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INTERFACE TEST UNITS

FOR AIRBORNE INTELLIGENT DISPLAY SYSTEMS

by

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LETTER REPORT:
INTERFACE TEST UNITS FOR AIRBORNE INTELLIGENT DISPLAY SYSTEMS

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ABSTRACT

This document presents the description and operating instructions for two interface test units for the Airborne Intelligent Display (AID) systems. The test units were designed and constructed by ACT-100A.3 personnel to enhance operation and installation verification efforts of the AID systems at the Technical Center. The AID systems are in continuous use on critical test projects and the lack of certification procedures warranted the design effort. The test units were designed to monitor their own operation through self testing and to verify AID operation under all options of signalling protocol. The test units are portable, self contained units suitable for both laboratory and flight line applications.

KEYWORDS:

Mode S, data link, test equipment, reliability.

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LIST OF ABBREVIATIONS AND ACRONYMS

AID	Airborne Intelligent Display
ATAS	Automatic Traffic Advisory Service
ATC	Air traffic control
Comm-A	An interrogation format of the Mode S system containing a 56-bit ground-to-air data communications field.
Comm-B	A reply format of the Mode S system, containing a 56-bit air-to-ground data communications field.
CRT	Cathode ray tube
DABS	Discrete Address Beacon System. Former name for Mode S
EPROM	Erasable programmable read only memory
ETIS	Enhanced Terminal Information System
LED	Light emitting diode
LCD	Liquid crystal display
Mode S	A radar beacon system in which all aircraft are assigned fixed, discrete, 24-bit addresses to allow selective interrogation/reply transactions to occur between the ground sensor and a particular aircraft.
NAS	National airspace specification
RAM	Random access memory
RS-232C	An Electronics Industries Association standard for serial data communications.
RF	Radio frequency
SMI	Standard message interface
TCAS	Traffic Advisory Collision Avoidance System

INTRODUCTION

PURPOSE

The Traffic Advisory Collision Avoidance System (TCAS) Interface Test Set and the Standard Message Interface (SMI) Test Set were developed by FAA Technical Center personnel to assist equipment technicians to certify Airborne Intelligent Display (AID) operation. The test sets accomplish this by duplicating the normal AID interface message signals and continuously verifying the content of the transmitted and received messages. Signalling protocols and all variations of processing and display modes pertaining to the interfaces are exercised by the test sets. The test sets will be used in the laboratory as part of an AID test bed. The sets will also be used on the flight line to give go/no-go indications of AID system operation.

BACKGROUND

The AID was developed by Lincoln Laboratories as a demonstration airborne terminal for the Mode S data link application programs. These programs include the data link services project which provides digital backup for ATC advisory and control messages and various weather products on pilot request. Other advisory information is displayed graphically or in tabular form as derived from the TCAS and Automatic Traffic Advisory Service (ATAS).

The AID consists of a microcomputer, a CRT display, a hand-held keyboard, a printer, and a voice synthesizer. With the AID installed in a Mode S transponder equipped aircraft, the pilot receives messages via the Mode S RF link or directly through the on-board TCAS equipment. The pilot can also initiate downlink request and confirmation reply messages.

DESCRIPTION OF TEST SETS

GENERAL

Both test units were designed to be expandable and flexible. Only where no changes are anticipated was the implementation rigidly fixed in hardware. For example, the SMI message lengths have been fixed by the Mode S National Airspace Specification (NAS) to 88 data bits and 24 address/parity bits for a total message length of 112 bits. The SMI test set has been hardware configured to use a maximum of 88 data bits (the address/parity bits of the message do not appear on the SMI). Only extensive hardware modifications will allow the test set to use more than 88 data bits per message. Message content and error checking however, have been implemented in firmware using erasable programmable read only memory (EPROM) and can be modified, as conditions warrant, with little additional effort. Other parameters such as regulated power and available space for additional circuitry have been chosen to provide for future expansion.

TCAS INTERFACE TEST SET (See figure 1.)

The TCAS Interface Test Set is a self contained, microprocessor controlled unit. The unit operates from a 110 volt AC source and contains a regulated power supply, three independent voltage monitors, a micro-

computer with a hexadecimal keyboard and eight character display, and an internal cooling fan. The internal circuitry is implemented using a mother board with two plug-in circuit cards. The first plug-in card is a general purpose microcomputer consisting of a 6809 microprocessor, up to eight kilobytes of EPROM, one kilobyte of random access memory (RAM), a programmable timer, two eight-bit parallel input/output ports, a two-way asynchronous communications interface, and the required clocking circuitry to operate the microprocessor and the communications lines. The second plug-in card is a wire-wrapped card containing the hardware necessary to drive the keyboard and voltage monitors. A third printed circuit card is attached to the front panel and supports the liquid crystal display (LCD) module and the display driver integrated circuits. The power cord and the cable required to connect the test set to the AID are stored in the test set lid.

To limit the training required to operate the test set, operator prompts are given by the display. Since there are several AID software versions using different message protocols presently in use, the test set will indicate software freeze level prior to running each test. The present TCAS Interface Test Set is programmed for AID freeze level 3.0 and this is the default condition when the test begins. Future improvements to the test set will allow AID software versions 5.0 and 5.1 to be tested. When these improvements are implemented, the test set will halt prior to running a test to receive the desired AID software freeze level from the operator.

When the test set is first turned on, a request for one of the two output options implemented to date is displayed. The options implemented have been chosen to exercise the interface to the maximum extent possible. Future expansions will select subsets of these outputs. The operator must input his choice of output option to begin the test. All message transmissions are constantly monitored to detect any failures. The test can be terminated at any time by the operator, or can be made to cycle indefinitely.

The test set operates by transmitting an easily recognizable pattern of data to the AID for display on the CRT. Any deviation from the pattern will be evident to the test operator. Certification of the interface is dependent on viewing the anticipated patterns. The test set can be connected either directly to the AID, or into the aircraft cabling runs to verify cable integrity. Each test can be terminated immediately, at the normal conclusion, or the test can be placed into a loop to cycle the selected test indefinitely.

TCAS INTERFACE TEST SET OPERATING INSTRUCTIONS. The TCAS Interface Test Set is designed to input messages into the AID through the TCAS interface jack J1. The messages have been formatted as described in Reference [5] and are applicable to AID units containing version 3.0 software.

The test set requires 110 volt AC, 60 Hz power for operation. The following procedure details operation:

1. Remove the cable connecting the AID and the TCAS at the TCAS unit and connect the test set to this cable in place of the TCAS. If the AID to be tested is not aboard the aircraft, or if the AID/TCAS cable is known to be good, the test set can be connected directly to the AID using the cable stored in the test set lid.

2. Apply power to the AID. Turn on the test set by placing the front panel control switch to ON position.

3. The three test set voltage monitors must be on. If any lamp is not on, check the test set internal voltages prior to continuation. If all three lamps are not on, lack of power is indicated. Reset the test set circuit breaker by placing the front panel toggle switch down, then up.

4. The test set will display ENTER TEST CODE. The output option test codes are identified in table 1. Respond by entering "nE" on the keyboard where n is the test number selected from table 1.

5. The test set will display PUSH B TO BEGIN. Pressing the "B" key will begin the test selected in step 4. Pressing the "D" key will delete the test code and return the test set to step 4. Pressing the "F" key will begin the test selected in step 4 and will cause the test to loop continuously instead of terminating after completing one cycle of the test.

6. Once the test is initiated, the AID software freeze number must be declared. The test set will display "FREEZE" and stop to accept freeze number from the keyboard. The operator must input the freeze level of the AID under test. In case all known AID software releases require the same program formats, the test set will display "ALL FREEZES" without stopping for operator input. For the case where only one AID software release has been implemented in the test set, this freeze will be automatically selected as a default condition; the test set will display the implemented freeze number without stopping for input. For example, the test set will display "FREEZE 3.0" and continue to the next step without operator intervention. In this case, the test set will operate properly only with AID units at the freeze 3.0 level.

7. The test set will display "RUN SCnn". The number nn corresponds to the test code selected in step 4.

8. While the test is running, the keyboard will be inactive except that pressing the keys "A" and "1" in order will reset the test set back step 4.

9. At the conclusion of the test, the test set will display "END SCnn" where the number nn depends upon which test was chosen in step 4. The test set will return to step 4 automatically.

The display pattern produced on the AID by test code 1 and the scenario generated by test code 2 are described in table 2.

SMI TEST SET (See figure 2.)

The SMI Test Set is a self contained, microprocessor controlled, unit. The device operates from a 110 volt AC source. It contains a regulated power supply, visual monitors for each of three internal voltages, a hexadecimal keypad, a microcomputer, an eight-character alphanumeric display, a circuit card cage, and a cooling fan.

The electronics for this unit is contained on four circuit cards. Three cards are contained in the circuit card cage and the fourth card is attached to the front panel as a mount for the display. Within the card cage, two cards contain the specialized logic required to transmit and receive messages over the SMI and to operate the test set keyboard, display, and recorder interfaces. The third card is a general purpose microcomputer card containing a 6800 type microprocessor, 1024 bytes of RAM, up to 4 kilobytes of EPROM, 6-eight bit parallel input/output ports, and the required processor clocking circuitry.

Each message transmitted or received by the test set can be stored on magnetic tape for later reduction by a mainframe computer. A prewired terminating plug to allow the test set to operate without the magnetic recorder is also included for use at times when the recorder is inconvenient or not required. The cables required to connect the test set to the AID SMI port and to a Kennedy nine track digital tape recorder, are stored in the unit's lid.

As in the case of the TCAS Interface Test Set described above, the operator responses are prompted by the test set. When the unit is turned on, a menu of operations is flashed across the display to aid the user in selecting the desired operation. Additional prompts to guide the user through the chosen operation reduce the operator training required.

SMI TEST SET OPERATING INSTRUCTIONS. The SMI test set is designed to transfer messages to the AID through the SMI input jack J3. The messages have been formatted as described in References [2] and [4] and can be used with all current software versions of the AID.

The test set requires 110 volt AC, 60 Hz power for operation. The following procedure details operation:

1. Remove the cable connecting the AID with the transponder's SMI at the Mode S transponder. Connect this cable to the test set jack labeled SMI. If the AID to be tested is not aboard an aircraft, or if the AID/transponder cable is known to be good, the test set can be connected directly to J3 on the AID by using the cable stored in the test set lid.

2. If a recording of all message transfers between the test set and the AID is desired, connect a Kennedy model 9832, nine track tape unit to the test set jack labeled RECORDER using the cable stored in the test set lid. If the tape unit is not used, the recorder terminating plug must be attached to the RECORDER jack.

3. Apply power to the test set by placing the front panel toggle switch up.

4. The three green lamps above the power switch should be illuminated. If any lamp is not on, the power supply monitored by that lamp is out of tolerance and must be adjusted or repaired prior to continuing the test. If all three lamps are not on, lack of power is indicated. Reset the test set circuit breaker by placing the front panel toggle switch down, then up.

5. When the test set is first powered on, the following messages should be displayed in sequence:

```
SMI TEST
MENU
1-SURV
2-COMM A
3-COMM B
9-MENU
```

Refer to Table 6 for an analysis of error conditions that may arise at this point or any point during this test.

6. A choice is required. See Table 4 for a selection of tests. A description of indications for each test is found in Table 5. Press n E on the test set keypad, where n is the test number selected from Table 4.
7. If an incorrect test number is entered, simply reselect the correct number prior to pressing E.
8. If an invalid test number is selected and the E key is pressed the display will indicate "CHOICE ?". Select a valid test number from Table 4 and press E or press 9 E to review the menu.
9. After a valid test has been chosen the implemented AID software freeze number must be selected. The test set will display "FREEZE" and stop to accept the freeze number from the test set keypad. In case all known AID software freezes are accommodated by a single tester program, the test set will display "ALL FREEZES" without stopping.
10. As each test is run, the test set continually monitors all parameters of the message transactions. Refer to Table 6 for explanation if an error indication appears on the test set display.
11. If test number 1 is selected, the display will indicate "10 SURV XMISSION". 10 surveillance interrogations will be sent to the AID, 1 interrogation every 4 seconds for 40 seconds. The DABS CONTACT LOST message should disappear from the AID display within 4 seconds. The DABS CONTACT LOST message should reappear on the AID after the 40 second test terminates.
12. If test number 2 is selected, five selected Comm-A messages will be transmitted to the AID. Prior to message transmission, the test set display will ask "WILL YOU RESPOND?". Press 1 on the test set keyboard if pilot acknowledgement will be given to each message. Press 0 on the keyboard if messages are to be transmitted without acknowledgement. Refer to Table 5 for the exact sequence of test number 2.
13. If test number 3 is selected, the test set will continuously interrogate the AID, waiting for a pilot request to be generated. When such a request is sent by the AID, the test set will accept the request, analyze it for format, and display "WX RCVD" if the request corresponded to the weather request format. The test set will display "ETIS RCVD" if the request corresponded to the ETIS request format. The test set will then recycle and await another pilot request. Press A 1 on the test set keypad to terminate the test and return to the menu.
14. While any test is running, the test set keypad will be inactive except that pressing the keys A and 1 in order will reset the test set back to step 5.
15. At the conclusion of tests 1 and 2, the test set will return to step 5. Test 3 runs continuously and can only be concluded by pressing A 1 on the test set keypad.

DESIGN VERIFICATION TESTS

Testing of the units was accomplished using a Tektronix 7D02 logic analyzer and a commercial AID with freeze 3.0 software. Message transfers to and from the AID interfaces were examined to verify the proper operation of the test sets and the AID system.

The testing performed established that the TCAS Interface Test Set will operate with the commercial AID software freeze level 3.0 when messages are formatted according to the protocol given in reference 5. Testing also uncovered major message protocol variations among the several commercial AID units. Tests further discovered that the TCAS interface in two general aviation AIDs cannot accept data without causing the AID software to malfunction.

The SMI Test Set will operate with commercial AID serial number 3 and general aviation AID serial number 2G using the ADS and BDS codes specified in reference 2. The test set will format the messages, transmit the messages to the AID, verify that the messages have been transmitted properly, receive the replies, check the replies for pilot acknowledgements, and verify that the replies are formatted properly. The test set will also output, to a magnetic tape recorder, the content of each transmitted message and each received reply.

SUMMARY

The TCAS Interface Test Set will generate the RS-232C format messages required by the AID TCAS input. The present test set will format these messages as required by commercial AID software version 3.0. Minor software additions to the test set should permit operation with commercial AID software versions 5.0 and 5.1. The messages transmitted by the test set will allow the observer to detect AID malfunctions quickly and with a minimum of training.

The TCAS interfaces of the two general aviation AIDs used in testing do not function properly. When data is delivered to these interfaces, the AID software malfunctions. The only way to return control to the AID keyboard, after such failure, is to reconnect the TCAS input terminator and reinitialize the AID by recycling its power supply.

The SMI Test Set will generate and receive data from the AID SMI jack. The test set operates as though it was a Mode S transponder in contact with a Mode S beacon site. Each message transfer is checked by the test set to verify proper content. Error messages are flashed on the test set display whenever an error is detected. Test set operation has been verified with both commercial and general aviation type AID systems. All message transfers can be recorded on 9 track magnetic tape for further processing on a main frame computer.

Both units have been constructed to allow their use either on the flight line or in the laboratory. They are lightweight and self-contained and contain all cables required for interconnection. Message transfers between the test sets and the AID have been chosen to provide simple, easy to observe indications of malfunctions. Prompting by the test sets will allow users with minimal training to operate the units. Error messages displayed on the test sets will give maintenance personnel indications of improper operation. Use of the test sets will provide a means of certifying the AID.

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TABLE 1. SELECTION OF TCAS TESTS.

TEST NO.	TEST	OPERATION WITH AID SOFTWARE RELEASE NO.
1	Verify the ability of the AID to receive up to eight messages in the same transmission. Verify proper formatting of these messages. Verify all combinations of values and colors can be represented in every AID display field.	3.0
2	Single aircraft flight encounter scenario. Aircraft approaches from above, encounters own aircraft, then recedes from below.	

TABLE 2. DESCRIPTION OF TCAS TEST READOUTS

TEST CODE 1

PAGE 1

<u>TRACK</u>	<u>RANGE</u>	<u>RATE</u>	<u>ALTITUDE</u>	
11	1.1	110	1100	(white)
22	2.2	220	2200	(red)
33	3.3	330	3300	(white)
44	4.4	440	4400	(red)
55	5.5	550	5500	(white)
66	6.6	660	6600	(red)
77	7.7	770	7700	(white)
88	8.8	880	8800	(red)

PAGE 2

<u>TRACK</u>	<u>RANGE</u>	<u>RATE</u>	<u>ALTITUDE</u>	
99	9.9	990	9900	(white)
11	11.1	1110	1100	(red)

PAGE 3

<u>TRACK</u>	<u>RANGE</u>	<u>RATE</u>	<u>ALTITUDE</u>	
1*	1.1	-110	-1100	(red)
2*	2.2	-220	-2200	(white)
3*	3.3	-330	-3300	(red)
4*	4.4	-440	-4400	(white)
5*	5.5	-550	-5500	(red)
6*	6.6	-660	-6600	(white)
7*	7.7	-770	-7700	(red)
8*	8.8	-880	-8800	(white)

PAGE 4

<u>TRACK</u>	<u>RANGE</u>	<u>RATE</u>	<u>ALTITUDE</u>	
9*	9.9	-990	-9900	(red)
11*	11.1	-1110	-1100	(white)

TEST CODE 2

Test code 2 is a simulated flight encounter. Messages are transmitted to the AID to simulate an approaching aircraft. The test begins with the AID showing an approaching aircraft at 15.9 nmi., with an approach rate of -1280 kts., and a relative altitude of 9900 ft. The track number is 1 and the information is displayed in white. With each scan, the range is reduced by 0.625 nmi., the range rate is reduced by 30 kts., and the altitude is reduced by 300 ft. The reductions continue for 25 scans. These values were chosen to allow the most varied numbers possible to appear on the display. After 25 scans, two scans are transmitted with the message in red. The range, range rate, and relative altitude are set to zero for the next scan. For the last 25 scans the messages, displayed in white, indicate the aircraft is receding after the near-miss with range increasing by 0.625 nmi., range rate increasing by 30 kts, and altitude decreasing by 300 ft.

TABLE 3. TCAS TEST SET ERROR MESSAGE ANALYSIS

ERROR MESSAGE	PROBABLE CAUSE
RCV OVRN	One or more characters have been lost in the receive register of the test set
FRAMING	Test set receive register did not receive serial message properly. Message not transmitted by test set properly.
DCD/CTS	Control signals for test set transmitter or receiver are invalid. Problem is within the test set.
T NEQ R	The transmitted message has not been properly received by the test set receive register.
NO RCVR	The receive register is empty following attempted transmission of a message.
NO SCEN	An invalid test code number has been selected.
NO BYTES	The test set transmit table is empty
INVL KEY	An invalid keyboard code has been received by the processor. Check the test set PIA.
BAD INT	An interrupt has been received by the processor, but no circuit has requested it.
RCV SWI	A software interrupt has been received by the test set processor.
RCV NMI	A non-maskable interrupt has been received by the test set processor.

TABLE 4 SELECTION OF SMI TESTS.

TEST NO.	TEST	OPERATION WITH AID SOFTWARE RELEASE NO.
1	Ten surveillance transactions. Checks AID ability to recognize Mode S contact.	A L L
2	Five Comm-A/Comm-B transactions consisting of: a) Minimum safe altitude level 1500 ft. b) Maintain 5000 ft. c) Climb to and maintain flight level 230 d) Descend to and maintain 12,000 ft. e) Cleared for takeoff runway 27R Options: 0. If key 0 on the test set is pressed in response to the WILL YOU RESPOND? message on the display, the test set will deliver the above messages, at four second intervals, without waiting for a pilot acknowledgement. 1. If key 1 on the test set is pressed in response to the WILL YOU RESPOND? message on the display, the test set will deliver the message and await the pilot acknowledgement. The operator must push the yes button on the AID keyboard for the test to continue.	
	Receive pilot requests Options: 1. Weather requests will cause WX RCVD to be displayed on the test set. 2. ETIS requests will cause ETIS RCVD to be displayed on the test set. Note: Use "A 1" reset code on keyboard to exit test.	
3		

TABLE 5. DESCRIPTION OF SMI TEST READOUTS

TEST NUMBER	TEST SET DISPLAY	AID DISPLAY OUTPUT	AID VOICE OUTPUT
1	10 SURV XMISSIONS	DABS CONTACT LOST disappears at begining of test reappears at end of test.	none
2	MSAW ALRT	MINIMUM SAFE ALTITUDE LEVEL 1500 FT.	LOW ALTITUDE ALERT
	MTAIN 50	MAINTAIN 5000 FT	ALTITUDE CLEARANCE
	C+MFL230	CLIMB TO AND MAINTAIN FL 230	ALTITUDE CLEARANCE
	D+M 120	DESCEND TO AND MAINTAIN 12,000 FT	ALTITUDE CLEARANCE
	T/C 27R	CLEARED FOR TAKEOFF RUNWAY 27R	TAKEOFF CLEARANCE
3	REQUEST	depends upon requested weather or ETIS product	tone when key is pushed

TABLE 6. SMI TEST SET ERROR MESSAGE ANALYSIS

ERROR MESSAGE	PROBABLE CAUSE
REPLY ERROR	Comm-B reply received from the AID does not contain the expected bit structure.
MISSION ERROR	The bit structure of the Comm-A message transmitted by the test set was in error.
RECORDER ERROR	The magnetic tape unit is not ready to write to tape. If no tape unit is used, the termination plug supplied with the test set must be placed on the RECORDER jack of the test set.
INTERRUPT ERROR	An invalid interrupt was detected in the test set. This indicates a malfunction of the interrupt logic of the test set.
CHOICE ?	The test number selected by the operator is not valid. Reselect the test number or press 9 E on the test set keypad to review the menu.

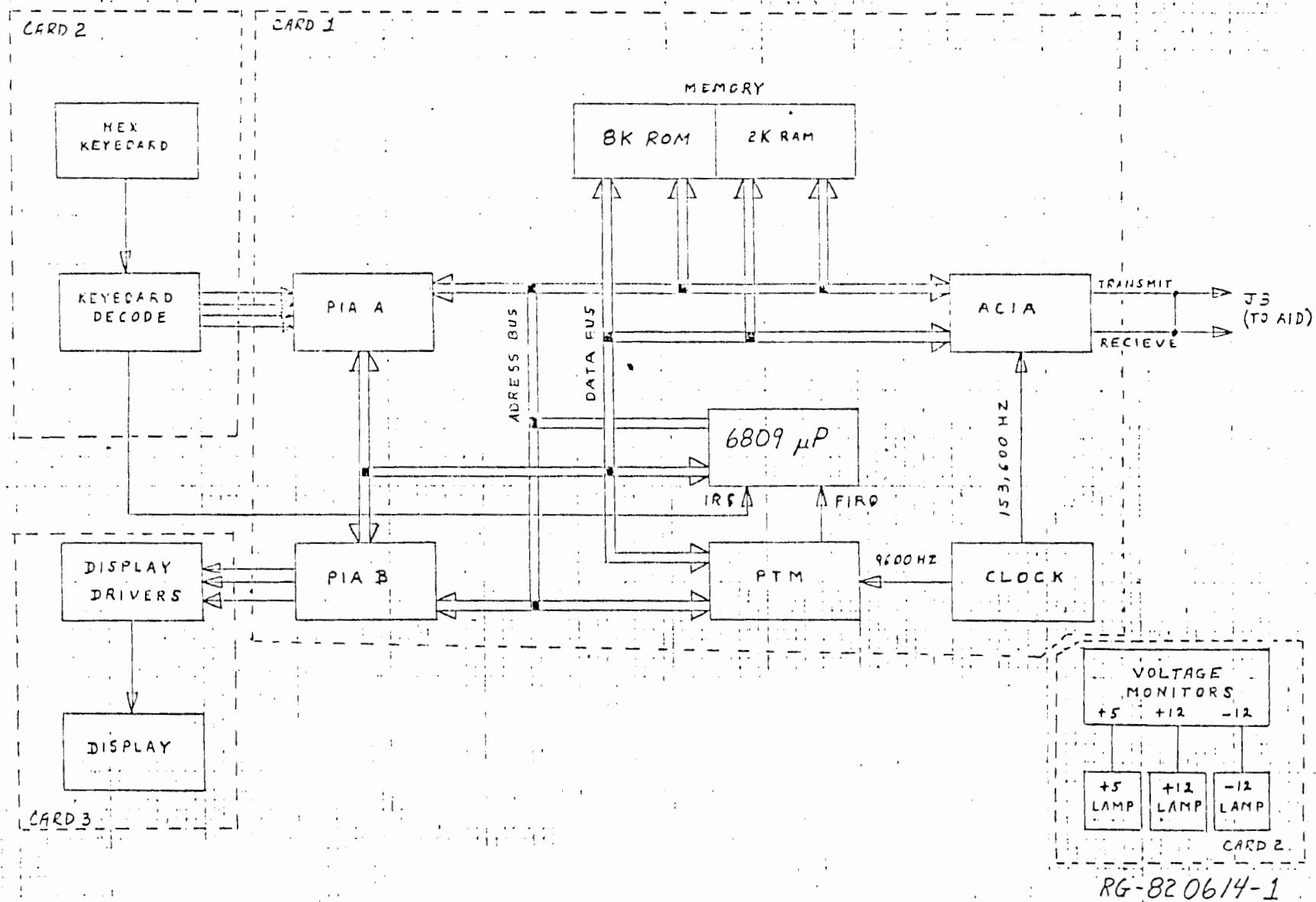


Figure 1. TCAS Test Set Block Diagram

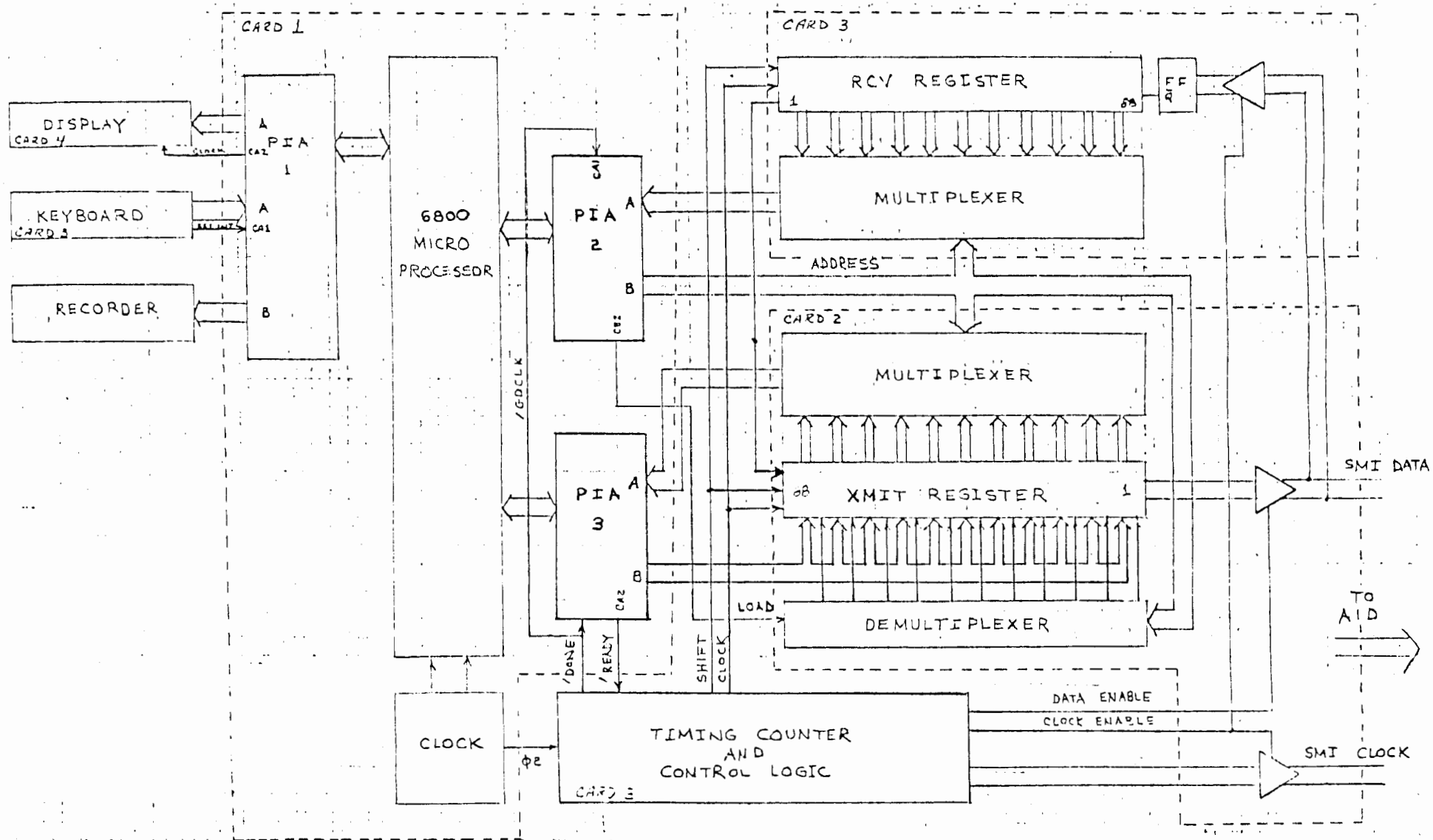


Figure 2. SMI Test Set Block Diagram