Design of a Charge Measurement Device

DESIGN DOCUMENT

Sdmay20-11
Honeywell
Long Que

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Executive Summary

Development Standards & Practices Used

IEEE standards

Summary of Requirements

Requirements:

- Can measure the charge between 10 nano-Coulombs and 300 nano-Coulombs
- Can operate in voltages between 250- and 750-volts DC
- Confirmation of our output's accuracy

Recommendations:

- Small scale prototype circuit by the end of first semester
- Final design size approximately 3" by 6" PCB

Applicable Courses from Iowa State University Curriculum

- EE 201
- EE 230
- EE 303
- EE 311
- EE 333
- ENGL 314

New Skills/Knowledge acquired that was not taught in courses

- High Voltage Safety
- Larger team professional interactions
- Working with a client

- Following a budget

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List of figures/tables/symbols/definitions (This should be the similar to the project plan)

Figure 1: Example Charge Measurement Circuitry

1 Introduction

1.1 Acknowledgement

The company we will be receiving both technical advice and financial aid from is Honeywell. Jacob Starr and Nathen Orton are the project design leads we will be in contact with throughout the year. Another source of technical advice is Long Que, our group's advisor through Iowa State University (ISU). Sources for equipment and other necessities have yet to be determined. We suspect that outside equipment may come from either the Electronics Technology Group (ETG), Honeywell, or Ames Laboratory.

1.2 Problem and Project Statement

Problem statement-

Honeywell needs a way to accurately measure the accumulation of charge on electronic devices they are testing. The desired device should be reasonably sized and capable of handling any conditions or operating points that Honeywell specifies. The application of this device is important for extending Honeywell's ability to accurately test and understand the behavior of the electronics they are developing.

Solution approach-

Our team is currently exploring potential solutions through both research of new information and recollection of relevant material from previous courses taken at ISU. We have created a process flow that will be referenced throughout the duration of the project. This will help everyone to stay organized and in sync with the current state of the design. An Agile-based process will also be of use to our team for organization and execution of all tasks.

1.3 Operational Environment

The charge measurement device will be used in a lab/test environment. Since it will not be exposed to irregular or uncontrolled weather conditions, it is unnecessary to spend extensive time on an enclosure that will protect against such instances. However, in a lab setting there are still potential hazards such as dropping the device, unintentional use outside of its capabilities, and high voltage contact. The final product's enclosure will ideally be a solid, well fitted casing that will primarily protect users from high voltage contact while protecting the device from small daily wear and tear events. Overall the enclosure will remain simple, economic, and easily duplicatable.

1.4 Requirements

- Capable of operating at 250-750 V
- Accurately measure charge accumulation from 10-300 nC
- Only DC operation
- Connect to a computer UI
- Easily duplicated/simple design
- Relatively small PCB (around 3"x6") and final product enclosure

- Enclosure should protect the user from the high voltage
- Remain within budget restrictions ($2500 per semester)

1.5 Intended Users and Uses

This design is purposed for company use; the user is expected to be experienced or knowledgeable regarding the functionality and application. The intended application for this device is to measure the accumulation of charge in a testing environment. Because of this, the information Honeywell can share with our team is limited. With a testing application, we anticipate that the device will be used multiple times on a regular basis, so the end-product should be durable, reliable, and safe.

1.6 Assumptions and Limitations

Assumptions-

- The end-product is only intended for company use at Honeywell
- Honeywell plans to duplicate the design and create more units
- Only intended for DC operation
- Device will only measure the charge on one pin at a time

Limitations-

- PCB should be small (around 3”x6”)
- $2500 budget for two year-long projects
- System must be capable of operating safely between 250-750V
- Prototype is expected at the end of first semester
- Accessibility to a high voltage power supply for testing

1.7 Expected End Product and Deliverables

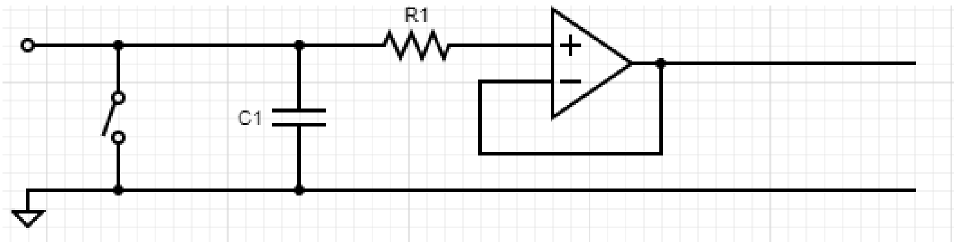
In the project proposal form, there were a few examples of expected deliverables listed. Since the product is not intended for commercialization, the deliverables expected are limited to a final presentation, final report, and any developed prototype(s). The final presentation will be an outline of the design process used throughout the course of the project. This includes a timeline of events, difficulties faced in the design and testing processes, methods of how the team overcame the obstacles, and a summary on the general success of the project. The presentation will near the end of the second semester. A final report will be included to document functionality of the final product in comparison to expectations, components used in the design, a list of costs accumulated through developing prototypes, etc. This will also be near the end of the second semester. The final product or prototype is expected to be an accurately functioning charge measurement device. A prototype will be developed by the end of the first semester. With the device, we will include a list of specifications that describe the basic functions and capabilities.

2. Specifications and Analysis

2.1 Proposed Design

The design that we have decided to try to implement for our charge measurement circuit is simple. As seen in Figure 1, the circuit takes an input voltage compared to system ground. The input voltage will be from the shell of the connector. This circuit will be able to tell us the charge on the shell by having a voltage across the capacitor. The Charge is equal to voltage multiplied by capacitance. This will then go into a buffer. The output of the buffer will be going into an ADC to be read digitally. The resistor is in place to limit the current going into the amplifier and the switch is to discharge any leftover charge between measurements. The charge will correspond directly with the value of C1, so we will choose this value depending on the accuracy the client requires.

Figure 1: Example Charge Measurement Circuitry



2.2 Design Analysis

The difficulty with this design come from working in a high voltage system. We will need to find components that are able to hold close to 1000 volts. Another difficulty that we will have will pertain to choosing our capacitor. The value of the capacitor needs to be as exact as possible to have the best accuracy in our measurement. We will also want to have a way to control the offset of the amplifier. This needs to be as precise as possible. Some pros of this circuit are that it is a simple design. This should give us the ability to replicate the circuit easily for all the pins in the system. We should also be able to find a plethora of parts to make the circuit as small as possible at an affordable price.

2.3 Development Process

We are following the Agile process for this project. We want to use this style because it encourages communication between the members of the group. We believe that to get the best product we all need to contribute and voice our opinions. Agile allows everyone to be a part of every step in the process and encourages discussion between everyone.

2.4 Design Plan

Our design plan for this project begins with researching different charge measurement methods. After weighing the pros and cons of the different circuits, we will begin testing smaller versions of the circuit. For us this will mean inputs with smaller voltages. We will transition this design to the higher voltages per the requirements. After running tests on this iteration, we will connect the circuit to SHV connectors. After testing this with one pin of the connector, we will attempt to expand to multiple pins of the connector if time permits. A PCB will be developed on this last iteration of the design.

3. Statement of Work

3.1 Previous Work And Literature

Electrometers have been used since the 18th century but could only handle nanovolts. Modern day electrometers can handle much larger voltages. For DC, a vibrating reed electrometer is used to measure charge. These can handle much larger DC voltages and the output will supply a constant current to keep the capacitance constant. Value electrometers use vacuum tubes with a very high gain and input resistance. The value model has a very small leakage making it less accurate than most others designs.

3.2 Technology Considerations

The vibrating reed electrometer is the only electrometer that can used for DC voltage. The issues with this design are the size and cost of the capacitors. It also is not as accurate as other designs but those are for AC only.

3.3 Task Decomposition

- Charge Measurement Research
- Low voltage testing
- Part research
- High voltage testing
- Pin expansion (optional)
- Computer UI
- PCB design
- Enclosure Design

3.4 Possible Risks And Risk Management

This project involves working with high DC voltages. This can be a dangerous to team members and to the components. The team will need to create safety procedures and redundancy to protect themselves and the project. This can include arc flash training, lock out tag out, and ground safety procedures.

3.5 Project Proposed Milestones and Evaluation Criteria

Milestones for this project will be the first circuit design, ordering parts for the prototypes, functioning prototypes, and finalization of the product.

3.6 Project Tracking Procedures

A shared calendar and planner will be used in Microsoft Teams.

3.7 Expected Results and Validation

A PCB that can measure the charge given the requirements of the customer. It should be easy and safe to use. Accuracy of the design will be determined while prototyping.

4. Project Timeline, Estimated Resources, and Challenges

4.1 Project Timeline

Project Step	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Charge Measurement Research							
Low voltage model							
Part research							
PCB design							
High voltage model							
Pin expansion (optional)							

Computer UI					Purple	Purple	Purple
Enclosure Design					Purple	Purple	Purple

Figure 2: Timeline chart

Blue – Research and Design

Green – Construction and Testing

Purple – Finalization

This timeline is being proposed as we do not currently have a lot of experience with the concept in general, searching for appropriate parts, and using high voltage. A lot of time will be spent researching the principles of charge measurement. We will use a low voltage model to safely develop testing and usage procedures. Dring this time, appropriate parts will be selected for the high voltage model. After understanding how charge measurement works, we will scale up the voltage to meet the requirements of the project. After a few months with that model and the accuracy and safety have been thoroughly verified, the team will break up into subgroups to finalize the product. A lot of time to finalize is desired so changes may still be made if necessary.

4.2 Feasibility Assessment

The final product will be a finished PCB with optional enclosure. The PCB will, regardless of enclosure, have all high voltage circuitry protected for safety reasons. A jack will be mounted to the board for connecting to a computer. The PCB will be able to measure charge and store little if any charge. If the PCB does store charge, it shall be measurable.

4.3 Personnel Effort Requirements

Task	Personnel Effort
Charge Measurement Research	Continuous Research on charge measurement until low-voltage model has been developed. All members are expected to understand the principles of how charge can be measured and weigh the advantages and disadvantages of different methods. This will be done on an individual basis with the preliminary design chosen as a group.
Low Voltage Model	As a team, the preliminary design will be tested on a breadboard prototype. This can be accomplished by just a few individuals, but testing will require the group's effort. Half of the group will focus primarily on this model and the whole group will work on testing.

Part Research	The other half of the group as described above will start investigating parts for the high voltage model. This group will give input for both models but will have more focus on selecting and ordering parts as necessary. This will be continuous until a working prototype for the high voltage model is developed.
PCB Design	Members of the team not working on part research will work on designing a PCB for the high voltage model. This will be a major factor at the beginning of the high voltage model and intermittently throughout that timeline.
High Voltage Model	After the low voltage model is developed and testing has shown good indications, work on the high voltage model will begin. There will still be ongoing research for parts as this task is being handled. Testing will also require the group's effort. This will be held back slightly by the PCB design group initially.
Pin Expansion (Optional)	A small amount of time will be dedicated to expanding to the other pins of the connector. Two personnel will be dedicated to this but will be less of a priority.
Computer UI	At this point, the design has entered the finalization stage. One person will be solely dedicated to this one aspect for the time specified in the Gantt chart.
Enclosure Design	This team will be formed after the PCB team is approaching their final design. Enclosure design members will work intermittently with the PCB design team.

Table 1: Timeline Descriptions

4.4 Other Resource Requirements

Breadboards

Perforated Boards

ICs necessary for low-voltage model

Resistors necessary for low-voltage model

High voltage rated ICs

High voltage rated resistors

Access to PCB design software

Access to electrical simulation software

Access to 3D modeling design software

High voltage power supply

Equipment capable of measuring high voltages

Wires and connectors

Soldering irons

Solder

Heat-shrink

4.5 Financial Requirements

We are given $2500 for each semester to work on this project. For the entire duration of the project, we will receive $5000.

5. Testing and Implementation

5.1Interface Specifications

The circuit will be tested on a small scale first semester using a breadboard. A multimeter can provide us the readings to verify that the concept behind the circuit is correct. In the second semester, once we have a working concept, the testing will move into the large-scale model. The GUI will need to be perfected so that testing can be safe and as hands-off as possible with these high voltages.

5.25.2Hardware and software

First Semester (small scale prototype testing)

- Multimeter
- DC power supply
- JUnit testing

Second Semester (large scale prototype testing)

- High voltage DC power supply

- GUI
- Multimeter

– Provide brief, simple introductions for each to explain the usefulness of each

High voltage DC power supply – we will have to access this through Ames Laboratory or through Honeywell. Using this supply is mandatory for making sure our large-scale testing is functioning properly.

Multimeter – this will give us the voltage readings. This well help ensure that our concept is correct.

JUnit testing – This will test the computer GUI. This will help making sure that the correct value of the voltage is being displayed.

GUI – software that will enable the user to read the charge measurements. This will allow our users understand the measurements without having to interact directly with the high voltage circuit.

5.3 Functional Testing

Each unit of our system will be tested individually prior to the integration of the circuit – the ADC, the GUI, etc.

5.4 Non-Functional Testing

Testing for performance, security, usability, compatibility

5.5 Process

– Explain how each method indicated in Section 2 was tested

– Flow diagram of the process if applicable (should be for most projects)

5.6 Results

– List and explain any and all results obtained so far during the testing phase

- – Include failures and successes
- – Explain what you learned and how you are planning to change it as you progress with your project
- – If you are including figures, please include captions and cite it in the text

  • This part will likely need to be refined in your 492 semester where the majority of the implementation and testing work will take place

-**Modeling and Simulation**: This could be logic analyzation, waveform outputs, block testing. 3D model renders, modeling graphs.

-List the **implementation Issues and Challenges**.

6. Closing Material

6.1 Conclusion

The work we have done so far is researching the project. We have now picked out a low voltage system that we will be implementing in the next couple of weeks. We plan to pick out components and then get together and build the circuit and test it.

6.2 References

This will likely be different than in the project plan, since these will be technical references versus the related work / market survey references. Do a professional citation style (ex. IEEE).

6.3 Appendices

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

If you have any large graphs, tables, or similar that does not directly pertain to the problem but helps support it, include that 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.