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Application note 022

Average current isn't the whole story

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In a large number of wireless sensor application the provision of a long battery life is of the utmost importance. Often the wireless device is in an inaccessible location, without any external power sources nearby, and the manpower cost of frequent battery replacement cycles would soon dominate the installation cost of the network.

Techniques used to achieve long battery life are well understood. Careful design of ancillary circuits reduces un-necessary leakage currents, while the dominant current drain of the radio circuits (and associated micro controllers) is minimised by greatly reducing the duty cycle (off time vs. on time). If the power hungry transceiver only sends a burst of (say) 12mS every minute, then it's average current will only be 0.0002 times it's operating current drain.

In this way, an average supply current of below 10uA can be easily designed for, leading to a theoretical battery live from even a small lithium cell measured in years.

RX1L receiver draws 1mA @ 3.1V

To consider a real-world application example, among the better single chip Zigbee solutions we can find a transceiver with 27mA 'on' current (tx or rx) and 0.5uA in 'sleep'.

Assuming the sensor network data throughput is low (temperature monitoring in commercial buildings for instance could only require a few bytes per hour from each sensor) then the network can operate in the slowest "BLE" mode (beacon synchronised, with the longest (n=14) 251 second cycle).

The sensor nodes (which only need to support minimal "end device" functionality) will only be active (once synchronised) for two burst periods, to receive the beacon transmission and to send their own transmit burst. Active time is therefore roughly 32mS in every 251 second frame, or a duty cycle of 1/7800 !

This resolves to an average current consumption per node of 3.4uA, plus any leakage or sleep mode current. Even allowing 0.6uA for these, that still results in an impressive 4uA current drain

So a 180mA/hr lithium coin cell would last five years ?

Unfortunately, no.

There is another consideration that is conveniently glossed over in many discussions of low power network designs, and that is that the maximum (peak) current output of long shelf life lithium batteries (especially the inexpensive lithium manganese dioxide coin and button cells) is very limited.

The popular CR2032 coin cell (abused in many miniature LED torches) is only rated for a 3mA continuous current drain. Even 1/2AA lithium thionyl cells can be problematical (some parts are limited to as little as 6mA, others can deliver 40mA).

Adding large storage capacitors to take up the short term load is only a partial solution, as the necessary 'farad' rating parts can easily exceed the cost of the battery they are protecting.

Reducing the duty cycle of the radio components can only be taken so far, before the increase in wireless link data rate necessary to reduce burst length will result in an increase in the receiver circuit current (and the necessary transmit power to achieve a useful range at the higher rate) that will exceed the ability of small batteries to cope with the instantaneous drain.

Depending on the application, and the power source available, it is sometimes worth considering a lower data rate architecture. Simple FSK radios with data rates in the order of a few kbit/sec can be used with receivers drawing 10mA or less (narrowband VHF receivers have been realised that have a supply current of only 1mA at 3v)

At these data rates, link sensitivities of better than -115dBm are common (compared to a typical -100dBm for a professional Zigbee radio) so transmit power can also be reduced.

Let us imagine the same sensor system as previously considered, redesigned around low data rate (3kbit/sec) VHF radios:
The same 250 second beacon synchronisation cycle will be retained
The transmit burst length increases to 25mS (64 bits plus preamble)
RX current is 10mA (Radiometrix NRX1-173)
TX current is 9mA (Radiometrix TX1-173)

So average current is (0.025 x 2)/251 x (10+9mA) = 3.8uA
But the peak current is reduced to 10mA

By adopting the older, simpler radio link the average current remains unchanged, but the peak current falls markedly

(If this is considered against a 2.4GHz radio of equivalent range to a 1mW VHF link the difference is even more extreme. A claimed-200m range Bluetooth unit can require over 250mA, and even the long range 'professional' (+20dBm output) Zigbee modules draw up to 100mA).

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