

Luke McNeil

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Milestone 1

1) Wednesday, September 30, 2020

[10 min]

Talked with team through chat and decided to do a stack architecture.

2) Saturday, October 3, 2020

[2 hours]

Wrote a first draft of the GCD and RELPRIME functions This included making up instructions as I went along. I used instructions presented in Sid's lecture on the stack architecture, as well as borrowing ideas for stack manipulation from Forth.

3) Sunday, October 4, 2020

[1 hour]

Spent some time trying to figure out what actually uses a stack architecture in the real world, and get a better idea of how it is implemented in hardware. Did some googling and wikipedia reading. Watched youtube videos on Forth and Java Bytecode.

4) Monday, October 5, 2020

[2 hours]

Met with team to discuss various requirements for M1. These include coming up with what additional registers we would need (none). We designed the format types O and A. After the meeting and having talked to Sid for some advice I decided that we could have two stacks of registers. One is the main stack which is for computations, and the other is a return address stack. This way nested functions can always remember where they should return to. This also allowed me to describe the function calling conventions. I wrote a code fragment where main calls f1 which calls f2 which calls f3 showing these conventions in use.

5) Tuesday, October 6, 2020

[1 hour]

I converted my RELPRIME and GCD to the table format that is in the design doc. I then refined the descriptions of our format types. I then listed out all of our instructions so far in a table providing their format type, argument if any, and a description. I also then created a table explaining how to convert O types to machine code which is pretty easy.

[1.5 hours]

Met as a group discussed how to convert all instructions to machine code. Figured out the addressing modes we are going to use. I wrote some additional code fragments explaining simple addition and getting input.

This is what we decided on was our plan for Milestone 2

M2 task assignment:

- a) 1st meeting: break instructions into small steps and move data from one register to another, determine single-cycle or multi-cycle

- b) Luke & Austin: RTL Description of each instruction
- c) Jinhao & Yiju : A list of generic components specifications needed for RTL
- d) 2nd meeting: debug and test the processor through Xilinx ISE and fix existing problems

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Milestone 2

#### 1) Thursday, Friday October 8-9, 2020

[4 hours]

Created a simulator for our stack language written in Chez Scheme. The simulator can take a program such as our relprime example and then run it, simulating the stack as a list.

#### 2) Tuesday, October 13, 2020

[3.5 hours]

Wrote the RTL descriptions for add, sub, or, dup, swap, drop, and over. While doing this I had to figure out how we would refer to the stack of registers in RTL. The way I decided to do it was with Reg.push(value) which pushes onto the stack a value and Reg.pop() which pops off the top thing on the stack.

I also edited our design document in response to Sid's feedback of M1. This includes making places for a title page, table of contents, executive summary, and additional sections. I then combined the table showing instruction description with the table showing opcode and funct into 1 table. I also replaced exit with halt, an instruction which always jumps to itself.

I then wrote an assembler for our stack language in Chez Scheme. I used several procedures from the simulator to read in the program. I then used a hashtable to match opcodes and functs, and then had to do some annoying stuff with converting a number to binary. This seems like it should have been easier since the number is actually being stored in binary, I just don't know how to get to that.

#### 3) Wednesday, October 14, 2020

[3.5 hours]

I recreated the RTL for the ones I had previously done and added it for all of the instructions. I changed from using Reg.pop() and Reg.push() to treating the stack as an array of size 64 where stack[0] is the top of the stack.

I had to think about what would happen when our stack machine runs out of registers on the stack. I decided there would be 64 registers in the stack and 64 registers in the return address stack. For this round of RTL I just assumed that data would be lost when the user tries to add something to an already full stack. This is not ideal, but it will make the implementation easier. This might change in the future.

I then made a factorial program and put it in implementation/example-programs/fact.asm. I used this to see if limit of 64 registers would be enough. In this example it is. This is because of the fact that factorial(8) is already bigger than a 16 bit number. Using updates to the simulator I found that factorial(8) only had a max-stack-size of 11 and a

max-return-stack-size of 10. This is plenty less than 64. This might not be true though in other examples where the result does not grow to be more than 16 bits so quickly. A good one to try would be fibonacci.

I also refactored the Design document to contain many different sections to make it more readable.

For M3 I will

- a) Get up to speed in Xilinx
- b) Start on datapath
- c) Write tests for small components

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Milestone 3

1) Saturday, October 17, 2020

[1.5 hours]

I created a xilinx project and pushed it to git. It has a mux and a test file from the course website.

I added a note in the design doc that specifies what will happen if a programmer tries to use more than 64 registers. (some information will be lost)

2) Sunday, October 18, 2020

[2.5 hours]

We met as a teams and spent a while verifying RTL. This consisted of drawing out what would happen in various parts and seeing if it was what we wanted.

We then started drawing out a datapath on the whiteboard. We ended up just keeping to add things until we basically had a datapath that could work for all of our instructions.

I then started playing around with what our stack of register component would need as input and output and what it should actually do. I started trying to draw out how it would work with a numPush and numPop input as well as 3 write wires. The output was the top of the stack and second from the top. I quickly realized that this was too much. I realized that when doing an add rather than doing two pops and then a push, it is simply a pop and then a replace.

3) Monday, October 19, 2020

[4 hours]

Jinhao and I met with Sid during office hours. This helped a lot in our design of the datapath and register stack. He gave us the inspiration to simplify the register stack into having two inputs: a stackOP, and a w which is write data. The outputs remain the same just being the top and next value. This makes the design of the register stack much simpler.

I met with Jinhao to further discuss the datapath. We drew a neater version of what we had on to the whiteboard. We ended up having to make some design decisions. For one we added another memory block separate from instruction memory. This is similar to what was done in single cycle in the book. Next we decided to push back some functionality into the ALU. We needed for example only to get out the second input given to the ALU. Rather than add a multiplexor to

the first input giving an option for it just to be zero and telling the ALU to add, we decided that we could just make a special OP to give to the ALU to just give back the second input.

I then implemented the register stack in Verilog. Most of the time spent here was figuring out how to get everything set up, not necessarily working on the logic. Once I got to the logic part it was pretty easy to just use for loops to shift the stack up or down. One thing I need to think about is when the write is done. Right now I have it set to do it on the posedge. I think we might want to switch that so that the ALU can read from the register stack, put a result on w, then on the negative edge of the clock w will be put on top of the stack. From my first implementation I had the for loop iteration for pushing and popping backwards which meant that I was overriding some data. Testing helped me find this issue.

### 3) Tuesday, October 20, 2020

[2 hours]

I spent a lot of time messing with the register stack to make it faster and smaller. It seems to be making a bunch of flip-flops for some reason that has to do with me doing something wrong. I'm not really sure what that is, but I will probably return to this component later to make it more efficient.

I then implemented the merger component which was a verilog one-liner.

### 4) Wednesday, October 21, 2020

[2 hours]

We met as a group and ironed out the component list. I then added a unit testing plan description for each component. Jinhao and I then created several integration plans for testing to be done going forward.

#### Things for Milestone 4

- Continue implementing necessary components and adding unit tests
  - Jinhao - sign-extender
  - Austin - adder
  - Jinhao - left-shifter
  - Luke - register
  - Someone - memory blocks
- Start on integration testing plans
  - Group Meetings (might split out individual work later)
- Implement Control
  - Luke

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Milestone 4

### 1) Sunday, October 25, 2020

[2 hours]

Met as a team and started implementing the push/pop integration test. I decided that we should add more outputs to integration test then we had previously thought. I added a topOfStack, SecondOfStack, and ALUResult so we could thoroughly test the pieces. Additionally, we created a table that completely describes our control components logic. Since we are doing single-cycle this is simply a truth table.

2) Monday, October 26, 2020

[2.5 hours]

I finished up the testing for push/pop integration step. I then created a verilog component for control. I had to document in the design document what each control signal value meant. I also had to add an input option to the stackControl control signal so that we could correctly implement getin.

3) Tuesday, October 27, 2020

[4 hours]

We met as a group and implemented the updating PC integration test. This went pretty good, but there was some confusion with timing. We also do not have a memory block component yet, so we could not include that component in this test.

I then added a blockmemory component. I had to think about how big we wanted both the data memory and instruction memory blocks to be. I decided that the data memory should have  $2^{12}$  addresses because that is how big our immediates are in instructions. Instruction memory can then be as big as we want or as little as it needs to be.

Things for Milestone 5

- finish integration testing
- get processor working, I think we should have it running relprime for this milestone

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Milestone 5

1) Wednesday, October 28, 2020

[2 hours]

I got the Spartan board and tried to run the aluIO project on it. This worked, but only on Windows which was a pain. I then altered the project to contain our register stack instead of the ALU. I fed the same op output to the register stack. So for example you would go to the or operator "|" do to a push. To do these operations at discrete times I set the clock of the register stack to be a button on the Spartan board.

2) Friday, October 30, 2020

[2 hours]

I worked with Austin to get the last of the integration tests up and running. Here I had to determine which instructions we could actually test with this subset of hardware. This included pop and push which had not yet been tested. During this we made the change to the smaller memory blocks as discussed in the previous milestones.

3) Saturday, October 31, 2020

[5 hours]

Met with Austin to try and put the whole datapath together in verilog. Reading through the code a second time to make sure it matched our datapath caught several small bugs. This turned out pretty good and we ended up getting every instruction working

except for push and pop. To do this we had to think carefully about the clock. We made instruction memory read on the rising edge, and on the falling edge we had PC be set, and the register stacks written to. This allowed us to get RelPrime running in the simulator. We then spent maybe an hour or two trying to get it on the Spartan board with little success.

#### 4) Sunday, November 1, 2020

[2 hours]

Met with Jinhao and Austin. Tried to get Jinhao in a place where he could change the coe file then regenerate and run those instructions. After this meeting I spent time running through the push and pop instructions to see exactly what we would need to do with the clock to make them work. I decided that we needed a clock edge between the rising edge and the falling edge of the one we currently had. I was not sure how to do this though.

#### 5) Monday, November 2, 2020

[4 hours]

Met with Sid in the morning to discuss the clock issues we were facing. He gave the insight that we could put our fast and slow clock into and/or gates to produce the kind of clocks we wanted. I then added this logic to our verilog and made sure that push/pop worked by running a simple set of instructions.

I then spent a couple hours getting RelPrime running on the spartan board. This was made much easier by getting the ability to push to the spartan board from Linux (thanks Sid). I then took out the alu from the aluIO project and replaced it with our final\_processor component. I made a couple additional modifications. The reset pin to the processor is the wire that is high whenever the rotary is changed. This way, whenever the input value is changed, PC will be reset to 0 and the processor will rerun the current program. This required me to replace our current PC which used synchronous clear with another 16 bit register with asynchronous clear. With these changes I could now see the results of RelPrime with any input.

#### 6) Tuesday, November 3, 2020

[2 hours]

Met with Austin and added system test specifications to the design doc. This includes plans to test small sets of similar instructions then move up to trying bigger programs like RelPrime.

I also added another instruction "getin2" to get input from a second input wire. I just added this because I wanted to be able to do computations on two numbers on the Spartan board.

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Milestone 6

#### 1) Monday, November 9, 2020

[5 hours]

I tried to add an addi instruction. This includes adding a multiplexer to the datapath right before the ALU. For some reason this change nearly double the processor's overall clock speed. I can not really figure out why this is since control is already setting the ALUOP, so another control on a mux which is the input to that ALU should not matter. Anyhow, I decided not to add addi

because of this.

I also added the timing stuff as requested in Milestone 6. The only tricky thing I had to do here was add an instruction count register to the control component to count up whenever the instruction was anything but halt.

2) Wednesday, November 11, 2020

[3 hours]

I implemented all of the system tests. In final\_processor\_tb I added code snippets and machine code translations to test every instruction and some bigger programs. To perform these tests you should copy the machine code for a specific system test into blockmemorykx1.mif and then uncomment that test in final\_processor\_tb. I had to make a couple fixes here. First, a push directly after a pop would not work correctly. I fixed this by connecting the top of the stack directly to data memory write data instead of waiting for the ALU. The second fix was to shift the top of stack left 1 bit before sending it to PC for the instruction js.