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

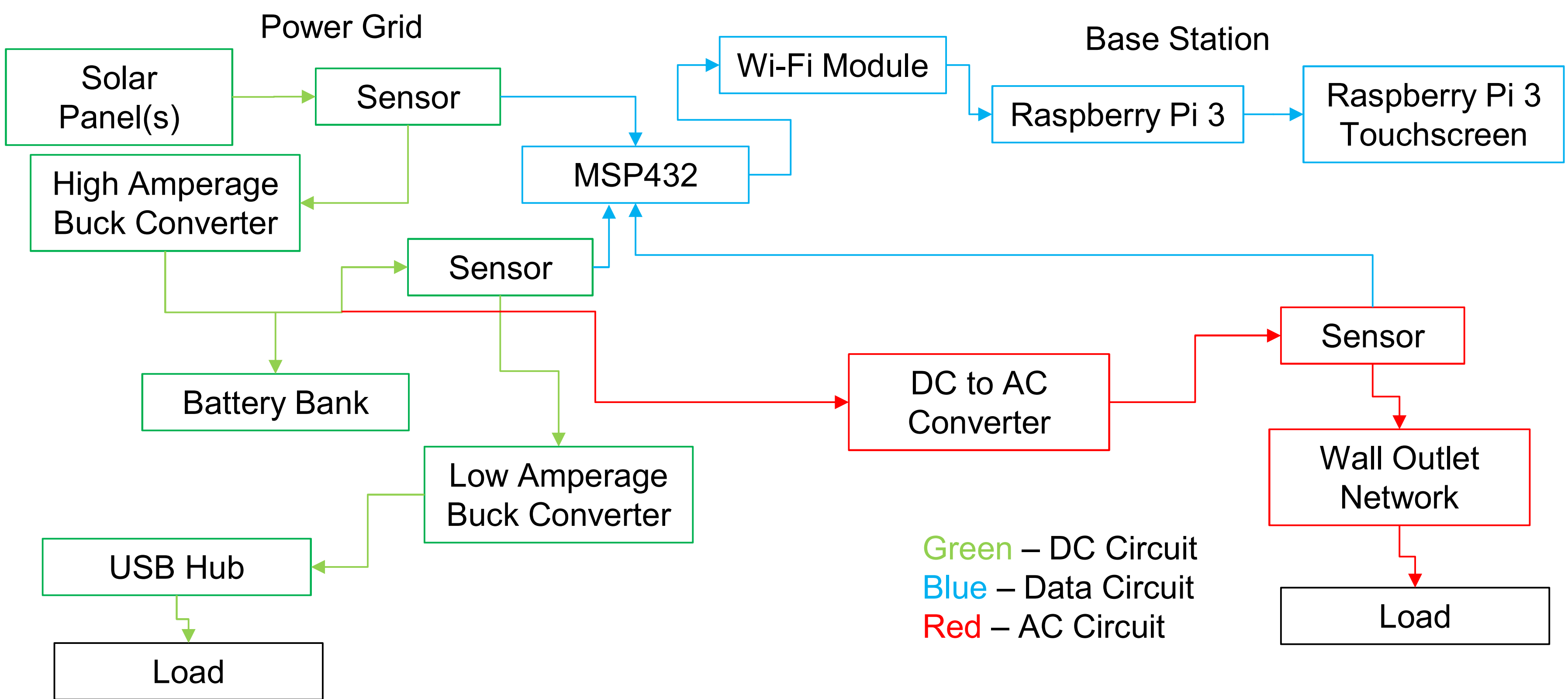
Electrical Engineer – Team Lead

March 1, 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 where data about the system is displayed.

Hardware Flowchart



Jared Tulio

Division of Labor

Base Station Software and UI: Kenneth

Microgrid Sensors and Communication: Justin

Battery and Power: Juan

Power Conversion and Grid Construction: Jared

Deliverables for Previous Week

- Continue development of Kivy application – Incomplete
- Begin UART communication development – Complete
- Begin development of backup GUI plan – Complete
- Prototyping DC to AC converter – Complete

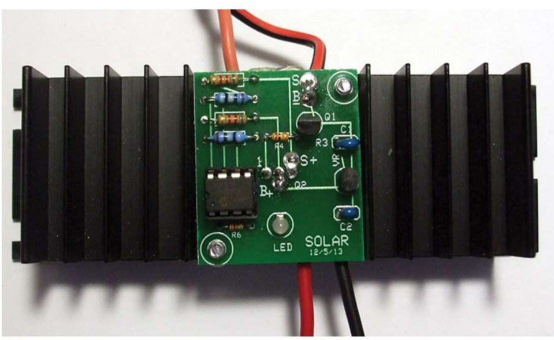
Safety

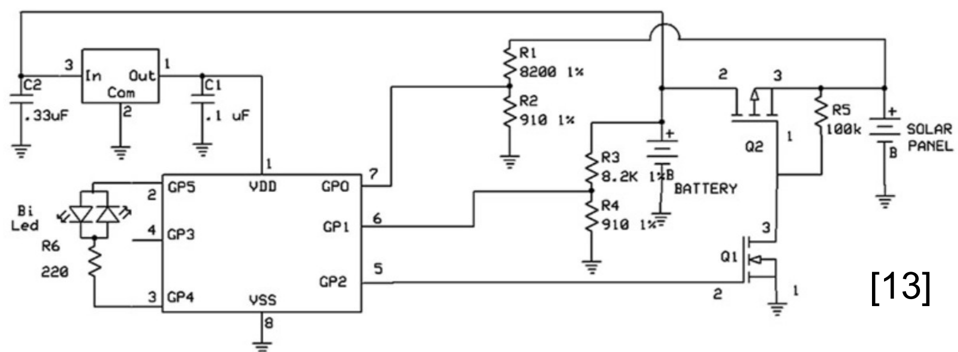
- Lead-Acid Batteries are made up of sulfuric acid and water solution. Lead-acid batteries also produce Hydrogen gas when charged. Careful for hydrogen is flammable in nature.
- Sulfuric Acid has a PH lower then two. Therefore it is corrosive material and will burn your eyes and skin.
- Never open battery caps with your face over the battery.
- Even disconnected batteries can be dangerous for some are capable of discharging extremely high rates of current.
- Make sure to remove jewelry before working near batteries.
- There is a emergency stop button in the lab do not forget to use it if you need to.

Charge Controller Microcontroller

[11]

- Standby Current:
  - 1 nA @ 2.0V, typical
- Operating Current:
  - 8.5 μA @ 32 kHz, 2.0V, typical
  - 100 μA @ 1 MHz, 2.0V, typical





[13]

Resettable Fuse

Mouser #: 530-0ZRB0600FF1A

[12]

Electrical Characteristics (23℃)

HALOGEN FREE = HF

	Part Number (Bulk)	Hold Current IH, A	Trip Current IT, A	Max Time to Trip @ 5xIH Seconds	Max Current Imax, A	Rated Voltage Vmax, Vdc	Typical Power Pd, W	Resistance Tolerance Rmin Ohms	Rmax Ohms	R1max Ohms	Agency Approvals cULus	TÜV
A	0ZRB0090FF1C	0.90	1.8	5.9	40	30	0.6	0.07	0.160	0.22	Y	Y
B	0ZRB0110FF1C	1.10	2.2	6.6	40	30	0.7	0.05	0.140	0.17	Y	Y
C	0ZRB0135FF1E	1.35	2.7	7.3	40	30	0.8	0.04	0.095	0.13	Y	Y
D	0ZRB0160FF1E	1.60	3.2	8.0	40	30	0.9	0.03	0.080	0.11	Y	Y
E	0ZRB0185FF1E	1.85	3.7	8.7	40	30	1.0	0.03	0.070	0.09	Y	Y
F	0ZRB0250FF1E	2.50	5.0	10.3	40	30	1.2	0.02	0.050	0.07	Y	Y
G	0ZRB0300FF1A	3.00	6.0	10.8	40	30	2.0	0.02	0.050	0.08	Y	Y
H	0ZRB0400FF1A	4.00	8.0	12.7	40	30	2.5	0.01	0.035	0.05	Y	Y
I	0ZRB0500FF1A	5.00	10.0	14.5	40	30	3.0	0.01	0.022	0.05	Y	Y
J	0ZRB0600FF1A	6.00	12.0	16.0	40	30	3.5	0.005	0.018	0.04	Y	Y
K	0ZRB0700FF1A	7.00	14.0	17.5	40	30	3.8	0.005	0.015	0.03	Y	Y
L	0ZRB0800FF1A	8.00	16.0	18.8	40	30	4.0	0.005	0.012	0.02	Y	Y
M	0ZRB0900FF1A	9.00	18.0	20.0	40	30	4.2	0.005	0.011	0.02	Y	Y

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.

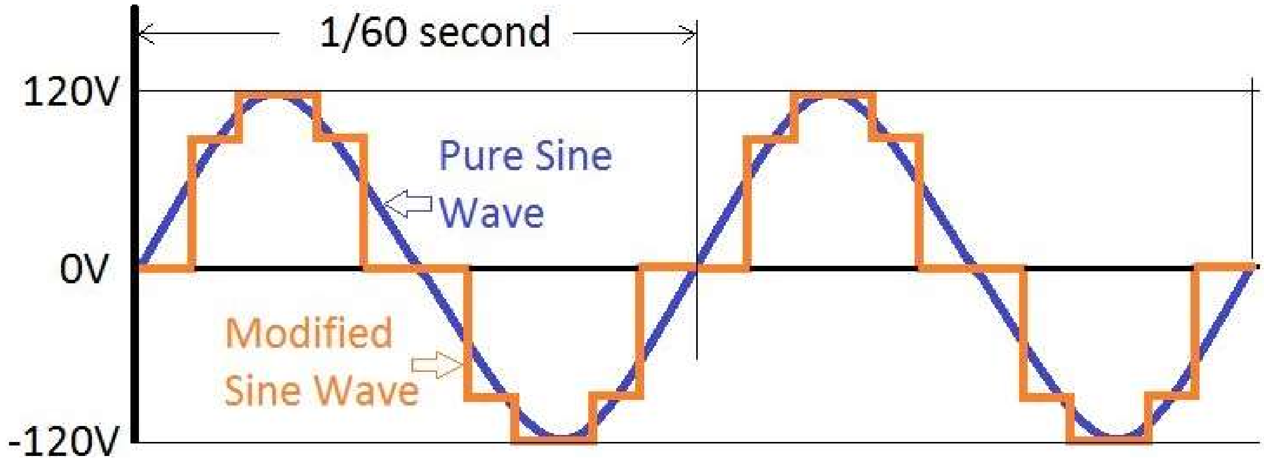


Figure 1: Pure Sine Wave vs Modified Sine Wave [2]

DC to AC Inverter

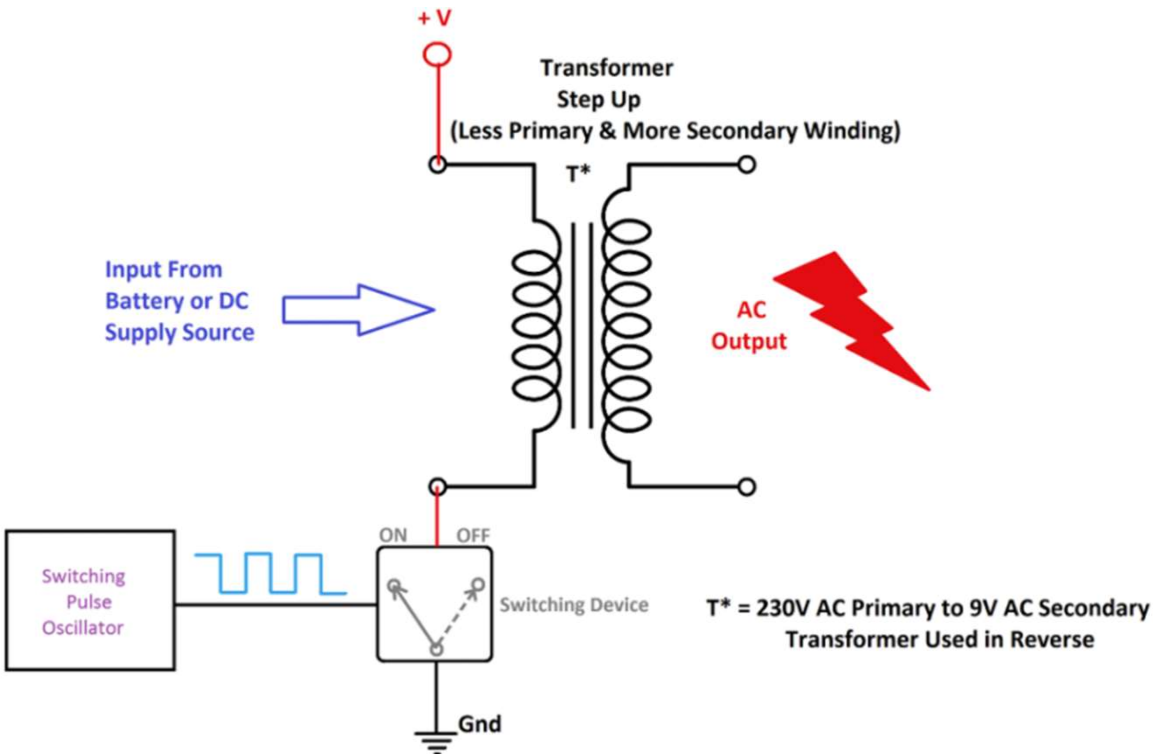


Figure 2: How a switching inverter works[1]

DC to AC Inverter

- Inverter circuits are useful for portable power sources. When the load connected to the inverter circuit is very small there is no need for a perfect sine wave. Instead a much more simple inverter circuit can be utilized to power low power devices.
- The IC used is a LM555 timer which is being used as a switching pulse oscillator. The LM555 is configured as a Astable Multivibrator to give a switching pulse.
- The two transistors TIP41A (NPN) and TIP42A (PNP) drive the transformer according to the pulse input.
- The transformer is 230V primary to 9V secondary connected in reverse, so that it can react as a step up transformer.
- By applying a +5V to +15V DC bias to this circuit a 110V to 230V AC output is acquired with 50Hz to 60Hz frequency however output is a pulsated AC

Convert DC to AC

- The output frequency of this circuit can be varied by varying VR1 resistor.
- The equation for calculating frequency is shown below with R2 = R2 + VR1.
- The transistors use a heat sink in order to avoid overheat.
- The transformer is rated to 500mA.

$$f = \frac{1}{T} = \frac{1.44}{(R_1 + 2R_2)\,C_1}$$

Figure 3: Frequency Calculation[1]

Convert DC to AC

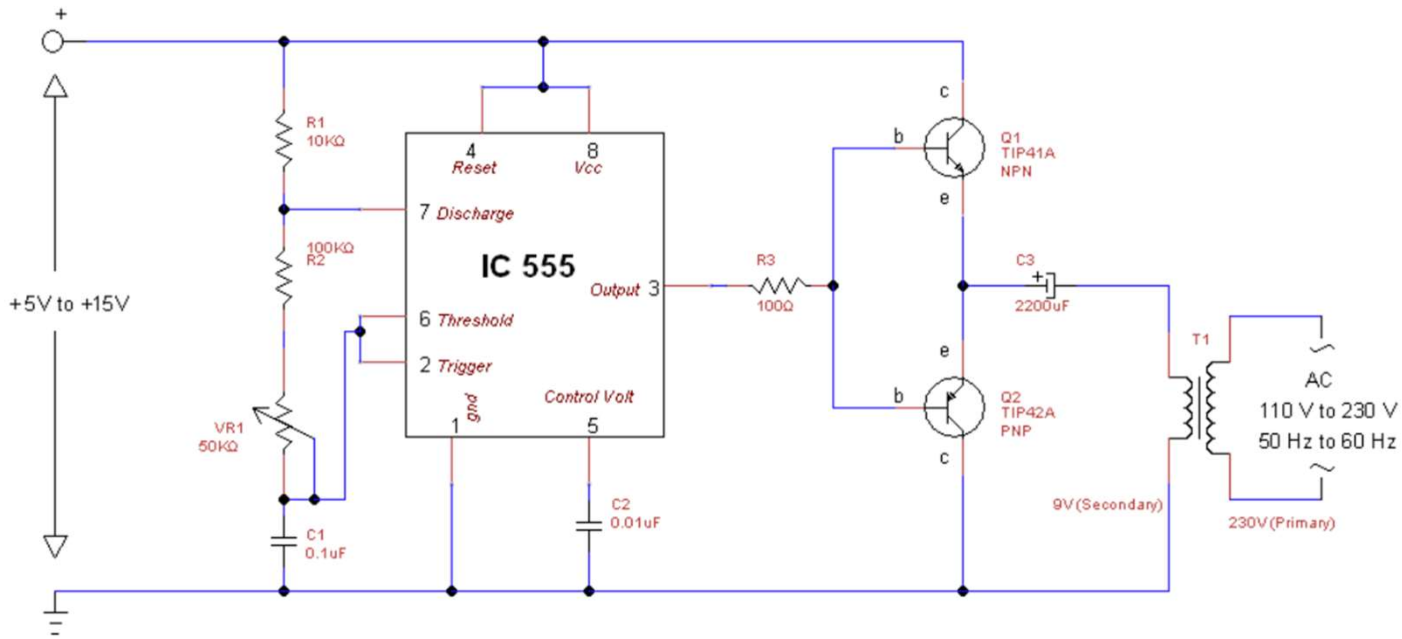


Figure 4: DC to AC Inverter[1]

Information on the LM555

Applications

- Precision Timing
- Pulse Generation
- Sequential Timing
- Time Delay Generation
- Pulse Width Modulation
- Pulse Position Modulation
- Linear Ramp Generator

Figure 5: Applications for LM555 [2]

PIN NO.	PIN NAME	I/O	DESCRIPTION
5	Control Voltage	I	Controls the threshold and trigger levels. It determines the pulse width of the output waveform. An external voltage applied to this pin can also be used to modulate the output waveform
7	Discharge	I	Open collector output which discharges a capacitor between intervals (in phase with output). It toggles the output from high to low when voltage reaches 2/3 of the supply voltage
1	GND	O	Ground reference voltage
3	Output	O	Output driven waveform
4	Reset	I	Negative pulse applied to this pin to disable or reset the timer. When not used for reset purposes, it should be connected to VCC to avoid false triggering
6	Threshold	I	Compares the voltage applied to the terminal with a reference voltage of 2/3 Vcc. The amplitude of voltage applied to this terminal is responsible for the set state of the flip-flop
2	Trigger	I	Responsible for transition of the flip-flop from set to reset. The output of the timer depends on the amplitude of the external trigger pulse applied to this pin
8	V^+	I	Supply voltage with respect to GND

Figure 6: Pinout Descriptions[2]

Information on the LM555

	MIN	MAX	UNIT
Supply Voltage		18	V
Temperature, T_A	0	70	°C
Operating junction temperature, T_J		70	°C

Figure 7: Supply Voltage for LM555[2]

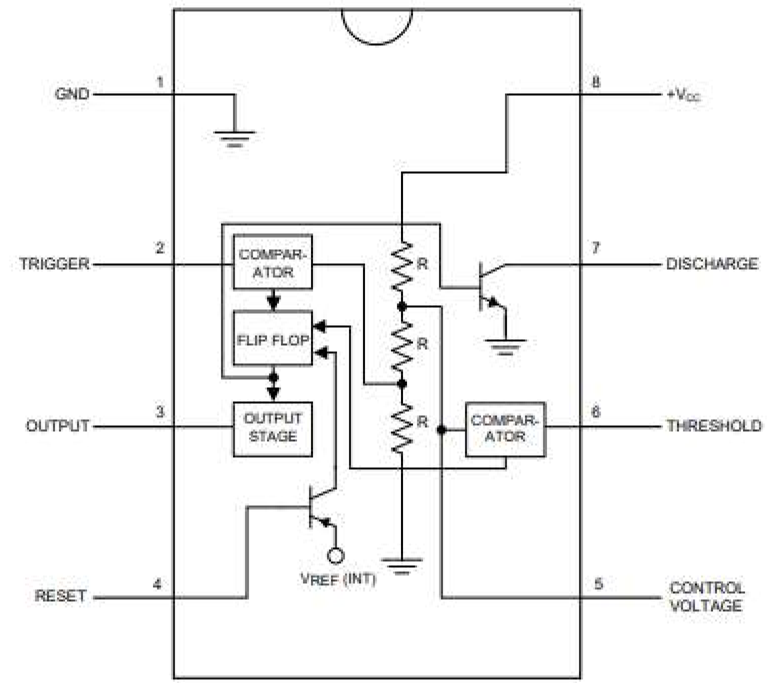


Figure 8: Pinout for LM555[2]

Information on the TIP41A and TIP42A

Features

- COMPLEMENTARY PNP-NPN DEVICES
- NEW ENHANCED SERIES
- HIGH SWITCHING SPEED
- h_{FE} IMPROVED LINEARITY

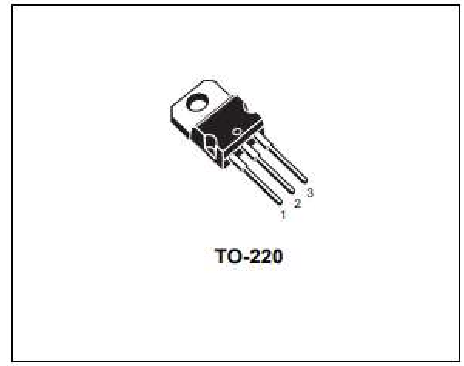
Applications

- GENERAL PURPOSE CIRCUITS
- AUDIO AMPLIFIER
- POWER LINEAR AND SWITCHING

Description

The TIP41A is a silicon base island technology NPN power transistor Jedec TO-220 plastic package with improved performances than the industry standard TIP41A that make this device suitable for audio, power linear and switching applications. The complementary PNP type is TIP42A.

Figure 9: TIP41A and Tip42A[3]



Internal Schematic Diagram

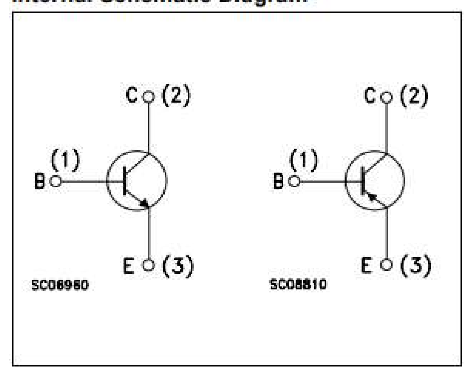


Figure 10: Pinout Descriptions[3]

Information on the TIP41A and TIP42A

Symbol	Parameter	Value	Unit
V_{CBO}	Collector-Base Voltage ($I_E = 0$)	60	V
V_{CEO}	Collector-Emitter Voltage ($I_B = 0$)	60	V
V_{EBO}	Emitte-Base Voltage ($I_C = 0$)	5	V
I_C	Collector Current	6	A
I_{CM}	Collector Peak Current	10	A
I_B	Base Current	3	mA
P_{TOT}	Total dissipation at $T_{case} = 25°C$ $T_{amb} = 25°C$	65 2	W W
T_{stg}	Storage Temperature	-65 to 150	°C
T_J	Max. Operating Junction Temperature	150	°C

Figure 11: TIP41A and Tip42A Absolute Maximum Power Ratings [3]

Information on the Transformer

- 9v 500mA Transformer (230V to 9V) [9-0-9]
- Step down 230 V AC to 9V with a maximum of 500mAmp current. Generally known as 9-0-9
- Voltage: 2 x 9V
- Current: 1 x 500mA
- Rated power: 9VA

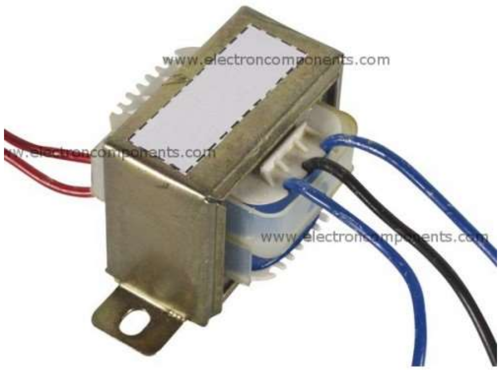


Figure 12: Picture of Transformer [4]

MSP430g2553 ADC10 Logic Diagram

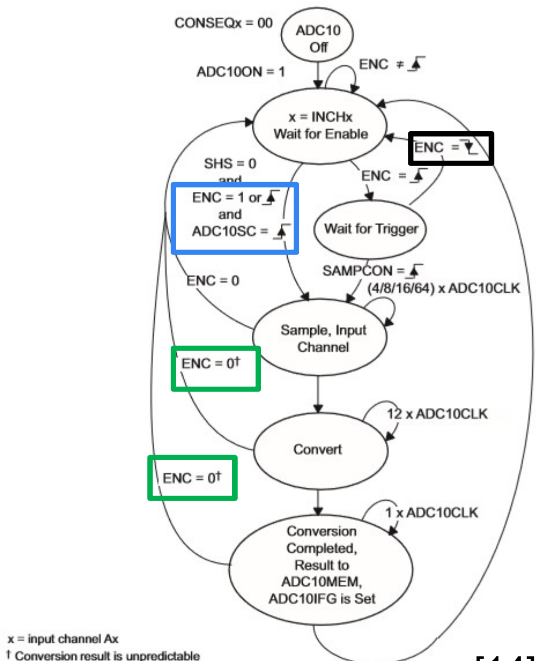


Figure 22-5. Single-Channel Single-Conversion Mode [14]

- Start sampling on rising edge of ENC and ADC10SC (Blue square)
- On falling edge of ENC, stop the ADC with unpredictable results (Green squares)
- Set ENC to 0 at end of conversion (Black square)

ADC10 Setup and interrupt Code

```
// Setup ADC10
ADC10CTL0 = SREF_0 | ADC10SHT_2 | ADC10IE; // 3.3V and GND references, 16 sample cycles, ADC off, interrupts enabled
ADC10CTL1 = SHS_0 | ADC10DIV_0 | ADC10SSEL_0 | CONSEQ_0; // activate on SC bit, Straight binary, no divisions,single channel single conversion
ADC10AE0 = BIT0 | BIT2 | BIT3 | BIT4; //Set channel A0, A3, A4, and A5 as analog inputs
```

```
#pragma vector=ADC10_VECTOR
__interrupt void ADC10_ISR (void) {
    while(ADC10CTL1 & BUSY);
    //ADC10CTL0 &= ~ENC;  // Stop conversion
    ADC10CTL0 &= ~ADC10ON; // Turn off ADC
    switch(Channel){
    case 0 : { VoltageCH0 = ADC10MEM; break;}
    case 3 : { VoltageCH3 = ADC10MEM; break;}
    case 4 : { VoltageCH4 = ADC10MEM; break;}
    case 5 : { VoltageCH5 = ADC10MEM; break;}
    }
    ADC10CTL0 &= ~ADC10IFG; // clear interrupt flag
    TACCTL0 = CCIE; //Enable Timer 0 interrupt
}
```

- Channel variable keeps track of which channel the ADC is reading (Blue square)
- Turn off the ADC before reading so that it does not keep sampling (black square)
- Use a timer_A0 interrupt to give a 20ms delay between readings

Problems with ADC code

- Channel that the ADC reads does not switch in the timer interrupt (only read the first channel selected)
- ADC values change between MSP resets (0x360 to 0x3F0 for a 3V input)

ZigBee Module Communication

TTL-234X-3V3 – UART Converter Cable

Parameter	Description	Minimum	Typical	Maximum	Units	Conditions
V_{CC}	Supply Voltage	4.75	5.0	5.25	V	Dependant on the USB port that the TTL-234X-3V3 is connected to
I_{CC}	Supply Current	-	-	450	mA	Assuming connected to direct to a host port or a powered hub, and enumerated
T	Operating Temperature Range	-40	-	+85	°C	

Table 4.4 TTL-234X-3V3 Electrical Parameters

TTL-234X-3V3	USB to UART cable with +3.3V TTL level UART signals.	6 pin SIL, 0.1" pitch	6 core, UL2464 24 AWG, diam=5mm

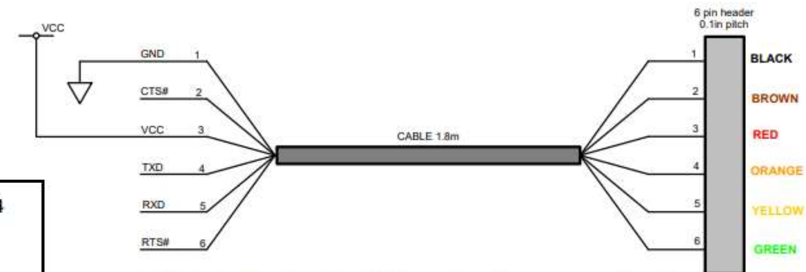


Figure 4.1 TTL-234X-5V and TTL-234X-3V3, 6 Way Header Pin Out

Tables and Figures from TTL-234X-3V3 Datasheet on Mouser.com [10]

UART Communication Program

Simple UART program for the ZigBee module to send the received data from the with the base station for display in the GUI. Made in the PyCharm IDE

```
import serial
import time

# open serial port @9600 baud and 100ms timeout
port = serial.Serial("/dev/ttyAMA0", baudrate=9600, timeout=0.1)


while True:  # main loop

        port.write("!")  # Send character to request data transmission from the ZigBee
        panelV_S = port.read(2) # Read the first 2 chars as the panel voltage
        panelI_S = port.read(2) # read next 2 as panel current and so on...
        DC_loadV_S = port.read(2)
        DC_loadI_S = port.read(2)
```

```
        # Conversion from ADC output ro real numbers happens here, not done at present time

        panelV = float(panelV_S)  # convert string to float, not how it will actually happen
        panelI = float(panelI_S)
        DC_loadV = float(DC_loadV_S)
        DC_loadI = float(DC_loadI_S)
```

UART Communication Program

```
panelP = panelV * panelI  # Calculate Power for each component
DC_loadP = DC_loadV * DC_loadI
inverterP = inverterV * inverterI
Buck_1_P = Buck_1_V * Buck_1_I
Buck_2_P = Buck_2_V * Buck_2_I

# Call write to GUI program
time.sleep(1) # wait 1 second before repeating
```

Alternate Plan for Base Station

Due to problems encountered in the creation of the Kivy Application, a backup plan has been created that uses a PC as the base station instead of the Raspberry Pi.

This will not change the that the GUI will be designed or the way the data will be transmitted from the Grid to and received by the Base Station. It only changes the platform used to develop the GUI and the data interface of the ZigBee module and the input device will be a mouse instead of a touchscreen.

Total Budget

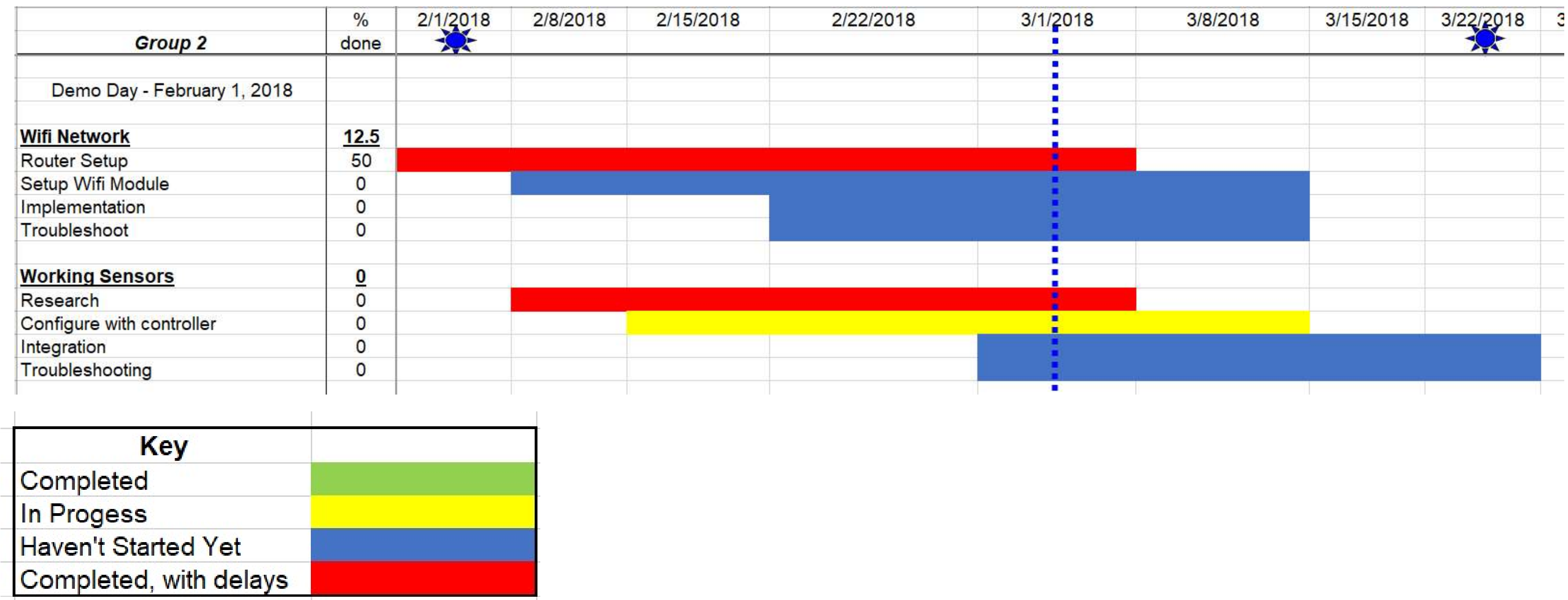
Lab 1 - Group 2	*Running Total*			*Total Estimate*			Start Date	2/1/2018
Direct Labor:							Today	3/1/2018
Category or individual:	*Rate/Hr*	*Hrs*		*Rate/Hr*	*Hrs*			
Kenneth	18	42	$756.00	18	215	$3,870.00	End Date	5/5/2018
Jared	18	37	$666.00	18	215	$3,870.00	Days Past	28
Justin	18	41	$738.00	18	215	$3,870.00	Total Days	93
Juan	18	36	$648.00	18	215	$3,870.00	Days Left	65
DL Subtotal (DL)		Subtotal:	$2,808.00		Subtotal:	$15,480.00		
Labor Overhead	*rate:*	100%	$2,808.00	*rate:*	100%	$15,480.00		
Total Direct Labor (TDL)			$5,616.00			$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	2	$400.00	$200	20	$4,000.00		
Total Contract Labor (TCL)			$400.00			$6,400.00		
Direct Material Costs:			$120.00			$650.00		
(from Material Cost worksheet)								
Total Direct Material Costs: (TDM)			$120.00			$650.00		
Equipment Rental Costs:	Value	Rental Rate		Value	Rental Rate		Date begin	Date end (or today)
Oscilloscope	$5,300.00	0.20%	$296.80	$5,300.00	0.20%	$985.80	2/1/2018	5/5/2018
Function Generator	$500.00	0.20%	$28.00	$500.00	0.20%	$93.00	2/1/2018	5/5/2018
DMM	$958.00	0.20%	$53.65	$958.00	0.20%	$178.19	2/1/2018	5/5/2018
Power Supply	$1,700.00	0.20%	$95.20	$1,700.00	0.20%	$316.20	2/1/2018	5/5/2018
Soldering Station	$100	0.20%	$5.60	$100.00	0.20%	$18.60	2/1/2018	5/5/2018
Total Rental Costs: (TRM)			$473.65			$1,573.19		
Total TDL+TCL+TDM+TRM			$6,609.65			$39,583.19		
Business overhead		100%	$6,609.65		100%	$39,583.19		
Total Cost:		**Current**	$13,219.30		**Estimate**	$79,166.38		

Jared Tulio

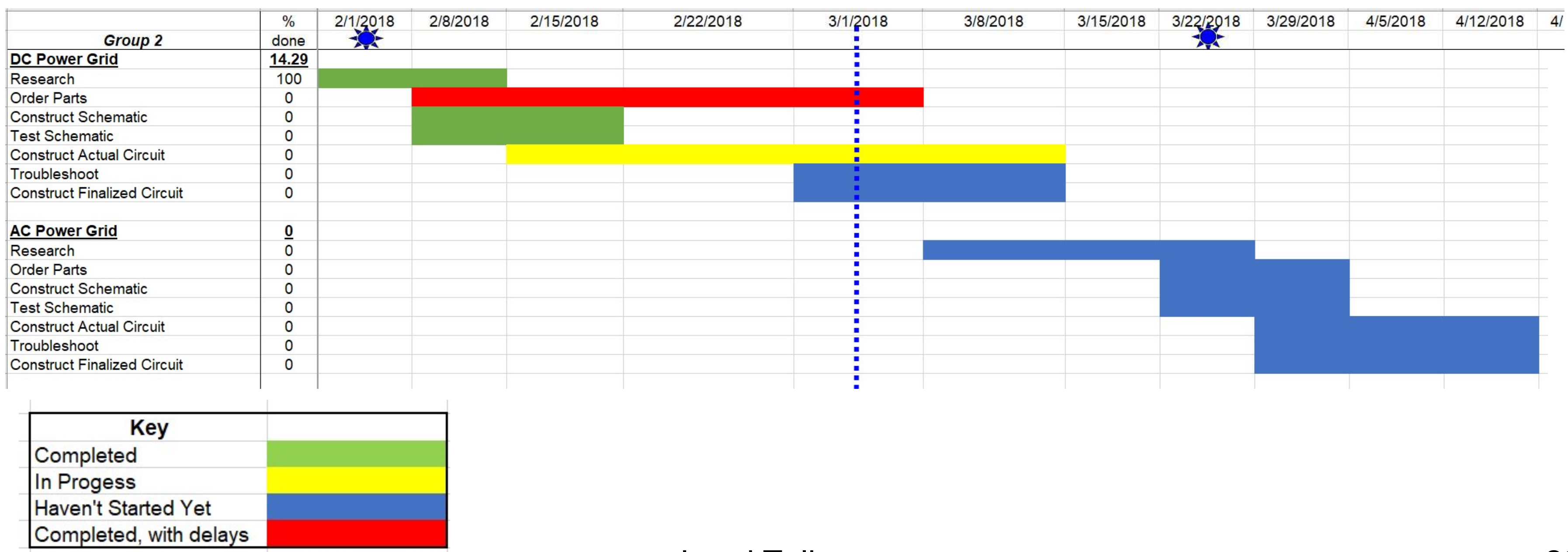
Total Budget Cont'd

Name	Cost	Quantity	Website	Notes	Purchase Date	Total		TOTAL
XB WiFi Module	$19.00	3	SparkFun	NA		$57.00		$601.64
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		
SMAKN 20A Buck Converter	$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		
Tamura 10A Current Sensor	$16.61	3	Mouser	NA		$49.83		
Power Inverter	$70.00	1	Amazon	NA		$70.00		
Sparkfun Beefcake 2.0	$7.95	3	Digikey	NA		$23.85		
8-bit Microcontroller	$1.22	1	Mouser	NA		$1.22		
Heat Sink	$4.00	1	Mouser	NA		$4.00		
Resettable Fuse	$0.63	2	Mouser	NA		$1.26		

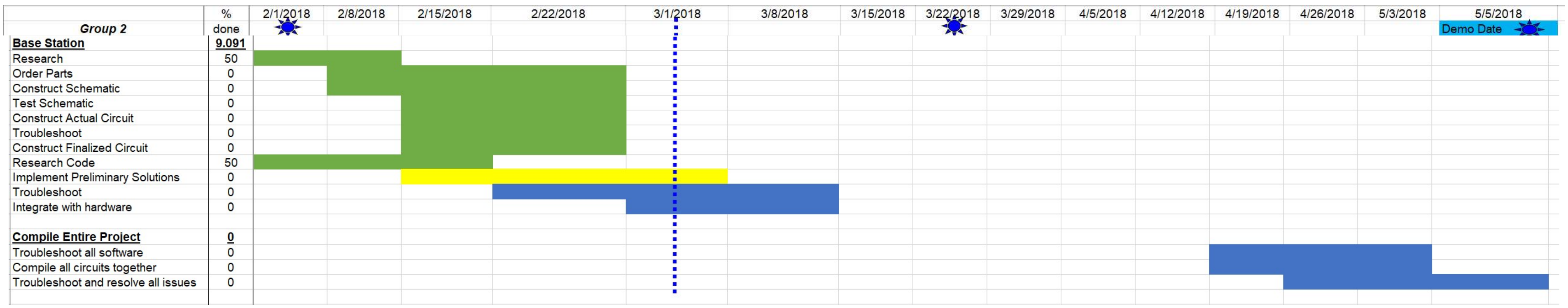
Gantt Chart


Group 2
% done
2/1/2018
2/8/2018
2/15/2018
2/22/2018
3/1/2018
3/8/2018
3/15/2018
3/22/2018
Demo Day - February 1, 2018
Wifi Network 12.5
Router Setup 50
Setup Wifi Module 0
Implementation 0
Troubleshoot 0
Working Sensors 0
Research 0
Configure with controller 0
Integration 0
Troubleshooting 0
Key
Completed
In Progess
Haven't Started Yet
Completed, with delays

Gantt Chart Cont'd



Gantt Chart Cont'd



Key	
Completed	
In Progess	
Haven't Started Yet	
Completed, with delays	

Jared Tulio

Gantt Chart Cont'd

Milestones	Date
Wife Network	3/15/2018
Working Sensors	3/22/2018
DC Power	3/15/2018
AC Power	4/12/2018
Base Station	3/22/2018
Combining Everything	5/3/2018

Deliverables for Next Week

- Finish and test UART program
- Continue development of PC GUI program
- Build DC to AC 1 to 1 Inverter
- Receive parts and build charge controller

References

[1] http://www.theorycircuit.com/simple-inverter-circuit-using-ic-555/

[2] http://www.ti.com/lit/ds/symlink/lm555.pdf

[3] http://www.st.com/content/ccc/resource/technical/document/datasheet/f7/e1/96/88/57/15/4a/23/CD00000922.pdf/files/CD00000922.pdf/jcr:content/translations/en.CD00000922.pdf

[4] http://www.electroncomponents.com/9-0-9-500mAmp-9V-Transformer

[5] http://www.uni-kl.de/elektronik-lager/418072

[6] https://www.energymatters.com.au/components/micro-string-central-inverters/

[7] http://www.theorycircuit.com/pv-solar-inverter-circuit-diagram/

[8] http://www.efxkits.us/12v-dc-to-120v-ac-inverter-circuit/

[9] http://www.electroncomponents.com/9-0-9-500mAmp-9V-Transformer

[10] https://www.mouser.com/ProductDetail/FTDI/TTL-234X-3V3

[11] https://www.mouser.com/ds/2/268/41190G-890246.pdf

[12] https://www.mouser.com/ds/2/643/0ZRB_Jan2017-1131096.pdf

[13] http://www.nutsvolts.com/index.php?/magazine/article/March2014_Newton

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

Questions?