Troubleshooting Random Access Memory Hard Errors

David Hua, Edward J. Lazaros, Andrew Mattingly, David Van Milligan, Cameron Davidson

Ball State University

dhua@bsu.edu, ejlazaros@bsu.edu, apmattingly@bsu.edu, dqvanmilliga@bsu.edu, cjdavidson@bsugmail.net

Abstract

This manuscript discusses some of the history of Random Access Memory (RAM) and some of the evolutionary steps that occurred as the technology developed. In addition to the history of RAM, how it is incorporated in the modern computer, as well as the function that it serves are topics discussed in this manuscript. The relationship between RAM, the Central Processing Unit (CPU), and computer performance will be presented at length. Types of RAM that are available in today's market are discussed as well as some potential developments for the future. Hard errors caused by hardware failure can render a computer inoperable. An activity allowing students to troubleshoot RAM modules will be presented.

An Introduction to Random Access Memory

To make an analogy, a physical working area is similar to a computer. The hard drive is the filing cabinet where documents are stored, and RAM is the desk where the work occurs (Gulens, 2012). When the working area is full, it won't hold all of the work. It is slower to find things and it becomes more difficult in general. This is a similar thing that happens when operating with smaller than required RAM. The hard drive on a computer stores the operating system, applications, and data that users require. The CPU, however, is unable to directly access any of this information from the hard drive. In order for the CPU to access any information, it must first be loaded into RAM. That means that RAM has to hold the operating system, applications that are currently running and the corresponding user files in order to get anything done. When the RAM on a computer starts to reach its capacity, the computer will commandeer a portion of the hard drive and use it as if it were RAM. When the hard drive is used for RAM storage it is referred to as virtual memory. While this increases the amount of "workspace" available to the computer, virtual memory is significantly slower than actual RAM modules. Virtual memory is used while large programs are running, such as games, video editing, streaming videos, or photo editing (Gulens, 2012). Virtual memory can also be used in large portions when two or more programs are open and operating at once (Allbritton, 2002). The rate at which physical RAM modules transfer data to the CPU is significantly faster than the virtual memory space on hard drives. It is this difference in transfer rates that prompted the recommendation that adding RAM to a computer is the cheapest and easiest way to speed up a computer. It is not that the existing hardware is operating any faster with the additional RAM. The resulting performance boost is a result of the CPU no longer having to access the slower virtual memory.

CPU speed appears to be an easy number to advertise to consumers, but the dirty secret is that CPU speed does not matter much anymore, it's all about RAM (Allbritton, 2002). To illustrate

this point, computers back in the early nineteen nineties were shipped with 16-MHz CPUs. Today, they operate at 2.4 GHz, which is roughly one hundred and fifty times faster, but one will notice that they are not one hundred and fifty times more powerful. While CPU speed is a factor, RAM is essential to today's computer speed (Allbritton, 2002; Smith, 2010). RAM is the computer's main memory. There are two distinct types of RAM that serve different purposes and have different requirements they are: Static RAM (SRAM) and Dynamic RAM (DRAM) (Schmidt, 2013).

SRAM chips store only a single binary digit, or bit, in each of their memory cells (Tyson & Couston, 2000). Each cell has transistors that act as an on/off switch. When the switch is on, electricity constantly flows through the cell indicating a binary digit of 1. When the switch is off, the electricity stops and the computer registers that cell as a binary digit of 0. The advantage of this architecture is that it is very fast. It would seem that if SRAM is so fast, it should be the de facto architecture for all RAM. One of the limitations of SRAM is that it requires relatively more hardware components when compared to DRAM. Because of this, the amount of physical space required to provide the same amount of storage capacity that is capable with DRAM would be prohibitively large. The second issue is that constant flow of electricity required for each cell in memory that is representing a binary value of 1. This increase in power consumption would make SRAM a less sustainable and more expensive option than DRAM. SRAM is typically used in computer design as cache memory that holds the data most frequently accessed by the CPU (Schmidt, 2013).

A DRAM chip requires the charge on the individual cells to be refreshed periodically to retain the data. DRAM also requires less space than SRAM since it has fewer components. The result is a higher storage density that allows DRAM modules to store more data and be less expensive than SRAM. DRAM is also a more sustainable alternative since it consumes less electricity. What DRAM gains in memory, it loses in speed (Soper, Mueller, & Prowse, 2010). Both of these are used in computers today, with the SRAM used to help the CPU's speed while the DRAM forms the larger system RAM space (Tyson & Couston, 2000), DRAM is the most common.

Chips for RAM are only available as a piece of a card called a module (Tyson & Couston, 2000). These modules have their memory listed by two numbers. The first number is the amount of chips on the module and the second number is the amount of capacity for each individual chip measured in megabits (one million bits). Expressed in common numerical form, it looks like this: 8x32. With this example, there are eight chips on the module and each of the chips capacity is thirty two megabits. To get the total power, you multiply the two numbers together. For this example, we get a total of 256 megabits. RAM is traditionally measured in bytes. A simple conversion (1 byte = 8 bits) leads us to the conclusion that our example module is 32 megabytes. Trading up from a 4x32 module to a 8x32 module will cause a jump from 16 megabytes to double that at 32 megabytes. Increasing the amount of RAM typically improves the overall speed of computer by reducing the need to access slower virtual RAM on the hard drive.   RAM now is available in a variety of sizes ranging from 2-GB to 8-GB modules. As stated earlier, RAM is measured in bytes; 1 gigabyte (GB) is equivalent to 1,024 megabytes (MB) which is equivalent to 1,048,576 kilobytes (KB) (Gulens, 2012).

Once the form factor of RAM was standardized, there has been a race to fit increasing amounts of memory in each RAM module (Smith, 2010). For the near future, it appears that improvements to the current system of RAM will follow the smaller and more mantra. Some of the possible new avenues for RAM include: RAM memory that will not be erased with inconsistent power, using magnetic plastics, quantum dots, and carbon nanotubes (Smith, 2010).

Purpose of Activity
The purpose of this activity is to educate students about the functionality and role RAM plays in a computer and engage them in problem solving and troubleshooting techniques. Students will identify RAM, determine if it is functioning properly, and learn how to replace it safely. Students will discover how to interpret the beep patterns emitted by a computer that is registering a hardware component failure.

Students pursuing a career in information technology are likely to begin their careers as computer repair technicians. As with any computer hardware component, RAM modules are subject to errors and failures. Errors in RAM can have a significant impact on computer reliability. Memory errors due to RAM can result in a range of errors from software failure (Murphy, 2004) to an overall system failure (Tang, Carruthers, Totari, & Shapiro, 2006). The source of these errors can be hard errors caused by physical failure requiring replacement of the RAM modules. They can also be caused by soft errors which are transient errors resulting from a temporary anomaly (Messer et al., 2004). Aspiring IT professionals need to be able to diagnose and fix these types of errors. The transient nature of soft errors makes it difficult to troubleshoot and repair them. The process of doing so is beyond the scope of this activity.

Hard errors are relatively straightforward. They are the result of a hardware failure that prevents the CPU from being able to communicate with the memory cells contained in RAM modules. Symptoms of hard errors typically manifest in two outcomes. It is not uncommon for RAM modules to fail intermittently before complete hardware failure. The hard errors created by this condition typically cause the computer to stop functioning and display a blue screen containing cryptic error messages and hexadecimal string. This is typically referred to as the "blue screen of death".

Activity Learning Objectives
Upon completion of the activity:
1. The student will be able to identify what a RAM module is and how to determine its specifications accurately.
2. The student will be able to locate, remove, and replace RAM modules in a desktop computer.
3. The student will be able to determine which RAM module in a bank of memory is not functional.

Key Definitions
BIOS: The BIOS is a low-level coding embedded on a computer's motherboard. The BIOS is responsible for managing the input and output of data between

	hardware components. Errors in these communications between components cause the BIOS to issue a beep pattern at startup indicating a hardware error.
CPU:	The central processing unit (CPU) is commonly referred to as the "brains" of the computer. The CPU executes commands required by the operating system and applications.
RAM:	Temporary storage where a computer's CPU retrieves data to be processed. Contents of RAM are lost when power is interrupted or the computer is turned off.
RAM Module:	This is the physical component in which RAM resides (See Figure 5). RAM modules can be purchased in a variety of form factors, capacities, and speeds based
Hard Error:	This is an error caused by a hardware failure that prevents the CPU from being able to communicate with the RAM module's memory cells.

Materials
- Desktop computer
- One Non-functional RAM module
- Screwdriver
- Anti-static wrist guard
- Anti-static bag

Procedure

Prior to the activity, the instructor should place one non-functioning RAM module into a randomly determined RAM slot in a working desktop computer. The remaining RAM slot(s) should contain functional RAM modules. The activity should begin with the computer turned off.

1 The student should turn on the computer. This should result in a series of beeps as the computer tries to read the non-functioning RAM module.
2 The student should document the beep pattern and power off the computer.
3 To determine what the beep pattern signifies, the student will need to determine the version of the BIOS being used by the computer. The student should turn the computer back on. As the computer tries to boot up, it will present the name of the BIOS manufacturer (See Figure 1).
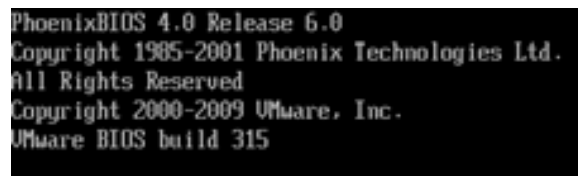

Figure 1

4 The student should conduct an Internet search of the BIOS manufacturer's beep codes. For example, if the student saw the screen output seen in Figure 1, the student would enter "Phoenix BIOS beep codes" into an Internet search engine.

5   Once the student has found the BIOS manufacturer's beep codes, the student should find the documented beep pattern that was heard and determine its significance.

6   The student should have found that the beep pattern indicated a RAM failure. It should be noted to the student at this time that non-functioning RAM modules will always cause system beeps at startup.

7   Replacing or removing the non-functioning RAM module is the only solution to the problem. The task is to determine which of the RAM modules is non-functioning.

8   The students will ground themselves to avoid electrostatic shock damaging computer components by putting on the grounding strap provided. The clip should then be attached to a metallic portion of the computer case (See Figure 2).

Figure 2

9   The student should open the computer to expose the interior of the computer. How this is accomplished is dependent on the case design. Typically, a cover panel can be removed by latches or screws located on the back of the computer case (See Figure 3).

Figure 3

10 The students will locate the RAM card slots on the computer motherboard.

11 The student should remove the first RAM module by pressing down on the tabs holding the RAM module. This should cause the RAM module to lift partially out of the RAM slot (See Figure 4).
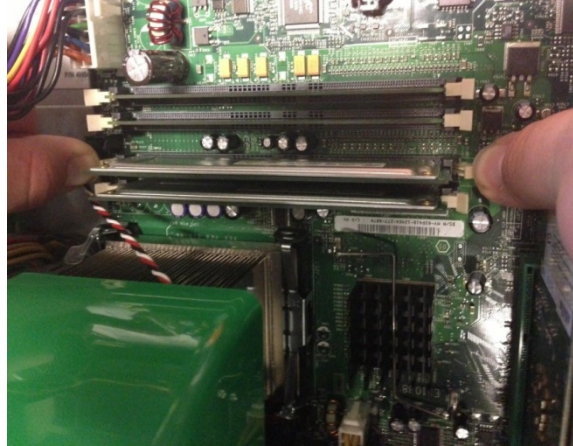

Figure 4

12 The students remove the RAM module and document the type, speed, and capacity of the RAM module on the Activity Sheet. The type of RAM will be DDR, DDR2, or DDR3. The speed of the RAM module will be list in MHz or by a name. The name would begin with the letters "PC" followed by a 4-6 digit number. The number indicates the speed of the RAM module. For example, PC5300 RAM modules operate at 667 MHz. The capacity is typically presented in GB. This information is typically printed on the RAM module as seen in Figure 5.

Figure 5

13 The student should then place the RAM module in an anti-static bag (See Figure 6). This is done to ensure that static electricity does not cause damage to the RAM module.

Figure 6

14 The student should turn the computer on. If the beep pattern still occurs, the non-
    functioning RAM module is still installed in the computer and the one in the bag is a
    functional RAM module.
15 The student should turn off the computer.
16 The student should reinstall RAM module from the anti-static bag. It should be noted to
    the student that when installing RAM, the notch in the RAM module should line up with
    the corresponding spot in the RAM slot. If there is resistance when trying to install the
    RAM module into the slot, the module probably needs to be turned around. Excessive
    force when trying to install any computer component can result in damage to the device.
17 The student should place the RAM module in the RAM slot and press down firmly and
    evenly on both sides of the module until the holding tabs lock.
18 The student should repeat the process of removing the remaining RAM modules
    individually and documenting them on the Activity Sheet. The student will have found
    the non-functioning RAM module when the computer boots into the operating system
    without any beeps.

Conclusion
While the CPU dictates what can be done on a computer, it has been shown that RAM allows the
CPU to do its job. RAM provides the workspace from which the CPU draws its instructions and
data. It was shown how increasing RAM provides a larger workspace for the CPU, resulting in
faster processing. This manuscript discussed some of the history and evolution of RAM. From
DIP chips to DRAM, RAM has performed the same function. The continued micronization of
RAM components will allow manufacturers to produce RAM modules with increasing storage
capacities. Due to its vital role to the computer, problems that can arise from RAM failures or
errors were discussed. In response to these problems, an activity was presented that provides
students with hands-on experiences with troubleshooting and replacing RAM modules in a
computer.

References
Allbritton, C. (2002, June 1). RAM Is More Important Than Chip Speed. *Popular Mechanics*.
        Retrieved from http://www.popularmechanics.com/technology/how-to/build-pc/1278856

Gulens, M. (2012). How to get more RAM: Add more memory to your computer. Retrieved from http://www.microsoft.com/athome/setup/addmemory.aspx#fbid=6ZJxIgvgXbA

Messer, A., Bernadat, P., Fu, G., Chen, D., Dimitrijevic, Z., Lie, D., Milojicic, D. (2004). Susceptibility of Commodity Systems and Software to Memory Soft Errors. *IEEE Trans. Comput.*, *53*(12), 1557–1568. doi:10.1109/TC.2004.119

Murphy, B. (2004). Automating Software Failure Reporting. *Queue*, *2*(8), 42–48. doi:10.1145/1036474.1036498

Schmidt, C. A. (2013). *Complete CompTIA A+ guide to PCs*. Indianapolis, Indiana: Pearson.

Smith, M. S. (2010, January 22). The Development of RAM Technology. *Bright Hub*. Retrieved May 13, 2013, from http://www.brighthub.com/computing/hardware/articles/60758.aspx

Soper, M. E., Mueller, S., & Prowse, D. L. (2010). *CompTIA A+ cert guide*. Indianapolis, Ind.: Pearson.

Tang, D., Carruthers, P., Totari, Z., & Shapiro, M. W. (2006). Assessment of the Effect of Memory Page Retirement on System RAS Against Hardware Faults. In *International Conference on Dependable Systems and Networks, 2006. DSN 2006* (pp. 365–370). Presented at the International Conference on Dependable Systems and Networks, 2006. DSN 2006. doi:10.1109/DSN.2006.13

Tyson, J., & Couston, D. (2000, August 25). HowStuffWorks "Static RAM." *HowStuffWorks*. Retrieved from http://computer.howstuffworks.com/ram.htm

Name: _____

Score: _____

Activity Sheet

RAM Module #	Type of RAM	Speed of RAM	Capacity of RAM	Did it function properly?
#1				
#2				
#3 (if applicable)				
#4 (if applicable)				