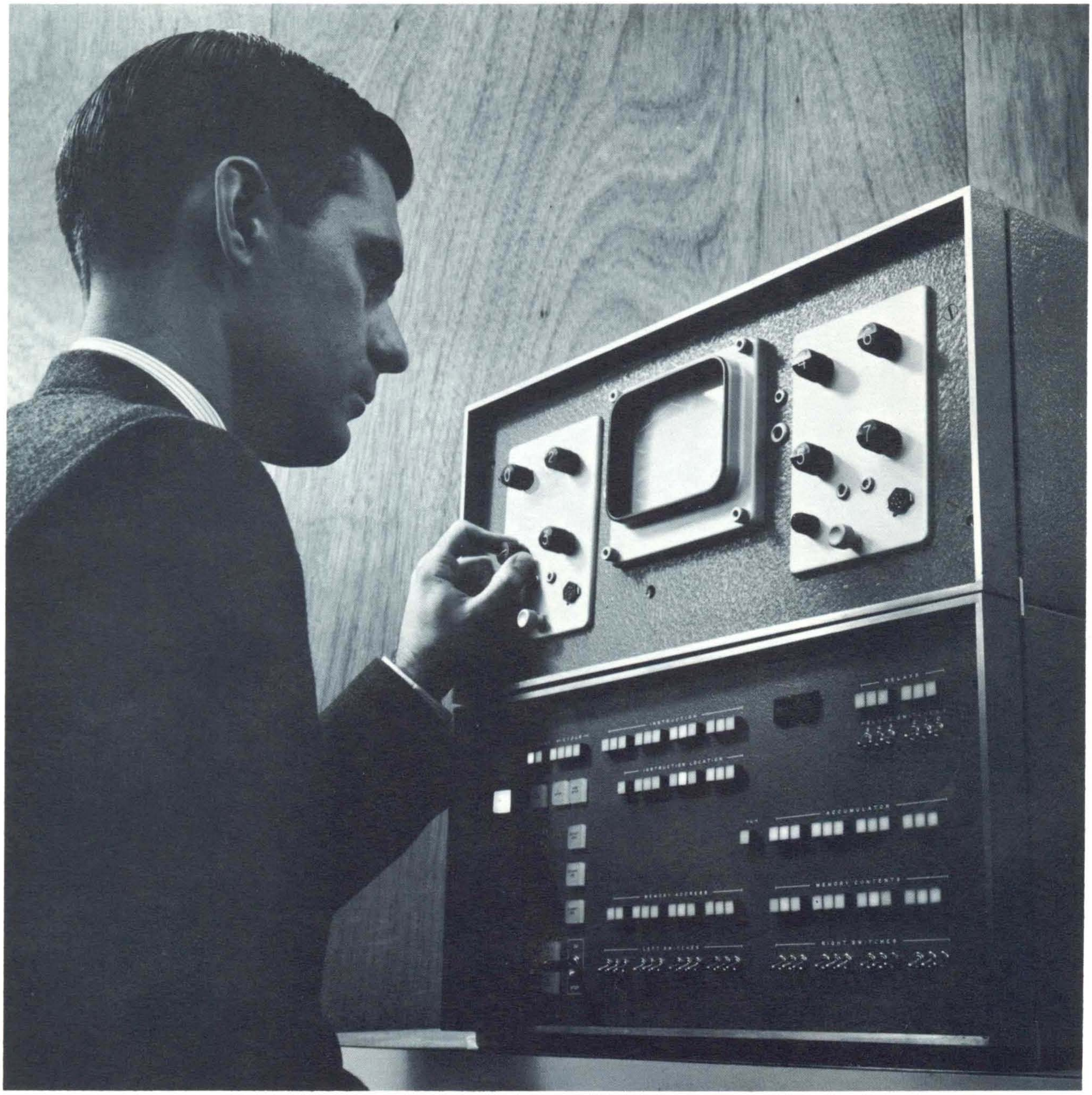
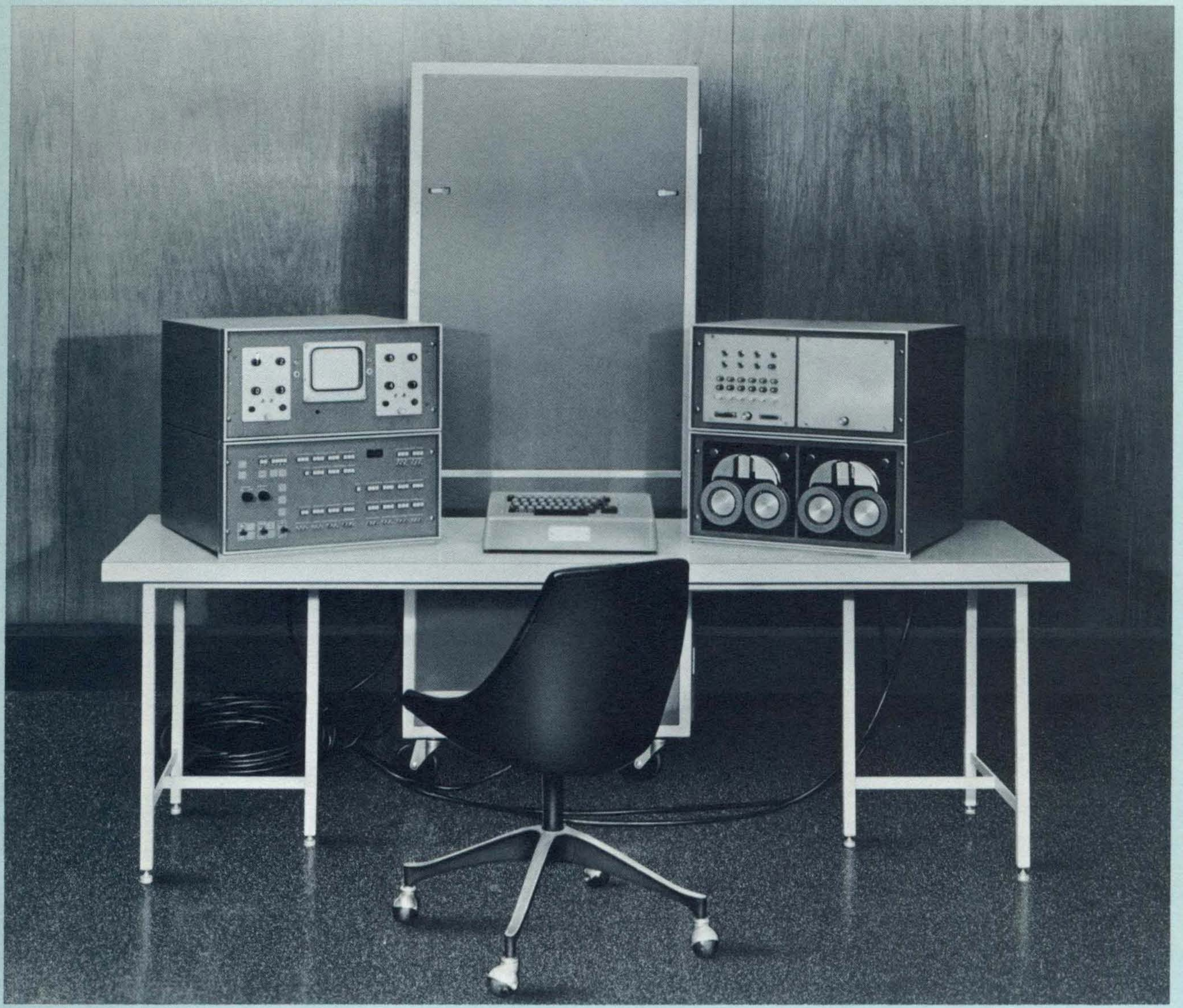


# LINC

*. . . the Laboratory Instrument Computer developed specifically for biomedical research, now made and sold by Digital Equipment Corporation.*

DIGITAL EQUIPMENT CORPORATION • MAYNARD, MASSACHUSETTS



## LINC SPECIFICATIONS

LINC is designed with the laboratory in mind. Where space is limited, any or all of the four operator modules — Console, Terminal, LINC Tape, and Display — can be readily moved to an operator's station up to 30 feet away. The electronics cabinet can then be rolled on built-in casters out of the immediate working area. All the usual operations are controlled at the modules, which can be placed on a table or mounted in an equipment frame. One operator module occupies just over two square feet of bench area.

*Basic Specifications*

| | |
|---|---|
| Word length | 12 bits |
| Arithmetic | 1's complement |
| Memory | 2048 words, 8 microseconds |
| Instructions | 48, including high-speed multiply, half-word, mag tape |
| Input channels | 16 analog. Converts a voltage to an 8-bit digital number and stores it in memory at a rate of about 30,000 per second<br>4 digital, 12-bit. Transfer rate, 125,000 words per second max |
| Output channels | 2 analog for displays and plotters<br>2 digital, 12-bit<br>6 sets relay contacts (DPDT)<br>16 digital pulse lines |
| Power requirement | 1000 watts, 115 volts |

*Standard System*

Console Module — for numerous controls and indicators

Terminal Module — front panel connections for I-O

Display Module — mounting one oscilloscope and controls

LINC Tape Module — containing LINC dual transport

Keyboard — for information input

Electronics Cabinet — containing the central processor and associated circuits

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# LINC ...... *AT WORK IN BIOMEDICAL LABORATORIES*

The range of LINC's usefulness is suggested by the following applications. The work described was done with LINC in various existing installations.

*ARTERIAL SHOCK WAVE MEASUREMENTS* — Comparative hydrodynamic measurements were made in the ventricular cerebro-spinal system in order to determine the dissipation and attenuation factors in shock waves attributable to the arterial pulse. The computer program was designed to work directly with amplifier signals from strain gauges.

*IN-PHASE TRIGGERING OF STIMULI FROM EEG ALPHA WAVE* — Simple criteria were applied to portions of EEG signals to identify and mark the occurrence of rhythmic bursts of alpha activity, and to trigger stimuli which were phase-related to the alpha wave.

*RESOLVING A SUM OF DECAYING EXPONENTIALS* — In a problem of compartmental analysis, a sum of decaying exponential signals was resolved into its individual components by displaying the logarithm of the waveform being analyzed and fitting a straight line to portions of the resulting curve. Using the parameter knobs on the computer, the experimenter adjusted the slope and position of a straight line, also displayed to get the best fit to the data. The component thus determined was subtracted from the original waveform and the process repeated with the remainder until all of the components were resolved.

*CURSOR PROGRAM* — An experimental curve stored in core memory was displayed on the scope along with an adjustable cursor mark. This cursor designated a desired point on the curve and its location was controlled by a parameter knob. The amplitude of the point under the cursor was displayed numerically on the scope.

*PROCESSING OF SINGLE-UNIT DATA FROM THE NERVOUS SYSTEM* — Programs have been written to determine, from micro-electrode recordings, the times at which single neurons fired, and to calculate the distribution of intervals between successive firings. These programs can also be used to determine the distribution of firing times following the presentation of a discrete stimulus.

*AVERAGING OF ELECTROPHYSIOLOGICAL RESPONSES* — Acoustical stimuli were presented to an animal and the computer averaged cortical and thalamic responses. The averaged responses, as well as information relating to the variability of the responses, were immediately displayed and automatically stored on magnetic tape for later detailed examination.

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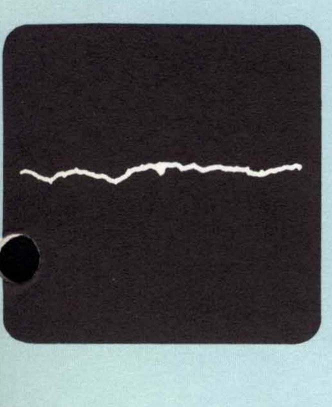
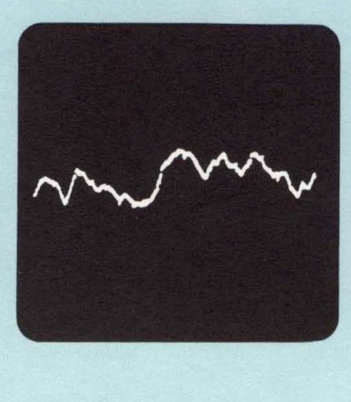
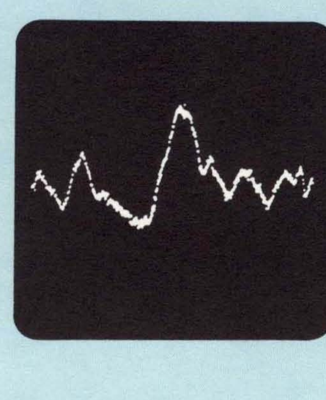
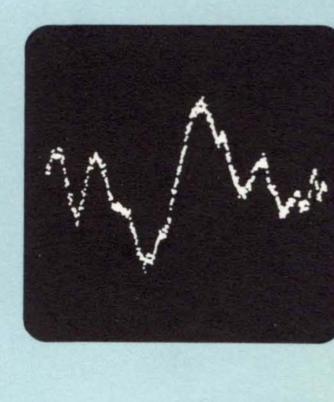

## INSTRUCTIONS

The LINC order code is built on nine basic functions, as shown in the list that follows. Instruction times are multiples of the memory cycle, 8 microseconds. Add, for example, is a two cycle instruction requiring 16 microseconds. High speed multiply (about 120 microseconds) is built into the computer.

### ADD

add to accumulator
add to memory
add link to memory

### MULTIPLY

multiply

### LOAD

load full register
load half register

### STORE

store the accumulator
store and clear the accumulator
store half the accumulator

### SHIFT/ROTATE

rotate left
rotate right
scale right

### OPERATE

halt
clear accumulator
no operation
complement accumulator
bit clear (any of 12 bits)
bit complement (any of 12 bits)
bit set (any of 12 bits)
set register n to contents of register Y
jump to register Y

### SKIP

Skip the next instruction if:
accumulator equals register Y
left half of accumulator does not equal
left half of register Y
sense switch n is set
accumulator is cleared
accumulator contains a positive number
link bit equals zero
an external level is present
key has been struck
least significant bit of register Y equals
zero tape between blocks
unconditional skip

### INPUT — OUTPUT

accumulator to relay buffer
relay buffer to accumulator
sample analog to digital converter
display point on oscilloscope
display character on oscilloscope
read console switches
generate output pulse
read keyboard
read digital input to memory
read digital input into accumulator
read out of memory to a device
pause

### LINC TAPE

read and check one block
read and check consecutive blocks
read tape
check sum
move either direction towards next block
write and check one block
write and check consecutive blocks
write gate
write

## SAMPLE PROGRAM

An example of the use of LINC instructions is shown in the following short program, part of a common averaging technique. Typically, responses of a subject to repeated stimuli are averaged to minimize irrelevant signals and bring out the significant response curve. In this example, $100_8$ points on an incoming waveform are sampled $100_8$ times each, and the totals stored in $100_8$ memory locations. This routine assumes that overflow will not occur. To complete the averaging, each total would then have to be divided by $100_8$.

```
SAM   0110   /SAMPLE AND CONVERT
                CHANNEL 10
      1140
ADM   0100   /ADD AND STORE
      0220
XSK   0022   /INDEX STORAGE LOCATION
      1000
LDA   0022   /LOAD ADDRESS OF
                STORAGE LOCATION
      1460
SAE   0200   /SAMPLED 100 POINTS/
JMP   6020   /NO, SAMPLE NEXT POINT
      1620   /YES, START OVER
BSE   0100
STA   1040
      0022
XSK   0220
      1001   /INDEX COUNTER
SAE   1440   /CONVERTED 100 TIMES/
      1001
JMP   6020   /NO, CONTINUE
HLT   0000   /HALT
```

## LINC'S DEVELOPMENT

LINC (for Laboratory Instrument Computer) was developed specifically for biomedical research under grants from the National Institutes of Health. Development began at Massachusetts Institute of Technology and is continuing at Washington University in St. Louis. Over twenty LINC's have been installed in various laboratories throughout the country and have been operating for a year or more. These machines were assembled using parts from various suppliers, with Digital's System Modules making up the major part of the electronic circuits.

Digital's LINC is the same instrument, assembled, tested, warranted for six months of operation, and field-supported by Digital's service organization. Equipment used with earlier LINC's will operate on Digital's LINC without modification. Programs written for earlier LINC's are completely compatible with Digital's new product.

## BASIC ADVANCE IN RESEARCH INSTRUMENTATION

LINC is essentially a small, general-purpose digital computer equipped with devices and logical circuits particularly suited to biomedical research. It brings many advantages of digital processing into the laboratory where experiments are performed.

LINC controls, processes, displays, and stores data under the research worker's guidance. LINC presents him with visual experimental results for direct inspection and simultaneous photographing as the raw data is coming in. LINC allows him to detect trends and perhaps alter the course of the experiment as it progresses. Data for final evaluation is prepared at computer speeds.

In short, LINC has the capability not only to perform tasks usually assigned to assistants and to various special purpose devices, but also to render services not previously available to the research worker.

## DESIGN FOR RESEARCH

LINC was designed for use by the biomedical research worker in his own laboratory. Programs are prepared in simplified symbolic language, and they are assembled automatically by LINC. Controls, indicators, and connectors for laboratory equipment are front-mounted within easy reach. A built-in oscilloscope presents words, numbers, and graphical displays of incoming or processed data. Data or processed results are stored directly on magnetic tape in pocket-sized reels.

Other characteristics that make LINC a highly effective aid to medical research are:

*COMPACT SIZE* — LINC is small enough so that the responsibility for administration, operation, programming, and maintenance can be assumed by the individual research worker or small laboratory group.

*FLEXIBILITY* — Front-panel connectors and built-in conversion equipment allow direct connection of LINC to many kinds of laboratory apparatus, such as amplifiers, timers, transducers, plotters, and peripheral digital equipment.

*VERSATILITY* — LINC is fast enough for simple data processing while the experiment is in process, and logically powerful enough to perform complex calculations afterward.

## MULTI-PURPOSE SYSTEM

The capabilities of LINC can be brought to bear on virtually any laboratory problem for which the research worker can prepare a program, or set of logical steps corresponding to the experimental procedure or analysis. Each new type of experiment can be handled by simply preparing a new computer program, which can be inserted in the computer in a few seconds without need for altering the equipment. Research time is spent on the problem itself, not in searching for special equipment for each different application.

LINC performs several of the functions that external devices or people are normally required to perform. Data recording, analog-to-digital conversion, experiment monitoring, control, and analysis are built-in capabilities of the computer. Specifically, LINC gives direct assistance to the research worker in the following ways:

*Generates* stimuli under program control
*Converts* analog responses to digital numbers
*Controls* stimuli in relationship to responses
*Processes* responses for on-line monitoring
*Displays* responses before or after processing
*Stores* data on high-density magnetic tape
*Extracts* stored data selectively for observation
*Calculates* distributions, correlations, histograms, etc.

One of the most significant benefits arising from these capabilities is that LINC can compress or expand data, both in time and physical volume, process it into observable form, and display or store it at controlled speeds. By contrast, conventional laboratory equipment, while able to detect and record sufficient amounts of data, may be incapable of presenting it to the investigator in a useful or recognizable form.

digital

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