PMUX—The Interface for Engine Data to AIDS

Joseph A. Bluish* and William Lorenz†
The Bendix Corporation, South Bend, Indiana

The propulsion multiplexer (PMUX) unit, a new component of the Aircraft Integrated Data System, promises to improve the accuracy and reduce the weight of condition-monitoring equipment in commercial engines. The new configuration will improve accuracy by packaging advanced technology pressure sensors within the electronic unit and by using digital signal conditioning, made more practical by placing the microprocessor near the engine sensors. To reduce weight, the system will replace multiconductor cables with a serial digital data link. This paper discusses typical design requirements and describes the approach used in a unit designed for the 747-300 aircraft.

Introduction

OVER a decade ago, the interest in Aircraft Integrated Data Systems (AIDS) triggered a desire for gathering information useful in aircraft maintenance. At that time, the use of electronic computers was expanding, thus providing a means to conveniently store the details of individual airplane system performance on supporting ground-based equipment. Performance data from airborne operation could be recorded, since it became practical to extract pertinent information from existing avionic systems. Soon AIDS was used to record in-service engine performance. These data were obtained simply by monitoring cockpit instruments and incorporating a few additional sensors on the engine.

During the early planning of AIDS, engineers did not consider a signal summing box at the engine. In its absence, the task was to design an interface with existing engine instruments and to add pressure and position sensors that would monitor the major engine parameters. The latter effort required installing electrical wiring between the actual sensor and the support electronics. The new equipment significantly increased aircraft weight and was vulnerable to the typical problems associated with a large bundle of electrical wires.

When the AIDS concept was evolving, the viability of using electronic systems in the harsh engine environment had not been proven. Today, as AIDS and engine electronics have matured and the specific requirements for engine data are better defined, the propulsion multiplexer (PMUX) unit has gained acceptance as a better way to monitor engine parameters on both the 747-300 and the A310 aircraft.

By changing from the original AIDS system to the new PMUX AIDS system, each 747 can be lighter in weight. The new system will feature a signal summing unit at each engine and serial digital communication to the AIDS data gathering box in the avionics bay.

In progressing from the original AIDS configuration to that employing a PMUX, the on-engine pressure sensors were incorporated within the PMUX unit. Here, these critical sensors are in a more hospitable environment and can also allow the use of a design concept that takes advantage of the digital computer within this subsystem.

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*Assistant Director of Engineering, Energy Controls Division. Member AIAA.

†Senior Project Engineer, New Programs-Electronic Dept., Energy Controls Division.

Several items influence the design of any PMUX unit which, in turn, is a component of an AIDS installation (see Fig. 1). The subject of engine condition monitoring and the need to tailor each monitoring system to the specific requirements of individual airlines was amply covered in a 1979 paper by Danielson.[1] This paper noted the dependence of systems on engine type, operating practice, maintenance systems, maintenance organization, and integration with other systems.

The design of any specific PMUX unit can be linked to individual requirements and there will be a range of features

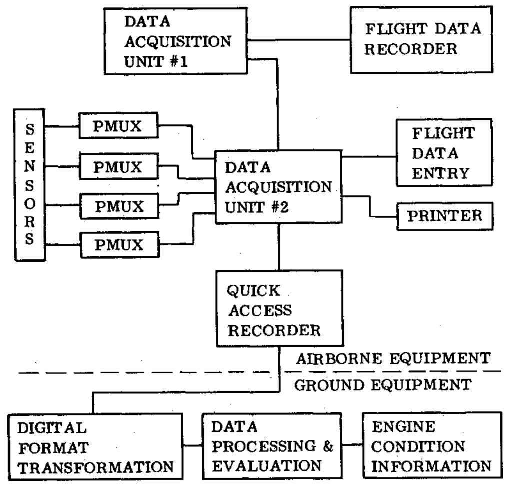

Fig. 1 AIDS installation with PMUX.

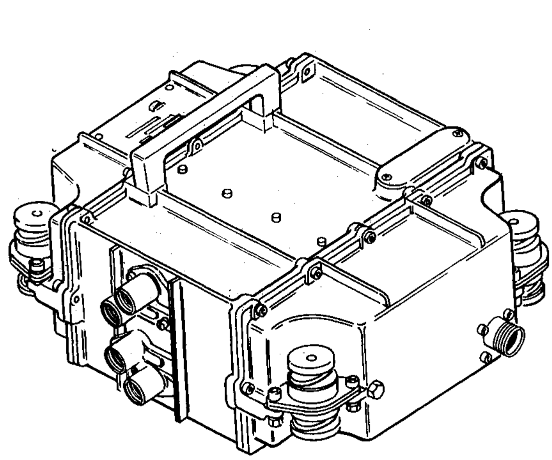

Fig. 2 PMUX unit for 747 aircraft.

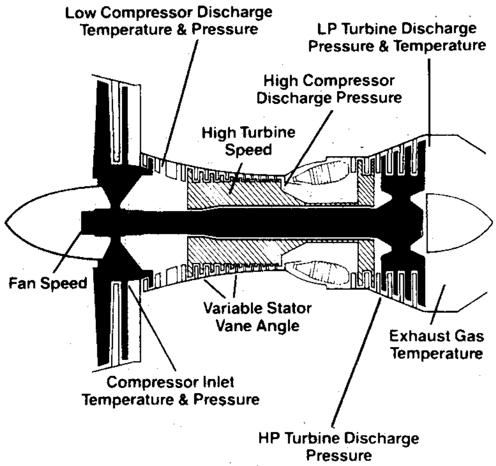

Fig. 3 Typical PMUX engine parameters.

Table 1 PMUX input parameter listing

Engine parameter	Operating range	Repeatability and accuracy required
PT2, Fan inlet	2-30 psia	0.025 psi + 0.0025pt
PT3, Exit LPC	2-50 psia	0.5% of pt © cruise
PS4, Exit HP	5-500 psia	0.5% of pt © cruise
PT7, Exit LPT	2-30 psia	0.025 psi + 0.0025 pt
PT5	2-400 psia	0.5% of pt©cruise
TT3	−20- + 160°C	2.2°C © cruise
TT4.5	−20- + 610°C	2.2° © cruise
EGT	125-1050°C	3.8°C
EGT (6 EA)	125-1050°C	3.8°C
N1, low rotor	1-85 Hz	0.5% pt
N2, high rotor	1-85 Hz	0.5% pt
Wf, fuel flow	615-27,000 pph	0.6% pt © cruise
SVA angle	−40- + 10 deg	0.3
3.0 BLD		0.5%
Oil temperature	−40- + 300°C	1.5°C
8 discretes	On/off	—

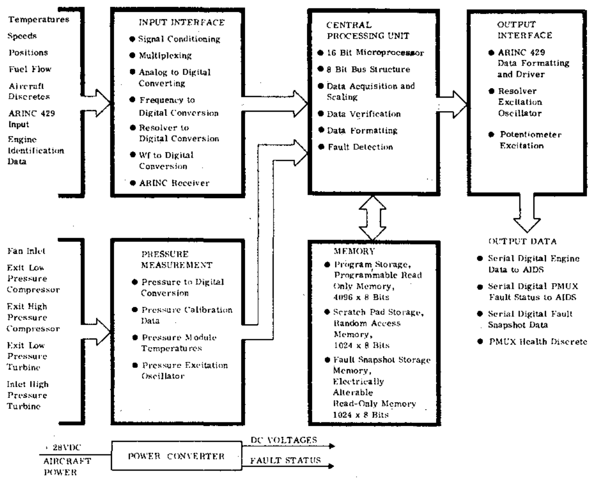

Fig. 4 PMUX functional block diagram.

that can be included in a given unit. While this paper addresses the general features of the PMUX concept, certain sections deal specifically with the PMUX unit designed for the JT9D engine on the 747-300 aircraft (Fig. 2).

Discussion

The PMUX is a compact, modular, digital electronic device that measures and processes engine parameters, converts them to a serial data format, and then transmits these data to an AIDS digital data acquisition unit for subsequent recording and/or display. Figure 3 identifies typical parameters of interest to PMUX users.

Functional Description

Functionally, the PMUX consists of: 1) an input interface; 2) pressure measurements; 3) a central processor unit; 4) a solid-state memory; 5) an output interface; and 6) a power converter. Also, the PMUX can receive serial data and provide an output discrete for fault identification. A functional block diagram of PMUX is shown in Fig. 4.

Data flow within the PMUX system is controlled by the central processing unit (CPU), which is generally microprocessor based. The instructions for the CPU are stored in programmable read-only memory (PROM), while a random access memory (RAM) supplies extra computational workspace. Other functions of the PMUX digital subsystem are typical: the system clock synchronizes digital operations and is guarded by a watchdog circuit to insure that the system does not lose track of real time; address decoding circuitry deciphers the CPU's requests for data and activates the proper data source circuit.

The CPU begins repetitive sampling of the input parameters and the reporting of these data at regular intervals. Output data from the PMUX system is in the form of a continuous digital stream in ARINC 429 format. The data channels are updated every 200 ms.

The serial data transmitter chip accepts up to eight 32-bit words from the microprocessor. It fulfills all of the timing and protocol requirements to transmit the data serially to any receiving station. It also has a feature to accept commands that initiate self-test or interrogate stored data.

To remove the need to individually wire engine discrete logic to AIDS, PMUX has select circuits to accommodate these data conveniently. These circuits transform the input information to transistor-transistor logic (TTL) levels and then interface it directly to the CPU through a digital multiplexer. Other engine information such as fuel flow and rotor speed must also undergo processing to establish a signal that can be interpreted and relayed on a serial bus.

In addition to those signals that are generated in a digital fashion, there are also analog outputs available from certain sensors. All analog signals must be converted to a digital form before they can be processed by the CPU. A single 12-bit analog-to-digital (A/D) converter handles this task for the system. When this approach is used, the different analog inputs are interfaced to the A/D converter by means of a multiplexer. Channel selection is controlled by the CPU enabling the example system to select any of 24 different inputs. For an installation monitoring five different pressure areas, 10 channels are allocated to pressure measurement. Each pressure requires both a pressure signal and a temperature signal. This technique has been employed in the system developed for the 747-300.

Additional capabilities of this system can be viewed as typical of the advantages offered by digital electronics in general and a PMUX approach in particular. Many signals are multiplexed through common circuitry. A phase sensitive demodulator processes each amplitude modulated input to obtain the voltages that are fed to select inputs of the analog multiplexer. High-level analog inputs are simply conditioned and fed directly to the analog multiplexer. Low-level thermocouple inputs are differentially multiplexed to share a single precision instrumentation amplifier among nine input channels; the output of the instrumentation amplifier is a high-level signal that can be accommodated by the analog multiplexer.

In addition to its primary function of gathering sensor information, any PMUX unit should have a built-in test (BIT) capability to provide an operator with detailed information on its health. This self-test capability can provide data

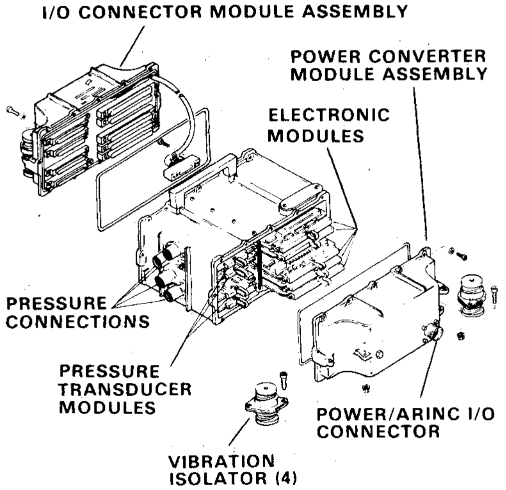

Fig. 5 PMUX exploded view.

identifying PMUX faults and isolating them at the module level. PMUX could acquire these data continuously so that it can be read either as part of the routine in-flight data transmission or upon command after the plane lands. Many self-diagnostic test routines can be used in the PMUX approach to data gathering, including 1) range and rate checks of all data; 2) hardware and software checks of speed and resolver circuits with internal test signals; 3) A/D self-tests with internal calibration signals; 4) random access memory (RAM) tests and read-only memory (ROM) sum check tests; 5) CPU operational checks; 6) watchdog timer tests; 7) output data verification tests; and 8) power converter fault logic tests.

Capabilities and Advantages of PMUX

In progressing to a second generation of engine parameter measurement for AIDS, a PMUX unit provides the following benefits: aircraft weight savings; more accurate engine data, more reliable engine data, integral pressure sensors, engine parameters on ARINC 429 bus, reduced aircraft maintenance costs, improved built-in test, integral fault recording, PMUX fault interrogation, and engine (or engine strut) mounting.

The engine parameters that are presently handled by PMUX are summarized in Table 1.

The PMUX and the older individual sensor-wiring systems have the same total cost. The cost of the PMUX unit is offset by the savings realized by not having to install the larger cables and the separate pressure sensors of the original AIDS package. Also, PMUX is a small and lightweight unit and hence can be mounted on the engine fan case or within the engine strut.

A requirement of any avionic unit is that it be producible and maintainable. To help meet this requirement, the PMUX unit should be modular in construction. For the unit selected as an example, all system functions and features are distributed among 15 modules or subassemblies. An exploded view diagram (Fig. 5) illustrates the various modules and their locations within the package.

The weight savings that can be realized by grouping engine signal conditioning near the engine was reviewed earlier. This location also allows improved signal accuracy since signals are conditioned near the sensor from which they originate. The environment here is relatively severe and this requires special electronic packaging and installation considerations for the unit.

Some of the special thermal design techniques that have been adopted for the extreme thermal considerations are: polyimide printed circuit boards, copper heat rails, positive subassembly clamping, electronic component placement based on part heat dissipation, use of low-power circuits and use of high-reliability parts. Reliability is a function of part temperature.

Studies show that up to five pressure measurements can be used in engine condition monitoring. Placing the unit near these points where these measurements are taken would minimize the amount of pneumatic plumbing. Two such locations are the engine fan case and the engine strut. Individual maintenance considerations play a part in making the choice. In either case, the high-vibration levels necessitate a design that is mechanically isolated. In addition, the engine fan case location may require special temperature considerations that could include a need to have cool airflow near the unit.

Most of the electrical connections to PMUX are from the engine. Only aircraft power and the serial digital output are wired to the aircraft. The split destination of PMUX connections led to the design of a unit with connectors at each end.

Pressure readings are received by PMUX in the form of pneumatic signals which, in the 747-300 installation, are conditioned by a unique analog/digital servo device capable of accuracies better than one quarter of one percent of point.[2] For example, the sensor used for fan inlet pressure on this aircraft will provide an accuracy of 0.015 psia when measuring a 6 psia pressure. Evaluation tests have shown that the subject pressure subsystem is capable of a deviation (over a temperature range from -65 to $+200°$F) of one-half of this value.

The PMUX unit can enhance the accuracy of temperature measurements by using signal processing that measures and compensates for the amplifier offsets and drift.

Regarding the built-in test capability (BIT) discussed above, PMUX should include the results of such tests (in terms of good health or bad health) in the serial data transmission. The unit should also generate some maintenance diagnostics to be gathered in a special memory location.

The weight savings realized by the use of PMUX in an AIDS-equipped aircraft is primarily attributed to a reduction of aircraft wiring. The four PMUX units on a 747 weigh 13.5 lb each. In addition, there are some mounting brackets and other airframe considerations that are offsetting. The resulting 100-lb weight savings represents an aircraft harness weight reduction of almost 154 lb; the main AIDS equipment remains the same for the comparison performed.

Features

This paper discusses key PMUX features to evaluate both its present capability and its potential as a tool in engine condition monitoring.

Engine Speed Measurement

Engine speed is a parameter that is compatible with a digital interface circuit. Early circuit designs relied simply on pulse counting and thus were limited in their accuracy. As more accurate schemes were developed, the quantity of electronic parts grew and it became practical to replace this large combination of standard parts with a custom integrated circuit. Today, the PMUX can be provided with this small, accurate, electronic part in a standard dual-in-line package (DIP). This DIP has a unique circuit with a constant percent-of-point accuracy over the entire speed range while maintaining a fixed conversion time.

The signal from the speed sensor is first reduced to TTL levels. The resulting pulse train is applied to the large-scale integration (LSI) circuits where it is filtered digitally and then fed to a coarse counter. The latter counts the pulses over a fixed interval. Since the number of pulses in the interval can vary by one count, which can cause large errors when the frequency is low, an adjustment is made by a second counter, the vernier counter. At the end of each time interval, the vernier counter contains the number of vernier clock periods between the last tooth count and the end of the interval. Since intervals are precise, vernier counts from two consecutive intervals are used to determine the actual time over which the

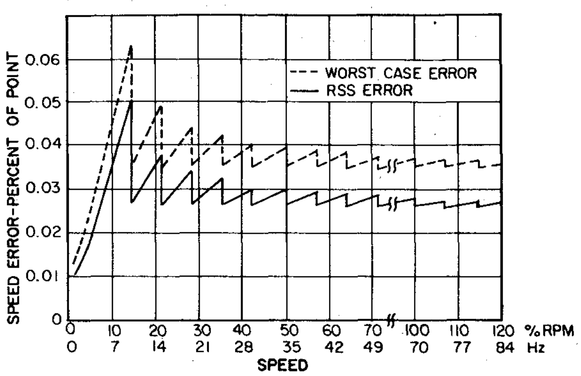

Fig. 6 PMUX speed circuit measurement error.

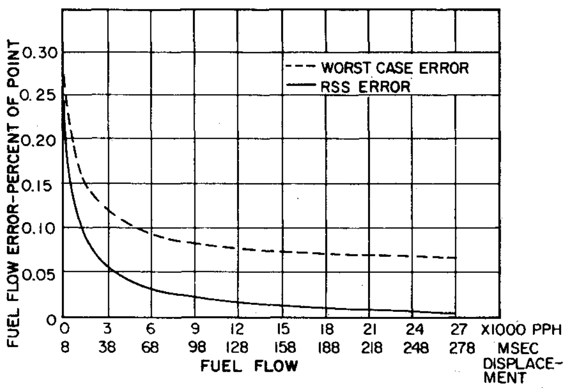

Fig. 7 PMUX fuel flow measurement error.

tooth count was taken. This is done by adding the difference between the previous and present vernier counts to the total number of counts in the interval (a fixed value). This design determines accuracy by the stability of the time interval (strobe) and the vernier clock. It determines resolution by the number of vernier clock pulses that occur in one time interval. Since the vernier counter will resolve the space between tachometer pulses to 12 bits, the speed measurement will be much better than the present 0.5% of point requirement established for the AIDS application. Typically the speed measurement error is less than 0.05% of point as illustrated in Fig. 6.

Fuel Flow Measurement

Fuel flow, *Wf*, is sensed by a device with a frequency output proportional to flow. This signal is best measured by an "event" circuit that determines the time between successive pulses. Signal conditioning circuits must first convert the *Wf* sensor signals to logic levels. These are then applied as start and stop signals to the "event" circuit. This circuit accumulates a count that measures the time between the leading edges of start and stop pulses. The counter data are read by the CPU over its data bus. Measurement accuracy with this method is much better than 0.2% of point over the useful range of the flow signal, as shown in Fig. 7. At extremely high rates of fuel flow (above 20,000 pph), the length of time between start and stop signals (278 ms) will limit the fuel flow data update rate to approximately 3 Hz.

Temperature Measurement

The thermocouple conditioning circuit is also extremely accurate. The nine thermocouple input channels of the 747 PMUX system are individually conditioned and then sent to a single thermocouple instrumentation amplifier via a differential multiplexer. A reference test input and a zero reference input are supplied to the differential multiplexer as well as the thermocouple inputs. The output of the instrumentation amplifier is one of the A/D multiplexer inputs.

Gain and offset tests are performed once per second by switching test inputs through the differential multiplexer into the instrumentation amplifier. This performance feature also serves to self-test the operation of the circuit.

The cold junction compensation circuit uses a temperature sensitive current source to develop compensation for the thermocouple input connection temperature. The sensor output ($1 \mu A/K$) is converted to a voltage and amplified by an isolation amplifier. An offset is then added to the signal to yield a compensation voltage output of zero at 290 K with an accuracy of 1°C. The accuracy capability of the nine thermocouple channels ranges from 2 to 2.4°C.

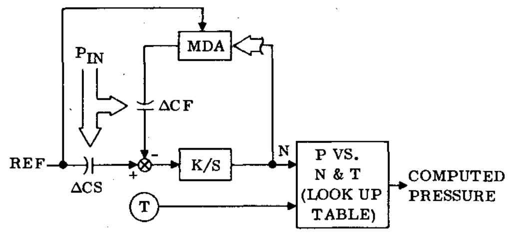

Fig. 8 Individual pressure subsystem block diagram.

Pressure Measurement

The incorporation of the pressure sensors within the PMUX provides several advantages. It provides a more benign environment than the location of individual sensors on the engine and permits a common installation of all pressure sensors with the system electronics. Also, a design with an intimate relationship between the basic sensing element and the system CPU is utilized.

Pressure sensors (a proprietary design) for the 747-300 PMUX unit are single quartz capsule, absolute pressure transducers which are employed in individual pressure subsystems that have a high percent-of-point accuracy over a wide range of pressures. Figure 8 is a block diagram of an individual pressure subsystem. The major assembly for each pressure measurement is a pressure transducer module. Up to five self-contained transducer modules can be accommodated by the PMUX unit.

Each module contains a quartz disk capacitor mounted within a pressure cavity. The disk responds to applied pressure by changing capacitance. This capacitance is measured in a bridge circuit, which is balanced by controlling an excitation voltage through a multiplying digital-to-analog converter (MDAC).

The pressure module accepts a digital input, called N number, from the system CPU. This number is supplied to the MDAC which attempts to balance the bridge. An error signal (bridge unbalance) is produced as a module output. The CPU digitizes this error signal, which is applied in software to modify the N number, and the new N number is again sent to the MDAC. This closed-loop configuration ultimately nulls the bridge.

N number is constant at a given pressure and temperature but varies nonlinearly with each. In this design, calibration data[2] are taken over the pressure and temperature range of the module. The data are processed by matching them to the theoretical performance of the module. This step employs an equation that defines the performance of the module over the complete temperature and pressure range. These complex equations are used to generate a lookup table of pressure for each value of N number and temperature. This lookup table is then stored in a calibration memory located in the pressure transducer. The CPU then uses N number and module temperature to read actual pressure from the pressure module memory. This configuration achieves high accuracies with no degradation with temperature. The accuracy capability of the pressure transducer is shown in Fig. 9.

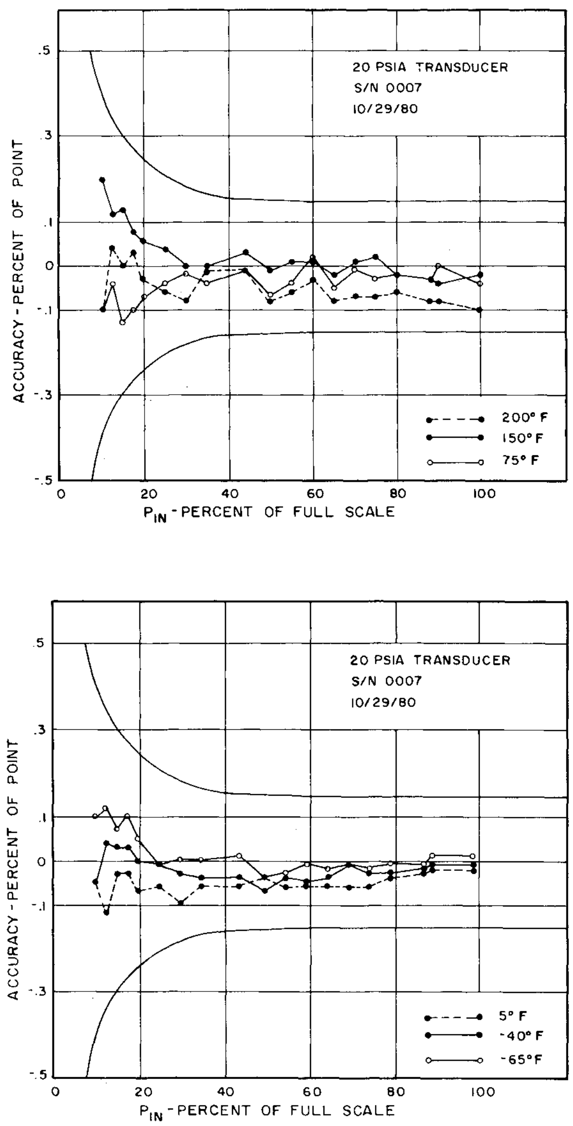

Fig. 9 Pressure transducer accuracy.

ARINC 429 Interface

Input parameters and failure information are output from the PMUX on an ARINC 429 low-speed serial data link. With the exception of setting the output levels and providing the data bus interface, all functions are performed by a single LSI chip. The processor writes data to the device in groups of eight 32-bit words. The LSI chip handles all timing and protocol.

The same device also accepts ARINC 429 inputs. Use of the receiver feature allows an operator to send information to the PMUX. A test mode is implemented whereby the output signal is fed back into the receiver to test both portions of the system.

Central Processing Unit

The heart of the 747-300 PMUX system is a Texas Instruments TMS9995 microprocessor. This central processing unit (CPU) has a 16-bit internal structure with an 8-bit data bus and 16-bit address bus to interface the various system memory and LSI components. The CPU features *N*-channel metal oxide semiconductor (NMOS) technology and single 5-V supply operation. Its architecture includes 256 bytes of on-chip RAM, seven prioritized hardware interrupts, and serial input/output (I/O) capability. The CPU also generates the system clock. The extensive instruction set of the TMS9995 includes signed multiply and divide and, coupled with a 2 MHz system clock, yields ample computation ability to meet 200-ms frame data update rates with extra provision for extensive background self-testing.

System memory is partitioned into blocks of 8-bit bytes. The program code is held in PROM occupying 6144 bytes (6K) with provision for expansion to 8K. 1024 bytes (1K) of RAM are provided for active manipulation and storage of data. Approximately 500 bytes of the allotted RAM are unused, leaving a large potential growth space.

The memory of the PMUX system contains 1024 bytes (1K) of electrically alterable read-only memory (EAROM). This EAROM is a nonvolatile means of storing engine and PMUX operational data. A fault data history is logged by the unit. With each fault occurrence, a snapshot of key parameter values is encoded to aid in fault analysis.

The contents of the EAROM are read via the ARINC 429 interface. Accidental erasure is precluded by sequencing the EAROM power supplies and by executing dummy READ operations after each ERASE or WRITE operation and upon system power-up.

CPU and memory self-test capability includes periodic checks of CPU operation, data retention, and system timing. The CPU checks its own performance by running sample calculations with known results at regular intervals. Program memory is summed periodically to insure the integrity of program data. Checks are performed on the RAM to insure that each location retains data properly. System clock frequency is continuously monitored to detect slow clock rates, and a watchdog circuit assures that all tasks are performed within the allotted cycle time. The CPU also range checks all parameters and maintains responsibility for initiating and evaluating self-tests of the ARINC, A/D, speed, and event interfaces.

Design Considerations

General

The PMUX design (Fig. 2) meets the environmental, maintainability, reliability, and installation requirements for either engine strut mounting or engine fan case mounting applications. The packaging design was configured to meet the requirements of the installation envelope and to meet the temperature, vibration, and shock requirements. Part of this requirement was the ambient temperature range specified for the installation in the 747-300 (−67 to +194°F). The electromagnetic interference (EMI)/lightning requirements were met by use of protection circuits on all input/output lines and through the use of a metal housing. The reliability of the unit is achieved through the use of established reliability components and extensive derating of components. The electronic circuits and packaging have also been designed to minimize the thermal rise in the unit which also enhances the reliability. Maintainability is achieved through modular construction and built-in test features. Through the built-in test features, problems are diagnosed to the replaceable module level for the majority of faults.

Maintainability

The AIDS system in itself is a maintenance tool. The PMUX unit as a new component for AIDS should have a maintenance philosophy that corresponds with airline maintenance objectives. The following maintenance concepts should be considered.

1) Built-in tests (BIT) to provide fault identification information via the ARINC 429 serial data output to the AIDS system on a continuous basis.

2) Fault identification information resulting from BIT that can be stored in EAROM and can be conveniently extracted on demand. BIT-identified fault resulting from components exterior to the PMUX, such as sensors and cables, may be further identified.

3) A modular construction with each module being easy to replace—no calibration or adjustment when a module is

replaced. The architecture and partitioning of the electronics should facilitate fault identification to the module level.

4) The circuit cards, pressure modules, and power converter should be conveniently replaceable without unsoldering.

5) All plug-in cards should be mechanically indexed to avoid the possibility of improper placement.

The PMUX unit designed for the 747-300 has considered these objectives. The unit hardware and software was designed to facilitate fault detection and repair. Data from the ARINC output can be used to determine which of the data words are not being sensed correctly. The partitioning of the hardware is arranged such that for a majority of failures the problem can be immediately traced to a single replaceable module.

Software self-tests are conveniently used to insure correct operation of the CPU and memory. Since these functions are normally on a single module, these tests will identify CPU faults and insure correct operation of the software. All software tests are run continuously as a background task. The iteration rate is not constant but varies and some tests may require 1-2 s before they are repeated, depending on foreground activity. Tests that are performed include:

1) CPU Check. A portion of code which uses most instruction types can be executed with known inputs and the output verified to be correct.

2) PROM Check. Each PROM chip in the program memory and in the pressure transducers has a sum taken of all memory locations. This sum must agree with the designed value. For example, a pressure calibration PROM failure will invalidate the data from that module only.

3) RAM Check. Each RAM location is loaded with a pseudorandom number which is then read back to assure the location is functioning properly. Certain tests are also performed to test for row, column, and address line failures.

4) Iteration Check. A test is performed each frame to assure that a minimum background execution rate is being maintained. This test also assures that the interval time and watchdog systems are operating.

5) Real-time Task Timeout. During each major cycle, the allotted real-time task must be completed or an appropriate fault is set.

Hardware self-tests are practical to perform on all major sensing circuits. The various sensing circuits are confined to single modules; thereby once a failed parameter has been identified, the failed module is also identified. The signal processing circuits and software are designed such that, during the background tasks, test signals are applied and the accuracy of each data channel is verified. Hardware tests that are built into the unit are described as follows:

1) N2 Speed. A test frequency is applied to the counter inputs and read by the processor to verify proper operation of the speed counters.

2) Fuel Flow. A known interval is applied to the counter inputs and read by the processor to verify proper operation of the counters.

3) Thermocouple. Gain and zero calibration signals are applied to the instrumentation amplifier. If either signal fails range or rate tests, the thermocouple circuit is considered to have failed.

4) A/D Converter. The reference ground signal is fed through the multiplexer. If it fails a narrowband range test, the A/D circuit is considered to have failed.

5) ARINC 429 Interface. On command from the processor, ARINC output signals are wrapped around internally to the inputs. Any difference between data sent and received indicates a failure of the ARINC circuit.

None of the above self-tests perform an evaluation of the input signal conditioning circuitry. Failures there must be detected by input range and rate checks.

The PMUX (EAROM) memory is also helpful in diagnosing engine, engine sensor, and PMUX signal processing problems. The EAROM in the 747-300 unit is organized into 32 data blocks. The first data block contains 16 words (bytes) that contain PMUX fault history. The remaining 31 blocks record "snapshots" of the full set of engine data at the time of a failure. Data contained in the EAROM data blocks are shown in Table 2.

Table 2 EAROM Data

Bytes	Data
	Block 0 PMUX history data
0-1	Number of faults to date
2-5	Identification of sensors which have failed the range test
6-9	Identification of sensors which have failed the rate tests
10-11	Identification of hardware self-tests that have failed
12-13	Identification of software self-tests that have failed
	Blocks 1-31—Fault snapshots
Bytes	Function
0-1	Fault code
2-3	Failed parameter value
4-15	System status words at time of fault
16-24	Selected parameter values at time of fault
25-29	Maintenance words—image of ARINC words 155, 156, 157, 160, and 161

The fault snapshots provide insight into the details of the recorded sensor information at the time of a parameter fault. To prevent continuous logging of intermittent faults, software was added to record continuous faults only once. If faults appear intermittently at rates greater than once every 2.5 min, the fault is recorded twice and then not recorded in EAROM again. No single fault will be recorded more than three times for any reason.

Given the fault information contained in the ARINC data words, the EAROM history data block and the fault snapshot data blocks provide an accurate picture of PMUX and engine sensor faults. This information, combined with the modular construction and functional partitioning of the PMUX, results in easy identification of faults to the replaceable module level.

Status

PMUX equipment from various suppliers has been selected by individual airlines for several aircraft. Among these are the 747-300, the A300, and the A310. On these aircraft it remains a customer option and may be obtained as part of the engine or as a component that is procured by the airframe company.

The major discussion of specific capability has been centered on the unit selected by Swiss Airlines for their 747-300 aircraft. Some of the growth features of this component accommodate the additional requirements anticipated from other airlines.

PMUX as a separate electronic unit may be a transition component. Today, it has a place on engines that have mechanical controls and on those engines with electronic controls developed without addressing the values of full engine condition monitoring. Several engines have electronic controls with varying degrees of technology and some of the information that is desired for engine condition monitoring. Some of these systems did not address a concept for using this information for purposes other than engine control. Those that did will require less additional signal conditioning for the engine monitoring task. For all of these applications there remains a reasonable need for the PMUX concept. On these installations, the PMUX unit will accept the conditioned engine information from the electronic engine control, add the other monitoring signals desired, and provide the same output as though the total engine information was gathered within the PMUX unit.

It is reasonable to expect that, as full authority electronic engine control reaches maturity, most of the data of interest for engine condition monitoring will be incorporated. From this position, it will be practical to add some nominal considerations for this maintenance task and generally reduce the complexity of the total engine package.

The advent of the digital computer and system intercommunication such as ARINC 429 has established a completely new concept for the design of future aircraft. This serial data can be adapted for engine instrumentation. Concern for signal integrity could be handled by redundancy in a manner that would provide more reliable instrumentation. The redundancy concepts would be compatible with the trends in engine control technology.[3] This concept is new and significant development work is required to establish a baseline system.

As the value of engine condition monitoring is appreciated, it is probable that future engine controls will include all the features presently included in PMUX.

Conclusions

PMUX is a component that was developed as an aid in engine maintenance. As engine condition monitoring became cost effective, individual sensors have been installed on the engine to make various data available for analysis. The evolution of data records was gradual and individual designs that were optimum for each of a series of small additions are not necessarily optimum for the overall task. The PMUX concept can replace the distributed approach because it gathers all the engine data and conditions it into a format that provides accurate data for a low-cost, lightweight installation.

PMUX may be a transition component. As full authority electronic control becomes the technology for more engines, the electronic unit of these systems may include all of the requirements for engine condition monitoring.

The maintenance EAROM memory that is being incorporated in the PMUX unit will provide snapshot information that will greatly aid engine system fault identification.

References

[1] Danielson, S.G. and Dienger, G., "A European View on Gas Turbine Engine Monitoring on Current and Future Civil Aircraft," AIAA Paper 79-1200, June 1979.

[2] Antonazzi, F. Sr., "Pressure Transducer Calibration Process," SAE Paper 811076, Oct. 1982.

[3] Kniat, J. and Bluish, J.A., "An Application of Redundancy in Digital Electronic Engine Control," SAE Paper 801200, Oct. 1980.