Achieving Lowest Power consumption on system level: the RTC module enables it!

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IoT, Internet of things opens up a wealth of new applications and generates hunger for more functions to monitor or control. Unfortunately this goes often in line with increased power consumption. This is the starting point for a systematic check the power demand. The various function blocks draw specific maximum currents. Fortunately not all the functions need to be operating continuously at peak performance. The goal is switching off everything not required at the very moment. The device, always staying on, needs to be drawing ultra-low power. Why not consider an RTC, since it stays on anyhow.

State of the art RTC modules consume as low as 60 nA at full operation. Such a RTC tracks the time of the day and has the ability to periodically turning on the system controller to check for action. Cutting down the overall current demand by >90 % has been proven to be often possible.

This article not only pin points the neuralgic and sensitive points in applications where additional current could leak, but also proposes measures for reducing the impact.

Content:

1 Low Power ≠ low power

Today everything claims to be low power (LP). The next generation of an application is likely consuming little less power and already the LP label is attached.
Put in context: for battery operated systems the actual current consumption must be considered in relation to the battery capacity.

1.1 Current consumptions

Wearable, portable and many applications in the IoT space are forced to use the least amount of energy. Utilizing a low supply voltage is a good starting point, since most dissipation have ohmic characteristic: Reducing the voltage by a factor of 1.5 (e.g. 5.0 → 3 V) will cut the power in half. Selecting and optimizing the circuitry for lowest power consumption. Comparison of different elements is illustrating the magnitude of the individual current consumption: The microcontroller unit (MCU) doesn't need to be running continuously!

2 Comparison LED, passive LCD, MCU low power, RTC, low power RTC

Assumption: 3.0 V supply voltage

	Component	current	duty cycle	average current	comment
a)	LED	10 mA	20 %	2000 µA	blinking LED *
b)	MCU low power	3 mA	10 %	300 µA	Main action ongoing
c)	MCU sleep mode	50 µA	50 %	25 µA	
d)	MCU RTC only	2 µA	100 %	2 µA	RTC always stays on
e)	RTC module	130 nA	100 %	0.13 µA	RTC always stays on
	RTC module	40 nA	100 %	0.04 µA	RTC always stays on

* use of high efficient LEDs delivering same brightness already at 2mA (average 200 µA)

2.1 Battery capacities

Li-ion batteries (or Li battery packs) are very popular exploiting several parameters:
- The supply voltage is relatively high with 4.2 …3.9 V, ideal to power functions with peak power
- Have high capacity per volume and also high capacity per weight
- Respectable high number of charge / discharge cycles
- Offered with various capacities e.g. several 1000 mAh

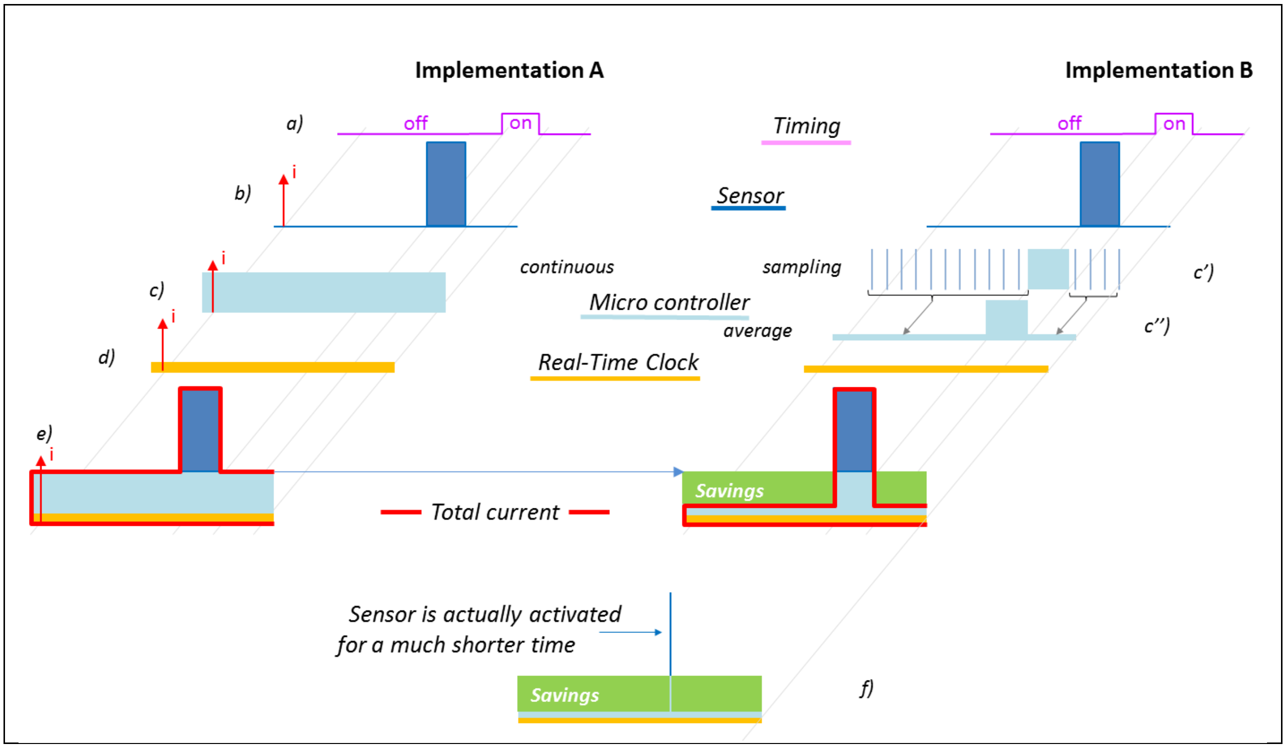
Using a second battery is ideal for keeping the system alive all the time. Key parameters are:
- Low leakage and therefore small self-discharge
- Ideal to feed a low power RTCs and memory functions

As back-up batteries coin cell batteries are enjoying popularity:
e.g. primary cell Li 2032 CR2032 MFRR, it is
- Small size: ∅ 20 mm, thickness 3.2 mm
- Constant supply voltage: 3.0 V
- Capacity: 225 mAh
- Low cost: a few cents in high volumes
- large number of suppliers: Renata, Duracell, Varta….
- high availability

2.2 Operating time

Current consumption over time:
Example: Wireless remote monitoring module. The action: the sensor is periodically checked, upon changes correction in the control system are executed and upon large deviations the values are transmitted to the base station. (Implementation A) In a typical case the action occurs at random points

in time *a)*. The action *b)* is consuming the largest current. The microcontroller *c)* is running all the time to be ready in time to catch necessary action. The RTC, integrated in the microcontroller *d),* allows to time stamp the actions. The envelope summarizes all currents *e)*.
With the help of the *LOW POWER* RTC module (Implementation B) the microcontroller is only turned on periodically to sample if any action is required *c')*, the remaining time it is put back in hibernation mode, the average current *c'')* is therefore reduced to the technical possible minimum. In actual cases the time of action (on) is likely only of short duration, a tiny fraction of the overall time period, therefore the savings *f)* represent the major part.



3 Partitioning for low power on system level

Considering the architecture for power distribution early in the design phase proofed to be a good practice. The supply lines should be routed the way that the different functional blocks can be fully switched off.

3.1 Generic example of a process monitoring block

a) Ideally all sensors are activated continuously (1000s times per second), but is this crucial? A closer look at each individual block explores potential to reduce the power consumption. Just stretch the time between sampling

b) Sensor 1 — needs to be read only once per minute as long as the temperature is <55°C, above 55°C it must be checked every 10s

c) Sensor 2 — The water level cannot change fast, so checking it every 15 min is sufficient

d) Communications The module will communicate once per day at a fixed time or immediately when a parameter is exceeding critical limits.

3.2 Critical points

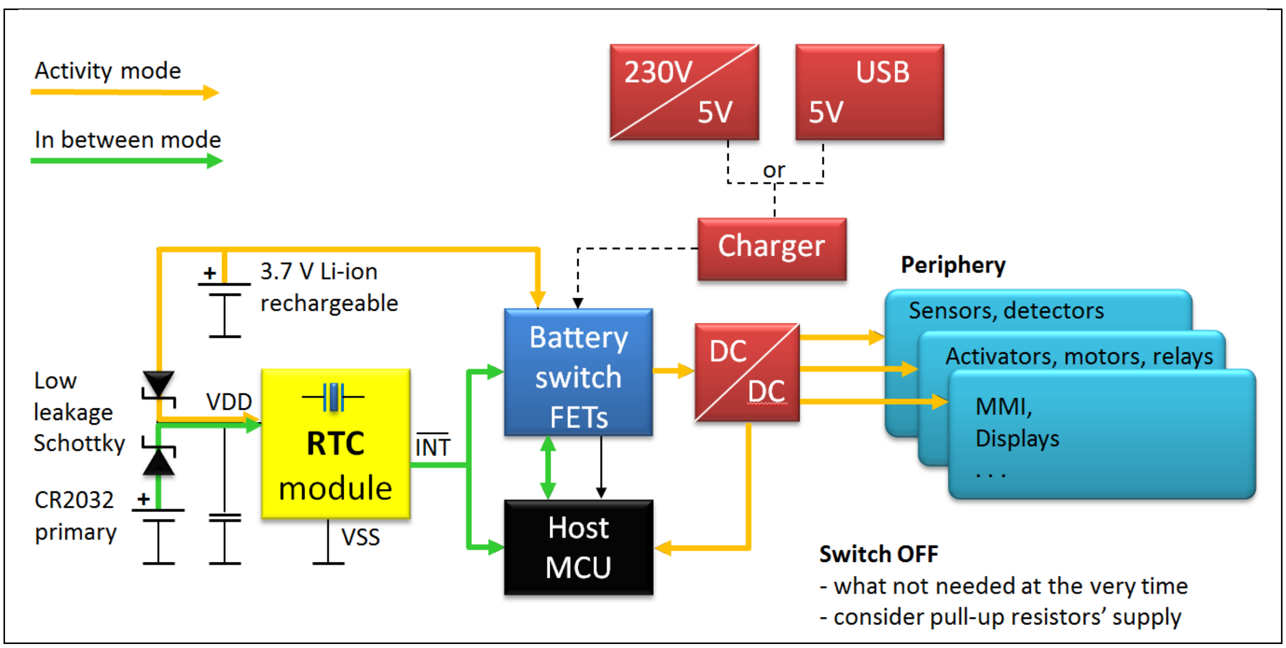
After a supply is switched off check all the lines in respect to leakage currents. Standard FET switches can easily be leaking in the order of several µA. Communication lines with open drain configuration are also a potential source. Make sure the pull-ups are connected to the supply of the controller. Diodes used for switching supplies have to be low leakage Schottky type.
Test frequency outputs must be switched off and configured for lowest power consumption.

4 Controlling the activity levels

Lowest system power consumption is reached when:

- Only one ultra-low power device is staying on all the time, controlling the periodic wakeup and keeping the time
- all other blocks are switched off or if not feasible
- the blocks need to put in hibernation or lowest power idling mode

This could mean that >>95% of the time the only powered circuit is the RTC-module.



5 Selecting the key element: the RTC Module

RTC modules are superior to general purpose RTC with separate Xtal, especially when used in IoT and power critical applications. Integrating the RTC circuit with the 32 kHz crystal into a module enhances minimal 5 parameters:

- Higher accuracy since the crystals is matched with the oscillator and trimmed accordingly. Tolerance at room temp is limited to ±2 to ±20 ppm, versus a RTC with external Crystal results in ±30 ... 35 ppm due to matching spreads
- The form factor is much smaller, about the same size as a crystal in a standard package: 1.5 x 3,2mm
- Since the oscillator circuit is in the hermitically sealed package and no high impedance contacts are accessible outside, it withstands harsh environmental conditions like moisture and contamination dust. The close proximity of crystal and RTC circuit reduces the susceptibility to spurious signal coupling.
- The design of the package guarantees an excellent temperature tracking. This behavior is the base for accurately compensating the quartz's parabolic temperature characteristics. A tolerance of ± 3 ppm respectively 2 seconds / week can be expected from -40°C to +85°C.
- Additional features like Time-stamp or integrated switch for battery back-up are also available.
- The standalone RTC-module is able to act as fully independent watchdog to supervise the software during execution.

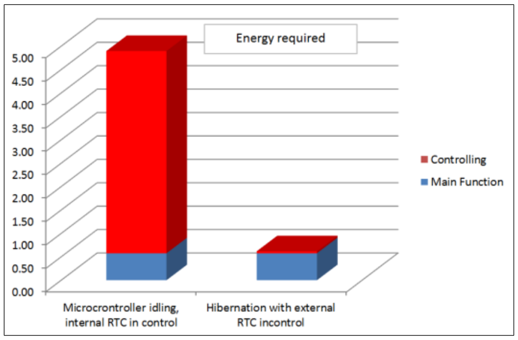
RTC modules ideal for saving power on application level:

Real-Time Clock	Interface	Current I_{DD} [nA	Supply V_{DD} [V]	Time Accuracy	Offset Comp.	Temp. Comp.	Backup Switch	Event Input	RAM [Bytes]
I²C Interface									
RV-3028-C7	I²C	40	1.2 to 3.6	±1 ppm @ 25°C Factory calibrated	✓		✓	✓	43 NV
RV-1805-C3	I²C	60	1.5 to 3.6	±2 ppm @ 25°C Factory calibrated	✓		✓	✓	256
RV-8523-C3	I²C	130	1.2 to 5.5	±20 ppm @ 25°C	✓		✓		
RV-8803-C7	I²C	240	1.5 to 5.5	±3 ppm @ -40°C to +85°C		✓		✓	1
RV-4162-C7	I²C	350	1.0 to 4.4	±20 ppm @ 25°C	✓				
SPI Interface									
RV-2123-C2	SPI	130	1.1 to 5.5	±20 ppm @ 25°C	✓				
RV-8063-C7	SPI	190	0.9 to 5.5	±20 ppm @ 25°C	✓				1

6 Results and conclusions

There are numerous of applications requiring high computing power at once to digest the data and performing the special task for a very short time. Afterwards the system can fall back to idling mode. Adding a dedicated low power RTC module for scheduling the wake-ups cuts the power consumption to its minimum.

Activity level	active time [ms]	frequnecy [n times /h]	total time [s]	current [uA]	current [A]	charge needed [As] / day
System fully on	4	60	5.76	100'000	0.1	0.576
Microcntroller idling internal RTC in control		idling time	86394.24	50	0.00005	4.320
Microconroller in hibetrnation with external RTC in control		idling time	86394.24	0.5	0.0000005	0.043



Combining the microcontroller with a low power RTC module increases the system performance:

- Lowest power budget
- Saves on cost for the back-up power source: requiring a smaller battery
- Accurate time
- Autonomous watch-dog function

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