A Low Gate Count UWB Transmitter Circuit

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ABSTRACT

To satisfy the different radiated power requirements for the ultra-wideband (UWB) data transmitting in the implantable electronic devices or the wireless component inter connections, a novel low-power high- speed UWB transmitter with radiated power tuning was proposed. The tunable radiated power is achieved by a UWB RF buffer with a peak value controller. The designed low-complex narrow pulse generator and digital ring on–off VCO ensure a high speed transmitting. The low power is realized by using a sub tractor to eliminate the base-band component from the output of the VCO and making the UWB RF buffer and the VCO operating in standby mode. The design was fabricated by a standard 0.12 µm CMOS technology. The count gates are 34 instead of 45 to the previous work, simulate frequency bandwidth from 5 to 13 GHz and 1.104Mw power consume by circuit area of 0.12mm^2.

I INTRODUCTION

The ultra-wide band (UWB) communication technology meets the crucial requirements for future high data rate and low-power wireless applications of component inter connection and implantable electronics [2–5]. A licensed UWB radio-frequency (RF) signal must satisfy regulations such as U.S. Federal Communications Commission (FCC) spectrum mask regulation. FCC defined that UWB characterizes transmission systems with instantaneous spectral occupancy in excess of 500MHz, mean while regulated power level sarevery low (below 41.3 dBm in the 3.1–10.6 GHz frequency band), which allows UWB technology to overlay currently available services [2]. The rear several methods to generate licensed UWB RF signals. One way is that a base-band narrow pulse is shape do filtered out to satisfy the FCC regulation. However, it needs to integrate a large area of LC circuit which is not beneficial to the miniaturization of the devices [6–8]. Another way is to transpose a base-band signal in the licensed frequency band of operation using a mixer and a voltage controlled oscillator (VCO) with a few of LC components [9–11]. Although the second way has good performance in signal peak magnitude, it is not suitable to the low-power and high-speed design for its high static power consumption and long start-up time. The third way is to use an all-digital method to generate licensed UWB RF signal by combining multiple base-band single- pulse to meet FCC regulation [12, 13]. Such technique requires an accurate relative delay control of each pulse, resulting in some design difficulties. In order to meet the crucial requirements for future high data-rate and low-power wireless applications, the performances of UWB transmitter should be improved in area, power consumption, speed, complexity and implementation. In order to reduce the interferences too their facilities and wireless communications, the output power spectrum density (PSD) for UWB transmitting should be designed as low as possible be sides meeting FCC regulation. However, for implantable devices application, the sensitivities of different biological tissue to the microwave radiated power are not the same in the implantable biomedical environment. Therefore, a suitable intensity of the radiant power should be chosen to ensure that the signal can pass through the living skin and at same time not damage the tissue of them ensured organism such as the brain. While for the application of the wireless component interconnection, there is also a requirement to choose an applicable radiated power to deal with different transmission distances, different obstructions and different interferences. In this paper, a novel 5–13 GHz UWB transmitter is proposed to adapt to the different application requirements of implantable electronic devices and wireless component interconnections. The radiated power tuning is realized by introducing a novel UWB RF buffer with standby mode. Low power design is also considered by making the transmitter operating in burst mode and employing a sub tractor to remove the static current consumption of a novel on–off voltage controlled oscillator (VCO) and hence to reduce the base line power dissipation of the transmitter.

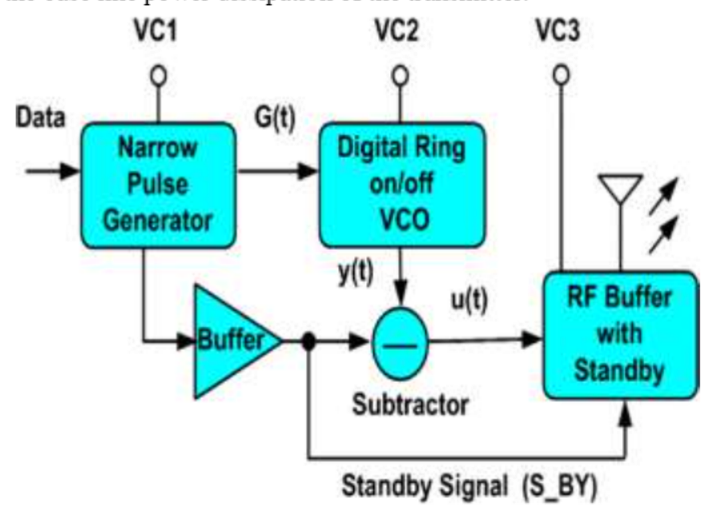


Fig 1 Block Diagramme of Proposed Tx

II TRANSMITTER STRUCTURE AND WORKING PRINCIPLE

Fig.1 is the block diagram of the proposed tunable UWB transmitter which includes a narrow pulse generator, a digital ring on–off VCO, a sub tractor and a UWB RF buffer with standby function. In Fig. 1, the unipolar return to zero (RZ) code D (t) is transported to the base-band narrow pulse G (t) by the narrow pulse generator. The G (t) controls the digital ring on–off VCO operating in the burst mode. Thus, the modulation of the UWB on–off keying (OOK) is implemented. y (t) is the output of the VCO and can be expressed as

$$y(t) = G(t)[A + A\cos(\omega t)] = AG(t) + AG(t)\cos(\omega t) \quad (1)$$

Where ω is the radian frequency of the digital ring on–off VCO and A is the direct current (DC) component from the VCO. Apart from the dc component A, it is seen from Eq. (1) that there is also a base-band component [AG (t)] in the y (t). In order to avoid the base-band component [AG (t)] reducing the radiated efficiency and violation of the licensed UWB RF signal spectrum mask of the UWB transmitter, a subtractor is employed. The output of the buffer from the narrow pulse generator is [AG (t)]. The output of the sub tractor u (t) can be express as

$$u(t) = y(t) - AG(t) = [AG(t) + AG(t)\cos(\omega t)] - AG(t) = AG(t)\cos(\omega t) \quad (2)$$

Eq. (2) shows that after sub tractor the base-band component A.G (t) included in y (t) is eliminated and the OOK UWB RF signal u (t) is obtained. Finally, the u (t) corresponding to the unipolar RZ code D (t) can be radiated by the UWB RF buffer with standby mode. The feasibility of the proposed UWB transmitter is firstly validated by the Matlab software. The power spectrum density (PSD) of the output from the transmitter with and without the sub tractor is shown in Fig.2. Obviously, the base-band energy is eliminated by the sub tractor. Thus, converting the base-band narrow pulse G (t) to the OOK UWB RF signal u (t) was implemented by the digital ring on–off VCO combining with the sub tractor and the energy efficiency of the transmitter is improved.

Because of employing the OOK modulation, controlling the bias voltage VC1 can regulate the pulse width of the base-band narrow pulse G (t) and hence can calibrate the frequency band width of the UWB RF signal u (t). Calibrating the center frequency of u (t) can be achieved by regulating the oscillation radian frequency ω of the VCO through the control of the bias voltageVC2. The radiated power of output UWB RF signal can be adjusted by controlling the bias voltage VC3 conveniently. Moreover, before the base-band narrow pulse G (t) turning up; the proposed VCO and RF buffer keep in standby mode. Therefore they can only operate during very short pulse duration (can be less than 1ns), and hence the base line power dissipation can be reduced significantly. In this way, the novel solution of the UWB transmitter for future high data rate wireless applications was achieved, which has benefits of low-complexity, low-power, and radiated power tuning. The detail of the design will be discussed in the next section.

III KEY CIRCUITS DESCRIPTION

(a) Narrow pulse generator

In order to provide a dependable base-band narrow pulse for OOK UWB modulation, a feasible low-complexity pulse generator circuit was employed and shown in Fig 2 The circuit consists of transistors NM1, NM2 and a INV and a AND gate. In order to achieve the pulse width adjusted, the INV (inverter) and transistors make up a pair of delay as well as opposite pulse with the reference signal, tunable delay by controlling the charging and discharging current of the transistor NM1 to the NMOS-connected capacitor NM2. The advantage of employing delay structure is that the relative time delay between the two paths can be controlled by the bias voltage easily. Finally, after an INV gate and an AND gate, a dependable base- band narrow pulse G (t) for OOK UWB modulation is generated.

From Eq. (2), after OOK UWB modulation, the frequency band width (B) of the UWB RF signal u (t) controlled by VC1 can be approximately written as:

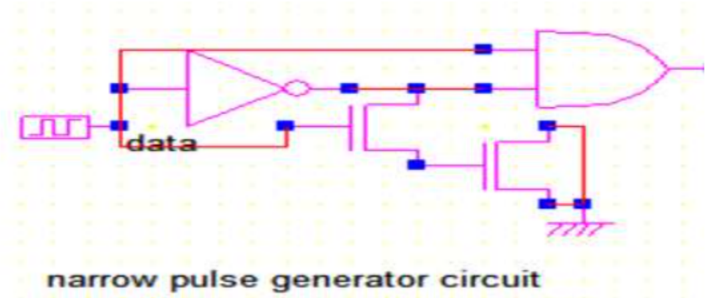
$$B \approx 2/[\tau + (t_r + t_f)/2] \quad (3)$$

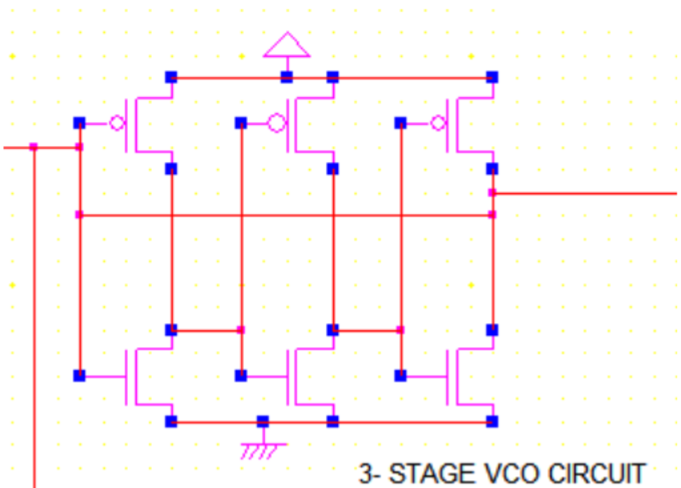
where τ is the pulse width of G (t), tr and tf are the rise time and fall time of the G (t), respectively. In this design, the frequency band width of the UWB RF signal u (t) , needs to be calibrated from 5 to 13 GHz (corresponding to the pulse width 1ns of the base-band narrow pulse G (t)). For achieving the function mentioned above, the adjustment redundancy mentioned above has been taken in to account.

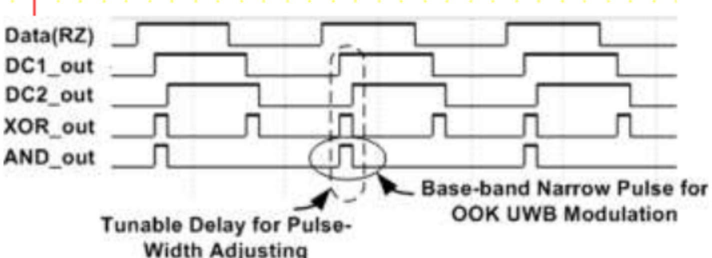
(b) Digital ring on–off VCO

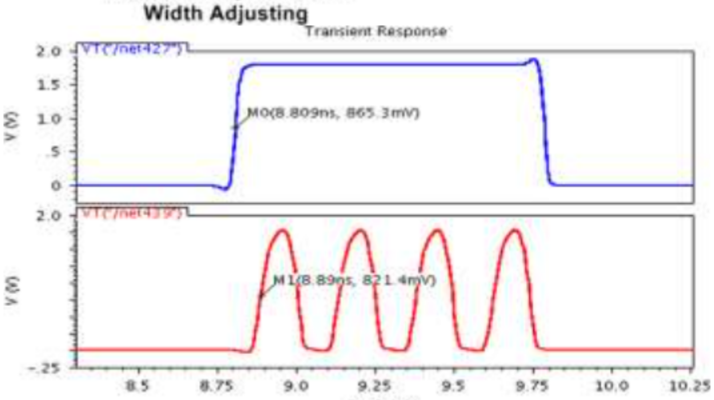
The core circuit of the novel digital ring on–off VCO for OOK UWB modulation is shown in Fig 3. The proposed VCO consists of an on- off digital ring oscillator employed [14], but it is not beneficial to the miniaturization of the chip. Therefore a sub tractor is employed in this design. The principle diagram of sub tractor is shown in , This circuit is based in the delay of the inverter gate switch. The output of each inverter changes in a finite amount of time after the input has changed, and then the loop of an odd number of inverter gates creates an oscillation. To reduce the frequency of oscillation is necessary to add more inverter gates to the loop, increasing the total propagation delay. The VCO based on this architecture uses the alimentation of the inverter gates to change the delay time, changing the global oscillation frequency. Two VCO's were added in order to create two different waves for comparison in the output.

The on–off mode of the VCO is implemented by controlling the transistor M1 and M2 through the base-band narrow pulse signal G (t).When the narrow square pulse G (t) turns up, the switch (M1) closes the oscillation loop, the oscillation occurs, the G (t) is up-converted to UWB RF frequency band. When the G (t) pulse vanishing, the switch (M5) breaks the oscillation loop, the oscillation turns off the static current does not occur. The VCO should constantly remain in standby mode, except when the G (t) turning up. Since the oscillation occurs only in very short pulse duration (some times can be even short to a nanosecond), the energy efficiency of the transmitter is greatly improved. Based on the principle of digital ring oscillation, the VCO has a fast transient response to ensure a sufficient oscillation during very short pulse duration. The start-up time of this ring VCO shown in Fig. 4 is close to 41ps, which is closed to the start-up time of conventional digital ring VCO. But like other VCOs based on the principle of digital ring oscillation, when the oscillation turns off, the output of the VCO will be connected to the power or the ground, inducing a high base-band energy corresponding to the base-band switch pulse, shown as Eq. (1). In order to eliminate the base-band component A.G (t) LC filter can be









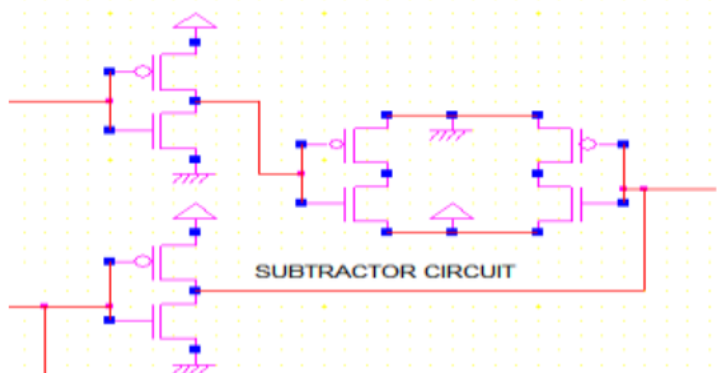
Through inverters the signal A.G (t) will become –AG (t). After signals –AG (t) and y(t) passing through the analog multiplexer, the base-band energy component will be eliminated, and the pure output UWB radio-frequency signal u(t) will be obtained theoretically. The center frequency of the VCO output radio-frequency signal u(t) is determined by the transmission delay of each inverter in the oscillating loop, and can be expressed as:

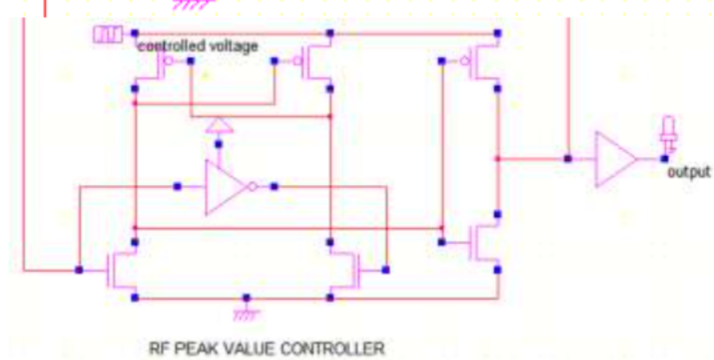
$$CF \approx \frac{1}{2}\cdot\frac{1}{t_1+t_2+t_3}=\frac{1}{2}\cdot\frac{1}{2t_1+t_3}=\frac{1}{2}\cdot\frac{1}{2\left(0.693\frac{1}{R_{M1}C_{M1}}\right)+t_3} \quad (4)$$

where t1, t2 and t3 are the transmission delay of inverter M1, M2 and M4–M6, RM1 is the equivalent transmission resistance of M1, CM1 is the output equivalent capacitance of M1, t3 is depended on the transmission resistance and output equivalent capacitance of M5 and M6, the dynamic charging current provided by M4.

(c) UWB RF buffer with standby mode

There were some problems with traditional RF buffers when they were used in the UWB transmitter for future high data rate Wireless component interconnection sand implantable electronic applications. One is that the radiated power of the RF buffer is fixed and not adjustable to adapt to different radiated power requirements. Another one is that there is a static

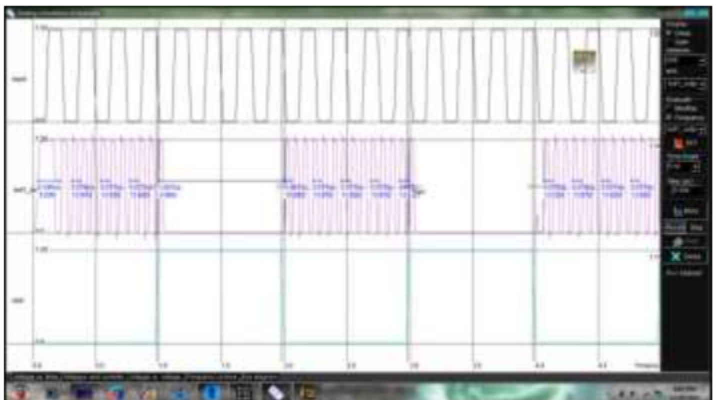




current in the buffer, which will increase the power consumption. In order to solve above problems, a peak-value-controlled UWB RF buffer with standby mode is designed. The simplified circuit of the proposed RF buffer is shown in Fig.4.6. Its out voltage level can be changed by regulating the value of controlled voltage and then tunes the radiated power of the UWB transmitter through transistor. The output drive capability of the peak value controller is improved due to the cross-coupled positive feedback (M11andM12). Similar to the VCO mentioned above, the RF buffer would constantly keep standby mode so that the static current does not occur, except when the stand by signal S_BY (same as G (t) shown in the Fig. 4.1) turning up. Thus, the RF buffer only operates during the very short pulse duration and hence has high energy efficiency. In this design, the adjustment range of controlled voltage is finite with the range from0.1V to 0.9V.

IV SIMULATION RESULTS

To simulate the functions of the transmitter circuit with a standard 0.12 µm or 120nm RF CMOS process shown in Fig. 8 The transmitter is compact and highly integrated without inductor. The core is 0.12mm^2 excluding pads. The transmitter operates with1.2V supply and the input data is unipolar return-to-zero (RZ). The output power is obtained by Microwind2.6 software eye pattern 5-13 GHz frequency is generated to the proposed transmitter circuit. The maximum power consumption of the transmitter is 1.104mW, showing that employing standby mode in the proposed VCO and RF buffer with a sub tractor can save the power efficiently. Table1 shows the performances comparison with previously reported UWB transmitter.



References	Proposed Work	Paper Work
Process (µm)	0.12	0.18
Core area (µm^2)	0.12	0.18
Used Gates	34	45
Frequency (GHz)	5-13	3-5
Power consumption	1.104mW	2mW
Energy(pJ/s)	0.38	11

V CONCLUSION

This paper has shown that there are four major factors that can limit the performance of high-speed, reduce circuit complexity, increase frequency as well as signal bandwidth, and timing accuracy for the UWB transmitter. The proposed UWB transmitter consists of a UWB RF buffer with stand by operating mode, a digital ring on–off VCO, a subtract or for eliminating base-band component from the output of the VCO and a narrow pulse generator. The novel digital ring on–off VCO makes it reliable to transmit a maximum high speed data-rate data band width of 5–13 GHz. By adding a peak value controller of the UWB RF buffer, the radiated power of the UWB transmitter can be tuned from. The static power of the transmitter is reduced by making the UWB RF buffer and the VCO operating in standby mode. In this way, the transmitter has consumed low-power 1.104mW of 0.38 pJ/bit and small circuit area of 0.12mm^2.

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