Hutale 4.2 LCR-DDS-F meter: LCR bridge meter / DDS function generator / frequency meter kit – © dr. Le Hung

*The **Hutale LCR-DDS-F (shortly LCR) bridge meter kit** is a multifunction device. The instrument firstly is a **LCR** meter (sometimes is called **RLC meter** - in other words **LC meter**, **Ohm meter**, in-circuit **ESR meter**) that precisely measures **inductance, capacitance and resistance**. The measurements can be carried out on 9 different, accurately made sine wave measuring frequencies (**100Hz, 250Hz, 500Hz, 1kHz, 2.5kHz, 5kHz, 10kHz, 25kHz, 50kHz**). Besides the main measuring parameters (inductance: **Ls, Lp**, capacitance: **Cs, Cp**, resistance: **R**) the secondary measuring features (impedance: **Z**, series resistance: **Rs** or **ESR**, reactive impedance: **Xs**, quality factor: **Q**, loss factor: **D**, phase angle: θ) are measured too. The device is able to automatically choose the optimal measuring frequency and range to assure the optimal measuring conditions and best accuracy.*

*Besides these the device is **a function generator** that can produce **10Hz-100kHz sine, square, triangle** and **saw-tooth waves.** It can also function as **frequency meter** that measures **2.5V-15V** amplitude frequencies between **3Hz-12.5MHz**.*

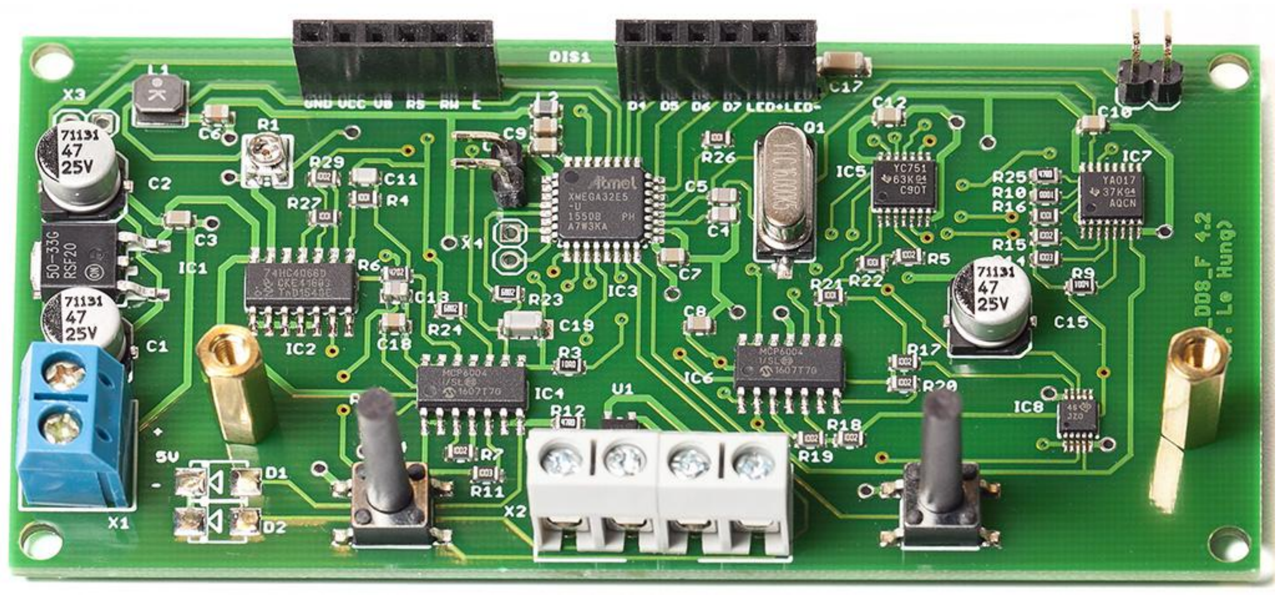
*The **4.2 LCR meter kit** is functioning base on one of the recently developed small voltage (<3.6V) AVR XMEGA microprocessor's capabilities. A ready-to-use **4.2 LCR meter kit** includes 1 pc. **tested, calibrated meter** assembled on a galvanized, 2-side, **professionally made SMD PCB**, 1 pc. tested **LCD display**, as well as 1 pc. **4 wire measuring cables with high quality Kelvin clips**. The 4.2 LCR bridge meter kits are available.*

- ***Webpage:*** **http://lcr-dds-f.atwebpages.com/en**
- ***E-mail:*** **hutale@gmail.com**

1. *Some pictures about Hutale 4.2 LCR-DDS-F bridge meter kit*

4.2 LCR-DDS-F bridge meter

4 wire measuring cables with high quality Kelvin clips



4.2 LCR-DDS-F bridge meter's PCB

2. ***Hutale 4.2 LCR bridge meter's features***

2.1 LCR meter's feastures

- ***Measuring parameters****:*

- ***Ls / Lp / Cs / Cp / R / ESR / Z / Xs / Q / D / θ*** *(the „s" letter means „series" model, while the „p" letter means „parallel" model)*
- ***In-circuit*** *electrolytic capacitance (C and ESR) can be measured too*
- *In* ***R / ESR measuring*** *mode meter can* ***measure the internal resistance of a battery / rechargeable battery*** *so the actual condition of the battery can be determined independent of the level of its charge. That is we can answer questions: How good condition is it in? Is it worth keeping it? Should we dispose it off? (To use this feature 2 small capacitors must be installed on the measuring cables to block the DC source from flowing into the meter – see later)*

- ***Measuring ranges:***
  - *In case of measuring resistance (R):* ***5mΩ – 20MΩ*** *(it can measure bigger resistance but I have not checked this)*
  - *In case of measuring capacitance (C):* ***1pF - 22000µF*** *(it can measure bigger capacitance but I have not checked this)*
  - *In case of measuring inductance (L):* ***0.01µH – 100H*** *(it can measure bigger inductance but I have not checked this)*

- ***Accuracy:*** *(Watch video. Some results have been compared to the results of a professional meter)*

  - ***Resistance measurements:***

Range	Accuracy
1Ω – 100Ω	***0.5%***
100Ω – 1MΩ	***0.3%***
1MΩ – 5MΩ	***1%***
5MΩ – 10MΩ	***3%***
0.1Ω - 1Ω	***5% +- 5mΩ***
<0.1Ω, >10MΩ	***NA***

Range	Optimal measuring frequency
<30Ω	***2.5kHz***
>30Ω	***100Hz***

  - ***Capacitance measurements*** *(at optimal measuring frequency)****:***

Range	Accuracy
1pF - 200pF	***1.5% +- 1pF***
200pF - 1µF	***0.5% +- 1pF***
1µF - 1000µF	***1%***
1000µF - 4700µF	***2%***
>4700µF	***NA***

Range	Optimal measuring frequency
< 1nF	***10kHz***
1nF – 100nF	***1kHz***
>100nF	***100Hz***

- ***Inductance measurements*** *(at optimal measuring frequency)***:**

Range	Accuracy
1µH – 60µH	***3% +- 0.1µH***
60µH – 100mH	***1% +- 0.2µH***
100mH - 100H	***2%***
<1µH	***5% +- 0.01µH***
>100H	***NA***

Range	Optimal measuring frequency
<1mH	***10kHz***
1mH – 100mH	***1kHz***
>100mH	***100Hz***

- ***Measuring frequency****:*
  - *Precisely made* ***100Hz / 250Hz / 500Hz / 1kHz / 2.5kHz / 5kHz / 10kHz / 25kHz / 50kHz*** *sine waves are used*
  - ***Fix measuring frequency:*** *can be chosen manually*
  - ***Automatic measuring frequency:*** *meter can automatically choose the optimal measuring frequency depending on the component under test. This is the default mode to help measuring a component under test (DUT) in any range without having to manually changing the frequency.*

- ***Voltage of measuring signal****:* ***0.35Vrms, 0.5Vrms automatically*** *chosen*

- ***Measuring technique****:* ***auto balancing bridge****; amperage and voltage are measured separately by using 4 wire (Kelvin) measuring cables*

- ***Measuring mode: series and parallel mode*** *(ex. Cs, Ls is measured with series model, while Cp, Lp is with parallel model)*

- ***Impedance ranges:***
  - ***9 impedance ranges:***
    - *0. range:* ***from 20MΩ***
    - *1. range:* ***3.3MΩ –20MΩ***
    - *2. range:* ***333kΩ –3.3MΩ***
    - *3. range:* ***33kΩ – 333kΩ***
    - *4. range:* ***3.3kΩ –33kΩ***
    - *5. range:* ***335Ω –3.3kΩ***
    - *6. range:* ***20Ω –335Ω***
    - *7. range:* ***1.2Ω –20Ω***
    - *8. range:* ***5mΩ –1.2Ω***
  - ***Impedance range-selection is automatically*** *done to get more accurate measuring results*

- ***Compensation, calibration:***
  - ***Compensation with open measuring cables*** *(this is done by me once after preparing the meter. You can but don't need to do it again)*

- ***Compensation with short measuring cables*** *(this is done by me once after preparing the meter. You can but don't need to do it again)*
- ***Calibration with 0.1% resistances*** *(this is done by me once after preparing the meter. You can but don't need to do it again)*

- ***Input protection:*** *The **4.2 LCR meter** is built with the PCB that has **input protection** that is based on a **protection IC**. This IC has low capacitance TVS diode arrays that are specially designed to protect sensitive components from **overvoltage** caused by **electrostatic discharge (ESD)**, **electrical fast transients (EFT)**, and **lightning**. It can bear a peak pulse power (tp=8/20µs) **300W**, peak pulse current (tp=8/20µs) **12A**, air voltage **Vesd_air=15kV**, contact voltage **Vesd_contact=8kV***

- ***Measuring speed: 1 measurement/3s***

2.2 <u>DDS function generator's features</u>

- ***Generated functions**: **sine**, **square, triangle, saw-tooth***
- ***Range**: **10Hz-100kHz***
- ***Resolution**:*
  - *10Hz-600Hz:1Hz*
  - *600Hz-1kHz: 0-4Hz*
  - *1kHz-4kHz: 0-30Hz*
  - *4kHz-10kHz: 0-200Hz*
  - *10kHz-20kHz: 0-400Hz*
  - *20kHz-50kHz: 0-600Hz*
  - *50kHz-100kHz: 0-900Hz*

  Explanation for the resolution range: the DDS function generator can produce waves with 1 Hz increment until 600Hz (ex. 10Hz, 11Hz, 12Hz, etc.) From 600Hz it is not sure that it can exactly produce the frequency the user wants. In this case it will modify the frequency a bit that it can produce precisely. The maximal difference is the resolution range's upper value. For example the user wants 1 kHz. The DDS function generator can produce it exactly, so it will do it (here: 0Hz difference). But if the user wants 1001Hz, then the function generator will modify the frequency to 1004Hz, because this is the value it can produce accurately. In all cases the frequency it produces will be displayed on the LCD. Another example: 10kHz is wanted. This is OK. But instead of 9999Hz the 10kHz, or instead of 10001Hz the 10204Hz will be produced. Among others the 100Hz, 250Hz, 500Hz, 1kHz, 2.5kHz, 5kHz, 10kHz, 12.5kHz, 20kHz, 25kHz, 50kHz, 100kHz frequencies will be generated without any changes.

2.3 <u>Frequency meter's features</u>

- ***Measureable amplitude**: **2.5V-15V** (if the signal has smaller amplitude it must be amplified)*
- ***Range : 3Hz-12.5MHz***
- ***Accuracy: 0.1%***
- ***Measurement speed: 1measurement/s***

2.4 Other features

- ***Power source:* 5.0-5.5V DC. *Attention!*** *We must connect stable (not necessary to be precise)* ***5V power source*** *or* ***USB power/charger*** *to the meter! On the PCB there is a* ***stabilizer IC*** *that makes* ***stable*** *and* ***precise 3.3V*** *for the circuit so the circuit is protected from big power if it is accidentally connected. But the LCD display is working with 5V and it gets power directly from power source so if bigger voltage is connected, the LCD display can go wrong. The LCD display is sensitive to the negative voltage so care (correct polarity) should be taken when connecting the power. Connecting power source supplying big amperage (>1A) with reserve voltage (-5V) would ruin the LCD. (There is no LCD-protection diode so 4.5V power could be used as well). A 6 voltage power source can also used if a diode is used between it and the meter. In this case the voltage on the meter will be reduced to 5.3V and this works well.*
- ***Power consumption:*** *about 30 mA (with LCD display backlight on).*
- ***The 4.2 LCR bridge meter kit*** *is a ready-to use LCR meter. To use it no need to use computer neither other device.*

3. *Hutale 4.2 LCR bridge meter kit includes*

- *1 pc.* ***assembled, tested PCB,*** *built with* ***input-protection IC***
- *1 pc. 2x16 character* ***tested LCD display****, fixed on PCB*
- *1 pc. 20cm* ***silicon insulated 4-wire measuring cables*** *with* ***high quality Kelvin clips***
- ***Calibrated*** *with 0.1% resistances,* ***ready-to-use meter***

4. *Hutale 4.2 LCR bridge meter kit's connectors*

- *Connector for power source: according to the text on PCB* 
- *Connectors for measuring cables: look at the picture* 

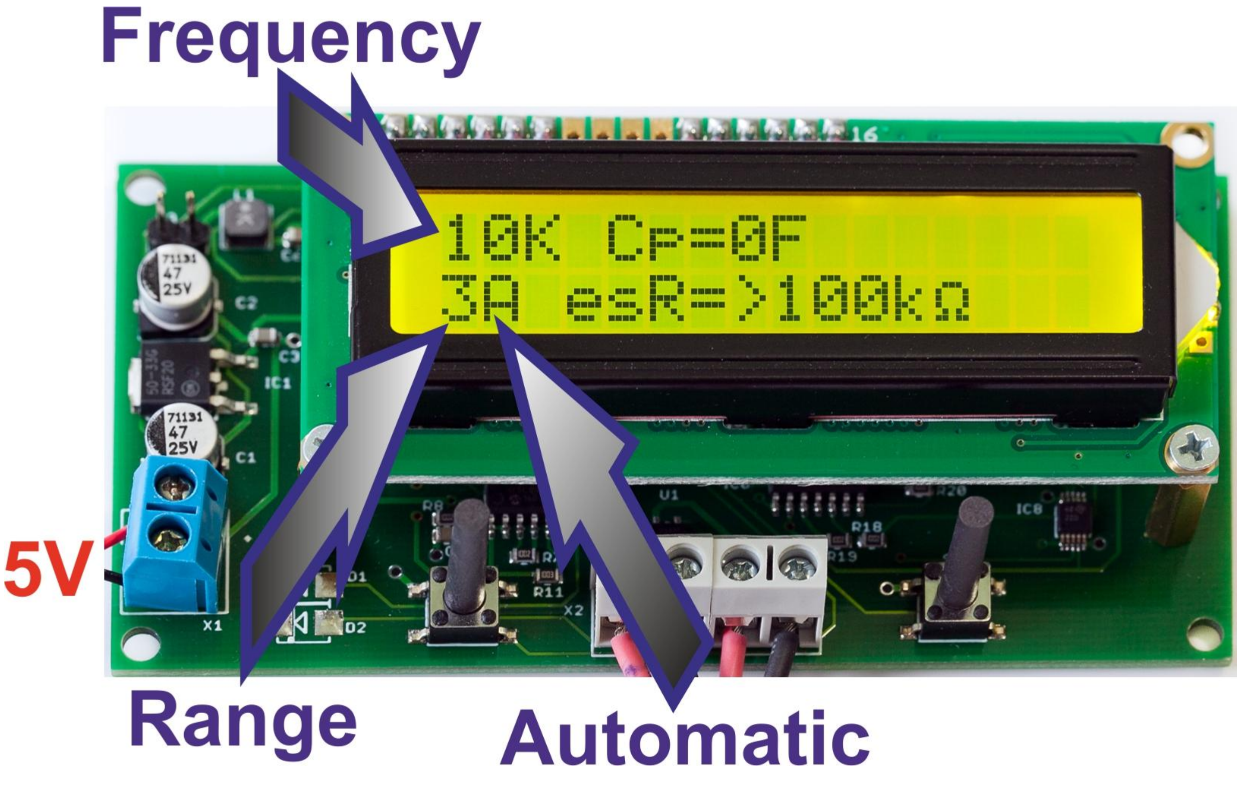
Hc Lc Hp Lp

Hc=High current, amperage measurement, + potential -> connect the marked measuring red wire (the ink mark is at the end of the wire)
Lc=Low current, amperage measurement, - potential -> connect the black (grey) twisted wire that is the pair of the marked measuring red wire
Hp=High potential, voltage measurement, + potential -> the other red wire
Lp= Low potential, voltage measurement, - potential -> the other black (grey) wire

5. Hutale 4.2 LCR-DDS-F bridge meter kit in operation - setup

5.1 Operation of LCR meter

After switching on, the ***4.2 LCR bridge meter kit*** *shows the actual automatically chosen measuring frequency and the value of the* ***primary parameter*** *(****Ls / Cp / R****) on the first row of the LCD display. At the same time on the second row, the* ***actual impedance range*** *– this can be any range between the earlier mentioned 0 and 8 ranges – and the value of the* ***secondary parameters*** *(****Lp / Cs / ESR / Rs / Z / Xs / Q / D / θ phase angle****) can be seen.*



Automatic frequency-choosing mode:

The ***4.2 LCR meter*** *basically* ***works in C capacitance measuring mode with automatic frequency-choosing mode****, when it is turned on. This mode is shown by the* ***"A" letter*** *(as "Automatic frequency") at the beginning of the 2. row of the display. The* ***meter*** *in this mode* ***automatically determines the optimal frequency*** *for the capacitance under test (DUT) and will use it to perform the measurement. It will show the result and of course the applied frequency.*

Meter does the same for measurements of inductances and resistances.

At automatic frequency R-mode, meter uses ***100Hz test signal*** *to measure* ***resistance value*** *bigger than* ***30Ω, and 2.5kHz test signal to*** *measure* ***resistances that are*** *smaller than* ***30Ω.***

*As I experienced the device with these 2 frequencies could measure the **whole range of resistors** with the **most accuracy** so that two are used.*

*Earlier we could read opinions that to determine the state of **electrolyte capacitors** we should use the **ESR** because it is more important than the knowledge of the **capacity**. This is generally true – there are lots of faulty **capacitors with big ESR** but their capacity seems not too bad. But there are cases where **faulty capacitors** have **ESR** value that seems OK. These can be **caught with capacity measurement** (capacity-reduction). So the **state of a capacitor** is determined the **best way** if we know **both the ESR and capacity**. ESR-meters have shortage: they only measure ESR and can't measure capacity. There are **simple capacity-meters** that **can't measure ESR**, neither **in-circuit ESR**. Users who use **general LCR-meters** experience that to get nominal value of electrolyte capacitors they must switch the test signal to **100Hz** (at bigger frequencies capacity will reduce – the capacity at certain frequency is strongly frequency-dependent). However the **ESR** value measured at **100Hz** is bigger than values in **tables** found on **Internet** or given by **ESR-meters / capacitors manufactures**, because these are measured at **bigger frequency**. So to get the capacity and comparable ESR value, general LCR-users (here it is worth mentioning that if a meter uses voltage with **big amplitude** then **it can't measure in-circuit ESR/capacity**) have to **take 2 measurements**: first measure capacity at 100Hz, then manually switch to higher frequency to measure ESR. The Hutale meter can **do both the measurements automatically in one step**. First it **measures the capacity** by using the optimal frequency, and then it immediately **switches to 2.5kHz and measure the ESR** (the difference of ESR value measured with 2.5kHz and with bigger frequency is not considerable, the ESR value measure at 2.5kHz is well useable) . If the ESR value <30**Ω** the meter displays that, else it displays the value measured with optimal frequency. With this new technique the Hutale meter is a better to use instrument compared to other meters.*

*So despite the fact that generally LCR meter is complicated to be used, the **4.2 LCR bridge meter** with **automatic frequency-choosing mode** is very **convenient to use** regarding to the whole measurement range.*

The user should review the table below, where the optimally measureable and well measureable ranges can be seen. Note that the last is much bigger. The use of table is rather needed, if the user wants to select measuring frequency manually:

Measuring frequency	***Range for capacitance***		***Range for inductance***	
	Optimally measurable	***Well measurable***	***Optimally measurable***	***Well measurable***
100Hz	***>1µF***	***>100nF***	***>1H***	***>100mH***
1kHz	***1nF-1µF***	***500pF-10µF***	***1mH-1H***	***500µH-10H***
10kHz	***<1nF***	***<10nF***	***<1mH***	***<10mH***

Manual frequency-choosing mode:

*The **test signal** however can **be manually changed cyclically** any time by pushing the **frequency-switching (right-side) button: automatic -> 100Hz -> 250Hz -> 500Hz -> 1kHz -> 2.5kHz -> 5kHz -> 10kHz -> 25kHz -> 50kHz ->automatic, etc.** The **Hutale LCR meter** is interpreting the state of this button according to the next: If it senses one time push, then it*

will switch to the next frequency; if it senses a twice slow push, then it will switch to the frequency that is following the next.
*It is worth noting that the measured value of electrolyte capacitors and big value inductors is reducing as the measuring frequency increases. Some **inductors and capacitors** at some frequency **do not behave linearly, that is they are strong frequency-dependent.***

Measuring modes, zeroing measuring cables:

*The meter has another button on the left side. This is the **measuring mode-switching button**. When meter senses a push – depending on the state of one time or twice push – it switches between the **L / C / R** mode to the next or to the one following the next.*

*The buttons also has alternative functions. If we push and hold the **frequency-switching (right-side) button for 3 seconds**, and then release it, the **4.2 LCR meter kit** will switch to the **„Zeroing measuring cables" mode**. This time follow the meter's instructions to complete the cables zeroing process (or switch OFF and ON the meter to skip):*
- open measuring clips: place the clips on the table so one is on top of the other (do not pinch, touch and short the clips)
- push left button and wait
- short clips: short the clips with a bare wire or metal of about 2 cm long and place them on the table
- push left button and wait
- save?: Push left button to save the results or right button to exit without save.

*By placing the clips as described we assure that the distance of the measuring clips are the same as when measuring a component so we can **minimize the effect of the stray capacitance of the clips** when measuring very small capacitors or inductors. To make the zeroing result more accurate, the **4.2 LCR meter kit** make **lots of measurements** and at the end make an **average**. It will calls for patience to complete it. If we order the meter to save the zeroing result to the **EEPROM** memory, then this **setting will remain**, even after the meter is turned off. It is recommended to complete the zeroing process after the meter works stably! This can be expected about **15 minutes** after the meter was switched on. The measuring cables with Kelvin clips are zeroed after the meter is prepared so zeroing them is not necessary (if new cables are prepared then it must be zeroed!)*

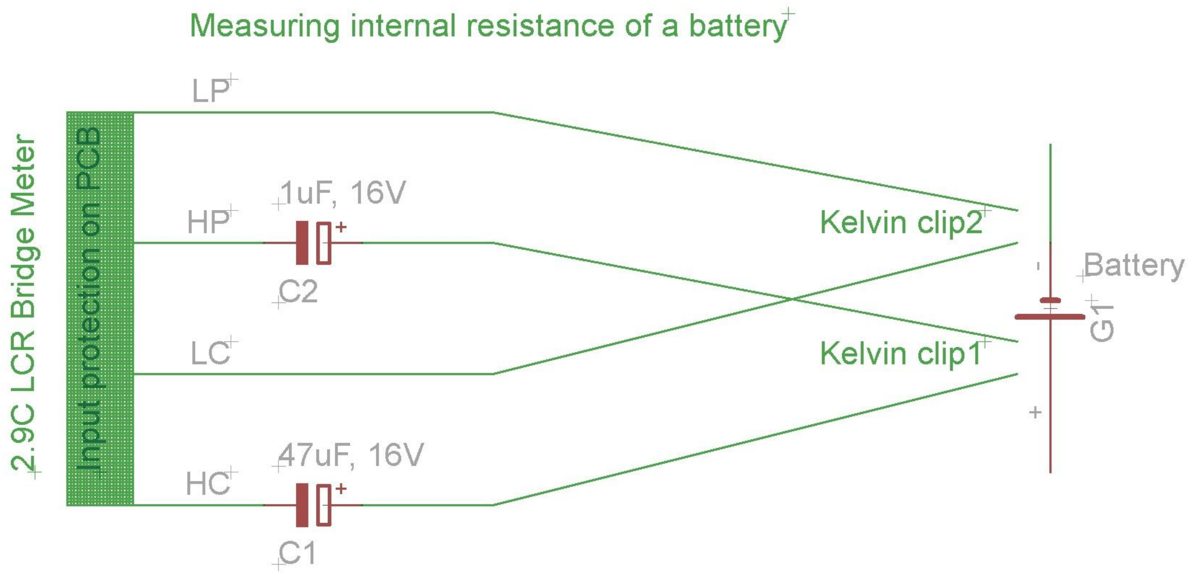
*Similarly, if we push the **measuring mode-switching button for 3 seconds,** and then release**,** the meter will switch to the **secondary parameter-switching mode.** It will show and keeps on flashing the value of the actual secondary parameter (**ESR / Rs / Cs / Lp / Z / Xs / D / Q / θ phase angle)** on the 2. row of the LCD display. Until the value is flashing (meter keeps doing this for a few seconds) we can go on changing the parameter by pushing the **left button**. If meter does not sense any push on the button then it will exit from this mode. The chosen secondary parameter now will be displayed and will remain.*

*The **meter** has also **averaging measuring mode** to give **more stable and more accurate results** – it takes lots of measurements for 6 second and then display the **average** of them. To activate this mode, we activate the **secondary parameter-switching mode** (see earlier) and when display-flashing is happening, we now push once the **right button** (not the left button). Meter then enters **averaging measuring mode**. In this mode we **must remember** that **after attaching a component** to begin to measure it, we **should discard the first result** because of the nature of component-changed-while-measuring state (the result cannot be correct). We **should wait for the 2-th, 3-th, etc. result** of measurements. Then result are (close) similar.*

We do the same way to get back to the normal (faster) measuring mode (or just switch off-on the meter).

Measuring internal resistance of batteries or rechargeable batteries:

*We can **measure the internal resistance of a battery or rechargeable battery** that has the voltage in the range 1.2V-12V. To do this we have to block the DC source by using **2 plus capacitors** on the measuring cables given in the kit according to the next schematic (the accuracy of the 47uF and 1uF capacitors is not important; on the picture we see "2.9C LCR" text but this is OK for LCR 4.2 version as well):*



*After connecting the new cables we have to enter **R / ESR measuring mode.** First close the clips (as if we zero the cables) measure once and note the value meter reads – we can call this value CABLE_ESR value. Then we can measure **the internal resistance of a battery or rechargeable battery.** By subtracting CABLE_ESR value out of the result we will get the actual internal resistance.*

As I experienced, rechargeable AA batteries in good condition had about 100 mΩ and AAA small types had about 200 mΩ internal resistance. When they are used a lot, the internal resistance will increase 2 times, 3 times. When the value is 4 times, 5 times or more, we should be thinking of disposing them off (they are worn out so if we try to charge, it will not charge as expected and will discharge very fast).

***Attention!** During measuring batteries the DC blocking capacitors will charge up to the level voltage of the battery so we should take care of not touching the clips each other and we finish the battery measurements by measuring a 10kΩ resistor – we do this to discharge the DC blocking capacitors.*

5.2 Operation of DDS function generator

*By pushing-holding the **mode-changing (left) button** for **6-7s** the meter will changing cyclically between modes: **LCR meter -> DDS function generator -> frequency meter -> LCR meter**, etc.*

*By default the **DDS function generator** produces **3.3V amplitude 10 kHz sine wave** on **Kelvin clips**. This is a good enough signal but a **better quality** one can be detachable from **red Kelvin (Hc/Hp) clip and GND terminal**.*

*The **frequency** and the **waveform** of the **DDS signal** can be **changed**: push the **left button** to change the **frequency**, and the **right button** to shift the **waveform!***

*At pushing once the left button the **function generator** displays all the **6 digits of the actual frequency with zero-leading** (ex. "**010000Hz**" in case of 10 kHz) and **blinks the cursor** on the first digit (ex. '0' digit that stands before '1') indicating that **the digit can be changed**. If then we push the **right button the digit will be increasing** one by one, ex. 1,2,3...,8,9,0, etc... If we push the **right button for 3s** then instead of increasing, the digit will be **set to 0** – this is* a *rapid adjustment to zero. If we push the **left button** then the function generator will **shift to the next digit** and **blinks** that indicating it **can be changed**. If the function generator doesn't sense any button-push, then it will exit from frequency-changing mode and will produce the chosen frequency (or will slightly change that to the value it can produce precisely – see DDS range resolution above).*

*While producing waveform the **function generator** will sense **the right button-push** and will **change** the **waveform cyclically: sine -> square -> triangle -> saw-tooth -> sine**, etc.*

*Because the **function generator** was firstly designed to produce **good quality sine** it has **active low-pass filter**. This nevertheless will spoil a bit the other waveforms (square, triangle, saw-tooth) at higher frequency. This can be avoided, if we detach the signal **directly from DDS** (not after but **before the low-pass filter**). This **connection** can be seen on the **next picture**:*

5.3 Operation of frequency meter

*From DDS "function-generator" mode by pushing the **mode-changing (left) button** we can enter the **frequency measuring mode**. If there is no signal on **frequency input terminals,** the meter will display 0 Hz or if there is a noise source nearby, it will show 50 Hz (in EU) or 60 Hz (in USA). When it senses a **signal**, it will **measure** and **display** the frequency of it. The measurement speed: 1measurement/s.*

*The frequency meter has **separate input connectors that we must use**. At this input a **1kΩ current limiter resistor and 100nF AC decouple capacitor** is found so **maximum 15V amplitude signal** can be connected. Bigger signal can be measured with a help of a **resistor voltage divider** (it is best if the signal is divided to 5V).*

*The meter can **measure maximum 12.5MHz signal**. **Bigger frequency** can be **measured** by the help of a **frequency divider**.*

The frequency input connector can be seen on the next picture: 

6. Attention to pay when using the 4.2 LCR meter kit:

- ***Better quality** measuring clips **(especially Kelvin clips)** give more **accurate and stable results**. The **Kelvin clips** are **good**, because: **gold-plated** – this gives very **good conductivity**; has **strong spring** to make a **stable contact**; the 2 halves are **electrically isolated** from each other (they conduct only at the point where they touch the DUT) so they do not affect the accuracy of the measurements. But to be able to solder the measuring wires to the Kelvin clips we have to lift up the metal bar against the spring by using a screwdriver. If you want to make yourself 4-wire measuring cables then you have to solder the cables to one-one Kelvin clip like this: solder the short wire straight to one soldered-point of clip, then lead the longer wire inside the clip by forming an arc and solder it to the other solder- point. After soldering, twist the 2 straight short wires and then twist the 2 long wires (watch my Kelvin clips to see how it is done). Literatures recommend we prepare the cables that way - it helps to make measurements more accurate and stable (besides this the clips are easier to use).*
- *To **protect** the **4.2 LCR meter** the best and **maintain sustained efficiency of input-protection**, always **DICHARGE CAPACITANCES BEFORE MEASURING!** In the worst case, the input-protection IC U1 (CM1224-04SO) would not survive a long lasting discharge (amperage), it would go wrong, and then multiplexer IC8 (TS3A24157DGSR) (or maybe OP amplifier IC6 MCP6004) can go wrong too. Fortunately these ICs can be bought and replaced easily.*
- *To measure frequency **we must use the frequency input connectors.** We must not use Kelvin clips to connect the signal because a power-source with amplitude bigger than 3.8V can ruin a few ICs (see above).*

Hungary, 2021.12.08

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