Integrated RF transmitter based on SAW Oscillator

Albert Heuberger Thomas Drischel

Fraunhofer Institut Integrierte Schaltungen IIS-A
Am Weichselgarten 3
D-91058 Erlangen
e-mail: heb@iis.fhg.de
Phone: +49 9131 776-330
Fax: +49 9131 776-399

Abstract

For the use in small, low power and low cost RF transmitters an oscillator ASIC in 1.2 µ BICMOS technology operating at 433 MHz has been built. The ring oscillator topology with a phase shifter in the feedback loop provides as a novel feature also FM modulation.
Integration of the oscillator ASIC together with the SAW resonator in a single package allows single device operation with very few external components.

Introduction

Wireless telemetry and telecommand systems have found broad high volume applications in Europe in the 433 MHz ISM (Industrial Scientific Medical) band [1]. These are among others: keyless entry systems in cars, remote meter reading for heating, gas, water and electricity, garage door openers, indoor audio distribution services or data transmission links. Most of the applications require only single channel, one-way communication at low data rates of up to 10 kbits per second and moderate coverage radius using a simple amplitude or frequency modulation scheme. In all cases, however, the requirements for transmitter circuits are low space consumption, low power consumption and, most of all, low production cost. Therefore, the use of microelectronic technology bears large potential to realize RF telemetry transmitters at lower cost and higher integration level. Based on this perspective, an integrated RF transmitter has been developed requiring only an external antenna connection.

Design considerations for low cost RF transmitters

SAW oscillators operate at RF frequency using a Surface Acoustic Wave (SAW) resonator. This leads to a number of advantages making them the best choice for many low power, low cost telemetry applications:

- Operation at the fundamental frequency avoids spurious emissions
- The circuit topology is simple and reliable
- The high Q factor ($Q > 10\,000$) of the resonator gives low phase noise
- SAW devices are manufactured at very low cost in high volume (typically less than $ 0.75 per device)

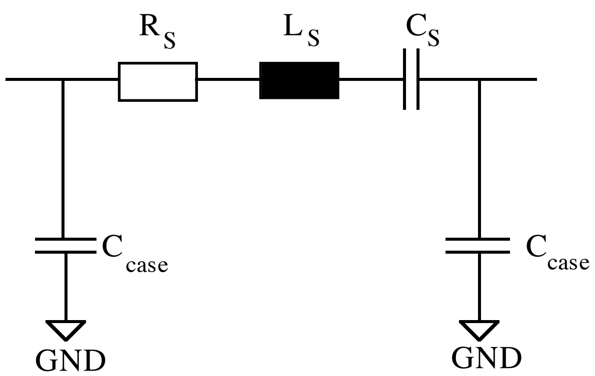
However, the use of SAW devices entails a number of restrictions :

- The center frequency is sensitive to effects of temperature (± 75 ppm) manufacturing tolerance (+/-200 ppm) and ageing (± 10 ppm/yr).
- Frequency modulation capability is limited

Although Phase Locked Loop (PLL) circuits are very common in RF frequency synthesis and many single chip realisations have been presented, they inherently need higher power consumption, larger chip area and more external components as compared to a SAW oscillator design. Also, spurious output signals, settling time and temperature stability are critical.

In practical realisations, SAW based transmitters with Amplitude Shift Keying (ASK) are commonly built as reflection oscillators with discrete packaged transistors and SAW devices. For ASK also integrated oscillators are already available on the market [2],[3].
FM modulation is realized by changing the phase shift within the active oscillator element with an external tuning diode device.

SAW-resonator



$R_s = 31\ \Omega$

$L_s = 0.122$ mH

$C_s = 1.1$ fF

$C_{case} = 1.7$ pF

Fig. 1 : Equivalent π circuit of the SAW resonator

The SAW resonator is represented by an equivalent π - circuit as shown in fig. 1, where R_s, L_s, and C_s describe the motional parameters and the cp parasitic capacitances between the interdigital structure and the package.
The paramters of the equivalent circuit were determined by fitting of data taken from an on-waver measurement.

Oscillator Circuit

The oscillator was realized as a ring oscillator rather than a single port reflection oscillator. This topology provides more robustness against parasitic shunt capacitance and allows frequency modulation with a phase shifter in the feedback loop. The analog phase shifter provides 90 degree range controlled by an external voltage.
The ASIC consists of five building blocks (see block diagram in fig. 2): the actual oscillator circuit, the amplifier stage, the output stage and two bias circuits. The bias circuits are current mirrors and reference voltage sources which can be used to activate or deactivate the oscillator circuit and to realize the ASK-modulation.

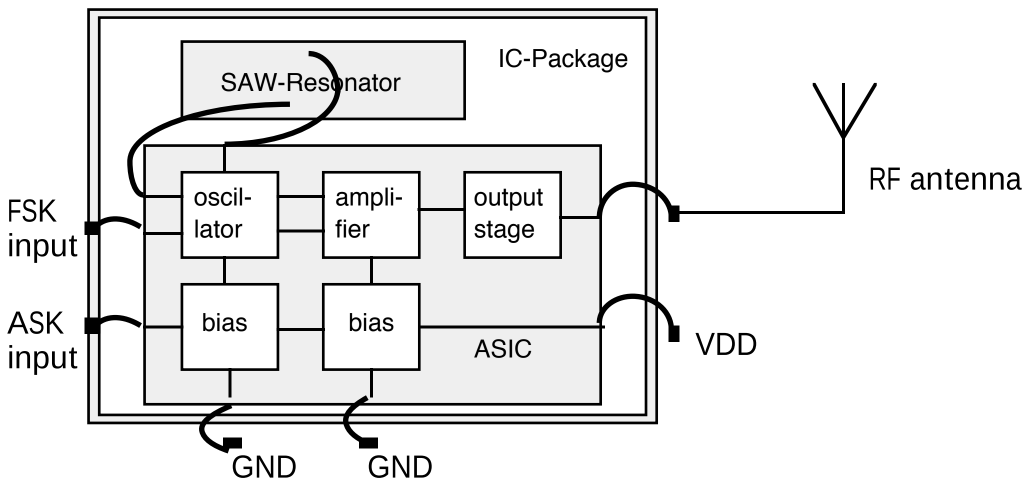


Fig 2 : Block diagram of the integrated RF transmitter

The oscillator core is followed by a buffer amplifier to minimize load pulling effects. Final amplification is done in the push-pull output stage in AB operation mode with low bias current and high efficiency.

Implementation Results

The circuit was realized as a full custom design for a 1.2μm BiCMOS-technology. The die was bonded together with the SAW resonator in a ceramic test package providing additional test pins. The final package will have 6 pins.

Table 1 shows the measured performance of the oscillator. A photograph is shown in fig. 3 with the resonator located on the left hand side inside the ceramic package.

Technology	1.2μm BiCMOS
Chip area	< 2mm^2
Transmit frequency:	433 MHz
Supply voltage	3 V
Current consumption	9.5 mA
Modulation schemes	ASK / FSK
FSK modulation bandwidth	30 kHz
FSK frequency shift deviation	50 kHz pp
Phase noise (10 kHz offset)	- 110 dBc/Hz
Output power (into 50 Ohms)	+5 dBm

Table 1 : measured performance of the integrated RF transmitter

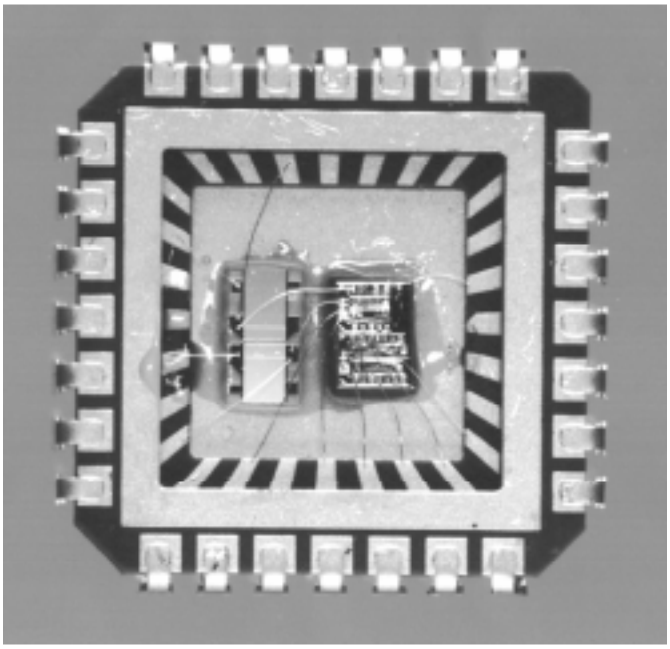


Fig. 3 : Photograph of the integrated RF transmitter

Conclusion

An integrated RF telemetry transmitter has been presented comprising an integrated oscillator togther with a Surface Acoustic Wave (SAW) resonator mounted in a single package. The ring oscillator allows adjustable phase shift and frequency modulation without special tuning devices. The transmitter operates a 433 MHz and delivers 3 mW into a 50 Ohm antenna.

References

[1] Clark, Earl, SAW Transmitters for Unlicensed Wireless, Applied Microwave and Wireless, Vol 1, 1995

[2] RF Monolithics; 1995 Product Data Book (First Edition), RF Monolithics, Dallas Texas, 1995

[3] Odyniek, Michael et al, Oscillator Design Using Modern Nonlinear CAE Techniques, RF and Microwave Measurement Symposium, Palo Alto CA, 1991