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Praktische Anwendungen Zerstörungsfreier Prüfungen und Zukunftsaufgaben

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Event-triggered Dynamic Strain Measurements using Wireless Sensor Networks

Monitoring by Wireless Sensor Networks

Maintenance costs and lifetime prognosis of civil engineering structures become more and more important. Different exposures have to be considered, e.g. dynamic and static loads, strains as well as temperature and moisture. Today, the inspection of civil structures and especially of bridges is mainly done visually. This examination process can be significantly improved using structural health monitoring techniques.
Wireless monitoring systems (Fig. 1) are deployed and operated easier than wired systems. A long maintenance-free operation time is desired. By using advanced measurement techniques (event based monitoring), this key feature can be achieved. For the monitoring of railroad bridges a sensor node was designed, consisting of the three components: a wireless sensor network platform, a strain measurement module and an event detection module (Fig. 3).

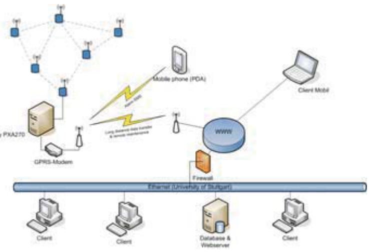

Fig. 1

Wireless Sensor Network Platform

- Ultra low power microcontroller (µC): TI MSP 430
- Low power radio in free frequency band (2.4 GHz) with multi-hop routing of sensor reading messages
- Competitive low power sensors and signal conditioning boards are mountable easily
- Alarm level settings for event based monitoring
- In-mote signal processing (filtering, array processing) for data reduction and data analysis (classification, characterisation etc.)

Strain Measurements Module

A gauge sensor adaptation board (Fig. 2) was developed, which supports any type of sensors requiring a Wheatstone bridge-type signal conditioning. Hence, supported sensors comprise

- piezo-resistive,
- ceramic-thick film or
- steel membrane sensors.

The sensor board offers two channels at up to 15 bit ADC resolution and offset and temperature drift compensation. Calibration software allows the simple setting of the sensor's parameters.
Current drain in a typical configuration is about 25 mA, depending on the number of channels (1 or 2) and the type of sensor used. The module can be switched off by software; the current drain is then very small (µA).

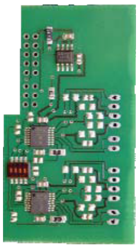

Fig. 2

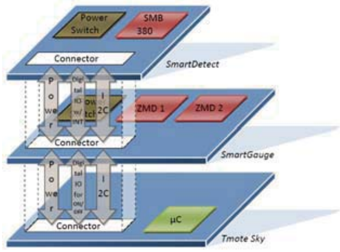

Fig. 3

Event Detection Module for Triggering Data Acquisition

To determine when to switch the gauge adaptation board on or off, an event detection module was developed. Two options were evaluated in detail:

- a vibration-sensitive micro-switch (Sensolute, Fig. 4a) and
- an acceleration MEMS-IC (Bosch Sensortec SMB380, Fig. 4b).

The highly application specific decision came to the acceleration MEMS.
Railroad bridges vibrate due to the train crossing of the bridge. This vibration (=acceleration) of the bridge is measured by the acceleration sensor and an on-chip signal processing routine (Fig. 5 + 6) issues an interrupt to wake up the µC and to initiate the strain measurements. Depending on the sensitivity of the detection, some less important strain values of the beginning of the crossing might be missing.
Further advantage of this solution: if the threshold is set adequately, only data of interest is recorded, which keeps the amount of acquired data low.

Fig. 4a

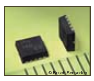

Fig. 4b

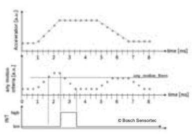

Fig. 5

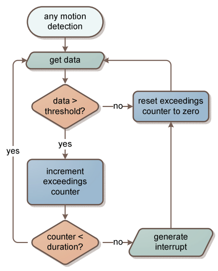

Fig. 6

Field Test Results

A deployment for dynamic strain measurements on a steel railroad bridge (Fig. 8) was made in July 2007 near Luleå, Sweden in cooperation with EMPA, Switzerland. Maximum strain values of less than 150 µstrain for a typical freight train (loaded with iron ore) were obtained (compare Fig. 7), thus the bridge is not endangered.

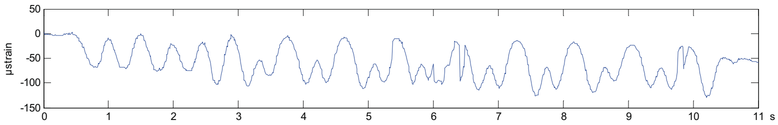

Fig. 7

Fig. 8

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