Automatic Charger For Lead Batteries

AVT 3120

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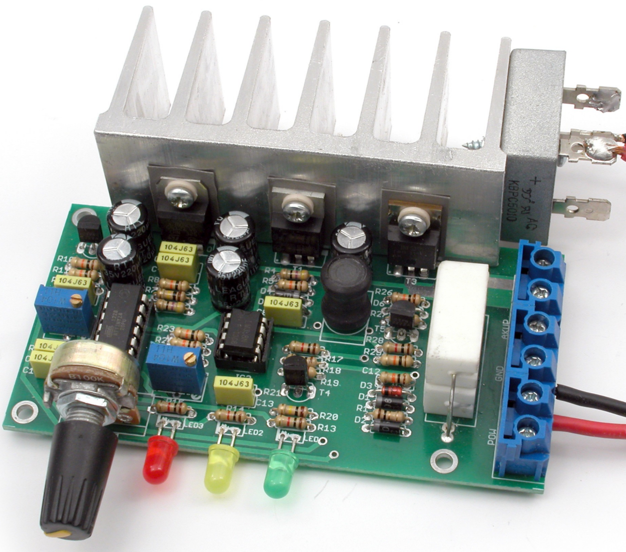


ASSEMBLY DIFFICULTY

The device monitors the charging process and determines its optimal performance. The whole cycle is divided into 4 stages automatically switched depending on the battery charge level. When the battery reaches its correct voltage, charging is automatically terminated. Battery condition and charging stage are indicated by 3 LEDs. The charger features adjustable charging current, so it prevents damage to the battery (too much current) and saves time (too little current).

Characteristics

- charging of 12 V lead-acid batteries with a capacity of 10...100 Ah
- charging current regulation in the range of approx. 1...10 A
- battery overcharging protection
- multi-stage charging process
- power supply: 17 V transformer or factory rectifier
- PCB size: 103×54 mm

Circuit description

Traditional rectifier has two main disadvantages. First: it has no protection against overcharging and even if you watch over it while it is charging, you will not be able to see from the ammeter alone that it is time to stop charging. Whilst, charging until gassing of the electrolyte is a conscious overcharging. Second disadvantage: no charging current regulation. The charging current should not exceed the permissible value for the battery in question, which depends on its capacity. Charging with excessive current can irreversibly damage the plates (cells) of which the battery is composed. Exceeding the permitted voltage or current you adversely affect the performance and service life of the battery. The presented device allows to avoid both of these disadvantages. This module can be a standalone unit, such as the model shown on the photographs, but can also be an attachment to a simple, classic rectifier. In both cases you receive an automatic charger. Its diagram is shown in Figure 1 and it can be divided into several blocks.

1. Current measurement block - built using lM358 chip (IC3A, IC3B). Positive output from the rectifier is fed to the POW terminal and goes to a measuring shunt R16 composed of two low-resistance power resistors. Operational amplifier IC3B including transistor T4 and adjacent components form a current-to-voltage converter. At its output there is a filter built of elements R20, C13 and amplifier IC3A. Output signal is calibrated using precision potentiometer R24 and goes to the microcontroller - the signal marked CV.

2. Power stage - built with transistors T3 and T5. T3 is used to control the voltage/current waveform supplied to the battery. Transistor T5 with adjacent components allow the MOSFET to be controlled directly from the microcontroller lead.

3. Voltage converter block - elements L1, T1, D4. It is a classic boost converter, on an output (signal marked PVCC) it reaches voltage of approx. 29V, which is necessary for the correct operation of the current measurement block. Adjacent elements are used to output voltage stabilisation and filtering.

4. Power block - IC2 stabiliser and adjoining components. The block task is to obtain and filter voltage from 10 V to max. 26 V, which is taken through the diodes D1 and D2 from a battery or rectifier. Then, the 5 V needed to supply the microcontroller is obtained through the IC2 stabiliser. Precision potentiometer R3 and resistor R2 form a divider for reading the battery voltage values. The potentiometer allows to calibrate the reading.

5. AC voltage sensor block - made of the transistor T2 and adjacent components. Its task is to detect the halves of the sine wave applied on the battery DC voltage - this process will be discussed in more detail later in this instructions.

6. Control block - potentiometer R12 is used to set charging current, LEDs indicate state of the circuit and the microcontroller controls the entire process. However, the most important element of the system is not visible in the diagram, and it is a programme contained in the memory of the microcontroller. The tasks its performs are: booster inverter control - maintaining a constant output voltage, reading of all analogue values, regulating the charging current and switching stages of the charging process. Charging current control is achieved by phase control applied to thyristors and triacs with the difference that without thyristor or triac, but with MOSFET transistor with P-channel. This solution simplified the circuit and reduced energy losses accumulaterd on the executive

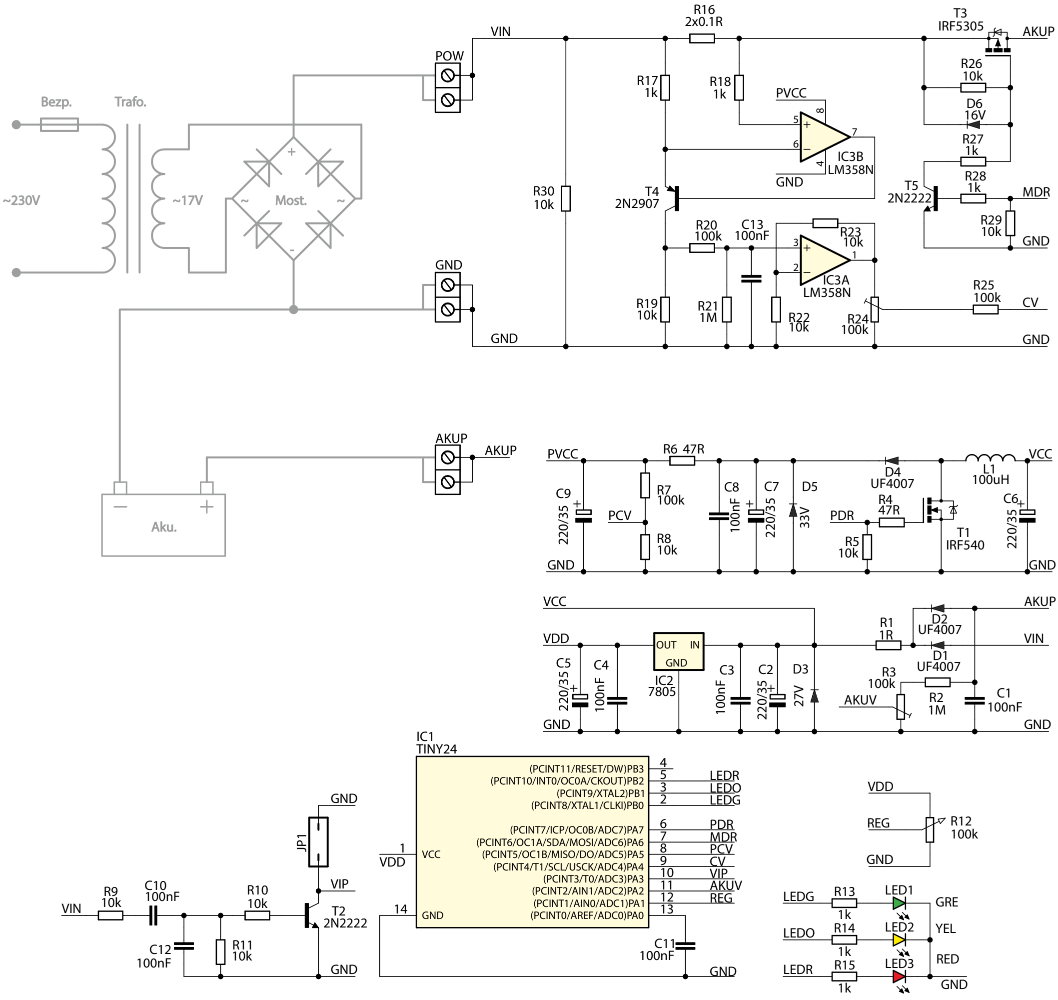


Figure 1. Schematic diagram of the charger

element. Waveforms in the circuit are shown in Figure 2. Waveform A is the rectifier output, B is the superimposed output of the rectifier and the battery's DC voltage (VIN in the diagram). The C waveform is the waveform at the output of the AC voltage sensor (VIP in the diagram) - it accurately determines the time at which the voltage waveform from the rectifier exceeds the battery voltage and a charging current can be obtained, the descending ramp marks the beginning of the phase control period. The D waveform is the power stage control signal (MDR in the diagram), the greater the filling, the greater part of B waveform will be brought to the battery - E waveform (AKUP in the diagram).

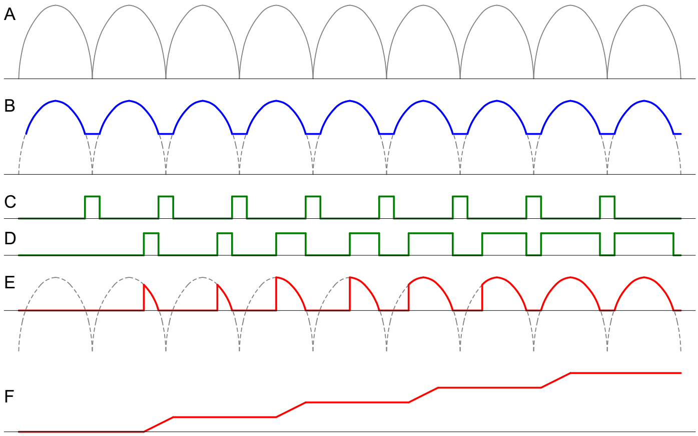


Figure 2. Waveforms in the circuit

The F waveform is the output from the current-to-voltage converter block (CV in the diagram).
The charging process is divided into several stages selected according to the battery charge level, i.e., the voltage at its terminals. Figure 3 shows the full process. The symbols in A are the charging stages, graph B is the charging current values, graph C is the voltage waveform on the battery, while the symbols in point D show how the LEDs indicate the status.

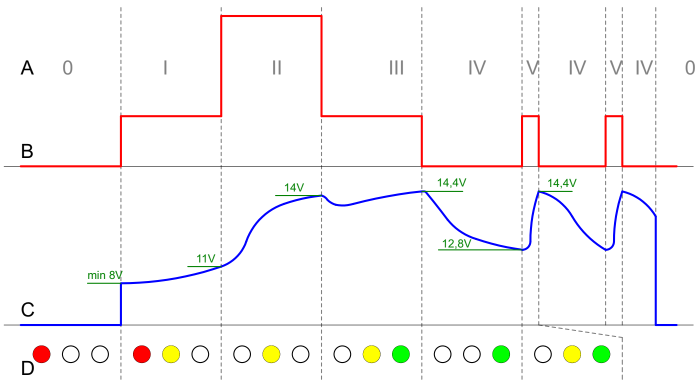


Figure 3. Full charging process

Stage 0 - no battery. If the rectifier is switched on, the circuit signals this stage with the red LED steady on. The power stage is switched off, there is no voltage at the output terminals, and also no risk of accidental short-circuiting, such a state continues until the voltage of at least 8 V at the output.
Stage I - pre-charging. When to the output terminals a battery will be connected with a voltage of no more than 11 V, this means that it is in a deep discharge state. Such a battery connected to a normal rectifier

can force a very high current due to the significant voltage difference. In this case, the circuit presented reduces the charging current to 1/3 of the set range and waits until the battery has partially regenerated - the voltage exceeds 11 V.

Stage II - baseline charging. At this stage, the charging current reaches the full set value, but unlike a classic rectifier, it will not decrease as the charge level increases, but is kept constant, thus reducing charging time. This stage continues until the voltage reaches 14 V. Here, it is worth noting the way the voltage is measured, which is different to the other stages - charging is cycled, each cycle is about half a minute of charging, followed by a short pause, stopping charging - and at this point the battery voltage is measured. As a result, the measurement is not subject to error due to voltage drops on the connection wires.

Stage III - final charging. When the voltage exceeds 14V, the charging current is reduced to 1/3 of the set value. Charging with a lower current allows the battery to be 'saturated' with energy and allows a more precise timing of termination. At first, the battery will respond with a sudden drop in voltage, as can be seen in Figure 3, but will then slowly reach a maximum value of 14.4 V.

Stage IV - charging completed. When the green LED is on it indicates the end of the charging process, the battery is fully charged and ready for use. The voltage on the battery drops quickly to around 13V and then more slowly to around 12.6 V, so do not expect to measure14.4 V on the battery when charging is completed. If the battery is left attached to the presented charger its voltage will be monitored at all times and when it drops to a value of approx. 12.8V, an additional stage will be triggered.

Stage V - maintenance charging. As for the final charge, the charge current is 1/3 of the set value and the final voltage is 14.4 V. This stage is designed to keep the battery charged if it remains attached, even long after the charge has ended.

When a battery is connected to the circuit and the power supply to the circuit is disconnected (rectifier off), the LEDs will indicate the status of the battery in the same way as during charging, except that the LEDs will flash. The circuit measures the charging current and, if it does not reach the minimum value, signals it like this. The same will happen if, for example, the 230 VAC mains voltage fails during charging, flashing LEDs will signal this emergency condition. Note that the device then draws power from the battery and discharges it with a small current.

Mounting and start-up

The circuit was designed and manufactured on a double-side board in a through-hole design. Mount according to general principles, the mounting diagram is shown in Figure 4. First, screw lightly in transistors T1 and T3 and the stabiliser to the heatsink, using washers and insulating sleeves, and then mount them on the board. Finally, mount the heatsink on the board. If the device will be used to build a new rectifier, you can attach the rectifier bridge to the heatsink side, as in the model. If the device will work as an attachment to thee rectifier, then a bridge is not necessary. Fit the circuit in a well-ventilated enclosure. The heatsink should not be too warm during operation, while the measurement resistors R16 and the rectifier bridge may even be hot. A front panel sticker has been designed for the circuit - Figure 5, the dial has been scaled from 0 to 100, this can be thought of as % power or as the capacity of the battery being charged.

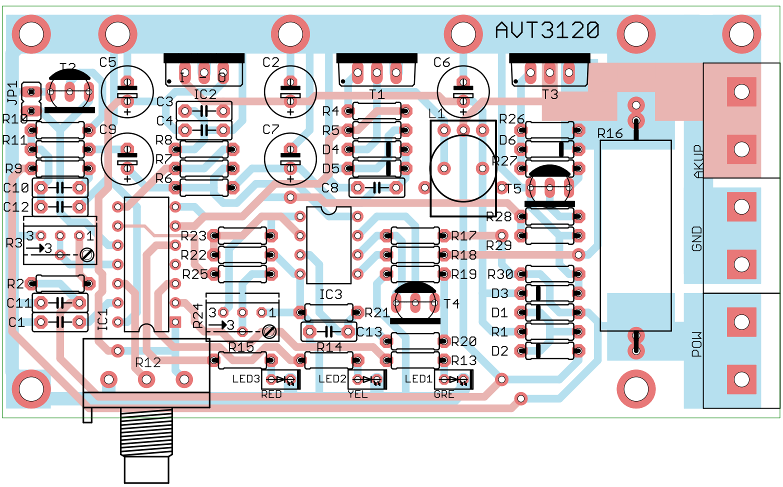


Figure 4. Arrangement of components on the PCB.

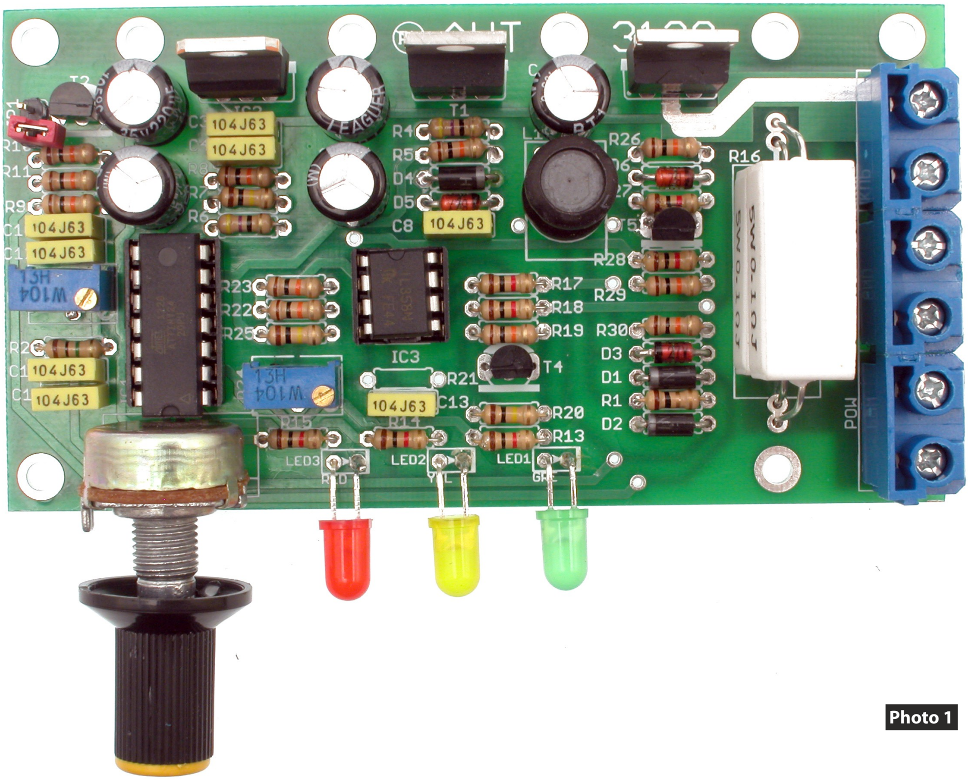
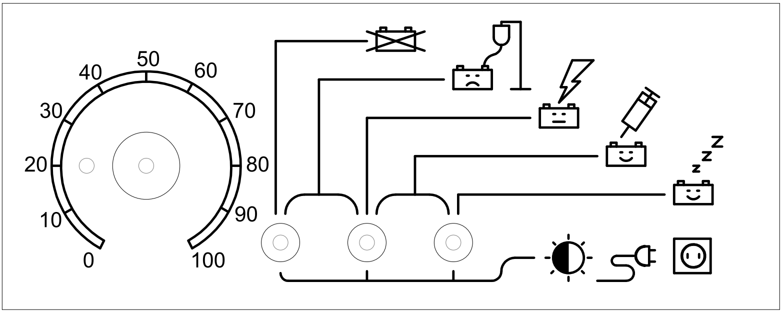


Photo 1

Once you cleaned the board visually inspected your assembly, you can start your device up. You will need a regulated power supply, a multimeter and a battery. First, remove the ICs from their sockets and apply a voltage of approximately 10 V from the power supply to the AKUP and GND terminals. Now measure whether 5 V is present on pins 1 and 14 of the microcontroller socket.
Then disconnect the power supply, mount the microcontroller in the socket and reconnect the power supply. Now measure whether there is a voltage of approx. 29...30 V on pins 4 and 8 of the IC3 chip socket. If the voltages are correct then you can move on to the next step.
Mount the ICs in their sockets and connect the power supply with the voltage set to approx. 7V, the red LED should be on, then raise the voltage to 8V and with the potentiometer R3 adjust until the red and yellow LED are on. Now it is advisable to check whether the switching of successive stages occurs at voltages of 11 V, 14 V, 14.4 V and possibly to correct the setting of R3 (14.4 is the most relevant voltage).



Rysunek 5. Przykład nalepki na panel frontowy 1:1

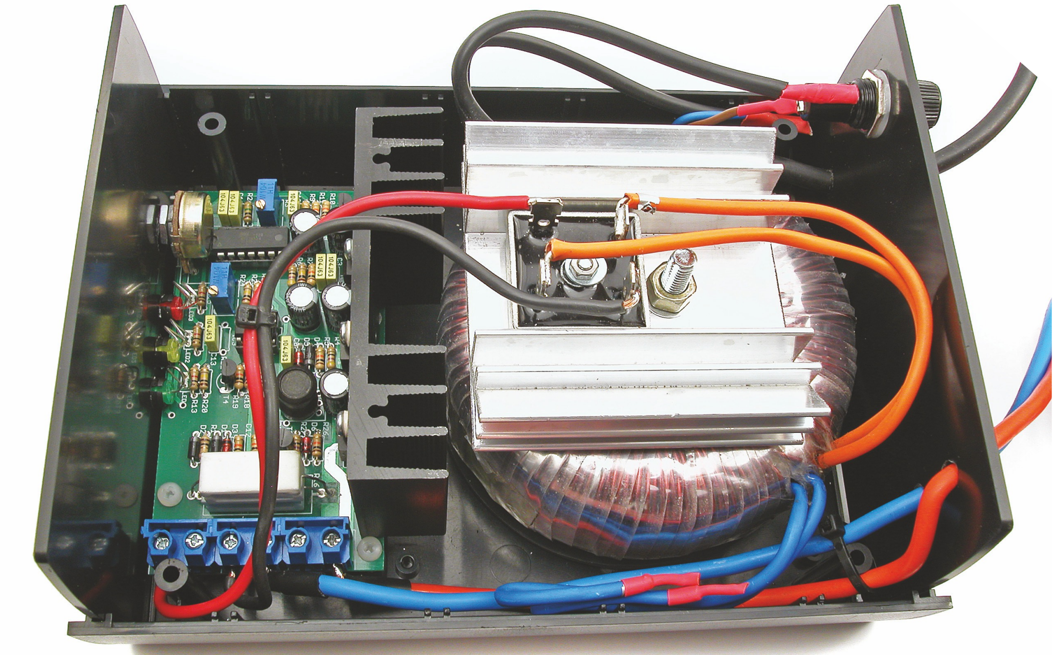


Photo 2

Important note - the voltage should be increased slowly because the voltage measurement is cycled, not continuous, and the voltage thresholds for switching stages have large hysteresis in the direction of the falling voltage - switching from stage I to stage II occurs when 11 V is exceeded, but from stage II to stage I occurs at 10.8 V. The exact voltage values are stored in the program in the analog.h file. The next step is to connect the target transformer (via a rectifier bridge) or the rectifier to the POW and GND terminals. However, before you do so, make sure that the secondary voltage of the transformer/rectifier will not exceed 18 VAC (26 VDC). Applying a voltage higher than this will damage the resistor R1. The voltage should also not be too low, as it will not allow the full range of regulation, the optimum value is 17 AC and a power of about 150...200 W. If the full 10 A range is not going to be used, then the transformer can be of lower power. No filter capacitor is allowed at the output, as the circuit will not form synchronising pulses (VIP signal - Figure 2, signal C).
Finally, calibrate the current measurement block.
Set the control knob to minimum, connect the minus of the battery to the GND terminal and the plus of the battery via the ammeter to the AKUP terminal and connect the transformer/rectifier.
Now, adjust the knob an d, following the ammeter readings, set a small current, e.g. 2 A, (the circuit must be in the base charge stage). Adjust potentiometer R24 so that the dial indication corresponds to that of the ammeter (assuming, for example, that 20% is 2 A). There may be discrepancies here - the charging current has a heavily distorted waveform and the ammeter may not indicate correctly, the current measurement block also introduces slight distortions. It is best to set the correct current in the middle position of the dial (current approx. 5 A), allowing the extreme settings to deviate slightly.
How to connect the circuit safely? The charger is to some extent immune to reverse battery connection and to short-circuiting of the output terminals, but the following sequence must be followed. First, the charger's power supply must be disconnected from the 230 VAC mains. Then, connect the battery and watch the LEDs - if none of the LEDs turn on then the battery is incorrectly connected or extremely discharged/damaged. If the red and/or yellow starts flashing, the battery is correctly connected, then the charging current can be set and the power supply (transformer or rectifier) can be connected to the 230 VAC mains.
Finally, one note. Modern rectifiers - switching rectifiers are simply switching power supplies with the appropriate parameters. The output of such a power supply is DC voltage so we will not connect our circuit to such a rectifier.

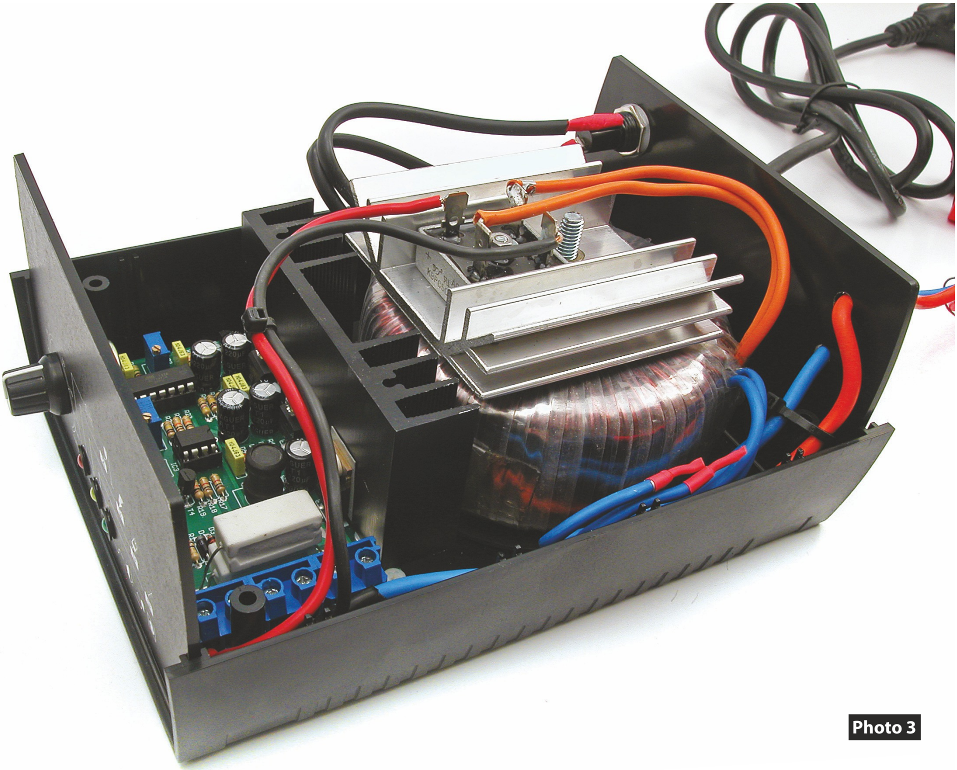


Photo 3

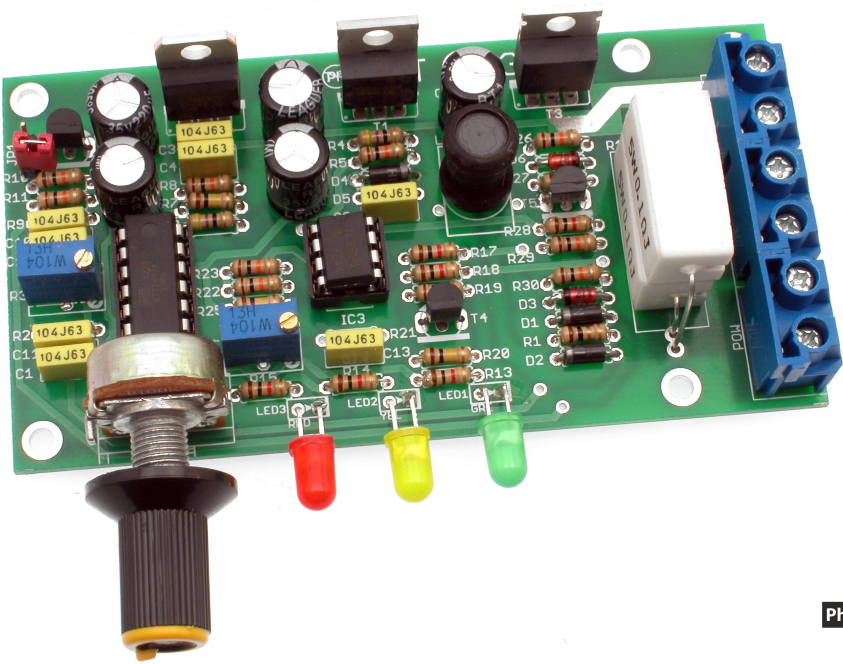


Photo 4

List of components

Resistors:
R1:...1 Ω
R2:...1 MΩ
R3, R24: ....mounting potentiometer 100 kΩ
R4, R6: ....47 Ω
R5, R8-R11, R19, R22, R23, R26, R29, R30:..........10 kΩ
R7, R20, R25: ....100 kΩ
R12:. ....potentiometer 100 kΩ
R13, R14, R15, R17, R18, R27, R28: ....1 kΩ
R16:. ....2 x 0.1 Ω / 5 W
R21:..do not mount
Capacitors:
C1, C3, C4, C8, C10-C13:...100 nF
C2, C5, C6, C7, C9:...220 uF / 35 V
Semiconductors:
D1, D2, D4:..UF4007
D3: ....Zener diode 27 V
D5: .... Zener diode 33 V
D6: ....Zener diode 16 V
LED1-LED3:..LED 5mm, R, Y, G
T1: ....IRF540 or similar
T3:..IRF5305 or similar
T2, T5:..2N2222
T4:..2N2907
IC1: ATTINY24
IC2:..7805
IC3: LM358

Other:
L1:..100 uH / 0.5 A
AKUP, GND, POW:........................DG365-7.5/2
JP1:..DO NOT MOUNT
Rectifier bridge min. 15 A

AVT SPV Sp. z o.o.

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This symbol means do not dispose of your product with your other household waste. Instead, you should protect human health and the environment by handing over your waste equipment to a designated collection point for the recycling of waste electrical and electronic equipment.