Real-Time System Measures Aircraft Flight Characteristics

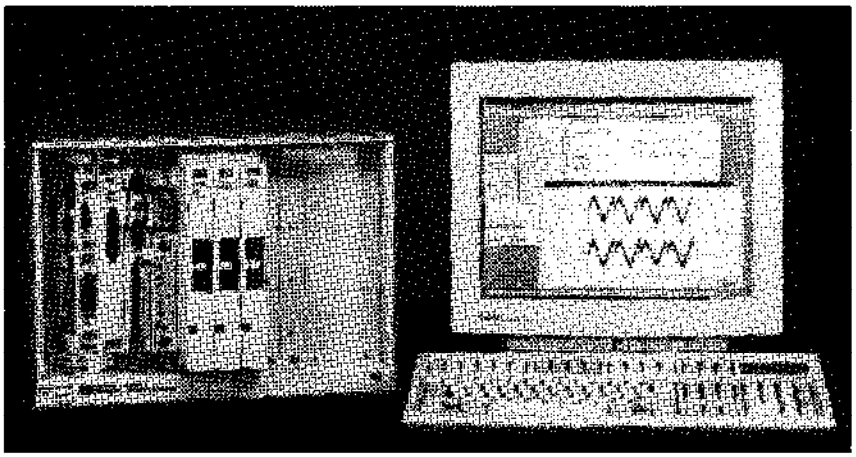
Application Note 1253

Overview

Symmetrix, an HP Channel Partner, is supplying a real-time data acquisition system to Flight Safety International, for use in measuring the flight characteristics of commercial aircraft. Flight Safety, the largest provider of private and commercial pilot training, is a major developer and user of virtual reality training systems. Developing these systems requires that all flight characteristics of the aircraft be accurately measured for realistic simulation.

The acquisition system provided uses a combination of HP VXI modules and EPC-7 computer (VXI based) running the Lynx real-time operating system to acquire the aircraft signals. The heart of this system is two HP E1413A ADC modules, which can acquire data from over 1OO sensors. These are augmented by modules which monitor the ARINC-429 communications bus (from the flight computer and laser gyro), measure engine RPM, record airframe torque, monitor fuel flow, and record discrete events such as landing gear up or down.

The software structure is unusual in that a separate portable PC is used to define all parameters associated with data collection, and to display the measured data. This PC communicates with the EPC-7 over LAN, via file sharing over NFS and a socket interface to transmit commands. Using a separate PC off-loads the EPC-7 and prevents operator reporting, printing or user interface operations from interfering with data collection.



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Introduction

When analyzing the performance of a physical device or system, there is a need to accurately measure its operation under varying conditions. In some cases, it is possible to measure the desired parameters individually, repeating the test conditions until all parameters are observed and recorded. However, in many cases the test conditions only occur once (such as in a destructive test of the device), or the conditions are expensive or difficult to repeat (the in-flight characteristics of an aircraft). For these cases, all data must be accurately acquired in real-time, and correlated to assure time alignment without missing data.

The system described in this application note is used to fully measure and quantify the flight characteristics of commercial aircraft. The data recorded is used to construct an FAA certified simulator for pilot training by matching the simulator response to the data acquired during flight tests. This results in the following requirements for the measurement system:

- Highly accurate and repeatable measurements, traceable to national standards (FAA certified system).
- Real-time acquisition of several hundred signals, accurately time tagged, with no missing data.
- Variable, independent sample rates up to 1000 samples/sec for each signal input.
- Compact size and low (DC) power for operation from batteries in small aircraft.
- Immediate display of measured parameters in engineering units (linearized), allowing the flight engineer to determine if a test should be repeated.
- On-line calibration and self test to determine if the system is operational and within specification.
- Data analysis system to manage the extensive amount of data (over 1 Gbyte per aircraft) accumulated by the system, and generate meaningful reports for use by the FAA and simulator design engineers.

The hardware requirements are satisfied through the use of HP VXI modules and an embedded VXI computer. This computer, which is controlled by a real-time operating system, provides the guaranteed response time required to assure no data is lost.

System Hardware

The hardware used for a real-time data acquisition system is generally based on the needs of the measurements being made, and varies between applications. The primary requirements for the measurement hardware are:

- Condition the input signal to minimize noise, and make an accurate measurement.
- Sample at the required rate and in a deterministic manner (so the time for each sample can be determined).
- Buffer the measurements to minimize loading of the computer and resolve contention when multiple signals are sampled simultaneously.

An overview of the hardware used for recording aircraft performance is shown in figure 1, consisting of a data acquisition system (on the aircraft) and a data analysis system (for data reduction on the ground). The heart of the system is the VXI chassis, which contains the following modules:

ADC—Most signals (all voltages) are sampled with the HP E1413A high speed ADC. This unit is a 100 Ksa/sec ADC, preceded by a 64 input multiplexer. Key specifications include 16 bit resolution with autoranging, autocalibration, selectable signal conditioning, programmable sampling sequences, and 64K sample output buffer.

Synchro—The Transmagnetics 5410C-47 synchro/resolver module measures angular displacements for up to 8 inputs. The instantaneous angle is reported as requested by the computer.

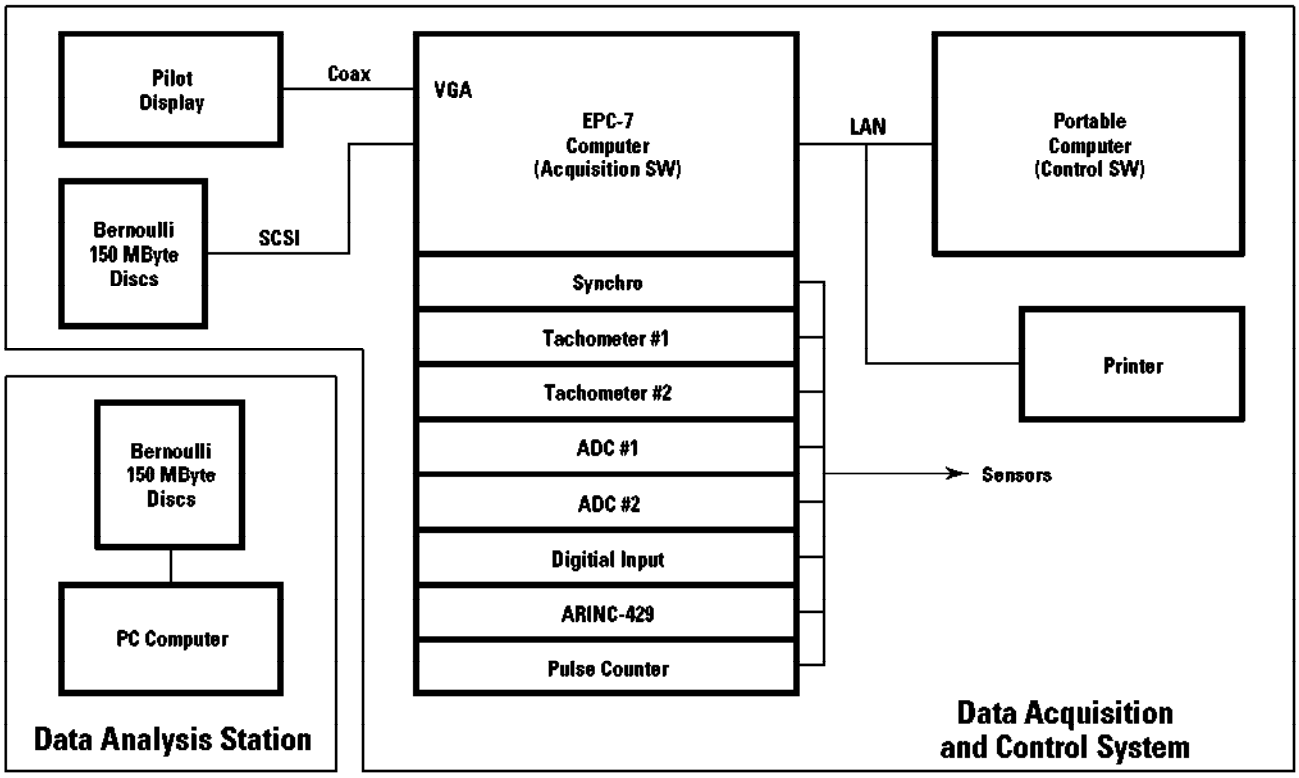

Fig. 1 Hardware overview for recording aricraft performance

Tachometer—The HP CENC-TAC8 module provides high speed tachometer measurement capability for signals such as engine RPM. This module includes 8 input channels with built in signal conditioning and pulse counting to 100K pulses/sec. A 512 measurement output buffer minimizes loading of the computer.

Counter—The HP E1332A counter/totalizer continuously measures the fuel expended during a flight (in order to compute parameters such as aircraft weight and center of gravity). This counter has differential inputs, built in filtering and programmable threshold level for signal conditioning.

ARINC-429—The HP TASC-429 module monitors all traffic on the ARINC-429 avionics bus, filters this data based on message type, and records all messages of the selected types. The module includes a 1000 message buffer to minimize loading of the computer.

Digital—Digital inputs are monitored using an HP Z2404A 64 channel isolated digital input module, which interrupts the computer when an event occurs on one of the lines being monitored. The hardware includes selectable input threshold levels, and programmable (hardware) debounce.

IRIG B—Time stamping of the measurements to IRIG B is handled with the HP BANC-350 module, which returns the time-of-day as commanded by the computer.

The majority of these modules are register programmed, allowing them to be commanded by the computer using memory-mapped operations. This results in minimum overhead or loading of the computer resources. (Note that programming is handled with standard SCPI style messages, and translated to register calls through the HP Compiled SCPI driver routines).

The system operates in a mechanically harsh environment on an aircraft (high vibration), which is a problem for reliable disc drive operation. The system software operates from a shock mounted HP 2247 disc drive (1 Gbyte), which is a relatively rugged 3.5" unit. All test data is stored to a Bernoulli disc (not shock mounted) which is relatively immune to vibration (the drive is too small to use for the main software disc).

Note the use of two computers in the system. The EPC-7 is limited to real-time acquisition of the input signals and pilot display. All data reporting and control, which are compute intensive operations, are relegated to a separate (portable) computer. This prevents operator interactions and reporting from impacting the data acquisition process.

System Operation

User control of the system is handled at the portable computer with a Windows style interface, written in Visual C++. An elaborate set of menus are provided which allow all signal parameters to be specified, including:

Physical Connections—Pin used to connect each input signal, and the label used to refer to this signal.

Signals—Measurement parameters for each signal, based on the type of signal, such as bandwidth, input threshold, units, expected limits and a table of correction factors (to linearize and convert to engineering units).

Measurements—List of the signals to be measured for a particular flight configuration or profile, and the associated sample rate for each signal (the signals are sampled at programmable rates to minimize data storage requirements).

Reports—Format of the (graphical) reports generated, including plotting measured signals versus each other or over time.

After all data collection parameters for the flight are specified, a particular measurement run is initiated by the operator from the PC. This begins collection of 'pre-test' data for all parameters (stored in a circular buffer), then ends when the pilot indicates the aircraft is stable and the test is beginning (signaled by a mechanical start switch). The data for all signals defined are then collected and time stamped until the run is halted by the operator.

Data collection is performed entirely by the EPC-7 computer, running the Lynx (real-time) operating system. Note that the signal collection parameters defined by the operator are accessible over an NFS network both by the EPC-7 and the PC, and this data is loaded into memory by the EPC-7 at the start of a flight. A socket interface is used to send commands between the two computers, while most data is passed using shared files.

A data measurement run is initiated when the PC sends a command to the EPC-7 to start collection. This computer then starts each VXI module to begin data collection, and generally polls the modules to determine when data is available. The digital input mode is an exception, as it has no buffering, and is serviced on an interrupt basis. The guaranteed response time of the Lynx operating system (70 µs) prevents data from being lost, as the digital inputs change less than 100 times per second.

The data collected is stored in EPC-7 memory initially, where it can be easily accessed by the PC (via socket commands) for real-time reporting purposes. The data in memory is handled as a circular buffer, with the oldest data discarded as more space is required. This data is also copied to (Bernoulli) disc for long term storage and off-line data analysis.

System Calibration

A typical problem in the past for data collection systems of this type has been calibrating the system to achieve accurate measurement results. This has required adjustment of the final output data recorded for variations in gain and offset over time. Since a flight can run for many hours, with a wide range of temperatures and altitudes, these corrections vary over time and are difficult to estimate accurately.

Calibration for these errors is handled automatically by the VXI modules in this system (primarily the HP E1413 ADC), with a built in calibration which is executed once at the start of the flight. The ADC is sufficiently accurate and stable over time, temperature, and altitude so that no corrections are required (errors associated with the VXI hardware are negligible).

The primary error sources in the resulting system are the transducers (thermocouples, strain gages, pressure transducers, etc). These are calibrated in two ways. Sensors to measure conditions such as flap position, which must be calibrated after mounting on the aircraft, are measured using precision standards (to set the position) and software to automatically acquire and store the correction factors. Other sensors (such as temperature) are calibrated off-line and the correction factors supplied to the software.

Virtual Signals

A unique capability of the system is the ability to measure signals which are not physical, but derived from other measured signals. These do not need to be defined in software previously, but can be selected on the fly by the operator.

The operator interface screens provide the capability to enter a set of equations for manipulating any measured data. These can be linearized as well with an interpolation table for non-linear corrections, and converted to other units. This allows the operator to easily display and analyze simple parameters (such as summing left and right pedal force to view total force), as well as more complex parameters (such as alpha) which are computed from multiple, independent types of signals.

Data Analysis

The data collected for an aircraft is very extensive (over 1 Gbyte of data) and must be analyzed to assure it is correct, then archived for future reference. This is handled with the data analysis system.

Data collected from each flight is stored on a 150 MByte Bernoulli disc . This is a removable cartridge media, which allows the data collected to be carried easily from the aircraft to the analysis station at the end of each flight. The data is then copied from this disc to an HP optical disc for long term storage. An HP optical stacker is used for this purpose, which allows automatic access to data from multiple aircraft (up to 20 Gbytes).

The analysis station provides the capability to generate both engineering and final (FAA) reports for all data collected. These reports are plotted to an HP 4si LaserJet printer.

Summary

The use of HP VXI modules and a real-time VXI computer, combined with the appropriate control software, provides a high performance solution to the problem of real-time data acquisition. For more information about the hardware and software used to configure this solution, please contact Symmetrix at (512) 328-7799.

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