EY–1173E–WB–0201

RA60 Disk Drive Maintenance Course

Workbook II

digital

EY-1173E-WB-Ø2Ø1

RA6Ø Disk Drive Maintenance Course

Workbook II

Lesson 6
Subsystem Functional Description

A Portion of Course
EY-1173E-VØ-VUØ1

Prepared by Educational Services

Digital Equipment Corporation

First Edition, July 1983

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Printed in U.S.A.

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INTRODUCTION

Lesson six gives you an overview of how an RA60 Disk Subsystem functions. Since each RA60 Disk Drive operates on a Standard Disk Interconnect (SDI) interface, this lesson begins with a brief review of the SDI interface in Section I. Section II describes the physical and logical organization of the RA60 disk pack. Section III describes the function of each of the assemblies inside the disk drive. Section IV explains how the drive performs its seek, write, and read operations.

OBJECTIVES

In Section I, you are asked to describe the function and operation of the following SDI elements:

- SDI cables
- SDI bus electrical encoding scheme
- SDI line functions
- SDI real-time data transfer commands
- SDI command messages
- SDI response messages
- SDI write/read operation

In Section II, you are asked to describe the following characteristics of the RA60 disk layout:

- RA60 physical disk layout
- Digital standard disk format
- RA60 logical disk format

In Section III, you are asked to describe the functions performed by each of the following RA60 assemblies.

- SDI interface module
- Drive logic module
- Post amp/data separator
- Preamp module
- Front panel module

- Motor control module
- Positioner motor
- Spindle motor
- Switchplate assembly
- Transformer assembly
- Cap/rectifier assembly
- Regulator module
- Heat sink module

In Section IV, you are asked to describe the following general RA60 operations:

- Servo system
- Servo data
- Servo linear mode
- Servo seek mode
- Seek command sequence
- Rate 2/3 code modulation process
- Write command sequence
- Read command sequence

RESOURCES

The only resource needed for this lesson is the student workbook now in your hands.

NOTE

Begin this lesson by turning the page and start reading the SDI Overview. Read all the material in Section I and then do the exercise at the end.

SECTION I SDI OVERVIEW

SDI OVERVIEW

SDI Elements

The elements of the SDI interface covered in this overview are:

- SDI cables
- SDI bus electrical encoding scheme
- SDI line functions
- SDI real-time data transfer commands
- SDI command messages
- SDI response messages
- SDI write operation
- SDI read operation

SDI Cables

The SDI cables are connected radially from the disk controller to each disk drive as shown in Figure 1. This arrangement allows the disk controller to handle simultaneous transactions with more than one drive at a time. Bus arbitration and drive addressing needs are eliminated with only one drive on each radial bus. This bus structure also supports real-time disk rotational position sensing by the disk controller which is always receiving index and sector information from each drive when the disk are spinning.

Responsibility for data error detection and correction is in the SDI disk controllers. The disk controller generates error correction codes (ECC) and error detection codes (EDC) and appends them to the write data sent to the drives. When data is read from the disk surface, the controller checks the ECC and EDC codes for read, write or control data transmission errors.

```
-------------                          ------------
|           |      SDI CABLE           | DRIVE    |
|           |--------------------------|          |
|           |                          ------------
|           |      SDI CABLE           ------------
|           |--------------------------|          |
|           |                          | DRIVE    |
|   DISK    |                          ------------
|CONTROLLER |      SDI CABLE           ------------
|           |--------------------------|          |
|           |                          |  DRIVE   |
|           |                          ------------
|           |      SDI CABLE           ------------
|           |--------------------------|          |
|           |                          |  DRIVE   |
|           |                          ------------
|------------
```

Figure 1 Radial SDI Cable Connections

SDI Bus Electrical Encoding Scheme

Each SDI cable is also referred to as an SDI bus, even though it only has four signal lines. Data is transmitted on the SDI bus via bipolar pulses of fixed duration (12 nanoseconds, ± 2 nanoseconds). A positive pulse at the leading edge of a bit cell indicates a 1; a negative pulse indicates a Ø. If the next bit requires a pulse in the same direction as the first, a second opposite direction pulse immediately follows the first to keep the net dc effect on the line at zero. Refer to Figure 2 for an illustration of this bus encoding scheme.

The controller and drive can detect missing or added pulses. A missing or added pulse is known as a transmission error. A transmission error is likely to occur when the controller switches drives or the drive switches ports. At these times, the error is ignored.

```
              BIT CELL TIME (VARIES
              FROM ONE DRIVE MODEL TO ANOTHER)
            ------>|        |<------
                   |        |
          |BIT CELL|BIT CELL|BIT CELL|BIT CELL|BIT CELL|BIT CELL|
          |  TIME  |  TIME  |  TIME  |  TIME  |  TIME  |  TIME  |
          |        |        |        |        |        |        |
          |        |        |        |        |        |        |
BINARY    |        |        |        |        |        |        |
DATA      |   1    |   Ø    |   1    |   1    |   Ø    |   Ø    |
          |        |        |        |        |        |        |
          +--------+        +-----------------+
NRZ       |        |        |                 |
DATA      |        |        |                 |
        --+        +--------+                 +----------------


          +--+              +--+     +--+        +--+
ENCODED   |  |              |  |     |  |        |  |
DATA    --+  +-----+  +-----+  |  +--+  +-----+  |  +--+  +-----
                   |  |        |  |           |  |     |  |
                   +--+        +--+           +--+     +--+

                   |  |
            ------>|  |<------
               PULSE WIDTH
                  (12 ns)
```


Figure 2 Bus Encoding Scheme

SDI Line Functions

Each SDI cable contains the four signal lines shown in Figure 3. The two data lines transmit read data, write data, controller command messages, and drive response messages. The other two lines repeatedly transmit serial real-time information on the controller state or drive status.

```
           -------+                                    +--------
                  |--- REAL-TIME CONTROLLER STATE --->|
                  |                                    |
                  |------- WRITE/COMMAND DATA ------->|
     CONTROLLER   |                                    |   DRIVE
                  |<------ READ/RESPONSE DATA --------|
                  |                                    |
                  |<---- REAL-TIME DRIVE STATE -------|
                  |                                    |
           -------+                                    +--------
```


Figure 3 Standard Disk Interface Bus

Real-Time Controller State Line

The real-time controller state line carries the live status information on the controller state. The information on the real-time controller state line consists of two bytes shown in Figure 4. The first bit on the right side of the illustration is the first bit transmitted. This two-byte pattern is sent repeatedly any time the drive is selected by the controller.

The controller may send the pattern shown in Figure 4 continuously for an on-line drive or may transmit it only when a drive is selected. It is the responsibility of the drive to maintain the last state received and assume that this state is valid until the next update is received. The command timer mechanism causes shutdown if the cable is disconnected or if power fails.

The following list describes the use of each logical signal on the real-time controller state line. These logical signals are transmitted from the controller to the drive.

- **RECEIVER READY** - This signal, when asserted, indicates that the controller is ready to receive a response on the Read/Response data line.

- **WRITE GATE** - This signal is used in the following ways:

  - During a write data operation, WRITE GATE is asserted at the beginning of the data field preamble and remains asserted until after the postamble. The drive uses this signal to generate its internal Write Gate signal. In the event of a header compare error, the controller does not assert WRITE GATE.

  - During a select track and format on index operation, or a format on sector or index operation, WRITE GATE is asserted after the command has been transmitted and the Write/Command data line transmits Øs. At the trailing edge of the next index pulse or sector pulse, the drive enables its internal WRITE GATE and begins writing.

  The trailing edge of the WRITE GATE indicates to the drive that the current data transfer command is finished.

- **READ GATE** - This signal is used in the following ways:

  - During a read data operation, READ GATE is asserted after the header splice and before the beginning of the data field preamble. It remains asserted until after the last ECC symbol has been read.

  - During a read data, write data, format on index, or format on sector or index operation, READ GATE is asserted for at least 16-state bit transmission times and then lowered to cause the operation to be aborted.

  The trailing edge of READ GATE indicates to the drive that the current data transfer command is finished.

- **INIT** - This signal initializes the drive. The leading edge of this signal instructs the drive to go to a known memory location and execute the initilization sequence. This sequence aborts all operations which are in progress, including any data transfers that are underway, and brings all mechanical movements to a controlled stop.

- **PARITY** - This signal is odd parity over the six logical signals or even parity over the entire byte, including the sync bit. If a parity error is detected, the status information for the byte in error is ignored by the drive. The old state is used until a valid update is received.

```
|<-- REPEATED 16-BIT PATTERN -->|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|P| | | | | | |1|Ø|Ø|Ø|Ø|Ø|Ø|Ø|Ø|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 | | | | | | | | |             |
 | | | | | | | | |             |
 | | | | | | | | +------   -----+
 | | | | | | | |        \/
 | | | | | | | |        |
 | | | | | | | |        +--- PREAMBLE (8 Øs)
 | | | | | | | +------------ SYNC (1)
 | | | | | | +-------------- RECEIVER READY
 | | | | | +---------------- WRITE GATE
 | | | | +------------------ READ GATE
 | | | +-------------------- INIT
 | | +---------------------- UNUSED
 | +------------------------ UNUSED
 +-------------------------- PARITY
```


Figure 4 Real-Time Controller State Line

Real-Time Drive State Line

The real-time drive state line carries the live drive status. The information on the real-time drive state line consists of the two bytes shown in Figure 5. The first byte (preamble) consists of eight Øs. The second byte consists of the following items.

```
|<-- REPEATED 16-BIT PATTERN -->|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|P| | | | | | |1|Ø|Ø|Ø|Ø|Ø|Ø|Ø|Ø|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 | | | | | | | | |             |
 | | | | | | | | |             |
 | | | | | | | | +------   -----+
 | | | | | | | |        /
 | | | | | | | |        |
 | | | | | | | |        +--- PREAMBLE (8 Øs)
 | | | | | | | +------------ SYNC (1)
 | | | | | | +-------------- RECEIVER READY
 | | | | | +---------------- ATTENTION
 | | | | +------------------ READ/WRITE READY
 | | | +-------------------- SECTOR PULSE
 | | +---------------------- INDEX PULSE
 | +------------------------ AVAILABLE
 +-------------------------- PARITY
```


Figure 5 Real-Time Drive State Line

Except during execution of the topology command, this 2-byte pattern is sent continuously by on-line drives to all controllers for which the drive port switches are enabled. If an error is detected on the real-time drive state line, the controller will not issue any "select track and format on index" or "format on sector or index" real-time data transfer commands. Also, the controller aborts any such commands in progress if an error is detected until the leading edge of the next index pulse.

The following list describes the use of each logical signal on the real-time drive state line. These logical signals are transmitted from the drive to the controller.

- **RECEIVER READY** - This signal, when asserted, indicates that the drive is ready to receive a command on the write/command data line.

- ATTENTION - This signal notifies the controller that a potentially significant status change has occurred in the drive.

  When in the drive on-line state, the drive asserts the attention signal whenever any of its generic status bits change. The three exceptions to this are:

  1. When a generic status bit changes as a direct consequence of the correct operation of a command

  2. When a generic status bit changes as the result of an error in the reception, validation, or execution of a command

  3. When the RE status bit changes due to a transmission error outside of a command

  If it is appropriate for a on-line drive to assert ATTENTION, the signal is asserted regardless of whether a command is in progress or not. The drive continues to assert this signal until it receives a valid get status command from the controller. At this point, the drive lowers the signal.

  When in the drive-available state, a drive asserts the ATTENTION signal if the following two conditions exist.

  1. The RUN/STOP switch is in the (RUN) position

  2. There are no interlocks broken that would prevent the drive from spinning.

  The ATTENTION signal has no effect on any other activity on the SDI bus. While it is asserted, all other SDI bus activities may continue normally, including control message and data transfers in both directions.

- READ/WRITE READY - This signal, when asserted, signifies that the drive is capable of handling a data transfer to and from the disk surface.

  Upon receipt of a start frame of a command, the drive lowers this signal prior to reasserting RECEIVER READY. Once lowered, the READ/WRITE READY signal remains lowered until the drive has processed the command and has transmitted the end frame of the response.

Any head motion lowers the READ/WRITE READY until the operation is completed and the drive is again ready to perform I/O operations.

The drive asserts READ/WRITE READY after the successful completion of a seek operation. If the operation is unsuccessful, the drive keeps the READ/WRITE READY signal negated and uses ATTENTION to signal the problem.

- **SECTOR PULSE** - This signal divides the disk into sectors. The controller uses the leading edge of SECTOR PULSE for rotational position sensing and the trailing edge for the beginning of any sector.

- **INDEX PULSE** - This signal is asserted once every revolution at pack index. The controller uses the leading edge of INDEX PULSE for rotational position sensing and the trailing edge for the beginning of sector Ø.

- **AVAILABLE** - This signal indicates that the drive is in the drive-available state relative to the controller. It is asserted whenever the drive enters the drive-available state and remains asserted for as long as the drive remains in that state. The signal is lowered when the drive leaves the drive-available state.

- **PARITY** - This signal is odd parity over the six logical signals or even parity over the entire byte, including the sync bit. If a state parity error is detected during a formatting operation, the operation is aborted. At other times, the state in error is ignored by the controller. The old state is utilized until a valid update is received.

Write/Command Data Line

The Write/Command Data line transmits self-clocking digital data from the controller to the drive. When data is transmitted down this line, the least significant bit is always transmitted first.

The Write/Command Data line serves the following three functions.

1. It transmits write data to be recorded onto the disk surface.

2. It transmits real-time data transfer commands to the drive.

3. It transmits command messages from the controller to the drive.

During a write command, the controller sends serial WRITE DATA to the drive over the WRITE/COMMAND DATA line. There is no protocol or format associated with this type of transfer.

Real-Time Data Transfer Commands

There is a format associated with real-time data transfer commands. A real-time data transfer command is sent from the controller to the drive and consists of a 32-bit frame (refer to Figure 6). The first two bits transmitted on the line are Øs, followed by the 12-bit sync character, two more Øs, and a 16-bit control frame.

```
|                                                               |
|<-------------------------- 32 BITS ------------------------->|
|                                                               |
|<------- 16 BITS ----------->|<---------- 16 BITS ---------->|
|                               |                               |
|                               |        SYNC CHARACTER         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       CONTROL FRAME           |Ø|Ø|1|Ø|Ø|1|1|Ø|1|Ø|1|1|1|1|Ø|Ø|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```


Figure 6 Real-Time Data Transfer Command

Figure 7 shows the control frame format of the six real-time data transfer commands. The following list describes each of these commands.

- Select Group - This command causes the drive to lower READ/WRITE READY, select the specified group, and then raise READ/WRITE READY when the drive is able to perform an I/O operation. The Select Group is frequently treated more as a command message than a Real-Time Data Transfer Command because no data is included with the command.

- Select Track and Read - This command causes the drive to select the appropriate track and initiate a read data operation at the trailing edge of the next sector or index pulse. The track number information is ignored by RA6Ø drives because they have only one track per group.

- **Select Track and Write** - This command causes the drive to select the appropriate track and initiate a write data operation at the trailing edge of the next sector or index pulse. The track number information is ignored by RA60 drives because they have only one track per group.

- **Select Track and Format on Index** - This command causes the drive to select the specified track and setup to format the entire track. The track number information is ignored by RA60 drives because they have only one track per group.

- **Format on Sector or Index** - This command causes the drive to use the last selected track and setup to format one sector at the trailing edge of the next sector or index pulse.

- **Diagnostic Echo** - This command causes the drive to transmit the entire frame (using a diagnostic echo frame code) back to the controller as soon as it raises RECEIVER READY.

```
SELECT GROUP:
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
               |1|0|0|0|1|1|1|0| GROUP NUMBER|
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

SELECT TRACK AND READ:
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
               |0|0|0|1|0|1|1|1| TRACK NUMBER|
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

SELECT TRACK AND WRITE:
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
               |1|0|1|0|0|1|0|1| TRACK NUMBER|
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

SELECT TRACK AND FORMAT ON INDEX:
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
               |0|0|1|0|1|0|1|1| TRACK NUMBER|
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

FORMAT ON SECTOR OR INDEX:
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
               |0|1|0|0|1|1|0|1|  UNDEFINED  |
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

DIAGNOSTIC ECHO:
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
               |1|1|1|0|1|0|0|0|  UNDEFINED  |
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```


Figure 7 Control Frame Format for Real-Time Data Commands

Command Messages

Command messages are also sent over the Write/Command Data line. Unlike real-time data transfer commands that have only one 32-bit frame, a command message has a minimum of two 32-bit frames and up to a maximum of sixty-four frames. Figure 8 shows the data that goes into the control frame portion of command messages. Figure 9 shows the complete format for a Get Subunit Characteristics Command.

```
MESSAGE START:
         +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
         |0|1|1|1|0|0|0|1|MESSAGE DATA |
         +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

MESSAGE CONTINUATION:
         +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
         |1|1|0|1|0|1|0|0|MESSAGE DATA |
         +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

MESSAGE END:
         +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
         |1|0|1|1|0|0|1|0|  CHECK SUM  |
         +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```


Figure 8 Control Frame Format for Command Messages

```
|                                                               |
|<--------------------- 32 BITS ------------------------------>|
|                                                               |
|<-------- 16 BITS ------------>|<---------- 16 BITS ---------->|
|                                                               |
| MESSAGE START | MESSAGE DATA  |       SYNC CHARACTER          |
|                 (BYTE 1)                                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Ø|1|1|1|Ø|Ø|Ø|1|1|Ø|Ø|Ø|1|Ø|Ø|Ø|Ø|Ø|1|Ø|Ø|1|1|Ø|1|Ø|1|1|1|1|Ø|Ø|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

FIRST FRAME

```
| MESSAGE CONT. | MESSAGE DATA  |       SYNC CHARACTER          |
                  (BYTE 2)
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1|1|Ø|1|Ø|1|Ø|Ø|SUBUNIT MASK   |Ø|Ø|1|Ø|Ø|1|1|Ø|1|Ø|1|1|1|1|Ø|Ø|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

SECOND FRAME

```
| MESSAGE END   |  CHECK SUM    |       SYNC CHARACTER          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1|Ø|1|1|Ø|Ø|1|Ø|  CHECK SUM    |Ø|Ø|1|Ø|Ø|1|1|Ø|1|Ø|1|1|1|1|Ø|Ø|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

THIRD FRAME

Figure 9 Get Subunit Characteristics Command

Read/Response Data Line

The read/response data line carries self-clocking read data and response messages from the drive to the controller. When data is transmitted down this line, the least significant bit is always transmitted first.

Read Data

During a read command, the drive sends self-clocking serial read data from the drive to the controller. There is no protocol or format associated with this type of transfer.

Response Messages

Response messages are also sent over the read/response data line. Response messages consist of a minimum of two frames and up to a maximum of sixty-four frames. The response messages use the same message formats as the controller command messages. The data that goes into the control frame for a response message is the same as shown in Figure 8.

Figure 10 shows a complete response message. The first frame of a command message is the message start. The first byte of the response is in the message data area. If the response consists of more than one byte, the second frame sent is a message continuation. The second byte of the response is in the message data area. For any succeeding byte of the response message, a message continuation frame is sent. The last frame sent is the message end. The message end has a checksum for the bytes that are in the message data area for the response.

```
|<------------------------- 32 BITS ------------------------->|
|                                                             |
|<-------- 16 BITS ------------>|<---------- 16 BITS ---------->|
|                                                             |
| MESSAGE START | MESSAGE DATA  |       SYNC CHARACTER        |
|                (BYTE 1)                                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Ø|1|1|1|Ø|Ø|Ø|1|Ø|1|1|1|1|1|1|Ø|Ø|Ø|1|Ø|Ø|1|1|Ø|1|Ø|1|1|1|1|Ø|Ø|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

FIRST FRAME

```
| MESSAGE END   |  CHECK SUM    |       SYNC CHARACTER        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1|Ø|1|1|Ø|Ø|1|Ø|  CHECK SUM    |Ø|Ø|1|Ø|Ø|1|1|Ø|1|Ø|1|1|1|1|Ø|Ø|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

SECOND FRAME

Figure 1Ø Complete Response Message

SDI OVERVIEW

SDI Write Operation

Let's assume, for the sake of demonstration, that the controller is writing two sectors of data on the disk. The write operation sequence over the SDI bus follows.

A real-time data transfer command, Select Track and Write, is sent to the drive prior to the SECTOR PULSE. The drive negates RECEIVER READY upon receipt of the command. RECEIVER READY is held low so that no other command can be sent during a data transfer. The Select Track and Write command conditions the drive to read the sector header. On the trailing edge of the SECTOR PULSE, the controller reads the header over the read/response data line. After reading the header, the controller asserts WRITE GATE over the real-time controller state line at the beginning of the data area. Data is sent over the write/command data line to be written on the disk. When the write of the sector is complete, the controller negates WRITE GATE and the drive asserts RECEIVER READY. The write operation begins again for the next sector when the controller sends the select track and write command again.

SDI Read Operation

The read operation sequence over the SDI bus is as follows. The real-time data transfer command, Select Track and Read, is sent to the drive prior to the SECTOR PULSE. The drive negates RECEIVER READY upon receipt of the command. RECEIVER READY is held low until near the end of the sector so that no other command can be sent during the data transfer. The Select Track and Read command conditions the drive to read on the trailing edge of the SECTOR PULSE. On the trailing edge of the SECTOR PULSE, the controller reads the header over the read/response line. After reading the header, the controller asserts READ GATE over the real-time controller state line to read the data. The read data is transferred to the controller over the read/response line. READ GATE is then negated at the end of the sector, terminating the data transfer.

EXERCISES

This is an open book test. Answer these questions and then check your answers with the solutions given on the following page.

1. Several RA60 drives may be connected to a SDI-type disk controller over a single SDI cable. Is this statement true or false? False.

2. What technique is employed to prevent a dc voltage from building up on the SDI cable when an unequal distribution of similar polarity pulses are sent over the cable?
   Bipolar pulses.

3. Over which SDI signal line is the real-time data commands sent? Read or Write data/command lines.

4. Which SDI signal line carries the WRITE GATE signal from the controller to the drive?
   Real-time controller state

5. Which SDI signal line is used to inform the disk controller of the drive status?
   Real time drive state

6. Why does the RA60 Disk Drive ignore the track information sent during the real-time data transfer commands?
   Only one track per group.

7. What is the minimum number of frames required to send a drive response message? 2

8. During an SDI write operation, what command conditions the drive to read the sector header?
   Select track & write-Sector Pulse.

9. During an SDI read operation, when does the drive negate RECEIVER READY? When Select Group transmitted
   Select track & read.

10. What does the diagnostic echo command do?

NOTE
After completing this exercise, compare your answers with the solutions on the next page, and then begin reading Section II of the workbook.

Causes drive to Xmit entire frame back to controller as soon as receiver ready raised

SOLUTIONS

1. False. Only one RA6Ø drive may be attached to each SDI cable.

2. The technique employed to prevent a dc voltage offset from building up on the SDI cable from an unequal distribution of polarity pulses is to add a pulse of the opposite polarity whenever there are two preceding pulses of the same polarity.

3. The write/command data line carries the real-time data transfer commands.

4. The real-time controller state line carries the WRITE GATE signal to the drive. The WRITE GATE signal is embedded as a bit in the message packet.

5. The real-time drive state line carries the drive status information back to the controller.

6. The RA6Ø Disk Drive ignores the track information in the real-time data transfer commands because it only needs the group number. The RA6Ø pack format is organized so there is only one track per group. Other drives may be formatted with more than one track per group, thus requiring the track information in the real-time data transfer commands.

7. Drive response messages require a minimum of two frames.

8. During an SDI write operation, the select track and write command conditions the drive to read the sector header.

9. During an SDI read operation, the drive negates RECEIVER READY upon receipt of the select track and read command.

1Ø. The diagnostic echo command causes the drive to transmit a message frame back to the controller as soon as the controller raises RECEIVER READY.

SECTION II RA60 DISK LAYOUT

RA60 DISK LAYOUT

RA60 Physical Disk Layout

The RA60 disk pack contains five disk platters. The three middle platters are used for data storage, while the two outer ones are for protection. The three data storage platters provide a total of six read/write data surfaces, each containing 1600 physical data tracks. Each track contains 39 sectors on 18 bit data packs or 43 sectors on 16 bit data packs. The last sector on each track in the host operating systems area of the disk is always reserved for revector control information. The data field within each sector contains 256 data words, regardless of whether the information is written in 16 bit or 18 bit words.

DIGITAL Standard Disk Format

The RA60 disk pack logical format meets the criteria set forth in the DIGITAL Standard Disk Format (DSDF) specification, which is DEC Standard 166. This standard describes how a physical disk is constructed into the logical format for Standard Disk Interconnect (SDI) devices. It also describes the host view of mass storage device formats. This specification redefines many of the classical disk terms, such as sector, track, and cylinder, as a function of their access characteristics. It also introduces the concept of groups as a fixed number of tracks. The following terms will help you to understand the Digital Standard Disk Format.

1. Sector - A sector is the smallest unit by which data is physically addressed. Sectors are available for reading or writing once per disk revolution.

2. Track - A track is a logical entity that represents sets of sectors occupying contiguous physical disk locations. This is a strictly logical entity that relates sectors to each other as a function of their access characteristics.

3. Group - The DSDF Specification defines a group as as a logical entity that contains a set of tracks. Each of the sectors with the same physical address on these tracks are simultaneously available for reading and writing. Groups also have the property that any track within the group can be selected within the inter-sector rotation time. This definition of groups is independent of the physical construction of the device and relates tracks to each other as a function of their access characteristics. In the case of the RA60, there is only one track per group.

4. Cylinder - A cylinder is a logical entity that represents a collection of groups. Cylinders have the property that individual groups on the same cylinder can be accessed in less than the minimum seek time. The selection of a new cylinder has the longest average positioning time. In the RA6Ø, one logical cylinder equals four groups.

5. Physical Block Number (PBN) - A PBN is a 28 bit number which identifies a physical sector's position within a set of sectors on a subunit.

6. Logical Block Number (LBN) - An LBN is a 28 bit number which identifies a physical sector's position within a set of sectors directly accessible to the host. These are used for host data storage and revector control information.

7. Replacement Block Number (RBN) - An RBN is a 28 bit number which identifies a physical sector's position within a set of sectors used as replacements for bad sectors.

8. Bad Block - A bad block is a sector that contains a defect which exceeds the error correction capability of the subsystem.

9. Bad Block Replacement - The substitution of a spare sector (replacement block) for a bad sector.

1Ø. Bad Block Revectoring - The act of locating the replacement block associated with a bad sector upon attempting to access that bad sector.

11. Primary Replacement Block - A replacement block with the lowest RBN on a track which has been allocated to replace a logical block on the same track.

12. Secondary Replacement Block - A replacement block that is not a primary. It is either not the replacement block with the lowest RBN on a track or is allocated to replace a logical block on another track.

13. External Block Number (XBN) - A 28 bit number which identifies a physical sector's position within a set of sectors in the external format area of the subunit.

14. Diagnostic Block Number (DBN) - A 28 bit number which identifies a physical sector's position within the set of sectors in the diagnostic area of the subunit.

RA60 DISK LAYOUT

RA60 Logical Disk Format

This section describes how the RA60 disks are organized into the new Digital Standard Disk Format. This disk organization is sometimes referred to as the RA60 disk topology. Figure 11 provides an overview of the RA60 logical disk format. Note that the X axis shows the physical sectors for both the 16 and 18 bit data formats. Note also that the last sector is always reserved for replacement information. This is similar to the skip sector concept used in the RM80 Disk Drive to replace bad blocks. The Y axis gives the physical cylinder numbers that define the boundaries of the major logical areas on the disk. These physical cylinders are defined as six vertical tracks, one on each of the six disk data surfaces.

Note that the 1600 physical cylinders on an RA60 disk surface are divided into the following four logical areas.

- Host applications area (cylinder 0 - 1587)
- Replacement and caching tables (cylinder 1588 - 1591)
- Format area (cylinder 1592 - 1595)
- Diagnostic area (cylinder 1596 - 1599)

Host Applications Area

The host applications area is the space made available to normal customer host activities. Each sector in this area is assigned a logical block number (LBN). The only exception is the last sector on each track. They are assigned replacement block numbers (RBNs). If the controller encounters a bad block, (a block header that cannot be read), it will skip that block and store the information in the the last sector on the track, the RBN.

Bad blocks are detected when a disk pack is manufactured. These blocks are always replaced when the disk packs are formatted. Other blocks become bad during normal use and must be replaced dynamically. During dynamic bad block replacement, the host accesses and updates the replacement and caching tables and informs the disk controller. This allows the controller to reformat the disk to reflect the bad block replacement.

Replacement and Caching Tables

The replacement and caching area of the disk also contains LBNs and RBNs. This area is used to store the revector addresses for the RBNs in the host applications area. It contains a look-up table for the controller to locate revectored information.

The revectored information may be stored in the RBN at the end of the track if it has not already been used to replace a bad block. If it has already been used, then the bad blocks may be stored in RBNs on adjacent tracks.

Format Area

The format area is only visible to the controller and has addresses known as external block numbers (XBNs). The format tables store manufacturing format control information and media error lists. This area is inaccessible to the host. It is always written in 512 byte format and is used when formatting the disk in either 512 or 576 bytes.

Diagnostic Area

The diagnostic area contains blocks used for controller-resident diagnostics. These blocks have addresses known as diagnostic block numbers (DBNs). The DBNs are visible only to the disk controller.

The diagnostic area occupies the last four cylinders in the pack. They are used by the drive-resident diagnostic tests to verify the drive's ability to read and write data. They are also used in test four of the UDA50 subsystem diagnostics to exercise the disk without endangering customer data.

RA60 DISK LAYOUT

```
          |<----  PHYSICAL CYLINDERS ---------------------->|

           0         1587 1588    1591 1592   1595 1596    1599
   18  16 ---------------------------------------------------
   BIT BIT|             |           |          |            |
 -        |-------------|-----------|----------|------------|
 |  0   0 |             |           |          |            |
 |        | HOST        |REPLACEMENT| FORMAT   | DIAGNOSTIC |
PHYSICAL  | APPLICATION |    AND    | AREA     |    AREA    |
SECTORS   | AREA        |  CACHING  |          |            |
 |        | (LBNs)      |  TABLES   | (XBNs)   | (DBNs)     |
 |        |             |   (LBNs)  |          |            |
 | 37  41 |             |           |          |            |
 |        |-------------|-----------|          |            |
 V 38  42 | REPLACEMENT AREA (RBNs) |          |            |
 ---------|-------------|-----------|----------|------------|

          | VISIBLE     |           |                       |
          |<-- TO ----->|           |                       |
          |   HOST      |           |                       |
          |APPLICATIONS             |                       |
          |                         |                       |
          |<--- VISIBLE TO HOST --->|                       |
          |     OPERATING SYSTEM    |                       |
          |                                                 |
          |<----- VISIBLE TO THE CONTROLLER --------------->|
          |                                                 |
```

Figure 11 Overview of the RA60 Logical Disk Format

RA6Ø DISK LAYOUT

RA6Ø Disk Topology

The RA6Ø disk topology defines how the physical cylinders, tracks, and sectors of the disk pack are organized into logical addressable units that can be accessed in the most efficient manner. These logical units are:

- Groups
- Logical cylinders
- Logical block numbers
- Replacement block numbers

RA6Ø Groups

In the RA6Ø Disk Drive, a group is defined as one track. Other drives may have more tracks per group.

Logical Cylinders

In the RA6Ø Disk Drive, a logical cylinder is defined as four groups. The number four is chosen on the basis of most efficient access times for the RA6Ø Drive characteristics. Several other logical cylinder sizes were tested. The final choice was affected by the fact that it takes longer to do a head switch than a one track seek in the RA6Ø. A head switch requires a level one SDI command from the disk controller.

The way that the logical cylinders are organized in the RA6Ø disk pack is somewhat determined by how the RA6Ø Disk Drives will be used. The RA6Ø was first developed to be used mostly as a backup disk for the RA8Ø and RA81. For this reason, the old topology used in the pre-production RA6Ø Disk Drives alligned the logical cylinders sequentially along one disk surface (from Ø to 396), and then dropped vertically to 397 on the next disk surface and so on. This arrangement, which was published in the first edition of the <u>RA6Ø Disk Drive Service Manual</u>, gave good efficiencies in the storage of linear sequential data. The entire disk was arranged as one long sequential file. However, this disk topology prevented the use of seek optimization by the SDI disk controllers, which operates most efficiently with randomized data. When it became obvious that the RA6Ø would also be used in system operations as well as for data backup, a new RA6Ø disk topology became imperative for greater data access speeds.

The new RA6Ø disk topology is shown in Figures 12 and 13. Notice that the logical cylinders, shown inside parentheses, are arranged in vertical order from top to bottom disk. After the bottom disk is reached, the next sequential logical cylinder starts at the top again. This arrangement allows for seek optimization by the disk controller and can increase system throughput by ten to twenty percent, depending on the systems application.

Logical Block Numbers

Logical block numbers (LBNs) are the smallest addressable units. Each physical sector in the host applications and replacement area of the disk is assigned an LBN. These LBNs are arranged sequentially over the four groups (tracks) in each logical cylinder. After the last LBN in logical cylinder 0 is reached, the next LBN begins in logical cylinder 1. In Figures 12 and 13, the LBNs are given in the middle positions with no parentheses or brackets. In 16 bit formatted packs, the LBNs run from 0 to 401183. In 18 bit formatted packs, the LBNs runs from 0 to 362975.

In 16 bit formatted packs, there are 168 LBNs per logical cylinder. This is the product of four tracks times 42 sectors per track. In 18 bit formatted packs, there are only 152 LBNs per logical cylinder. This is the product of four tracks times 38 sectors.

Replacement Block Numbers

The replacement block occupies the last sector on each track. This replacement block is assigned a replacement block number (RBN). Since there are four tracks in each logical cylinder, there are also four RBNs per logical cylinder. Figures 12 and 13 show these RBN numbers in square brackets. There are a total of 9551 RBNs in an RA60 disk pack.

RA60 DISK LAYOUT

```
                          PHYSICAL CYLINDERS
      |0 ---------------------->|1588 --------->|1592 -->|1596-1599
------|-------------------------|---------------|--------|--------|
      | (0)        (2376)       | (2382)        | (2388) | (2394) |
   0  | 0-167      399168-399335| 400176-400343 | 0-171  | 0-171  |
      | [0-3]      [9504-9507]  | [9528-9531]   |        |        |
   ---|-------------------------|---------------|--------|--------|
P     | (1)        (2377)       | (2383)        | (2389) | (2395) |
H 1   | 168-335    399336-399503| 400344-400511 |172-343 |172-343 |
Y     | [4-7]      [9508-9511]  | [9532-9535]   |        |        |
S---  |-------------------------|---------------|--------|--------|
I     | (2)        (2378)       | (2384)        | (2390) | (2396) |
C 2   | 336-503    399504-399671| 400512-400679 |344-515 |344-515 |
A     | [8-11]     [9512-9515]  | [9536-9539]   |        |        |
L---  |-------------------------|---------------|--------|--------|
      | (3)        (2379)       | (2385)        | (2391) | (2397) |
S 3   | 504-671    399672-399839| 400680-400847 |516-687 |516-687 |
U     | [12-15]    [9516-9519]  | [9540-9543]   |        |        |
R---  |-------------------------|---------------|--------|--------|
F     | (4)        (2380)       | (2386)        | (2392) | (2398) |
A 4   | 672-839    399840-400007| 400848-401015 |688-859 |688-859 |
C     | [16-19]    [9520-9523]  | [9544-9547]   |        |        |
E---  |-------------------------|---------------|--------|--------|
S     | (5)        (2381)       | (2387)        | (2393) | (2399) |
  5   | 840-1007   400008-400175| 401016-401183 |860-1031|860-1031|
      | [20-23]    [9524-9527]  | [9548-9551]   |        |        |
------|-------------------------|---------------|--------|--------|
      |              (LOG. CYL.)                | (LOG. CYL.)     |
      |<------------ LBN'S -------------------->|< XBN'S>|< DBN'S>|
      |              [RBN'S]                    |        |        |
```

NOTE: (X-XXXX)* = LOGICAL CYLINDER NUMBERS
X-XXXXXX = LOGICAL BLOCK NUMBERS (LBN'S)
[X-XXXX] = REPLACEMENT BLOCK NUMBERS (RBN'S)

* LOGICAL CYLINDERS SEQUENCE THROUGH THE DISK SURFACES IN A VERTICAL MANNER WITH THE NEXT LOGICAL CYLINDER AFTER THE ONE ON SURFACE FIVE, BEING ON SURFACE ZERO. FOR EXAMPLE: LOGICAL CYLINDER (6) IS ON SURFACE ZERO.

Figure 12 RA60 Disk Topology for 16 Bit Format

RA6Ø DISK LAYOUT

```
                           PHYSICAL CYLINDERS
        |Ø ---------------------->|1588 ---------->|1592 -->|1596-1599
 -----|------------------------|---------------|--------|--------|
      | (Ø)      (2376)        | (2382)        | (2388) | (2394) |
    Ø | Ø-151    361152-361303 | 362Ø64-362215 | Ø-155  | Ø-155  |
      | [Ø-3]    [95Ø4-95Ø7]   | [9528-9531]   |        |        |
   ---|------------------------|---------------|--------|--------|
  P   | (1)      (2377)        | (2383)        | (2389) | (2395) |
  H 1 | 152-3Ø3  3613Ø4-361455 | 362216-362367 |156-311 |156-311 |
  Y   | [4-7]    [95Ø8-9511]   | [9532-9535]   |        |        |
  S---|------------------------|---------------|--------|--------|
  I   | (2)      (2378)        | (2384)        | (239Ø) | (2396) |
  C 2 | 3Ø4-455  361456-3616Ø7 | 362368-362519 |312-467 |312-467 |
  A   | [8-11]   [9512-9515]   | [9536-9539]   |        |        |
  L---|------------------------|---------------|--------|--------|
      | (3)      (2379)        | (2385)        | (2391) | (2397) |
  S 3 | 456-6Ø7  3616Ø8-361759 | 362672-362823 |468-623 |468-623 |
  U   | [12-15]  [9516-9519]   | [954Ø-9543]   |        |        |
  R---|------------------------|---------------|--------|--------|
  F   | (4)      (238Ø)        | (2386)        | (2392) | (2398) |
  A 4 | 6Ø8-759  36176Ø-361911 | 362672-362823 |624-779 |624-779 |
  C   | [16-19]  [952Ø-9523]   | [9544-9547]   |        |        |
  E---|------------------------|---------------|--------|--------|
  S   | (5)      (2381)        | (2387)        | (2393) | (2399) |
    5 | 76Ø-911  361912-362Ø63 | 362824-362975 |78Ø-935 |78Ø-935 |
      | [2Ø-23]  [9524-9527]   | [9548-9551]   |        |        |
 -----|------------------------|---------------|--------|--------|
      |             (LOG. CYL.)                |   (LOG. CYL.)   |
      |<------------- LBN'S ------------------>|< XBN'S>|< DBN'S>|
      |               [RBN'S]                  |        |        |
```

NOTE: (X-XXXX)* = LOGICAL CYLINDER NUMBERS
X-XXXXXX = LOGICAL BLOCK NUMBERS (LBN'S)
[X-XXXX] = REPLACEMENT BLOCK NUMBERS (RBN'S)

* LOGICAL CYLINDERS SEQUENCE THROUGH THE DISK SURFACES IN A VERTICAL MANNER WITH THE NEXT LOGICAL CYLINDER AFTER THE ONE ON SURFACE FIVE, BEING ON SURFACE ZERO. FOR EXAMPLE: LOGICAL CYLINDER (6) IS ON SURFACE ZERO.

Figure 13 RA6Ø Disk Topology for 18 Bit Format

RA6Ø DISK LAYOUT

Converting RA6Ø LBNs to Head Numbers

It may be necessary at times to correlate an LBN number with a read/write head number to determine which head is bad. This conversion is done by a two step process. First, find the logical cylinder number in which the LBN is located. This is done by dividing the LBN number by the number of LBNs in a logical cylinder. For 16 bit formatted packs, divide the LBN by 168. For 18 bit formatted packs, divide the LBN by 152.

EXAMPLE: FIND LOGICAL CYLINDER FOR 16 BIT FORMATTED RA6Ø PACKS:

LBN NO. 36147Ø / 168 = LOGICAL CYLINDER 2151.6Ø71

EXAMPLE: FIND LOGICAL CYLINDER FOR 18 BIT FORMATTED RA6Ø PACKS:

LBN NO. 36147Ø / 152 = LOGICAL CYLINDER 2378.Ø921

In the above divisions, only the whole number part of the answer is important. The whole number gives you the logical cylinder address in which the LBN is located. The results show that in 16 bit formatted packs, an LBN of 36147Ø is located in logical cylinder 2151. For 18 bit formatted packs, it is located in logical cylinder 2378.

The second step of the process involves converting the logical cylinder address to a disk surface by dividing by the number of read/write heads. Since the RA6Ø has six read/write heads, you will be dividing by six. In this division, it's the decimal part of your answer that will be important.

EXAMPLE: FIND HEAD SURFACE FOR 16 BIT FORMATTED RA6Ø PACKS:

LOGICAL CYLINDER 2151 / 6 = 358.5

EXAMPLE: FIND HEAD SURFACE FOR 18 BIT FORMATTED RA6Ø PACKS:

LOGICAL CYLINDER 2378 / 6 = 396.3333

In the above divisions, the decimal part of the answer gives what disk surface (or head) the logical cylinder is on. Ignore the whole number and convert the decimal part of the answer to a fractional part of a sixth, and you will have the disk surface number. For example, .5 = 1/2 = 3/6, or head surface 3. If you have a decimal .3333, it yields 1/3 = 2/6 or a head surface of 2.

EXERCISES

This is an open book test. Answer the following questions, and then compare your answers with the solutions on the following page.

1. How many data surfaces are there in an RA6Ø disk pack?

   6

2. How many physical data tracks are there on each RA6Ø disk surface?

   1600

3. RA6Ø disk packs are formatted with the same number of sectors for both 16 bit and 18 bit data. Is this statement true or false?

   False

4. The Digital Standard Disk Format Specification describes how a physical disk is constructed into a logical format for what kind of devices?

   RA disks operating from SDI controller.

5. How is a group defined in the Digital Standard Disk Format Specification?

   A logical cylinder which may be one or more cylinders. (4 tracks)

6. How is a cylinder defined in the Digital Standard Disk Specification?

   Collection of groups.

7. What four logical areas is each RA6Ø disk data surface divided into?

   Host, Diagnostic, Caching and RBN's, Format

8. What is an LBN?

   Logical block no. 28 bit no. indicating position of a block accessible to host within a physical block.

9. How many groups are within each RA6Ø logical cylinder?

   4

RA6Ø DISK LAYOUT

1Ø. In the new RA6Ø disk topology, are the logical cylinders arranged vertically or horizontally in sequential order.

Vertically

NOTE
After you finish this exercise, compare your answers with the solutions on the next page and then begin reading Section III of the workbook.

SOLUTIONS

1. The RA6Ø disk pack contains six data surfaces.

2. Each RA6Ø disk surface contains 16ØØ physical tracks having logical address from Ø to 1599.

3. False. RA6Ø disk tracks contain either 39 sectors of 18 bit data or 43 sectors of 16 bit data. The number of bits in the data word for the CPU dictates how many sectors can fit on a track.

4. The Digital Standard Disk Format Specification describes how a physical disk is constructed into a logical format for SDI devices.

5. A group is a logical entity that contains a set of tracks. In the RA6Ø this set is equal to one. Groups have the property that any tracks within the group can be selected within the inter-sector rotation time.

6. A cylinder is defined as a logical entity that represents a collection of groups. Cylinders have the property that groups within the cylinder can be accessed in less time than the minimum seek time.

7. Each RA6Ø disk surface is divided into the following logical areas.

   - Host applications area
   - Revector control tables
   - Format area
   - Diagnostic area

8. An LBN is the abbreviation for Logical Block Number. It is a 28 bit number which identifies a physical sector's position within a set of sectors directly accessible to the host.

9. Each RA6Ø logical cylinder contains four groups.

10. In the new RA6Ø disk topology, the logical cylinders are arranged in a sequential vertical order from top to bottom of the six disk durfaces.

SECTION III RA60 INTERNAL ASSEMBLIES

RA60 Disk Drive Assemblies

Figure 14 shows a simplified block diagram of the assemblies in the RA60 disk drive. Refer to this diagram of the RA60 as you read the functional descriptions of these assemblies in the following paragraphs.

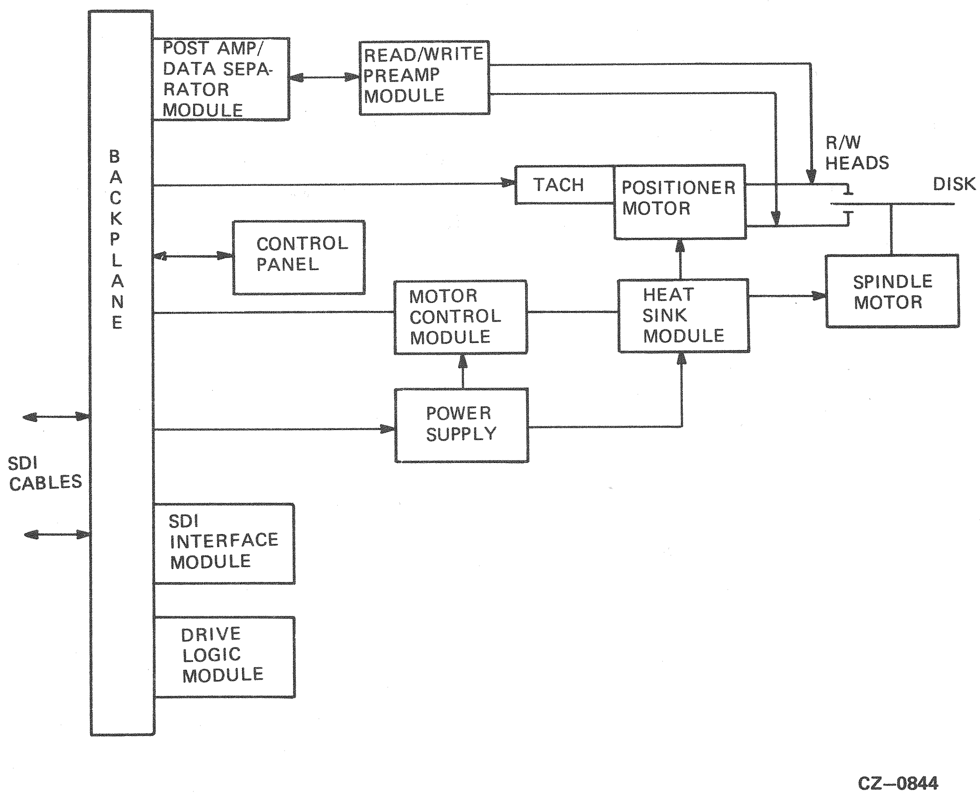

Figure 14 RA60 Simplified Block Diagram

SDI Interface Module

The SDI interface module converts the serial SDI messages sent by the disk controller into a parallel command format recognizable by the drive master microprocessor. In the process, it strips away the sync byte and frame bytes, leaving only the actual command bytes that are stored in RAM memory on the drive logic module.

The SDI interface module also encodes the parallel drive response messages into serial SDI format and transmits them to the controller. In the process, it adds the sync byte and frame bytes. In additon, this module contains all the SDI cable receivers and drivers.

During write data transmission, the SDI interface module converts the SDI bipolar data into Non-Return to Zero (NRZ) data. When reading data from the disks, this module converts the NRZ data back into the SDI bipolar data required for transmission. Refer to Figure 15 for a block diagram of the SDI module.

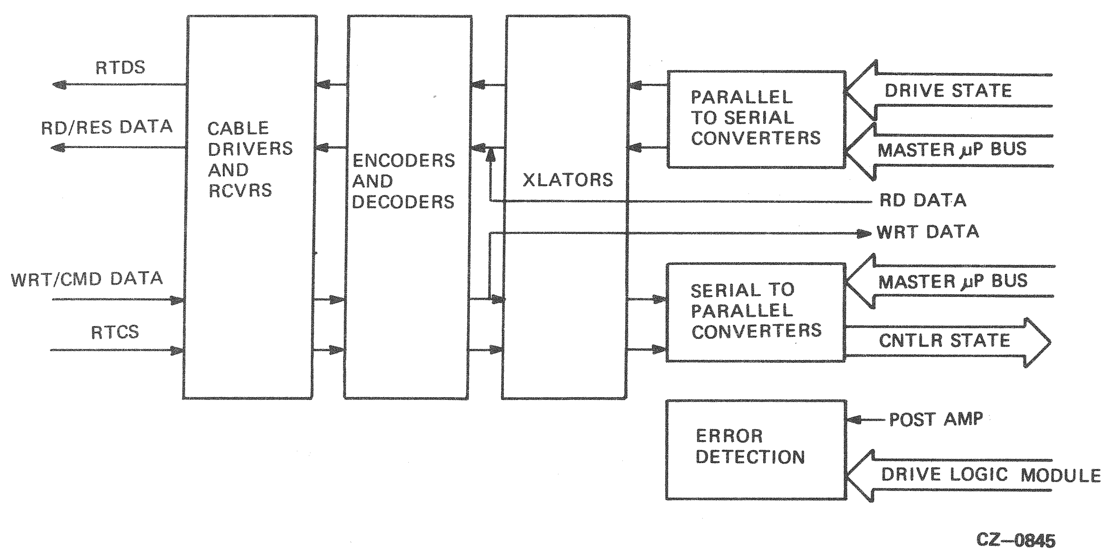

Figure 15 SDI Interface Module Block Diagram

RA6Ø INTERNAL ASSEMBLIES

Drive Logic Module

The drive logic module contains a master microprocessor (8Ø85), a slave microprocessor (8Ø85), some RAMs and ROMs, and other servo associated logic. Refer to Figure 16 for a block diagram of the drive logic module.

The master microprocessor controls the SDI interface handshaking logic, the slave microprocessor, and the operator control panel. When command bytes are received from the SDI interface module and stored in RAM, the master microprocessor interprets them to determine how many more bytes are needed to complete that command sequence. When the full command sequence is received, the slave microprocessor executes them.

The slave microprocessor operates under the control of the master microprocessor. It controls the spindle motor, positioner motor, and the other real-time drive operations. An analog to digital converter changes the serial tachometer signal and disk track information into the parallel format needed by the slave microprocessor. Similarly, a digital to analog converter reformats the microprocessor parallel information back into the serial signals required by the seek mode circuits. More is explained about how the linear and seek mode operation works in the RA6Ø servo system paragraph.

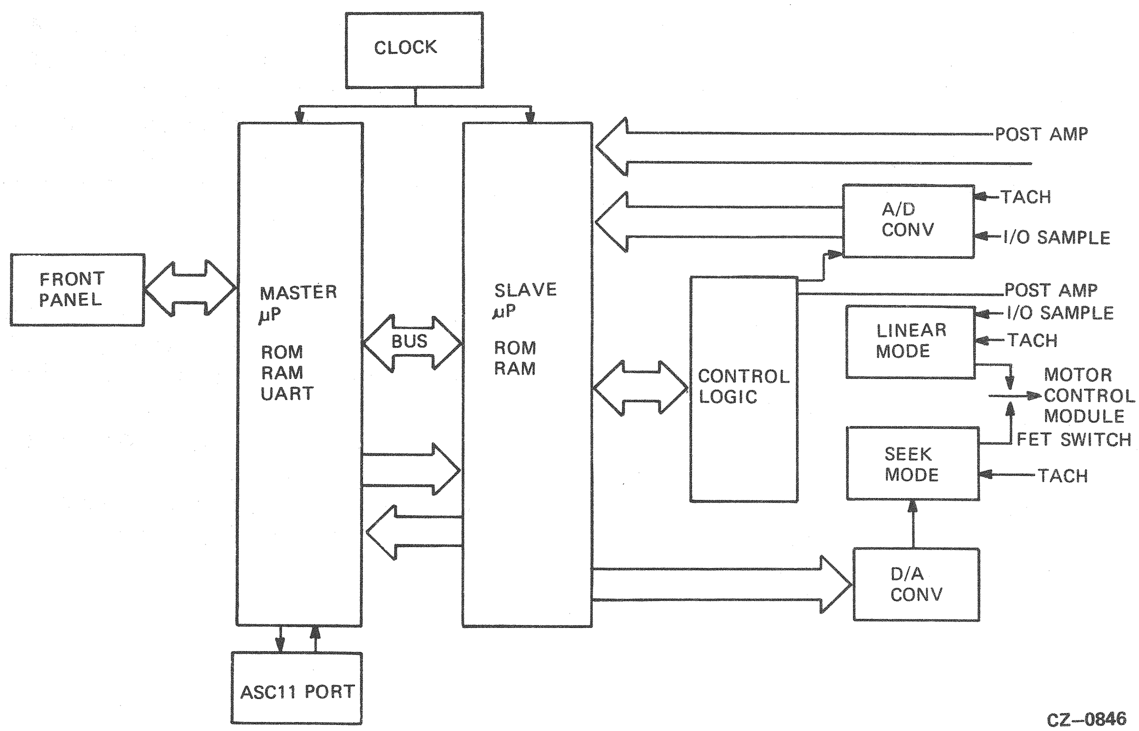

Figure 16 Drive Logic Module Block Diagram

Post Amp/Data Separator Module

The post amp/data separator module performs both data read/write functions and some servo positioning functions. This module is included in the servo positioning loop because the read heads detect the embedded servo bursts as well as read and write data. Refer to Figure 17 for a block diagram of the post amp/data separator module.

During the write operation, the 2/3 encoder circuit transforms the incoming NRZ write data into the 2/3 format to be written on the disk. When the data is read back, it is passed through an amplifier and equalizer circuit to slim the pulses and equalize their rise times. These equalized pulses are then converted into digital information in the data digitizer circuit. The read data out of the data digitizer is then passed through the 2/3 decoder for conversion back to NRZ read data.

The phase lock loop (PLL) oscillator may lock onto one of three different frequencies. It is normally locked onto the 15 Mhz oscillator signal when the drive is neither reading or writing. During a write operation, the PLL oscillator locks onto the WRITE CLOCK signal. During a read operation, it locks onto the READ DATA signal.

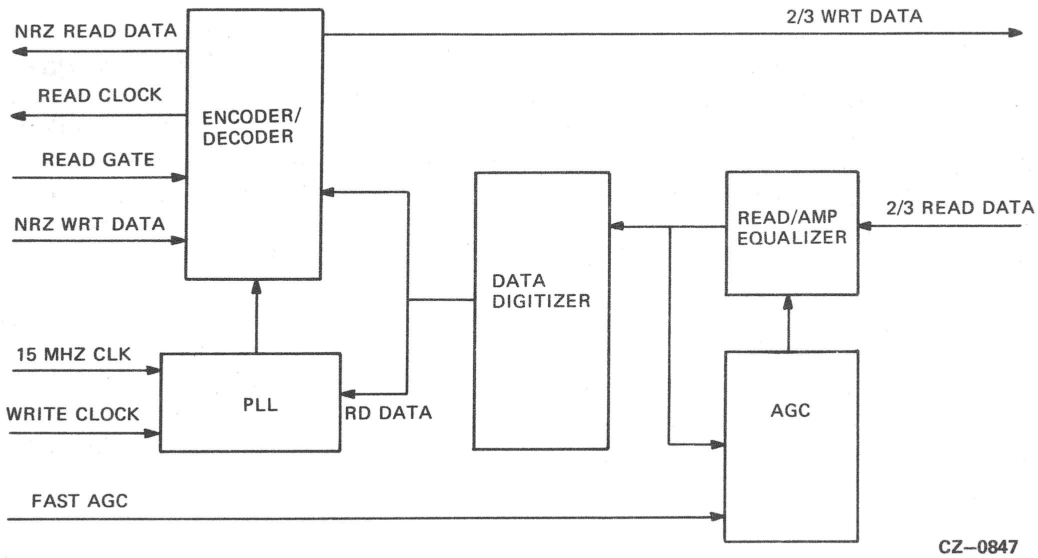

Figure 17 Post Amp/Data Separator Block Diagram

Preamp Module

The preamp module contains the head select logic, the write drivers, and low noise read preamplifiers. Refer to Figure 18 for a block diagram of the preamp module.

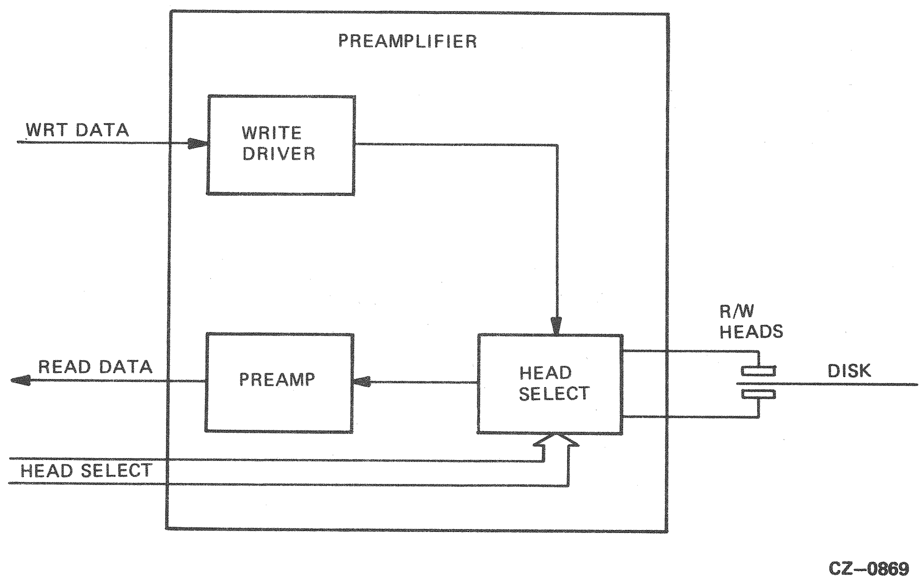

Figure 18 Preamp Module Block Diagram

RA6Ø INTERNAL ASSEMBLIES

Front Panel Module

The RA6Ø front panel is located on the front of the disk drive and consists of five switches and one logic plug (Unit/Ready), mounted onto an elctronic module. A cable runs from the front panel module to the backplane module located at the bottom of the logic cage. Under each indicator cap on the front panel module, is a light that can be on or off regardless of the switch position. The state of the lights is controlled by the master microprocessor. The state of each switch is periodically sampled by the master microprocessor.

A front cover interlock switch is mounted on the cover latch assembly near the front panel. A cable on the front cover interlock switch plugs into the front panel module. This switch prevents the drive from spinning-up whenever the front cover is open. The state of the switch is sampled periodically by the master microprocessor.

Motor Control Module

The motor control module contains the low level signal portion of the power amplifier circuits that drive the positioner motor voice coil. The power transistors for this function are located on the heat sink module. The motor control module also contains the circuitry to control the spindle motor. Refer to Figure 19 for an overview block diagram of how the motor control module drives the motors.

Positioner Motor

The positioner motor is a linear dc motor actuated by a voice coil. Its function is to move the read/write heads in and out across the disk tracks. On the rear of the positioner motor is a tachometer that converts the carriage velocity into an analog signal.

Also located on the positioner motor assembly is the home switch that informs the microprocessor and the power down logic when the read/write heads are home (off the disk pack).

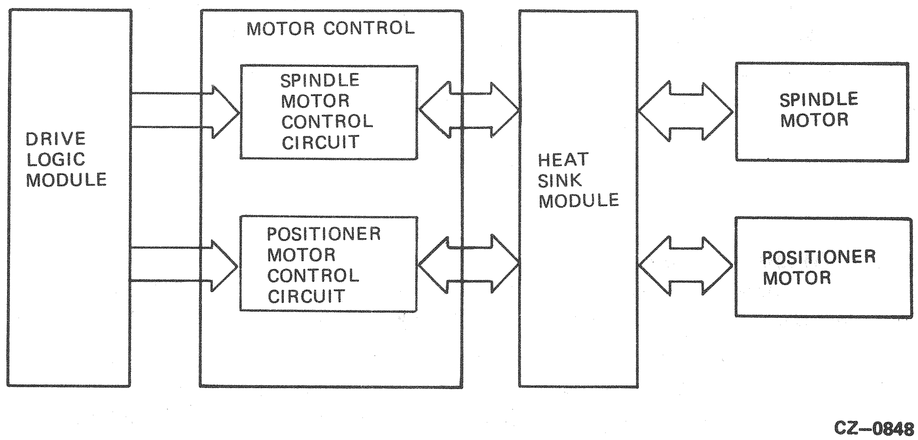

Figure 19 Motor Control Module Block Diagram

RA60 INTERNAL ASSEMBLIES

Spindle Motor

The spindle motor is the dc motor that rotates the disk spindle directly without any belt or pulley. Since this dc motor requires significantly less start current than the ac spindle motors in the RA80 and RA81 disk drives, the RA60 does not require power sequencing cables like the other two drives. The RA60 spindle motor also has a built-in encoder that converts the motor rotation into digital pulses. The signals from this encoder are monitored by the slave microprocessor to sense disk speed during the spin-up sequence. As soon as the disks are up to speed, the heads are loaded onto the disk, and the servo data between sectors is used to control the speed of the spindle motor.

Power Supply Assemblies

The RA60 power supply includes three assemblies and two modules. These are the switchplate assembly, transformer assembly, cap/rectifier assembly, regulator module, and heat sink module. Figure 20 shows a block diagram of the power supply and Figure 21 provides an RA60 power distribution diagram.

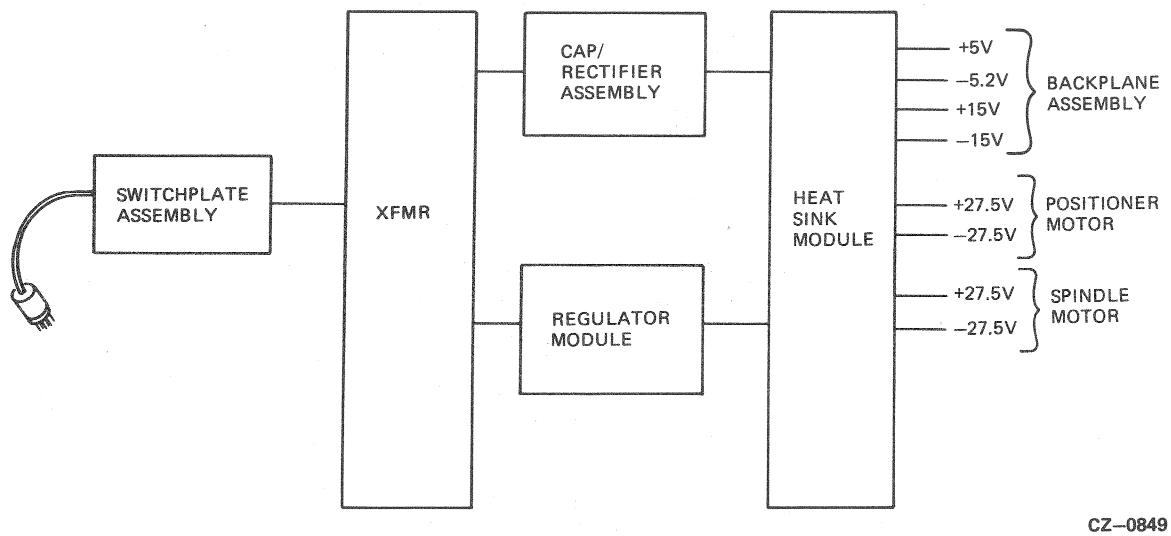

Figure 20 RA60 Power Supply Block Diagram

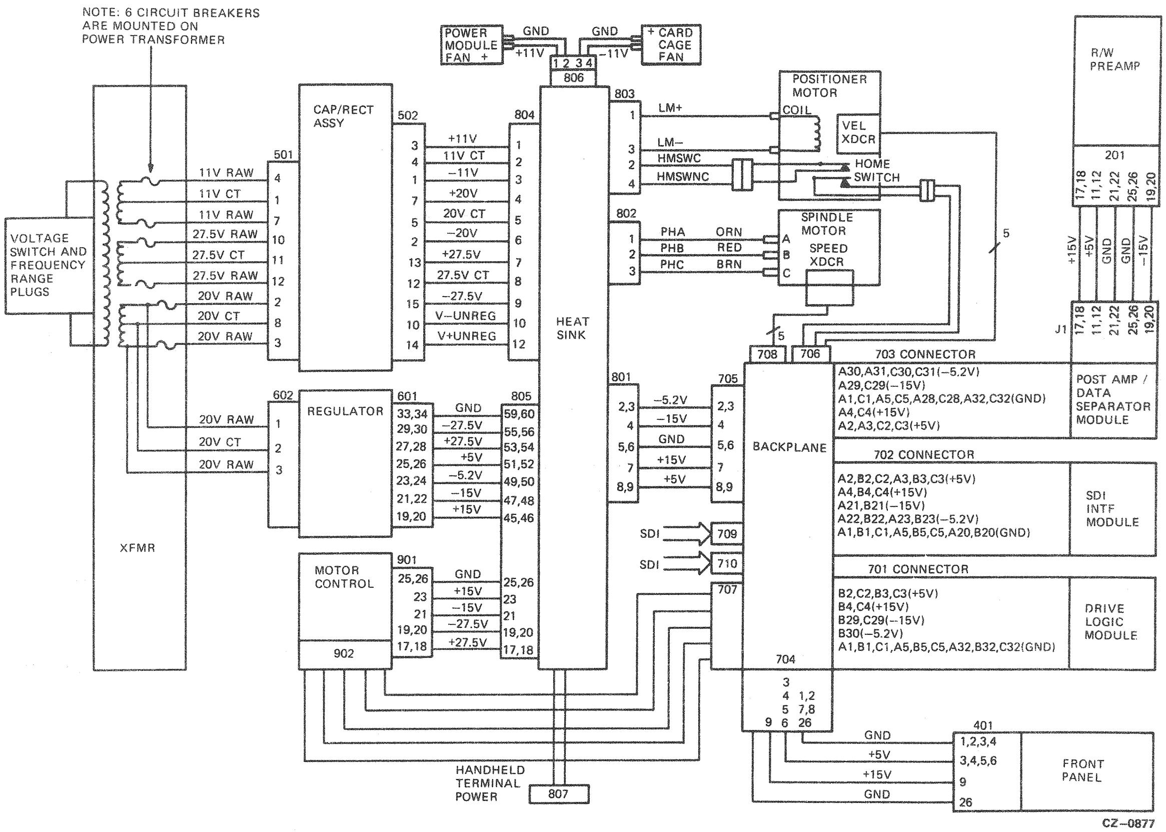

Figure 21 RA6Ø Power Distribution Diagram

RA6Ø INTERNAL ASSEMBLIES

Switchplate Assembly

The switchplate assembly contains the main ac line circuit breaker and line filter. The circuit breaker has three poles rated at 12 amps, 6 amps and 6 amps respectively. Current ratings are 12 amps at the 12Ø volt setting and 6 amps at the 24Ø volt setting.

Transformer Assembly

A ferro-resonant transformer is used in the RA6Ø Disk Drive to obtain good line voltage regulation. The raw output voltages from the transformer are fed to the cap/rectifier assembly for rectification and filtering. The transformer puts out ac voltages of 11 volts, 27.5 volts, and 2Ø volts. Six thermal circuit breakers are mounted on the top of the transformer assembly to protect the output windings from short circuits and over heating.

Also mounted on top of the tranformer assembly is an ac voltage range switch and two frequency range plugs that permit easy voltage and frequency range selections. The location of the ac voltage range switch and the frequency range plugs is shown in Figure 22.

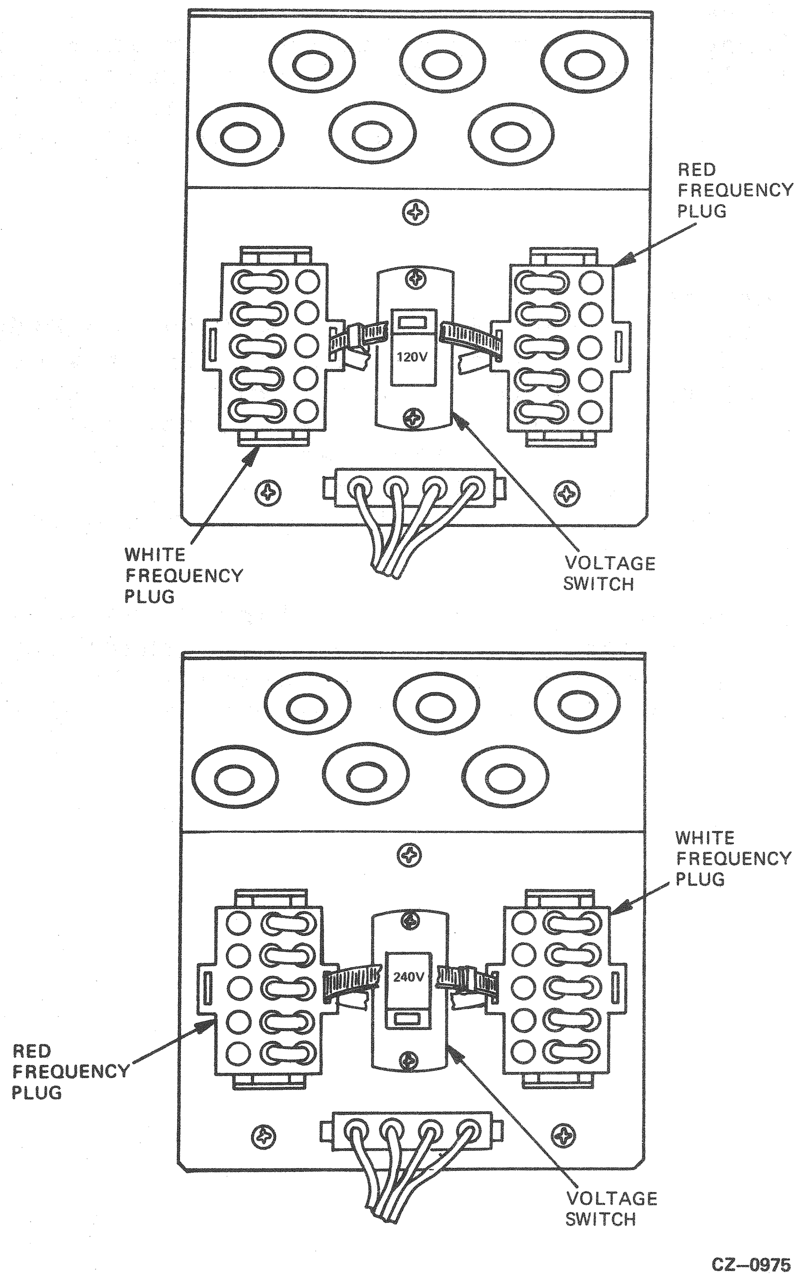

Figure 22 Voltage Range Switch and Frequency Plugs

RA60 INTERNAL ASSEMBLIES

Cap/Rectifier Assembly

The cap/rectifier assembly rectifies and filters the raw transformer output voltages. It supplies dc voltages of plus and minus 11 volts, plus and minus 20 volts, and plus and minus 27.5 volts.

Regulator Module

The regulator module regulates all the dc voltages in the drive. This module derives its own dc power from the raw ac 20 volts out of the transformer. These 20 volt lines are protected on the regulator module by two 5 amp fuses.

The regulator module contains the low level circuitry that regulates the rectified dc voltages on the heat sink module. This module does not supply power but senses the dc voltage levels on the heat sink module and controls the series-regulating transistors located there.

The regulator module also contains all the shut-down and power-up logic that protects the storage data from ac or dc failures. In the RA60, an ac failure is defined as losing ac power for more than 20 milliseconds. An ac power failure will cause the shut-down logic to implement the following activities.

- Wait for 20 millisecond power outage.
- Assert COMMAND INHIBIT.
- Wait 2 milliseconds.
- Assert the NOT RETRACT signal to unload the heads.
- Assert the PSFLT signal to prevent writing on the disk.
- Turn off the regulated dc power.

When the ac power resumes, the power-up logic will implement the following sequence.

- Assert the PSFLT signal to prevent writing on the disk.
- Assert the NOT RETRACT signal to unload the heads for 200 milliseconds.
- Turn on the regulated dc power.

In addition to ac shut-downs, the regulator board also controls dc shut-downs. This is necessary to protect the power supply from momentary or permanent short circuits. The following three conditions can cause a dc power shut-down.

- A dc over-voltage condition
- A dc under-voltage condition
- A dc over-current condition

Figure 23 shows a block diagram of the functions provided by the regulator module. It has an on-board power supply that provide dc voltages for its own logic circuits and reference voltages. Also located here is the fault circuitry to detect ac failures, dc over-voltage, and dc under-voltage conditions. There are also some timers to control power shut-down and resumption. Monitoring all these failure conditions is the fault control logic circuit. The regulator module also provides accurate voltage references for the regulator control circuits.

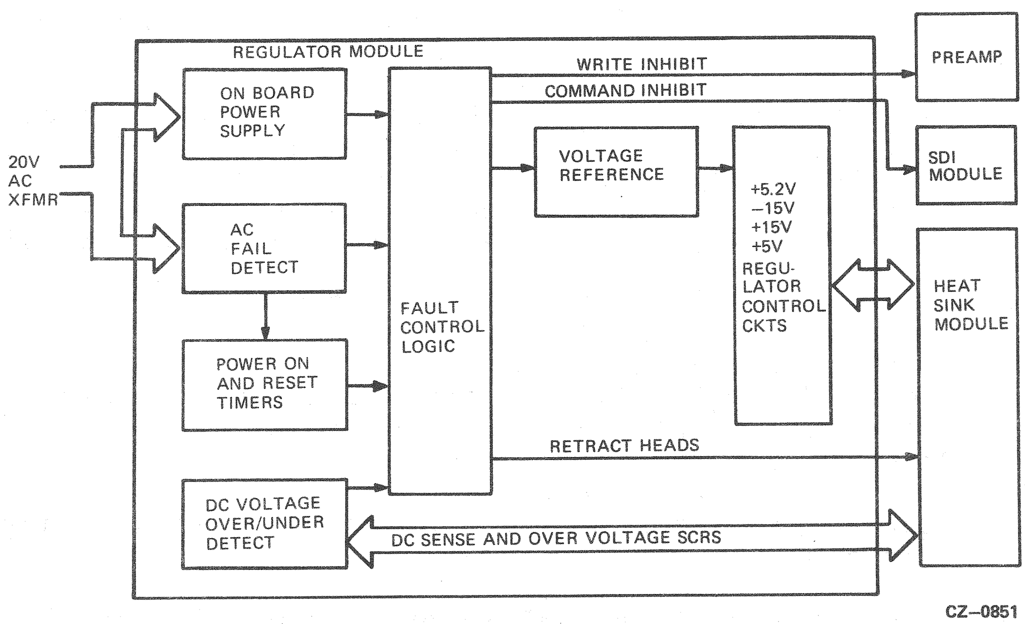

Figure 23 Regulator Module Block Diagram

Heat Sink Module

The heat sink module contains the series-pass transistors used for voltage regulation and the power transistors used for motor control. All these power transistors share a common heat sink. The heat sink module supplies the backplane with the dc regulated voltages of plus 5 volts, minus 5.2 volts and plus and minus 15 volts.

The heat sink module also supplies the motor control module with plus and minus 15 volts and plus and minus 27.5 volts. Power to the dc fans is also supplied from the heat sink module. Refer to Figure 24 for a block diagram of the heat sink module.

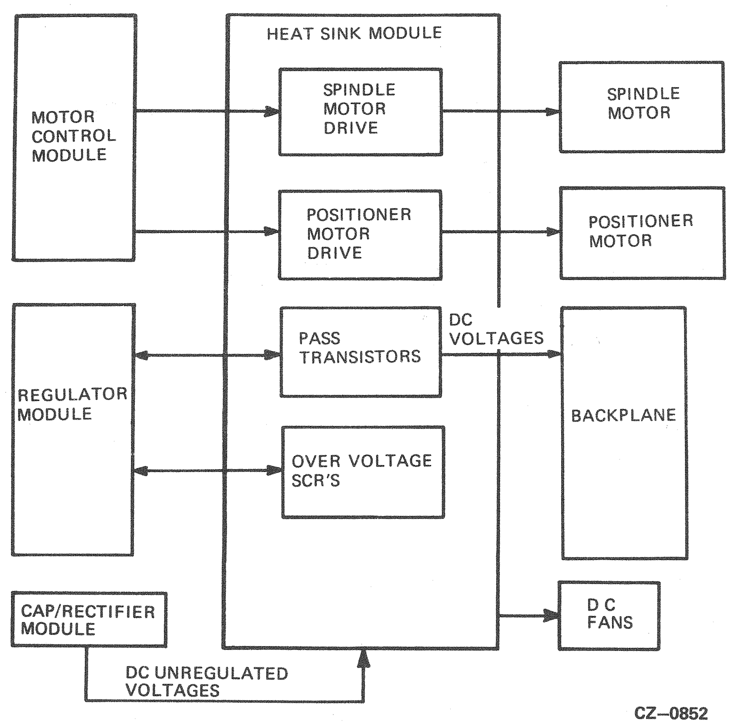

Figure 24 Heat Sink Module Block Diagram

EXERCISES

Answer the following questions and then compare your answers with the solutions given on the following pages.

1. Which RA60 module converts serial SDI messages sent by the disk controller into the parallel message command bytes recognized by the drive.

   SDI I/F module

2. Which RA60 module converts SDI bipolar data into Non-Return to Zero (NRZ) data?

   SDI I/F module.

3. Which RA60 module contains the master and slave microprocessors?

   Drive logic module

4. Which microprocessor controls the spindle and positioner motors?

   Slave

5. Which RA60 module converts NRZ data into the 2/3 format written on the disk?

   Post amp /data seperator

6. On which RA60 module is the head select logic located?

   R/W Preamp

7. Is the RA60 spindle motor a dc or an ac motor?

   dc

8. Which RA60 module contains the shut-down and power-up logic that protects storage data from ac or dc failures?

   Regulator in P.S.

9. Which RA60 module contains the power transistors used for voltage regulation and motor control?

   Heat Sink

1Ø. Where does the RA6Ø drive derive its rotational position sensing information to control the spindle motor speed, both before and after the read/write heads load?

Encoder on spindle motor

NOTE

After completing all these exercise questions, compare your answers with the solutions on the following page, and then read Section IV of this workbook.

SOLUTIONS

1. The SDI interface module converts the serial SDI messages sent by the controller into the parallel command messages recognized by the drive.

2. The SDI interface module converts the SDI bipolar data into NRZ data during write operations and converts the NRZ data back into the SDI bipolar data during read operations.

3. The drive logic module contains the master and slave microprocessors.

4. The slave microprocessor controls the spindle and positioner motors.

5. The post/amp data separator module converts the NRZ data into the 2/3 format written on the disk.

6. The head select logic is located on the preamp module.

7. The RA6Ø spindle motor is a dc motor.

8. The regulator module contains the shut-down and power-up logic that protects storage data from ac or dc failures.

9. The heat sink module contains the power transistors used for voltage regulation and motor control.

1Ø. Prior to the RA6Ø heads loading onto the disk, the drive senses the spindle motor rotation by monitoring the pulses from an encoder inside the spindle motor. After the disks spin-up and the read/write heads load, the rotation speed is derived from the sector information on the disk.

SECTION IV RA60 DRIVE FUNCTIONS

RA6Ø DRIVE FUNCTIONS

RA6Ø Drive Operations

Section IV describes the following RA6Ø operations.

- RA6Ø servo system
- Servo data
- Servo linear mode
- Servo seek mode
- Seek command sequence
- Rate 2/3 code modulation process
- Write command sequence
- Read command sequence

RA6Ø Servo System

The RA6Ø does not have a dedicated servo module (PC board). Instead, the servo control circuits are distributed over most of the electronic modules in the drive. Figure 25 shows a block diagram of the RA6Ø servo control system. This block diagram will be used for the following discussion on how the servo control system works.

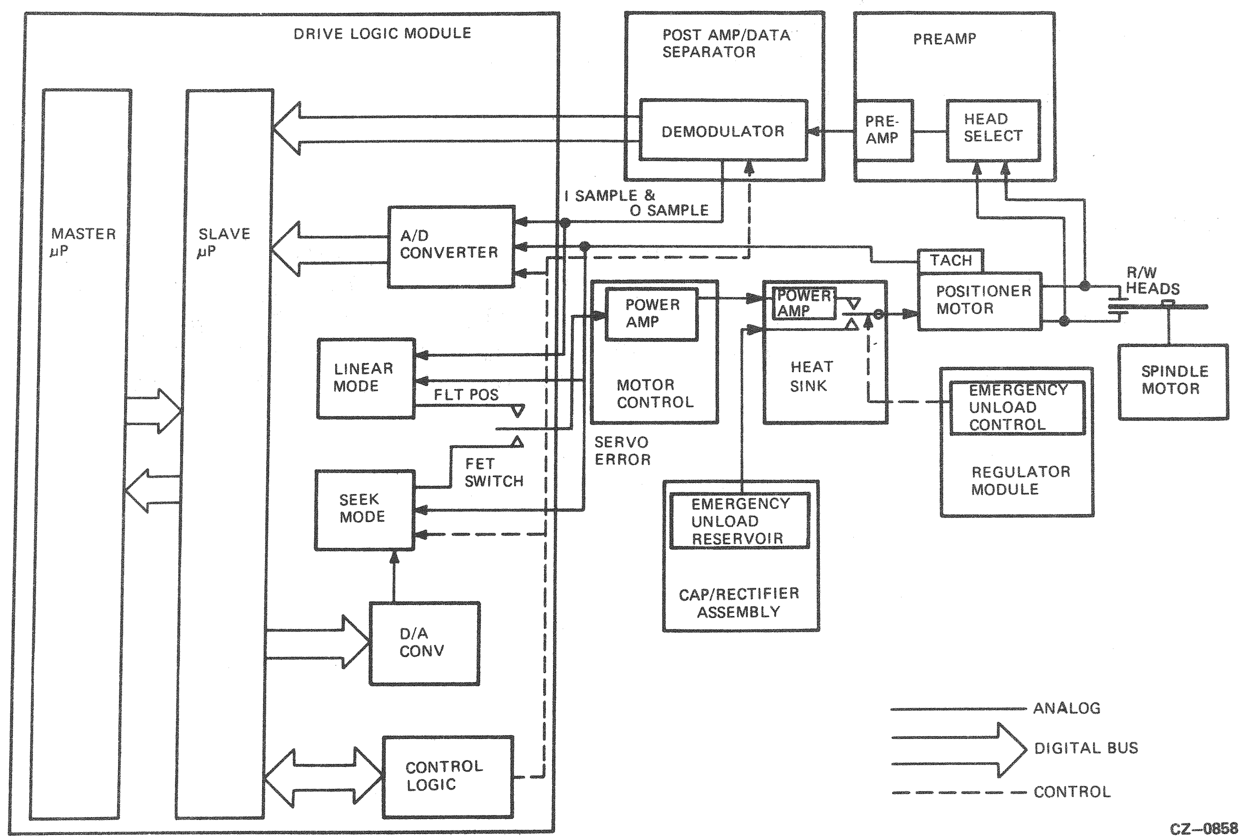

Figure 25 Servo Control System Block Diagram

Servo Data

The RA6Ø disk drive does not have a dedicated servo disk surface in its disk pack. Instead, the servo information on the disk is embedded on each data surface in the interval between sectors. We refer to this time, when the servo data is present, as the servo data interval.

The format of the servo data during the servo data interval is shown in Figure 26. Prerecorded in this servo data interval is the following information.

- Servo sync pulses - to synchronize servo timing circuits
- Sector index code - to mark sector Ø on each track
- Modulo 16 gray code - to indicate track crossings
- Two guard band codes - to distinguish guard bands from the data area
- Two offset servo burst - to indicate an offset from track centerline

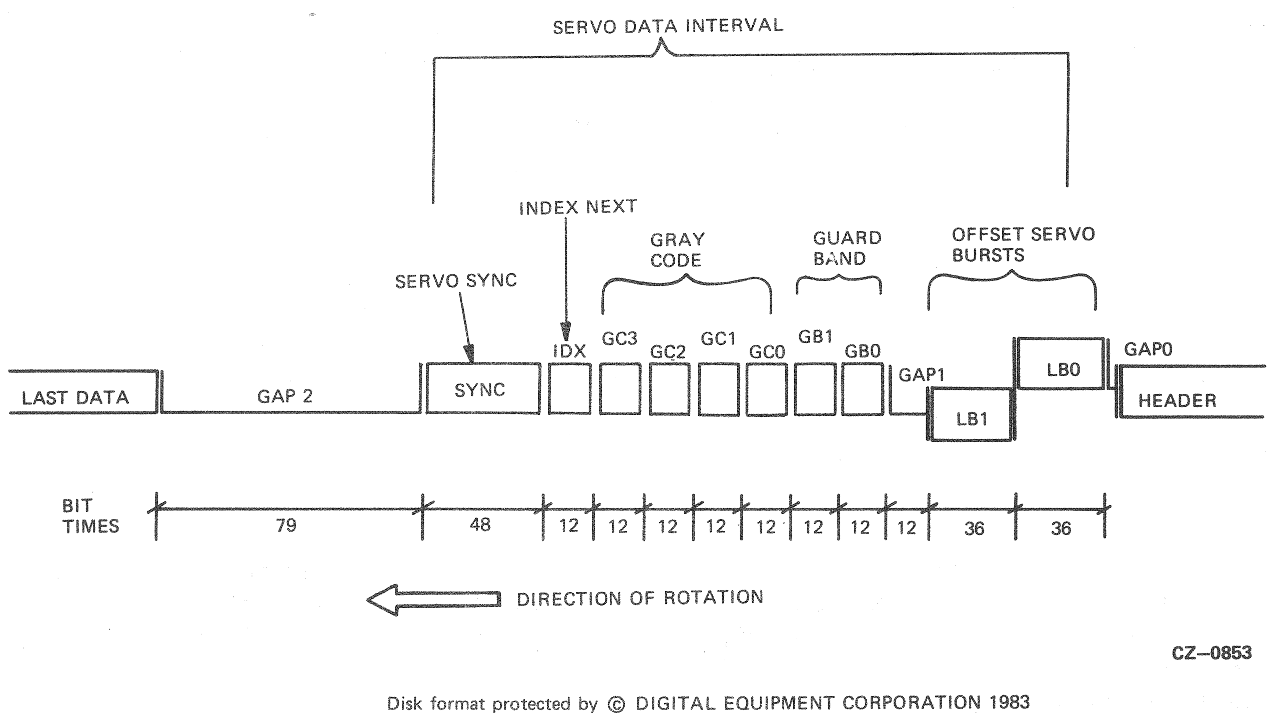

Figure 26 RA6Ø Servo Data Interval Format

Servo Linear Mode

In the linear mode, the servo circuits use the embedded servo information on the disk to detect and correct the head position relative to track centerline. This servo information consists of two bursts of high frequency signals that are each offset in opposite directions from track centerline. As the read/write head passes over them, the amplitude of one servo burst will be greater than the other if the head is slightly off track centerline.

The servo burst information is detected by the read/write heads and is amplified on the preamp module. This servo information is then demodulated on the post amp/data separator module. These servo bursts go through a bandpass filter to separate the servo burst signals from the rest of the data coming off the disk. Once separated, the servo bursts are rectified, integrated, and pass through sample and hold circuits. The two dc signals produced by this process are I SAMPLE (for the inner servo burst) and O SAMPLE (for the outer servo burst), which are sent to the drive logic module.

On the drive logic module, the I SAMPLE and O SAMPLE signals enter a differential amplifier in the linear mode circuits and produce an error signal called FLT POS. FLT POS is passed through a FET switch to produce two servo error signals, SVO ERR1 and SVO ERR2, which are sent to the motor control module.

The servo control signals are amplified by the motor control module and heat sink modules and drive the positioner motor through a relay contact on the heat sink module.

A difference signal is derived from the I SAMPLE and O SAMPLE signals entering the drive logic module. This difference signal is converted to a digital format by the a/d converter and is monitored by the slave microprocessor.

Servo Seek Mode

The servo system normally operates in linear mode to keep the read/write heads above track centerline. However, when the drive receives a seek command, the servo system is placed into seek mode. The slave microprocessor is given the number of tracks that the heads must cross, and it fetches a value from a velocity table to send to the seek mode circuits. This velocity value is converted into an analog voltage in the d/a converter and then applied to the velocity error circuits. The control logic on the drive logic module places the FET switch in the correct state to allow the seek mode signals to pass to the motor control module. The motor control module and heat sink module amplify the seek mode signal and start the positioner motor moving.

As the read/write heads cross tracks, the servo system detects the track crossings by monitoring a four bit gray code at the beginning of each sector. This gray code is demodulated and passed on to the slave microprocessor, where the number of track crossings is used to decrement a track counter.

As the heads get closer to the destination track, the slave microprocessor issues smaller velocity values to the d/a converter. When the destination track is reached, the servo system switches back to linear mode and centers the heads over the track.

Rate 2/3 Code Modulation Process

The RA60 Disk Drive uses a new rate 2/3 modulation code for encoding the write data on the disk. This coding technique allows 1/3 more data to be stored on the disk than is possible with the former Modified Frequency Modulation (MFM) code. For a given data stream, the rate 2/3 code spreads out the magnetic transitions on the disk, reducing the need for peak shift compensation. Since the data transitions are further apart due to the 2/3 code, they can be electrically squeezed back together to obtain 1/3 more data than MFM would allow. The data transitions are not squeezed to the point where peak shift problems become significant.

Table 1 shows the encoding scheme used to convert NRZ write data into the rate 2/3 coded data. The rate 2/3 encoder looks at either two bits or four bits of NRZ data at a time. Which number of bits is chosen depends on the bit pattern in the NRZ data. For example, if the NRZ data starts with 00, 01, or 10, then the rate 2/3 encoder converts only two NRZ bits at a time. If the NRZ data starts with a (11) pattern, then the rate 2/3 encoder converts four bits at a time. The C in the rate 2/3 code means to take the complement of the previous bit.

Table 1 Rate 2/3 Encoding Scheme

NRZ DATA	RATE 2/3 DATA
00	C00
01	C01
10	010
1100	C00000
1101	C00001
1110	010000
1111	010001

NOTE: C MEANS COMPLEMENT THE PREVIOUS BIT

Figure 27 gives an example of an NRZ data bit string and its corresponding rate 2/3 code data. Note that the NRZ data has a bit cell time of 63 nanoseconds while the corresponding rate 2/3 data has a bit cell time of only 43 nanoseconds. More information is compressed into the same 126 nanaoseconds interval because three rate 2/3 code bits replace the two NRZ bits.

Waveform (c) in Figure 27 shows what the 2/3 WRITE DATA signal looks like prior to entering the final flip flop. Waveform (d) shows the flip flop WRITE DATA going to the disk. Waveform (e) shows the READ DATA that the preamp module sees coming off the disk. The READ DATA is pulse-shaped on the post amp/data separator module to produce waveform (f). Note that waveforms (c) and (f) correspond, so that what was written on the disk is recovered during the read operation.

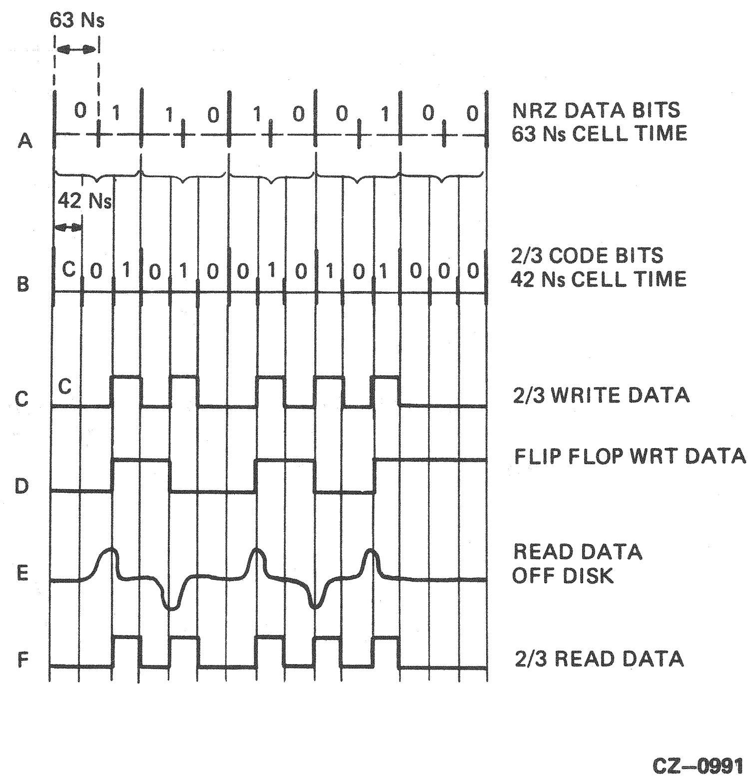

Figure 27 NRZ Data Conversion Waveforms

Write Command Sequence

Figure 28 shows a simplified flow diagram for the RA60 Write command. Use this diagram as a reference when reading the following description.

Prior to issuing the write command to the drive, the controller issues a seek command, if necessary, to position to the desired cylinder.

When a write command is issued by the disk controller, the drive sends the next sector header encountered to the controller. The disk controller reads the header and does a compare with the desired header. If they don't match, the write command is terminated. Otherwise, the controller asserts WRITE GATE and sends the data.

The controller asserts WRITE GATE on the SDI cable Real Time Controller State (RTCS) line. The RA60 SDI interface module decodes the WRITE GATE signal and enables the Phase Locked Loop (PLL) oscillator on the post amp/data separator module. The PLL oscillator locks onto a multiple of the write clock frequency and begins clocking NRZ write data into the 2/3 encoder. The 2/3 encoded write data is then sent on to the preamp and write heads to be recorded on the disk. Because of the high data speeds, the microprocessors on the drive logic module do not get involved in the writing process.

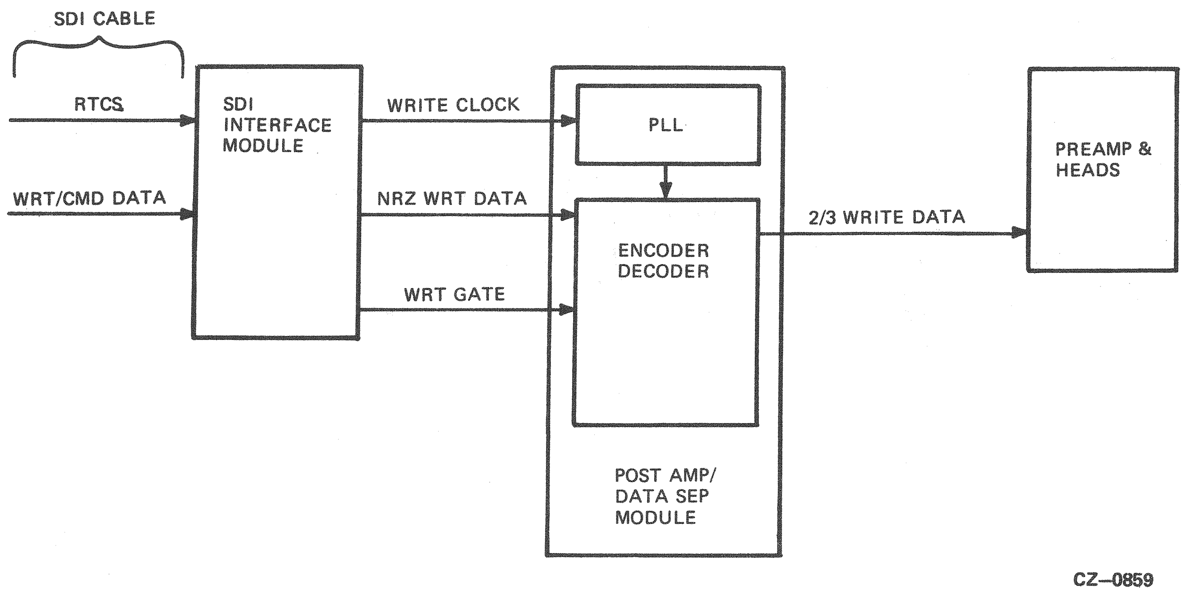

Figure 28 RA60 Simplified Write Command Diagram

Read Command Sequence

Figure 29 shows a simplified flow diagram of the RA60 read command. Use this diagram as a reference when reading the following description.

When a read command is issued by the disk controller, the drive sends the next sector header encountered to the controller. The disk controller reads the header and does a compare with the desired header. If they don't match, the read command is terminated. Otherwise, the controller asserts READ GATE and receives the data. READ GATE enables the 2/3 decoder circuits on the post amp/data separator module. The 2/3 READ DATA comes off the disk through the read heads and preamp module. This 2/3 READ DATA is an analog waveform that is amplified and shaped in an equalizer circuit. The output of the read/amp equalizer circuit is then digitized in the data digitizer circuit. Once digitized, the READ DATA is then decoded from its 2/3 format back into the NRZ READ DATA which is sent to the SDI interface module for transmission to the disk controller.

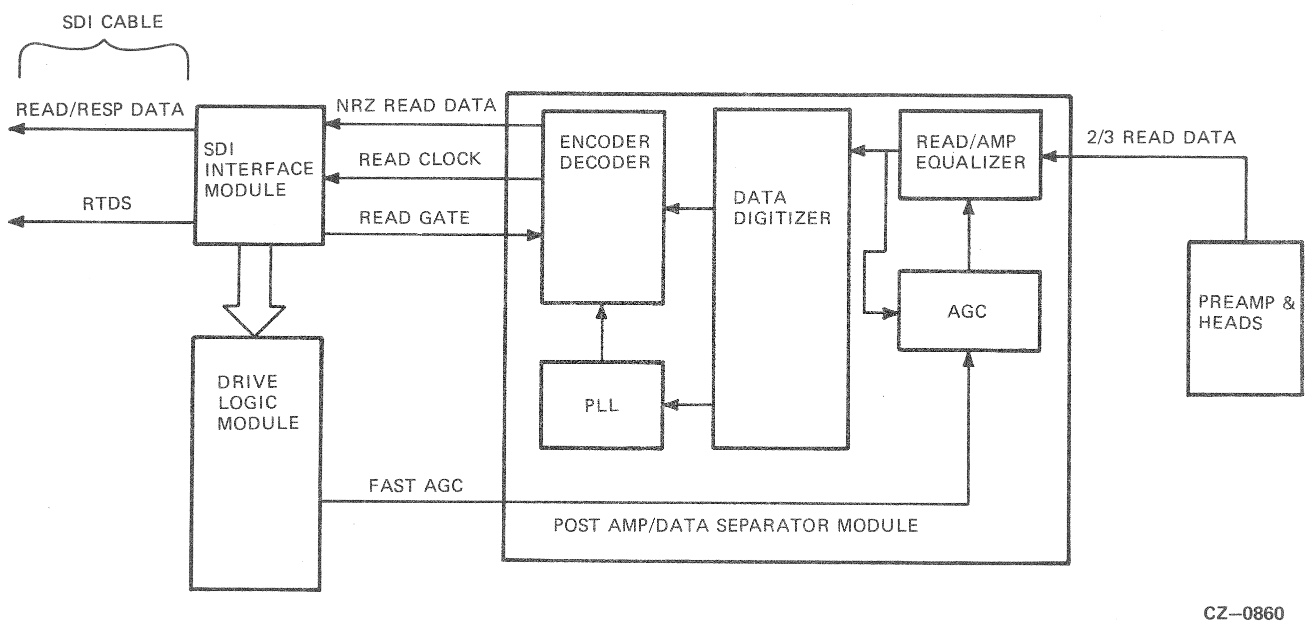

Figure 29 RA60 Simplified Read Command Diagram

RA60 DRIVE FUNCTIONS

SUMMARY

This lesson gave you an overview of the operation of the SDI interface, the RA60 data storage organization, and a functional description of the drive assemblies and operations. This background information should support your efforts to troubleshoot drive problems with the fault isolation information provided in the next lesson.

RA60 DRIVE FUNCTIONS

EXERCISES

1. In the RA60 Disk Drive, one module performs all the servo control circuit functions. Is this statement true or false?

   False

2. The bottom disk in the RA60 disk pack serves as a dedicated servo data surface. Is this statement true or false?

   False

3. What is the purpose of the modulo 16 grey code bits in the servo data interval? Detect track crossing

4. What is the purpose of the two offset high frequency servo bursts at the end of the servo data interval?

   To enable feedback to move heads back onto track centreline.

5. Is the servo system operating in linear mode or seek mode when it is trying to keep the heads above the track centerline?

   Linear

6. What is the purpose of the two guard band codes in the servo data interval?

   Data protection. (in seek mode enables whereabouts to be known).

7. How is the rate 2/3 code able to squeeze 1/3 more data than the old MFM code onto the disk?

   42nS v 63nS MFM cell time. Recording transitions further apart hence able to squeeze up again

8. What does the C in the rate 2/3 code shown in Table 1 mean?

   Compliment previous bit.

9. During a write command operation, what enables the PLL oscillator circuit to lock onto a multiple of the write clock frequency?

   header compare match. → Write gate signal.

10. After a read command is issued by the disk controller, what

happens if the next sector header that is read does not match the desired sector header the controller is expecting?

Read abort.

NOTE

After completing this exercise, compare your answers to the solutions on the following page and then begin Lesson 7 in Workbook III.

RA60 DRIVE FUNCTIONS

SOLUTIONS

1. False. The servo control circuit functions are scattered over most of the modules in the RA60 drive.

2. False. The RA60 Disk Drive uses servo data embedded on each data surface and does not require a dedicated servo data surface.

3. The modulo 16 grey code bits in the servo data interval are used to indicate track crossings.

4. The two high frequency offset servo bursts at the end of the servo data interval are used to detect when the heads stray off track centerline.

5. The RA60 servo system is operating in linear mode when it is trying to keep the read/write heads centered over track centerline.

6. The two guard band codes in the servo data interval provide a means for the drive to recognize, during a seek operation, when it leaves the data surface and enters either the inner or outer guard band areas.

7. The rate 2/3 code is able to squeeze 1/3 more data onto the disk than the old MFM technique because it uses a data encoding scheme that can represent the same data stream with 1/3 less data bits. This has the effect of creating more space between data transitions. With this extra space now available, the data bits are squeezed closer together electronically before they are recorded on the disk surface.

8. The C in the rate 2/3 encoding scheme in Table 1 means that the previous NRZ data bit must be complemented when converting to the rate 2/3 code.

9. During a write command operation, the SDI interface module decodes the WRITE GATE signal from the SDI cable and issues a WRITE GATE signal that enables the PLL oscillator.

10. If a read command is issued and the next sector read does not match the expected sector header, the read command is terminated.

NOTE

After completing Workbook II, start reading Workbook III.

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