The Xerox 550 Computer

XEROX

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The Xerox 550 is a high-performance, real-time computer system. Its integrated hardware and software capabilities make it ideally suited for such applications as data acquisition, analysis, simulation, control, and communications.

The memory-centered architecture of the Xerox 550 computer system is responsive, flexible, and modular. Centralized system control is provided for up to 17 separate processors. Basic processors feature a microprogrammed arithmetic and logic unit. Input/output processors permit a wide range of peripherals and interfaces to operate simultaneously with computation. Use of main memory is efficiently managed by the Memory Map.

The Xerox 550 system emphasizes reliability and maintainability. Large-scale and large-board technology is used throughout. Maintainability is maximized by use of extensive error-detecting hardware and a hierarchical diagnostic system which includes microdiagnostics.

The Xerox 550 control software, the Control Program for Real Time (CP-R), takes advantage of the real-time hardware architecture to create a responsive and flexible multiprogramming, multitasking environment. Interactive, concurrent program development capabilities are also included.

In addition to a fully-integrated real-time computing capability, the Xerox 550 system includes the comprehensive customer support that has become synonymous with Xerox leadership in real-time computing.

Features

The Xerox 550 hardware architecture offers configuration flexibility and high throughput capabilities. The architecture features a multi-unit memory permitting high throughput and a multiple bus structure allowing independent processors to simultaneously access memory. The hardware architecture of the Xerox 550 system is designed to facilitate real-time responsiveness. The modularity of the architecture permits the 550 system to be optimized for each application.

The Xerox 550 Basic Processor, which includes the arithmetic and logic unit, is ideally suited for critical real-time applications. The 550 system offers computational speed and exceptional responsiveness. The instruction set, oriented for real-time requirements, is flexible and powerful, yet easy to use.

The Xerox 550 memory management capabilities optimize memory usage which makes the system very easy to use in a real-time environment. The Memory Map permits a powerful real-time multiprogramming capability, eliminating memory fragmentation problems without requiring base registers, program rebiasing, or memory repacking. Dynamic memory allocation is greatly facilitated. The 550 system also incorporates two stages of memory protection facilities.

The Xerox 550 system performs input/output transfers while the Basic Processor simultaneously satisfies real-time synchronization requirements and performs time-critical computations. Multiplexing Input/Output Processors directly interact with memory via independent memory busses. Each of these processors can support multiple peripherals. External interrupts and operator control commands are input, independently of other input/output transfers, through the centralized System Control Processor.

Many digital and analog interfacing requirements can be satisfied with the Xerox 550 system's extensive complement of systems interface units. The Xerox modular, "off-the-shelf" digital and analog capability permits satisfying most interface requirements without necessitating special hardware. Included with these interfaces are software handlers. The 550 system also features a comprehensive line of conventional peripherals, including fixed and moving head disk units, magnetic tape transports, and unit-record equipment.

The 550 control software, the Control Program for Real-Time (CP-R), optimizes the capabilities of the Xerox 550 hardware, creating a flexible environment for satisfying a wide range of real-time processing requirements. CP-R is a responsive and efficient virtual-memory, multiprogramming, multitasking control system. Included are hardware and software scheduling, task intercommunication, resource enqueing, task roll-in and roll-out, symbionts, and dynamic memory and file allocation. CP-R features interactive program development facilities permitting on-line editing, job-entry, and debugging. Processors include FORTRAN and the Assembly Program.

To maximize the availability of the Xerox 550 system, comprehensive reliability and maintainability capabilities are designed into both the hardware and software. Extensive availability features are included in the Xerox 550 hardware, the Diagnostic Programming System and CP-R. Operating within a hierarchical structure, this capability permits verification of each level of system operation before proceeding to test the next. The Xerox Remote Assist capability further enhances maintainability by permitting all diagnostic operations to be controlled remotely via a telephone connection.

When a special requirement is outside the Xerox 550 system's broad range of capabilities, Xerox will help. The Xerox Custom Systems organization will assist in defining these requirements, and in identifying and optimizing potential solutions. If requested, Xerox will also implement such solutions including hardware development, software development, software conversion, system integration, and documentation.


XEROX
550

Hardware

Architecture

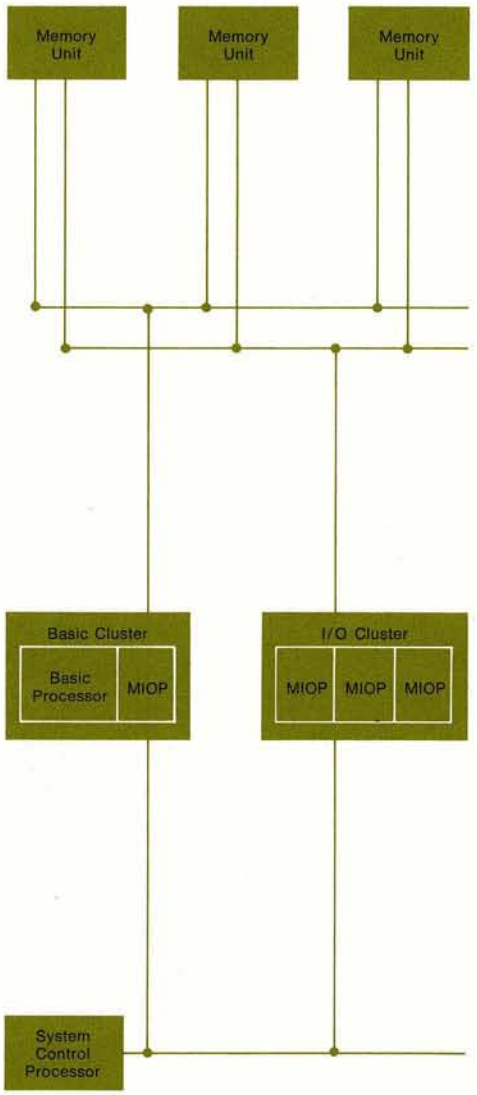
Architecture The architecture of the Xerox 550 system is both flexible and modular. Only the elements required for each application need be included in a 550 system. If these requirements subsequently change, so can the 550 configuration.

Main Memory Main Memory is divided into units, each of which may be accessed simultaneously. This overlap greatly increases total memory bandwidth. To automatically increase the occurrence of access overlap, unit addressing may be interleaved. The number of units and their size can be selected for the application.

Memory Bus Structure The parallel memory bus structure allows all clusters to independently access main memory. Each bus serves one cluster and has a port into each memory unit. Clusters may access different memory units simultaneously. Coincident accesses to a single unit are serviced by port priorities.

Cluster Configuration Clusters are groups of processors which are available in two standard configurations—the Basic Cluster and the I/O Cluster. The 550 Basic Cluster includes a Basic Processor and a Multiplexer Input/Output Processor (MIOP). Along with a System Control Processor, the Basic Cluster incorporates all the processor capability required for many applications. Each Input/Output Cluster permits adding up to three additional MIOPs. Processors within a cluster share the bandwidth of a single memory bus but access memory independently. Additional Basic and I/O Clusters may be configured as required by each application.

System Control Processor The System Control Processor (CP) is a centralized manager for interrupts, clocks, configuration and operator control. The optional Direct I/O Interface also is controlled by the CP. A separate processor bus provides a centralized responsive communication link between clusters and the CP. Intercommunication proceeds independently of memory operation.



System Specifications

Memory Word Size	32 bits plus 1 parity bit per 8-bit byte
Memory Cycle Time	645 nanoseconds per word (full-cycle)
Memory Size	16,384 to 262,144 words
Memory Unit Structure	1 to 8 memory units
Memory Unit Size	16,384 or 32,768 words
Interleaving	modulo 2 between memory units
Number of Busses	one per processor cluster
Number of Ports	up to 6 per memory unit
Bandwidth per I/O Processor	up to 1 million bytes/sec
Number of Processor Clusters	up to 6 per system
Types of Processor Clusters	Basic Cluster I/O Cluster
Types of Processors	Basic Processor Multiplexer I/O Processor (up to 3 per I/O Cluster) System Control Processor

Basic Processor and System Control Processor

The Basic Processor of the Xerox 550 system contains an arithmetic and logic unit operating under microprogrammed control. Also included are four blocks of sixteen (64 total) general registers and the Memory Map. The System Control Processor is a centralized interface for controlling Basic Processor execution and synchronizing the operation of all processors.

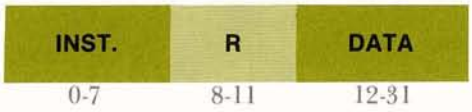
Instruction Format

Programming the sophisticated and powerful instruction set of the Xerox 550 is extremely straightforward. Only two instruction formats, Basic and Immediate are required. The Basic format is:

I = Indirect addressing flag (1 bit)
INST = Instruction code (7 bits)
R = General Register select (4 bits)
X = Index Register select (3 bits)
MEM = Memory address operand (17 bits)

The register block in use is accessed as the first 16 memory locations. As a result, no additional set of special register-to-register instructions is required. The resulting status of each executed instruction is automatically stored into the Condition Code Register. Use of this register greatly simplifies compare and branch operations. The 17-bit memory address field permits 131,072 words of memory to be addressed directly. Base registers are not required. The Memory Map allows this directly addressed area to be relocated, at the programmer's option, anywhere in physical memory.

Frequently, constants are required whose precision is considerably less than 32 bits. The Xerox 550 immediate format combines the memory address and index register fields into a single 20-bit data field. This format, illustrated below, eliminates the requirement for a second memory access.



Addressing

In addition to the word format, memory may be accessed in byte, half-word, and doubleword modes. When indexing is invoked, the index register automatically scales itself according to the size of the data involved. For example, if the selected index register contains a 27, an indexed Load Byte instruction automatically loads the 27th byte; an indexed Load Word instruction automatically loads the 27th word, etc. This permits a single index register to be used to access the Kth element of an array, regardless of the type of elements in the array, without the need to perform complex index register calculations.

Protection Modes

The Xerox 550 system makes available, when required by an application, the entire instruction set including context, interrupt, input/output, and memory management control. Programs permitted full access to instructions operate in the Master Mode. Since program security is extremely important in real-time applications, programs alternatively may be limited to one of two progressively more restricted instruction subsets, using either the Master-Protected or the Slave Mode. These modes prohibit programs from executing classes of instructions which may alter the overall operation of the Basic Processor. In the Slave Mode, no instruction may be performed which alters Basic Processor context.

Program Status Words

When the Basic Processor switches from one program to another or responds to

Basic Processor Specifications

Data Formats
- A short floating-point number with a 24-bit fraction plus sign and a 6-bit hexadecimal exponent plus sign.
- A long floating-point number with a 56-bit fraction plus sign and a 6-bit hexadecimal exponent plus sign.
- A signed 16-bit integer.
- A signed 32-bit integer.
- A signed 64-bit integer.
- A variable-length string of 8-bit bytes.
- An immediate operand, 20 bits including sign.

Operand Addressing Modes
- Direct
- Direct Indexed
- Indirect
- Indirect Indexed
- Immediate

Memory Access Modes
- Mapped (virtual)
- Unmapped (real)

Arithmetic Modes
- Fixed Point
- Floating Point

General Register Blocks
- Quantity — 4 blocks
- Number of registers per block — 16
- Number of indexable registers per block — 7
- Register size — 32 bits

Basic Processor Operation Modes
- Master
- Master-Protected
- Slave

Instruction Compatibility
- A compatible superset of the Sigma 5 and Sigma 9 Model 3 computer instruction repertoires.
- A compatible subset of the Sigma 6, 7,8,9 and Xerox 560 computer instruction repertoires.

Instruction Set

Load/Store Instructions

LI	Load Immediate
LB	Load Byte
LH	Load Halfword
LW	Load Word
LD	Load Doubleword
LS	Load Selective
LM	Load Multiple
LCH	Load Complement Halfword
LAH	Load Absolute Halfword
LCW	Load Complement Word
LAW	Load Absolute Word
LCD	Load Complement Doubleword
LAD	Load Absolute Doubleword
LCFI	Load Conditions and Floating Control Immediate
LCF	Load Conditions and Floating Control
LVAW	Load Virtual Address Word
LRA	Load Real Address
LAS	Load and Set
STB	Store Byte
STH	Store Halfword
STW	Store Word
STD	Store Doubleword
STS	Store Selective
STM	Store Multiple
STCF	Store Conditions and Floating Control
XW	Exchange Word with Memory

Fixed Point Arithmetic Instructions

AI	Add Immediate
AH	Add Halfword
AW	Add Word
AD	Add Doubleword
SH	Subtract Halfword
SW	Subtract Word
SD	Subtract Doubleword
MI	Multiply Immediate
MH	Multiply Halfword
MW	Multiply Word
DH	Divide Halfword
DW	Divide Word
AWM	Add Word to Memory
MTB	Modify and Test Byte
MTH	Modify and Test Halfword
MTW	Modify and Test Word

Comparison Instructions

CI	Compare Immediate
CB	Compare Byte
CH	Compare Halfword
CW	Compare Word
CD	Compare Doubleword
CS	Compare Selective
CLR	Compare with Limits in Register
CLM	Compare with Limits in Memory

Logical Instructions

OR	Or Word
AND	And Word
EOR	Exclusive-Or Word

Shift Instructions

S	Shift
SF	Shift Floating

Conversion Instructions

CVA	Convert by Addition
CVS	Convert by Subtraction

Push/Pull Instructions

PSW	Push Word
PLW	Pull Word
PSM	Push Multiple
PLM	Pull Multiple
PSS	Push Status
PLS	Pull Status
MSP	Modify Stack Pointer

Execute/Branch Instructions

EXU	Execute
BCS	Branch on Condition Set
BCR	Branch on Condition Reset
BIR	Branch on Incrementing Register
BDR	Branch on Decrementing Register
BAL	Branch and Link

Call Instructions

CAL1	CALL 1
CAL2	CALL 2
CAL3	CALL 3
CAL4	CALL 4

Analyze/Interpret Instructions

ANLZ	Analyze
INT	Interpret

Control Instructions

LPSD	Load Program Status Words
XPSD	Exchange Program Status Words
LRP	Load Register Pointer
MMC	Move to Memory Control
WAIT	Wait
RD	Read Direct
WD	Write Direct
LMS	Load Memory Status

Input/Output Instructions

SIO	Start Input/Output
HIO	Halt Input/Output
TIO	Test Input/Output
TDV	Test Device
AIO	Acknowledge Input/Output Interrupt

Floating Point Arithmetic Instructions

FAS	Floating Add Short
FAL	Floating Add Logic
FSS	Floating Subtract Short
FSL	Floating Subtract Long
FMS	Floating Multiply Short
FML	Floating Multiply Long
FDS	Floating Divide Short
FDL	Floating Divide Long

an external interrupt, the current context of the Basic Processor is assembled into two Program Status Words (PSWs), which may be stored anywhere in main memory. From another memory location, the new PSWs are obtained. A single instruction performs the entire exchange. The PSWs also indicate the general register block to be used. When new PSWs are loaded, the 550 will automatically select the proper register block.

Internal Interrupts and Traps

All interrupts input to the System Control Processor. External interrupts are reserved for use by the application programmers. The Xerox 550 system internal interrupts include processor fault, input/output, and console interrupts as well as four independent, programmable real-time clocks.

The 550 trap system is a powerful extension to the interrupts. Traps permit automatic detection and recovery from most programming errors without requiring alteration of the current execution priority. Four special traps, the CALL instructions, permit programs to request 550 control software services.

Memory Management

The Xerox 550 system, when used in conjunction with the Control Program for Real-Time (CP-R), utilizes main memory both flexibly and efficiently. Depending on application requirements, programs may address memory directly or, using the 550 Memory Map, relocatably. Directly-addressed memory areas are used for highly time-critical programs which constantly must be resident. Similarly, portions of CP-R itself are unmapped. Mapped memory areas offer comprehensive multiprogramming facilities, including dynamic allocation and deallocation of memory. Each access mode includes a comprehensive memory protection mechanism.

Memory Map

The Xerox 550 Memory Map improves memory allocation efficiency. Instead of a single continuum, mapped memory is organized into a series of discrete pages, each containing 512 words. For example, if a program's size requires four pages for execution, any four pages, together or separate, can satisfy this requirement. The Memory Map makes these pages appear contiguously addressed to the program. Mapping permits virtually addressed program execution independent of the fragmentation or the actual locations of these programs.

The Map contains 256 hardware relocation registers, each corresponding to a memory page. Mapping allows the 131,074 word direct addressing capability of the Xerox 550 instruction format to be relocated anywhere in physical memory. When a mapped program is dispatched for execution, CP-R loads the Map registers necessary to correspond the program's virtual and physical page locations, permitting the program to execute using contiguous virtual addresses.

Among the benefits of the mapped memory environment are:

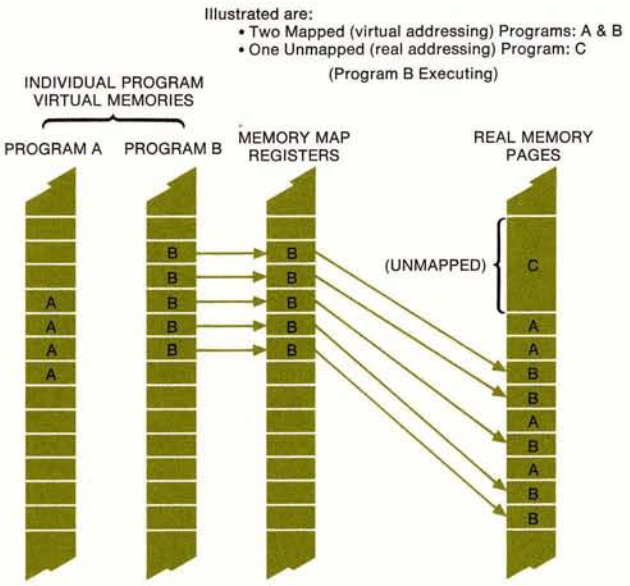
- Multiprogramming does not require either fixed memory partitions, base registers, or software rebiasing.
- Programs that have been temporarily rolled out to disk storage need not be rolled in to the same set of pages.
- The classic memory fragmentation problem is solved automatically. Dynamic allocation is greatly simplified, and memory never needs repacking.
- Reentrant programs may be shared using separately-mapped data areas. Context-saving stacks are not required.

Memory Protection

The Xerox 550 system features two levels of memory protection. Access protection for all mapped programs is incorporated into the Map. Each memory page may be specified for:

- Free access
- Read and execute access only
- Read access only
- No access

Example of 550 System Memory Management



When programs access memory directly (not using the Map), each memory page is protected by a write lock containing a 4-bit code. To write into a page, a program must be executing with a proper write key.

Input/Output Capabilities

At the heart of the Xerox 550 real-time system is its responsive, powerful I/O system. The 550 can process simultaneously six classes of input/output. Together, these capabilities can satisfy the most demanding real-time interfacing requirements.

External Interrupts

The external interrupts provide a highly responsive facility for synchronizing computation with external events. When an interrupt is triggered, testing for arm, enable, and inhibit conditions and queing for execution are performed automatically by the hardware. A unique memory location is reserved for each interrupt. As a result, when an interrupt becomes active, additional identification processing is not required. External interrupts are input to the 550 System Control Processor.

Direct Input/Output Interface

The Direct Input/Output Interface (DIO) provides a flexible and straightforward interface optimized for discrete data acquisition and control. DIO transfers are performed directly by programs. The Read Direct and Write Direct instructions permit 32-bit data word transfers between Basic Processor general registers and external devices via a bi-directional bus. An additional 16-bit address bus permits multiple devices to be attached to the DIO bus. The DIO Interface is an option which, when included in a system, resides in the System Control Processor.

Multiplexer Input/Output Processor

Each Multiplexer Input/Output Processor (MIOP) permits multiple peripheral

devices to simultaneously access main memory. All MIOP data transfers occur independently of Basic Processor computation. The 550 system may include up to sixteen MIOPs, six of which optionally may interface to both 550 peripheral devices and Xerox Sigma-series peripherals. The first MIOP and Sigma-series adapter is included as standard in the Basic Cluster. This MIOP shares with the Basic Processor the bandwidth of a common memory bus. However, the two processors function independently of each other. Additional MIOPs optionally may be added, three per Input/Output Cluster. One Sigma-series adapter may also be included in each Cluster.

Direct Memory Processor

When an application requires a specialized interface permitting extremely rapid transfers directly to memory, the Xerox Custom Systems organization can supply real-time interfaces which attach directly to a memory port. Such Direct Memory Processors offer the highest bandwidth available in a 550 system.

External Control Subsystem

Operator control communications are managed by the External Control Subsystem (ECS). The ECS permits the Xerox 550 system to perform the functions of both conventional processor control panels and consoles by providing centralized control of both hardware and software from a single point in the system. The ECS resides in the System Control Processor. The ECS also provides a Remote Assist connection for remote control and access of the system via a communication link.

Input/Output Specifications

External Interrupts	
Maximum Number	48
Increment Quantity	12
Interrupt States	Armed Enabled Waiting Active Inhibited
Triggering Methods	External Internal
Direct Input/Output Interface	
Data Bus	32 bits bi-directional
Address Bus	16 bits
Multiplexer Input/Output Processor	
Maximum Number of Channels	16 multiplexed channels 14 multiplexed channels for Basic Cluster MIOP
Maximum Nominal Bandwidth	1 megabyte/sec.
Direct Memory Processor Capability	
Maximum Number of Processors	4 multiplexed processors
Maximum Nominal Bandwidth	1.35 megawords/sec.

Peripherals

The wide range of Xerox 550 peripherals permits a close match between specific peripheral device capabilities and application requirements. Most conventional low- and medium-speed peripherals are attached to an MIOP. Peripheral controllers communicate to the MIOP via a multiplexed I/O bus. Each MIOP is configured so that all peripheral controllers may concurrently access main memory. Controllers for the fixed-head and cartridge disk drives, for the disk pack drives, and for the medium and high-speed magnetic tape transports may optionally operate with dual-access. The MIOP peripherals are:

Line Printers
300 LPM
700 LPM
1250 LPM

Card Equipment
200 CPM Reader
400 CPM Reader
1500 CPM Reader
100 CPM Punch

Magnetic Tape Transports
45 IPS, 800 & 1600 BPI
75 IPS, 800 & 1600 BPI
125 IPS, 800 & 1600 BPI

Disk Drives
2.88 Megabyte head-per-track RAD (Rapid Access Device)
755 Kilobyte/sec. transfer
8.5 Millisec. av. total access time

5.7 and 11.4 Megabyte cartridge disks
312 Kilobyte/sec. transfer
50.5 Millisec. av. total access time

49 Megabyte disk pack drive
312 Kilobyte/sec. transfer
47.5 Millisec. av. total access time

Message-Oriented Communication Equipment

Character-Oriented Communication Equipment

Most analog and digital interfacing requirements may be satisfied with standard, modular components. Peripheral devices are attached to either the MIOP, or the Direct Input/Output (DIO) Interface, and are supplied with standard handlers and diagnostic software.

Real-Time Interfaces
The digital and analog input/output interfaces can attach to either the DIO, the MIOP, or both.* Included are:

Digital Input/Output Controller
Standard Interface Modules
Photo-Isolated Interface Modules
Conditioner Modules

Analog Input Controller
Converters
Low-Level Multiplexers
High-Level Multiplexers
Sample-and-Hold System

Analog Output Controller
Channel Converters
Distributor Converters

Frequency Control Unit
Manually-Selected Frequencies
Programmably-Selected Frequencies

System Control Unit
Microprogrammable, Intelligent Preprocessor.

*Software for these real-time interfaces is available from the Xerox Exchange Program Library. Software for the System Control Unit may be obtained from the Xerox Custom Systems Organization.


Low-Speed Tape


Medium-Speed Disk Drives

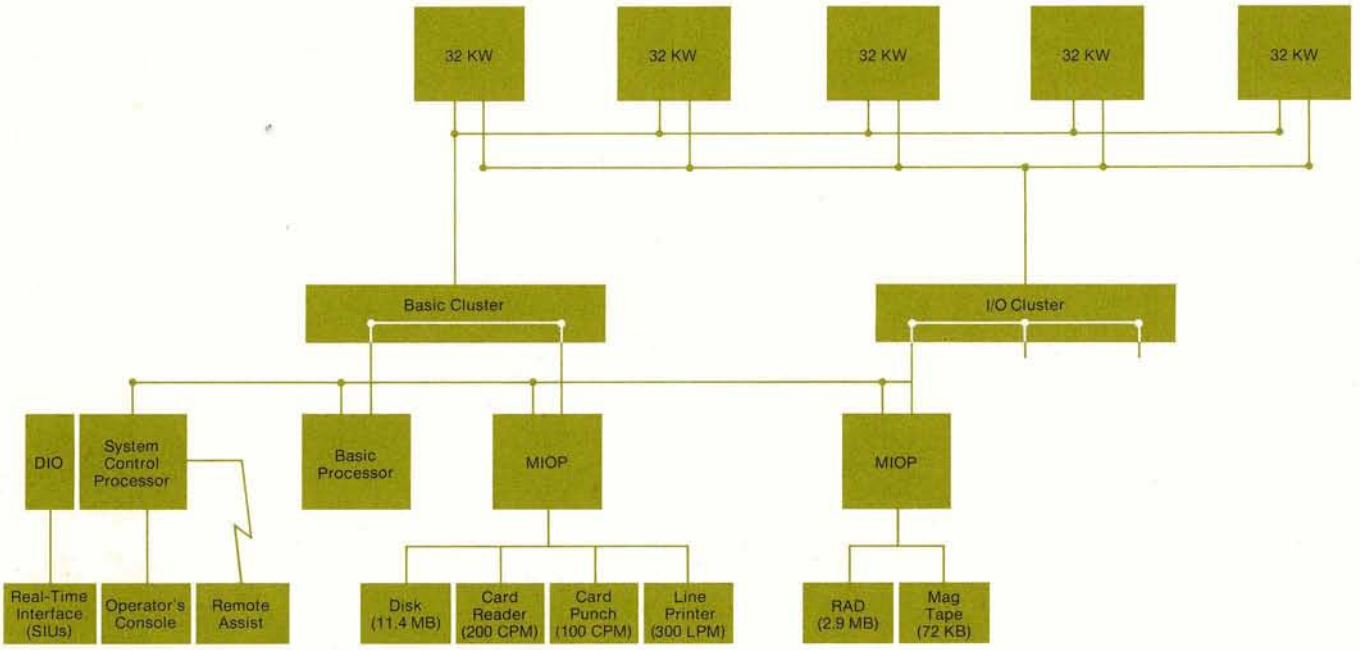

Line Printer


Low-Speed Card Reader


Card Punch


Cartridge Disk/RAD

Typical Xerox 550 System Configuration



Includes 4 register blocks, memory map, memory protection, 4 real-time clocks, power fail safe, internal priority interrupts, floating point arithmetic

Software

The Xerox 550 computer operates under the Control Program for Real-Time (CP-R). CP-R is a sophisticated control system capable of satisfying a wide range of time-critical programming requirements while concurrently performing terminal operations and processing batch-oriented background jobs. CP-R is designed to exploit the capabilities of the Xerox 550 system and is a compatible superset of the Xerox Real-Time Batch Monitor (RBM). CP-R is a RAD/disk-oriented system that utilizes the Xerox 550 Memory Map to provide optimum memory management for both real-time and batch uses. The Map permits programs to execute using virtually contiguous addresses while being fragmented physically into available memory areas.

CP-R supports three modes of processing:

- Multiple primary real-time (foreground) programs
- Multiple secondary real-time (foreground) programs
- Background processing from a single batch stream

Primary real-time programs (tasks) are connected to and scheduled by hardware interrupts and typically have a response time of less than 100 microseconds. Secondary real-time programs are software scheduled in a multitask environment, and operate in the mapped mode. Batch programs, also mapped, execute during periods not required for foreground processing and are scheduled as the lowest priority secondary task.

Features

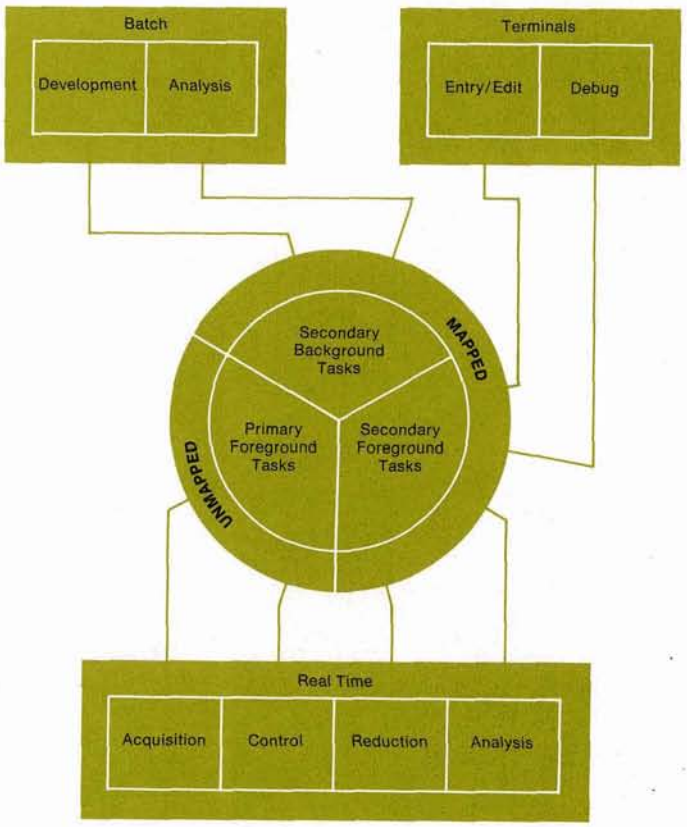
CP-R is a true multitasking real-time system incorporating sophisticated features valuable to a wide variety of real-time and batch users. Among these capabilities are:

- MULTIPROGRAMMING — Support is provided for up to 32 jobs (one background).
- MULTI-TASKING — Support is provided for up to 255 tasks.
- DYNAMIC REAL MEMORY MANAGEMENT — CP-R provides services to manage pools of dynamic real memory among primary and secondary real-time tasks.
- TASK SCHEDULING — Primary tasks are scheduled through the external interrupt structure of the 550 System Control Processor. Secondary tasks are priority scheduled and dispatched at multiple dispatcher levels upon the completion of I/O, logical events, wake-up, and timer intervals, or upon demand by other foreground tasks.
- INTERTASK COMMUNICATION — Services are provided for foreground tasks to communicate directly through CP-R service calls, through shared files, and through shared segments between tasks.
- COMPLETE MEMORY PROTECTION — All secondary (including background) tasks are isolated virtually through memory access protection as established by the Memory Map. Primary tasks are protected by the memory write locks.
- ROLL-IN/ROLL-OUT — All secondary tasks, unless they request to be "locked" in memory, may be rolled out by CP-R to make room for higher priority tasks.
- MAPPED PUBLIC LIBRARY MANAGEMENT — Public Library routines may be shared between primary tasks (unmapped) or between secondary tasks (mapped). For mapped public library management, all user (task) dependent data areas are mapped into the virtual memory assigned to each task so that reentrancy overhead is almost eliminated and data protection between tasks is assured.
- FILE MANAGEMENT — CP-R provides for dynamic cataloging of files (allot and delete) and also for file sharing through enqueue/dequeue services. All files are addressed by name and can be read or written in several modes: Compressed, Sequential, and Random.
- DEVICE INPUT/OUTPUT — CP-R input/output may be either device-dependent or device-independent. The user may refer to I/O devices by symbolic designators or by I/O device address in order to perform I/O. All I/O services are FORTRAN callable.
- INPUT/OUTPUT QUEUEING — All input/output requests are queued on the basis of task priority as opposed to first-in/first-out (FIFO).
- SYMBIONT INPUT/OUTPUT — The optional symbiont facilities provide disk-spooled I/O for Xerox card readers and line printers concurrent with batch job processing. Flexible operator controls assure efficient management and utilization of these peripheral devices.
- MEDIA CONVERSION ROUTINES — These routines, such as card-to-tape and tape-to-printer, are optional under CP-R and operate concurrently with the batch and symbiont facilities, adding significant flexibility to scheduled operations.
- DEBUG SERVICE — The Debug Service program can be used to debug either primary or secondary tasks and to set breakpoints, snapshots and dumps. These features are available from local and remote terminals. Multiple programs may be debugged concurrently from separate terminals.
- TERMINAL JOB ENTRY — Remote terminals may be concurrently connected through a communications subsystem for purposes of job entry, program development, editing and debugging.
- RMA FACILITIES — Advanced Reliability, Maintainability, and Availability facilities (including error logging, dump analysis, on-line exercisers, and improved maintenance and control features) assure superior system integrity.

- PROGRAM INITIATION — Programs can be either resident or non-resident (called into execution from the disk). They are initiated by the operator, by request from the batch job stack, by a terminal, or by other real-time programs. They may be restarted from a suspended (wait) state by other tasks, by external events, by I/O completion or by a real-time clock.
- REENTRANT ROUTINES — Reentrant CP-R service routines and sharable in-core public libraries eliminate the need for duplicate copies of frequently utilized routines.
- FORTRAN PROCESSOR — Xerox Extended FORTRAN IV is a three-pass compiler that is a superset of ANS FORTRAN X 3.9. Extended FORTRAN IV incorporates many features not found in other FORTRAN processors. Features include: bit manipulation functions, compiler-generated reentrant code, reentrant real-time library, and in-line assembly language coding.
- ASSEMBLY PROCESSOR — The Xerox Assembly Program (AP) is a four-phase macro assembler. AP allows recursive procedures, conditional coding to govern assembly, arithmetic and Boolean operators, and updating of source program during assembly.

CP-R provides a broad spectrum of real-time and batch capabilities. The accompanying diagram summarizes these capabilities and relates them to a typical division of CP-R task and memory management services. These services permit system designers to closely match processing requirements with appropriate CP-R facilities. Resulting systems maximize efficiency and throughput while effectively operating in time-critical environments.

CP-R Processing Capabilities



Reliability/Maintainability/Availability

Comprehensive Reliability, Maintainability, and Availability (RMA) capabilities are critically important to the success of real-time systems. The 550 system incorporates extensive RMA capabilities which have been designed along system concepts. Contributing to the total RMA capability of the Xerox 550 system are:

- Hardware reliability features including microdiagnostics
- Redundant configuration capabilities
- On-line monitoring by CP-R®
- Diagnostic Programming System
- Remote Assist

The combination of the above features permits the Xerox 550 system to have a high inherent reliability, to assist in diagnosing possible malfunctions, and to be repaired rapidly.

Hardware Reliability

High reliability is inherent in Xerox 550 hardware. The 550 system is constructed using LSI, MSI, and microprogramming techniques which allow, for example, the entire Basic Processor to reside on only 12 circuit boards. As a result, the hardware has relatively few cables and interconnects, items which historically have been a major source of system malfunctions.

The Xerox 550 hardware incorporates extensive error detection and reporting capability. Error detection is performed by all processors and memory units. Error detection features include:

- Date transmissions between units (processors, memory units, controllers, and peripherals) include parity information which is checked by the receiving unit.
- Memory units include error detection by various parity and operational checks.
- Register blocks include parity bits with the stored data. Parity is generated

at the time the data is being written into the register. Data is checked upon read out.

- Control memories include parity bits which are stored with the appropriate data. Parity error detection permits checking of much of the control logic in the system.
- Control sequence errors are detected for special situations. Mutually exclusive control terms simultaneously active, or undefined operations, may be detected.
- Critical system problems are detected such as power failures or over-temperature.

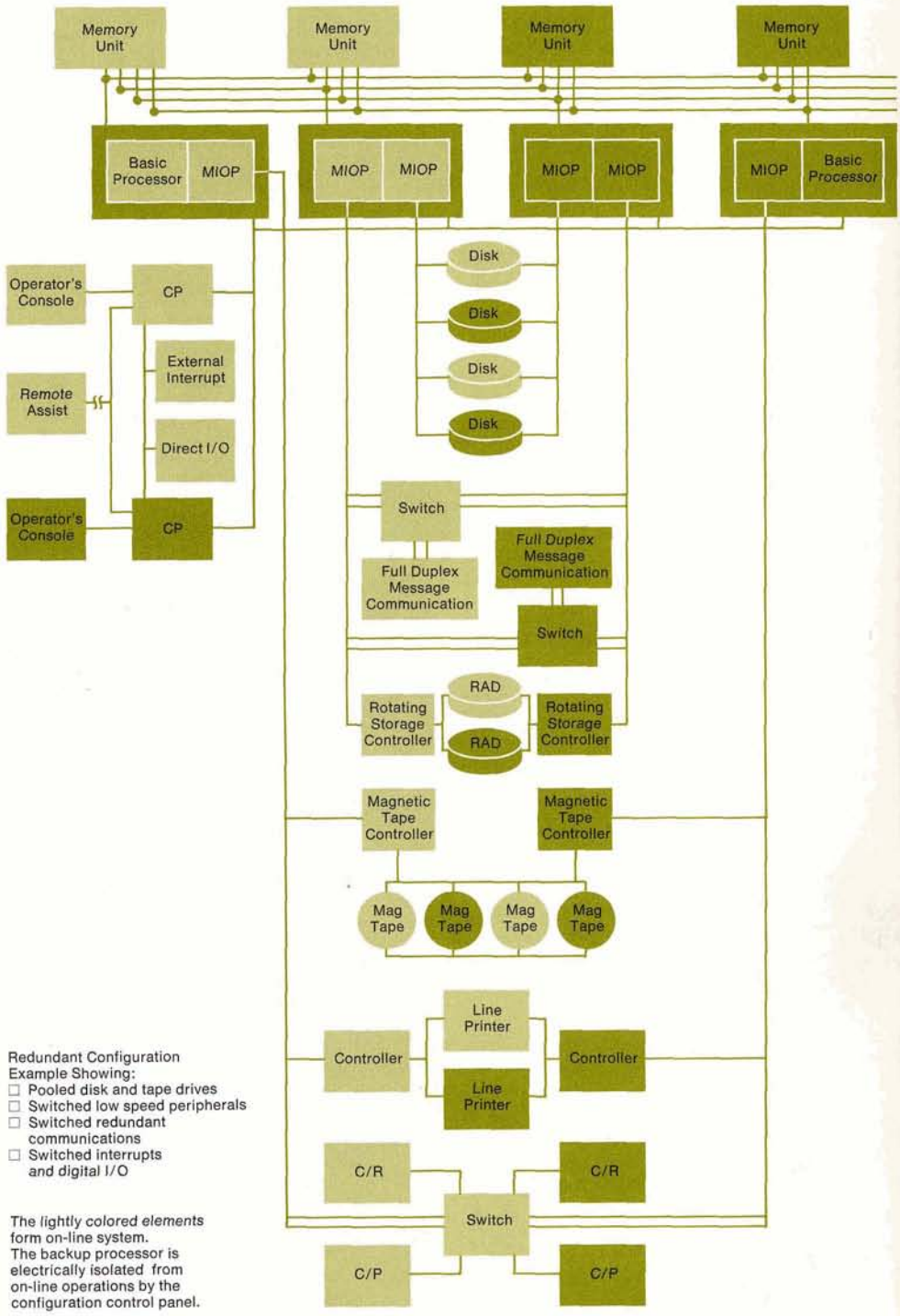
The Basic Processor will automatically attempt instruction retry whenever possible after detecting an error. The input/output processors detect errors in the processors themselves and in device controllers, adapters, and peripheral devices. Detected memory unit errors include data, address, and protection errors as well as hardware malfunctions. The Watchdog Timer assures non-stop operation of the processor, memory, and DIO busses by automatically timing the execution of all Basic Processor instructions.

Each processor and memory unit contains a status register in which information about a detected error is stored. These registers may be read by the diagnostic programs. When errors or timeouts are detected, the System Control Processor also is automatically notified using either an internal interrupt, a trap, or a condition code setting. Even if a reported error is recoverable and processing continues, the occurrence will be output to the CP-R error log.

Redundant Configuration Capabilities

For applications requiring computer system availabilities greater than those possible with a single computer, the Xerox 550 may be configured redundantly. Then, when one computer is

Redundant Configuration Example



Redundant Configuration Example Showing:
- ☐ Pooled disk and tape drives
- ☐ Switched low speed peripherals
- ☐ Switched redundant communications
- ☐ Switched interrupts and digital I/O

The lightly colored elements form on-line system. The backup processor is electrically isolated from on-line operations by the configuration control panel.

unavailable during preventive maintenance or a malfunction, the other can continue the processing. Depending on the required total availability, a 550 system can include some or all of the following redundancy capabilities:

- Redundant Basic Processors
- Redundant Input/Output Processors
- Redundant System Control Processors
- Shared Main Memory
- Backup Operator's Console
- Pooled RAD, Disk and Magnetic Tape Peripherals
- Switched Unit-Record Peripherals
- Switched Digital and Analog Interfaces

The Configuration Control Panel (CCP) provides a central control for configuring and partitioning processors and memory. Included are such services as memory starting address control, memory port disable, memory interleave control, and processor unit address control. When operating in a redundant environment, the CCP permits preserving the on-line system's integrity by electrical partitioning while making possible rapid reconfiguration of a back-up system should a malfunction occur. Because of the inherent power partitioning of the Xerox 550 system, isolated processors and memory units may be individually powered-down without affecting on-line operation.

Diagnostic Programming System

The Diagnostic Programming System (DPS) is a comprehensive, off-line error detection and isolation facility. A stratified fault isolation strategy is used permitting identification of system, processor, unit, and module faults. Starting with the most basic level of operation, the DPS verifies each phase of system operation before proceeding to test the next. Operation of the DPS is controlled at the operator console or via the Remote Assist facility. Maintenance operations are

augmented by the System Control Panel which provides additional status displays. The testing hierarchy of the DPS begins with three hardcore tests:

- MICRODIAGNOSTICS HARDCORE TEST A microprogrammed test sequence is incorporated into the Basic Processor control memory. Data registers, transfer paths, control logic, and the access to main memory are tested. The test is automatically activated during the load sequence.
- ROM HARDCORE TEST After successful completion of the microdiagnostic hardcore test, a read-only memory (ROM) hardcore test is automatically performed. A micro-sequence will cause the transfer of a diagnostic from the ROM in the Basic Processor to main memory. This program tests the instructions used by the Software Hardcore Diagnostic, the I/O data paths via the I/O turnaround feature (permitting input/output processors to be exercised in a closed-loop mode), and the instructions to be used by the hardware bootstrap loader.
- SOFTWARE HARDCORE TEST The Software Hardcore test is the first diagnostic program that is loaded via the I/O hardware. This diagnostic further checks out Basic Processor and memory operation.

The following functional diagnostics are run under control of the Diagnostic Monitor and the Load-and-Go Software Processor. These programs execute after the successful completion of all hardcore tests and use only the facilities tested by the hardcore sequence.

- System Control Processor and Processor Interface Diagnostic
- Basic Instruction Diagnostic
- Multiple Word and Convert Instruction Diagnostic
- Memory Diagnostic
- Priority Interrupt Diagnostic
- Input/Output Processor Diagnostic
- Extended Arithmetic Diagnostic
- Map and Access Protect Diagnostic

After all the elements of the system have been tested individually, the System Exerciser program operates these elements simultaneously. An attempt is made to approach the system failure threshold. After validating system operation, peripheral diagnostics are then selectively executed.

On-Line Monitoring by CP-R

CP-R incorporates a comprehensive on-line RMA capability which streamlines maintenance activities and improves system availability. Included in these capabilities are error logging, device isolation, on-line verification, shut-down procedures, and error analysis. Many of these services are available to both user personnel and Xerox service representatives. As a result, the user can be a highly effective factor in maximizing system availability.

Error Log and Analysis

The error log, stored on a disk file, is used by CP-R to record processor, memory and I/O errors. This information assists in determining specific hardware and software error sources. In addition, analysis of recoverable errors may permit scheduling maintenance prior to actual stoppage, thus increasing availability by reducing unscheduled downtime.

Device Isolation

Malfunctioning peripherals can be isolated from the system by the operator. This capability is especially useful for marginally-functioning devices which may be causing intermittent problems. While the peripheral is being diagnosed or repaired, CP-R can operate any programs not requiring the isolated device. Since program I/O is device-independent, devices can be reassigned without altering the programs that use them. After the peripheral fault has been corrected, the on-line exerciser can be used to verify proper operation.

Device Verification

The device exercisers perform readiness verification tests on isolated peripherals. Each exerciser tests the functional performance of a device without interfering with the on-going operation of CP-R. Recoverable errors are entered in the error log. Non-recoverable errors are reported to the operator's console for further maintenance attention.

System Shut-Down

In the event of a system failure, CP-R will isolate the system from its external environment, institute a smooth shut-down, and provide specific information about the possible cause of the failure.

Remote Assist

The Remote Assist facility provides each Xerox 550 system with a remote-troubleshooting communication link to a Xerox Field Engineering Center. This interface is independent of any other communication equipment. Using Remote Assist, a Xerox Customer Engineer can assist with operator problems; debug software; control the operation of CP-R; run verification programs; run off-line diagnostics; and operate the system exerciser — all without actually visiting the 550 installation site.

Remote Assist aids in detecting and identifying defective components. Before visiting an installation, the Xerox Customer Engineer can usually determine which replacement parts are required. As a result, machine availability can be significantly increased.

Applications

Hundreds of Xerox real-time systems, installed with applications similar to those shown here, have established Xerox as the leader in real-time computing. The 550 system further extends Xerox's broad range of capabilities. Whether you are solving everyday requirements or charting new application frontiers, Xerox should be on your team.

Energy Management
Generation Control
Network Monitoring
Economic Analysis
Service Dispatch
Facility Simulation

Communications
Store-Forward Message Switching
Remote Information
Retrieval and Update
Remote Data Display
Data Concentration
Order Entry
Data Collection

Telemetry
Data Conversion
Data Editing
Data Compression
Data Quality
Data Display

Radar
Precision Tracking
Target Identification
Impact Prediction
Coordinate Transformation

Industrial
Process Control
Process Monitoring
Automatic Testing and Checkout
Environmental Control
Accounting
Inventory Control
Traffic Monitoring and Control
Transportation Control

Simulation
Aircraft and Missile Simulation
Pilot Training
Fire Control Officer Training
Direct Digital Control
Test Report Generation
System Analysis and Parameter Optimization
Hybrid Computation

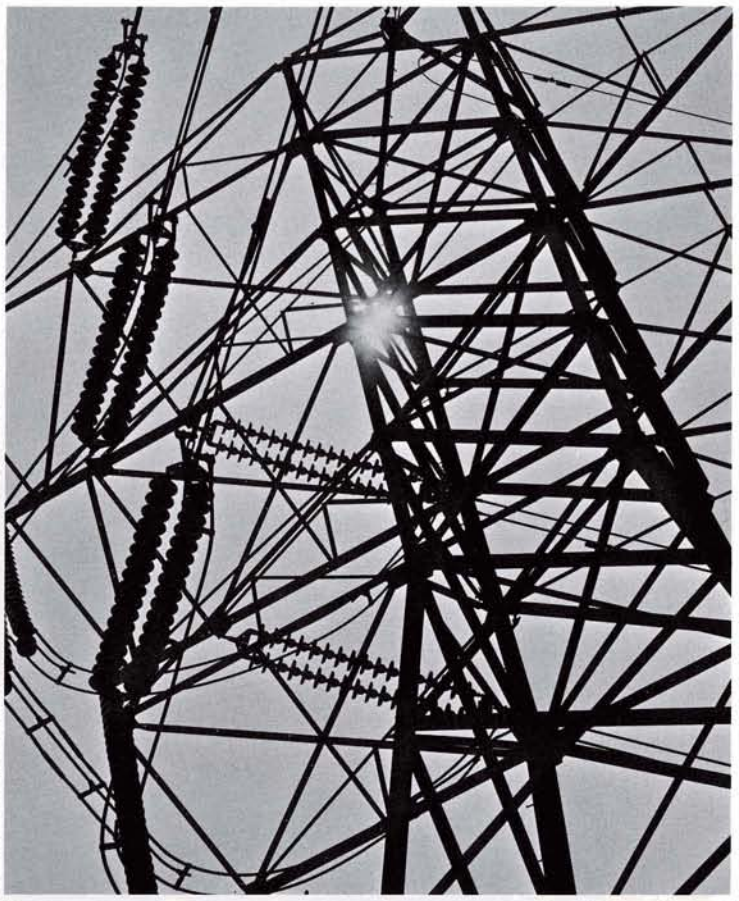
Nuclear Physics
Reactor Monitoring
Film Scanning
Pulse Height Analysis
Spark Chamber Data Analysis
Instrument and Reactor Control

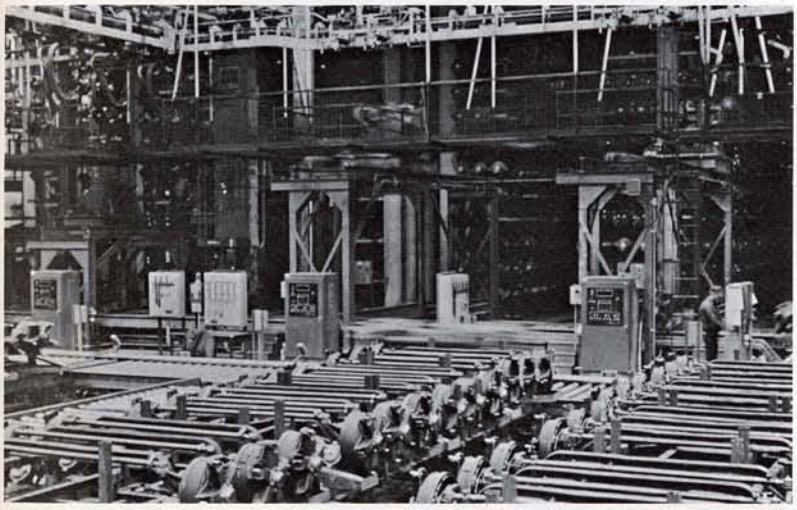
Analytical and Scientific Laboratories
Gas and Liquid Chromatography
Mass Spectrometry
X-Ray Diffractometry
Nuclear Magnetic Resonance Spectroscopy

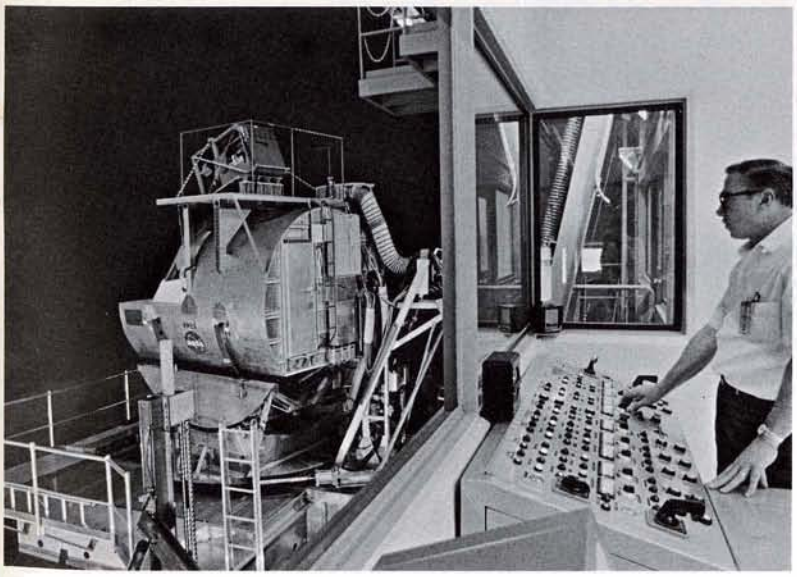
Scientific and Engineering Processing
Data Acquisition
Circuit Design and Analysis
Statistical Analysis
Control Applications

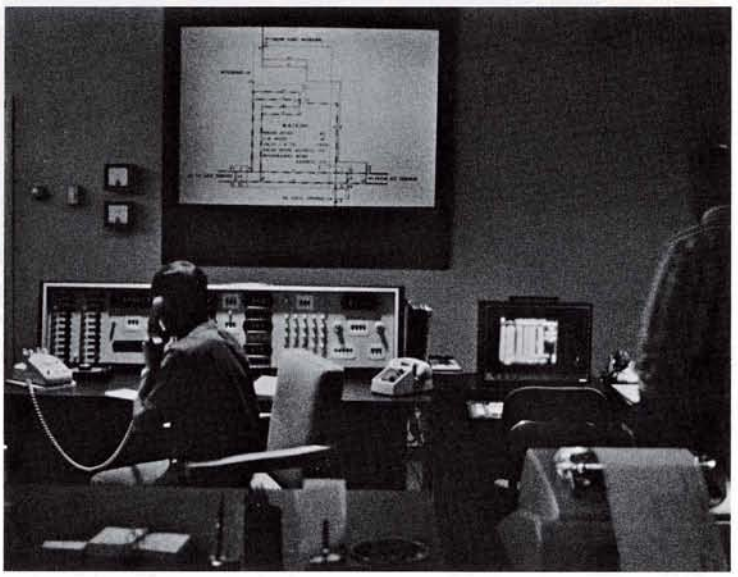
Health Care
Physiological Monitoring
Clinical and Research Laboratory Computerization
Analysis of Mathematical Models
ECG Analysis

Education
Teaching of Computer Sciences
On-Line, Real-Time Monitoring and Control of Laboratory Experiments
Student Use in Solving Homework Problems









Support Services

Custom Systems

The Xerox Technology Centers can assist both end-user, OEM and reseller customers in adapting standard Xerox products to specialized applications.

Successful real-time systems require more than a highly efficient systems-oriented computer; they need hardware and software capable of interfacing the computer with specialized input/output devices, and capable of dealing with many kinds of information formats. In developing such systems, the degree of Xerox Technology Center involvement is negotiable on any specific contract; however, there are definite advantages to the customer in allowing Xerox to take single-source, turnkey responsibility for the entire system. These advantages include highest performance standards, greater confidence in the implemented solution, lower operational and maintenance costs, maximum system availability, and prevention of premature obsolescence.

Application Services

Xerox Application Services has proved, with years of indepth experience, that conversion can be accomplished efficiently and cost-effectively in a prespecified length of time. Many of our customers have taken advantage of these services because Xerox:

- Provides off-site systems and computer support dedicated solely to conversions.
- Performs on-line programming and testing using highly effective and efficient language translators and media conversion aids.
- Commits to contract specifications on a fixed-task, fixed-price basis.
- Supports either complete or partial systems design.

Thus, the flexible approach, the efficiency gained from indepth experience, and predictable schedules and pricing make it possible for Xerox to reduce conversion and systems design to an easily controlled process that allows you to realize the full benefits of Xerox computers.

Other Services

All too frequently the computer vendor's extensive pre-sales support seemingly evaporates after the sale is made. It won't after a Xerox computer is delivered. Customer support and corporate maturity have become synonymous with the Xerox name. In addition to the services described above, support from Xerox includes:

- On-going application analyst services
- Field engineering support
- Field engineering software analyst services
- Complete documentation
- Software program library
- Software update distribution
- Customer hardware education
- Customer software education

The key member of the computer support team is the Xerox marketing representative. In addition to assisting in the selection of Xerox computer products and services, he is the customer's personal representative in all matters related to achieving maximum utilization from his computer systems.

EXCHANGE — The Xerox Computer Users' Group

The Xerox Computer Users' Group was formed for the purpose of affording representatives of companies that own or lease Xerox computers an opportunity to exchange technical knowledge and experience with their counterparts in other companies.

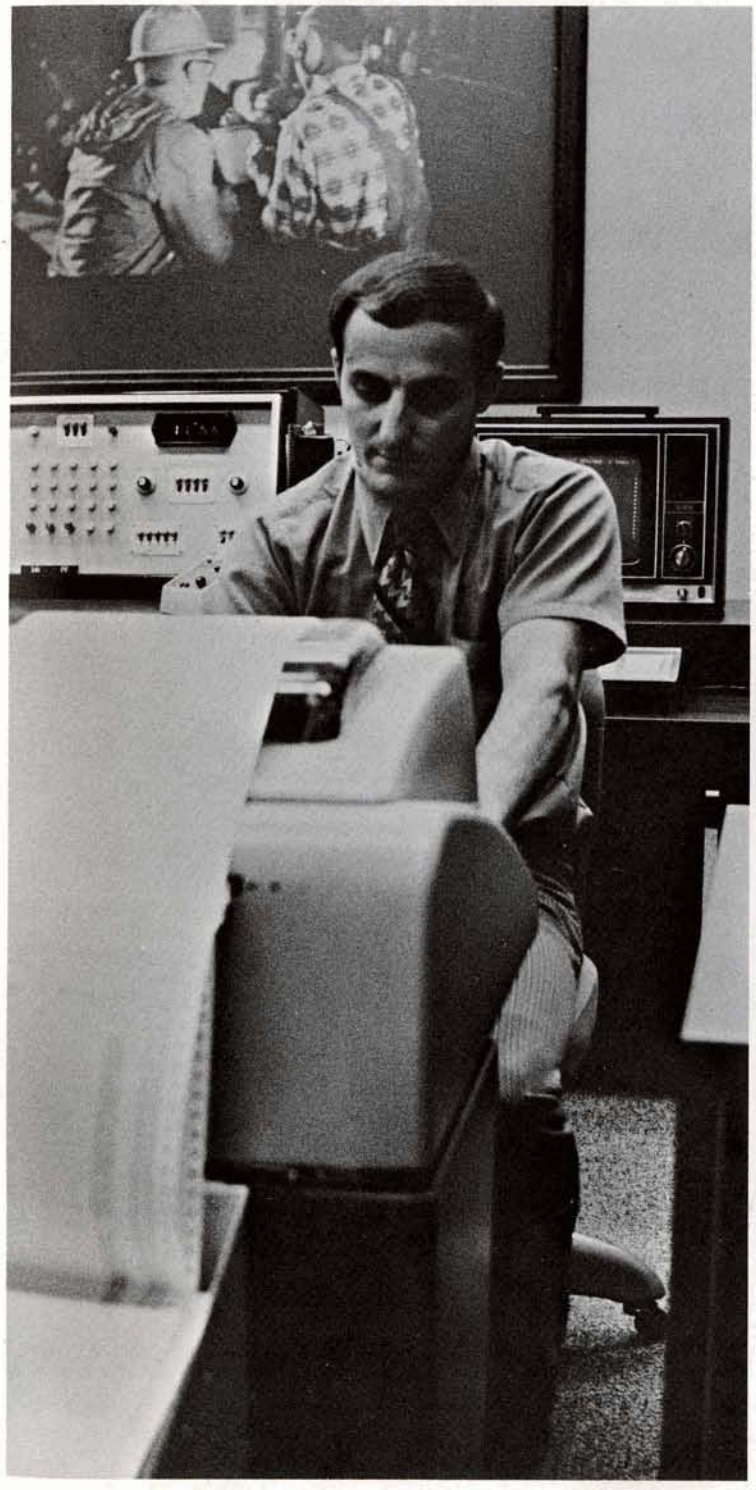
The organization today serves as a formal information exchange for representatives of many different companies. Membership in the group offers many benefits — most of which are inherent in the following major goals of the Xerox Computer Users' Group:

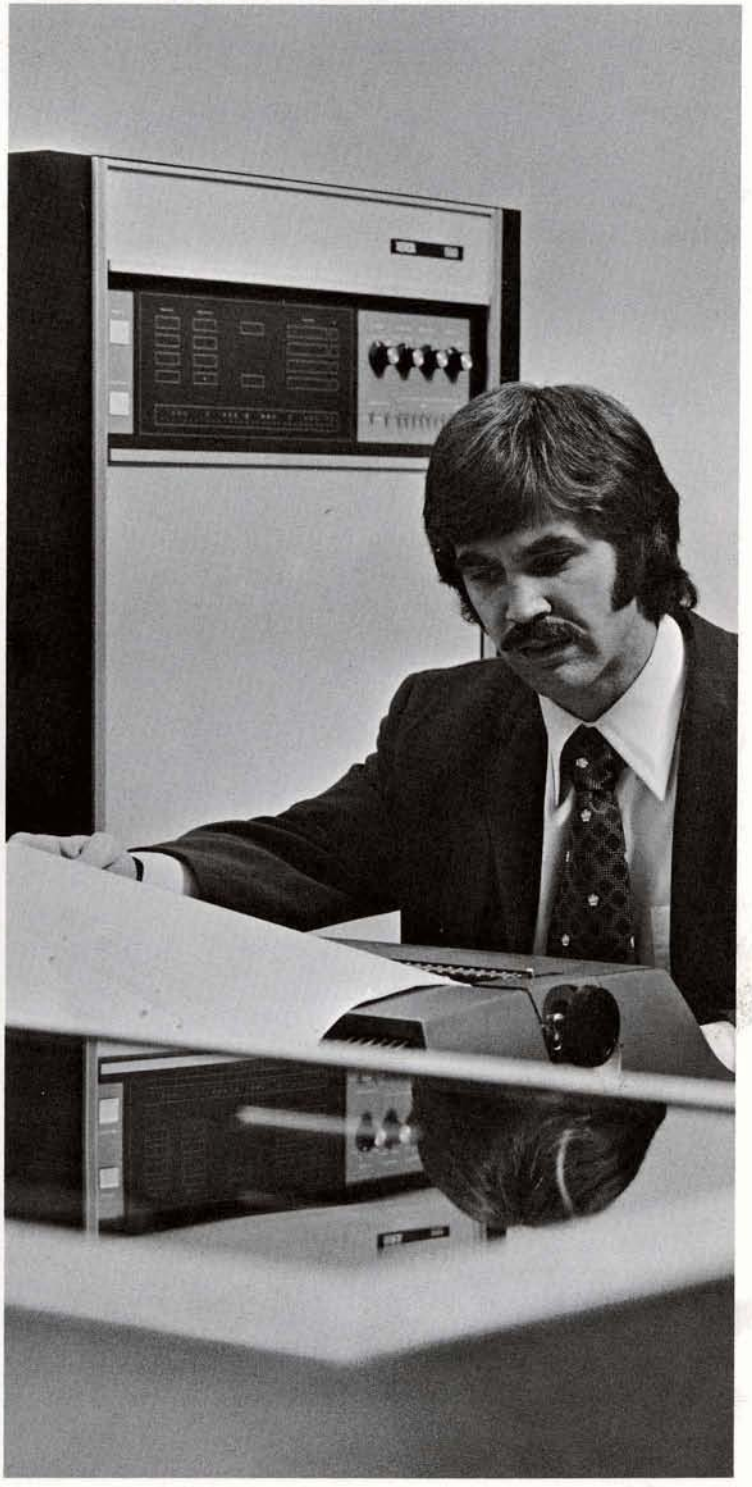
- To advance the science of information processing through mutual education and interchange of ideas
- To reduce redundant effort among machine users in the preparation of computer programs
- To establish standards and to provide channels to facilitate the exchange of relevant information
- To provide feedback to Xerox pertaining to equipment and programming needs

Benefits

Some of the benefits of this professional interchange, more specifically, are:

- USERS' GROUP PROGRAM LIBRARY — Membership in the Users' Group allows a company to obtain programs from the program library at no charge.
- PUBLICATIONS — As a part of the continuous effort to keep members well informed, Xerox publishes the USER NEWS every other month.
- GENERAL, SEMI-ANNUAL MEETINGS — The international meetings are normally held in the spring and fall each year.
- EXECUTIVE BOARD — In order to ensure that the Users' Group remains active between meetings, the Executive Board meets to determine policy and implement decisions of the Group.
- INTEREST GROUPS AND COMMITTEES Several general and special interest groups and committees assist the Executive Board in conducting the business and implementing the goals of the Users' Group.





Xerox 550 Specification Summary

Memory	
Memory Capacity	16,384 to 262,144 32-bit words
Memory Cycle Time	645 nanoseconds
Memory Word Size	32 bits plus 4 parity bits
Maximum Number of Memory Units	8
Number of Memory Ports	6
Basic Processor	
General Registers	64 in 4 blocks of 16
Data Formats	Doubleword Word Halfword Byte
Memory Access Modes	Unmapped (Real addressing) Mapped (Virtual addressing)
Memory Map Page Size	512 words
Number of Pages	256
System Control Processor	
Internal Interrupts	14
Maximum number of external interrupts	48
Clocks	4

Input/Output Capabilities	
Maximum number of MIOPs	16
Number of channels per MIOP	16
Nominal maximum MIOP bandwidth	1 megabyte/sec.
Typical Instruction Execution Times (microseconds)	
Load Immediate	1.51
Load Word	1.72-1.94 (min-max.)
Store Word	2.37-2.80
Branch (Yes)	1.29
(No)	1.72
Logical AND	1.72-1.94
Add Immediate	1.51
Add Word (Fixed)	1.72-1.94
Multiply Word (Fixed)	6.23
Add Word (Floating)	6.13 (typical)
Multiply Word (Floating)	9.14 (typical)

XEROX

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