Designing a virtual-memory implementation using the Motorola MC68010 16 bit microprocessor with multi-processor capability interfaced to the VMEbus

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DESIGNING A VIRTUAL-MEMORY IMPLEMENTATION USING THE MOTOROLA MC68010 16-BIT MICROPROCESSOR WITH MULTI-PROCESSOR CAPABILITY INTERFACED TO THE VMEbus

by

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June 1990

Thesis Advisor: Larry W. Abbott

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MULTI-PROCESSOR CAPABILITY INTERFACED TO THE VMEbus

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The primary purpose of this thesis is to explore and discuss the hardware design of a bus-oriented microprocessor system. A bus-oriented microprocessor system permits it to be expanded to a multi-processor system. Through the use of a bus controller and bus arbiter, as discussed in this thesis, the necessary logic is in place to control bus access by system users. Bus access may be initiated to share another sub-system's resource, such as memory. To accommodate memory sharing between two systems, a dual-port memory controller can be used to resolve memory access between the two systems. This thesis discusses the design of a MC68010 microprocessor system integrated on the VMEbus with dual-ported memory capability. Additional features of the MC68010 microprocessor system include memory-management and interrupt control. The memory-management features permit protected memory and virtual-memory to be implemented on the system, while an interrupt handler is used to assist the MC68010 microprocessor in exception processing.
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I. INTRODUCTION

Economic pressure constantly forces computer design and technology to produce more cost-effective system implementations. Computers are made more cost-effective by lowering operating cost through increased speed and power and by lowering design, maintenance and upgrade costs through modular design techniques. Architectural innovations can accelerate this process. Hence, new innovations in system architecture are constantly sought after. Architecture is used here to mean the structuring of the modules which are organized into a computer system [Ref. 1:p. 1]. These modules include processors, memory and input/output (I/O) devices.

A uni-processor system consists of a single processor subsystem and various supporting modules integrated to form a system. In contrast, a multi-processor system is comprised of two or more processor subsystems connected into one interrelated functional system. In a multi-processor system, the interconnection of the processor subsystems must be done in such a way as to maintain control and manage the data flow of the entire system. This may be accomplished through multi-ported memory, a serial link or as in this thesis, by a system bus. A number of computer architectural designs that accommodate growing needs are examined in this thesis. Key architectural features of bus structures, memory-management and interrupt control are described in this chapter.
Bus structures allow for the integration of peripherals, memory and application-specific boards into one coherent system. Bus structures permit the exchange of data and control signals between circuit boards. This allows circuit boards to communicate with each other and to share resources. However, a strict adherence to protocols must be maintained so the integrity of information and control is preserved.

Memory-management features include memory protection and virtual-memory. Special memory schemes have been used to protect a system’s integrity, to make more effective use of its physical memory’s address range and to permit multi-ported memory so that the memory resource can be shared in a multi-processor system. A memory protection scheme prevents users from inadvertently or maliciously tampering with the operating system, its associated memory-mapped hardware or other users. To accomplish this, a portion of the processor’s address range can be reserved for the operating system, while the remaining portion is allocated to system users. The operating system is protected because the user is not permitted to cross into the operating system’s memory.

The virtual-memory aspect of memory-management permits a greater dynamic range and flexibility for user memory than actually exists with the system’s physical memory. Virtual-memory allows each user to run programs as if he or she has full use of the processor’s address range, independent of the memory used by the operating system or the other users. The user is unaware of how the physical memory in the system is allocated. Therefore, memory
resources can be allocated automatically and respond to the dynamic needs of the operating system and the users. In a system without virtual-memory, programs must be executed in a specific memory space and for large programs, the user must provide complex overlay schemes to circumvent the fixed user memory allocation. It is difficult for such a system to support several large programs concurrently. In a virtual-memory system, the operating system breaks up the user’s program into segments called pages and moves these pages as needed between physical memory and a secondary storage device such as a hard disk. Thus, a virtual-memory system can easily support several large programs concurrently as long as each program only requires a modest amount of memory at any given time.

Multi-ported memory, such as dual-ported memory, allows a common memory resource to be shared between two or more processors or peripheral devices. Thus, different processes or different processors can communicate with each other via a multi-ported memory mailbox equipped with an accompanying semaphore to maintain access control and data integrity. Also, multi-porting provides a communication link between tightly coupled systems where there is a high degree of interaction.

Interrupts optimize the performance of a processor. An interrupt is a control signal generated asynchronously by a device, such as a serial port, requesting service from the processor. The processor is free to process other tasks between interrupts from devices requiring service [Ref. 2:pp. 220-223]. When it is ready
to service an interrupting device, the processor saves its current state and then performs the servicing tasks. When the servicing tasks are completed, the saved state of the processor is restored and the operation prior to the interrupt is resumed. Consequently, the processing power of the processor is increased because the overhead from polling peripheral devices for a service request is eliminated.

In a general sense, a generic multi-processor system can be viewed as illustrated in Figure 1.1. Various subsystems such as data processing, storage and data communications are integrated along a system bus to make up a complete system. Each subsystem is comprised of memory, I/O and processor modules configured to accommodate the unique requirements of the users of the multi-processor system. A system controller acts as the arbiter for the entire system. The system controller directs the information flow, much as a traffic policeman directs traffic, between the various subsystems along the system bus to ensure that the system is properly coordinated. In order for each subsystem to have access to the system bus, logic must be incorporated within each subsystem to allow it to interface to the system bus.

The main thrust of this thesis is to explore the concepts of bus structure, memory-management and interrupt control. These concepts are addressed in a greater depth than would be possible in a classroom environment.
Figure 1.1: Generic Multi-Processor System
II. DESIGN CONCEPTS

The concepts addressed in this thesis are limited to bus structure organization, memory-management and interrupt control. These features are commonly used in today's processor systems. However, many options are available within each area. This thesis design is a virtual-memory implementation of a MC68010-based microprocessor system integrated on the VMEbus with dual-ported memory capability.

Borrill [Ref. 3] highlights several advantages of the VMEbus. The VMEbus, through its non-multiplexed address lines and data lines, does not have multiplexing delays as do other buses, nor does it have the transactional protocol overheads as do some other buses. In addition, the non-multiplexed address lines will support address pipelining. For interested readers, Borrill has made a detailed comparison of the features and performance of the VMEbus, Futurebus, Multibus II, Nubus and Fastbus [Ref. 3].

In addition to the advantages that Borrill highlights, the VMEbus structure was selected because of the relative ease of integrating Motorola and Signetics peripheral hardware devices. These hardware devices include a memory management unit, VMEbus controller, bus arbiter, interrupt handler hardware and dual-port dynamic random access memory (DRA11) controller.

The following discussion presents a broad overview of the VMEbus structure and memory-management. This should facilitate
understanding of the concepts that are incorporated into the final system (master circuit board) design.

A. VMEbus SPECIFICATION

1. Background

The VMEbus specification originated with Motorola’s 68000 microprocessor products. The 68000 series was introduced to the marketplace in the late 1970s, using the VERSAbus specification. In the early 1980s, Motorola’s European Microsystems group in Munich, Germany, introduced the Eurocard version of the VERSAbus, referred to as the VERSAbus-E specification. A joint agreement was reached to adopt the VERSAbus-E as the baseline bus specification for Motorola 68xxx devices with Mostek and Signetics as second-source suppliers of the 68xxx family of devices. The VERSAbus-E was renamed the VMEbus. The VMEbus specification [Ref. 4] delineates the mechanical and electrical characteristics of the bus and the protocols to interface devices on the VMEbus.

2. VMEbus Description

The VMEbus offers a versatile combination of timing strategies and support features. It also offers several data transfer sizes, several addressing modes and several arbitration methods. The VMEbus is an asynchronous, non-multiplexed bus that accommodates 8, 16 and 32-bit data transfers. [Ref. 5]

Asynchronous data transfers are flexible and do not impose timing control signals. Completion signals from the asynchronous devices ensure that adequate time is allowed for the data transfer. In contrast, synchronous data transfers impose a timing constraint
on the data transfer which must accommodate the slowest device attached to the bus.

A non-multiplexed bus is one that accommodates data transfers and address transfers as separate signals on separate lines of the bus. This contrasts with the multiplexing strategy where data signals and address signals share the same set of lines. As a simple description, during a write cycle, multiplexing address signals are gated on one clock cycle and data signals are gated on the same lines during a subsequent clock cycle. The non-multiplexing strategy speeds up data transfer by eliminating the second clock cycle.

The VMEbus can be used with 24 or 32 address lines depending on the microprocessor's requirements and it is easily adaptable to the entire family of Motorola 68xxx microprocessors and peripherals.

The VMEbus is composed of four sub-buses that play unique roles within the overall VMEbus functional structure. These include the data transfer bus (DTB), the data transfer arbitration bus, the priority interrupt bus and the utility bus. The VMEbus functional specification describes how each sub-bus interacts and the rules which govern the behavior of each sub-bus (Ref. 4:pp. 15-194). The DTB provides the pathways for the data signals, the address signals and their associated control signals. The process of resolving bus ownership takes place on the data transfer arbitration bus. The priority interrupt bus is used to accommodate processes which request servicing from another subsystem. An
interrupt stops normal bus activity until the interrupt is serviced. The utilities bus is sometimes referred to as a "miscellaneous functions bus". It includes a system reset line, an alternating current (AC) power failure line, a system failure line and a system clock [Ref. 2:p. 475].

The design in this thesis uses the VMEbus controller and the interrupt handler hardware devices which are designed for use with the VMEbus.

3. Configurations

In a multi-processor VMEbus-based system with a variety of peripheral devices, each subsystem can fulfill one of three primary roles. The subsystem can serve as a slave-only, as a master-only or as a master-slave combination. A subsystem can also have the role of direct memory access (DMA) in a master-slave configuration. (To limit the size and complexity of this thesis, the DMA master-slave configuration is not discussed.) These roles determine the way the subsystem is integrated to the system bus.

a. Slave-Only Application

In the slave-only configuration, the subsystem is slaved to the VMEbus. In other words, this subsystem is incapable of making a request to obtain access and control of the VMEbus. The slave subsystem is a device which other subsystems utilize. Examples of slave subsystems include communication ports and stand alone memory boards. If intelligence (logic) is added, the subsystem can evolve into an input/output (I/O) channel or a mass storage subsystem. Figure 2.1 shows the simplicity of a slave
subsystem interfaced to the VMEbus. The 74LS245s octal-bus transceivers with 3-state outputs provide the drive capability for transmitting signals onto the VMEbus and the receiver capability for receiving signals from the VMEbus. If desired, the 74LS245s can also be disabled to isolate the slave subsystem from the VMEbus.

SLAVE SUBSYSTEM

...  

SLAVE DEVICE(S)  

74LS245s  

...  

VMEbus  

...  

Figure 2.1: Slave-Only Subsystem

b. Master-Only Application

In the master-only configuration, the subsystem has the ability to gain control of the VMEbus. A master-only subsystem has an onboard central processor unit (CPU) with or without local slave devices. It is interfaced to the VMEbus with a bus controller. When the subsystem has gained control of the VMEbus, this subsystem is said to be in a master role. Figure 2.2 gives a simplified illustration of a VMEbus system with a master-only subsystem
attached to it. Comparison of Figures 2.1 and 2.2 shows the added complexity required in a subsystem which can gain control of the VMEbus. In addition, a system controller is included in Figure 2.2 to illustrate the added system complexity required to control bus accesses.

**Figure 2.2: Master-Only Subsystem**

Given a request by the CPU, the bus controller generates a bus request signal through an 74LS245 to the system controller’s bus arbiter. (The abilities of the 74LS245 were described in the slave-only subsystem.) The bus arbiter receives requests from subsystems on the VMEbus through the 74LS244 octal-buffers and line drivers with 3-state outputs. The function of the bus arbiter is to resolve prioritized requests from the subsystems and to generate a bus grant signal through the 74LS244 to the
highest priority requesting subsystem. The subsystem's bus controller maintains system integrity by ensuring that a bus grant signal is received prior to permitting a data transfer. The requesting subsystem, after receiving the bus grant signal, negates its bus request and asserts the bus busy signal so that other subsystems cannot gain control of the bus while the data exchange is in process. Also, the bus busy signal informs the bus arbiter that a data exchange is currently in progress and that the bus arbiter can release the bus grant signal. The requesting device is now the bus master. When the data exchange is complete, the requesting device releases the bus busy signal to allow the bus arbiter the opportunity to grant the bus to another subsystem.

If the bus is in use and a higher priority bus request is asserted, the bus arbiter asserts the bus clear line. The bus clear signal informs the current bus master that another subsystem with a higher priority is requesting bus ownership. Each potential bus master should accommodate either a "release when done" or a "release on request" strategy to resolve pending higher priority requests for bus access.

c. Master-Slave Application

A master-slave configuration combines the master-only and slave-only capabilities into a single subsystem. As illustrated in Figure 2.3, the CPU residing on the master-slave subsystem has the ability to gain control of the VMEbus. The system controller and bus arbiter perform the same roles as described in the master-only subsystem.
Shared slave devices are onboard the master-slave subsystem. These devices can be accessed by another subsystem when it has control of the VMEbus (Fig. 2.3). The bus controller isolates the shared slave devices from the CPU by putting the 74LS244s outputs into a high impedance state, whenever another subsystem accesses the shared slave devices. When this happens, the shared slave devices become a global asset to the system. The 74LS245s not only act as line drivers and receivers, they also prevent access from the VMEbus to shared slave devices when the appropriate control signal is asserted by the bus.
controller. Whenever the local master (in this case the CPU) is accessing the shared slave devices, these devices become a local asset. As discussed in the master-only application, the bus controller preserves the VMEbus protocol.

4. Arbitration Protocols

Arbitration protocols ensure conflict-free access to the system bus from all subsystems and are crucial in a multi-processor environment [Ref. 6:p. 100]. An arbitration protocol ensures that only one bus master has access to the bus at a time, thus safeguarding the bus from collisions in which information is transferred on the bus by multiple sources. The VMEbus supports both serial and parallel arbitration schemes or a combination of both methods. These two methods are described in the following paragraphs.

Daisy chaining is a method of arbitrating a shared communication bus by serial prioritization. Figure 2.4 illustrates daisy chain arbitration. If the bus is in use, any subsystem requesting ownership must wait till the present bus master relinquishes control of the bus. A subsystem requests access to the bus by asserting the bus request (BR) signal. The bus arbiter or other controlling device acknowledges the bus request by asserting a bus grant (BG) signal to the bus grant input (BGIN) of SUBSYSTEM1, the first subsystem in the daisy chain. If SUBSYSTEM1 is requesting the bus, it asserts the bus busy (BBSY) signal and it continues to negate its bus grant output (BGOUT) signal. SUBSYSTEM1 can now begin data transfer. If the bus request was
made by any subsystem other than SUBSYSTEM1, the BG signal is passed by SUBSYSTEM1 to the next subsystem in the chain (SUBSYSTEM2). The BOUT signal from SUBSYSTEM1 becomes the BGIN signal to the next subsystem in the chain (SUBSYSTEM2). This process is repeated until the highest priority requesting subsystem receives the BGIN signal. SUBSYSTEM1 has a higher priority than SUBSYSTEM2. The last subsystem in the chain (SUBSYSTEMn) has the lowest priority.

Figure 2.4: Daisy Chain Arbitration

The BR and BBSY signals are wire-ORed (open collector-active low), i.e., the logic is tied together at a wire connection. Consequently, the BR signal will cause the BBSY signal to be asserted once the BGIN signal is received through the daisy chain.

Parallel arbitration is a method of arbitrating a shared communication bus by priority levels. An example of a three-level parallel arbitration scheme is shown in Figure 2.5. In Figure 2.5,
bus request zero (BR0) has the lowest priority level, while bus request two (BR2) has the highest priority level. The highest priority subsystem with a pending request is granted access to the bus. In this parallel arbitration scheme, the subsystems desiring use of the bus make bus requests (BRx) through the bus arbiter. The bus arbiter or other controlling device then sends out a bus grant (BGx) onto the bus to the highest priority subsystem with a pending bus request.

![Parallel Arbitration Diagram](image)

**Figure 2.5: Parallel Arbitration**

The main advantage of the daisy chain arbitration scheme over the parallel arbitration scheme is that subsystems can be inserted sequentially, one after the other. Consequently, new subsystems are easily added to the system.

The main advantage of the parallel arbitration scheme over the daisy chain arbitration scheme is that arbitration can be performed faster. Parallel arbitration does not propagate a bus grant signal down a chain, but rather the bus grant signal is sent
directly to the highest priority subsystem requesting service. However, the parallel arbitration scheme limits the number of subsystems that the bus arbiter can accommodate.

Any fixed priority arbitration cannot ensure that the subsystem with the lowest priority level will be serviced if higher priority subsystems make frequent requests. The daisy chain arbitration and parallel arbitration methods may need to be modified or a controller may need to be incorporated to ensure each subsystem can be serviced fairly.

The VMEbus uses a serial-parallel combination for bus arbitration with only one bus arbiter. VMEbus arbitration uses a scheme with four parallel priority levels similar to Figure 2.5. Each priority level, however, can have subsystems daisy-chained as illustrated in Figure 2.4. In other words, the bus arbiter grants bus access to a given level and then the daisy chain at that level determines which subsystem actually gets the bus.

The VMEbus arbitration process includes the BBSY signal (as shown in Figure 2.4) and the bus clear (BCLR) signal. The BBSY and BCLR lines are added to the bus arbiter and all subsystems on the VMEbus. The VMEbus BBSY signal is asserted by the subsystem which is granted bus access. The BCLR output signal informs all subsystems on all priority levels that a subsystem on a higher priority level than the current bus master has requested access to the VMEbus. As mentioned earlier, the requesting subsystem should accommodate a "release when done" or "release on request" strategy to resolve pending higher priority requests for bus access.
B. MEMORY-MANAGEMENT

Memory-management can employ a combination of methods to organize the physical memory associated with a microprocessor or system. These methods effectively free the programmer using the system, from being concerned where the program code and program data will reside in memory. This thesis addresses the memory-management concepts of memory protection, virtual-memory and dual-ported memory.

1. Memory Protection

One method used to organize the address range of a microprocessor is to divide its address space into two or more blocks. Each block of the address space can be designated for a specific purpose, such as supervisor memory or user memory.

The MC68010 microprocessor has two modes of operation. These modes are the user mode and the supervisor mode. The user mode provides an instruction set for the programmer to accommodate a majority of applications. The supervisor mode provides additional instructions and privileges for use by the operating system and other system-related software [Ref. 7:p. 1-1].

The user memory is the area designated for non-privileged individuals to use. Such an individual executes programs in the user mode. The address range for the user is normally limited because it does not include the addresses associated with the operating system and the memory-mapped peripherals. Additionally, the user is restricted from executing privileged supervisor instructions. In contrast, the operating system executes programs
in supervisor mode and can address supervisory memory and memory-mapped peripherals as well as user memory. This segregation of the supervisor and the user precludes the user from reconfiguring the system, but still allows the user access to part of the physical memory and to the computational power of the microprocessor. Typically, the user must request the operating system to perform operations which the user is not allowed to perform.

2. Virtual-Memory

Virtual-memory allows programs to be executed which require more memory space than is physically resident. Therefore, the maximum program size is not limited by the size of physical memory. Originally, this method was designed to reduce and more effectively use memory.

A virtual address is an address located within the address space of the microprocessor. Consequently, with the MC68010 microprocessor, there exists 16 megabytes of virtual-memory. A virtual-memory implementation groups the virtual addresses into blocks called pages. Figure 2.6 shows such a grouping with zero through N pages of virtual-memory but with only enough physical memory to accommodate two virtual pages in physical memory. In Figure 2.6, virtual PAGE 1 and virtual PAGE N are mapped into separate physical pages.

When the CPU generates a virtual address, the virtual address is translated into a physical address. The address translation process includes fairly sophisticated memory protection so that tasks cannot interfere with each other or access resources.
not allocated to them. Figure 2.7 illustrates a simplified memory-mapping mechanism. The high order virtual address bits are referred to as a virtual page number. The virtual page number references a location of the translation table. The translation table has as its contents a physical page number which references the starting location of the physical memory's page address. The low order virtual address bits give the relative address offset of the desired address within the physical page selected.

![Virtual-Memory-Mapping Diagram]

**Figure 2.6: Virtual-Memory-Mapping**

Generally, each processing task has its own translation table similar to Figure 2.7. These tables are switched whenever the active task changes which avoids interference between processing tasks.
When the CPU generates a virtual address in a page that is not present in physical memory, for instance PAGE 2 as in Figure 2.7, the memory manager senses that fact and generates a page fault. The page fault triggers a chain of events which ultimately retrieves the desired page of the program from secondary storage and places it in physical memory. The instruction which caused the page fault is then continued or restarted. [Ref. 2:pp. 326-330]
3. Dual-ported Memory

Dual-ported memory permits two nearly simultaneous accesses to the memory resource without conflict. Figure 2.8 illustrates a typical configuration of a dual-port memory device. One approach to arbitrating concurrent memory requests in a dual-ported random access memory (RAM) is to sample one request line on the rising clock edge and the other on the falling clock edge. A PORT 1 REQUEST is assumed to be sampled on the rising clock edge.

If a PORT 1 REQUEST is asserted, a PORT 1 GRANT is generated which gates the PORT 1 address, data and control lines through the left-hand 74LS244s and 74LS245s in Figure 2.8. The address and control signals are sent to the dual-port memory device and the data
signals are sent directly to memory. The dual-port memory device then gates the address lines to memory. While the PORT 1 GRANT is active, the PORT 2 GRANT cannot be asserted. PORT 2 is thus locked out from gaining access to memory. In contrast, if a PORT 2 REQUEST is asserted and PORT 1 is inactive, a PORT 2 GRANT is generated. This causes PORT 2 to gate the control and address lines through the other 74LS244s to the dual-port memory device and to gate the data lines directly to memory via the 74LS245s.

In the event that both request lines are active, a PORT 1 GRANT will be generated on the rising clock edge or a PORT 2 GRANT will be generated on the falling clock edge. The other request is locked out until the request line of the recognized port is no longer asserted. The other port will then gain access on the appropriate clock edge.
III. SYSTEM OVERVIEW

This thesis seeks to design a system that satisfies the design requirements for a system that can be expanded to a multi-processor system. Additionally, the subsystem design is interrupt-controlled with both virtual-memory and dual-ported memory support. This chapter gives a system perspective on the hardware associated with the system controller circuit board and master circuit board (Fig. 3.1) integrated to the VMEbus.

A. SYSTEM CONTROLLER CIRCUIT BOARD

The VMEbus specification describes the system controller as a board which resides in slot one of the VMEbus back plane [Ref. 4: pp. 5]. The system controller circuit board design provides priority bus access arbitration, a manual system reset and a interrupt acknowledge (IACK*) daisy chain driver. The system controller subsystem uses line drivers to buffer the arbitration signals and IACK* signal on the VMEbus.

1. Priority Bus Arbitration

The Motorola MC68452 bus arbitration module (BAM) peripheral device [Ref. 8] was selected to perform the VMEbus access arbitration. The BAM is configured to accommodate four bus request (BRx*) inputs and four bus grant (BGx*) outputs. After parallel arbitration, a bus grant signal is generated by the BAM at the level of the highest priority bus request. The bus grant signal is then daisy chained down on the level of the highest
priority bus request. This VMEbus arbitration method combines the advantages of both the daisy chain arbitration and parallel arbitration methods discussed in Chapter II.

![System Block Diagram](image)

**Figure 3.1: System Block Diagram**

2. Manual Reset

The manual system reset provides a system-wide master reset of all devices within all subsystems. Resetting the system re-initializes various devices within it. This is necessary in order to restart the system after system failure.
3. Interrupt Driver

The VMEbus structure provides the IACK* signal daisy chain. However, a driver is provided on the system controller circuit board to drive the IACK* signal onto the VMEbus.

B. MASTER CIRCUIT BOARD

The master circuit board is the primary design focus of this thesis. As shown in Figure 3.1, the master circuit board subsystem is composed of nine functional blocks. These functional blocks are the central processor unit (CPU), dual universal asynchronous receiver/transmitter (DUART), dynamic random access memory (DRAM), static random access memory (SRAM), erasable programmable read-only memory (EPROM), memory management unit (MMU), dual-port DRAM controller, VMEbus controller and interrupt handler. The master circuit board is configured in a master-only role as discussed in Chapter II.

1. Central Processor Unit

The Motorola MC68010, 16-bit CPU, was selected to be the processing element because it has the necessary features to support virtual-memory but lacks the added complexity of a 32-bit architecture. It also affords easier wire-wrap assembly than the other Motorola CPUs supporting virtual-memory because wire-wrap is better supported for a dual in-line package (DIP) and there are fewer data and address signals. The signals and programming capabilities of the MC68010 microprocessor are discussed in further detail in Appendix A.
2. Dual Universal Asynchronous Receiver/Transmitter

Two asynchronous serial (RS-232) ports are implemented with the Motorola MC68681 DUART. One serial port is configured to drive a terminal, while the second serial port is used to down-load files from an IBM XT/AT compatible computer. The first serial port is used to permit a human interface to the system. The intent of the second serial port is to provide the ability to develop software on an IBM XT/AT compatible computer with a cross assembler and then to down-load the software through the second serial port to the master circuit board’s random access memory (RAM) for testing, debugging and execution.

3. Erasable Programmable Read-Only Memory

The EPROM in this thesis design, contains the exception vector table and the monitor/debugger program. The exception vector table contains the addresses of the routines to be executed as a result of an interrupt or other exception. The monitor program configures the subsystem when it is powered up and handles communications with the terminal for interaction between the microprocessor and the user. It also provides debugging commands and coordinates the previously mentioned down-loading of files. Sixty-four kilobytes of EPROM are provided in the master circuit board.

Once an operating system is developed, it would not be desirable to freeze the interrupt part of the exception vector table into read-only memory (ROM). It should be noted that the
design of an operating system to take advantage of the system’s hardware features is beyond the scope of this thesis.

4. Random Access Memory

Sixteen kilobytes of SRAM and one megabyte of DRAM are provided on the master circuit board.

5. Memory Management Unit

The use of the Motorola MC68451 MMU affords several advantages to the microprocessor system. The MMU provides the advantages of virtual-memory and a sophisticated memory protection scheme (both previously discussed in Chapters I and II). The MC68451 provides the capability to:

- Translate logical addresses to physical addresses.
- Provide segment descriptors to implement memory protection.
- Detect page faults and other situations requiring operating system intervention.
- Aid the operating system in managing the virtual-memory system efficiently (by use of the segment status registers).

6. Dual-port DRAM Controller

The Signetics 74F765 dual-port DRAM controller provides access to the DRAM by either a local bus master or a global bus master. If DRAM is accessed by the local bus master, i.e., the CPU on the master circuit board subsystem, it becomes a local asset. It is not desirable for the local CPU to access DRAM via the VMEbus because long access times would be the result. If DRAM is accessed by a global bus master, i.e., another subsystem controlling the VMEbus, it becomes a global asset. The ability to access DRAM locally or globally is desirable for a system that includes...
subsystems that interact closely with one another. In addition, the dual-port DRAM controller provides refresh cycles to the dynamic memory integrated circuit chips.

The global memory accesses in this master circuit board subsystem design, use physical addresses to permit the implementation of mailboxes with attached semaphores as discussed in Chapter I. An operating system needs to lock the mailbox page in physical memory at a specified physical address.

7. **VMEbus Controller**

The Signetics SCB68172 VMEbus controller preserves the VMEbus data transfer and VMEbus access protocols. The VMEbus controller and the MC68010 CPU are configured in a master-only role as illustrated in Figure 2.2 and discussed in Chapter II. The VMEbus controller provides the necessary logic to interface the master circuit board subsystem to the VMEbus.

8. **Interrupt Handler**

The Signetics SCB68155 interrupt handler is used in the master subsystem design to assist the CPU with interrupt processing. The interrupt handler receives global and local interrupt requests and arbitrates their priority. The arbitration priority is non-maskable interrupts, first, then local interrupts and finally global interrupts.

The interrupt handler acts as a mediator between the CPU and the interrupting device or between the CPU and the interrupting subsystem. Once a local interrupt is generated by the DUART or MMU, control signals are sent between the interrupting device and
the interrupt handler as well as between the interrupt handler and the CPU. The DUART or the MMU responds with a pre-programmed status/ID vector as an interrupt response.

A subsystem can request an interrupt at any time by asserting the appropriate interrupt request line. On detecting an interrupt request, the interrupt handler sends a control signal to the VMEbus controller to request the VMEbus during the interrupt acknowledge cycle. The subsystem making the request then sends the status/ID vector to the master circuit board's CPU.
This chapter discusses the design of the minimal system and of the fully integrated system (master circuit board and system controller circuit board). The minimal system provides the foundation of core resources necessary to construct a computer system. The fully integrated system design can be implemented by integrating additional resources to the minimal system. For comparison, the fully integrated system is illustrated in Figure 3.1, while the minimal system is illustrated in Figure 4.1.

![Diagram of system components]

**Figure 4.1: Minimal System**
A. MINIMAL SYSTEM

Currently at the Naval Postgraduate School (NPS), there exists no computer-aided design (CAD) tools which can simulate the fully integrated system designed in this thesis. This is in part due to the inability of the CAD vendors to keep pace with the profusion of extremely complex very large scale integrated (VLSI) circuit chips. The CAD systems at NPS, Valid Inc.'s SCALD and Futurenet's CAD50, do not support all the peripheral devices incorporated within this thesis. Consequently, a step-by-step progression was made to fully integrate the system. The first stage, referred to as the minimal system, includes the core resources which form the foundation to which more complex devices can be added. When more complexity is added to the minimal system, operational testing can be conducted to insure proper integration of the new devices into the system.

1. Memory Map

Memory-mapping determines how the microprocessor accesses physical memory and peripheral devices. The Motorola MC68010 microprocessor has 23 address lines, A1 through A23. The upper data strobe (UDS*) and lower data strobe (LDS*) lines collectively determine address bit A0. Effectively, there are 24 address lines giving an virtual address range of 16 megabytes. Physical memory elements such as static random access memory (SRAM), dynamic random access memory (DRAM) and read-only memory (ROM) are mapped into this 16 megabyte range as are the memory-mapped peripherals.
The memory-mapped peripheral devices have multiple internal registers. The high order physical address bits are used to select a particular peripheral device. The low order physical address bits are decoded inside the peripheral device and subsequently select one of the internal registers. These registers are programmed to configure the device to meet desired performance specifications.

Table I displays the specific locations of the minimal system’s memory-mapped devices and the physical memory components within the address space of the MC68010 central processor unit (CPU).

TABLE I: MINIMAL SYSTEM MEMORY MAP

<table>
<thead>
<tr>
<th>PHYSICAL ADDRESS</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>$000000</td>
<td>64K BYTES OF EPROM</td>
</tr>
<tr>
<td>$00FFFF</td>
<td>64K BYTES OF EPROM</td>
</tr>
<tr>
<td>$010000</td>
<td>16K BYTES OF STATIC RAM</td>
</tr>
<tr>
<td>$013FFF</td>
<td>NOT USED</td>
</tr>
<tr>
<td>$014000</td>
<td>NOT USED</td>
</tr>
<tr>
<td>$7F6FFF</td>
<td>MC68681 DUART</td>
</tr>
<tr>
<td>$7F7000</td>
<td>NOT USED</td>
</tr>
<tr>
<td>$7F7FFF</td>
<td>NOT USED</td>
</tr>
<tr>
<td>$7F8000</td>
<td>NOT USED</td>
</tr>
<tr>
<td>$FFFFFF</td>
<td>NOT USED</td>
</tr>
</tbody>
</table>

The 64k bytes of erasable programmable read-only memory (EPROM) contain the exception vector table and the monitor/debugger program. Appendix B gives the source code listing of the exception
vector table and the monitor/debugger program. The 2500AD MC68010 cross assembler [Ref. 9], running on an IBM XT/AT compatible computer, was used to cross assemble the monitor/debugger source code into a Motorola S-record format [Ref. 10:pp. A-1 - A-4]. In order to program the S-record code into the EPROM, a Data I/O System 29 Universal Programmer was configured to accept Motorola S-records. The S-record file was then sent from the IBM XT/AT to the Data I/O System 29 via an RS-232 interface. Finally, the EPROM programming process was initiated on the Data I/O System 29.

The 16K bytes of SRAM are used to test development software. Files can be down-loaded to the SRAM for debugging. SRAM is used in the minimal system design instead of DRAM to avoid the additional logic necessary to generate refresh cycles for the DRAM.

The MC68681 dual universal asynchronous receiver/transmitter (DUART) is a communications peripheral device that can accommodate two independent full-duplex (receiver/transmitter) ports. The operating mode and data format of each port can be programmed independently. One port of the DUART is configured by the monitor/debugger program to accommodate the down-loading of files from an IBM XT/AT compatible computer. The other port of the DUART is configured to communicate with the terminal. The memory map (Table I) delineates a physical address range of $7F7000 through $7F7FFF for the DUART. A chip select signal will be generated for the DUART when a physical address is in the range $7F7000 through $7F7FFF. The physical addresses in the range
$7F7010$ through $7F7FFF$ are multiple maps for the DUART. Multiple maps provide valid addresses to chip select the DUART. They also permit address decoding logic to be simplified. However, to avoid ambiguity, only the physical addresses $7F7000$ through $7F700F$ are used to address the DUART.

2. Hardware Interface

Appendix C illustrates the circuitry involved in the minimal system. Figures C.1 through C.8 illustrate the minimum system in its entirety.

Figure C.1 illustrates the MC68010 microprocessor used in the minimal system design.

Figure C.2 illustrates the HALT* and RESET* generation circuitry. The NE555 timer provides an automatic system reset when the system is powered up. There is also a manual system reset switch (push button). Resetting the system initializes the internal circuitry of the CPU and DUART. A two-input OR gate in the reset circuitry has one input grounded, so it acts as an unneeded buffer. However, in the fully integrated system (discussed later in this chapter), this input is tied to the VMEbus system reset (SYSRESET*) line. This permits a system-wide reset to the master circuit board illustrated in Figure 3.1.

Figure C.3 illustrates the clock generation circuitry. The 8 MHz CPU clock signal is produced by using a 74LS161 binary counter to divide a 16 MHz signal from a crystal controlled oscillator. A 4 MHz signal from the 74LS161 provides the clock
input for the shift register which is used to help generate the data transfer acknowledge (DTACK*) and bus error (BERR*) signals.

Erasable programmable logic devices (EPLDs), specifically Altera EP310s, were used to reduce the chip count in the minimal system. EPLDs were used for address decoding, generating DTACK and BERR signals, performing interrupt control and generating SRAM write enable and RAM and ROM output enables.

Figure C.4 shows the EPLD implementation for the minimal system address decoder. The minimal system address decoder implements the memory map of Table I. Listing D.1 in Appendix D presents the Abel software program for the address decoder. Abel software will be discussed in the next section.

Figure C.5 shows the logic of the circuitry which generates the DTACK* and BERR* signals to the CPU. The circuitry prior to the 74LS05 open collector inverters, is implemented by an EPLD. The DTACK and BERR signals are passed through the 74LS05s to give the open collector outputs and the proper assertion levels (DTACK* and BERR*). In the event that the MC68010 microprocessor tries to address a location not supported by the design, a bus error (BERR*) time-out signal is generated after two microseconds. The BERR* signal causes the CPU to begin bus error exception processing. This invokes the routine whose address is in the longword at address $000008. The circuit which generates the delay time for BERR* is referred as a watchdog timer. Listing D.2 in Appendix D presents the Abel description of the DTACK and BERR signals.
The circuitry for EPROM and SRAM is illustrated in Figure C.6. Since random access memory (RAM) and ROM cannot generate a DTACK* signal to the CPU, additional circuitry is required. The DTACK* signal informs the CPU that the data transfer has been completed by the slave device. The 74LS164 shift register generates the data transfer delay times for the RAM and the ROM and the bus time-out delay for a bus error condition (Fig. C.5). A 250 nanosecond delay is provided to ensure an adequate time for data transfer between the CPU and the RAM. A 500 nanosecond delay is provided for data transfer between the CPU and the ROM. These transfer times accommodate the data propagation delay, the system address decoding delay and the internal address decoding delay of the RAM and the ROM. The logic for the output enable and the write enable signals are implemented on an EPLD. Listing D.3 in Appendix D presents the Abel description of the SRAM write enable and RAM and ROM output enable signals.

Figure C.7 shows the logic for the interrupt priority level (IPL0* through IPL2*) and the interrupt acknowledge (IACK681*) signal. A level one interrupt request (HHL) is sent to the MC68010 CPU when the MC68681 DUART asserts its interrupt request output (low). An IACK681* signal is sent to the DUART when a level one interrupt acknowledge is output by the CPU. The logic for the IACK681* and the IPL0* through IPL2* signals are actually implemented with an EPLD. Listing D.4 in Appendix D presents the Abel description of the IACK681* and IPL0* through IPL2* signals.
Figure C.8 illustrates the circuitry which supports the dual serial ports. As mentioned earlier, one port (Port A) of the DUART is configured to communicate with the terminal. The other port (Port B) is configured by the monitor/debugger program to accommodate the down-loading of files from an IBM XT/AT compatible computer.

3. Software Support

   a. Exception Vector Table and Monitor/Debugger Program

      The exception vector table contains the addresses of routines to be executed when an exception (trap or interrupt) is detected. The monitor program sets up communications with the terminal, provides debugging commands as well as a down-load command. The exception vector table and the monitor/debugger program (Appendix B) reside in the EPROM starting at physical address $000000. The exception vector table occupies physical addresses $000000 through $0003FF [Ref. 7:p. 4-5]. Physical addresses $000400 through $001FFF are not used and the monitor/debugger program begins at the arbitrarily selected physical address $002000.

      The monitor/debugger program was developed on the Motorola Educational Computer Board (ECB) [Ref. 10]. After a system reset, the microprocessor’s program counter is initially loaded with address $002000 to start the monitor/debugger program.

   b. Monitor/Debugger Commands

      The monitor/debugger program provides a user with six commands. These commands are not intended to be comprehensive, but
they do provide assistance in program development and debugging.

The user commands are as follows:

- GO address <,break point address>
- MM start address <,end address>
- MD start address <,end address>
- RCH {Axx, Dxx, PC, US, SP, SR}
- REG
- LOAD

where <...> implies optional
{...} implies select one entry

The GO command is used to execute a program that resides in the system’s memory. The program can be placed in memory by using the memory modify command or by down-loading a program from an IBM XT/AT compatible computer. The address in the GO command gives the location where program execution will begin. An optional break point address can be added within the GO command. The break point will stop program execution at the address specified. This is particularly useful if one desires to know the state of the machine, i.e., memory contents or register contents, at that point.

The memory modify command (MM) is used to modify the contents of an address or, if desired, a range of addresses. This command can modify code or data residing in RAM.

The memory display command (MD) is used to display the contents of an address or a range of addresses, if desired.

The change register command (RCH) is used to modify the contents of an address register (Axx), a data register (Dxx), the program counter (PC), the user stack pointer (US), the system stack...
pointer (SP) or the status register (SR). One of these options must be specified with the RCH command.

The display register command (REG) displays the contents of the address registers, data registers, program counter, user stack pointer, system stack pointer and status register. This information gives the state of the MC68010. This command is particularly useful when a breakpoint is reached in the debugging process.

The down-load command (LOAD) permits the minimal system to receive software that was developed on an IBM XT/AT compatible computer. After code has been assembled and linked using software such as the 2500AD MC68010 cross assembler, it can be down-loaded to the absolute address (or addresses) specified during the linking process.

c. Programmable Logic Device Programming

As already mentioned, EPLDs are used to reduce the chip count on the printed circuit board. The Data I/O Abel [Ref. 11] program was used to compile a high-level language representation of desired digital logic. The output of Abel is a joint electron device engineering council (JEDEC) standard file for programming the EPLDs. This file is then down-loaded to the Data I/O System 29 Universal Programmer to program the EPLDs. Appendix D shows the Abel source code that generates the logic implementations discussed in this chapter and illustrated in Figures C.4, C.5, C.6 and C.7.
B. FULLY INTEGRATED SYSTEM

The intent of this thesis is to design a hardware system so that at some future date an operating system could be developed to control its hardware facilities. These facilities accommodate virtual-memory, protected memory, serial communications, interrupt control and multi-processor abilities interfaced to the VMEbus. A hard disk controlled by a direct memory access (DMA) controller would be needed to implement the paging function required to support virtual-memory. The operating system would use the memory management unit (MMU) to implement user/supervisor memory allocations (protected memory) and virtual-memory. Considerations for a future operating system will be discussed throughout the following sections.

The fully integrated system is composed of the master circuit board subsystem and the system controller subsystem (Fig. 3.1). Each subsystem is decomposed into functional units. The functional units for the master circuit board subsystem are shown in Figure E.1 and the functional units for the system controller subsystem are shown in Figure E.2. Each of the functional units for the subsystems is discussed in the following sections.

1. Memory Map

The memory map (Table II) of the master circuit board’s physical address space contains the memory-mapped peripheral devices and the physical memory. This mapping is an enhanced version of the minimal system’s physical memory map (Table I).
<table>
<thead>
<tr>
<th>Physical Address</th>
<th>Memory Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$000000</td>
<td>64K BYTES OF EPROM</td>
</tr>
<tr>
<td>$00FFFF</td>
<td></td>
</tr>
<tr>
<td>$010000</td>
<td>16K BYTES OF SRAM</td>
</tr>
<tr>
<td>$013FFF</td>
<td></td>
</tr>
<tr>
<td>$014000</td>
<td>OFF-BOARD RESOURCE</td>
</tr>
<tr>
<td>$7F4FFF</td>
<td></td>
</tr>
<tr>
<td>$7F5000</td>
<td></td>
</tr>
<tr>
<td>$7F5FFF</td>
<td>MC68451 MMU</td>
</tr>
<tr>
<td>$7F6000</td>
<td></td>
</tr>
<tr>
<td>$7F6FFF</td>
<td>SCB68155 INTERRUPT HANDLER</td>
</tr>
<tr>
<td>$7F7000</td>
<td></td>
</tr>
<tr>
<td>$7F7FFF</td>
<td>MC68681 DUART</td>
</tr>
<tr>
<td>$7F8000</td>
<td></td>
</tr>
<tr>
<td>$7FFFFF</td>
<td>OFF-BOARD RESOURCE</td>
</tr>
<tr>
<td>$800000</td>
<td></td>
</tr>
<tr>
<td>$8FFFFF</td>
<td>ONE MEGABYTE OF DRAM</td>
</tr>
<tr>
<td>$900000</td>
<td></td>
</tr>
<tr>
<td>$FFFFFFF</td>
<td>OFF-BOARD RESOURCE</td>
</tr>
</tbody>
</table>

The memory map allocates 64K bytes of ROM to include the interrupt vector table, monitor/debugger program and operating system. The interrupt vector table and monitor/debugger program perform the same roles as described in the minimal system. However, an operating system would have to be incorporated to handle the enormous code requirements to manage user/supervisor memory allocations (protected memory), page faults (for virtual-memory) and an operating system kernel. The intent is for the core of the operating system to reside in ROM, since a mass storage
device is not incorporated in this subsystem design. A design of a multi-disk control module for a VMEbus-based system was presented in an earlier thesis [Ref. 12].

The 16k bytes of SRAM retains upward compatibility with the minimal system. The SRAM will be used until the DRAM can be incorporated into the master circuit board subsystem. However, if an operating system requires more than the 64K byte size of ROM, which is a likely possibility, any range spanning the physical addresses $010000$ through $7F4FFF$ could be allocated for more ROM or RAM. This would require changing the address decoding logic and adding ROM or RAM chips to the master circuit board subsystem design.

The MC68451 MMU [Ref. 13] is memory-mapped because its internal registers must be programmed for the desired virtual-memory configuration and address translation. By using the MC68010’s function codes (see Appendix A) along with the desired address translation scheme, an operating system can separate the supervisor’s address space from the user’s address space, thus implementing a memory protection scheme.

The SCB68155 interrupt handler hardware [Ref. 14:pp. 2-369 - 2-385] is memory-mapped so that it can be initialized for the desired mode of operation. The interrupt handler can accommodate local interrupts from the DUART and the MMU as well as interrupts from global bus masters.

The MC68681 DUART [Ref. 15] provides the interface to two RS-232 serial links. One link is used for communications with the
terminal, while the other link is used for communications with an IBM XT/AT computer. The DUART is configured to provide the desired serial communications characteristics such as baud rate, parity and stop bits.

One megabyte of DRAM is provided for the master circuit board subsystem. The operating system would manage this resource by assigning virtual pages to physical memory. It is intended that a portion of the DRAM's physical address range map to the same virtual address range. This will permit global memory access to pass semaphores and messages between the master circuit board and other subsystems, as discussed in Chapter I.

It is important to note that if an address falls into the ranges of $014000 through $7F4FFF, $7F8000 through $7FFFFF or $900000 through $FFFFFF, the CPU is accessing an off-board device.

2. Master Circuit Board
a. Microprocessor

The MC68010 CPU (Fig. E.3) is the processing element of the master circuit board subsystem. The signals of the CPU can be organized into functional groups (see Appendix A) which describe the role of the signals within the subsystem.

The CPU has two bi-directional open collector pins, HALT* and RESET*, which require pull-up resistors to ensure that the signals are not asserted until the appropriate events occur.

The only bus master on the subsystem is the MC68010. Hence, the bus request (BR*) and the bus grant acknowledge (BGACK*)
signals require a pull-up resistor to ensure that the CPU does not perform bus arbitration.

No Motorola M6800 peripherals are used in the master circuit board design. Hence, the valid peripheral address (VPA*) signal is tied to a logical one.

The circuitry to generate the DTACK* and BERR* signals (discussed later) are open collector signals. Hence, pull-up resistors are used to ensure that these signals are not inappropriately asserted.

b. Halt and Reset Generation

The HALT* and RESET* generation circuitry (Fig. E.4) provides manual and automatic power-on subsystem reset to the CPU and peripheral devices. The NE555 timer provides an automatic power-on reset to the subsystem. The NE555 timer is configured as a one-shot to generate the power-on reset signal. This automatic reset occurs within the first few tenths of a second after the subsystem is powered on. An external system reset can also reset the subsystem. This system reset is generated from the system controller subsystem via the VMEbus. A debounced switch is used to cause a manual reset of the subsystem.

A reset causes the CPU to read into the SP register and PC register the longword (32-bits) contents of physical addresses $000000$ and $000004$, respectively. Recall that ROM begins at physical address $000000$. Consequently, the two longwords beginning at physical address $000000$ are retrieved from non-volatile memory. The initial PC vector at physical address $000004$ contains the
value $002000$, so when this value is read into the PC, execution of the monitor/debugger program is started.

c. Clock Generation

The clock generation circuitry (Fig. E.5) provides clocking signals to the CPU and to the peripheral devices. A 74LS161 binary counter is used to divide the 16 MHz signal from the crystal oscillator into rates that accommodate the CPU, the MMU, the dual-port DRAM controller and the interrupt handler hardware. A 4 MHz signal is sent to additional circuitry to help generate the DTACK* and BERR* signals.

d. Local Bus Address Decoding

Once a virtual address is mapped to a physical address, the local bus address decode circuitry (Fig. E.6) is used to generate chip select signals for RAM, ROM or a peripheral device based upon the system memory map (Table II). Two Altera EP310 EPLDs [Ref. 16:pp. 2-57 - 2-62] were used in the design to be programmed via Abel software [Ref. 11]. As mentioned earlier, Abel is software developed by Data I/O Corporation that permits a high-level language description of the logic function to be programmed on a EPLD, programmable array logic (PAL) or similar logic device.

e. Memory Management Unit

The MMU circuitry (Figs. E.7 and E.8) provides the subsystem with virtual-memory support and memory protection. The address translation from a virtual-address-to-physical-address is done by this device. Once the MC68451 MMU has been configured by the operating system, the address translation is performed.
internally within the MMU and is thus hidden from the subsystem unless a page fault occurs. The internal details of the MMU are given in its reference manual [Ref. 13].

A page fault (FAULT*) signal is generated if the MMU detects a write violation or if address translation cannot be performed successfully. The write violation occurs if an attempt is made to write to a write-protected portion of physical memory. If address translation cannot be performed, this denotes to the operating system that a new memory page may need to be brought into memory from a hard disk or that there is a system error. The operating system configures the MMU to write-protect memory segments and to implement virtual-memory-mapping by the MMU.

The circuitry to inhibit virtual-address-to-physical-address translation during an interrupt cycle is illustrated in Figure E.7. The mapped address strobe (MAS*) and ALL input signals to the MMU are generated during an interrupt acknowledge cycle.

The physical data strobe generation circuitry (Fig. E.8) is used to generate the physical upper data strobe (PUDS*) and the physical lower data strobe (PLDS*) signals. The PUDS* and PLDS* signals are generated during normal virtual-address-to-physical-address translation. Normal address translation is the mapping of a virtual address to a physical address without a page fault occurring. The physical data strobes will not be generated if there is a write cycle for a write-protected segment. This is accomplished by the write inhibit (WIN*) signal generated by the MMU.
The physical address strobe circuitry (Fig. E.8) generates a physical address strobe (PAS*) signal to denote that the address translation has taken place and the physical address is valid and stable.

f. Dual-port DRAM Controller

The dual-port DRAM controller circuitry (Figs. E.9, E.10 and E.11) provides two paths into RAM [Ref. 17]. The local bus master (the CPU) can be ported to the RAM or a global bus master can be ported to the RAM via the VMEbus. Two paths into RAM are especially useful because processor subsystems can pass information-carrying semaphores. Also, The 74F764 dual-port DRAM controller provides DRAM refresh.

The 3-state capability of the 74LS244s (Fig. E.9) octal-buffers and line drivers with 3-state outputs are used to isolate one port access to the dual-port DRAM controller from the other port. The port is selected by the appropriate clock edge and control signal to the request input (REQ1* or REQ2*) of the 74F764 dual-port DRAM controller.

The control signal for REQ1* of the 74F764 (CS764REQ1*) is generated by the local bus address decoder and the control signal for REQ2* of the 74F764 (CS764REQ2*) is generated by the VMEbus address decoder. If CS764REQ1* is active on a rising clock edge and SEL2* is not asserted, the local master is granted access to the 74F764. The dual-port DRAM controller then asserts SEL1* to enable the 74LS244s and 74LS245s on the local bus side.
If CS764REQ2* is active on a falling clock edge and SEL1* is not asserted, the global bus master is granted access into the 74F764. The dual-port DRAM controller then asserts SEL2* to enable the 74LS244s and 74LS245s for the global bus side. In each case, the select line is released after the request signal is no longer asserted.

If both request lines are asserted and neither select line is asserted, on the next (rising or falling) clock edge, the select signal will be generated for the appropriate port access. The request that is locked out cannot gain access to the dual-port DRAM controller until the other port has completed its task and is no longer asserting its request signal.

The 74LS245s octal-bus transceivers with 3-state outputs, illustrated in Figure E.10, are used to buffer the data signals. Data can be sent between the CPU and the VMEbus, between the CPU and the DRAM or between the DRAM and the VMEbus. The data enable signal (DATAEN*) enables data to flow between the CPU and the VMEbus. The select port one (SEL1*) signal enables data to flow between the CPU and the DRAM, while the SEL2* signal enables data to flow between the DRAM and the VMEbus. The data flow direction to the 74LS245s is controlled by the read/write (R/W*) signal during local DRAM accesses, while the global R/W* signal (GP/W*) controls the direction for global DRAM accesses. The data direction enable (DDEN) signal controls the data direction flow between the CPU and the VMEbus.
The 74F764 can only effectively accommodate 18 address lines. Consequently, additional logic illustrated in Figure E.11 must be incorporated to handle address bit A19, which is required to give access to the desired one megabyte of RAM.

When the row address strobe (RAS*) signal becomes inactive, the data transfer acknowledge output from the 74F764 (DTACK764) is asserted. The DTACK signal of the 74F764 signals that data has been transferred to or from memory.

g. Dynamic Random Access Memory

The dynamic random access memory circuitry (Figs. E.12, E.13, E.14 and E.15) provides one megabyte of DRAM for the master circuit board subsystem. The DRAM is divided into two 512k byte blocks. The odd bytes are stored in one 512k byte block (Figs. E.12 and E.13), while the even bytes are stored in the other 512k byte block (Figs. E.14 and E.15).

The DRAM receives refresh cycles from the dual-port DRAM controller. Although the 74F764 dual-port DRAM controller seizes control of the DRAM during refresh cycles, a bus arbitration process is not needed. An 8 MHz clock pulse (RCP) is divided by 64 to produce a refresh request internal to the 74F764. If no request signal (REQ1* or REQ2*) is asserted on the 74F764, a nine-bit counter internal to the 74F764 is incremented. The counter value which represents the row in memory to be refreshed is then placed on output lines MA0 through MA8 of the 74F764. The RAS* signal is then asserted for four clock cycles to refresh a row in memory.
Finally, the RAS* signal is released and the refresh cycle is complete.

h. EPROM and SRAM

The EPROM and SRAM circuitry (Fig. E.16) provide 64k bytes of ROM and 16k bytes of SRAM. The EPROM contains the resident exception vector table and the monitor/debugger program. The SRAM is upward compatible from the minimum system. If additional memory is required by a resident operating system, a modification to the local bus address decoding logic would permit the size of ROM or RAM to be increased.

i. Dual Serial Port

The MC68681 dual universal asynchronous receiver/transmitter serial port circuitry (Fig. E.17) is used to provide serial communications with the terminal and the IBM XT/AT computer. Port A is dedicated to the terminal and Port B is dedicated to the IBM XT/AT computer. The 3.6864 MHz crystal is used to generate the baud rates for data transmission for both ports. The terminal provides an interface to the system for the user. The IBM XT/AT is used to down-load files into the master circuit board subsystem's memory.

j. Interrupt Handler

The interrupt handler circuitry (Fig. E.18) provides the necessary logic to accommodate interrupts from devices residing on the master circuit board subsystem and global devices residing on other subsystems. The SCB68155 interrupt handler can
accommodate six local interrupts, seven global interrupts and a non-maskable interrupt (NMI).

Local interrupts (LRQ1* through LRQ6*) have a higher precedence than the global interrupts (IRQ1* through IRQ7*). The local interrupt signal LRQ6* has the highest priority, while local interrupt signal LRQ1* has the lowest priority. The global interrupt signal IRQ7* has the highest priority, while global interrupt signal IRQ1* has the lowest priority. The NMI signal has priority over local and global interrupts and it is provided for a catastrophic occurrence such as an alternating current (AC) power failure.

Local interrupts are generated by the DUART and the MMU. The DUART is programmed to provide an interrupt request when a port buffer full condition is met. The buffer full condition of the MC68681 DUART occurs whenever a character is received from the terminal keyboard or from the IBM XT/AT. The local interrupt generated by the MC68451 MMU occurs when the interrupt bit of the page status register is set during normal address translation.

When a local or global interrupt occurs, the interrupt handler hardware generates an interrupt priority level output on lines IPL0* through IPL2* to the CPU. The CPU responds by acknowledging the interrupt with the interrupt acknowledge signal (IACK*) and places the interrupt level on address lines A1 through A3. The interrupt handler hardware reads the interrupt level on address lines A1 through A3 to determine which level is being acknowledged. If the interrupt was from a local device, the
interrupting device provides the vector number on the local data bus. If the interrupt was from another subsystem on the VMEbus, the interrupt handler hardware generates a bus interrupt acknowledge (BIACK*) signal to the VMEbus controller and the VMEbus. The VMEbus controller obtains control of the data transfer bus (DTB) so that an interrupt vector can be obtained from the interrupting subsystem. The BIACK* signal is only generated if the bus interrupt level is not masked (within the interrupt handler) and a local interrupt is not pending.

Once the local CPU has acknowledged the (local or global) interrupt request and has obtained an interrupt vector, the local CPU saves the state of the machine and transfers control to the appropriate interrupt handling routine. This prepares the CPU to perform an interrupt handling routine. After completion of the interrupt handling routine, the stored state of the machine is restored and the CPU resumes processing where it left off at the interrupt. [Ref. 7:pp. 4-3 - 4-16; Ref. 18:pp. 5-1 - 5-15]

k. Data Transfer Acknowledge and Bus Error Generation

The data transfer acknowledge and bus error generation circuitry (Fig. E.19) provides control signals to the CPU. This circuitry physically resides within a Altera EP310 EPLD. The DTACK* signal denotes that a data transfer has been completed by the slave device addressed. The MC68681 DUART, MC68451 MMU, SCB68172 VMEbus controller, SCB68155 interrupt handler and 74F764 dual-port DRAM controller peripheral devices possess the necessary
logic to generate their own DTACK* signal to acknowledge receipt or availability of data.

The master circuit board's RAM and ROM chips cannot generate their own DTACK* signals so external circuitry must do it for them. The DTACK* generation circuitry for the SRAM and ROM must allow adequate time for the data transfer. All these DTACK* signals are ORed together to produce the MC68010 DTACK* input.

If the CPU on the master circuit board makes an off-board access using the off-board (OFFBOARD*) signal to the VMEbus controller, the DTACK* signal (DTACK172*) is generated from the VMEbus controller. The off-board device provides a global DTACK* signal (GDTACK*) to the VMEbus controller (Fig. E.20) via the VMEbus DTACK* line. In turn, the VMEbus controller would provide the DTACK172* signal for the DTACK* circuitry. This arrangement permits long access times on the VMEbus.

If the master circuit board's DRAM is being accessed as a global asset, the GDTACK* signal is generated by the SEL2* and DTACK764 signals as illustrated in Figure E.11.

The BERR* signal is generated under one of three conditions. First, the BERR* signal is generated when the maximum allowable SRAM and ROM data transfer time has been reached and a DTACK* signal has not been received by the CPU. Secondly, a global bus error (BERR172*) signal can be received from a VMEbus watchdog timer if the master circuit board subsystem has control of the VMEbus. Finally, if a page fault signal (FAULT*) is generated by the MMU, this also causes a bus error condition.
The bus error condition causes exception processing to occur. The current state of the machine is saved. Information from the saved state of the machine can be used to determine the cause of the bus error. This is handled by the bus error exception routine as part of an operating system.

If the first port of the dual-port DRAM controller is not active and a refresh cycle is not taking place, a global bus master can have access to the DRAM. The master circuit board’s CPU is unaware of the access to the DRAM through the second port. Consequently, the burden is placed upon a global master or a VMEbus watchdog timer to provide a global BERR* signal (GBERR*) on the VMEbus BERR* line, when appropriate, to the VMEbus controller. The GBERR* signal is sent to the BERR* circuitry (Fig. E.19) via the BERR172* signal.

1. VMEbus Controller

The VMEbus controller circuitry (Fig. E.20) provides the necessary logic for the master circuit board subsystem to gain access to the VMEbus. The SCB68172 VMEbus controller provides control signals (VMEEN*, DATAEN* and DDEN) to the master circuit board subsystem’s drivers and transceivers. The purpose of the VMEbus enable (VMEEN*) signal is to enable the bus drivers only when there is an off-board (OFFBOARD*) access. In addition, the data flow (DATAEN*) and its direction (DDEN) are controlled. Parallel jacks are provided which permit jumper selection of the master circuit board subsystem’s priority on the VMEbus.
m. VMEbus Address Decoding

The VMEbus address decode circuitry (Fig. E.21) permits access of a global bus master to the second port of the dual-port DRAM controller and ultimately into DRAM. Any subsystem, which has gained control of the VMEbus, has the ability to access the designated (by the operating system) area of DRAM for semaphore passing. The VMEbus address decoder provides the chip select signal CS764REQ2* to the dual-port DRAM controller (Fig. E.9). If the CS764REQ2* is asserted when clock edge falls and SEL1* signal of the 74F764 is not asserted, the isolation drivers are enabled to permit the flow of data and addresses from the global resource to the DRAM.

n. VMEbus Drivers

The circuitry for the master circuit board’s VMEbus drivers (Figs. E.22, E.23 and E.24) provides control of signals from the local bus to the VMEbus and from the VMEbus to the local bus. The VMEbus controller controls the direction of the signal flow as requested by the CPU. Whenever the local bus master, the CPU, is not in control of the VMEbus, all signals from the local bus are isolated at the drivers by the VMEbus controller. Thus, in this case, no signals are gated onto the VMEbus from the local bus. However, another subsystem, if in control of the VMEbus, has direct access to the DRAM through the dual-port DRAM controller. The global addresses on the VMEbus fall into the range of the one megabyte of user DRAM in the master circuit board subsystem’s memory map (Table II).
3. System Controller Circuit Board

a. Bus Arbiter

The VMEbus arbitration circuitry (Fig. E.25) provides the logic to arbitrate prioritized bus requests in parallel. Each bus request is then daisy chained down to the requesting device. Each subsystem capable of VMEbus access must have the ability to provide a bus request at one of four priority levels. The highest priority signal used is DBG7*, while the lowest priority level signal used is DBG4*. The process of resolving the VMEbus requests was described in Chapter II. Since the MC68452 bus arbitration module (BAM) [Ref. 8] is an asynchronous device, the bus grant signals (DBGx*) are not guaranteed to be spike-free. Consequently, a 50 nanosecond delay circuit is used to disable the DBGx* signals during the parallel arbitration process.

b. System Reset

The system reset circuitry (Fig. E.26) provides a system-wide master reset. This signal is sent on the VMEbus to all circuit boards and it is used to reset the entire system much like the local reset discussed earlier in this chapter.

c. VMEbus Drivers

The circuitry for the system controller drivers (Fig. E.27) provides the drive capability for signals to/from the VMEbus. Since circuitry was not designed to detect an AC power failure, the ACFAIL* signal is never asserted. This signal is input to the non-maskable interrupt of the interrupt handler (Fig. E.17). The bus clear (BCLR*) signal informs the current bus master that there is
a higher pending bus request. Burden is placed upon the current bus master to either relinquish control of the bus or to continue control until its task is completed. For the sake of simplicity, the master circuit board subsystem was designed to relinquish control upon the completion of its task. Finally, an IACK* daisy chain driver is provided for VMEbus interrupts.
V. RESULTS

Once the minimal system and fully integrated system hardware was designed, the schematic drawings drafted and the pin-out list implemented, software support was required to implement the minimal system. The monitor/debugger program required a thorough check of all its software features. These software features include the capability to set and remove a breakpoint, to display and modify memory, to display and change registers, to start program execution and to down-load software from a development system.

It was discovered while debugging the down-load portion of the monitor/debugger program that the 2500AD 68010 cross assembler's linking process incorrectly resolved external references. The linking process generates a file in the Motorola S-record format. The problem was isolated only after comparing the Motorola S-record to Motorola's instruction format. It was identified that the 2500AD cross assembler was improperly resolving external references. A corrected version of the 2500AD cross assembler was obtained from the vendor that resolved this problem. With the monitor/debugger software developed, the minimal system design was complete.

The monitor/debugger and vector table were programmed in the erasable programmable read-only memory (EPROM) with the Data I/O System 29 Universal Programmer. The Data I/O System 29 segregated
the even bytes and odd bytes into separate EPROMs as required by the Motorola MC68010 central processor unit (CPU).

Erasable programmable logic devices (EPLDs) were used to reduce the chip count in the minimal system design. The minimal system used an EPLD to perform the interrupt request (IRQ681*) and the interrupt acknowledge (IACK681*) logic. Also, EPLDs were used to implement the circuit logic required for the generation of the data transfer acknowledge (DTACK) and the bus error (BERR) signals and for address decoding. In order to program the EPLDs, Abel software was used to compile the source code representation of the logic to be implemented with the EPLD. Once all of the source code for the EPLDs had been written, compiled and software tested, the EPLDs were programmed.

On the Data I/O System 29, once the EPLD is programmed, the test vectors are again tested against the programmed EPLD. During this test run, the System 29 failed for every EPLD that was programmed, even though they passed the software tests. On the advice of an applications engineer at Data I/O Corporation, the test vectors were removed from the source code. This code was compiled, then the EPLDs were programmed. The EPLDs were bread-boarded, while determining with reasonable certainty that the devices were actually implementing the desired logic.

The ultimate goal in this thesis was to implement the master circuit board subsystem design. One of the steps to achieve this goal requires the memory management unit (MMU) to translate a virtual address to a physical address. To avoid significant wiring
modifications to the minimal system to build up to the master subsystem, the MMU was wire-wrapped into the minimal system design. However, the MMU was not programmed at the minimal system stage. The MMU translates a virtual address to the same physical address when the MMU is not programmed after being reset. The MMU was configured to accommodate an automatic, manual and programmed (CPU reset instruction) reset.
VI. SUMMARY AND CONCLUSIONS

A. SUMMARY

The goal of this thesis was two-fold: first, to explore hardware ramifications of designing a microprocessor system for a multi-processor environment; and secondly, to implement the minimal system design.

1. Design Concepts

In exploring hardware ramifications, the scope was limited to features of the VMEbus structure, in memory-management and interrupt control. The memory-management features included memory protection, dual-ported memory and virtual-memory.

a. VMEbus Structure

The VMEbus permits an exchange of data and control beyond the boundaries of a single circuit board. Other subsystems or circuit boards which may include processing elements, memory and/or input/output (I/O) devices can be integrated to the VMEbus. A strict adherence to data transfer protocols over the VMEbus ensures the reliability and integrity of the system. The ability to integrate various subsystems along the VMEbus supports a multi-processor environment.

b. Memory-Management

The Motorola MC68010 central processor unit (CPU) generates function codes which can be used by the memory management unit (MMU) to partition memory into supervisor and user portions.
An operating system would manage memory partitioning. Normally, systems are designed so that the supervisor memory portion contains the memory-mapped I/O devices and the read-only memory (ROM) and some random access memory (RAM). The ROM is mapped to the supervisor portion of memory since it provides the exception vector table and start-up program.

The function codes reflect the CPU’s two modes of operation, the supervisor and user. The supervisor mode is a privileged mode which permits access to all instructions and the full range of memory (supervisor and user memory). The user mode permits access to only user instructions and the user memory. Typically, in the user mode, permission must be granted through the operating system to use system resources. The separation of supervisor memory from user memory prevents the user from tampering with the system assets or gaining supervisor privileges.

Dual-ported memory permits two separate sources to access the same memory block and provides the refresh signals for the dynamic random access memory (DRAM). Dual-ported memory permits RAM to be used as a shared asset. It is especially useful when a portion of the physical RAM is dedicated to passing parameters between microprocessor subsystems. Dedicating a portion of RAM for parameters is analogous to a mailbox delivery system. The mail courier (subsystem 1) delivers mail (parameters) to the mailbox (RAM). The addressee (subsystem 2) picks up the mail (parameters) and responds as required. If appropriate, the occupant (subsystem 2) places mail (parameters) in the mailbox.
(RAM) to be delivered (to subsystem 1). These parameters can be used in managing a multi-processor operating system.

A MC68010-based system typically has memory-mapped I/O devices, RAM and ROM. DRAM is added the master circuit board subsystem to supplement the minimal system's static random access memory (SRAM). The MC68010 CPU has a virtual address range of 16 megabytes. However, the physical RAM's size is usually considerably less than the size of the virtual address space. Virtual-memory is used to extend the range of programming beyond the range of physical RAM. An MMU is used to map virtual addresses into RAM physical addresses. Also, the MMU detects an attempt by the CPU to access a virtual-memory address which is not currently present in physical memory. When such an attempt is detected, the MMU generates a page fault. This page fault causes the page fault exception routine to be invoked. The exception routine reads a page of information from secondary storage into RAM. The MMU maps the virtual addresses associated with the page into addresses in the physical RAM. After completion of the exception routine, program execution resumes with the completion of the instruction that caused the page fault.

c. Interrupt Control

Using interrupts results in more effective use of the microprocessor because the microprocessor is not kept waiting for a device to respond. The devices requesting interrupts in this thesis are programmed to provide an interrupt vector number during an interrupt acknowledge cycle for local interrupts. The interrupt
vector number causes the address of the exception routine to be obtained from the exception vector table by the CPU so that it can be executed.

2. Design Implementation

a. Hardware Configurations

The recommended wiring configurations that accompanied the product specifications for the MMU, VMEbus controller, dual universal asynchronous receiver/transmitter (DUART), dual-port DRAM controller, interrupt handler hardware and bus arbitration module (BAM) greatly assisted in the designs of the minimal system, system controller subsystem and master circuit board subsystem. However, in order to integrate these components into a system, care was taken to ensure that the control signals were interfaced properly. Since no computer-aided design (CAD) tools existed at the Naval Postgraduate School (NPS) to fully simulate even the minimal system design, prototyping the minimal system was necessary. The minimal system has a foundation of core resources. The intent was to prove the system design by building up a master circuit board subsystem from the minimal system.

The system controller subsystem provides a bus arbiter, interrupt acknowledge (IACK*) daisy chain driver and system-wide reset. The bus arbiter determines bus ownership between subsystems that make bus requests and it grants bus ownership to the subsystem with the highest priority. An IACK* daisy chain driver sends the IACK* signal on to the bus during an interrupt acknowledge cycle.
The system reset is used to reset all devices on all subsystems after a system failure.

The master circuit board subsystem accommodates the VMEbus structure, virtual-memory-mapping facilities, a protected memory scheme, dual-ported memory and interrupt handling hardware. The master circuit board subsystem design is an extension of the minimal system and should not be implemented until the minimal system is operational. In the master circuit board subsystem, the VMEbus controller provides the necessary logic to meet the VMEbus specification for setting up the baseline bus structure. Drivers and transceivers are incorporated to meet the specified signal drive capability and isolation requirements.

b. Erasable Programmable Logic Devices

The erasable programmable logic device (EPLD) used in the minimal system's address decoding must be modified to include the additional memory-mapped devices of the master circuit board subsystem. The EPLD used for interrupt handling in the minimal system is replaced by the interrupt handler hardware in the master circuit board subsystem design.

The master circuit board subsystem design is an upgraded version of the minimal system. A pin-out list for all wiring connections was developed in order to reduce wire-wrap errors, but it is not included as part of this thesis. The small scale integrated circuit (SSI) logic shown for the generation of the data transfer acknowledge (DTACK), bus error (BERR), physical upper data strobe (PUDS*), physical lower data strobe (PLDS*) and
physical address strobe (PAS\(^*\)) signals was actually implemented with EPLDs to reduce the chip count.

### B. CONCLUSIONS

Meeting all the goals set in this thesis made this thesis an ambitious undertaking. The major integrated circuit (IC) chips included the CPU, DUART, interrupt handler hardware, dual-port DRAM controller, MMU, VMEbus controller and BAM. These IC chips required an extensive study of product specification and application notes to understand the wiring configurations and programming of the devices. Study of the specification notes invoked support ideas in the design that required further investigation. These support ideas included DRAM memory refresh accommodations, driver characteristics, noise reduction and virtual-memory. Once each device was reasonably understood, the problem of integrating the devices into a single system remained. Care was exercised to ensure that control signals were properly integrated to the devices. Consequently, a major portion of this thesis was spent in the research and design process without the assistance of CAD tools.

The design and implementation work of this thesis spanned almost two years. A major problem encountered was the inability to simulate the system designs. Hence, the system's validity could only be verified by actual design implementation.

The design phase took a considerable length of time because the inter-relationships between the devices to support a multi-processor environment, dual-port memory, virtual-memory, memory
protection, dual serial ports and interrupt control features were not trivial. Some of these features should have been eliminated so that a simpler design could have been implemented. However, using the approach of building a complex subsystem from a minimal system is an important technique. For a growing number of new application IC chips, facilities to simulate designs using these chips do not yet exist. Thus, there is a strong need for advanced design tools and engineering practices to support complex designs.

An important restriction of the master circuit board subsystem design is the lack of an operating system. The capability provided in this thesis could not be fully utilized without an operating system and a mass storage device, such as a hard disk. Managing the virtual-memory and protected memory requirements would require a tremendous amount of code which is beyond the scope of this thesis. However, while designing the master circuit board subsystem, foresight was exercised to consider the requirements of an operating system. This confirms the need for a dialogue between system designers and operating system designers to communicate the system requirements.
APPENDIX A: MC68010 16-BIT MICROPROCESSOR

Since the entire hardware system design revolves about the MC68010 microprocessor, a description of the microprocessor, its external signals and its programming is appropriate.

A. MC68010 DESCRIPTION

The MC68010 has seventeen 32-bit general purpose registers, a 16 megabyte address space, virtual-memory/machine support, 57 instructions with 14 addressing modes using five main data types and memory-mapped input/output (I/O) [Ref. 7:p. 1-1]. Motorola provides a complete signal description and timing analysis of the MC68010 microprocessor [Ref. 18].

B. MC68010 SIGNALS

The MC68010 central processing unit (CPU) comes in a 64-pin package. As shown in Figure A.1, the signals are organized into groups and the direction of the signal flow is denoted by the arrows. To avoid any confusion over logic assertion levels, the asterisk (\*) at the end of a signal name is used to denote an active low assertion level.

1. Address Bus

The address bus consists of 23 address lines giving an eight megaword address range for the CPU.
2. Data Bus

The data bus is a 16-bit bi-directional bus used for transferring byte or word length data.

3. Asynchronous Bus Control

The asynchronous bus control group provides information about the data that is being transferred. The address strobe (AS*) signal signifies that valid address signals are being gated from the CPU. The read/write (R/W*) line denotes that the CPU is reading from a device (active high) or that the CPU is writing to the device (active low). The upper data strobe (UDS*) indicates that the data being transferred is on an even byte boundary. The lower data strobe (LDS*) indicates that the data being transferred is on an odd byte boundary. When UDS* and LDS* are both asserted, a word (16-bits) of data is being transferred. The UDS* and LDS*
signals together determine address bit A0, thus giving an address range of 16 megabytes for the CPU. The UDS*, LDS* and R/W* signals control the flow of the data on the data bus as illustrated in Table III [Ref. 18:p. 4-2]. Finally, the data transfer acknowledge (DTACK*) signal informs the CPU that the current data transfer has been completed by the peripheral device or memory location addressed.

**TABLE III: DATA STROBE CONTROL OF THE DATA BUS**

<table>
<thead>
<tr>
<th>UDS*</th>
<th>LDS*</th>
<th>R/W*</th>
<th>D8 - D15</th>
<th>D0 - D7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1 or 0</td>
<td>NO VALID DATA BITS</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>VALID DATA BITS</td>
<td>VALID DATA BITS</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>NO VALID DATA BITS</td>
<td>VALID DATA BITS</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>VALID DATA BITS</td>
<td>NO VALID DATA BITS</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>VALID DATA BITS</td>
<td>VALID DATA BITS</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>#VALID DATA BITS 0-7</td>
<td>VALID DATA BITS</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>VALID DATA BITS</td>
<td>#VALID DATA BITS 8-15</td>
</tr>
</tbody>
</table>

# These conditions are a result of current implementation and may not appear on future devices.

4. **Bus Arbitration Control**

As a group, the bus arbitration control signals provide a mechanism for the CPU to give up control of the bus. However, these signals do not determine (directly) which alternate bus master gets control. The bus request (BR*) signal is a signal generated by a device or devices requesting access to the bus. The bus grant (BG*) is a signal from the CPU indicating that it will release the bus at the end of the current bus cycle. The bus
grant acknowledge (BGACK*) is a signal asserted by an alternate bus master while it has control of the bus.

5. Interrupt Control

The interrupt priority levels (IPL0* through IPL2*) are signals which represent the encoded priority level for the highest priority device desiring interrupt service. The signal IPL0* is the least significant bit and the signal IPL2* is the most significant bit of the group. A level zero interrupt (all signals are asserted high) indicates there is no interrupt request pending. A level seven interrupt (all IPLx* signals are asserted low) has the highest priority and is non-maskable. This implies that level seven is not an ordinary interrupt level for requesting routine interrupt service. Rather, a level seven interrupt should be reserved for catastrophic events such as alternating current (AC) power failure where the non-maskable property is essential.

6. System Control

The system control group is used to reset the CPU and to indicate to the CPU that a bus error has occurred. It is also used to reset peripheral devices and to generate a bus error exception. The halt signal (HALT*), active low, is a bi-directional signal. As an input, it is used to stop the CPU at the completion of the current bus cycle. As an output, HALT* is asserted only when a double bus error or address error exception has caused the MC68010 to enter a halt state.

The reset signal (RESET*), active low, is also a bi-directional signal. It can be used as an input to reset the
internal microcircuitry within the CPU. When a reset instruction is executed by the CPU, it can be used to reset system devices.

Typically, a maximum time is allotted for data transfer. If the data transfer is not completed within the allotted time, bus error (BERR*) is asserted by a time out circuit called a watchdog timer. Often, the BERR* signal is used to inform the CPU that the current address on the address bus is invalid because no physical memory or peripheral device is mapped at that address. The BERR* signal can also be used to flag the condition that the CPU is making an attempt to write to read-only memory (ROM). In a virtual-memory system, BERR* is asserted by the memory management unit (MMU) when a page fault occurs.

7. M6800 Peripheral Control

The M6800 peripheral control group is a group of signals which are used to interface the MC68010's 16-bit asynchronous data bus to synchronous peripheral devices in the Motorola M6800 eight-bit family.

The enable (E) signal which acts as the 6800 phase two clock is used to synchronize data transfer between the MC68010 CPU and M6800 peripheral device. The E signal's period is ten clock periods of the MC68010's clock input. The valid peripheral address (VPA*) signal denotes to the CPU that the device selected is a M6800 peripheral device. The VPA* signal indicates to the CPU that it should initiate a data transfer synchronized with the E signal. The valid memory address (VMA*) signal from the CPU indicates to a
M6800 device that there is a valid address on the address bus and that the MC68010 is synchronized with the E signal.

8. Processor Status

The MC68010 has three function code lines (FC0 through FC2) which delineate the current processor state (user or supervisor) and the address space (program or data) being accessed as defined by Table IV [Ref. 18:p. 5-3]. The address strobe (AS*) signal from the CPU indicates that a valid address and function code are available from the CPU.

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<thead>
<tr>
<th>FUNCTION CODE OUTPUT</th>
<th>ADDRESS SPACE</th>
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</table>

9. Miscellaneous

Both Vcc pins and both GND pins must be connected in order to power the CPU. The clock (CLK) input signal is used to develop all the synchronizing signals required within the CPU.
C. PROGRAMMING

Motorola provides programming information in its reference manual [Ref. 7]. The MC68010’s instruction set includes the following operations:

- Data Movement         - Bit Manipulation
- Integer Arithmetic    - Binary Coded Decimal (BCD) Arithmetic
- Logical               - Program Control
- Shift and Rotate      - System Control
- Bit Manipulation      - Multi-processor Communications

supporting the following data types:

- Bit
- BCD (Four-bits)
- Byte (Eight-bits)
- Word (16-bits)
- Long Word (32-bits)

Fourteen addressing modes that are available to the assembly language programmer. The addressing modes available include:

- Data Register Direct
- Address Register Direct
- Address Register Indirect
- Address Register Indirect with Postincrement
- Address Register Indirect with Predecrement
- Address Register Indirect with Offset
- Address Register Indirect with Index and Offset
- Absolute Short
- Absolute Long
- Program Counter with Offset
- Program Counter with Index and Offset
- Immediate Data
- Quick Immediate
- Implied Register
The following assets are available:

- Eight Data Registers
- Seven Address Registers
- User Stack Pointer (User Mode)
- Supervisor Stack Pointer (Supervisor Mode)
- Program Counter
- *Status Register (Supervisor mode)
- Vector Base Register (Supervisor Mode)
- Alternate Function Code Registers (Supervisor Mode)

* The condition code register is the lower byte of the status register and it is accessible in the user mode.

To support virtual-memory, the MC68010 microprocessor allows an interrupted bus cycle to be re-run after a bus error exception. The return from exception (RTE) instruction uses the format field of the exception stack to determine whether the exception was caused by bus or address error. After a bus or address error caused the exception, the CPU continues the interrupted instruction after completion of the exception routine. [Ref. 19]
APPENDIX B: MINIMAL SYSTEM EXCEPTION VECTOR TABLE AND MONITOR/DEBUGGER PROGRAM

This appendix contains the source listings of the exception vector table and monitor/debugger program. The separate file names are as follows:

- VECTABLE.ASM
- MAIN.ASM
- MESSAGE.ASM
- CONSOLE.ASM
- GETSTRIN.ASM
- GET_ADDR.ASM
- IO_UTIL.ASM
- DECODER.ASM
- BYTEOUT.ASM
- MEM_LIST.ASM
- HEXCONV.ASM
- GO.ASM
- STUB.ASM
- REG.ASM
- REGCHANG.ASM
- DOWNLOAD.ASM
- UNUSED.ASM

Using the 2500AD 68010 cross assembler and linker, a Motorola S-record format file was generated as a load module. The load module was loaded as an ASCII file into a Data I/O System 29 Universal Programmer. Once resident in the programmer, the load module was programmed to erasable programmable read-only memory (EPROM). It should be noted that the data section as contained in MAIN.ASM was not programmed on EPROM, but rather it resides in random access memory (RAM).

The first two entries in the exception vector table are used during the system boot up to provide the initial contents for the stack pointer and the program counter. The exception vector table contains the addresses of exception routines. The monitor/debugger
program initializes the MC68681 peripheral device and provides facilities for performing software debugging and the downloading of files from an IBM XT/AT compatible computer.
EXTERNAL BKPT, INIT, INIT_SP, MESSAGE, MONITOR
EXTERNAL UNUSED

ORG 0 VECTOR TABLE STARTS AT ABSOLUTE ADDRESS $000000
LONG INIT_SP INITIAL STACK POINTER VECTOR
LONG INIT INITIAL PROGRAM COUNTER (PC);
    VECTOR
LONG UNUSED BUS ERROR VECTOR
LONG UNUSED ADDRESS ERROR VECTOR
LONG UNUSED ILLEGAL INSTRUCTION VECTOR
LONG UNUSED ZERO DIVIDE VECTOR
LONG UNUSED CHK INSTRUCTION VECTOR
LONG UNUSED TRAPV INSTRUCTION VECTOR
LONG UNUSED PRIVILEGE VIOLATION VECTOR
LONG UNUSED TRACE VECTOR
LONG UNUSED LINE 1010 EMULATION VECTOR
LONG UNUSED LINE 1111 EMULATION VECTOR
ORG $38 NOTE: VECTOR NUMBERS 12 AND 13
    ARE UNASSIGNED, RESERVED
LONG UNUSED FORMAT ERROR VECTOR
LONG UNUSED UNINITIALIZED INTERRUPT VECTOR
ORG $60 NOTE: VECTOR NUMBERS 16-23 ARE
    UNASSIGNED, RESERVED
LONG UNUSED SPURIOUS INTERRUPT VECTOR
LONG UNUSED LEVEL 1 AUTOVECTOR VECTOR
LONG UNUSED LEVEL 2 AUTOVECTOR VECTOR
LONG UNUSED LEVEL 3 AUTOVECTOR VECTOR
LONG UNUSED LEVEL 4 AUTOVECTOR VECTOR
LONG UNUSED LEVEL 5 AUTOVECTOR VECTOR
LONG UNUSED LEVEL 6 AUTOVECTOR VECTOR
LONG UNUSED LEVEL 7 AUTOVECTOR VECTOR
LONG BKPT TRAP 0VECTOR USED AS MONITOR BKPT
LONG UNUSED TRAP 1 VECTOR
LONG UNUSED TRAP 2 VECTOR
LONG UNUSED TRAP 3 VECTOR
LONG UNUSED TRAP 4 VECTOR
LONG UNUSED TRAP 5 VECTOR
LONG UNUSED TRAP 6 VECTOR
LONG UNUSED TRAP 7 VECTOR
ORG $100 NOTE: VECTOR NUMBERS 48-63 ARE UNASSIGNED, RESERVED
LONG MONITOR USER INTERRUPT 0 VECTOR
; DEFINED FOR MONITOR
LONG UNUSED USER INTERRUPT 1 VECTOR
LONG UNUSED USER INTERRUPT 2 VECTOR
LONG UNUSED USER INTERRUPT 3 VECTOR
LONG UNUSED USER INTERRUPT 4 VECTOR
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<td>USER INTERRUPT 186</td>
</tr>
<tr>
<td>LONG</td>
<td>UNUSED</td>
<td>USER INTERRUPT 187</td>
</tr>
<tr>
<td>LONG</td>
<td>UNUSED</td>
<td>USER INTERRUPT 188</td>
</tr>
<tr>
<td>LONG</td>
<td>UNUSED</td>
<td>USER INTERRUPT 189</td>
</tr>
<tr>
<td>LONG</td>
<td>UNUSED</td>
<td>USER INTERRUPT 190</td>
</tr>
<tr>
<td>LONG</td>
<td>UNUSED</td>
<td>USER INTERRUPT 191</td>
</tr>
</tbody>
</table>

END
**MAIN IS THE ENTRY POINT INTO THE MONITOR. MAIN initializes the RS-232 PORT BEFORE ENTERING THE MONITOR. ALSO, MAIN CONTAINS THE MEMORY MAPS, EQUATES AND MEMORY ALLOCATIONS.**

68K MONITOR VERSION V1.3 - AN ACCUMULATION OF ALL PRIOR VERSIONS

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FILENAME: MAIN.ASM

**VERSION 1.3**

REV. MODIFIED BY DATE DESCRIPTION
A LARRY ABBOTT 11/7/86
B LARRY ABBOTT 12/14/86 MONSTAT-ESCAPE
C LARRY ABBOTT 6/6/87 ADAPT TO MC68681
D DAVID M. SENDEK 29 SEPT 87 -INCLUDE VECTOR TABLE
   -INCLUDE MONITOR PROMPT
   -CORRECT FOR 68681

**DEFINING MODULES OF EXTERNALLY DECLARED VARIABLES:**

CMD DECODE - DECODER.ASM
GETSTRING - GETSTRING.ASM
MESSAGE - MESSAGE.ASM
MONMSG - MESSAGE.ASM
SCRLF - IO_UTIL.ASM

**DATA**

ALL R/W DATA IS STORED IN SRAM AT ADDRESS $010000

**EQUATES**

BS EQU $08 ASCII CODE FOR <-- (BACKSPACE)
CR EQU $0D ASCII CODE FOR RETURN
EPROMRNG EQU $3FF EPROM RNG 0 -> $3FF (EXCEPTION TBL)
ESC EQU $1B ASCII CODE FOR ESCAPE
FWDARW EQU $3E ASCII CODE FOR ’>’ (FORWARD ARROW)
LF EQU $0A ASCII CODE FOR LINEFEED

***************
NULL EQU $00 ASCII CODE FOR NUL
SPACE EQU $20 ASCII CODE FOR SPACE
BTLEN EQU $10 BREAKPOINT TABLE LENGTH IN WORDS

* MEMORY ALLOCATIONS *

BKPTAB BLKW 3/2*BTLEN RESERVE BTLEN/2 32-BIT BKPT’s
BUFFIN BLKB $3F RESERVE 63 BYTE INPUT BUFFER
END_ADDRESS BLKW 2 RESERVE WORD FOR END ADDRESS
MONSTAT BLKW 1 RESERVE A WORD FOR MONITOR STATUS
STAX BLKW 36 SAVE AREA FOR APPLICATION REG’S
SYSTAX BLKW 2 RESERVE MEMORY FOR STACK POINTER
CK_SUM BLKW 1 CHECK SUM STORAGE
SRAM EQU BKPTAB DATA BEGINS AT LOW ADDR OF SRAM
SRAMSIZE EQU $3FFF 16K BYTES OF STATIC RAM
INIT_SP EQU $013FFE INITIAL STACK POINTER

* DEFINITION OF MONSTAT (MONITOR STATUS WORD) *

EPROMWR EQU 0 WRITE TO EPROM FLAG
ESCAPE EQU 1 ESCAPE FLAG
CONTINUE EQU 2 CONTINUATION FLAG
FOUND EQU 3 CMD FOUND FLAG
HEX_ERR EQU 4 HEX CONVERSION ERROR
MODIFY EQU 5 MEMORY MODIFY FLAG
STRING EQU 6 STRING BUILDING IN PROGRESS
STRINGEND EQU 7 END OF STRING BUILDING
CHECKSUM EQU 8 CHECKSUM ERROR FLAG

* 68681 EQUATES *

RECFULL EQU $00 SRA(0)=1=>RECEIVE FIFO HAS A CHAR
XEMPTY EQU $02 SRA(2)=1=>XMIT HOLDING REG EMPTY
MR1RFSET EQU $1A RESET MODE REG PTR & DISABLE XMIT/RECV
CLK_SRC EQU $30 XTAL/16 CLOCK
CONF1AB EQU $13 8-BIT DATA, NO PARITY
CONF2A EQU $07 1 STOP BIT
CONF2B EQU $0F 2 STOP BITS
BAUD2400 EQU $88 2400 BAUD
BAUD9600 EQU $BB 9600 BAUD
EN_PORT EQU $45 RESET ERROR, ENABLE XMIT & RECV
RUPTASK EQU $02 ENABLE RECV READY RUPT
RUPTVECT EQU $40 USER INTERRUPT 0 VECTOR

* 68681 REGISTERS *

* CRT <- PORT A:9600 BAUD,8 DATA BITS,
* NO PARITY,1 STOP BIT
* DOWNLOAD <- PORT B:2400 BAUD,8 DATA BITS,
* NO PARITY,2 STOP BITS

85
DUART EQU $7F7000  BASE ADDRESS FOR MC68681
PORT1 EQU DUART  PORT A
PORT2 EQU DUART+$10 PORT B
MR1A EQU 1  R/W:MODE REG 1 FOR PORT A
MR2A EQU 1  R/W:MODE REG 2 FOR PORT A
SRA EQU 3  R :STATUS REGISTER FOR PORT A
CSRA EQU 3  W:CLOCK SELECT REGISTER A
CRA EQU 5  W:COMMAND REGISTER FOR PORT A
RBA EQU 7  R :RECEIVER BUFFER FOR PORT A
TBA EQU 7  W:TRANSmitter BUFFER FOR PORT A
IPCR EQU 9  R :INPUT PORT CHANGE REGISTER
ACR EQU 9  W:AUXILIARY CONTROL REGISTER
ISR EQU $B  R :INTERRUPT STATUS REG
IMR EQU $B  W:INTERRUPT MASK REGISTER
CUR EQU $D  R :COUNTER MODE: CURRENT CNTR MSB
CTUR EQU $D  W:COUNTER/TIMER UPPER REGISTER
CLR EQU $F  R :COUNTER MODE: CURRENT CNTR LSB
CTLR EQU $F  W:COUNTER/TIMER LOWER REGISTER
MR1B EQU $11  R/W:MODE REG 1 FOR PORT B
MR2B EQU $11  R/W:MODE REG 2 FOR PORT B
SRB EQU $13  R :STATUS REGISTER FOR PORT B
CSRB EQU $13  W:CLOCK SELECT REGISTER B
CRB EQU $15  W:COMMAND REGISTER FOR PORT B
RBB EQU $17  R :RECEIVER BUFFER FOR PORT B
TBB EQU $17  W:TRANSmitter BUFFER FOR PORT B
IVR EQU $19  R/W:INTERRUPT VECTOR REGISTER
OPCR EQU $1B  W:OUTPUT PORT CONFIGURATION REG

* CODE *

INIT:  LEA  DUART,A4  A4 <-- PTR TO DUART
       CLR.W MONSTAT  CLR MONITOR STATUS WORD
       MOVE.B #MR1RESET,CRA(A4)  RESET PORT A MR1 PTR,
       * MOVE.B #MR1RESET,CRB(A4)  RESET PORT B MR1 PTR,
       * MOVE.B #CLK_SRC,ACR(A4)  CNTR/TMR CLK FROM CRYSTAL/16
       MOVE.B #CONF_1AB,MR1A(A4)  PORT A:8 DATA BITS & NO PARITY
       MOVE.B #CONF_2A,MR2A(A4)  PORT A: 1 STOP BIT
       MOVE.B #BAUD9600,CSRA(A4)  PORT A: 9600 BAUD
       MOVE.B #CONF_1AB,MR1B(A4)  PORT B:8 DATA BITS & NO PARITY
       MOVE.B #CONF_2B,MR2B(A4)  PORT B: 2 STOP BITS
       MOVE.B #BAUD2400,CSRB(A4)  PORT B: 2400 BAUD
       MOVE.B #RUPTVECT,IVR(A4)  SET DUART INTERRUPT SERVICE
       AT USER INTERRUPT 0
       MOVE.B #EN_PORT,CRA(A4)  RESET ERRS & ENABLE XMIT/RCV
       MOVE.B #EN_PORT,CRB(A4)  RESET ERRS & ENABLE XMIT/RCV
       MOVE.B #RUPTMASK,IMR(A4)  RUPT WHEN PORT A RCVS CHAR

86
BANNER: BSR SCRLF MOVE CURSOR TO NEXT LINE
LEA MONMSG,A5 SET MESSAGE POINTER TO MONMSG
BSR MESSAGE CRT<--68010 MONITOR V1.3
BSR SCRLF MOVE CURSOR TO NEXT LINE
LEA PROMPT,A5 SET UP FOR A PROMPT TO THE CRT
BSR MESSAGE SEND PROMPT TO CRT
LOOP: BRA.S LOOP WAIT FOR AN INTERRUPT

* 

MONITOR: MOVE.L SP,SYSTAX SAVE PTR TO APPL REGs
MOVEM.L A0-A7/D0-D7,-(SP) SAVE ALL REGISTERS
LEA STAX,A6 SET MONITOR STATE PTR
MOVEM.L (A6)+,A0-A5/D0-D7 GET LAST MONITOR STATE
BSR GETSTRING ENTER MONITOR
BCLR.B #STRINGEND,MONSTAT CHECK FOR END OF STRING
BEQ RESTORE NOT THE END, SO EXIT
BCLR.B #STRING,MONSTAT CLEAR NEW STRING FLAG
BSR CMD DECODE IF END THEN DECODE
LEA PROMPT,A5 SET MSG PNTR TO PROMPT
BSR MESSAGE CRT <- '>

RESTORE: MOVEM.L A0-A5/D0-D7,-(A6) SAVE MONITOR STATE
MOVEM.L (SP)+,A0-A7/D0-D7 RESTORE ALL REGISTERS
RTE
END
THIS PROGRAM OUTPUTS MESSAGES TO THE CRT SCREEN.

* WRITTEN BY DR. LARRY ABBOTT
* FILENAME: MESSAGE.ASM
* VERSION 1.3
* REV. MODIFIED BY DATE DESCRIPTION
* A  DAVID M. SENDEK  29 SEPT 87  INCLUDE A MONITOR PROMPT
* -INCLUDE BUFFER FULL
*
* DEFINING MODULES OF EXTERNALLY DECLARED VARIABLES:
* ECHO1   - CONSOLE.ASM

GLOBAL    BKPTMSG,EPROMSG,ERRMSG,HEXMSG,ILLMSG
GLOBAL    MONMSG,REGERR,REGMSG,SREC_ERR,USEMSG
GLOBAL    MESSAGE,PROMPT,BUFFULLMSG,SPCE
EXTERNAL   ECHO1

CR        EQU $0D    ASCII CODE FOR RETURN
LF        EQU $0A    ASCII CODE FOR LINEFEED
NULL       EQU $00    ASCII CODE FOR NUL

MESSAGE: MOVE.B (A5)+,D0 ; GET MESSAGE CHAR,
*              INCREMENT POINTER
BEQ.S MSGRET IF CHAR = NULL THEN EXIT
BSR ECHO1 ; OUTPUT CHAR TO CONSOLE
BRA.S MESSAGE ; GET ANOTHER CHARACTER
MSGRET: RTS

BKPTMSG: BYTE 'BREAKPOINT TRAP AT'
        BYTE NULL
ERRMSG:  BYTE 'ERROR RE-ENTER',CR,LF
        BYTE NULL
EPROMSG: BYTE 'ATTEMPTED WRITE TO EPROM',CR,LF
        BYTE NULL
HEXMSG:  BYTE 'HEX CONVERSION ERROR...RE-ENTER',CR,LF
        BYTE NULL
ILLMSG:  BYTE 'ILLEGAL INSTRUCTION TRAP',CR,LF
        BYTE NULL
MONMSG:  BYTE '68010 MONITOR V1.3',CR,LF
        BYTE 'WRITTEN BY DR. LARRY ABBOTT',CR,LF
        BYTE '@ COPYRIGHT 1986',CR,LF
        BYTE NULL
REGERR:  BYTE 'REGISTER CONTENTS ERROR RE-ENTER',CR,LF
        BYTE NULL

88
REGMSG: BYTE 'D0=','NULL,' D1=','NULL,' D2=','NULL,' D3=',' NULL, CR, LF
BYTE 'D4=','NULL,' D5=','NULL,' D6=','NULL,' D7=',' NULL, CR, LF
BYTE 'A0=','NULL,' A1=','NULL,' A2=','NULL,' A3=',' NULL, CR, LF
BYTE 'A4=','NULL,' A5=','NULL,' A6=','NULL,' A7=',' CR, LF
BYTE 'SR=','NULL,' PC=','NULL,' (PC)=','NULL, CR, LF
BYTE 'US=','NULL,' SS=','NULL, CR, LF
BYTE NULL
SREC_ERR: BYTE 'S RECORD ERROR MESSAGE',LF,CR
BYTE NULL
USEMSG: BYTE 'UNUSED EXCEPTION ENCOUNTERED',LF,CR
BYTE 'WITH FORMAT WORD = '
BYTE NULL
PROMPT: BYTE '>
BYTE NULL
SPCE: BYTE '
BYTE NULL
BUFFULLMSG: BYTE LF,CR,'INPUT BUFFER IS FULL, TRY AGAIN.',LF,CR
BYTE NULL
END
**THIS MODULE INPUTS FROM THE KEYBOARD AND DOWNLOAD PORT, **
**AND IT OUTPUTS CHARACTERS TO THE CRT.**

**NEW CONSOLE WRITTEN DEC. 19, 1986 BY DR. LARRY ABBOTT**

**FILENAME: CONSOLE.ASM**

**VERSION 1.3**

**REV. MODIFIED BY DATE DESCRIPTION**

A LARRY ABBOTT 6/6/87 ADAPT TO 68681

B DAVID M. SENDEK 30 SEPT 87 DOCUMENTATION UPGRADE

**DEFINING MODULES OF EXTERNALLY DECLARED VARIABLES:**

- **ESCAPE** - MAIN.ASM
- **MONSTAT** - MAIN.ASM
- **PORT1** - MAIN.ASM
- **PORT2** - MAIN.ASM
- **RECFULL** - MAIN.ASM
- **RBA, RBB** - MAIN.ASM
- **SRA, SRB** - MAIN.ASM
- **TBA, TBB** - MAIN.ASM

GLOBAL
GLOBAL
GLOBAL
EXTERNAL
EXTERNAL
EXTERNAL
EXTERNAL
GLOBAL
GLOBAL

ESC EQU $1B ASCII CODE FOR ESCAPE

GETCHAR1: LEA PORT1,A4 POINT TO RS-232 PORT 1
BTST.B #RECFULL,SRA(A4) CONSOLE CHAR READY?
BEQ GETCHAR1 - NO, CHECK AGAIN
MOVE.B RBA(A4),D0 - YES, GET CHAR
RTS

GETCHAR2: LEA PORT2,A4 POINT TO RS-232 PORT 2
BTST.B #RECFULL,SRB(A4) CONSOLE CHAR READY?
BEQ GETCHAR2 - NO, CHECK AGAIN
MOVE.B RBB(A4),D0 - YES, GET CHAR
RTS

SCANCHR1 LEA PORT1,A4 POINTS TO RS-232 PORT 1
BTST.B #RECFULL,SRA(A4) DOES PORT 1 HAVE A CHAR?
BEQ.S SCAN1_EX - NO, EXIT
MOVE.B RBA(A4),D0 - YES, GET CHAR

SCAN1_EX RTS
SCANCHR2 LEA PORT2, A4   POINTS TO RS-232 PORT 2
    BTST.B #RECFULL, SRB(A4) DOES PORT 2 HAVE A CHAR?
    BEQ.S SCAN2_EX          - NO, EXIT
    MOVE.B RBB(A4), D0      - YES, GET CHAR
SCAN2_EX RTS

* WHILE DOWNLOADING CHARACTERS FROM PORT 2, THIS PROCESS CAN BE
* HALTED BY SENDING AN ESC CHARACTER FROM THE KEYBOARD TO PORT 1
*
GETCHR2 BSR SCANCHR1 GET CHAR FROM PORT 1, IF PRESENT
    CMP.B #ESC, D0          IS THE CHAR AN ESCAPE?
    BEQ GC2_EXIT           - YES, SO EXIT
    BSR GETCHAR2           - NO, GET DOWNLOAD CHAR
    BRA.S EXIT_GC2
GC2_EXIT BSFT.B #ESCAPE, MONSTAT IF ESC CHAR, SET MONSTAT BIT
EXIT_GC2 RTS

ECH02 LEA PORT2, A4   POINTS TO RS-232 PORT 2
    BTST.B #XEMPTY, SRB(A4) IS CONSOLE XMIT RDY?
    BEQ ECHO2              - NO, CHECK AGAIN
    MOVE.B D0, TBA(A4)     - YES, OUTPUT CHAR TO PORT 1
    RTS
ECH01 LEA PORT1, A4   POINTS TO RS-232 PORT 1
    BTST.B #XEMPTY, SRA(A4) IS CONSOLE XMIT RDY?
    BEQ ECHO1              - NO, CHECK AGAIN
    MOVE.B D0, TBA(A4)     - YES, OUTPUT CHAR TO PORT 1
    RTS

END
GLOBAL GETSTRING
EXTERNAL BS,BUFFIN,CR,CMD_DECODE,ECHO1,GETCHAR1
EXTERNAL MONSTAT,STRING,STRINGEND
EXTERNAL BUFFULLMSG,SPCE
EXTERNAL MESSAGE

GETSTRING:BSET.B #STRING,MONSTAT IS THIS A NEW STRING?
   BNE BUILD - NO, SKIP PTR INIT
   BCLR.B #STRINGEND,MONSTAT - YES, CLR STRG END BIT
   LEA BUFFIN+1,AO - YES, INIT STRING PTR
BUILD:
   BSR GETCHAR1 D0 <- CHR FROM CRT
   CMP.B #CR,D0 IS CHAR A CR?
   BNE ADD STRING - NO, ADD CHAR TO STRG
   BSET.B #STRINGEND,MONSTAT - YES, SET STRG END BIT
   MOVE.W A0,D0 - YES, D0 <- CURRENT
   * 
   SUB.W #BUFFIN+1,D0 - YES, CALC BUFFIN LEN
   MOVE.B D0,BUFFIN - YES, BUFFIN(0) <- BUFFIN LENGTH
   * 
   BRA STRING_EXIT - YES, EXIT
ADD_STRING: BSR ECHO1 ECHO CHAR TO CRT
   BSR CONCAT ADD CHAR TO END OF STRG
STRING_EXIT:RTS

92
* CONCAT CONCATENATES THE CHAR ONTO THE END OF THE STRING
* CONCAT:  CMP.B #BS,D0  IS INPUT CHAR A BACKSPACE?
          BEQ  BKSPACE  - YES, GOT BACKSPACE
          CMPA.L BUFFIN+63,A0  IS BUFFIN FULL?
          BNE  ADD TO STRING  - NO, ADD BYTE TO STRING
          LEA  BUFFULLMSG,A5  - YES, SET UP POINTER
          BSR  MESSAGE  - YES, SEND MSG TO CRT
          BRA  CONCAT.EXIT  - YES, NOW EXIT
ADD_TO_STRING:  MOVE.B D0,(A0)+  ADD BYTE TO STRING
          BRA  CONCAT.EXIT
BKSPACE:  CMPA.L BUFFIN,A0  IS BUFFIN PTR POINTING TO 1st BYTE?
          BEQ  CONCAT.EXIT  - YES, EXIT
          SUBQ.W #1,A0  - NO, BACKUP BUFFIN PNTR
          LEA  SPCE,A5
          BSR  MESSAGE
CONCAT.EXIT:  RTS
END
GET_ADDRESS CONVERTS THE START AND END ADDRESS TO HEX.

WRITTEN BY DR. LARRY ABBOTT

FILENAME: GET_ADDR.ASM

VERSION 1.3

REV. MODIFIED BY DATE DESCRIPTION
A DAVID M. SENDEK 30 SEPT 87 DOCUMENTATION UPGRADE

DEFINING MODULES OF EXTERNALLY DECLARED VARIABLES:
BUFFIN - MAIN.ASM
END_ADDRESS - MAIN.ASM
HEX_CONV - HEXCONV.ASM
HEX_ERR - MAIN.ASM
MONSTAT - MAIN.ASM
HEXMSG - MESSAGE.ASM
MESSAGE - MESSAGE.ASM

GLOBAL GET_ADDR
EXTERNAL BUFFIN, END_ADDRESS, HEX_CONV, HEX_ERR
EXTERNAL MONSTAT, HEXMSG, MESSAGE

GET_ADDR:
CLR.L D2 CLEAR HEX BUFFER
LEA 0,A2 CLEAR START ADDRESS
LEA 0,A3 CLEAR END ADDRESS
CLR D3
MOVE.B BUFFIN,D3 D3 <-- BUFFIN LENGTH
BLE EXIT EXIT IF NULL CMD STRING
SUBQ.W #1,D3 ADJUST FOR DBCC INST

START_ADDR:
MOVE.B (A0)+,D0 D0 <-- BUFFIN(I) &
I <- I + 1
CMP.B '#',',D0 IS CHAR IN D0 A COMMA?
BEQ STORESTART - YES, INDICATE END OF

STORE_START:
BSR HEX_CONV CONVERT 1 CHAR OF START ADDR TO HEX
BTST.B #HEX_ERR,MONSTAT WAS THERE AN HEX CONVERSION ERROR?
BNE ADDR_ERR - YES, EXIT ROUTINE

ADDR_ERR:
DBF D3,START_ADDR IF MORE CHARACTERS CONT

STORE_START:
SUBQ.W #1,D3 ADJUST LENGTH FOR COMMA
MOVE.L D2,A2 STORE START ADDRESS IN A2
CLR.L D2 CLEAR HEX BUFFER

D3 CONTAINS THE LENGTH OF THE REMAINING COMMAND LINE

TST.W D3 IS BUFFIN LENGTH < 0?
BMI ADDREXIT - YES, EXIT WITH END_ADDR=0
END_ADDR: MOVE.B (A0)+, D0  ; DO <-- BUFFIN(I, & I <-- I+1
  BSR  HEX_CONV  ; CONVERT 1 CHAR OF END
  BTST.B #HEX_ERR,MONSTAT  ; WAS THERE AN HEX
                     ; CONVERSION ERROR ?
  BNE  ADDR_ERR  ; YES, EXIT ROUTINE
  DBF  D3,END_ADDR  ; IF MORE CHARs CONTINUE
  MOVE.L D2,A3  ; ELSE STR END ADDR IN A3
  ADDREXIT  MOVE.L A3,END_ADDRESS  ; SAV ENDADR IN MEM
  BRA  EXIT
ADDR_ERR  LEA  HEXMSG,A5
  BSR  MESSAGE
EXIT  RTS
END
* THIS PROGRAM CONTAINS A GROUP OF CONSOLE UTILITIES. *

* WRITTEN BY LARRY ABBOTT JAN. 1986 *

* FILENAME: IO_UTIL.ASM *

* VERSION 1.3 *

* REV. MODIFIED BY DATE DESCRIPTION *
  A   DAVID M. SENDEK 30 SEPT 87 -DOCUMENTATION UPGRADE *
  -CORRECT FOR 68681 *

* DEFINING MODULES OF EXTERNALLY DECLARED VARIABLES: *
  * BS   - MAIN.ASM  PORT1 - MAIN.ASM *
  * CR   - MAIN.ASM *
  * ECHO1 - CONSOLE.ASM *
  * ESC  - CONSOLE.ASM *
  * FWDARW - MAIN.ASM *
  * GETCHAR1 - CONSOLE.ASM *
  * LF   - MAIN.ASM *
  * RECFULL - MAIN.ASM *
  * SRA  - MAIN.ASM *
  * SPACE - MAIN.ASM *

GLOBAL BACKSPACES,SCROLL,SCRLF,SPACES
EXTERNAL BS,CR,ECHO1,ESC,FWDARW,GETCHAR1,LF
EXTERNAL RECFULL,SPACE
EXTERNAL SRA,PORT1

* BACKSPACES MOVES THE CURSOR ON THE CRT TO THE LEFT *
* N TIMES *
BACKSPACES:SUBQ.W #1,D2  ADJ INDEX FOR THE # OF BK_SP
BK_SPACE: MOVE.B #BS,D0  D0 <-- ASCII CODE FOR BACKSPACE
        BSR ECHO1   OUTPUT BACKSPACE TO CONSOLE
        DBF D2,BK_SPACE IF MORE BCKSP LOOP TO BK_SPACE
        RTS

* SCRLF SEND A CARRIAGE RETURN AND A LINEFEED *
* TO THE CONSOLE *

SCRLF: MOVE.B #CR,D0  D0 <-- ASCII CODE FOR CR
        BSR ECHO1   OUTPUT CR TO CONSOLE
        MOVE.B #LF,D0  D0 <-- ASCII CODE FOR LF
        BSR ECHO1   OUTPUT LF TO CONSOLE
        RTS

96
SPACES MOVE THE CURSOR ON THE CRT TO THE RIGHT N TIMES

SPACES:  SUBQ.W #1,D2  ADJUST INDEX FOR THE # OF SP
SPACE_LOOP: MOVE.B #SPACE,D0  ASCII CODE FOR ','
            BSR  ECHO1  OUTPUT SPACE TO CONSOLE
            DBF  D2,SPACE_LOOP IF MORE SPACES LOOP TO SPACE
            RTS

SCROLL ALLOWS THE SCREEN SCROLL TO BE ABORTED BY AN ESC
OR STOPPED AND STARTED BY ANY OTHER KEY

SCROLL:  LEA  PORT1,A4
            BTST.B #RECFULL,SRA(A4) GET CONSOLE STATUS
            BEQ.S SCROLL_EXIT IF NO CHAR FROM
            * CONSOLE, EXIT
            BSR GETCHAR1 ELSE GET CHAR
            CMP.B #ESC,D0 IS THE CHAR AN ESC?
            BEQ.S SCROLL_EXIT - YES, ABORT

PAUSE_CHK: LEA  PORT1,A4
            BTST.B #RECFULL,SRA(A4) GET CONSOLE STATUS
            BEQ.S PAUSE_CHK IF NO NEW KEY STROKE, WAIT
            BSR GETCHAR1 ELSE GET CHAR

SCROLL_EXIT: RTS
            END

97
**THIS PROGRAM DECODES Commands FROM THE COMMAND LINE.**

**68K MONITOR VERSION 1.3**

**WRITTEN BY DR. LARRY ABBOTT NOV. 7, 1986**

**FILENAME: DECODER.ASM**

**VERSION 1.3**

**REV. MODIFIED BY DATE DESCRIPTION**

A DAVID M. SENDEK 1 OCT 87 DOCUMENTATION UPGRADE

**DEFINING MODULES OF EXTERNALLY DECLARED VARIABLES:**

BUFFIN - MAIN.ASM  
BKPT_LIST - STUB.ASM

ERRMSG - MESSAGE.ASM  
DOWNLOAD - DOWNLOAD.ASM

FOUND - MAIN.ASM  
GO - GO.ASM

MESSAGE - MESSAGE.ASM  
MEM_LIST - MEM_LIST.ASM

MONSTAT - MAIN.ASM  
MEM_MODIFY - MEM_LIST.ASM

NULL - MAIN.ASM  
NO_BKPT - STUB.ASM

SPACE - MAIN.ASM  
REG - REG.ASM

SCRLF - IQ_UTIL.ASM  
REGCHANG - REGCHANG.ASM

BKPT - GO.ASM

**COMMAND FORMATS:**

**LEGEND:**  
<..> - OPTIONAL

{..} - SELECT ONE ITEM

xx - NUMBER 0 -> 15

**NOTE:** ALL ADDRESSES AND VALUES IN HEX

**BREAK POINT**  
BR (NOT IMPLEMENTED)

**NO BREAKPOINT**  
NOBR (NOT IMPLEMENTED)

**DOWNLOAD**  
LOAD

**GO**  
GO address <,break point address>

**MEMORY MODIFY**  
MM start address <,end address>

**MEMORY DISPLAY**  
MD start address <,end address>

**REGISTER CHANGE**  
RCH { Axx,Dxx,PC,US,SP,SR} value

**DISPLAY REGISTERS**  
REG

GLOBAL CMD DECODE
EXTERNAL BUFFIN,ERRMSG,FOUND,MESSAGE,MONSTAT,NULL
EXTERNAL SPACE,SCRLF
EXTERNAL BKPT,BKPT_LIST,DOWNLOAD,GO
EXTERNAL MEM_DISPLAY,MEM_MODIFY,NO_BKPT,REG,REGCHANG

CMD_DECODE: LEA COMMANDS,A1 INITIALIZE COMMAND POINTER
BCLR #FOUND,MONSTAT

DECODE_INIT:LEA BUFFIN+1,A0 INITIALIZE BUFFIN POINTER
MOVE.L #3,D1 INIT INDEX FOR 4 CHARS
SCAN: MOVE.B (A1)+,D0  GET COMMAND.TABLE(I)

*   & I←←I+1

CMP.B #SPACE,D0  IS CHARACTER A SPACE ?
BEQ  FOUND_CMD  - YES, FOUND COMMAND

CMP.B #NULL,D0  IS CHARACTER A NULL ?
BEQ  NO_CMD  - YES, EXHAUSTED COM TABLE

CMP.B (A0)+,D0  IS BUFFIN = COMMAND.TABLE ?
DBNE  D1,SCAN  - YES & MORE CHAR, CONT

BNE  ADDRFIELD  - NO, ADJUST ADDR FOR NEXT
COMMAND

FOUND_CMD: BSET  #FOUND,MONSTAT  SET COMMAND FND STATUS BIT

CMPI.W #0,D1  IS COMMAND A 4 CHAR COM?
BMI  CMD_FOUND  - YES, SKIP ''JUMP ADDRESS''

ADJUST

ADDR_FIELD: ADDQ.L #2,D1  ADJUST INDEX FOR NEXT COM

ADD.L D1,A1  ADD INDEX TO COMMAND PNTR

BCLR  #FOUND,MONSTAT  CLEAR COM FOUND STATUS BIT

BEQ  DECODE_INIT  CHECK NEXT CMD

SUB.L #5,D1

ADD.B D1,BUFFIN  ADJUST BUFFIN LENGTH

SUBQ.L #2,A1  ADJUST ADDRESS FOR JUMP

CMD_FOUND: MOVE.W (A1),A1  GET JUMP ADDRESS

JSR  (A1)  JUMP TO COMMAND

BRA  DECODEXT  EXIT DECODER

NO_CMD: BSR  SCRLF

MOVE.W #ERRMSG,A5  SET MESSAGE POINTER

BSR  MESSAGE  PRINT ERROR MESSAGE TO CRT

DECODEXT: RTS

*  EVEN ON

COMMANDS:

BYTE  'BR'

WORD  BKPT_LIST

BYTE  'LOAD'

WORD  DOWNLOAD

BYTE  'GO'

WORD  GO

BYTE  'MD'

WORD  MEM_DISPLAY

BYTE  'MM'

WORD  MEM_MODIFY

BYTE  'NOBR'

WORD  NO_BKPT

BYTE  'RCH'

WORD  REGCHANG

BYTE  'REG'

WORD  REG

BYTE  NULL,NULL,NULL,NULL, NULL

EVEN OFF

END
THIS PROGRAM CONVERTS A BYTE INTO 2 ASCII CHARACTERS AND IT SENDS THE CHARACTERS TO THE CRT DISPLAY.

WRITTEN BY DR. LARRY ABBOTT

FILENAME: BYTEOUT.ASM

VERSION 1.3

A DAVID M. SENDEK 1 OCT 87 DOCUMENTATION UPGRADE

DEFINING MODULES OF EXTERNALLY DECLARED VARIABLES

GLOBAL OUTPUT_BYTE
EXTERNAL ECHO1

OUTPUT_BYTE: MOVE.B D0,D2 MAKE A TEMPORARY COPY OF BYTE
LSR.B #4,D0 SHIFT M.S. NIBBLE TO L.S. NIBBLE
BSR ASCONV CONVERT M.S. NIBBLE TO ASCII
MOVE.B D2,D0 D0 <-- TEMPORARY COPY OF BYTE
ANDI.B #$0F,D0 MASK OFF M.S. NIBBLE
BSR ASCONV CONVERT L.S. NIBBLE TO ASCII
RTS

ASCONV: ADDI.B #$30,D0 ADD ASCII BASE
CMP.B #$3A,D0 IS NUMBER 0-9 ?
BLT ASCOUT YES, OUTPUT TO CONSOLE
ADDQ.B #7,D0 ADJUST FOR A - F (HEX)

ASCOUT: BSR ECHO1 OUTPUT TO CONSOLE
RTS
END
This program modifies or lists the contents of the specified memory locations.

Written by Dr. Larry Abbott

Filename: MEM_LIST.ASM

Version 1.3

Rev. Modified by Date Description
A David M. Sendek 1 Oct 87 Documentation Upgrade

Defining modules of externally declared variables:
- BUFFIN - MAIN.ASM
- BACKSPACES - IO_UTIL.ASM
- END_ADDRESS - MAIN.ASM
- ESC - MAIN.ASM
- GET_ADDR - GET_ADDR.ASM
- GETSTRING - GETSTRING.ASM
- HEX_CONV - HEX_CONV.ASM
- HEX_ERR - MAIN.ASM
- MODIFY - MAIN.ASM

---

GLOBAL MEM_DISPLAY, MEM_MODIFY
EXTERNAL BUFFIN, BACKSPACES, END_ADDRESS, ESC
EXTERNAL GET_ADDR, GETSTRING, HEX_CONV, HEX_ERR, MODIFY
EXTERNAL MONSTAT, OUTPUT_BYTE, SCRLF, SCROLL, SPACE, SPACES
EXTERNAL STRINGEND, STRING

MEM_MODIFY: BSET.B #MODIFY, MONSTAT
BSR MEM_DISPLAY
BCLR.B #MODIFY, MONSTAT
RTS

MEM_DISPLAY: CMPI.B #SPACE, (A0)
               BNE START_ADDR
               ADDQ.W #1, A0
               SUBQ.B #1, BUFFIN
               BRA MEM_DISPLAY

START_ADDR: BSR GET_ADDR
            BCLR.B #HEX_ERR, MONSTAT
            BNE MD_EXIT

NEWLINE: BSR SCRLF
         BSR LINE_NUMBER

101
GETABYTE: MOVE.B (A2)+,D0          D0 <-- (START ADDRESS)
BSR  OUTPUT_BYTE              OUTPUT BYTE TO CRT
BTST #MODIFY,MONSTAT          IS MEMORY MODIFY STATUS
            BIT SET ?
*  
BEQ  WORD_SPACE               - NO, SKIP CHANGE
BSR  CHANGE                   - YES, MODIFY MEMORY
BCLR.B #HEX_ERR,MONSTAT       CLR HEX STATUS BIT ERROR
BNE  MD_EXIT                  IF ERROR EXIT

WORD_SPACE: MOVE.W #2,D2      SETUP FOR 2 SPACES
BSR  SPACES                   OUTPUT 2 SPACES TO CRT
MOVE.L END_ADDRESS,D1         GET END ADDRESS
MOVE.L A2,D0                  D0 <- START ADDRESS
SUB.L D0,D1                   D1<--END ADDR-START ADDR
BLT  MD_EXIT                  IF START > END THEN EXIT
ANDI.B #$0f,D0                DOES L.S. NIBBLE = 0 ?
BNE  GETABYTE                 - NO, GET ANOTHER BYTE
BSR  SCROLL                   SCROLL PAUSE CHECK
CMP.B #ESC,D0                 ABORT SCROLL ?
BEQ  MD_EXIT                  - YES, SO EXIT
BRA  NEWLINE                  - NO, START A NEW LINE

MD_EXIT: BSR SCRLF            MOVE CURSOR TO NEXT LINE
RTS

*  
LINE_NUMBER:MOVE.L A2,D0       GET CURRENT ADDRESS
ROR.L  #8,D0                  MOVE M.S. BYTE TO L.S. BYTE
BSR  OUTPUT_BYTE             DISPLAY BYTE ON CRT
ROR.L  #8,D0                  MOVE M.S. BYTE TO L.S. BYTE
BSR  OUTPUT_BYTE             DISPLAY BYTE ON CRT
ROR.L  #8,D0                  MOVE M.S. BYTE TO L.S. BYTE
BSR  OUTPUT_BYTE             DISPLAY BYTE ON CRT
ROR.L  #8,D0                  MOVE M.S. BYTE TO L.S. BYTE
BSR  OUTPUTBYTE              DISPLAY BYTE ON CRT
MOVE.W #4,D2                  SETUP FOR 4 SPACES
BSR  SPACES                   OUTPUT 4 SPACES TO CRT
RTS

*  
CHANGE: MOVE.W #2,D2          SETUP FOR 2 BCKSPCES
BCLR.B #STRING,MONSTAT       SET FOR NEW STRING
CHGAGAIN: BSR BACKSPACES     MOVE 2 SP TO THE LEFT
MORE_CHAR:BSR GETSTRING      GET ANY NEW CHARACTERS
BCLR.B #STRINGEND,MONSTAT    CHECK FOR END OF STR
BEQ  MORE_CHAR                IF MORE STRING, BRANCH
MOVE.B BUFFIN,D3             GET STRING LENGTH
BEQ  NO_ENTRY                 IF STR LEN=0
            THEN NO ENTRY
*  
CMPI.B #2,D3                  DOES STRING LEN = 2 ?
BNE  CHGAGAIN                 - NO, THEN RE-ENTER
BSR  GET_DATA                 CONVERT BYTE TO HEX
BTST.B #HEX_ERR,MONSTAT       IS THERE A HEX ERROR ?
BNE  CHG.EXIT                 - YES, EXIT
MOVE.B D2,-(A2)              BUFFIN(I) <-- HEX
ADDQ.W #1,A2

102
NO_ENTRY: CLR.W D2
MOVE.B D3,D2
NEG.W D2
ADDQ.W #4,D2
BSR SPACES

CHG_EXIT RTS

GET_DATA CLR.L D2
CLR D4
MOVE.B BUFFIN,D4
SUBQ #1,D4
LEA BUFFIN+1,A0

DATALOOP MOVE.B (A0)+,D0
BSR HEX_CONV
BTST.B #HEX_ERR,MONSTAT
DBNE D4,DATALOOP

DATAEXIT RTS
END
GLOBAL HEX_CONV
EXTERNAL HEX_ERR,MONSTAT

HEX_CONV: SUB.B #$30,D0
          ADJUST ASCII TO HEX BASE
          CMPI.B #9,D0          IS CHARACTER <= 9 ?
          BL.S ZERO_CHECK      - YES, CHECK >= 0
          SUB.B #7,D0          ADJUST FOR A-F
          CMPI.B #$A,D0        IS CHARACTER >= A ?
          BCS.S HEXERR         - NO, HEX ERROR
          CMPI.B #$F,D0        IS CHARACTER <= F ?
          BHI.S HEXERR         - NO, HEX ERROR
          ZEROCHECK: CMPI.B #0,D0 IS CHARACTER >= 0 ?
          BMI.S HEXERR         - NO, HEX ERROR
          BSR HEX_SHIFT        HEX # INTO HEX BUFFER
          BCLR.B #HEX_ERR,MONSTAT CLR HEX CONVERSION ERROR
          BRA.S HEX_EXIT       EXIT HEX CONVERSION
          HEXERR: BSET.B #HEX_ERR,MONSTAT SET HEX CONVERSION ERROR
          HEX_EXIT: RTS

HEX_SHIFT: LSL.B #4,D0  SHIFT L.S. NIBBLE TO M.S. NIBBLE
            MOVE.W #3,D1   SET FOR INDEX TO 4 SHIFTS
NIBBLE_SHF: LSL.B #1,D0  SHIFT HEX CHARACTER OUT
            ROXL.L #1,D2  SHIFT INTO HEX BUFFER
            DBF D1,NIBBLE_SHF BRANCH IF MORE BITS
            RTS
            END
**THE GO ROUTINE EXECUTES A PROGRAM FROM THE MONITOR.**
*THE FORMAT IS:*
*GO <start address>, [optional breakpoint]*

**WRITTEN BY DR. LARRY ABBOTT**

**FILENAME: GO.ASM**

**VERSION 1.3**
*REV. MODIFIED BY DATE DESCRIPTION*
*A DAVID M. SENDEK 1 OCT 87 DOCUMENTATION UPGRADE*
*B DAVID M. SENDEK 5 OCT 87 BSET,BCLR ASSEMBLY*
*LANGUAGE CORRECTION*

**DEFINING MODULES OF EXTERNALLY DECLARED VARIABLES:**
*GLOBAL BKPT,GO
EXTERNAL BKPTAB,BKPTMSG,BTLEN,BUFFIN,CONTINUE
EXTERNAL GET ADDR,GETSTRING,HX_ERR,ILLMSG,MESSAGE
EXTERNAL OUTPUT_BYTE,SCRLF,SPACE,STRING,STRINGEND
EXTERNAL MONSTAT,SYSTAX,CMD_DECODE*

```
GLOBAL BKPT,GO
EXTERNAL BKPTAB,BKPTMSG,BTLEN,BUFFIN,CONTINUE
EXTERNAL GET ADDR,GETSTRING,HX_ERR,ILLMSG,MESSAGE
EXTERNAL OUTPUT_BYTE,SCRLF,SPACE,STRING,STRINGEND
EXTERNAL MONSTAT,SYSTAX,CMD_DECODE

*TRAP0 EQU $4E40       OP CODE FOR TRAP #0
*GO
   CMPB. #SPACE,(A0)+   IS BUFFIN(X) A SPACE ?
   BNE GO_ADDR         - NO, GET GO ADDRESS
   SUBQ.B #1,BUFFIN    - YES, ADJUST BUFFIN LENGTH
   BRA GO              - YES, SCAN FOR NEXT SPACE
GO_ADDR
   SUBQ #1,A0          ADJUST FOR POST INCREMENT
   BSR GET_ADDR        A2<-GO ADDR, A3<-BREAKPOINT
   CMPA #0,A2          IS THERE A START ADDRESS ?
   BEQ CONTINU         - NO, THIS IS A CONTINUATION
   BCLR.B #4,MONSTAT   CHECK FOR HEXCONV ERROR
   BNE GO_EXIT         IF HEX ERROR THEN EXIT
   MOVEA.L SYSTAX,A0   ELSE GET SYSTAX POINTER
   MOVE.L A2,(A0)      SYSTAX(PC) <- -- GO ADDRESS
   CMPA #0,A3          IS THERE A BREAKPOINT ?
   BEQ GO_EXIT         - NO, SO EXIT
   LEA BKPTAB,A0       SET BREAK TAB POINTER
   MOVEA.L A3,(A0)     STORE BREAKPOINT IN TABLE
   MOVE.W (A3),BTLEN(A0) STORE INSTRUCTION AT BKPT
```

105
MOVE.W #TRAP0,(A3)       STORE ILL INSTRUCT AT BKPT
CONTINU: BSET.B #CONTINUE,MONSTAT SET CONTINUE FLAG
GO_EXIT RTS

* THE BREAKPOINT (BKPT) ROUTINE RESTORES THE INSTRUCTION
* AT THE BREAKPOINT

BKPT:  BCLR.B #CONTINUE,MONSTAT INIT CONTINUATION FLAG
       LEA    BKPTAB, A0       SET BREAK TABLE POINTER
       MOVE.L (A0), A3      GET BKPT ADDRESS
       MOVE.W 16(A0),(A3)  RESTORE INSTRUCTION
       LEA    BKPTMSG, A5   SET BREAKPOINT MESSAGE
BADINST BSR MESSAGE PRINT MESSAGE
       MOVE.L A3, D0 GET BKPT ADDRESS
       MOVE.W #3, D3 SET BYTE INDEX
ADDROUT ROL.L #8, D0 ROTATE D0 BY 1 BYTE
       BSR OUTPUT_BYTE CRT <-- D0<0..7>
       DBF D3, ADDROUT MORE ADDRESS THE LOOP
       BSR SCRLF MOV CURSOR TO STRT OF LINE
       SUBQ.L #2, 2(SP) ADJUST RETURN ADDRESS
       MOVE.L SP, SYSTAX SAVE POINTER TO RETURN ADDR
EXAMINE BSR GETSTRING ALLOWS EXAM AT BKPT
       BCLR.B #STRINGEND,MONSTAT END OF STRING ?
       BEQ  EXAMINE - NO, SO LOOP
       BCLR.B #STRING,MONSTAT CLEAR NEW STRING FLAG
       BSR CMD_DECODE IF END THEN DECODE
       BCLR.B #CONTINUE,MONSTAT IS THIS A CONTINUATION ?
       BEQ  EXAMINE - YES, LOOP AGAIN
       RTE
END
* THIS FILE CONTAINS PROGRAMMING STUBS TO COMPLETE THE  *
* LINKING PROCESS WHILE BUILDING AND TESTING HIGHER  *
* LEVEL MODULES.  *
* WRITTEN BY DR. LARRY ABBOTT  *
* FILENAME: STUB.ASM  *
* VERSION 1.3  *
* REV. MODIFIED BY DATE DESCRIPTION  *
* DAVID M. SENDEK 1 OCT 87 -DOCUMENTATION UPGRADE  *
* -INCORPORATE PROMPT MSG  *
* DEFINING MODULES OF EXTERNALLY DECLARED VARIABLES:  *
* PROMPT - MESSAGE.ASM  *
* MESSAGE - MESSAGE.ASM  *

GLOBAL BKPT_LIST,NO BKPT
EXTERNAL PROMPT,MESSAGE

BKPT_LIST:LEA PROMPT,A5
BSR MESSAGE
RTS
NO_BKPT: LEA PROMPT,A5
BSR MESSAGE
RTS
END
THIS ROUTINE PRINTS OUT THE CONTENTS OF THE REGISTERS.

WRITTEN BY DR. LARRY ABBOTT

FILENAME: REG.ASM

VERSION 1.3

REV. MODIFIED BY DATE DESCRIPTION
A DAVID M. SENDEK 1 OCT 87 DOCUMENTATION UPGRADE

DEFINING MODULES OF EXTERNALLY DECLARED VARIABLES:

MESSAGE - MESSAGE.ASM  SCRLF - IO_UTIL.ASM*
OUTPUT_BYTE - BYTEOUT.ASM  SPACES - IO_UTIL.ASM*
REGMSG - MESSAGE.ASM  SYSTAX - MAIN.ASM *

GLOBAL REG
EXTERNAL MESSAGE,OUTPUT_BYTE,REGMSG
EXTERNAL SCRLF,SPACES,SYSTAX

REG  BSR  SCRLF
    LEA  REGMSG,A5  GET POINTER TO MESSAGE
    MOVEA.L SYSTAX,A2  GET STACK POINTER AT MONITOR
    ENTRY
    SUB.L #$40,A2  OFFSET OF THE STACK
    MOVE.W #15,D3  SET REGS CNTR FOR 16 REGS
REGLIST  BSR  MESSAGE  PRINT PART OF REGISTER MESSAGE
    MOVE.W #3,D4  SET FOR 32-BIT REGISTER
    BSR  REG_DUMP  PRINT CONTENTS OF A REGISTER
    DBF  D3,REGLIST  IF MORE REGS, THEN GO TO
    REGLIST
    BSR  MESSAGE  PRINT "SR ="
    MOVE.W #1,D4  SET FOR 16-BIT REGISTER
    BSR  REG_DUMP  PRINT CONTENTS OF STAT REG (SR)
    MOVE.W #4,D2  SET FOR 4 SPACES
    BSR  SPACES  PRINT 4 SPACES
    BSR  MESSAGE  PRINT "PC ="
    MOVE.W #3,D4  SET FOR 32-BIT PC REGISTER
    BSR  REG_DUMP  PRINT CONTENTS OF PC REGISTER
    MOVE.W #1,D2  SET FOR 1 SPACES
    BSR  SPACES  PRINT 1 SPACES
    BSR  MESSAGE  PRINT "(PC) ="
    SUBQ.L #4,A2
    MOVE.L (A2),A2
    MOVE.W #1,D4  SET FOR WORD POINTED TO BY PC
    BSR  REG_DUMP  PRINT CONTENTS OF WD PNTD BY PC
    BSR  SCRLF  FORMAT DISPLAY
RTS
* REG_DUMP
  MOVE.B (A2)+,D0     GET A BYTE OF THE REG
                     FROM APPLICATION PSW
  BSR OUTPUT_BYTE OUTPUT BYTE TO CONSOLE
  DBF D4,REG_DUMP IF MORE BYTES THEN REG_DUMP
  RTS                ELSE EXIT
  END
* THIS ROUTINE CHANGES THE CONTENTS OF DESIRED REGISTERS. *
* WRITTEN BY DR. LARRY ABBOTT *
* FILENAME: REGCHANG.ASM *
* VERSION 1.3 *
* REV. MODIFIED BY DATE DESCRIPTION *
* A DAVID M. SENDEK 1 OCT 87 DOCUMENTATION UPGRADE *

* DEFINING MODULES OF EXTERNALLY DECLARED VARIABLES: *
* BUFIN - MAIN.ASM *
* GET_ADDR - GET_ADDR.ASM *
* HEX_CONV - HEXCONV.ASM *
* HEX_ERR - MAIN.ASM *
* MESSAGE - MESSAGE.ASM *
* MONSTAT - MAIN.ASM *
* REG - REG.ASM *
* REGERR - MESSAGE.ASM *
* SPACE - MAIN.ASM *
* SYSTAX - MAIN.ASM *
* SCRLF - IO_UTIL.ASM *

GLOBAL REGCHANG
EXTERNAL BUFIN,GET_ADDR,HEX_CONV,HEX_ERR
EXTERNAL MESSAGE,MONSTAT,REG,REGERR,SPACE,SYSTAX,SCRLF

ESC EQU $1B

REGCHANG: BSR REG DISPLAY REGISTERS ON CRT

BLANKSCAN: MOVE.B (A0)+,D0
SUBQ.B #1,BUFIN
CMPI.B #SPACE,D0
BNE START_REG
BRA BLANKSCAN CONTINUE SCANNING BUFIN

START_REG: CMPI.B #ESC,D0
BEQ REG DONE - YES, RTS
CMPI.B #’A’T,D0
BEQ REGA - YES, ADJUST POINTER
CMPI.B #’D’,D0
BEQ REGD - YES, ADJUST POINTER
CMPI.B #’P’,D0
BEQ REGP - YES,CK FOR ‘C’ & ADJUST PNTR
CMPI.B #’U’,D0
BEQ REGU - YES, CHECK FOR ’S’
CMPI.B #’S’,D0
BNE PRINTERR - NO,PRINT ERR D0 <> A,D,P,U,S
MOVE.B (A0)+,D0
SUBQ.B #1,BUFIN
CMPI.B #’P’,D0
BEQ REGSP
CMPI.B #’R’,D0
BEQ REGREP
CMPI.B #’S’,D0

110
BNE PRINTERR
MOVE.L #-4,D3
BRA REGREP

REGA: MOVE.L #-32,D3
BRA REGFIN

REGD: MOVE.L #-64,D3
BRA REGFIN

REGP: MOVE.B (A0)+,D0
SUBQ.B #1,BUFFIN
CMPI.B #’C’,D0
BNE PRINTERR
MOVE.L #2,D3
BRA REGREP

REGU: MOVE.B (A0)+,D0
SUBQ.B #1,BUFFIN
CMPI.B #’S’,D0
BNE PRINTERR
MOVE.L #4,D3
BRA REGREP

REGSP: MOVE.L #4,D0
BRA REGREP

PRINTERR: LEA REGERR,A5
BSR MESSAGE
BRA REG_DONE

REGFIN: MOVE.B (A0)+,D0
SUBQ.B #1,BUFFIN
CLR.L D2
BSR HEX_CONV
BTST.B #HEX_ERR,MONSTAT
BNE PRINTERR
LSL.L #2,D2
ADD.L D2,D3

REGREP: LEA SYSTAX,A1
MOVE.L (A1),A1
ADD.L D3,A1

RCA: CMPI.B #SPACE,(A0)
BNE FFF
ADDQ.W #1,A0
SUBQ.B #1,BUFFIN
BRA RCA

FFF: BSR GET_ADDR
MOVE.L A2,(A1)
BSR REG

REG_DONE: RTS
DOWNLOAD ALLOWS THE MONITOR TO DOWNLOAD Sxx RECORDS TO ITS* RESIDENT 680XX MICROCOMPUTER OVER A SECOND RS-232 PORT. *

* WRITTEN BY DR. LARRY ABBOTT    APRIL 24, 1986 *

* FILENAME: DOWNLOAD.ASM *

* VERSION 1.3 *

REV. MODIFIED BY   DATE        DESCRIPTION
A  LARRY ABBOTT  12/18/86    INIT DEBUG PROCESS
B  DAVID M. SENDEK 1 OCT 87  -DOCUMENTATION UPGRADE
  -CORRECT FOR MC68681
C  DAVID M. SENDEK 5 OCT 87  BCLR, BSET ASSEMBLY
  -LANGUAGE CORRECTION
D  DAVID M. SENDEK 4 JAN 88  -CORRECT DOWNLOADING OF
  S1, S9 FORMAT RECORDS.
  NOTE: FINAL S9 RECORD WILL*
  HAVE A '++' AFTER LAST *
  CHARACTER IN THE RECORD *

DEFINING MODULES OF EXTERNALLY DECLARED VARIABLES:
CHECKSUM - MAIN.ASM     CK_SUM  - MAIN.ASM
ECHO1 - CONSOLE.ASM    ECHO2  - CONSOLE.ASM
EPROMRNG - MAIN.ASM    EPROMSG  - MESSAGE.ASM
EPROMWR - MAIN.ASM
HEX_CONV - HEXCONV.ASM  SCRLF  - IO_UTIL.ASM
HEX_ERR - MAIN.ASM     SREC_ERR  - MESSAGE.ASM
MESSAGE - MESSAGE.ASM  SCANCHR2  - CONSOLE.ASM
MONSTAT - MAIN.ASM     SRB  - MAIN.ASM
RECFULL - MAIN.ASM     GETCHR2  - CONSOLE.ASM

GLOBAL DOWNLOAD
EXTERNAL CHECKSUM, CK_SUM, ECHO1, ECHO2, EPROMRNG, EPROMSG
EXTERNAL EPROMWR, ESCAPE
EXTERNAL HEX_CONV, HEX_ERR, HEXMSG, MESSAGE, MONSTAT
EXTERNAL RECFULL, SCRLF, SREC_ERR
EXTERNAL SCANCHR2, SPACES
EXTERNAL SRB, GETCHR2

DOWNLOAD: BSR SCANCHR2 DO DUMMY RD TO CLR CHAN B
BTST.B  #RECFULL,SRB ANY THING ELSE IN CHAN B ?
BNE.S  DOWNLOAD - YES, SCAN CHANNEL B AGAIN
BSR SCRLF ECHO CR & LF TO CRT

DOWNLOOP: BCLR.B  #HEX_ERR, MONSTAT CLEAR HEX ERROR FLAG
S_LOOP BSR GETCHR2 GET A CHAR FROM DWNLNK PORT
BTST.B  #ESCAPE, MONSTAT ESC THE DOWNLOAD PROCESS ?
BNE  DOWNEXT - YES, EXIT
CMPI.B '#S',D0 IS CHARACTER = 'S' ?
BNE S_LOOP - NO, SEARCH FOR A 'S'
BSR ECHO2 ECHO 'S' TO CONSOLE
MOVE.W #1,D3 SET FOR 16-BIT ADDR
BSR GETCHR2 GET A CHAR FROM DWNLNK PORT
BSR ECHO2 ECHO DWNLNK CHAR TO CONSOLE
CMPI.B '#0',D0 IS THIS A S0 RECORD ?
BEQ S_RECORD - YES, GO TO S RECORD
CMPI.B '#1',D0 IS THIS A S1 RECORD ?
BEQ S_RECORD - YES, GO TO S RECORD
CMPI.B '#9',D0 IS THIS A S9 RECORD ?
BEQ S_RECORD - YES, GO TO S9 RECORD
ADDQ.W #1,D3 SET FOR 24-BIT ADDR
CMPI.B '#2',D0 IS THIS A S2 RECORD ?
BEQ S_RECORD - YES, GO TO S RECORD
ADDQ.W #1,D3 SET FOR A 32-BIT ADDRESS
CMPI.B '#3',D0 IS THIS A S3 RECORD ?
BEQ S_RECORD - YES, GO TO S RECORD
LOADERR: LEA SREC_ERR,A5 IF NO Sxx RECORD
; THEN 'S RECORD ERROR' MSG
BSR ERRMSG

DOWNEXIT: BSR SCRLF ECHO CR & LF
LEA EPROMSG,A5 SET UP *
BCLR.B #EPROMWR,MONSTAT WAS THERE A WRITE TO EPROM?
BEQ.S ERRMSG - YES, PRINT ERROR MESSAGE
RTS

ERRMSG: BSR MESSAGE PRINT ERROR MESSAGE
RTS

S_RECORD: BSR SN_RECORD PROCESS S RECORD
BCLR.B #HEX_ERR,MONSTAT IF NOT HEX CONVERSION ERR
BEQ DOWNEEXEC THEN GET NEXT RECORD
LEA HEXMSG,A5 ELSE HEX CONV ERROR MSG
BRA ERRMSG PRINT ERROR MSG *

S9_RECORD: BSR SN_RECORD PROCESS S RECORD
BTST.B #HEX_ERR,MONSTAT IF HEX CONVERSION ERROR
BEQ DOWNEEXEC THEN TERMINATE XMISSION
RTS *

SN_RECORD: CLR.W D6 SET FOR 1 BYTE
CLR.B CK_SUM CLEAR CHECK SUM
BSR GETFIELD GET DOWNLOAD FIELD
BTST.B #HEX_ERR,MONSTAT IF HEX CONVERSION ERROR
BNE.S SN_EXIT THEN EXIT SN_RECORD
MOVE.W D2,D4 D4<-HEXBUFFER (S REC LEN)
SUB.W D3,D4 LEN = (S REC LEN) - ADDR
SUBQ.W #2,D4 ADJUST FOR DBF INST & ADDR
MOVE.W D3,D0 SET ADDRESS SIZE
BSR GETFIELD
GET ADDRESS FIELD

BTST.B #HEX_ERR,MONSTAT
IF HEX CONVERSION ERROR

BNE.S SN_EXIT
THEN EXIT SN_RECORD

MOVE.L D2,A0
A0 <-- LOAD ADDRESS

BSR DOWN_DATA
GET DOWN LOAD DATA

SN_EXIT
RTS

* DOWN_DATA

BSR GETCHR2
GET FIRST CHARACTER

BSR ECHO2
ECHO DWNLD CHARACTER
TO CONSOLE

CLR.L D2

BSR HEX_CONV
CONVERT CHAR TO HEX

BTST.B #HEX_ERR,MONSTAT
IF HEX CONVERSION ERROR

BNE.S DD
EXIT

THEN EXIT DOWN_DATA

BSR GETCHR2
GET SECOND CHARACTER

BSR ECHO2
ECHO DWNLD CHAR TO CONSOLE

CMPA.L #EPROMRNG,A0
IS THIS A WRITE TO EPROM?

BLS.S EPROMERR
- YES, GO TO EPROMERR

BSR HEX_CONV
CONVERT CHARACTER TO HEX

MOVE.B D2,(A0)
LOAD BYTE INTO MEMORY

BRA.S CHK

EPROMERR
BSET.B #EPROMWR,MONSTAT
FLAG EPROM WRITE

CHK_SUM
ADDQ.L #1,A0
INCREMENT MEM LOAD ADDR

TST.W D4
ARE NXT CHARs CHECK SUM ?

BEQ.S LOOP_END
- YES, DONT ADD TO CHK SUM

ADD.B D2,CK_SUM
ADD THIS BYTE TO CHK SUM

LOOP_END
DBF D4,DOWN_DATA
IF MORE DATA THEN LOOP

NOT.B CK_SUM
COMPLEMENT CHECK SUM

MOVE.B -(A0),D2
GET COMPUTED CHECK SUM

CMP.B CK_SUM,D2
COMP CALC'S AND

XMIT CHK SUMS

BEQ.S ERRCHECK
IF CHECK SUMS AGREE

THEN EXIT DOWNLOAD

MOVE.L MONSTAT,D3

BSET.L #CHECKSUM,D3
SET FLAG IF CHECK SUM ERR

MOVE.L D3,MONSTAT

BRA.S ERR_MARK

ERRCHECK
BTST.B #EPROMWR,MONSTAT
A WRITE TO EPROM ?

BEQ.S DD_EXIT
- NO, EXIT

ERR_MARK
MOVE.W #"*",D0
- YES, MARK ERROR WITH *

BSR ECHC1

DD_EXIT
BSR SCRLF
ECHO CR & LF

* GETFIELD
CLR.L D2
CLEAR HEX BUFFER

LOOPINIT
MOVE.W #1,D5
SET COUNT TO

PACK 2 NIBBLES

GF_LOOP
BSR GETCHR2
GET DOWNLOAD CHARACTER

BSR ECHO2
ECHO DOWNLOAD CHARACTER
TO CONSOLE

BSR HEX_CONV
CONVERT ASCII CHAR TO HEX

BTST.B #HEX_ERR,MONSTAT
IF HEX CONVERSION ERROR
BNE.S GF_EXIT THEN EXIT GET FIELD
DBF D5,GF_LOOP GET SECOND NIBBLE
ADD.B D2,CK_SUM COMPUTE CHECK SUM
DBF D6,LOOPINIT IF MORE CHAR THEN LOOP
  GF_EXIT RTS ELSE EXIT
END
* THIS ROUTINE IS VECTORED TO BY ALL EXCEPTIONS THAT LACK A DEFINITE EXCEPTION SERVICE ROUTINE.

* WRITTEN BY DR. LARRY ABBOTT

* FILENAME: UNUSED.ASM

* VERSION 1.3

* REV. MODIFIED BY DATE DESCRIPTION
* A DAVID M. SENDEK 1 OCT 87 -DOCUMENTATION UPGRADE
* -INCORPORATE A PROMPT

* DEFINING MODULES OF EXTERNALLY DECLARED VARIABLES:
* OUTPUT_BYTE - BYTEOUT.ASM MESSAGE - MESSAGE.ASM
* REG - REG.ASM SCRLF - IO_UTIL.ASM
* SYSTAX - MAIN.ASM USEMSG - MESSAGE.ASM
* PROMPT - MESSAGE.ASM

GLOBAL UNUSED
EXTERNAL OUTPUT_BYTE,MESSAGE,REG,SCRLF,SYSTAX,USEMSG
EXTERNAL PROMPT

UNUSED:MOVEM.L SP,SYSTAX SAVE POINTER TO APPLICATION REGISTERS

MOVEM.L A0-A7/D0-D7,-(SP) SAVE ALL REGISTERS
BSR SCRLF MOVE CURSOR TO NEXT LINE
LEA USEMSG,A5 SET MSG POINTER TO MONMSG
BSR MESSAGE CRT<UNUSED EXCEPTION MSG
MOVE.L SYSTAX,A5 GET TOP OF STACK AT ENTRY
ADDQ.L #6,A5 POINT TO STACK FORMAT WORD
MOVE.B (A5)+,D0 GET FORMAT.HIGH
BSR OUTPUT_BYTE OUTPUT FORMAT.HIGH
MOVE.B (A5),D0 GET FORMAT.LOW
BSR OUTPUT_BYTE OUTPUT FORMAT.LOW
BSR SCRLF MOVE CURSOR TO NEXT LINE
BSR REG DISPLAY REGISTERS
MOVEM.L (SP)+,A0-A7/D0-D7 RESTORE ALL REGISTERS
RTE
END
The figures (Figs. C.1 through C.8) contained in this appendix are discussed in Chapter IV. These figures were created using the OrCAD/SDT III computer-aided design (CAD) tool. Each signal's source(s) and/or destination(s) are noted on the diagrams. It is, however, the integration of these various components into a minimal system that comprises the work that is original to this thesis.
One-shot Connection

Debouncing Circuitry

COMMENT:
(1) - To CPU
(2) - To CPU and DUART Circuitry

TITLE: Minimal System HALT* and RESET* Generation Circuitry
Figure: C.2
COMMENTS:
(1) - To CPU
(2) - To DTACK* and BERR* Circuitry
NC = Not Connected

TITLE: Minimal System Clock Generation Circuitry
Figure: C.3
COMMENTS:
(1) - From CPU
(2) - ROM Enable; To ROM Circuitry and DTACK* Circuitry
(3) - Chip Select MC68681 DUART; To DUART Circuitry
(4) - SRAM Enable; To SRAM Circuitry and DTACK* Circuitry
NC = Not Connected

TITLE: Minimal System Address Decode Circuitry
Figure: C.4
(2) DTACK681*  (1) DTACK*  
(3) SRAMEN  
(3) ROMEN*  
ROM Delay 500ns  
SRAM Delay 250ns  
(5) 4 MHz  
+5V  
(4) UDS*  
(4) LDS*  

COMMENTS:
(1) - To CPU
(2) - From DUART Circuitry
(3) - From Address Decode Circuitry
(4) - From CPU
(5) - From Clock Circuitry

TITLE: Minimal System DTACK* and BERR* Generation Circuitry
Figure: C.5
(1) LDS*
(1) UDS*
(1) R/W*
(1) (2) D0 - D7
(1) A1 - A15

(3) SRAMEN
(3) ROMEN*
(1) (2) D8 - D15

COMMENTS:
(1) - From CPU
(2) - To CPU
(3) - From Address Decode Circuitry
OELB = Output Enable Low Byte
OEHB = Output Enable High Byte
WELB = Write Enable Low Byte
WEHB = Write Enable High Byte

TITLE: Minimal System EPROM and SRAM Circuitry
Figure: C.6
(1) FC0
(1) FC1
(1) FC2
(1) A1
(1) A2
(1) A3
(1) AS*
+5V

+5V
MSB
IPL2* (2)

+5V
IPL1* (2)

(3) IRQ681*
LSB
IPL0* (2)

COMMENTS:
(1) - From CPU
(2) - To CPU
(3) - From DUART Circuitry
(4) - To DUART Circuitry
MSB = Most Significant Bit
LSB = Least Significant Bit

TITLE: Minimal System Interrupt Request and Interrupt Acknowledge Circuitry
Figure: C.7
(4) DTACK681*  
(1) R/W*  
(5) IRQ681*  
(3) IACK681*  
(2) CS681*  
(10) RESET*  

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<td>TXDA</td>
</tr>
<tr>
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<td>RXDB</td>
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<td>26</td>
<td>OP6</td>
</tr>
<tr>
<td>15</td>
<td>OP7</td>
</tr>
</tbody>
</table>

**COMMENTS:**
1. From CPU
2. From Address Decode Circuitry
3. From Interrupt Acknowledge Circuitry
4. To DTACK* Circuitry
5. To Interrupt Request Circuitry
6. To Terminal
7. To XT/AT Development System
8. From Terminal
9. From XT/AT Development System
10. From RESET* Circuitry
11. To CPU
NC = Not Connected

Port A is for a Terminal
Port B is for an XT/AT Development System

**TITLE:** Minimal System Dual-port Receiver Transmitter Serial Port Circuitry

**Figure:** C.8
APPENDIX D: MINIMAL SYSTEM'S PROGRAMMABLE LOGIC
DEVICE SOURCE CODE

In order to reduce the chip count, Altera EP310 erasable programmable logic devices (EPLDs) were used within the minimal system. Abel, a logic software design tool by Data I/O Corporation, was used to program Altera EP310 EPLDs [Ref. 16:pp. 2-57 - 2-62]. Abel files provides a high-level representation of the logic to be implemented on the EP310s. The EP310 comes in a 20-pin package. Nine pins are used strictly for input logic; one pin can be used for input logic or as a clocked input; eight pins can be used for input logic or output logic; the remaining two pins are used for Vcc input and ground input.

The following Abel modules were implemented:

- minimal_system_address_decoder
- dtack_and_bus_error_generation
- output_enable_write_enable
- interrupt_controller
THIS FILE USES DATA I/O'S ABEL DESIGN LANGUAGE TO GENERATE A JEDEC FILE TO PROGRAM AN ALTERA EP310 ERASABLE PROGRAMMABLE LOGIC DEVICE (EPLD).

MODULE minimal_system_address_decoder  FLAG '-X0'
TITLE '68010 ADDRESS DECODER FOR THE MINIMAL SYSTEM'

u61 DEVICE 'E0310'; "Abel V2 must be used for this device.

"DEFINE LABELS ASSOCIATED WITH INPUT AND OUTPUT PINS
" FOR THE EP310
" - INPUT PINS
  a12,a13,a14,a15,a16,a17,a18,a19,a20,a21,a22,a23,
as PIN 1,2,3,4,5,6,7,8,9,11,12,13,15;
" - OUTPUT PINS
  cs681,romen,sramen PIN 16,18,19;

"ASSIGNMENT STATEMENTS
  h = 1;  "HIGH
  l = 0;  "LOW
  x = .X.;  "DONT CARE
  ramaddr = [a23,a22,a21,a20,a19,a18,a17,a16,a15,a14,
x,x,x,x,x,x,x,x,x,x,x];
  romaddr = [a23,a22,a21,a20,a19,a18,a17,a16,x,x,x,
x,x,x,x,x,x,x,x,x,x];
  duartaddr = [a23,a22,a21,a20,a19,a18,a17,a16,a15,a14,
a13,a12,x,x,x,x,x,x,x,x,x,x,x,x];

"DEFINE EQUATIONS AS PER MEMORY MAP
"  ! = INVERSION
"  & = AND
"  # = OR
EQUATIONS
  sramen = (ramaddr >= ^h010000)&(ramaddr <= ^h013FFF)&!as;
  !cs681= (duartaddr >= ^h7F7000)&(duartaddr <= ^h7F7FFF)&!as;
  !romen = (romaddr <=^h00FFFF)&!as;

END minimal_system_address_decoder
THIS FILE USES DATA I/O'S ABEL DESIGN LANGUAGE
TO GENERATE A JEDEC FILE TO PROGRAM AN ALTERA
EP310 ERASABLE PROGRAMMABLE LOGIC DEVICE (EPLD).

MODULE dtack_and_bus_error_generation  FLAG '-X0'
TITLE 'DTACK AND BUS ERROR GENERATION FOR THE MINIMAL SYSTEM'

u64 DEVICE 'E0310'; "Abel V2 must be used for this device.

"DEFINE LABELS ASSOCIATED WITH INPUT AND OUTPUT PINS
" FOR THE EP310
" - INPUT PINS
  berr_delay,rom_delay,sram_delay,romen,
  dtack681,sramen PIN 1,8,9,11,13,16;
" - OUTPUT PINS
  dtack,berr PIN 18,19;

"ASSIGNMENT STATEMENTS
  h = 1;    "HIGH
  l = 0;    "LOW
  x = .X.;  "DONT CARE

"DEFINE EQUATIONS
" NOTE:  ! = INVERSION
"   & = AND
"   # = OR
EQUATIONS
  dtack=(!dtack681)#(sramen&sram_delay)#(!romen&rom_delay);
  berr = berr_delay;

END dtack_and_bus_error_generation
THIS FILE USES DATA I/O'S ABEL DESIGN LANGUAGE TO GENERATE A JEDEC FILE TO PROGRAM AN ALTERA EP310 ERASABLE PROGRAMMABLE LOGIC DEVICE (EPLD).

MODULE output_enable write enable FLAG '-X1' TITLE 'SRAM WRITE ENABLE AND SRAM AND ROM OUTPUT ENABLES FOR THE MINIMAL SYSTEM'

u63 DEVICE 'E0310'; "Abel V2 must be used for this device.

"DEFINE LABELS ASSOCIATED WITH INPUT AND OUTPUT PINS FOR THE EP310"

- INPUT PINS
  rw, win, uds, lds, mas, as, pudsi, pldsi PIN 1, 2, 3, 4, 5, 6, 8, 9;

- OUTPUT PINS
  oelb, weu34, weu35, oehb, pudso, pldso, pas
  PIN 13, 14, 15, 16, 17, 18, 19;

"ASSIGNMENT STATEMENTS"

h = 1; "HIGH"
1 = 0; "LOW"
x = .X.; "DON'T CARE"

"DEFINE EQUATIONS"

"NOTE: ! = INVERSION"

& = AND
#
= OR
rw = read
!rw = write

EQUATIONS
!weu34 = !rw & !pldsi;
!weu35 = !rw & !pudsi;
!oehb = rw & !pudsi;
!oelb = rw & !pldsi;

END output_enable_write_enable
THIS FILE USES DATA I/O'S ABEL DESIGN LANGUAGE TO GENERATE A JEDEC FILE TO PROGRAM AN ALTERA EP310 ERASABLE PROGRAMMABLE LOGIC DEVICE (EPLD).

MODULE interrupt_controller FLAG '-Xl'
TITLE 'INTERRUPT CONTROLLER FOR THE MINIMAL SYSTEM'

"THIS IS NOT UPWARDS COMPATIBLE FOR THE FULLY INTEGRATED SYSTEM u00 DEVICE 'E0310'; "Abel V2 must be used for this device.

"DEFINE LABELS ASSOCIATED WITH INPUT AND OUTPUT PINS
"FOR THE EP310
" - INPUT PINS
  a1,a2,a3,as,irq681,fc1,fc2,fc3 PIN 1,2,3,4,5,6,7,8;
" - OUTPUT PINS
  ipl0,ipl1,ipl2,irack681 PIN 16,17,18,19;

"ASSIGNMENT STATEMENTS
  h = 1; "HIGH
  l = 0; "LOW
  x = .X.; "DONT CARE

"DEFINE EQUATIONS
" NOTE:  ! = INVERSION
" & = AND
" # = OR
EQUATIONS
!irack681 = a1 & !a2 & !a3 & !as & fc1 & fc2 & fc3;
ipl0 = h;
ipl1 = h;
ipl2 = irq681;

END interrupt_controller
APPENDIX E: SYSTEM DIAGRAMS

In this appendix are the wiring diagrams which implement the master circuit board subsystem and system controller subsystem which are discussed in Chapter IV. These diagrams were produced by the OrCAD/SDT III computer-aided design (CAD) tool. It is, however, the integration of these various components into a multi-processor system that comprises the work that is original to this thesis.
TITLE: System Controller Circuit Board
Functional Block Diagram
Figure: E.2
COMMENTS:

(1) - From VMEbus
(2) - To CPU
(3) - To CPU, MMU Circuitry, DUART Circuitry, Interrupt Handler Circuitry and VMEbus Controller Circuitry

TITLE: HALT* and RESET* Generation Circuitry
Figure: E.4
COMMENTS:

(1) - To CPU, MMU Circuitry, Interrupt Handler Circuitry, Dual-port DRAM Controller Circuitry and VMEbus Controller Circuitry
(2) - To DTACK* and BERR* Circuitry
NC = Not Connected

TITLE: Clock Generation Circuitry

Figure: E.5
COMMENTS:

(1) - Chip Select Request Line 1 of 74F764; To Dual-port DRAM Controller Circuitry
(2) - Off Board Resource; To VMEbus Controller Circuitry and BERR* Circuitry
(3) - ROM Enable; To EPROM Circuitry and DTACK* Circuitry
(4) - Chip Select MC68681 DUART; To DUART Circuitry
(5) - Chip Select MC68451 MMU; To MMU Circuitry
(6) - Chip Select SCN68151 Interrupt Handler Hardware; To Interrupt Handler Circuitry
(7) - SRAM Enable; To SRAM Circuitry and DTACK* Circuitry
(8) - From MMU Circuitry
NC = Not Connected

TITLE: Local Bus Address Decode Circuitry
Figure: E.6
TITLE: Memory Management Unit Circuitry (Page 1 of 2)

Figure: E.7
TITLE: Dual-port DRAM Controller Circuitry (Page 1 of 3)
Figure: E.9
(9) PUDS*
(9) PA19
(9) CASEN*
(9) PLDS*

(9) DTACK764
(9) SEL2*

UBUCAS* (8)
UBUCAS* (8)
LBUCAS* (8)
LBUCAS* (8)

GDTACK* (10)

+5V
2.2K

COMMENTS:
(1) - From MMU Circuitry
(2) - From CPU
(3) - From Local Bus Address Decode Circuitry
(4) - From VMEbus Address Decode Circuitry
(5) - From VMEbus
(6) - To Page 3 of 3
(7) - From Clock Circuitry
(8) - To DRAM Circuitry
(9) - From Page 1 of 3
(10) - To VMEbus
(11) - From VMEbus Controller Circuitry
(12) - To CPU
(13) - From DRAM Circuitry
(14) - To DTACK* Circuitry
(15) - To Page 2 of 3

UBLCAS* = Upper Bank Lower Byte CAS* Enable
UBUCAS* = Upper Bank Upper Byte CAS* Enable
LBLCAS* = Lower Bank Lower Byte CAS* Enable
LBUCAS* = Lower Bank Upper Byte CAS* Enable
NC = Not Connected

TITLE: Dual-port DRAM Controller Circuitry (Page 3 of 3)
Figure: E.11
(1) SEL2*  
COMMENTS:  (1) SEL1*  
(1) - From Dual-port DRAM Controller Circuitry  
(2) - To Page 2 of 4  
(3) - To Dual-port DRAM Controller Circuitry  
NC = Not Connected
COMMENT:
(1) - From Page 1 of 4
(1) SEL2*
(1) SEL1*

COMMENTS:
(1) - From Dual-port DRAM Controller Circuitry
(2) - To Page 4 of 4
(3) - To Dual-port DRAM Controller Circuitry
NC = Not Connected

TITLE: Dynamic Random Access
Memory Circuitry (Page 3 of 4)
Figure: E.14
(4) PLDS*
(4) PUDS*
(1) R/W*

(1)(2) D0 - D7

(4) PA1 - PA15

(3) SRAMEN
(3) ROMEN*

(1)(2) D8 - D15

COMMENTS:
(1) - From CPU
(2) - To CPU
(3) - From Local Bus Address Decode Circuitry
(4) - From MMU Circuitry
OELB = Output Enable Low Byte
OEHB = Output Enable High Byte
WELB = Write Enable Low Byte
WEHB = Write Enable High Byte

TITLE: EPROM and SRAM Circuitry
Figure: E.16
**TITLE: Dual-port Asynchronous Receiver/Transmitter Serial Port Circuitry**

Figure: E.17

Port A is for a Terminal
Port B is for an XT/AT Development System
COMMENTS:
(1) - From CPU
(2) - From Clock Circuitry
(3) - From RESET* Circuitry
(4) - To DTACK* Circuitry
(5) - To VMEbus and VMEbus Controller Circuitry
(6) - From VMEbus
(7) - From DUART Circuitry
(8) - From Local Bus Address Decode Circuitry
(9) - To DUART Circuitry
(10) - From MMU Circuitry
(11) - To CPU
(12) - To MMU Circuitry

(10) PA1 - PA3
(2) 8 MHz
(1) R/W*
(3) RESET*
(4) DTACK155*
(1)(11) D0 - D7

(1) LDS*
(1) FC0
(1) FC1
(1) FC2
(11) IPL0* - IPL2*
(1) AS*

TITLE: Interrupt Handler Circuitry
Figure: E.18
(1) - To CPU
(2) - From CPU
(3) - From Clock Circuitry
(4) - From Local Bus Address Decode Circuitry
(5) - From MMU Circuitry
(6) - From Dual-port DRAM Controller Circuitry
(7) - From Interrupt Handler Circuitry
(8) - From DUART Circuitry
(9) - From VMEbus Controller Circuitry

TITLE: DTACK* and BERR* Generation Circuitry
Figure E.19
COMMENTS:
(1) - From VMEbus
(2) - To VMEbus
(3) - To VMEbus Drivers Circuitry
(4) - From Local Bus Address Decode
(5) - From RESET* Circuitry
(6) - From Clock Circuitry
(7) - From Interrupt Handler Circuitry
(8) - From MMU Circuitry
(9) - To DTACK* Circuitry
(10) - From CPU
(11) - To Dual-port DRAM Controller Circuitry
(12) - To BERR* Circuitry
NC = Not Connected

TITLE: VMEbus Controller Circuitry
Figure: E.20
COMMENTS:
(1) - From VMEbus
(2) - Chip Select Request Line 2 of 74F764; To Dual-port DRAM Controller Circuitry

TITLE: VMEbus Address Decode Circuitry
Figure: E.21
(5) (10) D0 - D7

(5) GUDS*
(5) GLDS*
(5) GR/W*
(1) (6) GAS*

(3) PUDDS* 1
(1) DSEN* 2
(7) (10) GDTACK*

(1) DSEN* 2
(2) R/W*

+5V

(1) VMEEN* 2.2K

(4) BIACK*

(3) PA1 - PA7

(1) VMEEN*

(5) GA1 - GA7

COMMENTS:
(1) - From VMEbus Controller Circuitry
(2) - From CPU
(3) - From MMU Circuitry
(4) - From Interrupt Handler Circuitry
(5) - To Dual-port DRAM Controller Circuitry
(6) - To VMEbus Address Decode Circuitry
(7) - To VMEbus Controller Circuitry
(8) - To Interrupt Handler Circuitry
(9) - To HALT* and RESET* Circuitry
(10) - From Dual-port DRAM Controller Circuitry

TITLE: Master Circuit Board VMEbus
Drivers Circuitry (Page 1 of 3)
Figure: E.22
Debouncing Circuitry

+5V

Reset Switch (Red)

GND

+5V

2.2K

2.2K

1 2

1 2

1 2

2 1

74L50S

SYSRESET* (1)

COMMENT:

(1) - To VMEbus

TITLE: SYSRESET* Generation Circuitry

Figure: E.26
COMMENTS:

(1) From BAM Circuitry
(2) From SYSRESET* Circuitry
(3) To BAM Circuitry

TITLE: System Controller VMEbus Drivers Circuitry
Figure: E.27
LIST OF REFERENCES


8. MTT8 Course Notes, Motorola Semiconductors, Phoenix, Az, 1986.


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