

DESIGN AND MAKE A TRIANGULAR WAVE OSCILLATOR WITH APPLICATION TO EXTRACT THE V-I CHARACTERISTICS OF ZN-O VARISTORS

F. Harirchi, S.M. Hasanli*

Islamic Azad University, Tehran South Branch (IRAN), harirchi@gmail.com

*Institute of physics, National Academy of sciences of Azerbaijan,
H. Javid pr., 33, Baku, AZ 1143, Azerbaijan, hasanli_sh@rambler.ru

I. Introduction

Varistors (variable resistors) are polycrystalline ceramic devices exhibiting highly nonlinear (non-ohmic) electrical behavior and greater energy absorption capabilities. Several conduction mechanisms for the varistor have been proposed based on this ceramic microstructure, which has led to varistor behavior being widely interpreted as resulting from the series-parallel network formed by the zinc-oxide intergranular-phase junctions. Capacitance measurements as a function of voltage have supported the model of Schottky barriers at grain boundaries. Electrically, the varistors show highly nonlinear (I-V) characteristics similar to the back-to-back Zener diode, but with much higher voltage, current and energy handling capabilities [1]. As a result, they are widely used as surge absorbers in electronic circuits and core elements of surge arresters in electric power systems.

The fabrication of zinc-oxide varistors is done by mixing semiconducting zinc-oxide powder with other oxide powders such as Bi, Co, Mn, and Pr, and subjecting the powder mixture to conventional ceramic pressing and liquid-phase sintering techniques [2]. A simple equivalent circuit for varistor is shown in fig. 1,a. The sintering results in a polycrystalline ceramic with a singular grain boundary property which produces the nonlinear current-voltage (I-V) characteristic of the device. A typical (I-V) characteristic of a varistor is shown in fig. 1,b.

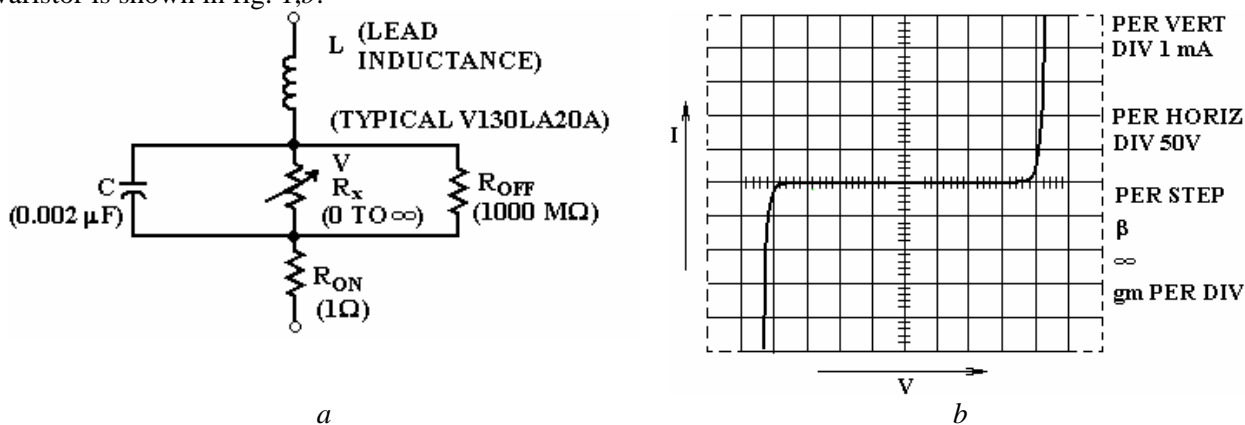


Fig. 1. a: Varistor equivalent circuit model, b: Typical Varistor's (V-I) Characteristics

Microstructurally, the zinc-oxide varistors are comprised of semiconducting n-type zinc-oxide grains, surrounded by very thin ($1-10^{-3}$ μm) insulating intergranular layers.

Testing new fabricated varistors in recent years is done using old methods. These old methods are based on an operator, who measures voltage and current of varistor point by point, and using measured values, he estimates the I-V characteristic plot. This procedure is time consuming, operator based and not accurate [3]. Moreover in the quality control (QC) systems, we need an automatic system in order to test varistors.

In many cases hysteresis occurs in specific frequencies in the I-V characteristic of varistors. For finding these hystereses and to illustrate them, we can use the proposed device in this paper.

In this paper we proposed a device, which can test new fabricated varistors automatically. This device is produced for the first time and it is independent from operator. We can illustrate I-V characteristic of varistors in the forward and backward case, so we can see hysteresis in the illustrated figures. Proposed device can work in the frequency range of 0.001Hz to 100 Hz and amplitude range of 0v to 600v.

II. Circuit Block Diagram

Device consists of five main parts:

1. Power Supply
2. Main Oscillator
3. Power Amplifier
4. Personal Computer
5. Oscilloscope Card

The connection of various Blocks of the device is shown in fig. 2.

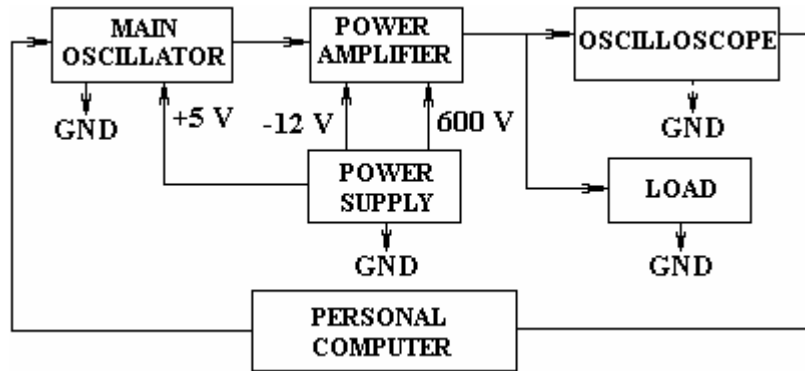


Fig. 2. Block Diagram of the Proposed Oscillator

III. Power Supply

The block diagram of the power supply is shown in fig. 3. To reduce the noise of main supply we put on RF-filter in the input of circuit, output of filter pass through a rectifier and a low pass filter to become DC. The next step is a switching element which makes a square wave from the DC input. Amplitude of the square wave reduces via an isolated transformer and after rectifying and filtering goes to an Optocoupler to have a constant voltage in output. The PWM controller supplies the pulses which should apply to the switching element which is a power Mosfet here. These two blocks as shown in fig. 10 are named power switch. If we look at the feedback loop of the diagram we can see the optically isolated error amplifier, which consists of two parts. The first part is the voltage reference block which takes a reference from output and the second part is the Optocoupler which compare and isolate the reference voltage and send a control signal to the PWM block to fix the output voltage of power supply. The efficiency of this circuit is more than 70% and the peak to peak ripple voltage in maximum load is less than 20 mv. The 20% variations in main supply (180–260 volt) in maximum load make 15% changes in the DC output of the power supply.

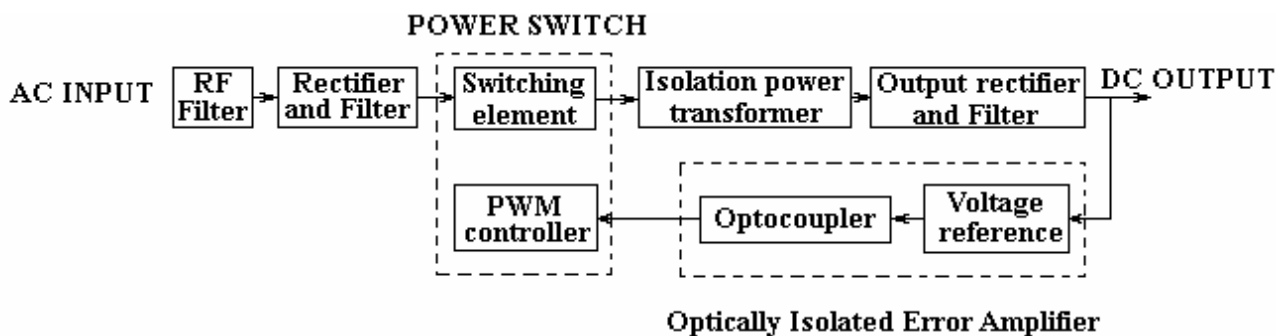


Fig. 3. Power supply Block Diagram

IV. Main Oscillator

The main part of this circuit is an 8051 Microcontroller which is connected to PC via a RS232 connection. A program is written in C# Language which gives user friendly interface to select the output frequency. The schematic of this software is shown in fig. 4. As shown in the Figure there are 46 Buttons, each one for selecting a frequency. When the user click on one of the Buttons, The frequency goes to the microcontroller via serial port and the frequency of output signal will be selected. The structure of circuit to make a symmetric Triangular wave as shown in fig. 5 includes of a Microcontroller and some Latches and the resistors which put in the circuit in a Ladder form.

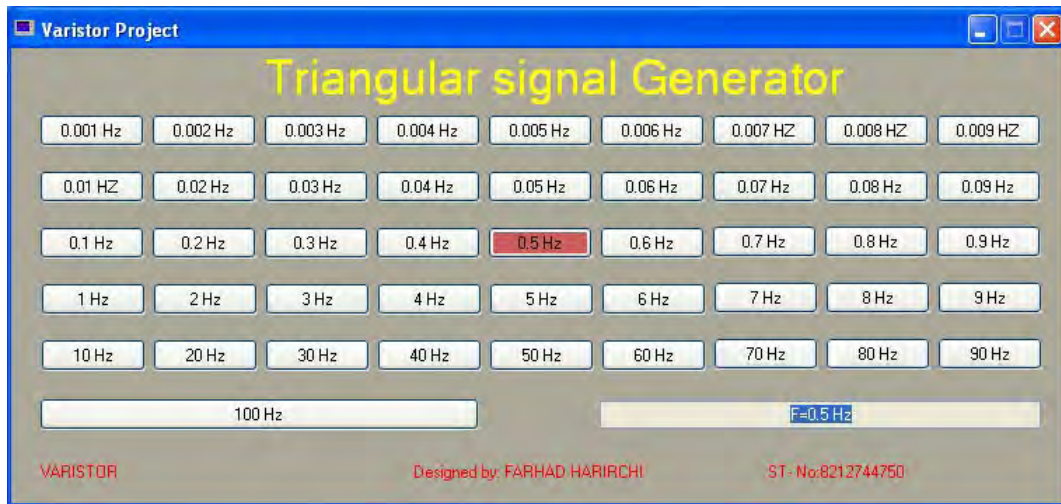


Fig. 4. Software Scheme

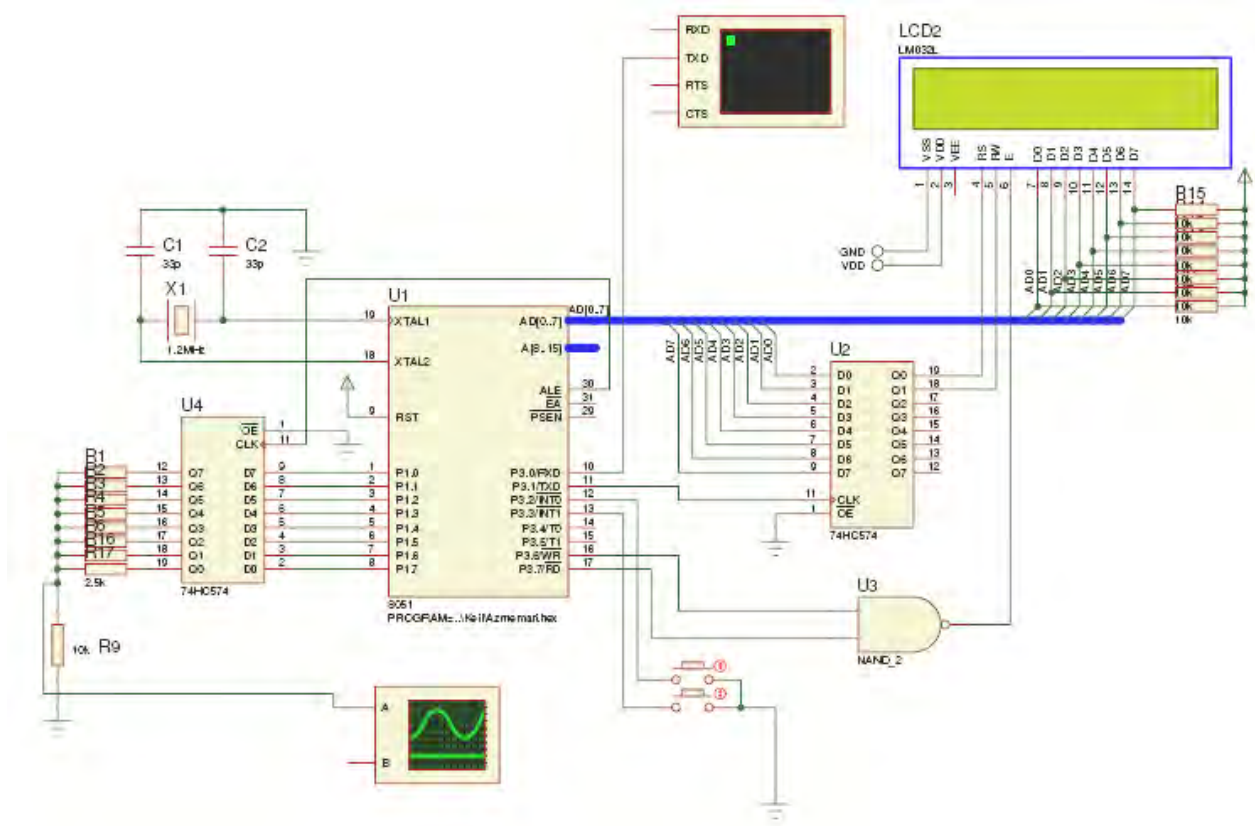


Fig. 5. Main Oscillator Schematic

V. Power Amplifier

In this project, we need an op-amp with the working voltage of 620 volts, but according to our best knowledge, we don't have such an op-amp in market. Instead of using an op-amp, we make a differential amplifier, which its output is consisting of a buffer and a Darlington amplifier. A differential amplifier, make a relation among its output, input and the current of current source. This relation is shown in Eq.1.

$$\Delta I = I_{c2} - I_{c1} = \dot{K}I(v_{i+} - v_{i-}). \quad (1)$$

Where (v_2-v_1) is the differential input, I is the current of the current source and \dot{K} is a constant.

A typical differential amplifier is shown in fig. 6. In this figure, transistors Q5 and Q6 are connected in the differential form. The amplification factor of this circuit is proportional to I .

Using the internal circuit of an op-amp and adjusting the parameters of it, we could make an op-amp which could act on the 0-620 volts range. The schematic diagram of this circuit and the frequency response

of it are shown in fig. 7. Like all of the amplifiers we should discuss on important parameters to understand the efficiency of circuit. The input impedance of the circuit, which is derived from a simulation, is about 800 kΩ and the output impedance is less than 50Ω. The voltage gain of this circuit is derived from the following equation:

$$A_v = \frac{R_2}{R_1} \quad (2)$$

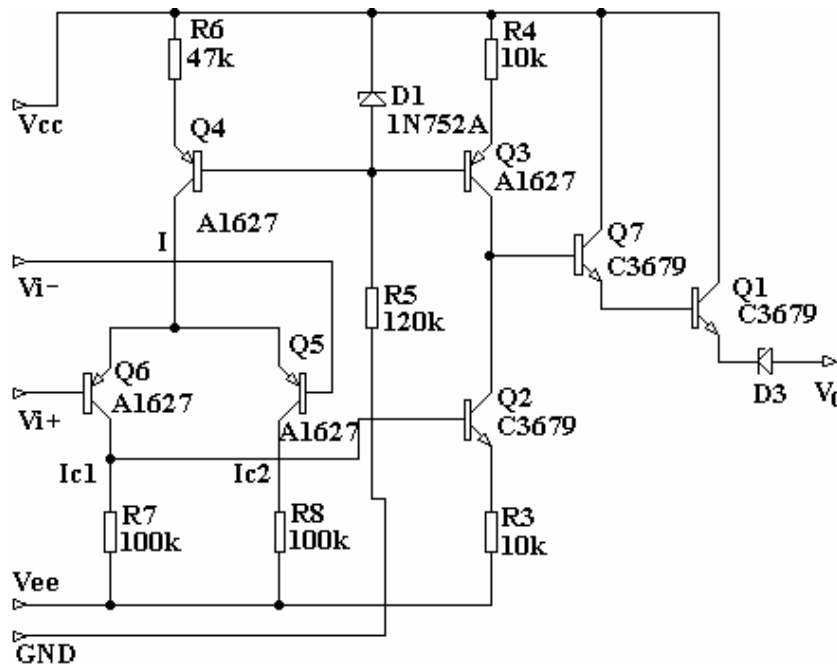
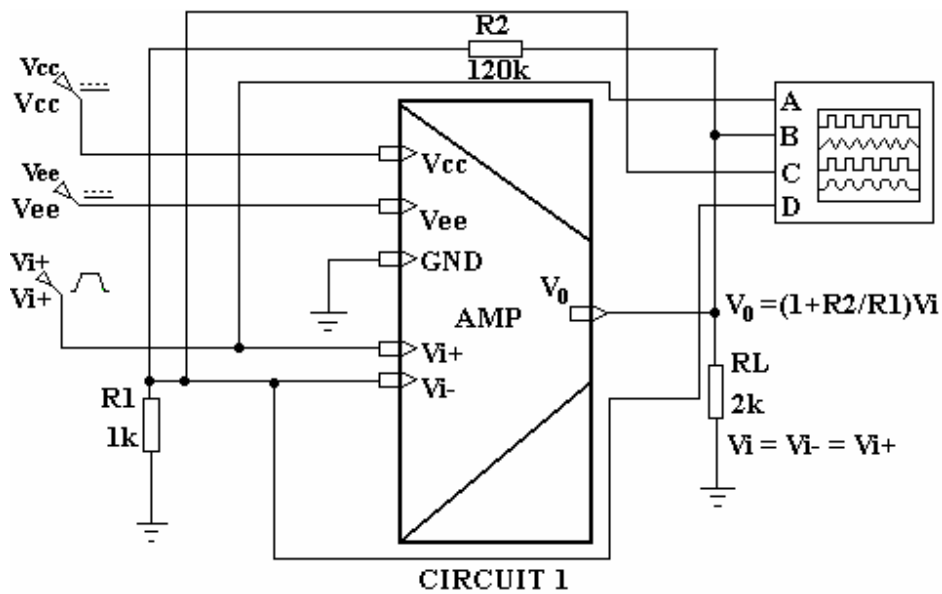


Fig. 6. A typical differential amplifier



a

If we consider That R is a 1 kΩ resistor then we will calculate A_v according to the following equation

$$A_v = R_2 (k\Omega). \quad (3)$$

If the maximum of peak to peak input voltage is 5 V, and we want to have 600 V in output, so we need to use a 120 kΩ resistor instead of R_2 . We use Pspice simulator this circuit in Transient, DC and AC Analysis Fig.6 shows the frequency response , input and output wave forms.

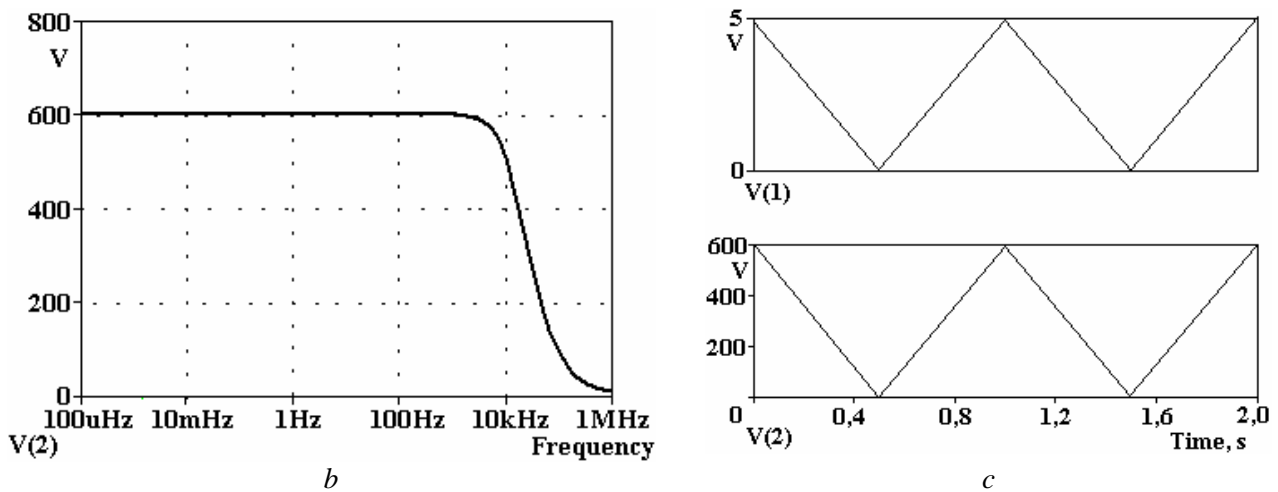


Fig. 7. a – schematic Diagram of Power Amplifier; b – the frequency response; c – top figure shows triangular wave, which is the input of the circuit and the bottom one shows the output voltage

VI. Conclusion

In this paper we discussed a device which can be used to achieve the (I–V) characteristics of varistors and even for many other power components in different frequencies and in an automatic way. Previously testing new fabricated varistors was a time consuming and operator based procedure, which could estimate I–V characteristics after finding some discrete points. With our proposed device this procedure will be done automatically and can accurately estimate the I–V characteristics of new fabricated varistors. In the prepared device we can make some changes to be more effective to multipurpose analysis, for example we can change the discrete frequency range to a continuous one with changing the microcontroller's and C# program, and another change which can be occurred is to replace the symmetric triangular wave with a square wave to achieve to other aims.

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Summary

To determine the (current-voltage) characteristics for the fabricated Disks of varistors, we need to design a circuit, which can generate voltages with different Amplitudes and frequencies. This device can change the voltage and frequency automatically and linearly. We can use this device to study characteristics of the fabricated components or in QC procedures. Device gets the frequency of output voltage from 46 quantized values between 0.001 HZ to 100HZ in the computer software. The peak to peak Amplitude of symmetric triangular voltage can change from 0 V to 600 V.