Two Wheels Instrument Station Tester (TWIST)

User Manual

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

18 febbraio 2018

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Summary

1 Hardware Framework

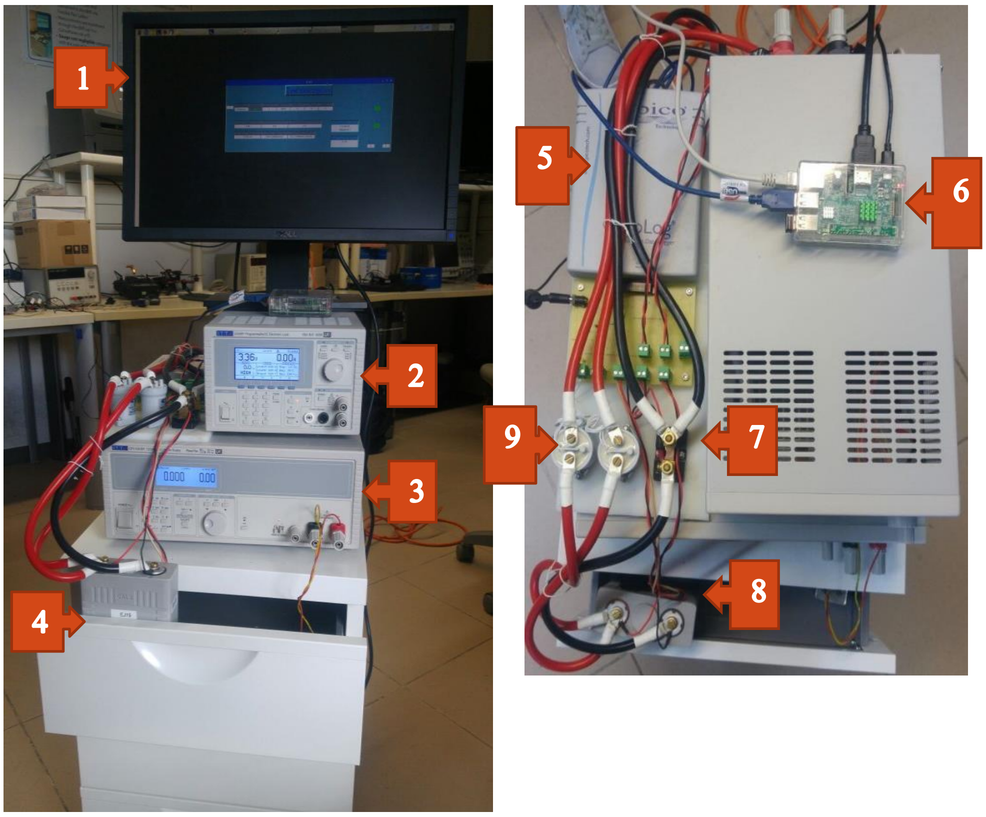


FIGURE 1: HARDWARE FRAMEWORK

	Components	Specification
1	LCD Screen	
2	Electronic LD400P[1]	Max input: 80A;80V Max Power: 400W Setting Accuracy (CC): ±0.2% ±30mA Setting Accuracy (CV): ±0.2% ± 2digits
3	Electronic charger QPX1200SP[2]	Max output: 50A;60V Max Power: 1200W Setting Accuracy (CC): 0.3% ± 20mA Setting Accuracy (CV): 0.1% ± 2mV
4	Cell under test typology	Capacity: 0 – 80Ah Voltage range: 0-5V
5	DAQ PicoLog[3]	16 channels Max input voltage: ± 1250mV Measure Accuracy: 0.1% ± 36μV (input voltage set to ± 1250mV)
6	Raspberry Pi 3 B	
7	Shunt-Resistor[4]	Murata_3020-01108-0 Scale Factor 100 mV/100 A

[1]See datasheet LD400P.
[2] See QPX1200SP datasheet.
[3]See PicoLog ADC-24 datasheet.
[4] See Murata datasheet

8	Relays[5]	KILOVAC LEV100 Coil voltage:12V Max Continues Current: 100A
9	Temperature Sensor[6]	LM35 Scale factor: 10 mV/°C

1.2 TWIST specification

Supported test typology:	Pulse Current Test (PCT) Hybrid Pulse Current Test (HPCT)
Input voltage:	0 – 4.5V
Max discharging current:	80A
Max charging current:	50A
Max sampling frequency:	2Hz
Voltage Accuracy[7]:	Offset = 21.5uV, Gain = 0.2%
Current Accuracy[8]:	Offset = 1.256 mA, Gain = 0.075%

2 Installing Procedure

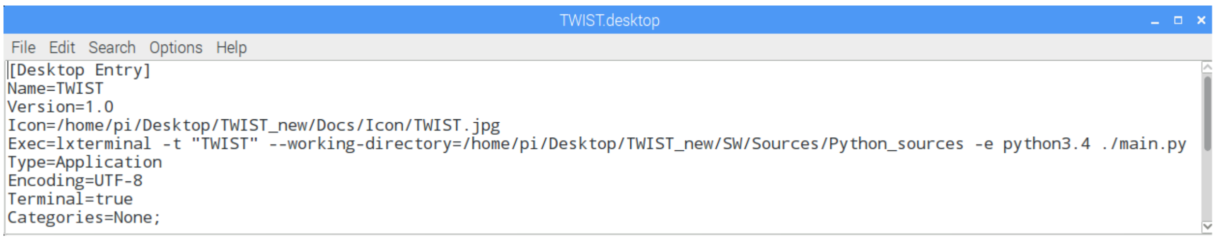
1. Install *Python3.4* repository on Raspbian OS. Follow the indication at https://docs.python.org/3.4/installing/index.html.
2. Transfer TWIST folder in Raspbian OS on Raspberry Pi 3 model B.
3. Install Picolog-ADC-24 driver (***libusbdrdaq*** package) according to the procedure indicated at https://www.picotech.com/support/topic14649.html. If the installing procedure has not terminated with errors, you can find the *"libpicohrdl.so","libpicohrsl.so.2"* and *"libpicohardl.so.2.0.0"* files, at Raspberry absolute path *"/opt/picoscope/lib"*;
4. Copy the *"libpicohrdl.so", "libpicohrdl.so.2"* and *"libpicohardl.so.2.0.0"* files in *"./TWIST/SW/Sources/C++_sources";*
5. Open *Geany* or an equivalent g++ Integrated Development Environment (IDE).
6. Click on *Build* menu and then on *Set building commands* one;
7. Enter "*g++ -Wall -c "%f" init.cc*" and "*g++ -Wall -o "%e" main.o init.o libpicohrdl.so*", in *Compile* and *Build* fields, respectively;
8. Start first the compiling, and then the building procedure through the *Build menu* of Geany IDE;
9. Type from command line: *sudo chmod +x < path of main.py >;*

Note: main.py is at *"./TWIST/SW/Sources/Python_sources"*.

[5] See relays datasheet
[6] See temperature sensor datasheet
[7]See Article.
[8] See Article.

10. Change the default LAN interface settings of LOAD (LD400P) and CHARGER (QPX1200SP) according with the IP addresses and the port numbers contained in *“./TWIST/SW/Setting_file/loadinfo.txt”* and *“./TWIST/SW/Setting_file/chargeinfo.txt”*, files, respectively[9] [10];
11. Change the IP address of Raspberry PI with another that has the same prefix of load and charger one according to the procedure described in https://www.raspberrypi.org/learning/networking-lessons/rpi-static-ip-address/;
12. Click on TWIST icon with mouse’s right button in “./TWIST/SW”, and select *Text-Editor* menu bar. Finally, insert in “*Icon=”* and *“–working-directory=”* fields, the new ABSOLUTE PATH of TWIST icon picture and of main.py, respectively (see Figure 3);

Note: the icon’s picture is available at *“./TWIST/Docs/Icon*



```
[Desktop Entry]
Name=TWIST
Version=1.0
Icon=/home/pi/Desktop/TWIST_new/Docs/Icon/TWIST.jpg
Exec=lxterminal -t "TWIST" --working-directory=/home/pi/Desktop/TWIST_new/SW/Sources/Python_sources -e python3.4 ./main.py
Type=Application
Encoding=UTF-8
Terminal=true
Categories=None;
```

FIGURE 3:TEXT EDITOR OF TWIST ICON

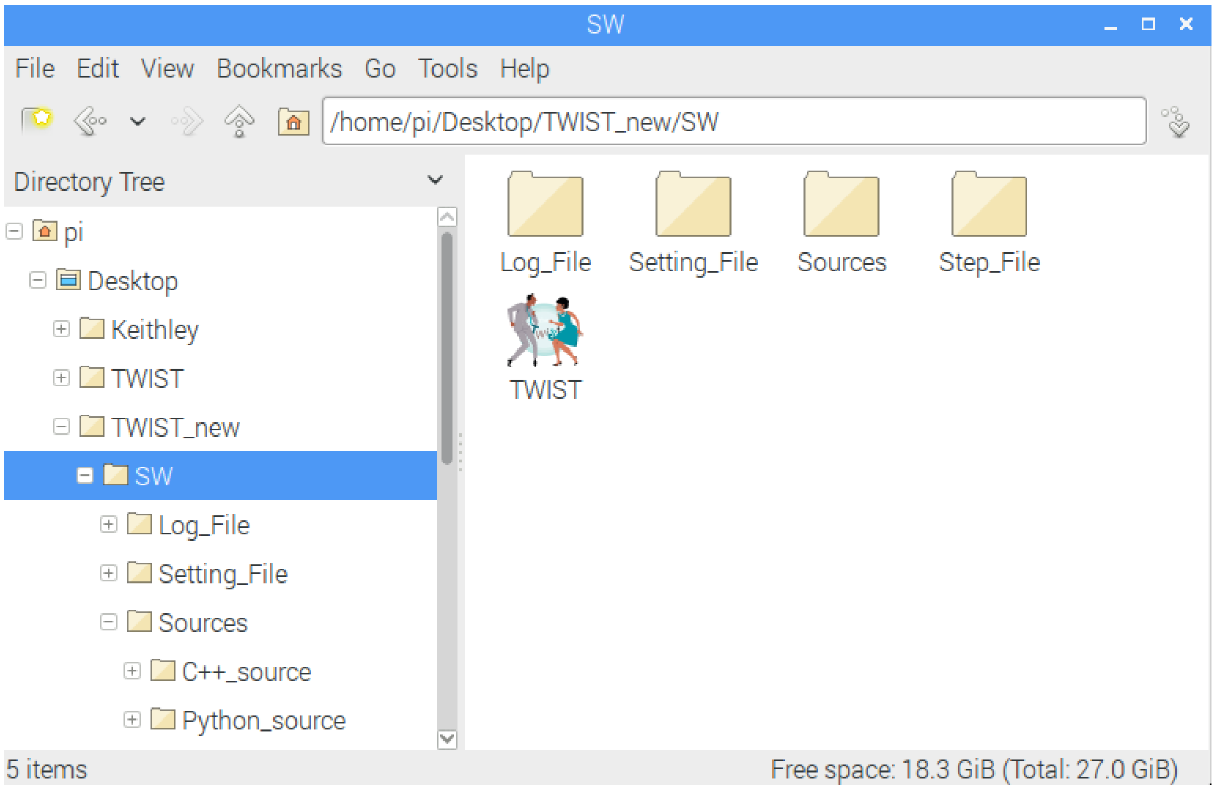


FIGURE 2:./TWIST/SW FOLDER VIEW

[9] See LD400P user-manual p. 36.
[10] See QPX1200SP user manual p.11.

If the procedure is correctly done, the TWIST icon aspect will be like that shown in Figure 2.

Note: Repeat the step number 4, every time that the TWIST folder absolute path changes.

3. Test execution

3.1 Procedural test definition

Before starting the test characterization of a Li-ion cell, the operator must define the test protocol trough a specific file named "Step-file". The file is available at "./TWIST/SW/Step_file". The textual commands are divided in two typologies: commands and comments.

The first category produces actions on the cell through the LD400P and QPX1200SP, and it is composed by seven fields:

TYPE	***LOG_EN***	***SAMP_TIME***	***TEST_LEN***	***TEST_I***	***TEST_V***	***STOP_I***

- *TYPE s*pecifies the type of operation to perform over the cell under test, and it can assume three values:
  - *Charge,* define a cell charging phase.
  - *Discharge,* define a cell discharging phase.
  - *Measure,* define a rest cell period.

- *LOG_EN* can assume two values*:*
  - *0* means that any Log-files will be generated at the end of test step.
  - *1* means that Log-files will be generated at the end of test step.

- *SAMP_TIME* specifies the LD400P and QPX1200SP sampling time in seconds. Anyway, the DAQ Picolog sampling time is always fixed to 0.5s.
- *TEST_LEN* specify the total step duration in seconds. Moreover, it can assume the value of '-1'. In this case, the temporal stop condition "TEST_LEN" is no longer relevant.
- *TEST_I* specifies the charging or discharging current amplitude in ampere.
- *TEST_V* specifies the upper or lower lithium-ion cell cut-off according to the step "TYPE", in voltage.
- *STOP_I* specifies the current stop condition. If the current amplitude goes below STOP_I value, the test ends.

The Second instruction type are preceded by # character, and they are ignored from the program execution. In Figure 4 a Step file instance is shown.

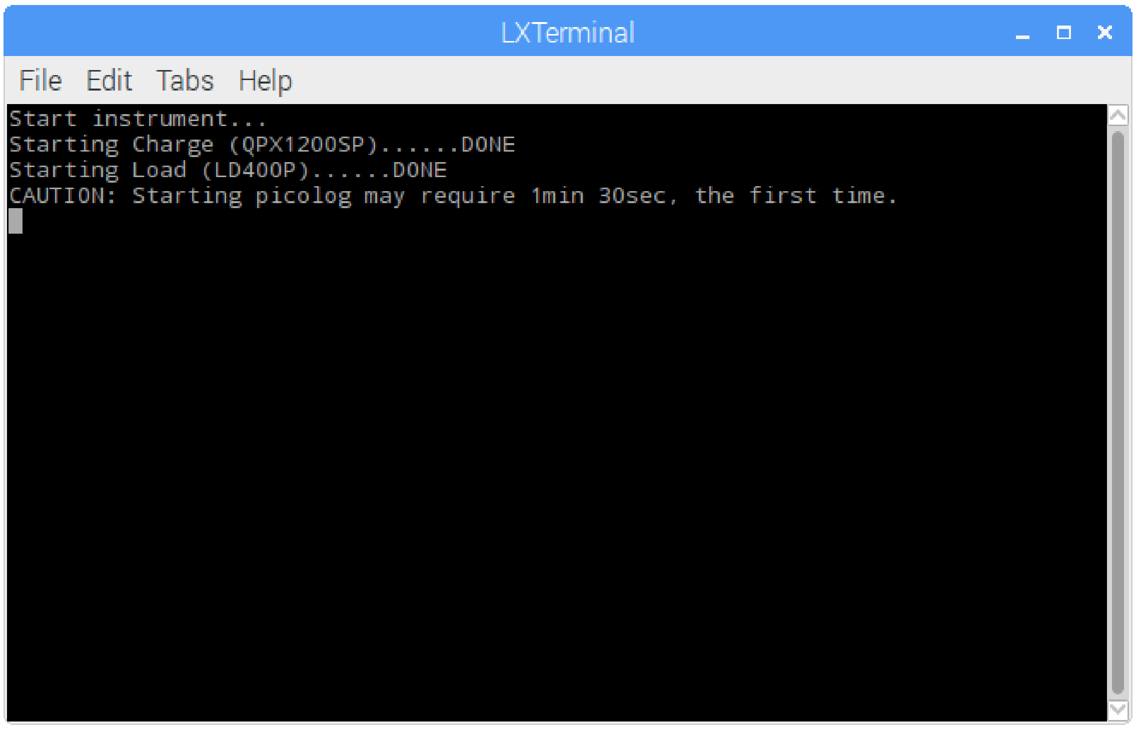
Note: to set the cell temperature range, the user could modify *TempRange* parameters contained in textual file at "./TWIST/SW/Setting_file/picologinfo.txt".

```
#full charge
charge              1       1       -1      20      3.6     0.1

#full discharge
discharge           1       1       -1      40      2.8     0.1

#full charge
charge              1       1       -1      20      3.6     0.1
```

FIGURE 4: A STEP FILE INSTANCE

3.2 Starting phase

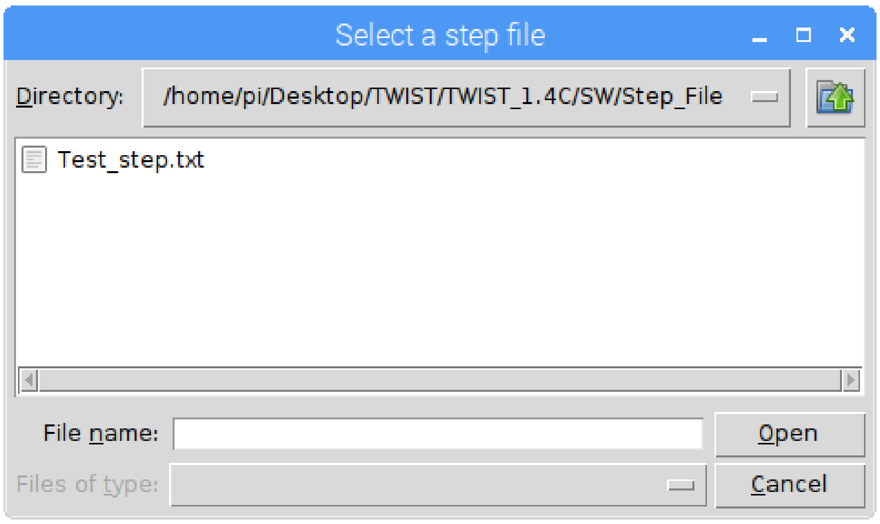
To start the test, the operator must click on TWIST icon. After that the LXTerminal showed in Figure 5 will open.



```
Start instrument...
Starting Charge (QPX1200SP)......DONE
Starting Load (LD400P)......DONE
CAUTION: Starting picolog may require 1min 30sec, the first time.
```

FIGURE 5: LXTERMINAL

After the instruments initialization phase, the software asks to the user to select three folder paths. First, the operator chooses the Step-file path as show in Figure 6.


Select a step file

Directory: /home/pi/Desktop/TWIST/TWIST_1.4C/SW/Step_File

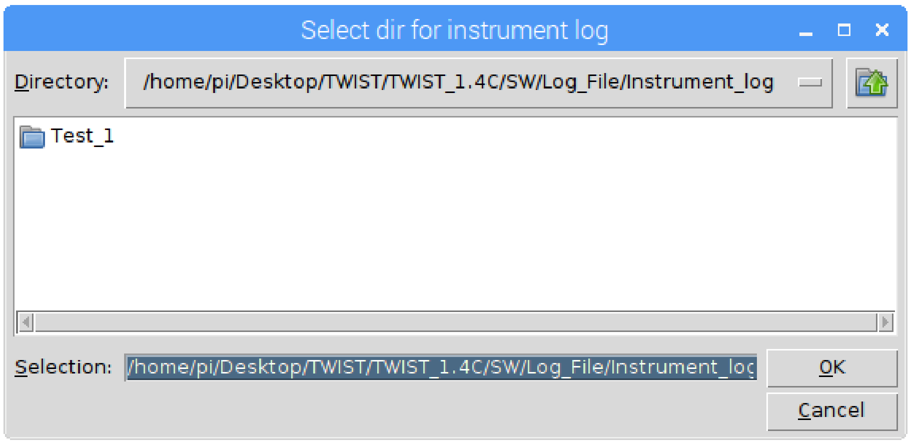
Test_step.txt

File name:

Files of type:

FIGURE 6: STEP-FILE CHOOSING

Then, the operator chooses the Log-files paths for: TTi-instruments and Picolog DAQ as shown in Figure 7 and Figure 8, respectively

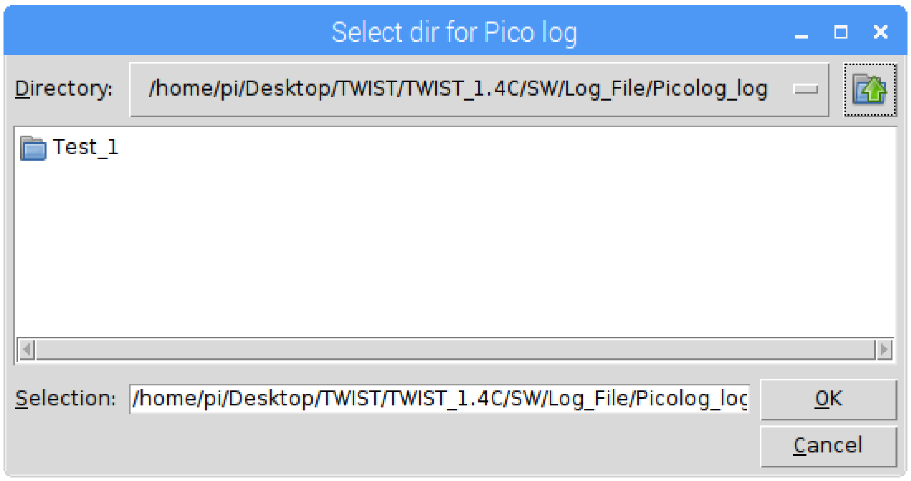

Select dir for instrument log

Directory: /home/pi/Desktop/TWIST/TWIST_1.4C/SW/Log_File/Instrument_log

Test_1

Selection: /home/pi/Desktop/TWIST/TWIST_1.4C/SW/Log_File/Instrument_loç

FIGURE 8:LD400P AND OPX1220SP LOG-FILES DESTINATION CHOOSING


Select dir for Pico log

Directory: /home/pi/Desktop/TWIST/TWIST_1.4C/SW/Log_File/Picolog_log

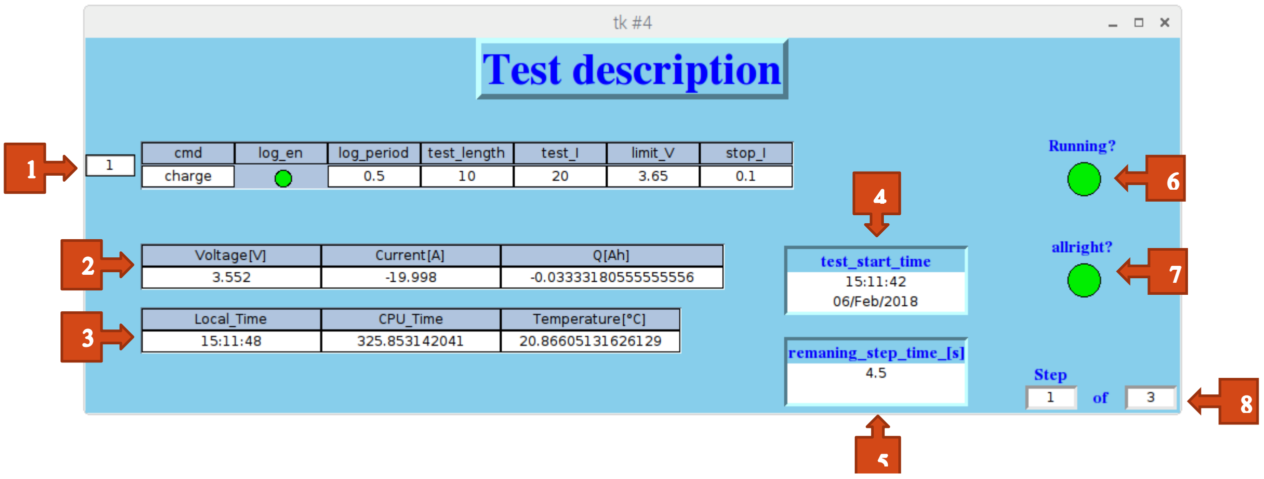
Test_1

Selection: /home/pi/Desktop/TWIST/TWIST_1.4C/SW/Log_File/Picolog_loç

FIGURE 7: PICOLOG FILE-LOG DESTINATION CHOOSING

3.3 Periodic acquisition phase

After starting phase operations, the program enters in the periodic acquisition of voltage, current and temperature of the cell under test. During this phase, the Graphical User Interfaces (GUI) represented in Figure 9 are opened.



1

cmd	log_en	log_period	test_length	test_I	limit_V	stop_I
charge	●	0.5	10	20	3.65	0.1

Voltage[V]	Current[A]	Q[Ah]
3.552	-19.998	-0.0333318055555556

Local_Time	CPU_Time	Temperature[°C]
15:11:48	325.853142041	20.86605131626129

test_start_time
15:11:42
06/Feb/2018

remaning_step_time_[s]
4.5

Running? ●

allright? ●

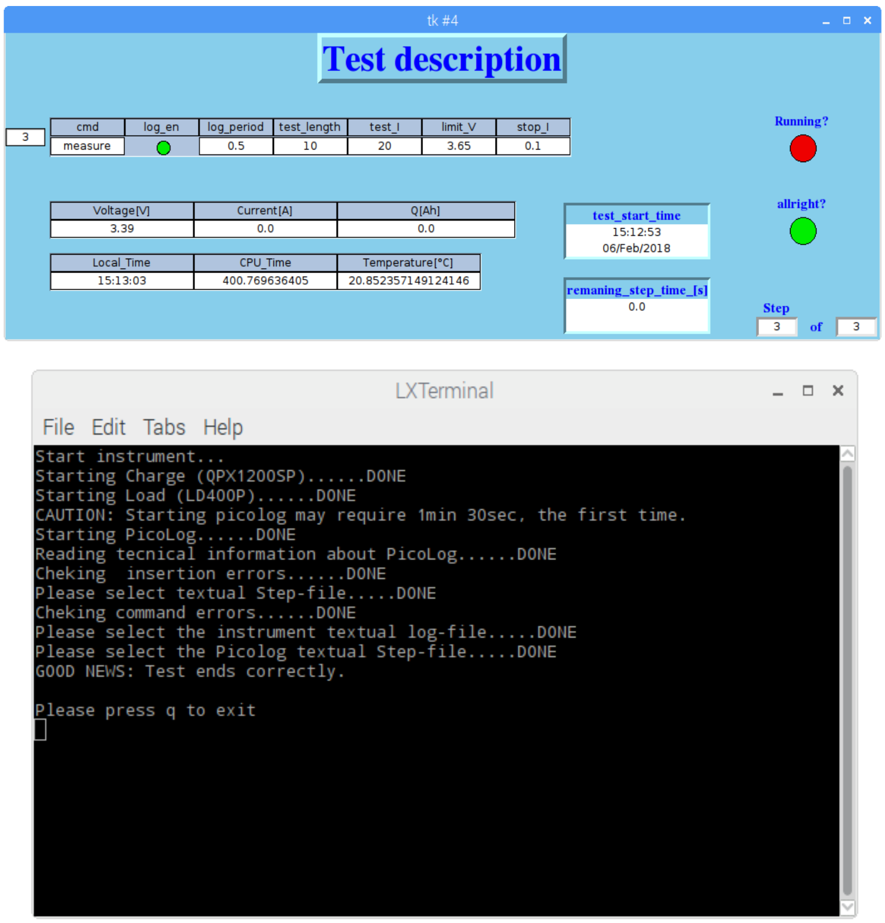
Step 1 of 3

FIGURE 9: GUI INTERFACE

1	Identifier number of the step-file raw in execution
2	Real-time cell measurement done by TTi-instruments
3	Time information and temperature measurements provide by Picolog DAQ
4	Test starting Date and Time in hh:mm:ss
5	Remaining time before the current step ending.
6	*Running?* LED indicates the test executing state of the test: if GREEN the test is still running; if RED the test is stopped.
7	*Allright?* LED indicates the presence of SW/HW error: if GREEN any errors are still happened else, if RED an error is occurred.
8	Step number indicators

3.4 Ending phase

The test can stop without or with HW/SW errors. In the first case, on LXTerminal the message *"GOOD NEWS: Test ends correctly."* is reported, and only the "Running?" LED is RED, as shown in Figure 10.



	cmd	log_en	log_period	test_length	test_I	limit_V	stop_I
3	measure	🟢	0.5	10	20	3.65	0.1

Voltage[V]	Current[A]	Q[Ah]
3.39	0.0	0.0

Local_Time	CPU_Time	Temperature[°C]
15:13:03	400.769636405	20.852357149124146

test_start_time: 15:12:53 06/Feb/2018

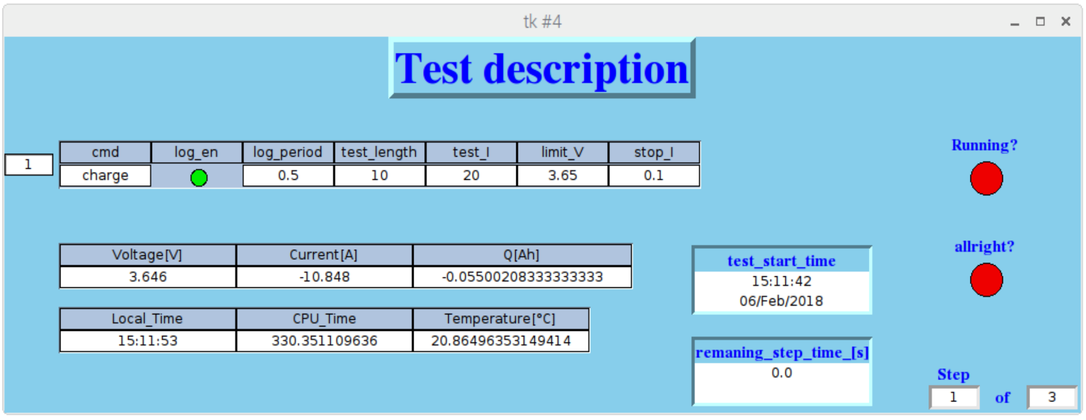
remaning_step_time_[s]: 0.0

```
Start instrument...
Starting Charge (QPX1200SP)......DONE
Starting Load (LD400P)......DONE
CAUTION: Starting picolog may require 1min 30sec, the first time.
Starting PicoLog......DONE
Reading tecnical information about PicoLog......DONE
Cheking  insertion errors......DONE
Please select textual Step-file.....DONE
Cheking command errors......DONE
Please select the instrument textual log-file.....DONE
Please select the Picolog textual Step-file.....DONE
GOOD NEWS: Test ends correctly.

Please press q to exit
```

FIGURE 10: (UP) GUI INTERFACE, (DOWN) LXTERMIANL ENDING STATE

In the second case, when an HW/SW error has occurred, on LXTerminal an error message shows an identifying error number and the name of python function within the error has occurred. At the same time, the *"Running"* and *"Allright?"* LEDs are both RED. An instance of this condition is shown in Figure 11.

To understand the meaning of the error number identifier, the operator must read the Table 1 where, the correlations between number identifier an error typology are shown.



	cmd	log_en	log_period	test_length	test_I	limit_V	stop_I
1	charge	●	0.5	10	20	3.65	0.1

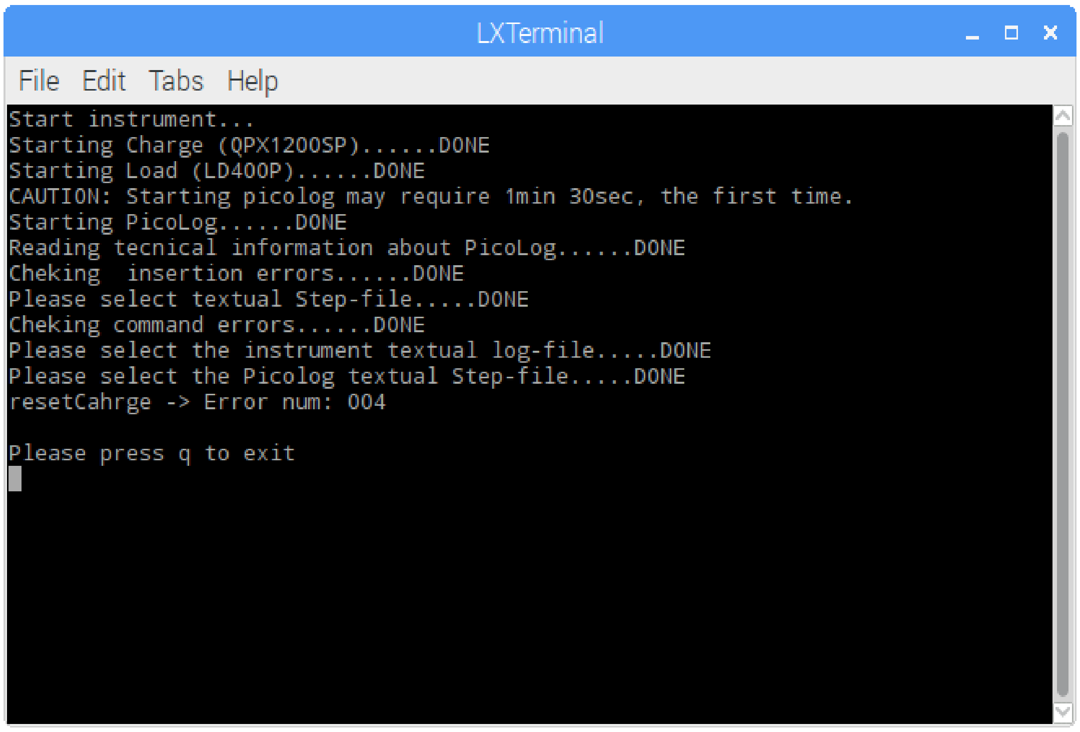
Voltage[V]	Current[A]	Q[Ah]
3.646	-10.848	-0.0550020833333333

Local_Time	CPU_Time	Temperature[°C]
15:11:53	330.351109636	20.86496353149414

test_start_time
15:11:42
06/Feb/2018

remaning_step_time_[s]
0.0

Step 1 of 3



```
Start instrument...
Starting Charge (QPX1200SP)......DONE
Starting Load (LD400P)......DONE
CAUTION: Starting picolog may require 1min 30sec, the first time.
Starting PicoLog......DONE
Reading tecnical information about PicoLog......DONE
Cheking  insertion errors......DONE
Please select textual Step-file.....DONE
Cheking command errors......DONE
Please select the instrument textual log-file.....DONE
Please select the Picolog textual Step-file.....DONE
resetCahrge -> Error num: 004

Please press q to exit
```

FIGURE 11: GUI INTERFACE ENDING STATE WITH ERROR; (DOWN) LXTERMINAL ENDING STATE

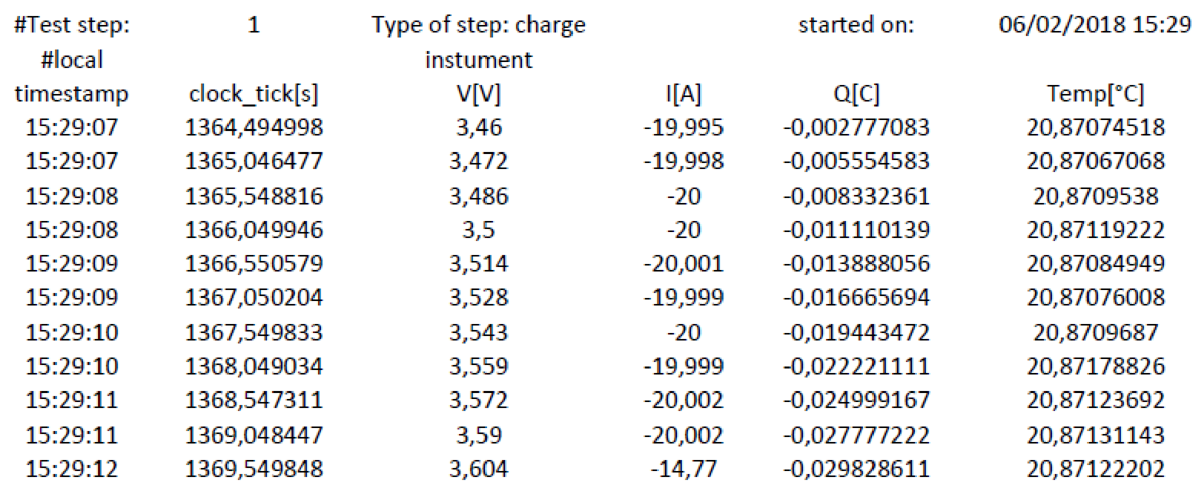
TABLE 1: ERROR NUMBER

Error Number	Error meaning
1	Timeout exception occurred
2	Connection failed
3	Model name not match
4	Some problem are occurred on instruments configuration, retry
5	Trip error on charger
6	Python miss an Ack response
7	Position of digital pin is incorrect (the available range is from 1 to 4)
8	Analog channel number is incorrect (the available range is from 1 to 8)
9	Relays positions are overlapping
10	Relays voltage threshold must be positive

11	The number of bit used in Picolog ADC-Channel conversion must be positive
12	Tmin,Tmax values must be positive
13	Tmin must be smaller than Tmax
14	The number of columns of command raw must be 7
15	TestLength must be bigger than 0,5s
16	TestLength mast be multiple of sample time
17	Sample time range is from 0,5s to 5 s
18	Sample time must be a multiple of 0,5s
19	TestLength must be bigger than sample time
20	Writing errors in command raw, the correct types are "charge","discharge","measure"
21	LOG_EN must be 1 or 0
22	Sharing buffer between dataAcquisition thread and main thread is empty
23	Sharing buffer between dataAcquisition thread and main thread is full
24	CAUTION: Safe temperature range exceeding
25	CAUTION: Some issues is present on relay state, checking hardware is required
26	CAUTION: Some issues is present on powerline, checking hardware is required

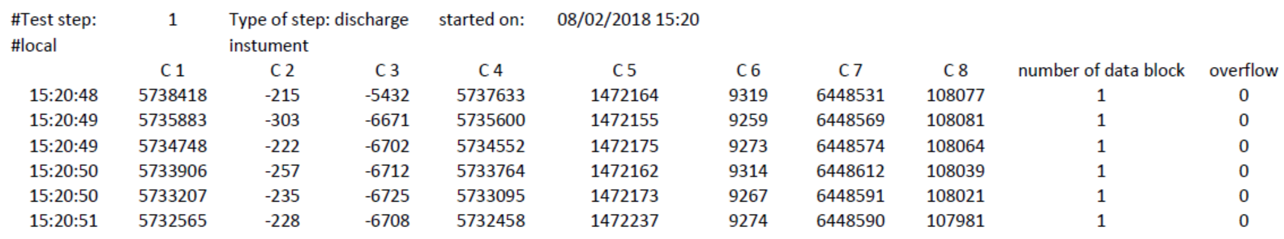
4.Data extraction

When test ending, all Log-files are saved in the paths previously chose by the user. For each step, two type of Log-files are generated: one by TTi instruments and one by Picolog DAQ; as shown in Figure 12 and Figure 13.



#Test step:	1	Type of step: charge		started on:	06/02/2018 15:29
#local timestamp	clock_tick[s]	instument V[V]	I[A]	Q[C]	Temp[°C]
15:29:07	1364,494998	3,46	-19,995	-0,002777083	20,87074518
15:29:07	1365,046477	3,472	-19,998	-0,005554583	20,87067068
15:29:08	1365,548816	3,486	-20	-0,008332361	20,8709538
15:29:08	1366,049946	3,5	-20	-0,011110139	20,87119222
15:29:09	1366,550579	3,514	-20,001	-0,013888056	20,87084949
15:29:09	1367,050204	3,528	-19,999	-0,016665694	20,87076008
15:29:10	1367,549833	3,543	-20	-0,019443472	20,8709687
15:29:10	1368,049034	3,559	-19,999	-0,022221111	20,87178826
15:29:11	1368,547311	3,572	-20,002	-0,024999167	20,87123692
15:29:11	1369,048447	3,59	-20,002	-0,027777222	20,87131143
15:29:12	1369,549848	3,604	-14,77	-0,029828611	20,87122202

FIGURE 12: TTI INSTRUMENTS FILE LOG VIEW



#Test step:	1	Type of step: discharge		started on:	08/02/2018 15:20					
#local		instument								
	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	number of data block	overflow
15:20:48	5738418	-215	-5432	5737633	1472164	9319	6448531	108077	1	0
15:20:49	5735883	-303	-6671	5735600	1472155	9259	6448569	108081	1	0
15:20:49	5734748	-222	-6702	5734552	1472175	9273	6448574	108064	1	0
15:20:50	5733906	-257	-6712	5733764	1472162	9314	6448612	108039	1	0
15:20:50	5733207	-235	-6725	5733095	1472173	9267	6448591	108021	1	0
15:20:51	5732565	-228	-6708	5732458	1472237	9274	6448590	107981	1	0

FIGURE 13 PICOLOG DAQ LOG-FILE VIEW

As shown in Figure 13, the data acquired by Picolog ADC-24 are shown as a 32bit integer. The integer represents the Picolog ADC-24 Analog-Digital Converter (ADC) coding. To decoding these values, the equation (1) is need.

$$Data_{decoding} = Data_{coding} * \frac{\left(\frac{Vrange_{in}}{2}\right)}{Nbit - 1} * Coeff \qquad (1)$$

where:

-*Vrange*$_{in}$ is the Picolog ADC-channels voltage input range (it is chosen of ± 1.250 mV, so Vrange$_{in}$ = 2500 mV);
-*Nbit* is the conversion bit number of ADC-Channels (24bit);
-*Coeff* is a coefficient which value change according with the kind of measurement that a single ADC-Channel has to performe (the Coeff values are reported in Table 2 and Table 3).

The Coeff's values are strictly dependent to the hardware framework of the system. In this case the values are correlated to the use of:

- A 4 time voltage divider in the cell voltage measurement path (See the file source of hardware at *"./TWIST/HW";*
- A shunt-resistor with a scale factor of 1 mV/A (sensor for current measurement);
- LM35 sensor for cell temperature measurement with a scale factor of 10 mV/°C

TABLE 2: COEFF VALUES

Measurement type (ADC-Channel ID)	Coeff Values
Voltage (C1, C4)	$4\left[\frac{V}{V}\right]$
Current (C3)	$1000\left[\frac{A}{V}\right]$
Temperature (C5)	$100\left[\frac{°C}{V}\right]$

The Coeff's values are strictly dependent to the hardware framework of the system. In this case the values are correlated to the use of:

- A 4 time voltage divider in the cell voltage measurement path (See the file source of hardware at *"./TWIST/HW";*
- A shunt-resistor with a scale factor of 1 mV/A (sensor for current measurement);
- LM35 sensor for cell temperature measurement with a scale factor of 10 mV/°C4.

TABLE 3: ADC-CHANNEL SETTING INFORMATION

Num of channel ID (SW)	Physical channel (HW)	Channel input mode	Measurement typology
C1	Ch1	Single-ended	Cell voltage
C2	Ch2	Single-ended	Free (not used)
C3	Ch3(-), Ch4 (+)	Differential-ended	Cell current
C4	Ch5	Single-ended	Cell voltage
C5	Ch6	Single-ended	Cell temperature
C6	Ch7	Single-ended	Free (not used)
C7	Ch8	Single-ended	Charging relay state
C8	Ch9	Single-ended	Discharging relay state