Smart Power for IoT Applications

General overview with key factors

These days there are many IoT applications and many more coming soon. The vast majority use and will use wireless devices. One of the greatest barriers to IoT technology proliferation and deployment is power.

The expanding capabilities of IoT devices and increased interest in Artificial Intelligence at the Edge will make power a priority in the future. IoT applications often require unconnected power sources such as batteries or supercaps. Despite remarkable improvements in the battery and supercap technology, the higher performance and features need more and more power. A good power source is essential to get acceptable performance.

Some applications require absolute battery life in the region of tens of hours (e.g. for wearables such as smart watches), others in the region of tens of years (e.g. smart meters and environmental sensors). All of them have to use low power, to maximize battery life, in order to fulfill regulatory requirements, satisfy the customer and save costs.

Satisfactory results can be achieved by designing appropriate hardware and software, such as implementing optimal power consumption in active mode, but also triggering deep sleep modes or short startup/shutdown phases. Power consumption also strongly depends on the use of power saving features, application behavior and interaction with the wireless network. Particularly IoT devices that use wireless low-power technologies (LPWAN) such as LTE-M or NB-IoT require best-in-class designs. They also need to consider all aspects affecting the power consumption of the operational modes and features like PSM, eDRX or CE.

Here comes a new challenge: very low power consumption requires very sensitive measurement equipment, able to deal with uA or nA, while on the other hand the overall system may require several amperes, and the test equipment shall also be able to measure also high currents. This wide dynamic range of the power consumption which depend on the multiple operating modes and network configuration of the entire system requires innovative and performing instruments. Some Vendors of instruments are winning this challenge offering new generation test equipment.

Key factors are:

- Accurate power consumption measurements correlated with activities on the device's digital and analog channels, power buses or RF interfaces.
- Long-term power measurements with a high dynamic range linked to signaling events of wireless and IP networks.
- Power consumption tests and analysis in an emulated, well-controlled network environment,

To address the need to save power consumption in the vast majority of the applications not connected to the power grid network, there are new ICs dealing with power management. I is not always possible to maximize the performance of the battery: it might be better to smartly handle the operation of the IOT devices themselves and/or to harvest energy also from the environment.

The attractive features of the Internet of Things (IoT) all use power. While traditional battery power is the most obvious solution for remote applications, it's not always optimal. First, battery capacity may be insufficient for emerging IoT devices with outstanding processing and network connectivity capabilities. There is a very limited number of batteries suitable to RF IoT applications: transmission and in particular the negotiation phase, is when the amount of power consumption is largest. The required current peaks may vary from approximately 25 mA for 6 seconds (SigFox) up to 2 A for a few milliseconds (for the 2G standard - NB-IoT is draining a few hundred milliamps). Even 25 mA is a high current level for tiny batteries. Given a certain energy level, a load working in a pulsed application will discharge the battery faster than a load working at a constant power drain.

Within the above range of combinations of time-peak current, the internal resistance (Ri) of the battery is a key factor.On the market there aren't many small batteries with the desirable internal resistance and only a few vendors disclose its value. The value of the internal resistance (Ri) impacts the performance more than the value of the capacitance as it depends on the level of charge of the capacitor and the temperature.

The available batteries are too bulky for these applications where size and volume should be as small in size as possible. The same applies to small super-capacitors.

The experts at BlackIOT solved the problem by means of an accurate characterization of the available batteries and of the available capacitors technologies: ceramic, tantalum, aluminum, etc. The combination able to provide good performance in terms of durability and of peak current handling capability is a lithium battery in parallel with a tantalum capacitor with a very low leakage current.

RF Engineers involved in IOT designs are hoping to get next generation batteries soon, specifically designed for handling peaks of power for very small duty cycles.

There is also a concern about the cost of new batteries and the impact to the environment, like extracting the raw material necessary to build them. Even if batteries are rechargeable, eventually they need to be tdiscarded.

Hence, accessing effective power source is a very strong challenge for many IOT systems.

There are two primary ways to mitigate these common problems of IoT power consumption for applications (including IoT) with constant loads, not to RF IoT applications.

Energy-harvesting techniques, which capture energy from a device's surrounding environment, have come a long way in the past few years and could be a good option for some deployments. There are a variety of techniques for energy harvesting. It is also possible to combine several methods of energy reduction and harvesting to increase IoT device power efficiency. These techniques include the following:

- Piezoelectric materials capture power from mechanical stress, such as swiping a keycard over a key reader.
- Thermoelectric materials, which rely on a temperature differential to create electrical potential.
- Solar energy, which is an option for IoT devices exposed to sunlight.
- Wind energy, which can be used in a range of applications including agricultural monitoring.

IoT device designers already have a reasonable set of energy-harvesting options. Some Vendors of IoT device kits provide a small solar panel, along with an energy-efficient motherboard and a Bluetooth-USB bridge. Others offer boards that convert kinetic energy into electrical energy.

Another promising source of energy harvesting is vibration. Some vendors offer devices that harvest energy from vibrations that naturally occur in manufacturing, mining and transportation environments. Vibration harvestering can be tailored to the specific environment. For example, the vibrations caused by passing trains can power sensors on rail switches. Harvestering designed for low frequency vibrations (10 to 30 Hz) is especially useful in mining applications.

Ambient energy harvesting can be a powerful tool for devices attached to moving machinery or those with regular sun exposure, and almost all deployments can benefit from low power consumption protocols. Many of these solutions can be applied and utilized after an IoT device is already installed in the field so it is never too late to start saving energy.

In addition to employing energy-harvesting techniques, IoT device designers can employ protocols that conserve power. Three examples of low-power-consumption techniques are: the use of power-saving mode (PSM), employing Extended Discontinuous Reception (eDRX) protocols and wake-up signals. Most cellular technologies turn off their cellular module when they do not need to connect to the cellular network as reconnecting to the network requires power.

- PSM, on the other hand, uses network connection timers to reduce IoT power consumption. While using power-saving mode, IoT devices will stay registered with a network for a set amount of time ,even when not in use, before being disconnected,. This set time can be more than a year in many cases. If the device communicates with the network within this window, then no extra power is used to reconnect.
- Similar to PSM is eDRX. This method saves power by periodically shutting off the cellular reception module of the device to halt communication. This means data may be delayed in getting to its destination, but this may not be a problem for many IoT applications.

- Finally, wake-up signals allow IoT devices to remain asleep and not periodically check for incoming signals. While the device is asleep it must receive a wake-up message before turning back on again. This method is especially useful for devices that don’t need to communicate for long periods of time.

Good design methodology approach from Dimac Red’ Partners

We saw that the problem of power management is complex and has many aspects. We also understood that a careful approach to the design is key in order to get good and scalable results. Let’s see what Dimac Red’s partner, Microchip Technology, offers as solutions for low power consumption IOT applications, which we will call from now on “sensor”.

Analog design is about making compromise between several parameters, across many blocks made of multiple components:

- How to make the right choices for the application ?
- What are good practices, the do’s and don’ts when optimizing battery life ?
- How to gain agility and thus enable innovation ?
- How to control or even shorten my design cycle ?
- Insure the highest robustness ?
- Optimize the cost ?

Tips

Building a power efficient application requires system a approach when defining the architecture and selecting components

A good strategy depends first and foremost on your application requirements
Solutions are often unique although there is always the temptation to get « inspired » from legacy block diagrams or reference designs

There is no « one size fits all »

Thanks to Microchip system solution approach and broad portfolio (Analog, Smart, Connected &
Secure), Microchip has the devices, the tools and expertize to help the Customer design the optimal solution

Step 1: start from your power requirements and the available power sources

1 Is there a power source to recharge my battery ?

- Solar Panel ?
- Wall charger ?
- Energy harvesting ?
- Other ?

YES ▷

2a What rechargeable battery do I need ?

- Temperature range
- Capacity & aging
- Charge rate
- Self-discharge rate
- Internal impedance
- Reliability, life time.....
- ...

NO ▽

2b What non rechargeable battery do I need ?

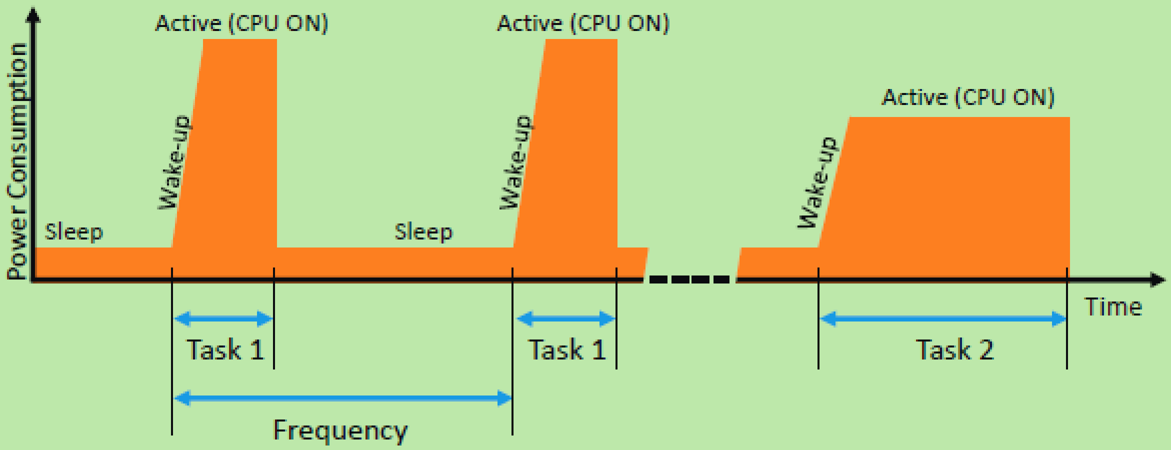
- Temperature range
- Capacity & aging
- Self-discharge rate
- Internal impedance
- Reliability, life time.....
- ...

These multiple choices will heavily influence your Analog Signal Chain and Power Management
Thus your BOM and architecture
Don't worry, we have a solution

Step 2: define your power budget and select your battery

3 Define your Activity Profile

How long is your application active ? How often ?
What tasks get executed with which peripherals (connectivity, secure element, sensor..)?



4 Calculate your Power Budget

Based on Activity Profile, calculate how much power will be needed overall

5 Calculate your Battery Life

Evaluate battery life for different batteries, typical and max conditions.
If needed, test other options such as different radio or key components

BATTERY					BATTERY LIFE							
Brand Type PN	% of usage	Nominal Battery Voltage (used for PSU efficiency)	CAPACITY		CURRENT BUDGET		NOMINAL		MID-POINT		WORST CASE	
			Nominal	Worst Case	Nominal	Worst Case	RF CASE 1	RF CASE 2	RF CASE 1	RF CASE 2	RF CASE 1	RF CASE 2
Battery 1	70%	3.6V	2554.57mAh	1680.mAh	19.44µA	12.79µA	15.8 years	17.1 years	11.5 years	12.4 years	7.3 years	7.7 years
Battery 2												
Battery 3												

	Match Target
	Below but in Range
	No Match

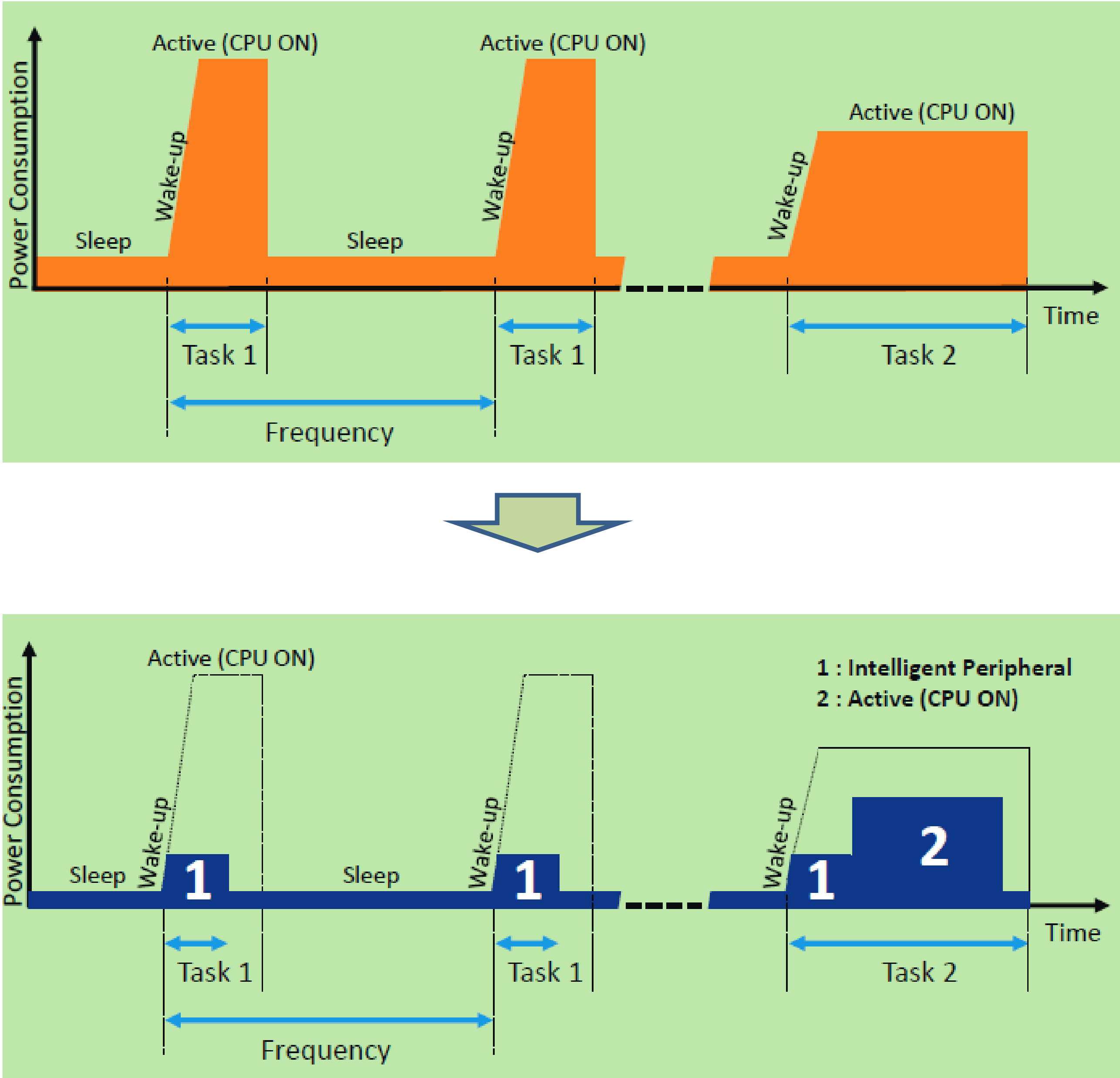
6 Select Your Battery !

Compare your data with Application Requirements
Find best compromise between capacity, power efficiency during Active Mode and/or Sleep Mode, size and cost
And that's it : you are done !

Designing a Power efficient IOT Sensor

- There is **NO ONE SIZE FITS ALL**
- Many options to select from : rechargeable or not, type of battery with different characteristics and cost
- An IoT Sensor with 90% of active time will have a completely different architecture compared to one operating 0.1% of the time!
- Time matters : **START EARLY** on Analog to maximize efficiency and savings
- Your application requirements drive your signal chain Precision and Power Budgets
- Engaging with Analog & Power Management at the very last stage of your design leads to over specification, oversized battery and extra cost
- The sooner you start, the higher the optimization and savings
- Implement **SYSTEM APPROACH** instead of considering components one by one
- Accurate Signal Chain
- Low Power and efficient connectivity
- Secure Element to off load CPU when connectivity is on: less computing time (crypto) saves energy
- Ultra Low Power MCU with intelligent peripherals to minimize CPU activity thus Active mode (see Core Independent Peripherals and Sleep Walking on Microchip website)

System Approach : Ultra Low Power MCU



Extensive portfolio of over 360 Ultra Low Power MCUs to find the right balance of power consumption and performance

- 8-bit, 16-bit and 32-bit eXtreme Low Power (XLP) PIC® microcontrollers,
- 32-bit SAML MCUs and SAMR34/SAM30 Wireless MCUs with picoPower® technology
- Microchip's low-power technology enables MCU sleep currents down to 9 nA and run currents down to 25 µA/MHz
- Consistent low-power features, peripherals and tools for ease of migration
- Intelligent Peripherals : Core Independent CIP / Sleep Walking so peripherals runs autonomously in low power modes without CPU usage
- Multiple power sources and clocking options - Multiple Power Domains
- Fast context switch
- Low Power Peripherals - Low Power Analog

• Flexible Sleep Modes

We saw that full system approach matters, from analog components (Power Management, Sensors, Amplifiers and Linear Devices, Data Converters, Timing) to Smart components (advanced chipset devices, RF + Network processors).

Dimac Red’s Partners are supplying sensors with unprecedented values:

- High accuracy
- High power efficiency
- Ultra low power consumption and voltage operation
- High robustness
- Web tool
- Support: for example Microchip offers excellent online tools for estimations and simulations of the power budget. MPLAB® Mindi™ Analog Simulator is available!

Conclusions

Power Efficiency In IoT Is Complex, but Microchip has the tailored solutions for Customers.

To maximize power efficiency and savings, engage EARLY with Analog design

- Start with POWER BUDGET
- Implement SYSTEM APPROACH
- Adjust your design until you FIND THE RIGHT
- COMPROMISE FOR YOUR APPLICATION (cost /
- performance / integration)