ADVANCED INSTRUMENTATION FOR ADVANCED AIRCRAFT

David Penharlow
Applications Manager
Aydin vector Division
47 Friends Lane
Newtown PA 18940-0328

ABSTRACT

Advanced aircraft require sophisticated instrumentation system designs. New concepts incorporated in distributed data acquisition systems allow the flight test instrumentation engineer a selection of hardware with reduced size and weight, which requires minimal vehicle wiring between components. Improved accuracy and resolution are additional benefits of the distributed data acquisition systems described in this paper. These systems, currently being delivered by Aydin Vector for several major flight test programs, allow conditioning and encoding to be achieved near the sensors through a variety of remote units. The remote units for these applications differ as the measurement requirements and test program requirements differ.

We will examine the distributed data acquisition systems used for several test vehicles and briefly describe vehicle for test program requirements which led to unique designs. The systems described for these applications are variations of the Aydin Vector ADAS-7000 System. The common element for these systems is the PMU-700 Programmable Master Encoder.

INTRODUCTION

Aydin Vector provides a family of distributed data acquisition systems which are used primarily for flight test instrumentation. These systems are identified as ADAS-7000 systems. These ADAS-7000 systems consist of a PMU-700 Programmable Master Encoder and one or more remote units.

The PMU-700 Programmable Master Encoder is the controlling element of a distributed data acquisition system. The PMU is programmed through an RS-232 port and contains EEPROM memory for storage of instructions which can be used for gain, offset, and formatting of all channels in the system. The PMU-700 can be used with up to 24 remote units located through the vehicle. Bit rates to 2 MBPS and analog encoding to 12 bit resolution are available features. The architecture of these systems is a star structure with 5 two-conductor cables from the master to each of the remote units. This serial digital communication is achieved through the use of differential line drivers and differential line receivers similar to RS-422. A failure in any remote unit will not effect any of the other data.

Standard options for the PMU-700, which have been developed as part of the programs described in this paper, include a built in time code generator, tracksplit for reduced tape recording time, built in test, and special output formatting to a computer and 9-track digital tape.

The family of remote units which can be used with the PMU-700 have been expanded to include the following:

a. MMP-900 Microminiature PCM Encoder
b. RSU-700 Remote Slave Unit
c. CEU-901 Rotating Conditioning Encoder
d. CEU-902 Non-Rotating Conditioning Encoder
e. SSC-900 Super Signal Conditioning Unit
f. ARU-800 Analog Remote Unit
g. DRU-800 Digital Remote Unit
h. PBM-1553-RS Programmable Data Bus Monitor
i. PBM-1773-RS Programmable Fiberoptic Bus Monitor

We will now examine several unique flight test applications of the ADAS-700 systems which led to the development of this family of remote units.

CASE NUMBER 1

The vehicle being tested is a solid rocket booster used for space launches. The instrumentation requirements include conditioning and encoding of strain gages, bridge type transducers, resistance temperature devices and thermocouples. The hardware being supplied for this application required the use of high-reliability components and space qualified connectors.

The desired signal conditioning for bridges included constant voltage excitation with individual regulators per channel for fault isolation. Amplification and two-pole pre-sample filtering was required per channel for these measurements. Solid state shunt calibration was desired to ensure proper operation under the high shock conditions of launch. Resistance temperature devices required multiplexed constant current excitation to minimize self-heating and to compensate for the resistance of the long wire runs.

Conditioning for Platinum-Rhodium thermocouples was required for high temperature measurement. Small isothermal reference junctions were desired which would allow the conversion from thermocouple material to copper material to be achieved near the sensor to minimize the use of thermocouple wire through the vehicle.

A sophisticated built-in-test system was desired to ensure the proper operation of the entire system during flight. An integral time code generator was desired which could be preset to zero at some time prior to launch.

The design was implemented using a modified PMU-700 Programmable Master Unit and RSU-700 Remote Slave Units. The flight configuration consists of one master and three slave units per solid rocket booster. The PMU-700 contains the ability of conditioning local parameters in addition to interfacing with the remote units. The RSU-700 units accept up to 15 plug-in conditioning cards. The conditioning cards which can are used in the PMU and RSU's are identified below:

a. Bridge Conditioning Card - contains the signal conditioning circuitry for 8 bridges. The card also contains shunt calibration circuitry using solid state devices. The bridge conditioning is achieved through four PDF-203 hybrids. Each hybrid provides two channels of instrumentation amplifier and two-pole Butterworth filtering. The filter outputs are multiplexed on the conditioning card and applied to the sample-and-hold and analog-to-digital converter card.

b. Resistive Temperature Device Conditioning Card - contains the signal conditioning circuitry for 16 resistive temperature devices. The design uses multiplexed constant current excitation to the sensors and multiplexes the signals from the RTDs. This technique is used with sensors up to 300 feet from the conditioning encoder. The multiplexer output is applied to the sample-and-hold and analog-to-digital converter card.

c. Thermocouple Conditioning Card - contains the signal conditioning circuitry to interface with up to 16 thermocouples which have been converted to copper wire in a CJC-900 Isothermal Reference Junction. This card accepts the reference signal from the CJC and corrects the data for the temperature of the reference.

The BITE system operates as an internal real time monitor which compares the digitized signal with the expected digital signal for up to 128 parameters in the system. Several channels are connected to a precision reference input which is conditioned, encoded and used for BITE. The encoder is programmed through the RS-232 port for the expected value of the digitized signals for these references. This technique ensures that all components of the system are operational. The following items can be checked using this technique:

a. Bridge excitation
b. Amplifier-filter gain/offset stability
c. Programmable amplifier stability
d. A/D converter stability

The BITE signals are programmed for "destination" through the RS-232 port of the PMU. Seven discrete BITE output signals can be used in addition to a composite BITE signal which ensures that the entire system has passed all tests. These signals can be incorporated into the output format under program control and are also available as discrete outputs for use by other systems.

A time code generator is incorporated into the master unit which operated in a preset to zero mode at some point prior to launch. The generator counts up from zero and outputs time of day in IRIG format. The time data can be inserted into the PCM data stream under program control. A serial-IRIG B signal (modulated and unmodulated) is also provided.

CASE NUMBER 2

The vehicle being tested is an European advanced fighter aircraft which is being instrumented for technology update programs. The instrumentation requirements for this program are typical of aircraft flight test programs. An advanced system was desired with minimal ground time and software control over pre-flight operations. A triple data bus monitor was required which would interface with a fiberoptic version of MIL-STD-1553. Custom missile interface units were also required which would interface to the vehicle missile systems. An advanced cockpit display system was required which provided engineering unit display of parameters in minimal panel space.

The design was implemented using a modified PMU-700 with a new signal conditioning unit with software control. The PBM-1553-RS was modified for use with fiberoptic inputs. Two custom remote units were created for this application. A new cockpit display panel was created.

The signal conditioning remote unit designed for this application is the SSC-900. The SSC-900 uses the Aydin Vector SSC-2008 Super Signal Conditioner. The SSC-2008 is a hybrid device which offers the following features:

a. Dual tracking constant current sources.
b. Programmable constant voltage source from 1 to 12 Volts with 4096 steps.

c. Programmable bridge balance with 4096 steps.
d. Programmable amplifier offset with 4096 steps.
e. Programmable gain amplifier with 16 gains (non-binarily related).
f. Selectable 6-pole low-pass Butterworth pre-sample filter (one of four pre-set values).
g. A sample-and-hold amplifier and 12-bit analog-to-digital converter.

The SSC-900 signal conditioning remote unit consists of 32 plug in conditioning boards. Each board contains the SSC-900 hybrid and calibration relays. The SSC-900 also contains the required serial digital interface to be a remote unit to the PMU-700. The SSC-900 contains an RS-232 interface and EEPROM memory for programming and storage of the software controlled parameters.

The PBM-1773 Programmable Data Bus Monitor is capable of monitoring up to 3 fiber optic data buses with MIL-STD-1553 data. The unit is capable of monitoring up to 240 complete messages (of 32 words) from each of the data buses. Each selected message is stored in Random Access Memory. Individual 1553 data words are extracted from memory when addressed from the PMU-700 master encoder. The 1553 data is returned to the PMU-700 in serial digital form.

The advanced cockpit display system consists of an Arithmetic Processing Unit (APU-700) and a Cockpit Display Panel (CDP-700). This display system is designed to interface with the PMU-700 master encoder and provide 16 parameters in engineering units to the pilot or flight test engineer. Switch selection is used to allow four groups of four channels to be displayed along with the units.

CASE NUMBER 3

The vehicle being tested is a tilt-rotor aircraft which takes off as a rotary wing aircraft, transitions from vertical to foreward flight through the use of tilt-rotors, and flies as a fixed wing turbo-prop aircraft. The instrumentation requirements for the vehicle are typical of a rotary wing aircraft with a large number of strain gages and thermocouples. Many of the strain gages are on the rotor blades which require precise phase correlation.

Flight tests will be performed onboard aircraft carriers in a severe EMI/RFI environment. Operation of the complete system in an RFI field of 10 volts/meter is required with no degradation of data. Connectors with RFI contacts were required to ensure compliance with the specification.

The system was implemented using the modified PMU-700 and two new remote units (CEU-901 and CEU-902). The system was modified for operation to 2 MBPS and incorporates a high speed programmble gain amplifier in the master and remote units. The high bit rate output was split into four PCM data streams at 500 KBPS to allow tape recording at lower rates. The PMU-700, CEU-901 and CEU-902 employ 115 VAC 400 Hz power supplies for this application instead of the more typical 28 VDC.

Each remote unit contains 16 plug in conditioning boards which can be configured for voltage or current for a total of 64 channels per unit. The high level outputs of the conditioners are multiplexed and applied to the high speed programmable amplifier for limited software control of gain and offset. The normalized signal is digitized to 12-bit resolution. The remote unit communicates to the PMU through the standard serial digital interface. The CEU-901 is designed to operate in the center of the rotor hub. It accepts 64 measurements from the rotor blades and interfaces to the master unit through 10 slip rings. It is structurally designed as the load carrying member between the rotor blades and the engine. TheCEU-902 is similar in electrical design but is packaged in a more conventional enclosure for use in the cabin and nacelles. These signal conditioners accept the following cards:

a. Universal Conditioning Card - contains the signal conditioning circuitry for 4 channels of voltages or bridges. The input can be configured for bridge, voltage, or high voltage inputs through molded, encapsulated color coded, plug-in headers. The card also contains calibration relays for zero and shunt or voltage substitution calibration. The conditioning uses four Aydin Vector PDF-108 hybrids. Each hybrid provides an instrumentation amplifier and six-pole low-pass Butterworth filter. The PDF-108 hybrid is actively laser trimmed for amplitude matching and phase matching to within 1 degree. The filter outputs are multiplexed on the conditioning card and applied to the sample-and-hold and analog-to-digital converter card.

b. Resistive Temperature Device Conditioning Card - contains the signal conditioning circuitry for 4 resistive temperature devices. The design uses constant current excitation to the sensors and provides amplification and filtering of the signals from the RTDs using the PDF-108 hybrid. The filter outputs are multiplexed and applied to the sample-and-hold and analog-to-digital converter card.

The PBM-1553-RS Programmable Data Bus Monitor is capable of monitoring up to 3 MIL-STD-1553 dual redundant data buses. The unit is capable of capturing up to 240 complete messages (of 32 words) from each bus. Each selected message is stored in Random Access Memory. Individual 1553 data words are extracted from memory when addressed from the PMU-700 master encoder. The 1553 data is interfaced to the PMU-700 through a standard serial port.

CASE NUMBER 4

The vehicle being tested is an advanced tactical fighter aircraft. The remote units for this system must be very small to fit in locations of the vehicle such as the wings and vertical stabilizer.

Signal conditioning is required for strain gage and bridge type sensors as well as synchro signals which are used for precision position measurement. Twelve bit resolution is required on all analog channels and 14 bit resolution is required on the synchro-to-digital converters. The remote units must be microminiature and modular in nature to allow the smallest possible system to be used in some locations. High accuracy is required over a high temperature range.

The design was implemented using the new standard PMU-700 with operation to 2 Mbps. The PMU operates (in this application) with up to 12 clusters of remote microminiature conditioning and encoding units. These remote units were created for analog (voltage and bridge inputs) and digital (bi-level, synchro, resolver, and frequency inputs). The PMU also incorporated the time code generator option and the tracksplit option.

The ARU-800 Analog Remote Unit was created for strain gage, voltage or bridge sensor inputs. The ARU is capable of conditioning and encoding up to 50 channels. The ARU-800 uses microminiature, modular frames similar to the MMP-900 encoder and uses thick film hybrid circuitry. The bridge conditioning modules are designed with two channels per module. Each module contains an excitation regulator, two channels of programmable amplification, and two channels of six-pole Butterworth low-pass filtering, and output signal multiplexing. The multiplexed analog signal is applied to the programmable offset amplifier and 12-bit analog to digital converter. The ARU-800 interfaces to the PMU-700 through the standard serial digital interface.

The DRU-800 Digital Remote Unit was created for all conditioning which used a direct digital conversion. The DRU-800 will accept the following input data modules:

a. Synchro or resolver - This module accepts a synchro or resolver input signal which is converted to 16-bit digital word. This data is formatted into two adjacent 12 bit words in the output format.
b. Frequency - This module accepts two frequency input signals which are converted to 12-bit digital words.
c. Bi-level Multiplexer - This module accepts up to 24 discrete input signals and formats this data into 2 12-bit words.

DISTRIBUTED DATA ACQUISITION SYSTEM SUMMARY

Master	Remote Units	- Unique Features
Application 1: PMU-700	Solid Rocket Booster RSU-700	- High Reliability, Space Qualified Hardware
Application 2: PMU-700	European Fighter Aircraft SSC-900	- Software Controlled Signal Conditioner
	PBM-1773	- Data Bus Monitor with Fiber Optic Inputs
		Other System Components include:
		Advanced Multichannel Modular, Cockpit Display System with Engineering Unit Conversion APU-700 Processor CDH-700 Display Head
		- Missile Interface Remote Units
Application 3: PMU-700	Tilt Rotor Vehicle CEU-901	- 64 Channel Signal Conditioning Remote Unit for use in the Rotor Hub
	CEU-902	- 64 Channel Signal Conditioning Remote Unit for use in the Cabin, Wings, and Nacelles
Application 4: PMU-700	Advanced Tactical Fighter ARU-800	- Microminiature 50 Channel Bridge Conditioning Remote Unit with 12-bit Resolution
	DRU-800	- Microminiature Digital Remote Unit for Bi-level, Synchro or Resolver, and Frequency Inputs
Application 5: PMU-700	Engine Test Bed MMP-900	- Standard MMP-900 Encoder with Integral Signal Conditioning used as a Remote
Application 6: PMU-700	Commercial Aircraft Development	Master Unit was modified for interface to an onboard Compaq 386 computer. Also a selected data output port was provided for 9 track digital tape.

The design allows up to 8 remote units to be “clustered” in a remote location and interface to a single remote port on the PMU-700. Up to 96 remote units can be accomodated with the PMU-700 in this configuration.

CASE NUMBER 5

The vehicle being tested in an engine test bed used for flight testing new engine designs. The user required microminiature conditioning and encoding with the flexibility of the MMP-900 to be located in the engine area and the sophisticated features of the PMU for a controller in the cabin area. The design was implemented by modifying the MMP-900 Remote Interface Module to be compatible with the ADAS-7000 family. For this application, the PMU operates in high resolution (12 bit) mode and the MMP operates in 10 bit mode with 2 filler bits.

CASE NUMBER 6

The vehicles being tested are experimental commercial aircraft. The user had an existing (lower technology) system which incorporated an on-board computer and 9-track digital tape. A sophisticated system was desired which offered expandability for more parameters in the future. The user was in the process of upgrading the computer system to a Compaq 386 machine.

The design was implemented using a PMU which was modified for the Compaq 386 parallel digital output and also the 9-track digital tape output with the appropriate handshakes. Both of these outputs offer the capability of pre-selecting parameters which are a subset of primary PCM output. This compression technique is used to ensure that the throughput requirements of the computer and tape are not exceeded.

SUMMARY AND CONCLUSIONS:

We have analyzed several applications of ADAS-7000 systems which have used the PMU-700 Programmable Master Unit with a variety of remote units to solve unique requirements of various flight test programs. These systems have taken advantage of the flexible architecture and features of the ADAS-7000 system. Remote unit capabilities, system speed, and optional features of the PMU-700 have been expanded through these unique flight test programs.