OrcaProbe

Reconfigurable Electrical Probing System for Thin Film Devices

User Manual

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1. Introduction

1.1 Overview of the Device

The OrcaProbe is a reconfigurable electrical probing system designed to efficiently characterize thin-film devices used in a variety of industries, including electronics and materials science. This versatile device integrates multiple measurement techniques into a single platform, allowing users to perform a wide range of electrical measurements on materials with minimal setup and configuration.

At the core of the OrcaProbe system is a four-probe measurement setup, which can be configured for 2, 3, or 4-probe configurations depending on the measurement requirements. This flexibility ensures that the system can be adapted to different types of tests.

The device features high precision and low error rates, ensuring reliable and accurate results across different measurement types. The probes are designed to minimize sample damage, allowing for high-throughput testing without compromising material integrity. OrcaProbe is controlled through an intuitive graphical user interface (GUI), making it easy for operators to select the measurement method, configure probe settings, and view results.

1.2 Package Contents

Upon receiving the package, ensure that all the following items are included. If any items are missing or damaged, please refer to the contents list below.

1. **OrcaProbe - the main device fully assembled:**
    a. Top chassis
    b. Bottom chassis
    c. Probe toggle switches x 4
    d. Gold probes x4
    e. Cover plate for the probe toggle switches
    f. PCB
    g. Brass standoffs x4
    h. 8 M2 x 8mm screws

2. **Zipped file - non-physical deliverables:**
    a. GUI source code files (.py)
    b. Microcontroller firmware source code (.c and .h files)
    c. Final firmware build outputs for the device (.elf / .bin files)
    d. PCB CAD files - schematic and layout captures
    e. CAD files for the chassis
    f. Comprehensive technical report
    g. Bill of materials

2. Safety Information

2.1 General Safety Guidelines

Below are basic precautions for operating the device safely:

1. Always follow the instructions in this manual to ensure safe use of the OrcaProbe device.
2. Only use the OrcaProbe for its intended purpose. Improper use can lead to damage or malfunction.

2.2 Electrical and Handling Precautions

Below are warnings about voltage levels, grounding, and other electrical risks, as well as Instructions on how to safely transport and handle the device.

1. **Power Supply**: The OrcaProbe device operates on USB 2.0 (or higher) power. Do not connect the device to any power source other than what is specified in the user manual.
2. **Voltage and Current Levels**: Be cautious when handling probes during measurements. The device can supply up to 5V and 10mA. Avoid contact with the probes while the system is in operation to prevent electrical shock or injury.
3. **Static Electricity**: Always handle the device and probes with care to avoid electrostatic discharge (ESD). Ground yourself before making any connections to avoid damaging sensitive components.
4. **Probes**: Ensure the probes are not bent or damaged during handling. Probes should be connected to the material under test with proper force to avoid damaging both the probes and the material.

2.3 Environmental Considerations

Below are guidelines for the environmental conditions in which the device should be operated and stored to ensure optimal performance and longevity.

1. **Operating Conditions**: The OrcaProbe device should be used in a clean, well-ventilated environment with a temperature range of 10°C to 35°C (50°F to 95°F). Ensure the device is placed on a stable, non-conductive surface.
2. **Storage**: When not in use, store the OrcaProbe in a dry place at room temperature. Do not expose it to direct sunlight, extreme heat, or humidity.
3. **Maintenance**: Regularly inspect the device for any signs of wear or damage. If you notice any issues, consult the troubleshooting section or contact technical support.

3. Installation & Setup

3.1 System Requirements

This section outlines the minimum hardware and operating system specifications necessary to ensure the proper operation of the OrcaProbe software.

- **Operating System**: The OrcaProbe software is compatible with Microsoft Windows 10 or later versions. Ensure your system is up to date to avoid compatibility issues.
- **Hardware Requirements**:
    - **Processor**: A minimum of 2.0 GHz dual-core processor.
    - **Memory (RAM)**: At least 4 GB of RAM.
    - **Storage**: Minimum of 500 MB of free disk space for installation.
    - **USB Port**: One available USB 2.0 (or later) port for connecting the OrcaProbe device.

Make sure your system meets or exceeds these requirements to ensure the smooth operation of the OrcaProbe device and software.

3.2 Installing the Software

To install and run the OrcaProbe software, follow these steps:

1. **Unzip the File**: Extract the zipped file you received to a folder of your choice on your computer.
2. **Install Python**: Ensure you have Python 3.6 or later installed on your system. If you don't have Python installed, download and install it from the official Python website.
3. **Navigate to the Project Directory**: Open your terminal and change the directory to where you unzipped the OrcaProbe project files. Use the `cd` command to navigate:
    a. `cd /path/to/your/unzipped/project`
4. **Install Required Packages**: After activating your virtual environment, install the necessary Python packages using `pip`. Run the following command:
    a. `pip install matplotlib numpy PyQt5 pyserial`
5. **Verify Installation**: Once the packages are installed, verify the installation by typing:
    a. `python --version`

4. Device Operation

4.1 Powering On/Off

To power on and operate the OrcaProbe device, follow these simple steps:

1. **Connect the Device**: Connect the OrcaProbe device to your computer via the USB cable. Ensure that the USB connection is secure.
2. **Check the LED Indicator**: Once the device is connected, check the LED on the device. The LED should light up to indicate that the device is receiving power and is ready for use.
3. **Verify Terminal Connection**: Open your terminal and navigate to the project folder where the OrcaProbe files are located. Use the following command to navigate to the directory:
    a. `cd /path/to/your/project/folder`

4. **Powering On the Software:** To run the OrcaProbe software and begin the testing process, type the following command in your terminal:
    a. `python main.py`
5. **Powering Off:** When you are finished using the OrcaProbe device, you can safely disconnect it from the USB port. Ensure that you close the software by pressing “x” on the upper right side of the screen before physically disconnecting the device.

4.2 Navigating the GUI

The OrcaProbe GUI is designed to be intuitive and user-friendly. Here’s a guide to navigating the main features:

1. **Measurement Type Selection**:
   On the left side of the window, you'll find the options for 2-probe Measurements, 3-probe Measurements, and 4-probe Measurements. Choose the measurement type that suits your testing needs. For example, if you want to perform a DC Resistance measurement, click on DC Resistance under the 2-probe Measurements section.
2. **Input Fields for Data Logging**:
   Once a measurement type is selected, you can choose how to log the data. Below the measurement options, you’ll see two radio buttons. Choose the file format that best fits your needs.
3. **Probe Configuration**:
   In the bottom section of the window, you'll see options for configuring each probe. There are four probes (Probe 1, Probe 2, Probe 3, Probe 4) with dropdown menus for both Supply and Measurement. Select the appropriate supply (e.g., voltage, current) and measurement type for each probe.
4. **Start and Stop Measurement**:
   After configuring the probes and input settings, you can initiate the measurement by clicking the Start button, which will appear in green.

4.3 Using the Probes

The OrcaProbe supports 2-probe, 3-probe, and 4-probe configurations, each tailored to specific measurement methods. Selecting the appropriate configuration is essential for accurate and reliable test results. The following guide outlines recommended probe setups for each measurement type and explains how to configure them in the GUI.

4.3.1 2-Probe Configurations

- **DC Resistance**
  - One probe: Current supply and voltage measurement
  - One probe: Ground
- **Current-Voltage (I–V)**
  - If sweeping current:
    - One probe: Current supply and voltage measurement
    - One probe: Ground
  - If sweeping voltage:
    - One probe: Voltage supply and current measurement
    - One probe: Ground
- **Capacitance-Voltage (C–V)**
  - One probe: AC voltage supply
  - One probe: Ground and current measurement
- **Impedance Spectroscopy**
  - One probe: AC voltage supply
  - One probe: Ground and current measurement

4.3.2 3-Probe Configuration

- **Transfer Characteristics**
  - Two probes: DC voltage supply
  - One probe: Ground and current measurement
- **Output Characteristics**
  - Two probes: DC voltage supply
  - One probe: Ground and current measurement
- **Capacitance-Voltage**
  - Two probes: DC voltage supply
  - One probe: Ground and current measurement

- **Electrochemical Measurements**
    - Two probes: DC voltage supply
    - One probe: Ground and current measurement

4.3.3 4-Probe Configuration

- **Probe Resistance**
    - One probe: Current supply
    - Two probes: Voltage measurement
    - One probe: Ground
- **Low Resistance Measurement**
    - One probe: Current supply
    - Two probes: Voltage measurement
    - One probe: Ground
- **Impedance Spectroscopy (4-terminal)**
    - One probe: Current supply
    - Two probes: Voltage measurement
    - One probe: Ground

Note: For all 4-probe measurements, voltage measurement probes must be the middle two (Probes 2 and 3) to ensure proper voltage drop detection across the material.

Note: Actual ground to the probes are only available on the outer probes. The inner probes can be set to virtual ground by being set to measure current. In any case where the probes need to be connected to just ground, the outer probes should be used.

4.4 Performing Basic Measurements

1. **Select the Measurement Type**:
   In the GUI, choose the desired measurement type from the available options
2. **Fill Out the Input Parameters**:
   Fill out the required input parameters for the measurement. This may include values such as voltage, current, frequency, or sweep range, depending on the selected test.

3. **Choose Data Logging Type**:
   Select the type of data logging you would like to use. This will allow you to save the measurement data for later analysis.
4. **Configure Probes and Functionalities**:
   Choose the appropriate probes for the measurement. Configure each probe for its intended functionality through the GUI.
5. **Start the Measurement**:
   Once all settings are configured, click the "Start" button in the GUI to begin the measurement. The device will perform the test, and the results will be displayed once the test is done. Keep the probes stable and ensure contact with the material until the result is visible.

5. Troubleshooting & Maintenance

5.1 Common Issues and Solutions

This section provides solutions to common problems that may arise during the operation of the OrcaProbe device.

Device Not Powering On:

- Ensure the device is properly connected to a USB port that provides sufficient power (USB 2.0 or later).
- Check for any loose connections and ensure the power supply is functioning properly.

Probes Not Responding:

- Verify that the probes are correctly configured through the GUI.
- Ensure there is no physical damage to the probes and that they are securely connected to the device.

Measurement Data is Inaccurate:

- Check the probe configuration and make sure the correct measurement method is selected.
- Ensure the probes are properly calibrated and make good contact with the material under test.

Software Not Detecting the Device:

- Confirm that the device is properly connected via USB. Ensure the GUI is run after the device is connected to the host computer.
- Check for driver issues or updates in the system settings. Ensure the host computer meets the system requirements for the OrcaProbe software.

5.2 Maintenance Tips

This section outlines general guidelines for maintaining the OrcaProbe device to ensure optimal performance over time.

- **Regular Inspection**: Periodically inspect the probes for wear or damage. Clean the probe tips gently with a soft, dry cloth to prevent any debris from affecting measurements.
- **Keep the Device Clean**: Wipe down the device with a soft cloth to remove dust or any materials that may have accumulated during use. Avoid using harsh chemicals that could damage the device.
- **Check Connections**: Routinely verify that all USB and probe connections are secure before each use. Loose or faulty connections can lead to inaccurate readings or device malfunctions.

6. Adding a Measurement Type

6.1 Software Changes

To add a new measurement type to the OrcaProbe software, you will need to modify both the GUI (`gui.py`) and the backend calculation module (`calc.py`). The following steps outline how to properly implement a new measurement method:

1. **Add the Measurement Type to the Sidebar**
    a. In the `gui.py` file, locate the following line of code: "`self.add_measurement_selection(sidebar_layout,`"
    b. Under the appropriate measurement category (e.g., 2-probe, 3-probe, or 4-probe), add the name of the new measurement type to be displayed in the sidebar.

2. **Create a GUI Page for the Measurement Type**
    a. Still in `gui.py`, locate the function: "`def customize_measurement_page(self, title, layout):`"
    b. Within this function, add a new conditional block for your measurement type: "`elif title == "New Measurement Title":`"
    c. You can use existing measurement sections as references when determining what inputs (e.g., voltage, current, sweep range) are needed for your new measurement.

3. **Implement the Calculation Function**
    a. Open the `calc.py` file and scroll to the end of the document. Create a new function that performs the required calculations for the measurement: "`def new_measurement_type(input_parameters):`"
    b. Add the calculation logic inside the function.

4. **Add Register Map Inputs**
    a. Navigate to the `scripts/` folder and open the file `JY85-FW_Register_Map.xlsx`.
    b. Add the necessary input variables related to your new measurement type to the appropriate section of the table.
    c. Save the file, then run the following command in your terminal to regenerate the firmware header: "`python generate_registermap.py`"
    d. This will update the register map used in the firmware and create corresponding variables that can be used in your GUI logic.

5. **Define the Measurement Execution Logic**
    a. At the bottom of the gui.py file, define a new function for executing the measurement backend: "`def start_new_measurement_type(self):`"
    b. This function should handle all necessary operations to carry out the measurement and communicate with the device accordingly.

By following these steps, new measurement types can be seamlessly integrated into the OrcaProbe system with full GUI support and backend functionality.

6.2 Firmware Changes

To support a new measurement type at the firmware level, several updates must be made to integrate the measurement routine into the microcontroller's operation. Follow the steps below to implement the necessary changes:

1. **Copy Register Variables**
    a. After generating the updated register map (via `generate_registermap.py`), open the `registers.py` file and locate the new variables created for the measurement type.
    b. Copy these variable definitions and paste them into the `device_constants.h` file located at: `"Firmware/DeviceProcessor04/Device/Inc/device_constants.h"`
2. **Implement the Measurement Routine**
    a. In the firmware source directory, open the file `measurement_routines.c` located at: `"Firmware/DeviceProcessor04/Device/Src/measurement_routines.c"`
    b. Add a new function that performs the required microcontroller actions for the new measurement type. This may include relay switching, power supply control, and ADC sampling.
    c. You can refer to existing routines for similar measurement types as templates.
3. **Update Measurement Configuration Enum**
    a. In the `device_constants.h` file, locate the `MeasurementCfg_Type` enum, add a new label corresponding to the new measurement type. This enables the firmware to recognize and map the configuration to the correct routine.
4. **Add Routine to Switch-Case Logic**
    a. Open `run_device.c` in the same firmware source directory: `"Firmware/DeviceProcessor04/Device/Src/run_device.c"`
    b. Locate the switch-case statement that handles measurement configuration.
    c. Add a new `case` block that calls your measurement routine based on the new configuration enum label.

For Steps 2 through 4, you may refer to the existing measurement implementations in the codebase as examples for formatting and structure.

Once these changes are complete, rebuild and flash the firmware to apply the updates. Your new measurement type will now be fully supported at the hardware level.