ECE 3334 Group 4
Week 4 Presentation

Solar Panel Powered Microgrid and Monitoring Station

Kenneth Cody

Computer Engineer

Justin Price

Computer Engineer

Juan Torres

Electrical Engineer

Jared Tulio

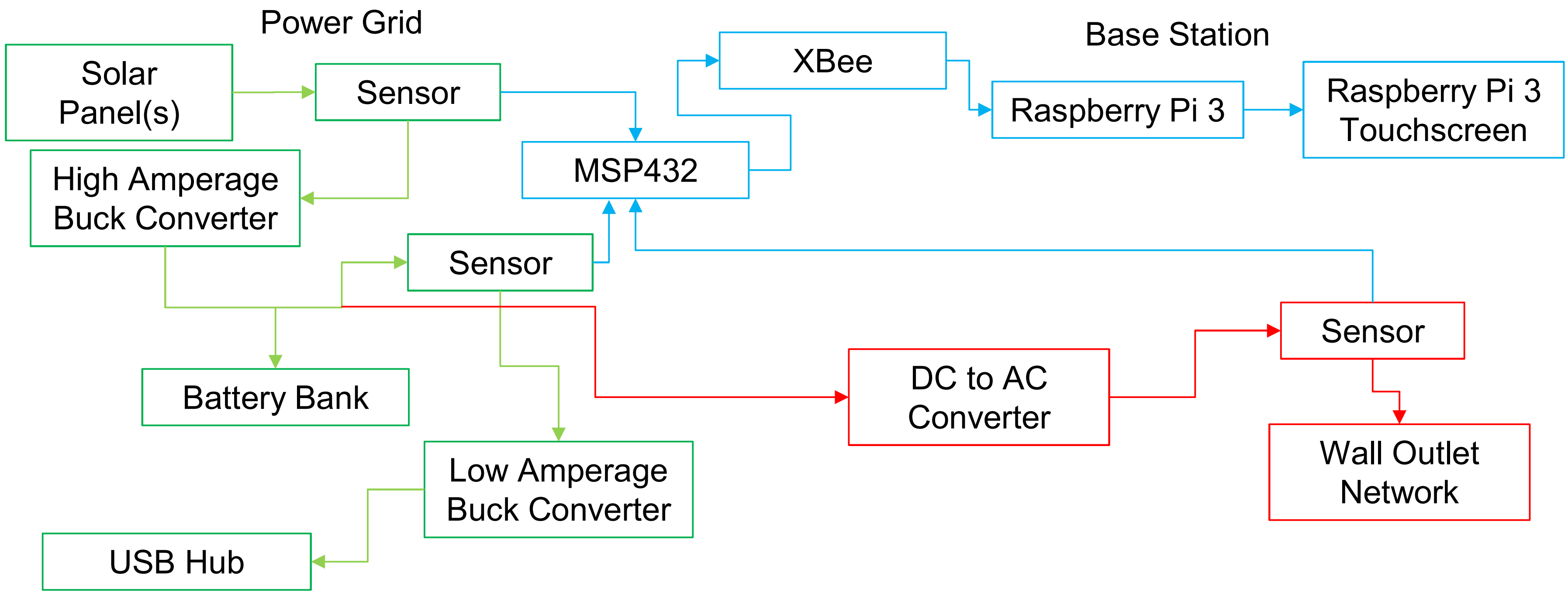
Electrical Engineer – Team Lead

February 14, 2018

System Description

- The microgrid will use a solar panel to charge a battery while the different sections of the grid are monitored using sensors.
- System data is set via Xbee Wi-Fi Modules to a base station built using a Raspberry Pi where data about the system is displayed on a touchscreen.

Hardware Flowchart



Jared Tulio

Division of Labor

Base Station Software and UI: Kenneth

Micro-grid Sensors and Communication: Justin

Battery and Power: Juan

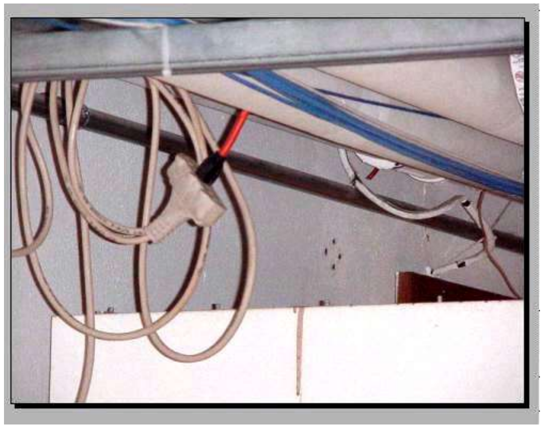
Power Conversion and Grid Construction: Jared

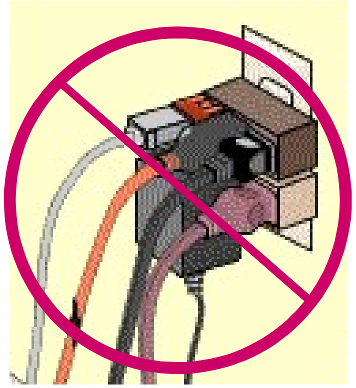
Deliverables for Previous Week

- Research monitoring sensors – Completed
- Research Python – Completed
- Research Kivy- Incomplete
- Research DC-AC Converter – Completed
- Research 100W solar panel – Completed
- Research XBee – Complete
- Submit budget - Complete

Safety

- Be sure to have safety certificates for Lab Bench
- Check for frayed or worn wires
- Be sure not to daisy chain wires
- Be sure not to overload a powerstrip





Grape Solar 100W Panel

Model	GS-STAR-100W
Maximum Power P_{max}	100 W* (0%, +6%)
Voltage at Maximum Power Point V_{mpp}	18.0 V
Current at Maximum Power Point I_{mpp}	5.56 A
Open Circuit Voltage V_{oc}	21.9 V
Short Circuit Current I_{sc}	6.13 A
Module Efficiency (%)	14.63%
Temperature Coefficient of V_{oc}	-0.32% /ºC
Temperature Coefficient of I_{sc}	+0.04% /ºC
Temperature Coefficient of P_{max}	-0.45% /ºC
Weight	8.9 kg (19.66 lbs)
Module Dimension (L x W x T)	1020mm x 670mm x 35mm (40.16” x 26.37” x 1.38”)

Other Performance Data

Power Tolerance	Operating Temperature	Max Series Fuse Rating	NOCT*
0%, +6%	-40 ºC to +85 ºC	10A	45 +/-2ºC

[1]

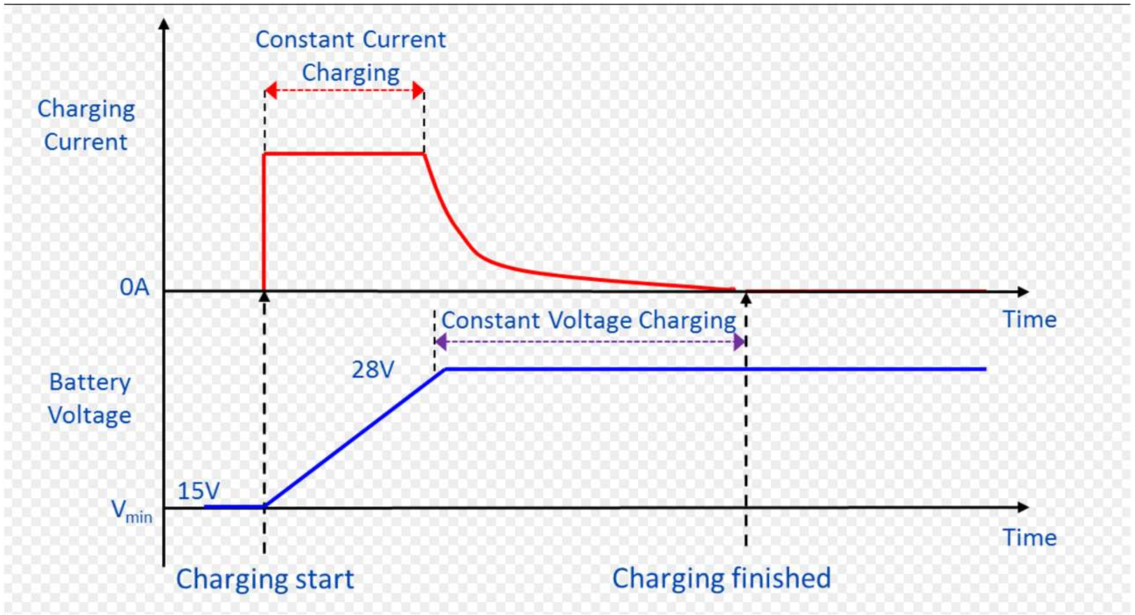
Buck Converter – High Amperage

SMAKN® DC-DC High Power 20A Buck

[2]

*Input voltage: DC10V-40V 10V enter below the undervoltage protection
*Output voltage: 0.8V-13V (onboard potentiometer adjustable)
*Cooling: natural cooling
*Rated power: 150W (natural cooling)
*Rated power: 250W (plus fan forced cooling)
*Current Rating: 20A
*Peak current: 30A ≥35A enter overcurrent
*Efficiency: 96% (24V switch 12V / 10A measured)
*Output Ripple: 200-300mV and input-output differential and power-related
*Operating frequency: 100KHz
*Load regulation ≤1% (0-30A output drop of about 50mV)
*Short circuit protection: There can be a long short re-power recovery
*Reverse protection: reverse current is 0
*Over-temperature protection: There reaches a certain temperature automatically shut down output
Dimensions and wiring instructions:
*Dimensions: 64 * 61.5 * 32mm including heat sink, fan-free
*Fixation: four M3 screws
*Wiring: high-current-free solder terminals
Vin +, Vin- input positive and negative
OUT +, OUT- output positive and negative
*Work instructions: blue for the output voltage is normal.
*Scope: 12V turn 5V, 3.3V, 24V switch 12V, 9V, 5V, 3.3V, 36V switch 12V, other voltage conversion deration is required.

Buck Converter



[3]

Charge Controller

ALLPOWERS 20A Solar Charger Controller

Specification:
*Voltage: DC 12V/24V
*Self-consuming: 10MA
*Rated Charge Current: 20A
*Rated Load Current: 20A
*Over charge Protection: 14.4V/28.8V
*Over charge Floating charge: 13.7V/27.4V
*Charge recover voltage: 12.6V/25.2V
*Over discharge Protection: 10.7V/21.4V
*Over discharge Recover: 12.6V/25.2V
*USB output: 5V/3A
*Operating temperature: -35℃-60℃
*Size:150 * 78 * 35mm / 5.9 * 3 * 1.4in

Features:
--Automatically manage the working of solar panel and battery in solar system.
--Overloading and short-circuit protection.
--Build-in short-circuit protection, open-circuit protection, reverse protection, over-load protection.
--Protection from lightning strike.
--Prolong the battery life cycle and keep the load work well.
--Easy to set up and operate.
--Suitable for small solar energy system.

[4]

DC to AC Inverter

- The focus of a DC to AC inverter or DAC is to transform DC power to AC power similar to that of a wall outlet
- There are two forms of a DAC's output: a modified sine wave and a pure sine wave.

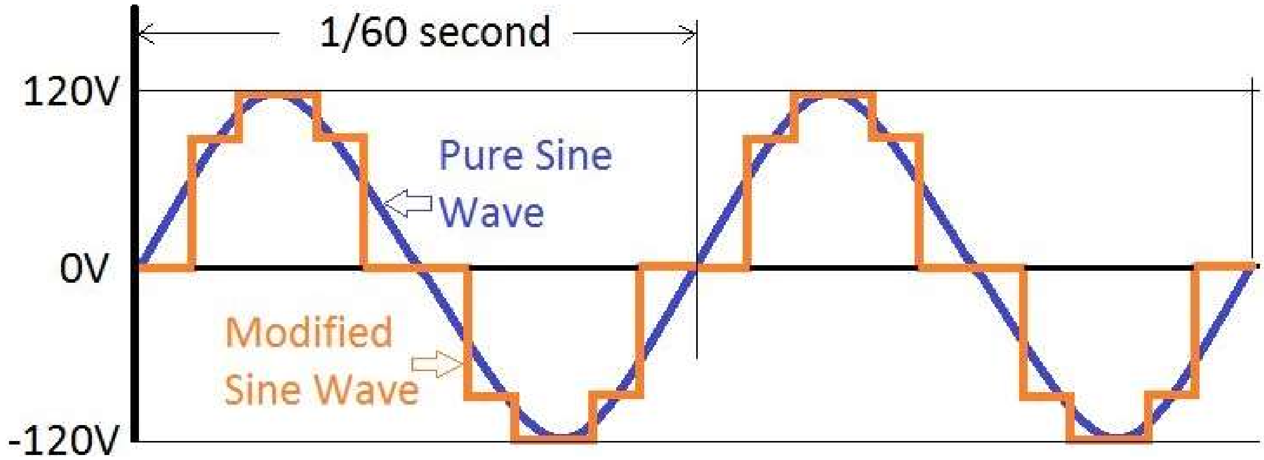


Figure 1: Pure Sine Wave vs Modified Sine Wave [5]

DC to AC Inverter

- A pure sine wave output is identical to that of a normal wall outlet.
- In order to create a pure sine wave a Oscillator was utilized.
- Oscillation occurs when the feedback system can not find a stable steady-state because its transfer function can not be satisfied.
- The key to designing an oscillator is forcing the denominator in Fig 3 to zero.
- $A\mathcal{B}$ must be set to -1 this requires a phase shift of 180°.

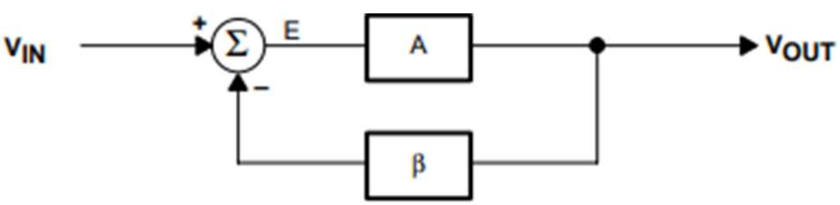


Figure 2: Feedback System [6]

$$\frac{V_{OUT}}{V_{IN}} = \frac{A}{1 + A\beta}$$

Figure 3: Loop Equation [6]

DC to AC Inverter

- In order to have an $A\mathcal{B}$ of -1 and a phase shift of 180° a Bubba Oscillator is utilized.
- A Bubba Oscillator can create pure sine waves using op amps and RC circuits.
- The RC networks within the Bubba oscillator schematic ensure a phase shift will not occur over time.
- A Bubba Oscillator is made up of four op amps running in series with RC networks.
- Each op amp provides a 45° phase shift resulting in a total phase shift of 180°.
- The total attenuation of the circuit is ¼ of the original signal therefore A or gain must be equal to 4.

$$A\beta = A\left(\frac{1}{RCs+1}\right)^4$$

Figure 4: Bubba Loop Equation [6]

$$\phi = \tan^{-1}(1) = 45^\circ$$

Figure 5: Phase of Bubba [6]

$$|\beta| = \left|\left(\frac{1}{j+4}\right)^4 = \frac{1}{\sqrt{2}^4} = \frac{1}{4}\right|$$

Figure 6: Magnitude of Bubba [6]

DC to AC Inverter

- In the region where the phase shift is 180°, the frequency of oscillation is very sensitive to the phase shift. Therefore, the circuit requires that the phase shift be kept within narrow limits so that the changes in frequency are small at 180° .
- Each op amp gets the circuit more stable with four sections being the most stable frequency stability.

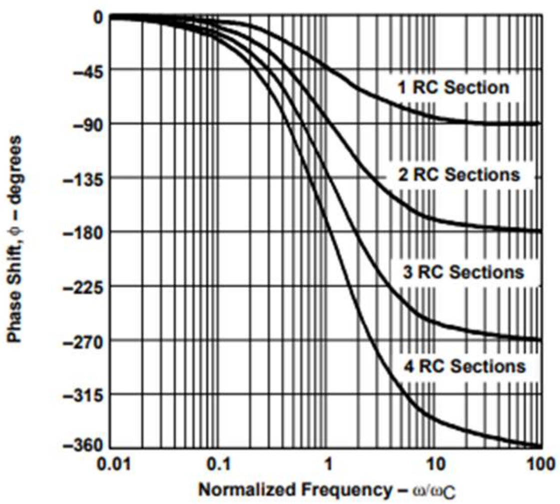


Figure 7: Phase Plot of RC Sections [6]

DC to AC Inverter

- Black Box shows the Gain being set to 4

- Blue Boxes sets the desired frequency using the equation: $f = \frac{1}{2\pi RC} = \frac{1}{2\pi(5.6k)(470n)} = 60.4\text{Hz}$

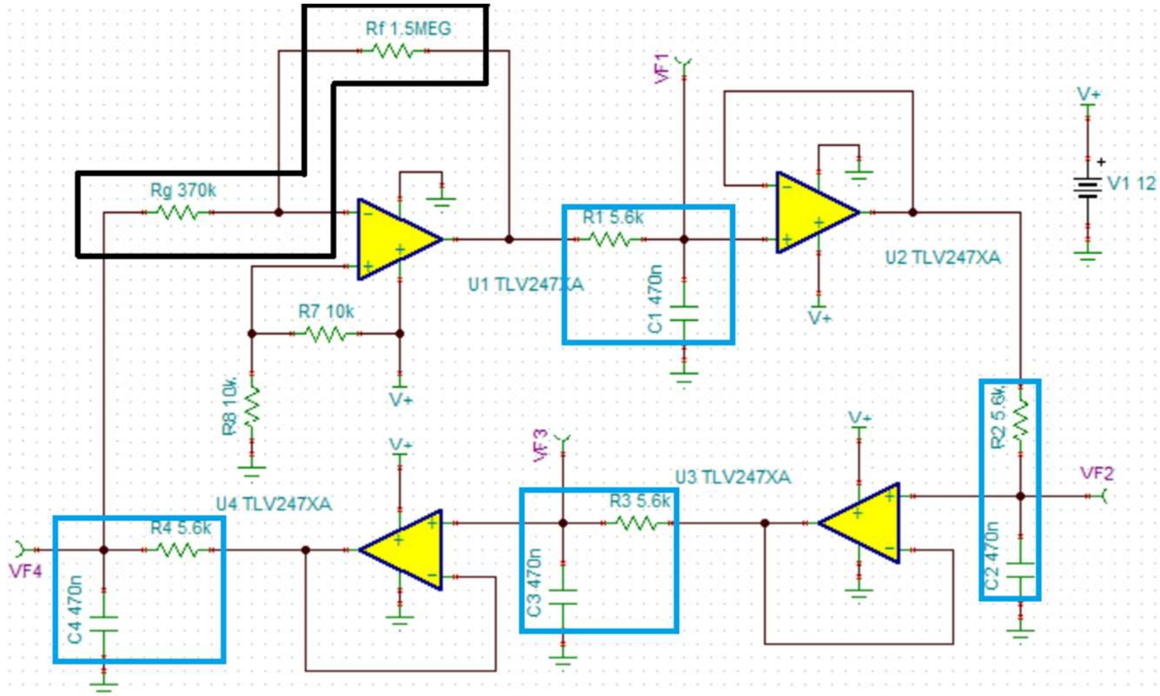


Figure 8: Bubba Oscillator Schematic

DC to AC Inverter

- Each graph shows output at each op amp.

- B – A is the length of a period of the sinusoid
  B – A= $\frac{1}{16.58*10^{-3}}$ = 60.31Hz

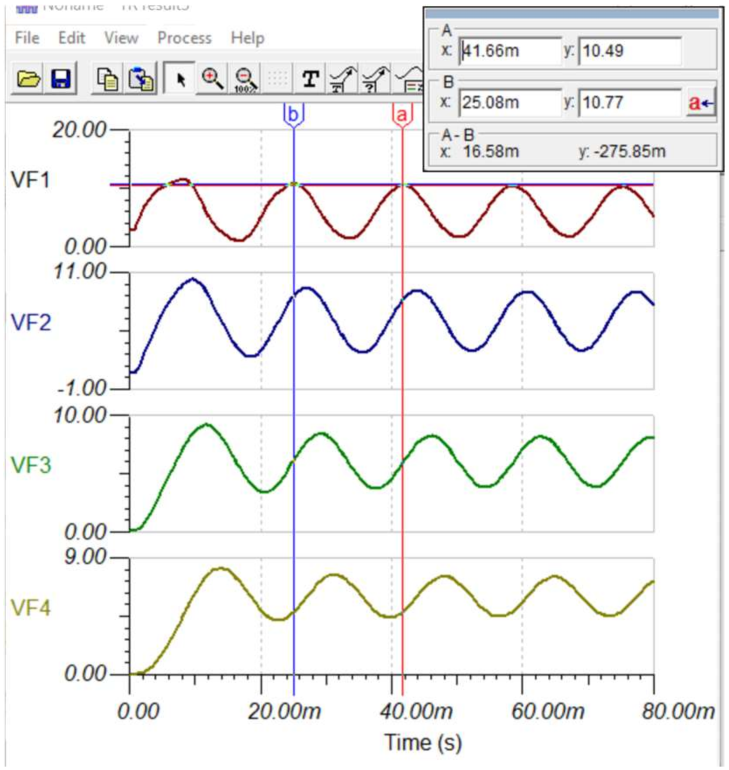


Figure 9: Bubba Oscillator Schematic

DC to AC Inverter

- LM348 Quadruple Operational Amplifier

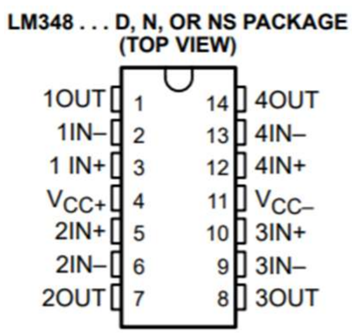


Figure 10: LM348 Pinout [7]

Supply voltage, V_{CC+} (see Note 1):	LM148	22 V
	LM248, LM348	18 V
Supply voltage, V_{CC-} (see Note 1):	LM148	–22 V
	LM248, LM348	–18 V
Differential input voltage, V_{ID} (see Note 2):	LM148	44 V
	LM248, LM348	36 V
Input voltage, V_I (either input, see Notes 1 and 3):	LM148	–22 V
	LM248, LM348	–18 V
Duration of output short circuit (see Note 4)		Unlimited
Operating virtual junction temperature, T_J		150°C
Package thermal impedance, θ_{JA} (see Notes 5 and 6):	D package	86°C/W
	N package	80°C/W
	NS package	76°C/W
Package thermal impedance, θ_{JC} (see Notes 7 and 8):	FK package	5.61°C/W
	J package	15.05°C/W
Case temperature for 60 seconds: FK package		260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: J package		300°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: D, N, or NS package		260°C
Storage temperature range, T_{stg}		–65°C to 150°C

Figure 11: LM348 Datasheet [7]

Digi XB24-AWI-001

RF DATA RATE	250 kbps
INDOR/URBAN RANGE	100 ft (30 m)
OUTDOOR/RF LINE-OF-SIGHT RANGE	300 ft (100 m)

SERIAL DATA INTERFACE	3.3V CMOS UART
CONFIGURATION METHOD	API or AT Commands, local or over-the-air
FREQUENCY BAND	2.4 GHz

SUPPLY VOLTAGE	2.8 - 3.4VDC
TRANSMIT CURRENT	45 mA @ 3.3VDC
RECEIVE CURRENT	50 mA @ 3.3VDC
POWER-DOWN CURRENT	<10 uA @ 25° C

XBEE module Specifications [10]

- Outdoor range of 300 ft (Blue box)
- Connects to Microcontroller using UART (Orange box)
- Configured with AP commands
- VCC of 3.3V (Green box)

XB24-AWI-001 Pinout

Module Pinout [2]

Pin #	Name	Direction	Description
1	VCC	-	Power supply
2	DOUT	Output	UART Data Out
3	DIN / $\overline{\text{CONFIG}}$	Input	UART Data In
4	DO8*	Output	Digital Output 8
5	$\overline{\text{RESET}}$	Input	Module Reset (reset pulse must be at least 200 ns)
6	PWM0 / RSSI	Output	PWM Output 0 / RX Signal Strength Indicator
7	PWM1	Output	PWM Output 1
8	[reserved]	-	Do not connect
9	$\overline{\text{DTR}}$ / SLEEP_RQ / DI8	Input	Pin Sleep Control Line or Digital Input 8
10	GND	-	Ground
11	AD4 / DIO4	Either	Analog Input 4 or Digital I/O 4
12	$\overline{\text{CTS}}$ / DIO7	Either	Clear-to-Send Flow Control or Digital I/O 7
13	ON / $\overline{\text{SLEEP}}$	Output	Module Status Indicator
14	VREF	Input	Voltage Reference for A/D Inputs
15	Associate / AD5 / DIO5	Either	Associated Indicator, Analog Input 5 or Digital I/O 5
16	$\overline{\text{RTS}}$ / AD6 / DIO6	Either	Request-to-Send Flow Control, Analog Input 6 or Digital I/O 6
17	AD3 / DIO3	Either	Analog Input 3 or Digital I/O 3
18	AD2 / DIO2	Either	Analog Input 2 or Digital I/O 2
19	AD1 / DIO1	Either	Analog Input 1 or Digital I/O 1
20	AD0 / DIO0	Either	Analog Input 0 or Digital I/O 0

Pin Definitions [11]

MSP430G2553 ADC

- 10 bit ADC with references V+=3.3 and V-=0, giving a minimum step of around 3mV
- Result of conversion written to ADC10MEM
- Up to 8 channels can be read sequentially with CONSEQx = 01
- Starts at channel selected with INCHx and goes down to A0
- Can start the conversion by toggling the ADC10SC bit [12]

Base Station: Raspberry Pi 3 Model B

Specifications:

SoC: Broadcom BCM2837
CPU: 4× ARM Cortex-A53, 1.2GHz
GPU: Broadcom VideoCore IV
RAM: 1GB LPDDR2 (900 MHz)
Networking: 10/100 Ethernet, 2.4GHz 802.11n wireless
Bluetooth: Bluetooth 4.1 Classic, Bluetooth Low Energy
Storage: microSD
GPIO: 40-pin header, populated
Ports: HDMI, 3.5mm analogue audio-video jack, 4× USB 2.0, Ethernet, Camera Serial Interface (CSI), Display Serial Interface (DSI)
Power: 5V, 2A power supply necessary to power the Raspberry Pi and the attached touchscreen

Raspberry Pi 3 Model B[13]

Base Station: Raspberry Pi 3 7” Touchscreen

Features & Benefits of the Pi LCD Touch Screen:

- Multi-touch capacitive touch
- 7 inch display
- 800 x 480 pixel resolution at 60 frames per second
- No electronic interference
- Full Raspbian OS functionality without a keyboard
- Kivy touch screen development software available
- Connects to the Raspberry Pi board using the DSI port
- Adapter board is used to power the display
- Will require the latest version of Raspbian OS to operate

Raspberry Pi 7” Touchscreen[14]

Base Station: GUI Software

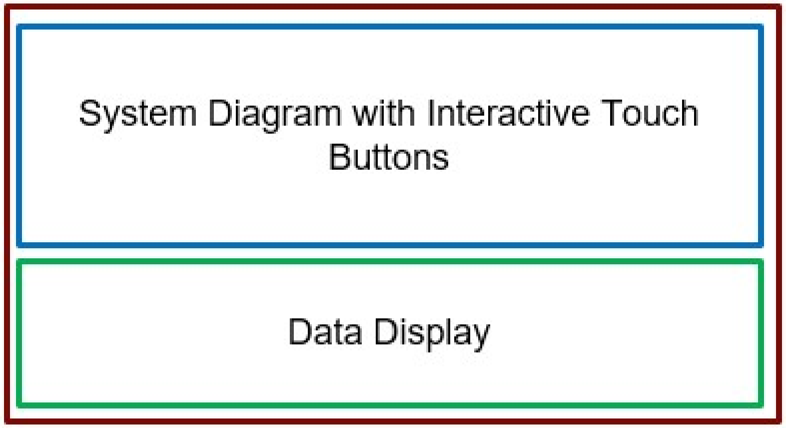
"Open source Python library for rapid development of applications that make use of innovative user interfaces, such as multi-touch apps."[15]

Kivy allows for touchscreen compatible GUI development on the Raspberry Pi 3.

Raspberry Pi	KivyPie - Image for Raspberry Pi containing Kivy	Installation for Raspberry Pi	532 Mb

Base Station: GUI

The GUI displayed on the touchscreen will allow users to select any section of the microgrid to access detailed information about the specific section. The GUI will also display basic information by default without any buttons being pressed.



Raspberry Pi Touchscreen Display

Base Station: Kivy Application

To create the interactive system diagram, the box layout is used and two horizontal rectangles are created, the top box contains the system diagram graphic with touch events dedicated to each separate system part.

```
on_touch_up(touch)
```

Event called when a touch event is released (terminated).

Touch Event[16]

```
layout = BoxLayout(orientation='vertical')
btn1 = Button(text='Hello')
btn2 = Button(text='World')
layout.add_widget(btn1)
layout.add_widget(btn2)
```

Example Box Layout Initialization[17]

Base Station: Kivy Application Cont'd.

The second horizontal rectangle will display the system information about the selected part until another part is selected via touch. To do this the Kivy text module is used and the data passed to the Raspberry Pi from the Xbee will be displayed in the box.[18] The data that will be shown includes the current and voltage of solar panel, power consumption of the load. A button to remotely shut down the system will also be included.

Base Station: Learning Python

Resources:

1. The Python Tutorial, Python.org [19]
2. Learn Python in 10 Minutes, Stavros.io [20]
3. Hands on Python, Dr. Andrew N. Harrington [21]

Total Budget

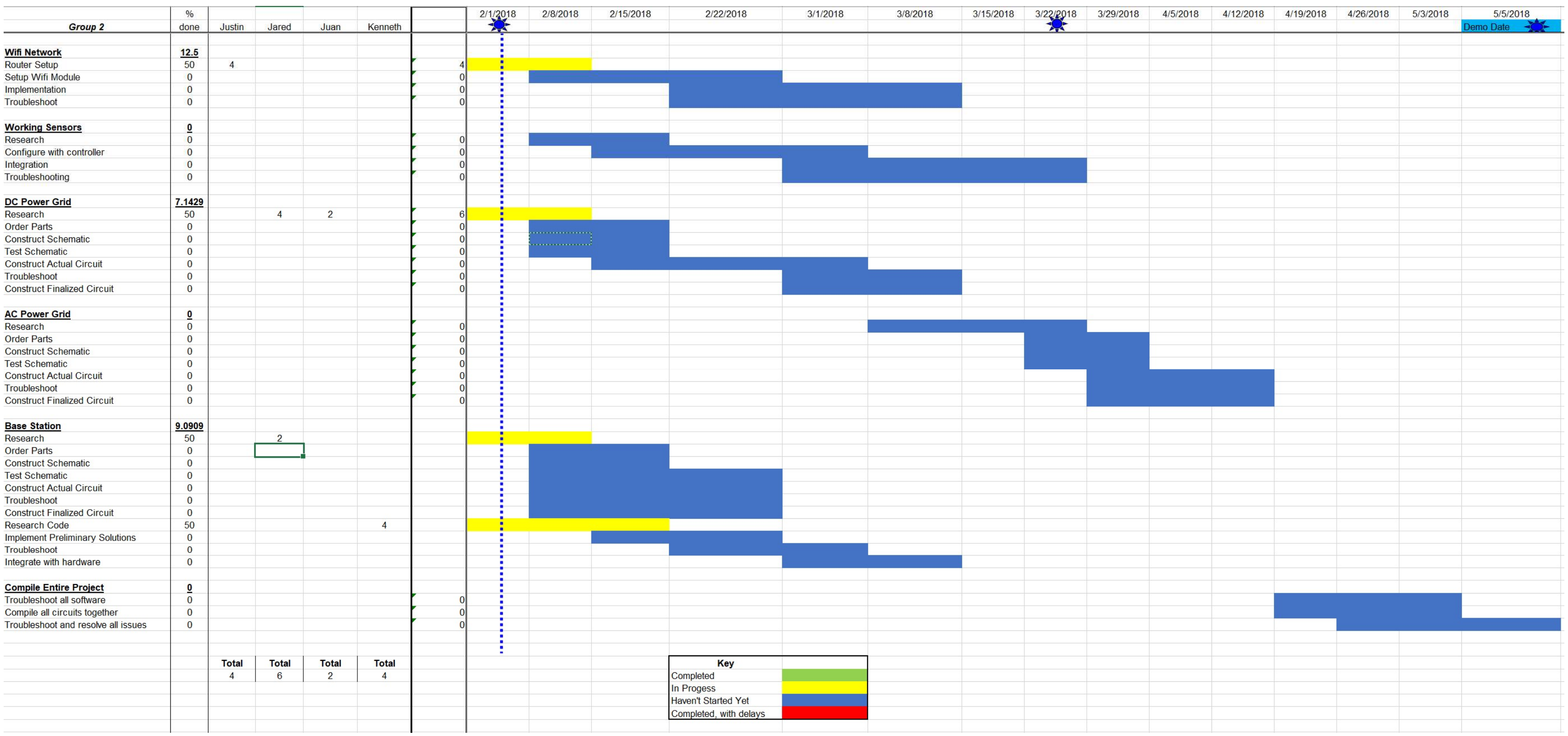
Lab 1 - Group 2	Running Total			Total Estimate			Start Date	2/1/2018
Direct Labor:							Today	2/7/2018
Category or individual:	*Rate/Hr*	*Hrs*		*Rate/Hr*	*Hrs*			
Kenneth	18	8	$144.00	18	215	$3,870.00	End Date	5/5/2018
Jared	18	8	$144.00	18	215	$3,870.00	Days Past	6
Justin	18	8	$144.00	18	215	$3,870.00	Total Days	93
Juan	18	8	$144.00	18	215	$3,870.00	Days Left	87
DL Subtotal (DL)		Subtotal:	$576.00		Subtotal:	$15,480.00		
Labor Overhead	*rate:*	100%	$576.00	*rate:*	100%	$15,480.00		
Total Direct Labor (TDL)			$1,152.00			$30,960.00		
Contract Labor:								
Lab 1 Help	$15	0	$0.00	$15	0	$0.00		
Lab 2 Help	$18	0	$0.00	$18	0	$0.00		
Lab 3 Help	$18	0	$0.00	$18	10	$180.00		
Lab 4 Help	$18	0	$0.00	$18	15	$270.00		
Lab 5 Help	$25	0	$0.00	$25	10	$250.00		
Tutors	$40	0	$0.00	$40	15	$600.00		
Lab Assistants	$40	0	$0.00	$40	15	$600.00		
Woodcock	$100	0	$0.00	$100	5	$500.00		
Prof. Ray	$200	0	$0.00	$200	20	$4,000.00		
Total Contract Labor (TCL)			$0.00			$6,400.00		
Direct Material Costs:			$0.00			$650.00		
(from Material Cost worksheet)								
Total Direct Material Costs: (TDM)			$0.00			$650.00		
Equipment Rental Costs:	Value	Rental Rate		Value	Rental Rate		Date begin	Date end (or today)
Oscilloscope	$5,300.00	0.20%	$63.60	$5,300.00	0.20%	$985.80	2/1/2018	5/5/2018
Function Generator	$500.00	0.20%	$6.00	$500.00	0.20%	$93.00	2/1/2018	5/5/2018
DMM	$958.00	0.20%	$11.50	$958.00	0.20%	$178.19	2/1/2018	5/5/2018
Power Supply	$1,700.00	0.20%	$20.40	$1,700.00	0.20%	$316.20	2/1/2018	5/5/2018
Soldering Station	$100	0.20%	$1.20	$100.00	0.20%	$18.60	2/1/2018	5/5/2018
Total Rental Costs: (TRM)			$101.50			$1,573.19		
Total TDL+TCL+TDM+TRM			$1,253.50			$39,583.19		
Business overhead		100%	$1,253.50		100%	$39,583.19		
Total Cost:		**Current**	$2,506.99		**Estimate**	$79,166.38		

Jared Tulio

Total Budget Cont'd

Name	Cost	Quantity	Website	Notes	Purchase Date	Total		TOTAL
ESP8266 WiFi Module	$6.95	2	SparkFun	NA		$13.90		$538.38
100W-Solar Panel - Grape Solar	$97.00	1	Home Depot	NA		$97.00		
35Ah 12V Lead Acid Battery	$64.99	1	Amazon	NA		$64.99		
7Ah 12V Lead Acid Battery	$28.49	1	Amazon	Pack of 2		$28.49		
Buck Converter - High Amperage	$26.00	2	Amazon	NA		$52.00		
Buck Converter - Low Amperage	$8.00	4	Amazon	NA		$32.00		
Rasberry Pi 3	$35.00	1	Allied Electronics	NA		$35.00		
Rasberry Pi Touch Screen	$70.00	1	Allied Electronics	NA		$70.00		
Rechargeable Battery	$15.00	1	Amazon	NA		$15.00		
Current Sensor	$20.00	3	Mouser	NA		$60.00		
Power Inverter	$70.00	1	Amazon	NA		$70.00		

Gantt Chart


Group 2
% done
Justin
Jared
Juan
Kenneth
2/1/2018
2/8/2018
2/15/2018
2/22/2018
3/1/2018
3/8/2018
3/15/2018
3/22/2018
3/29/2018
4/5/2018
4/12/2018
4/19/2018
4/26/2018
5/3/2018
5/5/2018
Demo Date
Wifi Network 12.5
Router Setup 50 4 4
Setup Wifi Module 0 0
Implementation 0 0
Troubleshoot 0 0
Working Sensors 0
Research 0 0
Configure with controller 0 0
Integration 0 0
Troubleshooting 0 0
DC Power Grid 7.1429
Research 50 4 2 6
Order Parts 0 0
Construct Schematic 0 0
Test Schematic 0 0
Construct Actual Circuit 0 0
Troubleshoot 0 0
Construct Finalized Circuit 0 0
AC Power Grid 0
Research 0 0
Order Parts 0 0
Construct Schematic 0 0
Test Schematic 0 0
Construct Actual Circuit 0 0
Troubleshoot 0 0
Construct Finalized Circuit 0 0
Base Station 9.0909
Research 50 2
Order Parts 0
Construct Schematic 0
Test Schematic 0
Construct Actual Circuit 0
Troubleshoot 0
Construct Finalized Circuit 0
Research Code 50 4
Implement Preliminary Solutions 0
Troubleshoot 0
Integrate with hardware 0
Compile Entire Project 0
Troubleshoot all software 0 0
Compile all circuits together 0 0
Troubleshoot and resolve all issues 0 0
Total 4
Total 6
Total 2
Total 4
Key
Completed
In Progess
Haven't Started Yet
Completed, with delays

Deliverables for Next Week

- Work on ADC Code – Justin
- Work on Raspberry Pi Code – Kenneth
- Continue to Research Kivy Application – Kenneth
- Research Power Controller System – Jared, Juan

References

[1] https://www.homedepot.com/catalog/pdfImages/1d/1d1b46a0-4979-46fa-b5d2-73cc1f950f30.pdf

[2] https://www.amazon.com/SMAKN%C2%AE-Adjustable-Converter-10-40V-0-8-13V/dp/B00VY1CYL2

[3] https://en.wikipedia.org/wiki/Buck_converter

[4] https://www.walmart.com/ip/PWM-30A-Solar-Charge-Controller-Intelligent-LCD-Display-Solar-Panel-Controller-12V-24V-Solar-Panel-Charge-Regulator/949471097?wmlspartner=wlpa&selectedSellerId=15389&adid=22222222227093695580&wmlspartner=wmtlabs&wl0=&wl1=g&wl2=c&wl3=216277860649&wl4=pla-349633573193&wl5=9028551&wl6=&wl7=&wl8=&wl9=pla&wl10=118787840&wl11=online&wl12=949471097&wl13=&veh=sem

[5] https://www.altestore.com/blog/2015/10/pure-sine-wave-vs-modified-sine-wave-whats-the-difference/

[6] https://www.ti.com/lit/an/sloa060/sloa060.pdf

[7] https://www.hscott.net/bubba.pdf

[8] https://web.wpi.edu/Pubs/E-project/Available/E-project-042507-092653/unrestricted/MQP_D_1_2.pdf

[9] http://www.ti.com/lit/ds/symlink/lm348.pdf

[10] https://www.mouser.com/ds/2/111/ds_xbeemultipointmodules-19140.pdf

References

[11] https://www.sparkfun.com/datasheets/Wireless/Zigbee/XBee-Datasheet.pdf

[12] http://www.ti.com/lit/ug/slau144j/slau144j.pdf

[13] https://www.raspberrypi.org/products/raspberry-pi-3-model-b/

[14] https://www.alliedelec.com/raspberry-pi-raspberry-pi-7-touchscreen/

[15] https://kivy.org/#home

[16] https://kivy.org/docs/api-kivy.core.window.html#kivy.core.window.WindowBase.on_touch_down

[17] https://kivy.org/docs/api-kivy.uix.boxlayout.html#module-kivy.uix.boxlayout

[18] https://kivy.org/docs/api-kivy.core.text.html

[19] https://docs.python.org/3/contents.html

[20] https://www.stavros.io/tutorials/python/

[21] http://anh.cs.luc.edu/handsonPythonTutorial/

Questions?