Multipurpose use of radiofrequency sources for probing passive wireless sensors and routing digital messages in a wireless sensor network


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J.M Friedt & al.

Outline and basics
Passive SAW sensor
Radiomodem → WSN
Application
Conclusion

Introduction

Objective:

- Alternative strategy to energy harvesting: no energy at all!
- Passive transducer acts as sensor remotely characterized
- Reader must communicate recorded data on the physical property
- Since the transducer is an analog radiofrequency component, use of the **same hardware** for digital communication
- wireless sensor network (WSN) ⇒ port the software to an executive environment ("operating system" like)
- demonstration on high temperature (550 °C) measurement
Basics of SAW resonator interrogation

- sensor appears to the user as an **electric dipole** characterized by a sharp resonance in the **RF range** (wireless probing)
- physical principle is the measurement of the velocity of a surface acoustic wave (mechanical vibration) propagating on a **single crystal substrate** (quartz, lithium niobate, langasite ...)
- sensor is **passive** (no local battery source)
- resonance **frequency** is characteristic of the physical property under investigation
- **frequency sweep monostatic** RADAR
- separate emission (sensor load) and listening (sensor discharge) steps
- if the emitted pulse spectrum overlaps the sensor resonance, returned signal at $f_0$
SAW resonator interrogation characteristics

- time constant defined by the sensor $Q$ factor: $Q/\pi$ periods is $6 \mu s$
  $\Rightarrow$ load/unload duration is $30 \mu s$, and at least two measurements to identify resonance frequency

- basic frequency sweep measurement (no assumption on resonance frequency): $f_0/Q/3$ frequency step $\Rightarrow$ 128 steps or $7.5 \text{ ms}$.

$\Rightarrow$ short measurement time compatible with very low duty cycle $\Rightarrow$
low power consumption if sleep mode is low power

$\Rightarrow$ passive transducer (no need for energy harvesting on the sensor site)

$\Rightarrow$ emphasis on a low power reader electronics with enhanced capability
Reader compatible with wireless sensor network applications

- Use of a commercially available radiomodem as frequency source and receiver
- Thanks to the long returned signal time constant, even low bandwidth radiomodem is compatible with the measurement
- I and Q analog outputs ⇒ rich dataset for signal processing
- switch between two modes: passive (batteryless) acoustic sensor transducer characterization through a wireless link (medium range, 0.1-10 m), and digital data communication over a wireless sensor network (long range, 1-100 m).
TinyOS port to STM32

Wireless digital data communication
⇒ complex communication protocol targeted at automated message routing in a dynamic network of SAW readers
⇒ port of TinyOS to the STM32 microcontroller (ARM Cortex M3 core)
⇒ port of the control software to TinyOS

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TinyOS port to STM32

- multiple software interfaces linking the low level drivers (A/D converters and radiomodem) to the TinyOS functionalities
- the standard expected message is in the ActiveMessage structure
- this format allows the use of the CTP routing protocol (TinyOS)
- dedicated signal processing functions for sensor characterization

Layers

Physical

Xe1203
SPI configuration

Xe1203SawSensor
ADC for SAW reader

Xe1203Uart
raw RS232

Xe1203Radio
interfaces

Link

Xe1203XCorr
FFT

ActiveMessageXe1203
ActiveMessage

Network

CTP
WSN routing

Application

CrossCorrelation
+data trasnfer

Xe1203
SPI configuration

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Measurement example

- A sensor is located in a high temperature oven (T > 500 °C) ⇒ wireless sensor avoids wiring issues
- The recording station is located in a remote location
- A second reader records the room temperature and transmits data through the WSN.

![Graph showing temperature over time](image-url)
Power consumption budget

Battery powered remote reader ⇒ aim of reduced power consumption

<table>
<thead>
<tr>
<th>Operation mode</th>
<th>Consumption (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF digital communication</td>
<td>140</td>
</tr>
<tr>
<td>Probing SAW resonators</td>
<td>80</td>
</tr>
<tr>
<td>Standby mode microcontroller and transceiver in reception mode</td>
<td>22.3</td>
</tr>
<tr>
<td>Standby all components</td>
<td>1.2</td>
</tr>
</tbody>
</table>

→ RF link is always highest source of power consumption
→ STM32 is hardly a low power microcontroller
→ leakage current towards some of the unpowered chips (RS232-USB interface)
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Conclusion

- Acoustic wireless passive readers withstand harsh environmental conditions incompatible with silicon-based sensors
- Dual use of available radiomodem: WSN and probing acoustic sensors in a RADAR-like approach
- Digital communication through a digital wireless link
- Port to the STM32 of TinyOS for advanced routing capability

**Perspectives:** correct the omission of the MAC layer
⇒ conflict between all readers waking up at the same time and using the same frequency
⇒ conflict between digital communication and sensor characterization

All source codes at http://sourceforge.net/projects/tinyosonstm32

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