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An Ultra-Low Power Multi-Rate FSK Transmitter for Wireless Sensors and Biomedical Applications

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Abstract

An ultra-low power multi-rate FSK transmitter implemented in 0.18 μm CMOS process is presented. A digital frequency interpolator is adopted in the transmitter for achieving multiple data rate transmission. Power consumption of the transmitter is dependent on the required transmitted data rate. Thus, high power efficiency can be achieved. As applying for implantable or wearable biomedical devices, the feature of high power efficiency leads to a great improvement of lift time of the implantable or wearable biomedical devices. Moreover, all transistors of the transmitter are operated under sub-threshold region for realizing ultra-low power consumption. The transmitter consumes 378 μW to 424 μW according to the transmitted data rate varying from 200 kb/s to 2 Mb/s under a supply voltage of 0.7 V. Therefore, minimum energy consumption per transmitted bit of 212 pJ/bit can be achieved under the maximum transmitted data rate of 2 Mb/s.

Keywords: Ultra-low power, multi-rate, frequency-shift keying, transmitter.

1. Introduction

FSK transmitters are widely used in wireless sensors and biomedical wearable/implantable devices. In order to extending lift time of the wireless sensors and biomedical wearable/implantable devices to several years, the FSK transmitter should be ultra-low power [1]. Moreover, the required transmitted data rate of the FSK transmitter varies with the type of transmitted data. For example, as transmitting physiological information, the required transmitted data rate is about several kilobits per second. But, for transmitting physiological image information, a data rate of several megabits per second is required.

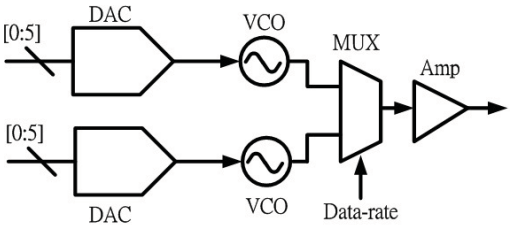

Fig. 1 Architecture of the multi-rate transmitter

Therefore, a multi-rate transmitter is needed for wireless sensors and biomedical wearable/implantable devices. On the other hand, owing to that power consumption of the transmitter is strongly dependent on the transmitted data rate, a transmitter with adjustable data rate is much more power efficiency.

In this paper, an ultra-low power (ULP) multi-rate FSK transmitter applied for wireless sensors and biomedical wearable/implantable devices is proposed. A digital frequency interpolator is adopted in the transmitter for achieving multiple data rate transmission. This paper is organized as follows. The architecture and circuits design of the proposed ULP FSK transmitter are presented in Section Ⅱ. Then, Section Ⅲ is dedicated to the simulation and measured results of the transmitter, in terms of frequency tuning characteristics and consumed power. Finally, conclusion is remarked in Section Ⅳ.

2. Architecture and circuits design of proposed ULP FSK transmitter

Fig. 1 shows the architecture of the entire ULP FSK transmitter. The FSK transmitter is implemented by two voltage control ring oscillators (VCO), two DACs, a multiplexer and an amplifier. The schematic of the ring oscillator used in bulk voltage control delay-cell is shown in Fig. 2. The ring oscillators are used to generate different transmission frequencies.

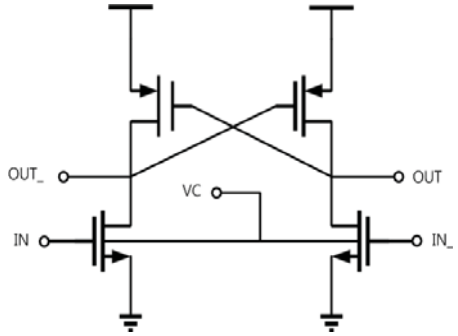

Fig. 2 Architecture of bulk voltage control delay-cell.

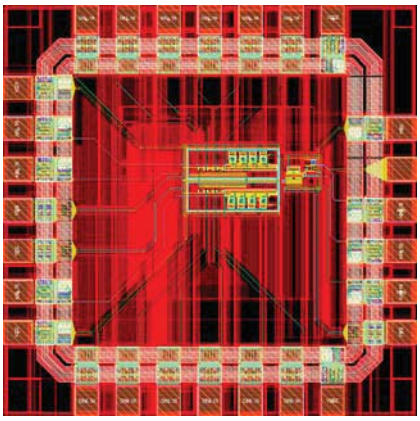

Fig. 3 Chip layout of the ULP multi-rate transmitter.

Frequency tuning is realized by changing the control code of the digital to analog converter (DAC) which is used to generate the bias voltage. The DAC implemented by the SAR control totally consumes from 16 μA to 32 μA according to operating frequency from 78MHz to 98MHz.

For reducing power consumption of the multi-rate FSK transmitter, all transistors in the multi-rate FSK transmitter are operated in sub-threshold region under a supply voltage of 0.7 V

3. Simulation and Measurement result

The proposed ULP multi-rate FSK transmitter is designed in 0.18 μm CMOS process. Fig. 3 shows the chip layout of the FSK transmitter in 0.18 μm CMOS process. The simulated difference frequency with changing the control code of the DAC is shown in Fig. 4. The proposed ULP multi-rate FSK transmitter can provides output frequency from 72 MHz to 98 MHz as current consumption varies from 16 μA to 32 μA. The modulation spectrum under a data rate of 1 Mb/s is shown in Fig. 5, where the center frequency and frequency deviation are set to 85 MHz and 1 MHz, respectively.

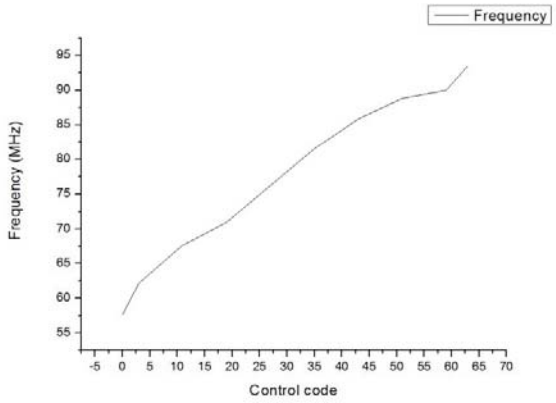

Fig. 4 The simulated difference frequency with changing the control code of the DAC.

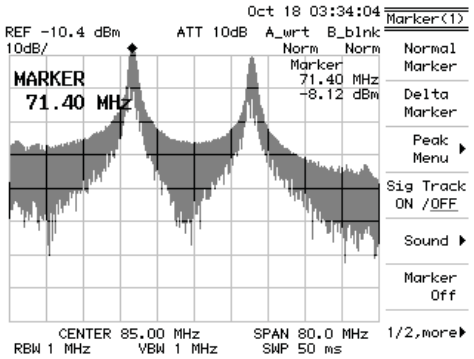

Fig. 5 Transmitter modulation spectrum under a data rate of 1 MHz.

4. Conclusion

An ultra-low power multi-rate FSK transmitter implemented in 0.18 μ m CMOS process was presented. The transmitter consumes 378 μW to 424 μW according to the transmitted data rate varying from 200 kb/s to 2 Mb/s under a supply voltage of 0.7 V. Therefore, minimum energy consumption per transmitted bit of 212 pJ/bit can be achieved under the maximum transmitted data rate of 2 Mb/s.

References

[1] Christian C. Enz, Nicolari, Uroschanit Yodprasit, “Ultra Low-Power Radio Design for Wireless Sensor Networks,” IEEE RFIT Nov 30, Dec. 2005.