EDITOR/ASSEMBLER

USER'S GUIDE

A SOLID STATE SOFTWARE™ PROGRAM

FOR THE

TEXAS INSTRUMENTS

COMPACT COMPUTER 40

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Table of Contents

CC-40 EDITOR/ASSEMBLER USER'S GUIDE

CHAPTER 8--DEBUG MONITOR

CHAPTER 1
CC-40 E/A PACKAGE

This chapter introduces assembly-language programming and assembly-language program development with the CC-40 Editor/Assembler (E/A) package, an assembly language program development system. The chapter also includes a detailed description of the development of a small program through use of the E/A package.

The Editor/Assembler cartridge for the Compact Computer 40 (CC-40) contains two major programs, an editor and an assembler, which perform major tasks in development of programs written in assembly language. In addition, the cartridge contains other programs which support assembly-language program development. All of these programs are integrated into a system designed to aid in the development of software which uses the maximum capabilities of the CC-40.

The most popular method of programming the CC-40 involves writing programs in the language called BASIC (Beginner's All-purpose Symbolic Instruction Code). The BASIC language is the easily learned programming code supported by the firmware (programs in read-only memory) in every CC-40 console. It permits rapid development of programs, and it is "friendly" in pointing out programming errors.

Despite its advantages and popularity, BASIC cannot be used as the programming language for the development of some important applications programs. Programs which require fast execution and maximum efficiency in the use of memory space cannot be written in BASIC. For these reasons, word-processing, spreadsheet, data-communication, and many other valuable programs are usually written in a language other than BASIC, usually in "assembly language." Assembly-language programs run up to 200 times faster than BASIC programs which perform the same tasks, and they require as little as one-tenth the memory-storage space.

BASIC	ASSEMBLY LANGUAGE
quick program writing	faster program execution
easy to learn to use	more efficient use of available memory
easy error checking	

Programs in BASIC and programs in assembly language can be combined in program development. Programs written in BASIC can use subprograms (subroutines) developed in assembly language whenever speed and memory economy are important. A video display, for example, can be driven by a subprogram developed in assembly language and called by a BASIC program. Additionally, many of the existing machine-language subroutines in CC-40 BASIC firmware can be used to simplify assembly-language programming. The CC-40 liquid-crystal display, for example, is easily controlled through assembly-language "calls" to the display subroutines that are used by BASIC.

CHAPTER 1
CC-40 E/A PACKAGE

An Introduction to Assembly-Language Programming

Assembly language permits direct control of computer-processor operations. Through assembly-language programming, each step of processor operation is specified by a machine-language program stored in CC-40 memory. Because of such comprehensive program control, programs written in assembly language can be executed faster and provide much more computing power per unit of memory than programs written in any other programming language. Assembly language provides the means for using the CC-40 at its maximum capability.

Assembly language is a "command and control" language specifically created for use with individual computer processors. The assembly language for the CC-40 is created specifically for use with the TMS7000-family microprocessor which controls all CC-40 operations.

Operation of the CC-40 is controlled by a program stored electronically in memory. The program is read from memory one step at a time by the CC-40 processor. The processor interprets what it reads into electronic control signals which guide processing operations, as shown below. In this manner, the CC-40 proceeds through many program steps to execute a program.

Program in Memory → Processor Interpretation → Data Processing

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Eight data lines carry the electrical signals from each program-memory storage location to the processor. Binary voltage states (High/Low or ON/OFF) of these eight lines correspond to "bits" (binary digits) of information which compose an eight-bit information unit called a "byte" (binary term). When a byte of program information stored in program memory is present on the data-bus lines of the processor, the processor interprets the byte to be one of the following.

- A command code which directly controls processor operation
- A data byte
- An address byte

The way the processor interprets the electrical signals from program memory is incorporated into the "machine-language" design of the processor. The relationship between machine language and assembly language is described in chapter 2 of this guide. Individual assembly-language instructions are described in detail in chapter 7 of the *CC-40 Editor/Assembler Reference Manual.*

Execution of Commands

Bit combinations in the command code cause the processor to perform a certain operation according to processor machine language. If the command code contains certain bit combinations, it causes the processor to add. Other bit combinations cause it to subtract, output a byte, jump to another program memory address, or perform other processing operations. Unless the processing of a command (such as a jump, subroutine call, idle, or similar instruction) determines otherwise, the processor always executes commands in the sequence in which they are stored in program memory.

In addition to guiding the processor by specifying the type of operations to be performed in a program step, command codes identify any bytes which must follow the command code to produce a complete machine-language command. If a command code so specifies, the processor considers a subsequent byte to be a value to be used in an addition operation. Similarly, if another command code specifies it, the next byte is read by the processor as an address in memory from which the processor is to read data for a subtraction operation.

Two Programming Techniques

Programming the CC-40 consists of storing appropriately encoded command codes, data values, and address values into program memory. The CC-40 permits the storage of such machine-language codes by two methods.

The first method is a primitive (but workable) one. Numeric values which correspond directly with the electrically stored command-bit combinations are entered into the CC-40 keyboard for memory storage by the CC-40 DEBUG Monitor program. Such programming is called "machine-language programming" (see chapter 8 of this guide).

The second method is much more sophisticated and practical. It demands less time, effort, and patience of a programmer, because it uses the computing capabilities of the CC-40 to replace the laborious tasks of command-table lookup, unautomated computation, and copious note taking. This method uses the programs in the Editor/Assembler cartridge. The editor, the assembler, the linker, and the various utility programs are themselves machine-language programs which make the computing power of the CC-40 available for program development.

Assembly Language and the E/A Package

In programs stored directly into CC-40 memory by the DEBUG Monitor, commands are represented by hexadecimal (base 16) numbers. Commands with hexadecimal numbers in the series >18, >28, . . . >78, for example, direct the processor to add numbers from various storage locations in CC-40 memory. Subsequent hexadecimal numbers in the commands identify the storage locations for the values to be added and the sums of those values.

Hexadecimal numbers which represent commands are difficult to remember during programming, and remembering memory addresses is tedious. Hexadecimal command codes are not like words: "add," "subtract," "compare," and so on. The command to "add the number in register 12 to the number in register 49," for example, is the following sequence of numbers: >48 >0C >31. With a substantial program, a programmer could spend a lifetime remembering—and misremembering and correcting—such numbers. Short of spending such a lifetime, a programmer can use the E/A program called the assembler to perform these tedious tasks.

The E/A assembler is a translation program which is conceptually the central program in the CC-40 Editor/Assembler package. Problems in machine-language programming are solved by the assembler by translating English words or mnemonic expressions into machine-language commands. The sequence of numbers for the command listed above, >48 >0C >31, results directly from assembler translation of the simple statement ADD R12,R49. (The assembler is described in detail in chapter 5 of this guide.)

Other programs in the E/A package are designed to support the work done by the assembler in its production of processor commands from mnemonic English words and phrases. Programs other than the assembler—the editor, the linker, the DEBUG Monitor, and the utility programs—provide for text entry of assembly-language programs to the assembler and process the machine-language output of the assembler for specific uses in the CC-40.

The E/A editor provides a means for entering and revising assembly-language commands for subsequent translation by the assembler. Through the editor, entire programs can be written before they are assembled. An editor option provides for viewing either single program lines on the CC-40 console display or a multiline program segment on a CRT terminal connected to the CC-40 through an RS232 input/output device. (The editor is described in detail in chapter 4 of this guide.)

The E/A linker further translates the numbers produced by the assembler into an executable machine-language program for the TMS7000-family processor (much as the DEBUG Monitor does for numbers entered at the CC-40 keyboard). The linker performs the necessary tasks of adding memory-addressing information to the assembled program and converting machine code into a memory image of what it must be in order to run on the CC-40. (The linker is described in detail in chapter 6 of this guide.)

The E/A utility programs are a group of special-purpose E/A programs which further support editing, assembling, and linking. The utility programs include the following.

- A file-dump utility: a program which prints the contents of any file stored on mass-storage media.
- Loader utilities: two programs which bring E/A-developed programs into memory for execution.
- A save utility: a program which saves E/A-developed programs in RAM to mass-storage media.
- A file-conversion and transfer utility: a program which enables communication between the CC-40 and external computers used to develop assembly-language programs.
- BASIC editing utilities: two programs which permit the E/A screen editor to be used for development of BASIC programs.

The DEBUG Monitor, in addition to its memory-access functions described above, provides for controlled execution of programs being developed. Loaded programs can be started, stopped, examined, and changed as they are executed in order to detect and eliminate programming errors. (The DEBUG Monitor is described in detail in chapter 8 of this guide.)

Chapter 2 of this guide describes machine language and assembly language in detail, and chapter 7 of the *CC-40 Editor/Assembler Reference Manual* describes each assembly-language instruction used with the E/A package. Chapters 4 through 8 of this guide describe the uses and operation of the editor, assembler, linker, utility programs, and the DEBUG Monitor. The remaining parts of this chapter provide instructions for using the E/A package to develop a small program without such detailed knowledge.

The "BEEP" Demonstration Program

Use of the E/A package to develop CC-40 programs is simple and straightforward. The E/A programs are run in a sequence that processes an assembly-language program into a completed, working machine-language program. The following pages of this chapter show how each program is used in the development of a short program which emits a "beep" from the CC-40 beeper.

The instructions provided below for development of the beep-emitting program are complete, and when they are followed with exacting care they result in the completely developed program which demonstrates all of the major features of the E/A package. Many problems, however, can result from seemingly trivial mistakes in programming when any programming system is used, particularly with a system such as the E/A (with its being more resourceful but more "unforgiving" than, for example, BASIC). As with even BASIC, thorough understanding can easily uncover mistakes which are not even noticed in the careful following of directions. If the following instructions do not produce the expected results at any stage, consult the appropriate chapter of this guide to find the solution to the problem.

Figure 1-1 shows a small program called "BEEP," which is written in assembly language. After the program is processed by the E/A package into machine language and executed, it activates the beeper in the CC-40. Activation of the beeper requires that electrical pulses be sent to the CC-40 beeper which transforms electrical pulses into sound waves, and this short program provides 1024 such pulses to produce a single "beep." The "BEEP" program causes the processor to alternately turn on and turn off electrical current to the beeper a total of 1024 times in order to produce the pulses that emit a tone.

```
00001 COUNTER  EQU  >5D              COUNTER MEMORY LOCATION
00002 BEEP     MOVD %>400,COUNTER   SET CYCLE COUNT TO 1024
00003 BEEP2    MOVP %1,P21          TURN ON THE BEEPER
00004          MOV  %29,B           DELAY COUNT FOR ON PERIOD
00005 ONLOP    DJNZ B,ONLOP         LOOP BACK FOR COUNT
00006          MOVP %0,P21          TURN BEEPER OFF
00007          MOV  %32,B           DELAY COUNT FOR OFF PERIOD
00008 OFFLOP   DJNZ B,OFFLOP        LOOP BACK FOR COUNT
00009          DECD COUNTER         COUNT OF CYCLES DONE
00010          JC   BEEP2           LOOP BACK UNTIL ALL DONE
00011          RETS                 RETURN TO CALLING PROGRAM
00012 NAMLOW
00013          RTEXT 'BEEP'         PROGRAM NAME (REVERSE CAPS)
00014          BYTE NAMHGH-NAMLOW   NAME LENGTH
00015 NAMHGH   EQU  $-1             FILE STORAGE SPECIFICATIONS
00016          DATA BEEP            PROGRAM ENTRY POINT
00017          DATA 0000            NEXT SUBPROGRAM
00018          DATA NAMHGH-$+1      OFFSET TO NAME
00019          BYTE 0,>44           HEADER INFORMATION
```

Figure 1-1. The "BEEP" Assembly-Language Program

The function of each line of the program in terms of CC-40 operation is explained in the comment phrases printed to the right of the assembly-language instructions. More exact meanings of the instructions and each element within them are given in chapter 2 of this guide and in chapter 7 of the *CC-40 Editor/Assembler Reference Manual*.

Development of the "BEEP" program requires only the CC-40 console with the Editor/Assembler cartridge installed and a single mass-storage device.

Preparing the CC-40 for "BEEP" Program Development

The "BEEP" program is complete and ready for entry into the E/A editor as the first step in transforming the assembly language into the machine language which controls CC-40 beeper operation. The following instructions describe how to prepare the CC-40 for program development.

STEP 1: Ensure that the mass-storage device is connected to the CC-40 by a *HEX-BUS*™ connecting cable and that AC-adaptor cables are connected or batteries are installed in each unit.

STEP 2: Insert the Editor/Assembler cartridge into the cartridge port of the CC-40.

STEP 3: Turn on the mass-storage device, and then press the **[ON]** key at the upper right of the CC-40 keyboard.

STEP 4: Press the **[ENTER]** key when the BASIC cursor, the `System initialized` message, or the message `Memory contents may be lost` appears.

STEP 5: Insert a blank medium into the mass-storage device.

STEP 6: If the storage medium requires formatting type in **FORMAT n**(substitute for **n** the **device-number** of the storage device) and press **[ENTER]** to initialize (prepare) the medium for writing and reading files.

STEP 7: If a message containing the phrase `I/O error` appears in the display, the mass-storage unit or medium is malfunctioning. Check the *HEX-BUS*™ cable, check for both units receiving power, and try a fresh medium to correct the malfunction. See the storage device *Owner's Manual* for additional details.

STEP 8: Enter RUN "ALDS" (note the double quotes surrounding the word "ALDS"). The message `© 1983 Texas Instruments` momentarily appears; then the E/A main menu `E)dit A)ssemble L)ink B)asic?` appears.

When these steps have been followed, the CC-40 is ready for editing the "BEEP" program.

Editing the "BEEP" Program

The editor is a program which accepts both characters and text-formatting commands from the keyboard. The CC-40 console functions much like an electronic typewriter which allows for correctable typing of program text into memory. From characters and commands typed into the keyboard, the editor composes the text of the assembly-language program in CC-40 memory, and it saves the file on a mass-storage medium for later use by the assembler.

The following steps enter the program text into CC-40 memory from the keyboard and save the text onto a mass-storage medium. (Chapter 4 of this guide contains a detailed description of editor operation.)

STEP 1: The display shows `E)dit A)ssemble L)ink B)asic?` Press the **E** key to start the editor program.

STEP 2: When the display shows `L)ine S)creen D)efine Q)uit`, press the **L** key to permit use of the CC-40 console keyboard and display for editing.

STEP 3: When the `Copy file` prompt appears, press **[ENTER]**. (If a file were to be reloaded for editing, the filename would be typed in following this prompt.)

STEP 4: In response to the editor ">" prompt, enter **AUTO** to have the E/A automatically provide line numbers for each program line.

STEP 5: In response to each line number displayed, type in each line (followed by **[ENTER]**) exactly as it is shown in Figure 1-1. Where several spaces are used to keep columns of the text in line, however, only one space is required. Proofread each line carefully and make any changes to the line before pressing **[ENTER]**, using the ← key to backspace the cursor for correcting characters and **[SHIFT]** ← for deleting and closing-up characters. Use ← and → to move the 31-character display "window" over longer lines during proofreading and correcting.

STEP 6: With all text entered, press **[BREAK]** to stop automatic line numbering after line 19 has been entered.

STEP 7: As a special precaution against mistakes, review the lines that have been typed by entering **LIST** when the ">" cursor appears. Read through and verify each line, pressing **[ENTER]** when a line is verified to be correct. If a line must be corrected, use the correction keys described in step 5 to correct it. Press **[ENTER]** when the line is correct, and check the next line. When all lines have been verified, press **[BREAK]**.

STEP 8: When the cursor appears, enter **SAVE n.SRC** (substitute for **n** the device number of the mass-storage device you are using). Wait for the program to be saved (indicated by the reappearance of the cursor in the display).

STEP 9: In response to the cursor, enter the word **QUIT**. After the message `Are you sure (Y/N)?` appears in the display, press **Y** to leave the line-edit mode.

STEP 10: In response to the edit menu, `L)ine S)creen D)efine Q)uit`, press **Q**.

When step 10 has been completed, the assembly-language source program is stored. Now the assembly-language instructions must be converted into processor commands by assembling the source program.

Assembling the "BEEP" Program

The assembler converts the assembly-language program stored on mass-storage medium into a machine-language program which can subsequently be processed to run from CC-40 memory. (Chapter 5 of this guide contains a detailed description of assembler operation.)

The following steps assemble the "BEEP" program into machine language.

STEP 1: With the E/A menu, `E)dit A)ssemble L)ink B)asic?` displayed, press **A** to start the assembler program.

STEP 2: With the display showing the prompt `Source file`, enter the name by which the source has been stored on tape: **n.SRC** (substitute for **n** the device number of the storage unit).

STEP 3: With the display showing the prompt `Object file`, enter the name by which the machine-language object code is to be stored on tape: **n.OBJ**.

STEP 4: When the CC-40 display shows the question `In memory assemble (Y/N)?`, press **Y** for YES.

STEP 5: With `List file` in the display, press **[ENTER]** (or enter the device number and other data for a printer to produce an assembly listing).

STEP 6: Wait while the program is displaying the message `Assembling...` until it displays `Write object file (Y/N)?` Answer **Y** to the question in order to direct the assembler to write the machine-language program to tape.

STEP 7: The display should contain the message `NO errors NO warnings`. Press **[ENTER]** to return to the main E/A menu. If the display contains some other message, refer to chapter 5 of this guide for a description of assembly errors. When assembly errors are present, return to the instructions in the section on Editing the "BEEP" Program to answer **n.SRC** to the `Copy file` prompt, and follow the remaining editing steps to correct the errors in source-file statements. Then the error-free source file can be reassembled.

With the main E/A menu in the display, assembly of the program is complete. The program can now be processed into executable object code by the linker.

Linking the "BEEP" Program

The linker converts the assembler-output code into commands which can be executed in random-access memory (RAM) from the BASIC interpreter. (The linker, in addition, performs many other tasks, as explained in chapter 6 of this guide.)

The following instructions link the "BEEP" program to run it from the BASIC command level of the CC-40.

STEP 1: After the assembler has written the object program onto mass-storage media and the display once again shows the E/A menu, `E)dit A)ssemble L)ink B)asic?`, press **L** to start the linker.

STEP 2: When the linker asks `Is there a control file (Y/N)?`, answer **N** for NO.

STEP 3: When the linker prompts with `Enter line:`, enter **I n.OBJ** to tell the linker which file it is to include in the linking process from mass-storage media.

STEP 4: When the linker again prompts with `Enter line:`, enter **E** for END to tell the linker to begin execution of the instruction provided in step 3.

STEP 5: When the linker requests `Linked output file`, respond with **n.BEEP**, the name of the executable machine-language program which is to be run under BASIC.

STEP 6: When the linker requests `List file`, press **[ENTER]** to indicate that a listing is not wanted. The display then shows `Linking...`

STEP 7: When `Write linked output file?` appears in the display, press **[ENTER]**.

STEP 8: When `LINK COMPLETE` is displayed, press **[ENTER]** to return to the E/A main menu. If any other message appears, refer to chapter 6 of this guide for an explanation of linking errors and correct them accordingly.

STEP 9: The program is complete and ready to test. Press **B** from the main E/A menu to return to BASIC for testing the program.

Loading and Running the "BEEP" Program

Although various utility programs are provided for such special purposes as loading *Constant Memory*™ program cartridges (see chapter 7 of this guide), the "BEEP" program has been linked to be loaded and executed as a BASIC subprogram. The steps required for loading and executing the program as it has been linked above are listed below.

STEP 1: When the BASIC cursor appears in the display, enter **CALL LOAD ("n.BEEP")** to load the assembled and linked program as a BASIC subprogram into memory.

STEP 2: When the BASIC cursor again appears, enter the BASIC command **CALL BEEP** to execute the BEEP subprogram.

STEP 3: Listen to the "beep" made by the program developed using the E/A package, and compare the results of running it with the results of the beeper command normally used by the BASIC statement DISPLAY BEEP.

Using the DEBUG Monitor

After the machine-language program is loaded into memory, the DEBUG Monitor program can be used to (1) monitor the execution of the "BEEP" program or (2) alter the program as it is being run. Chapter 8 of this guide provides instructions for using the DEBUG Monitor to perform both of these tasks.

Advanced Program Development on the CC-40

The steps listed above develop the small "BEEP" program for execution as a BASIC subprogram and demonstrate the use of each E/A program. Much larger, more sophisticated, and more powerful programs can be developed with the E/A package. The following chapters of this guide describe in detail the full complement of techniques and tools provided by the E/A package for program development.

CHAPTER 2
TMS7000 ASSEMBLY LANGUAGE

Editor/Assembler User's Guide Chapter 2, Part 1

This chapter contains a description of the TMS7000-family assembly language as it is implemented in the E/A package. Data processing and storage, classifications and addressing modes of assembly-language instructions, and instruction syntax are described.

TMS7000-Family Processing Overview

Machine-language, and therefore assembly-language, instructions for the CC-40 represent the capabilities of the TMS7000-family processor. The instructions are a direct reflection of the way the processor manipulates, stores, inputs, and outputs data.

Representation of data in this chapter is in conventional binary, hexadecimal, decimal, and binary-coded decimal (BCD) number systems, as reviewed in appendix A of the *CC-40 Editor/Assembler Reference Manual*. The special symbol ">" preceding a number indicates that it is a hexadecimal or BCD number, and the special symbol "?" preceding a number indicates that it is a binary number. Numbers prefaced by no symbol are decimal numbers.

Processing Operations

The TMS7000-family processor performs all customary operations on eight-bit units (bytes) of data. As described later in this chapter, it performs arithmetic operations (including multiplication), comparisons, logical operations, bit "rotations" or shifts, jumps, calls, control operations, data moves, and similar operations.

Data Storage

Processing done by TMS7000-family processors is performed entirely on data stored within the 65,536 addresses it can directly access.

General-Purpose Register File

There are 128 general-purpose registers within the processor; these registers are accessed at addresses >00 to >7F. Within this general-purpose register file, a stack can be implemented to store, in a last-in-first-out manner, data and addresses.

Peripheral Register File

An additional 256 addresses from >100 through >1FF provide for data input and output (peripheral) registers. Not all addresses within this peripheral-register block are used in the CC-40.

Other Memory Addresses

Addresses above >1FF are used in the CC-40 for system firmware, console random-access memory (RAM), cartridge RAM, and cartridge read-only memory (ROM). Fewer instructions are available to access memory in this block than are available to access general-purpose and peripheral registers.

In addition to being accessed by fewer instructions than registers are, memory is accessed by instructions which produce longer machine-language commands and which take more processor time for execution. General-purpose and peripheral registers have an advantage over memory-addressing commands: they are accessed by commands which use less program memory and consume less processing time.

Chapter 2 of the *CC-40 Editor/Assembler Reference Manual* contains detailed information about register and memory usage and conventions in the CC-40, and chapter 6 of the manual contains detailed information about hardware implementation of registers and memory.

A map showing TMS7000-family memory usage is shown below.

>0000	A register
>0001	B register
>0002 >007F	Register file (R2 – R127) and Stack area
>0080 >00FF	UNUSED
>0100 >01FF	Peripheral file (P0 – P255)
>0200 >FFFF	Other Memory

Processor Registers

Three additional registers are internal to the processor chip: a 16-bit program counter (PC), an 8-bit status register (ST), and an 8-bit stack pointer (SP). The program counter contains the address of the next machine-language command which the processor executes after it finishes the command currently being executed. This address is computed from the address and length of the current command unless the current command is a branch or jump command. A branch or jump command causes the program counter to be loaded with a new value for out-of-sequence command execution.

The status register contains four single-bit flags in the four high-order bits. One of these flags describes the status of processor interrupts (enabled or disabled). The remaining three flags describe whether the execution of a command has (1) resulted in a value of zero, (2) resulted in a negative value, or (3) resulted in a carry-out of an eight-bit value. The table below shows the assignment of flag bits in the status register.

FLAG BITS IN THE STATUS REGISTER

Carry	Negative	Zero	Interrupt	Unused	Unused	Unused	Unused
7 (MS)	6	5	4	3	2	1	0 (LS)

The stack pointer can be set to addresses >00 through >7F in the general-purpose register file. The pointer is incremented before a byte of data is "pushed" onto the stack, and it is decremented after a byte is "popped" off of the stack. Similarly, the stack pointer is incremented once before each byte of a two-byte return address is pushed onto the stack by a subroutine call command (high byte first). The stack pointer is decremented once after each byte is popped off by a return-from-subroutine command. The stack pointer is usually set to >01 or greater to avoid conflict with registers A and B.

Chapter 6 of the *CC-40 Editor/Assembler Reference Manual* contains further details about processor-hardware operation.

TMS7000 Assembly-Language Instructions

TMS7000 assembly-language programs consist of line-by-line instructions provided to the processor after the E/A package translates them into machine-language commands. These mnemonic instructions, in general, are related to machine-language commands as described in chapter 1 of this guide.

The basis for classification of instructions is twofold: (1) instruction function in the operation performed by the processor, and (2) source and destination of data which is processed. The function of an instruction determines its type. The source-and-destination of data for an instruction determines its addressing mode.

Instruction Types

If an instruction adds bytes of data, it is of one type; if it stores bytes of data, it is of another type.

Sixty-five processing operations can be performed by a TMS7000-family processor. These 65 operations, however, are of only seven general types, as shown in the following table.

INSTRUCTION TYPES

INSTRUCTION TYPE	PROCESSOR OPERATION
ARITHMETIC	Process values arithmetically
BRANCH AND JUMP	Control command-execution sequence
COMPARE AND TEST	Compare and test values in registers, memory
CONTROL	Set conditions for subsequent processing
LOAD AND MOVE	Transfer values between registers, memory, and input/output devices
LOGICAL	Perform logical operations on bits in registers
ROTATE	Rotate bits in registers

The most significant part of an assembly-language instruction is an operation code ("op code" for short). Op codes are mnemonic representations of operations which the processor can perform.

Brief descriptions of each instruction type and of each op code within the classification are presented below.

More detailed descriptions of each op code (including addressing modes, resulting machine-language commands, command execution times, and other relevant information) are given in chapter 7 of the *CC-40 Editor/Assembler Reference Manual.*

Arithmetic Instructions

Instructions related to numeric computation (addition, subtraction, and multiplication) are classified as arithmetic commands. Eleven instructions, as shown in the table below, belong to this classification.

ARITHMETIC INSTRUCTIONS

FUNCTION	MNEMONIC OP CODE
ADD	ADD
ADD WITH CARRY	ADC
DECIMAL ADD WITH CARRY	DAC
DECIMAL SUBTRACT WITH BORROW	DSB
DECREMENT	DEC
DECREMENT DOUBLE	DECD
INCREMENT	INC
INVERT	INV
MULTIPLY	MPY
SUBTRACT	SUB
SUBTRACT WITH BORROW	SBB

The binary-addition and -subtractions instructions ADD and SUB add or subtract single-byte values. The operations they produce set or reset the carry flag so that subsequent operations can be based on overflow or underflow occurring during the operation.

The binary-addition and -subtraction instructions ADC and SBB produce the same operations as the ADD and SUB instructions except that they account for the conditions of the carry flag set (by a carry in a previously performed ADD or ADC instruction) or reset (by a borrow in a previously performed SUB or SBB instruction).

The decimal-addition and -subtraction instructions DAC and DSB add and subtract register or immediate values according to binary-coded decimal (BCD) arithmetic. In BCD arithmetic, as explained in appendix A, each nibble (half-byte) of the sum or difference is considered to be a binary representation of a decimal number (ranging from ?0000 to ?1001 or >0 to >9).

The multiply instruction MPY multiplies two single-byte values to form a two-byte product in the A and B registers.

The increment and decrement instructions INC and DEC increment or decrement the value in a register by one.

The decrement-double instruction DECD decrements the value of a register pair by one. There is no corresponding increment double instruction for TMS7000-family processors.

The invert instruction INV inverts or complements each bit in a register. The result is the one's complement of the value before the operation: each ONE bit is changed into a ZERO bit, and each ZERO bit is changed into a ONE bit.

Branch and Jump Instructions

Instructions that can determine the sequence in which program commands are executed are members of the branch and jump classification, as shown in the following table.

BRANCH AND JUMP INSTRUCTIONS

FUNCTION	MNEMONIC OP CODE
BRANCH	BR
BIT TEST AND JUMP IF ONE	BTJO
BIT TEST AND JUMP IF ONE—PERIPHERAL	BTJOP
BIT TEST AND JUMP IF ZERO	BTJZ
BIT TEST AND JUMP IF ZERO—PERIPHERAL	BTJZP
CALL	CALL
DECREMENT REGISTER AND JUMP IF NON-ZERO	DJNZ
JUMP	JMP
JUMP IF CARRY	JC
JUMP IF EQUAL	JEQ
JUMP IF HIGHER OR THE SAME	JHS
JUMP IF LOWER	JL
JUMP IF NEGATIVE	JN
JUMP IF NO CARRY	JNC
JUMP IF NOT EQUAL	JNE
JUMP IF NOT ZERO	JNZ
JUMP IF POSITIVE	JP
JUMP IF POSITIVE OR ZERO	JPZ
JUMP IF ZERO	JZ
RETURN FROM SUBROUTINE	RETS
RETURN FROM INTERRUPT	RETI
TRAP	TRAP

Instructions of the branch and jump type produce commands that change the value in the program counter so that the next command executed is out of the normal sequence of program execution. These instructions produce either simple operations, or they produce operations that combine a jump with a previous test for a condition.

The BR, JMP (including conditional jumps, such as JC, JEQ, and JHS), TRAP, CALL, RETS, and RETI instructions alter the sequence of execution of program steps (either unconditionally, or conditionally based on the state of the zero, carry, or negative flags). The decrement and jump on non-zero (DJNZ) and the bit-test-and-jump (BTJO, BTJZ, BTJOP, and BTJZP) instructions first perform an arithmetic or logical operation and then alter the sequence of execution based on the result of the arithmetic or logical operation.

The unconditional instructions in the branch and jump classification are BR, JMP, CALL, RETS, RETI, and TRAP. These instructions always alter the value in the processor program counter for execution of the subsequent instruction.

The branch instruction BR loads the program counter with a two-byte value which becomes the address of the next command executed.

The subroutine-call instruction CALL saves the current program-counter value on the stack and then loads the program counter with a two-byte value, providing a return address at the end of subroutine execution.

The TRAP instruction is a special one-byte "call" instruction to one of 24 addresses stored at the top of memory. The processor "branches" to the appropriate address for the completion of the subroutine call. In programming terms, the addresses are "vectors" which are accessed by an economical, single-byte command. In execution, the TRAP instruction saves the current program-counter value on the stack and then loads the program counter with one of the 24 two-byte values which are stored in a table in firmware from >FFD0 through >FFFF. Functionally, when the table has been appropriately set up with subroutine addresses, the TRAP instruction is essentially a CALL instruction that produces a single-byte machine-language command.

The return-from-subroutine instruction RETS loads the program counter with a two-byte value from the top of the stack, effectively restoring the program counter with the value saved by the last CALL or TRAP instruction.

The return-from-interrupt instruction RETI is the same as the RETS instruction, except that it restores both the program counter and the status register from the stack. The RETI instruction is intended to restore all three registers in the processor to the state that they were in prior to the processor's responding to a hardware interrupt signal (see chapter 6 of the *CC-40 Editor/Assembler Reference Manual*).

The unconditional-jump instruction JMP loads the program counter with a value displaced from the current program-counter value after the two bytes of the jump instruction are read; this displacement must be within a range of − 128 through + 127.

The conditional jump instructions—JC, JEQ, JHS, JL, JN, JNC, JNE, JNZ, JP, JPZ, and JZ—are all the same as the JMP instruction, with the exception that their alteration of the value in the program counter is conditional on the state of status flags specified by each instruction. If the zero flag, for example, is set prior to the execution of a JZ instruction, then the JZ instruction produces the same processor operation as the JMP instruction; if the zero flag is reset, the JZ instruction has no effect except to increment the program counter to the next instruction in sequence and to expend processor time.

The combination jump instructions all function similarly to the conditional jump instructions, except that they perform an operation before they test for a condition required for a jump.

The decrement-and-jump-on-non-zero instruction DJNZ first decrements the value in a register. If the result of the decrement is non-zero, the condition is met for the DJNZ instruction to function as a JMP instruction. If the result of the decrement is zero, the condition for the jump is not met and the next instruction in sequence is executed.

The bit-test-and-jump instructions perform logical tests on the bits in a byte in order to determine whether conditions for executing a jump are met.

The bit-test-and-jump-on-one instruction BTJO performs an AND operation on bits of a general-purpose register and bits from another byte and then discards the resulting byte. The other byte specifies the bits of the register to be tested by the bits within it being set to ONE. If the result of the AND operation on any bit is ONE, conditions for executing the jump are met and the value in the program counter is altered. The bit-test-and-jump-on-one-peripheral instruction, BTJOP, performs an identical operation except that the register tested is from the peripheral register file instead of the general-purpose register file.

The bit-test-and-jump-on-zero instructions BTJZ and BTJZP perform operations which are the same as those performed by the BTJO and BTJOP instructions except that the bits in the byte being tested are inverted before the test. If any of the register bits being tested were—before being inverted—ZERO, conditions are met for the jump.

Compare and Test Instructions

Compare and test instructions produce operations similar to the first simple operation in a bit-test-and-jump instruction. They perform an operation and discard the resulting byte (they do not write the result into a register or memory). The operation results in the setting of status flags which can determine the execution of conditional jump instructions.

The operation performed by compare instructions is binary subtraction. One byte is subtracted from another with the the result affecting status flags.

The operation performed by test instructions is a logical OR.

The four compare and test instructions and the corresponding op codes are listed in the following table.

COMPARE AND TEST INSTRUCTIONS

FUNCTION	MNEMONIC OP CODE
COMPARE	CMP
COMPARE A TO MEMORY	CMPA
TEST A REGISTER	TSTA
TEST B REGISTER	TSTB

The register-compare instruction CMP subtracts the value in a register or the value in an immediate operand from the value in another register.

The memory-compare instruction CMPA subtracts the value in register A from the value stored in a memory location.

The test instructions produce the same results as performing a corresponding logical OR of the A register (for TESTA) or the B register (for TESTB) with itself. The test instructions, however, translate into single-byte machine-language commands, while OR instructions which have the same results produce two-byte commands.

Control Instructions

Control instructions are miscellaneous instructions that set the state of either the processor or the registers for subsequent operations. The functions of the control instructions are listed in the table below.

CONTROL INSTRUCTIONS

FUNCTION	MNEMONIC OP CODE
CLEAR	CLR
CLEAR CARRY FLAG	CLRC
DISABLE INTERRUPTS	DINT
ENABLE INTERRUPTS	EINT
IDLE UNTIL INTERRUPT	IDLE
NO OPERATION	NOP
SET CARRY FLAG	SETC

The clear instruction CLR writes binary ZEROs into a register. It also resets the carry and negative flags and sets the zero flag.

The clear-carry instruction CLRC and the set-carry instruction SETC respectively reset and set the carry flag.

The disable-interrupt instruction DINT and the enable-interrupt instruction EINT determine whether processing can be interrupted by a hardware-interrupt signal to the processor. After an EINT command is executed, the processor can respond to interrupts. After a DINT command is executed, the processor ignores interrupts. With interrupts enabled, the processor's responding to an interrupt causes further interrupts to be ignored until interrupts are again enabled by an EINT or a RETI command.

The processor-idle instruction IDLE halts processing. Only hardware reset or interrupt signals to the processor can cause processing to resume with a reset or an interrupt routine.

The no-operation instruction NOP causes the assembler to insert a byte containing binary ZEROs (the NOP command code) into the machine-language program. The NOP command has no effect on processing except to expend processing time, but it does provide a location in program memory where a byte of a "patched-in" machine-language command can be inserted.

Load and Move Instructions

Load and move instructions are data-transfer instructions which copy the values from one register or memory location to another. The following table lists the functions of the load and move instructions.

LOAD AND MOVE INSTRUCTIONS

FUNCTION	MNEMONIC OP CODE
LOAD A REGISTER	LDA
LOAD STACK POINTER	LDSP
MOVE	MOV
MOVE DOUBLE	MOVD
MOVE TO OR FROM PERIPHERAL FILE REGISTER	MOVP
POP FROM STACK	POP
PUSH ONTO STACK	PUSH
STORE A REGISTER	STA
STORE STACK POINTER	STSP
SWAP NIBBLE	SWAP
EXCHANGE WITH B REGISTER	XCHB

The load-A-register instruction LDA copies the value in a memory location into the A register. Similarly, the store-A-register instruction STA copies the value in the A register into a memory location.

The load-stack-pointer instruction LDSP copies the value in the B register into the single-byte stack pointer. The store-stack-pointer instruction STSP copies the value in the stack pointer into the B register.

The move instruction MOV copies a byte into a register.

The move-double instruction MOVD copies two bytes into a register pair.

The move-peripheral instruction MOVP copies a byte into a peripheral-file register, or it copies the value from a peripheral-file register into register A or B.

The push-onto-stack instruction PUSH increments the stack pointer and copies either the value in a general-purpose register or the status register into the register-file location pointed to by the stack pointer. The pop-from-stack instruction POP, conversely, copies the value pointed to by the stack pointer into either a register or the status byte and decrements the stack pointer. The PUSH and POP instructions are used together to effect last-in-first-out storage in the register file.

The swap-nibble instruction SWAP exchanges the high and low nibbles (half-bytes) stored in a register. The instruction is useful for conversion between BCD, binary, and ASCII representations of values.

The exchange-with-B instruction XCHB exchanges the contents of the B register with the contents of another register.

Editor/Assembler User's Guide Chapter 2, Part 2

Logical Instructions

Logical instructions, listed in the following table, provide operations on individual bits within a byte stored in a register.

LOGICAL INSTRUCTIONS

FUNCTION	MNEMONIC OP CODE
AND	AND
AND PERIPHERAL FILE REGISTER	ANDP
EXCLUSIVE OR	XOR
EXCLUSIVE OR PERIPHERAL FILE REGISTER	XORP
OR	OR
OR PERIPHERAL FILE REGISTER	ORP

The AND and ANDP instructions produce a logical AND operation on the bits in a byte and the corresponding bits in a general-purpose or peripheral register. The resulting byte is stored in the general-purpose or peripheral register.

The OR and ORP instructions produce a logical OR operation on the bits in a byte and the corresponding bits in a general-purpose or peripheral register. The resulting byte is stored in the general-purpose or peripheral register.

The XOR and XORP instructions produce a logical EXCLUSIVE-OR operation on the bits in a byte and the corresponding bits in a general-purpose or peripheral register. The resulting byte is stored in the general-purpose or peripheral register.

Rotate Instructions

Rotate instructions transfer bits in a register to either higher- or lower-order bit locations. The following table lists rotate instructions.

ROTATE INSTRUCTIONS

FUNCTION	MNEMONIC OP CODE
ROTATE LEFT	RL
ROTATE LEFT THROUGH CARRY	RLC
ROTATE RIGHT	RR
ROTATE RIGHT THROUGH CARRY	RRC

The rotate-left instruction RL and the rotate-right instruction RR respectively transfer register bits into higher- and lower-order bit positions. Bits which are transferred "out of the byte" are "rotated" respectively into the lowest- and highest-order bit positions in the register (the bit position emptied by other bit transfers). The bit rotated out of the byte is also copied into the carry flag.

The rotate-left-through-carry instruction RLC and the rotate-right-through-carry instruction RRC produce essentially the same operation, except that they treat the carry flag as a single-bit high-order extension of the register. Bit rotations therefore occur through the carry flag.

Addressing Modes

The source and destination of data processed by each instruction determines its addressing mode.

Some commands contain no explicit source or destination addresses: they use the "implied" addressing mode. These commands, such as NOP, consist only of op codes.

Other commands have data source and destination addresses explicitly designated in operands, expressions which follow op codes in instructions. The instruction which decrements the A register, for example, includes a single operand as follows.

```
DEC A
```

TMS7000-family processors use the following five modes of addressing.

- Implied Addressing
- Single Register Addressing
- Dual Operand Addressing
- Program-Counter Relative Addressing
- Memory Addressing
- Trap-Instruction Addressing

Implied Addressing

When an instruction uses implied addressing, it has no operand to specify a source or destination for data. Source and destination are uniquely assigned to the instruction by the op code alone.

The following twelve instructions use implied addressing.

CLRC	IDLE	RETI	STSP
DINT	NOP	RETS	TSTA
EINT	LDSP	SETC	TSTB

Single-Register Addressing

When an instruction uses single-register addressing, a single operand which specifies a register follows the op code. Fourteen commands, listed below, use single-register addressing.

CLR	DJNZ	POP	RLC	SWAP
DEC	INC	PUSH	RR	XCHB
DECD	INV	RL	RRC	

All of these instructions take A, B, or a numbered register from the file (R2 through R127) for an operand. The PUSH and POP instructions, in addition, take the status register, ST, for an operand, as shown in the following examples of single-register addressing instructions.

```
CLR R58
PUSH ST
DJNZ R58,LABEL0
```

The second operand for the DJNZ instruction uses program-counter relative addressing, described below.

Dual Operand Addressing

Instructions using dual operand addressing can use immediate values, peripheral file registers, and general-purpose registers for their operands. Every dual operand instruction has at least two operands—a source and a destination. The three types of operands can be mixed with some restrictions. Each of these operands and the restrictions for mixing them are discussed below.

Immediate Values

When an instruction uses an immediate value, the source value is stored in the machine language instruction rather than in a register or data memory location. Immediate values can be the source operand whenever a general-purpose or a peripheral register is specified in the destination operand. The value specified in the source operand must be prefaced by a percent symbol, "%", as in the following:

```
MOV %128,A
```

Twenty-one instructions, listed below, use immediate values.

ADC	BTJO	CMP	MOVD	ORP	XORP
ADD	BTJOP	DAC	MOVP	SBB	
AND	BTJZ	DSB	MPY	SUB	
ANDP	BTJZP	MOV	OR	XOR	

Four specific combinations of source and destination operands use immediate values. The combinations are the following, with "N" representing any valid register number (R0 through R127) or peripheral register number (P0 through P127) or single-byte value (0 through 255) and a percent-symbol prefix indicating an immediate value.

```
%N,A      %N,B      %N,RN      %N,PN
```

An immediate value is not always a single-byte value. In the special case of the move-double instruction, an immediate value is a two-byte value, as in the following example.

```
MOVD %>3FFF,R0
```

In a variation of this same special case, the MOVD instruction can also combine an immediate value and a source-register value. The sum of the immediate value and the contents of the B register are moved into the destination register pair. In the following example, the byte in the B register is added to 1024, and the sum is stored in R31 and R32.

```
MOVD %1024(B),R32
```

General-Purpose Registers

When an instruction uses general-purpose register addressing, two operands with a comma separating them follow the op code. The source of data is specified in the first operand. The destination of data is specified by the second operand.

The source operand can be any general-purpose register (R0 through R127), or it can be an immediate value.

The destination operand is always a register.

Fifteen instructions, listed below, use register-file addressing.

ADC	BTJO	DAC	MOVD	SBB
ADD	BTJZ	DSB	MPY	SUB
AND	CMP	MOV	OR	XOR

Seven specific combinations of source and destination operands are permitted with all of these op codes. The combinations are the following, with "N" representing any valid register number (R0 through R127) or single-byte value (0 through 255) and a percent-symbol prefix indicating an immediate value.

```
RN,A    RN,B    B,A    RN,RN    %N,A    %N,B    %N,RN
```

The MOV instruction has three special operand combinations. These combinations are the following.

```
MOV A,B
MOV A,RN
MOV B,RN
```

For bit-test-and-jump instructions, an additional operand follows the first two. This operand uses program-counter relative addressing (see below) to specify a jump destination.

The move-double-register instruction, MOVD, is a special two-byte instruction which transfers two bytes from one pair of registers to another. The higher-addressed register in the source pair is the first operand, and the higher-addressed register in the destination pair is the second operand. Registers must be specified within the range R1 through R127. In addition to register-file addressing, MOVD uses a special combination of immediate value and register addressing for a source operand. As above.

Peripheral File Registers

When an instruction uses peripheral-file addressing, in general, two

Peripheral File Registers

When an instruction uses peripheral-file addressing, in general, two operands follow the op code. For most of these instructions, the source operand for all instructions can be register A, register B, or an immediate value (see immediate value addressing, below). The destination operand can be a peripheral-file register from P0 through P255.

Six instructions, listed below, use peripheral-file addressing.

```
ANDP    BTJOP    BTJZP    MOVP    ORP    XORP
```

Three specific combinations of source and destination operands are permitted with all of these op codes. The combinations are the following, with "N" representing any valid peripheral register number (P0 through P127) or single-byte value (0 through 255) and a percent-symbol prefix indicating an immediate value.

```
A,PN    B,PN    %N,PN
```

Additionally, the MOVP instruction (but not the logical or bit-test-and-jump instructions) can have a peripheral register as the source operand and either register A or register B as the destination operand, as shown below.

```
MOVP PN,A   MOVP PN,B
```

In bit-test-and-jump peripheral-file instructions, an additional operand follows the first two. This operand uses program-counter relative addressing as described below to specify a jump destination.

Program-Counter Relative Addressing

All jump instructions use program-counter relative addressing. The operand used in this addressing mode has the value of a program address within the range of − 128 through + 127 bytes of the "current" program-counter value after the jump command is read by the processor. The assembler computes a single-byte displacement value by subtracting the current program-counter value from the value of the jump operand.

The instructions that use program-counter relative addressing are listed below.

BTJO	BTJZP	JEQ	JMP	JNE	JPZ
BTJOP	DJNZ	JHS	JN	JNZ	JZ
BTJZ	JC	JL	JNC	JP	

The program-counter relative operand is the only operand for the JMP and conditional-jump instructions; it is an additional operand for the DJNZ and bit-test-and-jump instructions, as the following examples show.

```
JMP LABEL1
DJNZ R5,LABEL2
BTJO %>AA,R43,LABEL3
```

Memory Addressing

Five instructions can address all memory (including the general-purpose and peripheral register files). These instructions are the following.

BR	CALL	CMPA	LDA	STA

In addressing memory, the instructions use direct, indirect, and indexed addressing modes.

Direct Addressing

When direct addressing is used by instructions, the source of the value is a double-byte value obtained directly from the machine-language instruction. Similar to immediate addressing, direct addressing uses this 16-bit value as the address for branching, calling, comparing, loading, or storing. Through direct addressing, the following instructions can address all memory.

Direct addresses must be expressed in operands that contain the "at" sign (@) as a prefix, as shown in the following subroutine call instruction (also see the "Instruction Syntax" section below).

Indirect Addressing

When indirect addressing is used, the source of the value is a register pair specified in the operand as the higher-addressed register.

Indirect addresses must be expressed in operands that contain an asterisk (*) as a prefix, as in the following example.

```
STA *R44
```

Indexed Addressing

When indexed addressing is used, the source of the value is a combination of a direct address and the value the B register contains at the time of command execution. The direct-address value and the value in the B register are added by the processor to obtain the address used in the instruction.

Indexed addresses are expressed in operands that contain the direct address (prefixed by "@") followed without comma or space by "(B)", as shown in the branch instruction below.

```
BR @>1000(B)
```

Trap-Instruction Addressing

Addressing used with a TRAP instruction is similar to that used by a memory-addressing instruction which obtains a value indirectly. The operand for a TRAP instruction, however, is not a register pair. Instead, the operand for a TRAP instruction is a value from 0 through 23 which is in inverse correspondence with the 24 pairs of bytes at the top of memory from >FFD0 through >FFFF. A TRAP 0 instruction references the pair of bytes at >FFFE and a TRAP 23 instruction references the pair of bytes at >FFD0.

In the CC-40, values referenced by TRAP instructions are part of firmware, and they cannot be changed. The values for TRAP 9, TRAP 10, and certain other TRAP instructions, however, point to system RAM within which branch instructions can, under certain conditions be stored (see chapter 3 of the *CC-40 Editor/Assembler Reference Manual).*

Instruction Syntax

An assembly-language program for the CC-40 consists of a sequence of instructions. Each instruction is expressed in the form of a single displayed or printed line. The CC-40 assembler translates the sequence of instructions expressed in assembly or "source" code into numeric machine-language instructions (in "object" code) for later execution by the CC-40 processor.

An instruction line contains one or more entries which cause the assembler to produce the intended machine-language commands or provide better program readability. These entries—by the way they are made up and the combination and sequencing which is required of them—are in accordance with the instruction-line syntax that the assembler is designed to recognize.

Instruction-Line Entries: Makeup and Sequence

The following figure shows a 19-line segment of a CC-40 program written in assembly language. The segment, a subroutine which performs a "bubble sort" to arrange 50 one-byte values in memory into ascending order, is typical of the assembly or source code used with the CC-40.

```
*
BSORT   CLR   R58             INITIALIZE: clear swap flag
        MOV   %49,B           Sort count minus 1
*
BSLP1   LDA   @TABLE(B)       LOOP: get high byte of pair
        CMPA  @TABLE-1(B)     Compare to low byte
        JHS   NOSWP           Skip swap if in right order
        PUSH  A               Save higher byte on stack
        LDA   @TABLE-1(B)     Swap lower byte to higher
        STA   @TABLE(B)
        POP   A               Restore used-to-be higher
        STA   @TABLE-1(B)     And store in lower
        INC   R58             Set flag to show swap made
*
NOSWP   DJNZ  B,BSLP1         Continue through all 49 pairs
*
        BTJO  %>FF,R58,BSORT  Do table again if swap made
        RETS                  Return to calling routine
```

A line containing an assembly-language instruction consists of four fields. The fields are separated from each other by one or more spaces, and they appear as follows.

```
LABEL   OP CODE   OPERAND(S)   COMMENT
```

Each field in an instruction line has a particular purpose.

Labels

Labels, called "symbols," can be used in any instruction line. A label is a "word" which identifies or names a line so that it can be referenced by name in other lines in a program. In general, the E/A assembler identifies the word in the label field with the memory address of the machine-language command produced by the line. Other instructions, such as those requiring a jump to the labeled instruction, can therefore refer to the instruction by name rather than by memory address.

Labels consist of either an initial uppercase or lowercase alphabetic character or the symbol "$" and any number of subsequent alphabetic or numeric characters. Only the first eight characters of a label are significant: for example, the assembler considers a label "SPECIFIC1" to be the same as "SPECIFIC2".

The assembler interprets any character which is placed in the first column of the line to be the first character of a label. Therefore, if no label is used in an instruction, the first character position in the instruction line must be a space.

A label can be the only item on a line. In such a case, the program address to which the assembler evaluates it is the next address in the program.

Op Codes and Operands

An op code is required on each assembly-language instruction line which, through assembly, produces a machine-language command.

In an instruction line, op codes follow labels (with at least one space between the two). If there is no label in a line, an op code on that line must be preceded by at least one space.

Operands follow op codes on instruction lines, and they must be preceded by one or more spaces. When multiple operands are required, they are separated by commas.

Single- or multiple-operand fields must not contain spaces.

Comments

Comments can be written in an optional field following the operand field (or the op code field in instructions in which no operand is required). At least one space must precede a comment. Any printable (ASCII) characters can be used in a comment. When comments are printed in an assembly listing (see chapter 5 of this guide), characters in a comment past the 60th column are not printed.

Comments must not directly follow labels on a line, or they are interpreted as erroneously formed op codes and operands. If the dummy directive and operand EQU $ is, however, inserted between a label and a comment, assembly proceeds without error.

Comments can use the entire length of an instruction line if they are preceded by an asterisk (*) in the first column of the line. Comments are ignored during assembly: they produce no machine code.

Editor/Assembler User's Guide Chapter 2, Part 3

Expression-Formation Rules

Expressions that have a value which is not changed by assembly are called constants. In their simplest form, they are numbers, such as those providing immediate values to commands. They can also be the ASCII values that represent alphabetic, numeric, and control characters. In addition, constants can also be represented by symbols defined elsewhere in the program (see discussion of the EQU directive in chapter 5 of this guide). The definition must be in accordance with the conventions described below.

Expressions that are assigned a value by the assembler are called assembly variables. In assembly language, these variables are represented as symbols that are defined numerically at the time of assembly by labels.

Additionally, expressions can be formed from mathematical combinations of two or more constants or variables.

Constants

Constants can be expressed by numbers or strings of alphanumeric characters.

Numbers

Constants specified by decimal, hexadecimal, or binary numbers are used primarily as immediate operands.

If a constant is not prefixed with a special symbol, the assembler evaluates it as a decimal number. The number 1000, for example, is translated into the two-byte binary number "0000 0011 1110 1000" (>03E8). If a constant is prefixed with a ">" (greater-than) symbol, it is evaluated as a hexadecimal number. The number >1000 is translated into the two-byte binary number "0001 0000 0000 0000." If a constant is prefixed with a "?" (question-mark) symbol, it is evaluated as a binary number. The number ?1000 is translated into either a single-byte binary number "0000 1000" or the two-byte binary number "0000 0000 0000 1000."

The "precision" with which a number is evaluated (whether it is translated into a single-byte or double-byte number by the assembler) depends on the instruction in which the operand occurs. A constant in the first (source) operand of a MOV instruction is always translated into a single-byte number; a constant in the first operand of a MOVD instruction is always translated into a double-byte number. If, however, a constant with a value too large for representation in a single byte (that is, a number greater than 255 or >FF) is used as an expression the assembler evaluates into a single byte, the assembler flags the instruction with a warning message. Similarly, a double-byte operand must not contain constants greater than 65,535 or >FFFF, or the instruction which contains the operand is flagged with a warning.

The assembler evaluates negative numeric constants in 16-bit two's complement form within the modulus or precision appropriate to the instruction operands in which they occur.

When numbers are used in operands, they must be prefixed by an additional symbol which identifies them as appropriate for particular commands in accordance with the following rules.

Numbers used to identify general-purpose registers must be prefixed by an "R" symbol. General-purpose registers can also be specified as memory addresses by use of an "@" symbol (press **[CTL] 2** on the console keyboard) as described below. The register names "B", "R1", and "@1" all designate the same register in all commands in which a register operand is appropriate. Register numbers can be expressed in either decimal or hexadecimal; "R>A" specifies, for example, the same register as "R10".

Similarly, numbers used to identify peripheral-file registers must be prefixed with a "P" symbol. Hexadecimal or decimal numbers can be used: the same peripheral register, for example, is designated by "P>D" and "P13".

Immediate values (single- or double-byte) for use in all operands except those specifying memory addresses must be prefixed with a "%" (percent) symbol. Numbers used to specify direct addresses must be prefixed with an "@" (at) symbol.

Strings

Printable ASCII (American Standard Code for Information Interchange) characters with values between >20 (32) and >7F (127) are evaluated into single-byte binary values when their assembly-language representation is placed in single quotation marks. The letter 'A' is translated into >41, the space into >20, and the underline character into >5F. The correlation between string-characters and hexadecimal and decimal values is provided in a table in appendix H of the *CC-40 Editor/Assembler Reference Manual*.

Two-character strings are similarly translated by the assembler when they are present in an instruction operand evaluated into a two-byte machine-language value. The operand %'AB' in a MOVD instruction produces the two-byte number >4142. Strings longer than two characters can be used as data for storage in memory by the assembler (see TEXT and RTEXT directives, chapter 5 of this guide).

Single quotation marks can be included within a string constant by writing two such marks adjacent to each other. The string represented by '''' has a value of >27, and the string '''''' (six single quotes) has a value of >2727.

Variables and Labels

Variables assigned during assembly have values related to memory locations determined during assembly. Variables used as operands are assigned the values of corresponding "labels" during assembly.

At the time of assembly, the assembler assigns a label to the address value of the memory location containing the command code which is assembled from the instruction. Any operand which uses the same sequence of characters is thus translated into a command as if the numeric value were in the operand. The following instruction, therefore, forms an "infinite loop" regardless of where it is assigned to memory. (Note that the "@" character must be used with the direct memory-addressing instruction.)

```
LOOP1     BR      @LOOP1
```

Operands of jump or conditional-jump instructions, however, are evaluated differently. The assembler evaluates a label in such an operand as the difference in value between the label and the memory address following the jump instruction. Thus, the second byte of the "infinite-loop" jump command assembled from the following instruction is – 2 (>FE).

```
LOOP2     JMP     LOOP2
```

The memory location at which an instruction currently being assembled begins is maintained by the assembler at all times as the symbol "$" (dollar sign). If a dollar sign is used in an instruction operand, the assembler assigns the value of the address of the initial byte of the current command. The two "infinite-loop" instructions listed above are equivalent to the following instructions containing a dollar sign.

```
LOOP1     BR      @$          A three-byte command
LOOP2     JMP     $           A two-byte command
```

Expressions

Four symbols (+, –, *, and /) provide for arithmetically combining the values of multiple constants and variables in operands by, respectively, addition, subtraction, multiplication, and division.

In evaluating expressions, the assembler first evaluates each term. Then the specified operations are performed to arrive at an overall value for the expression. Thus, the value of the expression 'A' – >40, which combines the values of an ASCII character with a value expressed in hexadecimal, is >01.

Addition, subtraction, multiplication, and division operations are performed in left-to-right order with no order of precedence assigned among operations. Fractions are truncated to integers after each operation (for example, 17/3 – 1 is evaluated to be 4).

The following examples show the manner in which the assembler evaluates expressions.

1 + 1*2 – 1 = 3 = >0003

1000 + 3/2 – 1*5 = 2500 = >09C4

Precedence can be assigned through conventional use of parentheses within expressions. Elements of an expression enclosed in parentheses are evaluated before elements outside of parentheses. In contrast with the examples listed above, the following examples show the use of parentheses.

1 + (1*2) – 1 = 2 = >0002

1000 + (3/2) – (1*5) = 996 = >03E4

Any combination of constants and variables defined within a program, except as noted below, is allowed in an expression.

The following table identifies legal combinations of absolutely evaluated constants and relocatable variables, and it identifies the result of the combination after linking as absolute or relocatable.

X	Y	X+Y	X–Y	X*Y	X/Y
ABS	ABS	ABS	ABS	ABS	ABS
ABS	RELOC	RELOC	ILLEGAL	ILLEGAL	ILLEGAL
RELOC	ABS	RELOC	RELOC	ILLEGAL	ILLEGAL
RELOC	RELOC	ILLEGAL	ABS	ILLEGAL	ILLEGAL

Absolute and relocatable values can be added to produce a relocatable value. An absolute value can be subtracted from a relocatable value to produce a relocatable value. One relocatable value can be subtracted from another to produce an absolute value. No other combinations which contain relocatable values are valid expressions.

When multiple-program modules are assembled and linked (see chapters 5 and 6 of this guide), externally referenced symbols are subject to certain restrictions.

Externally referenced values are like relocatable values except that an expression which contains an external reference has two restrictions. An instruction can contain only one external reference. An expression such as X – 1, 1 + X, or X + 1 (where X is externally referenced) is a valid expression; however, X – X is invalid. In addition, an expression cannot contain both an externally referenced value and a relocatable value. The expression X – Z, where X is an externally referenced value and Z is a relocatable value, is invalid.

The Op Code Map

The relationships between op codes, addressing modes, and command codes (first bytes of a machine-language instruction) are shown in complete detail in the TMS7000-family op code map which follows.

CHAPTER 3
CC-40 OPERATION WITH THE E/A PACKAGE

This chapter describes the use of the CC-40 console and peripheral units with the E/A package. Use of the keyboard and display units in the console and operation with the *HEX-BUS*™ is described.

CC-40 Assembly-Language Development Configuration

Greater system hardware capability permits use of more powerful E/A programming features. The CC-40 console with a single mass-storage device is sufficient for development of small programs (or large programs with the exercise of considerable patience and forbearance). In a minimal configuration, the E/A package provides convenient development of small assembly-language programs through use of the single-line display and the compact keyboard in the CC-40 console. Further expansion of the CC-40 system permits use of advanced E/A features. In a fully expanded system, the E/A package provides much more convenient and rapid development of large programs through the use of full-screen external-display editing and an external full-size keyboard.

Minimal E/A Hardware Configuration

The minimal device configuration consists of the CC-40 console with an Editor/Assembler programming cartridge and a mass-storage device installed. The programming cartridge contains the editor, assembler, linker, and utility programs in read-only memory (ROM).

The following illustration shows the minimal CC-40 configuration for assembly-language program development.

Enhanced E/A Hardware Configuration

The device configuration required for convenient development of longer programs consists of the CC-40 console with an Editor/Assembler programming cartridge, several mass-storage devices, an RS232 device for a video terminal or a video interface, and another RS232 device for a full-size line printer.

Additional peripheral units for E/A operation provide for faster, more convenient, and more powerful programming. These units are connected to the CC-40 by an eight-wire cable which carries the signals on the *HEX-BUS*™ interface (an intelligent-peripheral interface bus).

Additional peripheral devices which augment E/A operation through the bus include the following.

- One or more additional mass-storage devices to minimize media "swapping" during programming and to provide storage for development of larger programs

- One or more RS232 interface devices to permit interface of standard serial and parallel peripherals (such as a display device or a line printer) to the *HEX-BUS*™
- A four-color printer/plotter to provide hardcopy output of programs, text, and graphics
- A video-interface device to provide multiple-line display of source files during editing

Use of RS232 interface devices, in turn, permits connection of a wide variety of additional input/output devices to the CC-40 system with (1) a standard Electronic Industries Association (EIA) serial data interface and (2) a conventional transistor-transistor logic (TTL) level 8-bit parallel output port with handshaking to control character transmission. Additional I/O devices include the following.

- A video-display device or video-display terminal with a full-sized keyboard to aid in program editing
- A line printer connected to the CC-40 via a serial or parallel interface device to permit hardcopy examination of program listings and dumps
- A modem to permit data communications over telephone lines

The following figure shows the use of the *HEX-BUS*™ and the RS232 interface to provide enhanced performance in assembly-language development by the CC-40 system.

Console Devices

In the minimal hardware configuration, the CC-40 keyboard provides input to all E/A programs. A 31-character liquid-crystal display provides for horizontally scrolled line-by-line listing of programs and messages.

Console Keyboard

The CC-40 console keyboard provides for keystroke entry of characters in accordance with the American Standard Code for Information Interchange (ASCII). Both printable characters and ASCII control characters can be entered.

Keys are arranged in the conventional typewriter layout (called "qwerty"—according to the arrangement of the top, leftmost alphabetic keys). An additional pad of 20 keys to the right of the "qwerty" keys provides for single-key CC-40 control-character entry and 10-key numeric-character entry. Four keys which control console power and program execution are located at the upper right of the keyboard area.

A reset button is located immediately to the right of the **[SPACE BAR]** on the "qwerty" keyboard. This button should not be used when E/A programs are running. The button causes all E/A programs and data to be lost and the BASIC operating environment to be reinitialized.

With one exception, all printable characters are input from clearly labeled keys. There is no key labeled for the "at" symbol (@). This symbol is entered by pressing **[CTL] 2**.

A detailed hardware description of keyboard operation appears in chapter 6 of the *CC-40 Editor/Assembler Reference Manual*.

CHAPTER 3
CC-40 OPERATION WITH THE E/A PACKAGE

Power-Control and Execution-Control Keys

Four keys in the upper right of the keyboard area control power to the console and provide for convenient entry into and exit from E/A programs.

The Editor/Assembler cartridge must be inserted in the console before the CC-40 is turned on. Pressing **[ON]** powers up the console and executes the BASIC interpreter. Entering **RUN "ALDS"** with the Editor/Assembler cartridge in the console begins execution of the E/A package.

While any program in the E/A package is running, pressing **[OFF]** has no effect. Control must be returned to BASIC from the E/A main menu `E)dit A)ssemble L)ink B)asic?` before **[OFF]** can remove power.

Automatic powerdown (as if [OFF] had been pressed) occurs after the CC-40 has awaited input to a BASIC program for approximately eight minutes. The automatic powerdown feature, however, is disabled during E/A operation.

Pressing **[RUN]**, followed by typing **ALDS** inside quotation marks and **[ENTER]** can be used for entering the E/A package from BASIC after power-up. The effect of pressing **[RUN]** is the same as typing **[RUN]** and a space. During E/A operation, **[RUN]** has no effect.

The break key, **[BREAK]**, is used more extensively to return to the E/A main menu from the editor, the assembler, and the linker. During any input/output operation while the CC-40 is running under E/A control, pressing and holding **[BREAK]** interrupts the operation and provides an opportunity to discontinue it by answering the prompt `BREAK, Continue (Y/N)?` with **N**.

Keyboard Uppercase-Shift Operations

The shift key **[SHIFT]** preconditions the CC-40 to input the next character as an uppercase alphabetic character or one of the symbols listed above the number keys.

The shift key operates as a toggle, the ON state of which is indicated by the appearance of SHIFT in the upper-left corner of the LCD display. When **[SHIFT]** is pressed successively, the SHIFT indicator alternately appears and disappears to indicate whether the next character pressed is in uppercase. Holding down **[SHIFT]** while simultaneously typing characters causes the indicator to disappear from the display after the first character is typed; all characters typed until **[SHIFT]** is released, however, are entered as uppercase characters.

The sequence **[SHIFT] [CLR]** locks the keyboard for uppercase-character entry. During uppercase-lock operation, all alphabetic characters from the keyboard are entered in uppercase. Numeric, punctuation, and symbol characters, however, are unaffected. Uppercase-lock operation, sometimes called "alpha-lock" operation, permits entry of uppercase characters into a program without the requirement of toggling **[SHIFT]** to enter numbers. Regardless of whether uppercase lock is in effect, toggling **[SHIFT]** provides single-character entry of punctuation and symbol characters listed above the numbers on the "qwerty" keyboard.

The uppercase-lock key, [UCL], also operates as a toggle, the ON state of which is indicated by the appearance of UCL in the upper-right corner of the LCD display. When [SHIFT] [CLR] is pressed successively, the UCL indicator appears and disappears alternately to indicate whether alphabetic characters pressed are in upper case.

Keyboard Control-Character Entry

The control key [CTL] conditions the CC-40 to accept the next alphabetic character pressed as a corresponding ASCII control character. The sequence [CTL] a or [CTL] A enters ASCII "SOH," a hexadecimal value of >01. The sequence [CTL] z or [CTL] Z enters ASCII "SUB," a hexadecimal value of >1A. Other ASCII control codes with values between hexadecimal >2 and >1A are entered by pressing [CTL] and a corresponding alphabetic key in the range of "B" through "Z."

Six ASCII control characters which cannot be entered through the sequence [CTL] ALPHABETIC CHARACTER can be entered through the sequences listed in the following table. The sequence for entering one unlabeled printable character, "@," is also listed in the table.

ASCII CHARACTERS FROM
NON-ALPHABETIC KEYSTROKE SEQUENCES

ASCII CHARACTER	HEX VALUE	KEY SEQUENCE
NULL	>00	[CTL] 0
ESC	>1B	[CTL] [CLR]
FS	>1C	[CTL] =
GS	>1D	[CTL] ;
RS	>1E	[CTL] .
US	>1F	[CTL] ,
@	>40	[CTL] 2

Like [SHIFT] and [UCL], [CTL] operates as a toggle, the ON state of which is indicated by the appearance of CTL to the left of center in the top row of the display. When [CTL] is pressed successively, the CTL indicator appears and disappears successively to indicate whether subsequent character keys pressed enter control codes.

Display-Editing Keys

Three groups of keys control text entered into the display buffer. Cursor-positioning keys control the point of text entry by positioning the cursor among the columns of the display. An insert-mode key determines whether a character being entered overwrites the character currently at the cursor or is inserted in front of it. Deletion keys erase characters, groups of characters, or all characters from a line.

Cursor-Positioning Keys

During editing, the cursor can be moved to various columns (character positions) in the line of text being entered or modified. This positioning requires cursor-control keys to be used.

The → key moves the cursor (column position pointer) one character position to the right. When the cursor is advanced past the 31st character position in the line, the line scrolls to the left so that the cursor is always visible. Pressing → when the cursor is in the 80th (last) character position of the line has no effect.

The ← key moves the cursor one character position to the left. When the cursor is positioned at the leftmost character of the display and ← is pressed, the line scrolls to the right so that the cursor is always visible. Pressing ← when the cursor is in the first character position of the line has no effect.

The tab keys, entered by the sequence [CTL] → for forward tab and [CTL] ← for back tab, cause the cursor to be positioned at the next tab stop to the right or left. After a tab operation, the display window on the line moves so that the cursor will be at the tab in the leftmost position of the display. Tab stops for line editing are fixed at the 1st, 25th, and 50th character positions.

The home key, entered by the sequence [CTL] ↑, moves the cursor to the first (leftmost) column of the display.

Insert-Mode Key

The insert-mode key, actually the sequence [SHIFT] →, sets up the CC-40 to enter characters from the keyboard beginning at the current cursor position. Characters at the current cursor position and in any positions following it are shifted to the right with each character insertion. Every character entered is inserted into the line until another editing key (a cursor positioning or delete key, for example) is pressed, after which characters entered overwrite any characters at the current cursor position.

Character-Delete, Erase-Field, and Display-Clear Keys

Three keys are used to delete characters from a displayed line. One deletes a single character, another deletes all characters from the current cursor position to the end of the line, and the third deletes the entire line of characters.

The delete key, effected by the sequence [CTL] ←, causes the character in the current cursor position to be deleted. Characters following the cursor on the line are then shifted to the left one character position in order to close up the line.

The erase-field key, the sequence [CTL] ↓, causes the character at the cursor and all characters to the right of the cursor to be erased from the line.

The clear key, [CLR], causes the entire line of characters to be erased.

Liquid-Crystal Display (LCD)

The liquid-crystal display (LCD) unit located above the CC-40 keyboard consists of a 31-character display surrounded by indicators. The LCD unit, with all character positions and indicators activated, is shown in detail in the following figure.

The Character-Display Line

The display line shows up to 31 characters of a command or program line which can be as long as 80 characters. The display provides a "window" which can be positioned over any 31 characters of a longer line. Positioning of the window is performed by movement of the cursor "against" the left or right side of the window. As the cursor is moved to a character position which would be beyond the window, the character at that position is scrolled into the window.

A description of display hardware appears in chapter 6 of the *CC-40 Editor/Assembler Reference Manual.*

Indicators

Above and below the 31-character display are indicators which display various kinds of information about the CC-40. Keyboard entry status is displayed by SHIFT, UCL, and CTL indicators. That a CC-40 input or output operation is in progress is shown by the I/O indicator.

Six additional indicators which can be turned on and off under program control are located below the 31-character display. These downward-pointing arrows can point to messages on keyboard overlays or templates especially prepared for application programs.

HEX-BUS™ DEVICES

Devices other than the console keyboard, display, and beeper are included in the CC-40 system through use of the *HEX-BUS*™ interface. The management of input/output operations carried out through the *HEX-BUS* interface is software-based. The processor and peripherals coordinate the transfer of data by messages, rather than by many dedicated electronic control lines.

Software control of the interface uses a standard message-and-response format. Data sources and destinations, including devices and files, are designated in CC-40 commands by device number and any device-particular parameters. The number and parameters are used by software to "open" the data source or destination by standard-format bus communications. The same format is used by mass-storage devices, printers, and external display units. Chapter 2 of the *CC-40 Editor/Assembler Reference Manual* contains a detailed description of the *HEX-BUS*™ communication format and the methods used to communicate with *HEX-BUS* devices in programs developed by the E/A package.

CHAPTER 4
THE LINE AND SCREEN EDITOR

This chapter provides an overview of the editor and the two ways it is used. Line-editing operation, screen editing operation, and editing command descriptions are discussed in detail.

The editor is the E/A program which provides for the entry and storage of text. The editor accepts keystroke entry and modification of lines of text which compose, for example, assembly language programs or linker commands, and it stores the lines in internal random-access memory (RAM). The text in memory can be written to a file on an external mass-storage device. Conversely, a file from such a device can be read into the CC-40 for editing.

The editor provides two methods of editing: line editing and screen editing. Line editing uses the 31-character LCD display and keyboard in the CC-40 console, and it provides single-line display for line-number oriented text entry and display. Screen editing uses a terminal or a CRT display device connected to the HEX-BUS™ interface through an RS232 device or a Video Interface peripheral to provide cursor-oriented screen editing. Screen editing uses either the CC-40 keyboard or an external full-size keyboard for text entry.

SYSTEM REQUIREMENTS

In a minimal CC-40 system configuration, line-editing operation requires that at least one mass-storage device is connected to the CC-40. The mass-storage device provides storage and retrieval for any text which is stored in RAM.

Line-editing operation with a minimal CC-40 configuration permits fully functional assembly-language program development through the use of the console display. The portion of the text shown by the display, however, is limited to a 31-character segment of a single line. Also, because the display shows only one line at a time, line numbers are necessary for keeping track of multiple lines in relation to each other.

More complete configurations, however, enhance editor performance by enabling the screen editing option. Significant improvement in editor performance, flexibility, and convenience results from including an RS232 device and a terminal or an external display for screen editing.

Screen editing with an external display provides longer display lines (typically 80 characters), and it provides multiple-line display (typically 24 lines). With screen editing, line numbers are largely unnecessary for referencing lines during text editing. Lines of text can be viewed in spatial sequence and addressed graphically on the display screen by a cursor. The logic of program statements is easily studied on the multiple lines simultaneously displayed. Additionally, if a CRT terminal (display combined with keyboard) is used, the full-sized keyboard permits more rapid, accurate, and convenient entry of keystrokes than does the compact keyboard of the CC-40.

RUNNING THE EDITOR

After the E/A package is entered from BASIC with a [RUN "ALDS"] command, the E/A program menu appears in the LCD display as shown below.

E)dit A)ssemble L)ink B)asic ?

The editor is entered when [E] is pressed. When the editor begins to run, the display shows the editor menu as follows.

L)ine S)creen D)efine Q)uit ?

The four functions which appear in the display make up only a part of the menu. Two other functions are scrolled into the display when either the [SPACE BAR] or [μ] is pressed, as shown below.

C)runch U)ncrunch ?

Line Editing: "L" Option

Pressing [L] causes the editor to enter line-editing operation. The editor prompts with Copy file to determine if any file is to be copied from a mass-storage device into RAM for editing. Pressing [[ENTER]] in response to the prompt indicates that no file is to be copied. Typing in a device number and a mass-storage filename (separated by a period, as in [120.FILE]) before pressing [[ENTER]] loads the file of that name from the device. After [[ENTER]] is pressed (and a file is loaded if a name has been entered), the editor places the command prompt ">" in the otherwise blanked display.

Screen Editing: "S" Option

Pressing [S] causes the editor to enter screen editing mode. The screen of the CRT is cleared, an asterisk and the end-of-file abbreviation (*EOF) appear at the upper left of the screen to indicate that no text is in RAM, and a Copy file prompt appears on the bottom line of the screen. A file can be copied into RAM from a mass-storage device by entering a device number, a period, and a filename. Pressing [[ENTER]] alone initializes the editor for keyboard entry of lines of text. Subsequently, the prompt disappears, and the cursor appears in the upper left corner of the screen.

Screen Definition: "D" Option

Pressing [D] causes the editor to enter the screen-definition option. In screen definition, a mass-storage file can be used to install or customize the editor for particular characteristics of the terminal or display to be used.

Screen editing relies on a number of CRT-display characteristics, such as communication parameters (data-transfer speed, etc.), screen size (number of columns and lines), display-control commands (for cursor positioning, clearing the screen, and so on). In addition, if screen editing is to use a terminal keyboard instead of the CC-40 compact keyboard, particular terminal keys are used to produce command codes (unprintable ASCII control characters or characters following ASCII "escape") for issuing editing commands. Both display and keyboard characteristics are defined during screen-definition operations. Screen definition can (1) modify (or create) a table of display and keyboard characteristics, (2) load a previously saved file of display and keyboard characteristics for use during editing, or (3) save a table of displayed keyboard characteristics to a file.

Two sets of default characteristics are stored in E/A firmware. One set contains screen and keyboard characteristics of the Televideo 920 terminal. The other set contains screen definitions for a HEX-BUS™ Video Interface device and key definitions for the CC-40 keyboard.

Uncrunched Format Text: "U" Option

Pressing [U] causes the editor to operate in "uncrunched" mode. The display then contains the message UNCRUNCHED MODE. Pressing any key causes the edit menu to once again be displayed. With the editor in uncrunched mode, any text typed into RAM or any file copied into RAM is represented in ASCII character codes with null bytes to separate lines. No end-of-line characters such as carriage returns or line feeds are used in the text. If a "crunched" (see below) file is copied into RAM while the editor is in uncrunched mode, text from the file is automatically converted to uncrunched text after it is read into memory.

In uncrunched mode, no data-compression techniques are used to conserve memory and decrease file-transmission time. Uncrunched mode is the default mode of the editor; therefore, pressing [U] has no effect upon the editor unless compressed or "crunched" mode (see below) has previously been selected.

Selection of uncrunched text storage remains in effect until crunched storage is selected while the edit menu is displayed. Text written to mass-storage files while uncrunched mode is selected is written as it is stored in memory.

Crunched Format Text: "C" Option

Pressing [C] causes the editor to store text in RAM in compressed or "crunched" format. The display then contains the message CRUNCHED MODE. Pressing any key causes the edit menu to once again be displayed. In crunched mode multiple-character assembly-language mnemonic codes (keywords) are stored as single byte "tokens," spaces surrounding keywords are suppressed, and multiple spaces within a line are replaced with space suppression codes. Other line characteristics are the same as in uncrunched format. The use of crunched format results in a savings in file memory space and file transmission time.

An uncrunched-mode file copied into memory while the editor is in crunched mode is automatically converted to crunched text after it is read into memory.

Crunched format remains in effect until either (1) the mode of storage is changed while the edit menu is displayed or (2) operation of the E/A package is terminated and the CC-40 returns to BASIC.

Quitting the Editor: "Q" Option

Pressing [Q] causes an exit from the editor menu. The E/A menu returns to the display.

LINE-EDITOR OPERATION

After line editing is entered by pressing [L] in response to the edit menu and the Copy file prompt receives a response, the command prompt ">" appears in the display to indicate that the editor is ready to receive a command.

Text Lines and Line Numbers

The editor references each line of text with a line number. The command to enter a line in response to the ">" prompt is a line number followed by a space, the text of the line, and [[ENTER]]. The line number can be any five digit number from 00001 through 32767; leading zeros are provided by the editor if they are not entered at the keyboard. If a line with the number typed is already present, the old line is replaced by the new line.

Entering a line number followed by no text inserts a blank line of text into memory.

Editor line numbers provide the means of accessing particular lines. With the command prompt ">" in the display, lines of text are called into the display by line number for editing, insertion, and deletion.

Line numbers are not stored with the text in memory. They are computed by the editor each time a line is displayed. The effect of entering [1000 This] as the initial line in the text area of memory is to store the text [This] in memory for display as 00001 This in any subsequent display. Typing in another line with the number 1000 produces a text line numbered 00002. A displayed line number (always with a trailing space) indicates the position of a line relative to the beginning of text. The number of any line changes as the number of lines between it and the first line of the text changes.

Line Editing Commands

Commands available for use in line editing are listed below. Where a parenthesis sets off the last characters of a command, only the first characters need be typed to issue the command. Detailed descriptions of commands appear on the pages noted in the list.

AUTO--Sets up the editor to produce a line number for the first line and to produce a new line number after each line is entered.

COPY--Loads a file from mass-storage device into memory for subsequent line editing.

DEL(ETE)--Deletes a line or range of lines from the text in memory.

E(DIT)--Displays a line of text for line editing.

F(IND)--Finds the next character string that matches the string specified in the command.

FORMAT--Initializes the mass-storage medium in the specified device.

LINE--Sets the editor so that it displays line numbers with each line in the display.

LIST--Shows lines of text in memory in the display or transfers the lines to an external unit such as a printer.

MOVE--Moves a line or a range of lines to another location in the text.

NOLINE--Sets the editor so that it does not display line numbers with each line in the display.

QUIT--Terminates line editing and returns to the main edit menu.

R(EPLACE)--Replaces one or more occurrences of a character string in the text with another specified string.

SAVE--Saves the text currently in memory to a mass-storage device with the specified device number and filename.

UNDO--Cancels the effects of the last delete command, line modification, or replacement operation by reinserting into the text the lines deleted or changed.

VERIFY--Compares character-for-character the text stored in memory with a file present in an external storage device.

New Text Entry

When the AUTO command is typed in response to the ">" prompt, the editor is set to number each line automatically. The LCD display shows the number 00001 followed by a space and the blinking cursor. For normal keystroke entry of a line, the line is typed and the cursor advances to the next position to the right after every keystroke. When [[ENTER]] is pressed, the line is moved from the display buffer into the text-storage area of memory.

The display buffer is then filled with spaces, and the line number 00002 and a space appear in the display. Successive lines are always numbered in increments of 1. In automatic line-numbering operation, for example, the line editor always displays a line following the entry of line 00002 with the number 00003, a line following line 00053 with the number 00054, and so forth.

The [[BREAK]] key terminates AUTO and returns the ">" command prompt to the display.

Editing Previously Entered Lines

When lines are already present in the text area of memory and the ">" prompt is displayed, the editor displays any line upon entry of a command of the format [E] [NNNNN] [[ENTER]]. For example, the command line E 12 [[ENTER]] causes the editor to read the 12th line of the text into the display buffer. When [[ENTER]] is pressed after the line is edited, the edited line is stored in the text area of memory and the ">" command prompt returns to the display.

If, while a line is being displayed, the [Up Arrow] key is pressed, the line currently in the display buffer is transferred into the text area of memory. Then the line with the next lower number is displayed. In effect, the text is scrolled backward through the display window by one line.

Similarly, if the [Down Arrow] key is pressed, the display-buffer line is transferred to the text area, and the text line with the next higher number is displayed. In effect, the text is scrolled forward through the display window.

Using the Display Buffer

Whenever a numbered line is present in the display buffer after entering an EDIT or LIST command, the buffer functions as a scratchpad for entry of the line into the text area of memory. When [[ENTER]], [Up Arrow], or [Down Arrow] is pressed, the display-buffer line is transferred to memory and the adjacent line is transferred from memory into the display buffer. Whenever [[BREAK]] is pressed while a numbered line is in the display buffer, the buffer is cleared and the ">" command prompt returns, but the line from the display is not stored in memory.

If a line number (followed by a space) in the display buffer is altered, then the new number determines the point of entry into the text area of memory after the line has been entered.

If the space following the line number is replaced by a [-] (minus sign), then the line is inserted into the text area as a new line before the one currently with that number. If a [+] (plus sign) replaces the space, the line is inserted into the text as a new line immediately after the line with the number displayed.

Clearing the Display Line

The contents of the display buffer are cleared when [[CLR]] is pressed. A new line can then be typed into the display buffer.

The prompt ">" does not appear in the cleared display, although the cleared line is used in exactly the same manner as the command line on which the prompt appears. In command mode (where a line originating with the prompt has been cleared), the lack of a prompt is the only result of pressing [[CLR]] rather than [[BREAK]]. The display returns the command prompt ">" when a new line is entered.

In text entry during AUTO mode, however, the difference between [[CLR]] and [[BREAK]] has the added significance that [[CLR]] returns the editor to AUTO mode after the new line is entered while [[BREAK]] causes the editor to reenter command mode. A new numbered line of text entered during AUTO mode causes the line-numbering sequence to be reset to the number of the new line, and the editor continues in AUTO mode. However, if a command is entered in the cleared display and executed during AUTO mode, the editor exits AUTO and reenters command mode upon completion of the command.

Using the Playback and Recover Buffers

Two buffers in the CC-40 save text for repeated entry of commands or cancellation of delete commands, text modification, or replacement performed in error.

The playback buffer always contains the last command line entered into the editor. Pressing [[SHIFT]] [Up Arrow] causes the contents of the playback buffer to be transferred to the the display buffer. Through the use of the playback buffer, an editor command such as FIND can be executed numerous times without being retyped. The command is entered into the display buffer only once through the keyboard, and thereafter the command is transferred into the display buffer from the playback buffer.

Similarly, the recover buffer always contains the line or lines most recently deleted from the text area of memory, the original text of the line most recently modified, or the line last replaced. The editor, by referencing the lines in the recover buffer, can cancel the most recent deletion or line-editing operation. When UNDO is entered, the lines in the recover buffer are reinserted into the text area in their original position.

Line-Number Display Commands

The NOLINE command eliminates the display of line numbers, providing a greater number of text characters to be viewed at the beginning of each line. The NOLINE command has the effect of shifting the characters of the display line six character-positions to the left (corresponding to a five-digit line number followed by a space). The line number, even though not in view, is usable for line-indexing operations. For example, setting the editor for NOLINE operation and then typing in a command to edit line 15 still brings line 15 into the display; the only difference is that the line number cannot be seen without forcing the cursor against the left side of the display window into the line.

The LINE command causes the line numbers to once again automatically appear in the display.

Cursor Control

When a line is in the display, five keys control cursor position in the display. The cursor can be moved to the right or to the left one character, it can be moved to preset tab stops, and it can be moved to the first position of the line (home).

The [Right Arrow] key moves the cursor one character to the right of its current position. The [Left Arrow] key positions the cursor one character to the left. When either key is held down, repeated one-character cursor movement begins; when the key is released, cursor motion stops.

The left- and right-arrow keys have no effect if the cursor is at, respectively, the the beginning or end of the 80-character line. If the cursor moves to a character position not in the display, the display window is shifted one character in the direction of the motion of the cursor.
The forward tab key [[CTL]] [Right Arrow] moves the cursor to the closest tab stop to its right. If the cursor is to the left of character position 25, pressing the key moves it to position 25. If the cursor is between character positions 25 and 50, pressing the key moves it to position 50. Pressing the forward tab key when the cursor is beyond position 49 has no effect.

The back-tab key, [[CTL]] [Left Arrow], moves the cursor to the closest tab stop to its left. If the cursor is to the right of character position 50, pressing the key moves it to position 50. If the cursor is between character positions 25 and 50, pressing the key moves it to position 25. Pressing the back-tab key when the cursor is to the left of character position 26 moves it to position 1.

The home key, [[CTL]] [Up Arrow], regardless of the current cursor position, moves the cursor to the first character of the line (the most significant digit of the line number if a text line is being displayed).

Deletion of Text in the Display

Text in the display can be deleted character-by-character, erased from the current cursor position to the end of the line, or completely cleared (as described above).

The delete key, [[SHIFT]] [Left Arrow], deletes the single character at the current cursor position and shifts all subsequent characters one position to the left.

The erase-to-end-of-line key, [[CTL]] [Down Arrow], deletes all characters from the one at the current cursor position to the end of the display line.

None of the delete display-control keys has any immediate effect on a line already stored in the text area of memory. For example, if there is a line 30 which has been moved from memory into the display buffer and [[CLR]] is pressed, line 30 remains in the text area of memory exactly as it was before its being copied into the display buffer. Line 30 in the text area of memory is replaced by a line in the display buffer numbered 30 only after [Down Arrow], [Up Arrow], or [[ENTER]] is pressed.

Insertion of Characters into Displayed Text

Insertion of characters into the display buffer occurs after the insert [[SHIFT]] [Right Arrow] key is pressed. The editor is set to insert characters at the current cursor position, moving all characters from the one at the cursor position to the end of the line to the right. Insertion of characters continues until a subsequent line-editing control key (cursor-position key or delete key) or line entry key ([[ENTER]], [Up Arrow], or [Down Arrow]) is pressed.

If the number of characters in the display buffer (including the line number and trailing space) exceeds 80 during insertion of characters, the line is truncated with the 80th character. In effect, characters in excess of the 80th "fall off the end of the line."

Insertion of Single Lines of Text

From the command prompt, a line can be entered before or after a line presently in memory by typing, respectively, a "-" (minus sign) or a "+" (plus sign) in lieu of the space between the line number and the text of the line. Entering [10-*] creates a new line 00010 which contains an asterisk, and the old line 00010 becomes line 00011. Entering [10+LABEL1] creates a new line 11 containing the word "LABEL1", line 00010 remains as it was before the entry, and the previous line 00011 is renumbered to become line 00012.

Using "+" and "-" in the column following the line number while a line is being displayed in AUTO mode, is being edited after an EDIT command is given, or is being listed after a LIST command is given has the same effect that it does from command mode. Automatic entry, editing, and listing, however, continue until AUTO mode is terminated with [[BREAK]], editing is terminated with [[ENTER]], and listing is terminated with [[BREAK]] or the end of the text.

Insertion of Multiple Lines of Text

With lines of text in memory, AUTO mode effectively produces line insertion. Entering AUTO mode with the number of a line already present in memory causes the number of the line followed by a trailing "+" (plus sign) to automatically appear in the display. When the text for the line is entered, the line is assigned the next higher number, and that number followed by "+" appears in the display.

With four lines of text already in memory, for example, entering [AUTO 3] causes 00003+ to appear in the display. Text entered becomes part of a new line numbered "00004," and after entry 00004+ appears in the display for additional insertion of lines. The original fourth line remains the next line of the text; its line number is incremented with each new inserted line.

If AUTO mode is entered at the last line of text, the display lines are slightly different. Again with four lines of text in memory, if AUTO mode is entered with AUTO 4, the display contains 00004+. When the text for the new line is entered, the line is stored as line 00005. The display then contains 00006 followed by a space, indicating that new lines entered are being appended rather than inserted.

Text Line Replication

A line of text currently in the display can be replicated into a line above or below it by backspacing the cursor to the space following the line number and pressing [+] or [-].

Entering a line in which [+] replaces the space trailing the line number causes two changes to the text. First, the text of the previously displayed line appears in the display with the next higher line number: it has become the second line with that text in memory. Second, numbers of lines following the replicated line are incremented. Using this process, a line can be replicated "after itself" any number of times by moving the cursor to the space trailing the line number, pressing [+], and entering the line.

The [-] key performs the same function, except that the replicated line becomes the line previous to the one which has been displayed. The replicate has the same number as the original line, and the original line appears in the text as the line with the next higher number. A line can be replicated before itself any number of times by repeatedly moving the cursor into the space trailing the line number, pressing [-], and entering the line.

SCREEN-EDITOR OPERATION

In screen editing, an external terminal or display becomes a multi-line "window" for viewing the text stored in CC-40 memory. All lines (rows) on the screen except the last one are available for display of text lines. The last line is reserved for display of editor commands entered through the keyboard.

Screen addressing (for both lines and columns) is performed by a keyboard-controlled cursor. The cursor marks either the position at which characters are entered by keystroke or the position at which the next cursor-relative command or display-control function (delete character, for example) takes effect. The cursor can be moved to any line or column of text on the screen. For text in which the number of lines exceeds the number of rows in the display, the lines of text displayed on the screen are selected by either line number or page scrolling (moving the display window to the previous or subsequent "screen" of lines).

Any RS232-compatible terminal or external display terminal can be connected to the CC-40 console through an RS232 device for screen editing. Terminal or display characteristics, however, must be defined for the editor. These characteristics include the column and line format of the display screen, the transmission characteristics used for RS232 communication, and the display-control characters used to determine operations such as cursor positioning. The characteristics are stored into memory for use by the screen editor with the D)efine option in the main edit menu.

The keyboard used for screen editing can be either the CC-40 compact keyboard or another keyboard which is part of the terminal providing the display. The D)efine option also specifies which keyboard is used and defines the keys which are to be used to issue editor commands. Saving text as a mass-storage file, for example, can be chosen to be the sequence [[CTL]] [S], [[ESC]] [S], or some other key or key sequence, depending on user preference.

The D)efine option must be used before the S)creen option is used each time the E/A package is entered from BASIC. Screen and keyboard default values for the Televideo 920 terminal and the internal keyboard and a HEX-BUS™ Video Interface display device are included in firmware, and through D)efine they can be selected for use as they are or they can be modified for other devices. Alternately, previously saved sets of characteristics can be loaded from a mass-storage device. If neither of these steps is taken before the S)creen option is selected from the main edit menu, the screen editor cannot be used and the No screen parameter table message appears in the console display.

Screen-Editing Commands

Like line editing, screen editing uses display-function keys. These keys are pressed during text entry to cause cursor movement in columns and lines, vertical paging (scrolling page-by-page), insertion and deletion of text within lines, and other similar operations. Also as in line editing, screen editing uses commands.

In screen editing, however, the text remains on the screen while the commands are typed. In general, a two-keystroke sequence initiates command entry. The editor then prints out the full word or phrase for the command in the last line of the display and places the cursor after the word or phrase. Additional command information (containing line numbers, device numbers, and filenames, for example) is then typed into the command line.

The command line can be edited using keys previously defined for clear-line, delete-character, insert-character, left-and right-arrow, forward- and back-tab, and erase-field keys. All printable characters can be entered. Pressing [[ENTER]] begins execution of the command. Pressing [[COMMAND EXIT]] clears the command line and returns the cursor to the text display area of the screen.

Most of the commands and functions available in line editing are available in screen editing. Some additional commands are also available to make full use of the greater speed and convenience of the screen display.

Entry of screen editing commands is, in the default command set for the Televideo 920 terminal, initiated by escape sequences. The nonprintable ASCII character "ESC" is entered through the keyboard, followed by a character which is generally the first letter of the full word or phrase which names the command. Command keys in the CC-40 keyboard default set are similarly defined for use following the [[FN]] key. For example, entry of the delete-line command requires the sequence [[ESC]] [D] on the Televideo 920 and [[FN]] [D] on the CC-40 keyboard.

Screen editing commands are listed below. Detailed descriptions of commands are referenced on pages noted with each command.

COPY--Copies a file from mass-storage device into memory for subsequent editing.

DELETE--Deletes a line or range of lines from the text in memory.

FIND--Finds the next string of characters that matches the string specified in the command.

FORMAT--Initializes the mass-storage medium in the device specified.

HELP--Displays a list of screen-editor commands and cursor-control keystrokes on the screen.

JUMP TO LINE--Places the cursor on the line with the number specified in the command.

LIST--Outputs the text in memory to a HEX-BUS™ device such as a printer.

MOVE--Moves a line or a block of lines to another location in the text.

QUIT--Leaves the screen editor and returns to the main editor menu.

REPLACE--Replaces one or more occurrences of a character string in the text with another specified string.

SAVE--Saves the text currently in memory to a specified mass-storage device.

TAB DEFINE--Redefines the display tab stops to be other than those set by default.

UNDO--Cancels the effects of the last delete command, line modification, or replacement operation by reinserting into the text the lines deleted or changed.

VERIFY--Compares character-for-character the text stored in memory with a file present in an external storage device.

Text Entry

Text is entered by typing a line and pressing [[ENTER]]. After the line is entered, the cursor moves to the first column of the text area of the following line.

A special AUTO provision in the screen editor inserts a new blank line of text each time [[ENTER]] is pressed. Lines from the new blank one to the end of text have their line numbers incremented by one. AUTO mode permits new lines to be inserted into text as easily as if they were being appended to the end of text.

When the editor is first entered, automatic line-entry mode is in effect. Pressing [[CTL]] [A] the first time turns it off, and pressing the key a second time turns it on again. Throughout editing, pressing the key toggles insertion mode on whenever it is off and toggles it off whenever it is on.

Text is displayed after five-digit line numbers and a space, as in line editing. The line number and space in screen editing, however, are inaccessible to the cursor.

Cursor Positioning

The cursor is stepped through the columns of the current (cursor) line with the [Right Arrow] and [Left Arrow] keys. The right-arrow key [Right Arrow] positions the cursor one character to the right of its current position, and the left-arrow key [Left Arrow] positions the cursor one character to the left.

If [Right Arrow] moves the cursor past the last character typed in the line without a displayable character being typed, the character positions between the last character and the cursor are ignored when the line is stored into the text area of memory. No trailing spaces are entered into the text. If, however, a printable character is typed after the skipped character positions, then the positions are entered as spaces into the text.

The [Up Arrow] and [Down Arrow] keys perform similar functions in moving the cursor one line up and one line down on the screen.

The home key ([HOME] on the terminal keyboard, [[CTL]] [Up Arrow] on the CC-40 keyboard) positions the cursor to the first character of the first line in the display.

The forward tab key ([TAB] on the terminal keyboard, [[CTL]] [Right Arrow] on the CC-40 keyboard) moves the cursor to the closest tab stop to its right. The tab stops are those set either by the screen-editing definition file or by the TAB DEFINE command during screen editing. Pressing the forward tab key when the cursor is to the right of the last tab stop moves the cursor to the first column of the same display line.

The back-tab key ([[CTL]] [U] on the terminal keyboard, [[CTL]] [Left Arrow] on the CC-40 keyboard) moves the cursor to the closest tab stop to its left. Pressing the back-tab key when the cursor is to the left of the first tab stop in a line moves the cursor to the last column of the same display line.

Display Paging Control

The page-forward key ([[ESC]] [Down Arrow] for the terminal and [[CTL]] [+] for the CC-40) and the page-back key ([[ESC]] [Up Arrow] for the terminal and [[CTL]] [-] for the CC-40) scroll the text lines up and down one screen page at a time. When the page-forward key is pressed, the text line following the one in the last line of the text area becomes the first line of the new page. The display is effectively moved up "a page" (i.e., the number of lines within the text-display area of the screen). Similarly, the page-back key scrolls the lines of the text one page downward.

Screen Refresh (View)

The [[CTL]] [V] (view) key rewrites text lines to the current display. If a terminal or display is cleared locally through keystroke or power interruption, view can rewrite the text display to the screen.

Line-Number On/Off Toggle

The line-number display key [[CTL]] [T] controls the position of text lines on the display screen. If no line numbers are to be displayed, the line is effectively shifted to the leftmost six columns--five line-number digits and a space--in either display so that only the typed-in portion of the line is displayed. (Whether displayed or not, the six line-number columns count toward the maximum 80 characters permitted in each line.)

Initially, the editor displays line numbers. During editing, pressing [[CTL]] [T] the first time causes the line-number columns to be shifted from view. Pressing the key a second time causes them to again be shifted into view. The key operates as a toggle which causes the line numbers to alternately disappear and appear.

Text Deletion

Displayed characters can be deleted by (1) single character, (2) all characters from the cursor position to the end of the line, and (3) all characters in the line.

The delete key ([[DEL]] for the terminal, [[SHIFT]] [Left Arrow] for the CC-40) deletes the single character at the current cursor position and shifts all subsequent characters one position to the left.

The erase-to-end-of-field key ([[CTL]] [E] for the terminal, [[CTL]] [Down Arrow] for the CC-40) deletes all characters from the one at the current cursor position to the end of the display line.

The clear key ([[CTL]] [C] for the terminal, [[CLR]] for the CC-40) erases all characters, except the line number and space trailing it, from the line. Screen editing enters lines into the text area of memory differently from line editing. Lines displayed on the screen are not operated on as if they were line-by-line scratchpads. Pressing [[CLR]] during line editing for example, clears the line number and results in only the display being cleared; the current text line is not affected. When the clear key ([[CTL]] [C] for the terminal or [[CLR]] for the CC-40 keyboard) is pressed during screen editing, a blank line remains on the screen (with the line number unless it has been toggled off).

The screen editor, like the line editor, has a provision for recovery from erroneous entries through the use of the recover buffer and the UNDO command ([[ESC]] [U] for the terminal, [[FN]] [U] for the CC-40). If the text of a line is accidentally cleared, for example, regardless of whether the cursor remains on the line or is moved to some other text line, the cleared text is restored to the line with UNDO. In screen editing, as in line editing, the recover buffer stores the original text of the last line modified or replaced, or it stores the last line or block of lines deleted.

Text Insertion

Characters typed into the text area of memory after the character-insert key ([[CTL]] [Q] for the terminal, [[SHIFT]] [Right Arrow] for the CC-40 keyboard) displace all other characters from the cursor to the end of line. When the character-insert key is initially pressed, the editor is set to insert any characters at the current cursor position, moving all following characters to the right. If the text in the line reaches 74 characters, no further characters are accepted into the line (they do not "fall off the end of the line" as in line editing). Character-insertion continues until a subsequent display-control key (cursor-position or delete key or [[ENTER]]) is pressed.

Screen-Editing Keyboard and Display Definition

Particular keyboard and terminal characteristics are defined by a table of values stored in memory for use during screen editing. The screen-definition menu provides for selection of particular values used during editing with three options.

Pressing [D] in response to the main edit menu causes the editor to display the screen-definition menu shown below.

M)odify S)ave L)oad Q)uit

Pressing [M] in response to the screen editor menu causes the editor to begin displaying a series of prompts for modification of current table values by use of line editing and the console keyboard and display. Normally, the values displayed are the "default" values available in editor firmware: they are values which work with a Televideo 920 terminal or with the console keyboard and the HEX-BUS™ Video Interface device. With each prompt, previous or default selections can be retained by pressing [[ENTER]], or they can be modified through the use of line editing functions.

Pressing [Up Arrow] or [Down Arrow], respectively, causes the display to "scroll" to the previous or following prompt. Pressing [[BREAK]] in response to any prompt returns the definition menu to the display (with characteristics already modified retained in the screen parameter table in memory).

All modifications made to the table during screen definition are in effect in the screen editor as long as the E/A package is running. The editor can be tested by exiting the screen-definition menu with [Q] in order to return to the main edit menu. Selecting S)creen from the main edit menu by pressing [S] starts screen-edit operation with all new characteristics from the table in effect.

After new screen-editor characteristics have been tested, they can be saved to a mass-storage file. They can be conveniently reentered from the file instead of the keyboard at a later time. Pressing [S], and entering the mass-storage device number and filename saves the file.

Pressing [L] and entering a mass-storage device number and filename results in the loading of any previously stored definition file for use or further modification.

Note carefully that until the Define option is selected and either a file has been loaded or the M)odify option has been selected to specify at least the keyboard and screen default values, no table is present in RAM. Attempting to enter the screen editor from the main edit menu results in a No screen parameter table message.

The table of values for screen editing requires the following information.

- Selection of internal (CC-40) or terminal keyboard use

- The device number and data-transmission characteristics (such as RS32 parameters) of the HEX-BUS™ device connected to an external terminal or display

- The specification of which keys on the keyboard (usually control characters or escape sequences) are used for screen-editor functions and commands

- The specification of terminal display characteristics (such as screen size and display-control codes)

Keyboard Selection

The editor first displays the prompt Internal keyboard (Y/N)μ. Pressing [Y] selects the CC-40 keyboard and the associated default values for table entry. Pressing [N] selects the external terminal keyboard with associated default values. The default values are loaded only if no screen parameter table resides in memory.

Selection of Device and Data-Transmission Characteristics

The editor displays the prompt Screen Device for entry of display and any terminal keyboard device data-transmission characteristics, such as the RS232 device code and transmission characteristics. Device number, baud rate, no carriage return with lines (R=N), wait mode (T=W), no echo (E=N) and no data overrun reporting (O=N) must be provided. Entry of other characteristics depends on terminal requirements. Shown below is an example entry setting up RS232 characterics through device 20 to communicate with a terminal or external display device set for a baud rate of 4800, seven-bit data transfer, one stop bit, and even parity. Pressing [[ENTER]] with these default values displayed stores them into the RAM table from editor firmware. At this prompt or any subsequent one, pressing [[BREAK]] stores values previously modified into the table along with the remaining default values. The screen-definition menu returns to the display. For information on how to use the screen editor with the HEX-BUS™ Video Interface device, see appendix D of the Reference Manual.

20.B=4800,R=N,T=W,O=N,P=E,E=N

Command Keystroke Definition

A series of prompts following the entry of the terminal characteristics provides for definition of command and function keys. These definitions differ according to terminal design and user preference. The codes produced by special terminal keys are usually listed in the user documentation for each terminal.

The prompts for the command keys contain the names of edit commands and functions (copy, delete, and the like) and the default values assigned to them. Entry in response to each of the prompts is the value of the byte or bytes originating from the keyboard when the key is pressed. The values of bytes can be expressed in either decimal or hexadecimal notation (for example, [[ESC]] = 27 or >1B). Alphabetic characters can be expressed directly (without referencing their ASCII values) for entry in two cases: (1) when they are surrounded by double quotes, as in "Q", and (2) when they are preceded by the letters CTL to convert them to equivalent control-code values. Typing in "Q" stores the ASCII value of the letter (>51 or 81), and typing in CTL A stores the value of CTL-A (>01 or 1).

Either one or two values can be typed in for each command or function definition. If one value is typed, zero is assigned to the second value in the table. If two values, separated by a comma, are typed, both values are entered into the table.

The specific commands for which keystrokes must be defined are as the following.

Copy	Help	Quit	Undo
Delete	Jump	Replace	Verify
Find	List	Save	
Format	Move	Tab define	

Pressing [[ENTER]] to store values for the screen device number and transmission characteristics, for example, brings the prompt shown below into the console display. The pairs of values shown are the default values for the two keys which initiate the COPY command from either keyboard selected: they are the decimal representation of the ASCII characters "ESC" and "C".

Copy key: 27, 67

If these values are to be modified, the first keystroke for the new value(s) entered clears the display and show the character entered. Changing the values to the single value of CTL-C (>03 or 3) requires that one of the entries shown below appear in the display before [[ENTER]] is pressed.

CTL C

3

>3

Function-Key Definition

Following the prompts for and entry of screen-editor commands are prompts for defining display-function keys. Display-function keys, like keys which can be selected for commands, are dependent on terminal design, and the user documentation for each terminal lists the codes which they produce.

Function-key definitions are modified from the default values in exactly the same way command-key definitions are. The specific display-functions which must be defined are listed below.

Auto	Delete line	Insert char	Page forward
Back tab	Down cursor	Insert line	Right cursor
Clear line	Enter	Left cursor	Tab
Command exit	Erase field	Line display	Up cursor
Delete char	Home	Page back	View

Default Values for Command and Display-Function Keys

Default values for commands and functions are represented in the following table by the keys which produce them on both Televideo 920 and CC-40 keyboards.

EDITOR DEFAULT KEYBOARD DEFINITION ENTRIES

FUNCTIONS OF KEYS	KEYS USED: EXTERNAL KEYBOARD (Televideo 920)	KEYS USED: INTERNAL KEYBOARD (CC-40)
Copy	[[ESC]] [C]	[[FN]] [C]
Delete	[[ESC]] [D]	[[FN]] [D]
Find	[[ESC]] [F]	[[FN]] [F]
Format	[[ESC]] [N]	[[FN]] [N]
Help	[[ESC]] [H]	[[FN]] [H]
Jump	[[ESC]] [J]	[[FN]] [J]
List	[[ESC]] [L]	[[FN]] [L]
Move	[[ESC]] [M]	[[FN]] [M]
Quit	[[ESC]] [Q]	[[FN]] [Q]
Replace	[[ESC]] [R]	[[FN]] [R]
Save	[[ESC]] [S]	[[FN]] [S]
Tab define	[[ESC]] [T]	[[FN]] [T]
Undo	[[ESC]] [U]	[[FN]] [U]
Verify	[[ESC]] [V]	[[FN]] [V]
Auto	[[CTL]] [A]	[[CTL]] [A]
Back tab	[[CTL]] [U]	[[CTL]] [Left Arrow]
Clear	[[CTL]] [C]	[[CLR]]
Command exit	[[CTL]] [X]	[[CTL]] [X]
Delete char	[[DEL]] (>7F)	[[SHIFT]] [Left Arrow]
Delete line	[[CTL]] [D]	[[CTL]] [D]
Down	[:] ([[CTL]] [J])	[:]
Enter	[[ENTER]] ([[CTL]] [M])	[[ENTER]]
Erase field	[[CTL]] [E]	[[CTL]] [:]

Home	[HOME] (>1E)	[[CTL]] [Up Arrow]
Insert char	[[CTL]] [Q]	[[SHIFT]] [Right Arrow]
Insert line	[[CTL]] [N]	[[CTL]] [N]
Left	[Left Arrow] ([[CTL]] [H])	[Left Arrow]
Line display	[[CTL]] [T]	[[CTL]] [T]
Page back	[[ESC]] [Up Arrow]	[[CTL]] [-]
Page forward	[[ESC]] [!]	[[CTL]] [+]
Right	[Right Arrow] ([[CTL]] [L])	[Right Arrow]
Tab	[TAB] ([[CTL]] [I])	[[CTL]] [Right Arrow]
Up	[Up Arrow] ([[CTL]] [K])	[Up Arrow]
View	[[CTL]] [V]	[[CTL]] [V]

Definition of Required Display-Control Information

Following function-key definitions, the editor provides prompts for entry of terminal or display screen size and display-control codes. Like control and function key definitions, screen size and display-control codes are particular to each terminal. User documentation on each terminal lists the parameters to be entered. Values for some terminals are listed in appendix B of the CC-40 Editor/Assembler Reference Manual.

The prompts for screen size and display control codes, and the information which is entered in response to them, are listed below.

Screen size--The number of rows (lines) available on the display and the number of columns (character positions) in each line must be entered in the following format: columns,rows (without a space following the comma).

Clear screen--The character code or codes used to clear the screen of the terminal must be entered.

Move cursor--The first character code or codes used to initialize the sequence which positions (addresses) the cursor on the terminal must be entered. Following this byte or bytes in the sequence are two bytes which specify the cursor addresses (row and column).

Row first, Offset--Specification of two format elements for the cursor-address bytes must be entered here. For the first element, a numeric non-zero response to Row first element indicates that the row is addressed by the first byte and the column is addressed by the second. A zero response indicates that the column is addressed by the first byte. For the second element, the numeric response indicates the value of the Offset used in both address bytes (this value is usually >20 to make the addresses more easily "printable" in older high-level languages).

Definition of Optional Display-Control Information

Five other prompts list the definitions of display-control codes which can be modified or accepted for default values. When a terminal or display does not support features described in a prompt, the corresponding value must be set to zero. When a terminal or display can perform the functions specified in the prompts, faster and more convenient operation results from entering the codes. The prompts, in the order in which the editor presents them, are listed below.

Bell--The code used to activate the bell or beeper inside the terminal. If a value of 0 is entered, the CC-40 uses the internal beeper.

Erase to end of line--The code used to erase all displayed characters from the current cursor position to the end of the current line.

Erase to end of screen--The code used to erase all displayed characters from the current cursor position to the end of the screen.

Insert line--The code used to enter a blank line on the screen.

Tab stops--The column or character positions of the default tab stops. Up to ten column numbers can be entered in pairs separated by commas in response to the five appearances of this prompt.

Default Values for Display-Control Characteristics

Default values for screen size and display-control codes are represented in the following table.

DEFAULTS FOR DISPLAY-CONTROL CODES, DISPLAY SIZE, AND OPTIONAL CODES

DISPLAY FUNCTION	EXTERNAL KEYBOARD (Televideo 920)	INTERNAL KEYBOARD (CC-40)
Screen size	80,24	40,24
Clear screen	ESC	31
Move cursor	ESC =	ESC =
Row first,	1 (yes)	1 (yes)
offset	32	0
Bell	CTL G	0 (CC-40 internal)
Erase to EOL	ESC T	ESC T
Erase to EOS	ESC Y	ESC Y
Insert line	ESC E	ESC E
Tab stops	2,8,15,25 32,44,60,79	2,8,15,25,32

Using or Saving the Definition Table

After the response to the final Tab stops prompt is given, the screen editor definition menu returns to the display. Pressing [Q] for Q)uit causes a return to the main edit menu display for selection of the S)creen option for testing the table.

After the table values are tested and the main edit menu reappears, pressing **D** to select D)efine once more displays the screen-definition menu. Pressing **S** for S)ave and entering a mass-storage device number and filename saves the table in a file for later use.

Line and Screen-Editor Command Descriptions

Editor commands, in general, perform identical functions in both line and screen editing. Complete descriptions of these commands follow. Any differences between command use in line editing and command use in screen editing are noted in the descriptions. For clarity, only the default keys for the terminal are listed: default keys for the CC-40 keyboard can be referenced above in the table of keyboard default values. Syntax requirements and options available for each command are summarized at the end of this chapter.

AUTO: Automatic Line Number Command

The AUTO command provides new line numbers automatically during line editing. Followed by an optional line number (which defaults to 00001) in response to the command cursor ">", AUTO displays the text line with the number entered. If there is no line with that number, the line number and a trailing space are displayed for entry of a new line at the end of text. If a line with the number is already in the text, AUTO provides a line number followed by " + ", indicating that upon entry it is inserted into the text after the line of that number. When **[ENTER]** is pressed, the line number is incremented by one, and the next line number (followed by a space or " + ", depending on whether the line is to be appended or inserted) is displayed.

Initial entry into automatic line-number operation requires that the editor be in command mode with the ">" being displayed. The word **AUTO** is typed, followed by an optional line number and **[ENTER]**. Pressing **[BREAK]** abandons the current display line without storing it in the text area of memory and returns the editor to command mode with the ">" prompt being displayed.

The forms of the AUTO command are shown in the following examples.

AUTO: AUTOMATIC LINE NUMBERING

LINE EDITING ONLY

AUTO	Begin auto operation with line 1
AUTO 100	Begin auto operation with line 100

COPY: Copy (Load) a File into Text Area

The COPY command loads a file for editing from a mass-storage device into the text area of memory.

In line editing, if other text is already in memory and no line number is included in the command, the file is loaded at the beginning of the text area. If a line number corresponding to a line in the text area of memory is specified, the file is loaded (inserted) before the line in memory. In screen editing, the file is always loaded before the line containing the cursor.

If crunched mode has been specified in response to the main edit menu, then the lines in memory contain command-representative tokens and suppressed spaces. Otherwise the lines are ASCII-character representations of the lines originally entered. If the file being copied into memory has been saved in a mode different from the one currently in effect, the editor performs the necessary conversion.

At the outset of COPY execution, when the editor attempts to open a file, an error results in an `Open error NN [file name],Retry?` prompt. Changes in media are permitted before a **Y** response is given. With a **N** response, the COPY command is terminated.

If an error occurs while file lines are being loaded into memory or if there is not enough space in memory to load the complete file, loading terminates with the record being loaded when the error occurs. An error message is displayed. All file lines successfully loaded into memory before the record during which termination occurs are retained in memory for editing, saving, or other operations.

The forms of the COPY command are shown in the following examples.

COPY: LOAD FILE FROM MASS STORAGE UNIT INTO RAM

LINE EDITING

COPY 1.XYZ	Load file named "XYZ" from device 1 into empty text area of RAM
COPY 1.XYZ	Insert file named "XYZ" from device 1 into RAM before the text now in RAM
COPY 1.XYZ 12	Insert file named "XYZ" from device 1 into the current memory text before line 12
COPY 1.XYZ 1000	Append file named "XYZ" from device 1 after the current memory text of less than 1000 lines

SCREEN EDITING

[ESC] C 1.XYZ	Load file named "XYZ" from device 1 into text area of RAM at line before cursor

DELETE: Delete Line or Block of Lines

The DELETE command removes specified lines from the text area of memory. A single line is deleted when the command is followed by the number of the line (e.g. DELETE 5). A range of lines to be deleted is specified by line numbers separated by a hyphen. For example, DELETE 2-5 causes lines 2, 3, 4, and 5 to be deleted. The first line in the range defaults to 1 (DELETE-5 deletes lines 1 through 5). The last line number defaults to the last line in the text (DELETE 1-removes all lines from the text).

When DELETE removes lines from the text area of memory, the deleted lines are moved to another area of memory called the recover buffer. The lines remain in the recover buffer until some action is taken to change the text area of RAM or until a MOVE, VERIFY, LIST, COPY, or SAVE command is issued. The contents of the recover buffer are lost if a line is modified, a line is inserted, or a line is deleted. If no action has been taken which alters the contents of the recover buffer and an UNDO command is entered, the lines in the buffer are inserted into the text once more. The recover buffer and the UNDO command minimize the possibility of accidentally destroying text.

A special form of DELETE causes the editor to remove all lines from the text area of RAM without the delay necessary in first copying the text into the recover buffer. DELETE ALL performs very rapid text deletion, but it provides for no subsequent recovery of the deleted text from the recover buffer.

The forms of the DELETE command are shown in the following examples.

DELETE: REMOVE A LINE OR A BLOCK OF LINES FROM THE TEXT

LINE EDITING

DELETE 25	Delete line 25
DELETE 25-30	Delete lines 25 through 30
DELETE 25-	Delete line 25 and all following lines
DELETE-25	Delete all lines up to and including line 25
DELETE ALL	Delete text without copying to recover buffer

SCREEN EDITING

[ESC] D 25	Delete line 25
[ESC] D 25-30	Delete lines 25 through 30
[ESC] D 25-	Delete line 25 and all following lines
[ESC] D-25	Delete all lines up to and including line 25
[ESC] D ALL	Delete text without copying to recover buffer

EDIT: Display a Line for Editing

The EDIT command, used in line editing only, transfers a line from the text area of memory into the display buffer. If the line editor has not been given a NOLINE command to eliminate the display of line numbers, the display contains a five-digit line number, a space, and the text of the line. If a NOLINE command is in effect, the first column of the display contains the first character of text in the line.

The forms of the EDIT command are shown in the following examples.

EDIT: DISPLAY LINE FOR EDITING

LINE EDITING

EDIT 38	Display line 38 for line editing
E 38	Display line 38 for line editing

FIND

The FIND command is used to display the next line in the text area of memory which contains a specified string (sequence) of characters. In both line and screen editing, the search for the string begins at the current line (with line editing) or the cursor (with screen editing) and continues until either (1) the string is found or (2) the end of the text is reached.

One option can be specified in the search: W. With the W option, no distinction is made in the search between uppercase and lowercase characters. Also, with the W option, the search is carried for an exact word match (including word boundaries); ABC does not match XABC or ABCY. For the string ABC to be matched by the identical sequence in the text, a string must be both preceded and followed by a nonword character. A nonword character is any character other than an ASCII alphabetic character, numeric character, or "$".

If the W option is not specified, alphabetic-character case is significant: ABC does not match AbC. The string is found in text regardless of the context in which it occurs or the delimiters surrounding it: ABC does match XABC and ABCY.

When a match occurs during the text search, the line in which the match occurs is displayed and the cursor appears over the first character in the matched string.

In the FIND command, any nonword character except "space" can be used to mark the beginning and end of the string to be found. Any printable character or a space can be used inside the string, except for the character used as the beginning and end marker. The second occurrence of the marker signals the end of the string. In other words, the marker should be selected from among punctuation characters which are not part of the string to be searched for.

In line editing, the FIND command is transferred to the playback buffer each time [ENTER] is pressed. For repeated searches for the same string, pressing [SHIFT] ↑ transfers the FIND command back into the display buffer for re-execution (subsequent search for the next occurrence of the string in the text area of memory). In screen editing, the string to be found defaults to the string previously used: pressing the command initiation key followed by [ENTER] continues the search.

The forms of the FIND command are shown in the following examples.

FIND: DISPLAY NEXT LINE CONTAINING STRING IN COMMAND

LINE EDITING

FIND .XY.	Find "XY" in the current line or in a line following it and display the string
F /X.Y/	Find "X.Y" in the current line or in a line following it and display the string
FIND W .XY.	Find "XY", "Xy", "xY", or "xy" in the current or following lines and display the string
F W .XY.	Find "XY", "Xy", "xY", or "xy" in the current or following lines and display the string

SCREEN EDITING

[ESC] F .XY.	Find ".XY" in the current line or in a line following it and display the string
[ESC] F W .XY.	Find "XY", "Xy", "xY", or "xy" in the current or following lines and display the string

FORMAT: Prepare New Mass-Storage Medium

The FORMAT command followed by a mass-storage device number causes the media in the device to be initialized for use.

The medium must be placed in the device before the command is issued. All files previously stored on the medium are erased.

The forms of the FORMAT command are shown in the following examples.

FORMAT: INITIALIZE MEDIUM IN MASS-STORAGE DEVICE

LINE EDITING

FORMAT 2 Initialize new medium in device 2

SCREEN EDITING

[ESC] N 2	Initialize the new medium in device 2

HELP: Show Commands and Display Functions

The HELP command, used in screen editing only, displays a list of the commands and functions used in editing. The commands are displayed one at a time. While a command or function is being displayed, pressing keys on the keyboard indicates the key sequence defined for it. All key sequences except the correct one cause the terminal or console to emit a beep.

Pressing ↑ displays the previously displayed command or function. Pressing ↓ displays the subsequent one. Pressing **[COMMAND EXIT]** terminates the HELP display and returns the cursor to the text.

The form of the HELP command is shown in the following example.

HELP: DISPLAY COMMANDS AND FUNCTION KEYS

SCREEN EDITING

[ESC] H	Display commands and functions

JUMP: Move the Cursor (and Screen) to Another Point in the Text

The JUMP command causes the cursor to be placed in the line of the text which corresponds to a line number specified in the command. If the line is currently being displayed on the screen, the cursor moves to the line without any paging. If the line is not on the screen, the display is paged so that the specified line appears on the screen with the cursor.

The line number specified in the JUMP command can be written in two ways: absolutely or relatively. An absolute line number simply specifies the number of the line to next appear with the cursor (e.g. "JUMP 10" causes the cursor to move to line 10). A relative line number (a number prefaced by – or +) specifies a number of lines before or after the current line. (A "JUMP + 1" command, with the cursor currently on line 10, causes the cursor to move to line 11, and "Jump – 1" causes it to move to line 9).

Two special forms of the JUMP command cause the cursor (and screen) to be moved to the top (beginning) and bottom (end) of text. The form "JUMP T" causes the first page of text to be displayed with the cursor in the first line; "JUMP B" causes the last page of text to be displayed with the cursor in the last line.

If a relative line number calls for cursor placement in a line with a number of less than 1 or greater than the number of the last line of the text, the cursor appears, respectively, at the first line or last line of the text.

The four forms of the JUMP command are shown in the following examples.

JUMP: MOVE THE CURSOR (AND SCREEN) TO ANOTHER LINE

SCREEN EDITING

[ESC] J 100	Move the cursor to line 100
[ESC] J +3	If the cursor is on line 100, move it to line 103, if it is on 5, move it to 8; and so on.
[ESC] J T	Move to the top (first) line of the text
[ESC] J B	Move to the bottom (last) line of the text

LIST: Display or Print Lines of Text

The LIST command causes specified lines in the text area of memory to be displayed or printed. Device parameters for this command must be enclosed in double quotes. If no line-number range is specified, the entire text is listed. When no first or last line number is specified in the command, line numbers default (respectively) to line 00001 and the last line in the text (as in the DELETE command).

In line-editing, the first line appears in the LCD display if the LIST command contains no device parameters. It can be edited as if the E command had been pressed in response to the command-mode prompt ">". Subsequent lines appear sequentially each time [ENTER] is pressed. If a device number of a printer, for example, or a device number and filename for a mass-storage device are specified in the LIST command, the file lines are printed or transferred to the specified device or file rather than displayed.

Lines are printed either with or without numbers in accordance with the LINE/NOLINE command in effect during line editing or the [CTL] T toggle in effect during screen editing.

In screen editing, the LIST command must contain device parameters. There is no provision for listing to the screen device. The device number must not specify the terminal or display device being used for screen editing.

At the outset of LIST execution, when the editor attempts to open a device an error results in an `Open error NN [device],Retry?` prompt. With an N response, the LIST command is terminated. If an error occurs while file lines are being output, listing terminates with the record being listed when the error occurs. An error message is displayed.

The forms of the LIST command are shown in the following examples.

LIST: DISPLAY OR PRINT LINES OF TEXT

LINE EDITING	
LIST	List memory text line-by-line to display
LIST 250-	List text lines 250 and following
LIST-250	List text lines through line 250
LIST "20"	List text to device number 20
LIST "1.DATA"	List all lines to a file named "DATA" on mass-storage device number 1
LIST "20" 50-	List lines 50 and following to device 20
LIST "1.A"-50	List lines through 50 to a file named "A" on device 1

SCREEN EDITING	
[ESC] L "20"	List text to device number 20
[ESC] L "1.DATA"	List all lines to a file named "DATA" on mass-storage device number 1
[ESC] L "20" 50-	List lines 50 and following to device 20
[ESC] L "1.A"-50	List lines through 50 to a file named "A" on mass-storage device 1

MOVE: Move a Line or Block of Text

The MOVE command copies a specified line or group (block) of lines from one point in the text area of memory to another and deletes the original lines. The block to be moved is specified by line number as in the list and delete commands: if no last address is specified for a block, only one line which corresponds to the first line number is moved. The line of the text before which the line or block is to be moved is also specified by line number. The command MOVE 1-10,20 moves lines 1 through 10 to a position in the text just before line 20.

The default for the line that begins the block of lines is 1, and the default for the line that ends the block is the last line in the text.

The forms of the MOVE command are shown in the following examples.

MOVE: MOVE LINE OR LINES TO ANOTHER POINT IN TEXT

LINE EDITING

MOVE 3,6	Move the third line so that it becomes the fifth
MOVE 1-10,21	Move the first 10 lines of the text so that they become the second 10

SCREEN EDITING

[ESC] M 3,6	Move the third line so that it becomes the fifth
[ESC] M 1-10,21	Move the first 10 lines of the text so that they become the second 10

QUIT: Return to the E/A Menu

The QUIT command causes the CC-40 to exit the editor and return to the E/A menu. Before the editor is exited, however, the prompt `Are you sure (Y/N)?` appears in the console display or in the last line of the screen display. Pressing Y for YES permits the exit to occur. Pressing N, causes a return to the editor.

Once Y is pressed in response to the prompt, all text in memory is lost.

The forms of the QUIT command are shown in the following examples.

QUIT: RETURN TO EDIT MENU

LINE EDITING

QUIT	Leave line editing and return to edit menu

SCREEN EDITING

[ESC] Q	Leave screen editing and return to edit menu

REPLACE: Find One String and Replace It with Another

The REPLACE command searches for the next occurrence of a specified string (sequence of characters) in the text area of memory and replaces it with another specified string. All alphabetic and numeric characters and spaces are significant in the search. There are three options which can be, either alone or in combination, selected with the REPLACE command: the word W option, the verify V option, and the all A option.

The W option following a REPLACE command indicates that the search is for a "word" bounded by nonword characters. Individual characters of the word can be either lowercase or uppercase. The W option in the REPLACE command operates just as in the FIND command.

With V option in effect when a string is found during line editing, the display shows 19 characters of the line beginning with the string. Following the string is the prompt `Replace?` A **Y** response to the prompt causes replacement to occur; an **N** response causes the string to be skipped over without replacement. While the editor awaits a (Y/N) response, a line can be scrolled right or left within the 19-character window by the use of ← and →. If option A is in effect, the search is continued; if not, the search is terminated.

With the verify option in effect when a string is found during screen editing, the cursor is placed over the first character of the string. The prompt `Replace: Y)es N)o S)top` appears in the command line. A **Y** response to the prompt causes replacement to occur; an **N** response causes replacement to be skipped over. An **S** response terminates the REPLACE command.

The REPLACE command followed by A indicates that all occurrences of the searched-for string in the text are to be replaced. When the verify option is also specified, the replacement operation stops each time the searched-for string is found to query about replacement. After replacement of the string is effected or skipped over by a **Y** or an **N** response, the search continues through subsequent lines. If a **S** response instead of a yes-or-no response is given to the prompt, no replacement occurs and the REPLACE ALL command is terminated. If the verify option is not specified in a REPLACE ALL command, every occurrence of the searched-for string is replaced. The display reports the number of times that replacement has occurred with the message `Number of replacements = NN` when the ALL option is in effect.

When a string is replaced, the original text of the line is saved in the recover buffer. If, before the recover buffer is overwritten in another operation (such as another replace operation, line modification, or line deletion), **[UNDO]** is pressed, the last replacement is voided: the original text line is restored.

If the string which is to replace the searched-for string is null (that is, no characters are typed between delimiters), the effect of the replacement is to delete the searched-for string from the text area of memory.

The forms of the REPLACE command are shown in the following examples.

REPLACE: FIND ONE STRING AND REPLACE IT WITH ANOTHER

REPLACE .XX.YY.	Replace the next occurrence of "XX" with "YY"
REPLACE W ?X.X?XX?	Replace the next occurrence of "X.X", "X.x", "x.X", or "x.x" with "XX"
REPLACE V .XX.YY.	Replace the next occurrence of "XX" with "YY" after displaying the line, prompting with "Replace?", and receiving a **y** or **Y** response
REPLACE A .XX.YY.	Replace all subsequent occurrences of "XX" with "YY"
R A .XX.YY.	Same as "REPLACE A .XX.YY."
R AWV .XX.YY.	Replace as above with all options specified

SCREEN EDITING

[ESC] R .XX.YY.	Replace the next occurrence of "XX" with "YY"
[ESC] R W .XX.YY.	Replace the next occurrence of "XX", "Xx", "xX", or "xx" with "YY"
[ESC] R V .XX.YY.	Replace the next occurrence of "XX" with "YY" after placing the cursor at the string, prompting with `Replace: Y)es N)o S)top`, and receiving a **y** or **Y** response
[ESC] R A .XX.YY.	Replace all subsequent occurrences of "XX" with "YY"
[ESC] R AWV .XX.YY.	Replace as above with all options specified

SAVE: Write the Text to a Mass-Storage File

The SAVE command causes the text in memory to be transferred to a file on a mass-storage device. The text is saved with lines separated from each other by single-byte nulls. If the text is in crunched format, it is saved to the file in crunched format. Line numbers are not saved.

The SAVE command permits optional specification of record size. If no record size is specified, the text is saved as one record. If a size of less than 80 bytes is specified, the text is saved in 80-byte records. If a size greater than 80 is specified (1024, for example), records written during SAVE command execution are of that length.

At the outset of SAVE execution, when the editor attempts to open a file, an error results in an `Open error NN [device],Retry?` prompt. Changes in media are permitted before a **Y** response is given. With an **N** response, the SAVE command is terminated. If an error occurs while text is being written to the file, the output operation terminates with the record being listed when the error occurs. An error message is displayed.

The forms of the SAVE command are shown in the following examples.

SAVE: SAVE THE TEXT IN FILE ON MASS-STORAGE DEVICE

LINE EDITING

SAVE 1.TABLE	Save the current memory text to device 1 with the filename "TABLE" in a single record
SAVE 1.TABLE R = 70	Save "TABLE" to device 1 in 80 character records
SAVE 1.TABLE R = >FF	Save the text as "TABLE" to device 1 with a record size of >FF (255)

SCREEN EDITING

[ESC] S 1.TABLE	Save the current memory text to device 1 with the filename "TABLE" a single record
[ESC] S 1.TABLE R = 70	Save "TABLE" to device 1 in 80 character records
[ESC] S 1.TABLE R = >FF	Save the text as "TABLE" on device 1 with a record size of >FF (255)

TAB DEFINE: Set Display Tab Stops Other Than as Defined

The TAB DEFINE command, used only in screen editing, redefines video-display tab stops during editing. The column positions of up to 10 stops, separated from each other by commas, are entered on the last line of the display before **[ENTER]** is pressed. (The leftmost column is column 0, and the rightmost is column 79.)

The form of the TAB DEFINE command is shown in the following example.

SET TABS: TO POSITIONS OTHER THAN THOSE SET IN DEFINE

SCREEN EDITING

[ESC] T 5,10,15,20,25,30,35,40	Set tabs after every five columns

UNDO: Cancel the Last Modification, Deletion, or Replacement

The UNDO command transfers a line or block of lines from the recover buffer into the text area of memory. The recover buffer always contains the most recently deleted line or block or the most recently modified line of the text. Through UNDO, deleted lines are reinserted into the text or a modified line is replaced by the original text of the line.

The forms of the UNDO command are shown in the following examples.

UNDO: RESTORE TEXT TO STATE BEFORE MODIFICATION OR DELETION

LINE EDITING

UNDO	After line modification, replace the modified line with the original; after deletion, restore deleted lines to the text

SCREEN EDITING

[ESC] U	After line modification, replace the modified line with the original; after deletion, restore deleted lines to the text

VERIFY: Compare the Text with a Mass-Storage File

The VERIFY command compares character-for-character the text in memory with a specified file on a mass-storage device. If one or more of the respective characters in the text and the file differ, the message `I/O error 24, filename` is displayed. (Other errors, such as file-not-found and device errors, can also occur during a verify operation). The primary use of VERIFY is to ensure that file transfer between mass-storage and memory (through COPY or SAVE commands) introduces no errors.

No record size is specified in the verify command.

The forms of the VERIFY command are shown in the following examples.

VERIFY: COMPARE MEMORY AND MASS-STORAGE FILES

LINE EDITING

VERIFY 1.ABC	Compare the memory text with the file named "ABC" on device 1; issue message if text and the file are different

SCREEN EDITING

[ESC] V 1.ABC	Compare the memory text with the file named "ABC" on device 1; issue message if text and the file are different

CHAPTER 5
THE ASSEMBLER

This chapter describes the way the assembler is used to produce object files from source-file text. It also describes, in overview and in detailed discussion, the assembler instructions called pseudo operations and directives, and it discusses assembly errors.

The assembler is an E/A program which converts an assembly-language source program stored on a mass-storage device into a machine-language program. It translates the easily remembered (mnemonic) expressions for processor commands, program addresses, and program-related values (source code) into machine language (object code). The object code, when suitably linked with other programs and loaded into CC-40 system RAM or CC-40 cartridge RAM, can be executed by the TMS7000-family processor.

Source and Object Files

The assembler source file is an assembly-language text file which has been written to a mass-storage device. The object file, also written to a mass-storage device, contains machine-language commands, references to variables in other programs, and information required for linking and running TMS7000-family machine-language programs.

Source Files

The assembly-language program, stored as a file on a mass-storage device by the E/A editor, can be in either crunched or uncrunched format. In crunched format, keywords (assembly-language op codes and assembler instructions) are represented by single-byte tokens and multiple spaces are suppressed. Crunched format thus saves storage space. The input file can be stored as either a single- or multiple-record file as specified in the editor SAVE command. Single null (>00) bytes separate the lines of text in the file.

Object Files

The assembler output (object) file consists of an absolute or relocatable machine-language program which can subsequently be processed for execution from CC-40 memory. The object file can be saved on a mass-storage device in a single record or in multiple records of a specified length. Relocatable object code flags address values in object code produced by direct addressing commands such as LDA, STA, CALL, and BR. These addresses are subsequently evaluated by the linker relative to the start of the machine-language program.

The format of the object-code program is tagged-object format. In this format, assembly-language labels which have been converted into absolute or relocatable values within a single object file can be resolved from other tagged-object files being linked with it for execution. Linking resolves references external to the assembler-output file by transferring labeled addressing and value information among files to be linked.

Tagged object format stores object code in a series of variable-length fields. Each field begins with a single alphabetic label or tag. The label or tag for each field uniquely identifies the format, the contents, and the type of data in the field. A complete description of CC-40 tagged-object code appears in Appendix E of the *CC-40 Editor/Assembler Reference Manual*.

Running the Assembler

After the E/A package is entered from BASIC with a **RUN "ALDS"** command, the E/A program menu appears in the display as shown below.

```
E)dit A)ssemble L)ink B)asic?
```

The assembler is entered when **A** is pressed. The assembler displays a series of prompts which request the names of mass-storage files and the designations of peripheral devices which are to be used during assembly.

Upon entry, the assembler prompts for (1) source file, (2) object file, (3) type of assembly, and (4) listing device number or filename. These prompts, along with typical responses, are shown below.

```
Source file 1.SRC
Object file 1.OBJ R=1024
In memory assemble (Y/N)? N
List file 21.B=300,R=N
```

The object file is optional. No object file is produced if **[ENTER]** is pressed. Assembly without an object file is useful for displaying or printing assembly errors in minimal time.

When an object-filename is entered, it can be followed by spaces and a specification for record length (of the form R = nnn, with nnn being the number of bytes in a record). Specifying no record length with the filename indicates that the object file is to be written as a single record. In the example above, the object file is given the name "OBJ"; the file is written to device 1 in 1024-byte records.

The `In memory assemble?` prompt does not always appear: it appears only if an object file is to be provided by assembly. An answer to the prompt depends on the length of text being assembled and CC-40 system configuration. An **N** answer to the prompt, when mass-storage devices are used that permit only one file to be open at a time, requires that separate devices be used for source file and object file. A **Y** answer indicates that the object code is stored in memory until the source file can be closed and the object file written to the storage device. For an in-memory assemble, memory must be large enough to contain source code, object code, and assembly tables at the same time.

Much larger files can be assembled when an **N** answer is given to the `In memory assemble?` prompt than when a **Y** answer is given, but the mass-storage device configuration of the CC-40 system must support two files being open simultaneously, either with two devices, or with some single device that permits multiple open files.

If no listing device or filename is entered, no listing is produced and assembly errors are displayed on the console. When the `List file` prompt is answered with a device number, as with the RS232 device specified in the example above, the listing can be printed or displayed on an external device.

particularly useful because the TMS7000-family processor has a memory-pointer decrementing instruction (DECD) but no pointer incrementing instruction. A label preceding the RTEXT instruction is evaluated to the address of the last byte of the string (highest address).

Assembler Directives

Assembler directives specify the manner in which program assembly is carried out. Although they do not produce object code, these instructions are also typed into the op-code field, and any values used with them are placed in the operand field.

Assembler directives cause, for example, assembly of object code for use at particular locations in memory (relative or absolute), and they cause listing or suppression of listing of assembly source and object code.

The assembler directives include the following groups of instructions.

- Four instructions for specifying the location at which subsequent code and data are to be written into the object file
- An instruction for equating symbols with values during assembly
- An instruction for specifying the end of code for a program
- Two instructions for producing object-code symbols which enable multiple object-file linking
- An instruction for including another source file within the current one during assembly
- Five instructions for printing and formatting assembly-output listing pages
- An instruction for setting assembler options, such as producing cross-reference (symbol/location) listings and truncating the listing of lines of object code for byte, data, and text lines

The instructions within each group of directives are described below.

Code and Data Location Instructions

Four instructions control program memory locations in which code and data can be stored during program execution. Two instructions directly set the assembler "program counter," and the other two cause the assembler program counter to increment past memory locations where data is to be stored.

AORG: Absolute origin: Set the absolute-address origin of subsequent object code to the value specified in the operand.

RORG: Relocatable origin: Set the relative-address origin of the object code to an address displaced from relative address 0 by the value specified in the operand.

BSS: Block starting with symbol: Skip past object-code locations for the number of bytes specified in the operand and assign any label for the skipped bytes to the address of the first byte skipped.

BES: Block ending with symbol: Skip past object-code locations for the number of bytes specified in the operand and assign any label for the skipped bytes to the address of the first byte after the block skipped.

Symbol Value Equating Directive

The EQU directive assigns values to symbols which precede it in the label column of the line.

EQU: Equate: Assign the value in the operand to the label.

End of Source Statement

The END directive marks the end of the assembler source code. Any source-code instructions following an END directive are ignored by the assembler.

END: End source code: Terminate assembly at this line.

Linking Information Directives

Two directives provide the E/A linker with information making program variables accessible to linked programs and permit the use of similar variables in the other programs. (Also, see "IDT," below.)

DEF: Define symbol: Include the symbol specified in the operand as a "public" symbol in the object file with a value made available to the linker for use in other programs being linked to the current one.

REF: Reference symbol: Include the symbol specified in the operand as an "external" symbol in the object file with a value to be searched for by the linker among other programs being linked to the current one.

Source File Copy (Include) Directive

The COPY directive enables the assembler to produce object files from multiple source files.

COPY: Copy file: Copy or include another source file named in the operand into the current file during assembly only (source files remain separate following assembly).

Assembly-Listing Control Directives

Five directives control the listing of the assembly (and identify the program in the object file for access by the linker).

IDT: Identify program: Identify the program by the string in the operand both for the listing page heading and for access by the linker.

TITL: Title the following pages: Provide a page title for the next page and subsequent pages from the string in the operand.

LIST: List lines: List the lines of the assembled program following this directive and set the number of lines to be printed on each page prior to automatic end-of-page eject.

PAGE: Eject page: Eject a page in listing.

UNL: Unlist lines: Do not list the lines of assembled program following this directive.

Assembler Option Directive

The OPTION directive turns on and off the listing of multiple lines of object code following DATA and TEXT instructions, and it turns on and off the listing of a cross-reference map of assembly variables. When OPTION is placed in a line in the position of an op code, the following option specifications (separated by commas if more than one is required) can be listed in the operand field.

B: Truncate byte lines: Print only the first line of object code generated by each BYTE pseudo-op.

D: Truncate data lines: Print only the first line of object code generated by each DATA pseudo-op.

T: Truncate text lines: Print only the first line of object code generated by each TEXT pseudo-op or the last line of each RTEXT pseudo-op.

F: Finish line truncation: Print full object code generated by BYTE, DATA, TEXT, and RTEXT pseudo-ops.

X: Produce a cross-reference table: Produce a detailed cross-reference table listing the value of each symbol, the source-file line on which the value definition occurs, and the source-file lines containing references to the symbol (in operands).

R: Produce a reduced cross-reference table: Produce a cross-reference as above, except that only symbols from copied files which are referenced are listed in the table.

Pseudo Operations in Detail

All pseudo operations which produce binary data in the object code are written into source lines in the op-code field. The expressions to be evaluated into binary data are written into the operand field of the line.

Each instruction can be preceded by a label which, for BYTE, DATA, and TEXT, is evaluated during assembly to the location at which the first byte representing the operand is stored. A label for the RTEXT instruction, however, is evaluated to the location at which the last byte representing the operand is stored.

Numeric Data-Storage Instructions: BYTE and DATA

The BYTE instruction causes one or more single-byte values specified by the operand to be written into the object file. If one byte is to be written, the instruction has the following form.

```
BYTE >D
```

Multiple bytes can be written with a single instruction by entering multiple values separated by commas into the operand field of the line, as in the following.

```
BYTE 13,>D
```

The DATA instruction causes one or more two-byte values (words) specified by the operand to be written into the object file. If one word is to be written, the instruction has the following form.

```
DATA >D
```

Multiple words can be written with a single instruction by entering multiple values separated by commas into the operand field of the line, as in the following.

```
DATA 1023,-1023
```

The assembler evaluates negative values into binary form according to two's complement convention. The hexadecimal representation for the evaluation of −1 is >FFFF, for example, and the hexadecimal representation of −65535 is >0001.

String characters can be used in expressions in BYTE or DATA instruction operands. The instruction BYTE 'A'−>40 writes >01 or CTL−A into the object file. Similarly, the instruction DATA 'AB' writes >4142 into the object file.

ASCII Data-Storage Instructions: TEXT and RTEXT

The TEXT instruction causes a quoted string of ASCII characters specified in the operand to be written into the object file in normal order: the first character in the operand is written at the lowest object-file location, and the last character is written at the highest object-file address. If the initial quotation mark in the operand is preceded by −, the highest bit (bit 7) of the last byte of text stored is set to ONE to mark the end of the string.

The RTEXT instruction, like the TEXT instruction, causes a quoted string of ASCII characters specified in the operand to be written into the object file. The order in which the characters are written, however, differs with the RTEXT instruction: the last character in the operand is written at the lowest object-file location, and the first character is written at the highest object-file address. A label used with RTEXT is assigned the value of the location of the first character (at the highest location). Decrementing a memory pointer set to this label with a DECD instruction during program execution scans through the reversed text in normal order. If the initial quotation mark in the operand is preceded by −, the highest bit (bit 7) of the lowest-addressed byte of text stored is set to ONE to mark the end of the string.

Assembler Directives in Detail

Assembler directives can be divided into several classifications. Each of these classifications is discussed below.

Code- and Data-Location Instructions: AORG, RORG, BSS, and BES

When translating assembly-language instructions and data into object code, the assembler progressively maintains a two-byte counter which points to the location of each byte of a machine command or data block in the object code. As each byte of the object code is written, the pointer is incremented to the next location in memory.

In general, when the assembler reads a label in the source code (during "pass 1," the initial assembler scan of the source code), it stores the label and the value of the corresponding location counter in a table called the symbol table. After the table is complete, the assembler scans the source code again (during "pass 2" in which the object code is written). During pass 2, when a symbolic (non-numeric) operand is found, the assembler searches the symbol table in order to find a numeric value corresponding to the operand. The numeric value from the table is then incorporated into the object code for the assembly-language or data instruction currently being processed.

Four assembler directives provide control over the assembler location counter from statements in the source program. The AORG (absolute origin) and RORG (relocatable origin) instructions determine both the value of the location counter and the action taken by the linker in processing the object code for execution at specific memory addresses. The AORG and RORG instructions are mutually exclusive during the assembly of any program. Assembly set by AORG to produce absolute code cannot also produce relocatable code. Likewise, relocatable-code assembly set by RORG cannot produce absolute code. The assembler produces a `Mixed module` error message and disregards any origin statement that is not of the same type as the first origin statement.

When the AORG instruction is encountered, the two-byte location counter is set immediately to the value specified in the operand. Subsequent assembly-language and data instructions increment the counter from this value. If this value is >4567, for example, then any label on the AORG instruction itself or on the instruction following it is stored in the assembler symbol table along with the value. If the label appears in an instruction operand, the assembler uses >4567 appropriately in the object code for the instruction during pass 2 of the assembly.

The RORG instruction performs essentially the same task as the AORG instruction, except that it flags the object code following it for subsequent relocation by the linker. The linker subsequently "biases" address-related words in the object code following an RORG instruction by the address at which the object code is later to be loaded. An RORG instruction assigning the location counter a value >567, when the linker is set to relocate the origin of the program to location >4000, results in an address of >4567 for the next instruction.

If no AORG instruction occurs before the first object-code producing instruction or memory-block skip instruction in a program (see BES and BSS below), the origin for the program defaults to RORG 0. If an AORG directive is subsequently encountered, a `Mixed module` error occurs.

The object code in a program can be stored discontinuously: the assembler location counter can be incremented past a specified number of addresses to reserve the skipped block of memory for data storage during processing. Two directives cause such blocks of memory to be skipped: BSS (block skipped defined by starting symbol) and BES (block skipped defined by ending symbol). The operand of each instruction specifies the number of bytes added to the location counter during both passes of assembly.

The only difference between the BSS and the BES instructions lies in the value which the assembler assigns to a label included with the instruction during first pass. With a BSS instruction, the value assigned is the value in the location counter when the instruction is encountered in the source code. With a BES instruction, the value assigned is that of the location counter after the length of the block skipped has been added to it. The value is the address of the next byte of object code to be stored.

Value-Assignment Instruction: EQU

When the assembler encounters an equate instruction in the source code during the first assembly pass, it stores the value specified in the operand of the instruction in the symbol table as the value assigned to the label of the instruction. If the operand is itself a symbol, it must be a symbol previously evaluated to a number and stored in the symbol table.

Registers can be given mnemonic names through the use of equate statements. C EQU R2, for example, can enable programming with another register designated by letter. Equate statements which define registers should, however, be encountered in the source code before the assembler scans any instructions using the register name, because register instructions vary in length according to the registers being used. Designating the symbolic name of a register after the assembler has incremented the location counter past a statement with the name in an operand can result in an erroneous value in the location counter during assembly pass 1; all symbols stored in the symbol table thereafter can be in error. The assembler detects and reports this error with an `Invalid register value` message. The error can be avoided by placing equate statements which rename registers at the beginning of a source file.

Linking Directives: DEF and REF

The define-symbol (DEF) instruction causes the assembler to include a symbol and its value in the tagged-object file within a table used for resolving symbolic references from other files. The DEF instruction declares the value of a symbol in the operand to be the value substituted while linking with other files in which the symbol occurs undefined (provided the symbol is in the operand of a REF instruction within the other files: see below). The symbol is "public" and available for use by other files being linked for memory execution with the current file.

The external-reference (REF) instruction directs the assembler to put a symbol in the operand into a list of tagged-object code symbols with values to be determined from other files during the linking process. Upon linking, symbols tagged as REF symbols in one file are searched for among symbols tagged with DEF in other files being linked: values in DEF tables corresponding with entries in a program's REF list are returned to the program for use in producing executable object code.

End-of-Assembly Instruction: END

The END instruction causes any succeeding lines in a source file to be ignored during both passes of the assembly. The END directive is optional at the physical end of a file being assembled.

Multiple Source File Directive: COPY

The COPY instruction directs the assembler to include a source file other than the one specified at the outset of assembly. This instruction does not actually copy source code between mass-storage files. It does, however, at the point of inclusion in the source file originally specified for assembly, copy the file named in the operand into memory for continuation of assembly during both passes. When the copied file is completely scanned during either pass of assembly, the assembler resumes its scan of the primary file specified in response to the assembler `Source file` prompt with the instruction following the COPY directive.

Files included in assembly by a COPY instruction can not contain COPY instructions. Only one level of source-file nesting is permitted.

If the filename in the COPY directive is preceded by the letter "P" and a comma, the assembler issues a prompt for insertion of media containing the file to be copied during all passes of the assembly. For example, the directive COPY P,1.COPYFILE produces an `Insert: 1.COPYFILE` message in the display.

The COPY instruction also requires that both the original file and the file being copied into it be open simultaneously. Therefore, if a mass-storage device is used that permits only one file to be open at a time, two such devices must be used. A third device is required if `In memory assemble (Y/N)?` has been answered with N.

Listing Directives: IDT, TITL, PAGE, LIST, and UNL

If a device number or filename is entered in response to the `List file` prompt at the beginning of assembly, an assembly listing is printed during the second assembly pass. This listing, an example of which is shown in figure 5-1, consists primarily of the object code generated during assembly against the left margin of the paper in correspondence with the source-code line from which it is generated to its right. (Note that the listing has been edited to align the elements of each line into columns so that they can be labeled; the actual listing has fewer spaces between elements of each line.)

Following assembly, the assembler can be directed to perform a third pass to produce a cross-reference table, an example of which is shown in figure 5-2. The cross-reference table correlates the name of each symbol used in the assembled program, the value assigned to the symbol during assembly, the number of the source-code line on which the value is assigned, and the numbers of lines on which the symbol is referenced (in operands).

Both listings and cross-reference tables are controlled by assembler directives. Some directives control listing format, including page headings, title lines, and page length. Other listing-control directives control whether selected parts of a listing are to be suppressed and whether a cross-reference table is produced.

Listing Format Directives

The file-identifier (name) instruction IDT specifies in the operand the name of the file being assembled. This name appears, along with a page title and page number, in a heading at the top of each page. The IDT directive also causes the name of the program to be included in the assembler output file, thus providing the linker with the program name. The name is also stored in the object file for use by the linker in reporting on files successfully linked. It can contain as many as eight characters and must be surrounded by single quotation marks. If no IDT instruction is present, the default name "NO$IDT" is printed in the heading.

The page-title instruction TITL causes additional text to appear in the heading line beside the program identifier. The content of the line, typed into the operand of the instruction and surrounded by single quotation marks, can contain up to 40 characters. For a page title to appear on the first page of the listing, the TITL instruction for it must precede any line which is to be printed in an assembly listing. After a page title is specified, it appears at the top of every page following the TITL instruction until it is subsequently changed to the text in a subsequent TITL instruction. The line containing the TITL directive is not printed in the listing. If no TITL instruction is present to specify the title to appear in the heading, the default title "CC-40 TMS7000 Assembler Version 1.0" is printed.

The page-eject instruction PAGE causes an ASCII form-feed character (>0C or CTL – L) to be sent to the printer. An ASCII form-feed character can also be sent automatically after a preset number of lines are printed on a page, as specified in a LIST directive (see below).

Directives to List or Not List Lines

An entire program need not be printed in a listing. Selected lines can be listed by preceding them with a LIST instruction. Selected lines can be suppressed by preceding them with an unlist, UNL, instruction. Lines containing either the LIST or the UNL instruction are not printed in the listing.

The LIST instruction can, in addition, be used with a numeric operand to set the number of lines to be printed on a page before a page is automatically ejected. The instruction LIST 45, for example, causes 45 lines of text (including the heading and blank line following it) to be printed before a new page is begun. A LIST instruction with the number 0 in the operand, however, has a special purpose: LIST 0 suppresses the heading and all form feeds. A LIST 0 directive is in effect when listing begins.

A LIST directive without an operand causes printing to resume with the number of lines on each page set at the same value as in the most recent LIST directive with an operand.

Option Directive: OPTION

The OPTION directive provides for automatic deletion of listing lines which consist of only object code produced by BYTE, DATA, and TEXT instructions. It also provides for printing a cross-reference table of assembly variables. Like other directives, OPTION is placed in the op code field of an instruction, and letters representing selected options are placed in the operand field. Multiple selection of options in the operand field requires that commas separate each letter, as in the following example.

```
OPTION T,R
```

The BYTE, DATA, TEXT, and RTEXT pseudo ops sometimes result in the printing of many unwanted lines of object code. Each byte of object code produced by BYTE, TEXT, and RTEXT (each word of object code produced by DATA) is listed on a separate line beginning with the line on which the instruction occurs. A 30-character string in a TEXT statement therefore produces 30 lines of listing. To eliminate such long segments of listing, four directives are used. The OPTION B, OPTION D, and OPTION T directives cause

only the initial line of object code generated respectively by BYTE, DATA, and TEXT (or RTEXT) statements to be listed. Listing of all object-code lines following the first is suppressed. The OPTION F option cancels the effect of any and all OPTION B, OPTION D, or OPTION T directives issued in the source code preceding it.

An X or an R option in the operand field of an OPTION directive causes the assembler to perform a third assembly pass to generate a cross-reference table.

Both X and R produce identical tables if no file is being copied (included) during assembly. If one or more files are copied, however, the two directives produce different tables. The X instruction causes all symbols defined in both the primary file and copied files to be listed. The R instruction also causes all primary file symbols to be included in the table, but it reduces the symbols included from the copied files to those which are referenced.

When copied files are assembled and cross-referenced, line-numbers in cross-reference listings for symbols within them are keyed with alphabetic characters. The letter "A" precedes line numbers in the first copied file encountered during assembly, the letter "B" precedes numbers in the second copied file, and so on. The cross-reference table in figure 5-2, above, shows an assembly which includes two copied files.

Assembly Errors and Error Messages

During passes 1 and 2, the assembler screens the source file for errors in instruction entry. If a listing is being printed during pass 2, the assembler prints a message identifying any error on an unnumbered listing line immediately following the instruction line on which the error occurs. If no listing is being printed, the assembler outputs the assembly-listing of the line containing the error to the display. Pressing any key brings any subsequent lines of object code produced by the source line or the error message into the display.

Assembly error messages do not necessarily indicate that the object code produced by corresponding instructions is incorrect. Error messages do mean that the object code can be in error and should be examined. Likewise, the absence of assembly errors does not indicate that "error-free" programs can be executed as expected. The absence of assembly errors indicates the acceptability of source-code instructions to the assembler on an instruction-by-instruction basis; the logical flow of the program remains unchecked until the program is executed and debugged. (See chapter 8 of this guide, "The DEBUG Monitor.").

The three tables shown below list error messages and explain the errors which correspond to each message. The first table lists warning messages. The object code produced by a warning can be usable, but it should be inspected carefully. The second table lists errors classified as "severe errors." Severe errors indicate a very high probability that incorrect object code has been produced. The third table lists errors classified as "fatal errors." Fatal errors cause immediate and unrecoverable termination of assembly.

WARNING MESSAGES

MESSAGE	EXPLANATION
Value truncated	A numeric value is too great. For example >1FFFF has been evaluated to a word expression as >FFFF
Symbol truncated	A symbol string contains more than eight characters (only the first eight are significant)
Trailing operands	Too many expressions in the operand field: extra expressions ignored

SEVERE ERROR MESSAGES

MESSAGE	EXPLANATION
Invalid op code	The command field does not contain a valid instruction mnemonic, pseudo operation, or directive
Undefined symbol	An expression in an operand field has not been defined by a label or a REF operand, and it cannot be evaluated
Multiply defined	A symbol is defined more than once
Invalid symbol	A symbol contains characters other than "A"-"Z", "a"-"z", "0"-"9", ">", and "$"
Invalid constant	A string constant contains an invalid delimiter or a numeric constant contains an invalid character
Invalid expression	Expression contains illegal operations or invalid symbols
Missing operand	An operand required with this op code is not present
Invalid operands	Operand(s) present are not valid for op code
Invalid use of symbol	A symbol was REFed and DEFed, or a REFed symbol is used as a label
Reserved symbol	"$","A","B","R0"-"R127","R>0"-"R>7F", "P0"-"P255", "P>0"-"P>FF" or "ST", all predefined symbols, are being redefined
Invalid register value	A register value exceeds 255, is not absolute, or contains an undefined value (external or forward referenced symbol)
Divide by 0	Expression contains division by 0
Too many nested parentheses	Expression has too many nested parentheses (normally five levels): simplify the expression
Missing ")"	Expression lacks closing parenthesis of pair

Syntax error	Invalid syntax in an operand
Displacement too big	Offset generated by the jump instruction out of −128 to +127 value range
Mixed module	The source contains both absolute and relocatable code (AORG and RORG)

FATAL ERROR MESSAGES

MESSAGE	EXPLANATION
Memory full	The source, object, and/or copy files and the symbol table do not fit simultaneously in memory (reducing record sizes can remedy the difficulty)
PASS1/PASS2 conflict	A symbol is defined only in pass 2 or it has a value different in pass 2 from in pass 1, usually because of undetected file error or a different file being used during the second pass. This is also a severe error if a symbol is defined recursively, as in X EQU X + 1.
Nested copy files	A copied file contains a COPY directive

CHAPTER 6
THE LINKER

This chapter describes the way the linker is used to convert tagged-object code into machine language object files and to link multiple assembler-output files together into a single machine language program.

Assembler-output files must be processed by the linker before the object program can be executed. Assembler-output files are in tagged-object format (see chapter 6 and appendix E of the *CC-40 Editor/Assembler Reference Manual*). These files must be converted into TMS7000-family machine-language commands.

In addition to converting file format, the linker resolves (assigns values to) references which have been produced by assembler REF and DEF directives. It produces either (1) relocatable-code programs or subprograms which can be loaded and run under BASIC or (2) relocatable- or absolute-code programs which can be loaded and run in CC-40 system or cartridge RAM. Programs output by the linker contain either absolute code or relocatable machine code (the assembler does not produce an output file from a mixture of both).

Like assembly, linking requires two passes. The first pass determines the length of the object file and builds a symbol table for references among files. The second pass produces a memory image of the object code (and a relocation table if the object code is relocatable).

Running the Linker

After the E/A package is entered from BASIC with a **RUN "ALDS"** command, the E/A program menu appears in the console display as shown below.

```
E)dit A)ssemble L)ink B)asic?
```

Pressing **L** when the menu appears causes the linker to begin execution.

Linking is controlled by commands stored in CC-40 memory. The commands can be entered directly on the keyboard at the time of linking, or they can be read in from mass-storage after they have been created and saved by the E/A editor.

Upon entry, a linker prompt asks if there is a control file on a mass-storage device which is to control the linking process. The prompt `Is there a control file (Y/N)?` appears in the display. The control file contains linking commands entered through the E/A editor.

If **N** is pressed, the display clears and the linker prompts with `Enter line` for keyboard entry of commands to control linking. Each command is entered on a single line. The last line entered is an E command which signals the end of the commands list. As each command is entered, the linker checks it for errors and displays any appropriate error message.

If **Y** is pressed in response to the prompt, the linker then prompts for the control-filename. When the control-filename is entered, the linker opens the file and scans it for any incorrect linker commands. The scanning continues until an E command code is found or until the end of the control file is reached. If the end of the file is reached before an E command is found, a warning message is displayed and an E command code is appended to the file. Any other errors found are printed on a "link map," a comprehensive listing which records the result of the linking process.

After the linker receives commands from the keyboard or reads from the control file, it prompts for an output filename with the prompt `Linked output file`. If no name is given, no object code is output. The code is nevertheless generated internally so that errors can be determined.

Next, the linker prompts for the *HEX-BUS*™ device which is to print the link map. A listing can be printed regardless of whether an object-code file is written. If no list filename is entered, no link map is printed.

Linking Commands

Five commands control linker operation. These commands identify the assembler-output files to be linked, the type of machine code to be produced (absolute or relocatable), and the format of the linker-output file. Each command consists of a single-character code followed by any appropriate argument or parameter.

Spaces are allowed—but not required—between a command code and an argument. Only one command can appear in each line. Lines preceded by an asterisk (*) permit comments within a link-control file. Comments appear in the link map.

Input-File Commands

An input file is included in the linking process if it is named in an include command code (I or J). The argument for either include command is the name of the file to be included. The J command code is identical to I, except that J prompts the user to mount a mass-storage medium (*Wafertape*™ medium, for example) with the file on it. From a J code, a message such as `Insert: 2.PROG2` appears in the console display.

As many as 255 input files can be processed in a single link operation.

Absolute-Output Command

The absolute-address command A results in the output code which is absolutely addressed beginning with the value in the argument. If no A command code is found by the linker (and an AORG instruction from the assembler is not found before any code-producing assembler-output command is found, the output code defaults to relocatable code. If the linker is processing both relocatable and absolute files and the first file specified in an I or J command is a relocatable file, an A command must precede the command specifying the file. The linker can process combinations of absolute and relocatable input files into an absolute output file, but it cannot process such combinations into a relocatable output file.

As in assembler AORG instructions, linker A commands must have arguments in which subsequently specified absolute addresses are higher than any address previously assigned in the linking process. The file currently being linked cannot produce code with memory addresses lower than or the same as addresses used by code from a previous file.

Output-File Format Command

The multiple-record output command code M sets the linker to produce an output file containing more than one record of code. The argument for the M command is the record length. The M command must precede the specification of any assembler-output filenames (see the I command, above). If an M command is not present, the linked file is accumulated in memory for subsequent writing to mass-storage at the end of linking, either as a single-record relocatable-code file or as a two-record absolute-code file.

Only one M command can be issued in a single linking operation. When multiple-record output files are to be produced and mass-storage devices such as *Wafertape*™ units (which permit only one open file to be open at one time) are being used, the output device must be separate from the input device.

The END Command

The E command code signifies the end of the commands issued to the linker.

Linker Command Text and Listing

The following figure shows a series of commands provided to the linker by a control file. Each valid command is represented, and one invalid command is included.

```
A       >9000
* START THE CODE AT THE BEGINNING OF A 16K CARTRIDGE
M       255
* NOTE THAT THE FOLLOWING ARE FILE (NOT PROGRAM) NAMES
I       1.CARTHEAD
I       1.PROG1
J       1.PROG2
* NOTE THAT THE FOLLOWING COMMAND IS INVALID
Z
E
```

When a link map listing is produced, the first item in the map is a list of the commands. Errors in the control file are documented in the map, as shown in the figure below. Note that the commands in this figure must have been issued in a control file, because the bad command code Z would not have been accepted in keyboard entry of command text by the linker. Also note that if *Wafertape*™ devices are being used, a device other than device 1 must have been specified in response to the `Linked output file` prompt because of the M command.

In a link map, the M command is always moved to the top of the command listing, and the value of the argument it contains is always expressed in a decimal number.

```
M       255
A       >9000
* START THE CODE AT THE BEGINNING OF A 16K CARTRIDGE
* NOTE THAT THE FOLLOWING ARE FILE (NOT PROGRAM) NAMES
I       1.CARTHEAD
I       1.PROG1
J       1.PROG2
* NOTE THAT THE FOLLOWING COMMAND IS INVALID
Bad command code: Z
E
```

Link Map Format

In a link map, the beginning addresses and lengths of each module (assembler-output file) code are listed in hexadecimal values beside the names assigned in assembler IDT instructions for each file. For identification in error messages and the symbol (definition) table in the link map, the linker numbers modules with decimal numbers in the order in which they are linked. The following figure shows a typical link map with one error identified. A public symbol called "SCAN" has multiple definitions: it is defined or "DEFed" in two modules, once in the module with the IDT name NO$IDT and a second time in the module with the IDT name 01234567.

```
CC-40 TMS7000 LINKER  Version 1.0

                    CONTROL FILE

M    64
* PUT OUT 64 BYTE RECORDS
I    1.FILE1
Bad command code:  TYYYY
I    1.FILE2
I    1.FILE3
E

                    MODULE MAP

NUMBER          MODULE          ADDRESS         LENGTH

1               NO$IDT          0000            0034
2               01234567        0034            0072
3               XY              00A6            018E
                                —               —
                                0233            0234

*** Warning SCAN in #    2 already defined in #   1

                    DEFINITIONS

NAME    VALUE  NO     NAME    VALUE  NO     NAME    VALUE  NO

 ASTART 0000'  1      BLOOP   0049'  2      DLOOP   0023'  1
 FLOOD  0043   2      GO      0093   2      HGG     0045'  2
*INPUT  0190'  3      METER   0069'  2     *NEXT    00A6'  3
*ONLY   0234'  3      SCAN    0014'  1     *SCAN    0053'  2
*ZREF01 0119'  3
```

```
****    2 : UNRESOLVED _ REFERENCES
NAME      NO      NAME      NO      NAME      NO      NAME      NO
Z2         2      ENTRYPT   3

LINK COMPLETE
```

In the module map portion of the link map, relocatable values are marked with single quotation marks following the assigned value. In the example, all symbols except "FLOOD" and "GO" are address-related in the three files which have been assembled to produce relocatable code. Symbols preceded by asterisks are "DEFed" in the numbered files, but they are not referenced or "REFed" in other files.

When symbols are defined more than once, the value assigned to the symbol is the value associated with the first DEF instruction found. Occurrences of the symbol after the first DEF instruction appear in the listing, but they are marked with asterisks because they are not REFed.

Following the symbol table, unresolved references are listed. There are no DEFed symbols to correspond to the listed REFed symbols.

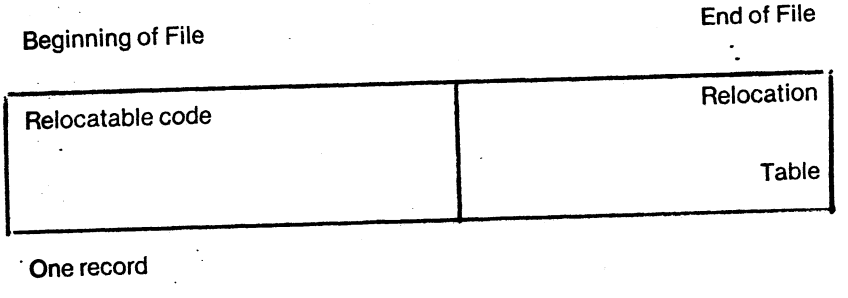
Linker Input and Output Formats

Assembler output files—input files for the linker—contain tagged-object code and are described in appendix E of the *CC-40 Editor/Assembler Reference Manual.*

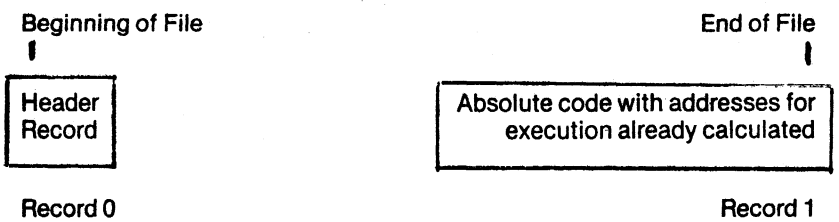
Output from the linker is a file which is a memory image of the program to be executed. If the file contains relocatable object code, memory-image code is followed by a relocation table containing offsets to words of code which must be relocated prior to program execution.

Headers, Memory-Images, and Relocation-Table Records

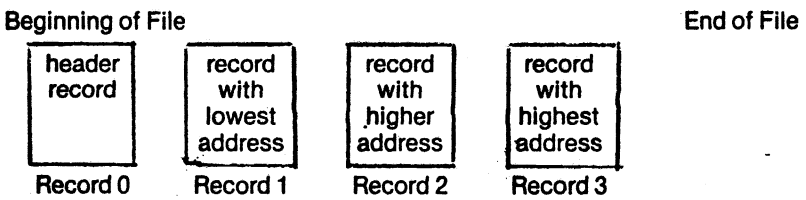
Unless an M command is in effect, relocatable code is output in a single data record for loading, relocating, and running under BASIC. The single record has no separate header record, as shown below.



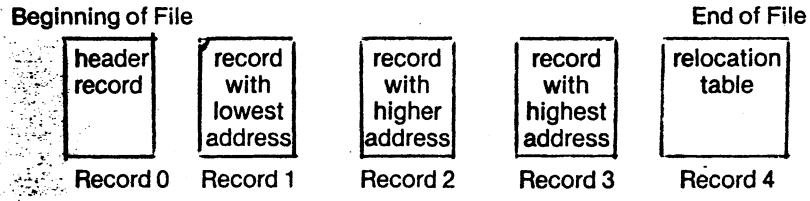
Absolute code which is output with no M command in effect is saved in a file which contains two records. As shown below, the first record contains a header and the second contains a memory image of the absolute code. The memory image of the absolute code is filled with NOP commands (>00) between segments of code set with AORG instructions not to be contiguous. When a relocatable code module follows absolute code, the relocatable module becomes absolute and machine code from the module immediately follows the last byte of the previous module.



With an M command in effect, absolute code is output as a memory image multiple-record file with a header record, as shown below. The length of the records is specified in the M (although the last record can be less than the record length specified if fewer bytes remain to be written).



With an M command in effect, relocatable code is also output as a memory-image following a header. Additionally, a relocation table is written as the last record of the file, as shown below. The relocation table is saved as a single record, regardless of the length specified in the M command.



Header Records

An 11-byte header record contains the six fields of information used in subsequent loading of linked files.

1. A file-type word, set to >0F05 to indicate a linker-output file
2. A flag byte, indicating whether the file contains relocatable or absolute code and a single- or multiple-record memory image (and relocation table)
3. A word specifying the maximum memory space required for writing the relocation table into memory
4. A word specifying record length for multiple-record files
5. A word specifying memory-image code length
6. A word specifying either absolute load address or minimum relocation-table length for multiple-record files

The function of each of the header-record fields is as follows.

File-Type Word

The file-type word, stored in memory at the highest address of the header block, has the value >0F05. This word uniquely identifies linker output files which contain absolute-code or multiple records of relocatable code so that they cannot be erroneously read by BASIC and loader programs for which they are not designed.

Flag Byte

The flag byte indicates whether a file is written in multiple records and whether the file contains relocatable or absolute code. The individual flags in the byte are set in accordance with the hexadecimal values shown in the following table.

FLAG-BYTE VALUES

	TYPE OF CODE OUTPUT	
Record Output	**Relocatable**	**Absolute**
Single	>04	>00
Multiple	>84	>80

Maximum Relocation Table Length

The maximum length (in bytes) of a relocation table is two more than twice the number of relocatable words and external references (REF's) in the program.

Block Size

The block size provides a loader with information required to load multiple-record images into memory (from high to low address) for the correct load address.

Length of Memory Image

The length of the memory image (without relocation table) permits a loader to verify that a program can fit into available memory.

Absolute Load Address or Minimum Relocation Table Length

This dual-purpose header word contains different information about absolute images and relocatable images.

For absolute images, it provides the load address for the start of absolute code.

For relocatable images, this word and the maximum relocation table length permits a loader to verify that sufficient memory is present for loading the file. The minimum relocation-table length is calculated to be two more than the number of relocatable bytes in the program.

Error Messages

The following tables list error messages resulting from control-file errors and errors occurring during linking.

CONTROL-FILE ERRORS

Multiple M code	Second M command code found in control file. Second one is ignored.
M code after include	M code found after first I or J command. Second M code has been ignored.
Bad value	Incorrect or missing number found in control file. Command is ignored.
Bad filename	Illegal filename found in control file. Command has been ignored.
Bad command code X	"X" is not a legal linker command.
Missing E command code	No E command code found before end of linker control file. Appears in display.
Too many files to be linked	More than 255 I and J control codes are used in a single control file.
Bad file type	Control file is of the wrong type (not a text file without special characters).

ERROR MESSAGES OCCURRING DURING LINKING

Code wraps around address space	Code generated for beyond address >FFFF. A warning only for absolute code, but also causes fatal memory-full error for relocatable code.
Memory full	More RAM needed than available.
Too many errors	Too many errors (multiply defined symbols) and extra module (IDT-specified) names.
Missing EOR tag in # N	End-of-record tag in assembler object code missing.
Missing module name in # N	Module name tag not the first item found in tagged-object file.
Bad program type in # N	File of incorrect type specified in control file. Not an assembler-output tagged-object file with >0F04 in the header.
Missing load address in # N	No load address tag in object code found before tag generating memory image code found.
Mixed code in module in # N	Both absolute code and relocatable code in a module.
Pass1/Pass2 data conflict in # N	Data in the first pass and the second pass are different (possibly two files of same name or mass-storage read error).
Code overlaps existing code in # N	Load address tag less than the current address being linked.
Abs address < current address in # N	Address in A command is less than the current absolute address of the code being linked. Number is of last module linked.
Extra module name in # N	A second module name tag found in a single tagged-object file. The second name is ignored.
*** Warning XXXXX in # N2 already defined in # N1	The public symbol "XXXXX" has been "DEFed" in two files and is a multiply defined symbol.
Illegal tag XX XX XX XX XX in # N	Illegal assembler tag has been encountered. Bad tag and the 4 following bytes are displayed or printed.
Checksum error in # N	File checksum calculated by the linker does not agree with the checksum generated by the assembler.
Absolute in relocatable link in # N	Absolute code found after relocatable code (possibly AORG after RORG in assembly).

CHAPTER 7
E/A UTILITY PROGRAMS

This chapter describes the use of E/A programs which provide support for the development of programs written in assembly language (and BASIC as well). These utility programs work with the files which are input to and output from the editor, assembler, and linker during assembly-language program development.

The Editor/Assembler cartridge contains E/A utility programs which are used to print or display files, to convert files to various formats used by the CC-40 and other computers, and to transfer files. The utility programs include the following.

- A hexadecimal file-dump utility to permit output of the contents of any E/A file.
- A cartridge loader and an absolute-code loader which load—for subsequent execution—linked object files into CC-40 cartridge RAM or internal RAM.
- A cartridge-save utility which writes the contents of a RAM cartridge into a mass-storage file.
- Several file-conversion and -transfer utilities: programs which convert between E/A-format files and files from external computers, from the TI-990 assembler or linker, and CC-40 BASIC; and programs which provide for RS232 data transmission to transfer these files.

Hexadecimal Dump Utility (HEXDUMP)

The hexadecimal dump utility (HEXDUMP) outputs each byte in every record of a file as both a hexadecimal number and an ASCII character. Files which are output by the editor, the assembler, the linker, and other utility programs can be examined in detail.

Running the Hexdump Program

When **RUN "ALDS"** is entered in response to the BASIC cursor, a partial display of the E/A menu appears in the display as shown below.

```
E)dit A)ssemble L)ink B)asic?
```

Pressing the **[SPACE BAR]** shifts the window to show the three remaining E/A commands, as shown below.

```
H)ex dump D)ownload T)ransfer?
```

Pressing **H** while either part of the menu is displayed causes the CC-40 to run HEXDUMP. An `Input file` message prompts for entry of the name of the file to be dumped. After the source of the file is entered, an `Output file` prompt appears. After the destination is entered and the output device is opened, the prompt `Memory image file (Y/N)?` appears.

A **Y** response to the memory-image prompt causes the dump to be output in the order in which it appears in memory (from lower to higher addresses). An **N** response causes the dump to be output in the order in which it is read into memory from the mass-storage device (from higher to lower addresses).

Following the **Y** or **N** response to the memory image prompt, the dump begins. It continues until **[BREAK]** is pressed or until the last byte of the last record in the input file is printed or sent to an output file. If **[BREAK]** is being held down when an input/output operation occurs, HEXDUMP operation is interrupted with the prompt `BREAK, Continue (Y/N)?` Pressing **Y** causes the dump to continue. Pressing **N** causes the E/A menu to appear once more.

Use of Hexdump

The `Memory image file (Y/N)?` option provides for dumping both text files and machine-code files in the most readable order.

Each text area created by the E/A, to make most powerful use of the 7000-family DECD (decrement double register) instruction, has text and tokens stored from the top of the area downward in memory. (Mass-storage of an area has no effect on the order of bytes in text; bytes read back into memory are in the same order in memory as when they were written to a mass-storage device.) The result is that a text file, if it is viewed in the order of ascending memory locations, appears to be "backwards." An answer of N to the `Memory image file (Y/N)?` prompt causes the bytes to appear in "correct" order so that text displayed in the ASCII portion of the display is "readable."

In memory-image sequence, bytes from a machine-language record are output in the bottom-to-top order in which they are executed in memory. HEXDUMP outputs bytes stored at lower memory addresses first.

Each record output by HEXDUMP is preceded by a heading which lists the record number. The location of each byte in the record is referenced by column and row numbers respectively at the top and left of the hexadecimal area of the output.

Sixteen bytes of a record appear in each line of HEXDUMP output. The bytes are first output in two-digit hexadecimal values separated by spaces. Following the hexadecimal representations of the bytes, 16 ASCII representations of the bytes are output. When a byte cannot be represented by a printable ASCII character, a dot (period) is printed in its place.

A HEXDUMP output of the first and last four lines in a text file which contains the source code for the "BEEP" program appears in the following figure.

```
OPENED FILE:   1.SRC

RECORD    1

NUMBER    0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F
 0000 0F 00                                              ..

RECORD    2

NUMBER    0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F
 0000    43 4F 55 4E 54 45 52 20 20 20 45 51 55 20 20 3E   COUNTER  EQU >
 0010    35 44 20 20 20 20 20 20 20 20 20 20 20 43 4F   5D           CO
 0020    55 4E 54 45 52 20 4D 45 4D 4F 42 59 20 4C 4F 43   UNTER MEMORY LOC
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 0330    46 53 45 54 20 54 4F 20 4E 41 4D 45 00 20 20 20   FSET TO NAME.
 0340    20 20 20 20 20 20 20 42 59 54 45 20 30 2C 3E 34       BYTE 0,>4
 0350    34 20 20 20 20 20 20 20 20 20 20 48 45 41 44 45   4          HEADE
 0360    52 20 49 4E 46 4F 52 4D 41 54 49 4F 4E 00         R INFORMATION.
```

The >0F byte which begins record 1 indicates that the record is a header record. The header contains the single byte (a >00 file-type flag) which identifies the file as an uncrunched text file.

Record 2 contains the text of the source code. Note the null byte (>00) which separates each line within the record and the representation of the null byte by a dot, because it is an unprintable character.

See chapter 5 of this manual for comparison of the dump with the assembler-output listing of the source code for this file.

The following figure shows a complete HEXDUMP output of the tagged-object file output from the assembler when 1.SRC is assembled.

```
OPENED FILE:   1.OBJ

RECORD    1

NUMBER    0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F
 0000     0F 04 41 00 00 4E 4F 24 49 44 54 20 20 44 00 00   ..A..NO$IDT  D..
 0010     48 88 49 04 00 49 5D A2 49 01 15 49 52 1D 49 CA   H.I..I].I..IR.I.
 0020     FE 49 A2 00 49 15 52 49 20 CA 49 FE DB 49 5D E3   .I..I.RI .I..I].
 0030     49 EE 0A 49 50 45 49 45 42 48 04 4A 00 00 49 00   I..IPEIEBH.J..I.
 0040     00 49 FF FC 49 99 44 4C EA A8 4F                      .I..I.DL..O
```

Note that the tagged-object dump shows most of the code to be made up of fields containing "I" (absolute data) tags followed by two-byte words containing commands and data for the header. The initial >0F byte is a header identifier, and the >04 byte following it indicates that the file contains compressed tagged object code. The single-byte "O" tag identifies the end of the file.

See appendix E of the *CC-40 Editor/Assembler Reference Manual* for a complete description of the tagged-object code shown in this dump.

The following figure shows a dump of the linker output file as a single-record relocatable code file for loading as a subprogram under BASIC's CALL LOAD subprogram.

```
OPENED FILE:   1.BEEP    Memory image file

RECORD 1

NUMBER    0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F
 0000     00 04 00 1D 88 04 00 5D A2 01 15 52 1D CA FE A2 .......]...R.....
 0010     00 15 52 20 CA FE DB 5D E3 EE 0A 50 45 45 42 04   ..R ...]...PEEB.
 0020     00 00 00 00 FF FC 00 44
```

The ASCII columns of the dump show with significance only the subprogram name (stored "in reverse" by the RTEXT directive from the assembler). The hexadecimal columns show the most significant information: a four-byte relocation table at the start of the record and the machine code of the program. The relocation table begins with a two-byte word specifying the length of the table (including the length word itself) and contains a single offset to the only relocatable word—the program entry point in the header—in the code.

Hexdump Error

A record output by HEXDUMP must reside completely in memory. If not enough memory is available for loading the record, a `Memory full` error message is displayed. The E/A menu returns after any key is pressed.

Object-File Loaders

Two loader programs are present in E/A ROM: an absolute-code loader called ABSLOAD and a cartridge-RAM loader called CARTLOAD. Loading absolute programs anywhere in system or cartridge RAM requires ABSLOAD. Loading relocatable programs into RAM cartridges so that they can be run under BASIC requires the use of CARTLOAD.

Saving and Loading ABSLOAD and CARTLOAD

The CARTLOAD utility cannot be run while the Editor/Assembler cartridge is being used, and the ABSLOAD utility cannot be used to load RAM cartridges while the Editor/Assembler cartridge is in place. The Editor/Assembler cartridge overlaps much of the area of memory into which programs might be loaded. Therefore, loaders must be "downloaded" (saved from the cartridge) to mass-storage media for later loading under BASIC when the Editor/Assembler cartridge can be replaced by a RAM cartridge.

The `D)ownload` option in the E/A menu provides the means for saving the loaders (and also the MEMSAVE utility described below). The loaders are saved as single-record subprograms containing relocatable object code for loading by BASIC with the CALL LOAD subprogram.

From the E/A menu, **D** is pressed (as prompted by the second part of the E/A menu). The downloader menu, shown below, then appears.

```
M)emsave A)bsload C)artload
```

The loader to be saved to a mass-storage file is selected from the downloader menu. The `Output file` prompt then requests the name of the file in which the loader is to be stored.

With the loader code in a mass-storage file, CC-40 cartridge RAM can replace the E/A ROM cartridge, and the loaders can be loaded into CC-40 internal RAM by a BASIC CALL LOAD subprogram, as in the following examples.

```
CALL LOAD("1.ABSLOAD")
```

or

```
CALL LOAD("1.CARTLOAD")
```

Absolute-Code Loader

Programs produced by the linker in absolute code are loaded into internal RAM or cartridge RAM by the absolute loader.

After the absolute loader is copied from mass-storage by the CALL LOAD subprogram, it is run from BASIC with the CALL command, exemplified by the following.

```
CALL ABSLOAD("1.PROG")
```

When the BASIC cursor returns (provided that there are no I/O errors reported and that the BASIC environment has not been altered by the loaded program), the absolute-code program is present in memory at the address set during assembly or linking. The program can then be executed from BASIC by an EXEC subprogram such as the following, in which the entry address (the decimal equivalent of >9000, is given as the argument for the command.

```
CALL EXEC (36864)
```

The following table explains error messages which may appear in the display when ABSLOAD is executed.

ABSLOAD ERROR MESSAGES

Illegal syntax	Bad syntax in the assembly language call,
Can't do that	An absolute address of the program conflicts with the memory space used by ABSLOAD.
Bad program type	The input file is not in absolute format.

Cartridge Loader

The cartridge loader loads relocatable assembly language programs and subprograms into cartridge RAM to reside within >5000 through >CFFF.

The cartridge loader initializes CC-40 RAM cartridges and loads relocatable code developed by assembly-language programs and subprograms into cartridge RAM. The cartridge loader consists of two subprograms, CARTINIT and CARTLOAD.

The CARTINIT Subprogram

The CARTINIT subprogram is called from BASIC with the name of the file to be loaded inside of double quotes which are inside of parentheses, as in the following.

```
CALL CARTINIT("1.EXAMPLE")
```

The file must be in multiple-record, relocatable format.

The primary purpose of CARTINIT is to load and relocate a machine-code cartridge header into cartridge RAM at >9000. This header enables BASIC to access programs and subprograms in a cartridge by pointing to the first of the programs the cartridge contains.

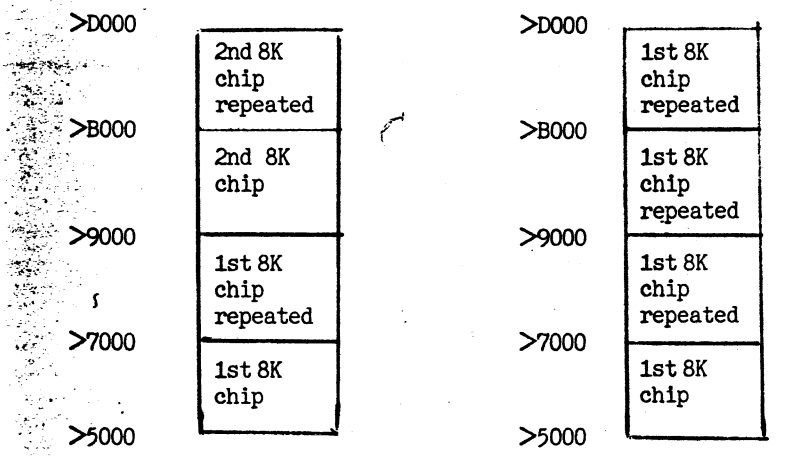
The file loaded by CARTINIT can also contain one or more programs linked together by offsets in their individual program headers. In the cartridge header, the pointer to the first program must be initialized with the program-header address, and the offset in the header of the last program must be initialized with >0000. If no programs are included in the file, the pointer in the header is initialized with >0000.

The following source program illustrates the relationship of cartridge and program headers. A complete explanation of headers is included in chapter 1 of the *CC-40 Editor/Assembler Reference Manual.*

```
BYTE    >A5,>5A     Tell BASIC that a cartridge is present
BYTE    >81         16K cartridge; version 1
BYTE    >1E         Cartridge access speed set to 3 micro-
                    seconds
DATA    SUB1        Pointer to header of first subprogram
DATA    0           Reserved
DATA    TOPCART     Pointer to next RAM location for load-
                    ing
DATA    >5000       Pointer to lower next RAM location
                    for loading

* ASSEMBLY LANGUAGE PROGRAM (SUBROUTINE)

ENTRY
   MOV     A,B      A trivial program for illustration

* ASSEMBLY LANGUAGE PROGRAM HEADER

NAMLOW
    RTEXT       'SOMNAME'           Subprogram name
    BYTE        NAMHGH-NAMLOW       Length of the subprogram
                                    name
                NAMHGH              EQU $-1
    DATA        ENTRY               Pointer to entry point
    DATA        0000                Offset to next program/sub-
                                    program header
    DATA        NAMHGH-$+1          Offset to name
    BYTE        0,>44               Program-type information
    SUB1        EQU $-1
    TOPCART     EQU $               First free byte in cartridge
```

The name of the program in each program header must be assembled from upper-case (all-capitals) letters for BASIC to find it.

Cartridge RAM addressing is dependent on the type of cartridge being used and the size of the memory chips used in it. The illustration below shows the address blocks corresponding to RAM chips currently available in cartridges.



16K CARTRIDGE RAM 8K *CONSTANT MEMORY*™ CARTRIDGE

With a 16K cartridge, RAM is available in two 8K blocks beginning at >5000 and >9000. With a *Constant Memory*™ cartridge, a single 8K block at >9000 is available.

The CARTLOAD Subprogram

Loading programs into a cartridge after the cartridge header (and perhaps other programs) have been loaded requires CARTLOAD. Information in the cartridge header and in the header of any last program already loaded is updated by CARTLOAD. The subprogram is called from BASIC as in the following example.

```
CALL CARTLOAD("1.PROG5")
```

The pointer at >9004 in the cartridge header points to the header of the first program or subprogram in the cartridge. The program header for the first program, in turn, contains an offset which points to the header for the next program. The program header for the last program in the cartridge contains >0000 in the offset word. In this manner, the cartridge header and program headers taken together contain a linked list of programs stored in the cartridge. CARTLOAD loads in any new program or programs, relocates them appropriately for execution at their current addresses, and patches the offset of the (first) header in the new program(s) to replace the >0000 offset in the header of the program which had been the last one in the list. The new program(s) must contain >0000 in the offset of the (last) header to indicate the new end of the list.

All files loaded by the cartridge loader must be in relocatable multiple-record format produced by the linker M command. An attempt to load an absolute file or a single-record relocatable file causes a `Bad program type` error.

If memory is unavailable for loading a program into cartridge RAM from >9000 through >CFFF, the loader attempts to load the program in RAM from >5000 through >9000.

In addition to I/O errors, five other types of errors are identified by messages from CARTLOAD and CARTINIT, as shown in the following table.

CARTLOAD AND CARTINIT ERROR MESSAGES

`Illegal syntax`	Bad syntax in the assembly language call
`Can't do that`	Missing cartridge header
`Bad program type`	Input file is not a multiple-record relocatable file
`No RAM in cartridge`	No RAM in the cartridge
`Memory full`	Insufficient space in system RAM for the relocation table or in the cartridge for the program

Cartridge-Save Program (MEMSAVE)

The cartridge-save utility MEMSAVE saves a block of memory as a multiple-record absolute file for later loading by the absolute loader. All of the programs which are loaded into a RAM cartridge can be saved as a block with beginning and ending addresses provided in the MEMSAVE command. Blocks containing code from ROM or the register-file area cannot be saved by MEMSAVE.

Like ABSLOAD and CARTLOAD, MEMSAVE cannot be used to save data from cartridge RAM while the Editor/Assembler cartridge is in the CC-40. Downloading MEMSAVE follows the procedures used in downloading the two loaders (see "Saving and Loading ABSLOAD and CARTLOAD," above).

When MEMSAVE has been loaded by BASIC with the CALL LOAD subprogram, the program is run with a CALL command which specifies a filename, a beginning address, an ending address, and a record length. If a record length is not included, the file is saved as a single record. The following command, for example, saves the 8-kilobyte block from >9000 through >AFFF in records of 256 bytes.

```
CALL MEMSAVE("1.HICART",">9000,>AFFF",256)
```

Address values are entered by hexadecimal numbers within quotes and separated by commas. The ">" sign is optional. Record lengths are in decimal.

In addition to I/O errors, four other types of errors are identified by messages from MEMSAVE, as shown in the following table.

MEMSAVE ERROR MESSAGES

`Illegal syntax`	Bad syntax in the assembly language call
`Can't do that`	Attempt to save block from ROM memory or the register-file area (>0000 to >0200) to a mass-storage file; also attempt to save block which does not contain RAM
`Bad value`	1. Record length specified in filename is either negative or greater than 32767 2. Non-hex characters were used in addresses provided with the MEMSAVE command 3. Hexadecimal value in an address is greater than >FFFF
`Bad argument`	Starting address is greater than the ending address

File Conversion and Transfer Utilities

The following utility programs are provided to convert between files with E/A format and files of other formats (BASIC, 990) and to transfer files to the CC-40 from external computers.

- Multiple-record to single-record relocatable files
- List file to E/A text file
- External-computer text files to E/A text files
- 990 tagged-object to E/A tagged-object files
- BASIC program image to E/A text file
- E/A test file to BASIC program image

Multiple- to Single-Record File Conversion Utility (CONVERT)

The utility program called CONVERT reformats a file saved as multiple records of relocatable object code into a single-record relocatable file. Multiple-record files can, after this conversion, be loaded and run directly under BASIC.

The conversion program is accessed from the E/A menu by typing C. No prompt appears in the E/A menu for CONVERT.

The prompt `Input file` requests the name of the multiple-record relocatable object file to be converted. The prompt `Output file` then requests the name of the single-record object file to be written.

In addition to I/O errors, CONVERT identifies two other types of errors by the messages shown in the table below.

CONVERT ERROR MESSAGES

`Bad program type`	The input file is not a multiple-record relocatable object-code file
`Length error`	The input file is of incorrect type or it contains a header with incorrect block size

File Transfer Utility (TRANSFER)

The utility program called TRANSFER permits the CC-40 to perform three file transfer operations. It can input a list file with records of 80 or fewer bytes from one *HEX-BUS*™ mass-storage device and write it to a file on another *HEX-BUS* device. A list file contains lines of printable ASCII text without end-of-line bytes.

The TRANSFER utility can also input a file from an external computer and convert it to an E/A text file on a mass-storage device. In addition, it can input files containing TI-990 tagged-object code and convert them to E/A tagged-object format.

Text Transfer from One Device to Another

The transfer utility program is accessed by pressing T in response to `T)ransfer` from the E/A menu.

The message `S)ource O)bject` prompts for input to determine whether a standard text or 990 tagged-object code is to be received.

Next, **TRANSFER** issues the prompt C)runch U)ncrunch. If **C** is pressed, the file to be output is set to be in crunched (tokenized) form. If **U** is pressed, the file is output in the same form in which it is input.

When the Input file prompt appears, the name of the file to be transferred is entered.

The Handshake (Y/N)? prompt appears to permit using communications protocol with computers external to the CC-40. For CC-40 device-to-device transfer, **N** is pressed to use internal *HEX-BUS*™ protocol.

Next TRANSFER displays an Output file prompt. The name of the file to receive the text is entered. An optional record length can be specified following the name by typing a space and R = NNNN.

The message Transferring... appears in the display until the file copying is complete and the E/A menu returns to the display.

Text Transfer from an External Computer

The computer from which the file is being transferred must be programmed to send the file with the format and protocol required by TRANSFER. The listing shown below provides an example of such a program written in BASIC. The program uses handshaking (line 150) to determine when to send the next line; no echo is provided to the display. An asterisk (*) is sent by TRANSFER each time it is ready to receive an 80-character line. An end of the file is recognized by TRANSFER when it receives an ASCII >7F or 127 (DEL).

```
100 OPEN #2:"RS232.BA=4800.EC" • Open RS232, no echo
110 INPUT "File download utility Enter file name: ":NAME$
120 OPEN #1:NAME$              • Open input file
130 LINPUT #1:TXT$             • Get line from source
                                 file
140 PRINT #2:SEG$(TXT$,1,80);  • Transfer first 80 charac-
                                 ters
150 INPUT #2:HSK$              • Get clear to send
                                 character (handshake)
160 IF EOF(1)=0 THEN 130       • If not end of file,
                                 continue
170 PRINT #2:CHR$(127)         • Signal end of trans-
                                 mission
180 CLOSE #1                   • Close source
190 CLOSE #2                   • Close RS232
```

For transfer of files external to the CC-40, the prompts through C)runch U)ncrunch are answered as they are for CC-40 internal file-to-file copying. When the prompt Input file appears, however, the number of the device (and characteristics such as RS232 transmission speed) through which the text is to be transferred must be provided.

The prompt Handshake (Y/N)? appears. When **Y** is pressed, TRANSFER is set to send an "*" character to the external computer when it is ready to receive text. Without handshaking, data is lost during transfer operations.

Next, the prompt `Echo? (Y/N)?` appears. Responding **Y** to the prompt causes the CC-40 to expect the external computer to echo the handshaking character upon receipt.

When TRANSFER displays an `Output file` prompt, the name of the file in which received text is to be stored is entered.

With TRANSFER running, the message `Ready...` must appear in the display before the external computer begins to transmit. With reception of the first character from the external computer, the message `Transferring...` closes the file and the E/A menu returns to the display.

TI-990 Tagged-Object File Transfer

When TRANSFER is to receive TI-990 tagged-object code files from an external computer, all prompts except one are answered as above. The `S)ource O)bject` prompt is answered by pressing **O**.

After 990 code is received and before TRANSFER writes it to the output file, the code is converted to E/A format tagged-object code.

The table below shows the correspondence between 990 tagged-object format and the tagged-object format output by the E/A assembler.

The primary difference between 990 and E/A format is that the 990 assembler always outputs uncompressed tagged-object code while the E/A assembler always outputs compressed tagged-object code. Code in E/A format has bytes and words represented directly in binary values, while code in 990 format has bytes and words represented in ASCII characters. In E/A format, a byte of data with a value of 32 is represented in a two-byte field containing an ASCII "H" tag and a binary >20 value. In 990 format, the same byte is represented in a three-byte field containing an ASCII "*" tag, an ASCII "2," and an ASCII "0."

Most tags, although designated by different characters, have similar functions in both formats. Tags which do not have the same functions are noted with a ".." in the table.

Differences in the content of files are primarily in the expression of symbols expressing assembled DEF and REF directives. Both DEFed and REFed symbols from the 990 linker are fixed-length six-character symbols with spaces to the right of symbols containing fewer than six characters. The E/A assembler produces symbols which are one to eight characters long with a length byte preceding the symbol. The length byte has a value of one less than the number of characters in the symbol. The 990 REFs also contain an unused word that is not stored in CC-40 linker format.

CORRESPONDENCE 990 AND E/A TAGGED OBJECT CODE

990 Tag	E/A Tag	Value	Description
..	A	Word Program ID	Cartridge indentifier-Compressed Word = Highest relocatable address
K	..	Word Program ID	Cartridge indentifier-Uncompressed Word = Highest relocatable address
0	..	Word Program ID	Cartridge indentifier-Uncompressed Word = Highest relocatable address
..	B	Reserved	Reserved tag
9	C	Word	Absolute load address
A	D	Word	Relocatable load address
..	E	Byte Symbol	REFed symbol byte = symbol length – 1
3	..	Word 990-symbol	REFed symbol (Ignore Word)
4	..	Word 990-symbol	REFed symbol (Ignore Word)
..	F	Byte Word Symbol	Absolute DEFed symbol Word = symbol value, Byte = symbol length – 1
6	..	Word 990-symbol	Absolute DEFed symbol Word = symbol value
..	G	Byte Word Symbol	Relocatable DEFed symbol Word = symbol value, Byte = symbol length – 1
5	..	Word 990-symbol	Relocatable DEFed symbol Word = symbol value
*	H	Byte	Absolute byte of data
B	I	Word	Absolute data
C	J	Word	Relocatable data
E	K	Word1 Word2	External reference Word1 = Reference number Word2 = Value added to reference
7	L	Word	Checksum
8	M	Word	Ignore checksum
F	N		End of record
:	O		End of file

Value definitions

Word	= 16 bit value	Symbol	= 1..8 ASCII characters
Byte	= 8 bit value	Program ID	= 8 ASCII characters
		990-symbol	= 6 ASCII characters

Transfer Utility Errors

In addition to I/O errors, TRANSFER identifies four other errors with messages listed in the following table.

TRANSFER ERROR MESSAGES

`Invalid module`	The first tag in a 990 file is not a "K" or "0" (IDT) tag.
`Duplicate module`	A second IDT tag has been found.
`Invalid value`	An ASCII character which is not a valid hexadecimal digit is present in a data field.
`Invalid tag`	An ASCII character which is not a valid 990 tag appears where a valid one should appear.

BASIC to E/A Text Utilities (SAVEA and COPYA)

Two utility programs called SAVEA and COPYA permit using the E/A screen editor to edit BASIC program files.

For saving a program currently in BASIC program memory in E/A format, SAVEA is used. From BASIC, with the Editor/Assembler cartridge in the CC-40, SAVEA produces a file named "BASPROG" on device 1 in 128-byte records when the following command is entered.

```
CALL SAVEA("1.BASPROG",128)
```

The SAVEA utility cannot be called from within a BASIC program. The name of the file must be typed in double quotes, and the filename and optional record length must be enclosed in parentheses. If no record length is specified, SAVEA selects a length as great as free memory permits.

The COPYA utility permits BASIC to copy an E/A text file into memory in BASIC format. The E/A-format "BASPROG" file from device 1, for example, is read into program memory by BASIC with the following command.

```
CALL COPYA("1.BASPROG")
```

The COPYA utility cannot be called from within a BASIC program. The name of the file must be entered inside double quotes which are enclosed in parentheses.

In addition to I/O errors, errors occurring during SAVEA and COPYA cause the messages listed in the following table to appear.

CHAPTER 7
E/A UTILITY PROGRAMS

SAVEA AND COPYA ERROR MESSAGES

`Illegal syntax`	Bad syntax in the assembly language call
`Protection violation`	Attempt to save a protected BASIC program (SAVEA only)
`Illegal in program`	SAVEA or COPYA is called from within a program
`Bad value`	Specified record length is either negative or greater than 32767
`Bad program type`	Attempt to load other than an uncrunched E/A text file

E/A File-Transfer and Conversion Summary

The following figure summarizes the transfer of files among various E/A programs and external computers.

E/A text format consists of one or more lines per record with a maximum of 74 characters in a line and each line terminated by a zero.

External text format consists of single-line records with the record length fixed at 80 characters (using trailing spaces as necessary).

CHAPTER 8
DEBUG MONITOR

This chapter describes the DEBUG Monitor and gives an example of the use of the monitor to alter and run a machine-language program.

The DEBUG Monitor allows examination, modification, and controlled execution of machine-language programs which have been developed by the E/A package.

The monitor permits displaying and modifying data in memory, moving blocks of data in memory, executing programs until preset breakpoints are reached, and executing programs in steps of single machine-code commands.

The BASIC and DEBUG Monitor operating environments (RAM locations) are compatible. An E/A-developed program called from a BASIC program, for example, can have breakpoints set by DEBUG; when the BASIC program is run and CC-40 control is transferred to the machine-language subroutine, the breakpoints cause the monitor to be entered. All elements supporting BASIC program execution remain intact, and the machine-language and BASIC programs can resume when use of the monitor is complete.

Running the DEBUG Monitor

The DEBUG Monitor is entered by a CALL DEBUG BASIC interpreter command or a CALL DEBUG statement line in a BASIC program. The monitor prompts with a colon (:) for single-letter commands and appropriate values.

Monitor Commands

Keyboard-entered command lines which control DEBUG Monitor operation consist of a single-character uppercase or lowercase alphabetic command followed by any required numeric values and **[ENTER]** or **[SPACE BAR]**. Multiple values are separated by a single space.

Command values are expressed in hexadecimal or decimal numbers. Decimal values must be preceded by a period; numbers without a period in front of them are evaluated as hexadecimal values. The symbol for hexadecimal value is not used in the DEBUG Monitor. Values greater than 65535 or >FFFF are truncated to the left. All displayed values are in hexadecimal form.

For command-line editing, the ← and → keys position the cursor over any character entered except a period. At any time during command-line entry, the **[BREAK]** key can be pressed to clear the line and return to monitor command level (with the ":" prompt displayed). When the DEBUG Monitor encounters an error in a command line, it clears the display and prompts again with `WHAT:`.

Display-Memory Command: D

The display-memory command causes the content of eight bytes of memory beginning at the starting address expressed in the command to appear in the display. Display of the contents of subsequent eight-byte blocks of memory is caused by pressing + or **[SPACE BAR]**. Display of the contents of previous eight-byte blocks of memory is caused by −. Further display terminates when **[ENTER]** is pressed.

Because 7000-family data registers are in memory, the display-memory command can be used to display registers in the general purpose file (>0000 through >007F) or the peripheral file (>0100 through >01FF).

The syntax of the display memory command is shown below.

Enter: **D NNNN**

Note: Values may be entered in either decimal or hexadecimal. Entering **D** without a value is equivalent to **D 0000**.

Memory-Modify Command: M

The memory-modify command permits display and keyboard entry of single-byte memory contents.

The value stored at the address specified in the command is displayed. (The default for the modify-memory command starting address is >0000, the A register.) If a new value is entered, the value replaces the value displayed. If + or **[SPACE BAR]** is pressed following display of the memory contents or following entry of a replacement value, the contents of the subsequent address are displayed. If – is pressed at either time, the contents of the previous address are displayed. The command terminates when **[ENTER]** is pressed at either time.

Contents of the registers can be easily examined and modified by the memory-modify command because they are addressed as memory registers. General-purpose file registers 0 through 127 are addressed as memory locations >0000 through >007F, and peripheral file registers 0 through 255 are addressed as locations >0100 through >01FF.

The syntax of the memory-modify command is shown below.

Enter: **M NNNN**

Note: Values can be entered in decimal and hexadecimal. Entering **M** without a value is equivalent to **M 0000**.

Processor-Register Modify Command: P

The processor-register modify command permits the three registers in the processor, the program counter (PC), status register (ST), and stack pointer (SP), to be displayed and modified in much the same manner in which the contents memory locations are modified. The modification is effective with the next E (execute) or S (single-step) command.

After **P** has been pressed, the value stored in the current DEBUG Monitor program counter (PC) is displayed. If a value is then typed in at the keyboard, it becomes the new DEBUG Monitor PC, which specifies the point in the program at which the program begins execution with the next execute (E) or single-step (S) command. If **[SPACE BAR]** is pressed in response to the PC display or in termination of the new PC value, the contents of the status register (ST) are displayed. If a value is typed, it becomes the new ST after the next E or S command; pressing **[SPACE BAR]** or terminating the new ST value with [SPACE BAR] causes the stack pointer (SP) to be displayed. If a value is entered it becomes the new SP with the next E command.

Pressing **[ENTER]** or terminating any new value with **[ENTER]** at any time terminates the command (but retains any values entered).

The modify-register command can display and prompt for all three register values, as shown below.

Press: **P**

Displays: PC=MMMM
ST=PP
SP=RR

Note: Proceed from one display to the next by pressing **[SPACE BAR]** or exit from the P command by pressing **[ENTER]**. To alter any of the values in the displayed registers, type the new value and press either **[ENTER]** or **[SPACEBAR]**. Values may be entered in either decimal or hexadecimal.

Copy-Memory Command: C

The copy-memory command causes the contents of one block of memory to be moved to another block. One byte is moved and the source and destination addresses are incremented by one. The single-byte moves continue for the length specified in the command. If the destination address is less than or equal to the source address plus the length of the move, blocks can overlap.

The overlap feature of the copy-memory command can effect a "fill memory" operation. When an initial "fill" character is stored by a modify-memory command (M) at the beginning of a source block and the start of the destination block for the move is set one byte higher, the whole block is filled with the character.

The syntax of the copy memory command is shown below.

Enter: **C NNNN MMMM PPPP**

Note: NNNN-PPPP may be entered in either decimal or hexadecimal. **NNNNN** specifies the address of the first byte to move. **MMMM** specifies the address into which the first byte is moved. **PPPP** specifies the number of bytes to move.

Execute Command: E

The execute command transfers processor control to the program location specified by the DEBUG Monitor program counter (set by the P command, described above).

The E command must be followed by **[ENTER]**. If **E** is pressed accidentally and **[ENTER]** has not been pressed, pressing **[BREAK]** causes the command to be ignored.

Any new system- or cartridge-memory page selection (see R command, below) or new status register or stack-pointer value takes effect with the E command.

The syntax of the execute command is shown below.

Enter: **E**

Note: No parameters are used with the execute command. The address at which execution begins is the address in the DEBUG Monitor program counter.

Breakpoint-Modify Command: B

The breakpoint-modify command, in a manner like the memory-modify and register-modify commands, displays the current breakpoints and permits the assignment of new addresses to them. Breakpoints are addresses at which program execution is halted so that the DEBUG Monitor commands can be used to examine memory and register contents at that point in the program. Breakpoints can only be used with programs which are stored in RAM, and they should not be set at the current program-counter value.

When the DEBUG Monitor is reentered after a program reaches a breakpoint, both breakpoints are turned off.

Breakpoints are set for particular addresses by the breakpoint-modify command. After being set, either of the two breakpoints can be turned off by entering >0000 for an address in the breakpoint-modify command.

A breakpoint remains in effect until it is cleared with a breakpoint-modify command or until the processor "executes" it.

The syntax and procedure used with the breakpoint-modify command are shown below.

Press: **B**

Displays:
```
B MMMM
  PPPP
```

Note: MMMM and **PPPP** are addresses at which program execution is to be halted for memory and register examination and modification. Proceed from one display to the next by pressing **[SPACE BAR]** or exit from the B command by pressing **[ENTER]**. To alter any of the displayed breakpoints, type the new value and press either **[ENTER]** or **[SPACEBAR]**. Values may be entered in either decimal or hexadecimal.

ROM-Page Modify Command: R

The ROM-page modify command permits setting the cartridge (addresses >5000 through >CFFF) page and the system ROM (addresses >D000 through >FFFF) page to any page from 0 through 3.

Pressing **[SPACE BAR]** after display or modification of the cartridge page causes the system-ROM paging prompt to be displayed. Pressing **[ENTER]** terminates the page-modify command without display of the system-ROM page-modify prompt.

The cartridge page-modify command takes effect immediately. The DEBUG Monitor commands used to display ROM or RAM, modify RAM, set breakpoints in RAM, and other functions use the page which has been set. The system-ROM page-modify command takes place only after an execute (E) command is entered. All commands except E reference the page from which the DEBUG Monitor runs, page 3. Displays of system ROM are, for example, always from page 3. An address in system ROM at which execution is to begin, however, is on the page last selected.

The syntax and procedures used with the page-modify command are shown below.

Press: **R**

Displays:
```
CARTRIDGE PAGE=M
SYSTEM PAGE=P
```

Note: Proceed from one display to the next by pressing **[SPACE BAR]** or exit from the R command by pressing **[ENTER]**. To alter any of the displayed page numbers, type the new page number and press either **[ENTER]** or **[SPACE BAR]**. Page numbers are within the range 0–3. The cartridge page number displayed (M) is currently in effect, but the system page number displayed (P) is only in effect upon exit from the DEBUG Monitor.

Single-Step Command: S

The single-step command causes only the single processor command at the location in the program counter (PC) to be executed. After command execution, program control returns to the monitor for subsequent examination or modification of registers and memory, single-stepping, and so on. The effect of the single-step command is as if a breakpoint were set at the command following the one pointed to by the DEBUG Monitor program counter. One consequence of the way the single-step command operates is that an instruction which jumps or branches to itself cannot be single-stepped. Another effect is that single-step operation cannot be used with programs in ROM or during calls to subroutines in ROM.

Execution of a single-step command turns off both breakpoints.

Single-step command syntax is shown below.

Enter: **S**

Note: No parameters are used with the single-step command. The address of the instruction executed is the address in the DEBUG Monitor program counter.

The Quit Command: Q

The quit command causes the CC-40 to exit the DEBUG Monitor and reenter BASIC in one of two ways. The BASIC program being executed when the CALL DEBUG instruction was encountered can be resumed with a QB instruction, or BASIC can be restarted at the command-interpreter level with a QI instruction.

The syntax of the quit command is shown below.

Enter: **QI** or **QB**

Note: QI returns the CC-40 to the command level of the BASIC interpreter, and QB returns the CC-40 to any program running under BASIC.

The Help Command: ?

The help command displays all of the command codes used by the DEBUG Monitor. Use the help command as shown below.

Enter: **?**

Display: `COMMANDS= Q,B,E,M,C,S,D,P,R`

Note: The help command displays the codes until **[ENTER]** is pressed.

DEBUG Monitor Operation Concepts

When the DEBUG Monitor is called from BASIC by a CALL DEBUG command or program statement, it sets up the last 80 bytes of the BASIC program-line crunch buffer (>0900 through >094F) for temporary storage; therefore anything stored in this area is overwritten. The colon (:) is the display prompt while the monitor is active.

Setting a breakpoint in a program location causes the DEBUG Monitor to save the command and to place a single-byte TRAP 11 command (command code >F4) at the location specified. (The bytes replaced by TRAP 11 commands for both breakpoints and their addresses are stored in >08F4 through >08F9.)

The program containing the breakpoint executes all machine-language commands until the TRAP 11 is read. The TRAP 11 command causes the DEBUG Monitor to be reentered at a point at which both breakpoints are cleared and the original command is restored to its memory location.

Storing a TRAP 11 in memory through a modify-memory instruction has the same effect as setting a breakpoint, with one very useful difference: the directly-stored TRAP 11 is not cleared upon return to the monitor. The breakpoint remains set for future use after control is transferred to the monitor.

The following events occur when a breakpoint is encountered.

1. The program counter, current status, registers A and B, current ROM page, and two reserved bytes are pushed onto the stack. The stack used for saving these values is the stack set by the program being executed; therefore, the design of programs to be debugged with breakpoints or single stepped must account for eight additional bytes being pushed onto the stack.

2. R0-R53 and R83-R103 are saved in the crunch buffer (along with five other bytes of temporary data).

3. Both breakpoints are cleared.

4. The program counter, status register, and stack pointer are displayed (followed by a colon as the prompt which indicates return to the DEBUG Monitor).

Breakpoints remain active (as long as either or both are not equal to 0) when BASIC is reentered from the DEBUG Monitor. When the machine-language program is executed by calling it from BASIC and a breakpoint is reached, the monitor is called.

Breakpoints are not cleared when the DEBUG Monitor is reentered from BASIC with a CALL DEBUG. Breakpoints are, however, cleared when the single-step command is entered. When the CC-40 is initialized, breakpoints are cleared.

DEBUG Monitor Use with an E/A-Developed Program

The "BEEP" program developed in chapter 1 of this guide contains no relocatable addresses in the executable code. It can therefore be entered for execution at any memory location that does not destroy BASIC or DEBUG Monitor RAM. The figure below shows a memory image of the executable code in "BEEP" with addresses beginning at >1000.

ADDRESS	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
1000	88	04	00	5D	A2	01	15	52	1D	CA	FE	A2	00	15	52	20
1010	CA	FE	DB	5D	E3	EE	0A									

Entering the Machine-Language Program

The following steps show how to use the DEBUG Monitor to enter and display the "BEEP" machine-language program.

STEP 1: In response to the BASIC command prompt, type in **CALL DEBUG**.

STEP 2: When the MONITOR: prompt appears, type in the modify-memory command **M 1000** (the monitor inserts the space after "M").

STEP 3: Type in each of the 23 bytes of the machine-language program exactly as they appear above. After each byte until the last is typed, press **[SPACE BAR]**. After the last byte is typed, press **[ENTER]** to return the DEBUG monitor command ":" prompt to the display.

STEP 4: Type in **D 1000** to display the first eight bytes of "BEEP," and verify each byte with the commands listed above. Note the values and memory locations of any incorrectly entered bytes.

STEP 5: Press + to display the second eight bytes for verification. Again note the locations of incorrect bytes.

STEP 6: Press + again, and verify the first seven of the third eight-byte display.

STEP 7: With verification done, press **[ENTER]** to return to the ":" prompt.

STEP 8: If any incorrect bytes have been found, use the addresses of these bytes with the M command to correct them.

The machine code "BEEP" program is now entered into memory.

Testing the "BEEP" Program

The "BEEP" program is executed by setting the program counter in the 7000-family processor to the entry point of the program (>1000). When the program executes the return from subrouting (RETS) command (>0A in the memory-image dump), program control is returned to BASIC. When a breakpoint is set at >1016, control returns to the DEBUG Monitor. The following steps show how to execute the "BEEP" program and return control to both BASIC and the DEBUG Monitor.

STEP 1: Press **P** to modify the program counter in the processor. The display shows the current value of the counter in the form: PC=NNNN.

STEP 2: Type 1000 to set the program counter to >1000, the entry point of "BEEP."

STEP 3: Press **E** to execute the program and return to BASIC.

STEP 4: After the beeper has sounded and the BASIC cursor appears, type in the **CALL DEBUG** command to once more enter the monitor.

STEP 5: When the MONITOR: prompt appears, press **P** and enter 1000, as in step 2, to once again set the program counter to the start of the "BEEP" program.

STEP 6: Type **B** and **1016** to set a single breakpoint at >1016.

STEP 7: Execute the program by pressing **E**.

STEP 8: After the beeper sounds, the breakpoint address, the value in the status register, and the value in the stack pointer appear in the display followed by the ":" prompt.

Modifying the "BEEP" Program Machine Code

The sound emitted by the beeper is controlled by values entered into registers (Review figure 5-1 for exact details of how the program works). The registers are decremented to zero to establish the duration of the sound, and the period of the electrical impulses are sent to or withheld from the beeper to establish the frequency of the sound.

In the "BEEP"program machine-language commands listed above, the immediate value loaded into >1001 and >1002 controls the duration of the sound. The values at >1008 and >100F control the pitch of the sound. The value at >1008 controls the period in which electrical current is sent to the beeper, and the value at >100F controls the period in which no current is sent.

Changing the value in >1001 and >1002 to a lower value shortens the duration of the beep. Changing it to a higher value lengthens the sound. Changing the >0400 value in these locations to >0080 produces a short, crisp beep. Changing the value to >FFFF causes the beep to last longer than 30 seconds.

Changing the immediate values in >1008 and >100F to lower values raises the pitch of the sound, and increasing the values lowers the pitch. A value of >10 at each location provides a noticeably higher pitch, and a value of >60 in each register provides a noticeably lower pitch.

Figure 4-1

LINE EDITING COMMAND SUMMARY

AUTO	Begin automatic line numbering with line 1
AUTO 100	Begin automatic line numbering with line 100, or if text contains line 100 begin insertion
COPY 120.XYZ	Load or insert file "XYZ" from device 120 into RAM at the beginning of the text area
COPY 120.XYZ 10	Insert file named "XYZ" from device 120 into the current memory text before line 10
COPY 120.XYZ 1000	Append file named "XYZ" from device 120 to current text of less than 1000 lines
DEL)ETE 25	Delete line 25
DEL)ETE 25-30	Delete lines 25 through 30
DEL)ETE 25-	Delete line 25 and all following lines
DEL)ETE -25	Delete all lines up to and including line 25
DEL)ETE ALL	Delete text without copying to recover buffer
E)DIT 38	Display line 38 for line editing
F)IND .XX.	Find the next occurrence of "XX" and display it
F)IND W .XX.	Find the next occurrence of "XX", "Xx", "xX", or "xx" and display it
FORMAT 2	Initialize the media in device 2
LINE ENTRY COMMANDS	
100 This[ENTER]	With ">" showing, enter the string "This" into text line 100 or replace the line currently at position 100 of the text with the string "This"
100+This[ENTER]	Enter (insert) "This" into new line 101
100-This[ENTER]	Enter (insert) "This" into new line 99
100 This[Up Arrow]	While editing, enter "This" as line 100 and thereafter display line 99
100 This[Down Arrow]	While editing, enter "This" as line 100 and thereafter display line 101
LIST	List memory text line-by-line to display
LIST 250-	List text lines 250 and following
LIST -250	List text lines through line 250
LIST "20"	List text to device number 20
LIST "120.DATA"	List lines to a file named "DATA" on mass-storage device 120
LIST "20" 50-	List lines 50 and following to device 20
LIST "120.A" -50	List lines through 50 in file named "A" on mass-storage device 120
MOVE 1-10,21	Move the first 10 lines of the text so that they become the second ten
MOVE 20-,1	Move lines 20 and following so that they become the first block of lines in the text
QUIT	Leave line editing and return to edit menu
R)EPLACE .XX.YY.	Replace the next occurrence of "XX" with "YY"
R)EPLACE W .XX.YY.	Replace the next occurrence of "XX", "Xx", "xX", or "xx" with "YY"
R)EPLACE V .XX.YY.	Replace the next occurrence of "XX" with "YY" after verifying
R)EPLACE A .XX.YY.	Replace all subsequent occurrences of "XX" with "YY"
R)EPLACE AWV .XX.YY.	Replace as above with all three options in combination

SAVE 120.TABLE	Save the current memory text to device 120 with the file name "TABLE" in a single record
SAVE 120.TABLE R=0	Save "TABLE" to device 120 in record size of 80!
SAVE 120.TABLE R=>FF	Save the text as "TABLE" on device 120 with a record size of 255
UNDO	After line modification, replace the modified line with the original or after deletion restore deleted lines to the text
VERIFY 120.ABC	Compare the memory text with the file named "ABC" on device 120; issue message if the text and the file are different

Figure 4-2

SCREEN EDITING COMMAND SUMMARY

[ESC][C] 120.XYZ	Load file named "XYZ" from device 120 into empty text area of RAM
[ESC][C] 120.XYZ	Insert file XYZ before line containing cursor
[ESC][D] 25	Delete line 25
[ESC][D] 25-30	Delete lines 25 through 30
[ESC][D] 25-	Delete line 25 and all following lines
[ESC][D] -25	Delete all lines up to and including line 25
[ESC][D] ALL	Delete text without coping to recover buffer
[ESC][F] .XX.	Find the next occurrence of "XX"
[ESC][F] W .XX.	Find the next occurrence of "XX", "Xx", "xX", or "xx"
[ESC][H]	Display editor commands and functions
[ESC][J] 100	Jump the cursor to line 100
[ESC][J] +3	If the cursor is on line 100 jump it to line 103, if it is on 5 jump it to 8, etc.
[ESC][L] "20"	List text to device number 20
[ESC][L] "120.DATA"	List lines to a text file named "DATA" on mass-storage device number 120
[ESC][L] "21" 50-	List lines 50 and following to device 21
[ESC][L] "120.A" -50	List lines through 50 to a file named "A" on mass-storage device 120
[ESC][M] 1-10,21	Move the first 10 lines of text so that they become the second ten
[ESC][M] 20-,1	Move lines 20 and following so that they become the first block of lines
[ESC][N] 2	Initialize (format) the medium in device 2
[ESC][Q]	Leave screen editing and return to edit menu
[ESC][R] .XX.YY.	Replace the next occurrence of "XX" with "YY"
[ESC][R] W .XX.YY.	Replace the next occurrence of "XX", "Xx", "xX", or "xx" with "YY"
[ESC][R] V .XX.YY.	Replace the next occurrence of "XX" with "YY" after verification
[ESC][R] A .XX.YY.	Replace all subsequent occurrences of "XX" with "YY"
[ESC][R] AWV .XX.YY.	Replace as above with all three options
[ESC][S] 120.TABLE R=0	Save the text currently in memory to device 120 the file name "TABLE" in 80-byte records
[ESC][S] 120.TABLE R=>FF	Save the text as "TABLE" on device 120 with a record size of 255
[ESC][S] 120.TABLE	Save the text as "TABLE" on device 120 in one record
[ESC][T] 5,10,15,20,25,30,35,40 !	Set tabs after every five columns
[ESC][U]	After line modification, replace the modified line with the original; after deletion restore deleted lines to the text
[ESC][V] 120.ABC	Compare the memory text with the file named "ABC" on device 120; issue message if the text and the file are different

Figure 5-1

Listing of an Assembled Program

```
                                                    SOURCE PROGRAM LINE NUMBER
                                                    LOCATION OF OBJECT CODE
                                                    MACHINE OBJECT CODE IN HEX
                                                    LABEL
                                                    OP CODE
                                                    OPERAND(S)
                                                    COMMENTS

0001        005D  COUNTER  EQU   >5D               COUNTER MEMORY LOCATION
0002 0000    88   BEEP     MOVD  @>400,COUNTER     SET CYCLE COUNT TO 1024
     0001 0400
     0003    5D
0003 0004    A2   BEEP2    MOVP  @1,P21            TURN ON THE BEEPER
     0005    01
     0006    15
0004 0007    52             MOV   @29,B           DELAY COUNT FOR ON PERIOD
     0008    1D
0005 0009    CA   ONLOOP    DJNZ  B,ONLOOP         LOOP BACK FOR COUNT
     000A    FE
0006 000B    A2             MOVP  @0,P21           TURN BEEPER OFF
     000C    00
     000D    15
0007 000E    52             MOV   @32,B           DELAY COUNT FOR OFF PERIOD
     000F    20
0008 0010    CA   OFFLOP    DJNZ  B,OFFLOP         LOOP BACK FOR COUNT
     0011    FE
0009 0012    DB             DECD  COUNTER          COUNT OF CYCLES DONE
     0013    5D
0010 0014    E3             JC    BEEP2            LOOP BACK UNTIL ALL DONE
     0015    EE
0011 0016    0A             RETS                   RETURN TO CALLING PROGRAM
0012 0017        NAMLOW
0013 0017    50
     0018    45
     0019    45
     001A    42             RTEXT 'BEEP'           PROGRAM NAME
0014 001B    04             BYTE  NAMHGH-NAMLOW    NAME LENGTH
0015        001B' NAMHGH    EQU   $-1              FILE STORAGE SPECIFICATIONS
0016 001C 0000'             DATA  BEEP             PROGRAM ENTRY POINT
0017 001E 0000              DATA  0000             NEXT SUBPROGRAM
0018 0020 FFFC              DATA  NAMHGH-$+1       OFFSET TO NAME
0019 0022    00             BYTE  0,>44            HEADER INFORMATION
     0023    44
 NO Errors  NO Warnings
```

Figure 5-2

A Typical Cross-Reference Table

```
A24       CC-40 TMS7000 Assembler Version 1.0                PAGE 0001

 0002               IDT    'A24'
 0003       *
 0004       *This is an example of a cross reference map with copy files
 0005       *
 0006               OPTION X    Generate cross reference map
 0007       0001    X1     EQU  1
 0008       0002    X2     EQU  2
 0009       COPY    120.A24A
A0001       IDT     'A24A'
A0002
A0003       AA11    A1     EQU  >AA11
A0004       AA22    A2     EQU  >AA22
A0005 0000 AA11     DATA   A1,B1
      0002 BB11
 0010       COPY    120.A24B
B0001               IDT    'A24B'
B0002
B0003       BB11    B1     EQU  >BB11
B0004       BB22    B2     EQU  >BB22
B0005 0004 AA22     DATA   A2,B2
      0006 BB22
 0011 0008   62     MOV    X1,A
 0012 0009 AA11     DATA   A1,B1
      000B BB11
      NO Errors     NO Warnings


A24       CC-40 TMS7000 Assembler Version 1.0                PAGE 0002


LABEL     VALUE   DEFN   REFERENCES

A1        AA11    A0003  A0005     0012
A2        AA22    A0004  B0005
B1        BB11    B0003  A0005     0012
B2        BB22    B0004  B0005
X1        0001    0007   0011
X2        0002    0008
```

Figure 7-1

Flowchart Summary of E/A File Conversion and Transfer

External text file	BASIC program	E)ditor L)ine S)creen
Optional RS/232	BASIC -> E/A utility (SAVEA)	
T)ransfer S)ource	E/A text file	E/A -> BASIC utility (COPYA)
990 tagged object file	A)ssembler	BASIC program
T)ransfer O)bject	E/A tagged object file	
Linker control file or keyboard	L)inker	
Single-record Memory-image file	Multiple-record Memory-image file	
Relocatable	Absolute	Relocatable !
CONVERT		
"CALL LOAD" "OLD" / "RUN"	Absolute Loader	Cartridge Loader
RAM	RAM / Cart. RAM	Cartridge RAM
Memory Save Utility	Absolute Memory Image file	

Figure 2-1 Op Code Map

MOST-SIGNIFICANT NIBBLE

LEAST SIGNIFICANT NIBBLE	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	NOP								MOVP PN,A			TSTA/ CLRC	MOV A,B	MOV A,RN	JMP J	TRAP 15
1	IDLE									MOVP PN,B			TSTB	MOV B,RN	JN J	TRAP 14
2		MOV RN,A	MOV %N,A	MOV RN,B	MOV RN,RN	MOV %N,B	MOV B,A	MOV %N,RN	MOVP A,PN	MOVP B,PN	MOVP %N,PN	DEC A	DEC B	DEC RN	JZ/JEQ J	TRAP 13
3		AND RN,A	AND %N,A	AND RN,B	AND RN,RN	AND %N,B	AND B,A	AND %N,RN	ANDP A,PN	ANDP B,PN	ANDP %N,PN	INC A	INC B	INC RN	JC/JHS J	TRAP 12
4		OR RN,A	OR %N,A	OR RN,B	OR RN,RN	OR %N,B	OR B,A	OR %N,RN	ORP A,PN	ORP B,PN	ORP %N,PN	INV A	INV B	INV RN	JP J	TRAP 11
5	EINT	XOR RN,A	XOR %N,A	XOR RN,B	XOR RN,RN	XOR %N,B	XOR B,A	XOR %N,RN	XORP A,PN	XORP B,PN	XORP %N,PN	CLR A	CLR B	CLR RN	JPZ J	TRAP 10
6	DINT	BTJO RN,A,J	BTJO %N,A,J	BTJO RN,B,J	BTJO RN,RN,J	BTJO %N,B,J	BTJO B,A,J	BTJO %N,RN,J	BTJOP A,PN,J	BTJOP B,PN,J	BTJOP %N,PN,J	XCHB A	XCHB B	XCHB RN	JNZ/JN E J	TRAP 9
7	SETC	BTJZ RN,A,J	BTJZ %N,A,J	BTJZ RN,B,J	BTJZ RN,RN,J	BTJZ %N,B,J	BTJZ B,A,J	BTJZ %N,RN,J	BTJZP A,PN,J	BTJZP B,PN,J	BTJZP %N,PN,J	SWAP A	SWAP B	SWAP RN	JNC/JL J	TRAP 8
8	POP ST	ADD RN,A	ADD %N,A	ADD RN,B	ADD RN,RN	ADD %N,B	ADD B,A	ADD %N,RN	MOVD %NN,RN	MOVD RN,RN	MOVD %NN(B), RN	PUSH A	PUSH B	PUSH RN	TRAP 23	TRAP 7
9	STSP	ADC RN,A	ADC %N,A	ADC RN,B	ADC RN,RN	ADC %N,B	ADC B,A	ADC %N,RN				POP A	POP B	POP RN	TRAP 22	TRAP 6
A	RETS	SUB RN,A	SUB %N,A	SUB RN,B	SUB RN,RN	SUB %N,B	SUB B,A	SUB %N,RN	LDA @NN	LDA *RN	LDA @NN(B)	DJNZ A	DJNZ B	DJNZ RN	TRAP 21	TRAP 5
B	RETI	SBB RN,A	SBB %N,A	SBB RN,B	SBB RN,RN	SBB %N,B	SBB B,A	SBB %N,RN	STA @NN	STA *RN	STA @NN(B)	DECD A	DECD B	DECD RN	TRAP 20	TRAP 4
C		MPY RN,A	MPY %N,A	MPY RN,B	MPY RN,RN	MPY %N,B	MPY B,A	MPY %N,RN	BR @NN	BR *RN	BR @NN(B)	RR A	RR B	RR RN	TRAP 19	TRAP 3
D	LDSP	CMP RN,A	CMP %N,A	CMP RN,B	CMP RN,RN	CMP %N,B	CMP B,A	CMP %N,RN	CMPA @NN	CMPA *RN	CMPA @NN(B)	RRC A	RRC B	RRC RN	TRAP 18	TRAP 2
E	PUSH ST	DAC RN,A	DAC %N,A	DAC RN,B	DAC RN,RN	DAC %N,B	DAC B,A	DAC %N,RN	CALL @NN	CALL *RN	CALL @NN(B)	RL A	RL B	RL RN	TRAP 17	TRAP 1
F		DSB RN,A	DSB %N,A	DSB RN,B	DSB RN,RN	DSB %N,B	DSB B,A	DSB %N,RN				RLC A	RLC B	RLC RN	TRAP 16	TRAP 0

SYMBOLS: RN = R0 THROUGH R127 PN = P0 THROUGH P255 N = ONE-BYTE VALUE NN = TWO-BYTE (WORD) VALUE
J = JUMP DISPLACEMENT @ = DIRECT MEM ADR * = REGISTER INDIRECT (B) = DIRECT, INDEXED ON REGISTER B