**IV Sweep GUI Documentation**

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A screenshot of a computer

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1. **Installation and Important Notes**

The current distribution of this program was designed to work on a Windows 7 platform, mainly on the PC connected to the Keithley 2400 Sourcemeter Unit (SMU) in JHE 322. It will still work on newer versions of Windows, however, will not run on Mac OS or Linux. Support for Mac OS can be created in the future.

Simply download the **IV Sweep GUI.exe**into the desired location and click to run (it may take a few moments to boot up). It is executable on a USB or external hard drive. Ensure the laptop/PC being used is connected to the SMU. All input definitions are explained in the next section.

1 For the GUI to connect and send data to the SMU, the correct port ID must be stated in the *Resource Name* input field, as will be described below. If the SMU is connected to a different PC or via a different cable connection, this name must be correctly changed to the corresponding port. That requires running a separate python code to identify the ports and installation of the PyMeasure scientific package, explained in Appendix B. A function to detect and display connections within the GUI will be added in future versions, if this becomes necessary.

1. **Inputs**
2. **Resource Name:**

*Text Field*

The default is set to “GPIB::1”, configured for use with the current PC and connection in JHE 322. Only change if the SMU is connected via a different port1.

**2.1 Instrument Configuration**

1. **Front Panel/Rear Panel:**

*Select Field: Front Panel/Rear Panel*

Select where the wires/probes are connected on the SMU (front panel or rear panel).

1. **2-Wire Mode/4-Wire Mode:**

*Select Field: 2-Wire Mode/4-Wire Mode*

Select how many wire/probes are connected to the SMU and being used for the measurement.

**2.2 Setup Parameters**

1. **Source Type:**

*Drop Down Menu: VOLT/CURR*

Select the desired property (voltage or current) to be produced by the sourcemeter.

1. **Measure Type:**

*Drop Down Menu: VOLT/CURR*

Select the desired property (voltage or current) to be measured by the sourcemeter.

1. **Start Level:**

*Number (Floating Point):*

Input the desired voltage [V] or current [A] sweep start value.

1. **Stop Level:**

*Number (Floating Point):*

Input the desired voltage [V] or current [A] sweep stop value.

1. **Step Level**

*Number Field (Integer):*

Input the desired number of measurements to be taken.

1. **Compliance:**

*Number (Floating Point):*

Input the desired voltage [V] or current [A] compliance value.

The compliance value sets the current limit when sourcing voltage and sets the voltage limit when sourcing current. The sourcemeter output will not exceed this compliance value.

1. **NPLC (Number of power line cycles):**

*Number (Floating Point):*

Input the desired NPLC value.

NPLC controls the integration time for measurements, which affects the measurement speed and noise reduction. A higher NPLC value results in more accurate measurements but a longer measurement time. Around 1 is typically sufficient for IV measurements. Some recommended values are given below:

SLOW ~ 10

MEDIUM ~ 1

FAST ~ 0.1

1. **Source Delay:**

*Number (Floating Point):*

Input the desired source delay value.

The source delay is the time between sourcing and measuring. It allows the circuit to settle before performing another measurement. Around 0 is typically fine for IV measurements, however it can be changed accordingly.

1. **Measuring and Visualizing Data**

After inputting the port ID into the *Resource Name* field, click on “Connect” to connect to the SMU. There will be a pop-up stating whether the connection was successful. If no SMU was detected, double check the port ID or any loose connections.

Select the correct instrument configuration options and input all required values. Click on “Perform IV Sweep” to begin the measurement. After the measurements are taken, the plot on the right will automatically update with the data points.

The x-axis on the plot is automatically set to be the property selected as the *Source Type* and the y-axis to be the *Measure Type* property. Two toggle fields, *Log Scale X* and *Log Scale Y* can be selected to log that respective axis data.

1. **Saving and Importing Data**

Data is currently only saved as a .txt. Click on the button “Save Data” after the measurement is completed and save the file to the desired location. The resulting file has two columns, the first representing the x-axis data (Source Type) and the second representing the y-axis data (Measure Type).

Lastly, .txt or .csv files can be imported to display on the plot. First, change the *Source Type* and *Measure Type* input fields to correspond to the x- and y- axis properties first, and then click on “Import I-V Data”. Select the desired file and the output should display on the plot.

**Appendix A: IV Sweep GUI Python code**

# BACKEND

import pyvisa

class Keithley2400Controller:

def \_\_init\_\_(self, resource\_name='GPIB::1', timeout=25000):

self.resource\_name = resource\_name

self.instrument = None

self.timeout = timeout

self.current\_compliance = 0.01 # 10 mA default

# Connect to Keithley 2400

def connect(self):

rm = pyvisa.ResourceManager()

self.instrument = rm.open\_resource(self.resource\_name)

self.instrument.timeout = self.timeout # Set timeout

self.instrument.write("\*RST") # Reset the instrument

self.instrument.write("\*CLS") # Clear the status

def identify(self):

return self.instrument.query("\*IDN?")

def select\_panel(self, panel='FRONT'):

if panel.upper() == 'FRONT':

self.instrument.write(":ROUT:TERM FRON")

elif panel.upper() == 'REAR':

self.instrument.write(":ROUT:TERM REAR")

else:

raise ValueError("Invalid panel option. Choose 'FRONT' or 'REAR'.")

def set\_measurement\_mode(self, mode):

if mode == 2:

self.instrument.write(":SYST:RSEN OFF") # 2-wire mode

elif mode == 4:

self.instrument.write(":SYST:RSEN ON") # 4-wire mode

else:

raise ValueError("Invalid measurement mode. Choose 2 or 4.")

def iv\_sweep(self, source\_type, measure\_type, start\_level, stop\_level, step\_level,

measure\_compliance, nplc=1, source\_delay=0.1, ovp=20):

# Disable concurrent functions

self.instrument.write(":SENS:FUNC:CONC OFF")

# Calculate number of points for the sweep

num\_points = int(abs((stop\_level - start\_level)) / abs(step\_level)) + 1

# Set Over Voltage Protection (always present)

self.instrument.write(f":SOUR:VOLT:PROT {ovp}")

# Set source function and enable auto-range

self.instrument.write(f":SOUR:FUNC {source\_type.upper()}")

if source\_type.upper() == 'CURR':

self.instrument.write(":SOUR:CURR:RANG:AUTO ON")

else: # 'VOLT'

self.instrument.write(":SOUR:VOLT:RANG:AUTO ON")

# Set sense function, enable auto-range, and set compliance

self.instrument.write(f":SENS:FUNC '{measure\_type.upper()}:DC'")

if measure\_type.upper() == 'CURR':

self.instrument.write(f":SENS:CURR:PROT {measure\_compliance}")

self.instrument.write(":SENS:CURR:RANG:AUTO ON")

else: # 'VOLT'

self.instrument.write(f":SENS:VOLT:PROT {measure\_compliance}")

self.instrument.write(":SENS:VOLT:RANG:AUTO ON")

# Configure source for sweep

self.instrument.write(f":SOUR:{source\_type.upper()}:START {start\_level}")

self.instrument.write(f":SOUR:{source\_type.upper()}:STOP {stop\_level}")

self.instrument.write(f":SOUR:{source\_type.upper()}:STEP {step\_level}")

self.instrument.write(f":SOUR:{source\_type.upper()}:MODE SWE")

self.instrument.write(":SOUR:SWE:RANG AUTO")

self.instrument.write(":SOUR:SWE:SPAC LIN")

# Set NPLC, trigger count and source delay

self.set\_nplc(nplc, measure\_type)

self.instrument.write(f":TRIG:COUN {num\_points}")

self.instrument.write(f":SOUR:DEL {source\_delay}")

# Enable output and initiate measurement

self.instrument.write(":OUTP ON")

raw\_data = self.instrument.query\_ascii\_values(":READ?")

# Disable output after measurement

self.instrument.write(":OUTP OFF")

voltage = [raw\_data[i] for i in range(0, len(raw\_data), 5)]

current = [raw\_data[i + 1] for i in range(0, len(raw\_data), 5)]

return voltage, current

def set\_source\_current\_range(self, range\_value):

self.instrument.write(f":SOUR:CURR:RANG {range\_value}")

def set\_source\_voltage\_range(self, range\_value):

self.instrument.write(f":SOUR:VOLT:RANG {range\_value}")

def set\_measure\_current\_range(self, range\_value):

self.instrument.write(f":SENS:CURR:RANG {range\_value}")

def set\_measure\_voltage\_range(self, range\_value):

self.instrument.write(f":SENS:VOLT:RANG {range\_value}")

def set\_current\_compliance(self, compliance):

self.current\_compliance = compliance

self.instrument.write(f":SENS:CURR:PROT {compliance}")

def set\_nplc(self, nplc, measurement\_type='CURR'):

if measurement\_type.upper() == 'CURR':

self.instrument.write(f":SENS:CURR:NPLC {nplc}")

elif measurement\_type.upper() == 'VOLT':

self.instrument.write(f":SENS:VOLT:NPLC {nplc}")

else:

raise ValueError("Invalid measurement type. Choose 'CURR' or 'VOLT'.")

# GUI

import tkinter as tk

from tkinter import ttk, messagebox, filedialog

import threading

import matplotlib.pyplot as plt

from matplotlib.backends.backend\_tkagg import FigureCanvasTkAgg

from matplotlib.figure import Figure

import numpy as np

import csv

class KeithleyGUI:

def \_\_init\_\_(self, master):

self.master = master

master.title('Keithley 2400 Controller')

self.is\_connected = False # Track connection status

self.data\_collected = False # Track if data has been collected

# Initialize the instrument controller

self.instrument = None # Initialize without creating an object yet

# Resource name field

self.frame\_resource = ttk.Frame(master)

self.frame\_resource.grid(row=0, column=0, padx=10, pady=5, sticky='ew')

ttk.Label(self.frame\_resource, text="Resource Name:").pack(side=tk.LEFT)

self.resource\_name\_entry = ttk.Entry(self.frame\_resource, width=30)

self.resource\_name\_entry.pack(side=tk.LEFT, fill=tk.X, expand=True)

self.resource\_name\_entry.insert(0, 'GPIB::1')

# Connection Frame

self.frame\_connection = ttk.Frame(master)

self.frame\_connection.grid(row=1, column=0, padx=10, pady=5, sticky='ew')

self.connect\_button = ttk.Button(self.frame\_connection, text="Connect", command=self.connect\_instrument)

self.connect\_button.pack(fill=tk.X)

# Configuration Frame (Panel and Measurement Mode)

self.frame\_config = ttk.LabelFrame(master, text="Instrument Configuration", padding=(10, 10))

self.frame\_config.grid(row=2, column=0, padx=10, pady=5, sticky='ew')

self.panel\_var = tk.BooleanVar(value=True)

self.front\_panel\_radio = ttk.Radiobutton(self.frame\_config, text='Front Panel', variable=self.panel\_var, value=True, state='disabled', command=self.change\_panel)

self.front\_panel\_radio.grid(row=0, column=0, padx=5, pady=5)

self.rear\_panel\_radio = ttk.Radiobutton(self.frame\_config, text='Rear Panel', variable=self.panel\_var, value=False, state='disabled', command=self.change\_panel)

self.rear\_panel\_radio.grid(row=0, column=1, padx=5, pady=5)

self.mode\_var = tk.BooleanVar(value=False)

self.two\_wire\_radio = ttk.Radiobutton(self.frame\_config, text='2-wire Mode', variable=self.mode\_var, value=False, state='disabled', command=self.change\_mode)

self.two\_wire\_radio.grid(row=1, column=0, padx=5, pady=5)

self.four\_wire\_radio = ttk.Radiobutton(self.frame\_config, text='4-wire Mode', variable=self.mode\_var, value=True, state='disabled', command=self.change\_mode)

self.four\_wire\_radio.grid(row=1, column=1, padx=5, pady=5)

# Setup Frame

self.frame\_setup = ttk.LabelFrame(master, text="Setup Parameters", padding=(10, 10))

self.frame\_setup.grid(row=3, column=0, padx=10, pady=5, sticky='ew')

# Setup fields

self.setup\_fields = {

'Source Type': ttk.Combobox(self.frame\_setup, values=['VOLT', 'CURR'], state="readonly"),

'Measure Type': ttk.Combobox(self.frame\_setup, values=['VOLT', 'CURR'], state="readonly"),

'Start Level': ttk.Entry(self.frame\_setup),

'Stop Level': ttk.Entry(self.frame\_setup),

'Step Level': ttk.Entry(self.frame\_setup),

'Compliance': ttk.Entry(self.frame\_setup),

'NPLC': ttk.Entry(self.frame\_setup),

'Source Delay': ttk.Entry(self.frame\_setup),

}

for i, (label, widget) in enumerate(self.setup\_fields.items()):

ttk.Label(self.frame\_setup, text=label).grid(row=i, column=0, padx=5, pady=5)

widget.grid(row=i, column=1, padx=5, pady=5)

# Plot Area

self.figure = Figure(figsize=(8, 6), dpi=100)

self.plot = self.figure.add\_subplot(111)

self.canvas = FigureCanvasTkAgg(self.figure, master)

self.canvas.get\_tk\_widget().grid(row=0, column=1, rowspan=5, padx=10, pady=5)

# Log Scale Toggles

self.log\_scale\_x = tk.BooleanVar()

self.log\_scale\_y = tk.BooleanVar()

self.log\_frame = ttk.Frame(master)

self.log\_frame.grid(row=5, column=1, sticky='ew')

ttk.Checkbutton(self.log\_frame, text='Log Scale X', variable=self.log\_scale\_x, command=self.update\_plot).pack(side=tk.LEFT)

ttk.Checkbutton(self.log\_frame, text='Log Scale Y', variable=self.log\_scale\_y, command=self.update\_plot).pack(side=tk.LEFT)

# IV Sweep Button

self.sweep\_button = ttk.Button(master, text="Perform IV Sweep", command=self.perform\_iv\_sweep)

self.sweep\_button.grid(row=6, column=0, padx=10, pady=5, sticky='ew')

# Save Data Button

self.save\_button = ttk.Button(master, text="Save Data", command=self.save\_data)

self.save\_button.grid(row=6, column=1, padx=10, pady=5, sticky='ew')

# Import Data Button (New functionality)

self.import\_button = ttk.Button(master, text="Import I-V Data", command=self.import\_data)

self.import\_button.grid(row=7, column=1, padx=10, pady=5, sticky='ew')

self.update\_button\_states()

def update\_button\_states(self):

if self.is\_connected:

self.connect\_button.config(state='disabled')

self.sweep\_button.config(state='normal')

self.save\_button.config(state='normal' if self.data\_collected else 'disabled')

self.front\_panel\_radio.config(state='normal')

self.rear\_panel\_radio.config(state='normal')

self.two\_wire\_radio.config(state='normal')

self.four\_wire\_radio.config(state='normal')

else:

self.connect\_button.config(state='normal')

self.sweep\_button.config(state='disabled')

self.save\_button.config(state='disabled')

self.front\_panel\_radio.config(state='disabled')

self.rear\_panel\_radio.config(state='disabled')

self.two\_wire\_radio.config(state='disabled')

self.four\_wire\_radio.config(state='disabled')

def connect\_instrument(self):

resource\_name = self.resource\_name\_entry.get()

try:

self.instrument = Keithley2400Controller(resource\_name)

self.instrument.connect()

self.is\_connected = True

messagebox.showinfo("Connection", "Successfully connected to the instrument.")

except Exception as e:

messagebox.showerror("Connection Failed", str(e))

self.is\_connected = False

finally:

self.update\_button\_states()

def change\_panel(self):

if not self.is\_connected:

messagebox.showerror("Error", "Instrument is not connected.")

return

panel = 'REAR' if not self.panel\_var.get() else 'FRONT'

self.instrument.select\_panel(panel)

def change\_mode(self):

if not self.is\_connected:

messagebox.showerror("Error", "Instrument is not connected.")

return

mode = 4 if self.mode\_var.get() else 2

self.instrument.set\_measurement\_mode(mode)

def perform\_iv\_sweep(self):

if not self.is\_connected:

messagebox.showerror("Error", "Instrument is not connected.")

return

# Gather the setup parameters

source\_type = self.setup\_fields['Source Type'].get()

measure\_type = self.setup\_fields['Measure Type'].get()

start\_level = float(self.setup\_fields['Start Level'].get())

stop\_level = float(self.setup\_fields['Stop Level'].get())

step\_level = float(self.setup\_fields['Step Level'].get())

compliance = float(self.setup\_fields['Compliance'].get())

nplc = float(self.setup\_fields['NPLC'].get())

source\_delay = float(self.setup\_fields['Source Delay'].get())

# Start the IV sweep in a separate thread

threading.Thread(target=self.async\_iv\_sweep, args=(

source\_type, measure\_type, start\_level, stop\_level, step\_level,

compliance, nplc, source\_delay

)).start()

def async\_iv\_sweep(self, source\_type, measure\_type, start\_level, stop\_level, step\_level, compliance, nplc, source\_delay):

try:

# Execute the IV sweep without range parameters

self.voltage, self.current = self.instrument.iv\_sweep(

source\_type, measure\_type, start\_level, stop\_level, step\_level,

compliance, nplc, source\_delay

)

# Update the plot

self.master.after(0, self.update\_plot)

self.data\_collected = True # Data has been collected

except Exception as e:

messagebox.showerror("Error", str(e))

finally:

self.master.after(0, self.update\_button\_states) # Update GUI elements from the main thread

def update\_plot(self):

# Determine what is being sourced and measured

source\_type = self.setup\_fields['Source Type'].get()

measure\_type = self.setup\_fields['Measure Type'].get()

if source\_type == 'VOLT' and measure\_type == 'CURR':

x\_data, y\_data = self.voltage, self.current

x\_label, y\_label = 'Voltage (V)', 'Current (A)'

else:

x\_data, y\_data = self.current, self.voltage

x\_label, y\_label = 'Current (A)', 'Voltage (V)'

self.plot.clear()

# Apply log scale if selected and adjust data to absolute values for log scale

if self.log\_scale\_x.get():

x\_data = np.abs(x\_data)

self.plot.set\_xscale('log')

else:

self.plot.set\_xscale('linear')

if self.log\_scale\_y.get():

y\_data = np.abs(y\_data)

self.plot.set\_yscale('log')

else:

self.plot.set\_yscale('linear')

self.plot.plot(x\_data, y\_data, marker='o', linestyle='-')

self.plot.set\_xlabel(x\_label)

self.plot.set\_ylabel(y\_label)

self.plot.set\_title('IV Sweep Results')

# Set formatter for automatic scientific notation

# self.plot.xaxis.set\_major\_formatter(ticker.ScalarFormatter(useMathText=True))

# self.plot.ticklabel\_format(style='sci', axis='x', scilimits=(0,0), useOffset=False)

plt.setp(self.plot.get\_xticklabels(), rotation=45, ha="right", rotation\_mode="anchor")

# Update the plot

self.canvas.draw()

def save\_data(self):

if not self.data\_collected:

messagebox.showerror("Error", "No data available to save.")

return

filepath = filedialog.asksaveasfilename(defaultextension=".txt", filetypes=[("Text Files", "\*.txt")])

if filepath:

with open(filepath, 'w', newline='') as file:

writer = csv.writer(file, delimiter='\t')

writer.writerow(["Voltage", "Current"])

for v, c in zip(self.voltage, self.current):

writer.writerow([v, c])

messagebox.showinfo("Save File", "Data saved successfully.")

def toggle\_autorange(self):

state = 'disabled' if self.autorange.get() else 'normal'

self.setup\_fields['Source Range'].config(state=state)

self.setup\_fields['Measure Range'].config(state=state)

def import\_data(self):

filepath = filedialog.askopenfilename(filetypes=[("CSV files", "\*.csv"), ("Text files", "\*.txt")])

if not filepath:

return

voltage, current = [], []

try:

with open(filepath, 'r') as file:

reader = csv.reader(file, delimiter='\t' if filepath.endswith('.txt') else ',')

next(reader) # Skip header row

for row in reader:

voltage.append(float(row[0]))

current.append(float(row[1]))

except Exception as e:

messagebox.showerror("Error", f"Failed to read file: {e}")

return

self.voltage, self.current = np.array(voltage), np.array(current)

self.data\_collected = True

self.update\_plot()

if \_\_name\_\_ == "\_\_main\_\_":

root = tk.Tk()

app = KeithleyGUI(root)

root.mainloop()

**Appendix B: SMU Port ID**

from pymeasure.instruments.resources import list\_resources

list\_resources()

The snippet above is the code required to identify all connections to the PC. It requires the package [PyMeasure](https://pymeasure.readthedocs.io/en/latest/quick_start.html#installing-pymeasure). The output will list all connections like below:

0 : ASRL2::INSTR : Not known

1 : ASRL10::INSTR : Not known

2 : GPIB0::1::INSTR : KEITHLEY INSTRUMENTS INC.,MODEL 2400,1248014,C30 Mar 17 2006 09:29:29/A02 /K/J

Out[1]:

('ASRL2::INSTR', 'ASRL10::INSTR', 'GPIB0::1::INSTR')

Input the correct port into the *Resource Name* field.