AIR FORCE FLIGHT TEST INSTRUMENTATION SYSTEM

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ABSTRACT

In January, 1983 SCI Systems, Inc. initiated design under a contract with the U.S. Air Force for the development of the Air Force Flight Test Instrumentation System (AFFTIS). This system is being developed to provide for the flight test instrumentation needs of the Air Force through the 1990s.

The requirements specification was derived from the results of a survey conducted by the Air Force approximately two (2) years prior to contract award. The results of this survey were that the new system should provide more channels and higher frequencies, all in smaller size. In addition, the system should be modular and easily expandable to accommodate testing of yet undefined future aircraft systems. This paper describes the AFFTIS System as it is presently designed and some of the unique concepts used to meet the specified design goals.

AIRBORNE SYSTEM DESIGN

The Airborne PCM System utilizes a remote multiplex approach with a central control unit and some number of distributed data acquisition units. The central unit or AFFTIS System Controller (ASC) orchestrates the function of the PCM System via a high speed serial command/response data bus. Each of the remote data acquisition units (DAUs) includes a memory which contains format information. The command from the central controller (ASC) simply "points" to the correct format instruction location within the DAU.

AFFTIS BUS

The distributed nature of the AFFTIS system is depicted in Figure 1. The command/response bus, which carries commands from the ASC to the DAUs and the DAU data response to the ASC for PCM output is the AFFTIS bus.

FIGURE 1

The AFFTIS bus is a 10 Megabit, full duplex serial bus. The bus consists of a command bus and a separate reply bus. All units are transformer coupled and connected in a “daisy chain” sequence. The command bus operates continuously at 10 Mbits/sec utilizing Bi-Phase-Space modulation. Each ASC to DAU command contains 20 bit times and occurs in synchronism with each PCM output word time. Any time on the command bus which exists between the end of a command and the beginning of the next PCM output word time is filled with filler bits.

This overall scheme offers several unique design advantages. First, the use of Bi-Phase-Space modulation simplifies the generation and recovery of data. This is due in large part, to the fact that, as shown in Figure 2, each bit period begins and ends with a transition. As well as other advantages, this insures that, unlike 1553, the second sync waveform will

always be 1.5 bit times wide. (The reader should recall that a MIL-STD-1553 bus uses Bi-Phase L modulation and that the first bit after sync can be a “0” thereby making the second sync waveform “appear” to be 2 bit times long.) Secondly, the command bus transmits continuously thereby allowing all of the remote units to “lock on” and synchronize with the ASC. As a result, all activities of the DAUs are synchronous and are supplied with a clock of the same accuracy as the ASC’s master oscillator.

FIGURE 2

AFFTIS SYSTEM CONTROLLER

The ASC is the heart of the Airborne System and has been designed with a variety of features to provide the needed flexibility and capability to meet mission goals for the next 15 years.

All of the PCM format structure is user definable and programmable. The format commands are stored in a non-volatile EEPROM memory which can be altered electrically by the AFFTIS Ground Support Equipment. The characteristics of the ASC are:

Processor Type	- AMD 29116
Output Bit Rate	- Class I - 10K to 5M Bits Class II - 100K to 40M Bits
PCM Word Length	- 10/12/14/16 Bits, Programmable
Number of Formats	- 8 Separately Programmable
Number of Words/Frame	- 2-256/Format
Subcommutation Rates	- 2-256/Format
Number of Subcoms	- All Data Words
Number of Remote Units	- 64
Operating Temperature	- -54°C to +71°C

ASC INTEGRAL DATA PROCESSOR

The ASC includes the ability to perform real time data conversion to engineering units (EU). The EU conversion routines are user programmable with complete programming support provided via AFFTIS Ground Support Equipment. The resulting EU conversion may be displayed in flight as well as routed to PCM for output.

ASC INTEGRAL TIME CODE GENERATOR

A high performance IRIG Time Code Generator which may be externally synchronized is included as a part of the ASC. All functions are processor controlled with all outputs synthesized for maximum performance.

ASC PROGRAMMABLE SECONDARY

Secondary PCM outputs are provided for those applications where the tape recorder or telemetry transmitter does not have the bandwidth necessary to accommodate the primary PCM bit rate, or where the user wishes to partition the data into separate secondary outputs. There are two types of secondary PCM outputs provided:

- Dedicated (max. of 8 outputs)
- Programmable (2 independent outputs)

With the dedicated outputs, the primary PCM data is divided evenly at a correspondingly lower bit rate among the active secondary outputs. With the programmable outputs, the user is free to choose any of the primary PCM words to appear in each programmable secondary PCM output.

DATA ACQUISITION UNITS

The Data Acquisition Units (DAU) consist of two major types; the avionics data bus monitors and the Analog-Discrete Unit. The avionics bus monitor DAU allows the user to selectively capture data which may appear on an aircraft's avionics bus. The avionics bus DAUs under development include the MIL-STD-1553 DAU, (F-15) H009 DAU and ARINC DAU.

In each case, the DAU offers the user two methods of decommutating avionics bus data traffic. The first method utilizes standard techniques of capturing selected traffic and storing it in specified memory locations for later retrieval by the ASC. The second method utilizes a "ring buffer" mode. In this mode each specified item of avionics data traffic is stored in the next available "ring buffer". The result is that the message data integrity is

maintained since all contiguous data is retrieved in proper temporal order. The characteristics of the Avionics Bus DAU are:

Processor Type	- AMD 29116
Interfaces	- MIL-STD-1553/H009/ARINC 429
Decom Mem Size	- 1020 Words
Time Tag	- Tag all Words 20 Microsecond
Status	- Bus ID/Stale/Overflow
Operating	- -54°C to +71°C

ANALOG-DISCRETE DAU

The Analog-Discrete DAU or ADAU consists of an “overhead” section as well as a signal conditioning section. The overhead section contains a 32 channel direct input analog multiplexer, a programmable gain amplifier, a 12 bit A/D converter and interface, a format memory and control circuitry. The signal conditioning area consists of six (6) general purpose signal conditioning card slots. These are designed to provide maximum user flexibility in signal conditioning selection by allowing any of the signal conditioning cards to operate in any slot.

The most difficult challenge of the ADAU design is to provide high sample rates (over 400K) while maintaining flexibility in channel and gain selection without undue sacrifice of accuracy. In order to accomplish this several unique design techniques are utilized.

The first problem to be overcome is the settling time of the input multiplexer. This problem is solved by utilizing a “pre-charge” technique. As shown below, a unity gain instrumentation amplifier is used to settle the mux to within a few percent of its final value. Prior to sample capture, the “pre-charge” amp is disconnected and the mux allowed to complete accurate settling using the precision matched passive multiplexer.

The second problem to overcome is the programmable gain amplifier. The major task is to design an amplifier which will slew and settle quickly while maintaining the offset performance characteristics usually found in lower speed precision instrumentation amplifiers. The solution applied here is the use of a “composite” amplifier. This solution, as depicted below, utilizes a low offset/low drift amplifier to set the offset compensation of the high speed amplifier.

PRECHARGE MUX

COMPOSITE AMPLIFIER

The last major hurdle is to allow sufficient time for the conversion of the analog data to digital form. This is accomplished by the utilization of dual track and hold circuits. While one circuit is holding data for A/D conversion, the second is connected to the composite amplifier output taking a sample for the next digital conversion. The general performance characteristics of the ADAU are:

Processor	- N/A
Direct Input MUX	- 32 Differential Channels
Sample Rate	- 400K Samples/Second
Input Range	- ± 10 Volts
Digital Conversion	- 12 Bit
Accuracy	- .2 to .5% depending on range)
Gain	- 1 to 1000 Programmable
Operating Temperature	- -54° to $+85^{\circ}\text{C}$

SIGNAL CONDITIONING

As discussed previously, the AFFTIS signal conditioning has been designed to provide maximum flexibility. The signal conditioning cards go into one of six slots within the ADAU housing. Listed below are the Signal Conditioners currently being developed:

Resistance Thermometer	- Programmable Constant Current .2 to 5MA - 8 Channels
Synchro/Resolver	- 11.8V & 90V - 2 Channels
Frequency Converter	- 5Hz to 50Hz/5Mv to 100v 4 Channels
Pulse Accumulator	- 5Hz to 50Hz/5Mv to 100v
Elapsed Time Counter	- .01 Msec Resolution 6 Channels
Serial Digital	- 4 to 30 Bits - 4 Channels
Parallel Digital	- 16 Bit/Isolated Input 1 Channel
Analog Attenuator	- 1 to 1/32 - 8 Channels
Control Signal Generator	- 4 Outputs/TTL & Relay Closure
Presample Data Filters	- 2Hz to 2KHz - 4 Channels
Linear Variable/	- 400Hz to 2.5KHz/2VRMS to 10VRMS
Differential Transformer	3 Channels
Transducer Ref. Supply	- $\pm 2.5/5/10\text{V}$ - 4(+) & 4(-) Channels

The Signal Conditioners are designed with many user definable options. Virtually all of these options can be programmed via the AFFTIS Ground Support Equipment without removal from the aircraft.

GROUND SUPPORT EQUIPMENT

In order to provide the user the support necessary to easily handle the programmability and checkout of the airborne hardware, the AFFTIS system includes a full spectrum of Ground

Support Equipment. This equipment ranges from a multi-user Laboratory Support System with a complement of automatic test equipment to a hand-held Portable Flightline Unit (PFU) used for a singlechannel decom.

The AFFTIS GSE includes both general purpose and specific equipment. The general purpose GSE includes:

<u>Unit</u>	<u>ID</u>	<u>Usage</u>
Laboratory Support System	LSS	Laboratory
Ground Support Unit	GSU	Tow Cart
Remote Site Unit	RSU	Hand Carry

The general purpose GSE is designed utilizing standard equipment and software which enhances its ability to be tailored to each user's specific requirements.

<u>Hardware</u>	<u>Software</u>
Motorola 68000	UNIX (tm)
VNE Bus	ADA (tm)
3-10 MByte Disks	Relational DBMS

This complement of hardware and software is maintained throughout the general purpose GSE thereby enhancing the ease of use and maintainability.

LABORATORY SUPPORT SYSTEM

The Laboratory Support System is a computer-based set of equipment that provides complete support of the airborne system to include (1) conduct of Acceptance Test Procedures; (2) generation of airborne formats; (3) PCM quicklook display and (4) engineering unit conversion. As a multi-user station, the LSS will conduct several different activities simultaneously. Designed as a "user-friendly" system, the LSS will automatically account for formatting requirements, evaluation of test results, and performance of PCM data limit checking. Automatic test of the airborne equipment is facilitated by a set of IEEE-488 standard lab test gear.

The LSS also serves as a software development facility for the GSE. Based on the UNIX (trademark Bell Labs) operating system, the GSE provides an ADA language compiler and a relational data base management system. The AFFTIS system user may develop and add his own software to the standard package.

GROUND SUPPORT UNIT

The Ground Support Unit (GSU) is a mobile subset of the LSS functionality. Enclosed in a wheeled tow cart, the GSU provides the complete capability of the LSS except that it cannot perform airborne unit acceptance tests, or shop-level diagnostics. The GSU cart may be transported by air if necessary. Since the GSU is used in a wide variety of environmental extremes, a special terminal based upon a plasma display device is used instead of a traditional CRT. Extra rack space is available for the installation of mission-specific customer equipment. The GSU may be powered either from a standard aircraft power cart or commercial power.

REMOTE SITE UNIT

Where it is inconvenient to use a GSU, the Remote Site Unit will perform the equivalent functions of a GSU. Instead of a cart, the RSU is packaged in a man portable container. Like the GSU; the RSU uses a plasma terminal for its operator interface. The RSU may be powered from 110 volts from 47Hz to 440Hz.

The characteristics of the General Purpose GSE are shown in Table 1.

SPECIFIC GSE

Other ancillary ground equipment comprises the Specific Category. This includes:

Party Line Decom	- PLD	AFFTIS Bus Decom and Test
Time Code Head	- TCH	Time Code Generator Display and Set
Portable Memory Loader	- PML	Load, verify and dump of airborne memories without using LSS, GSU, RSU
Portable Flightline Unit	- PFU	Single-channel raw data decom in a hand-held unit.

PROGRAM SCHEDULE

Shown below is the overall development program schedule. As can be seen, the conceptual design phase is essentially complete and the Engineering Model development is underway. The System is scheduled to be ready for operational application by the end of CY 1986.

	<u>Mission</u>	<u>Environment</u>	<u>Packaging</u>	<u>Users</u>	<u>Memory</u>
LSS	Lab	Room	Desk/Rack/Bench	2-16	1 MB
GSU	Flightline	0-130F	Mobile Cart	1-2	1 MB
RSU	Remote	0-130F	Suitcase	1	0.5 MB

	<u>68000</u>	<u>VMEbus</u>	<u>UNIX (tm)</u>	<u>ADA (tm)</u>	<u>Relational DBMS</u>
LSS	X	X	X	X	X
GSU	X	X	X	X	X
RSU	X	X	X	X	X

	<u>110 Volt</u>	<u>Disk</u>	<u>Printer</u>	<u>Display</u>	<u>D/A Capability</u>
LSS	47-440Hz	30Mb	600lpm	ANSI X3.64 CRT	16-Channel
GSU	47-400Hz	30Mb	600lpm	Plasma	16-Channel
RSU	47-440Hz	20Mb	tbd	Plasma	8-Channel

	<u>PCM Bit Sync</u>	<u>AFFTIS Format Sync</u>	<u>General Format Sync</u>
LSS	X	X	external
GSU	external	X	external
RSU	external	X	external

	<u>ATP</u>	<u>LRU Fault Iso</u>	<u>Format Utility</u>	<u>SRU Diagnostic Capability</u>
LSS	X	X	X	X
GSU		X	X	
RSU		X	X	

	<u>PCM Decom</u>	<u>Project History</u>	<u>A/B Mem Support</u>
LSS	X	X	X
GSU	X	X	X
RSU	X	X	X

TABLE 1

AFFTIS PROGRAM SCHEDULE

	QTR	1983				1984				1985				1986				1987			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
PHASE 1 DESIGN		██████████				██████████															
PHASE 2 EM DEVELOPMENT						██████████				██████████				██████████							
PHASE 3 PRE PRODUCTION														██████████				██████████			
PROGRAM MILESTONES						PDR ▲ 2/15				CDR ▲ 1/15				FLT TEST IOC ▲ ▲ 1/31 10/30							
HARDWARE DELIVERIES						▲██████████				EM				▲██████████				▲ PRE PRODUCTION ▲			

SUMMARY AND CONCLUSIONS

In conclusion, the AFFTIS development is very ambitious and has demanded a lot of innovative design to accomplish. Any design which is meant to serve many applications must have built in a high degree of flexibility to allow the tailoring needed to meet specific applications.

The AFFTIS design is meeting these goals.