A HUMAN MACHINE INTERFACE FOR SILICON COMPILATION

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Abstract

This paper describes a new human machine interface as a design environment for silicon compilation. It is important for a human machine interface to support a tool which realize quick Turn Around Time with few possibility of user errors. Designers should be able to work with little disturbance in thinking process. To realize such a design environment, we have developed an LCD digitizer, and it has been demonstrated that it can be a designer friendly human machine interface.

1. Introduction

Today various silicon compilation systems have been proposed[1][2][3]. In many cases, designers describe the hardware behavior in a text-style Hardware Description Language. Although text-style languages are suitable for processing in a computer, they don't fit to design hardware behavior directly. It is clear by the fact that schematics have been used as the most dominant hardware design representation, and that text-style languages have been used by few hardware designers. Diagrammatic description appeals to the sense of sight and is intuitively understood in comparison with text-style description.

When designers use an Engineering Work Station (EWS), they want to know immediately what happens in a system when they give a command[4]. It is important for a human machine interface to allow designers to work with little pain and no disturbance of thinking in operations. Besides, they are demanded to complete their designs in a short time. Therefore, Quick Turn Around Time (QTAT) is also very important to evaluate a design environment.

Basic functions of an EWS, for example, interactive design activities, logic simulation, and verification, are also necessary for smooth design activities.

To satisfy these requirements, we have developed a new human machine interface which has the following features:

1) Realize diagrammatic entry
2) Not disturb designers' thinking
3) Provide basic functions of an EWS

A new interactive tool, a Liquid Crystal Display (LCD) digitizer, has been developed for this system. The LCD digitizer plays a key role to realize quick response and smooth design activities, like drawing on paper. Clean copies of handwritten design are displayed on the LCD panel immediately. Designers' eyes are always focused on the pen point during the design process. So they are able to concentrate their attention upon their design for a long time. Besides, the system offers some basic editing functions as menu commands, and recognizes handwritten characters. Designers have only to draw sketches on the LCD digitizer.

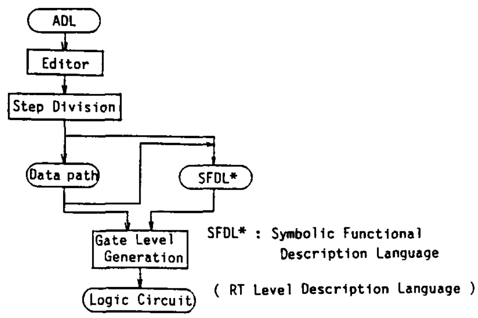

Fig.1 Configuration of the Silicon Compilation System

Fig.1 shows the configuration of our silicon compilation system, which adopts Algorithm Description Language (ADL)[5] to describe the hardware algorithm. ADL is a tree-structured diagrammatic hardware description language, and an ADL description consists of two parts; variable declaration and behavior description. By the variable declaration, external terminals, registers, and memories are declared, while by the behavior description, the target hardware algorithm is described using box symbols (Table 1) based on the structured programming system of Problem Analysis Diagram[6]. ADL has the following features:

1) It is easy to understand the process flows because ADL describes the hardware algorithm hierarchically by a tree-structured diagram.
2) It is easy to describe the hardware algorithm in a compact form using control functions expressed by box symbols.
3) It is easy to describe parallel processes such as pipelines by "process" description.

Fig.2 shows an example of an ADL description and its text-style description. Obviously, the diagrammatic description of the algorithm is much easier to understand than the text-style description.

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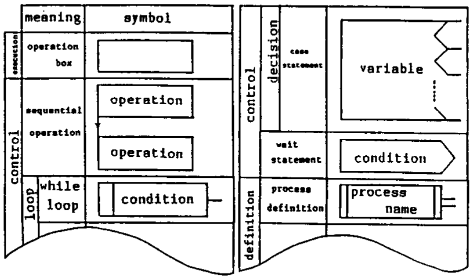
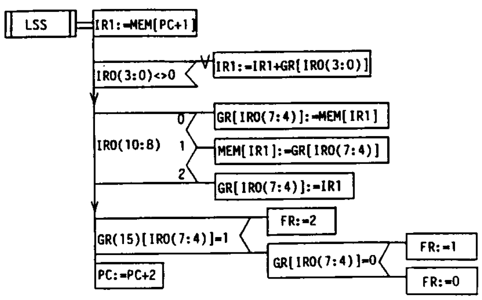
Table 1 ADL Syntax





(a) ADL description

```
 1 PRO  ***  = 2        :LSS
 2 SMT  - 3  ***        :IR1:=MEM[PC+1]
 3 DEC  V 5  V 4   ***  :IR0(3:0)<>0
 4 SMT  ***  ***        :IR1:=IR1+GR[IR0(3:0)]
 5 CAS  V 9             :IR0(10:8)
   0         - 6
   1         - 7
   2         - 8
 6 SMT  ***  ***        :GR[IR0(7:4)]:=MEM[IR1]
 7 SMT  ***  ***        :MEM[IR1]:=GR[IR0(7:4)]
 8 SMT  ***  ***        :GR[IR0(7:4)]:=IR1
 9 DEC  -14  -10   -11  :GR(15)[IR0(7:4)]=1
10 SMT  ***  ***        :FR:=2
11 DEC  ***  -12   -13  :GR[IR0(7:4)]=0
12 SMT  ***  ***        :FR:=1
13 SMT  ***  ***        :FR:=0
14 SMT  ***  ***        :PC:=PC+2
```

(b) Text-style description

Fig.2 Example of an ADL description and its Text-style

An ADL description is divided into "step"s which include operations carried out in parallel. Both the data path structure and a Symbolic Functional Description Language (SFDL)[7], which is a register transfer level language, are generated from these "step"s. Logic circuits are synthesized from them automatically.

Our goal is to make a design environment for silicon compilation, developing the LCD digitizer to satisfy the three features of human machine interface as mentioned above.

2. The LCD Digitizer

In case of a conventional manual design style on paper, designers can focus on the pen point, and

Table 2 Comparison of Entry Tools

Item \ Tool		CRT+Keyboard	CRT+Mouse	CRT+ Digitizer	Light Pen or Touch Panel	LCD Digitizer
Diagrammatic Entry		△	○	○	○	○
Hand-writing	Entry	×	△	○	△	○
	Traceability of Handwritten Symbols	×	○	○	△	○
Correspondence between Designers' Eyes and Their Pen Points		×	×	×	○	○
Entry on a Horizontal Plane with a Pen		×	△	○	△	○
Editing Ability		△	○	○	○	○
All-around Estimate		×	△	○	○	◎

◎ : Superior ○ : Suitable △ : Possible × : Difficult

concentrate on design activities without disturbance of troublesome operation. So, a manual style design is suitable for designers' contemplation.

Several kinds of entry tools[8][9] have been evaluated as to whether they have a feature similar to the pencil and paper design style, and whether they can realize a diagrammatic design and QTAT. Table 2 shows the results of that analysis.

These results show that the LCD digitizer can offer an environment more similar to the handwriting design style than any other conventional entry tools. And, the LCD digitizer allows the designer to input diagrammatic descriptions directly. Therefore the intermediate processes of transforming from diagrammatic data to text data and its entry with keyboard are not necessary, which thereby reduces the possibility of errors.

2.1 Development of the LCD Digitizer

A new design environment, the LCD digitizer shown in Fig.3, which allows designers to work as smoothly as a manual design (pencil and paper design style) and also to utilize the advantages of an EWS, has been developed. Designers draw their design on an LCD panel with a stylus pen as if they designed on paper with a pencil. Drawn sketches are recognized and displayed on the LCD panel as clean copies immediately. Simultaneously, diagrammatic description entered from the LCD digitizer is transformed into the text-style language, and transmitted to the silicon compilation system in the Host Computer. Fig.4 shows the configuration of the LCD digitizer, which consists of three main parts; an LCD panel, a digitizer, and a control board, which are stacked on the other. Its overview is shown in Fig.5.

2.2 Specifications

Specifications of the digitizer and the LCD panel are as follows:

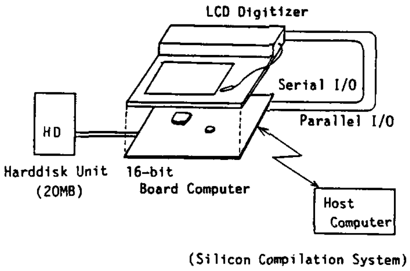


Fig.3 System Configuration

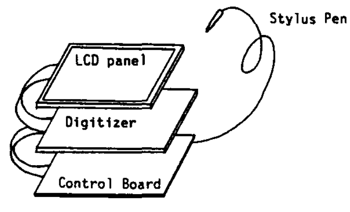


Fig.4 Configuration of the LCD Digitizer

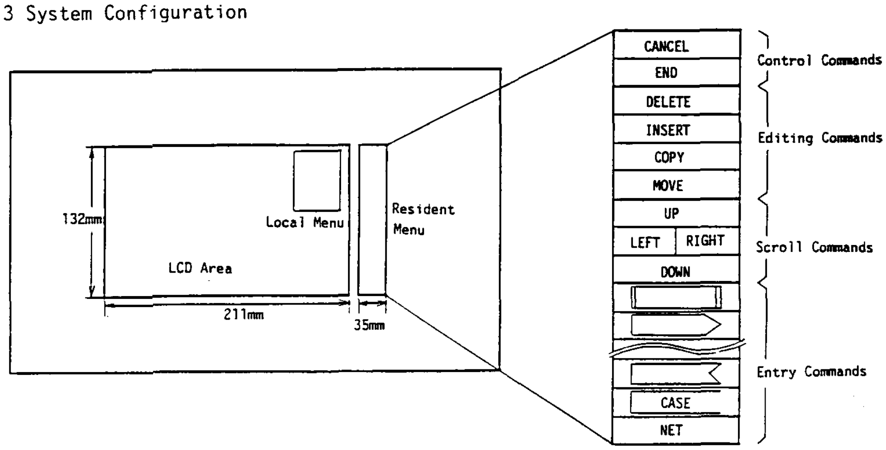


Fig.5 Overview of the LCD Digitizer

1) The Entry Part (Digitizer)
   a) Read-out method : Electromagnetic induction
   b) Entry area : 246 x 132 mm
   c) Sampling rate : 100 points/sec
   d) Data transmission rate : 9600 baud
   e) Resolution : 0.1 mm
   f) Accuracy : 0.5 mm
   g) Interface : RS-232C
2) The Display Part (LCD panel)
   a) Display device : Liquid Crystal Display
   b) Display area : 211 x 132 mm
   c) Dots range : 640 x 400 dots
   d) Interface : 8 bits parallel

The whole LCD area is available for input. In addition, the dedicated area for the resident menu is provided beside it.

2.3 Features

The LCD digitizer is a new entry tool which has two functions; entry and display. The three parts are stacked one on the other as shown in Fig.4. Then these entry and display functions can be done on the same plane. It has five features:

1) When symbols and characters are written by hand with a stylus pen, the traces of the drawn design are displayed on the LCD panel in real time.
2) Handwritten designs on the digitizer are recognized and displayed as clean copies on the LCD panel immediately.
3) All information necessary for entry and editing is displayed on the LCD panel interactively.
4) An electromagnetic induction digitizer supports high resolution, and assures high tolerance of electronic noises.
5) Fine resolution display for complex pictures. Thus, the LCD digitizer allows designers to input diagrammatic description directly.

By 1)-3), designers' eyes are always focused on their hands during the design process. So they are able to concentrate their attention upon their design throughout the design process. Besides, designers can describe their ideas directly by diagrammatic description. QTAT and interactive design activities are realized by these features.

Thus, the developed LCD digitizer realizes a new design environment which allows the designers to design with little pain and no disturbance of their thinking process.

3. Design Environment

Fig.6 shows the software configuration, consisting of the five main parts.

3.1 Specifications

In this section, the specifications of this system are described.

1) Input : Hardware algorithm described in ADL
2) Output : Input code for the silicon compiler
Feedback of the entered design on the LCD panel
3) Handwriting entry :
Handwriting entry has been enabled by Symbol Recognition Package. Following specifications should be accomplished.
* Recognition time < 0.5 sec/char
* Recognition rate > 99 %
4) Dictionary modification function :
If recognition fails, the reference dictionary data for recognition are modified interactively. Dictionary modification contributes to the improvement of the recognition rate.
5) Editing functions :
This system has basic editing functions such as deleting, inserting, copying, moving, and so on. Any objects, such as characters, character strings, ADL symbols, and blocks are processed by these functions.
6) Transformation function :
ADL description is transformed automatically into the input code for the silicon compiler.
7) Description area :
The ADL description area is set at 422 x 264 mm, which is four times as large as the LCD panel. To cover the area, the scroll and paging functions are used.

3.2 Recognition of Handwritten Symbols

The Symbol Recognition Package (SRP) has been developed to realize handwriting entry. Symbols and characters written on the digitizer are recognized by matching coordinates of some feature points extracted from each stroke. For recognition, two kinds of dictionaries are prepared; a standard dictionary and personal dictionaries. For design activities, the personal dictionaries are mainly used. The standard dictionary is used as the source of the personal dictionaries. The effectiveness of the personal dictionaries has been confirmed by some experimental results. Fig.7 shows an example of reference pattern. Recognition targets are alphanumeric and some operational symbols.

3.3 Entry and Editing

This system supports all basic editing functions such as deleting, inserting, copying, and moving in order to edit symbols and characters easily. Display area of the LCD panel is 211 x 132 mm. Though this LCD panel is one of the largest commercial LCD panels, the area is not large enough to use as an entry tool. To solve this problem, the system prepares the description area which is four times as large as the LCD panel, and has such functions as scrolling, multi-window, and paging.

To attain simple entry processes and minimum entry and editing time, the commands frequently used in the entry and editing processes are set in the resident menu outside the LCD panel. It

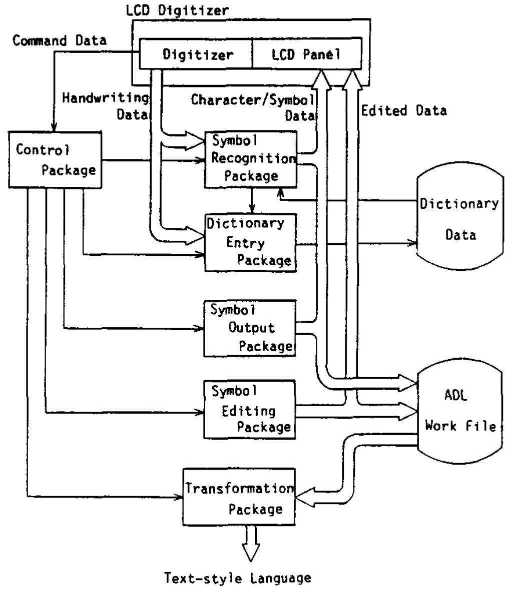


Fig.6 Software Configuration

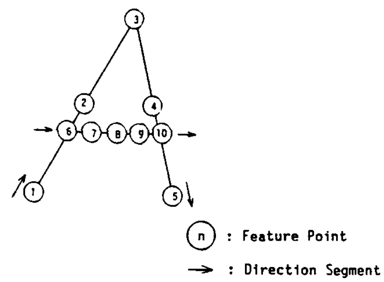


Fig.7 Example of Reference Pattern ('A')

includes four kinds of commands; 1) entry commands for symbols and nets, 2) editing commands for deleting, inserting, copying, and moving, 3) commands for scrolling, and 4) control commands. The commands for temporary use in the current editing phase are displayed on the LCD panel, if necessary. It keeps the menu simple and hierarchical.

The operations of entry processes are as follows:

(1) Symbol Entry
1) Point to the position to display an ADL symbol on the LCD panel.
2) Handwrite characters for ADL description.
3) Choose one of the ADL symbols from the resident menu.
4) The ADL symbol is displayed at the position chosen.

(2) Net Entry
1) Pick the beginning point and the ending point.
2) Hit 'NET' in the resident menu.

The editing commands for deleting, inserting, copying, and moving can deal with any objects, such as characters, character strings, ADL symbols, and rectangular areas including each of these. The object to be managed is selected automatically, not by hitting the menu, but by pointing to the target area with a stylus pen.

(3) Recognition Error Correction

1) Pick up the character which failed recognition. The menu shown in Fig.8 is then displayed on the LCD panel.
2) Point to the target character in the menu.
3) Hit the 'SET' command to modify the reference pattern in the personal dictionary by employing the entered data.

This simple correction procedure assures the designers that any modification of the personal dictionary scarcely interrupt their work. This function has improved the whole recognition rate during the entry and editing processes.

4. Performance

This system has been implemented on the Intel 8086 CPU based microcomputer system. The program was written in C language, and the total source statement is 5,900 steps.

To evaluate the performance of this system, some experiments have been carried out as follows:

1) Measurement of recognition time and recognition rate
2) Design feasibility in comparison with i) a system using a CRT and ii) on paper
3) Required time for the whole process from specification to text style description in comparison with a design on paper

4.1 Recognition Time and Recognition Rate

Table 3(a) shows recognition rate. "Experts" mean those who developed this system. "Beginners" mean those who used this system for the first time. Experts have attained the specified recognition rate, 99 %, by using personal dictionaries. For beginners, the specified rate was hard to achieve, but effectiveness of personal dictionaries has been confirmed.

Table 3(b) shows recognition time. Processing time from entry to display is defined as recognition time. Recognition time for a character was about 0.21 sec. This performance has satisfied the specified time, 0.5 sec/char. In case of a two-stroke character, recognition time is at its maximum, because the number of two-stroke characters is the largest in the dictionary.

These results show the system is practical as an entry system for handwritten characters.

4.2 Comparison with a System Using a CRT

This LCD system and a CRT system have been compared with respect to design capability. Required time for entry of regular character strings and recognition rate have been measured. The CRT system is composed of a digitizer for entry and a CRT for display. It has been demonstrated that the correspondence between designer's eyes and his pen and the two-dimensional operation improve

0	1	2	3	4	5	6	7	8	9
A	B	C	D	E	F	G	H	I	J
K	L	M	N	O	P	Q	R	S	T
U	V	W	X	Y	Z	*	/	+	-
=	<	>	:	&	^	(	)	[	]
SET									

Fig.8 Menu for Data Modification

Table 3 Experimental Results

(a) Recognition Rate

		Standard Dictionary	Personal Dictionary
Experts	A	96.8%	99.4%
	B	98.4%	99.6%
	Average	97.6%	99.5%
Beginners	C	89.6%	97.2%
	D	93.4%	98.6%
	Average	91.5%	97.9%

(b) Recognition Time

Number of Strokes	Recognition Time (sec/char)
1	0.18
2	0.25
3	0.22
4	0.20

(c) Comparison with a System Using CRT

	LCD digitizer		CRT	
	Time (sec)	Recognition Rate	Time (sec)	Recognition Rate
A	326	94%	392	85%
B	230	100%	240	93%
C	230	96%	284	90%
Average	262	96.3%	305	89.3%

(d) Comparison with a Design on Paper

	Design on Paper (sec)	Design with Our System (sec)
Deleting	13	5
Inserting	42	29
Copying	27	12
Moving	51	11

(e) Required Time for the Whole Processes

	Design on Paper (min)	Design with Our System (min)
PIT01	210	150
PIT02	300	180
Average	255	165

design capability. The results of this experiment are shown in Table 3(c).

In case of the CRT system, designers have to watch the CRT, so the traces of pen strokes become unstable and recognition rates are worse. As recognition rate becomes lower, the design by the CRT system was accompanied by more stress than by the LCD digitizer.

This result shows that this system improves design capability and recognition rate and that it will shorten design time.

4.3 Comparison with a Design on Paper

The aim of this experiment is to evaluate effectiveness of the basic editing functions provided by this system. Examples of an ADL description have been prepared for this experiment. Each editing command, such as deleting, inserting, copying, and moving, has been executed for these examples. Required time to complete these commands has been evaluated. The result is shown in Table 3(d). The result shows smoother operation of this system in comparison with a design on paper.

4.4 Required Time for the Whole Process

The required time for the whole process to design a logic system has been compared with that of a design on paper. Here, the process from specification to input code for the silicon compilation system is defined as the whole process.

In this experiment, two Programmable Interval Timers (PIT's) have been designed. A PIT is a peripheral equipment of a Micro Processing Unit. Table 3(e) shows the experimental result. The result is the average of the two cases. In case of this system, the time shortened by about 35 % in comparison with the design on paper. Editing functions and transformation function are the main factors of shortening time for the design process.

In addition to these experiments, a single processor has been designed. The size of the processor is about 20k gates. Through these designs, the advantages of the LCD digitizer design style have been confirmed.

5. Discussion

The experimental results have demonstrated that this system is effective to support hardware design activity. This effectiveness is mainly offered by the editing functions and the screen control commands, such as scrolling. Editing commands prepared in the resident menu help the editing activities in the handwriting interactive design process. In case of character entry, this system is inferior to a keyboard system with respect to speed. But, this system is much more suitable for diagrammatic entry than a keyboard system. Thus, this system provides an interactive design environment to support a longtime design activity without stress.

There are some future works as follows:

1) The screen control commands, such as scrolling and multi-window, now supported by the software, should be supported by the hardware, so that they will be processed more quickly and the design capability will be improved.
2) The size of the display area isn't large enough. A larger LCD panel (as large as 300mm x 400mm) is desirable.

6. Conclusion

We have developed a new type LCD digitizer system for a silicon compilation system. This system offers desirable human machine interface with the following features:

1) Design by diagrammatic description can be carried out by handwriting.
2) Designers can focus on the pen point every time, so they can design without disturbance.
3) Interactive design and QTAT, which are indispensable to EWS's, have been realized.

Although the LCD digitizer has the disadvantage of insufficient display area, it supports a design approach similar to conventional design work with pencil and paper, attaining the same functions of an EWS.

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