# A HIGH SPEED AIRBORNE DATA ACQUISITION AND CONTROL SYSTEM WITH AN INTEGRATED DIGITAL COMPUTER

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**Summary**   AIFTDS-4000 has been developed as a modularly expandable instrumentation and control system primarily for use in aircraft and system flight test. The bidirectional data processing capacity of Remote Multiplexer/Demultiplexer Unit, however, permits the system to be applied to data processing and control loop functions as well as the classical role of a data gathering system. The basic system was developed for NASA-FRC under three different contracts; NAS4-1848 (the ACS and RMDU's), NAS4-1940 (the integrated signal conditioner cards) and, NAS4-1943 (the expanded test set). The system comprises Airborne Hardware, Ground Support Equipment and Software. The Airborne Hardware is divided into two major elements; The Airborne Computing System (ACS), and the Remote Multiplexer/Demultiplexer Unit (RMDU). Ground Support Equipment is presently restricted to the ACS Test Set (ACS/TS) which permits total checkout of the ACS without the RMDU's or checkout of the full AIFTDS, as well as performing the function of an autonomous mini-data reduction ground station and the Portable Address Generator which permits testing of one RMDU (or one zone of the airplane) without the ACS or the ACS/TS. Software may be grouped into System Checkout and Diagnostic Software, Flight Test Program Software and Quick Look/Reduction Software. The prototype AIFTDS-4000 was qualified in two stages; the RMDU was qualified in October 1972 with the ACS qualified in April 1973. The Expanded Test Set and supporting software were delivered in May 1973.

**Introduction**   AIFTDS flight hardware consists of the ACS with from 1 to 16 RMDU's for the gathering or disseminating data and real time processing and formatting of data for simultaneous application to mass storage media (tape recorder or other bulk memory), an RF Transmitter for real time telemetering and, display of selected parameters on a cockpit control/display unit. Key features of AIFTDS not generally found in the classical PCM system include:

1.   A man/machine interface permitting in-flight changes in sampling programs and automatic or manual callup and display of selected parameters for use by the test pilot/engineer.

2. Complete randomness in sampling of up to 4096 analog and 576 discrete data points at data rates up to a maximum word rate of 128K WPS.

3. An autoranging gain programmable amplifier which has 11 preselected gains under software control which automatically adjusts the gain (if necessary) to the input signal level before data is sampled.

4. Integration of sensor excitation and sensor signal conditioning in the RMDU with sensor type and quantity of each type sensor accornmodated dependent on the signal/conditioning multiplexer card complement selected for each RMDU.

5. Built-in calibration channels which provide a complete cal/data cycle for each RMDU plus the ability to fault isolate to the PC card level and box to box interchangeability for each PC card without recalibration of the card or the box.

6. Real time data processing through the computer in the ACS plus the ability to use the computer to generate control signals for dissemination through the RMDU to an external control loop.

The 65K word memory of the ACS permits many different PCM sampling formats to be stored for a single flight, as well as permitting the CPU to manipulate sampled data so both raw and processed data may be generated in real time. Storing limit exceedance information (fixed-or-floating-point) permits performing real time data compression. PCM formats may be written for any frame length, any number of subframes in the mainframe, and any depth of subframes desired. The Channel Sampling Format may be completely random and the frame rate may be any of eleven rates with word lengths of 8, 9 or 10-bits of resolution, producing 33 different bit rates under software control. It is possible to address four different RMDU's simultaneously so with 8-channel parallel sample and hold cards in the RMDU's simultaneous address can be made of 32 different channels for phase correlation measurements in different parts of the airplane. A block diagram of the AIFTDS-4000 configured for maximum data processing capacity is depicted on Figure 1.

The ACS/TS is used for testing the ACS Processor, the ACS Memory, the complete ACS without RMDUts and/or a complete AIFTDS-4000 with 16 RMDU's. It also can compile sampling programs, data processing programs, fill and dump memory and perform a pre- and post-flight test (as well as bench test) of the entire AIFTDS. The ACS/TS can be used to reduce data, print out raw and/or reduced data and produce an archivable copy of memory contents to provide permanent records of system configuration for each flight (and each test mode of a flight). It can produce computer compatible tapes from airborne tapes and it can display data from the system (or the tape being read) in real time.
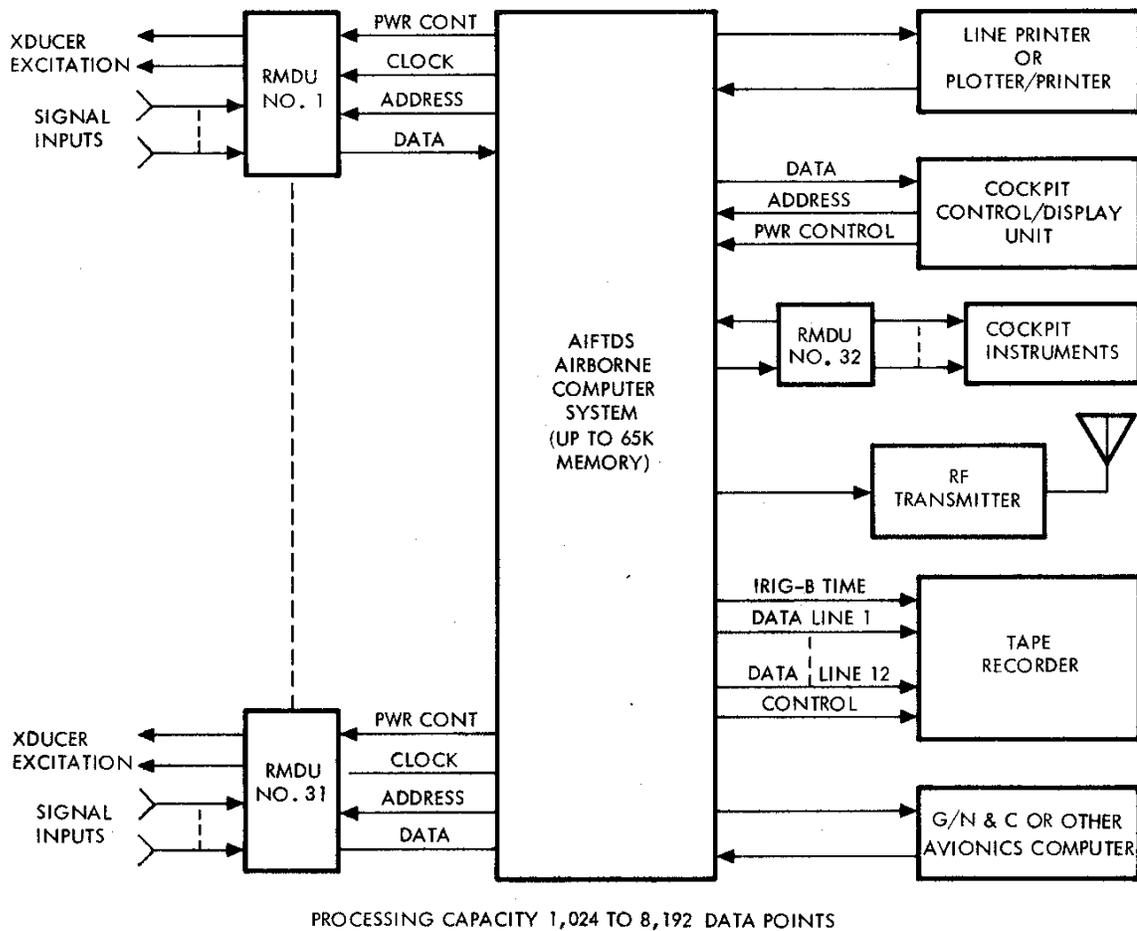
Figure 1

## THE AIRBORNE COMPUTING SYSTEM (ACS)

The ACS is a central subsystem of the AIFTDS packaged in two 1/2 ATR long housings. It is composed of four functional elements; a PCM Controller, a Central Processor (a high speed, general purpose digital computer), an IRIG Time Code Generator and a 65,536 Word (16-bit words) Memory System. A block diagram of the ACS is shown on Figure 2. The PCM Controller, the Time Code Generator, and the Central Processor are packaged in the Processor housing with the memory subsystem packaged in its own housing. The ACS has been designed and tested to MIL-E-5400 environmental requirements of sea level to 100K ft. altitude, 20 Hz to 2 KHz, 10 g sine vibration, an operating temperature range of -29° to +60° C and EMI per MIL-STD-461. One of the unique features of the ACS is the modular memory subsystem which is expandable in 4K word increments to 65K words by adding two memory cards for each additional 4K of memory desired. The memory interface permits the use of any type of memory media so that either semiconductor, core or plated wire memory system can be used. The prototype system contains a dynamic RAM semiconductor memory made NDRO by incorporating a rechargeable battery pack which protects from power transients and interrupts and keeps the memory refresh alive
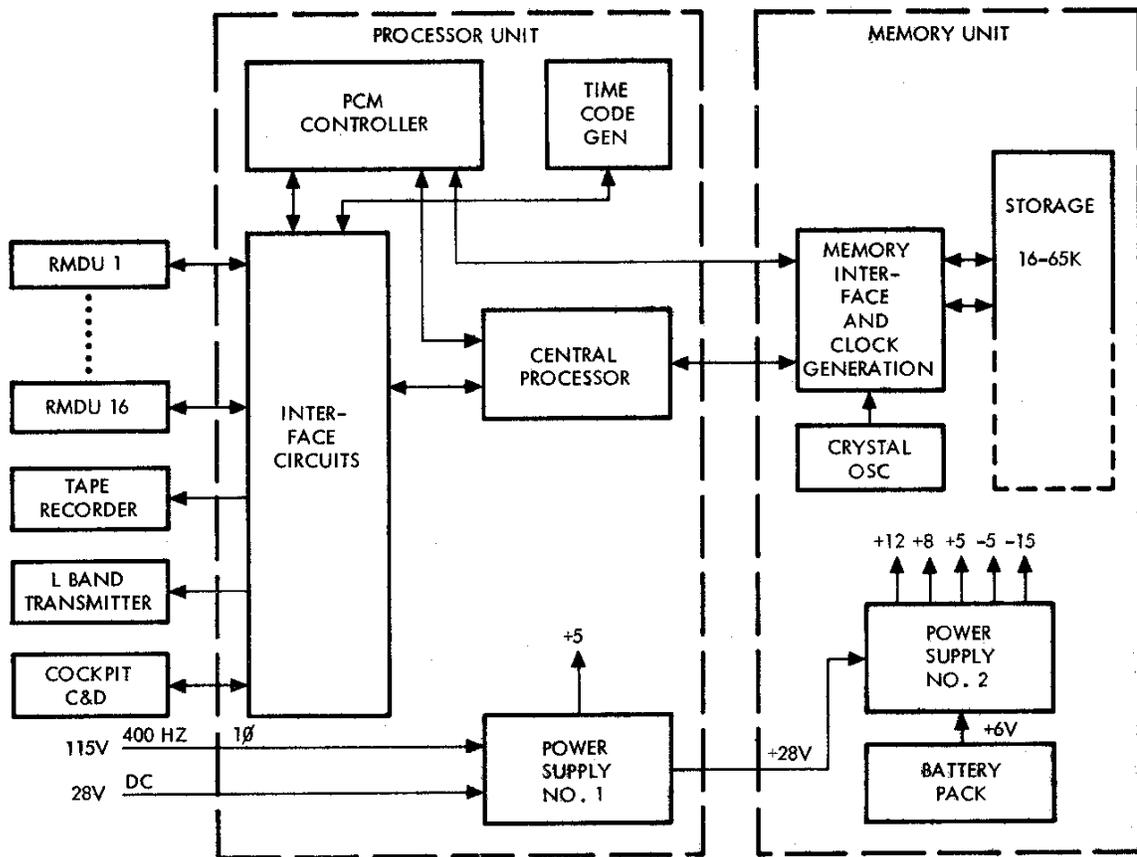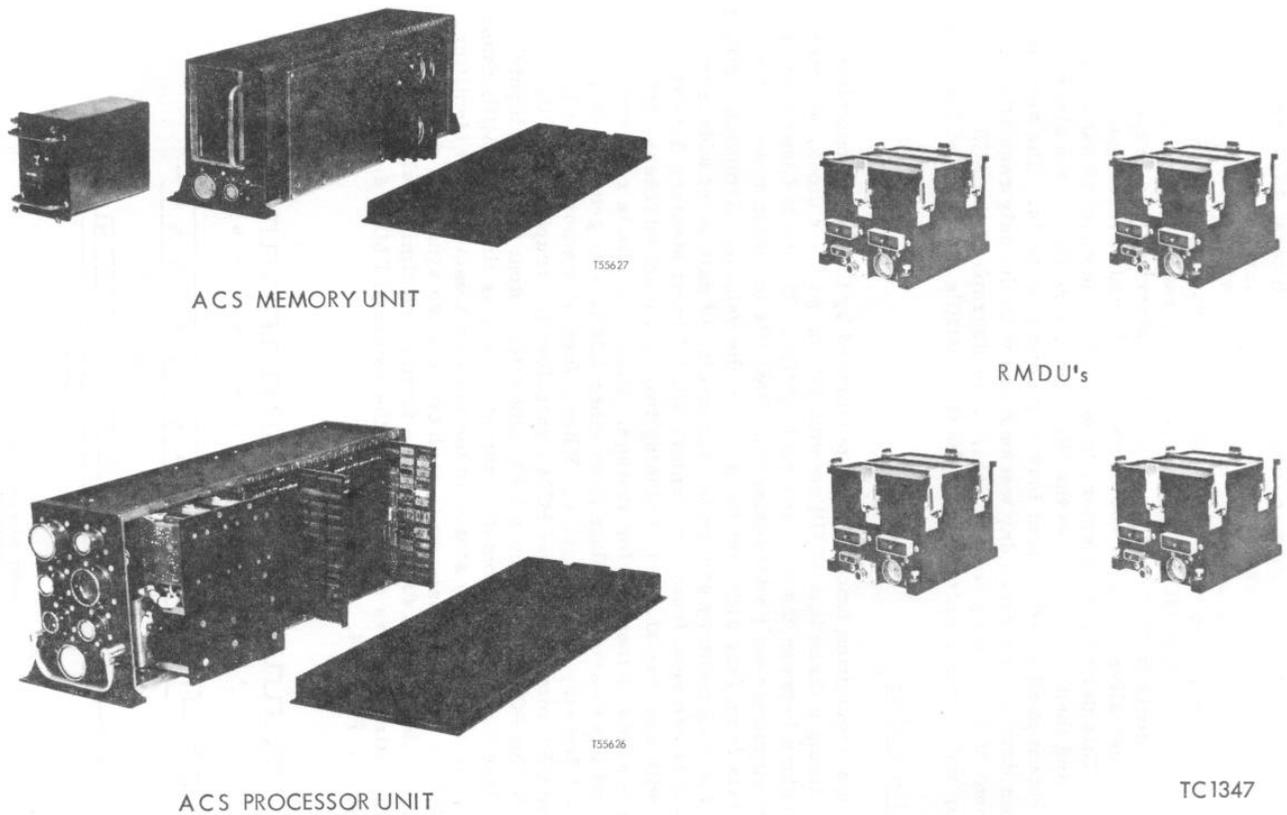
**Figure 2**

for up to 100 hours of continuous system power down operation. This permits the memory to be loaded and checked out in the laboratory and then carried out to the flight line, installed in the aircraft and the system preflighted without loss of memory contents. The aircraft can be shut down over a three day weekend and with the only requisite replacement of the battery before flight. A photograph of the AGS Processor and Memory Unit and four the the RMDU's is shown on Figure 3.

**PCM Controller**

ACS data acquisition functions are performed by the PCM Controller section utilizing a three line (TSP) communication path for clock, address and data return between the ACS and each RMDU. The PCM Controller is capable of simultaneously addressing four RMDU's to obtain time correllation of data from four different locations in the vehicle. Sampling formats stored in the ACS memory govern the sequencing of data point addresses. Format words are read from the memory via a Direct Memory Access Channel, with one format word producing two data point addresses and requiring 3 words of memory for storage. Digitized data is received, buffered and interleaved with data from other RMDU's to generate two contiguous telemetry output signals. When a format memory word is nagged for CPU monitoring, the PCM Controller interrupts the CPU,

**Figure 3**

inserts into the PCM bit stream a CPU generated output word and inputs to the CPU the RMDU generated data sample. At this time the RMDU channel address is automatically stored in memory as a data sample identifier.

RMDU data point address words each contain two sync bits, followed by 14 RMDU function control data bits. The format and timing relationship of the transmitted address and clock and the returned RMDU data as illustrated below in Figure 4.
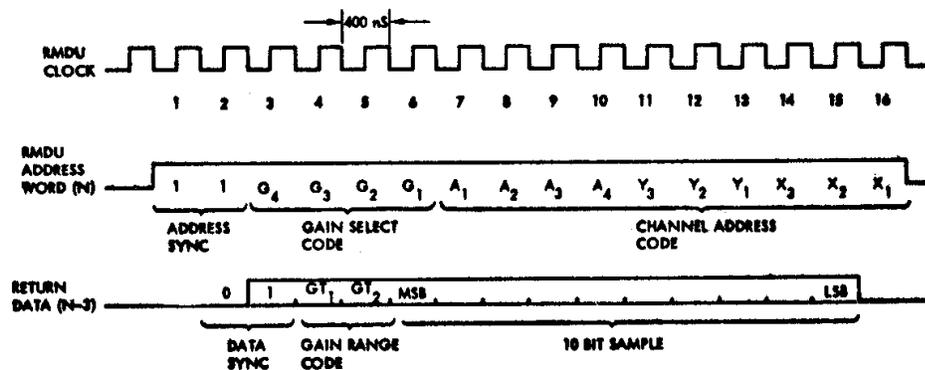


**Figure 4**

The PCM main frame consists of a serial time representation of 3 words of frame synchronization, 1 subframe ID counter word and from two to 32,768 RMDU data words. The system is capable of processing supermultiplexed data, submultiplexed data or a combination of both types within the main frame. The ACS can be programmed for main frame lengths up to 32,768 words (or time divisions) of 10, 11, or 12 binary bits per word with cycle lengths from one to 4,096 frames. The main frame ID word is the fourth word or time division in the main frame and provides a unique identification of each main frame within the total data cycle. The first main frame in the data cycle has the binary ID word 000000000001. Each succeeding main frame increments the ID word one count until the end-of-data cycle word, at which time the ID word is reset indicating the beginning of a new data cycle. The ACS can be programmed to operate at any one of the eleven selectable word rates shown in Table 1.

<div align="center">

**TABLE 1**
**SOFTWARE SELECTABLE PCM WORD RATES VS WORD SIZE**

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| Word Rates | 12-Bit Words | 11-Bit Words | 10-Bit Words |
|---|---|---|---|
| *RO = Max. Word Rate = | 128,000 WPS | 126,942.15 WPS | 123,966.94 WPS |
| . | . | . | . |
| . | . | . | . |
| . | . | . | . |
| . | . | . | . |
| R10 = Min. Word Rate = | 125 WPS | 123.96 WPS | 121.06 WPS |

* Word rates between RO and R10 are powers of two related.

Word rate selection is made by the issuance of a single software command. The system provides proper sequencing of the synchronization word, ID words, and data within five seconds plus one complete cycle after application of power to the system. The PCM Controller provides premodulation filtered serial NRZ for a RF Transmitter. The recorder interface provides one serial data Bi-phase L data line and an associated serial bit rate clock output plus 12 parallel Bi-phase L data outputs with associated bit and word rate clocks. Each of the 15 line drivers is capable of driving a 25 foot MIL-W-16878D, 26 gauge TSP cable.

**Time Code Generator**

The ACS contains an integral Time Code Generator (TCG) that produces "time-of-day" in a BCD format in seconds, minutes and hours in addition to a modified IRIG B (B-122) output. The TCG is driven from the main ACS clock which has a stability of two parts in $10^7$ per minute and two parts in $10^6$ per day. Provision has been made for time display, stop/start control and counter preset via a cockpit control and display interface. A means

has been provided to synchronize the TCG to a WWV audio input. Synchronization consists of an operator procedure which presets the time display counters and arms the TCG so that it can automatically detect the start of any minute (excluding the first minute of the hour), to within 50 μsec.

## Central Processor Unit

The Central Processor Unit (CPU) of the AGS is a general purpose binary, digital computer that operates with 16-bit instruction and operand word lengths using the formats as shown in Figure 5. A natural binary numbering system is used with negative values coded as 2's complement. The CPU has 70 operational instructions implemented in logic which includes: Load/Store, Logical, Branch/Compare, Shift, Arithmetic and Input/Output.
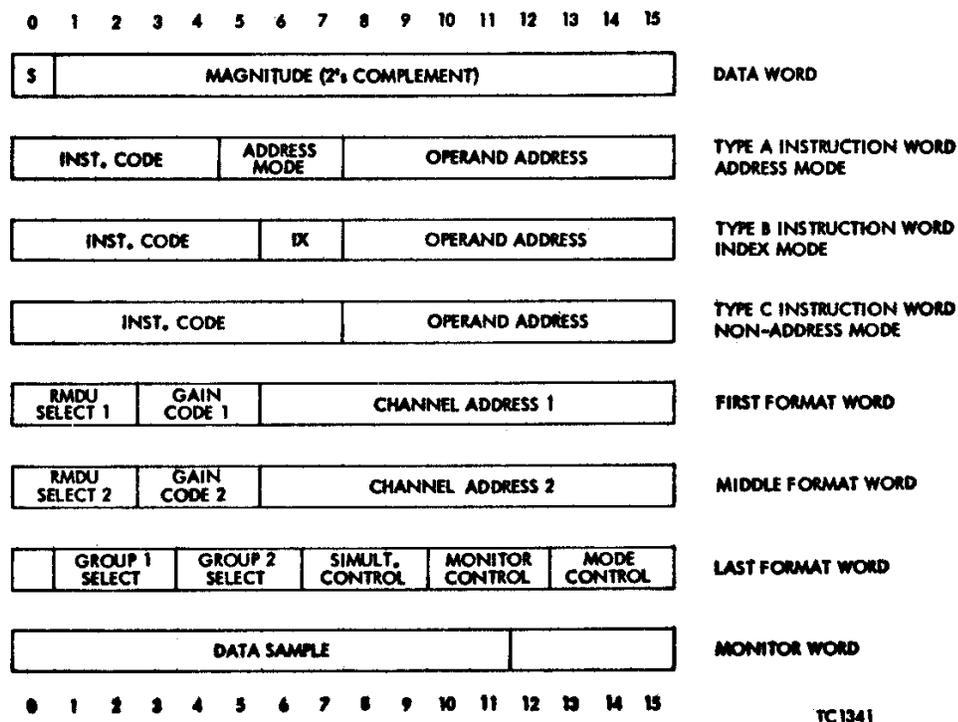
Figure 5

Sixteen priority interrupts including power sequencing are provided with hardware lockout of lower priority interrupts. All interrupts except for power ON may be masked by the programmer individually or en Masse. An interrupt consists of a hardware forced Transfer and Save instruction execution cycle, which resets the Interrupt Enable state to the Disable condition. Once an interrupt has occurred, the ACS remains in the Disable state until re-enabled by the software. The ACS performs an add to memory in 3.33 μsec., a multiply to memory in 6.67 μsec., and a divide in 9.33 μsec. It has three hardware index registers, and when an operand address is modified by indexing, the effective address is within the range

of zero to 225 locations from the value of the Index Register. Two complete sets of working registers are reserved for processing of PCM words flagged for CPU monitoring.

**Memory System**

The Memory System architecture permits the use of 16, 20 or 24-bit memory modules. Detailed interface and timing differences for any alternate memory system are contained within the logic modules of the memory unit so as to present an identical interface between the memory unit and the processor unit irrespective of the memory media selected. The semiconductor memory is composed of an array of Random Access Memory (RAM) devices which operate in a non-destructive readout mode. The memory module is physically identical to the other logic modules and provides 4K words of 8 -bits each. Sixteen-bit word memories are mechanized with two 4K-word modules which produce an 4K x 16-bit block. Twenty or twenty-four bit words by 4K are mechanized with 3 memory modules. Non-volatility is provided by a wide temperature range rechargeable battery capable of supporting a typical 16K word memory up to 2 weeks without application of external power (or a 65K memory for 100 hours). The memory is organized so that the full complement of 65,536 words may be randomly addressed in any sequence. It is partitioned into blocks of 8, 192 words which are assigned to the Central Processor and/or the PCM Controller so that the blocks may be read simultaneously by their respective control logic. The CPU has the capability of reading and writing into any location in memory on a first priority basis. Memory fill and verify is accomplished via the CPU port which is connected to the Processor Unit Test Connector. Memory contents can also be loaded or dumped in flight through one of the spare I/O ports not mechanized in the prototype system.

**THE REMOTE MULTIPLEXER/DEMULTIPLEXER UNITS (RMDU's)**

The AIFTDS Remote Multiplexer/Demultiplexer Unit (RMDU) is a multifunction data processing unit which can be used as a remotely controlled, bidirectional data processing unit for gathering and disseminating analog, discrete and/or digital data. It can be used in a master/slave configuration or as a standalone unit. In the master/slave configuration it is a slave unit that is controlled via a digital interface from a controller such as the ACS, which can be located up to 300 feet away. By interchanging the communications (DDP) card in the RMDU with a standalone timing card, the RMDU is immediately converted from a remotely controlled data processor to a self-contained conventional PCM system. The RMDU is capable of processing, in a random sequence, up to 256 differential analog and 36 discrete data points. Signal conditioning may be performed within the RMDU which also provides transducer excitation. Maximum signal processing capacity of the RMDU is dependent on the length of the housing and the mix of optional signal conditioning and multiplexer cards used in a given configuration. Figure 6 is a summary level block diagram of the RMDU configured as a self-contained PCM system (using the Standalone Timing
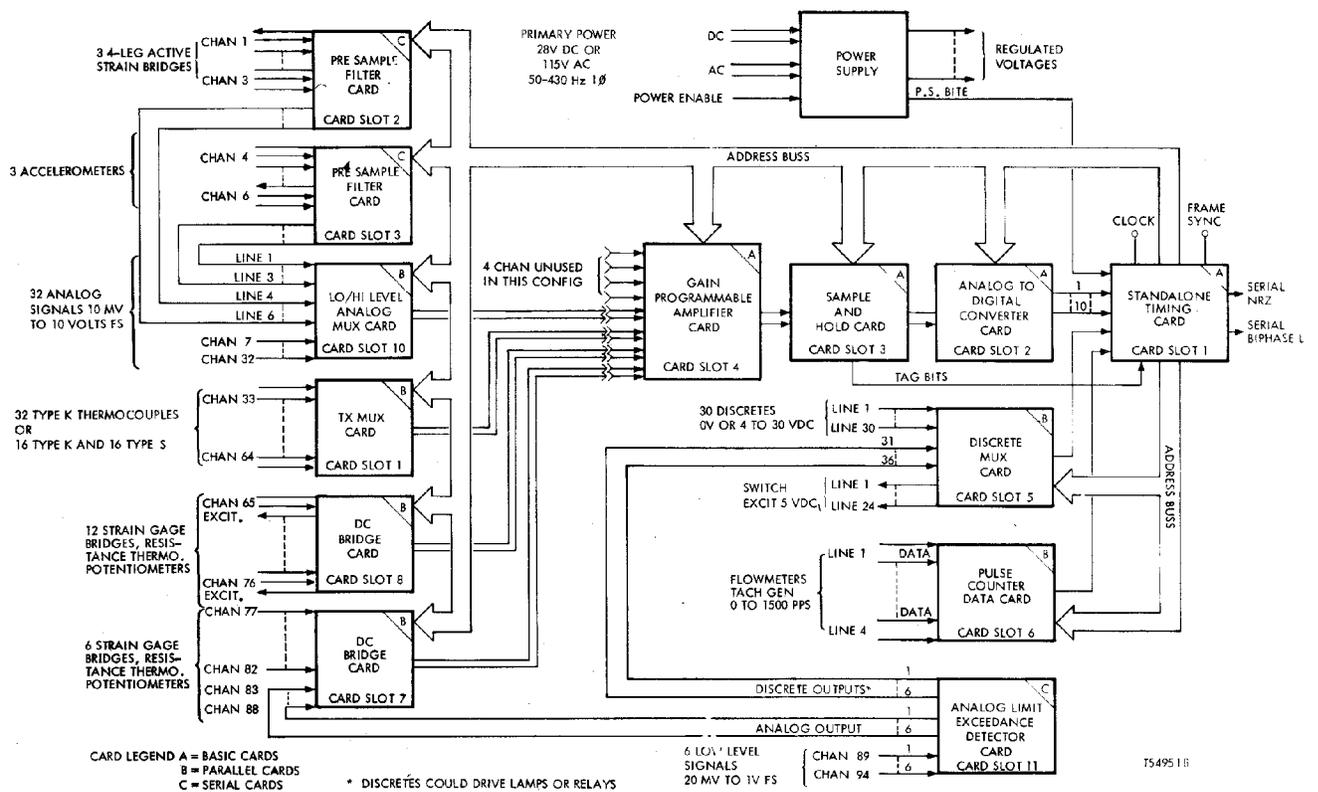
**Figure 6**

Card). The STC module can be interchanged with the DDP module so the RMDU can also operate with the ACS, the Portable Address Generator or any other device that can generate addresses and clock and provide the associated timing to recognize returned data.

The Basic RMDU consists of the housing, the power supply module and the overhead PC cards which are necessary to process analog and digital data. The overhead cards are: (1) The Digital Data Processor Card (DDP) or the Standalone Timing Card (STC), (2) The Analog to Digital Converter Card (ADC), (3) The Sample and Hold Card (SHC), and (4) The Gain Programmable Amplifier Card (GPA). To the basic RMDU card complement may be added from 3 optional cards (in the Short Housing) to 9 optional cards (in the Long Housing) which perform signal conditioning and/or multiplexing. The number of channels per optional card can vary from one to sixty-four depending on the complexity of the signal conditioning. Housing cabling has been configured so that all of the different types of analog signal conditioning and multiplexer cards can be inserted in any of the optional card slots. Examples of RMDU signal processing capacity vs. sensor type are shown in Table 2.

## Table 2

| AIRCRAFT SENSOR/LOAD (SIGNAL COND.) | NO. OF CHAN. PER CARD | SIG. COND. CARD NOMENCLATURE | TYPE OF CARD |
|---|---|---|---|
| DIFFERENTIAL DC ±10 MV TO ±10 V F.S. | 32 | AMX | ANALOG INPUT |
| SYNCHRO OR RESOLVER | 5 | SYN | |
| SINGLE ENDED DC (HIGH LEVEL) | 64 | HLMX | |
| VAR. RELUCTANCE (LVDT) OR AC BRIDGE (PHASE SENS. DEMOD) | 8 | PSD | |
| STRAIN GAGES RESISTANCE THERMOMETERS POTENTIOMETERS | 12 | DCB | |
| THERMOCOUPLES — NOTE 1 | 31 | TCMX | |
| PIEZOELECTRIC ACCELEROMETERS | 8 | CAC | |
| DUAL PURPOSE PRESAMPLE FILTERS (LOW LEVEL SIGNALS) | 4 | PSF | |
| 3-INPUT SELECTABLE PROGRAMMABLE KNEE PRESAMPLE FILTERS | 4/2 | MPSF | |
| FLOWMETERS TACH GENERATORS (PULSE GEN 0 – 1500 PPS) | 4 | FDC | DIGITAL INPUT |
| DISCRETES/PARALLEL DIGITAL (WITH SWITCH EXCITATION) | 36/24 | DMX | |
| RELAY/VALVE/LAMP — NOTE 2 (20 MA LOADS) | 32 | RVC | OUTPUT |
| COCKPIT INDICATORS — NOTE 2 (ANALOG METERS) | 4 | AOC | |
| DIGITAL INDICATORS/SYSTEMS — NOTE 2 | 4 | DOC | |

NOTES:

1. EACH CARD CAN BE CONFIGURED TO PROCESS FROM 1 TO 16 OF TWO DIFFERENT TYPES OF THERMOCOUPLES. THERMOCOUPLE MULTIPLEXERS CAN ONLY BE USED IN CARD SLOTS 6 & 7 OF THE SHORT RMDU AND IN CARD SLOTS 12 & 13 OF THE LONG RMDU

2. THESE CARDS CANNOT BE USED IN STANDALONE RMDU – FOR USE IN AIFTDS 4000 USING AIRBORNE COMPUTING SYSTEM

When configured with the DDP module, the RMDU receives a fixe frequency clock (up to 2.5 MHz) and data point addresses from a controller and sends back digitized data three word times after an address is received. For data dissemination, the card/chan address and the output data are contained in the same word. Randomness of the RMDU is typified by the fact that one channel can be addressed continually (but with different gains) at any rate up to 131K words per second or 64 channels can be addressed 2000 times per second, or any channel or group of channels can be addressed at any rate from 1 SPS up to a maximum word rate of 131K WPS in any numerical order.

The RMDU decodes the address word to set up the required mode of operation for that particular address and turns on the proper logic to control the various functional parts of the unit. The circuitry normalizes analog signals for conversion by the A/D converter and subsequent transmission. Discrete or digital signals are transferred via a two-word delay circuit directly to the line driver on the DDP card. A three-word delay is experienced from the time of address transmission when sampling analog data. One word time is required for amplifier autoranging while a second word of delay is consumed by the analog to digital conversion process. The data word is then transmitted during the third word time after the receipt of the data point address. The same internal delays are experienced when the STC module is used in place of the DDP module.

Analog input signals are routed from the optional signal conditioning/multiplexer cards to the Gain Programmable Autoranging Amplifier (GPA). The GPA can be controlled via software to provide any of eleven gains from G=1 to G=1024 in powers of two. The autoranging feature of the GPA permits it to double its gain if the input signal is less than 1/2 F. S. or half its gain if the input signal is over 9/10 F.S. Appropriate gain tag bits are appended to the digital data to indicate whether the gain used was different than that programmed. The amplified signal is processed by a conventional 10-bit analog to digital converter (ADC card) and transferred to the digital data processor (DDP card) for transmission to the ACS.

Digital/Discrete input signals are transferred from the optional input card(s) directly to a two word delay on the DDP card for subsequent transmission to the ACS. Analog/Digital/ Discrete output information is transferred in digital form from the DDP receiver to the appropriate I/O card for output signal conditioning. An integral Cal/BITE data capability is provided in addition to the normal I/O capacity, that permits fault isolation to the PC card level and real time calibration of all internal analog error sources.

**Signal Conditioning/Multiplexer I/O Cards**

The Basic RMDU has been designed to work with a wide variety of optional signal conditioning/multiplexer cards. The optional cards can be plugged into any of the optional

card slots in the housing. Once, however, a card is installed and software is prepared, the same type of card should remain in that card slot unless the software program is modified. The label on the housing provides a place to record the part number and serial number of each optional card installed in the basic unit.

**Analog Multiplexer Card (AMX)**   The AMX card provides thirty-two differential signal inputs that may be randomly addressed. Signal levels may be from ± 10MV F. S. to ± 10V F. S. The AMX circuitry in conjunction with the GPA provides CMR to ± 10 volts and it will sustain overvoltages of -15V to +30V without damage. An adressable thirty-third channel on the AMX card is dedicated to calibration and has been identified as Low Level Cal (LLC). The divider network on the card, however, can be changed in the field by the user to calibrate any gain of the amplifier by changing the values of the divider network connected to the + 10V reference supply.

**Discrete Multiplexer Card (DMX)**   The DMX card accepts 36 parallel discrete or digital input lines. It produces a logic 0 for signals of less than +0.8 volts or an open circuit or grounding of an input. It produces a logic 1 for signals from +2V to +30V. Signal current limiting to 1 MA maximum is provided for all signals. The DMX card also provides twenty-four 5-volt excitation sources current limited to 1 MA through the signal input connector. Therefore, discrete switch closure detection can be made closed loop without connection to the vehicles' power source. Each DMX card provides three adressable 12-bit words. An addressed discrete word is shifted out through 2-word delay registers before transmission so as to provide the same time delay as analog data. If the DMU/ACS sampling program is written to produce 8 or 9 bit resolution, bits No. 1 (for 9-bit resolution) or 1 and 2 (for 8-bit resolution) of each of the discrete words (or the least significant bits of an analog word) will be dropped by the DMU/ACS. Therefore, discrete inputs 1 and/or 2 should not be used unless a ten bit resolution sampling program is used. A 37th bit is provided at the output of the DMX card and is addressable as part of the power supply BIT word.

**Thermocouple Multiplexer Card (TCMX)**   The Thermocouple Multiplexer Card (TCMX) provides signal conditioning for thirty-one thermocouples of one or two different types of base metal wire (up to 16 of each type). The thermocouple wire is brought directly into the RMDU through the signal input connector. Unwanted junctions (i.e., Chromel to Copper and Alumel to Copper) are placed in two small isothermal zone boxes along with one chromel/alumel reference thermocouple. The reference thermocouples are connected to compensating bridge circuits whose outputs are connected to channels 15 and 33 on the PC card. Thereby the temperature of the inside of the isothermal modules is sampled whenever channels 15 and 33 of the TCMX card are addressed. Copper leads from the zone box are connected to a 33 channel MOS-FET differential multiplexer that is identical to that used on the AMX card. The thermal delay produced by the zone boxes is several

minutes in duration so that sampling of the thermocouple of interest and the zone box thermocouple have no real time proximity relationship. The airborne or ground computer then subtracts the unwanted zone box thermocouple temperature from the total signal (junction of interest temperature plus the zone box temperature).

**DC Bridge Card (DCB)**   The DC Bridge Card is a 12-channel signal conditioning/ multiplexer for use with strain gauges, resistance thermometers, potentiometers and other types of resistive sensors. Six of the twelve channels are configured to provide bridge completion circuitry (including signal offset, signal loading and sensitivity adjustments) for one, two or four active leg Wheatstone bridge circuits. The remaining six channels provide only signal input, source excitation voltage and a sensitivity adjustment. A precision voltage regulator is provided on the card along with current limiting resistors for each of the twelve excitation sources. The voltage regulator may be configured in the field to provide either 5V, 10V or 15V for bridge excitation by selection of the proper set of resistors on the card.

A thirteen channel differential multiplexer on the DC bridge card is the same as the AMX card with the excitation supply connected to the thirteenth channel. Resistors used for excitation supply current limiting, bias and signal loading may be tailored in the field for the specific type of strain gauge or sensor being used. The network may be configured so offset bias will balance bridges under strain in quiescent conditions. A signal loading network can be added to permit precise setting of scale factor to match one of the gains of the GPA.

**Relay/Valve Driver Card (RVD)**   The Relay/Valve Driver Card is a discrete data dissemination card that provides thirty-two (32) bilevel outputs with sufficient power capacity to operate small relays or valves. The data dissemination mode is established in the RMDU when an address with an "invalid" gain code is sent from the ACS. The 10 bits of the address word between the G bits and the Z bits can be usable information that is decoded on the output card. In the case of the RVD, the first 5 bits after the gain bits provide a 1 of 32 hi-lo command.

**Mode Selectable Presample Filter Card (MPSF)**   The Mode Selectable Programmable Filter Card provides two differential low-level active filters whose 3 db points may be set periodically to either of two frequencies (under software control). The filter inputs may also be switched between any of three different transducers during flight so that the same filter can be used for the gathering of data under different flight modes. Either filter's input circuit can be configured with three sets of bias/signal loading networks so that the MPSF card may be used in conjunction with the excitation and bias sources available on the dc bridge card. The signal input offset network and signal source connected to the filter preamplifier is determined by the three-position selector switch in front of the preamplifier.

Input selector switching and filter knee switching are controlled by the XY logic that normally operates the multiplexer gates of an AMX card. However, since source select/bandpass switching is a periodic mode function, it is performed at a time when data is not being sampled from a filtered channel.

The preamplifier is a fixed, high-gain, differential amplifier that has the same input characteristics (other than bandwidth) as the Gain Programmable Amplifier on the GPA card. The gain of the amplifier ($G = 128$ to $G = 1024$) can be set in the field by changing the gain adjust feedback resistor. The preamplifier provides a 0 to 5V full scale signal to the three-section (low pass) active filter which provides a rolloff characteristic of 18 db per octave from the -3 db point. Switch selectable RC components in the filter module permit the knee point to be changed to either of two frequencies (between 5 Hz and 100 Hz) under software control. The outputs of the programmable presample filters are sampled through a 2-channel multiplexer whose output is connected to the GPA so that gain may be used after the filter for unwanted frequency discrimination.

In addition to these cards, Teledyne has developed a score of additional different types of optional cards which may be used in the RMDU to process signals from any type of sensor or output commands to any type of load.

## PCM GROUND STATION

The AIFTDS Test Equipment consists of two independent subsystems; the ACS Test Set (a test set and PCM ground station) and the RMDU Portable Address Generator. The AIFTDS Ground Station is an equipment complex consisting of a mini-computer and several computer -controlled peripherals which with the appropriate software to provide the user with the following basic capabilities:

1)   Control and display features to allow hardware and software verification of the ACS and its I/O ports.

2)   Load and verify either the ACS or PDP-11 memory from magnetic tape and dump the ACS or PDP-11 memory contents onto magnetic tape and/or provide hard copy documentation of the ACS memory contents and/or the PCM data stream.

3)   Provide the capability to synthesize various PCM formats and related ACS programs in preparation for loading into ACS memory for a flight test.

4)   Provide general engineering computation capability and format flight tapes into IBM compatible tapes.

The equipment which performs these functions include a PDP-11 minicomputer, a CRT display and associated keyboard, a cassette-loaded ma gnetic tape system, a printer/plotter, a switch assembly, a magnetic disk file system, a card reader, special purpose logic, power supplies and appropriate enclosures, cables, etc. A functional block diagram and a photograph of the complete Ground Station is presented in Figure 7.
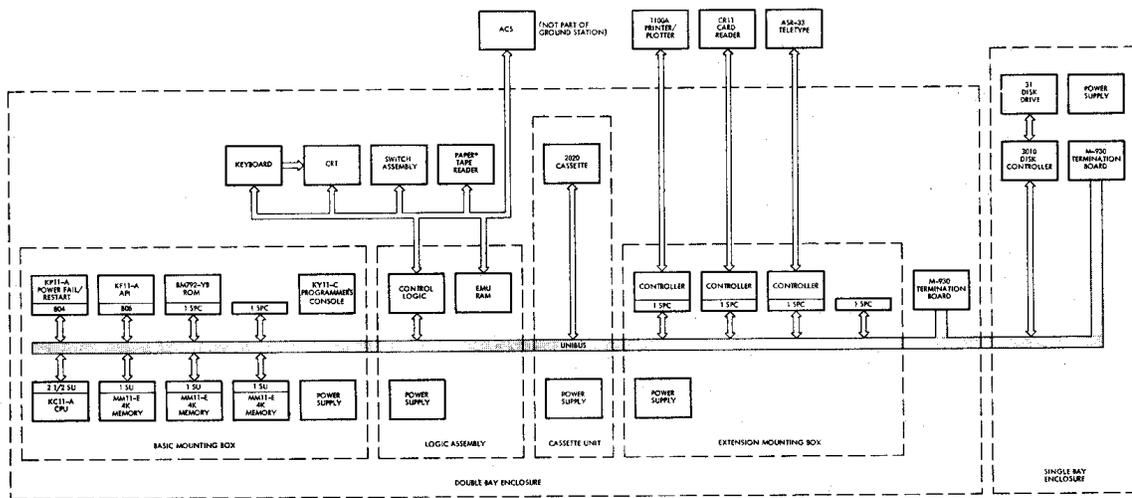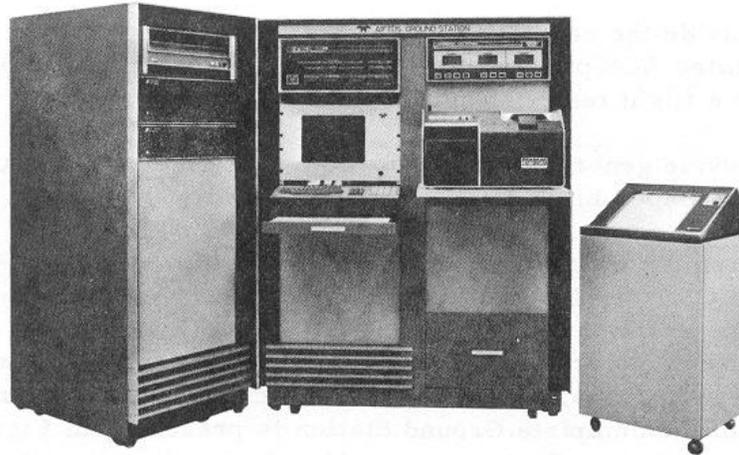


**Figure 7**

The Ground Station System is capable of operating in either of two basic configurations: Laboratory configuration with all equipments available; and Flight-line configuration with only those equipments housed in the central two-bay enclosure available. The laboratory configuration provides all basic capabilities. The Flight-line configuration provides only capabilities 1 and 2. The Ground Station software will accommodate both configurations.

**SUPPORT SOFTWARE**

An extensive and easily used system of support software for the AIFTDS ACS Test Set has been developed which includes a Symbolic Assembler, an Object Program Librarian, a Linkage Editor/Loader and Utility Programs. These software programs are written principally in Fortran IV and are readily adaptable to alternate host computer facilities. They are currently operational on IBM 36o/370 series installations.

The Symbolic Assembler is used to generate and maintain operational programs. The Assembler enables the programmer to generate programs using a symbolic representation for operational machine instructions, constants and variables. Inputs to the assembler can be punched cards, punched paper tape, or magnetic tapes from previous assemblies. Outputs from the assembler are of several optional forms so that a combination of outputs can be specified for one assembly. Optional outputs include; Perforated paper tape or cassette magnetic tapes containing the object program for loading the ACS, Magnetic Tape containing the updated source program, Perforated Tape containing the updated source program, and an Assembly Listing - including sorted symbol and reference dictionary and appropriate error message references. The Assembler is capable of creating both relocatable and absolute location object programs as an operator option. An update process, within the Assembler, allows additions, deletions, and revisions of code from a previously produced object program and merges these changes into an integrated "new" object program.

The Object Program Librarian allows storage of groups of object programs on a single magnetic tape. Programs are maintained in the same format as the outputs from the Symbolic Assembler. Provisions are made to add a new program to the library, delete a program from the library, and list the statistical characteristics of any program including name, type (absolute or relative), system data base referenced, and system data base defined.

The Linkage Editor/Loader combines programs assembled at different times, relocates these programs as required, and generates the tape used to load the ACS. Inputs to the Linkage Editor/Loader are object programs (either absolute or relocatable), program patches, subroutines, and suitable control parameters for directing the operation of the program. Outputs from the linkage editor can include; an absolute located object program, a memory map specifying allocations of system-defined symbols, and linkage error and warning messages such as: Memory allocation overlap, absolute-relative assignment conflict, duplicate system symbol reference, undefined system symbol reference, and an undefined program reference.

Utility programs are available for use in the object computer (the ACS) to perform varied functions. Among these are a bootstrap loader for filling memory, a fault isolation and diagnostics program, program debug aids, a library of subroutines and memory dump and peripheral interface routines.

**RMDU ADDRESS GENERATOR (PORTABLE TEST SET)**

The RMDU Portable Address Generator may be used as an address generator/data display unit (the sole interface with one RMDU), or it may be used in the monitor mode as a remote display unit for an RMDU that is being controlled by the ACS. The address generator is capable of powering the RMDU from an internal frequency converter so that any zone of a vehicle may be instrumented and checked out without the need for ship's power to be applied to the aircraft. The Portable Address Generator has the capability of selecting any of the RMDU's five modes of operation and dynamically exercising all of the functions of an RMDU except those of signal input simulation. A photograph of the Portable Address Generator is shown in Figure 8.
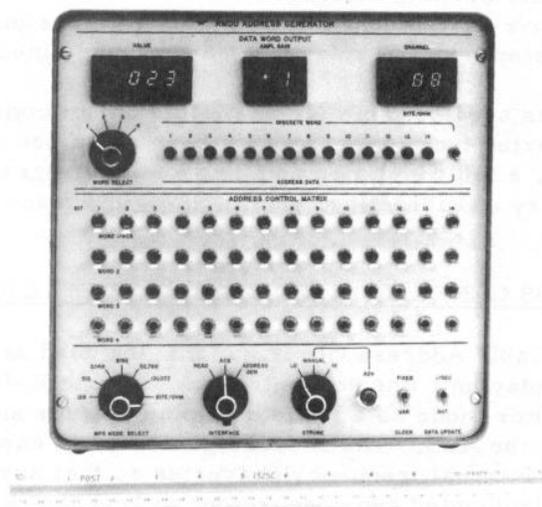


**Figure 8**

Four different random addresses can be transmitted to the RMDU at any one of six different word rates. Data from any of the four transmitted addresses is converted in the test set from Binary to Decimal and displayed on the numerical VALUE indicators (0 to 1024). The GPA autoranging gain tag bits are displayed on the AMPL GAIN indicators (0, +1 or -1). Discrete data words are displayed on lamps 1 through 12 of the 14 display lamps located under the numerical display indicators.

In the BITE/OHM mode the address generator disconnects the card select and gain select switches and substitutes an incremental channel advance counter which permits the operator to automatically or manually step through each of the analog channels. In the

manual advance mode, the operator can stop the multiplexer on any given channel and dynamically exercise the transducer while watching the data point readout on the Value display indicator.

In the read-only mode the test set can trap any one of the RMDU addresses transmitted from the ACS and display the address on the 14 indicator lights. The digital data word of the selected address is sampled as it is transmitted to the ACS and is converted to decimal form and displayed in the same manner as when the unit is operating in the address generator mode. The Read Only function does not interfere with normal operation of the system as the RMDU is at all times under control of the ACS sampling program.

In the Standby Mode the clock, data and address lines from the ACS are connected directly through the test set to the RMDU. This permits the operator to electrically bypass the circuits in the test set to verify whether any operating problems experienced are a function of a possible malfunction within the test set itself.