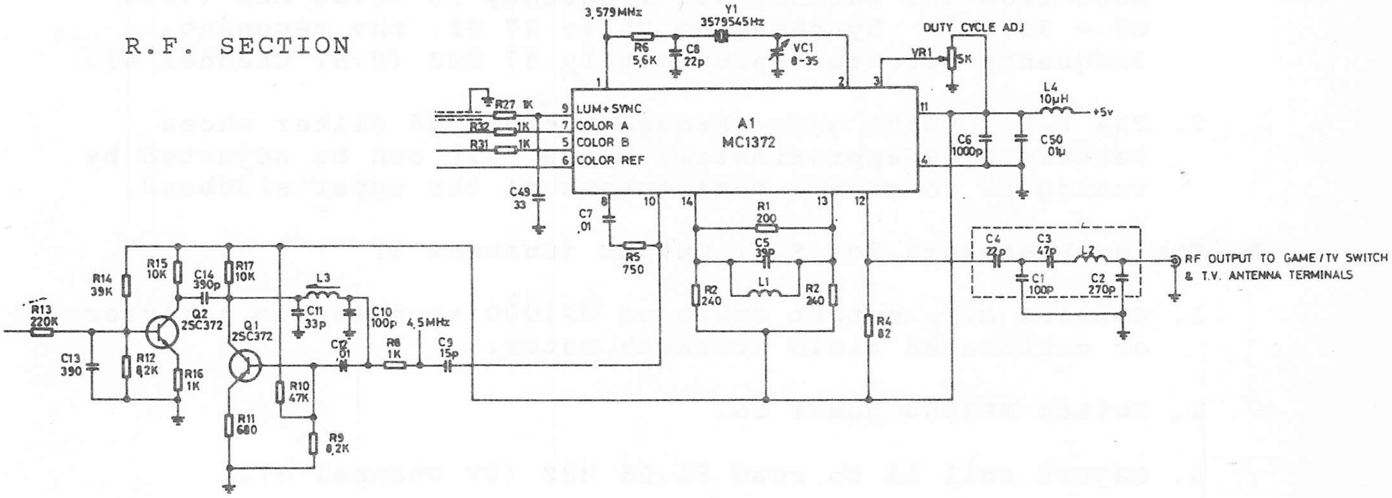
READ DATA FROM MEMORY OR PERIPHERALS

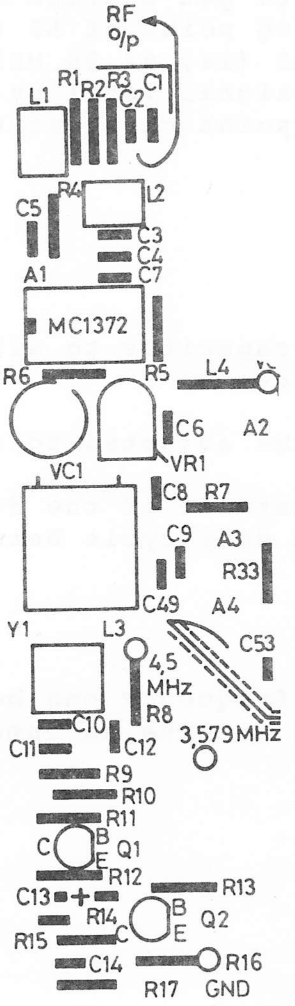


ADJUSTMENTS AND TUNING

Inside the MP1000 there are several adjustments that can be made

R.F. SECTION





R.F. OUTPUT

A. 1. The R.F. Output Frequency is set by L1 and C5. L1 is an air core coil and will allow approximately a ±6 MHZ adjustment from the factory set frequency of 61.25 MHZ (with C5 = 39 PF). By changing C5 to 27 PF, the resonant frequency becomes approximately 67 MHZ (U.S. Channel 4).

2. The R.F. Output goes through a sideband filter whose bandwidth is approximately 6 MHZ. It can be adjusted by tuning L2 to give a peak output of the upper sideband.

B. Tuning Procedure for R.F. Output (Channel 3)

1. Connect R.F. output cable of MP1000 to spectrum analyzer or calibrated field strength meter.

2. Switch MP1000 power on.

3. Adjust coil L1 to read 61.25 MHZ (TV Channel 3).

4. Adjust coil L2 to get maximum output signal strength then adjust the tuning point of L2 to 1 MHZ higher than TV Channel 3 signal (ie, 62.25 MHZ) or tuning of L2 to reduce maximum output signal level by about 1 db. This also gives a tuning point close to 62.25 MHZ.

CRYSTAL OSCILLATOR

A. VC1 is a variable capacitor to allow adjustment of the xtal oscillator frequency.

This clock should be adjusted to give exactly 3.579545 MHZ.

B. VR1 allows an adjustment of the duty cycle. It should be adjusted to give a duty cycle between 45 and 55%.

SOUND OSCILLATOR

The sound subcarrier frequency can be adjusted by tuning L3. It should be adjusted to give an unmodulated frequency of 4.500 MHZ.

CHAPTER II

THE MPA-10

The MPA-10 base unit adds the following to the MP1000

1. An interconnection (the J Connector)
2. A main unit with 8K of RAM and keyboard
3. A power supply for the MPA-10 circuits and expansion
4. A tape deck for both audio and digital recording/playback
5. A cartridge with a Basic interpretor
6. Provision for expansion

J CONNECTOR

The MP1000 and MPA-10 are electrically joined by the J Connector (this is so named because its physical configuration looks like the letter J).

Besides connecting the signals between the 2 units, it buffers the address and data lines.

MAIN UNIT

The main unit of the MPA-10 has the following subsections

1. A memory section
2. A PIA
3. A decoding section

The memory is comprised of 8 - 8K x 1 dynamic memory chips.

The MC3242 chips multiplexes the 13 addresses to the memory as 7 row addresses, and 7 column addresses. The control of these is determined by $\overline{\text{ROWEN}}$. The MC3242 also performs the task of memory refresh during Phase 1 when the MPU is not addressing memory. The rest of the memory section is comprised of timing and control implemented using a TTL delay line to develop RAS (row address strobe), $\overline{\text{CAS}}$ (column address strobe) and ROWEN.

Memory timing is in Figure 2-2.

The PIA is used to strobe the keyboard lines (similar to the MP1000 strobing) and to control the tape system. A 3-bit code is put into PB0-PB2, and decoded by a 74LS145 (1 of 8 decoders). These become the strobe lines and are looked at by the PA0-PA7 inputs of the PIA. As in the MP1000, all decoding and debouncing of the keyboard is performed by the software. To deal with tape are the following signals:

PB3 - AUDEN - Enables or disables audio section of tape deck
PB4 - MOTEN - Enables or disables tape deck motor. This can be overridden by the fast forward or rewind buttons
PB5 - $\overline{\text{WREN}}$ - Indicate to tape whether to read or write to digital track.
PB6 - WRDATA - Digital data to tape deck from the MPU
PB7 - READDATA - Digital data from tape deck to the MPU

Decoding Section - The rest of the MPA-10 base unit has address decoding and expansion bus signal generation.

Keyboard - The keyboard consists of 53 keys. It is set up as a 7 x 8 matrix. All reading of keyboard, decoding and debouncing is performed in software.

Tape Deck/Power Supply

The MPA-10 has its own power supply. The supply receives an A.C. input from the A.C. adaptor. 4 D.C. voltages are developed

+ 5 volts ±5%
+ 12 volts ±5%
- 12 volts
- 5 volts

These supplies feed all the circuits of the MPA-10 plus go to the expansion bus.

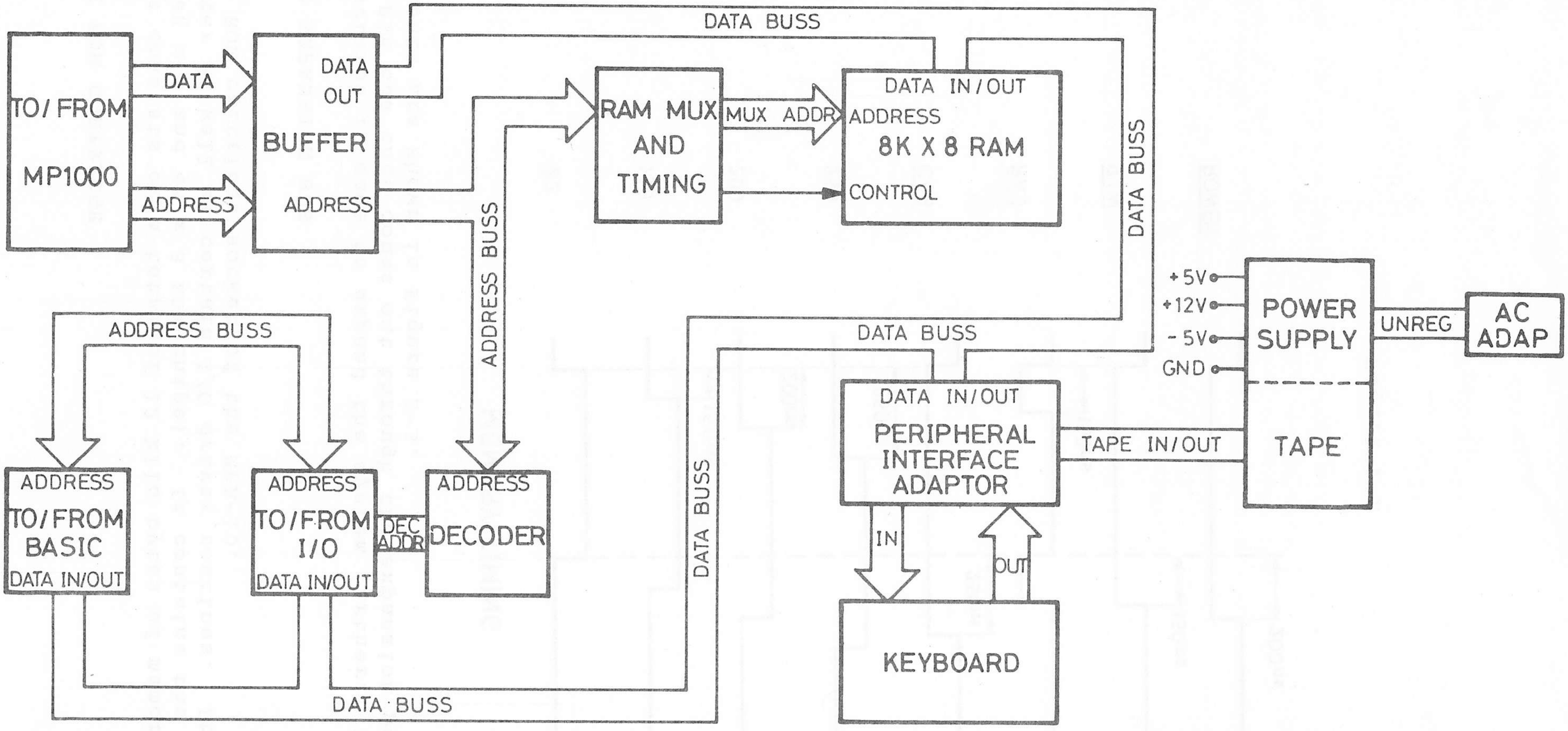
The tape circuits are comprised of 2 parts

Audio Section - This is for monural record or playback of audio signals. The 2 changes from standard designs are:

a) A half track erase head that only erases the audio portion of the tape.

b) An enable or disable to the audio section (from the MPA-10 PIA). This enables/disables both recording of audio or playback.

Digital Section - Saturated recording is used to write digital data. Sufficient current is driven through the record head to fully polarize the tape in one direction or the other. All encoding of digital ones and zeros is performed in software. The digital recovery circuits take the magnetic field from the tape and recover them into logic levels which then go back to the PIA. All decoding of digital data is performed by the software.



APF ELECTRONICS INC.
BLOCK DIAGRAM - MPA10

Figure 2-1
MPA-10 Block Diagram

THE ROM CARTRIDGE

This consists of a total of 12 kilo bytes of memory (comprised of an 8K x 8 and 4K x 8 ROM chips). It contains the Basic interpreter as well as certain I/O driver routines. It plugs into the ROM cartridge socket of the MPA-10.

THE EXPANSION BUS

Provision is made to expand the system further. There is a 50 Pin bus that comes out through the expansion ports. Its pinouts are shown in Figure D-3.

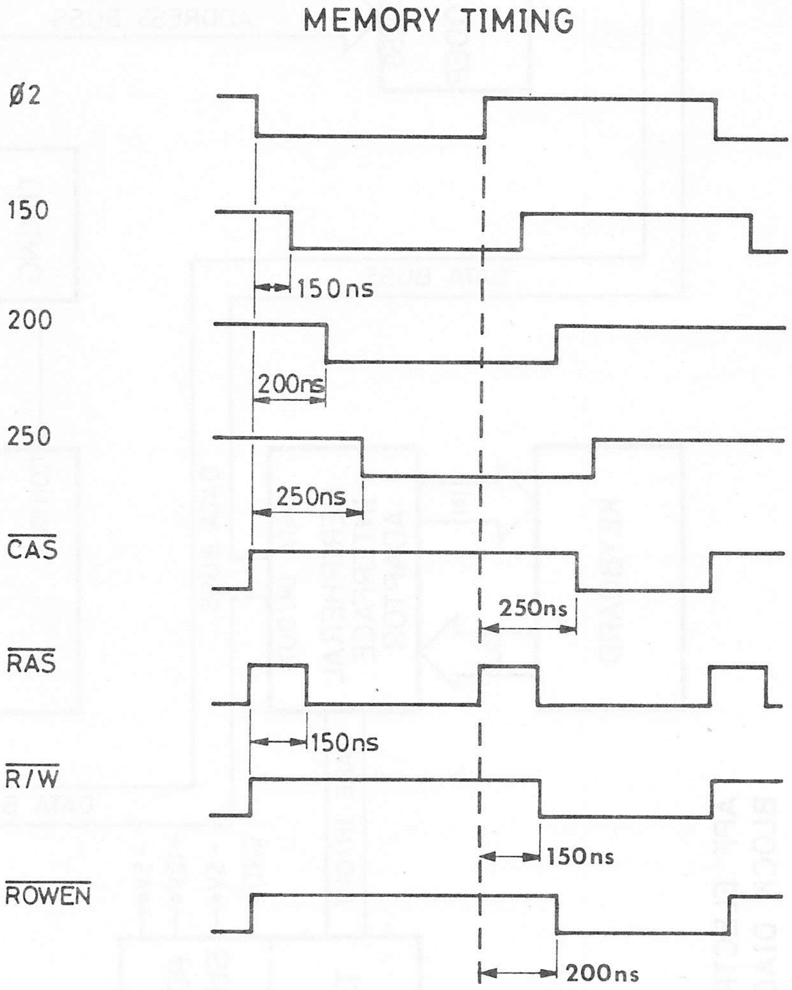


Figure 2-2

CHAPTER III

THE IMAGINATION MACHINE MEMORY MAP

Address		
Hex	Decimal	Description/Useage
0000-03FF	0-1023	MP1000 internal memory. 1K of memory is used. See Figure 3-2 for details of useage.
0400-1FFF	1024-8191	Each 1K block is same as 0000-03FF.
2000-2003	8192-8195	Peripheral interface adaptor (Motorola MC6821) used in MP1000. See Figure 3-3 for details.
2004-3FFF	8196-16383	Each 4 consecutive adress same as 2000-2003.
4000-5FFF	16384-24575	Internal ROM of MP1000
6000-6003	24576-24579	Peripheral interface adaptor used in MPA-10 section.
6004-63FF	24580-25599	Each 4 consecutive address same as 6000-6003.
6400-67FF	25600-26623	For external I/O devices.
6800-77FF	26624-30719	Basic interpretor ROM cartridge (4K).
7800-7FFF	30720-32767	For ROM expansion
8000-9FFF	32768-40959	Basic interpretor ROM cartridge (8K).
A000-BFFF	40960-49151	Read/Write memory. See Chapter IV for details.
C000-DFFF	49152-57343	Expansion read/write memory
E000-FFEF	57344-65519	Not used.
FFF0-FFFF	65520-65535	MC6800 reset/interrupt vectors - ROM.

Figure 3-1

1K Internal MP1000 Useage

$ = Hexadecimal; Otherwise Decimal

$0000 0000	384 Bytes	0383 $017F	Graphics Mode - used for screen map. Alpha/Semi Mode - not used. Not used by Basic interpretor
$180 384	128 Bytes	511 $01FF	Used only by ROM cartridge games as scratch pad and stack area. Not used by Basic interpretor.
$0200 512	512 Bytes	1023 $03FF	Alpha/Semi Mode - used for screen image Graphics Mode - used for object shape definitions.

Figure 3-2

MP1000 Peripheral Interface Adaptor Addressing (Addresses in Hex)

$2000 - Data Register A
$2001 - Control Register A

$2002 - Data Register B
$2003 - Control Register B

Figure 3-3

CHAPTER IV

HOW IS MEMORY USED AND ALLOCATED

The 8192 bytes of memory from A000-BFFF (decimal 40960-49151) is used for all storage except screen maps. It is allocated as follows:

Decimal	Hex	
40960	A000	SYSTEM VARIABLES, LABEL TABLES, SIMPLE VARIABLES
▼	▼	
41727	A2FF	
41728	A300	I/O BUFFER
▼	▼	
41983	A3FF	
41984	A400	PROGRAM TEXT
		▼
		COMPLEX VARIABLE STORAGE
		▼
		FREE MEMORY
▼	▼	▲
49151	BFFF	STACKS

PROGRAM STORAGE

Program steps are stored in the following format:

First 2 bytes are for the line # (in packed BCD Code).

Then ASCII and token code for statement with all spaces removed except those in quotes, print using definitions or remarks. Note all keywords are stored as a 1 byte token code. See Appendix D for the complete list.

Finally, carriage return symbol (Hex 0D).

A400 and A401 are used to point to the next locations to store a statement (they start off upon initialization set with Hex A402). Actual program storage starts at A402.

As an example of program storage, let's enter the following program:

<u>10 PRINT 123</u>

To look at memory, do a <u>CALL 28672</u>. This enters the machine language monitor mode. You now should get an * instead of the cursor.

Using the M Command (Examine/Change Memory) type:

```
                 ┌──────────── You type these
*   M   A400    A4
                 └──── And see the contents of A400
```

Next, press / (Don't press Return after the A4 is shown.). This command will show the next memory address and its contents.

```
A401 09
```

The contents of A400 and A401 are A409. This is the next free location. If we went back to Basic and entered another statement, its storage would start at A409. Before returning to Basic, let's look at the next 8 memory locations. Just keep pressing the Slash Key. You will see the following:

Hex Address	Hex Data	
A402	00/	Line Number - This is packed BCD Code --
A403	10/	Line Number is 0010.
A404	91/	Token for print Command
A405	31/	ASCII Codes for 123
A406	32/	
A407	33/	
A408	0D/	Carriage return - end of statement line delimiter
A409	00	

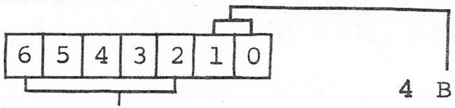
VARIABLES

The variable list or label table (for 26 variable names) is stored starting at hexadecimal A0C3. Each label or name takes 9 bytes as follows:

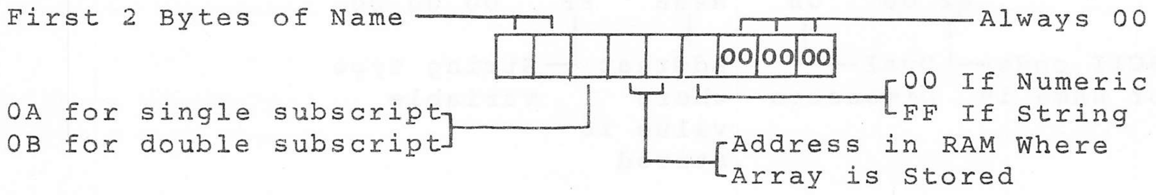
First 2 bytes are for variable name. Variable names can be longer, but only the first 2 characters are stored.

Then 7 bytes:

If non subscript numeric variable (such as I), they are 7 byte value in packed BCD.



If the variable is of the subscripted type (dimensioned), then the 9 bytes are as follows:



Let's try an example. Clear the machine and enter the following:

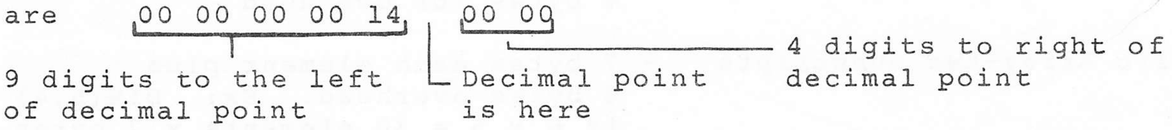
```
10 I = 14
20 DIM A(6), B$(7,4)
30 J = 12345678.99
40 DIM C(1,1)
```

If we go examine the label table now, we will find it empty. The label table will only contain entries when statements using variables are executed, not when they are keyed in.

Type RUN
Now let's go to the examine memory mode
CALL 28672
As opposed to examining single memory bytes at a time, we will use the D Command to display 16 bytes at a time. We get

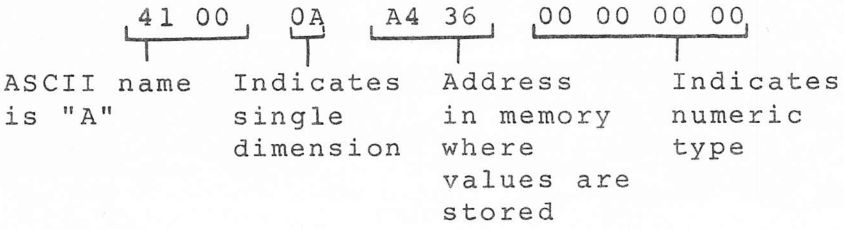
```
*DA0C3 49 00 00 00 00 00 14 00 00
41 00 DA A4 36 00 00
```

Examing the first 9 bytes only
The first 2 are 49 00. The 49 is ASCII for the Letter I and 00 is null. So, the first entry in the table is the variable I. The next 7 bytes are the value in packed BCD form. They are



Let's continue with the next entry in the table. Its entry starts at A0CC (A0C3+9).

Using the D Command again (DA0CC), let's look at the 9 bytes starting at A0CC



Continuing in the table, the next entry is at A0D5. The 9 bytes will be

```
              42 00    0B    A46B    FF    00 00 00
                 |      |     |       |
ASCII code ------  Dual --    Address  -- String type
for name is      Dimension    where       variable
B                             value is
                              stored
```

If you continue on your own, you will find the entries for J and then C.

MEMORY AMOUNT USED BY VARIABLES

The pointers for where to store dimension variables are at 41009, 41010 (Hex A031, A032). As dimension statements are executed, the pointers direct the interpreter where to allocate space and are updated with each allocation.

A RUN command initializes 41009, 41010 to have the same numbers as 41984 and 41985 respectively.

For all dimensioned variables there are always 4 bytes preceding the actual stored values. These bytes contain the actual dimensions of the array and are called the overhead.

Simple (numeric non subscript) - 9 bytes in name table only

String (single dimension) - 1 byte per character dimensioned plus 4 bytes for overhead.

Numeric Array-single subscript - 7 bytes per dimension plus 4 bytes for overhead

Numeric Array-two subscripts - 7 bytes each element plus 4 bytes overhead. Ex: DIM(5,4) is 6 x 5 = 30 elements x 7 bytes = 210 plus 4 overhead = 214 bytes

String-two subscripts - 1 byte per character dimensioned plus 4 bytes overhead.

CHAPTER V

ENTERING AND USING MACHINE LANGUAGE PROGRAMS

Machine Language Programs (those written in MC6800 code) can be entered and used as part of a Basic program. They also can be saved on tape with a Basic program.

Machine Language Programs are useful where speed is essential (and a program written in Basic is too slow) or to implement routines that are not available in the Basic language.

ASSEMBLING AND ENTERING MACHINE LANGUAGE PROGRAMS

MC6800 programs for machines with a cassette only have to be hand assembled. Units with disks can use the APF Assembler/ Editor.

Appendix A gives a table of MC6800 machine code. For more details refer to a MC6800 programming reference manual. Once a program is assembled, it can be entered into the machine in hexadecimal format by using the machine Language Reference Mode. This is entered by a Call Statement (See Appendix B for details).

METHOD 1 - THIS METHOD IS FOR AN ENTIRELY WRITTEN MACHINE LANGUAGE PROGRAM.

Statement #10 will always be CALL 42200 (42200 is Hex A4D8). Then the machine program is entered starting at A4D8.

A problem that must be overcome is that a RUN command will clear to "00" all memory locations from the end of program storage to the end of memory. If we just type in statement 10 as above, then key in our machine language program, a RUN command will wipe out the program since the Basic Interpretor only knows about line 10 in the program and clears everything after it to 0. The solution is very simple. After entering the machine language codes, we change the end of program pointer so it points past our machine language program. The end of program pointer is 2 bytes contained at A400 and A401. They must be set to BF and F0 respectively before giving a RUN command. They also are saved to tape so once changed they will stay changed.

As an example - to write a program to fill the screen with all blue. This, of course, could be done with HLIN, but Machine Code will be faster and serves as a simple example.

First reset the system and key in

```
10 CALL 42200
15 STOP
```

This will be the entire Basic program and a Run Command will execute it. (Don't type RUN yet since we haven't entered the program at 42200.)

Now enter the machine language mode (CALL 28672). The machine program will start at Hex A4D8 (decimal 42200). The program is:

ADDRESS	CONTENTS	INSTRUCTION	COMMENT
A4D8	CE	LDX #$200	Load X reg with starting screen address
A4D9	02		
A4DA	00		
A4DB	86	LDAA #$DF	Load A reg with code for blue square
A4DC	DF		
A4DD	A7	STAA 0,X	Store A indexed
A4DE	00		
A4DF	08	INX	Increment X register
A4E0	8C	CPX #$400	Is X equal to end screen address yet
A4E1	04		
A4E2	00		
A4E3	26	BNE -8	If not, do next address
A4E4	F8		
A4E5	7E	JMP #$8894	Jump back to Basic
A4E6	88		
A4E7	94		

Enter the machine language program by using the M Command. See Appendix B if you are unclear on how to use this mode.

Before returning to Basic, change A400/A401 to BF and F0 respectively so a RUN command doesn't wipe out your program.

```
MA400    BF/
A401     F0 Return Key
```

Next return to Basic with G8894.

Now run the program and then save it to tape if you want.

Note: If you try to list the program now, you will get garbage on the screen. The List command will go from beginning of program memory to end of program memory (and we changed the end pointer) and interpret everything as an ASCII Code or Token.

METHOD 2 - YOU CAN USE A MACHINE LANGUAGE ROUTINE AS PART OF A BASIC PROGRAM. YOU CAN ENTER ONE OR MORE MACHINE LANGUAGE ROUTINES, ACCESS THEM FROM A BASIC PROGRAM AND PASS VARIABLES BETWEEN THEM.

The way this is done is to enter "dummy" Remark Statements in the program. In the comment field of the Remark Statement type in enough characters to allow space for the machine program (it is suggested you use a single letter, repeated in the Remark Statement so it is easy to find exactly where in memory it is stored).

As an example, let's do a program to set the screen to have 1 single character code fill it up. The code we put to the screen will be found in memory location 0000. (We can POKE location 0 with a code.) The steps are:

1. Write the machine language routine first so we can get a count of the number of bytes it will use up. Don't try to figure the actual addresses in memory where it will go since we have to put the "Basic" program in first. The machine language program will be:

   ```
   CE 0200     LDX#$0200     Start of screen adding

   96 00       LDAA 0        Character to be put to screen
                             is stored at Location 0.

   A7 00       STAA 0,X      Store A indexed

   08          INX           Increment index register

   8C 0400     CPX #$400     Is X equal to.end screen address
                             yet

   26 F8       BNE -8        If not, do next address

   39          RTS           Return from subroutine
   ```

   Adding up the number of bytes for the above routine, we get 14.

2. Next we enter the Basic program

```
10    REM    AAAAAAAAAAAAAA
20    POKE   0,223
30    CALL   11111
```

Line 10 is the Dummy Remark Statement. It is in the space occupied by Line 10 in memory that we will put in the machine language program. We put in the Remark Statement 14 letter A's (you could put in 14 of anything). Line 20 pokes to Location 0,223. Location 0 is used by our machine program to contain the value to be stored to the screen (223 is Hex DF, which is a blue square). Line 30 is the Call to machine language routine. Right now we have called 11111. We don't know yet exactly where in memory the routine will be located, so again we use a temporary number (it will be a five-digit address).

3. We are now ready to enter the machine language routine. Type CALL 28672 then press Return Key. We enter the monitor mode now to find where the Remark Statement of Line 10 is stored.

Do a D A400 and you see

```
* A400 A4 27 00 10 94 20 20 41 41
  41 41 41 41 41 41 41
```

These numbers are the 16 bytes of memory starting at A400. The first 2 (A427) are the end of program storage pointers.

The next 2 (0010) are the first line number in packed BCD Code.

The 94 20 20 is the token code for a remark command (A remark uses 3 bytes for token storage).

Next we see a series of 41. This is the ASCII Code for the letter A, and it is here we want to put our machine routine. Since the first 41 is the 8th byte in the display, its address is A407. Going back to our machine language routine, we can now fill in address

```
ADDRESS     CODE

 A407      CE 0200
 A40A      96 00
 A40C      A7 00
 A40E      08
 A40F      8C 0400
 A412      26 F8
 A414      39
```

Press Return and type

```
M A407   You see the data is 41.  Change it to CE and hit
         /.  You will see the next line.
A408 41  Change this to 02 and hit /.
```

Continue with this till you enter the 14 bytes of program.

After keying in the program, it is a good idea to check it.

```
Type DA407   CE  02 00 96 00 A7 00 08 8C
     04 00 26 F8 39 0D 00
```

If the memory matches the above, press Return. If not, go to the incorrect address (use the M Command) and correct it.

Let's return to Basic.

```
G8894
```

4. We are almost ready. We just have to change the Call Address in line 30. Our program starts at A407 which is 41991 in decimal.

   Change Line 30 to be

   ```
   30 CALL 41991
   ```

5. If you followed everything OK, then let's give a Run Command.

   ```
   RUN Return
   ```

   The screen should have turned blue almost instantly, and the cursor is back. (The cursor is blue, so press Return a couple of times to clear the screen.)

6. You have now successfully done a machine language routine. It can be saved on tape with the rest of the program (just give a CSAVE).

   You can add to the program. Just don't add anything in front of Line 10. That would shift Line 10's code in memory, and the CALL address in Line 30 would become wrong.

Some Guidelines on Writing Machine Language Routines

1. When writing a program in both Basic and CALLS to Machine routines, the most important thing is to PLAN IT OUT VERY CAREFULLY. It can be very difficult to make changes later

on. Once a Remark Statement is put in and then replaced by a machine routine, do not put in any "Basic" Statements with lower line numbers than the Remark Statement. An insert of a "Basic" Statement will shift all memory contents upward, and you will have to change your CALL Statement.

2. Leave extra places in a Remark Statement (at least 3). If you later find you have to add something in machine code, you can do a jump to subroutine if you leave room.

3. The end of your routines should be an RTS (Return from Subroutine) and not a jump to 8894.

4. If you want to access dimensioned variables in machine language, <u>FORCE</u> them to be located where you want them. By Poking 41009 and 41010 prior to a Dimension Statement, you can force where a variable is located.

5. The next 3 chapters have lists of several machine language routines that might be useful.

CHAPTER VI

SOME USEFUL ROUTINES

You might find that there are some routines or functions not built into the Basic interpreter that you need. Most can be implemented using either PEEKS/POKES/CALLS in machine language or with subroutines written in Basic.

"PRINT AT"

If you want to print anywhere on the screen, use a routine that changes the cursor pointer and do a GOSUB to it before doing a Print Statement. The screen resides at locations 512-1023. Remember, you can print anywhere in memory, but only 512-1023 appears on the screen.

The cursor is stored as 2 bytes in memory locations 40960 and 40961 (Hex A000/A001).

```
 10 GOTO 100
 20 REM:  ROUTINE TO MOVE CURSOR POSITION TO VALUE OF CU.
 25 POKE 40960, INT (CU/256):  POKE 40961, CU:  RETURN
100 FOR I = 1 TO 32:  PRINT:  NEXT:  REM CLEAR SCREEN TO GREEN
110 INPUT "LINE AND COLUMN TO START PRINT", L, C
120 CU = 512 + L * 32 + C:  GOSUB 25:  PRINT "HI"
125 INPUT "MORE", K:  GOTO 100
```

Line 100 - will clear the screen to all green.

Line 110 - asks for a horizontal line number (L), and a vertical column number (C) where you want to start printing at. It converts these to the actual memory location on the screen. 512 is the top corner of the screen so we add to it the number of lines (L) times 32 (32 characters per line), and add the column.

Line 25 - We enter line 25 with the variable CU having the memory location we want to change the cursor pointers to have. Since the cursor pointer is a double byte location (it takes 2 bytes to point to a memory location between 0 and 65536), we have to break CU into 2 numbers. The most significant number (into 40960) is the number of 256's contained in CU. We get this by taking the integer portion of CU/256. Into 40961 we have to POKE the remainder of dividing 256 into CU. The POKE instruction automatically does this. So, into 40961 effectively goes CU - INT(CU/256) * 256.

Run the program and enter various numbers for L (between 0 and 15), and C (between 0 and 31). After their entry you will see the word "HI" printed on the screen. The program next says MORE?, and just press Return to run again.

HOW MUCH MEMORY IS LEFT FOR PROGRAMS AND VARIABLES

Program storage starts at 41986. Dimensioned variable storage usually occurs after the last statement.

41984, 41985 point to next location to store a step
41009, 41010 point to next location to store dimensioned variables

Using the Above:

Amount of space used for program and variable storage is

```
   AMT = (PEEK (41009) *256 + PEEK (41010)) - 41986
```

Amount of program space only is

```
   AMT = PEEK (41984) x 256 + PEEK (41985) - 41986
```

Amount of free space left is

```
   AMT = 49151 - (PEEK (41009) *256 + PEEK (41010))
           ↑
   End of memory for an 8K system
```

USING KEY $(O) FUNCTION

The purpose of KEY$(0) is to get an input from the keyboard without waiting for a Return Key (which is needed in an input statement). KEY$ does not debounce a key, nor does it put the depressed Key's code to screen. Below is a program utilizing KEY$(0) and does the following:

1. Will wait in a loop for a key to be pressed.

2. Will put the character code to the screen. If it is a Return, the program will stop.

```
 10 DIM A$(1)
 20 GOTO 100
 30 A$ = KEY$(0):  IF A$ = "" THEN 30
 40 A = ASC(A$):  RETURN

100 GOSUB 30:  IF A = 13 THEN STOP
110 PRINT A$
120 IF KEY$(0)    "" THEN 120
130 GOTO 100
```

Line 10 - dimensions a string variable A.

Line 30-40 - The function KEY$(0) is called and its value is assigned to A$. If A$ is NULL (empty), then no key is pressed, and we remain at Line 30.

When a key is pressed, the program moves from Line 30 to 40 where the ASCII value of the key pressed is assigned to variable A. Then the subroutine returns.

Line 100 - goes to subroutine 30 to get a key input. If A (the ASCII value of the key pressed) is 13, then it was a Return Key, and we stop the program.

Line 110 - prints the value of A$ (the key pressed). Note the use of the semicolon so we will print on the same line each time a key is pressed.

Line 120 - checks that the key has been released. Without Line 120 you will find it very difficult to press a key and get only one entry (try the program without Line 120).

Line 130 - goes to Line 100 and repeats the process.

TRIG FUNCTIONS

Although Trig Functions are not part of APF Basic, they can be easily implemented as subroutines utilizing series approximations.

The series approximations are

$$\mathrm{SIN(S)} = \frac{S}{1} - \frac{S^3}{3!} + \frac{S^5}{5!} - \frac{S^7}{7!}$$

$$\mathrm{COS(S)} = 1 - \frac{S^2}{2!} + \frac{S^4}{4!} - \frac{S^6}{6!} + \frac{S^8}{8!}$$

$$\mathrm{TAN(S)} = S + \frac{S^3}{3} + \frac{2*S^5}{15} + \frac{17*S^7}{315}$$

The angle S is in radians and less than or equal to $\Pi/2$ (90°).

A simplified implementation is as follows:

```
 10 GOTO 100
 20 Y = S - S*S*S/6 + S*S*S*S*S/120 - S*S*S*S*S*S*S/5040:
    RETURN:  REM

100 INPUT "ANGLE ",S1
110 IF S1<= 90 THEN IF S1>= 0 THEN 130
120 PRINT "ILLEGAL ANGLE":  GOTO 100
130 S = 3.1428 * S1/180
140 GOSUB 20
150 PRINT "ANGLE"; S1, "SIN"; Y: GOTO 100
```

Line 20 - does the SIN calculation of the Angle S (in radians). For a speedier calculation, the values of 3!, 5! and ! have been put in instead of calculating them each time.

Line 100 - inputs the angle (in degrees).

Line 110 - checks that angle is in range of 0 to 90°. This line could be replaced by a calculation that converts the angle to the first quadrant (0 - 90°).

Line 130 - converts the Angle S1 which is in degrees to an Angle S in radians.

Line 140 - goes to subroutine at Line 20 and returns with Y as the SIN(S).

MOVING THE DIMENSION POINTER

The pointer that directs Basic where to allocate space for dimensioned variables is contained in 2 bytes at Locations 41009 and 41010. By using POKES, these pointers can be changed.

One use of this is there are 512 bytes of memory (Locations 0-511) that are not normally used by Basic. You can force dimensioned variables to be stored here and gain 512 bytes of memory space. Example:

```
 5 GOSUB 50
10 POKE 41009, 0:  POKE 41010, 0.
20 DIM A (10), B$(99).
25 GOSUB 50
30 STOP
50 PRINT PEEK(41984), PEEK(41009), PEEK(41985), PEEK(41010):
   RETURN
```

When a RUN Command is given, the dimension pointers are set equal to the end of program storage pointers.

```
(41009) = (41984)
(41010) = (41985)
```

Line 5 - goes to subroutine at 50 and prints these values.

Line 10 - changes the dimension pointers, and Line 20 uses these new values for the Dimension Statements.

Line 25 - goes to subroutine 50 again. You can see the dimension pointers have allocated space for A, and B$.

STRINGS

There are several features of APF's Strings that might differ from some other Basics.

1. All Strings must be dimensioned before useage. Otherwise the error message "ILLEGAL VARIABLE" will occur.

   ```
   20 INPUT A$
   ```

   Running the above will produce an error message. You must add Line 10 as follows

   ```
   10 DIM A$(X)
   ```

   Where X is the number of characters plus 1 that you want to allocate space for A$. X must be a number (not a variable) and be less than 100.

2. You can dimension an array of Strings

   10 DIM B$(3,10) - This dimension is 4 Strings, each with eleven characters.

3. You can designate the starting position of a String variable in a statement.

   Ex:

   ```
   10 DIM A$(10):    REM Dimensions A$ as 11 characters.

   20 INPUT A$(4):   REM - This means to get an input from the
                     keyboard and place it in A$ starting at
                     the 5th character position.

   30 INPUT A$(O):   REM start inputting to the first character
                     position

   40 INPUT A$:      REM - This is a default condition to start
                     at the first character position
   ```

4. A String always has some value assigned to each of its character positions. The values are what is contained in memory where the String is dimensioned at. Usually the Dimension Statement places the storage area in memory that has been cleared to 0. A zero is a null character and is non-printable. When assignments of values are made into the String, they remain until another assignment is made. This means that Strings are not cleared to null automatically.

Ex:

```
10 DIM A$(5):  PRINT A$
20 A$ = "ABCDEF":  PRINT A$
30 A$ = "GHI":  PRINT A$
```

Line 10 Dimensions A$ and the Print will show nothing (nulls are non-printable characters).

Line 20 sets each character position of A$ and prints it

Line 30 will change only the first 3 characters of A$. The Print Statement will print GHIDEF.

If you want to clear out a string variable, then assign it to a clear or null string.

Add Line 15

```
15 DIM NULL$(5):   REM null is dimensioned and contains nulls.
                   If we never set it equal to anything, it
                   will remain with nulls.
```

Add Line 25

```
25 A$ = NULL$:  REM - This causes A$ to be cleared to nulls.
```

5. STRING CONCATENATION AND DISSECTION

String concatenation can be implemented by using the LEN Function

```
10 DIM A$(5), B$(5), C$(11), NULL$(11)

20 A$ = NULL$:  B$ = NULL$:  C$ = NULL$

30 INPUT A$, B$

40 C$ = A$:  C$(LEN(A$)-1) = B$

50 PRINT A$, B$, C$:  GOTO 20
```

Dissection (right part, left part, etc) can be done in a similar manner.

MACHINE LANGUAGE ROUTINES

There are a number of built-in subroutines in the Basic ROMS which can be accessed. Most of these cannot be called directly from Basic since they either require the A, B, or X register of the MC6800 to be set up with a certain value, or return with a result in the A, B or X register. Therefore, routines have to be written to deal with these registers and make their inputs and outputs accessible to Basic. For the purposes of this manual we will keep these accesses very general purposes (to enter the machine language routine, CALL 28672).

Note: All addresses are in hexadecimal.

1. MOVE MEMORY BLOCK

USE: to move a block of data from one section of memory to another.

LIMITS: block of data is less than or equal to 256 bytes

```
SETUP:  A Register - none
        B Register - number of bytes to be moved
        X Register - none
    Memory A029/A02A - first address to move to
    Memory A02B/A02C - first address to move from
```

CALL: JSR 7700 (Hex)

RETURNS: none

EXAMPLE: will move block of 10 bytes stored starting at Location Hex 50 to screen at Location Hex 0300.

First enter the data - we will use the ASCII Codes for the first 10 letters of the alphabet.

```
*0050 41/   (REM  ASCII for 'A')
 0051 42/
 0053 43/
   etc.
```

Now the program - We will locate the program starting at Address 0000.

```
0000  C6    LDAB#0A     10 bytes to be moved
0001  0A
0002  BD    JSR 7700    go to move routine
0003  77
0004  00
0005  7E    JMP 7000    Jump back to monitor mode
0006  70
0007  00
```

Next setup A029 - A02C

```
A029  03    To Address
A02A  00
A02B  00    From Address
A02C  50
```

Run the program by typing

```
G0000
```

Instantly you will see the first 10 alphabet characters appear on the screen in reverse video, and the program jumps back to the monitor mode.

2. CLEAR SCREEN TO BLACK

USE: to clear screen to all black
LIMITS: none
SETUP: none
CALL: JSR 4296
RETURNS: none

3. SET SCREEN TO HAVE ALL ONE CODE

USE: similar to 2, but instead of Hex 80 (black character), can fill screen with any character code.

LIMITS - none

SETUP: A Register - code to be put to screen.

CALL: 4298

RETURNS: none

Ex:

```
*M0000  86    LDAA #$8F
 0001   8F
 0002   BD    JSR $4298
 0003   42
 0004   98
 0005   7E    JMP to monitor
 0006   70
 0007   00
```

4. INPUT FROM CONTROLLERS

USE: to check if a key is pressed on either hand controller

LIMITS: none

SETUP: none

CALL: JSR$41BE - left hand controller
JSR$41D9 - right hand controller

RETURNS: carry flag of status register
If clear, no key pressed.
If set, key pressed and ASCII code for key is contained in memory Hex 01F2

5. INPUT FROM KEYBOARD

USE: to get key input from main keyboard

LIMITS: will not return a shifted keyword (CTRL Key and top 2 rows).

SETUP: none

CALL: JSR $80CF

RETURNS: ASCII Code for key pressed in A register
If (A) = 0, then no key pressed.

6. ADD TO INDEX REGISTER

USE: allows a number to be added to the index register

LIMITS: number to be added is 256 or less

SETUP X Reg - setup
A Reg - value to be added

CALL: JSR $771B

RETURNS: A Register added to X and result in X

7. OUTPUT TO SCREEN

USE: will take a code from the A Register and output it to the screen.

A. If token code, it will decompress it to actual token word (ex $94 will go to screen as REM).

B. If scrolling necessary, will scroll screen.

C. If backspace code, will do a backspace.

D. If carriage return, does a return and scroll if necessary.

SETUP: A Register - code to output
B,x - none
$A000/$A001 - screen address

CALL: JSR $8473

CHAPTER VII

THE TAPE SYSTEM

The Imagination Machine tape system was designed to be simple, reliable, fast, and versatile. This chapter will give some more explanations and some further possible uses of the tape system.

First the Basic commands and what they do

CSAVE - This is the save to tape command and the sequence of events is

1. The motor and audio are enabled. With the audio enabled, you can hear the digital data through the speaker when it is recorded. You can also do audio/recording through the mike jack at this time.

2. The message to REWIND TAPE, PRESS PLAY THEN RETURN is put up. There is a 2 second delay before this occurs to allow the motor to get up to full speed. The computer will now wait till the RETURN KEY is pressed before continuing.

3. There will now be approximately 11 seconds of "Header" put out to the tape. This is to allow during the read sequence of syncing up with the data.

4. After the header, 512 bytes will be put out. Depending upon the mode flag (location 41452), these 512 bytes will come from 0-511 (flag=non 0 number) or from 512-1023 (flag=0).

5. The next block of data put out will be the contents of user RAM in the system. The computer will start with the byte at 41984 (Hex A400), and send out consecutive bytes till it reaches the indicated end of memory. The end of memory pointer is contained in locations 41446-41447. This means that program storage as well as data storage is saved to tape.

6. As data has been sent out, a check sum has been calculated. This check sum byte is next written.

7. The tape motor and audio are disabled, and the computer returns to the keyboard mode.

CLOAD - This is the opposite of CSAVE and will bring data/ information back to the computer.

1. The motor and audio are enabled. Any recorded audio can be heard during playback through the built-in speaker.

2. The message to REWIND TAPE, PRESS PLAY THEN RETURN is put up. Again there is a 2 second delay from motor enable till this message occurs. The computer now waits for the return key.

3. The computer will now wait 6 seconds before trying to get in sync. This is to allow the tape leader to fully pass the head as there is a chance of the computer getting a false start from the leader.

4. Next the computer syncs up with the tape data and puts the first 512 bytes to the screen. This gives the picture you see loaded to the screen from APF made tapes.

5. After the screen is filled, the computer will read data and put it in memory starting at 41984. It will keep looking for data until it has filled up all available user memory (indicated by 41446/41447).

6. Finally it looks for a checksum byte. White it has been reading it has recalculated a checksum and then compares the read and calculated checksum. If they match, it prints "OK."

7. The motor and audio are turned off.

CALL ROUTINES

There are several routines that can be called to use the tape instead of using CSAVE and CLOAD.

CALL 34040 - Motor and audio are enabled with a 2 second delay. No message is put to screen.

CALL 34061 - Motor and audio are turned off.

CALL 34138 - Will put out header, 512 bytes from either 0-511 or 512-1023, memory data, and checksum.

CALL 34225 - Will read from tape. First 512 bytes go to screen, then data goes to memory. The checksum is checked.

SAVING THOSE FRONT PICTURES

All APF prerecorded programs have a front picture that is loaded to screen. There are several ways that this can be done.

A. A picture can be created in memory 0-511 by a program. By moving the cursor pointer, all print statements can be print in 0-511. Using POKES, colors and shapes can be added. Once the picture is placed there, you can load a tape with your program (it won't destroy memory in 0-511). Next change 41452 (the flag) to non-0 (such as 255), then do a CSAVE.

As example (remarks are not necessary to type in)

```
 10 CU=0:  GOSUB 500:  REM MOVE CURSOR TO 0
 20 FOR I=1 to 16:  PRINT SPC(32) ;:  NEXT I:  REM ALL GREEN SCREEN
 30 CU=256:  GOSUB 500
 40 PRINT  SPC(9); "THIS IS A TEST"
 50 FOR I=0 TO 31:  POKE I, 191:  NEXT I:  REM RED SQUARE
 60 FOR I=478 to 511:  POKE I, 255:  NEXT I:  REM ORANGE SQUARE
 70 CU=512:  GOSUB 500:  REM MOVE CURSOR BACK TO SCREEN
 80 END
500 POKE 40960, INT (CU/256):  POKE 40961, CU-(INT(CU/256)*256)
510 RETURN
```

Run the program

Now
POKE 41452,255 - change the flag
Do CSAVE, then try a CLOAD

B. Many of APF's front screens have been created using our Artists & Easel program. After ARTISTS AND EASEL is used to create a picture, it is relocatedin memory from 0-511 (using a machine language move routine). Then the tape with the program that goes with that screen is loaded, 41452 is changed and then CSAVE is done.

USING THE TAPE TO LOAD NEW SCREEN FROM A PROGRAM

It is possible to have a program running and periodically load a new front screen from tape and then have the program continue. (With a little imagination other things can be selectively loaded.)

Since the tape system saves and loads the screen plus only INDICATED PROGRAM MEMORY, we can changed INDICATED PROGRAM MEMORY.

End of memory is contained in 2 bytes at 41446 and 41447.

It's best to illustrate this in an example. We will create a picture, save it, create a second picture and also save it. Then we will read the picture in, wait for a return key, and then read the 2nd picture in.

TO CREATE AND SAVE THE PICTURE

```
 10 CALL 17046:  REM CLEAR SCREEN
 20 SHAPE=15: REM   CREATE SCREEN THAT IS COLORED HLIN
 30 FOR I=0 TO 15
 40 COLOR=I:  HLIN 0, 31, I:  NEXT I
 50 GOSUB 500: REM   GOTO ROUTINE TO SAVE
 70 CALL 17046: REM   CLEAR SCREEN
 80 FOR I=0 TO 31: REM   CREATE SCREEN THAT IS COLORED VLIN
 90 COLOR=I:  VLIN O, 15, I:  NEXT I
100 GOSUB 500
110 END:  REM END
500 POKE 41446, 164:  POKE 41447, 1:  REM TO CHANGE END OF MEMORY
                                      POINTER TO 41985 (Hex A401)
510 CALL 34040:  CALL 34138:  CALL 34061:  REM MOTOR ON, SAVE,
                                      MOTOR OFF END MEMORY POINTER
520 POKE 41446, 191:  POKE 41447, 255:  REM CORRECT END OF MEMORY
                                      POINTER
530 RETURN
```

Enter the program, place a tape in the deck, rewind it and press play (it won't start without a motor enable). Now run the program.

The second part is to load the screen back in. Clear the machine (press reset), then

```
 10 GOSUB 500:  REM GOTO ROUTINE TO READ FIRST SCREEN
 20 POKE 40960, 0:  INPUT R:  REM MOVE CURSOR AND WAIT FOR RETURN
                               KEY
 30 GOSUB 500:  REM GO READ SECOND SCREEN
 40 END
500 POKE 41446, 164:  POKE 41447, 1:  REM CHANGE END MEMORY
                               POINTER
510 A=PEEK (41984):  B=PEEK (41985):  REM SAVE TRUE END OF
                               PROGRAM
                               IT WILL BE CHANGED WITH LOAD
520 CALL 34040:  CALL 34225:  CALL 34061:  REM:  READ TAPE
530 POKE 41446, 191:  POKE 41447, 255  REM:  CHANGE MEMORY END
                               POINTER BACK
540 POKE 41984, A: POKE 41985, B: REM:  CHANGE END PROGRAM POINTER
550 RETURN
```

Enter the program, then place the tape in deck, rewind and press play.

Now run the program. After the first screen is loaded press Return to get the 2nd picture.

TO SAVE PROGRAM DATA ON TAPE

When a CSAVE command is given, all of user memory is saved. This means all program statements as well as dimensioned variables. You can enter data into a program, and it can be saved on tape with the program for future use. One problem that has to be overcome is that a RUN command clears all memory from the last statement to the end of memory. Normally a RUN command clears all variable space to zero. There are several ways to get around this.

A. Using a GOTO statement instead of a RUN command to start a program will not clear the variable area. If the first statement of your program is 10, then start the program with GOTO 10 instead of RUN.

   The only thing else to note is that after a system reset, a RUN command must be executed to perform system initialization, otherwise erroneous messages occur. Once a RUN command has been executed, a GOTO may be given as a direct command. Several of APF's program tapes use this method to save and retrieve data.

B. An alternate and more general way to save data is to

   1. Determine amount of memory required for dimensioned variables.

   2. Have the first statement of the program do:
      `POKE 41009, PEEK (41984) - X:  POKE 41010, PEEK (41985) - Y`
      where X * 256 + Y = amount of memory required for variables

   3. Before the first RUN of the program
      `POKE 41984, PEEK (41984) + X:  POKE 41985, PEEK (41985) + Y`

41984, 41985 - points to end of program storage
41009, 41010 - points to where next variable is stored

As an example

```
 10 POKE 41009, PEEK (41984) - 1
 20 DIM NA$ (30)
 30 IF NA$<>"" THEN 100
 40 INPUT "NAME ", NA$
 50 CSAVE:  STOP
100 PRINT "NAME ";NA$
110 STOP
KEY IN THE PROGRAM
    POKE 41984, PEEK (41984 + 1)
RUN THE PROGRAM
```

The first time you RUN, NA$ is not set to anything and the program asks for an input. Then it saves the program and data to tape.

To see that data was retained:

Reset the system, type CLOAD and load the tape.
RUN the program (type RUN). Your entry for NA$ was saved and is printed.

SAVING AND RETRIEVING SELECTED AREAS OF MEMORY

Using CALLS, PEEKS and POKES it is possible to save and retrieve selected segments of memory. (A program can bring into memory more data or statements from tape.) To do this, the following CALLS and PEEKS are needed.

Hex	Decimal	Operation
$84F8	34040	CALL - Enable motor and audio. Wait 2 seconds, then returns.
$850D	34061	CALL - Shuts off motor and audio.
$8550	34141	CALL - Puts out 11 second header. Then saves memory contents to tape. Memory area saved is indicated by "High," "Low." Also mem end must equal the same as "High."
$854B	34228	CALL - Reads from tape to memory. Where it goes in memory is set by "Low," "High."
$A007	40967	Low - 2 bytes indicating lowest byte of memory to save or read to tape.
$A009	40969	High - 2 bytes indicating highest byte of memory to save/read to tape.
$A1F6	41446	Mem End - 2 bytes indicating end of memory

Let's illustrate this in an example (It's not necessary to key in Remarks)

```
10 DIM A(5)                               Rem set up array space

15 Print "Place tape in deck and engage"  Rem print tape message

20 For J = 1 to 3                          Rem will do loop 3 times

30 For I = 0 TO 5:  Input A(I):  Next I   Rem get inputs for 6 elements
                                          of Array A.

35 GOSUB 200                              Rem:  Go set up high, low,
                                          mem end.

40 CALL 34141:  CALL 34061                Rem:  CALL save routine,
                                          then stop motor

50 GOSUB 300                              Rem restore mem end value

60 Next J                                 Rem:  get 6 more values
                                          for A
```

```
 70 Input "Rewind tape, press play, then return key ", K
                                         Rem: wait for rewind

 80 For J = 1 TO 3                       Will read back 3 groups
                                         of data

 90 GOSUB 200                            Go set high/low/mem end

100 CALL 34228                           Go read from tape

110 CALL 34061                           Stop motor

120 For I = 0 TO 5                       Print out values of A

130 Print A(I); "  ";

140 Next I

150 Next J                               Go get next group of
                                         data from tape

160 End


200 POKE 40967, PEEK(41984)              Rem set low pointers to end
210 POKE 40968, PEEK(41985)              of program memory
220 POKE 40969, PEEK(41009)              Rem set high pointer to
230 POKE 40970, PEEK(41010)              end of variable storage
240 POKE 41446, PEEK(41009)              Rem set memend to same
250 POKE 41447, PEEK(41010)              as high
260 CALL 34040:  Return                  Rem start motor and return

300 POKE 41446, 191                      Rem:  restore mem end
310 POKE 41447, 255
320 Return
```

Place a blank tape in the deck and RUN the program. Enter values for A(I) when asked. The program will ask for 3 groups of 6 values each to use for Array A. After you enter each group it will save them to tape.

When the 3 groups are entered and saved, follow the directions and you will see the program retrieve from tape each of the 3 groups and display them.

CHAPTER VIII

HIGH RESOLUTION GRAPHICS

The Imagination Machine has two modes of high resolution graphics.

MODE 1 - 128 x 192 dots of resolution with 2 color sets, each with 4 colors per set.

MODE 2 - 256 x 192 dots of resolution with 2 color sets, each with 2 colors per set.

These are, in addition to the regular alphanumerics/semigraphics mode, used by the "BASIC" operating system. Both graphics modes are implemented as an "OBJECT DEFINED SYSTEM." An object or shape is defined, and then the screen map shows which object shape is placed in object boxes of the screen. This is analogous to the regular alphanumeric mode where the object shapes - the alphanumeric character set - is predefined in ROM as the ASCII character set. You place the object number (the ASCII code) in the screen map and the VDG decodes the object number into the appropriate video signal. The main difference in the graphics mode is the object shape is defined by the programmer in read/write memory. Therefore we need 2 sections of memory - one for object shape definitions, the other for a screen map.

In either Mode 1 or Mode 2 the screen map is divided into 32 x 12 boxes (384 total). Any one of the defined object shapes can be selected to be placed in any of these 384 boxes, and each box must have an object number assigned to it.

Each box is subdivided into 16 rows, each row with either 4 dots wide (mode 1) or 8 dots wide (mode 2).

Each object shape will require 16 bytes for its definition (1 byte for each of the 16 rows, and each byte is interpreted as 4 dots wide or 8 dots wide depending on which mode is used).

There are 512 bytes of memory allocated for object shape definition. Since each object shape requires 16 bytes for its definition, there can be a maximum of 32 objects that are defined at any one time. Since they are in RAM, they can be redefined.

THE MAP AREAS

The object shape definitions are stored in memory from Hex 200 - 3FF. The first 16 bytes are the definition for object number 0, the next 16 bytes for object #1, etc. Figure 8-1 shows the object shape map.

Figure 8-1 OBJECT SHAPE MAP

Addresses are in hexadecimal

*Object 0: 200 - 20F

Object 1: 210 - 21F

Object 2: 220 - 22F

Object 3: 230 - 23F

Object 4: 240 - 24F

Object 5: 250 - 25F

Object 6: 260 - 26F

Object 7: 270 - 27F

Object 8: 280 - 28F

Object 9: 290 - 29F

Object A: 2A0 - 2AF

Object B: 2B0 - 2BF

Object C: 2C0 - 2CF

Object D: 2D0 - 2DF

Object E: 2E0 - 2EF

Object F: 2F0 - 2FF

Object 10: 300 - 30F

Object 11: 310 - 31F

Object 12: 320 - 32F

Object 13: 330 - 33F

Object 14: 340 - 34F

Object 15: 350 - 35F

Object 16: 360 - 36F

Object 17: 370 - 37F

Object 18: 380 - 38F

Object 19: 390 - 39F

Object 1A: 3A0 - 3AF

Object 1B: 3B0 - 3BF

Object 1C: 3C0 - 3CF

Object 1D: 3D0 - 3DF

Object 1E: 3E0 - 3EF

Object 1F: 3F0 - 3FF

*Address 200 is byte to define top row of Object 0

201 is byte to define next row down of Object 0

202 is byte to define next row down of Object 0

20F is byte to define bottom row of Object 0

The Object Number Map (screen map) is located at Hex 0000-017F. It looks as follows in FIGURE 8-2.

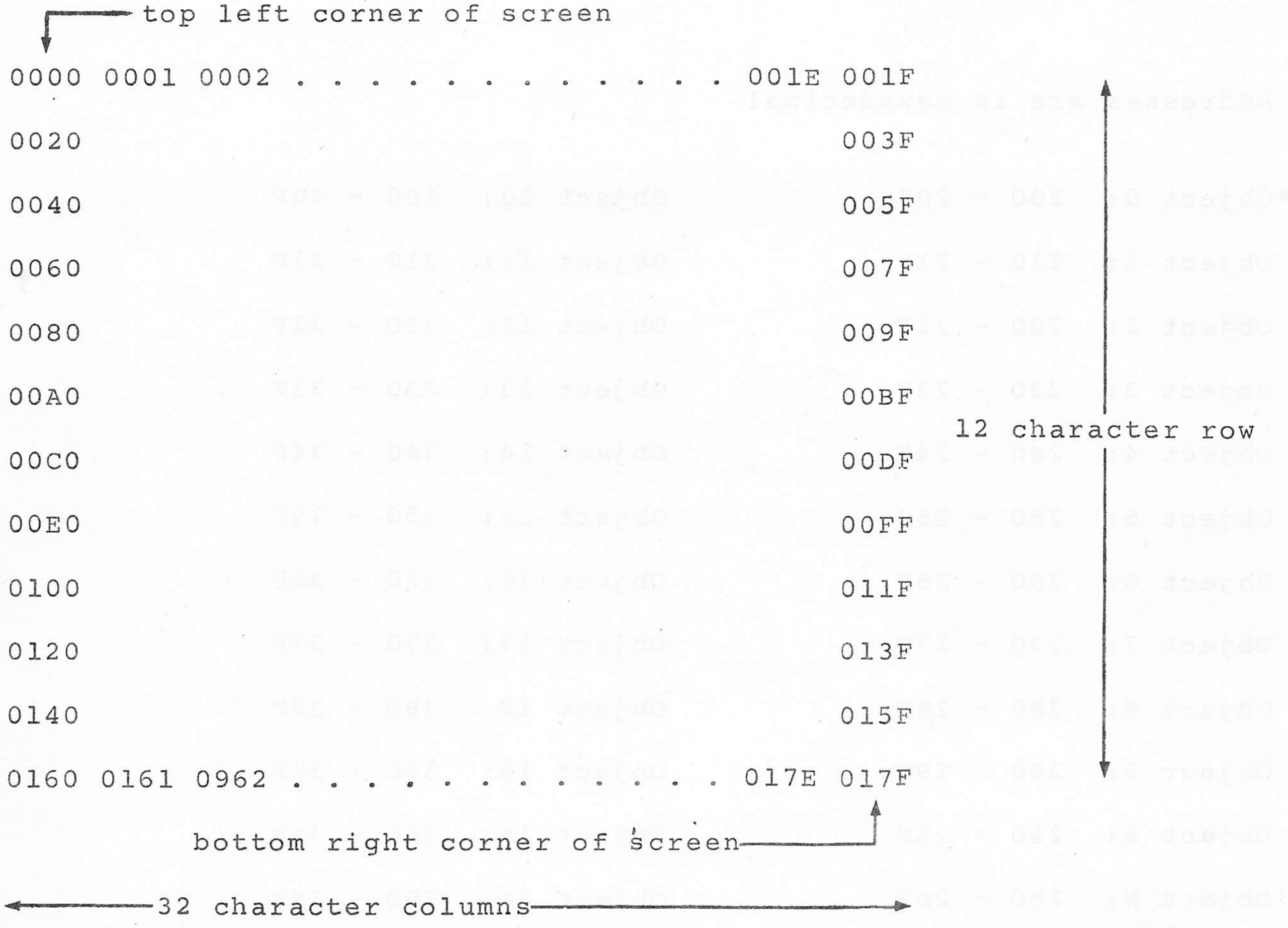
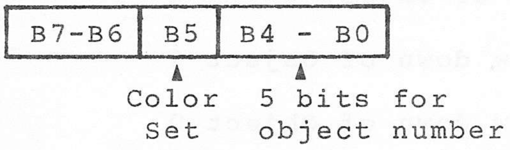


Figure 8-2

Since there are only 32 definable objects, we require only 5 bits in the screen map word to select which object is selected. One more bit of this word is used to select which color set is used. This means an objects color set is selectable on a character by character basis. The screen can actually show each of the 32 objects in both color sets. The final 2 bits of the word are not used.



COLORS OF AN OBJECT SHAPE DEFINITION

Mode 1 - In Mode 1 each byte of a definition is interpreted as 4 bit pairs. Each bit pair selects 1 of 4 colors as follows:

Bit Pair	Color Set 0	Color Set 1
0 0	Green	White
0 1	Yellow	Green
1 0	Blue	Purple
1 1	Red	Orange
Border	Green	White

BORDER COLOR - The border color (screen that is visible outside of the 384 character boxes) takes the color of green or white depending upon the color set used in the right most character box of a line. If Box 001F has color set 0, then the border on those 16 rows is green. If it has color set 1 selected, then its border is white. The top and bottom borders take the color set from the bottom right character (Box 017F).

Mode 2 - In this mode each bit of the object shape definition byte is interpreted as 1 of 2 colors.

Bit	Color Set 0	Color Set 1
0	Black	Black
1	Green	White
Border	Green	White

Border color is determined like Mode 1.

WRITING PROGRAMS IN HIGH RESOLUTION GRAPHICS

USING BASIC

High resolution screens can be created by using just Basic program statements.

Switching Between Modes

To go from alphanumeric to graphics mode, 2 POKES are required

POKE 8193, 60 - This enables the object latch. It also allows orange color set in alphanumeric mode. From this point on, this address does not have to be changed. In inverted alphanumeric mode you will get orange/black letters instead of green. If you want to disable this, then POKE 8193, 52.

POKE 8194, 158 - This will set the display to graphics (128 x 192) mode. Sets $\overline{A}/G=1$: GMO=0. When this is done you will no longer see alphanumeric characters. Also, 8193 must be set to 60 previously.

POKE 8194, 222 - This will set the display to graphic (256 x 192) mode. Sets A/G=1 and GMO=1
POKE with 30 to return to ALPHA/SEMI

SETTING UP SHAPES

Object shapes can be set up by using POKE instructions.

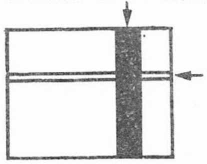
The codes to POKE can be stored as data statements, as arrays, or as absolute statements.

As an example:

To create a high resolution graphics screen where the objects are vertical and horizontal lines.

The object will be a green box with yellow lines for ½ the screen and a white box with green lines for the other ½. Both will be in 128 x 192 mode.

This will be 3rd pair from left



The 16 bytes for the shape will be
4,4,4,4,4,4,4,85,85,4,4,4,4,4,4,4

```
 10 POKE 8193, 60:  POKE 8194, 158:  Rem set up graphics mode
 20 For I = 512 to 518:  Rem   Set up object definition
 30 POKE I, 4:  POKE I + 9, 4
 40 Next I
 50 POKE 519, 85:  POKE 520, 85
 60 For I = 0 to 191:  Rem   Set object numbers to screen map
 70 POKE I, 0:  POKE I + 192, 64:  Next I
 80 POKE 40960, 1:  POKE 40961, 129: Rem   Move cursor off screen
 90 Input K:  POKE 40960, 2: Rem   Wait for return key
100 POKE 8194, 30: Rem   Return to alphanumeric mode
```

It is a good idea before trying to do graphic programs to sit down and carefully sketch out on paper the picture you want to create. Define the various objects and where they are to be placed.

WRITING PROGRAMS IN HIGH RESOLUTION GRAPHICS USING MACHINE LANGUAGE

The examples shown do not give specific addresses where to locate but are general relocatable programs.

Example 1

Entering into the Various Modes

To enter Mode 1 or 2, the PIA in the MP1000 must be changed. There are 3 signals that control graphics mode.

$\overline{A}$/G - Alphanumeric or Graphic select - must be logic "1" for graphics

GMO - Logic "0" - Mode 1 (128 x 192)
Logic "1" - Mode 2 (256 x 192)

$\overline{CLR}$ - Must be 1, to enable objects codes

The program to enter from semigraphics to graphics mode is

HEX CODE	INSTRUCTION	COMMENTS
B6	LDAA $2002	Load "A" with PIA Data Register B
20		
02		
84	ANDA #$3F	Set $\overline{A}$/G high and GMO low
3F		
8A	ORAA #$80	If ORAA with $C0, will set GMO high and go into Graphics Mode 2. ORAA with $80 goes into Graphics Mode I.
80		
B7	STAA #$2002	
20		
02		
B6	LDAA $2001	Load "A" with PIA control Register A
20		
01		
84	ANDA #$C7	Will set CA2=1 (which is $\overline{CLR}$ Signal).

```
HEX CODE   INSTRUCTION         COMMENTS

   C7

   8A      ORAA #$38

   38

   B7      STAA $2001

   20

   01
```

EXAMPLE 2 Routine to set same value to a consecutive group of addresses.

Routine is at $477C (in internal ROM)

Enter routine with

X REGISTER ◄ start address in memory to get set

B REGISTER ◄ number of consecutive bytes from x register addresses that get set

A REGISTER ◄ value to be stored

As a simple example, set the top of screen to all have Object 3 in them. First set Object 3 to have all bytes at $AA.

```
HEX CODE   INSTRUCTION         COMMENTS

   CE      LDX #$0230     Load x with first address
                          Object #3 starts at $0230

   02

   30

   C6      LDAB #$10      Load B with count

   10

   86      LDAA #$AA      Load A with value

   AA

   BD      JSR $477C      Jump to subroutine
```

HEX CODE	INSTRUCTION	COMMENTS
47		
7C		
CE	LDX #$0000	Load X with top of screen address in graphics mode
00		
00		
C6	LDAB #$20	Load B with count (32)
20		
86	LDAA #$03	Load A with value. Value is object 3 code number.
03		
BD	JSR $477C	Jump to subroutine
47		
7C		

INTERRUPTS

The Imagination Machine has a built-in $\overline{\text{IRQ}}$ Interrupt Servicing Routine. This can only be used during a machine language program. Never allow the interrupts to be enabled while Basic statements are being executed. (The system initialization routine disables the interrupt mask of the 6800 status register.)

The interrupt system is driven by the field sync output of the VDG. This occurs every 1/60 of a second. It is fed to the MC6800 $\overline{\text{IRQ}}$ input via the MP1000 PIA.

INTERRUPT ENABLING/DISABLING

1. TO ENABLE THE INTERRUPTS
   - A. CB1 of the PIA must be programmed to accept and input. CB1 Mode is set by the CONTROL REGISTER SB which is Hex Address 2003.

     2003 ← Hex 35 - IRQ set by high to low transition of field sync

     2003 ← Hex 37 - IRQ set by low to high transition of field sync
   - B. A CLI instruction must be given (clear interrupt mask bit in status register).
2. TO DISABLE THE INTERRUPTS
   - A. Set 2003 with Hex $34
   - B. Give an SEI instruction

INTERRUPT SERVICING ROUTINE

The built-in interrupt servicing routine does the following

1. Allows jumps to subroutines whose addresses are set by the user.
2. Keeps count of number of interrupts as well as seconds and minutes.

There are several flags and counters used by the Interrupt Routine as follows

I60 - ($01FC) - if non zero, causes an immediate JSR from interrupt routine. The JSR address is contained in I60J. Both I60 and I60J are user set.

I60J - ($01C5-01C6) - JSR address if I60 is non zero.

ISEC - ($01FD) - if ISEC is non zero, then every 60 interrupts (1 second) a JSR will occur. JSR address is contained in ISECJ. Both ISEC and ISECJ are user set.

ISECJ - (01C7-01C8) - JSR address if ISEC is non zero and 1/60 second counter overflows.

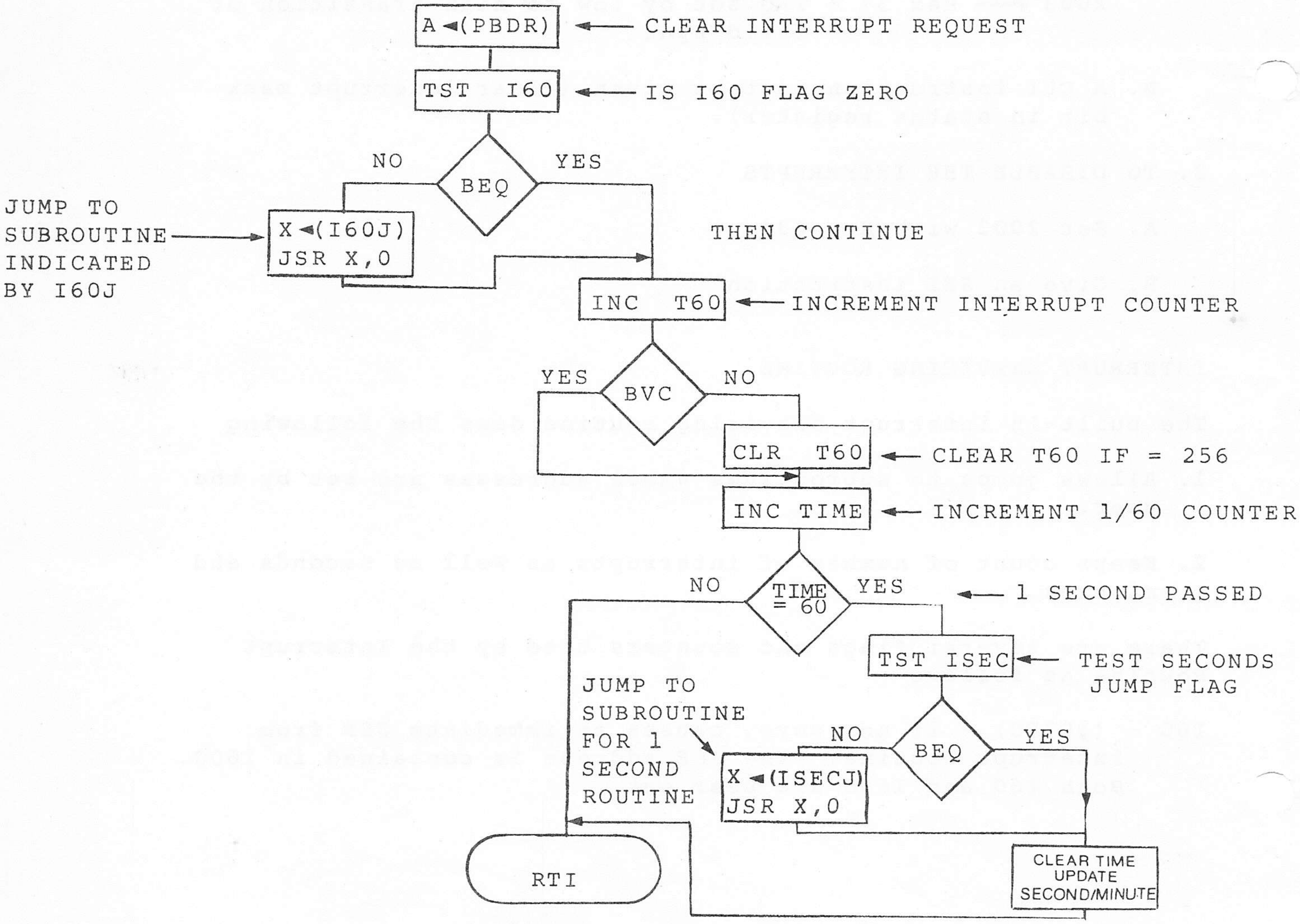
T60 - (01F8) - incremented by each interrupt. Clears to zero when overflows (at 256th interrupt) and starts count again.

TIME - (01FB) - keeps count of 1/60 of seconds. Clears when reaches 60 and then causes SECOND to be incremented.

SECOND - (01F9) - incremented every SECOND. Clears when reaches 60 and increments MINUTE.

MINUTE - (01FA) - increment every 60 SECONDS. Clears when reaches 60.

Below is a flowchart of the interrupt servicing routine.



EXAMPLE OF INTERRUPT USEAGE

As an example to show how to use the interrupts

1. Each 60th of a second we will add a character to the screen.

2. After 5 seconds we will clear the screen and return to the monitor routine.

SOLUTION

1. First we need 2 routines for the interrupts.

   A. 1/60 interrupt - put character to screen

```
0010     DE 00     LDX(00)     SCREEN POINTER

0012     96 02     LDAA (02)   CODE TO SCREEN

0014     A7 00     STAA, 0, X  STORE IT

0016     08        INX         INCREMENT SCREEN POINTER

0017     DF 00     STX 00

0019     4C        INCA        INCREMENT CODE

001A     97 02     STAA 02

001C     39        RTS         RETURN
```

   B. The 1 second interrupt routine

```
0020     B6 01F9        LDAA SECOND

0023     81 04          CMPA #4

0025     2C 01          BGE +1

0027     39             RTS

0028     0F             SEI

0029     BD 4296        JSR 4296

002C     7E 7000        JMP MONITOR
```

2. The initialization and main routine

```
0030     CE 0010     LDX# 0010     SET UP JSR ADDRESSES

0033     FF 01C5     STX 01C5      FOR INTERRUPT ROUTINES
```

```
0036      CE 0020      LDX# 0020

0039      FF 01C7      STX 01C7

003C      86 35        LDAA 35        SET UP PIA

003E      B7 2003      STAA 2003

0041      4F           CLRA           CLEAR COUNTERS

0042      B7 01F8      STAA T60

0045      B7 01FB      STAA TIME

0048      B7 01F9      STAA SECOND

004B      97 02        STAA 02        SET CHARACTER CODE

004D      4C           INCA

004E      B7 01FC      STAA I60       CLEAR FLASS FOR INTERRUPT

0051      B7 01FD      STAA ISEC      ROUTINE

0054      CE 0200      LDX# 0200      SET SCREEN ADDRESS

0057      DF 00        STX 00

0059      0E           CLI            ENABLE INTERRUPT

005A      3E           WAI            WAIT FOR INTERRUPT

005B      20 FD        BRA -3
```

If you have everything loaded in correctly, type G0030.

You will see the screen fill up with characters. Since it is putting up 1 character every 60th of a second, for 5 seconds, there will be 300 characters and then the screen clears and goes back to the monitor.

CHAPTER IX

SAVING SPACE AND TIME

There are several things that can be done in a program to save memory space and speed up programs.

SAVING SPACE

1. After a section of a program is running, all Remark statements should be removed to save space.
2. Use multistatements per line. Each new line takes 3 extra bytes. A line can have up to 128 characters, and all keywords are only 1 character.
3. Using subroutines can save space instead of retyping a common used routine.
4. Do not over-dimension strings and arrays.

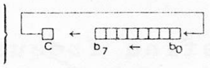
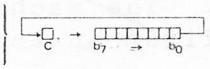
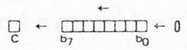
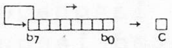
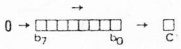
SPEEDING UP PROGRAMS

1. Place all subroutines at the beginning of a program (lowest step numbers). All statements are stored in ascending order of statement number and when a GOSUB is executed, it starts at the beginning of the program looking for the correct line number. This means a subroutine at step 9000 is found only after the machine looks at all line numbers preceding 9000.
2. Remove Remark statements if possible.
3. Try to use nonsubscripted variables in for/next loops or in frequent calculations. It takes about 3 times as long to find a subscripted variable's value as opposed to a non-subscripted variable.
4. Use multistatements per line.
5. Use and define frequently used variables early in program execution. The machine develops variable lists. Those first used are first on the list and are found quickest.
6. Don't over-dimension strings and arrays.
7. Use machine language routines if possible. Remember Basic is an interpreted language and not compiled.

Appendix A

MC6800 Instruction Set

D I E

ACCUMULATOR AND MEMORY		ADDRESSING MODES															BOOLEAN/ARITHMETIC OPERATION (All register labels refer to contents)	COND. CODE REG.					
		IMMED			DIRECT			INDEX			EXTND			INHER				5	4	3	2	1	0
OPERATIONS	MNEMONIC	OP	~	#	OP	~	#	OP	~	#	OP	~	#	OP	~	#		H	I	N	Z	V	C
Add	ADDA	8B	2	2	9B	3	2	AB	5	2	BB	4	3				A + M → A	↕	●	↕	↕	↕	↕
	ADDB	CB	2	2	DB	3	2	EB	5	2	FB	4	3				B + M → B	↕	●	↕	↕	↕	↕
Add Acmltrs	ABA													1B	2	1	A + B → A	↕	●	↕	↕	↕	↕
Add with Carry	ADCA	89	2	2	99	3	2	A9	5	2	B9	4	3				A + M + C → A	↕	●	↕	↕	↕	↕
	ADCB	C9	2	2	D9	3	2	E9	5	2	F9	4	3				B + M + C → B	↕	●	↕	↕	↕	↕
And	ANDA	84	2	2	94	3	2	A4	5	2	B4	4	3				A • M → A	●	●	↕	↕	R	●
	ANDB	C4	2	2	D4	3	2	E4	5	2	F4	4	3				B • M → B	●	●	↕	↕	R	●
Bit Test	BITA	85	2	2	95	3	2	A5	5	2	B5	4	3				A • M	●	●	↕	↕	R	●
	BITB	C5	2	2	D5	3	2	E5	5	2	F5	4	3				B • M	●	●	↕	↕	R	●
Clear	CLR							6F	7	2	7F	6	3				00 → M	●	●	R	S	R	R
	CLRA													4F	2	1	00 → A	●	●	R	S	R	R
	CLRB													5F	2	1	00 → B	●	●	R	S	R	R
Compare	CMPA	81	2	2	91	3	2	A1	5	2	B1	4	3				A − M	●	●	↕	↕	↕	↕
	CMPB	C1	2	2	D1	3	2	E1	5	2	F1	4	3				B − M	●	●	↕	↕	↕	↕
Compare Acmltrs	CBA													11	2	1	A − B	●	●	↕	↕	↕	↕
Complement, 1's	COM							63	7	2	73	6	3				$\overline{M}$ → M	●	●	↕	↕	R	S
	COMA													43	2	1	$\overline{A}$ → A	●	●	↕	↕	R	S
	COMB													53	2	1	$\overline{B}$ → B	●	●	↕	↕	R	S
Complement, 2's (Negate)	NEG							60	7	2	70	6	3				00 − M → M	●	●	↕	↕	①	②
	NEGA													40	2	1	00 − A → A	●	●	↕	↕	①	②
	NEGB													50	2	1	00 − B → B	●	●	↕	↕	①	②
Decimal Adjust, A	DAA													19	2	1	Converts Binary Add. of BCD Characters into BCD Format	●	●	↕	↕	↕	③
Decrement	DEC							6A	7	2	7A	6	3				M − 1 → M	●	●	↕	↕	④	●
	DECA													4A	2	1	A − 1 → A	●	●	↕	↕	④	●
	DECB													5A	2	1	B − 1 → B	●	●	↕	↕	④	●
Exclusive OR	EORA	88	2	2	98	3	2	A8	5	2	B8	4	3				A ⊕ M → A	●	●	↕	↕	R	●
	EORB	C8	2	2	D8	3	2	E8	5	2	F8	4	3				B ⊕ M → B	●	●	↕	↕	R	●
Increment	INC							6C	7	2	7C	6	3				M + 1 → M	●	●	↕	↕	⑤	●
	INCA													4C	2	1	A + 1 → A	●	●	↕	↕	⑤	●
	INCB													5C	2	1	B + 1 → B	●	●	↕	↕	⑤	●
Load Acmltr	LDAA	86	2	2	96	3	2	A6	5	2	B6	4	3				M → A	●	●	↕	↕	R	●
	LDAB	C6	2	2	D6	3	2	E6	5	2	F6	4	3				M → B	●	●	↕	↕	R	●
Or, Inclusive	ORAA	8A	2	2	9A	3	2	AA	5	2	BA	4	3				A + M → A	●	●	↕	↕	R	●
	ORAB	CA	2	2	DA	3	2	EA	5	2	FA	4	3				B + M → B	●	●	↕	↕	R	●
Push Data	PSHA													36	4	1	A → M_{SP}, SP − 1 → SP	●	●	●	●	●	●
	PSHB													37	4	1	B → M_{SP}, SP − 1 → SP	●	●	●	●	●	●
Pull Data	PULA													32	4	1	SP + 1 → SP, M_{SP} → A	●	●	●	●	●	●
	PULB													33	4	1	SP + 1 → SP, M_{SP} → B	●	●	●	●	●	●
Rotate Left	ROL							69	7	2	79	6	3				M	●	●	↕	↕	⑥	↕
	ROLA													49	2	1	A 	●	●	↕	↕	⑥	↕
	ROLB													59	2	1	B	●	●	↕	↕	⑥	↕
Rotate Right	ROR							66	7	2	76	6	3				M	●	●	↕	↕	⑥	↕
	RORA													46	2	1	A 	●	●	↕	↕	⑥	↕
	RORB													56	2	1	B	●	●	↕	↕	⑥	↕
Shift Left, Arithmetic	ASL							68	7	2	78	6	3				M	●	●	↕	↕	⑥	↕
	ASLA													48	2	1	A 	●	●	↕	↕	⑥	↕
	ASLB													58	2	1	B	●	●	↕	↕	⑥	↕
Shift Right, Arithmetic	ASR							67	7	2	77	6	3				M	●	●	↕	↕	⑥	↕
	ASRA													47	2	1	A 	●	●	↕	↕	⑥	↕
	ASRB													57	2	1	B	●	●	↕	↕	⑥	↕
Shift Right, Logic.	LSR							64	7	2	74	6	3				M	●	●	R	↕	⑥	↕
	LSRA													44	2	1	A 	●	●	R	↕	⑥	↕
	LSRB													54	2	1	B	●	●	R	↕	⑥	↕
Store Acmltr.	STAA				97	4	2	A7	6	2	B7	5	3				A → M	●	●	↕	↕	R	●
	STAB				D7	4	2	E7	6	2	F7	5	3				B → M	●	●	↕	↕	R	●
Subtract	SUBA	80	2	2	90	3	2	A0	5	2	B0	4	3				A − M → A	●	●	↕	↕	↕	↕
	SUBB	C0	2	2	D0	3	2	E0	5	2	F0	4	3				B − M → B	●	●	↕	↕	↕	↕
Subract Acmltrs.	SBA													10	2	1	A − B → A	●	●	↕	↕	↕	↕
Subtr. with Carry	SBCA	82	2	2	92	3	2	A2	5	2	B2	4	3				A − M − C → A	●	●	↕	↕	↕	↕
	SBCB	C2	2	2	D2	3	2	E2	5	2	F2	4	3				B − M − C → B	●	●	↕	↕	↕	↕
Transfer Acmltrs	TAB													16	2	1	A → B	●	●	↕	↕	R	●
	TBA													17	2	1	B → A	●	●	↕	↕	R	●
Test, Zero or Minus	TST							6D	7	2	7D	6	3				M − 00	●	●	↕	↕	R	R
	TSTA													4D	2	1	A − 00	●	●	↕	↕	R	R
	TSTB													5D	2	1	B − 00	●	●	↕	↕	R	R

INDEX REGISTER AND STACK POINTER OPERATIONS	MNEMONIC	IMMED			DIRECT			INDEX			EXTND			INHER			BOOLEAN/ARITHMETIC OPERATION	5	4	3	2	1	0
		OP	~	#	OP	~	#	OP	~	#	OP	~	#	OP	~	#		H	I	N	Z	V	C
Compare Index Reg	CPX	8C	3	3	9C	4	2	AC	6	2	BC	5	3				$(X_H/X_L) - (M/M + 1)$	●	●	⑦	↕	⑧	●
Decrement Index Reg	DEX													09	4	1	X − 1 → X	●	●	●	↕	●	●
Decrement Stack Pntr	DES													34	4	1	SP − 1 → SP	●	●	●	●	●	●
Increment Index Reg	INX													08	4	1	X + 1 → X	●	●	●	↕	●	●
Increment Stack Pntr	INS													31	4	1	SP + 1 → SP	●	●	●	●	●	●
Load Index Reg	LDX	CE	3	3	DE	4	2	EE	6	2	FE	5	3				$M \rightarrow X_H, (M + 1) \rightarrow X_L$	●	●	⑨	↕	R	●
Load Stack Pntr	LDS	8E	3	3	9E	4	2	AE	6	2	BE	5	3				$M \rightarrow SP_H, (M + 1) \rightarrow SP_L$	●	●	⑨	↕	R	●
Store Index Reg	STX				DF	5	2	EF	7	2	FF	6	3				$X_H \rightarrow M, X_L \rightarrow (M + 1)$	●	●	⑨	↕	R	●
Store Stack Pntr	STS				9F	5	2	AF	7	2	BF	6	3				$SP_H \rightarrow M, SP_L \rightarrow (M + 1)$	●	●	⑨	↕	R	●
Indx Reg → Stack Pntr	TXS													35	4	1	X − 1 → SP	●	●	●	●	●	●
Stack Pntr → Indx Reg	TSX													30	4	1	SP + 1 → X	●	●	●	●	●	●

JUMP AND BRANCH OPERATIONS	MNEMONIC	RELATIVE			INDEX			EXTND			INHER			BRANCH TEST	5	4	3	2	1	0
		OP	~	#	OP	~	#	OP	~	#	OP	~	#		H	I	N	Z	V	C
Branch Always	BRA	20	4	2										None	●	●	●	●	●	●
Branch If Carry Clear	BCC	24	4	2										C = 0	●	●	●	●	●	●
Branch If Carry Set	BCS	25	4	2										C = 1	●	●	●	●	●	●
Branch If = Zero	BEQ	27	4	2										Z = 1	●	●	●	●	●	●
Branch If ⩾ Zero	BGE	2C	4	2										N ⊕ V = 0	●	●	●	●	●	●
Branch If > Zero	BGT	2E	4	2										Z + (N ⊕ V) = 0	●	●	●	●	●	●
Branch If Higher	BHI	22	4	2										C + Z = 0	●	●	●	●	●	●
Branch If ⩽ Zero	BLE	2F	4	2										Z + (N ⊕ V) = 1	●	●	●	●	●	●
Branch If Lower Or Same	BLS	23	4	2										C + Z = 1	●	●	●	●	●	●
Branch If < Zero	BLT	2D	4	2										N ⊕ V = 1	●	●	●	●	●	●
Branch If Minus	BMI	2B	4	2										N = 1	●	●	●	●	●	●
Branch If Not Equal Zero	BNE	26	4	2										Z = 0	●	●	●	●	●	●
Branch If Overflow Clear	BVC	28	4	2										V = 0	●	●	●	●	●	●
Branch If Overflow Set	BVS	29	4	2										V = 1	●	●	●	●	●	●
Branch If Plus	BPL	2A	4	2										N = 0	●	●	●	●	●	●
Branch To Subroutine	BSR	8D	8	2										See Special Operations	●	●	●	●	●	●
Jump	JMP				6E	4	2	7E	3	3					●	●	●	●	●	●
Jump To Subroutine	JSR				AD	8	2	BD	9	3					●	●	●	●	●	●
No Operation	NOP										01	2	1	Advances Prog. Cntr. Only	●	●	●	●	●	●
Return From Interrupt	RTI										3B	10	1		⑩					
Return From Subroutine	RTS										39	5	1	See special Operations	●	●	●	●	●	●
Software Interrupt	SWI										3F	12	1		●	S	●	●	●	●
Wait for Interrupt	WAI										3E	9	1		●	⑪	●	●	●	●

CONDITIONS CODE REGISTER OPERATIONS	MNEMONIC	INHER			BOOLEAN OPERATION	5	4	3	2	1	0
		OP	~	=		H	I	N	Z	V	C
Clear Carry	CLC	0C	2	1	0 → C	●	●	●	●	●	R
Clear Interrupt Mask	CLI	0E	2	1	0 → I	●	R	●	●	●	●
Clear Overflow	CLV	0A	2	1	0 → V	●	●	●	●	R	●
Set Carry	SEC	0D	2	1	1 → C	●	●	●	●	●	S
Set Interrupt Mask	SEI	0F	2	1	1 → I	●	S	●	●	●	●
Set Overflow	SEV	0B	2	1	1 → V	●	●	●	●	S	●
Acmltr A → CCR	TAP	06	2	1	A → CCR	⑫					
CCR → Acmltr A	TPA	07	2	1	CCR → A	●	●	●	●	●	●

CONDITION CODE REGISTER NOTES:

(Bit set if test is true and cleared otherwise)

① (Bit V) Test: Result = 10000000?
② (Bit C) Test: Result = 00000000?
③ (Bit C) Test: Decimal value of most significant BCD Character greater than nine? (Not cleared if previously set.)
④ (Bit V) Test: Operand = 10000000 prior to execution?
⑤ (Bit V) Test: Operand = 01111111 prior to execution?
⑥ (Bit V) Test: Set equal to result of N ⊕ C after shift has occurred.
⑦ (Bit N) Test: Sign bit of most significant (MS) byte of result = 1?
⑧ (Bit V) Test: 2's complement overflow from subtraction of LS bytes?
⑨ (Bit N) Test: Result less than zero? (Bit 15 = 1)
⑩ (All) Load Condition Code Register from Stack. (See Special Operations)
⑪ (Bit I) Set when interrupt occurs. If previously set, a Non-Maskable Interrupt is required to exit the wait state.
⑫ (ALL) Set according to the contents of Accumulator A.

LEGEND:

OP	Operation Code (Hexadecimal);
~	Number of MPU Cycles;
#	Number of Program Bytes;
+	Arithmetic Plus;
−	Arithmetic Minus;
•	Boolean AND;
M_{SP}	Contents of memory location pointed to be Stack Pointer;
+	Boolean Inclusive OR;
⊕	Boolean Exclusive OR;
$\overline{M}$	Complement of M;
→	Transfer Into;
0	Bit = Zero;

00	Byte = Zero;
H	Half-carry from bit 3;
I	Interrupt mask
N	Negative (sign bit)
Z	Zero (byte)
V	Overflow, 2's complement
C	Carry from bit 7
R	Reset Always
S	Set Always
↕	Test and set if true, cleared otherwise
●	Not Affected
CCR	Condition Code Register
LS	Least Significant
MS	Most Significant

Hexadecimal Values of Machine Codes

00	*			40	NEG	A		80	SUB	A	IMM	C0	SUB	B	IMM
01	NOP 4E			41	*			81	CMP	A	IMM	C1	CMP	B	IMM
02	*			42	*			82	SBC	A	IMM	C2	SBC	B	IMM
03	*			43	COM	A		83	*			C3	*		
04	*			44	LSR	A		84	AND	A	IMM	C4	AND	B	IMM
05	*			45	*			85	BIT	A	IMM	C5	BIT	B	IMM
06	TAP			46	ROR	A		86	LDA	A	IMM	C6	LDA	B	IMM
07	TPA			47	ASR	A		87	*			C7	*		
08	INX			48	ASL	A		88	EOR	A	IMM	C8	EOR	B	IMM
09	DEX			49	ROL	A		89	ADC	A	IMM	C9	ADC	B	IMM
0A	CLV			4A	DEC	A		8A	ORA	A	IMM	CA	ORA	B	IMM
0B	SEV			4B	*			8B	ADD	A	IMM	CB	ADD	B	IMM
0C	CLC			4C	INC	A		8C	CPX	A	IMM	CC	*		
0D	SEC			4D	TST	A		8D	BSR		REL	CD	*		
0E	CLI			4E	*			8E	LDS		IMM	CE	LDX		IMM
0F	SEI			4F	CLR	A		8F	*			CF	*		
10	SBA			50	NEG	B		90	SUB	A	DIR	D0	SUB	B	DIR
11	CBA			51	*			91	CMP	A	DIR	D1	CMP	B	DIR
12	*			52	*			92	SBC	A	DIR	D2	SBC	B	DIR
13	*			53	COM	B		93	*			D3	*		
14	*			54	LSR	B		94	AND	A	DIR	D4	AND	B	DIR
15	*			55	*			95	BIT	A	DIR	D5	BIT	B	DIR
16	TAB			56	ROR	B		96	LDA	A	DIR	D6	LDA	B	DIR
17	TBA			57	ASR	B		97	STA	A	DIR	D7	STA	B	DIR
18	*			58	ASL	B		98	EOR	A	DIR	D8	EOR	B	DIR
19	DAA			59	ROL	B		99	ADC	A	DIR	D9	ADC	B	DIR
1A	*			5A	DEC	B		9A	ORA	A	DIR	DA	ORA	B	DIR
1B	ABA			5B	*			9B	ADD	A	DIR	DB	ADD	B	DIR
1C	*			5C	INC	B		9C	CPX		DIR	DC	*		
1D	*			5D	TST	B		9D	*			DD	*		
1E	*			5E	*			9E	LDS		DIR	DE	LDX		DIR
1F	*			5F	CLR	B		9F	STS		DIR	DF	STX		DIR
20	BRA		REL	60	NEG		IND	A0	SUB	A	IND	E0	SUB	B	IND
21	*			61	*			A1	CMP	A	IND	E1	CMP	B	IND
22	BHI		REL	62	*			A2	SBC	A	IND	E2	SBC	B	IND
23	BLS		REL	63	COM		IND	A3	*			E3	*		
24	BCC		REL	64	LSR		IND	A4	AND	A	IND	E4	AND	B	IND
25	BCS		REL	65	*			A5	BIT	A	IND	E5	BIT	B	IND
26	BNE		REL	66	ROR		IND	A6	LDA	A	IND	E6	LDA	B	IND
27	BEQ		REL	67	ASR		IND	A7	STA	A	IND	E7	STA	B	IND
28	BVC		REL	68	ASL		IND	A8	EOR	A	IND	E8	EOR	B	IND
29	BVS		REL	69	ROL		IND	A9	ADC	A	IND	E9	ADC	B	IND
2A	BPL		REL	6A	DEC		IND	AA	ORA	A	IND	EA	ORA	B	IND
2B	BMI		REL	6B	*			AB	ADD	A	IND	EB	ADD	B	IND
2C	BGE		REL	6C	INC		IND	AC	CPX		IND	EC	*		
2D	BLT		REL	6D	TST		IND	AD	JSR		IND	ED	*		
2E	BGT		REL	6E	JMP		IND	AE	LDS		IND	EE	LDX		IND
2F	BLE		REL	6F	CLR		IND	AF	STS		IND	EF	STX		IND
30	TSX			70	NEG		EXT	B0	SUB	A	EXT	F0	SUB	B	EXT
31	INS			71	*			B1	CMP	A	EXT	F1	CMP	B	EXT
32	PUL	A		72	*			B2	SBC	A	EXT	F2	SBC	B	EXT
33	PUL	B		73	COM		EXT	B3	*			F3	*		
34	DES			74	LSR		EXT	B4	AND	A	EXT	F4	AND	B	EXT
35	TXS			75	*			B5	BIT	A	EXT	F5	BIT	B	EXT
36	PSH	A		76	ROR		EXT	B6	LDA	A	EXT	F6	LDA	B	EXT
37	PSH	B		77	ASR		EXT	B7	STA	A	EXT	F7	STA	B	EXT
38	*			78	ASL		EXT	B8	EOR	A	EXT	F8	ADC	B	EXT
39	RTS			79	ROL		EXT	B9	ADC	A	EXT	F9	ADC	B	EXT
3A	*			7A	DEC		EXT	BA	ORA	A	EXT	FA	ORA	B	EXT
3B	RTI			7B	*			BB	ADD	A	EXT	FB	ADD	B	EXT
3C	*			7C	INC		EXT	BC	CPX		EXT	FC	*		
3D	*			7D	TST		EXT	BD	JSR		EXT	FD	*		
3E	WAI			7E	JMP		EXT	BE	LDS		EXT	FE	LDX		EXT
3F	SWI			7F	CLR		EXT	BF	STS		EXT	FF	STX		EXT

Notes: 1. Addressing Modes:
A = Accumulator A
B = Accumulator B
REL = Relative
IND = Indexed
IMM = Immediate
DIR = Direct
2. Unassigned code indicated by "*"

MACHINE LANGUAGE REFERENCE

The Imagination Machine contains a machine language reference mode. You can use this to create, display, change, and execute machine language programs.

To use this appendix, you must be able to write programs in 6800 machine language. You must also have a working knowledge of hexadecimal notation.

CALL 28672

This BASIC statement takes you out of BASIC. You are now talking to the Imagination Machine Monitor. The monitor puts a "*" at the beginning of each line on the screen. When you see the "*", you can enter one of the three monitor commands:

D nnnn where nnnn is a hexadecimal address
G nnnn where nnnn is a hexadecimal address
M nnnn where nnnn is a hexadecimal address

D nnnn - DISPLAY MEMORY

This command will display the 16 bytes of memory beginning at address nnnn. To display the next 16 bytes, press the "/" key. To end the command, press the RETURN key.

Example:
```
* D 9B3C
* 9B3C 20 E0 B6 A0 58 BD 9A B6 CE
  A0 9C 7E 9A 28 7C a0/
* 9B4C AA 20 D4 86 04 CE A0 AA 0C
  69 00 09 8C 80 9C 26 (Return)
*
```

G nnnn - GOTO MEMORY ADDRESS

This command acts much like the BASIC GOTO statement except the value NNNN is a four digit hexadecimal memory address. The computer immediately begins executing the machine language program at that address.

```
*G 8894
```

Address 8894 is the start of the Imagination Machine's BASIC. This is how you reenter BASIC. If you had a BASIC program in memory when you called the monitor, it should still be there.

M nnnn - MODIFY MEMORY

This command immediately displays the contents at memory address nnnn. You can do one of four things:

> reply with the "/" key and the command proceeds by displaying the next position in memory.
>
> reply with " " key and the command proceeds to display the previous memory position.
>
> reply with the RETURN key and the command is ended.
>
> reply with a two-digit hexadecimal number and the RETURN key and the command stores this new number in the current memory position. Then you can press Return, /, or   with the results as above.

If the M command cannot change the memory location, it will respond with a "?."

APPENDIX C

Schematics/Parts Layouts

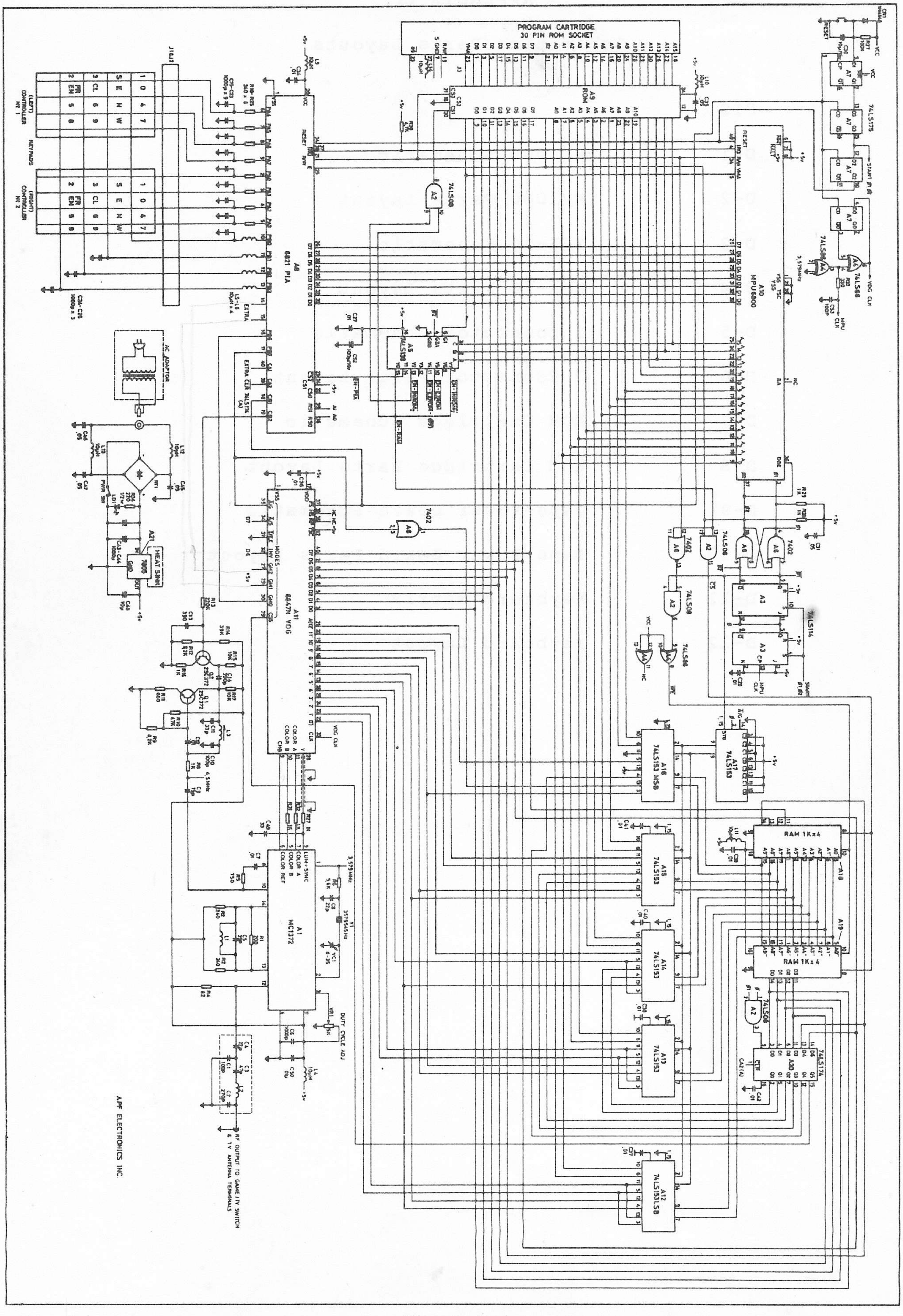
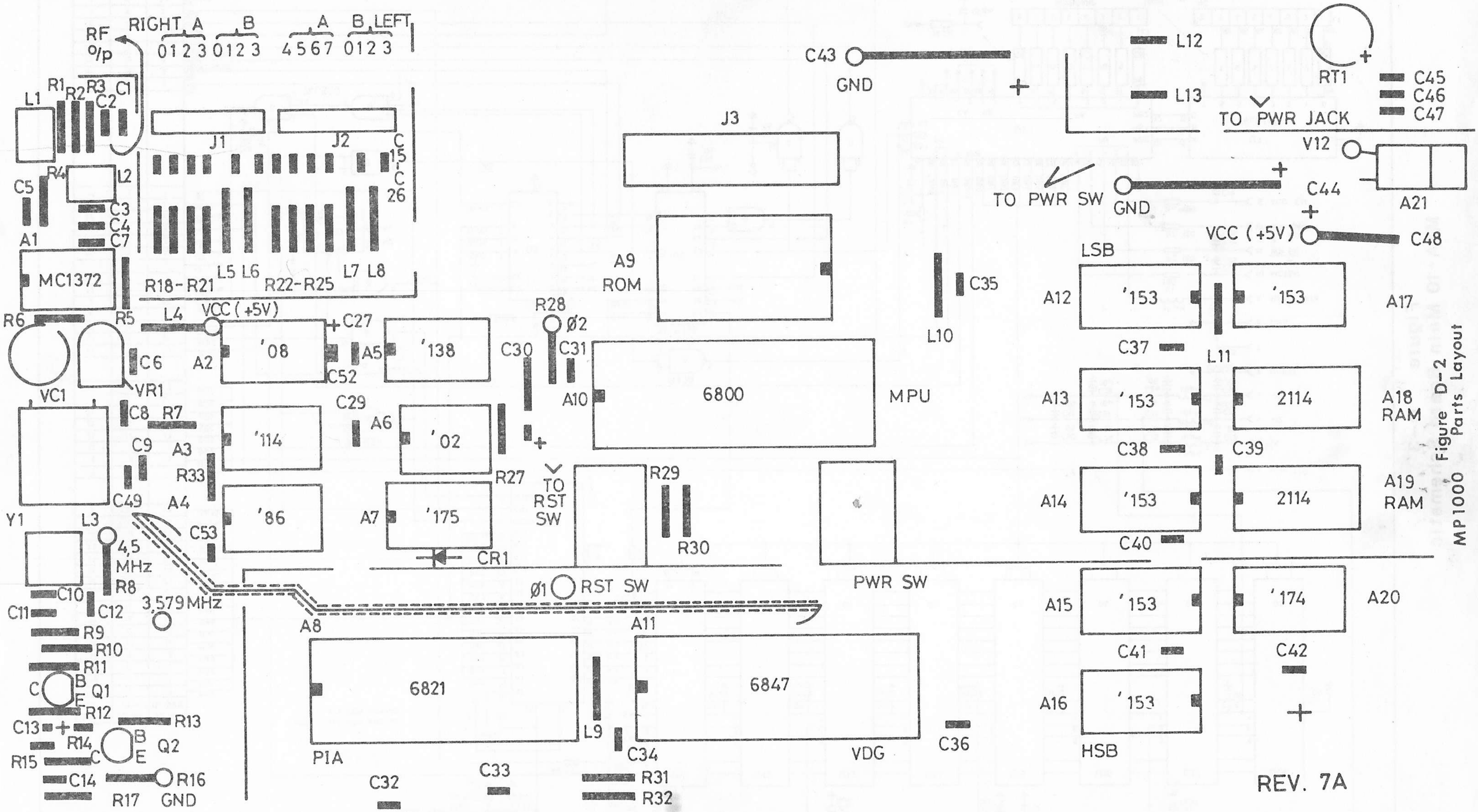


Figure D-1
MP1000 Schematic



MP1000 Figure D-2
Parts Layout

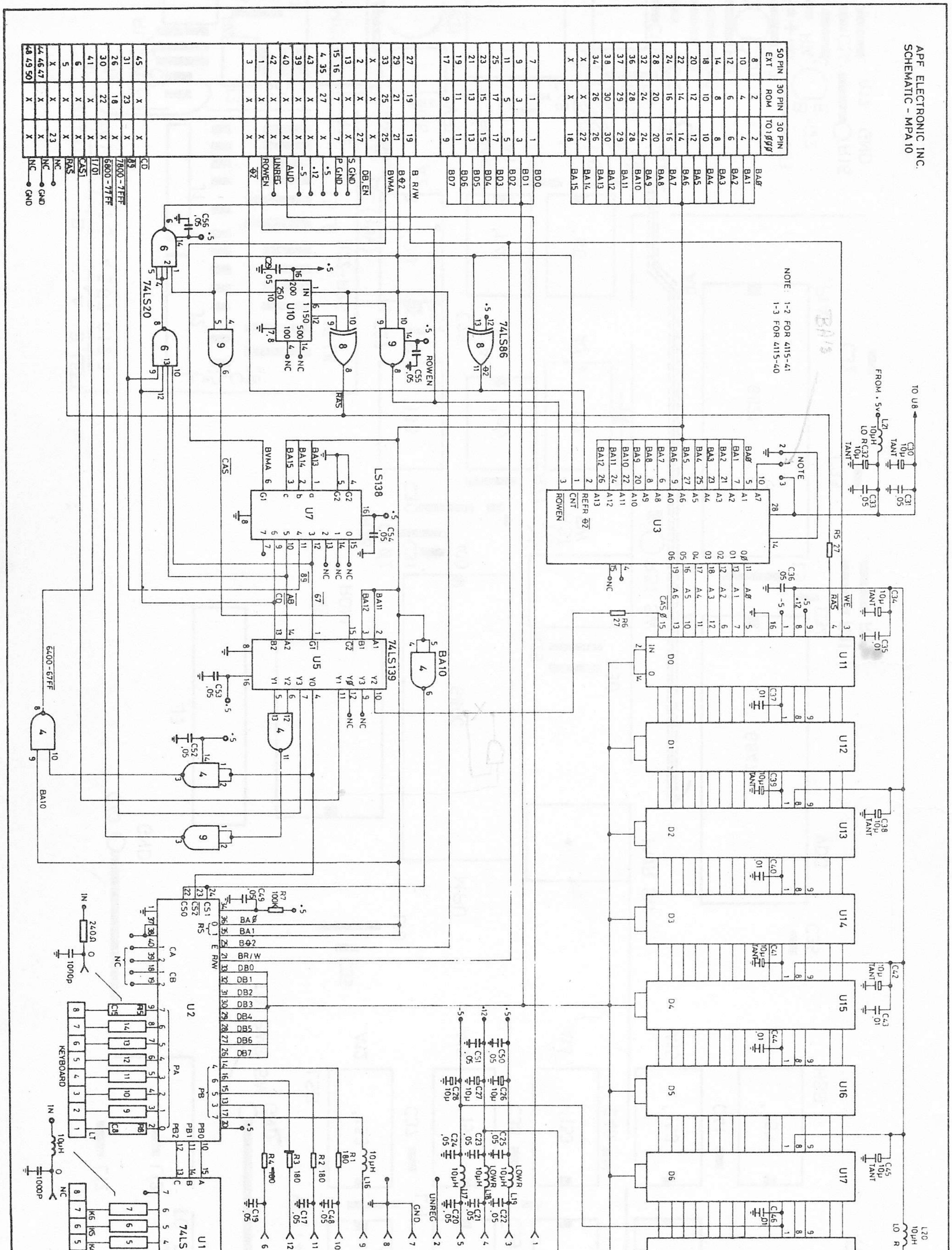


Figure D-3
MPA-10 Main Board Schematic

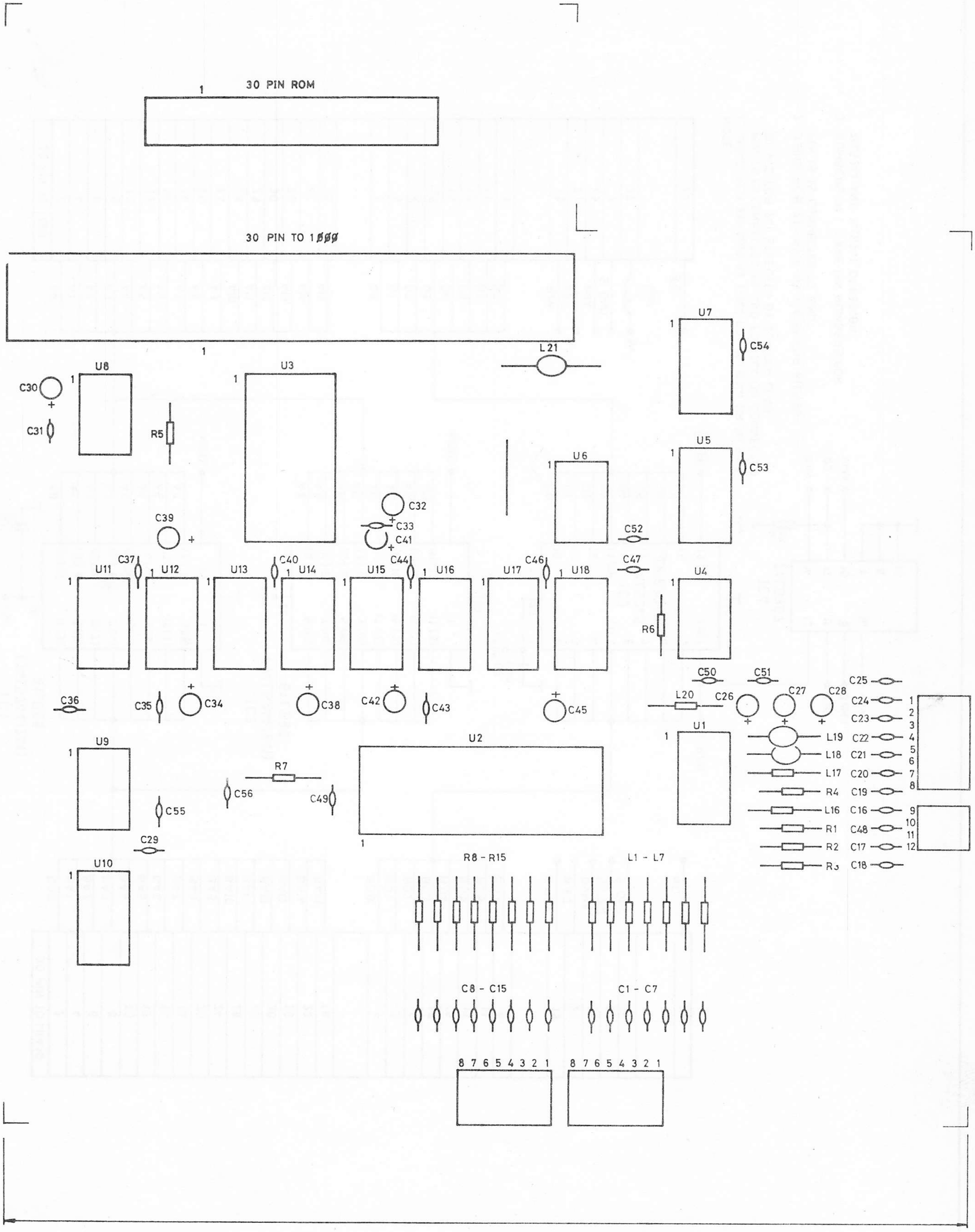
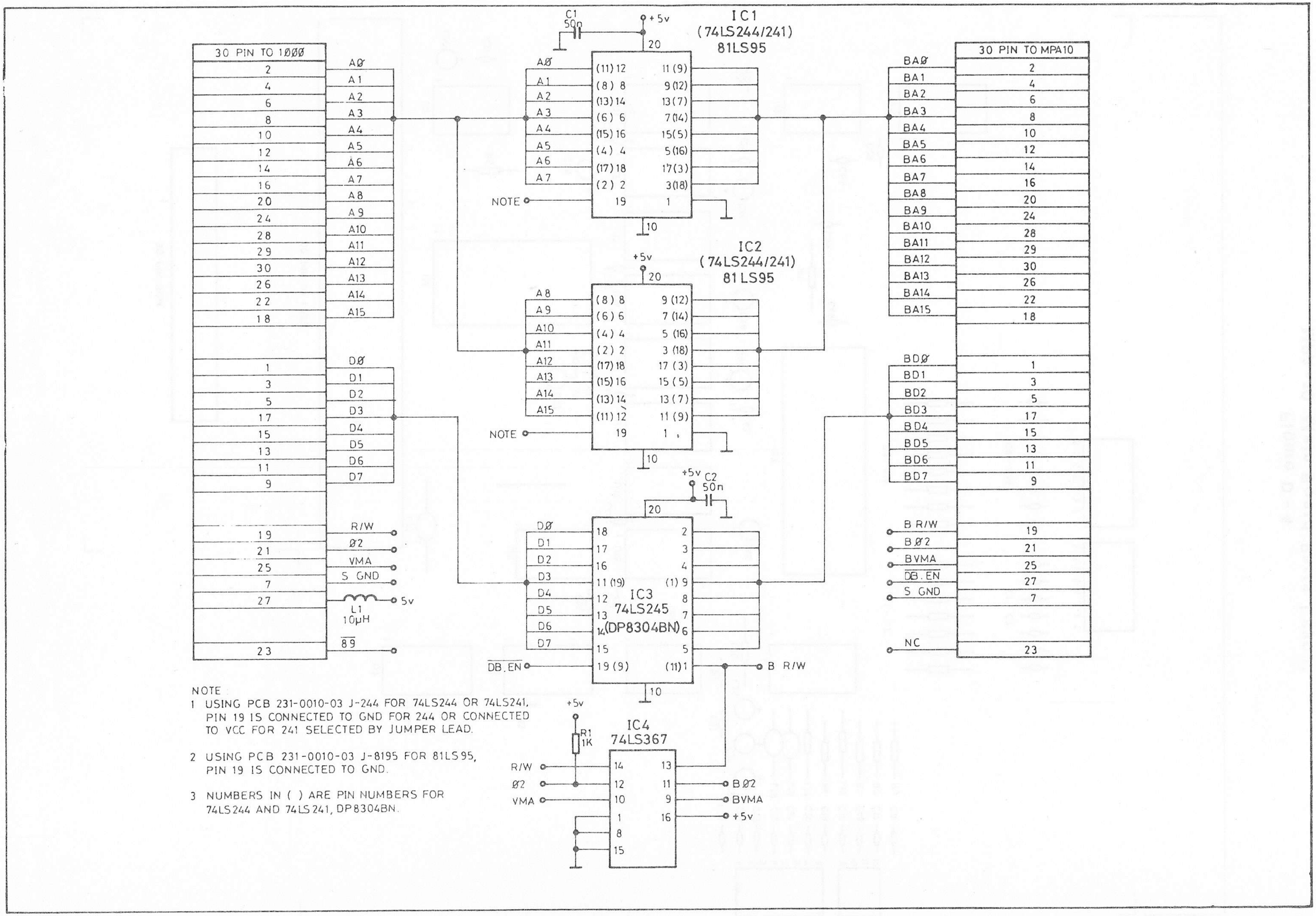


Figure D-4
MPA-10 Main Board Parts Layout



NOTE

1 USING PCB 231-0010-03 J-244 FOR 74LS244 OR 74LS241, PIN 19 IS CONNECTED TO GND FOR 244 OR CONNECTED TO VCC FOR 241 SELECTED BY JUMPER LEAD.

2 USING PCB 231-0010-03 J-8195 FOR 81LS95, PIN 19 IS CONNECTED TO GND.

3 NUMBERS IN ( ) ARE PIN NUMBERS FOR 74LS244 AND 74LS241, DP8304BN.

Figure D–5
J Connector Schematic

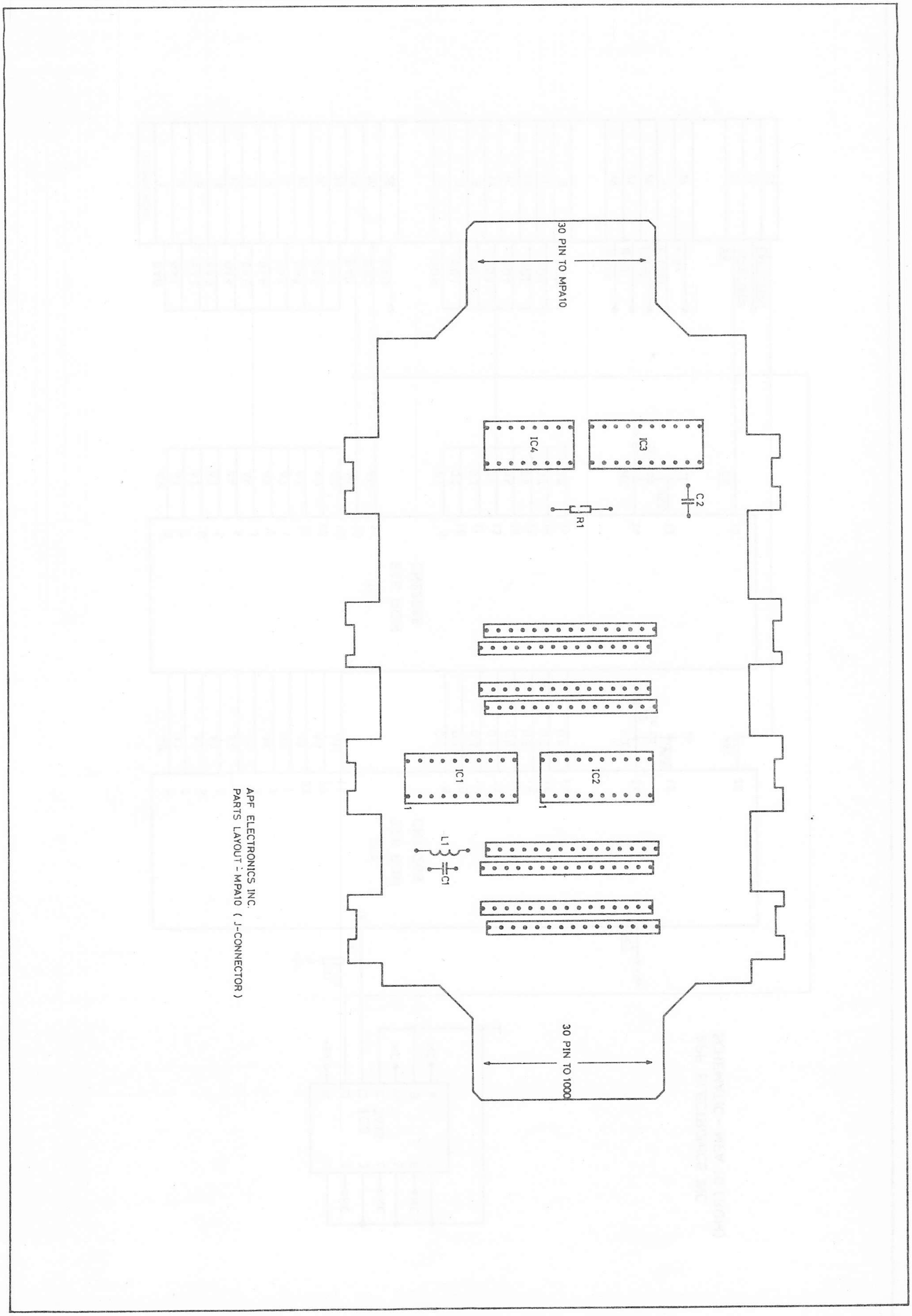
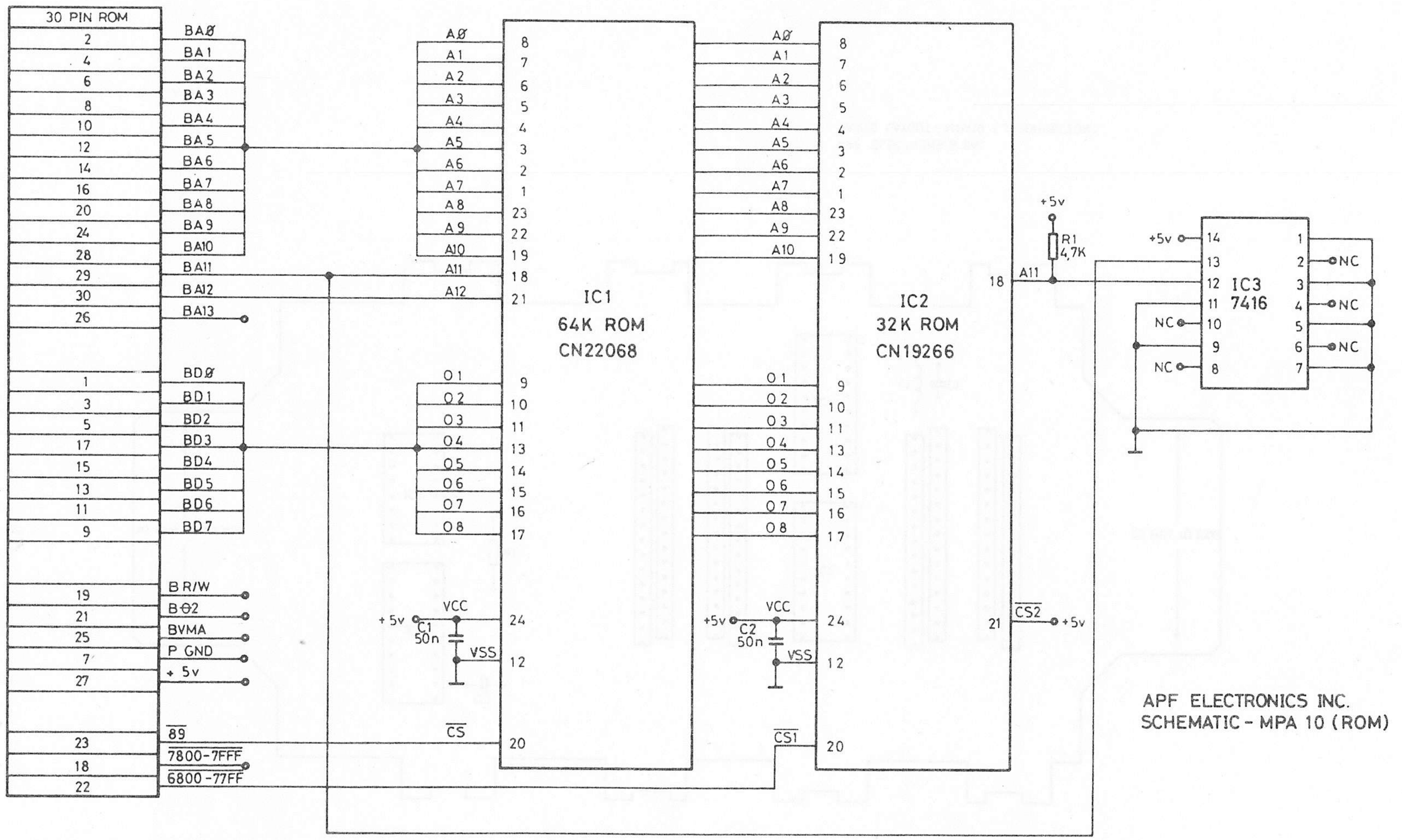


Figure D-6
J Connector Parts Layout



APF ELECTRONICS INC.
SCHEMATIC - MPA 10 (ROM)

Figure D - 7
ROM Cartridge Schematic

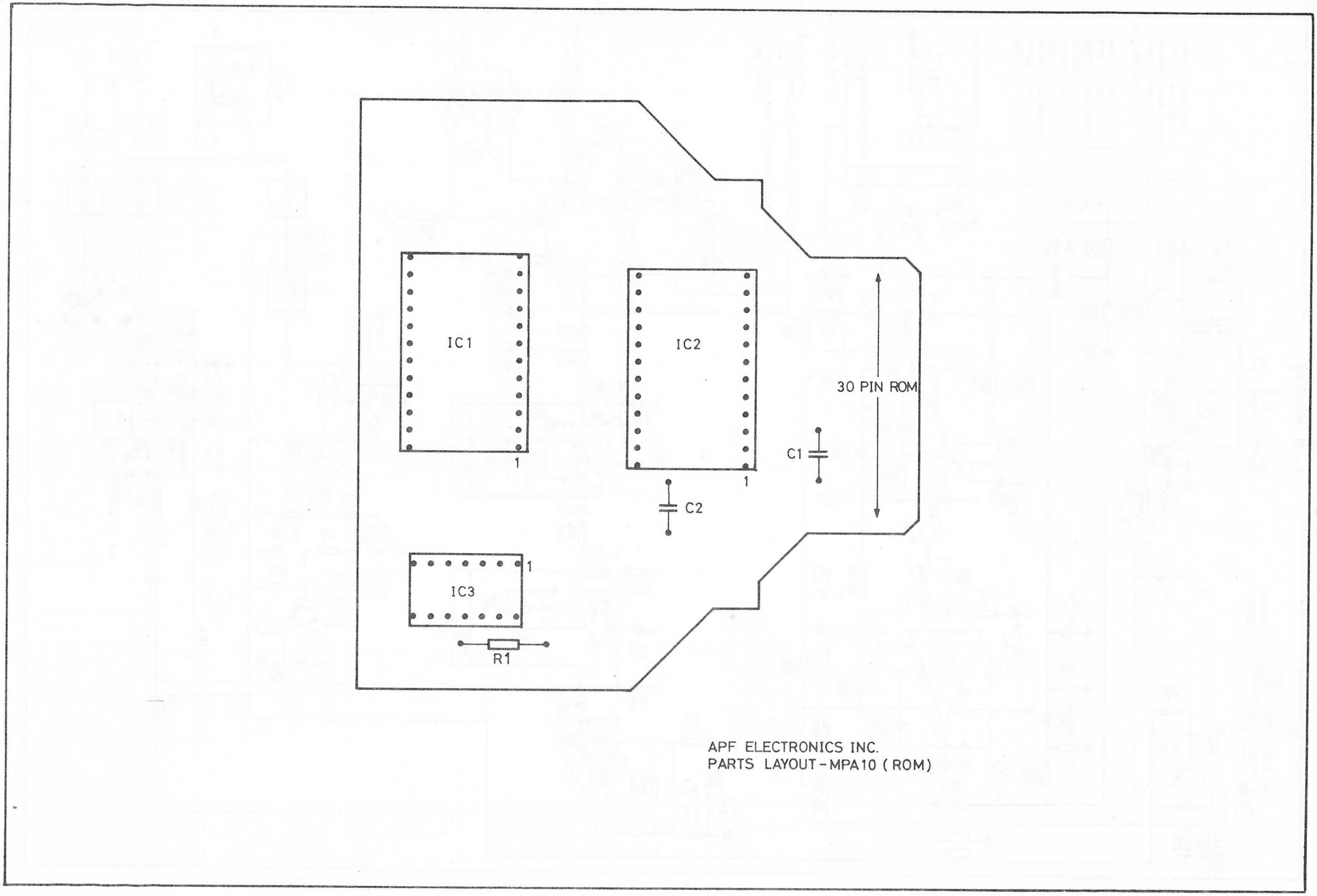
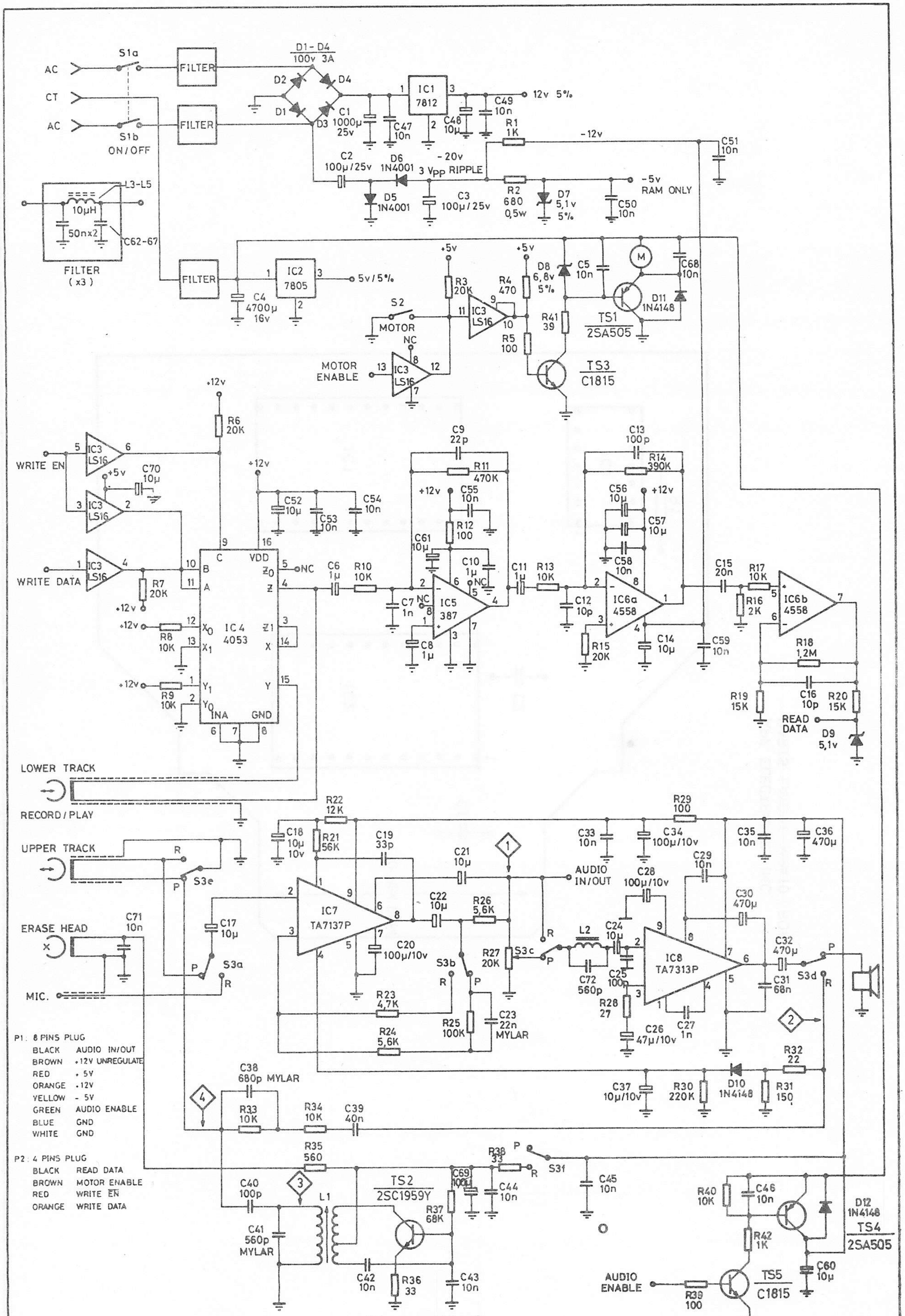


Figure D-8
RO.M Cartridge Layout



P1: 8 PINS PLUG

BLACK	AUDIO IN/OUT
BROWN	+12V UNREGULATE
RED	+ 5V
ORANGE	+12V
YELLOW	- 5V
GREEN	AUDIO ENABLE
BLUE	GND
WHITE	GND

P2: 4 PINS PLUG

BLACK	READ DATA
BROWN	MOTOR ENABLE
RED	WRITE $\overline{EN}$
ORANGE	WRITE DATA

Figure D-9

Tape - Power Board Schematic

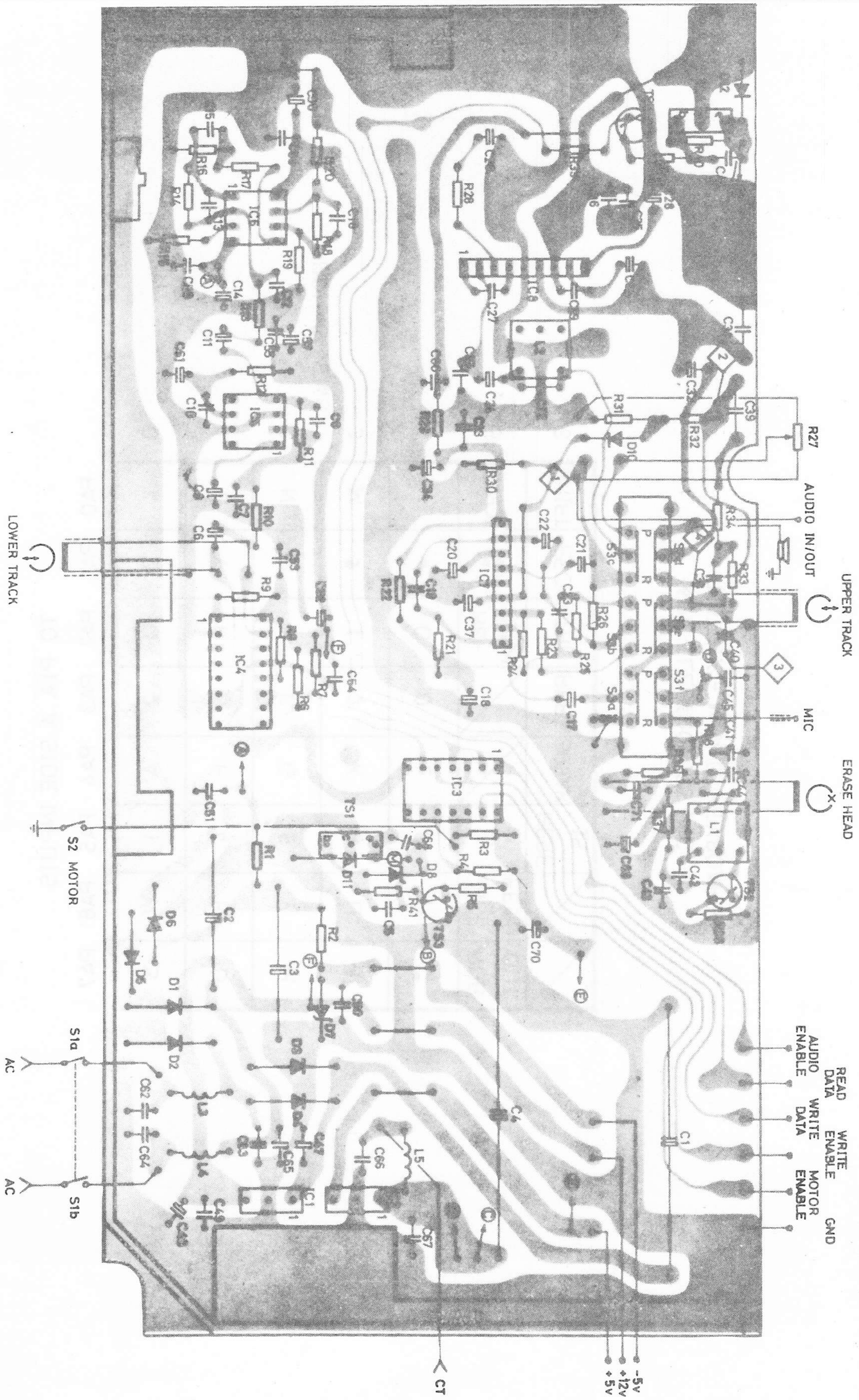


Figure D-10
Tape-Power Board Parts Layout

TO PIA A SIDE INPUTS

FROM 74LS145

	PA0	PA1	PA2	PA3	PA4	PA5	PA6	PA7
0	X	Z	Q	2	A	1	W	S
1	C	V	R	3	F	4	E	D
2	N	B	T	6	G	5	Y	H
3	M	,	I	7	K	8	U	J
4	/	.	O	0	L	9	P	;
5	SPACE	:	RE-TURN			—	LINE FEED	RUB OUT
6	SHIFT	ESC	CTRL	REPT	BREAK	HERE IS		

APF ELECTRONICS INC.
MATRIX – MPA10 (KEYBOARD)

Figure D–11
Keyboard Matrix

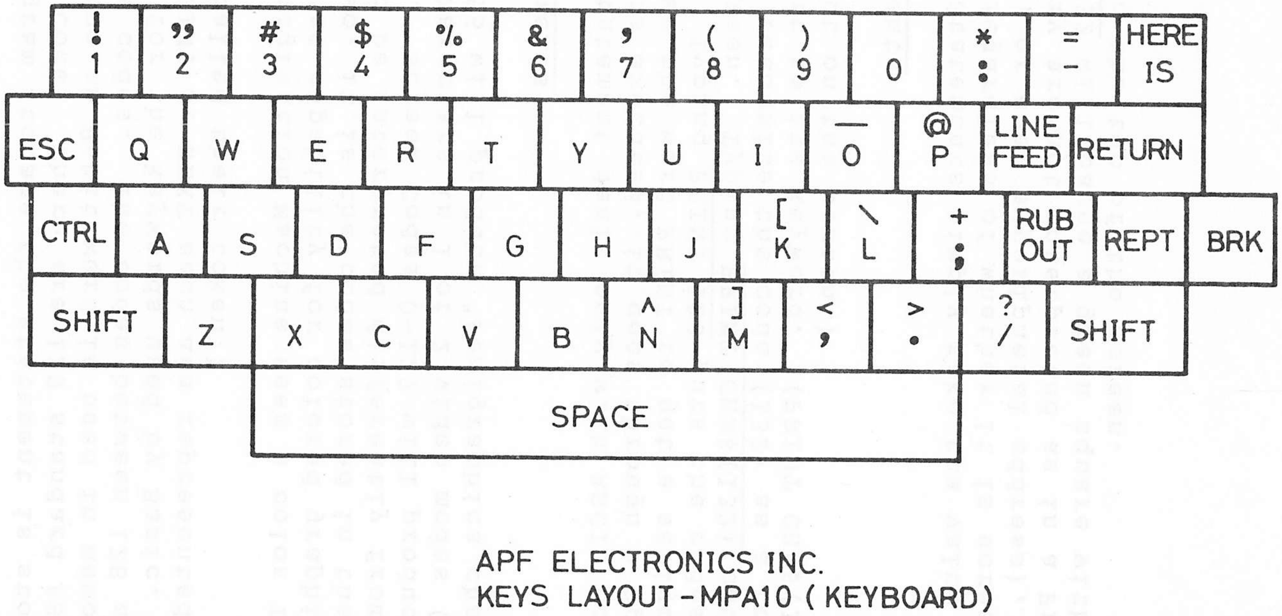


Figure D-12
Keyboard Layout

APPENDIX D

ASCII CODES AND IMAGINATION MACHINE INTERNAL STORAGE

Although the Imagination Machine uses an 8-bit word (1 byte) for all memory storage, different interpretation by the machine of these codes occurs. This appendix will clarify how and when a code is interpreted.

1. For all program storage the statement is stored in standard 7-bit ASCII Code. There are 128 standard ASCII Codes (Codes 0-127). Since an 8-bit word is used in memory, there are 256 possible codes. The codes between 128 and 255 are used as "tokens" for the keywords used by Basic. (This means the words PRINT or NEXT each are represented by a single 8-bit code called their token.)

2. Since the Imagination Machine uses a color T.V. for its output and has capability for colored graphics as well as reverse video, it is the codes stored in the screen maps that have to be interpreted differently from the standard ASCII Codes. Screen Codes 0-127 will produce only 64 of the ASCII characters in 1 of 2 video modes (normal or reverse). Codes 128-255 will produce "semigraphics characters."

3. PRINT Statements

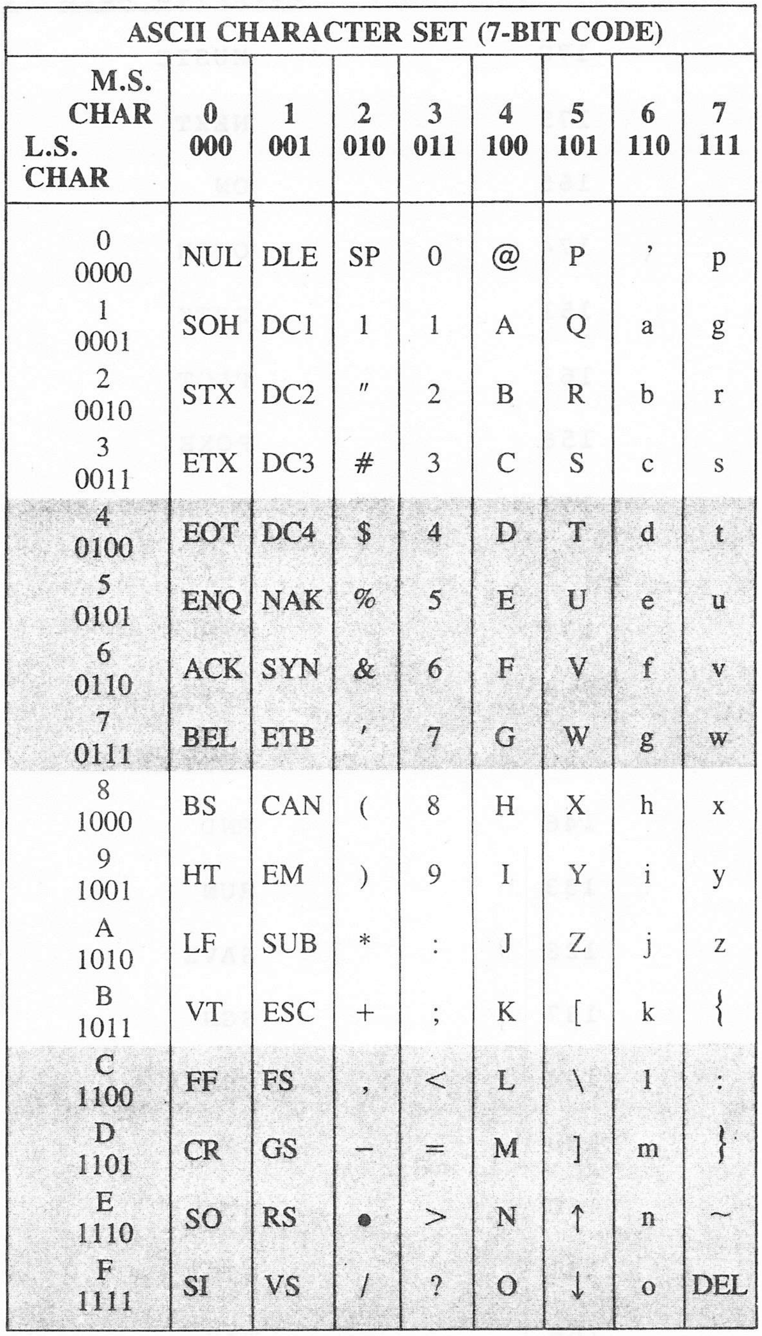
   The Print Statement deals only with ASCII Codes. When the word PRINT is executed, it goes through a special routine. You can't use the word PRINT to get a semigraphics shape on the screen. Typing PRINT 123 puts the codes for 1, 2, and 3 to the screen. Typing PRINT CHR$(132) causes the print routines to recognize the code (132) as a token code, and it expands it to its keyword. (PRINT CHR$(132) will cause DIM to be put on the screen.)

4. POKE Statements

   Since Poke Statements simply take the value and place it in memory (regardless of whether it is screen memory, program memory, or even a peripheral address), codes poked to screen memory are not interpreted as in a Print Statement. POKE 512, 132 will cause a green square with a shape of 8 to be put in the top of the screen.

RESERVED WORDS AND THEIR TOKEN CODES

Reserved Word	Token Code (Decimal)	Reserved Word	Token Code (Decimal)
ABS	170	MUSIC	164
ASC	175	NEXT	144
CALL	165	ON	136
CHR$	174	OPEN	162
CLOAD	151	PEEK	173
CLOSE	163	PLOT	153
COLOR	156	POKE	152
CSAVE	150	PRINT	145
DATA	130	READ	143
DIM	132	REM	148
DIR	166	RESTORE	139
EDIT	158	RETURN	134
END	146	RND	176
FOR	133	RUN	161
GOSUB	128	SAVE	159
GOTO	137	SGN	171
HLIN	154	SHAPE	157
IF	140	SPC	168
INIT	160	STEP	141
INPUT	131	STOP	142
INT	169	TAB	167
KEY$	177	THEN	135
LEN	176	TO	138
LET	129	USING	149
LIST	147	VLIN	155



ASCII CHARACTER SET (7-BIT CODE)								
M.S. CHAR L.S. CHAR	0 000	1 001	2 010	3 011	4 100	5 101	6 110	7 111
0 0000	NUL	DLE	SP	0	@	P	’	p
1 0001	SOH	DC1	1	1	A	Q	a	g
2 0010	STX	DC2	″	2	B	R	b	r
3 0011	ETX	DC3	#	3	C	S	c	s
4 0100	EOT	DC4	$	4	D	T	d	t
5 0101	ENQ	NAK	%	5	E	U	e	u
6 0110	ACK	SYN	&	6	F	V	f	v
7 0111	BEL	ETB	′	7	G	W	g	w
8 1000	BS	CAN	(	8	H	X	h	x
9 1001	HT	EM	)	9	I	Y	i	y
A 1010	LF	SUB	*	:	J	Z	j	z
B 1011	VT	ESC	+	;	K	[	k	{
C 1100	FF	FS	,	<	L	\	l	:
D 1101	CR	GS	–	=	M	]	m	}
E 1110	SO	RS	●	>	N	↑	n	~
F 1111	SI	VS	/	?	O	↓	o	DEL

ASCII CODE

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