FIRMWARE CONTROLLED, HIGH SPEED, RANDOM DATA ACQUISITION UNIT

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Summary A firmware controlled, integrated data acquisition unit for computer controlled or standalone operation reduces the users Data Acquisition system programming task to preparation of a parameter list in IBM card deck format. Data cycle format generation is accomplished on a host computer which produces program tapes for the Data Acquisition system’s field erasable PROM format memory. The completely random data system can be programmed for a wide spectrum of data cycle sizes. Cycle rate can be remotely controlled in flight permitting the operator to select any of 256 word rates from 244 WPS to 125,000 WPS. Analog and digital signal conditioning can be included in the unit which also provides excitation power for all conventional sensors. Sensor capacity is from 44 to 352 channels depending on the type of signal conditioning required for a specific application. Up to eleven of over 20 different types of signal conditioner/ multiplexer I/O modules, plus the overhead modules and the system power supplies, may be accommodated at one time in a package of less than 450 cu in. (4" x 8" x 14"). All I/O cards and modules regardless of type are interchangeable at any of the eleven I/O locations in the unit housing. A miniature data display module which can be mounted in any standard cockpit control console permits the pilot or test engineer to have real time access during flight to any data point in the system. Two or more data systems may be used at remote locations in the same aircraft in synchronized operation to accommodate higher data throughput rates without increasing recorder bandwidth requirements by recording separate serial data streams on parallel tracks of a single multi-track recorder. Ground support equipment permits sensor installation, calibration and system checkout without the need for aircraft ground power or finalization of a sampling format for a test flight. Interchanging the Standalone Timing Module with a Digital Processor Module permits the Data Acquisition Unit to become a remotely controlled bidirectional data processor of a larger system performing both data acquisition and control loop functions.

Introduction The constantly increasing cost per flight hour of aircraft flight testing, coupled with a corollary change in accounting techniques of several major airframe companies as to how they treat aircraft flight test instrumentation hardware, has resulted in data system users taking a different approach to system mechanization. Increasing flight hour costs are being combatted by performing several test objectives per flight with more use of real time data on-board the aircraft. The accounting technique of capitalizing flight test hardware, instead of expensing it to a given project has made the user think in terms of achieving a ten year (or longer) life cycle from his equipment [1]. In the area of PCM hardware these two constraints have helped force the development of software controlled modular flexibility permitting a single family of instrumentation hardware to be applied to any unforeseen instrumentation task. Development of this type of PCM hardware was started in 1971 under a contract with NASA-FRC which produced the Prototype AIFTDS-4000 system [2]. The primary conceptual goals of the AIFTDS-4000 development program were to produce a computer controlled random access PCM system which had a much higher data throughput rate than that dictated by most aircraft flight test requirements. It was generally agreed, that with sampling rates, amplifier gains, etc., under software control, there would be no constraints in applying the hardware to a non-defined test task many years in the future. The integration of a computer with a large memory in the data acquisition system would permit real time calculations so the flight crew might have the use of data in engineering units in flight. This program was successfully completed in 1973 with the qualification of an Airborne Computing System and several Remote Multiplexer/ Demultiplexer units. However, as in all cases where the state-of-the-art is advanced, analysis of the delivered hardware showed where minor changes and design improvements could greatly enhance the capability and usefulness of the hardware. Thus the need for production engineering to eliminate the schedule forced design deficiencies of the prototype system.

Productionizing of the AIFTDS-4000 hardware has been accomplished under contract NAS2-7727 with Ames Research Center where one element of the system, the Remote Multiplexer/Demultiplexer Unit (RMDU) becomes the major building block of the flexible/modular system concept. The RMDU's will be configured for use as conventional PCM systems, that will be used in free flight aircraft, and then reconfigured as computer controlled PCM systems that will be used in wind tunnel test applications [3, 4]. In the production engineering process all of the hardware flexibility limitations of the Prototype RMDU were eliminated, greatly increasing its capability as a data processing unit [5]. A major technological advancement developed in conjunction with the production engineering of the hardware (under contract NAS4-2084 to NASA-FRC) has been the writing of software programs for PCM format generation on a host computer. The AIFTDS data system user now need only prepare an IBM card for each parameter (data point) in the data system specifying assigned RMDU location (i.e. card, channel, gain) and the anticipated maximum frequency (or sampling rate desired) of the data. From this card deck (or teletype tape) the software program in the host computer produces a printout of all RMDU address codes, an illustration of the data cycle, a tabulation of desired sampling rates, hardware imposed actual sampling rates (if they differ from desired rates due to hardware restrictions) and the punched tapes for programming the EPROM memory which controls the hardware operation. This paper describes the AIFTDS-4000 production RMDU, its companion hardware, software and GSE.

BASIC REMOTE MULTIPLEXER/DEMULTIPLEXER UNIT (RMDU)

When used as an autonomous PCM system, the RMDU may be treated as an analog/ digital data processor whose data point capacity is largely a function of the different types of sensors used in the aircraft, the quantity of each type of sensor and whether or not the integral signal conditioning capability of the unit is used on a given test or program. Here, of course, the test engineer has three options: (1) he can use his existing signal conditioning modules to normalize or process sensor signals before applying them to the RMDU, (2) he can use the AIFTDS integral signal conditioner/ multiplexers, or (3) he can use a combination of either type of hardware. Depending on these user determined variables, the maximum data processing capacity of the RMDU is 396 discrete/digital inputs or 352 analog data points or some lesser mix of both. The physical limitation is the availability of I/O card slot locations which accept the many different types of signal conditioner/multiplexer cards available.

To best understand the modularity and flexibility of the RMDU, it is first necessary to describe the modular packaging and hardware division of the system circuits. All electrical functions have been divided into two categories: (1) Overhead Circuits - those time-shared circuits for processing analog signals and digitizing them, the system timing and digital data processing and output format generation plus the system power supplies, and (2) Input/Output Circuits - those signal conditioners and multiplexers necessary to interface between different types of sensors and loads and the analog or digital data processors within the RMDU. The overhead circuits have been divided into three basic categories and packaged as three separate pluggable modules:

Module	Function
Standalone Timing Module (SAT-M), Or	Generates system timing, stores sampling format in EPROM’s, controls sampling, amplification and output data formatting.
Digital Data Processor Module (DDP-M)	Interfaces with DMU, accepts clock and address, controls internal functions and transmits digital data to DMU.
Analog Data Processor Module (ADP-M)	Contains gain programmable differential amplifier, auto-ranging amplifier (an option) and analog to digital converter.

Power Supply Module (PS -M)	Provides regulated and unregulated sensor supply voltages as well as internal supply voltages for operation of overhead and I/O cards.

Note: SAT-M and DDP-M are electrically and mechanically interchangeable.

The three overhead modules and the housing(s) are identified as the basic RMDU, to which may be added up to eleven identical or different types of I/O modules. The number and type of I/O cards required for a specific test application depends on the number of data points to be processed and the type of sensor used for each data point. The number of sensors of a given type processed by any one I/O card is a function of the complexity of the signal conditioning necessary to process the signal as either an analog signal or a discrete/digital signal and varies between 3 channels/card and 36 channels/card. Therefore, the RMDU's card configuration for any type of test requirement can be infinitely variable. A block diagram of the basic RMDU with a typical mix of I/O cards is presented in Figure 1.

The basic RMDU chassis is a two-piece dip-braze aluminum housing with the power supply contained in one section and the I/O and overhead cards (modules) contained in the other section. The two sections of the housing may be separated and mounted to the aircraft as separate units if space or heat dissipation problems become critical at the location where the RMDU is to be installed. Photographs of the RMDU and its power supply module are shown in Figure 2.

The housing length is a variable, dependent on the number of I/O cards desired. The standard unit has eleven I/O card slots. It can, however, be produced with as few as one or two I/O card slots if space were a critical factor. Also, if only a few I/O cards were required, a smaller power supply module could be used further reducing the total unit size. Each I/O card slot has a dedicated signal on the front face of the housing connector which provides 64 wires plus a shield and a ground for connection of the sensors to the ci rcuits on the I/O card. This provides a total input capability of 704 signal wires (352 differential pairs). A twelfth signal connector on the housing is used to bring thermocouple reference wires from the isothermal units outside the RMDU to the four I/O card slots which have been allocated to thermocouple multiplexers. In ad dition to the signal connectors there is a power input connector (for primary power), a transducer excitation connector and a communications connector. The communications connector serves a dual purpose. When the SAT-M is used to control the RMDU it provides the serial data output lines (including frame sync pulses, end-of-cycle pulses and PCM clock), the external clock and sync input lines and the word rate programming control lines. When the DDP-M is used in place of the SAT-M (operating the RMDU as a slave unit to the central data management unit), the communications connector serves as the clock, address and data interface with the DMU.

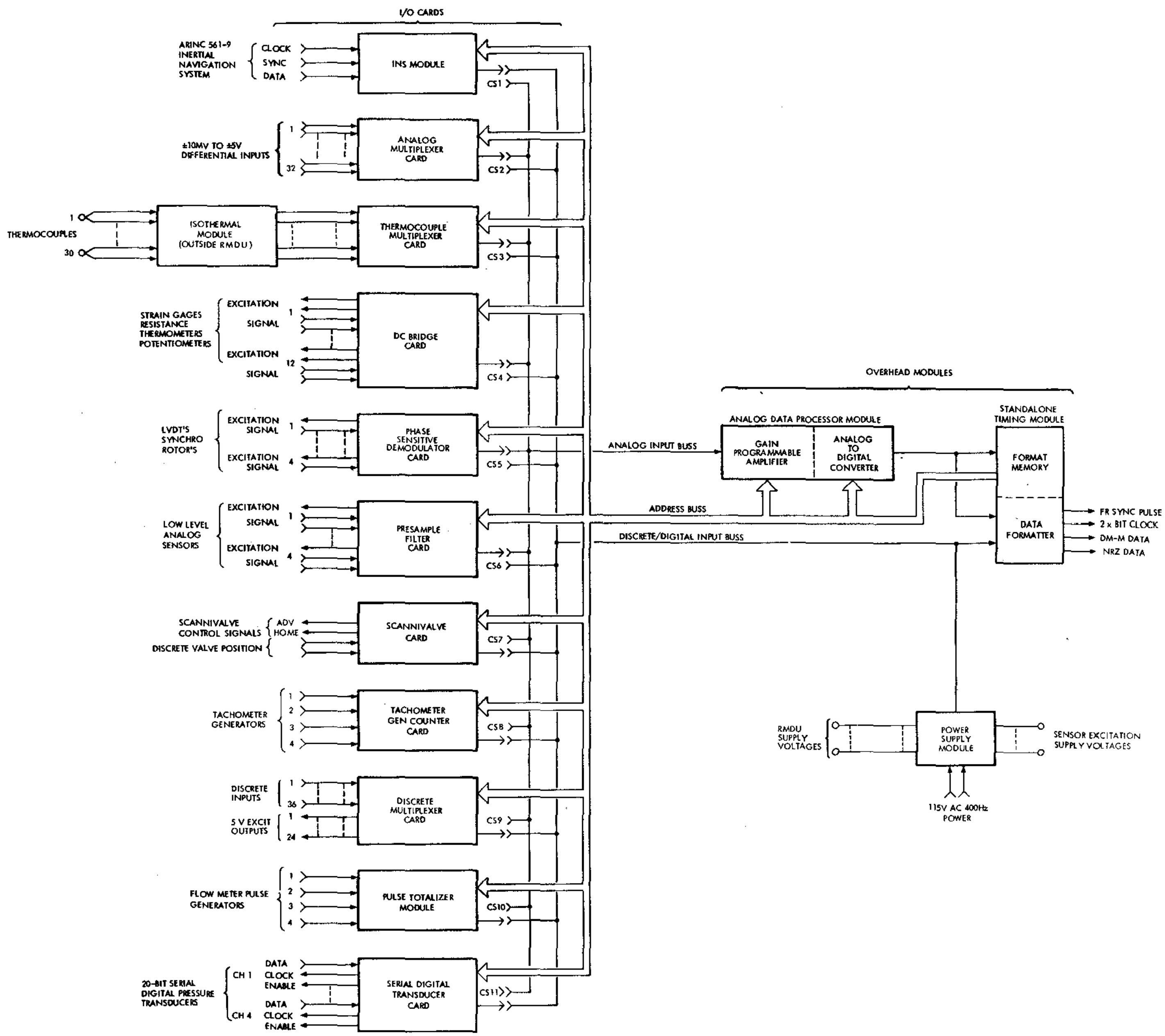

I/O CARDS
ARINC 561-9 INERTIAL NAVIGATION SYSTEM
CLOCK
SYNC
DATA
INS MODULE
CS1
±10MV TO ±5V DIFFERENTIAL INPUTS
ANALOG MULTIPLEXER CARD
CS2
THERMOCOUPLES
ISOTHERMAL MODULE (OUTSIDE RMDU)
THERMOCOUPLE MULTIPLEXER CARD
CS3
STRAIN GAGES RESISTANCE THERMOMETERS POTENTIOMETERS
EXCITATION
SIGNAL
DC BRIDGE CARD
CS4
LVDT'S SYNCHRO ROTOR'S
PHASE SENSITIVE DEMODULATOR CARD
CS5
LOW LEVEL ANALOG SENSORS
PRESAMPLE FILTER CARD
CS6
SCANNIVALVE CONTROL SIGNALS
ADV
HOME
DISCRETE VALVE POSITION
SCANNIVALVE CARD
CS7
TACHOMETER GENERATORS
TACHOMETER GEN COUNTER CARD
CS8
DISCRETE INPUTS
5 V EXCIT OUTPUTS
DISCRETE MULTIPLEXER CARD
CS9
FLOW METER PULSE GENERATORS
PULSE TOTALIZER MODULE
CS10
20-BIT SERIAL DIGITAL PRESSURE TRANSDUCERS
CH 1
CH 4
DATA
CLOCK
ENABLE
SERIAL DIGITAL TRANSDUCER CARD
CS11
ANALOG INPUT BUSS
ADDRESS BUSS
DISCRETE/DIGITAL INPUT BUSS
OVERHEAD MODULES
ANALOG DATA PROCESSOR MODULE
GAIN PROGRAMMABLE AMPLIFIER
ANALOG TO DIGITAL CONVERTER
STANDALONE TIMING MODULE
FORMAT MEMORY
DATA FORMATTER
FR SYNC PULSE
2 x BIT CLOCK
DM-M DATA
NRZ DATA
RMDU SUPPLY VOLTAGES
POWER SUPPLY MODULE
SENSOR EXCITATION SUPPLY VOLTAGES
115V AC 400Hz POWER

Figure 1.

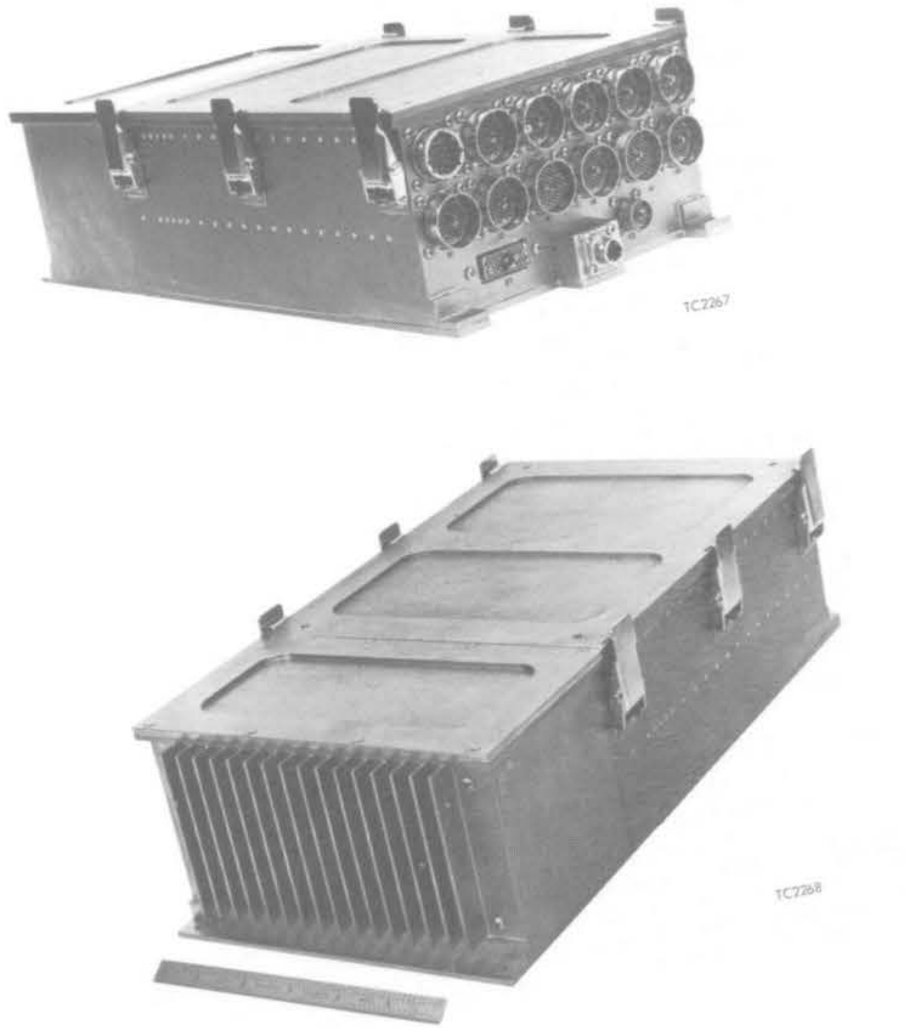


Figure 2.

Thereby, the only change necessary to convert an RMDU from an autonomous PCM system to an element of a larger computer controlled system is interchanging the pluggable digital processor modules (remove the SAT-M and plug in a DDP-M or visa-versa).

The RMDU has an integral calibration capability under software control which does not detract from the channel capacity of the I/O cards. Because a calibration signal is available on every card/module the Cal data cycle may be used as Built-In-Test Equipment (BITE) for fault isolation to the card level. Use of the Cal/BITE data points generates from four to fourteen additional addressable data words (not available outside the box) which produce a dynamic calibration of each analog error source within the RMDU. The Cal words are identified as follows:

Acronym	Cal Function
PSB	A go/no-go sum of all power supply secondary voltages measured for an overvoltage or undervoltage condition.
HLC	A 3/4 F.S. signal injected directly into the ADC to calibrate the ladder network.
GPA-0	A short applied across the input to the GFA to measure the amplifier’s offset voltage (HLC minus GPA -0 = Offset).
LLC-l thru LLC-11	A 33rd Cal Channel addressable on each of the I/O cards used in a box.

The signal levels of the Cal channels on the I/O cards can be set to provide plus or minus 3/4 F. S. Cal signals for each of the gains used by the GPA. Thus, all of the analog error sources (gain, offset and ADC ladder) may be calibrated each data cycle. The Cal data, if used to correct sampled data in the data reduction process, will increase the accuracy of the system to at least 0.1%.

RMDU/Sensor Power Supply

The RMDU/Sensor Power Supply is a pluggable module with pluggable cards that provides a multiplicity of both regulated and unregulated voltages for sensor excitation as well as supply of all of the regulated voltages for operation of the SAT-M, the ADP-M and any of the I/O modules used in the system. It is an integrated power supply module which accepts 115 VAC, 400 Hz, MIL-STD-704B power and is capable of operating more cards and sensors than required to satisfy the average parameter list. It is the reserve capacity of the power supply which permits the RMDU to achieve the flexibility of using different types and quantities of I/O cards to satisfy different aircraft sensor list requirements.

For example, the sensor supply section of the power supply module produces five different sources of excitation power which are available at both the I/O card connectors and at the external transducer power connector. The following sensor excitation voltages are provided:

28 VDC		500 MA	
20.5 VDC		102 MA (15 VDC)	
12.5 VDC	Note 2 (20.5, 12.5, 7.5 VDC)	144 MA (10 VDC)	Available on I/O cards - See Note 1
7.5 VDC		240 MA (5 VDC)	
10 VRMS 2KHz		100 MA	

Note 1 - Voltage regulators on PSF, EBC or DCB cards may be set to provide 5V, 10V or 15V sensor excitation, but no more than 14 watts of sensor power may be drawn from any one supply regardless of the I/O card and sensor complement.

Note 2 - These unregulated voltages are also available at the excitation (output/control) connector for use by external voltage regulators.

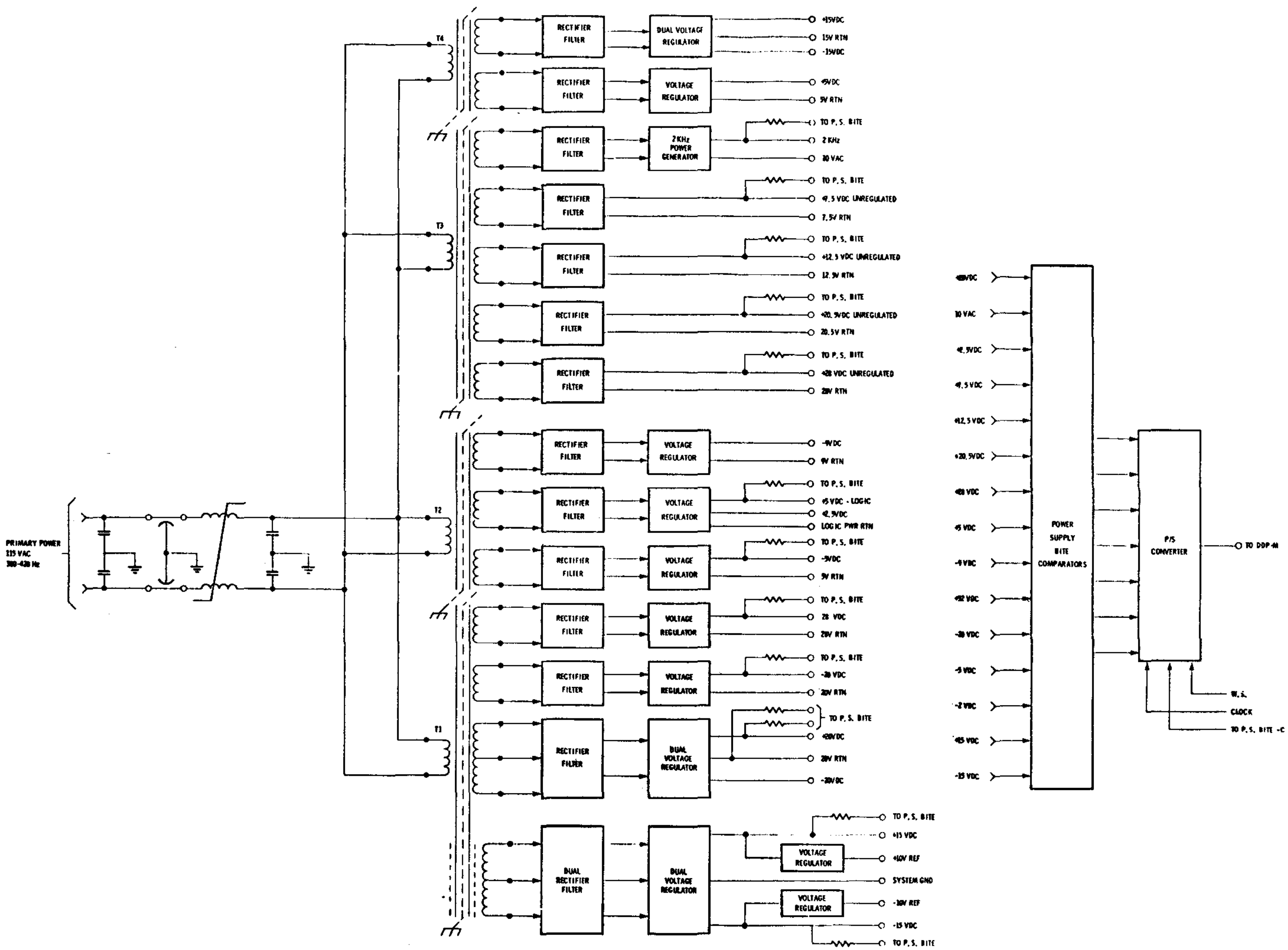
A block diagram of the RMDU power supply module is shown in Figure 3. Primary power is applied through an RFI filter to the primary windings of four power transformers having multiple secondary windings. Rectified and filtered regulated and unregulated secondary supply voltages are connected to the overhead side (the LH 84 pins) of each PC connector in the RMDU. This distributes the power to each I/O and overhead module. Printed circuit connections on each module pick-off the required voltages to operate the circuits on the card/module. Isolated taps on all of the power supply secondaries are summed together and applied to a sensitive bi-polar comparator which produces a fault status bit addressable as PSB.

Standalone Timing Module (SAT-M)

The Standalone Timing Module is the heart of the RMDU as it contains the format memory, controls all internal and external time bases and RMDU functions and formats digital data for transmission. The following are the key characteristics of the SAT-M:

PCM Outputs	(1) RF XMTR-Serial Data (2) Tape Recorder-Serial Data	NRZ-L, NRZ-M, Bi-Phase-L, or DM-M at either port
	(3) Frame Sync Pulses (4) 2 x Bit Clock (5) EOC Pulses	For System Test
Output Signal Amplitude:	Isolated dual data outputs (TTL compatible) at cable lengths to 250 feet from RMDU irrespective of bit rate.	
Data Cycle Size:	Infinitely variable up to 33K words (MF words x deepest SF column).	
Frame Sync:	Any sync code of any length, software programmable at start or end of frame.	
Main Frames:	MF lengths to 124 words, excluding frame sync, SF ID counter and SF columns (max MF length = 256 words).	

Subframe Counter:	SF binary counter word software programmable to any word slot in main frame.
Subfrarnes:	Total number of subframe data point addresses is 128. Number of SF time slots is 256. The product of SF columns times the deepest SF depth is limited to 256 time slots maximum.
Internal Clock:	XTAL controlled (10. 56 MHz to 5. 28 MHz). Changing pluggable crystal oscillators sets the highest word rate and thus gives a 2:1 expansion of programmable word rates.
External Clock Input:	2. 64 MHz to 5.28 MHz (also available from SAT-M as clock output) used when two or more RMDU's are slaved together in a single system with clock supplied from master SAT-M.
Word Lengths:	Hardware programmable 8 bits to 12 bits, with or without autoranging (G_T Bit), and/or with or without parity.
Word Rates:	256 different externally program word rates in 1 /n WPS increments from 488 WPS to 125, 000 WPS (or 244 WPS to 62, 500 WPS). Highest word rate set by selection of XTAL frequency.
Bit Rates:	1. 9K BPS to 1. 5M BPS - set by word rate and word length.
Gain/Card/Channel:	Random data point sampling with any of 8 GPA gains selectable for each analog channel.
Documentary Data:	Flight test documentary data such as aircraft number, engine number and even date and crew can be stored in memory and f ' ormatted as data words without using I/O channels (treated as additional sync words).
Master/Slave Opern:	Additional RMDU's may be operated in a synchronized master/slave relationship to increase throughput rate or to decrease bandwidth (parallel data s tr eams).



PRIMARY POWER
115 VAC
T4
T3
T2
T1
RECTIFIER FILTER
DUAL VOLTAGE REGULATOR
+15VDC
15V RTN
-15VDC
VOLTAGE REGULATOR
+5VDC
5V RTN
2 KHz POWER GENERATOR
TO P. S. BITE
2 KHz
7.5V RTN
+12.5 VDC UNREGULATED
12.5V RTN
+20.5VDC UNREGULATED
20.5V RTN
VDC UNREGULATED
+5 VDC - LOGIC
LOGIC PWR RTN
DUAL RECTIFIER FILTER
+15 VDC
+10V REF
SYSTEM GND
-15 VDC
10 VAC
+12.5 VDC
+20.5VDC
-2 VDC
-15 VDC
POWER SUPPLY BITE COMPARATORS
P/S CONVERTER
TO DDP-M
CLOCK
TO P. S. BITE -C

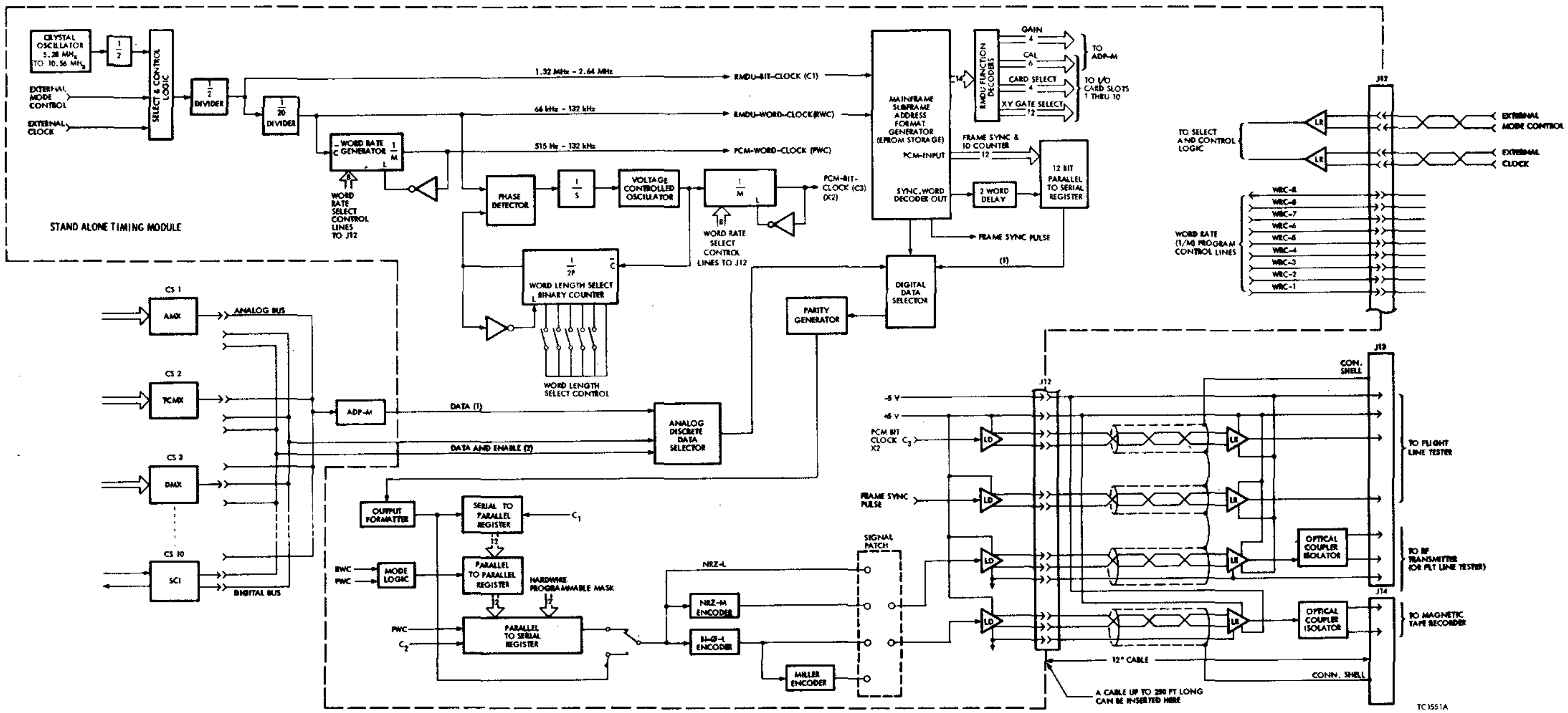
Timing of the RMDU generated within the SAT-M is divided into two categories: (1) internal or RMDU timing and (2) external or PCM timing, providing a semi-asynchronous timing relationship between internal word rates and external word rates and lengths. The use of digital phase lock loops to produce two different time bases from the same crystal clock is the basis for the programmable word rates and word lengths. The RMDU bit/word clock is set by the selected crystal frequency and the fixed dividers on the SAT-M, and is the systems highest PCM word rate that is used for internal data processing irrespective of the programmable PCM word rate (and length) used to produce the output serial data streams. A block diagram of the SAT-M is shown in Figure 4.

The ratio between the internal RMDU word rate and the PCM word rate is a 1/n number where the PCM output word rate can be any integer between 1/2 and 1/256 of the highest word rate determined by the crystal frequency. Additional word rate granularity may be achieved by using different pluggable crystal oscillator units to produce any maximum word rate between 125K WPS and 62.5K WPS. This combination of pluggable crystal units and (remotely) programmable word rates gives infinite granularity to sampling rates for any given data system application.

The flexibility of word rates is further expanded by the hardwire programmable word length generator which operates from the PCM word clock to generate the output PCM bit rate so that the data word may be truncated from its maximum length of 12 bits (eleven bits resolution, plus parity or the autoranging G_T bit) down to 8 bits. This means that without changing crystal modules, the RMDU can be programmed to produce any of 1280 different bit rates, 256 of which may be controlled remotely by the system operator during flight from a word rate selector switch in the cockpit.

During system operation the MF/SF format memory counter increments through the format memory at the PCM word clock rate until all of the programmed main frame and sub-frame memory locations have been addressed (until end of cycle - EOC is reached). EOC resets the memory address counters and the subframe counter and the sequencing process starts again. The subframe counter memory is used to permit the subframe data point addresses in the MF/SF format memory to be used more than once per data cycle, as is the case for data points sampled at a rate inbetween the slowest sampling rate (deepest subframe column) and the main frame rate.

Each of the MF/SF format memory words contain the internal control information for data processing within the RMDU, i.e., which I/O card to select, which channel to address on the selected I/O card, the gain of the Gain Programmable Amplifier (GFA), and whether the next address in memory is MF, SF, EOF or EOC. The composition of a 16-bit MF/SF format memory is as follows:



CRYSTAL OSCILLATOR 5.28 MHz TO 10.56 MHz
SELECT & CONTROL LOGIC
EXTERNAL MODE CONTROL
EXTERNAL CLOCK
DIVIDER
WORD RATE GENERATOR
WORD RATE SELECT CONTROL LINES TO J12
1.32 MHz - 2.64 MHz
RMDU-BIT-CLOCK (C1)
66 kHz - 132 kHz
RMDU-WORD-CLOCK (RWC)
PCM-WORD-CLOCK (PWC)
PHASE DETECTOR
VOLTAGE CONTROLLED OSCILLATOR
PCM-BIT-CLOCK (C3) (X2)
WORD RATE SELECT CONTROL LINES TO J12
WORD LENGTH SELECT BINARY COUNTER
WORD LENGTH SELECT CONTROL
STAND ALONE TIMING MODULE
MAINFRAME SUBFRAME ADDRESS FORMAT GENERATOR (EPROM STORAGE)
PCM-INPUT
SYNC, WORD DECODER OUT
RMDU FUNCTION DECODERS
GAIN
CAL
CARD SELECT
XY GATE SELECT
TO ADP-M
TO I/O CARD SLOTS 1 THRU 10
FRAME SYNC & 10 COUNTER
2 WORD DELAY
12 BIT PARALLEL TO SERIAL REGISTER
FRAME SYNC PULSE
DIGITAL DATA SELECTOR
PARITY GENERATOR
TO SELECT AND CONTROL LOGIC
EXTERNAL MODE CONTROL
EXTERNAL CLOCK
WORD RATE (1/M) PROGRAM CONTROL LINES
CS 1
AMX
ANALOG BUS
CS 2
TCMX
CS 3
DMX
CS 10
SCI
DIGITAL BUS
ADP-M
DATA (1)
DATA AND ENABLE (2)
ANALOG DISCRETE DATA SELECTOR
OUTPUT FORMATTER
SERIAL TO PARALLEL REGISTER
PARALLEL TO PARALLEL REGISTER
HARDWIRE PROGRAMMABLE MASK
MODE LOGIC
PARALLEL TO SERIAL REGISTER
NRZ-L
NRZ-M ENCODER
MILLER ENCODER
SIGNAL PATCH
-5 V
+5 V
PCM BIT CLOCK X2
FRAME SYNC PULSE
CONN. SHELL
TO FLIGHT LINE TESTER
OPTICAL COUPLER ISOLATOR
TO RF TRANSMITTER (OR FLT LINE TESTER)
TO MAGNETIC TAPE RECORDER
12" CABLE
A CABLE UP TO 250 FT LONG CAN BE INSERTED HERE
TC1551A

Figure 4.

A1 A2 A3 A4	G1 G2 G3 G4	X1 X2 X3 Y1 Y2 Y3	C1 C2
Card Select	Gain Select	Gate Select	Control

This same code without the control bits is used when a data management unit is used to control operation of an RMDU [6].

Analog Data Processor Module (ADP-M)

The Analog Data Processor Module (ADP-M) converts PAM signals from all analog I/O cards to eleven bit digital words which are formatted with words from digital I/O cards in the SAT-M to produce the continuous serial PCM data stream. The ADP-M and the I/O cards always operate at the highest RMDU word rate (the PCM word rate). The only difference between the RMDU word rate and the highest PCM word rate is the RMDU bit clock frequency which is a constant 20 bits per word as opposed to the 8-bits to 12-bits per word of the PCM word.

Functionally, the ADP-M is a two card module composed of a Gain Programmable Amplifier (GPA) with an (optional) autoranging amplifier, and an eleven bit analog to digital converter. The ADP-M is shown in block diagram form in Figure 5. The GPA is a wide band, high quality, differential instrumentation amplifier that uses a switch selectable feedback resistor network to produce any eight gains desired (from 1 to 1024) under software control. It amplifies the PAM signal from the output of the analog signal conditioner/multiplexer card selected for a given channel to a full scale range of ±5 VDC. Dual (ping-pong) follow and hold circuits hold the amplified signal while the ADC is digitizing it to an eleven bit word.

The GPA without autoranging can operate much faster than 8 microseconds per sample as the ADC is capable of making a full eleven bit conversion in less than 5 microseconds (200K WPS). However, when the autoranging amplifier (ARA) is used, it must (in one eight microsecond period) sense when the GPA output exceeds 90% F. S. (± 4.5V), switch to a gain of one-half, come out of saturation and then settle on the signal at the reduced gain. If the ARA switches gain, a gain tag bit (GT) is generated, passed through a one-word delay (to account for the ADC encoding period) and appended to the digital word in the SAT-M. The GT bit per mits the ground station to determine whether the gain used was the same as the programmed gain stored in format memory. The addition of the GT bit makes the full data word twelve bits long.

The ADC is a conventional bi-polar successive approximation converter with a self generated high frequency clock and makes an 11-bit conversion in less than 5 microseconds. It has an addressable calibrate function (HLC) which operates in the same

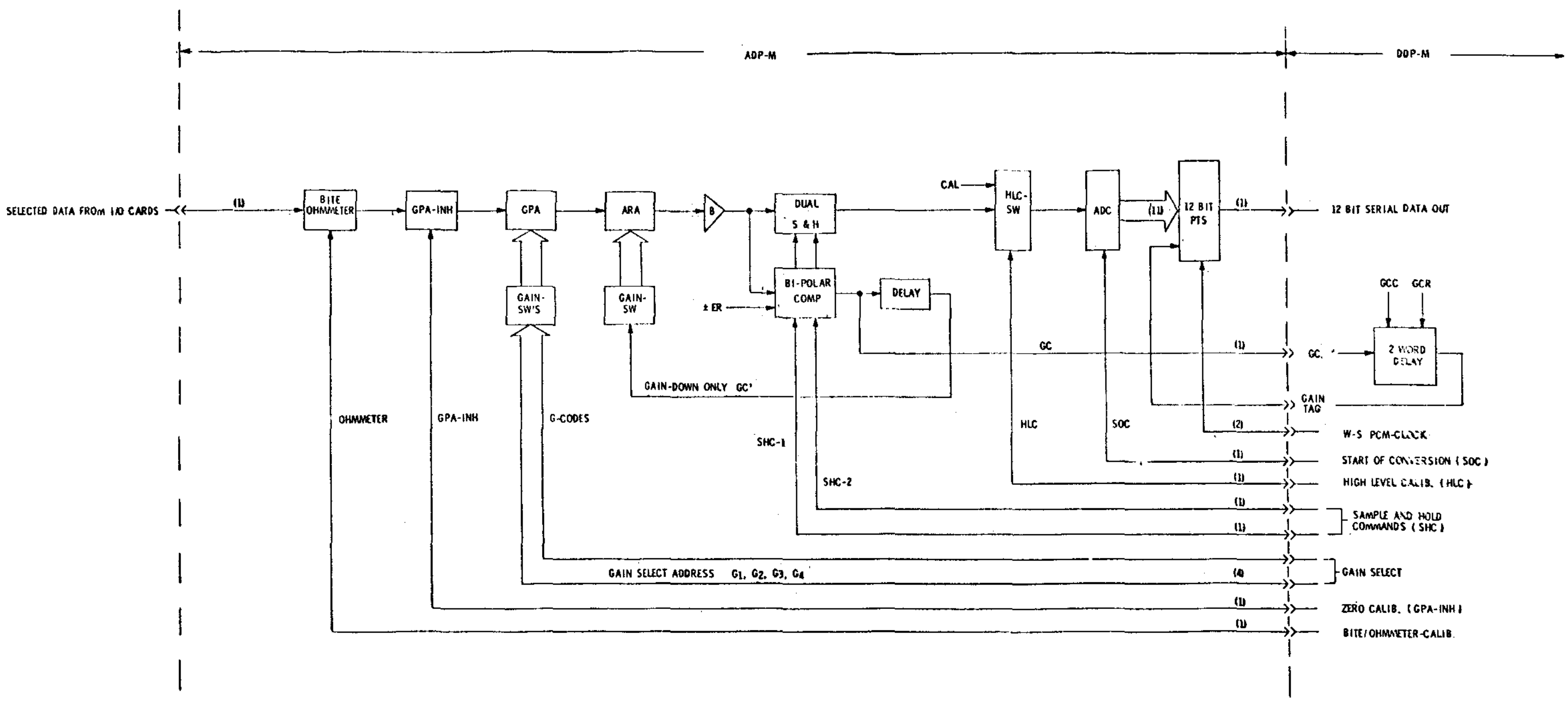

ADP-M
DDP-M
SELECTED DATA FROM I/O CARDS
(1)
BITE OHMMETER
GPA-INH
GPA
ARA
B
DUAL S & H
CAL
HLC-SW
ADC
(11)
12 BIT PTS
(1)
12 BIT SERIAL DATA OUT
GAIN-SW'S
GAIN-SW
± ER
BI-POLAR COMP
DELAY
GCC
GCR
GC
(1)
GC.
2 WORD DELAY
GAIN-DOWN ONLY GC'
GAIN TAG
OHMMETER
GPA-INH
G-CODES
SHC-1
SHC-2
HLC
SOC
(2)
W-S PCM-CLOCK
(1)
START OF CONVERSION (SOC)
(1)
HIGH LEVEL CALIB. (HLC)
(1)
(1)
SAMPLE AND HOLD COMMANDS (SHC)
GAIN SELECT ADDRESS G1, G2, G3, G4
(4)
GAIN SELECT
(1)
ZERO CALIB. (GPA-INH)
(1)
BITE/OHMMETER-CALIB.

Figure 5.

manner as any other data point in the system. HLC disconnects the F&H outputs from the GPA card and connects a precis ion +3. 75 VDC from the RMDU isolated reference supply directly into the ADC ladder network.

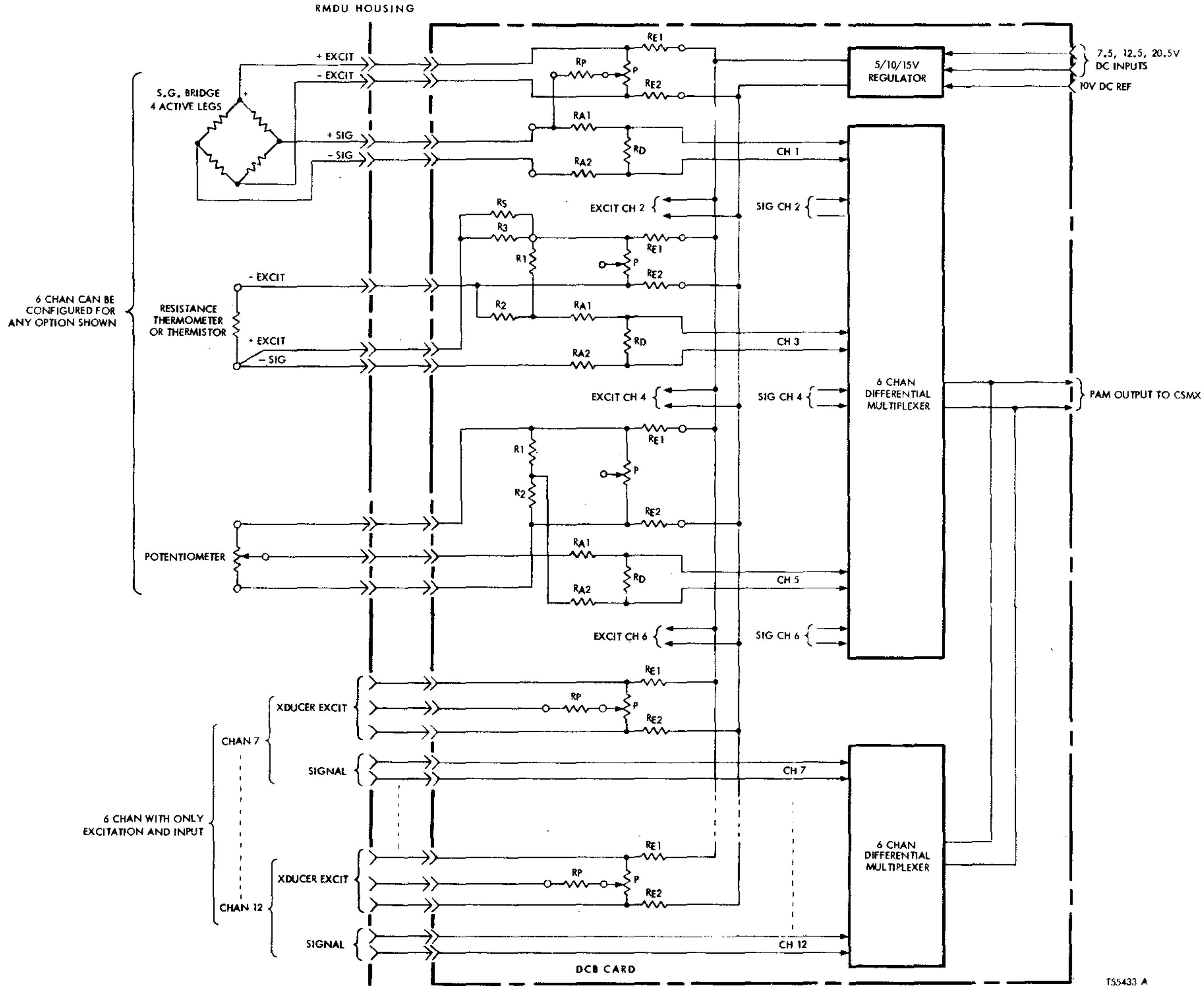
The cards of the ADP-M can be calibrated individually. Therefore, for maintenance purposes, any calibrated GPA or ADC card can be combined to produce a useable ADP-M requiring no further calibration. Any ADP-M can be used in any RMDU without affecting the system accuracy or without further calibration. This modular calibration concept (i.e., each card/ modules calibration is independent of any other card/module) reduces system repair time. It is only necessary to replace a suspected module with another unit to return the RMDU to serviceability.

Signal Conditioner/Multiplexer I/O Cards

The eleven I/O card slots in the housing can accept any of the more than twenty different types of signal conditioner/multiplexer cards of which have so far been designed for the system. All I/O cards are divided into two categories with two types of each category: i. e., (1) signal input cards - analog or digital and (2) signal output cards - analog or discrete/digital. Output cards, of course, can only be used when the RMDU is part of a computer controlled system so, at this time, we will limit I/O card des criptions to signal input cards.

Analog Multiplexer Card (AMX) The AMX card is a 32-channel differential multiplexer for use with any analog sensor having a signal output of ±10 mV to ±5V full scale. The calibration on this card (LLC) is the 33rd channel whose precision wire would divider may be set to cal ± 3/4 F. S. of any of the GPA gains. With eleven AMX cards the RMDU would have a data processing capacity of 352 channels.

DC Bridge Card (DCB) The DCB card is a 12-channel differential multiplexer that is designed to accommodate one, two or four-leg bonded strain gages, potentiometers or resistance thermometers. It provides a programmable voltage regulator for sensor excitation which may be set by jumpers on the card to provide 5V, 10V or 15V to excite the sensors. Excitation current limiting resistors and sensitivity controls are supplied for all twelve sensors, and adjustable signal offset, bridge completion and signal loading capability circuits for six of the twelve sensors. The voltage regulator on the board may be bypassed and an external excitation supply may be connected to the card through spare I/O cable wiring. A block diagram of the DCB card showing the different kinds of bridge circuits which may be accommodated is shown in Figure 6.



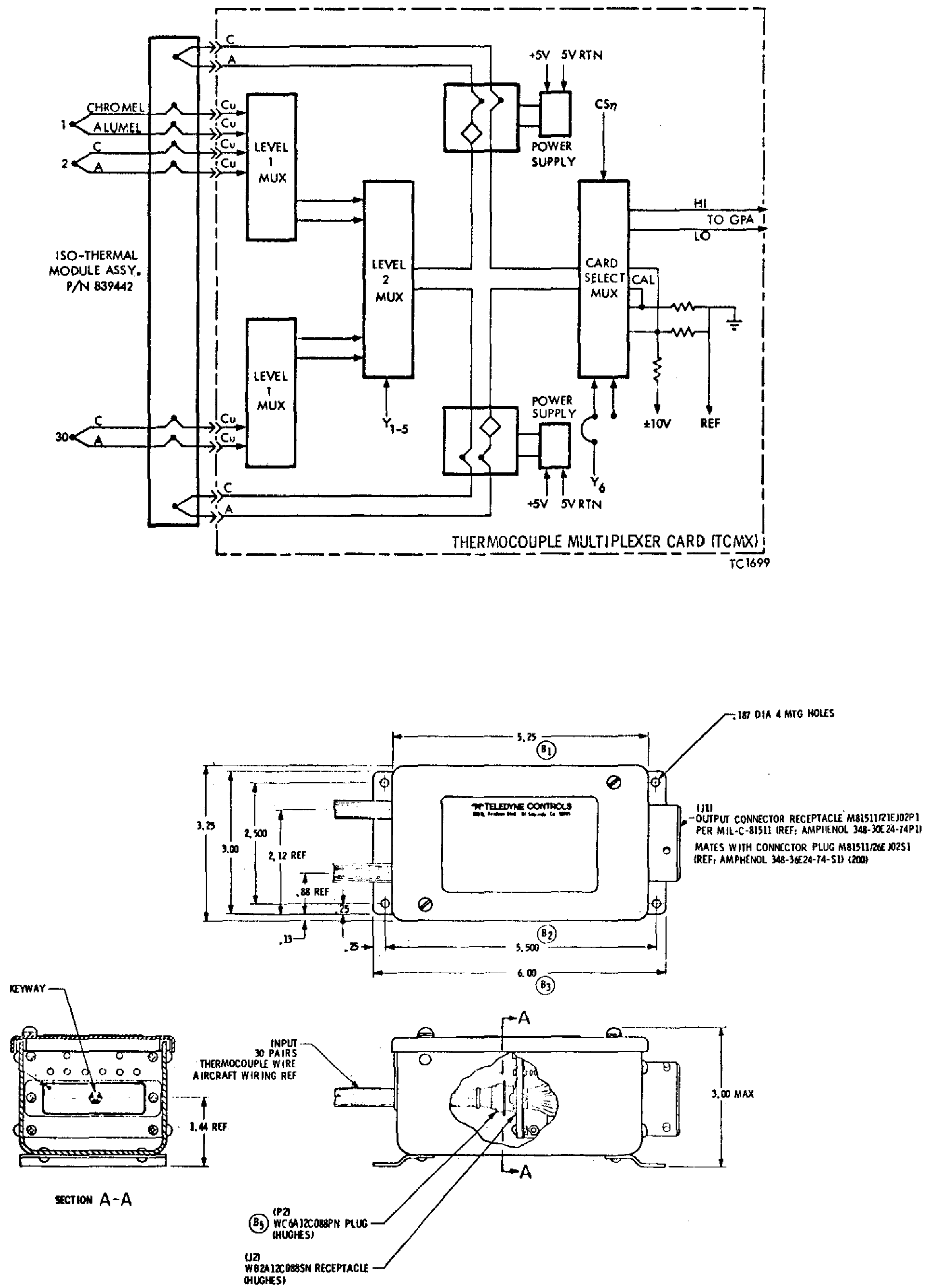
RMDU HOUSING
+ EXCIT
- EXCIT
S.G. BRIDGE
4 ACTIVE LEGS
+ SIG
- SIG
RE1
RP
P
RE2
RA1
RD
RA2
5/10/15V
REGULATOR
7.5, 12.5, 20.5V
DC INPUTS
10V DC REF
CH 1
EXCIT CH 2
SIG CH 2
RS
R3
R1
R2
6 CHAN CAN BE
CONFIGURED FOR
ANY OPTION SHOWN
RESISTANCE
THERMOMETER
OR THERMISTOR
- EXCIT
+ EXCIT
- SIG
CH 3
EXCIT CH 4
SIG CH 4
6 CHAN
DIFFERENTIAL
MULTIPLEXER
PAM OUTPUT TO CSMX
POTENTIOMETER
CH 5
EXCIT CH 6
SIG CH 6
XDUCER EXCIT
CHAN 7
SIGNAL
CH 7
6 CHAN WITH ONLY
EXCITATION AND INPUT
CHAN 12
CH 12
DCB CARD
T55433 A

Discrete Multiplexer Card (DMX) The DMX card is used to process discrete switch signals or parallel digital data. It will develop a logic “one” from any signal between +2V and +30V and a logic “zero” from any signal of +0.8V to -15V. The DMX card is a 36-channel card which is programmed in the SAT-M as three 12-bit data words. When the SAT-M word length is truncated to less than 12 bits/word, the channel capacity of the DMX decreases accordingly. In addition to the 36 inputs the DMX provides 24 current limited 5V excitation sources for discrete switch excitation. The DMX-I version of the card provides three TTL compatible inhibit lines so that source registers may be inhibited from being updated during the period that each of the 12-bit words is being read into the data stream. A differential input version of the card (D-DMX) for use with long, noisy signal lines is a 24 channel card.

Thermocouple Multiplexer Card (TCMX) The TCMX card and it companion isothermal module assembly are used to process up to 30 thermocouples of any SAE type (K, T, E, J, S, SX, RX or Y). It will operate with floating or grounded thermocouples and its time shared reference junction compensators eliminate the unwanted base metal to copper junction signals so that only the temperature of the junction of interest is processed by the RMDU. The isothermal module is a passive unit which may be mounted in the vehicle as close to the temperature measurement points as possible. TSP copper cables plus two pairs of base metal wires from the reference junctions in the isothermal module are then used to connect the isothermal module to the RMDU. The reference wires are brought into the RMDU through a TC reference connector which uses base metal pins and sockets.

The TCMX card is the only I/O card which is restricted to prescribed card slot locations in the RMDU due to the need to connect the reference junction wires from the TC reference connector to the I/O PC card connector. The standard housing is configured for I/O card slots I thru 4 to accept TCMX cards. However, by rewiring the housing TC reference wires, any four card slots could be used for TCMX cards.

The TC reference junctions are connected to two temperature compensated bridge circuits located on the TCMX card which are excited from isolated, low power, DC-DC power supplies. The signal outputs of the compensator bridges are connected in series with the HI-LO signal lines between the input multiplexer and the card select gates. The TCMX card has a 33rd channel Low Level Calibration (LLC) channel as do all analog input cards. Because only four TCMX cards can be accommodated by one RMDU the number of thermocouples which may be processed is limited to 120. A block diagram of the TCMX card and an illustration of the isothermal module are shown in Figure 7.



C
A
+5V
5V RTN
CHROMEL
ALUMEL
Cu
1
2
C
A
LEVEL 1 MUX
POWER SUPPLY
CSn
HI
TO GPA
LO
LEVEL 2 MUX
ISO-THERMAL MODULE ASSY. P/N 839442
CARD SELECT MUX
CAL
±10V
REF
Y1-5
Y6
30
THERMOCOUPLE MULTIPLEXER CARD (TCMX)
TC1699
.187 DIA 4 MTG HOLES
5.25
B1
3.25
3.00
2.500
2.12 REF
.88 REF
.25
.13
5.500
B2
6.00
B3
(J1)
OUTPUT CONNECTOR RECEPTACLE M81511/21EJ02P1
PER MIL-C-81511 (REF: AMPHENOL 348-30E24-74P1)
MATES WITH CONNECTOR PLUG M81511/26EJ02S1
(REF: AMPHENOL 348-36E24-74-S1) (200)
KEYWAY
INPUT
30 PAIRS
THERMOCOUPLE WIRE
AIRCRAFT WIRING REF
A
3.00 MAX
1.44 REF.
SECTION A-A
(P2)
B5
WC6A12C088PN PLUG
(HUGHES)
(J2)
WB2A12C088SN RECEPTACLE
(HUGHES)

Figure 7.

Frequency to Digital Converter (FDC) The FDC card is a four channel digital signal conditioner designed to operate from flow meter pulse generators. It will accept pulse trains with signal amplitudes of from 20MV to 20V having full scale pulse intervals of from 1100 PPS to 11,000 PPS. It can be programmed (hardwire on the card) for any of three different counter clear intervals per channel having a time ratio of 1, 3 & 5. The FDC card has an asynchronous time base for counter clear rate generated by a crystal oscillator on the card. The minimum clear interval is set by selection of the time base crystal and is determined by the anticipated maximum pulse rate and the desired resolution. Each of the four counters is a 10-bit counter. The time base is usually set to provide 1000 counts at the sensors maximum pulse rate before the counter is cleared. Because the FDC timing is independent from RMDU timing, any channel may be addressed at any sampling rate desired. When the SAT-M is programmed for 11 or 12 -bit words, the last bit(s) of the FDC word are logic 0's.

Pulse Totalizer Module (FTM) The PTM is a four channel digital signal conditioner also designed for use with fuel flow pulse generator sensors, but it is configured to measure total fuel consumed on a flight. It has adjustable threshold controls for each channel and can operate from signal levels between 10mV to 20V. Each channel is treated as two independent data points as far as SAT-M programming is concerne This means that the MSB word (the 1st 10 bits) of each channel may be sampled at a much slower sampling rate than the LSB word (the 2nd 10 bits), thereby conserving data cycle bandwidth. C-MOS counters supported by a rechargeable battery on the module permit the counters to retain their information for up to 30 hours of powered down operation. When a word of one channel is addressed by the SAT-M the counter's data is transferred in parallel to a latch so that data will not change during readout into the PCM data stream.

Tachometer Generator Counter Card (TGC) The TGC card is a four channel card that is designed to process signals from low frequency tachometer generators used to measure N1 and N2 RPM of gas turbines (0 to 100 Hz data). In order to improve resolution and accuracy of the low frequency pulse train from the tach generator, the TGC uses the incoming pulse intervals to gate a high frequency precision clock into the counter. The crystal frequency is selected to permit gating of 1000 clock pulses into the counter at the highest pulse rate of the tach generator.

Phase Sensitive Demodulator Card (PSD) The PSD card contains four classical phase sensitive demodulators which may be used with Linear Variable Displacement Transformers (LVDT's) or two wire synchro information. The card provides an accurate 2KHz 10VRMS excitation source for the LVDT or synchro. Each PSD, however, may also be used with sensors excited from the 400Hz vehicle power. Hardwire jumpers on the card will permit either type of operation for any of the four channels. The PSD outputs

(±5V = ±180° Phase) are selected.by one-of-four multiplexer on the card and applied to the ADP-M for digitizing.

Synchro Card (SYN) The SYN card is a 3-channel card designed to condition signals from classical 3-wire synchros. Scott-tee transformers convert each 3-wire signal into the Sine and Cosine of the angle. The sine/cosine information is stored in dual, pin-pong, sample and hold circuits operated by a peak detector controlled by the 40OHz synchro power. The sine/cosine information of each channel is treated as two sequential data points by the SAT-M program. The start of F&H switching is delayed by address control logic if the cosine data word (the second address of the pair of data points representing one angle measurement) has not been read out when the peak detector switches. This precludes the sine measurement of one peak being computed with the cosine value of the next peak. The use of dual F&H circuits means that one pair of angle data points is always available for digitization irrespective of the SAT-M sample rate programmed.

Scannivalve Driver Card (SVD) The SVD card is designed to control Ledex type Scannivalves used for pneumatic subcommutation of pressure transducers making static types of pressure measurements. The SVD contains hardwire programmable counters which divide down the pressure transducer valve position sensors sampling rate to generate low frequency pulse rates to increment and home the Scannivalve. Two 7-line discrete multiplexers on the card are used to monitor the binary position sensors of two different Scannivalves. Since Scannivalve position is required in addition to sensor pressure, the counters used to increment the valves are invisible in the sampling format. The advance counter is a programmable 8-bit counter which permits the Scannivalve to be advanced at rates down to 1/256 of the position sensor address rate. The 6-bit home counter permits use of any number of the Scannivalve’s 48 ports to be used on a given test.

Serial Digital Transducer Card (SDT) The SDT card is a four channel digital input card designed to operate with extremely accurate 20-bit digital pressure transducers (0 to 80,000 ft.). Each channel provides an inhibit line and gated clock so that each half of the 20-bit word stored in the transducers output register may be clocked into the RMDU data stream as two sequential 10-bit words. The inhibit line prevents the transducer from updating its output register until both halves of the 20-bit word have been read out by the RMDU.

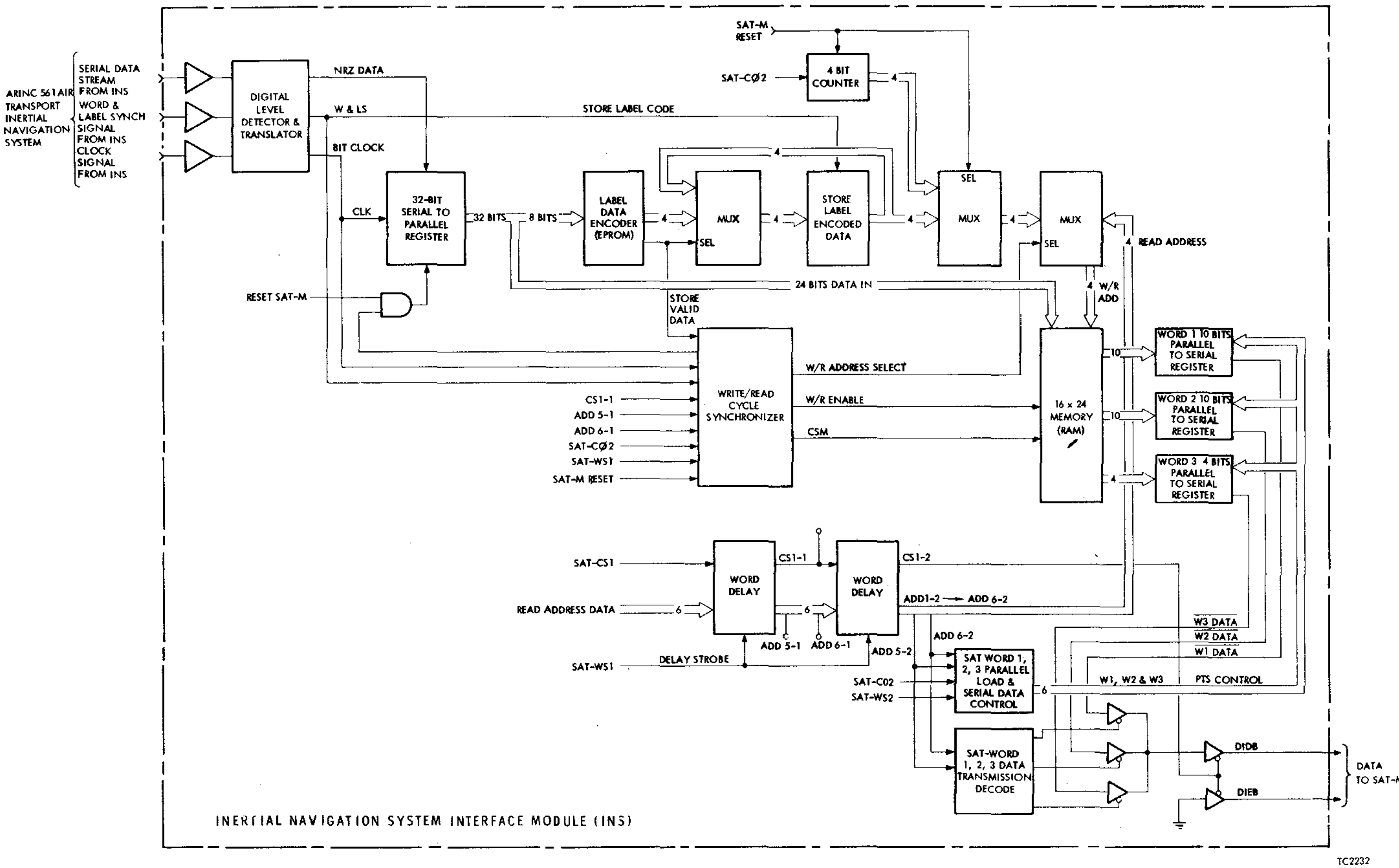
Inertial Navigation System Interface (INS) The INS module is designed to interface with any ARINC-561 Inertial Navigation System’s computer output port and transfers selected 24-bit words of INS data into the PCM data stream. The INS module can be programmed via pluggable EPROM’s on the module to strip out up to 16 of the 256 different serial data point words produced within the INS computer. The sixteen 24-bit data words are stored in a dynamic RAM on the module which is addressed by the SAT-M sampling program as 48 different data points (each 24-bit INS word is treated as three 8-bit data points). The remaining bits of the RMDU word are filled out as 01s. A block diagram of the INS module is shown in Figure 8.

Presample Filter Card (PSF) The presample filter card is a multipurpose card for use in either an RMDU or a dedicated Pre-Amplifier and Filter Unit (PAF). The PSF card has six different configurations depending on the ultimate intended uses of the card. For classical low-level signal sources such as skin vibrations, it is a four channel card with a high quality instrumentation amplifier followed by a three-pole unity gain active filter per channel. The knee locations of the filter can be programmed in the field to any 3db point from 10Hz upwards. The preamplifier gain can also be changed in the field to any gain up to 1024. Each filter has two isolated outputs, one of which is connected to a 1 of 4 multiplexer so the filter's signal may be processed by the ADP-M. The second buffered output of each filter is available at the I/O connector for use in driving analog instruments for real time photo panel displays. Options include bias pots on the preamplifter input so the filters may be used with bonded strain gages or other sensors requiring offset controls. Another option is a voltage regulator (the same as the one used on the DCB card) so that sensors connected to the PSF inputs may be excited from a precision 5V, 10V or 15V source on the PSF card. For low level signals, the dynamic range of the preamplifier is four times selected full scale gain so that semiconductor pressure transducers (or any other bridge circuit) need not be balanced and/or the autoranging feature of the GPA in the ADP-M may be preserved without saturation of the filter.

SYSTEM PROGRAMMING

Preparation of the PCM data cycle format has been computerized so that the AIFTDS user need only prepare a master parameter list containing the sensor type (the I/O card and channel assigned to an RMDU card slot for a particular type of sensor), the full scale gain (if it is an analog channel), and the desired minimum sampling rate. This parameter list is then converted to either a deck of IBM. pi-inch cards or a punched paper tape for entry into the computer (the software for format generation has been developed for use on a PDP-11 T-iost computer with 28K core memory).

The computer program tests the ratio of the number of channels of the highest sampling rate with the second highest sampling rate and compares the sum of 2 times the number of channels at this highest sampling rate plus the number of channels at the next highest sampling rate against the EPROM main frame format memory limitation of 128 data point address locations (including frame sync and subframe counter words). Depending on the fit, the main frame rate is thus established. All other desired data point sampling rates are grouped into arrays which are integer submultiples of the main frame rate. If the specified



ARINC 561 AIR TRANSPORT INERTIAL NAVIGATION SYSTEM
SERIAL DATA STREAM FROM INS
WORD & LABEL SYNCH SIGNAL FROM INS
CLOCK SIGNAL FROM INS
DIGITAL LEVEL DETECTOR & TRANSLATOR
NRZ DATA
W & LS
BIT CLOCK
CLK
32-BIT SERIAL TO PARALLEL REGISTER
32 BITS
8 BITS
STORE LABEL CODE
LABEL DATA ENCODER (EPROM)
MUX
SEL
STORE LABEL ENCODED DATA
SAT-M RESET
SAT-CØ2
4 BIT COUNTER
MUX
MUX
READ ADDRESS
24 BITS DATA IN
W/R ADD
RESET SAT-M
STORE VALID DATA
WRITE/READ CYCLE SYNCHRONIZER
CS1-1
ADD 5-1
ADD 6-1
SAT-CØ2
SAT-WS1
SAT-M RESET
W/R ADDRESS SELECT
W/R ENABLE
CSM
16 x 24 MEMORY (RAM)
WORD 1 10 BITS PARALLEL TO SERIAL REGISTER
WORD 2 10 BITS PARALLEL TO SERIAL REGISTER
WORD 3 4 BITS PARALLEL TO SERIAL REGISTER
SAT-CS1
READ ADDRESS DATA
WORD DELAY
CS1-1
WORD DELAY
CS1-2
ADD1-2 → ADD 6-2
ADD 5-1
ADD 6-1
ADD 5-2
ADD 6-2
SAT-WS1
DELAY STROBE
SAT-C02
SAT-WS2
SAT WORD 1, 2, 3 PARALLEL LOAD & SERIAL DATA CONTROL
SAT-WORD 1, 2, 3 DATA TRANSMISSION DECODE
W3 DATA
W2 DATA
W1 DATA
W1, W2 & W3
PTS CONTROL
DIDB
DIEB
DATA TO SAT-M
INERTIAL NAVIGATION SYSTEM INTERFACE MODULE (INS)
TC2232

Figure 8.

minimum sampling rates of the lower frequency data are not integer submultiples, their sampling rate is adjusted upwards until this test is satisfied.

Next, the number of subframe columns times the deepest subframe column is tested to verify that the total number of subframe time slots is less than the 256 word physical limit of the subframe steering memory on the SAT-M, and that the number of different subframe data point addresses is less than the 128 word limit of the MF/SF format memory.

Any time an impossible data cycle format condition is reached in the iterative process, the computer prints out the parameter limit exceeded. If no parameter limits are exceeded, the computer prints out a picture of the data cycle format with the channel numbers assigned to each time slot and the crystal frequency for the SAT-M that will produce the desired main frame word rate. It prints out a tabulation of the requested sampling rates versus the actual sampling rates achieved by the data cycle and prints out the binary address codes to be stored in MF/SF format memory identified by memory location. Finally it punches four separate paper tapes which may be used on the PROM programmer so that a set of EPROM's for the SAT-M may be programmed to produce the computed data cycle.

DATA DISPLAY UNIT

A portable data display unit has been developed which may be used for either pre- or post-flight checkout of the system or for use in flight as a real time data point monitor. Identified as the Flight Line Tester (FLT) this unit is a miniature bit/frame/subframe synchronizer which operates from any IRIG serial data stream, where frame sync pulses and the PCM bit clock are also available, as they are from the SAT-M output ports of the RMDU. Two sets of lever action thumb-wheel type selector switches permit the operator to select any main frame word location (0 to 512) and any subframe location (0 to 512) in a data cycle and then display the data word and gain tag bit from that time slot in the data cycle on numerical displays in sign/magnitude binary format. Discrete/digital data is displayed on a bank of twelve indicator lamps located below the analog data display indicators.

An output code selector switch selects an integral decoder to match any of five types of PCM output code (available from the SAT-M). A display update rate selector permits selection of a broad range of data display update rates from continuous to Z per second. The operator can also trap and hold any given data word for as long as desired by depressing a hold switch.

The FLT operates either as a termination load for the line drivers on the SAT-M in the RMDU, or as a party line receiver listening to either of the output ports of the SAT-M when the RMDU is connected to a magnetic tape recorder and a UHF transmitter as would be the case during a test flight.

Test jacks on the front panel provide buffered outputs of the four signal lines from the SAT-M (XMTR, RCDR, Fr Sync, Bit Clock). A D/A converter and GT shift register provide a continuous bipolar analog output of the selected data point to drive an instrument or a single channel strip chart recorder. A programmable display converter card permits the display indicators to always display the data in single scale, sign/magnitude format, irrespective of the type of encoding format used in the RMDU A/D converter and whether or not autoranging is used or inhibited on the GPA. A drawing of the FLT control panel is shown in Figure 9.

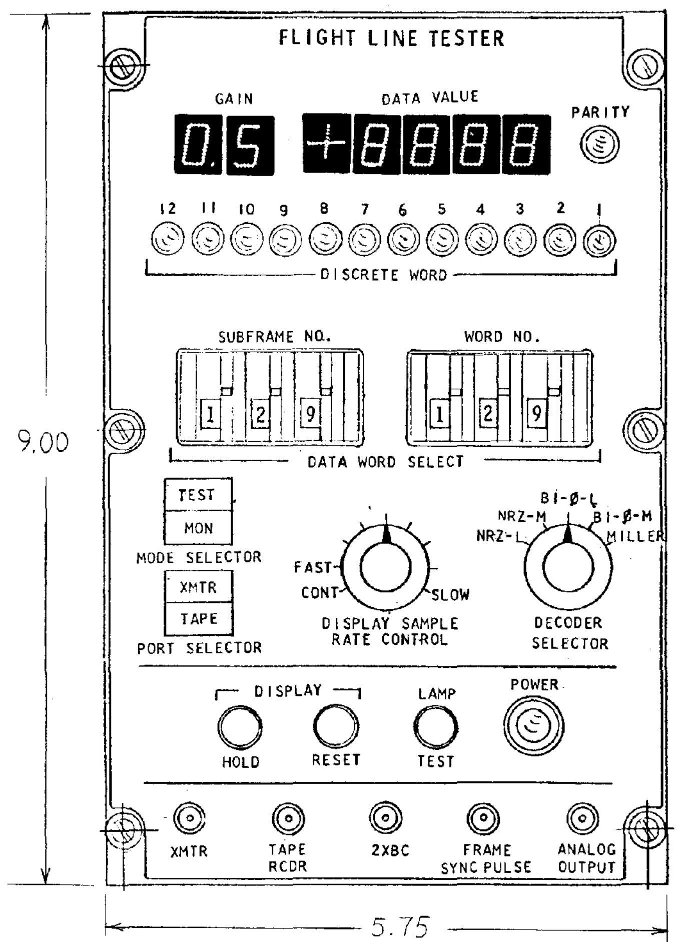


Figure 9.

PORTABLE ADDRESS GENERATOR (PAG)

Another piece of essential RMDU GSE is the PAG, a tester for both laboratory and flight line testing of the RMDU. To use the PAG [51 it is only nec e s s ar y to r eplac e the SAT-M with a Digital Data Pr oc e s s or Module (DDP-M) which is used as the digital control/interface when the RMDU is slaved to a central DMU. By using the PAG/DDP-M it is possible to interrogate any channel or function of an RMDU without having a sampling program written for the EPROM's in the SAT-M. The primary flight line use here is for dynamic sensor calibration or checkout. Since the RMDU powers the sensors, and a frequency inverter in the PAG powers the RMDU, data system checkout can be made without the need for ship's power on the vehicle. Position sensors can be set precisely while reading the data value on the PAG. Control surface calibration curves can be prepared or tailored to a specific scale factor without the laborious procedure of making an airborne tape and then reducing the data through the ground station to see the end-to-end results. A photograph of the PAG is shown in Figure 10.

Figure 10.

In the laborator y the PAG can be used to perform periodic calibration tests on the RMDU. The ability to randomly address any five data points in the RMDU and read out the data from any of the addresses permits measurement of crosstalk under conditions of common mode voltages, overvoltages, etc. It will also provide digital signal sources for checkout of analog and discrete/digital signal output cards residing in RMDU I/O card slots.

As with the FLT, the PAG provides two modes of communication cable termination. In the "test" mode the PAG acts as a DMU and provides the line drivers and receivers for the RMDU communication lines. In the "monitor" mode it acts as a party line receiver trapping both selected data point addresses transmitted by the DMU and the selected data value word transmitted by the RMDU to the DMU. The PAG address functions are in English language with the data point controls stored in EPROM’s within the PAG. The address display indicators display the address of the data word selected by the display word selector switch to ensure the operator that the data being monitored is from the location in the RMDU the operator has selected (not data from one of the other five addresses sent to the RMDU by the PAG). For flight line use where only sensor calibration is involved, a cover panel may be installed over Word 2 through Word 5 selector switches inhibiting their operation and thus reducing the possibility of human error in use of the PAG.

RMDU Power Monitor meters on the control panel indicate the voltage and VA being supplied to the RMDU from the internal frequency inverter. The digital and analog Data Outputs jacks provide the same function as their FLT counterparts. As with the FLT different display converters can be installed to match the encoder format of the A/D converter in the RMDU.

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