RA60

RA81

RA80

# THE RA60, RA80 AND RA81 DISK DRIVES
# AND THE DIGITAL STORAGE ARCHITECTURE

**digital**

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## AND THE DIGITAL STORAGE ARCHITECTURE

**TABLE OF CONTENTS**                                                          **PAGE**

# DIGITAL STORAGE ARCHITECTURE

**RA81 DISK DRIVE**
- 456 Mb Fixed Media Disk
- $26,000 Subsystem ($120 BMC)
- $19,000 Add-On ($90 BMC)
- Type I Discountable

**UDA 50 CONTROLLER**

**RA80 DISK DRIVE**
- 121 Mb Fixed Media Disk
- $21,000 Subsystem ($111 BMC)
- $14,000 Add-On ($81 BMC)
- Type I Discountable

**RA60 DISK DRIVE**
- 205 Mb Removable Media Disk
- $22,000 Sybsystem ($110 BMC)
- $15,000 Add-On ($80 BMC)
- Type I Discountable

**RA81 TRIPLE DRIVE OPTION**
- 1.4 Billion Bytes
- $55,000 Subsystem ($300 BMC)
- $50,000 Add-On ($270 BMC)
- Type I Discountable

**The Digital Storage Architecture (DSA)**

A megabyte of disk storage that cost over $1,000 ten years ago costs under $40 today — a consequence of increased recording densities. But there are other consequences: High density disks require controllers that accommodate high transfer rates and technologies that protect against media defects which can otherwise corrupt databases. Your subsystem could be limited to yesterday's disk technology and yesterday's disk prices!

At Digital, we design both disk drives and controllers, and hence understand the subsystem requirements to take advantage of evolving disk technologies. In order to optimize data integrity, throughput and availability, as well as to provide flexible, expandable, migratable products, Digital has taken an architectural approach to storage subsystem design, fitting the products into a framework which will remain constant across product generations. Like the VAX architecture for computer systems, the Digital Storage Architecture (DSA) is the storage architecture for the Eighties.

**The DSA Product Family**

The RA60, RA80 and RA81 disks and the UDA50 controller are the first members of the DSA Product Family which feature:

- Standardized hardware interconnect and software protocols
- A single operating system driver and set of utilities
- Throughput, data integrity and availability features
- Industry leading capacities for rack mounted disks
- Up to three drives per cabinet - mix and match flexibility
- Low lifetime cost of ownership

The DSA family is the only state-of-the-art 100 to 1400 megabyte product set which offers both Winchester fixed media and removable media technologies to service diverse applications.

**The Product Family and the Architecture**

Industry leading performance features as well as superior space efficiency and cost of ownership are why DSA subsystems are the smart decision for your present systems. The architecture is why a smart decision today will prove to be an even better decision in the future.

**System Support**

The DSA products are initially available on selected systems. Consult your Digital Sales Representative for information.

1
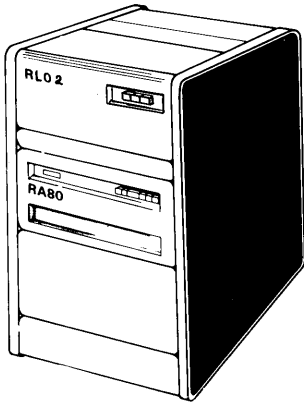
## UDA50 — The Intelligent Controller

UDA50 subsystems lead the industry in comprehensiveness and power of data integrity features. A break-through data error correction system corrects multiple error bursts totaling up to 80 bits. The UDA50 accelerates throughput by performing multiple levels of performance optimization. Radial interconnects, microdiagnostics in every subsystem component, and standard dual access provide outstanding availability. If you thought subsystems were all alike, the UDA50 is something new to think about!

## RA80 Disk — The Lowest Cost Solution

The price-reduced RA80, the entry level member of the family, has 121 megabytes of formatted user capacity. The Winchester RA80, and removable media 10 megabyte RL02 subsystem, is the complete storage solution for a 100 to 200 megabyte database.
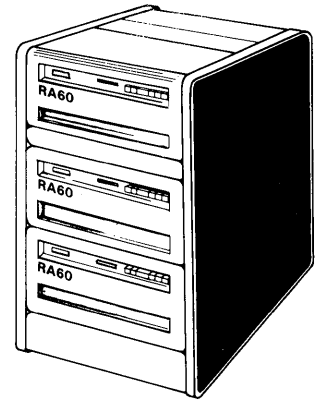
## RA60 Disk — The Removable Media Solution

The RA60 is the industry's highest capacity and lowest price-per-megabyte rack mounted, removable media disk. With 205 megabytes of user formatted capacity, 615 megabytes are available in a 42-inch high cabinet — 50% more than any other removable media product. The RA60 provides 205 megabytes of removable media flexibility for $15,000.
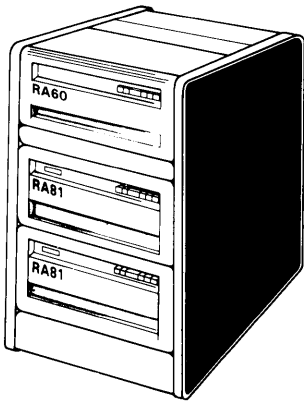
## RA81 Disk — The Lowest Cost Per MB Solution

The Winchester RA81, the industry's highest capacity rack-mounted disk drive, defines new frontiers in data storage — 456 megabytes of user formatted capacity in a 10.4-inch high enclosure. Almost 1.4-billion bytes are available in a waist-high cabinet, about 250 megabytes per square foot of floor space. The RA81 provides 456 megabytes of reliable Winchester disk capacity for $19,000 or, for real economy, the triple-drive option for $50,000.
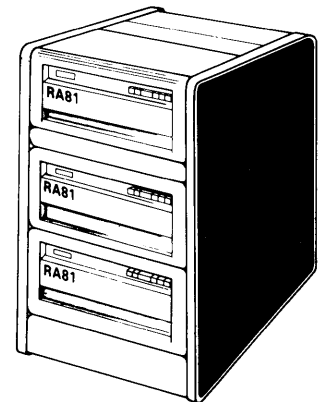
## State-of-the-Art Technology

The obvious path to leadership products is state-of-the-art technology. With disks, the challange is advancing in both areal density, the key metric of disk technology, and data reliability. The RA60 and RA80 areal density numbers speak for the themselves (refer to the charts below). But to achieve areal density, we didn't compromise data reliability: We enhanced it with embedded servo positioning technology and a comprehensive set of data protection features.
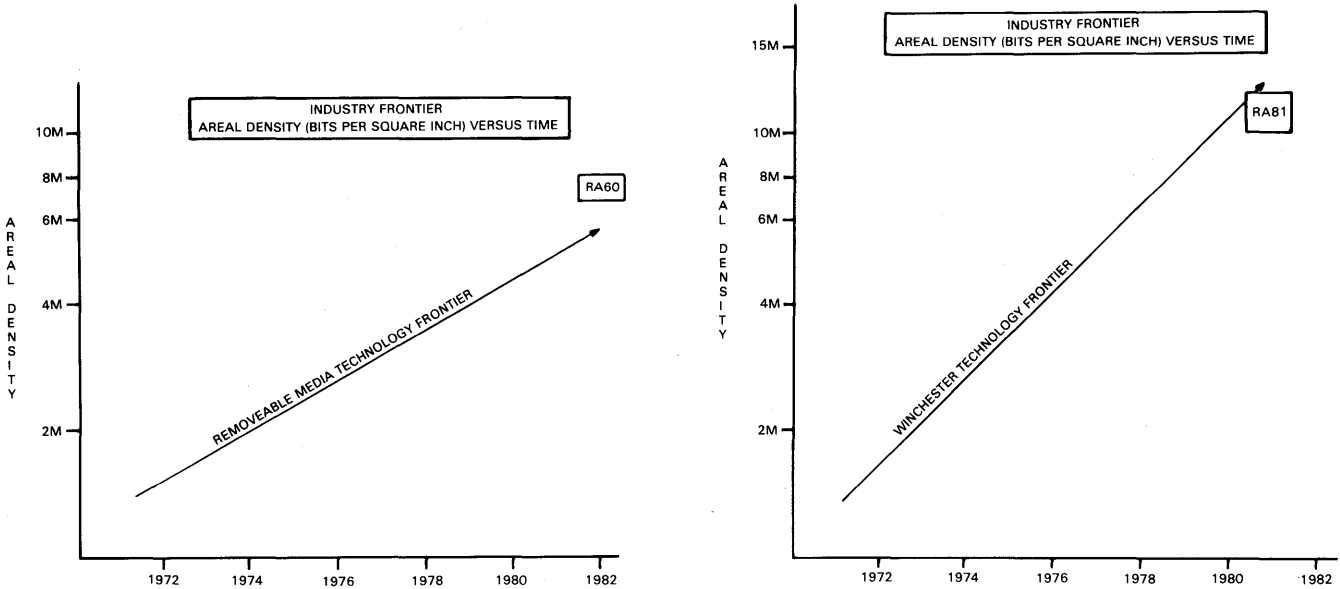


## Price Comparison

The RA60, RA80, and RA81 define a new price-per-megabyte frontier for system suppliers. What is even better, Digital is the only supplier to offer both state-of-the-art removable and Winchester fixed media disk drives. The chart below shows how Digital stacks up against its closest system competitors.



\* Triple Drive Option

3
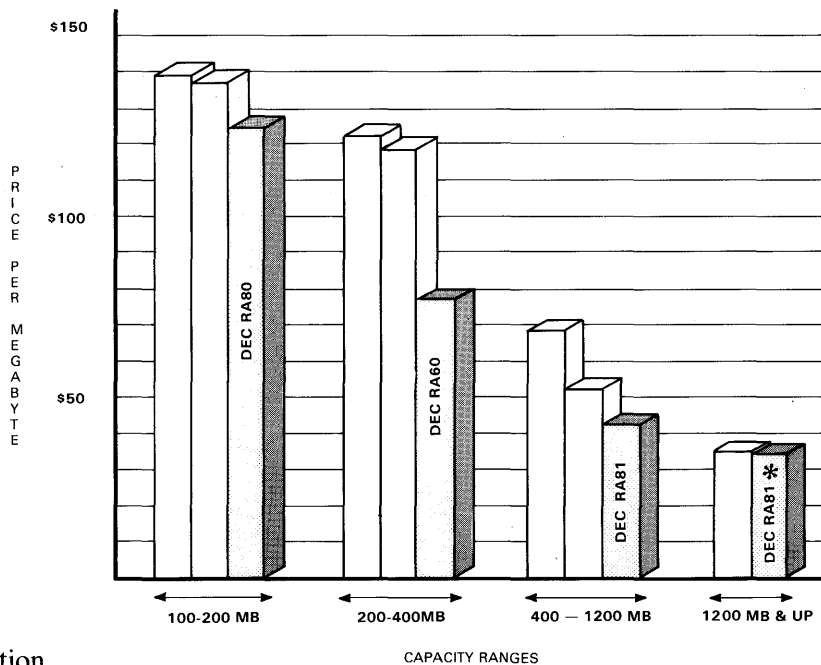
**Shopper's Guide to Disk Subsystems**

Cost of Ownership

Some subsystems are cheap to buy but expensive to own. DSA subsystems not only carry low hardware price tags but also low maintenance prices. Compare lifetime cost of ownership.

Actual Capacity

Some disk suppliers advertise gross, unformatted capacity that includes a significant amount of space unavailable for user data. The advertised capacities on DSA disks are 100% available for user data. In addition, since all DSA disks have space reserved for replacement blocks, user capacities never shrink.

Data Integrity

How much does it cost you to reconstruct a file because the subsystem cannot find or cannot read a block of data? That is why DSA subsystems include the industry's most comprehensive set of data protection features.

I/O Throughput

Look at the disk specifications and then look more carefully at the subsystem performance optimization features. Seek ordering, overlapped seeking and rotational optimization in DSA subsystems significantly increase throughput.

Subsystem Availability

System downtime is disruptive, frustrating and expensive. High reliability, automatic self-testing and fault isolating microdiagnostics are built into every DSA disk and controller. Our radial interconnect prevents a problem in one disk from affecting the operation of other disks.

Extra Charges

A removable media disk is not very useful without a pack, nor a subsystem without cabinetry and cabling. With some products these are expensive optional features. In DSA products, not only are these standard, but so is drive dual access. Purchase a second I/O cable, and your DSA disk can be shared between two controllers.

# DIGITAL STORAGE ARCHITECTURE (DSA)

The software, controller and disk technologies involved in data management and storage advance at different rates. Our storage architecture decouples these technologies to allow advancements to be easily, quickly and non-disruptively incorporated into our product set. Ten reasons make the Digital Storage Architecture the standard for comparison.

## Reason #1 — Solid Data Integrity

Features:
- 170 bit error correction code (ECC)
- New error detection code (EDC)
- Address verification system
- Seek error recovery and parity checking
- Automatic sector retirement system
- Improved disk mapping system
- Data compare and access commands
- Multi-block transfer control
- Autocorrelated synchronization

## Reason #2 — High I/O Throughput

Features:
- Command queue for seek ordering
- Express queue for FIFO service
- Overlapped seeking
- Rotational optimization
- Speed matching buffer and DMA transfers
- Direct revectoring system

## Reason #3 — Improved System Availability

Features:
- Radial interconnect with bus isolation
- On-board microdiagnostics
- Console fault display
- Off-line repair and remote diagnostic support
- Power-up verification
- Dual access as a standard feature

### Reason #4 — Off-Loading of the Host System
Feature:
- Throughput, data integrity and availability are the responsibility of the subsystem and are provided at no cost in host system overhead.

### Reason #5 — Lower Lifetime Cost of Ownership
Feature:
- Balanced integration of hardware, software and reliability features focused on lowering the total cost of buying, installing and maintaining subsystems.

### Reason #6 — Hardware/Software Independence
Features:
- New controllers can be introduced without requiring a new disk class driver in the host system.
- New disks can be introduced without requiring any changes to either the host system software or the subsystem controller.

### Reason #7 — Support for New Technologies
Features:
- Supports higher disk transfer rates.
- Accommodates increased media defects associated with higher disk areal densities.
- Automatically adapts to disk drive specific geometries.

### Reason #8 — Migratable Products
Features:
- Standard host-to-controller protocol
- Standard controller-to-disk protocol
- Standard controller-to-disk hardware interconnect
- Standard media format
- Standard diagnostics and utilities protocol

### Reason #9 — Increased Functionality and Ease of Use
Features:
- Disks appear as perfect logical volumes to the host
- Subsystem handles logical-to-physical translation
- New data compare, erase and access commands
- Alternative I/O request servicing facilities

### Reason #10 — Support for a Wide Range of Products
Features:
- Varying disk capacities with different transfer rates
- Removable media and Winchester fixed media technologies

### Architecture Overview
- Host-to-Controller Interface — Two layers of software define the host system-to-controller interface. Class drivers perform generic disk functions and communicate with the controller via message packets. Port drivers provide the communication protocol to send and receive message packets over a specific communications bus.

- Controller-to-Disk Interface — The Standard Disk Interface (SDI) defines the hardware interconnect and communications protocol between the SDI driver in the controller and the SDI driver in the disk drives. The Digital Standard Disk Format partitions physical disk space into logical areas for user data, replacement blocks, format control tables and diagnostic tests.

COMPONENT                      LAYER                          MAJOR SEGMENTS

```
         ┌─────────────────────────────────────────┐        ┐
         │            OPERATING SYSTEM              │        │
         │                                          │        │
         ├────────────────────┬─────────────────────┤        │
  HOST   │  DISK              │  DUP                │        │
         │  CLASS             │  CLASS              │        │
         │  DRIVER            │  DRIVER             │        │
         ├────────────────────┼─────────────────────┤        │
         │  UNIBUS            │  SERIAL BUS         │        │
         │  PORT DRIVER       │  PORT DRIVER        │        ├ HOST-
         └────────────────────┴─────────────────────┘        │  CONTROLLER
                                                             │
  HOST                                                       │
  INTERCONNECT                                               │
                                                             │
                  ┌───────────────────────────┐              │
                  │       PORT DRIVER          │              │
                  ├───────────────────────────┤              │
  CONTROLLER      │         SERVER             │              │
                  ├───────────────────────────┤              ┤
                  │       SDI DRIVER           │              │
                  └───────────────────────────┘              │
                                                             │
  DISK                          SDI                          │
  INTERCONNECT                                               │  CONTROLLER-
                                                             ┤  DISK
                     ╱──────────────────╲                    │
                    │     SDI DRIVER      │                   │
  DISK              ├─────────────────────┤                   │
                    │  DIGITAL            │                   │
                     ╲ STANDARD          ╱                    │
                      ╲ DISK FORMAT     ╱                     ┘
                       ╲──────────────╱
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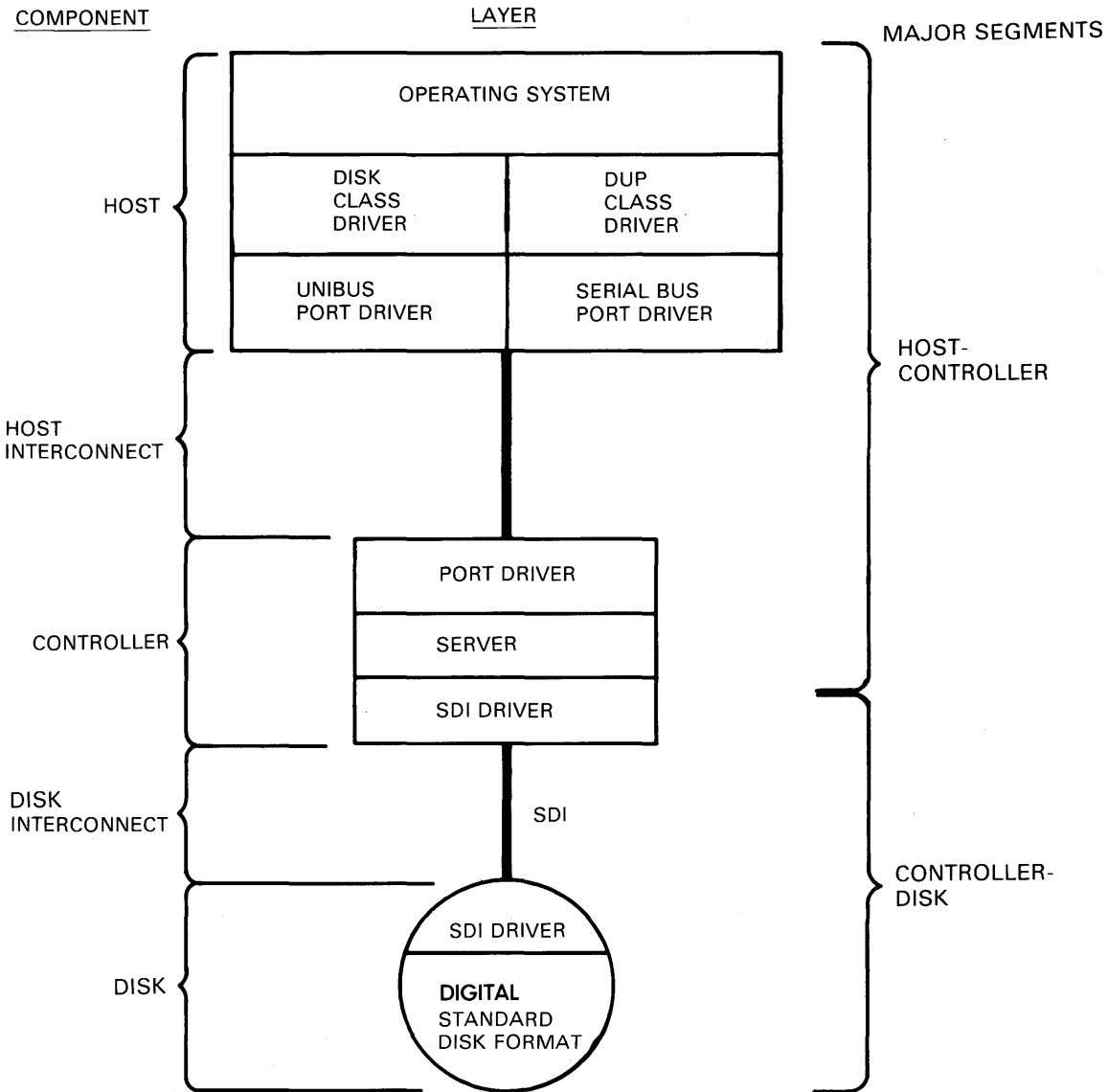
## Host-to-Controller Interface

The host system uses two levels of software to accomplish I/O operations. The higher level, named class drivers, performs generic functions (such as reading and writing) to classes of devices (such as disks). The class driver's knowledge of a disk is limited to a logically perfect storage device with a fixed linear address space. The controller determines and translates specific disk geometries into error free logical block capacity and passes this information to the class driver. The class drivers are independent of the specific characteristics of the communications bus, the controller and the storage devices. Class drivers communicate with the controller's servers via message packets.

The lower level of host system software, named port drivers, passes the message packets along the communications bus. Port drivers operate with a specific communication bus and are unaware of the meaning of the messages. In UDA50-based subsystems, the UNIBUS provides the communications path between the port drivers.

In the controller, there are two corresponding levels of software. The higher level of software is named the server. The UDA50 has two servers — the Mass Storage Control Protocol (MSCP) Server and the Diagnostics and Utilities Protocol (DUP) Server. The servers constitute the intelligence of the controller and, therefore, define the functionality of the subsystem. The lower level of software is also a port driver and functions analogously to its counterpart in the host system.

◄————————► Indicate physical communications
◄— — — — —► Indicate logical communications
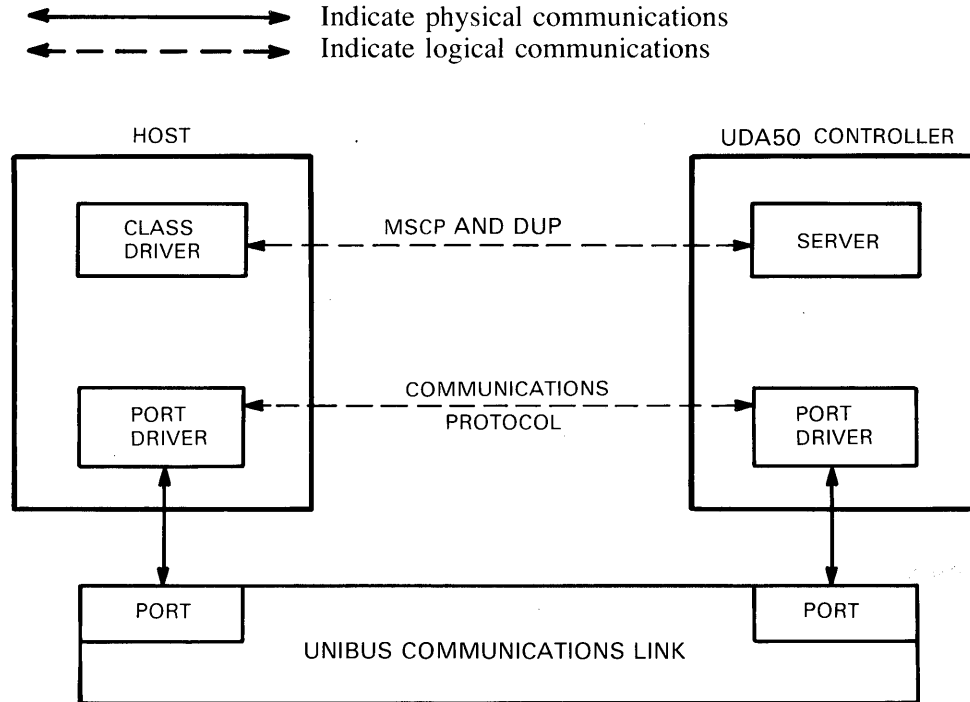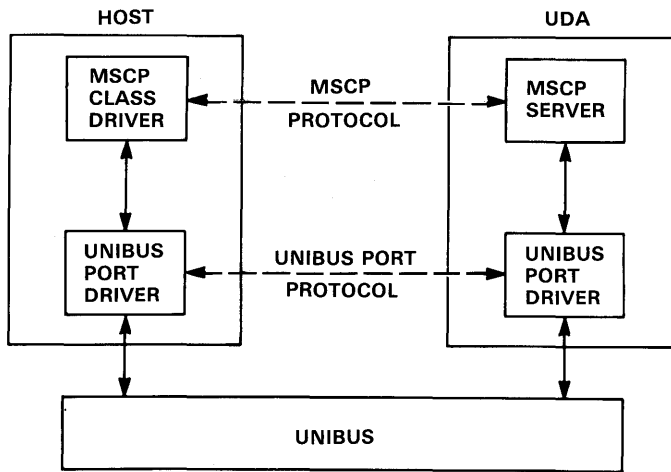


## Disk Class Driver and MSCP Server

The disk class driver in the host system uses the Mass Storage Control Protocol (MSCP) to communicate with the MSCP server in the UDA50. MSCP is a message based protocol which defines those functions generic to disks. Hence, new controllers and new disk drives do not require changes to the disk class driver. MSCP has commands for performing I/O transfers, controlling devices and obtaining status. Three types of communication services are used between the disk class driver and the MSCP server:

- A sequential message communication service used for MSCP control messages.

- A block data communication service used to move data between the host system and the UDA50 controller.

- A datagram communication service used for error log messages.

The MSCP server performs the following functions:

- Determines the number of disks in the subsystem, their type and number of logical blocks, their availability and status, and communicates this information to the disk class driver.

- Receives and optimizes I/O requests, performs the requests, transfers data between the host system and the disks, and buffers the data transfers as necessary.

- Translates between logical addresses in I/O requests and physical addresses on disks.

- Performs error detection and recovery, and reports any significant errors to the host system.

Since the disk class driver is only concerned with the number of logical blocks on a disk, new disk drives can be introduced without requiring any changes to the host system software.

## DUP Class Driver and DUP Server

The Diagnostics and Utilities Protocol (DUP) is the method of communicating between the host system and the DUP server in the controller. Using this protocol, the host system may request the server to load and execute a diagnostic or a utility supplied by the host system. DUP provides mechanisms to do the following:

- Load controller-resident remote programs from the host

- Communicate with the controller-resident remote program

- Provide host-resident virtual terminal services

- Make progress inquiries to the server

- Terminate the program

- Run and monitor controller resident utilities or diagnostics

The advantage of this approach is that only one set of diagnostics and utilities (that run in the controller) need be developed, no matter how many host computer operating systems support the controller. The host based DUP code is the only software that needs to be unique to a specific operating system or host computer.

Two types of communications services are used across the connection between the DUP class driver and DUP server.

- A sequential message communication service used for DUP control messages.

- A block data communication service used to move data between the host system and the controller.
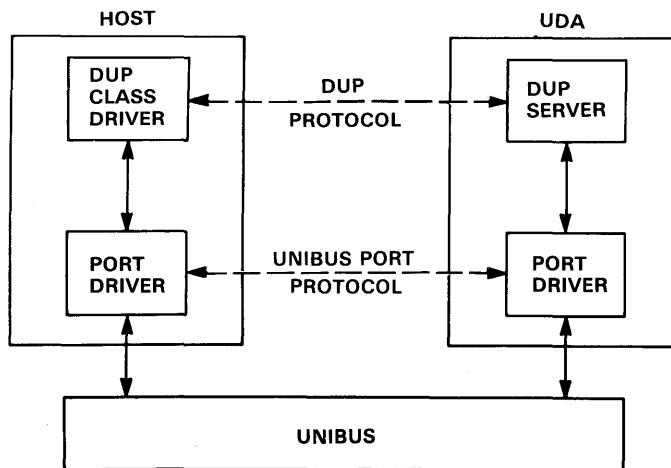
## Port Drivers

Port drivers, resident in both the host system and controller, are the interface between the host system and controller. The port drivers:

1.  Supply information for verifying correct operation of the subsystem controller during initialization.

2.  Minimize host interrupts during peak I/O load periods.

The port consists of two layers.

1.  The Transport Layer: This is the physical communications bus for the bi-directional transmission of data and control signals.

2.  The Logical Layer: This is a set of rules and procedures implemented in the host and the controller. The tasks of the logical layer are the exchange of control messages and the verification of correct operation of the transport mechanism.

The port's logical layer is implemented as a set of data structures in host memory which are operated on by both the host system and the subsystem controller according to a set of rules.

The UNIBUS port architecture uses interrupts and UNIBUS I/O page registers for the operation of the port but not directly for the I/O devices attached to the controller. The port design assumes a command/response relationship. The actual transmission of commands and responses is affected by the port via DMA transfers to and from a communication region in host system memory. The port polls this region for commands; the host system polls it for responses. From the viewpoint of the host system, an I/O operation begins when it deposits a command descriptor in the command ring. When the operation is complete, the corresponding response packet is removed by the host system from the response ring.

## Controller-to-Disk Interface

The controller-to-disk interface is defined by the Standard Disk Interface which specifies the hardware and software interconnect as well as the format of the media.
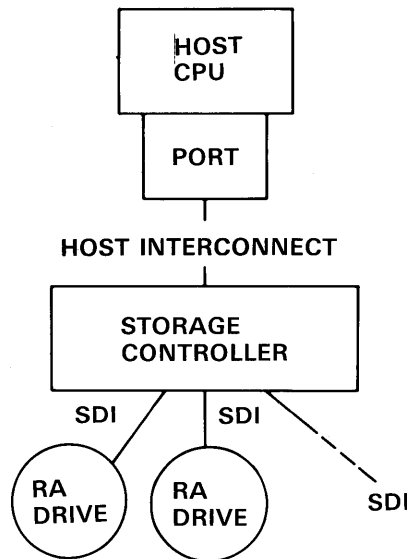


## Standard Disk Interface (SDI)

The SDI consists of three components:

*   SDI bus
*   SDI protocols
*   Digital Standard Disk Format (DSDF)

## SDI Bus

The SDI bus is a radial drive-to-controller interconnect with a maximum length of 80 feet (30 meters). Hence, for multi-drive subsystems, SDI buses are configured in parallel to prevent a failure in one drive from affecting operation of other drives. The bus is a four line coaxial cable:

- Controller-to-drive data and control
- Drive-to-controller data and control
- Controller-to-drive status information
- Drive-to-controller status and attention information
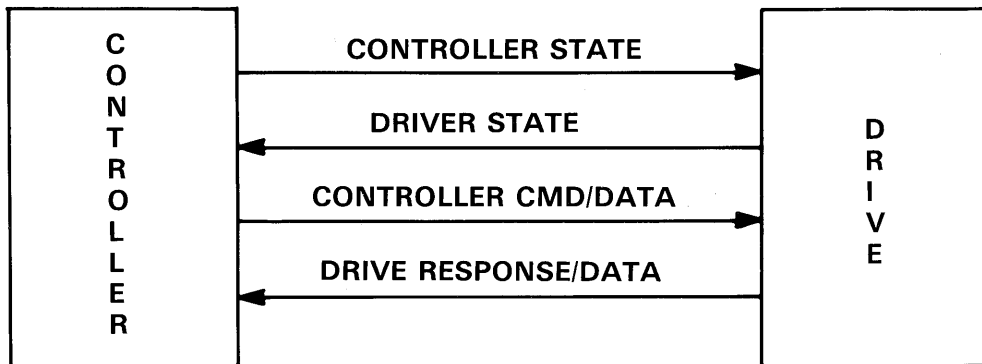


## SDI Protocol

The SDI provides the following commands:

- Obtain disk drive parameters (retry counts, timeouts, error thresholds, etc.) and geometry characteristics (sectors/track, number of tracks, number of cylinders, etc.)

- Obtain and release drives, spin up/down, get drive status, etc.

- Read, write, and format drives

## Digital Standard Disk Format (DSDF)

DSDF defines how a physical disk is partitioned into logical areas. The disk is formatted to contain four logical areas: The user area, the diagnostic test area, replacement block area and the format control table area.

The bad block replacement strategy provides error free virtual user space and a means of identifying correctly written but logically incorrect sectors. One replacement block is reserved on every track on the disk for improved performance. The Format Control Table provides a master list of media defects. The diagnostic test area is reserved for diagnostic reading and writing to the disk. This area is physically separated from user data space by several cylinders.



11
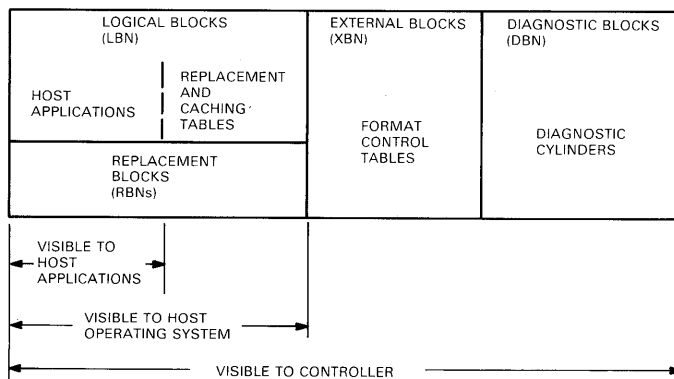
# NOTES

# DSA SUBSYSTEMS SUPERIOR THROUGHPUT, DATA INTEGRITY, AND AVAILABILITY

DSA subsystems provide significant improvements in:

- I/O throughput
- Data integrity
- Subsystem availability

## Throughput Enhancement Features

I/O throughput as seen by the user is more dependent on performance optimization features than performance related disk specifications. In DSA subsystems, the optimization algorithms in the UDA50 significantly enhance I/O throughput. A buffer memory in the UDA50, named the command queue, stores up to twelve I/O requests from the host system. Firmware controlled operations on the command queue optimize disk accesses and data transfers without imposing any overhead burden on the host system.

## Seek Ordering

I/O requests in the command queue are logically sorted into individual queues by disk volume. The I/O requests are reordered by an elevator algorithm and executed by cylinder address rather than in the order received from the host system. The command queue is dynamically updated as new requests are received. A fairness counter prevents any disk from monopolizing the I/O channel.

### BENEFIT
Seek ordering can dramatically improve throughput in single drive systems (up to 35% improvement has been observed), as well as in multiple drive systems.

## Express Queueing

First-in, first-out (FIFO) servicing of I/O requests can be specified through a mechanism named the express queue. In addition, FIFO servicing can be specified for some requests and seek ordering for others.

### BENEFIT
Provides the flexibility to select the request servicing that will optimize throughput.

## Overlapped Seeking

The UDA50 initiates simultaneous seek operations to all disks in the subsystem with an I/O request in the command queue. One drive can perform a data transfer while other drives are seeking.

**BENEFIT**

Overlapped seeking provides a major throughput improvement in multiple drive systems.

## Rotational Optimization

When multiple disks are simultaneously positioned on requested cylinders, the UDA50 selects the drive nearest its beginning sector to perform a data transfer.

**BENEFIT**

Rotational optimization provides an incremental throughput improvement in multiple drive systems that employ overlapped seeking.

## Speed Matching Buffer

The UDA50 contains twelve sectors of RAM memory that allow disk-to-controller transfers to occur at higher speed than controller-to-host system transfers.

**BENEFIT**

The deep UDA50 buffer improves performance by minimizing missed disk revolutions due to a buffer full condition.

## Direct Revectoring System

When a retired sector is encountered, the drive automatically references the replacement sector which generally is located on the same track.

**BENEFITS**

The direct revectoring system avoids wasting time reseeking to a look-up table to determine the address of replacement sectors. Also, since file structures never have to be rearranged to accommodate bad blocks, disks can be backed up and restored with a high speed volume copy.

## DMA Transfers

Data is transferred directly to and from host system memory.

**BENEFITS**

System throughput is improved by avoiding interrupts to transfer data.

## Data Integrity Features

The UDA50 controller has the most powerful and comprehensive set of data integrity features in the industry. Most manufacturers specify that unrecoverable errors (data loss) can occur as often as every time 1012 or 1013 bits are read. By contrast, it is unlikely that data loss will ever occur with properly functioning DSA subsystems. This level of data protection is accomplished without imposing any overhead on the host system. All UDA50 recovery operations are initiated and completed in the subsystem.

## 170-bit Error Correction Code (ECC)

In write operations, the UDA50 calculates a 170-bit ECC which is written in the sector postamble. On read operations, the UDA50 checks the ECC to verify that the data is correct. The ECC will detect all errors and correct: (A) A single error burst up to 80 bits; or (B) up to eight independent one-to-ten bit error bursts.

**BENEFIT**

Loss of data due to uncorrectable data errors caused by media degradation is virtually eliminated. The 170-bit code is far more powerful than conventional 32-bit ECC which only corrects up to an 11-bit single error burst.

14

**Error Detecting Code (EDC)**

As data is received from host system memory, the UDA50 calculates a code corresponding to each word and accumulates the codes. The result, named write EDC, is written on the disk in the sector postamble. On read operations, the same process occurs in reverse as data is sent to host memory and a read EDC is calculated. The write and read EDCs are compared and a retry is automatically initiated if a miscompare occurs.

**BENEFIT**

Undetected (and hence uncorrected) errors due to a controller malfunction are virtually eliminated. In addition, the EDC verifies proper functioning of the ECC hardware by catching ECC errors.

**Memory Parity**

The UDA50's RAM and ROM memories include parity checking.

**BENEFIT**

Parity checking detects single bit memory errors. (Note: The EDC detects multiple bit memory errors occurring in the data buffer and causes the controller to retry the operation.)

**Address Verification System**

In the header preamble of each sector, four copies of the address are recorded. On read operations, the UDA50 compares the four copies and requires only a single match between two of the four copies to verify that the sector address was correctly written and read.

**BENEFIT**

Loss of data due to header errors caused by media defects is virtually eliminated. The UDA50's address verification system outperforms conventional CRC systems which only provide address error detection capability.

**Seek Error Recovery System**

After validating the sector address read from the disk, the UDA50 compares this address to the requested address retained in the UDA50 memory. If a miscompare occurs, the UDA50 will automatically reinitiate the seek operation.

**BENEFIT**

The UDA50 detects mispositioning errors by verifying cylinder, track and sector address. (Note: DSA disks also provide for seek error recovery by verifying cylinder and head selection).

**Error Logging and Automatic Sector Retirement System**

During initialization, DSA disks provide to the UDA50 two error severity thresholds for: (A) Reporting recoverable errors to the operating system error log; and, (B) retiring the sector. The UDA50 compares data errors against both thresholds. If the severity of an error exceeds the lower threshold, it is reported to the host system error log. If it exceeds the higher threshold, the UDA50 reports the error and requests authorization from the operating system to retire and revector the sector to a replacement sector.

**BENEFIT**

Sectors are retired before the phenomenon of error propagation causes recoverable errors to become unrecoverable errors and hence cause data loss.

**Disk Mapping System**

The UDA50 performs logical-to-physical sector address translation. A quadruplicated header code identifies active and retired sectors. In the case of retired sectors, the code specifies the alogorythm to revector to the replacement sector which is generally located at the end of the same track or on an adjacent track. The UDA50 processes this information and automatically revectors to the replacement sector. As a failsafe procedure, revectoring addresses are also copied in a look-up table stored on the disk.

15

The mapping system virtually eliminates data loss caused by revectoring errors as well as improves performance by generally avoiding seeks to a look-up table for revectored addresses.

## Data Compare Commands

The MSCP protocol provides commands to perform read and write compares as well as to compare host memory data with data on a disk.

**BENEFIT**
Provides an additional level of data integrity.

## Access and Erase Commands

The MSCP protocol provides an access command to perform surface checking to determine if any media degradation has occurred and an erase command to eliminate files.

**BENEFIT**
The access command verifies that sectors are error free and the erase command provides for data security.

## Multi-Block Transfer Control

The UDA50 controls the data transfers from the disk to the speed matching buffer in the UDA50. If a data transfer involving a high number of sectors causes a buffer-full condition, the UDA50 will suspend the transfer and automatically resume it when buffer space becomes available.

**BENEFIT**
Eliminates the occurrence of UDA50 data-late errors and the associated need for retry operations.

## Autocorrelated Synchronization Character

An autocorrelated sync character preceeds a data transfer between a DSA disk and the UDA50. The autocorrelation mechanism allows synchronization even if up to three bits in the sync character are in error.

**BENEFIT**
Minimizes the occurrence of sync byte errors which require retry operations. This mechanism outperforms conventional synchronization systems that cannot tolerate even single bit errors.

## Availability Enhancement Features

The UDA50 and DSA disk drives offer a set of high-availability features not typically found in other disk subsystems. These features, together with high MTBF hardware, provide high system uptime and low maintenance prices.

## Radial Interconnect

DSA subsystems have a point-to-point interconnect between each disk and the UDA50 controller for data as well as control and status information.

**BENEFIT**
Improves system uptime because a drive can be logically isolated from the subsystem and repaired without disrupting the operation of other drives in the subsystem.

## On-Board Microdiagnostics

All DSA drives and the UDA50 controller contain a comprehensive set of fault-isolating diagnostics which isolate over 80% of all failures to a single field replaceable unit.

**BENEFIT**
High diagnostic fault isolation capability decreases mean time to repair (MTTR). Most failures can be diagnosed and repaired in less than one hour. No special test equipment is needed.

**Console Fault Display**

In DSA disks, a fault causes illumination of the fault console light. By depressing the fault console light switch, a code will be displayed via illumination of other console lights. The code identifies the failure class.

**BENEFIT**

This information allows most failures to be quickly diagnosed and identifies the required replacement part.

**Remote Diagnostic Support**

The microdiagnostics can be operated: (A) Locally with the drive off-line; (B) locally with the drive on-line through the system console; or, (C) remotely with the drive on-line through Digital's diagnostic service.

**BENEFIT**

The remote diagnostic service insures that field engineers are dispatched with the correct replacement parts.

**Power-up Verification**

Functional tests which include reading and writing on reserved diagnostic cylinders, run automatically during power-up and initialization.

**BENEFIT**

Power-up verification prevents initiating a job stream with a malfunctioning drive. This is especially important in certain classes of applications such as a real-time process control.

**Dual Access**

All DSA disks have dual access logic as a standard drive feature. Port switches on the drive console allow the drive to be dedicated to a single UDA50 or statically shared between two UDA50s. Static sharing implies that one UDA50 cannot access a disk that is already in the process of accessing or transferring data to another UDA50. Static dual access is provided primarily for high availability as opposed to high performance switching of disks between systems.

**BENEFIT**

Dual access provides the redundancy required for high availability systems, or, it can be used to share disks between systems. In DSA subsystems, only the purchase of a second I/O cable is required to connect a DSA disk to a second UDA50 controller.

**Bus Isolation**

Pulse transformers on the drive-to-controller I/O cable provide for electrical isolation between subsystem components. The I/O cable plugs into bulkhead connectors on the disk and CPU cabinets.

**BENEFIT**

Systems can be quickly and easily reconfigured without concern for ground loops caused by different power sources.

**Last Fault Register**

The UDA50 contains an error register that is dynamically updated.

**BENEFIT**

The last fault register is used as a troubleshooting aid.

17

**DSA Subsystem Features Vis-A-Vis Competition**

| Features | DSA Subsystems | Typical Competitive Subsystems |
|---|---|---|
| Throughput features: | | |
| Seek ordering | Yes | No |
| Express queue | Yes | Yes |
| Overlapped seeking | Yes | Yes |
| Rotational optimization | Yes | No |
| Speed matching buffer | 12 sectors | 3 sectors |
| Direct revectoring system | Yes | No |
| DMA transfers | Yes | Yes |
| Data integrity features: | | |
| ECC capability: | | |
|     Max. error bits | 80 bits | 11 bits |
|     Max. error bursts | 8 bursts | 1 burst |
| EDC | Yes | No |
| Address verification | Detection/ Correction | Detection |
| Seek error recovery | Yes | Yes |
| Disk mapping system | Yes | No |
| Multi-block transfer control | Yes | No |
| Data compare commands | Yes | No |
| Access command | Yes | No |
| Autocorrelated synchronization | Yes | No |
| Availability Features: | | |
| Interconnect | Radial | Radial/Daisy chain |
| On-board diagnostics | UDA50 & drives | Controller only |
| Remote diagnostic Support | Yes | No |
| Power-Up check-out | UDA50 & drives | Controller only |
| Dual access | Standard | Optional |
| Bus isolation | Yes | No |
| Other Features: | | |
| System off-loading | Yes | No |
| Max. disk data rate | 3 MB/sec | 1.2 MB/sec |
| Software independence | Yes | No |

The UDA50 is the first controller implementation of the Digital Storage Architecture (DSA). It connects up to four DSA disks via the radial SDI interconnect to Digital systems (see diagram below). Many controllers limit systems to disks with data rates not exceeding 1.2 megabytes per second. The UDA50 can handle disk data rates up to almost 3 megabytes per second.
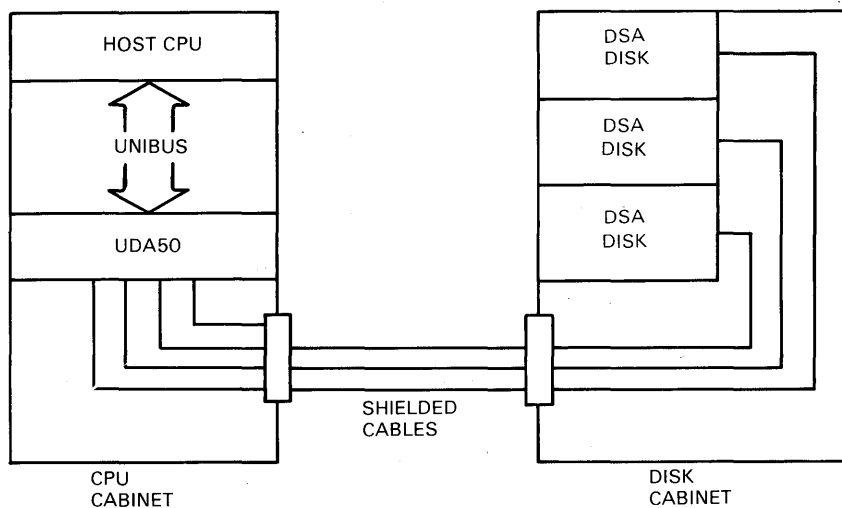


The UDA50:

- Supports high speed disk technology
- Provides powerful error correcting systems for high density recording
- Provides multiple level, performance optimizations for both single and multiple drive subsystems.
- Provides superior availability features
- Supports Winchester fixed-media disks as well as removable-media disks of varying capacities and transfer rates
- Unburdens the host system of the overhead associated with error handling and I/O throughput optimization

19

## UDA50 OPERATION AND HARDWARE

UDA50 operations are controlled by a high-speed, 16-bit processor which simultaneously executes host interface and drive interface programs.

### The Host Interface Program
- Reads MSCP packets from host system memory
- Decodes MSCP packets
- Transfers data to and from host system memory
- Calculates the EDC and checks for EDC errors
- Performs seek ordering
- Manages the host interface

2048-word (16-bit) memory contains constants used in error corrections and logical-to-physical address conversions.

Logic to timeshare the processor for simultaneous execution of host and drive interface programs.

**UDA50 Microprocessor Board**

Dual Sequencer

Table Memory

Processor

Control Logic

Program Memory

Timing
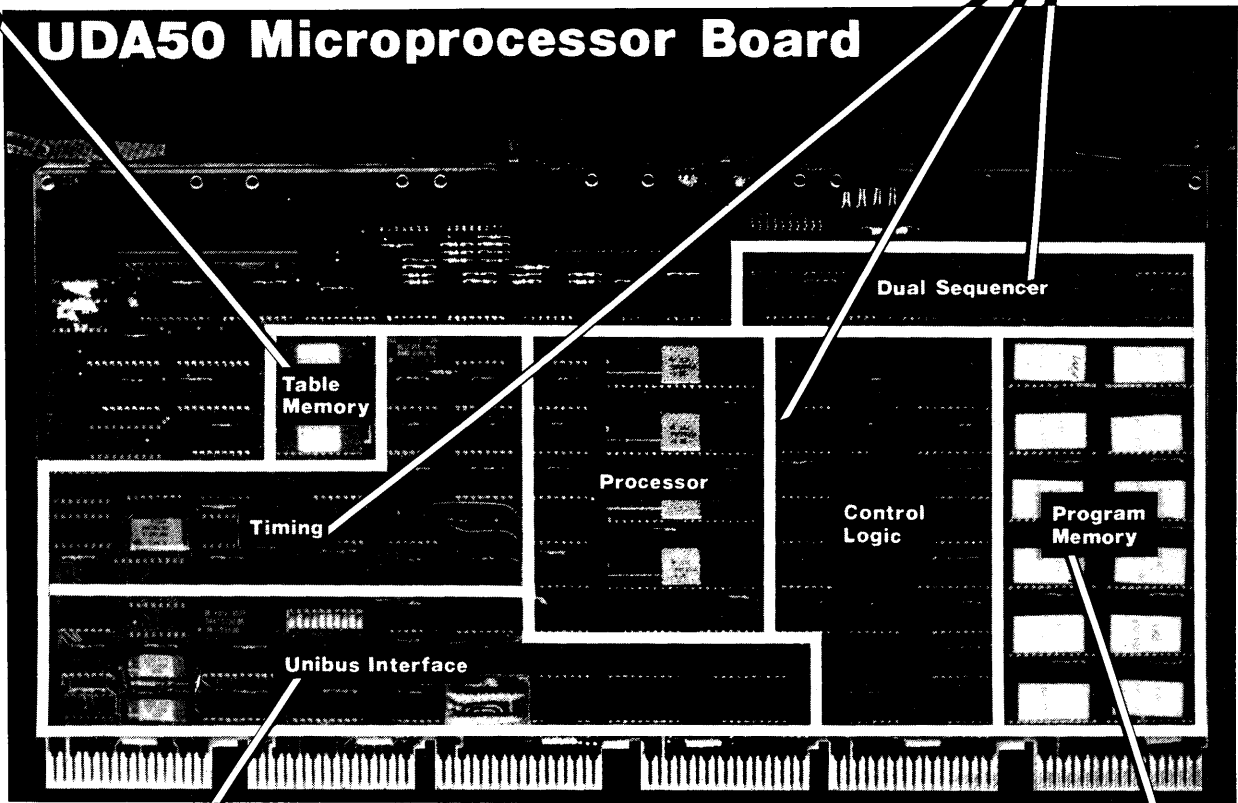
Unibus Interface

Custom LSI logic to interface to UNIBUS requires only two UNIBUS I/O page addresses.

4096 words (48 bits) of control memory with parity protection. Stores both the host and drive interface programs and the UDA50 microdiagnostics.

20

**The Drive Interface Program:**
- Checks for ECC errors and performs error recovery
- Generates and checks the autocorrelated sync character
- Performs overlapped seeks and rotational optimization
- Performs seek error recovery
- Transfers data to and from the disk drives
- Manages the drive interface

The physical configuration of the UDA50 consists of two HEX-size modules that interface to Small Peripheral Controller (SPC) slots in a PDP-11 or VAX UNIBUS.

Custom LSI logic to implement the 170-bit error correction code.

Logic to implement the SDI protocol and radial disk interconnect. The encode/decode logic converts data between NRZ and SDI code.

Custom LSI logic converts data between serial disk data and parallel data for UDA50 processing and transfer to host.

**UDA50 SDI Board**

ECC Logic

SDI Drivers/Receivers

Serializer/Deserializer

SDI Status and Control Logic

SDI Encoders Decoders

-15 to -5v Converter

4k Ram with Parity

4096-word RAM (16-bit) with byte parity. Used for temporary storage of data, commands, and drive characteristics.

Modularized Power Converter

21

# NOTES

## THE RA60: THE REMOVABLE MEDIA SOLUTION

The RA60 with 205 megabytes of user capacity is the industry's highest capacity removable-media disk in a 10.4-inch high form factor. Up to three drives can be packaged in a waist-high cabinet.

**Purchase Price** — Note the low quantity one purchase prices and service charges. All products are Type I discountable.

205 Mb Per Drive
615 Mb Per Cabinet
820 Mb Per Subsystem

$22,000 Subsystem with $110
Monthly Maintenance Charge

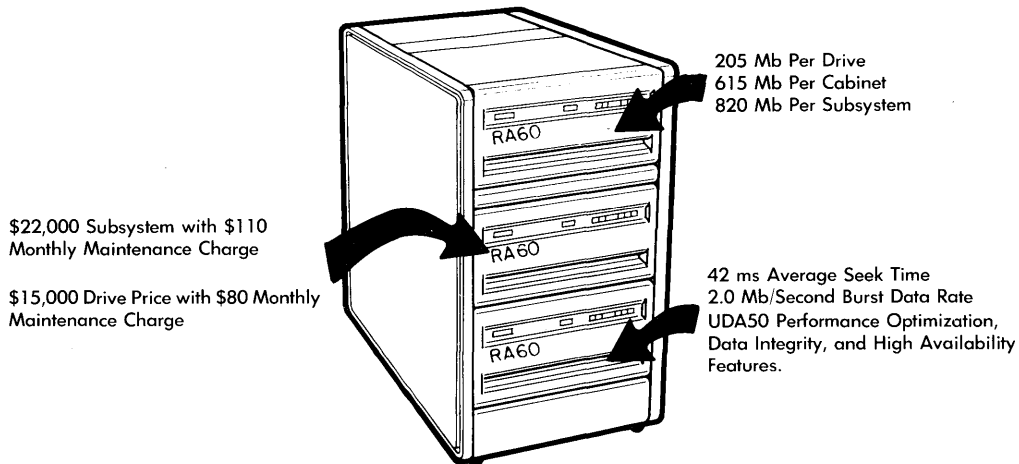$15,000 Drive Price with $80 Monthly
Maintenance Charge

42 ms Average Seek Time
2.0 Mb/Second Burst Data Rate
UDA50 Performance Optimization,
Data Integrity, and High Availability
Features.

**Lifetime Cost of Ownership** — Lifetime cost of ownership represents the total cost of purchasing, installing and maintaining a product. Since the cumulative cost of service sometimes exceeds the initial purchase price, the only sensible way to compare price is on a lifetime cost-of-ownership basis. The following lifetime cost-of-ownership figures were calculated on an after-tax, discounted cash flow basis over a five year period, for a company using double declining balance depreciation, with a 50% tax rate and paying 10% for the cost of capital (discount rate). Before making a decision, calculate the full cost of ownership for your company!

**LIFE CYCLE COST OF OWNERSHIP**
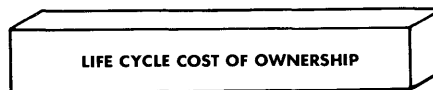
| | |
|---|---|
| Subsystem cost-of-ownership | $15,800 or $77 per megabyte |
| Drive (with pack) cost-of-ownership | $11,100 or $54 per megabyte |

23

# FEATURES SUMMARY

## UDA50/RA60 SUBSYSTEM

### ● Data Integrity Features

- 170 bit ECC
- Error detecting code (EDC)
- Address verification system
- Improved disk mapping
- Automatic sector retirement
- Data compare commands
- Access command
- Seek error recovery
- Error reporting
- Multi-block transfer control
- Parity checking
- Autocorrelated synchronization

### ● Throughput Features

- Command queue
- Seek ordering
- Overlapped seeks
- Rotational optimization
- Express queue
- Speed matching buffer
- Direct revectoring system
- DMA transfers

### ● Availability Features

- Radial interconnect
- On-board microdiagnostics
- Console fault display
- Off-line repair
- Remote diagnosis support
- Power-up verification
- Electrical bus isolation
- Environmental sensors
- No head alignment
- High MTBF/low MTTR

## RA60 DISK DRIVE

### ● Formatted User Capacity

- 205 MB per drive
- 615 MB per cabinet
- 820 MB per controller

### ● Performance

- 7 ms single track seek
- 42 ms average seek
- 50 ms average access
- 2.0 MB/second data rate

### ● Space Efficiency

- 111 MB/square foot

### ● Dual Access

- Standard feature

### ● Other Drive Features

- Advanced read/write system
- Embedded servo technology
- Dual microprocessors
- Misalignment compensation
- Optimized spindle motor
- LSI and modular design
- Universal power supply

### ● Recording Technology

- 779 tracks per inch
- 9,668 bits per inch

### ● Drive Dimensions

- Height — 10.4'' (26.7 cm)
- Width — 18.9'' (48.0 cm)
- Depth — 33.5'' (71.4 cm)

# RA60 DISK DRIVE FEATURES

## Advanced Read/Write System

The read/write system uses a unique encoding/decoding scheme, named 2/3 rate tree code, to store data on the disk. The code achieves an optimum balance between maximizing data compaction (three flux changes express four bits) and minimizing error propagation (transition detection window equals .67 bit length).

### BENEFIT

Provides a third more capacity by converting 7251 magnetic flux changes per inch (FCI) into 9668 bits per inch (BPI) without compromising data reliability.

## Embedded Servo Positioning System

A unique servo code embedded between sectors is used for seeking and track following. Each read/write head self-positions on the track center line before transferring data.

### BENEFIT

Reliable pack interchange at 779 tracks-per-inch (TPI) eliminates the need for costly head alignments; results in higher capacity by eliminating the need to allocate a disk surface for servo information.

## Optimized Cylinder Configuration

A logical cylinder consists of a group of four adjacent tracks on the same surface.

### BENEFIT

Horizontal arrangement of cylinders minimizes head switch latency in drives that utilize only embedded servo systems by canceling the effect of any vertical misalignment of tracks or heads.

## Dual Microprocessor Architecture

One microprocessor controls major drive functions while a second microprocessor communicates with the controller.

### BENEFIT

Enhances performance by allowing simultaneous tasks to occur.

## Universal Power Supply

The RA60 operates with any combination of 50/60 Hz and 120V/240V input power. Reversing two plugs on the transformer converts frequency, and a switch, also on the transformer, converts voltage.

### BENEFIT

The ease of power conversion minimizes inventory for system OEM customers and provides flexibility for multi-national corporations.

## Automatic Misalignment Compensation System

The drive automatically senses and compensates for radial misalignment by phase-locking position and spindle speed to the microprocessor. For axial misalignment, it uses a grey code compensation system.

### BENEFIT

Insures data integrity and reliable pack interchange. Eliminates the need for periodic head alignment.

**Optimized Spindle Motor**

A brushless DC spindle motor is used to drive the rotating pack. An impeller, mounted on the motor, is the primary air flow mechanism in the cooling system.

**BENEFIT**

Decreases power consumption, heat dissipation and acoustic noise. Eliminates the conventional motor-to-spindle pulley belt and blower assembly.

**Extensive LSI and Modular Design**

The drive uses gate array and hybrid LSI components extensively. The logic is functionally partitioned on the modules. Every component is part of a field replaceable unit.
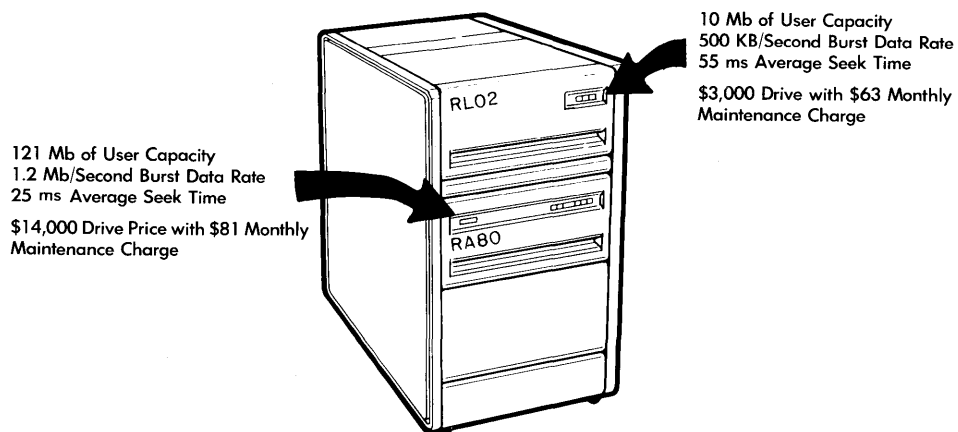
**BENEFIT**

Improves mean time between failures (MTBF) by reducing parts count and improves MTTR through design modularity.

Paired with the RL02, the RA80 disk provides a complete storage solution that includes 121 megabytes of high performance Winchester disk capacity and a 10 megabyte removable media companion disk for software distribution, private files, data interchange and data back-up.

**Purchase Price** — Note the low quantity one purchase prices and service changes. All products are Type I discountable.

10 Mb of User Capacity
500 KB/Second Burst Data Rate
55 ms Average Seek Time

$3,000 Drive with $63 Monthly
Maintenance Charge

RL02

121 Mb of User Capacity
1.2 Mb/Second Burst Data Rate
25 ms Average Seek Time

$14,000 Drive Price with $81 Monthly
Maintenance Charge

RA80

**Lifetime Cost of Ownership** — Lifetime cost of ownership represents the total lifetime cost of purchasing, installing and maintaining a product. Since the cumulative cost of service sometimes exceeds the initial purchase price, the only sensible way to compare price is on a lifetime cost-of-ownership basis. The following lifetime cost-of-ownership figures were calculated on an after-tax, discounted cash flow basis over a five year period, for a company using double declining balance depreciation, with a 50% tax rate and paying 10% for the cost of capital (discount rate). Before making a decision, calculate the full cost of ownership for your company!

**LIFE CYCLE COST OF OWNERSHIP**

**RA80**
- Subsystem — $15,100
- Add-on — $10,400

**RL02**
- Subsystem — $5,900
- Add-on — $3,300

27

# FEATURES SUMMARY

## UDA50/RA80 SUBSYSTEM

● **Data Integrity Features**

- 170 bit ECC
- Error detecting code (EDC)
- Address verification system
- Improved disk mapping
- Automatic sector retirement
- Data compare commands
- Access command
- Seek error recovery
- Error reporting
- Multi-block transfer control
- Parity checking
- Autocorrelated synchronization

● **Throughput Features**

- Command queue
- Seek ordering
- Overlapped seeks
- Rotational optimization
- Express queue
- Speed matching buffer
- Direct revectoring system
- DMA transfers

● **Availability Features**

- Winchester technology
- Radial interconnect
- On-board diagnostics
- Console fault display
- Off-line repair
- Remote diagnosis support
- Power-up verification
- Electrical bus isolation
- Environmental sensors
- High MTBF/low MTTR
- No scheduled PM

## RA80 DISK DRIVE

● **Formatted User Capacity**

- 121 MB per drive
- 363 MB per cabinet
- 484 MB per controller

● **High Performance**

- 6 ms single track seek
- 25 ms average seek
- 33 ms average access
- 1.2 MB/second data rate

● **Space Efficiency**

- 83 MB/square foot

● **Dual Access**

- Standard feature

● **Other Drive Features**

- Innovative head-disk assembly
- Recirculating air filtration
- Dual read/write heads
- Modular design

● **Recording Technology**

- 478 tracks per inch
- 6,339 bits per inch

● **Drive Dimension**

- Height — 10.4'' (26.7 cm)
- Width — 18.9'' (48.0 cm)
- Depth — 26.5'' (71.4 cm)

28

# RA80 DISK DRIVE FEATURES

**Winchester Technology**

The enclosed head disk assembly protects the recording environment from external contaminants. Lightweight head suspension allows heads to fly closer to the surface.

### BENEFIT

Improved data reliability by virtually eliminating head-disk inter-
ference. Increases recording density for higher capacity and lower
cost per megabyte.

**Innovative Head-Disk Assembly (HDA)**

The HDA is formed from two symmetrical aluminum castings with top and bottom spindle bearings.

### BENEFIT

Stiff platform with double bearings minimizes axial runout and
off-track errors.

**Recirculating Air Filtration System**

An absolute filter is designed into the spindle assembly. The disk platters provide a pumping action which exhausts air from the space between the disk platters causing air flow through the absolute filter.

### BENEFIT

The recirculating air filtration system protects data. If an oxide
particle becomes free within the HDA, it will be trapped in the
filter before damage occurs.

**Computer Designed Positioner**

The low mass rotary positioner includes an innovative moving magnet design.

### BENEFIT

High seek performance, compact size and low power consump-
tion.

**Dual Read/Write Heads**

Two read/write heads address each data surface. A logical cylinder consists of two physical cylinders.

### BENEFIT

Two heads per surface provide twice the data at every actuator
position. This reduces seek activity and shortens average seek
distances for improved performance.

**Environmental Sensors**

Thermal and speed sensors monitor air temperature and spin-up acceleration.

### BENEFIT

Protects data from degradation caused by extreme heat or line voltage variations.

**Modular Design**

The electronics are functionally partitioned on separate modules. Every component is part of a field replaceable assembly.
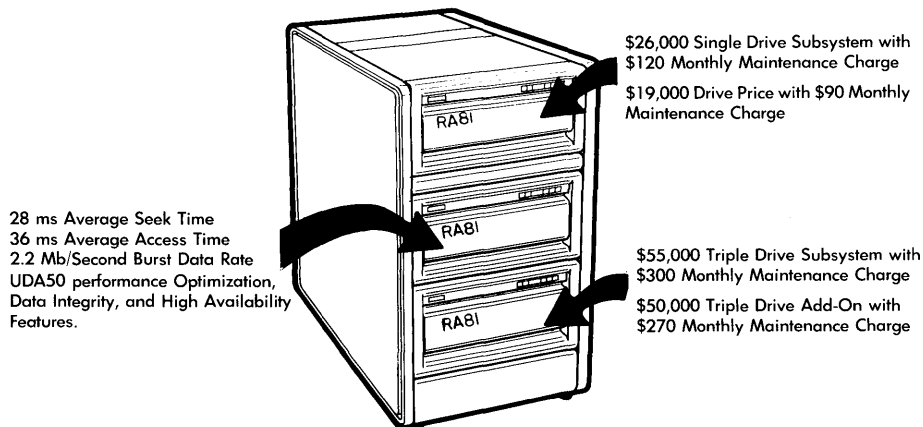
### BENEFIT

Improves system uptime by reducing mean time to repair (MTTR).

# NOTES

# THE RA81: THE LOWEST COST PER MEGABYTE SOLUTION

The RA81 with 456 megabytes of user capacity is the industry's highest capacity Winchester fixed-media disk in a 10.4-inch high form factor. The triple drive RA81 option stores almost 1.4-billion bytes in about five square feet.

**Purchase Price** — Note the low quantity one purchase prices and service changes. All products are Type I discountable.

28 ms Average Seek Time
36 ms Average Access Time
2.2 Mb/Second Burst Data Rate
UDA50 performance Optimization,
Data Integrity, and High Availability
Features.

$26,000 Single Drive Subsystem with
$120 Monthly Maintenance Charge

$19,000 Drive Price with $90 Monthly
Maintenance Charge

$55,000 Triple Drive Subsystem with
$300 Monthly Maintenance Charge

$50,000 Triple Drive Add-On with
$270 Monthly Maintenance Charge

**Lifetime Cost of Ownership** — Lifetime cost of ownership represents the total lifetime cost of purchasing, installing and maintaining a product. Since the cumulative cost of service sometimes exceeds the initial purchase price, the only sensible way to compare price is on a lifetime cost-of-ownership basis. The following lifetime cost-of-ownership figures were calculated on an after-tax, discounted cash flow basis over a five year period, for a company using double declining balance depreciation, with a 50% tax rate and paying 10% for the cost of capital (discount rate). Before making a decision, calculate the full cost-of-ownership for your company!

**LIFE CYCLE COST OF OWNERSHIP**

Single Drive Subsystem — $18,400 or $40 per megabyte
Single Drive Add-on     — $13,700 or $30 per megabyte

Triple Drive Subsystem — $39,600 or $29 per megabyte
Triple Drive Add-on      — $36,000 or $26 per megabyte

31

# FEATURES SUMMARY

## UDA50/RA81 SUBSYSTEM

### ● Data Integrity Features

- 170 bit ECC
- Error detecting code (EDC)
- Address verification system
- Improved disk mapping
- Automatic sector retirement
- Data compare commands
- Access command
- Seek error recovery
- Multi-block transfer control
- Parity checking
- Autocorrelated synchronization

### ● Throughput Features

- Command queue
- Seek ordering
- Overlapped seeks
- Rotational optimization
- Express queue
- Speed matching buffer
- Direct revectoring system
- DMA transfers

### ● Availability Features

- Winchester technology
- Radial interconnect
- On-board diagnostics
- Console fault display
- Off-line repair
- Remote diagnosis support
- Power-up verification
- Electrical bus isolation
- Environmental sensors
- High MTBF/low MTTR
- No scheduled PM

## RA81 DISK DRIVE

### ● Formatted User Capacity

- 456 MB per drive
- 1368 MB per cabinet
- 1824 MB per controller

### ● High Performance

- 6 ms single track seek
- 28 ms average seek
- 36 ms average access
- 2.2 MB/second data rate

### ● Space Efficiency

- 253 MB/square foot

### ● Dual Access

- Standard feature

### ● Other Drive Features

- Advanced read/write system
- Dual positioning system
- Innovative head-disk assembly
- Recirculating air filtration
- Dual read/write heads
- Modular design

### ● Recording Technology

- 960 tracks per inch
- 11,400 bits per inch

### ● Drive Dimensions

- Height — 10.4'' (26.7 cm)
- Width — 18.9'' (48.0 cm)
- Depth — 26.5'' (71.4 cm)

# RA81 DISK DRIVE FEATURES

**Advanced Read-Write System**

The read/write system uses a unique encoding/decoding scheme, named 2/3 rate tree code, to store data on the disk. The code achieves an optimum balance between maximizing data compaction (three flux changes express four bits), and minimizing error propagation (transition detection window equals .67 bit length).

**BENEFIT**

Provides a third more capacity by converting 8,550 magnetic flux changes per inch (FCI) into 11,400 bits per inch (BPI) without compromising data reliability.

**Dual Positioning System**

A high bandwidth servo system using a dedicated disk surface is complemented by an inter-sector embedded servo code for fine positioning.

**BENEFIT**

Provides for high performance seeking and high precision positioning at 960 tracks per inch (TPI).

**Winchester Technology**

The enclosed head disk assembly protects the recording environment from external contaminants. Lightweight head suspension allows heads to fly close to the surface.

**BENEFIT**

Improves data reliability by virtually eliminating head-disk interference and increases recording density for higher capacity and lower cost per megabyte.

**Innovative Head-Disk-Assembly (HDA)**

The HDA is formed from two symmetrical aluminum castings with top and bottom spindle bearings.

**BENEFIT**

Stiff platform with double bearings to minimize axial runout and off-track errors.

**Computer Designed Positioner**

The low mass, rotary positioner includes an innovative moving magnet design.

**BENEFIT**

High seek performance, compact size and low power consumption.

**Dual Read/Write Heads**

Two read/write heads address each data surface. Each logical cylinder consists of two physical cylinders.

**BENEFIT**

Two heads per surface provide twice the data at every actuator position. This reduces seek activity and shortens average seek distance for improved performance.

**Environmental Sensors**

Thermal and speed sensors monitor air temperature and spin-up acceleration.

**BENEFIT**

Protects data from degradation caused by extreme heat or line voltage variations.

**Modular Design**

The electronics are functionally partitioned on separate modules. Every component is part of a field replaceable unit.

**BENEFIT**

Improves system uptime by reducing mean time to repair (MTTR).

**Dual Microprocessor Architecture**

One microprocessor communicates with the UDA50 and controls major drive functions except real time operations (such as the servo system) which are controlled by the second microprocessor.

**BENEFIT**

Enhances performance by allowing simultaneous tasks to occur.

**Recirculating Air Filtration System**

An absolute filter is designed into the spindle assembly. The disk platters provide a pumping action which exhausts air from the space between the disk platters causing air flow through the absolute filter.

**BENEFIT**

The recirculating air filtration system protects data. If an oxide
particle becomes free within the HDA, it will be trapped in the
filter before damage occurs.

**UDA50 Specifications**

| Characteristics | Specification |
|---|---|
| Physical Components | UDA Module #1 |
| | UDA Module #2 |
| | 50-pin flat cable assembly |
| | 40-pin flat cable assembly |
| | UDA50 to I/O bulkhead cable |
| | I/O bulkhead assembly |
| Power Consumption | 75 Watts |
| Heat Dissipation | Approximately 256 Btu/hour |
| Electrical Voltage and Current Requirements | 11 amps at +5 volts |
| | 60 millamps at +15 volts |
| | 2 amps at -15 volts |
| Operating Temperature Range | 10°C to 40°C (50°F to 104°F) with a temperature gradient of 20°C/ hour (36°F/hour) |
| Operating Relative Humidity Range | 10% to 90% with a wet bulb temperature of 28°C (82°F), and a minimum dew point of 2°C (36°F) |
| Operating Altitude Range | Sea level to 2438 meters (8000 ft) Maximum allowable operating temperature derated by 1.8°C/1000 meters (1°F/1000 feet) for operation above sea level |
| Mounting Restrictions | Mounts in two hex-height UNIBUS SPC slots in the CUP box or the following UNIBUS expander boxes: |
| | BA11-A |
| | BA11-K |
| | BA11-L |
| Controller-to-Drive Cable | Standard length: 12 feet (3.7) meters Optional lengths: 25, 50, 80 feet (7. 6, 15.2, 24.4 meters) |

35

**RA80, RA81, RA60 Specifications Summary (Cont)**

|  | RA80 | RA81 | RA60 |
|---|---|---|---|
| **Data Organization** | | | |
| Physical Specifications: | | | |
| Sectors per track | 32 | 52 | 43 |
| Tracks per surface | 1116 | 2496 | 1600 |
| Recording surfaces | 7 | 7 | 6 |
| Tracks per disk | 7812 | 17612 | 9600 |
| | | | |
| User Data Capacity: | | | |
| Bytes per sector | 512 | 512 | 512 |
| Sectors per track | 31 | 51 | 42 |
| Tracks per logical cylinder | 14 | 14 | 4 |
| Logical cylinders per drive | 546 | 1248 | 2382 |
| Megabytes per disk | 121 | 456 | 205 |
| Drives per cabinet | 3 | 3 | 3 |
| Megabytes per cabinet | 363 | 1368 | 615 |
| Drives per controller | 4 | 4 | 4 |
| Megabytes per controller | 484 | 1924 | 820 |
| | | | |
| Reserved Space: | | | |
| Replacement sectors/track | 1 | 1 | 1 |
| Replacement sectors/disk | 7700 | 17528 | 9552 |
| Tracks for bad block table | 104 | 112 | 48 |
| Tracks for diagnostic use | 56 | 28 | 24 |
| **Recording Density** | | | |
| Tracks per inch (TPI) | 478 | 960 | 779 |
| Bits per inch (BPI) | 6339 | 11400 | 9668 |
| | | | |
| **Performance*** | | | |
| Peak transfer rate | 1.2 MB/Sec | 2.2 MB/Sec | 2.0 MB/Sec |
| Seek times: | | | |
| Track-to-track | 6 ms | 6 ms | 7 ms |
| Average | 25 ms | 28 ms | 42 ms |
| Maximum | 50 ms | 52 ms | 70 ms |
| Rotational latency | 8.3 ms | 8.3 ms | 8.3 ms |
| Average access time | 33.3 ms | 36 ms | 50 ms |
| Typical head switch time | 0 ms | 4 ms | 7 ms |

* Note: In most observed seek performance will be significantly better than the (above) specified seek times for the drives due to the UDA50's performance optimizations. In single drive systems with a heavy I/O load, seek ordering will reduce the effective average seek time by up to 35%. In multiple drive systems, overlapped seeking and rotational optimization can provide additional significant reductions in effective seek performance. The actual performance that the user will see is dependent on the I/O workload, the number of drives in the subsystem and the distribution of files on the drives. In general, the increase in I/O throughput in DSA subsystems caused by the performance optimization features is positively correlated with the number of drives in the subsystems - the more drives, the better the performance.

## RA80, RA81, RA60 Specifications Summary (Cont)

| | RA80 | RA81 | RA60 |
|---|---|---|---|
| **Operation** | | | |
| Start time | 50 seconds | 50 seconds | 35 seconds |
| Stop time | 20 seconds | 20 seconds | 35 seconds |
| Rotational speed | 3600 RPM | 3600 RPM | 3600 RPM |
| **Power** | | | |
| 120V, 60Hz, single phase | | | |
| Turn-on current | 31.0 A | 36.6 A | 10.4 A |
| Running current | 7.1 A | 7.8 A | 8.6 A |
| 240V, 50Hz, single phase | | | |
| Turn-on current | 17.0A | 18.0A | 5.2 A |
| Running current | 3.5 A | 3.5 A | 4.3 A |
| Plug types | | | |
| 120V | NEMA 5-15P | NEMA 5-15P | NEMA 5-15P |
| 240V | NEMA 6-15P | NEMA 6-15P | NEMA 6-15P |
| **Heat Dissipation** | | | |
| BTUs per hour | 2200 | 2200 | 2400 |
| Watts | 650 | 650 | 700 |
| **Heads and Disks** | | | |
| Number of platters | 4 | 4 | 3 |
| Data surfaces | 7 | 7 | 6 |
| Servo surfaces | 1 | 1 | Embedded |
| Heads per data surface | 2 | 2 | 1 |
| **Acoustics** | | | |
| 60 Hz drive | 60 dB(A) | 60 dB(A) | 65 dB(A) |
| 50 Hz drive | 58 dB(A) | 58 dB(A) | 65 dB(A) |
| **Operational Environment** | | | |
| Temperature range at sea level | | | |
| 60 Hz drives | 10° to 40° C (50° to 104° F) | 10° to 40° C (50° to 104° F) | 16° to 40° C (60° to 104° F) |
| 50 Hz drives | 10° to 38° C (50° to 101° F) | 10° to 40° C (50° to 104° F) | 16° to 40° C (60° to 104° F) |
| Altitude (maximum) | 2438m (8000 ft) | 2438m (8000 ft) | 2438m (8000 ft) |
| Relative humidity | 10% to 85% (no condensation) Maximum wet bulb temperature of 28°C (82°F) and minimum dew point of 2°C (36°F) | 10% to 85% (no condensation) Maximum wet bulb temperature of 28°C (82oF) and minimum dew point of 2°C (36°F) | 8% to 80% (no condensation) Maximum wet bulb temperature of 26°C (79°F) and minimum dew point of 2°C (36°F) |

**RA80, RA81, RA60 Specifications Summary (Cont)**

|  | **RA80** | **RA81** | **RA60** |
|---|---|---|---|
| **Mechanical** | | | |
| Drive | | | |
| Height | 10.4'' (26.4 cm) | 10.4'' (26.4 cm) | 10.4'' (26.4 cm) |
| Width | 17.5'' (44.5 cm) | 17.5'' (44.5 cm) | 17.5'' (44.5 cm) |
| Depth | 26.5'' (67.3 cm) | 26.5'' (67.3 cm) | 33.5'' (85.1 cm) |
| Weight | 148 lbs (67 kg) | 148 lbs (67 kg) | 165 lbs (75 kg) |
| | | | |
| Drive in Cabinet | | | |
| Height | 41.8'' (106.3 cm) | 41.8'' (106.3 cm) | 41.8'' (106.3 cm) |
| Width | 21.3'' (54.2 cm) | 21.3'' (54.2 cm) | 21.3'' (54.2 cm) |
| Depth | 36'' (14.2 cm) | 36'' (14.2 cm) | 36'' (14.2 cm) |
| Weight | 363 lbs (185 kg) | 363 lbs (185 kg) | 370 lbs (168 kg) |
| **Regulatory Agencies** | | | |
| UL | Yes | Yes | Yes |
| VDE | Yes | Yes | Yes |
| CSA | Yes | Yes | Yes |
| FCC | Compliant | Compliant | Compliant |

**digital**

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