ON-BOARD DATA ACQUISITION SYSTEM FOR EMBRAER'S CBA123

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ABSTRACT

The 90's will be a challenge to many industries, but in particular to airframe manufacturers like EMBRAER that wish to grow up on a solid basis not only for this decade, but also for the next one. This paper describes the requirements of the on-board data acquisition system and alternatives proposed for the EMBRAER's new 19-seat, twin engine turbo prop commuter aircraft, the CBA-123.

PUTTING IDEAS ON PAPER

EMBRAER's previous experience with on-board data acquisition systems dictated the search for a better design and more advanced technology. Requirements were small size, light weight, modular design, reduced cabling and "easy-to-install" connectors, easy programming and reprogramming by an inexpensive tool (like a PC-computer), in a few words, something that would suit an already-crowded test aircraft in a very tight flight test program.

Basically, the on-board data acquisition system should be capable of:

1. being modular installed in the aircraft, as close as possible to transducers.

2. "listening" to ARINC 429 and CSDB avionic buses.

3. accommodating a high number of analog channels with programmable gain, offset and (maybe) excitation voltage settings.

4. acquiring data from digital sources (such as switches, digital counters, BCD outputs, etc).

5. handling bit rates up to 1 Megabit per second.

6. local programming through connection to a PC computer.

Besides that, a requirement of monitoring engineering data was added to the on-board system, that should additionally provide display and hardcopy of real-tine engineering data (not raw data), to assist flight test engineers aboard the aircraft in analysing and validating test maneuvers (their “own ground station”).

All this, if possible, should speed up the certification of the aircraft, allowing the company to reach the actual production phase as soon as possible, reducing development cycle (time) and nonrecurring costs (money).

The next paragraphs shall illustrate in more detail some requirements of the on-board data acquisition system and for its new aggregate, the on-board data display system. Starting from a more general requirement, a specific “feature” is addressed and an alternative to its implementation proposed. All these “features” were part of the on-board systems specification and will be available when the systems are delivered.

REQUIREMENTS OF THE ON-BOARD DATA ACQUISITION SYSTEM

o LISTENING TO AVIONIC BUS DATA

The ARINC 429 and CSDB avionic buses presented a “small” problem regarding the length in bits required by some of their “labels” or “addresses”:

1. the ARINC bus delivers up to 20 bits of usable data.

2. the CSDB bus delivers up to 32 bits of usable data.

Instead of increasing the PCM word length to 16 bit, which would also increase the overall bandwidth, bus listener cards should allow extracting variable length “bit fields” from anywhere inside a valid range (1 to 32 for the ARINC 429 bus, 1 to 64 for the CSDB bus), and encoding them into a number of “fixed-length” 10 or 12 bit-long PCM word (see Figure 1).

The process of getting those “bit fields” back in the right order (something that EMBRAER Ground Station software already does) should be transferred to the data acquisition software module running in the on-board data display system.

- THE “LEFT-RIGHT” BIT-DECISION ON ARINC 429 BUS

Some ARINC labels use a two-bit field addressed as “Source Destination Information (SDI)” bits to separate two different sources of data (such as “left engine data” from “right engine data”).

selection of bus data according to its “SDI” bit configuration, separating data sources right inside the data acquisition system, should avoid the use of software (in on-board or in ground station systems) to performing data “decommutation” based on this 2-bit field.

Therefore, the ARINC 429 bus listener card should allow the engineer to enter the desired SDI-bit-combination, so that only labels containing the pattern match should be encoded into the PCM stream.

- INCREASING CHANNEL CAPACITY

To reducing as much as possible the overhead on “reprogramming” the on-board data acquisition was a great concern: such an operation might reduce the speed at which changes could be introduced in the airborne instrumentation.

On the other hand, the so-called “merged” systems offered a very comfortable and modular solution, but normally required extra attention to major frame design and channel distribution on each system to be merged.

The on-board data acquisition system programming software should provide for transparent word sequencing only by their system (box, slot, etc) and their word/frame location, even when data is to be encoded in different systems.

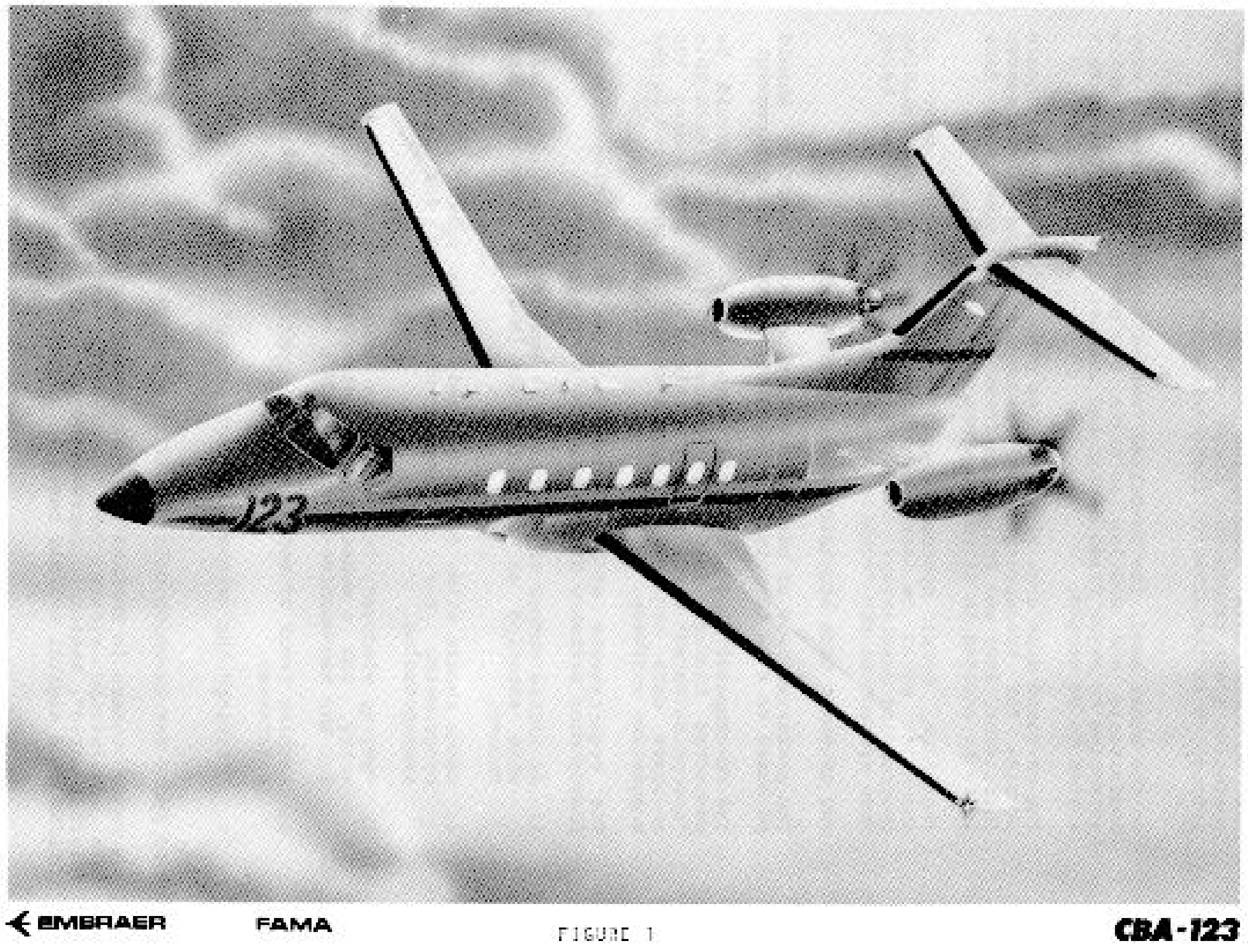

FIGURE 1

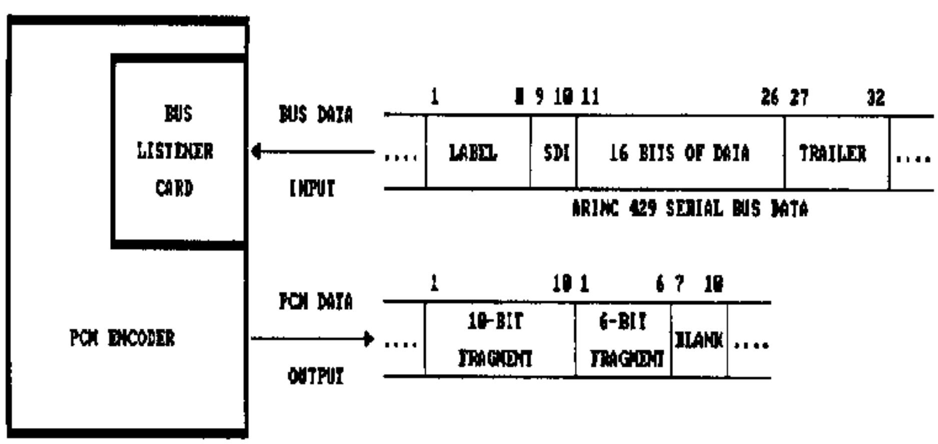

Figure 1 - Bus Data Extraction

Therefore, total system capacity in terms of “number of channels” could be increased without proportionally increasing programming complexity: the whole system should look as being “one system” to the “outside world” (see Figure 2).

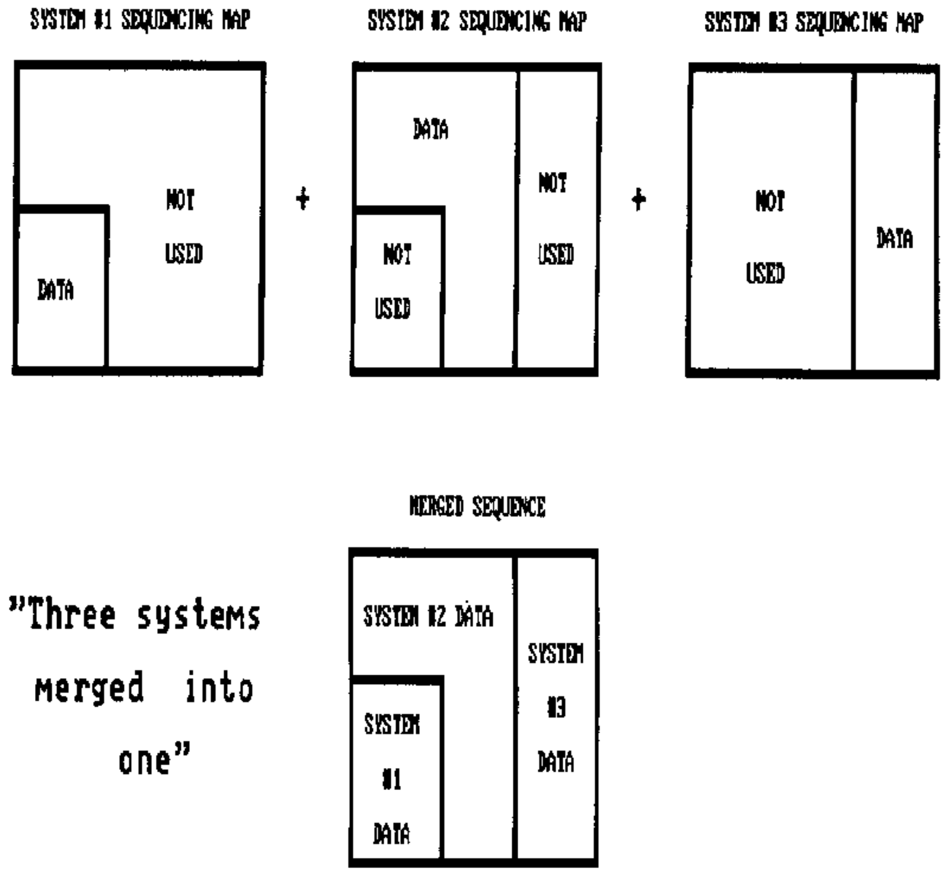

Figure 2 - An alternate merging

o THE ON-BOARD DATA ACQUISITION SYSTEM PROGRAMMING

The preferred type of hardware performing this function should be based on a PC computer that would “tolerate” the environment.

The PC-computer and the data acquisition system should be connected through serial communication (RS-232). With this “unsophisticated” hardware, the complexity of programming the on-board data acquisition system should be transferred to the supporting software.

The requirements of the on-board data acquisition system programing software should stick to simple rules:

1. as little number of keystrokes as possible should be used when entering or modifying data (edit “old”, modify, save “new”).

2. menus should allow for fast access to a specific channel programming for a small change and for immediate reprogramming.

3. “pop-up windows”, from which an user should pick up an entry, and a mouse should be strongly recommended features for the man-machine-interface (MMI) design.

4. keeping track of modifications (“configuration control”) in a database.

5. “listing” the database through printed reports.

MORE ABOUT THE ON-BOARD DATA ACQUISITION SYSTEM

One major concern in EMBRAER’s specification for the new on-board data acquisition system for the CBA-123 was clearly toward the “digital world”, basically represented by the ARINC 429 and the COLLINS CSDB digital avionic buses.

Requirements and capabilities of analog signal acquisition modules were not even mentioned, and that for a good reason: most of the features of such a module are already settled and completely exhausted, except (maybe) size and weight.

Data acquisition modules for digital sources can be more easily designed to meet specific requirements, such as ARINC data fragment extraction and ARINC data selection by looking specific SDI-bit pattern match, as defined by EMBRAER for the CBA-123 program.

Following the same principle, there are also future plans for a “totalizer” nodule specification that shall take information such as “fuel flow” from the ARINC 429 bus and integrate it along the time.

Another major concern was to adapt ourselves to “merged systems”, since we were accustomed to “master and slave” system design.

Basically, the engineer should only worry about correlation between word/frame location and subsystem/ box/slot/... location, the rest should be taken care of automatically. The actual solution is generally made at the merged system programming software level, where the actual “sampling sequence” is encoded.

Using a PC-computer to running the system programming software was derived from previous experience with “special programming boxes”, in general uniquely designed and very expensive, and still requiring some sort of “compiler” run in a ground station computer.

Inexpensive equipment, such as a lap-top PC, cuts hardware costs at once. The remaining software costs shall be shaped around user (engineer or other technical people) needs, but the benefits of a PC platform are evident: it is programmable in a number of high level languages, has a great number of support software in the market, and can easily be connected to other computers, such as the VAX.

All these new features shall greatly improve the daily operation required in a flight test program from technical personnel involved with the on-board instrumentation, after all, the whole system shall use a total of 21 data acquisition boxes connected together in 4 subsystems merged into a special merging box, making a total of 900 instrumented channels from 7 ARINC buses, 13 CSDB buses, 90 thermocouples, 40 discrete inputs, 7 scanivalves and 320 high and low analog inputs.

REQUIREMENTS OF THE ON-BOARD DATA DISPLAY SYSTEM

- SINGLE HARDWARE PLATFORM

  The same PC-computer used for programming the on-board data acquisition system should be used for the on-board data display system.

- INTERFACING WITH THE GROUND STATION DATABASE

  EMBRAER keeps track of modifications in the airborne instrumentation configuration in a large database residing in the Ground Station cluster of VAX computers. The database management software should be redesigned to supporting the new instrumentation equipment and to providing an interface to the remote database located on-board the aircraft.

  A removable media (cartridge, floppy disk) loaded in our Ground Station with all necessary information to programming the on-board data acquisition system and displaying real-time engineering data should be taken to the test aircraft and used for loading a “remote” database in the PC-computer.

- SPECIAL FEATURES

  REASSEMBLING DATA FRAGMENTS

  Once the on-board data acquisition system had “split” data words acquired from ARINC 429 and CSDB buses, and encoded then into the PCM stream, a data acquisition software module should provide for the “reassembling” of the original bus data word transparently to the engineer before scaling and displaying it.

  DIRECT TEMPERATURE TRANSFORMATION FOR THERMOCOUPLES

  Due to the number of temperature readings, instrumentation technicians chose using thermocouples connected to a single reference junction in order to keep a low “dollar-per-channel” ratio.

  Therefore, the data acquisition software module should provide reference junction compensation for at least two different thermocouple types (“K” and “E”), so that engineers could directly monitor temperatures in “degrees C” (or “degrees F”).

  EMBEDDED TIME SUPPORT

  Time correlation is essential to an engineer in most circumstances (such as a following aircraft behavior after a “rudder kick”), so that “mission time” should always be available with other displayed data.

Since BCD output is normally available in airborne time code generator units, so, “copying" time digits from it should fall strictly under normal on-board data acquisition hardware requirements concerning digital signal sources.

There should be support for defining “syllables" inside the PCM stream containing time information (hours, minutes, seconds and miliseconds) to be assembled together and interpreted by the data display system as the source for “mission time”.

- WORKING WITH ENGINEERING UNITS

  Engineers should monitor data in engineering units, therefore raw data should be scaled before being displayed using basically two different types of algebraic transformations

  1. Polynomial - from first (“linear”) to the third degree, at least.

  2. Linear Interpolation - using data pairs taken from a lookup-table.

  The last one is very important because it provides an alternative to “polynomial fit" when calibration data is not a “smooth” line (such as from position reading potentiometers connected to mechanic systems), and also an easy way of “scaling” weighted sign-magnitude or two’s-complement data from the avionic buses.

- REAL-TIME DISPLAYING TEST DATA

  Display styles should be defined according to the nature of the data monitored:

  1. alphanumeric displays of the “bar-chart” type for up to 8 different channels at the same time, for slow changing data.

2. status displays (“ON/OFF”, “UP/DOWN”, etc) for up to 16 discrete outputs at the same time.

3. scrolling graphics for up to 4 different analog channels at the same time, for fast changing data.

In all displays, “mission time” should be displayed at the top, and there should be support for quickly redefining which data should be displayed, so that the engineer could select whatever suits him at any moment during a test.

- HARD-COPYING TIME HISTORY DATA

Engineers would appreciate if data monitored on-board the aircraft could be hard-copied on paper and included in their flight test reports.

The most popular hard-copy produced at EMBRAER’s Ground station is called the “EU Strip Chart”, a simulation in engineering units of a standard strip-chart recorder, only done with a VAX computer on a VERSATEC printer.

Advantages are obvious, and an alternative to the “EU Strip Chart” (at low cost of CPU power) could be achieved on-board by using a D-to-A card connected to a strip-chart recorder using a scaling feature which would allow the engineer to associate EU values to the full range of the D-to-A card (for instance, +5 to -5 Volts).

Installing a laboratory rack-mount type of strip-chart recorder was investigated, and with no surprise EMBRAER was not the first company using one aboard a test aircraft without any special mechanical design, besides shock-mounts.

- RECORDING TEST DATA

The need for having records of flight test data is unquestionable, so, displayed data should also, as much as possible, be recorded for quick reviewing, specially if a data analysis program is at hand.

There should be support to record engineering data during small portions of a test flight (“time-slices”) in disk files. The data to be recorded should be selected by the engineer among those of interest for a specific test.

The format of the disk file should be compatible with a known data analysis program for quick “importing” of test data.

MORE ABOUT THE ON-BOARD DATA DISPLAY SYSTEM

The major concern in the specification for the data display system was mainly “closing the loop”, that is, once the data acquisition system is programed, the PCM data generated can also be monitored inside the aircraft, preferably in the same computer used for the data acquisition system programming.

Advantages are obvious, specially if the data acquisition and display software have features available in the past only at EMBRAER’s ground station systems, such as engineering data display and recording, reference compensation for thermocouples and time history plots, a great benefit to technical personnel involved in preparing and checking the on-board instrumentation, so scaled data can be checked immediately without involving the ground station.

For flight test engineers, test evaluation shall be facilitated, since one may look at engineering data in real-time, record test data during portions of a flight and look at time history data in hard-copy.

For the CBA-123 flight test program a COMPAQ 386/25 shall be used for both on-board data acquisition system programming and on-board engineering data display system. It shall be equipped with a Math co-processor, enhanced graphics adapter, fast graphics co-processor, data acquisition hardware and serial communication ports. An 8-channel D-to-A converter card shall be used connected to a thermal-array type strip recorder for hard-copying time history data.

The data display system shall be completed when a data analysis software package is available for analysing flight test data, and when more automated instrumentation checkout procedures are developed.

The current system design provides an “open door” to these future enhancements.

A FINAL WORD

Since the beginning of the EMB-120 “BRASTLIA” flight test program EMBRAER has invested a great deal seeking out new technology to supporting the Flight Test Division in its continuously growing needs for more and more efficiency in conducting flight test programs. The CBA-123 project demanded again new investments in flight test instrumentation and ground station equipment, but that shall revert to the company in production cost savings and higher competitivity.

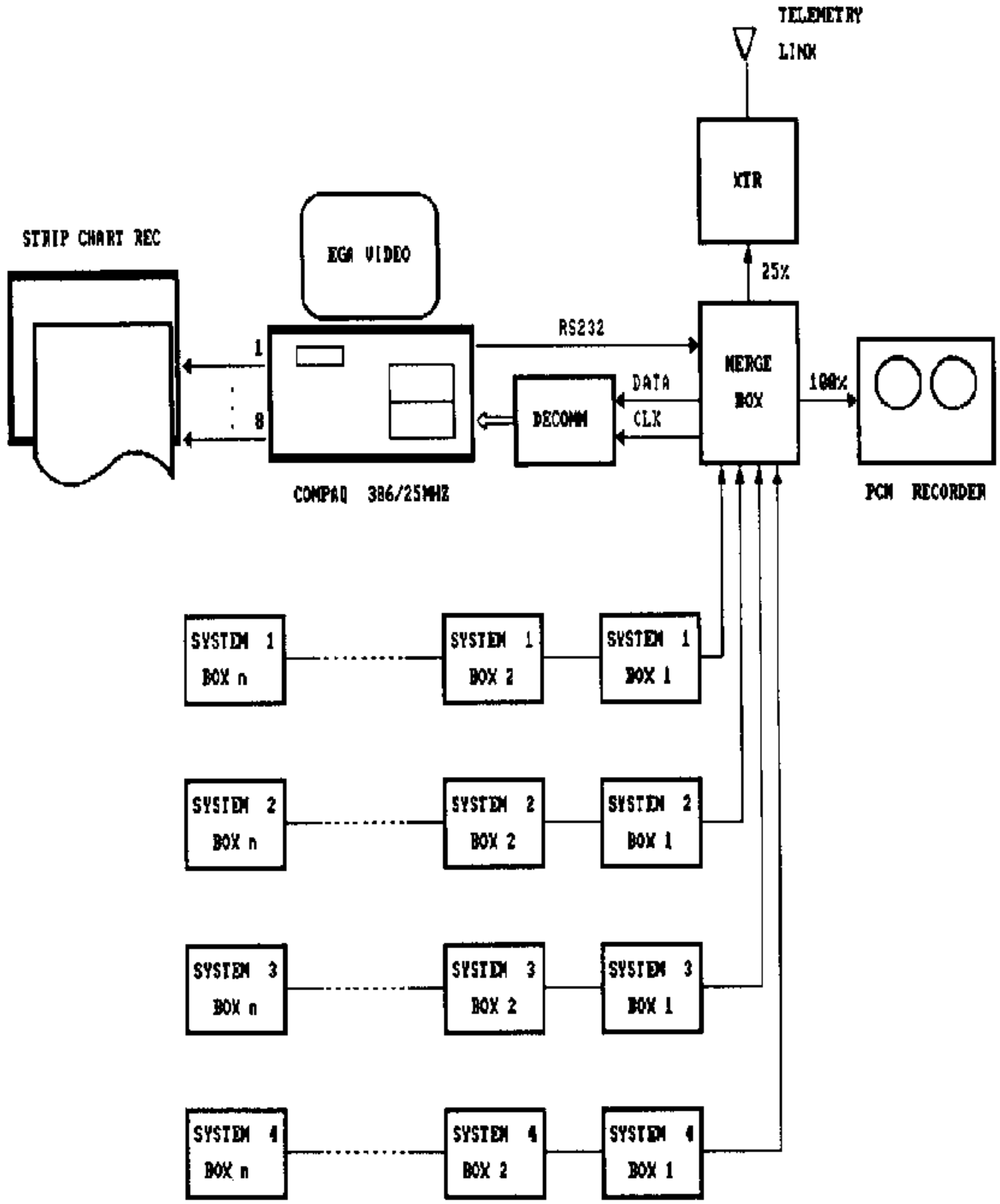

Figure 3 - System Block Diagram