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An Analog Subsystem for the Plutonium Protection System

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Sandia Laboratories

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MASTER

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Unlimited Release
Printed December 1978

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ABSTRACT

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CONTENTS

ILLUSTRATIONS

AN ANALOG SUBSYSTEM FOR THE PLUTONIUM PROTECTION SYSTEM

Introduction

The Plutonium Protection System (PPS) is an item protection system that demonstrates advanced storage concepts which integrate detection and delay elements with careful monitoring and control of operational procedures. In addition, the accountability, operations, and security centers are physically separated to reduce vulnerability to insider threat. Organization of the PPS is illustrated in Figure 1. The five components of the PPS are interconnected with a data communications network:

- The Storage Vault is an Item Control Area (ICA) in which advanced detection and delay elements reduce the vulnerability to insider and to forced entry threats. Personnel access is carefully controlled and the three control centers continually interact to assure the proper movement of material.
- The Container Module Packaging (CMP) room is an ICA which provides point of entry to the PPS, i.e., material is packaged into standardized containers to prepare it for storage. For this demonstration, the CMP room is under the direct control of the Material Operations Center; in actual application, its structure would be similar to that of the vault, with access control and interaction among three control centers.
- The Material Operations Center (MOC) is a control center which monitors and controls all operations involving movement of items in the system.
- The Material Accountability Center (MAC) is a control center which maintains the accountability of all items in the system.
- The Security Operations Center (SOC) is a control center which monitors and responds to all alarms in the system and controls personnel access to the system.

Movement of material between the ICAs is accomplished in a secure fashion by means of a Secure Transport Module (STM) which is essentially a minivault on wheels. The STM must be securely docked at a port in the wall of the ICA before material can be loaded or unloaded. The actual transport of material is carefully timed to minimize the time available for tampering or diversion.

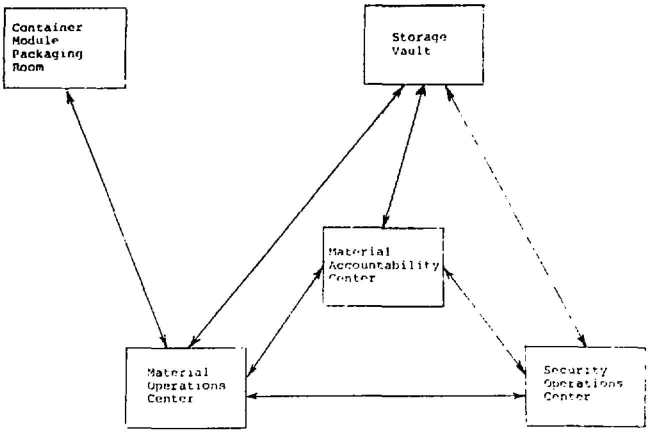


Figure 1. Plutonium Protection System Organization

The focal point of the PPS is the vault, which includes a personnel entry corridor, alarm and assessment components, a protected computer, and a storage room that contains Secure Storage Modules (SSM). The first three items carefully control access to the storage area, while the SSM provides physical barriers and alarms to detect any attempt to gain unauthorized access to the stored items once entry to the storage area is achieved. Figure 2 illustrates how the PPS has been set up in the Sandia Systems Integration Laboratory.

The SSM consists of four concrete cubicles, each housing a carrousel containing 35 storage locations in seven layers of five positions each. The storage locations are staggered so that the door assembly limits access to one location at a time. Specially designed Container Modules (CMs) are used to house the stored plutonium metal or oxide. Each CM is instrumented with an electronics package that contains several analog sensors to monitor state-of-health such as temperature and the "bulge" of the inner can. The SSM also contains rotary potentiometers which monitor the position of the carrousels. These analog signals must be digitized to be compatible with the microprocessor-based SSM controller.

The Analog Subsystem discussed in this report accomplishes the signal conditioning required so that the analog outputs are compatible with the SSM controller. The controller in the CMP room and the controller for the vault dock utilize the Analog Subsystem to monitor the rotary position of the STM carrousel as well as the sensors in the Container Modules. In the CMP room the weight of the CM is determined by a linear potentiometer (coupled with a spring) that must be conditioned by the Analog Subsystem.

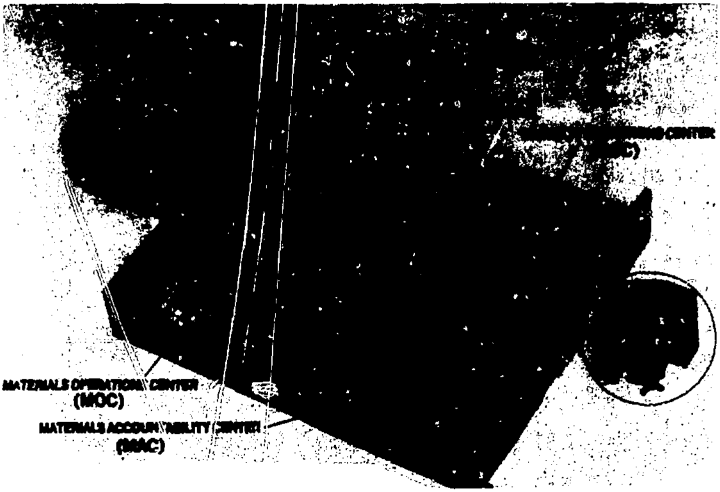


Figure 2. Plutonium Protection System/Systems Integration Laboratory

Summary

Several analog sensors are used in the Plutonium Protection System; those that interface with one of the microcomputer-based controllers must first have their outputs digitized. Signal conditioning is provided for the following measurements:

- Two temperature monitors in the Container Module (CM)
- A reading of the "Bulge" of the inner can in the CM
- The rotary positions of the carrousels in the Secure Storage Module (SSM)
- The rotary position of the carrousel in the Secure Transport Module (STM)
- The weight of the CM as measured in the CAP room.

The Analog Subsystem provides the signal conditioning required by the analog sensors. The subsystem utilizes an analog multiplexer (MUX) and an Analog-to-Digital Converter (ADC) to convert these analog signals to eight-bit digital words suitable for the microcomputer controllers.

The analog inputs are divided into direct and indirect channels. The direct channels monitor a single sensor such as the position of each carrousel in the SSM, the carrousel in the STM, and the spring-balance in the CMP room. These sensors are potentiometers powered by +5 and -5 volt references, whose outputs go directly to the analog MUX. The indirect channels monitor the sensors in each CM. Because of the large number of sensors involved, a "CM selection" scheme is used which activates only the CM of interest, even though as many as 35 monitors may be connected to a single input of the Analog Subsystem. The indirect channels are buffered by current summing amplifiers before going to the analog MUX.

System Description

The Analog Subsystem uses an Analog Multiplexer (MUX) and an Analog-to-Digital Converter (ADC) to convert analog inputs to eight-bit digital words suitable for the microcomputer controllers[1] in the PPS. The term ADC/MUX is commonly used when referring to the Analog Subsystem. This subsystem is used in three distinct applications:

- In the SSM, analog signals from the rotary potentiometer[2] on the carrousels, and the state-of-health monitors in the containers[3] are digitized by the ADC/MUX. This unit is located on the far right-hand end of the electronics enclosure, when viewed from the front.
- In the vault portal controller the sensors in the CMs are monitored as well as the position of the STM carrousel.[4] This unit is located in the vault control room in the controller marked "STM Controller."
- In the CMP room the same sensors are monitored as in the vault portal controller, with the addition of the spring-balance potentiometer[5] that weighs the CM. This unit is located in the rack chassis marked "CMP Controller."

Figure 3 illustrates the layout of the SSM Analog Subsystem. Each block shown represents a plug-in printed circuit (PC) card. These four cards plug into a small black anodized aluminum heat sink chassis which all system diagrams have labeled ADC/MUX (sometimes chassis C). The 16-channel input multiplexer card, and the ADC card are commercially available from Phoenix Data, and the current-to-voltage converter card and the power supply card are made at Sandia. Appendix A contains all pertinent schematics and data sheets.

An 11-bit, two's complement, binary ADC was selected for this prototype system in case an 8-bit word proved to have insufficient resolution. The 8-bit capability has been found to be quite adequate for all analog measurements as currently utilized, and system accuracy is limited more by system power supply voltages and mechanical couplings, especially in regards to carrousel rotational position.

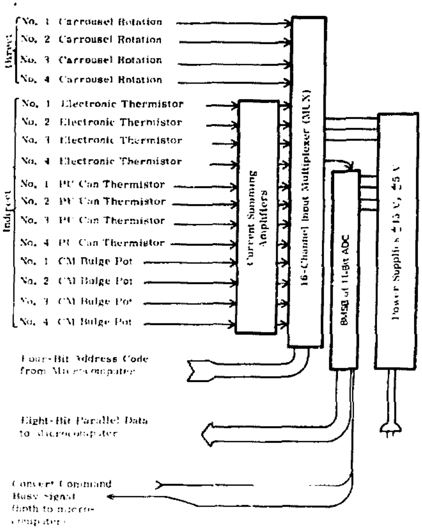


Figure 3

SSM Analog Subsystem

The ADC/MUX systems operate in a similar manner regardless of where they are used. The system in the SSM monitors sensors (Figure 3). The Vault Port Controller and the CMP Room Controller use the ADC/MUX system to monitor STM rotation and/or CM weight rather than SSM carrousel rotation (Figure 4). In each system, input signals can be divided into direct and indirect channels (Figures 3 and 4).

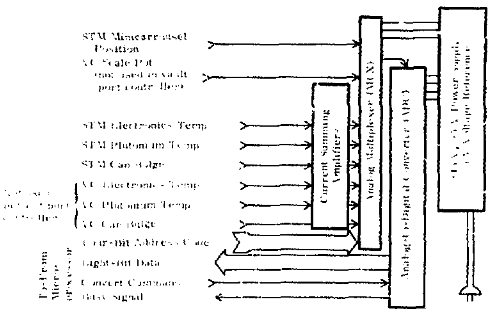


Figure 4. Vault Port and CMP Room Analog Subsystem

Direct Channels

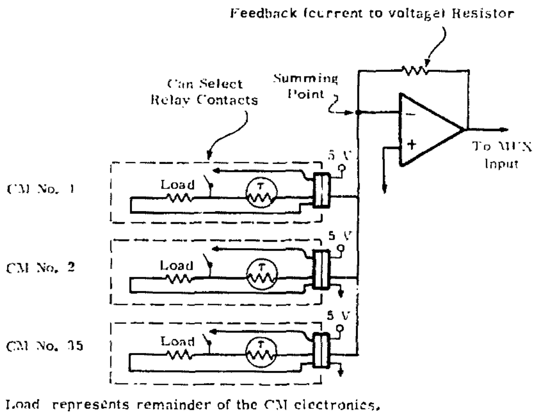
Direct channels monitor only a single sensor such as the position of each carrousel in the SSM, the carrousel in the STM, and the detector of the spring-balance weighing scale in the Verification Chamber (VC). In every case, the transducer is a potentiometer powered by -5 and -5-volt reference voltages on the ADC/MUX power supply card. These voltages may be monitored at pin jacks on the front of the chassis.

These channels are direct because there is no signal conditioning or additional multiplexing between the signal source (potentiometer) and the analog MUX card in the system. The microprocessor needs only to address the proper input channel, send a convert command, and then wait for the busy line to go low before taking a reading.

Indirect Channels

The remaining channels monitor temperatures (thermistors) and food-pack can bulging (linear potentiometer) inside the CMs. A multiplexing scheme is used which takes advantage of the fact that most of the electronics in each CM are turned off until interrogated by the PPS.

Figure 5 shows how the variable resistance sensors are used to feed signal current into the common summing point of the ADC/MUX input amplifiers.



Load represents remainder of the CM electronics.

(T) represents a thermistor or bulge sensor.

Figure 5. Variable Resistance Sensors

The concept of the scheme is simple. When a CM is interrogated, the relay contacts on the selected CM close, applying voltage to both the digital electronics and the sensor(s) inside the CM. A signal current, inversely proportional to the sensor resistance, then flows through the carrousel cabling to the op-amp summing junction. The op-amp outputs a voltage to the feedback resistor so as to keep the summing point near zero volts. The current from the sensor is then converted to an output voltage across the feedback resistor.

This concept assumes that only one CM in each carrousel will be selected for interrogation at one time. The other 34 CMs will be off so that the voltage across their sensors will be near zero and they will contribute little or no current to the summing junction, regardless of their resistance.

Because of leakage currents, ground loops, and millivolt drops due to power currents flowing in common ground returns, there will be noticeable errors generated as a result of this technique. However, the information needed does not require high precision and these add-on analog measurements have been included for very small per-unit costs (~ $10.00) per CM. The main purpose of these indirect measurements is to warn the system if:

- The electronics is becoming hot enough to fail
- The plutonium can seal is approaching its integrity temperature
- The plutonium can starts to bulge
- There is no longer any heat flow out of the CM, indicating that the radioactive material is gone.

This last measurement has a time lag of one-half hour or so and is not a fast tamper indicator.

Drawing CK-T42789 in Appendix A shows how the indirect measurements come straight to this card through a flat ribbon cable on connector CP4 (P4 on chassis C). The op-amps are labeled U-1 to U-12. The feedback and input bias resistors have been selected to give the desired output voltage. The thermistors have a nonlinear negative temperature coefficient; the data are listed in Table B-1 of Appendix B. A 2200-ohm resistor has been placed in series with each thermistor to make the current more proportional to temperature over the range of interest (25° to 130°C). The resulting voltage out is also in Appendix B.

The feedback resistor on each op-amp is by-passed by a capacitor to provide a low pass-filter function with a -3 dB frequency of about 1000 Hz. This filter action reduces high frequency noise, especially clock noise from the microprocessor. A lower cutoff frequency would cause excessive settling time when a CM is selected during inventory.

One important step inherent in this current-summing scheme is to assure that the reference ground for the noninverting op-amp input is as close as possible to the potential of the power common to the unselected CMs. Whatever voltage difference exists will contribute to small but cumulative inputs from the sensors in those CMs.

This problem has been minimized by providing one bus wire labeled ANALOG RETURN to each carrousel. This wire carries no dc power current, so it experiences no IR drop. By being connected to each of the seven carrousel junction box grounds through a 51-ohm resistor, this analog return bus seeks a potential that is an average between the ground voltages at all seven levels. The result will be an averaging of the positive and negative ground loop biases, and a considerable cancellation of error. The analog ground return comes back separately from each carrousel to the noninverting inputs of the three corresponding op-amps.[1] A series resistor helps balance the effects of input bias currents.

In some installations that use longer cables, such as the umbilical cable in the vault STM port controller, small signals from the summing junction apparently couple over to the noninverting input, causing an oscillation of several hundred kilohertz. Therefore, 0.022-microfarad bypass capacitors have been added to the positive input of each op-amp.

Troubleshooting

The repair philosophy of this chassis calls for field replacement rather than field repair. The troubleshooting approach will depend on the PPS status at the time, but, in any case, every effort should be made to confirm that the trouble lies in this chassis and not elsewhere. This may save a trip into the vault and may obviate opening the electronic enclosure.

Computer System Up and Running (Vault ICA or MOC)

The fact that the same ADC/MUX not only rotates the carrousels but also senses the CM detectors can provide a major clue. If all can measurements are correct, but the carrousel does not turn properly, the ADC or MUX cards are probably not at fault. Check for presence of ±5 volts on the front of the ADC/MUX chassis. If some carrousels turn properly but others not, a check should be made for bad rotary potentiometers or cables, or defective MUX address-bits from the microprocessor. When carrousels turn well, but some or all analog CM channels give bad readings, the analog board needs replacing.

If any of the above steps indicate that the problem may lie in this chassis, and time or radiation exposure is a problem, the most expedient solution is to replace the whole chassis. If conditions allow, replacing individual boards will save time later on, but the power supply voltages should be checked to see if they are proper before replacing other cards.

It is important to remember that all active components are mounted on the set of four cards, and it is extremely unlikely that any internal wiring will fail. To replace the boards, turn off power to the chassis and fan. Remove fan assembly, and flat ribbon connectors and slide the cards out.

WARNING:

Cards are not keyed and if they are plugged into the wrong slot or inserted upsidedown, damage will result. Figure 6 illustrates proper location and orientation.

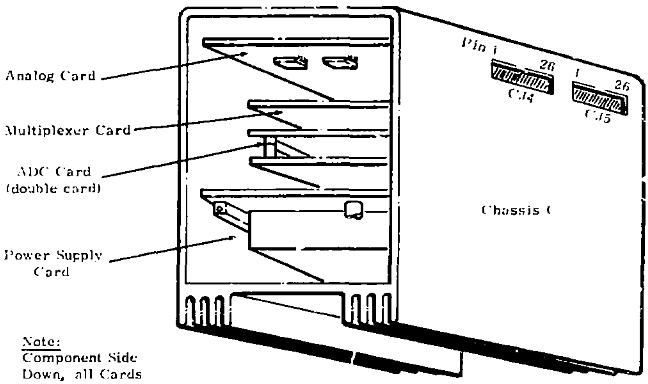


Figure 6. Location and Orientation of PC Cards

Computers Down or Not Available

A special ADC/MUX tester allows stand-alone testing of this chassis. Remove all existing cables except for the power cord. Connect the tester cables according to the labels. Check for polarity on the flat ribbon cables since they are not keyed. To check a particular channel, toggle the four binary switches to get the desired MUX address as displayed on the tester. Press the CONVERT command button. The reading obtained should be within ±1 bit of the value printed on the table attached to the tester. As before, if addresses C, D, E, F check out alright, but some or all of the remaining 12 channels do not, the problem lies in the analog card. If none of the channels test correctly, the problem is in the commercial cards or in the power supply. The power supply should be checked with a voltmeter. The 15-volt supplies may vary ±0.5 volt and the ±5-volt jacks should each measure 4.985±0.015 volts after a 15-minute warmup.

If the negative 5-volt output does not track the positive 5-volt supply, adjust the trimmer pot on the power supply board by removing the back cover and fan.

If any of the power supply modules are burned out, they may be replaced by removing the two 4-40 mounting screws from the PC board.

Replaceable Parts

Nonfunctioning parts should be returned to Sandia Laboratories in Albuquerque for repair; the following components may be replaced with spare parts:

- The entire unit may be replaced with a spare
- Each of four individual cards may be replaced with those from the chassis in the spare unit
- The power-supply modules on the power-supply card may be replaced individually but these are not stocked by Sandia.

References

1. Leslie H. Minnear, A Family of Digital Controllers for the Plutonium Protection System, SAND78-0384 (Albuquerque: Sandia Laboratories, 1978).
2. H. Duane Arlowe, Wiring for the Secure Storage Module for the Plutonium Protection System, SAND78-0689 (Albuquerque: Sandia Laboratories, 1978).
3. H. Duane Arlowe and R. S. Howard, A Special Nuclear Material Container Module for the Plutonium Protection System, SAND78-0695 (Albuquerque: Sandia Laboratories, 1978).
4. H. Duane Arlowe, Wiring for the Secure Transport Module and Vault Dock for the Plutonium Protection System, SAND78-0690 (Albuquerque: Sandia Laboratories, 1978).
5. H. Duane Arlowe, Wiring for the CMP Room and Verification Chamber for the Plutonium Protection System, SAND78-0694 (Albuquerque: Sandia Laboratories, 1978).

APPENDIX A

Schematic Diagrams

APPENDIX A

Schematic Diagrams

ECONOMY

ANALOG TO DIGITAL CONVERTERS*

ADC 400 Series

HIGH SPEED CONVERSION

[illegible] for 12 Bits

[illegible]

8 Microseconds for 8 Bits

ACCURACY

.001% of Full Range [illegible]

ECONOMY

14 Bits for $345

VERSATILITY

Binary, Pin Compatible with [illegible]

Non Standard Input Voltages [illegible]

SELF CONTAINED

Including Precision Reference Voltage

REPAIRABLE

No Potted Active Circuitry

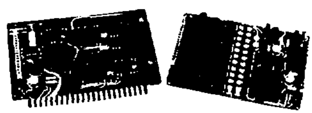
GENERAL DESCRIPTION

The ADC 400 Series Analog to Digital Converters are designed to provide an exceptional price/performance ratio. The technique of voltage switching successive approximation is *utilized to provide very fast, accurate conversion, with* excellent repeatability, linearity, and monotonicity.

An ADC 400 Series Converter is a complete, fully assembled, tested, and calibrated, "system ready" plug in module. It incorporates all the functions necessary to perform the conversion except for the power supplies. No external reference voltage source, amplifiers, or trimming potentiometers are required.

Each ADC 400 Series Converter is a complete functional unit. The accuracy and temperature coefficient specifications can, should, and do, include the errors due to the analog switches, the internal reference voltage generator, comparator offset, gain error, non-linearity, calibration resolution, resistor network tracking, quantizing error, and power supply variations within ± 5% tolerance.

The ADC 400 units are available in 8 thru 14 bit binary configuration, with four input voltage ranges offered as standard. Options offered include a high speed, high input impedance buffer amplifier, and units with an extended operating temperature range.



OPTIONS AVAILABLE

High Input Impedance Buffer Amplifier

Extended Operating Temperature Range of —55°C to +125°C

Special Input Voltage Ranges

Package size can be extended to suit particular applications

*Reprinted from brochure issued by

PHOENIX DATA, INC.

3384 WEST OSBORN ROAD • PHOENIX, ARIZONA 85017 •

FUNCTIONAL DESCRIPTION
ADC400 SERIES

The ADC 400 Series [illegible] Digital Converters [illegible] high [illegible] [illegible] voltage generator [illegible] switches [illegible] precision resistor network [illegible] The units [illegible] completely [illegible] construction [illegible]

[illegible] together [illegible] [illegible] [illegible] [illegible] high speed [illegible] ADC 400 Series [illegible] most [illegible] speed [illegible]

SPECIFICATIONS

MODEL	ADC [illegible]	ADC [illegible]	ADC [illegible]	ADC [illegible]	ADC [illegible]	ADC 40[illegible]	ADC 40[illegible]
[illegible] FSR [illegible]	[illegible]	0.015	0.025	0.05	0.1	0.2	0.4
[illegible]	12 PPM [illegible] FSR						
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	11.0	[illegible]	[illegible]	[illegible]

N[illegible] [illegible] LSB quantizing error [illegible]

ANALOG INPUT SIGNAL

[illegible]	[illegible]
[illegible]	Single Ended
Input Impedance	20K [illegible] Standard; 100 Megohms with Option [illegible] Input Amplifier
[illegible]	[illegible] Maximum; [illegible] with Input Amplifier
[illegible]	[illegible] FSR at 25°C; [illegible] months

CONTROL INPUTS AND OUTPUTS

[illegible] Voltage	2.4V [illegible] 5.0V
[illegible] Input	80 Microamps, Maximum
[illegible] Voltage	0V [illegible]
[illegible] Input	[illegible] 2 Ma max
[illegible] Convert	Conversion is initiated on [illegible] edge of positive pulse
Code	Binary 2's complement and offset Binary for negative numbers (Sign [illegible] are brought out)
B[illegible]	[illegible] during conversion
$\overline{B[illegible]}$	Complement [illegible] Busy

POWER REQUIREMENTS

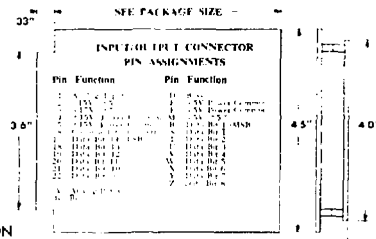
Voltage	[illegible]	[illegible]	[illegible]
	15V	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible] maximum

ENVIRONMENTAL

Temperature	
Operating	0°C to +70°C
Storage	[illegible] to +100°C
Humidity	0 to 95% Relative Non-condensing

PACKAGE SIZE (8-12 bits) [illegible]

PACKAGE SIZE (13 & 14 bits) [illegible]



Model ADC [illegible] A-BF

ORDERING INFORMATION

ADC 4 XX X — X XX XX

08	8 bits	Blank 0 to 70°C
09	9 bits	[illegible] [illegible] to [illegible]125°C
10	10 bits	
11	11 bits	[illegible]
12	12 bits	[illegible]
13	13 bits	
14	14 bits	B Bipolar Input
		U Unipolar Input

A Input Amp
Blank No Input Amp

LOCAL REPRESENTATIVE

MUX 1670

GENERAL DESCRIPTION

The MUX1670 is an easy to use 16 channel multiplexer providing high speed, very accurate analog signal switching. The unit is divided into two eight input switching sections. Each switching section has 3 binary coded address lines and an inhibit line. Decoding, drive circuitry, MOSFET switching, and optional buffer amplifiers and overvoltage protection are all included on the card which inserts into an Elco 6022 or Viking 2VH22 edgeboard connector.

A complete 128 channel analog commutator may be readily constructed by using additional MUX1670's and a PDI Model 140051 Multiplexer Control Card.

The optional buffer amplifiers can be specified as to gain (up to a gain of ten) by the user to achieve the desired voltage range at the output of the multiplexer.

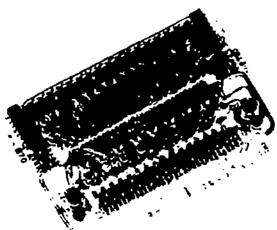
FEATURES

ACCURATE
- No Offset Voltage
- Low Leakage (typically 2 [illegible])
- Low Crosstalk [illegible] Range [illegible]

FAST
- Up to 200K channels sec [illegible]

ECONOMICAL
- Plugs into Standard Edgeboard Connector
- Fully Decoded
- Completely Repairable
- Easily Expandable

OPTIONAL BUFFER AMPLIFIERS



ADDRESSING

Eight Channel Differential Operation

Straight binary inputs to the decoders with AA and BA weighted as (1), AB and BB as (2), AC and BC as (4) and AD and BD as inhibit.

Sixteen Channel Operation

As above only the binary 8 output to the MUX 1670 is connected to AD input and the 8 output connected to the BD input.

ORDERING INFORMATION

MUX 1670 – 05 for ± 5V Input

MUX 1670 – 10 for ± 10V Input

Options Must Be Stated

SPECIFICATIONS

ANALOG INPUTS

Number of Analog Inputs	16 Single ended or 8 differential
Input Voltage Range	±10V (with ±15V and ±20 to ±24V Supplies) ±5V (With ±15V Supplies)
Input Overvoltage	±15V Max., any input
Input Capacitance	Less than 200 pf (worst case)
"Off" Impedance	Greater than 100 megohms
"Off" Input Current (25°C)	Less than 1nA
Crosstalk (R$_s$ = 1K)	Less than ±.001% of full range for ±10V input with other 7 inputs driven ±10V at 1KHz
"On" Resistance (Typical)	400 Ohms Maximum
"On" Input Current (25°C, Output Open)	Less than 6 nA
Settling Time (R = 1K)	5 Microseconds to ±.001% of final value

CONTROL INPUTS

Logic Levels	
Logic "1" Voltage	+2.4V to +5.0V
Logic "1" Current	40 Microamperes
Logic "0" Voltage	0.0V to +0.4V
Logic "0" Sink Current	1.6 Milliamperes
Address Inputs	3 lines for each 8 input switching section; Binary Code (4, 2, 1)
Inhibit Inputs	1 line for each 8 input switching section; Logic "1" level inhibits all 8 switches regardless of address inputs

POWER REQUIREMENTS

Logic Supply	+5 volts ± 5%, 60 ma nominal
V+ Supply	+15 volts, ± 5%, 30 ma nominal
V− Supply	−15 volts Min. (for switching ±5 volt levels) 30 mA nominal; −24 volts Max. (for switching ±10 volt levels), 40 mA nominal

ENVIRONMENTAL

Temperature (External Ambient)	
Operating	0°C to +70°C
Storage	−55°C to +200°C
Humidity	0 to 95% relative non-condensing

APPLICATIONS

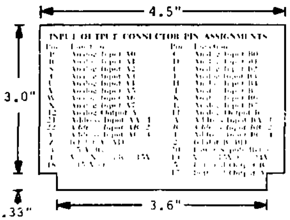
Time Division Multiplex (Time Share) of many analog voltage input signals into a single output device such as an analog signal sample and hold and/or analog to digital converter.

Time Division Demultiplex (Data Distribution) of a single input signal to many output devices such as analog holding circuits, recorder channels, et cetera.

Single Selection of multiple gain determining circuits around or within an instrumentation amplifier.

Other applications which require the selection and connection of precision analog voltage at high rates.

PACKAGE CONFIGURATION



OPTIONS AVAILABLE

Overvoltage Protection (No Additional Price)
- Increases Input Overvoltage to ±30V, Maximum
- Increases "On" Resistance to 2.5K Ohms
- Increases Input Leakage Current to 25 na. Maximum
- Increases Settling Time

Buffer Amplifiers (one per eight switches)
- Customer must specify characteristics of amplifiers (gain, input impedance, et cetera)

Hermetically Sealed Active Components

Extended Operating Temperature Range
- −55°C to +125°C

LOCAL REPRESENTATIVE

Nov. 1971

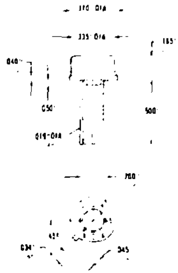
SPECIFICATIONS

MODELS 3500 A B C
3500 R S T

OPEN LOOP GAIN	[illegible]	[illegible]	[illegible]
RATED OUTPUT	[illegible]	[illegible]	[illegible]
FREQUENCY RESPONSE	[illegible]	[illegible]	[illegible]
INPUT OFFSET VOLTAGE	[illegible]	[illegible]	[illegible]
INPUT BIAS CURRENT	[illegible]	[illegible]	[illegible]
INPUT DIFFERENCE CURRENT	[illegible]	[illegible]	[illegible]
INPUT IMPEDANCE	[illegible]	[illegible]	[illegible]
INPUT NOISE	[illegible]	[illegible]	[illegible]
INPUT VOLTAGE RANGE	[illegible]	[illegible]	[illegible]
POWER SUPPLY	[illegible]	[illegible]	[illegible]
TEMPERATURE RANGE	[illegible]	[illegible]	[illegible]

TO-99 PACKAGE

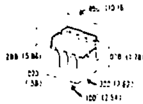
Specify 3500A, etc



BOTTOM VIEW

MINI-DIP PACKAGE

Specify 3500AN, etc



TOP VIEW

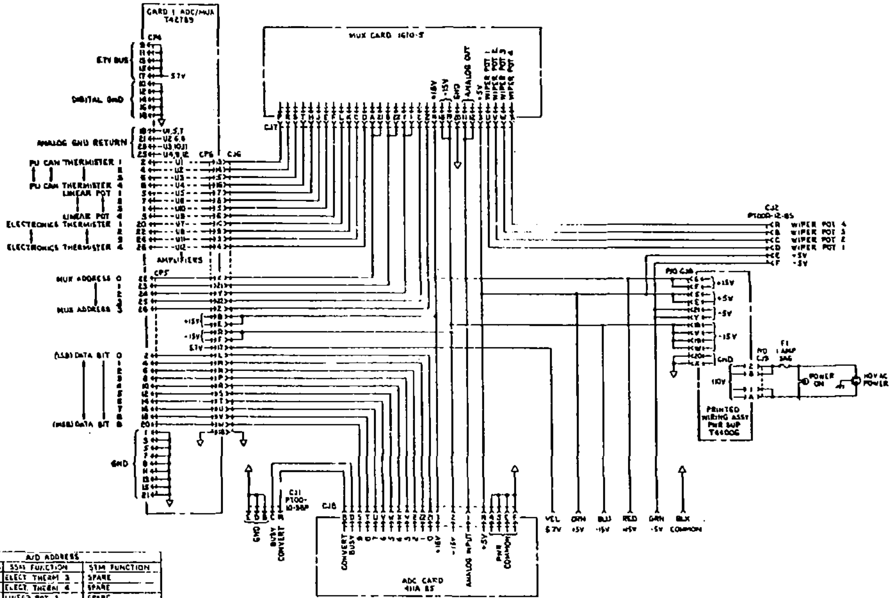
Dimple appears over pin space

Note: Dimensions in millimeters are shown in parentheses.

PIN CONNECTIONS

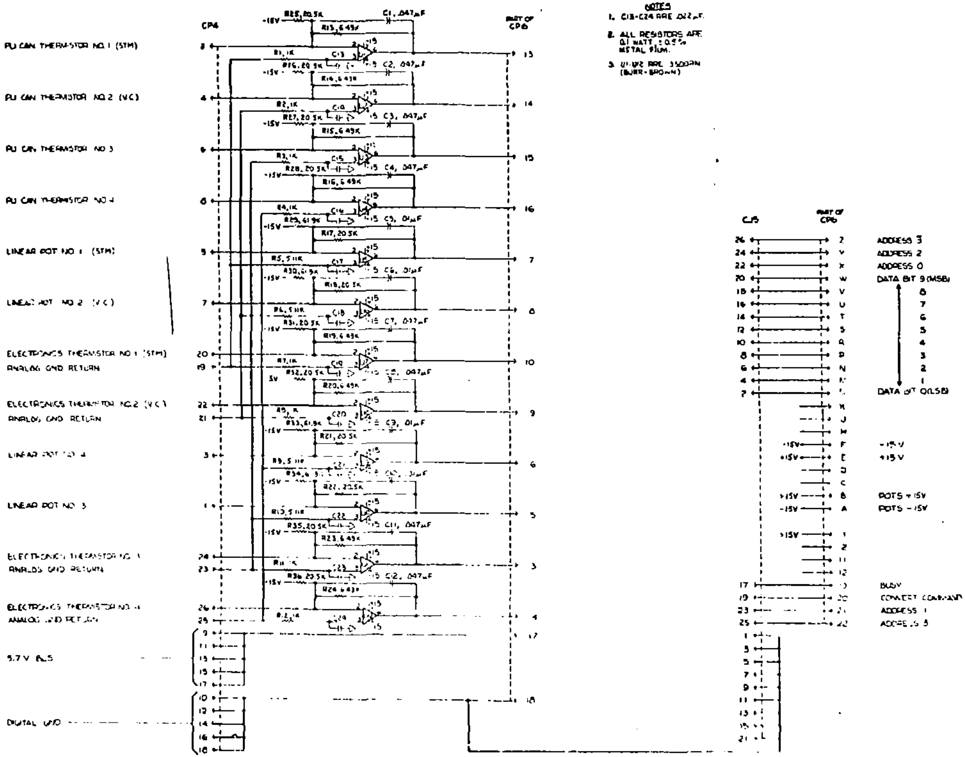
1) NULL	5) NULL
2) -IN	6) OUTPUT
3) +IN	7) V+
4) V-	8) N.C.

Pin 4 is connected to the case on the TO-99 package.

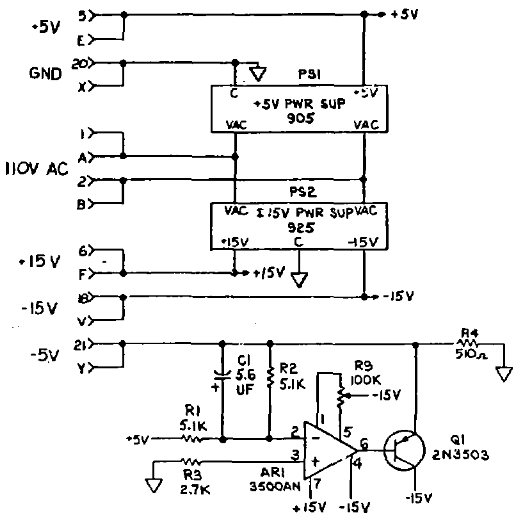


A/D ADDRESS		
ADDRESS	SSM FUNCTION	STM FUNCTION
0000	ELECT THERM 3	SPARE
0001	ELECT. THERM 4	SPARE
0010	LINEAR POT 3	SPARE
0011	LINEAR POT 4	SPARE
0100	LINEAR POT 1	LINEAR POT STM
0101	LINEAR POT 2	LINEAR POT VC
0110	ELECT. THERM 2	ELECT THERM VC
0111	ELECT THERM 1	ELECT THERM STM
1000	PU CAN THERM 1	PU CAN THERM STM
1001	2	PU CAN THERM VC
1010	3	SPARE
1011	PU CAN THERM 4	SPARE
1100	POT WIPER 1	POT WIPER STM
1101	2	VC WEIGHT POT
1110	3	SPARE
1111	POT WIPER 4	SPARE

Drawing No. CK-T42560 - ADC/MUX



Drawing No. CK-T42789 - Analog Card, ADC/MUX



Drawing No. CK-T44006 - Power Supply

APPENDIX B

Conversion Tables

APPENDIX B

Conversion Tables

The analog subsystem components have been designed to yield the following digital output for the temperature values shown. These values have been confirmed experimentally when there is 5.8 volts applied to the power connections to the Container Module.

TABLE B-1

Temperature Conversion

Decimal	R_T/R_{25}	Temp (°C)	Hex
-128	0.038	120	80
-127	0.038	120	81
-126	0.038	120	82
-125	0.039	119	83
-124	0.039	119	84
-123	0.040	119	85
-122	0.040	119	86
-121	0.041	118	87
-120	0.041	118	88
-119	0.042	117	89
-118	0.042	117	8A
-117	0.043	116	8B
-116	0.043	116	8C
-115	0.044	115	8D
-114	0.044	115	8E
-113	0.045	114	8F
-112	0.045	114	90
-111	0.046	114	91
-110	0.046	114	92
-109	0.047	113	93
-108	0.047	113	94
-107	0.048	112	95
-106	0.048	112	96
-105	0.049	111	99
-104	0.049	111	98
-103	0.050	110	99
-102	0.050	110	9A
-101	0.051	110	9B
-100	0.052	109	9C
-99	0.052	109	9D
-98	0.053	109	9E
-97	0.053	109	9F
-96	0.054	108	A0
-95	0.054	108	A1
-94	0.055	107	A2
-93	0.056	107	A3
-92	0.056	107	A4
-91	0.057	106	A5
-90	0.057	106	A6
-89	0.058	105	A7
-88	0.059	104	A8
-87	0.059	104	A9
-86	0.060	104	AA
-85	0.061	104	AB
-84	0.061	104	AC
-83	0.062	103	AD
-82	0.063	103	AE
-81	0.063	103	AF

TABLE B-1 (cont)

Decimal	R_T/R_{25}	Temp (°C)	Hex
-80	0.064	102	B0
-79	0.065	101	B1
-78	0.065	101	B2
-77	0.066	101	B3
-76	0.067	100	B4
-75	0.067	100	B5
-74	0.068	100	B6
-73	0.069	99	B7
-72	0.070	99	B8
-71	0.070	99	B9
-70	0.071	98	BA
-69	0.072	98	BB
-68	0.072	97	BC
-67	0.073	97	BD
-66	0.074	97	BE
-65	0.075	96	BF
-64	0.076	96	C0
-63	0.077	96	C1
-62	0.077	96	C2
-61	0.078	95	C3
-60	0.079	95	C4
-59	0.080	94	C5
-58	0.081	94	C6
-57	0.082	94	C7
-56	0.082	94	C8
-55	0.083	93	C9
-54	0.084	93	CA
-53	0.085	92	CB
-52	0.086	92	CC
-51	0.087	92	CD
-50	0.088	91	CE
-49	0.089	91	CF
-48	0.090	90	D0
-47	0.091	90	D1
-46	0.092	90	D2
-45	0.093	89	D3
-44	0.094	89	D4
-43	0.095	89	D5
-42	0.096	88	D6
-41	0.097	88	D7
-40	0.098	88	D8
-39	0.099	87	D9
-38	0.100	87	DA
-37	0.101	87	DB
-36	0.102	86	DC
-35	0.103	86	DD
-34	0.105	86	DE
-33	0.106	85	DF
-32	0.107	85	E0
-31	0.108	85	E1
-30	0.109	84	E2
-29	0.110	84	E3
-28	0.112	84	E4
-27	0.113	83	E5
-26	0.114	83	E6
-25	0.115	83	E7
-24	0.117	82	E8
-23	0.118	82	E9
-22	0.119	82	EA
-21	0.121	81	EB
-20	0.122	81	EC
-19	0.124	80	ED
-18	0.125	80	EE
-17	0.126	80	EF
-16	0.128	79	F0
-15	0.129	79	F1
-14	0.131	79	F2
-13	0.132	78	F3
-12	0.134	78	F4
-11	0.135	78	F5
-10	0.137	77	F6
-9	0.139	77	F7
-8	0.140	77	F8

TABLE B-1 (cont)

Decimal	R_T/R_{25}	Temp (°C)	Hex
-7	0.142	76	F9
-6	0.144	76	FA
-5	0.145	75	FB
-4	0.147	75	FC
-3	0.149	75	FD
-2	0.151	74	FE
-1	0.152	74	FF
0	0.154	74	00
1	0.156	73	01
2	0.158	73	02
3	0.160	73	03
4	0.162	72	04
5	0.164	72	05
6	0.166	71	06
7	0.168	71	07
8	0.170	71	08
9	0.173	70	09
10	0.175	70	0A
11	0.177	70	0B
12	0.179	69	0C
13	0.182	69	0D
14	0.184	68	0E
15	0.186	68	0F
16	0.189	68	10
17	0.191	67	11
18	0.194	67	12
19	0.197	67	13
20	0.199	66	14
21	0.202	66	15
22	0.205	65	16
23	0.208	65	17
24	0.210	65	18
25	0.213	64	19
26	0.216	64	1A
27	0.219	64	1B
28	0.223	63	1C
29	0.226	63	1D
30	0.229	62	1E
31	0.232	62	1F
32	0.236	61	20
33	0.239	61	21
34	0.243	61	22
35	0.246	60	23
36	0.250	60	24
37	0.254	59	25
38	0.258	59	26
39	0.262	59	27
40	0.266	58	28
41	0.270	58	29
42	0.275	57	2A
43	0.279	57	2B
44	0.284	56	2C
45	0.288	56	2D
46	0.293	55	2E
47	0.298	55	2F
48	0.303	55	30
49	0.308	54	31
50	0.314	54	32
51	0.319	53	33
52	0.325	53	34
53	0.331	52	35
54	0.337	52	36
55	0.343	51	37
56	0.349	51	38
57	0.356	50	39
58	0.362	50	3A
59	0.369	49	3B
60	0.375	49	3C
61	0.384	48	3D
62	0.392	48	3E
63	0.400	47	3F
64	0.408	47	40
65	0.416	46	41
66	0.425	46	42

TABLE B-1 (cont)

Decimal	R_T/R_{25}	Temp (°C)	Hex
67	0.434	45	43
68	0.444	44	44
69	0.454	44	45
70	0.464	43	46
71	0.475	43	47
72	0.486	42	48
73	0.497	42	49
74	0.509	41	4A
75	0.522	40	4B
76	0.535	40	4C
77	0.549	39	4D
78	0.563	39	4E
79	0.578	38	4F
80	0.594	37	50
81	0.610	37	51
82	0.627	36	52
83	0.646	35	53
84	0.665	34	54
85	0.685	34	55
86	0.707	33	56
87	0.729	32	57
88	0.753	32	58
89	0.779	31	59
90	0.806	30	5A
91	0.835	29	5B
92	0.865	28	5C
93	0.898	27	5D
94	0.934	27	5E
95	0.972	26	5F
96	1.013	25	60
97	1.057	24	61
98	1.106	23	62
99	1.158	22	63
100	1.215	21	64
101	1.278	19	[illegible]
102	1.348	18	66
103	1.425	17	67
104	1.511	16	68
105	1.607	14	69
106	1.716	13	6A
107	1.840	12	6B
108	1.982	10	6C
109	2.147	8	6D
110	2.341	7	6E
111	2.572	5	6F
112	2.851	3	70
113	3.197	0	71
114	3.636		72

TABLE B-2

Bulge Sensor Conversion

Upper Deflection	E_{in} L_{in} · Pot Wiper (volts)	E_o Amplifier Output (volts)	Decimal	Hex (ADC)
0-1 mm	0.00	4.96	127	7F
2	0.38	4.18	107	6B
3	0.76	3.40	87	57
4	1.14	2.62	67	43
5	1.52	1.84	47	2F
6	1.90	1.06	27	1B
7	2.28	0.286	7	07
8	2.66	-0.49	-12	F4
9	3.04	-1.27	-32	ED
10	3.42	-2.05	-52	CC
11	3.81	-2.85	-73	B7
11.5	4.00	-3.24	-83	AD

Note: $E_o = 4.96 - 2.05E_{in}$

TABLE B-3

Verification Chamber Scale

$$\left(wt_{kg} = \frac{reading_{Dec} - 18}{13} \right)$$

Scale Tare (wt kg)	Decimal	Hex
	-4	FC
0	14	0E
0.5	20	14
1.0	27	1B
1.5	34	22
2.0	40	28
2.5	46	2E
3.0	53	35

TABLE B-4

Carrousel (STM) Rotation Conversion

STM Position	SSM Position	Pot Wiper (volts)	Decimal	Hex
End	End	-5.00	-128	80
	1	-4.88	-125	83
1	2	-4.36	-112	90
	3	-3.85	-99	9D
Null	4	-3.33	-85	AB
	5	-2.82	-72	B8
2	6	-2.30	-59	C5
	7	-1.78	-46	D2
Null	8	-1.27	-33	DF
	9	-0.75	-19	ED
3	10	-0.24	-6	FA
	Null	0.02	0	00
	11	0.28	7	07
Null	12	0.79	20	14
	13	1.31	33	21
4	14	1.82	47	2F
	15	2.34	60	3C
Null	16	2.85	73	49
	17	3.37	86	56
5	18	3.88	98	62
	19	4.40	113	71
	20	4.91	126	7E
End	End	5.00	127	7F

TABLE B-5

Resistance - Temperature Conversion

The following information may be used to test or calibrate the temperature channels in the SSM, STM, or Verification Chamber. The resistance values represent precision resistors commonly available at Sandia and correctly simulate the thermistor resistance plus 2200 ohms when 5.0 volts is applied to one side of the resistor and the other end of the resistor is connected to pin E (electronics temperature) or pin V (plutonium thermistor).

The current column is the resulting current that flows into the ADC/MUX amplifier summing junction when the simulator resistor is used with 5.0 volts impressed.

Temp (°C)	R_{in} (k ohms)	Amplifier I_{in} (mA)	E_o	Hex
119	3.48	1.43	-4.53	89-8A
100	4.22	1.18	-2.9	B4-B5
86	5.36	0.932	-1.3	DE
70	7.50	0.666	0.42	0A-0B
50	12.7	0.393	2.20	39
29	27.4	0.182	3.56	5B
VC		0	4.75	79

Very cold

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