Micro-Electro-Mechanical Systems (MEMS) Based Sensing System for Soil Conditions Monitoring

http://sddec18-05.sd.ece.iastate.edu/

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Team: sddec18-05
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Project Plan

Problem Statement/Background

- Currently, the CCEE department is using expensive, unreliable sensors for monitoring temperature and moisture content of soil. This project will create a low cost data acquisition system for the MEMS sensors designed by the ECpE department. The system will gather soil moisture and temperature data for up to one month, to be later used by the CCEE department for research purposes.

MEMS Sensors

- Sensors are currently not functional
- Designing system around assumed sensor values
- Sensors will be fabricated next semester

Requirements and Specifications

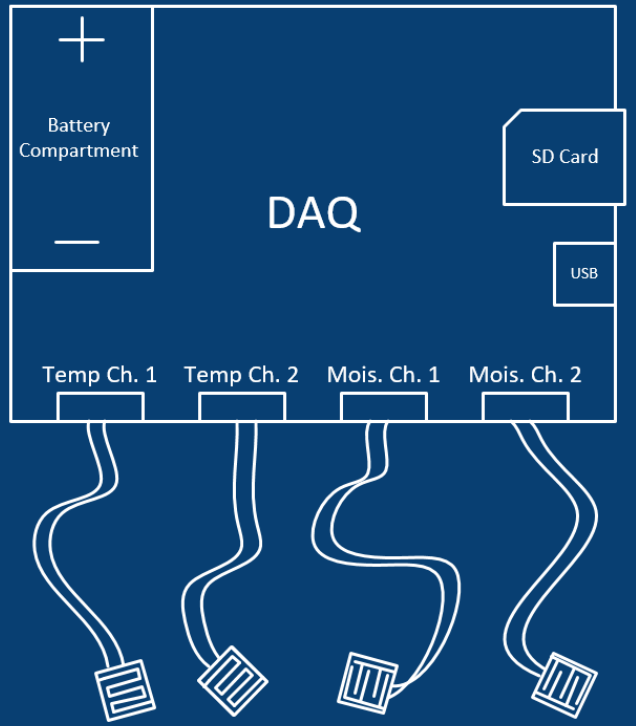
Requirement	Implementation	Associated Test
Four independent sensor channels	Two temperature, two moisture channels	NA
One month data storage	Onboard micro SD card	Test 1A
Resistance measurement range 200-300 ohms	100-400 ohms with 0.5 ohm accuracy	Test 2A
Capacitance measurement range 1-3pF	0-4pF with 40fF accuracy	Test 3A
One month battery life in favorable conditions	Battery sized for average battery life of 1 month	Test 1B
15 minute sampling period	Adjustable sample period, default 15 minutes	Test 1C
Cable length of three feet	Meets requirements with 3ft sensor cables	NA

Current Systems in Use

Data Acquisition/Data Loggers	Associated Sensors	Total Cost
Data Acquisition Module 	Temperature Sensor 	$159 (per sensor) $230 (data acquisition module) **$389 total**
Data Acquisition Module 	Soil Moisture & Temperature Sensor 	$206 (per sensor) $750 (data acquisition module) **$956 total**

System Design

- Weatherproof enclosure
- Removable battery
- 4 Independent water resistant sensor connectors
- USB streaming to PC for data analysis
- Removable SD Card



User Interface

- Logs saved to CSV file on SD card
- Each time the DAQ is reset, a new log file will be created
- Displays date, time of measurement, and corresponding measurements

Date	Time	Channel 0 (Temp, C)	Channel 1 (Temp, C)	Channel 2 (RH, %)	Channel 3 (RH, %)
4/16/2018	10:31:26 PM	45	45	50	50
4/16/2018	10:31:41 PM	45	45	50	50
4/16/2018	10:31:56 PM	45	45	50	50
4/16/2018	10:32:11 PM	45	45	50	50
4/16/2018	10:32:26 PM	45	45	50	50
4/16/2018	10:32:41 PM	45	45	50	50
4/16/2018	10:32:56 PM	45	45	50	50
4/16/2018	10:33:11 PM	45	45	50	50
4/16/2018	10:33:26 PM	45	45	50	50
4/16/2018	10:33:41 PM	45	45	50	50
4/16/2018	10:33:56 PM	45	45	50	50
4/16/2018	10:34:11 PM	45	45	50	50
4/16/2018	10:34:26 PM	45	45	50	50
4/16/2018	10:34:41 PM	45	45	50	50
4/16/2018	10:34:56 PM	45	45	50	50

Figure: Sample Output Log File

Deliverables

- A functional and reliable DAQ system
- Gather soil moisture and temperature throughout the course of month.
- Sensor and DAQ module can be used outside in the harsh Iowa environment.
- DAQ system must be able to last one month in an average climate.
- In addition, we will be working in conjunction with Dr. Tuttle to recreate MEMS sensors for the DAQ system

Project Management

- Weekly team meetings and work sessions were scheduled to keep the project on task
- A Gantt Chart was created with major milestones for the project
- A shared Google Drive folder was created for quick access to written team documents
  - Weekly status reports
  - Meeting minutes
  - Team meeting notes
  - Faculty advisor meeting notes

Project Milestones and Schedule

Tasks	**Progress**
Project Plan Final Version	Completed
Board Assembly	Testing phase: 90% completed.
Software Development : Resistance and Capacitance Readings	Resistance implemented. Capacitance in progress. 60% completed.
Design Document Version 2	Completed
Sensor Recreation Materials and Requirements	Completed
Prototyping	60% completed.
Requirement Verification / Testing	30% completed.
Sensor Recreation	Logistics coordinated. Start fabrication first week of Fall 2018 semester.

Risks

- Drift over temperature
- Low capacitance resolution
- Cable parasitics
- Unknown measurement ranges (sensors not available)
  - Future sensor characterization needed

Resource/Cost Estimate

- The cost estimate for our entire project is shown below
- No labor costs
- No specific budgetary constraints
  - Our goal was to spend no more than $500 during the duration of our project

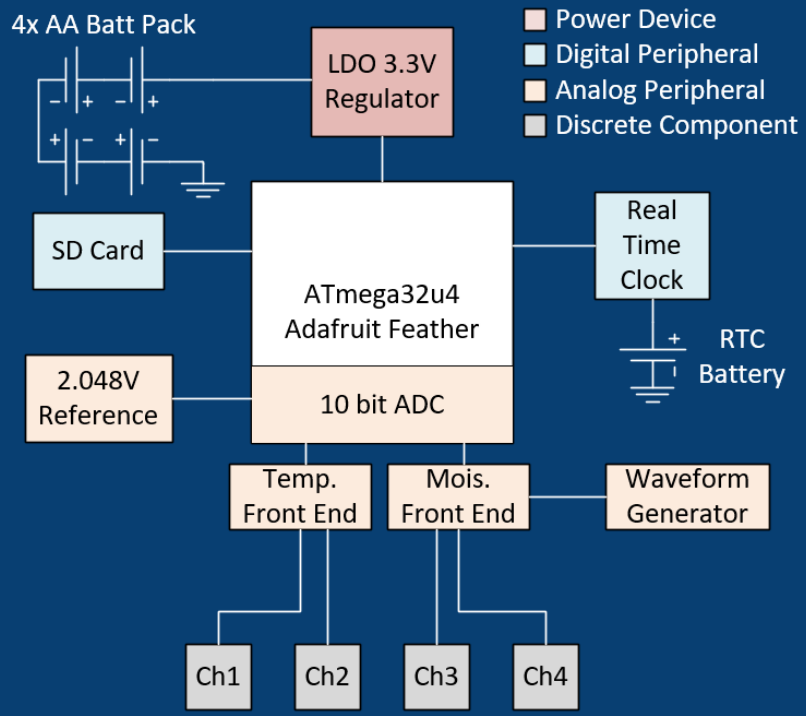
Project Cost Estimate

	MATERIAL COST ($)
Current Expenses (as of 4/22/18)	
Procure Prototyping Hardware	186.00
Projected Future Expenses	
Enclosure	30.00
Procure Final Hardware	130.00
Total	**346.0**

Design Document

Technical Details: Hardware Architecture

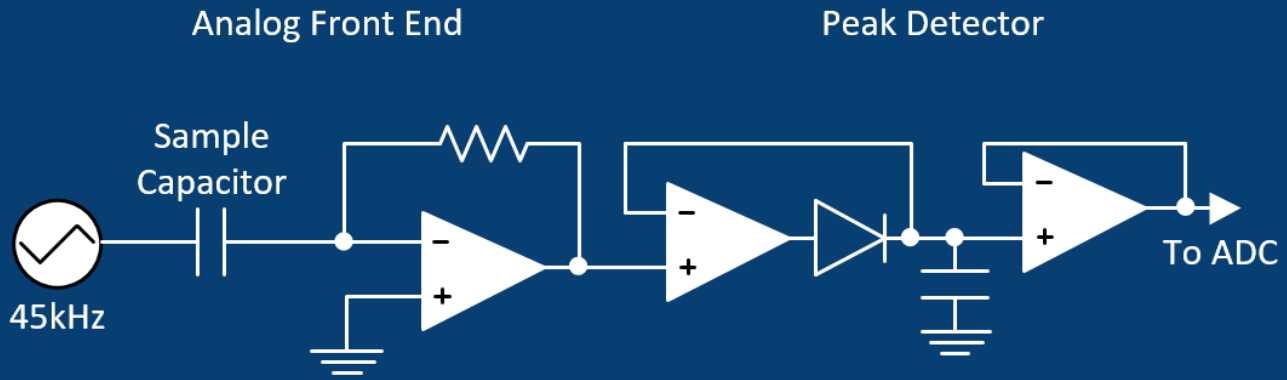
- Data storage on removable micro SD card
- Four total sensor channels
  - Two temperature front ends (2mV resolution)
  - Two moisture front ends (40fF resolution)
- Microchip ATMEGA32u4 Microcontroller
  - USB transceiver
  - 10 bit ADC
- Real-time clock for precise timestamp
- External triangle wave generator
- External ADC reference
  - 2.048V 0.5%
- 4x AA Batteries



Detailed Design: Moisture Analog Front End

- Two Stages
  - Current to voltage stage
    - Converts ~4uA current into 0-3.3V
    - JFET op-amp for ultra-low input bias current
  - Peak Detector stage
    - Sample and hold peak current for microcontroller
    - Schottky diode, low leakage capacitor, JFET op-amps

$$C = \frac{I}{\left(\frac{dV}{dt}\right)}$$



Detailed Design: Triangle Wave Gen

- Triangle Wave
  - Constant slope (dV/dt)

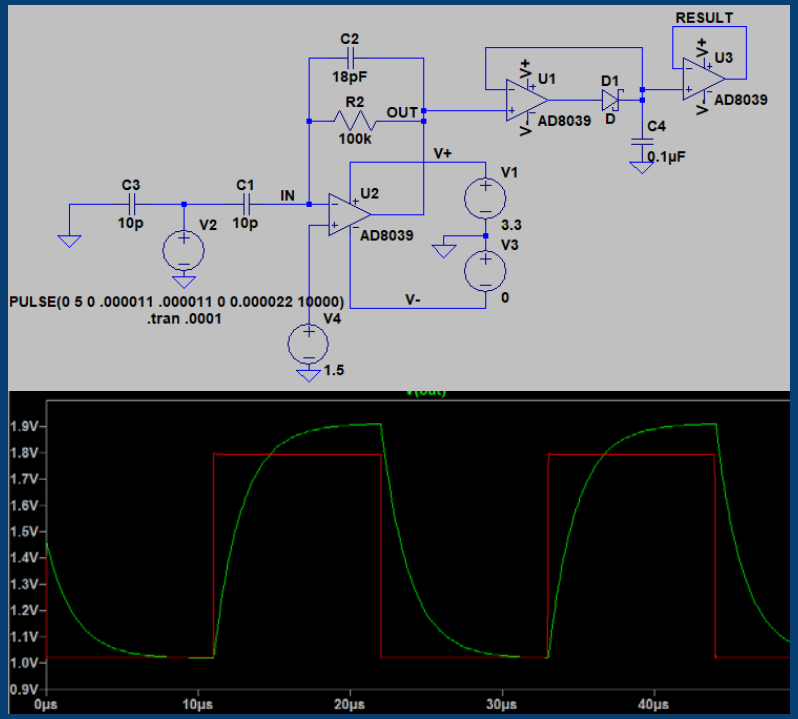
$$= \frac{3.3V}{\frac{1}{2*45{,}000Hz}} = 297{,}000\frac{V}{s}$$

$$C = \frac{I}{\left(\frac{dV}{dt}\right)}$$

- Discrete Implementation
  - Generate square wave w/ 50% duty cycle
  - Integrate square wave
- Our Implementation
  - MAX9000 application circuit
    - SOIC8 with internal comparator, voltage reference, and op-amp configured as integrator
    - Stable across temperature

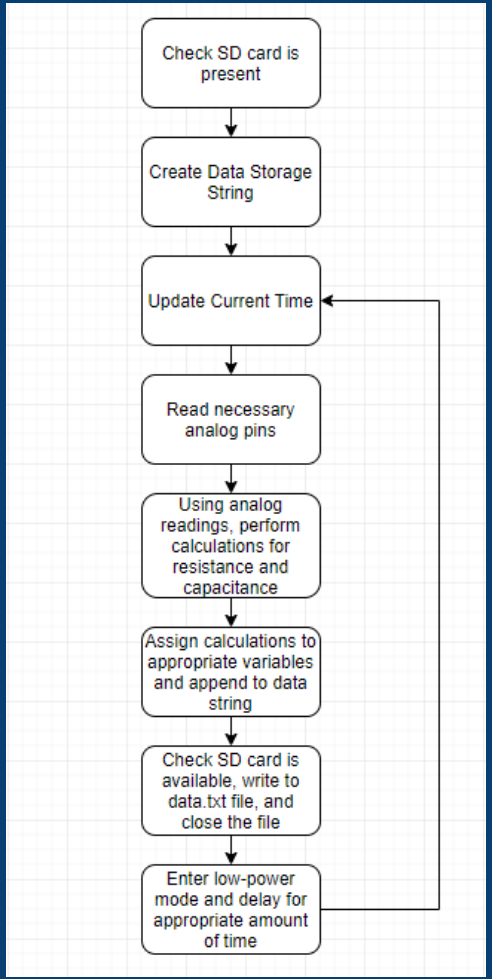
Basic Implementation: Hardware Simulation

- Analog front end simulation in LTspice
  - Verified each input stage independently
- Verified in hardware on bench
  - Identified issues with parasitics, preventative design in prototype
  - Breadboard prototype, perfboard prototype, now assembling first pcb prototype



Detailed Design: Software

- Software development has been done in the Arduino programming environment
- Used standard libraries compatible with the Adafruit Feather 32u4 Basic Proto board
  - SPI.h
  - SD.h
  - Wire.h
  - RTClib.h



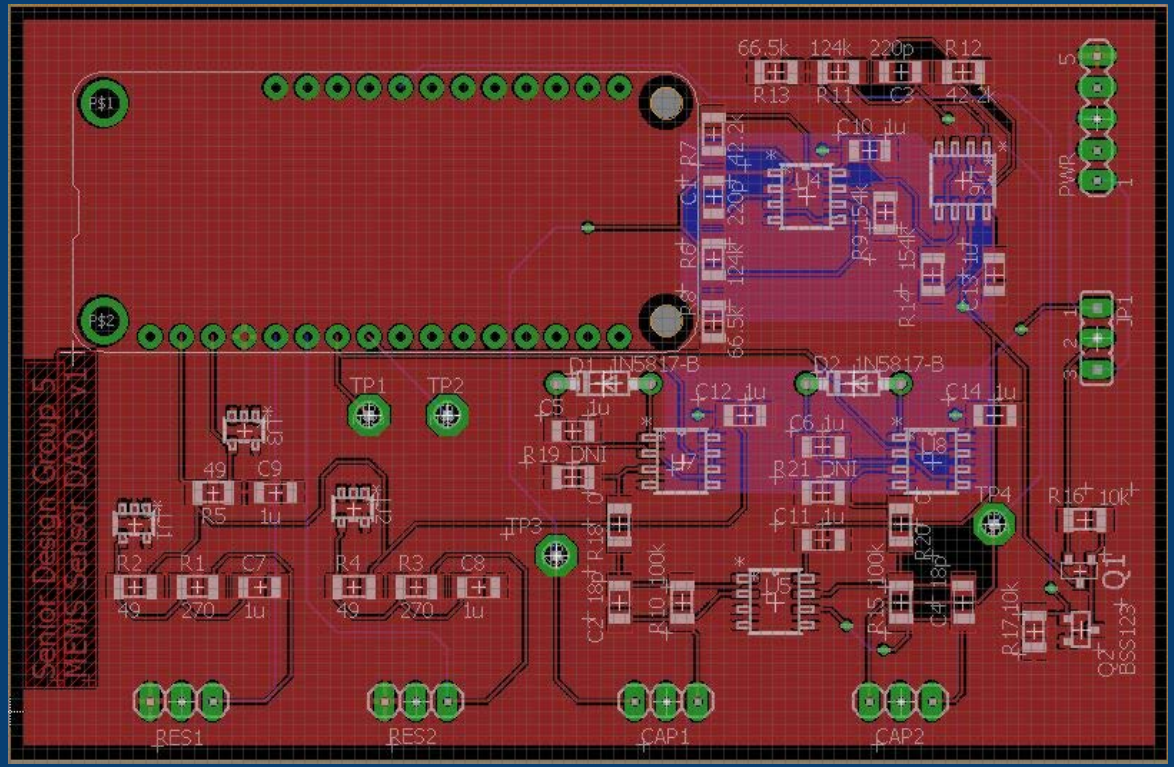
Test Plans

- All test plans are documented in our design document on the website
- Would like to touch on specifically the resistance measurements of our DAQ system
- More extensive test plans for each individual requirement listed in our design document

Test Results

- We have not had the chance to perform all the tests we would like
- However, currently our project plan and design document articulate our testing plans and procedures
- Some preliminary prototype results for measuring resistance values
  - We measured resistance at 30 data points between 10 and 1000 ohms, with an emphasis on values between 100 and 400 ohms.
  - The average difference between DMM readings and our DAQ readings was 0.4 ohms.
- Temperature Testing

Prototype and Refined Board Design



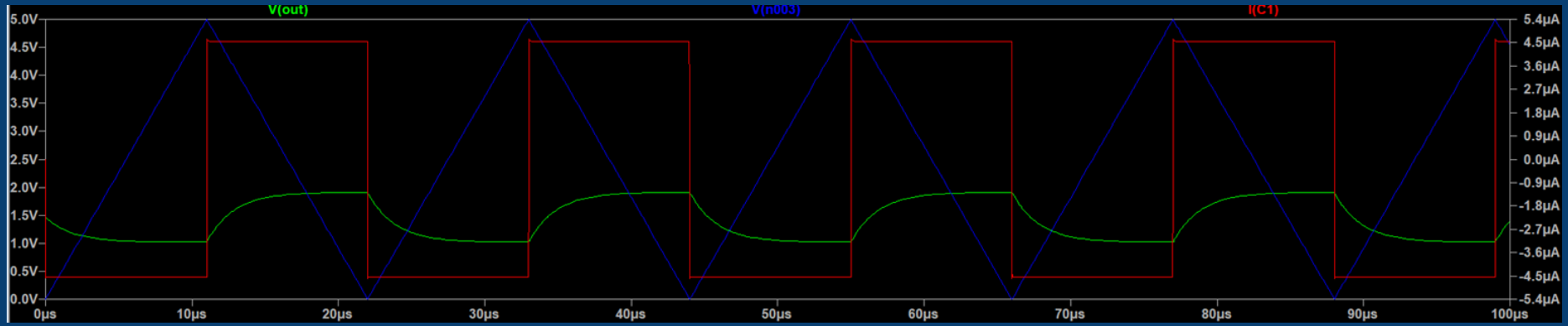
Conclusion

Current Status & Plan for Fall Semester 2018

- We are about finished with our third prototype
- Tested resistance measurement circuitry
  - PSpice Simulations as well for capacitance measurement circuitry
- Beginning next semester we will recreate sensors and continue with our more refined prototype along with implementing capacitance measurements

Questions?

Supplementary



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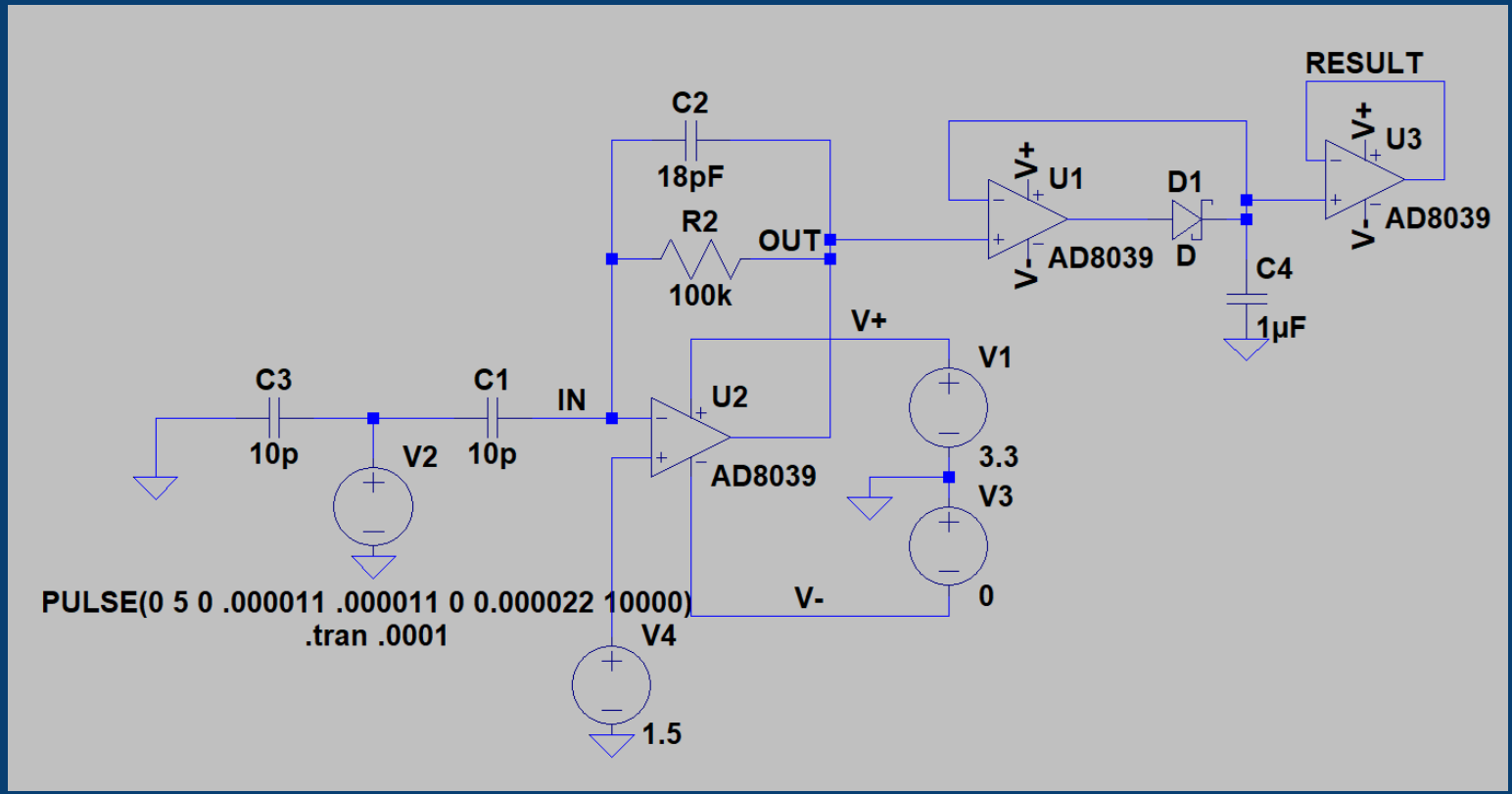

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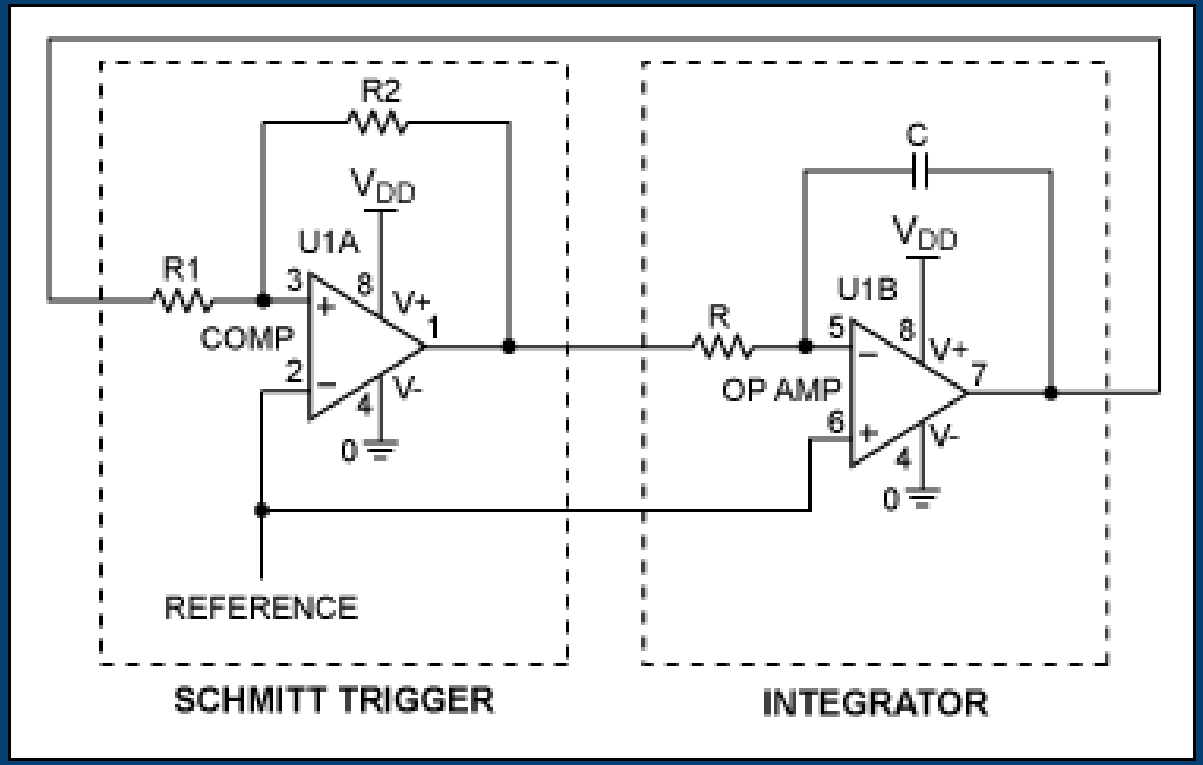

Supplementary

Project Planner Spring 2018

% Incomplete %Complete

ACTIVITY	PERCENT COMPLETE	Period (Week)															
		1/8 - 1/12	1/15 - 1/19	1/22 - 1/26	1/29 - 2/2	2/5 - 2/9	2/12 - 2/16	2/19 - 2/23	2/26 - 3/2	3/5 - 3/9	3/19 - 3/23	3/26 - 3/30	4/2 - 4/6	4/9 - 4/13	4/16 - 4/20	4/23 - 4/27	Next Sem
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Lightning Talk #1	100%																
Weekly Status Report(1-10)	10%																
Project Plan V1	100%																
Project Plan V2	0%																
Project Plan Final	0%																
Team Website V1	100%																
Biweekly Customer Meeting	20%																
Weekly Team Meeting	20%																
MEMS Tour	100%																
Lightning Talk #2	100%																
Design Document V1	100%																
Design Document V2	50%																
Lightning Talk #3	100%																
Capacitance measurement circu	50%																
Temperature measurement circ	100%																
Temperature circuit software	70%																
PCB	50%																
Find Source of information	90%																
Define Project Requirements	50%																
Prototype	50%																
Verify Feasibility	50%																
Test Protoype	50%																
Verify Requirements met	60%																
Verify Functionality	60%																
Design Final Product	0%																
Testing Final product	0%																
Deliverable Product	0%																
Sensor recreation	10%																