Study on the Switching Time-Variation of Simultaneously Controlled IGBT: Case of Defibrillators Design

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Summary: Samples of integrated gain bipolar transistors (IGBT) of the same type but produced under different technologies were tested about the switching time-variation. This is of high importance when several IGBT are connected in series to commutate high voltage defibrillation shocks. Very often, a short voltage overload of one of the IGBT in group leads to electrical breakdown of all transistors, due to non-synchronised driving of the gate-emitter circuits. The goal of the study was to check whether compensation of the delays introduced throughout the IGBT control circuits might be efficient despite the own dispersion of the transistor parameters.

Keywords: Defibrillation shocks, High voltage generator, Synchronised control of serial connected IGBT.

1. INTRODUCTION

Most of the sudden cardiac arrests begin with ventricular fibrillation [6, 8]. In such cases an immediate defibrillation (DF) is recommended since each delay reduces the probability of patient survival [4].

The so called public access defibrillators (PAD) are introduced on the market for more efficient treatment of out-of-hospital sudden cardiac death [1, 2]. They are strongly recommended by ILCOR Guidelines [7]. PADs are used normally by untrained people at streets, sports centers, airports, and other public areas. Therefore, the devices have to be portable, with reduced dimensions and weight.

The main module of any kind of defibrillators is the high voltage generator (HVG), which delivers a specific defibrillation shock (high voltage pulse) to the patient, using a preliminary charged capacitor. There are many different shapes of the DF pulse: monophasic dampened sinusoid, monophasic, biphasic and triphasic truncated

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exponents, chopped biphasic waveforms. An improved control of the HVG allowed dynamic pulse duration adjustment for energy delivering independently of the patient's transthoracic impedance [3].

Complex biphasic pulse waveforms are suitable to be generated by a bridge structure, which provides advantages in the alternative switching of both polarities. Usually, integrated gain bipolar transistors (IGBT) are used for commutation. Very often several IGBT are cascaded in serial since the DF voltage may reach up to 5 kV. In such cases, the simultaneous control of the transistor group becomes extremely crucial. Relatively small time-variation during the switching-on phase may inadmissibly overload the belayed transistor, while the same during the switching-off phase is true for the faster one. Most of such commutations end with electrical breakdown of all transistors in the group.

The solution of the problem can be found in such sophisticated control of the gate-emitter (G-E) input that provide equal in amplitude and precisely synchronized voltage pulses throughout the entire additionally insulated circuit for IGBT on/off switching [5]. However, this approach will be efficient only if the individual transistor parameters of the production series have limited dispersion. Otherwise, every control circuit has to be matched to the corresponding IGBT that is intolerable both in production and maintenance phases.

The aim of this study was to assess the switching time-variation of IGBT that were used for development of the public access defibrillator FRED, and later for manufacturing it by Schiller AD as a result of a scientific collaboration with the Centre of Biomedical Engineering of the Bulgarian Academy of Sciences.

2. MATERIALS AND METHODS

A relatively small sample of IGBT type IXBH16N170 (TP0143 TF964 Philippines) was subjected to multiple testing.

Test panel

The experimentation stand is shown in Fig. 1. It allows the parallel study of two IGBT. The topology is conformable to the measured times in the nanosecond range and provides total identity of the load circuits for the two compared transistors. Otherwise, even a small displacement of the load contact points leads to visible edge shifting of the output pulses. The tests were carried out with reduced voltage in order to connect the oscilloscope probe directly to the IGBT collectors. Thereby, the obtained high quality recordings were not achievable with the rated voltage. The time-variations were assessed assuming that the switching points are located in the middle of the interval from zero through the supply voltage.

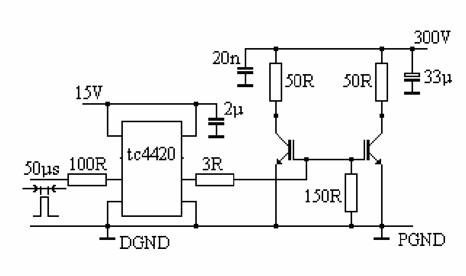


Fig. 1 Measuring circuit

3. RESULTS AND DISCUSSION

Fig. 2 presents the oscillograms of the turning on and off obtained by one transistor of the tested series. The first channel (Ch1) tracks the control gate voltage (yellow traces). The output voltage (green traces - going down in the left diagram and up in the right diagram) is shown in a 50 V zoomed scale of the second channel (Ch2). As it can be seen, the gate voltage, even though supplied by a powerful driver, is influenced by the parameters of the two-terminal G-E network, as well as by the internal back-feed of the transistor. Still, the corresponding edges can be well discriminated.

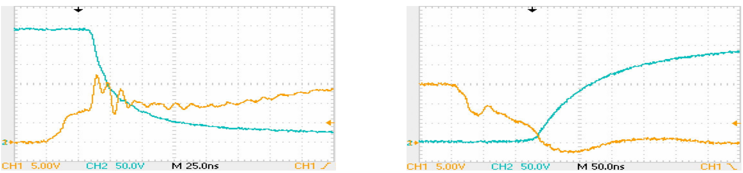
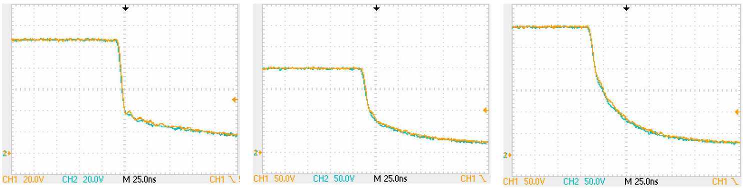


Fig. 2 Control (Ch1) and commutation (Ch2) of one transistor of the tested series. The delay of turning on is about 10 ns, the same delay of turning off is 130 ns.

Turning on

According to the layout of the semiconductor components, the process of turning the IGBT on, most specifically their own delay and steepness, depend on the current through the load. This is the reason why changes of the supply voltage influence the parameters turning on, even with constant load. However, the transistors of one technological series switched practically simultaneously (Fig. 3), which was an important result of the study.

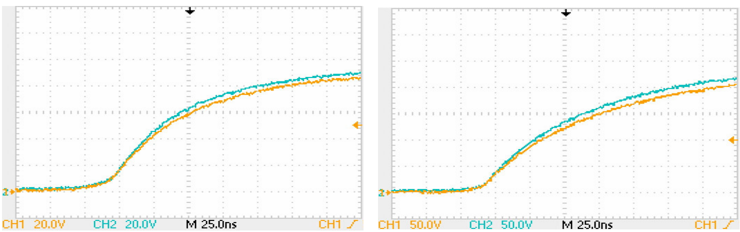


a) b) c)

Fig. 3 Turning on of two transistors taken from a series at: a) 100 V, b) 200 V and c) 300 V supply voltage. The time shifting of the edges is indefinably low within the test conditions.

Turning off

The turning off is slightly influenced by the supply voltage (100 V in Fig. 4a and 300 V in Fig. 4b). This phenomenon enabled the use of data obtained with one voltage for predicting the results carried with another supply voltage, which might extremely impede the experiment.



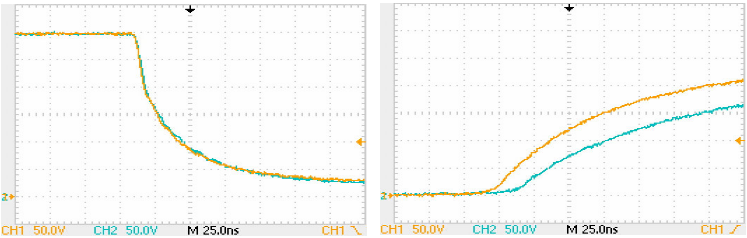
a) *b)*

Fig. 4 Switching-off recorded with two IGBT from one series at 100 V and 300 V supply voltage (left and right diagrams, respectively). The lower yellow trace (Ch1) points out the slowest transistor, the upper green trace (Ch2) is for the fastest one. The edge time-variation measured at the half of the final voltage is lower than 8 ns.

The most important result of the test was that the recorded edges time-variations were small, in the range of 8 ns. The examples shown in Fig. 4 are selected as border cases.

The impact of the technology

Despite the insufficient diversity of the tested IGBT series, the results obtained non-ambiguously led to the conclusion that even transistors of one and the same type demonstrate perceptible time-variations, if produced under different technology. One experiment with IXBH16N170 manufactured in Philippines (TP0143 TF964) and Korea (SK0229 K0227) is illustrated in Fig. 5.



a) b)

Fig. 5 Switching on and off with two identical type IGBT, produced in the Philippines (TP0143 TF964) and South Korea (SK0229 K0227) shown in Ch1 (yellow trace, the upper in subplot b) and Ch2 (green trace, the lower in subplot b), respectively. The observed switching time-variation is substantial.

4. CONCLUSIONS

The sample of IGBT subjected to the study was limited down to 12 transistors. However, the results were quite informative. Transistors of one technological series commutated practically simultaneously, therefore the efforts for generating identical control signals to the input of each of the IGBT in series is productive. The individual small shifts of the edges may be smoothed by some of the known approaches, e.g. by adding a small capacitor in parallel to the emitter-collector circuits. Thus, a compromise is obtained between the transient increase of the peak-current during the switching-on phase and the equalised voltage distribution due to the slightly prolonged active state.

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