

THE APPLICATION OF A BUBBLE MEMORY TO A BALLOON-BORNE DATA SYSTEM

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ABSTRACT

This paper describes an eight megabit bubble memory used as a mass memory storage device on a high altitude helium filled balloon flight package. The balloon flight designated as Gamma Ray VI, a coordinated effort of Sandia National Laboratories and Bell Laboratories, was conducted in the fall of 1981 at Alice Springs, Australia. Eight one-megabit Intel bubble modules were mounted on a custom designed multilayer printed wire board to maximize the memory in the available space. A microprocessor based data interface was designed to test and control the bubble memory.

The selection of bubble memory modules for this application, the design considerations of the bubble printed wire board and the microprocessor interface are discussed. The flight test and results of Gamma Ray VI are described. Future developments and applications are briefly presented.

INTRODUCTION

Sandia National Laboratories in cooperation with Bell Telephone Laboratories has developed a special telescope for research in gamma-ray astronomy. Still in its infancy, gamma-ray astronomy may give us new insights into the origins of elements, the dynamics of galaxies, and the structure of neutron stars (1,2,3,4,5). The heart of the telescope is a single-crystal germanium diode (the largest of its kind) cryogenically cooled 67 mm diameter detector. The complete experimental system includes; a mechanism for pointing the detector, the telemetry package for two way data transmission, a cryogenic system for cooling the germanium crystal, a fast anticoincidence electronic package, a data handling electronic package, and a system of launching and recovering the balloon. The telescope and supportive electronics are built on a special platform which weighs 750 kg and is lifted to an altitude of approximately 40 km by a large helium balloon. The capricious upper winds determine the duration of flight which ranges from 10 to over 60 hours and the balloon may float up to 640 km from the launch point. The flight package is under computer control at all times. It controls the pointing of the telescope toward the selected

target, the data collection mode and the transmission of data to the ground station. A special onboard memory is used to collect data in a statistical data format of counts versus energy. This data is transmitted to the ground station every 20 minutes and is added to the data base for a given target. The system requires constant control and monitoring which limits its efficiency and the flight duration. An onboard pointing controller and a large mass memory will reduce the direct control time now required. Two microprocessor based pointing and data systems, and a large mass memory (greater than one megabyte) are being developed to increase the flight time of each balloon launch.

MEMORY SELECTION

Requirements for the mass memory are tabulated below:

- Larger than one megabyte
- Low average power
- High density
- Nonvolatile
- Operating temperature range- -20 C to 70 C
- shock- 30 G's
- Vibration- 1 G
- Access time- less than 100ms
- Soft errors- 1 in 10^{*6}
- Life- greater than 1000 hours
- Altitude- Sea level to 40 km
- Transfer Rate- greater than 50 k bits per second

The following memory elements were considered:

- Discs - Hard and floppy
- Magnetic tape
- Solid state devices - Dynamic and static random access memories (RAM), and bubble memories

Magnetic tape, hard and floppy disc drives are mechanical devices which use more power and are considered to be less reliable than solid state memories, especially in a cold environment. Bubble memory modules require more support circuits than dynamic and static RAMs but they are more dense than RAMs when used in large memories. A printed wire board will hold eight bubble modules for a total of one megabyte of memory in an area of 600 square centimeters. A pseudo-nonvolatile memory built with 16 k static RAMs and a battery keep-alive circuit would have a capacity of 100 k bytes for the same board area. A memory using 64 k RAMs of the same package size would have a capacity of only 400 k bytes. Therefore, bubble memories were chosen as the mass memory element.

These bubble manufacturers were considered:

Intel	one megabit module
Fujitsu	256 k bit module
National - Motorola	Not in production
Rockwell	Out of commercial bubble business
Texas Instruments	out of bubble business
Western Electric	128 k bit module

The Intel bubble module was selected as the only one megabit module that was in production and had the best support circuitry. The Intel bubble controller (7220) provides automatic error correction, transparent handling of redundant loops, direct memory access and power fail protection. At the time there were no commercial board-level bubble memories with greater than one megabit of capacity. We decided to buy bubble modules, support circuits and layout a new printed wire board to fit the existing electronic chassis.

THE INTEL BUBBLE MODULE

The Intel bubble module (7110) is a dense one megabit nonvolatile, solid state memory. The gross capacity is 1,310,720 bits of which 1,048,576 bits are usable. Logically, the data is organized as a 512 bit page with 2048 total pages. Internally the 7110 module has a major track-minor loop organization with 320 loops of 4096 bits per loop. A minimum of 272 good loops are required for operation with error correction. The remaining 48 loops are available as redundant loops to improve the chip yield in production. An internal boot loop contains information on the location of good/bad loops.

THE BUBBLE MEMORY

The bubble memory was designed to operate part-time in parallel with the regular data system to evaluate its performance for future balloon flights. The bubble memory as used on the gamma ray telescope consists of three major subsystems: the bubble memory microprocessor, the bubble memory board, and microprocessor interface. A block diagram of the memory is shown in Figure 1. Each subsystem will now be discussed in greater detail.

Bubble Memory Microprocessor

The bubble memory module controller's command input looks like a medium-speed access RAM but it requires several commands to initialize its internal control registers for a data transfer cycle. A microprocessor with conditional status feedback is the best device to set up the control registers. The microprocessor subsystem consists of a Motorola 6809

microprocessor, a 4-k static RAM, an 8-k electrically programmable read only memory (EPROM), two peripheral interface adapters (PIA's), one asynchronous communication interface (ACIA), a direct memory access controller (DMAC), and a bus interface port. The block diagram is shown in Figure 2. The programs in the microprocessor interact with commands sent from the ground based computer while the microprocessor sends status information to the PCM encoder for transmission to the ground computer. The microprocessor has two main programs; a set of diagnostic routines and a set of operating routines. A listing of the software commands is shown in Table 1. The diagnostic routines are used in testing the system. In the normal operating mode, the microprocessor interface acts as an input/output data buffer. The data rate from the pulse height analyzer (PHA) varies from several times a second to several hundred a second so two 1024 byte buffers are used to accumulate data. After one of the buffers has filled, its contents are transmitted to the bubble controller. Reading the bubble memory also uses the buffers. The direct memory access (DMA) transfer technique is used to move data to and from the bubble memory controller in the fastest possible mode. A teletype terminal connected to the ACIA port is used in the diagnostic mode to command the selected routines and print the error messages.

The Microprocessor Interface

The PHA, the spectral memory and the PCM encoder uses 16-bit wide buses while the bubble memory microprocessor has an eight-bit wide bus so a 2-1 data multiplexer under the control of the microprocessor is used to pack and unpack the data bytes. A 16-bit one millisecond counter in the interface is used to time tag the individual events (an event is a gamma ray striking the detector) so as to increase the event timing accuracy. These four bytes (two address and two time bytes) of data are stored in the microprocessor's buffers and later in the bubble memory in sequential order.

BUBBLE MODULE BOARD

The bubble module printed wire board has one bubble memory controller and eight bubble modules, each with its supporting custom IC's. A picture of the bubble memory board is shown in Figure 3. Each memory module has 128 k bytes of memory so the eight modules have a maximum capacity of one megabyte. The printed wire board has four layers to permit the maximum module density and to provide room for the special conductor layout. The bubble module sense lands must be guarded and spaced at least one cm from all other lands especially if they are on other layers. The layout of the ground returns for all IC's must be considered carefully to reduce ground loops and all power source lands must be decoupled as close to the IC's as possible. The eight bubble modules are operated in a multiplexed, one at a time, mode for an average data transfer rate of 68 k bits per second

which provides minimum power dissipation (both standby and data transfer). This mode also limits the data lost in case of a module failure.

GENERAL CIRCUIT OPERATION

A gamma ray striking the crystal detector generates a small electrical signal which is amplified before it is applied to the pulse height analyzer. The output from the analyzer is a 13-bit digital address word which increments the selected RAM location in an 8 k bit spectral memory system. In turn the memory system produces a 16-bit data word. The address word, the data word, and a 16-bit time word are continuously transmitted via a telemetry link to a ground station. During the bubble-memory data-recording mode only the address word and the time word are stored in the bubble modules. After a selected time interval, the data in the bubble memory is transmitted to the ground station on the telemetry link.

THE GAMMA RAY VI BALLOON FLIGHT

During the fall of 1981, the gamma ray telescope and all support equipment were shipped to Alice Springs, Australia for a flight to gather scientific data. On the morning of November 21, the balloon lifted the gamma ray telescope into the air for a 25-hour flight. Sixteen hours into the flight, the bubble memory was turned on and operated for three hours. During this time, several hours of data were stored in the bubble memory and then transmitted to the ground station. Status data transmitted with the real time data permitted the ground station personnel to monitor the operation of the bubble memory. Problems with the printed wire board layout prevented the operation of all eight bubble modules so only 256 k bytes of memory (two bubble modules) were fully operational. All test objectives were met. About 22 hours into the flight, when the bubble memory housing had cooled to -2.8 degrees C, the bubble memory was turned on and exercised successfully.

FUTURE DEVELOPMENTS AND APPLICATIONS

A complete redesign of the bubble memory printed wire board corrected all of the problems of the old board. A fully checked out one megabyte of bubble memory is now operating on a single printed wire board. Future gamma ray balloon flights will use multiple bubble memory boards for a full six megabytes of memory. The fully developed bubble memory boards will also be used on a Seafloor Earthquake Measuring System that Sandia is developing for the U.S. Geological Survey and five major oil companies (6). Bubble memories are being considered for small, low power, stored data systems applied to underground studies and long term (one year) system monitoring.

CONCLUSIONS

Bubble memories are very effective and reliable for use on applications in hostile environments. They are very dense and therefore useful in large, medium-speed access, memories. As bubble memory module power requirements and costs continue to drop, they will be used in many more applications.

ACKNOWLEDGMENT

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Table 1

SOFTWARE COMMAND MODES

DIAGNOSTIC MODE:

1. RAM check
2. Terminal check
3. Bubble memory dummy module
4. Bubble memory PIA
5. Bubble memory DMA
6. Bubble memory seed regeneration
7. Bubble write boot loop

OPERATIONAL MODE:

1. Standby
2. Bubble module readout
3. Bubble module write
4. Bubble module clear
5. Bubble module write check pattern
6. Bubble module selected initialization

BUBBLE MEMORY COMMANDS:

1. Initialize
2. Abort
3. Purge
4. Read bubble module
5. Write bubble module
6. Read boot loop
7. Write boot loop

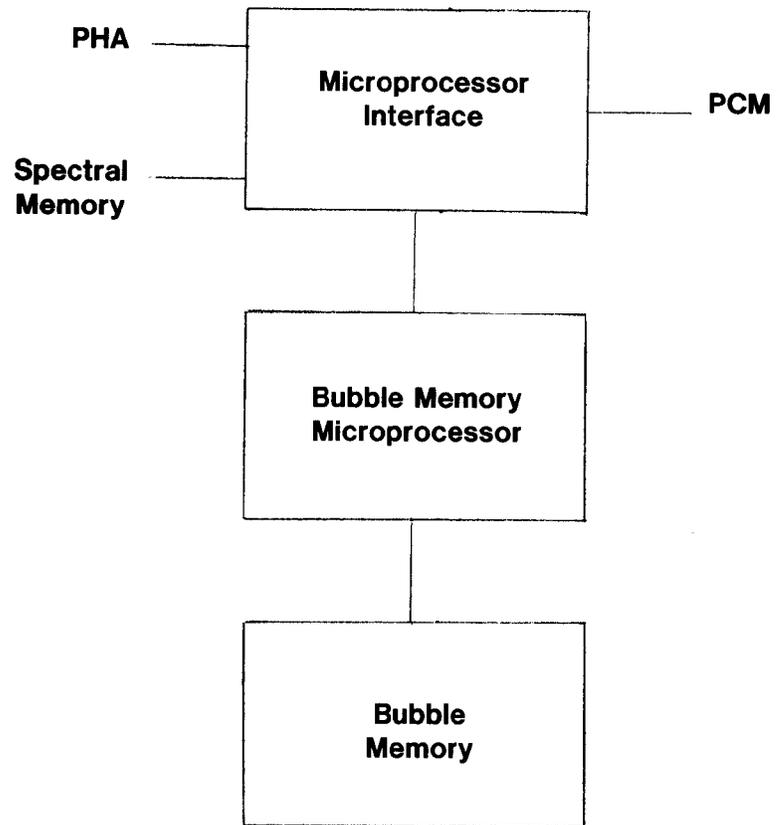


Figure 1. Bubble Memory Block Diagram

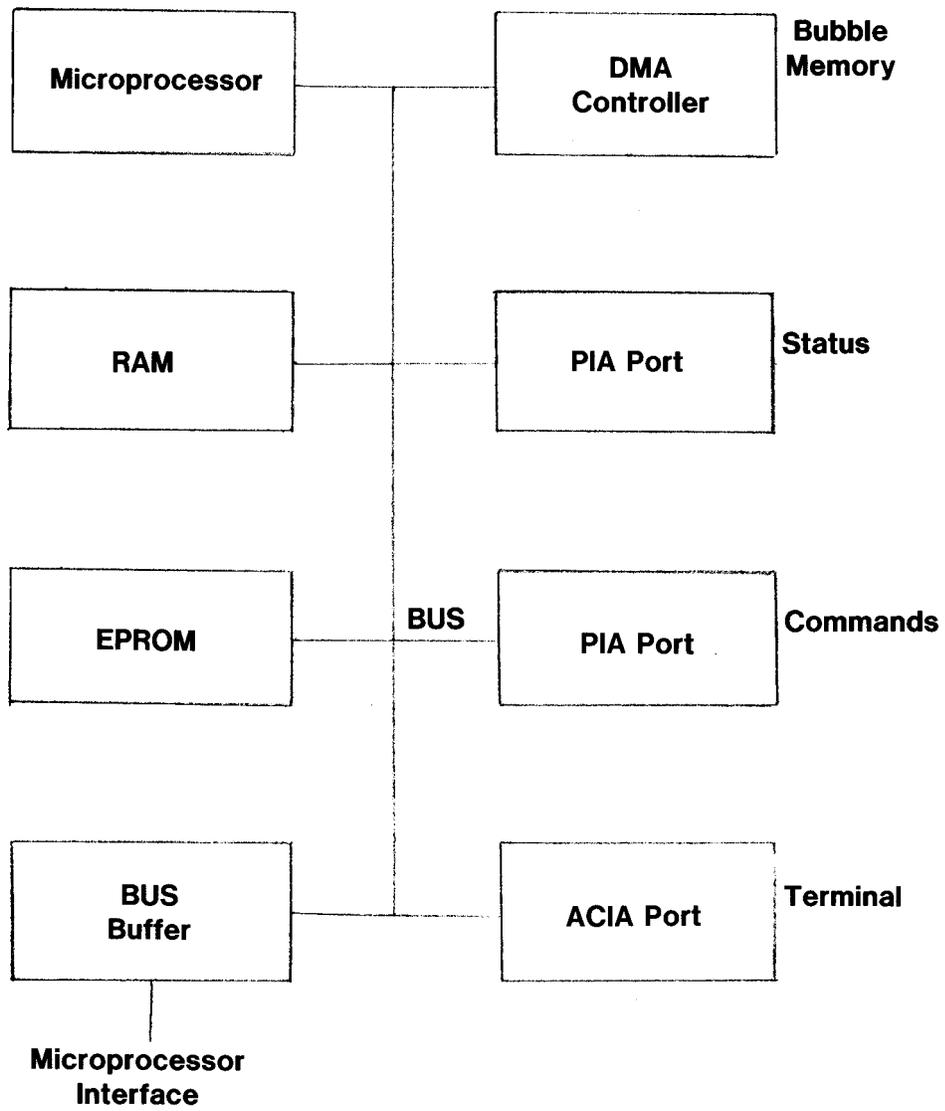


Figure 2. Bubble Memory Microprocessor Block Diagram

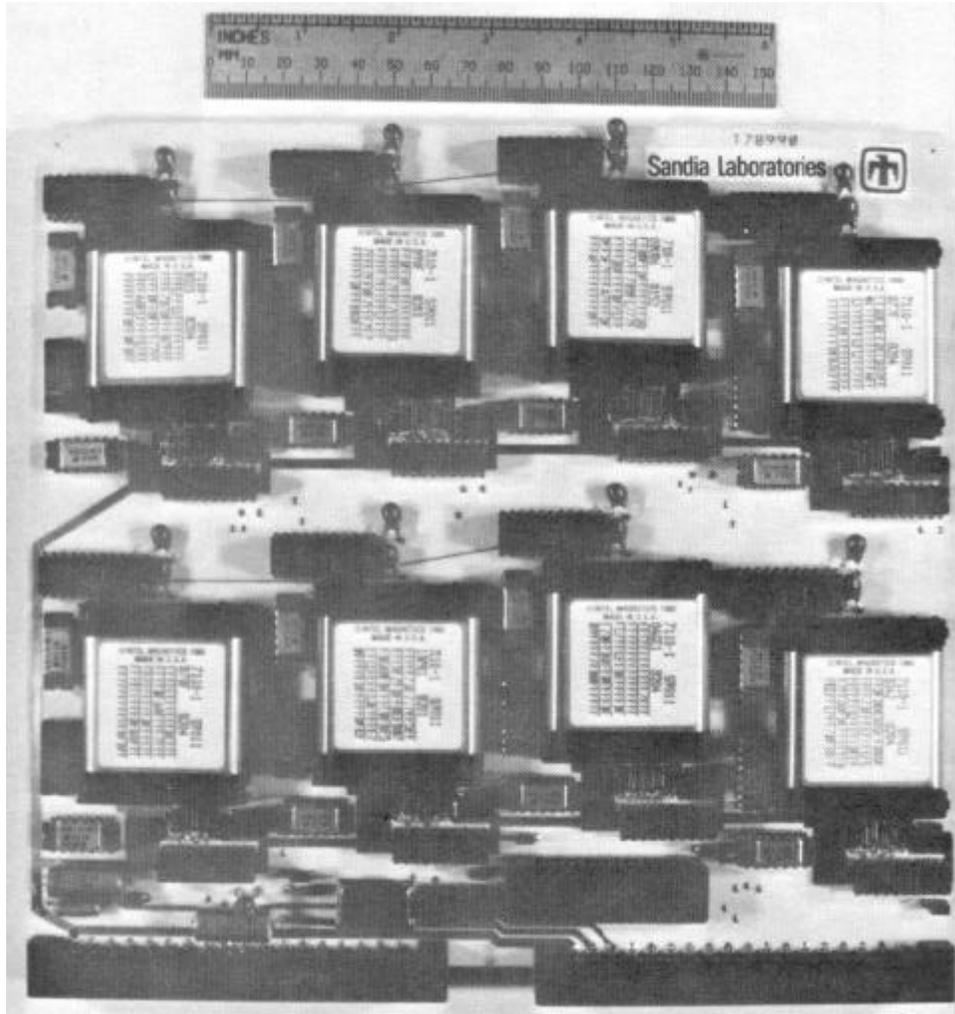


Figure 3. Bubble Memory Board