Real-Time, electro-optic, control circuit for medical cold plasma system

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Introduction

The therapeutic effect of electrical discharge has been known for about a century. Later on, in the middle of the last century, a plasma electrosurgical device was introduced under the name "Hyfrecator" which is a common device for dermatology treatment. Other plasma forms have been investigated and implemented for skin treatments, blood coagulation, electrosurgical "scalpel", tissue re-connection and more(1). Several additional species resulting from plasma such as gases (ozone, nitrogen monoxide etc.), emitted light (UV) and charged particles are also employed to support the healing processes. Recently, new plasma methods have been introduced under the name of "cold-plasma", "non-thermal plasma" and dielectric barrier discharge (DBD) (2). More recently, a novel patented cold plasma technology for skin dermis and epidermis dermatology and oncology was developed. It is based on Electrical Discharge in conjunction with the support of an active gas flow or just the ambient air at atmospheric pressure (2). The therapeutic effect is attributed to the interaction of the pulse with the treated tissue with no significant pain or sense of heat during the treatment. Yet, the interaction of the pulse with the live tissue could not be verified and it has to be thoroughly investigated and understood in order to determine the therapeutic mechanism of operation as well as safety issues during the treatment. (3) This paper is dedicated to the real-time control of cold plasma pulse, in order to measure the introduced plasma power and to maintain the pulse stability during the treatment. It will enable the physicians to determine the required plasma parameters for any individual, regardless of the treated lesion or skin type. Moreover, the collected data is monitored and stored as data base for possible integration in AI

Experimental setup

A block Diagram of the control system is presented below in figure 1, with the details of them.

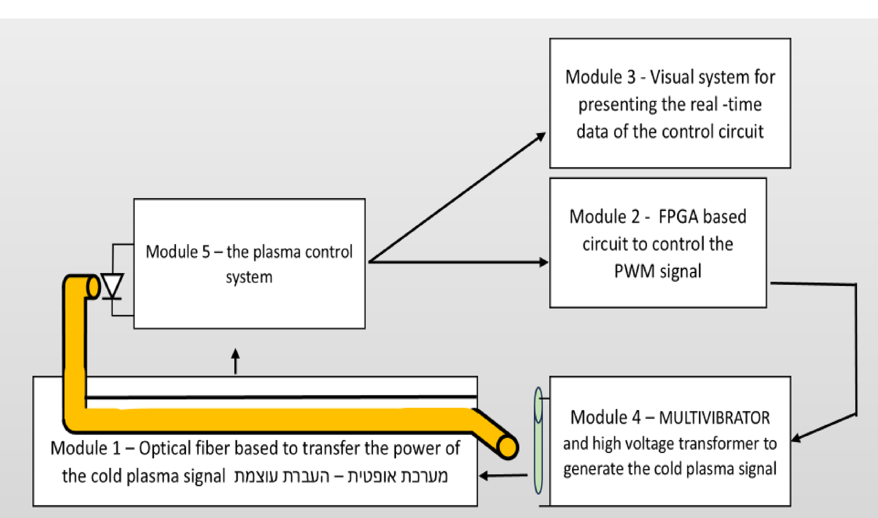

Figure 1 : Block diagram of the control system.

The optical fiber (module 1), shown below in figure 2, drives the emitted light of the plasma signal into a photodiode, while it is calibrated to an appropriate distance and normalized to determine the output plasma power. Module 2 is the FPGA (Field Programmable Gate Array-Artix7), it is employed to program the required PMW frequency of f=500[Hz] to maintain plasma power stability. Figure 3, shows an uno-Arduino micro controller (module 3), it is applied to collect the data from the control circuit and display it. It is also connected in cereal mode to a central computer for post treatment data analyses.

Last, but not least, figure 6 below shows a schematic of module 5 which connects the plasma signal generator to the plasma power sensing and calibration modules, in which all sub circuits of the system modules are included and connected together.

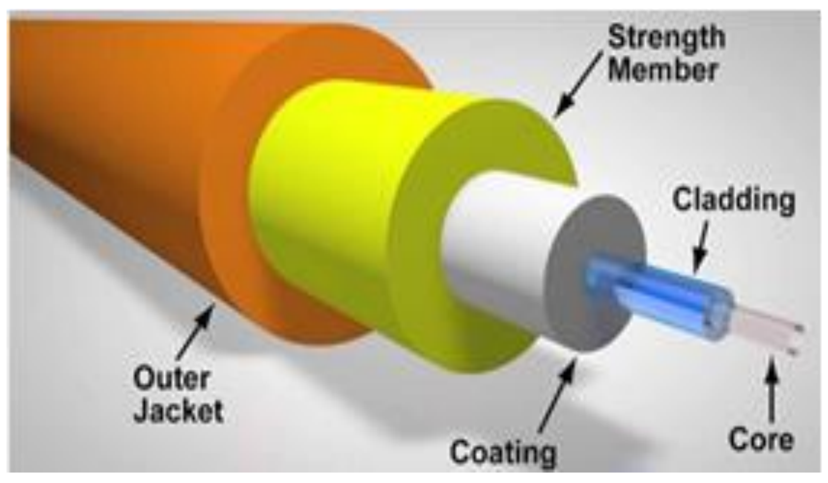

Figure 2 : schematic illustration of the optical fiber.

Next is a multivibrator (module 4), which is connected to a high voltage transformer and generates the plasma signal.

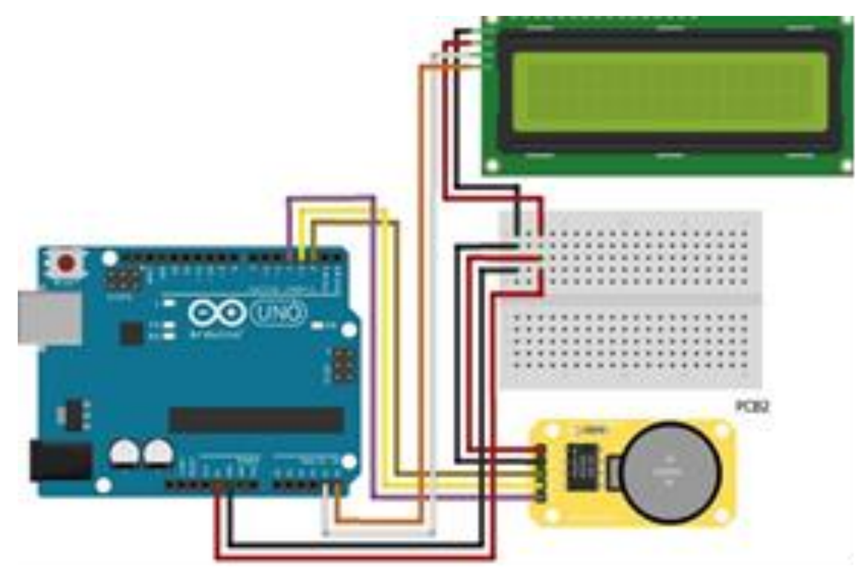

Figure 3 : Schematic of the Arduino circuit.

Its output is characterized by producing a square wave with an optimal frequency (to fit the impedance) during the positive part of the PMW signal. Any deviation of the impedance during the treatments will be sensed and regulated by the control circuit. Figure 4 illustrates the dedicated transformer and figure 5 shows the designed circuit.

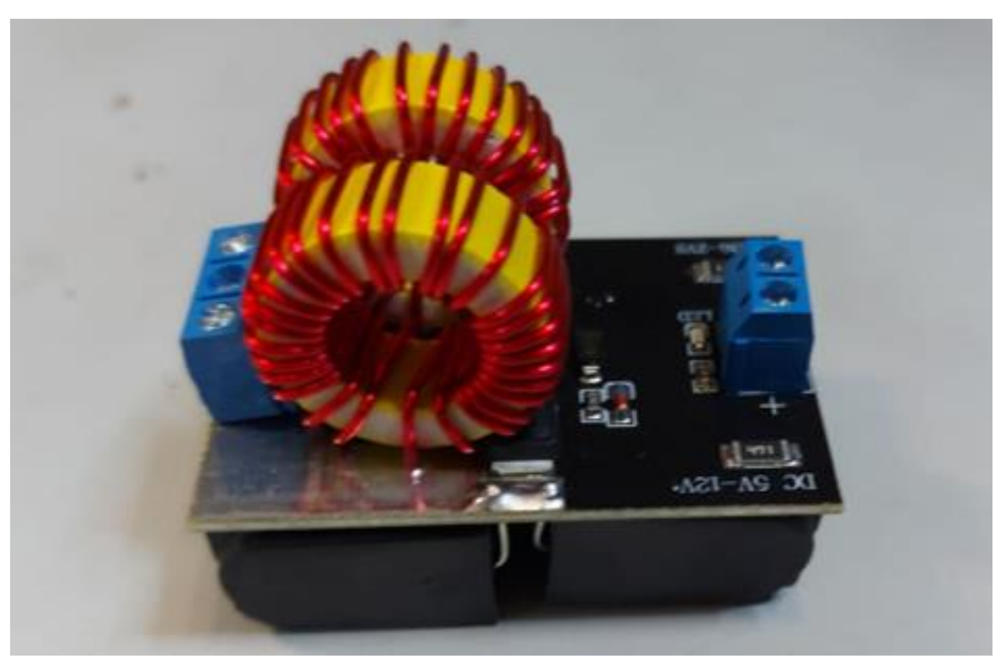

Figure 4 : Illustration of the dedicated transformer which is the main part of the multivibrator.

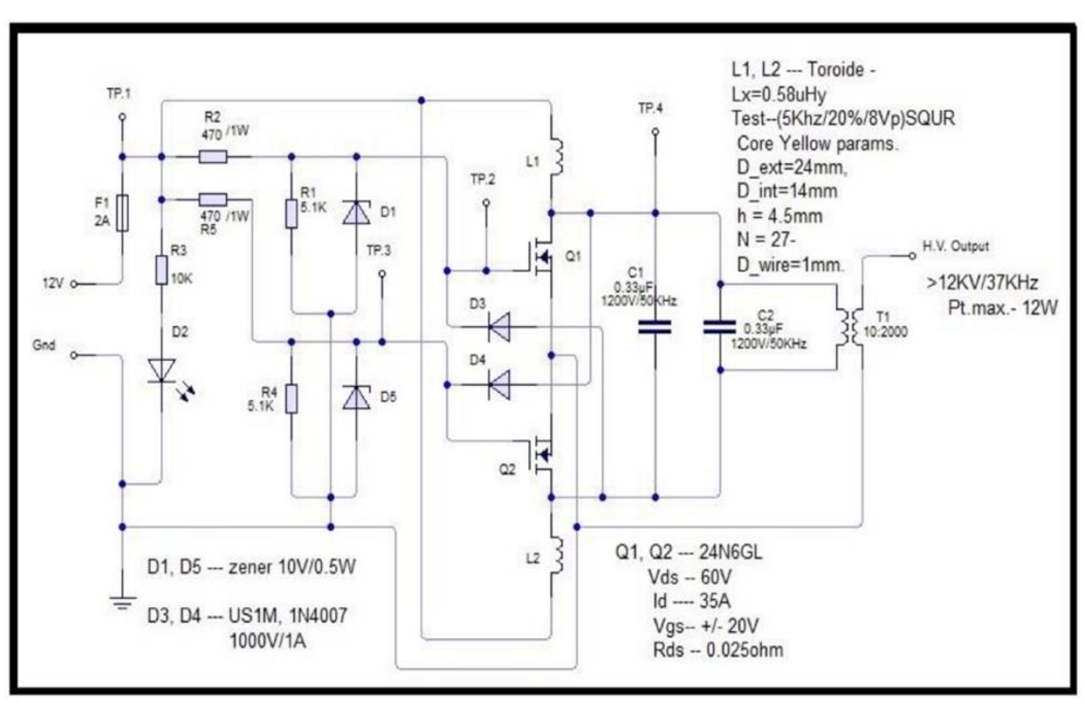

Figure 5 : Schematic of the multivibrator circuit.

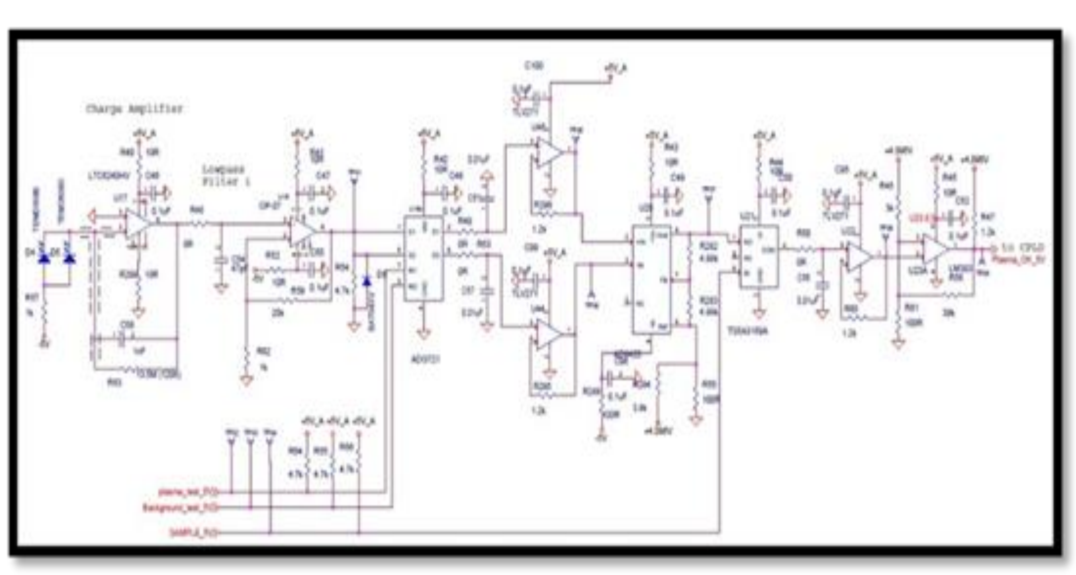

Figure 6 : Schematic of the integrated circuit.

Results

Figure 7 : A stable sinusoidal signal was monitored for a resonance frequency of 27.39 KHz

Figure 8 : Simulation data for PMW signal that was produced with 500 Hz and duty cycle of 50%.

It is seen above at figure 7 that a stable sinusoidal signal was monitored for a resonance frequency of 27.39 KHz. Following, we present the experimental data that was measured during the testing of various branches of the system. Figure 8 shows the simulated results of the PMW signal that was produced with 500 Hz for a duty cycle of 50% and the real-time signal of the PMW, recorded on the oscilloscope, directly from the FPGA, for frequency of 500 Hz and duty cycle of 80%.

Conclusions

The work presented here points out, for the first time, that the stability and control of ACP (atmospheric cold plasma) signal can be performed by sensing the optical emission of the generated plasma. It has been shown that the calibrated signal can fit particular parameters to a range of responses from any type of skin or treated lesion. Ongoing, we are implementing a prototype that will be suitable for clinical tests.

References

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