AA-M879B-TC

RA81 Disk Drive Maintenance Guide

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RA81 Disk Drive Maintenance Guide

Digital Equipment Corporation
Colorado Springs, Colorado

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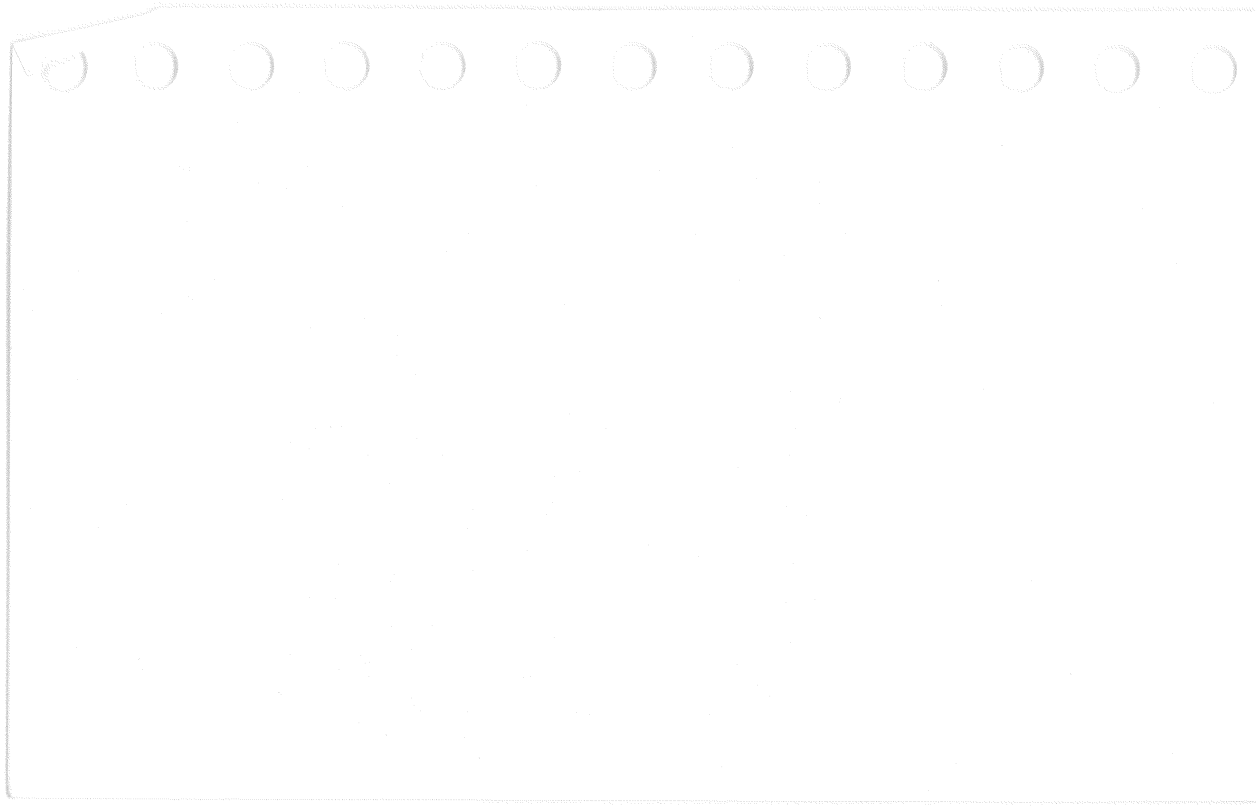
PREFACE

This manual covers two different versions of the RA81 Disk Drive. One is the initial configuration and the other is an updated version which contains one less circuit module. In the earlier units, the drive personality logic is located on a separate circuit module. In the newer RA81 drives, however, the personality logic has been included on the microprocessor board. Except for this difference, the operating characteristics of both drives are the same.

There are, however, some differences in the diagnostic tests and error codes associated with these drives. Although the majority of tests apply to both versions of the RA81, some are unique for each drive configuration.

In order to cover both versions of the RA81 Disk Drive in the same manual, some means of distinguishing between the drives had to be adopted. This has been done primarily with astrisks, footnotes, and other forms of notation throughout the text. Similar notations have also been included on illustrations. When reading this manual, particular attention should be given to any and all special notations.



1 INTRODUCTION

1.1 SCOPE

This maintenance guide provides diagnostic and troubleshooting information for the RA81 Disk Drive and outlines corrective maintenance procedures. This manual is a condensed version ofthe RA81 Disk Drive Service Manual.

1.2 RELATED DOCUMENTATION

The following documentation may be ordered from Printing and Circulation Services, 444 Whitney Street, Northboro, MA. 01532.

- *RA81 Disk Drive User Guide* (EK-0RA81-UG)
- *RA81 Disk Drive Service Manual* (EK-0RA81-SV)
- *RA81 Disk Drive Illustrated Parts Breakdown* (EK- ORA81-IP)

The following documentation may be ordered from the Software Distribution Center, 20 Forbes Road (NR4), Northboro MA. 01532.

- *RA81 Field Maintenance Print Set* (MP-01359)
- *UDA50 Maintenance Documentation Kit** (QP904-GZ)
- Looseleaf binder for maintenance guides (AV-L980A- TK)

* (This kit contains the *UDA50 Maintenance Guide* and currently available disk drive maintenance guides in a looseleaf binder.)

2 REMOVAL AND REPLACEMENT

2.1 FRU LOCATIONS

This chapter shows the location of the RA81 field replaceable units (FRUs). No removal/replacement procedures are documented in this chapter. For specific directions on how to remove and/or replace any particular FRU, refer to Chapter 2 in the *RA81 Disk Drive Service Manual*.

The RA81 field replaceable units are shown in four separate illustrations. Figure 2-1 shows the location of the logic modules in the upper chassis area. Figure 2-2 shows the RA81 assemblies in the lower chassis area. Figure 2-3 shows the lower chassis area with the HDA removed. Figure 2-4 shows the back view of the RA81 with the power supply removed.

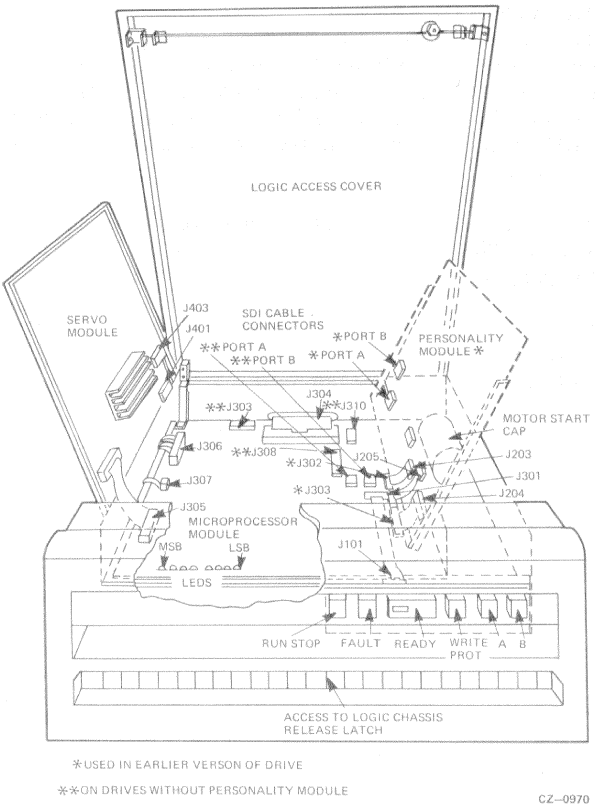


Figure 2-1 RA81 Upper Chassis Area

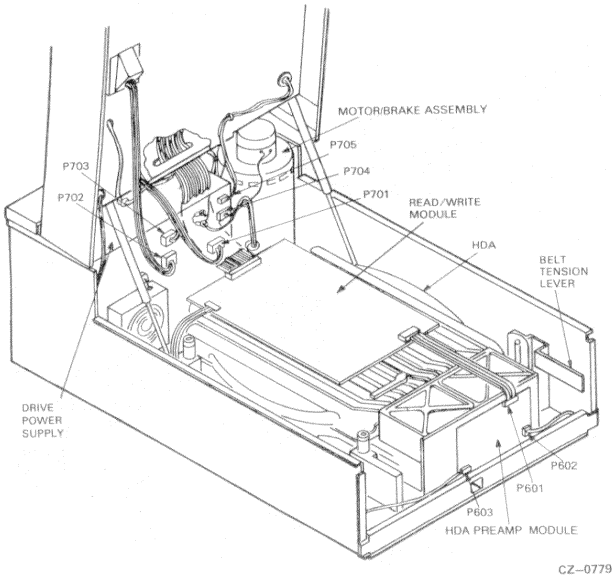


Figure 2-2 RA81 Lower Chassis Area (with HDA)

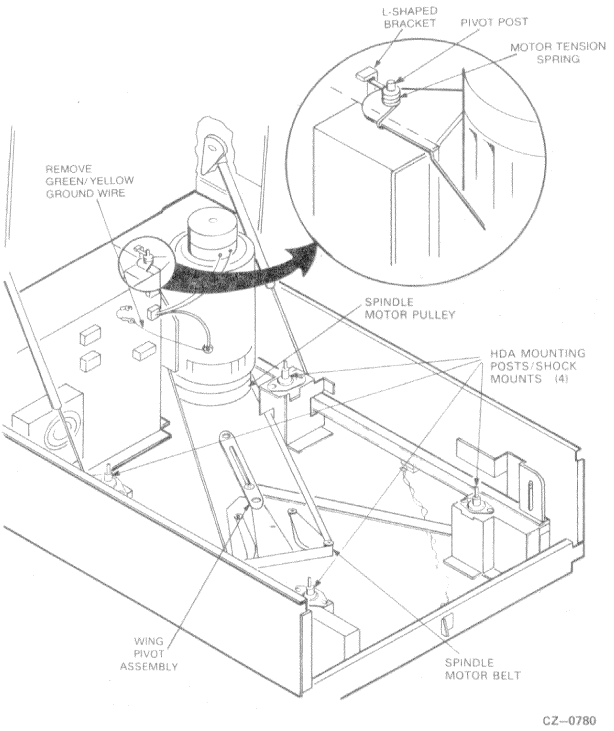


Figure 2-3 RA81 Lower Chassis Area (without HDA)

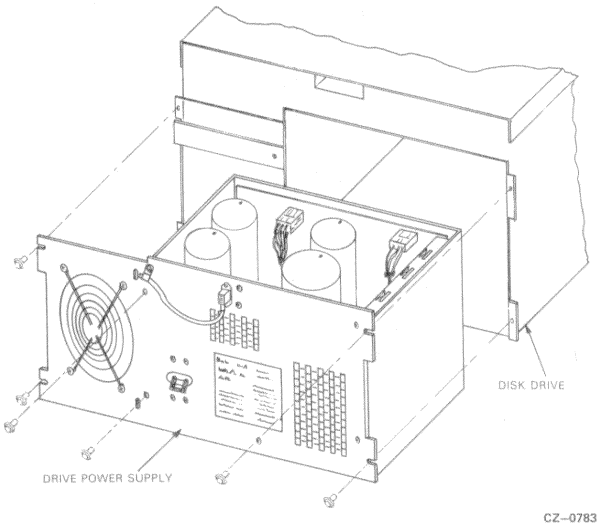


Figure 2-4 RA81 Back View

3 ADJUSTMENTS

3.1 INTRODUCTION

This chapter describes the belt tension adjustment on the RA81. This is the only adjustment necessary and needs to be performed by field personnel.

3.2 BELT TENSION ADJUSTMENT

1. Place the RUN switch in the OUT position to stop the spindle drive motor.

NOTE

Before performing this adjustment, ensure that the power is turned off at the ac power controller.

2. Raise the drive logic chassis.
3. Find the belt tension adjustment screw and brass-colored slider(Figure 3-1).
4. The brass-colored slider should be even with the reference marker (Figure 3-2). If not, an adjustment is necessary.
5. Loosen the locking nut (Figure 3-1) and adjust the belt tension screw until the brass-colored slider is even with the adjustment indicator. Turn the screw clockwise to move the slider forward.
6. Tighten the locking nut after the adjustment has been made.
7. Restore ac power to the drive and apply power to the spindle drive motor by pushing the RUN switch to the IN position.

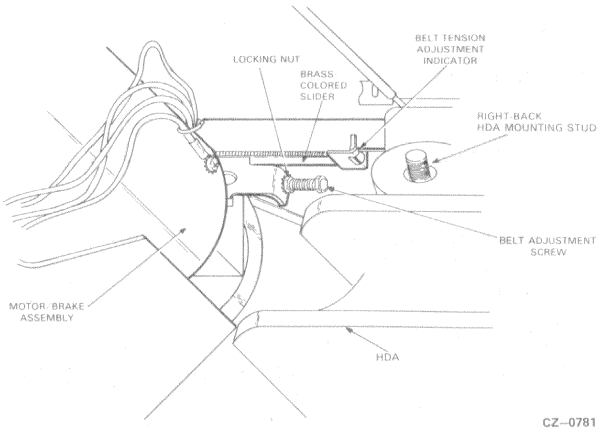


Figure 3-1 Belt Tension Adjustment Screw

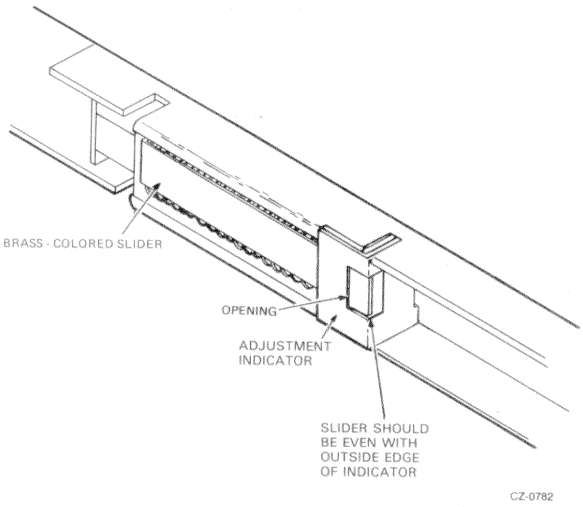


Figure 3-2 Belt Tension Reference Marker

4 DRIVE-RESIDENT DIAGNOSTICS

4.1 INTRODUCTION

This chapter describes how to run the drive-resident diagnostics using the field service diagnostic terminal distributed in the CD kit.

4.2 DIAGNOSTIC TERMINAL CONNECTION AND SET-UP

The following paragraphs tell how to connect the field service diagnostic terminal to an RA81 Disk Drive.

NOTE

Any 300 baud, EIA compatible terminal with an RS232 interface can be used to communicate with the RA81.

1. Ensure that the RUN/STOP switch and both port select switches are in the OUT position.
2. Apply power to the drive. At this time, the drive runs the hardcore test sequence (Appendix B). All front panel lights turn on. Successful completion of the power up sequence is indicated by the front panel lights going off in about 3-4 seconds. Refer to Appendix F for front panel error code definitions if any lights fail to turn off.
3. The drive idle loop test sequence is run next. This test starts automatically 30 seconds following the end of the hardcore test sequence. Allow 30 seconds for the execution of the drive idle loop test. Observe the microprocessor LEDs for a display of a hexidecimal E7. The lights go out after a successful completion. Errors are reported through the front panel lights and the micro LEDs (Appendices E and F).

4. Connect the diagnostic terminal to the mating connectors located on the microprocessor module. See Figure 4-1. These connectors are located in the motor start capacitor compartment in earlier versions of the RA81 Disk Drive.

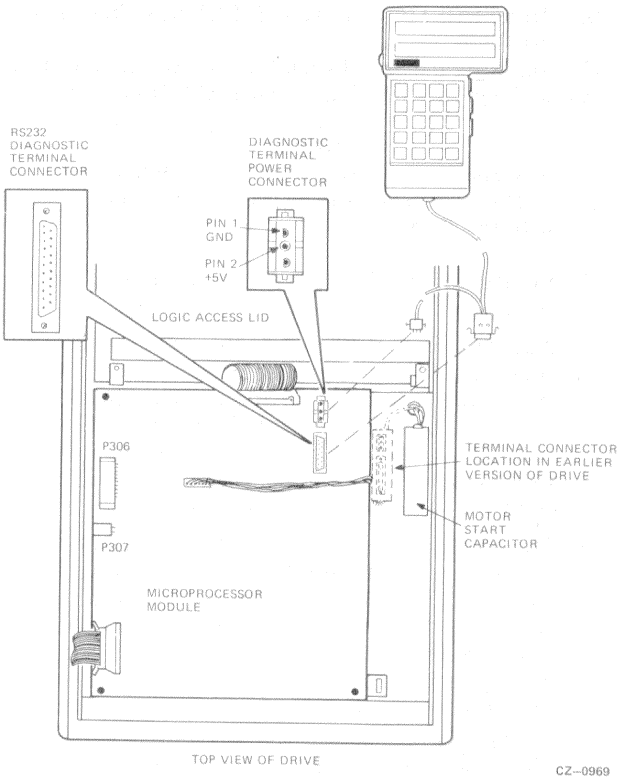


Figure 4-1 Diagnostic Terminal Connections

5. Press the continue (CONT) key on the terminal keyboard.
6. Input a CTRL C (^C) on the terminal keyboard.
7. Wait for the terminal to display the diagnostic prompt RA81>. Then, start the testing by keying in one of the ten diagnostic commands.

4.3 DIAGNOSTIC COMMANDS

The ten diagnostic monitor commands and their corresponding abbreviations are listed below. Descriptions of these commands are included in Chapter 4 of the *RA81 Disk Drive Service Manual.*

Command Name/ ABBREVIATION
Run Diagnostics RUN DIAG
Run Seek RUN SEEK
Run Recalibrate RUN RECA
Run Read/Write RUN READ
Run Servo RUN SERV
Run Interface RUN INTE
Run Alternate RUN ALTE
Run Random RUN RAND
Run Incremental RUN INCR
Run Diagnostic Test=xx DIAG RUN TEST=xx

A command abbreviation may be typed on the terminal to cause a particular diagnostic to run. RUN DIAG TEST=xx must include a test number in the xx position of the command. The valid test numbers that may be used with this command are found in Appendix D as well as descriptions of the tests.

NOTE

The terminal displays COMMAND NOT FOUND for any command that is miskeyed, spelled wrong, or not preceded by the word RUN.

Appendix B lists the subtests that are run in the various test sequences.

Appendix C lists the drive-resident tests that may be run by the subsystem diagnostics.

4.4 DIAGNOSTIC UTILITY COMMANDS

The utility commands and their abbreviations are listed below. Descriptions of these commands are provided in Chapter 4 of the *RA81 Disk Drive Service Manual*.

Command Name/ ABBREVIATION

```
Help
  HELP

Set Terminal Speed=xxxx
  SET TERM SPEED=xxxx

Show Radix
  SHOW RADI

Show Device
  SHOW DEVI

Show Version
  SHOW VERS

Show Terminal Speed
  SHOW TERM SPEED

Show Diagnostic Loop Mode
  SHOW DIAG LOOP

Show Diagnostic Faults
  SHOW DIAG FAUL

Show Diagnostic Status xxxx
  SHOW DIAG STAT xxxx
```

Command Name/
ABBREVIATION (Cont.)

```
Show Diagnostic Memory xxxx=aaaa
  SHOW DIAG MEMO xxxx=aaaa

Set Diagnostic Loop xxxx
  SET DIAG LOOP xxxx

Exit
  EXIT
```

4.4.1 Diagnostic Loop Mode

To enter a diagnostic loop mode, use the SET DIAG LOOP xxxx command.

1. Type ON in the xxxx field of the command to run the test until a CTRL C (^C) is input.
2. Type OFF in the xxxx field to run the diagnostic test once and then stop (default mode).
3. Type HALT in the xxxx field to run the test until an error is encountered.

4.5 DIAGNOSTIC ERROR REPORTS

If a test fails, the terminal displays the following message:

```
%RA81-TEST:aaaa SUBTEST:xx ERROR:xx UNIT:xxx
%RA81-FRU- (a FRU callout list is printed here)

                    OR

%RA81-FRU- (instructions to fix the specific fault)
```

4.6 EXITING DIAGNOSTIC MONITOR MODE

To exit the diagnostic monitor mode, input an EXIT command or a control Z (^Z). An alternate method is to push one or both of the port select switches.

5 FAULT ISOLATION

5.1 INTRODUCTION

This chapter describes the RA81 fault isolation procedures. A description of the subsystem drive error message is followed by troubleshooting notes and drive check-out procedures.

5.2 SUBSYSTEM ERROR MESSAGE INTERPRETATION

Below is a sample subsystem error message indicating a failure within the drive. The last two lines of the message (the real-time drive state and unit status) contain information that may be used to troubleshoot the drive.

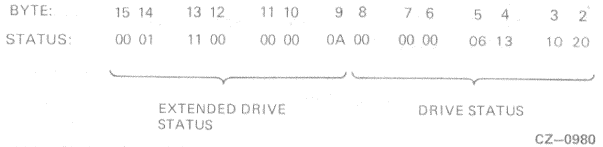
```
CZUDC HRD ERR 00044 ON UNIT TST 004 SUB 000 PC:021044
DISK EXERCISER DM PC:5110 UDA AT 172150 DRIVE 032 RUNTIME 0:00:23
ENTIRE RCT AREA SEARCHED, COULD NOT FIND RBN TO REPLACE
LBN WITH HEADER COMPARE ERROR
SEARCHING FOR LBN:  900

UDA SFT ERR 00006 ON UNIT 00 TST 004 SUB 000 PC:021044
DISK EXERCISER DM PC:5324 UDA AT 172152 DRIVE 032 RUNTIME 0:00:37
TIME-OUT OF DRIVE DURING WRITE ATTEMPT
WRITE ATTEMPT RETRIES: 0
L/DBM NUMBER 5252
ACTUAL L/R/DBN 0
TRK 1 CRP 0 CYL 6
ORIGIN OF LAST SEEK WAS CYL 5 GROUP 1
REAL TIME DRIVE STATE 8001
STATUS: 0001 1100 0000 0A00 0000 0613 1020
```

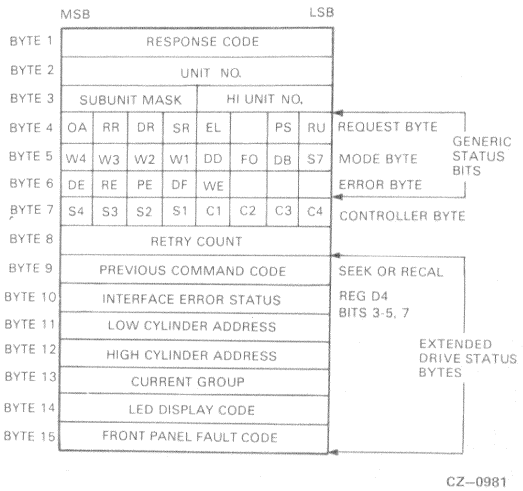
5.2.1. Error Message Status Line Interpretation

The status line found in the error message above is the response to a get status command sent to the unit. The get status command is represented by an 09 opcode and the response to the command (the get status) has an F6 opcode. The diagnostic performs get status commands in the reporting of certain error messages. Fourteen of a possible fifteen status bytes are printed out by the error message routine as shown by the sample printout.

Figure 5-1 contains details of the RA81 status bytes. Bytes 2 through 8 are drive specific error/status information. Note in Figure 5-1A that that first byte is not printed out. The first byte is a response code to the get status command and is therefore not needed in the error report. Bytes 9 through 15 are the RA81 extended drive status bytes. Figure 5-1B shows the response to the get status command.



(A) Drive-Specific Status Location



(B) Response to Get Status Command

Figure 5-1 Drive Status Details

The following paragraphs describe the contents of each status byte.

5.2.1.1 Byte 1 (Response Code Field) – This byte is the response code to a controller command.

5.2.1.2 Byte 2 (Unit Number) – The unit number consists of two hexadecimal digits representing the unit number of the selected disk drive returning the status (0-254).

5.2.1.3 Byte 3

- Subunit Mask Bits – This portion of byte 3 contains a four-bit representation of the subunit that is returning the status message. The right-most bit position represents subunit 0. The left-most bit position represents subunit 3. For drives that contain no subunits, the right-most bit position is always set indicating subunit 0. Only one bit can be set at a time.
- High Unit Number Bits – This portion of Byte 3 contains the upper four bits of a 12-bit (3 hexadecimal digits) unit number.

5.2.1.4 Byte 4

- OA Bit – A logical 1 in this bit position indicates that the drive is unavailable to the controller. A logical 0 indicates that the drive is available to the controller.
- RR Bit – A logical 1 in this bit position indicates that the drive requires an internal readjustment. Some drives do not use this bit.
- DR Bit – A logical 1 in this bit position indicates that there is a request for a diagnostic to be loaded in the drive microprocessor memory. A logical 0 in-

dicates that no diagnostic is being requested of the host system.

- SR Bit – A logical 1 in this bit position indicates that the drive spindle is up to speed. A logical 0 indicates the drive spindle is not up to speed.
- EL Bit – A logical 1 in this bit position indicates that there is loggable information in the extended status area (bytes 9-15). A logical 0 indicates that no information is available in the extended status area.
- PS Bit – A logical 1 in this bit position indicates that the drive port select switch for this controller is pushed in (selected). A logical 0 indicates that the switch is out.
- RU Bit – A logical 1 in this bit position indicates that the RUN/STOP switch is pushed in (RUN). A logical 0 indicates the switch is out (STOP).

5.2.1.5 Byte 5

- W4-W1 Bits – Logical 1s in any of these four bit positions represent the write-protect status for the subunit represented. (e.g., a 0001 indicates that subunit 0 within the selected drive is write-protected.)
- DD Bit – A logical 1 in this bit position indicates that the drive has been disabled by a controller error routine or diagnostic. The FAULT light is on when this bit is set. A logical 0 indicates that the drive was enabled by a controller error routine or diagnostic.
- FO Bit – A logical 1 in this bit position indicates that the drive can be formatted.
- DB Bit – A logical 1 in this bit position indicates that the diagnostic cylinders on the drive can be accessed.

- S7 Bit – A logical 1 in this bit position indicates that the 576 byte sector format is selected. A logical 0 indicates that the 512 byte sector format is selected.

5.2.1.6 Byte 6

- DE Bit – A logical 1 in this bit position indicates that a drive error has occurred and the drive FAULT lamp may be on.
- RE Bit – A logical 1 in this bit position indicates that an error occurred in the transmission of a command between the drive and the controller. The error could be a checksum error or an incorrectly formatted command string.
- PE Bit – A logical 1 in this bit position indicates that improper command codes or parameters were issued to the drive.
- DF Bit – A logical 1 in bit this postion indicates a failure in the initialization routine of the drive.
- WE Bit – A logical 1 in this bit position indicates a write lock error has occurred.

5.2.1.7 Byte 7

- S4-S1 Bits – This is a four-bit representation of the subunits that have their attention-available messages suppressed in the controller. The right-most bit position represents subunit 0. The left-most bit position represents subunit 3.

  If one of the bits is set, it indicates that the controller is not to interrupt the host CPU with an attention-available message when the specified subunit raises its available real-time drive status line to the controller. The S4-S1 bits reflect the results of a change

controller flags command in which attention-available messages are not desired for certain subunits.

- C1-C4 Bits – This is a four-bit drive status code indicating various states of drive operation. At the present time, only three codes are valid. A code of 0000 = drive normal operation. A code of 1000 = the drive is off-line due to being under control of a diagnostic. A code of 1001 = the drive is off-line due to another drive having the same unit identifier (e.g. serial number, drive type, class etc.).

5.2.1.8 Byte 8 (Retry Count/Failure Code) – This 8-bit byte contains one of two types of information depending upon the status of the DF bit (byte 6). The DF bit monitors the drive initialization process. The DF bit remains a 0 if initialization is successful. In this case, byte 8 contains the retry count from the previous operation, i.e., a seek operation required 14 retries to be successful. If a get status command is initiated, byte 8 contains the number 14.

The DF bit being set indicates that the drive initialization failed; therefore, byte 8 now contains a specific drive or code. This error code can be looked up in the appropriate drive service manual.

5.2.1.9 Byte 9 – This byte contains the controller command function code last executed by the drive.

Command	Opcode
Change mode	81
Change cont flags	82
Diagnose	03
Disconnect	84
Drive clear	05

Command	Opcode (Cont.)
Error Recovery	06
Get common character	87
Get subunit character	88
Get status	09
Initiate seek	0A
Online	8B
Run	0C
Read memory	8D
Recalibrate	8E
Topology	90
Write memory	0F

5.2.1.10 Byte 10 – This byte contains SDI error status bits 3,4,5,7.

- Bit 3 (overrun error) – This bit sets when either a read or a write command extends past the sector or index pulse that the operation started from.
- Bit 4 (parity error found) – This bit sets when a parity error is discovered during the transmission of a real-time command on the real-time controller state line. The real-time controller state line of the SDI bus carries the following four commands to the selected drive:

  1. Init.6,15,6,J
  2. Read gate
  3. Write gate
  4. Receiver ready

- Bit 5 (control pulse error) – This bit sets during the transmission of a real-time command if two or more pulses of the same polarity are detected on the real-time controller state line.

- Bit 7 (data pulse error) – This bit sets during the transmission of a real-time command if two or more pulses of the same polarity are detected on the write command data line.

5.2.1.11 Byte 11 – This byte contains the low order bits of the cylinder address of the last seek operation.

5.2.1.12 Byte 12 – This byte contains the high order bits of the cylinder address of the last seek operation.

5.2.1.13 Byte 13 – This byte contains the present RA81 group address. An RA81 group is defined as one of the 14 addressable read/write heads (0-13 decimal).

5.2.1.14 Byte 14 – This byte contains the hexadecimal error codes that are displayed by the diagnostic terminal or microprocessor LEDs during the execution of drive-resident diagnostics. Refer to Appendix E.

5.2.1.15 Byte 15 – This byte contains the hexadecimal codes representing the front panel fault indicators. Refer to Appendix F.

5.2.2 Real-Time Drive State (RTDS) Interpretation

The RTDS line in the error message sample above is the hexadecimal number 8001. Figure 5-2 shows the location of the drive state bits within the hexadecimal number. The following paragraphs describe the four RTDS state bits.

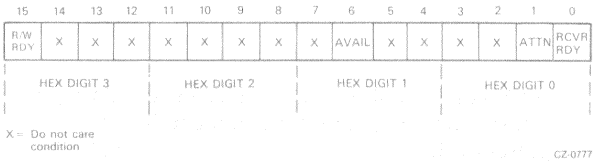


Figure 5-2 RTDS Code Bit Locations

5.2.2.1 Read/Write Ready (R/W RDY) – This bit indicates that the drive is capable of performing a data transfer. Any seek operation negates this signal.

5.2.2.2 Drive available (AVAIL) – The drive is not currently in an on-line state to either of the controllers in a dual controller configuration and is capable of executing an on-line command to either. The drive is unavailable to one controller when it is in on-line to the controller on the other port. A drive that is unavailable is capable of communicating with, but may not be fully utilized by, the controller on this port.

5.2.2.3 Attention (ATTN) – This bit notifies the controller that a generic status bit change has occurred in an on-line drive. The generic status bits are found in bytes 4, 5, and 6 of the GET STATUS command response. Refer to the appropriate controller maintenance guide for information about the generic status bits.

5.2.2.4 Receiver ready (RCVR RDY) – This bit indicates that the drive is ready to receive and negates while the drive is processing a command.

5.3 TROUBLESHOOTING PROCEDURES AND TIPS

The following text describes general troubleshooting tips that are useful in performing RA81 fault isolation.

5.3.1 Basic Drive Troubleshooting

One of the following approaches may be taken to troubleshoot the drive.

- Error Messages from the Host-Resident Diagnostics – A drive error code is contained in byte 14 of the error message status line (paragraph 5.2). Use Appendix G to look up the probable FRU replacement from the error code.
- Front Panel Error Code Displays – The front panel lights display an error code when a drive fault occurs. These error codes are identified in Appendix F, Table F-1. These errors are also displayed as a hexadecimal code in the microprocessor LEDs. When a specific error code is obtained, use Appendix G as a suggested FRU replacement guide.
- Error Displays From the Diagnostic Terminal – All error messages resulting from running the drive-resident diagnostics call out an FRU replacement.
- Drive Fault Light ON – Errors incurred while running subsystem diagnostics or customer software may result in the fault light coming ON. The fault light should be depressed once to cause the front panel to display an error code. See Appendix F.

Figure 5-3 is a flowchart for RA81 troubleshooting procedures.

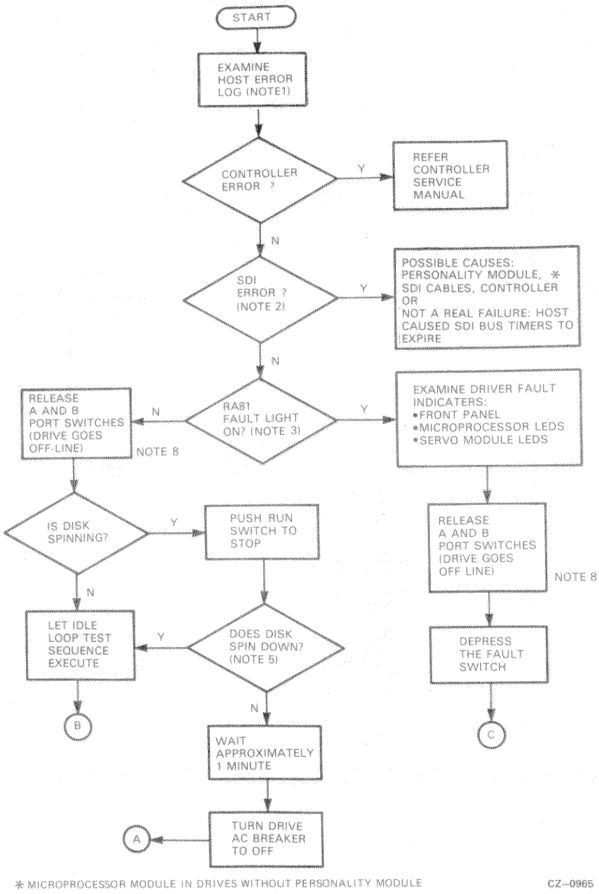


Figure 5-3 RA81 Troubleshooting (Sheet 1 of 7)

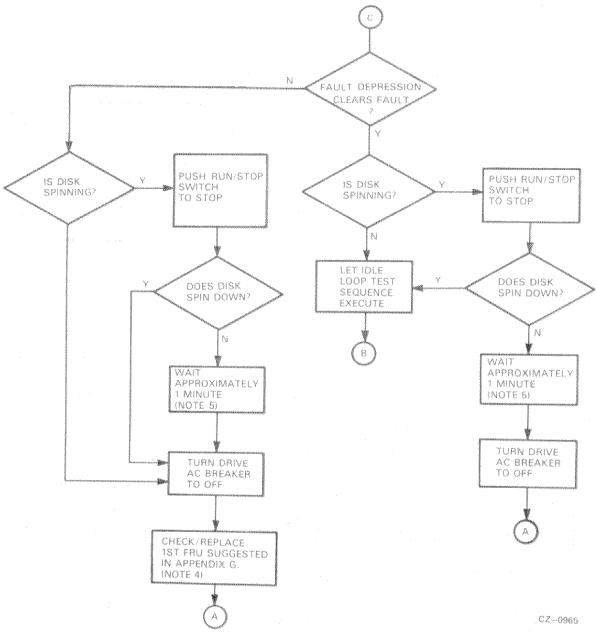


Figure 5-3 RA81 Troubleshooting (Sheet 2 of 7)

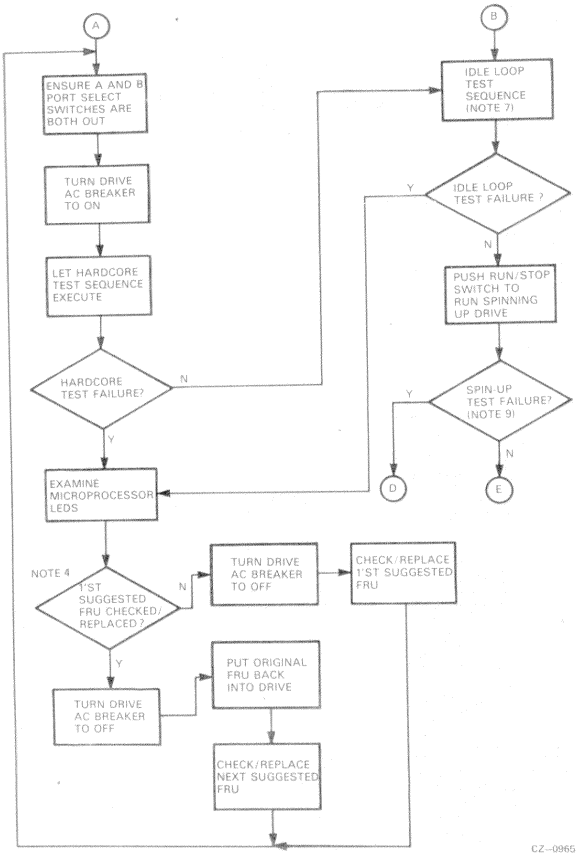


Figure 5-3 RA81 Troubleshooting (Sheet 3 of 7)

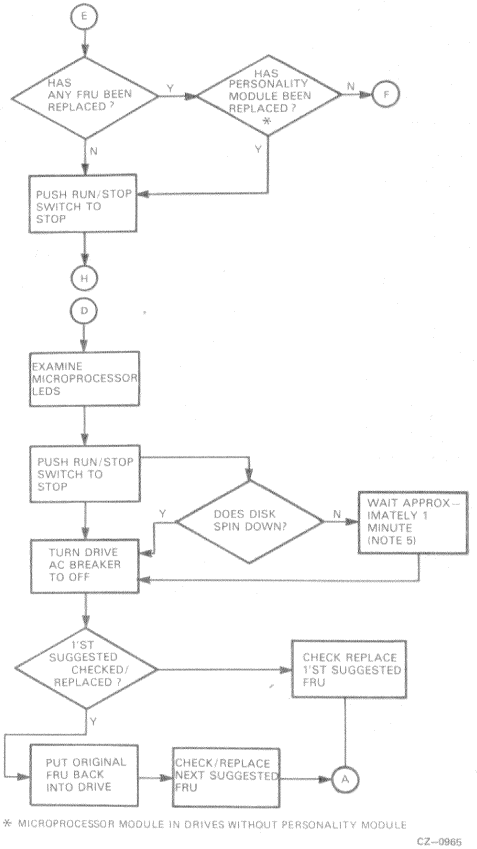


Figure 5-3 RA81 Troubleshooting (Sheet 4 of 7)

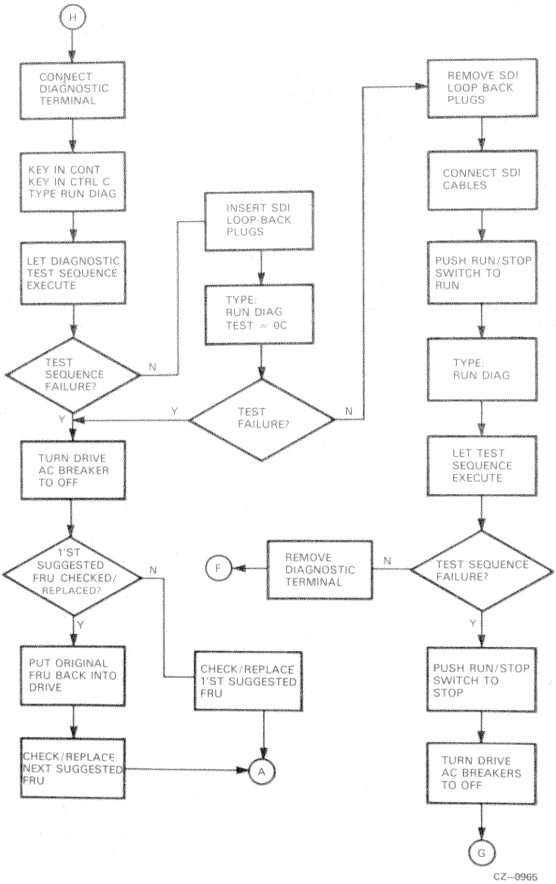


Figure 5-3 RA81 Troubleshooting (Sheet 5 of 7)

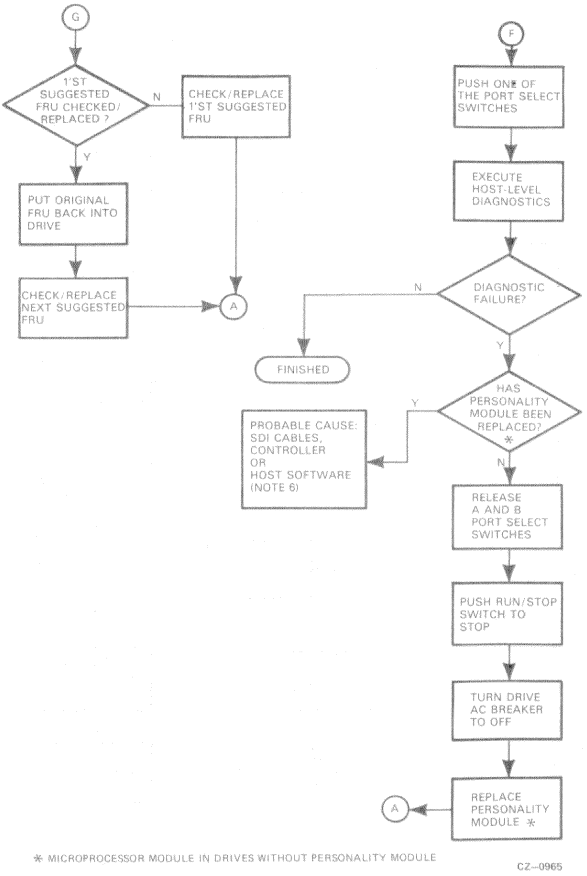


Figure 5-3 RA81 Troubleshooting (Sheet 6 of 7)

FLOW CHART NOTES

1. The host error log is used to isolate problems to the drive or controller and to log intermittent failures.

2. SDI errors may be controller or drive detected. The RA81 Fault light may be on.

3. The drive Fault light may have been cleared by the subsystem or by the pushing of the Fault switch.

4. Suggested FRU replacement sequence is found in Appendix G. Microprocessor LED's form a hexadecimal error code which is translated into FRU replacements.

5. If the drive idle loop test sequence has already started, the drive will not spin down until completion (about one minute). A drive failure may also cause the drive not to spin down. During on-line modes of operation, the controller governs the timing of the spin-down cycle even though the operator may have pushed the RUN/STOP switch to stop.

6. The RA81 stores up to 16 fault codes provided the drive is not powered off. This information is useful for troubleshooting intermittent drive faults. Intermittent drive faults are not logged by the host system software. Use the SHOW DIAG FAUL utility command with the diagnostic terminal to obtain these error codes. Paragraph 4.5.9 in the RA81 Service Manual describes this command.

7. Idle loop diagnostics execute for about 30 seconds every 10 to 20 seconds provided the port select switches are in the OUT position. The drive may be either spun up or down.

8. Normal operating states of the RA81 drive:

   - A and B port select switches out with neither light on = OFF-LINE.
   - A or B port select switches in but neither light on = AVAILABLE.
   - A or B port select switches in or out with either light on = ON-LINE.

9. An entire spin-up test sequence is executed each time the drive is spun up in the OFF-LINE state (port switches out). With the port switches in, the spin-up tests are run with the exception of the read/write diagnostics.

CZ–0965

Figure 5-3 RA81 Troubleshooting (Sheet 7 of 7)

5.3.2 LED Indicators

There are five sets of LED indicators in the RA81. Refer to Figures 5-4 and 5-5.

1. Eight LEDs located in the left front corner of the microprocessor module monitor the drive diagnostics. These LEDs display a hexadecimal code of E7 whenever the diagnostics are running. Failures that occur during the execution of these diagnostics are reflected in the LEDs as discrete error codes (Appendix F).
2. Four LEDs are also located on the left side of the microprocessor module in earlier drives equipped with a personality module. These LEDs monitor the integrity of the master microprocessor. The first three LEDs are normally off and the last LED is normally on. If all LEDs are off, it is an indication that +5 volts from the power supply are missing or incorrect. It also may indicate that the microprocessor module or personality module is defective. If any LED is on in addition to the one on the end, the microprocessor module is probably defective.

   The four LEDs described above are not present in drives without a personality module. Instead, these drives have a single LED located as shown in Figure 5-4. This LED indicates interaction between the master and slave microprocessors and lights each time the master microprocessor communicates with the slave.
3. One LED located on the left side of the servo module monitors the integrity of the slave microprocessor. Replace the servo module whenever this LED goes out. Ignore all other error codes.

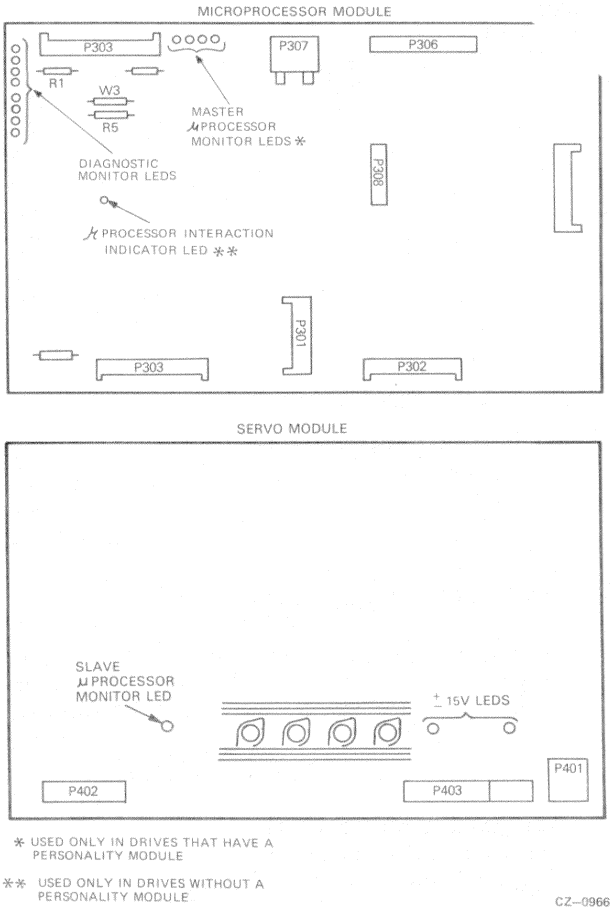


Figure 5-4 LED Locations

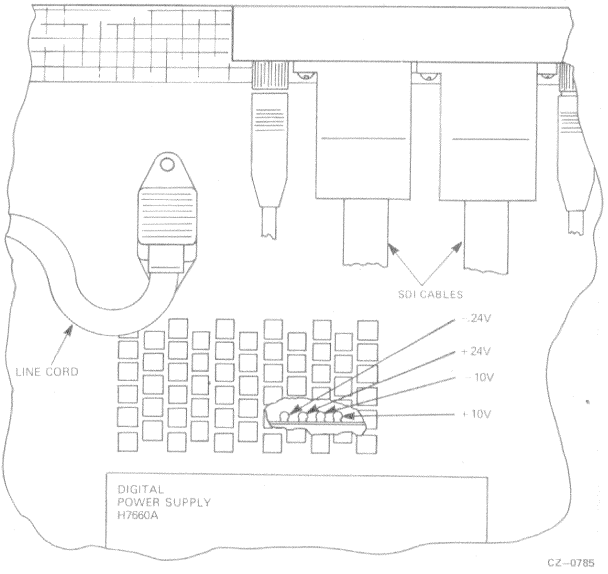


Figure 5-5 Power Supply LEDS

4. Two LEDs located on the right side of the servo module represent the status of the ±15 volt power supply. Refer to Table 5-1 whenever either of these LEDS goes out.
5. Four LEDs located in the power supply can be seen by looking in the top grill vent of the power supply rear panel (Figure 5-4). These LEDs monitor the ±24V and ±10V supplies. Refer to troubleshooting Table 5-2 when any of the lights go out.

Table 5-1 Power Supply Checks

Check	Action
+5 volt	Check that the operator control panel indicators flash on momentarily when power is applied to the drive. The flash indicates that +5 volts is present. If the drive cannot be powered up, check that +5 volts is present at the WRITE PROT switch. The WRITE PROTect switch lamp should light when pushed if +5 volts is present and the drive is on-line. If the front panel lights fail to come on, check the front panel light bulbs. This can be accomplished either visually or with an ohmmeter. If the +5 volts is missing, the power supply should be replaced.
±12 volt	Check that the two green 12-volt LEDs on the servo module (to the right of the heatsink) are on. When on, they indicate that both +12 and −12 volts are present. If either or both are off, the regulator for the voltages is bad, +24 volts and/or −24 volts is missing. If either of these voltages is missing, the power supply is probably at fault. If both voltages are present but the corresponding LED or LEDs are out, the servo module is probably defective.

Table 5-1 Power Supply Checks (Cont.)

Check	Action
±24 volt ±10 volt	Check that the four LEDs located on the power supply (Figure 5-4) are on. When all LEDs are on, it indicates that the ±24 and ±10 volt supplies are working properly. If any are out, replace the power supply.
FAULT indicator off, all other operator control panel indicators on	This condition (only in drives that use a personality module) occurs only when the DC LOW signal is asserted. Possible causes are the power supply servo module or microprocessor module. Check the powersupply LEDs.

5.3.3 Power Supply Troubleshooting

Table 5-1 contains power supply troubleshooting procedures to be used if a problem is suspected in the power supply. All power supply voltage measurements are taken on the circuit modules at the connector pins as indicated in Figure 5-6. The tolerances for these measurements are given in Table 5-2.

Table 5-2 DC Voltage Testpoints and Tolerances

Voltage	Test Points
+5 ±0.2	Pins 1, 2, 3 of J205
−5.2 ±0.2	Pins 15, 16 of J306
+24+3,−1	Pin 13 of J403
−24+1,−3	Pin 11 of J403
DC low	Pin 1 of J306

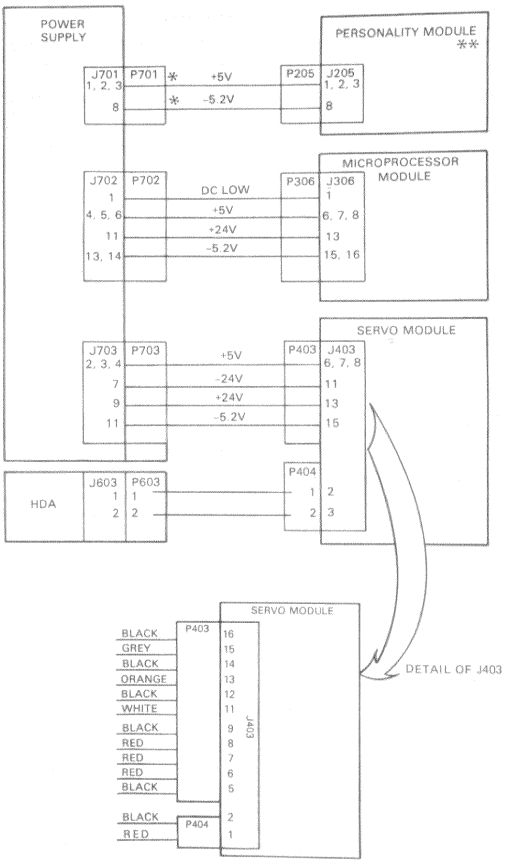


Figure 5-6 Voltage Test Points

5.3.4 HDA Formatting Procedure

Replacement HDAs (part number 70-18491-01) do not have to be formatted before use in the RA81 disk drive. Each HDA is formatted at the point of manufacturing.

5.3.5 HDA Identification

HDAs are identified by labels found on the front plastic cover. RA81s to be used for 16-bit applications have the following label: R81 16BIT (black lettering on a red background).

5.3.6 HDA Fault Isolation

If it appears that the HDA is defective, check the voltages applied to the HDA before replacing the unit. These connectors are found on the read/write preamp module.

1. J601, pins 7, 8 contain −4v.
2. J601, pins 9, 10 contain +6v.
3. J602, pin 2 contains −8.2v.

If either of the first 2 voltages is missing or incorrect, it is probably the result of the associated voltage regulators on the read/write module and not a defective HDA.

If the −8.2v is missing or incorrect, the problem is with the servo module or cables and not with the HDA.

5.3.7 HDA Substitution Procedure

After checking the HDA voltages and everything possible has been done to verify that the HDA is defective, use the following procedure to replace it. At this point, all original FRUs should be in the drive.

1. Backup the data from the HDA to another media if possible.
2. Reformat the suspected HDA.

3. Run the on-line host diagnostics.
4. If the diagnostics fail, record the error data.
5. Replace the HDA with the spare.
6. Run the same diagnostics that failed previously.

   - If the diagnostics fail using the new HDA, return the original HDA to the drive.
   - Call for support as the HDA is probably not the failing FRU.
   - If a different error occurs running the diagnostics, it is possible that the fault is in multiple areas or that the spare HDA is defective.
   - If all of the host-level diagnostics run without error, the drive should be reformatted and returned to the customer.

5.3.8 HDA Shipment Procedure

The following procedure should be used when shipping an HDA.

1. The positioner lock should be in the lock position.
2. The spindle pulley should be taped to the HDA housing.
3. The HDA should be packed in the proper shipping carton (Figure 5-7).
4. A repair tag should be filled out correctly.
5. Error data (diagnostic printouts and/or the system error log) documenting the failure should be shipped with the HDA.
6. The HDA Support/Removal Form should be filled out and packed with the repair tag and the HDA. If this form is not available, use the sample in Figure 5-8 of the *RA81 Service Manual* to provide the necessary information. Answer all questions and send one copy with the HDA. Another copy must be mailed to:

   Maintainability Engineering, CXO1-1/N27
   Digital Equipment Corporation
   301 Rockrimmon Boulevard South
   Colorado Springs, Colorado 80963

7. The packed HDA should be shipped to Field Service Logistics Returns Stockroom.

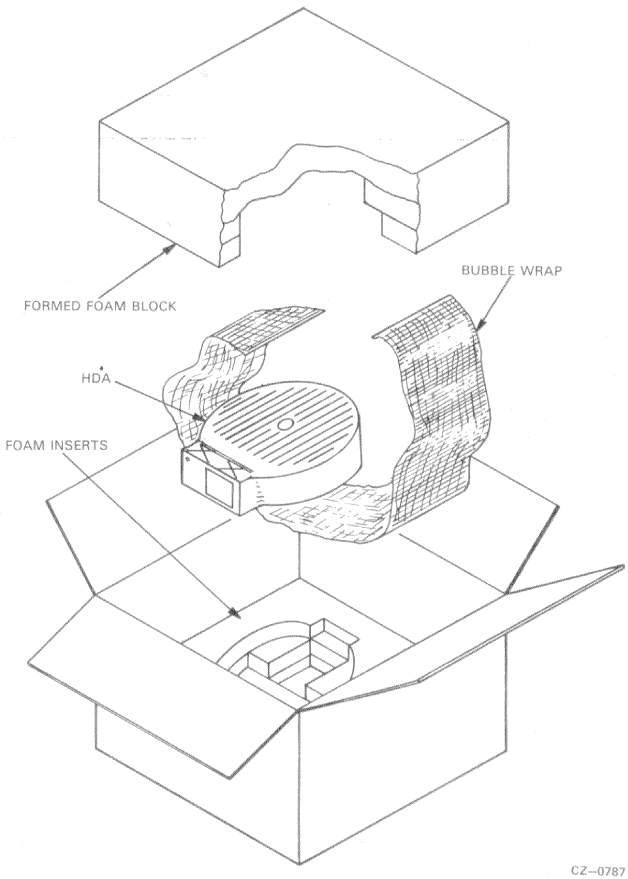


Figure 5-7 HDA Shipping Container

5.3.9 Write-Protect Function Test

1. Spin-down the disk by releasing the RUN/STOP switch.
2. Push in the WRITE PROTect switch.
3. Spin-up the disk by pushing the RUN/STOP switch IN. The FAULT indicator lights if the write-protect function is working properly.
4. Push the FAULT indicator to enter the fault display mode. The operator control panel displays a R/W diagnostic fault code. Both the FAULT and PORT A indicators should be ON.
5. Push the FAULT indicator to clear the fault condition/display mode.
6. Release the WRITE PROTect switch.

5.3.10 Spindle Motor Thermal Time-outs

A three minute delay should occur between successive start-up cycles of the spindle drive motor. This delay prevents the spindle drive motor from overheating. An overheated motor trips a thermal circuit breaker in the drive motor causing one of the following front panel codes to be displayed.

- Operator control panel spin-up fault code of 18
- Microprocessor LED error code of 02, 03, 04

To recover from a motor thermal breaker trip, first check the cooling fans for operation. If the fans are operating, let the motor cool down for 10 to 15 minutes with power applied to the drive. The fans help cool the motor with power applied to the drive.

5.3.11 Changing a Drive Unit Number

Drive unit numbers between 0 and 251 (decimal) may be programmed into the READY switch cover. To set up a number, cut off the tabs that add up to the required number (Figure 5-8). For example, if unit number 113 is required, tabs 64, 32, 16, and 1 are cut. For a unit number of 0, all tabs are left on. Unit numbers 252 through 256 are illegal.

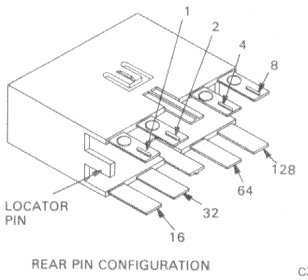


Figure 5-8 Drive Unit Address Plug

5.3.12 RA81 Signal Diagram

Figure 5-9 is provided as a cabling reference. All signals and all cables between modules are represented in this diagram.

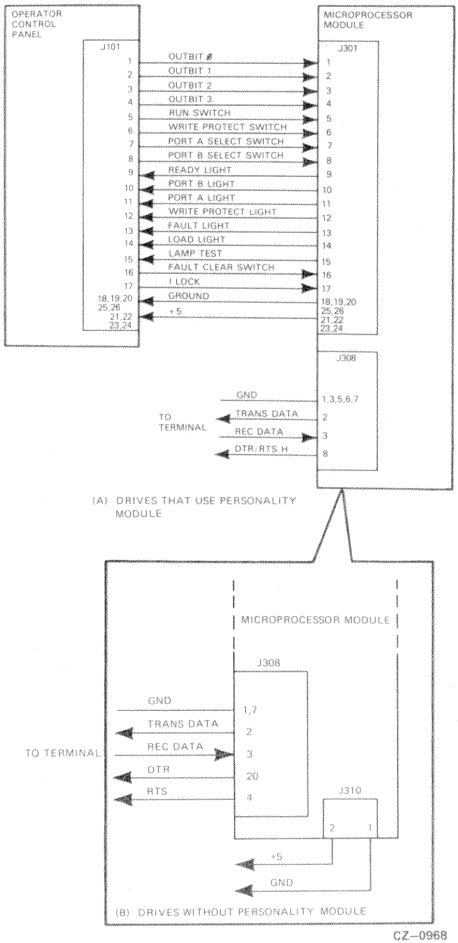


Figure 5-9 RA81 Signal Diagram (Sheet 1 of 7)

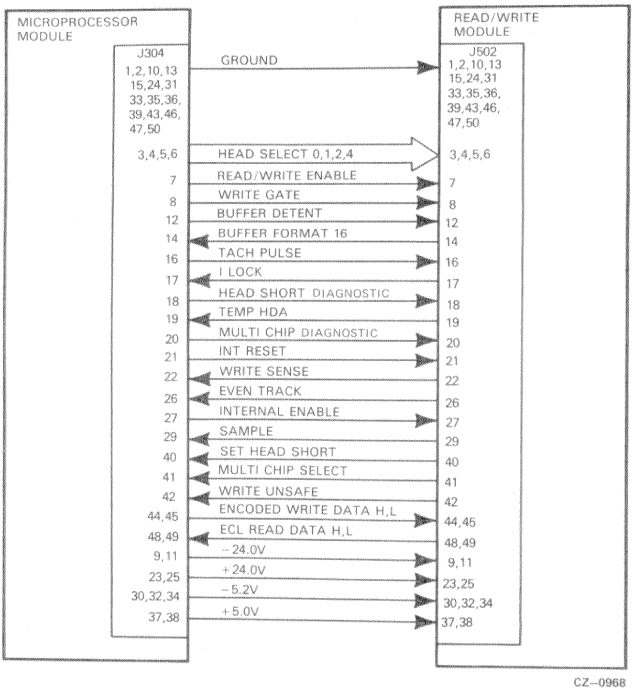


Figure 5-9 RA81 Signal Diagram (Sheet 2 of 7)

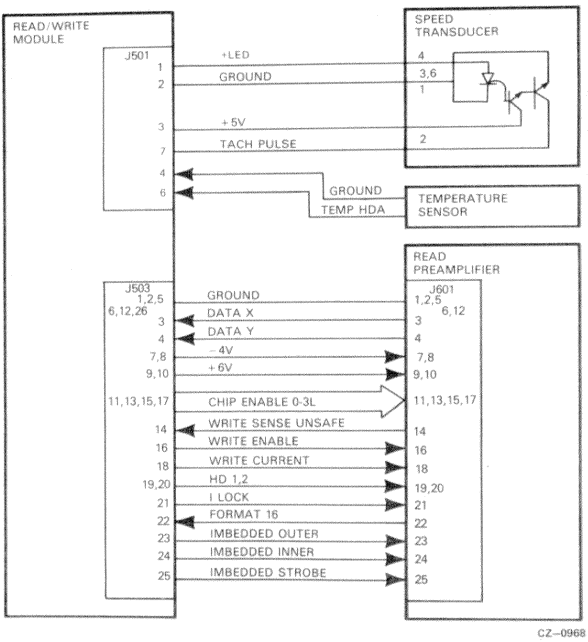


Figure 5-9 RA81 Signal Diagram (Sheet 3 of 7)

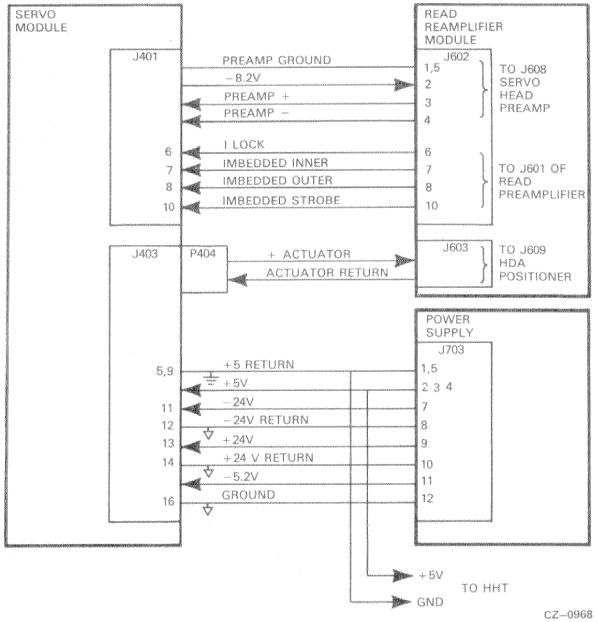


Figure 5-9 RA81 Signal Diagram (Sheet 4 of 7)

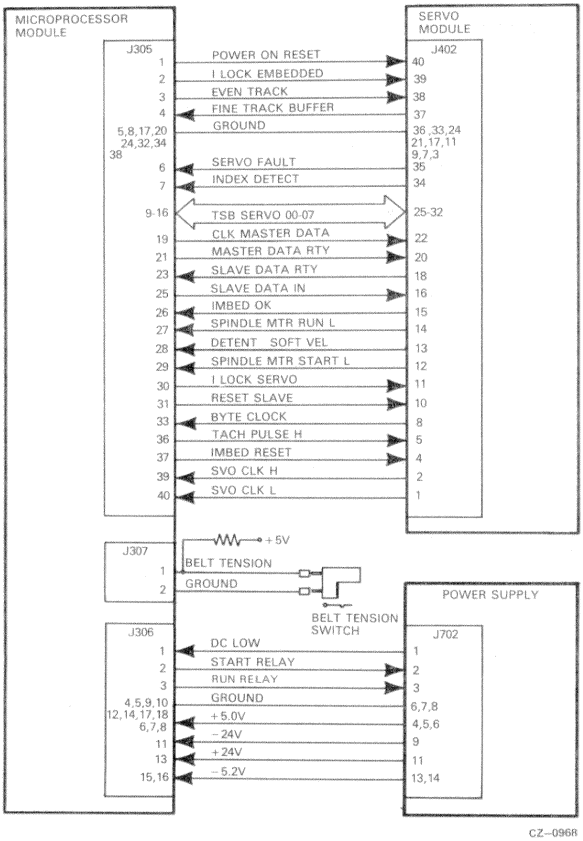


Figure 5-9 RA81 Signal Diagram (Sheet 5 of 7)

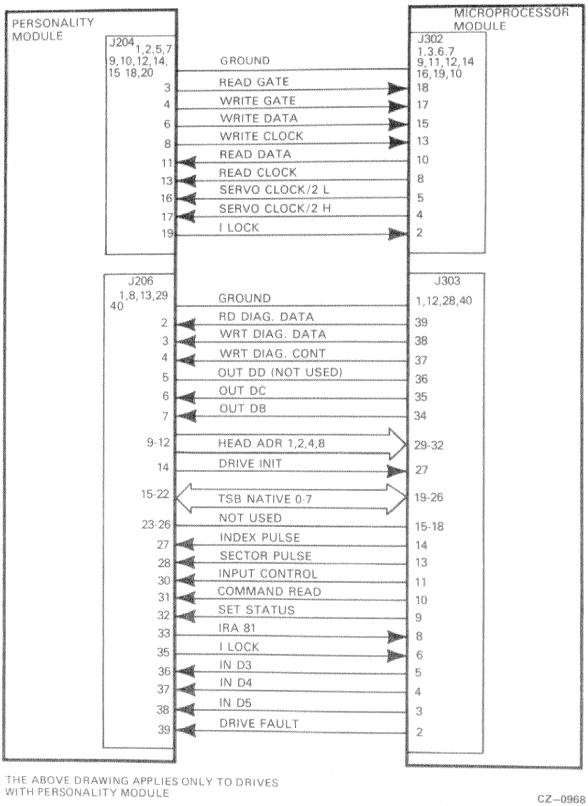


Figure 5-9 RA81 Signal Diagram (Sheet 6 of 7)

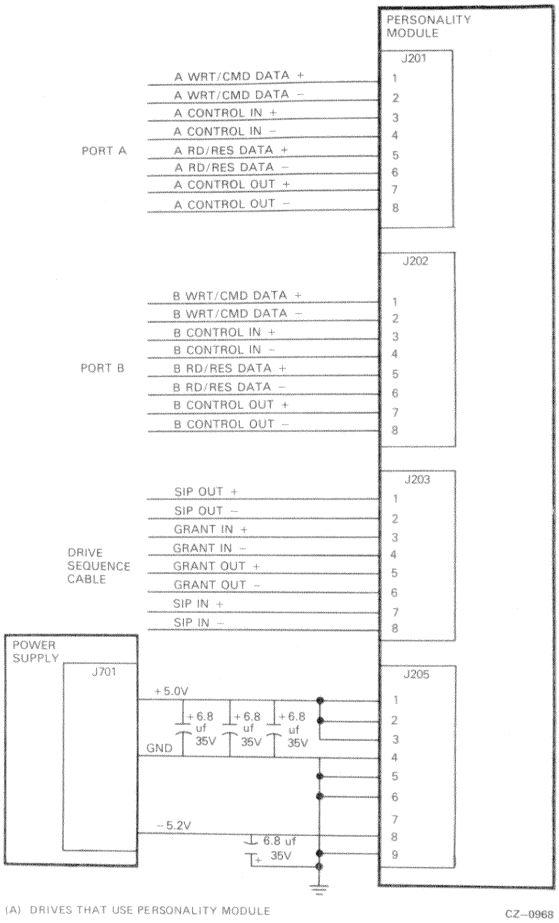


Figure 5-9(A) RA81 Signal Diagram (Sheet 7 of 7)

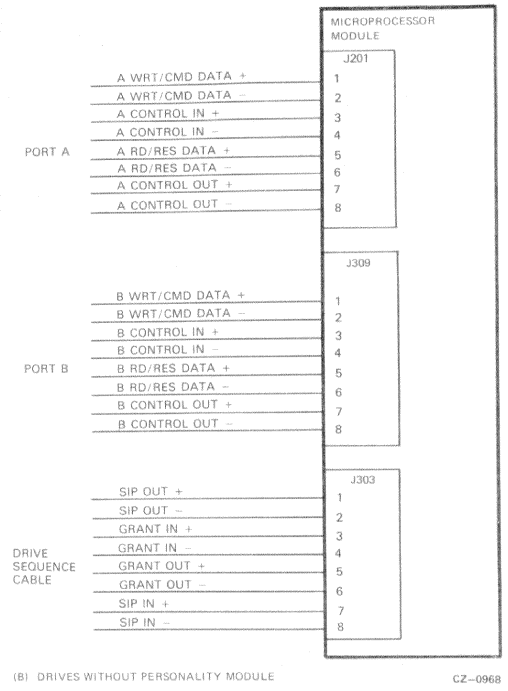


Figure 5-9(B) RA81 Signal Diagram (Sheet 7 of 7)

5.4 RA81 DRIVE CHECK-OUT PROCEDURES

Use the following procedure to verify the operation of each RA81 after installation or corrective action.

1. Place both port select switches (A and B) in the OUT position.
2. Place the RUN/STOP switch in the OUT position.
3. Open the logic access cover and raise the servo module (also the personality module in earlier versions of the drive).
4. Place the ac circuit breaker on the back of the drive to the ON position.
   - Internal drive diagnostics (hardcore test sequence) run automatically when the circuit breaker is turned on.
   - The front panel indicators turn on while the test is being executed.
   - The front panel indicators go off in approximately three to four seconds if the drive passes the tests.
   - One or more of the front panel indicators remain on if an error is found during execution of the tests. Refer to Appendix E.

   NOTE

   The diagnostic terminal must not be connected to the drive before the drive is powered up. Some terminals will cause the hardcore tests to fail.

5. The drive idle loop tests are run next.
   - The tests start automatically in about 30 seconds following the completion of the hardcore tests.

- The tests take about 30 seconds to complete.
- Observe the microprocessor LEDs for a hexadecimal E7 during the execution of the tests.
- Errors are reported through the front panel lights and the micro LEDs (Appendices E and F).

6. Connect the diagnostic terminal to the drive (Figure 4-1).

NOTE

The diagnostic terminal may be any 300 baud, EIA compatible terminal.

7. Input a CTRL C (^C) on a terminal. RA81> is displayed as a prompt to enter commands.
8. Press the continue (CONT) key on the terminal to disable the automatic X-On, X-Off feature.
9. Type in RUN DIAG.
   - An entire drive test sequence is run with the drive spun-down.
   - As the sequence is executed, the terminal displays the following message for each subtest run.

```
%RA81-COMPLETED TEST:DIAG SUBTEST:xx
```

   - At the completion of the sequence, the terminal returns with the diagnostic prompt RA81> .
   - The microprocessor LEDs increment and then settle on a hexadecimal E7 during the test sequence.
   - The diagnostic prompt is displayed in about 30 seconds and indicates that the entire drive test sequence was successfully completed.
   - The following is a sample error message that may be displayed during the execution of the sequence.

The second line of the message displays the preferred order of FRU replacement to correct the problem.

```
%RA81-TEST:DIAG SUBTEST:xx ERROR:xx UNITxxx
%RA81-FRU-xxxx,xxxx,xxxx
```

10. Push the RUN/STOP switch to spin-up the drive.
    - The terminal displays the following message:

```
FRONT-PANEL SWITCH OPERATION IN PROGRESS
```

    - During the spin-up, the drive logic executes a spin-up test sequence.
    - The microprocessor LEDs remain off while the drive spins up.
    - When the drive is up to speed, the LEDs display an E7 code.
    - The terminal displays the following message for each subtest run in sequence:

```
%RA81-COMPLETED TEST:DIAG SUBTEST:xx
```

    - At the completion of the sequence (about 45 seconds), the terminal displays the diagnostic prompt.
11. Type RUN DIAG to initiate the entire drive checkout test sequence with the drive spun-up.
    - The terminal displays messages similar to those displayed when the drive was spun-down.
    - The microprocessor LEDs increment and then settle on a hexadecimal E7 while the test is being executed.

12. At the completion of the sequence (about 7 minutes), the terminal displays the diagnostic prompt RA81> .
13. Type SET DIAG LOOP=HALT to place the drive in a continuous loop, halt-on-error mode.
14. Type RUN DIAG when the terminal returns with the diagnostic prompt. This initiates the entire drive test sequence once again.
    - Run this test for 25 minutes.
    - Refer to the fault isolation procedures if any errors occur during this time.
    - Input a CTRL C (^C) to terminate the loop mode and testing.
15. At the completion of the sequence, the terminal displays the diagnostic prompt RA81>.
16. Type EXIT to terminate the diagnostic monitor mode.
17. Push the desired port select button to place the drive in the available state.
18. Run the main system diagnostics.
19. Upon successful completion of all tests:
    - Disconnect the diagnostic terminal.
    - Fold the servo module (and personality module when applicable) back into the proper position.
    - Close and secure the logic access cover on the drive.

A HEXADECIMAL NUMBER CONVERSIONS

The maintenance terminal used to execute the internal diagnostics displays error codes in hexadecimal format. Table A-1 may be used to convert the hexadecimal numbers to binary, decimal, or octal.

Table A-1 Hexadecimal Number Conversions

HEXADECIMAL	BINARY	DECIMAL	OCTAL
0	00000	0	0
1	00001	1	1
2	00010	2	2
3	00011	3	3
4	00100	4	4
5	00101	5	5
6	00110	6	6
7	00111	7	7
8	01000	8	10
9	01001	9	11
A	01010	10	12
B	01011	11	13
C	01100	12	14
D	01101	13	15
E	01110	14	16
F	01111	15	17
10	10000	16	20
11	10001	17	21
12	10010	18	22
13	10011	19	23
14	10100	20	24
15	10101	21	25
16	10110	22	26

Table A-1 Hexadecimal Number Conversions(Cont.)

HEXADECIMA	BINARY	DECIMAL	OCTAL
17	10111	23	27
18	11000	24	30
19	11001	25	31
20	11010	26	32

B DIAGNOSTIC SEQUENCE LISTS

Test sequences make up many of the diagnostics that are executed using the terminal. There are also several automatically run tests that are sequences. This appendix lists the various test sequences with the subtest names and hexadecimal codes. Refer to Table B-1.

NOTE

The last four tests in the spin-up sequence are not executed if the drive is in an on-line state when the RUN/STOP button is pushed. The last four tests comprise the read/write sequence (test 13).

Table B-1 Diagnostic Sequence Lists

Test Code	Name
Hardcore Sequence (run on power-up)	
	Master RAM test
01	Master ROM check
0B	Master RAM timer test
03	Board bus test
	UART test
	Slave RAM test
19	Slave ROM check test
Drive Idle Loop Sequence (same as test 18)	
01	Master ROM check
07	Head select MUX test
08	Sector byte counter test
0B	Master RAM timer test

Table B-1 Diagnostic Sequence Lists (Cont.)

Test Code	Name
03	Board bus test
19	Slave ROM check
1B	PLO test
1A	Slave communication bus test
1C	Servo sanity timer test
1D	ADC test
1E	Positioner loop test
1F	Velocity loop test
20	Track counter test
Spin-up Sequence	
1B	PLO test
1C	Servo sanity timer test
1D	ADC/DAC test
1E	Positioner loop test
1F	Velocity loop test
20	Track counter test
0A	Stream test
0F	Read check test
10	Write check test
0E	Read/write force fault test
Entire Drive Checkout, Spun-Down (same as test 17)	
02	Master LED check
01	Master ROM check
07	Head select MUX test
08	Sector byte counter test
0B	Master RAM timer test
0D *	PCB wrap test

* Used only in drives with personality module

Table B-1 Diagnostic Sequence Lists (Cont.)

Test Code	Name
19	Slave ROM check
1B	Servo PLO check
1C	Servo sanity timer test
1D	ADC/DAC test
1E	Positioner loop test
1F	Velocity loop test
20	Track counter test
Entire Drive Checkout, Spun-Up (same as test 16)	
02	Master LED check
01	Master ROM check
07	Head select MUX test
08	Sector byte counter test
0B	Master RAM timer test
03	Board bus test
19	Slave ROM check test
1B	PLO test
1C	Servo sanity timer test
1D	ADC/DAC test
1E	Positioner loop test
1F	Velocity loop test
20	Track counter test
21	Servo slow seek test
22	Guard band detect test
25	Random seek test
26	Seek-seek test, default mode
27	Incremental seek test, default mode
0A	Stream test
0F	Read check test
10	Write check test
0E	Read/write force fault test
2A	Servo recalibration

* Used only in drives with personality module

Table B-1 Diagnostic Sequence Lists (Cont.)

Test Code	Name
Hardcore Sequence (same as test 12)	
02	LED check
01	Master ROM check
07	Head select MUX test
0B	Master RAM timer test
03	Board bus test
Read/Write Sequence (same as test 13)	
0A	Stream test
0F	Read check test
10	Write check test
0E	Read/write fault force test
Servo Spin-up Sequence (same as test 14)	
1B	PLO test
1C	Servo sanity timer test
1D	ADC/DAC test
1E	Positioner loop test
1F	Velocity loop test
20	Track counter test
Entire Servo Sequence (same as test 15)	
19	Slave ROM check
1A	Slave communication bus test
1B	PLO test
1C	Servo sanity timer test
1D	ADC/DAC test
1E	Positioner loop test

* Used only in drives with personality module

Table B-1 Diagnostic Sequence Lists (Cont.)

Test Code	Name
1F	Velocity loop test
20	Track counter test
21	Servo slow seek test
22	Guard band detect test
25	Random seek test
26	Seek-seek test, default mode
27	Incremental seek test, default mode
2A	Servo recalibration

* Used only in drives with personality module

C SUBSYSTEM RUN DIAGNOSTICS

Table C-1 contains a list of the drive-resident tests that can be initiated by the present subsystem diagnostics through the SDI controller.

Any of the tests in Table C-1 may be run under control of the host-resident diagnostics and may be called in using the drive-resident diagnostic for the subsystem. For a UDA50 subsystem, the host-resident diagnostic is CZUDCxx, part two. Use the following procedure to call in one of the tests listed in Table C-1.

1. Answer Y to the question CHANGE SW (L)?
2. Answer Y to the question ENTER MANUAL INTERVENTION MODE FOR SPECIAL DIAGNOSIS (L)?
3. The diagnostic allows the drive to begin the drive idle loop test sequence. It then responds with the following message:

```
TEST 2 MANUAL INTERVENTION ON UNIT x UDA AT 172150 DRIVE x
TO WRITE AND READ MEMORY:

       W DATA REGION OFFSET
       R REGION OFFSET

TO RUN A DIAGNOSTIC:
   D REGION
TO EXIT QUESTIONING:
   E
DATA, REGION AND OFFSET ARE HEX VALUES.
```

(A) ? Type in the D followed by the specific test number found in Table C-1)

(A) ? (Type in another test number or an E to exit the questioning)

Table C-1 Subsystem Run Diagnostics

Test Code	Name
01	Master ROM check
02	Master LED check
03	Board bus test
04	Microprocessor only bus test
05*	Personality/microprocessor bus test
06	Servo/microprocessor bus test
07	Head select MUX test
08	Sector/byte counter test
0B	Master RAM timer test
14	Servo spinup test sequence
18	Drive idle test sequence
19	Slave ROM check test
1A	Slave communication bus test
1B	PLO test
1C	Servo sanity timer test
1D	ADC/DAC test
1E	Positioner loop test
1F	Velocity loop test
20	Track counter test
21	Servo slow seek test
22	Guard band detect test
25	Random seek test
26	Seek-seek test, default mode
27	Incremental seek test, default mode
28	Servo outer guard band seek test
29	Servo inner guard band verify test
2A	Servo recalibration test

* Used only in drives with personality module.

A diagnostic error message is printed and the drive fault light comes on if an invalid test number is requested.

Byte 14 of the status line (see paragraph 5.2.1) contains the error code of 2B (invalid region specified). The diagnostic then requests a new test to be run. This causes the diagnostic to print another error message and the drive to execute another drive idle loop test sequence. At the completion of the test sequence, the test number question is once again asked and legitimate testing can be continued.

NOTE

Do not depress the FAULT button to obtain a specific fault code during this time. The only way to clear the fault if the FAULT button has been depressed is to ^C the diagnostic.

Depressing a ^C exits testing from the system level and cuts off communications between the drive and the controller. Testing continues until the current test sequence is complete. This can result in an unwanted error code of 41 (response timed out).

This is also accompanied by a front panel display of an SDI error. Both of these faults may be ignored under these circumstances only.

D RUN DIAG TEST LIST

Table D-1 lists the tests available for the command RUN DIAG TEST=xx. Successful completion of any test is noted by the terminal displaying the diagnostic prompt RA81>. Descriptions of the tests are provided in Chapter 4 of the *RA81 Service Manual.*

If the test selection entered under the RUN DIAG/TEST =xx is not available or not defined on the drive, the terminal responds with the following message:

```
%RA81-TEST:DIAG SUBTEST:xx ERROR:EE UNIT xx
%RA81-FRU-TEST NOT AVAILABLE
```

Table D-1 RA81 Diagnostic Test List

Test Number	Name
Test 0	Entire drive test sequence
Test 1	Master ROM test
Test 2	LED test
Test 3	Board bus test
Test 4	Microprocessor only bus test
Test 5*	Personality/microprocessor bus test
Test 6	Servo/microprocessor bus test
Test 7	Head select MUX test
Test 8	Sector/byte counter test
Test 9	FE front panel test
Test A	Stream test
Test B	Master RAM timer test

* Used only in drives with personality module.

Table D-1 RA81 Diagnostic Test List (Cont.)

Test Number	Name
Test C	Personality module logic test (when this module is used) Interface wrap test (when personality module is not used)
Test D	Personality module wrap test (when this module is used Usart test (when personality module is not used)
Test E	R/W fault force test
Test F	Read only test
Test 10	Write and read test
Test 11	Read only cylinder formatter
Test 12	Master hardcore sequence tests
Test 13	Master read/write sequence tests
Test 14	Servo sequence tests
Test 15	Entire servo sequence tests
Test 16	Entire drive sequence, spun-up
Test 17	Entire drive sequence, spun-down
Test 18	Drive idle sequence tests
Test 19	Slave ROM test
Test 1A	Slave microprocessor bus test
Test 1B	Servo PLO test
Test 1C	Servo sanity timer test
Test 1D	Servo DAC test
Test 1E	Servo positioner loop test
Test 1F	Servo velocity loop test
Test 20	Servo track counter test
Test 21	Servo slow seek test
Test 22	Guard band detect test
Test 23	Incremental seek, FE mode
Test 24	Seek-seek, FE mode
Test 25	Random seek test
Test 26	Seek-seek, default mode
Test 27	Incremental seek, default mode

* Used only in drives with personality module

Table D-1 RA81 Diagnostic Test List

Test Number	Name
Test 28	Servo outer guard band seek
Test 29	Servo inner guard band verify
Test 2A	Servo recalibration

* Used only in drives with personality module

E SYSTEM FAULT CODES

Table E-1 lists the RA81 drive error codes and fault conditions.

Table E-1 Drive Error Display Codes

LED Error Code	Condition
01	Spindle motor speed transducer timeout
02	Spindle speed of 1000 r/min not reached in 6 seconds during spin-up
03	Spindle not accelerating during spin-up
04	Spindle speed of 3420 r/min not reached in 40 seconds during spin-up
05	Start-up inhibited by absence of drive spin-up sequencing grant or presence of start in progress (SIP). (This could be legitimate status).
06	Microcode fault
07	Level 2 message frame sequencing error
08	Level 2 message checksum error
09	SDI message framing error

* Used only in drives with personality module.
** Used only in drives without personality module.

Table E-1 Drive Error Display Codes (Cont.)

LED Error Code	Condition
0A	Invalid operation code parity for a level 1 or 2 message
0B	Invalid operation code for a level 1 or 2 message
0C	Invalid command length for a level 2 message
0D	Status error byte non-zero while attempting to execute a command
0E	Group select code non-zero while attempting to execute a command
0F	Write-protect switch in the PROTECT position while attempting to write enable the drive
10	Invalid error code sent by slave
11 **	SDI transfer command when read/write error pending
12 **	SDI transfer command when drive error pending
13	Fine track not reached during detent mode
14 **	Attempt to format when format disabled
15	Too much time to execute a seek or recal command

* Used only in drives with personality module.
** Used only in drives without personality module.

Table E-1 Drive Error Display Codes (Cont.)

LED Error Code	Condition
16	Guard band detected while performing a seek command
17	Seek logic difference counter decremented past zero before expected cylinder reached
1A	Seek command contains an invalid cylinder address
1B	Velocity calibration detects too many bad seeks
1C	Unsuccessful recalibrate command detected during a velocity calibration
1D	Drive seeks more than 10% too fast
1E	Drive seeks more than 15% too slow
1F	Sector pulse detected during execution of sector read or write
20 *	Parity error detected on controller real-time state line
21 *	Two or more pulses of same polarity detected on controller real-time state line (control pulse error)
22 *	Two or more pulses of same polarity detected on controller write command data line (data pulse error)

* Used only in drives with personality module.
** Used only in drives without personality module.

Table E-1 Drive Error Display Codes (Cont.)

LED Error Code	Condition
23	Spindle motor interlock broken, belt tension lever released
25	Servo error (SVOCHK) detected, off track during detent mode
26	Spindle speed detected as being less than 3420 r/min (3600-5%)
27	HDA temperature too high
28	Servo module temperature too high
29	Invalid error recovery level specified
2A	Invalid subunit specified
2B	Invalid region specified in a diagnostic command
2C	Seek or recal command attempted while spindle not spinning
2D	Invalid command timeout value given
2E	Controller flags detected prohibiting drive spin-up
2F	RUN/STOP switch in stop position while attempting run command

* Used only in drives with personality module.
** Used only in drives without personality module.

Table E-1 Drive Error Display Codes (Cont.)

LED Error Code	Condition
30	Write current turned on without write gate being asserted
31	Read command attempted with write gate asserted
32	Read or write command attempted while drive faulted
33	Burst error detected while writing
34*	Read data separator/encoder error
35	Write unsafe error detected while attempting a write command
36	Short circuit detected in head winding
37	No write current detected with write gate asserted
38	Read command attempted with multiple heads selected
39	Write command attempted while positioner is off track (not detented)
3A	Write command attempted while drive is write-protected
3B	Servo/HDA interlock broken
3C	Servo interlock broken

* Used only in drives with personality module.
** Used only in drives without personality module.

Table E-1 Drive Error Display Codes (Cont.)

LED Error Code	Condition
3D	R/W interlock broken
3E	Control panel interlock broken
3F *	Personality module interlock broken
40	Invalid R/W region specified
41	SDI controller response timed out
42	Drive not in an on-line state while attempting seek command
43	R/W READY not set while attempting real-time command
44	Format enable not set while attempting format command
45	Real-time command contains invalid head (track) address
46	R/W safety interrupt occurrs with no cause bits set
47	Disconnect command contains incorrect TT bit
48	Write memory offset or byte count invalid
49	Invalid command while in topology mode

* Used only in drives with personality module.
** Used only in drives without personality module.

Table E-1 Drive Error Display Codes (Cont.)

LED Error Code	Condition
4A	Drive disabled by DD bit
4B	Index pulse error
4D	Bad embedded servo data during write command
4E **	Can write or format when drive write-protected
4F **	SDI transfer error
50	Slave diagnostic timeout (error could be result of positioner lock lever in lock position.)
51	Sector/byte fails to count properly
52 *	Group zero cannot be selected
53 *	Group one cannot be selected
54	R/W head select error detected while executing head select multiplexer test
57	Master timer faulty
60	R/W head select error detected while executing read/write test
61	R/W data set-up error (diagnostic write data register not equal to diagnostic read data register)

* Used only in drives with personality module.
** Used only in drives without personality module.

Table E-1 Drive Error Display Codes (Cont.)

LED Error Code	Condition
62	Bad data from three or more heads while executing read-only test
63	Bad data from one or two heads while executing read-only test
65	Read/write test sector not found within two revolutions of the disk
66	Read failure caused by servo being off-track
67	Write test not executed because Test F has not run or failed
68	Read-only cylinder cannot be reformatted without jumper
69	Read/write diagnostic comparison circuitry never detects error
6F	Diagnostic write attempted while write-protected
70 *	Command available timeout error during execution of PCB wrap test
71 *	SDI INIT always asserted
72 *	No control clock or framing error during execution of PCB wrap test

* Used only in drives with personality module.
** Used only in drives without personality module.

Table E-1 Drive Error Display Codes (Cont.)

LED Error Code	Condition
73 *	Microprocessor and PCB board data bus communication error
74 *	Initial personality board status incorrect for off-line condition
75 *	Failure in control clock error detect circuit
76 *	Failure in data clock error detect circuit
77 *	Failure of port A select latch
78 *	Port A data transmitter/receiver error
79 *	Port A control line transmitter/receiver error
7A *	Failure of port B select latch
7B	Spindle motor spinning while attempting PCB test
7C *	Receive error in frame code during PCB wrap test
7D *	Receive error in data byte during PCB wrap test
80	Consistency fault detected in master ROM
81	Command available not reset after reading data
82	Frame code not reset after reading data

* Used only in drives with personality module.
** Used only in drives without personality module.

Table E-1 Drive Error Display Codes (Cont.)

LED Error Code	Condition
83	SDI INIT not received from Port B
84	INIT bit not reset following INIT
85	Master RAM 0 fails RAM test
86 *	Master RAM 1 fails RAM test
87	Checksum error in master ROM 0
8A **	Unable to reset SDI error register
8B **	Drive SDI interface not ready to start
8C **	Error during frame transmission
8F	Checksum error in master ROM 1
90 *	Port B data transmitter/receiver error
91 *	Port B control line transmitter/receiver error
92 *	Port A wraparound error
93 *	Response serializer error
94	Loop-around frame not received properly
95	Loop-around frame not decoded properly

* Used only in drives with personality module.
** Used only in drives without personality module.

Table E-1 Drive Error Display Codes (Cont.)

LED Error Code	Condition
96	Loop-around frame data byte not received properly
97	Checksum error in master ROM 2
9F	Checksum error in master ROM 3
A0	Unable to clear faults at R/W safety register
A1	Unable to force head short error while writing
A2	Unable to force multiple head select error while reading
A3	Unable to force read gate and write gate active at the same time
A4	Unable to force write current without write gate
A5	Unable to force write gate without write current
A6 *	Unable to force a miscompare of the data from the write compensation logic and the read encoder logic
A7 *	Checksum error in master ROM 4
A9	Servo fault causes a R/W forced fault
AA	Diagnostic firmware has good prompt code

* Used only in drives with personality module.
** Used only in drives without personality module.

Table E-1 Drive Error Display Codes (Cont.)

LED Error Code	Condition
AF *	Checksum error in master ROM 5
B0	Test not running due to drive fault
B3	Bus test error in microprocessor module
B4 *	Bus test error in personality module
B6	UART transmitter/receiver error
B8	Stream test write clock not active
B9	Stream read clock not active
BA	Stream buffered servo clock not active
BB	Stream ECL write data not present
BC	Stream encoded write data not present
BD	Stream decoded read data not present
BE	Stream ECL read data not present
BF	Unable to reset stream bit
C0	Fine track timer error
C1	Fine track status not asserted

* Used only in drives with personality module.
** Used only in drives without personality module.

Table E-1 Drive Error Display Codes (Cont.)

LED Error Code	Condition
C2	Fine track status not deasserted
C3	Fine track over range error
C4	Fine track under range error
C5	Wrong fine track channel
C6	PLO error
C8	ADC/DAC reference voltage not within range
C9	ADC/DAC bit error
CA	ADC/ODAC bit error
CB	Servo velocity test acceleration status error
CC	Seek difference counter not loading correctly
CD	Seek difference counter error or wrong old gray code bits
CE	Servo sanity tests timer error
D0	Load attempt failed
D1	Outer guard band detected following head load operation

* Used only in drives with personality module.
** Used only in drives without personality module.

Table E-1 Drive Error Display Codes (Cont.)

LED Error Code	Condition
D2	Inner guard band detected following head load operation
D3	Seek into outer guard band failed
D4	Outer guard band not detected following seek into outer guard band
D5	Load from outer guard band failed
D6	Spindle not up to speed
D7	Seek into inner guard band failed
D8	Inner guard band not detected following seek into inner guard band
D9	Load from inner guard band failed
DA	Spindle not spinning
DB	Diagnostic seek failed
DC	Incorrect parameters entered during execution of drive-resident diagnostics
DD	Recalibrate error
DE	Low velocity seek error

* Used only in drives with personality module.
** Used only in drives without personality module.

Table E-1 Drive Error Display Codes (Cont.)

LED Error Code	Condition
DF	Spin-up failed
E0	Random seek error
E1	Integrator error
E2	Slave ROM consistency error
E3	Checksum error on slave ROM 0
E4	Checksum error on slave ROM 1
E5	Checksum error on slave ROM 2
E6	Checksum error on slave ROM 3
E7	Test execution code
E8	Error in slave RAM 0
E9	Error in slave RAM 1
EE	Incorrect test parameter entered
F0	Slave uncommanded spin-down
F1	Slave load timeout
F2	Slave sent unexpected message

* Used only in drives with personality module.
** Used only in drives without personality module.

Table E-1 Drive Error Display Codes (Cont.)

LED Error Code	Condition
F3	Slave received bad command packet
F4	Slave operation code parity error
F5	Slave received invalid operation code
F6	Master received bad status packet from slave
F7	Slave recalibrate timeout (error could be result of positioner lock lever in lock position)
F8	Slave seek timeout
F9	Slave offset timeout
FA	Slave spin-up timeout
FB	Slave spin-down timeout
FC	Slave send-status timeout
FD	Slave initialization timeout
FE	Slave speed-check timeout

* Used only in drives with personality module.
** Used only in drives without personality module.

F FRONT PANEL FAULT IDENTIFICATION

This appendix is used to identify faults called out by the front panel indicator lights. Table F-1 shows the status of the front panel lights for each type of error reported. The column at the extreme right contains the hex code that appears in status byte 15 when a particular fault occurs. The hex code is not what is displayed by the front panel indicator lights.

NOTE

The dc low condition locks up the drive logic and therefore cannot have a hexadecimal code represented by the host system diagnostics.

Table F-1 Drive Front Panel Fault Codes

FAULT	RUN/ STOP	FAULT	RDY	WRITE PROT	A	B	STATUS BYTE 15 HEX CODE
Index error	on	on					11
Master/Slave error		on		on			12
Servo diagnostic test error	on	on		on			13
Microprocessor fault		on			on		14
Drive disabled by DD bit	on	on			on		15
Servo coarse positioning error		on		on	on		16
Diagnostic idle loop test error	on	on		on	on		17
Spin error		on				on	18
Write and bad embedded data	on	on				on	19
Servo fine positioning error		on		on		on	1A
R/W diagnostic test error	on	on		on		on	1B
SDI error		on			on	on	1C

* Only in drives with a personality module

Table F-1 Drive Front Panel Fault Codes (Cont.)

FAULT	RUN/ STOP	FAULT	RDY	WRITE PROT	A	B	STATUS BYTE 15 HEX CODE
Write enable and write-protect asserted error	on	on			on	on	1D
Spindle motor interlock error		on		on	on	on	1E
Servo or HDA overtemp error		on	on				30
Servo module/Microprocessor interlock error		on	on	on			32
R/W command error		on	on		on		34
Control panel/Microprocessor interlock error		on	on	on	on		36
R/W unsafe error		on	on			on	38
Read/Write microprocessor interlock error		on	on	on		on	3A
Servo/HDA interlock error		on	on		on	on	3C
Personality/Microprocessor interlock error *		on	on	on	on	on	3E
Microprocessor hardcore test error	on	on	on	on	on	on	3F
DC low *	on		on	on	on	on	—

* Only in drives with a personality module

G ERROR CODE TROUBLESHOOTING TABLE

Table G-1 correlates the error codes that are displayed by the subsystem diagnostics or the field service diagnostic terminal to an FRU reference code. Appendix H provides names and part numbers for FRUs. Note that more than one error code can result in the same FRU reference.

Table G-1 Drive Error Code/FRU Reference List

LED Error Code	Probable FRU Cause
01	Motor/brake assembly, belt, servo module, power supply, speed transducer
02	
03	
04	
05	Drive spin-up sequencing signals are inhibiting start-up of drive. Probably caused by preceding drive not being up to speed. Check if drive can spin-up with powersequencing jumper moved. If drive spins-up, problem is with preceding drive. Replace personality module (in drives that use this module), microprocessor module, and cables between two drives. If drive does not spin-up, problem is with drive that displayed error. Check modules and cables as outlined above.
06	Microprocessor module, servo module

* Used only in drives with personality module
** Used only in drives without personality modules

Table G-1 Drive Error Code/FRU Reference List (Cont.)

LED Error Code	Probable FRU Cause
07	Microprocessor module (personality module in drives that use this module), SDI cables, controller
08	
09	
0A	
0B	
0C	
0D	Personality module (microprocessor module in drives without personality module), SDI cables, controller
0E	
0F	
10	Servo module, microprocessor module
11 **	Microprocessor module, controller
12 **	
13	Servo module, R/W module, HDA
14 **	Microprocessor module, controller
15	Servo module, HDA
16	
17	
18	Servo module, microprocessor module
1A	Personality module (microprocessor module in drives without personality module), SDI cables, controller
1B	Servo module, R/W module, HDA
1C	

* Used only in drives with personality module
** Used only in drives without personality modules

Table G-1 Drive Error Code/FRU Reference List (Cont.)

LED Error Code	Probable FRU Cause
1D 1E	Servo module, HDA
1F	Microprocessor module, SDI cables, controller
20 *	Personality module, SDI cables, controller
21 * 22 *	Personality module, SDI cables, controller
23	Check cables or motor/belt interlock
25	Servo module, microprocesor module, motor/brake assembly, belt, power supply, HDA
26	Motor/brake assembly, belt, servo module, power supply, speed transducer
27	Check fans, ambient room temperature and temperature sensor for proper operation. Check proper seating of cable from R/W to microprocessor module. If above checks out, replace the R/W module, microprocessor module, cables, HDA.
28	Check fans and ambient room temperature. If good, replace servo module, microprocessor module, cables between microprocessor and servo modules.

* Used only in drives with personality module
** Used only in drives without personality modules

Table G-1 Drive Error Code/FRU Reference List (Cont.)

LED Error Code	Probable FRU Cause
29 2A 2B 2C 2D 2E 2F	SDI cables, controller
30	Microprocessor module, R/W module, personality module (in drives that use this module), HDA
31	Microprocessor module, personality module (in drives that use this module), SDI cables, controller
32	
33	
34 *	Microprocessor module, R/W module, personality module, HDA
35 36 37 38	R/W module, microprocessor module, HDA
39	Servo module, R/W module, HDA
3A	Microprocessor module, SDI cables, controller

* Used only in drives with personality module
** Used only in drives without personality modules

Table G-1 Drive Error Code/FRU Reference List (Cont.)

LED Error Code	Probable FRU Cause
3B	Check servo/HDA cable, read-write/HDA cable
3C	Check servo/microprocessor cable
3D	Check read-write/microprocessor cable
3E	Check control panel/microprocessor cable
3F *	Check personality/microprocessor cable
40	Personality module (microprocessor module in drives without personality module), SDI cables, controller
41	
42	
43	
44	
45	
46	Microprocessor module, power supply
47	Personality module (microprocessor module in drives without personality module), SDI cables, controller
48	
49	
4A	
4B	Servo module, microprocessor module, motor/brake assembly, belt, power supply, HDA

* Used only in drives with personality module
** Used only in drives without personality modules

Table G-1 Drive Error Code/FRU Reference List (Cont.)

LED Error Code	Probable FRU Cause
4D	R/W module, servo module, HDA, microprocessor module
4E ** 4F **	Microprocessor module, controller
50	Ensure that positioner motor lock is in the unlock position. If in correct position, replace servo module, microprocessor module
51 52 * 53 * 54 57 60	Microprocessor module
61	Microprocessor module, personality module (in drives that use this module)
62	R/W module, microprocessor module, personality module (in drives that use this module), HDA
63	R/W module, microprocessor module, HDA
65	Microprocessor module, servo module
66	Servo module, R/W module, HDA

* Used only in drives with personality module
** Used only in drives without personality modules

Table G-1 Drive Error Code/FRU Reference List (Cont.)

LED Error Code	Probable FRU Cause
67	Test 10 (write and read test) is attempted before a successful completion of test 0F.
68	Install the jumper to run test 11 successfully.
69	Microprocessor module, R/W module, reformat the read only cylinders using Test 11.
6F	Remove write-protect status from drive. If good, then replace microprocessor module, control panel module.
70 * 71 * 72 * 73 * 74 * 75 * 76 * 77 *	Microprocessor module, personality module
78 *	Insert SDI loop-back plugs, microprocessor module, personality module
79 * 7A*	Microprocessor module, personality module
7B	Spin-down the disk

* Used only in drives with personality module
** Used only in drives without personality modules

Table G-1 Drive Error Code/FRU Reference List (Cont.)

LED Error Code	Probable FRU Cause
7C *	Microprocessor module, personality module
7D *	Microprocessor module, personality module
80	Microprocessor module
81	Microprocessor module, personality module (in drives that use this module)
82	
83	
84	
85	Microprocessor module
86 *	
87	
8A **	
8B **	
8C **	
8F	
90 *	Insert SDI loop-back plugs, microprocessor module, personality module
91 *	Microprocessor module, personality module
92 *	
93 *	
94	
95	
96	

* Used only in drives with personality module
** Used only in drives without personality modules

Table G-1 Drive Error Code/FRU Reference List (Cont.)

LED Error Code	Probable FRU Cause
97 9F A0	Microprocessor module
A1	Microprocessor module, R/W module
A2	Microprocessor module, R/W module
A3	Microprocessor module
A4	Microprocessor module, R/W module
A5 A6 * A7 *	Microprocessor module
A9	Servo module, R/W module, HDA
AF *	Microprocessor module
AB	Servo module, HDA
B0	A drive fault is inhibiting the running of a test. Check microprocessor LEDs for a specific drive fault.
B3	Microprocessor module
B4 *	Microprocessor module, personality module

* Used only in drives with personality module
** Used only in drives without personality modules

Table G-1 Drive Error Code/FRU Reference List (Cont.)

LED Error Code	Probable FRU Cause
B6	Ensure the diagnostic terminal cable is not connected. Check the 24 volt supply to the microprocessor module. If 24 volts is missing, check cable to module then replace power supply. If good, replace the microprocessor module.
B7	R/W module, microprocessor module, personality module (in drives that use this module), HDA
B8	Microprocessor module, personality module (in drives that use this module)
B9	Microprocessor module, servo module
BA	Servo module, microprocessor module
BB BC	Microprocessor module
BD	R/W module, microprocessor module, HDA
BE	HDA
BF	Microprocessor module

* Used only in drives with personality module
** Used only in drives without personality modules

Table G-1 Drive Error Code/FRU Reference List (Cont.)

LED Error Code	Probable FRU Cause
C0 C1 C2 C3 C4 C5 C6 C8 C9 CA CB CC CD CE	Servo module
D0 D1 D2	Servo module, R/W module, HDA
D3	Servo module, HDA
D4	Servo module, R/W module, HDA
D5	Servo module, HDA
D6	Motor/brake assembly, belt, servo module, power supply, speed transducer
D7	Servo module, R/W module, HDA

* Used only in drives with personality module
** Used only in drives without personality modules

Table G-1 Drive Error Code/FRU Reference List (Cont.)

LED Error Code	Probable FRU Cause
D8	Servo module, HDA
D9	Servo module, R/W module, HDA
DA	Spin-up disk
DB	Servo module, R/W module, HDA
DC	Re-enter parameters
DD DE	Servo module, R/W module, HDA
DF	Motor/brake assembly, belt, servo module, power supply, speed transducer
E0	Servo module, R/W module, HDA
E1 E2 E3 E4 E5 E6	Servo module
E8	Servo module
E9	Servo module
EE	Illegal test parameter

* Used only in drives with personality module
** Used only in drives without personality modules

Table G-1 Drive Error Code/FRU Reference List (Cont.)

LED Error Code	Probable FRU Cause
F0	Motor/brake assembly, belt, servo module, power supply, speed transducer
F1	Servo module, R/W module, HDA
F2	Servo module, microprocessor module
F3	Microprocessor module, servo module
F4	
F5	
F6	Servo module, microprocessor module
F7	Servo module, R/W module, HDA
F8	
F9	Servo module, microprocessor module
FA	
FB	
FC	
FD	
FE	

* Used only in drives with personality module
** Used only in drives without personality modules

H FRU PART NUMBER LIST

Tables H-1 and H-2 contain lists of the FRUs and their part numbers. Part numbers may change after publication of this manual edition. When ordering FRUs, refer to the latest *RA81 Illustrated Parts Breakdown Manual* for part number information.

Table H-1 FRU Part Number List for 60 Hz - RA81-AA Drives

Part Number	Description
H7660-A	Power supply, 120v/60Hz
10-16924-00	Motor start capacitor, 115v/60Hz
12-10719-03	Fan, 25-35 ft 3/min PEWEE
12-12714-00	Switch cap (Run/Stop)
12-12714-01	Switch cap (Write-Protect)
12-12714-02	Switch cap (Fault)
12-12714-03	Switch cap (Port A)
12-12714-04	Switch cap (Port B)
12-12716-00	Lamp wedge, 6.3v
12-12635-03	Belt, 60Hz
12-14011-00	Microswitch (1PSA)
12-16817-00	Optical switch (speed sensor)
12-16870-01	HDA thermal switch
12-17715-02	Fan, 120 CFM P/S.
12-17072-00	Gas spring
12-18199-01	Unit select 0-255/READY
17-00083-23	Power cord assembly, 60Hz
29-24195-00	Hand-held terminal
54-15247-00 *	Microprocessor module (DCL)
54-15770-00	Microprocessor module

* Used only in drives with personality module.

Table H-1 FRU Part Number List for 60 Hz - RA81-AA Drives

Part Number		Description
54-15253-00		Read/write module
70-16215-00		Brush ground assembly
70-16230-00		Wing pivot assembly
70-16723-00		115v/60Hz motor brake assembly (use only on RA81-AA serial number 3470 and below)
70-16723-02		115v/60Hz motor brake assembly (can be used on all RA81-AA or AE)
70-16733-00		Logic ac power cable
70-16735-00		Servo preamp cable
70-16737-00	*	40 conductor (personality to microprocessor)
70-16737-01		40 conductor (servo to microprocessor)
70-16738-00	*	20 conductor (personality to microprocessor)
70-16739-00		50 conductor read/write cable
70-16740-00		Control panel cable
70-16742-00		Shock mount assembly
70-16980-00		Belt tension assembly
70-18331-01		Logic dc harness
70-18340-02		SDI cabinet I/O bulkhead assembly
70-18324-00		Control panel module assembly
70-18491-01		Head disk assembly (16 bit HDA)
70-19045-01		Servo/stiffener
70-19046-01	*	Personality module/stiffener
70-19060-01		26 conductor R/W to HDA cable
70-19074-01		SDI loop back connector (test plug)
70-19692-01		Spin-up sequence terminator
70-19689-6B		Drive SDI internal cable assembly
70-19690-06		Drive spin-up sequence cable, 6 foot.
70-19690-08		Drive spin-up sequence cable, 8 foot.
70-19690-12		Drive spin-up sequence cable, 12 foot.
70-19690-25		Drive spin-up sequence cable, 25 foot.
70-19690-50		Drive spin-up sequence cable, 50 foot.
70-19690-80		Drive spin-up sequence cable, 80 foot.

* Used only in drives with personality module.

Table H-1 FRU Part Number List for 60 Hz - RA81-AA Drives

Part Number	Description
70-19691-1J	Internal drive spin-up sequence cable (20 inches)
70-19693-01	Latch cable assembly, upper lid
70-19713-01	Spin sequence cab I/O bulkhead assembly
70-20021-06	RA80 to RA81 sequence spin-up adapter cable, 6 foot
70-20021-08	RA80 to RA81 sequence spin-up adapter cable, 8 foot
70-20021-12	RA80 to RA81 sequence spin-up adapter cable, 12 foot
70-20021-25	RA80 to RA81 sequence spin-up adapter cable, 25 foot
70-20021-50	RA80 to RA81 sequence spin-up adapter cable, 50 foot
70-20021-80	RA80 to RA81 sequence spin-up adapter cable, 80 foot
70-20022-01	ASCII port interface cable
74-22440-00	Motor tension spring
74-22816-00	Air filter
BC26V-12	Shielded SDI I/O cable, 12 foot
BC26V-25	Shielded SDI I/O cable, 25 foot
BC26V-50	Shielded SDI I/O cable, 50 foot
BC26V-80	Shielded SDI I/O cable, 80 foot

* Used only in drives with personality module.

The FRUs for 50 Hz RA81-AD Disk Drives are the same as those for the 60 Hz RA81-AA drives with the exception of the FRUs listed in Table H-2.

Table H-2 FRU Part Number Differences for 50 Hz RA81-AD Drives

Part Number	Description
H7660-B	Power supply, 220v/50 Hz
10-11248-00	Motor start capacitor, 220v/50 Hz
12-12635-05	Belt, 50 Hz
17-00083-24	Power cord assembly, 50Hz
70-16723-01	240V/50 Hz motor brake assembly (use only on RA81-AD serial # 1103 and below)
70-16723-03	240V/50 HZ motor brake assembly (can be used on all RA81-AD or AJ)

The FRUs for the 60 Hz RA81-AE Disk Drives are the same as those for the RA81-AA drives found in Table H-1 with the exception of the 18 bit HDA which is part number 70-18491-02 in the AE drive.

FRU for the 50 Hz RA81-AJ Disk Drives are the same as those for the RA81-AD drives with the exception of the 18 bit HDA which is part number 70-18491-02 in the AJ drive.

I DIAGNOSTIC TERMINAL INSTRUCTIONS

This appendix provides instructions on how to use the field service diagnostic terminal.

I.1 INTRODUCTION

Refer to Figure I-1. The terminal contains a two level LED display and a keyboard. The display holds a maximum of 32 characters while an internal buffer stores 2K characters for the display. The keyboard contains a standard ASCII set of alphanumeric characters. The larger character on each keybutton is the default character displayed when the button is pushed.

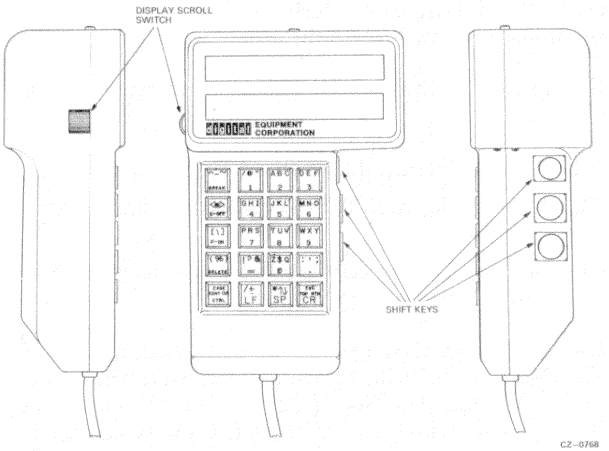


Figure I-1 Diagnostic Terminal Keypad

I.2 SHIFT KEYS

To obtain one of the other three possible characters shown on any key, one of the three shift keys on the right side of the terminal must be used. When the upper shift key on the terminal is pushed simultaneously with a keyboard button, the left most character is dislayed.

As an example, push the middle shift key and the number five key. The letter K is displayed. Pushing the lower shift key and the zero key results in the letter Q being displayed.

I.3 CONTROL CHARACTERS

A control character (e.g., ^C) is obtained by using the CTRL key, the shift keys, and the appropriate letter key. Push the CTRL key. Push one of the shift keys simultaneously with the appropriate letter key.

Example: A ^Z is desired. The following steps should be used.

1. Push and release the CTRL key.
2. Push the upper shift key on the right hand side of the drive.
3. Push the number zero key simultaneously with step two.

I.4 CONTINUE (CONT) AND CLEAR (CLR) KEYS

The X-On, X-Off feature is enabled upon applying power to the terminal. The CONT key disables the automatic X-On, X-Off feature, while the CLR key re-enables it. Keeping this feature in automatic allows the buffer to fill and then automatically transmit a signal (X-Off) to the microprocessor. This signal stops all transmission of data to the buffer until the buffer is unloaded. The terminal then automatically sends an X-on signal re-enabling

transmission. For the RA81 drive, disable the automatic X-On, X-Off feature.

I.5 X-ON, X-OFF KEYS

These keys manually control the display buffer of the terminal. If the buffer is full, an automatic X-Off signal stops all transmission to the buffer. The X-On key is used to reload the buffer with new information even though the buffer has not been read.

The X-Off key may be used to stop buffer loading even though the buffer is not full. For example, the automatic X-On, X-Off feature is disabled by the CONT key while test messages are being input to the terminal. These messages are received at a faster rate than can be read by the human eye. Pushing the X-Off key stops the diagnostic testing and the messages. This enables the user to read the display and manually scroll through the buffer.

I.6 DELETE KEY

The delete key is used to correct mistakes in keyboard entries. Once a mistake is discovered, the delete may be pushed causing a backslash to be displayed with the last character input. The new character may now be keyed in. For example, if RUN DIAF was keyed in, the delete key could be used as follows.

```
PUN DIAF \F \G
```

The command RUN DIAG is now input correctly.

I.7 DISPLAY SCROLL SWITCH

The display scroll switch is located on the left side of the terminal. Its function is to back up or advance the display within the 2K buffer. The display scroll switch is moved in the upward direction to scroll the display forward. The display scroll switch is moved downward to scroll the display backward.

I.8 BREAK KEY

The break key transmits a break character when pushed. Its function is the same as a VT100 break key and is not used in RA81 diagnostic operation.

I.9 CR KEY (CARRIAGE RETURN)

This key is pushed after typing a command string. Its effect is like an enter key on other computers.

I.10 ESCAPE KEY

This key transmits an escape character when pushed. Its function is the same as a VT100 escape key and is not used in RA81 diagnostic operation.

I.11 LINE FEED KEY (LF)

This key causes the display to advance 16 characters in the display buffer (one line of text).

I.12 SPACE KEY (SP)

This key causes a space to be input between characters in a string.

I.13 UP AND DOWN ARROW KEYS

These keys cause the cursor to be positioned at either the last or next carriage return character.

I.14 TOP AND BOTTOM KEYS (TOP/BTM)

These keys position the display to either the top or bottom of the display buffer.

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