# Digital Gates and A Full Adder Using Analog Components

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## Abstract

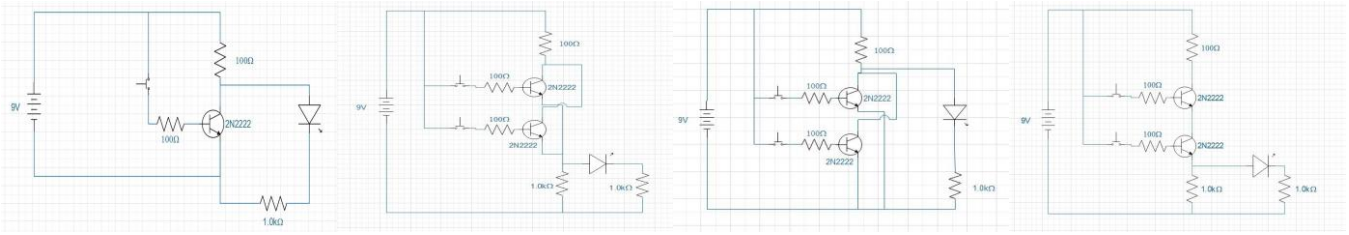
This poster demonstrates the process of building different logic gates and a full adder out of analog components. There are several ASICs (Application Specific Integrated Circuit) available that performs these logics; however, a group of students came up with these wonderful implementation as part of course project. Aside from the NPN transistors, resistors are used for limiting the base current to the transistors and for pulling up the outputs to the source voltage. Toggle switches work as bit inputs to the adder, while green LEDs display the output. Logisim is used to simulate different gate combinations. "NOR" gate is chosen for full-adder design, since it needs fewer transistors in comparison to others. An oscilloscope is used to measure the delay between the input and output of the full adder. The project allowed Electronics and Computer Engineering Technology students at Sam Houston State University to engage in a challenging hands-on project to brainstorm, think creatively, make simulations to back up the theory, assemble the components on a circuit level schematic that included soldering, do measurement results, and finally build a PCB prototype.

## Introduction

An integrated circuit is a small chip made of silicon that can house millions of electrical components and operate using either digital or analog values to transmit information [1]. The integrated circuits that operate using digital signals are most commonly found in computers [2]. Due to the advancement of technology, the number of transistors that can fit on a chip will double every year as stated by Moore's Law [2]. This ability to make compact circuits at the nanoscale means that the human eye is no longer able to observe the individual circuits. This project aims to help better understand how the seven logic gates operate by using larger versions of the circuits found inside integrated circuits. The logic gates are used to perform Boolean logic to output a single value of either a 1 or 0 [3]. The seven basic logic gates used are as follows: NOT, OR, NOR, AND, NAND, XOR, and XNOR. Each logic gate uses transistors to produce an electrical signal. The transistors used in this project are all bipolar junction, NPN transistors. A bipolar junction transistor (BJT) consists of three doped semiconductor regions separated by two PN junctions [4].

## Logic Gates and Full Adder

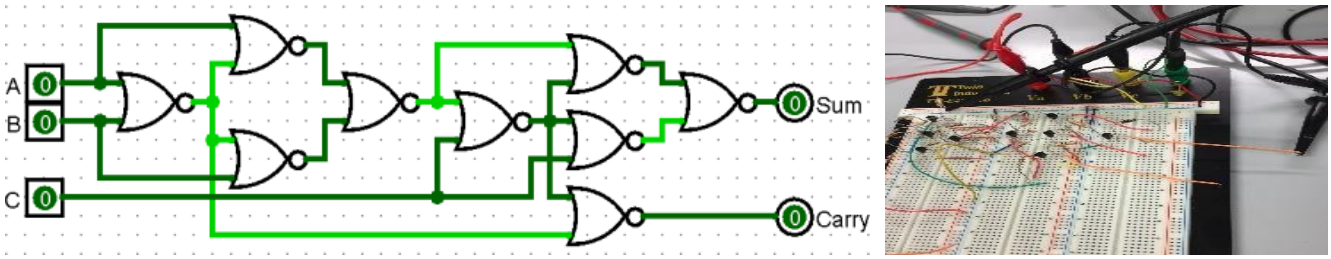
The seven gates mentioned above is implemented using 2N2222 NPN transistors and combinations of resistors. Figure 1 (a-h) shows the circuit schematic and built prototype. Then the working theory of a full adder is analyzed, truth table and logic equation simplified, different combination of logic gates are simulated to find the optimal design using NOR gates. For full-adder design 2N3904 NPN



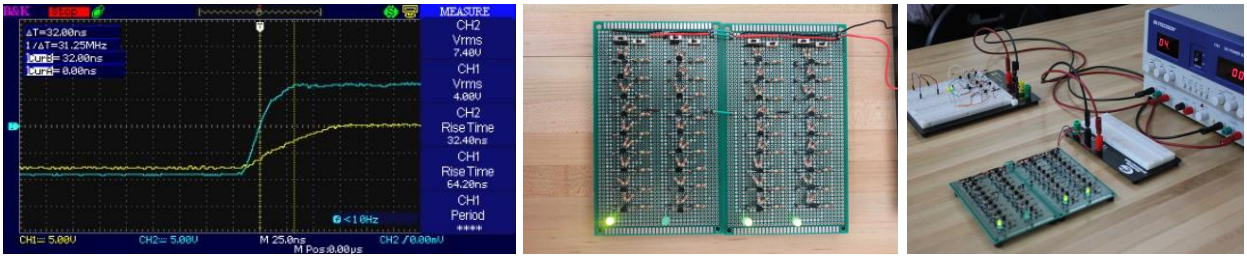
(a) NOT gate (b) OR gate (c) NOR Gate (d) AND Gate

(e) NAND gate (f) XOR gate (g) XNOR Gate (h) Built Prototype

Figure 1: Different Logic Gates




(a) Full Adder using NOR Gate [5] (b) Breadboard Prototype



(c) 32ns delay between input and output (d) PCB Prototype (e) Experimental Setup

Figure 2: Full Adder

transistors are used. The design is simulated and a breadboard prototype is built to verify the functionality. Simulation showed a 32ns delay between input and output. There is about a 32 ns delay between them. Also to notice is that the output is 3.4 volts less than input because of the resistor which is used to limit current for the LED, and also as a pull up for the transistor. A 54 X 33 blank board is used for PCB prototyping, soldering is done at $600^0$F. The first design didn't work because the components were too close to the board and shorted paths. However, in the second attempt a printed circuit board is successfully created and tested. Figure 2 (a-e) shows the full adder simulation and final prototype. The student outcomes met by this project are: possess problem solving skills, apply different principles and tools, demonstrate creativity, identify and use appropriate technical literature, produce clear and effective documents, and collaborate effectively with each other in teams.

## References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