Low Power Transmitter for Wireless Capsule Endoscope

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Abstract. This paper presents the transmitter circuit designed for the application of wireless capsule endoscope to overcome the limitation of conventional endoscope. The design is performed using CMOS 0.13 µm technology. The transmitter is designed to operate at centre frequency of 433.92 MHz, which is one of the ISM band. Active mixer and ring oscillator make up the transmitter and it consumes 1.57 mA of current using a supply voltage of 1.2 V, brings the dc power consumption of the transmitter to be 1.88 mW. Data rate of 3.5 Mbps ensure it can transmit high quality medical imaging.

1. Introduction

The evolution of wireless communication and circuit integration has brought medical science and devices to a new dimension. Conventional endoscope for gastrointestinal diseases diagnoses which are uncomfortable for patients, have certain limitations in performing diagnosis or treatment. It is not feasible for the conventional endoscope, in terms of travelling through a long and convoluted small intestine. Wireless capsule endoscopy addresses the disadvantages of the conventional wired endoscopes where it can reach the small intestine and achieve diagnosis without discomforting the patients as well as easily travel through the digestion tract [1], [2].

For the implementation of a capsule endoscope, several important characteristics need to be taken into account, particularly the power consumption of the system as the system is a battery operated device. The power supply must be able to sustain for approximately 8 hours, for a full cycle of digestion until the capsule reaches the bowel. Apart from power consumption, in order to have a highly reliable diagnosis the image quality cannot be tolerated, and for a good quality of image inevitably the data rate has to be high enough to transfer the image wirelessly to the receiver wound around the patients’ body. Size of the capsule should be minimized to avoid uncomfortable experience for patients in swallowing the capsule. The characteristics mentioned complicate the design of the wireless capsule endoscope and it is very much a challenge in realizing the system.
2. Design Consideration

Designing the system aims at optimizing each and every one of the crucial characteristics, basically with the trade off of power consumption versus performance, where the performance includes image size, bit depth, frame rates, which sums up to be the data rate. The balance of both criteria of performance and power consumption has to be reached so that a quality capsule endoscope system is designed.

2.1. Power consumption

The most essential aspect which gives the capsule endoscope to keep functioning is the power consumption. Considering it is a battery operated device, power management of the system must be well planned. Overall dc power consumption should not exceed 16 mW. Dividing the power consumption into functional area of lighting, camera etc, the power consumption of the transmitter of the system has to be within 7 mW. [3]

2.2. Carrier frequency

Carrier frequency of the system needs to be optimum for the performance of the system. Many standards of frequency have been utilized for data transmission such as Zigbee, Wireless Local Area Network etc [4]-[5]. Transmitting images wirelessly through human body causes loss in the signal, such as radiation loss, attenuation loss, reflection loss etc. Frequency range where the total loss are minimal is within 400 MHz to 600 MHz [6]. This frequency range covers several standards such as Medical Implant Communication Services (MICS) 402-405 MHz and Industrial, Scientific and Medical (ISM) 433.05 – 434.79 MHz. Another standard close to the range is Wireless Medical Telemetry Services (WMTS) 608 – 614 MHz. MICS is allocated by Federal Communications Commission (FCC) and are commonly utilized in implantable medical devices [7]. However, this standard offers low data rate of up to 500 kbps, which is not sufficient to meet the high data rate requirements to transmit high quality images. WMTS is only covered in the United States and it has inadequate spectrum thus not appropriate for this application. ISM band is widely available and there is no restriction on the bandwidth as well as modulation technique, and hence suitable to be used for wireless capsule endoscope.

2.3. Quality of imaging

Resolution, bit depth, frame rates and data rates all combines to determine the quality of the capsule endoscopy imaging, which essentially is the main objective of diagnosis. Poor quality of imaging would bring to uncertainty of diagnosis and leads to time and financial loss. Resolution of the image should be large enough to be examined by physicians without doubt. The proposed resolution for the system is Quarter Video Graphics Array (QVGA) where the pixel size is 320 x 240 pixels. Frame rate of the camera is set to be five frames per second (fps) in order not to miss any intestinal area in concerned, contrast to 2fps used in other work [8]. Flashes of lighting have to be synchronous with the frame rate in order to keep the power consumption low. Bit depth is another important attributes as difference in colour in intestine leads to discovery of diseases. 8 bits of colour is used in the design of the system to produce high quality imaging. Coming together with the mentioned characteristics, the data rate needed would be 320 x 240 x 5 x 8, which is equivalent to 3 Mbps. The transmitter of the system is designed to cater for data rate of 3.5 Mbps, compare to existing system of 1 -2 Mbps [9], [10].

3. Proposed Transmitter

Wireless capsule endoscope architecture consists of LEDs for lighting, image sensor, battery, transmitter and antenna, as shown in Figure 1. The building block in interest is the transmitter where it accounts for large percentage of the total power consumption and determines the quality of
transmission. The proposed transmitter uses an active mixer and a ring oscillator to transmit the signal obtained from image sensor. Ring oscillator is used instead of LC voltage-controlled oscillator due to several reasons, one of which is the start-up time of ring oscillator is faster than that of the LC oscillator. Apart from that, ring oscillator offers lower power consumption and due to the inductorless architecture, requires smaller die area and better circuit integration [11].

Figure 2 shows the transmitter architecture which consists of a mixer and a ring oscillator. The mixer basically up converts the signal from the image sensor with the centre oscillation frequency of 433.92 MHz.

4. Results
The transmitter circuit has been designed and simulated using 0.13 um CMOS technology. The layout of the active mixer and ring oscillator is as shown in Figure 3 with die area within 1 mm x 1 mm. The small area is important for achieving highly integrated circuit with optimized performance. The choice of using mixer and ring oscillator which are without inductors greatly contributes to the minimization of die area.
The combination of mixer and ring oscillator consumes 1.57 mA of current with voltage supply of 1.2 V which translates to power consumption of 1.88 mW. The resulted power consumption is way below the targeted power performance of 7.7 mW. The achievement of low power consumption enables complete diagnosis without interruption of possible power failure. Apart from that, the reduction of power consumption can be utilized for other blocks of the system, which consequently able to boost the overall performance of the system. Figure 4 shows the simulated output waveform of the transmitter. Performance of the designed transmitter is shown in Table 1.

![Layout of the designed mixer and ring oscillator](image1)

**Figure 3.** Layout of the designed mixer and ring oscillator

![Simulated output waveform of the transmitter](image2)

**Figure 4.** Simulated output waveform of the transmitter
Table 1. Performance table of designed transmitter

| Technology  | CMOS 0.13 µm |
|-------------|--------------|
| Voltage supply | 1.2 V       |
| Current Consumption | 1.57 mA    |
| Power Consumption  | 1.88 mW     |
| Carrier Frequency  | 433.92 MHz  |
| Data Rate         | 3.5 Mbps    |
| Die Area          | 1mm²        |

5. Conclusion

Low power transmitter for wireless capsule endoscope has been designed which achieves the purpose of low power consumption and high data rate for high quality medical imaging. It offers higher frame rates by having higher data rates of 3.5 Mbps than other works done and better imaging quality which could improve the diagnosis accuracy and acceptance among surgeons and patients. The low power design of 1.88 mW ensures the capsule endoscope works without power failure for the whole diagnosis, as well as enables more voltage headroom to other parts of capsule endoscope system.

The transmitter designed will be integrated with CMOS image sensor and other peripheral circuitries in order to develop a complete prototype of wireless capsule endoscope. Performance testing will be performed and image recovery experiment will be carried out using the prototype capsule endoscope.

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