ACUPUNCTURE STIMULATOR DESIGN: SIMULATING STUDY

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Stimulatorul electric de acupunctură prezentat în acest articol este folosit pentru a produce analgezia necesară unor intervenţii chirurgicale. Două microcontroalere PIC16F877 sunt folosite pentru a realiza acest stimulator. Sistemul proiectat conţine şi o structură pentru detecţia punctelor de acupunctură şi are o interfaţă activă intre utilizator si dispozitiv, pentru a selecta parametrii de operare. Testul de simulare a proiectului a demonstrat cu succes că au fost obţinute formele de unde aşteptate pentru frecvenţele selectate şi modul de stimulare ales, precum şi faptul că se poate controla digital în timp real amplitudinea pulsului.

Electrical stimulation of acupuncture points has been used to produce analgesia in some types of surgery, for decades now. The study presented in this paper uses microcontroller to design an acupuncture stimulator; The design also contains a structure for acupuncture points detection, the design has an interactive interface between the user and the device, to choose the operation setting. The simulating test of this design proved that the device has produce the expected form of pulses at the chosen frequencies and stimulation mode, while it can digitally control the pulse amplitude in real time.

Keywords: acupuncture stimulator, electrical stimulator, acupuncture analgesia.

1. Introduction

The ancient Chinese believed that there is the energy which is circulating throughout the body along specific pathways which are called meridians. These meridians come near the skin surface at specific points known as acupuncture points. As long as this energy flows freely throughout the meridians and acupuncture points, health is maintained, but once the flow of energy is perturbed, the system is disturbed and pain or illness occur.

Acupuncture involves the insertion of very fine needles in the acupuncture points and manipulating these needles mechanically by the hand of acupuncturist or combined with thermal stimulation, in order to influence the physiological functions of the body. There are a few related procedures that fall within the range of acupuncture treatments. Electro-acupuncture is another way to stimulate

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acupuncture points, by sending electrical pulses through Acupuncture needles, to stimulate particular points. It is generally used for pain relief but some times it is used to create a state of analgesia to perform surgery. The first reported successful use of Electro-acupuncture in surgery was in 1958 in China for a tonsillectomy. Today, it is a common method for surgical analgesia in China [1].

Analgesia produced by acupuncture point stimulation offers an alternative for anesthesia, especially for patients who have allergy or can't support treatment with drugs. The effects of acupuncture stimulation is considered to be achieved by stimulating Encephalin producer neurons in the posterior horn of the spinal cord. The stimulation of these neurons can be done by stimulating the peripheral nerves with various frequencies to activate inhibitive control over the thalamus Para fascicle where a lot of paleospinothalamic trunk fibers meet together, carrying pain massages [2].

The circuit is designed with the use of ISIS LITE PROTEUS 6.7 simulation program. It gives us the ability to simulate the microcontroller functions beside a large variety of other electrical components, and to observe our circuit during operation, and to interact with the procedure, while the results are displayed on the LCDs, and the pulses appears on the oscilloscope.

2. Stimulator description

The design in this study was intended first to have three outputs to apply the electrical pulses at the chosen suitable acupuncture points. The design later was modified to operate on one output, because the memory of the microcontroller ran full, although the program with minor modification was perfectly capable to operate for three outputs if the lack of memory problem is resolved. The memory problem however was resolved later by using two microcontrollers working synchronously, and dividing the tasks between both of them and using both of their 8K flash program memory.

The proposed device here has two modes of operation, the detection mode and stimulation mode.

The detection mode allows the user to detect the acupuncture points, by measuring the resistance of these points on the skin surface. The results are then displayed on an 4x20 LCD *LM044L* display.

A constant current first will be injected to the suspected acupuncture point by sharp narrow headed electrode placed on the skin which has resistance R.

The reference electrode has large surface and should be held in the patient's hand, while the voltage is measured on the analog input of the $PIC_{1,}$ the input is connected to the A/D converter from where the point resistance can be calculated.

The measurements are performed in two ranges, the first one measure up to 10 MΩ , while second range is 0-1 MΩ .

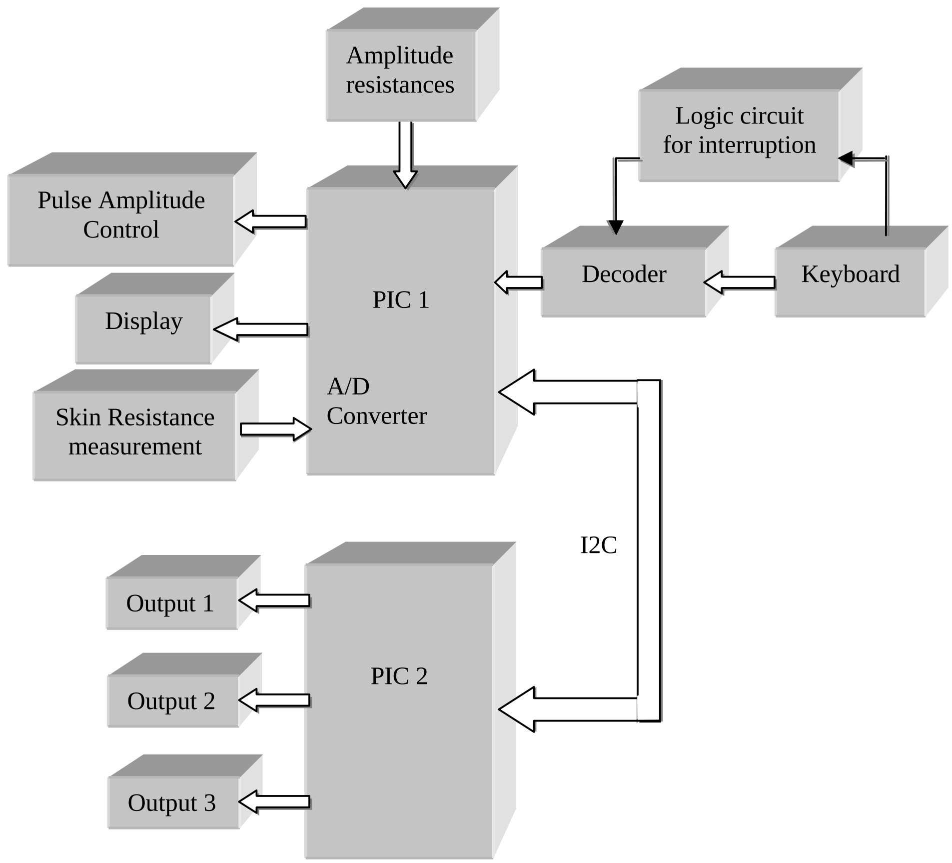

Fig. 1. Box diagram of the stimulator

The stimulation provided by this device has four modes; the operator will be offered to choose between these modes through the preparation steps to operate the device. These operation modes are listed below as the following.

Continuous mode: the user chooses the frequency, and the circuit will produce a square continuous pulse with the same frequency.

Discontinuous mode: the device here produces a train of pulses at the chosen frequency followed by rest period, and the total duration T of the train of pulses and the following pause is no longer than 5 s.

Alternative mode: the user have to introduce two values of frequencies $f_{1,}$ f_2, the circuit then continues to produce signals but it will switch between both frequencies, T here is also equal to 5 s.

Discontinuous alternative mode: the signals will alternate between f1 and f2, with a pause period follows each changing in frequency.

After choosing an operating frequency like f1, the duration of the train of pulses before the following pause when the operation mode requires switching between frequencies is decided by what is called duty cycle; it usually has the value between 10-90 % of the 5 s. In the case of alternative discontinuous stimulation there are three duty cycles, the first one is associated with the duration of the train of pulses generated at frequency f1, the second factor associated with the next train pulse generated at f2, while 5 s period with two trains of pulses at different frequencies has it's own duty cycle, which decide how long both trains of pulses will occupy from the 5s. These cycles are required to be introduced by the user for each output, according to the chosen stimulation type; they are stored in the EEPROM [3].

The following figure is a graphic illustration for the four stimulation modes.

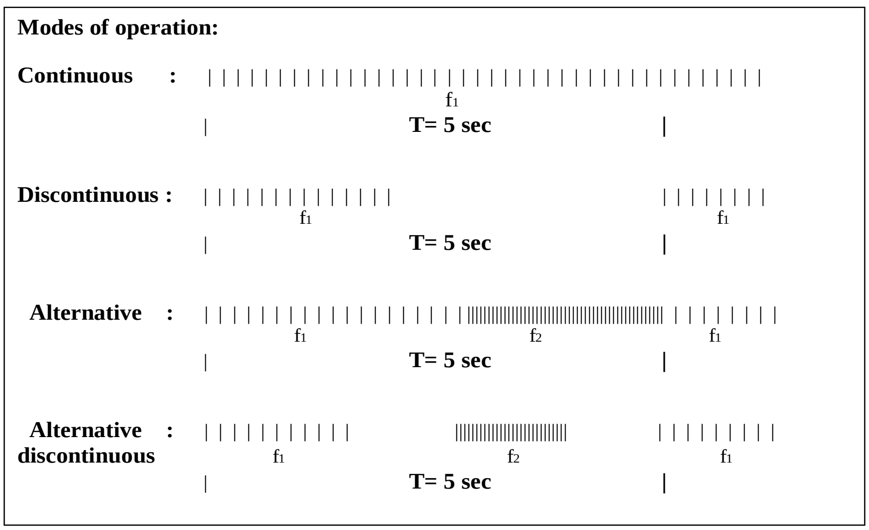

Fig. 2. Illustration for the stimulation modes.

3. Output circuit and amplitude controlling

The microcontroller will generate numerical square pulses to control voltage source, and to feed pulses to the isolation amplifier to produce the required pulses at the output; the auto-inductance of the output transformer serves to generate the negative part of the pulse.

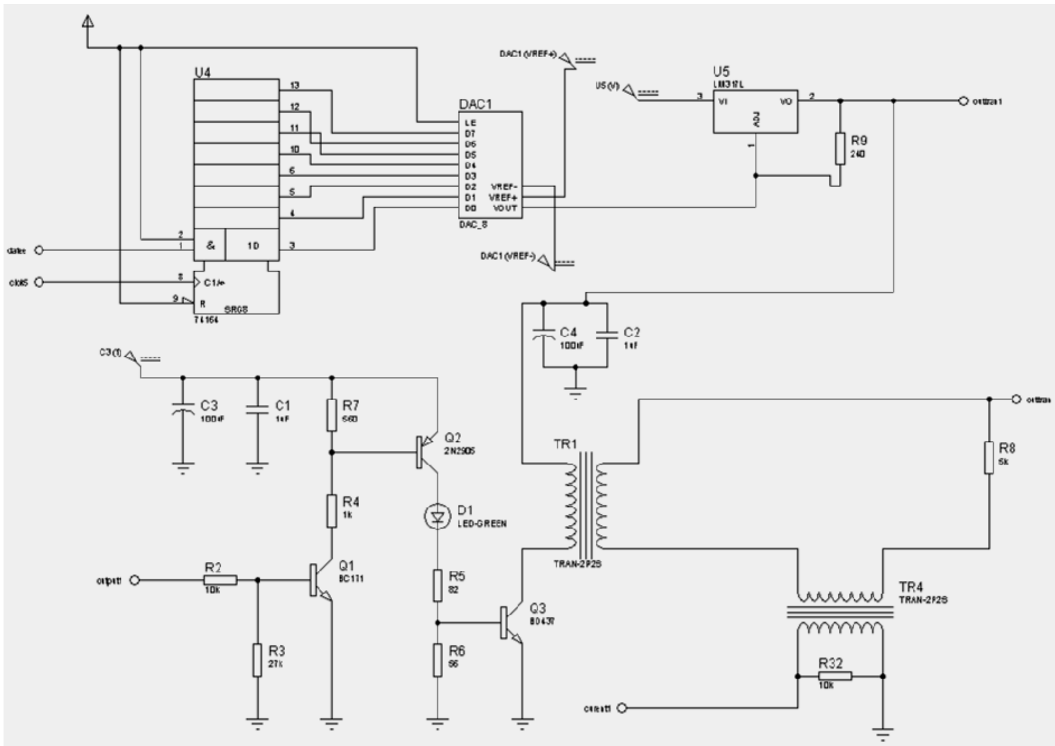

Fig. 3. The output circuit.

Pulse amplitude on all three outputs are regulated in two ways, first the user should select one between three domains of stimulation 0-10 V, or 0-50 V, or 0-100 V. Then the amplitude is regulated in the real time through changing resistances for each output. The resistance task is to regulate the output voltage level within the selected domain in the real time, and these resistances are connected to PIC_1 also through port A to the converter. PIC_1 reads the value of each resistance and calculates the corresponding voltage level according to the required selected domain, the calculated value then is send to D/A converter, the output of the converter is connected to the control pin of the voltage regulator LM317.

The maximum level of D/A output varies according to chosen stimulation level as the following.

If the selected domain of stimulation is 0-10 V, the regulator output value will vary between 0-1 V.
If the selected domain of stimulation is 0-50 V, the regulator output value will vary between 0-5 V.

If the selected domain of stimulation is 0-100 V, the regulator output value should vary between 0-10 V.

The output voltage is then to be amplified through isolation amplifier to match the real required value.

The voltage wave is more suitable to be applied on the design output than the current wave.

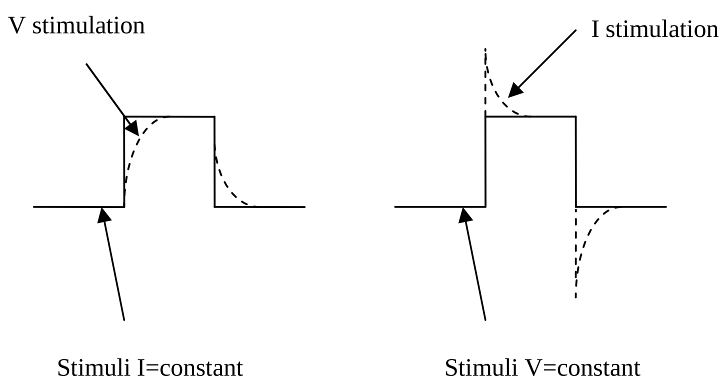

Fig. 4. The difference between current wave and voltage wave in stimulation.

In current pulses, the current takes some time till it reaches its maximum value; that is because of the capacitance effect of the electrode-tissue interface, so the human cells start to adapt to the stimulation pulses.

While in the case of voltage pulse as illustrated in Fig 4, the sharp edges with rapid rise rate prevent this adaptation, helping to perform better stimulation.

Fig. 5 illustrates the steps for choosing the range of the stimulation pulse's amplitude. It illustrates also the possibility to adjust the settings of all three outputs separately. Starting the stimulation is done by assigning 1 to the variable called *active*, after that the settings of each output are sent to PIC_2 to start generating the pulses [4].

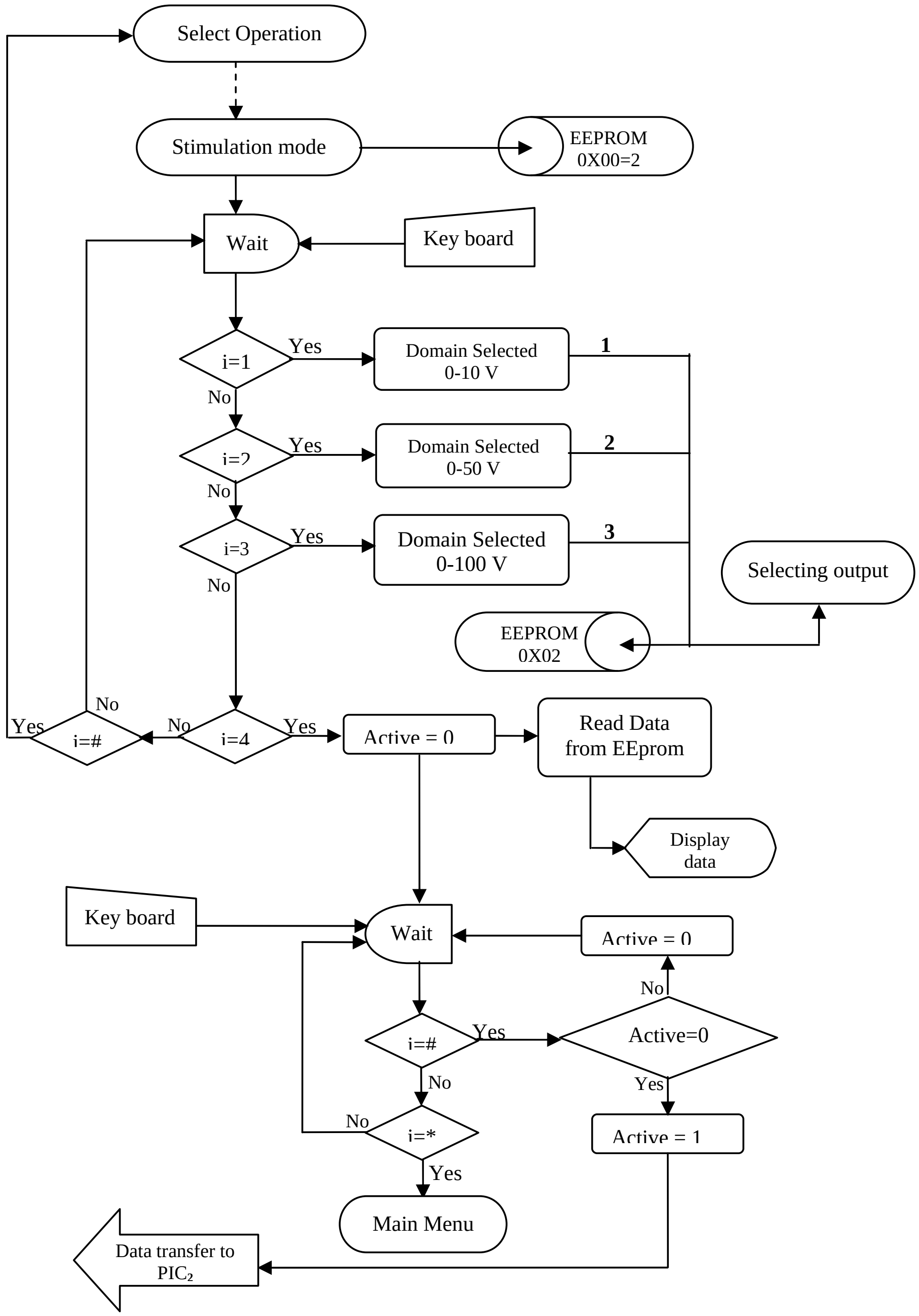

Fig. 5. Flow chart of stimulation mode and domain selection.

4. Results

- The pulses generated and illustrated in the charts below show that this design succeeded to generate the desired pulses at it's output at the chosen frequency every time.
- The pulse amplitude is regulated in the real time.
- Detection operation succeeded to measure the resistance value with good precision in the two ranges.

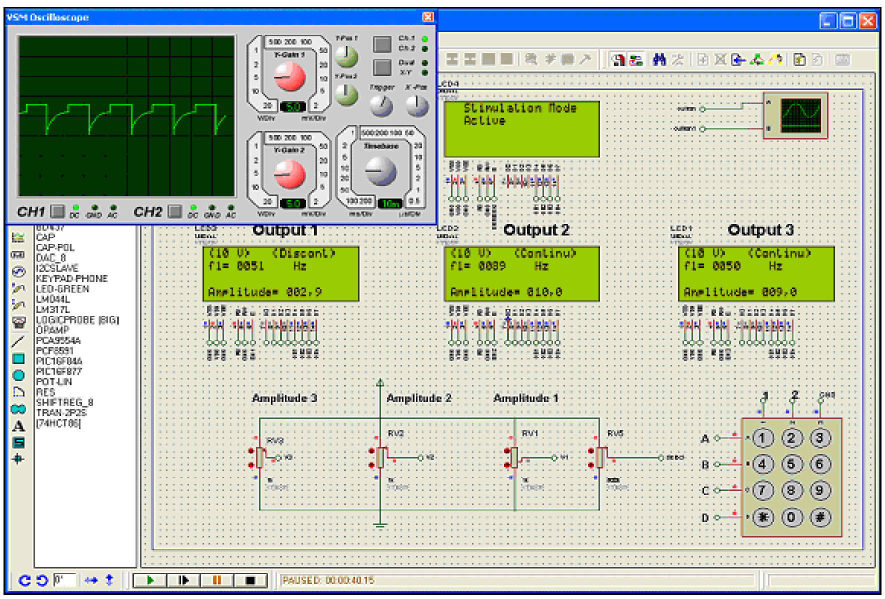

Fig. 6. Program interactive interface which shows the generated pulses in continues mode at 51 Hz, on the first output.

Fig. 6 is an illustration of the program interface where there are 4 displays, the first one in the upper center of the screen is used to view step instructions and choices, while the settings of each output are viewed on the display prepared for that specific output. There are three amplitude regulators which help to set or change the output amplitude, while the last resistance is used as a test for acupuncture point resistance measurement, the oscilloscope in the program is used to display the generated pulses on the output, in this case the program generates continues pulses at 51 Hz.

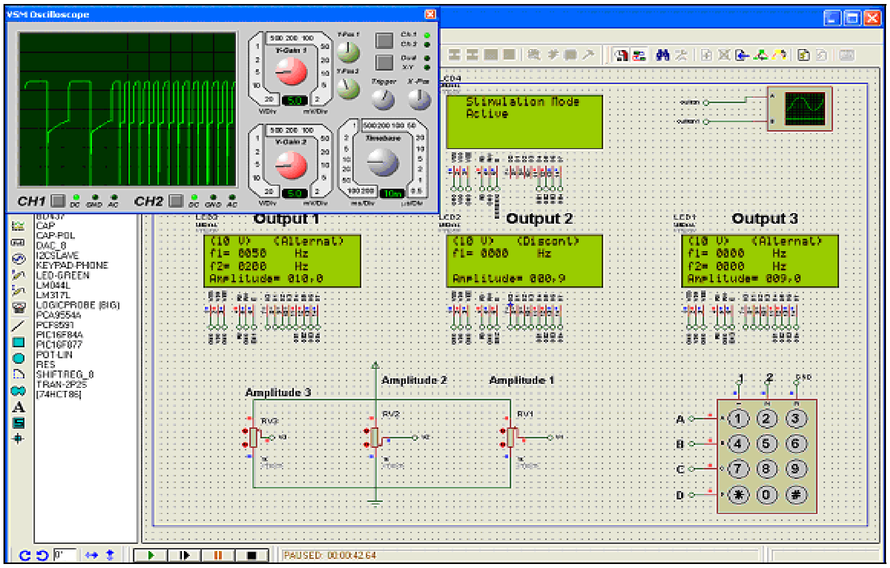

Fig. 7. Generating pulses in alternative mode at 50 Hz.

Fig. 7. shows the same previous program interface as in fig. 6. But here the generated pulses are alternating between two frequencies; the frequencies are set by the user on the corresponding output, before pulse generating procedure starts.

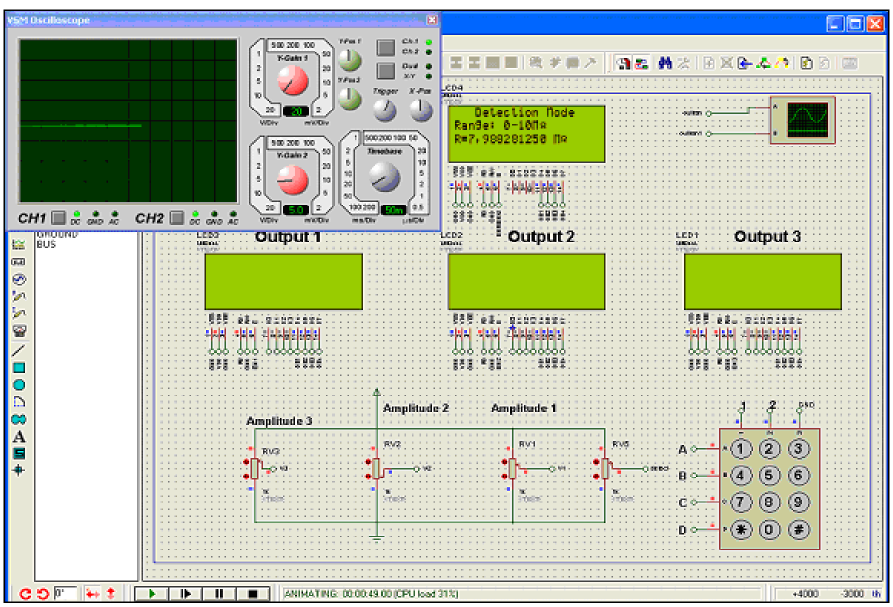

Fig. 8. The device is operating in detection mode in the range of 0-10MΩ.

Fig. 8 shows the program operating in measurement mode, where the measured resistance displayed on the main center display. In this mode there is no output settings or pulse generation.

5. Conclusions

The design is a step to produce a stimulator for acupuncture digitally controlled by microcontroller, but the work on this stimulator should continuous to measure the injected current in the acupuncture point when the pulse is applied, which indicates the stimulation occurrence. The second transformer TR4 in Fig. 3 is intended to measure the injected current at its output which has to be connected to an analog input in the microcontroller. The problem with the current measurement is that the current has irregular shape, so it has to measure as samples and digitally processed. All this need to use Digital Signal Processor DSP, which is not available in our simulating program.

The device should also be electronically realized and tested, and the obtained results should be compared with the results of this simulation study.

R E F E R E N C E S

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