

# Garrett's Workshop

## GW4203B "RAM2E II"

RAM Expansion Card for Apple IIe

### User's Guide

## Overview

RAM2E II (GW4203B) provides the Apple IIe with 8 MB of auxiliary memory and enables double-high-resolution graphics and 80-column text display modes.

### Low-Power, SDRAM-Based Design

Thanks to a modern, low-power design, RAM2E II uses only 0.2 watts (40 mA @ 5V) in typical use and 0.4 watts (80 mA @ 5V) in heavy use with an accelerator<sup>1</sup>. In contrast, a typical 80-column card consumes over 1 watt of power, and a 1 MB RAMWorks III consumes 2 watts or more. Unlike other IIe auxiliary memory cards, which are built with vintage asynchronous DRAM chips, RAM2E II uses modern SDRAM. This design allows for low power consumption and improved reliability over other memory cards using 15+ year old chips.

### Small Size, Low-Profile

RAM2E II features a small board outline and is the thinnest Apple IIe auxiliary memory card ever produced, at under 4mm thin. Small and thin dimensions improve the mechanical compatibility between RAM2E II and peripheral cards installed into the IIe's Slot 1.

### Adjustable Capacity, Highly Compatible

RAM2E II is highly compatible with existing software that utilizes RAMWorks memory standard. An adjustable capacity feature allows the memory size to be set to 64 kB, 512 kB, 1 MB, 4 MB, or 8 MB, improving compatibility with software expecting a particular memory capacity. Capacity settings can be set temporarily or saved in nonvolatile memory. The capacity adjustment utility is available on our website, <http://garrettsworkshop.com>.

### Ecologically Friendly, Gold-Plated PCB

RAM2E II is built with a lead-free, ENIG gold-plated, 4-layer PCB and is fully EU RoHS-compliant. All units are tested extensively before shipment, and only new parts are used to build RAM2E II.

### Open-Source Design

RAM2E II's design is fully open-source. The schematics, board layouts, CPLD firmware, and utility software are all freely available for commercial and noncommercial use. To download the design files, visit the Garrett's Workshop GitHub page, <https://github.com/garrettsworkshop>.

### Note for Revision A Apple IIe Owners

If you own the uncommon revision A Apple IIe and are interested in RAM2E II, please read this! RAM2E II requires a small modification to be compatible with the with the rev. A Apple IIe. The modification consists of removal of the "DHGR" jumper resistor or cutting the associated jumper trace.

Revision A machines can be identified by their part number "820-0064-A" printed at the top of the motherboard near the slots. If you have a rev. A Apple IIe, please contact us before purchasing and we can make the modification before shipping your RAM2E unit. However, do note that with the modification made, RAM2E II will not support the double-high-resolution graphics display mode.

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<sup>1</sup> Maximum power consumption measured with quadruple-unrolled auxiliary RAM read/write loop running on FastCHIP IIe accelerator at 16.6 MHz.

## Installation

RAM2E II must be installed into the Apple IIe auxiliary slot. Do not install the card into one of the seven expansion card slots. Also ensure that RAM2E II is inserted in the correct orientation. Markings on the card indicate the side which must face towards the power supply of the Apple IIe.

## Changing RAM Capacity

In order to maximize compatibility, the memory capacity of RAM2E II can be changed to 64 kilobytes, 512 kilobytes, 1 megabyte, 4 megabytes, or 8 megabytes. The capacity can be set either temporarily until the Apple IIe is powered off, or in nonvolatile memory where the setting will persist.

Capacity adjustment is accomplished using the “GWRAM” utility program available for download from our website, at <http://garrettsworkshop.com/files/GWRAM/GWRAM.po>. The program is packaged as a 140 kB .po format disk image containing the GWRAM utility and ProDOS 2.4.2.

After launching GWRAM on an Apple IIe with a RAM2E II card, the following menu is shown:

```
-- RAM2E Capacity Settings --
Current RAM2E capacity: 512 kB
Select desired memory capacity:
  1. 64 kilobytes
  2. 512 kilobytes
  3. 1 megabyte
  4. 4 megabytes
  5. 8 megabytes

Capacity will be saved until power-off.
To remember capacity setting in
nonvolatile memory, press Apple+number.
Press [Q] to quit
```

For example, by pressing the “1” key, the capacity can be set to 64 kilobytes until the computer is powered off. By pressing Apple+1 (open-Apple or closed-Apple), the 64 kilobyte capacity setting can be saved in nonvolatile memory as well, so that it is restored on power-up.

## Technical Specifications

### Physical Dimensions

| Parameter | Value                  |
|-----------|------------------------|
| Height    | 50.038 mm $\pm$ 0.2 mm |
| Width     | 78.232 mm $\pm$ 0.2 mm |
| Thickness | < 4 mm                 |
| Weight    | < 28 g                 |

### Electrical Specifications

Specifications are valid over temperature range of 0 °C – 85 °C and  $V_{CC} = 4.5\text{ V} - 5.5\text{ V}$ .

| Parameter        | Value                 | Conditions                           |
|------------------|-----------------------|--------------------------------------|
| $V_{IHmin}$      | 2.0 V                 |                                      |
| $V_{ILmax}$      | 0.8 V                 |                                      |
| $V_{OHmin}$      | 3.8 V                 | $I_{OH} = -8\text{ mA}$              |
| $V_{OLmax}$      | 0.5 V                 | $I_{OL} = 8\text{ mA}$               |
| Output Slew Rate | < 1.5 V/ns            |                                      |
| $I_{Imax}$       | $\pm 20\ \mu\text{A}$ | $V_{in} = 0\text{ V} - 5.5\text{ V}$ |
| $C_{IOmax}$      | 20 pF                 | data bus MD[7:0]                     |
|                  | 10 pF                 | all other signals                    |
| $I_{CCmax}$      | 120 mA                |                                      |

## Theory of Operation

The operation of RAM2E II is somewhat different from that of other expansion RAM cards for the Apple IIe. While other cards are implemented with asynchronous DRAM chips, RAM2E II uses modern synchronous DRAM (SDRAM).

Since the IIe's memory expansion slot was designed for use with asynchronous DRAM, additional circuitry on the RAM2E II card is required to interface the IIe with SDRAM. There are numerous differences between asynchronous DRAM and SDRAM, but the most significant is that in SDRAM, operation is pipelined over multiple clock cycles. Although SDRAM is a much newer technology than asynchronous DRAM, and therefore much faster, multiple clock cycle "steps" are required to perform an SDRAM access.

RAM2E II's logic circuitry is implemented in a single CPLD which runs from the Apple IIe's C14M 14.31818 MHz master clock signal. A buffered copy of this clock is supplied to both the RAM2E II's CPLD and its SDRAM. Running from the Apple's master clock, the RAM2E II translates auxiliary memory and 80-column video access commands issued by the Apple II into SDRAM commands which implement the same functionality.

The RAM2E II state machine runs from the C14M master clock of the Apple IIe. A 4-bit state counter is reset to 0x1 at the beginning of each PHI1 period and counts up to 0xE in a 14-clock cycle. In the last two clocks of a 16-clock "long cycle," the state counter is equal to 0xF. State 0x0 is only used during initialization.

To implement the auxiliary memory card functionality, SDRAM read/write commands are issued based on the current state index, the /WE80 signal, and the /EN80 signal. Unlike a traditional auxiliary RAM card, the /RAS and Q3 signals are not used for SDRAM control at all. The SDRAM command and address signals are implemented as registered outputs.

The data bus, as input to the RAM2E II and output to the SDRAM, is implemented as an asynchronous tristate buffer, and the data bus output is implemented as a registered output latched at the falling edge in the middle of state 0xC. Similarly, the video data bus output is registered at the falling edge of state 0x6. Both the video and 6502 data buses are output using 74AHCT-series buffers running at 5V. 74AHCT was chosen for its low power consumption, fast propagation delay, and slow output edge rate. Moreover, the 74AHCT-series outputs are desirable for their 3.8 V Voh specification at 8 mA of source current and 4.5V Vcc. This allows RAM2E II to meet the Vih specification of newer 65C02 processors with "pure CMOS" input buffers.

RAM2E II also supports a proprietary command set which allows software to adjust the RAM capacity and access other features. For more information on this command set, see the RAM2E and GWRAM utility program source code on the Garrett's Workshop GitHub page, at <http://github.com/garrettworkshop>.

## Timing Diagram

The timing diagram given below shows the behavior of the major signals in the system, including the SDRAM command sequence used when reading and writing auxiliary RAM.

### Video Access

### 6502 CPU Access

