DATA RECORDERS FOR BOEING 777 FLIGHT TEST

Lee H. Eccles
Boeing Commercial Airplane Group
Flight Test Engineering
Seattle, Washington

ABSTRACT

A family of data recorders are being developed for use by the Boeing Commercial Airplane Company in flight testing the 777 airplane. The intention is to have a family of recorders which all have the same interface to the recording and monitor systems but have vastly different data rates and capacities. At this time two recorder systems are being developed. The large recorder will be an Ampex DCRSi with a custom interface for the new data acquisition system. The small recorder will be an Exabyte Model 8500 with a similar interface to the one being used in the DCRSi. An intermediate recorder may be developed if the economics of the system show that it would be cost effective but, it is not presently under development. This paper discusses the recorders, the modifications necessary to develop the interfaces and the interfaces themselves for both the large and small recorders.

INTRODUCTION

Figure 1 is a high level diagram of the data system being developed for flight testing the Boeing 777 airplane. The emphasis in this drawing is on the recording subsystem. The data flow in the system is from the data acquisition system to the recording system interface and from there to both the recorder and the monitor system. The monitor system is an on-board real time data processing system which is used for real time monitoring of test conduct. The subject of this paper is the recording subsystem that is being developed. There are two sizes of recorder being developed. Both utilize existing commercially available recorders with a custom interface to make it work in the overall data system. The large recorder is an Ampex DCRSi II which uses one inch tape in an Ampex. cassette. The small recorder is an Exabyte eight millimeter recorder.
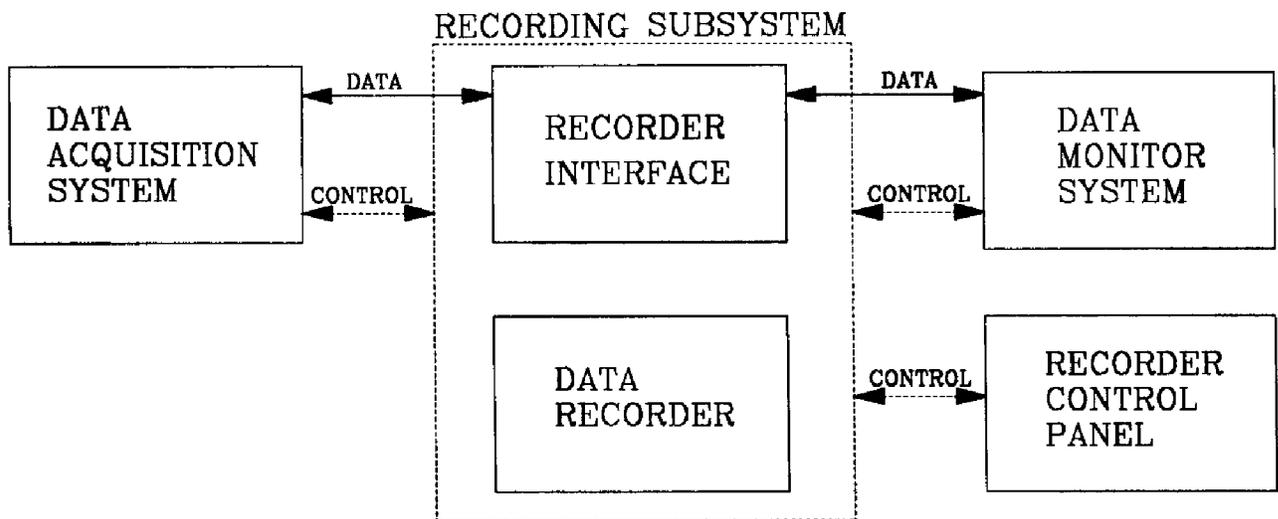
RECORDING SUBSYSTEM

| DATA ACQUISITION SYSTEM | DATA → / CONTROL → | RECORDER INTERFACE | DATA / CONTROL | DATA MONITOR SYSTEM |
| | | DATA RECORDER | CONTROL | RECORDER CONTROL PANEL |

Figure 1 System Block Diagram

NEED FOR MULTIPLE SYSTEMS

Boeing Commercial Airplane Groups Flight Test organization has requirements to install data acquisition and recording systems in many different airplanes for a wide variety of tests. The most obvious of these requirements is to install a system to acquire and record the data needed to certify a new airplane. This class of system will require measuring over ten thousand parameters on flights lasting up to fourteen hours. At the other end of the spectrum are the tests required to certify a new avionics box or to investigate a customer complaint. These tests may only require that a few parameters be recorded. In addition some tests, which are performed on airplanes which are in airline service require a physically small system so that it can be installed in any available space. To meet the range of requirements this places on the recorders we have chosen to develop two different sizes of recorders.

SYSTEM LEVEL REQUIREMENTS

There are two high level requirements placed on the recording subsystem by the overall system design. The first is that both recorders look the same to the other elements in the system. This means the data interface must be the same for both recorders. It also means the control interface must be the same and respond to the same set of commands. The second requirement is that the data must fall through the recorder to the monitor without being delayed. The monitor systems in use are real time systems which expect the data to arrive at its input in the same time sequence that it was acquired by the data acquisition system. This implies that no buffer memories may be placed between the data input and output ports.

THE SERIAL DATA INTERFACE

Data is received from the data acquisition system as a series of twenty-four bit words. Since the recorders are incremental these twenty four bit words do not need to make up a continuous bit stream but will have gaps between words. The time of appearance of a data word is controlled by the time that a particular data word is sampled by the data acquisition system. In the case of analog data, the data rate for any given input data stream will be carefully controlled, but there will be several of these units in a system, and they will not be synchronized, so there will be peaks in the output data rate. The time that a sample of data is acquired from one of the aircraft data buses is controlled by the airplane systems themselves. Data is usually put out at regular intervals, except for maintenance data, but, again, there are over a hundred systems on the airplane running asynchronously so the data will be coming into the recorder at a variable rate. A frame synchronization pattern will be inserted into the data stream after every 512th data word to allow the monitor system or the ground based tape-data-retrieval system to obtain word synchronization. The average data rate will be different for each recorder, but it is the data acquisition system which must be set up to control this average data rate. On tape playback, using the on-board monitor system, the data would normally be put out by the recorder at a constant rate, but since it was not received at a constant rate, the programs in the monitor system do not want to receive it at a constant rate. The monitor system has hardware built in to use the time embedded into the data stream to control the rate at which it takes data from the recorder.

RECORDER CONTROL

The recorders are controlled using an RS-422 link from a control processor. This control processor will be in the data acquisition system when a small system has been assembled and no monitor system is present on the airplane. In most cases when an operator is present, a recorder control panel will be installed to give the operator manual control of the recorder. In other cases the control of the recorder can come from the monitor system. The set of commands which will be used by both recorders is a subset of the DCRSi commands as defined by Ampex.

THE LARGE RECORDER

The large recorder is used in major test programs such as the certification of a new aircraft. These programs normally require the recording of several thousand different parameters at a wide variety of different sample rates. A block diagram of the large recorder is shown in Figure 2. Data is received from the data acquisition system over a forty-megabit-per-second serial link. It is converted to a byte wide parallel format and passed in this form to the recorder and to the data transmitter. The data transmitter
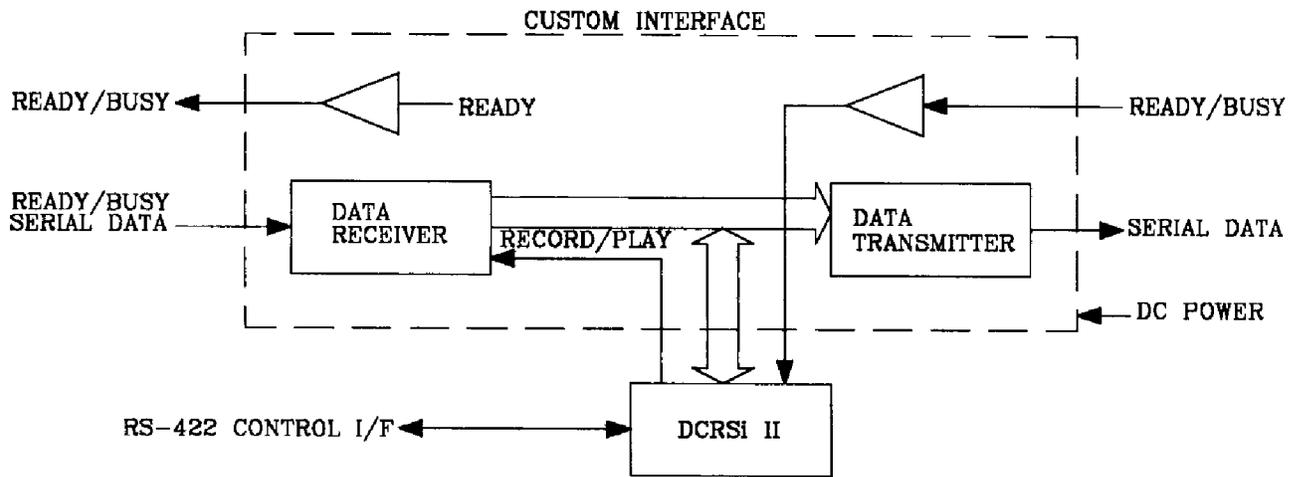
Figure 2 Large Recorder Block Diagram

converts the data back to the serial format in which it was received and passes it along to the monitor system. The recorder interface has the capability of sending a Ready/Busy signal back to the data acquisition system if data is coming in too fast for the recorder. However, since the DCRSi is capable of running much faster than forty megabits per second, it is tied to the ready state. When the recorder is placed into the playback mode, data flows from the recorder to the data transmitter for transmission to the monitor system. In this mode a Ready/Busy signal from the monitor system to the recorder is used to control the data transmission rate. Since the monitor system is used many times when it is not necessary to be recording data, the interface must always be in the mode of passing data from the acquisition system to the monitor system, except when it is in the playback mode. This includes times when the recorder is powered down. For these times the power for the interface is supplied by the monitor system.

THE SMALL RECORDER

The small recorder is used in systems where a limited amount of data is being acquired. This may be a test with a limited objective being run before an airplane is delivered to the customer airline or a test being run on an airplane which is in service with an airline. A block diagram of this recording subsystem is shown in figure 3. The interface to the small recorder is the same as the interface to the large recorder. The serial data input and output lines are the same, but internally, the data is passed to the recorder through a byte wide SCSI interface. The Ready/Busy line back to the data acquisition system is required to be active since this recorder cannot accept data at the rate at which it can be sent. Since SCSI is a block transfer bus, there is a small buffer memory in the SCSI interface to collect a block of data before it is transferred to the recorder. However, the data does not pass through this buffer before being applied to the data transmitter. The buffer only needs to be large enough that the micro processor does not normally need to set the Ready/Busy line to

RECORDER INTERFACE

READY/BUSY ◄─────

SERIAL DATA ──────► DATA RECEIVER

RECORD/PLAY

CONTROLLER

RS-422 CONTROL I/F ◄─────

SCSI

EXABYTE 8500

DATA TRANSMITTER ──────► SERIAL DATA
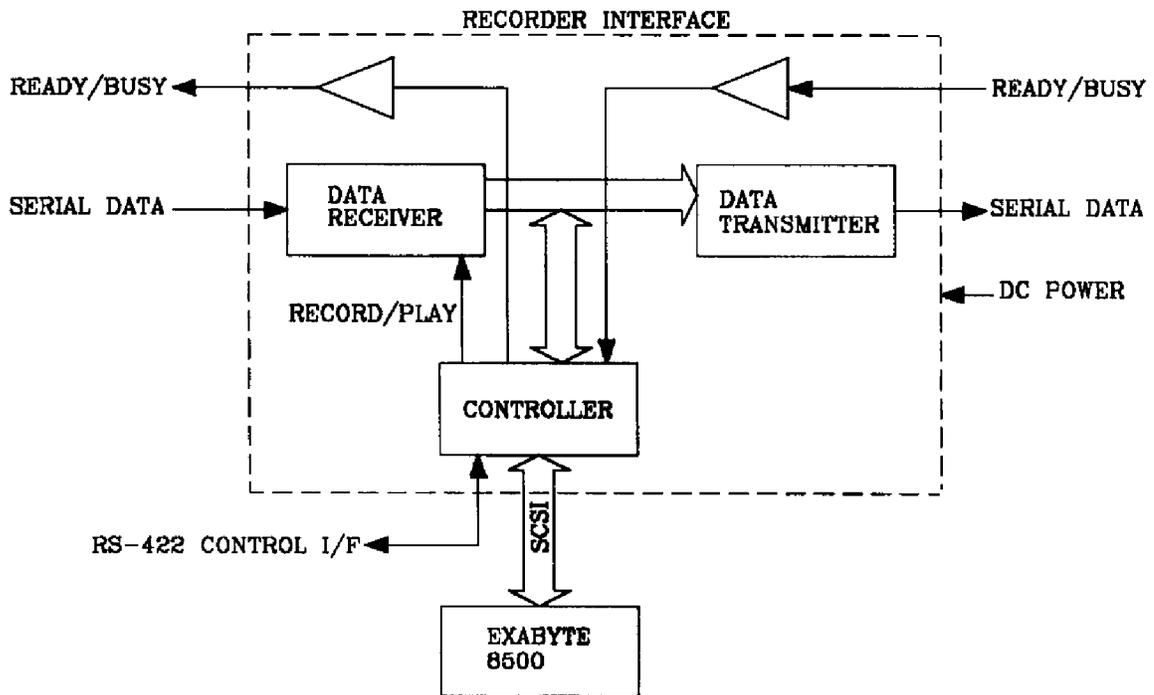
READY/BUSY

◄─ DC POWER

Figure 3 Small Recorder Block Diagram

busy when making a transfer. There is a one megabyte buffer in the recorder itself which can be used to handle peaks in the incoming data rate. It is important that the recorder not set the Ready/Busy line to busy more than is absolutely required since it interrupts the flow of data to the monitor which will cause distortion of the time of arrival of the data at the monitor system. In the tape playback mode the recorders data output rate is controlled by the monitor system using the other Ready/Busy line. This recorder responds to the same command set as the large recorder. The primary requirement for the micro processor in the system is to translate the commands received from the RS-422 interface into commands that the Exabyte recorder can understand.

SIMILARITIES AND DIFFERENCES

The basic recorders are both designed to be incremental recorders, and that is about where the similarities end. To take these two recorders and make them appear the same to the system has presented a challenge. The DCRSi was designed as an instrumentation data recorder with a large set of commands which are tailored for this usage. The ExaByte was designed as a computer peripheral device. One of the features of the DCRSi is that it accepts an interface to an IRIG B time signal and can record the time on a separate track from the data. This allows the tape to be searched at a high rate for a particular time during tape playback. The ExaByte recorder does not have either an auxiliary track or a time interface. To solve this problem we specified the interface to the small recorder so that it could obtain time of day information from the data stream itself. This solves the problem of

providing a source of time that was synchronized to the data acquisition system. Without an auxiliary track the problem of doing a high speed search for that time needed another solution. This was accomplished by providing a directory which related time to block number. Data is recorded on the tape in logical blocks and the directory is maintained in the micro controller memory until a power failure or the tape is unloaded. When either of these events occur a long file mark is written to the tape followed by the directory and an End-of Data mark. If additional data is to be written to the same tape the heads are positioned ahead of the file mark and the file mark, the directory and the End-of-Data mark are overwritten. This has required the addition of one command which does not exist on the DCRSi. That is a command to read back the directory over the RS-422 port.

The other differences between the units are mainly those characteristics unique to the requirements of the large and small recorders. The Exabyte is physically smaller and has less capacity and bandwidth but, the requirement was for a physically small recorder to be used for field service type work. The DCRSi has a large capacity and high bandwidth but is necessarily much larger. A larger machine is not a problem on commercial transport aircraft during testing out of the factory.

The two machines and their respective cassettes were also designed to be used in different environments. The DCRSi is available in either a laboratory version or an airborne version. The airborne machine was designed to meet the kind of environments normally encountered in an airplane. The Exabyte Model 8500 and it's cassette tape was designed to be used in a computer room. In order to be able to use the Exabyte recorder in an airplane it is necessary to condition the environment around the recorder to keep it within acceptable limits. The primary area of concern is temperature. The Exabyte Recorder and cassette are specified to operate over a temperature range of 5ºC to 40ºC, which is considerably less than the desired range of -15ºC to 55ºC. To meet the desired temperature range it is necessary to provide an enclosure which is heated to handle low temperatures and cooled to handle the high temperatures. This enclosure is well enough insulated to limit the rate-of-change of the temperature inside it not to exceed the 1ºC per minute specification of the Exabyte, even with the external temperatures changing at rates up to 2ºC per minute. Vibration isolators are provided to prevent the aircraft shock and vibration from influencing the recorder. The enclosure is also designed to prevent dripping water from getting into the recorder. The small recorder must also meet stringent electromagnetic interference requirements.

CONCLUSION

The Boeing Commercial Airplane Company is in the process of acquiring a family of recorders which are expected to meet our needs for most applications into the next century. The large recorder will be adequate for major test programs and the small

recorder will meet most needs for small test programs. We have not evaluated the middle ground to determine if there are enough programs with requirements for more capability than the small recorder can provide but not enough to justify the capabilities of the DCRSi. It is possible that a third recorder will be determined to be economically justifiable but that has not yet been investigated.

The Boeing Commercial Airplane Group, Flight Test organization is always looking for ways to improve its test equipment and techniques. However, the major changes which are being required to support the 777 airplane are well beyond improving the system requiring total replacement of many systems. These recorders are but one part of the major changes that we are making as we look forward to certifying the Boeing 777 and later commercial airplanes.