Achieving Lowest Power Consumption on System Level with Real-Time Clock Module

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1. Introduction

IoT, Internet of things opens up a wealth of new applications and generates hunger for more functions to monitor or control. Badly, this goes often in line with increased power consumption. This is the starting point for a systematic check of 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 a Real-Time Clock (RTC) module, since it stays on anyhow.

State of the art RTC modules consume as low as 60 nA at full operation. Such an 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.

2. 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.

2.1. 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 is the track to follow.

Comparison of different elements is illustrating the magnitude of the individual current consumption:

The microcontroller unit (MCU) doesn't need to be running continuously!

3. Comparison LED, passive LCD, MCU low-power, RTC, low power RTC

Assumption: 3.0 V supply voltage

Table 1: Component current consumption comparison

	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 on-going
c)	MCU sleep mode	50 µA	50%	25 µA	
d)	MCU RTC only	2 µA	100%	2 µA	RTC always stay ON
e)	RTC module	130 nA	100%	0.13 µA	RTC always stay ON
	RTC module (Typ. RV-3028-C7)	45 nA	100%	0.045 µA	RTC always stay ON

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

3.1. 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: Ø 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

3.2. Operating time

Let's explore current consumption over time in an example.

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 amount of 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)**.

Implementation B: With the help of the LOW POWER RTC module, the microcontroller is only turned on periodically to sample if any action is required **c')**, the remaining time it is put back in sleep (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.

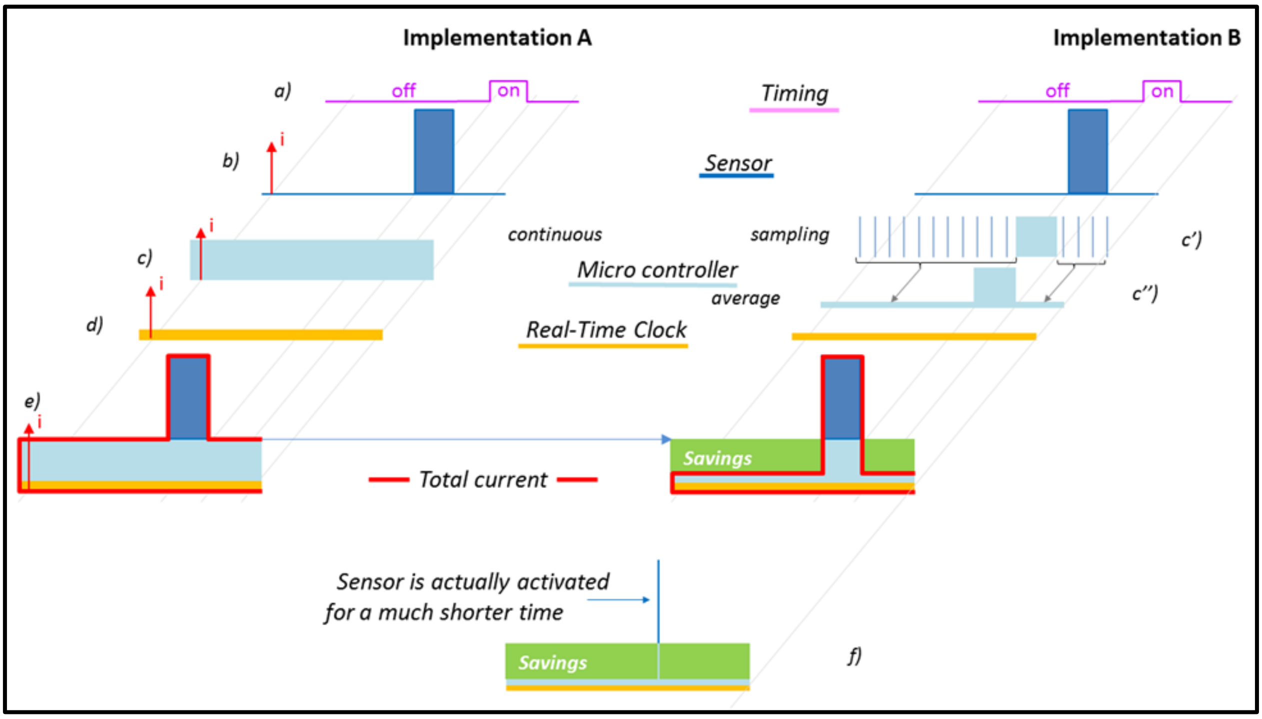

Figure 1: Current consumption profiles with use cases

4. 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 in order to allow the different functional blocks to be fully switched off.

4.1. Generic example of a process where 2 sensors are monitoring temperature (sensor #1) and water level (sensor #2)

a) Ideally all sensors are activated continuously; but is this crucial? A closer look at each individual block shows potential to reduce the power consumption. Just by stretching the time between sampling for instance.

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 more often like typically 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 alarming when a parameter is exceeding critical limits.

4.2. Critical points to consider

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 of wasted current. 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.

5. 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 accurate track of the time
- ✓ All other blocks are switched off
- ✓ If blocks cannot be switched off, the blocks need to be put in sleep or lowest power idling mode

This means that in many cases, more than 95% of the time, the only powered circuit is the RTC-module.

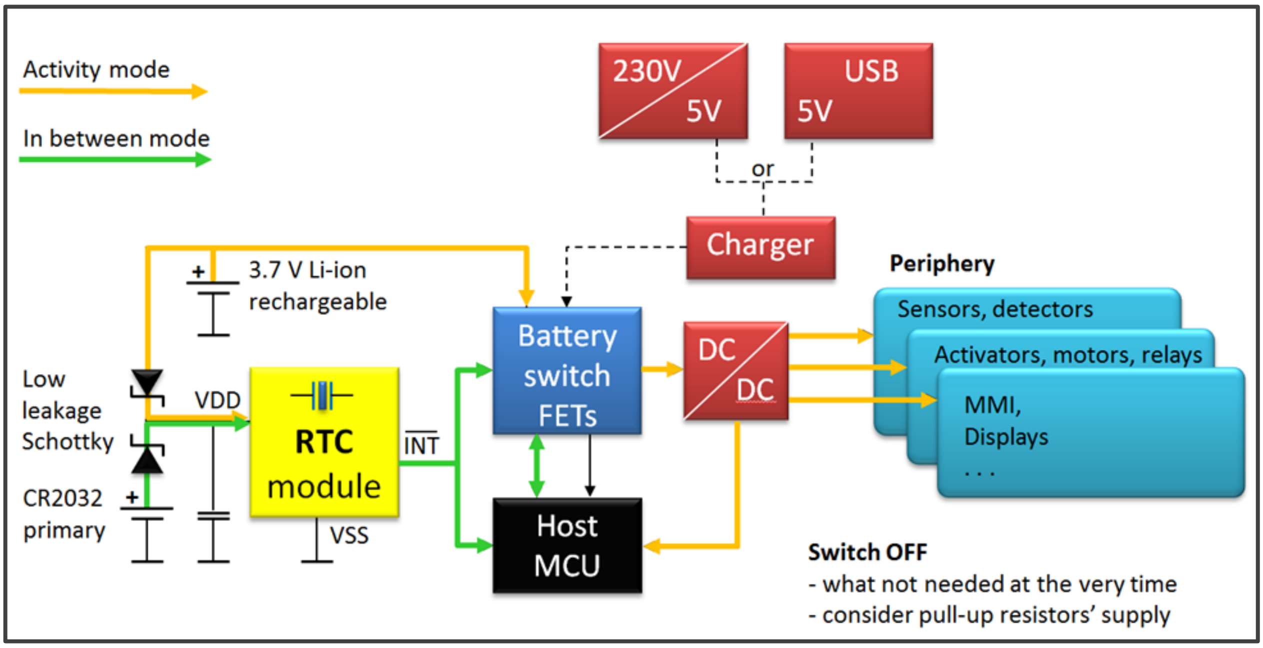

Figure 2: Illustration of activity levels

6. 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 several key 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 where a ±30 ... 35 ppm tolerance is obtained due to matching spreads.
- ✓ The form factor is much smaller, it is about the same size as a crystal in a standard package: 1.5 x 3,2mm
- ✓ Since the oscillator circuit is in the hermetically 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 corresponding to less than 2 seconds / week can be expected from -40°C to +85°C.
- ✓ Additional features like Timestamp 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.
- ✓ The standalone RTC-module and function is available with AEC-Q200 qualification increasing the reliability of system design.

Table 2: RTC modules ideal for saving power on application level

Product Type	Main Feature	Interface	Time Accuracy	Supply V_{DD} [V]	Current I_{DD} [nA]	T_{OP} [°C]	Offset Comp.	Temp. Comp.	Backup Switch	Trickle Charge	Event Input	RAM [Bytes]	EEPROM [Bytes]
I²C Interface													
RV-3028-C7	High Accuracy, Small Package, Low Power	I²C	±1 ppm @ 25°C Factory calibrated	1.1 to 5.5	45	-40 to +85	✓		✓	✓	✓	2	43
RV-8523-C3	Low Power	I²C	±20 ppm @ 25°C	1.2 to 5.5	130	-40 to +85	✓		✓				
RV-3032-C7	High Accuracy, Small Package, Low Power	I²C	±1.5 ppm @ 0°C to +50°C ±3 ppm @ -40°C to +85°C	1.2 to 5.5	180	-40 to +85	✓	✓	✓	✓	✓	16	32
RV-8263-C7	Small Package, Low Power	I²C	±20 ppm @ 25°C	0.9 to 5.5	190	-40 to +85	✓					1	
RV-8564-C3		I²C	±20 ppm @ 25°C	1.2 to 5.5	250	-40 to +85							
RV-8803-C7	High Accuracy, Small Package, Low Power	I²C	±1.5 ppm @ 0°C to +50°C ±3 ppm @ -40°C to +85°C ±7 ppm @ +85°C to +105°C	1.5 to 5.5	240	-40 to +105	✓	✓			✓	1	
RV-4162-C7	Small Package	I²C	±20 ppm @ 25°C	1.0 to 4.4	350	-40 to +85	✓						
SPI Interface													
RV-2123-C2	Low Power	SPI	±20 ppm @ 25°C	1.1 to 5.5	130	-40 to +85	✓						
RV-8063-C7	High Accuracy, Small Package, Low Power	SPI	±20 ppm @ 25°C	0.9 to 5.5	190	-40 to +85	✓					1	

High Accuracy Small Package Low Power

7. Conclusion

There are many 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.

As shown in **Table 3** and **Figure 3**, it can be observed that 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 (requires a smaller battery)
- ✓ Highest accurate time (temperature compensated and factory calibrated RTC with embedded quartz)
- ✓ Autonomous watch-dog function
- ✓ Power management function with no added components (trickle charge, backup switchover)

Table 3: External Real-Time Clock cuts system current consumption to minimum

Activity level	Active time [ms]	Activation Frequency [n per hour]	Duration at activity level per day [s]	Current consumption [µA]	Current consumption [A]	Charge required [As/day]
System in active mode **Main Function**	4	60	5.76	100'000	0.1	0.576
Microcontroller in Idle mode **Control through Internal RTC active**	**Idling time**		86394.24	50	0.00005	4.32
Microcontroller in sleep mode **Control through External RTC active**	**Sleeping time**		86394.24	0.5	0.0000005	0.043

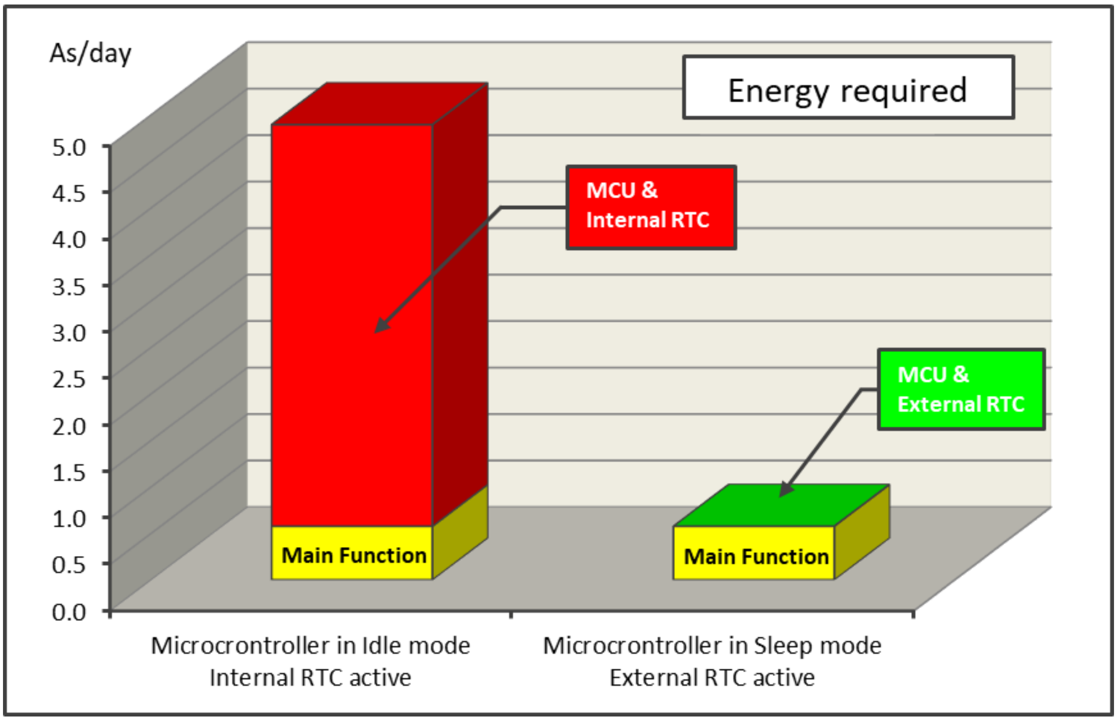

Figure 3: Chart showing comparison between internal and external RTC usage

Micro Crystal offers a wide portfolio of low-power, high-performance and small footprint RTC modules, do not hesitate to contact us for any question you may have about how our products can fit into your application and challenge our technical teams.

Additional resources:

For more information about the RV-3028-C7 which is the lowest power consumption RTC Module on the market and Micro Crystal's portfolio of Real-Time Clock modules, please visit:
RV-3028-C7 Real-Time Clock Module
www.microcrystal.com

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Markus Hintermann

Markus joined Micro Crystal AG in November 2015 as Product and Marketing Manager.
He benefits of in depth experience in applications of peripheral circuit from Real-Time Clocks, LCD drivers to capacitive touch switches.

Markus holds an EE degree from ETH Zürich with specialization in Communications.

He has deep knowhow of automotive supplier market worldwide.

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Nicolas joined Micro Crystal AG in June 2020 as Technical Marketing Manager.
He benefits of a strong expertise built on his roles and experience in Product Development, Technical Support, Product Management and Technical Sales in sensor business for industrial, consumer and automotive applications.
Nicolas holds an EE degree with specialization in Test & Measure and is fascinated by quantifying the world around us.
He thinks that any sensor measurement is significantly enhanced when combined with an accurate and reliable time reference.

8. Reference documents

Document	Name	Link
Data sheet	RV-3028-C7	Download
Application Manual	RV-3028-C7_App-Manual	Download

9. Document version

Date	Version #	Changes
April-11-2018	1.0	Initial version by Markus Hintermann
January-18-2021	1.1	Revised version by Nicolas Moser