Tire Pressure Monitoring System (TPMS) with SP37

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Direct TPMS – Sensing of Air Pressure within tyres

- **Gas Law**

\[ p \cdot V = n \cdot R \cdot T \]

- For a given mass at constant temperature,
  - Pressure \* Volume = Constant

- For a given mass at constant pressure,
  - Volume is directly proportional to temperature
Acceleration – Additional Feature for Flexibility

- "center seeking" force, $F_{\text{centripetal}}$
- object must be accelerating towards the center of rotation even at constant speed

\[ F_{\text{centripetal}} = \frac{v^2}{r_{\text{rim}}}, \quad \frac{v^2}{r_{\text{tire}}} \times \frac{r_{\text{tire}}}{r_{\text{rim}}} \]
Block Diagram of Direct TPMS

- ADC Signal Conditioning & Compensation
- RF Transmitter
- Microcontroller
- LF Interface
TPMS with SP37!

Build TPMS system with
- Single Chip Solution
- Integrated Sensors
  - Pressure
  - Acceleration
  - Temperature
  - Voltage
- Integrated Transmitter
- High LF Sensitivity

Sensors, MCU, LF and Transmitter on a single chip
SP37 Single Package TPMS Sensor

- Integrated Sensors:
  - Pressure
  - Acceleration
  - Temperature
  - Battery Voltage

- Integrated peripherals
  - 8051 Micrcontroller
  - on board FLASH
  - 3x GPIOs
  - ADC for signal conditioning
  - LF Receiver
  - 315/433 MHz RF Transmitter!!
SP37 Operating Range

- 1.9 – 3.6 V for RF & μC operation
- 2.1 – 3.6 V for Pressure & Acceleration measurements
- 2.5 – 3.6 V for FLASH Programming
- -40°C..+125°C full specified operation
- Limited time allowed up to 150°C in thermal shutdown
- Temperature transients to max. 175°C
Introducing the SP37

The SP37 is an extremely high integrated tire pressure monitoring sensor with a low power embedded micro-controller and wireless FSK/ASK UHF transmitter. It is a single-chip solution suited for the TPMS application. With its highly integrated, mixed signal peripherals, the SP37 requires very few external components to form a completely functioning device.

- Integrated FSK&ASK UHF transmitter
- Advanced power control features
- Ultra low standby current (<0.7μA)
- Supply voltage range 1.9V to 3.6V
- Operating temperature range -40 to +125°C
- DSOSP - 14 package (Type 6)
SP37 (PG-DSOSP 14)

Product Features

- Integrated Pressure Sensor
- Integrated Acceleration Sensor
- Integrated Temperature Sensor
- Integrated Battery Voltage Sensor
- Embedded 8051 µC
- 6KB FLASH Memory
- 256B Data RAM
- On-Chip Program/Debug Capability
- Pseudo-Random Number Generator
- CRC16 Generator/Checker
- Two 16-bit Timers
- Interval Wake-Up Timer
- I²C Master/Slave Interface
- 3 Ch. Differential 10-bit ADC
- 3 General Purpose I/O Pins
- 315/434 MHz ASK/FSK UHF Transmitter
- 125 KHz LF Receiver
SP37 Digital core

- **16 kB library subroutines in ROM (IFX)**

- **256 Byte RAM**
  - 128 bytes of RAM can be powered during power-down state by setting a control bit in the SFR.

- **16 Byte non-volatile registers**

- **Embedded peripherals for**
  - I²C Bus, Data encoder (Manchester, diff. Manchester, Biphase, diff. Biphase, Chip-mode), CRC-16, Random Number generator, GPIO Pins

- **No Interrupt-Controller**
  - Timing is triggered by wakeup- and resume events for ultra low-power applications

- **Further Modifications form Standard 8051 core**
  - Clock gating, Reduced instruction cycling, MOVX command redirected
SP37 Benefits to Customer

- **System cost savings**
  - integration of TPM Sensor and RF transmitter in single package
  - integration of crystal pulling capacitor
  - small number of external components required for complete system

- **Rapid Development Cycle**
  - complete software development environment
  - 6KB FLASH memory avoids need to spend time “crunching code”
  - commonly needed functions already included in on-chip ROM library

- **Energy Efficiency**
  - on-chip system controller manages power savings modes
  - very low standby current for long battery life
  - powerful wakeup logic (GPIO, LF Signal, Interval Timer)
SP37 Sensor System

- **Powerful Sensor System**
  - **Sensor Measurement**
    - Pressure measurement
      - Supported by ROM Library function call
      - Returns compensated pressure value
    - Acceleration measurement
      - Supported by ROM Library function call
      - Returns compensated acceleration value
    - Temperature measurement
      - Supported by ROM Library function call
      - Returns compensated temperature value
    - Supply Voltage measurement
      - Supported by ROM Library function call
      - Returns compensated voltage value
  - **ADC Selftest**
    - Supported by ROM Library function call
  - **Sensor Integrity Check**
    - Supported by ROM Library function call
    - Return status flag
  - **Bond Wire Surveillance**
    - Supported by ROM Library function call
    - Returns status flag
SP37 UHF Transmitter Details

**Multi-Band UHF Transmitter**
- 315 and 434 MHz bands
  - One PLL supports both bands of operation
  - PLL Monitoring
  - Two power classes (+5/8 dBm nominal)
  - Overcritical “class C” output stage

**Crystal Oscillator**
- Software trimming of RF center frequency
- Integrated crystal load capacitor

**ASK and FSK Modulation**
- Software trimming of FSK deviation
- FSK deviation up to +/-50kHz

**Data Encoder**
- Manchester and Bi-Phase to 20kb/s
- “Chip” encoding supports PWM, NRZ, etc.
- Simple UART-like interface to CPU
- RF bitrate controlled by Timer 1
- CPU can be idled during RF transmission

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![UHF Transmitter Diagram](image-url)

**UHF Transmitter**

<table>
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<th>Phase Locked Loop</th>
<th>RF Power Amplifier</th>
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<td>Crystal Oscillator</td>
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<tr>
<td>FSK Modulator</td>
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125 KHz Low Power Low-Frequency (LF) Receiver

- TPMS High Sensitive ASK Receiver
  - Sensitive analog frontend amplifier
  - Automatic Gain Control (AGC) feature

- LF Carrier Detector
  - Optional CPU wakeup on LF carrier
  - Programmable carrier detector filter response
  - Self-calibrating threshold detector

- Digital Baseband Data Decoder
  - May be configured to wakeup CPU on LF sync
  - Manchester or Bi-Phase, 3.92Kb/s
  - Simple UART-like interface to CPU
  - “Chip” decoding supports special wakeup patterns

- Dedicated LF Polling Interval Timer
  - Allows LF polling without CPU intervention
  - Programmable ON and OFF polling times

- RC LF Oscillator
  - Low Power RC LF Oscillator
  - Allows Low Power Digital Baseband functionality
SP37 ROM Firmware Library

ROM Firmware Library Routine Examples

- Sensor Measurement
  - Compensated Pressure measurement Library Function
  - Compensated Acceleration measurement Library Function
  - Compensated Temperature measurement Library Function
  - Compensated Supply Voltage measurement Library Function

- Interval Timer and LF On/Off Timer Calibration
  - Interval timer can be calibrated to between 50mS…1S resolution
  - LF On/Off Timer is calibrated to 50mS resolution
  - Can be calibrated from Crystal or 12 MHz RC oscillator source

- Data Security
  - CRC8 calculation Library Function

- Fault Protection
  - ADC Selftest
  - 12 MHz Clock check
Notes:  C3 and C4 are optional pulling capacitors
SP37 Development Kit

- Quick-start development kit
  - Device operating at 315 MHz or 433.92 MHz
  - Real time debugging
  - USB interface for programming
  - Digital I/O for further experiments / RS232 Interface
SP37 Development Kit

- SP37 Development RF Kit is Available in two “flavors”
  - Operating frequency of 315 MHz or 433.92 MHz
  - Output power of 8dBm

- Complete and “Ready to go” out of the box
  - CD with Windows drivers and documentation
  - Sample code provided

- Capability Highlights
  - Download and debug code in FLASH via USB
  - 50-ohm SMA output connector facilitates RF testing
  - SMA input connector /placeholders for antenna facilitates LF testing
  - RS232 Interface allows easy input to PC
SP37 Timeline

- Engineering Samples available
- Samples for Qualification available
- Qualified samples

- Development kit for SP37, price 1800 Euro

- SP37 Target Datasheet V1.0
- SP37 Target ROM Library Guide V0.3

Application Notes:

- RF Baudrate Timer
- RF Transmitter Usage
- Interval Timer Calibration
- Programming Guide, in work