Ashwin Chakravarthy K *et al*, International Journal of Computer Science and Mobile Applications,
Vol.6 Issue. 4, April- 2018, pg. 85-108 **ISSN: 2321-8363**
Impact Factor: 5.515

8-Bit Computer

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CHAPTER 1

INTRODUCTION

Architecture is important parts of Computer Engineering and Computer Science body of knowledge that created by IEEE and ACM. The important issues to learning is how to define and representing their structure to students. Computer attribute is computer system associated with programmer such as arithmetic used, set of instruction, addressing technique, the mechanism of the I/O. Then Computer Organization is studying how part of computer associated with the operational unit and their relationship. Two departments who meet an advance of ARCHITECTURE is Computer Science (CS) and Computer Engineering (CE). Based on ACM of CS Curricula and CE Curricula, their body of knowledge is different. ARCHITECTURE on CS has 16 core hours and CE has 60 Core hours , so that hours will give a huge impact to what kind and deep of course that given to the student. Based on previous research to earn about details and characteristic of each simulator that provides CPU design that has an ability for learning support on CE student is Logisim. CE have competency to design multipurpose computers so it would be done in CE students. The criteria of selections simulators based on a simulator that can accommodate teaching material and have the capacity to delivers materials to the student. For CE Students includes Computer Arithmetic, Processor Organization, Memory System Organization and Architecture, I/O Interfacing and Communication. Logisim is an educational tool for designing and simulating the digital logic circuit. Even though can only simulate the circuit, Logisim has an ability to simulate each of CPU component. It has a Graphical User Interface (GUI) which students can make, see and modify the digital logic circuit . To teach the student about CPU

(Central Processing Unit), it needs a working simulation. The simplest CPU design is 8- bit CPU that was created and called Von Neumann architecture. That design should make sequentially that includes first Simple ALU, Datapath, Control Unit and Integrates all. Several scientists developed CPU with their own approaches, but for students learning purpose needs simple methods that can be understood. The CPU design architecture can make with different approaches. Many commercial computer architecture and organization concept that has been used is 8051, MIPS, x86 and ARM architecture . Based on Von Neumann architecture there are developed Mic-1, Mic-2, Mic-3 and Mic-4 architecture. The simplest architecture that used is Mic-1 because the architecture is simple and can accommodate student needs . So in this research, we want to design and implemented a CPU-8 bit design based on Mic-1 architecture. The CPU design should meet student requirement for learning ARCHITECTURE on CE. It will be implemented in Logisim which has a GUI, so the student can learn and understand how CPU works, the student can analyze about the detail of how CPU works and student can and make a specific purpose computer. This research focus is how to design CPU and examine its relationship with CE learning outcome

Course design started by specifying Learning Objective, this research use Learning Outcome (LO) that explained CE Computing Curricula . Before giving instruction how LO based on a textbook that used, we need to give an assessment of what tool used. The previous research explained that best tool is Logisim.

To teach the student Computer Organization and Architecture, it needs the simplest design. Other research gives an assessment that the simplest design that could use in learning is used Mic-1 architecture. So this research conducted by studying Learning Objective to give an Assessment only that represent

Learning Objective will be given by study and discussed what kind of LO that should deliver to a student based on Williams Stalling text book. Second, Assessment was made to selecting and designing about 8-bit computer.

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CHAPTER-2

LITERATURE SURVEY

2.1 Scope

One of the most important elements in a computer system is the bus structure that supplies the interface for all the hardware components. This bus structure contains the necessary signals to allow the various system components to interact with each other. The' bus supports two independent address spaces: memory and I/O. During memory cycles, the bus allows direct addressability of up to 16 megabytes using 24-bit addressing. During I/O bus cycles, the bus allows addressing of up to 64 kilobyte 1/0 ports using l6.bit addressing. Memory and 1/0 cycles can support 8-bit or 16-bit data transfers.

An American National Standard IEEE Standard Microcomputer System Bus

Sponsor

Approved February 17,1984	Reaffirmed January 23,1989
American National Standards Institute	Standards Committee of the
IEEE Computer Society	Approved December 9,1982
Reaffirmed June 9,1988	IEEE standards Board

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2017 International Conference on Sustainable Information Engineering and Technology (SIET)

Design and Implementation 8 bit CPU Architecture on Logisim For Undergraduate Learning Support

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Computer Architecture consists of some basic design based on Computer Organization and Architecture (COA) such as logic design. Leading students to improve knowledge about COA needs a comprehensive learning with a working simulation of a simple 8-bit Central Processing Unit (CPU). The Design based on Von Neumann Architecture that generally includes Registers, Bus Interface, ALU, Memory and their structures. The CPU Architecture simulation used Logisim which capable to performs the digital logic simulation. Logisim has an ability to perform digital logic to build subcircuit become a larger circuit in a single environment from low-level combinational and sequential circuits to build a complete CPU. An undergraduate student has suffered to study COA with the theory that explained in several lessons, the lesson explained a structure and an architecture computer only. There are not providing a simulation that explained step by step computer architecture. This research to propose design and implementation 8-bit CPU (Central Processing Unit) architecture that designed and implemented step by step that created in Logisim and used the simplest design that is Mic-1. So the simulation easy to visualize then the Undergraduate Student can learn about the next competency which is to design and make a specific purpose computer. To teach the student about CPU (Central Processing Unit), it needs a working simulation. The simplest CPU design is 8- bit CPU that was created and called Von Neumann architecture. That design should make sequentially that includes first Simple ALU, Datapath, Control Unit and Integrates.

CryptoBlaze: 8-Bit Security Microcontroller

XAPP374 (v1.0) September 26, 2003

This application note provides a basic outline for creating a cryptographic processor using CoolRunner™-II devices and a CPLD version of the PicoBlaze processor.

Standard microprocessors target very general applications. Their instruction sets are chosen for a broad ranges of tasks, with both numerical and data management actions at their centers. Some applications have been less-than-well served by standard instruction sets and architectures. Among these poorly served markets are error correction coding, cryptography, and digital signal processing. Due to a shift away from analog data methods over the last 40 years, digital signal processors have evolved to serve the DSP market needs. Error correction coding and cryptography are less served, but one methodology has received recent attention—the programmable logical sed "soft processor." While developing soft programmable processors for FPGAs, it became apparent that the same method could be used with CPLDs of sufficient density. Though somewhat restricted in capacity, CPLDs deliver ample speed and are nonvolatile, reprogrammable, and are very difficult to reverse engineer, if properly managed. These qualities are attractive to the cryptography field. These instructions are fairly straightforward and explained in detail in the PicoBlaze application note. A very useful aspect of PicoBlaze is that the instruction set isn't locked down. It can be altered. The architecture is written in procedural VHDL specifically *to* be altered. The assembler is also open for modification. That being the case, cryptographic extension instructions can be added to the architecture and the assembler. It is possible to expand the word width as desired. The instruction and data words interact, but are both alterable, also. Other operations that frequently occur include byte transformations, or “substitutions.” In "crypto land" this is called building an S-box. CoolRunner-II CPLDs are particularly efficient in building up these mappings where the CPLD function block is the equivalent of a small EPROM. Multiple S-boxes can be created with a utility that lets you key in the bit mappings, and it spits out the equations in HDL. Block ciphers frequently use S-boxes cascaded with EX-OR operations, rotates, and such. The Advanced Encryption Standard is built from a lot of these little operations. Cryptographers always worry about “attacks.” Attacks are either real or potential ways for intruders to gain access to the information the crypto folks seek to hide. Simple brute force attacks, such as lots of trials of passwords, are what many people think about when they think about crypto attacks. Most systems today are far beyond that level of concern. However, newer dimensions have arisen in recent years, whereby designers must be aware that “side channel” attacks do exist. Side channel attacks examine behavior outside the code program and look to identify electrical behavior indicating some degree of “what’s going on inside the chip.” The two common categories of side channel attacks are "Power Analysis" and "Tempest." Power Analysis falls into two further categories—Simple Power Analysis (SPA) and Differential Power Analysis (DPA). Tempest attacks are similar in nature to Power Analysis, but focus on measuring the fields emanating from the cryptographic devices. For our purposes we will focus on Power Analysis.

Design and construction of an 8-bit computer, along with the design of its graphical simulator for pedagogical purposes

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In an introductory course of computer architecture, it is of high value that students use a simple and special CPU designed for this purpose and also its graphical simulator for a systematic

better understanding of the computer hardware operation. In this paper, we present Abu-Reiahn, a simple 8-bit processor which we have specifically designed and built as the introduction part of computer architecture course to help students familiarize with hardware and software of a real CPU. Effective use of our computer graphical simulator along with the hardware allow the students to deepen their knowledge of logic circuits and the need for desired timing signals in a CPU to perform specific tasks. In the first course of computer architecture, it is important that students use the graphical simulator of a simple CPU along with its hardware to obtain a better understanding of a stored program computer. At such a course taught in the Department of Electrical Engineering, Sharif University of Technology, students become familiar with Intel 8085 processor as the main microprocessor and Intel 8051 microcontroller. There are also regular weekly lab sessions as part of the course that allows students to have hands on the real hardware/software experience. In this department, “Logic Circuits & Lab” is a prerequisite for computer architecture. In the former, the students learn basic logic IC’s basics and how to put together different logic IC’s to build digital systems. They are also taught how to use Verilog HDL to design simple systems and how to implement them on CPLD and FPGA.

For teaching computer architecture in a more efficient way, most universities as well as textbook authors have considered teaching how a simple educational processor operates. Moreover, these processors are usually simulated using CAD tools, HDL languages or a dedicated software specifically created to simulate that processor [1-8]. Some of these processors are too simple. For example, the Very Simple CPU, introduced by Carpinelli, has only 4 instructions [4]. Due to its simplicity, this processor may be suitable for the

very start of computer architecture. Nevertheless, it is not possible that we give students programming assignments.

CHAPTER 3

SPECIFICATIONS

3.1 Introduction

In this section will be given the results of a discussion that connects the LO on the CE of the ARCHITECTURE and its relationship with 8-bit CPU. So that will be obtained suitability between design 8-bit CPU with LO at CE. This section is to discuss how to reach Learning Outcome at Computer Engineering based on 8-bit CPU design at Logisim Computer architecture has their strength and weaknesses based on reasons and strategies. On Logisim performed by the numbers of bits that saved by the opcode. The opcode has the relationship with the amount of syntax which configured. Syntax represents with assembly language that could perform by computer. The amount of bit data represent how much syntax that could run by computer.

3.2 Project scope

Computer and organization has benefits to computer engineering. So, at Logisim student can build a specific multipurpose computer that made according to by the specific requirement. Identify high-performance computing by any techniques such as parallel and distributed computer architecture. On Logisim Parallel processing could represent by ALU, it will call Parallel if the computer has two or more ALU that runs the different process at same time. The distributed computer could represent by two or more Control unit which runs the same process at same time.

3.3 Project features

Constant Clock (CCLK*). The constant clock signal, which is driven by only one source, provides a timing source for any or dl modules on the bus. CCLK* is a periodic signal with a specified frequency and is driven by a clock driver circuit.

Address Lines (AO*-A23*). The address lines are used to specify the address of the memory location or the 1/0 device that is being referenced by the command. There are 24 address lines, binary coded, to allow up to 16 777 216 bytes of memory to be These lines are driven by three are always controlled by the Bus For 1/0 bus cycles, master option of gathering 8-bit or 16-bit Because of this, all 1/0 slaves should of being configured to decode eight bits (AO*-A7*) and ignore the upper bits or to decode all 16 bits of (A15*). Note that in a system using 8-bit addresses, the value of the upper 16 bits of address is unknown. **A** master generating only 8-bit address may set the upper 16 address bits to any arbitrary value.

Data **Lines** (DO*-D15*). These are 16 bidirectional data lines used to transmit and receive information to and from a memory location or 1/0 port. The 16 lines are 'driven by the master on write operations and by the addressed slave, memory or **I/O,** on read operations. Both 16-bit and %bit transfers *can* be accomplished by using only lines DO*-D7*, with DO* being the least significant bit.

3.4 Operating environment

3.4.1 Breadboard

A breadboard is used to make up temporary circuits for testing or to try out an idea. No soldering is required so it is easy to change connections and replace components. Parts will not be damaged so they will be available to re-use afterwards.

The photograph shows a circuit on a typical small breadboard which is suitable for beginners building simple circuits with one or two ICs (chips). Breadboards have many tiny sockets (called 'holes') arranged on a 0.1" grid. The leads of most components can be pushed straight into the holes. ICs are inserted across the central gap with their notch or dot to the left. Wire links can be made with single-core plastic coated wire of 0.6mm diameter (the standard size). Stranded wire is not suitable because it will crumple when pushed into a hole and it may damage the board if strands break off.

Converting a circuit diagram to a breadboard layout is not straightforward because the arrangement of components on breadboard will look quite different from the circuit diagram. When putting parts on breadboard you must concentrate on their connections, not their positions on the circuit diagram. The IC (chip) is a good starting point so place it in the centre of the breadboard and work round it pin by pin, putting in all the connections and components for each pin in turn.

3.4.2 Digital circuits

The connection indicates to the bus master that no other master is requesting the bus and therefore the present bus master can retain the bus. There are times when this can save the bus exchange overhead for the current master. This is because quite often when a master is controlling the bus, there are no other masters that are requesting the bus. Without CBRQ*, only BPRN* indicates whether or not another master is requesting the bus and, for BPRN*, only if the other master is of higher priority.

Between the master's bus transfer cycles, ***so* as** to allow lower priority masters to take the bus if they need it, the master should give up the bus. At the start of the master's next transfer cycle, the bus should be regained. If no other master **has** the bus, this can take approximately three BCLK* periods. To avoid this overhead of unnecessarily giving up and regaining the bus when no other masters need it, CBRQ* may be **used.** Any master that wants but does not have the bus should drive this line low (true). The master that **has** the bus can, at the end **of** a transfer cycle, sense CBRQ*. If it is not low, then the bus does not have to be released, thereby eliminating the delay of regaining the bus at the **start** of the next cycle. (At any time before the master's next cycle, any other master desiring the bus will drive **CBRQ*** and cause the master to relinquish. Masters that use CBRQ* disable that function **so** that with masters that do not signal.

3.5 Electrical Specifications

The electrical specifications for the IEEE Std796 bus are as follows:

(1) General bus considerations of the state relationships, signal line characteristics, and power supplies

(2) Timing specifications for the bus signals.

(3) Specifications for the signal line drivers and receivers, as well as the electrical termination Requirements.

When electrical specifications indicate minimum or maximum values for the bus, they should be measurable at any point on the bus. Note that a particular implemented bus could have any amount of bus propagation delay and ringing (before setup times), as long as all bus parameters (for example, setup, hold, and other times) are met at all points on the bus. However, to facilitate the design of a compatible set of modules (masters and slaves) that use the bus, the standard maximum bus propagation delay will be specified as tpD(maximum).

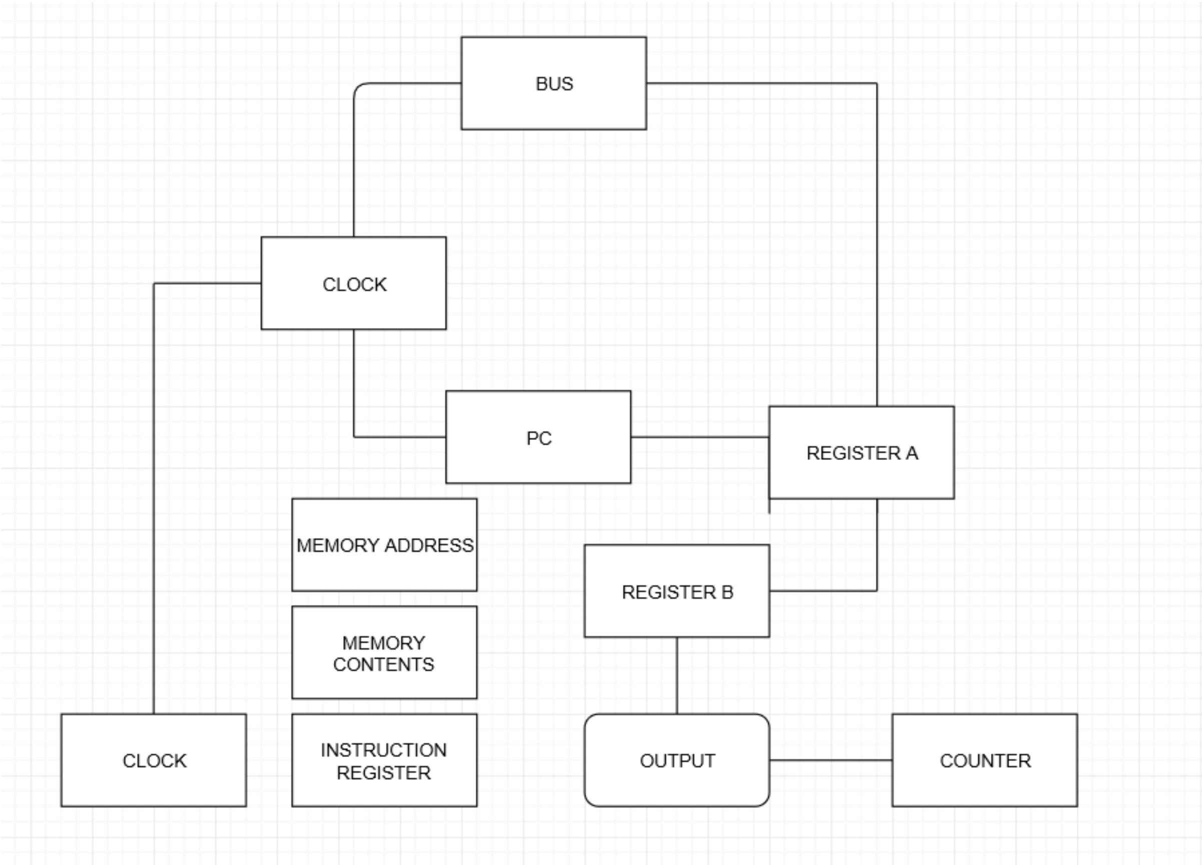
CHAPTER 4

SYSTEM DESIGN

4.1 Introduction

The basic system design is to build an 8-bit computer from scratch. This provides a deep understanding of how a computer works. This programmable 8-bit computer is built from scratch using only logic gates.

4.2 System architecture



The BUS brings all the modules together. Clock module sets the clock frequency of the system. PC acts as a program counter, keeps count. The output is displayed by highs and lows in LEDs and 7 segment displays. There's an instruction register to keep the instructions in check, that is to get the instructions from.

4.3 System requirements

4.3.1 Hardware

4.3.1.1 Resistors

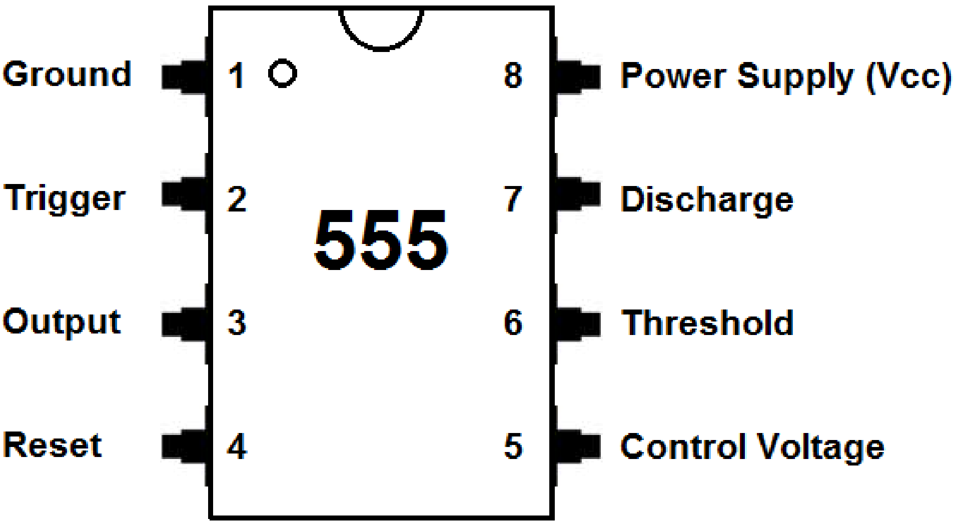
As this is an 8-bit computer the current and voltage required for this is minimalistic. So, many resistors like 1k ohm, 10 ohm, etc., are used to limit the current.

4.3.1.2 Capacitors

Capacitors are used so as to charge and discharge current in the 8-bit computer. This allow highs (1) and lows (0) in the system.

4.3.1.3 555 Timer IC

Timers are used to set the clock frequency of a computer. 555 timer is an integrated chip with 8 pins.



4.3.1.4 Logic Gates

Logic gates like AND, OR, NAND, NOR are used to solve logic based problems in the computer. Used in Arithmetic and Logic unit.

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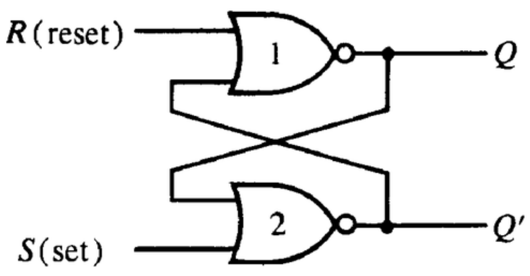
Name	NOT	AND	NAND	OR	NOR	XOR	XNOR
Alg. Expr.	$\overline{A}$	AB	$\overline{AB}$	$A+B$	$\overline{A+B}$	$A\oplus B$	$\overline{A\oplus B}$
Symbol							
Truth Table	A X 0 1 1 0	B A X 0 0 0 0 1 0 1 0 0 1 1 1	B A X 0 0 1 0 1 1 1 0 1 1 1 0	B A X 0 0 0 0 1 1 1 0 1 1 1 1	B A X 0 0 1 0 1 0 1 0 0 1 1 0	B A X 0 0 0 0 1 1 1 0 1 1 1 0	B A X 0 0 1 0 1 0 1 0 0 1 1 1

4.3.1.5 Flip flops and latches

In electronics, a flip-flop or latch is a circuit that has two stable states and can be used to store state information. A flip-flop is a bistable multivibrator. The circuit can be made to change state by signals applied to one or more control inputs and will have one or two outputs. It is the basic storage element in sequential logic. Flip-flops and latches are fundamental building blocks of digital electronics systems used in computers, communications, and many other types of systems.



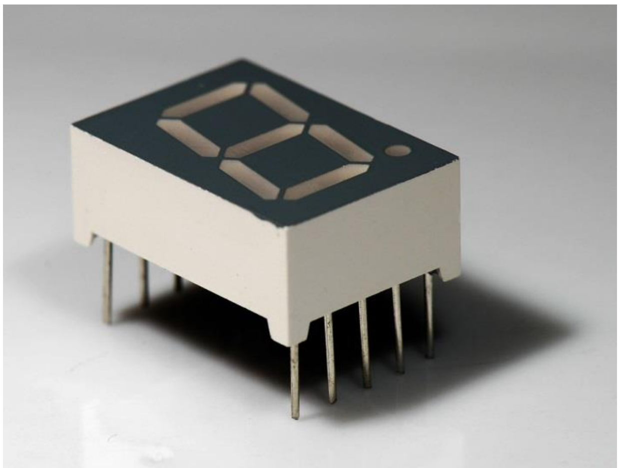
(a) Logic diagram

S	R	Q	Q′	
1	0	1	0	
0	0	1	0	(after $S = 1, R = 0$)
0	1	0	1	
0	0	0	1	(after $S = 0, R = 1$)
1	1	0	0	

(b) Truth table

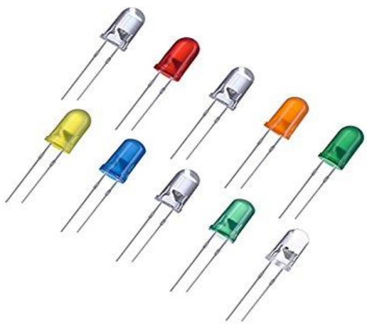
4.3.1.6 7 segment display

Common cathode 7 segment display is used to display numbers on the segments. A seven-segment display (SSD), or seven-segment indicator, is a form of electronic display device for displaying decimal numerals that is an alternative to the more complex dot matrix displays. Seven-segment displays are widely used in digital clocks, electronic meters, basic calculators, and other electronic devices that display numerical information.



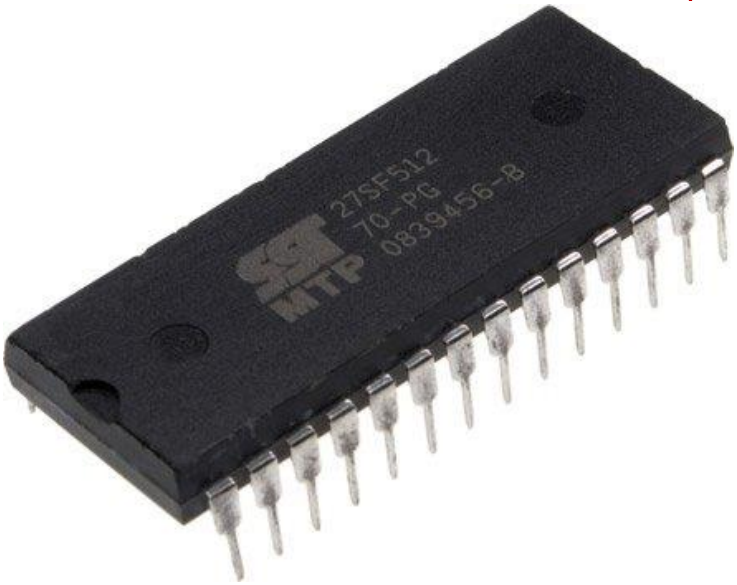
4.3.1.5 LEDs

A **light-emitting diode** (**LED**) is a two-lead semiconductor light source. It is a p–n junction diode that emits light when activated. When a suitable current is applied to the leads,[6][7] electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor.



4.3.1.6 EEPROM

EEPROM stands for *e*lectrically *e*rasable *p*rogrammable *r*ead-*o*nly *m*emory and is a type of non-volatile memory used in computers, integrated in microcontrollers for smart cards and remote keyless system, and other electronic devices to store relatively small amounts of data but allowing individual bytes to be erased and reprogrammed.



4.3.1.7 Double throw toggle switch

This switch is used to toggle between highs and lows of a system.

4.3.1.8 8 position dip switch

DIP switch with 8 individual switch positions. The pins have .1" spacing - fits great into a breadboard! Works great as general control switches.

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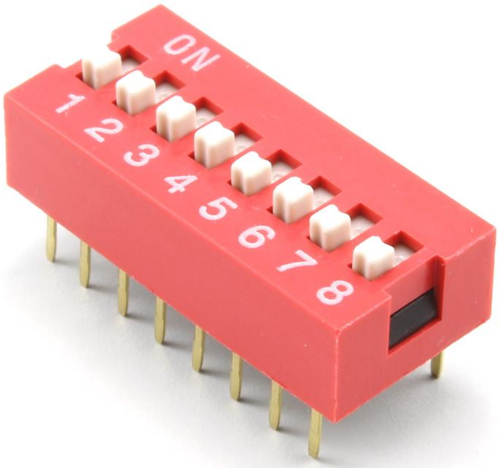
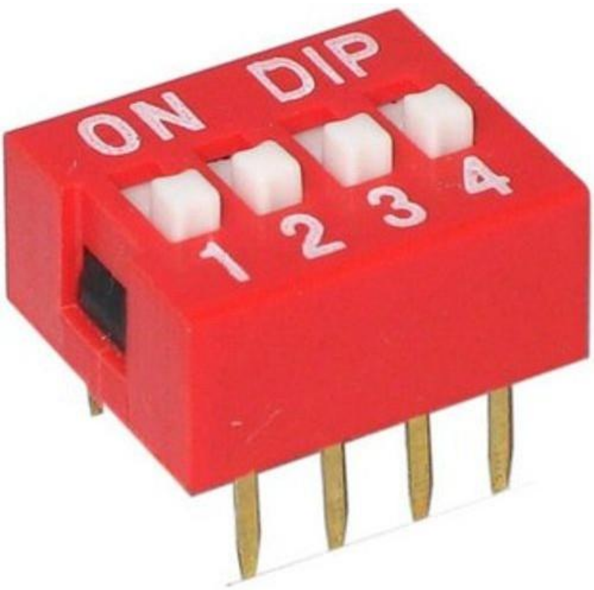


4.3.1.9 4 position DIP switch

DIP switch with 4 individual switch positions. The pins have .1" spacing - fits great into a breadboard! Works great as general control switches.



4.4 Summary

An 8-bit computer has been proposed so as to understand the working of a computer in depth and to remove abstractions in the process. This computer uses an electronically erasable programmable read only memory.

CHAPTER 5

MODULE DESCRIPTION

5.1 Introduction

The various modules can be classified under the internal modules as clock module, register, random access memory,

5.2 Clock module

The computer's clock is used to synchronize all operations. The clock we're building is based on the popular 555 timer IC. The videos go into some detail on the operation of the 555 and use it in three different ways.

Our clock is adjustable-speed (from less than 1Hz to a few hundred Hz). The clock can also be put into a manual mode where you push a button to advance each clock cycle. This will be a really useful feature for debugging the computer later on.

5.3 Registers

Most CPUs have a number of registers which store small amounts of data that the CPU is processing. In our simple breadboard CPU, we'll build three 8-bit registers: A, B, and IR. The A and B registers are general-purpose registers. IR (the instruction register) works similarly, but we'll only use it for storing the current instruction that's being executed.

5.4 Random Access Memory

The random access memory (RAM) stores the program the computer is executing as well as any data the program needs. Our breadboard computer uses 4-bit addresses which means it will only have 16 bytes of RAM, limiting the size and complexity of programs it can run. This is by far its biggest limitation.

5.5 Program Counter

The program counter (PC) counts in binary to keep track of which instruction the computer is currently executing.

5.6 Output Register

The output register is similar to any other register (like the A and B registers) except rather than displaying its contents in binary on 8 LEDs, it displays its contents in decimal on a 7-segment display.

5.7 CPU Control Logic

The control logic is the heart of the CPU. It's what defines the opcodes the processor recognizes and what happens when it executes each instruction.

CHAPTER 6

SYSTEM IMPLEMENTATION

6.1 Introduction

In computer architecture, 8-bit integers, memory addresses, or other data units are those that are 8 bits (1 octet) wide. Also, 8-bit CPU and ALU architectures are those that are based on registers, address buses, or data buses of that size. 8-bit is also a generation of microcomputers in which 8-bit microprocessors were the normal form and they performed basic arithmetic problems.

6.2 Overview of my platform

6.2.1 Breadboard

A breadboard is a construction base for prototyping of electronics. Originally it was literally a bread board, a polished piece of wood used for slicing bread. In the 1970s the solderless breadboard (a.k.a. plugboard, a terminal array board) became available and nowadays the term "breadboard" is commonly used to refer to these.

Because the solderless breadboard does not require soldering, it is reusable. This makes it easy to use for creating temporary prototypes and experimenting with circuit design. For this reason, solderless breadboards are also popular with students and in technological education. Older breadboard types did not have this property. A stripboard (Veroboard) and similar prototyping printed circuit boards, which are used to build semi-permanent soldered prototypes or one-offs, cannot easily be reused. A variety of electronic systems may be prototyped by using breadboards, from small analogue and digital circuits to complete central processing units (CPUs)

6.2.2 Breadboard Components

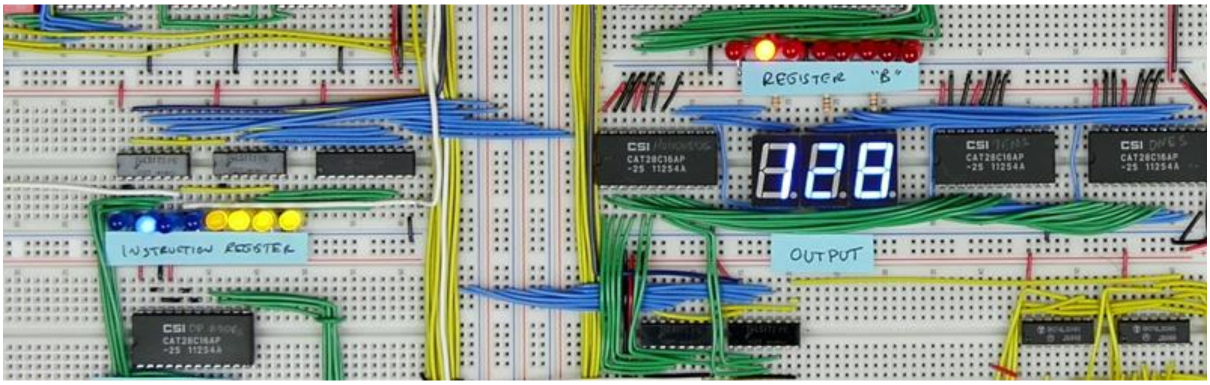
The computer is composed of several modules, each of which performs just a few basic functions. Check out these posts for more detailed information on building each module:

- Clock module (CLK)
- Registers (A, B, IR)
- Arithmetic and logic unit (ALU)
- Random access memory (RAM)
- Program counter (PC)
- Output (OUT)
- Bringing it all together (BUS)
- Control logic (CONT)

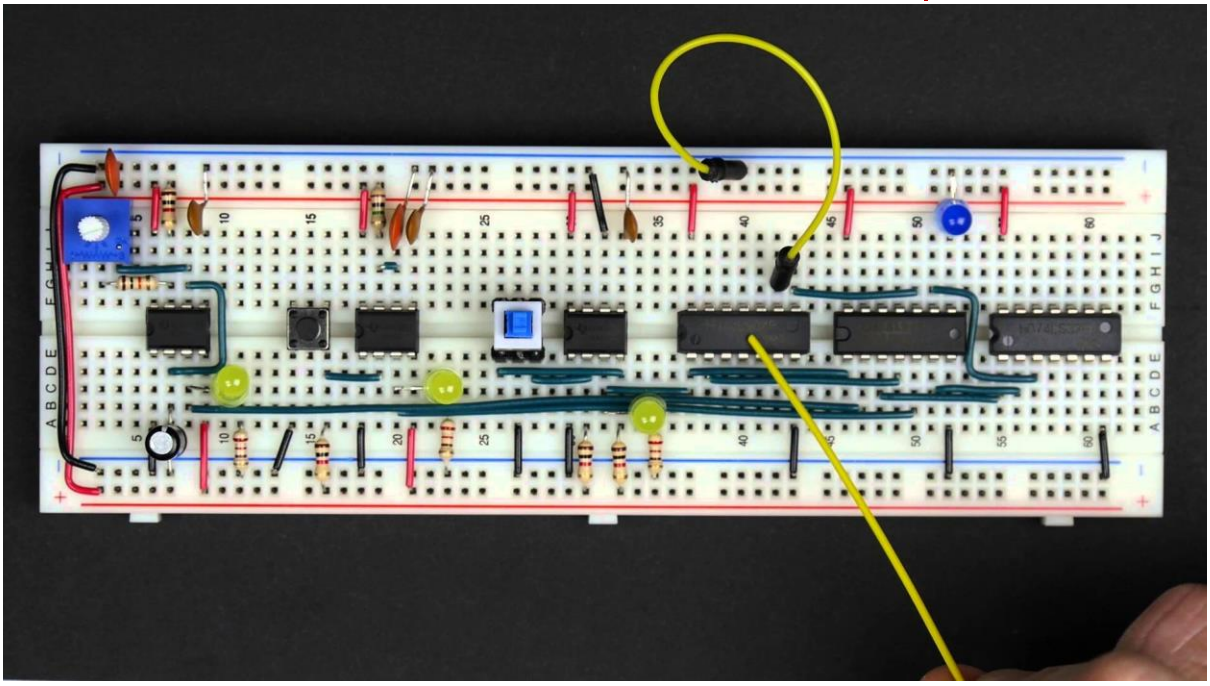
6.3 Implementation Details

The control logic is the heart of the CPU. It's what defines the opcodes the processor recognizes and what happens when it executes each instruction. Before building the control logic, we want to connect all of the modules to a shared bus and test things out. The modularity of the design makes it easier to test each module by itself so we won't ever get to a point where we put it all together and nothing works. The output register is similar to any other register (like the A and B registers) except rather than displaying its contents in binary on 8 LEDs, it displays its contents in decimal on a 7-segment display. Doing that requires some complex logic; luckily there's an easier way. The program counter (PC) counts in binary to keep track of which instruction the computer is currently executing. Most of the videos below explain how counting in binary works.

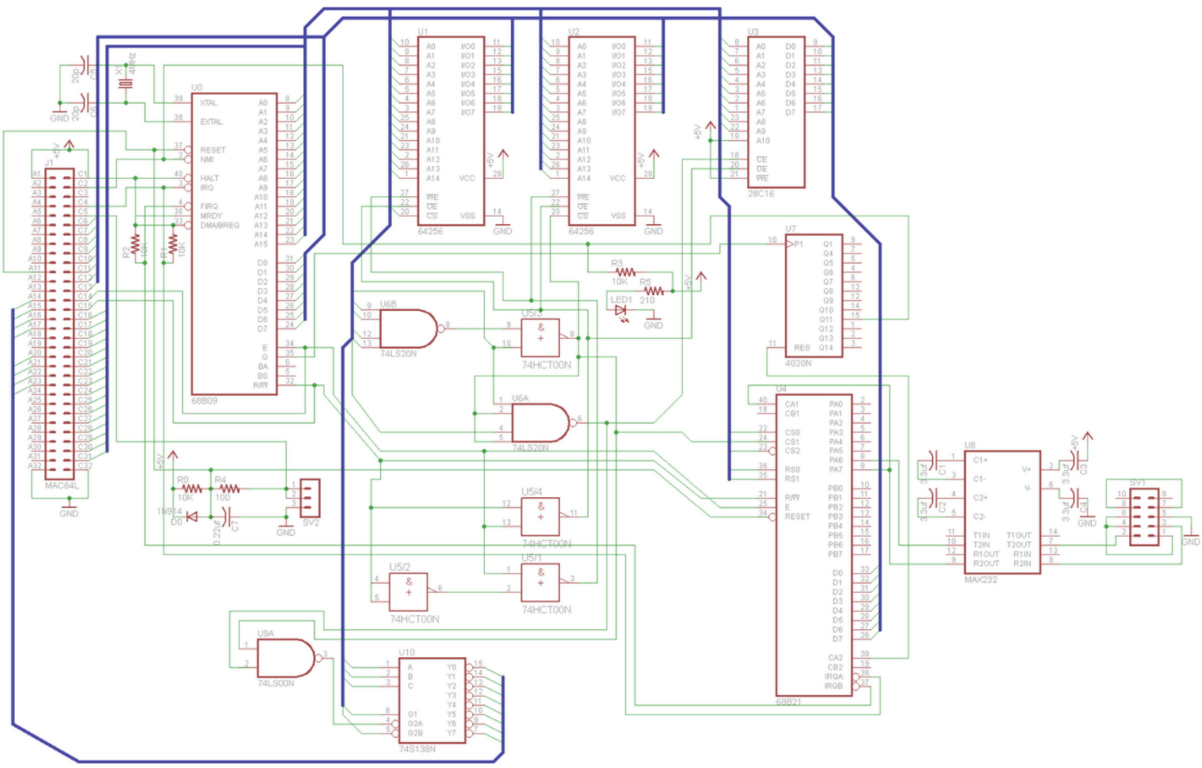
6.4 Sample working photos



SAMPLE WORKING-1



SAMPLE WORKING-2



INTERNAL CIRCUIT DESIGN

Ashwin Chakravarthy K *et al*, International Journal of Computer Science and Mobile Applications,
Vol.6 Issue. 4, April- 2018, pg. 85-108 **ISSN: 2321-8363**
Impact Factor: 5.515

6.4 Summary

Thus with the help of the above platforms the database was successfully created after which through the selected gateway, the linking was done. The linking helped to send the notifications to the respective worker for repairing. . The linking helped to send the notifications to the respective worker for repairing. This makes it easy to use for creating temporary prototypes and experimenting with circuit design. For this reason, solderless breadboards

CHAPTER-7

CONCLUSION AND FUTURE WORKS

7.1 SUMMARY

Computer System Architecture by Morris Mano can help you understand how to build a simple 8bit or 4bit computer from scratch provided u already have a prior knowledge of Digital Electronics. Registers, Bus Interface, ALU, Memory and their structures. The CPU Architecture simulation used Logisim which capable to performs the digital logic simulation. Logisim has an ability to perform digital logic to build subcircuit become a larger circuit in a single environment from low-level combinational and sequential circuits to build a complete CPU. An student has suffered to study COA with the theory that explained in several lessons, the lesson explained a structure and an architecture computer only. There are not providing a simulation that explained step by step computer architecture. . The linking helped to send the notifications to the respective worker for repairing.

7.2 FUTURE WORKS

The 8 bit computer does all basic arithmetic functions like addition, subtraction, etc., but doesn't do all the arithmetic functions. This computer can be made Turing complete. If the computer supports and runs all the Turing functions we can say that the 8 bit computer is Turing complete. This can be done by simple enhancements in the computer. This will make the computer do a whole lot of new functions and the possibilities will be greater than the previous generation. This makes it easy to use for creating temporary prototypes and experimenting with circuit design. For this reason, solderless breadboards and other components can be diminished into a suitable and user friendly environment. The microprocessors are considered to be one of the most enhanced product of this product and thus made to be used in an user friendly and accessible environment. The modularity of the design makes it easier to test each module by itself so we won't ever get to a point where we put it all together and nothing works. The output register is similar to any other register (like the A and B registers) except rather than displaying its contents in binary on 8 LEDs, it displays its contents in decimal The modularity of the design makes it easier to test each module by itself so we won't ever get to a point where we put it all together and nothing works. The output register is similar to any other register (like the A and B registers) except rather than displaying its contents in binary on 8 LEDs, it displays its contents in decimal.

CHAPTER 8

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