Design and Development of a PIC Microcontroller Based High Voltage Power Supply

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ABSTRACT

Design, development and simulation of a microcontroller based high voltage power supply (HVPS) have been presented in this paper. The HVPS consists of microcontroller (µC) based oscillator, transistor driver circuit, ferrite core high voltage (HV) transformer and quadruple voltage multiplier circuit. The PIC16F84A µC with 20 MHz crystal generates 9.09 KHz, 96.36%D, 5V signal which has been used as a input for transistor 2N2222A driver coupled with ferrite core HV transformer. Thereafter, the transformer's secondary voltage has been multiplied by a quadrupler circuit. A multi-turn potentiometer would be used to control the output voltage to a required level. An assembly language program based on MPLAB IDE has been developed for generation of the oscillator signal. The complete high voltage power supply (HVPS) has been designed and verified in Proteus 7.7 simulation platform.

KEYWORDS: Microcontroller based oscillator, Transistor driver circuit, High voltage transformer, Voltage multiplier circuit, PIC microcontroller and MPLAB IDE

1. INTRODUCTION

A power supply irrespective of category low voltage power supply (LVPS) or high voltage power supply (HVPS) must provide stable and ripple-free DC output voltage independent of line and load variations. There are mainly two types of high voltage power supply (HVPS) available in the nuclear field: those for very low current upto 100 µA used for biasing semiconductor detectors and gas-filled detectors. And those able to deliver higher currents needed when working with photomultiplier tubes [1]. In this regard, variable high voltage power supply with over-current alarm and time delay that gives 0 to 300 Volts and 100 mA based on a simple circuit employing zener diodes and series pass transistor for its regulation In [3], A variable high voltage power supply using phase angle control has been presented. The high voltage output is adjustable from 100-1000V and the current rating is 10 mA. Design, Fabrication and Performance Study of a Low Cost High Voltage Power Supply provides 100-900V and

12.5 mA constructed with (a) astable circuit, (b) monostable circuit, (c) transistor Driver Circuit, (d) HV X-former and (e) Voltage Multiplier Circuit. [4].

In the current research, a variable high voltage power supply with the introduction of a microcontroller based oscillator (9.09 KHz, 96.36%D, 5V) replacing (a) astable circuit and monostable circuit in previous research [4] has been presented. The output voltage is ranging from 0V to 673V. The schematic of this HVPS has been designed using Proteus 7.7 for electronics design and performance verification. The following blocks shown in fig.1 comprise the designed high voltage power supply (HVPS).

2. Methodology

A microcontroller based high voltage power supply (HVPS) consists of the microcontroller PIC16F84A with 20MHz crystal, driver transistor 2N2222A, ferrite core HV transformer, voltage multiplier circuit and low voltage power supply (LVPS) have been

presented. Block diagram, schematic diagram, circuit description, functional description and program flowchart for the designed HVPS also have been presented accordingly.

2.1. Block Diagram

Block diagram of the proposed HVPS comprises of the PIC microcontroller based oscillator, driver circuit, ferrite core HV transformer, voltage multiplier circuit as shown in Fig.1.
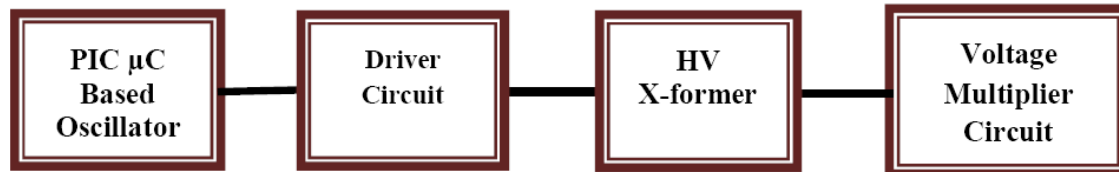

Fig.1: Block Diagram of the Proposed Microcontroller Based High Voltage Power Supply.

2.2. Schematic Diagram

Complete simulation model of the µC based high voltage power supply (HVPS) has been shown in fig.2. The description of individual circuit has been given below:
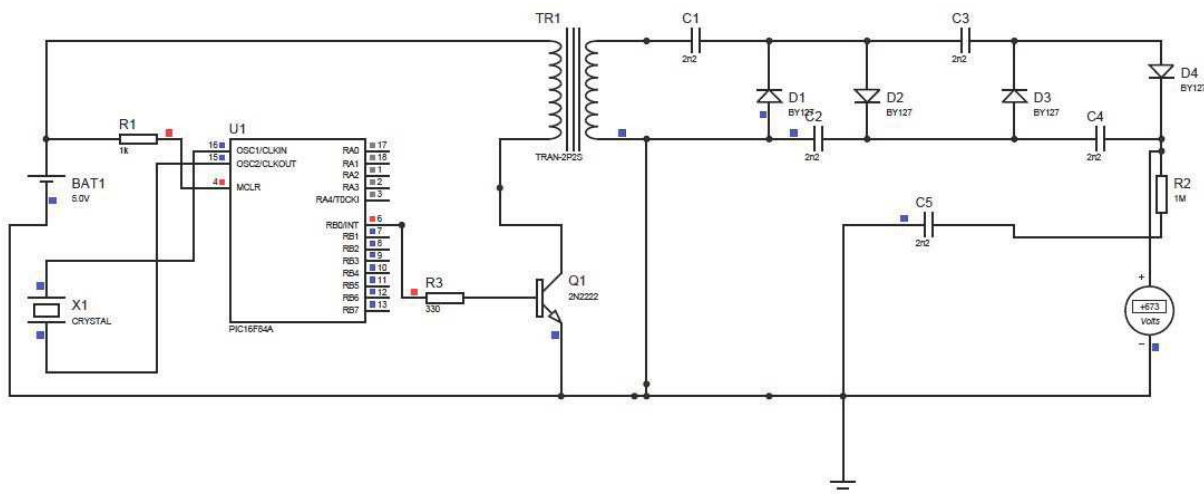

Fig.2: Schematic Diagram of the Proposed Microcontroller Based High Voltage Power Supply.

2.2.1. Low Voltage Power Supply: The low voltage power supply (LVPS) is essential for the system and a built-in 5V DC power supply has been used in Proteus 7.7 simulation platform.

2.2.2. Microcontroller Based Oscillator: The oscillator is an electronic circuit that produces a periodic, oscillating electronic signal, often a sine wave or a square wave [5]. In this context, the microcontroller based oscillator PIC16F84A µC with 20 MHz crystal X1 generates 9.09 KHz, 96.36%D, 5V signal. The PIC16F84A is a 18-pin DIP Package Enhanced Flash Microcontroller. It consists of CPU, Memory for data and Program, Special Function Registers (SFRs), General Purpose Registers (GPRs), 2-port (PortA & PortB), active low MCLR, Interrupts and free-run timer TMR0 and so on [6,7]. An assembly language program based on MPLAB IDE has been developed for generation of the oscillator signal. The microcontroller reset pin MCLR has been connected to Vcc through resistor R1.

2.2.3. Transistor Driver Circuit: Low power bipolar transistor Q1 2N2222 features are NPN silicon planar switching transistors, switching and linear application DC and VHF Amplifier applications [8] has been used in this HVPS to drive the transformer TR1 TRAN-2P2S with a view to circuit test and simulation purposes only instead of a ferrite core high voltage transformer as collector load and resistor R3 as base bias.

2.2.4. High Voltage Transformer: Transformers are used for increasing or decreasing the alternating voltages in electric power applications, and for coupling the stages of signal processing circuits. Ferrite cores are used for high voltage transformer at higher frequencies, typically between a few tens of kilohertz to hundreds of megahertz, to reduce losses, physical size and weight of inductive components [9].The primary voltage at the step-up ferrite-core transformer is adjusted according to the required output voltage.

2.2.5. Voltage Multiplier Circuit: A voltage multiplier can be understood as a series of half-wave rectifiers connected in cascade. It has been observed that D1 charges C1 to the peak, voltage Vp. This wave is

rectified through D2; and C2 is then charged to 2Vp. The same analysis determines that the peak voltage 2Vp, which rectified through D3, charges C3 to 3Vp. Likewise, this wave is rectified through D4; and C4 is then charged to 4Vp.

2.2.6. **Output Filter Circuit:** The output filter circuit for the designed HVPS comprises of resistor R2 and capacitor C5.
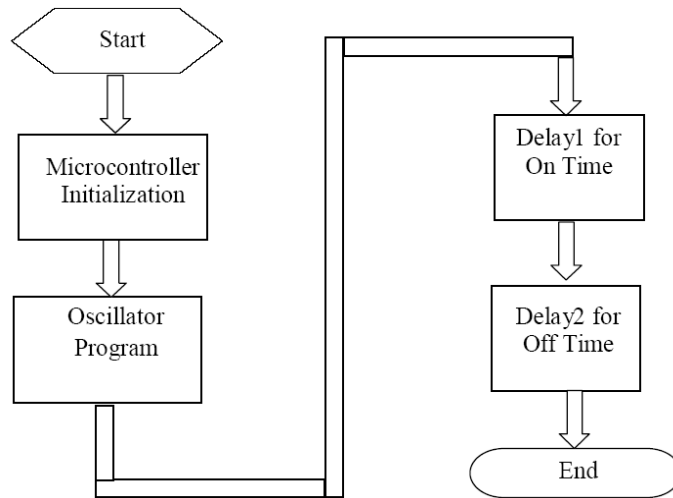

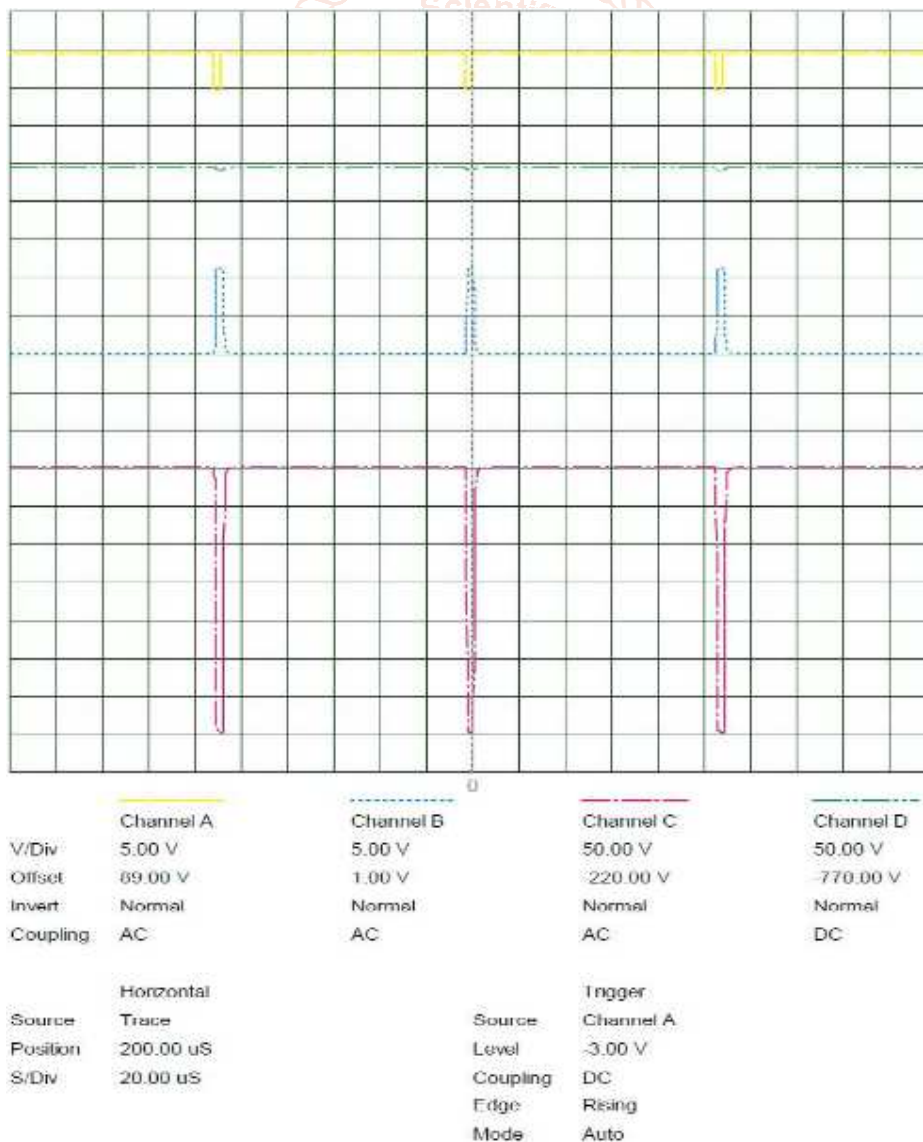**Fig.3: Shows the Program Flowchart for the Developed HVPS.**

Fig.4: Shows the Input and Output Waveforms for the Designed HVPS.

2.3. Results and Discussions

Design, development and simulation of a microcontroller based high voltage power supply (HVPS) have been presented in this research. The block diagram, schematic diagram, circuit description, functional description and program flowchart for the designed HVPS also have been presented accordingly.

The microcontroller based oscillator PIC16F84A µC with 20 MHz crystal X1 generates 9.09 KHz, 96.36%D, 5V signal as shown in the fig.2. And the fig.4 shows the program flowchart for the designed HVPS where an assembly language program based on MPLAB IDE has been developed for generation of the oscillator signal. The microcontroller reset pin MCLR has been connected to Vcc through resistor R1. Low power bipolar transistor Q1 2N2222 features are NPN silicon planar switching transistors has been used in this HVPS to drive TR1 TRAN-2P2S with a view to circuit test and simulation purposes only instead of a ferrite core high voltage transformer as collector load and resistor R3 as base bias. The primary voltage at the step-up ferrite-core transformer is adjusted according to the required output voltage. Ferrite cores are used in the high voltage transformer at higher frequencies, typically between a few tens of kilohertz to hundreds of megahertz, to reduce losses, physical size and weight of inductive components. The output of this circuit thereafter multiplied by using voltage multiplier circuit. The output filter circuit for the designed HVPS comprises of resistor R2 and capacitor C5. The input and output waveforms of the developed system has been shown in fig.3. Four channel digital oscilloscope consisting of Channel A shows the input signal, Channel B for transformer's primary voltage. The Channel C and Channel D show transformer's secondary voltage and HVPS output voltage in the Proteus 7.7 simulation platform respectively.

In the current research, a variable high voltage power supply with the introduction of a microcontroller based oscillator (9.09 KHz, 96.36%D, 5V) replacing (a) astable circuit and monostable circuit in previous research [4] has been presented. The output voltage is ranging from 0V to 673V as shown in fig.4. The schematic of this HVPS has been designed using Proteus 7.7 for electronics design and performance verification. The basic building blocks of a high voltage power supply (HVPS) consist of an oscillator, step-up transformer and rectifier circuit as shown in fig.5. Likewise, the designed high voltage power supply (HVPS) comprises the following blocks as shown in fig.1 such as (i) microcontroller based oscillator (ii) transistor Driver Circuit, (iii) HV X-former and (iv) Voltage Multiplier Circuit.

The high voltage power supply (HVPS) is a very important electronic instrument in the conventional nuclear instrumentation module (NIM) standard or stand-alone type of the nuclear radiation detection and measurements instrumentation field for biasing various nuclear detectors.
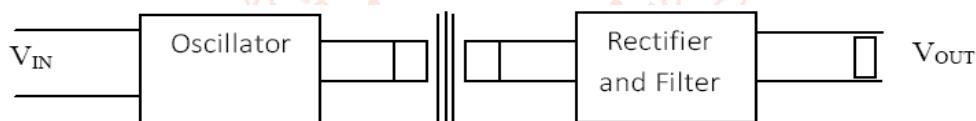

Fig.5: Shows the basic building blocks of a high voltage power supply (HVPS).

3. Conclusion

In this research, design, development and simulation of a microcontroller based high voltage power supply (HVPS) consists of the microcontroller PIC16F84A with 20MHz crystal, driver transistor 2N2222A, ferrite core HV transformer, voltage multiplier circuit and low voltage power supply (LVPS) have been presented. The design and verification of the PIC µC based HVPS in Proteus 7.7 simulation platform has been completed successfully. The designed system is cost effective, simple and reliable in operation. The HVPS has been tested repeatedly and its performance was found satisfactory.

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