NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

Ultra-wideband Pulse Generator for Radar System

by

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degree of Bachelor of Technology

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Certificate

This is to certify that the work in the project entitled *Ultra-wideband pulse generator for Radar System* by Sambit Garnaik, bearing roll number 109EC0072, is a record of an original research work carried out under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of *Bachelors of Technology* in *Electronics and Communication Engineering* during the session of 2012-2013. Neither this thesis nor any part of it has been submitted for any degree or academic award elsewhere.

Prof. S. Maiti

Acknowledgements

Abstract

Ultra-Wide Band is one of the communication method used in wireless networking in order to achieve high bandwidth connection with less power utilization. UWB concept have been known and well understood for many years. In this project work a transister based pulse generator is simulated with the P-SPICE and implemented in a bread-board.Though the experiment result does not match with the simulated one,the pulse generation method promises to generate better pulse shape meeting all the required UWB specification.

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Chapter 1

Introduction

Primarily Ultra wideband wireless radio technology developed for secure military communications and for radar application. UWB is a high-speed, short-range wireless technology which nearly 10 times faster than 802.11b. It can be used in transferring digital content between devices in different entertainment device and computing clusters in the house, such as digital video recorders, set-top boxes, TV and PCs. UWB is designed to replace the cables for short-range, wireless connections, but it can offers the much higher BW needed to support multimedia data streams at a very low power levels. Since UWB can communicate in both relative distance and position, it has a vital use in tracking equipment, containers or other objects.

Tough UWB has been used for a while by the military, it is now going through the necessary developments for public and commercial use. Since the advancement of UWB has been a bit slow, there's a possibility that it will be the "next best" technology for all types of wireless networks, such as wireless LAN.

1.1 Advantages of UWB

1. **High Capacity**

   According to the Shannon theorem, C = BW log 2(1 +) Where C is the capacity, BW is the bandwidth and is the signal to noise ratio.

   In fact the capacity has a linear increase when increasing bandwidth and only a logarithm increase as a function of signal to noise ratio.

2. **Low Implementation Cost and Less Power Consumption**

   The transmitter can be simply realized as a single transistor which operates in a digital mode (flipping from a 0 state to a 1 state) thus producing a step waveform that can be easily filtered to produce a monocycle. Therefore there is no necessity for a linear power amplifier and this reduces costs and power consumption. The receiver is also simpler than a narrowband receiver because it does not require IF stages and also because the control loop operates at low frequencies. And this saves cost.

3. **Fine Time Resolution**

   Such a big bandwidth, wider than the coherence bandwidth of the multipath channel, gives the system a fine time resolution. This makes the receiver able to resolve and combine individual multipath components and robust against multipath fading problems. Fine time resolution also allows an accurate delay estimate and this is a very nice feature for ranging and locating applications.

1.2   Applications of UWB

(a) **Wireless Communications**

   In particular the features of UWB technology perfectly suite the requirements for high speed, multi-user wireless networks with central regard on wireless PAN and LAN. Besides indoor video/data/voice distribution could also take advantage of the promising possibilities of it. Finally military applications are possible: tactical hand-held and network radios, but also non-line of sight groundwave communications could be implemented.

(b) **RADAR**

   The fine time resolution opens the way to the realization of high precision measurements equipment, while a very strong wall penetration capability (typical of IR-UWB signals) allows through wall imaging. Important technologies like vehicular radar for collision detection and for road conditioning sensing are also closely related to UWB technology development.

(c) **Tracking Applications**

   These range from intelligent transportation systems, in-building and aviation ground tracking, to the forthcoming UWB geolocation techniques for emergency, fire and rescue teams.

1.3   Problems Areas of UWB

i. Requirement of Appropriate Channel

   An appropriate channel model that describes the UWB signal propagation is needed. The channel should take into account the existence of multipath components and is simple enough for tractable analysis and computer simulation.

ii. **Limited Emitted Power**

   The limited emitted power makes UWB systems most likely to suffer from narrow-band interference, therefore interference suppression techniques may be required.

iii. **Synchronization Problem**

   Because of fine time resolution, synchronous acquisition time will increase and hence the synchronization might not be a critical task.

iv. **A Different Modulation Scheme**

   The design of effective modulation schemes for multiple access capability together with appropriate techniques to reduce interference caused by other users will be very challenging topics when using UWB technology for wireless communications.

1.4   Objective

The objective of this project was to design a monocycle pulse having nano second duration.Since UWB system required high frequency pulse, so this project's goal is to generate pulse nano-second duration.

Chapter 2

Methodology

2.1 Introduction

In this chapter we have tried to study and recognise the various steps and studies that were done prior to the start of this project. We have in this segment tried to give a brief accout on various topics like naarowband system, wideband system and methods to generate Ultra-wide band pulse.

2.2 Comparison between narrowband and UWB systems

UWB system is a new technology for wireless communications, this leads to different operating principles from a narrowband system. There are mainly two aspects to help defining the differences between these two systems. They are signaling method and transceiver architecture.

2.3 Narrowband system

In a narrowband system, a carrier is used to translate the signal from baseband to Radio Frequency (RF) and it just makes use of a small portion of frequency spectrum. Also, the signal waveform is time-continuous as shown in figure bellow and the radiated power level is fairly high. For the structure of the transceiver front-end, a narrow band low noise amplifier (LNA)is employed which is easy to be used to design the matching network. A mixer, oscillator, andphase-locked loop (PLL) are required to perform intermediate frequency (IF) processing. The transceiver s architecture is shown in figure.
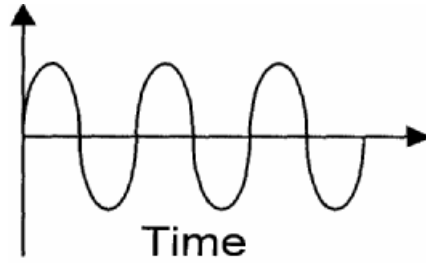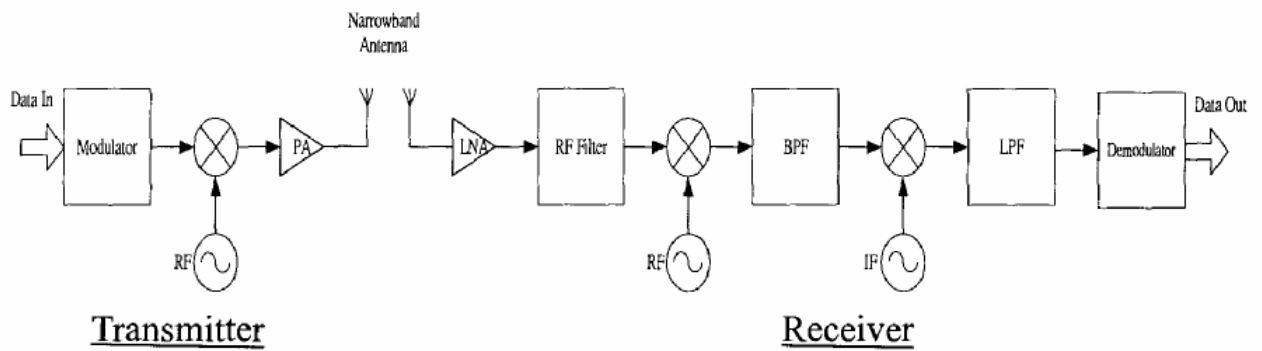
FIGURE 2.1: Waveform of narrowband signals

FIGURE 2.2: System configuration of narrowband transceiver

2.4 Wideband system

In contrast, UWB system is carrier-less because it utilizes an extremely wide spectrum for signals transmission. The signal is based on pulses as shown in figure and the radiated power is low. Because of this reason, frequency translation of the signal is not necessary (i.e. mixer, oscillator, and PLL can be eliminated) and hence the configuration of the transceiver front-end becomes much simpler. However, the design of a LNA is a challenging work since it is hard to achieve well matching while maintaining sufficient power gain across such wide bandwidth. Figure illustrates the transceiver s architecture of UWB system
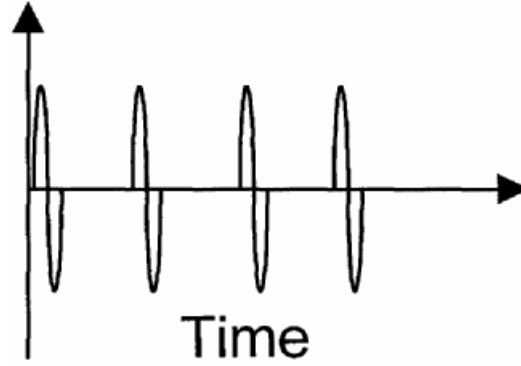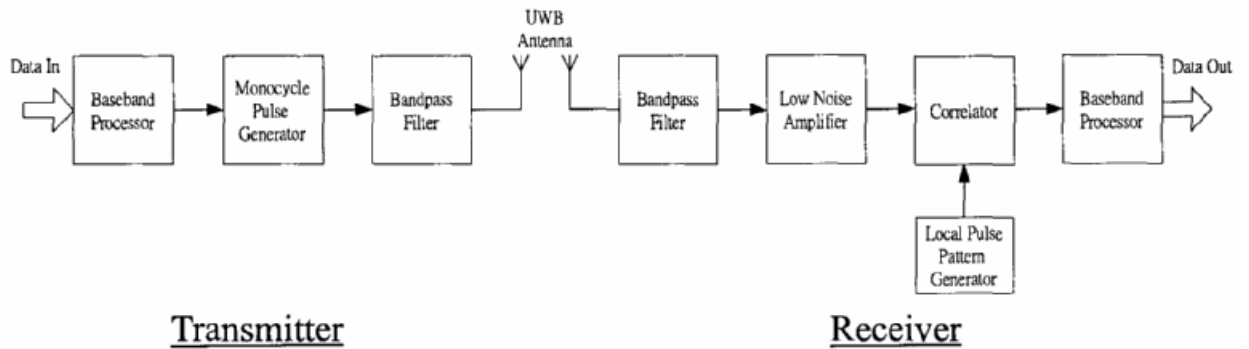
FIGURE 2.3: Waveform of UWB signals

FIGURE 2.4: System configuration of UWB transceiver

2.5 UWB Pulse Generator using Step Recovery Diode

There are different method to generate pulse .Using step recovery diode is one of them.

With reference to the first article stated in reference [1] observed how to generate ultra-wide band pulse which is as follow.

Step recovery diode has a important property, its ultra-fast switching speed, typically in the low-picosecond range. Similar to a PIN diode, the doping profile of a step recovery diode is not uniform. SRD is under forward bias acts as a normal PN diode. But under reverse bias condition the SRD is completely different from normal PN diode . Under reverse bias, the SRD still has a very high conductivity of current. But this situation only maintains for a very short period of time. Then it will stop conducting. So this property of SRD makes it function as a switch for pulse generation technique .It utilizes a SRD as a switch so that fast switching speed can be achieved. An external square wave drives the SRD which converts the signal into a step function. Generally, it connect with a short-ended stub used to reflect the step function and to provide a proper time delay. By combining the reflected and forward
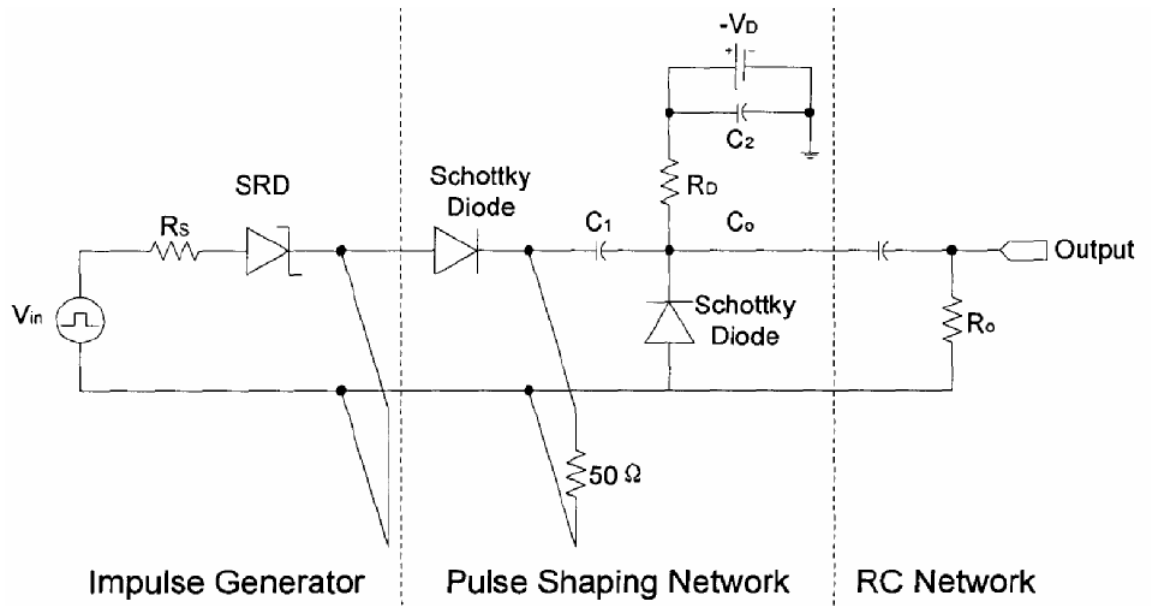
As stated in reference [2], due to the intensive used of solid-state switches to charge and discharge the energy storing capacitors stages, the circuit will be named here as All-Electronic Marx Generator. The basic topology of the Marx-bank, with n stages, able to deliver -ve high-voltage output pulses to a load, is presented in Fig. Each stage of the Marx-bank consists of a energy storing capacitor Ci, a diode Dci and two IGBTs (Tci and Tdi), where the subscript i1, 2, , n-1, n. Output positive pulses are simply obtained by inverting the polarity of all semiconductors as well as changing Dci with Tci.

2.7   Method Adopted

This method has been addopted for pulse generation because- by the use of then transistor circuit production and simulation of the monocycle pulse becomes too much cost efficient and simple. S the use of transistor circuit has been preferred over othe metods. This method has been explained and worked with in details in the following chapters.

In this segment of the thesis we have studied and discussed various functions and uses of the thansistor circuit for generation of the pulse. We have varied the component values keeping the inputs same and compared the pulse genarted in the final stage.

As the first derivative of the gaussian pulse and the monocycle pulse are alike. It can be represented by shows the waveforms of monocycle pulse in time domain and frequency domain.

$$w(t) = \frac{2\sqrt{e}A(t - T_c)}{T_{au}} \exp\left[-2\left(\frac{(t - T_c)}{T_{au}}\right)^2\right]$$
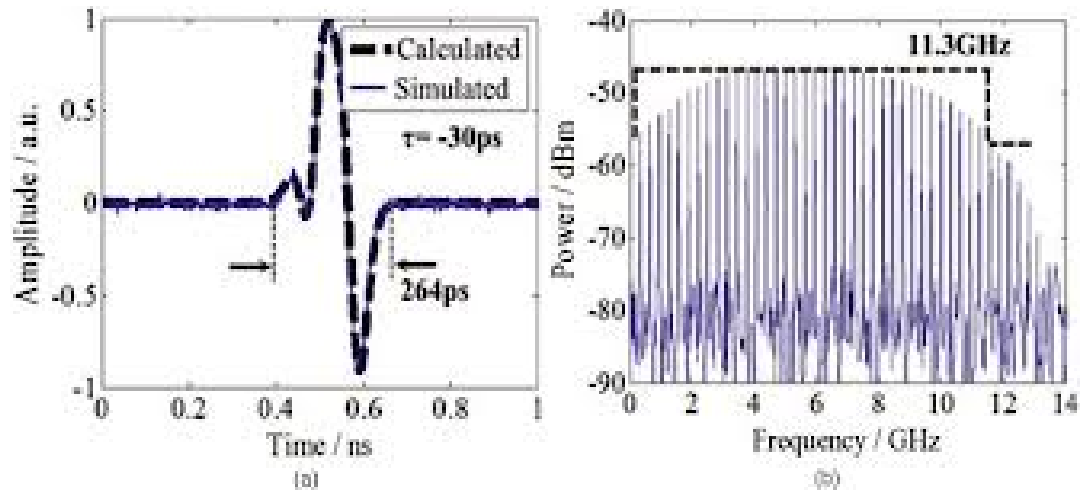
FIGURE 2.7: An Example of Wave form of Monocycle Pulse in Time and Frequency Domain
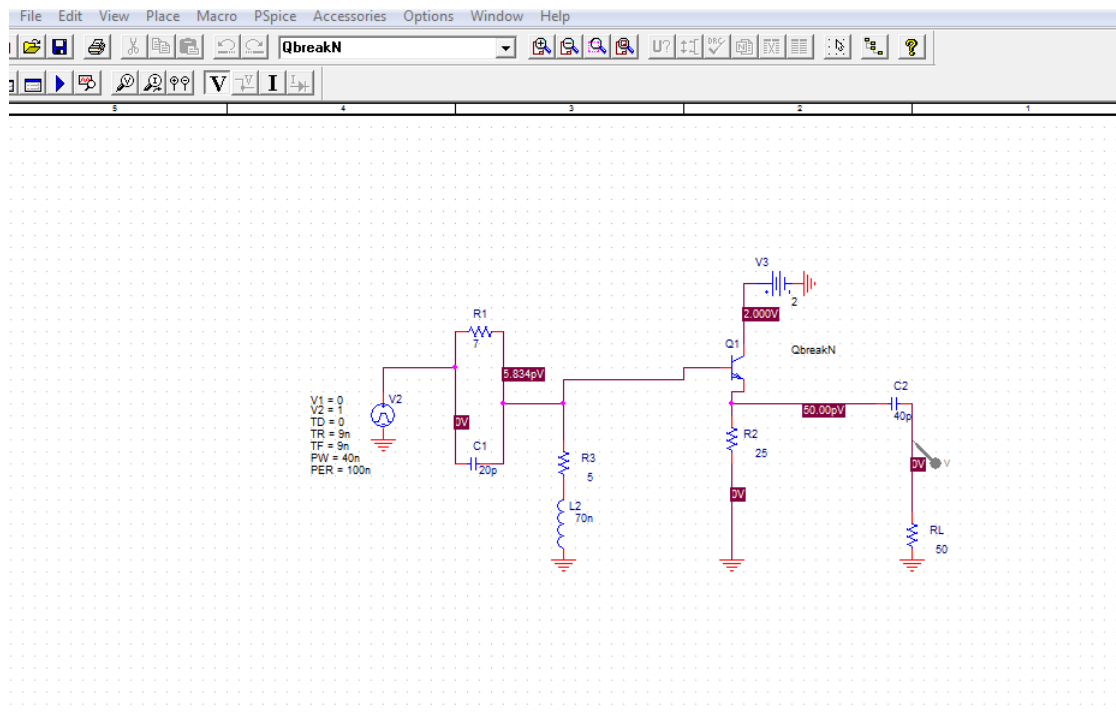
Circuit schematic of mono-cycle pulse generator circuit

FIGURE 2.8: PSPICE Model of Monocycle Pulse Generator
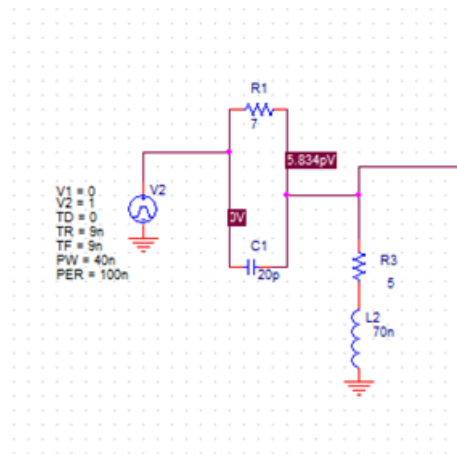
Circuit operation The RLC part

FIGURE 2.9: RLC part of the Pulse generator Circuit

In this circuit a square wave is send as input which pass through the RLC part of the circuit first. It converts a square wave into a waveform which contains positive and negative pulses which rising and falling edges correspond to the positive and negative pulses, respectively. However, the RLC circuit acts as a filter which produces ringing effect in the output. As a square wave is composed of infinite number of sine waves with different frequencies, The RLC circuit filters out some of these sine waves. In order to minimize this effect we have to by carefully determine the values of R1, C1 and L. We do this by examining the transfer function of this RLC circuit.

Transistor Switch
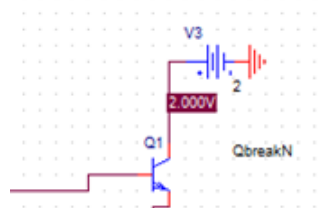
FIGURE 2.10: Transistor part of the Pulse generator Circuit

The output of the RLC circuit is fed into the base of the transistor. The voltage rises gradually. When once the voltage rises above 0.7V, the base and emitter junction is forward biased. And a wave is developed at the emitter end. Within a period, the output of the RLC circuit is greater than 0.7V only in for first few ns. So the pulse width at the emitter is in few ns range. As the pulse starts to go positive, transistor conducts and enters the saturation

region. Saturation region means no conduction. The switching speed of the transistor is also a limiting factor. Here we get a Gaussian pulse.

Output stage: RC Differentiator
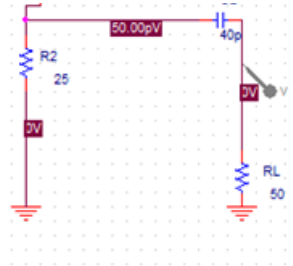
FIGURE 2.11: RC part of the Pulse generator Circuit

We can get a monocycle pulse differentiating a Gaussian pulse. At the output, there is a simple RC high-pass filter. We know that a high pass filter acts as a differentiator, it convert a Gaussian pulse into a monocycle pulse. The capacitance is calculated by considering the pulse width of the Gaussian pulse and the required time constant.

2.8 Conclusion

We have studied and analysed different metohds for pulse generation and study of diffenet works by other people has been done. Using and keeping in mind various factors like cost efficiency ans simplicity of the different methods used we have choosed to work with transistor circiut.

Chapter 3

Simulation and Analysis

3.1 Introduction

Circuit schematic of mono-cycle pulse generator circuit
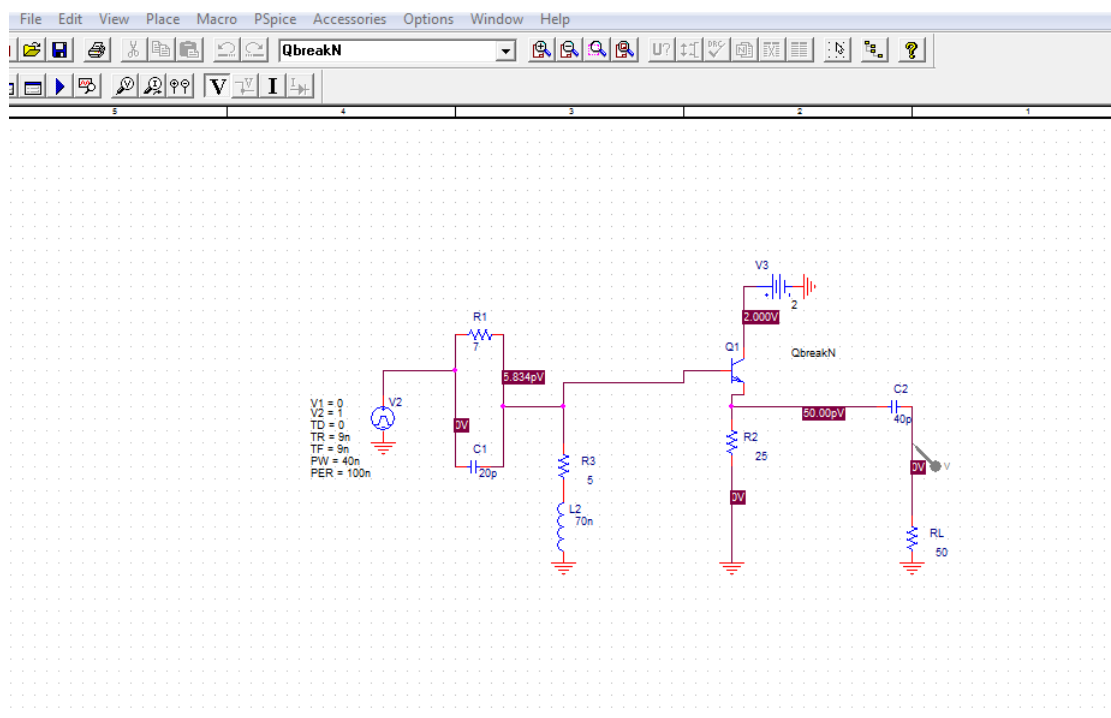
FIGURE 3.1: PSPICE Model of Monocycle Pulse Generator

3.2 Results Of PSPICE Analysis

Simulation of Circuit With First Set of Components

For the value R1-7 ohm, C1 -20 pF,L-70 nH,R2-25ohm,R3RL-50ohm C2- 5pF, V=2v

FIGURE 3.2: Waveform at base end

FIGURE 3.3: Wave form at emitter end (Gaussian pulse)

FIGURE 3.4: Wave form at output end (mono cycle pulse)

Simulation of Circuit With Second Set of Components

For R1-20 ohm, C1 -40 pF,L-80 nH,R2-100ohm. C2-20pF, V=2v
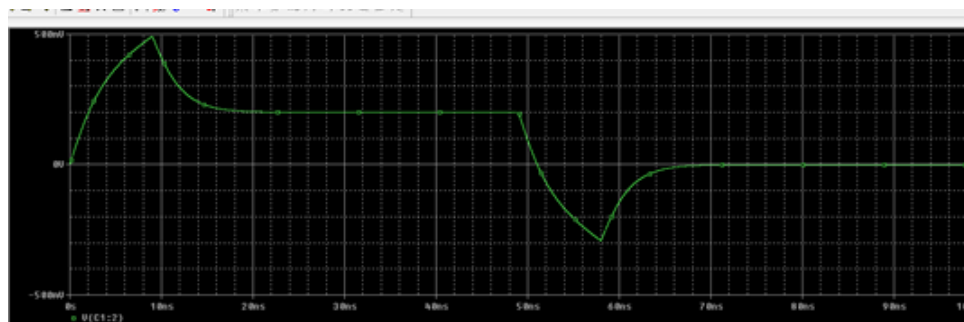
FIGURE 3.5: Waveform at base end
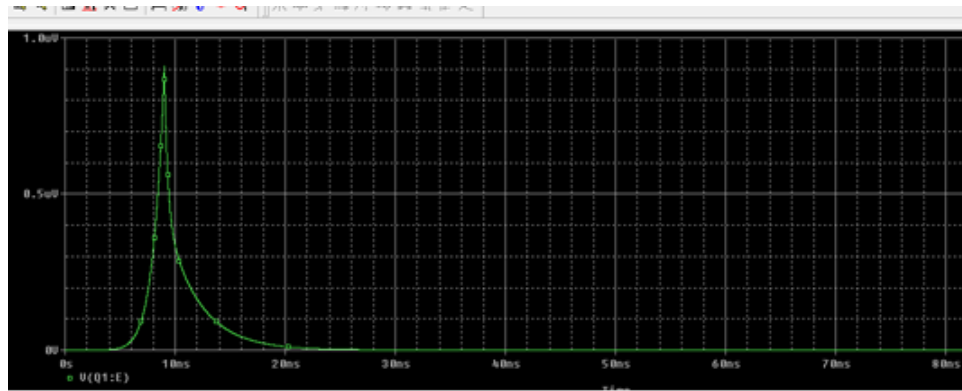
FIGURE 3.6: Wave form at emitter (Gaussian pulse)
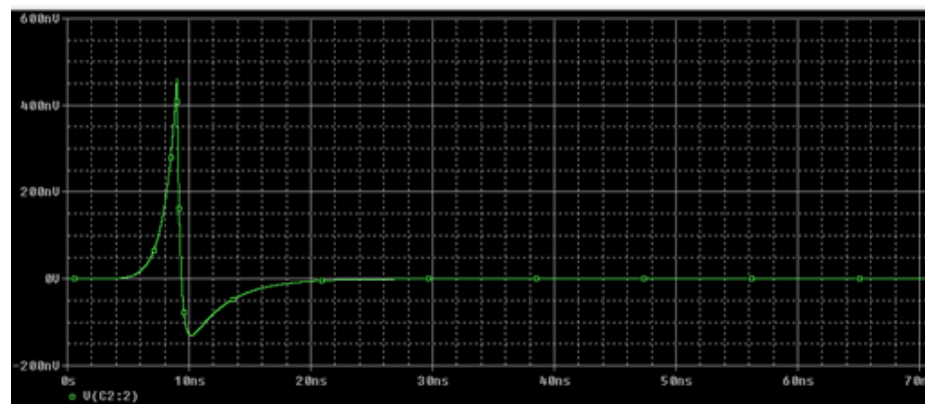
FIGURE 3.7: Wave form at output (mono cycle pulse)
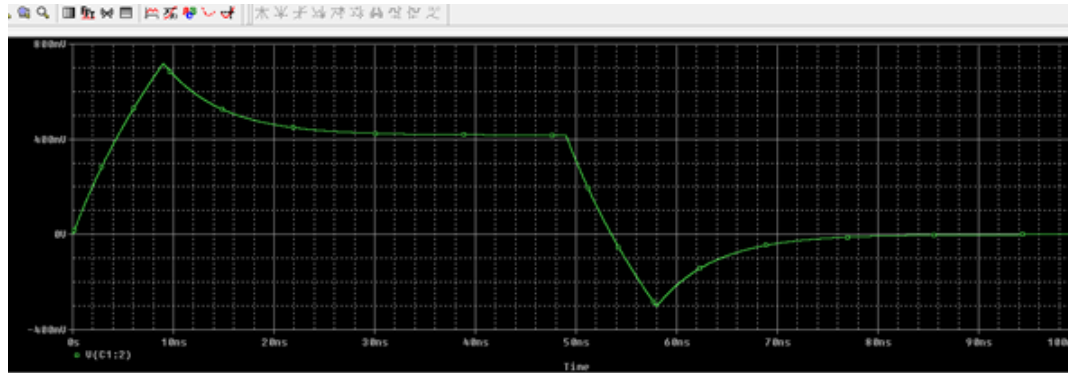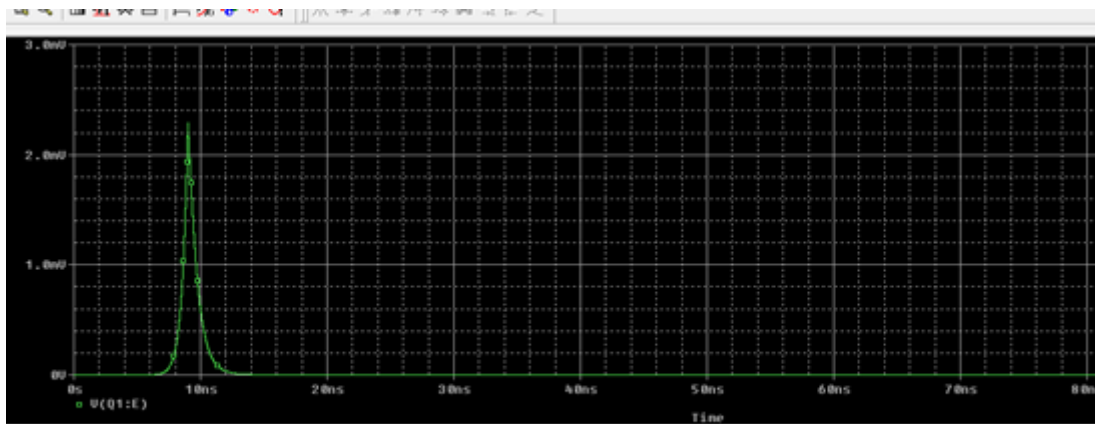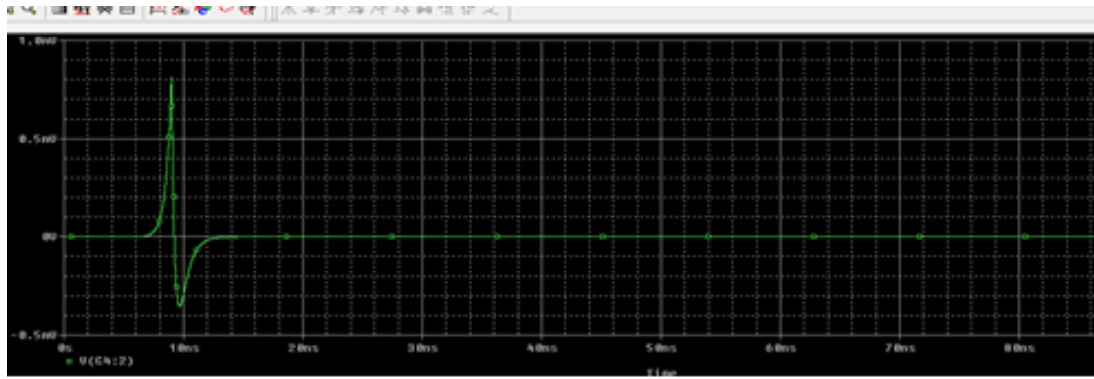
Simulation of Circuit With Third Set of Components

R1-40 ohm, C1 -100 pF,L-100 nH,R2-300 ohm.C2-40pF
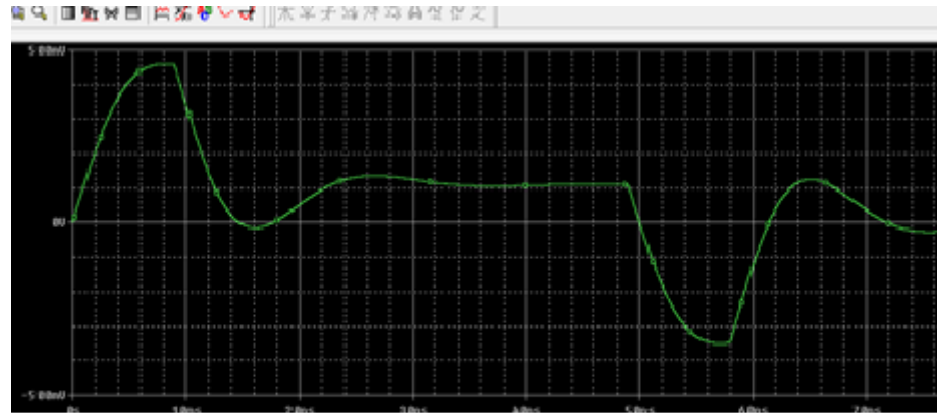
FIGURE 3.8: Waveform at base end
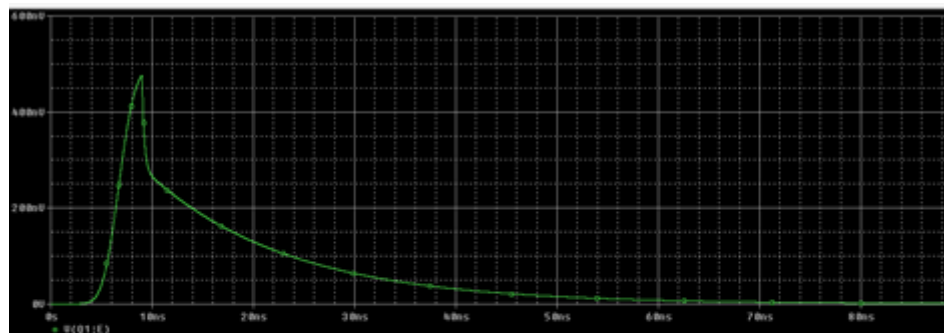
FIGURE 3.9: Wave form at emitter)
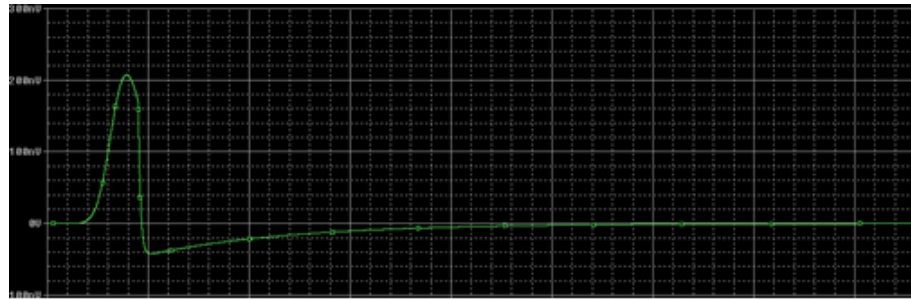
FIGURE 3.10: Final out put

Experiment No. 01	
Inputs given	
Resistors	
R1	7Ω
R2	25Ω
R3	5Ω
R$_L$	50Ω
Capacitor	
C1	20pF
C2	5pF
Inductor- L	70nH
Outputs Obtained at	
Waveform at Emmiter End	7ns duration or 1.4287*10^8 Hz
Waveform At output End	7.5ns duration or 13.333*10^8 Hz

FIGURE 3.11: Table for First Set of Component

Experiment No. 02	
Inputs Given	
Resistor	
R1	20Ω
R2	100Ω
R3	5Ω
R_L	50Ω
Capacitor	
C1	40pF
C2	20pF
Inductor- L	80nH
Outputs Obtained	
Emmiter end	16ns duration or $6.25*10^{11}$
Output End	17ns duration or $5.8825*10^{11}$

FIGURE 3.12: Table for Second Set of Component

Experiment No. 03	
Inputs Given	
Resistor	
R1	40Ω
R2	300Ω
R3	5Ω
R_L	50Ω
Capacitor	
C1	100pF
C2	40pF
Inductor- L	80nH
Outputs Obtained	
Emmiter end	50ns duration or $2.0*10^{11}$
Output End	52ns duration or $1.9321*10^{11}$

FIGURE 3.13: Table for Third Set of Component

3.3 Conclusion

We have simulated the circuit and generated the pulse by varying different component limits. And from the study made we obtain that in the 1st and 2nd case the generated pulse is efficient whereas in the 3rd case the pulse generated is not purely monocyclic. So we have used the 1st case of component limits for hardware implementation.

Chapter 4

Hardware Implementation

4.1   Component Selection

Used resister

R1-6.8 omh ,R2-22 omh ,R3-4.7 omh ,RL-47 omh

Capacetor

C1 - 22pF, C2 - 39pF

Inductor

L - 37H

transistor

BC548(npn)

The input is a 1-Vpp square wave with repetition frequency 5 MHz

Setp for Measurement

Equiment:- 1 GHz scope, 1 dc power supply, 1 signal generator

4.2   Measurement Procedure

1. Connect the equipment as per the circuit diagram
2. Connect the function generator
3. Connect the output to the channel-1 of scope
4. Turn on the power supply
5. Connect the positive terminal to the collector end of transistor
6. The ground terminal connect to the ground of the circuit
7. Adjust the dc voltage to 2v
8. Turn on the signl generator and set the frequency to 5khz
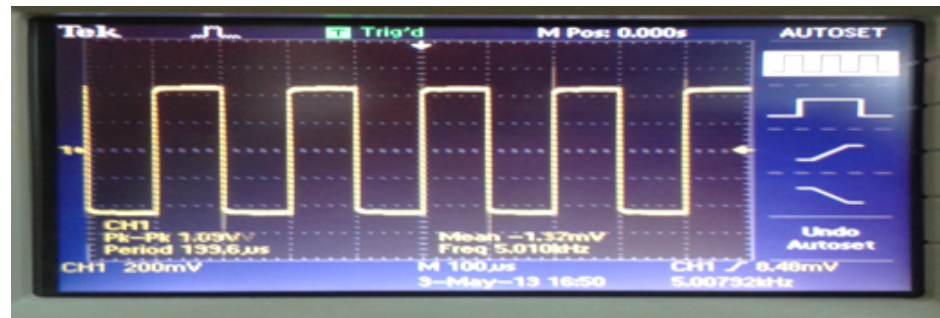
FIGURE 4.1: Input Wave Form of sorce

FIGURE 4.2: Input Wave Form of sorce

4.3 Result and Discussion

In measurement, we can only observe the output Gaussian monocycle pulse. It is difficult for us to observe the waveform at the intermediate stages of the whole circuit. For example, we may want to check the waveform at the base terminal to see whether there is any ringing effect. This will be good for us to study the circuit and optimize the circuit later on.

The pulse duration of the monocycle pulse is 0.01ns or 9.033MHz.In case of software using similar value of resister,capacetor and inductor we got slightly different time duration of the pulse

Chapter 5

Conclusions

From the different experiments conducted, we obtained that while the results that were obtained by simulation through P-Spice actually vary when conducted using hardwares.

The devaiation in resultsof hardware is due to

1.The inputs that were fed into the harwarare circuit were not upto mark and exact values of the inputs given during simulation were not similar to the ones fed by the function generator.

2.The resistors, inductor and capacitor values given during the simulation process could not be provided during experiments with hardware devices.

This is mainly due to the large rise time of the signal generator. The pulse width is limited by the rise time of the input square wave. The reason is that the output of the RLC circuit is resulted from the change in input voltage, i.e. within the rise time. So there will be a pulse formed in these few ns. If the time of voltage change is shorter, the output pulse will have a narrower width.

If further research will continue on the basis of the circuit and using proper specification of the componet used ,it can be get a better pulse.

Chapter 6

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