An Implementation of a Sub-nanosecond UWB Pulse Generator

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***Abstract*—In this paper, we present an ultra-wideband (UWB) pulse generator based on the step recovery diode. The principle of operation and the architecture of the developed pulse generator are explained. Furthermore, hardware implementation issues and the details on the generated UWB pulse including its peak voltage equal to 8.9 V, its full width at half maximum (fwhm) equal to 240 ps, and frequency spectrum are provided. The UWB pulse generator incorporates not only a high frequency part, but also a trigger signal part that is based on a low-power MSP430F2121 microcontroller. The averaged total power consumption of the complete UWB pulse generator is 185 mW @ 3.3 V supply voltage.**

I. Introduction

The ultra-wideband (UWB) technology offers promises for high accuracy (in the cm range) localization at distances of up to 10-20 m in challenging indoor environments with multipath [1]. However, such an accuracy typically involves the ultra short (sub-nanosecond) pulse generation. Research results on the practical validations of the performance of simple architecture UWB generators that are able to generate narrow (200-300 ps range) UWB pulses of high amplitude (6-9 V) and with relatively low power consumption (below 300 mW) are limited [2-3]. There are several solutions for generation of sub-nanosecond pulses which include the use of Emitter Coupled Logic gates, bipolar transistors driven in the avalanche mode, and Step Recovery Diodes (SRD). We decided to develop our pulse generator based on the latter approach as it provides a good tradeoff between the pulse width, its amplitude, and the overall power consumption [3]. Such a pulse generator constitutes a vital part of a transmitter in a UWB localization system. The presented in this paper work is a next step in the development of our UWB localization platform [4].

II. Pulse Generator Architecture

Fig. 1 shows the schematic of the pulse generator. The main component of the generator is the Aeroflex MMD840-0805-2 SRD with the transition time of 50 ps. The SRD requires a proper driving network that consists of the low-power Texas Instruments MSP430F2121 microcontroller (μC), the signal shaping part based on inverters and an AND gate, and the NXP PMBT2369 NPN bipolar switching transistor. The width of the triggering signal produced by the μC is decreased with use of the signal shaping part. This operation is performed in order to provide the optimal switching signal for the switching transistor. The signal shaping part consists of thirteen inverters connected in series and an AND gate. The inverters play a role of a 26 ns delay line. One of the inputs of the AND gate is connected to the output of the delay line, and the other to the μC, respectively. As a result, on the AND gate's output a 26 ns width signal is obtained. Next, the shaped signal, provided to the transistor's base, triggers the UWB pulse generation by the SRD. The optimal value of the delay width was found through Agilent Advanced Design System (ADS) simulations (Fig. 2) and measurements. The emitter of the switching transistor is connected to a pulse-shaping network (that consists of L101, C102, and L100 components - see Fig. 1) and the SRD. During forward-biasing, the charge is inserted into the diode. In this state, the SRD acts as a low impedance element. When the storage charge is being removed by reverse bias, the diode still acts as low impedance element until all charge is removed. At that point diode rapidly changes its impedance from a low to a high state. This rapid change of a SRD's impedance can be exploited for a sub-nanosecond pulse generation [5].

The 0.508 mm thick Rogers RO4003C material was used as a printed circuit board's (PCB) substrate. The chosen substrate thickness allows for designing well matched 50 Ω high-frequency signal traces with the 0603 size used SMD components (Fig. 3). The entire electrical circuit is powered with the 3.3 V supply voltage. In order to bias the transistor with 12 V voltage, a DC/DC booster is used. The measured averaged power consumption of the entire pulse generator is only 185 mW that allows for usage in portable, battery-powered devices.

III. Measurement Results

The measurements were performed with the use of a LeCroy SDA 816Zi real-time oscilloscope with a 16 GHz analog bandwidth. Due to the limitation on the maximum input voltage of the oscilloscope (5 V_{rms}), for some measurements, a 12 dB attenuator was used. Fig. 4 shows simulated in ADS and measured UWB pulses. The measured fwhm of the generated UWB pulse is 240 ps with a 8.9 V peak voltage. This result corresponds with the simulations performed in ADS. The first (falling) edge of the negative sub-nanosecond pulse (Fig. 4, orange curve) is narrower than the rising edge. In order to filter out low frequency components responsible for low rising time of the pulse, the Mini-Circuits VHF-3100+

high pass filter (HPF) with the 3.1 GHz cut-off frequency was connected at the output of the generator. Fig. 4 (green curve) shows the obtained UWB pulse with filtered low frequency components. Fig. 5 presents the frequency spectra of generated pulses with and without the HPF. The -10 dB frequency band of the UWB pulse after the HPF equals to 2.94 GHz.

IV. Conclusions

In this paper, we have presented an implementation of a UWB sub-nanosecond pulse generator. Our results show that it is possible to design and implement a low-power, high-peak voltage UWB pulse generator based on off-the-shelf components.

References

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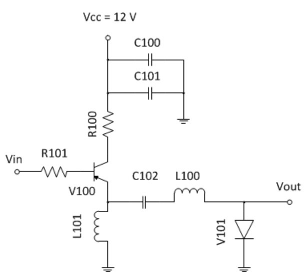

Fig. 1. The schematic of the HF part of the UWB pulse generator.

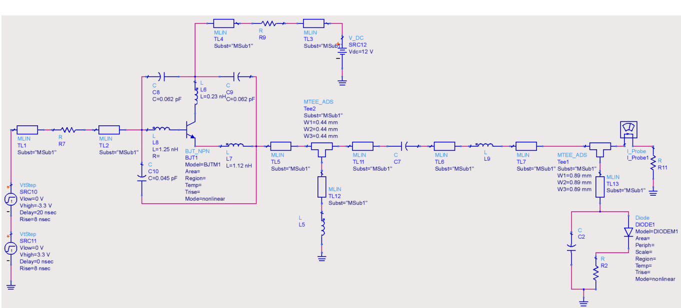

Fig. 2. The ADS schematic of the HF part of the UWB pulse generator.

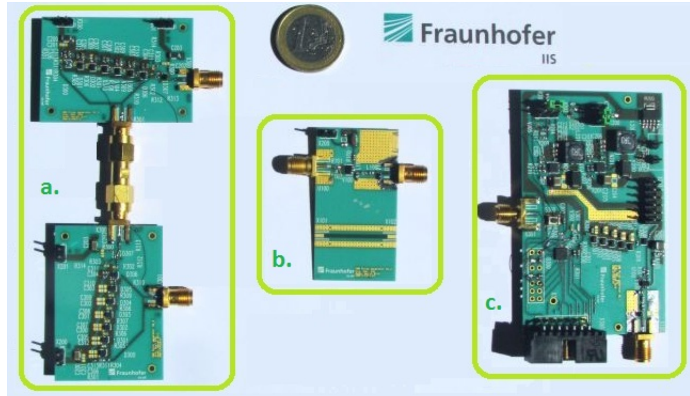

Fig. 3. PCBs of the UWB pulse generator: a) logical delay line part, b) HF part, c) the whole UWB transmitter incl. the HF and logic delay line parts.

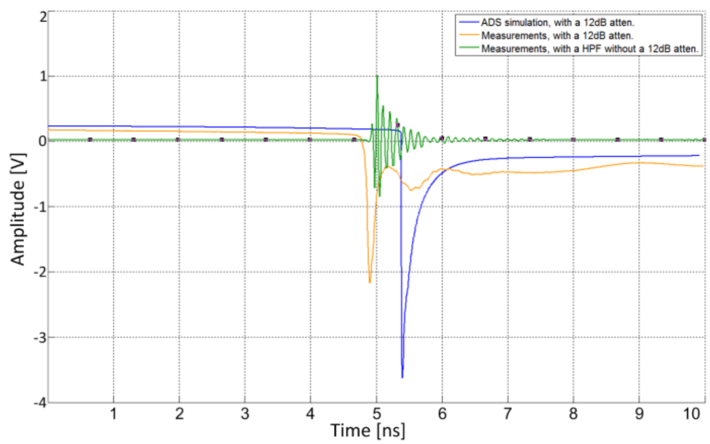

Fig. 4. The simulated pulse in ADS (blue) and the generated UWB pulse with (green) and without (orange) the HPF.

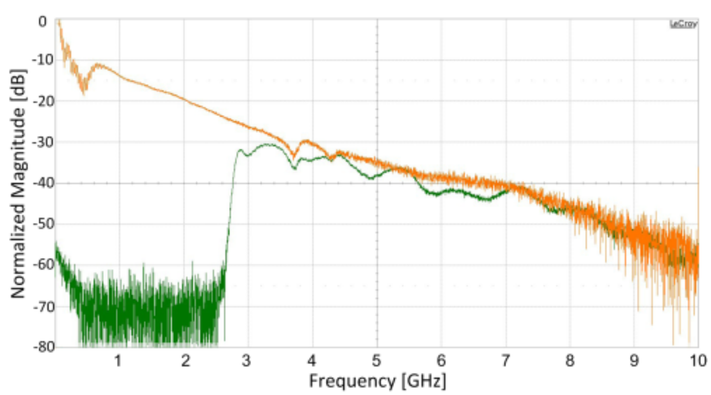

Fig. 5. Frequency spectra of the generated UWB pulses with (green) and without (orange) the HPF.