<u>Delhi Public School</u>

<u>PHYSICS PROJECT</u>

<u>Submitted to</u>: Mr. Darshan Lal

<u>Submitted by</u>: Kunal Gehlot

LOGIC GATES

AND THE SCIENCE BEHIND

Kunal Gehlot
Semiconductors
November 6, 2016

Declaration

I hereby declare that the project entitled "Logic Gates" made for the Physics Practical Examination of CBSE session 2016-17 is a record of original work completed under the guidance of "Mr. Darshan Lal", Physics Teacher, Delhi Public School, Jodhpur

Kunal Gehlot

XII-B

Certificate

This is to certify that "Kunal Gehlot" of class XII-B, Delhi Public School, Jodhpur has successfully completed the project work for class XII examination of CBSE in the year 2016-17.

It is further certified that this project is individual work of the candidate.

Signature

(Mr. Darshan Lal)

Preface

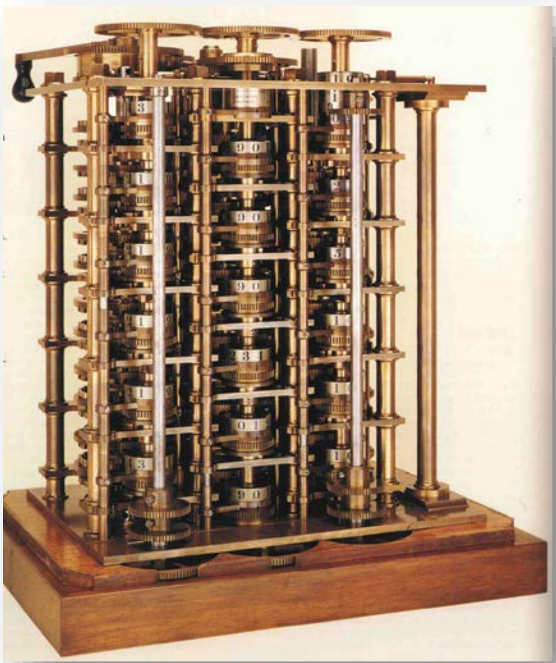
They store your money. They monitor your heartbeat. They carry the sound of your voice into other people's homes. They bring airplanes into land and guide cars safely to their destination—they even fire off the airbags if we get into trouble. It's amazing to think just how many things "they" actually do. "They" are electrons: tiny particles within atoms that march around defined paths known as circuits carrying electrical energy. One of the greatest things people learned to do in the 20th century was to use electrons to control machine and process information with the help of logic gates. The electronics revolution, as this is known, accelerated the computer revolution and both these things have transformed many areas of our lives. But how exactly do nano-scopically small particles, far too small to see, achieve things that are so big and dramatic? Let's take a closer look and find out! Nearly everything that we use contains logic gates. From old relics such as "E-M relays", to computers, and everything in between, logic-gates make modern human technology operate.

Content

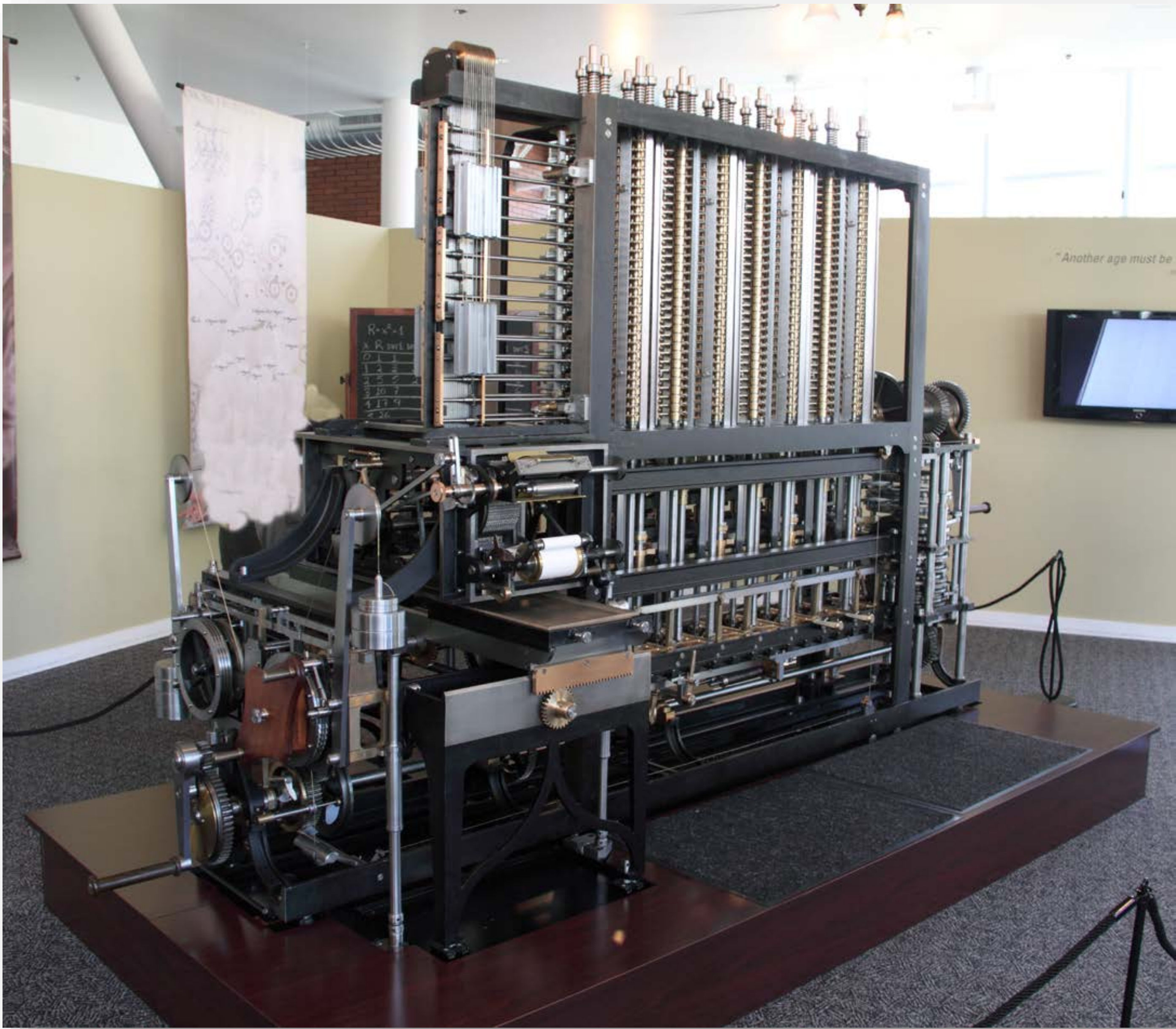
History of Logic-gates

The earliest logic gates were made mechanically. Charles Babbage, around 1837, devised the Analytical Engine. His logic gates relied on mechanical gearing to perform operations. Electromagnetic relays were later used for logic gates. In 1891, Almon Strowger patented a device containing a logic gate switch circuit. Strowger's patent was not in widespread use until the1920s. Starting in 1898, Nikola Tesla filed for patents of devices containing logic gate circuits. Eventually, vacuum tubes replaced relays for logic operations. Lee De Forest's modification, in 1907, of the Fleming valve can be used as AND logic gate. Ludwig Wittgenstein introduced a version of the 16-row truth table, as proposition 5.101 of Tractatus Logico-Philosophicus

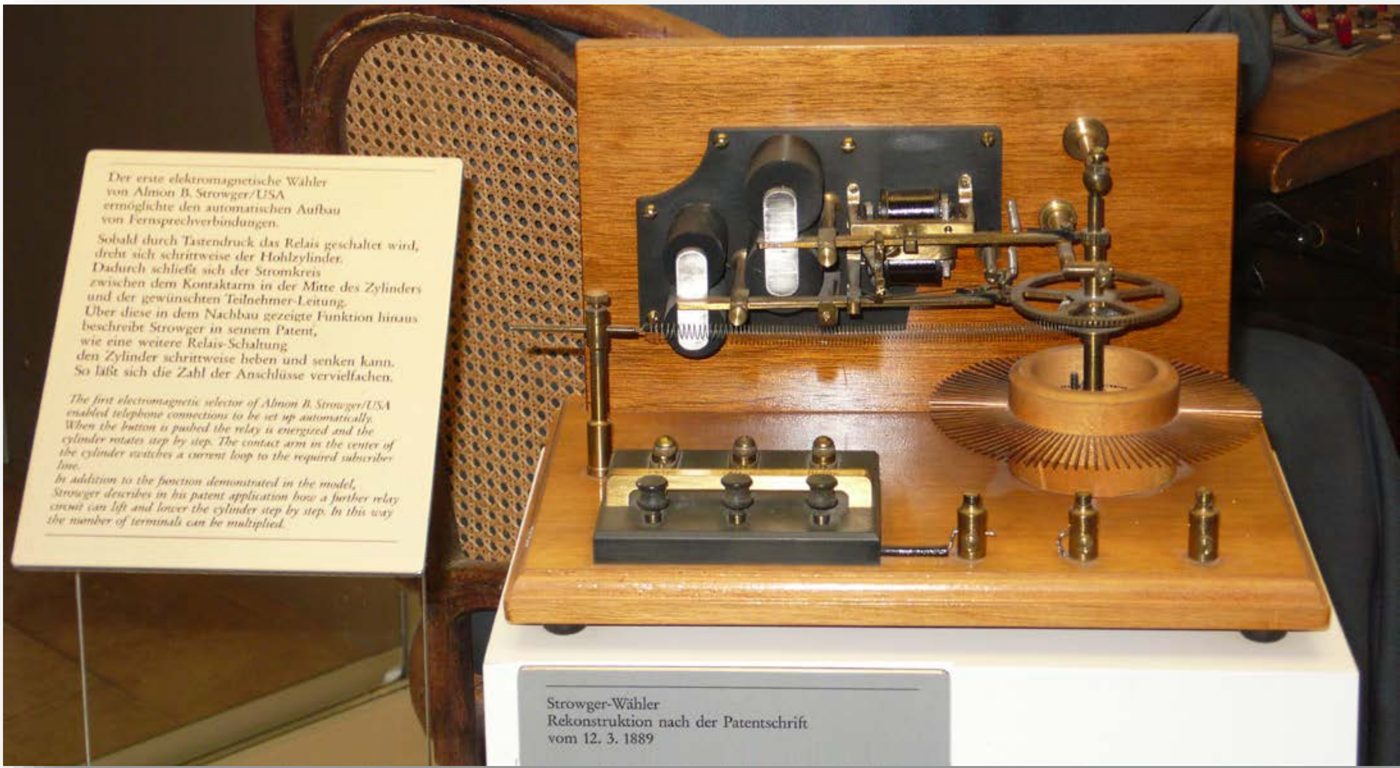
(1921). Claude E. Shannon introduced the use of Boolean algebra in the analysis and design of switching circuits in 1937. Walther Bothe, inventor of the coincidence circuit, got part of the 1954 Nobel Prize in physics, for the first modern electronic AND gate in 1924. Active research is taking place in molecular logic gates



Charles Babbage's Analytical Engine



Strowger's switch



Almon Strowger's switch

Claude E. Shannon's Boolean algebra in switch circuit

Introduction

In electronics, a logic gate is an idealized or physical device implementing a Boolean function; that is, it performs a logical operation on one or more logical inputs, and produces a single logical output. Depending on the context, the term may refer to an ideal logic gate, one that has for instance zero rise time and unlimited fan-out, or it may refer to a non-ideal physical device.

Logic gates are primarily implemented using diodes or transistors acting as electronic switches, but can also be constructed using vacuum tubes, electromagnetic relays (relay logic), fluidic logic, pneumatic logic, optics, molecules, or even mechanical elements. With amplification, logic gates can be cascaded in the same way that Boolean functions can be composed, allowing the construction of a physical model of all of Boolean logic, and therefore, all of the algorithms and mathematics that can be described with Boolean logic.

Logic circuits include such devices as multiplexers, registers, arithmetic logic units (ALUs), and computer memory, all the way up through complete microprocessors, which may contain more than 100 million gates. In modern practice, most gates are made from field-effect transistors (FETs), particularly MOSFETs (metal–oxide–semiconductor field-effect transistors).

Compound logic gates AND-OR-Invert (AOI) and OR-AND-Invert (OAI) are often employed in circuit design because their construction using MOSFETs is simpler and more efficient than the sum of the individual gates.

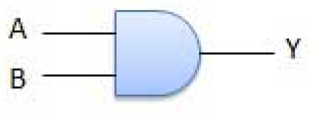
Electronic Gates:

To build a functionally complete logic system, relays, valves (vacuum tubes), or transistors can be used. The simplest family of logic gates using bipolar transistors is called resistor-transistor logic (RTL). Unlike simple diode logic gates (which do not have a gain element), RTL gates can be cascaded indefinitely to produce more complex logic functions. RTL gates were used in early integrated circuits. For higher speed and better density, the resistors used in RTL were replaced by diodes resulting in diode-transistor logic (DTL). Transistor-transistor logic (TTL) then supplanted DTL. As integrated circuits became more complex, bipolar transistors were replaced with smaller field-effect transistors (MOSFETs); see PMOS and NMOS. To reduce power consumption still further, most contemporary chip implementations of digital systems now use CMOS logic. CMOS uses complementary (both n-channel and p-channel) MOSFET devices to achieve a high speed with low power dissipation.

Classification of gates

These gates are the basic components from which everything is made and they are as follows:

- AND - *A circuit which performs an AND operation is shown in figure. It has n input (n ≥ 2) and one output.*

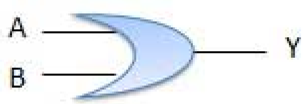


Logic diagram of AND gate

Inputs		Output
A	B	AB
0	0	0
0	1	0
1	0	0
1	1	1

Truth table for AND gate

- OR - *A circuit which performs an OR operation is shown in figure. It has n input (n ≥ 2) and one output.*

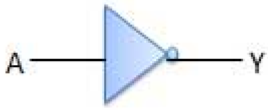


Logic diagram of OR gate

Inputs		Output
A	B	A + B
0	0	0
0	1	1
1	0	1
1	1	1

Truth table for OR gate

- NOT - *NOT gate is also known as Inverter. It has one input A and one output Y.*

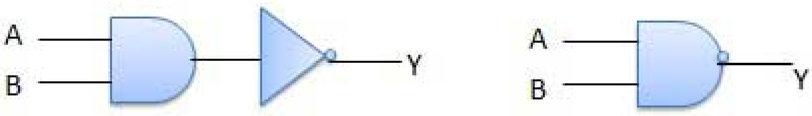


Logic diagram of NOT gate

Inputs	Output
A	B
0	1
1	0

Truth table for NOT gate

- NAND - *A NOT-AND operation is known as NAND operation. It has n input (n ≥ 2) and one output.*

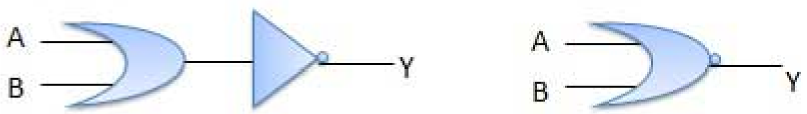


Logic diagram of NAND gate

Inputs		Output
A	B	$\overline{AB}$
0	0	1
0	1	1
1	0	1
1	1	0

Truth table for NAND gate

- NOR gate - *A NOT-OR operation is known as NOR operation. It has n input (n >= 2) and one output.*

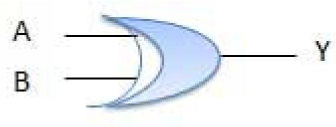


Logic diagram of NOR gate

Inputs		Output
A	B	$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

Truth table for NOR gate

- XOR - *XOR or Ex-OR gate is a special type of gate. It can be used in the half adder, full adder and subtractor. The exclusive-OR gate is abbreviated as EX-OR gate or sometime as X-OR gate. It has n input (n ≥ 2) and one output.*

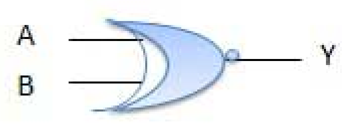


Logic diagram of XOR gate

Inputs		Output
A	B	$A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

Truth table for XOR gate

- XNOR - *XNOR gate is a special type of gate. It can be used in the half adder, full adder and subtractor. The exclusive-NOR gate is abbreviated as EX-NOR gate or sometime as X-NOR gate. It has n input (n ≥ 2) and one output.*



Logic diagram of XNOR gate

Inputs		Output
A	B	$A \ominus B$
0	0	1
0	1	0
1	0	0
1	1	1

Truth table for XNOR gate

Physics behind logic gates

The switching action of a transistor makes it especially suitable for use in digital logic circuits where the output is either 0 or 1 depending on the input, where the 0 stands for off and 1 stands for on. Applications of such circuits are to:

- *Switch on a water pump on a hot sunny day.*
- *Sound an alarm if the pilot light of a boiler went off.*
- *Sound an alarm if a burglar stepped on a pressure pad or shone his torch.*
- *Switch a light on if it was a cloudy day.*
- *Add two simple binary numbers together*.
- *Switch on a fan if a darkroom door was shut and it was warm inside.*

All these things and indeed many more can be done with ELECTRONIC LOGIC CIRCUITS. These circuits are ones that can make decisions. Different decisions need different circuits.

If you refer to the switching circuit for the transistor you will see that the output voltage is high (consider this as 1) when the input voltage is low (consider this as 0). This is the basic NOT gate - there is an output when there is not an input.

Combinations of these switching circuits can be made into logic gates that will perform simple decisions within a microprocessor. These logic gates are the basis of all decisions within computers and from now on we will consider their effects rather than their internal structure. We will consider the following types of logic gate:

1. NOT gate - *this gives an output 1 for an input of 0.*
2. NOR gate - *this gives an output 1 for neither of two inputs 1.*
3. OR gate - *this gives an output 1 for either of two inputs 1 and both inputs 1.*
4. AND gate - *this gives an output 1 for both two inputs 1.*
5. NAND gate - *this gives an output I for either but not both of two inputs 1 or both inputs 0.*
6. EXCLUSIVE-OR - *this gives an output I for either but not both of two inputs 1.*
7. EXCLUSIVE-NOR - *this gives an output 1 when both inputs are 0 or 1.*

Because of its wide use in modern digital electronics the NAND gate will be considered as a basic building block for a variety of logic circuits. In fact, a number of other logic gates can be constructed using NAND gate.

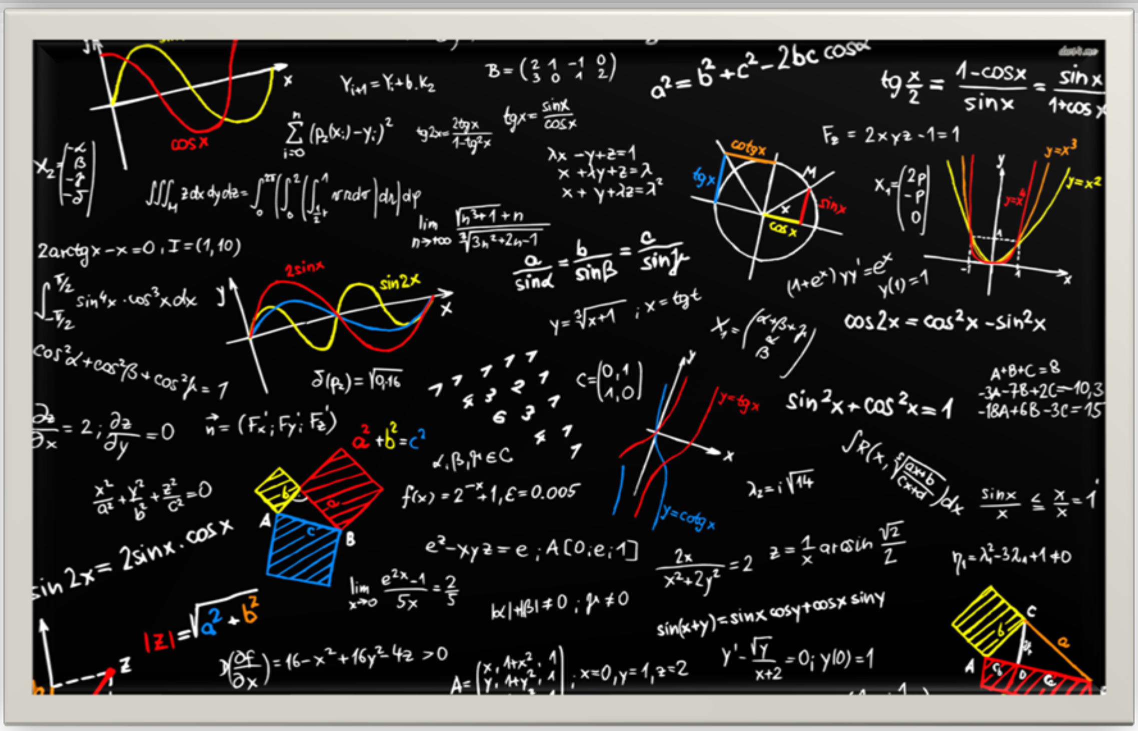
Uses of Logic gates

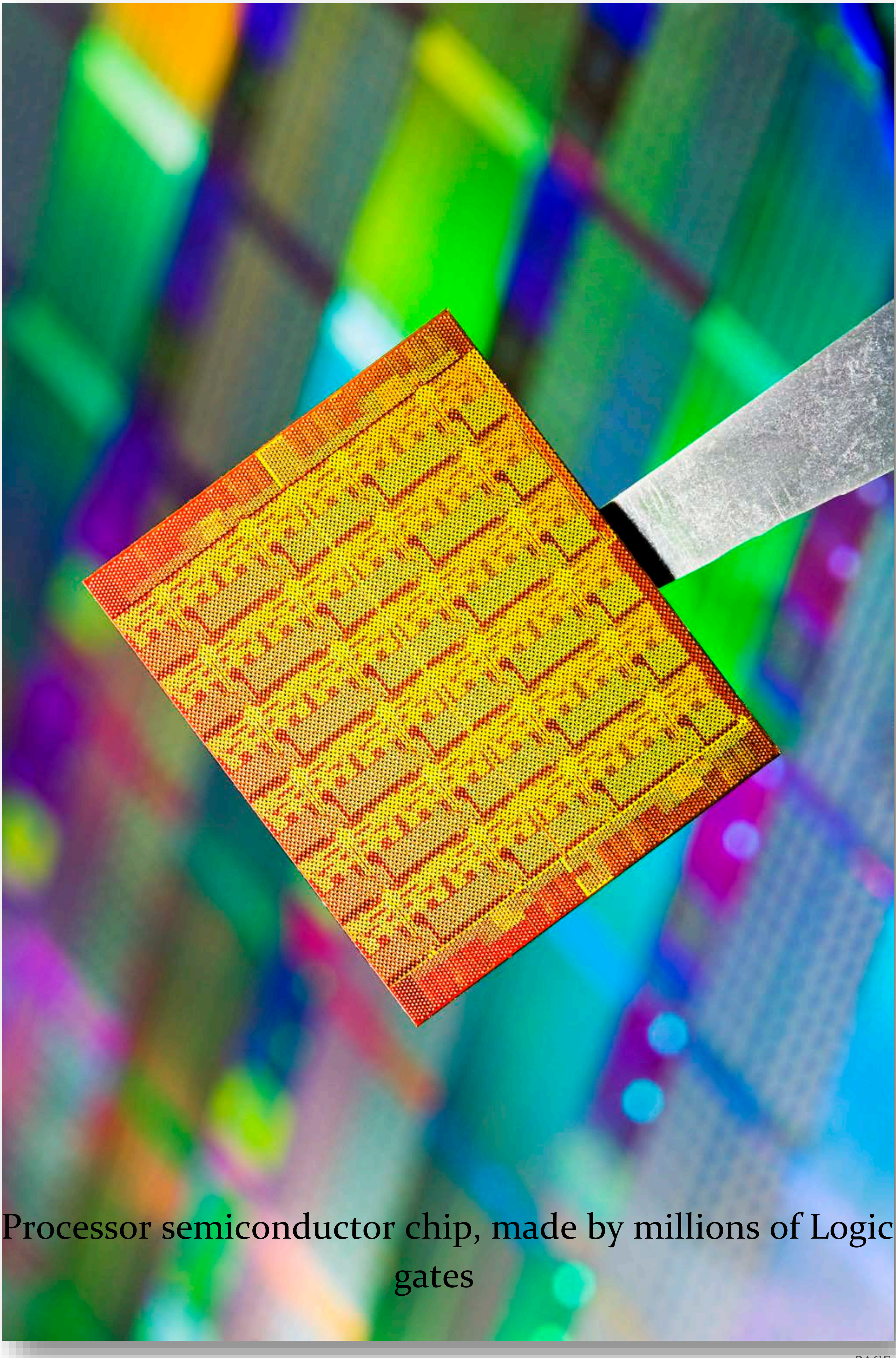
Since the 1990s, most logic gates are made in CMOS technology (i.e. NMOS and PMOS transistors are used). Often millions of logic gates are packaged in a single integrated circuit.

There are several logic families with different characteristics (power consumption, speed, cost, size) such as: RDL (resistor-diode logic), RTL (resistor-transistor logic), DTL (diode-transistor logic), TTL (transistor-transistor logic) and CMOS (complementary metal oxide semiconductor). There are also sub-variants, e.g. standard CMOS logic vs. advanced types using still CMOS technology, but with some optimizations for avoiding loss of speed due to slower PMOS transistors.

Non-electronic implementations are varied, though few of them are used in practical applications. Many early electromechanical digital computers, such as the Harvard Mark I, were built from relay logic gates, using electro-mechanical relays. Logic gates can be made using pneumatic devices, such as the Sorteberg relay or mechanical logic gates, including on a molecular scale. Logic gates have been made out of DNA and used to create a computer called MAYA. Logic gates can be made from quantum mechanical effects (though quantum computing usually diverges from Boolean design). Photonic logic gates use non-linear optical effects.

In principle any method that leads to a gate that is functionally complete (for example, either a NOR or a NAND gate) can be used to make any kind of digital logic circuit. Note that the use of 3-state logic for bus systems is not needed, and can be replaced by digital multiplexers, which can be built using only simple logic gates (such as NAND gates, NOR gates, or AND and OR gates). These logic gates are basically in everything in 21st century, in computers, mobile phones, televisions, cars, trains, etc. They help calculate complex equation in seconds.



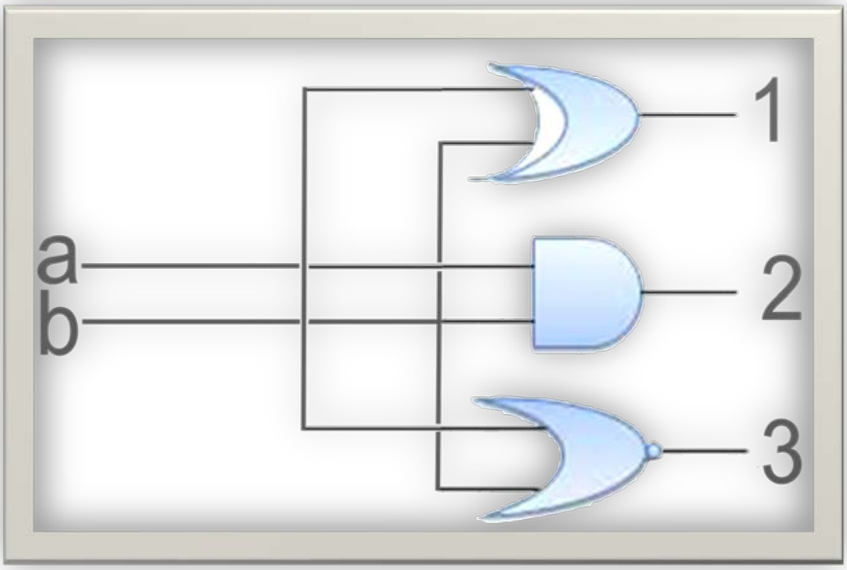


Processor semiconductor chip, made by millions of Logic gates

Project

Aim: *To prepare an investigatory modal, showing the working of logic gates for various purposes, I made a very basic computer which calculates $A + B = C$, where $A, B \in \{0,1\}$ and shows the result with the help of three LEDs which denotes to numerical zero, one and two.*

Simple circuit showing the combination of various logic gates: -



This diagram shows how XOR, AND, NOR gates are combined to make the computer.

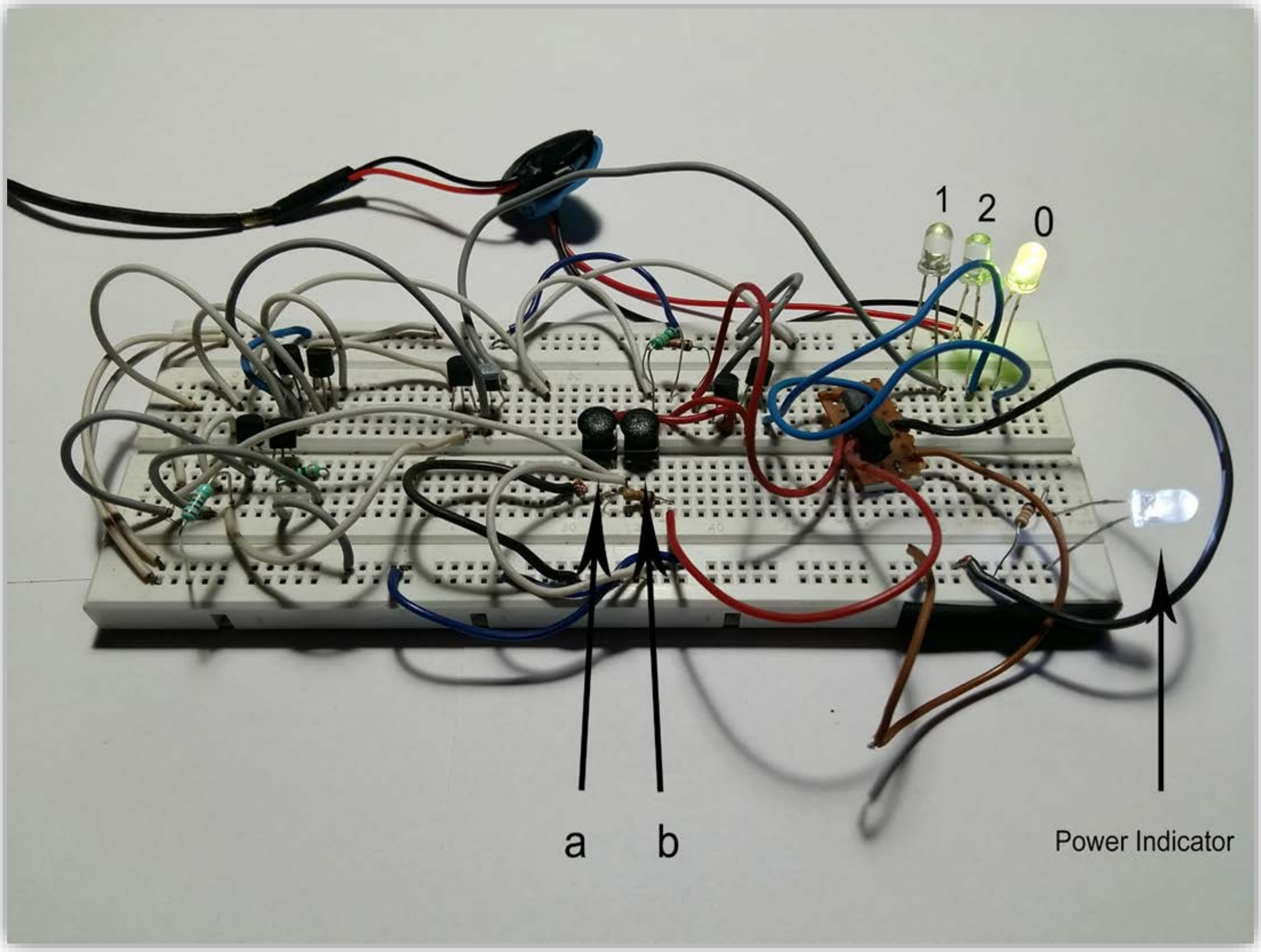
Apparatus: *Adapter, BC548 transistors, switches, resistors, LEDs, Jumper wires, breadboard, etc.*

Theory: *This computer works by connecting the three logic gates in parallel, which results in turning off of one gate when the other is on.*

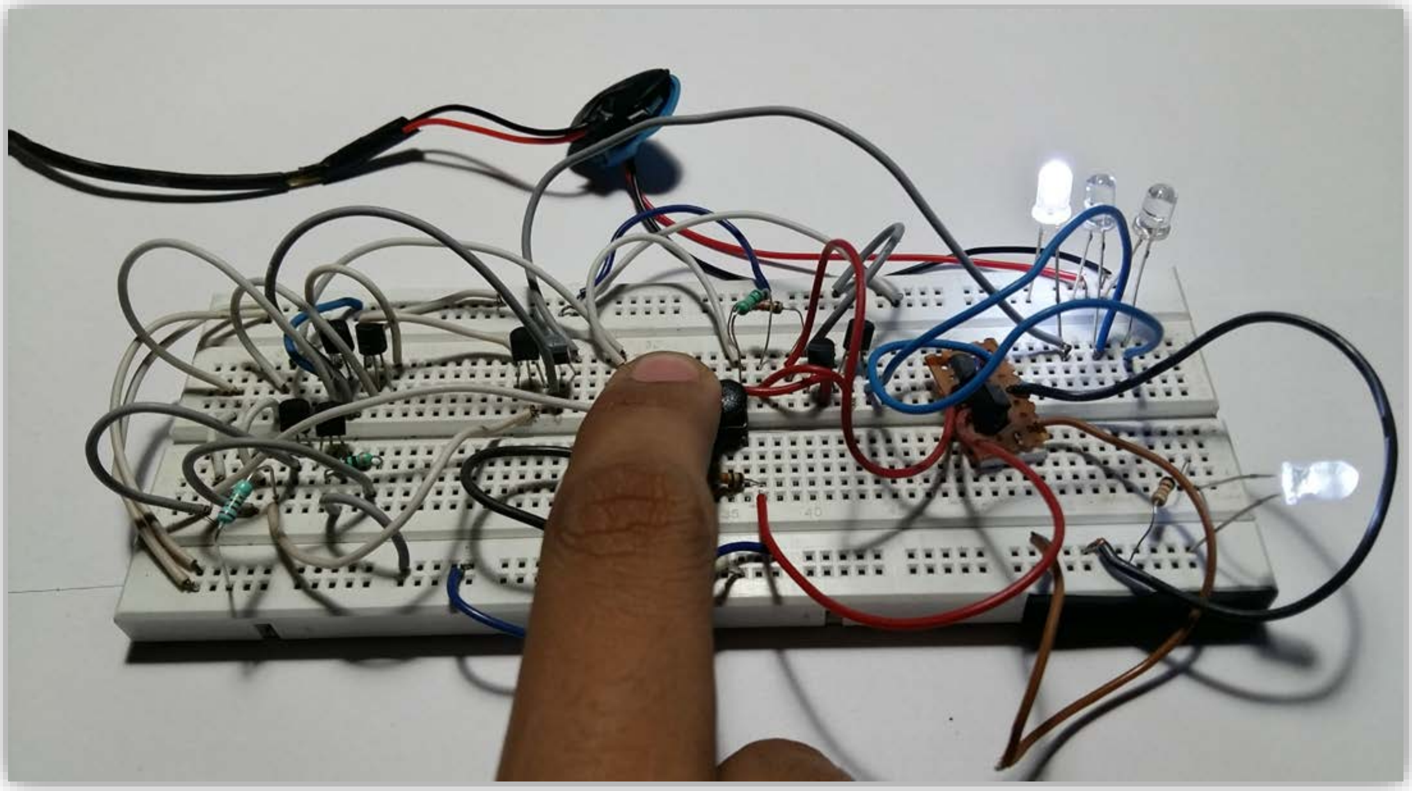
As you can see the Truth tables given in the introduction, when both the inputs are zero, the NOR gate comes into action thus turning on the LED indicating zero. When either of the input is turned on, given input one, the XOR gate comes into action thus turning on the LED indicating one. When both of the inputs are turned on, thus given input 1+1, the AND gate comes into action thus turning on the LED indicating two.

Input = 0+0

Output = 0

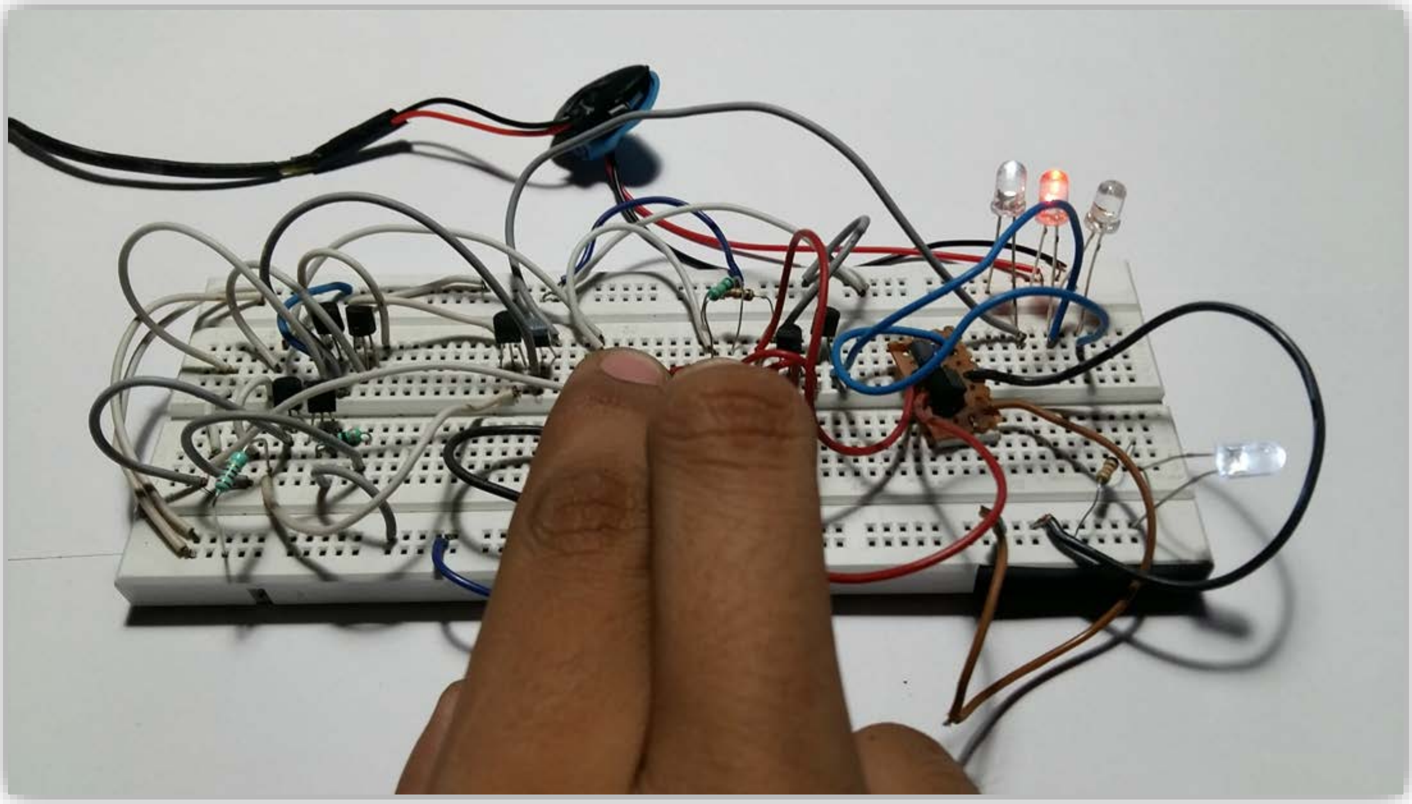


Input = 1+0



Output = 1

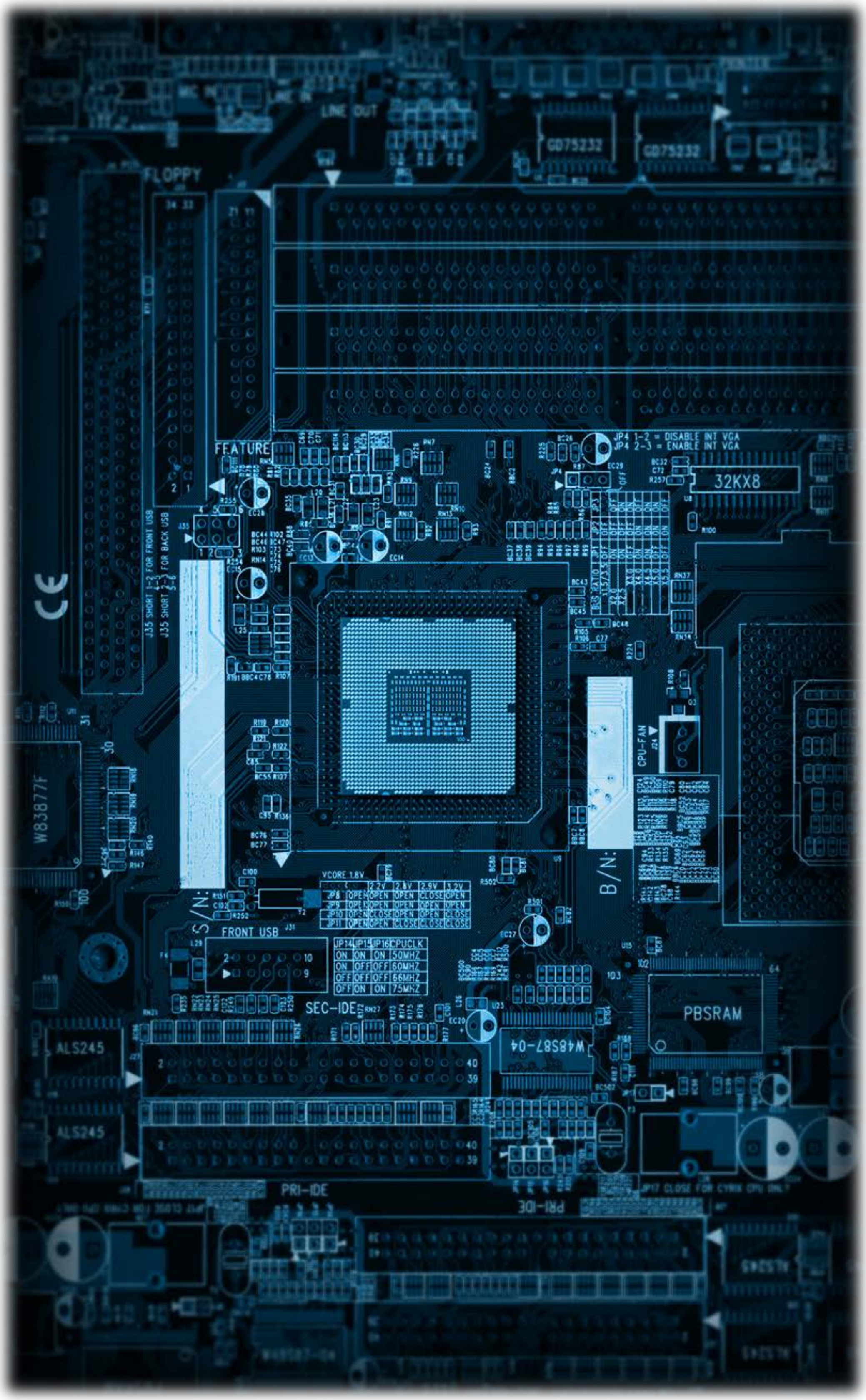
Input = 1+1



Output = 2

Conclusion

The following project successfully calculated the value of ‘c’ with the help of three logic gates’ combination.



Bibliography

- ◊ www.scribd.com
- ◊ www.scholar.google.com
- ◊ www.wikipedia.org
- ◊ www.libraries.mit.edu
- ◊ www.instructables.com
- ◊ www.images.google.com
- ◊ www.en.wikibooks.org
- ◊ www.wikia.com
- ◊ www.schoolphysics.co.uk