POWER CHARGER OF LEAD ACCUMULATORS

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Abstract: This charger is realized as a forward converter which works with frequency 150 kHz. The charger is determined by charging of lead accumulators with nominal voltage 6 or 12V. The regulation principle is based on regulation to constant voltage (7.2 or 14.4 V) with current limitation: 1A, 5A, 15A, 50A. The full device with maximal power 920W is fitted to dimension of 1.8 l (the power density is about 400W/l).

Keywords: EEICT, charger, forward converter, driving circuits

1. INTRODUCTION

Recently it is desired to solve chargers as switch-mode power supplies that work with high frequency because high frequency of these supplies causes low mass and volume of a power pulsed transformer (in contradiction to sources with a network transformer). That's important mainly for electromobils that contain a charger in their construction, because they are independent on place of charging. Thus, low mass and volume are necessary.

Next chapters describe unusual space-solving solution of magnetic circuit of transformer and inductor, special solving of power circuit of converter and unique construction solving of cooler system.

2. POWER CIRCUITS OF CONVERTER

The heart of the power circuits includes forward converter with a transformer (Figure 3). Working frequency 150 kHz enables low mass of power transformer TR1. Additional coil L1 and diode D3 are connected in parallel with TR1 (primary winding) to enlargement of transistors current. This reactive current is only reactive, so there is no influence on energetic balance of charger. Thus, this current only extends a total collector current I_D of transistor to faster parasitic capacity C_{DS} overcharging (between electrodes D and S of MOS-FET transistors). Thanks to this current, the time t_c will be shorter. So, t_c is the time, when the demagnetizing current flows during *non-lead* working. During *on-load* working will be time of demagnetization automatically shorter, because working current will be high. The capacity is overcharged with rate of rise

$$\frac{\mathrm{d}u}{\mathrm{d}t} = \frac{2U_d}{t_c} = \frac{I_D}{C_{DS}}. \tag{1}$$

where I_D is total collector current at the moment of switching off. Figure 1 shows the detailed scheme of this problematic and shows courses of transformer primary voltages and also magnetizing current.

As was written in the introduction, this charger has unusual space-solving solution of magnetic circuit: the output inductor is winded vertically to power transformer TR1. So, this parts' lines of flux are vertical to each other (Figure 2). Thus, the magnetic fields of these parts are independent to each other and magnetic material is fully used – only one ferrite core is used for both magnetic circuits.

Leakage inductance of transformer TR1 is extended knowingly by additional coil L4. Thanks to this coil are miniaturized commutation losses of secondary rectifier. The rectifier diode D7 and freewheeling diode D8 are both Schottky's diodes with reverse recovery time t_{rr} = 40ns. They are both equipped by R-C elements which reduce overshoot in the end of recovery time.

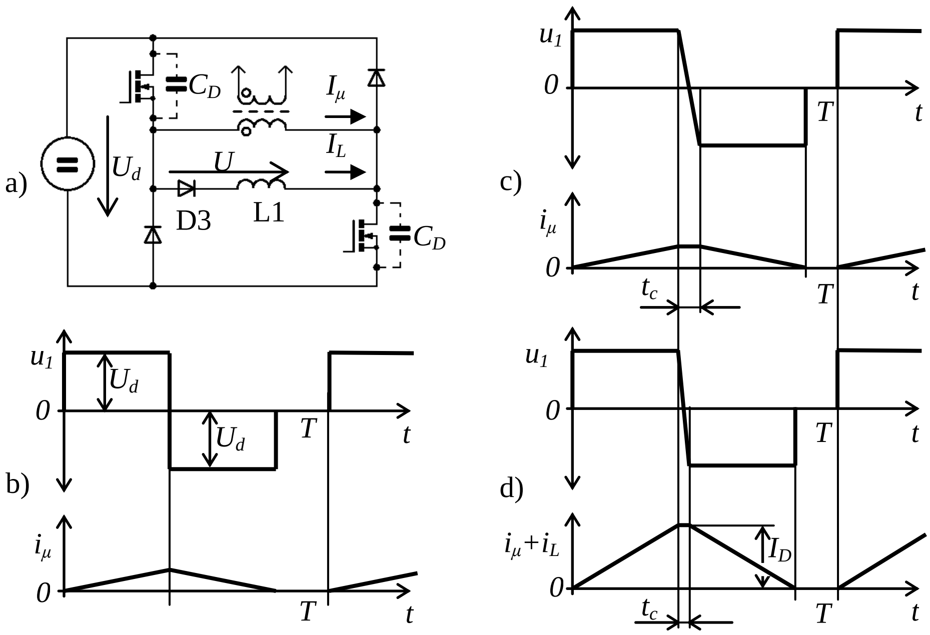

Figure 1: Influence of parasitic capacities C_{DS} during demagnetization of transformer. Where: a) detailed scheme of the problem, b) idealized process without of parasitic capacities influence, c) real process depended on the parasitic capacities C_{DS}, d) process with artificially extended demagnetization current (current flows thorough L1).

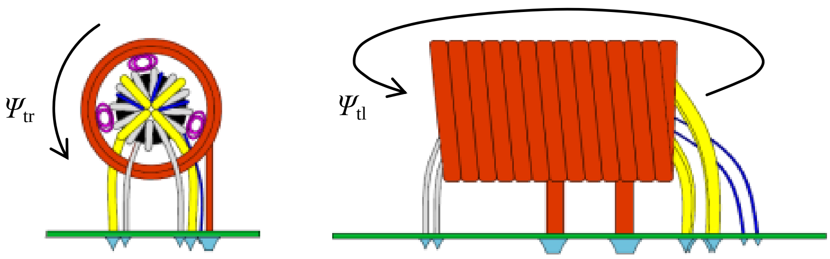

Figure 2: Power transformer and output inductor construction. Color legend: *Inductor*; *Transformer*: primary winding, secondary winding, additional secondary winding (feeding), ferrite rings; cantering rings.

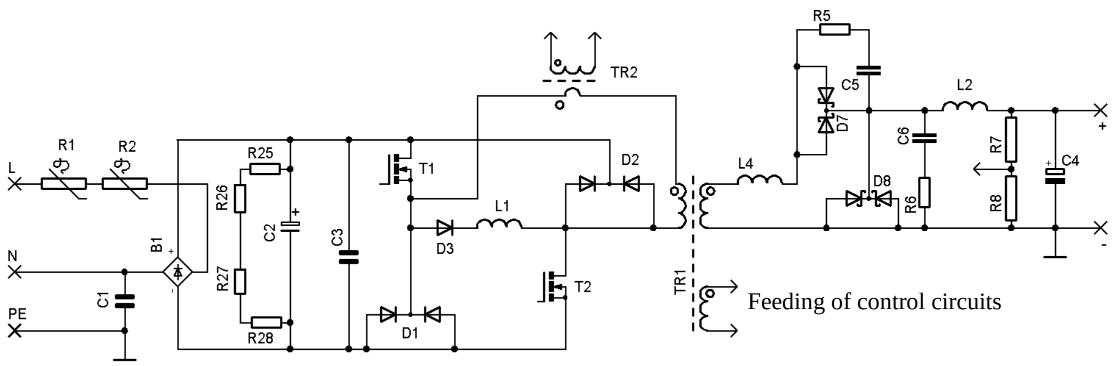

Figure 3: Power circuit's basic scheme.

3. DRIVING CIRCUITS OF POWER TRANSISTORS

Driving circuits' diagram shows Figure 4. If the top transistor of output stage (in integrated circuit UC3845) is switched on, the outside transistor T5 will be also switched immediately. The primary winding of transformer TR4 will be connected to driving voltage Ucc at the same time. So, the primary current will flow thorough the top transistor in UC3845 and thorough MOS-FET T5. As soon as the driving circuits switch off the top transistor of output stage, the transformer will be demagnetized to driving voltage Ucc thorough diodes D13 and D14. At the same time the down transistor of output stage will switch on and it will discharge the transistor's T5 parasitic capacity (between electrodes G and S), so the switching off the transistor T5 will be faster.

Thus, the top transistor of output stage, transistor T5 and diodes D13, D14 work as forward converter that feeds primary winding of isolation transformer.

Secondary part of driving circuits is consisted of two circuits. This both circuits must be galvanic separated to each other and also must be galvanic separated from control circuit's voltage, because both power transistors are situated on different potentials. Next description will be focused on the top circuit that switches transistor T1. During the transistor T5 is switching on, the driving voltage Ucc is transformed to secondary winding (transformation ratio 1 : 2). The parasitic capacity C_{GS} of power transistor T1 is charged through both diodes D15, D16. This capacity current is reduced by resistors R19, R20. These resistors' power losses could be counted by equation

$$P_R = f \cdot \frac{1}{2} \cdot C_{GS} \cdot U_{GS}^2 , \tag{2}$$

where U_{GS} = 15 V, $C_{GS} \cong$ 1 nF, f = 150 kHz. So, the power transistor's exciting is not quite lossless.

After the signal from driving circuits is switched off, the capacity C_{GS} in transistor T1 is discharged by emitter follower T3. The high resistance resistor R3 causes that the transistor T1 will be switched off, if the driving circuit is damaged.

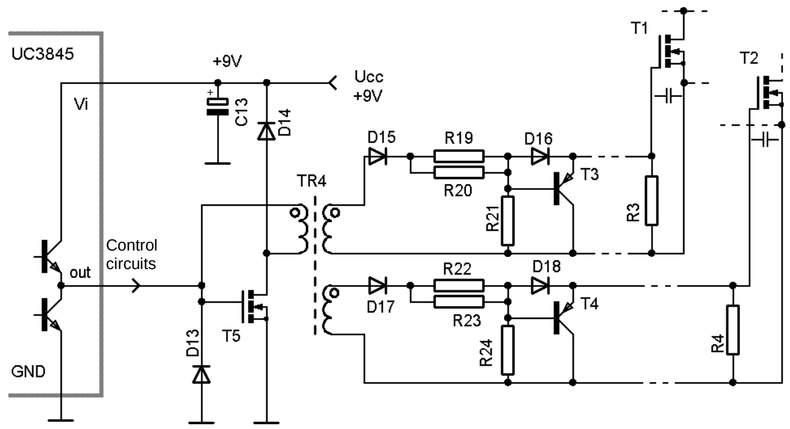

Figure 4: Driving circuit's scheme.

4. CONTROL CIRCUITS

The principal diagram of driving circuits shows Figure 5, where the integrated circuit UC3845 (Figure 6 - left) is the main element. The parts C10, R18 set up the working frequency. The voltage divider R7, R8 senses output voltage. The shunt R13, R14 converts current signal from current transformer TR2 to voltage signal. The diodes D10 and D19 are connected as a logic element OR. Thus, the control circuit reacts in the same way to overvoltage or overcurrent. Parallel parts R12, C9 with diode D19 represent a peak detector.

OZ1 is connected as a PI-regulator, which regulates output voltage. Thanks to the resistor's group R2 - R6 is possible to set up a value of output voltage. If the two-throw switch S2 is switched off, the output value of voltage is 14.4V. But if this switch is switched on, the output value of voltage is 7.2V.

The changeover switch S1sets this current limitations: 1A, 5A, 15A a 50A. Value 50A is not specified for charging, but it helps to a car battery during heavy starts (for example in winter).

This control circuit works as a PI-regulator with current limitation. Figure 6–right shows voltage and current curves during charging, whereas the horizontal part of current curve constitutes current limitation mode and horizontal part of voltage curve constitutes mode of regulation to constant voltage.

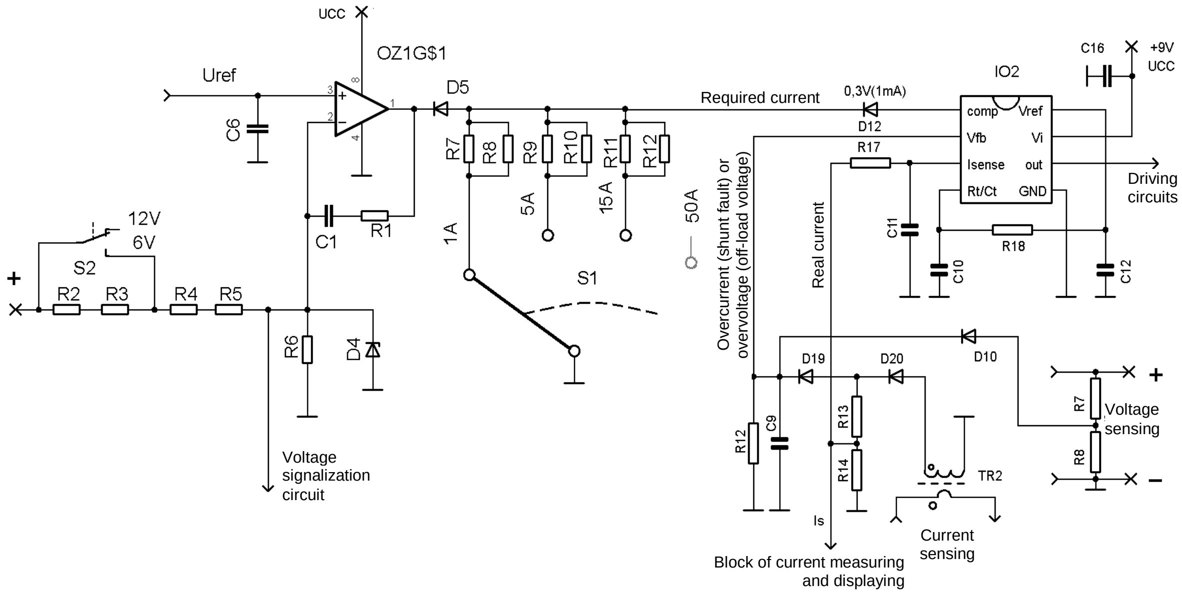

Figure 5: Control circuits‘ scheme.

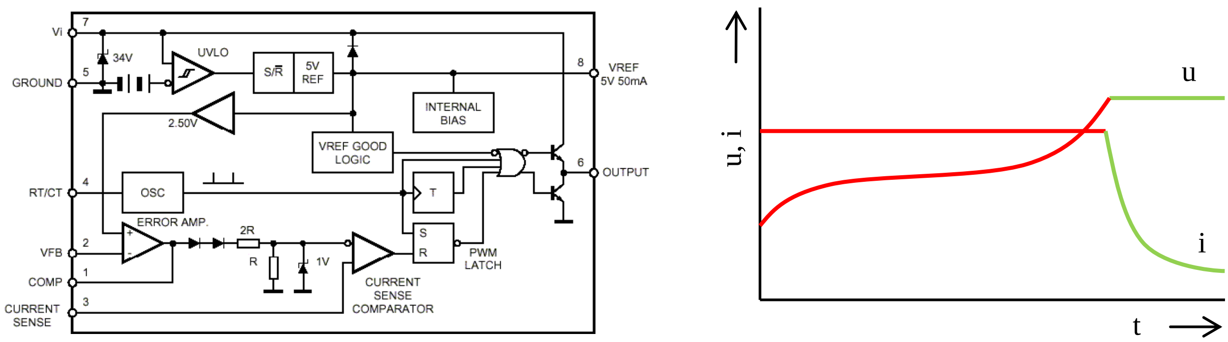

Figure 6: *Left*: Integrated circuit’s UC3845 block diagram (from [3]); *right*: Voltage and current curves during charging.

5. CONSTRUCTION SOLVING

Complete electric equipment is separated to the next PCB boards:

- Main board (MB) – contains every power parts,
- Voltage regulator’s board (VRB) – contains every control circuits, operating parts and signalizations.

So, that's evident, that MB is universal, however if the VRB is properly replaced, this charger device could charge another kinds of accumulators than lead accumulators (e.g. Li-Ion, $LiFePo_4$, etc.).

Inside space of charger is halved by MB. The device's cooling system shows next figure. Vents for input and output air are placed on the same side. This method could be realized thanks two groups of cooling fins, which are antagonistic oriented each other. Thus, some cooled air is inleted by first group of vents and it is exhausted by second group of vents (but to opposite direction). The air flux is realized by two powerful ventilators with different revolution directs. The ventilators are controlled by temperature range.

Device box is made from iron sheets with thickness 1.5 and 1.0 mm. Thanks to that, this device box is robust. Outside dimensions of box are: 125 x 62 x 235mm.

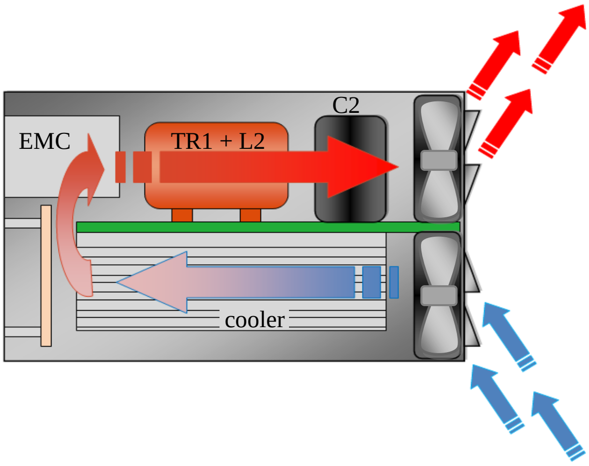

Figure 7: Cooling system of the charger.

6. CONCLUSION

The next work will be focused to develop of charger with much greater power that will be oriented especially for Li-Ion and $LiFePo_4$ traction batteries, which are recently used for electromobils. In this case, chargers must be able to manage charging current about 50Awith traction voltage approximately 300V, so charge power is about 15kW.

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