



Æ20204 LC METER



Assembly and Operation Manual

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Warning

Please read this manual before you assembly and use this kit. Keep it accessible for all users at all times.

Safety Information

Please make sure to know and follow the applicable regulations for electric devices in your region. In Germany, these are especially VDE 0100, VDE 0550/0551, VDE 0700, VDE 0711 and VDE 0860. Please pay attention to the following security advices:



- Before opening the case, make sure to disconnect the power supply.
- Only work on devices if you made sure that they are disconnected from any power supply and any possible charge inside is discharged.
- Devices must only be used if they are mounted in a case in a way that prevent the user from touching any live wires or parts. Disconnect from power supply during assembly.
- Always check the power cords for breaks or damaged insulation. Replace any defective parts immediately.
- If you are not sure about any specific value of a part, or an installation procedure, or how to connect accessories, seek advice from an qualified expert.

- Before putting the unit in use, always check if it is suitable for the intended purpose. If you are not sure, seek further inquiry from a qualified professional or the manufacturer.
- Please keep in mind that the manufacturer assumes no liability for errors made during assembly or operation.
- Devices which need a supply voltage greater than 24V may be assembled by professionals only, to avoid dangers from improper assembly.
- In schools, educational institutes or workshops the use of this unit must take place under the supervision of qualified staff.
- Do not put this unit in use in an environment where the risk of fire or explosion or explosive gas, vapor or dust is present.
- If the unit must be repaired, use original parts only. The use of inappropriate parts may lead to a security risk.
- Avoid working alone.
- Keep electronic parts away from children.
- Do not replace parts with such that does not meet the required parameters. For example, never replace a fuse with another one with higher nominal current!
- Other regulations may apply. Please check the local security regulations for assembling electronic devices.

Handover of a Device Built From a Kit *(in countries where applicable)*

If you hand over a device built from a kit, you legally become the manufacturer, this mean you are responsible for complying with the appropriate regulations for electronic devices. All accompanying papers, in particular this manual, must also be passed over. Where necessary (for example in the European Union) you must also publish you identity to the consignee.

Intended Use *(in countries where applicable)*

The intended use of this device is measuring the values of capacitors and inductors.

- Other uses are not approved!

ESD Warning

What is ESD?

ESD (*Electrostatic Discharge*) is the sudden flow of electricity between two objects caused by contact or an electrical short. It can reach very high voltages of many kV, in some cases even over 100kV!



Warning symbol for an electrostatic sensitive device

Causes of ESD

The main cause of ESD events is static electricity. Static electricity is usually generated through tribocharging, like walking on a rug, ascending from a fabric seat, removing some types of plastic packaging or using non-ESD compliant tools.

Danger of ESD

The high voltage pulse can easily destroy electronic parts. Especially ICs and FETs are very sensitive to high voltage. **Even a short, single touch may destroy a part!**

How do I prevent damage due to ESD?

Always ground yourself while working with electronic parts. A grounded conducting wrist strap and proper anti-static work surface mat will prevent ESD damage. Also make sure that the soldering iron is grounded and ESD-safe.

AE20204 LC METER

The AE20204 LC Meter allows the measurement of capacitance and inductance of passive components, particularly very small values, even below 1 pF / 1 μ H. The resolution thereby is 0.01 pF (10 fF) / 10 nH. It is an inestimable aid for amateur radio enthusiasts, as well as anyone engaged in electronics.

The RS232/USB interface¹ allows the included software to access the readings and show them on screen. Logging is also supported. The easy, plain text command protocol allows simply integration in own tools and systems.

No SMD (Surface Mounted Device) components are used, so the kit is also suitable for beginners in electronics. The comprehensive manual should help answer all questions that may arise during assembly.

Please read the complete manual (especially if you are not yet experienced in electronic engineering) before building the kit.

¹ *USB optional*

Specifications

Measuring Range: Capacitance (C): 0.01pF to ca. 1μF²
Inductance (L): 10nH to ca. 100mH³

Resolution: Capacitance (C):
0.01pF - 999.999pF: 0.01pF
1nF - 999.999nF: 10pF
>1μF : 10nF
Inductance (L):
10nH - 999.999μH : 10nH
1mH - 999.999mH: 10μH

Test Frequency: 15 kHz - 750 kHz sinus

Test Voltage: <2.5Vpp

Accuracy: +/- 0.5% reference

Display: 2x16 characters dot-matrix LCD

PC Interface: RS232 or USB (optional)

Supply Voltage: 7.5-12V DC

Temperature: +5°C - +40°C

Relative Humidity: < 85% non-condensing

2 depending on capacitor's type, electrolytic capacitors are not supported
3 the quality factor of the inductor must be sufficient to allow oscillation on test frequency

Circuit Description

To measure capacitance and inductance, the AE20204 LC Meter uses an oscillator, composed of IC2, C7, C8, C9, L1, R2, R3, R4, R5 and R9. The tested capacitor is switched in parallel to C9 to measure capacitance, the inductor in series to L1 to measure inductance, this lowers the oscillator's frequency.

The microcontroller IC1 is used to measure this frequencies and calculate the values. They are displayed on the LCD and output to the RS232/USB interface. T1, R8, R10 and R1 provides the correct voltage levels for the RS232 interface. IC4, C13, C14, R12 and R13 implements the USB interface. *Note: with the USB model, the UART-to-USB-Bridge FT232R (IC4) is pre-assembled.*

The positive regulator IC3 provides the 5V voltage for the device. C4, C5 and C11 are bypass filters, D1 is an input protection diode.

The relay K2 switches the input between series and parallel connection, which selects capacitance or inductance measurement. K1 is used to switch the precision capacitor C10 to the oscillator. D2 and D3 are flyback diodes for the relays.

The LC meter requires no calibration, as it uses a precision 0.5% tolerance reference capacitor (C10) to determine the exact values of the capacitor and inductor (C9 and L1) that forms the oscillator. The method is described below.

First, the frequency without C10 is measured (f1).

$$f1 = \frac{1}{2 \cdot \pi \cdot \sqrt{L1 \cdot C9}}$$

Then, the frequency f2 is measured with C10.

$$f2 = \frac{1}{2 \cdot \pi \cdot \sqrt{L1 \cdot (C9 + 1000\text{pF})}}$$

C9 can be obtained by equalizing both equations.

$$C9 = \frac{f2^2}{f1^2 - f2^2} \cdot 1000\text{pF}$$

Since C9 is known now, L1 can be calculated.

$$L1 = \frac{1}{4 \cdot \pi^2 \cdot f1^2 \cdot C9}$$

This self-calibration is performed on start-up. To measure components, frequency f3 is obtained with the component under test connected to the oscillator. The unknown capacitance Cx or inductance Lx can be calculated as follows:

$$Cx = \left[\frac{f1^2}{f3^2} - 1 \right] \cdot C9$$

$$Lx = \left[\frac{f1^2}{f3^2} - 1 \right] \cdot L1$$

This method allows the measurement of very small values, for example the capacitance of cables.

Note: the values of real capacitors and inductors are not constant, but depends (amongst others) on frequency. Measuring with different test frequencies will give different results!

Note: electrolytic capacitors can not be measured with this device.

Note: the quality factor of the inductor must be sufficient to allow oscillation on test frequency.

Soldering

Please read the following pages if you are not yet experienced in soldering. Good soldering is a matter of practice! Practice on old boards until you feel confident, before assembling the kit.

• **The parts are mounted on the PCB's side where the silkscreen is, except parts whose designators ends with an asterisk (like S1*), these are mounted on the other side!**

• **Do not inhale the fumes from the flux and wash your hands after soldering! Wear protective glasses.**

• If you use additional flux, make sure it is suitable for electronics use! Non suitable flux may contain acid, which will damage the traces on the PCB over time.

• Try to solder fast. Heating up for too long may damage the components and the board.

• Solder wire with a diameter between 0.5-0.75mm (0.02"-0.03") is most suitable for through-hole components. Lead solder is easier to use than lead-free solder.

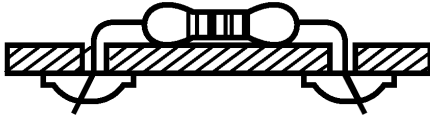
• To solder, use the tip of the soldering iron to simultaneously heat up the PCB and the component leg. Add solder, it should melt around the component leg. Wait a moment and remove the iron. With lead solder, the solder joint should be glossy.

- Do not move the part you just soldered for a few seconds while it is cooling down. Moving it may cause the solder joint to crack.
- A clean, non oxidized tip is essential for good soldering. Use a wet sponge or a metal wool tip cleaner to regularly clean the tip. The metal wool cleaners prevents the tip from a temperature shock, unlike a wet sponge.
- After soldering, use side cutters to cut the leads straight above the solder joint.
- When soldering active components (ICs, Transistors, LEDs...), it is very important to prevent overheating the components. They should be soldered in no more than about 5 seconds. Also it is important not to confuse the polarity! See the next chapter on individual components types and their correct orientation.
- After you are finished, check all components for correct placement and orientation. Also check for unintentional shorts on the board. Small solder leftovers may cause shorts, which can damage the board or the components.
- Use isopropyl alcohol (IPA) or a specific PCB cleaner fluid to remove flux residues. Flux is corrosive and should not remain on the board.

Component Reference

1 Resistors

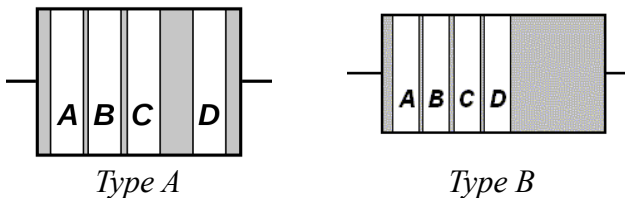
First, bend the leads in form and put the resistor through the corresponding mounting holes. Bend the leads aside to prevent the resistor from falling out, and solder it accurately on the back side. Then, cut the remaining leads above the solder joint.



The resistance value is given with colored bands on the resistor. The code consists of four, five or six bands. With four bands, the first two are the base value (see table below), the third is the multiplier to the base value and the fourth is the tolerance. Five-bands code uses the first three bands for base value. With six bands, the sixth is the temperature coefficient. The resistor value is:

base value * multiplier [\pm tolerance]

There are two possible arrangements for the bands order:



Color Codes:

Color	Digit	Multiplier	Tolerance ± in %
None	-	-	20
Silver	-	10^{-2}	10
Gold	-	10^{-1}	5
Black	0	10^0	-
Brown	1	10^1	1
Red	2	10^2	2
Orange	3	10^3	-
Yellow	4	10^4	-
Green	5	10^5	0,5
Blue	6	10^6	0,25
Purple	7	10^7	0,1
Grey	8	10^8	0,05
White	9	10^9	-

2 Capacitors / Electrolytic Capacitors

Capacitors are soldered the same way as resistors. **Electrolytic capacitors are polar, and must be mounted in the correct orientation! They will be destroyed when installed reverse, and may even burst!**

Please keep in mind that different manufacturers marks the polarity in different ways, the marking may represent the positive or the negative terminal! The actual polarity (+ or -) is printed inside the marker band that points at one of the leads.

Capacitance Identification

A three-digit number without letters is the capacitance in pF, calculated this way: $a \cdot 10^b$ where a is the first two digits and b is the third digit (105 becomes $10 \cdot 10^5$ pF = 1 μ F). One- or two-digit numbers states the capacitance directly in pF. A number including the letter "n" is the capacitance in nF, where 3n9 is 3.9 nF.

Upper-case character denote the tolerance according to this table:

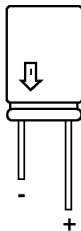
B	C	D	F	G	H
$\pm 0,1$ pF	$\pm 0,25$ pF	$\pm 0,5$ pF	$\pm 1\%$	$\pm 2\%$	$\pm 2,5\%$

J	K	M	S	Z	P
$\pm 5\%$	± 10	± 20	+50% -20%	+ 80% - 20%	0% -10%

A number following up indicates the electric strength.

Sometimes you may encounter a number like 0.5, this is the capacitance in μ F.

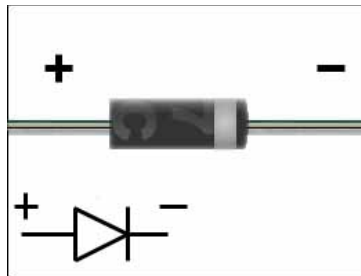
Electrolytic capacitors are usually labeled with the capacitance in μ F straight. μ is where the decimal point is: $\mu 33$ is 0,33 μ F, $3\mu 3$ is 3,3 μ F and 33μ is 33 μ F.



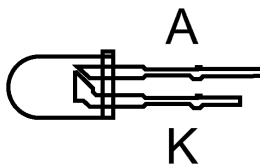
3 Diodes

The circular band on diodes identifies the cathode (negative terminal). The bar depicts the cathode in the symbol. The positive terminal is called the anode.

Diodes are mounted horizontal. While soldering, try not to heat up the body of the diode.



4 LEDs

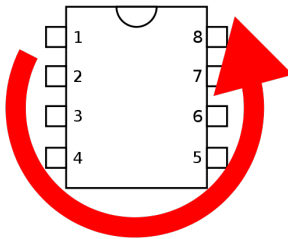


LEDs (light-emitting diodes) must be soldered with respect to the correct polarity as well. The cathode is identified by the short lead and the larger electrode inside.

5 IC-Sockets / ICs

With ICs (integrated circuits), it is essential to observe correct polarity. Most ICs will be damaged or destroyed when mounted incorrect. The mark on the silkscreen must match the notch on top of the IC.

Pin numbers are counted **counter**-clockwise, starting from the notch.



Note: Please also pay attention to the ESD warnings at the beginning of this manual. ICs are very ESD sensitive!

6 Transistors

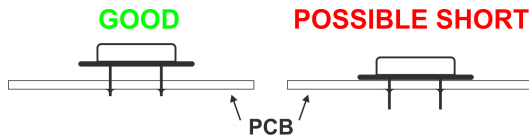
Transistors must be mounted in the correct orientation, too. The flat side of the transistor must match the correspondent side in the silkscreen drawing. The leads may not cross.



Note: field-effect transistors (FETs) are extreme sensitive to ESD.

7 Crystal

The polarity of the crystal is not relevant, but the bottom side of the package is conductive. To prevent shorts, the oscillator should be mounted with a little distance to the board (see the image on the next page).



8 Inductors

Inductors are soldered just like resistors. They also use similar color coding, with usually four bands. The first two are the base value (see table below), the third is the multiplier to the base value and the fourth is the tolerance. The inductor value is:

base value * multiplier [\pm tolerance]

Color Codes:

Color	Digit	Multiplier	Tolerance \pm in %
None	-	-	20
Silver	-	10^{-2}	10
Gold	-	10^{-1}	5
Black	0	10^0	-
Brown	1	10^1	1
Red	2	10^2	2
Orange	3	10^3	-
Yellow	4	10^4	-
Green	5	10^5	0,5
Blue	6	10^6	-
Purple	7	10^7	-
Grey	8	10^8	-
White	9	10^9	-

9 Relays

The side of the relay marked with a bar corresponds to the side marked with a "1" on the silkscreen. In contrast to the IC marking the notches have no meaning!

10 4mm Binding Posts

Use a large soldering iron tip and plenty of solder for the binding posts, as they need a lot of heat to solder. If your soldering iron's temperature is adjustable, set the temperature 20 - 30° higher than normal. Try to heat the binding posts, not the pcb, as too much heat may damage the tracks.

11 SUB-D9 Connector (*RS232 Model only*)

Mount the connector on the back plate of the case. Solder a wire from pin 2 to the "TX" pad and from Pin 5 to the "GND" pad on the board.

Bill of Materials

Quantity	Part(s)	Value / Description
3	C1, C3, C5	100nF
2	C2, C6	22pF
1	C9	680pF
1	C10	1000pF 0.5%
1	C4	220μF Electrolytic
3	C7, C8, C11	10μF Electrolytic
3	D1, D2, D3	1N4148 Diode
2	K1, K2	Relay
1	L1	68μH
1	Q1	Crystal 14.7456 MHz
1	R1	10kΩ
1	R7	2.4kΩ
3	R2, R3, R5	100kΩ
1	R4	47kΩ
1	R6	220Ω
1	R9	1kΩ
1	R14	10Ω
1	IC1	IC Socket 28Pol. / Microcontroller
1	IC2	LM311N Comparator
1	IC3	7805 Positive Linear Regulator
2	GND*, INPUT*	4mm Binding Post
1	LCD1*	2x16 Dot-Matrix LCD

2	S1*, S2*	Tact Switch
1	POWER	Power Connector
1	-	Header 16-pin <i>(for LCD mounting)</i>

RS232 Model only:

1	R8	10k Ω
1	R10	1.5k Ω
1	R11	100 Ω
1	T1	BC557 Transistor
1	-	SUB-D9 Connector

USB Model only:

2	C12, C13	100nF
1	C14	10 μ F Electrolytic
1	R13	10k Ω
1	R12	4.7k Ω
1	IC4	FT232RL USB UART Interface <i>(pre-assembled)</i>
1	USB*	USB Type "B" Connector

Other:

- PCB
- 4 spacer bolts and 8 M2,5 screws for LCD mounting
- *Case and 6 extension caps for the tact switches (optional)*
- *Mains adapter (optional)*
- *SMD Test Tweezers (optional)*

Assembly

General note

To minimize the possibility of faults is essential to work precise and systematic. Check every step, each component placement and orientation and any solder joint. Follow the assembly order given in the manual.

Take your time - it takes longer to troubleshoot than to prevent faults by working accurate.

The most common reason for a malfunctioning device is wrong component placement, either the component being placed in the wrong place or back to front. If you have difficulties reading the color bands of resistors, check them with a multimeter.

A common mistake is regarding capacitor labeling, such as $n10 = 0.10 \text{ nF} = 100 \text{ pF}$ as opposed to 10 nF . Also check if all leads of an IC are correctly inserted into the socket, they tend to bend during insertion.

After soldering, inspect the board for what is called cold and dry solder joints. Cold joints occur if the soldering temperature did not exceed the solder's liquidus temperature, or if the flux evaporated before it was applied on the surfaces being soldered (this is usually the result of the soldering iron being used to heat the solder directly, rather than the parts themselves). Dry joint occurs when the cooling solder is moved, and often occurs because the joint moves when the soldering iron is removed from the joint. When using lead solder, the joint should be smooth, bright and shiny. If it is not, it should be reworked.

Mounting

Start with the side of the board where the silkscreen is. All parts without an asterisk in the designator will be mounted on this side (see the picture on the next page). Wait to insert IC1 in the socket until you finished the assembly.

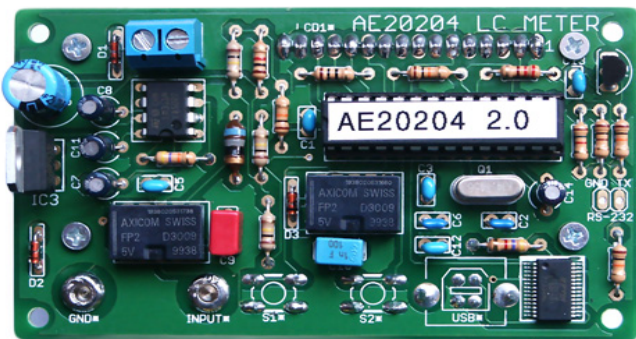
After all the parts on this side are soldered, please examine the board carefully for shorts, bad solder joints and correct placement. **The LCD will cover them, so you will need to desolder it to fix errors, which takes extra time and effort.** See the previous page for more information.

Afterward, solder the parts with an asterisk (LCD, the USB connector, the 4mm binding posts and the tact switches) on the opposite side.

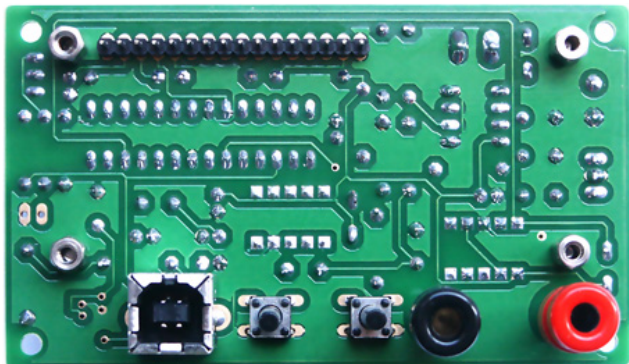
To attach the LCD, insert the header into the board first. Put the LCD on top of the header. Fix the LCD with the M2.5 screws and spacer bolts in place. Now, solder the header to the board and LCD. See the picture on next page for how it should look like when finished.

After completing the assembly, insert IC1 into the socket. The notch on the chip must correspond with the silkscreen marking.

Finished Component Side



Finished Solder Side, without the LCD



LCD Mounting



Troubleshooting Checklist

Check and tick off every step.

- ☐ Is the polarity of the supply voltage correct?
- ☐ Is the supply voltage in the range of 7.5-12V when the device is turned on?
- ☐ Are all resistors placed right? Check the color bands.
- ☐ Is the polarity of the diodes correct? The cathode band must match the bar on the silkscreen symbol.
- ☐ Verify the polarity of the electrolytic capacitors. Keep in mind that the marking on the capacitor can point to the (+) or (-) lead, the actual meaning is printed inside the marking.
- ☐ Are all ICs in the right place and with correct orientation?
- ☐ Are all IC leads plugged inside the socket? They can bend and stay outside easily.
- ☐ Measure the resistance between the power supply input terminals and between the regulated 5V rail and ground - they may not be shorted.

- Are there solder bridges on the solder side of the PCB, causing shorts? They are easier to find if you hold the PCB toward bright light.
- Are there bad/cold/dry solder joints? With a pair of tweezers, jiggle component leads at the solder joint - if it moves, re-solder them. If a solder joint look suspicious, better rework it just in case.
- Look if you missed a soldering point. With the USB model, all pads are used.

Power Supply

A 7.5-12V DC power supply capable of providing at least 100mA is required. The optional mains adapter, a 9V battery or any other supply that meets this criteria can be used.

Warning: An AC power supply may not be used!

Note: It is advisable to use a current limiting lab power supply when switching on for the first time. Set it to 9V and 120mA, this will help to prevent damage from potential shorts.

Please pay attention to the correct polarity of the power connection!

Case Mounting

Note: This describes the optional case available with the kit.

Remove the caps from the bindings posts before assembling the case.

The case is provided with all necessary cut-outs and labelings. First, put the extension caps on the tact switches. Join the front panel and the PCB and insert both in the respective brackets. The PCB fits the brackets behind the front panel precise.

Fasten the case with the included screws. This completes the case mounting.

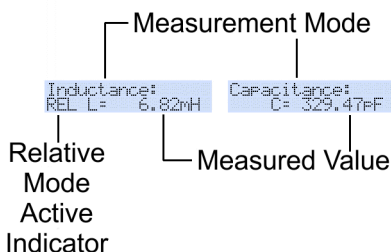


Operation

When the AE20204 is switched on, it performs a self-calibration. In the process, the oscillator's frequency and the exact values of the frequency determining inductor and capacitor are determined (see circuit description for details). If an error is detected during calibration (like the oscillator's frequency being outside the normal range, no oscillation at all etc.), calibration status is shown as "FAILED". In this case, check the device for assembly errors (see appropriate chapter). If the self-calibration and test were successful, "PASSED" is shown. The LC meter is ready for measurements.

Note: during start-up, no test leads may be connected! They will affect self-calibration and produce false readings. To take the lead's capacitance/inductance out of the measurements, use the Relative Mode.

Display indication:



The display shows the measurement mode, a relative mode indicator (if active) and the actual value. The working range is selected automatically.

Measurement Mode

Press the "L / C" button to change from capacitance measurement to inductance measurement and reverse. Each press cycles between the modes.

Relative Mode (Δ REL)

The capacitance/ inductance of the test leads or fixtures may affect the measurements, especially with very small values. After the test leads are connected, press the " Δ REL" button to set the current value to zero. "REL" is shown on the display, and the following measurements refer to this value.

The test leads should be shorted in inductance measuring mode and open in capacitance mode while pressing the " Δ REL" button.

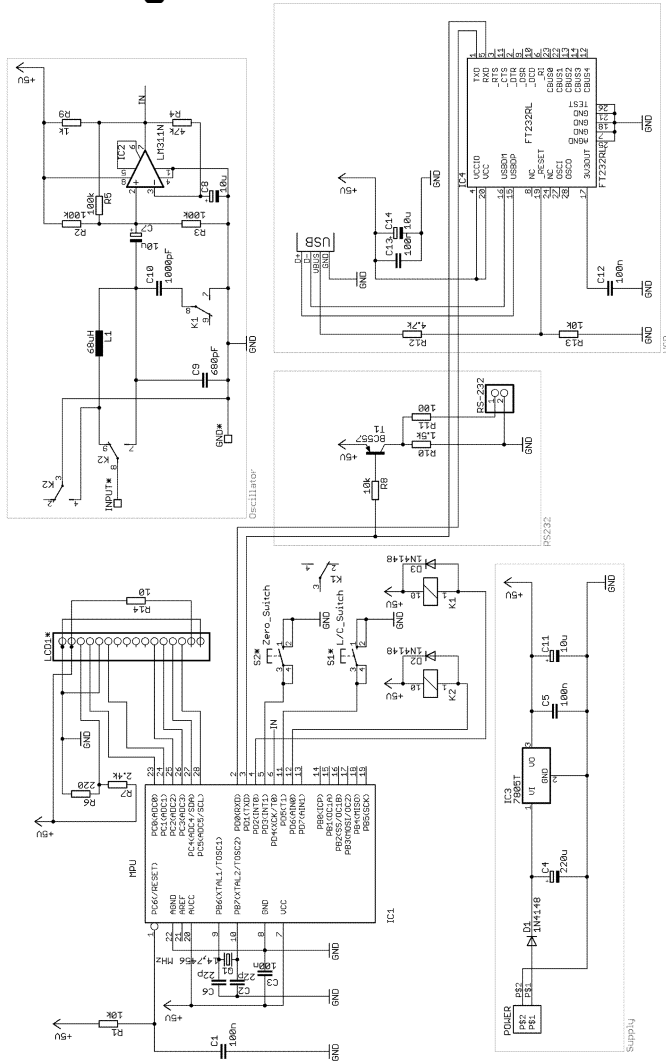
Press " Δ REL" again to leave the Relative Mode.

Note: in Relative Mode, negative values are possible, if the actual reading is below the recorded value, like when when you disconnect the test leads after zeroing them out.

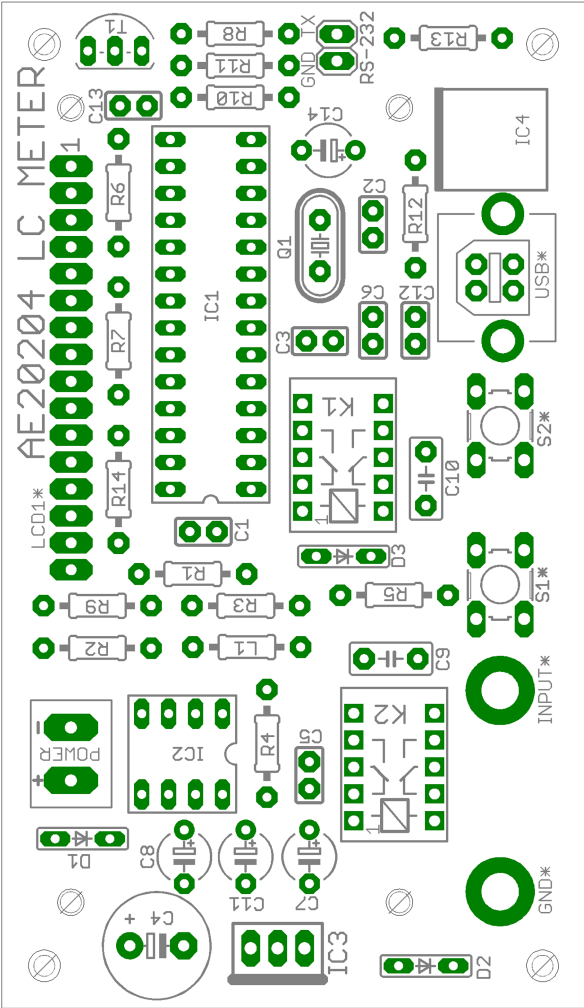
Manually Initiating Self-Calibration

Due to the high sensitivity of the AE20204 LC Meter and the temperature coefficients of components, the measured value will change slightly with the temperature rise after some minutes of operation. When nothing is connected to the inputs, the measured value will drift from 0.00pF to a typical value of just under 1pF. The final value will be reached after about 5 minutes at room temperature. To achieve the best possible accuracy, measurements should be taken when the device has reached operating temperature. To set the value to 0.00pF again, a self-calibration can be initiated by pressing and holding the "ΔREL" key down for 5 seconds.

Circuit Diagram



Component Placement



Note: Parts whose designators contains an asterisk are mounted on the opposite side of the PCB. See the chapter "Assembly" for details.

Data Interface

The AE20204 LC Meter has an RS232 or an USB (optional) interface, which allows to access the measurement values from a computer. The USB driver creates a virtual serial (COM) port, this makes integration in own tools and applications very easy.

System Requirements

RS232 Interface:

- free serial port

USB Interface:

- MS®¹ Windows® 98/ME/2000/XP/Vista/7/
Server 2003/Server 2008/Server 2008 R2
x86/x64
- Mac® OS X®
- Linux

PC-Software:

- MS Windows with .NET® -Framework *(at least version 2.0)*

¹ All trademarks are the property of their respective owners.

USB Driver Installation

The driver for the virtual serial port must be installed before the software can be used. Drivers for all supported operation systems are included with the device, and can be found in the "driver" directory on the CD.

Software Installation

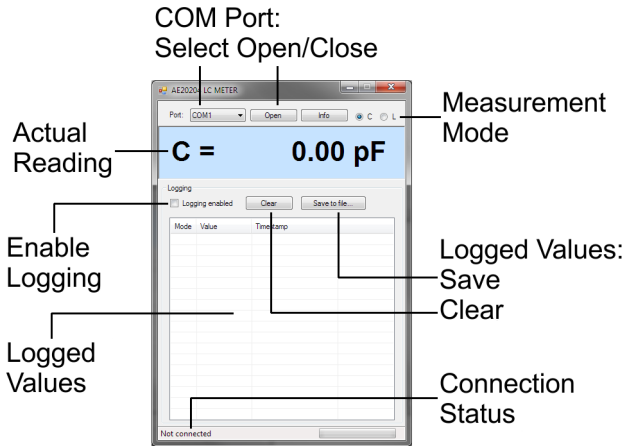
The software can be found in the "software" directory. Execute setup.exe to install the software.

Note: The .NET-Framework (at least version 2.0) must be installed prior to the software installation.

Software Operation

Connect the AE20204 to the PC using RS232 or USB. Launch the software and select the (virtual) COM port the device is connected to. Press "OPEN" - if the connection is successful, the status bar will show "Receiving data". The measurement mode and the actual reading is shown. Check "Logging enabled" to log the values. The logged values can be deleted by pressing "Clear" or saved with "Save to file..." in the csv format (Comma Separated Values). Various software like Microsoft Excel® can be used with these files. Press "Close" to close the connection.

Software Screenshot



Data Format

The data is output in packets, which have the following format:

IDENTIFIER:MODE:VALUE;

IDENTIFIER: "AE20204 LC METER"

MODE: "C" or "L"

VALUE: measurement value in units of 0.001pF or 0.001uH

Example: AE20204 LC METER:C:3451;

capacitance mode, $3451 \times 0.001\text{pF} = 3,45\text{pF}$