RADOME
POSITIONER FOR THE RFSS

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DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.
This report describes the design of a versatile gimbal structure for use in the West Aperture Room of the Army's Radio Frequency Simulation System for performing RF evaluation measurements of missile radomes and RF seekers. This gimbal is capable of rotating radomes of up to 18 inches in diameter and weighing as much as 50 lbs about fixed RF seeker antennas. The radome motion limit is \( \pm 40^\circ \) about boresight in both azimuth and elevation.
A second element used is a sturdy hinged seeker antenna mount that will permit accurate positioning of the seeker antenna when the radome is mounted or removed from the gimbal. The third element used is a movable cart that can lift the entire assembly off the door frame and carry it out of the way. A fourth element used is a specially designed cart to remove the aperture door and store it while the radome positioner is being used.

The radome positioner is controlled by a microcomputer that permits manual operation and the selection of one of several raster scan patterns to ease data taking. Precision speed and position controlling is accomplished by a closed-loop servo approach where the loop is closed via the computer.

The positioner provides additional capability to perform antenna pattern measurements using the RFSS array and anechoic chamber and may possibly function as a general purpose gimbal permitting closed-loop tracking of the array by experimental RF seekers.
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Pages 120 and 121 do not contain proprietary information.
Per Mr. Kevin Jackson, Army Missile Comd,
Systems Simulation Dir.
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1.0 INTRODUCTION

As originally designed, the Radio Frequency Simulation System (RFSS) provides a unique capability for closed-loop testing of RF guidance systems. The elements of the RFSS, notably the multi-element target array and the large anechoic chamber, can service three test point locations - the main central flight table and two off-axis aperture rooms. The two-axis gimbal described in this report is intended to be a portable structure that can be installed when needed in the West Aperture Room* providing the RFSS with an expanded capability for radome and RF seeker testing and for other uses such as microwave antenna testing and RF seeker evaluations.

The new radome positioner shown in Figure 1 utilizes a heavy duty structure capable of handling missile radomes from a variety of Army missiles from the large Pershing to the smaller Patriot and Hawk radomes. Other radomes from a variety of systems can also be handled. The positioner operation is controlled by a microcomputer providing two-axis closed-loop control via a simple keyboard and digital display. These elements are shown in Figure 2. The operator proceeds through a few simple steps to bring the unit to operational readiness and then selects one of several preprogrammed raster scan patterns, or complete manual positioning is possible.

The positioner then moves the radome while the RF seeker antenna remains stationary. This approach is based on the fundamental concept that if only the radome is moving, only the radome is contributing to the indicated bore-sight error. As a result, even small radome errors can be conveniently and accurately ascertained.

The following sections describe in detail background information associated with the positioner and the mechanical, electrical and software portions of the radome positioner.

*Only minor modifications would be required to install the radome positioner in the East Aperture Room.
Figure 2. Microcomputer Rack and Control Console for the RFSS Radome Positioner
2.0 BACKGROUND

In the past few years, closed-loop tests of RF seekers in the RFSS with and without radomes have suggested the need for a separate portion of the facility be made available for convenient radome and seeker evaluations that do not tie up the main flight table. The term convenience as used here has several meanings:

1. It is certainly desirable to make things easier for the designer and evaluator to install the bulky and typically awkward missile radome with ease and, above all, accurately and repeatably. This factor improves operator morale and the quality of test data.

2. It is desirable to have a unit that is capable of automatic operation since a large amount of angle space must be sampled to fully characterize the nature of the radome under evaluation and manual operations are not geared to taking a lot of data.

3. A versatile implementation is needed to permit the operator to examine in minute detail peculiarities that might be uncovered in an initial screening of a production or unusual radome specimen.

4. It is desirable for a government agency to have a facility capable of independent evaluation of radomes and RF sensors in a complementary manner to their existing facilities and with known radome test procedures as are used by radome manufacturers.

Thus, the current design described in this report was conceived and developed to meet the needs. Further, the unit as implemented is fully compatible with other Army RFSS computers and offers additional flexibility for testing in the RFSS itself, perhaps allowing improved facility utilization in the future.
3.0 MECHANICAL DESCRIPTION

The radome positioner consists of a large two-axis gimbal assembly designed to fit into the current opening in the west aperture room upon removal of the shielded door. Figures 3 and 4 show the final unit prior to installation. The mechanical design philosophy used to meet the positioner requirements listed in Table 1 was to use large standard size ball and thrust bearings, steel pins compatible with the bearings, aluminum alloys, and standard structural members. Previous experience has shown these methods improve operational reliability and are cost effective.

The inner gimbal is a ring 18 inches inside diameter with a 3-inch square tubular cross-section. This inner gimbal is supported by the outer gimbal through two 0.984 inch diameter steel pins and four single row, deep groove ball bearings. The outer gimbal is a rectangular structure 26 inches by 38.5 inches inside dimensions with a 3-inch square tubular cross-section. It is supported in the azimuth axis with two 0.984 inch diameter steel pins and four single row, deep groove ball bearings. There is also a thrust ball bearing mounted below the outer gimbal to carry the vertical loads of the entire gimbal system. The entire elevation and azimuth gimbal system is mounted to an external frame. This external frame is aluminum angle 4 inches by 3 inches by 0.250 inch thick and is mounted into the opening of the West Aperture Room of the RFSS. The entire gimbal and outer frame assembly is clamped to the internal edge of the aperture opening with eight special design C-clamps (Figure 5). The C-clamps have a large clamping surface to spread the clamping pressure over a broad area, thereby preventing local distortion to the contact finger brass extrusion mounted on the inner edge of the aperture opening.
Figure 3. Radome and Gimbals and Seeker Mount Rear View.
Figure 4. Radome and Gimbals Front View.
### TABLE 1

**RFSS RADOME POSITIONER REQUIREMENTS**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radome Diameter</td>
<td>18 inches, maximum</td>
</tr>
<tr>
<td>Radome Weight</td>
<td>50 pounds, maximum</td>
</tr>
<tr>
<td>Seeker Antenna Weight</td>
<td>20 pounds, maximum</td>
</tr>
<tr>
<td>Readout Accuracy</td>
<td>± 0.1 degrees</td>
</tr>
<tr>
<td>Scan Angle Elevation</td>
<td>± 40 degrees</td>
</tr>
<tr>
<td>Scan Angle Azimuth</td>
<td>± 40 degrees</td>
</tr>
<tr>
<td>Scan Rate (AZ or EL)</td>
<td>2 degrees/sec, nominal</td>
</tr>
<tr>
<td>Repositioning Accuracy</td>
<td>± 0.1 degrees</td>
</tr>
<tr>
<td>Seeker Repositioning after Boresighting</td>
<td>± 0.005 inches</td>
</tr>
</tbody>
</table>

**Sign of Angle**

(When Looking Toward the RFSS Array)

- Up and to the Right (1st Quadrant)  
  +AZ, +EL
- Up and to the Left (2nd Quadrant)   
  -AZ, +EL
- Down to the Left (3rd Quadrant)    
  -AZ, -EL
- Down to the Right (4th Quadrant)   
  +AZ, -EL

10
The seeker antenna mount and boresight adjustment mechanism is mounted directly to the external frame independent of the radome gimbal system mounting. The seeker antenna is located at the intersection of the gimbal's azimuth and elevation axis. It is mounted on a cantilevered 2-inch diameter aluminum tube supported at the rear-end by a plate which is attached to the boresight adjustment mechanism. This mechanism is an integral part of a stiff tubular structure that is attached to the external frame. Attachment to the external frame is accomplished through two large hand-operated screw locks. There are also four precision steel guide pins with stops located near the screw locks to act as precision references for the repositioning of the seeker antenna and its supporting structure after the test radome is installed. A hinge mechanism is used to swing the seeker antenna and its supporting structure out of the way while the test radome is being installed. This technique allows the seeker antenna to be installed or removed from the inside of the radome.

Associated with the positioner is a separate cart shown in Figure 6 used only for installation, removal and storage of the entire gimbal system. The cart is a modified commercial unit having a hydraulic lift and is mounted on wheels for ease of movement.

3.1 Design Approach

Three basic methods were used to design a gimbal assembly capable of meeting the requirements: 1 structural analysis was performed to select materials and geometries capable of meeting the desired very low deflections that occur as seeker and radome are mounted and moved, 2 basic drive train components were selected to have sufficient inherent accuracy needed to position the gimbal axes
Figure 6. Cart Used to Install, Remove and Store the RFSS Radome Positioner
accurately, and 3 critical components were accurately machined and when
precise alignment was needed stainless steel was used for improved
ruggedness.

**Structural Analysis**

During the design study phase preceding the hardware fabrication a
structural analysis of this approach was completed. This analysis indicates
the following:

a) The maximum possible rotation of the outer gimbal frame
at the location of the optical encoder is less than 0.00367
degrees. This is based on a maximum external moment of
525 pounds/inch caused by a 50 pound radome with a lever arm of
10.5 inches. This is not a system error, because it
can be calibrated out at assembly and periodically there-
after.

b) The maximum possible vertical deflection of the outer
gimbal frame with reference to the thrust bearing is
less than 8x10^-4 inches. This deflection is based on
the addition of a 50 pound radome.

c) The vibration frequency of the positioner structure is
calculated to be a minimum of 170 Hz.

**Readout Accuracy**

Readout accuracy is a summation of the errors of the various elements
of the system; these include the encoders, perpendicularity of the azimuth
and elevation axis and the deflections within the structure that are caused
by the installation of the test radome after the seeker antenna has been
boresighted. A discussion of how each of these error sources is minimized
is given below.

The encoders selected for this system are Itek Ra13/23C with an
accuracy of plus or minus 0.03 degrees (1/3 bit). The encoder is an
absolute type that is connected directly to the shaft in each axis.
(The encoder is described in detail in Appendix C.)
The error caused by the perpendicularity of the azimuth and elevation axes is dependent on the error (tolerance) in machining of the two axes in the outer gimbal. A typical machine tolerance would be approximately ± 0.005 inches which would result in an angular error of about 0.02°.*

The error caused by the installation of the radome after the seeker antenna has been boresighted is dependent on the deflection of the entire gimbal system with reference to the seeker antenna mount. In this case, the calculated deflection caused by the installation of a 50 pound radome is 0.0008 inches. The readout error caused by this deflection divided by the distance (48 feet) from the seeker antenna to the source array antenna at the far end of the microwave chamber is negligible (less than 1.5 x 10⁻³ milliradians).

Other sources of error are an accumulation of miscellaneous machining and assembly tolerances which are estimated to be less than ±0.015° (see Table 2).

Repositioning Accuracy of the Seeker Antenna and Radome

The seeker antenna must be swung out of the way while the test radome is being installed and must be repositioned to its original boresighted position to within ±0.005 inches. This repositioning accuracy is built into the basic structure and is dependent on the machine tolerances of the location precision reference guide pins. This tolerance can be easily held to less than ±0.005 inches by proper machining methods.

The seeker antenna will sag when placed on the 2 inch diameter attachment. The total calculated deflection caused by a 20 pound antenna system is less than 0.001 inches producing an angular rotation of less than 0.5 milliradians in the apparent antenna boresight axis.

The angular location of the test radome must be positioned to within ±0.1 degree. This is accomplished by the use of an accurately machined adapter/fixture that attaches the test radome to the inner gimbal ring. Normal machining methods to tolerances of ± 0.005 inches with well-made radomes will be adequate. Alignment dowel pins are also located on the

* 

\[
\tan \theta_{\text{error}} = \frac{\text{Machine Tolerance}}{\text{Smallest Width}/2} \quad (\text{See Figure 7})
\]

\[
\tan \theta_{\text{error}} = \frac{0.005}{24.5/2} = 0.00041
\]

\[
\theta_{\text{error}} = 0.023°
\]
Figure 7. Diagram Illustrating Gimbal Misalignment Factors due to Machining Tolerances.
TABLE 2
TOTAL READOUT ACCURACIES

<table>
<thead>
<tr>
<th>Error Source</th>
<th>Error Degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encoder Readout</td>
<td>± 0.030</td>
</tr>
<tr>
<td>Outer Gimbal/Perpendicularity</td>
<td>± 0.023</td>
</tr>
<tr>
<td>Structure Deflection</td>
<td>Negligible (1.5 x 10^{-3} milliradian)</td>
</tr>
<tr>
<td>Structure Twisting</td>
<td>Negligible (0.004 degrees)</td>
</tr>
<tr>
<td>Miscellaneous Machining &amp; Assembly Tolerances</td>
<td>± 0.015</td>
</tr>
<tr>
<td><strong>TOTAL SINGLE PLANE ERROR</strong></td>
<td>± 0.065 peak</td>
</tr>
<tr>
<td></td>
<td>± 0.056 RMS</td>
</tr>
</tbody>
</table>
fixture so that the radome can be removed and re-attached to the inner gimbal ring and maintain the same rotation position relative to the azimuth and elevation axes to within ±0.1 degree.

The weight of radome positioner less radome, seeker antenna and counter weights is:

<table>
<thead>
<tr>
<th>Inner Gimbal</th>
<th>43.67 pounds</th>
</tr>
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<tbody>
<tr>
<td>Gimbal Ring</td>
<td>19.01</td>
</tr>
<tr>
<td>Radome Adapter</td>
<td>14.17</td>
</tr>
<tr>
<td>Radome Mount</td>
<td>6.79</td>
</tr>
<tr>
<td>Elevation Shafts</td>
<td>3.70</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outer Gimbal</th>
<th>84.62</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gimbal Frame</td>
<td>41.59</td>
</tr>
<tr>
<td>Bearings Az and El</td>
<td>5.40</td>
</tr>
<tr>
<td>Azimuth Shafts</td>
<td>3.98</td>
</tr>
<tr>
<td>Drive Motors</td>
<td>10.00</td>
</tr>
<tr>
<td>Gear Trains</td>
<td>7.00</td>
</tr>
<tr>
<td>Encoders</td>
<td>2.00</td>
</tr>
<tr>
<td>Motor Mounting Brackets</td>
<td>4.65</td>
</tr>
<tr>
<td>Miscellaneous Brackets</td>
<td>10.00</td>
</tr>
<tr>
<td>and Clamps</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Outer Frame</th>
<th>30.83</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer Frame</td>
<td>23.53</td>
</tr>
<tr>
<td>Alignment Plate</td>
<td>3.20</td>
</tr>
<tr>
<td>Antenna Mount Hinge Brackets</td>
<td>4.10</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Seeker Antenna Mount</th>
<th>50.88</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna Mount</td>
<td>48.98</td>
</tr>
<tr>
<td>Dowel Pins, Hand Screw Lock, Hinge Pins</td>
<td>1.90</td>
</tr>
</tbody>
</table>

| Miscellaneous Hardware and Wiring | 5.00       |

| Total Weight Less             | 215.00 pounds |
| Radome Seeker Antenna and Counter Weights |            |

Note this weight is less than the door (-400 pounds) used to seal the West Aperture Room of the RFSS.
3.2 Mechanical Components

The overall design of the radome positioner system is based on a two axis system (elevation over azimuth) mounted in an aluminum angular outer frame designed to closely fit the aperture door opening. A rigid seeker antenna mounting frame shown in Figure 8 is also attached directly to the angular outer frame.

The outer mounting frame (See Drawing 5*) is fabricated from 4" by 4" by 3/8" aluminum angle-alloy 6061T6. The angle is welded into a rectangular frame and machined to fit the aperture opening, allowing a nominal 1/16" clearance on all four sides. During the machining operations the mounting surfaces for the azimuth upper and lower gimbal shaft (See Encoder Mounting Shaft Drawing 25) are machined parallel to each other to within 0.002". Also, the surfaces for mounting the seeker antenna alignment plates (See Drawing 6) and the seeker antenna support bracket hinges are machined perpendicular to the gimbal shaft mounting surfaces to within 0.002" and parallel to each other to within 0.002". Holes are also provided for mounting the four lifting buttons (See Drawing 28) on the sides.

The outer gimbal (Drawing 8) is fabricated from 3" readily available square aluminum of alloy 6061-T6. Solid aluminum blocks are also incorporated into the overall weldment at the azimuth and elevation bearing axis to provide solid cross-sections sufficiently large to support the large azimuth and elevation bearings. During the machining operation, the perpendicularity of the two axes was maintained to within ± 0.005". The main drive motor mounting brackets in both axes are also mounted on the outer gimbal. The mounting surfaces for these brackets are machined on the sides of the gimbal to be parallel to the appropriate axis within ± 0.005". The encoder mounting surfaces are also located on the outer gimbal. These encoder mounting surfaces are machined to locate encoders concentric and perpendicular to the center lines of the azimuth and elevation axis to within 0.001 inches to prevent excessive side loading on the encoder bearings.

*All mechanical and electrical drawings appear in Appendix A.
Figure 8. Seeker Antenna Mounting Frame Prior to Installation
The inner gimbal (See Drawing 9) is a total weldment fabricated from various thicknesses of aluminum sheet and solid aluminum blocks. Excess stock is left on all surfaces of the weldment to allow machining to final dimensions. General tolerances are held to ± 0.005 inches although clearance between the radome mounting ring (See Drawing 27) and the inner gimbal is held to less than 0.002 inches by hand fitting during the machining operations.

The seeker antenna bracket (See Drawing 11) is a machined weldment fabricated from standard 2 inch by 2 inch by 1/8 inch square aluminum tubing alloy 6061-T6. Solid aluminum sections are added where compression loading is required to prevent localized distortions of the tubing wall. Parallel tolerances of mounting surfaces are held to 0.002 inches. The location of main alignment dowel pin holes is accomplished by transferring the holes to the antenna alignment plate (See Drawing 6) after attachment to the outer frame. The seeker adjustment mechanism (See Drawings 22, 23, and 24) attaches directly to the seeker antenna mount and provides vertical and horizontal adjustments in both planes up to ± 0.750 inches. Adjustments in the third plane are accomplished with the 2 inch diameter round tube located at the center of the adjustment mechanism.

Drive motors and worm gear assemblies shown in Figure 9 are identical in both azimuth and elevation axis. There is an additional thrust bearing located in the worm gear mounting block (See Drawing 15) for the elevation axis. This thrust bearing is located above the worm to accept the loads of the radome when insufficient counter weight is applied.

The counter weights (See Drawing 41) are located on each side of the radome mounting. Eight counter weights are supplied and can be applied in increments of 10 pounds up to 80 pounds.
Figure 9. Elevation Axis Motor and Worm Gear Drive Assembly.
3.3 Installation Procedures

In order to install the Radome Positioner in the aperture door opening, the aperture door and its associated parts including door latch, limit stops, etc., must first be removed and stored for future replacement. The door removal is accomplished with a special cart shown in Figure 10 that is fabricated for that purpose.

The suggested procedure for removal of the door and installation of the Radome Positioner is:

A. Remove door closure mechanism from both the door and the wall above the door. Also remove the door latch and the electrical door-closed indicator switch from the wall on the right side of the door. (Save all of the hardware for reinstallation of the door.) Open the door to approximately 45° angle.

B. Manually move the door-removal hand cart under the door until the approximate center of gravity of the door is aligned with the approximate center of the platform on the cart. Align the edge of the door with groove on the top of the platform. With the foot lever raise the platform until the weight of the door is being supported by the cart. Tighten the upper door clamp. With the foot lever raise the door until the door hinges are separated (approximately 2 inches). Move the cart, with the door attached, away from the door opening until the door clears the wall. Slowly lower the platform with the door attached by releasing the hydraulic valve. The door and cart can now be moved for storage.

C. Manually move the Radome Positioner cart, with the Radome Positioner attached, into position in front of the aperture opening. Raise the Radome Positioner until the outer frame
Figure 10. Cart Used to Remove the RFSS West Aperture Room Door.
aligns with the aperture opening. Lock the foot brake on the cart and move the Radome Positioner forward into the opening by rotating the hand wheel located between the forks at the cart.

D. Install and tighten the eight special C-clamps around the periphery of the outer frame.

E. Remove the cart by lowering the forks with the lifting books approximately 1.5 inches. Release the foot brake and move the cart backward separating the lifting hooks from the lifting buttons located on the outer frame.

F. After completing the electrical connections to the drive motor and readout devices, the system is ready for the electrical check-out and operation.

G. Calibration adjustments and zero alignment of the optical encoders can also then be made.

To reinstall the aperture room door, the procedure given above is carried-out essentially in reverse.
4.0 ELECTRONICS

The basic requirement of the radome positioner electronics is to allow an operator to accurately position the azimuth and elevation gimbals. A simple solution would be a manual control of the motors for each axis and a calibrated scale to indicate angle. A more sophisticated system eases the operator's task permitting the taking of a lot of data from many radomes. Until recently the conventional approach to the problem involved a complex servo feedback system and electro-mechanical indicators and position control. With the introduction of the microprocessor in 1971, the means to implement a programmable and sophisticated control system with a minimum of hardware became readily available. In addition, a microprocessor is capable of performing a wide variety of complex logical operations under control of an easily modified program stored in digital memory.

The use of a microprocessor and its associated components forming a microcomputer, as the basis of the radome positioner electronics, results in a very flexible and easy to use system. To implement a similar system with conventional digital logic would require 400 - 500 integrated circuits compared to the 30 integrated circuits which actually comprise the heart of the microcomputer. This dramatic reduction in parts count results in a similar reduction in cost and power consumption and an increase in reliability and flexibility.

A block diagram of the radome positioner electronics is shown in Figure 11. The microcomputer closes a digital control loop between each shaft angle encoder and the azimuth or elevation motor and displays the current gimbal position. Commands from the keyboard or serial ASCII (American Standard Code for Information Interchange) data from an external source cause the microcomputer to update angle inputs to the control loop and to open or close the loop as required. Internally stored programmable raster patterns are provided for automatic positioning.

With the exception of the display and motor controller interface, all of the positioner electronics are contained on 5 plug-in circuit boards located in the main electronics chassis. Four of these boards, the enclosure,
Figure 11. Block Diagram of RFSS Radome Positioner.
and power supply are commercially available microcomputer and peripheral circuit cards that have been modified slightly for this particular application. A fifth wire-wrap board in the main chassis contains miscellaneous interface circuits for the keyboard, display and analog angle outputs. The only other non-standard electronics assembly is the dual, optically isolated D/A converter and amplifiers which are used to convert digital information from the microcomputer into isolated dc signals used to control the speed and direction of the gimbal motors. This is referred to as the motor controller and is contained in an enclosure mounted behind a rack panel in the bottom of the rack.

4.1 Electronics Components

The positioner electronics are comprised of several distinct components, each of which will be described individually. These components are: microprocessor board, RAM board, ROM board, parallel I/O board, I/O buffer circuits, display, keyboard, power supplies, shaft encoders, motors, and motor controller.

Microprocessor Board

The heart of the entire controller is a Motorola M6800 microprocessor and its associated circuits contained on the Motorola M68MM01A-1 micro-module (See Drawing 64). This board contains the 6800 microprocessor, 1k bytes of RAM, provisions for up to 4k bytes of ROM, two 20 bit parallel I/O ports and an RS232 serial I/O port. The controller software is contained in the four 2708 EPROMS located on this board. The two parallel I/O ports are used to operate the display and keyboard.

2k Static RAM

The Motorola M68MM06 board holds 2048 bytes of RAM that are used for temporary variable storage by the positioner software. (See Drawing 66) Sixteen 2102-1 1k bit static RAMs and their associated buffering and address decoding logic are contained on this board.
16k ROM Board

As additions are made to the software and if new rasters are added, the 4k bytes of ROM space available on the microprocessor board may not be adequate. The 16k ROM board M68MM04 (See Drawing 67) has room for 16 k byte EPROMS should additional memory be required.

32/32 Parallel I/O Board

The M68MM03-1 32/32 parallel I/O board (See Drawing 68) provides 32 parallel inputs and 32 parallel outputs to the microprocessor. These inputs and outputs appear as four memory locations beginning at address 8E00 and are used for motor speed and direction control and to read the two 13-bit shaft angle encoders. All inputs and outputs are buffered.

I/O Buffer Board

This board is a custom wire-wrapped board containing miscellaneous interface circuitry for the keyboard and display as well as a modular dc/dc converter and two 12 bit D/A converters used to provide analog azimuth and elevation angle outputs. A schematic and parts placement for these circuits are shown in Drawings 67 and 70.

Display

A Burroughs Self-Scan II 20 character alphanumeric display (See Appendix C) is used to output messages and position information to the operator. This display was chosen because it is entirely self-contained and required only power supply voltages and parallel ASCII data. The display requires +5 Vdc, -12 Vdc and -250 Vdc to operate. The -250 Vdc is provided by a modular dc/dc converter mounted on the rear inside wall of the main chassis. Characters in the display are multiplexed and thus require a periodic "refresh". This is provided by an external 100 ns clock on the I/O buffer board and appropriate interrupt driven software (See Section 4.3).
Keyboard

Commands to the positioner are entered via a custom 20-key keyboard attached to the front of the main chassis (See Drawing 71). Hall-effect switches were used to minimize key bounce problems. Integrated circuit U1 generates an interrupt to the microprocessor whenever a key is pressed causing the positioner software to execute a keyboard parsing routine which reads the switch closure via PIA lines PA0-PA7 and PB0-PB7 from the I/O buffer board.

Power Supplies

A power supply (See Drawing 75) within the main electronic chassis supplies +5 Vdc, and ±12 Vdc to the microcomputer components, keyboard, display and motor control electronics. A dc/dc converter located on the I/O buffer board converts 5 Vdc to ±15 Vdc for the D/A converters used to produce analog angle outputs and to the D/A converters in the motor speed controller. Another dc/dc converter in the rear of the main electronic chassis supplies 250 Vdc to the display.

Shaft Encoders

Two identical 13 bit shaft angle encoders located on the azimuth and elevation gimbal shafts converts angular displacement to parallel binary data used by the microcomputer to read the gimbal angles to within 0.09 degrees. +5 Vdc is supplied to each encoder via the 50 conductor cable connecting the encoders and microcomputer (See Appendix C for a complete description of the shaft angle encoders).

Motors

Identical 1/25 horsepower ac motors (See Figure 9) and gear reduction boxes are used to drive each gimbal axis. Motor speed is regulated by a triac speed controller which in turn is driven by optically isolated control signals from the motor controller. A tachometer on the motor shaft provides an ac voltage proportional to speed which is fed back to the motor speed controller to maintain constant torque under varying load conditions over a wide range of speeds.
4.2 Motor Control Electronics

A block diagram of the electronics utilized for motor speed and direction control (azimuth and elevation) is shown in Figure 12. The electronics perform three basic functions. They are:

1. Control of the rotational speed of the motor on each axis.
2. Directional control for each motor.

The heart of the motor control electronics is the O-CON C-10P-4 variable speed motor control. A block diagram of this motor controller is shown in Figure 13.

The controller maintains constant speed over a wide range of load torque by means of a feedback loop between the tachometer and a triac operated motor driver. The amplifier amplifies the error signal received from the tachometer in the feedback loop and drives the motor. The effective gain in the loop can be adjusted to be sufficiently high so that even a small error voltage will initiate a corrective action. The effective gain in the loop when using the C-10P-4 controller approaches 100 causing the speed of the motor to change a few percent with changes in the load.

Separate C-10P-4 motor speed controllers are used for the azimuth and elevation axes motors. The only modification made to the controller was to bring out a connection to allow motor speed to be controlled (V<sub>L</sub>) externally by a D/A converter which is driven by an output of the microcomputer.

Details of the controller are discussed below.
Figure 12. Motor Direction and Speed Control Block Diagram.
Figure 13. Motor Controller Feedback Loop.
Control of Motor Speed

Control of the rotational speed for each motor (azimuth and elevation) is accomplished by applying positive dc voltage reference ($V_1$) to pin 7 of the respective Q-CON C-10P-4 controller (See Figure 14). The motor's rotational speed is proportional to the reference voltage $V_1$, and at a reference voltage of zero (0) volts, each motor will be stopped. Maximum rotational speed is obtained with an input voltage of approximately 20 volts.

When the microcomputer issues a speed command to a motor (azimuth or elevation) it delivers an 8-bit digital word to its respective digital to analog D/A converter (Figure 12). The D/A then translates this digital word into a corresponding dc voltage level. This dc level is then amplified by U1 and applied to an optically coupled isolator through U2. The isolator's function is to isolate the C-10P-4 controller from the microcomputer and its associated components, thus providing protection against ground loops, power line transients, and noise. The isolated dc signal is then amplified by U2 and U3 and applied as the reference voltage ($V_1$) to pin 7 of the C-10P-4 controller.

The D/A used in this design is the Datel model 98BIR. Its 8 inputs provide for $2^8$ or 256 different dc voltage levels which are used to control the motor speed.

Directional Control

Directional Control of the rotation of each motor is accomplished by:

1. Disconnecting ac power from the C-10P-4 controller.
Figure 14. Q-Con C-1OP-4 Motor Speed Controller.
2. Reversing the red and blue motor leads between pins 3 and 4 of the controller.

3. Reapplying the ac power.

The sequence must be followed as it is stated above. MOTOR DIRECTION MUST NOT BE CHANGED WITH POWER APPLIED TO THE CONTROLLER.

During program control, if the microcomputer determines the need for direction reversal, it first sets ACEZ (ACEL) high turning off relay RY1 (RY2) and disconnecting power from the controller. Once ac power is disconnected, the motor's direction may be reversed. To do this the microcomputer complements DIRAZ (DIREL) reversing the red and blue motor leads between pins 3 and 4 of the C-10P-4 controller. Power is then re-applied to the controller by the microcomputer, and the direction reversal is complete. This is all done through program control and takes place automatically.

**Manual Over-ride Control**

During its normal operation, the microcomputer software will not allow the radome to be positioned at an angle greater than ± 40 degrees with respect to its center position in either azimuth or elevation. Should the microcomputer fail however, a standby method of shutting down the system, if it tries to rotate beyond its ± 40 degree limit, has been installed. This standby system is a set of four limit switches, two for each axis, which will interrupt the ac power to the C-10P-4 controllers if ± 40 degrees in either direction is reached by the radome. If this occurs, there is no way of returning the radome to within its boundaries through microcomputer control. For this reason, manually operated override switches have been provided to reposition the radome to within its boundaries so the microcomputer can regain control. THE OVERRIDE SWITCHES SHOULD NEVER BE OPERATED WHILE THE POSITIONER IS UNDER MICROCOMPUTER CONTROL.
Should the microcomputer software limits fail, and the limit switches engage, then the following directions apply:

1. Determine which limit has been reached (Azimuth or Elevation)
2. Throw the OVERRIDE switch to OVERRIDE.
3. Throw the switch corresponding to the limited position (Azimuth or Elevation) to its position opposite NORMAL. The radome will then reverse direction and proceed into its normal operating boundary.
4. When the radome has reached the desired position, return the switch thrown in step 3 to its NORMAL position. This will stop the radome.
5. If it is desired to reposition the other axis at this time, throw the appropriate switch (azimuth or elevation) to the position opposite its normal position. This axis will then reverse from the direction it was going when limiting occurred. When the radome is in the desired position on this axis, return the switch to its NORMAL position.
6. After repositioning the radome, return the OVERRIDE switch to its NORMAL position. The radome is then again under microcomputer control.

CAUTION

NEVER TRY TO MANUALLY REPOSITION THE RADOME WITH THE OVERRIDE SWITCH IN ITS NORMAL POSITION.

It should be noted here that once the OVERRIDE switch is returned to NORMAL, the microcomputer is again in control of the positioner. The possibility therefore exists that whatever caused limiting in the first place, could again cause limiting to occur. If this is the case, manually reposition the radome as in steps 1 thru 5 above, but do not carry out step 6. This will prevent the microcomputer from taking
control of the positioner and thus prevents limiting from again occurring.

Provision for manual control of the positioner was not meant as a secondary positioning system. Its sole purpose is to place the radome back within its boundary should the microcomputer software limits ever fail. It should be used only for this purpose.

4.3 Microcomputer Software

Operation of the Radome Positioner is controlled by a program which is stored in 6k bytes of Read Only Memory (ROM). This program is executed by the 6800 microprocessor and defines all the operations of the positioner. Logical operations defined by the program along with inputs from the shaft angle encoders, keyboard, limit switches and in the case of remote operation, serial ASCII data from an external source, completely specify the motion of the gimbals.

The controller software was written in assembly language for the 6800 microprocessor and converted into machine language instructions by a cross assembler on the Georgia Tech CDC CYBER 74 computer. A listing of this program appears in Appendix B. Each line of the listing consists of a line number followed by an address and either one, two, or three hex bytes corresponding to the machine language equivalent of the assembly language statement on the remainder of the line.

A simple flow chart of the positioner software is shown in Figure 15. This diagram represents the logical flow of the program with each block corresponding to several subroutines of from 10 to 100 lines of program. Program operation can best be understood by considering the main task of the microprocessor as the azimuth and elevation control loop. This portion of the software is constantly comparing the actual position of the gimbals with the desired position which is stored in Random Access Memory (RAM) that is accessed by the microprocessor and is modified by a number of other subroutines. The control loop program can alter the speed and
SYE ELEVATION ANGLES

AZIMUTH MOTOR CONTROL LOOP

ELEVATION MOTOR CONTROL LOOP

MANUAL OPERATION
SET AZIMUTH ANGLE
SET ELEVATION ANGLE
PROGRAMMED RASTER

a. Main Program Loop

b. Interrupt Service Routines

Figure 15. RFSS Radome Positioner
Microcomputer Software Flow Chart
direction of each gimbal in order to make the actual and desired angles equal. This digital control loop is analogous to a conventional analog servo control system with the servo amplifiers and loop filters replaced by a microprocessor program.

While the control loop program is operating, it is periodically briefly "interrupted" from one of three sources. An interrupt results in the execution of the current program being briefly suspended while the microprocessor executes another program called the Interrupt Service Routine. After the service routine is completed, the microprocessor resumes execution of the main program (in this case the control loop) at the exact place it was interrupted. The system is designed so that the interrupt service routines take only a few hundred microseconds to complete so in effect the processor's time is "shared" by more than one program without degrading its performance on the main program. The three interrupting devices in the case of the radome positioner are the display, the keyboard and the serial interface for remote operation. Since the display requires periodic refreshing, an interrupt from a 100 μs clock causes the microprocessor to transfer the contents of a specific 20 byte portion of RAM at the rate of one character (1 byte) every 100 μs. Thus the entire display is updated or "refreshed" every 2 ms, which is faster than the flicker response of the eye resulting in a display that appears to be continuous. (See Figure 16).

An interrupt is also generated whenever a key on the positioner keyboard is pressed. The keyboard interrupt service routine decodes the key that was pressed and determines what action to take by means of a key state table within the program. This table specifies what action the program will take based on which key was pressed and the current status or "state" of the program. For example, a particular state is associated with the prompt "Enter Azimuth Angle" which results from pressing the "SET AZ" key. If a number key is pressed, the keyboard service routine
recognizes it as a proper response and stores it as the first digit of the desired angle. If, however, the "SET EL" key or one of the manual direction keys are pressed, the keyboard program will recognize it as an invalid key resulting in the display of an "Invalid Entry" message and will then return to state 0 which is the "Resting State" and display the current azimuth and elevation angle.

A similar sequence of operations results from commands that are received via the serial interface from a remote device in the Remote Operation Mode. In this case the interrupts are generated by the interface each time a valid ASCII character is received. Error messages and prompts are sent over the interface as well as being displayed.
5.0 POSITIONER OPERATION

The radome positioner is capable of four basic modes of operation: manual azimuth and elevation movement, preset azimuth and elevation angles, internally stored raster patterns, and external computer control via a serial interface. The first three modes are accessed via the controller keyboard and the fourth via an RS232C serial interface when the local/remote switch is in the REMOTE position. The alphanumeric display will prompt the operator for any required keyboard inputs and provide error messages if any invalid key sequence is entered. In addition, failure of any one of several self-test programs will be indicated by an appropriate message. The display will also echo numeric entries and indicate the present azimuth and elevation angle.

System Initialization

When power is applied to the positioner by pressing the power switch located in the lower right-hand corner of the controller front panel, the button will be illuminated and an automatic reset sequence will be initiated in the microcomputer. This will cause the microcomputer to begin executing the controller program. A power-up message will be displayed on the controller's display indicating successful system initialization. See Table 3 for a complete list of system messages.

Manual Operation

Manual control of gimbal position is available via the four arrow keys on the keyboard. Depressing any of these keys will cause the gimbals to move in the indicated direction. Only one key at a time may be depressed. The azimuth and elevation angles will be displayed on the controller display. Gimbal motion will continue as long as the key is depressed or until the gimbal angle limit is exceeded.
<table>
<thead>
<tr>
<th>MESSAGE</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>THE GA. TECH - RFSS</td>
<td>Power on message giving current software version number.</td>
</tr>
<tr>
<td>RADOME POSITIONER VERSION 1.0.</td>
<td></td>
</tr>
<tr>
<td>RADOME POS. READY</td>
<td>Indicates proper initialization sequence complete.</td>
</tr>
<tr>
<td>XX.X' AZIMUTH</td>
<td>Present azimuth and elevation angle.</td>
</tr>
<tr>
<td>XX.X' ELEVATION</td>
<td>Denotes idle state if constant or follows gimbal motion.</td>
</tr>
<tr>
<td>ENTER ELEVATION ANGLE</td>
<td>Prompt for angle entry after pressing SET AX or SET EL key.</td>
</tr>
<tr>
<td>ENTER AZIMUTH ANGLE</td>
<td></td>
</tr>
<tr>
<td>ERROR-INVALID ENTRY</td>
<td>Improper key sequence entered.</td>
</tr>
<tr>
<td>ANGLE TOO LARGE ...</td>
<td>Entry of angle greater than azimuth or elevation angle limit.</td>
</tr>
<tr>
<td>POSITIONER HALTED</td>
<td>Result of pressing ( \text{START} ) key when gimbals are in motion.</td>
</tr>
<tr>
<td>ANGLE LIMIT EXCEEDED</td>
<td>Azimuth or elevation gimbal has reached preset limit.</td>
</tr>
<tr>
<td>ENTER &quot;PROGRAM&quot;-NUMBER</td>
<td>Response to PGRM key (see raster pattern descriptions).</td>
</tr>
</tbody>
</table>
Preset Angle Mode

The gimbals may be commanded to any azimuth and elevation angle via the SET EL and SET AZ keys. When either of these keys are depressed the operator will be prompted to enter the desired angle. Each angle may be set independently of the other. Gimbal motion will begin when the START key is depressed following the angle entry. The gimbals may be halted at any time by pressing the STOP key again. If entry of an angle greater than the gimbal angle limit is attempted, an error message will be displayed (See Table 3).

Internally Stored Patterns

Several commonly used raster pattern programs are stored internally in the controller's microcomputer. These programs may be accessed via the PRGM key on the controller keyboard followed by a program number. Each program will prompt the operator to enter any required pattern variables. A complete description of each program is given in Appendix E. Briefly, the choice of rasters is vertical and horizontal linear rasters, or circle or star rasters.

External Computer Control

The radome positioner has the capability to be controlled by an external device such as a computer or computer terminal that has the capability to send and receive ASCII characters over an RS232C interface. When the local/remote switch located on the front panel is placed in the remote position all of the functions available through the keyboard can also be commanded over the RS232C interface. In addition, messages and prompts similar to those displayed on the controller display are sent over the interface. Thus, an operator or computer program can operate the positioner in essentially the same manner as when the keyboard and display are used. See Appendix E for a detailed description of the computer interface operation.
Gimbal Angle Limits

In order to prevent the gimbals from being moved past an angle that could cause damage to the seeker antenna and hit the sides of the aperture or gimbal frame, two limiting mechanisms were implemented. The first is a set of four "soft" limit angles that can be manually set from the keyboard. These angles correspond to the positive and negative extreme of each axis and are initially set to $40^\circ$ when power is first applied to the system. They may be changed by entering the key sequence; "SET AZ (EL)" followed by one of the four manual direction controlled buttons; "+, -, "", "-". The display will then show the current limit and allow it to be changed. Attempting to set a limit greater than $40^\circ$ or less than $1^\circ$ for any axis will result in an error message and no change in the limit will occur. Should the angle reach the preset limit during positioner operation, the message ANGLE LIMIT EXCEEDED will be displayed and the gimbals will automatically move the opposite direction until within the limits.

A second fail-safe angle limit system consists of four microswitches mounted on the azimuth and elevation axis gears. These switches will interrupt ac power to the motors should the gimbals ever exceed the angle at which they are set. They are adjustable from $20^\circ$ to $40^\circ$ and are normally set at $40^\circ$. See Section 4.2 for instructions on how to reposition the gimbals after these "hard" limits are exceeded.

Rear Panel Connections

The display, motor controller, shaft encoders, and an external RS232 device connect to the system via connectors located on the rear panel of the main chassis (See Drawing 81). The two BNC connectors labeled "Azimuth dc Out" and "Elevation dc Out" provide dc voltages proportional to gimbal position. From $+40^\circ$ to $-40^\circ$ on either axis corresponds to $+4$ Vdc to $-4$ Vdc output with $0^\circ = 0$ Vdc. These outputs are unbuffered D/A converter outputs and can provide up to 5 mA of drive current.
APPENDIX A

RADOME POSITIONER DRAWINGS
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<th>Title</th>
</tr>
</thead>
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</tr>
<tr>
<td>2</td>
<td>Radome Positioner for the RFSS (Sheet 2 of 2)</td>
</tr>
<tr>
<td>3</td>
<td>Clamp for Radome Positioner</td>
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<td>4</td>
<td>Screw Assembly for Radome Positioner Clamp</td>
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<tr>
<td>5</td>
<td>Outer Mounting Frame for Radome Positioner</td>
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<tr>
<td>6</td>
<td>Alignment Plate for Seeker Antenna</td>
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<tr>
<td>7</td>
<td>Alignment Pin for Seeker Antenna</td>
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<tr>
<td>8</td>
<td>Outer Gimbal Assembly</td>
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<tr>
<td>9</td>
<td>Outer Gimbal Assembly</td>
</tr>
<tr>
<td>10</td>
<td>Insert for Outer Gimbal</td>
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<td>11</td>
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<tr>
<td>12</td>
<td>Bearing Block and Motor Mtg. Plate for Azimuth Axis</td>
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<td>Encoder Mounting Block</td>
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<td>16</td>
<td>Bearing Spacer - Az. &amp; El. Axis</td>
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<tr>
<td>17</td>
<td>Encoder Mounting Shaft - Azimuth Axis</td>
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<td>18</td>
<td>Bearing Clamp - El. Axis</td>
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<td>19</td>
<td>Worm Gear Shaft - Azimuth Axis</td>
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<td>Thrust Bearing Plate - Azimuth Axis</td>
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<td>21</td>
<td>Top Seal Plate Worm Gear Shaft - Azimuth Axis</td>
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<td>Seeker Antenna Alignment Assembly</td>
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<td>35</td>
<td>Worm Shaft - El. Axis</td>
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<td>36</td>
<td>Worm Gear Shaft Spacer - El. Axis</td>
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<tr>
<td>37</td>
<td>Hinge Pin for Seeker Antenna Bracket</td>
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<td>38</td>
<td>Shaft Coupling Motor to Worm</td>
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<td>39</td>
<td>Micro-Switch Actuator and Mounting Plate</td>
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# DRAWING LIST (CONTINUED)

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<td>Modified Set Screw for Centering of Inner Gimbal</td>
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<td>Modification of Front Panel M68MMCL Micro-Module</td>
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<td>Panel Modifications for Digital Readout</td>
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**Cart for Positioner**

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<td>Lifting Hook Details</td>
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<td>53</td>
<td>Retractor Mechanism Components for Radome Positioner</td>
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<td>Removal Cart</td>
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**Door Removal Cart**

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<tbody>
<tr>
<td>54</td>
<td>Modified Hand Truck for Removing Door of RFSS</td>
</tr>
<tr>
<td>55</td>
<td>Door Bottom Support Bracket</td>
</tr>
<tr>
<td>56</td>
<td>Door Clamp Screw Top</td>
</tr>
<tr>
<td>57</td>
<td>Door Clamp Top</td>
</tr>
<tr>
<td>58</td>
<td>Cap Support Bracket</td>
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<tr>
<td>59</td>
<td>Upright Support</td>
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<tr>
<td>60</td>
<td>Gusset Plate</td>
</tr>
<tr>
<td>61</td>
<td>Angle Support</td>
</tr>
<tr>
<td>62</td>
<td>Channel Support</td>
</tr>
<tr>
<td>63</td>
<td>Angle Stop</td>
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</table>

**Electronics**

<table>
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<tr>
<th>Drawing No.</th>
<th>Title</th>
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<tr>
<td>64</td>
<td>M68MM01A-1 Microcomputer Schematic</td>
</tr>
<tr>
<td>65</td>
<td>Parallel and Serial Interface Schematic for M68MM01A-1</td>
</tr>
<tr>
<td>66</td>
<td>M68MM06 2k Byte Static RAM Board Schematic</td>
</tr>
<tr>
<td>67</td>
<td>M68MM03 16k Byte EPROM Board Schematic</td>
</tr>
<tr>
<td>68</td>
<td>M68MM03 32 Channel I/O Board Schematic</td>
</tr>
<tr>
<td>69</td>
<td>I/O Buffer Board Schematic</td>
</tr>
<tr>
<td>70</td>
<td>I/O Buffer Board Parts Placement</td>
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**DRAWING LIST (CONTINUED)**

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<th>Drawing No.</th>
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<tbody>
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<td>Keyboard Schematic</td>
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<tr>
<td>72</td>
<td>Motor Power and Direction Control</td>
</tr>
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<td>73</td>
<td>D/A Converter and Isolated Amplifier</td>
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<td>74</td>
<td>Motor and Limit Switches Wiring</td>
</tr>
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<td>75</td>
<td>Motor Controller Panel Wiring</td>
</tr>
<tr>
<td>76</td>
<td>Microcomputer Power Supply Schematic</td>
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<td>78</td>
<td>Shaft Angle Encoder Cable</td>
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<td>81</td>
<td>Microcomputer Front Panel</td>
</tr>
<tr>
<td>82</td>
<td>Microcomputer Rear Panel</td>
</tr>
</tbody>
</table>
Drawing 2. Radome Positioner for the RFSS (Sheet 2 of 2)
3. Make 8 ea.
2. Finish:
1. Material: Steel

Tolerances:

<table>
<thead>
<tr>
<th>Tolerance</th>
<th>Value</th>
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<tbody>
<tr>
<td>X</td>
<td>±0.060</td>
</tr>
<tr>
<td>XX</td>
<td>±0.030</td>
</tr>
<tr>
<td>XXX</td>
<td>±0.010</td>
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</tbody>
</table>

Drawing 4. Screw Assembly for Radome Positioner Clamp
3- TRIM TO FIT INSIDE 3" SQ TUBING  
3 ENDS NONE  
3 PIERCED NO HOLE  

Drawing 10. Insert for Outer Gimbal.
Drawing 13. Worm Shaft for Azimuth Axis
Drawing 14. Bearing Block Mounting Bracket for Azimuth Axis
2: FINISH:
1: MATERIAL: ALUM

NOTES:

Drawing 15. Encoder Mounting Block
QTY. 4 EA
I. MATERIAL: ALU.
NOTES:

TOLERANCES:
X = ±0.030
XX = ±0.010
XXX = ±0.005

Drawing 16. Bearing Spacer - Az & El Axis
Drawing 20. Thrust Bearing Plate - Azimuth Axis.
Drawing 21. Top Seal Plate Worm Gear Shaft - Azimuth Axis.
Drawing 24. Seeker Antenna Vertical Adjustment Plate.
TOLERANCES:
X = ±0.030
XX = ±0.010
XXX = ±0.005

2. FINISH:

1. MATERIAL: STAINLESS STEEL

NOTES:

Drawing 25. Encoder Mounting Shaft - El. Axis
MAKE 4
MATERIAL: STAINLESS STEEL

Drawing 28. Lifting Button for Outer Frame
Drawing 29. Screw Lock for Seeker Antenna Mtg Frame
MODIFY 2 WORM GEARS (BROWNING PART NO. BWG2100-1) BY ADDING TAPPED HOLES FOR SETSCREWS

DRILL & TAP 8-32 x .30 DEEP, 2 PLACES

Drawing 31. Worm Gear Modifications
Drawing 35. Worm Shaft - El Axis.
MAKE 2
MATERIAL-STAINLESS STEEL

MATCH TO HOLES IN
PART NO. 1954-028

DRILL .125 THRU

3.25
.25
1.00
.25
500.222

Drawing 37, Hinge Pin for Seeker Antenna Bracket
RADOME POSITIONER FOR THE RFSS (RADIO FREQUENCY SIMULATION SYSTEM) (U) GEORGIA INST OF TECH ATLANTA ENGINEERING EXPERIMENT STATION D O GALLENTINE ET AL.

UNCLASSIFIED 27 FEB 78 DAAK40-77-C-0847

F/G 17/9
"A" DIMENSION .375 IN ONE, .394 IN OTHER

DRILL & TAP 10-24 THRU, 2 PLACES

1.80

.200

.100

SLOT .125 WIDE = .062 DEEP

MAKE-2
MATERIAL-STAINLESS STEEL

Drawing 38. Shaft Coupling Motor to Worm
Drawing 40. Counter Weight Mounting Blocks.

Make 6 sets
MATERIAL: ALUMINUM
3/8-24 EXTERNAL THREAD

MAKE 2

Drawing 43. Modified Set Screw for Centering of Inner Gimbal
Drawing 47. Box for Keyboard
NOTE: PAINTED SURFACE OF EXISTING PANEL MUST BE PROTECTED DURING MACHINING.
MAKE: STEEL

3.00
1.50
.75
1.50
1.50
4.5
.50

DRILL .312 DIA. THRU 2 PLACES

DRILL & TAP 5/16-11 THRU PLACE

Drawing 52. Threaded Plate for Lifting Hook
Drawing 53. Retractor Mechanism Components for Radome Positioner Removal Cart
Drawing 54. Modified Hand Truck for Removing Door of RFSS
TOLERANCES:
X = ±0.060
XX = ±0.030
XXX = ±0.010

2 - PAINT C
PROTECT THREADS

MATERIAL: STEEL

NOTES:

EXT. THREAD, 5/6-18

Drawing 56. Door Clamp Screw Top.
1. MATERIAL: STEEL
2. FINISH: NONE
NOTES:

TOLERANCES:
X  = ± .060
XX = ± .030
XXX = ± .010

Drawing 59. Upright Support
1. MATERIAL: STEEL
2. FINISH: NONE
NOTES:

TOLERANCES:
X = ±0.060
XX = ±0.030

Drawing 60. Gusset Plate.
Drawing 61. Angle Support
2-FINISH: NONE
1-MATERIAL: STEEL
NOTES:

TOLERANCES:
X = ±0.060
XX = ±0.030
XXX = ±0.010

Drawing 62. Channel Support
**Drawing 63. Angle Stop**

<table>
<thead>
<tr>
<th>TOLERANCES:</th>
</tr>
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<tbody>
<tr>
<td>$X = 0.060$</td>
</tr>
<tr>
<td>$XX = 0.030$</td>
</tr>
<tr>
<td>$XXX = 0.010$</td>
</tr>
</tbody>
</table>

2. FINISH: NONE

1. MATERIAL: STEEL

NOTES:

---

**Modified Hand Truck Details**

<table>
<thead>
<tr>
<th>NO. DESCRIPTION OF CHANGE</th>
<th>CH.</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Engineering Experiment Station**

GEORGIA INSTITUTE OF TECHNOLOGY

ATLANTA, GEORGIA

---

A 1954 017
Drawing 70. I/O Buffer Board Parts Placement.
Drawing 73. D/A Converter and Isolated Amplifier.
Drawing 74. Motors and Limit Switches Wiring.
Drawing 79. Motor to Controller Cable.
APPENDIX B

RADOME POSITIONER SOFTWARE LISTING
00084 0E5D 0002  AZMAG BLOCK 2
00085 0E5F 0002  ELMAG BLOCK 2
00086 0E61 0001  AZEL BLOCK 1
00087 0E62 0001  TEMPS BLOCK 1
00088 0E63 0001  PROCN BLOCK 1
00089 0E64 0001  PROCL BLOCK 1
0008A 0E65 0002  PROCA BLOCK 2
0008B 0E66 0002  PROCB BLOCK 2
0008C 0E69 0002  PROCC BLOCK 2
0008D 0E6E 0001  KFLAG BLOCK 1
0008E 0E6E 0001  DFLAGA BLOCK 1
0008F 0E6F 0001  DFLAG BLOCK 1
00090 0E6F 0001  SFLAGA BLOCK 1
00091 0E70 0001  SFLAG BLOCK 1
00092 0E72 0002  BCDVSR BLOCK 2
00093 0E72 0002  FTPTEL BLOCK 2
00094 0E72 0002  FTPTEZ BLOCK 2
00095 0E73 0001  FTPTEZ BLOCK 1
00096 0E74 0001  FTPTEA BLOCK 1
00097 0E75 0002  STADRE BLOCK 2
00098 0E75 0002  FSTADRE BLOCK 2
00099 0E76 0002  PEDANG BLOCK 2
0009A 0E76 0002  FEDANG BLOCK 2
0009B 0E78 0002  GINAG BLOCK 2
0009C 0E79 0002  SLINE BLOCK 2
0009D 0E79 0002  COSINE BLOCK 2
0009E 0E7E 0001  SSIGN BLOCK 1
0009F 0E7E 0001  CSIGN BLOCK 1
000A0 0E7F 0001  SAVEX BLOCK 1
000A1 0E80 0001  EMUPR BLOCK 1
000A2 0E80 0002  PELLIM BLOCK 2
000A3 0E80 0002  NELLIM BLOCK 2
000A4 0E88 0002  FAZLim BLOCK 2
000A5 0E88 0002  FZALIM BLOCK 2
000A6 0E88 0002  LFLAGA BLOCK 1
000A7 0E88 0002  LFLAG BLOCK 1
000A8 0E89 0001  NSEGFLG BLOCK 1
000A9 0E89 0001  SARRY BLOCK 1
000AA 0E89 0001  SAVEX3 BLOCK 2
000AB 0E8F 0002  GASPDP EQU 000H
000AC 0E8F 0002  GASPDP EQU 000H
000AD 0E90 0004  UBAR2 EQU 0B404H 1 MS 4 BITS OF DAC #1- AZIMUTH
000AE 0E90 0004  UBAR2 EQU 0B404H 1 MS 4 BITS OF DAC #1- AZIMUTH
000AF 0E90 0004  UBAR2 EQU 0B406H 1 LS 8 BITS OF DAC #1- AZIMUTH
000B0 0E90 0004  UBAR2 EQU 0B406H 1 LS 8 BITS OF DAC #1- AZIMUTH
000B1 0E90 0004  UBAR2 EQU 0B407H 1 MS 4 BITS OF DAC #2- ELEVATION
000B2 0E90 0004  UBAR2 EQU 0B407H 1 LS 8 BITS OF DAC #2- ELEVATION
000B3 0E90 0004  UBAR2 EQU 0B403H 1 MS 4 BITS OF DAC #2- ELEVATION
000B4 0E90 0004  UBAR2 EQU 0B403H 1 LS 8 BITS OF DAC #2- ELEVATION
000B5 0E90 0004  UBAR2 EQU 0B403H 1 MS 4 BITS OF DAC #2- ELEVATION
000B6 0E90 0004  UBAR2 EQU 0B403H 1 LS 8 BITS OF DAC #2- ELEVATION

TEKTRONIX  

00107  8E02  LSBSCL EQU  0BE02H
00108  8E01  LSBSAZ EQU  0BE01H
00109  8E00  LSBSAZ EQU  0BE00H
00110  8400  DBRA EQU  00400H
00111  8401  CRA EQU  03401H
00112  8402  DBRA EQU  00342H
00113  8403  CRD EQU  03403H
00114  8404  ACIA EQU  03404H ;ACIA STATUS/CONTROL REGISTER
00115  8405  ACIA0 EQU  03405H ;ACIA DATA REGISTER
00116  8406  ETPMD EQU  0704H
00117  2000  OG  2003H
00118
00119
00120  ;PIA INITIALIZATION
00121  2000  8E0FF FE  LDS #OFFFH
00122  2003  OF  SEI
00123  2004  8605  LDA A #3  ;"00000011" = MASTER RESET
00124  2006  B70408  STA A ACIAS ;RESET ACIA
00125  2009  8601  LDA A #01H ;"10000001" = 7 BITS, EVEN PARITY, AND 2 STOP BITS
00126  200B  B72400  STA A ACIAS ;SET ACIA FOR RCVR INTERRUPT, TXMIT INTERRUPT OFF
00127  200D  4F  CLR A
00128  200F  B72401  STA A CRA ;Cleans CONTROL REGISTER A
00129  2012  B74403  STA A CRB ;Cleans CONTROL REGISTER B
00130  2015  B72405  STA A CR3
00131  2018  B72407  STA A CR2
00132  201B  B72501  STA A CRA
00133  201E  B72803  STA A CRB3
00134  2021  CED400  LDX #3400H
00135  2024  86F0  LDA A #OF0H
00136  2026  A700  STA A 0.X
00137  2028  B607  LDA A #7
00138  202A  A701  STA 1.X
00139  202C  850F  LDA A #OF3
00140  202E  A700  STA A 0.X
00141  2030  A704  STA A 4.X
00142  2032  B6FF  LDA A #OFFFH
00143  2034  A702  STA A 2.X
00144  2036  A706  STA A 6.X
00145  2038  B72B30  STA A DD83
00146  203A  B72E32  STA A DDB3
00147  203C  8604  LDA A #C04H
00148  203E  B72405  STA A CRA2
00149  2040  B72407  STA A CRB3
00150  2042  B72501  STA A CRA
00151  2045  B72E33  STA A CRB3
00152  2048  863D  LDA A #G3DH
00153  204A  B72403  STA A CRB ;SELECTS OUTPUT REGISTER B

00154  ;INITIALIZES MOTORS TO ZERO SPEED, ETC
00155
00156
00157  2051  CE0029  LDY #TENP
00158  2054  4F  CLR A
00159  2055  A700  NEXTC STA A 0.X
BEGIN STATE TABLE

BEGIN STATE ZERO, MAIN CONTROL LOOP
00210 20C3 B028E3 JSR ADDCAL ;JUMPS TO ROUTINE TO CALCULATE NEXT STATE
00219 20C6 E000 LDX 0,X
00220 20C8 F000 JMP 0,X

00221 : AZIMUTH MOTOR CONTROL LOOP

00222 :

00223 :

00224 20CA BC2AF8 ST0A JSR SHA9NC ;READS BOTH AZ AND EL ANGLES
00225 20CD 9659 LDA A NL9AG
00226 20CF 2BE6 EMI ST9
00227 20D1 8600 LDA A #0001
00228 20D3 975B STA A SPEEDA ;SET UP SPEED VARIABLE TO FULL SPEED
00229 20D5 975C STA A SPEED2
00230 20D7 9657 LDA A AZKEYS ;TEST TO SEE IF BOTH SIGNS ARE EQUAL
00231 20D9 9143 CMP A AZSIGN ;BRANCH TO DO A BCDSUB IF SIGNS ARE THE SAME
00232 20DA 2712 DEX ST0X
00233 20DB 9654 LDA A AZKEY+1
00234 20DF 9856 ADD A AZBCD+1 ;FIND LSBYTE OF AZ MAGNITUDE DIFF
00235 20E1 19 DAA
00236 20E2 973E STA A AZNAG+1
00237 20E4 9650 LDA A AZKE
00238 20E6 9045 ADC A AZ9CD ;FIND MSBYTE OF AZ MAGNITUDE DIFF
00239 20E8 19 DAA
00240 20E9 D65E LDA B AZNAG+1
00241 20EA 975D STA A AZNAG ;AZ MAG DIFF NOW IN A AND B REGISTERS
00242 20EE 29E2 BRA ST0X
00243 20F0 9653 STA A AZKEY
00244 20F1 D65A LDA B AZKEY+1
00245 20F3 CE0045 LDY #AZBCD ;PUT ADDRESS OF BCD CURRENT LOCATION IN INDEX REG.
00246 20F6 D0295 JSR BCDSUB3 ;JUMPS TO ROUTINE TO SUBTRACT BCD NUMBERS
00247 20FC 875D STA A AZ9AG
00248 20FD 7D5E STA B AZNAG+1

00249 :

00250 : ADDITION TO TIGHTEN CONTROL LOOP (AZIMUTH) TO .1 DEGREE

00251 : (MODIFICATION 1.1)

00252 :

00253 20FD 8100 ST0X2 CMP A #0001 ;START <.2 DEGREE TEST
00254 20FF 260D BNE ST0X1 ;BRANCHES TO <.5 DEGREE TEST IF BCD WORD NOT <.2
00255 2101 C120 CMP B #00H ;COMPARING TO .05 DEGREE
00256 2103 2250 BNE ST0X1 ;BRANCHES TO <.05 DEGREE TEST IF BCD WORD NOT <.2
00257 2105 86FF LDA A #0FFH ;CURRENT POSITION IS LESS THAN .2 DEGREE
00258 2107 975E STA A 975A9 ;SETS AZ SPEED FLAG WITH CORRECT SPEED
00259 2109 E25030 STA B AZNAG ;STOP AZ ROTOR WITH ZERO SPEED
00260 210C 206A BRA ST0X3

00261 210E 8100 ST0X1 CMP A #0001 ;START <.3 DEGREES TEST
00262 2110 260A BNE ST0A ;BRANCHES TO <.5 DEG. TEST IF BCD WORD NOT <.3
00263 2113 C150 CMP D #050H ;BRANCHES TO <.5 DEG. TEST IF BCD WORD NOT <.5
00264 2114 2205 BIH ST1D ;BRANCHES TO <.5 DEG. TEST IF BCD WORD NOT <.5
00265 2116 88F0 LDA A #78F8D ;SET SPEED TO EIGHTH SPEED
00266 2118 973B STA A SPEEDA ;SET UP SPEED VARIABLE FOR USE LATER
00267 211A 2912 BRA S004H
00268
00269 211C 8104 ST0B CHN A #004H ;START TEST FOR <5.0 DEC
00270 211E 2206 BHI ST0C ;BRANCHES TO <10.0 TEST IF <5.0 TEST FAILS
00271 2120 26E0 LDA A ;#004SPD ;SET SPEED TO QUARTER SPEED
00272 2122 975B STA A SPEEDA ;SET UP SPEED VARIABLE FOR USE LATER
00273 2124 209B LRA ST0D ;BRANCH TO DECISION ROUTINE
00274 2126 5109 ST0C CNF A #009H ;START <10.0 DEC TEST
00275 2128 2204 BHI ST0D ;BRANCH TO DECISION ROUTINE IF TEST FAILS
00276 212A 26F3PD LDA A #1AFSPD ;SET SPEED TO HALF SPEED
00277 212C 975B STA A SPEEDA ;SETS SPEED VARIABLE TO BE USED LATER
00278 212E 9657 ST0D LDA A AKEYS ;DESTINATION NOT REACHED, CHECKS SIGNS
00279 2130 9143 CNF A A2SIGN
00280 2132 270A BEQ SAMEAZ
00281 2134 912B DIFFAZ CNF A #02BH ;DIFFERENT SIGNS
00282 2136 2703 BEQ B2
00283 2138 7E2C0E JMP LEFT
00284 213B 7E2C1B E2 JMP RIGHT
00285 213E 8‘2B SAMEAZ CNF A #02BH ;SAME SIGNS, WHICH ONE IS PLUS
00286 2140 270B BEQ YEASZ
00287 2142 7D0998 00AZ TST CARRY
00288 2144 2803 BNI B3
00289 2146 7E2C0E JMP LEFT
00290 214A 7E2C1B E3 JMP RIGHT
00291 214D 7D0998 YEASZ TST CARRY
00292 2150 2803 BNI B4
00293 2152 7E2C1B JMP RIGHT
00294 2155 7E2C0E B4 JMP LEFT
00295
00296
00297
00298 2156 9638 ST0E LDA A ELKEYS ;TEST TO SEE IF SIGNS ARE THE SAME
00299 215A 2144 CNF A ELSIGN ;BRANCHES IF SIGNS ARE NOT THE SAME
00300 215E 2712 BHI ST0C
00301 2156 9656 LDA A ELKEY+1
00302 2160 9B48 ADD A ELBCD+1 ;FIND LSBYTE OF EL MAG. DIFFERENCE
00303 2162 19 DAA
00304 2164 9760 STA A ELHAG+1
00305 2166 9655 LDA A ELKEY
00306 2167 9947 ADC A ELBCD ;FIND MSBYTE OF EL MAG. DIFFERENCE
00307 2169 19 DAA
00308 216A 9660 LDA B ELHAG+1
00309 216C 975F STA A ELHAG
00310 216E 200E BNE ST0Y
00311 2170 CE0047 ST0Y LDLX #ELBCD ;PUT ADDRESS OF CURRENT ANGLE IN INDEX REG.
00312 2173 9555 LDA A ELKEY
00313 2177 9656 LDA B ELKEY+1
00314 217B DD2AC4 JSR DC2ACS ;JUMPS TO ROUTINE THAT SUBTRACTS BCD NUMBERS
00315 217A 975F STA A ELHAG
00316 217C 9760 STA B ELHAG+1
00317
00318 ;ADDITION TO TIGHTED CONTROL LOOP (ELEVATION) TO .1 DEGREE
00319 217E 0100 ST0Y1 CMP A #00H ;START < 0.2 DEGREE TEST
00322 2163 256E BNE ST0Z ;BRANCHES TO < 0.3 DEGREE TEST IF ANGLE GREATER THAN 0.2 DEGREE
00325 2182 0120 CMP B #20H ;CO9ARES ANGLE TO 0.20 DEGREES
00328 2164 220A BHI ST0Z ;BRANCHES TO < 0.3 DEGREE TEST IF ANGLE GREATER THAN 0.2 DEGREE
00331 2136 06FF LDA A #06H ;POSITIONER NEEDS TO STOP VERY, VERY SOON
00334 2168 976F STA A SplATE ;SETS SPEED Toggle
00337 212A 8702 STA A LAzG1 ;STOPS ELEVATION MOTOR WITH ZERO SPEED
00339 2180 7C34C JRP CPFLAG ;POSITION REACHED, CHECK PROGRAM FLAG
00342 2190 0100 ST0Z CMP A #090H ;START < 0.5 DEG. TEST
00345 2192 260A BHI ST0F ;BRANCH TO < 3.0 DEG. TEST IF COMPAR. FAILS
00348 2194 0150 CMP B #050H ;COMPLETE < 0.5 DEG. TEST
00351 2196 2206 BHI ST07 ;BRANCH TO < 3.0 DEG. IF ACCB IS PLUS
00354 2198 86F0 LDA A #STESPD ;SETS MOTOR SPEED TO EIGHTH SPEED
00357 219A 975C STA A SPEEDS ;SETS SPEED VARIABLE FOR USE LATER
00359 219C 2012 BRA ST0H
00362 219E 0104 STOF CMP A #094H ;START < 3.0 DEG TEST
00365 21AO 2206 BHI ST0G ;BRANCH TO < 10.0 DEG TEST IF ACCA IS PLUS
00368 21A2 80F0 LDA A #QUASPD
00371 21A4 975C STA A SPEEDS ;SET UP SPEED VARIABLE FOR EL MOTOR SPEED
00374 21A6 2006 BRA ST0H ;BRANCH TO DECISION ROUTINE
00377 21A8 8109 ST0G CMP A #090H ;START < 10.0 DEG. TEST
00380 21AA 2204 BHI ST0H ;BRANCH TO DECISION ROUTINE IF ACCA IS PLUS
00383 21AC 60F0 LDA A #HAzPSPD
00386 21AE 975C STA A SPEEDS ;SET UP SPEED VARIABLE FOR HALF SPEED
00389 21B0 855E ST0H LDA A ELzEYS
00392 21B2 8144 CMP A #1z41
00395 21B4 2703 BZQ SAME1
00398 21B6 6128 D0FFL CMP A #02H
00401 21B9 2702 BEQ B3
00404 21BA 2012 BRA B3
00407 21BC 2012 B5 BRA B5
00410 21BE 81C0 SAME1L CMP A #02H
00413 21C0 2709 BEQ YES1L
00416 21C2 7B0920 30EL TST CARRY
00419 21C5 2102 BHI B7
00422 21C7 200A BRA B7
00425 21CA 2605 B6 BRA B6
00428 21CB 7B0928 YES1L TST CARRY
00431 21C8 2103 BHI B7
00434 21D0 7C26FA JRP JFFL
00437 21D3 7C26D6 JRP JFFL
00440 21D6 0040 LDA A #00H ;BEGIN STATE 1, MANUAL DOWN BUTTON
00443 21D9 2012 ST1 LDA A #06H ;BEGIN STATE 1, MANUAL DOWN
00446 21DA 00FF LDA B #06H
00449 21DB B2E2 LSR CPFLAG ;JUMPS TO ROUTINE TO COMMAND ELEVATION MOTOR
00452 21DF 8076 STA A #20H
00455 21E0 170400 STA A DPLA
00458 21E2 0040 LDA A DPRA
00461 21E5 0100 ST0Y1 CMP A #00H ;BEGIN STATE 1, MANUAL DOWN
00464 21E7 06F0 LDA B #06H
00467 21E8 06FF LDA B #06H
00470 21EA B2E2 LSR CPFLAG
00473 21EB 8076 STA A #20H
00476 21F0 170400 STA A DPLA
00479 21F2 0040 LDA A DPRA
BEGIN STATE TWO, MANUAL UP BUTTON

BEGIN STATE THREE, MANUAL LEFT BUTTON

BEGIN STATE FOUR, MANUAL RIGHT BUTTON
I. 4d!s 0

00425
00426: 2237 2500 ST4 LDA A #00FH :BEGIN STATE FOUR, LOAD A WITH SPEED
00427: 2239 C6FF LDA B #OFFH :LOAD B WITH DIRECTION
00428: 223D BD2C6 STA A 90RA
00429: 223E 06D0 STA A 90RA
00430: 2239 872400 STA A 90RA
00431: 223B 06B C3 STA A 90RA
00432: 223C 8166 CIP A #00BH :HAS LEFT KEY BEEN RELEASED?
00433: 223D 2668 BNE STA
00434: 223E BD2936 JSR RSTO :RESTORE KEYBOARD BEFORE READING ANGLES (MOD 1.1)
00435: 223F BD2A6F JSR SHACR :LEFT KEY HAS NOT BEEN RELEASED, SO READ ANGLES
00436: 2240 20EC STA A
00437: 2241 7F0094 ST4B CLR LPL6A :CLEAR LIMIT REACHED FLAG (MOD 1.1)
00438: 2242 C6FF LDA A #00FH
00439: 2243 C6FF LDA B #00FH :CLOCKWISE MOTION
00440: 2244 96 JSR 96Z
00441: 2245 BD2936 JSR RSTO :RESTORE KEYBOARD PIA, THEN BACK TO STATE ZERO
00442: 2246 7E2057 JIP STD
00443: BEGIN STATE FIVE, ERROR STATE

00444:

00445: 2248 CE3098 ST5 LDX #ESC4 :PRINTS "ERROR...INVALID ENTRY"
00446: 2249 BD2C2 JSR ASCDIS :PRINTS ASCII MESSAGE
00447: 224A C60A LDA B #10
00448: 224B BD2E3E JSR WAIT
00449: 224C 7E2007 JIP STD :BACK TO STATE ZERO
00450: BEGIN STATE SIX, ERROR STATE

00451:

00452: 224D CE30C6 ST6 LDX #ESC3
00453: 224E BD2C2 JSR ASCDIS :PRINTS "ANGLE TOO LARGE....."
00454: 224F 7E2002 JIP STD :WAIT 1 SECOND, THEN RETURN TO CONTROL LOOP
00455: BEGIN STATE SEVEN, MESSAGE STATE

00456:

00457: 2250 CE3124 ST7 LDX #ESC1
00458: 2251 BD2C2 JSR ASCDIS :PRINTS "POSITIONER HALTED"
00459: 2252 7E2002 JIP STD :WAIT 1 SECOND, THEN RETURN TO CONTROL LOOP
00460: BEGIN STATE TEN, SET AZ

00461:

00462: 2254 CE3070 ST10 STA A AZEL :REMEMBERS WHICH KEYCODE WAS PRESSED, SETAZ OR SETEL
00463: 2255 CE302A LDY #ESC2
00464: 2256 BD2C2 JSR ASCDIS :PRINTS "ENTER AZIMUTH ANGLE"
00465: 2257 CE0000 LDX #015E+1
00466: 2258 9F32 STX SAVEL :KEEPS TRACK OF WHERE THINGS ARE ON THE DISPLAY
00467: 225A CE315B ST10A LDA A KELOC
00468: 225B E670 JSR KTAC
00469: 225C 7F004D CLR ENTYA :CLEAR S KEYENTRY FLAG
00470: 2257 CE305C LDY #ESC5
00471: 2258 BD2C2 JSR ASCDIS :PRINTS "AZIMUTH"
00472: 2259 CE304D CLR ENTHA :CLEAR 30TH REGISTERS TO BE USED WHEN PACKING ENTRIES
00473: 225A 7F004E CLR ENTYB
00474: 225B
BEGIN STATE ELEVEN, SET EL

ST11 STA A NZCL ; REMEMBERS WHICH KEYPENTRY WAS MADE...SET EL
LDX #$3F-1
JSR ASCDISS ; PRINTS "ELEVATION ANGLE"
LDX #$181S.4+1

ST11A LDA A KFLAG ; WAITS FOR NEXT KEYPENTRY
BPL ST11A
CLR KFLAG ; CLEARS KEYPENTRY FLAG
CLR ENTRYA
JSR ASCDIS ; PRINTS "ELEVATION"

BEGIN STATE TWELVE, DISPLAYS ENTERED PLUS SIGN AND FIRST NUMBER

ST12 LDA A #$02B8 ; BEGINS STATE TWELVE, PLUS SIGN AND MAGNITUDE
LDX #50A0
STA B 0.X
JSR ASCDIS ; DISPLAYS PLUS SIGN
JSR ADRCAL ; INCREMENTS TRACKING POINTING
BPL DBC 0.B ; ROUTINE TO PACK KEYPENTRY
JSR ASCDISS ; CONVERTS BCD CODE TO ASCII CODE
JSR ASCDIS ; ECHOS KEYPENTRY ON THE DISPLAY
INX ; INCREMENTS TRACKING POINTER

ST12A LDA A KFLAG ; WAITS FOR ANOTHER KEYPENTRY
JSR ASCDIS ; CMPS KEYPENTRY FLAG
JSR ASCDISS ; LOADS INDEX REGISTER WITH STATE 12 POINTER
JSR ADRCAL ; CALCULATES THE NEXT ADDRESS
JSR ASCDIS ; ECHOS KEYPENTRY AGAIN
JSR ASCDISS ; LOADS INDEX REGISTER WITH STATE 13 POINTER
JSR ADRCAL ; CALCULATES THE NEXT ADDRESS
JSR ASCDIS ; ECHOS KEYPENTRY AGAIN
JSR ASCDISS ; LOADS INDEX REGISTER WITH STATE 14 POINTER
JSR ADRCAL ; CALCULATES THE NEXT ADDRESS
JSR ASCDIS ; ECHOS KEYPENTRY AGAIN
JSR ASCDISS ; LOADS INDEX REGISTER WITH STATE 15 POINTER
JSR ADRCAL ; CALCULATES THE NEXT ADDRESS
JSR ASCDIS ; ECHOS KEYPENTRY AGAIN
JSR ASCDISS ; LOADS INDEX REGISTER WITH STATE 16 POINTER
JSR ADRCAL ; CALCULATES THE NEXT ADDRESS
JSR ASCDIS ; ECHOS KEYPENTRY AGAIN

BEGIN STATE THIRTEEN, DISPLAYS ENTERED MINUS SIGN

ST13 LDA A #$02B8
LDX #50A0

BEGIN STATE SEVENTEEN, DISPLAYS ENTERED DECIMAL POINT

BEGIN STATE EIGHTEEN, DISPLAYS ENTERED SECOND NUMBER AFTER EITHER + OR -

BEGIN STATE NINETEEN, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE TWENTY, DISPLAYS ENTERED FIRST NUMBER AFTER MINUS SIGN

BEGIN STATE TWENTY-ONE, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE TWENTY-TWO, DISPLAYS ENTERED TWO DIGITS AFTER MINUS SIGN

BEGIN STATE TWENTY-THREE, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE TWENTY-FOUR, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE TWENTY-FIVE, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE TWENTY-SIX, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE TWENTY-SEVEN, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE TWENTY-EIGHT, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE TWENTY-NINE, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE THIRTY, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE THIRTY-ONE, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE THIRTY-TWO, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE THIRTY-THREE, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE THIRTY-FOUR, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

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BEGIN STATE EIGHTY-TWO, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

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BEGIN STATE EIGHTY-FOUR, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE EIGHTY-FIVE, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE EIGHTY-SIX, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

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BEGIN STATE EIGHTY-EIGHT, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE EIGHTY-NINE, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE NINETY, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE NINETY-ONE, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE NINETY-TWO, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE NINETY-THREE, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

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BEGIN STATE NINETY-FIVE, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

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BEGIN STATE NINETY-EIGHT, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE NINETY-NINE, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE HUNDRED, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE HUNDRED-ONE, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE HUNDRED-TWO, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE HUNDRED-THREE, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

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BEGIN STATE HUNDRED-SIX, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE HUNDRED-SEVEN, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE HUNDRED-EIGHT, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE HUNDRED-NINE, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE ONE-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE TWO-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE THREE-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE FOUR-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE FIVE-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE SIX-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE SEVEN-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE EIGHT-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE NINE-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE TEN-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE ELEVEN-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE TWELVE-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE THIRTEEN-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE FOURTEEN-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE FIFTEEN-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE SIXTEEN-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE SEVENTEEN-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE EIGHTEEN-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE NINETEEN-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN

BEGIN STATE TWENTY-THOUSAND, DISPLAYS ENTERED NUMBER AFTER MINUS SIGN
<table>
<thead>
<tr>
<th>Address</th>
<th>Opcode</th>
<th>Operation</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>00384</td>
<td>23B2 C62E</td>
<td>ST16 LDA B #32EH</td>
<td>Moves the decimal point</td>
</tr>
<tr>
<td>00383</td>
<td>2374 D032</td>
<td>LDX SAVEX</td>
<td>Stores tracking pointer</td>
</tr>
<tr>
<td>00382</td>
<td>235E 5700</td>
<td>STA B #0</td>
<td>Increment tracking pointer</td>
</tr>
<tr>
<td>00381</td>
<td>235A 0B</td>
<td>UNX</td>
<td></td>
</tr>
<tr>
<td>00380</td>
<td>23BD DF32</td>
<td>STX SAVEX</td>
<td>Stores tracking pointer</td>
</tr>
<tr>
<td>00379</td>
<td>23BD 966B</td>
<td>LDA A KFLAG</td>
<td></td>
</tr>
<tr>
<td>00378</td>
<td>23BD 2AFF</td>
<td>EPL ST16A</td>
<td></td>
</tr>
<tr>
<td>00377</td>
<td>235F 7F06B</td>
<td>CLR KFLAG</td>
<td></td>
</tr>
<tr>
<td>00376</td>
<td>2352 964F</td>
<td>LDA A KEYENT</td>
<td>Gets keyentry</td>
</tr>
<tr>
<td>00375</td>
<td>2395 CE317</td>
<td>LDX #SP16</td>
<td>Calculates next address</td>
</tr>
<tr>
<td>00374</td>
<td>2397 BE32B</td>
<td>JSR ANIMAL</td>
<td></td>
</tr>
<tr>
<td>00373</td>
<td>23A9 EE06</td>
<td>LDX #0</td>
<td>JMP to next state</td>
</tr>
<tr>
<td>00372</td>
<td>23E9 EE00</td>
<td>JMP</td>
<td></td>
</tr>
<tr>
<td>00371</td>
<td>2397</td>
<td>BEGIN STATE SEVENTEEN</td>
<td>Displays last entered number</td>
</tr>
<tr>
<td>00370</td>
<td>2399</td>
<td>BEGIN STATE 17</td>
<td>Converts keycode to BCD code</td>
</tr>
<tr>
<td>00369</td>
<td>239F 16</td>
<td>TAB</td>
<td></td>
</tr>
<tr>
<td>00368</td>
<td>23A0 BD2A9E</td>
<td>JSR PACK</td>
<td>Packs BCD numbers</td>
</tr>
<tr>
<td>00367</td>
<td>23A3 CB30</td>
<td>ADD B #05H</td>
<td>Converts BCD code to ASCII CODE</td>
</tr>
<tr>
<td>00366</td>
<td>23A5 DE32</td>
<td>LDX SAVEX</td>
<td></td>
</tr>
<tr>
<td>00365</td>
<td>23A7 E700</td>
<td>STA B #0</td>
<td>Increment tracking pointer</td>
</tr>
<tr>
<td>00364</td>
<td>23A9 08</td>
<td>INX</td>
<td></td>
</tr>
<tr>
<td>00363</td>
<td>23AA E31FD</td>
<td>LDA A DECMAR</td>
<td>Displays degree mark after last entered number</td>
</tr>
<tr>
<td>00362</td>
<td>23A0 A700</td>
<td>STA A #0</td>
<td>Increment tracking pointer</td>
</tr>
<tr>
<td>00361</td>
<td>23AF 08</td>
<td>INX</td>
<td></td>
</tr>
<tr>
<td>00360</td>
<td>23E0 0F22</td>
<td>STX SAVEX</td>
<td></td>
</tr>
<tr>
<td>00359</td>
<td>23E2 9661</td>
<td>LDA A AZEL</td>
<td></td>
</tr>
<tr>
<td>00358</td>
<td>23E4 BF1E</td>
<td>CMP A #01EH</td>
<td>Test to see if set el was entered</td>
</tr>
<tr>
<td>00357</td>
<td>23EE 2711</td>
<td>DEQ ST17A</td>
<td>Stores entered data into appropriate AZ registers</td>
</tr>
<tr>
<td>00356</td>
<td>23E6 9662</td>
<td>LDA A TEMPS</td>
<td></td>
</tr>
<tr>
<td>00355</td>
<td>23EB 9737</td>
<td>STA A AZEYES</td>
<td></td>
</tr>
<tr>
<td>00354</td>
<td>23EC 964B</td>
<td>LDA A ENTRYYA</td>
<td></td>
</tr>
<tr>
<td>00353</td>
<td>23EF B41E</td>
<td>LDA B ENTRYY</td>
<td></td>
</tr>
<tr>
<td>00352</td>
<td>23F0 D295E</td>
<td>JSR TS17AG</td>
<td>Test for entry angle &gt; 40.1</td>
</tr>
<tr>
<td>00351</td>
<td>23F3 D24D</td>
<td>LDX ENTRYYA</td>
<td></td>
</tr>
<tr>
<td>00350</td>
<td>23F5 2553</td>
<td>STS AZEY</td>
<td></td>
</tr>
<tr>
<td>00349</td>
<td>23F7 2011</td>
<td>LDX ST17C</td>
<td></td>
</tr>
<tr>
<td>00348</td>
<td>23F9 9662</td>
<td>LDA A TEMPS</td>
<td>Stores entered data into appropriate EL registers</td>
</tr>
<tr>
<td>00347</td>
<td>23FB 9735</td>
<td>STA A AZEYES</td>
<td></td>
</tr>
<tr>
<td>00346</td>
<td>23FC 964B</td>
<td>LDA A ENTRYYA</td>
<td></td>
</tr>
<tr>
<td>00345</td>
<td>23FD D41E</td>
<td>LDA B ENTRYY</td>
<td></td>
</tr>
<tr>
<td>00344</td>
<td>23FE D295E</td>
<td>JSR TS17AG</td>
<td></td>
</tr>
<tr>
<td>00343</td>
<td>23FF B41E</td>
<td>LDA B ENTRYY</td>
<td></td>
</tr>
<tr>
<td>00342</td>
<td>2400 2000</td>
<td>BRA ST17C</td>
<td></td>
</tr>
<tr>
<td>00341</td>
<td>23DA 966B</td>
<td>ST17C LDA A KFLAG</td>
<td>Waits for start key to be pressed</td>
</tr>
<tr>
<td>00340</td>
<td>23DA 2AFF</td>
<td>EPL ST17C</td>
<td></td>
</tr>
<tr>
<td>00339</td>
<td>23EE 7F06B</td>
<td>CLR KFLAG</td>
<td>Gets keyentry</td>
</tr>
<tr>
<td>00338</td>
<td>23F1 964F</td>
<td>LDA A KEYENT</td>
<td>Loads index register with state 17 pointer</td>
</tr>
<tr>
<td>00337</td>
<td>23F3 CE33F</td>
<td>LDX #017</td>
<td></td>
</tr>
<tr>
<td>00336</td>
<td>23F6 0F00</td>
<td>LDX #0</td>
<td></td>
</tr>
</tbody>
</table>
00637 23EB 6E80  JMP O,X  JUMPS TO NEXT STATE
00638  
00639  :  BEGIN STATE EIGHTEEN, GO TO MOTOR CONTROL LOOP
00640  
00641  23ED 7F0099  ST18  CLR MFLAG ; CLEARS MOTOR FLAG
00642  23F0 7F0098  CLR LFLAG ; CLEAR LIMIT REACHED FLAG
00643  23F0 7F0094  CLR LFLAG
00644  23F0 7E20B7  JMP ST9
00645  :  BEGIN STATE NINETEEN, DISABES CONTROL LOOP
00646  
00647  (MODIFICATION 1.1)
00648  
00649  23FO 86FF  ST19  LDA A #OFF  ; SETS THE MOTOR FLAG SO THAT THE CYC. LOOP IS DISABLED
00650  23FB 9759  STA MFLAG
00651  23FB D228B  JSR MLSTOP
00652  2400 7F0094  TST LFLAG ; CHECK FOR AZIMUTH LIMIT REACHED
00653  2403 2716  BSR ST19A ; BRANCHES IF AZ LIMIT NOT REACHED
00654  2405 4F  CLR A ; AZ LIMIT HAS BEEN REACHED
00655  2406 D66C  LDA B BFLAG ; GET CURRENT DIRECTION STATUS
00656  2408 33  CON B ; GET OPPOSITE DIRECTION
00657  2409 B22D86  JSR MTAL ; AZ MOTOR CONTROL SUBROUTINE
00658  240C C696  LDA B #10
00659  240E B02E3E  JSR WAITE ; ALLOW TIME FOR AZ MOTOR TO REPOSITION GIMBAL
00660  2411 86FF  LDA A #OFF
00661  2417 D66C  LDA B BFLAG
00662  241E D22D86  JSR MTAL ; STOP MOTOR IF LIMIT NOT EXCEEDED ANYMORE
00663  241E 7E20B7  JMP ST9 ; GO BACK TO CONTROL LOOP
00664  241F 7F0094  ST19A  CLR LFLAG ; CHECK FOR ELEVATION LIMIT EXCEEDED
00665  241E 7F0093  TST LFLAG
00666  2421 2719  BEQ ST19B ; BRANCHES IF EL LIMIT NOT EXCEEDED
00667  2423 4F  LDA A ; EL LIMIT HAS BEEN REACHED
00668  2424 D66D  LDA B BFLAGE ; GET CURRENT DIRECTION STATUS
00669  2426 53  CON B ; GET OPPOSITE DIRECTION
00670  2427 B22D82  JSR MTEL ; EL MOTOR CONTROL SUBROUTINE
00671  242A C69A  LDA B #10
00672  242C B02E3E  JSR WAITE ; ALLOW TIME FOR EL MOTOR TO REPOSITION GIMBAL
00673  242C E5FF  LDA A #OFF
00674  2431 D66D  LDA B BFLAGE  ; STOP EL MOTOR IF LIMIT NOT EXCEEDED ANYMORE
00675  2433 B22D82  JSR MTEL
00676  2436 7F0093  CLR LFLAG
00677  2437 7E20B7  JMP ST9 ; RETURN CONTROL TO ST9
00678  2436 7E2299  ST19B  JMP ST7 ; DISPLAYS "POSITIONER HALTED ", WAITS 1 SEC, THEN ST9
00679  
00680  :  BEGIN STATE TWENTY, INPUT BCD PARAMETERS FOR PROGRAMMED RASTER SCANS
00681  
00682  243F CE30FC  ST20  LDN #ESC ; PRINTS "ENTER PRC NUMBER"
00683  2442 CE32C2  JSR ANODS
00684  2435 CE600F  LPX #1821+5
00685  2446 UF32  STX SAVEX
00686  244A 766B  ST20A  LDA A KFLAG ; WAITS FOR ANOTHER KEYPRESS
00687  2450 2AFC  BPL ST20A
00688  244E 7F006B  CLR KFLAG ; CLEARS THE ENTRY FLAG
00689  2451 7F004D  CLR ENTRIA
BEGIN STATE TWENTY-ONE, DISPLAYS PROGRAM NUMBER

BEGIN STATE TWENTY-TWO, DISPLAYS FIRST NUMBER OF ONE

BEGIN STATE TWENTY-THREE, DISPLAYS SECOND NUMBER OF ONE

BEGIN STATE TWENTY-FOUR, CONVERTS KEYCODE TO BCD CODE

BEGIN STATE 23, CONVERTS KEYCODE TO BCD CODE

PACKS ENTERED BCD NUMBERS
00743 24AF CB30 ADD B #$0BH
00744 24B1 BE32 LDX $AVEX
00745 24B3 E700 STA B 0.X ;ECOES ENTERED BCD NUMBER
00746 24B5 58 INX
00747 24B6 LF3C STX $AVEX
00748 24BB 966B ST23A LDA A KFAC
00749 24BA 2AFC BPL ST23A ;WAITS FOR ANOTHER KEYENTRY
00750 24BC 7FC6B CLR $FAC ;CLES KEYENTRY FLAG
00751 24BF 964F LDA A KEYEN ;GETS KEYENTRY
00752 24C1 CE3DF LDX $FAC ;LOADS INDEX REGISTER WITH STATE 23 POINTER
00753 24CA BE2DE5 JSR ADDCAL
00754 24C7 EE00 LDY 0.X
00755 24C9 0600 JMP 0.X ;JUMPS TO NEXT STATE
00756 24C8 0600
00757 24C8 0600
00758 24CD G62E ST24 LDA B #$0CEH
00760 24CD BE32 LDY $AVEX
00761 24CF E700 STA D 0.X ;ECOES DECIMAL POINT
00762 24D1 00 INY
00763 24D2 BF32 STX $AVEX
00764 24D4 966B ST24A LDA A KFAC
00765 24D6 2AFC BPL ST24A ;CLES KEYENTRY FLAG
00766 24D8 7FC06B CLR $FAC ;GETS KEYENTRY
00767 24DB 964F LDA A KEYEN ;CALCULATES NEXT ADDRESS
00768 24DD CE3407 JSR ADDCAL
00769 24EE BE2DE5 LDX 0.X ;JUMPS TO NEXT STATE
00770 24E3 EE00 JMP 0.X
00771 24E5 EE00
00772 24E7 44 ST25 LSR A
00777 24ED 16 TAB
00778 24E9 D0CATE JSR PACK
00779 24EC CE30 ADD B #$0CH ;PACKS BCD NUMBERS
00780 24EE E232 LDY $AVEX ;CONVERTS BCD TO ASCII
00781 24F0 E700 STA B 0.X ;ECOES ENTERED NUMBER
00782 24F2 00 INY
00783 24F3 F631FD LDA B DECMARK
00784 24F6 EE00 STA 0.X ;INCLUDES DEGREE MARK
00785 24FB CE00F $INV=+3
00786 24FD BF32 STX $AVEX ;STORES TRACING POINTER
00787 24FD 9665 LDA A PROCL
00788 24FF 0142 GEP A #$52H ;BRANCH IF PROCL IS A "B"
00789 2501 2754 BEG ST23D
00790 2503 84D GEP A #$42H ;BRANCH IF PROCL IS A "C"
00791 2505 2756 BEG ST23C
00792 2507 964D LDA A ENTRYA
00793 2509 D64E LDA B ENTRYB
00794 250D 9765 STA A P00GA+1
00795 250D 9765
00796 250D 9765
ADDENDUM TO ST25:

CHECKS TO SEE IF PROC = 3 OR = 4 IS
BEING IMPLEMENTED.

DECLARATION 1.1

ADDITION TO ST25:

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BEING IMPLEMENTED.

DECLARATION 1.1
00849: (MODIFICATION 1.1)
00850:
00851 2578 9663 ST00 LDA A #00GH ;GET PROGRAM NUMBER
00852 257A B151 CMP A #011H
00853 257C 270B BEQ ST001 ;BRANCHES IF CURRENTLY IN PROC #1
00854 257E 0132 JMP A #22H ;BRANCHES IF CURRENTLY IN PROC #2
00855 2583 270A BEQ ST002 ;BRANCHES IF CURRENTLY IN PROC #3
00856 2584 2704 :BRANCHES IF CURRENTLY IN PROC #3
00857 2586 7E27A1 JMP ST29
00858 2589 7E2392 ST001 JMP ST26 ;GO TO PROGRAM #1
00859 258C 7E2395 ST002 JMP ST27 ;GO TO PROGRAM #2
00860 258F 7E2797 ST003 JMP ST30 ;GO TO PROGRAM #3
00861:
00862: BEGIN STATE TWENTY-SIX, PATTERN NUMBER ONE
00863: (MODIFICATION 1.1)
00864:
00866 2592 7F0039 ST26 CLR EFLAC
00867 2595 9665 LDA A #00CA ;GETS TWO-BYTE RASTER PARAMETER "A"
00868 2597 B266 LDA B #00CA+1
00869 2599 9753 STA A #AZKE ;ENTERS AZIMUTH PART OF FIRST POINT
00870 259B B754 STA B #AZKE+1
00871 259D F631FA LDA A #MINS ;ENTERS SIGN OF AZIMUTH PART OF FIRST POINT
00872 25A0 D757 STA A #AZKEY
00873 25A2 9669 LDA A #PROGC ;ENTERS SIGN OF AZIMUTH PART OF FIRST POINT
00874 25A4 066A LDA B #PRGC+1
00875 25A6 9774 STA A #FPTEL ;SAVES TWO-BYTE ANSWER
00876 25A8 D755 STA B #FPTEL+1
00877 25AA 9755 STA A #ELEY ;ENTERS ELEVATION PART OF FIRST POINT
00878 25AC D756 STA B #ELEY+1
00879 25AE F631FB LDA A #PLUS
00880 25B1 D75G STA A #EKEY ;ENTERS SIGN OF ELEVATION PART OF FIRST POINT
00881 25B3 D77B STA B #EKEY+1 ;SAVES VALUE OF ELEVATION
00882 25B5 CE25C0 LDY #ST26A ;SAVES RETURN ADDRESS
00883 25B9 DF7B STX #ST26A ;SAVES RETURN ADDRESS
00884 25BA 7F007A LDA A #PROCT ;CHECKS PROGRAM STATE COUNTER
00885 25BB 06FF LDA B #FFH ;SETS PROGRAM FLAG
00886 25BF D77D STA B #FFH ;GO TO CONTROL LOOP, ANTICIPATE RETURN
00887 25C1 7E20B7 JMP ST0 ;GO TO CONTROL LOOP, ANTICIPATE RETURN
00888 25C5 B644 ST26A LDA A EFLAC
00889 25C9 F131FA CIP B MINS ;CHECKING CURRENT STATUS OF POSITION
00890 25CD 260E BNE ST26A1 ;BRANCHES IF HLS RASTER IS NOT DONE
00891 25CD 9674 LDA A #FPTEL
00892 25CD D575 LDA B #FPTEL+1
00893 25CF CE30C7 LDY #L3BCD
00894 25D2 0034 JSK BCD9 ;COMPARES CURRENT POSITION TO RASTER LIMIT
00895 25D5 0056 LDA A #CARRY
00896 25D7 2976 BHI ST26A ;BRANCHES IF RASTER LIMIT REACHED
00897 25D9 065A ST26A1 LDA A #PROCT
00898 25DA F131FA CIP B #01H ;CHECKS STATUS OF PROGRAM COUNTER
00899 25E1 2756 BNE ST26A ;BRANCHES IF THIRD POINT OF SCAN NEEDED
0089A 25E4 0503 CIP B #03 ;BRANCHES OF FIFTH POINT OF SCAN NEEDED
00902 25E3 9643 LDA A AZSIGN
00903 25E5 012B CMP A #2BH
00904 25E7 2064 BNE NEG1
00905 25E9 8629 LDA A #2BH
00906 25EA 2092 BRA FIN
00907 25EB 8629 LDA A #2BH
00908 25EC 9757 FIN STA A AZKEYS
00909 25F1 7C007A INC PROCNT ; INCREMENTS PROGRAM STATE COUNTER
00910 25F4 7E20B7 JMP STO ; GO TO CONTROL LOOP, EXPECTING A RETURN
00911 25F7 B64A ST26B LDA B ELIGIN
00912 25F9 181FB CMP B #UH
00913 25FA 261A BNE ST26B1 ; BRANCHES IF IN THE PLUS SIDE
00914 25FB 9647 LDA A ELBCD ; ELIGIN IS MINUS, SO SUBTRACT
00915 25FC 2600 LDA B ELBCD+1 ; GET CURRENT POSITION
00916 2600 2606 CL0067 LDX #PROCB
00917 2607 2D2AC4 JSR BCDSUB ; ENTER IN THIRD POINT
00918 2609 9755 STA A ELKEY
00919 260A 2D26 STA B ELKEY+1 ; TEST TO SEE WHICH NUMBER IS BIGGER
00920 260C 7D009B TST CARRY ; BRANCHES IF ANSWER STILL PLUS
00921 260D 2611 BEQ ST26B2 ; BRANCHES IF ANSWER STILL PLUS
00922 2611 B631FA LDA A MINUS ; ANSWER IS MINUS
00923 2612 2614 STA A ELKEY
00924 2615 201D BRA ST26B2
00925 2616 2D26 STA B ELKEY+1 ; ELIGIN IS MINUS, SO ADD
00926 2618 9D68 ADD A PROCB+1
00927 2619 361  DAA
00928 261A 9755 STA A ELKEY+1 ; ENTER IN THIRD POINT
00929 261B 261F LDA A ELBCD
00930 261C 9967 ADC A PROCB
00931 261D 2622 DAA
00932 2623 9755 STA A ELKEY ; ENTER IN THIRD POINT
00933 2624 262F LDA A ELKEY
00934 2625 9655 LDA B ELKEY+1 ; CHECK TO SEE IF RASTER IS FINISHED
00935 2626 262A C06074 LDX #PETEL
00936 262B 2D2AC4 JSR BCDSUB
00937 262C 7D009B TST CARRY ; CHECK FOR SUBTRACTION OVERFLOW
00938 262D 2633 BNE ST26E ; BRANCHES IF RASTER IS FINISHED
00939 2634 2635 7C007A INC PROCNT ; INCREMENT PROGRAM STATE COUNTER
00940 2635 967A LDA A PROCNT
00941 2636 8104 CMP A #44H ; IS THIS CALCULATING 5TH POINT
00942 2637 2603 BNE ST26B3 ; BRANCHES IF CALCULATING 5TH POINT
00943 2638 7F000A CLR PROCNT ; CLEAR COUNTER TO RESTART SCAN PERIOD
00944 2639 2641 LDX S ST26B3 ; GO TO CONTROL LOOP, EXPECT A RETURN
00945 263A 263B LDA A MINUS ; CALCULATES 4TH POINT
00946 263B 9757 STA A AZKEYS
00947 263C 7C007A INC PROCNT ; INCREMENT PROGRAM STATE COUNTER
00948 263D 264C JMP STO ; GO TO CONTROL LOOP, EXPECT A RETURN
00949 263E 7F007D CLR PFLAG ; CLEAR PROGRAM FLAG
00950 263F 2E20B7 JMP STO ; GO TO CONTROL LOOP, DON'T COME BACK
00951
00952 ; BEGIN STATE TWENTY-SEVEN, PATTERN NUMBER TWO
00953 ; (MODIFICATION 1.1)
00955 2653 7F0059  ST27  CLR  McLAC  ;GETS TWO-BYTE RASTER PARAMETER "A"
00956 2655 2656 9665  LDA A  P'26CA
00957 2655 2655 2666  LDA B  1.26GA+1
00958 2655 2655 9776  STA A  FPTAZ
00959 2655 2655 9777  STA B  FPTAZ+1
00960 2660 2660 9753  STA A  AZKEY
00961 2662 2662 9754  STA B  AZKEY+1
00962 2664 2664 2665 F631FA  LDA B  MINUS
00963 2667 2667 2667 D757  STA B  AZKEYS
00964 2667 2667 2667 D779  STA B  FPTAZS
00965 2667 2667 2667 D669  LDA A  PROCQ
00966 2667 2667 2666 266A  LDA B  PROCQ+1
00967 266F 266F 266F 9755  STA A  ELKEY
00968 266F 266F 266F D755  STA B  ELKEY+1
00969 266F 266F 266F 2673  LDA B  PLUS
00970 266F 266F 266F 267D  STA B  ELKEY
00971 266F 266F 266F 2677  LDA B  ELKEY
00972 267B 267B 267B 2687  CLR  PROCT
00973 267D 267D 267D 2687  LDX  #ST27A
00974 267D 267D 267D 2687  STX  STADDR
00975 267D 267D 267D 2687  LDA B  #OFFH
00976 2683 2683 2683 D755  STA B  FFLAG
00977 2683 2683 2683 2683 D703  JMP  STO
00978 2683 2683 2683 2687  ST27A  LDA B  AZSIGN
00979 2683 2683 2683 2683 2691  CMP  B  PLUS
00980 2683 2683 2683 2683 2691  BNE  ST27A
00981 2683 2683 2683 2683 2691  LDA B  FPTAZ
00982 2683 2683 2683 2683 2691  LDX  #22CD
00983 2683 2683 2683 2683 2691  JSR  EC0SUB
00984 2683 2683 2683 2683 2691  JMP  TST
00985 2683 2683 2683 2683 2691  CAB
00986 2683 2683 2683 2683 2691  TST  Carr
00987 2683 2683 2683 2683 2691  BRZ  ST27B
00988 2683 2683 2683 2683 2691  BRN  ST27C
00989 2683 2683 2683 2683 2691  CMP  B  #21H
00990 2683 2683 2683 2683 2691  BNE  ST27D
00991 2683 2683 2683 2683 2691  CMP  B  #33H
00992 2683 2683 2683 2683 2691  BNE  ST27E
00993 2683 2683 2683 2683 2691  LDA B  HIUS
00994 2683 2683 2683 2683 2691  STA B  ELKEYS
00995 2683 2683 2683 2683 2691  INC  PROCT
00996 2683 2683 2683 2683 2691  STO  ST27E
00997 2683 2683 2683 2683 2691  JMP  STO
00998 2683 2683 2683 2683 2691  BRZ  ST27B
00999 2683 2683 2683 2683 2691  BRN  ST27C
01000 2683 2683 2683 2683 2691  BEQ  ST27D
01001 2683 2683 2683 2683 2691  BEQ  ST27E
01002 2683 2683 2683 2683 2691  LDA A  AZCST
01003 2683 2683 2683 2683 2691  JMP  TST
01004 2683 2683 2683 2683 2691  JSR  EC0SUB
01005 2683 2683 2683 2683 2691  JSR  EC0SUB
01006 2683 2683 2683 2683 2691  STA B  AZKEY+1
01007 2683 2683 2683 2683 2691  JSR  TST
01008 2683 2683 2683 2683 2691  JSR  TST
01009 2683 2683 2683 2683 2691  JSR  ST27B
01000 26D9 BE31FB LDA A PLUS  : ANSWER IS MINUS
01009 26D3 8757 STA A AZKEYS
01010 26D6 291D BRA ST27B2 : BRANCH AROUND ADD ROUTINE
01011 26D7 9646 ST27B1 LDA A AZBCD+1 : AZSIGN IS PLUS, SO ADD
01012 26D9 9666 ADD A PROGB+1
01013 26DB 19 DAA
01014 26D8 9754 STA A ENTER IN THIRD POINT
01015 26DE 9645 LDA A AZBCD
01016 26F0 9945 ADC A AZBCD
01017 26F2 9653 STA A ENTER ITN THIRD POINT
01018 26F5 9655 LDA A AZKEY : BEGIN RASTER LIMIT TEST
01019 26F7 9655 LDA A AZKEY+1 : GET NEXT POINT
01020 26F9 C50076 LDX *FPTAZ : GET END POINT
01021 35EC 22A600 JSR ECPSUB : NEXT POINT MINUS END POINT
01022 36EF 7D0096 TST CARRY : CHECK FOR WHICH IS DOMINANT
01023 26F2 281D BNE ST27E : BRANCHES IF SCAN IS FINISHED
01024 26F4 7C007A ST27B2 INC PROGNT : INCREMENT PROGRAM STATE COUNTER
01025 26F7 967A LDA A PROGNT
01027 26F9 B104 CMP A #04H : IS THIS CALCULATING 3RD POINT
01029 26FD 2811 BNE ST27D : BRANCHES IF THIS IS TRUE
01029 26FD 7C007A CLR PROGNT : IS CALCULATING 3RD POINT
01030 2700 7E2641 ST27B3 JMP STO : GO TO CONTROL LOOP, EXPECT A RETURN
01031 2703 D631FB ST27C LDA A PLUS : GO TO CONTROL LOOP, EXPECT A RETURN
01032 2706 9758 STA A ELKEYS
01033 2708 7C007A INC PROGNT : INCREASES PROGRAM STATE COUNTER
01034 270D 7E2637 JMP STO : GO TO CONTROL LOOP, EXPECT A RETURN
01035 270F 7E2641 ST27D JMP ST26B3
01036 2711 7F0017 ST27E CLR POLAG : CLEAR PROGRAM FLAG
01037 2714 7F2607 JMP STO : GO TO CONTROL LOOP, DON'T COME BACK
01038 2717
01039 2717
01040 2717
01041
01042
01043
01044 2717 7F007F ST28 CLR PROANG : INITIALIZE ANGLE COUNTER
01045 2717
01046 271D 7F0063 CLR COSINE : INITIALIZE TWO-BYTE VALUES
01047 2720 7F0033 CLR SINE
01048 2723 9665 LDA A PROCA : GET ANGLE
01049 2725 8666 LDA B PROCA+1
01050 2727 54 LSR B
01051 2729 54 ROR A
01052 272A 54 LSR B
01053 272B 54 ROR A
01054 272C 54 LSR B
01055 272D 54 ROR A
01056 272E 54 LSR B
01057 272F B329EB JSR BC2BIN : CONVERT THIS BCD VALUE TO BINARY
01058 2732 97B1 STA A BINANG : SAVE TWO-BYTE RESULT
01059 2734 B7C2 STA B BINANG+1

In the next section...

BEGIN STATE TWENTY-EIGHT, PATTERN NUMBER THREE
ENTER ANGLE LESS THAN 180 DEGREES TO SEPARATE SCANS
PROGRAM WILL GENERATE 360 DEGREES OF RASTER SCANS

(MODIFICATION 1.1)
BEGIN STATE TWENTY-NINE, PATTERN NUMBER FOUR

ENTER RADIUS (IN DEGREES) OF CIRCLE

PROGRAM WILL GENERATE ONE CIRCLE WITH RADIUS "A"

BEGIN STATE TWENTY-NINE, PATTERN NUMBER FOUR

ENTER RADIUS (IN DEGREES) OF CIRCLE

PROGRAM WILL GENERATE ONE CIRCLE WITH RADIUS "A"
<table>
<thead>
<tr>
<th>Address</th>
<th>Assembly Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01167</td>
<td>BPL ST30A</td>
<td>WAITS FOR KEY ENTRY</td>
</tr>
<tr>
<td>01168</td>
<td>BPL ST30A</td>
<td>KEY IS PRESSED; CLEAR KEYENTRY FLAG</td>
</tr>
<tr>
<td>01169</td>
<td>LDA A KEVENT</td>
<td>GET KEY ENTRY</td>
</tr>
<tr>
<td>01170</td>
<td>LDN $6760</td>
<td>LOADS INDEX REGISTER WITH STATE 30 POINTER</td>
</tr>
<tr>
<td>01171</td>
<td>JSR ADDCAL</td>
<td>SUBROUTINE CALCULATES NEXT ADDRESS</td>
</tr>
<tr>
<td>01172</td>
<td>LDN 0.X</td>
<td>JUMPS TO CALCULATED ADDRESS OF NEXT STATE</td>
</tr>
<tr>
<td>01173</td>
<td>JSR ENTURYA</td>
<td>JUST RETURNED FROM ENTERING NELLIN</td>
</tr>
<tr>
<td>01175</td>
<td>STX PELLIN</td>
<td>UPDATE NEGATIVE ELEVATION LIMIT</td>
</tr>
<tr>
<td>01176</td>
<td>BRA ST30A</td>
<td>BRANCH TO WAIT ON NEXT KEY ENTRY</td>
</tr>
<tr>
<td>01177</td>
<td>BEGIN STATE THIRTY-ONE, SET POSITIVE ELEVATION LIMITS</td>
<td></td>
</tr>
<tr>
<td>01179</td>
<td>MODIFICATION 1.1</td>
<td></td>
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<tr>
<td>01180</td>
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<tr>
<td>01181</td>
<td>LDN $66C7</td>
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<td>01182</td>
<td>JSR ASCD15</td>
<td>DISPLAYS &quot;POS EL LIMIT&quot;</td>
</tr>
<tr>
<td>01183</td>
<td>LDX $0010</td>
<td>DISEL+6</td>
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<tr>
<td>01185</td>
<td>STX SAVEX</td>
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<tr>
<td>01186</td>
<td>LDA A PELLIN</td>
<td>GET POSITIVE ELEVATION LIMIT</td>
</tr>
<tr>
<td>01186</td>
<td>LDA B PELLIN+1</td>
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<tr>
<td>01187</td>
<td>JSR RCD115</td>
<td>DISPLAYS CURRENT POSITIVE ELEVATION</td>
</tr>
<tr>
<td>01189</td>
<td>JSR MOVED</td>
<td></td>
</tr>
<tr>
<td>01190</td>
<td>STX STADD</td>
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</tr>
<tr>
<td>01191</td>
<td>LDA A KFLAG</td>
<td>SAVES RETURN ADDRESS</td>
</tr>
<tr>
<td>01192</td>
<td>BPL ST31A</td>
<td>WAITS FOR KEY ENTRY</td>
</tr>
<tr>
<td>01193</td>
<td>LDA A KEVENT</td>
<td>KEY IS PRESSED, CLEAR KEYENTRY FLAG</td>
</tr>
<tr>
<td>01194</td>
<td>LDN $6761</td>
<td>LOADS INDEX REGISTER WITH STATE 31 POINTER</td>
</tr>
<tr>
<td>01196</td>
<td>JSR ADDCAL</td>
<td>SUBROUTINE CALCULATES NEXT ADDRESS</td>
</tr>
<tr>
<td>01197</td>
<td>LDN 0.X</td>
<td>JUMPS TO CALCULATED ADDRESS OF NEXT STATE</td>
</tr>
<tr>
<td>01199</td>
<td>JSR ENTURYA</td>
<td>JUST RETURNED FROM ENTERING PELLIN</td>
</tr>
<tr>
<td>01200</td>
<td>STX PELLIN</td>
<td>UPDATE POSITIVE ELEVATION LIMIT</td>
</tr>
<tr>
<td>01201</td>
<td>BRA ST31A</td>
<td>BRANCHES TO WAIT ON NEXT KEY ENTRY</td>
</tr>
<tr>
<td>01202</td>
<td>BEGIN STATE THIRTY-TWO, SET NEGATIVE AZIMUTH LIMIT</td>
<td></td>
</tr>
<tr>
<td>01204</td>
<td>MODIFICATION 1.1</td>
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<tr>
<td>01206</td>
<td>LDN $66C8</td>
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<tr>
<td>01207</td>
<td>JSR ASCD15</td>
<td>DISPLAYS &quot;NEG AZ LIMIT&quot;</td>
</tr>
<tr>
<td>01208</td>
<td>LDX $0010</td>
<td>DISEL+6</td>
</tr>
<tr>
<td>01209</td>
<td>STX SAVEX</td>
<td>SAVES DISPLAY TRACKING POINTERS</td>
</tr>
<tr>
<td>01210</td>
<td>LDA A NAZLIN</td>
<td>GET POSITIVE ELEVATION LIMIT</td>
</tr>
<tr>
<td>01211</td>
<td>LDA B NAZLIN+1</td>
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</tr>
<tr>
<td>01212</td>
<td>JSR RCD115</td>
<td>DISPLAY CURRENT NEGATIVE AZIMUTH LIMIT</td>
</tr>
<tr>
<td>01213</td>
<td>JSR MOVED</td>
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<tr>
<td>01214</td>
<td>LDN $003B</td>
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<tr>
<td>01215</td>
<td>STX ST32B</td>
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</tr>
<tr>
<td>01216</td>
<td>LDA A KFLAG</td>
<td>SAVES RETURN ADDRESS</td>
</tr>
<tr>
<td>01217</td>
<td>BPL ST32A</td>
<td>WAITS FOR KEY ENTRY</td>
</tr>
<tr>
<td>01218</td>
<td>LDA A KEVENT</td>
<td>KEY IS PRESSED, CLEAR KEYENTRY</td>
</tr>
<tr>
<td>01219</td>
<td>LDA A KEVENT</td>
<td>GET KEY ENTRY</td>
</tr>
</tbody>
</table>
BEGIN STATE THIRTY-THREE, SET POSITIVE AZIMUTH LIMIT

BEGIN STATE THIRTY-FOUR, INPUT NUMBERS FOR SETTING LIMITS--1ST
BEGIN STATE THIRTY-FIVE, INPUT BCD CHARACTER NUMBER TWO

BEGIN STATE THIRTY-SIX, INPUT DECIMAL POINT

BEGIN STATE THIRTY-SEVEN, INPUT LAST BCD CHARACTER

"RESTO" SUBROUTINE
01326  THIS SUBROUTINE RETURNS THE KEYBOARD TO AN INITIALIZED STATE
01327  SO THAT ANY KEY PRESS WILL GENERATE AN INTERRUPT.
01330  2936  06F
01330  2933  B72:99
01331  293B  B69400
01332  293E  86FF
01333  2940  9759
01334  2942  39
01335  2943  9612
01336  2945  C62E
01337  2947  0713
01338  2949  0713
01339  294B  39
01340  MOVED LDA A DISEL+8
01341  LDA #.6H
01342  STA B DISEL+8
01343  STA A DISEL+9
01344  RTS
01345  "CPFLAG" ROUTINE
01346  (MODIFICATION 1.1)
01347  THIS ROUTINE IS REACHED ONLY AFTER POSITIONER HAS STOPPED
01348  CHECKS PROGRAM FLAG (PFLAG) TO SEE IF IT IS CURRENTLY IN
01349  A PROGRAMMED SEQUENCE.
01350  294C  966E
01351  GPF I A SFLAG
01352  CMP A #OFFH
01353  2950  2609
01354  2952  78007D
01355  TST PFLAG ;LOOKS AT PROGRAM FLAG
01356  2953  2704
01357  BNE GPIO ;BRANCHES TO CONTROL LOOP IF NOT IN A PROGRAMMED SEQUENCE
01358  2957  0E7E
01359  TST 0, 3 ;YES, A PROGRAMMED SEQUENCE IS CURRENTLY IN OPERATION
01360  2959  8600
01361  JSP 0, G ;JUMPS BACK TO THE PROGRAMMED CONTROL ROUTINE.
01362  295B  7E2937
01363  CPI JFP ;PROGRAM FLAG CLEARED, GO TO CONTROL LOOP
01364  295E  CE31F6
01365  TS/TARG LDX #.LIMIT
01366  2961  BCBAC4
01367  2965  780098
01368  2967  2203
01369  2969  7E2930
01370  296C  39
01371  NOPE RTS
01372  "BCMPY" SUBROUTINE
01373  REVISION 2.1
01374  MULTIPLIES TWO PACKED BCD (16-BIT) VALUES
01375  RC-ENTRANCE CODE (USES 7 BYTES ON STACIO
01376  ACCA, ACCB TIMES (X*Y) ACCC
01377  RESULT IN ACCA, ACCB
01378  "MODIFICATION 1.1"
01379  296D  37
01380  BCDMPY PST B ;PUSH MULTIPLIER INTO STACK
01381  296E  36
01382  PSR A
10379 296F A601  LDA A 1.X
10380 2971 36  PSH A  ;PUSH MULTIPLICAND ONTO STACK
10381 2972 A600  LDA A 0.X
10382 2974 36  PSH A
10383 2975 5610  LDA A  #16
10384 2977 36  PSH A  ;TRANSFERS BIT-COUNTER ONTO STACK
10385 2978 20  TSX  ;TRANSFERS STACK ADDRESS TO INDEX REGISTER
10386  : STACK NOW LOOKS LIKE
10387  : +0 COUNT
10388  : +1 NS BYTE OF MULTIPLICAND
10389  : +2 LS BYTE
10390  : +3 NS BYTE OF MULTIPLIER
10391  : +4 LS BYTE
10392  : +5 NS BYTE OF RETURN ADDRESS
10393  : +6 LS BYTE
10394 2979 A603  LDA A 2.X
10395 297E 53  ASL B  ;FORX RESULT
10396 297F 49  ROL A  ;SHIFT MULTIPLICAND
10397 2973 6802  ASL 2.X  ;SHIFT MULTIPLICAND
10398 297F 6901  ROL 1.X  ;SHIFT MULTIPLICAND
10399 2981 2404  BCC MPY167  ;BRANCHES IF NO RESTORE IS NEEDED
10400 2983 9736  STA A TENPA  ;SAVE ACCA
10401 2985 17  TBA  ;NEED TO DO BCD ADD IN ACCA
10402 2986 A904  ADD A 4.X  ;DECIMAL ADJUST
10403 2983 19  DAA  ;TRANSFER BACK TO ACCB
10404 2989 16  TAB  ;TRANSFER BACK TO ACCB
10405 299A 9636  LDA A TENPA  ;GET ACCA THAT WAS SAVED
10406 299C A933  ADC A 3.X  ;FINISH BCD MATH
10407 298E 19  DAA
10408 298F 6A00  DEC 9.X  ;BRANCHES IF COUNT NOT ZERO
10409 2991 2682  BNE MPY167
10410  : CLEAN UP STACK
10411 2993 31  INS
10412 2994 31  INS
10413 2995 31  INS
10414 2996 31  INS
10415 2997 31  INS
10416 2998 39  RTS
10417
10418  : "CCDDIV" SUBROUTINE
10419  : REVISION 1.2
10420  : BCD (16-BIT) VALUE INTEGER DIVIDE ROUTINE
10421  : LOAD ACCA. ACCB WITH BCD DIVIDEND AND LOAD
10422  : INDEX REGISTER WITH BCD DIVISOR
10423  : RETURNS WITH QUOTIENT IN ACCA, ACCB.
10424  : (MODIFICATION 1.1)
10425
10426 2999 37  BCDDIV PSH B  ;FORMS DIVIDEND IN STACK
10427 299A 36  PSH A
10428 299B A600  LDA A 0.X
10429 299D F601  LDA B 1.X
10430 299F 37  PSH B
10431 29A0 36  PSH A  ;FORMS DIVISOR IN STACK
L-44
co
ZN:-
'4EW
O
4f
-ME
= -~
(w ;z
CO)
00
M
A:
-4
0 1 UZH
al~
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5I-
4
227x422]0
F---Z-4:
9Q
~
UUE
C ti
r:
94
C',
-4:
0 C
214x340]Q)
+.4 4-+
128x302]Cl -
- -*
0 CI C
160x268]:
219x268].MDQ0
432x267]a
444x267]u
495x267]\-
113x249]n 2I
137x249]nf)v v
198x249].e
253x249).e
277x248)f
306x248~
OZ
347x248)D Z\Z01
418x248] . t
478x248]. z
344x203]0 (D 0 0 C D0(}
292x170]16

BCD151 INC A ;COUNT NUMBER OF TIMES DIVISOR IS SHIFTED LEFT
01440 29BC 6002 ASC 2.X
01449 29AB 6001 TST 1.X
01447 29AA 6000 LDA A *1
01438 29A2 3001 LDA A #1
01437 29A0 4C BCD151 INC A ;COUNT NUMBER OF TIMES DIVISOR IS SHIFTED LEFT
01435 29AD 6001 TST 1.X
01433 29AF 2000 BHI BCD153 ;BRANCHES IF DIVISOR HAS BEEN SHIFTED LEFT 16 TIMES
01431 29BD 8111 CMP A #17 ;CHECK FOR DIVISOR EQUAL TO ZERO
01429 29BE 26F5 BNE P'90151 ;BRANCHES IF DIVISOR NOT LEFT JUSTIFIED
01427 29BF A700 BCD153 STA A 0.X ;SAVE SHIFTS COUNT ON STACK
01426 29BB 6004 LDA A 3.X ;GET DIVIDEND FROM STACK
01424 29BA 6004 LOA B 4.X ;INITIALIZE DIVIDEND TO BECOME QUOTIENT
01422 29B9 6004 CLR 3.X
01420 29BC 6004 CLR 4.X
01418 29BD 6004 SMI.ST STACK LOOKS LIKE:  
01416 29BE PP32 BCD163 STX SAVEX ;SAVE POINTER TO STACK
01414 29B0 EE01 LDX 1.X ;GET DIVISOR
01412 29B2 28A4 JSE BCD165 ;DIVISOR MINUS DIVISOR
01410 29CA T0098 TST CALLY ;CARRY = 0, SUBTRACTION OVERFLOW
01408 29CE 270E BRA BCD163 ;BRANCHES IF DIVISOR STILL OKAY
01406 29CA 9756 STA A TEMPA ;BEGIN RESTORE, SAVE VALUE IN ACCA
01404 29CC 17 TBA
01402 29CD AB02 ADD A 2.X
01390 29CF 10 DAA
01388 29D0 16 TAB ;PUT BCD VALUE BACK IN ACCB
01386 29D1 9D56 LDA A TEMPA ;GET ACCA THAT WAS SAVED
01384 29D3 AB01 ADD A 1.X ;FINISH BCD MATH
01382 29D5 0C CLR ;CLEAR CARRY BIT, SHIFT IN ZERO
01380 29D6 2001 BRA BCD167 ;BRANCHES TO SHIFT IN ZERO TO QUOTIENT
01378 29D7 0B BCD167 SEC ;SET CARRY BIT, SHIFT IN ONE (1)
01376 29D9 6004 BCD167 ROL 4.X ;SHIFTS IN CARRY BIT INTO LSB OF QUOTIENT
01374 29DB 6006 POL 3.X
01372 29DF 6401 LSR 1.X ;SHIFTS DIVISOR RIGHT WITH ZERO FILL
01370 29F0 6602 ROR 2.X
01368 29F1 6A91 DEC 1.X ;DECREMENT COUNT
01366 29F3 26F9 BCD163 BRA BCD163 ;BRANCHES IF COUNTER EQUAL TO ZERO (0)
01364 29F5 0C CLEAN UP STACK
01362 29F7 31 INS
01360 29F9 31 INS
01358 29FD 31 INS
01356 29FE 32 PUL A ;PULLS CORRECTED BCD VALUE FROM STACK
01354 29F0 33 PHI B ;DESTROYS REMAINDER
01352 29FA 39 RTS
01350 29F4 :
SUBROUTINE BCDBIN CONVERTS FOUR BINARY CODED DECIMAL DIGITS TO A BINARY EQUIVALENT. THE BCD DIGITS ARE PACKED TWO PER BYTE. THE BINARY RESULT OCCUPIES TWO BYTES. THE BCD DIGITS ARE LOADED INTO THE ACCA AND ACCB (PSD TO ACCA) AND THE BCDBIN SUBROUTINE IS CALLED. THE ROUTINE EXITS WITH THE BINARY RESULT IN ACCA AND ACCB. (MODIFICATION 1, 1)

BCDBIN STA A SAVE1 ;SAVE 2 MS BCD VALUES
29EB 9789 BCDBIN STA A SAVE1 ;SAVE 2 MS BCD VALUES
29EC 7F008A CLR BINUPR
29ED 014-3 "BCDBIN" SUBROUTINE
29EE 01486 SUBROUTINE 01486 CONVERTS FOUR BINARY CODED DECIMAL DIGITS TO A BINARY EQUIVALENT. THE BCD DIGITS ARE PACKED TWO PER BYTE. THE BINARY RESULT OCCUPIES TWO BYTES. THE BCD DIGITS ARE LOADED INTO THE ACCA AND ACCB (PSD TO ACCA) AND THE BCDBIN SUBROUTINE IS CALLED. THE ROUTINE EXITS WITH THE BINARY RESULT IN ACCA AND ACCB. (MODIFICATION 1, 1)

BCDBIN STA A SAVE1 ;SAVE 2 MS BCD VALUES
29EB 9789 BCDBIN STA A SAVE1 ;SAVE 2 MS BCD VALUES
29EC 7F008A CLR BINUPR
29ED 014-3 "BCDBIN" SUBROUTINE
29EE 01486 SUBROUTINE 01486 CONVERTS FOUR BINARY CODED DECIMAL DIGITS TO A BINARY EQUIVALENT. THE BCD DIGITS ARE PACKED TWO PER BYTE. THE BINARY RESULT OCCUPIES TWO BYTES. THE BCD DIGITS ARE LOADED INTO THE ACCA AND ACCB (PSD TO ACCA) AND THE BCDBIN SUBROUTINE IS CALLED. THE ROUTINE EXITS WITH THE BINARY RESULT IN ACCA AND ACCB. (MODIFICATION 1, 1)

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01485 : "BCDBIN" SUBROUTINE
01486 : CONVERTS FOUR BINARY CODED DECIMAL DIGITS TO A BINARY EQUIVALENT. THE BCD DIGITS ARE PACKED TWO PER BYTE. THE BINARY RESULT OCCUPIES TWO BYTES. THE BCD DIGITS ARE LOADED INTO THE ACCA AND ACCB (PSD TO ACCA) AND THE BCDBIN SUBROUTINE IS CALLED. THE ROUTINE EXITS WITH THE BINARY RESULT IN ACCA AND ACCB. (MODIFICATION 1, 1)

01489 : OCCUPIES TWO BYTES. THE BCD DIGITS ARE LOADED INTO THE ACCA AND ACCB (PSD TO ACCA) AND THE BCDBIN SUBROUTINE IS CALLED. THE ROUTINE EXITS WITH THE BINARY RESULT IN ACCA AND ACCB.

01493 : (MODIFICATION 1, 1)

01494 :

01495 29EB 9789 BCDBIN STA A SAVE1 ;SAVE 2 MS BCD VALUES
01496 29ED 7F008A CLR BINUPR
01497 29FF 17 TBA
01498 29F1 C40F AND B #0FH ;SAVE ONLY LS BCD VALUE
01499 29F3 44 LSR A ;MOVE TENS BCD VALUE OF ACCA
01500 29F4 44 LSR A
01501 29F5 44 LSR A
01502 29F6 44 LSR A
01503 29F7 2705 TENLP BEQ D0HUND ;GO DO HUND WHEN TEN IS ZERO
01504 29F8 9689 BCDBIN STA A SAVE1 ;SAVE 2 MS BCD VALUES
01505 29F9 4A DEC A ;DECREMENT TENS DIGIT AND
01506 29FA 20F9 BRA TENLP ;REPEAT UNTIL ZERO
01507 29FB 9689 BCDBIN STA A SAVE1 ;SAVE 2 MS BCD VALUES
01508 29FC 20F9 BRA TENLP ;REPEAT UNTIL ZERO
01509 29FD 2604 NE TTM0UQ0 BRANCIF ;THOU DIGIT IS ZERO
01510 2A00 9689 LDA A BINUPR ;GET BINARY UPPER VALUE
01511 2A01 20F9 BRA HUNDP ;REPEAT UNTIL ZERO
01512 2A02 7C008A INC BINUPR ;ADD 236 TO BIN UPPER VALUE
01513 2A03 44 DEC A ;DECREMENT HUND DIGIT OND
01514 2A04 9689 DOTHOU LDA A SAVE1 ;GET THOU DIGIT
01515 2A05 C684 ADD B #100 ;ADD 100 TO BINARY VALUE
01516 2A06 2900 DEC A ;DECREMENT HUND DIGIT OND
01517 2A07 44 LSR A
01518 2A08 44 LSR A
01519 2A09 44 LSR A
01520 2A0A 44 LSR A
01521 2A0B 7C008A STA A SAVE1 ;SAVE THOU DIGIT
01522 2A0C 2500 BNE THU000 ;BRANCH IF THOU DIGIT IS ZERO
01523 2A0D 968A LDA A BINUPR ;GET BINARY UPPER VALUE
01524 2A0E 2900 CCR KXTIN
01525 2A0F 9689 THU00 LDA A BINUPR ;GET BINARY UPPER VALUE
01526 2A10 C684 THU0LP CLR A #0C ;RESET CARRY
01527 2A11 20F9 ADD B #032 ;ADD 322 TO BINARY LOWER
01528 2A12 2900 ADC A #2FH ;ADD 768 TO BINARY UPPER
01529 2A13 7A0089 DEC SAVE1 ;DECREMENT THOU DIGIT
01530 2A14 2606 BNE THU0LP ;REPEAT UNTIL THOU DIGIT ZERO
01531 2A15 39 XITBIN RTS

01532 :

01533 :

01534 :

01535 :

01536 :

01537 :

167
01530 2424 DF36  TRIGAB STX  TEMPA  ;SAVES UPDATED ANGLE
01540 242C 8000E  CPX  #0106H  ;COMPARES ANGLE TO 270 DEGREES
01550 242C 2916  DBS  TRIGA  ;BRANCHES IF ANGLE LESS THAN 270 DEGREES
01560 2C31 3301  LDA A #01H  ;ANGLE IN 2ND QUADRANT
01570 2435 8001  LDA B  ;GET 270 DEGREES
01580 2434 0037  SUB B  TEMPB  ;269 DEGREES HINUS (270 TO 259 DEGREES)
01590 2437 9336  SBC A  TEMPA  ;DIFFERENCE BETWEEN 0 AND 90 DEGREES
015A0 243D 9737  STA B  TEMPA  ;SAVE DIFFERENCE
015B0 243D 9737  LDA B  #C3H  ;FIX PROPER SIGNS FOR CURRENT QUADRANT
015C0 2443 C62D  STA B  CSIGN
015D0 2443 073B  STA B  CSIGN
015E0 2453 203A  BRA  TRIGB  ;GO TO FIND SINE AND COSINE
015F0 2447 8000B4  TRIGA  CPX  #0094H  ;COMPARES ANGLE TO 180 DEGREES
01600 244A 2914  BVS  TRIGB  ;BRANCHES IF ANGLE LESS THAN 180 DEGREES
01610 244C 8001  LDA A #01H  ;ANGLE IN 3RD QUADRANT
01620 244E 8000E  LDA B  #01H  ;GET 180 DEGREES
01630 2450 0037  SUB B  TEMPB  ;179 DEGREES HINUS (180 TO 269 DEGREES)
01640 2453 9336  SBC A  TEMPA  ;DIFFERENCE BETWEEN 0 AND 90 DEGREES
01650 2454 0737  STA B  TEMPA  ;SAVE DIFFERENCE
01660 2456 9736  STA A  TEMPA  ;FIX PROPER SIGNS FOR CURRENT QUADRANT
01670 2458 C62D  STA B  CSIGN
01680 245A 0737  STA B  CSIGN
01690 245C 0221  BRA  TRIGB  ;GO TO FIND SINE AND COSINE
016A0 2468 8000A5  TRIGB  CPX  #905AH  ;COMPARES ANGLE TO 90 DEGREES
016B0 246A 2916  BVS  TRIGC  ;BRANCHES IF ANGLE LESS THAN 90 DEGREES
016C0 246C 2900  LDA A #00H  ;ANGLE IN 4TH QUADRANT
016D0 246E 0040  LDA B  #00H  ;GET 180 DEGREES
016E0 2469 0037  SUB B  TEMPB  ;180 DEGREES HINUS (90 TO 179 DEGREES)
016F0 246B 9236  SBC A  TEMPA  ;DIFFERENCE BETWEEN 0 AND 90 DEGREES
01700 246D 9736  STA B  TEMPA  ;SAVE DIFFERENCE
01710 246F 9736  STA A  TEMPA  ;FIX PROPER SIGNS FOR CURRENT QUADRANT
01720 2471 C62D  LDA B  #08H  ;GO TO FIND SINE AND COSINE
01730 2473 D78B  STA B  CSIGN
01740 2475 C62D  LDA B  #07H  ;GO TO FIND SINE AND COSINE
01750 2477 800077  LDA B  CSIGN
01760 2477 8026  BRA  TRIGD  ;GO TO FIND SINE AND COSINE
01770 2478 D623  TRIGC  LDA B  #02H  ;ANGLE ALREADY BETWEEN 0 AND 90 DEGREES
01780 2479 D78B  STA B  CSIGN  ;FIX PROPER SIGNS FOR CURRENT QUADRANT
01790 247F D78B  STA B  CSIGN
017A0 2481 9636  LDA A  TEMPA  ;GET PROCESSED ANGLE
017B0 2483 DB37  LDA B  TEMPA  ;DOUBLE ANGLE
017C0 248A 8936  ABC A  TEMPA
017D0 248B FE7A7  ADD B  TRIGC+1 ADD TO BEGIN ADDRESS OF TABLE
017E0 248C 2926A  ABC A  TRIGC
017F0 248E 9736  STA A  TEMPA  ;STORE RESULT
01800 2491 D737  STA B  TEMPA
01810 2493 D335  LDX  TEMPA  ;LOAD RESULT INTO INDEX REGISTER
01820 2495 A600  LDA A  O.X  ;GET SIG
01591 2A97 F601    LDA B, X   GET COSINE
01592 2A99 9784    STA A, SINEX+1 SAVE ONE-BYTE RESULTS
01593 2A95 D766    STA B, COSINE+1
01594 2ADB 39    RTS
01595
01596    "PACK" SUBROUTINE
01597    PACKS BINARY NUMBERS INTO BCD FORM
01598    ACCA SHOULD CONTAIN THE UNPACKED BCD FORM
01599    ROUTINE DESTROYS CONTENTS OF ACCA.
01600
01601 2AD5 9B4E    PACK ADD A, ENTRYB ENTRYB LOOSES LIKE "NO"
01602 2A90 974X    STA A, ENTRYB PACKS 16 ANOTHER UNPACKED BCD FORM
01603 2A82 75206E    ASL ENTRYB THEN DOES 1-BIT LEFT SHIFT WITH ZERO FILL
01604 2A82 79006D    ROL ENTRYA
01605 2A82 75306E    ASL ENTRY3
01606 2A82 79006D    ROL ENTRYA
01607 2A82 75306E    ASL ENTRYB
01608 2A82 79006D    ROL ENTRYA
01609 2A82 75306E    ASL ENTRYB
01610 2A82 79006D    ROL ENTRYA SHIFTS 16-BIT BINARY INFORMATION OVER ONE CHARACTER
01611 2ADA 39    RTS
01612
01613    "ALSTOP" SUBROUTINE
01614    ROUTINE THAT STOPS BOTH MOTORS FOR EXCEEDING ANGLE LIMIT
01615
01616 2ADD 05FF    ALSTOP LDA A 0FFH
01617 2ADD B7EE00    STA A LSESAZ STOPS AZIMUTH MOTOR
01618 2AC6 B7EE32    STA A LSESAL STOPS ELEVATION MOTOR
01619 2AC3 39    RTS
01620
01621 "BCDSUB" SUBROUTINE
01622 SUBLTRACTS TWO 16-BIT BCD PACKED NUMBERS
01623 SUBLTRACTS INDEXED ADDRESS FROM ACCA, ACCB
01624 INDEX REG. CONTAINS STARTING ADDRESS
01625 ACCA, ACCB CONTAINS NUMBER TO BE SUBTRACTED
01626 FRM. RETURNS WITH RESULT FROM SUBTRACTION IN
01627 ACCA, ACCB
01628
01629 ; # 9999 #
01630 ; -1256 
01631 ; - - - - - 
01632 ; * DIFF 
01633 ; + 1 
01634 ; ---- ---- 
01635 ; DIFF+1 
01636 ; -BCD 
01637 ; ---- ---- 
01638 ; * ANSWER 
01639 ; ---- ---- ---- 
01640 ; EGS TESTS OVERFLOW CONDITION
01641 ; EGS TESTS TO OVERFLOW CONDITION
01642
01643 2AC4 7F009B    BCDSUB CLR CARRY
"SHAENC" SUBROUTINE

ROUTINE THAT TAKES CARE OF READING SHAFT ANGLE ENCODERS

SHAENC LDA A MBSAZ ;READS AZIMUTH ANGLE
LDA B LSBAZ
STA A MDCENC ;STORES ANGLE IN TEMPORARY LOCATION
STA B LC2ENC ;SCALE DAC OUTPUT BY A FACTOR OF 2
ASL B
ROL A
STA A DOR2A ;OUTPUT MS 4 BITS OF AZ TO DAC
LDA D DOR2B ;OUTPUT LS 8 BITS OF AZ TO DAC
STA B LC2ENC ;GET OLD A AND B
LDA B LSBENC
STA B LSBENC
JSR DIVIDE ;DIVIDES ANGLE BY THE CONSTANT 14.912
LDA D DOR2B
JSR BINBCD ;RETURNS WITH A PACKED BCD NUMBER

ADDITION TO "SHAENC" SUBROUTINE

CHECKS BOTH POS AND NEG LIMITS
01697 2B1C DB37  STA B TMB       ; SAVES ACCB TEMP
01698 2B1E DB52  LDA B SIGN       ; START LIMIT CHECK
01701 2B20 F13F  CMP B PLUS
01702 2B23 271C  LDA 0, P,L  ; BRANCHES IF AZIMUTH COORDINATES ARE POSITIVE
01703 2B25 B637  LDA 0, TMB  ; AZIMUTH COORDINATES ARE NEGATIVE
01704 2B27 CB01  LDA #AZLIM  ; GET NEGATIVE AZIMUTH LIMIT
01705 2B2A CB24  JSR RPSUB       ; ACCX MINUS RAZLIM
01706 2B2D 9648  LDA A CARRY       ; BRANCHES IF THE ACCX ARE LARGER THAN RAZLIM
01707 2B2F 261C  BNE SIA2       ; POSITIONER HAS EXCEEDED THE LIMIT
01708 2B31 C6FF  PAL1  ; POSITIONER HAS EXCEEDED THE LIMIT
01709 2B33 97C6  STA B LFAGA  ; SET AZIMUTH LIMIT FLAG
01710 2B35 CB17  LDX #3615
01711 2B33 B2CC  JSR ASCH       ; DISPLAYS "ANGLE LIMIT EXCEEDED"
01712 2B3B B2AD  JSR ASTOP       ; BRANCHES TO STOP 30TH MOTORS
01713 2B3E 7E28  JRP RSCB       ; RETURNS TO CONTROL LOOP AFTER 1 SEC. WAIT
01714 2B41 0637  PAL  ; CHECKING FOR POSITIVE AZIMUTH LIMIT
01715 2B43 CE0656  LDX #AZLIM  ; GETTING POSITIVE AZIMUTH LIMIT
01716 2B45 B2A4  JSR RPSUB       ; ACCX MINUS RAZLIM
01717 2B49 9628  LDA A CARRY
01718 2B4C 27E4  DEX PAL1
01719 2B4D 9642  SIA2  ; LDA A SIGN
01720 2B4F 9743  STA A ASIGN
01721 2B51 8641  LDA A #041H
01722 2B53 973A  STA A RFTA
01723 2B55 CB4A  LDA A #05AH
01724 2B57 9735  STA A RELT
01725 2B59 33  PUL B
01726 2B5A 32  PUL A
01727 2B5B CE03F  LDX #ANGLE
01728 2B5E BD2F  JSR BCD10S
01729 2B61 CE0060  LDX #101A2
01730 2B64 BD139  JSR ASC2  ; DISPLAYS PACKED BCD ON THE PANEL
01731 2B67 F603  LDA A N886
01732 2B6A F602  STA B L886
01733 2B6D 9735  STA A 9888
01734 2B6F BD99  STA B 9888
01735 2B71 5B  ASL B
01736 2B72 59  POL A
01737 2B73 DB80  STA A #D83A
01738 2B76 FC02  STA B DB83
01739 2B79 9635  STA A 9689
01740 2B7B 9639  STA B 9689
01741 2B7D CE1F  LDX #DIV160
01742 2B83 BD2AE  JSR DIVIDE  ; DIVIDES ANGLE BY THE CONSTANT 14,912
01743 2B86 CE0067  LDX #EL203
01744 2B89 BD2C  JSR JN95  ; RETURNS WITH PACKED BCD NUMBER
01745 2B8C B739  JSR D99A  ; PSH A
01747 2B91 27A7  JSR 43
01748 2B9B D737  STA B TMB
01749 2B9D 85C3  LDA B SIGN  ; HANDLES CHANGE IN COORDINATE SYSTEM
<table>
<thead>
<tr>
<th>Address</th>
<th>Opcode</th>
<th>Instruction</th>
<th>Description</th>
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<tr>
<td>01750</td>
<td>2B0F</td>
<td>CMP B PLUS</td>
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</tr>
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<td>01751</td>
<td>2B02</td>
<td>BNE SHA3</td>
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<td>LDA B PLUS</td>
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<td>2B99</td>
<td>BRA SHA4</td>
<td></td>
</tr>
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<td>01755</td>
<td>2B9C</td>
<td>STA B SIGN</td>
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<td>ADDITION TO &quot;SHAEC&quot; SUBROUTINE.</td>
</tr>
<tr>
<td>01758</td>
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<td></td>
<td>CHECKS BOTH POS AND NEG ELEVATION LIMITS</td>
</tr>
<tr>
<td>01759</td>
<td></td>
<td></td>
<td>MODIFICATION 1.1</td>
</tr>
<tr>
<td>01760</td>
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<td></td>
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<tr>
<td>01761</td>
<td>2B8E</td>
<td>LDA B SIGN</td>
<td>START LIMIT CHECK</td>
</tr>
<tr>
<td>01762</td>
<td>2B5D</td>
<td>CMP B PLUS</td>
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</tr>
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<td>2B43</td>
<td>LDA TEMP</td>
<td></td>
</tr>
<tr>
<td>01764</td>
<td>2B55</td>
<td>BEQ PEL</td>
<td>BRANCHES IF ELEVATION COORDINATE IS NEGATIVE</td>
</tr>
<tr>
<td>01765</td>
<td>2B77</td>
<td>LDX #NELLIM</td>
<td>GET NEGATIVE ELEVATION LIMIT</td>
</tr>
<tr>
<td>01766</td>
<td>2B3A</td>
<td>JSR RCDS0B</td>
<td>ACCES HINUS NELLIM</td>
</tr>
<tr>
<td>01767</td>
<td>2B4B</td>
<td>LDA A CARY</td>
<td></td>
</tr>
<tr>
<td>01768</td>
<td>2B5F</td>
<td>BNE SHA1</td>
<td>BRANCHES IF THE ACCES ARE LARGER THAN NELLIM</td>
</tr>
<tr>
<td>01769</td>
<td>2BB1</td>
<td>STA B OFFF</td>
<td>POSITIONER HAS EXCEEDED THE LIMIT</td>
</tr>
<tr>
<td>01770</td>
<td>2B83</td>
<td>STA B LF1AG</td>
<td>GET ELEVATION LIMIT FLAG</td>
</tr>
<tr>
<td>01771</td>
<td>2B33</td>
<td>LDY #M015</td>
<td></td>
</tr>
<tr>
<td>01772</td>
<td>2BBB</td>
<td>JSR AS015</td>
<td>DISPLAY &quot;ANGLE LIMIT EXCEEDED&quot;</td>
</tr>
<tr>
<td>01773</td>
<td>2BEE</td>
<td>JSR AS027</td>
<td>BRANCHES TO STOP BOTH MOTORS</td>
</tr>
<tr>
<td>01774</td>
<td>2BEE</td>
<td>JSR ASA0B</td>
<td>RETURN TO CONTROL LOOP AFTER 1 SEC. WAIT</td>
</tr>
<tr>
<td>01775</td>
<td>2B5C</td>
<td>LDA B TEMP3</td>
<td>CHECKING POSITIVE ELEVATION LIMIT</td>
</tr>
<tr>
<td>01776</td>
<td>2B4C</td>
<td>JSR RCDS0M</td>
<td>GETTING POSITIVE ELEVATION LIMIT</td>
</tr>
<tr>
<td>01777</td>
<td>2B56</td>
<td>JSR RCDS0C</td>
<td>ACCESS HINUS PELLIM</td>
</tr>
<tr>
<td>01778</td>
<td>2B57</td>
<td>LDA A CARRY</td>
<td></td>
</tr>
<tr>
<td>01779</td>
<td>2B56</td>
<td>LDA A SHA</td>
<td></td>
</tr>
<tr>
<td>01780</td>
<td>2B5E</td>
<td>STA A C019</td>
<td></td>
</tr>
<tr>
<td>01781</td>
<td>2B56</td>
<td>STA A C019</td>
<td></td>
</tr>
<tr>
<td>01782</td>
<td>2B57</td>
<td>STA A STA</td>
<td></td>
</tr>
<tr>
<td>01783</td>
<td>2B58</td>
<td>STA A LSTA</td>
<td></td>
</tr>
<tr>
<td>01783</td>
<td>2B58</td>
<td>LDA A STA</td>
<td></td>
</tr>
<tr>
<td>01785</td>
<td>2B57</td>
<td>STA A STA</td>
<td></td>
</tr>
<tr>
<td>01786</td>
<td>2B58</td>
<td>STA A STA</td>
<td></td>
</tr>
<tr>
<td>01786</td>
<td>2B5B</td>
<td>STA A STA</td>
<td></td>
</tr>
<tr>
<td>01787</td>
<td>2B5A</td>
<td>STA A STA</td>
<td></td>
</tr>
<tr>
<td>01788</td>
<td>2B5B</td>
<td>STA A STA</td>
<td></td>
</tr>
<tr>
<td>01789</td>
<td>2B5B</td>
<td>STA A STA</td>
<td></td>
</tr>
<tr>
<td>01790</td>
<td>2B5B</td>
<td>STA A STA</td>
<td></td>
</tr>
<tr>
<td>01790</td>
<td>2B5B</td>
<td>STA A STA</td>
<td></td>
</tr>
<tr>
<td>01791</td>
<td>2B5B</td>
<td>STA A STA</td>
<td></td>
</tr>
<tr>
<td>01792</td>
<td>2B5B</td>
<td>STA A STA</td>
<td></td>
</tr>
<tr>
<td>01793</td>
<td></td>
<td></td>
<td>&quot;ADDCAL&quot; SUBROUTINE</td>
</tr>
<tr>
<td>01794</td>
<td></td>
<td></td>
<td>ROUTINE THAT CALCULATES ADDRESSES FOR NEXT STATE</td>
</tr>
<tr>
<td>01795</td>
<td></td>
<td></td>
<td>ACCA CONTAINS VARIABLE INDEX</td>
</tr>
<tr>
<td>01796</td>
<td></td>
<td></td>
<td>INDEX REG. CONTAINS CURRENT STATE TABLE</td>
</tr>
<tr>
<td>01797</td>
<td></td>
<td></td>
<td>ADDRESS FOR REFERENCING NEXT STATE</td>
</tr>
<tr>
<td>01798</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01799</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01800</td>
<td>2BFE</td>
<td>ADDCAL STA A TEMP3</td>
<td>STORES INDEX REGISTER TEMPORARILY</td>
</tr>
<tr>
<td>01801</td>
<td>2BEE</td>
<td>STX TEMPX</td>
<td></td>
</tr>
<tr>
<td>01802</td>
<td>2B0C</td>
<td>CLI B</td>
<td></td>
</tr>
</tbody>
</table>
ADD A TEMPX+1
ADCB TEMPX
STAB TEMPX
STA A TEMPX+1
LDX TEMPX
STA TEMPX
ADDS KEYCODE TO INDEX REGISTER

UP ROUTINE
INSTRUCTS MOTOR TO GO UP (CCW)

DOWN ROUTINE
INSTRUCTS MOTOR TO GO DOWN (CW)

LEFT ROUTINE
INSTRUCTS MOTOR TO GO LEFT (CCW)

RIGHT ROUTINE
INSTRUCTS MOTOR TO GO RIGHT (CW)

ASCDS DISPLAYS ASCI" MSG. ON DISPLAY PANEL
INDEX REG. HAS STARTING ADDRESS OF MSG.
01856 2C56 8C
01856 2C56 FB6
01856 2C57 860C14
01859 2C5A 2E3D
01856 2C50 39
01861
01862 * "BINECD" SUBROUTINE
01863 BINARY TO PACKED BCD CONVERSION ROUTINE
01864
01866 LOAD ACCA, ACCB WITH A 16-BIT BINARY NUMBER.
01867 LOAD INDEX REG. WITH ADDRESS OF MS BYTE OF
01868 WHERE PACKED BCD INFORMATION IS TO BE KEPT.
01869 ROUTINE DETERMINES SIGN OF 16-BIT ENTRY
01870 AND SAVES THAT INFORMATION IN "SIGN".
01871 ROUTINE RETURNS WITH PACKED BCD IN THE
01872 SPECIFIED MEMORY LOCATION AND ALSO IN ACCA,
01873 ACCB. THE LEAST FOUR MS DECIMAL VALUES
01874 WILL BE CONTAINED IN THE PACKED BCD NUMBER

01875 2C50 DF32 BINECD STX SAVEN ; SAVE DATA POINTER
01876 2C5F 9736 STA TEMP
01877 2C41 D737 STA B TEMP
01878 2C43 963D LDA A LBDNC
01879 2C45 D639 LDA B LBDNC ; SAVE THE 16-BIT SHAF T ANGLE CODE
01880 2C47 C090 SUB B #800H
01881 2C49 8210 SBC A #01H ; BRANCH IF 16-BIT VALUE IS POSITIVE
01882 2C48 2611 BRN PHS
01883 2C40 B598 LDA A LBDCH
01884 2C4F 659F LDA B #00H ; 16-BIT VALUE MUST BE NEGATIVE
01885 2C51 D037 SUB B TEMP
01886 2C33 9236 SBC A TEMP ; AFTER SUBTRACT ACCB WILL CONTAIN CORRECT VALUE
01887 2C55 9736 STA A TEMP ; SUBTRACT 16-31T VALUE FROM 360 DEGREES
01888 2C37 B09A LDA A #00H
01889 2C5A 9742 STA A SIGN ; SAVE ASCII VALUE OF MIRUS SIGN
01890 2C36 2007 BRA TOSN
01891 2C3E 8F1FB POS LDA A #03H
01892 2C61 9742 STA A SIGN ; SAVE ASCII VALUE OF PLUS SIGN
01893 2C63 D937 LDA D TEMP ; RESTORE ACCB TO PROPER VALUE
01894 2C65 9636 POS LDA A TEMP ; RESTORE ACCA TO PROPER VALUE
01895 2C56 CE31EC LDY #00X ; Initializes index reg. for first BCD conversion constant
01896 2C6A 700031 CVDEC1 CLR SAVEN ; CLEAR BCD CONVERSION COUNTER
01897 2C6D 9001 CVDEC2 ADD B 1.0X
01898 2C6F A200 SEC A 0.X
01899 2C71 2F65 BCS CVDC5 ; BRANCH IF SUBTRACTION PRODUCES OVERFLOW
01900 2C73 700031 INC SAVEN ; DECIMAL CHARACTER BEING BUILT, INCREMENT SAVEN
01901 2C76 2073 BRA CVDEC9
01902 2C78 ED31 CVDEC9 ADD B 1.0X
01903 2C7A 9900 ANL A 0.X ; RESTORES PARTIAL RESULT UPON OVERFLOW
01904 2C7C 26 PSH A ; SAVE ACCA
01905 2C7D 70003D ASL BCBB ; 16-BIT SHIFTS LEFT WITH ZERO FILL
01906 2C30 7003C ROL BCBB ; SO, NO NEED TO CLEAR EITHER REGISTER
01907 2C35 70003D ASC. BCBB
01908 2C36 70003C ROL BCDA
1.3. \[ \text{SHIFTS LAST BCD VALUE OVER ONE CHARACTER} \]

1.4. \[ \text{LOOPS LIKE "NO"} \]

1.5. \[ \text{PRODUCES BCD CHARACTER} \]

1.6. \[ \text{RESTORES PACKING REGISTER BCD WITH CORRECT VALUE} \]

1.7. \[ \text{RESTORES ACCA TO FORMER VALUE} \]

1.8. \[ \text{INCREMENTS INDEX REGISTER TO NEXT CONSTANT} \]

1.9. \[ \text{TESTS TO SEE LAST CONSTANT HAS BEEN USED} \]

1.10. \[ \text{BRANCHES IF LAST CHARACTER HAS NOT BEEN REACHED YET} \]

1.11. \[ \text{SAVES 16-BIT PACKED BCD NUMBER} \]

1.12. \[ \text{THIS IS AN ASSUMED DIVIDE ROUTINE.} \]

**DIVIDE** SUBROUTINE

1.13. \[16-BIT INTEGER DIVIDE ROUTINE]  

1.14. \[REVISION 1.1]  

1.15. \[LOAD ACCA, ACCB WITH 16-BIT DIVIDEND.]  

1.16. \[LOAD INDEX REGISTER WITH 16-BIT DIVISOR.]  

1.17. \[RETURNS WITH 16-BIT QUOTIENT IN ACCA, ACCB.]  

1.18. \[THIS IS AN ASSUMED DIVIDE ROUTINE.]  

**DIVIDE**  

- **STA A TEMPA**  
  \[\text{SAVES ACCA TEMPORARILY}\]

- **LDA A #000H**  
  \[\text{CLEARS SPACE ON STACK FOR QUOTIENT}\]

- **PSH A**  
  \[\text{PRODUCES CLEARED SPACE FOR THE LS BYTES OF DIVIDEND}\]

- **LDA A #000H**  
  \[\text{FORMS REST OF DIVIDEND BY ADDING ACCA, ACCB TO STACK}\]

- **PSH A**  
  \[\text{RETURNS WITH 16-BIT DIVISOR.}\]

- **PSH A**  
  \[\text{FORMS TWO LS BYTES OF DIVISOR BY ADDING ACCA, ACCB TO STACK}\]

- **LDA A #000H**  
  \[\text{PRODUCES REST OF 32-BIT DIVISOR BY ADDING ZEROS TO STACK}\]

- **PSH A**  
  \[\text{POINTER TO INDEX REG. TO STACKED DATA}\]

- **PSH DIV153**  
  \[\text{BRANCHES IF DIVISOR HAS BEEN LEFT JUSTIFIED}\]

- **LDA A #1**  
  \[\text{COUNTS NUMBER OF TIMES DIVISOR IS SHIFTED LEFT}\]

- **TST 1.X**  
  \[\text{SHIFTS DIVISOR LEFT ONE BIT}\]
BRNZ DIVISOR HAS BEEN SHIFTED LEFT 32 TIMES
Saves shift count on stack

; Stack looks like this 0
; 0 0
; +0 00 L3 BYTE OF DIVISOR
; +0 00 LS BYTE OF DIVISOR
; +0 00 LS BYTE OF DIVIDEND
; +0 00 CS BYTE OF QUOTIENT
; +1 00 LS BYTE OF RETURN ADDR.
; +2 00 LS BYTE OF RETURN ADDR.

BEGIN TO FORM NEW REMAINDER FROM OLD DIVIDEND

; SUBTRACTS DIVISOR FROM DIVIDEND

; BRANCHES IF NO BORROW FROM SUBTRACT

; BEGINS TO RESTORE REMAINDER TO PREVIOUS DIVIDEND

; RESTORES LAST SUBTRACT OPERATION IN CASE OF BORROW

; SETS, ASSUMES BINARY 1 FOR THIS PART OF THE DIVIDE

; Shifts binary 1 or 0 into LSB of quotient

; Shifts divisor right with zero fill

; Decrement count

; DIVIDE divides by 2 using 32-bit divisor
TECHNION: M6800 ASM V2.2

02035 2.21 25BA BPL DIV163 ;BRANCHES IF COUNT = 0
02036 2927 31 INS
02037 2924 31 INS
02038 2923 31 INS
02039 2926 31 INS
02040 2925 31 INS
02041 2923 31 INS
02042 2922 31 INS
02043 2921 31 INS
02044 2920 31 INS
02045 2931 31 INS
02046 2930 31 INS
02047 292F 973C BCDDIS STA A BCDAD
02048 2921 9603 LDA A 3
02049 2923 973E STA A SAVDEC
0204A 2925 963C LDA A BCDAD
0204B 2937 44 LSR A
0204C 2935 56 ROR B
0204D 2939 44 LSR A
0204E 293A 56 ROR B
0204F 293C 44 LSR A
02050 293C 44 ROR B
02051 2936 40FF ASC1
02052 293F 2E20 ADD A 00FF ;MASKS OFF BCD VALUE
02053 2942 2FCD ABD A 00BF ;CONVERTS THIS VALUE TO ASCII
02054 2942 2FCD STA A 0,X ;DISPLAYS THIS BCD VALUE
02055 2942 2FCD DEC SAVDEC ;DECREMENTS UNPACKING COUNT
02056 2943 2FCD TST SAVDEC
02057 2942 2FCD ROR ASC3 ;BRANCHES IF PACKED BCD NUMBER IS COMPLETELY UNPACKED
02058 2942 2FCD ASL B
02059 2935 49 POL A
0205A 2935 49 ASL B
0205B 2935 49 ROL A
0205C 2935 49 ASL B
0205D 2935 49 ROL A
0205E 2935 49 ASL B
0205F 2935 49 ROL A
02060 2935 49 ASL B
02061 2935 49 ASL B
02062 2935 49 ROL A
02063 2935 49 ASL B
02064 2935 49 ROL A
02065 2935 49 ASL B
02066 2935 49 ASC3
02067 2935 49 "ASC2" SUBROUTINE
E4 DISPLAYS DECODED BCD NUMBERS IN AZ, EL FORMATS
02059 LETA, LETD SHOULD CONTAIN ASCII VALUES OF LETTERS.
02070 MODIFICATION 1.1
02071
02072 2B36 B6315C ASC2 LDA A BLATK
02073 2B36 9700 STA A 0.X
02074 2B36 9642 LDA A SIGN
02075 2B36 A701 STA A 1.X ;DISPLAYS SIGN OF ANGLE
02076 2B36 963F LDA A ANGLE
02077 2B36 A702 STA A 2.X ;DISPLAYS ANGLE IN DEGREES
02078 2B36 9644 LDA A ANGLE+1
02079 2B36 A703 STA A 3.X
02080 2B36 B631FD LDA A P9INT
02081 2B36 A704 STA A 4.X ;DISPLAYS WHAT THE ANGLE IS 00D AZ, EL.
02082 2B36 9641 LDA A ANGLE+2
02083 2B36 A705 STA A 5.X
02084 2B36 B631FD LDA A DEGMIN
02085 2B36 A706 STA A 6.X ;DISPLAYS ANGLE IN DEGREES
02086 2B36 B631FC LDA A BLANK
02087 2B36 A707 STA A 7.X
02088 2B36 963A LDA A LSTA
02089 2B36 A708 STA A 8.X
02090 2B36 963B LDA A LSTB
02091 2B36 A709 STA A 9.X
02092 2B35 50 RTS
02093
02094 "NOTAZ" SUBROUTINE
02095 AZIMUTH MOTOR SUBROUTINE
02096 PLACE SPEED IN ACCA AND PLACE DIRECTION IN ACCB
02097
02098 2B36 B16C NOTAZ CMP B DFLAGA ;DECIDE IF DESIRED DIRECTION MATCHES CURRENT DIRECTION
02099 2B35 2732 BRA SAFE1 ;BRANCH IF BOTH DIRECTIONS ARE THE SAME
02099 2B3A 566C DIFF1 LDA B DFLAGA ;DESIZED DIRECTION IS DIFFERENT FROM CURRENT DIRECTION
02099 2B35 2833 BHI ;BRANCHES IF CURRENT DIRECTION IS CW (RIGHT)
02100 2B35 C600 0001 LDA B #000H ;DIRECTION, HERE, IS CURRENTLY CCW (LEFT)
02100 2B30 FT5E01 STA B RELAZ ;TRANS POWER OFF TO AZIMUTH MOTOR
02100 2B39 700E6E TST RELAGA ;FIND OUT WHAT THE SPEED IS
02100 2B39 2706 BRA Z2 ;BRANCH IF MOTOR IS CURRENTLY IN MOTION
02101 2B38 6601 LDA B #1 ;WAIT .1 SECOND
02102 2B39 2002 BRA Z3 ;BRANCH TO WAIT ONLY .1 SECOND INSTEAD OF 1
02103 2B39 C514 Z2 LDA B #20 ;BRANCH TO WAIT ONLY .1 SECOND INSTEAD OF 2
02104 2B39 692E3E 72 LDA B #20 ;BRANCH TO WAIT ONLY .1 SECOND INSTEAD OF 2
02105 2B3E 0210 LSR H ;WAIT FOR MOTOR TO STOP BEFORE SWITCHING DIRECTIONS
02106 2B39 1C02 LDA B #02H ;SWITCHING FROM CW TO CW DIRECTION
02107 2B3A F79E01 STA B RELAZ ;SWITCH FROM CW TO CW DIRECTION
02108 2B38 G601 LDA B #1 ;WAIT FOR DIRECTION RELAY TO HAVE TIME TO SWITCH
02109 2B38 G601 LDA B #02H ;TURN POWER ON, MOTOR NOW OPERATES CW (RIGHT)
02110 2B3A F79E01 STA B RELAZ ;SWITCH FROM CW TO CW DIRECTION
02111 2B39 G601 LDA B #02H ;DIRECTION IS CURRENTLY CW (RIGHT)
02112 2B39 G601 LDA B #02H ;DIRECTION IS CURRENTLY CW (RIGHT)
02113 2B3A F79E01 STA B RELAZ ;SWITCH FROM CW TO CW DIRECTION
02114 2B39 G601 LDA B #02H ;DIRECTION IS CURRENTLY CW (RIGHT)
02115 2B3D F79E01 STA B RELAZ ;SWITCH FROM CW TO CW DIRECTION
02116 2B36 G6FF LDA B #02H ;SWITCH FROM CW TO CW DIRECTION
02117 2B32 B704 STA B DFLAGA ;SAVE DIRECTION OF AZIMUTH MOTOR BY SETTING DIRECTION FLAG
02118 2B34 2026 BRA SAFE1
02119 2B36 G602 002H LDA B #002H ;DIRECTION IS CURRENTLY CW (RIGHT)
02120 2B39 F79E01 STA B RELAZ ;SWITCH FROM CW TO CW DIRECTION
0212 TST SPLAGA ;FIND OUT WHAT THE SPEED IS
0213 BSA 02 ;BRANCHES IF AZIMUTH MOTOR IS IN MOTION
0214 LDA B 21 ;BRANCHES TO WAIT ONLY FOR ON/OFF RELAY TO CHANGE
0215 LDA B 80 ;BRANCH TO WAIT ONLY FOR ON/OFF RELAY TO CHANGE
0216 JSR WAITE ;WAITS FOR AZIMUTH MOTOR TO STOP
0217 STA B NE50AZ ;CHANGES DIRECTION FROM CW (RIGHT) TO CCW (LEFT)
0218 STA B NE50AZ ;CHANGES DIRECTION FROM CW (RIGHT) TO CCW (LEFT)
0219 STA B NE50AZ ;CHANGES DIRECTION FROM CW (RIGHT) TO CCW (LEFT)
0220 STA B NE50AZ ;CHANGES DIRECTION FROM CW (RIGHT) TO CCW (LEFT)
0221 STA B NE50AZ ;CHANGES DIRECTION FROM CW (RIGHT) TO CCW (LEFT)
0222 STA B NE50AZ ;CHANGES DIRECTION FROM CW (RIGHT) TO CCW (LEFT)
0223 STA B NE50AZ ;CHANGES DIRECTION FROM CW (RIGHT) TO CCW (LEFT)
0224 STA B NE50AZ ;CHANGES DIRECTION FROM CW (RIGHT) TO CCW (LEFT)
0225 STA B NE50AZ ;CHANGES DIRECTION FROM CW (RIGHT) TO CCW (LEFT)
0226 STA B NE50AZ ;CHANGES DIRECTION FROM CW (RIGHT) TO CCW (LEFT)
0227 STA B NE50AZ ;CHANGES DIRECTION FROM CW (RIGHT) TO CCW (LEFT)
0228 STA B NE14 ;UPDATES RECORD OF SPEED OF AZIMUTH MOTOR
0229 RTS

"HOTEL" SUBROUTINE

ELEVATION MOTOR SUBROUTINE

PLACE SPEED IN ACCA AND PLACE DIRECTION IN ACCB

BRANCHES IF THE DIRECTIONS ARE THE SAME

BRANCHES IF CURRENT DIRECTION IS CW (DOWN)

TURNS POWER OFF TO AZIMUTH MOTOR, ORIENTED IN CCW (LEFT)

REMEMBERS DIRECTION OF AZ MOTOR BY SETTING DIR. FLAG

UPDATE RECORD OF SPEED OF AZIMUTH MOTOR

BRANCH TO WAIT ONLY FOR ON-OFF RELAY TO CHANGE

BRANCHES IF ELEVATOR MOTOR IS MOVING

BRANCHES IF ELEVATOR MOTOR IS MOVING

BRANCH TO WAIT .1 SECOND FOR ON-OFF RELAY TO SWITCH

WAITS 2 SECONDS FOR EL MOTOR TO STOP MOVING

SWITCHES DIRECTION TO CCW (UP) FROM CW (DOWN)
LDA B #1 ;WAITS .1 SECOND FOR DIRECTION RELAY TO CHANGE

AND B #00H ;TURNS POWER ON, ORIENTED IN CW (UP)

STA D ;RESUBMIT DIRECTION CHANGE BY SETTING DIRECTION FLAG

LEA E ;CHANGES SPEED OF ELEVATION MOTOR

RTS

"WAITE" SUBROUTINE

DELAY IS IN HUNDREDS OF MILLISECONDS

PLACE DESIRED DELAY IN ACC

THEN JUMP TO SUBROUTINE "WAITE"

VAITE LDX #34076

WAITE1 DEK

BHE WAITE1

BHE E

RTS

KEYBOARD SERVICE ROUTINE

SERVICE ON INTERRUPT BASIS ONLY

KEYBD LDA A #0F0H ;MAKE ALL FOUR ROWS OF KEYBOARD INOPERABLE

STA A ;READ CONTROL REGISTER OF PIA #1

BHE ASC A

ASL A

BHE ;DECODE ;BRANCH IF KEY IN FIFTH COLUMN IS SET

BCH ;BRANCH IF KEY IN COLUMNS 1-4 IS SET

CHR B #3E0H

DECL ;BRANCH 17 NO KEY Pressed, RESET PIA, RETURN FROM INTERRUPT

BRA D

AND B #3E0H

BRA C

AND B #0F0H

PREPARES ACC3 FOR NEXT ROW READ

CALL 17 ;BRANCH TO READ NEXT ROW

ROW LDA B ;READS DRA IF KEY IN COLUMNS 1-4 WAS Pressed

DECODE LDX #1 ;BEGIN COMPARING KEYPAD WITH KEY THAT WAS Pressed

DECODI LDA A #0

CALL 12 ;FOUND MATCH BETWEEN KEYPAD AND KEYPAD

BEQ ;BRANCH TO KEEP LOOKING FOR MATCH

GCHAR LDA A #20

RTS

#0FFH
02237 2EB1 B76B STA B KFLAG ;SET FLAG TO KNOW WHEN KEY WAS PRESSED
02238 2EC3 976F STA A KEYPNT ;STORE THE KEYCODE OF THE KEY THAT WAS PRESSED
02239 2EE3 E665 K1 LDA A #00H
0223B 2EE7 B76B STA A DBRA ;RESTORE KEYBOARD PIA
0223C 2EEA 666508 LDA A DBRA ;CLEAR PIA FLAG BY MPU READ
0223D 2ED0 33 LTI
0223E 2EB6 B68492 DISPL LDA A DB83 ;CLEAR PIA FLAG BY MPU READ
0223F 2EB0 1770 LDX TEMP
02240 2E93 6C0B-18 CPX #014H ;BRANCH IF FIRST CHARACTER OF DISPLAY NEEDED
02242 2EB6 2770 B2A STA SHORT
02244 2EE3 A600 LDA A 0,X
02245 2EEA B74092 STA A DB83 ;SUPPLY CHARACTER TO DISPLAY
02246 2EE9 68 INX
02247 2EE5 9770 STX TEMP ;INCREMENT CHARACTER COUNTER FOR DISPLAY
02248 2EE9 C620 START LDY #00H
02249 2EE6 5600 LDA A 0,X
0224A 2EE6 B7E892 STA A DB83
0224B 2EE9 62 INY
0224C 2EE5 9770 STY TEMP
0224D 2EE9 C635 RESET LDA A #083H ;MAKE PIA RESET BIT GO LOW TO RESET THE DISPLAY
0224E 2E81 B74092 STA A DB83
0224F 2E81 5601 LDA A #1
02250 2E93 6C0B BSR WAIT ;WAIT ONE MILISECOND
02251 2EE3 A600 LDA A #030H
02252 2EE7 B74093 STA A DB83 ;MAKE PIA RESET BIT GO HIGH TO FINISH NEEDED RESET TO DISPLAY
02253 2EE7 C620 RTI
02254 2EEB C654 WAIT LDA B #0AH
02255 2EEB 5A PEC B
02256 2EDE 56FD BNE WAIT1
02257 2EE5 5A DEC A
02258 2EE5 66FD ENE WAIT
02259 2EE3 3D RTS
0225A
0225B
0225C
0225D
0225E
0225F
02260 2EB5 B40E99 RCVR LDA A ACIA ;GET CHARACTER
02261 2EB7 C62F RCVRDEC LDX #00H ;LOAD POINTER TO COMMAND TABLE
02262 2EE4 5A CPY B
02263 2EDE A160 ACNVX CPY A 0,X ;COMPARE WITH VALID COMMAND
02264 2EE5 2505 BEQ MATCH ;NO MATCH, TRY ANOTHER ONE
02265 2EE5 BF66 STA B KEYPNT ;LOAD KEYBOARD COMMAND
02266 2EE5 BF67 LDA A #00H
02267 2EB3 976D STA A KEYP ;SET KEYENTRY FLAG
02268 2EE6 2507 BCP LDA ASOB ;RETURN HIGH-SOFTWARE
02269 2EB5 3D BNE MATCH INC ;MAKE NEXT COMPARISON AVAILABLE

This is an assembly language code for a computer program.
0229 2EF5 CE0014 INCMD LDH #$1BFE ;INITIALIZE VARIABLE WITH BEGINNING
0229 2EE3 DE02 STX CHAIRT ;ADDRESS OF SERIAL INTERFACE BUFFER
0229 2EE4 DF96 STX SAVEX2 ;INITIALIZE VARIABLE TO BEGINNING ADDRESS OF DISPLAY BUFFER
0229 2EE5 7F0050 CLR TEMP1
0229 2EE6 7F0051 CLF TEMP1
0229 2EEC B530 INC1 LDH TEMPA1 ;GET NEXT ADDRESS OF DISPLAY BUFFER
0229 2EEE .6060 LDA A 0.X ;FETCH ONE BYTE CONSTANT
0229 2EFF 0B08 INX TEMPA1 ;INCREMENT DISPLAY BUFFER ADDRESS
0229 2F03 DE06 LDH SAVEX2 ;GET NEXT ADDRESS OF SERIAL INTERFACE BUFFER
0229 2F03 A700 STA A 0.X ;PUT BYTE INTO BUFFER
0229 2F07 08 INX ;INCREMENT SERIAL INTERFACE BUFFER ADDRESS
0229 2F0D DF96 STX SAVEX2 ;SAVE ADDRESS OF NEXT BYTE
0229 2F0E 8C0028 CPX #$1BFE+20 ;SAVE ADDRESS OF NEXT BYTE
0229 2F0F 2ED0 DIF INC1 ;RD
0229 2F0F CE0014 LDH #$1BFE
0229 2F0F C615 LDA A #21
0229 2F0F BD08 JSR SEND
0229 2F0F 39 RTS

0231 2F15 DF3C SEND STX CHAIRT ;UPDATE CHARACTER POINTER
0231 2F15 DF3E STA A, CHAIRT ;SET BYTE COUNT
0231 2F15 DF4F LDA A #DF4
0231 2F15 DE05 STA A MSGFLG ;SET MESSAGE FLAG
0231 2F15 DF81 LDA A #0A1H
0231 2F15 DF98 STA A AC1H
0231 2F15 7F0030 CLF CRRUSH
0231 2F15 39 RTS

0232 2F15 0B2E TXMIT LDA A CHAIRT ;GET NUMBER OF CHARACTERS TO BE TRANSMITTED
0232 2F15 C615 LDA A CHAIRT ;GET CHARACTER LENGTH

0232 2F15 BD08 JSR SEND
0232 2F15 39 RTS

0232 2F15 0B2E TXMIT LDA A CHAIRT ;GET NUMBER OF CHARACTERS TO BE TRANSMITTED
INTERRUPT SERVICING ROUTINE

(BIOIFICATION 1.1)

LDA A DRA ; CHECKING ON STATUS OF KEYBOARD INTERRUPT FLAG

LDA A DRA2 ; KEYBOARD DOES NEED SERVICE, BUT FIRST CHECK SWITCH

LDA A DRA3 ; CHECK ON STATUS OF SERIAL INTERFACE

BPL INT3 ; BAD INTERRUPT

LDA A DRA2 ; CHECK ON CURRENT # OF HOW MANY BYTES HAVE BEEN SENT OUT

STA A AGIAD ; RETURN FROM SUBROUTINE

LDA A DRA1 ; CLEAR AGIAD

JMP KEYBD ; CLEAR KEYBD FLAG

LDA A AGIAD ; CHECK ON STATUS OF SERIAL INTERFACE

BPL INT3 ; NOT SERIAL INTERFACE, BAD INTERRUPT

LDA A AGIAD ; SWITCH OFF, SERVICE KEYBOARD

BRA INT4 ; SERVICE KEYBD, FRAME BACK

LDA A AGIAD ; NOT SMTP, BAD INTERRUPT

BRA INT4 ; SOLUTION, CAN BE RCVR OR TXMT

LDA A AGIAD ; NOT SMTP, BAD INTERRUPT

LDA A AGIAD ; CLEAR AGIAD

BEGIN TABLE FOR KEYBOARD
BEGIN TRIG. TABLE FOR SINE AND COSINE VALUES

THES VALUES ARE BETWEEN 0-90 DEGREES.

(MODIFICATION 1.1)

TRIG TABLE FOR SINE AND COSINE VALUES

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BEGIN TABLE FOR MESSAGES

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**RADOME POSITIONER FOR THE RFSS (RADIO FREQUENCY SIMULATION SYSTEM) (U)**

**GEORGIA INST OF TECH ATLANTA ENGINEERING EXPERIMENT STATION D O GALLENTINE ET AL.**

**UNCLASSIFIED 27 FEB 78 DAAR41-77-C-0047**
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<td>2DF8</td>
<td>Z5</td>
<td>2DFA</td>
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<td>ZERO1</td>
<td>2D8E</td>
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APPENDIX C

COMPONENT OPERATING MANUALS AND DATA SHEETS
OPERATION AND MAINTENANCE MANUAL
DIGISEC® RA ____/23C SERIES ENCODERS

MANUAL NO. 2802
REV. E, JANUARY 1976
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1. INTRODUCTION

1.1 SCOPE

This manual is to be used with the DIGISEC® RA _/23C series of absolute shaft position encoders. The manual covers installation, operation, theory of operation, and field maintenance. The discussion has general application inasmuch as design, operation, and maintenance features are similar for all encoders in this series. Refer to Section 6 for identifying nomenclature applicable to all models in this series. Differences in models are also tabulated in Section 6. Maintenance or repair beyond that covered in this manual must be performed by the manufacturer.

1.2 GENERAL DESCRIPTION

Encoders of the DIGISEC RA _/23C series are medium resolution, absolute shaft position encoders of the photoelectric, non-contacting type, which are designed for use wherever shaft position information is required in digital form. Typical applications include digital servos, stable platforms, navigation systems, theodolites, tracking radars, laser tracking systems, and numerical control systems.

An outline drawing applicable to all RA _/23C series encoders is contained in Section 6. All RA _/23C series encoders have a standard Size 23 synchro mount (2.25 inch diameter mounting flange) with 2-inch pilot diameters on both sides of the flange, as shown in the outline drawing. Thus, the encoder can be mounted with the flange located on either side of the mounting surface. The notch in the synchro flange mates with a standard zeroing ring (not supplied) which can be used to precisely align the encoder to the drive shaft zero reference.* RA _/23C series encoders are provided with either a plain or a standard splined 0.25 inch shaft. The drive shaft to be monitored is coupled to the plain shaft through a high accuracy flexible coupling, and to the splined shaft through a standard gear fastened to the latter. The choice of flexible coupling or gear hardware is left to the user.

RA _/23C series encoders are designed to operate from a +5V source (+6V optional). Except for this external source, the encoder is functionally self-contained. Within its cylindrical case are contained a shaft-mounted glass code disc, illuminating lamps, photodetectors, and signal processing solid state circuits, which provide a digital output word representing the instantaneous absolute angular position of the encoder shaft. The output word is in natural binary code and is provided in parallel format, with one bit per output channel. One pigtail cable supplies power to the encoder, brings out the parallel outputs, and provides a test point for the illuminating lamps. One cable lead (HOLD) is also used to apply an external HOLD

*Refer to MIL-HDBK-214A (Synchros) for information on applicable zeroing hardware (zeroing rings, pinion wrenches, etc.)
pulse when reading out "on the fly". To eliminate any possible ambiguity in the parallel readout, an inherent characteristic of the natural binary code, DIGISEC encoders utilize anti-ambiguity logic, which requires a finite amount of settling time for the signal to propagate from the least significant bit to the most significant bit. Application of the HOLD pulse freezes the state of the least significant bit and enables non-ambiguous parallel readout, subsequent to the settling period, for the remainder of the HOLD pulse duration.

All RA __/23C series encoders have field replaceable illuminating lamps and signal processing electronics to facilitate maintenance.

1.3 SPECIFICATIONS

General specifications applicable to all encoders of the RA __/23C series are contained in Table 1-1. Additional detailed specifications showing differences between various models are contained in Section 6. These differences include resolution, power supply voltage, direction of rotation for increasing count, shaft style, and temperature range. Output stages on all encoder channels are either 5404 or 7404 TTL (transistor-transistor logic) elements. 5404 elements are used in encoders with a "military" temperature range. 7404 elements are used in encoders with a "commercial" temperature range. Performance characteristics are similar for both types. Figure 1-1 provides output/load interface information.

1.4 DESIGN FEATURES

The DIGISEC RA __/23C series has been designed to meet the requirements of the most demanding military and industrial applications with emphasis on ruggedness, long life, and reliability. All electronic circuits are solid state and of conservative design with components substantially derated. Noteworthy design features are the following:

b. Optional shaft style (plain/splined).
c. One power supply voltage (+5V, +6V optional).
d. Optional temperature ranges (military/commercial).
e. Sealed bearings, field lubrication not required.
f. Hard-chrome-on-glass code disc.

1/ See Section 4.3.1
Table 1-1  General Specifications for DIGISEC RA __/23C Series Encoders*

<p>| | |</p>
<table>
<thead>
<tr>
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<tr>
<td><strong>Electrical</strong></td>
<td><strong>Mechanical</strong></td>
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<tr>
<td>Resolution</td>
<td>Refer to Section 6</td>
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<tr>
<td>Accuracy</td>
<td>1/3 Bit RMS, excluding quantization</td>
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<tr>
<td>Output Signals (Fig. 1-1)</td>
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</tr>
<tr>
<td>Data format</td>
<td>Parallel, one output channel per bit</td>
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<tr>
<td>Logic levels</td>
<td>ONE: +3.5 to +5.5 vdc, ZERO: ± 0.5 vdc</td>
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<tr>
<td>Rise and fall times</td>
<td>0.5 microseconds, maximum, with 3900-ohm load shunted by 1000 picofarads, or 10 TTL loads</td>
</tr>
<tr>
<td>Output stages</td>
<td>Fanout of ten 5404 or 7404 TTL elements</td>
</tr>
<tr>
<td>Settling time</td>
<td>3 microseconds, maximum</td>
</tr>
<tr>
<td>Note:</td>
<td>Readout can be initiated 3 microseconds after application of external HOLD pulse</td>
</tr>
<tr>
<td>Input HOLD pulse</td>
<td></td>
</tr>
<tr>
<td>Pulse levels</td>
<td>OFF (normal output): 0 to +0.5 vdc</td>
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<tr>
<td></td>
<td>ON (frozen output): +3.5 to +5.5 vdc</td>
</tr>
<tr>
<td>Pulse width</td>
<td>Refer to Section 2.5</td>
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<tr>
<td>Sink current</td>
<td>7 milliamperes, maximum</td>
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<tr>
<td>Power requirements</td>
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<tr>
<td>Voltage</td>
<td>Either: +5 vdc ± 2%, 1% max. peak to peak ripple</td>
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<tr>
<td></td>
<td>Or: +6 vdc ± 2%, 1% max. peak to peak ripple</td>
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<tr>
<td></td>
<td>(Refer to Section 6 for applicable voltage)</td>
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<tr>
<td>Current</td>
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<tr>
<td></td>
<td>650 milliamperes for 6 V option</td>
</tr>
<tr>
<td>Outline dimensions</td>
<td>Refer to Section 6</td>
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<tr>
<td>Shaft</td>
<td>0.25-inch diameter, plain or splined</td>
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<td>Weight</td>
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<tr>
<td>Rotation direction for</td>
<td>Refer to Section 6</td>
</tr>
<tr>
<td>increasing count</td>
<td></td>
</tr>
<tr>
<td>Rotation rate</td>
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<td>Operating</td>
<td>360 rpm maximum</td>
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<tr>
<td>Slew</td>
<td>3600 rpm maximum</td>
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<td>Rotor moment of inertia</td>
<td>0.4 oz.-in.² maximum</td>
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<td>Breakaway torque</td>
<td>0.5 oz.-in. maximum</td>
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<tr>
<td>Running torque</td>
<td>0.4 oz.-in. maximum</td>
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<tr>
<td>Shaft loading</td>
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<tr>
<td>Axial</td>
<td>5 lbs. maximum</td>
</tr>
<tr>
<td>Radial</td>
<td>2 lbs. maximum at shaft end</td>
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*Refer to Section 6 for differences in models
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<th>Commercial</th>
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<td>0 to +70°C</td>
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<tr>
<td>Non-Operating</td>
<td>-62°C to +90°C</td>
<td>-62°C to +90°C</td>
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<td>Humidity</td>
<td>MIL-STD-202, Method 103, Condition B, (0-95%) operating. Will withstand 100% humidity with condensation non-operating.</td>
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</tr>
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<td>Shock</td>
<td>MIL-STD-202, Method 213, Test Condition A (50g peak, half sine wave, 11 ms duration, 3 shocks each direction each axis, 18 shocks total)</td>
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</tr>
<tr>
<td>Vibration</td>
<td>MIL-STD-202, Method 204, Condition D, except that vibration amplitude is .075 (total excursion) or 25g (peak) whichever is less. (swept sine, 10 hz to 2000 hz).</td>
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<tr>
<td>Salt atmosphere</td>
<td>MIL-STD-202, Method 101, Condition B, 5% salt solution</td>
<td></td>
</tr>
<tr>
<td>Inclination</td>
<td>MIL-E-16400 Paragraph 4.5.14.2</td>
<td></td>
</tr>
</tbody>
</table>

**Rated Life**

- Mechanical, operating: \(10^9\) revolutions minimum
- MTBF: 50,000 hours minimum calculated per MIL-HDBK-217A ground factors. 30,000 hours minimum calculated per MIL-HDBK-217A shipboard factors.
For $e_{in} = 0$ vdc, $e_o$ High (One State)

$$e_o = \frac{5R_L}{R_L + R_{L} \times 130} - 0.6$$

For $e_{in} = +5$ vdc, $e_o$ Low (Zero State)

$$e_o = \frac{5}{R_{L} + 5} \frac{R_{L} \times 5}{R_{L} + 5}$$

Figure 1-1. Encoder Output and Load Interface Characteristics.
g. Small encoder diameter achieved by using integrated circuit modules.

h. Stainless steel case.

i. Low torque.

j. Field replaceable lamp assembly (long-life incandescent lamps).

k. Field replaceable signal-processing integrated circuit modules requiring no field adjustment.

l. The use of anti-ambiguity logic which synchronizes all coarser data to the fine code track and thereby permits all but the fine track to be of relatively low accuracy.

m. Capability for readout on the fly at any speed up to the maximum rated operating speed. To allow for non-ambiguous readout on the fly, the encoders are designed to accept an external HOLD pulse which freezes the parallel outputs during readout.

1 See Section 4.3.1
2. INSTALLATION AND OPERATION

2.1 HANDLING

DIGISEC RA 23C series encoders are precision instruments and should be handled with care. Avoid shock to the encoder, particularly to the encoder shaft which is mounted on bearings to extremely fine tolerances. The plastic covering and the protective cap should remain in place during shipment or storage and should be removed only at the time that the encoder is installed in its operating location.

2.2 MECHANICAL ALIGNMENT

RA 23C series encoders are supplied in standard Size 23 synchro mount configuration (see Fig. 2-1 and the outline drawing contained in Section 6). All encoders have a 1/4-inch OD shaft, either plain or splined.

CAUTION

No alterations may be made to the encoder shaft or body except by the manufacturer, or warranty will be voided. Drilling or machining of the shaft will cause serious damage to the code disc, readout optics, or bearings.

CAUTION

Do not use a rigid coupling between the encoder shaft and the drive shaft. A flexible coupling of high angular accuracy (Kinnemotive Corporation, Kinneflex series, or equivalent) must be used, unless the encoder is to be gear driven.

All splined shafts have a standard 22 teeth/96 pitch configuration with 1/4-28 outside thread, and are designed to accept a gear secured to the shaft by means of an MS 17186-4 or -8 drive washer and an MS 17178-3 drive nut.

The encoder may be installed in any attitude. However, the encoder shaft must be precisely aligned with the drive shaft because misalignment will degrade readout accuracy and shorten encoder life through excess loading of its bearings. The mounting hole must be bored to a diameter that is 0.001 inch (nominal) larger than the pilot diameter of the encoder.

CAUTION

All misalignments between the encoder mounting surface and the drive shaft must be such that the radial and axial loading on the encoder shaft (through either the flexible coupling or drive gear) do not exceed the limits specified in Table 1-1.
Figure 2-1 Installation of typical RA__23C encoder with plain shaft
Note that the encoder has zero reference marks at the base of the shaft and on the case. These marks, when coincident, set the shaft angular position to a coarse zero count. The encoder must be oriented on its mounting surface so that its zero approximately coincides with that of the drive shaft. A standard Size 23 zeroing ring, to be driven by a pinion gear, may be inserted between the synchro flange and the mounting surface to facilitate precise zeroing after installation (see Section 2.4). Refer to MIL-HDBK-214A (Synchros) for information on applicable zeroing rings and associated components.

2.3 ELECTRICAL CONNECTIONS

2.3.1 Encoder Cable Wire Functions

All input/output electrical connections for the encoder cable are identified in the outline drawing contained in Section 6. The Lamp Test connection is used for troubleshooting (Section 4).

2.3.2 Grounding

Power and signal common are tied together within the encoder and are isolated from case ground since many applications require independent electrical and case grounds. In order to minimize noise problems, the noise level between the electrical and case grounds should be kept as low as possible. It is recommended that case ground be connected to electrical ground at only one point in the user's system, at a location to be determined experimentally for the particular installation.

2.3.3 Power Supply Considerations

RA_/23C series encoders are designed to operate from either +6vdc or +5vdc. The voltage applicable to a particular encoder can be found in Section 6.

NOTE

The external power supply must be set to provide +5V (or +6V), ± 2%, 1% maximum peak to peak ripple, at the encoder cable end in order to avoid possible erroneous readings caused by interconnection losses.

2.3.4 HOLD Pulse Line Driver Protection

The encoder HOLD pulse input is normally customer energized from a circuit that is powered from the same supply that operates the encoder, thus ensuring simultaneous application of power to all circuits of the encoder. In the event that the encoder proper and external HOLD driver circuits are energized from separate, non-interlocked supplies, this could result in a high state (5V) HOLD signal applied to an unenergized encoder, which could damage the encoder. Operation in this latter condition is allowed as long as a series protection diode is connected between the encoder HOLD line and the user's equipment. Any small signal diode with a PIV rating 50V or larger may be used. The anode of the diode should connect to the encoder HOLD line. The diode is considered part of the user's drive circuitry which should be capable of meeting the limits of para. 2.5 (Page 10) at the input of the encoder.
2.4 ZERO ALIGNMENT

1. Check that encoder is properly installed and that coarse zero has been set in accordance with instructions contained in Section 2.2.

2. Connect encoder to power supply and to output receiving circuitry.

3. Turn on power supply and receiving circuitry.

4. Slightly loosen the synchro clamps securing the encoder synchro flange to the mounting surface.

5. Set drive shaft to zero reference position.

6. While monitoring the encoder output with the receiving circuitry, carefully rotate the encoder case (either directly or through a gear-driven zeroing ring) until the zero is set to the desired tolerance.

7. Carefully tighten the synchro clamps. The encoder is now ready for operation.

2.5 OPERATION

After the encoder has been properly installed and connected to a power source and suitable receiving circuitry, operation involves only the application of the external HOLD pulse, as described below, for non-ambiguous readout on the fly. No adjustments or preventive maintenance are required aside from normal external cleaning procedures.

The encoder parallel outputs are always present as dc levels once external power is applied to the encoder. However, the anti-ambiguity logic within the encoder (Section 3.3) requires a certain amount of settling time (3 microseconds, maximum) which could cause improper readings if these were taken on the fly during a "settling cycle". To assure correct readout on the fly, DIGISEC encoders are designed to accept an external HOLD pulse. The net function of this pulse is to guarantee reliable readout if sampling is initiated 3 microseconds (or more) after the leading edge of the pulse and is terminated with the trailing edge. The HOLD pulse requirements are as follows:

- OIT: ±0.5 vdc, 7 ma Sink
- ON: +3.5 to +5.5 vdc, 100 μa Source

Maximum Width: See below
The maximum width of the HOLD pulse can be determined from the following equation:

\[ T_H = \frac{13.2 \times K \times R}{S} \]

Where \( T_H \) = Maximum width of HOLD pulse in microseconds

\( S \) = Shaft rotation speed in rpm

\( R \) = Encoder resolution in seconds of arc

\( K \) = A constant determined by the encoder type, as follows:

<table>
<thead>
<tr>
<th>RA /23C</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
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<tr>
<td>11</td>
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<td>12</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>2</td>
</tr>
</tbody>
</table>

If the HOLD pulse is applied for longer than \( T_H \), the readout may show incorrect count. The maximum time, \( T_R \), allowable for correct readout is therefore

\[ T_R = (T_H - 3) \text{ microseconds} \]
3. THEORY OF OPERATION

A general functional block diagram applicable to all RA \(/23C series encoders is contained in Fig. 3-1. The encoder consists of an optical subassembly, trim board A1, logic and hold board A2, and logic board A3. Field replaceable assemblies are the lamp assembly (which is part of the optical subassembly) and boards A2 and A3.

3.1 OPTICAL SUBASSEMBLY

The optical subassembly consists of a shaft-mounted glass code disc, a lamp assembly, and a slit and photodetector assembly. The code disc contains a series of concentric annular code tracks, each consisting of alternating transparent and opaque segments describing equal arcs along the circumference. The number of code cycles (one transparent segment followed by one opaque segment) varies by a factor of two from track to track, starting with one cycle on the inner track. The transparent and opaque states of all tracks thus represent the ONE and ZERO states of a multi-digit natural binary word, with one track per digit. The state of each track is sensed by illuminating the code disc and detecting the modulated light behind each track (as the disc is rotated) with a precisely registered slit/photodetector assembly. Each photodetector's output is essentially a square wave, with one cycle corresponding to a code cycle. The frequency of each detector's output is therefore a function of shaft rotation speed. When the shaft is stationary, the output of any detector is simply a dc level corresponding to either a ONE or ZERO state.

3.2 TRIM BOARD A1

Trim board A1 contains several trimming components which are factory set to provide the required parallel signal levels as they enter boards A2 and A3. The trim board components are precisely set for the detector outputs of its particular optical subassembly. Consequently, board A1 is not field replaceable.

3.3 LOGIC AND HOLD BOARD A2

Logic and hold board A2 performs two basic functions. It processes the parallel photodetector outputs corresponding to the three finer tracks on the code disc to provide the least significant digit (LSD) for all encoders as well as a few more significant digits for the higher resolution encoders (see Fig. 3-1). A2 also initiates anti-ambiguity control for the entire encoder and receives the input HOLD pulse enabling unambiguous readout on the fly.
Figure 3-1 Encoder General Functional Block Diagram
The fine track circuit consists of the latching circuits, LSD processing circuits, and output stages shown in line in Fig. 3-1. This circuit generates one or more bits, depending on the encoder, from the fine track on the code disc. The CARRY signal represents the state of the fine track, which is used to synchronize the output transitions of all more significant bits. The CARRY cycle requires a maximum three microseconds of settling time after each fine track transition. Application of the HOLD pulse freezes the states of all bits through the latching circuits and through the nature of the CARRY logic. Reliable readout can then be initiated three microseconds after the leading edge of the HOLD pulse. The maximum duration of the HOLD pulse for reliable readout is dependent on the encoder resolution and shaft speed, as defined in Section 2.5. The output stages, which function as buffer amplifiers are either 5404 or 7404 TTL elements (refer to Section 1.3).

The two remaining tracks whose signals are processed by A2 each provide one of the parallel output bits. The CARRY from the fine track to the anti-ambiguity logic synchronizes the transitions of these two bits with those of the fine track. The more significant bit of the two, which is also the first CARRY for board A3, has its output stage on A3.

3.4 LOGIC BOARD A3

Logic board A3 processes the photodetector outputs of the remaining tracks to provide the remaining more significant bits. Each bit becomes the CARRY for the anti-ambiguity logic of the next more significant bit.

3.5 LAMP TEST CIRCUIT

The field replaceable lamp assembly contains several precisely aligned and potted lamps, all electrically connected in parallel. All RA 13/23C encoders contain four lamps. All remaining encoders (RA 12/23C, RA 11/23C, and RA 10/23C) contain three lamps. The LAMP TEST wire is connected to the less positive side of the parallel combination in each case. A voltmeter connected across the LAMP TEST wire and common will read the total current drain of all lamps through a series resistor. The normal readings can be found in Section 4. Failure of any lamp is indicated by a decrease in the current through the series resistor.

\[1/\] See Section 4.3.1
4. MAINTENANCE

1.1 SCOPE

The optical subassembly of RA 1/23C series encoders is factory aligned to extremely high precision. Therefore, field maintenance of encoders in this series is restricted to repair by replacement of the following three potted subassemblies: the lamp assembly, logic and hold board A2, and logic board A3. Refer to Section 6 for part numbers of replaceable assemblies applicable to any encoder. Trim board A1 is factory set for each encoder and is not field replaceable. It is partially hard-wired to the encoder.

The troubleshooting instructions which follow should help in isolating failure to either the external equipment, the three replaceable assemblies, or the rest of the encoder. Replace field replaceable assemblies in accordance with the instructions contained in Section 4.3. If failure is diagnosed in the non-replaceable portion of the encoder, no attempt should be made to correct the malfunction by opening the optical subassembly or forcing rotation of the encoder shaft. A detailed description of failure symptoms, suspected malfunctions, and operating conditions should be made. The encoder should then be carefully decoupled and removed from its mount, securely packed with its protective cap, plastic covering, and failure description, and returned to the manufacturer for repair.

If failure is diagnosed in the encoder cable, do not unsolder or solder wires where they connect to the encoder circuitry. Repair broken or shorted wires by splicing. If splicing does not correct the malfunction, replace the encoder.

RA 1/23C series encoders have sealed bearings and no field lubrication is necessary.

CAUTION

Do not open any portion of the encoder beyond providing access to the three field replaceable assemblies or warranty will be void. Repair of the optical subassembly beyond replacing the lamp assembly must be performed by the manufacturer.

1.2 TROUBLESHOOTING

Troubleshooting the encoder involves first checking each of the parallel outputs for proper waveform amplitude and frequency as specified in Section 4.2.1. If the parallel output waveforms do not conform to the performance standards, the
malfunction must be isolated either to the equipment external to the encoder (Section 4.2.2) or to the encoder itself (Section 4.2.3). Follow all steps in the order given. A voltmeter and a dual-trace oscilloscope equivalent to Tektronix Model 502A are required. Refer to the outline drawing contained in Section 6 for the encoder cable connections.

4.2.1 Encoder Output Test

Perform the output test as follows, using oscilloscope:

1. Shut off encoder power supply.
2. Disconnect encoder parallel outputs from receiving circuitry.
3. Turn on encoder power supply.
4. Rotate encoder shaft smoothly at maximum rated operating speed.
5. Connect oscilloscope (internal trigger) to parallel output in pairs, starting with LSD and LSD+1, then LSD+1 and LSD+2, (etc.) and check that all channel waveforms conform to the following standards:
   a. Each channel’s output is a square wave with logic levels as follows:
      
      \[
      \begin{align*}
      \text{ONE:} & \quad +3.5 \text{ to } +5.5 \text{ vdc} \\
      \text{ZERO:} & \quad 0.0 \text{ to } +0.5 \text{ vdc}
      \end{align*}
      \]
   
   b. Each channel’s square wave has one half the frequency of the next less significant channel.

6. If any performance standard is not met, proceed with Sections 4.2.2 and 4.2.3 as judged necessary.

4.2.2 Troubleshooting External Equipment

If any performance standards are not met in Section 4.2.1, proceed with the following steps to check out the external equipment.

1. Check that encoder power supply voltage is within proper tolerance.

   **NOTE**

   Ensure that external power supply is set to \(+5V^*\) (or \(+6V^*\)), \(\pm 2\%\), 1% maximum peak-to-peak ripple at the end of the encoder cable, to avoid possible erroneous readings caused by interconnection losses.

^*Voltage depends on particular encoder (Section 6)
2. Check that output wires and receiving circuitry are free of shorts.

3. Check that encoder shaft is not binding and that coupling is not loose. If shaft is binding, check that encoder is installed in accordance with the requirements of Section 2.2. Encoder must be replaced if it is properly aligned mechanically but the shaft still binds.

4.2.3 Troubleshooting Encoder

If any performance standards are not met in Section 4.2.1, proceed with the following steps to check out the encoder itself.

1. Turn on encoder power supply.

2. Check encoder lamps by connecting voltmeter across LAMP TEST wire (+) and common.

<table>
<thead>
<tr>
<th>Encoder Type</th>
<th>Performance Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA 10/23C</td>
<td>0.35 vdc Minimum</td>
</tr>
<tr>
<td>RA 11/23C</td>
<td>0.35 vdc Minimum</td>
</tr>
<tr>
<td>RA 12/23C</td>
<td>0.35 vdc Minimum</td>
</tr>
<tr>
<td>RA 13/23C</td>
<td>0.4 vdc Minimum</td>
</tr>
</tbody>
</table>

If performance standard is not met, replace lamp assembly (refer to Section 4.3). * If in doubt, replace lamp assembly.

3. Check boards A2 and A3, in that order, by monitoring the following output channels on oscilloscope and checking for output waveform standards indicated in Section 4.2.1, Step 5.

<table>
<thead>
<tr>
<th>Encoder Type</th>
<th>Board A2</th>
<th>Board A3</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA 10/23C</td>
<td>LSD</td>
<td>LSD+1 thru LSD+9</td>
</tr>
<tr>
<td>RA 11/23C</td>
<td>LSD, LSD+1</td>
<td>LSD+2 thru LSD+10</td>
</tr>
<tr>
<td>RA 12/23C</td>
<td>LSD, LSD+1, LSD+2</td>
<td>LSD+3 thru LSD+11</td>
</tr>
<tr>
<td>RA 13/23C</td>
<td>LSD, LSD+1 thru LSD+3</td>
<td>LSD+4 thru LSD+12</td>
</tr>
</tbody>
</table>

If any performance standard is not met, replace boards A2 and/or A3, in that order (refer to Section 4.3). Note that the anti-ambiguity control (CARRY) for the entire encoder is initiated on A2. If replacement of A2 and/or A3 does not correct the malfunction, failure resides in non-field-replaceable portions of the encoder.

* To test a lamp assembly outside the encoder, apply 3.5 to 4.0V to lamp block pins, and observe that all bulbs light. Bulbs also wear out due to gradual blackening, so that this test is not always conclusive. If in doubt, replace lamp assembly.

1/ See Section 4.3.1
4.3 PARTS REPLACEMENT

CAUTION

Shut off input power before removing or replacing components.

4.3.1 Removal/Replacement of Lamp Assembly (Figure 4-1)

NOTE

Replacement lamps are made up on a custom basis for specific encoders. Make sure the serial number on the replacement lamp matches the encoder serial number. Do not interchange lamps among encoders. The following three steps of this paragraph apply only to those encoders for which replacement lamps have been supplied.

Removal

1. CAREFULLY BRUSH AWAY ALL DIRT FROM THE FRONT OF THE ENCODER. Loosen two captive screws securing lamp assembly to encoder. Do not remove the screws from the lamp assembly.
2. Note the electrical contact pins, the alignment pins, and the sealing lip shown in Fig. 4-1.
3. Carefully remove the lamp assembly by pulling alternately on the two captive screws to overcome the friction from the sealing lip.

Replacement

Reverse removal procedures, taking care not to bend the electrical contact pins. Be careful not to get finger marks on the polished lamp reflectors. (See Page 19)

4.3.2 Removal/Replacement of Boards A2 and A3

Removal

1(a) Older Models - Pinch grommet at junction of encoder case and cable and push grommet and cable into case sufficiently to free cable.
1(b) New Models - Unscrew cable clamp packing nut and slide back nut and "O" ring.
2. Loosen two screws securing case to encoder on cable end of case. Remove screws.
3. Pull case back along cable to expose A2 and A3.
4. Carefully pull A2 and/or A3 back from its connector.

Replacement

Reverse removal procedures.

CAUTION

Plug-in boards are keyed to their proper sockets. Do not force a board into an improper socket or in reverse orientation.
NOTE

If cleaning of dirt or finger marks is required, use a cotton swab ("Q tip") and isopropyl alcohol. Swab gently and allow to dry. Do not use harsh or abrasive cleaning agents.

Electrical Contact Pin (2)

Captive Screw (2)

Hole for Alignment Pin (2)

(a) Rear 3/4 View

Sealing Lip

Lamp (3 or 4)

(b) Front 3/4 View

Sealing Lip

Captive Screws

Figure 4-1 Lamp Assembly
5. REPLACEMENT PARTS

Replacement parts applicable to any encoder of the DIGISEC __/23C series are listed in Table 5-1. These parts are the lamp assembly, logic and hold board A2, and logic board A3.
<table>
<thead>
<tr>
<th>Encoder Part Number (2785-_)</th>
<th>Replacement Part and Part Number</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Lamp Assy. 2757-16G_</td>
<td>Logic and Hold Board (A2) 2757-33G_</td>
</tr>
<tr>
<td>1, 33</td>
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1/ See Section 4.3.1
6. DIFFERENCES IN MODELS

This section contains detailed specifications for all DIGISEC RA __/23C series encoders in addition to those listed in Table 1-1. These detailed specifications are listed in Table 6-1. Also contained in this section is an outline drawing (C 2000-583) that shows pertinent dimensions of all encoders, as well as optional shaft details. The drawing also identifies the electrical connections to the encoder.

All RA __/23C series encoders are identified by type number and part number. The type number gives the major (but not all) encoder characteristics as follows:

RA(a)/23C(b)X

Where  R = rotary
    A = absolute
    (a) = resolution (Table 6-1, Column 1)
    23 = standard Size 23 synchro configuration
    C = contained electronics
    (b) = temperature range (M - Military; C-Commercial)
    X = modification of catalog unit; see supplement in front of manual for details.

The part number completely specifies the encoder.

Example: RA 12/23C(M), P/N 2757-47

Table 6-1 shows that this encoder has the following characteristics:

Resolution: 2\(^{12}\) transitions/revolution
Input voltage: +6VDC
Shaft style: Splined
Temperature range: Military
Direction of rotation for increasing count: CCW
Table 6-1  Detailed specifications for DIGISEC RA_/23C series encoders

<table>
<thead>
<tr>
<th>DIGISEC Type Number (RA_/23C)</th>
<th>Part Number (2785-__)</th>
<th>Angular Resolution (minutes)</th>
<th>Transitions per Revolution</th>
<th>Input Voltage (+ vdc)</th>
<th>Shaft (Note 5)</th>
<th>Temperature Range (Note 6)</th>
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</tbody>
</table>

Notes

(1) Outline dimensions shown on drawing C 2000-583
(2) Electrical connections listed on drawing C 2000-583
(3) Rotation for increasing count, defined looking at shaft end of encoder:
   (a) Part numbers 2757G1 through G32, clockwise
   (b) Part numbers 2757G33 through G64, counterclockwise
(4) Other specifications listed in Table 1-1
(5) P = plain, S = splined (see drawing C 2000-583)
(6) M = military, C = commercial (refer to Table 1-1)
NOTES:

1 MILITARY UNIT TO BE AS SHOWN. COMMERCIAL UNIT TO BE 2.25 ± 0.016.
The model SI10120-0030 SELF-SCAN II panel display is a single-line, intermediate size, 20-character-wide, alphanumeric display that is ideal where readability and visibility are primary considerations. The display presents a bright, flicker-free, soft neon-orange glow that is characteristic of gas plasma technology. An additional feature of the panel is its buttability, which permits it to be assembled into multi-panel large displays. For example, a 1920-character display consisting of 24 rows of 80 characters each can be mounted in an enclosure 4 feet by 5 feet by 5 inches.

The panel display operates in a multiplexed scanning mode, with scanning being performed from left to right. Because of the internal panel address feature, only 14 external connections are required to control all of the functions of the panel. The internal address feature also substantially reduces the drive electronics required in comparison to a standard X-Y address matrix display.

The light output is generated by a neon glow discharge between transparent anodes on the front glass plate (for the horizontal rows) and the cathodes (corresponding to the columns) on the rear glass.

The cathodes are bussed in a six-phase arrangement so that "01" cathodes are columns 1, 7, 13, etc. While the common "01" cathodes are all driven low simultaneously during clock periods 1, 7, 13, etc., a glow occurs only under one cathode column due to the internal panel characteristics. This glow is under the anodes addressed by the character generator or auxiliary data inputs. This matrix address results in only those display cells needed in that one vertical column being on at a given moment of time.

This display can be directly interfaced to computer/microprocessor-based systems because all logic level inputs/outputs are TTL compatible. The display is ideal for applications where information must be presented to an operator.

### ENVIRONMENTAL AND MECHANICAL CHARACTERISTICS

<table>
<thead>
<tr>
<th>Character</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Temperature</td>
<td>0° to 50°C</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>-40° to +85°C</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>90% max. (no condensation)</td>
</tr>
<tr>
<td>Weight</td>
<td>14 ounces</td>
</tr>
<tr>
<td>Size</td>
<td>14” x 2” x 1 3/4”</td>
</tr>
<tr>
<td>Shock</td>
<td>20 g, ½ sine wave, 11 ms in Y axis</td>
</tr>
<tr>
<td>Vibration Constant</td>
<td>2 g acceleration, 50 - 100 Hz, 10 min each axis</td>
</tr>
<tr>
<td>Vibration Sinusoid</td>
<td>0.018” double amplitude, 5 - 50 Hz</td>
</tr>
<tr>
<td>Operating Altitude</td>
<td>10,000 ft. max.</td>
</tr>
<tr>
<td>Storage Altitude</td>
<td>30,000 ft. max.</td>
</tr>
</tbody>
</table>

### OPTICAL CHARACTERISTICS

<table>
<thead>
<tr>
<th>Character</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Character Height</td>
<td>0.65 inch</td>
</tr>
<tr>
<td>Character Width</td>
<td>0.55 inch</td>
</tr>
<tr>
<td>Dot Size</td>
<td>0.05 inch square</td>
</tr>
<tr>
<td>Dot Center to Center Spacing</td>
<td>0.10 inch</td>
</tr>
<tr>
<td>Luminous Intensity</td>
<td>230 microcandelaas</td>
</tr>
<tr>
<td>Light Output</td>
<td>60 ft. Lamberts (Note 1)</td>
</tr>
<tr>
<td>Contrast Ratio</td>
<td>5 to 1 at 300 ft. L</td>
</tr>
<tr>
<td>Horizontal Viewing Angle</td>
<td>150°</td>
</tr>
<tr>
<td>Vertical Viewing Angle</td>
<td>50°</td>
</tr>
<tr>
<td>Color</td>
<td>Neon Orange</td>
</tr>
</tbody>
</table>
CHARACTER FORMAT (Actual Size)

as in a POS terminal. Each character is displayed in a 5 x 7 dot matrix, and formed of 0.050-inch square cells. Characters are defined by a positive logic six-bit ASCII code. Used in conjunction with the count logic, a character is formed by turning the display dot cells on and off as required at approximately 70 Hz.

The appropriate six-bit ASCII code for each desired character must be present for a minimum of five clock periods of each character position. After the 20th character is displayed, a reset pulse must be supplied to start a new scan. The character displayed in the extreme left location corresponds to the ASCII code present at the data input lines just after the reset pulse. The subsequent characters are displayed sequentially to the right according to the ASCII code provided to the display.

While the panel display is provided with a character generator capable of displaying a 64-character ASCII subset repertoire, seven auxiliary data input lines permit the character generator to be bypassed so that additional symbols or characters can be displayed. Each auxiliary data line controls one horizontal row of dot cells. A logic 0 at an auxiliary data input line turns on a cell; a logic 1 keeps the cell off.

When the auxiliary data inputs are used in conjunction with the character generator, either a logic 1 level must be applied to pin 1 (display disable) or a blanking code must be present at all the data input lines. In addition, a logic 1 level must also be present at all auxiliary data inputs during the entire reset period, during the last two columns of each character position, and for 14 us (min) after each high-to-low transition of the clock.

An external clock signal of 100 to 120 us provides the basic system timing. For complete scan cycle of the panel, 139 clock pulses are required: 138 clock pulses for the six-phase drive, and one pulse for scan reset. The screen of the panel can also be blanked by applying logic 0 level signal at the display disable input, provided all auxiliary data inputs are at logic 1 level.

The drive circuitry board is mounted with component side accessible to the user. This permits the character generator to be field-replaceable without dismantling the panel/driver board assembly.

For additional information or applications assistance on this panel, write to Burroughs Corporation, Electronic Components Division, P. O. Box 1226, Plainfield, New Jersey 07061; or call our special sales/applications number, (201) 757-3400 in New Jersey, or (714) 835-7335 in California.
ELECTRICAL CHARACTERISTICS (Note 4)

Power Required
- Positive Logic Supply: 4.75 to 5.25V @ 350 mA max.
- Negative Logic Supply: -11.4 to -12.6V @ -50 mA max.
- Display Supply: -237.5 to -262.5V @ -110 mA max.

Clock Input Signal (See Figure 1)
- Logic 1 Level: 2.0 to 5.25V @ 40 uA
- Logic 0 Level: 0 to 0.8V @ -7 mA
- Clock Period: 100 to 120 us
- Logic 0 Voltage Duration: 20 us to Clock Period -20 us

Data Input Signals
- Logic 1 Level: 3.75 to 5.25V @ 10 uA max.
- Logic 0 Level: -7.0 to 0.6V @ 10 mA
- Duration (Note 2): 5 Clock Periods

Auxiliary Data Input Signals (Note 3)
- Logic 1 Level: 4.35 to 5.55V @ 20 uA max.
- Logic 0 Level: 0 to 0.4V @ -4 mA max.
- Logic 1 Duration: 14 us min. to 1 Clock Period max.

Reset Input
- Logic 1 Level: 2.0 to 5.25V @ 40 uA
- Logic 0 Level: 0 to 0.8V @ -7 mA
- Duration: 2 to 4 us
- Reset Input Delay: 0 to 1 us

Display Disable Input (Blanking Control)
- Logic 1 Level: 2.0 to 5.25V @ 40 uA
- Logic 0 Level: 0 to 0.8V @ -7 mA

Data Update Output (Pulse Indicating End of Character)
- Logic 1 Level: 2.0 to 5.25V @ -2 mA
- Logic 0 Level: 0 to 0.4V @ 10 mA

Table 2. TRUTH TABLE

<table>
<thead>
<tr>
<th>BINARY INPUT</th>
<th>CHAR.</th>
<th>BINARY INPUT</th>
<th>CHAR.</th>
<th>BINARY INPUT</th>
<th>CHAR.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>@</td>
<td>22</td>
<td>V</td>
<td>43</td>
<td>+</td>
</tr>
<tr>
<td>1</td>
<td>A</td>
<td>23</td>
<td>W</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>24</td>
<td>X</td>
<td>45</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>25</td>
<td>Y</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>D</td>
<td>26</td>
<td>Z</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>E</td>
<td>27</td>
<td></td>
<td>48</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>28</td>
<td>~</td>
<td>49</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>G</td>
<td>29</td>
<td></td>
<td>50</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>H</td>
<td>30</td>
<td></td>
<td>51</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>I</td>
<td>31</td>
<td></td>
<td>52</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>J</td>
<td>32</td>
<td>BLANK</td>
<td>53</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>K</td>
<td>33</td>
<td></td>
<td>54</td>
<td>6</td>
</tr>
<tr>
<td>12</td>
<td>L</td>
<td>34</td>
<td>&quot;</td>
<td>55</td>
<td>7</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>35</td>
<td>#</td>
<td>56</td>
<td>8</td>
</tr>
<tr>
<td>14</td>
<td>N</td>
<td>36</td>
<td>$</td>
<td>57</td>
<td>9</td>
</tr>
<tr>
<td>15</td>
<td>O</td>
<td>37</td>
<td>%</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>P</td>
<td>38</td>
<td>&amp;</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Q</td>
<td>39</td>
<td></td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>R</td>
<td>40</td>
<td></td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>S</td>
<td>41</td>
<td></td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>T</td>
<td>42</td>
<td></td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>U</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1. PIN CONNECTIONS

<table>
<thead>
<tr>
<th>Pin</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Display Disable In</td>
</tr>
<tr>
<td>2</td>
<td>Data Update Out</td>
</tr>
<tr>
<td>3</td>
<td>Clock In</td>
</tr>
<tr>
<td>4</td>
<td>Not Used</td>
</tr>
<tr>
<td>5</td>
<td>Not Used</td>
</tr>
<tr>
<td>6</td>
<td>-250V</td>
</tr>
<tr>
<td>7</td>
<td>Reset In</td>
</tr>
<tr>
<td>8</td>
<td>Not Used</td>
</tr>
<tr>
<td>9</td>
<td>Ground</td>
</tr>
<tr>
<td>10</td>
<td>Aux. Data 2 In</td>
</tr>
<tr>
<td>11</td>
<td>Not Used (Leave Open)</td>
</tr>
<tr>
<td>12</td>
<td>Aux. Data 4 In</td>
</tr>
<tr>
<td>13</td>
<td>Binary 3 In</td>
</tr>
<tr>
<td>14</td>
<td>Aux. Data 6 In</td>
</tr>
<tr>
<td>15</td>
<td>Binary 2 In</td>
</tr>
<tr>
<td>16</td>
<td>Aux. Data 7 In</td>
</tr>
<tr>
<td>17</td>
<td>Binary 4 In</td>
</tr>
<tr>
<td>18</td>
<td>Aux. Data 5 In</td>
</tr>
<tr>
<td>19</td>
<td>Binary 8 In</td>
</tr>
<tr>
<td>20</td>
<td>Aux. Data 3 In</td>
</tr>
<tr>
<td>21</td>
<td>Not Used</td>
</tr>
<tr>
<td>22</td>
<td>Aux. Data 1 In</td>
</tr>
<tr>
<td>23</td>
<td>Binary 16 In</td>
</tr>
<tr>
<td>24</td>
<td>-12V</td>
</tr>
<tr>
<td>25</td>
<td>Binary 32 In</td>
</tr>
<tr>
<td>26</td>
<td>+5V</td>
</tr>
</tbody>
</table>

Figure 2. BLOCK DIAGRAM
1. This value is a typical time-averaged luminous intensity per dot at a current of 10 mA. The intensity may vary slightly with individual panels; but within any panel, all cells will have a constant luminous intensity.

2. Data input must remain constant for the first five clock periods of each character position. A logic 1 level is “true” data. These inputs may be left open-circuited when not used. These inputs must be pulled up to positive logic supply voltage level when used. They must be in logic 1 state for at least 14 us after every negative clock transition and during the entire reset period.

3. Absolute ratings beyond which life and performance will be impaired.

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Figure 3. SYSTEM TIMING DIAGRAM
APPENDIX D

EXTERNAL SERIAL INTERFACE
External Serial Interface

The serial interface on the microprocessor allows remote operation of the radome positioner. This interface is based on the RS-232-C interface standard*. ASCII commands are entered from a remote device which invokes the same responses as keyboard entries. A list of valid commands for the serial interface are given in Table D-1. A continuous display of current positioner status is sent to the external device. This device may at anytime send a valid command back through the interface to the microprocessor. Any invalid command received by the microprocessor will invoke an error message. The display on the radome positioner will echo any valid command just as it does for a keyboard entry. A switch, located at the front panel of the computer, will determine the mode of operation of the RFSS Radome Positioner. The two modes of operation are "Local" and "Remote". The local mode will allow only keyboard access and the remote mode will deny keyboard access and allow remote entry of valid commands. Note, however, that the arrow commands can only be used in setting their respective azimuth and elevation limits. Also, a valid command must be typed in to start the continuous display from the serial interface.

Access to the serial interface is by way of a EIA standard 25-pin connector located on the back panel of the microcomputer chassis. This connector, labeled "RS-232-C", is attached to connector P3 on the micromodule 1A board by way of solid wire ribbon cable as indicated on drawing #65. Pin identification using this standard is given in Table D-2.

The low data rates used in this system require no handshaking through the serial interface, therefore, a jumper from pin 15 to pin 14 of P3 (Drawing 65) has been used to constantly enable the I/O port of the microprocessor. For a software listing of the serial interface routine, please refer to Appendix B.

TABLE D-1

Valid Serial Interface Commands

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Start/Stop</td>
</tr>
<tr>
<td>E</td>
<td>Set Elevation</td>
</tr>
<tr>
<td>A</td>
<td>Set Azimuth</td>
</tr>
<tr>
<td>P</td>
<td>Program</td>
</tr>
<tr>
<td>.</td>
<td>Decimal Point</td>
</tr>
<tr>
<td>-</td>
<td>Minus Sign</td>
</tr>
<tr>
<td>+</td>
<td>DOWN</td>
</tr>
<tr>
<td>+</td>
<td>UP</td>
</tr>
<tr>
<td>+</td>
<td>LEFT</td>
</tr>
<tr>
<td>+</td>
<td>RIGHT</td>
</tr>
</tbody>
</table>

Manual positioning

1. E, 20.0, S
2. E, 20.0, A, 10.0, S

To pass limits

\[
\{E, A\} \left[ \rightarrow, \leftarrow \right] \]

Exceeding limit: change is limited.
To set limit OK S.

To run program

\[ P \quad \text{Enter \{E \{A \}} \quad \text{then} \quad S \]

It will ask for parameters (again see appendix E) then S.


**TABLE D-2**

**Pin Description for Serial Interface Connector**

<table>
<thead>
<tr>
<th>Pin Number (25 Pin Connector)</th>
<th>13-Edge Connector (20 Pin Connector)</th>
<th>Description</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Protective Ground</td>
<td>GND</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>Transmitted Data</td>
<td>Tx DATA</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>Received Data</td>
<td>Rx DATA</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>Request to Send</td>
<td>RTS</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>Clear to Send</td>
<td>CTS</td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>Data Set Ready</td>
<td>DSR</td>
</tr>
<tr>
<td>7</td>
<td>13</td>
<td>Signal Ground</td>
<td>GND</td>
</tr>
<tr>
<td>8</td>
<td>15</td>
<td>Received Line</td>
<td>SIG DET</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Ground</td>
<td>GND</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Ground</td>
<td>GND</td>
</tr>
<tr>
<td></td>
<td>11 - 19</td>
<td>x,x,x,2,4,6,8,10,12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>14</td>
<td>DTR</td>
</tr>
<tr>
<td></td>
<td>21 - 25</td>
<td>16,18,20,x,x,</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX E

PRESTORED RASTER SCAN PATTERNS
Raster Scan Patterns

The patterns are generated from keyboard entries made by the user. The entries are variable parameters that determine how each pattern is generated. The display is used to prompt user access through either the keyboard or external serial interface by the use of these variable parameters: A, B, and C. Currently, there are four user programmable patterns that are invoked by activation of the "PROC" key on the keyboard. The display will then ask the user to enter a programmed pattern number from 1-4. The user will then be prompted by the display to enter the required parameters upon which the processor will then wait for a "START" key to be pressed before the desired program will start.

Patterns 1, 2 and their associated variables are defined in Figure E-1. The microcomputer, using the entered values of "A" and "C", computes point 1 and promptly moves the positioner to that point. The positioner will briefly stop and then move to the next calculated position, point 2. Point 3 is computed by the entered parameter "B". The positioner is moved to point 4 taking advantage of the change in coordinate signs and then finishes one period of the scan after arriving at point 5. The remainder of the raster positions are calculated in a similar manner. Pattern 2 is generated in a similar manner, the only difference being a 90 degree shift of the AZ/EL axes.

Patterns 3 and 4, shown in Figure E-2, access stored trigonometric values which are used to generate the desired patterns. These stored values can be found in the software listing of Appendix B. Activation of pattern 3 will initialize the positioner at the origin of the coordinate system. This position is referred to in the figure as point 1. The positioner will then move up in elevation until it reaches point 2. One leg of the star has now been generated. It will then move down in elevation and stop when point 3 is reached. The positioner will move back up to the origin (point 1). The positioner moves in a similar manner to complete the star raster. The legs of the star are separated by the entered angle
Figure E-1. Linear Raster Patterns
Figure E-2. Star and Circle Raster Patterns

a) Pattern #3 (Star)

b) Pattern #4 (Circle)
and all the end points of the legs are computed using analytical geometry. These points are defined as points on a circle with a maintained radius. Pattern 4 is a circle of which the radius is a variable through an entered parameter \( r \). The circle is begun at point 1 on the elevation axis and moves in a clockwise direction with a constant increment of one degree. This angular resolution cannot be changed by the user and always completes a cycle of 360 degrees. The software listing of all four patterns can be found in Appendix B.
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