AN INTEGRATED GROUND BASED DATA ACQUISITION AND REDUCTION SYSTEM

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ABSTRACT

An integrated ground data acquisition and reduction facility for monitoring rocket motor testing is being implemented for a large commercial client at their northern Utah test site. This system is capable of recording and processing in near real time large amounts of data from varied types of instrumentation.

The system was developed as a stand alone data gathering and processing center and consists of one-of-a-kind integrating hardware, commercial off-the-shelf hardware and a DEC VAX 11-750 based computer system for data processing. This paper discusses the design of the system, the real time acquisition of data, and user friendly data reduction system.

INTRODUCTION

The primary purpose of the remote Ground Data Acquisition and Reduction Facility is to provide the client with a complete instrumentation system for monitoring, recording, and reducing data at their remote rocket motor test stand facility. Since the system is to be completely autonomous, it is designed to be extremely rugged and reliable while providing a quick look and full data analysis capability. At the present time, the system will condition, record, and process 344 analog signals with a digitized sample bandwidth of nearly 450 Hz. Complementing the analog digitizing is a 90 channel FM subsystem for recording of the analog signals.

In addition to the analog signals, the system monitors 50 discrete signals as well as countdown and IRIG time. The system is designed to be expanded to over 450 analog signals with the simple addition of signal conditioning equipment.

The system was designed by The BDM Corporation (BDM) and assembled and tested prior to site installation at the company's Albuquerque, NM site.

The test site location requires the system to be robust and to have operating characteristics that allow it to be operated and maintained by technician users. Some of the specific system requirements include:

1. Menu driven, user friendly software for system set-up, real time data acquisition, and data reduction.

2. Total system linearity and precision of ±0.1% of full scale on analog signals

3. Conditioning and recording equipment that is rugged and easily repaired and reconfigured while requiring minimum spares

4. Compatible with an existing data recording capability.

The physical configuration of the system is spread between two locations. One location is a buried instrument bunker as close to the test motor as possible. The equipment in this bunker is used primarily for signal conditioning. The other location is the command and control house. This facility is also buried and contains the recording equipment, control consoles, and the computer subsystem. The two locations communicate via several multi-strand fiber optic cable links.

The test site is located in a remote desert location. The principle hazards to the equipment are dust infiltration in the facilities and power transients on the data and electric lines due to the lightning strikes. Other environmental factors include vibration and shock due to seismic loadings. Safety requires that the equipment in the instrument bunker be remotely controlled. The final system requirement, and perhaps the most difficult to control, was that the system was originally scheduled to be designed, assembled, tested, and be ready for site installation in nine months.

PHYSICAL DESCRIPTION OF SYSTEM

The scheduled delivery date necessitated the use of many off-the-shelf hardware items. In general terms, this equipment included the signal conditioning subsystem, the FM multiplexing and demodulating subsystem, the PCM digitizer and encoding subsystem, the recording subsystem, and the computer subsystem. BDM designed and built the interface equipment including the control sequencer, the signal conditioning calibration and monitoring unit, and the control console. The real time and reduction software was a combination of a purchased analysis package and BDM written software.

The system is divided into subsystems according to the location of primary use. The equipment in the instrument bunker is housed in seven equipment bays. The bays are interconnected by wiring and were assembled prior to site delivery. These seven bays were shipped empty but still wired and placed in the equipment bunker while still assembled. The technique minimized installation and start-up time. Figure 1-1 shows the data flow in the instrument bunker.

The equipment in the instrument bunker is connected to the control house by 72 50-micron optical fibers. This subsystem can be used for the transmission of voice, data, and video information. The advantages of this subsystem are its immunity from the electromagnetic interference and lightning and the small size and weight of the fiber optic cables. The information is relayed through multi-mode fibers using light-emitting diodes and silicon detectors operating in the 0.8 μm wavelength band. The information rate is set by the PCM and decom equipment at 2 Mbps.

The data flow in the control house is shown in Figure 1-2. It consists of the data receiving and recording subsystem, the control console, and the computer system with the decom subsystem.

The computer system is based on the Digital Equipment Corporation VAX 11-750 computer. The CPU is configured with 5 MB of main memory with 4 kB of cache memory and two unibuses. One unibus contains the communications controllers, disk controllers, and other interfaces. The other unibus contains the real time data interface card. The use of two busses helps alleviate bus contention problems.

The VAX 11-750 operates under the VMS operating system. Primary data acquisition and reduction codes are written in FORTRAN-77. The operator interface to the computer is through various CRT terminals and printer/plotters. Data may be transferred directly during or after processing to a tri-density (800, 1600, or 6250 bpi) digital tape drive for data archiving.

The computer subsystem has three mass storage disks; a RL02 cartridge disk for installation of the operating system, a RA-81 disk as operating system and program storage, and a System Industries Model 9751 hard disk. This last disk is used primarily as the data disk because it has the greatest data transfer rate. For real time data use, it is configured with 5500 blocks of contiguous memory which provides nearly six minutes of real time recording capability for a single PCM stream.

There are seven PCM data streams transmitted from the instrument bunker to the control house. Three of these streams contain the primary system data and have been currently identified for immediate data reduction and analysis. These three streams presently operate at 5 Mbps with 159 words per frame. There are no sub frames nor super or sub decomming. The data acquisition software furnishes the interrupt service, writes a memory using a DMA without CPU control, formats the decom 12 bit data word into a 16 bit, two byte word, and transfers data to the mass storage disk from a two section moving buffer. A single PCM stream can be input to the computer at a time. The subsequent streams are recorded on analog tape and then played into the computer through the same real time software.

Each of the streams contain IRIG B time and countdown time embedded in the frame. This allows the software to quickly scan the data for particular points, such as the beginning of calibration signals, and reduce the data with a minimum of searching.

All the signal conditioning subsystems provide a remote calibration capacity which is variable according to channel assignment. In general, all the channels can accomodate a voltage insertion from the BDM designed sequenced voltage calibrator. In addition, all bridge type transducers can also be calibrated with shunt cals. Calibration is nearly simultaneous for all channels as it takes less than 30 seconds to sequence through all the steps.

SYSTEM SOFTWARE

The system software is presently separated into two main sections; the real time data acquisition software and the data reduction, analysis, and plotting routines. Due to the tight delivery schedule, the instrumentation system was not configured as totally computer controlled. Windows in the present configuration have, however, been left to accomplish this feature.

The software is set-up for two types of user; a system manager who would typically not be at the test site and the site technicians who are the primary users. The technicians will be the primary operators. Consequently, the acquisition, reduction, and recording features of the software are all menu driven. The only time the technicians have to leave the menu is to edit the instrumentation set up file.

The menus are structured to allow the technicians to quickly step through the options to the pertinent section. These options allow the operator to verify the precision of the entire instrumentation system, including the quality of the data, prior to testing. One part of the real time system allows technicians in the instrument house, via CRT, to monitor the signals from end to end and, if warranted, to record and reduce signals to verify set up file information. Other parts are for the transfer of data from the disk files to various digital tape formats.

REAL TIME DATA ACQUISITION SOFTWARE

The real time data acquisition system allows the technician operator in the control house to monitor record a single 2 Mbps data stream into the computer mass storage disk while viewing the count values of up to 16 selected data channels. The real time system is divided into two different operations - one for instrumentation set up, the second for test data. For either operations the technician has a full capability to remotely set up the decom system bit synch, decom unit, word selector and word selector slave displays. The operator has the option of recording a data stream from the decom unit or the 16 words displayed from the word selector.

The system set up technician can also operate the computer system from a remote terminal in the instrumentation bunker. From this remote site, the real time system can be activated and the technician can verify the end to end signal value of every data channel. This feature is valuable for at least two reasons. The technician can verify the signal conditioning amplifier set up and the configuration file for reducing the data and it aids in troubleshooting the system by comparing the signals in the instrument bunker with those received in the control house. Special system test data reduction software has written which allows the remote technician to record the data (usually calibration signals) on disk, reduce it using the set up file, scan and compare the data to norms for outliers, and highlight the non-conforming points.

The set up for actual test data is similar to the menus used for instrumentation set up. The computer operator verifies the equipment set up and finally displays a special data acquisition CRT screen information. This display includes information on whether the decom is locked up, the DMA card is receiving data, whether data is being recorded and if it is, how much disk space is left in terms of blocks and as a percentage. It also displays countdown time and IRIG time.

The communications portion and DMA card for the real time acquisition system was purchased from the decom equipment manufacturer, Decom Systems, Incorporated. BDM has modified this series of software programs to meet the customer’s special requirements.

DATA REDUCTION AND ANALYSIS SOFTWARE

The data reduction programs were all designed and written by BDM. These programs provide a wide variety of data reduction services. All the programs operate from command files which handle the housekeeping. The data reduction programs use the embedded time codes, either IRIG or countdown time, to quickly search for start and stop times.

The primary reduction program, called REDUCE, is used to convert raw data counts to engineering units. It will read the set up file for parameter information and then, in conjunction with the calibration and data files, calculate the conversions.

After the data has been converted to engineering units, several analysis options may be used. These options include an averaging program, a history program, statistical programs, and several types of hardcopy programs.

The averaging and history programs are constructed along similar lines. The averaging program takes the engineering units file and converts it to operator chosen averages. These averages, along with statistical deviations, can be defined as scan to scan or by specific time period averages. All points are examined for outliers and data compression is possible. The history program is similar except that comparable run to run data is stored for immediate examination. Again, the operator can choose the most pertinent format (engineering units or averages) with the best display (either terminal or printer output or plots).

To archive this information, the operator has the option to print the data or store it on tape. Again, all operations are menu driven with the operator supplying the start and stop time of the interval of interest.

In addition to storing the data, the operator has a number of data plotting options. These plotting routines are of two principle types - automatic standardized plots and operator specified plots. All plots include the standard test information such as date, time, parameter headers, data compression information, test run name, and whether any points are offscale.

The standardized plotting routines are set up prior to testing and display information for parameters of interest. The routines examine the start and stop times and the amplitude of the data to chose the appropriate scales. The programs also choose the optimum level of data compression. The plots are automatically output on the plotter and are of report quality.

The operator specified plotting routines use the same plot format as the standardized plots. The primary difference is that the operator can identify all plotting parameters. In this fashion, any piece of data from any parameter during any time period is immediately available for examination.

To aid in the quick analysis of data, a special interface was developed which enables the operator to integrate the data into a client specified data analysis program called RS-1 written by BBN Research Systems. This program is used in other client facilities to analyze other information and its familiarity was key in its selection.

SUMMARY

With the cooperation of equipment vendors and an extensive data acquisition and reduction software base, a large integrated data acquisition and reduction facility can be assembled and functioning in less than nine months. There are several key points for this success.

First, management has to ensure that appropriate technology is used. This requires the evaluation of the client needs and the operator's level of expertise. Second, the system design (at least the primary components) needs to be frozen as soon as possible. This minimizes the need to redo work. Finalizing the design also helps prevent delays due to equipment delivery schedules. Finally, a proper split between equipment and software development responsibilities with strong management control ensuring open communication channels is required. Open communications helps provide the information needed for scheduling assembly tasks and prioritizing development work.

Having the software development experience of several systems is also critical to fast implementation. Only with this experience and the associated developed software can the analysis and reduction needs be quickly identified and developed.

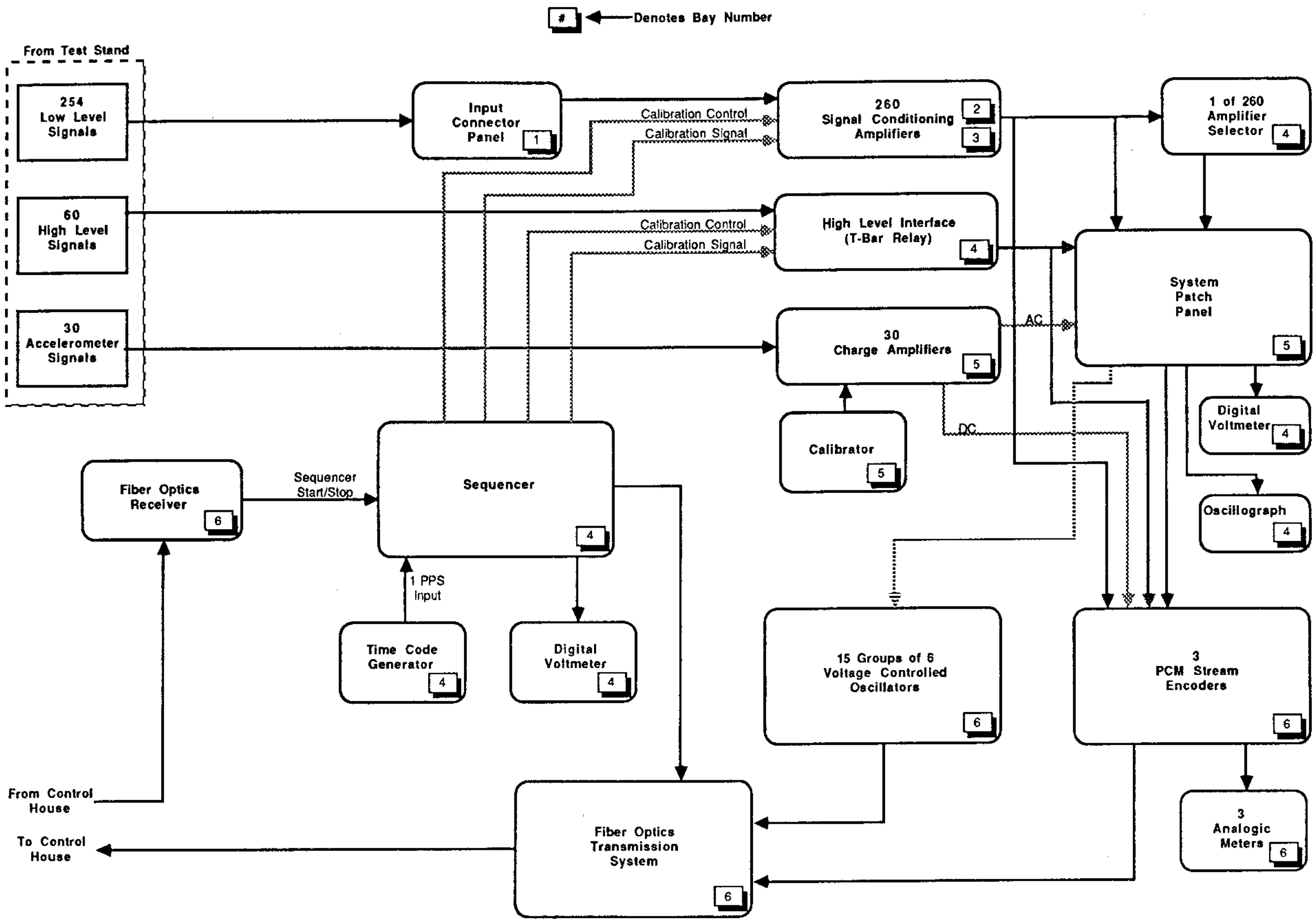

Figure 1-1 - Instrument House Assemblies

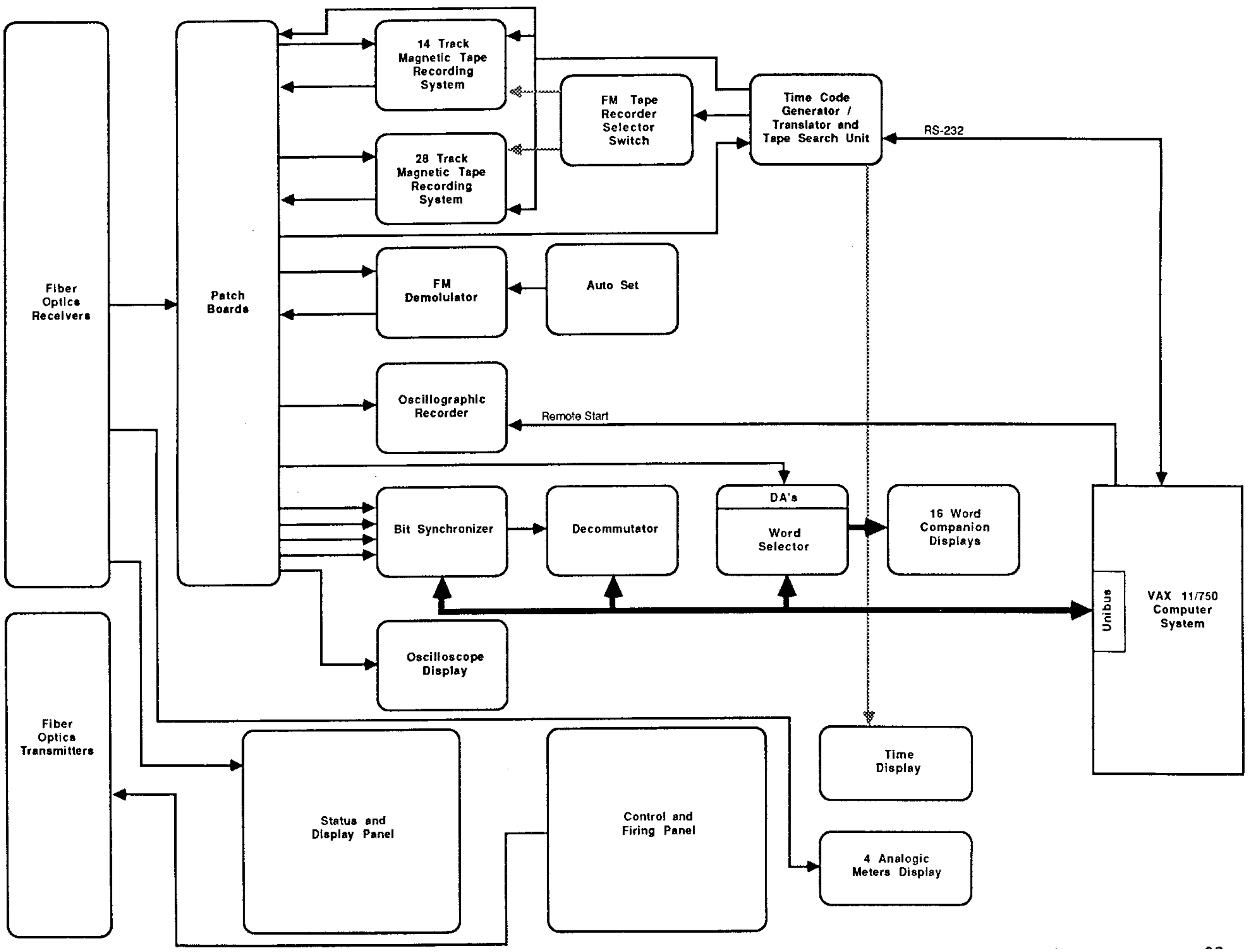

Figure 1-2 - Control House Assemblies