ACDC-CYCLE

Multi Cell
AC-DC-AC
Measurements

Table of contents

1. The R-MUX4 hardware

1.1. Components of the R-MUX4 hardware

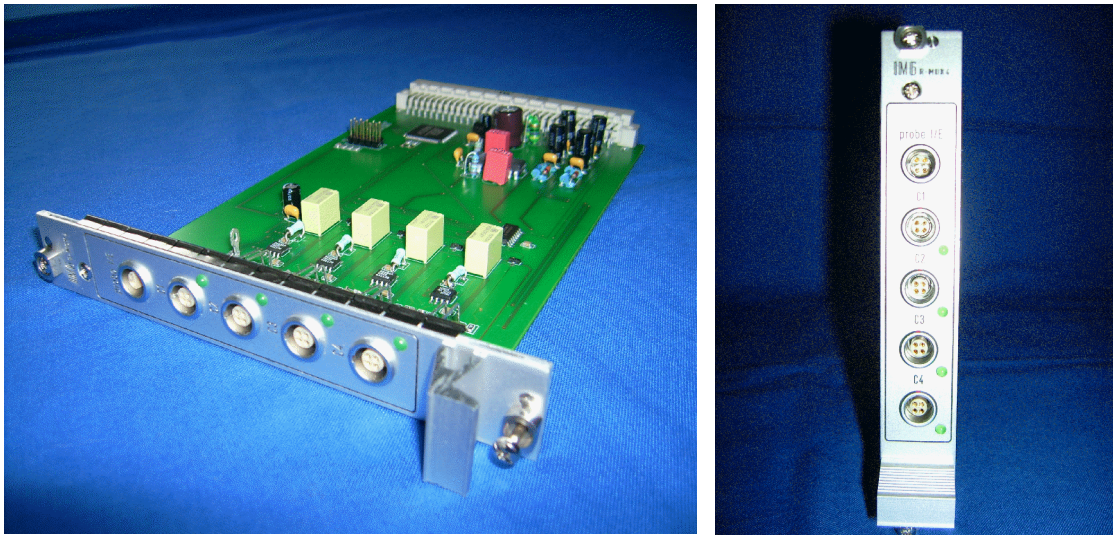


Fig. 1 The R-MUX4 card

The R-MUX4 hardware consists of the following components

- Plug in module(s) R-MUX4 (1)
- Connection cable to IM6/Zennium main potentiostat (2)
- Cell cables (3)

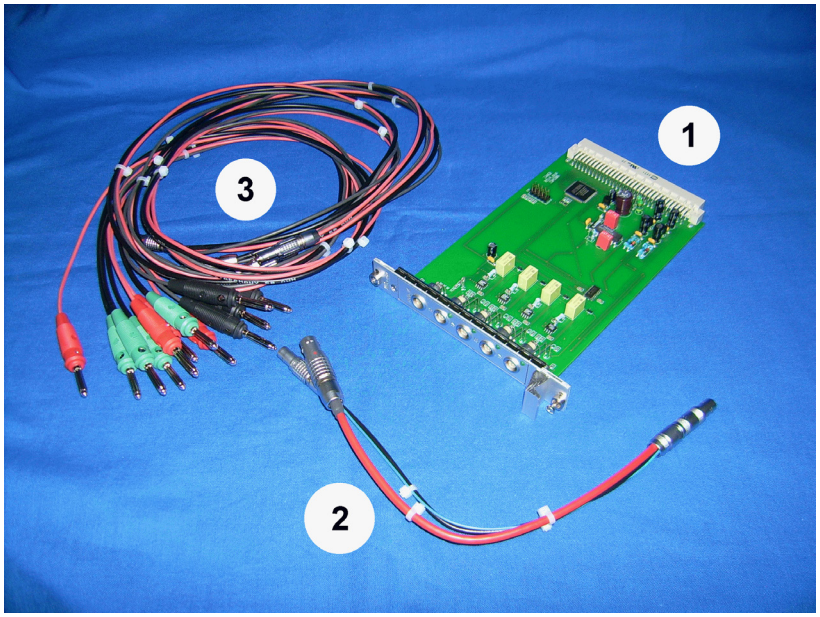
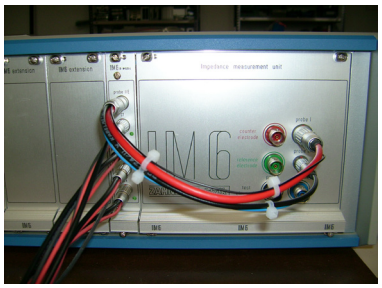


Fig. 2 Components of the single R-MUX4 hardware

1.2. Installation of the hardware

Usually the R-MUX4 hardware will be installed into the delivered system by ZAHNER. If you install a R-MUX4 system as an up grade follow the steps listed below.

- Switch of the IM
- Remove the dummy plate left of the potentiostat
- Insert the R-MUX4 (1) into an empty slot left of the FRA modules
- Fix mounting screws
- If necessary mount the dummy plate



Connect the R-MUX4 socket being named “probe I/E” to the sockets being named “probe I” and “probe E” of the main potentiostat using the delivered cable (2).

The cells will be connected to the R-MUX4 using the delivered 3-electrode connection cables (3). The cables allow a three-pole connection to the potentiostat.

WE	Working electrode	Black plug
CE	Counter electrode	Red plug
RE	Reference electrode	Green plug

Important Note!	The inputs WE are being connected internally!

1.3. General description of the R-MUX4 module

The R-MUX4 is both

- a 4-channel cell multiplexer card with an internal buffer amplifier of Gain=0.4

and

- a 4-channel data acquisition module with +/-10V voltage inputs.

Four R-MUX4 modules can be installed into one IM6/Zennium system in parallel offering the capability to multiplex 16 cells. The R-MUX4 hardware will be detected automatically by the software of the IM6/Zennium.

Important Note!	The individual sub-potentiostats of the R-MUX4 must be operated using a connection scheme ***with buffer*** and ***gainfactor Bfact=0.4***! Use either scheme 2 = two electrodes with buffer or scheme 4 = three electrodes with buffer!

1.4. Operation of the R-MUX4 as cell multiplexer

Up to four cells may be connected to one R-MUX4 module. The single cells (named C1 to C4) will then be addressed as slave potentiostats in section < control potentiostat > of the EIS program.

Example:
The sequence shown right will select channel C3 of a single R-MUX4 card.

To avoid limitations in bandwidth and signal to noise ratio the R-MUX4 sense amplifier has been designed as a fixed buffer with a gain factor of 0.4 (Gain=0.4 A Bfact=2.5) . Using the R-MUX4 thus demands the correct connection scheme (2 or 4) of the potentiostat's set up.

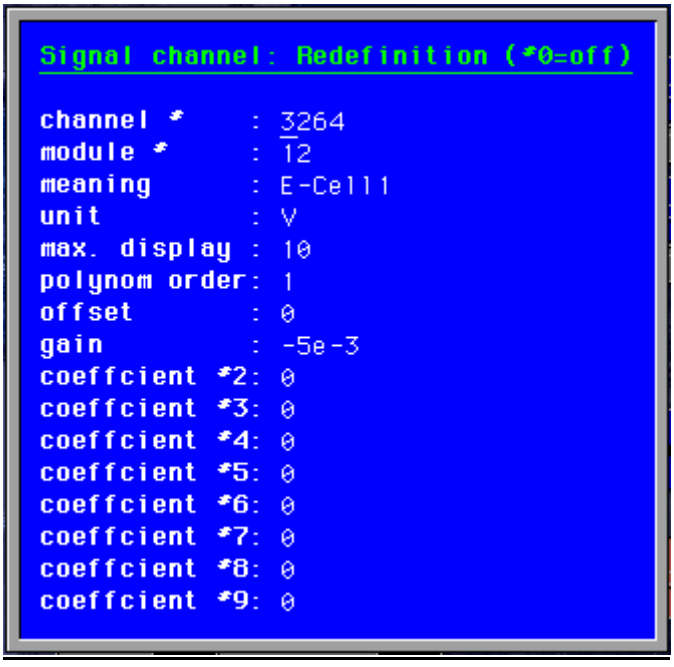
Not using a separate reference electrode select

Using a separate reference electrode select

Set the Gain = 0.4

1.5. Operation of the R-MUX4 as data acquisition module

The measured signal will be fed to the inputs WE (= common ground) and RE. The data acquisition set up is shown below (Input C1, channel=0, addressee=3264). Except the parameters "channel #" and "meaning" no parameter must be changed.



1.6. Addresses of the channels in a multi R-MUX4 system

Using a multi R-MUX4 set up the addresses of the single potentiostats are

$$DEVICE = (CARD - 1) \cdot 4 + CELL$$

The addresses of the data acquisition inputs are

$$ADDRESSE = 3264 + (CARD - 1) \cdot 4 + CHANNEL - 1$$

Single module set up Multi module set up

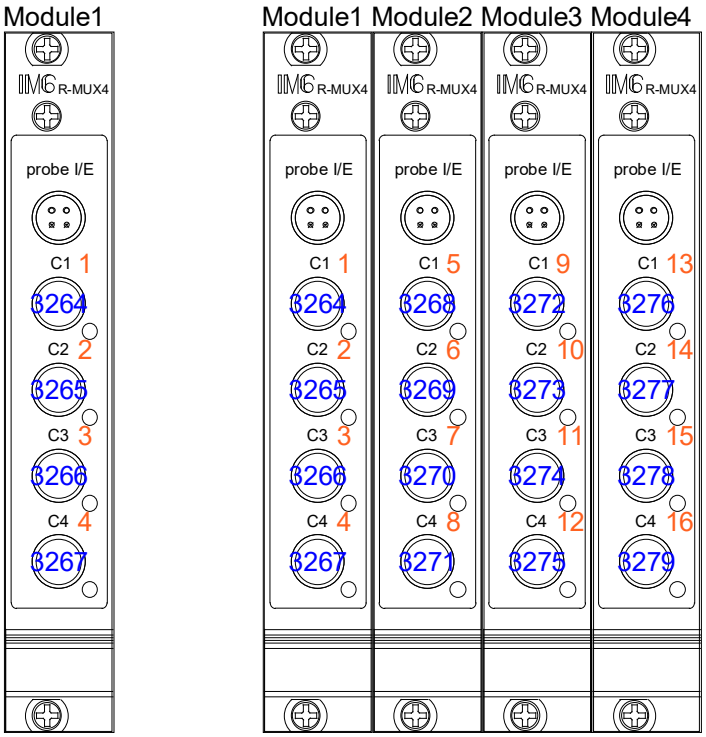


Fig.3 Addresses of single & multi R-MUX4 systems

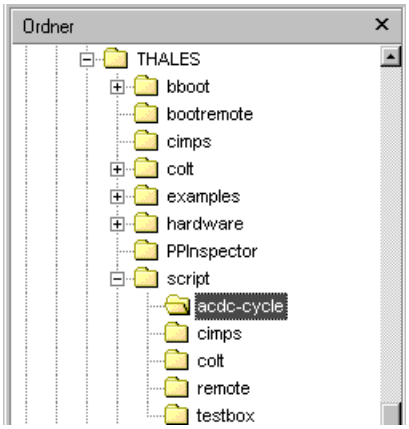
The cell addresses (= DEVICE numbers) are marked orange the data acquisition addresses are marked blue.

2. The software module ACDC-cycle

2.1. Resources and paths

The resources of the script “acdc-cycle” will be found in the directory

c:\thales\script\acdc-cycle



To guarantee the correct translation and operation of the script all files being listed in the table at the right must be present.

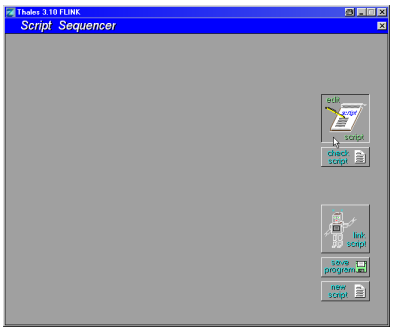
Dateiname	Größe	Typ
onli_b1.icd	1 KB	Datei ICD
onli_b2.icd	1 KB	Datei ICD
onli_b3.icd	1 KB	Datei ICD
onli_b4.icd	1 KB	Datei ICD
onli_b5.icd	1 KB	Datei ICD
onli_b6.icd	1 KB	Datei ICD
onli_b7.icd	1 KB	Datei ICD
onli_b8.icd	1 KB	Datei ICD
onli_b9.icd	1 KB	Datei ICD
onli_but.icd	1 KB	Datei ICD
onli_m4.icd	1 KB	Datei ICD
onli_man.icd	1 KB	Datei ICD
onli_mau.icd	1 KB	Datei ICD
onli_off.icd	5 KB	Datei ICD
onli_ons.icd	5 KB	Datei ICD
onli_pus.icd	1 KB	Datei ICD
openproj.icd	1 KB	Datei ICD
phases.icd	4 KB	Datei ICD
scr_b1.icd	1 KB	Datei ICD
scr_b2.icd	1 KB	Datei ICD
scr_b3.icd	1 KB	Datei ICD
scr_b4.icd	4 KB	Datei ICD
scr_logo.icd	8 KB	Datei ICD
acdc-cycle.is_	25 KB	Datei IS_
eis.ism	1 KB	Datei ISM
polar.isw	2 KB	Datei ISW
relax.isw	2 KB	Datei ISW
acdc-cycle.ini	1 KB	Konfiguration

In the following, the creation of the runtime file “acdc-cycle.rtm” will be described. Usually the programme will be installed at ZAHNER and will be found in c:\thales\examples\applications. The start of “acdc-cycle” will be described below.

2.2. How to enter ACDC-CYCLE

The functions of the Thales R-MUX4 provided in form of a script. Generally, a script can be activated from the Thales desktop by pressing the “script”-button and performing the following procedure:

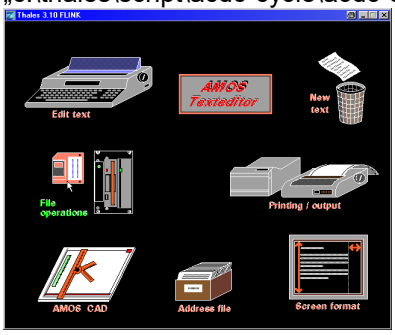
Start “script” from the Thales desktop script icon

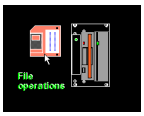


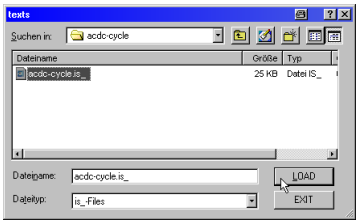
“edit script”

Open source

„c:\thales\script\acdc-cycle\acdc-cycle.is_“







Return to the script panel and link the script

Fig. 4 How to open and compile a script source

Generally, the source code is open for changes. However, we recommend this only to the experienced user.

After successful linking the ACDC-CYCLE panel appears:

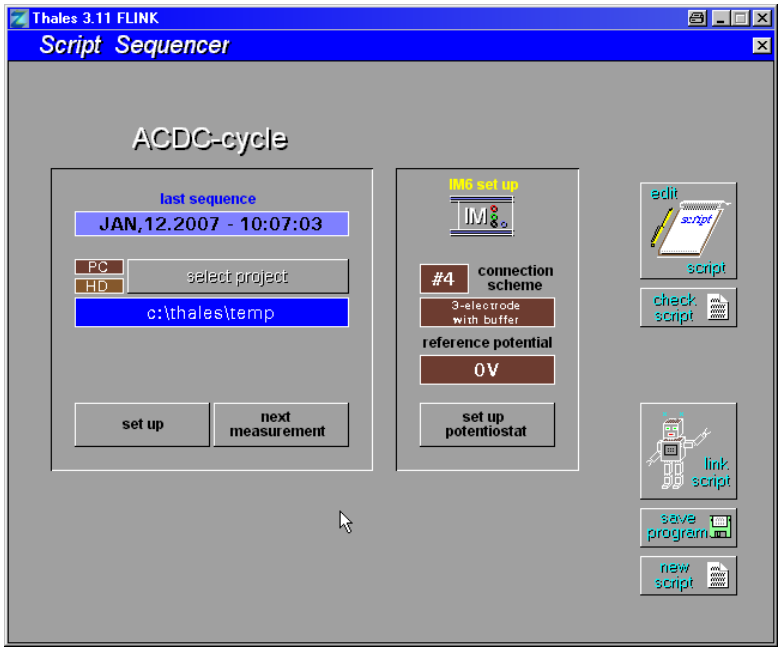
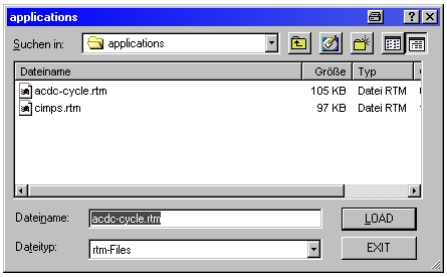


Fig. 5 ACDC-CYCLE script main menu

In the path “c:\thales\examples\applications“, usually precompiled versions of script applications are present. Alternatively, to the procedure described above, you can start RV like described in the following:

Enter “exe” from the Thales desktop

Use “browse” to search & start the program needed.



Re-enter by means of EXE, if necessary (right).

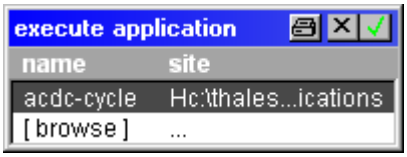
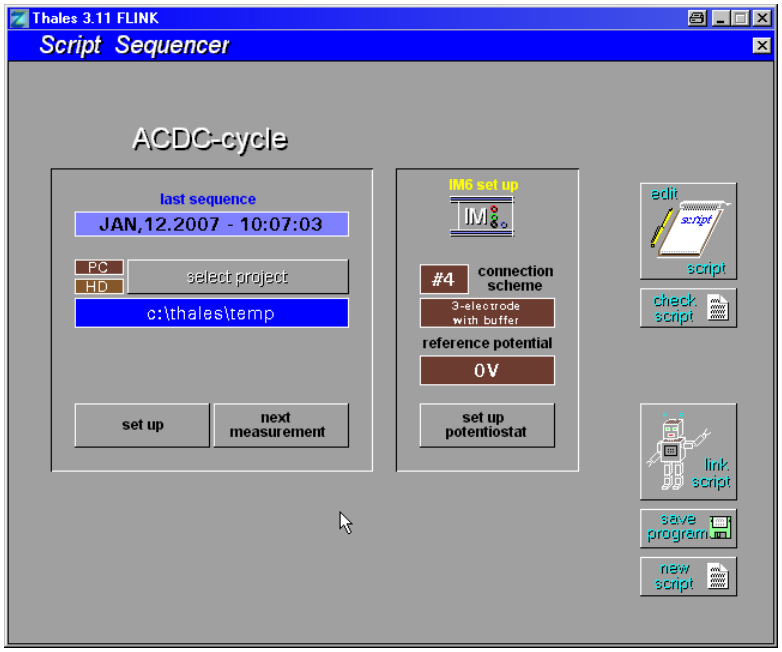


Fig. 6 Activating and re-entering a pre-compiled ACDC-CYCLE version by means of the EXE procedure

This procedure will save time. However, after exit of ACDC-CYCLE you will not find ACDC-CYCLE under the Thales desktop function “script”. Instead, you have to re-enter RMUX via the EXE function. Pre-compiled versions cannot be altered by the user.

3. Software manual of the ACDC-CYCLE script

3.1. The main menu of the ACDC-CYCLE script



The main menu offers entries

- to modify the runtime parameters of the script

- to store the measured data in individual projects

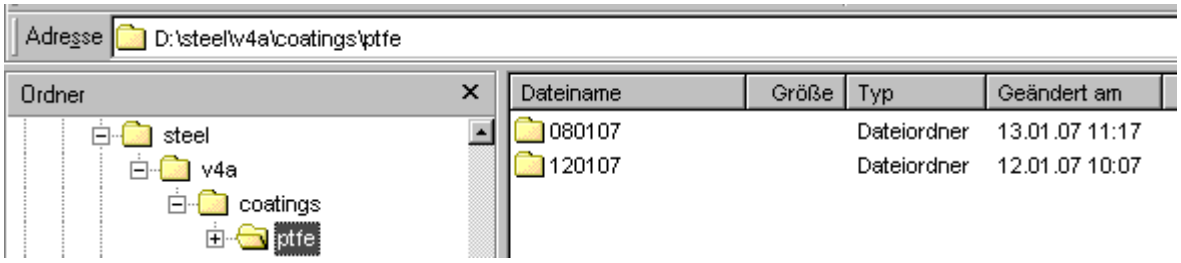
- to start the next series

- to set up the potentiostat

3.2. The ACDC-CYCLE project manager

To avoid erroneous overwriting of present data the measured data of a ACDC-CYCLE sequence will be stored as projects. The upper part of a project will be defined by the user, e.g.

d:\steel\v4a\coatings\ptfe



Within the selected project, the script will create new subdirectories for the next measurement. The names of these directories will be generated by use of date and starting time of the measurement.

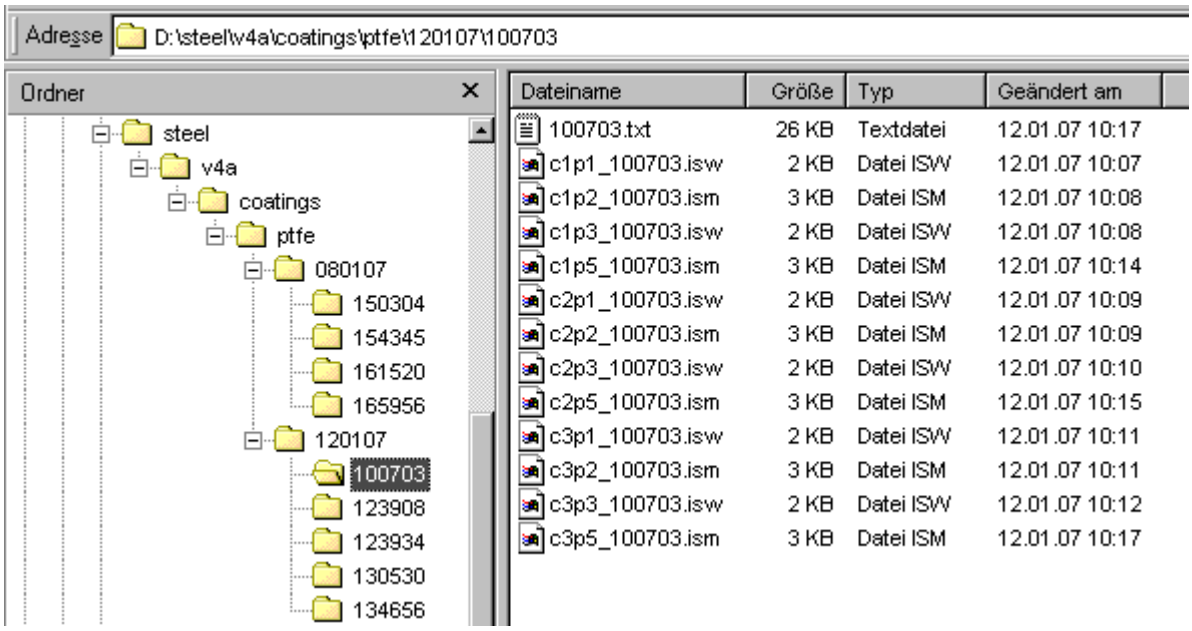


Fig. 7 The project structure of the ACDC-CYCLE cell series measurements

This structure offers many advantages, e.g.

1. no erroneous overwriting of former data
2. data of an equal type of probes can be stored in the same project
3. easy access to data for comparison of different measurements

The different files will be named in the following manner:

...

c1p0_100703.isw	cell1/phase init1	= relaxation
c1p0_100703.ism	cell1/phase init2	= initial impedance
c1p1_100703.isw	cell1/phase pol1	= polarisation cycle1
c1p1_100703.ism	cell1/phase EIS1	= impedance cycle1

…

c2p0_100703.isw	cell2/phase init1	= relaxation
c2p0_100703.ism	cell2/phase init2	= initial impedance

...

During a series, the individual cells will be treated by means of polarisation measurements and impedance measurements. The passive cells will be monitored by means of the data acquisition channels of the R-MUX4 card. An ASCII formatted list of the overall measured potential data will be present with the file being named „100703.txt“. The structure of the file „100703.txt“ is shown in the figure below.

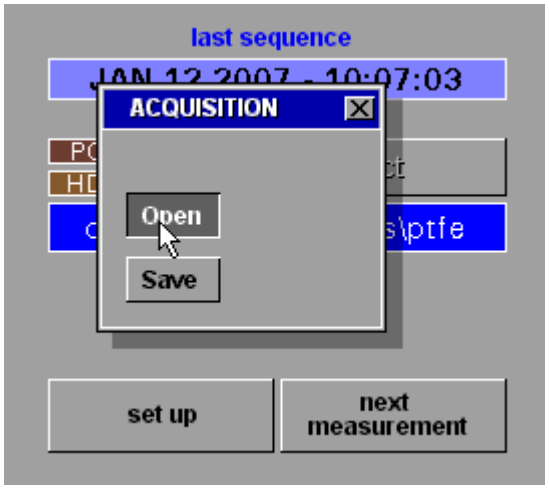
```
test with three cells                                          File descriptor block
material: steel
coating : ptfe

cell1 active
cell2 active
cell3 active

test at three different positions
plate size 30cm x 30xm
position at corners
Start  853062060.61     JAN,12.2007 - 10:07:03
-------------------------------------------------------------  ----------------------------

  Time/sec        C1 Pot/V   C2 Pot/V   C3 Pot/V        PHASE

       2.82       0.0377     0.0386     0.0377         OCP 1    Relaxation cell1
      .....
      32.03       0.0375     0.0374     0.0375         OCP 1
      38.28       0.038      0.0374     0.0337         EIS 1    Initial impedance cell1
      .....
      60.71       0.0388     0.0395     0.0395         EIS 1
      69.56       0.0563     0.0422     0.0418         POL 1    Polarisation cell1
      .....
      98.82       0.0397     0.0399     0.0402         POL 1
     104.84       0.029      0.04       0.0397         OCP 2    Relaxation cell2
      .....
     133.98       0.0396     0.0401     0.0406         OCP 2
     140.44       0.0388     0.0364     0.0365         EIS 2    Initial impedance cell2
     ......                                                     ....
     ......                                                     ....
     ......                                                     ....
     ......                                                     ....
     301.22       0.0402     0.0404     0.0406         POL 3    Polarisation cell3
     306.66       0.0396     0.0396     0.0396         REL ALL  Relaxation phase all cells
     ......
     400.16       0.0399     0.0399     0.0399         REL ALL
     405.18       0.0387     0.0382     0.0329         EIS 1    Final impedance cell1
     ......
     427.76       0.0386     0.0393     0.0394         EIS 1
     434.68       0.0398     0.0401     0.0394         REL ALL  Relaxation phase all cells
     ......
     500.23       0.0396     0.0398     0.0398         REL ALL
     504.11       0.0377     0.0363     0.0382         EIS 2    Final impedance cell2
     ......
     526.49       0.0386     0.0393     0.0393         EIS 2
     533.29       0.0397     0.0396     0.0399         REL ALL  Relaxation phase all cells
     ......
     602.72       0.0399     0.0397     0.0396         REL ALL
     606.78       0.0391     0.0382     0.0326         EIS 3    Final impedance cell3
     ......
     629.15       0.0388     0.0395     0.0395         EIS 3    End of series
```

Fig. 8 The structure of the sequential ASCII file

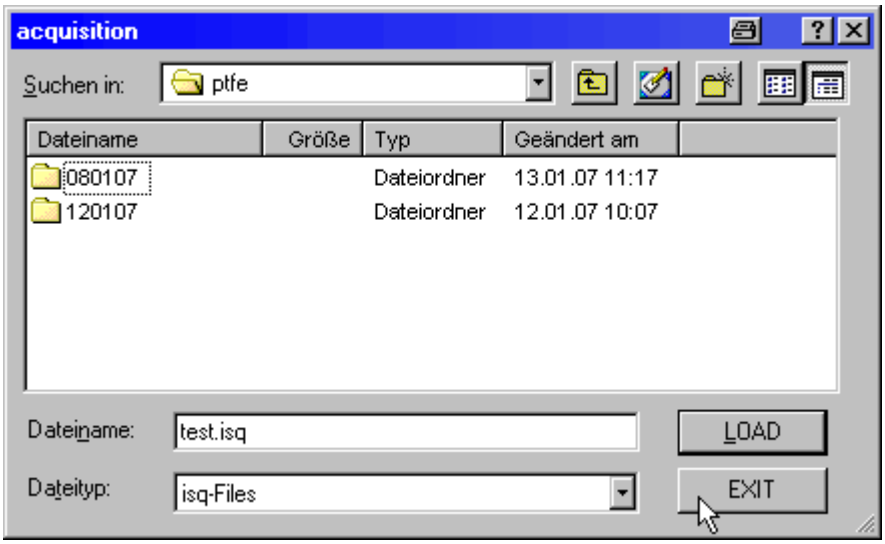
3.3. Selection of a project

The project manager will be called by use of the button <select project>.

The acquisition data menu will prompt.

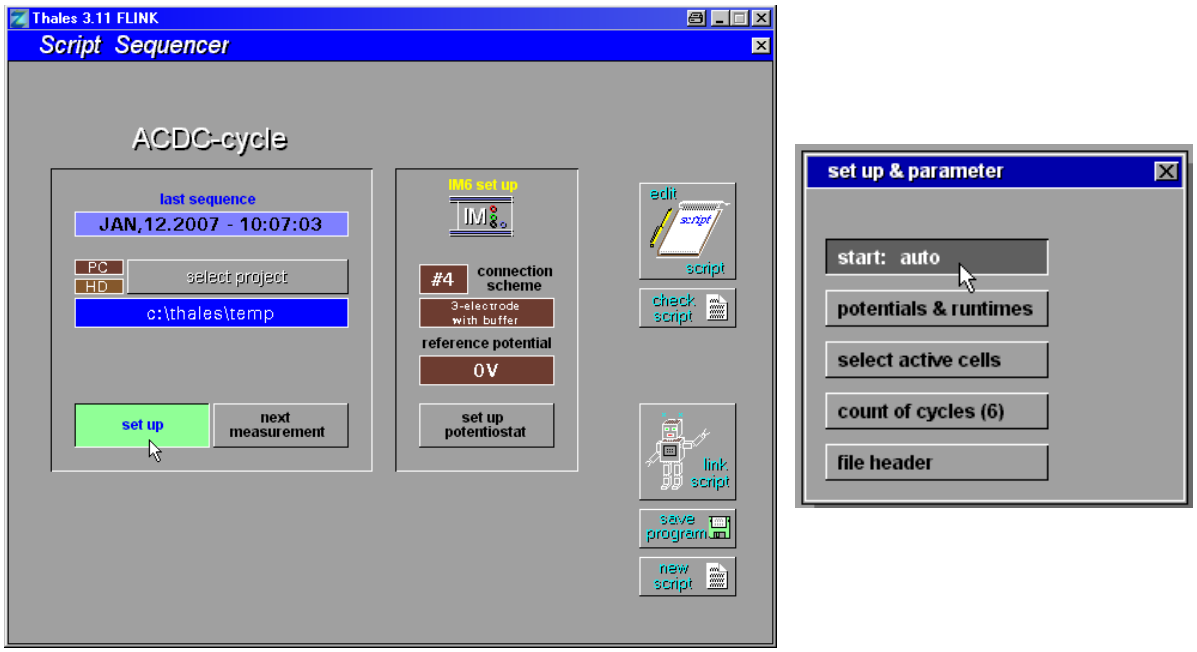


Now change the data path to the desired project or create a new project by means of a new folder. Then leave the project manager by using the <EXIT>-button.



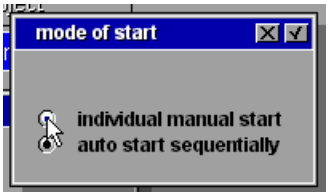
3.4. Individual parameter set up

Although the AC-DC_AX multicell sequence will be controlled by so called 'rule files' certain parameters may be altered within the ACDC-CYCLE script without the need to create new rule files. To enter the set up menu click on the button named <set up>.

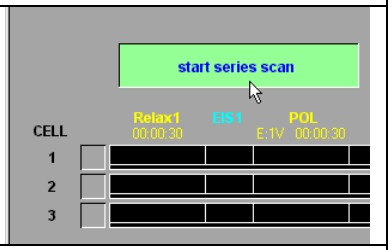
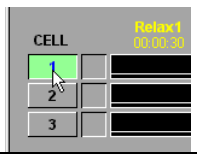


The 'set up & parameter' menu will pop up and will offer entries to different settings

3.4.1. Mode of start

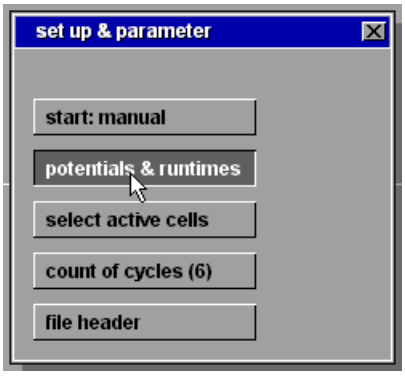


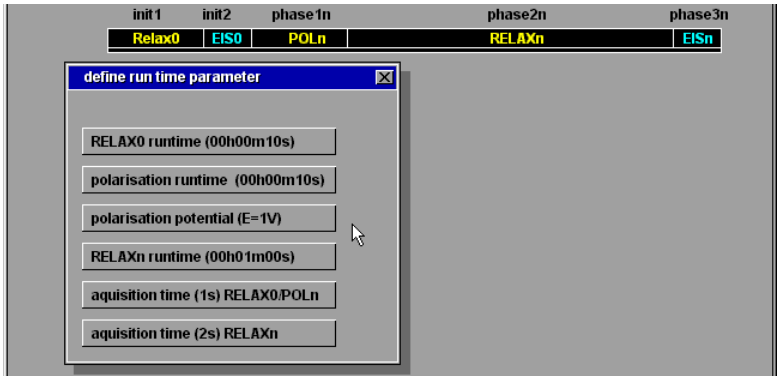
The sequence either can be started automatically or can be started by triggering each individual cell. The default setting is 'auto'.

Mode	Action	
Automatic start	The cells will be triggered automatically in sequence of the active cells	
Individual start	Each cell can be triggered individually in arbitrary sequence.	

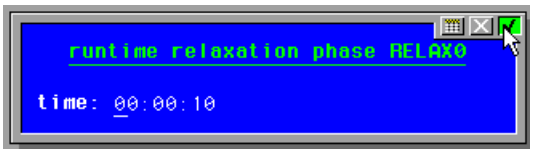
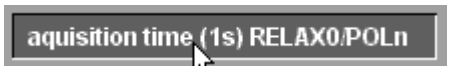
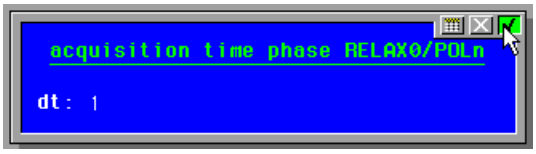
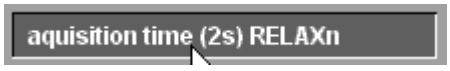
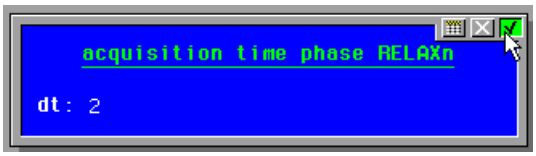
3.4.2. Parameter set up

The ACDC-CYCLE script offers to edit certain run time parameters within the script.





To modify any parameter follow the steps shown below.

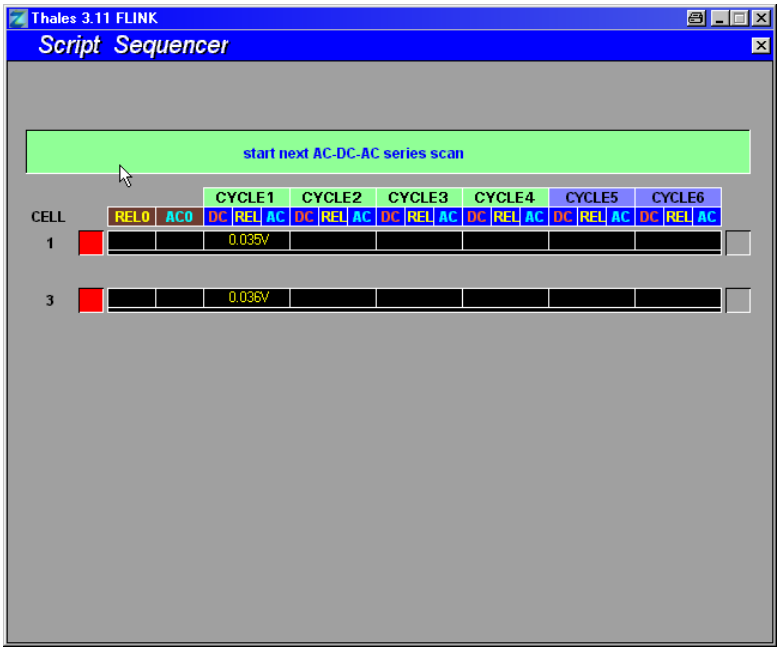
activate input box	put in parameter	Note
Runtime relaxation phase init1 		The maximum runtime of the relaxation phase init1 is max=10hours.
Runtime of polarisation phase POLn 		The maximum runtime of the polarisation phase POLn is max=10hours
Polarisation potential phase POLn 		The polarisation potential of the polarisation phase POLn
Runtime relaxation RELAXn 		The maximum runtime of the relaxation RELAXn is max=10hours
Data acquisition time of phases RELAX0&POLn 		The acquisition time is limited to $1s \leq t_{acq1} \leq 60s$
Data acquisition time of phases RELAXn4 		The acquisition time is limited to $1s \leq t_{acq1} \leq 60s$

3.4.3. Count of cycles

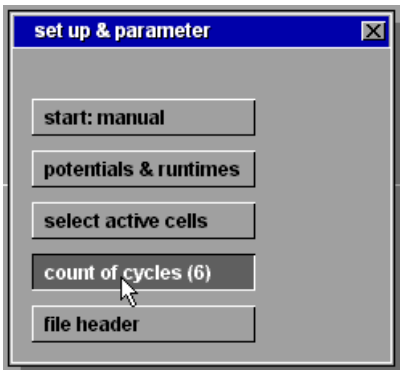
After the initial phases INIT1 = relaxation and INIT2 = impedance measurement up to six cycles of DC-AC measurements can be appended. Each cycle will execute the sequence

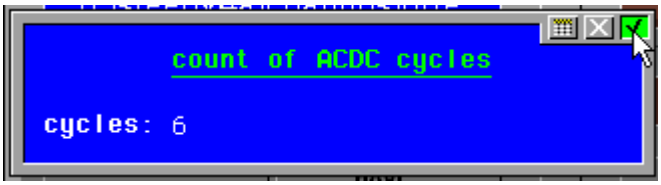
polarisation – relaxation – impedance measurement.

The active cycles will be inidicated within the start menu of the ACDC-CYCLE script.



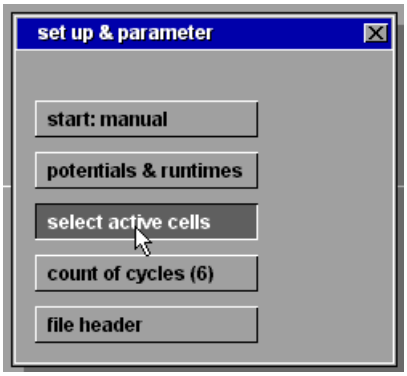
To modify the count of cycles do

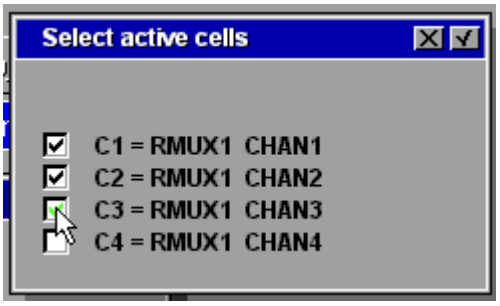




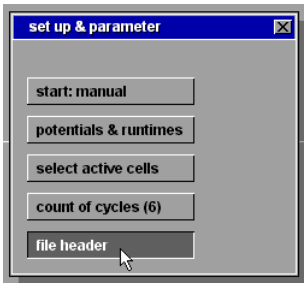
3.4.4. Set up of 'cell matrix'

The ACDC-CYCLE script offers the possibility to edit the cell matrix individually. Active cells and passive cells can be selected before each start of a new sequence.

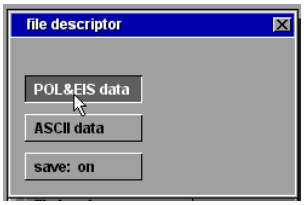


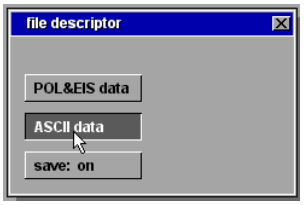


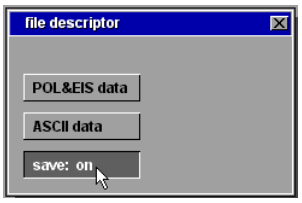
3.4.5. File descriptor blocks

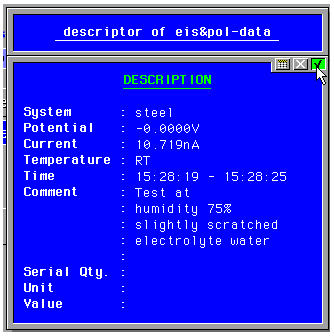


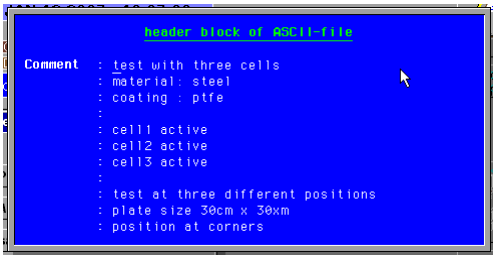
The file descriptor blocks may be different for the different phases. POL&EIS measure files may have a different descriptor block from that one of the overall ASCII list. Finally, the user can decide if the descriptor of the ASCII list shall be saved or shall not be saved (to avoid import problem).

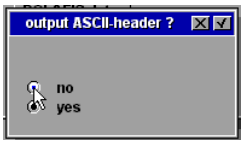












3.4.6. Setting up parameters by use of the ini file 'acdc-cycle.ini'

The second way to change the parameter set is given by the ini file

c:\thales\script\acdc-cycle\acdc-cycle.ini

The ini file will be read after the first start up of the application <acdc-cycle.rtm>. After each measurement, the script will write back the actual parameter set and the ASCII header block to 'acdc-cycle.ini'. The general structure of the in file is shown below and must not be altered. To modify the parameters put in the set value of the corresponding parameter after the equal sign.

c:\thales\script\acdc-cycle\acdc-cycle.ini	Meaning
TRELAX1=30	Runtime of relaxation phase1
POLTIME=30	Runtime of polarisation phase3
POLPOT=1	Potential of polarisation phase3
TRELAX2=300	Runtime of relaxation phase4
TACQ13=1	Data acquisition time phases 1&3
TACQ4=2	Data acquisition time phases 4
AUTOSTART%=-1	Mode of start -1=auto 0=individual
SCHEME=2	Cell connection scheme
REFERENCE=0	Reference electrode potential
CYCLES=6	Number of cycles to be done
CELL%(0)=-1	Cell matrix cell1-1=ON 0=OFF
CELL%(1)=-1	Cell matrix cell2-1=ON 0=OFF
CELL%(2)=-1	Cell matrix cell3-1=ON 0=OFF
CELL%(3)=0	Cell matrix cell4-1=ON 0=OFF
RESERVED04=0	Reserved for multi rmux4 application
RESERVED05=0	.
RESERVED06=0	.
RESERVED07=0	.
RESERVED08=0	.
RESERVED09=0	.
RESERVED10=0	.
RESERVED11=0	.
RESERVED12=0	.
RESERVED13=0	.
RESERVED14=0	.
RESERVED15=0	.
LASTSERIES=120107/100703	Date & Time of last measurement
PROJECT=d:\steel\v4a\coatings\ptfe	Name of project
RESERVED17=0	Reserved for future extension
RESERVED18=0	.
RESERVED19=0	.
RESERVED20=0	.
RESERVED21=0	.
RESERVED22=0	.
RESERVED23=0	.
RESERVED24=0	.
RESERVED25=0	.
RESERVED26=0	.
RESERVED27=0	.
RESERVED28=0	.
RESERVED29=0	.
RESERVED30=0	.
RESERVED31=0	.
RESERVED32=0	.
EOF	EOF delimiter

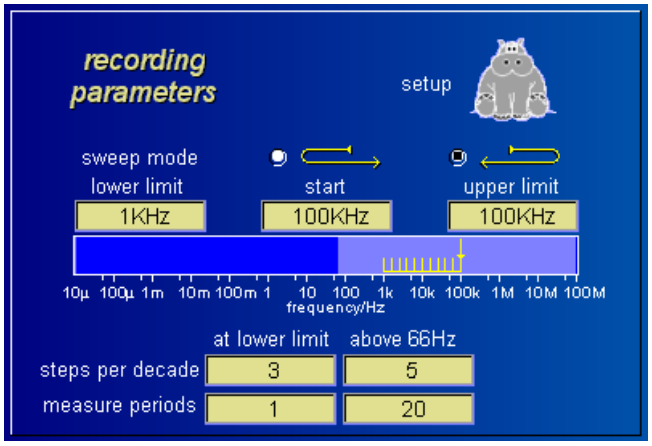
3.4.7. parameter set up of AC (EIS-measurement)

The AC control parameters are being stored in the impedance measurement file

c:\thales\script\acdc-cycle\eis.ism

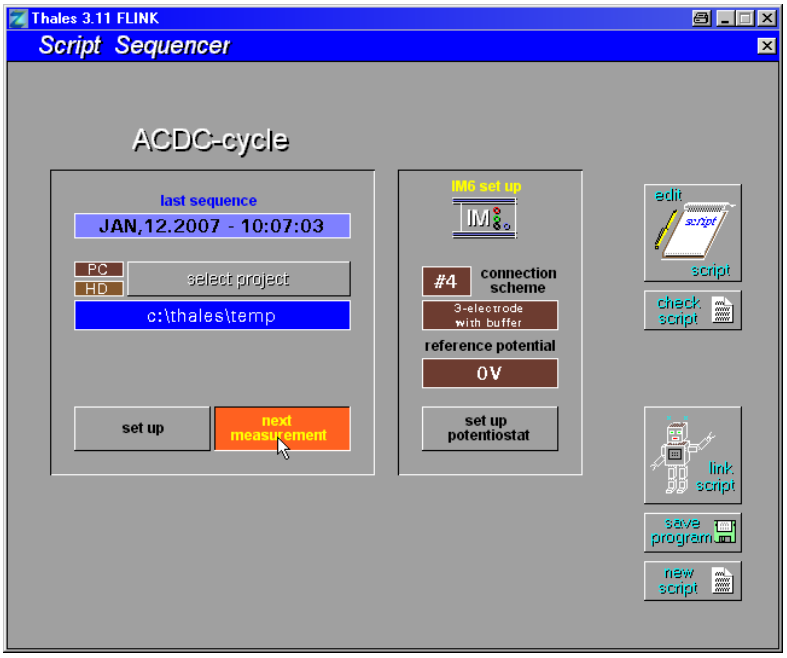
To modify any parameter follow the sequence being described below.

- enter EIS-programme
- load impedance measurement ***c:\thales\script\acdc-cycle\eis.ism***
- modify selected parameters

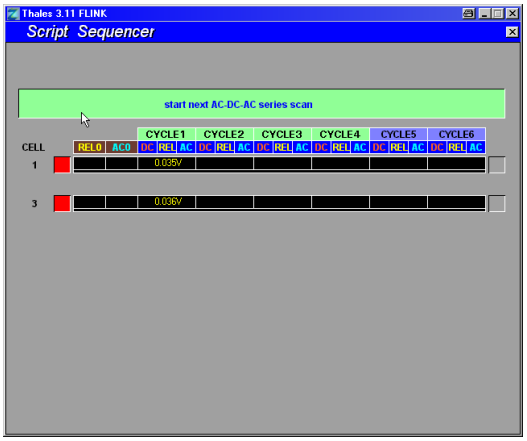
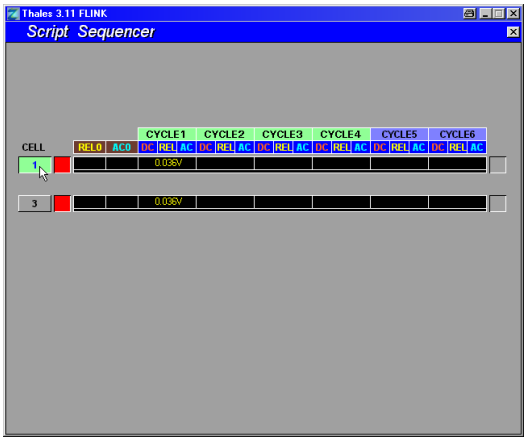


- start measurement
- wait for about 10 sampled measure points then stop measurement
- save data to ***c:\thales\script\acdc-cycle\eis.ism***

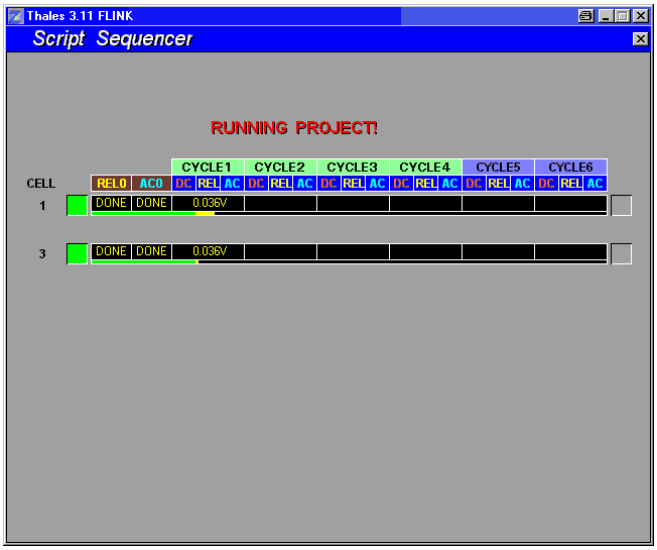
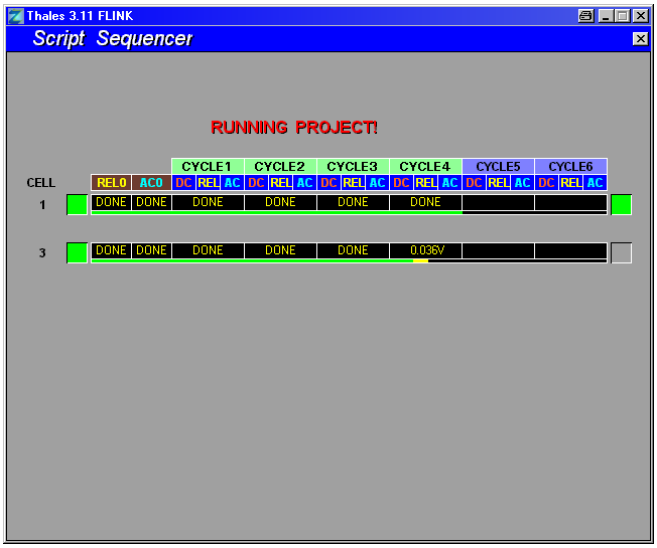
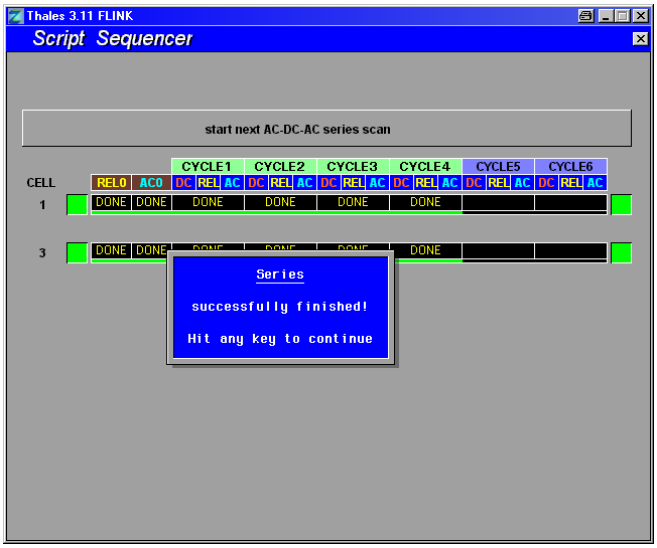
3.5. Start next measurement



Depending on the ***mode of start*** the sequence will be started by different triggering buttons.

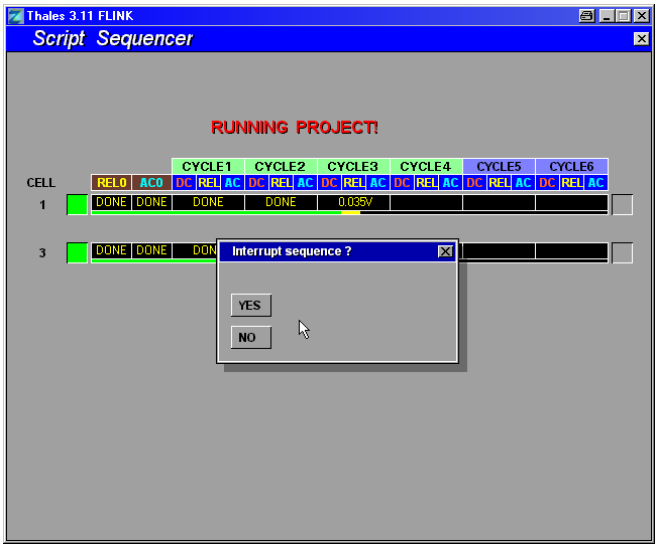
Automatic start	***Individual start***
	
The cells will automatically be activated in the sequence cell1 – cell2 – cell3	The cells may be triggered in any sequence by the user

After the sequence has been started the state of the individual cells will be displayed on screen.

State of the art	Display on screen
In the auto start mode, the cells will be triggered in sequence of the active elements of the cell matrix. Each cell will pass the 3 initial phases • Relaxation • Initial impedance • Polarisation The fourth phase will run as long, as the first cell will exceed the interval time of the second relaxation. After the final impedance, measurement that cell will be declared to 'finished'.	
First and second cell finished	
Total sequence finished	

3.6. In case of problems

If unexpected problem will occur a running sequence may be finished by the <escape>-function. To prevent erroneous termination the end of the sequence must be confirmed.



3.7. Set up of the potentiostat

The set up of the potentiostat will be restored during the start up of the ACDC-CYCLE script by the parameters being stored in the ini file 'acdc-cycle.ini'. If changes of the set up will become necessary, the actual set up may easily be changed by the <control potentiostat> menu of the EIS programme.
<set up potentiostat> offers a direct entry to the EIS programme. Modify the relevant parameters (e.g. connection scheme, reference electrode's potential,…) and return to the ACDC-CYCLE script by means of the escape function. The actual settings will be stored in the ini file after the next series measurement has successfully been finished.