Displaying of Graphics on CRO through 8051 Microcontroller and Digital to Analog Converter

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Abstract –
With a view to display various shapes and different types of characters on cathode ray oscilloscope through 8051 Microcontroller, 8255 programmable peripheral interface and Two 4-bit Digital to Analog Converters (DACs), an interfacing diagram was designed. The output of first 4-bit DAC is acting as a source of data for x-axis and the output of second 4-bit DAC is acting as a source of data for y-axis. The length of the scale varies in terms of digital inputs from 00 to 0FH on x axis and also on y axis. An assembly language program of 8051 Microcontroller was written and executed to determining analog output voltages V_A and V_B for all digital input combinations and the obtained outputs incremented systematically by increasing the digital inputs. Later, the outputs are connected to CRO through op-amps and written an assembly language program to transfer the data through port A of 8255 PPI. The characters A, M and the shapes Hexagonal and Circle were displayed in the present work. Due to 4-bit DACs, 2^4=16 outputs are possible for different digital input combinations from 00 to 0FH. For displaying more number of shapes and many characters, there is a need to enhance the digital inputs. To enhance the length of scale from 00 to FFH, one complete 8-bit port is connected to x- channel and another complete port to y- channel to display series of characters and many shapes on oscilloscope.

Keywords – *Microcontroller, Digital to Analog Converter, Interfacing, Graphics, Assembly language program, Time delay*

I. INTRODUCTION

In the digital era, it is an essential to transfer characters and shapes either in parallel mode or in serial mode to output devices to display them on liquid crystal displays (LCDs), seven segment LEDs or on dual slope cathode ray oscilloscopes (CROs). In the present work, efforts were made to transfer different types of characters and shapes through 8051 microcontroller as given in a book in [1] and displaying them on dual slope oscilloscope.

A. *Digital to Analog Converter (DAC)*

Many systems accept a digital word as an input signal and translate or convert it to an analog voltage or current as mentioned in a book in [2]. These systems are called digital to analog converters (DACs). The output voltage V_o of an N-bit DAC is given by the following equation

$$V_o=(a_{N-1}2^{-1}+a_{N-2}2^{-2}+a_{N-3}2^{-3}+.......+a_0 2^{-N})V_R.......(1)$$

Where the coefficients a_N represents the binary word and a_N=1 (0) if the n^{th} bit is 1 (0). The voltage V_R is a stable reference voltage used in the circuit. The most significant bit is corresponds to a_{N-1} and its weight is $V_R/2$, while the Least significant bit corresponds to a_0 and its weight is $V_R/2^N$. The vast majority of IC DACs, including MC1408 (DAC 0808) uses the R-2R method since it can achieve a much higher degree of accuracy. The first criterion for judge a DAC is its resolution, which is a function of the number of binary inputs. The number of data bit inputs decides the resolution of DAC since the number of analog output levels is equal to 2^n, where n is the number of data inputs. The 4 bit DAC provides 16 discrete voltage (Current) levels of outputs and an 8 bit DAC provides 256 outputs in hexadecimal format as given in a journal article in [3].

In the present work two 4-bit DACs were designed as given in a book in [4] and their outputs were obtained by using the equation as given below

$$V_A = V_B = -\frac{V}{8}[8\,D + 4\,C + 2\,B + A]........ (2)$$

Where V_A is the analog voltage at the output of first 4 bit DAC1, V_B is the analog voltage at the output of second 4 bit DAC2 and D is the Voltage at PA_7 / PA_4, C is the Voltage at PA_6 / PA_3, B is the Voltage at PA_5 / PA_2, A is the Voltage at PA_4 / PA_0. The negative sign indicates the inverted output from operational amplifier.

II. EXPERIMENTAL TECHNIQUES

The microcontroller used in the present work is the SDA 51-MEL, which is a system design aid for operation of microcontroller devices as given in a lab manual in [5].

It uses 8031/51 as the controller. It is a powerful microcontroller trainer for the INTEL 8051 microcontroller and it is operating at 11.0592MHz.

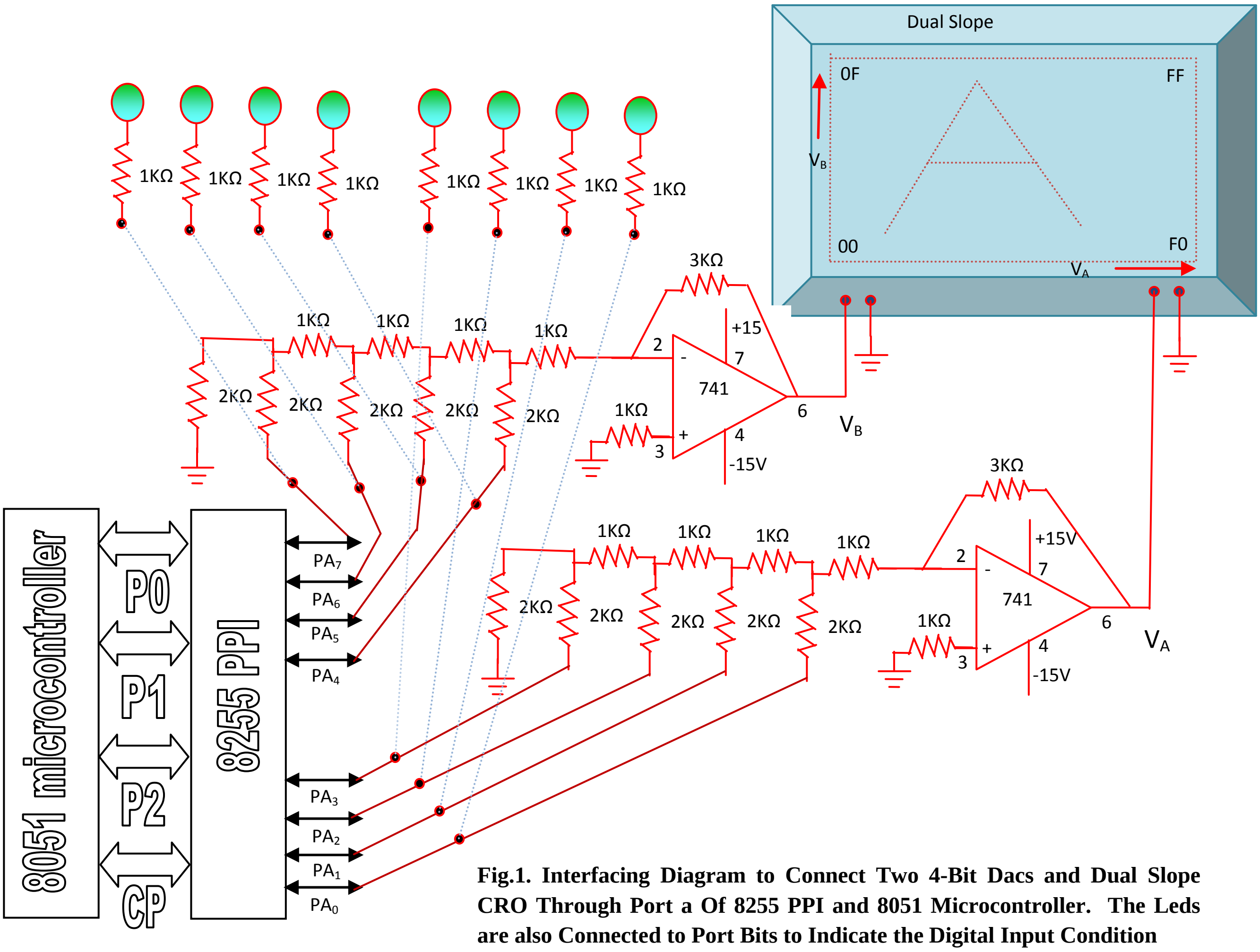

Fig.1. Interfacing Diagram to Connect Two 4-Bit Dacs and Dual Slope CRO Through Port a Of 8255 PPI and 8051 Microcontroller. The Leds are also Connected to Port Bits to Indicate the Digital Input Condition

The outputs obtained from port A of 8255 PPI is connected to the inputs of digital to analog converter. The R-2R ladder type DAC is designed with 1KΩ and 2KΩ resistors and it was connected to inverting operational amplifier (IC 741) to boost the outputs. The op-amp is activated with +15V and -15V dual power supply. Firstly, the outputs are connected to multi meter to obtain analog voltage for different combinations of digital inputs and finally, the outputs of DACs are connected to dual slope cathode ray oscilloscope, which must be operated in 'xy' mode to display graphs on it. The complete experimental circuit diagram was given in Fig. 1. More details about electronic components were given in a journal article in [6].

III. RESULTS AND DISCUSSIONS

The two 4-bit DACs were designed by using R-2R ladder method, which is a simple and most useful method with high resolution to design DAC. The inputs of DAC are connected to the outputs of 8255 PPI port A bits (PA0 – PA7). The inputs are also connected to LEDs to indicate the input condition in binary format. The output V_A and V_B are initially connected to multimeter to obtain analog voltage for each digital input. An assembly language program of 8051 microcontroller as given in Table 1 was written and executed to supply binary inputs with 8 seconds delay to DAC. The DELAY routine as given in Table 2 will produce an approximately 8 Seconds time delay to record analog voltage on multimeter.

The analog voltages for all digital input combinations were given in Table 3. The obtained output voltages are increasing systematically by increasing the digital input pattern. The loose contacts may give the disordered output voltage pattern. This may causes wrong pattern in displayed graph. So, precautions were taken to eliminate loose contacts in the circuit. After getting linear variations of the output voltages V_A and V_B are connected to channel 1 and channel 2 of the dual slope cathode ray oscilloscope through an inverting operational amplifier by keeping the CRO in 'xy' mode to accept the data to display dots based on input conditions.

If the datas 00, 0FH, FFH, F0H were transferred to port A, then a square wave frame will appear on CRO as shown in figure 1. Therefore, to display any character or any shape should be displayed with in this frame only. Therefore a group of data points were collected to display characters A, M and shapes hexagonal and circle and tabulated in Table 4.

All these data points were stored in RAM memory from 31H onwards. The total number of data points was taken as a counter value, which was stored at RAM memory location 30H. Now, an assembly language program of 8051 as given in Table 5 was written and executed to transfer all these data points one by one to port A of 8255 PPI to supply inputs to DAC. After transferring of one data the count value will be decremented by one. After receiving data from port A of 8255 PPI, the DAC output values will be modified and its corresponding dot will appear on CRO. After receiving all the data's, the required character or shape will be displayed on CRO. This process can be repeatedly performed to display the stable graph on CRO. In the first trail, the datas of character A as given in Table 4 was transferred and displayed letter 'A' on CRO.

In the similar way the character 'M' and the shapes hexagonal and circle were displayed on CRO by changing the data points at RAM memory locations from 30H onwards. All these graphs were shown in Fig. 2.

IV. Table 1

Assembly language program of 8051 microcontroller to determine Analog Voltages through digital to analog converter

ORG 8000; Initial address of the main program

Addre ss	**Lab -el**	**Mnemonic**	**Comments**
8000H		MOV DPTR,#2023H	; Load DPTR with Control port Address
8003H		MOV A,#80H	; Load Accumulator with 80H to 8255 control word to consider the ports (P0, P1 and P3) as output ports
8005H		MOVX @DPTR,A	; Transfer the control word to control port
8006H		MOV DPTR,#2020H	; Load DPTR with port A Address
8009H		MOV A,#00	; (A) = 00 = First data
800BH	BK:	MOVX @DPTR,A	; Transfer the first data to port A
800CH		LCALL DELAY	; Call delay routine to produce delay to note analog voltage
800FH		ADD A,#11	; (A) = (A) + 11, next data
8011H		CJNE A,#FF,BACK	; If (A) ≠ FFH then jump to BACK
8013H		LCALL 0003	End of the program

V. Table 2

The Delay Routine

VI. Table 3

Analog output Voltages of DAC for various combinations of digital inputs

PA_7 / PA_3	PA_6 / PA_2	PA_5 / PA_1	PA_4 / PA_0	V_B (Volts)	In Hex	V_A (Volts)
0	0	0	0	0	0	0
0	0	0	1	0.23	1	0.24
0	0	1	0	0.42	2	0.41
0	0	1	1	0.58	3	0.56
0	1	0	0	0.73	4	0.74
0	1	0	1	0.95	5	0.97
0	1	1	0	1.17	6	1.22
0	1	1	1	1.33	7	1.38
1	0	0	0	1.49	8	1.52
1	0	0	1	1.67	9	1.67
1	0	1	0	1.96	A	1.86
1	0	1	1	2.18	B	2.98
1	1	0	0	2.51	C	2.51
1	1	0	1	2.86	D	2.80
1	1	1	0	3.09	E	3.04
1	1	1	1	3.33	F	3.23

II. Table 4 ***Data Points to display letter A, M and shape s Hexagonal and Circle***

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Character / Shape	Data Points	Total Data's & Memory
A	00, F0, FF, F0, 22, 34, 59, 7E, 8C, 99, A7, C2, 59, 69, 79, 89, 99	17 = 11H (31H – 41H)
M	00, F0, FF, F0, 21, 23, 24, 25, 26, 27, 28, 29, 2B, 48, 65, 76, 88, AB, AA, A9, A8, A7, A6, A5, A4, A3, A2, A1	28 (31H to 4CH)
Hexagonal	00, F0, FF, F0, 34, 35, 36, 37, 38, 39, 3A, 4B, 5C, 6D, 7E, 8D, 9C, AB, BA, B9, B8, B7, B6, B5, B4, A3, 92, 81, 70, 61, 52, 43	32 (31H – 50H)
Circle	00, F0, FF, F0, 80, 52, 44, 36, 38, 5D, 7E, 8E, AD, C9, C7, A2,	16 (31H – 40H)

Address	Label field	Mnemonic field	Comments field
FF00	DLY:	MOV R5,#08	; (R5) = 08
FF02	LP3:	MOV R6,#0FF	; (R6) = FFH
FF04	LP2:	MOV R7,#0FF	; (R7) = FFH
FF06	LP1:	DJNZ R7,LP1	; Decrement R7 by 1 and jump to LP1 if it is not equal to 0
FF08		DJNZ R6,LP2	; Decrement R6 1 and jump to LP2 if it is not equal to 0
FF0A		DJNZ R5,LP3	; Decrement R5 and jump to LP3 if it is not equal to 0
FF0C		RET	; Return to the main program

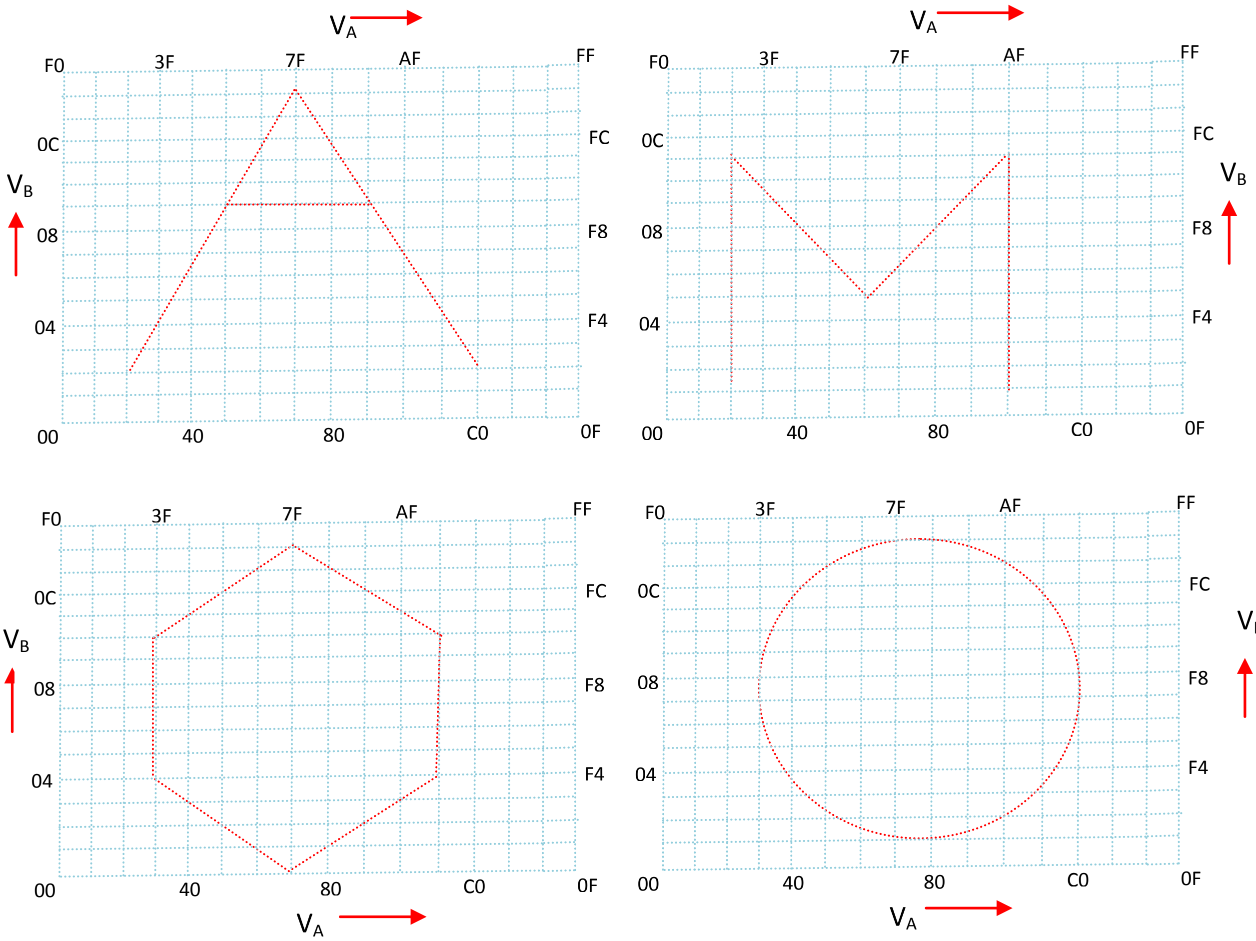

Fig. 2. The Characters A & M and the Shapes Hexagonal and the Circle in a coordinate system

On x-axis V_A and on y axis V_B in terms of their respective digital inputs were taken in Fig. 2. Register indirect addressing mode as mentioned in journal article in [7] is used to transfer the data's from RAM memory to port A of 8255 PPI, in which R0 register is acting as a memory pointer. It is observed from figure 2 that the graph with longer sides are matched well with the data points, where as the non linear shapes like circle, the matching points are very few. Therefore, there is a need to enhance the circuit to get more and more data points to draw a perfect picture.

B. Figure Captions

Fig.1.
Interfacing diagram to connect Two 4-bit DACs and Dual slope CRO through port A of 8255 PPI and 8051 Microcontroller. The LEDs are also connected to port bits to indicate the digital input condition

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C. Table Captions

Table 1
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Table 2
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Table 3
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Table 4
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Table 5
Assembly language program of 8051 to display character A, M and the shapes Hexagonal and the circle on CRO (Keep respective Count Value and data values to display a particular pattern as shown in Table 4 at RAM memory location from 30H onwards)

IX. CONCLUSIONS

1. The outputs of two digital to analog converters V_A and V_B are varying systematically with increasing digital inputs

2. It is convenient to display single character / shape with the present circuit. For non linear shapes like circle, there is a need to enhance the circuit.

3. The disordered outputs may display wrong pattern of graph on CRO.

VIII. Table 5

Assembly language program of 8051 to display character A, M and the shapes Hexagonal and the circle on CRO (Keep respective Count Value and data values to display a particular pattern as shown in Table 4 at RAM memory location from 30H onwards)

ORG 8100H; Initial address of the program

Address	Label	Mnemonic field	Comments field
8100H		MOV DPTR,#2023	;DPTR = Control port
8103H		MOV A,#80	; (A) = Control word
8105H		MOVX @DPTR,A	; (CP) =80H
8106H		MOV DPTR,#2020H	; (DPTR) = port A
8109H	AG	MOV R0,#30H	; (R0)= (30H)=Count
810BH		MOV A,@R0	; (A) = Count Value
810CH		MOV R1,A	; (R1) = Count Value
810DH	BK	INC R0	; (R0) = (31H) = Data
810EH		MOV A,@R0	; (A)= First data
810FH		MOVX @DPTR,A	;First data to port A
8110H		DJNZ R1,BK	; Decrement R1 and jump to BK if R1≠0
8112H		SJMP AG	; Jump to AG to transfer the data continuously

4. The CRO must be operated in 'xy' mode to display graphics on it, otherwise waveforms will be displayed on it.

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