THE DEFIBRILLATOR

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ABSTRACT

This paper describes the electrical circuits of the Defibrillator and their functions, such as DC/DC high voltage converter for capacitor bank charging, timing unit and the fire button circuit, safety discharge bottom circuit, etc. where this type of machine is very important in the medical world because it helps them to help the heart of the patient to return to his own function.

1 INTRODUCTION

Cardiac fibrillation is a condition where in the individual myocardial cells contract asynchronously without any pattern relating the contraction of one cell and the next. This serious condition reduces the cardiac output to near zero, and must be corrected as soon as possible to avoid irreversible damage to the patient. It is one of the most serious medical emergencies of the cardiac patient. Hence resuscitative measures must be instituted within 5 min or less after the attack, or irreversible brain damage will occur. The result of cardiac fibrillation is death of a person when the momentary help not exists. Electric shock to the heart can be used to re-establish a more normal cardiac rhythm. Electrical machines that produce the energy to carry this function are known as defibrillators. The defibrillator is very important equipment for operation rooms and for intensive care units. The defibrillator is proposed for operation rooms (for direct heart defibrillation). [3][4]

2 CONTROL UNIT

The control unit is very important part of the defibrillator. This control unit must to ensure the start of capacitor bank charging, charging of the capacitor bank to adjusted energy and when it is necessary, start of the defibrillation pulse. An indispensable part of this unit is a safety discharge button. For all these function, the control unit consists of an energy selector, a start button circuit, a fire button circuit, a timing circuit and the safety discharge button circuit. [1]

2.1 ENERGY SELECTOR

When the capacitor bank capacity is a constant value (for all defibrillators this condition is always valid), the energy which is stored by the capacitor bank we can calculate only from the capacitor bank voltage drop. Therefore, the energy selector is an adjustable voltage comparator which is used for the capacitor bank voltage measurement. By this selector, the five levels of defibrillator pulse energy may adjust. The principle of the energy selector function is very simple. When energy adjusted by the energy selector is stored by the capacitor bank, the charging of the capacitor bank by the DC/DC converter is stopped. This function is ensured by comparator (IC2).

2.2 START BUTTON CIRCUIT

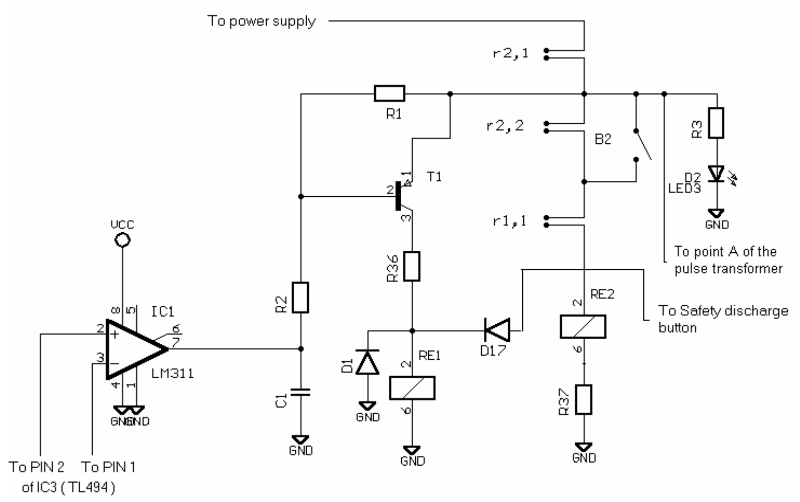

Fig. 1: *Start button circuit*

The start button circuit (see Fig1) is used for conduct of the capacitor bank charging. After depressing of the button B2 this circuit is switched on and the capacitor bank will be charged. Charging of the capacitor bank is signalled by diode D2 (LED). When the capacitor bank stored the energy which was adjusted by energy selector this circuit is switched off. This function is in parallel with blocking function of the error amplifier of the IC3. This system is used for patient's safety (This defibrillator has two independent circuits for capacitor bank voltage monitoring). The start button circuit consists of: the integrated circuit IC1 (voltage comparator), relay Re1 (for limiting the current across this relay is used R36), relay Re2 (for limiting the current across this relay is used R37), transistor T1, diode D1, capacitor C1 diode D3 (LED), resistor R3 and button B2. Function of this circuit is as follow:

When the button B2 is depressed, the contact r2, 2 is replaced by short circuit and relay Re2 will clip. This meant, that contact r2, 1 will be switched on. Now, when the button B2 is released, the contact r2, 2 is a self sealing contact and current is passing by relay Re2 even the button B2 is released. Power supply for pulse transformer of the DC/DC converter is switched on (by switched contact r2, 1) and the signal diode D2 (LED) is shinning.

Integrated circuit IC1 (LM311 - comparator) is connected with the reference voltage by pin 3 and with output of the energy selector by pin 2 (this meant that this comparator is connected in parallel with the error amplifier of the IC3). When the adjusted energy is stored by the capacitor bank, the transistor T1 is by IC1 switched on and contact r1, 1 of the relay Re1 is switched off. The result of this is current break of the Re2 coil and relay Re2 is switched off. This meant that the both contacts of this relay, r2, 1 and r2, 2 are switched off. The power supply for the pulse transformer is switched off and signal diode D2 is switched off too. D17 an electronic switch (switched on when the output from IC8" part of safety discharge button circuit" is positive pulse).

For correct function of Start Button circuit we must insert a small time delay for unbutton time of Re1, and it will be by C1.

2.3 TIMING UNIT AND THE FIRE BUTTON CIRCUIT

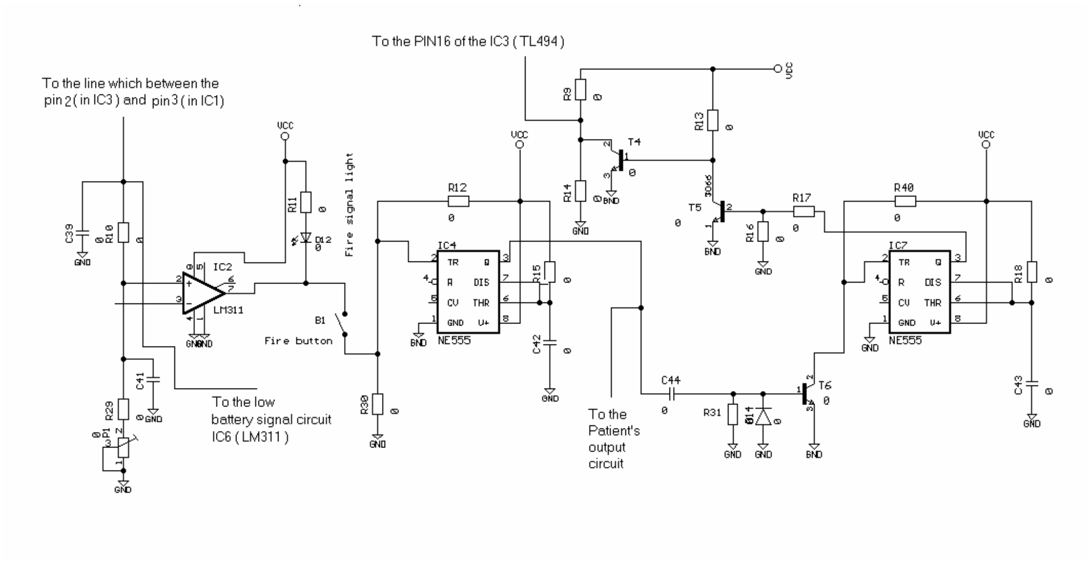

Fig. 2: *Timing unit and the fire button circuit*

The both this parts co-operate together. The fire button circuit is in function only when the adjusted energy (minus 2 % - fixed electric value) is stored by the capacitor bank.

The fire button circuit (see Fig 2) consists of integrated circuit IC2 (LM311 voltage comparator), adjustable voltage divider (resistors R10 and R29 and variable resistor P1), capacitor C41, signal diode D12 (LED) and the button B1. [3] [4]

The function of this part is as follow:

Pin 3 of the IC2 is connected with output of the energy selector. Pin 2 of the IC2 is connected with comparation voltage from IC3 which is lowered by the voltage divider about 2%. This means, when the capacitor bank output voltage is about 2 % lower then level which was adjusted by the energy selector, the pin 7 of the IC2 is grounded (by internal comparator switching transistor), diode D12 (LED) is shining and the button B1 is in function. When this button is depressed now, the pin 2 of the IC4 is grounded and IC4 is triggered. The blocking of the capacitor bank charging is guarded twice (for patient's safety). The first protection is the charging button circuit and the second protection is the output pulse from IC7.

3 DC/DC HIGH VOLTAGE CONVERTER FOR CAPACITOR BANK CHARGING

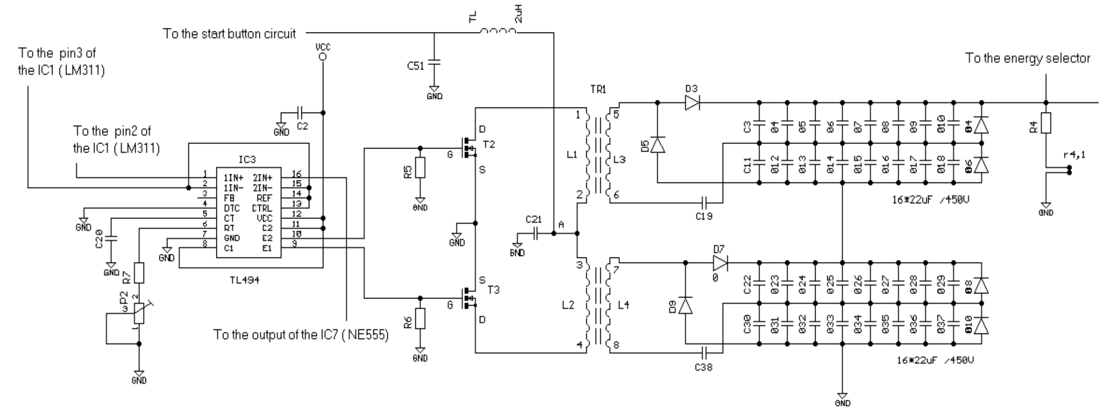

Fig. 3: *DC/DC high voltage converter for capacitor bank charging.*

This DC/DC high voltage converter (see Fig 3) is realized by pulse width modulator IC3 (TL494) which is complemented by two electronic switches and by pulse transformer. TL494 pulse width modulator combines into one integrated circuit - an oscillator of constant frequency of approximately 40 kHz, an internal reference voltage of +5 V and two comparators (only one is used in this design) [5]. The comparator senses an external voltage (from the energy selector - see previous text) and shortness the pulse width of complementary outputs if sensed voltage is close to the reference, reducing the duty cycle to the power stage and hence the energy present at the high voltage transformer secondary. If the external signal is equal to the reference the output stages shunt completely. These output signals (from pin 9 and pin 10) are applied to the gates of two power mosfets which, in push pull configuration, drive high voltage transformer primary.

3.1 CAPACITOR BANK

Capacitors C3 through C18 and C22 through C37 from a capacitor bank of 44 μF are storing the adjustable level of energy. The capacitors are arranged in such a way that the maximal voltage across each of them cannot exceed a safe value (420 V). For this reason the output of these two secondary coils will be about 350 V which is connected with doubler for charging four capacitances in series. Result of this is that output voltage at capacitor bank is divided by four for each capacitance of this bank. When the output voltage from the voltage divider is above 5 V the comparator input of the IC3 (TL494) which stops driving T2 and T3 terminates the charge momentarily. As soon as some of the charge leaks off, the comparator of IC3 is enabled again and other burst is replenished. By this means, the unit is maintained kept ready for firing indefinitely. [5]

4 SAFETY DISCHARGE BUTTON CIRCUIT

The safety discharge button circuit is very important part of the defibrillator. This circuit is in function in time when for any reason the capacitor bank must be discharged. [2]

5 OUTPUT CIRCUIT

According to this type of Defibrillation pulse must has shape of Damped sinus wave. The Defibrillation pulse duration must be approximately 8ms for 50Ω loading. [3]

6 POWER SUPPLY

The power supply is from an 18 V NiCd battery block (it has fifteen cells). The capacity of this battery is 12 Ah. The battery output voltage is from 18 V (when is fully charged - than the each of battery cell has 1.2V) to 16.5 V (when the battery is discharged each of battery cell has 1.1 V). This meant, that difference in the battery output voltage is 1,5 V (in dependence on the battery status of discharging). For correct function of the majority defibrillators' parts the power supply constant voltage is very important. Therefore, these part have power supply stabilised. Only the central point of the DC/DC converter pulse transformer has power supply directly from the battery. Very important part of the power supply is low battery signal circuit because when the battery is discharged the defibrillator is out from function.[6]

7 CONCLUSION

The work described above was the defibrillator for emergency use in operation rooms. This defibrillator has power supply from battery and output energy is adjustable from 10 to 50Ws. This level of the output energy is adequate for the direct defibrillation. In this case, the paddles are in direct contact with the patient's heart.

This device must contain different security circuits. This is very important for correct function of this defibrillator and for the patient's safety too.

REFERENCE

[1] Geddes, L. A., Baker, L. E.: Principles of APPLIED Biomedical Instrumentation John Wiley & Sons, Inc. New York 1968.

[2] Hill, D. W., Dolau, A. M.: Intensive Care Instrumentation Academic Press, London 1976.

[3] Defibrillator 360 SL - Technical Report Medical Research Laboratories, inc.

[4] Defibrillator Code Master XL + Model M1722A/B Technical Report Hewlett Packard Company.

[5] TL 494 PULSE-WIDTH-MODULATION CONTROL CIRCUITS Texas Instruments Inc. 1999.

[6] Ferrite core catalogue FONOX Pramet Šumperk.