Small Multipurpose Stored Data Acquisition System

G. C. Hauser and D. E. Ryerson
Sandia National Laboratories Telemetry Department
Albuquerque, New Mexico

ABSTRACT

Sandia National Laboratories Telemetry Department has designed and is fielding a small, inexpensive multipurpose stored data acquisition system in tests ranging from 6000 meters below the ocean surface in seafloor penetrators to 40,000 meters above sea level in gamma ray telescope balloons. The system consists of a simple microprocessor-controlled unit which digitizes analog data and stores the data in memory for readout after the test by a portable personal computer. The system has been used in over ninety tests consisting of parachute drops, water entry tests, vehicle environmental monitoring, and seafloor penetration tests. Data typically recorded with the system are acceleration, strain, temperature, pressure, and angular velocity. The system is also capable of generating control functions such as parachute release.

BACKGROUND

In 1980 Sandia's Parachute Design group approached the Telemetry Department about designing a small, low-power, inexpensive data acquisition system. Such a system was designed and has evolved into the system described in this report. The system has changed from a prototype wire wrap system through three different printed circuit board systems.[1, 2] Each system has been smaller and faster than the previous design. We often refer to this system as the Stored Data Acquisition System (SDACS) or Parachute Data Acquisition System (PDACS).

SYSTEM DESCRIPTION

The system consists of a microprocessor-controlled digital data acquisition system. The system takes data from up to eight analog gauge inputs and converts these analog signals to digital data. The digital data is stored in a memory for readout after the test. Figure 1 is a simplified block diagram of the system.

The microprocessor in the system is a single electrical integrated circuit similar to the device which controls a personal computer. It allows the system to make logical decisions and determine when and what data to record.

In a typical application, data is taken continuously and stored until one or more of the data channels exceeds a threshold level. When the threshold level is exceeded, the system is said to have a trigger. Since the system has a fixed amount of memory for storing data, new data is continuously being written over older data in a circular fashion with the latest data writing over the oldest data in memory. At any instant in time the system has data stored for only the last N samples of the data inputs. N is determined by the size of the system memory.

Data is recorded for a preset time following the trigger. This preset time is usually set so that some data recorded before the trigger is saved. This allows the user to determine what happened in the test just before the trigger occurred.

Data is held in the system memory until system recovery. After the test is complete, the data system is recovered and the data is read out into a personal computer.

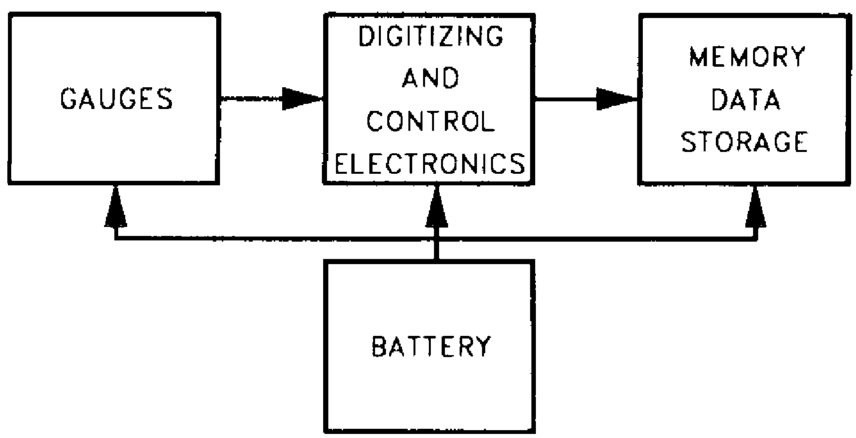

Figure 1. Simplified Block Diagram

SYSTEM SPECIFICATIONS

Data Acquisition Specifications

The third generation system, which is now being fielded, has the following electrical specifications:

1.	Bits per Sample:	8
2.	No. of Data Channels:	8
3.	Max Sample Rate/Channel:	3200 Samp/Sec
4.	Memory Size:	131,072 Samples
5.	Typical Battery Life:	15 Hours
6.	Memory Keep Alive:	5 Years

The change from second generation to third generation is a doubling of the sample rate and an increase in the data memory size by four. The package size has been reduced by a factor of two and a memory keep-alive battery has been incorporated.

Like all finite memory data acquisition systems, the relationship between the data sample rate and the number of channels recorded is interdependent and affects the total recording time. With the latest system operating at its maximum speed and with eight data channels being saved, the system would record eight times 3,200 samples per second for a total of 25,600 samples per second. Since the system has a total memory size of 131,072 samples, the time for which data can be recorded is 131,072 samples divided by 25,600 samples per second giving 5.12 seconds. A longer data record time can be achieved by reducing the number of channels recorded and/or the number of samples recorded per second.

We have built systems that recorded such signals as acceleration and strain at the fastest rate, to systems that record temperature at rates of once per minute giving record times of many hours.

Smart Data Acquisition

Since the system is microprocessor controlled, it is capable of being programmed to change sample rates and the data channels being stored depending upon the incoming data. In a typical parachute system deployed over water, the data acquisition system will be programmed to monitor one to three channels at a fast sample rate waiting for the parachute to deploy. When deployment is detected, the system begins monitoring an additional channel watching for water entry. At water entry, the sample rate is reduced and the system only monitors a depth sensor.

The only disadvantage of smart data acquisition is that the more decisions that are programmed into the system, the slower the data sample rate will be. The microprocessor requires time to make these decisions, and this time must be intermixed with the time used for data acquisition.

System Control Capability

The data acquisition system is also capable of controlling the system being monitored. In many of our parachute tests, we monitor a digital signal generated by a pin switch pulled when the parachute vehicle is released from an aircraft. The data acquisition system waits a preset time to release the parachute from the parachute vehicle. It then sends a signal to release the parachute. The preset time can be entered into the data acquisition system in the field just before aircraft takeoff if desired.

The system has the capability of controlling up to eight different functions. These functions must be able to be controlled by bi-level off/on type signals.

Data Acquisition System Costs

The latest version of this system consists of six small printed circuit boards, a battery pack, and a mechanical housing. The major cost of this system is not the components but the labor involved in assembling it. We presently assemble these systems in house. The approximate cost of a system without gauges is:

1. Electronic Components: $2,000
2. Batteries: $ 500
3. Assembly Time: 1 man month

This system is not produced in mass, but typically two or three hardware packages are tailor built for a specific application. The above costs do not include the development of new software or packaging for a test. The costs include only the reproduction of a fully designed system.

MECHANICAL DESCRIPTION

The systems being used most in the field at this time are the ones using the third generation version, which is enclosed in a circular package. The package is 4 inches in diameter and 7.125 inches long. This includes the battery pack and the memory keep-alive battery.(See Figure 2)

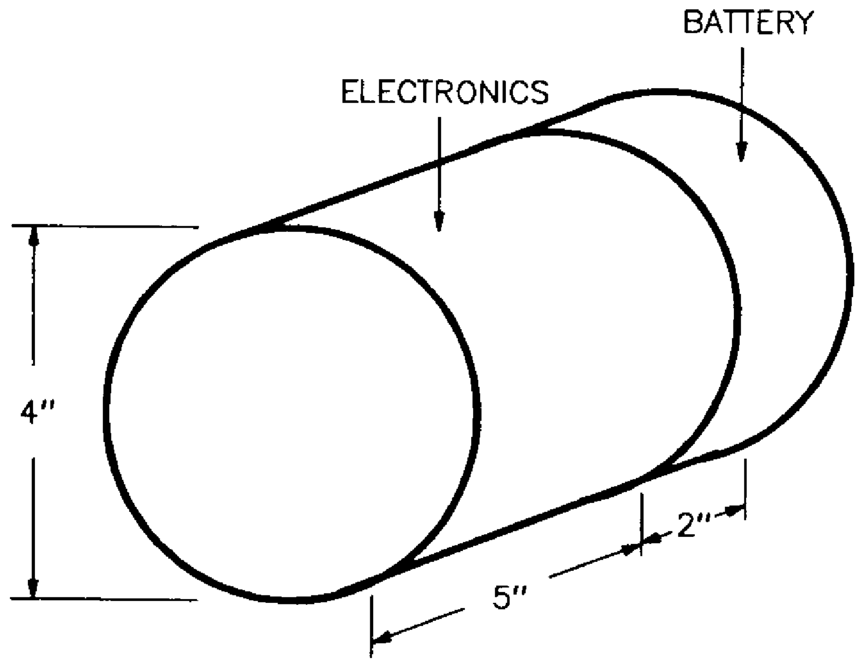

Figure 2. Mechanical Layout

This configuration has been able to withstand shock loads in excess of 300 g's from hard impacts. With a few added precautions, such as encapsulating boards, the system has survived shock loads in excess of 2000 g's.

ELECTRICAL AND SOFTWARE DESCRIPTION

A detailed block diagram of the system is shown in Figure 3. The entire system is controlled by an RCA 1805 microprocessor. This microprocessor is not exceedingly fast or the most modern, but it does consume very little power. This allows us a longer battery life. We also have considerable software developed for this microprocessor

Circuitry

Data is brought in from one to eight external gauges and passes through analog circuitry for gain and removing of unwanted high frequency data. The data from the analog circuitry is fed to a multiplexer, or n-way switch. The output of the multiplexer is fed to an analog-to-digital converter which converts the analog signals into digital numbers.

The microprocessor, called the central processing unit (CPU), works with two different memory systems. The first is called a read-only memory (ROM) and is used to store the instructions for the microprocessor. The other memory is called a random-access memory (RAM) and is used to store the digital data.

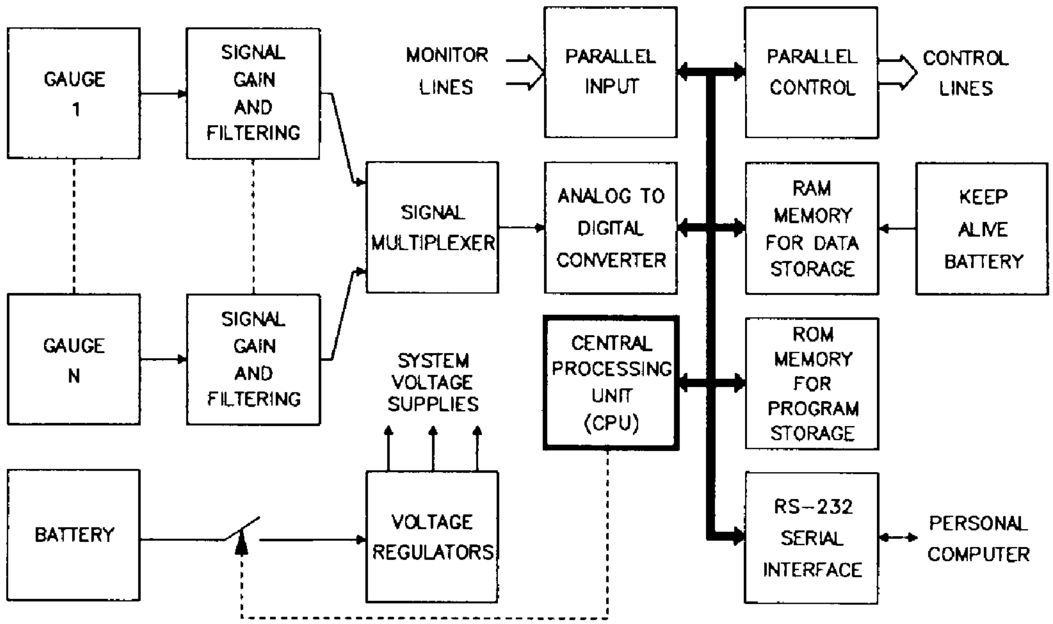

Figure 3. Detailed Block Diagram

The microprocessor under control of instructions from ROM takes digital data from the the analog-to-digital converter and stores it in the RAM. It may also examine the magnitude of the digital data and determine if a trigger has occurred.

The microprocessor can also be programmed to monitor the parallel input lines for external status such as aircraft release. It can set the parallel control lines to actuate external devices such as parachute release. Finally, the microprocessor communicates via the serial interface with the system operator before and after the test for system setup and data readout.

Gauges

Some of the different analog signals that we have monitored with this system are acceleration, strain, temperature, and pressure. The gauges used to measure these parameters are normally powered by the batteries from the data acquisition system, and they often strongly influence the battery life, since the gauges usually consume more power than the data acquisition system.

Batteries

The batteries normally used for this system are C size nickel-cadmium cells having a capacity of 1.5 ampere/hours. The battery pack consists of 12 cells in series. This gives a total run time of 15 hours. Also included is a memory keep-alive battery. This is a lithium cell similar to batteries used in personal computers. It will maintain data stored in memory for five years.

When a test is conducted, the system is powered up and parameters such as delay are entered. The test is conducted and when data has been gathered and memory is full, the system automatically powers down. The load is taken off main batteries and the keep-alive battery maintains memory. This allows repowering of the system on main battery for data retrieval after recovery without charging of the main battery. Also, depending on the time required to conduct a test, it can allow several tests to be conducted before recharging of the main battery pack.

Lithium cells have been used in the past, and they have the capacity of yielding much longer run times for the same size. However, with the Department of Transportation regulations, it is very difficult to ship systems using these larger cells.

Software

Since this data acquisition system is built around a microprocessor, software changes will allow system changes without having to change the hardware. The software for this system is written in assembly language to maximize the speed of the system. Since this software is relatively simple and written in modular sections, its maintenance in assembly language is not too difficult.

SYSTEM READOUT AND DATA REDUCTION

The system was originally designed to be controlled and read out by a simple computer terminal. With the advent of the personal computer, we have been using these devices to operate the system. They allow reduction and plotting of the data in the field. This allows a field operation consisting of multiple tests to be modified depending upon the results of each test.

Figure 4 shows a typical plot of bottom impact deceleration from a water entry test unit. Figures 5 and 6 are integration plots of the acceleration to obtain velocity and displacement. These plots are copies of those generated in the field.

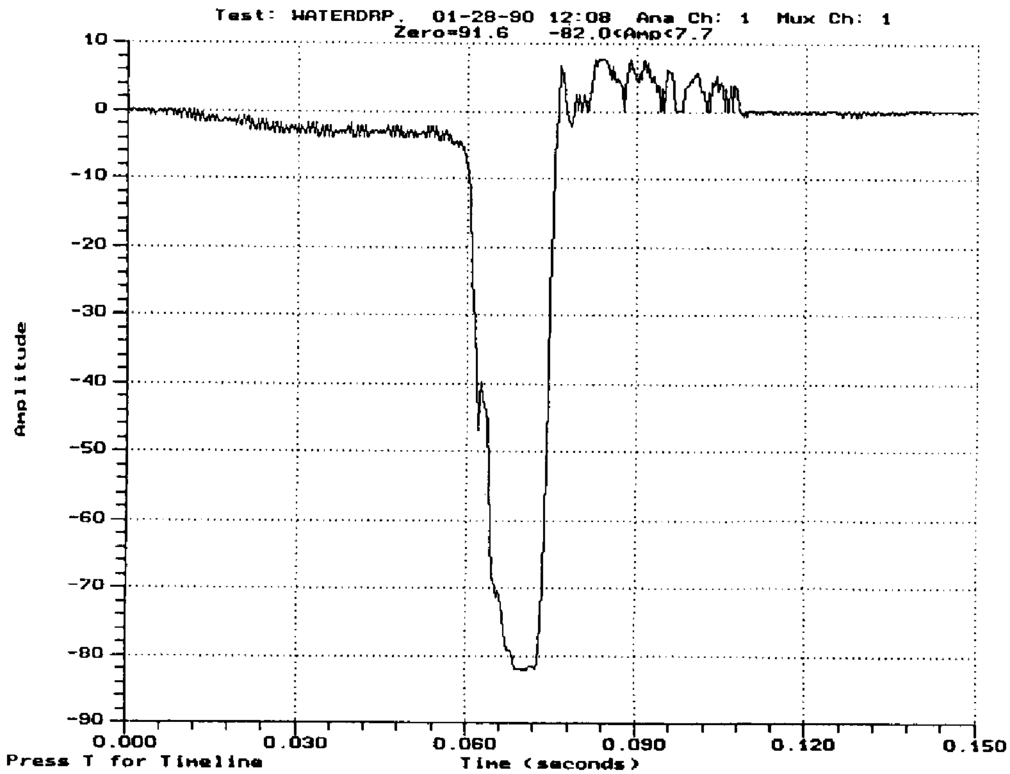

Figure 4. Field Acceleration Plot

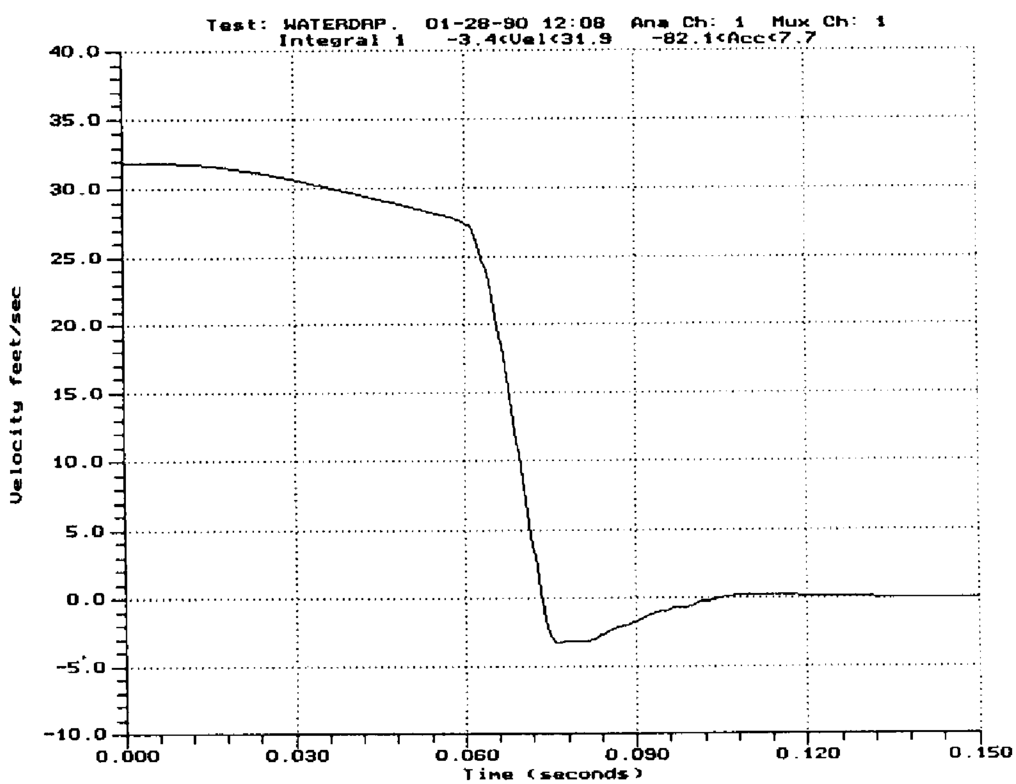

Figure 5. Field Velocity Plot

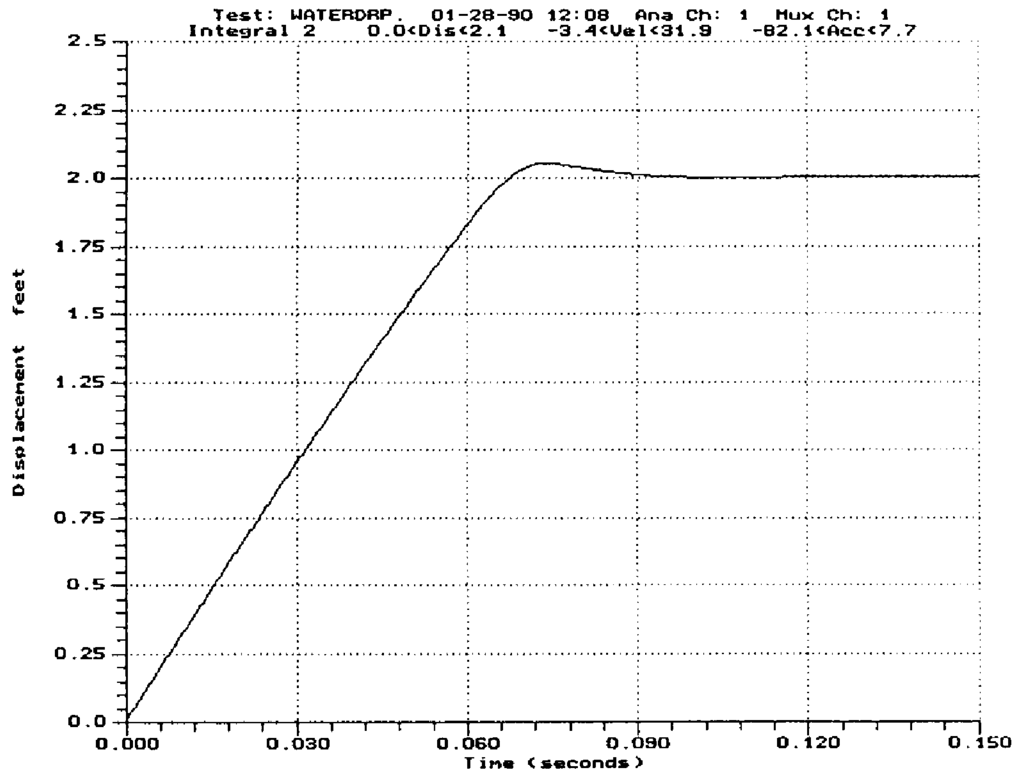

Figure 6. Field Displacement Plot

APPLICATION PROGRAMS

This data acquisition system was originally designed for use in parachute field tests but since that time, it has been adapted to many different types of field testing. In the last ten years we have conducted over 90 field tests with the system. Some of the applications, in addition to parachute testing, have been:

1. seafloor penetrators,
2. ice penetrators,
3. centrifuge calibration,
4. aircraft temperature monitoring,
5. rail car temperature measurements,
6. cruise missile temperature measuring,
7. high-altitude balloon environmental monitoring, and
8. weapon fireset lightning tests.

One of the most complex tests performed with this system was seafloor penetrator instrumentations.[3, 4] Systems were built with an axial accelerometer used to measure the penetration deceleration profile. From this profile, the impact velocity and depth were calculated.

The major problem with these tests was that they were performed in 20,000 feet of water from which the data package was not recoverable. To solve this problem, an explosive acoustic telemetry system was integrated into the data acquisition system. Forty small explosive pellets were mounted in the surface of the penetrator, and these devices were set off at calculated time intervals to transmit the data. The time between a pulse pair represented a 16-bit digital number. On board the penetrator launch ship, acoustic transducers connected to a magnetic tape recorder recorded the sound pulses generated by the explosives. Later, the times between the pulses were measured and the data decoded.

The sequence of operation for this test was that the data acquisition system recorded the deceleration profile as it penetrated the seabed. After the penetrator came to a stop, the microprocessor integrated the data once to determine the seabed impact velocity and integrated the velocity profile to get the depth of penetration. Finally, it generated a table of time intervals containing the depth of penetration, impact velocity, and summary of the deceleration profile. These data were encoded redundantly to ensure that they were transmitted correctly. Finally, the system set off the explosive charges separated in time by the intervals in the generated table.

The purpose of explaining the details of this particular test is to show the flexibility of this data acquisition system. The only hardware changes required for this test was the addition of some parallel control lines and some high power transistors to drive the explosive charges. The main change in the system for this test was the software.

CONCLUSIONS

The Stored Data Acquisition System (SDACS) has proven to be very valuable in recovering data from parachute or other field tests. It is simple, flexible, and inexpensive. Its flexibility comes mainly from the microprocessor controller which allows the system's operation to be changed without changing any hardware.

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