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Advanced Portable Device for Charging Battery of the Mobile Phone

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ABSTRACT: The development of portable device for charging battery of the mobile phone is presented in this paper. A device consists of NiMH battery, electronics for charging NiMH battery, boost DC/DC converter for getting 5 V on the output USB port and solar panel. Firstly, NiMH battery which occurs in this device is charged by electronics for charging NiMH battery and after that this device becomes power source which can be used for charging battery of the mobile phone on the remote places where there is no electric power source, especially in the nature. A solar panel is mounted on the box of the device and it gives an opportunity for charging NiMH battery of the device.

KEYWORDS: Microcontroller ATtiny 85, Boost DC/DC converter, NiMH battery, Solar panel.

I. INTRODUCTION

The device which enables battery charging of the mobile phone at the places where does not exist electric power source is presented in this paper. This device presents portable energy source. The device has NiMH battery and electronics for charging NiMH and boosts DC/DC converter [1]. The boost DC/DC converter raises voltage from the 3 serial connected NiMH batteries, to voltage of 5 V. The output current of this boost DC/DC converter is used for charging battery of the mobile phone. The maximum intensity of the output current of this boost DC/DC converter is 500 mA in the case when 3 NiMH batteries, which are serial connected, occur at the input of the boost DC/DC converter. The device can be connected to the external voltage power source of 9 V. This voltage source of 9 V is used for charging NiMH battery which occurs inside the device. This NiMH battery can be charged by a solar panel. A solar panel is mounted on the surface of the box. In that way it is enabled that NiMH battery can be charged by solar energy in the nature. The USB connector occurs on the output of the device. The mobile phone is connected to the USB connector of the portable device. The device is settled in the box which dimensions are 160 mm x 160 mm x 65 mm and it is very easy for transport. Figure 1 shows external view of the device which is described in this paper.

Fig. 1 Device for charging battery of the mobile phone

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Figure 2 shows front view of the device which is described in this paper.

Fig. 2 Front view of the device for battery charging of the mobile phone

II. ELECTRONICS FOR BATTERY CHARGING

Electronics for battery charging is consisted of power supply, timer, which is realised by microcontroller, controlled switcher and constant current source. Power supply of the device for getting voltage of 5 V is shown in the figure 3. The voltage of 5 V is necessary for power supply of the microcontroller ATtiny 85 [2]. This voltage of 5 V is got by integrated circuit LM7805. Extern voltage source of 9 V can be connected on the input of device. This external voltage source is used for battery charging inside the device and for getting 5 V.

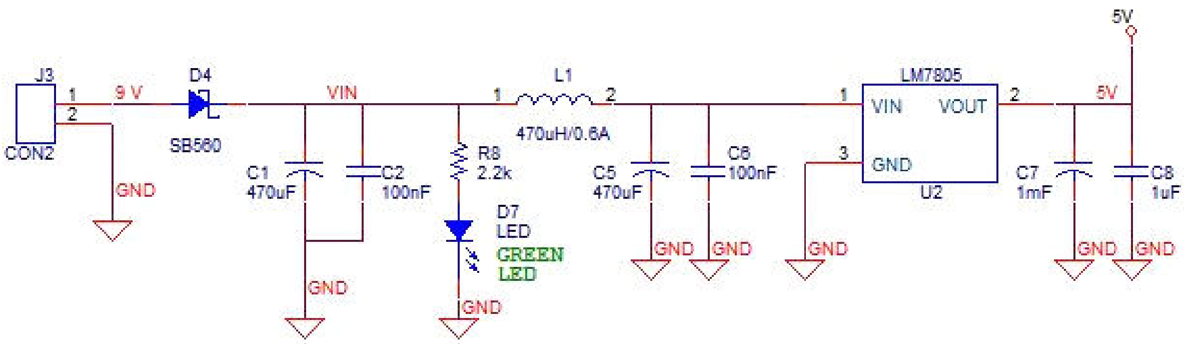

Fig. 3 Voltage source of 5 V

Green LED diode D_7 shows that the device is connected to the power supply of 9 V. Microcontroller ATtiny85 is used in this device only for realization timer. Timer is needed to constraint time of charging of NiMH battery in the device. This NiMH battery inside device is consisted of 3 serial connected rechargeable NiMH batteries type AA, which nominal voltage is 1.2 V and capacity is 2600 mAh. The battery, which is got by serially connected 3 NiMH batteries, has the nominal voltage 3.6 V and the capacity 2600 mAh. The chargers of NiMH battery have current source, A/D converter and safety timer. Current source charges NiMH battery with the constant current. The A/D converter measures voltage on the battery. The safety timer measures time of battery charging. The A/D converter should detect negative voltage peak on the battery, voltage dropout [3]. Negative voltage dropout of NiMH battery is 10 mV [4]. Negative voltage dropout of NiCd battery is 30 mV [4]. When the A/D converter detects negative voltage peak, it means that NiMH battery is fully charged and battery charging is stopped. Every battery has a limited number of cycles of charging and discharging. When NiMH battery becomes too old, then negative voltage peak decreases below 10 mV and it is very hard to detect voltage dropout by A/D converter. A/D converter of very high resolution is necessary and it

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makes the high price of a charger. Because of that, chargers beside A/D converter have a safety timer. The role of the safety timer is to stop battery charging if A/D converter did not detect voltage dropout. Some cheap chargers for NiMH batteries don't have an A/D converter. They only have safety timer because it decreases the price of a charger. During battery charging one part of energy is converted into the heating and electrolysis. Because of that, during battery charging it must input higher energy than the nominal capacity that later can be got from the battery nominal capacity. It is usual that the NiMH battery charges to 1.2 nominal capacity if before that it was fully discharged. Because of that all chargers of NiMH batteries have time of charging defined by the next equation:

$$t = \frac{1.2C}{I_{BAT}}$$

where is:

I_{BAT} – current of battery charging

C – nominal capacity of the battery

A/D converter is not used when the serial connected NiMH batteries are charged, because it does not makes sense to use a method of negative voltage peak in that case. The reason is that negative voltage peak does not appear in the same time to all serial connected batteries. In that case charging is stopped by safety timer. Example for that are chargers for charging NiMH batteries of 9 V. Every rechargeable NiMH battery of 9 V is consisted of 7 serial connected NiMH batteries which nominal voltage is 1.2 V. All chargers for charging NiMH batteries of 9 V finish charging by safety timer. In this device occur 3 serial connected NiMH batteries of 1.2 V. Because of that charging is done by constant current and stopping charging is done after time of timer is elapsed. The time of a timer is set on the less time than it is defined by the equation (1) to avoid overcharging battery.

$$t = \frac{C}{I_{BAT}}$$

If the NiMH battery is not quite empty, then it should be charged only a few hours. In that way battery is saved of overcharging and lifetime of battery is prolonged, but in that case capacity which can be used from the battery is less then nominal. In this device current of battery charging is constant and is equal to 250 mA. Because of that time of timer is set to 10 hours and 24 minutes. Microcontroller ATtiny85 is used for realization of timer because it has small current consumption on the frequency of 4 MHz and it has small dimension. In the figure 4 connections of a microcontroller with a controlled switch are shown. This microcontroller has only 8 pins. One output pin of microcontroller is connected to the controlled switch which is realized by two transistors and two resistors. During battery charging, voltage on the output pin PB1 of microcontroller is set to 5 V. Because of that bipolar NPN transistor BC337 Q_2 conducts and gets current from resistor R_9 which is connected between source and gate of PMOS transistor IRF9540N Q_1. During that time, voltage exists between source and gate of PMOS transistor and PMOS transistor conducts current. When PMOS transistor Q_1 conducts current, then it connects extern voltage source of 9 V with current source for battery charging. During battery charging, voltage on the output pin PB0 of a microcontroller is 0 V and red LED diode D_8 is lit off. When the time of a timer has elapsed, on the output pin PB1 of a microcontroller is set 0 V and bipolar transistor Q_2 and PMOS transistor Q_1 are turned off. In that way battery charging is stopped. In that moment voltage on the output pin PB0 is set to 5 V and red LED diode D_8 lit on which informs a user that charging is finished. PMOS transistor IRF9540N has very low resistance of 0.12 Ω in the ohmic mode (triode mode). In the ohmic mode PMOS transistor acts as resistor. In that case it is very low dissipation on the PMOS transistor during battery charging. Dissipation on the PMOS transistor IRF9540N is only 7.5 mW for the current of 250 mA, which is the current of a battery charging.

$$P_D = R_{MOS} \cdot I_{BAT}^2$$

where is:

R_{MOS} = 0.12 Ω (resistance of PMOS transistor IRF9540N in the ohmic mode)

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I_{BAT} = 0.25 A (current of battery charging)

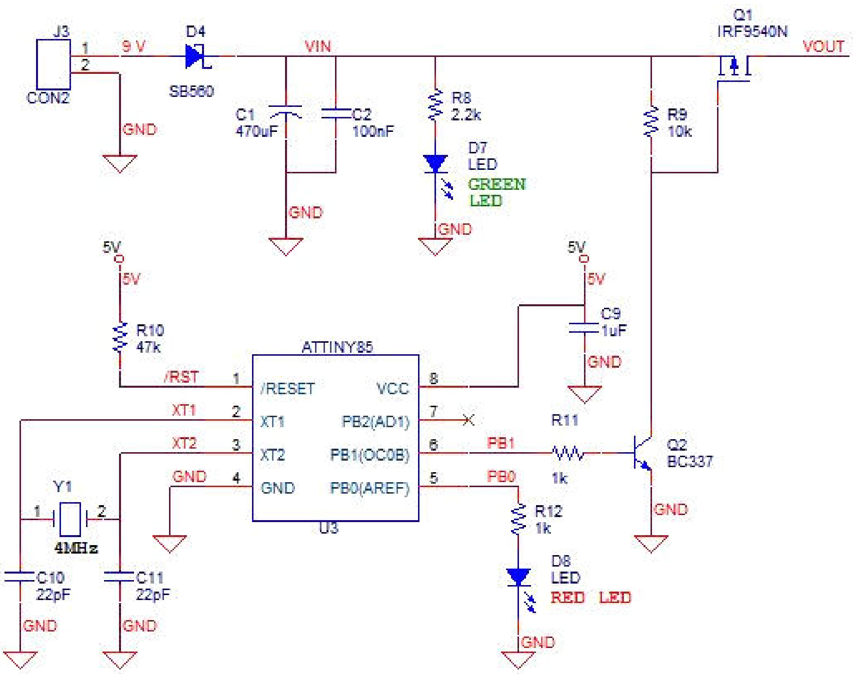

Fig. 4 Connections between microcontroller ATtiny85 and controlled switch

Battery charging is done by current source which is realized by integrated circuit LM317 [5]. Integrated circuit LM317 is multifunctional and it can be used as voltage source or as current source. Integrated circuit LM317 in configuration as it is shown in the figure 5 is used for realization of current source.

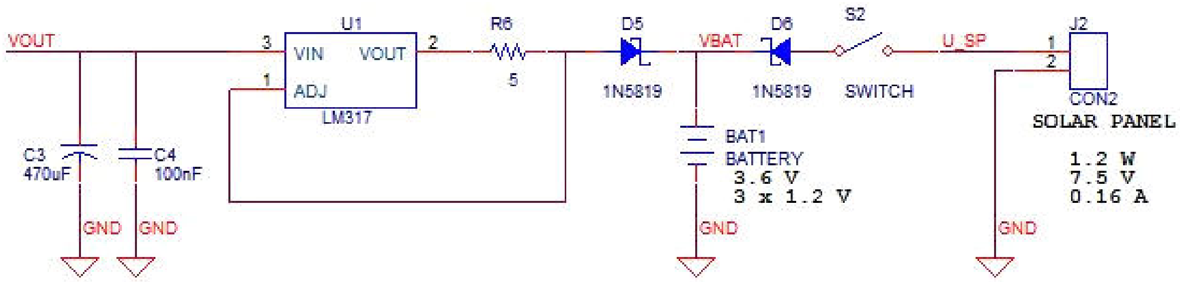

Fig. 5 Realization of battery charging

The current of a current source is matched by resistor R_6 which is connected between two pins of integrated circuit LM317 as it is shown in the figure 5. Voltage reference of 1.25 V is integrated into LM317. The two ends of this voltage reference outcomes on the pins of integrated circuits LM317 on which is connected resistor R_6.

$$I = \frac{U_{REF}}{R_6}$$

where is:

U_{REF} = 1.25 V (voltage of voltage reference integrated into LM317)

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R_6 = 5 Ω (resistor for matching current of current source)
In this case resistance of the resistor R_6 is 5 Ω and in that way current of battery charging is matched to the 250 mA. Higher current of charging NiMH battery enables less time of charging, but it brings to increasing dissipation on the integrated circuit LM317. When dissipation is high it is necessary to enable that cooler on the integrated circuit LM317 be higher and the device must be settled in the metal box with the holes. In the case of the high dissipation plastic box using is not possible. Because of that optimum choice of charging current is current of 250 mA. On the output of the current source, schottky diode 1N5819 is resided. This schottky diode D_5 prohibits battery discharges, when charging is turned off. Battery charging can be realized by a solar panel as well which is mounted on the surface of the box of a device. The switcher and one schotky diode is set between a solar panel and a battery. This schottky diode D_6 prohibits that current goes in the wrong direction, in the solar panel. Voltage of battery sets worked point on the characteristics of a solar panel. In that case voltage of solar panel U_{SP} is:

$$U_{SP} = U_{BAT} + U_D$$

where is:

U_{BAT} - voltage of battery

U_D – voltage on the schottky diode D_6

Current of solar panel is got as intersection of actual voltage of solar panel U_{SP} and current-voltage characteristic of solar panel. Solar panel which is used in this device is solar panel MSX-01 [6]. The power of this solar panel is 1.2 W. This power is achieved for intensity of sun’s radiation of 1000 W/m^2, which respond a very sunny day. In the point of the maximum power usage, voltage of a solar panel is 7.5 V and current is 160 mA. During battery charging, voltage from NiMH cell can be raised to 1.8 V and in that case the battery voltage from the 3 serial connected cells can be raised to 5.4 V. Voltage on the schottky diode is about 0.3 V when charging current is 160 mA. Time for full battery charging, which capacity is 2600 mAh, with the current of charging which is equal to 160 mA, is about 17 hours. From this analysis can be seen that voltage range of battery responds to voltage range of solar panel. Current-voltage characteristic of the solar panel is shown in the figure 6.

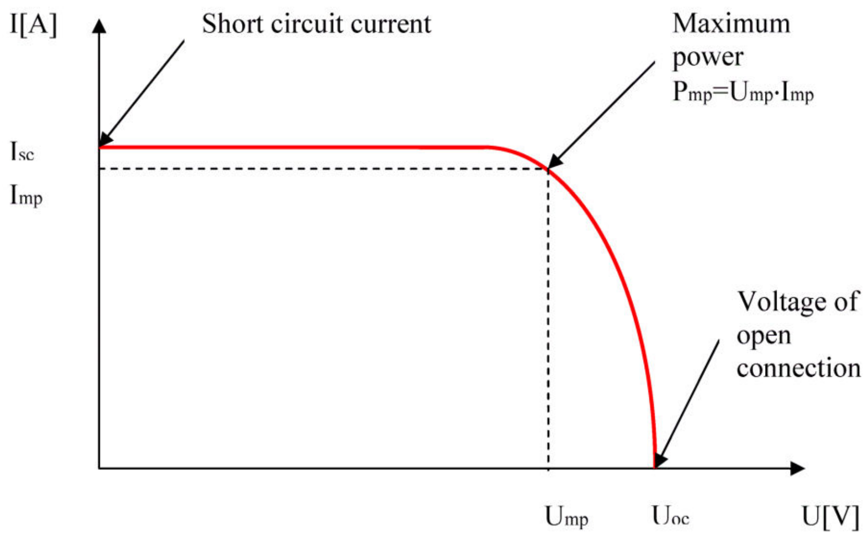

Fig. 6 Characteristic of solar panel

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III. BOOST DC/DC CONVERTER

Boost DC/DC converter raises voltage from the 3 serial connected NiMH batteries, to voltage of 5 V. It is very important that boost DC/DC converter has high grade of efficiency, especially in the case when battery occurs in the input of the boost DC/DC converter. The aim is that the output current of the boost DC/DC converter becomes as higher as it is possible because in that case the time of battery charging is less. Also it is necessary that ripple of the output voltage is negligible. For realization of the boost DC/DC converter is used integrated circuit LT1111-ADJ [7]. This integrated circuit presents adjustable switcher regulator by which the boost DC/DC converter is possibly created. By integrated circuit LT1111-5V or AD1111-5V [8] the realisation of boost DC/DC converter is possible with the output current of 200 mA. By using external transistor with switcher regulator LT1111-ADJ and additional resistors it is possible to increase output current to 500 mA (figure 7).

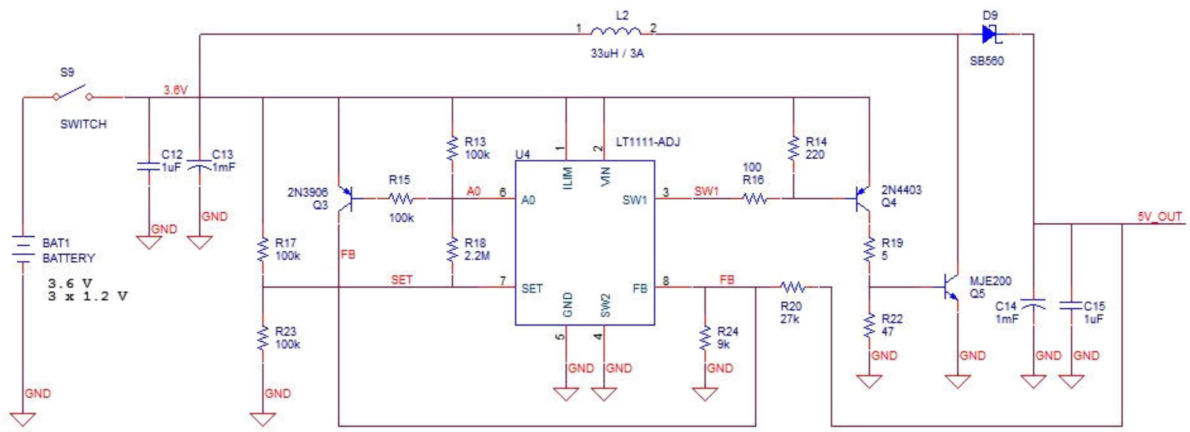

Fig. 7 Boost DC/DC converter based on the integrated circuit LT1111-ADJ

Integrated circuit LT1111-ADJ has integrated the voltage reference of 1.25 V. By this voltage reference and 2 resistors R_{20} and R_{24}, it is possible to set output voltage to 5 V.

$$U_{OUT} = \left(1 + \frac{R_{20}}{R_{24}}\right) \cdot V_{R1}$$

where is:

V_{R1} = 1.25 V (voltage of voltage reference integrated into LT1111-ADJ)

If resistance of resistor R_{20} = 27 kΩ and if resistance of resistor R_{24} = 9 kΩ then the output voltage is U_{OUT} = 5 V. Grade of efficiency of boost DC/DC converter is got by the measurement of the input voltage U_{IN}, input current I_{IN}, output voltage U_{OUT} and output current I_{OUT}. Output current is increased by adding output transistor, but in that case the grade of efficiency of the boost DC/DC converter is decreased because of the dissipation on the output transistor. Grade of efficiency of the boost DC/DC converter is got by the next equation:

$$\eta = \frac{U_{OUT} \cdot I_{OUT}}{U_{IN} \cdot I_{IN}}$$

Power supply of 3 V and maximum current of 5 A, which producer is Meanwell company, is used at the input of boost DC/DC converter for determination of efficiency grade. This input voltage responds to case when voltage of each of 3 NiMH batteries, serial connected, drop to voltage of 1 V. If current of discharging of NiMH battery is too high, in

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respond of the capacity of the NiMH battery, then voltage of NiMH battery drop too low. Grade of efficiency of boost DC/DC converter, which is used in this device, is computed for different current load. In the table 1 the results of measurement of these parameters are presented.

U_{IN} [V]	I_{IN} [A]	U_{OUT} [V]	R_{OUT} [Ω]	I_{OUT} [A]	η
3	1.51	4.52	8.25	0.55	0.55
3	1.23	4.70	10.2	0.46	0.59
3	1.15	4.72	11	0.43	0.59
3	1.05	4.73	11.75	0.40	0.60
3	0.86	4.77	14.33	0.33	0.62
3	0.82	4.77	15	0.32	0.62
3	0.79	4.78	15.67	0.31	0.62

Table. 1 Results of current and voltage measurement on the input and the output of the boost DC/DC converter for different current load

Boost DC/DC converter which is realized by switcher regulator AD1111-5V without using of external transistor has less output current which is about 200 mA, but higher grade of efficiency which is about 90%. In that way the energy accumulated in the NiMH batteries is saved but time of charging battery of mobile phone is much higher. By turning on switch S_9, battery voltage comes to the input of boost DC/DC converter. After that, the output voltage of boost DC/DC converter is the voltage of 5 V. For that time yellow LED diode D_2 lit on as indication that boost DC/DC converter is turned on. Switch S_9 must have very small resistance when it is turn on. This resistance must be maximum 0.1 Ω. It is from the reason that very high current runs through this switch when it is turn on and voltage drop on him must be as much smaller as it is possible. Resistors R_{17} and R_{23} are used to define the down level of voltage of NiMH battery on which boost DC/DC converter works. These 2 resistors R_{17} and R_{23} create splitter of voltage which is used to check voltage from NiMH battery. Voltage from NiMH battery comes to the input of the splitter of voltage. Output of the splitter of voltage comes to the pin 7 of integrated circuit LT1111-ADJ. Inside the integrated circuit LT1111-ADJ resided comparator which compares voltage from pin 7 and referent voltage of 1.25V. Voltage from the pin 7 comes to the positive input of comparator and referent voltage of 1.25V comes to the negative input of comparator. Integrated circuit LT1111-ADJ sets output voltage of the boost DC/DC converter to 0 V when voltage from pin 7 is less than referent voltage 1.25V. Boost DC/DC converter normally works when voltage from pin 7 is higher than referent voltage 1.25V. In that way it sets down the level of voltage of NiMN batteries on which boost DC/DC converter still works.

$$U_{B,MIN} = \left(1 + \frac{R_{17}}{R_{23}}\right) \cdot V_{R2}$$

where is:

V_{R2} = 1.25 V (voltage of voltage reference integrated into LT1111-ADJ)

If the resistance of resistor R_{17} = 100 kΩ and if the resistance of resistor R_{23} = 100 kΩ then $U_{B,MIN}$ = 2.5 V. It is the minimum voltage of 3 serial connected NiMH batteries. It means than minimum voltage of one NiMH battery is 0.83 V on which boost DC/DC converter still works. By USB standard, allowable voltage on the USB connector is in range from 4.4 V do 5.25 V [9]. Realized boost DC/DC converter satisfy this standard and it has stable 5 V, but necessary condition is that NiMH battery is not empty. Maximum current which can be delivered by the USB port of a computer is 500 mA [10]. On the output of the boost DC/DC converter there is protection of overvoltage realized by one schottky diode D_1 and one zener diode D_3 of 5.1 V (figure 8). The maximum dissipation of zener diode is 5 W.

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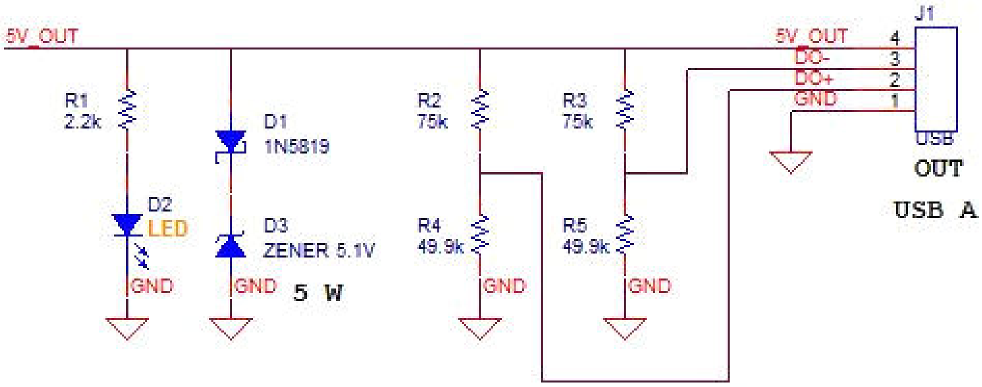

Fig. 8 Protection of overvoltage on the output of the boost DC/DC converter

Protection of overvoltage is set to 5.5 V by which mobile phone is saved. A huge number of electronic devices, which have battery and USB connector, demand only 2 wires for battery charger. One wire is connected to 5 V and the other wire is connected to 0 V. In that case pins D+ and D- can stay open or connected between each other by one resistor. Only few electronic devices, with battery and USB connector, demand that voltages on the pins D+ and D- on the USB connector to be set on the defined value. Because of that, pins on the USB connector D+ and D- are connected with the splitter of voltage (figure 8). In that way pins D+ and D- are set to voltage of 2 V.

IV. CONCLUSION

Always when battery current of discharging is relatively high in response of battery capacity, voltage of the battery decreases below nominal voltage. If NiMH battery is older then voltage drop is higher for the same current of discharging. The reason for this is that older NiMH battery has decreased capacity and its voltage to many drops for higher current of discharging. The NiMH batteries which are used in this device must be relatively new so that this device can work. In that case the output voltage and the output current have desired values. The only way to check capacity of NiMH battery is to fully charge NiMH battery and then connect it to resistor of 2 Ω. If the voltage on the NiMH battery immediately drops below 0.9 V then the capacity of the NiMH battery is too decreased and that NiMH battery is not usable any more. Because of that, a user should to save NiMH batteries and charge them only a few hours before the time of a timer is elapsed. There is the possibility of further development of this device in the direction of the increasing efficiency of the boost DC/DC converter. In that way power losses will be decreased and it is very important because of battery power supply. Also, further development of this device in the direction of increasing the output current of portable device is possible. In that way time of battery charging of a mobile phone will be less.

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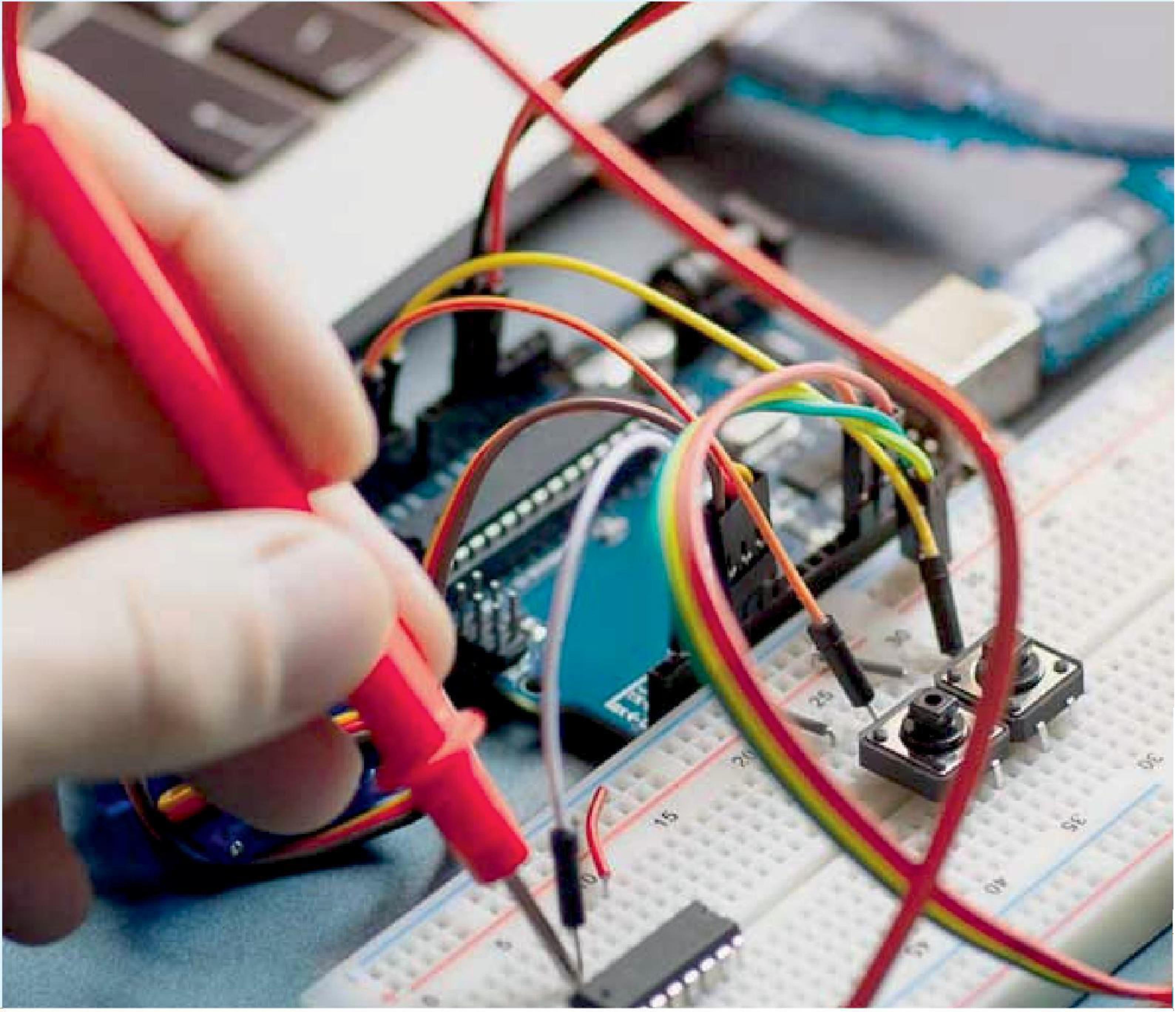
BIOGRAPHY

Vladimir Lapčević was born on the 27th of December, 1977. in Šabac (Serbia). He graduated on the Faculty of Electrical Engineering, department for electronics, of University of Belgrade (Serbia) in 2003. (BSc studies last 5 years). He completed MSc studies on the Faculty of Technical Science, department for measurement techniques, of University of Novi Sad (Serbia), in 2010. (MSc studies last 2 years). He works at the Institute Mihajlo Pupin in Belgrade. Until now, he has published 12 papers as a main author and 3 papers as co-author. His areas of interest are electronics and physics.



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