
THE DESIGN OF A LOW COST C.A.D./C.A.M. SYSTEM

by

Professor D. French, and B. Hughes
Dept. of Mechanical Engineering
The University of Waterloo
Waterloo, Ontario, Canada N2L 3G1

There are a number of CAD/CAM systems available to Industry today, ranging in cost from approximately \$25,000 to \$300,000. These systems vary greatly in the hardware and software facilities which they offer to the potential user. The small companies that make up the majority of the manufacturing industry cannot, in general, afford the highly sophisticated systems. In many of these companies, the need to carry out complex analyses is not necessary. However unless the small company has access to this new technology at a reasonable cost, it will be unable to manufacture its products on a competitive basis.

There is a great need for a low cost CAD/CAM system which has the facilities required by Industry, necessary to increase productivity. Such a system should be hardware independent thus enabling portability, flexibility and upward compatibility with the latest hardware technology. It should also be capable of expansion and have the ability to communicate with existing CAD/CAM systems.

The system should be designed to accommodate experienced users as well as those operators who have little or no knowledge of computers or CAD/CAM systems. It should be easy to use and employ extensive error checking functions. The operating manual, although explaining fully the operation of the system, should not be so large or complex that potential users cannot utilize the system without extensive reading.

These essential requirements of a CAD/CAM system raises many important points which must be considered when designing such a system. The two most basic considerations are the hardware and software requirements. From the standpoint of portability, compatibility and economics, it was decided that the system would be implemented on an IBM PC with a hard disk, 8087 coprocessor support, and a Microsoft Mouse. A development language for such a system must have extensive graphics capabilities, the ability to support arithmetic coprocessors, the capability to use assembly language routines, the flexibility to support I/O devices, and the extensibility to access large amounts of RAM memory needed to develop such a system. These requirements led to PC FORTH+ being chosen as the appropriate development language for this system.

The system was designed to be menu driven using a mouse to select the appropriate functions. All numeric data is input via the keyboard in a free format fashion. The menu system allows the operator to select various functions including:

- 1) System initialization
 - a. user defined units
 - b. size of the drawing window
 - c. user defined origin

d. scaling mode

- 2) Generation of geometric elements
- 3) Automatic labeling of geometric elements
- 4) Reentry, Verification and Erasure of geometric elements
- 5) Filing, Plotting and Dimensioning of geometric drawings

In order to offer the facilities of large CAD/CAM systems on a microcomputer, many problems arose during development which had to be addressed. Two of these problems dealt with graphics and numeric input and output.

The CAD system was written to execute in a graphics mode in order to accommodate the use of graphic drawing primitives and menu overlays. In creating a menu driven system, two problems must be considered. The first being that the menu will overwrite and destroy the existing geometry shown on the screen, and the second being the speed at which the menu can be created and displayed. These problems were resolved by creating and storing the menus as graphical objects along with that part of the screen which lay beneath the menus. As the part is being constructed, the main geometry menu is displayed. On selection of a sub-menu, the part of the screen which falls beneath this menu is saved and the sub-menu is displayed. Upon completion of data input, the sub-menu is erased and the screen element is replaced. This approach allows the operator to view the various menus without overwriting the screen and provides for a larger working window in which to display the drawing. A component is constructed using a variety of geometrical elements. A major problem is that when defining a geometrical element, using previous defined geometry, care must be taken to avoid ambiguities in the construction. To overcome this problem the system has been designed to allow the specification of the part using either APT type modifiers, or using a graphic display of all possible relationships for the particular geometrical configuration and using a "mouse" to select the appropriate entity.

CAD/CAM systems require numeric input of both fixed point (integer) and floating point (real) types. These input routines should contain some degree of error checking. All error checking, with respect to valid entries, should be handled interactively at the keyboard and should be internal to these input routines. Validity checks should include:

- 1) Negative sign
 - a. first position only
 - b. input once only
- 2) Decimal point
 - a. input once only
 - b. location
- 3) Input digits only
- 4) Limit the number of digits input

The input routines should also contain a backspace feature which allows the user to interactively make changes to incorrect entries.

By placing the error checks internal to the input routines, it eliminates the need to check the entries for validity after they have been entered. It should be noted that these input routines check the validity of encoded ASCII characters. It is important that the operator must be allowed to input data in a free format mode when using the system. However, the 8087 coprocessor requires that real numbers are specified in scientific notation. It is therefore necessary to convert the free format input into a format acceptable to the 8087 coprocessor. Integer conversion is relatively easy, however real number conversion is more complex, these conversion methods are illustrated in Figure 1 (Integer Conversion) and Figure 2 (Real Number Conversion).

FORTH has proven to be an excellent language for the development of this CAD/CAM system. It has reduced development time due to the virtue of its modular programming structure, its interactive environment, and its ability to selectively compile new code which needs to be tested without having to recompile the entire application. It has reduced memory requirements due to the compact nature of its code, and in addition is able to support a program up to 1 Mbyte (RAM) in size which allows for the development of such a large system on a microcomputer. However, the most impressive feature has been its performance. The system has been able to outperform similar minicomputer based CAD/CAM systems. It is able to search through a full data base in less than 1 second, which makes access to any geometric element relatively instantaneous. The FORTH language, because of its stack orientation base, has many advantages for use in this type of application. However, to utilize the language to such a high degree of complexity requires a greater knowledge of the language fundamentals than other high level languages.

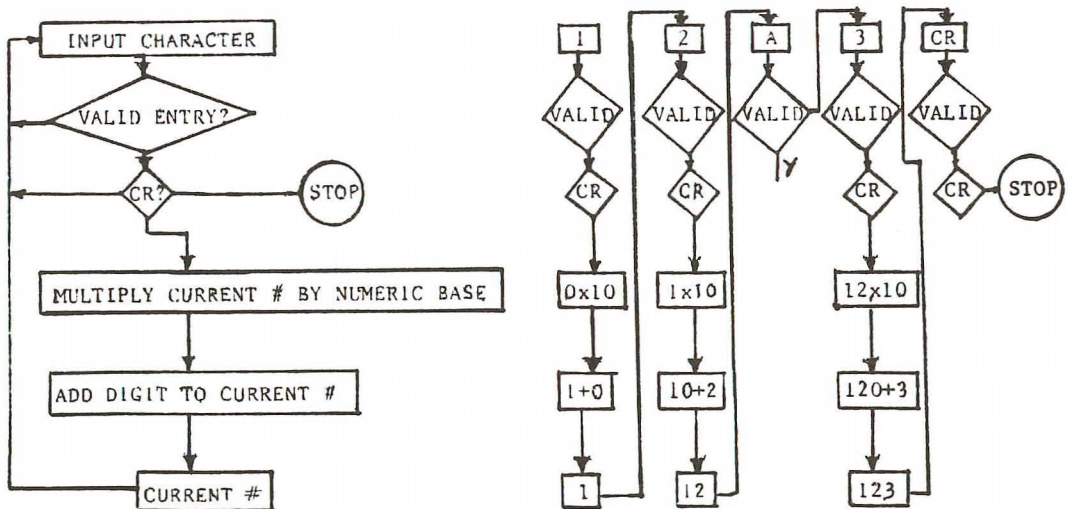


FIGURE 1

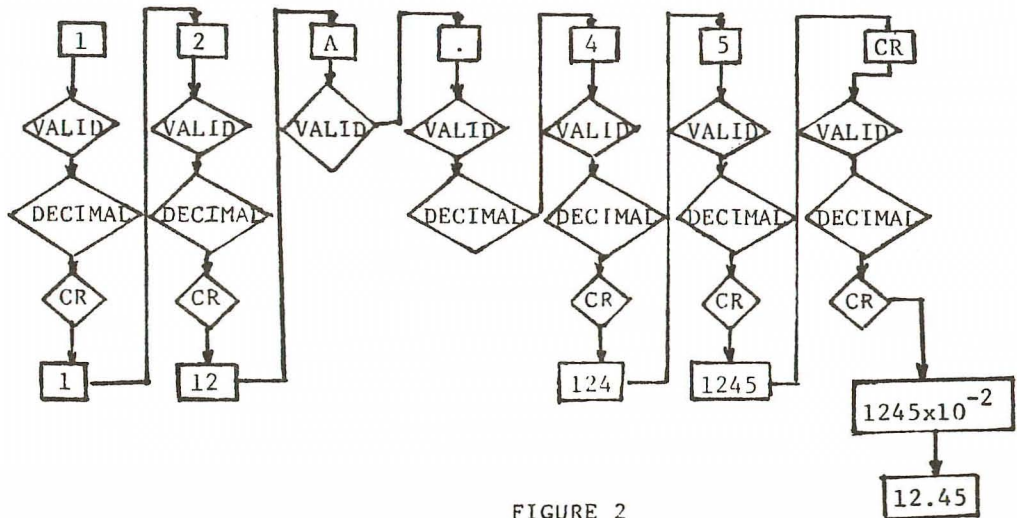
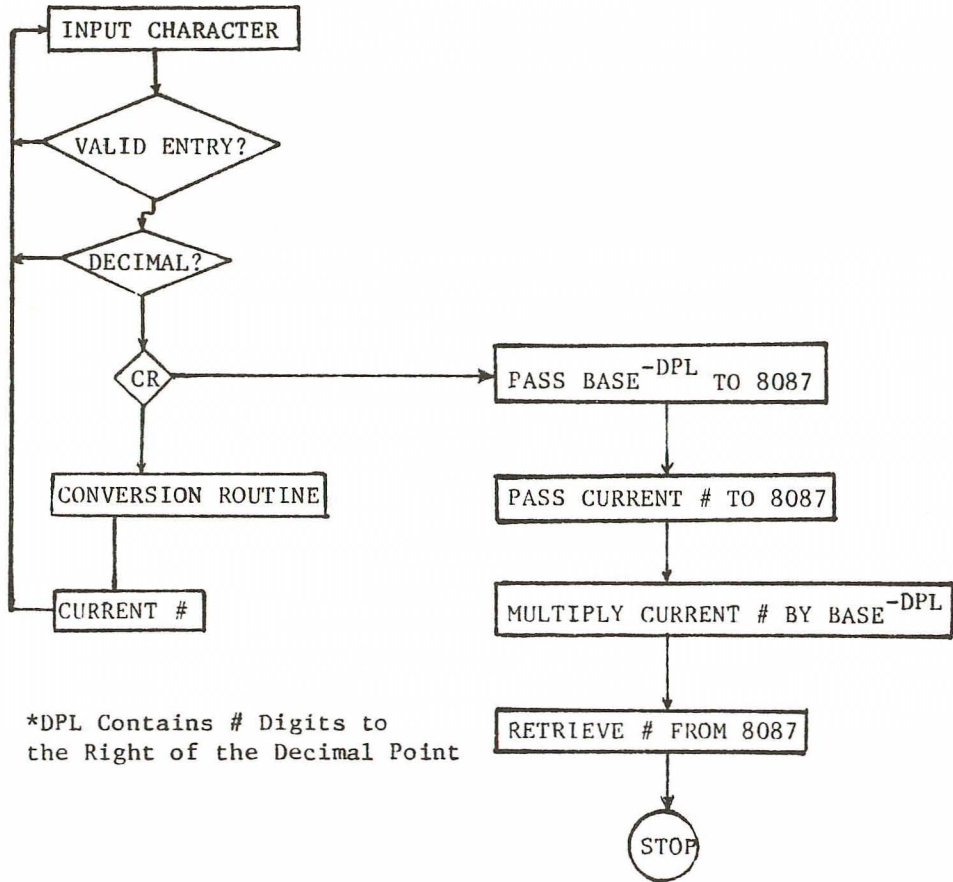


FIGURE 2