Höcherl & Hackl
The electronic load

Application Note #11

Energy Storage Test with PLI B Series

The integrated discharge function allows to discharge energy storage devices such as rechargeable batteries, ultracaps etc. with electronic loads of the PLI series in a simple and controlled way and to determine values such as charge and energy.
With the PLI production series B, the discharge can be carried out dynamically using the list function.

Safety Instructions

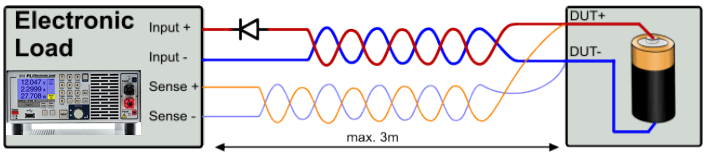
Incorrect handling can cause irreversible damage to the DUT up to fire development!

- Carefully read the operating and test conditions of your DUT and the user manual of the electronic load.
- Never leave your energy storage device unattended during the test!

Important Wiring Notes

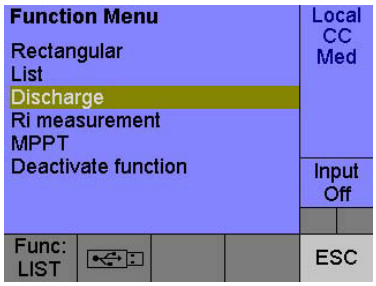
When connecting an energy storage device to the electronic load, special care must be taken! The PLI devices are protected against reverse polarity up to their rated current. This is achieved by a reverse diode. This means that a reverse polarity connection of the energy storage device can be compared to a short circuit. Uncontrolled high currents will flow, which can destroy not only the test object, but also the load.

- For this reason, switch an external reverse-polarity diode or a fuse into the load circuit.

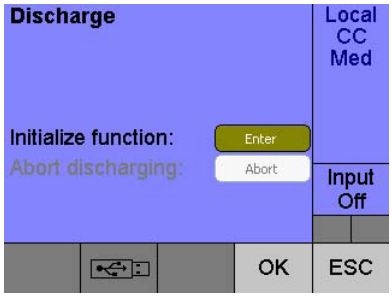


Operation via User Interface

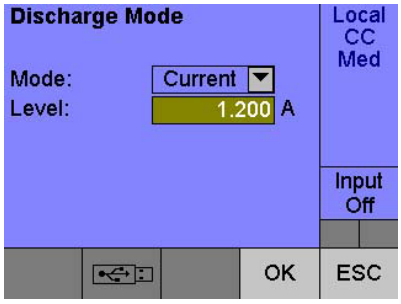
The discharge function is selected in the "Function Menu".



By "Initialize function" the next window for selection of the operating mode is set.



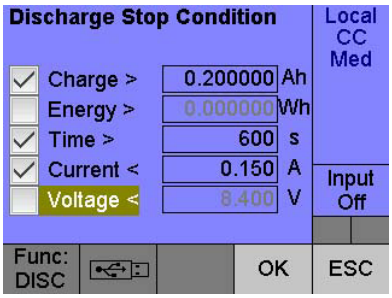
In the "Discharge Mode" menu one of the static operating modes Current, Power, Resistance with corresponding setpoint or the dynamic operating mode List is defined. We start with the static mode Current (example with list see below) and confirm with "OK" to enter the next dialog window. The value of the setting can also be changed later during ongoing discharge.



In the Discharge Stop Condition dialog the discharge stop criteria are activated.
At least one stop criterion must be activated, otherwise "OK" does not take you to the next menu, but takes you back to the "Discharge Mode" menu.
Any number of switch-off criteria can be activated. The first one that is reached terminates the discharge.

⚠ If possible, always select a second stop criterion to protect the DUT!

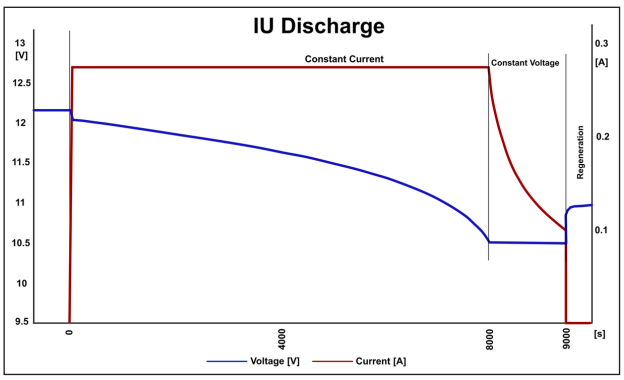
Example: You discharge a 10000 mAh battery up to a minimum voltage X as stop criterion. The discharge time assumed by you is about 30000 s. In addition, set the time criterion slightly above this time and/or activate and set the charge criterion to the capacity of the battery.



The quantity of charge and energy is checked for exceedance. This means that the discharge stops when the accumulated charge or energy is greater than or equal to the specified switch-off value. The charge criterion is well suited as an additional safety shutdown (when testing batteries and accumulators; we recommend setting the value to the specified capacity of the DUT).
The time is checked for exceeding. This means that the discharge stops when the time is greater than/equal to the specified value.
The voltage is checked for undercutting. This means that the discharge stops when the voltage is less than or equal to the preset value.

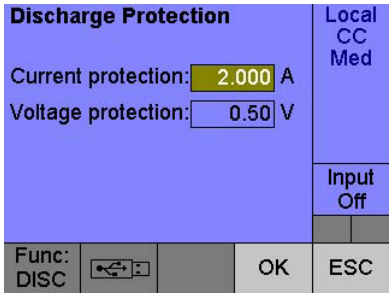
IUa Discharge, CC+CV, CP+CV, CR+CV Discharge

A special operating mode is discharge according to IUa characteristic curve. The DUT is first discharged with constant current up to a defined voltage. When this minimum voltage is reached, the electronic load implicitly switches to constant voltage operation, i.e. the specified voltage is kept constant until the measured current has decreased below the value of the stop criterion current (see below). Only then does the load switch off the load input and the test is completed. Basically, this is also possible in constant resistance or constant power mode.



The voltage limit at which the electronic load switches to voltage operation is set via the voltage protection, see next section.
Confirm the selected stop criteria with OK.

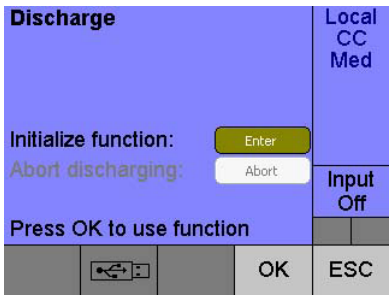
⚠ The "Discharge Protection" menu is the last step in configuring the discharge function and is also one of the most important settings that helps to protect the DUT.



Current protection: The maximum permissible current is set here. The default value is the maximum possible current of the electronic load. Adjust the value to the maximum permissible current of your DUT. This prevents destruction by overcurrent, especially in the operating modes power and resistance. When discharging in current mode, the value should be slightly higher than the discharge current.
Voltage protection: The minimum voltage up to which the load draws current from the test object is set here. The device monitors this voltage via hardware. The default value is 0.5 V.

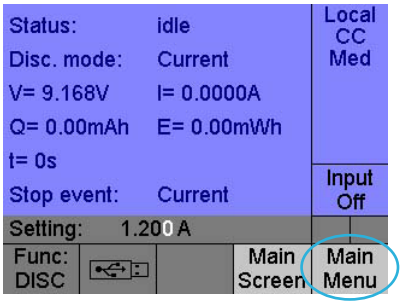
⚠ If the Current (I)< criterion is not activated, for safety reasons select the voltage so that the test object is not deeply discharged or even destroyed! If Current (I)< switch-off is activated, Voltage Protection is the setpoint for the transition from discharge mode to constant voltage control to reduce current consumption.

After the protection setting, press "OK" to return to the Discharge window.



With "OK" in the Discharge menu the initialisation of the discharge function is completed.

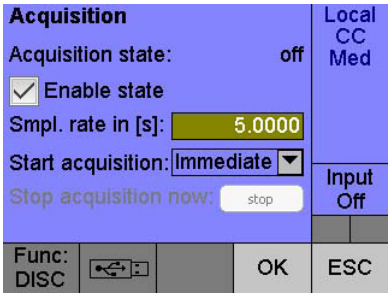
Discharge Screen



Before you start discharging, you can initialize simultaneous data logging.
To do this, go to the main menu with the "Main Menu" softkey and select "Settings".

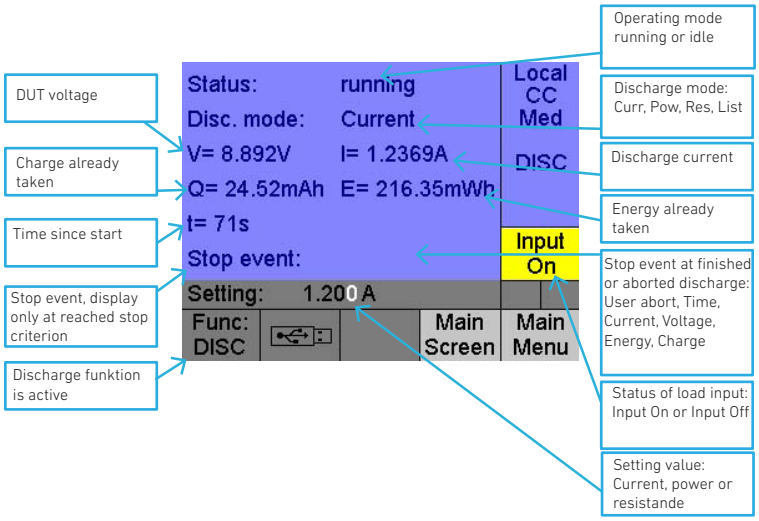
Data Acquisition and Data Logging

In the "Settings/Acquisition" menu you set whether and how often data records shall be stored in the internal memory of the electronic load.



At the end of the test, the data can be exported to a USB flash drive via the "Data/Export" menu.
In local mode, the data can also be stored directly on a USB flash drive without first having to store it in the internal memory. This is set in the "Settings/Data/USB logging" menu.

You can now start the unloading and logging function together with the key sequence Shift -> Start. The load input is switched on automatically. The DISC and LOG status displays alternate in the Discharge status field.



If one of the configured stop criteria is reached, the electronic load stops the test and switches off the load input. The shutdown criterion is displayed at "Stop event".
A running discharge can also be aborted manually at any time with Shift -> Stop. Then "User" is displayed as Stop event.

The Log File

The function "Settings/Acquisition" generates a folder with the name INT_MEM on the USB stick, the function "Settings/Data/USB logging" a folder with the name LOGGING. In each folder a file is created whose name is derived from the date and time of the electronic load at the start of the test:
Example: PLI_2016-02-04-01-02-33.CSV
Start of the test on 04.02.2016 at 1 o'clock, 2 minutes and 33 seconds.
The CSV file contains the following information:

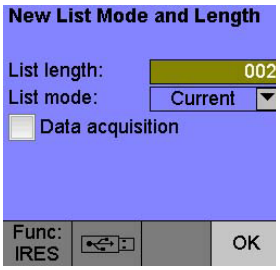
PLI_2016-02-04_01-02-33.CSV

Data log start: 2016-02-04 01:02:33		
Rel. time in s	Voltage in V	Current in A
0	12.038941	0
1	10.978352	7.99712
2	10.960367	7.997163
3	10.938271	7.997205
4	10.922342	7.997205
5	10.904871	7.997163
6	10.884831	7.997163
7	10.86813	7.997163
8	10.847833	7.997205
9	10.836528	7.997205
10	10.816489	7.997205
11	11.87939	0
12	11.895577	0
13	11.906368	0
14	11.909964	0

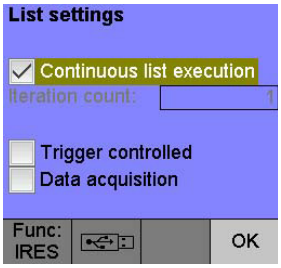
Row 1: date, time at start
Row 2: measurands with units
Row 3 and following: time, voltage, current
Second last row: date, time at stop (only when logging directly on USB flash drive)
Last row: stop condition, charge and energy taken (only when logging directly on USB flash drive)

Dynamic Discharge

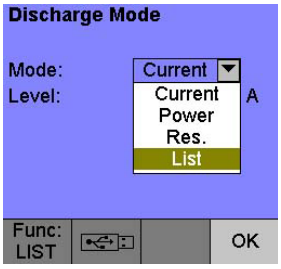
For applications that require pulsed or other dynamic discharge of the test object (e.g. e-bike battery), the list function of the electronic load is combined with the discharge function.
For this purpose, a list is defined before selecting the discharge mode. This is done in the "Settings/Functions/List" menu.



At the end of the list definition, the list execution must still be set to "Continuous list execution": Menu "Settings/Functions/List/List settings":



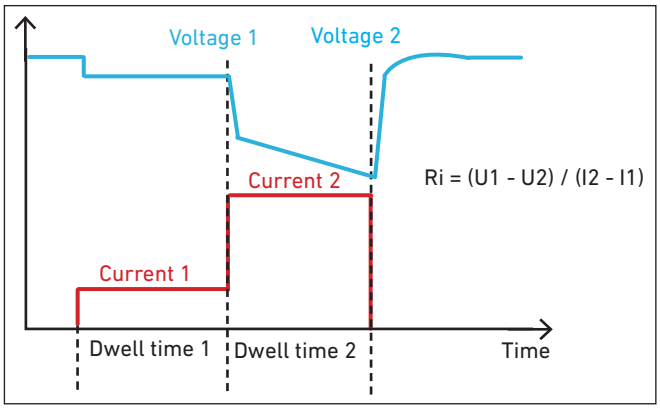
After confirming with "OK", set the operating mode "List" in the "Function/Discharge/Initialize function" window:



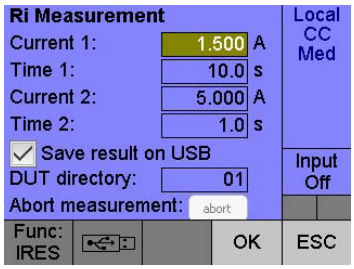
The logging function can also be combined with the dynamic discharge function - however, list synchronous sampling must remain deactivated in this case.
All functions are started again together with Shift -> Start.

Internal Resistance Measurement

A further function of the PLI series is the direct current internal resistance measurement of energy storage devices such as accumulators, batteries, capacitors, but also of cables, power supplies, etc. The measurement is based on the voltage change during a current jump. The current jumps from a low value to a high value. At the end of each current step, the voltage is measured and the voltage difference is divided by the current difference.

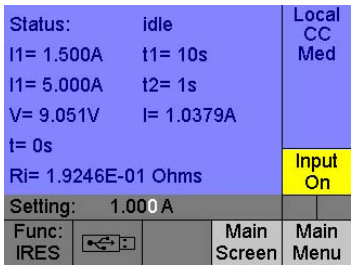


For the test, the two currents with the corresponding dwell times (=measurement time) can be set in the "Settings/ Functions/Ri" measurement menu.



Start the measurement with "OK" and Shift -> Start.

The result of the test is displayed on the user interface and (in our example) stored on the connected USB stick.



Programming

All locally operable functions shown so far can also be remote controlled via a data interface. The following shows the SCPI command sequence for an example with pulsed CC discharge (2 s with 12 A, 10 s with 1.5 A) and internal measurement data storage with subsequent reading of the data and measurement of the DUT's internal resistance.

Establish defined initial state, define current pulses with list:

```
*RST
LIST:MODE CURR
LIST:CURR 12.0,1.5
LIST:RTIM 0,0
LIST:DWEL 2.0, 10.0
LIST:COUNT 9.9E37
```

Set interval for data acquisition to 1 s:

```
ACQ:STIM 1.0
```

Initialize discharge function: IUa discharge to 35 V, then current reduction to 1 A, for safety's sake second stop criterion charge:

```
VOLT:PROT 35.0
FUNC:DISC:STOP:CURR 1.0
FUNC:DISC:STOP:ENAB CURR,ON
FUNC:DISC:STOP:CHAR 14.0
FUNC:DISC:STOP:ENAB CHAR,ON
```

Load input on, start all functions:

```
INP ON
LIST ON
ACQ ON
FUNC:DISC ON
```

Query stop event:

```
FUNC:DISC:STOP:EVEN?
```

If stop event other than NONE, discharge is complete. Read data (only 100 data records can be read at a time):

```
Data:POIN?      //Response e.g. 1678
DATA:REM? 100
DATA:REM? 100
...             //16 iterations
DATA:REM? 78
```

Measure the DUT's internal resistance:

```
FUNC:MEAS:IRES:CURR 1.0,5.0
FUNC:MEAS:IRES:DWEL 2.0,1.0
FUNC:MEAS:IRES:RES?  //as long as value other than 0
```