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Automatic External Defibrillator with Defibrillation Pulse-Shaping Unit by Digital Signal Processor

Introduction

The efficacy of electrical defibrillation therapy at terminating ventricular fibrillation is highly dependent on the waveform used, waveform parameters, waveform impedance-compensation schemes, and relative shock magnitudes [1-3].

At low-impedance, all biphasic shocks achieved near-perfect success, while efficacy was significantly lower for high-impedance shocks [3]. Despite impedance-compensation schemes in biphasic defibrillators, impedance has an impact on their efficacy. At high-impedance, modest efficacy differences exist among clinically available biphasic defibrillators, reflecting differences in both waveforms and manufacturer-provided doses.

Digital signal processor is very convenient for defibrillation pulse-shaping based on feedback loop with load impedance. Results of mathematical modeling have confirmed it [1].

This paper presents the result of verification such method.

Material and Methods

Bloc-diagram of defibrillation pulse-shaping unit by digital signal processor is presented on Fig.1.

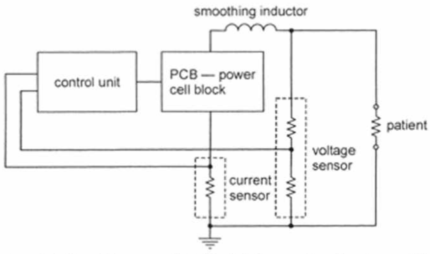

Fig. 1: Bloc-diagram of defibrillation pulse-shaping unit by digital signal processor

The unit contains several independently controlled power cells with reversible polarity, stacked in series to provide maximum voltage on the output up to 3600 V, voltage and current sensors to measure patient voltage and current, smoothing inductor to prevent rapid current changes during regulations and digital signal processor (DSP) based control unit to control the power cells. Unlike the preceding technology, all feedback control actions can be calculated in digital domain.

During the delivery of pulse the control unit continuously samples the signals from current and voltage sensors and makes analog-to-digital conversion/ Based on sampled values DSP calculates difference between the actual and reference waveforms and takes required control action to the power cells, by switching power cells on and off. Several control strategies can be implemented, including delivery of fixed energy and fixed current pulses. Shape of the waveform can be made insensitive to impedance changes during delivery of the pulse/ Implementation of the control loop with DSP provides the increased noise immunity and decreased quantity of analog components.

Results

Algorithms of defibrillation pulse-shaping control by means of DSP have been simulated on P-Spice-model. The sampling period of analog signals has been chosen equal 5 μs, and time for analog signal conversion and data processing is set equal 2 μs.

Results of simulation are shown on Fig.2 for Gurvich-Venin defibrillation pulse.

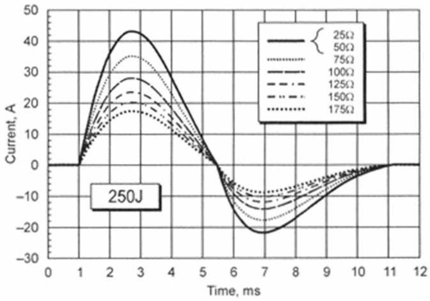

Fig. 2: Results of simulation for Gurvich-Venin defibrillation pulse.

Results of experimental verification are shown on Fig.3 and Fig.4.

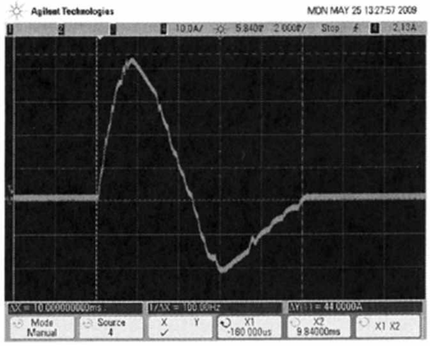

Fig. 3: Result of experimental verification (250 J, 50Ω load)

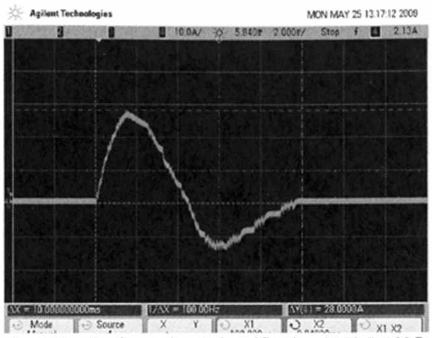

Fig. 4: Result of experimental verification (250 J, 100Ω load)

Discussion

Digital signal processor is very convenient for defibrillation pulse-shaping based on feedback loop with load impedance. Experimental verification of this method has demonstrated good results.

Literature

[1] Antropov A., et al.: Real-time control of the defibrillation waveform with digital signal processor. Proceedings of the 4th Russian-Bavarian conference on Biomedical Engineering, Zelenograd, Russia: 241-245, 2008.

[2] Hatib F., et al.: Transthoraric electrical impedance during external defibrillation: comparison of measured and modeled waveforms. Physiol. Meas., vol. 21, no.1: 145-153, 2000.

[3] Walker R., et al.: Comparison of six clinically used external defibrillators in swine. Resuscitation, vol.57, no.1: 73-83, 2003.

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