COMPACT AIRBORNE REAL TIME DATA MONITOR SYSTEM - PRODUCTION MONITOR

Grant H. Tolleth
Boeing Commercial Airplane Group
Flight Test Engineering
Seattle, Washington

ABSTRACT

This paper describes the Production Monitor (PM), a result of integrating very diverse hardware architectures into a compact, portable, real time airborne data monitor, and data analysis station. Flight testing of aircraft is typically conducted with personnel aboard during flight. These personnel monitor real time data, play back recorded data, and adjust test suites to certify or analyze systems as quickly as possible. In the past, Boeing has used a variety of dissimilar equipment and software to meet our testing needs. During the process of standardizing and streamlining testing processes, the PM was developed. PM combines Data Flow, VME, Ethernet, and PC architectures into a single integrated system. This approach allows PM to run applications, provide indistinguishable operator interfaces, and use data bases and peripherals common to our other systems.

KEY WORDS

Real time data monitor, Airborne, Multi-processor, VME

BACKGROUND

Most of Boeing's flight testing is accomplished with two data systems, the Certification Flight Test Data System(CFTDS) and the Portable Airborne Digital Data System(PADDS). Due to its small size, PADDS is used heavily for in-service testing(actual airline revenue flights). PADDS also gets a great deal of use locally for production testing conducted on pre-delivery aircraft. PADDS, like the certification system, contains acquisition hardware, a tape recorder, and a data monitoring system. The PADDS data monitor is used for real time data monitoring or for data reduction. As a data reduction tool it is used either on board the aircraft, in a hotel room (in remote service), or at a customer's site.

During the planning for the certification of B777, Flight Test determined that the capability of our present airborne data systems would be exceeded. This meant that both the CFTDS and PADDS would have to be replaced.

APPROACH

While developing the data systems requirements, Flight Test decided to make the new PADDS compatible with the CFTDS. The new PADDS, PADDS II, contains a duplicate of each of the main functions of the CFTDS. When we specified the new acquisition multiplexer, the Central MUltipleXer (CMUX), two versions differing only in enclosure size and appearance were specified, designed and built. The certification system recorder's electrical interface and communications protocol were duplicated and built into a smaller recorder. Finally the CFTDS Airborne Data Analysis and Monitor System (ADAMS) functions were repackaged into a significantly smaller unit; the result was the Production Monitor (PM).

As shown in Figure 1, there are four basic components to the CFTDS: signal conditioning, multiplexing and data selection, recording, and monitoring. The ADAMS sets up the acquisition system and provides several real-time data monitoring stations, as well as printers, strip chart recorders, and dedicated displays, called Panels. Test stations are PC based. Graphics are provided on a ruggedized HP 730 workstation. A central file server, the File Server Assembly (FSA), provides access to mass storage for the system. Application Processor Assemblies (APAs) provide for application program execution, peripheral device management, and system status reporting. The Acquisition Interface Assembly (AIA) provides data selection, engineering unit (EU) conversion, and management of the measurements being processed.

Figure 2 shows the PADDS II system production configuration. The most outstanding difference from the CFTDS is the replacement of ADAMS with the PM. The PM, like ADAMS, sets up the acquisition system, and provides monitoring of real time data on a video monitor, printer, strip chart recorders, and dedicated Panels displays. The PM is designed to be a single-user monitor; however, PMs can be daisy-chained together, thus supporting any number of users. When desired, the PM can produce a profile of tape events, command the tape recorder to position to a desired location, and replay the data for analysis.

Figure 3 is a block diagram of the PM. The enclosure is a standard 19 by 10.5 inch rack-mount chassis. Mounted inside is a 15-slot VersaModule European (VME) chassis, 3 mass storage devices (floppy, 4.3 Gbyte hard drive, and 8mm tape drive) on an 8-bit Small Computers System Interface (SCSI) bus, and a 5-port Ethernet hub.

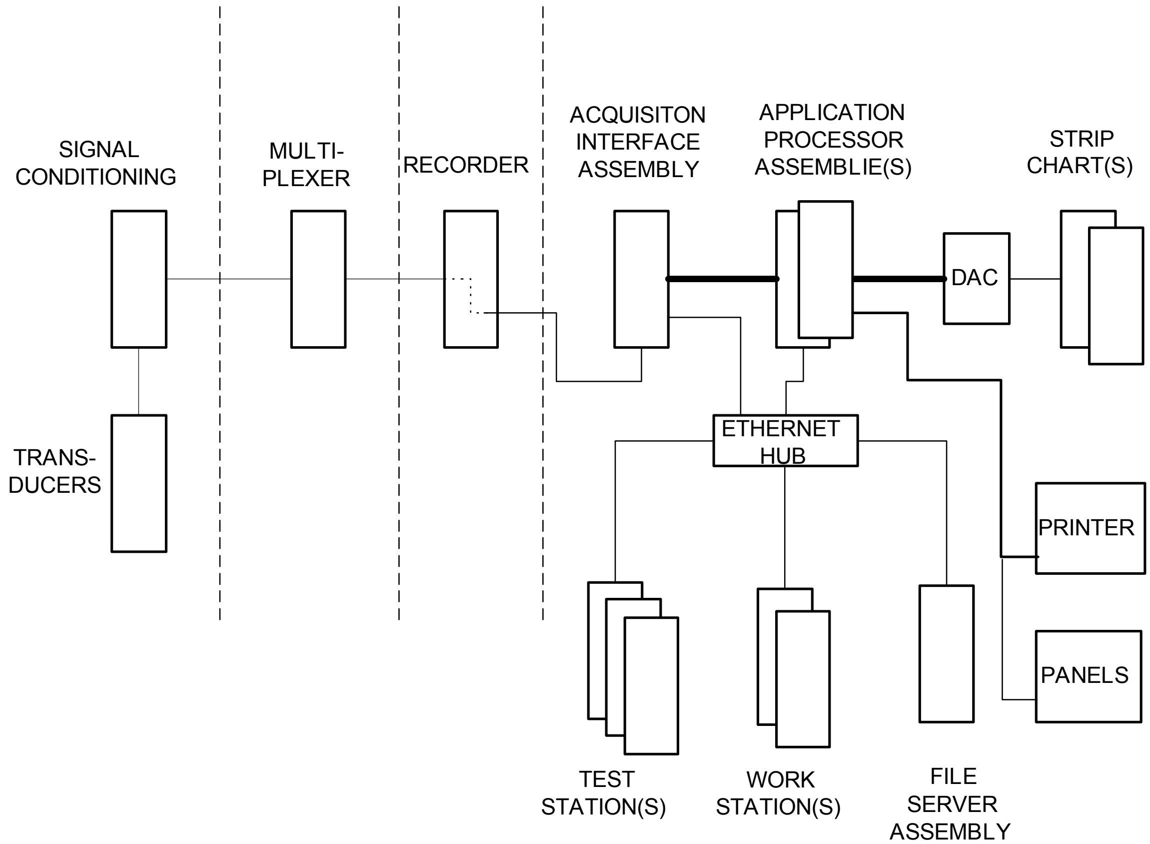

Figure 1- CFTDS Block Diagram

Selection of processors was based on performance criteria, availability of power-cycling tolerant software support packages, and compatibility with our existing software development systems. We tested an Alpha RISC, a 68060, and both 80386 and 80486 based single board computers (SBC). The 68060 based SBCs were selected for the Processor Module and Measurement Processor (MP) processors, and an 80486 PC was chosen for the operator interface.

Data conversion functions are implemented by recycling the input decoder design from the ADAMS AIA. This new interface, referred to as the DEC 24 card (24-Bit Decoder Card), has several added features for diagnostics and improved tape usage. We corrected "features" in the original decoder design (e.g. violations of VME timing specification) and took advantage of newer technologies to produce a front end that is faster than the original design. The DEC 24 card receives real-time data in a "24-bit format" from a CMUX or recorded data from a tape recorder, and performs synchronization functions, so that unique data words can be identified. When the data source is the tape recorder, the DEC 24 card also provides for time reconstruction of recorded data.

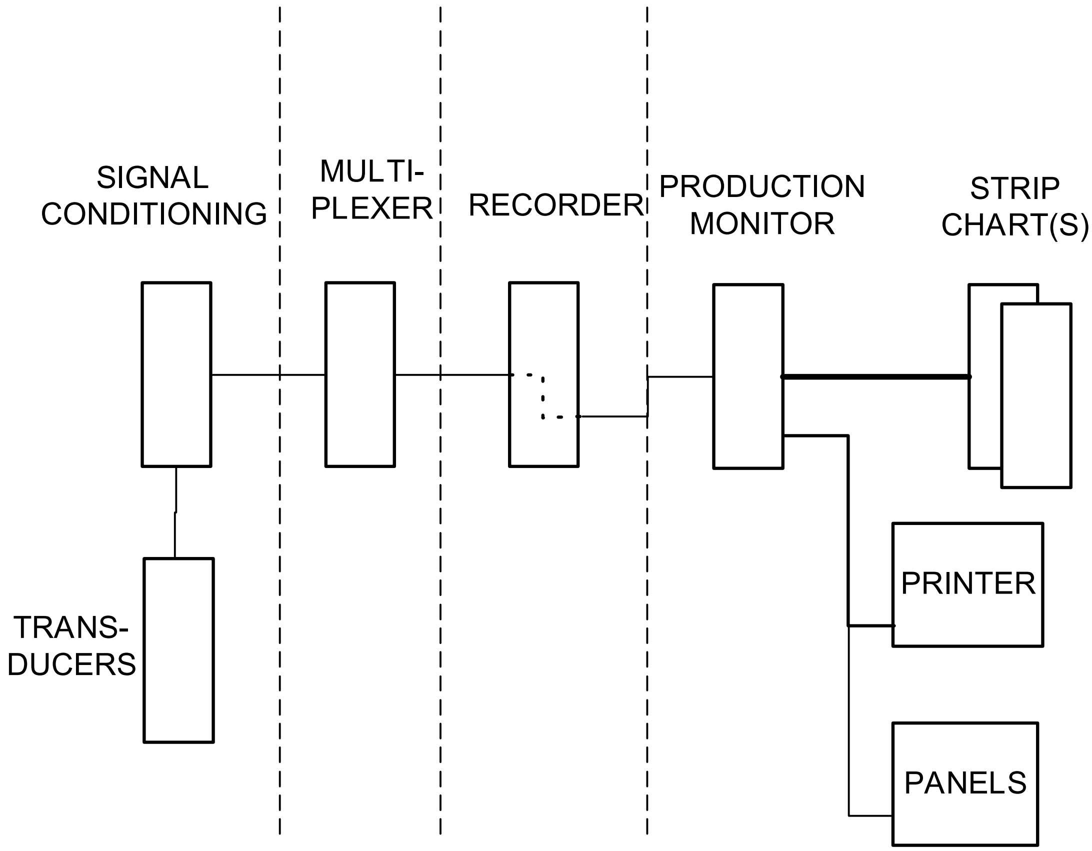

Figure 2 - PADDS II System Block Diagram

Our recording format, the 24 bit format, as described in [1] identifies unique data words by frame, time, and label synchronization. Frame synchronization is accomplished by detection of a synchronization pattern every 513 twenty four bit words. Major Time synchronization is accomplished by verifying the occurrence of Major Time words in the data stream every 10 milliseconds, and string synchronization occurs by tracking minor-time tagged, source-unique labels and their associated data words.

The DEC24 interface can handle a maximum of 42 Mbits/sec (1.75 Mwords/sec) of data directly from the CMUX. With fill pattern turned on and all data words selected, the maximum data rate is reduced to 23 Mbits/sec(.96 Mwords/sec). The interface produces modulated IRIG B and IRIG H time code[2] from major time words that are embedded in the data stream every 10 milliseconds.

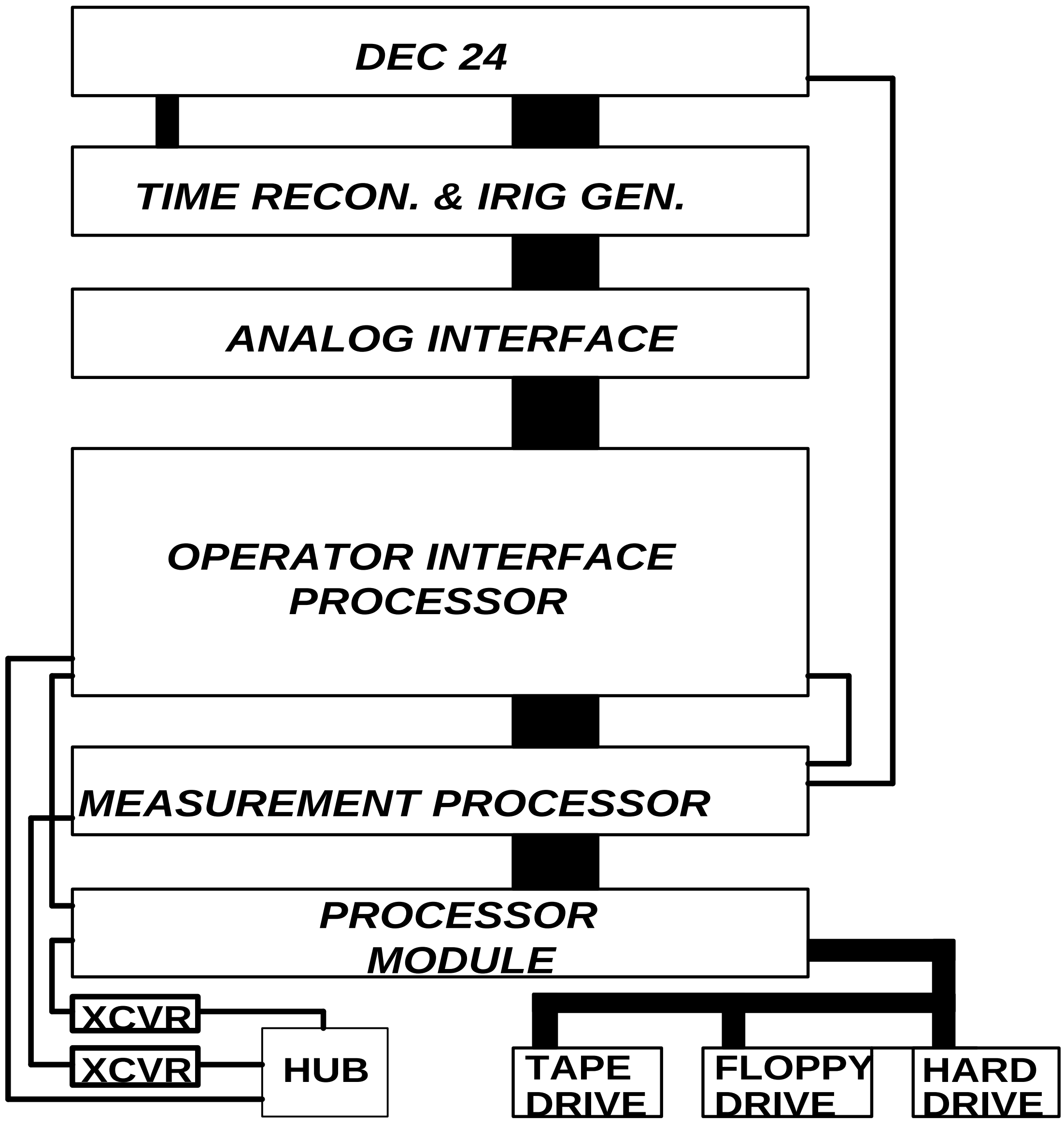

Figure 3 - Production Monitor Block Diagram

The function of converting raw data into engineering units is accomplished on the MP, a 68060-based SBC. We estimate (based upon limited testing) that this SBC's performance will allow us to display 4 channels of data sampled at 200 times per second, processed as Linear Single Section (a 1st order polynomial calibration) on the strip chart recorder. As resources permit we intend to upgrade the hardware to meet our ultimate target of 4 channels at 6400 samples per second.

For peripheral communication, control and data display functions, three special interfaces are provided. A Digital to Analog Converter is provided on the VME bus, giving up to thirty-two channels of analog data for strip charts or modal analyzers display. There are 4 channels of RS 485 along with 4 channels of RS 232 provided on PC104 serial communications cards. These serial cards are installed in an expansion assembly connected to and controlled by the 80486/PC.

An internal Ethernet network is implemented by use of a 5-port Ethernet hub connecting the Processor Module, Measurement Processor, and the Operator Interface Processor. A connection is provided to the outside world for File Transfer Protocol access. Future expansion could include a workstation card set, which would also use this internal network.

The PM is fully flightworthy. It meets cabin-mounted equipment Electro Magnetic Interference(EMI) emissions specification (Modified RTCA DO 160, Sec 21, category B curves) [3], withstands vibration (2.67G RMS 15 min. per Axis), temperature extremes (-15 to +55C), altitude (-15,000 to + 15,000), and shocks (6G and 15G crash safety) found in the often severe flight test environment.

The enclosure minimizes EMI by inclusion of several features: cover fastener spacing, EMI shielding air filters, ferrite cores (as required), and input power filtering. To ensure adequate cooling the unit has three 120 cubic feet/minute fans providing an airflow of greater 175 linear feet/minute per card. The internal components are shock mounted to provide resistance to shock and vibration.

Data flow through the PM begins by the selection of data required to support the test plan. The selected data set for the suite of tests is incorporated into set up files called a Request for Instrumentation Pre-flight (RIP). The PM is “booted up,” set-up files are loaded, and the acquisition system is initialized.

On initial power up, all the processor boards execute internal diagnostics. After the Processor Module and MP diagnostics are complete, they monitor their serial ports a few seconds for a keyboard key-press (in case debugging or diagnostics are being performed). In the absence of a key press, the Processor Module then reads the VxWorks operating system and PM Executive from the hard drive and starts execution. Once the Processor Module is executing the executive, the other processors can communicate with it.

The purpose of the Executive is to provide an interface (“wrapper”) between applications and both the VxWorks and Linux operating systems. The Executive consists of "servers" that communicate over the PM internal Ethernet communication network. The majority of Executive functions are located on the Processor Module. These include job manager, file manager, database manager, master node, datasaver, high-level device manager, print spooler, and MP setup. The operator interface and low-level device manager functions reside on the Operator Interface Processor(OIP).

Upon completion of its diagnostics, the Measurement Processors' processing code is read from its local EPROM, and its execution is started. The OIP loads its Linux operating system from its EPROM disk. A RAM disk is created, and the files required for system operation are moved from the EPROM disk to the RAM disk. Placing Linux in EPROM eliminates the possibility of file corruption and allows Linux to be power cycling tolerant. OIP then requests the operator interface application from the Processor Module, then loads and starts its execution. A partial list of available application programs is as follows:

1) MT (Measurement Trace): Sets up strip chart recorders for data display.
2) DV (Deviations): Calculates deviation from predicted performance.
3) GC/GP (General Calculation): Provides multi-function programmable calculator with real-time data.
4) DO (Discrete Output): Outputs data value when its state changes.
5) AV (Averages): Computes running average, standard deviation, min and max of monitored data
values.
6) PR (Printer history): Prints a list of measurements and their values at an operator-selected rate (e.g. once every 10 seconds).
7) PA (Panels): Drives small numeric displays with mach, altitude, and airspeed values.
8) CM (CMUX Monitor): Provides access to Central MUltipleXer(CMUX) built-in menu system.
9) AQ (Acquisition setup): Sets up the acquisition system to receive desired data.
10) RM (RMUX Monitor): Provides access to the Remote MUtipleXer(RMUX) built in menu system.
11) TH (Time History): Saves lists of measurement values at an operator selected rate.
12) QL(Quicklook): Displays a tabular list of 20 measurements.
13) ED (Editor): Modifies system setup, measurement calibrations, creates or modifies lists.
14) TX (Tape Log Transfer): Saves tape recorder log to floppy.
15) MD (Measurement display): Views measurement definitions.
16) DU (Dump list): Formatted dump of set-up files.
17) SO (Source): Provides data tape playback and time reconstruction.
18) FX (File exchange): Provides file utilities.
19) TU (Tape Utility): Tape controls including Stop, Play, and Position functions.
20) TP (Tape Profiler): Provides a directory of tape contents, start, and stop times.
21) HELP: Displays application users' manuals.

When the operator first enters a command, such as "QL," a series of actions takes place. The job manager verifies that the application is available, loads it into memory from the mass storage device, and schedules it for execution. The operator will then see a prompt appear on the display command line. The operator may then specify a list containing measurements he wishes to view. QL will request setup for the measurements on this list from the measurement manager. The measurement manager requests measurement setup information from the database manager. The database manager accesses the set-up files and returns the information necessary to set-up processing paths.

Measurement management is the process of setting up, replacing, or deleting processing paths. This is a dynamic process and occurs without disturbing the existing data processing paths. Processing paths start in the 24-Bit Decoder Module, go through a Corebus [4] interface to the MP, and end in a Current Value Table (CVT) on the MP.

The 24-Bit Decoder Module is initially set-up to pass or reject selected labels and associated data. Data not rejected is passed to the MP over the Corebus interface. If the operator is looking at recorded data (selected with application "SO"), the 24-Bit Decoder re-constructs the time sequence of the data being replayed. When the MP receives data in raw form, it converts and calibrates it into engineering units. The calibration of data is accomplished by use of a singly linked list of algorithms. Once a datum is identified, it and its processing algorithm starting address is passed to the data processing function. The datum is then acted upon in accordance with the algorithm linked list. The result from this process is up to five tagged (assigned to a unique address for storage) words written into the CVT. These are raw counts, collected counts (syllabalized words), processed counts (floating point representation of collected counts), engineering units (calibrated processed counts), and a time word indicating the time of this datum's processing completion. There is a special class of parameters reserved for the strip chart. If any of these parameters was set-up, the MP scales and converts the EU data word to a form suitable for the DAC, and writes it to the analog interface directly.

After the processing paths are setup, the locations of the measurements in the CVT are passed back to the QL application running on the Processor Module. As QL execution cycles once per second, those pointers are used to read data from the CVT. The data is then formatted for display, and transferred over Ethernet to the OIP, where it is output for display via SuperVGA video output port.

Any number of applications (we have not yet determined the limit) can be executing at the same time. The operator can be monitoring a list of measurements unique to each application on different peripherals simultaneously. Unique sets of data being output to a printer ("DO"), strip chart ("MT"), panel displays ("PA"), and the video monitor ("QL") are available to an operator in real-time. This allows a significant amount of flexibility in the information (and its format) that is readily available during test conditions.

CONCLUSION

The PM airborne data monitor system allows Boeing to conduct flight tests anywhere in the world, with on-site data monitoring and reduction. It is functionally identical to our large certification data monitor system, ADAMS, but is small enough to be quickly installed in production aircraft or a hotel room. PM is a conglomeration of architectures (VME, PC,SCSI, and Ethernet), and operating systems (VxWorks, Linux, and proprietary) integrated into a flight-worthy unit. This solution provides Boeing Flight Test with cross system commonality while preserving the lower cost, smaller size, and flexibility required of a portable monitor system.

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