

# Reconfigurable Pico-Pulse Generator for UWB Applications

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**Abstract-** We have designed, fabricated, and tested a low cost tunable narrow pico-pulse generator using a 60ps transition time step-recovery diode (SRD) device. Both the pulse duration and shape are electronically controllable using PIN diodes that are optimally connected in series. A simple concept of an input-matching network was developed and implemented that can significantly minimize pulse broadening and suppress pulse distortion. The developed pulse generator circuit has a wide adjustable pulse duration covering a 300ps to 1ns range and produces either monocycle or Gaussian pulses using novel pulse shaping circuitry. The proposed structure can be easily reconfigured to include more complicated pulse shapes such as polycycle signals.

**Index-** SRD, pulse generator, ultra-wide band (UWB), monocycle, Gaussian pulse, polycycle.

## I. INTRODUCTION

A pulse generator is an essential component of UWB systems and generally has a fixed pulse width and shape. System performance can be significantly enhanced if extremely narrow pulses are utilized. For pico-second pulses, step-recovery diodes (SRDs) are the most promising devices for UWB pulse generation. They are simple to design, inexpensive, and have low power consumption with relatively high output voltage swings.

Enabling features such as tunable pulse duration and shape to existing UWB systems is very advantageous. For example, in an impulse radar system, wider pulse width means higher signal energy level but worse range resolution ( $\delta R$ ) due to narrower bandwidth (BW) as given by  $\delta R = c/2BW$  [1]. In addition, Pulse Shape Modulation (PSM) can be achieved and utilized to encode data in logic states, which is widely used in communication systems.

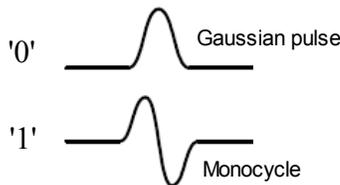


Fig. 1 - Gaussian pulse represents data '0' and monocycle represents data '1'

Fig. 2 shows our fabricated low cost SRD-based pulse generator that has adjustable pulse duration in the range of 300ps to 1ns with either monocycle or Gaussian pulse

shape output. Pulse duration and shape can be adjusted based on the type of application. Switching time between the two output states is within 10ns, corresponding to the time needed for the PIN diodes to switch between the ON and OFF states. Tunnel or varactor diodes can be used to achieve faster state-switching.

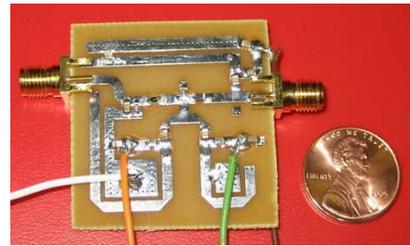


Fig. 2 - Photograph of the fabricated tunable pulse generator

## II. NOVEL INPUT MATCHING NETWORK

We have performed a theoretical analysis of SRD operation in the time domain to improve the quality of the output narrow pulse signal. A step by step model of the output pulse formation is given in detail to demonstrate the source of the distortion. The SRD device has low impedance in the ON state and much higher impedance in the OFF state [2]. After fast transition to OFF state, a step signal is generated and would propagate towards both the positive  $x$ -axis (step 'A' in Fig. 3) and in the direction of the short-circuited stub. The step signal traveling along the short-circuited line arrives at the end and is completely reflected back out of phase (i.e. inverted) and is step 'B' in Fig. 3. Finally, step signal 'A' and step signal 'B' combine at  $x=0$  to produce a Gaussian pulse with a width corresponding to the round trip delay along the short-circuited stub [3].

However, the previous description omits leakage caused by both the package parasitic capacitance  $C_p$  and the reverse depletion capacitance  $C_r$  of SRD during the OFF state, as shown in Fig. 4. The reflected step from the short-circuited termination will not only travel in the  $+x$ -axis direction, but also travel in the negative  $x$ -axis direction across the SRD device as a leakage step. When this leakage step meets triggering voltage source  $V_s$ , it reflects back again due to the source mismatch as represented by step 'C' in Fig. 3. The net result of the three combined step waves is a distorted Gaussian pulse as demonstrated in Fig. 5.

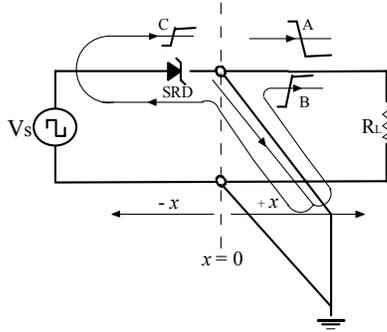


Fig. 3 - SRD based Gaussian pulse shaping circuitry

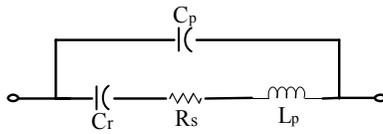


Fig. 4 - Equivalent circuit of SRD under OFF state

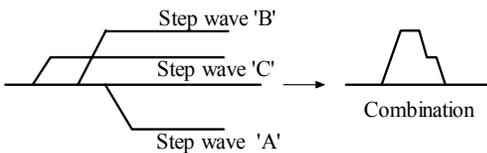


Fig. 5 - Step waves combination at the interface of  $x = 0$

Hence, we have developed an input-matching network for the SRD pulse generator to bypass this leakage step wave 'C' and thus eliminate Gaussian pulse distortion. The matching network is basically an R-C low-pass filter which allows only the triggering signal (10MHz) to pass and bypasses the leaked fast step signal. Simulation was carried out using Agilent ADS2003C as shown in fig. 6. Fig. 7 shows both the ADS simulation and measurement results before and after introducing the input-matching network. The pulse width is much wider and has severe distortion without the use of our newly developed input-matching network. After introducing the input-matching network, the output pulse has much narrower duration and the pulse shape becomes more symmetric.

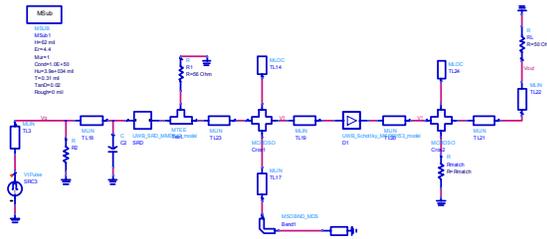
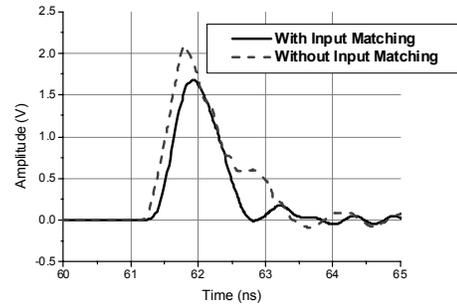
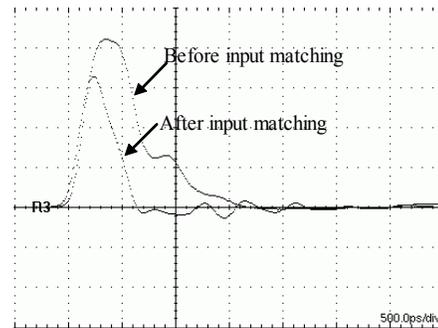


Fig. 6 – ADS simulation platform



(a) Simulation result using ADS



(b) Measurement result

Fig. 7 Simulated and measured Gaussian pulse output with/without input matching network

### III. GAUSSIAN PULSE WITH A TUNABLE DURATION

Recently J. Han et al [4] demonstrated a pulse generator with tunable duration, however they used a parallel-connected PIN diode structure, as shown in Fig. 8, which is capable of only producing a Gaussian pulse shape output signal.

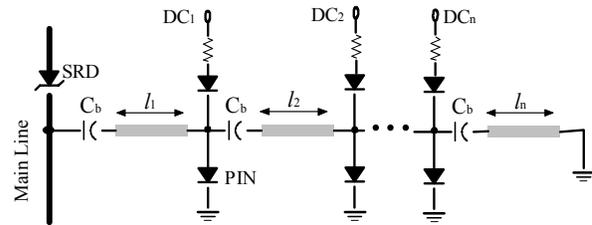


Fig. 8 - Parallel PIN diode structure controlling the short transmission line stub

Here we present an alternative circuit topology that provides more flexibility. As shown in Fig. 9, we have connected the PIN diodes in series to different stubs of distinct length rather than in parallel. Thus only half the number of PIN diodes is required as compared to [4]. For pulse duration selection, only one stub is connected at a

time, while the others are completely disconnected by turning their associated PIN diodes off.

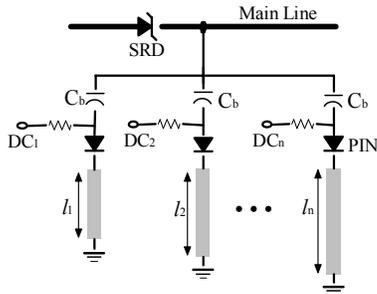


Fig. 9 - Series PIN diode structure controlling short transmission line stubs

Meanwhile, there is only one DC blocking capacitor  $C_b$  in series with each short line stub, which mitigates the pulse distortion caused by multiple DC blocking capacitors in a parallel PIN structure. Finally, switching time between any two durations is doubled in parallel structures as compared to series structures, since twice the number of PIN diodes is needed to complete the switching state. Table I summarizes the difference between parallel and series PIN diode structures.

TABLE I - COMPARISON BETWEEN PARALLEL AND SERIES PIN DIODE STRUCTURE

	Parallel structure	Series structure
Amount of PIN diodes	2n	n
Number of capacitors in series with short transmission line stub	n	1
Switching speed	20ns	10ns
Total cost	Higher	Lower

Fig. 10 shows our electronically tunable pulse circuit structure.  $R_f$  and  $C_f$  comprise the novel input matching network used to significantly reduce pulse duration and suppress pulse distortion.

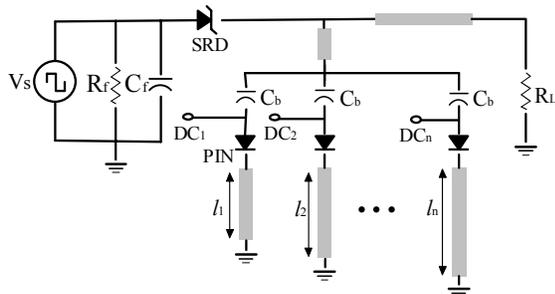


Fig. 10 - Schematic of pulse generator with tunable duration

Fig. 11 shows the measurement results of the fabricated tunable pulse generator. The output Gaussian pulse duration varies from 300ps to 1ns. All output pulses have minimal distortion and very low ringing level.

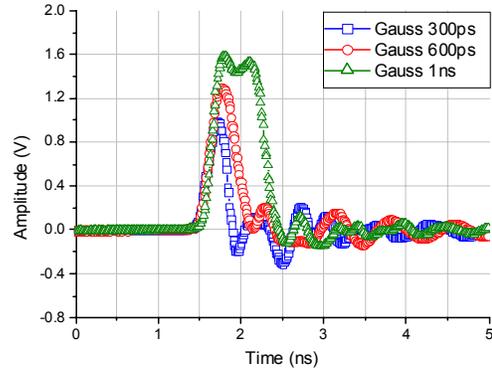


Fig. 11 - Measured Gaussian pulse output with tunable duration

#### IV. TUNABLE PULSE SHAPING CIRCUITRY

There are two main types of pulse shaping circuits used to transform Gaussian pulse to monocycle. A simple and straightforward way is to add an R-C differentiator circuit after the Gaussian pulse SRD circuit to produce a monocycle output [5]. However, this method lacks flexibility and does not offer tunable capability. In this paper, we propose a new reconfigurable approach to deliver a clean monocycle output signal from an input Gaussian pulse. A second section of PIN diode controlled short-circuited transmission line stub is added along the main output line of our pulse circuit, as shown in Fig. 12. When the PIN diode is in the ON state, the Gaussian pulse propagating along the line is intentionally split between the main line and the shorted transmission line  $l_s$ . The Gaussian pulse traveling along the short transmission line  $l_s$  will reflect back as a negative pulse after a certain time and recombine with the former positive pulse to create a monocycle.

When the PIN diode switches to OFF state, only Gaussian pulse will appear at output load. Thus the ON/OFF state of the PIN diode will fully determine the pulse shape of the output signal. Furthermore, more complicated output pulse shapes such as polycycle can be generated by properly adding more sections of PIN diode controlled short-circuited transmission line stubs.

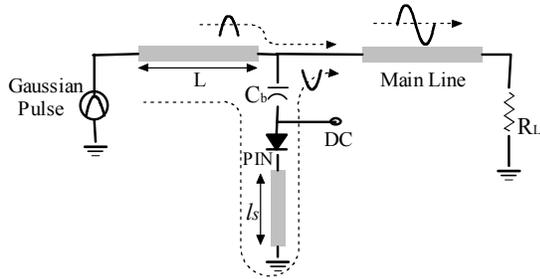


Fig. 12 - Schematic of pulse generator with tunable pulse shaping output

Fig. 13 shows the measured results of a tunable pulse shape output. The monocycle has very good symmetry and small ringing level. High data rate employing Pulse Shape Modulation scheme can be achieved due to the fast switching time of the PIN diode used to control output shape of the monocycle and Gaussian pulses.

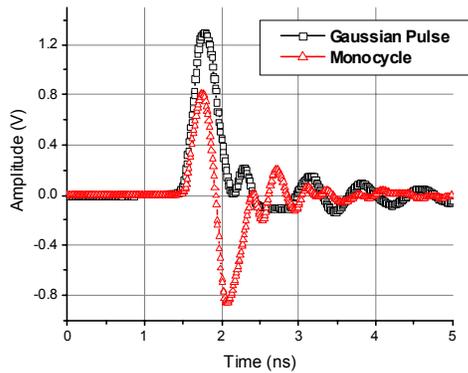


Fig. 13 - Measured pulse with both Gaussian and monocycle output pulses

Summary of the circuit fabrication information regarding our reconfigurable pulse generator is listed in Table II.

TABLE II  
CIRCUIT FABRICATION INFORMATION

Substrate	FR-4	62 mil, $\epsilon_r=4.4$
SRD	MSD700 (Micrometrics Inc.)	60ps transition time
PIN Diode	HSMS482x (Agilent Co.)	High freq. up to 3GHz, Low ON resistance
Trigger Source	Agilent 33220A function generator	10MHz square wave, 3V Peak-to-Peak

## VI. CONCLUSIONS

We have developed a low cost, multi-functional pulse generator with electronic tuning of both pulse duration and shape. A novel input matching network has been introduced at the input of the tunable pulse generator. Good agreement between simulated and measured results has been achieved. Both simulated and measured results show that the input matching network can greatly prevent the pulse width broadening and suppress any significant pulse distortion. Novel series-connected PIN diode structures are utilized for our pulse duration and shaping control. The developed pulse generator has wide adjustable pulse duration from 300ps to 1ns. The pulse generator is reconfigurable and could provide various output shapes such as monocycle and Gaussian pulses. These features will provide more flexibility in the design of adaptable UWB systems.

## REFERENCES

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