Project Report: An 8-bit Arithmetic Logic Unit

Abstract:

The primary purpose of this project is to demonstrate the use of logic gates and integrated circuits in creating an ALU (Arithmetic Logic Unit), which is the very core of all computing devices today. The function of an ALU is to perform arithmetic and logic operations, such as addition, subtraction, multiplication, division, comparison etc. using combinational and sequential circuits.

Introduction:

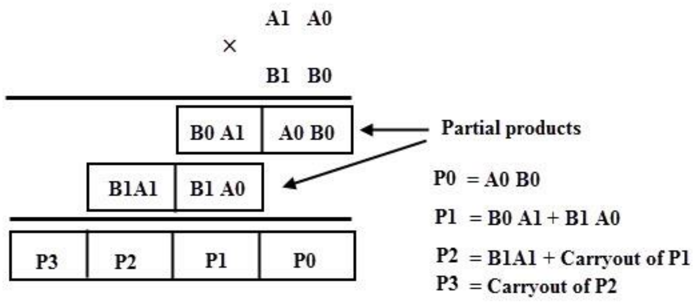
Using our knowledge and understanding of binary adders and subtractors, as well as concepts such as, but not limited to, the use of binary complements we have designed a circuitry that performs the function of a calculator that performs the operations of addition, subtraction and multiplication, and will output up-to 4 bits . The calculator takes two 4-bit inputs from the user and based on the user's choice performs either of the 3 operations.

Solution:

- The operation of binary addition is simply achieved using the 4-bit Full Adder IC which accepts two 4 bit inputs from a counter and outputs the a 4 bit sum and a 1 bit carry which is displayed using LED's.
- The operation of binary subtraction is achieved by taking the 2's complement of one of the inputs, and adding them together using a 4-bit Full Adder IC.
  The two's complement is achieved using EXOR logic. When the X input is 1, the output is the inverted Y input, whereas, when the X input is 0, the output is the same as the Y input. This helps us achieve the 1's complement.

Inputs		Outputs
X	Y	Z
0	0	0
0	1	1
1	0	1
1	1	0

The 2's complement is achieved by bridging the X input of the full adder's carry-in to the X input of the EXOR gate, such that when X = 1, carry-in = 1. The output is displayed in a similar way as for addition. The operation of binary-multiplication is achieved by repeated addition, as such:



AND gates are used to achieve the partial products, which are further added using two half – adder circuits achieved by AND & EXOR gates to give the final product.

- The user-inputs are taken using dip switches and two push-buttons, which allow clock pulses coming from a 555 timer IC to propagate to the clock inputs of two 4-bit binary counters. The counters individually count from 0 – 15 in binary. Their output is given as input to the arithmetic logic circuitry.
- The multiplier's output is displayed on a 7 segment display. This is achieved by feeding the output to a BCD to 7 Segment Display Decoder IC which decodes the binary value and feed's it to the 7 Segment Display.

Design Issues:

The design issue we faced was regarding the display of the output's using 7-segment displays. A 7 segment display can only display numbers from 0 – 9, and the input it takes need to be decoded before being feed to the 7 segment display.

We concluded that to display a 4-bit binary output/input required dual 7-segment displays and there was no decoder IC that would do that for dual displays, nor could individual decoder IC's be cascaded in any reasonable manner to apply the required logic. All other solutions required complex circuitry and resorting to microcontrollers/FPGA's, which were beyond the scope and cost effectiveness of our project. Hence, we only used 7 segment display to show the output of our multiplication circuitry, which only consists of digits in the range of 0 – 9.

Resourcing:

- One 74LS283 4-bit Full Adder IC for the addition/subtraction circuitry
- Two 74LS86 EXOR gate IC's; one for the subtraction circuitry, and one for the multiplication circuitry
- Two 74LS08 AND gate IC's for the multiplication circuitry
- One 555 Timer IC along with 100k and 10k resistors, as-well as two 10 nano and micro farad capacitors to generate a 1 Hz clock pulse for the counters.
- Two 74LS93 4-bit Asynchronous counter IC; one for each of the inputs
- Two push-buttons; to increase the counter counts
- One toggle switch; to switch between operations performed
- One dip switch; to input to the multiplier
- One 74LS47 BCD to 7 segment display decoder IC; for displaying the output of binary multiplication
- One 7-Segment Display
- Several LED's
- Wires; including male to male connectors.

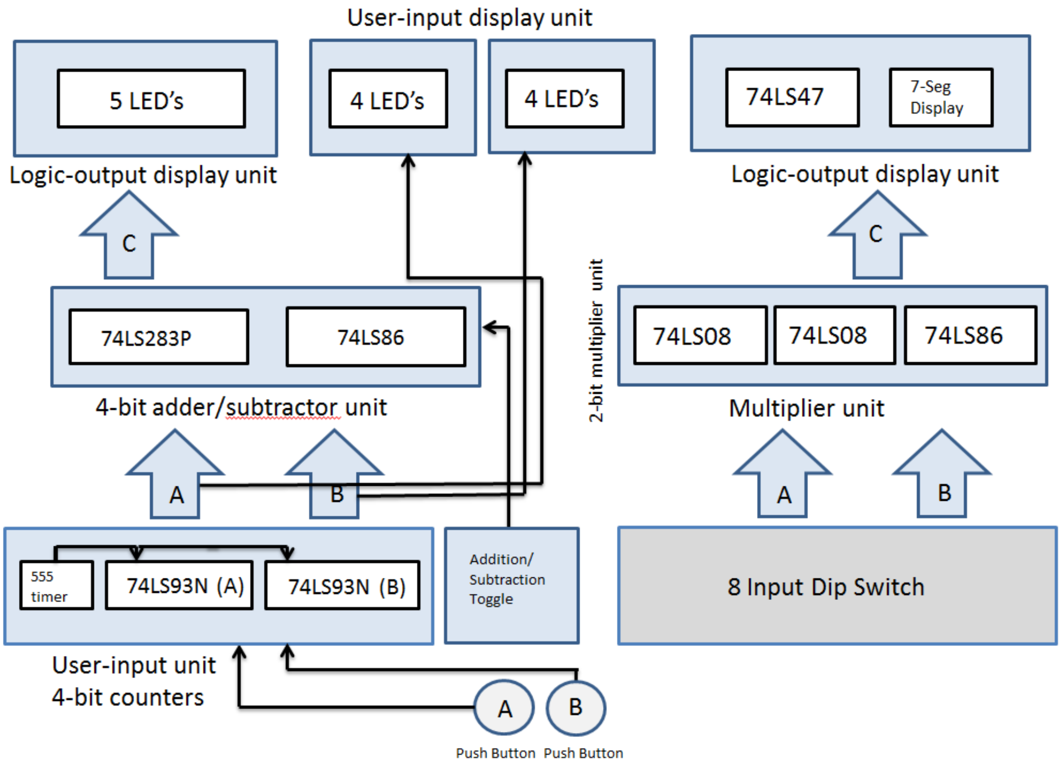
Cost Effectiveness:

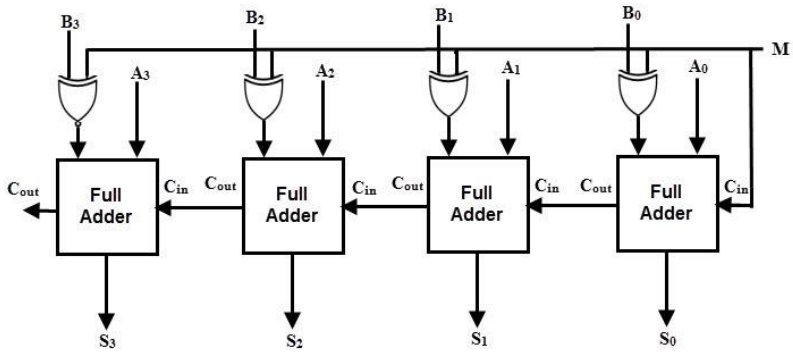
The cost of the project was well under PKR 1000, inclusive of the breadboards used, since all of the IC's used were basic and readily available.

Conclusion:

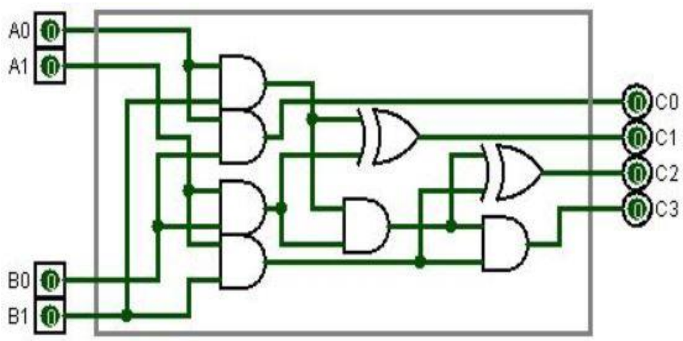
Though our project serves no practical purpose at its level, however, as an introductory project it implements a wide range of digital components and by doing so it has allows us to develop an understanding of how these components are used together to form larger digital systems and the complexities & limitations involved, such that it prepares us to approach future projects better. Furthermore, it makes us realize and leads to a greater appreciation for digital systems that we use in our daily lives and take for granted, and for the people who have work to make them possible. Keeping in mind the amount of logic involved in every minute task and the size it is factored to in devices such as smartphones, computers, calculators etc.

Block Diagram:





4-bit Adder/Subtractor Circuit



Multiplier Circuit