Power Management Analysis

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Background:

Our system includes a microcontroller and a light sensor, which has an average power consumption of 100uA - 1mA. The microcontroller is in charge of controlling the sampling processes and data processing, while the light sensor is in charge of detecting light and sending interrupts to inform the system of the light levels at regular intervals. The system needs to take a light sample every 15 minutes for 12 hours a day for a maximum of 15 seconds for each sample. For the other 12 hours, our system can be in low-power mode without interruptions. We also take both the running and low power modes into consideration when calculating the power measurements. To optimize battery life while ensuring all necessary functionalities are maintained, we're exploring all permutations of three running modes and seven low-power modes. This exhaustive analysis allows us to identify the most efficient power mode combination for our specific task requirements.

Our goal is to find the optimal power mode configuration that maximizes battery life while meeting operational needs. This involves fine-tuning the microcontroller's power modes to strike a balance between energy efficiency and functionality. We are focusing on the STML432KC microcontroller and TSL237 light sensor. We are using the CubeMX power consumption calculator in STMCubeIDE to determine the power consumption values.

Analysis:

Here is a table of all permutations of running modes with their respective sequence time, average consumption, battery life estimate, and average DMIPS:

Run Mode	Sleep Mode	Sequence Time	Avg Consumption	Battery Life Est.	Avg DMIPS
Run (Range 2)	SLEEP	1 ms / 104.95 C	225.1 uA	2 months, 23 days, 4 hours	5
Run (Range 2)	STOP 0	1 ms / 104.95 C	145.9 uA	2 months, 2 days, 20 hours	5
Run (Range 2)	STOP 1	1 ms / 104.95 C	50.48 uA	1 year, 6 months, 21 days, 15 hours	5
Run (Range 2)	STOP 2	1 ms / 104.95 C	47.36 uA	1 year, 11 months, 4 days, 3 hours	
Run (Range 2)	STANDBY + 32KB	1 ms / 104.95 C	46.36 uA		5
Run (Range 2)	STANDBY	1 ms / 104.95 C	46.08 uA	2 years, 1 months, 18 days, 7 hours	5
LPRUN	LPSLEEP	1ms / 104.97 C	86.42 uA	3 months, 16 days, 18 hrs	3
LPRUN	STOP 0	1ms / 104.97 C	121.7 uA	2 months, 15 days, 23 hrs	3
LPRUN	STOP 1	1ms / 104.97 C	26.6 uA	11 months, 13 days	3
LPRUN	STANDBY	1ms / 104.97 C	22.16 uA	1 yr, 1 month, 20 days, 12 hrs	3
Run (Range 1)	SLEEP	1 ms / 103.98 °C	912.73 uA	10 days, 6 hours	10
Run (Range 1)	LPSLEEP	1 ms / 103.98 °C	809.45 uA	11 days, 13 hours	9
Run (Range 1)	STOP 0	1 ms / 103.98 °C	892.73 uA	10 days, 11 hours	100
Run (Range 1)	STOP 1	1 ms / 103.98 °C	796.3 uA	11 days, 18 hours	100
Run (Range 1)	STOP 2	1 ms / 103.98 °C	793.18 uA	11 days, 19 hours	100
Run (Range 1)	STANDBY + 32KB	1 ms / 103.98 °C	792.41 uA	11 days, 19 hours	100

Here is a link to all plots and graphs for reference:

https://drive.google.com/drive/folders/13iDMvxL_5nxtgCbEciBWnzTzxtv3geeT?usp=sharing

Run 2 - Stop 1:

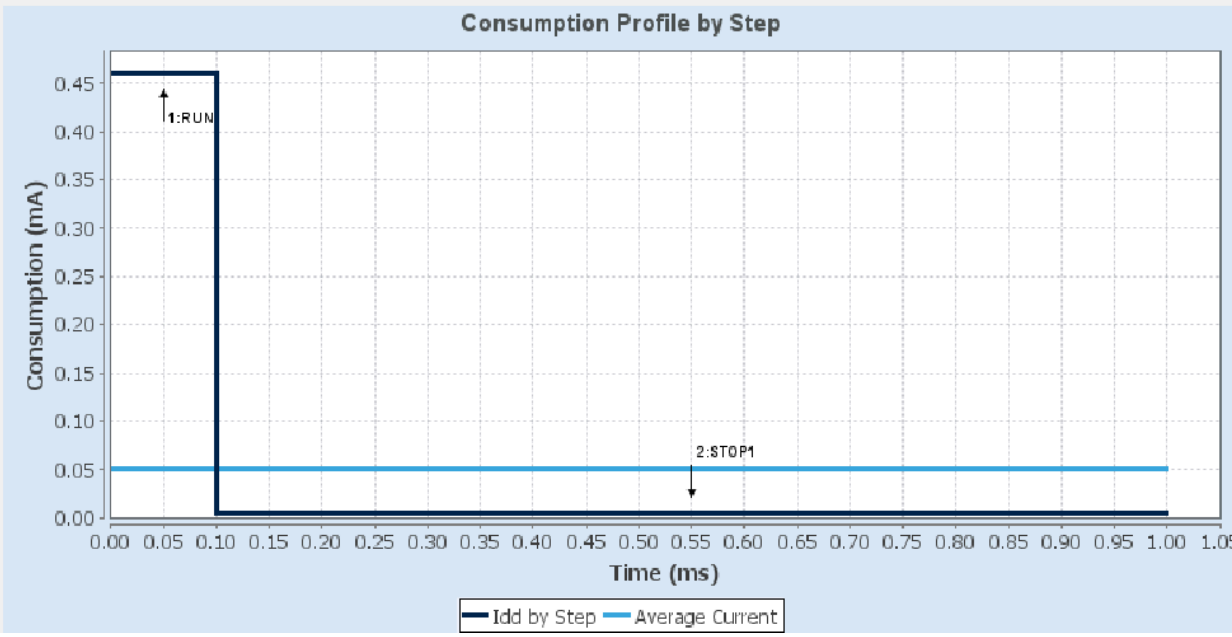
MCU Settings / Results Summary

MCU	STM32L432KCUx	Sequence Time / Ta Max	1 ms / 104.95 °C
V_{DD}	3.0 V	Average Consumption	50.48 µA
Datasheet	DS11451_Rev2	Average DMIPS	5 DMIPS
Battery	Li-MnO2(CR2032)	Battery Life Estimation	6 months, 1 day, 20 hours

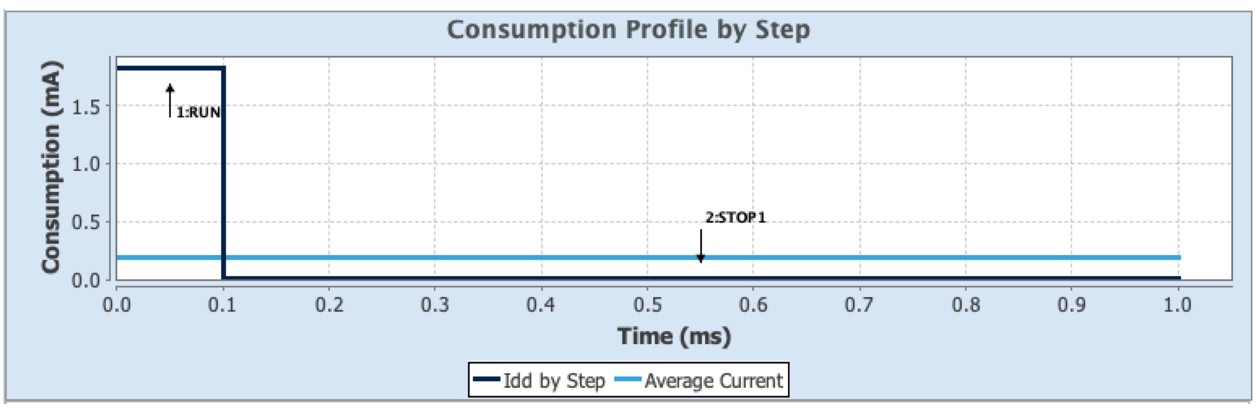
Sequence Table

Step	Mode	Vdd	Range...	Memory	CPU/...	Clock ...	Src Fr...	Periph...	Add. ...	Step ...	Durati...	DMIPS	Voltag...	Ta Max	Categ...
1	RUN	3.0	Range...	FLASH	4 MHz	HSE ...	6 MHz		0 mA	460 µA	0.1 ms	5.0	Battery	104.95	In DS ...
2	STOP1	3.0	NoRa...	n/a	32.76...	LSE ...	32.76...		0 mA	4.98 µA	0.9 ms	0.0	Battery	105	Not in ...

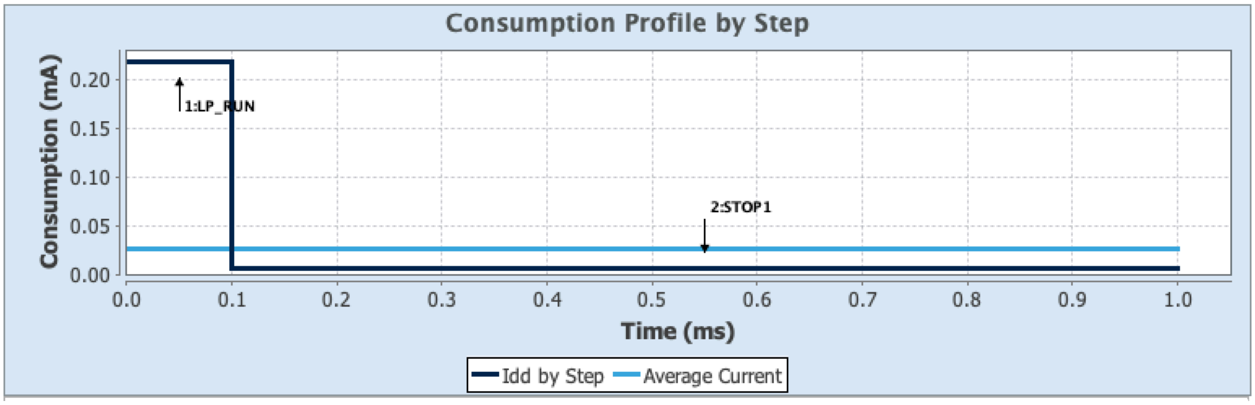
Results Chart



Run 1 - Stop 1:



LPRUN - Stop 1:



Through our analysis of power modes, we found that LPRUN had the greatest efficiency improvement overall. As seen in the plot and the table, LPRUN consumes the least power. It is mostly used for idle or low-demand power periods. This is crucial for devices where power efficiency is important such as devices on battery, or devices that need to minimize power use for sustainability. It may also be that this device simply needs to be prepared to run a little at all times. Run (Range 1) and Run (Range 2) were mostly the same and had negligible impact. However, Run (Range 1) can be used with more performance and power, whereas Run (Range 2) is more of a medium area. Run 1 would be more suitable for performance situations or if the device is used in high-demand or high-power computing tasks. We would recommend pairing that with stop 1. Stop 1 is a good middle ground between the stops and standby is too deep of a sleep. Because standby also shuts down peripherals, it would not be suitable for a light sensor that needs to be prepared to sense light periods. In addition, standby has a much slower wake-up period.

Conclusion:

In conclusion, the best power management system is the Run (Range 2) with Stop 1. While LPRUN has the best longevity, it limits power and limits the peripherals that can run. Because we need the light sensor, and maybe some other peripherals as well, it would be best to use a medium choice that bridges the gap between power efficiency and and function. Stop 1 would allow the peripherals to stay powered and prepared for data collection. In addition, the Run (Range 1)'s time efficiency is limited which would not be as suitable for a device that is meant to stay outdoors for a long period before data recovery. Therefore Run (Range 2) would be the best choice.