

Electromagnetic pulses bone healing booster

S R Sintea¹, V M Pomazan², D Bica³, D Grebenisan⁴ and N Bordea¹

¹Constanta Maritime University, Faculty of Naval Electro-Mechanics, 104 Mircea cel Batran Street, 900663, Constanta, Romania

²Ovidius University, Faculty of Mechanical Engineering, 124 Mamaia Blvd., 900527, Constanta, Romania

³C.M.I Daniela Bica, 10 Industrială, Constanta, Romania

⁴DG Engineering, Canada, 7 Headlands Crescent Witby, L1R1Z9, Ontario, Canada

E-mail: sinteasorin@hotmail.com

Abstract. Posttraumatic bone restoration triggered by the need to assist and stimulate compensatory bone growth in periodontal condition. Recent studies state that specific electromagnetic stimulation can boost the bone restoration, reaching up to 30% decrease in recovery time. Based on the existing data on the electromagnetic parameters, a digital electronic device is proposed for intra oral mounting and bone restoration stimulation in periodontal condition. The electrical signal is applied to an inductive mark that will create and impregnate magnetic field in diseased tissue. The device also monitors the status of the electromagnetic field. Controlled wave forms and pulse frequency signal at programmable intervals are obtained with optimized number of components and miniaturized using surface mounting devices (SMD) circuits and surface mounting technology (SMT), with enhanced protection against abnormal current growth, given the intra-oral environment. The system is powered by an autonomous power supply (battery), to limit the problems caused by powering medical equipment from the main power supply. Currently the device is used in clinical testing, in cycles of six up to twelve months.

Basic principles for the electrical scheme and algorithms for pulse generation, pulse control, electromagnetic field control and automation of current monitoring are presented, together with the friendly user interface, suitable for medical data and patient monitoring.

1. Introduction

In the latest years many people face with periodontal disease. Periodontal condition is favored when patients neglect early symptoms. This condition attacks the mandibular bone. After the bone is affected, the patient must start a very cost expensive treatment. Actually, for this disease the treatment is taking a long time and the used equipment is cost effective. The experimental methods used for healing periodontal disease are based on laser therapy method. Each physician recommends his own method and laser therapy scheme, depending on patient and the disease evolution. Up to know, the laser therapy has fair results in bone healing [1].

From 1996 year a new method for bone restoration process used in medical treatment cabinets replaces laser therapy. This method is based on impregnated oscillatory electromagnetic field in human body in area of affected tissue [2]. This method is also an experimental treatment for healing other human conditions, as it has an encouraging effect on various tissues.



The latest medical scientific research institutes have positive results in healing bone conditions by using impregnated oscillatory electromagnetic field [3]. The method is supposed to decrease the healing time of bones.

We use this method in dental domain for healing periodontal disease [4]. We propose an equipment that produces an impregnated oscillatory electromagnetic field, controlled by a microcontroller. This field will be applied in mandibular area of patient. The impregnated oscillatory electromagnetic field will determine a vibration in mandibular bone area that will boost bone healing [5].

2. Rationale

The system is developed based on microcontroller digital solution. The main task of the system is to generate oscillatory electromagnetic field. The field is created using electro-magnetic coil system. The coil is excited by a low voltage oscillatory power module controlled by microcontroller.

The source is powered by a power source module (figure 1). The power module is optimized to ensure optimal current to produce effective impregnated electromagnetic field in human tissue. Also the system monitors the impregnated current into the coil and verifies the coil circuit continuity.

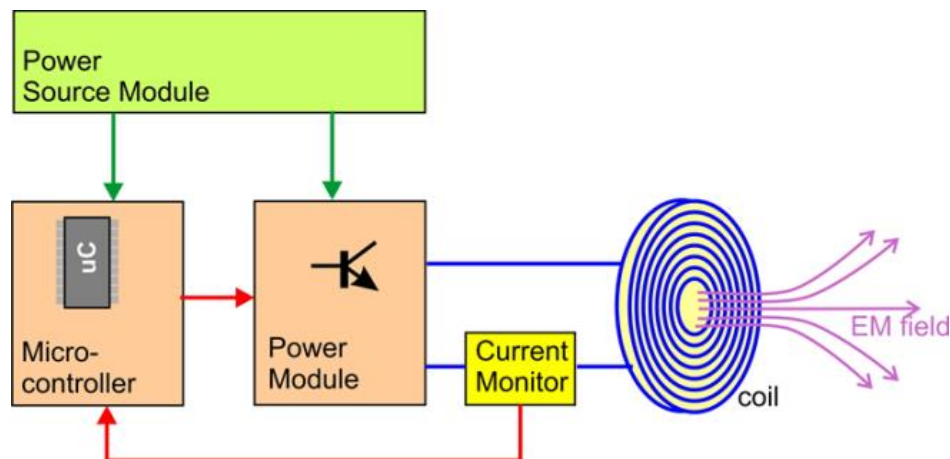


Figure 1. Power source module.

3. The Control

The system is controlled by a microcontroller. For this application we choose Atmel's ATtiny 24 microcontroller. The microcontroller is able to generate digital signals for controlling the power module. The system can generate sinusoidal form pulses simulated using a Pulse-width modulation PWM algorithm (figure 2) or fixed width pulses (figure 3).

Depending by the nature of disease and stage of the disease we can use sinusoidal pulses (figure 2) or train of pulses with different intensity (figure 3) corrected by the width of the pulse of impregnated electromagnetic field.

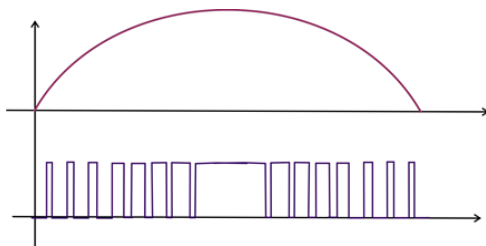


Figure 2. Sinusoidal form pulses.



Figure 3. Fixed width pulses.

4. Programming the Unit

4.1. Software Algorithm

The basic software for system control is running in microcontroller. The microcontroller generates the signals based of two algorithms. First one is a basic algorithm used for generating a pulse train with equal width pulses, for generating oscillatory magnetic field. This field is more power full and can be used in short train pulses sequences. Software algorithm is presented in function below, (named GENERATE_0, figure 4).

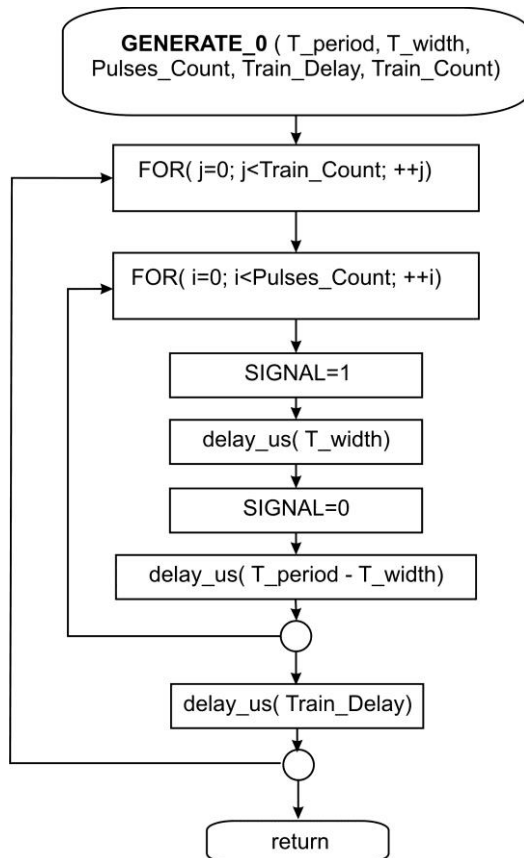


Figure 4. Basic pulse generating algorithm.

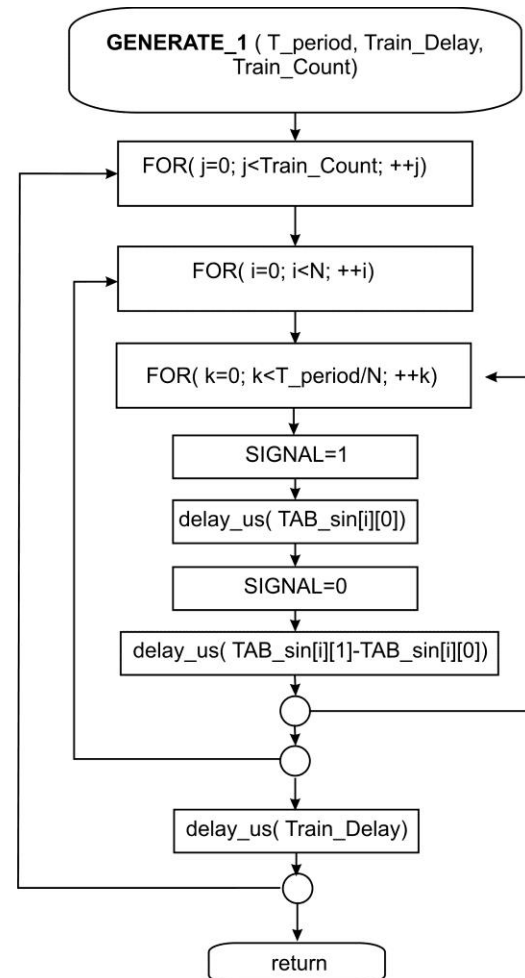


Figure 5. Half sinusoidal signal algorithm.

Parameters of this function are: T_{period} , represent time period of signal in microseconds, T_{width} is the time while the signal is active in microseconds, Pulses_Count represents the number of active pulses. This Pulses_Count creates a train of pulses. A sequence of more train of pulses counted by Train_Count is generated with Train_Delay milliseconds pause between them.

The other algorithm used for generating pulses creates an half of sinusoidal signal form based o PWM signal. This generated field is softer and can be used in any application of treatment. Software algorithm is presented in function below in function named GENERATE_1 (figure 5).

The central element of algorithm is table TAB_sin , table which includes integer values for PWM active time of the signal and the period of the PWM signal. These values are calculated so that the output signals to simulate a half of sinusoidal value. Parameters of this function are: T_{period} , represent time period of signal in miliesconds of half of sinusoidal signal, Pulses_Count represents

the number of active pulses. This Pulses_Count creates a train of pulses. A sequence of more train of pulses counted by Train_Count is generated with Train_Delay milliseconds pause between them.

To protect the system by any faults we have a procedure that can be called before applying any signal. This procedure generates a pulse of current through the coil and measure that current. If the current is zero the system is stopped automatically because the coil circuit is interrupted. If the current in coil circuit is greater than a preset value, then the system will be stopped because we have a short circuit.

4.2. The power source check

The microcontroller's software is responsible to check periodically the status of power supply. If power supply generated current is lower than a preset value the magnetic field will be too weak to achieve optimum results. To be able to access the value of power capacity the power line is connected to the microcontroller analog input (figure 6).

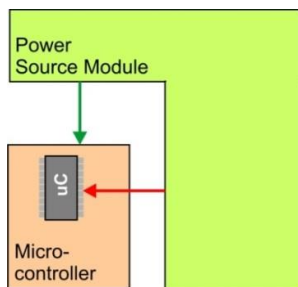


Figure 6. Power check connection.

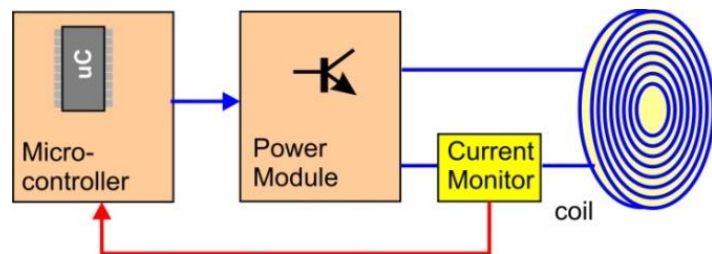


Figure 7. Coil current monitoring.

While generating the electromagnetic pulse, the microcontroller software will check the voltage of power supply. If measured value of power supply voltage will be lower than a preset value, then the controller will stop to activity and will signal error. The software module will return an error message if the value of power supply is lower than a preset value. And also, the function will return a success message if power supply voltage is over preset value. In this case the power supply is able to ensure the coil with enough energy to activate an optimal electromagnetic field.

4.3. The coil current control

The microcontroller's software is also checking the current in the coil.

To be able to measure the current through the coil, the microcontroller will read the current value through the coil (figure 7).

In the first step, before generating any pulse, the software algorithm (figure 8) will send a current pulse through the coil and measure its current value. If the measured value is greater than a preset nominal value, then we have a short circuit in coil electrical circuit. If measured value is lower than a preset as zero value, the coil will be considered as disconnected. In both cases the pulses through the coil will be disabled.

4.4. Main program

All modules are integrated into one software program, named main_program. This program controls modules activation and system checking. In according with external configuration switch (figure 9), the software will select one of the following signal generation forms: smooth algorithm or aggressive algorithm.

The main_program is started when microcontroller starts. First function is executed by the main_program program and configures the microcontroller's internal devices and resets the outputs of microcontroller.

The microcontroller's timer interrupts must be tackled in the programm. The software will attach two system events with internal hardware timer:

- at every one minutes the timer will generate *evPOWER_EVENT* and
- at every 15 seconds the timer will generate *evPULSE_EVENT*.

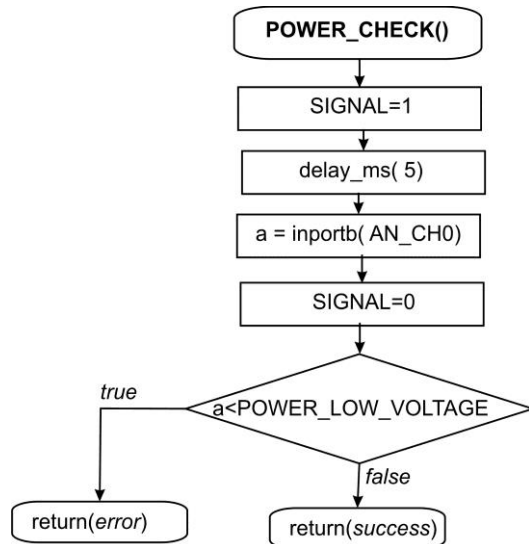


Figure 8a. Power Check Algorithm.

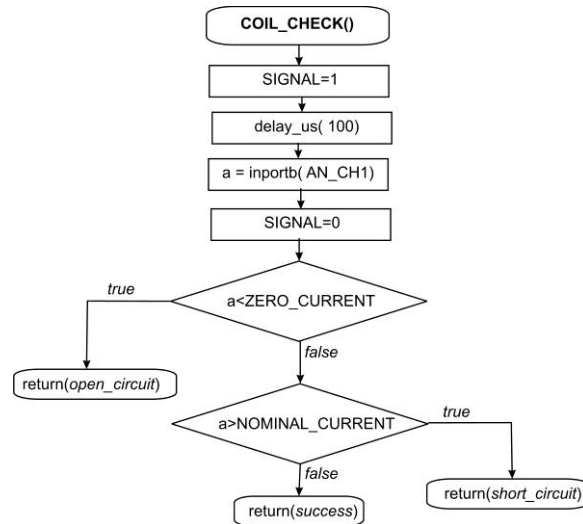


Figure 8b. Coil Check Algorithm.

After programming, the main_programm will opens an infinite loop to check the two timing events. When *evPOWER_EVENT* event appears the software will check the status of power supply using the *POWER_CHECK* function. If function returns error, then the main loop will be broken and the microcontroller stops until the power battery will be replaced. After *evPOWER_EVENT* event is processed the software will rearm the timer event.

When *evPULSE_EVENT* event appears, the software will re-arm the timer pulse event (*evPULSE_EVENT* event) and test the status of circuit with coil. If we obtain a negative response for the coil circuit test the algorithm will break the loop and the program will be stopped. If coil circuit test algorithm ended successfully, then the status of configuration switch will be checked. If switch is closed the system will generate a train of pulses, using function *GENERATE_0*. In this case the controller will generate an aggressive electromagnetic field through the coil. If switch is opened the system will generate a train of pulses that simulates a sinusoidal signal, using function *GENERATE_1*. In this case we obtain a smooth signal.

The controller's switch will select between two output types of signals. One type of generated signal is aggressive signal which conduct to aggressive treatment of disease and the other one type of generated signal is a smooth signal which can be used in therapeutic treatment of periodontal disease. All software modules are programmed into microcontroller Atmel's A.Tiny 24 [6]. This microcontroller is part of controller board, which is connected with the coil [7].

5. Conclusions

A pulsed electromagnetic field bone growth stimulator is presented, to offer a dynamic tool to fight with periodontal disease. The controlled wave forms and pulse frequency signal at programmable intervals are easy to be integrated in a light, portable device, easy to be endowed in dental cabinets and easy to manipulate and maintain, safe to be used.

This patient monitoring system enhances the doctor's ability to control the periodontal condition evolution, with strict treatment formulas, visual monitoring and patient history comparison, along with medical parameters monitoring. The research is open for further investigation related with the fine tuning of the magnetic parameters [7] and integration with larger monitoring systems. The algorithm below (figure 9) presents the main_program structure.

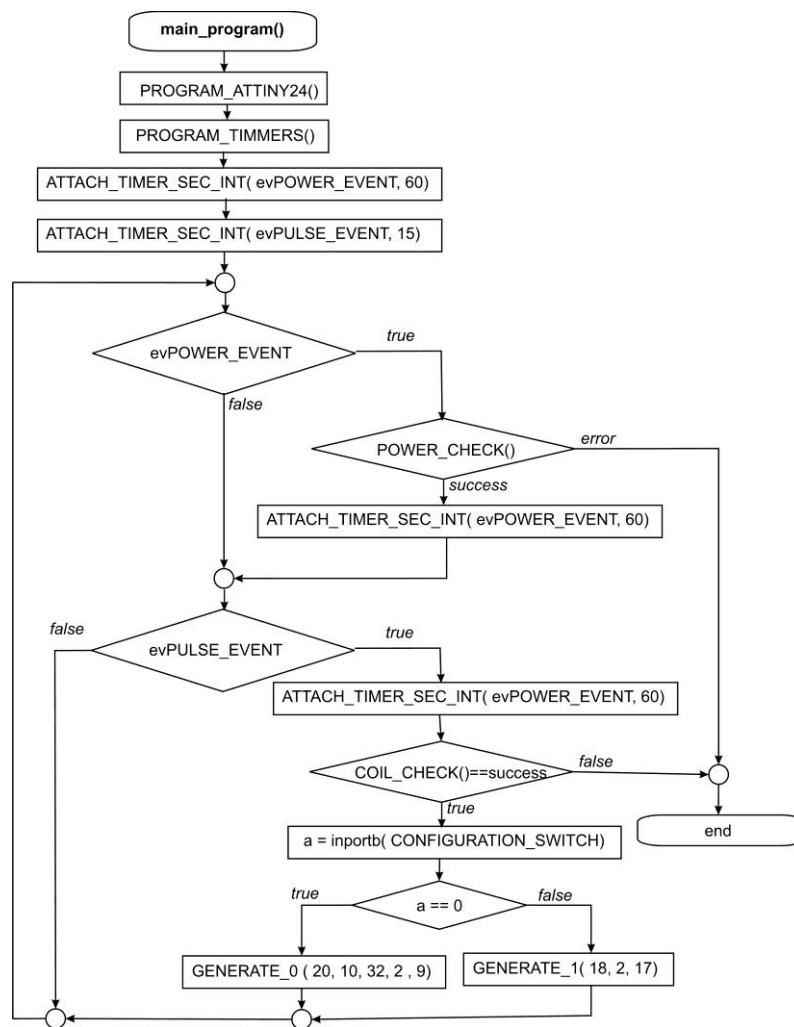


Figure 9. The main algorithm.

References

- [1] <http://drpawluk.com/updates/magnetics-for-dental-applications/>, accessed Feb 27, 2015
- [2] Aaron R K, Boyan B D, Ciombor D McK; Schwartz Z, Simon B J 2004 Stimulation of Growth Factor Synthesis by Electric and Electromagnetic Fields *Clinical Orthopaedics & Related Research* **419** pp 30-37
- [3] Behrens S B, Deren M E and Monchik K O 2013 A Review of Bone Growth Stimulation for Fracture Treatment *Curr Orthop Pract.* **24(1)** pp 84-91
- [4] <http://periodontitis-treatment.com/>, accessed 27 February 2015
- [5] <http://www.term.or.kr/journal/view.php?number=484>, accessed 27 Feb. 2015
- [6] Documentation: Atmel 8 bit AVR Microcontroller with 2k/4kBytes In-System Programmable Flash, ATtiny 24, Atmel, 2010
- [7] PEMF Stimulation Therapy Method and System, US Patent 5,743,844, Apr 28, 1998