

Power -Supply

DC-Power -Meter Module 2.0

published in Elektor 01/2008 (v1.16a)

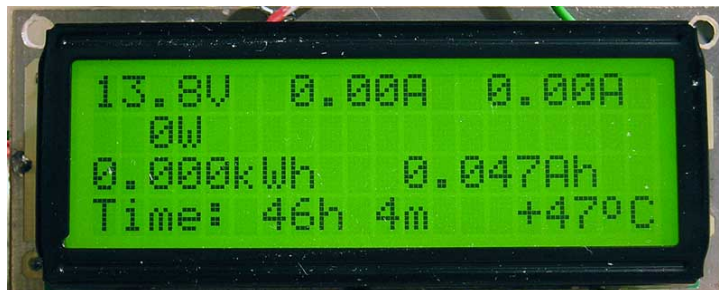


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Power-Supply DC-Power-Meter Module ^{2.0}

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Description and operation

In cqDL 12/2006 – German Amateur Radio Magazine – I described an “Shack DC-Power Meter”. Through the many proposals and suggestions I have received, here comes a module version which will upgrade a conventional power supply unit.

The complete module performs the following functions and indications:

- 2x16 or 4x20 character DIP LCD Module, see text
- Voltage in Volt (0 – 30V).
- Current in Ampere (0.1 – 5A or optional 0.1 – 50A, JP1)
- Peak current.
- Electrical power in Watt (1 – 9999W).
- Electrical work in Kilowatt-hours
- Ampere-hours (capacity) for battery operation or for batterie charging.
- ON-time in hours and minutes, after one week in days.
- Heat sink or battery temperature (with optional temp. sensor).
- Bar-graph-indication for Power, Ah, ON-time and temperature selectable by pushbutton
- The selected indication will be stored in an EEPROM (only with 2x16 display)
- Ah or I_{max} indication can be selected by a jumper (JP2) (only with 2x16 display)
- LC-display with either 2x16 or 4x20 DIP module (see below)

- LC-display with backlight illumination.
- LCD and measuring board as a module version (sandwich)
- Power measuring range for the bar graph depends on jumper (JP1) setting:
open: 50 Ampere or 800 Watt, closed: 5 Ampere or 150 Watt.
- Choice of 2x16 or 4x20 character LCD requires different firmware.
- Optional Crystal-version is more accurate than RC-oscillator (30 ppm instead of 1%).
- With undervoltage (10.8V) the output will be switched off automatically with jumper JP3 closed and the optional relay installed.

New in version 2.0 with 2x16 or 4x20 LC-display:

- ATmega168 controller for additional functions.
- Free choice shunt 1 or 10 milliOhm or 60mV DIN shunt up to 400 A
- Selectable bar-graph sensitivity from 60W to 4200W with overflow indication.
- The readings of Ah, kWh and ON-time will be stored every 3 minutes in the EEPROM
- Long-term measurements can be deleted by using the adjustment menu.
- Display of long-term measurement values during normal operation by pushbutton Operation or during power-up.
- Serial output (RS-232) of measurement values U – I – P – W – Ah at 9600 Bd, evaluation with “Putty/Excel” possible. (see Note 2).

For a compact design, a DIP LCD module is used. This module has on both sides a 9 pin bar which fits into female connectors on the measuring board which includes the necessary drilling holes for the front panel mounting.

For a compact design, a DIP LCD module is used. This module has on both sides a 9 pin bar which fits into female connectors on the measuring board which includes the necessary drilling holes for the front panel mounting.

With first power-on the operator is requested to adjust the indicated voltage: The pushbutton has to be depressed repeatedly until the display indicates the same voltage as a reference voltmeter, connected directly to the power supply. This should be done at 13.8 Volts and no load for the power supply and calibrates the internal voltage divider and the micro-controller. After 10 seconds the setting will be stored in the EEPROM. If recalibration is necessary, hold the pushbutton depressed during power-on until a notice on the display appears and repeat the above procedure. (For additional software-settings see below)

For a second adjustment the operational amplifier for current measurement has to be calibrated. With a reference ammeter the actual current must be checked and the ampere-display has to be corrected by adjusting the variable resistor PT2.

Finally the contrast of the LC-display is adjusted by the variable resistor PT1 (only with the 2x16 display) – no further adjustments are necessary.

If the temperature sensor LM335 is used for monitoring the heat-sink temperature or the battery, it must be calibrated too: Connect terminal "T-Adj." (contact 16 on IC1) to ground rises the indicated temperature by one degree Celsius. After reaching 20 deg. the value will go back to the starting value. The final setting will also be stored in the EEPROM after 10 seconds.

The buildup is done completely without SMD components in order to make the replica as easy as possible. All ICs are socket-mounted, and only precision sockets should be used. The most expensive component is the current shunt, its resistance value is very low to keep the voltage drop as low as possible. A shunt with 1mOhm and separate voltage sensors has to be used. For the 5 Ampere-version, a 10mOhm shunt has to be used and jumper JP1 has to be closed. To avoid false readings, the shunt is located in the positive power line (see schematic). Due to this OP-circuit, a current measurement is possible only with an output voltage above 4 to 5 volt.

During normal operation, voltage, current, peak current and electrical power will be indicated. The peak current is displayed right at the top, but because of lack of space without unit (on the 2x16 LCD only). This value will be updated every second until no measured value is greater than the previous measured ones and will be indicated.

Pressing the pushbutton on the display switches the bar-graph display from peak-power to electrical work, ampere-hours, ON-time and temperature and vice-versa, because on the little LC-display (2x16) is not enough space for all information the system can provide. By measuring the ON-time, a direct link of the electrical work and the elapsed time (or days) is possible.

When using the 4x20LCD version, all available data will be indicated at the same time and the pushbutton will function with firmware 2.0 with another function.

For battery operation the capacity measurement in ampere-hours was added.

With jumper 2 (JP2) open, the standard function will be active (see above).

Closing JP2 indicates ampere-hours instead of peak current, this can be done during normal operation. An additional toggle switch on the front panel could be used if the functions are to be changed frequently.

Due to the large current measuring range from 0 to 50 ampere a resolution of 50 milli-amperes per digit is obtained because the A/D converter a maximum of 10 bit can resolve. Additionally an error of +/- one to two digits caused by the A/D converter quantization noise can occur. With a current flow of 10 amperes the indicated error is approximately 1 percent or 100 milli-amperes. In the 5 ampere version the resolution is approximately 10 times better, say 5 milli-amperes and a 10mOhm shunt should be used.

The error is a bit less for voltage measurement, because here a resolution of 30 milli-volt per digit is achieved. These measurement errors can be tolerated and are in good relationship for cost/expense and the measurement accuracy.

Increasing the accuracy even more can be done by replacing the RC-oscillator by an 8 MHz crystal and C11/12. Additionally the "Fuse-bits" have to be set correctly (for crystal: CKSEL=1111 / for internal RC-oscillator CKSEL=0111) and please note the actual configuration.

NEW V1.16a: For portable operation (battery) an undervoltage monitoring has been added. Due to lack of space the components (relay and switching transistor) have to be mounted externally but are shown on the schematic. This function normally is not active, but operates with JP3 grounded. When the supply voltage drops below 10.8 volt, pin 17 of the micro-controller goes to 5 volt and can activate the external relay to switch off the load. At 11.8 volt the function is reversed and the relay is not longer energized (normal operation). These voltages have been selected to prevent the output relay from continuously switching on and off. An undervoltage detection will be indicated on the display.

NEW Firmware 2.00: Additional functions will be available with the new firmware and will be explained below. Adjustment at first power-on:

A regulated power supply (13.8 Volt, 200 milli-amperes set) should be used for safety reasons and to prevent any damage to the unit.

After switching the power on, a welcome note is displayed and the long-term data are shown. Due to the fact, that the EEPROM is still empty, only "1" will be indicated.

This is followed by the "configuration-section":

1. Selection of the current shunts, default 1/10mOhm or 60mV DIN up to 400A.
2. Adjustment of bar-graph sensitivity from 62 to 4200 watt.
3. Erasing the long-term data Ah, kWh and hours (for later).
4. Activate and delay setting for serial data transmission to the COM-port.
5. Adjustment of the voltage measurement with a separate DMM.

All adjustments will be made by the pushbutton. If the selected value is OK, just wait 10 seconds and the respective value will be taken. Before adjusting the voltage, a note on the display will appear which has to be confirmed by the pushbutton and after adjustment point 5 all settings will be stored in the EEPROM. The module now is ready for operation.

If an adjustment has to be repeated, the pushbutton must be depressed during power-on until a note on the display appears – the rest will be self-explanatory.

During normal operation pressing the pushbutton allows the indication of the entire stored long-term data, otherwise this information is available during power-on.

From 40 days continuous use, instead of hours only days will be indicated. The maximum indication for ampere-hours is 9999Ah, for electrical work 999 kWh.

To evaluate the measurement data with a personal computer, this can be done by a program named "PUTTY" [2] in connection with EXCEL. Data will be sent at 9600 Baud with the previously selected interval which can be set from 1 to 9 seconds, from 10 to 600 seconds in ten steps and above 600 to 3600 in 60-steps in the configuration menu (max. 60min). The string is as follows:

```
;/12.28;1.613;019;0.008;0.830;23  
/; U ; I ; P ; kWh ; Ah ; Temp
```

I have made a small EXCEL-macro [3] which uses the PUTTY-log, generates a table and finally a graphic diagram. Anybody who wants to create a little WINDOWS-program, is very welcome!

For a simple data transfer via USB a small circuit board is in preparation which converts the 5V TTL-signal into USB level and simulates a com-port in the PC.

By using an internal dynamic shift within the EEPROM memory cells a permanent record of 17 years is possible, after this time read-errors may occur.

The measured values are stored every three minutes in the EEPROM. To prevent data loss, do not switch off the power during this time! To indicate this, the display will show "WRT" instead of the "time" for approximately 10 seconds during writing.

The construction should be self-explanatory, see enclosed pictures.
A programmed micro-controller and printed circuit boards are available at cost price and the firmware can be sent by E-mail.

An option of **Wolfgang Baumert** allows for the measurement of electricity from 0V when the module is supplied externally. This is a relief -5V voltage and 2 small interventions in the layout required (only up layout V1.64). The conversion describes page 19 of this manual.
From the layout version V1.65 is only required JP5, open for -5V option and closed the JP5 for standard config without -5V.
On solder-pad "-5V" simply the auxiliary power source here.

The following documents are available on <http://www.dg7xo.de/selbstbau/nt-power-modul.html>:

The complete structure for downloading => nt-power-modul2.pdf (this PDF)

- A small video of the bar-graph-display at SSB-modulation on 100W on 80 m for the demonstration of the Shack-Power-Meter (4,7 MB).
- Important notice to FET BS250 (Q1) : DC-power-meter info bs250.pdf!!!
- The firmware is available in the format HEX and BIN for both printed circuit boards version 1.16a and 2.00 and can be requested via E-mail

73 de Oliver, DG7XO

NOTE:

The following versions are currently available:

- V1.16a with 2x16 or 4x20 LC-display, excluding 2.0 funct. µC ATmega8 ger/eng
- V2.00e with 2x16 or 4x20 LC-display only including 2.0 funct. µC ATmega168 ger/eng

Some operational amplifiers TL081 showed greater temperature response (e.g. TI).
Use type TL071 and adjust the current at operating temperature!

Important: JP5 under IC3 must be closed, who is not using the -5V option, it is the standard version! Otherwise, the current measurement does not work !!!!!

Who the blue LCD DIP type EA DIP204 B 4NLW want to use, must R2 bridges and R3 from 10Ω to 39Ω increase, because the LED current is smaller! (Reichelt-Order No.: LCD 204BL-4 DIP)

[1] DC-Power-Meter für das Shack , O. Micic, Amateurfunkmagazin cqDL 12/2006
<http://www.cqdl.de/cqdlarchiv/2006/inhalt0612.pdf>

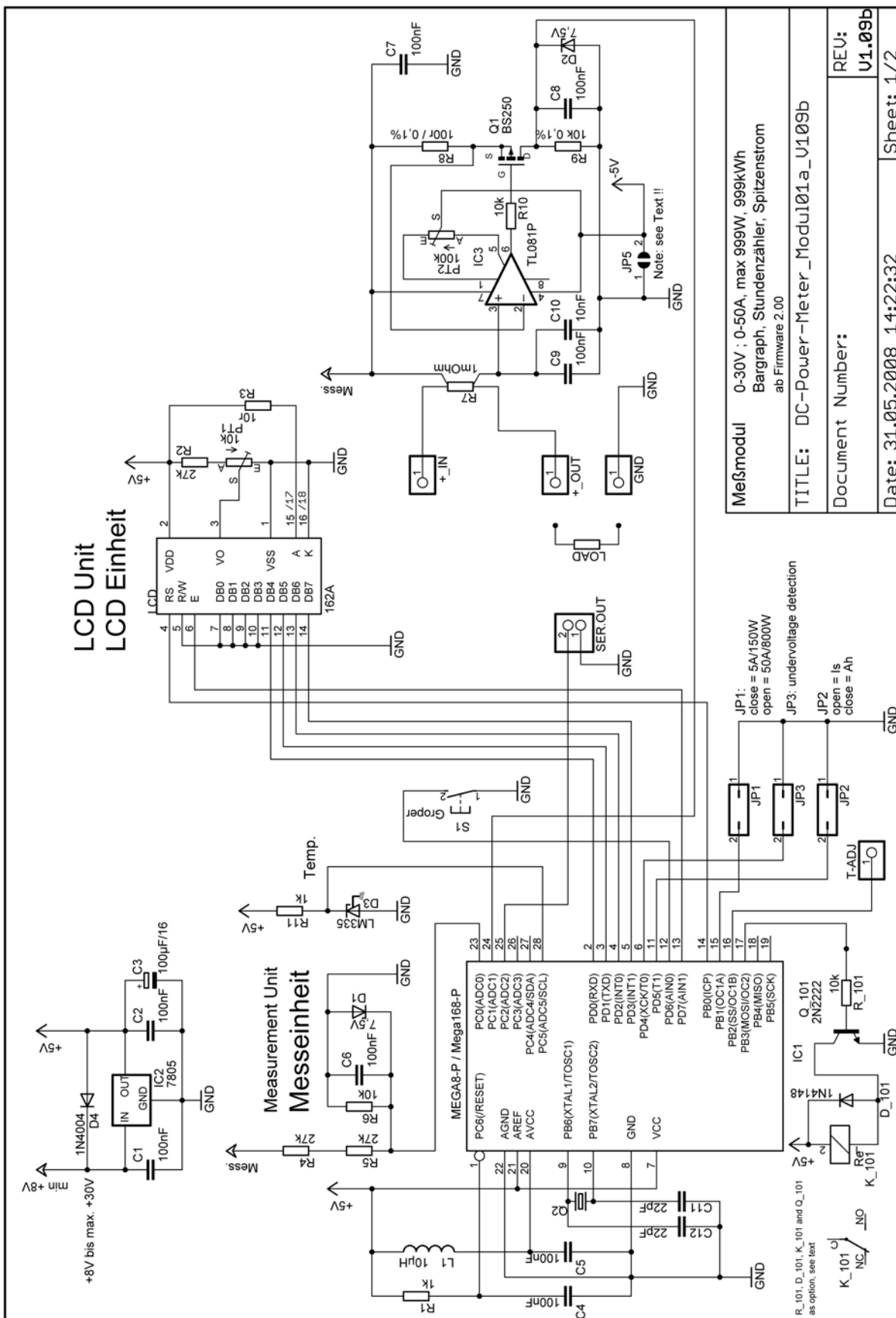
[2] Terminal Program PuTTY, Simon Tatham
<http://www.chiark.greenend.org.uk/~sgtatham/putty/download.html>

[3] Excel Macro for first steps, order via eMail

[4] „Vielseitiges DC-Power-Meter“, O. Micic, Elektor Ausgabe 445, 01/2008 (german)
<http://www.elektor.de/jahrgang/2008/januar/vielseitiges-dc-power-meter.321545.lynkx>

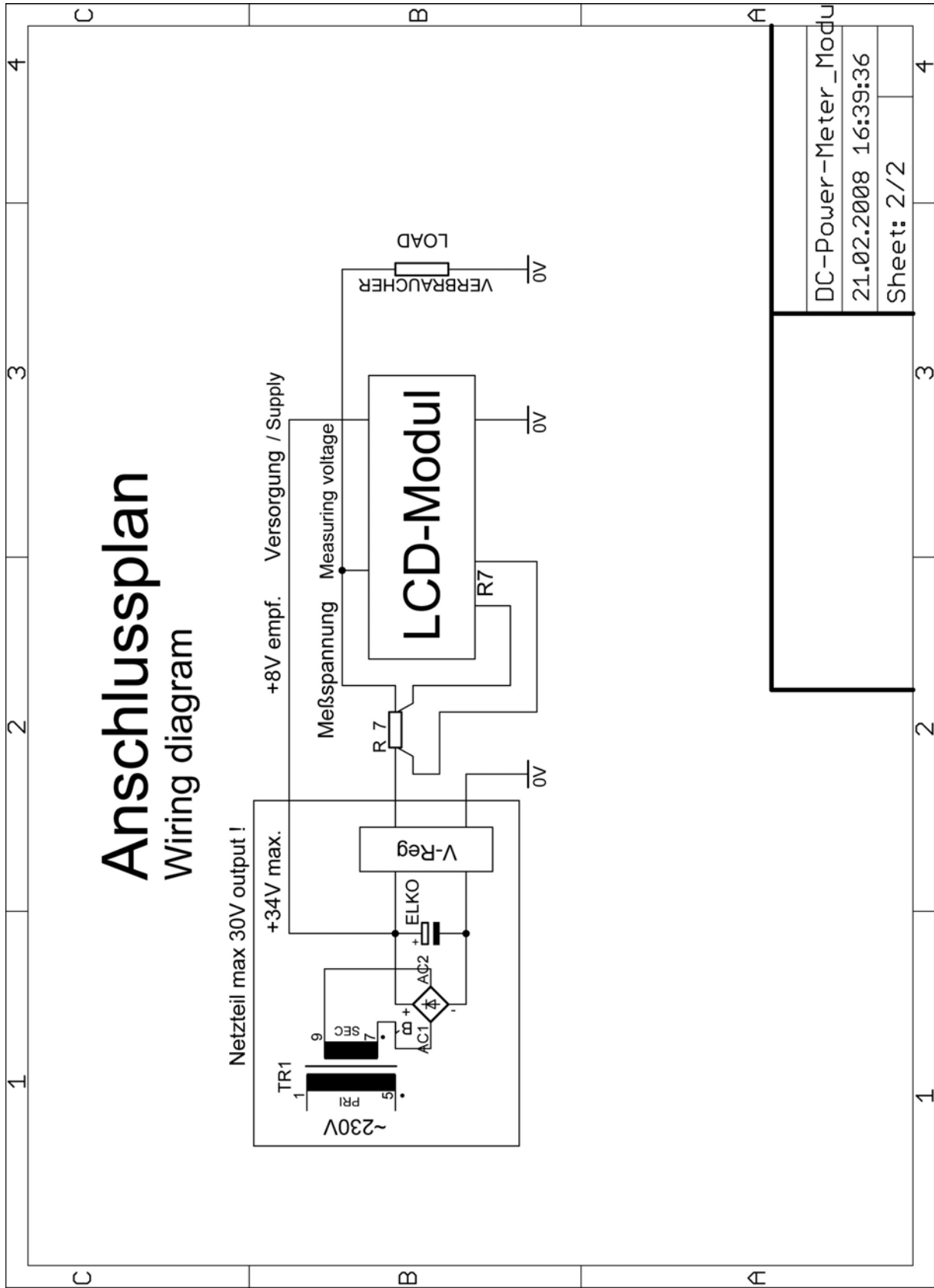
[4] „Versatile DC Power Meter, O. Micic, Elektor edition 445, 01/2008 (english)
<http://elektor-pt.project.nl/revistas/2008/marco/versatile-dc-power-meter.321691.lynkx>

schematic of the Module



Meßmodul	0-30V ; 0-50A, max 999W, 999kWh
Bargraph, Stundenzähler, Spitzenstrom	ab Firmware 2.00
TITLE:	DC-Power-Meter_Modul01a_V109b
Document Number:	
REU:	V1.09b
Date:	31.05.2008 14:22:32
Sheet:	1/2

Wiring diagram



Assembling list

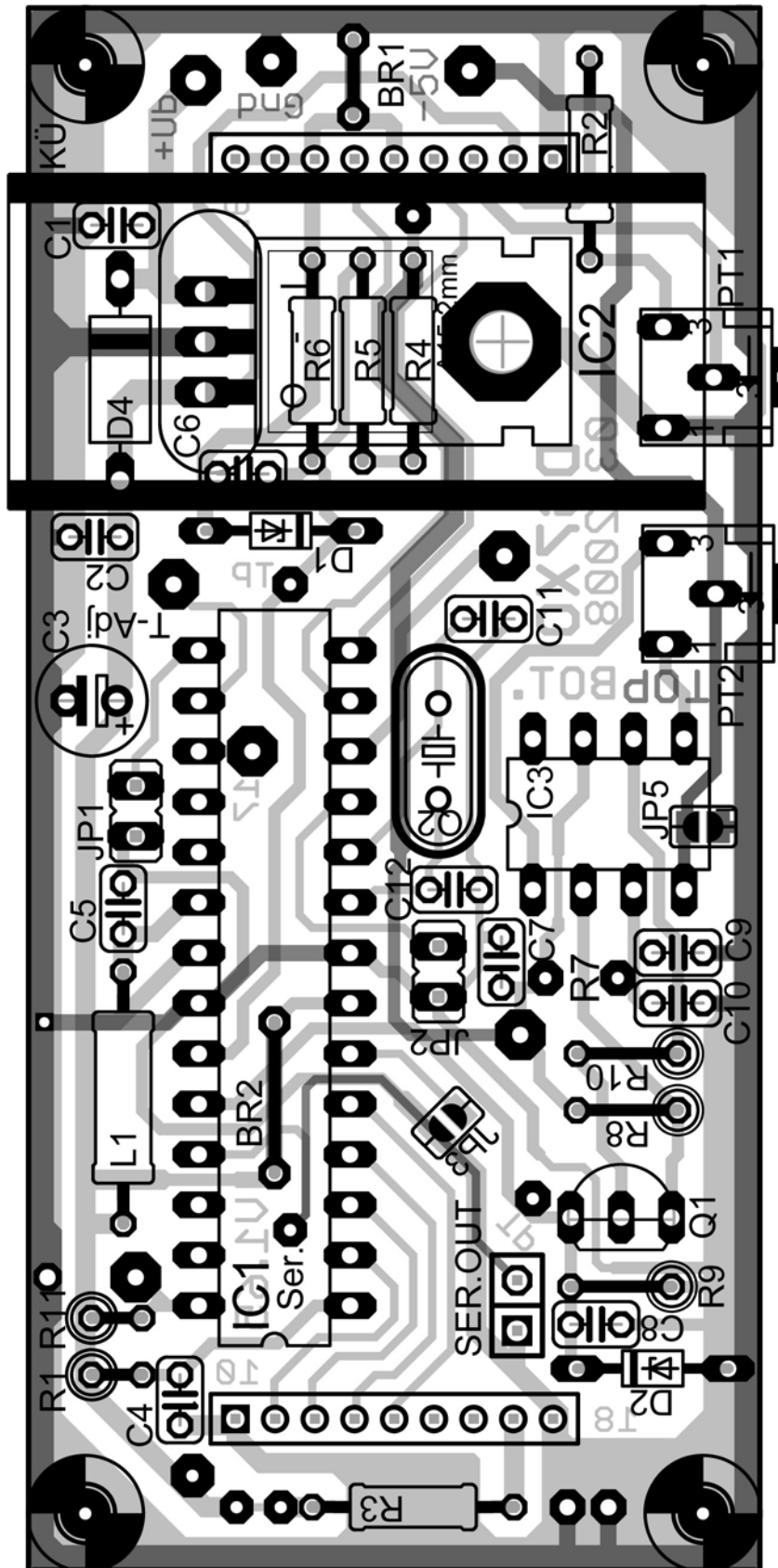
Part	Value	Type
C1	100nF	RM2,5
C2	100nF	RM2,5
C3	100µF/16V	RM2,5
C4	100nF	RM2,5
C5	100nF	RM2,5
C6	100nF	RM2,5
C7	100nF	RM2,5
C8	100nF	RM2,5
C9	100nF	RM2,5
C10	10nF	RM2,5
C11	22pF	see Text
C12	22pF	see Text
R1	1k	1/4W
R2	27k	1/4W
R3	10r	1/4W
R4	27k	1/4W
R5	27k	1/4W
R6	10k	1/4W
R7	1mOhm 0,5%	Prüz. R
R8	100r / 0,1%	Prüz. R
R9	10k / 0,1%	Prüz. R
R10	10k	1/4W
R11	1k	1/4W
PT1	10k	64P
PT2	100k	64P
L1	10µH	Ind.
IC1	ATMega168-16 DIL	see Text
IC2	µA7805	TO220
IC3	TL081P	DIL
Q1	BS250	TO92
Q2	8 MHz	see Text
D1	ZF7,5	RM7,5
D2	ZF7,5	RM7,5
D3	LM335	TO92
D4	1N4004	Diode
	IC Socket 8Pol	precision
	IC Socket 28Pol	precision
LCD	2x16 LCD DIP with LED.	DIP Version
or	4x20 LCD DIP with LED.	DIP Version
S1	Groper	
Br1, Br2	wirebridge	
V5616X	U-heat sink	Not so good
- V 4330K	Spec. KK with 12K/W	best
- screws	M3x15 ;3x M3 bolts, 2x M3 disc	
- Distance bolts	15mm or 18mm	
Bu	2x 10Pol Female bar RM2,0	

Order-list by Fa. Reichelt.de or Conrad.de (Shunt's)

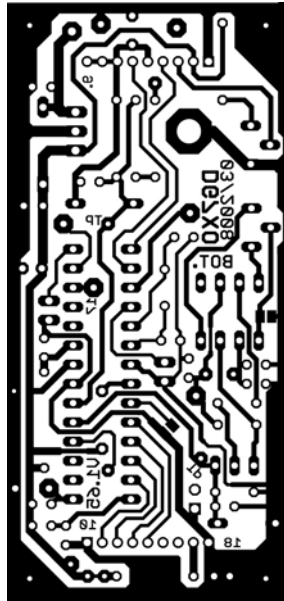
Teilnehmer	Anzahl Gesamt	Pcs.	Order-Nr.	price / pcs.	Preis / Ges.	price / all 1 Stück	with LCD 4x20	without	remarks
1	8	8	Z5U-2,5 100n	0,062 €		0,50 €	0,50 €	0,50 €	RM2,5
1	1	1	Z5U-2,5 10n	0,062 €		0,06 €	0,06 €	0,06 €	RM2,5
1	1	1	RAD 100/25	0,05 €		0,05 €	0,05 €	0,05 €	SMD 1206
1	2	2	Kerko 22p	0,04 €		0,08 €	0,08 €	0,08 €	see Text
1	2	2	Metall 1,00k	0,08 €		0,16 €	0,16 €	0,16 €	1/4W
1	2	2	Metall 10,0k	0,08 €		0,16 €	0,16 €	0,16 €	1/4W
1	3	3	Metall 27,0k	0,08 €		0,24 €	0,24 €	0,24 €	1/4W
1	1	1	Metall 10,0	0,08 €		0,08 €	0,08 €	0,08 €	1/4W
1	1	1	MPR 100	0,42 €		0,42 €	0,42 €	0,42 €	1/4W 0,1%
1	1	1	MPR 10,0k	0,42 €		0,42 €	0,42 €	0,42 €	1/4W 0,1%
1	1	1	64P-10K	0,55 €		0,55 €	0,55 €	0,55 €	Spindle trimmer
1	1	1	64P-100K	0,55 €		0,55 €	0,55 €	0,55 €	Spindle trimmer
1	1	1	SMCC 10µ	0,16 €		0,16 €	0,16 €	0,16 €	10µH Ind.
1	2	2	ZF 7,5	0,03 €		0,06 €	0,06 €	0,06 €	Z-Diode 7,5V
1	1	1	1N4004	0,02 €		0,02 €	0,02 €	0,02 €	Standard Diode
1	1	1	BS 250	0,26 €		0,26 €	0,26 €	0,26 €	FET-Transistor
1	1	1	LM 335 TO92	0,50 €		0,50 €	0,50 €	0,50 €	Temp.-Sensor s. Text
1	1	1	ATMEGA 168-20DIP	3,25 €		3,25 €	3,25 €	3,25 €	resp. ATMega168
1	1	1	µA 7805	0,17 €		0,17 €	0,17 €	0,17 €	5V/1A regulator
1	1	1	TL 081 DIP	0,15 €		0,15 €	0,15 €	0,15 €	DIL
1	1	1	8,0000-HC49U-S	0,24 €		0,24 €	0,24 €	0,24 €	8 MHz quartz, s. Text
1	1	1	LCD 162 DIP	16,35 €		16,35 €			LCD DIP 2x16 with LED green
1	1	1	LCD 204 DIP	21,75 €			21,75 €		LCD DIP 4x20 with LED green
1	1	1	GS 8P	0,10 €		0,10 €	0,10 €	0,10 €	socket
1	1	1	GS 28P-S	0,36 €		0,36 €	0,36 €	0,36 €	socket
1	1	1	T 113A gn	0,22 €		0,22 €	0,22 €	0,22 €	groper
1	2	2	BL 1X10G 2,00	0,37 €		0,74 €	0,74 €	0,74 €	Female bar RM2.0
1	1	1	V 4330K	0,77 €		0,77 €	0,77 €	0,77 €	Spez.KK 12K/W !!
1	1	1	Versand-Anteil	0 €		0 €	0 €	0 €	.
1	1	1	PCB	7,00 €		7,00 €	7,00 €		selfmade or. request
1	1	1	PBV 0,001Ohm 447315-62	10,21 €		10,21 €	10,21 €		Präz. Shunt, by Conradbuy
Cost over all:									
						44,60 €	50,00 €	11,04 €	
						Model I	Model II	Model III	
			price; status: 13.01.2008			1			
			from V2.00c ATMega168 DIP order !!!						
			Model I:			44,60 €			
			Model I: LCD 2x16 Zeichen, Zeichenhöhe 6,68mm						
			Model II: LCD 4x20 Zeichen, Zeichenhöhe 3,73mm						
			Model III: Ohne Shunt und LCD						
			Fett = Kostentreiber :-)						

Assembling plan

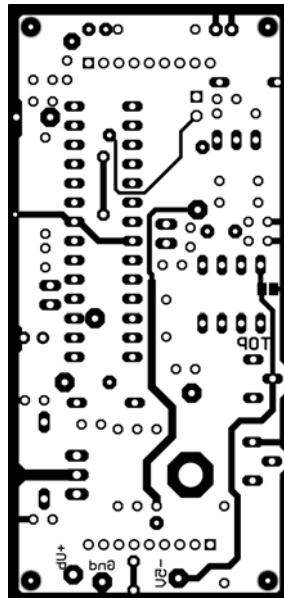
(Layout V1.65)



board layout BOTTOM in original size



board layout TOP in original size (optional)



The layout TOP is only an option to consider for those who want to produce double-sided boards, and / or can.

Otherwise, the 2-wire bridges and equip the voltage divider resistors to measuring voltage. The double-sided boards of me do these bridges as traces already.

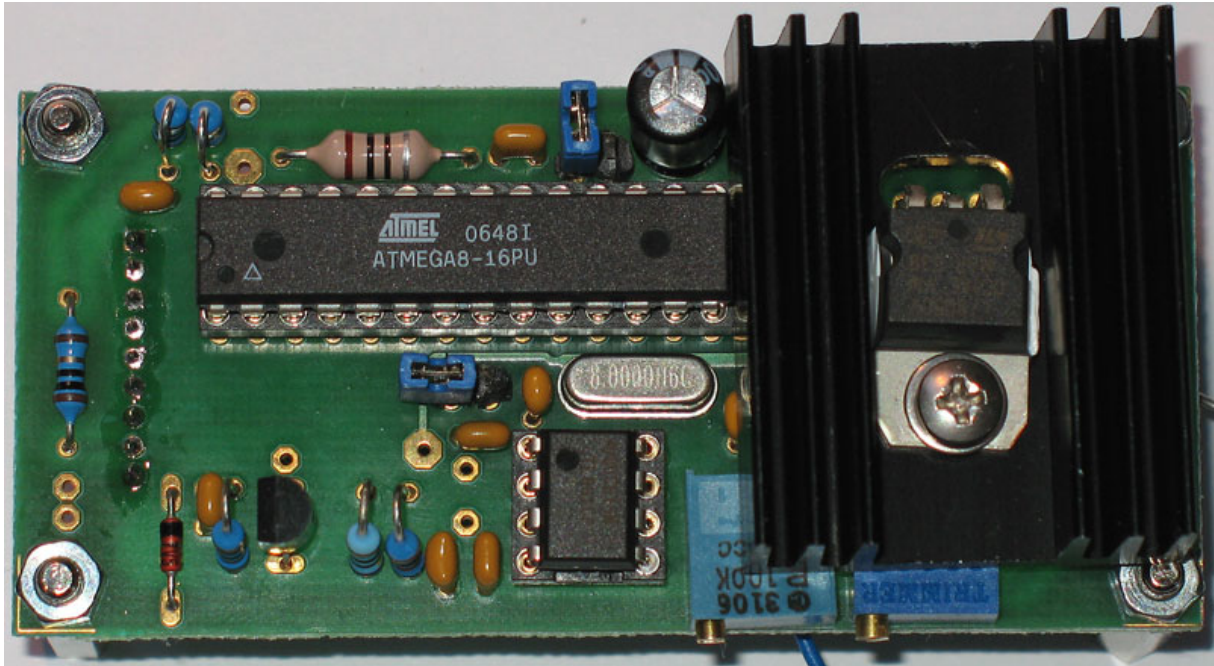
LCD-display with 2x16 character-Version



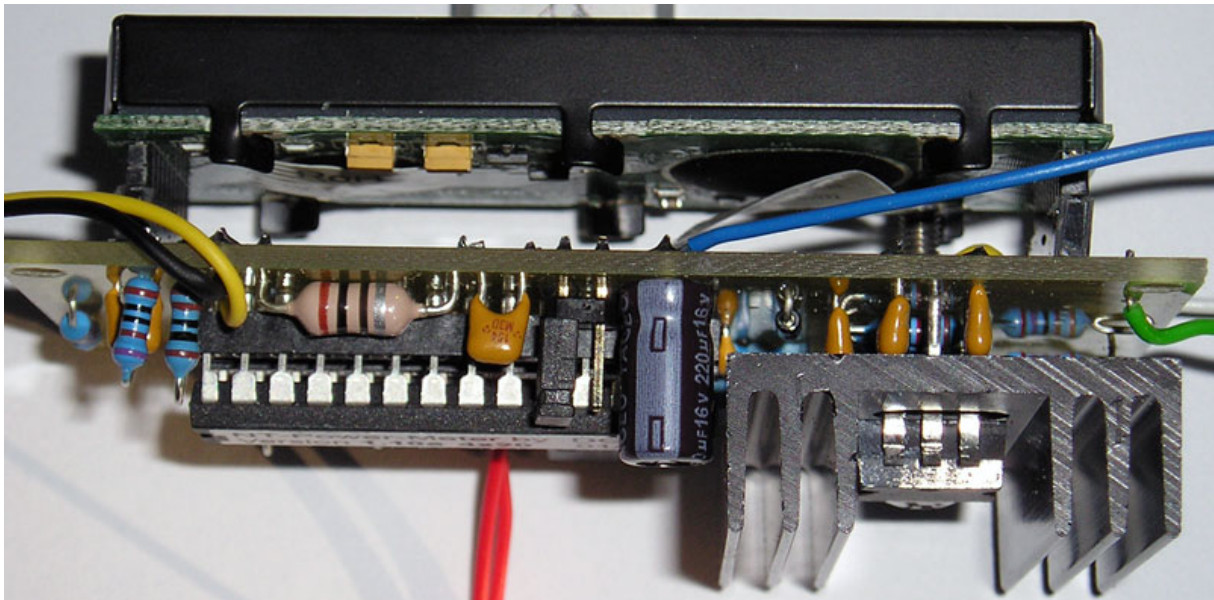
LCD-display with 4x20 character-Version



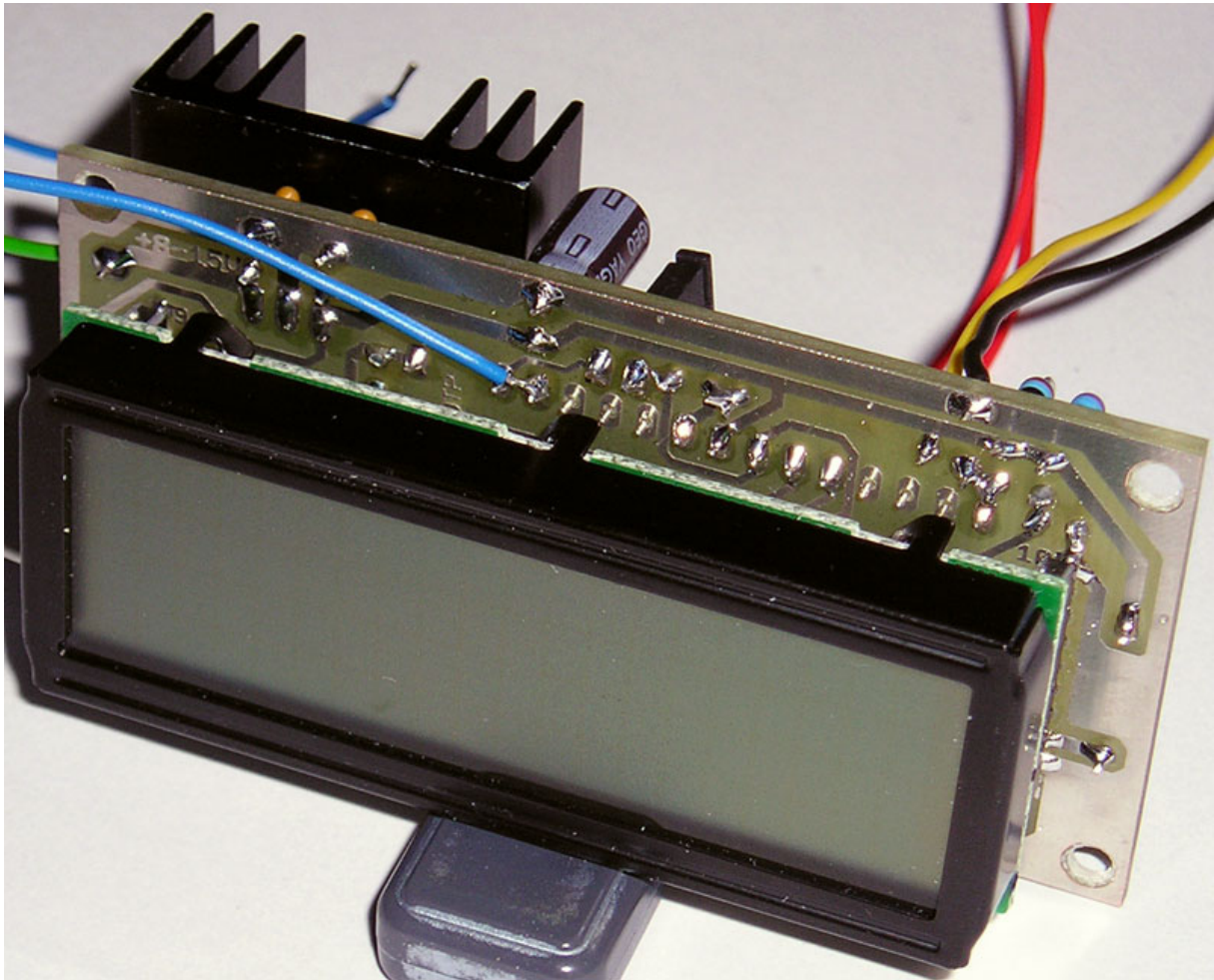
Assembling Site respectively Back (PCB V1.62)



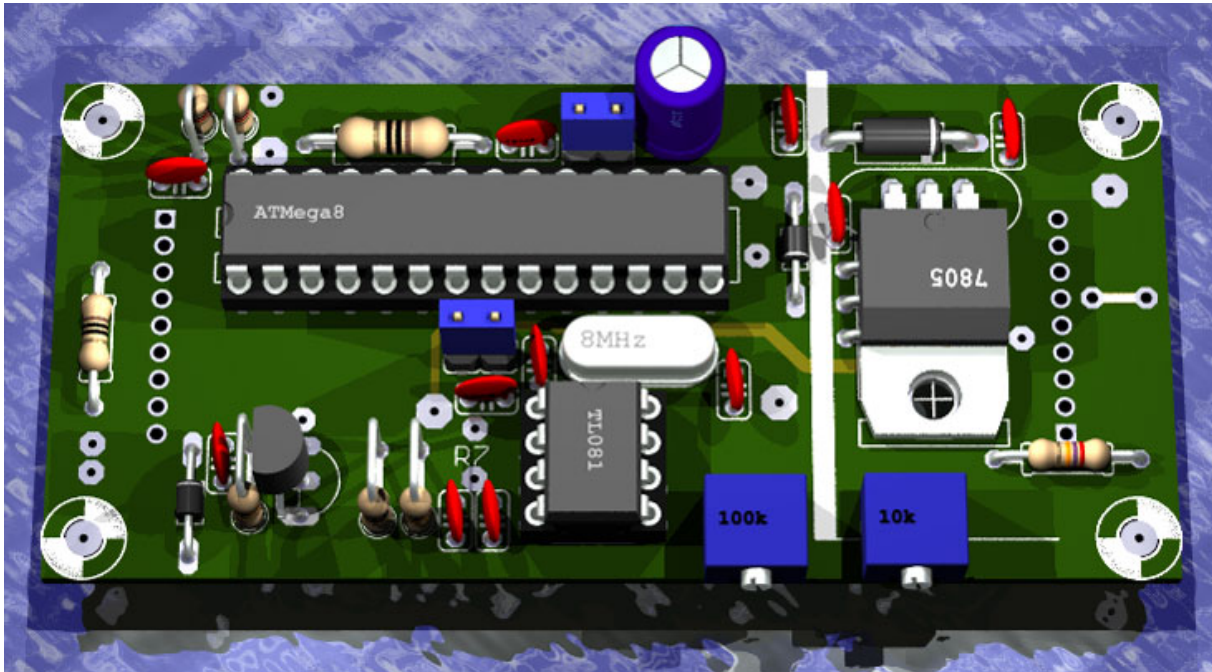
Module from above



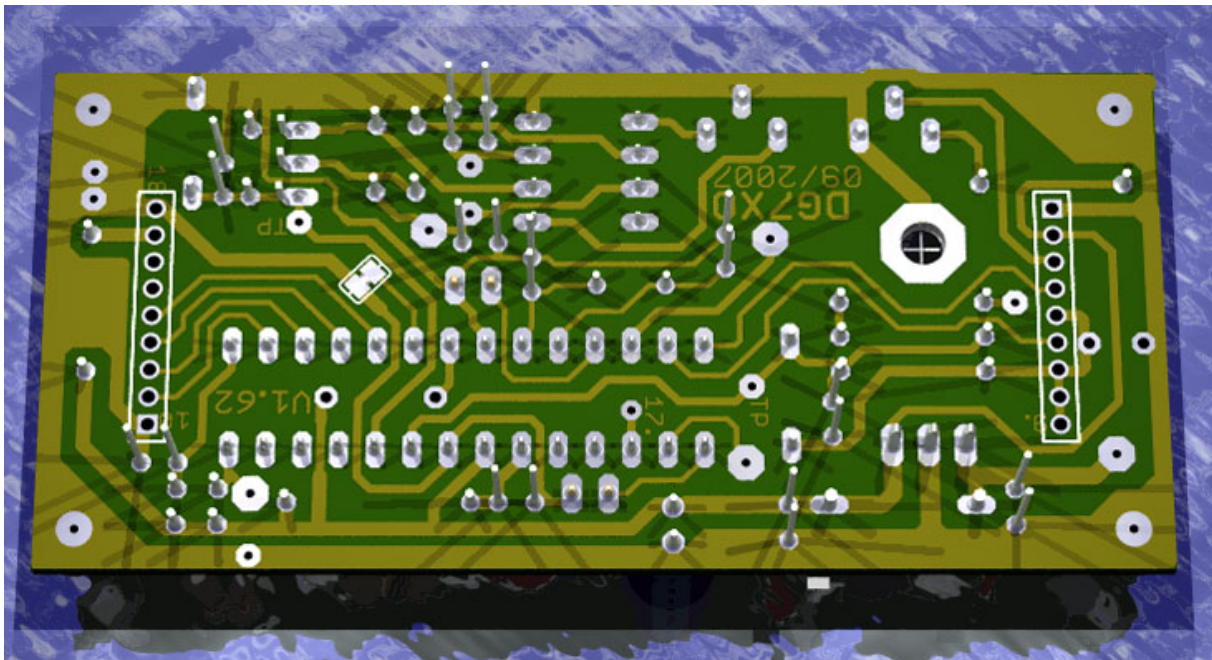
Module side of the front view



3D-Simulation Assembling site



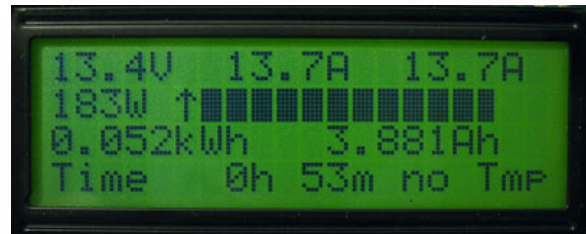
3D-Simulation Solder side



LC-display – text messages



Normal mode ads with a little power.



Normal mode with larger ads and the power bar is overridden (arrow).



Note "WRT!" Bottom left, that the EEPROM just described.



Show the total data when power turn on
P:129 = Pointer Address for EEPROM-values

Config Menu first power on



choose Shunts,
1/10mOhm with JP1 or 60mV DIN Shunt



choose maximum length of the bar graph
(4200W - 62W)



delete Long-term data Ah, kWh and hours with
button? Then press button ☺



Serial data output enable resp. Intervall set
(1-9, dann alle 10sec), default is OFF = 0

Config Menu first power on (continuation)



For voltage adjustment again confirm button and ..



with a DMM identified the nominal value

Note:

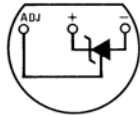
The LCD words are in english, if you order the μ C or Firmware.

Pin schematic of LM-335 Temperature sensor

LM135/LM235/LM335, LM135A/LM235A/LM335A

Connection Diagrams

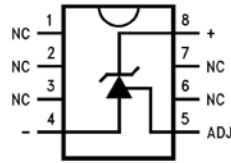
TO-92
Plastic Package



DS005698-8

Bottom View
Order Number LM335Z
or LM335AZ
See NS Package
Number Z03A

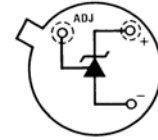
SO-8
Surface Mount Package



DS005698-25

Order Number LM335M
See NS Package
Number M08A

TO-46
Metal Can Package*



DS005698-26

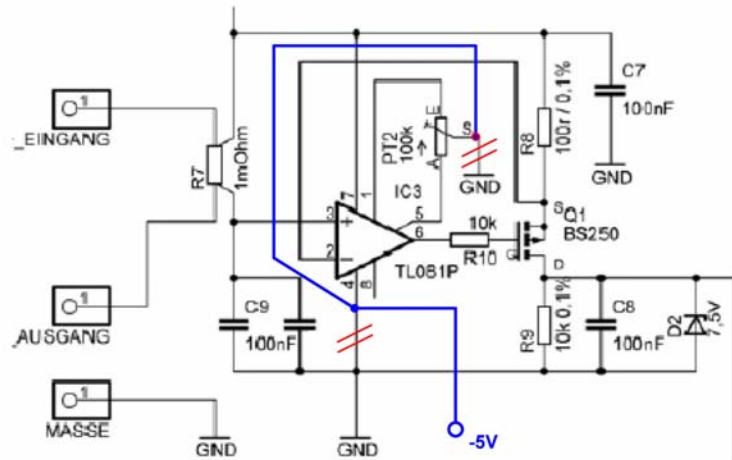
*Case is connected to negative pin

Bottom View
Order Number LM135H,
LM135H-MIL, LM235H,
LM335H, LM135AH,
LM235AH or LM335AH
See NS Package
Number H03H

Modification for current measurement from zero volts

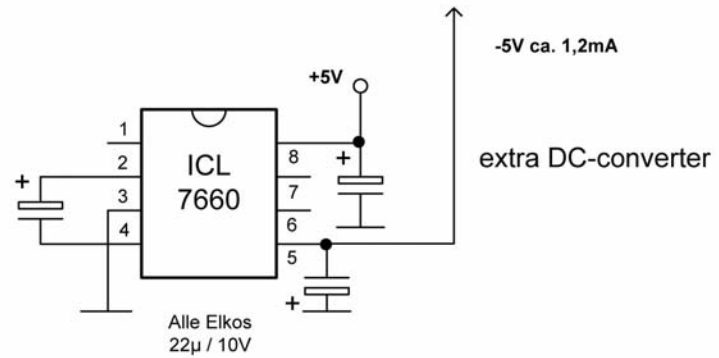
schematic extract with mods:

1. cut the OpAmp Pin4 from ground
2. cut middle pin PT2 from ground
3. connect both pins with the -5V wire

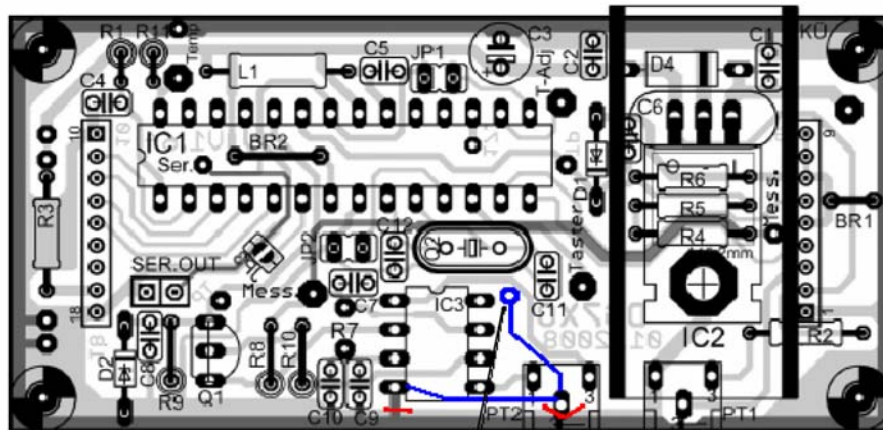


built the extra schematic

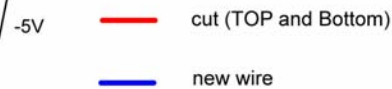
1. connect Pin8 ICL7660 with +5V
2. connect ground
3. connect -5V with OP, see up



Modifications to the layout only V1.64 or early.



current adjustment remains unchanged, see text



WBA 2008

History:

=====

V 1.00a => 15.12.2006

- Voltage V (0 - 30V), a standard feature at 13.8 V
- Power in A, Optional max. 5A and 50A (JP1)
- Leaders display without power unit
- Performance in W (1 - 999W)
- Electrical work in kWh
- Ah capacity battery for operation or for battery charge
- Duty in hours, after 1 week in days
- bar graph or kWh via button selectable in the display
- Ah or Is ad jumper selectable (JP2), also in operation

- LCD lighting
- LCD and measuring board as a module version (sandwich)
- Performance measurement range for the bar graph with jumper JP1 Adjustable, 200W/700W
- Optional 2x16 or 4x20 character LCD, different firmware!
- Optional quartz version, better than the RC-oscillator (approximately 30ppm Instead of 1%!)

V 1.10a => 03.01.2007

- Temperature measurement with LM335, revised layout
- If no sensor founded, Note: "no sensor" in the LCD

V 1.15a => 14.01.2007

- Temperature measurement calibration software possible
- Layout version 1.06 => solder pat for Temp_Adj added

V 1.16a => 10.03.2007

- Power-off for lower voltage 10.8 V when closed JP3
- Reclosing at 11.8 V
- Schematic version 1.06, layout remains the same

V 2.00e => 21.02.2008

- New Controller ATMegal68, with the same layout / board
- Free Shunt choose of 1/10mOhm or 60mV DIN shunts to 400A
- Free choice of max. of Bargraphen for power (4200-62W)
- Long-term storage of kwh, Ah and Time
- Serial output of measurement values U, I, P, W, Ah with 9600Bd (Evaluation with Putty / Excel)
- Ser. Issue Delay menu adjustable from 0-9sec, then in 10sec Steps up 10min, then 10min to 60min in one min step (0 = disabled)
- Relevant time readings are accurate with the new timing

Current versions:

Layout version: 1.65
Software version: 1.16a / 2.00e
Schematic-Version: 1.09a

IMPORTANT NOTE:

The Elektor board layout and mine are compatible but not identical.
Elektor boards for an article, there is only Elektor shop.