Implement I281 CPU

DESIGN DOCUMENT

Team Number: sddec22-20
Client: Dr. Alexander Stoytchev
Advisor(s): Dr. Alexander Stoytchev
Team Members/Roles
Alex Kiefer/Group Lead and Lead Hardware
Joseph De Jong/Hardware Testing, Communications, and Reporting
David Vachlon/Purchasing Lead, Software Testing, and Hardware Testing Lead
Saffron Edwards/Lead Software, Software Testing, and Website Maintenance
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Executive Summary

Development Standards & Practices Used

List all standard circuit, hardware, software practices used in this project. List all the Engineering standards that apply to this project that were considered.

Engineering Standards:

- 1012-2016 - IEEE Standard for System, Software, and Hardware Verification and Validation: We need this standard in order to test hardware and Professor Stoytchev's ISA (instruction set architecture) on our computer.
- 370-2020 - IEEE Standard for Electrical Characterization of Printed Circuit Board and Related Interconnects at Frequencies up to 50 GHz: We need this standard in order to make sure that we make our PCB of the high quality Professor Stoytchev expects.
- 162-1963 - IEEE Standard Definitions of Terms for Electronic Digital Computers: We need this standard in order to make sure that the pcb we build for students uses the correct names for its components. Because this will be used in a learning environment, it is essential that we do not lead students.

Summary of Requirements

- Must be visual so that students can learn
- Must be Reprogrammable
- Use less than 50W of power
- Must be able to run all of Dr. Stoytchev's ISA instructions

Applicable Courses from Iowa State University Curriculum

Cpre 281

Cpre 381

EE 201

EE 230

New Skills/Knowledge acquired that was not taught in courses

How to program EEproms

KiCad

Table of Contents

List of figures/tables/symbols/definitions

1) ISA : Instruction Set Architecture
2) CPU: Central Processing Unit
3) PCB: Printed Circuit Board
4) Breadboard: Board used to Prototype Circuits
5) LED: Light Emitting Diode
6) Assembly Language: The Lowest Level form of Programming, an Assembly Language consists of only 1's and 0's
7) OPCODE: An OPCODE is the Name for an Instruction Written in Assembly
8) ALU: The Arithmetic Logic Unit
9) EEPROM: Electrically Erasable Programmable Read-Only Memory

1 Team

1.1 Team Members

1) David Vachlon

2) Saffron Edwards

3) Alex Kiefer

4) Patrick O'Brien

5) Joseph De Jong

1.2 Required Skill Sets for Your Project

Electrical Engineering - The majority of this project will be Electrical Engineering focused. Students will work with their team to research and implement various devices to build a working i281 CPU on breadboards.

Computer Engineering - After completing the building phase, Computer Engineering will be used to implement a custom ISA onto the CPU to run a variety of programs.

Software Engineering - Software Engineering will be used throughout the course of the project to write test benches that will be used to test the functionality of the CPU and the ISA.

1.3 Skill Sets covered by the Team

Electrical Engineering - Patrick O'Brien, Alex Kiefer, Joseph De Jong

Computer Engineering - David Vachlon

Software Engineering - Saffron Edwards

1.4 Project Management Style Adopted by the team

Our project management style is waterfall. We will focus on completing a full stage before moving onto the next phase. This is important because we will be creating a PCB and PCBs are very costly if mistakes are made. It is because of this that it is essential to create a fully working prototype and get approval for printing before ordering the fully functional PCB. On top of saving money, waterfall will help us save time. Computers are built one module at a time and by having the entire team focused on distinct modules it will help us avoid mistakes that could cost us valuable time for troubleshooting later on in the project.

1.5 Initial Project Management Roles

Alex Kiefer - Group Lead and Lead Hardware

Joseph De Jong - Hardware Testing, Communications, and Reporting

David Vachlon - Purchasing Lead, Software Testing, and Hardware Testing Lead

Saffron Edwards - Lead Software, Software Testing, and Website Maintenance

Patrick O-Brien - Documentation, Progress Reports, and Meeting Notes

2 Introduction

2.1 Problem Statement

What problem is your project trying to solve? Use non-technical jargon as much as possible.

The College of Electrical and Computer Engineering at Iowa State offers programs that help to describe hardware and software to its students. However it seems that Iowa State, and many other universities around the country, lack material that effectively builds the connection between hardware and software with undergraduate students. Teaching Professor Alexander Stoytchev is seeking to bridge that gap by developing an easily understandable hardware implementation of a simple computer processor. Past senior design groups have developed an online simulation of the processor, but the professor wants a hardware implementation to prove that the design actually works in the real world. The current issue is to prove that the design works by using breadboards to implement each subcomponent of the computer, and resolve any issues with the current design. Once a design has been built and comprehensively tested using breadboards, we will design a pcb (printed circuit board) for the professor to use during lectures and labs.

2.2 Requirements & Constraints

List all requirements for your project . This includes functional requirements (specification), resource requirements, qualitative aesthetics requirements, economic/market requirements, environmental requirements, UI requirements, and any others relevant to your project. When a requirement is also a quantitative constraint, either separate it into a list of constraints, or annotate at the end of requirement as "(constraint)". Other requirements can be a single list or can be broken out into multiple lists based on the category.

Requirements	**Constraints**
CPU must be able to execute an	Building our project first on

instruction every clock cycle.	breadboards makes it much more difficult to implement since we really have to keep this requirement in mind as we build each component. Building one component incorrectly would result in this requirement not being met.
Must have a variable speed clock	Confined to low power and through hole chips due to chip availability.
Must be programmable	We are limited by a 5 volt power supply, which means we have a lot that this computer needs to be able to do with a limited amount of power.
Must run preset programs including Pong and Bubble Sort	Another constraint for this project is that we must use 22awg solid core wire for all connections, which means that we need to have a specific item in stock for us and cannot vary from it.Confined to low power and through hole chips due to chip availability.
Must be broken up into easy to understand modules	A technical constraint for us is that Stoytchev's design uses a 16 bit instruction memory and 8 bit data memory. This means that we have to get clever with our implementation due to these big differences.
Must display output on 7-seg display or LEDs	The completed project is due by December 2022.
Must include user inputs involving slide switches and push buttons	Breadboard implementation is slow to test and incredibly error prone.
Breadboard implementation must be functional first due to pcb costs	Limited budget (only get 1 or 2 attempts at printing a pcb so we have to get it right).
Must run commands based on Professor Stoytchev's assembly language	We are not entirely sure how to program the CPU yet.
Must be portable	The PCB needs to be very visual so students can learn but at the same time portable, which means it can't be too

	large.
Must easily demonstrate progress of a program throughout its execution	LEDS must be placed at carefully thought out locations on the pcb to convey useful information to students.
Create functional implementation of the i281 CPU on hardware	We are constrained by lack of experience in building a CPU.

2.3 Engineering Standards

What Engineering standards are likely to apply to your project? Some standards might be built into your requirements (Use 802.11 ac wifi standard) and many others might fall out of design. For each standard listed, also provide a brief justification.

Engineering Standard	Justification
1012-2016 - IEEE Standard for System, Software, and Hardware Verification and Validation - Redline	We need this standard in order to test hardware and Professor Stoytchev's ISA (instruction set architecture) on our computer.
370-2020 - IEEE Standard for Electrical Characterization of Printed Circuit Board and Related Interconnects at Frequencies up to 50 GHz	We need this standard in order to make sure that we make our PCB of the high quality Professor Stoytchev expects.
162-1963 - IEEE Standard Definitions of Terms for Electronic Digital Computers	We need this standard in order to make sure that the pcb we build for students uses the correct names for its components. Because this will be used in a learning environment, it is essential that we do not lead students astray and only use terms and names that they would see in industry.

2.4 Intended Users and Uses

Who benefits from the results of your project? Who cares that it exists? How will they use it? Enumerating as many "use cases" as possible also helps you make sure that your requirements are complete (each use case may give rise to its own set of requirements).

Both Professor Stoytchev and his students benefit from the successful implementation of this project. This is because this will be used to enhance the learning experience of future undergrads in the ECpE program here at Iowa State. Additionally, this project should cause a greater number of students to feel as though they have mastered the material, which should help them in future courses. The only person who currently cares that this project exists is Professor Stoytchev.

This is because students who have already gone through his class won't be concerned about this project since it doesn't impact them and future students don't know about it and will only care once it is implemented.

This project will be used in the lab setting of CprE 281 to teach students how the different aspects of digital logic that they have learned all semester coalesce into a single, functional computing unit. They will interact with it by running programs through it and examining the output as well as by identifying the different components which comprise this computing system.

3. Project Plan

3.1 Project Management/Tracking Procedures

Which of agile, waterfall or waterfall+agile project management style are you adopting? Justify it with respect to the project goals.

Our project management style is waterfall. We will focus on completing a full stage before moving onto the next phase. This is important because we will be creating a PCB and PCBs are very costly if mistakes are made. It is because of this that it is essential to create a fully working prototype and get approval for printing before ordering the fully functional PCB. On top of saving money, waterfall will help us save time. Computers are built one module at a time and by having the entire team focused on distinct modules it will help us avoid mistakes that could cost us valuable time for troubleshooting later on in the project.

What will your group use to track progress throughout the course of this and the next semester. This could include Git, Github, Trello, Slack or any other tools helpful in project management.

The team will be utilizing 3 tools to track progress. The first tool our team implemented was a discord server. Through discord we are able to share information instantly while being able to see what each member is working on. On top of discord, we have a weekly progress report. In the weekly progress report each member writes up what they are currently working on and what their next step in the project is. This is a way for our team to document progress while seeing that no two team members are working on the exact same thing on accident. Finally, we have utilized meeting times to create a weekly "to-do" list. This list is shared with the team members via the weekly progress reports and discord. This "to-do" list is meant as a quick stop to keep the team on track of what is due.

3.2 Task Decomposition

In order to solve the problem at hand, it helps to decompose it into multiple tasks and subtasks and to understand interdependence among tasks. This step might be useful even if you adopt agile methodology. If you are agile, you can also provide a linear progression of completed requirements aligned with your sprints for the entire project.

The i281 CPU will be broken down into 3 steps. The first step is to implement the i281 CPU onto a set of breadboards. Next, we test the breadboard CPU and design a schematic. Finally, we will design the CPU on a PCB and get it printed.

The first step, implementing the i281 CPU onto breadboards, will be the most tedious task and will be broken into subtasks. Each member will take on a subtask to lighten the load for everyone.

Our subtasks are as follows:

1. Instruction Memory
2. Registers
3. OpCode Decoder
4. ALU
5. Flags
6. Control
7. Multiplexors
8. Data Memory
9. Display
10. EEPROM Program

After each of these subtasks are implemented, we can begin testing. Testing will be broken down into subtasks of testing each instruction individually. The instruction set has 25 individual instructions that we will refrain from listing here to save space.

Finally, we will implement the CPU onto a PCB. The PCB implementation has three subtasks.

These subtasks are as follows:

1. Layout PCB using software
2. Print PCB
3. Solder devices onto PCB

After these three final subtasks are complete, the i281 CPU will be ready for use in a classroom setting.

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

What are some key milestones in your proposed project? It may be helpful to develop these milestones for each task and subtask from 2.2. How do you measure progress on a given task? These metrics, preferably quantifiable, should be developed for each task. The milestones should be stated in terms of these metrics: Machine learning algorithm XYZ will classify with 80% accuracy; the pattern recognition logic on FPGA will recognize a pattern every 1 ms (at 1K patterns/sec throughput). ML accuracy target might go up to 90% from 80%.

In an agile development process, these milestones can be refined with successive iterations/sprints (perhaps a subset of your requirements applicable to those sprints).

Key Milestone	Metrics
Implementation of every i281 CPU component	Each individual CPU component completes a testbench with 100% accuracy and the device has been properly documented via the progress report template.
Full implementation of the i281 CPU	Each component of the i281 CPU has been combined to create a working device. The testbench has been passed with 100% completion. The system has been fully documented via the progress report template.
Full PCB layout of the i281 CPU	The schematics of the i281 CPU have been transferred to the desired PCB design software. The PCB layout passes all geometry checks and is ready for printing.

Soldering of PCB	Upon arrival of the PCB, each device will need to be soldered into place. The device will need to pass all continuity checks.
Testing of PCB	The i281 PCB will be tested on completion of bubble sort and pong. Each program will be required to be executed at 100% correctness.

3.4 Project Timeline/Schedule

• A realistic, well-planned schedule is an essential component of every well-planned project

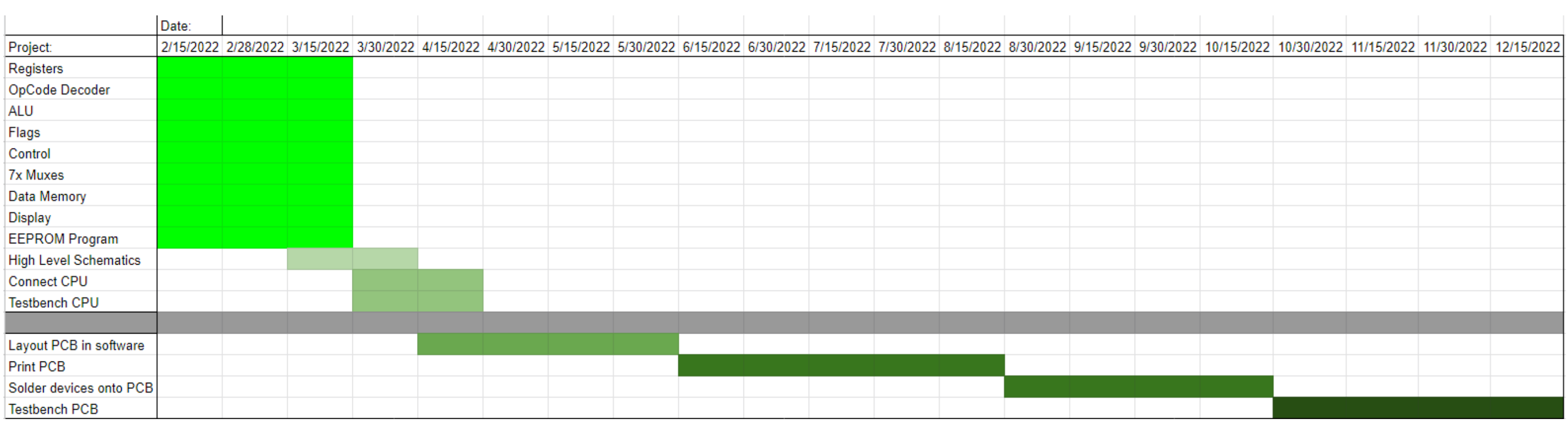
• Most scheduling errors occur as the result of either not properly identifying all of the necessary activities (tasks and/or subtasks) or not properly estimating the amount of effort required to correctly complete the activity

• A detailed schedule is needed as a part of the plan:

– Start with a Gantt chart showing the tasks (that you developed in 2.2) and associated subtasks versus the proposed project calendar. The Gantt chart shall be referenced and summarized in the text.

– Annotate the Gantt chart with when each project deliverable will be delivered

• Project schedule/Gantt chart can be adapted to Agile or Waterfall development models. For agile, a sprint schedule with specific technical milestones/requirements/targets will work.



3.5 Risks And Risk Management/Mitigation

Consider for each task what risks exist (certain performance targets may not be met; certain tools may not work as expected) and assign an educated guess of probability for that risk. For any risk factor with a probability exceeding 0.5, develop a risk mitigation plan. Can you eliminate that task and add another task or set of tasks that might cost more? Can you buy something off-the-shelf from the market to achieve that functionality? Can you try an alternative tool, technology, algorithm, or board?

Agile projects can associate risks and risk mitigation with each sprint.

Unfortunately, none of these tasks can be eliminated due to the scope of our project. However, despite the risk associated with some of these tasks, there are tools that we can use/buy that will make implementing them more palatable.

Tasks	Risk Factor	Mitigation Plan
Instruction Memory	0.5	We can use SRAM in place of the EEPROM that professor Stoytchev currently wants us to use if we determine that EEPROM will not be effective in this role.
Registers	0.3	N/A
OpCode Decoder	0.3	N/A
ALU	0.1	N/A
Flags	0.1	N/A
Control Logic	0.21	N/A
Data Memory	0.7	If we aren't able to implement the Data memory using EEPROM, we will use SRAM or general purpose registers as an alternative.
Multiplexors	0.01	N/A
Display	0.3	N/A

EEPROM Program	0.8	If we are forced to use EEPROM, we will buy an EEPROM programmer to make setting it up easier. Right now, without one, it will be extremely error-prone to set it up.

3.6 Personnel Effort Requirements

Include a detailed estimate in the form of a table accompanied by a textual reference and explanation. This estimate shall be done on a task-by-task basis and should be the projected effort in the total number of person-hours required to perform the task.

Job	Textual Reference	Explanation	Hour Estimate
Instruction Memory	Location to store instructions. 64x16 bit addresses	The instruction memory is where the i281 will hold the currently executed code. This code is written in binary and uploaded to an EEPROM that can hold data offline. When powered on, the EEPROM will upload the required program to a set of SRAM chips.	20
Registers	Location to store current data. 4x8 bit addresses	Registers are used for quick data access. If a mathematical function is occurring, the registers will be accessed. The i281 CPU utilizes 4 registers.	20
OpCode Decoder	Instruction to control operation	The OpCode Decoder takes an instruction and decides which mathematical function is expected to occur. The decoder will utilize a set of control bits to tell the ALU which actions to perform	20
ALU	Control of desired math function	The ALU is like the calculator of a CPU. It takes two values and does a mathematical	20

		operation on the values dependent upon the OpCode Decoder	
Flags	Detects irregularities in the ALU	Flags are used inside the ALU to detect certain irregularities. These flags let the user know when an unwanted value is created and the operator can take action if needed.	10
Control	Adjusts flow of data for each instruction	The control changes the direction of data flow depending upon the desired operation. It is in charge of making sure the right data gets to the right location.	20
7x Muxes	Used to select between which data will be used at intersections	Multiplexers are controlled by the control to tell data where to go. Multiplexers can be seen as "on-ramps" for an interstate. Multiplexers make sure data doesn't crash into other data.	20
Data Memory	long-term storage of data	Data memory is long-term memory. If you don't want to use a value immediately, it can be stored in data memory. The data memory can be accessed later on if a value needs to be referenced.	20
Display	Show current values of memory	Display is used to show values inside the data memory. This helps the user visualize the current actions being taken on the CPU.	40
EEPROM Program	Used as a microchip when needed	The EEPROM will be used to store code. This code will later be uploaded to the CPU during usage to run a program.	20
KiCad	Created a PCB for manufacturing	KiCad is used to design a PCB. KiCad is a free software. This software has a large learning	120

		curve which will need to be learned in order to design the i281 CPU onto a PCB.	
Soldering	Attached desired modules to the PCB	When the PCB arrives, we will need to attach various components. Soldering is a strenuous task that will take time to complete.	80
Other	Ordering, implementation, testing	Unknown issues may arise during the implementation of the i281 CPU. We will create another category to give our team wiggle room when an issue arises.	40
Total:			450 Hours

3.7 Other Resource Requirements

Identify the other resources aside from financial (such as parts and materials) required to complete the project.

Resource	Description
Ben Eater	Online resource about the design of 8 bit computers on breadboards.
CprE 281	Our project is based on the i281 CPU created during CprE 281. We will utilize the notes, simulations, software, and code from this class to create a working product.
ETG	The ETG will be our go-to for any miscellaneous parts. These parts will be used to implement the i281 CPU. Any parts that are out of stock can be purchased via a purchase order.
Digikey	Digikey provides a variety of chips, tools, controllers, and other equipment that might be necessary for the project.

4 Design

4.1 Design Context

4.1.1 Broader Context

Describe the broader context in which your design problem is situated. What communities are you designing for? What communities are affected by your design? What societal needs does your project address?

Our project is designed for students and faculty. We want to make the life of the faculty and students easier and help future students learn and grow in the field of Computer Engineering. We want to give faculty members the ability to share their knowledge without having to spend extra time creating class material. We also want every student to feel accomplished and every faculty member to feel proud of their students. As a result, our project is focused on improving CprE 281 and the education of the students who take that class. This will, ideally, elevate the quality of engineers graduating from Iowa State due to an improved education in a core class.

List relevant considerations related to your project in each of the following areas:

Area	Description	Examples
Public health, safety, and welfare	How does your project affect the general well-being of various stakeholder groups? These groups may be direct users or may be indirectly affected (e.g., solution is implemented in their communities) Our project directly affects the well-being of students, our shareholders, due to that being directly correlated with the educational quality of the lab section of the class CprE 281. This is because our project is focused on improving the labs in CprE 281 by implementing Dr. Stoytchev's i281 CPU in real life. By bringing this CPU to life, Dr. Stoytchev aim's to have students use it to better learn about the subject. This affects both the quality of the lab section of Dr. Stoytchev's CprE 281 course and the quality of the education of the undergraduates in that course.	-Taking time to analyze desired learning outcomes for students. -Taking time to analyze clear ways to display important concepts. -Taking time to cleanly design the layout so that it looks respectable to those using our CPU. -Limiting complexity by clearly labeling individual components. -Limiting confusion by using LEDS to show progression of execution. By taking into consideration these examples of how our project aims to improve the quality of these labs, we can reach this design goal.
Global, cultural, and social	How well does your project reflect the values, practices, and aims of the cultural groups it affects? Groups may include but are not limited to specific communities,	By building this CPU, we are striving to improve the curriculum in the lab section of CprE 281. This reflects positively on the

	nations, professions, workplaces, and ethnic cultures. Our project reflects not upon any specific cultural group, per se, however it does reflect upon the academic standards that Iowa State University holds high. This is because this project will directly impact the educational quality of a core class in the computer and electrical engineering curriculum, and as a result, it affects the Iowa State community as a whole. In our effort to improve the curriculum, it positively reflects the culture of the university which strives for excellence.	values of Iowa State which strives for excellence. Examples of this improving students lives are: -Students get to see how what they learn in class is relevant to future material. -Students get to see digital logic in action through the execution of programs. -Students get to see physical versions of the different components that comprise the CPU they learn about in class. -Students will be able to better understand the material in class with the physical version which positively reflects on Iowa State's values.
Environmental	What environmental impact might your project have? This can include indirect effects, such as deforestation or unsustainable practices related to materials manufacture or procurement. This project should have no discernable environmental impact. While it uses metals involved in circuitry (which can be hard to acquire and lead to pollution in their production), we are only developing one breadboard implementation of this CPU and are only producing one final PCB at the end of the class. Additionally, the power draw that this system will require to run will be relatively low. As a result, this won’t cause excess pollution in the way of power plants increasing the supply of energy. This means our project has little to no environmental impact.	-This system will require less power than the average lamp to run. -We only need to build a single system, so the amount of parts we are sourcing (and their environmental footprint) is limited. -This system has no plans to be mass produced, preserving our limited environmental impact. -The parts we require are not do not involve super rare metals, although their continued mining of what we do need, industry-wide, does have an environmental impact. However, as previously stated, we barely impact that trade with the limited amount of parts we require.
Economic	What economic impact might your project have? This can include the financial viability of your product within your team or company, cost to consumers, or broader economic effects on communities, markets, nations, and other groups.	-Lab maintenance costs will be reduced through more limited use of FPGAs -PCBs (should the one we produce get damaged) are significantly

	This project will significantly reduce the costs of maintaining the i281 lab for students. The current lab uses FPGA boards which can cost upwards of $1,000 each. A PCB will cost ¼ the price of an FPGA. This means that replacing the hardware that breaks each year will be a significantly reduced cost that can be used elsewhere. Additionally, this reduced cost could result in a lower technology fee for students taking that class.	cheaper to reproduce then a new FPGA would be if damaged. -Student lab/technology fees should be reduced as a result These impacts are rather positive impacts for Iowa State and its computer engineering department.

4.1.2 User Needs

List each of your user groups. For each user group, list a needs statement in the form of:

User group needs (a way t0) do something (i.e., a task to accomplish, a practice to implement, a way to be) because some insight or detail about the user group

The CprE 281 students need the physical i281 CPU because it will help them visualize a datapath of a processor, and help them connect the dots on the basics they have been learning. Because they might use this for a lab the processor must be reprogrammable.

Statements for users:

Dr. Stoytchev: Dr. Stoytchev needs a way to teach his students i281 because he cares about his students and their knowledge.

281 Students: 281 Students need a way to visualize the components of a CPU because it will help them better understand how their class material is used in the world.

4.1.3 Prior Work/Solutions

Include relevant background/literature review for the project

– *If similar products exist in the market, describe what has already been done*

The current solution to demonstrate our project to students is through loading the design onto an FPGA (Field Programmable Gamma Array). FPGAs are highly specific computers that can be designed to implement a niche set of functions. However, FPGAs are quite expensive and have a very steep learning curve.

– *If you are following previous work, cite that and discuss the advantages/shortcomings*

The previous work we have been following for implementing this system on breadboards is through a youtube series by Ben Eater. https://youtu.be/HyznrdDSSGM

The problem with Ben's work is that each instruction of the computer takes multiple clock cycles. The computer we are attempting to implement will utilize only one cycle/instruction. This means that we will have to redesign the bus system and other control components to run on a single clock cycle, a problem that is much easier said than done to fix.

– *Note that while you are not expected to "compete" with other existing products / research groups, you should be able to differentiate your project from what is available. Thus, provide a list of pros and cons of your target solution compared to all other related products/systems.*

Competitor Pros	Competitor Cons
• Large Quantity Available • Efficient • Looks Professional	• Price • Fragile • Hard to Understand

Our Project Pros	Our Project Cons
• Easy to Follow • Cheap • Reprogrammable • Redesignable	• Inefficient • Hard to Replicate

4.1.4 Technical Complexity

Provide evidence that your project is of sufficient technical complexity. Use the following metric or argue for one of your own. Justify your statements (e.g., list the components/subsystems and describe the applicable scientific, mathematical, or engineering principles)

1. The design consists of multiple components/subsystems that each utilize distinct scientific, mathematical, or engineering principles –AND–

2. The problem scope contains multiple challenging requirements that match or exceed current solutions or industry standards.

The current design can be broken down into several sub-components including the ALU, fetch logic, register file, data memory, and instruction memory. The ALU requires the ability to add, subtract, and shift. The fetch logic must be able to increment the program counter of the processor for normal instructions, in addition to executing branch operations. The instruction memory and data memory will need to be programmable, which will require the addition of a microcontroller.

In addition to the multiple components present in our project, the project itself can be broken down into multiple subprojects. The first subproject that must be completed in the construction of a breadboarded prototype of the processor. This will require extensive research of chips and careful design considerations for propagation and power requirements. The next subproject involves the design of a PCB, which will require software like KiCad to complete. The third subproject is the creation of an assembler to upload instruction files onto the processor. Considering all of these factors we believe that the project possesses the appropriate level of complexity to be considered for an ABET-accredited senior design.

4.2 Design Exploration

4.2.1 Design Decisions

List key design decisions (at least three) you have made or will need to make in relation to your proposed solution. These can include but are not limited to, materials, subsystems, physical components, sensors/chips/devices, physical layout, features, etc.

Decision 1: LED choice. The first major decision our team faced was implementing LEDs into the CPU design. LEDs are a great way to visualize data flow in a system. However, LEDs draw lots of power and create an extra footprint that will need to be accounted for. We decided to test a large set of LEDs to find the lowest power devices we could. Next, we decided that each bus only needs a single set of LEDs instead of implementing LEDs on each module.

Decision 2: Communication method: The second issue we struggled with was communication. At the start of the semester, we tested the water with 4 different communication methods. This was great because we were always connected as a team. When we started creating files for our project it was a trainwreck to look in 4 locations to find the file you desired. We ended up agreeing on Google Drive for data sharing and discord for group communication.

Decision 3: Memory Device. The third decision our team is still struggling with is how to implement memory. During each team meeting, we end up generating more ideas than we can handle. Although these new ideas are great, it hasn't made the decision easier. We hope to come to a conclusion within the next two weeks so we can order the parts required for our memory systems.

4.2.2 Ideation

For one design decision, describe how you ideated or identified potential options (e.g., lotus blossom technique). List at least five options that you considered.

The design decision we are going to focus on is the memory device. The way we went about comparing each device is by using a pros and cons table. We create a presentation showing each device we considered using. Each slide highlighted a different device that was considered. This method made it very easy for our team to meet with multiple groups of people to get recommendations. Along the way we revised our presentation before showing it to our client. Our client really enjoyed this method.

The list of devices we considered is as follows:

- EPROM
- EEPROM
- Flash
- Static Memory
- DRAM
- SRAM
- ROM
- Raspberry PI
- Registers

4.2.3 Decision-Making and Trade-Off

Demonstrate the process you used to identify the pros and cons or trade-offs between each of your ideated options. You may wish to include a weighted decision matrix or other relevant tool. Describe the option you chose and why you chose it.

As we previously stated the way we compared each device was via a presentation of pros and cons tables. We chose this to help our client understand what we were dealing with. This method broke each option into a simple to follow explanation. Our client didn’t have much knowledge on data types so we wanted them to get the most out of our research. This presentation was a great way to get advice on each device from faculty members and other students. No one person is an expert in every memory type, but some people are extremely well versed in a single type of memory. Presenting only one type of memory to these experts helped us collect critical data without any misinformation.

4.3 Proposed Design

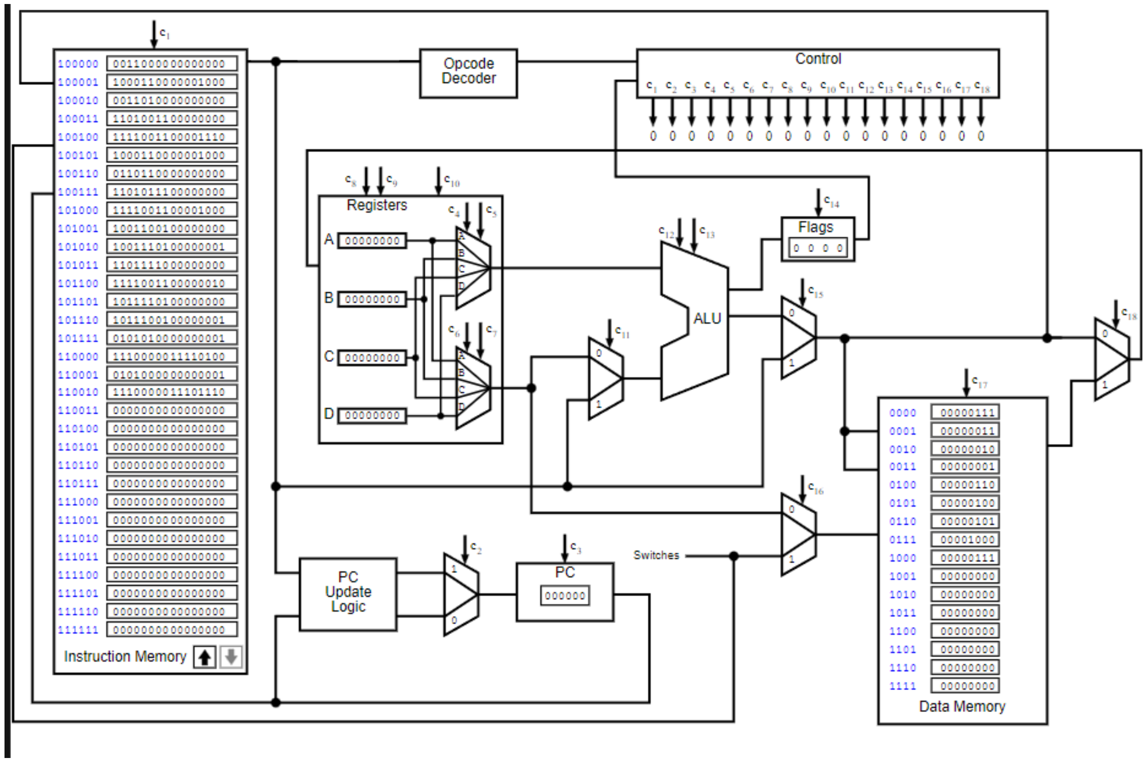
Discuss what you have done so far – what have you tried/implemented/tested?

So far, we have constructed a register file, ALU, and memory. We have attempted implementation of a program counter, but that failed on the first attempt. The ALU, register file, and memory have been extensively tested.

4.3.1 Design Visual and Description

Include a visual depiction of your current design. Different visual types may be relevant to different types of projects. You may include: a block diagram of individual components or subsystems and their interconnections, a circuit diagram, a sketch of physical components and their operation, etc.

Describe your current design, referencing the visual. This design description should be in sufficient detail that another team of engineers can look through it and implement it.



This is the data flow of the I281 CPU. The data flow consists of decoding instruction memory, changing control signals, and doing arithmetic. This visual provides the general layout of the I281 CPU, with lines that demonstrate the paths and connections that are needed between each component.

4.3.2 Functionality

Describe how your design is intended to operate in its user and/or real-world context. This description can be supplemented by a visual, such as a timeline, storyboard, or sketch.

How well does the current design satisfy functional and non-functional requirements?

The computer/processor will be able to take in machine code assembled by a custom assembler created by us. The processor will then process those instructions and output the current program being run on 7-segment displays or LEDs.

Our current design appears to satisfy all requirements laid out for us to meet.

4.3.3 Areas of Concern and Development

Based on your current design, what are your primary concerns for delivering a product/system that addresses requirements and meets user and client needs?

Our largest concerns for delivering a product are time constraints. Our project is to build an entire computer on breadboards. We estimated that our project will take over 400 hours to fully complete. Our team cannot guarantee that we can spend 400 hours to complete this project. We will need to find a way to make cuts in time to produce a CPU for our client.

What are your immediate plans for developing the solution to address those concerns? What questions do you have for clients, TAs, and faculty advisers?

One of the largest time consumptions we have run into thus far is waiting for parts to arrive. We have started to plan each module well in advance of implementation to ensure we don't have downtime while waiting for parts to come in. At this point we have a large surplus of parts and have worked with the ETG to understand what is readily available for us to use.

4.4 Technology Considerations

Highlight the strengths, weaknesses, and trade-offs made in technology available.

Discuss possible solutions and design alternatives

Data Memory Technology	**EEPROM**	**EPROM**
Pros	• Can Be Reprogrammed • Easy to Understand • Compatible with EEPROM programmer	• Cheap • Easy to use • Many sizes, Many Applications • Widely Supported
Cons	• Large Programming Learning Curve • Few Design Style	• Cannot be reprogrammed during use

4.5 Design Analysis

– *Did your proposed design from 3.3 work? Why or why not?*

– *What are your observations, thoughts, and ideas to modify or iterate over the design?*

Our proposed design was intended to complete a single set of instructions without error. However, we have changed our design to include completing any program. This means that our data memory and instruction memory will need to be rewritable. These two components will be redesigned to allow for changes in the data state. This means that we will need to find a new way to store and write data.

4.6 Design Plan

Describe a design plan with respect to use-cases within the context of requirements, modules in your design (dependency/concurrency of modules through a module diagram, interfaces, architectural overview), module constraints tied to requirements.

First we will implement all of the sub components on breadboards. After that we will create a dataflow with control signals on the breadboards. After we have a first dataflow, we will implement all required instructions. AFter this we will work on how to program the computer, and finally we will put the final design on the PCB and give it to the customer.

5 Testing

Testing is an extremely important component of most projects, whether it involves a circuit, a process, power system, or software.

The testing plan should connect the requirements and the design to the adopting test strategy and instruments. In this overarching introduction, given an overview of the testing strategy. Emphasize any unique challenges to testing for your system/design.

5.1 Unit Testing

What units are being tested? How? Tools?

There are multiple subsystems of the CPU, including the data memory, register file, ALU, instruction memory, and control logic. Each of the subsystems of the CPU are tested individually using dip switches to emulate data from the register file/instruction memory. The way that we have tested these is setting the switches to a specific value and observing the LED indicators on the output of the unit (tools include oscilloscopes, multimeters, and LED indicators). This is the most concrete way to test our project because we already know what outputs to expect, so it just becomes a matter of verifying that our breadboard builds match our expectations.

5.2 Interface Testing

What are the interfaces in your design? Discuss how the composition of two or more units (interfaces) are being tested. Tools?

Our interface is switches, LED's, 7-segment displays, and the text interface used to write the assembly. First, the LED's and switches will be tested by programming our instruction memory (which has not been setup yet) with basic instructions to make sure the LED values are correct. Next, the 7-segment displays will be tested to ensure the proper hexadecimal values are output with the correct inputs. Finally, the assembler will be tested by checking the output binary file it produces (tools for this are primarily visual verification, other tools are currently unknown).

5.3 Integration Testing

What are the critical integration paths in your design? Justification for criticality may come from your requirements. How will they be tested? Tools?

The integration of all subsystems of the CPU (ALU, Register File, Instruction memory, data memory, and control logic) will happen after all of them are completed. They will be slowly integrated to first make a basic data path that can do an add instruction. After the first datapath is completed more capability will be added to support more instructions until all of them are supported (tools include oscilloscopes, multimeters, and LED indicators).

5.3 System Testing

Describe system level testing strategy. What set of unit tests, interface tests, and integration tests suffice for system level testing? This should be closely tied to the requirements. Tools?

The system will be tested after all subsystems have been verified to work as intended. The testing will consist of creating a basic datapath and checking the LED indicators to ensure correct dataflow. If errors occur we shall use multimeters and oscilloscopes to debug problems.

5.4 Regression Testing

How are you ensuring that any new additions do not break the old functionality? What implemented critical features do you need to ensure they do not break? Is it driven by requirements? Tools?

All components are being tested individually before being fully integrated, so there is very little old functionality to break with new additions. When additions are made, they are made to individual components which we can test independently. What is very convenient about our project is that if the components work, the whole system should in theory work, so we know that when we connect the components together, there is very little risk that changing one component will break old components and their functionality. However, that said, each component is critical to the success of the project as a whole, and as a result of that, we need to ensure that our testing is incredibly thorough so find any issues with each component before we bring them all together. This testing is driven by the fact that CPU's require each of the components we are building, and we have been given a design by our client so we must follow it closely. Tools which we can utilize for this type of testing are primarily centered around LEDs which show us if our expected output is correct, which helps us verify if our components are correct and working properly. Additional tools we can use are oscilloscopes and multimeters for connection testing.

5.5 Acceptance Testing

How will you demonstrate that the design requirements, both functional and non-functional are being met? How would you involve your client in the acceptance testing?

Along with consistent meetings with our client to update him about the project, we also have a set list of requirements we created with the client. This keeps us on track by ensuring we know exactly what we need to do. During our weekly meetings, we demonstrate any progress, so if the client has any different requirements then we can change as we go.

5.6 Results

What are the results of your testing? How do they ensure compliance with the requirements? Include figures and tables to explain your testing process better. A summary narrative concluding that your design is as intended is useful.

The results of all of the testing should create results that match our need, which is making all of the assembly instructions run on our processor. Additionally, we should expect to see output (from the LEDS), in binary, which matches our assembly language mapping. After all of the testing is completed and we have the results we want, we will then take the breadboarded design and create a PCB layout to be fabricated and sent back to us (which will undergo its own set of testing similar to the breadboard implementation).

6 Implementation

Describe any (preliminary) implementation plan for the next semester for your proposed design in 3.3. If your project has inseparable activities between design and implementation, you can list them either in the Design section or this section.

The implementation plan for the next semester for our proposed design will be to finalize the functionality of the components that we built this semester, combine them, and then move on to the PCB. Due to the intensive time requirements to complete this project, execution of the plan we outlined in section 3.3 has already begun. At this point in time, most of the components have now been built and tested or are being tested, which should set us up to be ready to move onto the PCB implementation near the start of next semester. This semester, we divided up the completion of breadboard components between group members in order to tackle this massive project as completing our whole project next semester would have otherwise been impossible.

7 Professionalism

This discussion is with respect to the paper titled "Contextualizing Professionalism in Capstone Projects Using the IDEALS Professional Responsibility Assessment", *International Journal of Engineering Education* Vol. 28, No. 2, pp. 416–424, 2012

7.1 Areas of Responsibility

Pick one of IEEE, ACM, or SE code of ethics. Add a column to Table 1 from the paper corresponding to the society-specific code of ethics selected above. State how it addresses each of the areas of seven professional responsibilities in the table. Briefly describe each entry added to the table in your own words. How does the IEEE, ACM, or SE code of ethics differ from the NSPE version for each area?

Code of ethics chosen: IEEE #4. To reject bribery in all its forms.

Area of Responsibility	Relation to IEEE Code of Ethics
Work Competence	How it addresses this specific area: The IEEE code of ethics addresses this specific area through its points 6 and 7, which commit its engineers to both only undertake tasks if qualified by training or experience and to provide honest criticism, acknowledge errors, and credit contribution of others for their work. Point 6 is the one that primarily covers the work competence addressed by NSPE, however, point 7 further elaborates on the general idea NSPE was addressing. This means that both IEEE and NSPE agree that engineers should never participate in work in which they are not trained or being trained. How it differs from this specific area: These points from the IEEE code of ethics are very similar to the NSPE version, however, the IEEE code adds in providing honest criticism, acknowledging errors, and crediting others for

	their work, whereas the NSPE version only addresses competence and avoiding deceptive acts.
Financial Responsibility	How it addresses this specific area: The IEEE code of ethics addresses this specific area through its points 2, 3, and 4, which cover being honest about conflicts of interest with an employer, being honest about stating claims or estimates, and rejecting bribery. This is essentially the point of the NSPE canon for financial responsibility broken up into more specific points since following each would show faithfulness to one's employer. How it differs from this specific area: These points from the IEEE code of ethics are very similar to the NSPE version, however, the IEEE code breaks it into points that cover many different concepts (bribery, unethical estimates, etc.) which could be used to take advantage of one's employer. This difference is positive as it points out specific unethical practices which would impact the area of financial responsibility.
Communication honesty	How it addresses this specific area: The IEEE code of ethics addresses this specific area through its first point in the code, which covers the safety, health, and welfare of the public and addresses that one should disclose factors that might endanger the public or environment. This is somewhat similar to the NSPE version, as it informs engineers that they should issue only truthful statements. How it differs from this specific area: This point from the IEEE code of ethics, despite covering the point of committing engineers to only speak truthfully, publicly, is quite different from the NSPE canon. This is because the NSPE canon seems to be concerned with reporting one's own work to the business or stakeholders, while the IEEE is more concerned with the morality of the work.
Health, Safety, Well-Being	How it addresses this specific area: The IEEE code of ethics addresses this specific area through its first point in the code, which covers the safety, health, and welfare of the public and addresses that one should disclose factors that might endanger the public or environment. The NSPE canon almost directly covers the first part of this point of the IEEE code of ethics and means that the IEEE code and

	NSPE roughly line up on their stance on public health, safety, and well-being. How it differs from this specific area: This point from the IEEE code of ethics only differs from the NSPE canon in that it adds on that engineers must disclose these threats, while the NSPE canon only tells engineers to hold these ideas paramount, but not what to do when those ideas are affected by business decisions.
Property Ownership	How it addresses this specific area: The IEEE code of ethics addresses this specific area through point 9. Through this point, engineers agree to avoid injuring others, their property, reputation, or employment. Essentially, engineers have a duty to protect business property and to avoid intentionally causing harm (in general). This means that it aligns with the NSPE canon which entrusts engineers with acting faithful to their employers and to protect their business property, ideas, and information. How it differs from this specific area: This point from the IEEE code of ethics differs from the NSPE canon as they don't only focus on property, rather, they focus on property as just one aspect of an engineer's duty to not intentionally cause harm.
Sustainability	How it addresses this specific area: The IEEE code of ethics addresses this specific area through point 1. This point focuses on the safety, health, and welfare of the public and addresses that one should disclose factors that might endanger the public or environment. This means that engineers should act in the interest of public health and environmental protection. How it differs from this specific area: This point from the IEEE code of ethics differs from the NSPE canon as although both contain points about protecting the environment, the IEEE code does not include protecting natural resources (locally or globally).
Social Responsibility	How it addresses this specific area: The IEEE code of ethics addresses this specific area through points 8 and 10. These two points focus on treating all persons fairly and not discriminating against others, as well as supporting the professional development of colleagues and co-workers and to support them in following the IEEE code.

	This means that engineers should conduct themselves honorably and ethically in order to make the profession as respectable as possible. This is very close to the NSPE canon which wants engineers to do the same. How it differs from this specific area: This point differs from the IEEE code of ethics and differs from the NSPE canon as the NSPE canon focuses on producing products that benefit society while acting honorably. The IEEE code of ethics on the other hand, and its points that relate to this area, focus on treating others respectfully and also includes points on healthy professional development.

7.2 Project Specific Professional Responsibility Areas

For each of the professional responsibility areas in Table 1, discuss whether it applies in your project's professional context. Why yes or why not? How well is your team performing (High, Medium, Low, N/A) in each of the seven areas of professional responsibility, again in the context of your project. Justify.

Area of Responsibility	Application to EE491 Project	Group Performance
Work Competence	This applies to our project because we have to focus on hitting deadlines for our goals and making time every week to work on the project.	Medium. We have not been doing a great job hitting deadlines so this is something to improve on.
Financial Responsibility	This applies to our project because, as a senior design team, we are required to minimize resources used. This includes sourcing cheap parts, using quality parts, and avoiding breaking parts.	High. We spent a bit on hardware but got a deal on a larger order which should save us money in the long run.
Communication honesty	This applies to our project because it is important to make sure that all group members are on the same page and to	Medium. We are not great at communicating what has and has not been completed, organization has to be improved.

	respectfully be critical when a member falls short.	
Health, Safety, Well-Being	This applies to our project because although we aren't messing with components or electrical voltages that are deadly, we can still risk damaging our components with static discharges (which could get expensive). That said, safety should and will always be observed for both us and our components.	High. We have been constantly working to minimize risks of static discharge or shock to our components by creating many grounds.
Property Ownership	This applies to our project because we need to respect the intellectual property of the sources we use during our project. Proper documentation and citations in reports are necessary to give credit where credit is due.	High. We have been respectful with all equipment as to not break either our's or other people's equipment.
Sustainability	This applies to our project because we want to limit the waste we produce in this project as electronic waste is a growing problem on our planet. It is important to limit how much waste we produce from this project.	High. We have only purchased parts we currently or know we will need and have been cautious to avoid breaking anything.
Social Responsibility	This applies to our project because we are tasked with creating the i281 CPU. This project has the intention of enhancing the learning experience of future Iowa State undergraduates. We have a responsibility to produce and document the creation of the CPU so that future students may gain a deeper understanding of computer architecture.	High. The goal of our project is to increase education quality for engineering undergraduates, which improves the quality of life of these undergrads, which in turn is also the goal of social responsibility.

7.3 Most Applicable Professional Responsibility Area

Identify one area of professional responsibility that is both important to your project, and for which your team has demonstrated a moderate or high level of proficiency in the context of your project. Briefly describe what this responsibility means to your project, the ways in which your team has demonstrated the responsibility in the project, and specific impacts to the project that you have observed.

Communication is a very important part of our project due to the multiple subsystems that make up the project which must work together to create one computer. As a result, everyone has been assigned a couple of subsystems to work on which, without good communication, could cause problems down the road. As a result, we have been making sure that all of our systems will work together before we combine them by trying to be clear about what each component is expected to do. To do this, we have been working on communicating effectively since the levels of expertise in the context of this project varies from person to person. As we have two non-electrical engineers in the group, a focus has been made on clearing up any confusion that they may have. Additionally, we have also been sending emails and using discord to better organize and improve our communication capabilities. What this level of communication has done for our group is it has made the less experienced members more confident and it has resulted in us identifying future issues earlier.

8 Closing Material

8.1 Discussion

Discuss the main results of your project – for a product, discuss if the requirements are met, for experiments oriented project – what are the results of the experiment, if you were validating a hypothesis – did it work?

The main result of our project is a functioning CPU. Ideally, the CPU is a direct representation studied by students in CprE 281. This CPU has a custom ISA, unique data lines, and multiple display locations.

8.2 Conclusion

Summarize the work you have done so far. Briefly reiterate your goals. Then, reiterate the best plan of action (or solution) to achieving your goals. What constrained you from achieving these goals (if something did)? What could be done differently in a future design/implementation iteration to achieve these goals?

So far, we have built and tested all of the sub components of the processor except the data memory, control decode module, and the instruction memory. We are on schedule to make a working datapath by the end of the semester. We were constrained by the time it took to wire everything together. The best course of action to hit our goals is to keep working on it at least 4 hours per week.

8.3 References

List technical references and related work / market survey references. Do professional citation style (ex. IEEE).

" CprE 281: Digital Logic," *CPRE 281: Digital Logic [Fall 2021]*. [Online]. Available: https://www.ece.iastate.edu/~alexs/classes/2021_Fall_281/. [Accessed: 24-Apr-2022].

8.4 Appendices

Any additional information that would be helpful to the evaluation of your design document.

If you have any large graphs, tables, or similar data that does not directly pertain to the problem but helps support it, include it here. This would also be a good area to include hardware/software manuals used. May include CAD files, circuit schematics, layout etc,. PCB testing issues etc., Software bugs etc.

8.4.1 Team Contract

Team Members:

1) David Vachlon 2) Saffron Edwards

3) Alex Kiefer 4) Patrick O'Brien

5) Joseph De Jong

Team Procedures

Procedure Name	Execution Plan Notes
Weekly Meetings	Team Meeting: Tuesdays 4-5 PM Meet in open classrooms (In Person)
	Advisor Meeting: Friday 11-12 (Webex)

Team Updates/ Reminders	Discord
Decision Making Policy	Team lead or advisor has authority
Procedures for Record Keeping	Meeting Minutes: Patrick In "Meeting Minutes" Folder Weekly Reports: Joseph In "weekly Reports" Folder

1. Day, time, and location (face-to-face or virtual) for regular team meetings:

   Team Meeting: Tuesdays 4-5 PM Meet in open classrooms (In Person)

   Advisor Meeting: Friday 11-12

   (Webex)

2. Preferred method of communication updates, reminders, issues, and scheduling (e.g., e-mail, phone, app, face-to-face):

- Each meeting is to be held in person or on Webex.
- Additional meetings and communication can be held on Discord and in person.\
- Team members are expected to update the rest of the team on any progress made.

3. Decision-making policy (e.g., consensus, majority vote):

4. Procedures for record keeping (i.e., who will keep meeting minutes, how will minutes be shared/archived):

Meeting Minutes: Patrick In "Meeting Minutes" Folder

Weekly Reports: Joseph In "weekly Reports" Folder

Participation Expectations

Expectation	Notes
Attendance	All members are expected to attend every team meeting throughout the course of the project. If a team member needs to miss a meeting for any legitimate reason, they must notify the group at the earliest opportunity. One days notice is adequate.

	Team meetings are to start at the scheduled meeting time. Meetings have a reserved time of 50 minutes, although if the group finishes early they can collectively decide to end the meeting. If a meeting goes long, individual team members are free to leave if they have commitments after the meeting.
Timelines	Team members are expected to be engaged during each meeting. Each team member should try to bring a new question, comment, or discovery to each meeting.
Communication	● Each meeting is to be held in person or on Webex. ● Additional meetings and communication can be held on Discord and in person. ● Team members are expected to update the rest of the team on any progress made.
Commitment to Decisions	Meeting Minutes: Patrick In "Meeting Minutes" Folder

1. Expected individual attendance, punctuality, and participation at all team meetings:

- All members are expected to attend every team meeting throughout the course of the project. If a team member needs to miss a meeting for any legitimate reason, they must notify the group at the earliest opportunity. One days notice is adequate.

● Team meetings are to start at the scheduled meeting time. Meetings have a reserved time of 50 minutes, although if the group finishes early they can collectively decide to end the meeting. If a meeting goes long, individual team members are free to leave if they have commitments after the meeting.

2. Expected level of responsibility for fulfilling team assignments, timelines, and deadlines:

● Team members are expected to be engaged during each meeting. Each team member should try to bring a new question, comment, or discovery to each meeting.

3. Expected level of communication with other team members:

● Each meeting is to be held in person or on Webex.

● Additional meetings and communication can be held on Discord and in person.

● Team members are expected to update the rest of the team on any progress made.

4. Expected level of commitment to team decisions and tasks: Leadership

● Every team member must dedicate several hours a week to the completion of their respective tasks.

● If additional work is required by specific team members, they are responsible for completing that work, or asking for assistance from the rest of the team.

● The team should work together to ensure that each assignment assigned by the class is completed in a timely manner, in addition to the project work.

1. Leadership roles for each team member (e.g., team organization, client interaction, individual component design, testing, etc.):

Member	**Role**	
Alex Kiefer	Project Manager Lead Hardware Designer	
Saffron Edwards	Software Testing Manager Website Manager	
David Vachlon	Hardware Testing Manager Secondary Documenter	Purchasing Manager
Patrick O'Brien	Documentation Manager Meeting Scribe	Secondary Hardware Designer

2. Strategies for supporting and guiding the work of all team members:

Each team member will be given a Manager and secondary position. Managers are in charge of distributing work and completing tasks. Secondary roles will work with managers to complete all tasks. When groups fall behind the Project manager will help managers delegate work as needed.

3. Strategies for recognizing the contributions of all team members:

Each weekly report will contain a section called "weekly accomplishments". Completed tasks will be highlighted here and credit will be given to the respective member.

<u>Collaboration and Inclusion</u>

1. Describe the skills, expertise, and unique perspectives each team member brings to the team.

Alex Kiefer: As an EE undergrad, Alex brings a knowledge of electronics to the table that is needed for the successful completion of this project. Additionally, he brings leadership skills which will help to coordinate other group members as we progress through the project.

Saffron Edwards: As an SE undergrad, Saffron brings her ability to write software that can be used to test how effective our implementation of the i281 CPU turned out to be. In addition to this skill set, her unique perspective from being a purely software focused engineer will be useful in providing a different perspective on issues we encounter with this project.

David Vachlon: As a CprE undergrad, David brings both a knowledge of software engineering and hardware design, which will be useful in bridging the gap between the 3 electrical engineering undergrads we have on our team and the one software engineering

undergrad. Additionally, he brings solid organizational capabilities which will help to keep the team on track towards completing this project.

Patrick O'Brien: As an EE undergrad, Patrick brings his expertise in the field of electronics which will help in the design and implementation of the i281 CPU in real life. He brings a unique passion for electronics to the tables which will help provide the persistence to work through difficult problems that we will encounter throughout the course of this project.

Joseph De Jong: As an EE undergrad, Joseph brings his expertise in digital electronics to the table which will help us to understand how to break up the individual components of the CPU into teachable modules. Additionally, due to his interest in digital electronics (and embedded systems), he will be able to work well with David to combine their two skill sets.

2. Strategies for encouraging and support contributions and ideas from all team members:

Each manager is responsible for their team. The project manager is responsible for keeping each team on track.

3. Procedures for identifying and resolving collaboration or inclusion issues (e.g., how will a team member inform the team that the team environment is obstructing their opportunity or ability to contribute?)

Each weekly report will contain a section called "weekly accomplishments". Completed tasks will be highlighted here and credit will be given to the respective member.

Goal-Setting, Planning, and Execution

1. Team goals for this semester:

● Create a working i281 CPU

● Create a team that works in a fluid manner

● Satisfy clients expectations

- Get an A on our project

2. Strategies for planning and assigning individual and team work:

Each manager is responsible for their team. The project manager is responsible for keeping each team on track.

3. Strategies for keeping on task:

Using a tier-system will help each team member stay motivated. Additionally, team managers will be expected to help maintain focus when team members get off track.

Consequences for Not Adhering to Team Contract

1. How will you handle infractions of any of the obligations of this team contract?

First Infraction: A reminder from the team to the offender that they are to fulfill their required roles. Second Infraction: A meeting with the team to discuss additional actions. Potentially a meeting with the faculty advisor to discuss what to do with the offender.

2. What will your team do if the infractions continue?

It is known that any team member who does not fulfill their responsibilities will receive a poor review from their team and faculty advisor at the end of the semester.This will in turn have a negative impact on their final grade.

****

a) I participated in formulating the standards, roles, and procedures as stated in this contract.

b) I understand that I am obligated to abide by these terms and conditions.

c) I understand that if I do not abide by these terms and conditions, I will suffer the

consequences as stated in this contract.

1) David Vachlon DATE Apr 24, 2022

2) Saffron Edwards DATE Apr 24, 2022

3) Alex Kiefer DATE Apr 24, 2022

4) Patrick O'Brien DATE Apr 24, 2022

5) Joseph De Jong DATE Apr 24, 2022