Software

Lockheed Electronics

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MAC 16

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Standard software for the Lockheed Electronics MAC Computers is designed to meet the varied requirements of different user systems. Lockheed has developed a set of system building tools which permit the programmer to build his system on a MAC or other in-house computer. The tools include: assemblers, compiler, editor, debugging aides and many utility functions. In addition to the system building tools, Lockheed has software which may be incorporated directly into the user system, such as drivers for different peripherals (printer, card reader, drum, mag tape, etc.), I/O executives to facilitate fast response times and/or multiplexing I/O simultaneously, and a background-foreground executive to provide operator intervention capabilities. All software is available and system tested.

System Building Tools

Assemblers

The Lockheed Electronics Assembler Program (LEAP) is a language assembler with such advanced features as:

- Pre-defined macros
- External references to both data and subroutines
- Allocation of a COMMON core area
- Literals
- Automatic depaging
- Selective assembly of program modules and conditional processing
- Pseudo-operations
- Expressions with full range of operations

The LEAP assembler has been implemented in three different languages which provide system building capabilities for many different computers. These are:

- LEAP written in MAC language; operates in a minimum 4K MAC computer memory with an ASR33 teletypewriter.
- LEAP 360 written in IBM Basic Assembler Language (BAL); operates on an IBM 360/40 computer under DOS from disc with card I/O.
- LEAPFORT written in level 'E' FORTRAN IV language; operates on a user computer with 32K memory, 24-bit word size and a level 'E' FORTRAN IV compiler.

The LEAP system is easily modified to operate with different peripheral configurations. The basic version is set up for the teletypewriter; however, card reader, printer, magnetic tapes, drum, etc., can be interfaced to enhance the overall performance of the assembler.

Simulator

To aid in user system development, Lockheed Electronics has developed a MAC simulator, MACSIM. The simulator implements object program testing on large scale computers, thereby expediting software development. Operation of MACSIM requires a level 'E' FORTRAN IV compiler, 24-bit word size, and a minimum of 32K memory.

Compiler

A one-pass FORTRAN IV compiler is provided for computer systems having 8,192 or more words of memory. It performs all functions defined by USASI document No. X3.9-1966. A full package of standard intrinsic and external functions complements the compiler. At execution time, a run-time package is used to handle Assigned Go To, Computed Go To, and I/O functions.

Source Editor

The Source Tape Editor (EDIT) program assists the programmer in updating or correcting a symbolic tape. Among the functions available with EDIT are: deletion of a group of records, insertion of one or more records, and overlay of a record.

Editing can be done on a file-by-file or record-by-record basis. A listing of the edited tape can be generated. Control and corrections are accepted from the paper tape reader, ASR keyboard, or from the high-speed paper tape reader. Normally, two input devices are used; however, the pre-store option permits the use of a single input unit. In the latter case, the command stream is prestored in the Command Data Table and is then followed by the source files.

Loaders

Initial computer loading is accomplished by the Basic Loader (BLOD). The 64-word paper tape program is loaded with the minimum loader, the Hand-Loading Bootstrap (HLBT). The basic loader is also offered as a hardware option in diode memory and is loaded by depressing the BT switch on the control panel. BLOD loads programs that have been assembled in bootstrap format. This format provides the starting memory address for storage and the program execution address. The basic loader includes a checksum evaluation.

The Extended Loader (ELOD) has the capability of loading both absolute and relocatable programs generated in the extended mode by the LEAP assembler. The extended loader automatically depages inter-page addresses, places the address links in the appropriate base page, allocates common storage space and links all external references. A memory map can be printed after loading to show linkage space used in the base pages, the address of all programs by name, the common base and the starting address for execution. The loader can also generate a bootstrap format tape of the program instead of loading it into memory. This feature maximizes utilization of memory and speeds reloading operations.

Program Debug

The Debug program (DBUG) provides the programmer with communication to the computer for selectively controlling a program under test. Register and/or memory dumps can be specified and changes can be made to selected memory locations. Full and partial program trace selection is included. The debug program may be aborted by the operator at any time. Following is a list of debug options:

Access memory
Copy memory
Dump memory to printer
Punch memory to tape
Compare memory
Fill memory
Interrogate memory
Insert breakpoints
Trace effective addresses
Trace jumps or branches

Math Library

A complete library of routines is provided to assist the programmer in the development of a program. The following are included:

Integer

Multiply; Divide and reverse Divide.
Absolute Value; Transfer Sign; Positive Difference; Raise to Integer Power; Remainder
Maximum Value; Minimum Value.
Integer to Single Precision conversion.

Single Precision Fixed Point

Multiply; Divide; Square Root.
Sine; Cosine; Arctangent.
Exponential, base e, 2, 10.
Logarithm, base e.
Polynomial Evaluation.
Maximum Value; Minimum Value.
Fixed to Floating and Floating to Fixed conversion.

Double Precision Fixed Point

Add; Subtract; Multiply; Divide; Square Root.
Sine; Cosine; Arctangent.
Exponential, base e, 2, 10.
Logarithm, base e, 2.
Polynomial Evaluation; Negate.

Single Precision Floating Point

Add; Subtract; Multiply; Divide; Square Root.
Sine; Cosine; Arctangent: principle value and Y/X; Hyperbolic Tangent.
Exponential, base e, 2, 10.
Logarithm, base e, 2, 10.
Polynomial Evaluation; Negate; Positive Difference.
Load; Store.
Floating to Fixed and Integer to Floating conversion.
Normalize; Round; Remainder; Raise to Integer or Real Power; Absolute Value.
Truncate Fractional Bits, real and real to fixed.
Maximum Value, integer to floating and floating; Minimum Value, integer to floating and floating.

Double Precision Floating Point

Add; Subtract and reverse Subtract; Multiply; Divide and reverse Divide; Square Root.
Sine; Cosine; Arctangent: principle value and Y/X.
Exponential, base e, 2, 10.
Logarithm, base e, 2, 10.
Exponentiation, double base to double power, double base to integer power, double base to real power, real base to double exponent.
Polynomial Evaluation; Absolute Value.
Load; Store.
Single Floating to double floating, double floating to double fixed, double fixed to double floating, double floating to single floating conversion.
Maximum Value; Minimum Value; Remainder; Sign Transfer, Truncation.

Complex numbers

Add; Subtract and reverse Subtract; Multiply; Divide and reverse Divide; Square Root.
Sine; Cosine.
Exponential, base e.
Logarithm, base e.
Load; Store; Fetch Real Part.
Negate; Conjugate; Absolute Value.
Convert Imaginary to Real; Obtain Complex Quantity from Real; Raise to Integer Power.

Diagnostics

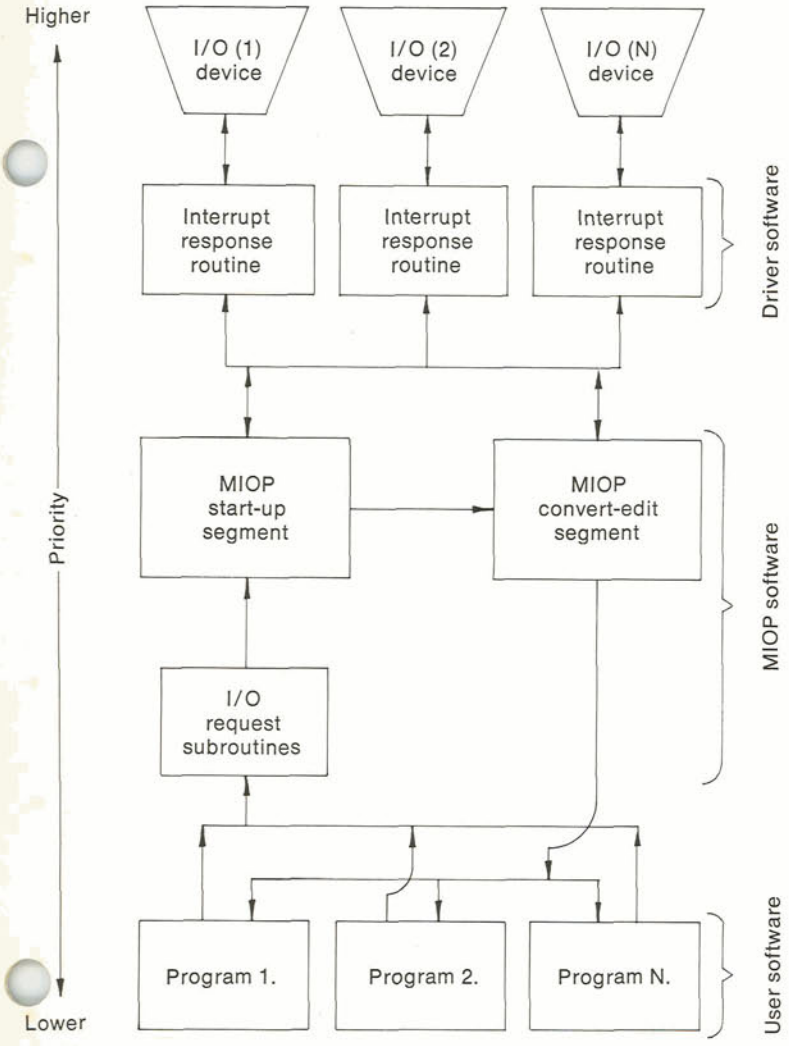
Test programs are provided to assist in the diagnosis of malfunctions of the processor, memory and peripherals. These programs provide a fast means for isolation of operator or program errors from system failures.

Multiplexing System

Executive

The Executive is a hardware priority scan technique which uses up to 64 priority interrupt levels to initiate software. Programs and/or software peripheral drivers may be dedicated or shared by a priority interrupt level. The drivers are initiated by external interrupts from a designated device while internally programs may be linking other programs to their own level or to other levels. This system responds to I/O device interrupts within 6 microseconds.

Multiplexing System Capability (MIOP)



I/O Executive

The Input/Output Executive allows the user program to be device-independent and to multiplex requests from many programs simultaneously. The user programs can make character or variable length table requests via a simple calling sequence. The request may be made with an immediate return to the calling function for further processing, or the function may be delayed until I/O has completed. The executive provides peripheral diagnostic checks and returns to the calling function with busy or bad status information. Software drivers in the library are:

Teletype output	Line printer
Teletype input	Card reader
Highspeed paper tape punch	Magnetic tape
Highspeed paper tape reader	Drum

Real Time Monitor

The Real Time Monitor is a core resident executive system which provides priority processing of programs in a competitive environment.

Programs executed under monitor control may be time-based or interrupt driven. A time-based program is one whose execution is dependent on a specific time of day or fraction of time such as a one-minute scan program. An interrupt-driven program is one which is dormant until activated by an external or program-generated interrupt. Interrupt-driven programs may go dormant after execution or become time based once activated.

The system programs, under control of the monitor, may be core resident or bulk file resident, dependent on frequency of execution and response requirements. As programs are required to be executed they are transferred from bulk storage by the monitor and executed. This technique allows for maximum utilization of available core memory.

The Real Time Monitor is functionally composed of an Executive, an Input/Output Controller, an interrupt response routine and additional support routines.

Executive

The Executive coordinates all operations occurring in the system. By maintaining a list of program descriptions it will activate and deactivate system programs as necessary. The primary function of the executive is scheduling. It determines, by scanning the program description table, if a program is ready for execution at a specific point in time. If more than one program is eligible for execution, the highest priority program is executed. Priorities are established by the user at system generation time. In addition to the running characteristics of the program, the executive maintains other information about the system programs, such as core and drum storage locations, status information, and relational characteristics to the rest of the system.

The executive is entered after execution of each program or after an interrupt. It is at this point that a scan of the program table is made to determine what program is to be executed. If no programs are active or scheduled, the executive enters the quiescent state until the next interrupt occurs.

Scheduling of program execution by the executive will allow for maximum use of peripheral equipment, core storage, and processor execution time. If a program is waiting for an input/output operation to complete, the executive will suspend the program and check for a higher or lower priority program which is eligible for execution. It would be possible, for example, to have five programs waiting for input/output functions to complete while a sixth program, perhaps a background task, is operating.

The core storage allocation for all programs is fixed, as opposed to dynamically allocated, and is defined at system generation time.

Input/Output Controller

The Input/Output Controller, in conjunction with the executive, coordinates all I/O operations. When a program requests an I/O operation, the I/O controller will deactivate the program, determine if the device is free and, if so, execute the operation. If not free, the request is queued and when the device becomes ready the request is executed. After the I/O request has been initiated or queued, control is returned to the executive to allow operation of other eligible tasks.

The Input/Output Controller is designed for the easy incorporation of additional drivers with a minimum of program interface to allow simple system configuration.

Interrupt Response

The Interrupt Response function implements executive level recognition of an interrupt to determine what action must be taken. In some cases the interrupt will cause a program to be set active in the program description table. In other cases it will direct the I/O controller to respond to a peripheral device. In most cases the interrupt will be processed by this function of the Real Time Monitor system. Occasionally, there will be programs which will require extremely fast reaction to an interrupt. With the very efficient interrupt structure present in MAC, these programs may be entered directly, bypassing the interrupt response handler. This is not a suggested procedure, however, and if done must adhere to some very rigid operating constraints.

Foreground/Background Processing

The Real Time Monitor provides both foreground and background processing in a priority sequence with the background function as the lowest priority. Most real time system foreground functions are input/output limited allowing a considerable amount of time for background processing. To utilize this spare time, the executive, upon finding all foreground tasks inactive or suspended, activate the Background Control Program.

Background Executive

The Background Executive provides for operator initiation and control of programs which operate in the background mode of a system. It operates in conjunction with the I/O Executive Program and provides on-line assignment of peripheral devices used by the I/O Executive.

Several common subroutines found in the background executive and available to the background functions are: peripheral diagnostic information upon a status request; decimal to binary conversion; source and binary input/output, and memory moves.

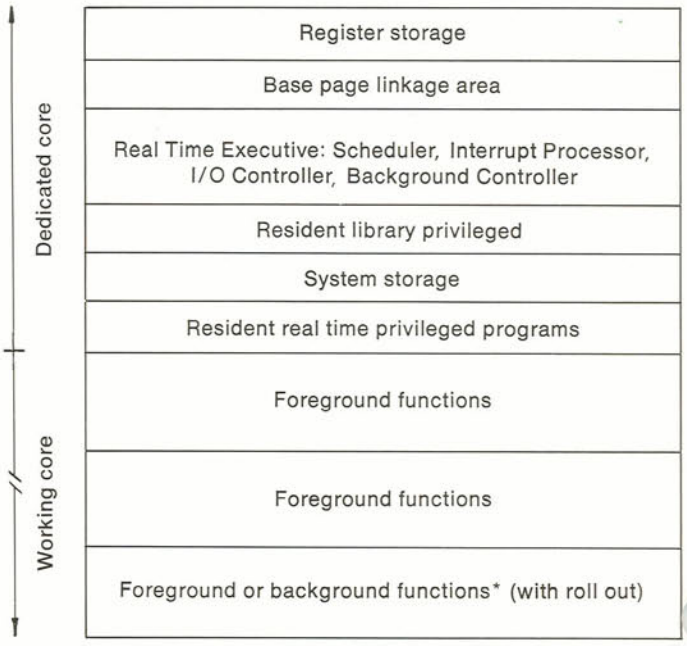
Communication with the background executive is initially established through the teletype keyboard. The operator can direct that subsequent commands to the background executive be accepted from other devices.

Background Control Program:

All background program execution and communication will be activated via the Background Control Program. This program provides the means of initiating background action routines such as:

LEAP Assembler
EDIT
FORTRAN
Extended Loader
Utility functions
System update
Bulk storage dump (System update compatible)
Keyboard entry
Clock/Calendar update

Real time system core allocations



*Language processing background functions require 8K of memory.

7 Basic Hardware Requirements

As with any general purpose software system, hardware requirements vary greatly, depending on the scope and complexity of the system. In describing the following requirements, we will assume that the DMA (direct memory access) option for Input/Output is available, as the PDC mode would require a considerable amount of core for Input/Output drivers. Further, the PDC will greatly reduce the effectiveness of the RTM system from a standpoint of I/O service time and core requirements.

Real Time Monitor System Configurations

Core size estimates include operating areas and data storage; user peripheral requirements are in addition to the given configurations.

Basic real time monitor without background processing:

8K core memory
8 priority interrupts with real time clock
Basic I/O device (ASR Teletype)
Bulk storage file (optional)

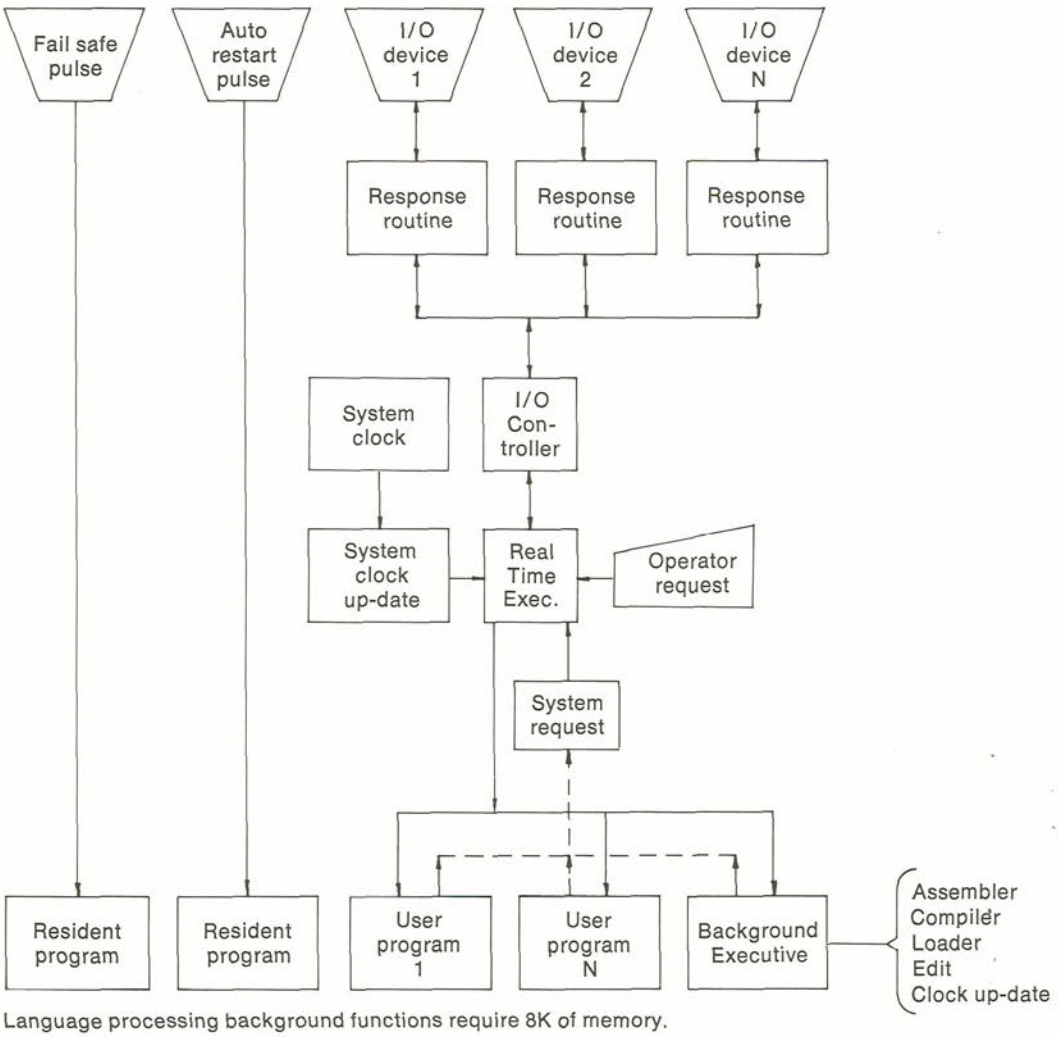
Real time monitor with limited background processing (utility functions):

16K core memory
8 priority interrupts with real time clock
Input/output devices (paper tape or cards)
Keyboard and listing devices (two teletypes minimum)
Bulk storage file

Real time monitor with full background processing:

20K core memory
8 priority interrupts with real time clock
Input/output devices (paper tape or cards)
Keyboard and listing devices (two teletypes minimum)
Bulk storage file

Real time monitor



Language processing background functions require 8K of memory.

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