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Ultra Low Power Pulse Generator for RFID Applications

R. Vauché[1], S. Bourdel[1], J. Gaubert[1]

[1] Aix-Marseille University, IM2NP, and CNRS, IM2NP (UMR 6242), France

Abstract

The design of a remotely UHF powered UWB transmitter is presented in 0.13µm CMOS standard process. Multi-Vt technique and CMOS logic allows pulse generator power consumption between two consecutive pulses to be reduced enough to be remotely powered. It achieves FCC compliant pulses having 2Vpp and a power consumption of 10.7uW@100kb.s^{-1}.

Keywords

Pulse Generator; Remotely Powered; RFID; Tag Localization; UWB;

1. Introduction

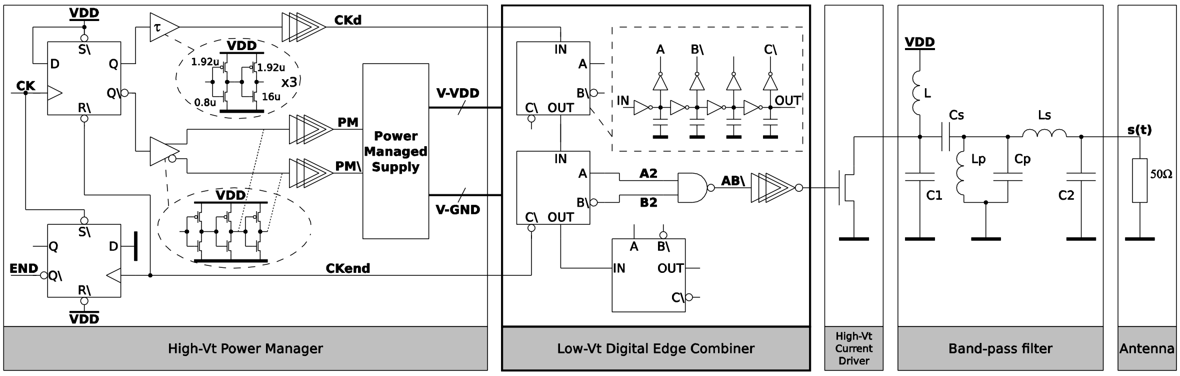
Due to its rapid adoption in industry, RFID technology is facing new application demands. Especially, accurate Real Time Location (RTL), robust and secure identification and management of large Tag number are needed to address new purposes and new markets is all the more difficult to satisfy since the Tag cost must be lower than few tens of cents. Consequently the tag must be fabricated using, low cost technologies: a single CMOS chip in a low cost technology with no external devices such as crystals or filter and moreover the chip must be remote-powered to avoid the use of costly cells or battery.

Because UHF RFID technology uses narrowband continuous waves around 900MHz, it is intrinsically limited for high resolution location, sensitive to multipath cancellation and affected by multi-users interferences. Even if improvements can still be achieved on UHF RFID systems, a technological breakthrough is needed to overcome all those limitations. According to recent works, [1] UWB-IR is a promising technique for the next generation of RFID systems and has been recently proposed as a possible physical layer of the new IEEE 802.15.4f standard. The very short time duration of the emitted pulse enables (i) accurate localization with TOA or TDOA techniques [1], (ii) efficient power gating which allows power consumption to be reduced, (iii) high multipath resolution which allows the coverage area to be increased, (iv) efficient multiple access and interference mitigation allowing the increase the number of Tags [2][3][4][5][6].

Several communication techniques can be implemented to achieve the uplink in a Remotely Powered UWB Tag. A first solution is to use UWB backscatter propagation [7]. Backscattering is very well suited to passive Tag because it consumes a very small amount of power since it consists in varying the input impedance of the circuit. Unfortunately, the backscatter signal has very low energy which degrades the localization accuracy [4]. Another solution is to use an ultra low power UWB pulse generator remotely powered by an UHF downlink [8]. Indeed UWB pulse generators are known to consume a very small amount of energy for a pulse emission. In [9] we demonstrated an energy consumption of 9pJ per pulse with 10dBm pulse peak power. Such low energy per pulse consumption enables ultra low power consumption at low data rate (few tens of microwatt for 1Mbs^{-1} bit rate) which can be supplied by a standard UHF energy harvesting unit.

Recent works showed the feasibility of UHF/UWB hybrid RFID Tags [8][10]. It appears that achieving high energy pulse with a very small power budget is a bottleneck which finally limits the localization accuracy and the range. To improve the energy efficiency of the pulse generator, high energy pulse must be used [1]. But in the same time the energy consumed by pulse must be minimized. Especially, reducing the power consumed between the emissions of two consecutive pulses is highly required to reach ultra low power consumption at medium or low rate. Moreover, the efficiency of the energy harvesting unit must also be maximized to increase the available power and so the localization accuracy and the tag reader range.

In this paper we present an Ultra Low Power pulse generator for RFID applications. The pulse generator is designed to be remotely-powered by an UHF harvesting unit. The next part deals with the power budget of the proposed system. The third part presents the design of the pulse generator. Measurement results are then given in the fourth part.



2. Power Budget

Due to the gated nature of an UWB signal, the mean power consumption of a pulse generator is a function of the mean bit rate ($D_{b\text{-}mean}$) and is given as follows:

$$P_{cons\_PG} = E_{ap} \cdot D_{b-mean} + P_{0\text{Hz}} \tag{1}$$

where $P_{0\text{Hz}}$ is constant DC power consumed at 0Hz PRF and E_{ap} is the active energy added while pulse is generated.

To properly power supply the pulse generator with UHF harvesting, the harvesting unit must provide an available power ($P_{av\text{-}HU}$) at least equal to P_{cons_PG}. $P_{av\text{-}HU}$ depends on the efficiency η of the harvesting unit and on the emitted power allowed for the UHF downlink EIRP as follows:

$$P_{cons\_PG} = P_{av\_HU} = \left(\frac{\lambda}{4\pi d}\right)^2 \eta \cdot EIRP \tag{2}$$

where λ is the wavelength of the UHF downlink.

Using (1) and (2), the mean bit rate is evaluated as a function of the communication range as follows:

$$D_{b-mean} = \frac{1}{E_{ap}}\left[\left(\frac{\lambda}{4\pi d}\right)^2 \eta.EIRP - P_{0\text{Hz}}\right] \tag{3}$$

3. Pulse generator design

Among the different UWB pulse generation techniques, many works show that filtered combined edge method is well-suited when an high energy efficiency is required as in remote powered UHF applications [9][15][16]. The presented generator is a derivative of a previous designed pulse generator which consumes a static current of 2.6mA due to integrated digital edge combiner based on Current Mode Logic (CML) gates [9]. To reduce the static power consumption, the choice of a standard CMOS logic associated to a power manager is assumed.

As shown in Fig.5, UWB pulse generator can be divided in four parts, the band-pass filter, the high-Vt current driver, the low-Vt digital edge combiner, and the high-Vt power manager.

Band-pass Filter is uses Bessel-Thompson coefficient which allows UWB pulse duration to be minimized. Its input and output are matched to 50Ω impedance in order to maximize power transfer to 50Ω antenna.

High-Vt Current Driver linked to Band-pass Filter is a C class amplifier where current driver drain is biased by L. C1 capacitor prevents V_{DD} biasing of others filter nodes. Finally, a baseband pulses must be applied on High-Vt Current Driver gate to emit UWB pulses. A sizing method of the driver regarding the application needs and the filter characteristics is given in [9].

Low-Vt Digital Edge Combiner generates baseband pulses needed by High-Vt Current driver for UWB pulses generation. It is only designed with low-Vt MOS devices and supplied by Power Managed Supply thanks to V-VDD and V-GND.

High-Vt Power manager consists in D flip-flops, a delay cell, logic buffers, and a balun and uses only high-Vt MOS devices. It allows complementary power management signals which drive Power Managed Supply (PM and PM\) to be generated.

To generate an UWB pulse, a rising edge has to be applied on High-Vt Power Manager input (CK) which allows power management to be disable (PM='0' and PM\='1'). Then, a 500ps delayed rising edge is generated on CKd thanks to three strings of balanced and unbalanced inverters. This ensures that all V-VDD and V-GND supplies of Low-Vt Digital Edge Combiner are enable when it is propagating into itself.

In Low-Vt Digital Edge Combiner, rising edge from CKd is propagating in a string of buffered inverters loaded by a capacitor. Next, the buffered rising edge A2 is combined with the buffered falling edge B2 to make an inverted baseband pulse thanks to fast NAND logic gate. Capacitors in buffered inverters string are sized with the help of post-layout simulations to have a 75ps width buffered baseband pulse on driver current gate. This baseband pulse width is sized regarding the designed band-pass filter [9].

After the baseband pulse and so UWB pulse are issued, a falling edge is generated on CKd and Low-Vt Digital Edge Combiner is put in its sleeping state. When the falling edge arrives on CKend, END is set to ‘1’ and power manager is enable (PM=’1’ and PM\=’0’). Finally, END is set to ‘0’ when CK is reset.

4. Measurement results

The pulse generator presented in this work has been realized in a 0.13µm CMOS process from STMicroelectronics and is shown on Fig. 2. Voltage supply is 1.2V and die area is $0.64mm^2$. It achieves FCC compliant pulses with 2Vpp on 50Ω resistive load. Central frequency and 10dB bandwidth are respectively equal to 6.15GHz and 5.2GHz. P_{0Hz} is equal to 3,91uW and Eap is 67.7pJ wich leads to total power consumption of $10.7uW@100kb.s^{-1}$.

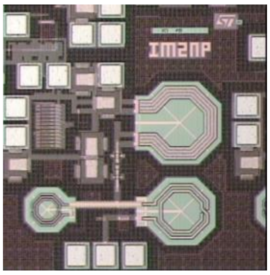


Fig.2 Die Photograph

According to Eq. 3, the mean bit rate when tag reader is at 10 meters is $4,3kb.s^{-1}$ assuming an UHF energy harvesting unit having an efficiency of 15 percent.

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About the Authors

Rémy Vauché was born in Epinal, France, in 1985. He was accepted for preparation for the competitive entrance examinations to French Engineering Schools, Metz, France, in 2003. He received the M.Eng degree in microelectronics and telecommunication from Polytech' Marseille and the M.S. in microelectronics and nanoelectronics from Aix-Marseille University, Marseille France, in 2008.He is currently a Ph.D. student of Aix-Marseille University with the IM2NP laboratory. His current research interests include UWB radio transceiver design in 0.13µm CMOS technology for low-power and low-cost applications.