LOW POWER EMBEDDED DESIGN PROJECT UPDATE #2

Team Name : WearTech

Team Mates:

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Part Selection:

Battery : LIPO 785060, 2500 mAH
PMU IC : LT1121
Processor : Blue gecko BGM11S module
As discussed, our project requires 2 Blue Gecko dev kits to act as devices in the mesh network.
Sensor1 : Triple Axis Accelerometer ADXL345

Sensor2 : Capacitive sense PCF8885

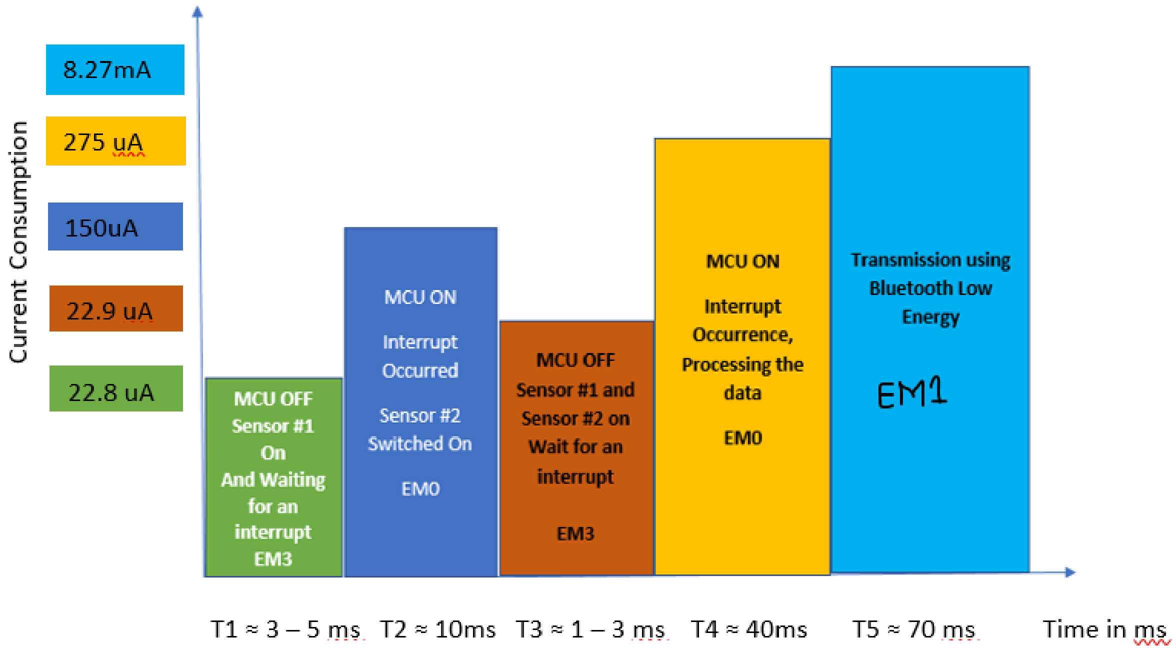
Table 1: Energy modes vs Current Consumption of Blue Gecko:

Energy modes	Current Consumption
EM0	130 uA
EM1	65 uA
EM2	3.3 uA
EM3	2.8 uA
EM4	1.1 uA

Table 2: Voltage and Current of all components:

Device	On Duty Cycle Current	Off Duty Cycle Current	Supply Voltage	Input Voltage
Blue Gecko (MCU)	EM0: 130 uA /MHz	EM3: 2.8 uA	2.4 - 3.8 V	
Cap Sense	20 uA	500 nA (Typical 100 nA)	2.5 - 5.5 V	2.5 to 3.3 V
Accelerometer	145 uA(100 Hz) , 40uA(<10Hz)	0.1 uA	2- 3.6 V	1.7V -Vs(Typ 1.8V) (Vs<=2.5) 2.0V- Vs(Typ 2.5) (Vs>=2.5)
BLE Radio Communication	8.2 mA(0 db)	-	-	-

Use Case Model:



Use Case model condition: When the user switches on the device and immediately sends the data (does an action)

State 1: MCU is off, Sensor #1 i.e Capacitive sense is On and it is waiting for an interrupt to switch on the entire device. The device stays in this state for about 3-5 ms after the user has used touch sense to switch on the device. The capacitive sense we have chosen uses I2Cs serial port interface which works in EM3 for Blue Gecko and also, we wait for an interrupt in EM3 energy mode.

State 2: MCU becomes on when an interrupt occurs, hence it will be in EM0 mode. In the interrupt service routine sensor #2(Accelerometer) is switched on. This state will take about 10 ms to handle the interrupt and switch on sensor #2.

State 3: In this state, MCU is off while sensor #1 and sensor #2 are on. Sensor #2 is waiting for an interrupt i.e sensor #2 is waiting to receive data from the user. As use case considered is when user switches on the device and immediately writes the data, this state will approximately take 1-3 ms.

State 4: In this state, MCU becomes on when an interrupt occurs i.e when data is received from the user and the data is processed. This state will approximately take 40 ms to handle the interrupt and process the data.

State 5: In this state, the data is transmitted to the mobile phone using BLE and it is interpreted to display the character received. This will take about 70 ms and operates in EM1 for transmission.

Calculations:

Duty cycle:

The worst case time-deduced from the Use Case model- to process a character is 300 ms.
Considering an idle user , say a maximum of 50 commands and 200 characters per day is expected.

Total On time of the device = On time for commands(character) + On time for text(string)
= 300ms * 50 + 300 ms * 200
= (15/(60*60)) + (60/ 60 * 60)
= 0.0042 hrs + 0.02 hrs
= 0.0242 hrs

The device should be usable for 12 hrs in a day.
On duty cycle = 0.0242 /12 => 0.2 %

Hence, Off time of the device = 12 - 0.0242
= 11. 9758 hrs
Off duty cycle = 11. 9758/12 => 99.8 %

Determining the average weighted power out of battery using Blue Gecko:

On duty cycle:
Blue Gecko's efficiency at ~3.3v input to ~2.5v out is 2.5v/3.3v = 75.75%
Weighted average power out of battery = (On duty cycle * On time current * 2.5v) / 75.75%
= (0.2 * 8.495mA * 2.5v) / 75.75%
Weighted average power out of battery = 56.07 uW

Off duty cycle:
Blue Gecko efficiency at ~3.3 input to ~2.5v out is 2.5v/3.3v = 75.75%
Weighted average power out of battery = (Off duty cycle * Off time current* 2.5v) / 75.75%
= (98.8 * 3.4 uA * 2.5v) / 75.75%
Weighted average power out of battery = 11.086 uW

Total average power out = Weighted on duty cycle average power + Weighted off duty cycle average power
= 56.07 uW + 11.086 uW
= 67.15 uW

Average energy the battery must provide on the use case:
= 12 hrs of use * 60 mins * 60 secs * 67.15 uW
= **2.9J**

Battery:

As per our calculation, we need a battery with the following specifications:

- Average energy 2.9J
- Vout from the Battery is ≈ 3.3v
- Max current required 8.495mA (all on - MCU, Sensors, BLE)
- If the product is targeted to be used for 1.5years , 5 days a week. We have 390 recharge cycles.
  With weighted average power = (0.2% * 8.495m) + (99.8% * 3.4 uA) = 2.03mA
  2.03mA * 12 (->12 hours) = 24.36mAh
  For rechargeable cells the battery nominal capacity should be 10x capacity
  Thus total => 243.6mAh

According to the above specifications we have chosen: (LIPO 785060)Lithium Ion Polymer Battery with 2500mAh & 3.7V output voltage => The energy would be 9.25J

3、 Specification

Item		Specifications	Remark
Nominal Capacity		2500mAh	0.2C_5A discharge，25℃
Nominal Voltage		3.75V	Average Voltage at 0.2C_5A discharge
Standard Charge Current		0.2 C_5A	Working temperature：0~40℃
Max Charge Current		1C_5A	Working temperature：0~40℃
Charge cut-off Voltage		4.2V	CC/CV
Standard Discharge Current		0.5C_5A	Working temperature：25℃
Discharge cut-off Voltage		2.75V	
Cell Voltage		3.7-3.9V	When leave factory
Impedance		≤35mΩ	AC 1KHz after 50% charge,25℃
Weight		Approx:46g	
Storage temperature	≤1month	-10~45℃	Best 20±5℃ for long-time storage
	≤3month	0~30℃	
	≤6month	20±5℃	
Storage humidity		65±20% RH	

Item	Test Methods	Performance
0.2C Capacity	After standard charging, laying the battery 0.5h, then discharging at 0.2C_5A to voltage 2.75V, recording the discharging time.	≥300min
1C Capacity	After standard charging, laying the battery 0.5h, then discharging at 1C_5A to voltage 2.75V, recording the discharging time.	≥54min
Cycle Life	Constant current 0.5C_5A charge to 4.2V, then constant voltage charge to current declines to 0.05C_5A stay 5min constant current 0.5C_5A discharge to 2.75V, stay 5min. Repeat above steps till continuously discharging time less than 36min.	≥400times
Capability of keeping electricity	20±5℃, After standard charging, laying the battery 28days, discharging at 0.2C_5A to voltage2.75V, recording the discharging time.	≥240min

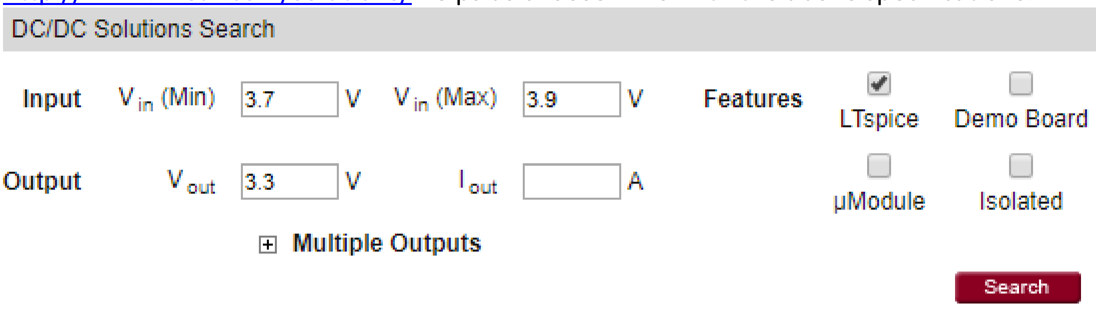
Above calculations (LIPO 785060) substantiates the choice of the Energy source to be Battery and not Super-Capacitor.
Batteries provide consistent voltage (3.3 V) - which is within the voltage range of the components we are using in our application. Since our application does not require any bursts of current and we need our device to discharge the power for a long time - we choose Battery.

Power Management Unit:

In our project, Blue Gecko MCU can be operated at 3.3 V which can in-return drive the sensors with the same 3.3V.
With LiPo Battery of 2500mAh and 3.7V (typical) we have

- Vin= 3.7V(min) to 3.9V(max)
- Vout = 3.3 V.

http://www.linear.com/solutions/ helps us choose PMU with the above specifications.



We have chosen "LT1121 5V Battery-Powered Supply with Shutdown" as our PMU

Features

- 0.4V Dropout Voltage
- 150mA Output Current
- 30µA Quiescent Current

- No Protection Diodes Needed
- Adjustable Output from 3.75V to 30V
- 3.3V and 5V Fixed Output Voltages
- Controlled Quiescent Current in Dropout
- Shutdown
- 16µA Quiescent Current in Shutdown
- Stable with 0.33µF Output Capacitor
- Reverse Battery Protection
- No Reverse Current with Input Low
- Thermal Limiting

More Info :
http://www.linear.com/solutions/4777
http://www.linear.com/product/LT1121
http://cds.linear.com/docs/en/datasheet/1121fg.pdf

The battery gives a range of 3.7 to 3.9 output voltage and the PMU is fixed at 3.3v output.
The MCU is driven from the PMU and MCU further drives Accelerometer, CapSense & BLE.
The MCU,sensors,BLE can work in the max-min 2.5V to min-max-3.6V.
Our digital/analog portion does not require a fixed voltage range but we have chosen a 3.3 fixed output voltage from the PMU.
Thus accordingly, we presume the power supply to be a regulated power supply.

Accomplishments:
- We are on schedule for the project.
- We have obtained energy profile determining current in each mode of operation and its functionality.
- We have completed parts selection including energy storage device and power management unit.
- We have calculated the peak current and the amount of energy that has to be supplied to the circuit from the battery.
- We have decided on regulated vs unregulated power supply

Next week:
- Schematics design for the circuit
- Energy spiked calculation
- Simulation of Voltage droop
- We need to work on the Machine Learning Algorithms to see which would be a good fit for data extraction and prediction.