Self-powered wireless air-flow sensor project – initial pointers

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1. Project aims (from proposal)

The aim of this project is to develop a wireless and battery-less air flow sensor. The project is linked to ongoing research within the EEE Department in the area of energy harvesting from fluid flows. The sensing element will be a miniature turbine/generator set which will also provide the power for the signal conditioning circuitry and radio link. The turbine/generator will be provided to the student, and the focus of the project will be on the design and implementation of the necessary low-power electronics for power management, signal conditioning and radio transmission. The aim will be to develop a working prototype sensor that can communicate wirelessly with a data collection node.

2. Sensor architecture

It is proposed that the overall architecture of the wireless sensor should be as shown in Figure 1 or along similar lines.

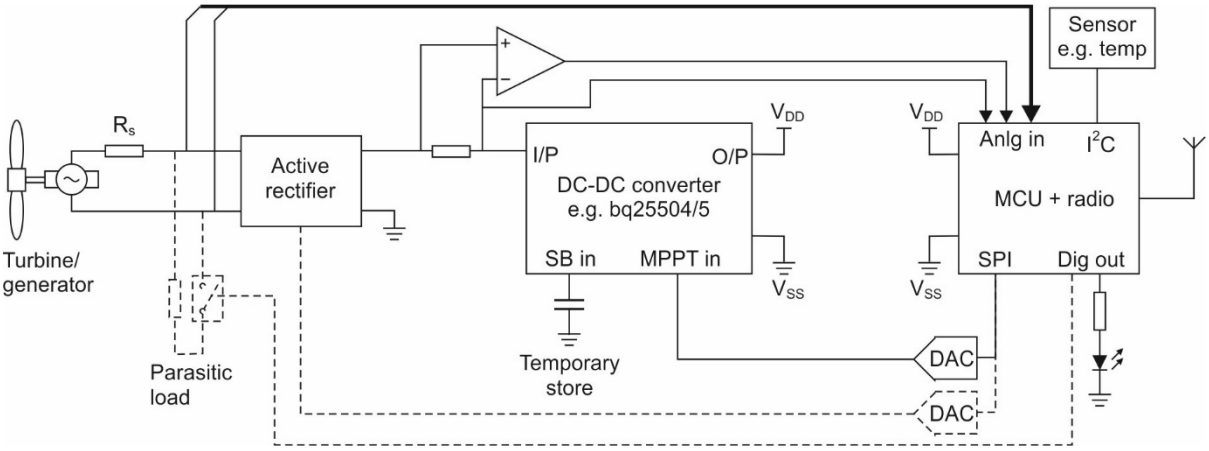

Figure 1: Proposed wireless sensor architecture.

The main circuit blocks in Figure 1 are:

- Active rectifier: converts low-voltage AC output from turbine to DC with as high efficiency as possible. Also needs to act as passive rectifier during cold-start when V_{DD} is too low to power active rectifier circuitry.
- DC-DC converter: transfers power from active rectifier output to temporary store with as high efficiency as possible. Assuming a battery-less implementation, the temporary store will be a capacitor or super-capacitor.
- MCU & radio: implements MPPT (maximum power point tracking) to maximise power extraction from turbine; measures turbine speed; reads any other sensors; communicates wirelessly with data collection node (mobile phone / tablet).

3. Project tasks

A prototype system, along the lines of Figure 1 but omitting the radio, was developed in an earlier project. The designs from that project can be taken either in part or in full as the starting point for the present project. In particular, it is suggested that use is made of the existing active rectifier design. The key tasks in the project (in no particular order) will then be as follows:

- Optimise the existing active rectifier design to improve its efficiency; characterise the performance in detail and compare with MATLAB/SPICE models.
- Look into available DC-DC converter chips and identify best device for this project. Fall-back position will be to use the BQ25504/5 from TI (which is a good device but may have been improved upon).
- Identify a suitable MCU/radio chip.
- Carry out a power budget analysis to establish limit on sensor update rate as a function of air speed (function of average power consumption) and to size storage device (function of peak power during radio TX/RX). Time taken to cold-start should also be taken into account.
- Develop MCU code for handling MPPT, data acquisition (turbine speed; other sensors) and wireless communication.
- Develop App to run on mobile phone / tablet. This should allow data to be displayed (e.g. turbine speed, rectifier output voltage & current, VDD, sensor data), and for the user to manually set the MPPT operating point.
- Transfer wireless sensor hardware to printed circuit that can be accommodated within microturbine housing (with modification to housing if required).

4. Resources available from earlier work

- Schematics for existing prototype system comprising active rectifier, BQ25505 (on separate EVAL board) and ATmega88PA microcontroller. These were produced using CircuitMaker and can be accessed online.
- Unpopulated PCB and components for existing prototype system.
- Microcontroller code (C-language) for ATmega88PA. This implements MPPT and outputs limited serial data via UART.
- MATLAB model for active rectifier of the type implemented in existing prototype.
- Wind tunnel data for microturbine.
- Electromechanical model of microturbine with parameters extracted from wind tunnel data.
- Microturbine (also needed occasionally by a PhD student).