Developing a Mega REU and RET Program Focused on Underrepresented Participants

CHALLENGES, LESSONS AND INSIGHTS

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2019 EEC Grantees Conference

Outline

- Motivation for the program
- Program goals and description
- Smart city research topics
- Program execution (recruitment, pre-projects, seminars, weekly updates)
- Virtual symposium
- Key challenges and insights from survey instruments
- Wrap Up

Program Motivation

- African Americans and Latinos receive just 7.6% of all STEM bachelors degrees and 4.5% of all STEM doctorate degrees[1]
- Underrepresented minorities and lower division students have not traditionally been well represented in REU programs
  - However, studies show both lower & upper division students report positive outcomes from undergraduate research experiences[2]
- Early intervention and exposure to research has been shown to improve retention, graduation and entry into graduate school by URMs[3]
- UG research experiences are associated with increased persistence in pursuit of UG degree and graduation education[4]

[1] REU Site Database, 2015, National Science Foundation

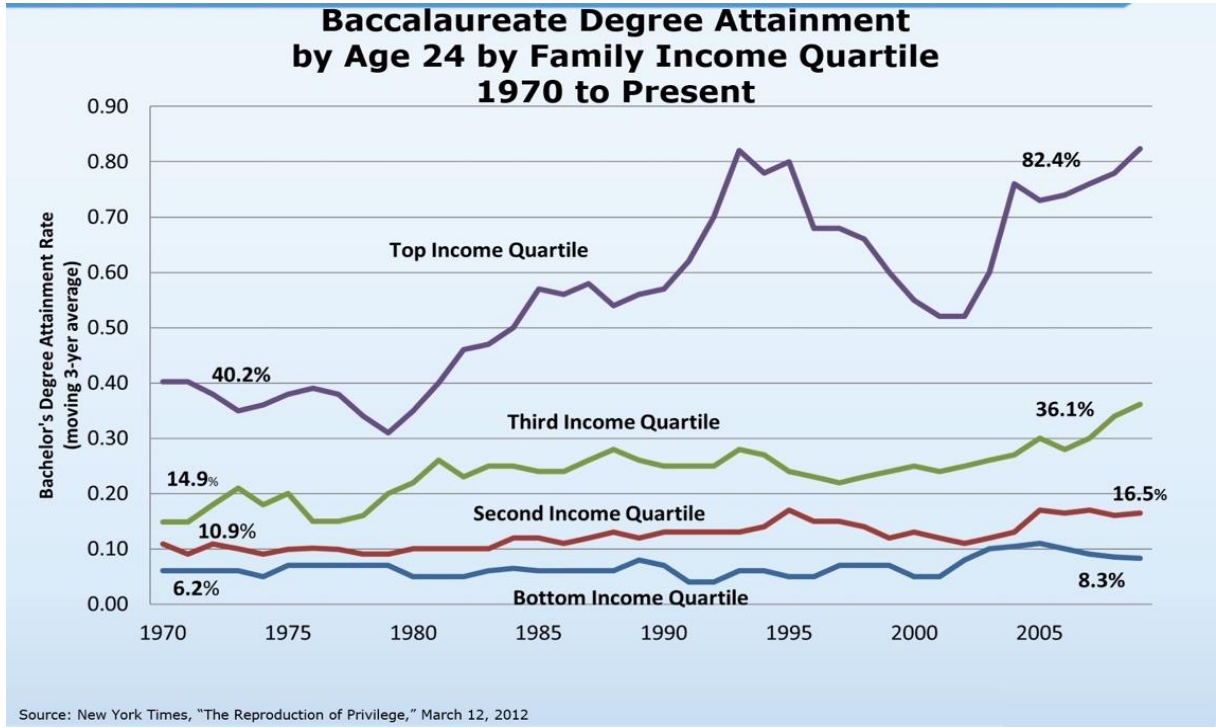
[2] Ken Conner, Yacob Astatke, et. al., "Collaborative Research: Center for Mobile Hands-On STEM," *Proceedings of 2015 American Society for Engineering Education (ASEE) 2015 Annual Conference*, Seattle, WA June 14-17, 2015.

[3] Davis, L., "Surmounting the Barriers: Ethnic Diversity in Engineering Education: Summary of a Workshop," National Academy of Engineering: Washington, D.C., 2014

[4] Maton, K.I. and Hrabowski III, F.A., "Increasing the Number of African American PhDs in the Sciences and Engineering." *American Psychologist*, 59(6): p. 547-556, 2004

Program Motivation

- Baccalureate degree attainment rate doubled from 1970 to 2005 for top two income quartiles, but not for bottom two
  - Two-thirds of African American students are Pell grant recipients and fall into the bottom two income quartiles
  - HBCUs tend to have a student body that reflects the bottom two income quartiles and are uniquely situated to positively impact this group



Program Motivation

- However HBCUs tend to lack the resources available to larger MSI
  - This is mitigated through the establishment of a HBCU mega-site
  - Leverage the resources and experience across several institutions
  - Requires leveraging existing collaborative relationships established from prior efforts (Experimental Centric Based Engineering Curriculum for HBCUs)
- Effectively motivating URM students starts prior to the 4-year engineering program
  - Underperforming URM students tend to lack significant exposure to the engineering field prior to a 4-year college
  - Combined RET program can help develop strong collaboration with STEM high school and community college teachers
    - Help improve quality of STEM education through hands on projects

Program Goals

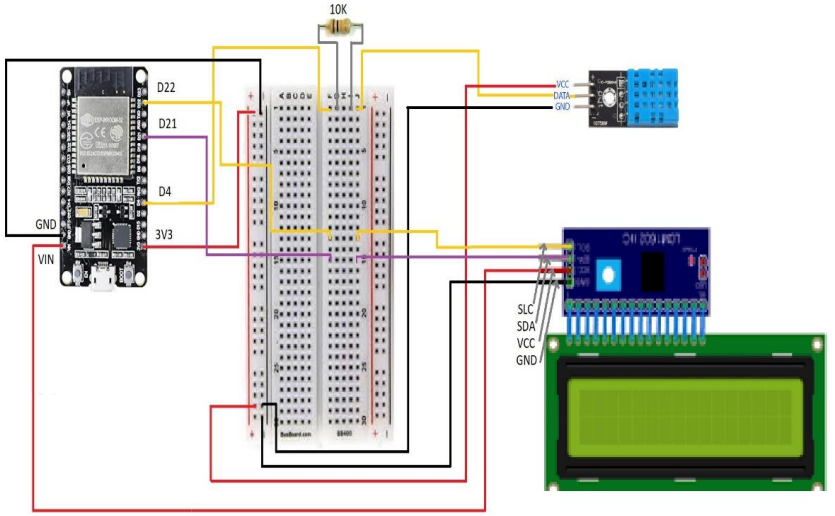
- Research Experience for Undergraduates
  - Increase the number of highly qualified and prepared African American engineers
  - Help increase the research interest and skills of underperforming students ("hidden gems") and make them more likely to participate and excel in other research experiences
- Research Experience for Teachers
  - Develop stronger collaboration with STEM teachers at community colleges (CCs) and high schools (HS) to improve the quality of STEM education
  - Stimulate the interest of under-represented minority (URM) HS students who might otherwise not pursue a STEM degree in college

Program Description

- The Smart City REU/RET (SCR^2) Is a combined, multi-institution REU/RET program focused on Smart City research
- Each host site (5 total) has a research strength that is connected to the program theme
  - IoT Security, Renewable Energy, Energy Storage, Smart Grid, Human Computer Interaction, Advanced Materials
- Students and teachers work together to tackle research problems
  - Focus on lower division, under performing students (GPA between 2.5 - 3)

Year 1 Smart City Research Topics
Internet of Things Security (Morgan State University)

- Summary
  - Develop components for a simulated internet of things test bed
  - Purpose is to generate traffic indicative of an IoT network
  - Testbed is the basis for other tasks, such as anomalous traffic detection
  - Participants develop various networked sensing units using Raspberry Pis and Arduinos
- Skills developed
  - Electronic circuit design/construction/troubleshooting
  - Computer hardware/components/architecture
  - Linux Operating system
  - Computer Programming



Year 1 Smart City Research Topics
Internet of Things Security (Morgan State University)

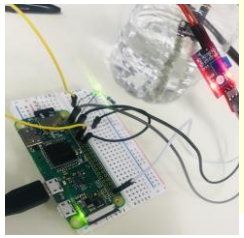
OUTCOMES

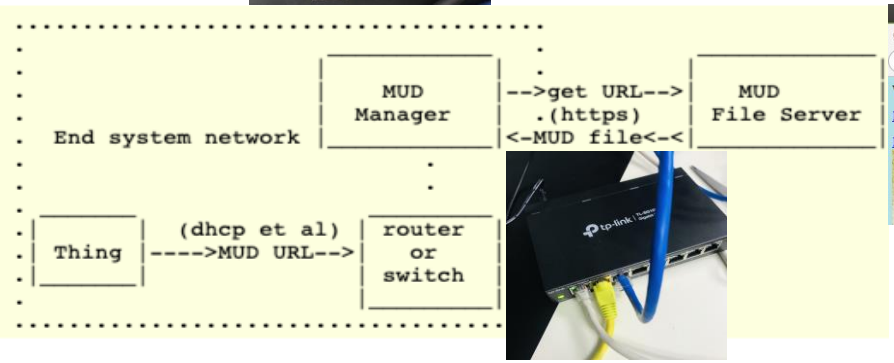
Sample Project Outcomes

Desired Outcome	Evaluation
Configure and implement SBCs and microcontrollers in a networked environment	Faculty/mentors will assess participant's ability to provision devices and properly network them together within one or more subnets
Operate within a Linux environment	Faculty/mentors will assess participant's ability to navigate through the Linux file system, conduct basic I/O operations, write and execute scripts, and modify key configurations files
Develop fully operational programs	Faculty/mentors will assess participant's ability to create fully functional programs in one or more languages (e.g. C/C++, Python, Java)
Understand basic circuits construction for data acquisition	Faculty/mentors will assess participants ability to develop basic circuits to sense environmental conditions and write programs to read, store, and transmit the sensed data

Year 1 Smart City Research Topics
Internet of Things Device Profiling using MUD (Morgan State University)

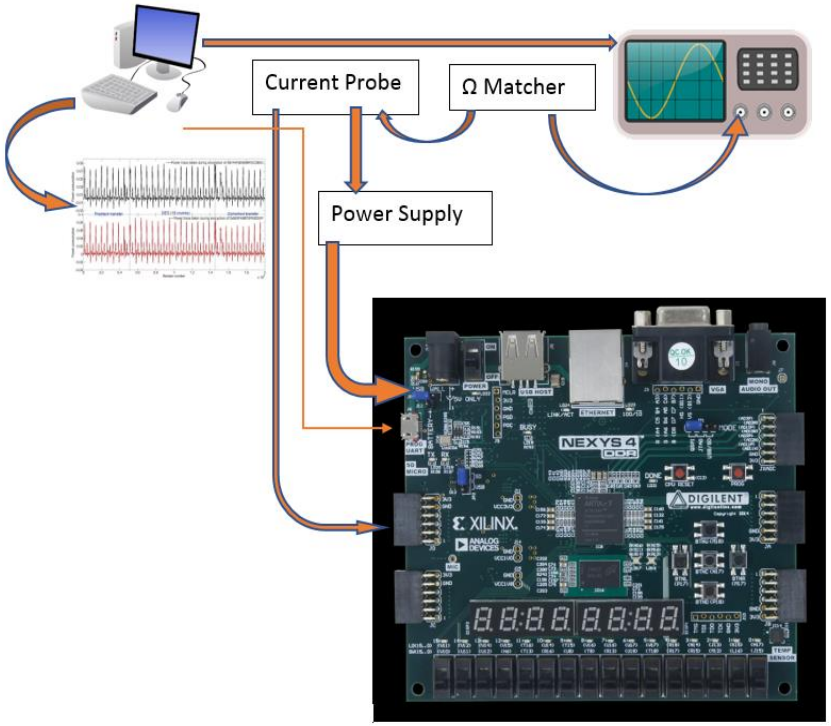
- Summary
  - Learn about Manufacture Usage Description (MUD) to help police lightweight IoT devices that can be compromised as part of a botnet
  - Implement MUD protocol on IoT network to automatically set network access policies for devices
- Skills developed
  - Embedded systems
  - Computer networking
  - Python
  - Linux operating system





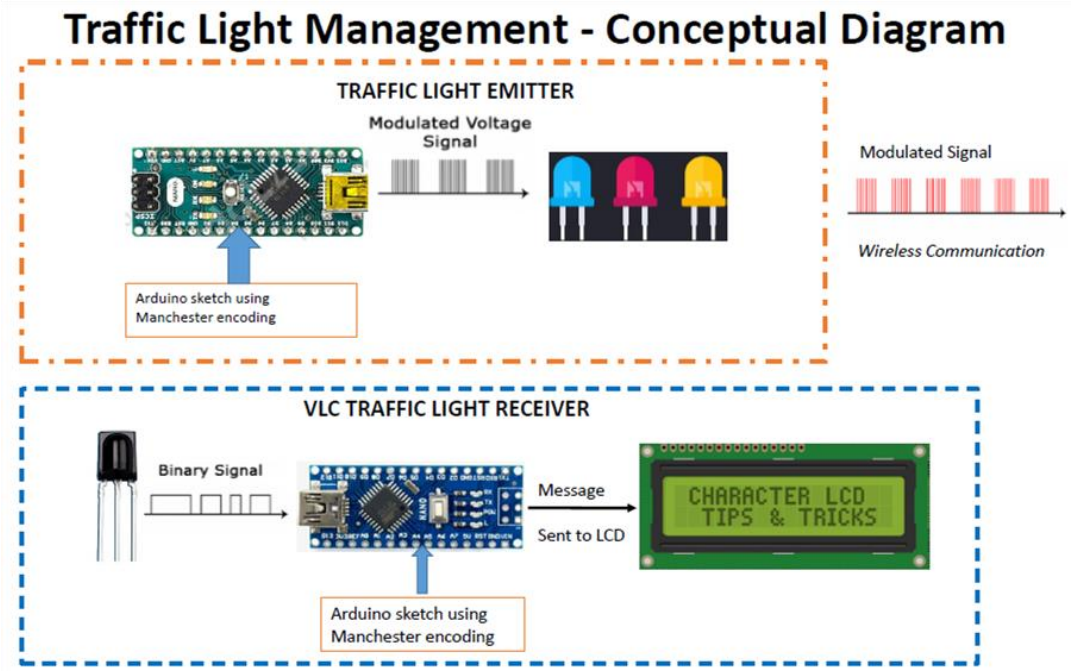
Year 1 Smart City Research Topics
Internet of Things Security Assessment using Side Channel Analysis (Morgan State University)

- Summary
  - Investigation of vulnerabilities of IoT devices that leak information via side channels (e.g. power traces) during cryptographic operation
  - Learn to explore vulnerabilities associated with side channel analysis: electromagnetics, timing, correlation power analysis, differential power analysis
- Skills developed
  - Electronic circuits
  - Computer architecture
  - Digital signal processing (DSP)
  - Programming (Java, VHDL)
  - Cryptography



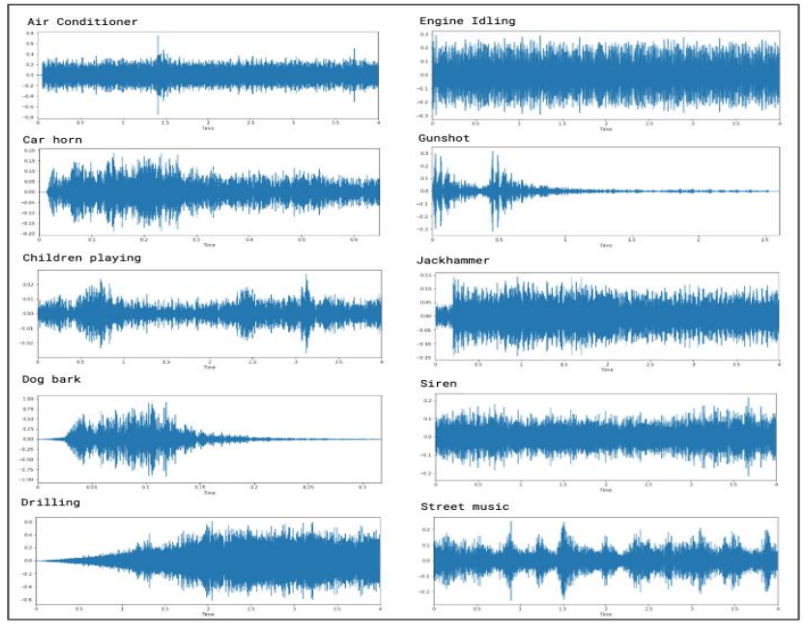
Year 1 Smart City Research Topics
Infrastructure to Vehicle Communication via Traffic Signals (Morgan State University)

- Summary
  - Develop visible light transmitter (traffic signal) and receiver (vehicle) to receive information from infrastructure
  - Traffic signal sends information to oncoming vehicles
- Skills developed
  - Electronic circuits
  - Computer hardware/components/architecture
  - Digital signal processing (DSP)
  - Computer programming (Arduino C)



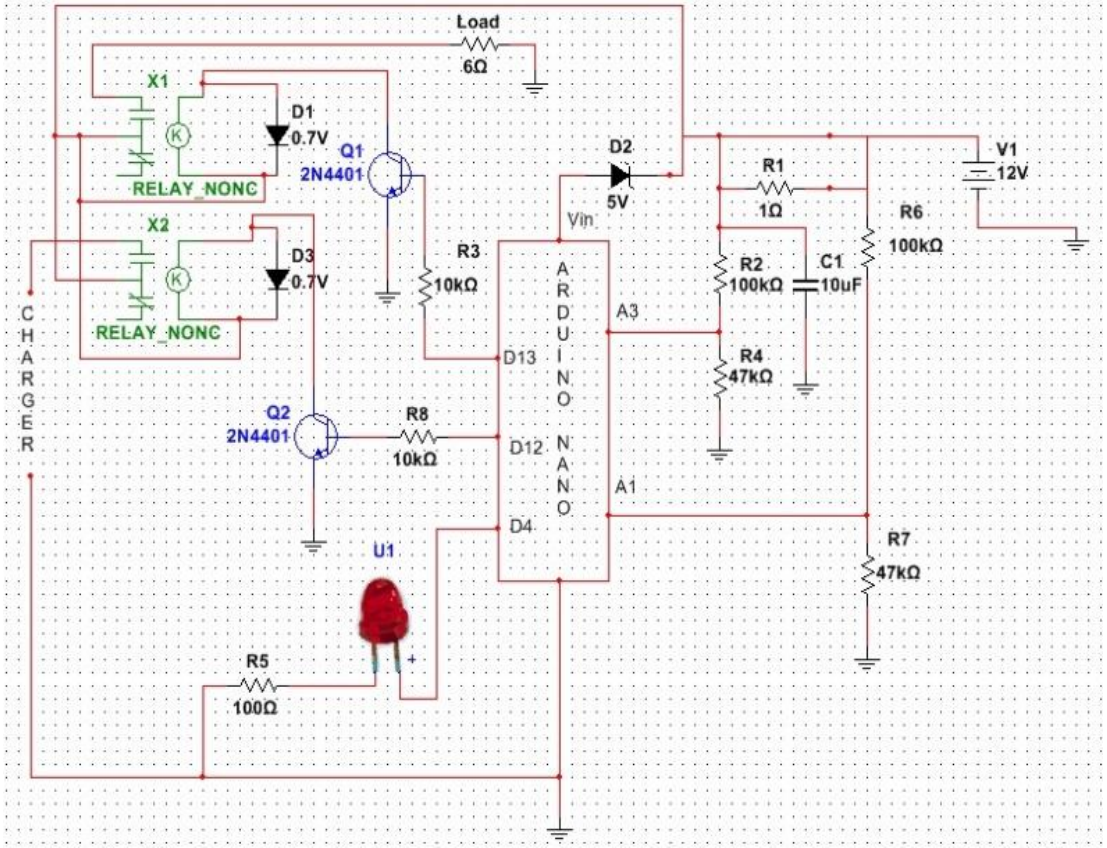
Year 1 Smart City Research Topics
Gunshot Detector through Smart Street Lights (Morgan State University)

- Summary
  - Develop modules to retrofit street lights to detect gunshots through machine learning
  - Modules consist of Raspberry Pi with microphone and network connection
  - Sound is run through a Convolutional Neural Network to determine if gunshot is heard and triangulate position from nearby units
- Skills developed
  - Electronic circuits
  - Computer hardware/components/architecture
  - Machine learning frameworks
  - Computer programming (python)



Year 1 Smart City Research Topics
Assessment of the Capabilities of Current Battery Technologies(Prairie View A & M University)

- Summary
  - Determined the characteristics of 3 different types of batteries- lithium ion, lead acid, and nickel cadmium
  - Designed an electronic circuit using Arduino to obtain the charging and discharging voltages of lead acid, lithium-ion, and nickel cadmium batteries.
- Skills developed
  - Circuit Design, breadboarding and troubleshooting
  - Arduino programming
  - Prototyping and Testing

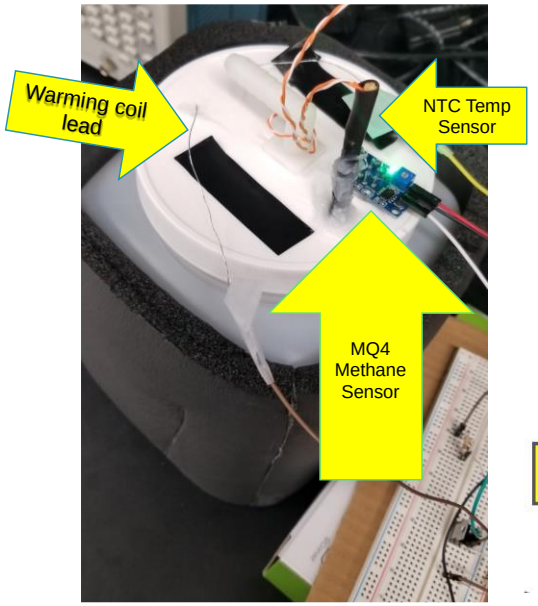


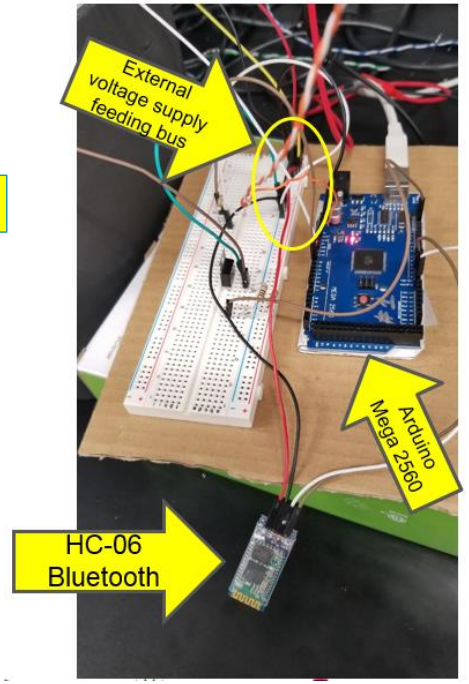
Year 1 Smart City Research Topics

Biogas Production and Data Analysis for PVAMU Goat Farm (Prairie View A & M University)

- Summary
  - Produced detectable methane in a small scale bio-gas digester
  - Monitored and controlled experiment parameters with a microcontroller
  - Established connectivity with a microcontroller and Bluetooth module

- Skills developed
  - Circuit Design, breadboarding and troubleshooting
  - Arduino programming for temperature control and data collection
  - Gas sensor programming
  - Prototyping and Testing





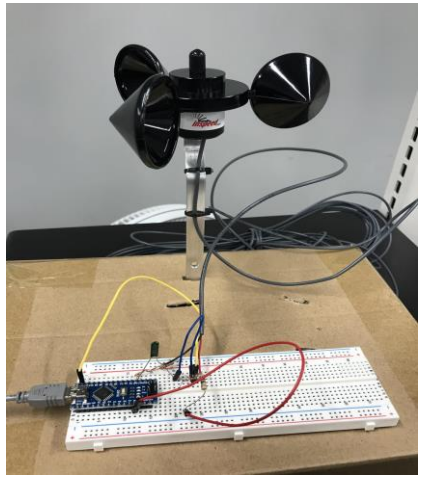
Year 1 Smart City Research Topics
Renewable Energy – Solar Cell (Prairie View A & M University)

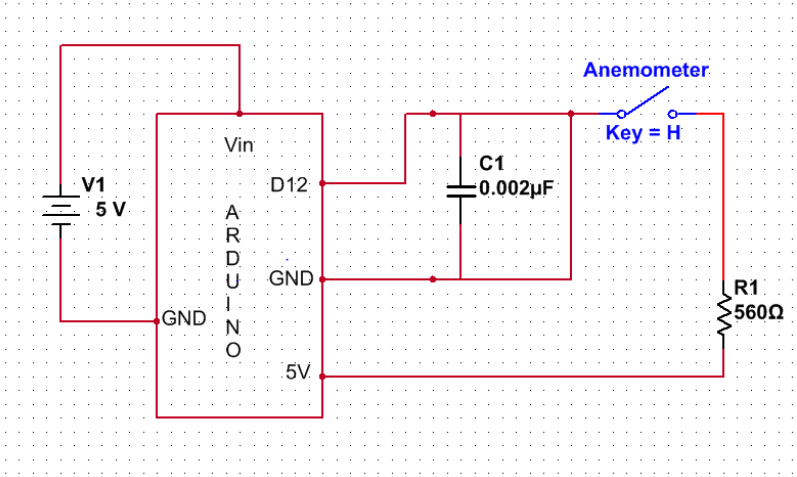
- Summary
  - Determined that angle of inclination influences the photovoltaic system energy output. The data collected from a solar panel in the field corroborated with those obtained in the lab.
  - The data collected in the lab for the highest power output during the year, matches those obtained by NREL.
  - Used smart grid module to perform operations from power generation, transmission and line protection all the way to power utilization.
  - Demonstrated that as the temperature of the solar panel increases the output voltage decreases.
- Skills developed
  - Use of SCADA systems
  - Data collection and analysis
  - Measurements involving angle of inclination, azimuth and temperature

Year 1 Smart City Research Topics

Wind Data Measurement at PVAMU able Energy – Solar Cell (Prairie View A & M University)

- Summary
  - Obtained and analyzed wind data provided by the Natural Resources Conservation Services
  - Selection of wind turbines appropriate for power generation at PVAMU
  - Construct and raise mast for Acu-Rite anemometers.
  - Estimating Wind Speed at Different Elevations
  - Collect and analyze the wind speed, wind direction, temperature and trends using Acu-Rite anemometers.
  - Complete Arduino Code for Inspeed Vortex Anemometer wind speed measurement
- Skills developed
  - Circuit Design, breadboarding and troubleshooting
  - Produced an Arduino code capable of recording & processing data.
  - Prototyping and Testing

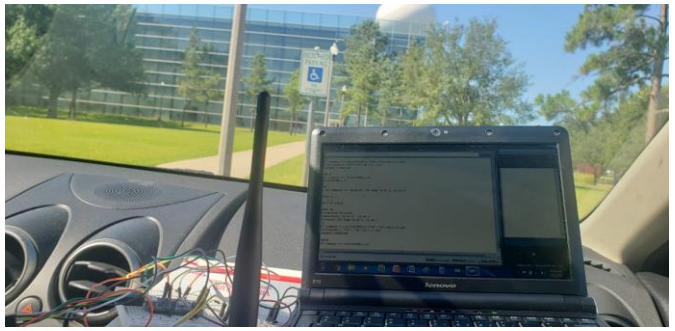


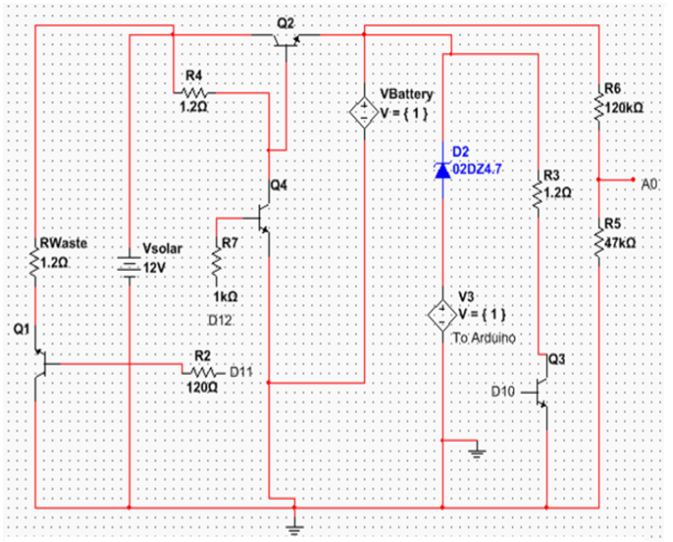


Year 1 Smart City Research Topics

Wireless Network System with Node and End Station Developments for Remote Sensing (Prairie View A & M University)

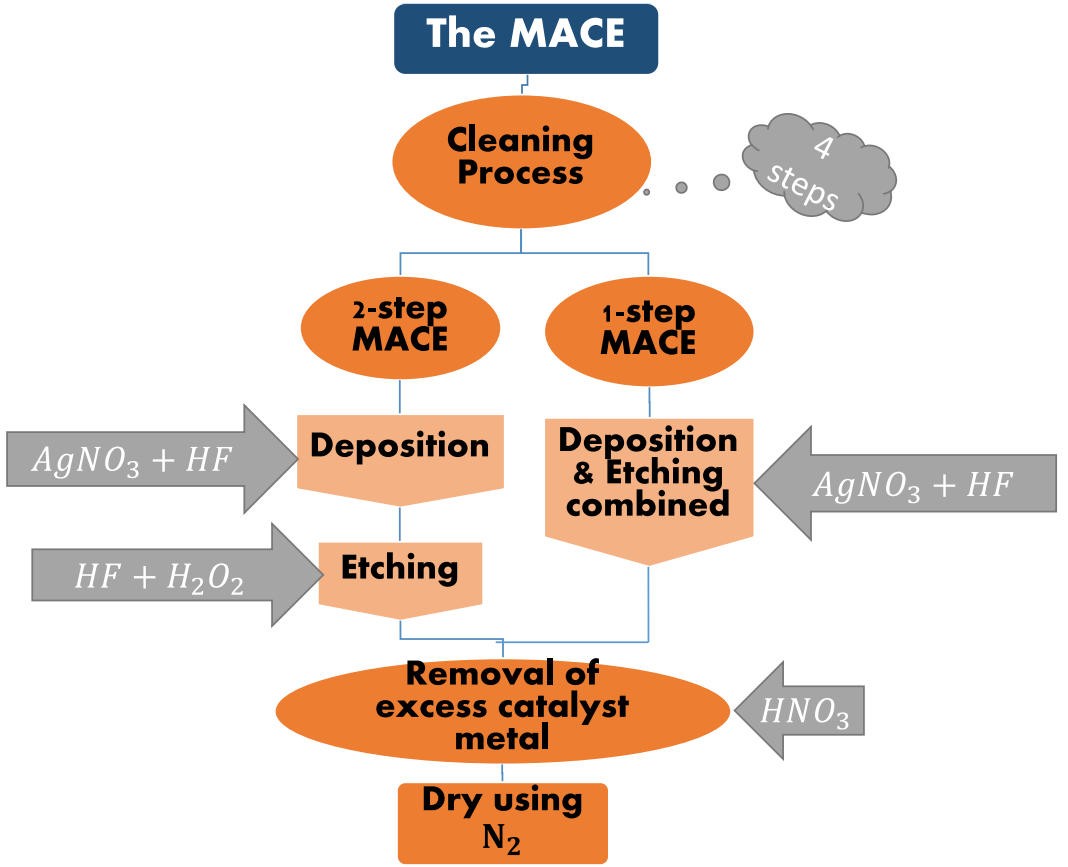
- Summary
  - Designed an Wi-Fi microcontroller application for microgrid system
  - Being able to send a Wi-Fi signal over extended distance
  - Built the solar PV and battery smart controller.
  - Built a Bluetooth hardware/software system using Arduino for smart charge controller.
  - Able to maintain communication signal between the workstation and the access point about 500 feet.
- Skills developed
  - Circuit Design, breadboarding and troubleshooting
  - Prototyping and Testing
  - Arduino programming for temperature control and data collection





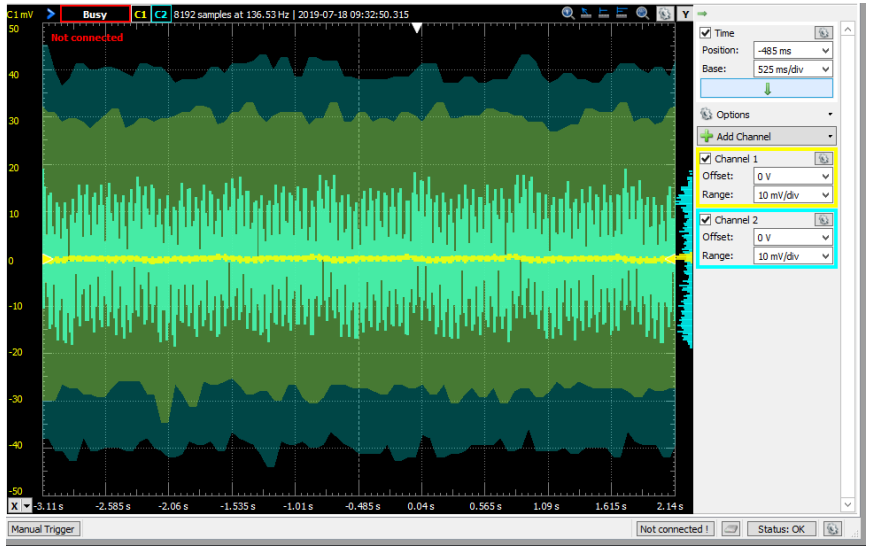
Year 1 Smart City Research Topics
Silicon Nanowires- Fabrication and Optical Characterization (Norfolk State University)

- Develop smart materials for reflectivity control
  - Effect of $AgNO_3$ concentration on SiNW produced by surface etching
  - Near-zero optical reflectivity of SiNW on Si
- Skills developed
  - Cleanroom operation and chemical safety
  - Optical instruments - reflectometer, spectrometer, and scanning electron microscope
  - Microfabrication
  - Data collection and analysis



Year 1 Smart City Research Topics
Wearable Sensors for Monitoring of Chronic Heart Diseases (Norfolk State University)

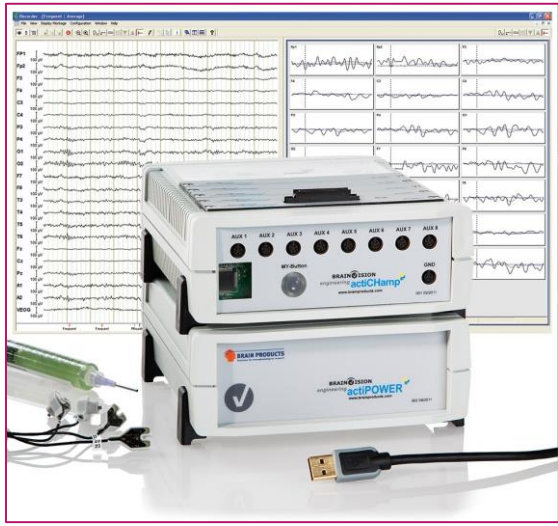
- Summary
  - Design piezoelectric thin film sensor network to accurately detect and measure the pulse rate for continuous monitoring of chronic heart disorders
- Skills developed
  - Piezo electric pulse sensors activated by wrist
  - Circuits for bandpass filtering
  - Signal processing using MATLAB
  - Android mobile app to display signal
  - 3-D printing cases for sensors to fit the wrist

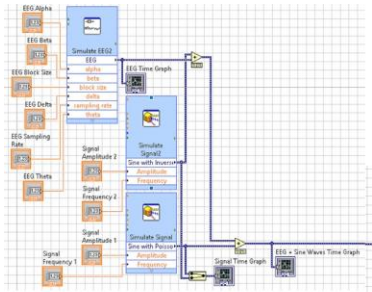


Year 1 Smart City Research Topics
Developing electroencephalogram Brain Activity (Norfolk State University)

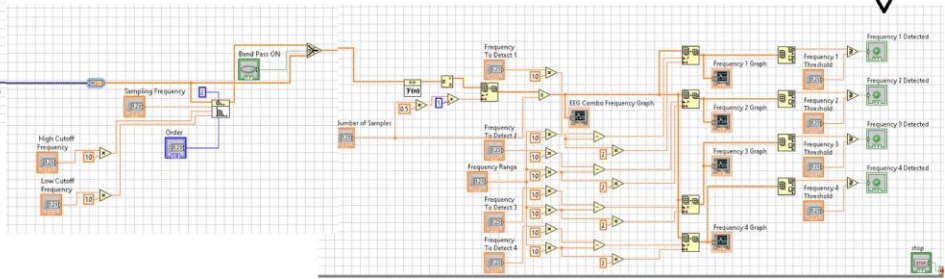
- Summary
  - Non-invasive imaging of brain activity

- Skills developed
  - Cleanroom Operation and Chemical Safety
  - EEG electrode array fabrication
  - Circuits for signal acquisition
  - LabView training system for GUI module
  - Signal processing to dispay





LAB View Programing



Insights from Participant's Research Experience

Challenge: Participants may not feel connected to research topic

Lesson Learned: Have participants review research and engage with pre-projects with an option to switch prior to start of program

Challenge: Fostering cross collaboration across research sites

Lesson Learned: Prior to start of program identify mechanisms for cross collaboration (e.g. co-developed project ideas, chat rooms/forums, messaging apps)

Challenge: Groups can become too large; teachers may not be paired with students on a single project (limiting transfer learning)

Lesson Learned: Teams should be limited to 3 participants (2 students and 1 teacher)

Group Activity 1

- Break into groups
- Each group brainstorm **top 3 ways** in which collaboration can be accomplished across research sites during summer program
- Make sure to include specific implementation details
- Group lead report on top 3

Program Execution

- Single institution (MSU) responsible for program management
  - Management institution must be host site across all years
  - Responsible for institutionalizing best practices learned from each subsequent year
  - There is a common point of contact for students and teachers for information and to report issues

Challenge: Cross-site collaborative meetings (GoTo meeting)

Lesson Learned:

- Ensure all presenters are trained on the use of GoTo meeting or having single point of control
- Have a designated technician at site (could be grad student)

Program Execution: Mentors

- Graduate student mentors provide day to day guidance
  - Mentors help develop and enforce weekly objectives
  - Mentors are selected by participating faculty based on their research projects
  - Care must be taken to select mentors who are not only knowledgeable in their area but are good communicators
  - It is helpful to have mentors help craft the program research projects such that they are tangentially related to current research

Program Execution: Recruitment

- MSU served as the central point for contact with recruiting
  - Ensure program is meeting recruitment goals
- Bi-Weekly meetings brings all consortium members together and all 15 schools are tasked with distributed recruitment materials
- Recruitment materials highlight the research conducted at each institution so participant can indicate research priority/location

Program Execution: Recruitment

- Issues with late recruitment late
  - Students tend to be committed to other programs in the Fall semester
  - Could not sufficiently engage in pre-projects
  - Lower performing students did not pay attention to GPA cut-off and assumed they did not qualify

Lesson Learned: Recruit rising freshmen (expose to pre-projects to ensure interest in electrical engineering)

Lesson Learned: Recruit from community colleges by offering workshops

Program Execution: Pre-Projects

- Each project had a set of pre-projects developed
- Purpose is to engage with both students and teachers in the spring semester
  - Get familiarized with a selected project
  - Learn necessary skills needed to “hit the ground running”
  - Build relationship with graduate student mentors
  - Asses if a selected project is one in which there is sufficient interest

Program Execution: Seminars

- Participants engaged in weekly seminars
  - Big data analytics and deep learning
  - Cybersecurity present and future
  - Smart cities, supercomputers, and threats: creating a resilient smart environment
  - Ethical conduct in research: avoiding research misconduct
  - Personal SWOT
- Seminars involved all host sites
  - Presenters were either on location at a host site or at another location
  - Slides and video streamed to all locations in real-time (GoTo Meeting)
  - Each site streamed video as well and could engage in Q&A live

Program Execution: Weekly Updates

- On a weekly basis, all participants submitted updates via GoToMeeting
- Each host site gathered participants in a single room with video streaming and viewing equipment
- Participants used a predetermined template to share research progress and receive feedback from participants, mentors and faculty across all three sites

IOT DEVICE SECURITY ASSESSMENT USING SIDE CHANNEL ANALYSIS

REU SAMPLE

RAKEB TEKLU AND MICAH BUSH

DATE: JULY 18, 2019

INTERIM PROJECT REPORT

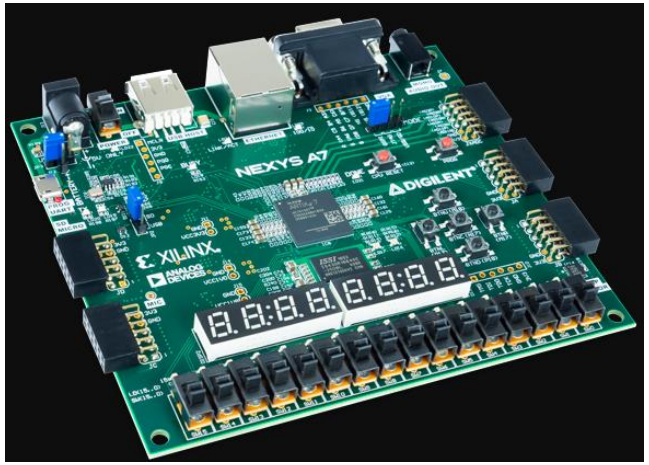
REU/RET SITE: Morgan State University

SCR^2 REU/RET, SUMMER 2019

PROJECT GOALS

REU SAMPLE

- Manually encrypt and decrypt using Simplified AES
- Code 128-bit AES encryption to implement on NEXYS 4 DDR Digilent board
- Perform side channel analysis to extract the key from the NEXYS 4 DDR Board



https://reference.digilentinc.com/_media/reference/programmable-logic/nexys-a7/nexys-a7-obl-600.png

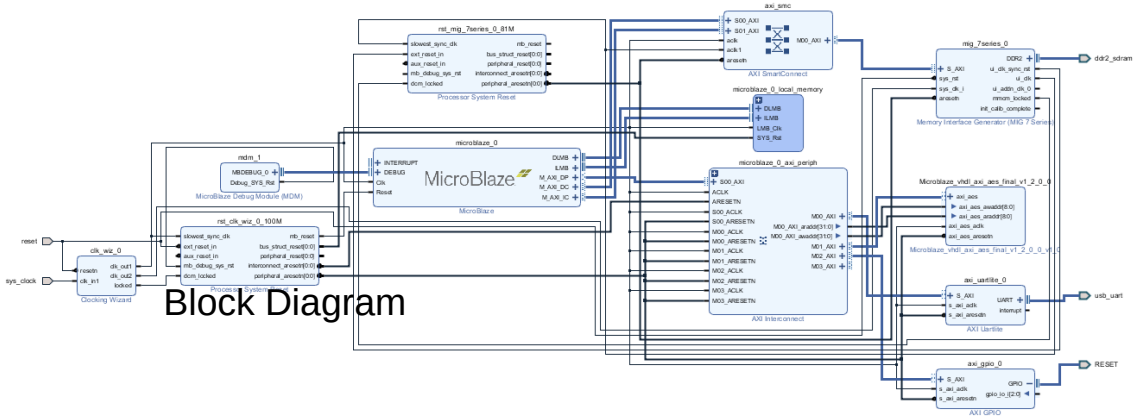
NSF
MORGAN STATE UNIVERSITY
NORFOLK STATE UNIVERSITY
PRAIRIE VIEW A&M UNIVERSITY
ALABAMA A&M UNIVERSITY

REU SAMPLE

PROGRESS

Accomplishments

- Generated bitstream
- Set up external GPIO reset



Block Diagram

Challenges

- Design Constraint Rule errors [DCR]
- Unassigned Pin errors

RET SAMPLE

Traffic light Management Through visible light communication

Dennis ndati

date: 07/17/2019

Interim project report

Reu/RET Site: Morgan state university

sCR² REU/RET, Summer 2019

RET SAMPLE

Project goals

- **Develop a sensor using raspberry pi or Arduino to display traffic signal time.**
  - The purpose of this sensor is to generate the time left for signal to turn Green or Yellow or Red and display it on the screen next to the signal or send it the car in-built visible light communication system (VLC).

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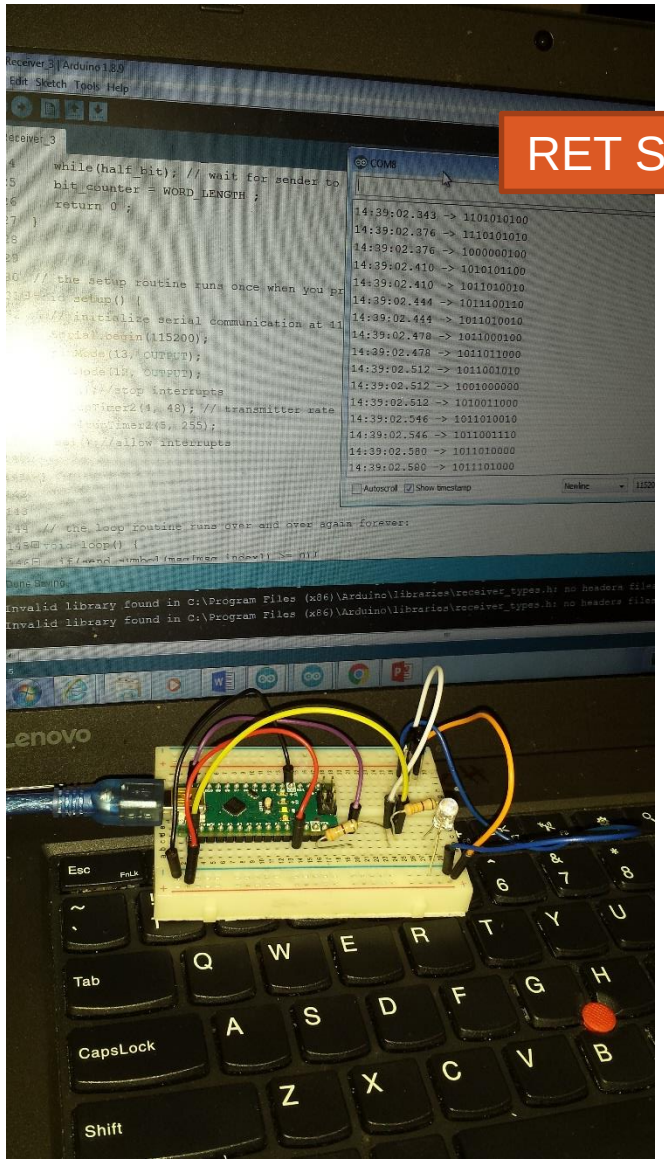
Progress

Accomplishments

- Replicated traffic lights with LED lights
- Created VLC system on Breadboard. The VLC has;
  - Emitter - using clear LED
  - Receiver - using IR sensor
- Completed Arduino sketches for Emitter and Receiver using Manchester encoding for modulation scheme



RET SAMPLE

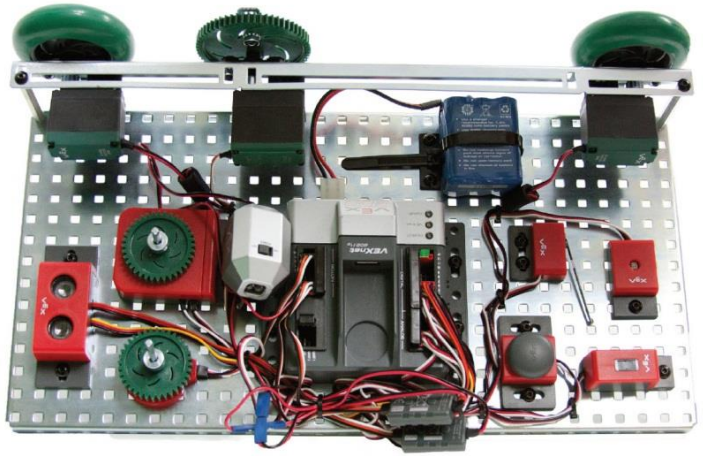
Progress: Lessons and Activity

Lessons/Activities

- POE Testbed to DE Testbed

  Materials
- Vex platform
- Microprocessor
  - Arduino Uno
  - Raspberry Pi
- Microcontroller - Arduino Nano
- Breadboard
- Resistors ohm 330
- USB cord for arduino nano
- LED light

VEX® Robotics Platform: Testbed for Learning Programming using RobotC



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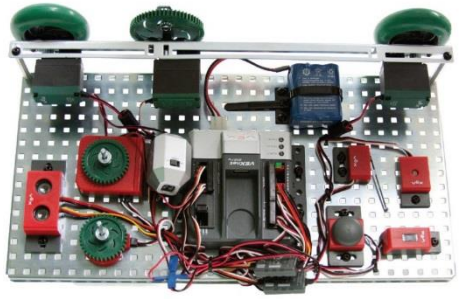
Activity

RET SAMPLE



```
33  task main()
34  {
35
36  turnLEDOn(LED1);          //Program begins
37  wait(3);                  //LED1 turns on
38  turnLEDOff(LED1);         //for three seconds
39                            //LED1 turns off
40  //FanMotor turns on
41  //Until Bumper is pressed
```

```
task main()
{
turnLEDOff(dgtl12);
wait (1);
turnLEDOn(dgtl12);
wait(1);
turnLEDOff (dgtl12);
wait (1);
turnLEDOn (dgtl12);
wait (1);
turnLEDOff (dgtl12);
}
```

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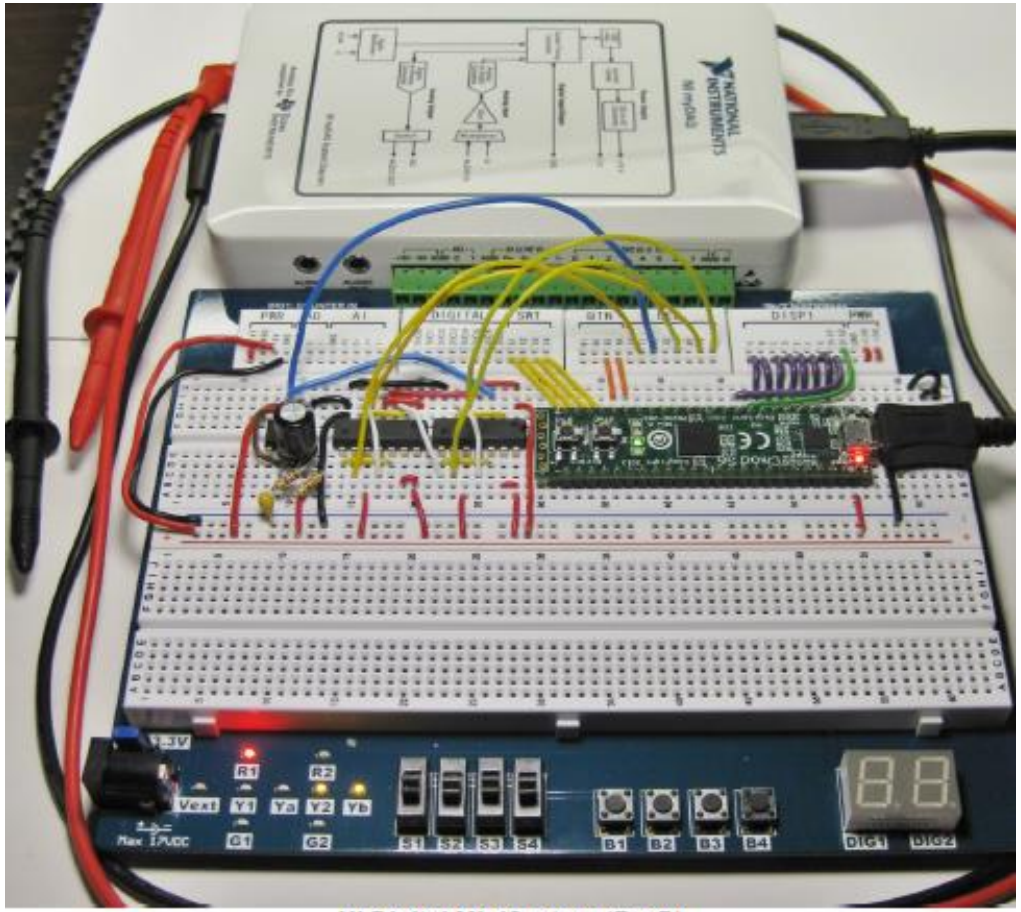
Activity 2: Digital Electronics



NI Digital MiniSystem (RevB)

RET SAMPLE

Materials:

- NI Digital MiniSystem (DMS)
- myDAQ
- myDigital Protoboard
- *Cmod s6 FPGA Module

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Program Execution: Weekly Updates

Challenge: Ensure research is progressing well without the burden of weekly whole program updates

Lesson Learned: Schedule updates on a bi-weekly basis and leverage tools like slack to monitor progress and allow other participants to provide feedback
- Participants post weekly demos to private program-wide youtube channel for feedback…similar to a project video log

Virtual Symposium

- How best to conduct a research symposium with participants across three non-local sites?
- Relied on Go-To meeting & YouTube
- The format was similar to weekly meetings, but participants more formally presented research at a podium
- The sessions were opened to entire consortium (conference session could handle 150 participants)
- Participants could ask questions or make comments via audio or text
- Participants produced "tutorial" style YouTube video to publicly share their research

Challenge: Supporting video demonstrations

Lesson Learned: Limit the length of videos and require narration over videos

Key Challenges and Insights from Survey Instruments

- Women reported lower knowledge and less confidence in their identity as a scientist than their male counterparts when entering the program
  - It is unclear how this experience led females to feel a stronger sense of scientific identity and belonging
- For teachers, reinforced the notion that they are effective teachers and have skills needed to succeed (boosted confidence)
- For students, increased desire to pursue graduate degrees and incorporate STEM concepts into teaching
- For mentors, they gained new insight into their own research projects

Group Activity 2

- Break up into groups
- Each group brainstorm **top 3 ways** to create an experience that helps women feel a stronger sense of scientific identity and belonging
- Make sure to have specific recommendations
- Group leads report on top 3

Wrap Up

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