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Photovoltaic Power Supply for an Airliner Wireless Sensor Network

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Abstract—We present here an autonomous, battery-free power supply, which captures, manages and stores energy from the environment, using photovoltaic cells and supercapacitors under harsh environmental conditions.

Keywords— Flight Tests, Sensor Network, Photovoltaic, Solar Energy, Supercapacitor, Power Management

Wireless Sensor Networks (WSN) have been considered for various aeronautical applications, such as Structural Health Monitoring (SHM) [1] and flight tests. However, these nodes need to be self-powered, many of the advantages of wireless sensor networking being obviously lost if wired power sources were used. Despite their obvious advantages, batteries present critical drawbacks, particularly for aeronautic applications.

However, combination of energy transducers and supercapacitors (SCs) are a good candidate as energy supply.

We present here hands-on experience related to on-going implementation of energy harvesters in airliners for the purpose of flight tests. As the system is designed to be situated on the top of the plane's wing, general requirements of our application translate into the following:

- use solar cells as main source of energy,
- be less than a few millimeters in thickness, and PV panel has to be flexible to preserve wing aerodynamic,
- deliver a mean electrical power of at least 2W under 48V, under modest (cloudy) illumination,
- operate between -50°C (cruise altitude) and $+85^{\circ}\text{C}$ (parking under direct sunlight), and down to 200hPa (typical pressure at 10000m),
- incorporate an energy storage (SC) unit in order to deal with transient absence of sunlight,
- is capable of autonomous start-up, with the help of solar cells alone, the storage unit being empty.

Considering the above specifications, we devised the general architecture depicted in Fig. 1.

A thin-film photovoltaic panel (SolbianFlex SP50-L, using SunPower "Back contact" cells, allowing a high efficiency with a good flexibility) supplies energy to the system.

A microcontroller (PIC18F1220) controls the power management. It commands the DC/DC Buck Converter in order to achieve a MPPT (Maximum Power Point Tracking) with a fractional V_{oc} algorithm. Fraction of open-circuit voltage is calculated to be optimized at low light, when achieving best efficiency is critical.

The storage buffer is composed of 2 stacks of 2 Maxwell

PC10 supercapacitor mounted in series. These supercapacitors have been submitted to constant current charges and discharges in a climatic chamber, at temperatures between -50°C and $+100^{\circ}\text{C}$. Then, at -50°C only, we submitted them to an identical charge and discharge cycle, at 200hPa, in another climatic chamber.

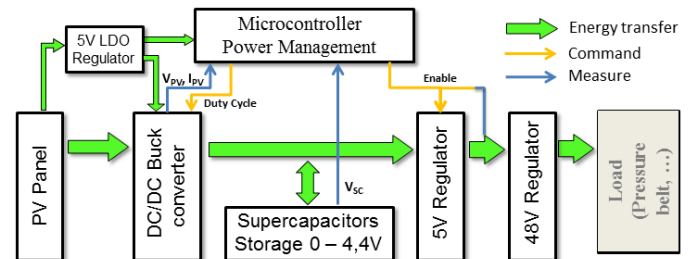


Fig. 1. Power supply: general architecture.

Charging and discharging SC at high current (about 1A) implies a variation of its terminal voltage of several hundreds of millivolts due to the Equivalent Series Resistance (ESR). Current regulation has been implemented to correctly full-charge SC by reducing progressively charging current.

In order to have enough power at low light, we need a large area of PV cells (0.31m^2) which leads to a high current during full light operation if the system operates at the maximum power point. Active current limitation has been implemented in the microcontroller to deal with this issue.

Finally, microcontroller enables the output regulators only when SC are charged enough to guarantee an input voltage above minimum operating value [2].

The output stage is composed of 2 regulators, a 5V regulator (LT3539) in series with a MAX1523 boost controller to go from 5V to 48V.

The overall system (Fig. 2.) supplies the 2W load from a solar irradiance as low as $80\text{W}/\text{m}^2$.

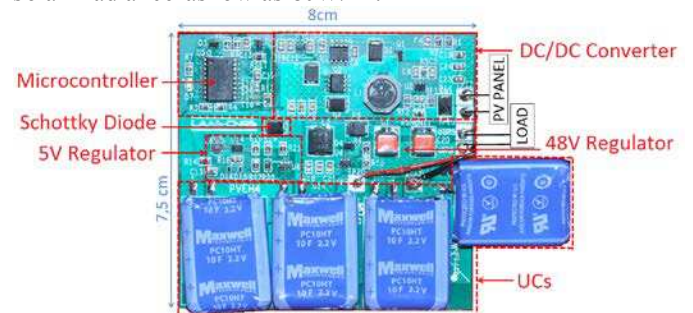


Fig. 4. Power management board.

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