Special High Voltage Function Generator

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Abstract— Goal of this project was to design, realize and test a special high voltage function generator. This generator was designed for special testing of soft tissues. The aim of this project was to generate electric field of defined shape. In course of design of the generator the properties of the output electrode voltage was the key element. In this article the construction and parameters measuring of the high voltage function generator is discussed.

1. INTRODUCTION

The generator was designed for special tests of soft tissues. Possibilities of the soft issue testing are described in literature (1). In this work the aim is to test the soft tissues in high voltage electric field. Tissues are exposed to defined shape electric field up to 20 kV. Voltage of the output electrode of the realized generator is possible to regulate in range 0 kV to 20 kV. Shape of the output voltage is possible to choose as sine, square or ramp. Frequency capabilities of this voltage source start on 0 Hz and reach 300 Hz.

2. HV GENERATOR FUNCTION SCHEME

The high voltage generator has two basic parts: a low voltage and a high voltage part. The low voltage part include a power source, isolation transformer, control module, optical isolation and function generator. Second part is the HV module. In the HV module a HV transformer as a border between low and high voltage part is the main part. The HV voltage transformer is designed as a flyback. Block diagram of the HV generator you can see in Fig. 1. Output voltage 20 kV is stabilized by the feedback signal FB — the voltage from HV output is connected throw the high voltage divider and optocoupler to the control module. According to the feedback signal the control module use a PWM signal for transistor and primary coil of the HV transformer switching.

Frequency and shape of the HV output signal is possible to change by the low voltage output signal of the function generator. Function generator signal is connected to the control module where will be actively integrated and throw the optical isolation connected to the PWM controller.

3. LOW VOLTAGE PART

Basic part of the low level part is the control module. Line voltage pass throw the separating transformer 230 V/230 V and consequently is in switching power supply regulate to 24 V. The switching power supply need to be design according to maximal output current for primary coil excitation. Primary coil voltage is switched by the PWM controlled MOSFET transistor. Used PWM controller precisely control output voltage according to the signal on this circuit comparator. Due to this design, the circuit is quickly react to the output current changes and is able to decrease

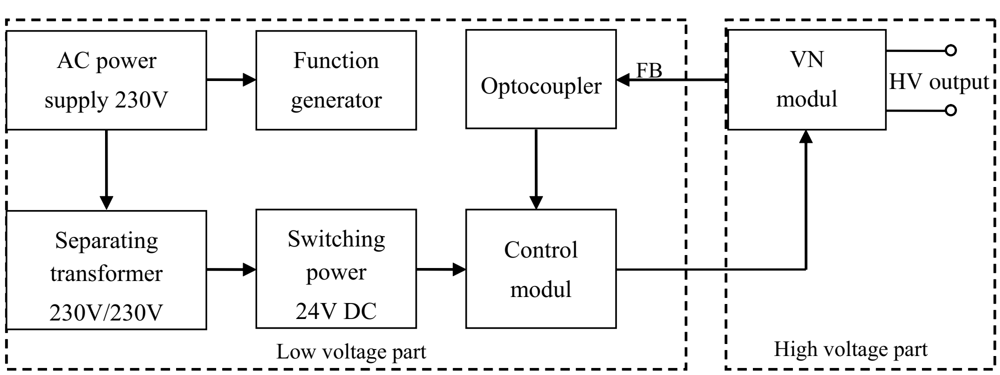


Figure 1: Block diagram of the high voltage generator.

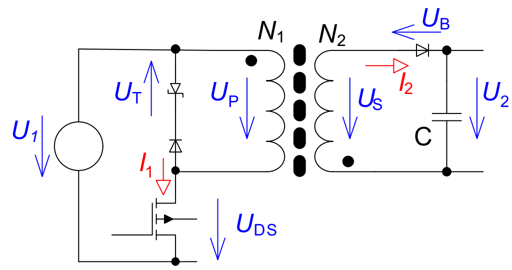


Figure 2: Scheme of the flyback convertor : U_1 — Source voltage, U_2 — Output voltage, U_p — primary voltage, U_s — secondary voltage, U_T — transil reverse voltage, U_{DS} — collector voltage of the transistor, U_B — diode reverse voltage, I_1 — primary current, I_2 — secondary current.

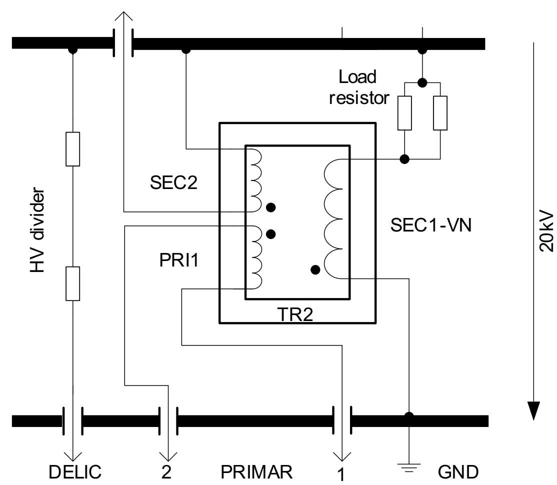


Figure 3: Block diagram of the high voltage part.

output current and voltage. This is very important for life protection in case of accidental touch. Setting of the output frequency is done by resistor and capacitor on the resonant frequency of the transformer. Comparator inside the PWM controller is comparing the current voltage with value of the requested voltage on the output electrode. High voltage is by HV divider decreased from 20 kV to 1 V on the input control unit. Comparison of the regulation and the output voltage is provided by an operation amplifier (OA). The operation amplifier work as a differential amplifier of the regulation deviation. OA is also compensating a voltage spikes from the HV divider. The voltage spikes could have influence on the device function and cause distortion of the output voltage.

The border between low and high voltage part is the HV transformer connected as a flyback convertor. Scheme of the flyback converter is shown in Fig. 2. Using of this schematic circuit is possible to calculate number of loops of the primary and secondary coil. Calculations are published in [6, 9, 11].

4. HIGH VOLTAGE PART

Block diagram of the high voltage part is in Fig. 3. The main part of the HV block is HV transformer TR2 working as a flyback converter. Inside the transformer a rectifier diode is connected. Secondary winding SEC2 is possible to link to next module for multiplying of the output voltage. Resistor 1 GΩ and the power resistor are as the HV divider connected between the output electrodes. Exceeding of the 20 kV output voltage value cause on the 1 GΩ resistor voltage drop higher then 1 V and consequently a change of pulse ratio of the PWM signal.

Limitation of the output current in case of direct contact is realized by pair of the 10 MΩ load resistors, Fig. 4. Maximal voltage rating of these resistors is 20 kV. Output current is limited to 4 mA.

Frame of the electrode is made from polystyrene ring. Design of the ring you can see in on the left Fig. 5. Homogenizer of the electromagnetic field is made by covering the ring by the aluminum foil.

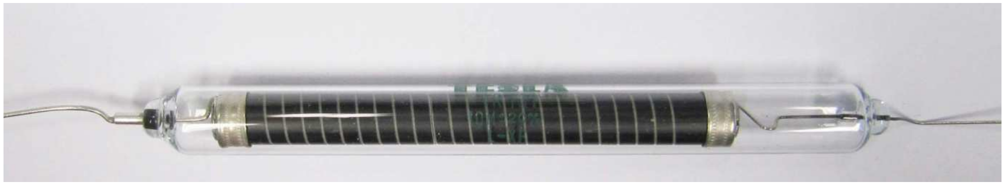
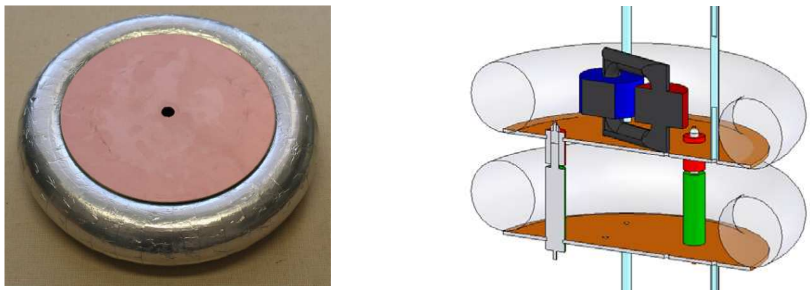
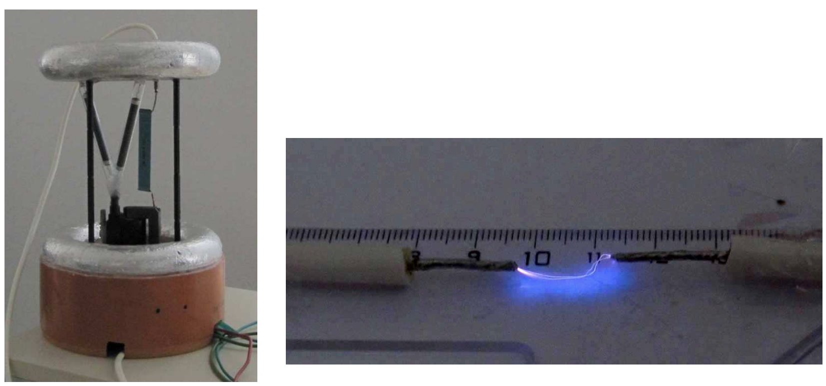


Figure 4: High voltage load resistor $-10\,\mathrm{M\Omega}$.



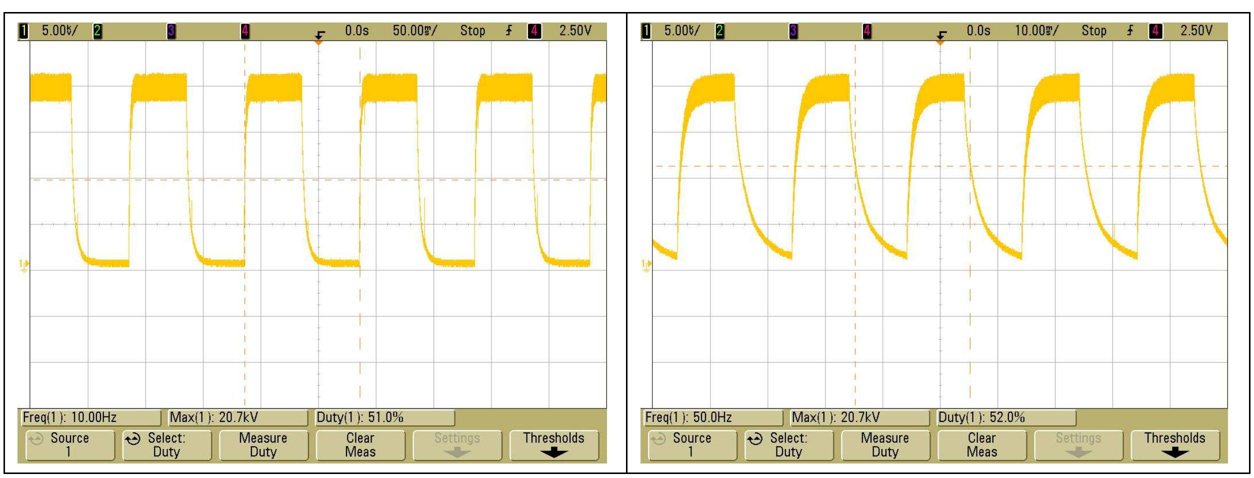
(a) (b)

Figure 5: (a) Homogenizer of the electromagnetic field with cuprextit board. (b) Linking of two modules by the isolated spacing element.



(a) (b)

Figure 6: (a) Realized VN module. (b) Electric Discharge. Electrode distance is approximately 1.5 cm.



(a) (b)

Figure 7: (a) HV generator output voltage, $U_{gen} = 1V_{pp}$ and $f_{gen} = 10\,\mathrm{Hz}$. (b) HV generator output voltage, $U_{gen} = 1V_{pp}$ and $f_{gen} = 50\,\mathrm{Hz}$.

Cuprextit board is conductively connected to the electromagnetic field homogenizer. By the linking of the five 20 kV modules is possible to design the 100 kV generator. Linking of two modules you can see in Fig. 5.

5. REALIZED HV GENERATOR

Realized HV generator, in detail ring electrodes, 1 GΩ resistors and flyback transformer you can see in Fig. 6. On the top the high voltage cable is connected. Voltage limit of this cable reach 30 kV. HV generator test is in Fig. 6. As you can see, discharge distance is approximately 1.5 cm.

6. HV GENERATOR PARAMETERS MEASUREMENT

Low voltage generator AGILENT was connected into the feedback loop of the flyback converter. Output square-wave voltage of the generator was set to $1V_{pp}$. Frequencies were changed in range from 1 Hz to 3 kHz. The control unit is changing the PWM signal in an effort to obtain the same shape of the secondary voltage as is the shape of the primary voltage. Amplitude of the output voltage is approximately 20 kV.

7. RESULTS AND CONCLUSIONS

The measurement confirms that the output voltage is possible to regulate in range from 0 V to 20 kV. Frequencies of the output voltage could be changed in range from 1 Hz to 3 kHz with low distortion. Frequencies over 300 Hz are under influence of the parasitic capacities. Voltage on the output electrode needs to be soft for soft tissue testing. The output voltage of the generator can be seen in Fig. 7. Input voltage has $1V_{pp}$ amplitude and frequency in range 10 Hz to 50 Hz. Square-wave input signal is under influence of parasitic capacities changed. The influence is dependent on the frequency of the input signal. In addition, over 100 Hz the output voltage amplitude is decreasing and signal start to have offset.

ACKNOWLEDGMENT

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