Apple 1 FRAM Board
May 31,2015

The FRAM board uses 2 FM1808B 32KX8 FRAM memory parts made by Cypress Semiconductor that are a non-volatile static rams using a ferrous memory cell. These memory cells do not have the fatigue problems of other memories and can be used safely like a standard SRAM. This board can use a mod to the Apple 1 where the VMA line short to +5 is replaced by a resistor and capacitor so the VMA can be become active. Using this modification any onboard memory including the Boot PROM can be disabled on a cycle by cycle basis by pulling down the VMA line and the FRAM board function can be enabled in its place. The board has no on board firmware and no additional software is needed for the boards operation. The board has switches to manage the memory by 4K blocks with the F, and 0 blocks managed by toggle switches and the 1 through B and E blocks managed by 4 position switches and and jumpers. Figure 1 is a photo of the board showing the switch locations and Figures 2 and 3 show details of the 4 position switches. One 4 position switch is used for the 4-7 spaces and another for the 8-B spaces when the jumpers are in the shown position. The spaces 4, 5, 6, 7, 8, 9, A, and B can be individually disabled by moving the jumper to the OFF position or individually enabled by removal of the jumper using the jumpers below the 4 position switches.

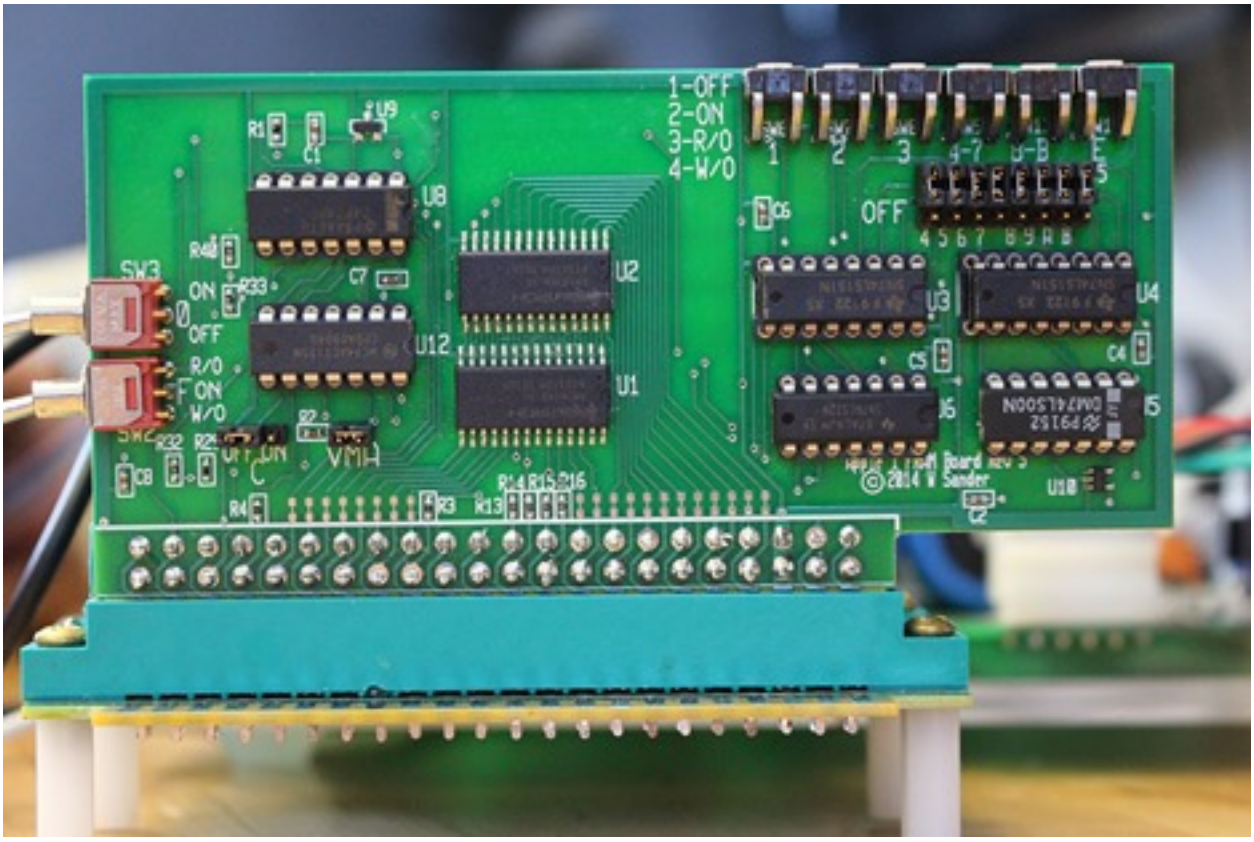

Figure 1

Table 1 shows the function of the 2 toggle switches. Of note is the switch down on switch F where the Read operations are from the on board Apple 1 PROM but the write operations go to the FRAM. This works well because writes to a PROM are not meaningful and the FRAM becomes a Write-Only-Memory. People have joked about WOM's but here is a useful application! This function is only available if the VMA mod has been made.

Switch	Address Range	Up	Middle	Down
0	$0000 to $0FFF	FRAM R/W	NA	Apple 1 RAM
F	$F000 to $FFFF $C000 to $CFFF*	FRAM Read Only	FRAM R/W	Read from PROM Write to FRAM
* $C000 to $CFFF active only if jumper J4 is in the Right Most position				

Table 1 Toggle Switches

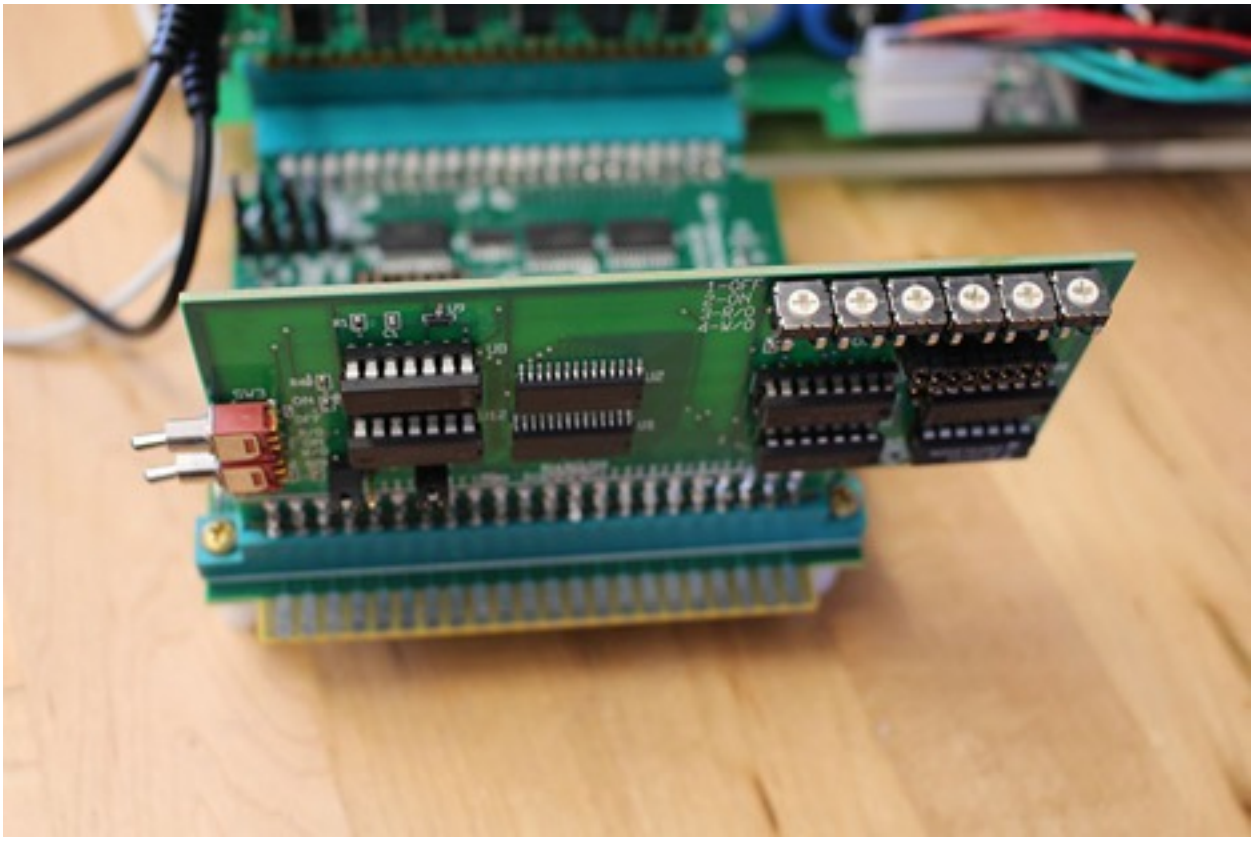

Figure 2

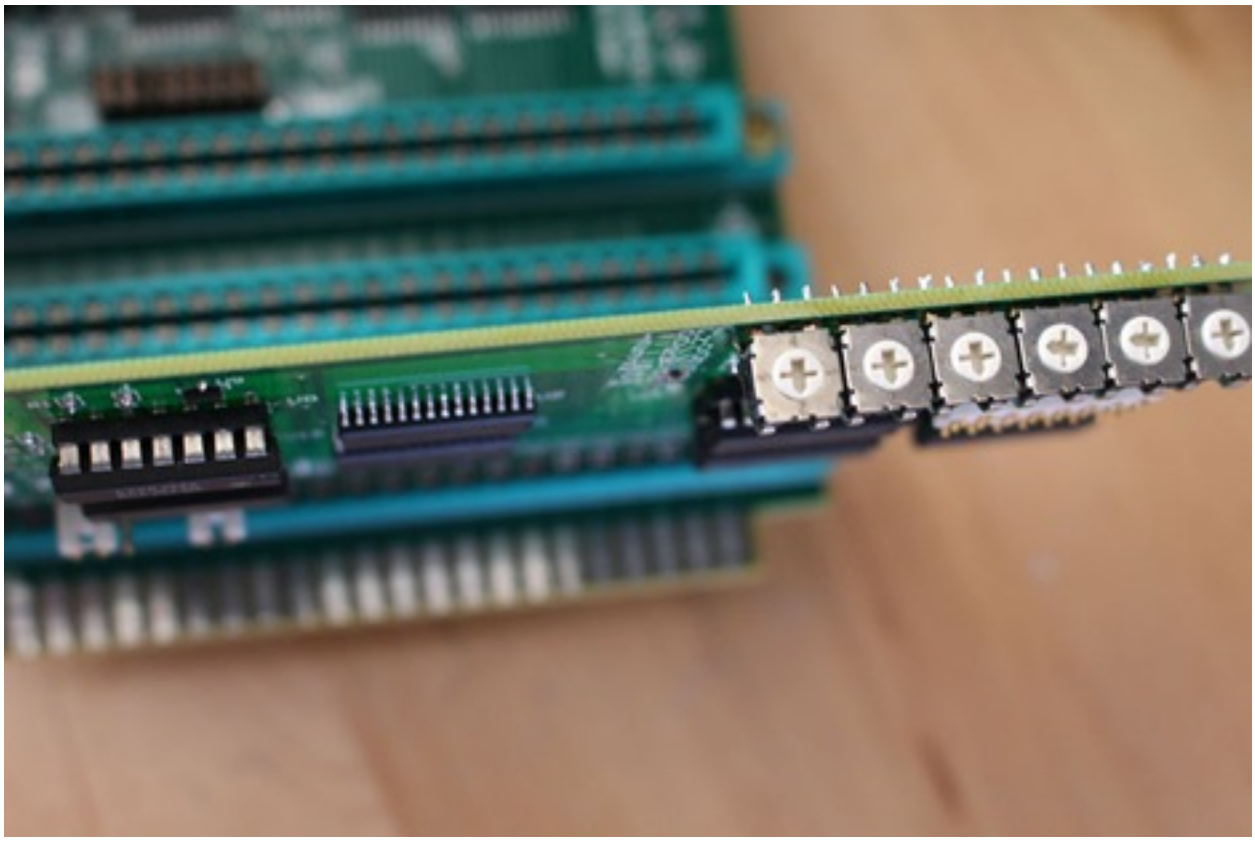

Figure 3

Table 2 shows the function of the 4 position switches. Memory ranges can be switched so that the FRAM can be disabled, enabled for either Read and Write, Read Only , or Write Only. Normally the VMA line will be pulled low on any FRAM access. If Jumper J3 is removed VMA operation is disabled and the VMA mod on the Apple 1 board is not needed. If operated in this mode care must be taken that the FRAM board not be active at the same time as the Apple 1 addressing. If space is to be used as permanent storage it is very important to Write Protect (set as Read Only Memory) that space as loose programs can easily modify writeable space. For some reason ROR and ROL ops often appear in unused space.

Switch Label	Address Range	Switch Position			
		1	2	3	4
1	$1000 to $1FFF	Apple 1 Memory	FRAM R/W	FRAM RO	FRAM WO
2	$2000 to $2FFF	Apple 1 Memory	FRAM R/W	FRAM RO	FRAM WO
3	$3000 to $3FFF	Apple 1 Memory	FRAM R/W	FRAM RO	FRAM WO
4 - 7	$4000 to $7FFF	Apple 1 Memory	FRAM R/W	FRAM RO	FRAM WO
8 - B	$8000 to $BFFF	Apple 1 Memory	FRAM R/W	FRAM RO	FRAM WO
E	$E000 to $EFFF	Apple 1 Memory	FRAM R/W	FRAM RO	FRAM WO

Table 2 4 Position Switches

The FM1808B operates a little differently than a normal SRAM in that it needs a clock for each memory cycle similar to a DRAM. One of the concerns with a non-volatile RAM is to be sure that no unexpected memory cycles take place during power up and power down. The best way to protect against that with these parts is to make sure no clock cycles occur during power up and power down. The circuit formed by U8, U9 and U12C prevent clocks from occurring on power up until there has been an Apple 1 reset or the U8 (a power-on reset circuit) has timed out whichever is later. On power down the clocks are stopped when the voltage goes below about 4.2 volts. The clocks are gated synchronously so that a narrow clock will not occur which could also be a problem.

Apple 1 FRAM Board Description

Using a CFFA1 Board

The CFFA1 Board should be installed in the on board socket of the Apple 1 and the ACI board moved to the Expansion Board as shown in Figure 5. If the CFFA1 were placed on the Expansion Board then data buffering could not be used since the CFFA1 maps directly to the data bus and data buffering is needed to add many boards.

Figure 5

For the ACI to function properly then the Expansion board jumpers should be configured as shown in Figure 6.

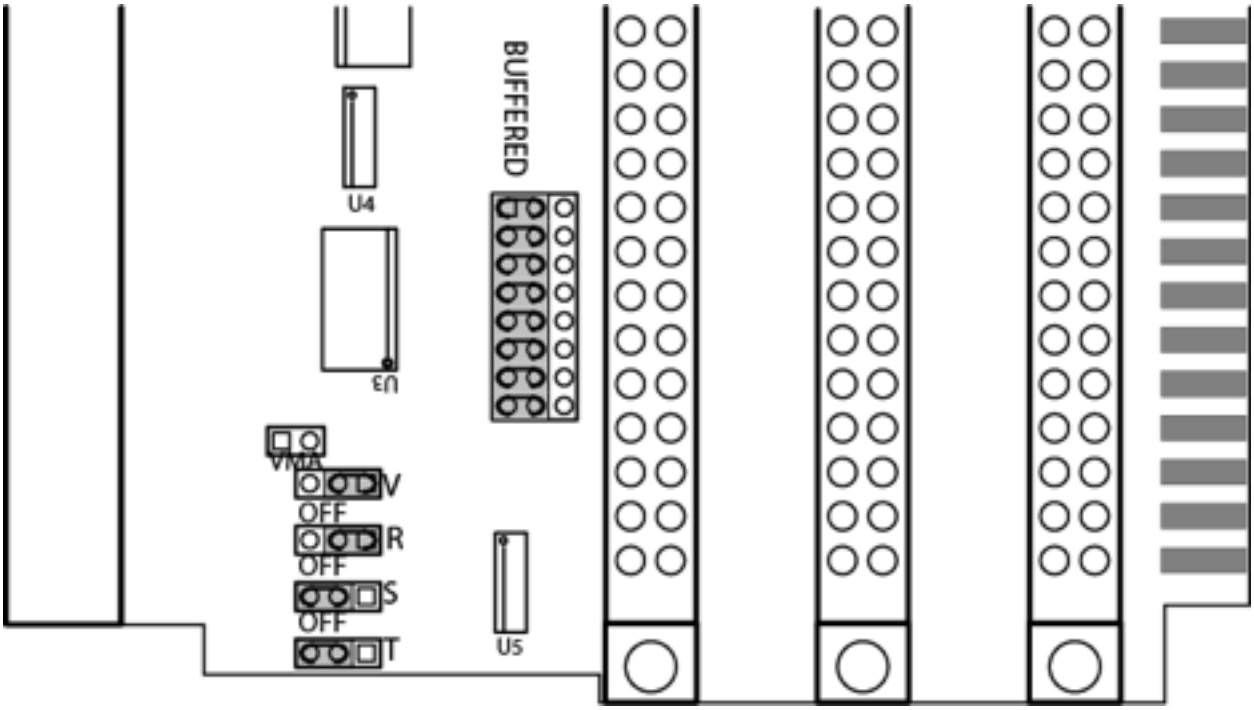

Figure 6

The CFFA1 board switches should be configured as shown in Figure 7 and the FRAM address jumpers should be configured as shown in Figure 8 to allow maximum use of the FRAM space without interfering with the CFFA1 address space.

Figure 7

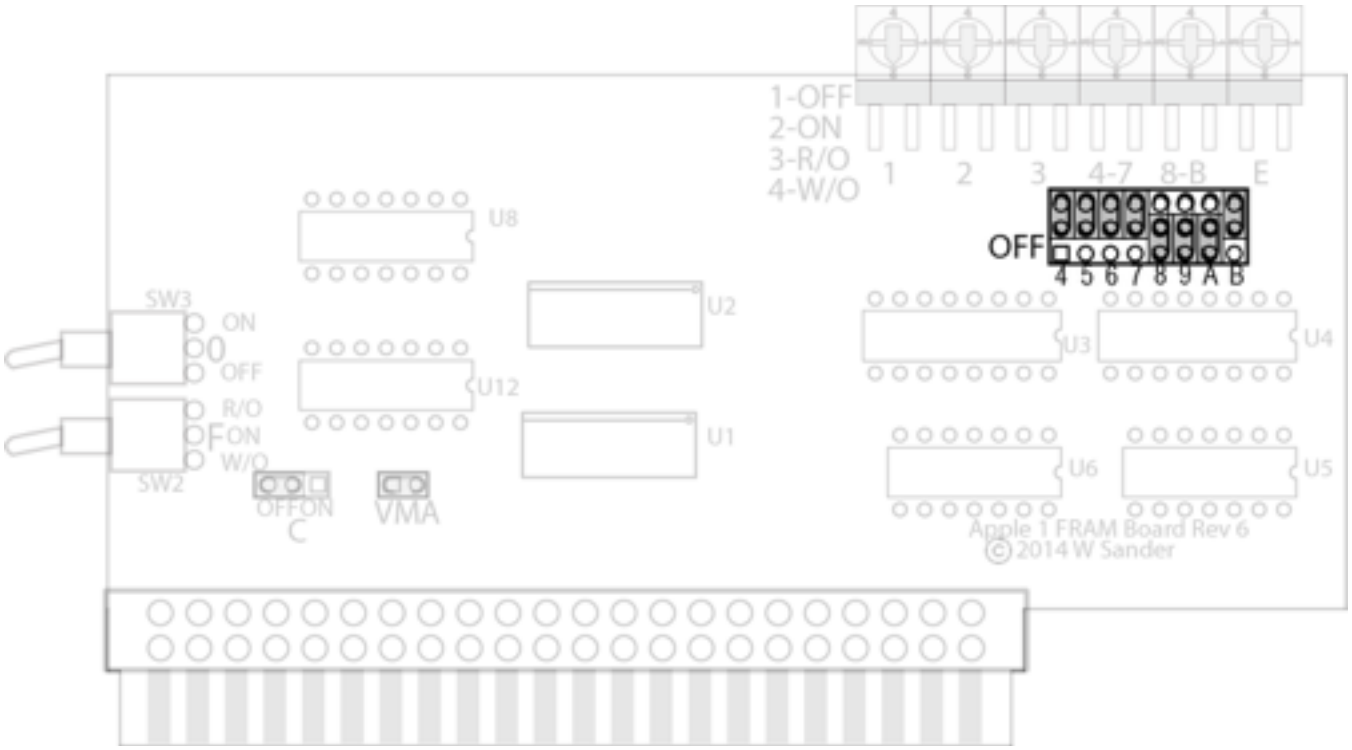
1-OFF
2-ON
3-R/O
4-W/O
1
2
3
4-7
8-B
E
OFF
4 5 6 7 8 9 A B
U8
U2
U12
U1
U3
U4
U6
U5
SW3
ON
0
OFF
R/O
ON
W/O
SW2
OFF ON
C
VMA
Apple 1 FRAM Board Rev 6
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Figure 8

VMA Activation

The VMA signal is a signal needed for the 6800 microcomputer but is not used on the 6502, the pin is a no-connect on the 6502 and a shorting connection area is provided on the Apple 1 board to short it to +5V. The signal is of interest because it is available on the I/O connector. The signal goes to the NAND gate at B1 where it is combined with refresh and the result goes to the 74514 decoder disable pins 18 and 191 disabling all the decoded addresses whenever there is either a refresh or the VMA is low. The signal also goes to a chip select pin on the 6820 PIA which is redundant because the 6820 is disabled whenever the decoder is disabled. The VMA signal can be restored to availability again by replacing the short at approximately A8 labelled 6502 with a pull up resistor. A 2200 ohm resistor in parallel with a 100 pf capacitor should be used, the capacitor controls some crosstalk that has been observed on the signal. When small surface mount parts such as the 0402 parts shown in Figure 1 are used the alteration is nearly invisible.

An alternate implementation is to remove the short at the location and put the added parts under the board between pins 5 and 8 of the 6502 at location A7 or pins 12 and 14 of the DIP at location B1. The capacitor must be connected to the +5V rail instead of GND.

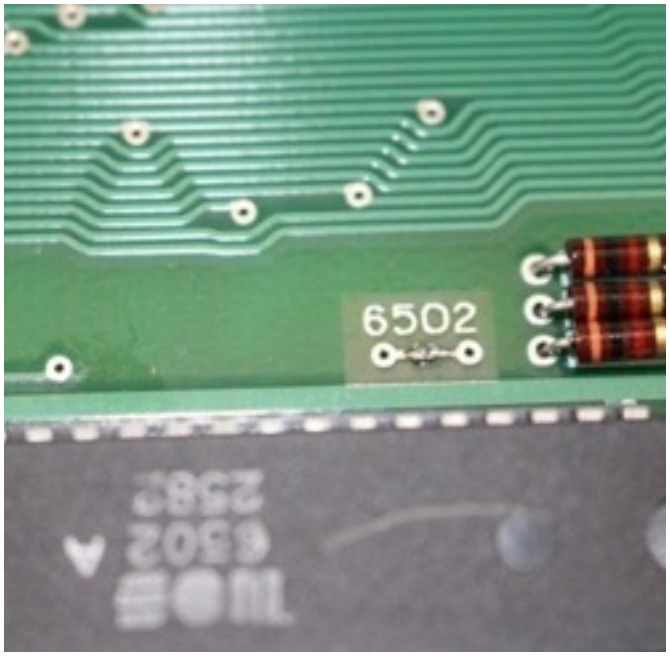


Figure 1

This modification makes available a signal on the peripheral connector that can be used to disable anything accessed using the decoder on a cycle by cycle basis. This includes the 6820 PIA, all on board RAM, the boot ROM and any peripheral using the R, S, or T signals. This permits a peripheral to perform hardware substitution for any of those functions.

For testing the FRAM Board the Apple 1 or Clone must have the VMA mod performed meaning that the short on the Apple 1 labeled “6502” near the 3 3K resistors and near pin 1 of the 40 pin socket at A7 should be removed and replaced by a 100pf Capacitor and 2200Ω resistor across the terminals with surface mount parts or between pins 5 and 8 of the 6502 at location A7 or pins 12 and 14 of the DIP at location B1. The FRAM board can be plugged onto the PC board connector of the Apple 1 or can be plugged into an expansion slot of a known good Expansion Board configured as shown in Figure 10. An Apple 1 ACI Board should be installed in the PC Socket on the Apple 1. The Apple 1 memory is assumed to be mapped into the $0XXX and $EXXX space, if the board has been modified for 16K chips then the modification must be made using the CS(N) pins for enabling the memory and not the Address lines directly, otherwise the VMA will not disable the on-board expanded memory.

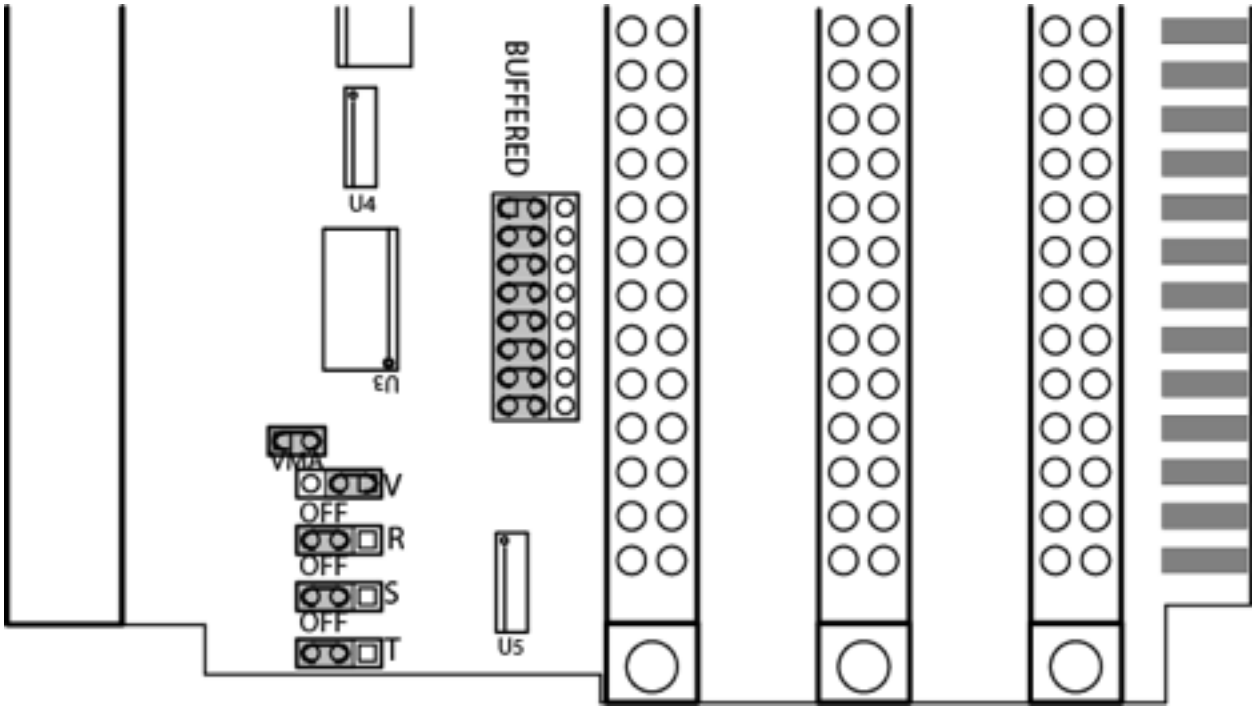


Figure 10

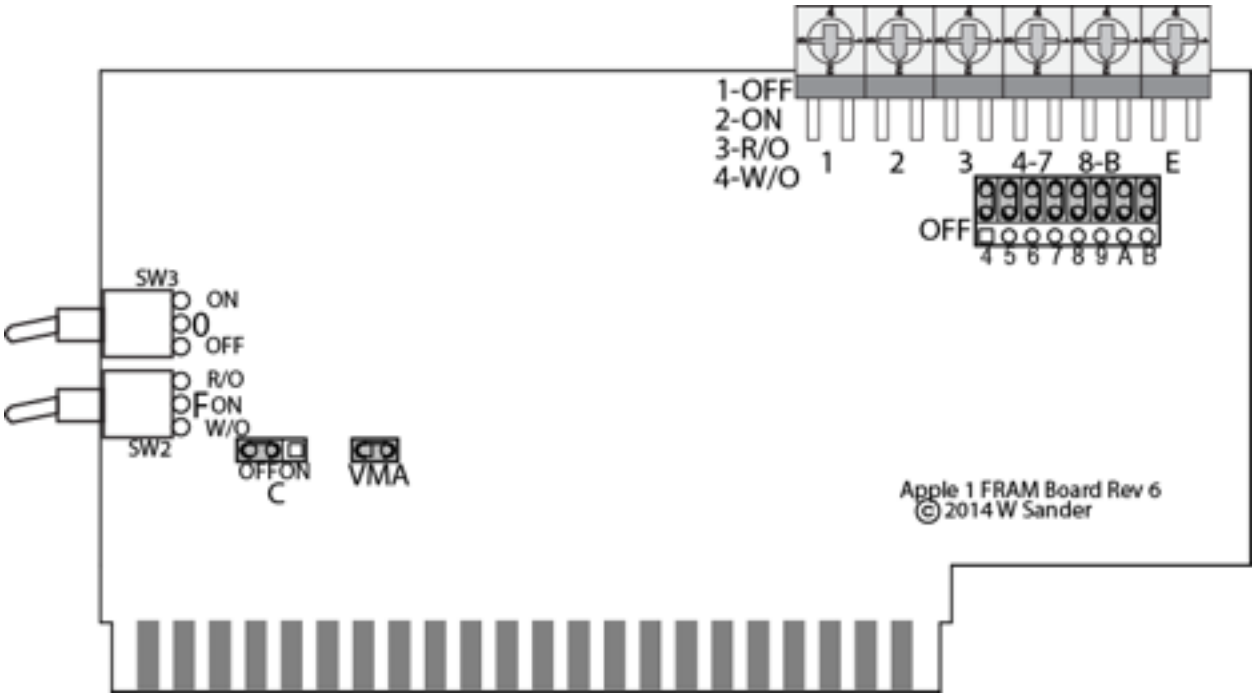


Figure 11

Configure the switches on the FRAM Board as shown in Figure 11, this will enable the FRAM board for R/W at addresses $1000 - $BFFF and $EXXX.

Power on the board and see that it Reset's correctly.

Reset ↘ Reset

To test for basic operation:

Type:	`1000:AA`	Write $AA to $1000
	`1000: ??`	Read undefined at $1000
Type:	`1000`	Read $1000
	`1000: AA`	$1000 = $AA
Type:	`1000:55`	Write $55 to $1000
	`1000: AA`	$1000 Was $AA
Type:	`1000`	Read $1000
	`1000: 55`	$1000 = $55

This verifies that the FRAM can read and write all data bits.

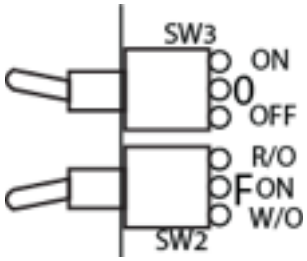
The next test covers the range from $1000 to $BFFF using a RAM test program from Mike Willegal. This program is documented on his web site "www.willegal.net" as "6502 Memory Test". Load the file "Memory Test" from an iPod or equivalent using the ACI Board. The program will load into the Apple 1 on-board memory at $280 to $3A1.

Type:	C100R	Run the ACI at $C100
	C100: A9*	
Type:	280.3A1R	Load Range
	\	Load Complete
Type:	0:00 10 00 C0	Sets the test range from $1000 to $BFFF
	0000: ??	Read undefined at $0000
Type:	280R	Run at $280
	0280: A9PASS 01	Test Completed 1st Pass
	PASS 02	Test Completed 2nd Pass
	PASS 03	Test Completed 3rd Pass
	PASS 04	Test Completed 4th Pass
Reset	\	

Now test the space from $E000 to $EFFF

Type:	0:00 E0 00 F0	Sets the test range from $E000 to $EFFF
	0000: ??	Read undefined at $0000
Type:	280R	Run at $280
	0280: A9PASS 01	Test Completed 1st Pass
	PASS 02	Test Completed 2nd Pass
	PASS 03	Test Completed 3rd Pass
	PASS 04	Test Completed 4th Pass
Reset	\	

In order to test the $0XXX memory bank the $0 bank is turned ON and the Memory Test program loaded into the FRAM bank $0 The memory from $0800 to $0FFF can be tested. Switch the 0 toggle switch ON.



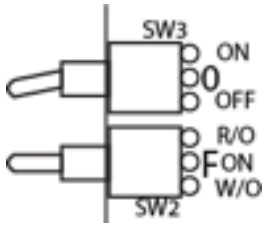
Press Reset and Load the “Memory Test” program from the ACI.

```
     \                          Reset
Type: C100R                     Run the ACI at $C100

     C100: A9*
Type: 280.3A1R                  Load Range
     \                          Load Complete
Type: 0:00 08 00 10             Sets the test range from $0800 to $0FFF

     0000: ??                   Read undefined at $0000
Type: 280R                      Run at $280

     0280: A9PASS 01            Test Completed 1st Pass
     PASS 02                    Test Completed 2nd Pass
     PASS 03                    Test Completed 3rd Pass
     PASS 04                    Test Completed 4th Pass
Reset \
```

In order to test the $FXXX address space the Woz Monitor ROM code must be loaded into the $FF00 to $FFFF space in the FRAM in order for the Apple 1 board to continue to operate properly. The F toggle switch has three positions, when the switch is in the W/O position all reads from the $FXXX space are from the on-board PROM and all writes are to the FRAM. When the Switch is in the R/O position then all reads are from the FRAM and write operations are not performed. In the ON position all reads and writes are to the FRAM space so that is the position needed for testing the space. With the 0 switch remaining in the W/O position load the “Woz Apple 1 Monitor” code using the ACI.

```
Type: C100R                     Run the ACI at $C100

     C100: A9*
Type: FF00.FFFFR                Load Range
     \                          Load Complete
```

The test will be run from the on-board RAM since that is the most demanding test mode. The 0 switch should move to the OFF position and the F switch to the ON position.



Reset the Apple 1, set the test range and run the test.

```
Reset \
     0:00 F0 00 FE              Sets the test range from $F000 to $FEFF

     0000: ??                   Read undefined at $0000
Type: 280R                      Run at $280
```

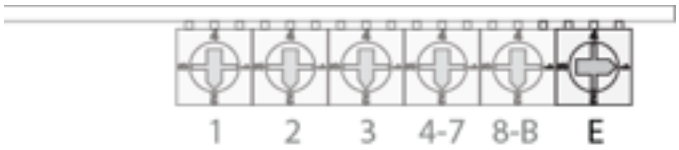
```
0280: A9PASS 01
PASS 02
PASS 03
PASS 04
```

Test Completed 1st Pass
Test Completed 2nd Pass
Test Completed 3rd Pass
Test Completed 4th Pass

Reset ↘

The next sequence tests the operation of the 4 position block switches. This test is performed on Block E since it is the only one that is certain to have memory both on-board and on the FRAM.

Set the E switch on the FRAM Board to position 1, FRAM OFF

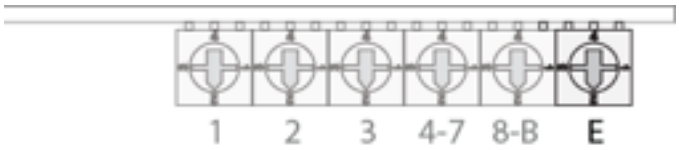


Type: `E000:AA` Write $AA to $E000 on the on-board RAM

`E000: ??` Read undefined at $E000
Type: `E000` Read $E000

`E000: AA` Read $AA from $E000 on the Apple 1 RAM

Set the E switch to position 2, FRAM ON

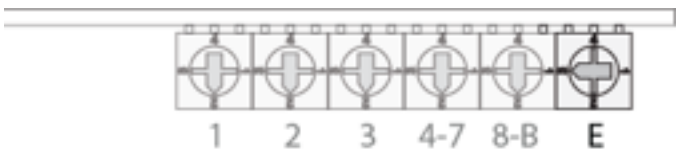


Type: `E000:55` Write $55 to $E000 on the FRAM Board

`E000: ??` Read undefined at $E000
Type: `E000` Read $E000

`E000: 55` Read $55 from $E000 on the FRAM Board

Set the E switch to position 3, FRAM R/O. In R/O (Read Only) Mode Read operations come from the FRAM and Write operations go to the on-board RAM.



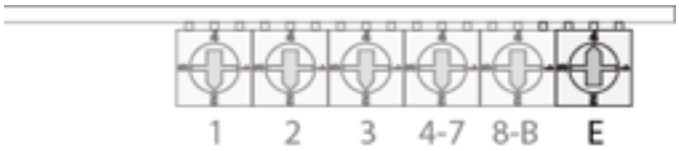
Type: `E000:FF` Write $FF to $E000 on the on-board RAM

```
     E000: 55
Type: E000
```

Read $55 from $E000 on the FRAM Board
Read $E000

```
     E000: 55
```

Set the E switch to position 4, W/O Mode. In W/O (Write Only) Mode Write operation go to the FRAM and Read Operations come from on-board RAM.




```
Type: E000:00
```

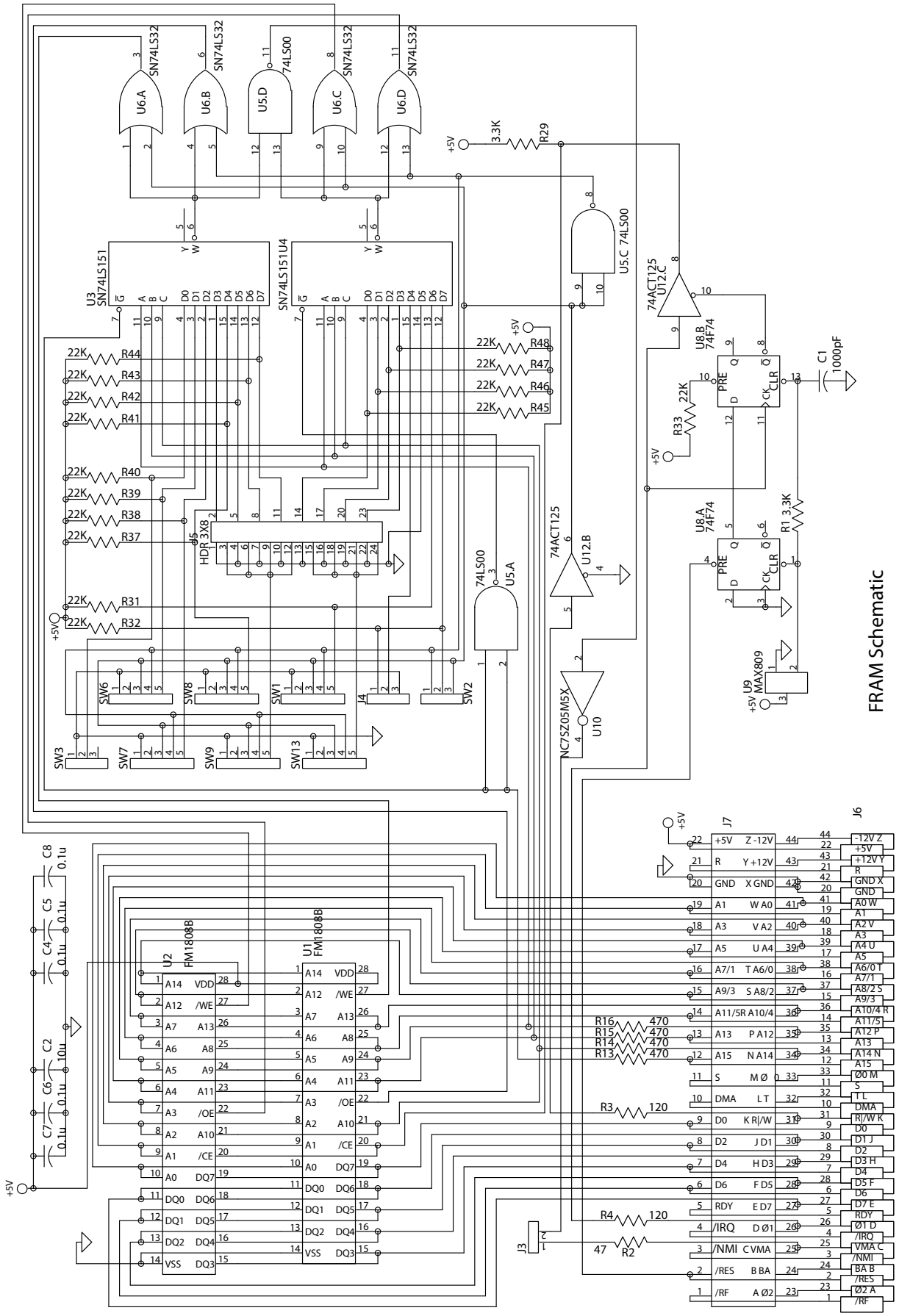
Write $00 to $E000 on the FRAM Board

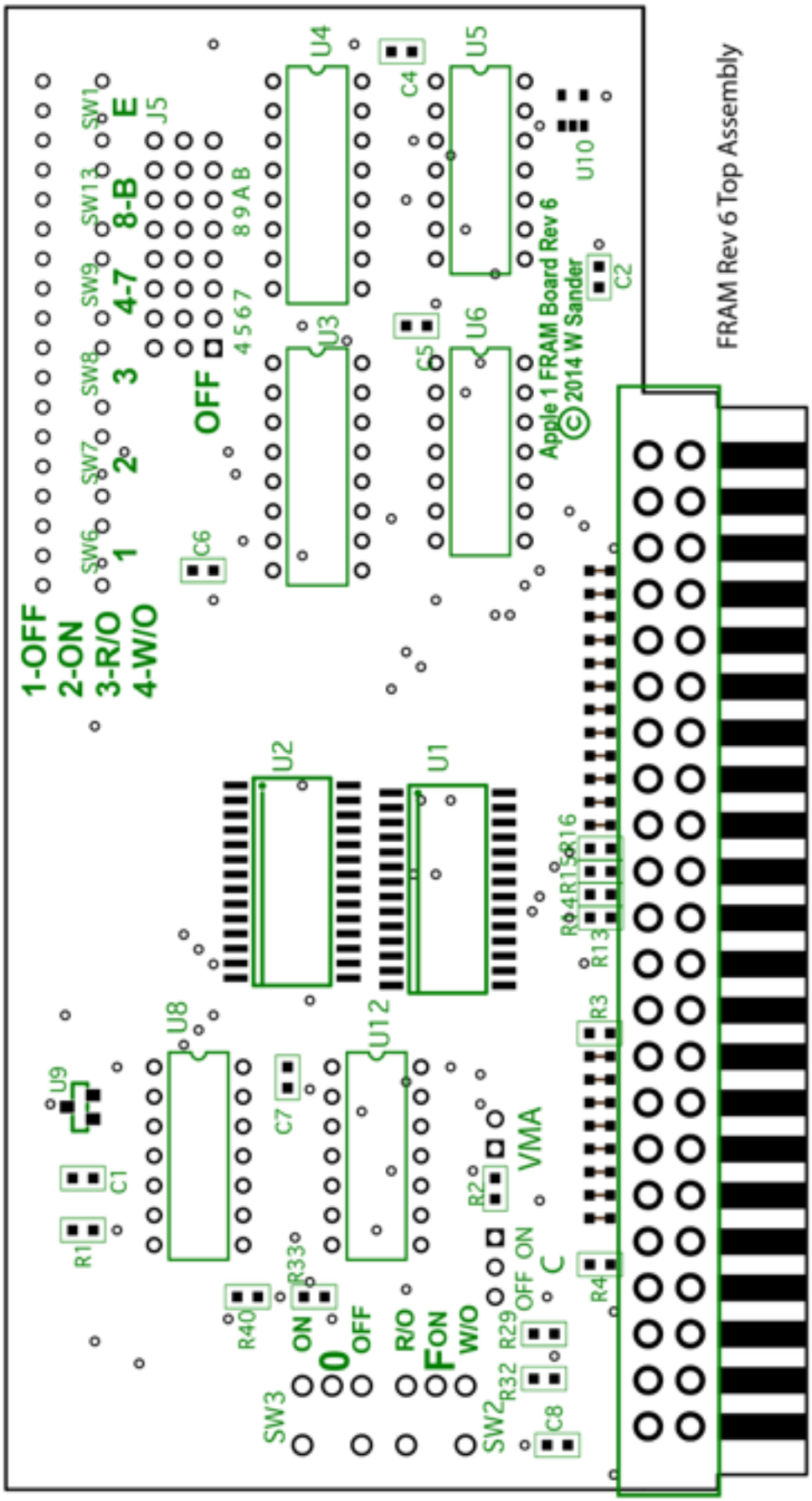
```
     E000: FF
Type: E000
```

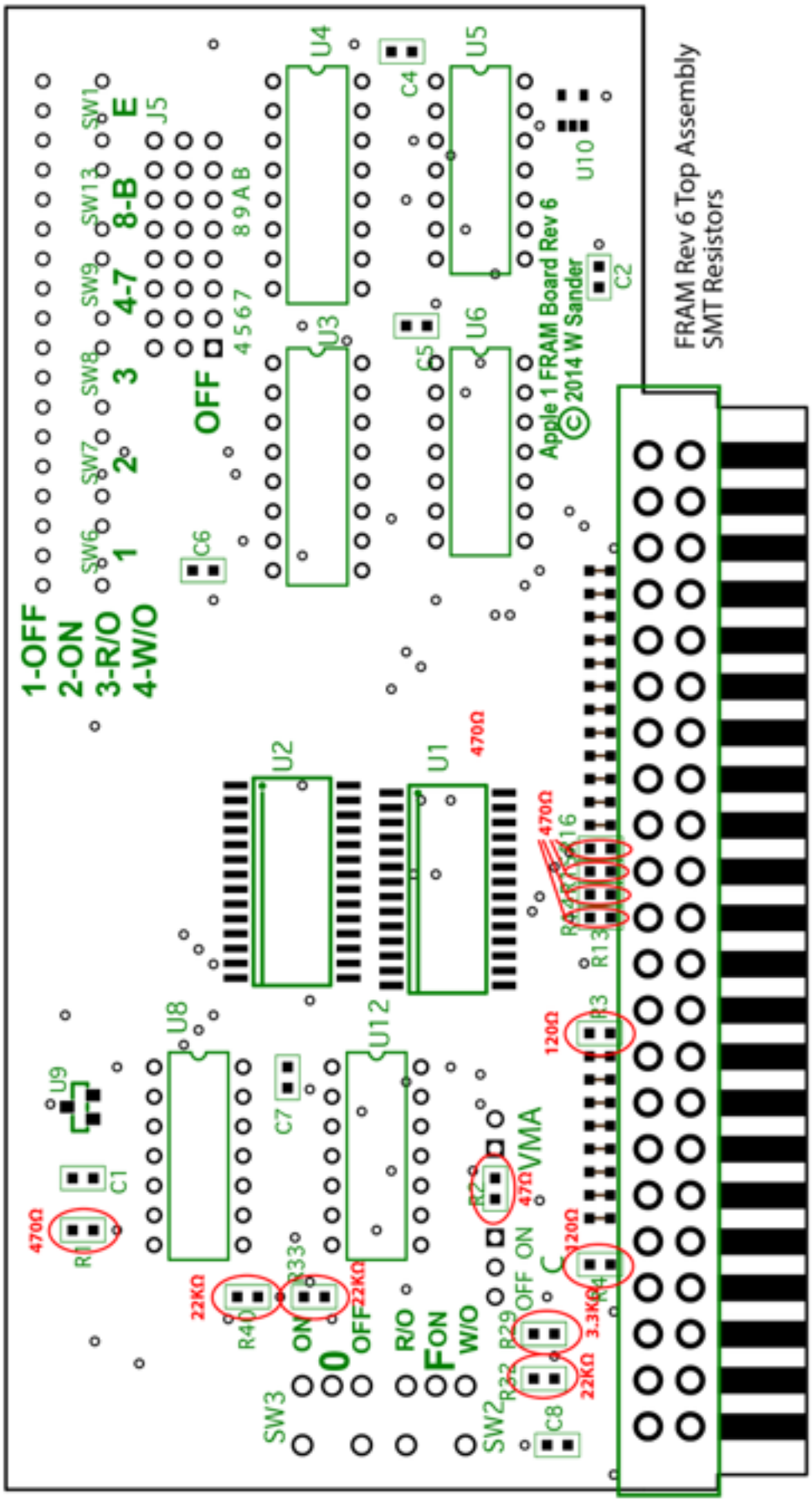
Read $FF from $E000 on the Apple 1 RAM
Read $E000

```
     E000: FF
```

Read $FF from $E000 on the Apple 1 RAM


FRAM Schematic
U6.A SN74LS32
U6.B SN74LS32
U5.D 74LS00
U6.C SN74LS32
U6.D SN74LS32
U5.C 74LS00
U3 SN74LS151
U4 SN74LS151
U12.C 74ACT125
U8.B 74F74
U8.A 74F74
U12.B 74ACT125
U5.A 74LS00
U10 NC7SZ05M5X
U9 MAX809
J5 HDR 3X8
U1 FM1808B
U2 FM1808B
J7
J6
R29 3.3K
R48 22K
R47 22K
R46 22K
R45 22K
R44 22K
R43 22K
R42 22K
R41 22K
R40 22K
R39 22K
R38 22K
R37 22K
R31 22K
R32 22K
R33 22K
R1 3.3K
C1 1000pF
R16 470
R15 470
R14 470
R13 470
R3 120
R4 120
R2 47
C8 0.1u
C5 0.1u
C4 0.1u
C2 10u
C6 0.1u
C7 0.1u
SW6
SW8
SW1
J4
SW2
SW3
SW7
SW9
SW13
+5V


FRAM Rev 6 Top Assembly
1-OFF
2-ON
3-R/O
4-W/O
OFF
4567
89AB
E
8-B
4-7
3
2
1
Apple 1 FRAM Board Rev 6
© 2014 W Sander
U1
U2
U3
U4
U5
U6
U8
U9
U10
U12
C1
C2
C4
C5
C6
C7
C8
R1
R2
R3
R4
R13
R14
R15
R16
R29
R32
R33
R40
SW1
SW2
SW3
SW6
SW7
SW8
SW9
SW13
J5
VMA
C
ON
OFF
R/O
W/O


FRAM Rev 6 Top Assembly
SMT Resistors
Apple 1 FRAM Board Rev 6
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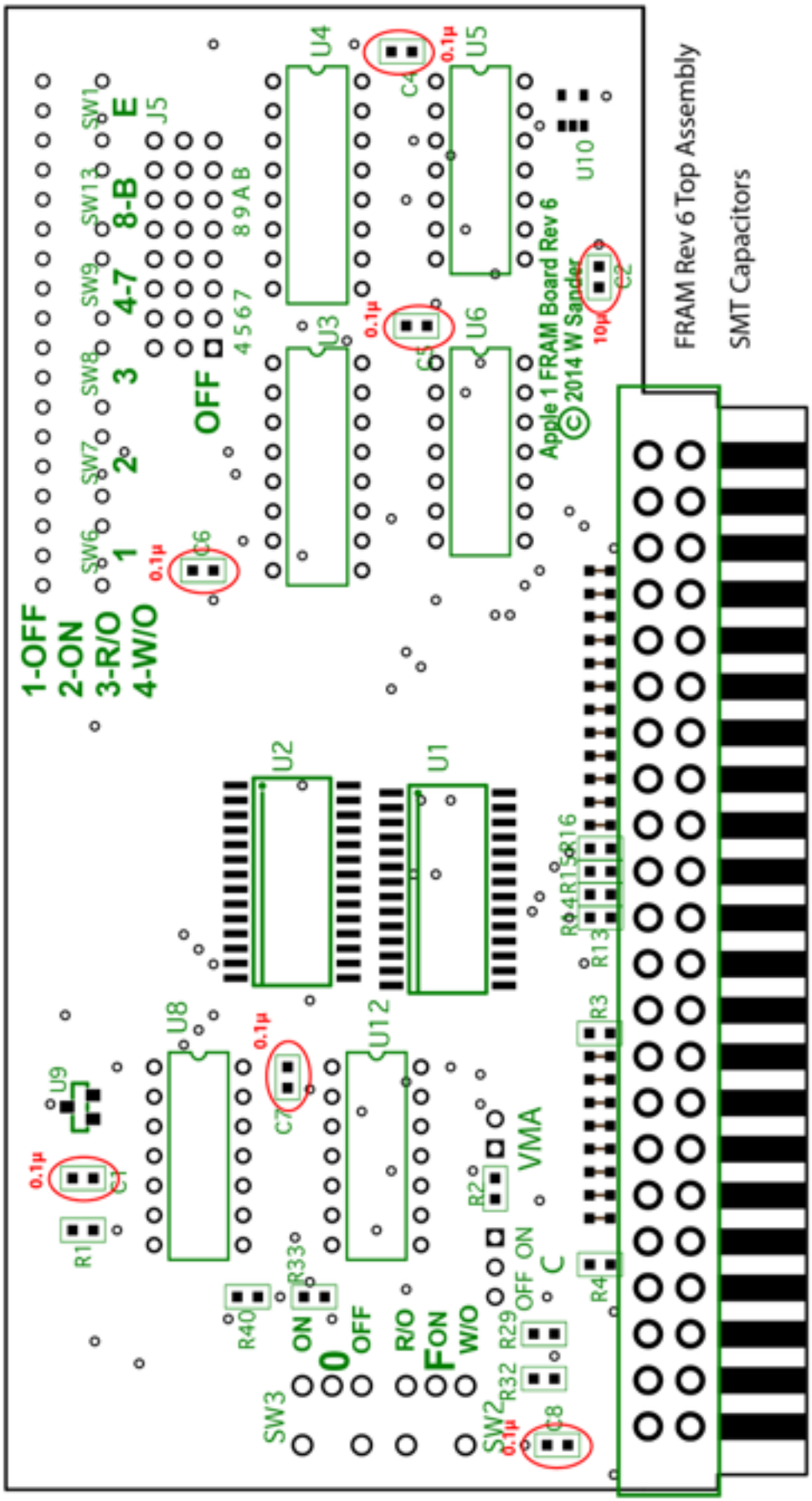
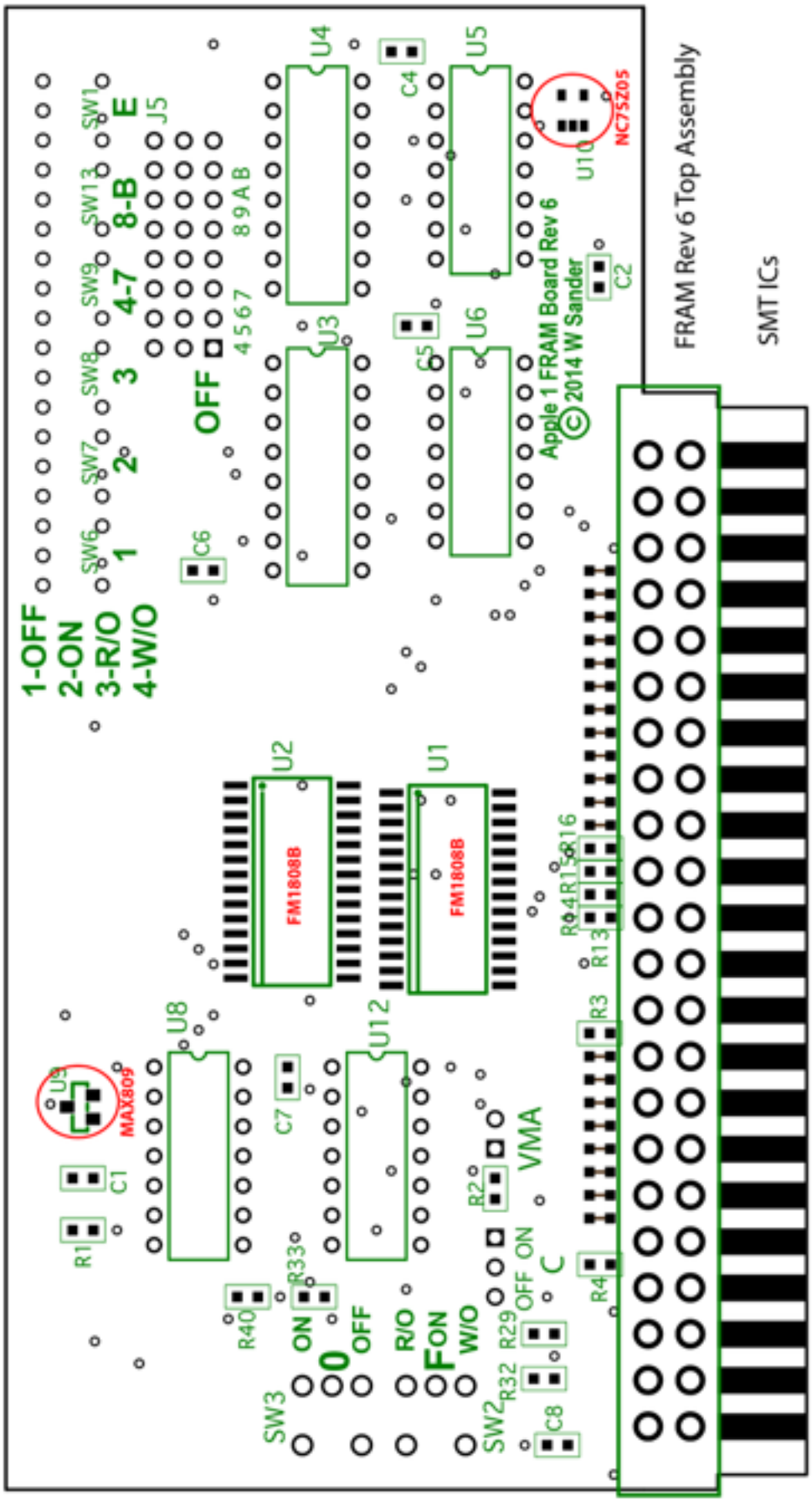
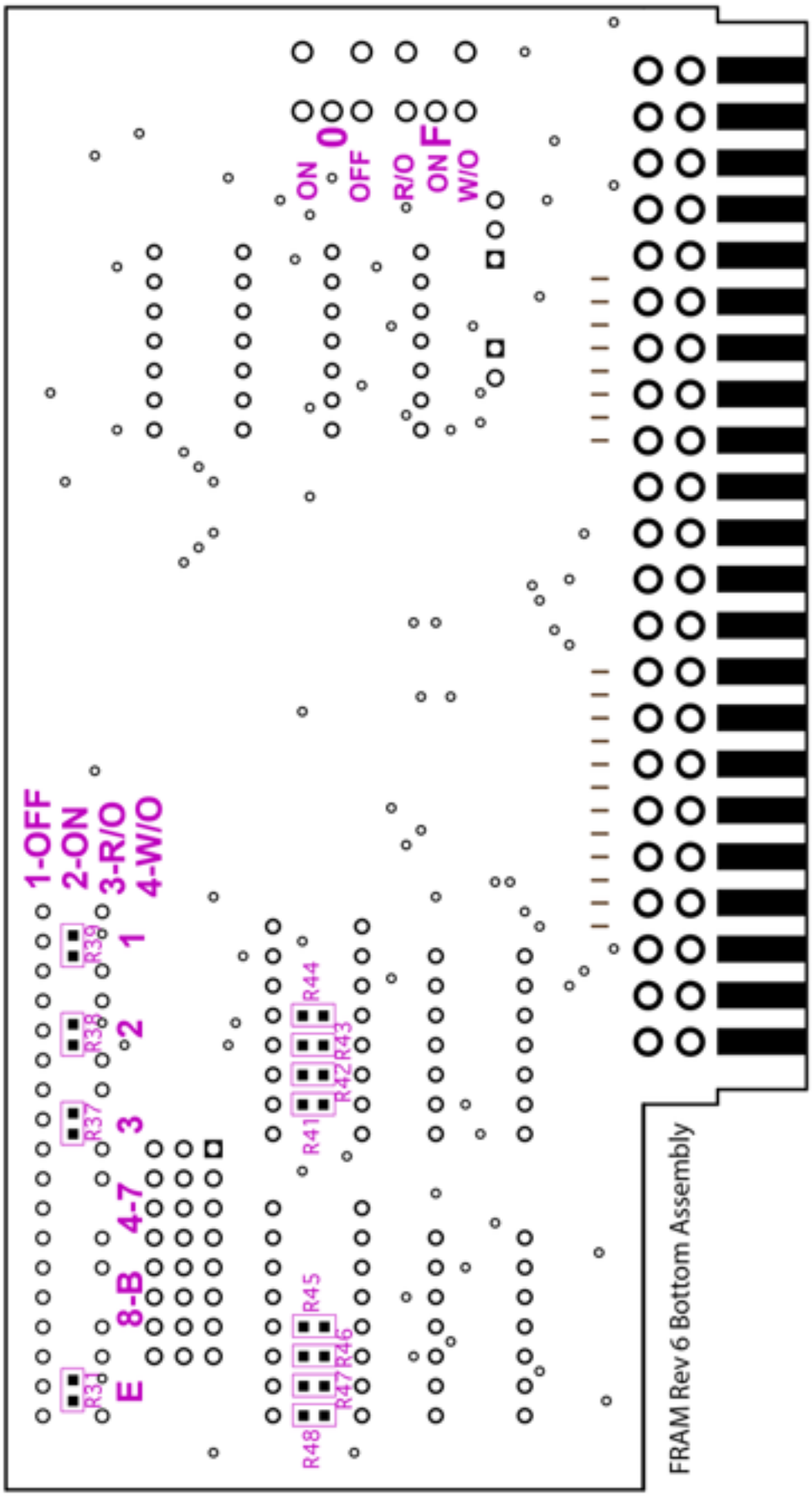
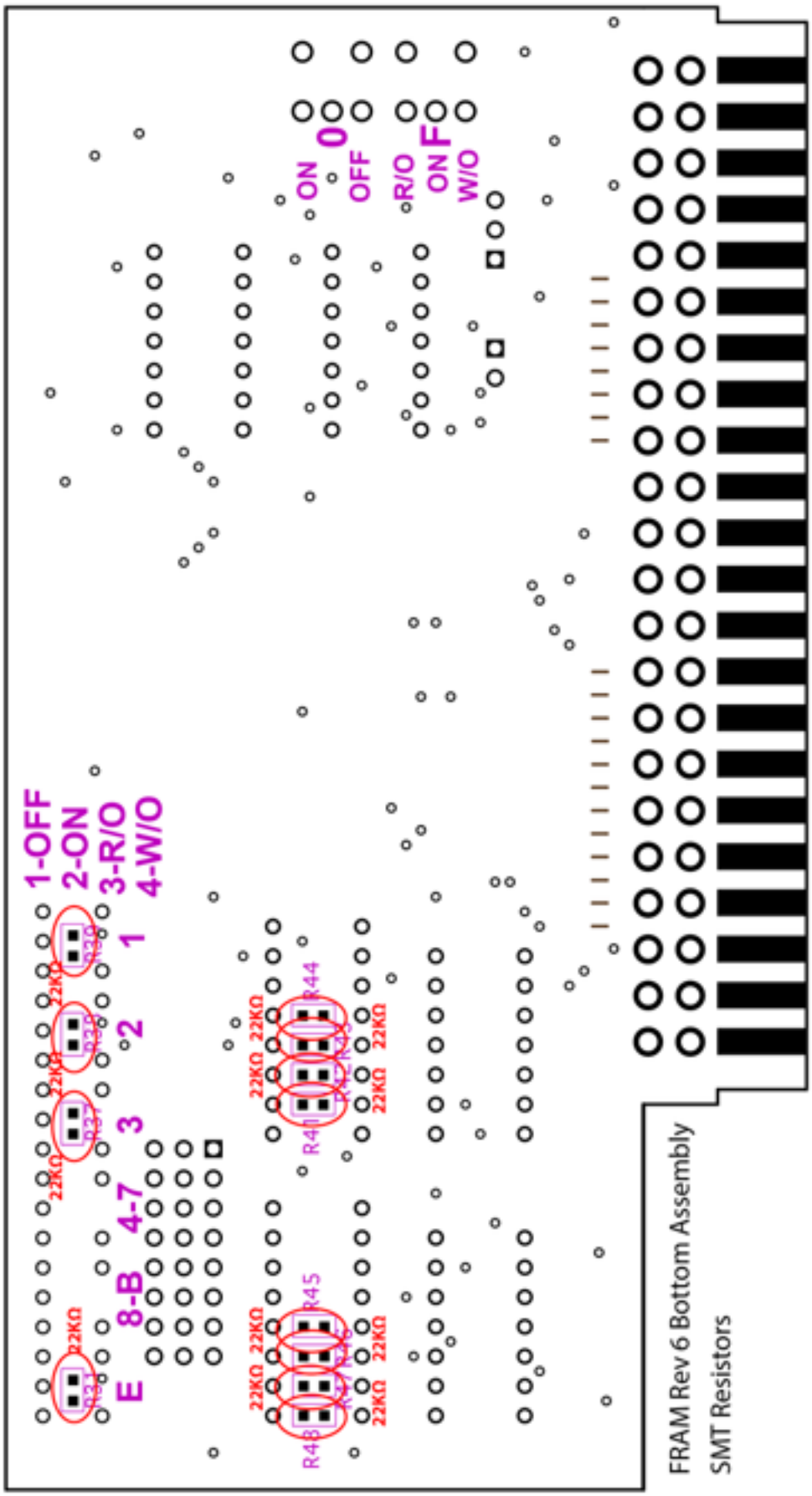
1-OFF
2-ON
3-R/O
4-W/O
OFF
4-7
8-B
E
SW1
SW2
SW3
SW6
SW7
SW8
SW9
SW13
J5
U1
U2
U3
U4
U5
U6
U8
U9
U10
U12
C1
C2
C4
C5
C6
C7
C8
R1
R2
R3
R4
R13
R16
R29
R32
R40
470Ω
120Ω
47Ω
22KΩ
3.3KΩ
VMA
ON
OFF
R/O
W/O


FRAM Rev 6 Top Assembly
SMT Capacitors
1-OFF
2-ON
3-R/O
4-W/O
OFF
Apple 1 FRAM Board Rev 6
© 2014 W Sander
SW3
SW2
ON
OFF
R/O
W/O
VMA


FRAM Rev 6 Top Assembly
SMT ICs
1-OFF
2-ON
3-R/O
4-W/O
OFF
Apple 1 FRAM Board Rev 6
© 2014 W Sander
FM1808B
FM1808B
MAX809
NC7SZ05
VMA
ON
OFF
R/O
W/O


1-OFF
2-ON
3-R/O
4-W/O
8-B
4-7
3
2
1
E
R31
R37
R38
R39
R41
R42
R43
R44
R45
R46
R47
R48
ON
OFF
R/O
W/O
0
F
FRAM Rev 6 Bottom Assembly


1-OFF
2-ON
3-R/O
4-W/O
E 8-B 4-7 3 2 1
ON 0
OFF
R/O
ON F
W/O
22KΩ
R31
R37
R38
R39
R41
R42
R43
R44
R45
R46
R47
R48
FRAM Rev 6 Bottom Assembly
SMT Resistors

FRAM Rev 6 Parts List

Designator	Side	Part	Value	Manufacturer	Mfg Part No.	Description
C1		CAPACITOR	0.1u			0603 CAPACITOR
C2		CAPACITOR	10u			0603 CAPACITOR
C4		CAPACITOR	0.1u			0603 CAPACITOR
C5		CAPACITOR	0.1u			0603 CAPACITOR
C6		CAPACITOR	0.1u			0603 CAPACITOR
C7		CAPACITOR	0.1u			0603 CAPACITOR
C8		CAPACITOR	0.1u			0603 CAPACITOR
J1		Card Connector	44 PIN 0.156	EDAC	305-044-520-202	44-Pin .156 Connector
J3		HEADER	1X2	SAMTEC	TSW-102-07-L-S	1X2 0.1 In Header
J4		HEADER	1X3	SAMTEC	TSW-103-07-L-S	1X3 0.1 In Header
J5		HEADER	3X8	SAMTEC	TSW-108-07-L-T	3X8 0.1 In Header
R1		RESISTOR	470Ω			0603 RESISTOR
R2		RESISTOR	47Ω			0603 RESISTOR
R3		RESISTOR	120Ω			0603 RESISTOR
R4		RESISTOR	120Ω			0603 RESISTOR
R13		RESISTOR	470Ω			0603 RESISTOR
R14		RESISTOR	470Ω			0603 RESISTOR
R15		RESISTOR	470Ω			0603 RESISTOR
R16		RESISTOR	470Ω			0603 RESISTOR
R29		RESISTOR	3.3KΩ			0603 RESISTOR
R31	B	RESISTOR	22KΩ			0603 RESISTOR
R32		RESISTOR	22KΩ			0603 RESISTOR
R33		RESISTOR	22KΩ			0603 RESISTOR
R37	B	RESISTOR	22KΩ			0603 RESISTOR
R38	B	RESISTOR	22KΩ			0603 RESISTOR
R39	B	RESISTOR	22KΩ			0603 RESISTOR
R40		RESISTOR	22KΩ			0603 RESISTOR
R41	B	RESISTOR	22KΩ			0603 RESISTOR
R42	B	RESISTOR	22KΩ			0603 RESISTOR
R43	B	RESISTOR	22KΩ			0603 RESISTOR
R44	B	RESISTOR	22KΩ			0603 RESISTOR
R45	B	RESISTOR	22KΩ			0603 RESISTOR
R46	B	RESISTOR	22KΩ			0603 RESISTOR
R47	B	RESISTOR	22KΩ			0603 RESISTOR
R48	B	RESISTOR	22KΩ			0603 RESISTOR
SW1		SP4T Switch		C&K	RTE0400V04	4 POLE SWITCH
SW2		SPDT Toggle		C&K	T103MH9ABE	SBDT TOGGLE 3 POS
SW3		SPDT Toggle		C&K	T101MH9ABE	SBDT TOGGLE 2 POS
SW6		SP4T Switch		C&K	RTE0400V04	4 POLE SWITCH
SW7		SP4T Switch		C&K	RTE0400V04	4 POLE SWITCH
SW8		SP4T Switch		C&K	RTE0400V04	4 POLE SWITCH
SW9		SP4T Switch		C&K	RTE0400V04	4 POLE SWITCH
SW13		SP4T Switch		C&K	RTE0400V04	4 POLE SWITCH
U1		FM1808B	32K X 8 FRAM	CYPRESS	FM1808B	SOIC 28-PIN
U2		FM1808B	32K X 8 FRAM	CYPRESS	FM1808B	SOIC 28-PIN
U3		74LS151			74LS151	16 PIN DIP
U4		74LS151			74LS151	16 PIN DIP
U5		74LS00			74LS00	14 PIN DIP
U6		74LS32			74LS32	14 PIN DIP
U8		74F74			74F74	14 PIN DIP
U9		MAX809	4.38V	ON SEMI	MAX809MTRG	SOT23
U10		NC7SZ05M5X			NC7SZ05M5X	SOT23-5
U12		74ACT125			74ACT125	14 PIN DIP