# Contents

# 1. Introduction

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# 2. Getting Started

## 2.1. Hardware Description

The ArC ONE system consists of a hardware instrumentation board (ArC ONE) and a dedicated software GUI (ArC ONE Control). The hardware is illustrated in Figure X.

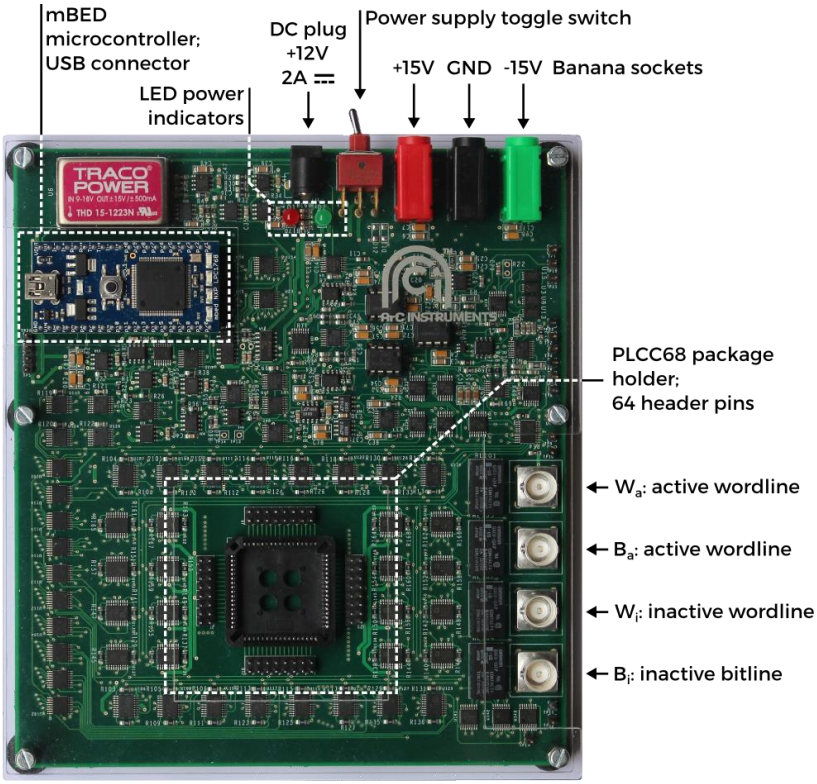


Figure X: ArC ONE hardware instrumentation board

To power up the board, either plug in the provided AC power adaptor in the DC plug, or connect a desktop power supply to the banana sockets. Toggle the power supply switch towards the required power supply input. The red and green LEDs should turn on, indicating the board is powered. For best results, utilise a battery supply.

The PLCC68 socket holds packaged samples. Its pin map is illustrated below.

In the case where devices need to be accessed away from the board, (eg via a probe card to solid-state devices on wafer), the surrounding headers provide access to individual word- and bitline addresses.

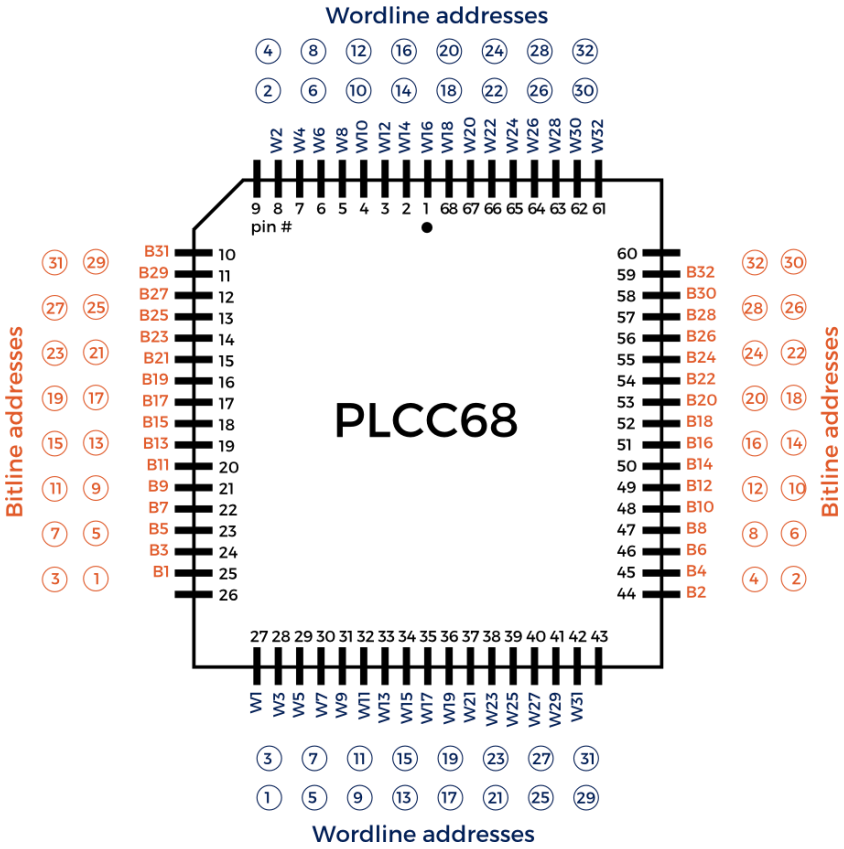


Figure X: PLCC68 and surrounding headers pin map

## 2.2. Software Installation

To install the ArC ONE Control GUI, follow the steps below: (for Windows 7 and 8)

1. Install mBED drivers:

   Go to: developer.mbed.org/handbook/Windows-serial-configuration
   Follow steps 1 and 2 to install the drivers.

2. Install Python 2.7.11

   Find out first your operating system type:
   Go to: Control Panel > Systems and Security > System and make a note: 32 or 64 bit.

   Go to: www.python.org/downloads/release/python-2711/ and download the Windows x86 MSI installer based on your operating system type.

   Run the python installer.

3. Setup ArC ONE Control GUI

   Unzip the GUI folder which you received via email from office@arc-instruments.co.uk to a folder of your choice.

   Go to: <your chosen folder>\ArC ONE Control v1.0\wheels\

   Double-click addModules.bat; This installs extra python libraries utilised by the GUI.

4. You're good to go!

   Go to: <your chosen folder>\ArC ONE Control v1.0\ and double click main.py to run the GUI.

If you encounter any problems in steps 2 or 3, please consult:
http://stackoverflow.com/questions/6318156/adding-python-path-on-windows-7
or contact us at office@arc-instruments.co.uk

# 3. Using the ArC ONE Control GUI

The ArC ONE Control GUI is distributed under the General Public License (GNU) Version 3. It is therefore an open-source copy, allowing any user to modify and re-utilise its contents. Keep a copy of the initial source file to ensure the operation of the ArC platform.

We are not responsible for any damage to the platform, or computer system utilised by this code. For more information, please consult:

https://www.gnu.org/licenses/gpl-3.0.en.html

## 3.1. At a Glance

The ArC GUI allows easy control of the ArC ONE platform. It is divided into a number of functional panels:

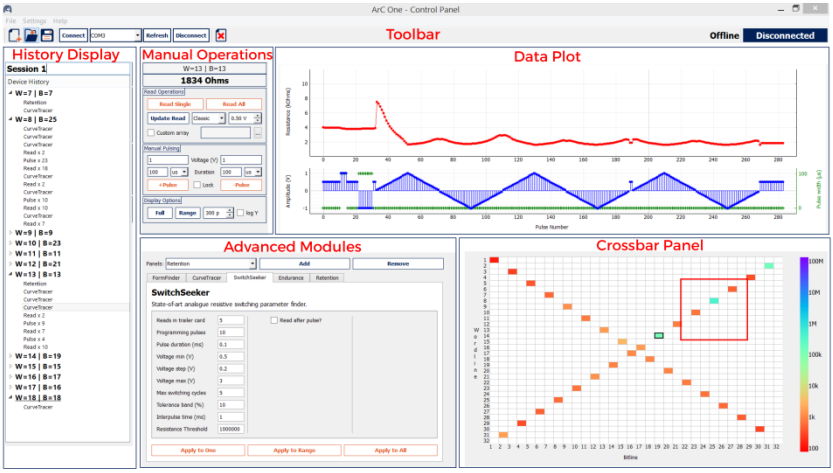


Figure X: At a glance – functional panels of the ArC ONE GUI

Toolbar: contains buttons for saving data, creating a new session, ArC ONE connection management as well as a GUI session mode indicator, and an ArC ONE connection indicator, on the right hand side.

Manual Operations panel: Contains buttons for reading a single selected cell or the full crossbar. the 'SA' checkbox restricts the crossbar active devices to any combination of devices in a 32x32 crossbar (explained later). The read type can be changed via the drop down menu. The reading voltage can also be set via the input text field. Clicking 'Update' updates the reading method on the ArC ONE board. Manual pulsing of 0 to ±12V and down to 90ns can be applied on the selected device by pressing +Pulse (positive pulse) or -Pulse (negative pulse). Separate input fields allow for independent setting of positive and negative pulsing polarities.

Crossbar Panel: Direct selection of individual devices is performed by left clicking the required position. The selected crosspoint is highlighted by a thick black outline and represents the current device under test (DUT) for any further operation. The resistive state of each device is represented by the colour of the cell, and the colour coding is illustrated at the right of the crossbar. Hovering over a cross-point reveals the absolute resistance value of the last read operation. Additionally, left clicking and dragging allows selection of a square region of devices in a crossbar if local testing is required.

Data Plot panel: Top plot shows the resistive state evolution of a device. Bottom plot shows the pulse amplitude and pulse duration per pulse number in chronological order. During the application of an automated pulsing script, the plot is updated live with incoming measurement data.

Device History panel: Contains the pulsing history for each device in the crossbar, if any is available. History entries can be accessed to display additional measurement results/analyses.

Pulsing Modules panel: The drop-down menu contains a number of custom pulsing scripts, and selecting one displays its corresponding options which the user can then set. Panels include custom device operation scripts such as FormFinder, SwitchSeeker, standard IV measurement protocols such as CurveTracer, and memristor specific characterisation pulsing scripts such as Endurance and Retention. The pulsing scripts are described in detail in Section

## 3.2. Starting a New Session

On starting the GUI, the window on the right below will appear which allows setting up a new measurement session. There are 2 main setting categories:

General Settings:

The Session Mode dropdown selects the operating mode of the system and four options:

1. Live: Local - normal operation mode, all outputs are applied to the on-board package holder, and to the surrounding headers.
2. Live: External BNC – all outputs are applied on the on-board BNC sockets.
3. Live: BNC to Local – the ArC platform only performs routing, and the selected device is connected to the on-board BNC sockets.
4. Offline – mode used to visualize previously acquired measurements through the ArC system.

Working Directory entry allows the user to choose the directory in which measurement sessions will be saved. Press the browse button on the right of the entry to navigate. This can be setup later as well.

Session Name entry sets the name of the session.

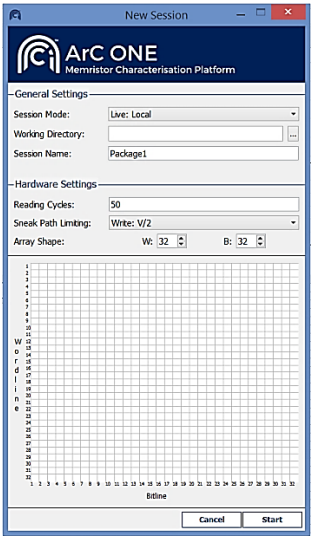


Figure X: new Session panel

Hardware Settings:

Reading Cycles entry sets the averaging reading cycles performed by the board during a READ operation. A higher number translates into a slower, but more accurate measurement. A number of 50 is a reasonable choice.

Sneak Path Limiting sets up the sneak path mitigation technique employed in selectorless crossbar arrays. The user can chose between V/2, V/3 and None.

Array Shape counters set up the size of the array. Any size is selectable between 1 and 32 word- and bitlines.

Press Start to start a new session with the new settings, Cancel to abort.

## 3.3. Connecting to ArC ONE

After the new session has been set up, the right hand side of the toolbar should indicate the session mode, and the connection status showing Disconnected as below.


Make sure ArC ONE is connected to the PC via an USB cable, and the board is power up. A blue LED on the on-board mBED indicates the board is connected to the PC, and red and green LEDs indicate the board is powered up.


From the toolbar (above), select the corresponding COM port of the ArC ONE board. If you don't know it, you can find it in Windows by going to:

- Right click **My Computer;**
- Select **Manage;**
- On the left hand side, select **Device Manager;**
- Search for **Ports (COM and LTP)** and expand;
- Look for a device named: **mbed Serial Port (COMX),** and make a note of the COM port number.

Return to the GUI and select the respective COM port from the dropdown list, and click Connect.
If the port is not there, click Refresh and wait for up to 10 seconds. The port should now appear.

Once the connection is successful, the connection status will turn green like below:


If any connection problems occur, please refer to Section 4 of this manual.

## 3.4. Basic Operations

Many basic operations such as reading and writing, as well as data display and device history visualisation are available at a click of a button. As a general rule of thumb, the buttons coloured in orange perform invasive operations on the selected device, or range of devices. Buttons coloured in dark blue perform non-invasive operations, such as updating ArC ONE settings or managing data display options.

### Device Selection

Left click the required device on the Crossbar Panel to select it. The device will be highlighted by a black outline. Any following invasive operation will be performed on that device.

Hovering the mouse over a crossbar device shows address and resistance information in the small floating information panel.

The address of the currently selected device appears on top of the Manual Operations panel, along with its corresponding last measured value of resistance.

Left click and drag in order to select a range of devices. A box with a thick red outline will indicate the selected sub-array. Right click anywhere on the Crossbar Panel to toggle the visibility of the box.

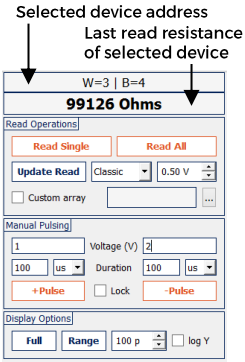


Figure Y: Manual Operations Panel

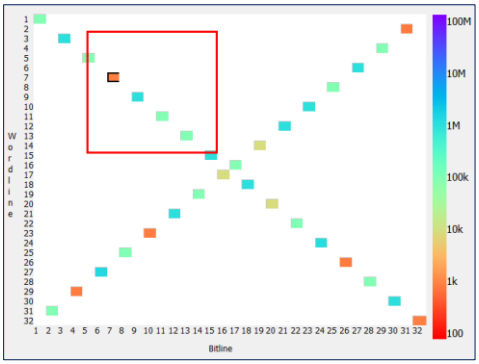


Figure X: Crossbar Panel showing current crossbar device status

## Custom Arrays

If only a particular set of crosspoints is required for a measurement session, these can be selected on the interface via checking the Custom Array checkbox. A file open dialogue will appear which allows the user to select a text file containing the required addresses, formatted in the following way:

```
1, 1
2, 31
3, 3
4, 29
5, 5
6, 27
7, 7
8, 25
9, 9
10, 23
11, 11
12, 21
```

Figure Y: Custom array file format example

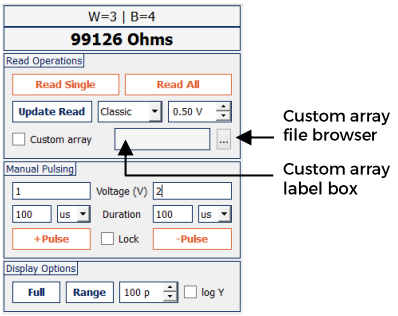


Figure X: Manual operations panel – custom array controls

The same open file dialogue will appear if the browse array file button is pressed.
The set of device addresses are then highlighted in the Crossbar Panel, while the others are hidden. Any device select, or device operation will be constrained to this set.
When selecting a range of devices by left clicking and dragging, only the ones contained in the red box will be accessible.

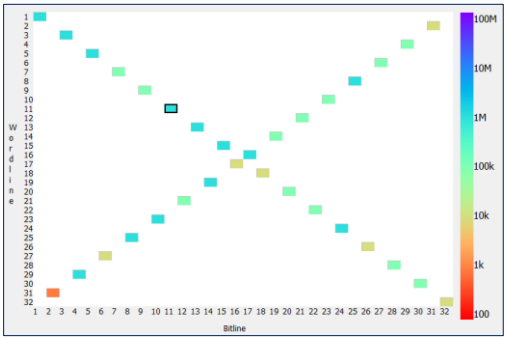


Figure X: Example of a custom array.

## Read Operation

In the Read Operations sub-panel, click Read Single to perform one READ operation on the selected device (highlighted in the Crossbar Panel, and listed on top of the Manual Operations panel). The new value of resistance is updated there.
The Data Plot panel will be updated with the new measurement.

Click Read All to read all devices in the crossbar.

Update Read updates the reading method on the ArC board. Select the reading method between:
1. Classic: reads at 0.5V, suitable for linear resistors, fast;
2. TIA: reads at a programmable voltage;
3. TIA4P: RECOMMENDED - Kelvin sensing at a programmable voltage;

Select the reading voltage by left-clicking the up and down arrows in the reading voltage counter, or introducing a float by hand.
Remember to click Update Read every time the reading method, or reading voltage is changed.

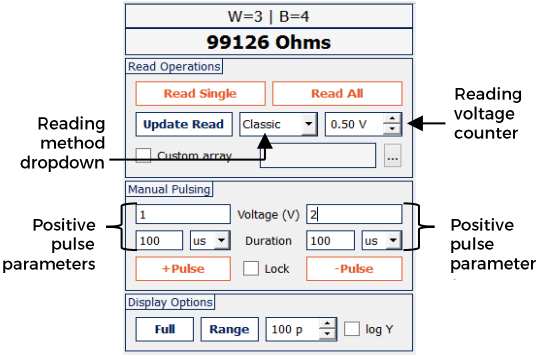


Figure Y: Manual Operations Panel

## Manual Write Pulsing

In the Manual Pulsing sub-panel, single WRITE pulses can be applied on a selected device.

Click the +Pulse to immediately apply a positive voltage pulse, and -Pulse to apply a negative pulse. The parameters of the pulse, such as amplitude and duration, can be changed via the entry fields above the corresponding buttons.

A READ operation is automatically performed after each manual pulse. The new measurement is added in the Data Plot panel, along with the applied manual pulse.

Checking the Lock checkbox disables the negative pulse parameter entry fields. Clicking -Pulse will then apply a negative pulse with the parameters of the positive pulse entry fields.
For example: positive pulse parameters are 1V 100ms, negative pulse parameters are 2V 1ms. Clicking +Pulse will apply 1V 100ms, -Pulse will apply 2V 1ms. After checking the Lock checkbox, clicking +Pulse will apply 1V 100ms, and -Pulse will apply -1V 100ms.

## Display Options

In the Display Options sub-panel, the user can modify the plot options in the Data Plot panel.

Press Full to display all data points for the selected device.
Press Range to display the last X number of points, where X is set in the adjacent counter.
Tick the log Y checkbox to set logarithmic Y axis in the top subplot of the Data Plot panel.

## History Display

All invasive device operations are logged in the Device History panel.
Device addresses are added from top to bottom in a chronological order following any operation.
The last device address where an operation was performed is underlined.
Selecting a device address from the Device History panel will also select and display its pulsing history in the Data Plot panel.

Single device operations are listed below its corresponding address from top to bottom in a chronological order.
These become visible by clicking the dropdown marker.

READ operations are tagged with Read x N, where N is the number of read pulses applied in sequence.
WRITE operations are tagged with Pulse x N, where N is the number of manual WRITE pulses applied in sequence.

Advanced pulsing algorithms are tagged with their corresponding name.
Double clicking some advanced pulsing algorithm entries displays further measurement results.
For example, following a CurveTracer measurement, double clicking the corresponding history entry will display the resulting IV curve. See Section 3.5 for more information.

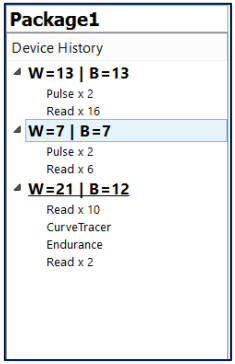

Figure X: Device History panel example

## 3.5. Advanced Pulsing Modules

Several advanced pulsing scripts are available in the Pulsing Modules panel. These are:

FormFinder: applies a pulsed voltage ramp; stops when the resistance has overshot an absolute, or proportional programmable value. Normally used for electroforming.

CurveTracer: standard, low frequency pulsed IV measurement module.

Endurance: Cycle switch a device between ON and OFF values, for any number of cycles.

Retention: Measure the resistive state of a device periodically for a fixed overall duration.

SwitchSeeker: Assuming a bipolar device, apply voltage pulses of increasing width and amplitude of both polarities in order to extract the pulse parameters which elicits repeatable analogue RS.

All pulsing scripts are available in the Panels dropdown list. Select the desired one and press Add to load it in the panel. To remove a module, select the corresponding tab and press Remove.

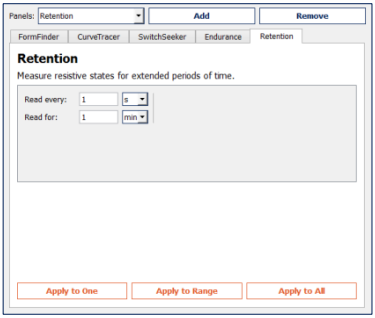


Figure X: Pulsing panel example

Apply to One, Apply to Range and Apply to All buttons are standard to all advanced pulsing algorithms.

Apply to One: applies the algorithm to the currently selected device only.
Apply to Range: applies the algorithm to the currently selected range of devices.
Apply to All: applies the algorithm to all available devices in the array.

## FormFinder

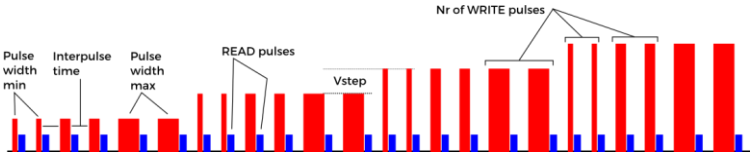


Figure X: Illustration of FormFinder pulsing algorithm

FormFinder is a versatile pulsing algorithm which applies a pulsed voltage ramp with an option of two stop conditions. After each WRITE pulse, a READ pulse is applied by default.

The algorithm has several programmable parameters:

Voltage min (V): sets the start voltage of the ramp.

Voltage step (V): sets the step voltage of the ramp.

Voltage max (V): sets the maximum voltage that the ramp can achieve; also acts as a stop condition.

Pulse width min (us): sets the start value of pulse width.

Pulse width step (%): sets the proportional pulse width step value.

Pulse width max (us): sets the maximum pulse width achievable during a pulse batch.

Interpulse time (ms): sets the interpulse timing between two adjacent WRITE pulses.

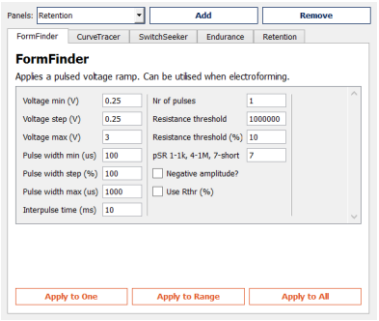


Figure X: FormFinder options panel

Nr of pulses: sets the number of identical pulses to be applied in sequence during one pulse batch.

Resistance threshold: halts the ramp when the resistance of the device has undershot this value. This stop condition is implemented by default.

Resistance threshold (%): halts the ramp when the resistance has changed by this % value compared to an initial read value.

pSR 1-1k, 4-1M, 7-short: sets a series limiting resistor: 1 - 1kΩ; 2 - 10kΩ; 3 – 100kΩ; 4 – 1MΩ; 7 – no series resistor (short circuit).

Negative amplitude checkbox: applies the full ramp with negative amplitude pulses.

Use Rthr (%): utilises the proportional (%) stop condition setup in Resistance threshold (%) entry.

A standard pulsed voltage ramp, with one pulse per step can be achieved by setting Nr of pulses to 1, and making Pulse width min (us) and Pulse width max (us) equal to the desired pulse width value.

## CurveTracer

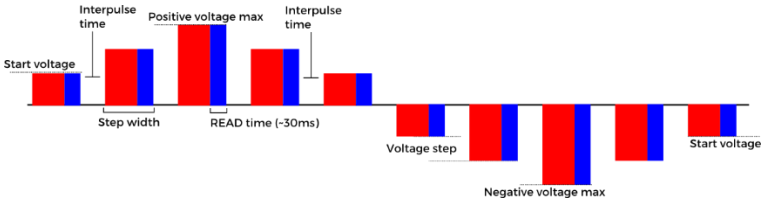


Figure X: Illustration of FormFinder pulsing algorithm

CurveTracer is a standard triangular pulsed IV measurement module. During each WRITE pulse, a current measurement is taken towards the end of the pulse.

Positive voltage max (V): sets the maximum voltage during the positive sweep.

Negative voltage max (V): sets the maximum voltage during the negative sweep.

Voltage step (V): sets the step voltage, for both positive and negative sweeps.

Start voltage (V): sets the start voltage value (limited to 50mV).

Step width (ms): sets the width of the pulses, minimum of 30 ms.

Cycles: sets the number of consecutive IV measurements to be taken.

Interpulse time (ms): sets the interpulse timing between two adjacent pulses.

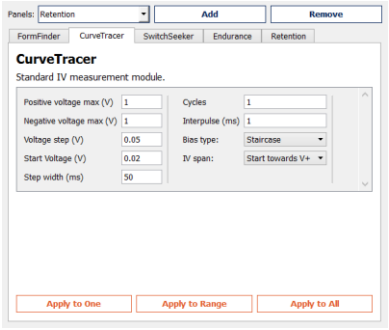


Figure X: FormFinder options panel

Bias Type: dropdown menu contains two options: Staircase – where Interpulse time is 0; Pulse – where the device is grounded in between measurement pulses for the interpulse duration.

IV span: dropdown containing self-explanatory options: select if the first sweep is towards positive or negative voltage, or if the IV measurement should be taken only for the positive or negative sweep.

A CurveTracer entry will appear in the Device History panel. Double click it to visualize the IV measurement.

Right click on the plots and select Export to save the figure, or corresponding data.

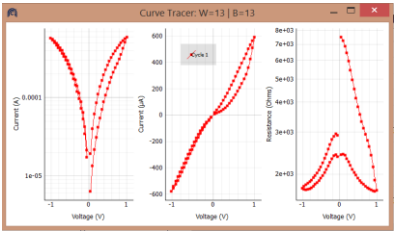


Figure X: CurveTracer result example

## SwitchSeeker

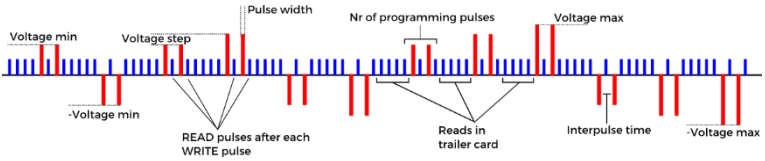


Figure X: Illustration of FormFinder pulsing algorithm

SwitchSeeker is a state-of-art analogue resistive switching parameter finder. It automatically extracts the pulse parameters which elicit repeatable analogue resistive switching. It achieves this by applying increasingly invasive alternative polarity pulsed voltage ramps, until the resistance of the device exits a programmable tolerance band. An illustration of the pulsing run is shown in Figure X.

Reads in trailer card: sets the number of reading pulses before each pulse batch.

Programming pulses: sets the number of identical pulses in a pulse batch.

Pulse duration: sets the constant pulse width;

Voltage min (V): sets the start voltage of each ramp;

Voltage step (V): sets the voltage step per consecutive batches in the same ramp.

Voltage max (V): sets the voltage step per consecutive batches in the same ramp.

Max switching cycles: sets the number of consecutive cycles the device is switched after the analogue resistive switching parameters have been found.

Tolerance band: sets the tolerance band, as % of the resistance value read before one ramp is applied.

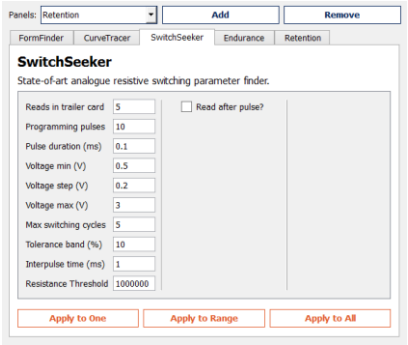


Figure X: FormFinder options panel

Interpulse time (ms): sets the interpulse timing.

Read after pulse?: checkbox activates reading after each voltage pulse is applied.

A SwitchSeeker entry will appear in the Device History panel. Double click it to visualize the analogue resistive switching results. An example of a SwitchSeeker run is illustrated in Figure X.

Right click on the plots and select Export to save the figure, or corresponding data.

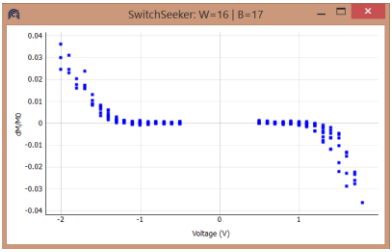


Figure X: SwitchSeeker resistive switching results

## Retention

Measure resistive state retention times with this module.

It repeatedly reads the resistive state of a selected, range or full array of devices a specific interval and for a set duration of time.

It utilises the reading method and reading voltage setup in the Manual Operations panel.

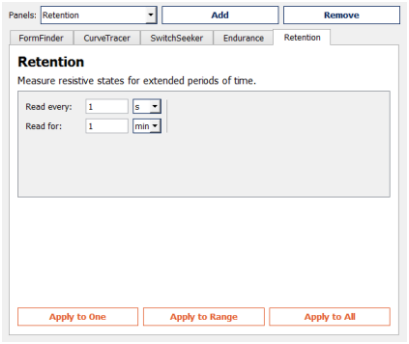


Figure X: FormFinder options panel

## Endurance

Measure resistive state switch endurance with this module.

It applies alternating polarity voltage pulses to toggle the state of single, range or full array of devices between some ON and OFF values.

A read pulse is applied after each programming pulse.

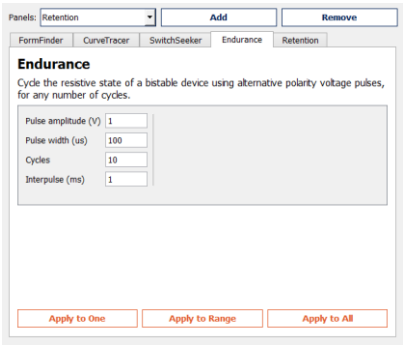


Figure X: Endurance pulsing module