

# Brain Board with Wozaniam Pack Assembly and Operations Guide

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version 5.1

## CAUTION!!!

Vintage computers should always be attended while powered up. Aging components in old computers can fail at any time in unpredictable and sometimes hazardous ways, including fire. Your house could burn down, or worse, if your vintage computer is left running without supervision.

## CAUTION #2!!!

Incorrect assembly or connecting of the Brain Board can cause fatal damage to the interface and/or the motherboard. Double and triple check your connections before powering on. Pay special attention to orientation of the card when you plug it into the motherboard's expansion slot. Plugging it in backwards will result in damage to the card and/or motherboard.

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## **Brain Board Overview**

The brain board is a firmware board for your Apple II/Apple II plus or Apple IIe computer. The board uses inexpensive and readily available 27c128 or 27c256 PROMs. Because of the denser PROMs used, 6 sockets are replaced with one and the resulting size of the board is reduced to under 3 by 4 inches.

The original Apple firmware board was able to replace motherboard ROM functionality with its own ROM's. This allowed an Apple II to have Applesoft in ROM or an Apple II plus to have Integer basic in ROM. A soft-switch (flip-flop) is included which allows for switching between the firmware card and motherboard ROMs through software control. The board also includes a little known and seldom used capability that allows multiple firmware cards to coexist in the same system as long as they are in adjacent slots. Firmware cards were normally located in slot 0, but they could be located in any slot.

Later on in time, a 16K ram (language) card was developed that had the same functionality, except the appropriate BASIC was loaded into the language card from disk when DOS was booted. The multiple card support was dropped.

The base design of the Brain Board includes all the capability of the Applesoft/Integer Basic Firmware ROM board that Apple Computer released around 1978 including:

- switch for enable/disable
- a software controlled switch (soft switch) for changing between motherboard ROMs and firmware board ROMs
- jumper for enabling monitor ROM F8 - this was a solder pad jumper in the Apple design
- daisy chain enable functionality via DMA bus connections for multiple card support.

In addition, I have added several enhancements in order to maximize usefulness of the board.

- The modified design will allow booting a ROM-less motherboard into DOS, which is not possible with the original firmware board
- 27C256 PROMs allow support of two complete ROM images on the Brain Board. Images of both Applesoft and Integer BASIC with matching monitors could be installed and used from the single PROM. An extra soft switch is used to select whether the high or low half of the PROM is in use. This soft switch can be configured by external switch, through software control or by jumper.
- The Apple II peripheral bus I/O select signal is connected to the lowest 256 bytes of the PROM bank that is currently selected by the bank select flip flop. I/O select is connected to a different address depending upon the slot the board is located in. Slot 0 does not have a I/O select signal, so this feature cannot be used if the Brain Board is installed in slot 0. The starting address for these 256 bytes is computed by multiplying 0x100 by the slot number and adding 0xC000. Thus slot 1 is 0xC100, slot 2 is 0xC200, etc.

## **Chapter 1 – Assemble Components, Tools, and Equipment**

### **1. Recommended Tools and Equipment**

- Quality soldering station - I use a Weller WES51. I recommend that whatever soldering iron you use, that it has some kind of temperature controlled tip. This will help prevent damage to the PCB when soldering. Soldering irons that do not have a temperature controlled tip can overheat and damage the PCB or component being soldered
- Solder - use quality solder - thinner solder is vastly easier to work with than fat solder. The fat stuff sold at hardware stores is not suitable for these sort of electronics projects. I have been using Qualitek 60/40 silver/lead with 3.3% flux .032" diameter (PN 50-30521). Note that lead is known to cause cancer and birth defects or other reproductive harm, so use with caution.
- Wire cutters – for trimming component leads to length
- Your favorite PCB cleaning agent - Isopropyl Alcohol will dissolve many kinds of soldering resin. Windex will also help with cleaning PCBs
- Ohm meter - to check for good connections and shorts
- Logic probe or oscilloscope – handy if you are having trouble with bring up
- Your Apple II computer schematics or hardware interfacing guide – Direction for connecting to Apple II/IIplus/IIe computers are provided in this manual
- When using the Wozanium Rom image (Apple 1 emulation) , the Apple 1 operations and ACI manuals are helpful. The software sections of the Apple 1 operations manual along with the ACI manual are provided with the Brain Board

### **2. Additional Components (not included)**

- Cassette Recorder - I can recommend the Panasonic RQ-2102
- Cassette Tapes - ordinary 30 or 60 minute tapes work well
- Two mono to mono 1/8" audio cables. One end plugs into the ACI, the other into jacks on the cassette recorder

### 3. Compare Received Components With Parts List

Examine and identify all parts provided with the kit.

PART	DESCRIPTION	QUANTITY	PRESENT
28 pin wide dip socket	For 27C128 or 27C256	1	
20 pin dip socket	For 74LS244	1	
16 pin dip socket	For 74LS138	1	
14 pin dip socket	For 74LS09(2), 74LS11 and 74LS74	4	
74LS09	Quad 2 input and gates with open collector output	2	
74LS11	Triple 3 input and gate	1	
74LS74	Dual D type flip flop	1	
74LS138	3 to 8 Demultiplexor	1	
74LS244	Data bus buffer	1	
27C256	32K byte EPROM. Low bank programmed with Wozanium, high bank unprogrammed	1	
.01uF capacitor	Input coupling capacitor	6	
3K resistor	orange-black-red Rom enable, device enable and DMA in pull-ups	3	
10K resistor	brown-black-orange-gold High bank, Low bank, I/O select and unused input pull-ups	4	
DIP switch array	for hard configuration	1	
DPSP switch	enable/disable after reset	1	
PCB	Printed circuit board	1	
<b>PARTS COUNT</b>		<b>30</b>	
<b>COUNT OF TYPES</b>		<b>16</b>	

## Chapter 2 – Building the Brain Board

### 1. Overview

The key thing here is to check orientation and make sure that you don't put the sockets or chips in wrong. For the IC sockets, make sure that the parts are oriented correctly with pin 1 of the socket or chip going into the location with the square pad. There is also a white dot in the silk screen near pin 1. All components go on the front of the board. This is the side with the words "www.willegal.net" etched in copper and Brain Board printed on the silk screen.

Directions are set up so that larger sockets are soldered in first. This prevents the builder from putting a small socket into a location meant for a larger one. Please follow assembly order from top to bottom. Make sure the socket or chip is fully seated. I accomplish this by resting the socket upside down on a small object with the board on top. The weight of the board should keep the socket or chip completely seated. Then tack down a couple of corner pins and recheck orientation and seating. Then finish soldering the rest of the pins.

I found the easiest way to solder discrete components is to find a way hold the board vertically in a fixture. Place the component in the hole and spread the legs a bit at which point it should stay in place. Then solder on one leg and check to make sure that the component is fully seated before soldering the other leg in place. Once soldered in, check your work, and then trim the leads using a small wire cutter. Don't mistake vias for component mounting holes. Vias have smaller diameter holes and are not connected to a mate on the silk screen.

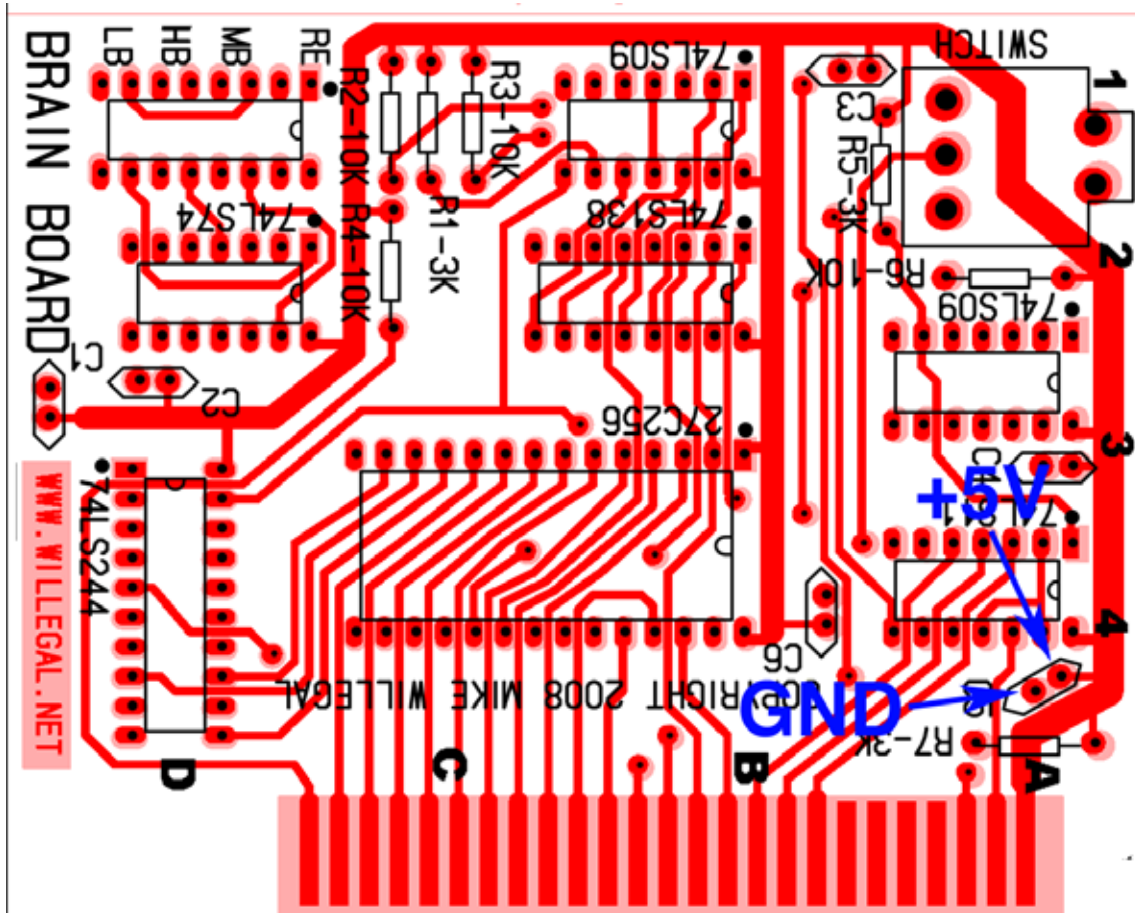
Take your time and enjoy the process, double checking orientation of devices as you go. The blue arrows indicate places to pay special attention when assembling this board

### 2. An Important Note About The Toggle Switch

The toggle switch is intended to allow the user to easily change default PROM bank selection after a reset operation. The switch is positioned to match the position of the original Apple Firmware board which was normally inserted into Slot 0 of an Apple II or Apple IIplus. In this location, it can be accessed by the operator through the opening lining up with slot 0 in the back of the case. If the Brain Board is installed in a different slot without a matching opening, clearance is very tight and operating the switch can be difficult and must be done after opening the top of the machine. This is also the case when installing into an Apple IIe. In any case, you should consider the alternative approach of installing the toggle switch remotely near the front of the computer where it can be more easily accessed.



If you decide to try this, instead of installing the switch on the Brain Board, simply run three wires from the three inboard switch connections on the PCB to a STDP switch which can be mounted in a small project box on or near the front of the computer. In this example, I used a 4 position moxex connection in the 22 series. The two middle pins went in the center hole and were only connected to one wire. The red and green wires were connected to the outside pins

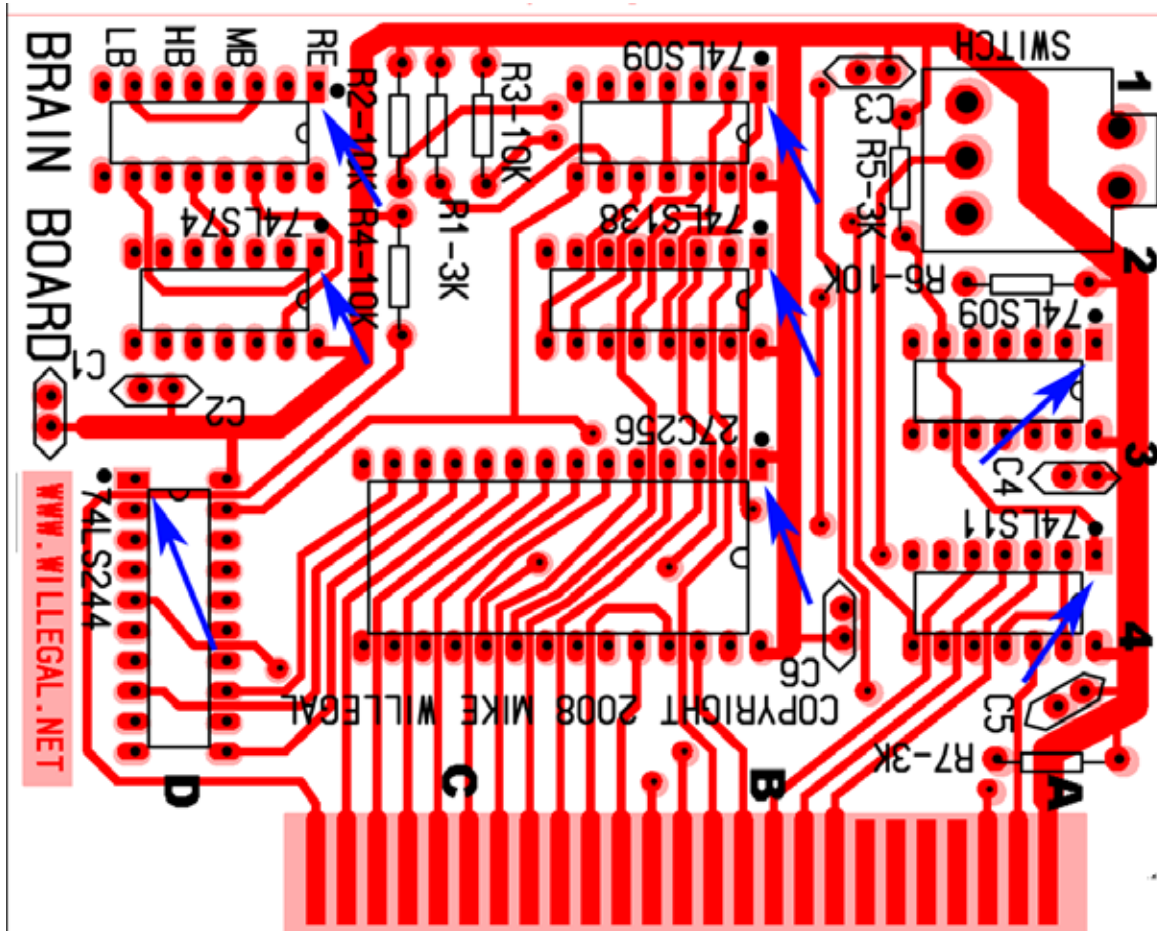


back side of board

### 3. Check for Power and Ground Shorts on PCB

The ground plane is the wide trace on the back of the board. The +5 volt plane is a similar trace on the front of the board. Easiest way to check for power ground shorts is to use an ohm-meter to make sure that there is no connection between +5 volts and ground. The Ohm meter should show no connection (or infinite resistance) between +5 volts and ground. A convenient place to check for shorts, is by using the pads of one of the six decoupling caps (blue arrows in the image above).

#### 4. Solder in All Components



front view of board (components are mounted on front side of board) pin 1 indicated by blue arrows

PART	DESCRIPTION	QUANTITY	COMPLETE
28 pin socket	B-4 - 27c256, pin 1 away from gold finger edge	1	
20 pin socket	D-4 - 74LS244, pin 1 toward edge of board	1	
16 pin socket	B-2 - 74LS138, pin1 away from gold finger edge	1	
14 pin sockets	A-3, A-4, B-1, D-2 - 74LS11, 74LS09(2) and 74LS74, pin 1 away from gold finger edge	4	
capacitors	D-3 (2), A-1, A-3, A-4, B-4, C1 through C6. Decoupling capacitors .1uF. Orientation is not important.	6	
3K ohm resistor	C-1, A-1 and A-4 orange-black-red Orientation is not important. At C-1 the 3K resistor goes between the two 10K resistors	3	
10K ohm resistor	C-1(2), C-2, and A-2. brown-black-brown Orientation is not important.	4	
DIP switch array	D-1	1	
Reset control switch	A-1 Important: read section 2 of this chapter before installing.	1	

#### 5. Recheck for Power and Ground Shorts on PCB

Easiest way to do this is to use an ohm-meter to make sure that there is no short between +5 volts, and ground.



## 6. Install ICs

Follow pin 1 markings on board (small white dot in silk-screen and square pad in copper layer).

ICs will be easier to insert, if the legs are bent to a angle that precisely aligns with the sockets. To do this, place the IC on it's side on a hard flat surface. One set of pins will be on the surface and pointed towards you. Keeping the IC's legs held firmly down, carefully roll the chip toward you to slightly bend the chip leads just a bit and then repeat with the process with the chip flipped to it's other side. Check for fit against socket and repeat accordingly.

When stuffing chips into sockets, be careful that pins are not inadvertently bent underneath the chip, instead of going into the socket. If you do bend a pin, they can be usually be straightened with a small pliers, if you do it carefully. Pins will usually break, right where they connect with the chip case, so do not bend the pin any more than necessary, especially at the joint, where it mates with the case.

PART	DESCRIPTION	QUANTITY	COMPLETE
74LS09 (2)	14 pin sockets at A-3 and B1	2	
74LS74	14 pin socket at D-2.	1	
74LS11	14 pin socket a A-2	1	
74LS138	16 pin socket at B-2	1	
74LS244	20 pin socket at D-4	1	
27C256	28 pin socket at B-3	1	

## 7. Clean PCB of Rosin and By-products of Soldering

Once soldering is complete, clean the back of PCB of excess flux and rosin. 90% or higher isopropyl alcohol. IPA will dissolve soldering resin. Note that the IPA will also remove the printing on the PROMs so keep it away from these parts. Spray it on the back of the board and lightly scrub with a very soft brush that will not scratch the surface of the PCB. Soak up the IPA and contaminates with a clean soft cloth before the IPA evaporates in order to remove the by products of soldering. I have also discovered that "Windex" window cleaner can help remove the by-products from the soldering job. Removing contaminates is important as many kinds of rosins are corrosive. Let dry overnight. Position a fan to blow over the board to make sure that all remaining moisture evaporates.

## 8. Check Board for Solder Bridges and Cold Solder Joints

While the board is drying, you should carefully check your work for bad solder joints and solder bridges.

## Chapter 3 – Installation, Operation and Help

### 1. Installation and Operation

#### Soft Switches

Two soft switches are implemented in the Brain Board hardware. They are used to control addressing of ROMs on the Apple II and PROMs on the brain board. If enabled, the soft switches can be accessed from software via the Apple II Device Select signal on the peripheral bus. The location is dependent upon the slot that the Brain Board is located. Depending upon setting of the hard switches, either none or one or the other of the soft switches will be cleared or set when the correct location is accessed.

SLOT	0	1	2	3	4	5	6	7
Clear	C080	C090	C0A0	C0B0	C0C0	C0D0	C0E0	C0F0
Set	C081	C091	C0A1	C0B1	C0C1	C0D1	C0E1	C0F1

When toggling the softswitches, it is best to run the program out of RAM. An example program follows.

```
1000- AD 90 C0    LDA C090
1003- 6C FC FF    JMP (FFFC)
```

This program clears the softswitch in slot one and jumps to the reset vector at location FFFC in memory. Entering 1000G from the monitor prompt will change the softswitch and jump to the PROMs restart location

The first soft switch is called the motherboard soft switch and is used to determine whether the PROM on the Brain Board is addressed or the ROMs on the motherboard when the processor addresses memory in the range of D000-FFFF.

If the motherboard hard switch (see hard switch section) is set to disable (switch 3 off and switch 4 on), then the hardware is set to use the Brain Board Proms and the motherboard PROMs cannot be accessed. This setting cannot be overwritten with the soft switch. This is the setting to use if you are trying to operate a motherboard without ROMs. Note that Apple DOS will only boot in this configuration if the PROM in the Brain Board contains images for both Applesoft in one bank and Integer basic in the other or if the init application on the disk being booted uses the same Basic as is installed in the default PROM bank.

If the motherboard hard switch is set to enable (switch 3 on and switch 4 off), then either the motherboard ROMs or Brain Board PROMs can be accessed depending upon the motherboard soft switch setting. If enabled, addressing the device select location on the Brain Board will set the Motherboard softswitch to use the BrainBoard PROMs. Addressing the device select location +1 will set the soft switch to use the motherboard ROMs. A program changing this setting should be running out of RAM, not ROM, since the ROM in use will be disabled during execution of this instruction. The default setting after reset is dependent upon the position of the Brain Board toggle switch. If the toggle switch is in the down position, a computer reset will set the softswitch to use the BrainBoard PROMS. If the toggle switch is in the up position, a computer reset will set the softswitch to use the motherboard ROMs.

The other soft switch is the bank select soft switch and is used to determine which bank of the Brain Board PROM is addressed. Standard ROM space on the Apple II is 12K running from address D000 to FFFF. A 27C256 PROM supports 32K bytes of read only memory. When used in the Brain Board, the 27C256 has the capability of supporting 2 complete 12K ROM banks.

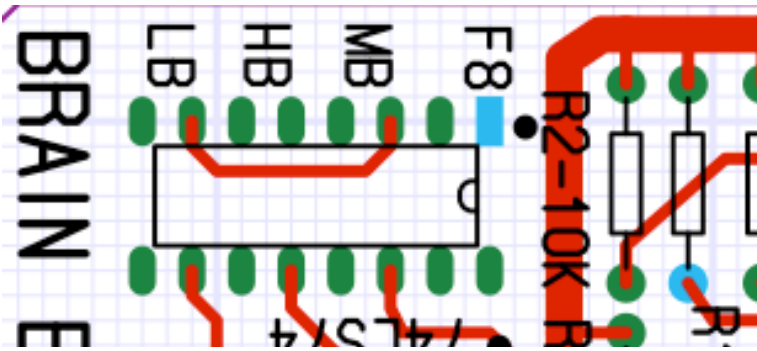
One application of this capability is to burn the Integer basic, with original monitor and Programmers AID rom in one bank and Applesoft with the autostart monitor in the other bank. That way you can have both Integer Basic and Applesoft in ROM, and don't even need ROMs on the motherboard.

This softswitch is used to determine which bank of the Brain Board ROM is selected. If enabled (hard switches 6 and 8 both off), this soft switch is controlled the same way as the motherboard soft switch. This is by either the toggle switch during reset or by accessing the device select address of the Brain Board with software to change the default soft switch setting.

When reset to zero, (address C090 for slot 1), the so called low bank is selected (which is PROM address 0 - 3FFF). When set to one, (address C091 for slot 1) the so called high bank is selected (which is PROM address 4000- 7FFF).

Note that the highbank and low bank hard switches (see next section) can be used to force the value of the bank select soft switch to a predetermined value that cannot be overwritten by the softswitches or toggle switch.

## Hard Switches



The top left corner of the Brain Board contains a bank of 8 switches. These switches are used to configure the default addressing of ROMs/PROMs on the Apple II and Brain Board. There is 1 individual switch, 1 switch that is not connected and 3 pairs of 2 switches. These hard switches in conjunction with the toggle switch and the two soft switches determine whether addresses in the range of D000-FFFF, address PROM memory on the Brain Board, or ROMs on the motherboard.

NUMBER	HARD SWITCH	FUNCTION	QUANTITY
1	F8 - one switch that can connect pin 1 to 16.	When this switch is set to off, memory in the range of F8XX addresses the motherboard monitor ROM, regardless the setting of the motherboard switches. When set to on, F8XX addresses depend upon other Brain Board selection criteria (the other hard switches, the soft switches, and the toggle switch). Normally this hard switch is set to on.	
2	pin 1 to 15	not connected - no function	1
3&4	MB - motherboard - set of two switches - can connect pins 3 to 14 or 4 to 13	<p>These two switches must not be both set on or off at the same time. One of the two switches should be set to on, and the other off.</p> <p>If switch 3 is on, then switch 4 should be set to off. With switch 3 set on (enabled), access to Brain Board PROMs or Motherboard ROMs is dependant upon the motherboard soft switch.</p> <p>If switch 3 is off, then switch 4 should be set to on - access to motherboard ROMs is disabled - all access from D000 to FFFF access Brain Board PROMs.</p>	1
5&6	HB - 27C256 high bank - set of two switches - can connect pins 5 to 12 or 6 to 11	<p>These two switches must not be both set on or off at the same time. One of the two switches should be set to on, and the other off.</p> <p>If switch 5 is on, then switch 6 should be set to off. If switch 5 is on, and switch 7 set on &amp; switch 8 set off, then the bank select soft switch can be programmed using the toggle switch (sampled during reset) or by accessing the Brain Board's soft switches.</p> <p>If switch 6 is on, then switch 5 should be set to off. If switch 6 is on, 27C256 high bank is perminately selected. Switch 7 should be set on and switch 8 set off.</p>	1
7&8	LB - set of two switches - can connect pins 3 to 14 or 4 to 13	<p>These two switches must not be both set on or off at the same time. One of the two switches should be set to on, and the other off.</p> <p>If switch 7 is on, then switch 8 should be set to off. If switch 7 is on, and switch 5 set on &amp; switch 6 set off, then the bank select soft switch can be programmed using the toggle switch (sampled during reset) or by accessing the Brain Board's soft switches.</p> <p>If switch 8 is on, then switch 7 should be set to off. If switch 8 is on, 27C256 low bank is perminately selected. Switch 5 should be set on and switch 6 set off.</p>	1

## Toggle Switch

The position of the toggle switch is sensed during system reset and can be used to select the bank selected by the soft switch after reset in the case when there is more than one possible PROM or ROM bank that could be selected. Moving the switch to the up position selects the low bank during the reset process.

## Example Hard Switch Configurations

There are five primary configurations that are most likely to be used by Brain Board operators.

### Single Bank Mode - Low bank of Brain Board always enabled

Bank select soft switch and toggle switch settings have no effect. Use this setting with the Wozanium PROM to force Apple 1 operation all the time. Also can be used to force usage of custom PROM low bank all the time.

1	3	4	5	6	7	8
ON	OFF	ON	ON	OFF	OFF	ON

### Single Bank Mode - high bank of Brain Board always enabled

Bank select soft switch and toggle switch settings have no effect. Use this setting to force usage of custom programmed PROM high bank all the time.

1	3	4	5	6	7	8
ON	OFF	ON	OFF	ON	ON	OFF

### Dual Bank Mode - Either low bank of Brain Board or Motherboard ROMs selected

Toggle switch determines bank in use after system reset. Programs can use the motherboard softswitch (device select) to select either motherboard ROMs or Brain Board low bank. This setting emulates Apple Firmware card operation using the Brain Board low bank. Use this setting with the Wozanium PROM to allow switching between Apple II and Apple 1 mode.

1	3	4	5	6	7	8
ON	ON	OFF	ON	OFF	OFF	ON

### Dual Bank Mode - Either high bank of Brain Board or Motherboard ROMs selected

Same as previous setting except the high bank of the Brain Board is utilized. Note that the Wozanium PROM's high bank is left unburned, so this mode should not be used with the Wozanium PROM unless the user programs the high bank of the Wozanium with a program of his choice.

1	3	4	5	6	7	8
ON	ON	OFF	OFF	ON	ON	OFF

### Dual Bank Mode - Either high bank of Brain Board or low bank of Brain Board is selected

Toggle switch determines bank in use after system reset. Programs can use the bank select softswitch (device select) to select either Brain Board high bank or Brain Board low bank. One interesting configuration is to program Apple Integer basic with Monitor into one bank of the 27C256 and Applesoft into the other and configure with this setting. When set up this way a ROM-less motherboard may boot DOS and run both Integer and Applesoft BASIC from PROM.

1	3	4	5	6	7	8
ON	ON	OFF	ON	OFF	ON	OFF

## Installing the Brain Board into Your Apple II

Power off your computer before installing the Brain Board. The Brain Board is installed like other Apple II peripheral cards with the component side facing away from the power supply. It may be installed in any slot, but the I/O select region of memory on the card changes with the slot. This is particularly important when using the cassette interface with the Wozanium pack.

## Multiple Brain Boards or Firmware Cards

Multiple Brain Boards or Apple Firmware Cards can be used in a system, but they must be placed in adjacent slots. Boards in lower slot numbers, if enabled, will automatically disable boards in higher numbered slots. Be aware that if F8 jumper is not connected on an enabled board in a lower slot next to a board with F8 enabled, the system will use the F8 address space on the high numbered slot and the rest of the ROM address space on the lower numbered slot.

## Interaction with the Apple Language Card

Brain Boards will co-exist with Apple Language Cards, but there are some limitations. Enabled Brain Boards will normally prevent automatic loading of Integer Basic into the Language card in Apple IIplus or Applesoft Basic into a Language card in an Apple II when DOS is booted.

## Burning PROMs

The following address table can be used to map the Apple address space to PROM space. Note that the I/O select address space in each slot from 1 to 7 can be used to address an additional 256 bytes in the PROM. The address varies depending upon slot and there is no I/O select signal for slot 0.

Processor Address	27c128 Address	27c256 Address (low bank selected)	27c256 Address (high bank selected)
<b>I/O SELECT- C000 plus slot times 0x100</b>	<b>0100 (256 bytes)</b>	<b>0100 (256 bytes)</b>	<b>4100 (256 bytes)</b>
<b>D000</b>	<b>1000</b>	<b>1000</b>	<b>5000</b>
<b>D800</b>	<b>1800</b>	<b>1800</b>	<b>5800</b>
<b>E000</b>	<b>2000</b>	<b>2000</b>	<b>6000</b>
<b>E800</b>	<b>2800</b>	<b>2800</b>	<b>6800</b>
<b>F000</b>	<b>3000</b>	<b>3000</b>	<b>7000</b>
<b>F800</b>	<b>3800</b>	<b>3800</b>	<b>7800</b>

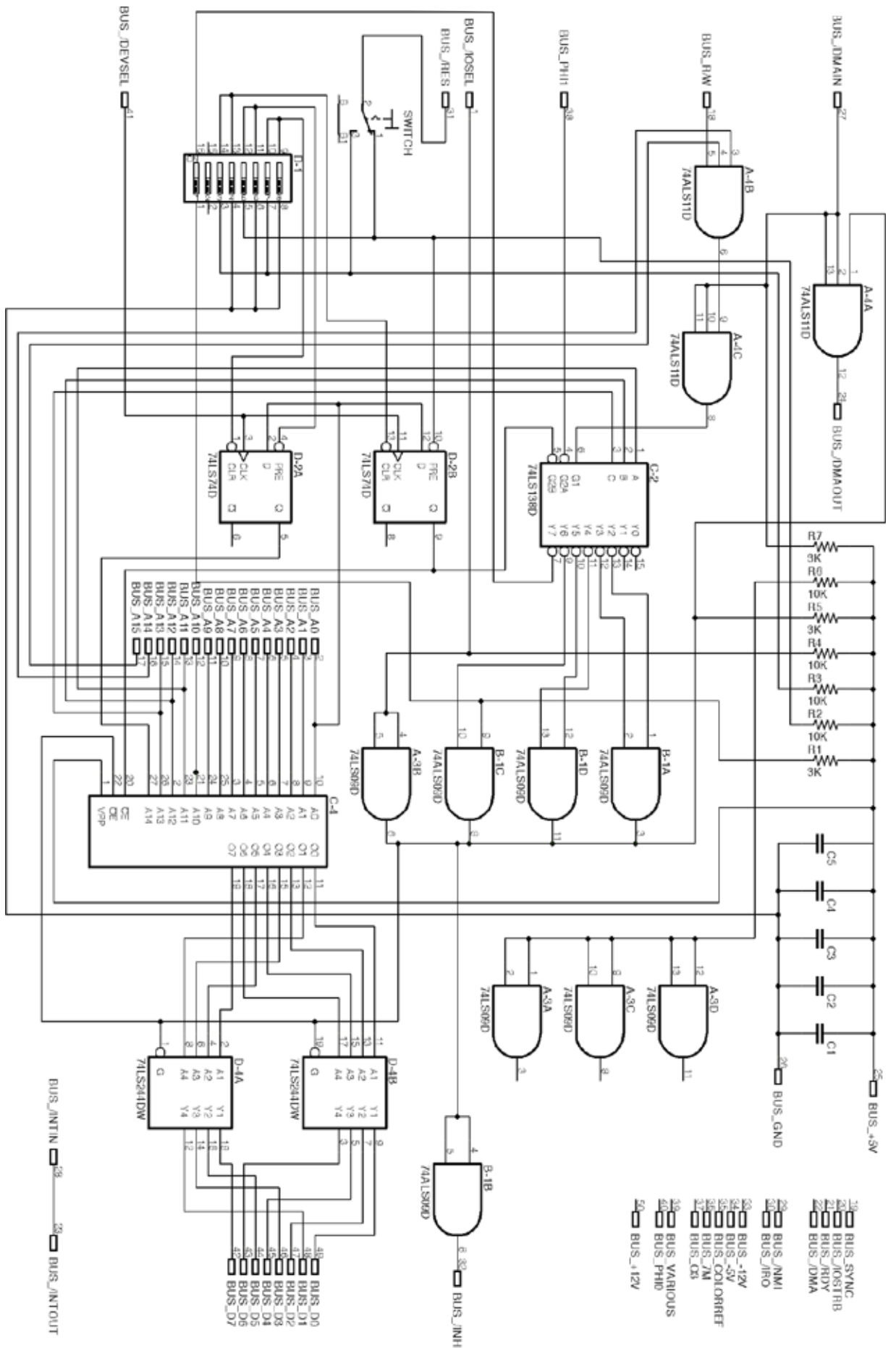
## 2. Troubleshooting and Help

A good job of soldering the components into place should eliminate most if not all trouble. First step, in case of trouble, should be to check for bad solder joints or bridges.

Refer to my Apple II repair page at [www.willegal.net](http://www.willegal.net) for some general troubleshooting hints.

Feel free to send email to: [mike@willegal.net](mailto:mike@willegal.net) if you run into difficulties.

# Chapter 4 - Schematics





## **Wozanium Pack Overview**

The low bank of the PROM provided with the Brain Board optionally includes a special program that will transform your Apple II into a operating facsimile of an original Apple 1 with 16K of expanded memory. This expanded memory was an authentic modification made to a number of original Apple 1s. If the Brain Board is installed in slot 1, you will also obtain access to an authentic Apple Cassette Interface (ACI) driver located at address C100, just like the original Apple 1. Input and output to your transformed Apple is now limited to the keyboard, video and cassette interfaces, also just like an original Apple 1. Software in PROM is limited to a ported version of the original Apple 1 monitor and the latest known version of Apple 1 BASIC (the so called Huston Basic) which is located at the same address in memory (E000) as it would be located at, in an actual Apple 1

Your transformed Apple will be able to run most original Apple 1 assembly and BASIC programs. Programs must either be keyed in through the monitor or loaded via the ACI (Apple Cassette Interface). No other options are standard, though you could add drivers for serial ports or other expansion cards, if you wished to. More details are provided later in this document.

Though I am solely responsible of the end result, I must give many thanks to Cameron Cooper who positively influenced a number of design tradeoffs that had to be made and implemented much of the video driver's core functionality.

### **Specifications**

**MICROPROCESSOR:** MOS TECHNOLOGY 6502 - same as original

Microprocessor Clock Frequency: 1.023 MHz - same as original

Effective Cycle Frequency: 1.0205 versus the original's 0.960 MHz

**VIDEO OUTPUT:** Composite positive video - same as original

Format: 40 characters/line. 24 lines; with automatic scrolling - same as original

Character Matrix: 5 x 7 - same as original

**RAM MEMORY:** 16K located at 0 - standard configuration with the original had 4k at 0x0 and another 4k at 0xE000. Several original systems were modified with the bank of memory at 0 expanded to 16K

**BASIC:** 4K at location 0xE000 contains Basic in PROM - With the original, BASIC was loaded into the 4K DRAM bank at location 0xE000 from the Apple Cassette Interface (ACI)

**APPLE CASSETTE INTERFACE:** built in - ACI was an option on the original

## Chapter 1 - Wozanium Pack - Apple 1 Users Guide

### 1. Introduction

Refer to chapter 3, which contains jumper configuration settings and instructions for installing the Brain Board with Wozanium. It is recommended that the Brain Board be installed in slot 1. These instructions assume this slot. If you use another slot, addresses for accessing the cassette interface driver will change.

Once the Brain Board is installed, you can power up your system. If the toggle switch is in the up position, the Wozanium will take over your system immediately upon power up. If the toggle switch is in the down position, the Wozanium can be invoked by accessing address C091.

When toggling the softswitches, it is best to run the program out of RAM. An example program follows. After entering the program into memory use the monitor R (Apple I) or G (Apple II) command to run it.

```
1000- AD 91 C0    LDA C091
1003- 6C FC FF    JMP (FFFC)
```



Upon startup - the screen will be full of alternating “@” and “\_” characters. Type the right arrow key to clear the screen and you will be presented with the Apple 1 monitor prompt. In the Wozanium, right arrow is mapped to the Apple 1 clear screen function. Any time you type right arrow, while the Wozanium is waiting for input, the screen will be cleared.

If the switch is set to enable the Wozanium upon power up, the reset key on your Apple keyboard behaves exactly the same as the reset on an actual Apple 1. If you entered Wozanium mode by accessing address C091, reset will return you to Apple II mode. You can re-enter Wozanium mode by accessing address C091 again, but any program loaded in memory will most likely have to be reloaded, since the Apple 2 monitor uses locations that are used to load Apple 1 programs. Since entering reset is a common activity for an Apple 1 user, it is recommended when running in Wozanium mode, that the user set the Brain Board to default to Wozanium mode after reset by setting the toggle switch to the up position

Sections 2 and 3 of this chapter contain edited content from the original “Apple-1 Operation’s Manual”. All commands are unchanged from the original Apple 1 manual. The only edits are to remove or edit content that is not applicable to the Apple II/Brain Board environment.

## 2. Test Program

The system monitor accepts only uppercase alpha (A—Z). If you are running the Wozanium in an Apple IIe, it is recommended that you set the caps lock key.

You can try a simple program to test if your Wozanium system is functioning well. While it does not test many possible areas of the microprocessor system, the test program will test for the correct operation of the Brain Board with Wozanium.

1) Hit the **RESET** button to enter the system monitor.

A backslash should be displayed, and the cursor should drop to the next line.

2) Type- **0:A9 0 AA 20 EF FF E8 8A 4C 2 0(RET)**

0 is a zero, NOT an alpha “O”; and (RET) hit the “return” key on the keyboard.

3) Type- **0.A (RET)**

This should print out, program you have just entered.

4)Type- **R(RET)**

R means run the program.

The program should then print out on the display a continuous stream of ascii characters. To stop the program and return to the system monitor, hit the “reset” button. To run again, type - R (RET).

## 3. Using The System Monitor

The Apple 1 Monitor is a PROM program in locations FF00 toFEFF (hex) which uses the keyboard and display to perform the front panel functions of examining memory, and running programs. The monitor program is entered by hitting (RESET), which displays a “\”(RETURN).

Commands are typed on a “line-at-a-time” basis with editing. Each line may consist of any number of commands (up to a total of 128 characters). None are executed until (RETURN) is typed. The left arrow key backspaces the input buffer and prints an underline. The (ESC) cancels a line and echos “\”(RETURN).

One or more hexadecimal digits (0—9, A—F) are used for address and data values. Addresses use the four least significant digits of a group, and data values, the two least significant digits. The following examples illustrate the variety of acceptable commands.

1. Opening a location (examining the contents of a single address),

USER TYPES/ **4F(RET)**

MONITOR TYPES/ **004F: 0F** (contents of 4F)

2. Examining a block; from the last examined location, to a specified one.

USER TYPES/ **.5A(RET)**

MONITOR TYPES/ **0050: 00 01 02 03 04 05 06 07**

**0058: 08 09 0A**

Note: 4F is still considered the most recently opened location.

3. Combining examples 1 and 2 to print a block of memory in a single command.

```
USER TYPES/      4F.5A (RET)
MONITOR TYPES/   004F: 0F
                  0050: 00 01 0a 03 04 05 06 07
                  0058: 08 09 0A
```

Note: Only the first location of the block (4F) is considered “opened”.

4.

```
USER TYPES/      4F 52 56 (RET)
MONITOR TYPES/   004F: 0F
                  0052: 02
                  0056: 06
```

Note: 56 is considered the most recently “opened” location. A space or comma, and is a delimiter for separation purposes only. A string of delimiters has the same effect as a single one (, , is as effective as ,)

5. Examining several blocks of memory at once.

```
USER TYPES/      4F.52 56 58.5A (RET)
MONITOR TYPES/   004F:0F
                  0050: 00 01 02
                  0056: 06
                  0058: 08 09 0A
```

Note: 58 is considered the most recently “opened” location. Refer to example 2.

6. Examining successive blocks.

```
USER TYPES/      4F. 52 (RET)
MONITOR TYPES/   004F: 0F
                  0050: 00 01 02
USER TYPES/      .55 (RET)
MONITOR TYPES/   03 04 05
USER TYPES/      .5A (RET)
MONITOR TYPES/   06 07
                  0058: 08 09 0A
```

7. Depositing Data in a Single Location

```
USER TYPES/      30:A0 (RET)
MONITOR TYPES/   0030:FF (prior contents)
```

Note: Location 30 is considered opened and now contains 30.

8. Depositing data in successive locations from that last used in a deposit command.

```
USERTYPES/      :A1 A2 A3 A4 A5 (RET)
```

This deposits A1 in location 31, A2 in 32, and so on.

9. Combining examples 7 and 8 in a single command.

USER TYPES/       **30: A0 A1 A2 A3 A4 A5 (RET)**  
MONITOR TYPES/ **30:FF** (prior contents of location 30)

10. Depositing data in successive locations with separate commands.

USER TYPES/       **30: A0 A1 (RET)**  
MONITOR TYPES/ **0030: FF**  
USER TYPES/       **:A2 A3 (RET)**  
USER TYPES/       **:A4 A5 (RET)**

NOTE: Capital letters enclosed in parenthesis represent single keystrokes.  
Example: (RET) means hit the “return” key.

Note: A colon in a command means ‘start depositing data from the most recently deposited location, or if none, then from the most recently opened one.

11. Examining a block, then depositing into it.

USER TYPES/       **30.35 (RET)**  
MONITOR TYPES/ **0030: A0 A1 A2 A3 A4 A5 A6**  
USER TYPES/       **:BC E1 B2 E3 B4 E5 (RET)**

Note: New data deposited beginning at most recently opened location (30)

12. Run a program at a specified address.

USER TYPES/       **10F0R (RET)**  
MONITOR TYPES/ **10F0: A9** (contents)

Note: The cursor is left immediately to the right of the “A9”, it is not returned to the next line.

13. Run at the most recently examined location.

USER TYPES/       **10F0 (RET)**  
MONITOR TYPES/ **10F0: A9**  
USER TYPES/       **R(RET)**

14. Enter a program into memory and run it in one line.

USER TYPES/       **40: A9 0 20 EF FF 38 69 0 4C 40 0 R (RET)**  
MONITOR TYPES/ **40: FF** (prior contents of 40)

15. An “on line” error correction.

USER TYPES/       **40: A1 A2 A3A4A5A6 A7**  
(data A6 will be loaded in location 42)

USER TYPES/       **40506070: AA**  
(data AA will be loaded in location 6070)

16. Useful routines in monitor which can be accessed by user programs.

GETLINE: location FF1F  
monitor entry point (jumping to FE1F will enter monitor and echo carriage return. You can then examine memory locations with the monitor.)

ECHO: location FFEF  
prints one byte (ASCII) (data from “A” (accumulator), contents of “A” not disturbed.)  
Example:  
20 EF FF (JSR ECHO)

PRBYTE: location FFDC:  
prints one byte (HEX) (data from “A”, contents of “A” disturbed.)

PRHEX: location FFE5:  
prints one hex digit (data from four least significant bits of “A”, contents of “A” disturbed.)

NOTE: RAM locations 0024 to 002E are used as index pointers by the monitor, and are invalid for user use, when using monitor. Also, locations 0200 to 027f are used as input buffer storage, and are also invalid for user use when using the monitor.

## **Chapter 2 - Wozanium Pack - Apple Cassette Interface Guide**

This chapter contains edited content from the original “Apple-1 Cassette Interface” manual. All commands are unchanged from the original Apple 1 manual. The only edits are to remove or edit content that is not applicable to the Apple II/Brain Board environment.

The Wozanium Cassette Interface [WCI] is a driver that emulates operation of the original Apple 1 Apple Cassette Interface (ACI) using Apple II hardware. This enables the user to store and retrieve information (data and programs) using a standard audio grade cassette recorder or an iPod. The operator can save and restore programs and data exactly as with the original Apple 1. The data format is identical, so data can be exchanged between original Apple 1's and an Apple II equipped with the Wozanium drivers. The WCI uses Apple II cassette interface hardware, so the cassette interface connection is the same as with an Apple II. The WCI reads and writes data at the rate of approximately 1500 baud (depending upon the data). Like the original, all the WCI timing is done in software, resulting in extreme accuracy, no adjustments, and consistency between cassette recorders.

With the original Apple 1 ACI card, performance with various cassette recorders can vary from not functional to works pretty well. The Apple II has an improved cassette interface circuit over the original Apple 1, so in general performance should be satisfactory, once a good play back volume is settled upon. I use and recommend a Panasonic RQ-2102, which is a direct descendant of the original Apple recommended cassette recorder.

### **1. Using The Cassette Interface**

The WCI program is contained in the low bank of the Wozanium PROM included with the Brain Board and runs at either D000 or if the Brain Board is installed in slot 1, C100. The original ACI software would be invoked at location C100, so for the most authentic, operation install your Brain Board in slot 1. When C100R is entered, the program should echo an “\*.” The format for specifying the memory address ranges to be either stored (write) or deposited into (read) is identical to the standard monitor format: **Beginning . End** , suffixed with either a ‘W’ (write) or an ‘R’ (read). Execution will start following a carriage return (CR). The cassette program will return control to the system monitor upon completion of a read or write. Illegal characters (or the absence of characters) in the address line will return control to the system monitor without execution, following a carriage return.

## 2. Multiple Ranges

The WCI is capable of reading and writing multiple address ranges. The format is: **A.BW C.DW** (R for read)., Again, spaces are ignored. The WCI will write a ten second header, the first range, another header and the second range. **100.200W 300.500W** will write a header, 100 in 200, a second header, and 300 to 500. When reading a multiple range tape. **YOU MUST USE THE SAME ADDRESS INCREMENTS AS WERE USED IN WRITING THE TAPE.** This does not mean the same absolute addresses, but rather the same increments.

The procedure for reading from a tape into memory is:

**C100R (RET)** This enters the cassette program and should echo an ‘\*’  
**1000 . 1FFFF** This will load the tape data into memory locations 1000.1FFF . ‘R’ denotes a read, and spaces are ignored. [Don’t hit ‘return’ yet.]

### Start the Tape

**Hit ‘RETURN’** A carriage return will start execution of a read. The ‘return’ can be hit immediately, however, it must be hit within 5 seconds after the start of tape motion.

When the last location (1FFF in this example) has been loaded, the program will print a ‘/’ and return control to the monitor.

The procedure for a write is identical except the suffix ‘W’ is substituted for ‘R’ in the address line. For both read and write, the tape should always be moving before hitting the RETURN.

## 3. Read Level

You will have to experiment to determine the proper sound level to use for reading tapes. Generally, if the read ends before the tape player reaches the end of the tape, you will probably find FFs at the start of the region of memory that you were reading into. In this case, you may have the volume too high. If the playback ends, before the computer finishes the read operation, you may have the volume set too low or possibly a bad connection between the player and the Apple motherboard. I have found that playing back on iPod works best a maximum volume. If you experience a bad read, change the setting a little, rather than a lot.

## 4. Speed

The ACI uses the technique of recording a whole cycle of either a 1kHz cycle (representing a ‘one’ data bit) or a 2 kHz cycle (representing a ‘zero’ data bit). Therefore, with an average data mix of one’s and zero`s, data will be recorded at 1500 baud. A ten second header of all ones will automatically be recorded on the tape prior to memory data. This is to insure that the clear leader portion of the tape will have passed.



### **Chapter 3 - Using an iPod or PC With the Apple Cassette Interface**

An iPod or PC may be used in place of a cassette player with the ACI. Almost any iPod can be used for loading programs with the same cable that is used for reading from a cassette player. Programs must be put into AIFF format prior to loading. I have listed several programs already in that format on this web page:

<http://www.willegal.net/appleii/apple1-software.htm>

This same page has the source code for a UNIX shell program that will convert programs in Apple monitor format into AIFF files, so that you can convert your own programs to be loaded from a iPod.

Writing to the iPod requires an iPod that supports microphone input, a special cable and an iPad application that uses a lossless recording format. A detailed write up on the process can be found here.

<http://www.apple1notes.com/Home/Notes.html>

A computer with mic input and line level output can also be used as a psuedo cassette tape drive. Software such as Audacity or Garage Band is used to control record and playback.

## Chapter 4 - Wozanium Pack - Functional Description

### What I/O capabilities did an original Apple 1 have?

An original Apple 1 had very few I/O capabilities

- a video port for composite video out - characters are output to the display using the PIA port located at address D000
- a parallel ASCII keyboard input port- characters are input to the computer from the keyboard using the PIA located at address D000
- an optional Cassette Interface - a 256 byte driver is located at location C100
- a 256 byte monitor located at FF00 in PROM

Standard memory was restricted to two 4K banks. One bank, starting at location 0, usually was loaded with program data. The other bank usually was located at address E000 and was loaded with Apple Basic from tape with the cassette interface. Some individuals modified their Apple 1's and replaced the 4K bank at zero with 16K in order to allow larger basic programs to be loaded.

An Apple II, II plus or IIE which has a Wozanium pack installed and properly configured appears to the user to be an Apple 1 in almost all respects. It will load and run original Apple 1 software from cassette tape. In addition, you can write programs to cassette tape that can be run on original Apple 1 hardware.

It was tempting during development of the Wozanium Pack to add extra features to take advantage of Apple II hardware capabilities. However, in the end, we remained true to the original Apple 1 hardware constraints and did not enhance it. The user is free to write additional drivers that could take advantage of Apple II hardware, such as serial and parallel ports that are commonly added to Apple II systems.

The next sections will describe what we did to emulate each major component of the Apple 1 on Apple II hardware.

#### 1. The Video Port

The Apple 1 video section has only two functions.

- Clear screen and set cursor to first location at top left hand corner. The clear screen function is a hardware function activated by directly connecting the clear input on the keyboard socket to +5volts for one screen refresh time period (60 milliseconds). This will clear all of screen memory and set the cursor to the top left hand corner. Note that upon power up, an Apple 1 screen will be filled with garbage including numerous cursors, which makes data input nearly impossible until the screen is cleared.
- Write a character to current cursor location and advance the cursor to the next location. If the cursor is on the last location on a line, the cursor is moved to the next line and that line cleared. If the cursor is at the bottom of the screen, the entire screen is scrolled up one line. If a carriage return is entered, the rest of the current line is cleared and the cursor advanced to the first position on the next line on the screen and that line is cleared of any old characters. If the cursor is at the bottom of the screen, the entire screen is scrolled up one line.

The Apple 1 assembly code for performing a write character to the display is shown here

```
WAIT: BIT DSP $D012           ; TEST MSB OF PIA REGISTER TO SEE IF TERMINAL IS READY
      BPL WAIT                ; NOT SET, THEN WAIT
      STA DSP $D012           ; STORE CHARACTER IN PIA TO WRITE TO SCREEN
```

Because the display memory is a large circular buffer that is constantly shifting, the write must wait until the moment that the position of the cursor is available to the PIA before a character can be written to the screen. This results in a display speed of about 60 characters per second, though entering carriage returns will appear to run faster because the hardware does the clear to end of line function automatically at a relatively fast speed.

There is an ECHO function located at location FFEF in the Apple 1 monitor that can be called instead of writing the code to write to the PIA directly. Many Apple 1 programs use the monitor ECHO call instead of accessing the PIA directly.

In contrast, the Apple II uses a memory mapped video system where writing to memory causes data to be displayed immediately on the video screen. There is no need for software waits or delays in using this video system. Several memory banks are allocated to video display and can be switched using software controlled soft switches.

- 0400 - default text and low res graphics
- 0800 - secondary text and low res graphics
- 2000 - primary hi res graphics
- 4000 - secondary hi res graphics

The Apple 1 has a memory bank starting at location 0 and running to either FFF (4K systems) or 3FFF (16K systems). Except for the stack at the page starting at location 200, Apple 1 programs assume that these locations are available for use. In order to run 16K Apple 1 programs on an Apple II, video display has to utilize the secondary hi res graphics space starting at address 4000. A video driver has been written that is called to display textual data in the secondary hi res graphics space. Behavior, performance and capabilities of this driver mimic behavior of the Apple 1 terminal driver as closely as possible.

The Apple 1 monitor ported to the Wozanium, is modified to use this video driver instead of the PIA of the Apple 1. Thus any Apple 1 software that utilizes the monitor's ECHO routine will automatically work in the Wozanium environment. Apple 1 software that directly accesses the PIA needs to be handled differently. How this is done, is covered under the cassette interface section of this chapter.

There are a couple subtle differences between this video emulation of the Apple 1 and the real thing.

- Since it is handled in software, rather than hardware, the cursor only flashes in this environment when the program is waiting for keyboard input
- Because the rest of the current line and the next line must be cleared in software, Carriage Return performance is somewhat less than on a real Apple 1, where the same function is handled in hardware

The Wozanium video output routine provides a capability for a user driver to replace or supplement the Wozanium video output (putchar) routine. Typical usage would be a Super Serial card driver that could be used to dump Apple 1 programs to a terminal or PC for archiving purposes. The user places the function address in the locations BC04 (LSB) and BC05 (MSB). The user has the option of returning directly from his replacement driver by executing RTS from his driver or to the Wozanium video output driver by jumping directly to the address that was in address BC04 and BC05 prior to the new driver being installed. For rev 5.1 PROM, this is initially D44A. All registers should be restored before returning or jumping to the Wozanium driver. The user driver can be loaded in and use the address range of 6000 to BBFF. The user driver should refrain from disturbing memory outside of this range. Loading this driver would typically be done through the cassette interface. The user vectors will be overwritten by default Wozanium vectors whenever the computer is reset.

## 2. Keyboard Input

Keyboard input on the original Apple 1 utilized 2 registers in the PIA located at D000.

- D011 - keyboard control register - high bit (bit 7) when set indicates that there is data from the keyboard ready to be read. Reading this register clears the flag
- D010 - keyboard data

The code sequence listed below is the normal routines used to read the keyboard.

```
WAIT: LDA  $D011          ; TEST CONTROL REGISTER TO SEE IF KEYBOARD DATA
                        ; IS PRESENT (THIS READ ALSO CLEARS BIT)
      BPL  WAIT          ; BRANCH TO WAIT, IF MSB NOT SET (NO DATA PRESENT)
      LDA  $D010          ; READ KEYBOARD DATA
```

The Apple 1 monitor does not have a routine for getting a single character from the keyboard.

Keyboard input on the Apple 2 is slightly different, but also utilizes 2 memory locations

- C000 - keyboard data, the most significant bit (bit 7) is set if new keyboard data is present
- C010 - keyboard control register - the high bit (bit 7 - new data available indicator) of keyboard data is reset when this location is accessed

Read Key from keyboard on Apple II:

```
WAIT: LDA  $C000          ; READ DATA REGISTER TO SEE IF KEYBOARD DATA
                        ; IS PRESENT (MSB SET IF NEW DATA PRESENT)
      BPL  WAIT          ; BRANCH TO WAIT, IF MSB NOT SET (NO DATA PRESENT)
      STA  $C010          ; CLEAR KEYBOARD DATA PRESENT BIT
```

Fortunately both Apple 1 and Apple 2 read keyboard sequences are 8 bytes long, so one can be substituted for the other. This has been done for you in the modified Apple 1 monitor provided with the Wozanium. Read the cassette interface section to find out how the Wozanium accomplishes this in downloaded Apple 1 programs.

The Wozanium keyboard routine provides a capability for a user driver to replace or supplement the Wozanium keyboard read (getchar) routine. Typical usage would might be a Super Serial card driver that could be used to allow remote control of the computer. The user places the function address in the locations BC02 (LSB) and BC03 (MSB). The user has the option of returning directly from his replacement driver by executing RTS from his driver or to the Wozanium keyboard input driver by jumping directly to the address that was in address BC02 and BC03 prior to the new driver being installed. For rev 5.1 PROM, this is initially address D250.

Note that if the Wozanium keyboard input driver does not detect that a character is ready from the keyboard, it will repeat the call to the user driver until a character is available from the keyboard to return to the calling function. This allows usage of both user input and keyboard input concurrently.

All registers should be restored before returning or jumping to the Wozanium driver. The user driver can be loaded in and use the address range of 6000 to BBFF. The user driver should refrain from disturbing memory outside of this range. Loading this driver would typically be done through the cassette interface. The user vectors will be overwritten by default Wozanium vectors whenever the computer is reset.

### 3. Cassette Tape Read Functions

The original Apple 1 uses a plug in card known as the ACI (Apple Cassette Interface) to read and write cassette tapes. On this card, there is a 256 byte program in PROM, located at address C100 that contains the driver for this interface. Like the original Apple 1, cassette read functions on the Wozaniam Pack are also accessed by running the ACI driver, which if the Brain Board is located in slot 1, is also at address C100.

When the Apple 1 is reading data off the tape, hardware tracks incoming signal and toggles a flip flop whenever the state of the incoming signal makes a transition from high to low or low to high. The output of the flip flop is used as the least significant address bit when reading the cassette interface PROM from address C000. Since PROM locations 0 and 1 have different contents, the cassette read driver can easily tell when a transition has occurred on the tape, since the data returned by a read from location C000 will change with every transition.

The Cassette driver simply measures the length of time between each transition to determine whether a zero or one is being read.

The Apple II uses similar hardware to track the input signal from the cassette player. One difference is that the flip flop is located at C060 in memory and can be directly read by the driver. One other difference is that the cassette interface circuitry that feeds the flip flop was improved somewhat for the Apple II, so reading tapes becomes a slightly more reliable affair than it was on the original Apple 1. Note that the data format on the Apple 1 and Apple II remained the same, except for a CRC was added to the end of the recording on the Apple II.

The Wozaniam Pack uses a modified version of the Apple 1 ACI cassette driver to read Apple 1 tapes on Apple II hardware. The following changes were made in this driver.

- Instead of monitoring address C000, C060 is monitored for transitions in the incoming cassette read signal
- After each block of data is read, the driver will scan input data looking for accesses to either the keyboard or video PIA ports and convert those accesses to work with the Wozaniam PROM and Apple II hardware
- Since an Apple II is about 5% faster than an Apple 1, software timing loops were slightly tweaked to reflect the increased speed of the Apple II

## 4. Cassette Tape Write Functions

Like the original Apple 1, cassette write functions on the Wozanium Pack are also accessed by running the ACI driver, which if the Brain Board is in slot 1, is also at address C100.

Both the Apple1 and Apple II use virtually the same technique to write data to the cassette tape interface. A hardware flip-flop is toggled by the cassette interface driver at a specific frequency to represent a zero or a one on the tape. The primary difference is the flip flop is located at different addresses on the two systems.

The Wozanium Pack uses a modified version of the Apple 1 ACI cassette driver to write Apple 1 tapes on Apple II hardware. The following changes were made in this driver.

- Before each block of data is written, the driver will scan output data looking for accesses to either the Apple II keyboard or Wozanium video driver and convert those accesses to work with original Apple 1 hardware
- Instead of writing to address C000, C020 is written to cause transistions in the output cassette write signal
- After each block of data is written, the driver will scan ouput data looking for accesses to either the keyboard or video PIA ports and convert those accesses back to work with the Wozanium PROM and Apple II hardware
- Since an Apple II is about 5% faster than an Apple 1, software timing loops were slightly tweaked to reflect the increased speed of the Apple II

## 5. Basic

There were several versions of Apple 1 basic released during the lifetime of the Apple 1. The version included with the Wozanium pack is the last known version, known as the Huston version. There are two differences between Apple 1 Basic in the Wozanium and running Apple 1 Basic on a real Apple 1.

- Apple 1 Basic is preloaded into PROM at address E000 on the Wozanium. In an actual Apple 1 you would have to load Basic into DRAM at address E000 from tape using the cassette interface
- The version of Apple 1 Basic on the Wozanium has been modified slightly to use Apple II hardware for keyboard input and the Wozanium video driver for output.

To return to Apple 1 Monitor without resetting the computer, you can do one of the following.

- To return to the Monitor without resetting user getchar and putchar vectors: type `CALL -225` from the BASIC prompt.
- To return to Monitor and reset user getchar and putchar vectors: type `CALL -256` from the BASIC prompt.

## 6. Useful Wozanium Pack Addresses

- C100 Run ACI driver if Brain Board is in slot 1  
D000 If Brain Board is another slot
- 6000-BBFF Space for user driver functions
- D24D Get character (getchar) from keyboard - Wozanium function
- BC02-BC03 Vector for user getchar routine  
Return from user getchar routine bypasses Wozanium getchar routine  
JMP D250 afterwards to continue with Wozanium getchar routine
- BC00 Turbo mode  
Set to 1 increase text output speed.  
Default setting of zero closely mirrors original Apple 1 display performance
- FFEF Put character to screen (putchar) - call standard monitor echo routine
- BC04-BC05 Vector for user putchar routine  
Return from user putchar routine bypasses Wozanium putchar routine  
JMP D44A afterwards to continue with Wozanium putchar routine
- BC01 Cassette input/output conversions. Controls conversions from original Apple 1 to Wozanium format and visa versa. This setting should be only used by experts who understand what they are doing.  
Set to 1 to stop conversion of cassette read and cassette write data  
Default setting of 0 enables conversion of cassette read and cassette write data
- D1CE Convert block of Wozanium code to original Apple 1 format (used by cassette write function). Before calling, fill in start and end address.  
BC11 (low) - BC12 (high) start address  
24(low) - 25 (high) end address (also used by monitor)
- D11B Convert block of original Apple 1 code to Wozanium format (used by cassette read and write functions). Before calling, fill in start and end address.  
BC11 (low) - BC12 (high) start address  
24(low) - 25 (high) end address (also used by monitor)
- DFFE-DFFF Wozanium PROM version - this document describes version 5.1

## 7. Troubleshooting and Help

Feel free to send email to: [mike@willegal.net](mailto:mike@willegal.net) if you run into difficulties.

## Chapter 5 - Wozanium Pack - Quick Start Guide

### Build Your Brain Board

Follow directions detailed in Chapters 1 and 2.

### Set slide switches

Dual Bank Mode - Either low bank of Brain Board or Motherboard ROMs selected

1	3	4	5	6	7	8
ON	ON	OFF	ON	OFF	OFF	ON

### Set Toggle Switch

Set toggle switch in up position: Enabling Brain Board low bank

### Insert Brain Board into Slot 1

With power turned off, insert Brain Board into slot 1 of your Apple II with components side of the Brain Board facing **away** from power supply.

### Power Up Computer and Clear Screen

Turn power on. It will take a few seconds for the Wozanium to initialize itself and display the Apple 1 start up screen. The start up screen is alternating flashing @ signs and underscore characters. You should then clear the screen by pressing the right arrow key.

### Enter Your First Apple 1 Program

At the prompt, type- **0:A9 0 AA 20 EF FF E8 8A 4C 2 0(RET)**

0 is a zero, NOT an alpha "O"; and (RET) hit the "return" key on the keyboard.

Type 0R (RET) to run the program. The program should then print out on the display a continuous stream of ascii characters. To stop the program and return to the system monitor, hit the "reset" button. To run again, type - 0R (RET).

### Enter The Basic Programming Language Environment

Unlike the original Apple 1, in the Wozanium environment, BASIC is preloaded into PROM. From the monitor prompt type E000R to enter BASIC and erase any existing program. To re-enter BASIC without destroying an existing BASIC program type E2B3R.

### Return to the Monitor from the Basic Programming Language Environment

To return to the Monitor without resetting user getchar and putchar vectors: type CALL -225.

To return to Monitor and reset getchar and putchar vectors: type RESET or CALL -256.

### To Return to Normal Apple II Operation

Set toggle switch to the down position and reset your computer.