Automated VCMA & AHE Measurement System – AutoVA

AutoVA - Automated VCMA/(magnetoelectric coupling) - Anomalous Hall effect Measurement System.

The software is used to control :

1. The E-field applied for the VCMA/Magnetoelectric coupling. (with the ramping function).
    1. The E-fields can have multi-variants - (dwelling, pulser).
2. The electromagnetic filed.
3. The Soure Measure Unit (SMU) to apply one bias-current, and meanwhile measuring the Hall Voltage. Hysteresis loops can be obtained by looping the electromagnetic field.

The software has following features:

1. compatible with a large amount of SMUs, and instruments.
2. Experiments procudures visualised
3. GUI for graphing live data
4. managing queues of experiments.
5. Data auto-generation

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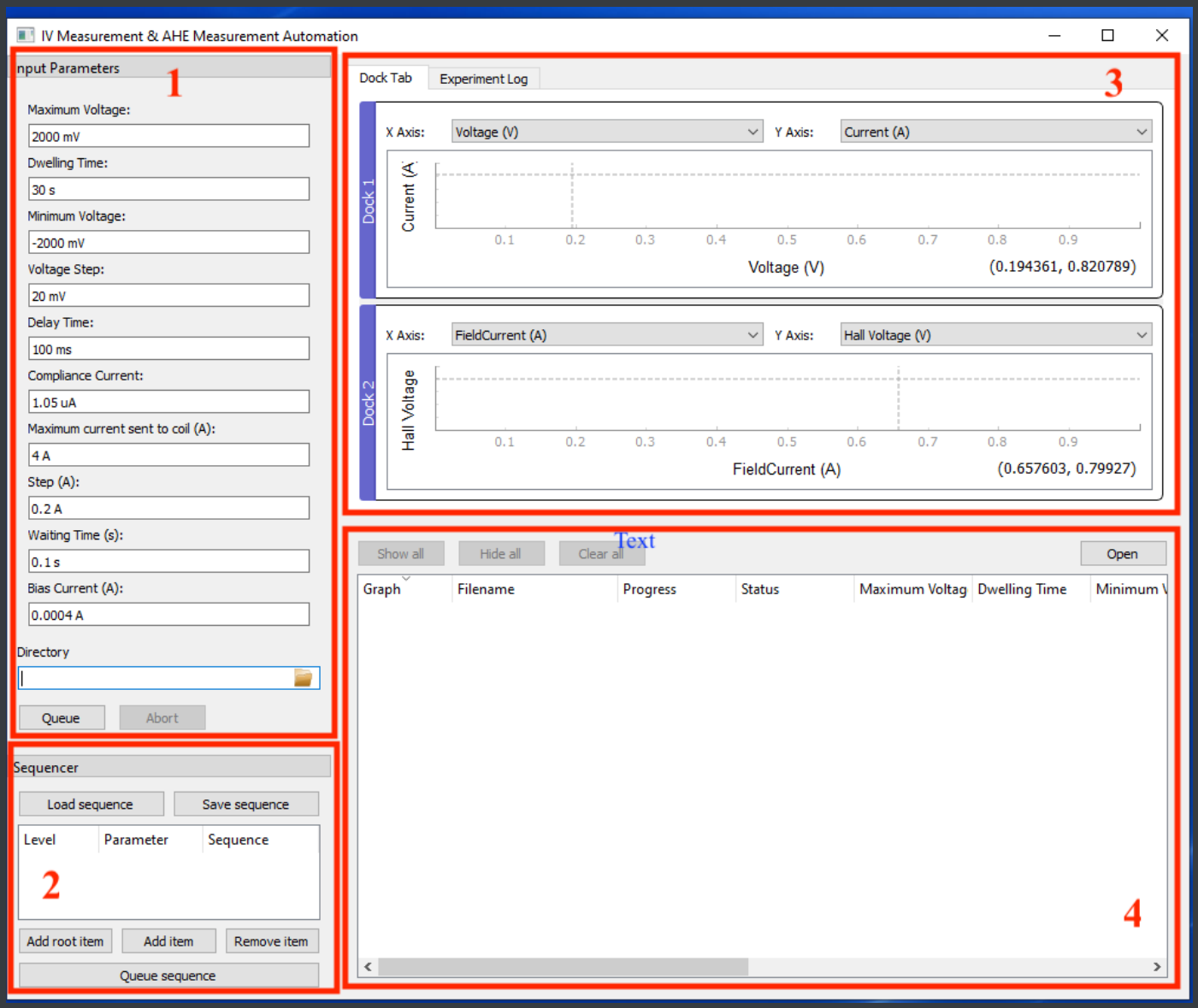
GUI introduction



Block 1:

- Maximum Voltage (mV): This setting determines the strength of positive electric fields. Use a positive value when you want positive electric fields, and set it to 0 if you prefer negative fields.
- Dwelling Time (s): This is the duration for which the targeting electric fields will be applied and held.
- Minimum Voltage (mV): This setting controls the intensity of negative electric fields. Set a negative value when you want negative electric fields and 0 when you want positive fields.
- Voltage Step (mV): This is the increment used when ramping up the voltage to reach the target electric field strength.
- Delay Time (ms): This delay time is used during the voltage step when ramping up to the target electric field strength.
- Compliance Current (uA): This current is applied to protect the sample from high leakage currents.
- Maximum Current Sent to Coil (A): This current is sent to the coil to create looping electromagnetic (EM) fields for generating hysteresis loops.
- Step (A): This is the current increment used during the looping of EM fields.
- Directory: Specify the path where you want to save the data.

Block 2:

The sequencer is provided which allows users to queue a series of measurements with varying one, or more, of the parameters. This sequencer thereby provides a convient way to scan through the parameter space of the measurement procedure.

The sequences can be extended and shortened using the buttons `Add root item`, `Add item`, and `Remove item`. The latter two either add an item as a child of the currently selected item or remove the selected item, respectively. To queue the entered sequence the button `Queue` sequence can be used. If an error occurs in evaluating the sequence text-boxes, this is mentioned in the logger, and nothing is queued.

```
-"Maximum Voltage", "[0]"
-- "Minimum Voltage", "[-1000]"
--- "Dwelling Time", "[540]"
-- "Minimum Voltage", "arange(-2000, -4500, -500)"
--- "Dwelling Time", "[60, 180, 300]"
```

Finally, it is possible to create a sequence file such that the user does not need to write the sequence again each time. The sequence file can be created by saving current sequence built within the GUI using the `Save sequence` button or directly writing a simple text file. Once created, the sequence can be loaded with the `Load sequence` button.

Block 3:

Graphical Display:

- live plotting for data
  - Dock1: IV curve when E-fields are applied
  - Dock 2: Coil currents (EM after calibration) looped as a function of the Hall Voltage measured
- Experiments log

Block 4:

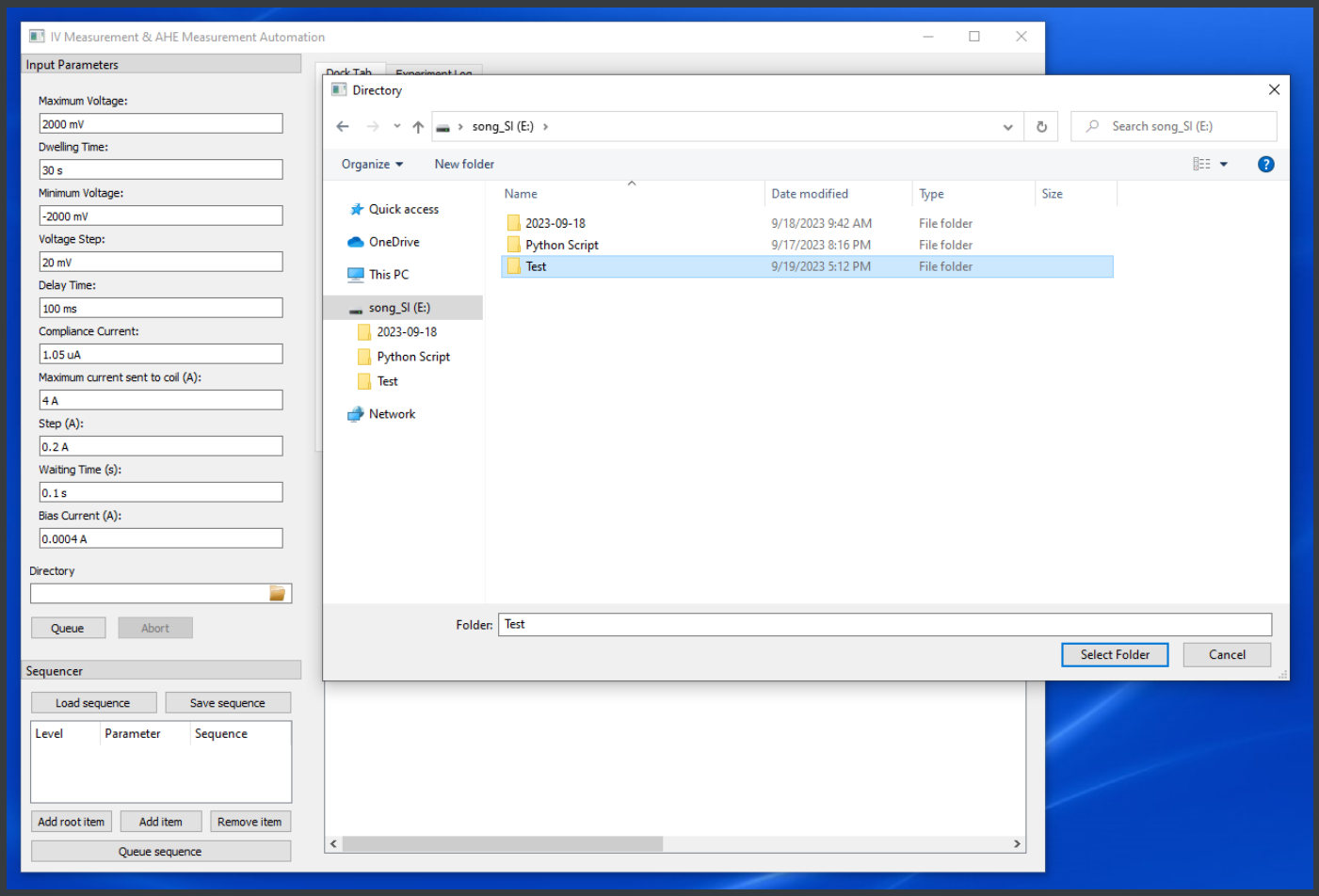
A queue system for managing large numbers of experiments

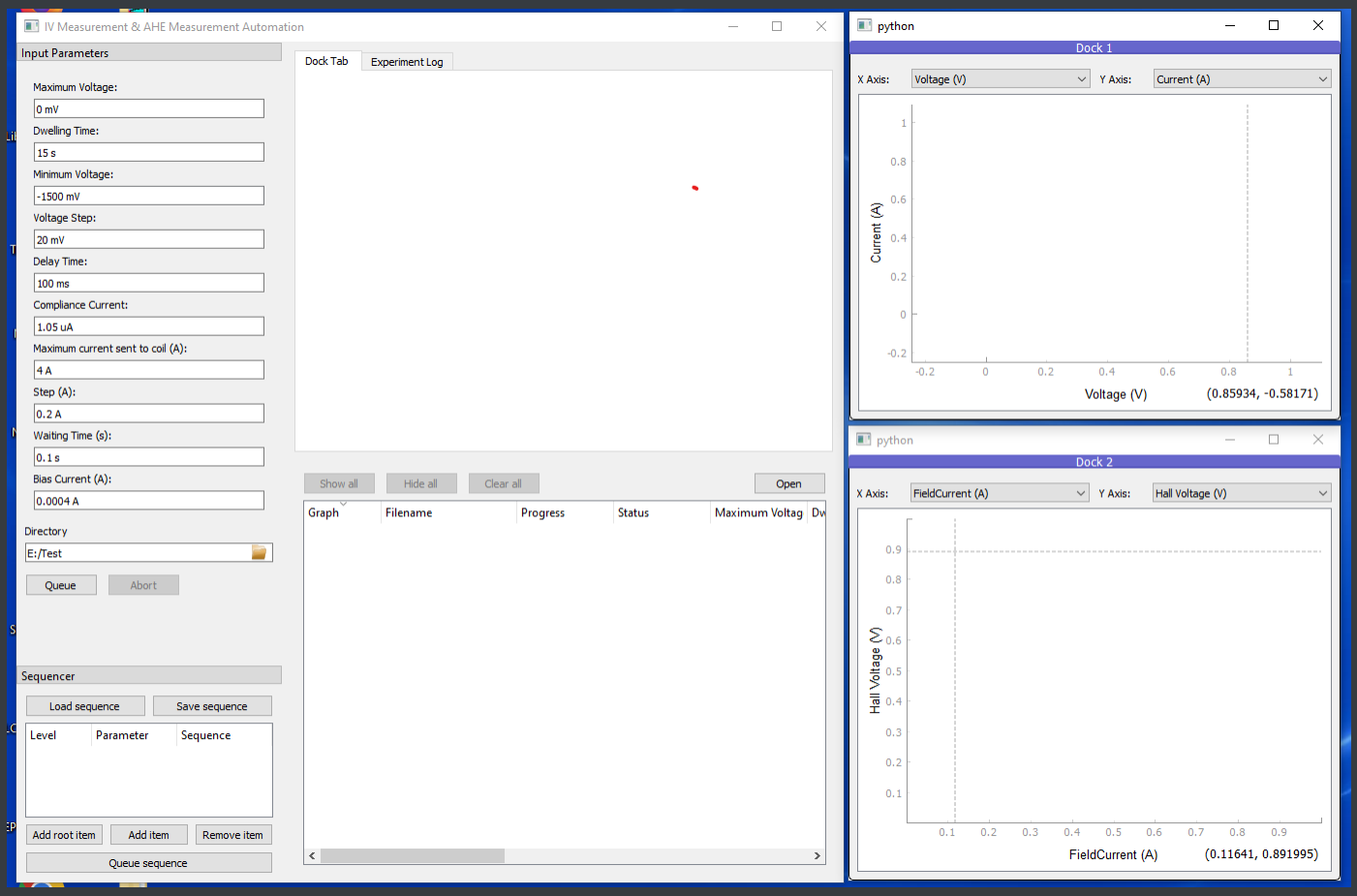
Experiment Running & Data Example

Experiment Running Example

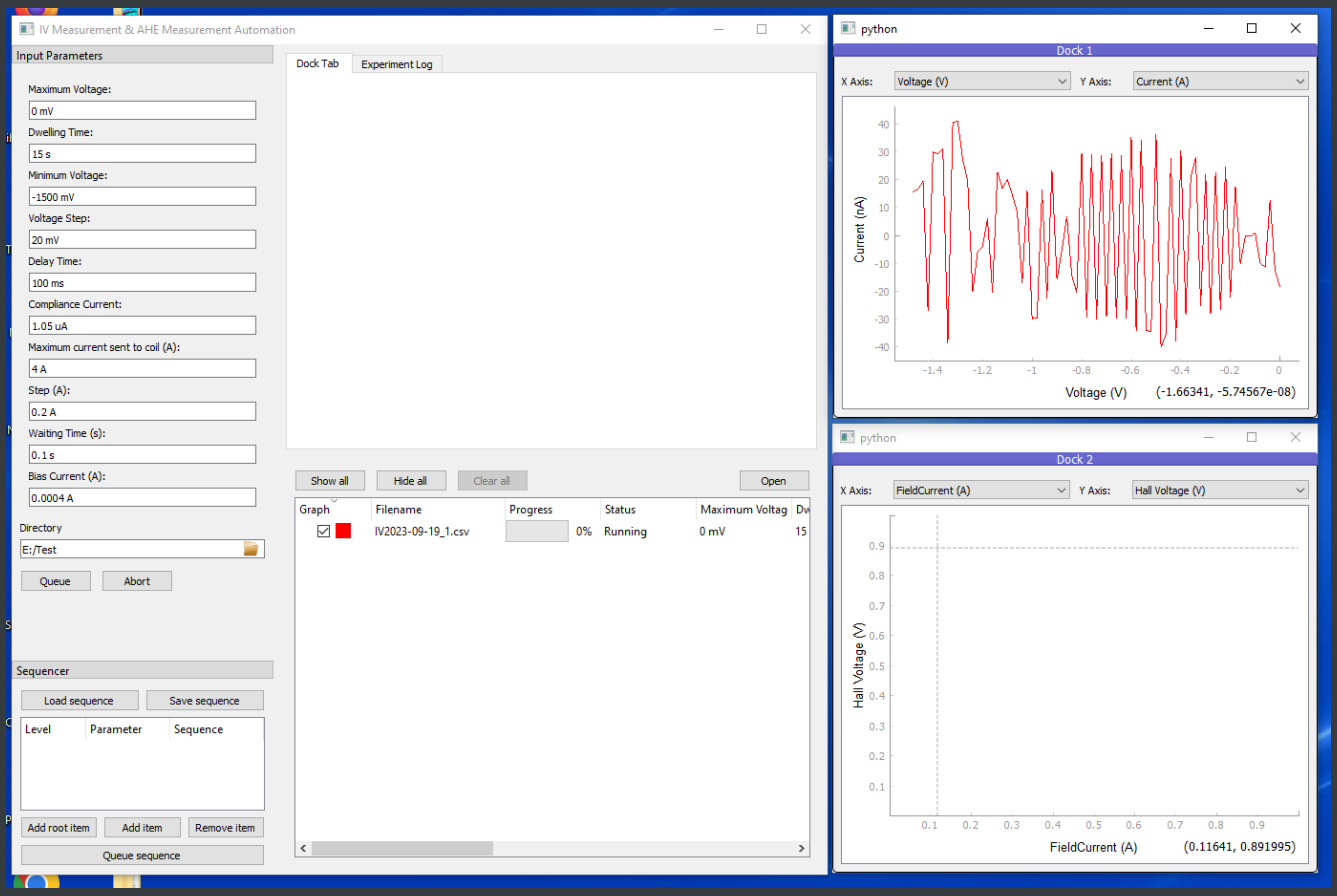
One experiment running example is shown as followings:

1. Parameters input:

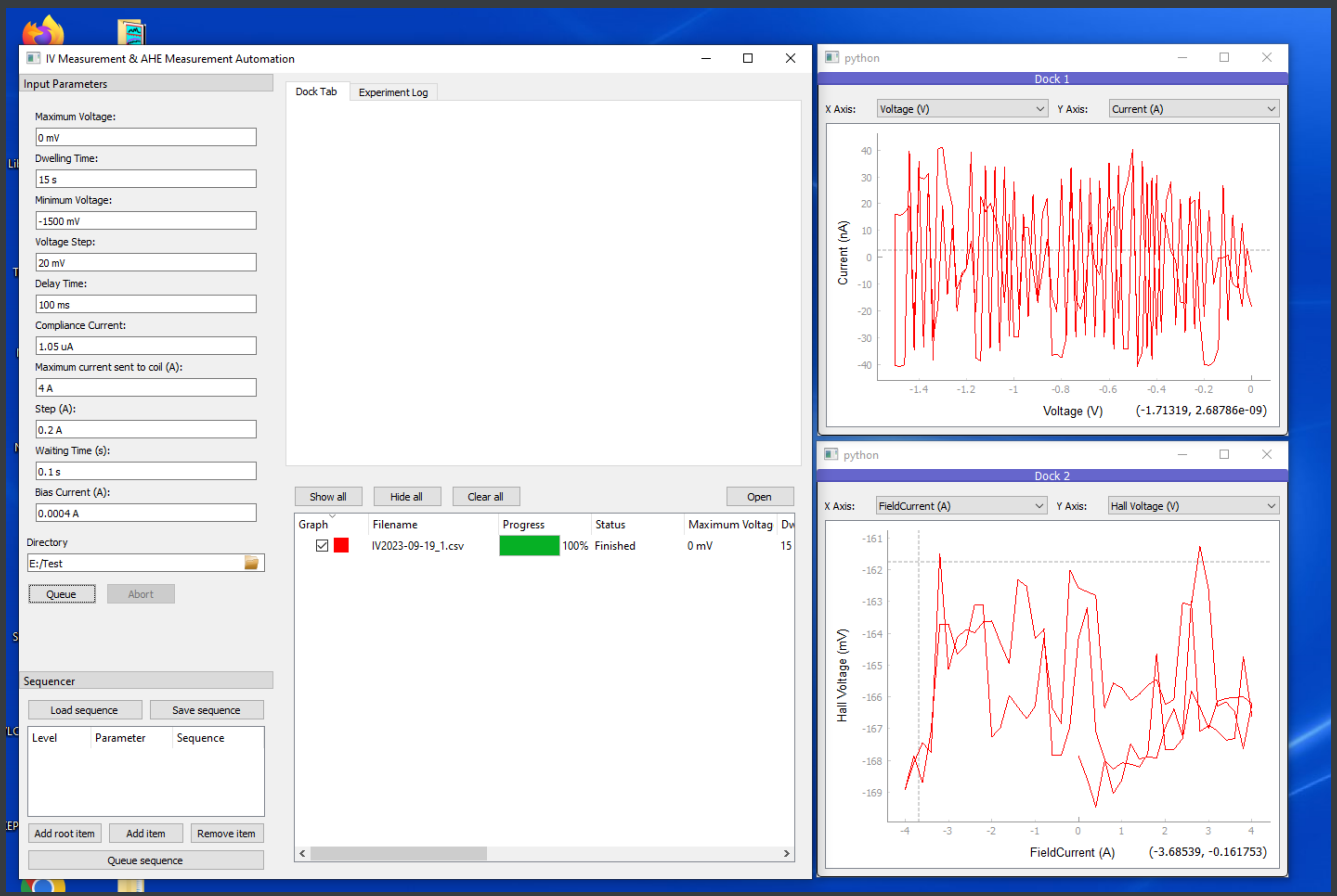




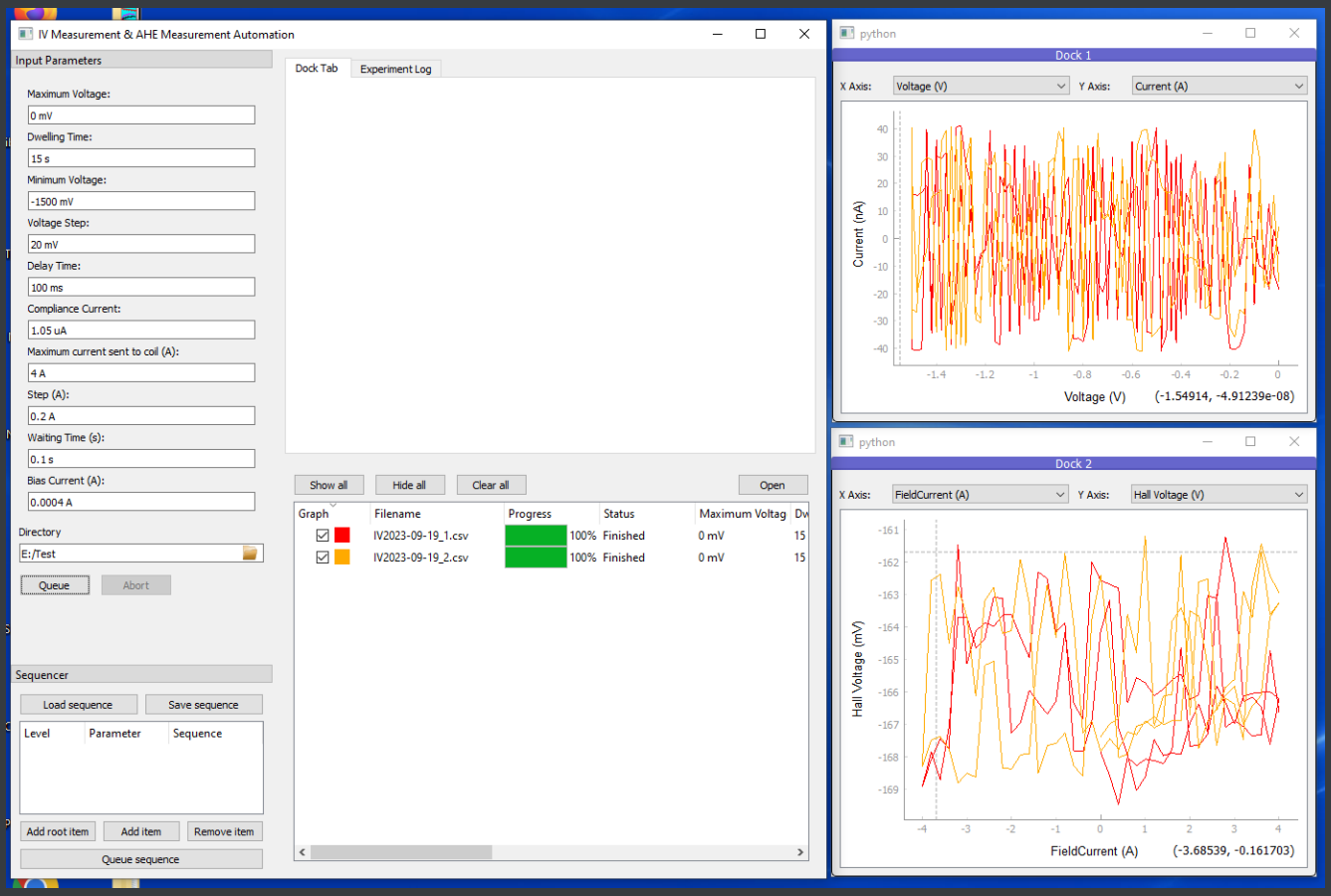
2. Applying the E-field:



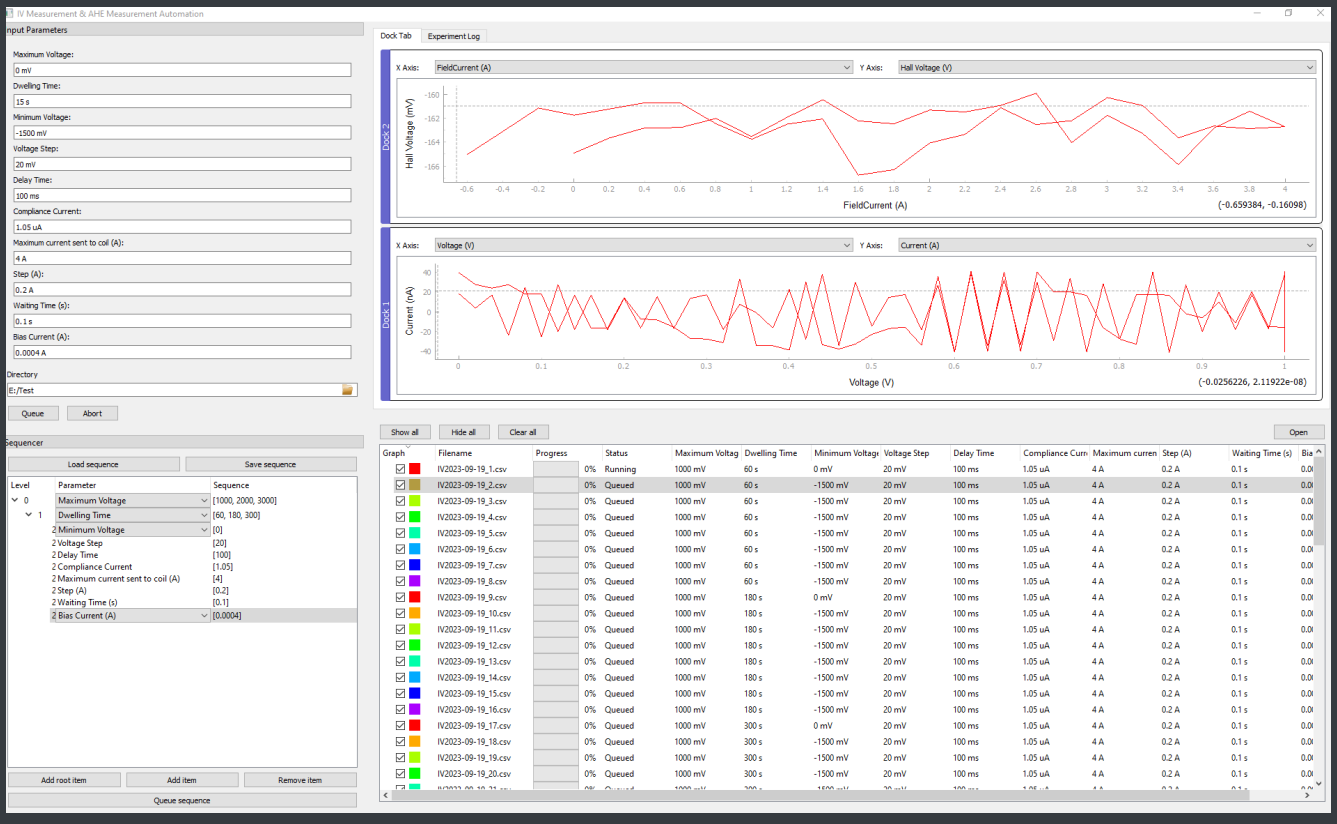
3. Looping the electromagnetic fields and receive the Hall voltages:



4. Applying another E-field and EM looping:



5. Making the sequencer (Automated Measurement):



Dataset Example

Two files will be generated: 1. the file containing all the data sets and one separate file containing the AHE data

	A	B	C	D	E
1	#Procedure: <__main__.IVProcedure>				
2	#Parameters:				
3	# Bias Current (A): 0.0004 A				
4	# Maximum current sent to coil (A): 4 A				
5	# Step (A): 0.2 A				
6	# Waiting Time (s): 0.1 s				
7	# Compliance Current: 1.05 uA				
8	# Delay Time: 100 ms				
9	# Devices: 1 No.				
10	# Maximum Voltage: 0 mV				
11	# Minimum Voltage: -1000 mV				
12	# Dwelling Time: 5 s				
13	# Voltage Step: 20 mV				
14	#Data:				
15	Voltage (V)	Current (A)	Resistance (o	FieldCurrent	Hall Voltage (V)
16	0	-3.99E-08	0	nan	nan
17	-0.02	3.41E-08	-587237.85	nan	nan
18	-0.04	-1.60E-08	2500048.44	nan	nan
19	-0.06	1.67E-08	-3595973.2	nan	nan
20	-0.08	2.68E-08	-2984820.7	nan	nan
21	-0.1	-2.58E-08	3878960.9	nan	nan
22	-0.12	2.75E-08	-4356306.7	nan	nan
23	-0.14	8.95E-09	-15648557	nan	nan
24	-0.16	-3.96E-08	4041897.3	nan	nan
25	-0.18	3.85E-08	-4676591.6	nan	nan
26	-0.2	-2.75E-08	7268522.1	nan	nan
27	-0.22	2.81E-08	-7822241.7	nan	nan
28	-0.24	-2.81E-08	8544507.27	nan	nan
29	-0.26	3.31E-08	-7852610.1	nan	nan
30	-0.28	-3.94E-08	7099494.08	nan	nan
31	-0.3	2.79E-08	-10744516	nan	nan
32	-0.32	-3.85E-08	8312059.66	nan	nan
33	-0.34	4.01E-08	-8488506.6	nan	nan
34	-0.36	-3.97E-08	9078302.63	nan	nan
35	-0.38	2.90E-08	-13122589	nan	nan
36	-0.4	-2.44E-08	16363739.8	nan	nan
37	-0.42	2.08E-08	-20174442	nan	nan

3	nan	nan	nan	0	0.5454546	
4	nan	nan	nan	0.19942	0.5575067	
5	nan	nan	nan	0.39949	0.5565896	
6	nan	nan	nan	0.59956	0.5569956	
7	nan	nan	nan	0.79963	0.5424007	
8	nan	nan	nan	0.9997	0.5587709	
9	nan	nan	nan	1.19912	0.5427202	
0	nan	nan	nan	1.3992	0.5608138	
1	nan	nan	nan	1.59927	0.558616	
2	nan	nan	nan	1.79934	0.5595382	
3	nan	nan	nan	1.99941	0.5612893	
4	nan	nan	nan	2.19948	0.5562355	
5	nan	nan	nan	2.39955	0.5590432	
6	nan	nan	nan	2.59962	0.5572236	
7	nan	nan	nan	2.79905	0.5545201	
8	nan	nan	nan	2.99912	0.5550638	
9	nan	nan	nan	3.19919	0.5549194	
0	nan	nan	nan	3.39926	0.5544061	
1	nan	nan	nan	3.59868	0.5558647	
2	nan	nan	nan	3.7994	0.5560151	
3	nan	nan	nan	3.99948	0.5578393	
4	nan	nan	nan	3.7994	0.5446938	
5	nan	nan	nan	3.59868	0.5395019	
6	nan	nan	nan	3.39926	0.5396025	
7	nan	nan	nan	3.19919	0.5450151	
8	nan	nan	nan	2.99912	0.5393209	
9	nan	nan	nan	2.79905	0.5540192	
0	nan	nan	nan	2.59898	0.5591146	
1	nan	nan	nan	2.39955	0.553203	
2	nan	nan	nan	2.19883	0.5532082	
3	nan	nan	nan	1.99941	0.5571428	

Controllable Instrument List

Controllable instrument is not limited as following, the equipments with VISA, GPIB adpater (most of the NI instruments) can be controlled.

Active Technologies

Active Technologies AWG-401x 1.2GS/s Arbitrary Waveform Generator

Advantest

Advantest R3767CG Vector Network Analyzer

Advantest R6245/R6246 DC Voltage/Current Sources/Monitors

Agilent

Agilent 8257D Signal Generator

Agilent 8722ES Vector Network Analyzer

Agilent E4408B Spectrum Analyzer

Agilent E4980 LCR Meter

Agilent 34410A Multimeter

HP/Agilent/Keysight 34450A Digital Multimeter

Agilent 4155/4156 Semiconductor Parameter Analyzer

Agilent 33220A Arbitrary Waveform Generator

Agilent 33500 Function/Arbitrary Waveform Generator Family

Agilent 33521A Function/Arbitrary Waveform Generator

Agilent B1500 Semiconductor Parameter Analyzer

AJA International

AJA DCXS-750 or 1500 DC magnetron sputtering power supply

Ametek

Ametek 7270 DSP Lockin Amplifier

AMI

AMI 430 Power Supply

Anaheim Automation

DP-Series Step Motor Controller

Anapico

Anapico APSIN12G Signal Generator

Andeen Hagerling

Andeen Hagerling AH2500A capacitance bridge

Andeen Hagerling AH2700A capacitance bridge

Anritsu

Anritsu MG3692C Signal Generator

Anritsu MS9710C Optical Spectrum Analyzer

Anritsu MS9740A Optical Spectrum Analyzer

Anritsu MS2090A Handheld Spectrum Analyzer

Anritsu MS464xB Vector Network Analyzer

Attocube

Attocube ANC300 Motion Controller

BK Precision

BK Precision 9130B DC Power Supply

Danfysik

Danfysik 8500 Power Supply

Delta Elektronika

Delta Elektronica SM7045D Power source

Edwards

Edwards nxds vacuum pump

EURO TEST

Euro Test HPP120256 High Voltage Power Supply

Fluke

Fluke 7341 Temperature bath

F.W. Bell

F.W. Bell 5080 Handheld Gaussmeter

Heidenhain

Heidenhain ND287 Position Display Unit

HC Photonics

HCP TC038 crystal oven

HCP TC038D crystal oven

Hewlett Packard

HP 33120A Arbitrary Waveform Generator

HP 34401A Multimeter

HP 3437A System-Voltmeter

HP 3478A Multimeter

HP 8116A 50 MHz Pulse/Function Generator

HP 8560A / 8561B Spectrum Analyzer

HP Signal generator HP8657B

Support class for HP legacy devices

HP System Power Supplies HP663XA

IPG Photonics

YAR fiber amplifier series

Keithley

Keithley 2000 Multimeter

Keithley 2260B DC Power Supply

Keithley 2306 Dual Channel Battery/Charger Simulator

Keithley 2400 SourceMeter

Keithley 2450 SourceMeter

Keithley 2700 MultiMeter/Switch System

Keithley 6221 AC and DC Current Source

Keithley 6517B Electrometer

Keithley 2750 Multimeter/Switch System

Keithley 2600 SourceMeter

Keithley 2200 Series Power Supplies

Keysight

Keysight DSOX1102G Oscilloscope

Keysight N5767A Power Supply

Keysight N5776C Power Supply

Keysight E36312A Triple Output Power Supply

Lake Shore Cryogenics

Lake Shore 211 Temperature Monitor

Lake Shore 224 Temperature Monitor

Lake Shore 331 Temperature Controller

Lake Shore 421 Gaussmeter

Lake Shore 425 Gaussmeter

LakeShore Channel Classes

LeCroy

LeCroy T3DSO1204 Oscilloscope

MKS Instruments

MKS Instruments 937B Vacuum Gauge Controller

Newport

ESP 300 Motion Controller

National Instruments

NI Virtual Bench

Novanta Photonics

Novanta FPU60 laser power supply unit

Oxford Instruments

Oxford Instruments Base Instrument

Oxford Instruments Intelligent Temperature Controller 503

Oxford Instruments Intelligent Power Supply 120-10 for superconducting magnets

Oxford Instruments Power Supply 120-10 for superconducting magnets

Parker

Parker GV6 Servo Motor Controller

Pendulum

Pendulum CNT91 frequency counter

Razorbill

Razorbill RP100 custrom power supply for Razorbill Instrums stress & strain cells

Rohde & Schwarz

R&S SFM TV test transmitter

R&S FSL spectrum analyzer

R&S HMP4040 Power Supply

Siglent Technologies

Siglent Technologies Base Class

Siglent SPD1168X Power Supply

Siglent SPD1305X Power Supply

Signal Recovery

DSP 7225 Lock-in Amplifier

DSP 7265 Lock-in Amplifier

Stanford Research Systems

SR510 Lock-in Amplifier

SR570 Lock-in Amplifier

SR830 Lock-in Amplifier

SR860 Lock-in Amplifier

T&C Power Conversion

T&C Power Conversion AG Series Plasma Generator CXN

TDK Lambda

TDK Lambda Genesys 40-38 DC power supply

TDK Lambda Genesys 80-65 DC power supply

Tektronix

TDS2000 Oscilloscope

AFG3152C Arbitrary function generator

Teledyne

Teledyne T3AFG Arbitrary Waveform Generator

Teledyne Oscilloscope base classes

Temptronic

Temptronic Base Class

Temptronic ATS525 Thermostream

Temptronic ATS545 Thermostream

Temptronic ECO560 Thermostream

TEXIO

TEXIO PSW-360L30 Power Supply

Thermotron

Thermotron 3800 Oven

Thorlabs

Thorlabs PM100USB Powermeter

Thorlabs Pro 8000 modular laser driver

Thyracont

Smartline V1 Transmitter Series

Smartline V2 Transmitter Series

Toptica

Toptica IBeam Smart Laser diode

Velleman

Velleman K8090 8-channel relay board

Yokogawa

Yokogawa 7651 Programmable Supply

Yokogawa GS200 Source