19 - Wireless Solar Temperature/Humidity Sensor

Group Number: May 1717

Advisor: Gary Tuttle

Client: Dan Stieler

Members: *Yi Qiu, Xiang Li, Kuk Jin Chung, Trevor Brown, Kebei Wang*

Our Advisor & Client

Advisor: Gary Tuttle

Client: Dan Stieler (Powerfilm Company)

Problem

- Design a low power consumption circuit system that measure temperature and humidity
- Data has to be wirelessly transmitted to mobile devices
- The system should be solar powered and physically small

Problem Statement

- This solar powered system needs to measure the temperature and humidity as well as translate the data through wireless transmission to mobile devices
- The view of design and analysis is on how much low power that the system can consume and be useable

Solution

- Consider different ways of data transmission and test different sensor technologies for lowest power consumption
- We also need to choose the solar panel and battery to work continuously in low light conditions

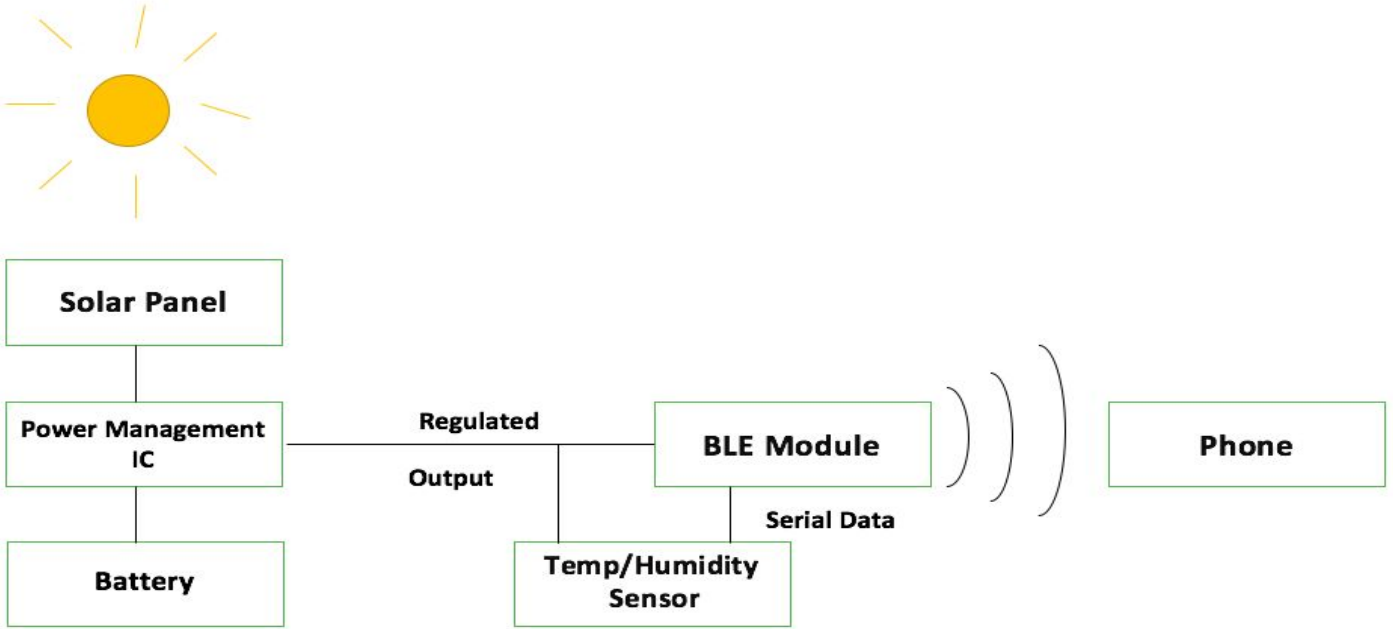
Purpose of Project

- Provide wireless temperature and humidity data on a mobile device
- Reduce power consumption
  - Extend the operating time for the battery
  - System last longer without recharging at night
  - Makes the system physically smaller

Requirements

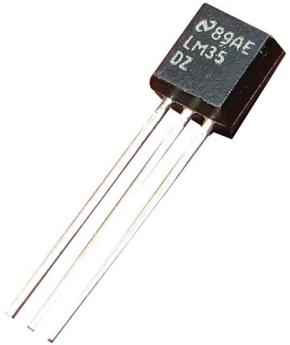
- Functional Requirements
  - Keep the system operable under 400 lux light level
  - Keep power consumption low
  - Precisely measure and record the temperature and humidity changes from the sensor
- Non-Functional Requirements
  - The scale of the system should be small
- Operating Environments
  - The system should work effectively within 10 meters indoors and outdoors

Functional Decomposition



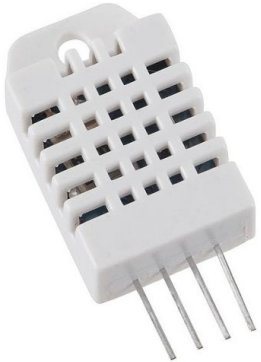
Design Detail

Temperature/Humidity Sensors:

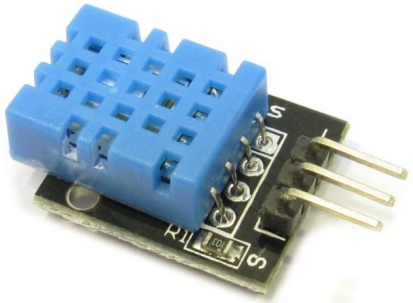


LM35

HDC1080



DHT22



DHT11

Sensor Details

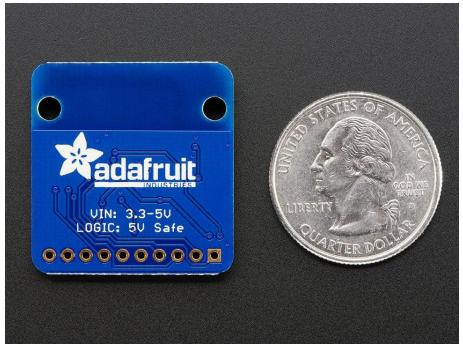
	LM35	HDC1080	DHT22	DHT11
Minimum Tested Voltage Supply (V)	4	2.7	3	3
Temp Range (°C)	-55 ~ 150	-40 ~ 125	-40 ~ 125	0 ~ 50
Temp Accuracy (°C)	0.5	0.2	0.5	2
Humidity Range (%)	NA	0 ~100	0 ~ 100	20 ~ 90
Humidity Accuracy (%)	NA	2	2	5
Idle Current	0.0529mA	0.100uA	40uA	150uA
Average Current During 1Hz Polling	0.0529mA	0.041mA	1.56mA	1.23mA

Wireless Communication

- We want to use Bluetooth for lower cost and decide to use Bluetooth low energy as it consume less power than traditional Bluetooth and WiFi

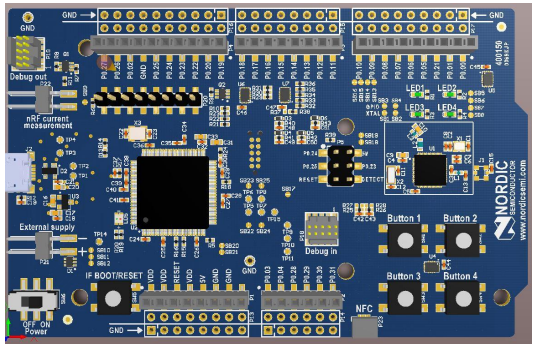
Design Detail

BLE Module: Nordic NRF8001 IC on Adafruit module board



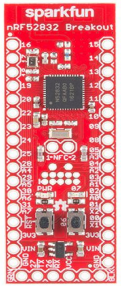
Design Detail

nRF52 DK



Design Detail

- Sparkfun NRF52832 Breakout
  - Uses reference design for NRF52832
  - Small usable package that is easy to program
  - Lower power consumption than the NRF52 DK

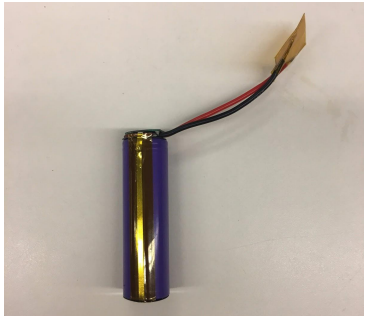


Design Detail

LG 18650 Rechargeable

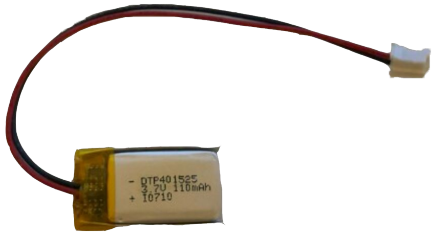
Lithium Ion with Protection Device

3200mAh 3.7V



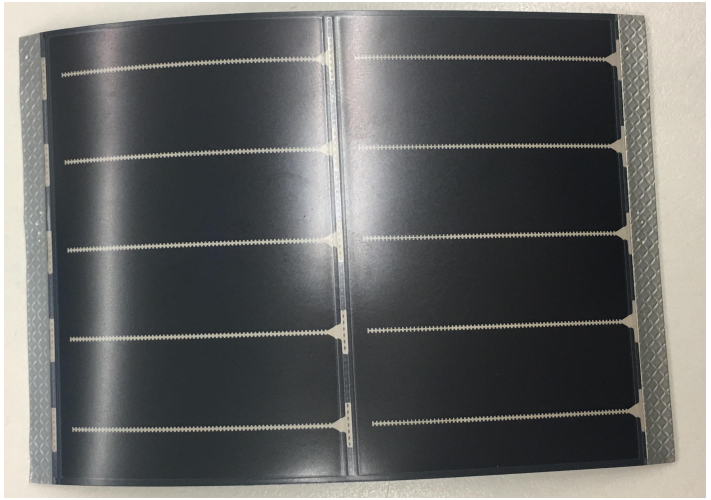
Lithium polymer battery 401525

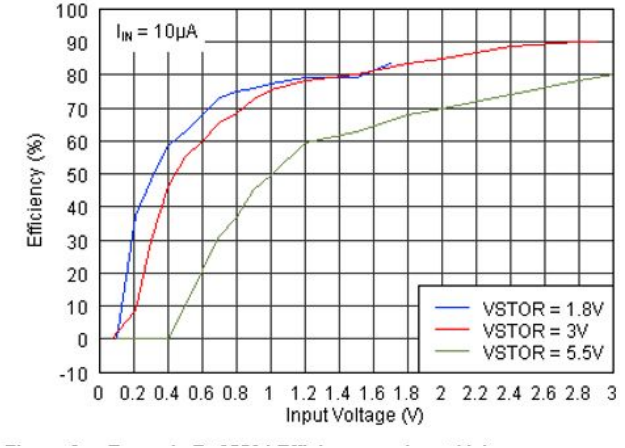
110mAh 3.7V



Design Detail

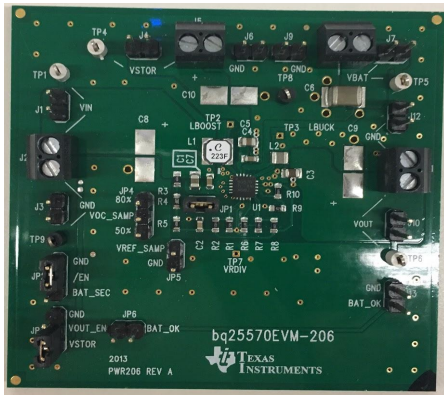
Solar panel: 2 Volt open circuit output, 35uA short circuit current at 400 lux test level



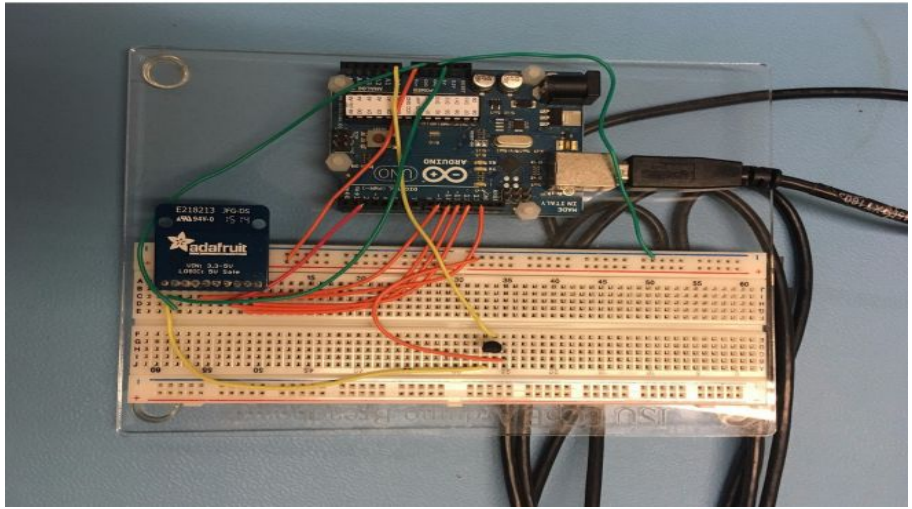


Design Detail

- Power Management: TI BQ25570 Energy Harvester Development Board
  - Takes the power from the solar panel and charges the battery using switching mode power supply



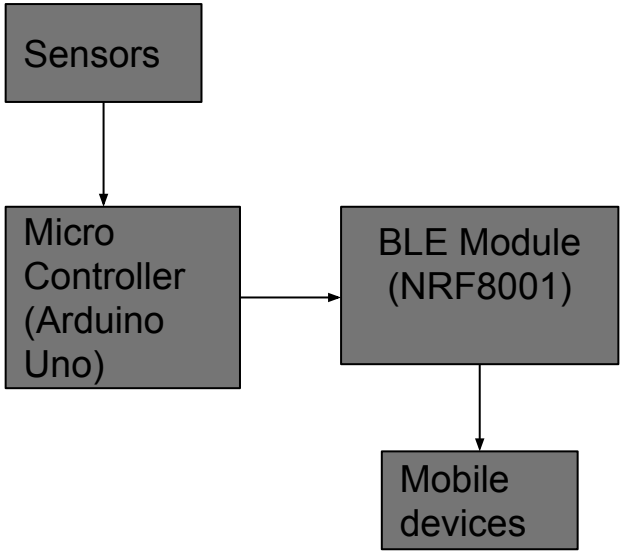
First Design Test Circuit



Components Used

- Arduino Uno
- NRF 8001
- Temperature sensors
  - LM35
  - DHT11
  - DHT22

First Design Test Circuit



Communication Protocol

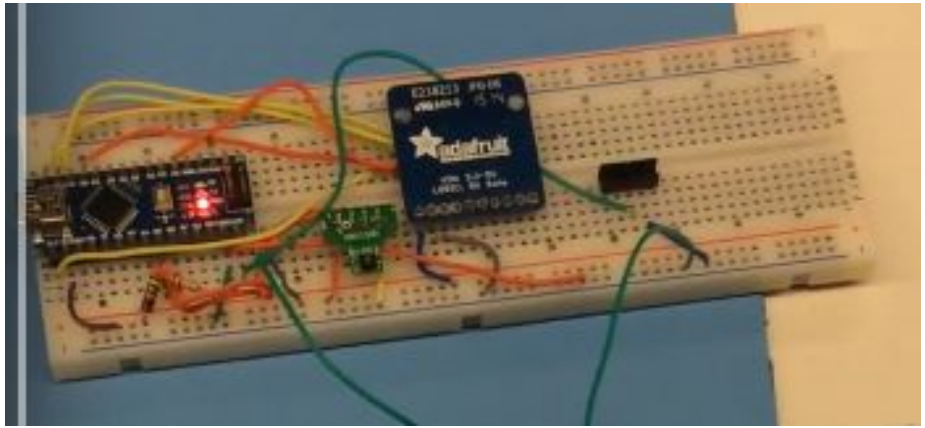
- LM35 - Analog signal
- DHT11 and DHT22 - Digital signal 1-wire

nRF8001 BLE - Arduino	
SCK	Pin 13
MISO	Pin 12
MOSI	Pin 11
REQ	Pin 10
RDY	Pin 2
RST	Pin 9
GND	GND
VIN	5V

LM35 - Arduino	
Vout	A0
Vcc	5V
GND	GND

DHT11 and 22 - Arduino	
Vout	Pin 4
Vcc	5V
GND	GND

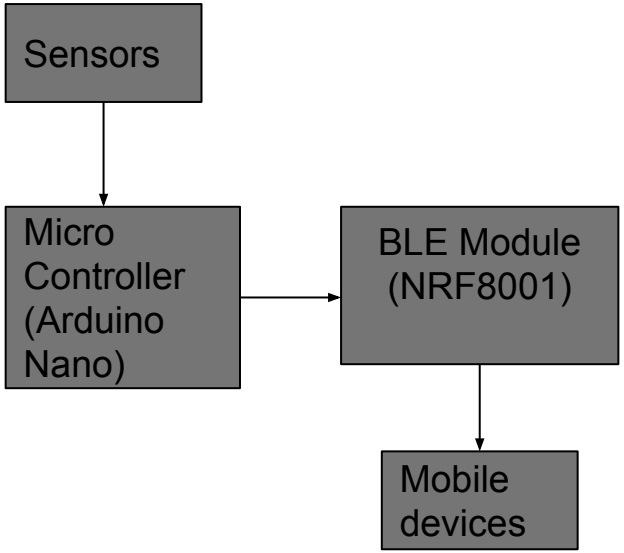
First Design Circuit Revised



Components Used

- Arduino nano
- NRF 8001
- Temperature sensors
  - HDC1080

First Design Circuit Revised



Communication Protocol

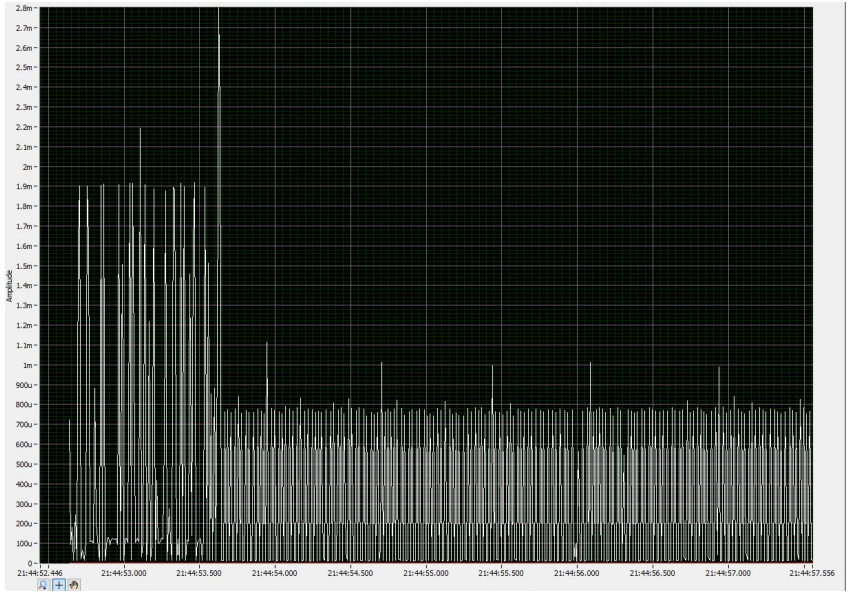
- HDC1080 - I2C

nRF8001 BLE - Arduino	
SCK	Pin 13
MISO	Pin 12
MOSI	Pin 11
REQ	Pin 10
RDY	Pin 2
RST	Pin 9
GND	GND
VIN	5V

HDC1080 - Arduino	
SCL	Pin 19
SDA	Pin 18
Vcc	3.3
GND	GND

First Circuit Testing

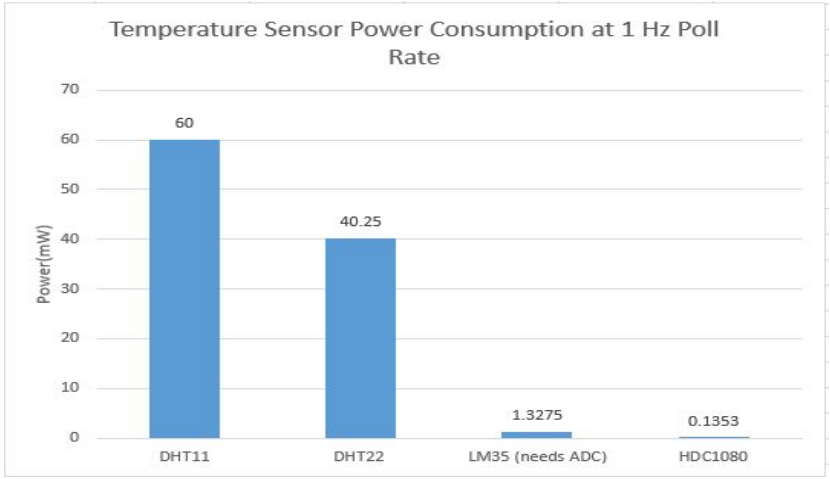
- Current is measured using Signal Express and a multimeter
- 500uA average current during transmission

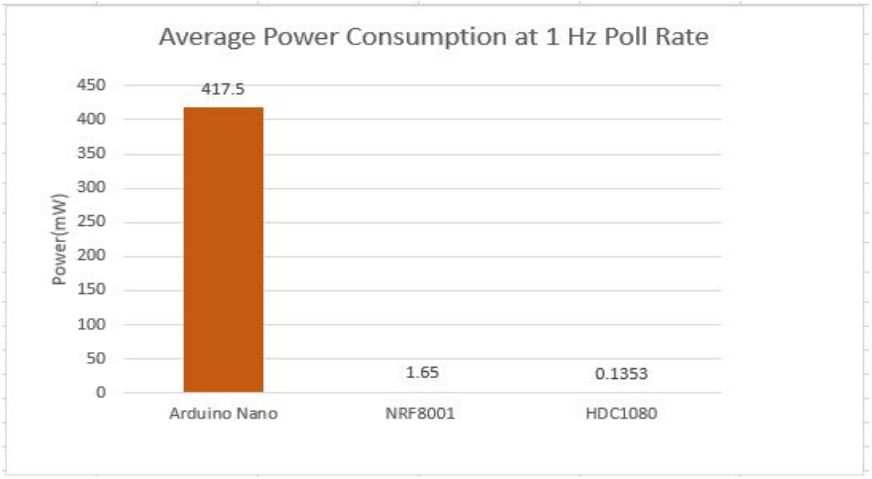


First Circuit Revised Bill of Materials

item	Qty.	cost($)	part Description	Supplier	Supplier #	Sub Total($)
1	1	1.5	rechargeable whole sale 3.7 small lithium battery 401525 100mAh	alibaba.com		1.5
2	1	19.95	BreakOUT LE BT BLE4.0 NRF8001 V1	digikey.com	1528-1199-ND	19.95
3	1	21.49	ARDUINO NANO BOARD	digikey.com	1050-1001-ND	21.49
4	1	10.95	HDC1080 High Accuracy Humidity/Temperature Sensor	tindie.com		10.95
Total						53.89

First Design Circuit





Results

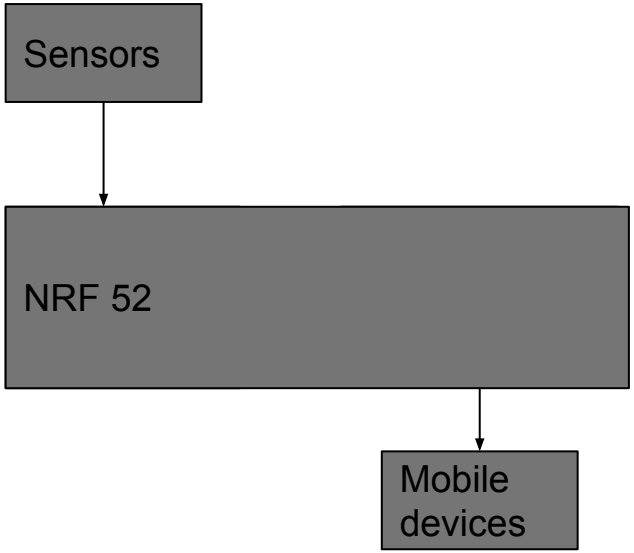
1. We found out which components consumed the most power
2. Chose the best sensor based on power consumption and accuracy

Programming

Libraries

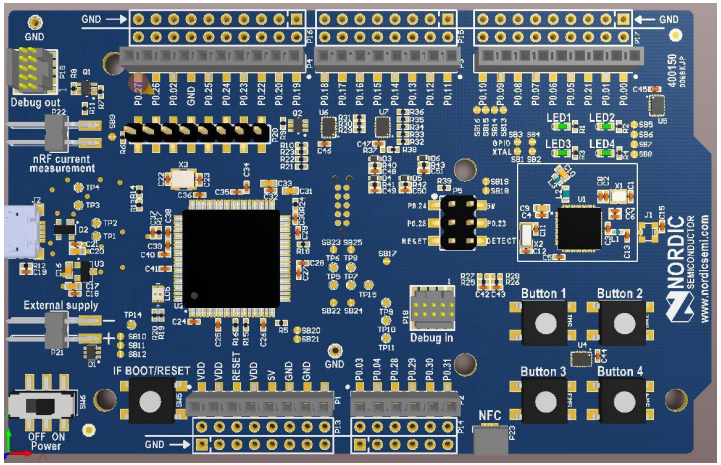
• SPI.h	- Serial Monitoring
• Wire.h	- I2C communication
• Adafruit_BLE_UART.h	- BLE UART communication
• ClosedCube_HDC1080.h	- HDC1080 Arduino functions
• DHT.h	- DHT sensor functions
• BLE Peripheral	- Final BLE functions

Second Design Circuit



HDC1080 - NRF52 Development kit	
SCL	Pin 26
SDA	Pin 27
Vcc	3.3V
GND	GND

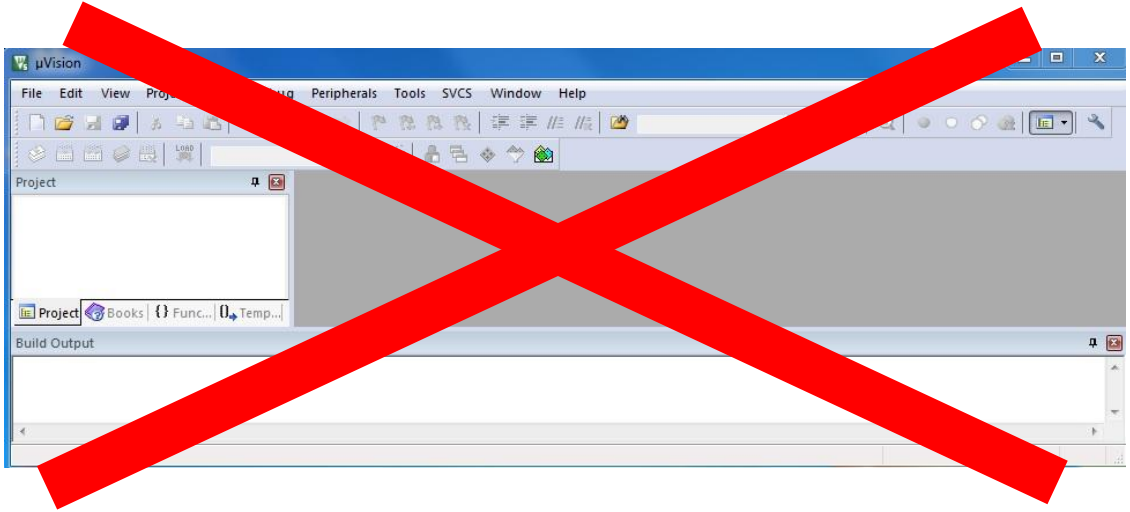
Second Design Circuit



NRF 52

- Lower power consumption
- Lower voltage supply(1.7 V - 3.7V)
- Include BLE module with microcontroller inside

Software Challenge



- Nordic programing software uVision5 to test the NRF52 BLE function inside the microcontroller

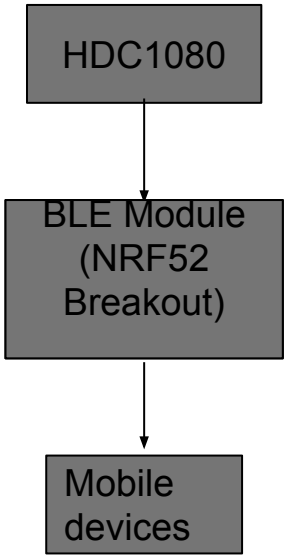
Second Design Circuit

- NRF52 Development kit design was abandoned due to programming difficulties
- uVision 5 was very hard to use and implement the library for our temperature sensor

Final Design Circuit

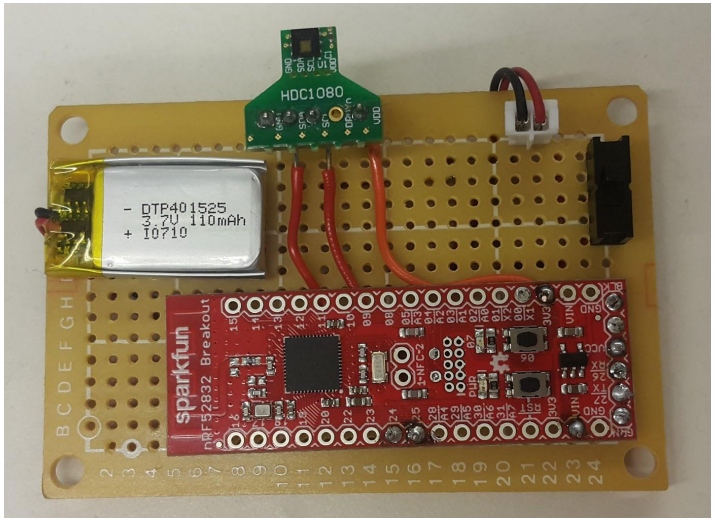
- The final version circuit uses the Sparkfun NRF52382 along with the temperature sensor
- This was easier to program than the NRF52 development kit
- Smaller and less board area than the development kit

Final Design Circuit



HDC1080 - NRF52 Breakout	
SCL	Pin 24
SDA	Pin 25
Vcc	3.3V
GND	GND

Final Design Circuit



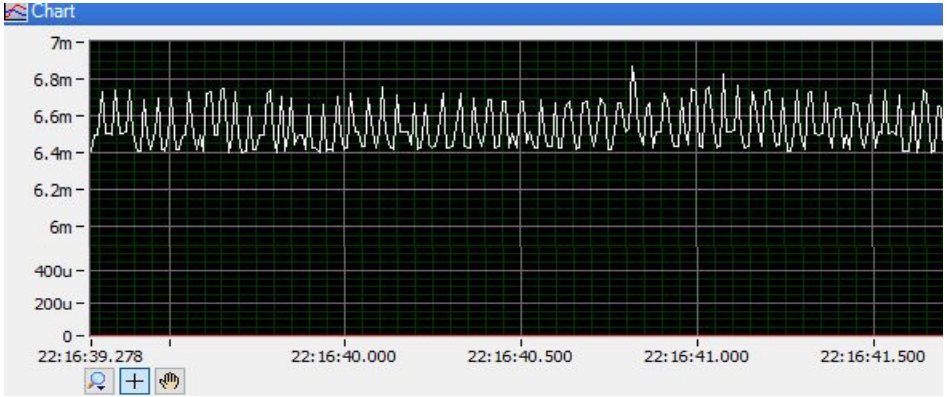
- Eliminates the NRF52 development kit extras to lower power consumption
- Easier to program

Final Design Circuit

- The final design circuit was easier to program via Arduino IDE
- The library for the HDC1080 was hard coded into the BLE serial program
- HDC1080 library did not work as wire.h library is implemented differently on the NRF52382
- BLE serial program from the BLE Peripheral library is the only way to get the same mobile functionality as the first circuit

Final Circuit Testing

- Consumed more current than the 2nd circuit
- Serial function is coded in a way that consumes more power than the 2nd circuit
- 6.5mA average current
- Battery lasted over 16 hours transmitting at 1Hz without the solar panel



Final Design Bill of Materials

item	Qty.	cost($)	part Description	Supplier	Supplier #	Sub Total($)
1	1	1.5	rechargeable whole sale 3.7 small lithium battery 401525 110mAh	alibaba.com		1.5
2	1	19.95	NRF52832 BREAKOUT	digikey.com	1568-1449-ND	19.95
3	1	10.95	HDC1080 High Accuracy Humidity/Temperature Sensor	tindie.com		10.95
Total						32.4

item	Qty.	cost($)	part Description	Supplier	Supplier #	Sub Total($)
1	1	1.5	rechargeable 3.7V small lithium battery 401525 110mAh	alibaba.com		1.5
2	1	2.11	HDC1080 sensor	digikey	296-43864-2-ND	2.11
3	1	2.53	NRF52 IC	digikey	1490-1055-2-ND	2.53
4	1	3.5	NRF52 supporting components	digikey	various	3.5
5	1	4	OSH park pcb medium run 2 square inches	osh park		4
Total						13.64

Conclusion:

- We figured out which part in the system consumes the most power
- We chose the lowest power consuming components to reconstruct the circuit.
- Different current consumption occurred based on the programing and different BLE modes.

Bill of Components

Wireless Solar Temperature and Humidity Sensor Circuit						
Bill of components						
Item	Qty.	Cost($)	part Description	Supplier	Supplier#	Sub Total($)
1	1	1.86	SENSOR TEMP ANLG VOLT TO-92-3	digikey.com	LM35DZ/NOPB-	1.86
2	1	5	DHT11 basic temperature-humidity sensor + extras	adafruit.com	386	5
3	1	9.95	DHT22 temperature-humidity sensor + extras	adafruit.com	385	9.95
4	1	29.09	LOW POWER HUMIDITY AND TEMP EVAL	digikey.com	296-43865-ND	29.09
5	1	21.49	ARDUINO NANO BOARD	digikey.com	1050-1001-ND	21.49
6	1	23.38	ATmega328P Arduino Uno AVR® ATmega MCU 8-Bit AVR Embedded Evaluation Board	digikey.com	1050-1024-ND	23.38
7	1	19.95	NRF52832 BREAKOUT	digikey.com	1568-1449-ND	19.95
8	1	19.95	BREAKOUT LE BT BLE4.0 NRF8001 V1	digikey.com	1528-1199-ND	19.95
9	1	1.5	rechargeable wholesale 3.7V small lithium battery 401525 100mAh	alibaba.com		1.5
Total						132.17

Market Research

Name of product	LACrosse Technology Solar Powered Wireless Temperature Station and Sensor -WS-8120U-IT-BR-T	Oregon scientific BAR206 Weather Forecast Temperature Station	Our Design
Price	$42	$44.99	$32.40
Transmission Distance	200 ft.	98 ft.	33 ft.
Maximum Humidity Range	20%-95%	25%-95%	0%-100%
Maximum Temperature Range	-39.6°C-59.9°C	-5°C - 60°C	-40°C-125°C
Operating time without solar panel	12 h	12h-24h	16h

Questions ?