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## Software Defined 8, 16 & 24 Bit Digital Logic Design by One Microcontroller

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# Software Defined 8, 16 & 24 Bit Digital Logic Design by One Microcontroller

Md. Khaled Hossain<sup>α</sup> & Md. Nasimuzzaman Chowdhury<sup>σ</sup>

**Abstract** - Now-a-days digital circuits are getting more complex. One IC in a digital circuit is used for a fixed purpose and its operation cannot be defined through software. Because of this limitation digital circuit becomes larger in size. When designing an 8bit digital circuit we do not include 16bit or 24bit components, but this limits our scope of design and versatility of the design. To overcome this problem an 8bit microcontroller is programmed which is able to do addition, subtraction, multiplication and 28 other digital operations in 8, 16 & 24 bit level. To add six 8 bit data 5 adder ICs are not needed anymore. This IC can do it all alone. For any logic operation the regarding mode needs to be selected in the same IC to perform desired operation. It is software defined digital logic design IC. This IC will save time, space & reduce cost in digital circuit designing.

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## 1. INTRODUCTION

Microcontrollers are capable of executing all digital logic design operations. In another paper we have implemented 28 digital logic design operation by one microcontroller [1]. But still if a 16bit operation is needed we have to cascade two 8bit microcontrollers. Instead of cascading two microcontrollers, it is possible to do operations up to 24bits with this IC. This IC can perform AND, OR, NOR, NAND, XOR, XNOR, Universal Shift Register, Counter operations etc. The Controller used in this project is Atmega1280. It has 86 GPIO. In this project there are 6sets of 8bit input, 25bit output, 6bit main operation selection option and additional 5bit to select sub operations. When user selects 16 bit operation mode, this IC combines Input1 & Input2 as 1st input of 16bit. Combination of Input3 & Input4 becomes 2nd input of 16bit. Input5 & Input6 are combined for 3rd input of 16bit. When user wants to do operation of 24 bit that time Input1, Input2 & Input3 combines & form 1st 24bit input. The rest Input4, Input5 & Input6 act as 2nd input of 24bit. And all the operations output is given through 25bit. Here 25th bit output is the carry bit for 24bit operations.

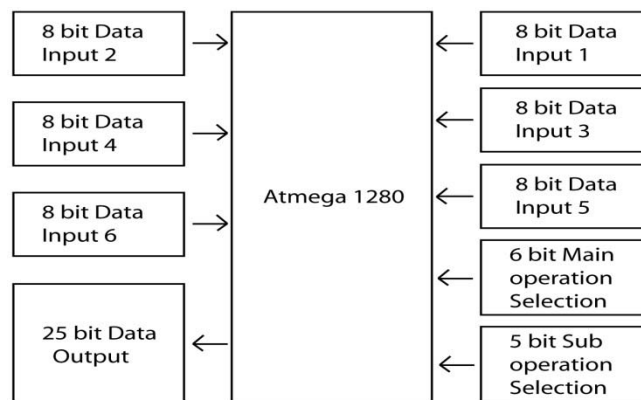


Figure 1 : Basic Project outline

Here input1, input2, input3, input4, input5 & input6 are accordingly portB, portC, PortF, portJ, portK, portL and outputs are portC, portD, portE & portG<sub>6bit</sub>. Rest of the pins of portG represent sub operations and to select main operation portH is used. Enable\_bar means to enable the IC we need to make portH<sub>6bit</sub> low. PortH<sub>7</sub> represent synchronous clock input. When 16bit operations are selected PortA are lower eight bits & PortB are higher eight bits. In the same way for input2 & input3 portF, Portk are lower eight bits and PortJ, PortL are higher eight bits accordingly. For 24bit operation in input1 portA are lower eight bits, portB are higher eight bits, portF are most significant eight bits. For second input PortJ are lowest significant bits, portK are higher eight bits, portL are highest eight bits. At output, portC are most significant 8bits, portD are higher 8bits, PortE are more higher 8bits & portG<sub>6bit</sub> is the MSB.

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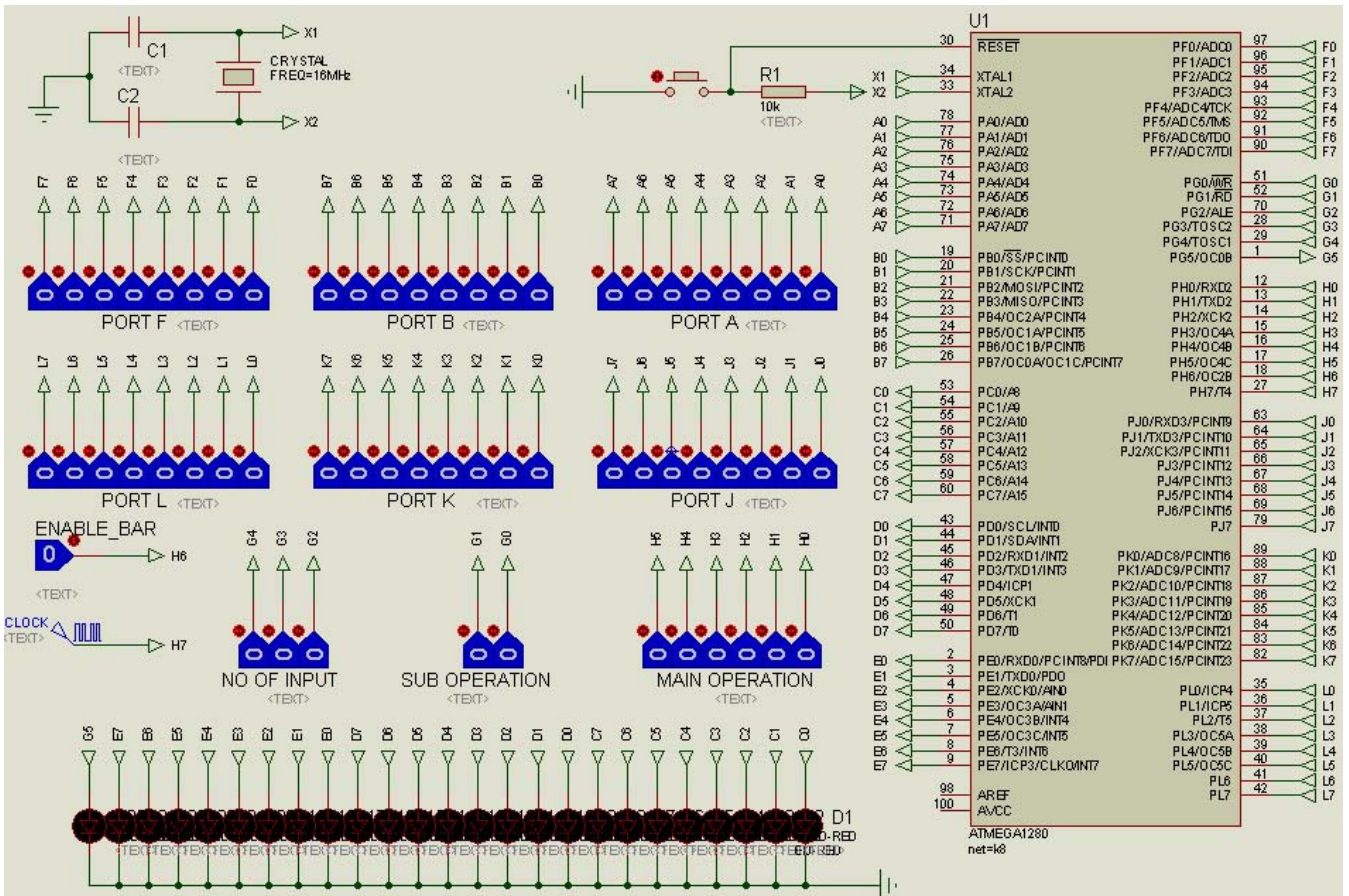


Figure 2 : Main Circuit Diagram

## II. CIRCUIT DESCRIPTION

Atmega1280 is used as microcontroller in this project. Operating voltage of atmega1280 is +5v. Here VCC is +5v. Atmega1280 has 86 GPIO, 11 GPIO ports. They are PORTA, PORTB, PORTC, PORTD, PORTE, PORTF, PORTG, PORTH, PORTJ, PORTK and PORTL. Among these ports PORTA, PORTB, PORTF, PORTJ, PORTK, PORTL, PORTH and PORTG are all input. PORTC, PORTD, PORTE & PORTG5\_bit are all output. To give input toggle switches are used and to see the output LEDs are used. There are two more inputs one is Enable and another is for clock. Microcontroller has its own clock connected to Xtal1 & Xtal2 pin. Value of oscillator is 16 MHz. A reset circuit is connected with RESET\_bar pin to reset the microcontroller. This microcontroller can execute 28 operations and lots of sub operations. To select main operation PORTH0 to PORTH5 total 6 pin is used and to select sub operation PORTG0 to PORTG4 is used. To Enable and disable the IC, Enable\_bar is used at PORTH6\_bit. External clock is used at PORTH7\_bit. This IC can operate in both asynchronous and synchronous mode. When there is no external clock it will operate in asynchronous mode and while clock is used it will operate based on the clock frequency. If Enable\_bar pin is high at that time

microcontroller will not take any clock input or will not work in asynchronous mode also.

### a) Main Technology Used

Main technology of this IC is the programming method. To perform any operation with this IC, at first the main operation mode and sub operation mode is selected. For example if we want to do an addition operation the mode 00 is selected. PortH0 to PortH5 has to be 0. Then we have to select sub operation like we want to do an 8bit, 16 bit or 24bit addition. If we want an 8bit addition we have to set the value of PortG0\_bit & PORTG1\_bit equal to 0. As this is an 8bit operation we have the option to choose with how many variable we would like to do the operation. We can choose an addition operation from two variables to six variables maximum. Let's choose 2 variables. Then Value of PortG2\_bit is 0, PortG3\_bit is 1 & PortG3\_bit is 0. Here PortG2\_bit is LSB and PortG3\_bit is MSB. Now it is ready to perform two 8 bit additions. Any value of PortA will be added with any value of PortB and output will be shown by LEDs in binary format. PortC0\_bit is the LSB bit of output and PortG5\_bit is the MSB bit.

For an 8bit operation we need to select number of inputs but for 16bit or 24bit operation this IC will start working instantly when main operation and sub

operation is set. There are some operations in 16 bit or 24 bit which have sub operations also. For example if we want to execute a 24bit Barrel shifter, we have to set the main operation first. H5=0, H4=1, H3=1, H2=0, H1=1, H0=0. Then we have to select sub operation that, shift it right or shift it left. So, the sub operation G0=0, G1=0 is set for shifting right arithmetic. Then we have to select the amount of shifting through Pin G2 to G4. The table below gives us the operation chart and bit values to set them

Table 1 : Main Operation Chart

	H4	H3	H2	H1	H0	Operation
00	0	0	0	0	0	Addition
01	0	0	0	0	1	Subtraction
02	0	0	0	1	0	Multiplication
03	0	0	0	1	1	Division
04	0	0	1	0	0	AND
05	0	0	1	0	1	OR
06	0	0	1	1	0	NOT
07	0	0	1	1	1	NOR
08	0	1	0	0	0	NAND
09	0	1	0	0	1	XOR
10	0	1	0	1	0	XNOR
11	0	1	0	1	1	Buffer
12	0	1	1	0	0	Universal Shift Register
13	0	1	1	0	1	Ones Counter
14	0	1	1	1	0	Binary Counter
15	0	1	1	1	1	Inverted Counter
16	1	0	0	0	0	Mux

17	1	0	0	0	1	Demux
18	1	0	0	1	0	Segment Decoder Common Cathode
19	1	0	0	1	1	Segment Decoder CC Dot
20	1	0	1	0	0	Segment Decoder Common Anode
21	1	0	1	0	1	Seg Dec CA Dot
22	1	0	1	1	0	Priority Encoder
23	1	0	1	1	1	Priority Decoder
24	1	1	0	0	0	Parity Checker
25	1	1	0	0	1	Comparator
26	1	1	0	1	0	Barrel Shifter
27	1	1	0	1	1	Ring Counter
28	1	1	1	0	0	John. Ring Counter

Table 2 : Sub operation chart

G1	G0	Sub Operation	Main Operation
0	0	8 bit	Addition, Subtraction, Multiplication, Division, All operations
0	1	16 bit	
1	0	24 bit	

Table 3 : Sub operation chart

G1	G0	Sub Operation	Main Operation
0	0	7 Segment	Segment Display
0	1	14 Segment	
1	0	16 Segment	

Table 4 : 8 bit level operations

G4	G3	G2	IN1	IN2	IN3	IN4	IN5	IN6	Equation	Operation
0	1	0	PortA	PortB	X	X	X	X	IN1+IN2	ADD
0	1	1	PortA	PortB	PortF	X	X	X	IN1+IN2+IN3	
1	0	0	PortA	PortB	PortF	PortJ	X	X	IN1+IN2+IN3+IN4	
1	0	1	PortA	PortB	PortF	PortJ	Portk	X	IN1+IN2+IN3+IN4+IN5	
1	1	0	PortA	PortB	PortF	PortJ	Portk	PortL	IN1+IN2+IN3+IN4+IN5+IN6	

Table 5 : 16 bit level operations

G4	G3	G2	IN1	IN2	IN3	Equation	Operation
0	1	0	PortB PortA	PortJ PortF	X	IN1+IN2	ADD
0	1	1	PortB PortA	PortJ PortF	PortL Portk	IN1+IN2+IN3	

Table 6 : 24 bit level operations

G4	G3	G2	IN1	IN2	Equation	Operation
x	x	x	PortF PortB PortA	PortL Portk PortJ	IN1+IN2	ADD

In the above table sub operation of addition is shown and how to select the operation bit values are also shown. In this way all the other operations are performed. If we wants to do subtraction IN1 has to be the largest number than second largest should be IN2, so that we don't get any wrong answer for subtraction. This order is maintained for division also. For two inputs,

the equation is IN1/ IN2. Segment Decoder takes input as binary value and gives output for common cathode without dot, common cathode with dot, common anode without dot and common anode with dot. For example if L3=0, L2=1, L1=0, L0=0 then segment with show 4 as output. Ones counter, binary counter, Mux, Demux all these operations are also divided according to the

above table. But Universal shifter and barrel shifter have other sub functions. These functions are shown below:

Table 7 : Sub operation chart

L7	L6	L5	SUB	MAIN
0	0	X	Serial In Parallel Out	Universal Shift Register
0	1	X	Serial In Serial Out	
1	0	X	Parallel In Serial Out	
1	1	X	Parallel In Parallel Out	
0	0	0	Shift Right Logic	Barrel Shifter
0	0	1	Shift Right Arithmetic	
0	1	X	Rotate Right	
1	0	0	Shift Left Logic	
1	0	1	Shift Left Arithmetic	
1	1	X	Rotate Left	

Table 8 : Commands of Sub operation chart

L3	L2	L1	L0	OPERATIONS	SUB
X	0	0	0	Hold	SIPO
X	0	0	1	Load	SISO
X	0	1	0	Load & Shift Right	PISO
X	0	1	1	Load & Shift Left	PIPO
X	1	0	0	Shift Circular Right	Barrel Shifter
X	1	0	1	Shift Circular Left	
X	1	1	0	Shift Arith Right	
X	1	1	1	Shift Arith Left	
0	0	0	0	Shift 0	
0	0	0	1	Shift 1	
0	0	1	0	Shift 2	
0	0	1	1	Shift 3	
0	1	0	0	Shift 4	
0	1	0	1	Shift 5	
0	1	1	0	Shift 6	
0	1	1	1	Shift 7	
...	...	...	...	.....	
1	1	1	1	Shift 15	

b) Device Used

Brain of this project is Atmega1280 microcontroller. It is an 8 bit Micro controller with RISC architecture. Its speed is up to 16 MIPS throughout at 16MHz. It has 128K bytes of flash and 4Kbytes EEPROM. Operating voltage 2.7v -5.5v, in active mode it consumes only 1.1mA & in sleep mode it consumes less than 1uA current. It has 86 GPIO, 16 PWM channels, SPI, 4 UART, I2C and other features which made it a perfect choice of designing a versatile digital design IC.

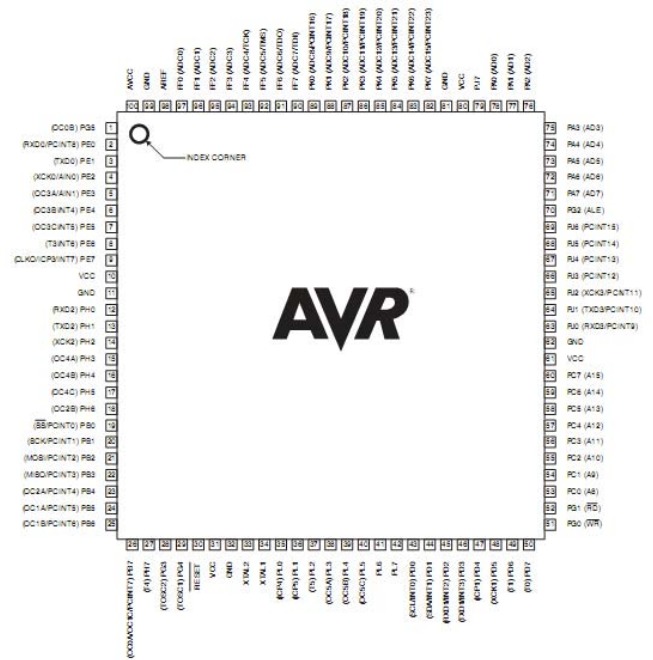


Figure 3 : Atmega1280 Microcontroller[8]

Our program consumes only 37kbytes of Flash memory. Still 91kbytes of Flash memory is available to design other operations.

As the outputs are shown in simulation no resistors has been used. In practical implementation with each LED 220ohm resistance is being used. Each input Pin has been pulled down through 10k resistor.

Atmega1280 contains 135 powerful instructions like addition, subtraction, shifting etc and most single clock cycle execution.32x8 general purpose working resistors, two 8bit timer & four 16bit timer, interrupt and wakeup on pin change. It comes in 100 lead TQFP, 100 Ball CBGA wich can be breakout easily and small in size. This microcontroller has the most number of GPIO and all 86 GPIO pins can be used as input or output. Brown out feature of this Ic makes it more stable output and long lasting.

### III. TEST RESULTS

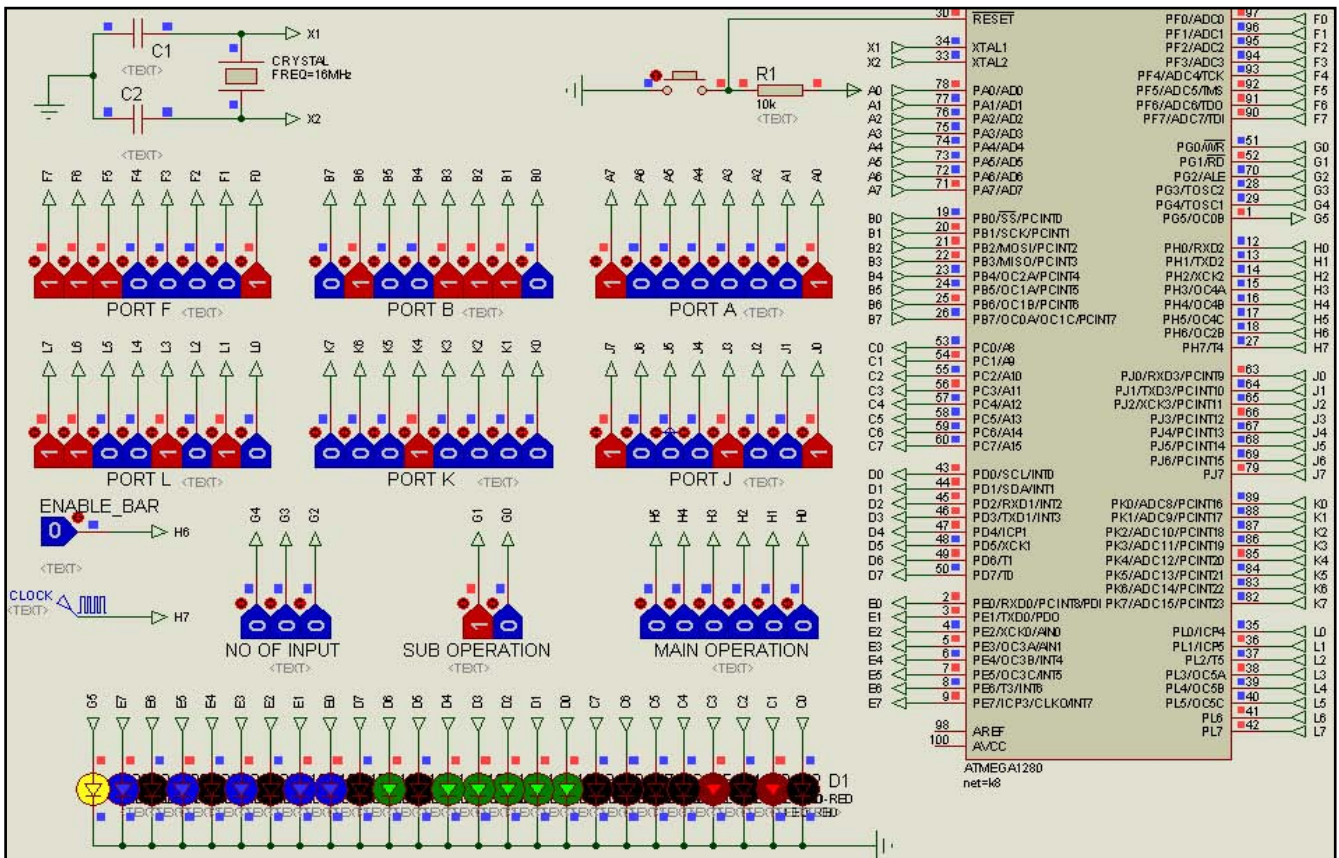


Figure 4 : 24bit Addition Operation[10]

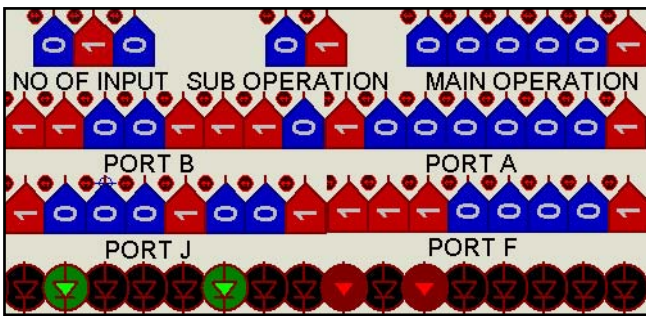


Figure 5 : 16bit 2input Subtraction Operation

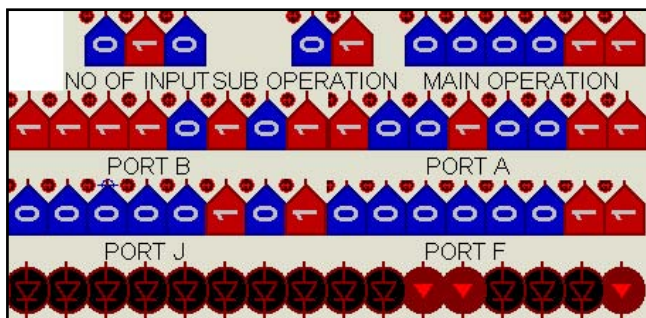


Figure 6 : 16bit 2input Division Operation

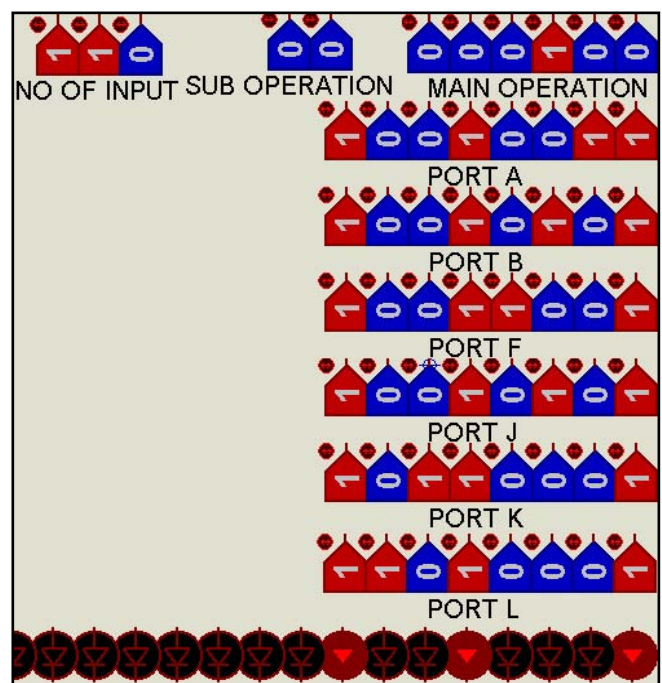


Figure 7 : 8bit 6input AND Operation

#### IV. FURTHER APPLICATIONS

- To practice large truth table up to 6 variables this IC can become handy.
- This IC can be used in many complex Digital design systems.
- Students can learn different type of Digital logic operation through only one IC.
- This IC can be used where expensive digital logic design lab can't be set up for education purpose.
- Rapid prototype for teaching Digital Logic Design.

#### REFERENCES RÉFÉRENCES REFERENCIAS

1. Md. Khaled Hossain and Md. Nasimuzzaman Chowdhury, International Journal of Emerging Technology and Advanced Engineering, Volume 3, Issue 6, June 2013, PP. 34-41.
2. Stanisavljevic, Z.; Pavlovic, V.; Nikolic, B.; Djordjevic, J., "SDLDS- System for Digital Logic Design & Simulation", Education, IEEE Transactions on (Volume: 56 , Issue: 2), May 2013.
3. Zemva, A.; Trost, A.; Zajc, B. "A Rapid Prototyping Environment for teaching Digital Logic Design", Education, IEEE Transactions on (Volume: 41, Issue: 4), Nov 1998.
4. Digital design principles and practices by John F. Wakerly.
5. [http://www.electronicstutorials.ws/sequential/seq\\_5.html](http://www.electronicstutorials.ws/sequential/seq_5.html) for details operation of Shift Register.
6. <http://tams-www.informatik.uni-hamburg.de/applets/hades/webdemos/20-arithmetic/10-adders/halfadd-fulladd.html> for lots of digital design simulation verification.
7. Guillermo A. Vera, Jorge Parra, Craig Kief, Marios Pattichis and Howard Pollard, "Integrating Reconfigurable Logic in the First Digital Logic Course", 9th International Conference on Engineering Education, July 23-28 2006.
8. Poulastya Mukherjee. Remote Control of Industrial Machines Using Mobile Phone. IJETAE, Volume 3, Issue 1, January 2013 for project outline diagram.
9. Atmega1280 datasheet by Atmel.
10. [www.mikroe.com](http://www.mikroe.com) for free demo compiler and help of compiler software.
11. [http://www.labcenter.com/products/vsm/vsm\\_overview.cfm](http://www.labcenter.com/products/vsm/vsm_overview.cfm) for simulator and demo videos of simulation.

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