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Title- LSI-UNIX System

Date- October 6, 1976

TM- 76-1352-4

Other Keywords- UNIX
Operating Systems
Personal Computer
Intelligent Terminal


| Author(s) | Location and Room | Extension |
|---|---|---|
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Charging Case- 39394

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## ABSTRACT


A modified version of the UNIX operating system has been written to run on the LSI-11 microcomputer with 20K words of primary memory and floppy discs for secondary storage. This configuration permits most of the UNIX user programs to run on the LSI-11 microcomputer. The main programming language used is the structured higher-level language C. A background process as well as foreground processes may be run. A set of subroutines have been written to interface to the file system on the floppy diskettes. Asynchronous read/write routines are also available to the user.

The LSI-UNIX System (LSX) has appeal as a stand-alone system for dedicated applications. It also has many potential uses as an intelligent terminal system. The decreasing costs of hardware make such a system a potential candidate for a very powerful and inexpensive personal computer system.


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Subject: LSI-UNIX System - Case 39394-11

date: October 5, 1976

from: H. Lycklama

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MEMORANDUM FOR FILE

## 1. Introduction

The LSI-11 microcomputer (1) marketed by DEC has a number of potential applications in Bell System projects. Its instruction set is compatible with other members of the PDP-11 family of computers. A modified version of the UNIX operating system (2) has been written to run on the LSI-11 microcomputer with 20K words of primary memory and floppy disks for secondary storage. This configuration permits most of the UNIX user programs to run on the LSI-11 microcomputer. The main programming language used is the higher-level structured language, C (3). The operating system (called LSX) allows a background process as well as foreground processes.

The fact that a minimum system can be configured for about $7000 makes the LSI-UNIX system an attractive stand-alone system for dedicated applications such as control of special hardware. The system also has appeal as an intelligent terminal.

This document describes some of the objectives of the LSX system as well as some of its more important features. Its capabilities are compared with the powerful UNIX time-sharing system which runs on the PDP-11/40, 11/45 and 11/70 computers, where appropriate. A number of current and planned applications are described in some detail. A summary and some thoughts on future directions are also presented.

## 2. Why UNIX on a Microprocessor?

Why develop a microprocessor-based UNIX system? The hardware costs of a computer system have come down substantially over the last few years (even over the past few months). Microprocessors on a chip are a reality. The cost of primary memory (e.g. dynamic MOS memory) is decreasing rapidly as 4K-bit chips are being replaced by 16K-bit chips.

There exists a large amount of expertise in PDP-11 hardware interfacing. The similarity of the Q-bus of the LSI-11 microcomputer to the UNIBUS of other members of the PDP-11 family of computers makes this expertise available.

The cost of software development has been ever increasing, thus dominating the total cost of a computer system. The operating system developed for the LSI-11 microcomputer supports most of the UNIX user programs which run under UNIX time-sharing (4), even though LSX is a single-user system. Thus most of the software for the system is already available, minimizing the cost of software development.

It is conceivable that in the next 5 years or so the power of a mini-computer system will be available in a microcomputer. It will become possible to allow a user to have a dedicated microcomputer rather than a part of a mini-computer time-sharing system. LSX is a step in this direction. This will give the user a cost effective interactive and powerful computer system with a known response time to requests, since the machine is not time-shared. A dedicated one-user system can be made available to guarantee "instantaneous" response to requests of a user. There are no unpredictable time-sharing delays to deal with. The system has applications in areas where security is important. A user can gain access to the system only in the room in which the system resides. It is thus possible to limit access to a user's data.

Local text-editing and text-processing features are now available. Other features can be added easily. Interfaces to special I/O equipment on the Q-bus for dedicated experiments can be added. The user then has direct access to this equipment. Using floppy disks as secondary storage gives the user a rather small data base. A link to a larger machine can provide access to a larger data base. Interfaces such as the DLV11 (serial interface) and the DRV11 (parallel interface) can provide access to other computers.

One of the main benefits of using the UNIX software base is that the C compiler is available for writing application programs in the structured higher-level language, C. The use of the powerful command interpreter (sh) is also a great asset. A general hierarchical file system is available.

The LSX system has two main areas of application:

(1) control of dedicated experiments
(2) intelligent terminals.

As a dedicated experiment controller, one can interface special I/O equipment to the LSI-11 Q-bus and both support and control the experiment with the same LSX system. The applications as an intelligent terminal are many-fold:

(1) development system
(2) general text-processing applications
(3) form editor
(4) two-dimensional cursor-controlled text editor.

Communication to a larger machine for occasional file transfers is desirable.

## 3. Hardware Configuration

The hardware required to build a useful LSI-UNIX system is minimal. The absolute minimum pieces required are:

LSI-11 microcomputer (with 4K memory)
16K memory (e.g. dynamic MOS)
EIS chip (extended instruction set)
Floppy disk controller with one drive
DLV11 serial interface
Terminal (e.g. TTY-33)
Power supply.

A more flexible and powerful system is shown in Figure 1. Here a floppy disk controller with up to 4 drives is shown. Another serial or parallel interface is often useful for connection to a larger machine that provides software support. The terminal used for the system may be either a TTY-33 teletype or an inexpensive CRT terminal. Various types of memory (core, MOS or RAM) are available either from DEC or outside vendors (16K boards are available (5)). The floppy disk controller may be bought either from DEC ( no DMA capability) or from an outside vendor (with DMA capability (6)). We have chosen to build our own floppy disk controller (one controller per disk (7)) for some special Bell System requirements. DEC floppy diskettes are formatted according to IBM standards. The comparative data for the various floppy diskettes are as follows:

| | DEC | Dept 1352 | AED Floppy |
|---|---|---|---|
| sector size (bytes) | 128 | 512 | 512 |
| sectors per track | 26 | 8 | 16 |
| number of tracks | 77 | 77 | 77 |
| total capacity(bytes) | 256256 | 315392 | 630784 |
| DMA capability | no | yes | yes. |

The outside vendor (AED Systems) supplies dual-density drives for an increase in storage capacity.

If necessary, a bus extender may be used to interface special devices to the Q-bus. One such device that we have interfaced to the Q-bus is a special-purpose TV terminal with cursor-control and user-labelled buttons (8). Applications of this terminal are discussed in later sections. Other systems are interfacing special signal-processing equipment to the Q-bus. As DEC provides more of the

interfaces to standard I/O peripherals, the applications will no doubt expand.

## 4. LSI-UNIX Capabilities

The LSX operating system is written in the C language and as such bears a strong resemblance to the multi-user UNIX system developed for the PDP-11/40, 11/45 and 11/70 computers. The total system occupies 8K words of memory and has room for only 6 system buffers. Because the C compiler itself requires up to 12K words of user address space, it is possible to run the C compiler using only 20K words of total memory. It is possible to increase the system size if more capabilities are required in the operating system since the total memory space available to the system and user is actually 28K words. More system buffers could be provided in the system. If the system is kept to 8K words, a 20K word user program could be run. However, this requires more swap space, which is at a premium.

The system is a single-user system with only one process running at any one time. However, a process may fork up to two levels deep, giving rise to a total of three active foreground processes. The last process forked will run to completion first. "Pipes" are not supported in the system, but pseudo-pipes are supported in the command shell. This is accomplished by expanding the shell syntax "|" to "> ._pf;< ._pf". Providing that sufficient disk space exists, the pipe implementation is transparent to the user.

The hierarchical file structure of UNIX is maintained. However there is no read/write protection on files. File protection is strictly the user's responsibility. The user is essentially given super-user permissions. Only execute and directory protection is given on files. Group id's are not implemented. File system space is limited to the capacity of the diskette in use. Each file system is only able to contain 96 files (i.e. six inode blocks each). The list of available inodes is not dynamically created by the system, but is created when the file system itself is created or salvaged. The system automatically mounts a user file system on a second diskette if so desired. The "mount" and "unmount" commands are not available to the user. Thus a reboot of the system is necessary to mount a new user diskette. The system diskette is normally configured with swap space and temporary file space. User programs and files may reside on the system diskette if a user diskette is not mounted.

The size of memory available and the lack of memory protection (i.e. memory segmentation unit) have put some restrictions on the capabilities of the LSX operating system. However these are not severe in the single-user environment in

which the system is run. Profiling is not provided in the system. Timing information only becomes available if a clock interrupt is provided on the LSI-11 event line at 60 times per second. Only one character device driver is allowed at present as well as only one block device driver. No raw I/O is provided for. There is also no read-ahead on file I/O. Only 6 system buffers are provided and the buffering algorithm is much simpler than in UNIX. All user programs must be relocated to begin execution at 8K in memory. This required modifications to the UNIX link edit (ld) and debugger (db) programs. Most other differences between LSX and UNIX are transparent to the user.

## 5. Background Process

It is possible to run a background process on LSX while running a number of foreground processes to get some concurrency out of the system. The background process is run only while the current foreground process is in an input wait state. Two new system calls have been added to LSX, "bground" and "kill", to enable the user to run and remove a background process. Only one background process is allowed to run and it is not allowed to fork another child process; however, it may execute another program. The background process may be either compute-bound or perform some I/O functions, such as outputting to a hard-copy terminal.

## 6. Stand-Alone Routines

Under LSX it is possible to run a dedicated program (<12K words) in real time using all of the conveniences of the UNIX system calls to communicate with the file system. For programs which require more than 12K words of memory or which require more flexibility than provided by the LSX system, a set of subroutines have been written to provide the user a UNIX-compatible interface to the file system without using the LSX system calls (9). A user is given more control over his program. Disk I/O issued by the user is buffered using the read-ahead and write-behind features of standard UNIX. A much greater number of system buffers are provided than is possible in the LSX system. Eight of the standard file system interface routines are provided. The arguments required for each routine and the calling sequence are identical to those required by the UNIX system C-interface routines. These include: read, write, open, close, creat, sync, unlink and seek. Three unique routines: saread, sawrite and statio are provided to enable the user to do asynchronous I/O directly into buffers in the user's area rather than into system buffers. These additional routines allow a user to start multiple I/O's to/from multiple files concurrently, do some computation and then wait for completion of a particular outstanding I/O transfer at his convenience. A 'load' program under LSX enables the

user to load his stand-alone program which must start execution at location 0 in memory.

## 7. A Development System

One system disk has been configured to contain a fairly complete program development system. The development programs include:

editor
assembler
C compiler
link editor
debugger
command interpreter
dump program

as well as a number of libraries which contain frequently used routines for use by the link editor. It is thus possible to compile, run and debug application programs completely on-line without access to a larger machine. In a typical application, the contents of the system disk remain quite stable, whereas all user programs are maintained on a permanently mounted user diskette. For minimal systems it is possible to run with only one diskette. Due to the lack of protection, it is possible to crash the system. However in practice, the use of the higher-level language C minimizes the number of fatal bugs which actually occur, since the stack frame and program counter are quite well controlled.

In our particular installation, it is often convenient to use the satellite processor system (10) to aid in the running and debugging of new user programs. This is possible since programs running in the LSI-11 satellite microcomputer behave as if they are running on the central machine with access to its file system. This emulates the environment on LSX quite closely. Thus a program may be compiled on a central machine supporting the C compiler, run on the LSI-11 microcomputer and debugged. When the program has been completely debugged, it is possible to load the program onto the floppy file system using the stand-alone routines (described in section 6) and the satellite processor system. The program may then be run under LSX.

## 8. Text Processing System

Another area of application for the LSX system is as a personal computer system for text processing. Files may be prepared using the editor and run off using the UNIX nroff command with a hard-copy device. This system disk includes programs such as:
editor

cat output ascii files
pr print ascii files
od octal dump files
roff
nroff
neqn mathematical equation formatter

The file transfer program referred to in the previous section enables one to transfer files to/from a machine with a larger data base. A user's files may be maintained on his personal mounted diskette. If a hard-copy device is attached to the computer as well as the user's interactive terminal, hard-copy output can be obtained using a background process while editing another file in the foreground.

## 9. Form Editor Program

Another area of application for which LSX seems well-suited is for the entry and retrieval of data records by computer-naive users. We have available an intelligent terminal(8) which has some advanced features particularly suitable for this application. It has scrolling capabilities, cursor control and user labelled buttons below the TV screen. The buttons can be used for cursor positioning as well as other dedicated functions defined by a user program. This terminal is well-suited for the input of data into computer-displayed forms. Protected fields are implemented in software rather than in hardware as for the TTY40 terminal. A general-purpose form entry program has been written for this terminal (11). Another program 'mkform' is available to enable a user to compose a form on the TV screen interactively. The form is then used with the 'fentry' program to create, update and delete entries in a data base whose record structure depends only on the structure of the form but is independent of the 'fentry' program. The LSX system provides the underlying support and file system for these programs. The programs are designed to be very easy to use for computer-naive users.

## 10. Two-Dimensional Scope Text Editor

The TV terminal described above is also well-suited for a two-dimensional text editor. The interactive two-dimensional cursor control features allow one to move the cursor anywhere on the face of the TV screen. The editor available on the UNIX system has some very powerful features. It is desirable to use these in the scope editor as well. Therefore the scope editor features have been imbedded in the existing UNIX text editor. Thus the user is capable of going back and forth between the standard UNIX editor features and the additional scope editing features. The labels on the buttons below the TV screen tell the user what mode he is in and what functions are available to him.

Complete cursor control is available. A window into the file being edited is displayed on the TV screen. The user has the ability to insert, remove and replace a character at the current cursor position or delete the remainder of the line to the right of the cursor on a per line basis. The user may also insert or delete whole lines or break a line in two. Block deletes, copies and moves are also available by means of three marks which may be set in a file. A position command is available to move any section of the file onto the TV screen window (26 lines). Further work is being done on this editor.

## 11. Summary

The LSI-UNIX system is currently being used for research in intelligent terminals and in stand-alone dedicated systems in Center 135. There are plans to use this system for further research in other areas of Bell Laboratories. Hard-copy features have yet to be incorporated into the system in a clean fashion. Currently, our system is connected to a larger machine using the Satellite Processor System. More general connections to larger machines or possibly to a network of machines has yet to be investigated. The LSX system also has potential uses in multi-terminal or cluster control terminal systems where multi-tasking features are important. These application areas have only been looked at superficially and warrant further investigation.

## 12. Acknowledgements

The author is deeply indebted to H. G. Alles for designing and building both the initial PERTEC floppy disk controller and the novel TV terminal. These two pieces of hardware have provided much of the motivation for doing the LSX system in the first place and for doing research in the area of intelligent terminals in particular. Many of the application and support programs described here have been written by two summer students, Glenn. A. Gladney and Eugene W. Stark. John S. Thompson wrote a floppy disk driver for the AED floppy disk controller to facilitate bringing up the LSX system on these disks. The author is grateful to J. C. Swartzwelder and D. R. Weller for their efforts in putting together the first LSI-11 system.

Heinz Lycklama

MH-1352-HL-pb

H. Lycklama

Atts.
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Figure 1

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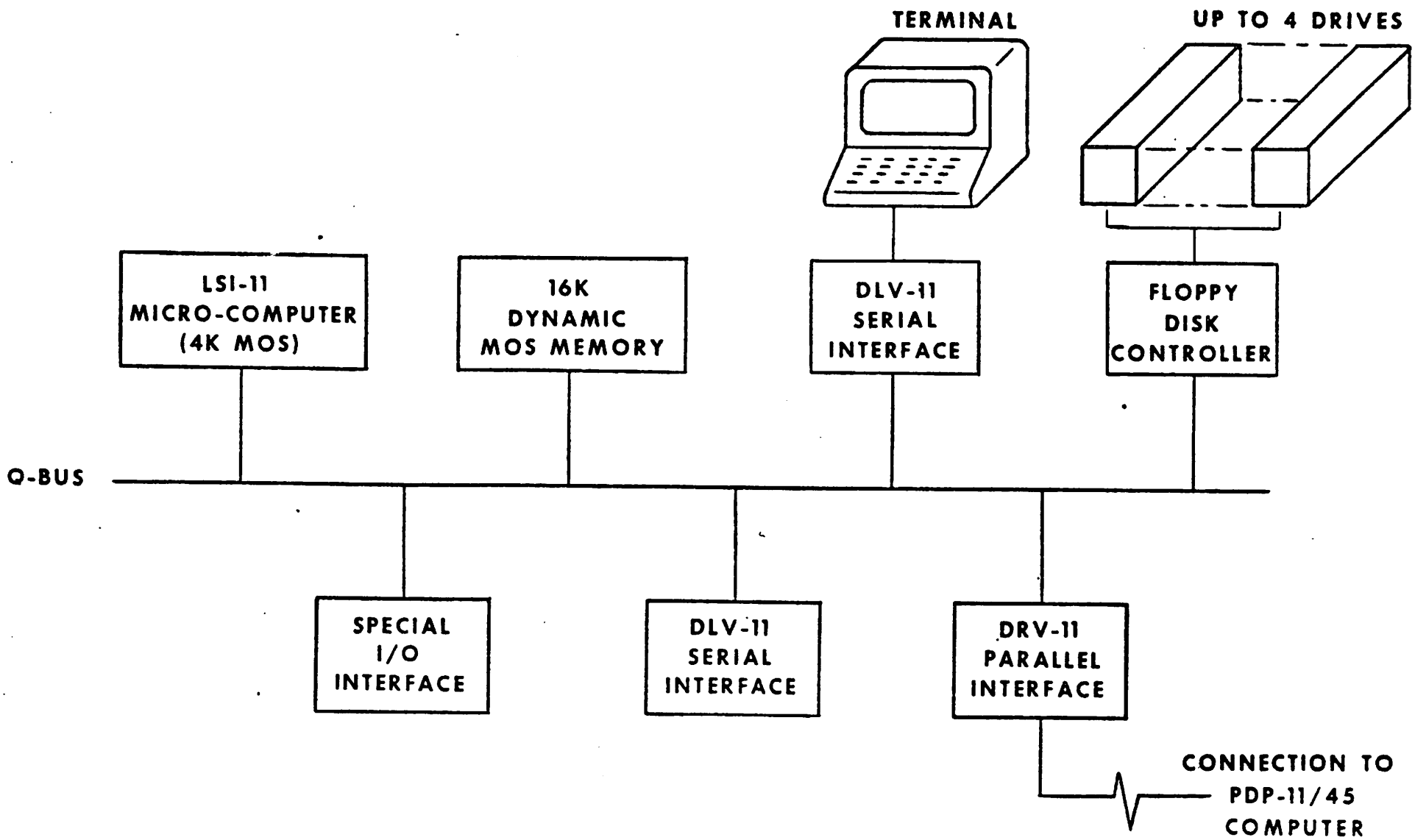


LSI-11 CONFIGURATION

FIGURE 1