GREEN DELICIOUS APPLE-1 EMULATOR

Green Delicious is an Apple-1 emulator that runs on Commodore 64.

It emulates the 40x24 monochrome display, 7x8 character cells (280x192 pixels), pixel-perfect Signetics 2513 character generator, instant 50/60 Hz hardware scrolling and an ASCII keyboard. It mimics somewhat sufficiently the PIA interface chip functions and it's almost as fast as the original.

Apple-1 was introduced the year I was born. This emulator was programmed 37 years later on a Mac.
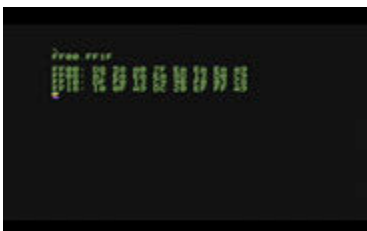
Quick Start

Run the emulator and type '`F000R`'. This executes the program at $F000, which displays a little help text I included there for you.

Apple-1 is a simple 6502-based computer with keyboard input and slooow text output (yes, approximately one character per frame) and uppercase characters only. There is no backspace and it's not possible to move the cursor back or up. And no sound, which is great!

'`F800R`' starts C'mon monitor, a machine code monitor I originally wrote for VIC 20 in 2001. With just a few modifications it worked fine on Apple-1 too.

BASIC programs are started by typing '`E2B3R`' and then '`RUN`'.

Emulator Keys

F1   Clear the screen and return cursor to top-left corner—on Apple-1 this is a hardware key and you can't do the same in software. Printing 24 carriage returns effectively clears the screen, but the cursor remains at the bottom row

F3   Cycle the display text color through a carefully crafted palette of historically relevant greens, grays, yellow and amber

F5   Switch cursor type between the colorful apple sprite and the standard '`@`'—It does look a bit like an apple as well, doesn't it?

F7   Apple-1 reset: Jumps to 'Woz Monitor' at $FF00 and prompts a '`\`'. Hold down F7 for a second to freeze the Apple-1 and enter disk options menu

Woz Monitor

Apple-1 ROM is a tiny 256-byte program, 'Woz Monitor', that allows inspecting memory, writing in hex values and executing programs, and not much else. Though minimal, it's much less user-hostile than the physical LED-and-switch user interfaces of the time.

View memory:
`0300` (Just type the address)

Hex dump:
`0300.03FF`

Write bytes to memory:
`0300:10 12 1A 13 1B ...`

Run program:
`0300R`

C'mon Monitor

Type 'F800R' in Woz Monitor to launch C'mon.

Assemble:
A 0300 LDA #$10 (Enter a blank line to stop)

Write bytes to memory:
W 0300 10 20 30 ...

Disassemble:
D 0300
D (continue)

Execute program:
G 0300

Hex dump:
H 0300
H

Text dump:
T 0300
T

View 6510 registers:
R

Memory Map & Useful ROM Calls

$0000-$0FFF   4K Low RAM
$1000-$3FFF   Extended 12K RAM (Non-standard)
$4000-$903F   Green Delicious
$C000-$C1FF   Tape interface (Not implemented, at least not yet)
$D010-$D013   PIA chip registers
$E000-$EFFF   4K High RAM (Integer BASIC is loaded here)
$F000-$F3FF   Help text
$F800-$FEFF   C'mon monitor
$FF00-$FFFF   Apple-1 ROM ('Woz Monitor')

JSR $FFEF   Output an ASCII character
JSR $FFDC   Output a byte in hex

Compatibility

All Integer BASIC programs should work fine. Most machine code programs should run fine too, although there's a few points to note.

Low RAM at $0002-$0FFF, High RAM at $E000-$EFFF and also Extended RAM at $1000-$3FFF are available. Zeropage locations $00 and $01 cannot be used, because 6510 reserves them for memory configuration and I/O. If your Apple-1 program uses these two locations you have to patch it manually. Tough luck!

PIA chip reads and writes must be patched too, but this is done automatically when loading a new program:

```
LDA $D010 -> JSR $8010  (Keyboard input: Reading this also clears bit 7 of $D011)
STA $D012 -> JSR $9012  (ASCII output: Writing to the register sets bit 7 of $D012)
```

Also:
```
LDX $D010 -> JSR $8020
LDY $D010 -> JSR $8030
STX $D012 -> JSR $9022
STY $D012 -> JSR $9032
```

Read keyboard example (returns ASCII value of key + 128):
```
.1
LDA $D011     ; Bit 7 is set when there's a new keypress
BPL .1
LDA $D010     ; This becomes JSR $8010
```

ASCII output example (same as Apple-1 ROM at $FFEF):
```
.1
BIT $D012     ; Bit 7 is cleared when the video terminal is ready to take a new character
BMI .1
STA $D012     ; This becomes JSR $9012
```

Actually, $D012 writes don't need to be patched if the high bit is always set. But some programs—like the Integer BASIC—occasionally write to $D012 with bit 7 cleared.

Memory location $8C00 holds the number of patches done. Patched addresses are stored at $8C02-$8CFF. Type '8C00' or '8C00.8CFF' in Woz Monitor to view this information. If you have typed in a program in the emulator and need to apply the automatic patches there, just type '8006R'. This handles the memory areas $0000-$3FFF and $E000-$EFFF.

When writing new Apple-1 programs, do not call the patched routines directly. Let Green Delicious do the job for you, and you will have a binary that is compatible with the real thing. If required, you can also skip the automatic PIA patching after loading a file. To do this press Shift+Return in the disk menu (instead of Return).

Disk Contents

APPLE-1 EMULATOR	Full version with Integer BASIC, help text and C'mon
APPLE-1 NO BASIC	No Integer BASIC preloaded, but C'mon is there
APPLE-1 WOZ ONLY	Only Apple-1 ROM: 256 bytes 'Woz Monitor' at $FF00
CMON.300	Relocated versions of C'mon
CMON.900	
CMON.E000	
CMON.E900	
BASIC.E000	Integer BASIC, which you can also load separately
MASTERMIND.300	A couple of games that were sold by Apple on tape in 1977
LUNAR LANDER.300	
BLACKJACK.E2B3	
HAMURABI.E2B3	
STARTREK.E2B3	

Binary File Format

Two first bytes of standard Commodore binary files define the loading address. Green Delicious follows this with two exceptions: Apple-1 Low RAM files ($0000-$0FFF) are relocated to $C000-$CFFF. 16K Extended RAM programs that span $0000-$3FFF also have the load address of $C000, but the Green Delicious loader skips to $1000 when reaching $D000. The first 4K is moved to the right place when the emulator is resumed.

Examples:

LUNAR LANDER.300 and CMON.300 actually have load address of $C300. Start the programs by typing '300R'.

BASIC.E000 loads to $E000. 'E000R' is BASIC cold start.

HAMURABI.E2B3 and other BASIC programs load to $0000-$0FFF. 'E2B3R' is BASIC warm start.

Low RAM and High RAM programs can be also loaded to C64 memory before starting the emulator:

```
LOAD"CMON.300",8,1
NEW
LOAD"APPLE-1 EMULATOR",8,1
RUN
```

Loading and Saving Files

Press and hold F7 for a second to freeze Apple-1 and reach the disk options menu:

Low RAM is $0000-$0FFF (4K), Extended RAM is $0000-$3FFF (16K) and High RAM is $E000-$EFFF (4K).

Apple-1 Information

http://en.wikipedia.org/wiki/Apple_I
http://www.applefritter.com/apple1
http://www.brielcomputers.com/wordpress/?cat=17
http://commons.wikimedia.org/wiki/File:Apple_I_Computer.jpg

Credits

Apple-1 ROM ('Woz Monitor') and Apple Integer BASIC by Steve Wozniak in 1976
Apple-1 photo by Ed Uthman and licensed under Creative Commons
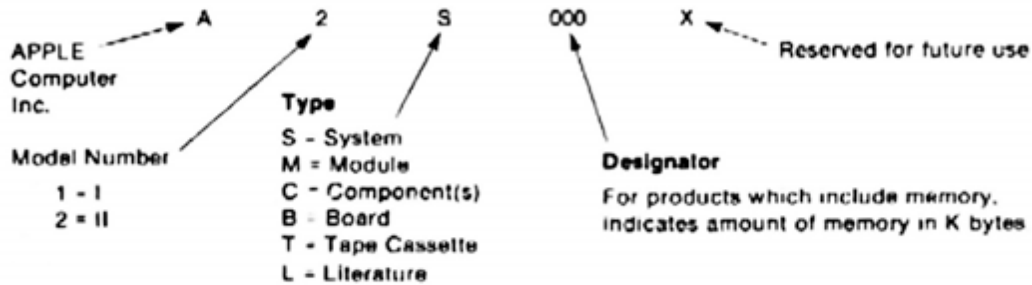Green Delicious Emulator and C'mon monitor by Aleksi Eeben in 2001 & 2013

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apple computer inc.

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Order Code Legend:

```
          A        2        S       000      X
APPLE                                              Reserved for future use
Computer
Inc.                 Type
                     S - System
Model Number         M = Module         Designator
   1 - I             C - Component(s)    For products which include memory,
   2 = II            B - Board           indicates amount of memory in K bytes
                     T - Tape Cassette
                     L - Literature
```

Apple I

Apple I is a completely assembled and tested single board computer

Boards

Single Board Computer (4K Bytes RAM)	A1B004X	$ 475 00
Single Board Computer (8K Bytes RAM)	A1B008X	575 00
Cassette Interface Board	A1B001X	75.00

Accessories

"BASIC" Tape Cassette	A1T001X	5.00
"Mastermind" Tape Cassette	A1T002X	5.00
"Lunar Lander" Tape Cassette	A1T003X	5.00
"Blackjack" Tape Cassette	A1T004X	5 00
"Hamurabi" Tape Cassette	A1T005X	5.00
"Mini-Startrek" Tape Cassette	A1T006X	5.00
"16K-Startrek" Tape Cassette	A1T007X	5 00
"Dis-Assembler" Tape Cassette	A1T008X	5.00
"Extended Monitor" Tape Cassette	A1T009X	5.00
Operator's Manual	A1L001X	3 00

Apple II

Apple II is a completely assembled and tested computer system. It includes 8K bytes of ROM, rugged plastic molded case, typewriter-style keyboard, high efficiency switching power supply, two game paddles, vinyl carrying case, all cords and cables, and a complete operator's manual.

Systems

Complete Computer — 4K Bytes RAM	A2S004X	$1298 00
Complete Computer — 8K Bytes RAM	A2S008X	1398 00
Complete Computer — 12K Bytes RAM	A2S012X	1498.00
Complete Computer — 16K Bytes RAM	A2S016X	1678.00
Complete Computer — 20K Bytes RAM	A2S020X	1778 00
Complete Computer — 24K Bytes RAM	A2S024X	1878 00
Complete Computer — 32K Bytes RAM	A2S032X	2158.00
Complete Computer — 36K Bytes RAM	A2S036X	2258.00
Complete Computer — 48K Bytes RAM	A2S048X	2638 00

ASCII CHARACTER FONT

2513N/CM2140

```
0300: D8 20 8B 05 A9 03 85 FE A0 00 84 FD F0 0E 20 22
0310: 03 20 52 03 20 5E 03 A9 01 69 00 A8 20 86 06 4C
0320: 0E 03 20 4D 03 AD 11 D0 10 FB AD 10 D0 20 EF FF
0330: 29 7F C9 5F D0 06 C6 F6 10 EB 30 E6 A4 F6 10 02
0340: A9 0D 99 00 02 C9 0D F0 04 E6 F6 D0 D8 A9 00 85
0350: F6 60 84 F5 A4 F6 E6 F6 B9 00 02 A4 F5 60 A0 07
0360: D9 98 06 F0 05 88 10 F8 38 60 B9 A0 06 85 FB B9
0370: A8 06 85 FC 6C FB 00 20 46 06 B0 43 20 FA 05 90
0380: 06 20 08 06 20 22 03 A0 00 20 52 03 C9 0D D0 05
0390: 18 60 20 52 03 99 00 02 C8 C9 0D D0 F5 A0 00 AD
03A0: 00 02 D9 75 08 D0 10 AD 01 02 D9 76 08 D0 08 AD
03B0: 02 02 D9 77 08 F0 09 C8 C8 C8 C0 AB D0 E1 38 60
03C0: 84 F7 A0 0B A2 00 98 48 B9 50 09 A8 B9 68 09 C9
03D0: 30 F0 0D DD 03 02 D0 11 C9 0D F0 14 C8 E8 D0 EC
03E0: BD 03 02 C9 30 B0 F5 90 00 68 A8 88 10 D6 30 CE
03F0: 68 85 F8 A0 00 B9 47 07 C5 F7 D0 11 B9 DE 07 C5
0400: F8 F0 11 C9 04 D0 06 A5 F8 C9 09 F0 07 C8 C0 97
0410: D0 E3 F0 AA A2 00 B9 B0 06 81 FD B9 DE 07 A8 B9
0420: 20 09 C0 00 F0 2A 85 F7 A2 00 A9 24 E8 DD 02 02
0430: D0 FA C0 09 F0 20 A5 F7 C9 02 F0 09 20 96 04 B0
0440: 72 A0 02 91 FD 20 96 04 B0 69 A0 01 91 FD A5 F7
0450: 20 15 06 4C 81 03 20 96 04 B0 58 85 FA 20 96 04
0460: B0 51 38 E5 FD 85 F9 A5 FA E5 FE 85 FA 10 14 A9
0470: 81 C5 F9 B0 1A A9 FF C5 FA D0 14 A6 F9 CA CA 8A
0480: 4C 4A 04 A9 81 C5 F9 90 06 A9 00 C5 FA F0 EC A9
0490: 21 20 EF FF 38 60 BD 03 02 E8 20 77 06 B0 14 2A
04A0: 2A 2A 2A 29 F0 85 FB BD 03 02 E8 20 77 06 B0 03
04B0: 05 FB 18 60 20 46 06 A9 10 85 FA 20 05 06 A0 02
04C0: B1 FD 85 F8 88 B1 FD 85 F7 88 B1 FD D9 B0 06 F0
04D0: 0A C8 C0 97 D0 F6 A9 00 AA F0 06 BE 47 07 B9 DE
04E0: 07 85 F9 A0 03 BD 75 08 20 EF FF E8 88 D0 F6 A4
04F0: F9 F0 2A 20 41 06 B9 38 09 A8 20 86 06 A4 F9 B9
0500: 2C 09 F0 25 30 05 A5 F8 20 DC FF A5 F7 20 DC FF
0510: A4 F9 B9 44 09 F0 06 A8 20 86 06 A4 F9 B9 20 09
0520: 20 15 06 C6 FA D0 94 18 60 85 F8 A5 F7 10 02 C6
0530: F8 18 69 02 90 02 E6 F8 18 65 FD 85 F7 A5 FE 65
0540: F8 85 F8 4C 06 05 20 46 06 A9 08 85 FA 20 05 06
0550: A2 20 20 1F 06 C6 FA D0 F4 18 60 20 46 06 A9 04
0560: 85 FA 20 05 06 A0 00 98 48 B1 FD 20 DC FF 20 41
0570: 06 68 A8 C8 C0 08 D0 EF A2 08 20 1F 06 C6 FA D0
0580: E1 18 60 20 46 06 B0 5F 20 A0 05 08 8D 84 02 8E
0590: 83 02 8C 82 02 BA 8E 81 02 68 8D 80 02 D8 18 60
05A0: 6C FD 00 A0 03 20 86 06 A0 04 B9 80 02 20 DC FF
05B0: 20 41 06 88 D0 F4 AD 80 02 85 F8 A2 08 A9 00 26
05C0: F8 69 30 20 EF FF CA D0 F4 18 60 20 46 06 B0 17
05D0: A9 00 85 FC 20 FA 05 B0 0D 20 5B 06 B0 09 A4 FC
05E0: 91 FD E6 FC D0 EE 18 60 20 46 06 B0 0C 85 F7 A5
05F0: FE 85 F8 20 46 06 B0 01 18 60 20 52 03 C9 20 D0
0600: 02 18 60 38 60 20 3E 06 A5 FE 20 DC FF A5 FD 20
0610: DC FF 4C 41 06 18 65 FD 85 FD 90 02 E6 FE 60 A0
0620: 00 B1 FD C9 A0 B0 08 C9 80 B0 0F C9 20 90 0B 20
0630: EF FF C8 CA D0 EB 98 4C 15 06 A9 2E D0 F1 A9 0D
0640: 2C A9 20 4C EF FF 20 FA 05 B0 0F 20 5B 06 B0 0A
0650: 85 FE 20 5B 06 B0 03 85 FD 18 60 20 52 03 20 77
0660: 06 B0 13 2A 2A 2A 2A 29 F0 85 FB 20 52 03 20 77
0670: 06 B0 03 05 FB 18 60 A0 0F D9 B6 09 F0 05 88 10
0680: F8 38 60 98 18 60 BE 5C 09 A0 00 BD 00 09 F0 06
0690: 20 EF FF E8 D0 F5 18 60 0D 41 48 54 57 47 44 52
06A0: 59 77 5B 46 CB 83 B4 A3 05 03 05 05 05 05 04 05
06B0: 69 65 75 6D 7D 79 61 71 29 25 35 2D 3D 39 21 31
06C0: 0A 06 16 0E 1E 90 B0 F0 24 2C 30 D0 10 00 50 70
06D0: 18 D8 58 B8 C9 C5 D5 CD DD D9 C1 D1 E0 E4 EC C0
06E0: C4 CC C6 D6 CE DE CA 88 49 45 55 4D 5D 59 41 51
06F0: E6 F6 EE FE E8 C8 4C 6C 20 A9 A5 B5 AD BD B9 A1
0700: B1 A2 A6 B6 AE BE A0 A4 B4 AC BC 4A 46 56 4E 5E
0710: EA 09 05 15 0D 1D 19 01 11 48 08 68 28 2A 26 36
0720: 2E 3E 6A 66 76 6E 7E 4D 60 E9 E5 F5 ED FD F9 E1
0730: F1 38 F8 78 85 95 8D 9D 99 81 91 86 96 8E 84 94
0740: 8C AA A8 BA 8A 9A 98 03 03 03 03 03 03 03 03 06
0750: 06 06 06 06 06 06 06 09 09 09 09 09 0C 0F 12 15
0760: 15 18 1B 1E 21 24 27 2A 2D 30 33 36 36 36 36 36
0770: 36 36 36 39 39 39 3C 3C 3C 3F 3F 3F 3F 42 45 48
0780: 48 48 48 48 48 48 48 4B 4B 4B 4B 4E 51 54 54 57
0790: 5A 5A 5A 5A 5A 5A 5A 5D 5D 5D 5D 5D 60 60 60
07A0: 60 60 63 63 63 63 63 66 69 69 69 69 69 69 69 69
07B0: 6C 6F 72 75 78 78 78 78 78 7B 7B 7B 7B 7B 7E 81
07C0: 84 84 84 84 84 84 84 84 87 8A 8D 90 90 90 90 90
07D0: 90 90 93 93 93 96 96 96 99 9C 9F A2 A5 A8 01 02
07E0: 03 04 05 06 07 08 01 02 03 04 05 06 07 08 00 02
07F0: 03 04 05 09 09 09 02 04 09 09 09 00 09 09 00 00
0800: 00 00 01 02 03 04 05 06 07 08 01 02 04 01 02 04
0810: 02 03 04 05 00 00 01 02 03 04 05 06 07 08 02 03
0820: 04 05 00 00 04 0A 04 01 02 03 04 05 06 07 08 01
0830: 02 0B 04 06 01 02 03 04 05 00 02 03 04 05 00 01

0840: 02 03 04 05 06 07 08 00 00 00 00 00 02 03 04 05
0850: 00 02 03 04 05 00 00 01 02 03 04 05 06 07 08 00
0860: 00 00 02 03 04 05 06 07 08 02 0B 04 02 03 04 00
0870: 00 00 00 00 00 00 3F 3F 3F 41 41 43 41 4E 44 41 53
0880: 4C 42 43 43 43 42 43 53 42 45 51 42 49 54 42 4D 49
0890: 42 4E 45 42 50 4C 42 52 4B 42 56 43 42 56 53 43
08A0: 4C 43 43 4C 44 43 4C 49 43 4L 56 43 4D 50 43 50
08B0: 58 43 50 59 44 45 45 43 44 45 58 44 55 59 45 4F 52
08C0: 49 4E 43 49 4E 58 49 4E 59 4A 4D 50 4A 53 52 4C
08D0: 44 41 4C 44 58 4C 44 59 4L 53 52 4E 4F 50 4F 52
08E0: 41 50 48 41 50 48 41 50 4C 41 50 4C 41 50 4C 4C 4C
08F0: 52 4F 52 52 54 49 52 54 53 52 52 42 43 53 45 43 53
0900: 45 44 53 45 49 53 54 41 53 54 58 53 54 59 54 41
0910: 58 54 41 59 54 53 58 54 58 41 54 58 53 54 59 41
0920: 01 02 02 02 03 03 03 02 02 03 02 80 80 80 80 80
0930: 01 01 01 80 80 00 01 80 00 04 05 05 05 05 05 06
0940: 06 05 06 05 00 00 00 07 00 07 08 09 0A 00 0B 08
0950: 00 01 07 0C 13 1A 23 2C 35 13 3E 47 F1 C7 C6 DB
0960: CA CB CD D0 D8 D3 D7 D5 0D 20 23 24 30 30 0D 20
0970: 24 30 30 0D 20 24 30 30 2C 58 0D 20 24 30 30 30
0980: 30 0D 20 24 30 30 30 30 2C 58 0D 20 24 30 30 30
0990: 30 2C 59 0D 20 28 24 30 30 2C 58 29 0D 20 28 24
09A0: 30 30 29 2C 59 0D 20 28 24 30 30 30 30 29 0D 20
09B0: 24 30 30 2C 59 0D 30 31 32 33 34 35 36 37 38 39
09C0: 41 42 43 44 45 46 3F 0D 2E 00 23 24 00 28 24 00
09D0: 2C 58 00 2C 58 29 00 29 2C 59 00 41 43 20 58 52
09E0: 20 59 52 20 53 50 20 4E 56 2D 42 44 49 5A 43 0D
09F0: 00 0D 43 27 4D 4F 4E 20 41 50 50 4C 45 0D 2E 00

300R
```