IMPLEMENTATION OF CLASS-D AMPLIFIER IN HIGH PERFORMANCE SYSTEM FOR ELECTRO STIMULATION

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Normally innervated muscles are stimulated to contraction through peripheral motor nerves and especially the intra-muscular innervating nerve fibbers. Various stimuli parameters can be used for non-denervated muscle stimulation, depending on the specific treatment. In difference with well-known applications used low frequency currents in the range 10-100Hz, the new devices for electrical stimulation are base on middle frequency range 2000-8000Hz modulated by low frequency. The middle frequency allows overcome the patient resistance and therapeutic treatment in depth. Taking into account the advantages of Class-D amplifiers we suggest new solution based on the specialized circuit ZXCD1000 by ZETEX. This solution considerably facilitates the development process. One circuit is used to realize two independent channels. The therapeutic energy transfers to the patient via high-frequency transformers with small sizes. In addition the selected circuit guarantees convenience and flexibility in development of the driving part.

Keywords: Electro physiotherapy, Electro stimulation devices

INTRODUCTION

The combination of the latest achievements in electronics with the relatively safe use makes electrical stimulation a preferred approach in many applications. Normally innervated muscles are stimulated to contraction through peripheral motor nerves and especially the intra-muscular innervating nerve fibbers. Various stimuli parameters can be used for non-denervated muscle stimulation, depending on the specific application. The specific goal of this type of stimulation is to obtain tethanic contraction of duration of several (about 3 to 5 or sometimes up to 10) seconds. Many stimulating current waveforms are used, but often the problems of stimulation efficiency versus injected current intensity and patient tolerance are ignored or neglected [1,2].

One new approach in development of devices for electrotherapy is directed to enlargement of the clinical applications by using of different current forms with dynamically changing parameters during the procedure [3, 4]. In difference with well-known applications used low frequency currents in the range 10 – 100Hz, the new devices are based on middle frequency range 2000 – 8000Hz, modulated with low frequency. The middle frequency allows overcome the patient resistance and therapeutic treatment in depth realizes by low frequency.

The subject of this paper is the application of specific hardware solution in new system for electrical stimulation.

HARDWARE SOLUTIONS

The tendency in development of the systems for electrical stimulation is connected with the possibilities for maximal therapeutic efficiency and minimal patient discomfort. All types of low frequency and middle frequency waveforms can produce contractions of desired strength with the application of sufficient intensity. The problem is that considerable or even intolerable discomfort can arise, especially when a maximum motor response is to be obtained. This was the reason for the investigation and application of new current forms and therapeutic devices. We suggest one new solution of electrostimulator obtaining next features:

- Adjustable carrying frequency in the range 2000-8000Hz
- Adjustable sweep in different time intervals of the low (modulating) frequency in the range 10-100Hz
- Dynamically changed amplitude during the procedure
- 8 independent channels.

These parameters allow the doctor to realize so called therapeutic complex presented in fig. 1. As can be seen the energy transferred to the patient (lightly increases and decreases), provokes movements like the normal muscle contractions.

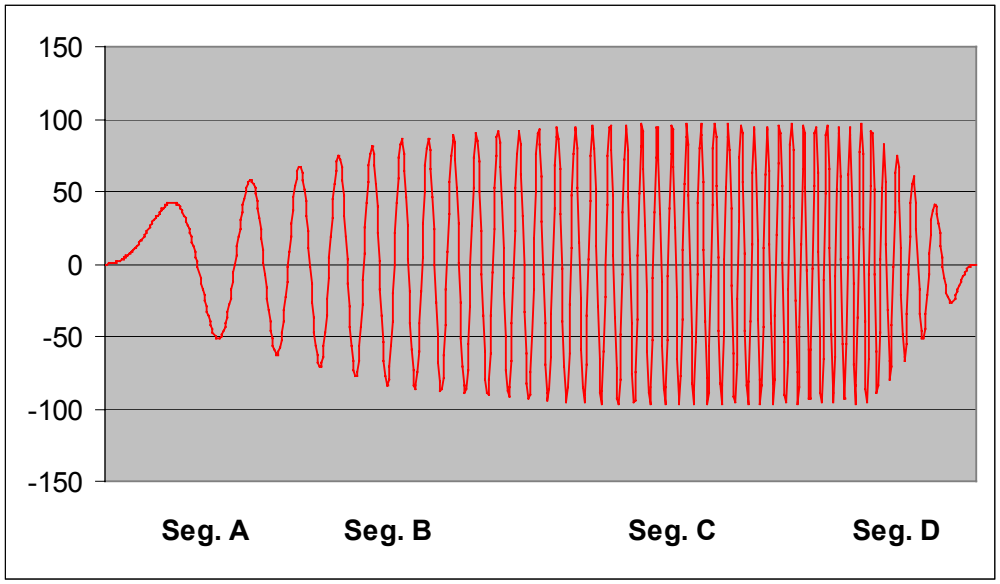

Fig. 1. Pulse waveform – therapeutic complex

The therapeutic complex consists of four segments: Seg. A sweep frequency 10Hz-30Hz, amplitude 35%-50% of fixed value; Seg. B – 30Hz-100Hz, 50%-100%; Seg. C – 100Hz-120Hz, 100%; Seg. D – 120Hz-10Hz, 100%-35%.

The block diagram of the developed system for electrical stimulation is shown in fig. 2. The micro controller PIC18F458 is a key element in circuit. It realizes user interface using keyboard (KBD), display (LCD) and valkoder. This configuration allows the initial set of the parameters realizes in short time. These parameters are:

caring frequency;
time duration of the segments a, b, c, d (fig. 1);
time duration of the procedure;

current in each channel;
active channel.

The caring frequency generator is realized by ICL8038 (Precision Waveform Generator/Voltage Controlled Oscillator). The ICL8038 waveform generator is a monolithic integrated circuit capable of producing high accuracy sine, square, triangular and pulse waveforms with minimum external components.

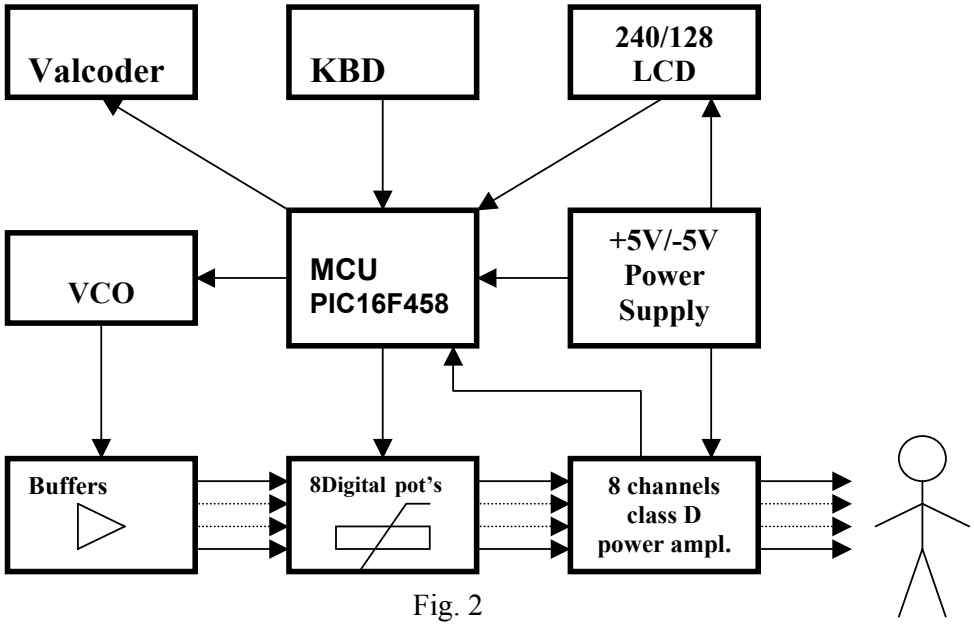

Fig. 2

The selected caring frequency sets by digital potentiometer (MCP42010). The same type of potentiometers is used to adjust the current in each channel. The new approach that we suggest is in the analogue part, especially in the "device-patient" connection. To be able to obtain 8 independent, galvanic insulated channels we choused transformer connection. Taking into account the advantages of Class-D amplifier we suggest a solution based on the specialized circuit ZXCD1000 (Class-D 25W Mono Open Loop) by ZETEX. The ZXCD1000 provides complete control and modulation functions at the heart of a high efficiency, high performance Class-D switching amplifier solutions. The main features it obtains are:

- >90% efficiency
- 4/8 Ω drive capability
- Noise Floor –115dB for solution
- Complete absence of crossover artifacts
- OSC output available for sync in multi-channel applications
- Available in a 16 pin exposed pad OSOP package.

The ZXCD1000 reference designs give output powers up to 100W rms with typical open loop (no feedback) distortion of less than 0.2%. This power and output characteristics are quite enough to cover requirements to therapeutic device.

The schematic of the analogue part is shown in fig. 3. In the second part of the transformer (patient part) is connected sample circuits realized by bridge rectifier, capacitor and optocoupler. The role of this feedback is the safety guarantees by

comparing the preset parameters with the parameters of patient's influence. In the case of unconformity the procedure stops.

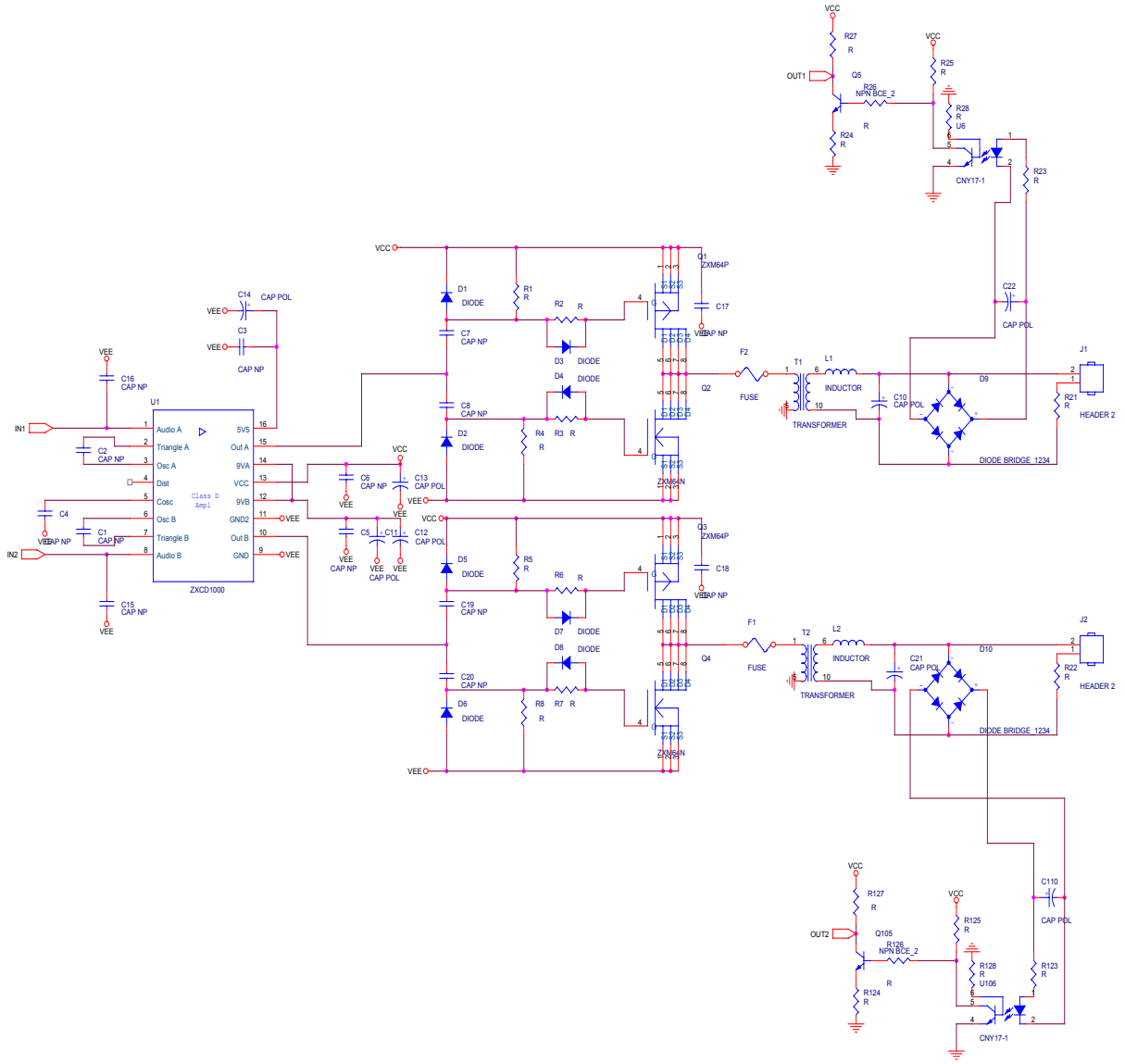

Fig. 3. Schematic diagram of the analogue part

The presented hardware solution allows realize two independent channels by one driving circuit. The therapeutic energy transfers to the patient via small sizes high-frequency transformers.

CONCLUSION

The applicability of new therapeutic procedures, new current forms and in result the enhancement of the physiotherapy efficiency are in dependence of the development of new circuit solutions and implementation of the latest achievements in electronics. The proposed solution gives flexibility and convenience in current form synthesis. As can be seen this process is completely realized by digital circuits or digital driving circuits (micro controller, digital potentiometers, functional

generator). The application of Class-D audio amplifier combines the advantages of these type amplifiers with the special features of physiotherapeutic procedures.

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