Remote-2

Remote control of ZENNIUM series potentiostats

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2024-03-07

1 Introduction

The *ZENNIUM* series potentiostats are controlled by the Thales software package providing a graphical user interface for measuring and analyzing electrochemical data. In addition, the *ZENNIUM* systems can be controlled by external software using a software interface to Thales. As this interface is based on the TCP/IP protocol it is not limited to the local Thales-PC but is also possible remotely over the network.

A dynamic link library (DLL) file is used to interface between external software (e.g. LabVIEW) and the Thales interface (Thales Remote Server). A SCRIPT application running on the *ZENNIUM* will call the specific procedures for each of the commands and parameters.

In our GitHub repository, we offer libraries for controlling the *ZENNIUM* series potentiostats via remote script. The programming languages Python and C++ are supported.

https://github.com/Zahner-elektrik

https://github.com/Zahner-elektrik/Thales-Remote-Python

https://github.com/Zahner-elektrik/Thales-Remote-Cpp

2 Thales Remote

To enable the Thales Remote server, a special application has to be started. This can be done either by:

1. Starting the runtime file
2. Linking a Thales Script source
3. Sending a command from the client

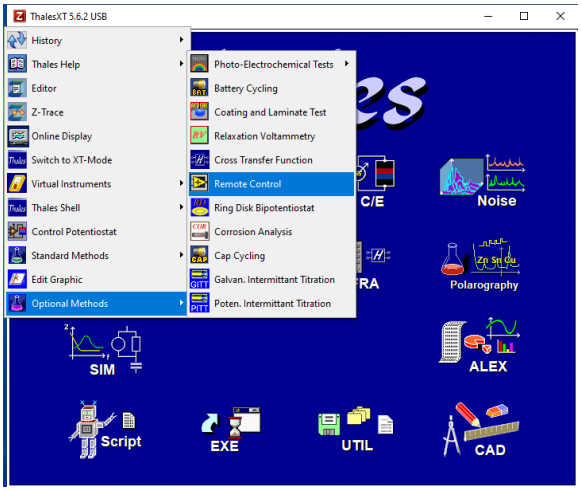
Select one of the described methods to start the remote operation. In chapters 2.1, 2.2, and 2.3 the above-mentioned methods are explained in detail.

The GitHub libraries use option 3 and automatically start the Thales Remote server.

2.1 Running the supplied runtime file

In case no modifications of the remote application are necessary, starting the runtime file is the most convenient way.

Start the Thales software and click on the red *Z*-icon to open the pull-down menu.



In the pull-down menu choose *Optional Methods* and then click on *Remote Control*.

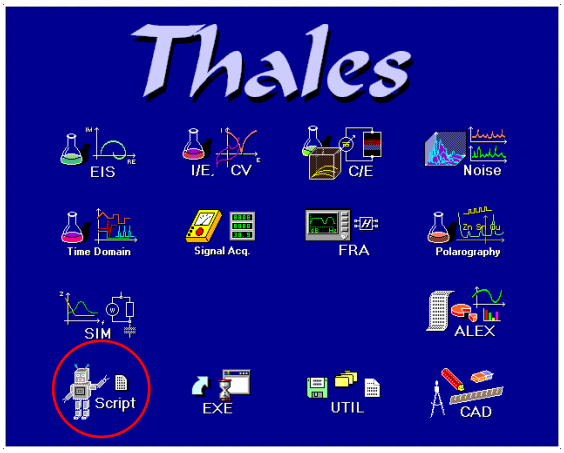
The remote application starts automatically and awaits a client connection.

At this stage, the communication indicator reads stopped because the communication is not set up so far. It will start as soon as a controller software is started.

IMPORTANT: This screen has to be active during the whole remote session. Quitting this screen will stop the remote session.

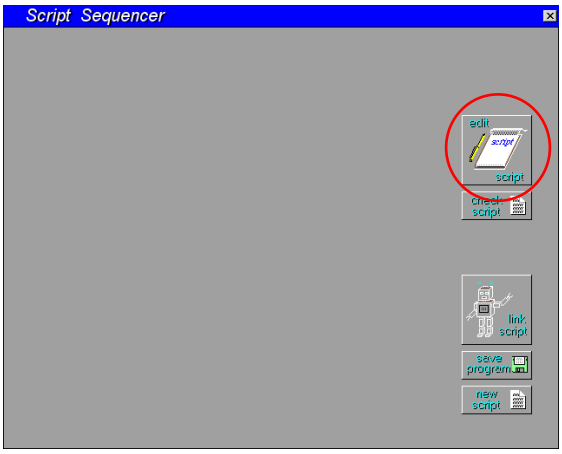
Alternatively, the runtime file can be loaded with the EXE-icon of the Thales main screen. Navigate to c:\thales\examples\applications and select remote.rtm.

2.2 Linking the script source

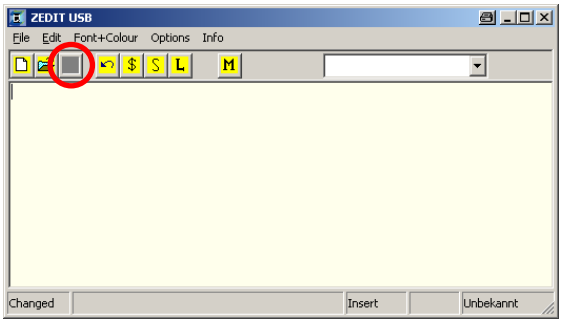


In case modifications of the remote application are desired, the script source is provided for editing.

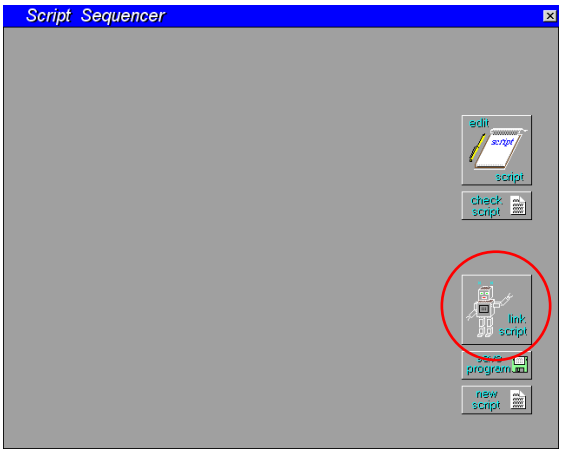
Start the Thales software and activate the Script.



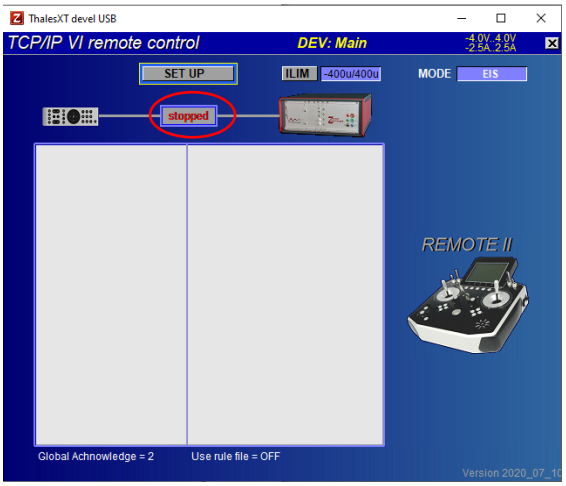
Click the “edit script” button to open the Zahner editor ZEDIT.



In ZEDIT, click the import button. In the folder c:\thales\script\remote2\source, load the remote2.is_ file and click “LOAD”. The source code can now be edited, if necessary.



In the Thales window, click on the “link script”. After linking, the script starts automatically.



At this stage, the communication indicator reads stopped because the communication is not set up so far. It will start as soon as a controller software is started.

IMPORTANT: This screen has to be active during the whole remote session. Quitting this screen will stop the remote session.

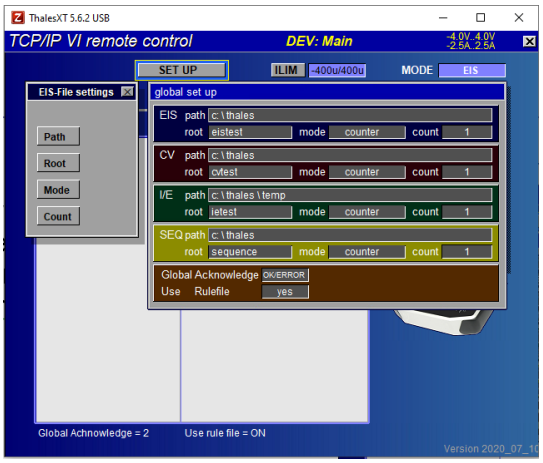
2.3 Automated start of Remote

When using the *ZENNIUM* remotely, the user can start the remote server without user-interaction, provided that the Thales software is running.

For a more comprehensive explanation of this feature, please refer to the Devcli.dll Programmer’s Reference manual, paragraph 5. “Synchronization”, function “DevRestartViaPD”.

2.4 Thales Remote – SET UP

In the Thales Remote → SET UP, the file path, file name, and saving format for different electrochemical measurement techniques can be defined.



In the global settings shown in the image above, one can set:

Path = the folder path, where the measured file will be saved.

Root = (base) file name.

Mode = saving mode for the measured files. A file can be saved using

- date and time mode
- counter mode
- individual mode.

Count = Count number (four digits) for the counter mode

Note: This means that a maximum of 9999 measurements of this type can be saved in a remote session.

All the above-provided parameters can also be remotely defined. For these, the user requires the relevant tokens (see section 5.6).

Allowed characters for file names and directories:

Alphanumeric characters:	a-z, A-Z, ä, ö, ü, Ä, Ö, Ü, ß, 0-9
Special characters:	+ , - , _ , and the space character

2.4.1 Rule file

In remote control, the client has to define every parameter required for the electrochemical measurement using the tokens described below. Alternatively, the client can also use rule files containing predefined parameter sets. In the folder *c:\thales\script\remote2\rules*, rule files for EIS, CV, and IE are present with the names *eis_rule.ism*, *cv_rule.isc* and *ie_rule.iss*, respectively. These files can be changed to the desired parameters. For using the rule file, the user must define "*Use Rulefile = ON*" in Thales Remote .

For each measurement method, only one rule file can be saved. The rule file names must be the same as that of the demo rule files. The process of making a rule file is explained in the SCRIPT- an introduction manual.

2.4.2 Global Acknowledge

In former versions of the Thales Remote, not all of the commands returned an "acknowledge-string". This restriction is now eliminated, leading to a more robust handshake.

In the Thales Remote-2 software only the Global Acknowledge = 2 mode is used by default. This mode cannot be changed as in previous Remote-2 versions.

The global acknowledge extended useful information about the errors is also provided besides the status of the measurement. This will facilitate the users to swiftly prepare error-free remote test routines. When the commands are correct and error-free then an "OK" will be shown in the acknowledge string. In the case of an error in the commands, wrong parameters, or a typo, an ERROR will be shown. The error message will follow the format → ERROR;error-type;status (i.e., ERROR;100;1). A complete table about the error-types is provided in chapter 6. The status will explain the expected problem. A small example of the error messages for different *Pot*= values is provided below.

Pot =	Message	Status	Meaning
Pot = 1	ERROR;100;1	1	value too large
Pot = 0.8	ERROR;101;2	2	not integer
Pot = - 2	ERROR;100;-1	-1	value too small
Pot = - 1	OK	0	ok

If the commands are provided in a sequence then the OK/error message will also be provided in sequence (see below). Different commands, status, and error messages are separated with the colon "**:**"

Command:

1:Pot=2:Pset=1;Gal=-2:Cset=1:CV_Pupper=5:

Response:

ERROR;100;1:OK:ERROR;100;-1:OK:ERROR;100;1:

The commands used in the remote software will also be logged in the Thales Remote window.

Further information regarding the commands is provided in Chapter 4.

3 Communication Functions of Remote Control

The communication functions are described in the DevCli.dll Programmer's Reference Manual.

4 Instruction Set of Remote Control

4.1 Format of command strings

The communication between the Thales Remote and the remote VI software uses ASCII-strings of the following format

X:Command:

X number of the communication channel from 1 to 9. Until now, Thales Remote does not distinguish among different channels, so channels 2 to 9 should be considered as reserved.

The command has to be delimited by a colon (:). Several commands can be sent in one string. In this case, all commands are separated by colons (:), e.g.

X:Command1:Command2:Command3:

Examples of valid command strings are

1:Pset=1.5: → Sets the potential to 1.5 V (unit V)

1:CURRENT:POTENTIAL: → Returns the actual current and potential value

In case one command in a string is erroneous, all commands within this string will be discarded.

In a sequential string of commands, no commands after CV, EIS, or IE will be processed. Hence no commands should be provided after these measurements. The user must write different command strings for commands after the above-mentioned measurements. An example is provided below

WRONG → 1:Gal=0:GAL=0:Pset=1:Pot=-1:EIS:CURRENT:POTENTIAL:

CORRECT → 1:Gal=0:GAL=0:Pset=1:Pot=-1:EIS:
1:CURRENT: POTENTIAL:

4.2 Potentiostat setup – commands

4.2.1 Changing devices

The Zahner ZENNIUM series potentiostats can be used with boosters i.e., power potentiostats or electronic loads to achieve a higher potential/current range. These additional devices are connected to the ZENNIUM via the EPC42 cards. Each EPC42 card can be used to connect up to 4 boosters and each ZENNIUM potentiostat can have 4 EPC42 cards. Therefore a maximum of 16 such boosters can be connected with the ZENNIUM series potentiostats.

In remote, ***DEV%=X*** is used to choose the main potentiostat or the booster. The main potentiostat (ZENNIUM series) has a *DEV%* number "0". The boosters connected via the EPC42 cards have the *DEV%*=1, 2, 3.....16.

If the ZENNIUM series potentiostats have a R-Mux card then the first 16 *DEV%* positions (1 – 16) are assigned to R-Mux and 17 onwards start the EPC42 connections.

4.2.2 Operating mode

With the commands ***Gal=X*** and ***GAL=X***, the potentiostatic/galvanostatic mode of the potentiostat is chosen. Setting the operating mode will disable the amplitude (amplitude value = 0).

	GAL = 1	GAL = 0	GAL = -1
Gal = 0	-	potentiostatic	pseudo-galvanostatic
Gal = -1	galvanostatic	-	-

1:Gal=0:GAL=0: → Potentiostatic mode

1:Gal=-1:GAL=1: → Galvanostatic mode

1:Gal=0:GAL=-1: → Pseudo-galvanostatic mode

4.2.3 Potentiostat turn on/off

With the command ***Pot=X***, the potentiostat can be turned on and off.

1:Pot=0: → Turn potentiostat off

1:Pot=-1: → Turn potentiostat on

4.2.4 Setpoint values

With the commands provided below different setpoint values can be defined in the Thales software.

1:Pset=1:	→ Set DC potential to 1 V (Unit: V)
1:Cset=1:	→ Set DC current to 1 A (Unit: A)
1:Ampl=5:	→ Set AC potential amplitude to 5 mV (Unit: mV)
1:Frq=1000:	→ Set frequency to 1000 Hz (Unit: Hz)

Similarly, a complete list of commands is available in chapter 6 which includes commands for many other setpoint values.

4.3 Measure single values

In the remote VI software, single values (like current, voltage, and impedance, etc.) can be easily read with the commands provided below

1:CURRENT:	→ Read actual current value
1:POTENTIAL:	→ Read actual potential value
1:IMPEDANCE:	→ Read impedance value (real and imaginary impedance)
1:PAD4IMP:	→ Read impedance values (real and imaginary impedance) from main channel and PAD4 channels (when activated)

These parameters will be shown with the format -##.@@@^^^^ (see ANDIbasic manual).

For impedance measurement, amplitude (***Ampl***) and frequency (***Frq***) must be defined beforehand and the cell must be switched ON (***Pot=-1***). Otherwise "*Impedance disabled!*" is returned. The command ***CURRENT*** should be issued before ***IMPEDANCE*** is called to automatically set the optimal current range of the potentiostat. Hence, a necessary string for single impedance value measurement should be as given below

1:Frq=1000:Ampl=5:Pot=-1:CURRENT:IMPEDANCE:

→ read real and imaginary part of impedance in Ω at frequency (Frq) and amplitude (Ampl)

4.3.1 Fast potential/current measurement – single value

With the commands *POTENTIAL*/*CURRENT*, the potentiostat measures 5000 times potential/current respectively, and then an average value of these 5000 measurements is shown. The extensive measurement with many averages is done to ensure a good signal to noise ratio. Due to 5000 measurements, the measurement time is in the milliseconds range. A ZENNIUM PRO potentiostat requires 300 ms time for a single current/potential measurement.

To quickly measure the potential or current value, the user can use the commands *POTFAST*, *CURFAST*. Before the measurements, the user must define the averages for the measurement. With the faster measurements, the drawback is a lower signal to noise ratio hence the user must use sufficient averages so that the signal to noise ratio is high. The command strings provided below can be used for such a fast single value measurement.

1:AVERAGES=1000: → Average range = 100 to 5000

1:POTFAST: → Fast potential measurement using averages

1:CURFAST: → Fast current measurement using averages

With ZENNIUM PRO, a POTFAST/CURFAST measurement with 500 averages will take around 100 ms.

4.4 Rule file

With *UseRuleFile=1*, the usage of the rule file is activated and all the parameters required for the EIS, CV, and/or IE are taken from the rule file and a measurement is completed.

1:UseRuleFile=1:EIS: → Measure EIS

1:UseRuleFile=1:IE: → Measure IE

1:UseRuleFile=1:CV: → Measure CV

With the above-provided command, EIS measurement will be carried out using the rule file and the data will be exported to a predefined folder. The measured spectrum is saved in both Zahner binary (.ism) and ASCII format (.txt). Refer to chapter 4.7 for ASCII format settings.

The user can save a single rule file for each measurement technique in Thales Remote. The process of saving the rule file is explained in the Script – an introduction manual.

4.5 Without Rule file

The measurement techniques (EIS, CV, and IE) can also be carried out without the usage of the rule files. Without a rule file, every parameter has to be individually defined. To deactivate the use of the rule files, the following command string is used.

1:UseRuleFile=0: → Deactivate the use of rule file

4.5.1 Electrochemical impedance spectroscopy (EIS)

In the strings provided below, the use of the rule file is deactivated (*UseRuleFile=0*) and an EIS measurement is setup.

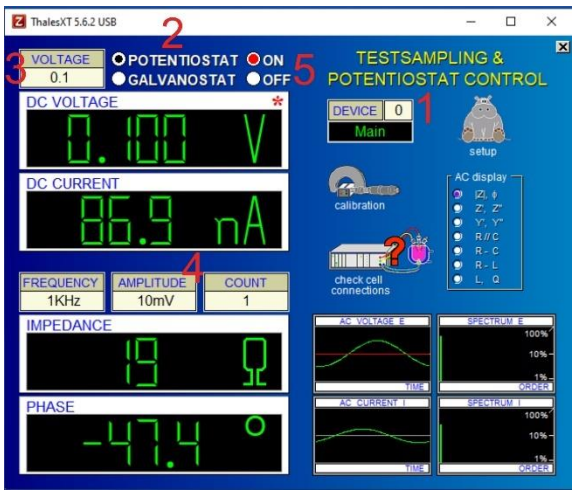
1:UseRuleFile=0:DEV%=0:Gal=0:GAL=0:Pset=0.1:Ampl=10:Pot=-1:

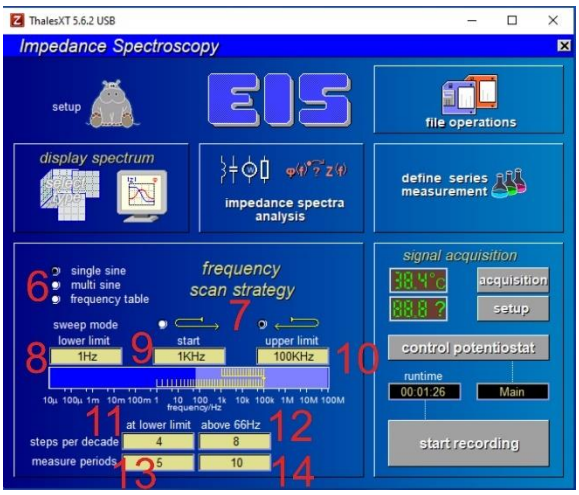
1:ScanStrategy=0:ScanDirection=0:

1:Fmin=1:Fstart=1000:Fmax=100000:

1:dfl=4:dfm=8:Nwl=5:Nws=10:

1:EIS:





Here,

1. DEV%=0 → Device = 0 (Main potentiostat ZENNIUM series)
2. Gal=0,GAL=0 → Potentiostatic mode
3. Pset=0.1 → Set potential = 0 V (DC voltage)
4. Ampl=10 → AC Amplitude = 10 mV (unit: mV)
5. Pot=-1 → Potentiostat (-1=turn on, 0= turn off)
6. ScanStrategy=0 → 0 = single sine, 1 = multi-sine, and 2 = frequency table

7. ScanDirection=0 → 0 = scan from Fstart to Fmax and down to Fmin
   1 = scan from Fstart to Fmin and up to Fmax
8. Fmin=1 → Minimum frequency=1 Hz (lower limit)
9. Fstart=1000 → Start frequency=1 kHz (start)
10. Fmax=100000 → Maximum frequency=100 kHz (upper limit)
11. Dfl=4 → Steps per decade=4 (at lower limit)
12. Dfm=8 → Steps per decade=8 (above 66 Hz)
13. Nwl=5 → Measure periods=5 (at lower limit)
14. Nws=10 → Measure periods=10 (above 66 Hz)

Without a rule file, each parameter is individually adjusted. These above-provided command strings will also make the corresponding changes in the Thales test sampling and EIS windows. With the command ***EIS***, an EIS measurement will be carried out and the data will be exported to a predefined folder. The measured spectrum will be saved in both Zahner binary (.ism) and ASCII format (.txt). Refer to chapter 4.7 for ASCII format settings.

In Thales EIS and test sampling window, the corresponding changes for the EIS parameters will only be made when an EIS measurement will be carried out using the command ***EIS***. Without this final command string, the changed parameter will not be visible in the Test sampling and EIS window.

The same is valid for the CV and IE measurements.

Amplitude parameter (Ampl=) has to be defined after the operating mode settings (GAL=, Gal=). The amplitude parameter will be set to zero after setting operating mode.

Note: A sprectrum requires at least 5 individual measuring points. Therefore, the frequency range and the step width must be sufficiently defined.

4.5.2 Current-voltage curve (IE)

In the IE measurement, three scan modes can be used. These scan modes are

- Steady-state sampling
- Fixed sampling
- Dynamic scan

In the command strings provided below, each parameter required for IE measurement is assigned a value and then strings relevant to each scan mode are provided. In the end, all the commands are checked and an IE is measured without the use of a rule file.

For Steady-state sampling:

1:IE_EckPot1=0:IE_EckPot2=0.5:IE_EckPot3=-0.5:IE_EckPot4=0:

1:IE_EckPot1rel=1:IE_EckPot2rel=1:IE_EckPot3rel=1:IE_EckPot4rel=1:

1:IE_Resolution=10m:

1:IE_SweepMode=0:

1:IE_Toabs=2n:IE_Torel=15m:IE_WZmin=10:IE_WZmax=50:

1:IE_Imi=-100m:IE_Ima=100m:CHECKIE:

1:IE:

Replace the coloured command strings with the following command strings for the fixed sampling and dynamic scan.

Fixed sampling:

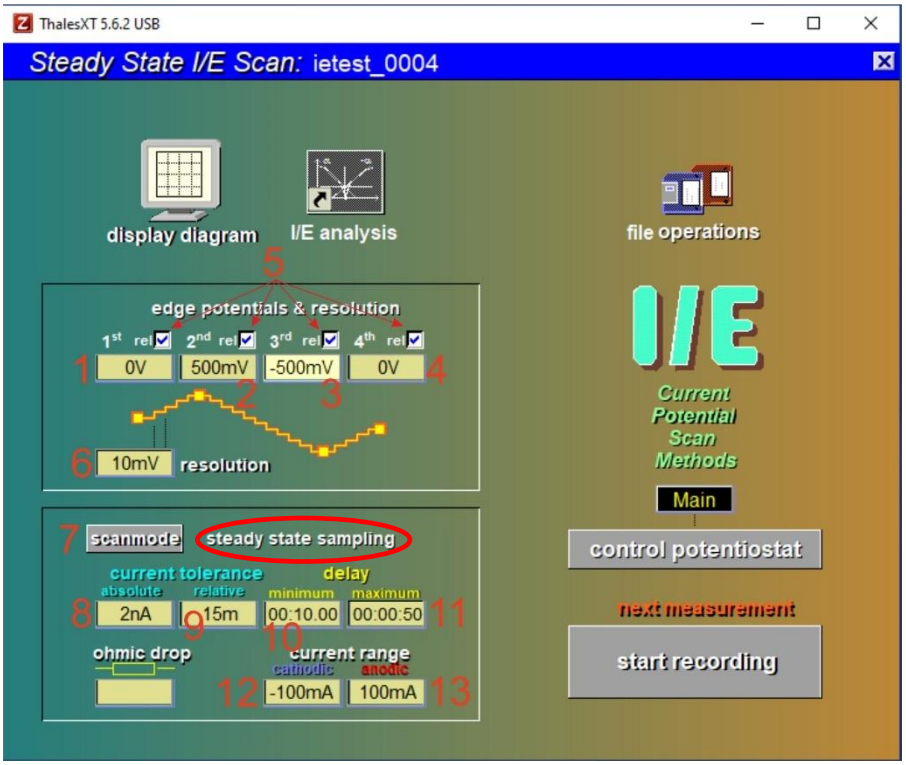
1:IE_SweepMode=1:

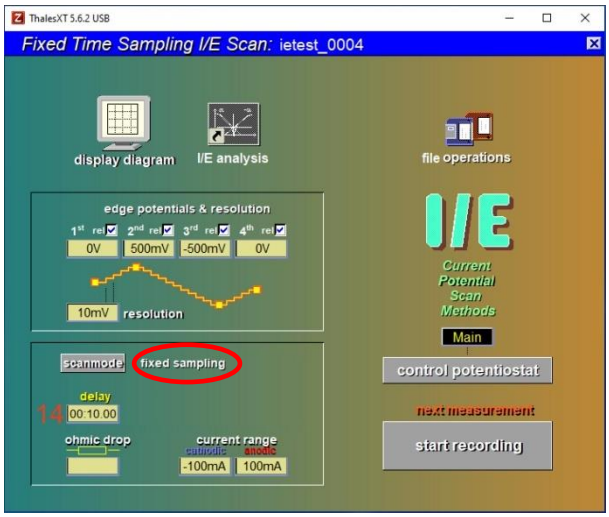
1:IE_WZmax=10:

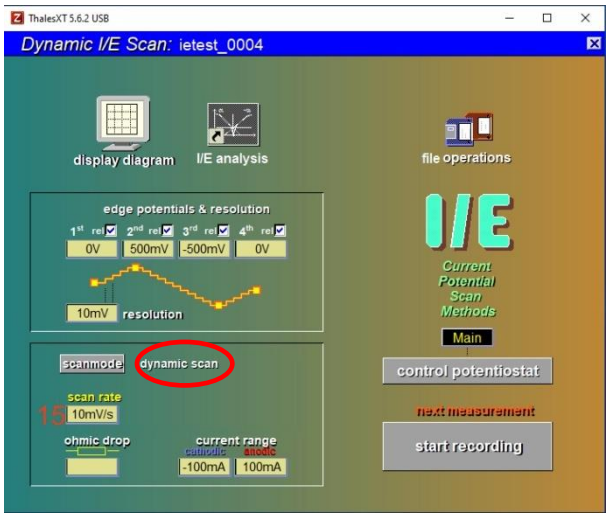
Dynamic scan:

1:IE_SweepMode=2:

1:IE_Srate=10m:







Here,

1. IE_EckPot1=0 → 1st edge potential = 0 V
2. IE_EckPot2=0.5 → 2nd edge potential = 0.5 V
3. IE_EckPot3=-0.5 → 3rd edge potential = -0.5 V
4. IE_EckPot4=0 → 4th edge potential = 0 V

5. IE_EckPot1rel=1 → 1st edge potential relative to OCP (1 = Yes, 0 = No)

IE_EckPot2rel=1 → 2nd edge potential relative to OCP (1 = Yes, 0 = No)

IE_EckPot3rel=1 → 3rd edge potential relative to OCP (1 = Yes, 0 = No)

IE_EckPot4rel=1 → 4th edge potential relative to OCP (1 = Yes, 0 = No)

6. IE_Resolution=10m → Resolution = 10mV (Unit: V)
7. IE_SweepMode=0 → Scan mode: 0 = steady state, 1 = fixed sampling, 2 = dynamic scan
8. IE_Toabs=2n → Absolute current tolerance (Unit: A)
9. IE_Torel=15m → Relative current tolerance (%)
10. IE_WZmin=10 → Minimum wait time = 10 s (Unit: second) WZ=Wartezeit
11. IE_WZmax=50 → Maximum wait time = 50 s (Unit: second)
12. IE_Imi=-100m → Minimum current range = -100mA (Unit: A)
13. IE_Ima=100m → Maximum current range = 100mA (Unit: A)
14. IE_WZmax=10 → Delay = 10s
15. IE_Srate=10m → Scan rate = 10mV/s (Unit: V/s)

The command *IE* will run the IE measurement and the data will be saved in Zahner binary file and the text file.

The command ***CHECKIE*** makes sure that all the parameters are in the range of the potentiostat.

4.5.3 Cyclic voltammetry (CV)

In the command strings provided below, each parameter required for CV measurement is assigned a value and then a CV is measured. Here also the use of the rule file is disabled (*UseRuleFile=0*).

1:CV_Pstart=0:CV_Pupper=1:CV_Plower=-1:CV_Pend=0:

1:CV_Tstart=10:CV_Tend=20:

1:CV_Srate=100m:CV_Periods=2:CV_PpPer=500:

1:CV_Imi=-100m:CV_Ima=100m:

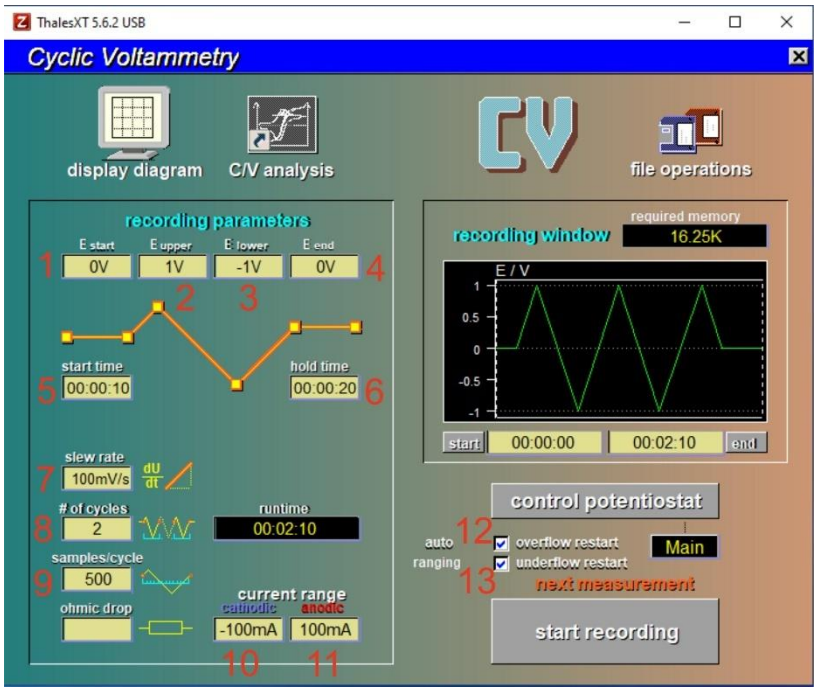
1:CV_AutoReStart=-1:CV_AutoScale=-1:

1:CHECKCV:

1:CV:

Here,

1. CV_Pstart=0 → Start potential (E start = 0 V)
2. CV_Pupper=1 → Upper potential (E upper = 1 V)
3. CV_Plower=-1 → Lower potential (E lower = -1 V)
4. CV_Pend=0 → End potential (E end = 0 V)
5. CV_Tstart=10 → Time before starting CV (start time = 10 s)
6. CV_Tend=20 → Time after ending CV (hold time = 20 s)
7. CV_Srate=100m → Slew rate = 100 mV/s (unit: V/s)
8. CV_Periods=2 → CV periods = 2 (# of cylces)



9. CV_PpPer=500 → Points per periods = 500 (samples/cycles)
10. CV_Imi=-100m → Minimum current = -100mA (unit: A) – cathodic current range
11. CV_Ima=100m → Maximum current = 100mA (unit: A) – anodic current range
12. CV_AutoReStart=-1 → Overflow restart (-1=on, 0=off)
13. CV_AutoScale=-1 → Underflow restart (-1=on, 0=off)

The command ***CHECKCV*** checks if all the values are correct and in the range of the potentiostat. It makes sure that the slew rate and points per period do not exceed range. If the values exceed the potentiostat's range then ***CHECKCV*** results in an ERROR and suggests the new value within the potentiostat's range. The command ***CV*** will run the CV measurement and the data will be saved in Zahner binary file and the text file.

For ZENNIUM potentiostat → CV_Srate * CV_PpPer / CV_span ≤ 2000
with CV_span = CV_Pupper - CV_Plower

Here: CV_span = CV_Pupper - CV_Plower = 1 – (-1) = 2 [V]
CV_Srate = 100m [V/s]
CV_PpPer = 500 [Samples]

Maximum CV_PpPer = 2000 / 100m * 2 = 40000 [Samples]

4.5.4 Remote Sequencer

The Thales Sequencer software can also be used via Thales Remote. For this, the user must write sequences before using Thales Remote. The Zahner Sequencer manual explains the method of writing a sequence.

The sequences must be saved with the name “SequenceXX” (XX= 00, 01, 02 to 09) in the folder **c:\thales\script\sequencer\sequences**.

Once the required sequences are saved, the user can use the following code in the Remote VI application for using the Thales Sequencer.

1:SELSEQ=04: → Select “Sequence04” and load included settings

1:DOSEQ: → Run selected sequence

The ***SELSEQ=04*** asks the Thales Remote to open the sequence04 file in Thales Sequencer and *DOSEQ* starts the sequence measurement.

4.5.4.1 Set Sequencer Parameters

Sequencer Parameters can be defined in the “sequence##.seq” file. For this refer to the sequencer manual.

Single parameters can be set by remote commands. The measurement parameters can be defined either by loading sequences (SELSEQ=) or by setting them manually.

Setting parameters and selecting sequences will overwrite the parameter values. Only the last setting is valid.

1:SEQ_MAXTIME= → maximum runtime [h] (0.1 ... 1000)

1:SEQ_EUPPER= → upper potential limit [V]

1:SEQ_ELOWER= → lower potential limit [V]

1:SEQ_POTOFLO= → potential latency window setting

=-1	do not turn off
=0	turn off immediately
=+t	turn off after t seconds beyond limits

1:SEQ_IUPPER= → upper current limit [A]

1:SEQ_ILOWER= → lower current limit [A]

1:SEQ_CUROFLO= → current latency window setting
=-1 do not turn off
=0 turn off immediately
=+t turn off after t seconds beyond limits

1:SEQ_IRANGE= → current range [A] (for pot. sequencer commands)

1:SEQ_RODROP= → ohmic drop [Ω] for iR-drop compensation
=0 disable iR-drop compensation
=+r ohmic value

After each sequencer measurement the SEQ_RODROP value is reset to "0" and iR-drop compensation is deactivated. So this value has to be defined before each sequencer measurement with iR-drop compensation.

1:SEQ_ACQ=*channel*;*select*; → select acquisition channels for sequencer
channel= number of ACQ channel
select = 0 disable ACQ channel for SEQ
1 enable ACQ channel for SEQ

The available ACQ channels for sequencer can be read by SENDSEQACQSETUP. Sequencer can record up to 8 additional ACQ channels. ACQ channels have to be acquired in the Thales software ACQ. All channels (maximum up to 8) marked as "display channels" are available for the sequencer software. Please refer to signal acquisition manual for details.

1:SEQ_ACQENA= → ACQ recording of selected channels
= 0 (disable ACQ recording in Sequencer)
= 1 (enable ACQ recording in Sequencer)

4.6 File handling

The file name, folder destination, and the file saving format (explained in section 2.4) can also be defined using the command strings in the Thales Remote software. The strings provided below handle the file name, folder path, and the saving format. The allowed characters are listed in section 2.4.

1:AAA_PATH=c:\thales\temp: → Save measured files in folder c:\thales\temp

1:AAA_ROOT=test: → File name=test

1:AAA_MOD=1: → Saving mode

(0=date and time, 1=incremental count, 2=individual)

1:AAA_NUM=0: → Count number (for AAA_MOD=1)

Here, AAA can be replaced for EIS, IE, CV, and SEQ to define the file name, folder path, and saving format for EIS, IE, CV, and SEQ measurement.

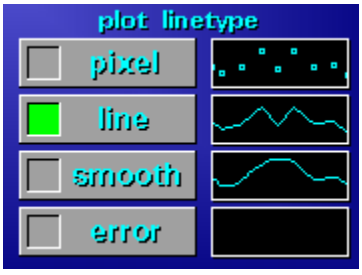
4.7 Export ASCII Data Settings

With the command ***EIS***, an EIS measurement will be carried out and the data will be exported to a predefined folder. The measured spectrum will be saved in both Zahner binary (.ism) and ASCII format (.txt).

The output format of the ASCII data corresponds to the display format in the Thales SIM program. To change the data of the ASCII export, the standard display format of ism files in SIM must be adapted.

To do this, an EIS spectrum must be loaded in SIM. Then the display format can be set accordingly (refer to SIM manual chapter 3.2). To save these settings as the new standard settings refer to SIM manual chapter 8 and ensure to leave the setup name empty (only confirm with ENTER) to save the settings as the default.

Choose between different data sets



The plot linetype will choose the type of data points:

- select “pixel” or “line” to export measured data points
- select “smooth” to export smoothed data points (with a frequency resolution defined in the SIM setup)
- select “pixel” AND “smooth” to export measured data points followed by a smoothed data table

4.8 Remote – FRA-Mode

The Thales FRA-mode can also be used in the Thales Remote software. For measurements using the FRA-probe, appropriate voltage and current gains must be provided. These gains and the current/voltage limits can be provided using the tokens provided below. The command strings define the FRA related parameters.

1:FRA=1: → Set FRA mode 0=off, 1=on

1:FRA_POT_IN=: → Gain-Factor FRA voltage-in

1:FRA_POT_OUT=: → Gain-Factor FRA voltage-out

1:FRA_POT_MIN=: → FRA minimum voltage (unit: V)

1:FRA_POT_MAX=: → FRA maximum voltage (unit: V)

1:FRA_CUR_IN=: → Gain-Factor FRA current-in

1:FRA_CUR_OUT=: → Gain-Factor FRA current-out

1:FRA_CUR_MIN=: → minimum current (unit: A)

1:FRA_CUR_MAX=: → maximum current (unit: A)

1:FRAGAL=1: → FRA Potentiostat-Mode (0=Pot, 1=Gal)

The rule file saved for the EIS measurements cannot be used in the EIS measurement using the FRA. Here, the user must save an EIS rule file with the FRA probe to be used for the FRA measurement.

Without a rule file, the user can use the commands used for EIS to carryout EIS measurement.

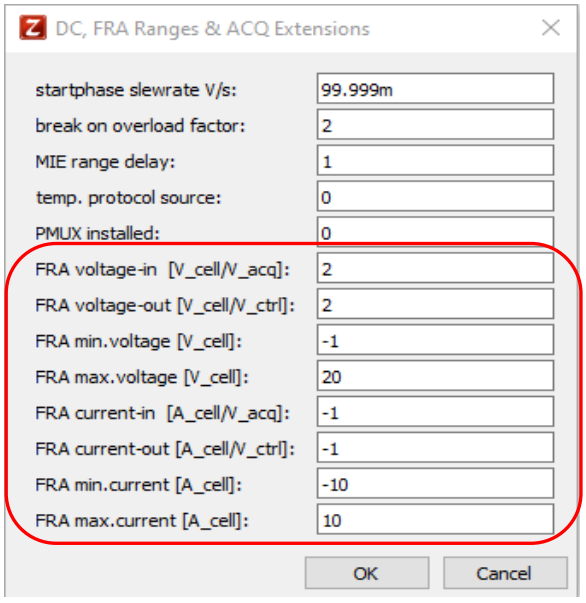
1:Cset=1:Ampl=500:Pot=-1:

1:ScanStrategy=0:ScanDirection=0:

1:Fmin=1:Fstart=1000:Fmax=50000:

1:dfl=4:dfm=8:Nwl=5:Nws=10:

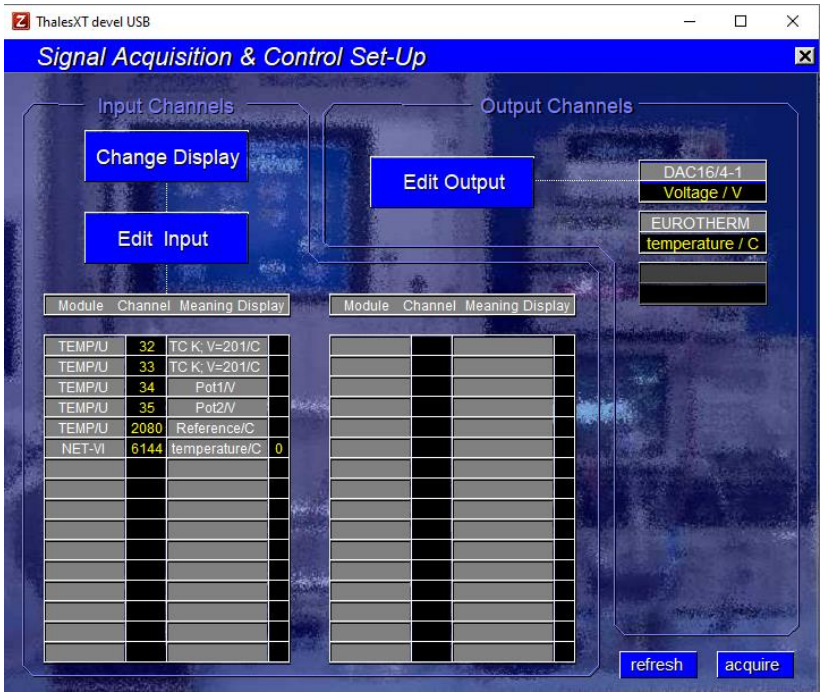
1:EIS:



Before making any change in FRA setting, please turn the FRA mode off. Make the required changes and then turn the mode on again to apply the changes.

4.9 Data acquisition / Virtual instruments

The ZENNIUM series potentiostats can be easily used with an external measurement system (i.e., temperature controller or a thermometer) and can incorporate the data from the external device in the EIS, CV, and IE measurements. To acquire the signal from the external device, the Thales “Signal Acquisition” software is used.



In this section, the Eurotherm (NET-VI, Channel:6144) will be used as an example of the external device and will be configured for use in the Thales Remote. First of all, the user must set up the Eurotherm as explained in the application note Eurotherm. Afterward, the user can use the command strings provided below to start the VI software (Eurotherm) and read the signal from channels in the Thales Signal Acquisition software.

1:VI_PATH=c:\flink\NetVI:	→ VI folder
1:VI_INI=Eurotherm:	→ Define the name of the EuroTherm.ini file
1:VI_EXE=EuroTherm:	→ Define the name of the EuroTherm.exe file
1:STARTVI:	→ Start VI software
1:CHANNEL=0:	→ Access channel display “0”
1:ANALOGIN:	→ Read analog-channel (defined with CHANNEL)
1:ANALOGALL:	→ Read all analog-channels

4.10 MIO card

If the user has a MIO card installed in ZENNIUM series potentiostat then the following commands can be used to set the analog/digital output. The user must define the channel to specify the output to that channel.

1:CHANNEL=:	→ Define channel
1:ANALOGOUT=:	→ Set analog output of the MIO
1:DIGITALOUT=:	→ Set digital output of MIO
1:DACOUT=:	→ Output function for DAC16/MIO

4.11 Acquire system parameters

Using remote software, the user can remotely control the Thales software. Here it is of utmost importance that the user can remotely check the system specification and the set values of every parameter in the Thales software. For example, the current/potential range, number of extension possible (DEV%), and potentiostatic/galvanostatic mode, and so on. To get this information the user can use the following commands

1:SENDSETUP:	→ Send ZENNIUM series potentiostats specifications
1:SENDCVSETUP:	→ Send CV setup information
1:SENDIESETUP:	→ Send IE setup information
1:SENDPAD4SETUP:	→ Send PAD4 setup information
1:SENDFRASETUP:	→ Send FRA setup information
1:SENDACQSETUP:	→ Send ACQ setup information
1:SENDSEQACQSETUP:	→ Send SEQUENCER ACQ setup information

The User can also access the series number of the main potentiostat and the available boosters/extensions.

1:ECWNUM:	→ Provide series number & name (main device)
1:DEVNUM:	→ Provide series number & name (active device)
1:ALLNUM:	→ Provide series numbers & names (all devices)

Here, ALLNUM will provide the information about the main potentiostat, connected boosters, and the RMux cards.

4.12 Additional commands

4.12.1 PAD4 setup

The user can define the PAD4 setup in Remote VI software. The commands *PAD4=* deals with 3 parameters i) card #, ii) channel #, and iii) status. For example

1:PAD4=1;1;1: → PAD4 card = 1, channel 1, switch on

1:PAD4=2;4;0: → PAD4 card = 2, channel 4, switch off

1:PAD4ENA=1: → Enable PAD4

The user can switch the type of PAD4 channels between voltage sense (standard configuration) and current sense (with additional shunt resistor).

1:PAD4MOD=0: → Set all PAD4 channels to voltage mode $Z_{pad4} = \frac{U_{pad4}}{I_{main}}$

1:PAD4MOD=1: → Set all PAD4 channels to current mode $Z_{pad4} = \frac{U_{main}}{I_{pad4}}$

In voltage mode the input voltage range (standard: 4 V) can be adjusted for user-defined voltage cables or different voltage ranges of the PAD4-LC and PAD4-HZ addon cards. The command *PAD4_PRANGE=* deals with 3 parameters i) card #, ii) channel #, and iii) range. For example

1:PAD4_PRANGE=1;1;8: → PAD4 card = 1, channel 1, 8 V input range

1:PAD4_PRANGE=2;4;1: → PAD4 card = 2, channel 4, 1 V input range

In current mode the input current range has to be defined corresponding to the used current shunt resistor. The command *PAD4_RSHUNT=* deals with 3 parameters i) card #, ii) channel #, and iii) range. For example

1:PAD4_RSHUNT=1;1;10m: → PAD4 card = 1, channel 1, 10mR shunt resistor

1:PAD4_RSHUNT=2;4;40m: → PAD4 card = 2, channel 4, 40mR shunt resistor

PAD4-LC has a standard input voltage range of ±1 V (normal PAD4/PAD4-HC have ±4 V). For this a shunt resistor in current mode has to be defined as 4x shunt resistor when using the PAD4-LC addon card type.

For Eample:
1:PAD4_RSHUNT=2;4;40m: → PAD4-LC card = 2, channel 4, 10mR shunt resistor

4.12.2 Potential range

The IM6/ZENNIUM series potentiostats work at different potential ranges. For example, a ZENNIUM PRO can be set for the measurements up to ±5 V or ±15 V. Using the command provided below the user can select the low potential or high potential range setting.

1:Potrange=X: → Potential range: 0 = low potential range

1 = high potential range

4.12.3 Shunt range

In the IM6/ZENNIUM series potentiostats, the user can also specify the minimum and maximum shunt resistance(s) for the measurement.

1:Rmin=X → Minimum shunt resistance index

1:Rmax=X → Maximum shunt resistance index

4.12.4 Clear memory

The IM6/ZENNIUM series potentiostats use internal memory during the measurements and once the measurement is done then save the measurement data at the computer hard disk. However, for a very long measurement (i.e., CV measurement with a very low slew rate) the available memory may not be enough. Here, with the commands below user can clean the potentiostats memory from the last measurement and increase the available memory for the measurement.

1:CLRSIM: → Clear SIM memory

1:CLRACQ: → Clear acquisition memory

1:CLREIS: → Clear EIS measurement from SIM memory

1:CLRCV: → Clear CV measurement from SIM memory

1:CLRIE: → Clear IE measurement from SIM memory

5 Commands

In this chapter, different commands for electrochemical measurements are provided.

SENDSETUP	**request potentiostat (IM6/ZENNIUM) for setup**
CURRENT	**measure current**
POTENTIAL	**measure potential**
IMPEDANCE	**measure impedance**
PAD4IMP	**measure parallel impedances at main and PAD4 channels**
EIS	**measure, save and export EIS spectrum**
CV	**measure, save and export CV spectrum**
IE	**measure, save and export IE spectrum**
DOSEQ	**measure a sequence (Sequencer)**
CURFAST	**measure current fast**
POTFAST	**measure potential fast**
ANALOGIN	**read ANALOG-Channel (ANALOGCHANN)**
ANALOGALL	**read all active ACQ-Channels**
DIGITALIN	**read DIGITAL-Channel (DIGITALCHANN)**
CALOFFSETS	**offset calibration**
ALLNUM	**print all devices & relay number**
ECWNUM	**print series number of main device**
DEVNUM	**print series number of controlled potentiostat**
STARTVI	**start virtual instrument (VI)**
SENDACQSETUP	**request ACQ settings**
CLRACQ	**delete old ACQ-Data**
CLRCV	**delete old CV-Data**
CLREIS	**delete old EIS-Data**
CLRIE	**delete old IE-Data**
CLRPOL	**delete old POL-Data**
CLRSIM	**delete old SIM-Data**
CHECKCV	**check CV-Parameters**
CHECKIE	**check IE-Parameter**
SENDCVSETUP	**request CV-settings**
SENDIESETUP	**request IE-settings**
SENDPAD4SETUP	**request PAD4-settings**
SENDFRASETUP	**request FRA-settings**
CHECKEIS	**request EIS-settings**
SENDSEQACQSETUP	**request SEQUENCER ACQ settings**
DEVINF	**print type and serial no of selected external potentiostat**
SETUSB	**switch selected PP2x2/XPot2/EL1002 to SCPI interface mode with turning off the device**

HOT2USB	switch selected PP2x2/XPot2/EL1002 to SCPI interface mode without turning off the device
DEV%=	choose controlled device (PP/EL/R-Mux)
DEVHOT%=	select PP2x2/XPot2/EL1002 device from SCPI interface mode without turning off the device
Pset=	set potential value (V)
Cset=	set current value (A)
Frq=	set AC-Frequency (Hz)
Ampl=	set AC-Amplitude (mA)
Nw=	set Number of averages
Pot=	turn potentiostat OFF/ON (Pot=0/-1 resp.)
Gal=	choose potentiostatic/galvanostatic and ……
GAL=	pseudo-galvanostatic mode
GlobalAck=	global acknowledge (0=off,1=ON,2=ON/error info)
UseRuleFile=	use rule file (1 = YES, 0 = NO)
Fmin=	lower AC frequency limit (Hz)
Fstart=	starting frequency (Hz)
Fmax=	upper AC frequency limit (Hz)
dfm=	steps per decade Frq >66Hz
dfl=	steps per decade Frq<=66Hz
Nwl=	averages for Frq <= 66Hz
Nws=	averages for Frq > 66Hz
ScanStrategy=	0=single sine, 1=multi sine,2=frequency table
ScanDirection=	0=from Fstart to Fmax, 1=from Fstart to Fmin
Rmin=	lower shunt resistance index
Rmax=	higher shunt resistance index
Potrange=	input potential range index
Imi=	minimum current limit
Ima=	maximum current limit
SELSEQ=	select sequence 00 → 09 (Sequencer)
FRA=	set FRA mode 0=off, 1=FRA mode
FRA_POT_IN=	Gain-Factor FRA Potential IN
FRA_POT_OUT=	Gain-Factor FRA Potential OUT
FRA_POT_MIN=	minimum potential (V)
FRA_POT_MAX=	maximum potential (V)
FRA_CUR_IN=	Gain-Factor FRA Current IN
FRA_CUR_OUT=	Gain-Factor FRA Current OUT
FRA_CUR_MIN=	minimum current (A)
FRA_CUR_MAX=	maximum current (A)
FRAGAL=	FRA Potentiostat-Mode 0=Pot, 1=Gal
CV_Pstart=	CV starting potential (V)
CV_Tstart=	CV starting hold time (s)

CV_Pupper=	CV upper (reversing) potential (V)
CV_Plower=	CV lower (reversing) potential (V)
CV_Pend=	CV ending potential (V)
CV_Tend=	CV ending hold time (s)
CV_Srate=	CV slew rate (V/s)
CV_Periods=	CV count of periods (number of cycles)
CV_PpPer=	CV points per period (samples per cycles)
CV_Imi=	CV minimum current (A)
CV_Ima=	CV maximum current (A)
CV_Odrop=	CV Ohmic drop (Ω)
CV_Sstart=	CV recording start time (s)
CV_Send=	CV recording end time (s)
CV_AutoReStart=	CV auto rescale at current overflow (0/-1)
CV_AutoScale=	CV auto rescale at current underflow (0/-1)
CV_AFGena=	CV enable optional Analog Function Generator (0/1)
PAD4ENA=	PAD4 enable PAD4 recording (0/1)
PAD4=	activate PAD4 channel e.g. PAD4=1;1;1 PAD1,Chan1,ON
PAD4MOD=	PAD4 mode potential/current (0/1)
IE_EckPot1=	IE first edge potential (V)
IE_EckPot2=	IE second edge potential (V)
IE_EckPot3=	IE third edge potential (V)
IE_EckPot4=	IE forth edge potential (V)
IE_EckPot1rel=	IE first edge potential 0=abs,-1=rel
IE_EckPot2rel=	IE second edge potential 0=abs,-1=rel
IE_EckPot3rel=	IE third edge potential 0=abs,-1=rel
IE_EckPot4rel=	IE forth edge potential 0=abs,-1=rel
IE_Resolution=	IE potential resolution (V)
IE_WZmin=	IE minimum waiting time (WZ=Wartezeit) (s)
IE_WZmax=	IE maximum waiting time (s)
IE_Torel=	IE relative current tolerance dI in %
IE_Toabs=	IE absolute current tolerance dI in A
IE_Odrop=	IE Ohmic drop (Ω)
IE_SweepMode=	IE sweep mode 0=steady state,1=fixed sampling,2=dynamic scan
IE_Srate=	IE linear scan slew rate (V)
IE_Imi=	IE minimum current (A)
IE_Ima=	IE maximum current (A)
PAD4_PRANGE=	PAD4 voltage range e.g. PAD4_PRANGE=1;1;8 PAD1,Chan1,8V
PAD4_RSHUNT=	PAD4 voltage range e.g. PAD4_RSHUNT=1;2;10m PAD1,Chan2,10mR
AVERAGES=	count of averages (100…5000) for potfast/curfast
CHANNEL=	I/O for ACQ-access (read analog, set digi, ……)
ANALOGOUT=	give value at ACQCHANN out

DIGITALOUT=	writes 0...15 to digital output of MIO
DACOUT=	separate Output function for DAC16/MIO
	solved problem with IN-OUT channel, same card
SEQ_RODROP=	ohmic drop value for IR-drop compensation in SEQUENCER (will be reset to "0" after performing a sequencer measurement)
SEQ_ACQ=	select ACQ channel e.g. =1;1 ACQ,Chan1,ON for SEQUENCER
SEQ_ACQENA=	activate ACQ channles in SEQUENCER (only selected channels)
SEQ_MAXTIME=	set maximum runtime [h] for SEQUENCER (0.1…1000)
SEQ_EUPPER=	set upper potential limit [V] for SEQUENCER
SEQ_ELOWER=	set lower potential limit [V] for SEQUENCER
SEQ_IUPPER=	set upper current limit [A] for SEQUENCER
SEQ_ILOWER=	set lower current limit [A] for SEQUENCER
SEQ_IRANGE=	set current range [A] for SEQUENCER
SEQ_POTOFLO=	set potential latency window (POT-OFF)
	=-1 -> do not turn off
	= t -> POT-OFF after "t" seconds in limitation
	= 0 -> turn off immediately
SEQ_CUROFLO=	set current latency window (CUR-OFF)
	=-1 -> do not turn off
	= t -> CUR-OFF after "t" seconds in limitation
	= 0 -> turn off immediately
EIS_MOD=	EIS file mode (0=date&time,1=counter,2=individual)
EIS_NUM=	EIS file counter (mode=1)
CV_MOD=	CV file mode (0=date&time,1=counter,2=individual)
CV_NUM=	CV file counter (mode=1)
IE_MOD=	IE file mode (0=date&time,1=counter,2=individual)
IE_NUM=	IE file counter (mode=1)
SEQ_MOD=	SEQ file mode (0=date&time,1=counter,2=individual)
SEQ_NUM=	rem SEQ file counter (mode=1)
EIS_PATH=	set EIS data path
CV_PATH=	set CV data path
IE_PATH=	set IE data path
SEQ_PATH=	set SEQ data path
VI_PATH=	set VI rtm path
EIS_ROOT=	set EIS file rootname (mode0,1)
CV_ROOT=	set CV file rootname (mode0,1)
IE_ROOT=	set IE EIS file rootname (mode0,1)
SEQ_ROOT=	set SEQ file rootname (mode0,1)
VI_INI=	call c:\thales\netvi\vi.exe VI-INI-file
VI_EXE=	name of the VI

5.1 New commands

Many tokens/commands are “RESERVED”, which are left for later development or user-defined functions. Each command/token must be 20 characters long and if a token is smaller than 20 characters, the rest must be filled with “blank” characters. A list of reserved tokens for future use is provided in the folder **C:\Thales\script\remote2\manuals**. Further information about the reserved

For user-defined functions, the user must also add a proof-read routine to make sure that the parameter is within the range of the potentiostat/or the defined range.

6 Errors - Table

In this chapter, an error list is provided. This list should help the users in swiftly preparing an error-free remote script. To get these error messages the Global Acknowledge must be set to 2. The same list is also provided in the folder c:\thales\script\remote2\manuals\error.xlsx.

Code	Meaning	Reason	Status	Tip
0	OK			
1	ERROR_TOO_MANY_FILES			
2	ERROR_FILE_ALREADY_OPEN			
3	ERROR_FILE_NOT_OPEN			
4	ERROR_FILE_NOT_FOUND			
5	ERROR_LOAD_ERROR			
6	ERROR_VERIFY_ERROR			
7	ERROR_DEVICE_NOT_PRESENT			
8	ERROR_NO_INPUT_FILE			
9	ERROR_NO_OUTPUT_FILE			
10	ERROR_NEXT_WITHOUT_FOR			
11	ERROR_SYNTAX_ERROR			
12	ERROR_RETURN_WITHOUT_GOSUB			
13	ERROR_OUT_OF_DATA			POT still ON
14	ERROR_ILLEGAL_QUANITITY			
15				
16				
17				
18				
19				
20				
21				

22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32	ERROR_LINE_NUMBER_TOO_BIG			
33				
34				
35				
36				
37				
38				
39				
40				
41				
42	ERROR_UNDEFINED			
43				
44				
45				
46				
47				
48				
49				
50				

51				
52				
53				
54				
55				
56				
57				
58				
59				
60				
61				
62				
63				
64				
65	ERROR_USER_INTERRUPT	HOME/ESCAPE	0	
67	ERROR_IMPEDANCE_DISABLED	NO AC DEFINED or POT OFF	0	
68	ERROR_POTENTIOSTATIC_ LOOP_ NOT_ STABLE		0	
69	ERROR_POTENTIOSTATIC_ LOOP_ INTERRUPTED		0	
70	ERROR_CURRENT_NOT_STEADY		0	
71	ERROR_CURRENT_LIMITS_EXC EEDED		0	
72	ERROR_POTENTIOSTAT_IS_OF F		0	
73	ERROR_POTENTIAL_LIMITS_E XCEEDED		0	
74	ERROR_NOT_ENOUGH_MEMORY		0	
75	ERROR_IMPROPER_DATA_FROM _NOISE_PROBE		0	
76	ERROR_NO_PROPER_TEXT_FIL E		0	

77	ERROR_MEASUREMENT_INTERRUPTED_BY_NMI		0	
78	ERROR_MEASUREMENT_STOPPED_POT_STILL_ON		0	
79				
80				
81				
82				
83				
84				
85				
86				
87				
88				
89				
90				
91				
92				
93				
94				
95				
96	ERROR_OUTA_CHANNEL_NOT_REGISTERED		0	
97	ERROR_ACQ_DISPLAY_NOT_REGISTERED		0	
98				
99	ERROR_NO_PAD4_INSTALLED	There is no PAD4 card present.		
100	ERROR_PARAMETER_OUT_OF_RANGE	Sent value too low/high	Val<MI =-1 Val>MA =1	
101	ERROR_PARAMETER_NOT_INTEGER	Sent value not integer	2	

102	ERROR_ILLEGAL_COMMAND	Illegal command token	0	
103	ERROR_ILLEGAL_COMMAND_DELIMITER	Wrong format of command token	0	
104	ERROR_PARAMETER_ERROR_IN_MULTICMD			
105				
106				
107				
108				
109				
110	ERROR_CV_REVERSING_POTENTIALS	Pupper<=Plower	0	Pupper<=Plower
111	ERROR_CV_STARTING_POTENTIAL_TOO_HIGH	Pstart>Plower	0	Pstart>Plower
112	ERROR_CV_POINTS_PER_CYCLE_TOO_HIGH	Maximum points in Status	Max value	Maximum points in Status
113	ERROR_CV_CYCLE_COUNT_TOO_HIGH	Maximum number of cycles in Status	Max value	Maximum number of cycles in Status
114				
115				
116				
117				
118				
119				
120	ERROR_IE_RESOLUTION_TOO_LOW	Minimum resolution in µV in status	Min value	Minimum resolution in µV in status
121				
122				
123				
124				

125				
126				
127				
128				
129	ERROR_SEQ_01_NOT_YET_DEFINED	SEQ ERR1	0	
130	ERROR_SEQ_02_NOT_EXECUTABLE_RAMP	SEQ ERR2	0	
131	ERROR_SEQ_03_TOO_MANY_LOOPS	SEQ ERR3	0	
132	ERROR_SEQ_04_LOOP_END_BEFORE_START	SEQ ERR4	0	
133	ERROR_SEQ_05_LOOP_WITHOUT_END	SEQ ERR5	0	
134	ERROR_SEQ_06_KERNEL_ERROR	SEQ ERR6	0	
135	ERROR_SEQ_07_PARAMETER_ERROR	SEQ ERR7	0	
136	ERROR_SEQ_08_TOKEN_DEFINITION	SEQ ERR8	0	
137	ERROR_SEQ_09_SEQUENCE_NOT_FOUND	SEQ ERR9	0	
138	ERROR_SEQ_10_CURRENT_OUT_OF_RANGE	SEQ ERR10	0	
139	ERROR_SEQ_11_POTENTIAL_OUT_OF_RANGE	SEQ ERR11	0	
140	ERROR_SEQ_12_SLOPE_EQUAL_ZERO	SEQ ERR12	0	
141	ERROR_SEQ_13_END_AND_START_EQUAL	SEQ ERR13	0	
142	ERROR_SEQ_14_BRACKET_ERROR	SEQ ERR14	0	
143	ERROR_SEQ_15_ASCII_ERROR	SEQ ERR15	0	
144	ERROR_SEQ_16_DOUBLE_COMMA	SEQ ERR16	0	
145	ERROR_SEQ_17_NO_REGULAR_EXPRESSION	SEQ ERR17	0	

146	ERROR_SEQ_18_TOO_MANY_PARAMETER	SEQ ERR18	0	
147	ERROR_SEQ_19_NOT_YET_DEFINED	SEQ ERR19	0	
148	ERROR_SEQ_20_NOT_YET_DEFINED	SEQ ERR20	0	
149	ERROR_SEQ_21_NOT_YET_DEFINED	SEQ ERR21	0	
150	ERROR_SEQ_22_USAGE_OF_VARIABLE_CUR	SEQ ERR22	0	
151	ERROR_SEQ_23_USAGE_OF_VARIABLE_POT	SEQ ERR23	0	
152	ERROR_SEQ_24_USAGE_OF_VARIABLE_TIM	SEQ ERR24	0	
153	ERROR_SEQ_25_BLOCK_ENDED_NO_START	SEQ ERR25	0	
154	ERROR_SEQ_26_BLOCK_STARTED_NO_END	SEQ ERR26	0	
155	ERROR_SEQ_27_NOT_YET_DEFINED	SEQ ERR27	0	
156	ERROR_SEQ_28_NOT_YET_DEFINED	SEQ ERR28	0	
157	ERROR_SEQ_29_NOT_YET_DEFINED	SEQ ERR29	0	
158	ERROR_SEQ_30_NOT_YET_DEFINED	SEQ ERR30	0	
159	ERROR_SEQ_31_NOT_YET_DEFINED	SEQ ERR31	0	
160	ERROR_SEQ_32_NOT_YET_DEFINED	SEQ ERR32	0	
161				
162				
163				