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Countermeasure Dispenser System Network Controller

DiPirro-Beard, William David, M.S.

The University of Arizona, 1989
COUNTERMEASURE DISPENSER SYSTEM
NETWORK CONTROLLER

by
William David DiPirro-Beard

A Thesis Submitted to the Faculty of the
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
In Partial Fulfillment of the Requirements
For the Degree of
MASTER OF SCIENCE
WITH A MAJOR IN ELECTRICAL ENGINEERING

In the Graduate College
THE UNIVERSITY OF ARIZONA

1989
STATEMENT BY AUTHOR

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APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Dr. J. Rozenblit 6/15/89
Assistant Professor of Electrical and Computer Engineering
DEDICATION

To
Sharon, Ashley, and Alexander
for the time I missed in their lives.
ACKNOWLEDGMENTS

I would like to thank Dr. Rozenblit for his support and encouragement. His guidance and instruction were invaluable aids in the development of this project.

I would like to personally thank Gordan Wong and Martin Hom for their help on this project.
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ABSTRACT

Presented in this thesis is the Airborne Countermeasures Ejection and/or Release (ALE)-XX Cockpit Control Unit (CCU) Countermeasures Dispensing System Network Controller (CMDSNC) design. ALE-XX CCU CMDSNC was designed as part of the total ALE-XX system to replace the problematic ALE-40. Fiber optic technology is incorporated into ALE-XX as the communication medium to eliminate Electromagnetic Interference (EMI). ALE-XX CMDSNC uses a star network to solve system operation failures from the existing daisy-chain topology. A comprehensive Built-In-Test (BIT) allows fault diagnose and isolation of hardware problems reported on the CCU Visual Display. Digital electronics replace the electro-mechanical devices, lowers the number of Line Replaceable Units (LRUs), and raises the Mean-Time-Between-Failures (MTBF). The information contained herein could be used as a design aid for future CMDSNCs or other related instrumentation.
CHAPTER 1

INTRODUCTION

An ALE Countermeasures Dispensing System (CMDS) is a chaff/flare dispensing system that provides a means to deploy from fighter aircraft expendable chaff and flare payloads as a countermeasure against Radio Frequency (RF), Infrared (IR), and Electro-Optical (EO) threats from Anti-Aircraft Artillery (AAA), Surface-to-Air Missiles (SAM), Air-to-Air Missiles (AAM), and Airborne Interceptors (AI).

Objective

This project was conceived as a star network fiber optic technological insertion application to prove that fiber optics would work on an airborne platform and a star network could help solve the communication breakdown problems. The design concept was to emulate the ALE-40, to update the electronics, use a star network communication system, and to incorporate fiber optic technology. The ALE-40 system being replaced is unreliable, susceptible to noise triggered release of munitions, and failures due to communications faults. My motivation for the project was to
explore concepts foreign to me along with being part of the team to introduce fly-by-light replacing fly-by-wire in fighter aircraft. I was software lead on a team of three, coordinating the overall software design and developing the CCU software. My work involved the integration of hardware, working on the hardware team of three for total system design and board level design on the CCU hardware.

As part of the prototyping team, I was to gain an understanding of the trade-offs made between the laboratory environment and real life applications. There were small contributions to the field of engineering as a result of moving the laboratory concepts into the hostile environment of a fighter aircraft in the areas of power, vibration, atmospheric tolerances, and communications. Filtering needs are much greater as fighter aircraft power is extremely dirty to the point where constant charge batteries were considered. Vibrations have broken loose fiber optic connections and board electrical connections. Temperature and humidity fluctuations cause a slowing of the computing speeds and board life. An effective communication system with no EMI filtering could be possible using a fiber optic star network.

**ALE-40 CMDS**

The existing ALE-40 CMDS installed on the A-10 aircraft, and scheduled for installation on the F-111
aircraft has the following areas of demonstrated problems.

1. The ALE-40 CMDS is susceptible to Electromagnetic Interference (EMI) in the copper wire communication links between the CMDS Line Replaceable Units (LRUs). The interference has caused inadvertent dispensing of ordinance.

2. The ALE-40 CMDS design uses electro-mechanical rotary switches for ordinance selection. These switches are susceptible to corrosion resulting in a low Mean-Time-Between-Failure (MTBF).

3. The ALE-40 CMDS communication link between LRUs is a daisy-linked topology. A single failure in this serial communication linkage has demonstrated complete system operation failure.

4. The ALE-40 CMDS was not designed with Built-In-Test (BIT). System verification and fault isolation at the Organization Level requires several man-hours and Aircraft Ground Equipment (AGE) to perform these tasks.

The ALE-40 CMDS is constructed using early 60's technology. The technology produced a product that has serial communications, nonmicrocontroller driven electronics, EMI susceptible copper wire, and aircraft unique black boxes (Fig. 1). Together these factors have caused many of the LRUs to have poor MTBF (Tab. 1).
CURRENT ALE-40
A-10 AIRCRAFT: 40 BOXES

SEQUENCER SWITCH (8)
CHAFF SWITCH (1)
COCKPIT CONTROL UNIT (1)
PROGRAMMER (1)
SELECT SWITCH (8)
LEFT INBOARD STATION #2
LEFT OUTBOARD STATION #1
RIGHT INBOARD STATION #3
RIGHT OUTBOARD STATION #4

DISPENSER (16)
EMI FILTER (3)
Table 1. A-10 ALE-40 CMDS LRU MTBF

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ALE-XX CMDS

In the following ways the ALE-XX CMDS has solved the ALE-40 CMDS demonstrated problems by a system design with increased reliability and maintainability utilizing fiber optic technology, digital electronics, star topology, and a comprehensive BIT.

1. The ALE-XX CMDS incorporates fiber optic technology thus eliminating EMI problems since the fiber optic cables are not being susceptible to electronic pulse/burst. LRU count is reduced by the elimination of communication EMI filters.

2. The ALE-XX CMDS incorporates digital electronics replacing the electro-mechanical devices currently used. This remedies the corrosion problems occurring in the LRUs. This also reduces the number of LRUs by combining LRU.

3. The ALE-XX CMDS incorporates a star topology network to replace the currently used daisy-chain topology network. Star topology solves system operation failure from daisy-chain topology by allowing system operation despite single link or LRU failure.

4. The ALE-XX CMDS incorporates a comprehensive BIT. BIT allows ground crews to identify faulty wiring harnesses and isolate system faults to a single LRU board. BIT also allows for system status updating for faster more reliable response during operation.
by updating system status arrays.

There are other enhancements as direct side effects to the ALE-XX CMDS development. One enhancement was the redesigning of the dispenser assembly retainer plate to sense payload type. In the past ground crews entered the chaff/flare information via the now eliminated chaff/flare selector switches. The elimination of the switches stops possible ground crew errors. The functions of the chaff/flare switches on the ALE-40 programmer are incorporated in the ALE-XX Cockpit Control Unit (CCU) LRU. Another enhancement is caused by the high speed electronics used, allowing the jettison of flares to be limited only by power bus and aircraft structural constraints. As a direct consequence to ALE-XX is a weight reduction of 27 pounds, a size savings of 345.6 cu. in., a reliability increase from approximately 250 hours to 5000 hours, and a LRU count reduction from 37 to 18 (Fig. 2 and Tab. 2).

Cockpit Control Unit

The part of the ALE-XX CMDS described herein is the Cockpit Control Unit (CCU). The CCU handles systems modes and states (off mode, setup mode, flare jettison mode, BIT mode, and operation modes). The system functions for the CCU include human interface, network control, tests manager, dispenser control, and external interface link. The CCU functional/performance requirements are visual display, mode
ALE-XX'
A-10 AIRCRAFT: 18 BOXES

- SEQUENCE CONTROLLER (3)
- CHAFF SWIT (1)
- SELECT SWITCH
- COCKPIT CONTROL UNIT (1) MODIFIED
- PROGRAMMER (1) MODIFIED
- LEFT OUTBOARD STATION #1
- LEFT INBOARD STATION #2
- RIGHT INBOARD STATION #3
- RIGHT OUTBOARD STATION #4
- MODIFIED DISPENSER (16)
- EMI FILTER (5)
Table 2. COMPARISON OF LRU COUNT

<table>
<thead>
<tr>
<th>LRU NAME</th>
<th>ITEM</th>
<th>ALE-40</th>
<th>ALE-XX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cockpit control Unit (CCU)</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Programmer (PROG)</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Chaff Single/Double Switch</td>
<td>1</td>
<td>0</td>
<td>Note 1</td>
</tr>
<tr>
<td>Chaff/Flare Select Switch</td>
<td>8</td>
<td>0</td>
<td>Note 2</td>
</tr>
<tr>
<td>EMI Filter</td>
<td>2</td>
<td>0</td>
<td>Note 3</td>
</tr>
<tr>
<td>Sequencer</td>
<td>8</td>
<td>0</td>
<td>Note 4</td>
</tr>
<tr>
<td>Dispenser Assemble (DA)</td>
<td>16</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

Note 1  The chaff single/double switch is incorporated into the CCU.

Note 2  The chaff/flare select switches are not used. The magazines identify type of ordinance present.

Note 3  All LRUs have internally filtered 28 VDC power from EMI. No EMI filter is required for fiber optics communication links.

Note 4  The sequencer electronics are integrated into the DA LRU.
selection, dispense initiation detection, network control, mode processing, and ordinance management.

Following were the goals for the CCU.
1. Master controller of the CMDS communication channels.
2. Fit all electronics into the ALE-47 outside dimension.
3. Display an accurate count of ordinances available.
4. Display system operation status.
5. Display system level of readiness (CMDS Initialization BIT for limited operation).
6. Detection of any faults in the CCU (BIT).
7. Display any faults detected in the entire system.
8. Allow programming of mission data.

Research and Development Approach

The research and development approach for ALE-XX CMDS CCU was a limited Yourdon "structured analysis" methodology. The basic approach was Analysis, Design, and Implementation.

1. The analysis process for ALE-XX CMDS CCU was done by creating an analysis data flow diagram for the existing system (ALE-40 CMDS CCU) and then to create a model data flow diagram for the new system (ALE-XX CMDS CCU).
2. The design process for ALE-XX CMDS CCU was
accomplished by defining the data requirements, creating a system structure, designing the database (file structures), and creating the specifications.

3. The implementation process ALE-XX CMOS CCU involves the physical development using structured techniques and documenting the system.

The following steps were used in the development of the CCU.

1. Verification stage of wirewrap for circuit boards.
2. Module definitions.
3. Diagnostic code development.
4. Operational source code development.
5. Packaging.
6. System mock-up.

**Resources**

The hardware for ALE-XX CMOS CCU construction was Intel's 8751 family of chips (RAM, EPROM, EEPROM, buffers, latches, UARTs etc.).

The software for ALE-XX CMDS CCU development was a basic software development environment on a PC coupled with an In Circuit Emulator (ICE). The ICE interfaces though the PC serial communication port and offered trace capabilities, and some limited logic analyzer functions. The package also has a cross assembler and ran independently of the hardware allowing parallel software and hardware development.
CHAPTER 2

STAR TOPOLOGY AND FIBER OPTICS

*Star Topology*

The ALE-XX system was designed to use a Star Topology Network. The CCU acts as the Master Controller and all sixteen of the DAs as slave peripherals. There were sixteen fiber-optic cables connecting the CCU to each DA with sixteen Transceivers in the CCU and one Transceiver in each DA has shown in figure 3 (Fig. 3). Each DA would be in a listening mode waiting for a serial stream of data with a transmission rate of 19.2 Kilobaud. The DA would have to respond within a specified amount of time after receipt of the communication with that particular DA or the DA is declared down. If a DA is declared down the CCU software would finish the task with one of the other remaining DAs. The system could have battle damage with a severed cable but continue to dispense ordinance by use of another communication channel. In wartime environment, a pilot could elect to continue flying the mission with only a partial complement of the total ordinances available. This allows for a graceful degradation of the system.

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The system really doesn't need the Programmer for minimal system configuration as implied by the ALE-40 functional replacement, therefore the ALE-XX was designed with the master controller in the CCU. The cockpit is a less hostile environmental location for all the Transceivers than in the Programmer which is located in the nose-cone of the aircraft. The intention was to not include the Programmer for all aircraft that was not ready to interface to the MIL-STD-1553B Multiples Data Bus and the MIL-STD-1760 Avionics and Electronics Warfare Bus for automatic dispense of ordinance. The Programmer was designed in the ALE-XX project merely as a verification of interface. The Programmer when completed would allow the pilot to select automatic mode to dispense ordinance. The Programmer by interfacing to Data and Weapons Buses would collect Radar, speed, altitude, and other information. Interpreting all or part of this information the Programmer would dispense ordinance without the pilot having to push either dispenser button. The Programmer connects to the CCU by a separate seventeenth fiber-optic cable. This communication link was designed for high data transfer rate. The Programmer with the other as yet no developed interface boards added for automatic mode would be controlling the system and the CCU would then be responsible as master controller of the star network and for human interface.

The eight Sequencers of the ALE-40 are eliminated
because the fiber-optic cables are connected directly to the DAs.

Each DA has a microcontroller operating the communications, ordinance selection, BIT, and ordinance inventory. Each DA requires only a four pin connector, one fiber-optic cable, one power line, one squib power, and one ground wire. The DA would only have about $300.00 worth of parts and could be a disposable item, thus eliminating the intermediate and depot level repairs.

The system would be very flexible with a configuration of one DA to as many as thirty two DAs in any combination of chaff/flare. For thirty two DAs a 1:2 "T" coupler is used at each of the sixteen DA connections. The F-4 has two DAs, the F-111 has eight, the A-10 has 16, the F-16 has 32, etc. The Sequencers are eliminated in the ALE-XX system with a reduction in cost and maintenance for all aircraft.

**Fiber Optics**

The communications from the CCU to the DA is done with only a few commands/parameters and is not data intensive. The speed of the serial data is relatively low for fiber-optic application. The system was designed with a round-robin type of polling, where only one transceiver was transmitting or receiving at a time. The CCU would open the channel with the first DA, transmit a command, wait for a
response, close the channel, open the channel for the next DA, transmit a command, and so on. The device selected that best suited this concept was the AT&T ODL 02X Lightwave Transceiver. This device allows fiber-optic cables for both transmit and receive. Conventional fiber-optic communication requires two transmitter devices, two receiver devices, and two fiber-optic cables. The AT&T ODL 02X is a new product that has all the features to meet our need for slow data rate transfers, small size, one package for transmit and receive, low power consumption, TTL compatible, and was commercially available. The major concern with this device is that it was designed for a commercial environment. The data sheet specified a maximum operating temperature of 60 degrees centigrade. The ALE-XX project required a higher operating temperature. Testing proved the environmental specification on the AT&T did meet the needs of the ALE-XX. Testing of the device showed a loss in power output from ceramic dust covering the lens of the device during severe vibration testing. AT&T provided an update to the device meeting the environmental needs with the fiber-optic cable connected to the lens of the device (Pigtailed). This would eliminate the connector problem of dust previously mentioned.
CHAPTER 3

HARDWARE ON CMDSNC

Following were the hardware design concerns for the CCU.

1. The external dimensions of the CCU had to be identical to the proposed ALE-47 CCU. The CCU had six constraints based on the slot within the cockpit.

2. There had to be bus compatibility with the Programmer. The Programmer in the future will interface with the MIL-STD-1553B Multiples Data Bus and the MIL-STD-1760 Avionics and Electronics Warfare Bus and act as master while the CCU acts as the network controller. If the CCU were set in the Automatic Mode then the Programmer would dispense ordinance based on information collected from the Data and Weapons Buses while the CCU would act as network controller.

3. There had to be parts compatibility and generic cards used where possible for increased reliability and maintainability between all the LRUs.
4. The CCU had to be easy to use, taking no more then 5 minutes to be completely programmed.

**Network**

The Cockpit Control Unit (CCU) is the master controller for the fiber optic star network. The network is configured to have a direct channel from the CCU to any of 16 Dispenser Assemblies (DA) and also a direct link to the Programmer LRU. The 16 DAs share a common Universal Asynchronous Receiver/Transmitter (UART) while the Programmer uses a dedicated UART. Only one DA communication channel is open at any one time. The channel selection of the DAs is done by the CCU hardware. This is done to alleviate keying each dispenser location for each address and allowed for generic resident software for each DA. The dedicated communication link to the Programmer is part of a future enhancement which allows the CCU to be interrupted when the Programmer receives urgent information from the Data and Weapons Buses. Immediate action could then be taken if necessary.

The communication protocol is a command/response scheme. The entire system is interrupt driven. Each DA will wait for the CCU to transmit a command. Upon receiving a command, it will respond to the command and take the appropriate action. If the CCU does not receive a response from the addressed DA, it retries the command. If there is
no response then the DA is declared down and another DA is selected. The commands and responses are detailed in Chapter 4.

**CCU Hardware**

The hardware design of the CCU is 5 circuit boards. The following is a list of the functional circuit boards.

1. One Power Board.
2. One Central Processing Unit (CCU) Board.
3. One Display Board.
4. Two 8 channel Fiber Optic Boards.

An alphanumeric display was used to present readable messages to the user. This allows the use of menus for easily programming mission data and understandable error and status messages.

The 2 fiber optic boards are identical. They are separately addressed using a wrap around bus scheme. This is in contrast to the parallel bus scheme used on all signals exclusive to the fiber optic board addressing.

**Microcontroller**

The microcontroller selection was based on a single-chip-CPU with all of the support and memory on-chip. Following are features of the 87C51 Microcontroller.

1. High performance HMOS process.
2. Internal timers/event counters.
3. 2-level interrupt priority structure.
4. 32 input/output lines, four 8-bit ports.
5. 64 K program memory space EPROM.
7. Bit-addressable RAM.
8. Programmable full duplex serial channel.
9. 111 instructions (64 single-cycle).
10. 64K data memory space.
11. Program memory security.

Table 3 describes how the microcontroller addressing is allocated in hardware with a brief description of each (Tab. 3).

The EEPROM can be altered without removing it from the board. It can withstand up to 10,000 write cycles to any single location. It is an 8K*8 configuration. The EEPROM is used sparingly to prevent premature failure.

The display is made up of 4 ICs. Each IC displays 4 characters for a total of 16 characters. Each of the display units (IC) may be controlled separately. That is the attribute for each chip may be different if desired. Table 4 shows the attribute word configuration (Tab. 4).

From table 4 it can be noted the attribute enable uses the attribute selected with the attribute bits (D3 and D2) of the word. It applies the attribute selected to any
Table 3. Microcontroller FUNCTIONAL ADDRESSING

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>ADDRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEPROM</td>
<td>0000H–1FFFH</td>
</tr>
<tr>
<td>A to D</td>
<td>2000H</td>
</tr>
<tr>
<td>Display Attribute 0–3</td>
<td>4010H</td>
</tr>
<tr>
<td>Display ASCII Char 0–3</td>
<td>4014H–4017H</td>
</tr>
<tr>
<td>Display Attribute 4–7</td>
<td>4020H</td>
</tr>
<tr>
<td>Display ASCII Char 4–7</td>
<td>4024H–4027H</td>
</tr>
<tr>
<td>Display Attribute 8–11</td>
<td>4040H</td>
</tr>
<tr>
<td>Display ASCII Char 8–11</td>
<td>4044H–4047H</td>
</tr>
<tr>
<td>Display Attribute 12–15</td>
<td>4080H</td>
</tr>
<tr>
<td>Display ASCII Char 12–15</td>
<td>4084H–4087H</td>
</tr>
<tr>
<td>Fiber Optic Status (RD)</td>
<td>6000H</td>
</tr>
<tr>
<td>Fiber Optic Select (A)</td>
<td>6000H</td>
</tr>
<tr>
<td>Mode Select Switch (RD)</td>
<td>8000H</td>
</tr>
<tr>
<td>Discrete Select SW (RD)</td>
<td>8001H</td>
</tr>
<tr>
<td>UART</td>
<td>A000H–A003H</td>
</tr>
<tr>
<td>RAM</td>
<td>C000H–DFFFH</td>
</tr>
</tbody>
</table>
Table 4. ATTRIBUTE WORD CONFIGURATION

<table>
<thead>
<tr>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3 D2</th>
<th>D1 D0</th>
<th>BRIGHTNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLR</td>
<td>LAMP</td>
<td>BLINK</td>
<td>ATEN</td>
<td>ATTRIBUTES</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

D7 - Clear
- 0 = standard operation
- 1 = Clear display and memory (0 all memory)

D6 - Lamp Test
- 0 = Standard operation
- 1 = Display all dots at 50% brightness

D5 - Blink
- 0 = Entire display blink off
- 1 = Entire display blink on

D4 - Attribute enable
- 0 = Disable attribute
- 1 = Enable attribute
of the ASCII characters that has a "1" in the D7 location. For example, load 30H into the display ASCII character "1". A "0" will appear on the display. If B0H is loaded in then the attribute selected will be applied to the character if the attribute enable bit is set.

From table 5 it can be noted if all display attributes are the same, a simple approach is to write the desired attribute word to location 40F0H (Tab. 5).

Attribute 0-15 40F0H

To display the desired character on the display, write the ASCII code to the appropriate display character number.

Location of Characters on the Board

| 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |

Analog to Digital Converter (ADC). The ADC is used to identify what the brightness setting that should be set at on the display. The ADC can monitor the dimmer knob and convert the position of the knob to an 8 bit binary number. The ADC will provide a linear response and will indicate 00FFH when the knob is at a maximum setting and 0000H at the minimum setting. The actual setting of the display (controlled by D0 and D1 of the display attribute word) is determined by the user.
Table 5. DISPLAY ATTRIBUTE AND BRIGHTNESS

<table>
<thead>
<tr>
<th>D3 D2</th>
<th>Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0</td>
<td>Display cursor instead of char in memory</td>
</tr>
<tr>
<td>0 1</td>
<td>Blink character</td>
</tr>
<tr>
<td>1 0</td>
<td>Display blinking cursor instead of char</td>
</tr>
<tr>
<td>1 1</td>
<td>Alternate char with cursor (cursor is all dots)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>D1 D0</th>
<th>Brightness</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0</td>
<td>Blank</td>
</tr>
<tr>
<td>0 1</td>
<td>25%</td>
</tr>
<tr>
<td>1 0</td>
<td>50%</td>
</tr>
<tr>
<td>1 1</td>
<td>100%</td>
</tr>
</tbody>
</table>
**Operation of the ADC**

The ADC must be given a start conversion command to begin the actual reading of the dimmer knob. The result will not be available for a 100 microseconds. The user may either wait the time limitation (100 usec) or the ADC READY FLAG can be polled. The flag is located at Port P1.2.

The conversion starts when writing to location 2000H.

The result is granted when reading from location 2000H.

**Fiber Optic Addressing**

There are 16 separate fiber optic lines. Only 1 fiber optic channel may be open at any one time. Writing to the address 6000H will determine which fiber optic line will be open as described in table 6 (Tab. 6).

Table 6 shows that to select a fiber optic line, write to address 6000H with the data for the fiber optic line desired.

**Fiber Optic Status**

The fiber optic status is a register that will show the state of important signals on the fiber optic boards. There are 2 controls for the fiber optic status and must be used together. The controls are P1.6 (FOSSTAT01) and address 6000H. P1.6 will select which fiber optic board will be
Table 6. FIBER OPTIC ADDRESSING

<table>
<thead>
<tr>
<th>ADDRESS</th>
<th>DATA</th>
<th>FIBER OPTIC LINE OPEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>6000H</td>
<td>00H</td>
<td>FO0</td>
</tr>
<tr>
<td>6000H</td>
<td>01H</td>
<td>FO1</td>
</tr>
<tr>
<td>6000H</td>
<td>02H</td>
<td>FO2</td>
</tr>
<tr>
<td>6000H</td>
<td>03H</td>
<td>FO3</td>
</tr>
<tr>
<td>6000H</td>
<td>04H</td>
<td>FO4</td>
</tr>
<tr>
<td>6000H</td>
<td>05H</td>
<td>FO5</td>
</tr>
<tr>
<td>6000H</td>
<td>06H</td>
<td>FO6</td>
</tr>
<tr>
<td>6000H</td>
<td>07H</td>
<td>FO7</td>
</tr>
<tr>
<td>6000H</td>
<td>08H</td>
<td>FO8</td>
</tr>
<tr>
<td>6000H</td>
<td>09H</td>
<td>FO9</td>
</tr>
<tr>
<td>6000H</td>
<td>0AH</td>
<td>FO10</td>
</tr>
<tr>
<td>6000H</td>
<td>0BH</td>
<td>FO11</td>
</tr>
<tr>
<td>6000H</td>
<td>0CH</td>
<td>FO12</td>
</tr>
<tr>
<td>6000H</td>
<td>0DH</td>
<td>FO13</td>
</tr>
<tr>
<td>6000H</td>
<td>0EH</td>
<td>FO14</td>
</tr>
<tr>
<td>6000H</td>
<td>0FH</td>
<td>FO15</td>
</tr>
</tbody>
</table>
read from when reading from address 6000H as described in table 7 (Tab. 7).

From table 7 it can be noted P1.6 is the bit set to choose which board will be accessed when reading from 6000H. 0 selects fiber optic board 0 (FOB0) and 1 selects FOB1. D3 is the bit to show if the selected fiber optic board is enabled. D2 and D0 are the bits to show which line is selected on the board being read.

Switches

The switch positions can be read in by reading from locations 8000H and 8001H as described in table 8 (Tab. 8).

Cockpit Control Unit Display Circuit

The Siemens MPD2547 is a green, 0.25", 4-digit, 5 x 7 dot matrix display chip in a hermetic sealed ceramic package which conforms to requirements set forth in MIL-STD-750 and MIL-STD-883. The display has built-in memory, decoders, multiplexer, and drivers along with a 96-character ASCII format character generating ROM, eliminating the need for external latches and multiplexers for displaying characters. An internal clock is available to synchronize all of the chips in a given display.

These features enable the display to be interfaced with a microcontroller like any other peripheral. The ASCII characters as well as an 8-bit control word that controls
Table 7. FIBER OPTIC STATUS

Address = 6000H

<table>
<thead>
<tr>
<th>Output</th>
<th>7 6 5 4 3 2 1 0</th>
<th>Enabled</th>
<th>FOE Board Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>(FOB)0</td>
<td>x x x x 0 0 0 0</td>
<td>Yes</td>
<td>FO0</td>
</tr>
<tr>
<td>(FOB)0</td>
<td>x x x x 0 0 0 1</td>
<td>Yes</td>
<td>FO1</td>
</tr>
<tr>
<td>(FOB)0</td>
<td>x x x x 0 0 1 0</td>
<td>Yes</td>
<td>FO2</td>
</tr>
<tr>
<td>(FOB)0</td>
<td>x x x x 0 0 1 1</td>
<td>Yes</td>
<td>FO3</td>
</tr>
<tr>
<td>(FOB)0</td>
<td>x x x x 0 1 0 0</td>
<td>Yes</td>
<td>FO4</td>
</tr>
<tr>
<td>(FOB)0</td>
<td>x x x x 0 1 0 1</td>
<td>Yes</td>
<td>FO5</td>
</tr>
<tr>
<td>(FOB)0</td>
<td>x x x x 0 1 1 0</td>
<td>Yes</td>
<td>FO6</td>
</tr>
<tr>
<td>(FOB)0</td>
<td>x x x 0 1 1 1</td>
<td>Yes</td>
<td>FO7</td>
</tr>
<tr>
<td>(FOB)1</td>
<td>x x x 1 0 0 0 0</td>
<td>No</td>
<td>FO8</td>
</tr>
<tr>
<td>(FOB)1</td>
<td>x x x 1 0 0 1</td>
<td>No</td>
<td>FO9</td>
</tr>
<tr>
<td>(FOB)1</td>
<td>x x x 1 0 1 0</td>
<td>No</td>
<td>FO10</td>
</tr>
<tr>
<td>(FOB)1</td>
<td>x x x 1 0 1 1</td>
<td>No</td>
<td>FO11</td>
</tr>
<tr>
<td>(FOB)1</td>
<td>x x x 1 1 0 0</td>
<td>No</td>
<td>FO12</td>
</tr>
<tr>
<td>(FOB)1</td>
<td>x x x 1 1 0 1</td>
<td>No</td>
<td>FO13</td>
</tr>
<tr>
<td>(FOB)1</td>
<td>x x x 1 1 1 0</td>
<td>No</td>
<td>FO14</td>
</tr>
<tr>
<td>(FOB)1</td>
<td>x x x 1 1 1 1</td>
<td>No</td>
<td>FO15</td>
</tr>
<tr>
<td>(FOB)1</td>
<td>x x x x 1 0 0 0</td>
<td>Yes</td>
<td>FO8</td>
</tr>
<tr>
<td>(FOB)1</td>
<td>x x x x 1 0 0 1</td>
<td>Yes</td>
<td>FO9</td>
</tr>
<tr>
<td>(FOB)1</td>
<td>x x x x 1 0 1 0</td>
<td>Yes</td>
<td>FO10</td>
</tr>
<tr>
<td>(FOB)1</td>
<td>x x x x 1 0 1 1</td>
<td>Yes</td>
<td>FO11</td>
</tr>
<tr>
<td>(FOB)1</td>
<td>x x x x 1 1 0 0</td>
<td>Yes</td>
<td>FO12</td>
</tr>
<tr>
<td>(FOB)1</td>
<td>x x x x 1 1 0 1</td>
<td>Yes</td>
<td>FO13</td>
</tr>
<tr>
<td>(FOB)1</td>
<td>x x x x 1 1 1 0</td>
<td>Yes</td>
<td>FO14</td>
</tr>
<tr>
<td>(FOB)1</td>
<td>x x x x 1 1 1 1</td>
<td>Yes</td>
<td>FO15</td>
</tr>
<tr>
<td>Address</td>
<td>Bit</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>-----</td>
<td>---------------------------</td>
<td></td>
</tr>
<tr>
<td>8000H</td>
<td>D7</td>
<td>Chaff Program</td>
<td></td>
</tr>
<tr>
<td>8000H</td>
<td>D6</td>
<td>Chaff Manual Multiple</td>
<td></td>
</tr>
<tr>
<td>8000H</td>
<td>D5</td>
<td>Chaff Manual</td>
<td></td>
</tr>
<tr>
<td>8000H</td>
<td>D4</td>
<td>Setup Mode</td>
<td></td>
</tr>
<tr>
<td>8000H</td>
<td>D3</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>8000H</td>
<td>D2</td>
<td>Flare Manual Multiple</td>
<td></td>
</tr>
<tr>
<td>8000H</td>
<td>D1</td>
<td>Flare Manual</td>
<td></td>
</tr>
<tr>
<td>8000H</td>
<td>D0</td>
<td>Test Mode</td>
<td></td>
</tr>
<tr>
<td>8001H</td>
<td>D7</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>8001H</td>
<td>D6</td>
<td>Flare Dispense</td>
<td></td>
</tr>
<tr>
<td>8001H</td>
<td>D5</td>
<td>Chaff Dispense</td>
<td></td>
</tr>
<tr>
<td>8001H</td>
<td>D4</td>
<td>Halt</td>
<td></td>
</tr>
<tr>
<td>8001H</td>
<td>D3</td>
<td>Jettison</td>
<td></td>
</tr>
<tr>
<td>8001H</td>
<td>D2</td>
<td>Select Button</td>
<td></td>
</tr>
<tr>
<td>8001H</td>
<td>D1</td>
<td>Down Button</td>
<td></td>
</tr>
<tr>
<td>8001H</td>
<td>D0</td>
<td>Up Button</td>
<td></td>
</tr>
</tbody>
</table>
display attributes can be easily addressed and read from or written to with the aid of the read or write enable lines in addition to two chip select lines.

The display circuit design uses a NAND gate (54LS08) which allows the sixteen characters in the display to be accessed by the four lowest order bits in the address (bits 0-3). This enables the rightmost character (digit 0) to be referenced by '0000' and the leftmost character (digit 15) by '1111'. The next most significant bit of the address (bit 4) designates whether the data written to the display is an ASCII character or the control word which sets the attributes for all of the characters in the display.

The circuit is configured such that the intensity of the display can be controlled by toggling the two lowest order bits of the control word to determine the display brightness. These bits are governed by the output of the timer (SE555) which provides a pulse-width-modulated waveform whose duty cycle is proportionate to the incoming 0-5V analog voltage from the cockpit dimming rheostat. The other six bits of the control word are preserved using an 8-bit latch (54LS373).

A pair of quad 2-to-1 data selectors (54LS157) is used to switch between ASCII character and control word data. Switching is controlled 4 bits of the address in conjunction with a 10kHz clock signal using a NAND gate (54LS00). This enables the control word to be updated every
0.25ms to adjust the display intensity, giving precise brightness control without microcontroller intervention. A divide-by-twelve counter (54LS92) reduces the 10kHz clock signal to 1kHz for the timer which produces the pulse-width-modulated output signal with a period of 1ms, allowing four brightness levels for display intensity.

The 10kHz refresh rate was selected after testing several creates in the lab. A 5kHz rate worked fairly well and even 1kHz and 2 kHz worked fine until the display was called down well below room temperature. At that point, the display flickered noticeable at 10 and 20 percent duty cycles. The upper limit for the display refresh rate is around 3MHz, which is dictated by the time necessary for a complete write cycle.

One area of concern in using this display chip with the Intel 87C51 microcontroller in the Cockpit Control Unit (CCU) was the fact that one of the microcontroller ports has a function to provide both address and data information. In the CCU design, there was no means to latch the data output from the microcontroller. Under certain operating conditions, this might not be adequate to establish the required data hold time for the display. If this were the case, some circuit modification might be necessary.

Another potential problem area was encountered when trying to incorporate this display circuit design into the
front panel space of the CCU. After the required space for the rotary and push-button switches as well as the 16-digit display was accounted for, very little room was available for other components, unless space could be found on other CCU circuit cards which were already crowded.

Since this seemed to be the case, it was decided that an alternate circuit design could be employed which was not as sophisticated but required fewer components and less space. A simple A/D converter would be used to change the analog voltage from the cockpit dimmer rheostat into a digital form which could be read by the microcontroller. The microprocess could then update the control word on the displays directly instead of using the divide-by-ten counter, timer, latch, and data selector.

Another idea for circuit reduction was to eliminate the address decoding circuitry with the 2-to-4 decoder and the NAND gates. Instead, a separate address bit would be used to enable each display chip, using only the last two address bits (bits 0-1) to designate character position on a given chip. The next address bit (bit 2) would determine whether ASCII data or the control word was being sent.

Display circuitry was reduced as described to provide only four screen intensity levels from a desired ten levels due to board space considerations.
CCU Hardware Breakdown

A list of the parts for the CCU is in Table 9 (Tab. 9). CCU board drawings are shown in figures 4 thru 10 (Fig. 4 thru 10).
Table 9 - CCU PARTS LIST

<table>
<thead>
<tr>
<th>Qty</th>
<th>Description</th>
<th>Manufacture</th>
<th>Part No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>POWER BOARD</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>DC to DC Converter</td>
<td>Integrated Circu</td>
<td>MHEZ805S</td>
</tr>
<tr>
<td>1</td>
<td>Capacitor, 100 uF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Resistor, 3 Ohm, 7 Watt</td>
<td>AT&amp;T</td>
<td>02X</td>
</tr>
<tr>
<td>1</td>
<td>Fiber Optic transceiver</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Crystal, 14.31818Mhz</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>DISPLAY BOARD</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Resistor Network, 2.2K</td>
<td>Allen Bradley</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Decoder</td>
<td></td>
<td>54LS139</td>
</tr>
<tr>
<td>2</td>
<td>Octal Buffer</td>
<td></td>
<td>54LS240</td>
</tr>
<tr>
<td>4</td>
<td>Switch, Toggle DPDT Momen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Switch, Toggle DPDT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Display, Alphanumeric</td>
<td>Seimens</td>
<td>MPD2547</td>
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<tr>
<td>2</td>
<td>Switch, Rotary DP5T</td>
<td>Grayhill</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>CPU BOARD</strong></td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>A to D converter (8 bit)</td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>Resistor, 10K ohm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Resistor, Network 10K</td>
<td>Allen Bradley</td>
<td>710A103</td>
</tr>
<tr>
<td>1</td>
<td>Capacitor, 10 uF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Resistor, 1K ohm</td>
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<td></td>
</tr>
<tr>
<td>2</td>
<td>Resistor, 2.2K ohm</td>
<td></td>
<td>1N916</td>
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<td>1</td>
<td>Diode</td>
<td></td>
<td>710A222</td>
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<td>Resistor Net 2.2K</td>
<td>Allen Bradley</td>
<td>710A103</td>
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<tr>
<td>1</td>
<td>EPROM, 32K byte</td>
<td>Intel</td>
<td>27C256</td>
</tr>
<tr>
<td>1</td>
<td>EEPROM, 8K byte</td>
<td></td>
<td>28C64</td>
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<tr>
<td>1</td>
<td>IC, Quad AND Gate</td>
<td></td>
<td>54LS00</td>
</tr>
<tr>
<td>1</td>
<td>IC, Quad Buffer</td>
<td></td>
<td>54LS125</td>
</tr>
<tr>
<td>1</td>
<td>IC, 3 - 8 Decoder</td>
<td></td>
<td>54LS138</td>
</tr>
<tr>
<td>1</td>
<td>IC, Hex Schmitt Inverter</td>
<td></td>
<td>54LS14</td>
</tr>
<tr>
<td>2</td>
<td>IC, Octal Buffer</td>
<td></td>
<td>54LS244</td>
</tr>
<tr>
<td>1</td>
<td>IC, Octal Transceiver</td>
<td></td>
<td>54LS245</td>
</tr>
<tr>
<td>1</td>
<td>IC, Quad 2 in OR Gate</td>
<td></td>
<td>54LS32</td>
</tr>
<tr>
<td>1</td>
<td>IC, Octal Latch</td>
<td></td>
<td>54LS373</td>
</tr>
<tr>
<td>1</td>
<td>IC, Divide by 12</td>
<td></td>
<td>54LS92</td>
</tr>
<tr>
<td>1</td>
<td>Microcontroller, 8 bit</td>
<td>Intel</td>
<td>87C51</td>
</tr>
<tr>
<td>1</td>
<td>USART</td>
<td>Harris</td>
<td>82C52</td>
</tr>
<tr>
<td>1</td>
<td>RAM, 2K byte</td>
<td></td>
<td>9128</td>
</tr>
<tr>
<td>1</td>
<td>Oscillator, 11.0592Mhz</td>
<td>AMD</td>
<td>M1144</td>
</tr>
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<td>Qty</td>
<td>Description</td>
<td>Manufacture</td>
<td>Part No.</td>
</tr>
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<td>-------------</td>
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</tr>
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<td>8</td>
<td>CHANNEL FIBER OPTIC BOARD</td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>IC, 2 In NOR</td>
<td>54LS02</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>IC, Quad Buffer</td>
<td>54LS125</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>IC, Quad D Flip/Flop</td>
<td>54LS175</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>IC, 8 in Multiplexer</td>
<td>54LS251</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>IC, Demultiplexer</td>
<td>54LS259</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>IC, 2 in XOR Gate</td>
<td>54LS86</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Fiber Optic Transceiver</td>
<td>AT&amp;T</td>
<td>02X</td>
</tr>
<tr>
<td>1</td>
<td>Oscillator, 14.31818Mhz</td>
<td>M1144</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 4. Diagram of Front Panel
Fig. 5. CCU Board (1 of 2)
Fig. 6. CCU Board (2 of 2)
Fig. 7. Display Board
Fig. 8. Power Board
Fig. 9. Fiber Optic Board 1
Fig. 10. Fiber Optic Board 2
CHAPTER 4

ALE-XX CCU INTERFACES

The ALE-XX CCU interfaces with the pilot and ground crew through the front panel. The hardware and software were designed for positive human interface and safety considerations. The ALE-XX CCU front panel is made up of a visual display, chaff mode select switch (setup, off, manual single, manual multiple, and program dispense), flare mode select switch (test, off, manual single, and program), flare jettison switch, halt program switch, and mission data select switches. Figure 4 is a diagram of the front panel (Fig. 4).

Visual Display

The CCU front panel provides positive indication that power is applied to the system. The CCU displays the number of ordinance remaining in each category, including after Jettison. If a particular magazine is installed, but there is none of that expendable category on board, then the display shows zero. The number of categories displayed is determined by sensing of magazine types installed
replacing the past external programming. All CCU messages are in alphanumeric form. Switch labels and legends of the front panel of the CCU are illuminated by an edge lighted panel. The CCU alphanumeric display is clearly legible in all lighting environments from full sunshine to complete darkness, including situations as sunset where the display is in deep shadows.

**Chaff Mode Select Switch**

The Chaff Mode Select Switch is a five position rotary switch, marked SETUP, OFF, MANSGL, MAN MULT, PGM DISP. The mode selection is the same as that on the ALE-40 with the addition of the Setup Mode. If the Chaff Mode Select Switch is turned from one selection to another, except for the Off position, the execution of the last programmed dispense continues unless either the chaff dispense button or the halt button is pressed. If the Chaff Mode Select Switch is turned to the Off position while a program is being executed the CCU terminates the chaff program. Selection of the Off Mode on the Chaff Mode Selection Switch does not affect the Flare Mode Select Switch.

**Setup (SETUP)**

The Setup Mode operation is used for review and/or modification of mission data to ALE-XX. Programming includes the entry of chaff burst count, chaff burst
interval, chaff salvo burst, chaff salvo interval, chaff single/double, flare burst count, flare burst interval, and flare single/double. Information programmed into the CCU in the Setup Mode is retained in EEPROM for retention even if aircraft power is off. The Setup Mode is initiated by selecting the Chaff Mode Select Switch to 'SETUP'. The visual display indicates to the user the current selection and the present mission data values. The user is able to review or modify the current data as required. The Set Mode applies power to the CCU only and can be performed with the ground safety flag installed. No initiation of dispense of chaff or flare is possible in this mode. Time required for modification of all mission data requires less then 5 minutes.

Off (OFF)

No dispense of chaff is possible when the Chaff Mode Select Switch is in the Off Mode. This select switch does not apply power to the ALE-XX, but ALE-XX could have power applied from the Flare Mode Select Switch or the Jettison Switch.

Manual Single (MAN SEL)

ALE-XX dispenses Single or Double Chaff ordinance (determined in the mission data) for each depression of the
Chaff dispensing button. This mode applies power to the ALE-XX system.

Manual Multiple (MAN MULT)

ALE-XX dispenses a single salvo chaff ordinance for each depression of the dispensing button. The number of chaff ordinance per salvo corresponds to the chaff burst count stored in the mission data. The time for dispensing each chaff ordinance is determined for the chaff burst interval data. The CCU upon detection of the chaff dispensing button during a chaff manual multiple dispensation, stops dispensing the current salvo and starts dispensing as required by the Mode selection switch. Detection of the Halt Program button or turning the Chaff Mode Select Switch to 'OFF' halts the dispensing of chaff ordinance. This mode applies power to the ALE-XX system.

Program Dispense (PGM)

ALE-XX dispenses a programmed number of chaff ordinance salvos, based on the burst count number, for each input from the programmer which acts as if there was a depression of the chaff dispensing button. The number of salvos per program correspond to the chaff burst count and chaff salvo count setting stored in the mission data. The time for dispensing each chaff ordinance is determined from the chaff burst interval is stored in the mission data. The time from the last dispensation of the previous salvo to the
beginning of the next salvo will be determined from the chaff salvo interval data. Upon detection by the CCU of the chaff dispensing button during a Chaff Program dispensation, current program is halted and starts dispensing as required by the Mode selection switch. Detection of the Stop Program button or turning the Chaff Mode Select Switch to 'OFF' stops the dispensing of chaff ordinance. This mode applies power the ALE-XX system.

**Flare Mode Select Switch**

The Flare Mode Select Switch is a four position rotary switch, marked TEST, OFF, MAN SGL, and PGM. If the Flare Mode Select switch is turned from one selection to another, except for the off position, the CCU continues to execute the last programmed dispense until either the flare dispense button or halt program button is pressed. If the Flare Mode Select Switch is turned to the off position while a program is being executed, the CCU immediately terminates that flare program. Selection of the Off Mode on the Chaff Mode Select Switch does not effect operation of the flare mode. Selection of the off position on the Flare Mode Selection Switch also does not effect the operation of the chaff mode.

**Test (TEST)**

Then the Flare Mode Select Switch is in the Test
position the CCU performs the test function as described in Chapter 6 'System Modes and States'. The visual display indicates the system status upon completion of IBIT and CBIT. The first message that appears is the system operational status (full operation, limited operation, no operation). The operator has the option to review the following status messages by depressing the select switches: fault detection error codes, DA LRU magazine ordinance identification, hours of operation indicator, and software revisions of all of ALE-XX LRUs.

Off (OFF)

No dispensing of flares is possible when the Flare Mode Select Switch is in the Off mode. This mode select switch does not apply power to the ALE-XX system, but the system could have power applied from the Chaff Mode Select Switch or from the Jettison Switch.

Manual Single (MAN SGL)

ALE-XX dispenses a single or double flare ordinance (determined in the mission data) upon detection of flare or chaff Dispense button depression. This mode applies power to the ALE-XX system.

Program Dispense (PGM)

ALE-XX dispenses a programmed number of flare ordinance salvos, based on the burst count number, for each
input from the programmer which acts as if there was a depression of the flare dispensing button. The number of salvos per program correspond to the flare burst count and flare salvo count setting stored in the mission data. Upon detection by the CCU of the flare dispensing button during a Flare Program dispensation, current program is halted and starts dispensing as required by the Mode selection switch. Detection of the Stop Program button or turning the Flare Mode Select Switch to 'OFF' stops the dispensing of flare ordinance. This mode applies power the ALE-XX system.

**Flare Jettison Switch**

The Flare Jettison Switch jettisons all on-board flares in the minimum time allowable for aircraft power and structural constraints. Other categories of expendables are capable of being jettisoned through reprogramming. This mode overrides the Off Mode and out prioritizes all operation mode dispensing. If the Jettison Switch is activated while the Safety Flag is installed or the WOW switch is engaged, the CCU does not initiate the jettison sequence. If the Jettison Switch remains in the activated position when the Safety Flag is removed or the WOW switch is disengaged, the CCU does not initiate the jettison sequence. If this condition should occur, it is necessary to turn the Jettison Switch 'off' and then 'on' to initiate the jettison mode after WOW and safety pins are removed.
Indication is provided to the pilot that the system is in the jettison/nonjettison problem. This applies power to the ALE-XX System.

**Halt Program Button**

The Halt Program Button, when depressed, terminates any Multiple, Program, and/or Jettison dispense program which is currently active.

**Mission Data Select Switches**

The Mission Data can be reviewed or modified when the Chaff Mode Select Switch is positioned to Setup. The visual display will indicate one of eight program selection and the selections current mission data. The selections can be reviewed or modified by depressing one of the three switches located on the CCU LRU front panel. The following explains the switch titles and functions.

1. Select - This scrolls through the program selections.
2. Data - This scrolls through the mission data.
3. Enter - This stores displayed program selection and mission data into memory. Memory data is retained is an EEPROM after the aircraft power bus is off.

The ALE-XX program selection options and mission data are the same values of the ALE-40. The program selection and mission data options are shown in table 10 (Tab. 10).
Table 10 - PROGRAM SELECTION AND MISSION DATA

<table>
<thead>
<tr>
<th>PROGRAM SELECTION</th>
<th>MISSION DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaff Burst Count</td>
<td>1, 2, 3, 4, 6, 8</td>
</tr>
<tr>
<td>Chaff Burst Interval</td>
<td>1, 2, 3, 4 seconds</td>
</tr>
<tr>
<td>Chaff Salvo count</td>
<td>1, 2, 4, 8, Continuous</td>
</tr>
<tr>
<td>Chaff Salvo Interval</td>
<td>1, 2, 4, 8, Random sec (note 1)</td>
</tr>
<tr>
<td>Flare Burst Count</td>
<td>1, 2, 4, 8 Continuous</td>
</tr>
<tr>
<td>Flare Burst Interval</td>
<td>3, 4, 6, 8, 10 seconds</td>
</tr>
<tr>
<td>Chaff</td>
<td>Single, Double</td>
</tr>
<tr>
<td>Flare</td>
<td>Single, Double (note 2)</td>
</tr>
</tbody>
</table>

Note 1 - Random is 3, 5, 2, 4 seconds in the order.

Note 2 - Flare double option was not available on the ALE-40.
Dispense Initiate Detection

The CCU LRU read switch inputs from the chaff dispense and flare dispense buttons.

Network Control

The CCU LRU provides all network control function as the star master with the DA LRUs functioning as slaves. The Programmer is also a slave but has override capabilities to interrupt the CCU in future growth.

The software performs a simple loop back error correction scheme for communication control and error detection.

Mode Processing

The CCU provides the capability to initiate commands and receive commands from other ALE-XX LRUs. Table 11 shows the protocol command list used to communicate between the CCU and DA (Tab. 11). Table 12 shows the identification codes used by type of flare or chaff (Tab. 12). The CCU receives commands for the mode selection process, dispense initiate and suspense process, and the ordinance inventory process. When the dispense button is detected the CCU evaluates the mode requirements then issues command for dispense of ordinance type, amount, and interval to the ordinance selection and dispense processor. The CCU issues commands for status from the ordinance management processor.
and issues commands is to update the visual display. The mode processing data, mission data, and error detection data are all stored in EEPROM to retain the information after the aircraft power is off.
Table 11 - PROTOCOL COMMAND LIST

FIRE COMMAND FROM CCU TO DA

Word 1 - Fire command
Word 2 - Time before start dispense (msec increments)
Word 3 - Quantity (1 to 60)
Word 4 - Time between burst (10 msec increments)
Word 5 - LRC-8 parity check (LRC-8 = Horizontal parity on LSB’s, vertical parity on MSB)

FIRE COMMAND RESPONSE FROM DA TO CCU

Word 1 - NACK - Not acknowledge (parity error)
or
Word 1 - ACK - Acknowledge (parity OK)

STATUS COMMAND FROM CCU TO DA

Word 1 - Status Command

STATUS COMMAND RESPONSE FROM DA TO CCU

Word 1 - NACK - Not acknowledge (parity error)
or
Word 1 - Quantity of remaining available ordinance (0-60)
Word 2 - Quantity of unsuccessful dispersion since last fire command issue (0-60)
Word 3 - Error codes
Word 4 - Magazine retainer plate identification (0-60)
and DA state (not busy/busy, dispensing,
jettison, stop prm)
Word 5 - LRC-8 parity check

JETTISON COMMAND FROM CCU TO DA

Word 1 - Jettison command

JETTISON COMMAND RESPONSE FROM DA TO CCU

Word 1 - NACK (parity error)
or
Word 1 - Identification code (not jettisonable or proceeding with jettison)
Table 11 – PROTOCOL COMMAND LIST continued

**HALT COMMAND FROM CCU TO DA**

Word 1 - Halt command

**HALT COMMAND RESPONSE FROM DA TO CCU**

Word 1 - NACK - Not acknowledge (parity error)

or

Word 1 - ACK - Acknowledge, stopping all dispense

**TEST COMMAND FROM CCU TO DA**

Word 1 - Test Command

**TEST COMMAND RESPONSE FROM DA TO CCU**

Word 1 - NACK - Not acknowledge (parity error)

or

Word 1 - four
Word 2 - most
Word 3 - severe
Word 4 - errors
Word 5 - LRC-8 parity check
Table 12 - IDENTIFICATION CODES

<table>
<thead>
<tr>
<th>ID4</th>
<th>ID3</th>
<th>ID2</th>
<th>ID1</th>
<th>ORDNANCE</th>
</tr>
</thead>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>no magazine</td>
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<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>chaff 1</td>
</tr>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>chaff 2</td>
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<td>0</td>
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<td>1</td>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>flare 4 (jettisonable)</td>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>flare 5 (jettisonable)</td>
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<td>0</td>
<td>growth 6 (jettisonable)</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>growth 7 (jettisonable)</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>growth 8</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>growth 9</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>growth 10</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>growth 11</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>growth 12 (jettisonable)</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>growth 13 (jettisonable)</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>growth 14 (jettisonable)</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>growth 15 (jettisonable)</td>
</tr>
</tbody>
</table>

Note 1 - ID3 determines jettisonable ordinance.
CHAPTER 5

PACKAGING

Packaging Regions

The ALE-47 envelope for the Cockpit Control Unit (CCU), shown in Figure 11 was used in designing the ALE-XX CCU (Fig. 11). Described below are the parameters of the ALE-47 envelope designates.

1. Mounting Hardware - Specific dimensions and hardware are prescribed for this LRU. The mounting hardware is made up of fasteners, manufactured by DZUS FASTENER CON. INC. (FSCM 72794) (part number: PFSC3.5AE PB).

2. Functional Regions - The ALE-47 CCU envelope illustrates three separate regions (the main box, the connector, and the display) (Fig. 11).

Region 1 Main Box

Region 1, the main box consists of the middle section of the CCU envelope having a maximum length of 4.55 inches, maximum width of 5.00 inches, and maximum height of 3.626 inches. This region houses and supports the five CCU
boards, including two fiber-optic boards, one power board, and one logic board (CCU board), and one display board.

Region 2 Connector

Region 2 is an area identified for connectors only. This region, located on the rear of the box and symmetrical about the center, extends from top to bottom and has maximum width and of 3.350" and depth of 0.759".

Region 3 Display/Front Cover

Region 3, the display or front cover is located at the front of the main box and has an envelope of maximum depth 1.500 inches (out from the mounting interface surface), maximum width 5.740 inches, and maximum height of 3.750 inches. This region is specifically for buttons, switches, and knobs.

Component Layouts

Figure 12 illustrates the major component layouts for the boards used within the CCU (Fig. 12). Real-estate was very scarce. This lead to thoughts of making the power board more of a general purpose board.

Materials and Methods of Construction

Three potential methods of box construction for potential use were identified as cast aluminum, injection molded nylon/graphite fiber composite, and aluminum wall and
Fig. 12. CCU Boards Component Layout
Fig. 12. CCU Boards Component Layout continued
frame. The design parameters for the above mentioned methods are presented below.

Cast Aluminum Construction Method

This method provides an economical process for mass production of the main box and will be instrumental in reducing random vibration origination from the box structure. If this method is to be considered at all, attention to correct casting design must be maintained from the outset and through out the design. For example, this method requires 1 degree of draft, rounded corners, and wall thicknesses from 0.160 to 0.22 inches. Thinner wall sections are possible with reduced strength accordingly.

Injection Molded Nylon/Graphite Fiber Composite

As with the cast aluminum process, injection molded nylon/graphite fiber composite will allow economical mass production. Prototype costs for production of only two main boxes was impractical due to the high injection mold die development cost.

Another negative, depending on design, was some structural components of the main box may have to be thicker using composite material instead of aluminum.

The use of graphite fibers, creating a composite material, strictly provides EMI protection and actually slightly reduces the strength of the molded part. Additional EMI protection can be provided by a process that
impregnates aluminum chips into the surface of the molded part. Acceptable amounts of EMI protection can be achieved by one or both of these processes if a plastic component is desired.

Wall and Frame Construction

The wall and frame method has not been investigated up to this time, because it was perceived from past experience to produce a bulkier part than either cast or molded processes. The ALE-47 Programmer box was constructed with this method.

Preliminary Design Parameters and Assumptions

The following is a list of components incorporated in the CCU.

1. 5 printed wiring boards:
   2 fiber optic boards with 8 transceivers each.
   1 central processing board with 1 transceiver.
   1 power board.
   1 display board.

2. 3 or 4 Raychem board mountable connectors with the ability to join optic fibers.

3. 5 64-pin ribbon cable connectors and 1 ribbon cable used as a bus.

4. 7 PC mountable control switches:
   1 rotary switch for chaff control.
   1 rotary switch for flare control.
   1 toggle switch for jettison.
   3 push button switch for preflight programming.
   1 push button switch for halt mode.
5. 4 PC mountable alpha-numerical displays with 4 characters each.

6. Additional parts may be necessary.

Figures 13 thru 16 show the top, bottom, right and left side views of the CCU (Fig. 13 thru 16). The figures give a view of board packaging with the LRU.

**Design Assumptions**

The following is a list of assumptions established for the CCU initial mechanical package design.

1. The LRU will be able to operate with the cover removed and an extended ribbon cable interface.

2. Each circuit board will be injection molded or cast.

3. The construction method will be injection molded or cast.

4. The wall thickness will be 0.180".

5. The display cover can project into region 2 further than is necessary for wall thickness, thus allowing cover and knobs to utilize region 2 to the fullest extent.

6. All switches will be Printed Circuit (PC) board mountable from the same board.

**Evaluation**

The following is an evaluation of the initial CCU mechanical package design. In figures 13 thru 16 is an
Fig. 14. CCU Bottom View
illustration of component/board placement as initially desired (Fig. 13 thru 16).

1. The display cover can not project out further than the "necessary wall thickness" as previously assumed.

2. The above change will move the display cover back approximately 0.500".

3. Interference exists between the sides of the cover and the displays. This interference is compounded by problem 1.

4. There is not enough board area for the Raychem connector, the 64-pin ribbon, cable connector and the eight transceivers.

The following are the advantages of the above initial mechanical package design.

1. Casting or molding the main box will allow the board guides to become an integral part of the box and eliminate separate board guides.

2. Use of the Raychem connector eliminates the use of bulkhead connectors and service loops, allowing the boards to go to the back of the box.

Changes

The following is a list of suggested changes necessary to correct some of the initial design problems.

1. Reduce the number of displays to three, thus
eliminating the interference problem.

2. Reduce the cover depth to proper requirement.

3. Use the piggy-back and parallel board connectors instead of ribbon cable connectors.
CHAPTER 6

ALE-XX SOFTWARE

The divisions of the ALE-XX software was based on the natural physical boundaries of the hardware (Programmer, Dispenser Assembly (DA), and Cockpit Control Unit (CCU)). The CCU software was further subdivided by functional area into 3 interlocked groupings, Driver, Bit, and Application Software.

Developing Environment

An intel assembly was chosen for development because of the system reaction time requirements, memory constrains, and available resources. The actual writing of programs was done on ASCII standard editor/word processor. All developed code was transferred from the developing PC via direct link to a VAX 780 for assembling. The VAX also contained a hardware simulator (Microtec 8051). Added into the project late was a Metlink 8751 ICE allowing direct assembly and emulation of the hardware from the PCs. The various development/simulation/emulation systems allowed for parallel development and knowledge sharing between the
members of the Programmer, DA, and CCU teams. The Hardware and software of the CCU was developed in parallel. The hardware was 80% complete as the software started. This allowed flexibility for change in the hardware. At one point by not having hardware finalized a timer was added to ease complexity of the interrupt structures. Also, as one piece of hardware was added to the boards, a driver could be written to test the piece of hardware.

**Drivers**

The driver library was written first in order to test the hardware and provide a kernel for Built In Test (BIT) and application software development. This would allow exchanging of hardware later with only the driver interfaces between hardware, BIT and application to be changed. This facilitates form, fit, function replacement. Since the chip set or subsets were basically the same on all LRUs, the drivers could be used on the different hardware divisions. An example of this was the serial communication software driver. Once the driver was proven on the CCU board, it was used by the DA and Programmer. The underlining idea was to minimize the development time and save on future maintenance cost of the software. Refer to Chapter 7 "DRIVERS" for detailed information about the CCU driver software.
BIT

BIT was divided into Initialization Built-in-Test (IBIT) and Continuous Built-in-Test (CBIT). IBIT is activated at power-up. IBIT initializes boards and checks hardware to determine if the system or parts are operable. CBIT is activated by a system event or onboard timer and performs runtime hardware checking and updates status words. Refer to Chapter 8 "BIT" for detailed information about the CCU BIT software.

CCU Interface to Programmer

The CCU sends information to the Programmer which performs a loop back test to the CCU. Later the Programmer could be expanded to interface with the MIL-STD-1553B Multiples Data Bus and the MIL-STD-1760 Avionics and Electronics Warfare Bus for automatic dispensing of ordinance. This Artificial Intelligence (AI) function would result in the CCU acting as a slave network controller. Refer to Chapter 9 "Application" for detailed information about the CCU to Programmer software.

CCU Interface to DA

The CCU sends commands to the DA and the DA responds. The DA is a slave command receiver in a star-topology network with the CCU as controller. The DAs primary action is to dispense squibs when given command by the CCU via the pilot or perhaps in the future the
Programmer. The DA also reports when commanded by the CCU, status of hardware and squib inventory. Refer to Chapter 9 "Application" for detailed information about the CCU to DA software.

**Cockpit Control Unit**

The following functions were designed for the ALE-XX Counter Measure Dispense System (CMDS) Cockpit Control Unit (CCU) to perform.

1. Provide a user interface to select CMDS mode of operation.
2. Display the quantity and type ordinance the CMDS has available for dispensing.
3. Serve as the communications controller for the CMDS.
4. Allow loading and sorting of mission data.
5. Administer command sequences to other CMDS LRUs.
6. Display fault information of the CMDS and control power to other LRUs of the CMDS.

The following functional areas are defined for the CCU.

1. Program Storage. The CCU application program resides in a 32 KB EPROM.
2. RAM. The CCU will temporarily store data received from other CMDS LRUs. This information is stored in 2K bytes of RAM.
3. Central Processing Unit. An 87C51 is used as the
main processor of the CCU.

4. Programmable Nonvolatile Memory. Nonvolatile memory is necessary to store mission data and fault information of the CMDS. An 8 KB EEPROM is dedicated for this purpose.

5. Alphanumeric Display. A 16 character alphanumeric display is made available on the CCU front panel. The display indicates the type and quantity of ordinance available for dispense, allows menu driven programming of mission data, and provides fault indication of CMDS operation.

6. Input/Output Latches. Registers are made available to the CPU for reading mode switch settings on the CCU front panel and for writing information to the alphanumeric display.

7. Mode Switches. Mode selection switches allow a user to manually select the CMDS mode of operation.

8. Setup Switches. Switches are necessary to allow the entry of mission data into the CCU. Mission data describes the type, quantity and time intervals of ordinance to be dispensed in CMDS modes.

9. Power Supply. It is necessary to provide 5 VDC to the microelectronics of the CCU. A DC to DC converter is used to convert the 28 VDC avionics power line to the 5 VDC that is needed.
10. Fiber Optic Transceivers. Fiber optic transceivers are used to communicate with all LRUs of the CMDS. Each LRU communicating to CCU has a dedicated transceiver to it. Electromagnetic interference for data transmission is eliminated by the use of fiber optic communications.

11. Address Decoding. The decoding circuit allows the CPU to access the functions of the CCU hardware available.

12. Power Controller. The power controller activates the power to other CMDS LRUs when required.

13. Display RAM. The display refresh, refreshes the display without the need of CPU intervention. This allows the display to output the current data in the display RAM until new data is loaded into it.

Each major component is a Printed Circuit Board (PCB) with a working area of 4.5" x 3.0". Each microcircuit board is connected to the CCU interface board (Backplane). Table 13 defines the major components of the CCU with their assigned functions (Tab. 13).

**CCU Software**

The CCU software is a star topological network controller and user interface. CCU software module layout is described pictorially by the flowchart charts and PDL in the Chapter 9. It is seen by the structure charts that all
Table 13 - CCU MAJOR COMPONENTS

1. CPU Board
   a. Central Processing Unit
   b. RAM
   c. Program Storage
   d. Programmable Nonvolatile Memory
   e. I/O latch
   f. Address Decoding

2. Switch/Display Board
   a. Alphanumeric Display
   b. Mode Switches
   c. Setup Switches

3. Power Board
   a. Power Supply
   b. Power Controller

4. 2 Fiber Optic Converter Boards
   a. Fiber Optic Transceivers
functions end with a screen updating. This provides positive feedback to the user. At power on the system would perform IBIT and if not in the jettison mode perform a system CBIT, collecting information from all LRUs. After the IBIT has performed the CCU then enters into mode processing.

Mode Processing

In mode processing CBIT is performed at the system level and activated by a timer interrupt or a system event. This CBIT collects status of all the LRUs and stores the information. The information collected and stored can be viewed in the test mode and contains LRU status and squib information.

The mode processing loop could in the future be hardware interrupted by the Programmer causing the CCU to act in a slave mode passing along commands and acting only as a star network controller. The programmer would send all the information now provided by the pilot and CCU such as what, how many, what intervals and sequences, when and which types of squibs to fire.

In the mode processing loop module, polling is used to monitor all buttons and switch states. The jettison switch and, if needed, the flare and chaff buttons could be hardware interrupts. By laboratory experimentation using a button switch counter and timer, it was determined the
fastest time a button could be depressed is 10 ms. To send a word on the serial link it takes \( \frac{1}{192000} \times 11 \) words + 0.573 ms or about .6 ms. Instruction cycles take between 1 us to 4 us which is negligible to the transfer time. Therefore, the time to push the button is more then the time to process a response and it was decided to poll and not hardware interrupt.

During the polling of the mode processing loop, if the jettison switch, flare button, or chaff button are set then the CCU goes to a data base to find the DA with the ordinances needed. The CCU then sends a fire command to the selected DA with timing and burst information. The screen is updated as the count of ordinances decreases. These screen updates are positive feedback to the pilot. Salvo count and interval timing is handled by the CCU which gives more flexibility to the CCU and frees up the DA to concentrate on the operation of firing and status transmittal. The flexibility at the CCU was needed for the case where a DA had less then a full load and dispensing would possible need to be spread out over several DAs.

Jettison

There is a special case in mode processing for safety reasons deals with the situation when power is on and the jettison switch set. There is a Weight On Wheels (WOW) switch providing information to the CCU weather the aircraft
is on the ground or in flight. The jettison switch can only be activated if the WOW switch is deactivated. If the jettison switch is set when the aircraft is on the ground (WOW activated) then the jettison switch must be reset to be reactivated with the WOW deactivated. If the CCU is off and the Jettison switch is used to power on the unit then a minimal IBIT is performed and a fire command is sent to all DAs, with the DAs having flares firing, and all DAs responding with status information. At any time the halt switch may be hit and stop processing of any fire command including jettison.

Power Switch

It should be noted at this point that the power switch is not needed. Power is turned on and off by the jettison, flare, and chaff switches. The power switch was installed to match the older version ALE-40.

Flare and Chaff Switches

The flare and chaff switches are used to program the fire response modes. At power up the old settings are installed in the CPU’s RAM from the EEPROM. If the programmed setting are changed the settings are updated in the EEPROM. The setup mode is available on the chaff switch setting. The setup mode allows review of all programmed settings and updating of any programmed settings. Table 10 in Chapter 4 shows programmable responses for the flare and
chaff switches (Tab. 10).

The flare switch can be set to test mode. During IBIT and CBIT the most critical error for each LRU is stored by the EEPROM for maintenance review later. A further complete testing of the system can be accomplished in the test mode via menu selection. A test command can be sent to each LRU and a complete error listing is read back from each LRU. Another test setting allows review of system status for each LRU. Error responses are numbered starting at 0 and going up. The numbers have a break point at which the CCU will declare the LRU down. A list of errors, error samples and a fault tree are in Chapter 7.

Display

All system actions have a positive response to the user in the form of a display. The CCU display communicates with the pilots and maintenance crews. Samples of the menus are listed in Table 14 (Tab. 14).

The General Action Format Screens are used to inform the pilot of system activities. An example is during power up of the complete system the message reads " PWRTST " (for power test). When power up is complete the system moves to Ready Mode or Jettison messages.

The General Setup Format Screens are used by the pilot to review and/or setup the squib firing information. An example is "CHFBRTINT .3" means Chaff Burst Interval .3
Table 14 - GENERAL ACTION FORMAT OF SCREENS

**Menus**

<table>
<thead>
<tr>
<th>BYTES</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td># # # M E S S A G E # #</td>
<td>General Action Format</td>
</tr>
<tr>
<td>P W R T S T</td>
<td>Power Up Test</td>
</tr>
<tr>
<td># # # F _ _ C _ _ # #</td>
<td>Ready Mode, M S = Man Single, M M = Man Mult, P R = Prog</td>
</tr>
<tr>
<td># # # J E T T # #</td>
<td>Jettison - flashing</td>
</tr>
<tr>
<td># # # H A L T # #</td>
<td>Halt - flashing</td>
</tr>
<tr>
<td># # # F L R C H F # #</td>
<td>Flare/Chaff firing - flash</td>
</tr>
</tbody>
</table>

**General Setup Format**

<table>
<thead>
<tr>
<th>DESCR</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C H F B R T C N T</td>
<td>CHF BRT CNT 1,2,3,4,5,6,8</td>
</tr>
<tr>
<td>C H F B R T I N T</td>
<td>CHF BRT INT .1,.2,.3,.4 sec</td>
</tr>
<tr>
<td>C H F S A L C N T</td>
<td>CHF SAL CNT 1,2,4,8, contin</td>
</tr>
<tr>
<td>or C N</td>
<td>CHF SAL INT 1,2,4,8, random (3,5,2,4)</td>
</tr>
<tr>
<td>C H F S A L I N T</td>
<td>CHF SAL INT 1,2,4,8,10 contin</td>
</tr>
<tr>
<td>or R N</td>
<td>FLR BRT CNT 1,2,4,8, contin</td>
</tr>
<tr>
<td>or C N</td>
<td>FLR BRT INT 1,2,4,8,10 contin</td>
</tr>
</tbody>
</table>

**CHF single**

**CHF double**

**FLR single**

**FLR double**

**General Test Format**

<table>
<thead>
<tr>
<th>M E S S A G E S</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>L I M I T</td>
<td>Limited, Full or No operation</td>
</tr>
<tr>
<td>L R T S E S</td>
<td>LRU, up/down, err, type, # of</td>
</tr>
<tr>
<td>L R E E E E</td>
<td>LRU, 4 highest errors, CBIT</td>
</tr>
<tr>
<td>L R I D E T S</td>
<td>LRU, ident, type, # of</td>
</tr>
<tr>
<td>H O U R S</td>
<td>hours of operation</td>
</tr>
<tr>
<td>V E R</td>
<td>software version, revision #</td>
</tr>
</tbody>
</table>
seconds. Another example is "FLR DBL " means fire flares two at a time.

The General Test Format Screens are used by the pilot and maintenance crews to review status and perform diagnostics on the system. An example is "04 DW K F 16" means LRU 4 is down with and error K to be reported and has 16 flares. Another example is "LIMITED 12" means limited operation with 12 LRUs up.

Design Language

The CCU application software was designed using Hamilton/Zeldin Flowcharts and Bullet Pseudo Code as the Program Design Language (PDL). The Flowcharts and PDLs are described in detail and presented in Chapter 9.

Memory Map

The memory map for the CCU can be outlined as the scratch pad area being used for the stack, with the bottom containing the quick access arrays for display, switch states and related information. If a switch state changes the operational state then the switch pad area and EEPROM is updated. Negative test information is also stored in the EEPROM. Bit Addressable Memory contains the status information and test results. Register banks are used for pointers and general register use. Refer to figure 17 for a picture of the memory map (Fig. 17).
<table>
<thead>
<tr>
<th>Address Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000H-1FFFH</td>
<td>EEPROM</td>
</tr>
<tr>
<td>2000H</td>
<td>A to D</td>
</tr>
<tr>
<td>4010H</td>
<td>Display Attribute 0-3</td>
</tr>
<tr>
<td>4014H-4017H</td>
<td>Display ASCII Char 0-3</td>
</tr>
<tr>
<td>4020H</td>
<td>Display Attribute 4-7</td>
</tr>
<tr>
<td>4024H-4027H</td>
<td>Display ASCII Char 4-7</td>
</tr>
<tr>
<td>4040H</td>
<td>Display Attribute 8-11</td>
</tr>
<tr>
<td>4044H-4047H</td>
<td>Display ASCII Char 8-11</td>
</tr>
<tr>
<td>4080H</td>
<td>Display Attribute 12-15</td>
</tr>
<tr>
<td>4084H-4087H</td>
<td>Display ASCII Char 12-15</td>
</tr>
<tr>
<td>6000H</td>
<td>Fiber Optic Status (RD)</td>
</tr>
<tr>
<td>6001H</td>
<td>Fiber Optic Select (A)</td>
</tr>
<tr>
<td>8000H</td>
<td>Mode Select Switch (RD)</td>
</tr>
<tr>
<td>8001H</td>
<td>Discrete Select SW (RD)</td>
</tr>
<tr>
<td>A000H-A003H</td>
<td>UART</td>
</tr>
<tr>
<td>C000H-DFFFFH</td>
<td>RAM</td>
</tr>
</tbody>
</table>

Fig. 17 Memory Map
CHAPTER 7

CCU DIAGNOSTIC SOFTWARE

Scope

The purpose of the Built-In-Test (BIT) is to detect any faults that have occurred during power-up and normal operation of the system. Fault isolation is to a single board level. This fault isolation allows any defective board detected to be replaced at the flight line. Flight line repair of the single board level is a requirement and therefore, fault isolation to any lower level is unnecessary. There is information given which can aid in depot level repair (component replacement).

Structure

ALE-XX software was implemented as modularly as could be done for maintainability. Modularlity is why the software was divided into three separate sections. A natural boundary for the software was the LRUs. These sections include the Dispenser Assembly (DA) BIT, Cockpit Control Unit (CCU) BIT, and the Programmer (PROG) BIT.

Each of these sections has basically the same
structure. Each section consists of two modules: an Initial Built-In-Test (IBIT) and a Continuous Built-In-Test (CBIT). The modules call individual test routines, such as a RAM test. These test routines only test one specific function of the board or chip. For example, a display chip test only tests to see if whatever is inputted is displayed. Each module is independent of any other module. A module or test routine is capable of calling, or being called by any other module or routine. Test routines are called by not only other BIT routines, but also by other control software routines of the particular LRU. Due to the limited amount of memory available, it was extremely important that no routines be duplicated unnecessarily. Figure 18 shows the structure of the CCU BIT software (Fig. 18).

**Operation**

The major function of IBIT is to set up initial conditions for the test routines, set baud rates, and run test routines. Originally, BIT was conceived only to be an IBIT, meaning that BIT executes upon initial power-up of the system only. Later, it was discovered that this was not a complete test given the fact that a number of items, for example the 28VDC line, had to be tested while the system was in operation. It was concluded that it was necessary to include a CBIT. CBIT is written as a separate module.
Fig. 18  CCU BIT Structure Chart
CBIT is executed each time an event occurs or a timer times out. The event can be anything from a switch being thrown to a squib being fired. However, there is a definite possibility the system will be at an idle state, meaning no events occurring for a prolonged period of time. In this case, a timer is incorporated to determine the time since the last event or CBIT execution. If it has been one second since an event has occurred, CBIT will then be executed. During any system idle period, CBIT will run every second. At no time during the execution of the CBIT does it interfere with the system’s normal mode of operation, such as change the value of a mission data memory location.

**Test Routines**

Test routines all follow a similar format. First, all the initial conditions for the test are set. This includes setting the IC to the proper mode. Next some parameter(s) is/are tested. If the test passes, no error flag is set and no message is displayed. If the test fails, that parameter is retested one more time to verified that the test did fail. If the test fails a second time, the error flag in the status word is set and an error message of no more than 16 characters are displayed on the LEDs depending on the priority of the error. For each error that occurs a priority number associated with that error. The
number is used to determine which error has the highest priority (most critical error) and only those errors are displayed. However, if the test passes the second time, the error flag is not set and no message is displayed. When a routine passes, the next test routine is called until all the routines have been executed.

Table 15 shows board components, errors and priority numbering (Tab. 15). From the table a priority 1 results in the system only functioning in the Jettison Mode (Jettison Mode is used if the aircraft is attempting a crash landing and releases possible flammable cargo). A priority 2 requires reprogramming by the user. A priority 3 indicates the Programmer LRU interface is down and there will be no Automatic Mode (Automatic Mode is currently unavailable). It should be noted that one or more DA boards may be down and the system continue to function in the degraded state. It should also be noted that only part of a DA board may be down and the rest of the DA board continues to function in a degraded state.

Following are the descriptions of the BIT software modules divided into groups based on boards. Note there is no test for the power board. If the power supply is down the CCU will not power up and reference to the Technical Order will point to the power supply board.
Table 15 - COMPONENT ERROR AND PRIORITIES

<table>
<thead>
<tr>
<th>Components</th>
<th>Error &amp; Priorities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CCU Main Board</strong></td>
<td></td>
</tr>
<tr>
<td>Decoder</td>
<td>1 1</td>
</tr>
<tr>
<td>Latch</td>
<td>2 1</td>
</tr>
<tr>
<td>Buffer/Driver</td>
<td>3 1</td>
</tr>
<tr>
<td>Transceiver</td>
<td>4 3</td>
</tr>
<tr>
<td>Random Access Memory</td>
<td>5 1</td>
</tr>
<tr>
<td>EPROM</td>
<td>6 1</td>
</tr>
<tr>
<td>EEPROM</td>
<td>7 2</td>
</tr>
<tr>
<td>Microcontroller</td>
<td>8 1</td>
</tr>
<tr>
<td><strong>CCU Display Board</strong></td>
<td></td>
</tr>
<tr>
<td>Dual 2-to-4 Decoders/Demultiplexers</td>
<td>A 1</td>
</tr>
<tr>
<td>8-to-3 Priority Encoders</td>
<td>B 1</td>
</tr>
<tr>
<td>Buffer/Driver</td>
<td>C 1</td>
</tr>
<tr>
<td><strong>CCU Fiber Optic Decoding Board # 1</strong></td>
<td></td>
</tr>
<tr>
<td>Data selectors/Multiplexers</td>
<td>D 1</td>
</tr>
<tr>
<td>8-bit Addressable Latches</td>
<td>E 1</td>
</tr>
<tr>
<td>Quadruple D-Type Flip-Flops</td>
<td>F 1</td>
</tr>
<tr>
<td><strong>CCU Fiber Optic Decoding Board # 2</strong></td>
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<tr>
<td>Data selectors/Multiplexers</td>
<td>G 1</td>
</tr>
<tr>
<td>8-bit Addressable Latches</td>
<td>H 1</td>
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<tr>
<td>Quadruple D-Type Flip-Flops</td>
<td>I 1</td>
</tr>
<tr>
<td><strong>DA Board</strong></td>
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<tr>
<td>Decoder</td>
<td>J 1</td>
</tr>
<tr>
<td>Quad MDTL Line Driver</td>
<td>K 1</td>
</tr>
<tr>
<td>Inverter</td>
<td>L 1</td>
</tr>
<tr>
<td>Lightwave Transceiver</td>
<td>M 1</td>
</tr>
<tr>
<td>MicroController</td>
<td>N 1</td>
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<tr>
<td><strong>Programmer Board</strong></td>
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<tr>
<td>Latch</td>
<td>O 1</td>
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<tr>
<td>Buffer/Driver</td>
<td>P 1</td>
</tr>
<tr>
<td>Transceiver</td>
<td>Q 1</td>
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<tr>
<td>Inverter</td>
<td>R 1</td>
</tr>
<tr>
<td>Lightwave Transceiver</td>
<td>S 1</td>
</tr>
<tr>
<td>MicroController</td>
<td>T 1</td>
</tr>
</tbody>
</table>
Main Board

Following is a general description for the CCU Main Board BIT.

Decoder (74LS138)

1. (Quantity: 1).
2. Set G1 (Enable) to high (1). Set Select Inputs (CBA) initially to 000b, increment inputs to 111b, and verify the addressed Data Output is high and all other outputs are selected low.
3. Set G1 (Enable) to low (0). Set Select Inputs (CBA) initially to 000b, increment inputs to 111b, and verify Data Outputs Y0 thru Y7 are all high (1).

Latch (74LS373)

1. (Quantity: 1).
2. Set Output Enable to low (0). Set Enable Latch to high (1). Set D to FFh. Verify Q (Output) is FFh. Set D to 00h. Verify Q is 00h. Set to 55h. Verify Q is 55h.
3. Set Enable Latch to 0. Verify Q is 55h. Set D to 00h. Verify Q is still 55h.

Buffer/Driver (74LS244)

1. (Quantity: 2)
2. Set D (input) to AAh. Verify Q (Output) is AAh. Set D to 55h. Verify Q is 55h.
Transceiver (74LS245)

1. (Quantity: 1).
2. Set G (Enable Input) to low (0) and B-bus (B1-B8) to AAh. Set direction control (DIR) input to 0.
   Verify A-bus (A1-A8) is AAh. Set B-bus to 55h.
   Verify A-bus is 55h.
3. Set A-bus to AAh. Set DIR to 1. Verify B-bus is AAh. Set A-bus to 55h. Verify B-bus is 55h.
4. Set G to 1. Set B-bus to 00h. Verify B-bus is 00h and A-bus is 55h.

Random Access Memory (AMD, Am9128-90D)

1. (Quantity: 1).
2. Set CE to 0. Set Write Enable (WE) to 0. Set I/O to AAh. Set a to 00h. and increment by 1 until 7Fh.
   Verify I/O is AAh at each memory location.
3. Set CE to 0. Set Write Enable (WE) to 0. Set I/O to 55h. Set A to 000h and increment by 1 until A equals 7FFh.
   Set WE to 1 and OE to 0. Set A to 000h and increment by 1 until 7FFh. Verify I/O is 55h at each memory location.
4. Set CE to 0. Set Write Enable (WE) to 0. Set I/O to 00h. Set A to 000h. Simultaneously increment A and I/O until A equals 7FFh and I/O equals FFh (resetting I/O to 00h every time it reaches FFh).
   Set WE to 1 and OE to 0. Set A to 000h and
increment by 1 until 7FFFh. Verify I/O at each memory location corresponds to the data stored in that location.

4. Set CE to 0. Set Write Enable (WE) to 0. Set I/O to FFh. Set A to 000h. Simultaneously increment A and Decrement I/O until A equals 7FFh and I/O equal 00h (resetting I/O to FFh every time it reaches 00h). Set WE to 1 and OE to 0. Set A to 000h and increment by 1 until 7FFh. Verify I/O at each memory location corresponds to the data stored in that location.

Erasable Programmable Read Only Memory (Intel, 27C256)

1. (Quantity: 1).

2. Read the consecutive memory locations of the EPROM and calculate a checksum. Verify this checksum is the same as the checksum programmed into the EPROM.

Electrically Erasable Programmable Read Only Memory (Intel, 2764-25D)

1. (Quantity: 1).

2. Read the consecutive memory locations of the EPROM and calculate a checksum. Verify this checksum is the same as the checksum programmed into the EPROM. The checksum for the EEPROM is only for the memory block in use at the time.
MicroController (Intel, 80C51)

1. (Quantity: 1).
2. Enable chip selftest.

**DISPLAY BOARD**

Following is a general description for the CCU Display Board BIT.

Dual 2-Line-to-4-Line Decoders/Demultiplexers (54LS155)

1. (Quantity: 1).
2. Set IS to low (0) and 2S to high (1). Set A to 00b and increment by 1 to 11b. Verify 1Y0 to 1Y3 are low respectively (outputs are high after inverters on output pins). Verify 2Y0 - 2Y3 are always high.
3. Set IS to high (1) and 2S to low (0). Set A to 00b and increment by 1 to 11b. Verify 2Y0 to 2Y3 are low respectively (outputs are high after inverters on output pins). Verify 1Y0 - 1Y3 are always high.

8-Line-to-3-Line Priority Encoders (74LS148)

1. (Quantity: 2).
2. Set El to low (0). Set D(0-7) to FFh. Verify Q is 000B. Set D to FEh the FDh, FBh, F7h, EFh, DFh, BFh, 7Fh and verify Q(20) is 000b to 111b correspondingly.

Buffer/Driver (74LS244)

1. (Quantity: 3).
2. Set D (input) to AAh. Verify Q (Output) is AAh.
3. Set D to 55h. Verify Q is 55h.

FIBER OPTIC BOARD
Following is a general description for the CCU Fiber Optic Decoding Board BIT.

Data Selectors/Multiplexers (74LS251)

1. (Quantity: 2).
2. Set E1 to low (0). Set Select Inputs (CBA) to 000b and increment by 1 to 111b. Verify Y is D0-D7 and W is D0 not - D7 not __ respectively. Set Enable to high (1). Verify high impedance on outputs.

8-bit Addressable Latches (74LS259)

1. (Quantity: 2).
2. Set Clear to low and G not to high. Set D to high. Set Select Inputs (CBA) to 000b and increment by 1 TO 111b. Verify all output Q is low.
3. Set Clear to low and G not to low. Set D to high. Set Select Inputs (CBA) to 000b and increment by 1 to 111b. Verify that the addressed output Q is high and all other output is low.
4. Set Clear to high and G not to low. Set D to high. Set Select Inputs (CBA) to 000b and increment by 1 to 111b. Verify that the addressed output Q is high
and all other output is at steady-state levels before input conditions were established.

Quadruple D-Type Flip-Flops (74LS175)

1. (Quantity: 4).

2. Set Clear to low (0). Verify Q is 0 and Q not 1.
   Set Clear to high (1). Set D to high. Send one pulse to the Clock and verify Q is high and Q not low. Set D to low. Send one pulse to the Clock and verify Q is low and Q not high. Set Clock to low. Verify Q is low and Q is not high.
CHAPTER 8

DRIVERS

The driver library concept was to offer an interface between application software and hardware. This allowed for the exchange of hardware if and when the hardware became unmaintainable, expanded, or enhanced.

The driver library was integrated at time of building the load modules (linking). Integration of the driver modules was chosen over threading for speed over memory space. Speed is the same reason Assembly was used as the development language.

All the drivers were tested using shells of an application around them. These shell covered drivers were also used in testing the hardware. Examples of the shell covered drivers can be found in the Appendix.

Use

These shelled driver routines were used to verify and validate the hardware functionality. They became the basis for the test routines. The driver library and the test routines were the first pieces of software to go under
configuration control. This was done because of the wide impact any change to a driver would have on the application and BIT software.
CHAPTER 9

APPLICATION SOFTWARE

The ALE-XX CCU interfaces with the pilot and ground crew through various modes and states. The hardware and software were designed for positive human interface and safety considerations. The ALE-XX CCU was designed in modules based on the interrupt structure of the hardware. The interrupts are chaff, flare, jettison and halt switches and the chaff and flare buttons.

Figure 19 shows the flowcharting standards used in describing the CCU software (Fig. 19).

**Top Level CCU Structure**

At power-on the chaff, flare, and/or jettison switch(s) is/are in the on position and the halt switch is in the off position. The system initializes, runs IBIT, and enters the control loop. The control loop is interrupt driven. Figure 20 illustrates the CCU structure (Fig. 20).

1. Timer interrupt is one way to activate CBIT.
2. Chaff and flare switches activate a menu selections.
3. Chaff or flare buttons, or jettison or halt switches
The techniques used to implement structured flow charting in this figure have been adapted from those developed, in part, by M. H Hamilton and S. Zeldin of the Charles Stark Draper Laboratories for use on the NASA Space Shuttle project. Proper use of the symbols listed below yields a structured software development process and end programs.

The basic unit of a structured flow chart is the SEQUENTIAL PROCESS which has a single entrance and a single exit.

The IF-THEN-ELSE structure provides for a choice between two alternatives. Program flow continues from the bottom in the same manner as in the SEQUENTIAL PROCESS block, after either alternative has been taken.

The CASE structure is a variation of the IF-THEN-ELSE structure. It is used when the selection of one of many alternatives is to be selected based on a conditional test.

Fig. 19 Flowcharting Standards
The FOR-WHILE structure is also based upon the IF-THEN-ELSE structure. Its use is based upon a conditional loop (FOR condition), plus an optional guard (WHILE-guard). FOR-condition, WHILE-guard, and FOR-condition-WHILE-guard are allowable variations of this structures.

The ENTRY block establishes the name of the program unit and its entry point.

The RETURN block is similar to the ENTRY block and serves to mark the exit from the program unit.

NEXT PAGE CONNECTORS are used to indicate program flow continuation across sequential pages.

Process performed in another program or subroutine is shown with the use of this box.

Process continuation is shown with the use of this box. The reference should show the follow-on figure or sheet number that the process is described on.

Fig. 19 Flowcharting Standards Continued
Fig. 20  CCU Structure Chart
activate/deactivate menu selected modes.

4. Any activity completion activates CBIT.

Debounce

A 500 millisecond software debounce was provided for the fire command signal or fire button. The interval is software controllable and can be reprogrammed to any desired interval.

CCU Applications Flowcharts

The flowcharts in figure 21 were generated using the flowcharting standards described in figure 19 and the top level CCU structure chart shown in figure 20 (Fig. 19, 20, and 21). These application flowcharts were used in conveying ideas to management, peer reviews, to show requirements were met, and in the development of testing software.
Flow 1

System Power On

Perform IBIT

Power on Indicator
Flow 2

Mode Processing
Flow 3

END

Display Messages

Power up test 'PWRTST'

Fig. 21 Application Flowcharts
FLOW 2

Display Messages

Fig. 21 Application Flowcharts Continued
Flow 3

Display Messages

Mode Processing

Hardware Interrupt

Programmer Interrupt

Flow 4

CBIT Timer Interrupt

Flow 5

Pollled Interrupt

Test Mode

Flow 6

Setup Mode

Flow 7

Man Single Mode

Flow 8

Return

Flow 3 Cont

Ready State

'### ###'

Fig. 21 Application Flowcharts Continued
Flow 3 Continued

Display Messages

Flow 3 Cont

Man Mult Mode
Flow 9

Prog Mode
Flow 10

Button Push Mode
Flow 11

Jettison Mode
Flow 12

Setup Mode
Flow 13

Halt Mode
Flow 14

Dimmer Mode
Flow 15

Fig. 21 Application Flowcharts Continued
Programmer interrupt will be activated by setting the chaff and/or flare switch to AUTO. This is a hard wired priority interrupt not now available.
At power up the system enters IBIT. A timer is set for 1 second. The timer actives CBIT. The 1 second delay allows the system be enter a quiescent state.
Display Messages

Flow 6

Test Mode

Load first Piece of Data

Flow 2

ENT button move to next date selection category

General Test Format

'MESSAGES ##'

Limited, Full, or No Oper

'FULL OPER'

Messages for TEST MODE convey information on limited, full, or no operation, LRU major errors, LRU top 4 errors on full system test, LRU identification and type of ordnance, hours of operation, and software version, revision Number (Tab. 14).

Fig. 21 Application Flowcharts Continued
Setup Mode displays information on chaff/flare single, double burst, salvo, count and interval (Tab. 14).
This mode sets ALE-XX in a position to dispenses a single or double ordnance in a single dispensing of chaff and/or flare.

Fig. 21 Application Flowcharts Continued
This mode sets ALE-XX in a position to dispenses a single or double ordnance in a single salvo/burst.

Fig. 21 Application Flowcharts Continued
This mode sets ALE-XX in a position to dispenses a single or double ordnance in a programmed number of salvo/burst releases of chaff.
Flow 11

Display Messages

Button Push Mode

Get Fire Info from RAM

Data Base Set up of Command

Trans/Receive Command

Flow 18/2

Update Data Base

Return

Flare/Chaff Firing

'###FLRCHF###'

flashing

The data base function keeps track of what fired where in case of miss fires and split ordinance dispensing among LRUs.

Note in the OFF Mode the Ram area is cleared and no firing can occur.

Fig. 21 Application Flowcharts Continued
The data base function keeps track of what fired where in case of miss fires and split ordinance dispensing among LRUs.

If Jettison is used to power up the CCU then the Jettison command is sent to all DAs with only those having jettisonable material dispensing ordinance with all DAs reporting back Status.

Fig. 21 Application Flowcharts Continued
The data base function is contains the information on what is being fired where. It also has the information for the display RAM on amounts and type of ordinance.
Flow 14

Display Messages

Dimmer Mode

Read A/D Dimmer info

Compare old and new A/D Dimmer info

- set 100% bit in word
- set 75% bit in word
- set 50% bit in word
- set 25% bit in word

Return

The dimmer knob in the cockpit is connected to an A/D converter. The A/D converter is polled. If the difference compares for a change, then the display word dimmer bits are changed.

Fig. 21 Application Flowcharts Continued
Driver sets the buffer flag full or empty (1 full/0 empty).

One word at a time is buffered out.
Flow 16

Display Messages

Fig. 21 Application Flowcharts Continued
The reason for a NACK at error detection is there is not ACK sent to the DA. This lets the Network module know to resend the command or declare the DA down.

Fig. 21 Application Flowcharts Continued
The pseudo code was used as the Program Design Language (PDL) to add to the understanding and fill in the gaps left by the flowcharts. Both the pseudo code and flowcharts were used in code development. Both were also used at peer reviews, to show requirements were met, and in the development of testing software.

**Processor Loop**

- **BITs**
  - **Switch Polling**
    -- service switch changes
    -- after firing command (long delays)
    --- Switch Polling

**Switch Polling**

- **command input**
  -- Chaff/Flare Button
  -- Jettison
  -- Halt
  -- Programmer
  - **switch setting changed**
    -- read EEPROM and update RAM
    -- write new pointer for RAM information
    --- if button pushed, new pointer
    -- display using format of Table 14

**Programmer Interrupt**

- **hardware interrupt**
  -- programmer, service first
  -- act as if chaff or flare button pushed

**Chaff/Flare Button**

- **read RAM into send buffer**
  -- set up message
  -- format as in Table 11
- if WOW is not on
  -- send message
  -- if WOW on
    --- display using Table 14, no firing
- display using Table 14
- Network

Jettison

- if RAM not show all status of DAs loads
  -- WOW off (off ground and power up by jettison)
  -- send jettison command to all
  -- update display by Table 14
  -- WOW on (on ground and power up by jettison)
    --- send flashing message to reset
    ---- message as in Table 11
    --- do not send jettison command
    --- jettison reset
    ---- WOW off
    ----- jettison
    ---- WOW on
    ------ same as above
- if RAM loaded
  -- WOW off
    --- jettison
  -- WOW on (on ground)
    --- send flashing message to reset
    ---- message as in Table 11
    --- do not send jettison command

Halt

- halt read
  -- send out halt command to DA in use
    ---- use format in Table 11
    ---- Network

Chaff Setup Mode

- read current data in RAM
- display pieces of data using format of Table 14
  -- read '^' or 'v' buttons
    --- forward or backward in current data entries
  -- 'ent' changes data options based on Table 10
  -- update RAM
- if data in RAM different then EEPROM
  -- update EEPROM
Manual Single

- read EEPROM and update RAM
  -- write new pointer for RAM information
    --- if button pushed, new pointer
  -- display using format of Table 14

Manual Multiple

- read EEPROM burst information and update RAM
  -- write new pointer for RAM information
    --- if button pushed, new pointer
  -- display using format of Table 14

Test

- CBIT
  -- display using format of Table 14
  - read EEPROM and report errors
    -- display using format of Table 14
  - 'ent' changes data options
    -- display using format of Table 14
    -- shows status and all errors
      --- read '^' or 'v' buttons
      --- forward or backward, each LRU largest error
    -- shows chaff/flare number on board, totals
      --- read '^' or 'v' buttons, chaff or flare
    -- perform system test
      --- read '^' or 'v' buttons
      --- forward or backward
        ---- complete test information for each LRU

CBIT

- perform IBIT
  - rotate to all LRUs
    -- Network
      -- send for status
        --- compare to older status
          ---- if different, check again
          ------ if different, update EEPROM
        --- no change
          ---- rotate
EEPROM Update

(EEPROM has 10,000 writes for each memory space)
- 160 blocks of 50 words
  -- forward only linklist
  --- word 1
  ----- 0 not in use
  ----- 1 current information
  --- words 2 to 8 mission data
  ----- based on Table 10
  --- words 10 to 18 spares
  --- words 19 to 50 error information
  ----- one entry for each LRU, 32 possible

Network

- Using format of Table 11
  -- send message out
  -- wait for ACK, time limit can cause NACK also
  --- NACK, retry
  ----- NACK again
  ----- declare LRU down
  ----- update EEPROM

Flowcharts, Pseudo Code, and Tables

The flowcharts, pseudo code, and tables were used as the basis during code development. If problems were found these foundation engineering documents were changed to reflect the solutions. All were also used at peer reviews, to show requirements were met, and in the development of testing software.
CHAPTER 8

CONCLUSIONS

Following are some of the ALE-XX system accomplishments and firsts for a modern countermeasures dispensing system.

1. All fiber optic communications.
2. Resistant to noise jamming.
3. Fault tolerant communication design.
4. Lowering of LRU count.
5. No inadvertent munitions releases.
6. Software configurable for updating operational capabilities.

Installation

Installation of the ALE-XX on the A-10 aircraft requires the following:

1. Removal of all eight sequencers.
2. Removal of the EMI filters.
3. Removal of the Programmer LRU.
4. Removal of most of the copper wiring related to the ALE-40 CMDs.

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5. Remove and replace the CCU LRU.

6. Remove and replace the DA LRU’s.

7. Run sixteen fiber optics cables from the CCU LRU to each of the DA LRU’s. The fiber optics cables would use the open connections at the bulk head connections made available from the removal to the copper wiring.

Each of the DA LRUs require only 4 connections, the 28 VDC LRU electronics power, the 28 VDC Squib power, the fiber optics cable and a ground connection.

The only major wiring modification is the fiber optics cables from the CCU LRU to the DA LRUs. There is a form, fit connector pin available for the fiber optics cable that fits into the standard MIL-STD-38909 connector.

Another wiring modification would be for the Weight-On-Wheels (WOW) safety switch. The WOW switch would be required by the Master On Switch incorporated on the CCU LRU. Having the LRU power available on the flight line allows for system verification of operation, mission data entry or review, inventory of ordinance, and for organizational level check-out. The current system has in flight line power. This has caused inadvertent dispensing of ordinance just after flight take-off as the system is charged and power surges pulse the units or the system is brought up in a firing mode.

The ALE-XX system was bench tested extensively.
Problems

Fiber Optics

Fiber optic components designed for airborne application and military qualified were not available during the conceptual and prototype phases of this project. There were no procedures available, at this time, for aircraft installation and repair of optical fiber cables. All of the components available were designed for commercial ground telecommunication applications.

Militarized fiber components, cables and connectors are becoming available commercially as standard production products. The Harsier AV-8 aircraft has been flying standard production fiber optic link. There has been only one broken fiber optic cable reported to date. The British are flight testing some fiber optic projects on helicopters at this time using standard commercially supplied militarized fiber optic components.

Transceivers

The attempt to insert 16 fiber optic channels to the CCU met resistance. The fiber optic communication device on the market are predominately separate receiver and transmitter variety. There simply was not enough room to fit 16 Receivers and 16 transmitters in the enclosure. The solutions available were to either find a transmitter/receiver (transceiver) encased in a very small
volume or to design a discrete fiber optic circuit board using very small fiber optic LEDs for transmitting and PIN diode for receiving. The discrete design would also need additional components to operate the discrete fiber optic devices. A practical fiber optic transceiver was made available by AT&T supplied test data for the device showing that it was designed to military qualified temperatures and vibration conditions. The results of our own environmental tests proved that the device could withstand military temperatures and vibrations. The environmental tests surfaced problem areas in the AT&T fiber optic ST connector. Under vibration tests, the glass face to the ST connector vibrated against part of the AT&T 02X housing causing debris to accumulate on the fiber optic lens. AT&T is currently working on a military version to the same device to handle a greater degree of environmental conditions. It will also feature a different connector (pigtail) to alleviate the ST connector problem.

There was a problem with getting the fiber optic cables off the fiber optic boards to the LRU connector. Following are some of the options to solve the problem.

1. Insert the fiber optic cable from the fiber optic board to a MIL-38999 connector. The problem here is that the fiber optic board cannot be removed from the LRU without disconnecting the fiber optic
cables from the MIL-38999 connector.

2. Use a board mountable fiber optic connector that will feed through the back of the LRU and will double as a fiber optic LRU connector. Raychem has a connector that looked promising. It was standard 16 gauge wire connector that used a different insert to make it fiber optic compatible. This approach appeared very good except that the connector was quite large. If this approach is taken, circuit board area must be evaluated to see if there is enough room to fit the electronics. A smaller connector may be available in the future.

Preparation

Fiber optic cable used for the project did have special preparation requirements. The particular Raychem cable has a special silicon coating over the optical fiber which requires a special oven to bake off the coating before connectorization. If the coating was not totally removed, the epoxy used to glue the optical fiber into the optical contact would not adhere properly. This would result in an optical contact passing all quality and optical checks and then fail after installation at some undetermined time in the future. The failure mechanism is called pistoning. Pistoning occurs when the epoxy bond breaks free of the fiber due to the this silicon coating that remains on the
fiber and pulls back into the optical contract. Once the piston gap is large enough, tens of micrometers, optical signal transmission ceases. Pistoning was a problem until vaporization of the residual silicon coating by the fiber oven was done.

A fiber optic cable has a maximum bend radius of 1 inch. This caused a failure.

Serminixed Dot Matrix

A problem surfaced with the selected Sermonized Dot Matrix displays. The displays were slightly larger and did not fit in the desired display panel dimensions. The Siemens display was chosen for it’s MIL-Qualification. HP makes a similar display but it is only commercially rated. The display may have to be limited to 12 characters unless a smaller MIL-Qualified part is produced.

Power

The A-10 aircraft 28VDC power bus was noisier than expected. The aircraft power bus was instrumented to look for transient noise spikes, and the power input lines into the ALE-XX LRUs are filtered. The 3 element filter consisted of 1 amp capacitors, a 500uF electrolytic and a 0.01 uf ceramic. All systems were protected by circuit breakers, which are located in the circuit breaker panel access.
Parts

Procurement of parts was one of the most challenging task of the project due to the long lead times for some items and a need for an expedient means for lead times for some items and a need for an expedient means for meeting the scheduled completion dates. Therefore, many of the components used were not the most appropriate but the most available. This may be a source of some potential reliability problems.

In the CPU board there were reliability problems due to the electronic components chosen. Packaging density problems need to be eased to stop congestion and to aid in cooling.

The 87C51 microprocessor used malfunctioned regularly. The problem was due to the repeated number of erasing, reprogramming, and insertion or the microprocessor during hardware software integration and debugging of the ALE-XX system.

Maintenance

There are some issues concerning the maintainability of fiber optics components which must be resolved. One area unresolved is the diagnostics and repair of a broken fiber optic airborne system. Currently, the only repair is replacement.
Software

The programming was done in Intel Assembler.

Software and hardware needs to be integrated earlier in the design phase for compatibility and fault isolation during the system integration phase.

Lessons Learned

The project ended at prototyping. It was unfunded in the new fiscal year for full scale development.

The project was a team effort. My responsibility and contribution was on the CCU. My motivation for the project was to explore concepts foreign to me along with being part of the team to introduce fly-by-light replacing fly-by-wire in fighter aircraft. I was software lead, coordinating the overall software design and developing the CCU software. My work involved the integration of hardware, working on the hardware team for total system design and board level design on the CCU hardware.

There are trade-offs made between the laboratory environment and the hostile environment of a fighter aircraft in the areas of power, vibration, atmospheric tolerances, and communications. Filtering needs are much greater as fighter aircraft power is extremely dirty to the point where constant charge batteries were considered. Vibrations have broken loose fiber optic connections and board electrical connections. Temperature and humidity
fluctuations cause a slowing of the computing speeds and board life. An effective communication system with no EMI filtering could be possible using a fiber optic star network.

The benefit of this thesis project was to present the ALE-XX CCU CMDSNC design as part of the total ALE-XX system as a replacement for the problematic ALE-40.

The ALE-XX CMDS has solved the ALE-40 CMDS demonstrated problems by a system design with increased reliability and maintainability utilizing fiber optic technology, digital electronics, star topology, and a comprehensive BIT.

The ALE-XX CMDS incorporates fiber optic technology thus eliminating EMI problems since the fiber optic cables are not being susceptible to electronic pulse/burst. LRU count is reduced by the elimination of communication EMI filters.

The ALE-XX CMDS incorporates digital electronics replacing the electro-mechanical devices currently used. This remedies the corrosion problems occurring in the LRUs. This also reduces the number of LRUs by combining LRU.

The ALE-XX CMDS incorporates a star topology network to replace the currently used daisy-chain topology network. Star topology solves system operation failure from daisy-chain topology by allowing system operation despite single link or LRU failure.
The ALE-XX CMDS incorporates a comprehensive BIT. BIT allows ground crews to identify faulty wiring harnesses and isolate system faults to a single LRU board. BIT also allows for system status updating for faster more reliable response during operation by updating system status arrays.

There are other benefits as direct side effects to the ALE-XX CMDS development. One enhancement was the redesigning of the dispenser assembly retainer plate to sense payload type. In the past ground crews inputted the chaff/flare information via the now eliminated chaff/flare selector switches. The elimination of the switches stops possible ground crew errors. The functions of the chaff/flare switches on the ALE-40 programmer are incorporated in the ALE-XX Cockpit Control Unit (CCU) LRU. Another enhancement is caused by the high speed electronics used, allowing the jettison of flares to be limited only by power bus and aircraft structural constraints. As a direct consequence to ALE-XX is a weight reduction of 27 pounds, a size savings of 345.6 cu. in., a reliability increase from approximately 250 hours to 5000 hours, and a LRU count reduction from 37 to 18.

Fiber optics and star networks are and will continue to be a viable alternative in aircraft usage. The information contained herein could be used as a design aid for future Countermeasure Dispenser System Network Controllers (CMDSNC) or other related instrumentation.
REFERENCES


APPENDIX

TEST DRIVERS

All the drivers were tested using shells of an application around them. These shell covered drivers were also used in testing the hardware. Following are some examples of the shell covered drivers.

**Character Set**

;This program contains the character set to display

```
ORG 00H
LJMP START
ORG 100H
START
MOV DPTR, #40F0H
MOV A,#80H
MOVX @DPTR,A
MOV A,#03H
MOVX @DPTR,A

;ATTRIB FOR ALL DISPLAYS
;CLEAR DATA DN TURN 100% ON

MOV DPTR,#MESS1
LCALL DISP
LCALL DELAY
MOV DPTR,#MESS2
LCALL DISP
LCALL DELAY
MOV DPTR,#MESS3
LCALL DISP
LCALL DELAY
LJMP START

;PROGRAM TO DISPLAY 3 MESSAGES
;FIRST MESSAGE

MOV R2,#80H
MOV P2,#40H
MOV B,#02H
MOV R4,#03H
```

;INITIALIZE FOR DISPLAY CHARACT
;R2 = BASE ADDRESS FOR DISPLAY
;SETS UP P2 AS PAGE SETTING
;B = DIVISOR
;R4 = # OF DISPLAY PAKS
NEXTPAK MOV A,R2
ADD A,#07H  ;ADD BEGINNING OF PAK OFFSET
MOV R0,A  ;R0 = CURRENT DISPLAY
MOV R3,#03H  ;R3 = # OF DISPLAY POSITION

NEXTCHR CHR A
MOVC A,@A+DPTR  ;GET CHAR
MOVX @RO,A  ;WRITE TO DISPLAY POSITION
INC DPTR  ;POINT TO NEXT CHARACTER
DEC R0  ;POINT TO NEXT DISPLAY POSITION
DJNX R3,NEXTCHR  ;GO TO NEXT CHARACTER IN MESSAGE
MOV A,R2  ;A = CURRENT BASE ADDRESS
DIV AB  ;GET NEXT BASE ADDRESS
MOV R2,A  ;SAVE IT BACK IN R2
DJNZ R4,NEXTPAK  ;DO NEXT PAK UNTIL DONE
RET

;DELAY  MOV R5,#016H
LOOP  MOV R6,#0FFH
LOOP1  MOV R7,#0FFH
LOOP2  NOP
DJNZ R7,LOOP2
DJNZ R6,LOOP1
DJNZ R5,LOOP
RET

; ORG 500H
MESS1  DB 'STAR DATE 2837.6'
MES2  DB 'DEFL FULL INTENS'
MESS3  DB 'PHASORS ON STUN'

END

Display Attributes

;This program tests all the attributes of the display
;
DISAT EQU 40F0H  ;DISPLAY ATTRIBUTES
;
LETA EQU 41H  ;STANDARD LETTERS
;
LETAB EQU 0C1H  ;BLINKING LETTERS
;
ORG 00H
LJMP START  ;JUMP TO START
;
ORG 100H
START  MOV DPTR,#4010H  ;LOAD DP WITH LOCATION
MOV A,#1DH  ;25% ALT WITH CLR
MOVX @DPTR,A
MOV DPTR,#4014H  ;CHAR 0 DISPLAY
MOV A,#LETAB    ;25% ALT W/CLR
MOVX @DPTR,A
LCALL DELAY
MOV DPTR,#4015H  ;CHAR 1 DISPLAY
MOV A,#LETAB    ;25% ALT W/CLR
MOVX @DPTR,A
LCALL DELAY
MOV DPTR,#4016H  ;CHAR 2 DISPLAY
MOV A,#LETA     ;25%
MOVX @DPTR,A
LCALL DELAY
MOV DPTR,#4017H  ;CHAR 3 DISPLAY
MOV A,#LETA     ;25%
MOVX @DPTR,A
LCALL DELAY
MOV DPTR,#4020H  ;LOAD DP WITH LOCATION
MOV A,#16H      ;50% BLINK
MOVX @DPTR,A
MOV DPTR,#4024H  ;CHAR 0 DISPLAY
MOV A,#LETAB    ;50% BLINK
MOVX @DPTR,A
LCALL DELAY
MOV DPTR,#4025H  ;CHAR 1 DISPLAY
MOV A,#LETA     ;50%
MOVX @DPTR,A
LCALL DELAY
MOV DPTR,#4026H  ;CHAR 2 DISPLAY
MOV A,#LETAB    ;50% BLINK
LCALL DELAY
MOV DPTR,#4027H  ;CHAR 3 DISPLAY
MOV A,#LETA     ;50%
MOVX @DPTR,A
LCALL DELAY
MOV DPTR,#4080H  ;CHAR DP WITH LOCATION
MOV A,#23H      ;100% BLINK
MOVX @DPTR,A
LCALL DELAY
MOV DPTR,#4084H  ;CHAR 0 DISPLAY
MOV A,#LETA     ;100% BLINK
MOVX @DPTR,A
LCALL DELAY
MOV DPTR,#4085H  ;CHAR 1 DISPLAY
MOV A,#LETA     ;100% BLINK
MOVX @DPTR,A
LCALL DELAY
MOV DPTR,#4086H  ;CHAR 2 DISPLAY
MOV A,#LETA     ;100% BLINK
MOVX @DPTR,A
LCALL DELAY
MOV DPTR,#4087H  ;CHAR 3 DISPLAY
MOV A,#0E0 ;100% BLINK
MOVX @DPTR,A
LCALL DELAY
MOV DPTR,#4010H ;CHAR 1 DISPLAY
MOV A,#40H ;LAMP TEST
MOVX @DPTR,A
MOV DPTR,#4020H ;CHAR 2 DISPLAY
MOV A,#40H ;LAMP TEST
MOVX @DPTR,A
MOV DPTR,#4040H ;CHAR 3 DISPLAY
MOV A,#40H ;LAMP TEST
MOVX @DPTR,A
MOV DPTR,#4080H ;CHAR 4 DISPLAY
MOV A,#40H ;LAMP TEST
MOVX @DPTR,A
LCALL DELAY
MOV DPTR,#4010H ;CHAR 1 DISPLAY
MOV A,#80H ;CLEAR DATA
MOVX @DPTR,A
MOV DPTR,#4020H ;CHAR 2 DISPLAY
MOV A,#80H ;CLEAR DATA
MOVX @DPTR,A
MOV DPTR,#4030H ;CHAR 3 DISPLAY
MOV A,#80H ;CLEAR DATA
MOVX @DPTR,A
MOV DPTR,#4040H ;CHAR 4 DISPLAY
MOV A,#80H ;LAMP TEST
MOVX @DPTR,A
LJMP START

;Delay
MOV R0,#016H
LOOP MOV R1,#0FFH
LOOP1 MOV R2,#0FFH
LOOP2 NOP
DJNZ R2,LOOP2
DJNZ R1,LOOP1
DJNZ R0,LOOP
RET
END

Mode Switch Sensing

;This program contains 10 different programs to be addressed
;the mode switch upon power up. Following is what the
;programs do.
;
;1. Write to the display RAM in a loop.
;2. Read from the display RAM in a loop.
;3. Write to the External RAM in a loop.
;4. Read from the External RAM in a loop.
;5. Read from Mode Switch in loop.
6. Read from External Switch in a loop.
7. Write to EEPROM 1 time.
8. Read from EEPROM in a loop.
9. Read form FOSTRATEN\ in a loop.
10. Write to SERSELWR\ in a loop.
11. Write to INT USART in a loop waiting for interrupt.
12. Read from INT USART in a loop.
13. Read from EXT ROM in a loop.

The CCU interface to the 82C52 USART AT A000H – A003H.

Initial equates to define system configuration

; usart definition

UART: EQU 0A000H ;UART BASE ADDRESS
TBR: EQU UART ;TRANSMIT BUFFER REGISTE (WRITE)
RBR: EQU UART ;RECEIVER BUFFER REGISTER (READ)
UCR: EQU UART+1 ;UART CONTROL REGISTER (WRITE)
USR: EQU UART+1 ;UART STATUS REGISTER (READ)
MCRWT: EQU UART+2 ;MODEM CONTROL REGISTER (WRITE)
MCRRD: EQU UART+2 ;MODEM CONTROL READ ADDR (READ)
BRSR: EQU UART+3 ;BIT RATE SELECT REGISTE (WRITE)
MSR: EQU UART+3 ;MODEM STATUS REGISTER (READ)

; UART CONTROL REGISTER

BIT 0

STOPB1: EQU 00H ;1 STOP BIT
STOPB2: EQU 01H ;1.5 OR 2 STOP BITS

BITS 1,2,3

PAREVN: EQU 00H ;TX AND RX EVEN
PARODD: EQU 02H ;TX AND RX ODD
PAREO: EQU 04H ;TX EVEN, RX ODD
PAROE: EQU 05H ;TX ODD, RX EVEN
PARTE: EQU 08H ;TX EVEN, TX DISABLED
PARTO: EQU 0AH ;TX ODD, TX DISABLED
PARDIS: EQU 0FH ;GENERATE AND CHECK DISAITS 4,5

WORDL5: EQU 00H ;5 BIT WORD LENGTH
WORDL6: EQU 010H ;6 BIT WORD LENGTH
WORDL7: EQU 020H ;7 BIT WORD LENGTH
WORDL8: EQU 030H ;8 BIT WORD LENGTH

; CCU SYSTEM EQUATES

; DISPLAYS

LEDADR: EQU 4000H ;BASE DISPLAY ADDRESS
LEDAT0: EQU LEDADR+010H ;ATTRIBUTE REG FOR DISPLAYS 0-3
LEDAT4: EQU LEDADR+020H ;ATTRIBUTE REG FOR DISPLAYS 4-7
LEDAT8: EQU LEDADR+040H ;ATTRIBUTE REG FOR DISPLAYS 8-11
LEDAT12: EQU LEDADR+080H ;ATTRIBUTE REG FOR DISPLAY 12-15
LEDATF: EQU LEDADR+OF0H ;ALL LED ATTRIBUTE REG
LEDKSB: EQU LEDADR+014H ;LSB DISPLAY
LEDBRT: EQU 003H ;100% BRIGHTNESS
LEDCLR: EQU 080H ;CLEAR ALL DISPLAYS
LEDINT: EQU 083H ;INITIAL VALUE
;
; GENERAL EQUATES
;
MINUS1: EQU OFFH ;MINUS 1 VALUE
COUNT3: EQU R3 ;GENERAL PURPOSE COUNTER REG
LEDMAX: EQU 004H ;16 DISPLAY
;
; BEGINNING OF PROGRAM
;
ORG 000H ;RESET DEFAULT LOCATION
LJMP START ;BEGIN OUT OF INTERRUPT AREA
ORG 100H ;START ADDRESS
START MOV DPTR,#40F0H ;ALL DISPLAY ATTRIBUTE
MOV A,#80H ;RESET DISPLAY RAM
MOVX @DPTR,A ;BLANK DISPLAY
MOV A,#03H ;FULL DISPLAY BRIGHTNESS
MOVX @DPTR,A
MOV R2,#0H ;SET MODE R2 TO CHECK #
MOV DPTR,#8000H ;GET MODE SWITCH ADDRESS
MOVX A,@DPTR ;READ MODE SWITCH INTO A
CJNE A,#0H,CK1 ;IF NOT ZERO GO TO CHECK 1
LJMP NOSEL ;IF '0' GO TO NONE SELECTED

; CHECK FOR 1 ON MODE SWITCHES
;
CK1 CJNE A,#01H,CK2 ;IF NOT '1' GO TO CHECK 2
MOV DPTR,#MESS1 ;LOAD DPTR WITH MESS1 ADDRESS
LCALL DISP ;GET MESSAGE 1
MOV DPTR,#4087H ;DPTR = FIRST CHARACTER
MOV A,#21H ;LOAD IN A '!' 
DRW MOVX @DPTR,A ;LOOP ON DISPLAY RAM WRITE
AJMP DRW ;DISPLAY RAM READ LOOP

; CHECK FOR 2 ON MODE SWITCHES
;
CK2 CJNE A,#02H,CK3 ;IF NOT '2' GO TO CHECK 3
MOV DPTR,#MESS2
LCALL DISP
MOV DPTR,#4087H ;READ 1ST CHARACTER (ASCII 32H)
DRR MOVX A,@DPTR
AJMP DRR ;DISPLAY RAM READ LOOP
;
; CHECK FOR 3 ON MODE SWITCHES
; CK3  CJNE A,#03H,CK4
    MOV DPTR,#MESS3
    LCALL DISP
    MOV DPTR,#0C000H ;WRITE 'AAH' TO 1ST LOCAT IN RAM
    MOV A,#0AAH
    EXRAMWR MOVX @DPTR,A
    AJMP EXRAMWR ;WRITE DISPLAY LOOP
;
; CHECK FOR 4 ON MODE SWITCHES
; CK4  CJNE A,#04H,CK5
    MOV DPTR,#MESS4
    LCALL DISP
    MOV DPTR,#0C000H
    MOV A,#55H
    EXRAMRD MOVX A,@DPTR
    AJMP EXRAMRD ;READ DISPLAY LOOP
;
; CHECK FOR 5 ON MODE SWITCHES
; CK5  CJNE A,#05H,CK6
    MOV DPTR,#MESS5
    LCALL DISP
    MOV DPTR,#8000H ;READ MODE SWITCHES LOOP
    RDM SW MOVX A,@DPTR
    AJMP RDM SW
;
; CHECK FOR 6 ON MODE SWITCHES
; CK6  CJNE A,#06H,CK7
    MOV DPTR,#MESS6
    LCALL DISP
    MOV DPTR,#8001H
    RDEXSW MOVX A,@DPTR
    AJMP RDEXSW
;
; CHECK FOR 7 ON MODE SWITCHES
; CK7  CJNE A,#07H,CK8
    MOV DPTR,#MESS7
    LCALL DISP
    MOV DPTR,#0H
    WREE MOVX @DPTR,A
    AJMP WREE
;
; CHECK FOR 8 ON MODE SWITCHES
; CK8  CJNE A,#08H,CK9
    MOV DPTR,#MESS8
LCALL DISP
MOV DPTR,#0H
RDEE
MOVX A,@DPTR
AJMP RDEE
;
; CHECK FOR 9 ON MODE SWITCHES
;
CK9
CJNE A,#09H,CK10
MOV DPTR,#MESS9
LCALL DISP
MOV DPTR,#6000H
RDFOST
MOVX A,@DPTR
AJMP RDFOST
;
; CHECK FOR 10 ON MODE SWITCHES
;
CK10
CJNE A,#0AH,CK11
MOV DPTR,#MESS10
LCALL DISP
MOV DPTR,#6000H
MOV A,#56H
SERSELW
MOVX @DPTR,A
AJMP SERSELW
;
; CHECK FOR 11 ON MODE SWITCHES
;
CK11
CJNE A,#0BH,CK12 ;WRITE TO USART
MOV DPTR,#MESS11
LCALL DISP
MOV DPTR,#0A000H
MOV A,#77H
UARTWR
MOVX @DPTR,A
AJMP UARTWR
;
; CHECK FOR 12 ON MODE SWITCHES
;
CK12
CJNE A,#0CH,CK13
MOV DPTR,#MESS12
LCALL DISP
MOV DPTR,#0A000H
UARTRD
MOVX A,@DPTR
AJMP UARTRD
;
; CHECK FOR 13 ON MODE SWITCHES
;
CK13
CJNE A,#0DH,CK14
MOV DPTR,#MESS13
LCALL DISP
MOV DPTR,#ROMCHK
ROMLP
CLR A
MOVC A,@A+DPTR
AJMP ROMLP

; CHECK FOR 14 ON MODE SWITCHES
;
CK14 CJNE A,#0EH,NOMODSW
MOV DPTR,#MESS14
LCALL DISP
MOV DPTR,#8001H
MOVX A,@DPTR ;VALUE TO SEND ON SERIAL PORT
LCALL SERIAL

; LONG JUMP NEEDED
;
NOMODSW LJMP NOSEL
;
SERIAL MOV TMOD,#20H
MOV 87H,#80H
MOV TH1,#0FDH
MOV TL1,#0FDH
MOV SCON,#40H
MOV IE,#90H
SETB TR1
MOV R6,A
MOV SBUF,A
WAIT AJMP WAIT
;
ORG 23H
AJMP SERLOOP
;
ORG 500H
SERLOOP MOV A,SCON
ANL A,#20H
JZ ERROR
MOV SCON,#40H
MOV SBUF,R6
RETI

ERROR AJMP ERROR
;
DISP PUSH 00H
PUSH 02H
PUSH 03H
PUSH 04H
PUSH P2
PUSH 0E0H
PUSH B
PUSH DPH
PUSH DPL
MOV R2,#80H
MOV P2,#30H
MOV R4,#04H
NEXTPAK
MOV A,R2
ADD A,#07H
MOV R0,A
MOV R3,#04H

NEXTCHR
CLR A
MOVC A,@A+DPTR
MOVC @R0,A
INC DPTR
DEC R0
DJNZ R3,NEXTCHR
MOV A,R2
MOV B,#02H
DIV AB
MOV R2,A
DJNZ R4,NEXTPAK
POP DPL
POP DPH
POP B
POP 0E0H
POP P2
POP 04H
POP 03H
POP 02H
POP 00H
RET

MESS1 DB '1) DISP WR TEST'
MESS2 DB '2) DISP RD TEST'
MESS3 DB '3) EX RAM WR TEST'
MESS4 DB '4) EX RAM RD TEST'
MESS5 DB '5) MODE SW RD TST'
MESS6 DB '6) EXT SW RD TEST'
MESS7 DB '7) EE 1 TIME WR T'
MESS8 DB '8) EE RD TEST LP'
MESS9 DB '9) POSTATEN RD TS'
MESS10 DB '10) SERSE;WR\ TST'
MESS11 DB '11) EX UART WR TS'
MESS12 DB '12) UART RD TEST'
MESS13 DB '13) EXT ROM RD TS'
; MESS14 DB '14)SERIAL LP TST'
;
ROMCHK DB 5AH
END