PSM 1

NANOSECOND SWITCHING FOR HIGH VOLTAGE CIRCUIT USING AVALANCHE TRANSISTOR

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CHAPTER 1 : INTRODUCTION

1.1 Background of Study

High voltage ultrafast electrical pulse has been used in laser technology, high speed photography and nuclear physics. For a variety of non-linear electrical and optical applications, an ultra compact, short pulse, high voltage and high current pulsers are needed. All the drivers are able of producing sub-nanosecond electrical and the optical pulses by gain switching semiconductor laser diodes with a fast risetime and short pulse width. A Q-switched lasers are often used in applications which demand high laser intensities in nanosecond pulses. Then the operation of an electro-optically Q-switched lasers requires fast switching of voltages in multi kilovolt regime.

The used of MOSFETs, SCRs, and avalanche transistor are the common switching techniques that has been applied. The avalanche transistor mode is ideally suitable to continue the operation. The avalanche transistor has wide used for switching high voltage in kilovolt region because of its high sensitivity optical detector. Besides that, this avalanche transistor is able to detect small amount of photon and can be used as photodetector in specific condition.

The avalanche transistor is operated close to their breakdown voltage. When one transistor is triggered,all the transistors are switched on and the transient pulse appears (A.R Tamuri, 2009). Then the pulse duration of the output laser will determined by apply the speed of switching and voltage across the crystal (W. Koechner, 2006).

1.2 Problem Statement

The developed a circuit consist of avalanche transistor is suitable for switching a high voltage circuit. Besides that,the function of an electro-optically Q-switched laser requires fast switching of voltage in multi-kilovolt. This research is mainly conduct the ability of a circuit that consist of avalanche transistor to switch an applied voltage up to 1 kilovolt with an average falling time in few nanoseconds.

1.3 Objectives

The objectives of this research are:

1) To develop a circuit to switch high voltage up to 1kV power supply in nanosecond.

2) To use computer interfacing to interface the circuit.

1.4 Scope of study

The scope of this research is about developing an avalanche transistor needs the voltage up to kilovolt to switch to zero within few nanoseconds in order to produce a short laser pulse. This project is also performed by considered the process of interfacing. Besides that, a PIC microcontroller is utilized as control unit to generate input trigger.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

A high-voltage switching transistor must have the charecteristic or requirements of having a minimum current at a required collector current and an emitter-collector when it is switched on and an emitter-collector sustaining voltage when it os switched off. An instanteneous voltage differential of the transistors will produce over volted and self break that known as avalanche (Luis L.Molina, 2002).

2.2 Theory of Operation

The best approach to increase the output voltage is to use a string of avalanche transistors, or a Marx bank-type design (L. Jinyuan, 1998). The advantage of this Marx bank-type design was it has a lower supply voltage. Besides that, the purpose of had a single long string avalanche transistor is it reduced the total stored charge of the system which prevents damage to the pulser due to self trigger or breakdown. To produce high voltage ultrafast pulses, the combination of two types of design is an ideal method.

The control unit was designed to operate in single and repitative mode. It was set to operate in a single mode for the calibration pupose. A java programming is connected to Microcontroller chip, PIC 18F14K50 was employed to perform the task. Then the output value from the transistor that connected to microntroller before is used to triggered the first avalnche transistor in the circuit.

2.3 Avalanche Breakdown

The generation of variable-width, fast rise pulses may be accomplished in a number of ways (W.G. Magnuson, 1962). The purpose of the circuit were fast rise times, flat top pulses, fast fall times and the convenience of controlling the width of the pulse. The basic operation of diffusion transistors relies on the physical process drift, diffusion, recombination and generation, and storage. The process of breakdown may occur in various ways either by surface conduction or by conduction within the body of the material. The avalanche process was include the produced of the holes and electrons that will may produced additional pairs.

2.4 Introduction to Electro-optic Q-switching

The giant pulse formation or Q-switching is a technique that a laser can be made to produce apulsed output beam. Q-switching leads to much lower pulse repitition rates, much higher pulse energies and much longer pulse durations. It is also another technique for pulse generation with lasers compared to modelocking. Electro-optical switches can be used to control the cavity Q by means an applied voltage.

2.5 Introduction to Interfacing

Interfacing is the process of connecting devices together so that they can exchange information. The process of reading input signals and sending output signals is called I/O. The I/O direction is relative to the Micro Computer Unit (MCU), which are the input data is read by the MCU while the output data is sent out by the MCU.

The computer interfacing is quite important in this modern world. It is because this computer interfacing is used as the human-machine interface determine the ultimate success or failure of many computer likes based systems. The digital system exist between the computer interfacing and it was successfully interact with an analogue natural environment.

There are several interfacing activities that common used like selecting software or hardware subsystem that can interact well with each other. Besides that, it can be used to resolve hardware incompatibilities like CMOS and TTL besides providing an appropriate hardware connection.

2.5.1 Java Programming

Java is a one of programming language that built for a world in which everything that has some sort of electronic component. The special thing of this java is it is designed to reduce many of the most common causes of programming errors. Besides that, this provides for secure program that can be executed on the internet use.

2.5.2 Microcontroller

Microcontroller is designed like single chip computers that are often embedded into other systems to function as process or controlling unit. There is no other components are needed in application of microcontroller because all necessary things are already built into this system. This microcontroller is designed to be all in one and usually will used in digital cameras, TVs, mobile phones and calculators.

Nowadays, the functionality of microcontroller is added on the single IC and often includes communications peripherals, control peripherals, integrated display drivers such as for LED and LCD and also as analogue peripherals.

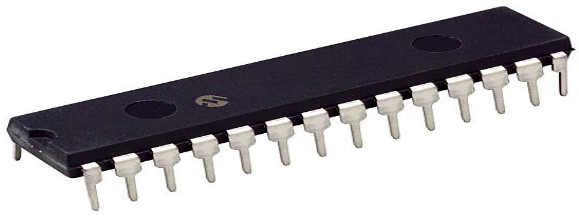

Figure 2.1 : Microcontroller

2.5.3 Universal Serial Bus (USB)

Universal Serial Bus (USB) is a serial bus standard to interface devices. USB was designed to allow many peripherals to be connected using a single standardized interface socket and to improve the plug-and-play capabilities by allowing devices to be connected and disconnected without rebooting the computer. The other convenient features includes providing power to low-consumption devices without the need for an external power supply. It also allowing many devices to be used without requiring manufacturer specific, individual device drivers to be installed.

CHAPTER 3: METHODOLOGY

3.1 Introduction

As mentioned in Chapter 1, the main component to generate high voltage circuit in this project is avalanche transistor. This avalanche transistor is used because of its characteristic that can be developed in order to investigate its stability and operating points in circuits. (William D. Roehr, 1963). Then, an electro-optical switch can be used to control the cavity Q by means of an applied voltage. The variable of high voltage DC power supply in the range of 0 to 1 kV is connected to the circuit. To avoid from electric shock or other noise besides for safety reason during this high voltage experiment, the experimental setup is arranged properly. Next, Figure 3.1 shows the flow chart of the measurement for this experiment.

3.2 The flow chart of experimental measurement

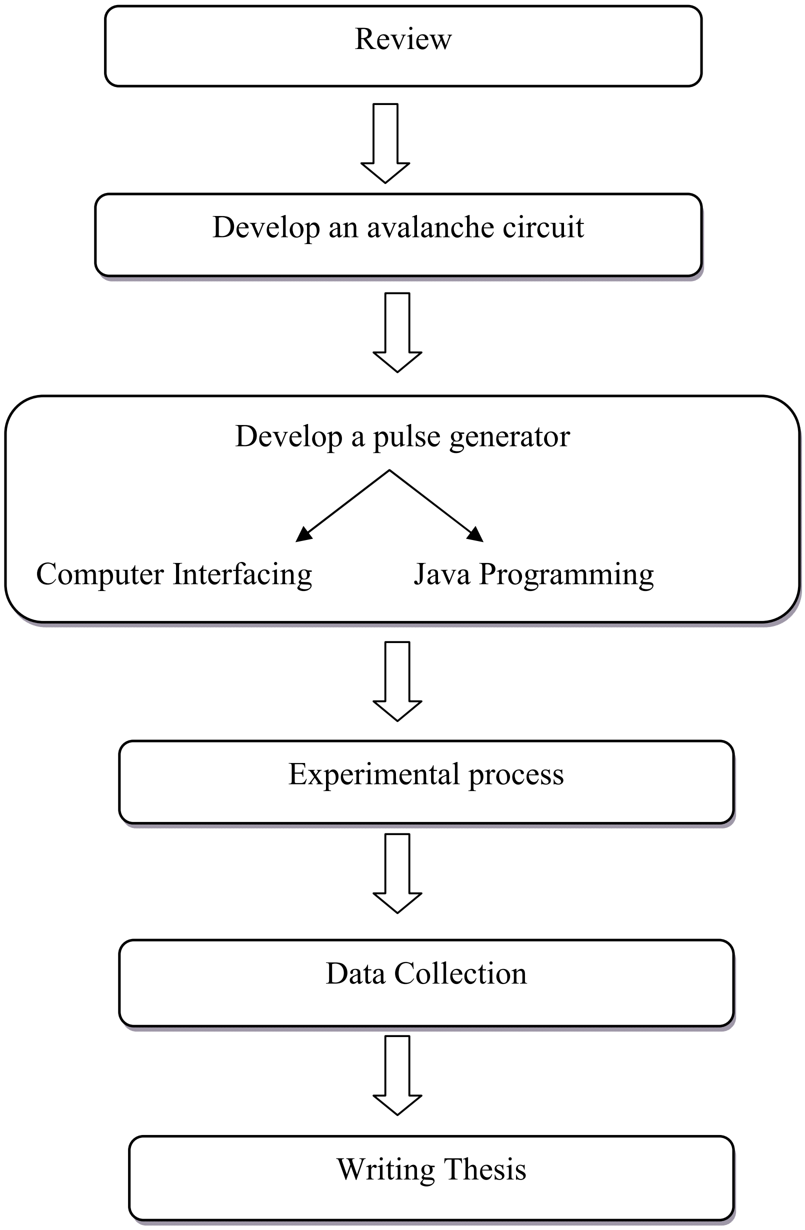

Figure 3.1: The flow chart of experimental work

3.2.1 Avalanche Transistor

The avalanche transistor is similar to the pn or PIN photodiode except the bias applied to the avalanche transistor is sufficiently large to cause impact ionization (Donald A. Neamen, 2006). The thorough characterization of transistor's avalanche region is necessary to properly utilized operation in the avalanche mode. The avalanche transistor that ideally suits for this experiment is ZTX415. This avalanche transistor has maximum voltage collector-emitter (V_{CBO}) of 260V (N. Chadderton, 1996). While the current that flows between these transistors are depends on the voltage applied on the circuit. This can be shown from the relationship between the current and voltage of avalanche transistor.

$$V = IR \quad ; \quad I = \frac{V}{R}$$

3.2.2 High Voltage Probe

Figure 3.2 : High Voltage Probe

Figure 3.2 shows a high voltage probe (Tektronix P6015A). It is always use for heavy-duty high-performance measurement of voltage over 2.5 kV. This probe are able to measure DC voltage up to 20 kV and pulses up to 40 kV peak pulse with maximum duration of 100ms. Besides that, with 75 MHz badwith, this probe enables to cature fast and high voltage signals.

3.2.3 Oscilloscope

Figure 3.3 : Digital Phosphor Oscilloscope

The digital oscilloscope devices usually employ a binary numbers which correspond to the sample of voltage while the analog oscilloscope make use of continually varying voltages. To change the measured voltage into digital information, an analog-to-digital converter (ADC) is used. In this experiment, a digital phosphor oscilloscope (DPO), Tektronix (TDS 3054B) is used. There is four channel color in this oscilloscope. Then the maximum bandwith is about 500 MHz while the maximum sample per second (Gs/s) is about 5 Gs/s. This DPO is used because it has a unique processing architecture which is a parallel processing setup.

3.2.4 Power Supply (1.5kV)

Figure 3.4 : High Voltage Power Supply (1.5kV)

This power supply has voltage range about (0 to 1.5) kV. While the maximum current that will flow in this experiment is about 1mA. Besides to supply a high voltage power, it is also use to protect against overload, avoid from short-circuit current and any transients that caused by the load of inductance.

3.3 Experimental Setup

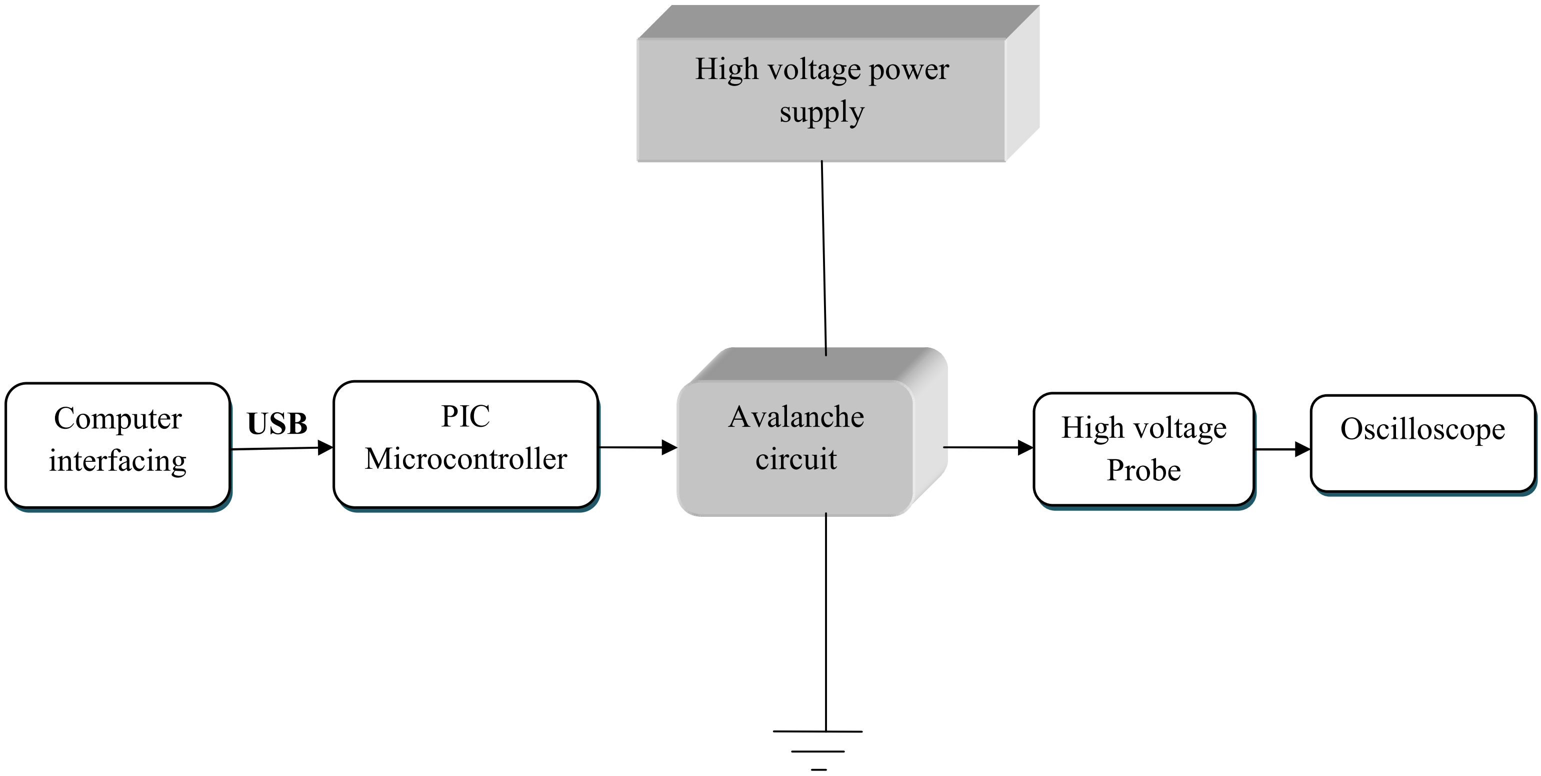

Figure 3.5: Experimental setup

The experimental setup for this research is shows in Figure 3.4 above. The high voltage power supply (up to 1.5 kV) is connected to the avalanche circuit. PIC Microcontroller is used as processing or controlling unit and it will connect to the computer interfacing. In this computer interfacing, the Java Programming is used to control the pulses produce in nanoseconds average falling time. Then, the complete of avalanche circuit will connect to high voltage probe and all data will appear on oscilloscope.

3.3.1 Avalanche Circuit Diagram

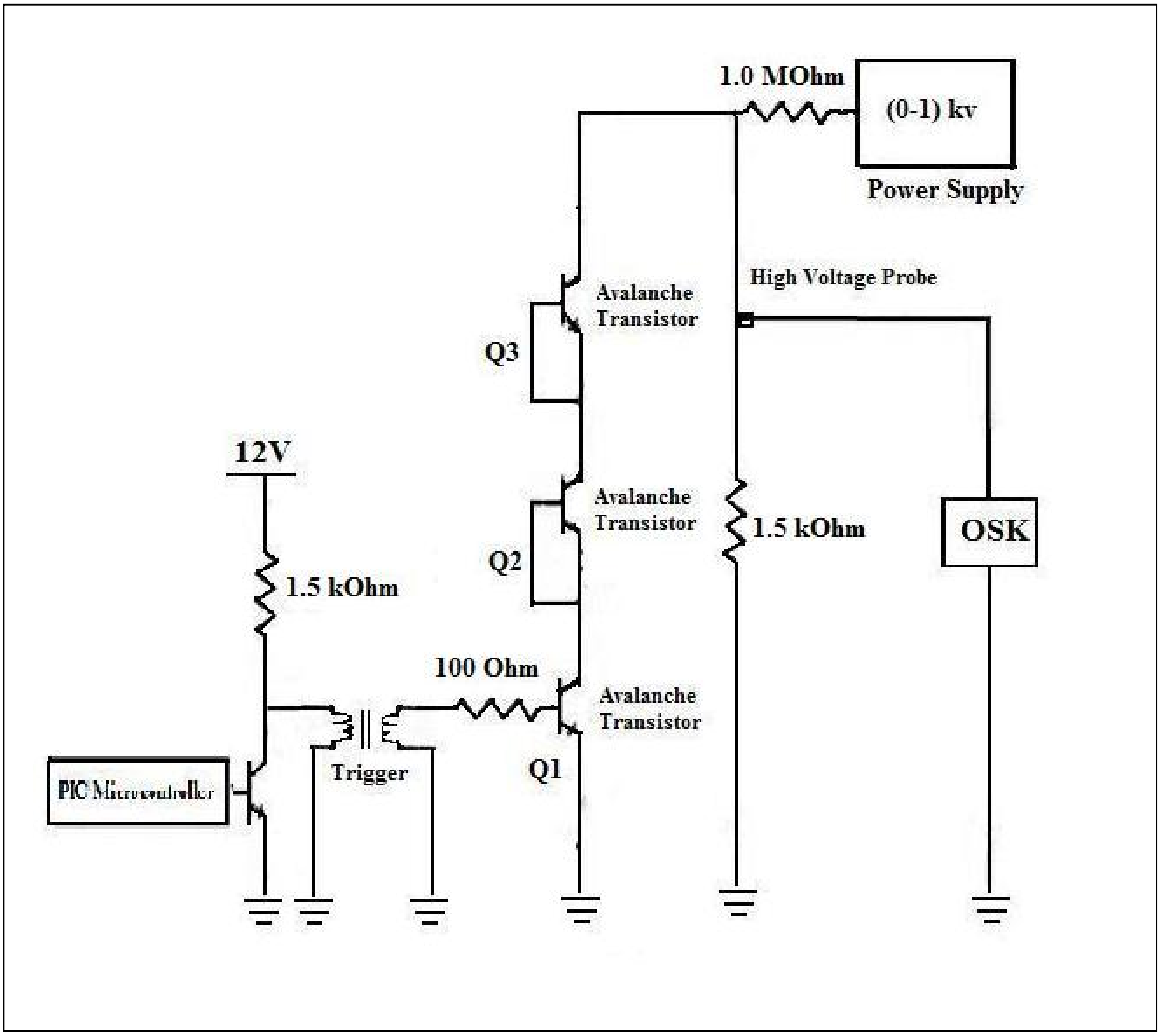

Figure 3.6: Avalanche circuit diagram

This circuit consists of three units of avalanche transistors. The first avalanche transistor (Q1) is trigger via a small bead pulse transformer and connected through a 100 Ohm resistor. The collector of this transistor is near to the ground potential. Another two avalanche transistor base is directly connected to emitter except Q1. Then the oscilloscope will display and measure the electronic signal which comes from high voltage probe that measure the high voltage supply across the circuit.

3.4 Equipment

The equipments that will use in this project are:

1) Avalanche transistor
2) Microcontroller chip PIC 18F14K50
3) Oscilloscope (5 MHz)
4) High voltage probe
5) Pulse transformer
6) Power supply (1 kV)
7) Diode
8) Capacitor
9) Digital multimeter

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