# **Building a computer from first principles - Course outline**

### **Instructor name: Varun Seshu**

### **Branch: Computer Science**

### **Semester: 3**

### **Prerequisite for the course:**

No prerequisites required

### **Deliverable from the course:**

1. Basic knowledge of boolean algebra

2. Making basic chips using Hack hdl

3. Making and testing ALU, RAM unit from provided software suite

4. Introduction to machine languages, building an assembler

5. Running basic programs for the hack computer

### **Final Project**

Students are to make either a CPU unit using ALU and basic gates or make an Assembler for the hack assembly language.

## **Week I – Introduction to boolean logic and hardware description language:**

### **1. Topics to be taught:**

#### **Part 1**

* Basic gates
* Boolean logic, multiplexers and demultiplexers
* Basic boolean functions
* Binary numbers
* Binary addition
* Negative numbers - 2’s complement

#### **Part 2**

* Introduction to HACK hardware description language
* Coding the basic gates using hdl
* Introduction to hardware simulation suite (provided)
* Multi-bit buses

#### **2. CHIPS BUILT THIS WEEK**

* And
* Or
* Not
* Xor
* Mux
* DMux
* HalfAdder
* FullAdder
* Add16
* Inc16

### **3. Weekly Project Work.**

* Construct and simulate the running of these gates using hdl and simulator provided
* Not16
* And16
* Or16
* Mux16
* Or8Way
* Mux4Way16
* Mux8Way16
* DMux4Way
* DMux8Way
* Building an ALU CHIP according to schematic given using hdl and simulate it’s working using the hardware simulator

## **Week 2 – Building RAM chips and introduction to hack machine language:**

### **1. Topics to be taught:**

#### **Part 1**

* Schematic of ALU, using the gates made previously
* Why is the ALU needed?
* Snippets of code and description of ALU’s functions
* Introduction to flip-flops and Registers
* Step by Step improvement on registers to eventually build a 16K RAM unit

#### **Part 2**

* Introduction to Hack assembly language
* Making adder programs using the language
* Introduction to input/output devices to the computer and complex programs using the hack machine language

#### **2. CHIPS BUILT THIS WEEK**

* Bit (Bit register)
* Register (16-Bit Register)
* RAM8 (8 Register RAM)
* RAM64 (64 Register RAM)

### **3. Weekly Project Work.**

* Simulating changes on monitor and keyboard of the hack computer using RAM and Hack ML.
* RAM512
* RAM4K
* RAM16K
* PROGRAM COUNTER CHIP

**Week 3 – Building a CPU and assembler for Hack computer:**

### **1. Topics to be taught:**

#### **Part 1**

* Building a CPU to process inputs using given schematic
* Solving the question of where the control bits are used

#### **Part 2**

* Introduction to the basics of assembling and the hack assembly language
* Description of algorithm to turn Hack assembly language to machine language
* Checking results using test bench

### **2. Final Project Work (either one of the options).**

* Making an assembler using a High Level Language to simulate and give character 0’s and 1’s output
* Connecting the CPU, RAM and ROM to make the Hack computer and test using the CPU and input/output devices using the simulator.