

# 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)

# 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

We have seen a few designs at this time. The first class of designs we referred the capacitor methods. We found these designs on Keysight's website. They had an integrator-type circuit and a shunt-type circuit. Both circuits work by putting a voltage across a capacitor and having the high and low voltages go into an ADC. The voltage is then shorted by a switch. When the voltage levels out, you can take the difference in the voltage when the switch is open and close. The difference multiplied by a known capacitance is equal to the charge that was stored. The second method we

referred to is the current sink method. This method works by putting a constant current sink between the pin and shell to discharge the system. We would then have circuitry to measure the time it took to fully discharge. We would then use the logic that the current multiplied by the time in seconds is equal to the charge dissipated.

## 2.2 DESIGN ANALYSIS

With the few different methods we have researched, we have noticed some pros and cons that will come with each. For the capacitor method, some pros will be the simplicity of the circuit and this method will have fewer components. The cons are that capacitors aren't extremely precise and high voltage capacitors can be very large. The current sink method gives us the ability to have more control over the circuit. However, finding parts that work at higher voltages will be more difficult.

## 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 be 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 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							
High voltage model							
Pin expansion (optional)							
Computer UI							
PCB design							
Enclosure Design							

**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 behind the design as well as using a low-voltage model to begin understanding the process. During this time, appropriate parts will be selected for the high voltage model. After testing procedures and device accuracy have been measured for the low voltage model, construction of the high voltage model will begin. 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 work 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. After the low voltage model is developed, the other half of the team will join in this process. This will be continuous until a working prototype for the high voltage model is developed.
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.
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.

PCB Design	All other members will be dedicated to the PCB design once the high voltage model has passed testing. This team will later be broken up into two as the PCB nears the final design.
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.

#### 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

### 5.1 INTERFACE 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.

### 5.2 HARDWARE 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 will 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. Our short term goal is to have the research done by the end of October and start to work on a design for measuring the charge of a low voltage system. The best plan of action to do this research by ourselves and then come together with our ideas and pick out the best one.

## 6.2 REFERENCES

This will likely be different than in project plan, since these will be technical references versus related work / market survey references. Do 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.