Capstone Design Project
Interface Board for the HC12 Microprocessor

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ABSTRACT

This project consists of the design and implementation of an interface board for the Motorola evaluation board M68HC12B32EVB. This interface will include eight different experiment for a laboratory course.

SINOPSIS

Este proyecto consiste en el diseño e implantación de una tarjeta de interface para la tarjeta de evaluación Motorola M68HC12B32EVB. Esta interface incluirá ocho diferentes experimentos de cursos de laboratorio.

I- INTRODUCTION

The purpose of this project is to design, implement and test a board to interface with the Motorola microprocessor HC12. This interface will include an experimental ready package for laboratory course purposes. This board will help the development of new microprocessor students with hands on experience.

This microprocessor is mounted on the evaluation board M68HC12B32EVB. The board has a serial connector for a direct link and control through a computer. With this link, the assembly programs can be loaded to the RAM and/or the EEPROM and can be executed as well.

The board we have developed will interface with the Motorola Evaluation Board (EVB) and will aid in the learning experience of future electrical engineers.

II- OBJECTIVES

1- Design and construct a cost effective ($100 production cost) interface system for the HC12 microprocessor.
2- Design a multi-experimental user-friendly board interface for an easy setup and usage. No more than two minutes spent for setup.
3- Maintain a safety priority to prevent injuries.
4- Protect the instruments against short circuits: ideal for a beginner's environment.

III- CONSTRAINTS

1- The maximum allowable cost of production is $100.
2- The maximum allowable size of the board should be 8" by 10".
3- The board should withstand drops and environmental damages like power surges or spikes.
4- The board should be esthetically pleasing with features like power cord in a corner, with LED's, displays and buttons for interruptions together on the same area.

IV- EXPECTED RESULTS

A functional board is desirable to be obtained after its design and construction. It will also include a PC Board layout, an assembly manual and an instructions manual. Students will be able to have experimental interaction with the Motorola HC12 microprocessor and the multi-experimental function board.

V- PROCEDURE

The following procedure was used to develop the project:

1- Decide which components are needed and buy them.
2- Build by sections:
   a- Build a Test Board with LED's, create a test program and test the section
   b- Build a Test Board with the switch buttons, create a test program and test the section
   c- Build a Test Board with a keypad, create a test program and test the section
   d- Build a Test Board with a LCD, create a test program and test the section
   e- Build a Test Board with a stepper motor, create a test program and test the section
   f- Build a Test Board with a DC motor, create a test program and test the section
   g- Build a Test Board with the two seven segments, create a test program and test the section
   h- Build the interface ribbon cable and design the pin-out of the board.

3- Design the schematics of the board with all the sections added.
4- Check schematics for errors and add protection from overvoltage and overcurrent.
5- Build and unify all individual sections in the interface board.
6- Test for functionality.
   a- Test electrically
   b- Run all the assembly programs
7- Write the assembly manual, the circuit schematics and the instruction manual.

VI- DESIGN SPECIFICATIONS

The breadboard complies with the following specifications:

1- A maximum size of 8" X 10"
2- Must be powered by a 5 VDC power source from witch it can draw a maximum current of 300 mA.
3- An on/off switch Button for main board power with power on/off led indicator.
4- Four 20 pin ribbon cable and its respective connectors.
5- Assorted cables of 8, 4 and 2 pin female connectors.
6- Eight LED's (5 V, 10 mA) buffered by the main 5 V source.
7- A 5V step motor (7.5 degrees per step).
8- A 5V, 78 mA DC motor (6,000 rpm).
9- A 16 characters by 2 lines LCD display (3.15" X 1.41" viewable area).
10- Four normally open push buttons (12 VDC, 50 mA maximum).
11- A 12 buttons Key Pad.
12- Two common cathode seven segments (0.56" display).

VII- GENERAL DESCRIPTION AND FEATURES

The Interface Board is the ideal tool to use with the EVB in a microcomputer interface course. This board simplifies the problem of building an interface for simple projects and helps the student to concentrate in the process of design and in code debugging.

The board consists of a 8.5 X 10 inches box with many different and interesting interface experiments.

A- HARDWARE FEATURES:

1- ON/OFF switch with a power on LED indicator
2- Single-supply +5 Vdc wall transformer
3- Four 20 pin cables to interface with the EVB
4- Cables of different lengths to simplify the connections between ports and projects
   a- Four 8 pin cables: two 8" and two 5"
   b- Five 4 pin cables: two 8" and three 5"
   c- Five 2 pin cables: two 8" and three 5"
5- Access to 6 different ports of the microprocessor
6- Eight different projects to work individually or combined
   a- Eight LEDs
   b- Four switches

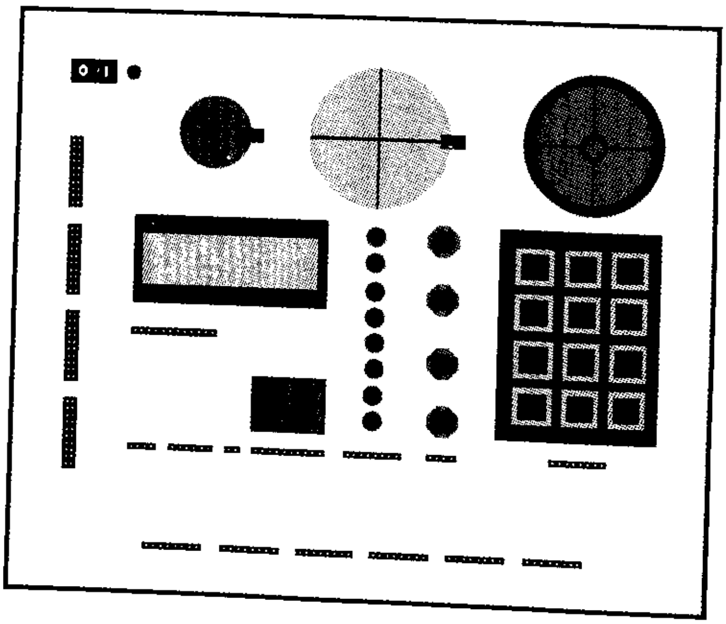

Figure 1: *Interface Board layout and Component Placement*

c- Keypad
d- Seven segments
e- LCD
f- Stepper motor
g- DC motor
h- Speaker

B- External Equipment Requirements

In addition to the Interface Board, the following user-supplied external equipment is required:

1- EVB and accessories to make it work
2- Four 20 pin 0.100 inch straight double row male headers
Note: These are required to be soldered to the EVB

C- Interface Board Specifications

The Interface Board specifications are listed in the Table 1.

D- Unpacking and Preparation

The user should verify that the following items are present in the Interface Board package:

1- The Interface Board assembly
2- Four 20 pin ribbon cables
3- Fourteen single row cables
    a- Four 8 pin
    b- Five 4 pin
    c- Five 2 pin
4- Interface Board User's Manual
5- Interface Board Technical Manual
6- Compact disk with all manuals and information

Table 1: *Interface Board specifications*

Characteristics	***Specifications***
LEDs	T1 ¾ (5 mm) Diffused, Red
Switches	Normally Open, ¼ in bushing, Red
Keypad	3 X 4 Normally Open, Telephone type
Seven Segments	2 digit Common Cathode, Character Height = 0.560 in
LCD	16 X 2 Line Display, Hitachi 44780 Controller
Stepper Motor	Two Phase Unipolar, 7.5 Degrees per Step
DC Motor	6000 RPM max
Speaker	8 Ω, 0.5 Watt

E- Setup and Connections

The only connections between the Interface Board and the EVB are the four 20 pin ribbon cables. As you can see in Figure 2, the black numbers in squares denote where the four ribbon cables have to be connected. The arrows indicate the pin # 1 of each connection. In the Interface Board of Figure 3, the numbers in squares have to match the connections on the EVB and, like in Figure 2, the arrows indicate the pin # 1.

With the four ribbon cables in place, the user shall verify that the on/off switch is located at the left side. Now the DC wall transformer can be plugged in and the board is ready to be used.

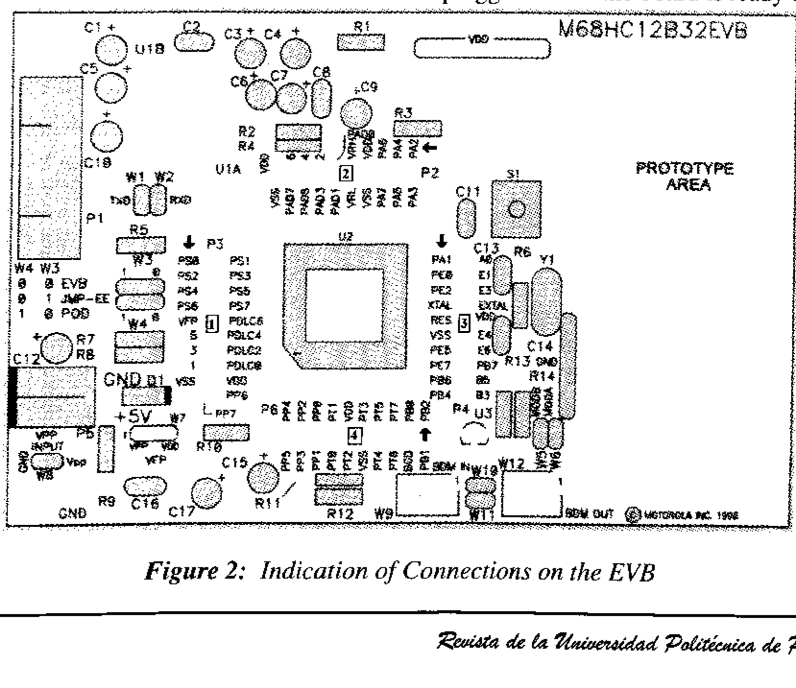

Figure 2: *Indication of Connections on the EVB*

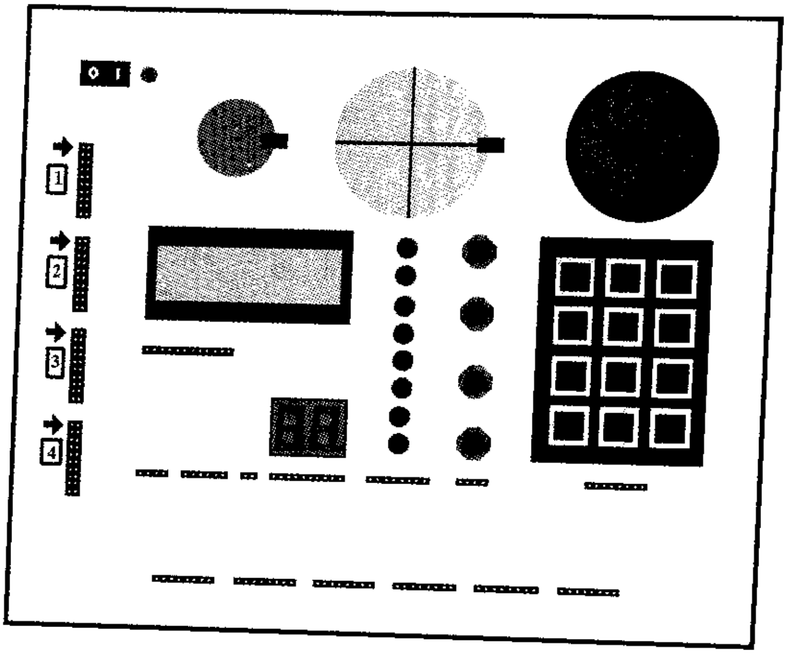

Figure 3: Interface Board Connections to EVB

F- Ports Used

The Interface Board has 6 ports to communicate with the microprocessor evaluation board. These ports are located on the bottom of the board. These are from right to left:

1- Port PWM
2- Port A/D
3- Port A
4- Port B
5- Timer Port
6- Interrupt Port

The user will control the different projects on the board with these ports. Each port has 8 pins corresponding to an 8 bit input or output of the microprocessor. The pins are numbered from 0 to 7, which 0 is the most significant bit (see Figure 4).

Bit 7 — Bit 0

Figure 4: Ports pin-outs

The pin-out will always be from left to right. Most of the pins on the board will have this general convention. They may only vary in quantity of pins.

G- Led

The LEDs are controlled by the 8 pins shown in figures 5 and 6. Each pin in this section corresponds to one LED. Pin 0 corresponds to the LED of the bottom, pin 1 corresponds to the second LED from the bottom, and so on.

Bit 7 — Bit 0

LED8	LED7	LED6	LED5	LED4	LED3	LED2	LED1

Figure 5: LEDs pin-outs

- LED 7 corresponding to Pin 7
- LED 6 corresponding to Pin 6
- LED 5 corresponding to Pin 5
- LED 4 corresponding to Pin 4
- LED 3 corresponding to Pin 3
- LED 2 corresponding to Pin 2
- LED 1 corresponding to Pin 1
- LED 0 corresponding to Pin 0

Figure 6: LEDs correspondence to pins

H- Switches

Like the LEDs, each of the four switches have a corresponding pin. The switches go from 0 to 3 from the bottom to the top, with their corresponding pins, which go from right to left (figures 7 and 8).

Bit 7			Bit 0
SW4	SW3	SW2	SW1

Figure 7: Pin-out of switches

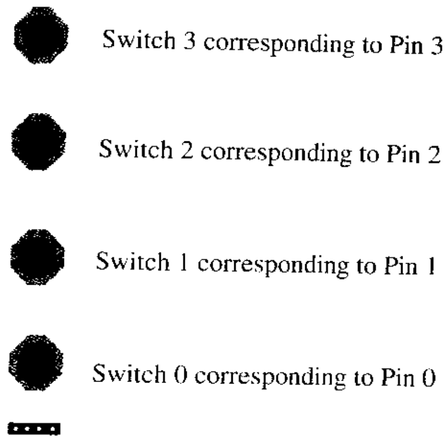

Figure 8: Switch correspondence to pins

I- KEYPAD

The keypad works like switches but with the small difference that if a button is pressed this will activate two pins instead of one. This is a combination of columns and rows. The keypad used is a 3 X 4 Telephone type pad. Even though we have 8 pins corresponding to the keypad only 7 will actually be used. The rows occupy the lower bits and the columns have the high bits with bit # 7 being the open one.

Bit 7							Bit 0
Open	C3	C2	C1	R4	R3	R2	R1

Figure 9: Keypad pin-outs

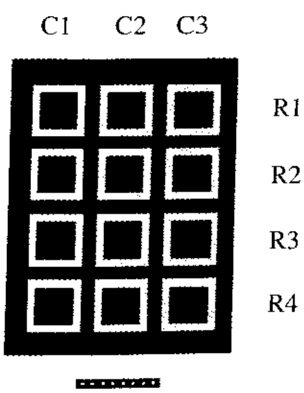

Figure 10: Keypad correspondence to pins

J- SEVEN SEGMENTS

The seven segments used, as you can see in Figure 11, are double so the user will be able to use them individually or combined.

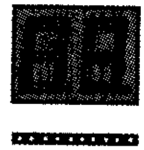

Figure 11: Seven Segment

Figure 13 shows the corresponding letter of each segment. Both seven segments have the same letters so the same combination of inputs will work with either seven segments. The way to select each seven segment will be with pin numbers 8 and 9. Pin # 8 will control the one on the left and pin # 9 will control the one on the right. The pin-outs are shown in Figure 12. Enabling one of these CTR pins will control its respective seven segment.

Bit 9									Bit 0
CTR 2	CTR 1	DP	Seg G	Seg F	Seg E	Seg D	Seg C	Seg B	Seg A

Figure 12: Pin-out of seven segments

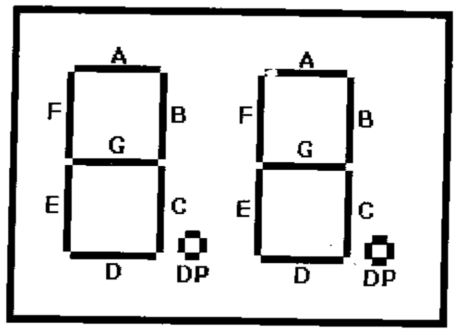

Figure 13: Corresponding letter to each segment

K- LCD DISPLAY

In this section we will only discuss the pin-out layout that the user will use to control the LCD. The instruction commands, timing, position of characters and the character code are specified in the tables 3 and 4. Figure 14 shows the 12 pins that controls the LCD.

Figure 15 illustrates the pins used to control the LCD. The eight DB pins from bit 0 to bit 7 are the Data Bus pins (refer to Table 2). With these pins, the user sends the data to be displayed in the LCD. Pin # 11 is the Enable Signal (E). This pin tells the LCD when the data from the microprocessor is ready to be sent. The RS pin is the Register Select.

Table 2: LCD Commands and Timings

Instruction	RS	R$\overline{W}$	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0	Execution Time (max)
Clear display	0	0	0	0	0	0	0	0	0	1	1.64 ms
Return cursor home	0	0	0	0	0	0	0	0	1	x	1.64 ms
Entry mode set	0	0	0	0	0	0	0	1	I/D	S	40 μs
Display on/off control	0	0	0	0	0	0	1	D	C	B	40 μs
Cursor or display shift	0	0	0	0	0	1	S/C	R/L	x	x	40 μs
Function set	0	0	0	0	1	DL	N	F	x	x	40 μs
Set CGRAM address	0	0	0	1	A_{CG}	A_{CG}	A_{CG}	A_{CG}	A_{CG}	A_{CG}	40 μs
Set DDRAM address	0	0	1	A_{DD}	A_{DD}	A_{DD}	A_{DD}	A_{DD}	A_{DD}	A_{DD}	40 μs
Read busy flag and address	0	1	BF	A_C	A_C	A_C	A_C	A_C	A_C	A_C	0 μs
Write data to CG or DDRAM	1	0	D7	D6	D5	D4	D3	D2	D1	D0	40 μs
Read data from CG or DDRAM	1	1	D7	D6	D5	D4	D3	D2	D1	D0	40 μs

DDRAM: Display data RAM
CGRAM: Character generator RAM
A_{CG}: CGRAM address
A_{DD}: DDRAM address; corresponds to cursor address
A_C: Address counter used for both DDRAM and CGRAM addresses

This pin tells the LCD where the user wants the character to be written. The R/W pin is the read and write pin. This pin tells the LCD if the user's microprocessor wants to read or write. This pin will have to be set to 0 (Data Write) because the LCD is set to write only. The microprocessor will not read from the LCD.

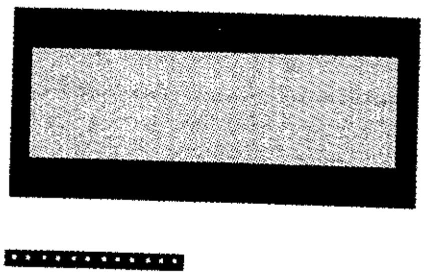

Figure 14: *LCD with pins*

Table 3: LCD Address Map

Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	...	Bit 16	...	Bit 39	Bit 40
$00	$01	$02	$03	$04	...	$0F	...	$26	$27
$40	$41	$42	$43	$44	...	$4F	...	$66	$67

Bit 12 … Bit 0

	E	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0

Figure 15: *Pin-out of LCD*

L- STEPPER MOTOR

The stepper motor is a 4-coil unipolar winding. This means that it will have 4 inputs which will control the motor. The motor steps are of 7.5 degrees per step so it will give a full turn in 48 steps. As you can see in Figure 16, the motor has a disk, which is divided in 15 degrees steps. It has also a sensor that will be able to detect 0 degrees to make precision calculated turns.

The pin-out shows the 4 Qs, which are the controls for the stepping sequence. Pin # 4 is the sensor output. This bit will change every time the slit pass through the sensor. Note that this will depend on how the user code is executed. Bit # 5 is open and is not used.

Table 4: Character code

Lower 4bit \ Higher 4bit	0000	0010	0011	0100	0101	0110	0111	1010	1011	1100	1101	1110	1111
××××0000			0	@	P	`	p		ー	タ	ミ	α	p
××××0001		!	1	A	Q	a	q	。	ア	チ	ム	ä	q
××××0010		"	2	B	R	b	r	「	イ	ツ	メ	β	θ
××××0011		#	3	C	S	c	s	」	ウ	テ	モ	ε	∞
××××0100		$	4	D	T	d	t	、	エ	ト	ヤ	μ	Ω
××××0101		%	5	E	U	e	u	・	オ	ナ	ユ	σ	ü
××××0110		&	6	F	V	f	v	ヲ	カ	ニ	ヨ	ρ	Σ
××××0111		'	7	G	W	g	w	ァ	キ	ヌ	ラ	g	π
××××1000		(	8	H	X	h	x	ィ	ク	ネ	リ	√	x̄
××××1001		)	9	I	Y	i	y	ゥ	ケ	ノ	ル	⁻¹	y
××××1010		*	:	J	Z	j	z	ェ	コ	ハ	レ	j	千
××××1011		+	;	K	[	k	{	ォ	サ	ヒ	ロ	ˣ	万
××××1100		,	<	L	¥	l	|	ャ	シ	フ	ワ	¢	円
××××1101		-	=	M	]	m	}	ュ	ス	ヘ	ン	£	÷
××××1110		.	>	N	^	n	→	ョ	セ	ホ	゛	ñ	
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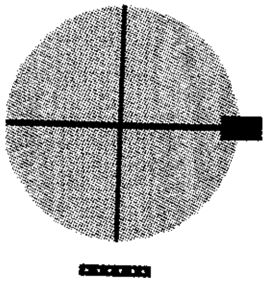

Figure 16: Stepper motor

Bit 5					Bit 0
Open	Sensor	Q1	Q2	Q3	Q4

Figure 17: Stepper Motor pin-out

Table 5 shows the stepping sequence. The inputs of the Q's are entered to the motor following the sequence shown in Table 5. If the sequence of the motor is entered from top to bottom (step 1 to 4 as in Table 5), the motor will rotate clockwise, and if the sequence is entered from bottom to top (step 4 to 1), then the motor will rotate counterclockwise.

In Table 6 the motor makes a half stepping sequence. The orientation of rotation will be the same as in Table 5.

Table 5: Normal 4 – step sequence (CW ↓ / CCW ↑)

Step	Q1	Q2	Q3	Q4
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	ON
3	OFF	ON	OFF	ON
4	OFF	ON	ON	OFF
1	ON	OFF	ON	OFF

Table 6: Half Step 8 – step sequence (CW ↓ / CCW ↑)

Step	Q1	Q2	Q3	Q4
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	OFF
3	ON	OFF	OFF	ON
4	OFF	OFF	OFF	ON
5	OFF	ON	OFF	ON
6	OFF	ON	OFF	OFF
7	OFF	ON	ON	OFF
8	OFF	OFF	ON	OFF
1	ON	OFF	ON	OFF

M- DC Motor

The DC motor used is a small motor used in any children toy. The DC motor used as a stepper motor has also a disk with a slit for the sensor, which will assist the user in measuring RPM to count turns.

The pin-out of this motor is showed in Figure 19. Bit 0 and 1, which are A and B control the motor. Bit 2 is used for the sensor and bit 3 is not used.

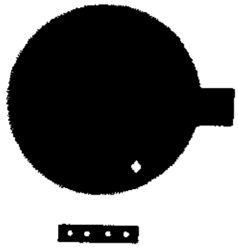

Figure 18: DC Motor

Bit 3			Bit 0
Open	Sensor	A	B

Figure 19: DC Motor pin-out

Table 7: DC Motor Control Sequence

A	B	Action of motor
0	0	Stop, motor will not run
0	1	Clockwise rotation
1	0	Counterclockwise rotation
1	1	Stop, motor will not run

Table 7 shows how the motor will operate depending of the sequence of A and B. If you leave one of the two control pins in high, this will make the motor rotate at max speed until it is changed. To control the speed of the motor, a pulse should be sent through the enabled pin. The speed of the motor will depend on the duty cycle.

N- Speaker

The speaker has only two pins, and one of them is open (see Figure 20). The pin that corresponds to the bit 0 is the speaker control. The speaker is normally used with the Pulse Width Modulation feature of the microprocessor, which is used to create different frequencies. Those frequencies are used as inputs for bit 0, and the tones generated will be heard through the speaker.

Bit 2	Bit 0
Open	S

Figure 20: Speaker pin-out

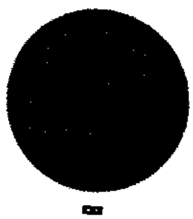

Figure 21: Speaker

VIII- DRAWING

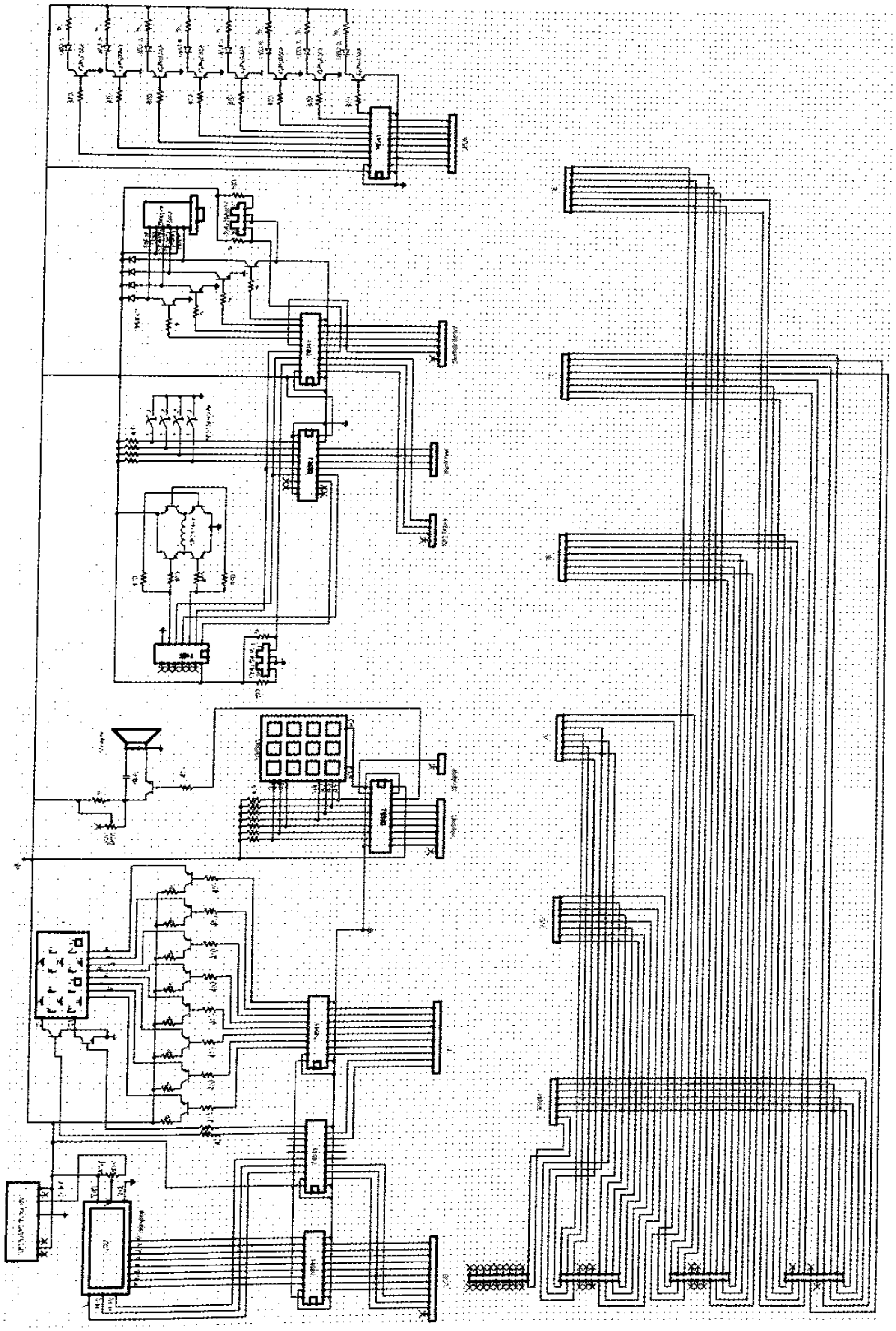

Figure 21: Schematics of the compete board

X- CONSTRUCTION COST

Table 8: *Cost Per Unit (Price based in 100 units)*

Part	Quantity	Unit Price	Cost
Resistors			
4.7k	11	0.01	0.11
1k	23	0.01	0.23
470	23	0.01	0.23
100	2	0.02	0.04
2.2k Pot Resistors	1	0.09	0.09
10k Pot Resistors	1	0.12	0.12
Transistors			
2N2222 NPN	22	0.09	1.98
1617 NPN	5	0.15	0.75
Capacitors			
100u	1	0.15	0.15
Buffers			
74540	2	0.39	0.78
74541	5	0.49	2.45
Diodes			
1n4007	4	0.03	0.10
Logic			
7408 - 2 Inputs AND Gate	1	0.17	0.17
Opto Switch	2	0.29	0.58
LED	9	0.08	0.72
NO Switch	4	0.30	1.20
ON/OFF Switch	1	0.35	0.35
DC to DC Converter +5 and -5V	1	1.00	1.00
DC Motor	1	1.50	1.50
Stepper Motor	1	2.00	2.00
LCD	1	8.95	8.95
Keypad	1	4.05	4.05
7 Segment	1	0.89	0.89
Speaker	1	1.00	1.00
Wall Transformer 5V DC	1	3.00	3.00
Connectors			
20 pin double row	9	0.22	1.98
8 pin single row	8	0.12	0.96
4 pin single row	10	0.12	1.20
2 pin single row	10	0.10	1.00
Connector pin for single row connector	124	0.06	7.44
20 pin ribbon cable	6	0.14	0.84
8 pin single	13	0.07	0.91
20 pin double	5	0.19	0.95
IC Sockets			
14 pin	1	0.04	0.04
20 pin	7	0.06	0.42
Breadboard	1	9.95	9.95
Miscellaneous	1	10.00	10.00
Total for 1 Unit			***$68.13***
Total for 100 Units	100	$68.13	***$6,813.00***

IX- BUDGET

Table 9: *Salary*

Design Cost per Hour	$ 50.00
Hours per week	10
Weeks in Project	24
Total Hours	$ 12,000.00

People Involved	2
Total Salary	$ 24,000.00

Table 10: *Expenses*

Office Materials	$ 200.00
Miscellaneous	$ 3,0000.0
Total Expenses	$ 3,200.00

Table 11: *Total Cost*

Salary	$ 24,000.00
Expenses	$ 3,200.00
Total	***$ 27,200.00***

XI- CONCLUSIONS

A functional interface board for the HC12 Motorola Microprocessor was designed and constructed. All constraints, such as budget, dimensions, safety and a esthetical appearance, were satisfied, as well as the objectives: an easy to use board was constructed with all its components protected from spikes and related damages.

Another part that were not included in the original design was added to the board to complement our learning experience and to make a more complete laboratory tool.

Our knowledge and expertise in micro-processor programming and interfacing electronics was greatly improved.

XII- BIBLIOGRAPHY

[1] M68EVB912B32 Evaluation Board User's Manual, Motorola Inc., February 1997

[2] Motorola Semiconductor Technical Data, Motorola Inc., 1997

[3] 68HC12 CPU12 Reference Manual, Motorola Inc., 1996 1997