STATIC RAM DATA RECORDER FOR FLIGHT TESTS

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ABSTRACT

A static Random Access Memory (RAM) data recorder has been developed to recover strain and acceleration data during development tests of high-speed earth penetrating vehicles. Bi-level inputs are also available for continuity measurements. An iteration of this system was modified for use on water entry evaluations.

INTRODUCTION

The Recorder stores digitized data in on-board, static RAM. It has a full eight bit half flash analog to digital converter to service up to 32 channels of analog data with an additional 16 channels of bi-level inputs. All control circuitry, signal conditioning, power supply module, and memory are contained in one seven inch diameter, four and one half inch long cylinder that weighs less than 10 pounds. (See figures 1 and 2 for mechanical assemblies.) This is larger in diameter and relatively shorter than most previous earth penetrator memory systems. The large diameter that was expected to be a problem with the axial g forces has not been a problem in tests completed thus far.

The earth penetrator version of the recorder stores 204.8 milliseconds of data in the 655,360 bits (81920 bytes) of CMOS RAM at a rate of 400,000 samples per second. However, in the water penetrator version, the record rate may be pre-selected to change up to three times during a flight to significantly increase the record time and up to four different formats may also be pre-programed.

Once the system is recovered, the data is off-loaded in either a parallel form (682.5 bytes per second) into a computer or serial form into a PCM decommutator at 5460 bits per second. The ability to store synchronization in the memory or to insert sync post test is also available, along with the option of basing the format on 192 or 256 words per frame to best utilize the desired number of channels and frequency response on any given test vehicle.

Key-words: Random Access Memory (RAM), Data Recorder, Acceleration.

OVERVIEW

The system power is an on-board +18 volt rechargeable nickel cadmium (NiCad) battery. The major portion of the control circuitry is implemented with the CD4000 series CMOS integrated circuit (IC) logic powered by +5 volts. Each system control command is initiated with +28 volts and a mode monitor is provided to verify the systems mode of operation; i.e. reset, armed (continuously writing into memory), triggered, or reading (playback). System clocks are based on free running, astable multivibrators with the frequency dependent on the RC time constant selected. Record and playback rates are independent of each other and use separate circuits to generate the desired frequencies.

The various inputs are selected according to a pre-determined format via a look-up table programmed in the fuse link Programmable Read Only Memory (PROM). The PROM provides the address and enable signals to the two 16 channel CMOS analog multiplexers and the two eight bit digital latching buffers. The multiplexed analog signal is converted to an eight bit digital representation and stored in the next available memory location. Once the maximum memory address (81920) has been reached, the address generator resets to zero. That is, a new set of data is constantly being written into memory until a trigger signal is received. The trigger signal allows a counter to time out which subsequently halts the writing process, thus saving the pre-determined amount of pre- and post-trigger data.

The RAM is implemented with ten 64K HM-6264 small outline packages. (See figure 3 for RAM board.) The stored data is retained by a back-up battery until the vehicle is recovered and the recorder package removed. A read command may now be initiated to output the data in either serial or parallel format. (See figure 4 for a block diagram of the system.)

SYSTEM POWER

The recorder will run in a range of +14 to +20 volts dc. The external power is diode coupled into the main power bus and upon turn-on produces a power-on-reset function. The internal power consists of five 3.6 volt NiCad batteries (VB 30) connected in series to produce +18 volts. The internal battery is also diode isolated from the main power bus and must pass through an explosive switch. The explosive switch is a one-shot squib actuated type and is normally blown approximately five minutes before initiating a field test.

Firing the squib actuated switch also places the two 3.5 volt lithium thionyl chloride (LTC-3PN) memory back-up batteries on the memory voltage bus. As the primary battery voltage decays to approximately 10 volts, a power shut down circuit triggers, turning the five volt regulators off. This alleviates the excess current drain on the back-up batteries that occurs when the primary battery drops to the level of the back-up battery. In the power down mode, the back-up battery has provided memory retention of real shot data for more than 60 days.

CONTROL AND MEMORY

All system control functions (reset,arm,trigger,read) are initiated by applying +28 volts dc. The control signals are lowered to +5 volts via a simple resistor network voltage divider. The purpose in using +28 volts for the control functions is so that no other voltage available to the recorder (i.e. internal or external power) is high enough to initiate a control function.

The "Reset" function, which may be initiated any time provides output disables to the various latches and reset or clear signals to the flip flops, counters, and multivibrators. The reset command must be removed prior to activating any other commands.

When the reset is followed by an "Arm" command, circuits are enabled or preset to specific states. As the binary counter changes from the maximum count of 8191 back to zero, the decade counter (memory chip select) increments one count. When the decade counter reaches it's maximum count, which selects RAM chip #10, it too resets to zero, thus selecting RAM chip #1. In this mode, recycling of the memory address generator provides for continuous updating of new data in the RAM.

The "Trigger" command can be initiated by either an external command or an internal source. An internal "trigger" requires sufficient acceleration in the proper direction to overcome the bias level preset on a comparator. This signal comes from one of the signal conditioning circuits monitoring an x-axis accelerometer and normally triggers at approximately 1000 g's for an earth penetrator test.

A "Trigger" signal allows the pre-settable counter to start counting every other frame of data. When the counter reaches it's terminal count of zero, it provides a carry out signal which stops the system from writing into memory. The counter pre-set value determines the number of pre-trigger frames that are retained in memory.

To retrieve the data stored in RAM a "Read" command is continuously applied. Each time the "Read" command is initiated, RAM address zero is output first regardless of where the last write or read was terminated. The two methods of playback available to the operator are serial and parallel. Serial mode is chosen when the user desires to look at the data on a PCM decommutator and is initiated by applying both "Read" and "Serial" commands. Putting the system in serial playback mode outputs 5460 bits per second of NRZL data with three words of synchronization at the beginning of each frame. These sync words replace samples of gage data and are superimposed in the pulse train without changing the actual value of the sample stored in RAM. However, the option to store sync in memory during the record mode is available.

The parallel data mode is used to down load the contents of memory to a computer. Parallel data is output at 682.5 bytes per second and does not require sync words because with the RAM address zero being selected first, the computer can keep track of all channel positioning. The computer performs all decommutating operations and produces plots of each data channel with engineering units conversion already applied.

The multi-format, multi-data rate requirement for the water entry program necessitated some modifications. The new requirements were met by adding a second PROM with its own address generator, a counter with a set of jumper options, and some additional logic gates. The PROM address generator is held at a count of zero until a "Trigger" signal is initiated, then increments one count every other frame. Hence the PROM can change formats or data record rates on any even count of frames.

SIGNAL CONDITIONING

The signal conditioning is designed to accommodate three different types of data channels. These include acceleration, strain, and bi-level information. The existing circuits have also been modified to monitor voltage (i.e. system power) and channels with external signal conditioning.

The accelerometer signal conditioning is designed for constant current type accelerometers with the output ac coupled to the amplifier input. The amplifier output is biased at mid-scale to facilitate monitoring positive and negative acceleration.

The strain gage monitor circuit is a 1/4 bridge type circuit for a 1000 ohm gage as one leg of the bridge.

The filtering network in each signal conditioning circuit consists of a four-pole Bessel filter. The selection of the filter frequency is based on five samples per cycle.

FIELD TESTING

During 1986-87 the recorder was flown on seven earth penetrator type shots at Tonopah Test Range. Six vehicles were shot out of the Davis gun into Antelope Tuff (hard rock) at velocities ranging from 1140 feet per second (fps) to 2135 fps at impact angles of 45 and 60 degrees and angle of attack ranging from 0 to 2 degrees. Depth of penetration was seven feet on the slow delivery vehicle and 13 feet on the highest velocity shot. There was one 2-stage Genie rocket shot, also into the Antelope Tuff target, that achieved a velocity of 2125 fps. The impact angle was 60 degrees with an angle of attack of less than two degrees, and the depth of penetration was over 27 feet.

Three water entry vehicles were deployed into the Barstur Hydrophone Range off the coast of Kauai in April/May 1987. Two were single stage Nike rocket boosters that had velocities of 1000 fps and the third was a 2-stage Nike/Genie rocket booster that impacted the water at 2000 fps. The impact angles ranged from 25 to 75 degrees with an assumed angle of attack of zero.

PROBLEMS

The NiCad battery has either failed completely or experienced a transient reduction on almost every earth penetrator test. The transients were monitored by a dedicated data channel. An improved battery is required to improve the reliability of the system.

CONCLUSION

A RAM data recorder has been implemented that acquires and stores acceleration, strain, and bi-level data in the severe environment of earth penetrating weapons. The system has also been modified to acquire similar data over longer time periods in water entry environments.

REFERENCES

1. Barnes D. E. “Shock-hardened, High Frequency, PCM System with Memory for Earth Penetrator Study Applications” Proceedings of the International Telemetry Conference, 1982.

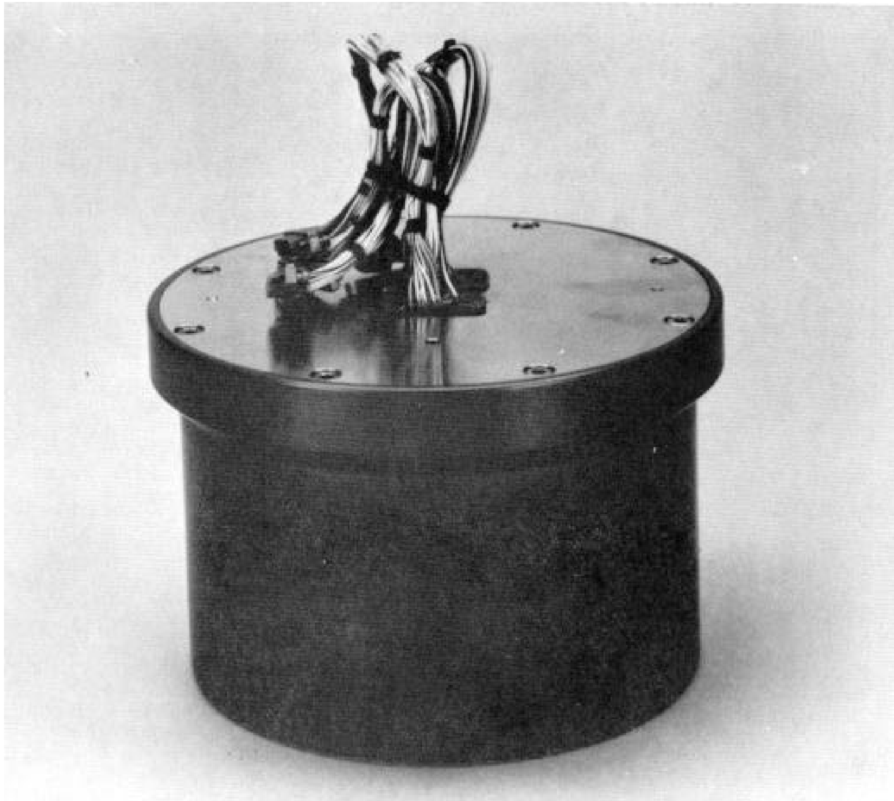

FIGURE 1 RECORDER READY FOR INSTALLATION IN TEST VEHICLE

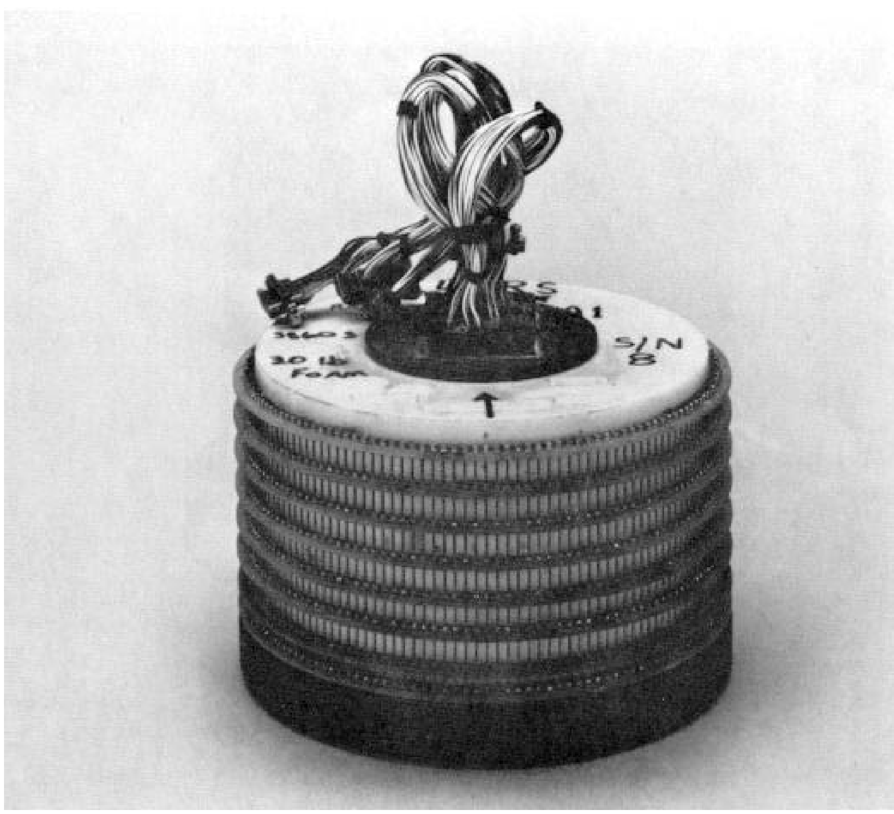

FIGURE 2 STACKED BOARDS PRIOR TO INSTALLATION IN CASE

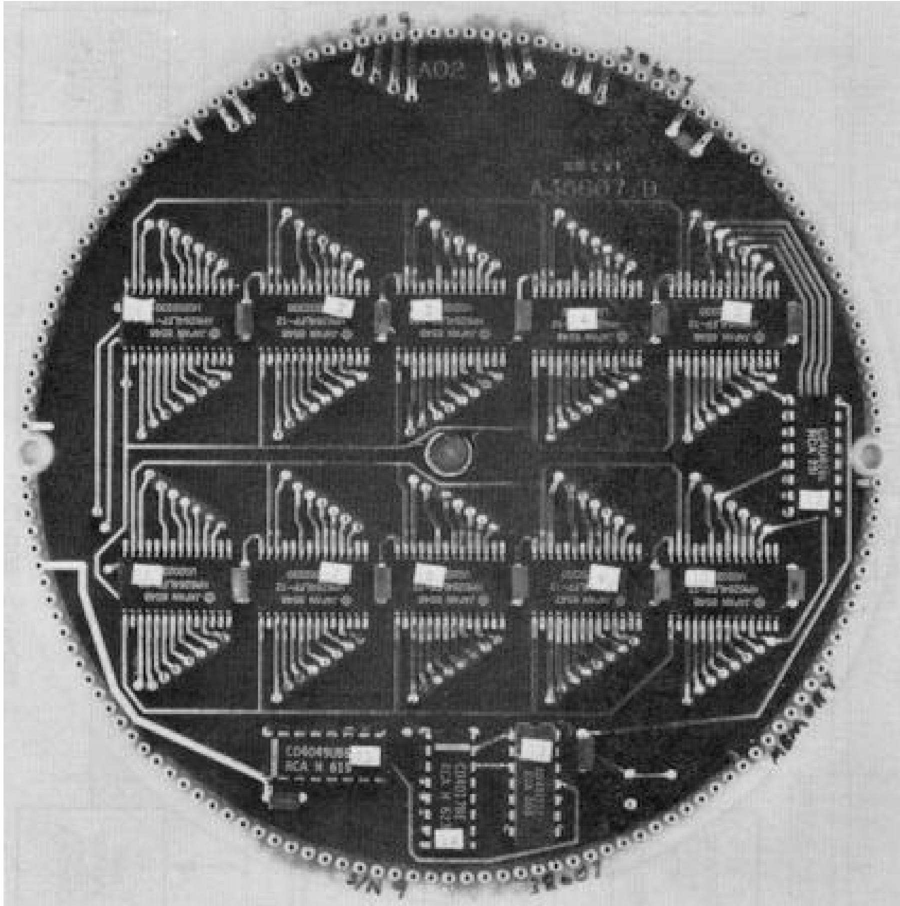

FIGURE 3 MEMORY BOARD

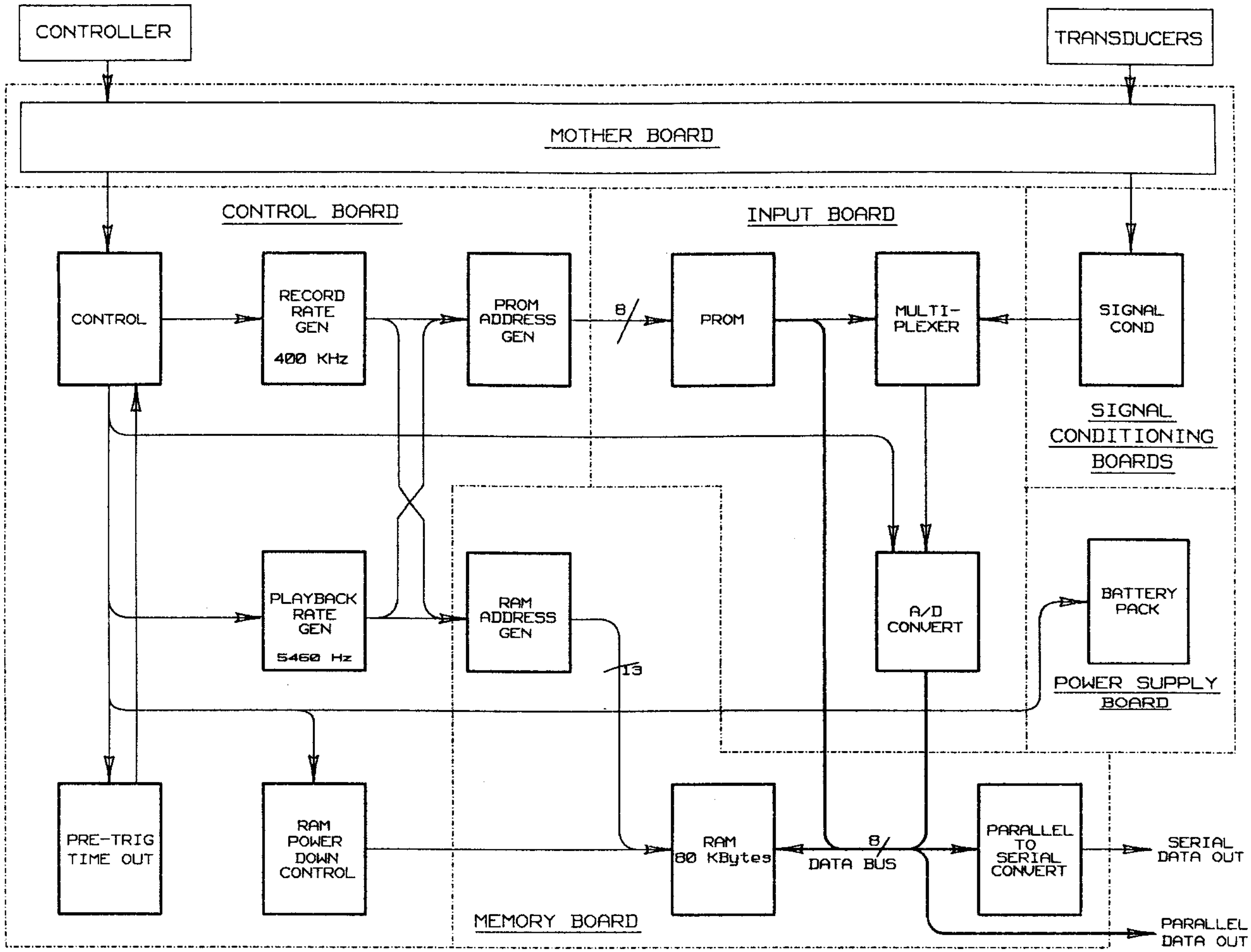

Figure 4. System Block Diagram