Minimalistic PWM Power Supply

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For everybody who is into electronics a power supply is an absolute need. We have to power all kind of devices and equipment nearly every day. For that purpose we need a reliable power supply unit which should have precise set of output voltage, digital readout for output voltage/current and over current protection. If a battery charger is added to all mentioned this gives us a winning combination.

Introduction

Those are basic demands for a bench power supply. But time showed that we need more than that. With all kind of rechargeable batteries around us we would also need a universal battery charger. Speaking of batteries it would also be handy to have a battery discharger, which is nice to have at LiPo accus. And because all the world is now turning around LEDs, it would be handy to have a stable current source to power most of LEDs with adjustable current source.

Having all this in my mind I have reconsidered what are my basic needs. Mostly I need DC voltage up to 20V with typically small currents like 0-2 Amps. That is also the limit for current generator, because most LEDs need < 2A of current to glow normally.

Having all demands on the table I have thought to use an AVR MCU, which has built in 10 bit A/D converter, it's got plenty of I/Os and a lot of Flash.

Being an experienced Bascom programmer a SW to produce PWM is not a big deal. See PWM programs in Download section of my web page [1].

To write a PWM program is simple however, to write a program for PWM Power supply, Battery Charger/Discharger, Current source and Voltage instrument is another story. Namely program has to be user friendly. With so many functions on board one has to make menus in a clever way. It is somehow hard to write SW and be SW tester – all in one person. I was lucky here. The core program for the PWM Power Supply was written by my colleague Marko

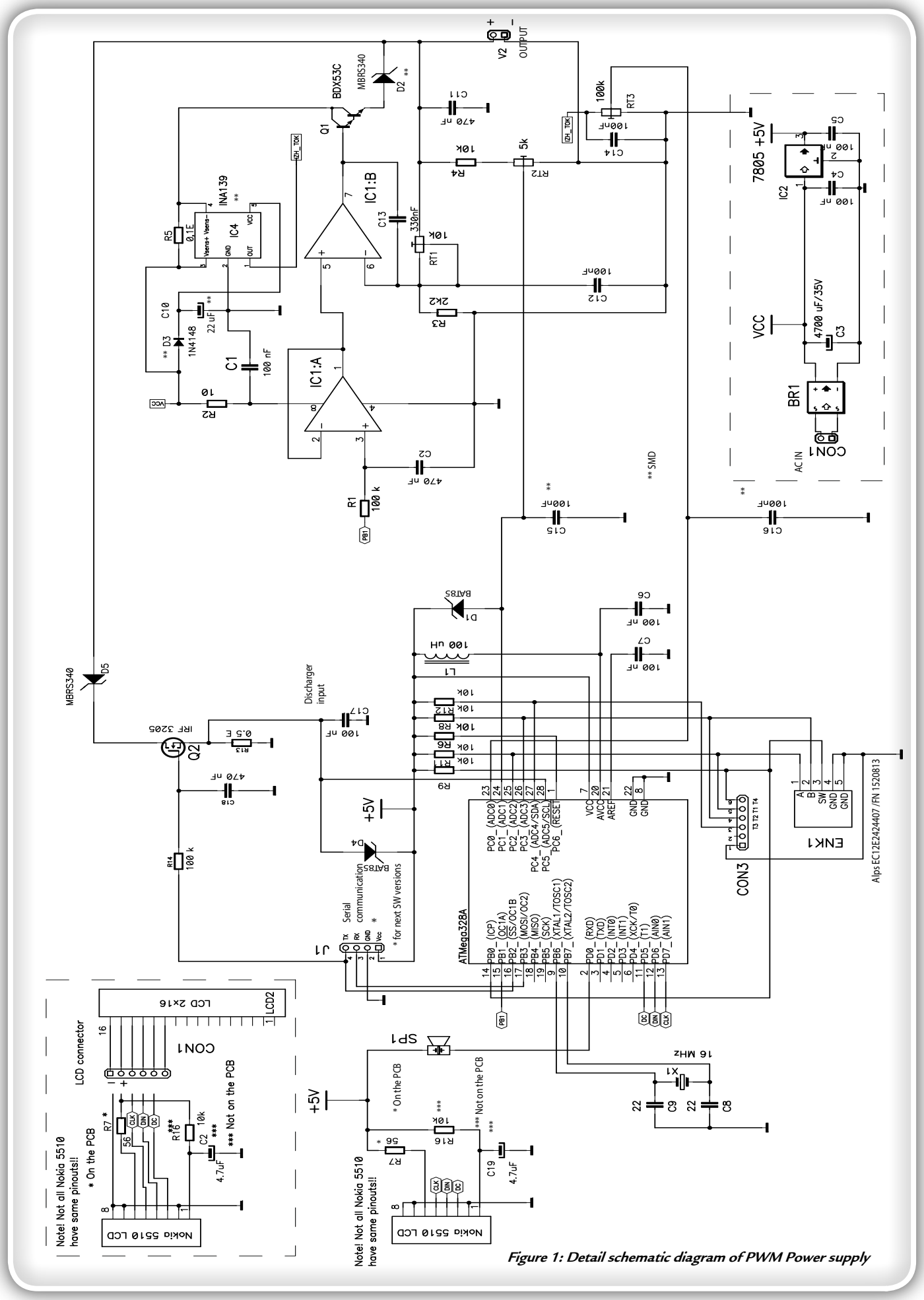

Figure 1: Detail schematic diagram of PWM Power supply

Sajovic [2] and he's done a great job indeed. All nice routines for reading A/D and driving output Opamp with PWM were written by him.

My job was to add to Marko's design a small Nokia 5510 LCD display, replace 6 buttons from his design with a rotary encoder and change menus accordingly. Buttons are nice to operate with however, they take a lot of space on the front panel. On the other hand rotary encoder with a button switch is something that is on nearly any photo camera for setting parameters.

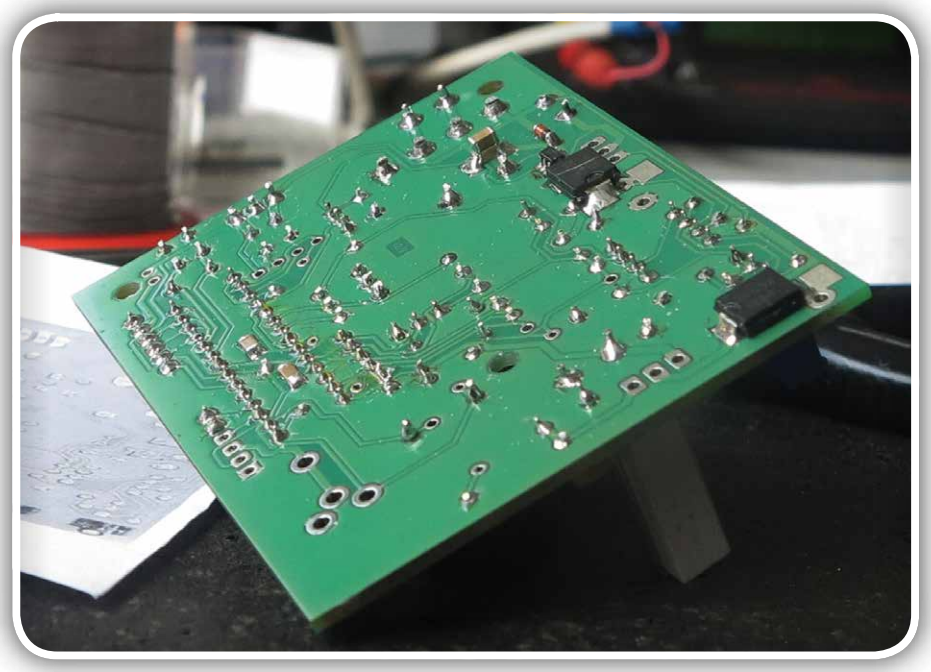

Figure 2: Photo of the Solder side

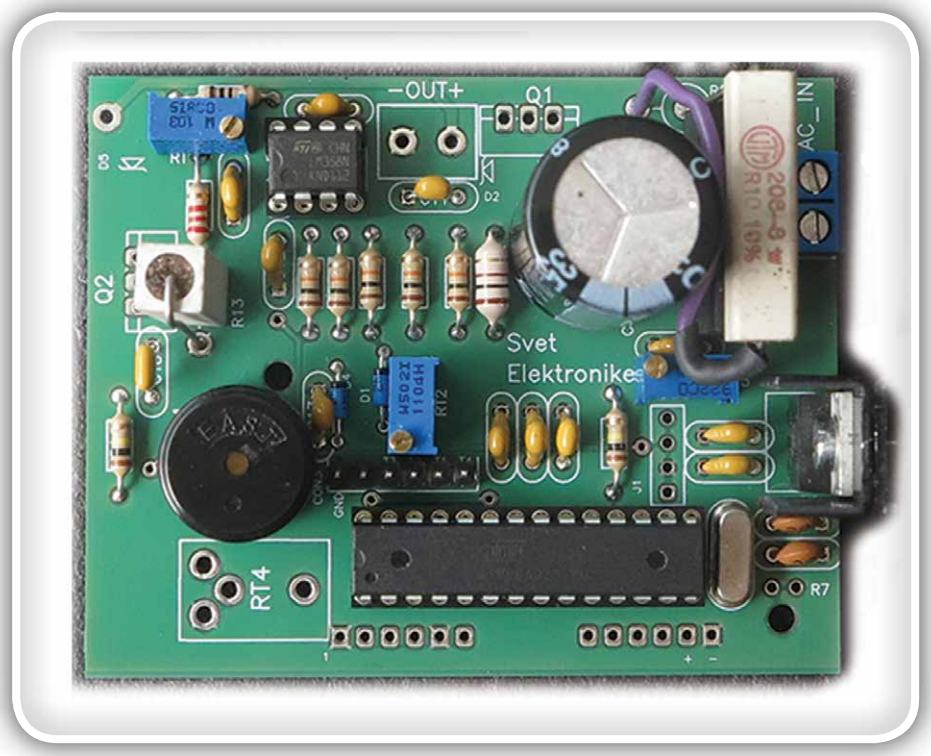

Figure 3: Photo of the Top side

Realization

As a »brain« an Atmega328 was used. It's got an A/D converter, PWM outputs and plenty of Flash memory. To it we added dual Opamp, some powerful transistors and an IC that helps at sensing of output current. See detail schematic diagram at Fig. 1.

There is no revolution in the schematic diagram. ATMega328 has its own circuitry to work normally. Added are decoupling 100 nF capacitors near power terminals. Also note that for A/D input protection a Schottky diode was connected to Vcc. In most designs around the globe as a protection of A/D inputs Zenner diodes are used. This does protect A/D inputs well however a Zenner diode has a knee where Zenner diode starts to conduct already prior to 5V. That knee unfortunately lowers input voltage and hence bad accuracy of voltage measurements. Schottky diode however does not introduce any voltage dropdown. Schottky diode will start to conduct when input voltage will exceed 0.2 Volts higher than Vcc. That effectively protects inputs which can handle voltages up to 0.5V higher than Vcc.

In the schematics you will notice also two op-amps that handle filtered PWM signal that comes from the AVR. You will also notice RT1 which sets output voltage to a level that we desire.

INA139 IC is the heart of current measurement. It measures voltage drop across R5, amplifies it and with RT3 sets it to a value that corresponds to actual current flow through R5. This voltage is fed to A/D input of AVR.

To that circuitry output power transistor is added. We have used Darlington transistor BDX53C because it's cheap and it can handle output current with ease. You will notice D2 diode connected to Emitter of the output transistor Q1. This diode protects Q1 when PSU is used as battery charger/discharger. Speaking of discharging you will notice Q2, which is driven with another PWM signal that sets discharge current to a suitable value. Discharge current is measured »directly« as a voltage drop across R13.

You will notice on the schematic also a beeper. I can tell

you from personal experience, that a beeper does help a lot when setting parameters with rotary encoder. Rotary encoder has a switch embedded and this switch also helps when setting parameters.

Also you will see a LED (LED1) that is not placed on the PCB, but it serves as optical indicator that output is »alive«, i.e. that there is a voltage present at output terminals generated either with voltage generator or current generator. It's handy to have such a LED because user quickly sees if output terminals are »live« or not.

Construction

PWM power supply is based on double side PCB with mostly »classically« through-hole (THT) components. There are few SMD capacitors, INA139 and two SMD diodes to solder on the solder side. I suggest firstly to solder SMD parts and then solder THT resistors, IC sockets, capacitors etc.

After checking for unwanted shorts on the circuit that may happen during soldering your PCB is ready to connect to power transformer.

Warning: Power transformer is connected to mains 230V (in USA 115V) AC high voltage. If you're not skilled person to handle connection of power transformer to mains AC avoid doing that.

Power transformer basically has two windings: primary and secondary. How one can tell which is which? That is easy, take a universal measuring instrument and measure resistance

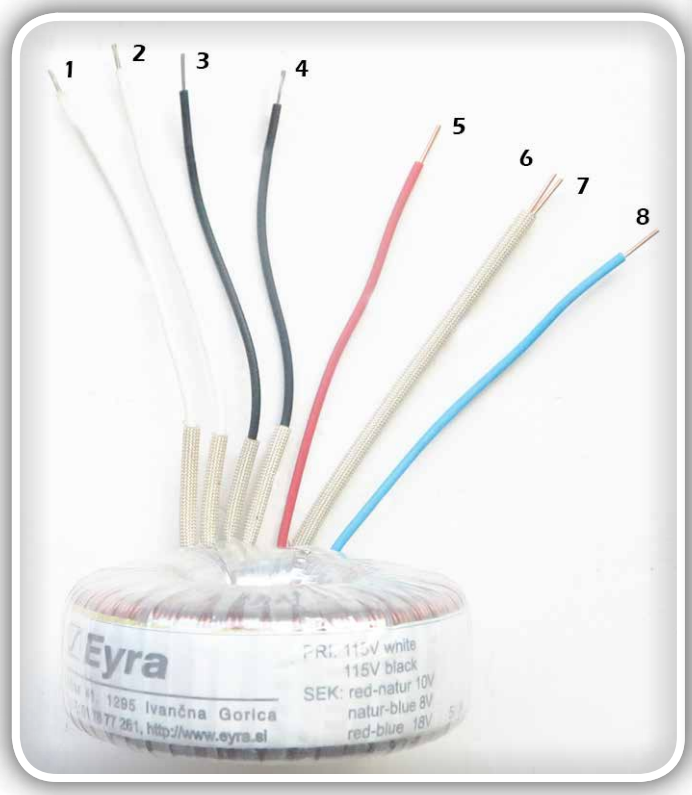

Figure 4: Photo of transformer windings (White_1,2: W1; Black_3,4: W2; Red_5; Natural_6,7; Blue_8: W3)

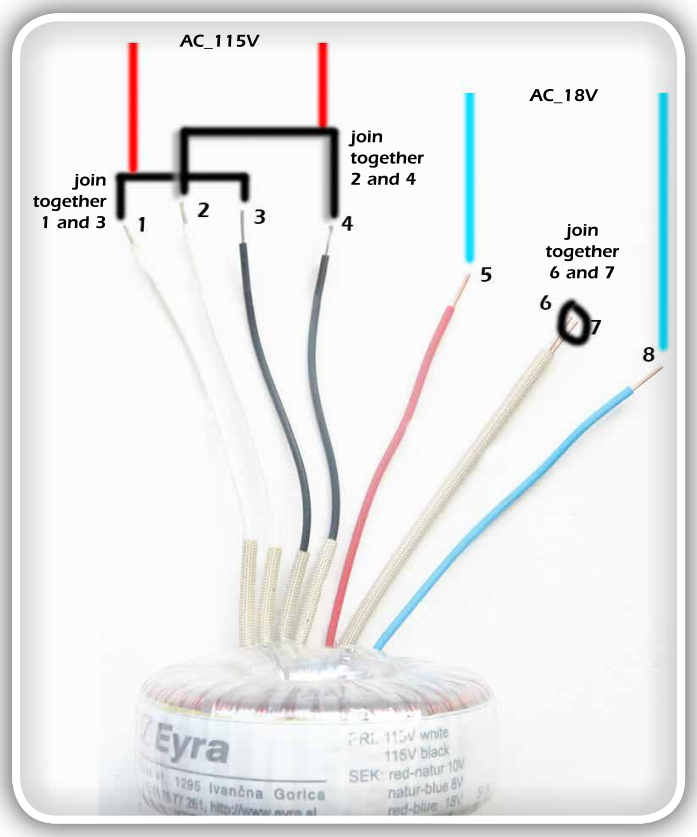

Figure 5A: US users connect primary windings in parallel as shown

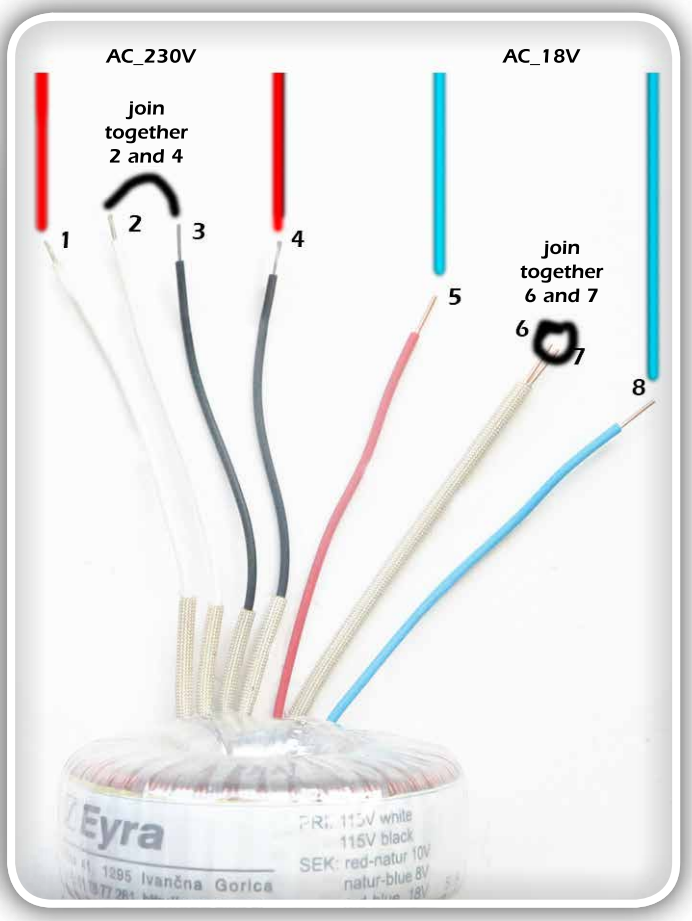

Figure 5B: EU and other users with 230v AC connect primary windings in series as shown

Figure 7A: Connect resistor, capacitor and a short wire to the LCD

on each winding (**without connecting transformer to mains AC!**). Primary winding is the one that has higher resistance, secondary winding has lower resistance.

US customers connect windings W1 and W2 in parallel as described in the Fig. 5A, while EU and other users that have 230V AC mains connect windings W1 and W2 in series as shown in Fig. 5B.

Secondary winding W3 consists of 3 wires: Red, two wires

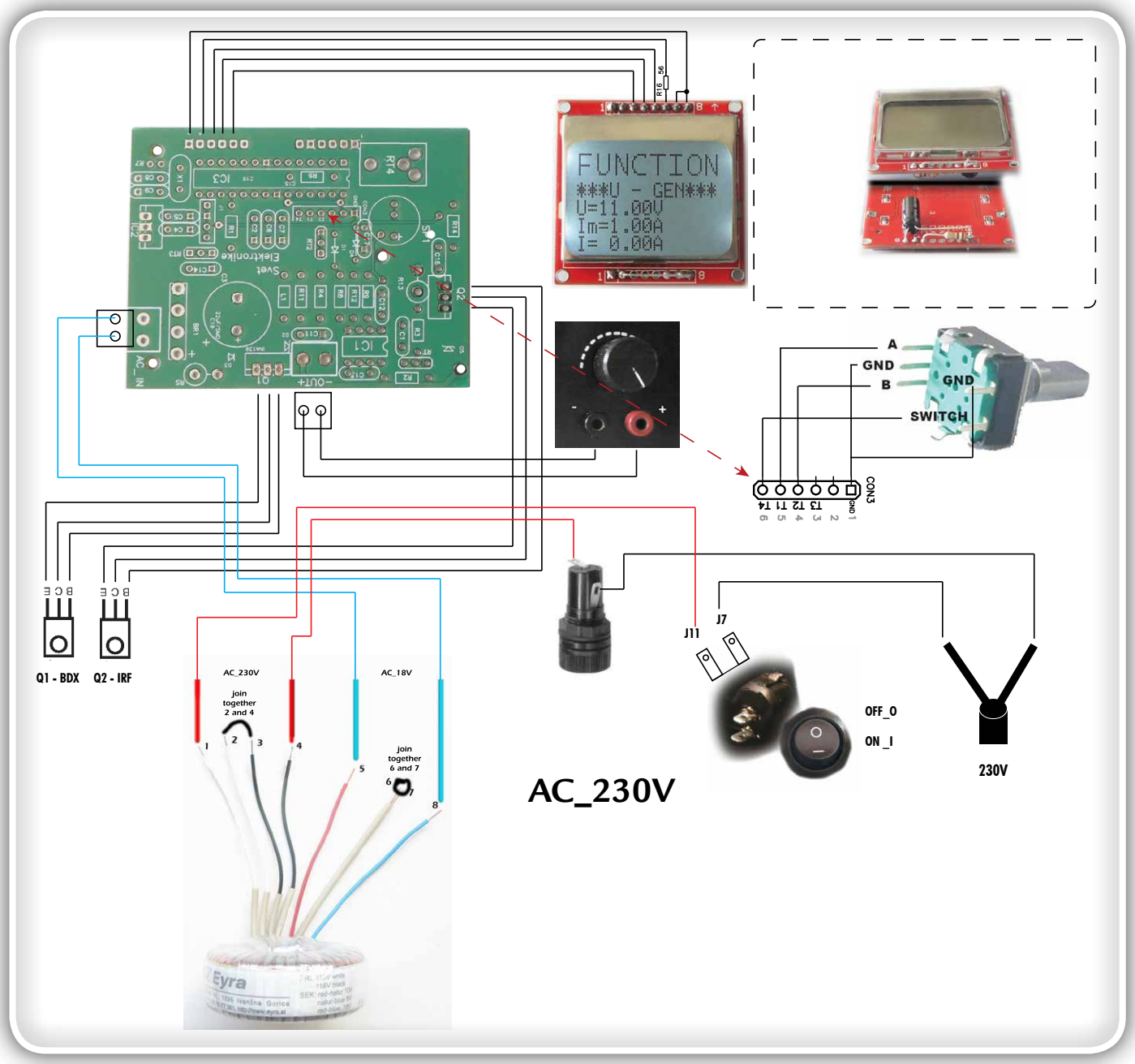

Figure 6: Inside finished PWM power supply (230V)

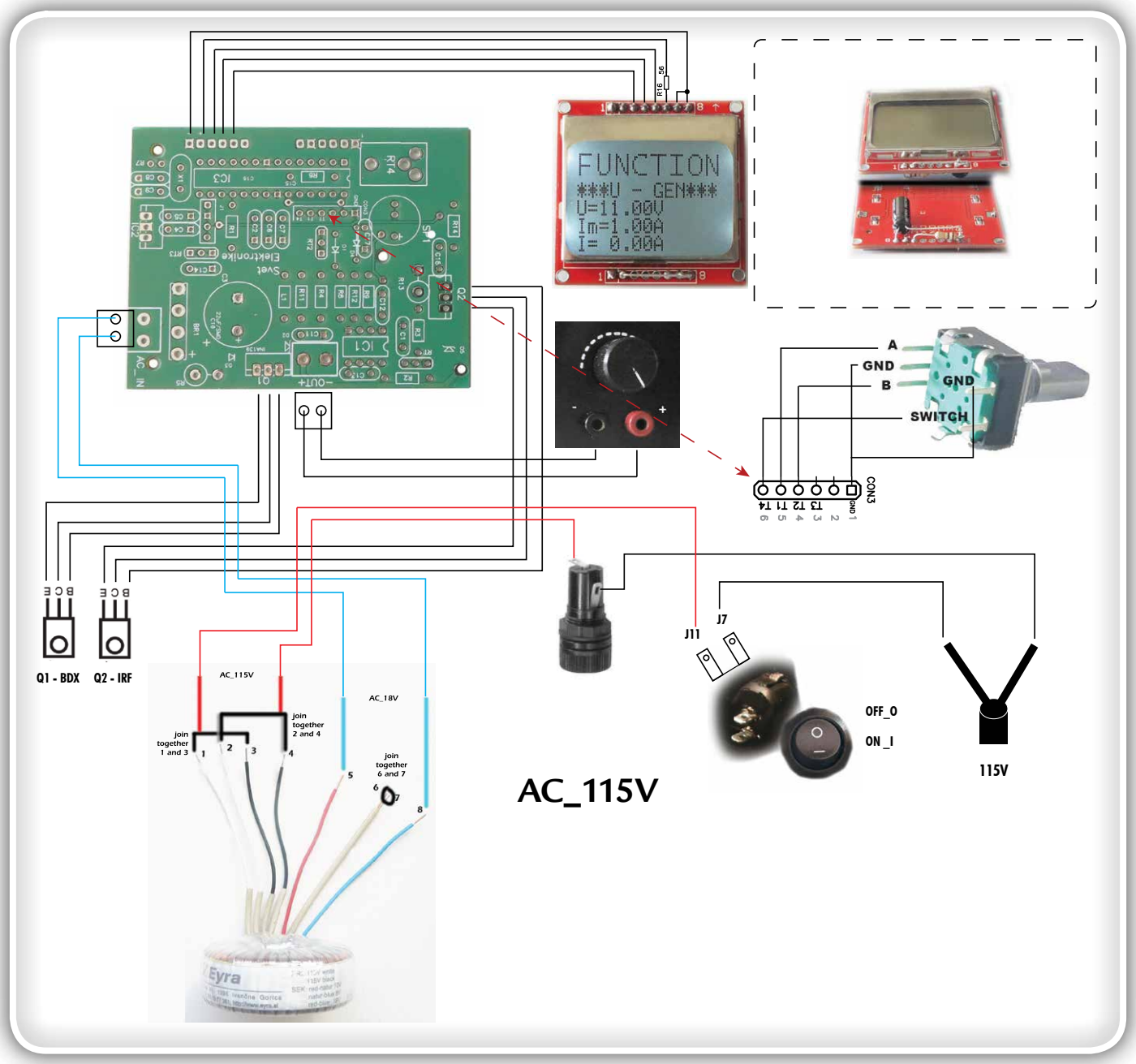

Figure 6A: Inside finished PWM power supply (115V)

in Natural sleeve and Blue wire. Connect two wires in the Natural sleeve together.

Connect primary winding to mains AC power via power switch in OFF position. Now connect secondary winding to PCB where AC IN is indicated (Fig. 6).

LCD display does need few components to work well. See Fig. 7A to see how to connect resistor, capacitor and a short wire to the LCD.

PWM power supply uses rotary encoder with switch to select menu items. Connect rotary encoder as seen in the Fig. 7B and 7C.

Placing LCD to enclosure is easy if you follow instructions.

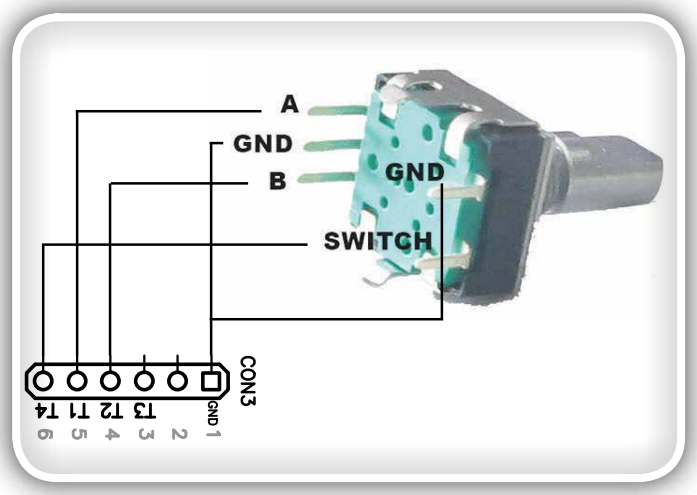

Figure 7B. Connect rotary encoder

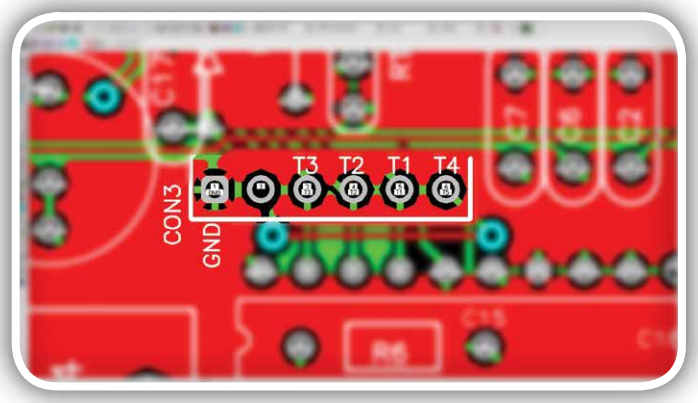

Figure 7C: There is a place on the PCB where you should connect rotary encoder

- Connect universal measuring instrument to output sockets and set it to Voltage measurement. With RT2 set voltage on PWM LCD to match measured voltage on measuring instrument.
- Set PWM PSU to low voltage (for example 1.0 Volt) and check that on universal instrument it should also show 1.0 Volt. If it does not repeat points 1 & 2 to get best result.
- Disconnect measuring instrument, set it to measure current, connect it in series with a load which should be connected to PWM output sockets (if you don't have suitable load, use an old lamp of car headlamps.
- Turn on PWM PSU, select I-GEN, set Is= 50 mA and make sure that measuring instrument and load are in

Before you start to apply double side sticky tape to back of the front plate, remove protective foil from the front plate. Then follow instructions on the images (Fig. 7D, 7E and 7F)

Turn on the mains switch and PWM power supply should wake up with displaying FUNCTION in the top line, while in lines below you will see U-GEN, V= XX.xxV, Im= YY.yyA, I = 0.00A.

Figure 7D: Double side sticky tape, LCD and front plate

Figure 8: Select function

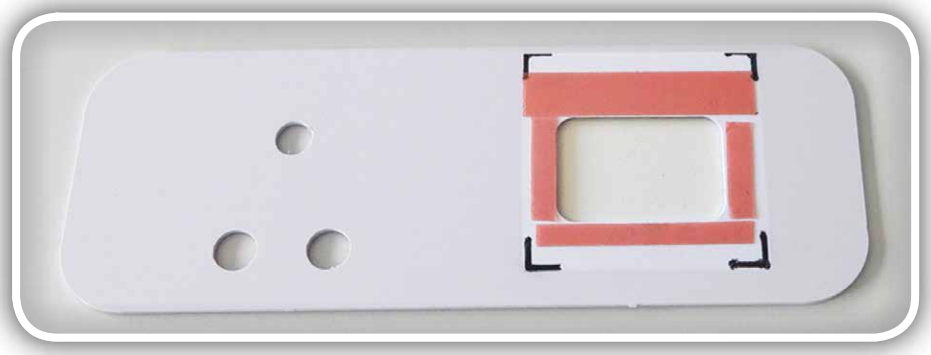

Figure 7E: Cut and apply double side sticky tape to marked places

Calibration

Now it's time to calibrate your PWM power supply. In the procedure you will need universal instrument for measuring voltage and current. Calibration is simple:

- Set PWM PSU to U-GEN and press encoder. You will see U= XX.xxV in the upper line and Im=YY.yyA I=0.00A in the lower lines. Set RT1 to max. Voltage that should be min. 3V lower than DC voltage measured on the AC/DC diode bridge. Normally we set that voltage to 20.46V.

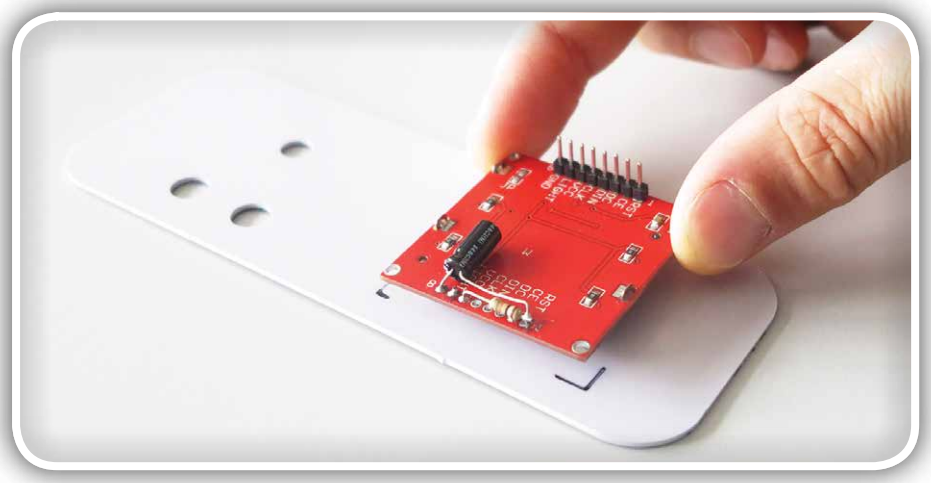

Figure 7F: Remove protective foil from the LCD and stick gently to marked places

series connected to output sockets. Now press encoder switch shortly so that you hear s short beep. You should read some current at measuring instrument. With RT1 set Im on PWM PSU LCD display to show same as you read on measuring instrument. Repeat that with different current values to make sure that PWM LCD display shows correct value of output current displayed as Im. Also note that Measured current »Im« will »jump« over Set current »Is« with a small change of current. That is normal behaviour because PWM PSU measures current and compares it with set current value. If it is not the same value MCU corrects it.

And you're done – PWM PSU is set and ready for use.

Figure 9: I-Gen menu

Using PWM power supply

Using PWM power supply is very easy. Menus are simple and without a guide you will quickly understand what's all about it. When PWM PSU turns on you will see the menu *U- Gen*, which corresponds to Voltage generator. By turning encoder knob to the right you will see in the menu: »*I-Gen*«, »*Charge*«, »*T-OFF*«, »*I-OFF*«, »*Measure V*« and again *U-Gen* which corresponds to Current generator, Charger (and discharger), Setting Cut-off time, Setting Cut-off current, Voltage measurement and Voltage generator respectively.

I- Gen menu is straight forward.

When pressing encoder switch you will see a message »Turn On«, below that you will see U=0.00V and »Is=Y. yyA« (whatever current you have set). »Is« represents stable output current that you can set by turning encoder, while U represents voltage measured at output terminals. **Important!! Please connect a load to output sockets PRIOR to turning on current source**.

After you've set output current and connected load to output sockets you can turn on current source by short press to encoder switch. You will see set current (Is on lower line) and measured current (Im on top line). To turn off current source shortly press encoder switch. If you wish to return to main menu press & hold encoder switch for approx. 2sec. You will hear 2 short beeps and you will be back in the main menu again where you select function.

Figure 10: Charge menu

»Charge« menu is next menu.

Make short press to encoder switch to enter Charge menu and you will see Accu selection menu »ACC TYPE«. In the bottom line you can select desired accu by turning encoder left/right. You may select from NiCd (Nickel Cadmium accu), LiPo (Lithium polymer accu), Pb (Lead accu) and Timer. In Timer selection you can set desired time during which charger will charge battery according to preset current needed to charge particular battery. You can set that current at your choice.

When selecting NiCd (and also Lipo/Pb), the system asks you how many cells you want to charge. Then you can set Charging current, Time to charge, Delay to charge and charging menu, where you can select from: Charge, Discharge and Discharge/Charge. If you select any of last three you will see on display »Connect« on the top line and »Start« at bottom line.

»T-OFF« and »I-OFF« are menus where you select Time to cut power from output sockets in case of overload. Same goes for I-OFF where max. current is set.

»Measure« menu serves for simple measurement of voltages in range of 0 to 20V.

Conclusion

There are many gadgets that an average electronics fan needs to power. Most of these gadgets require low voltage and low power for their work. Estimated highest output voltage proved to be chosen right. Namely after years of using PWM power supply I have only once needed 29V. As for the output current capabilities I've coped with 2A capability. What the PWM gives me extra is current source (for LED testing), current limit (very handy for prototype testing), battery charger/discharger for quick charging and simple voltage measurement. All this with a nice digital readout can be packed in a small enclosure which all together gives great satisfaction at its use. I love my PWM, make one for yourself and surely you'll love it too!

About the author

Jurij Mikeln S52CQ, publisher & owner of Svet Elektronike magazine, received his B.Sc. in Electronics Engineering from the University of Ljubljana. He has been programming in Bascom for over 15 years. He has written four books about Bascom topic and published many Bascom - related articles in Svet Elektronike. Over the last three years he has presented Bascom seminars for programming newbies, covering basics of Bascom programming. With more than sixty seminars under his belt, Jurij has got extensive insight into what a “programming newbie” needs to know

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to quickly start microcontroller programming. All this, combined with a personal flair for easy, innovative programming insures that seminar attendees and readers of his books will get the best training when entering into the interesting world of programming microcontrollers.

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