PiezoDrive

PDUS210
210 Watt Ultrasonic Driver

Contents

Safety Warnings

High Voltage

This product produces potentially lethal voltages up to 282 Vrms.

Observe Low-Voltage (as per ANSI C84.1-1989) safety precautions, e.g.

- Use an observer trained in low-voltage rescue
- Do not operate with exposed conductors
- Use appropriate signage, etc.

Overview

The PDUS210 is a complete solution for driving precision and high-power ultrasonic actuators. The amplifier includes high-speed resonance and anti-resonance tracking, power control, and functions such as impedance and frequency response analysis. The PDUS210 is well suited to both OEM product integration and laboratory use for research and development. Applications include ultrasonic drilling and cutting, medical devices, dental devices, ultrasonic testing, liquid cavitation, and vaporization.

The PDUS210 is controlled via USB and the included software package. An RS485 interface also provides a straight-forward method to control and monitor the amplifier for automatic test and OEM applications.

The PDUS210 generates a pure sine-wave output which avoids the excitation of secondary resonance modes by the drive harmonics. This makes it ideal for operating at the electrical parallel resonance, or “anti-resonance”. This operating point is close to the mechanical resonance frequency but is less sensitive to changes in load dissipation, which is useful in precision machining applications where constant vibration amplitude is desired.

The PDUS210 is available with standard output voltage ranges from 17 Vrms to 282 Vrms, and current ranges from 0.7 Arms to 11 Arms. These ranges are optimized for load impedances ranging from 1.5 Ohms to 400 Ohms at resonance.

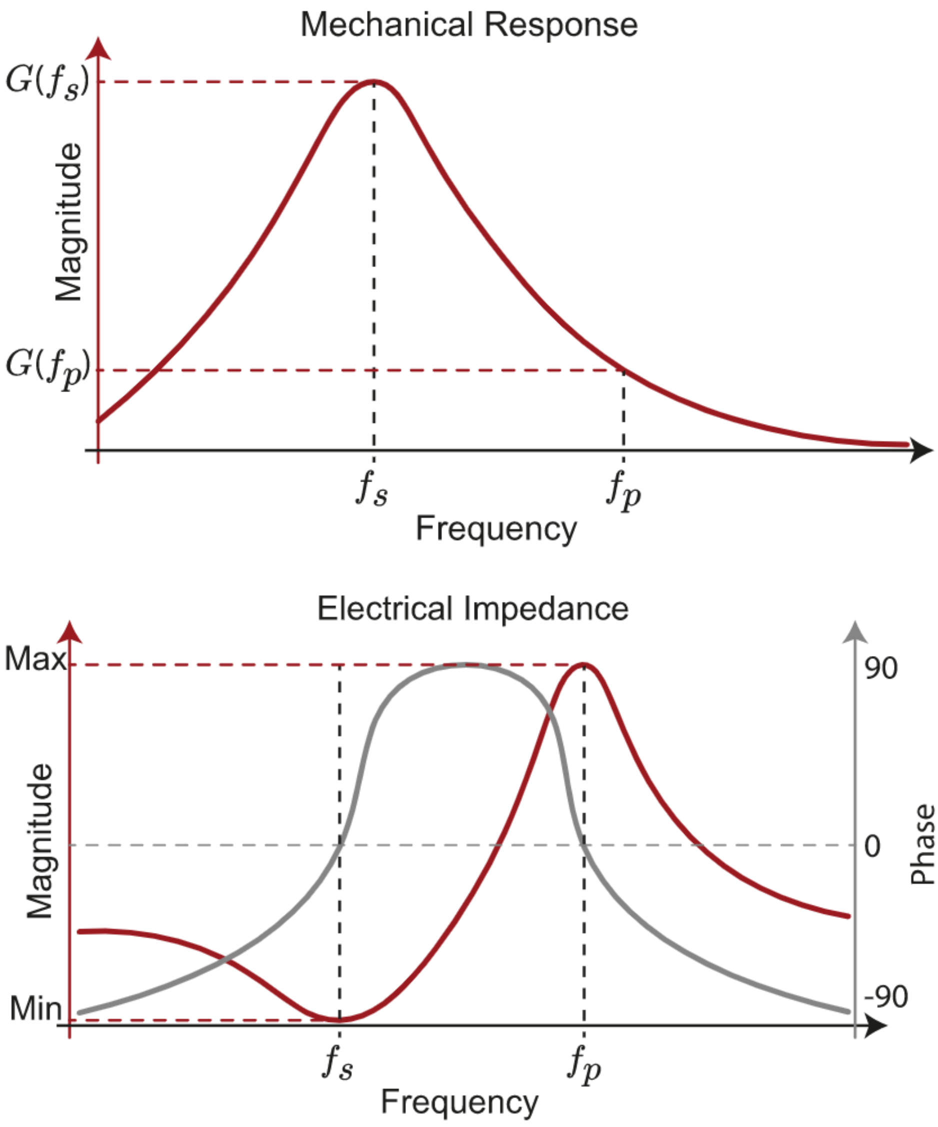
Ultrasonic Drive Methods

For an introduction to driving ultrasonic transducers, refer to:

- https://www.piezodrive.com/ultrasonic-drivers/intro-ultrasonic/

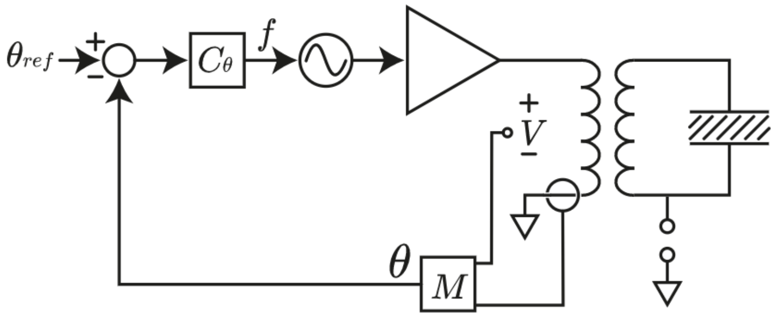
Resonance Tracking

The following figure plots the mechanical and electrical frequency response of an ultrasonic transducer. The impedance minima at f_s is known as the series resonance, which is approximately equal to the mechanical resonance frequency. At this frequency, the phase response has a high slope and value of zero degrees. Resonance tracking is achieved by varying the drive frequency to regulate the phase to zero. Alternatively, the phase set point can be selected to operate slightly above or below resonance, which may provide higher immunity to load variations at the expense of electrical efficiency. Furthermore, systems with low quality factor may have phase responses that are non-zero at resonance, particularly for the parallel resonance. In such cases, an impedance response should be performed to identify the desired operating point.



Electrical and mechanical response of an ultrasonic transducer

The resonance tracking system of the PDUS210 is described in the diagram below. A phase detector (M) measures the impedance phase angle between the primary voltage and current. The phase controller $C_\theta(s)$ varies the drive frequency to maintain a constant phase set point θ_{ref} .



Phase control loop in the PDUS210 driver.

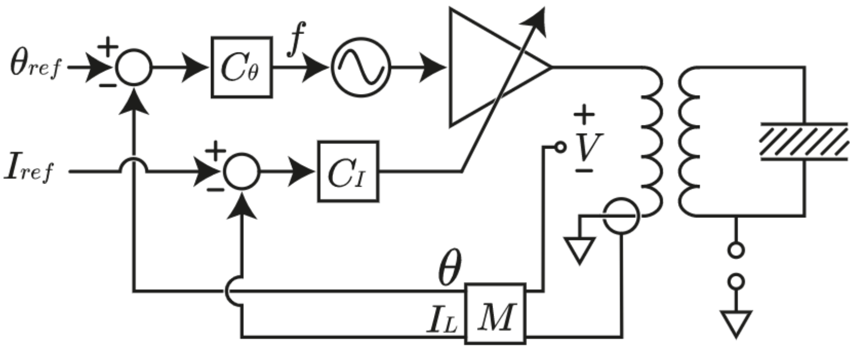
The electrical response also exhibits an impedance maxima, known as the parallel resonance. At this frequency the applied voltage is approximately proportional to the vibration amplitude. This operating mode is advantageous in applications that require constant vibration amplitude.

Phase tracking at the parallel resonance is identical to the series resonance, except for the opposite slope of the phase curve, which requires a negative controller gain. Any positive phase controller gain will track a series resonance mode, while any negative controller gain will track a parallel resonance mode.

Control of Vibration Amplitude

To achieve constant vibration amplitude, a transducer can be driven with constant voltage at the parallel resonance frequency, or constant current at the series resonance frequency.

In high power applications, constant current is achieved with the feedback loop illustrated below. In this mode, the primary objective is to regulate current, followed by phase tracking.

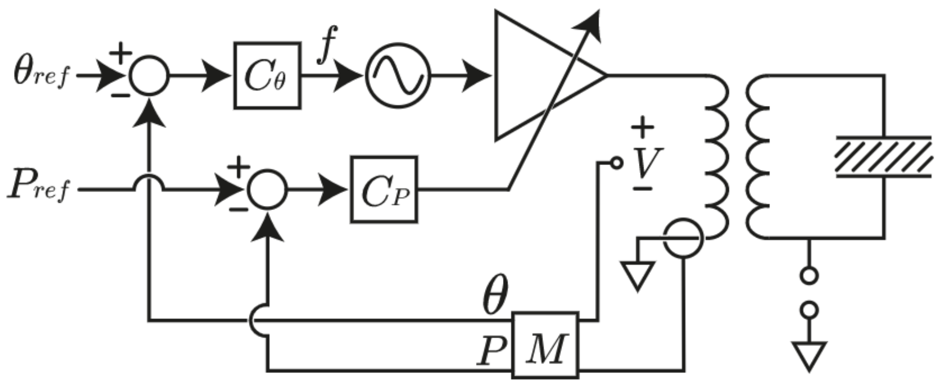


Phase and current control loop in the PDUS210 driver.

Power Control

While operating with constant vibration amplitude, there is no control over the power dissipated by the transducer, or delivered to the load. However, limits can be set on the maximum power dissipation regardless of the operating mode.

In many applications it is desirable to directly regulate the load power since this is proportional to parameters such as work-piece heating and cavitation. As shown in the diagram below, the power control loop varies the excitation voltage to maintain a constant load power. In applications such as ultrasonic machining where the tool is intermittently in and out of contact with the work piece, the power control loop is best disabled while the tool is unloaded. Power control is most effectively combined with constant current excitation while operating at series resonance, or constant voltage excitation when operating at parallel resonance.



Phase and power control loop in the PDUS210 driver.

Choosing the Voltage Range

The PDUS210 is available in voltage ranges from 17 Vrms to 282 Vrms, which correspond to impedances ranging from 1.5 Ω to 400 Ω. The optimal choice is determined by the transducer impedance at resonance, and the choice of series or parallel resonance.

The first step is to measure the impedance of the transducer at the series and parallel resonance. This can be performed with an impedance analyser or simply a signal generator and oscilloscope. If possible, these tests should be performed at moderate power with both minimum and maximum load conditions. Fill out the values in the table below:

	Unloaded	Fully Loaded
Series Resonance	$R_{1,min}$:	$R_{1,max}$:
Parallel Resonance	$R_{2,max}$:	$R_{2,min}$:

Table of operating impedance at resonance

Series Resonance

For operation at the series resonance, the most suitable amplifier has an optimal impedance which is close to, or slightly greater than the fully loaded impedance. Since transducer impedance tends to increase with applied power, an amplifier with a higher optimal impedance is recommended. If the amplifier has a higher optimal impedance than the load, the current limit will be reached before the voltage limit, and the maximum achievable output power is:

$$P = I_{rms}^2 R_{1,max}$$

where I_{rms} is the maximum driver current.

Parallel Resonance

For operation at the parallel resonance, the most suitable amplifier has an optimal impedance which is close to, or slightly less than the fully loaded impedance. Since transducer impedance tends to reduce with applied power, an amplifier with a lower optimal impedance is recommended. If the amplifier has a lower optimal impedance than the load, the voltage limit will be reached before the current limit, and the maximum achievable output power is:

$$P = \frac{V_{rms}^2}{R_{2,min}}$$

where V_{rms} is the maximum driver voltage.

Custom Voltage Range

Custom voltage ranges and optimal impedances are available to provide maximum power for a specific transducers.

Electrical Specifications

Specification	Value	Notes
Output Voltage	0 – 800 Vp-p	See standard load configurations
Output Current Max	0 – 32 Ap-p	See standard load configurations
Optimal Load Impedance	1.5 – 400 Ohms	See standard load configurations
Output Waveform	Sine wave	
DC Output Voltage	Zero	DC offset possible
Output Isolation	Isolated or grounded	
Max Output Power	210 W	With optimal load impedance
Internal Power Dissipation	130 W	Maximum
Frequency	20 – 200 kHz	5kHz to 500kHz possible
Power Supply	48 V, 280 Watt	
Controller	Phase tracking and power control	2ms frequency update rate Resonance or anti-resonance
Interface	USB, RS485	RS232 possible
Digital IO	4 DIO	For manual control

Standard Output Voltage Ranges

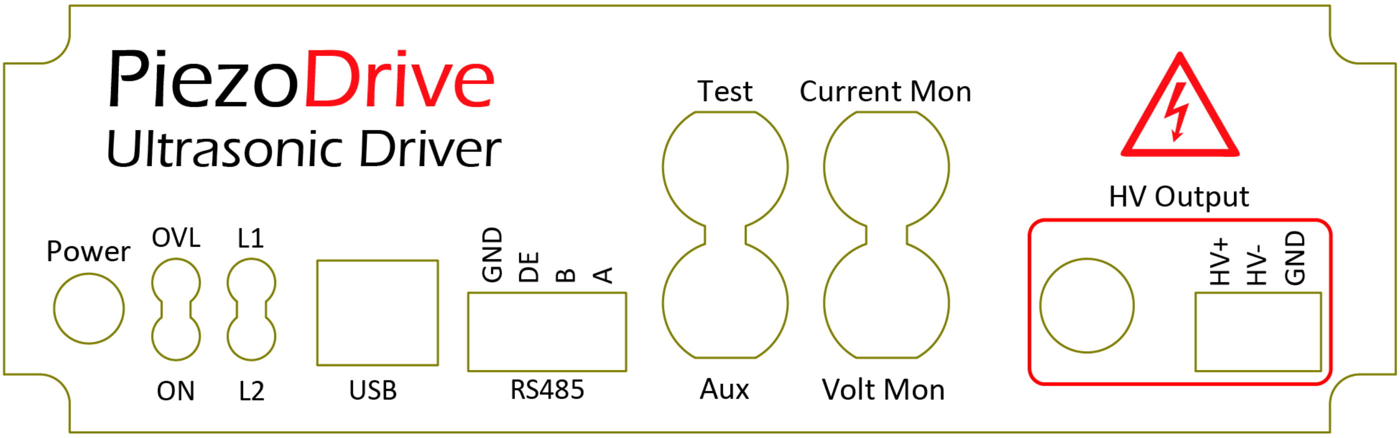
Order Code	Max Voltage Volts pk-pk	Max Voltage Volts RMS	Max Current Amps pk-pk	Max Current Amps RMS	Optimal Load Ohms
PDUS210-800	800	282	2	0.71	400
PDUS210-600	600	212	2.6	0.92	225
PDUS210-400	400	141	4	1.4	100
PDUS210-200	200	70	8	2.8	25
PDUS210-100	100	35	16	5.7	6.25
PDUS210-50	50	17	32	11.3	1.56

Note: The output voltage resolution and tolerance is 8 bits, or 256 levels. Therefore, the smallest possible change in voltage is FSR / 256, where FSR is the full scale range in any units. The minimum output voltage is also limited by resolution. When the amplifier is enabled and the output voltage is set to zero volts, the actual output voltage may be up to FSR / 256.

Mechanical Specifications

Specification	Value	Notes
Enclosure Dimensions	227 x 168 x 54 mm	L x W x H
Mass	1.4 kg	
Temperature Range	0C - 50C	
Humidity	Non-condensing	

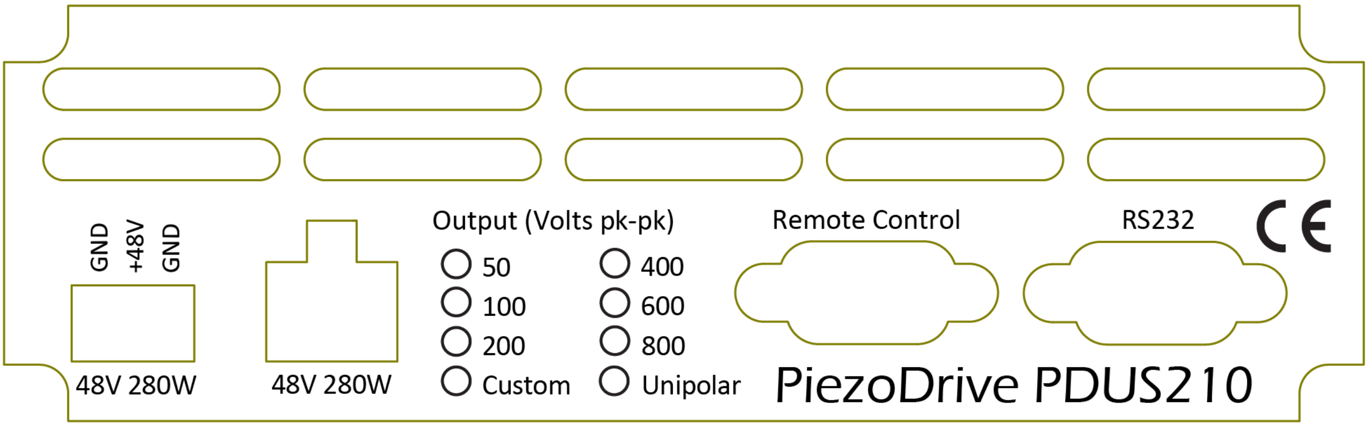
Front Panel



ON	Power indicator
OVL	Indicates an overload or shutdown state, see overload protection
USB	USB 2.0 Type-B device connector
L1	Uncommitted LED indicator
L2	USB Activity indicator
RS485	Isolated RS485 interface, GND is the remote ground
Test	+/-4V Input produces full-range output voltage. Test use only.
Aux	Connected to ADC converter, not presently used
Current Mon	Output current monitor, AC Coupled. The gain is $0.00264 \times V_{pp}$ V/A
Volt Mon	Output voltage monitor, AC Coupled. The gain is $5.06/V_{pp}$ V/V
LEMO HV Output	Suits LEMO 0B.302 Connector
Screw HV Output	Suits Amphenol TJ0331530000G Connector

The sensitivity of the current and voltage monitors are determined by the peak-to-peak output voltage range. For example, the peak-to-peak output voltage range of the PDUS210-400 is 400, so the current gain is 1.056 V/A, and the voltage gain is 0.01265 V/V.

Rear Panel



48V 280W	Suits Amphenol TJ0331530000G Connector
48V 280W	Suits 6-Pin power connector for Meanwell GST280A48-C6P
Remote Control	Digital Input-Output Connector (D-SUB9 Connector). The pinout is: 1. 3.3V Supply 2. In1 (3.3V to 24V logic, max 30V) 3. In2 (3.3V to 24V logic, max 30V) 4. Out1 3.3V logic (24V output optional) 5. Out2 3.3V logic 6. GND 7. GND
RS232	Isolated RS232 serial port. Uses same isolated supply as RS485, do not use both simultaneously (D-SUB9 Connector). The pinout is: 1. Not Connected 2. Receive In 3. Transmit Out 4. Not Connected 5. Isolated Ground

Overload Protection

There are three types of overload protection:

Hardware Overload

This overload is triggered when the current to the power amplifier exceeds 5.7 Amps average. When triggered, the power amplifier is shutdown, causing the “Overload” front panel LED to illuminate. To restart the amplifier, an enable command is required.

At power-on, the power amplifier is shutdown by default and requires an enable command to start.

Load Power Dissipation Overload

This overload is triggered when the real power dissipated by the load exceeds the threshold defined in the user interface. An enable command is required to clear this overload.

Amplifier Power Dissipation Overload

This overload is triggered when the real power dissipated by the power amplifier exceeds 100 Watts. An enable command is required to clear this overload. Triggering this overload usually means that the load impedance is poorly matched to the output voltage and current range of the amplifier.

Thermal Overload

This overload is triggered when the heatsink temperature exceeds 70C. An enable command is required to clear this overload. Check the fan and heatsink for blockages.

Desktop Software

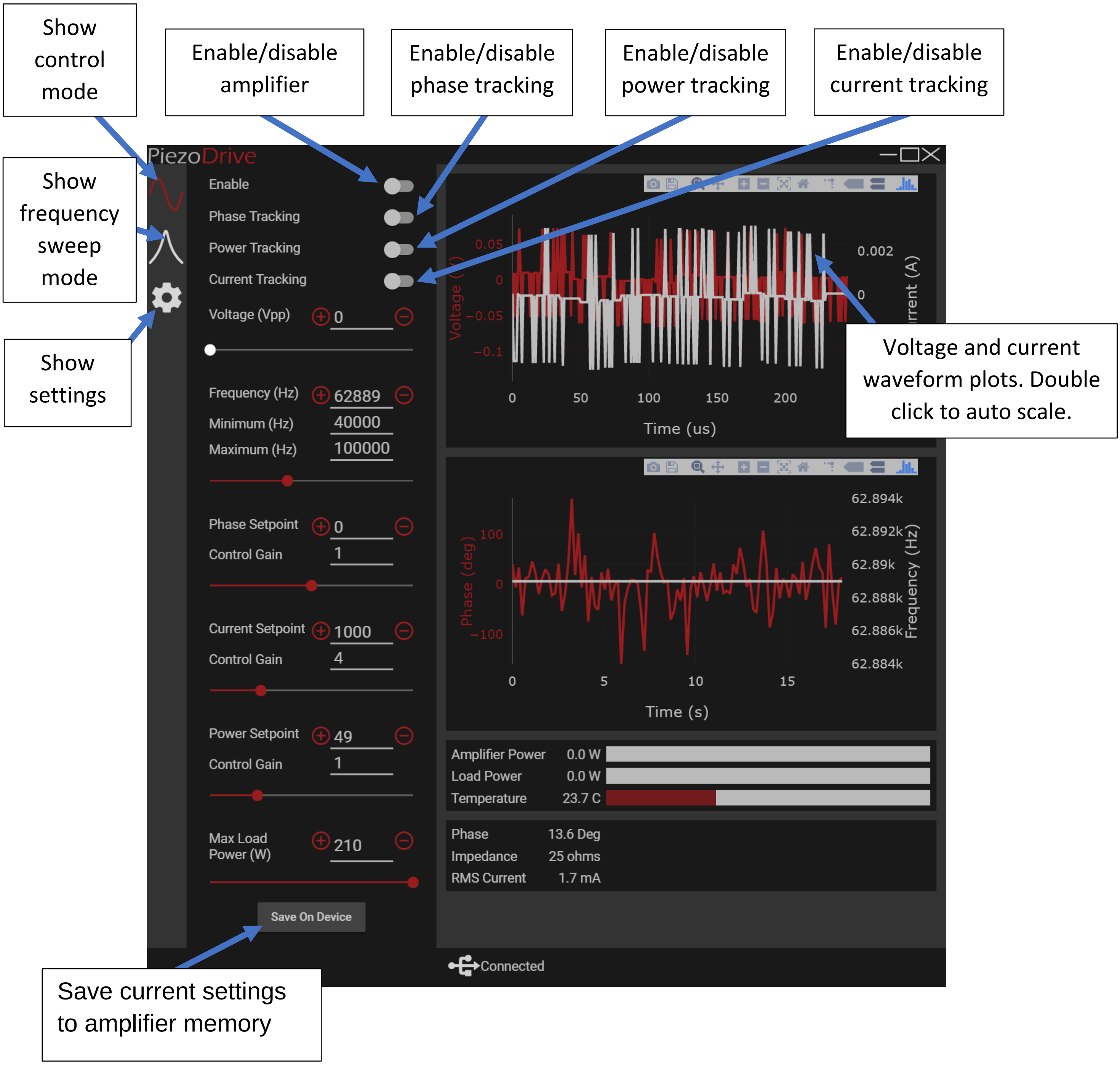
Installation

Open installation file and unzip to a convenient location, e.g. Desktop/PDUS210

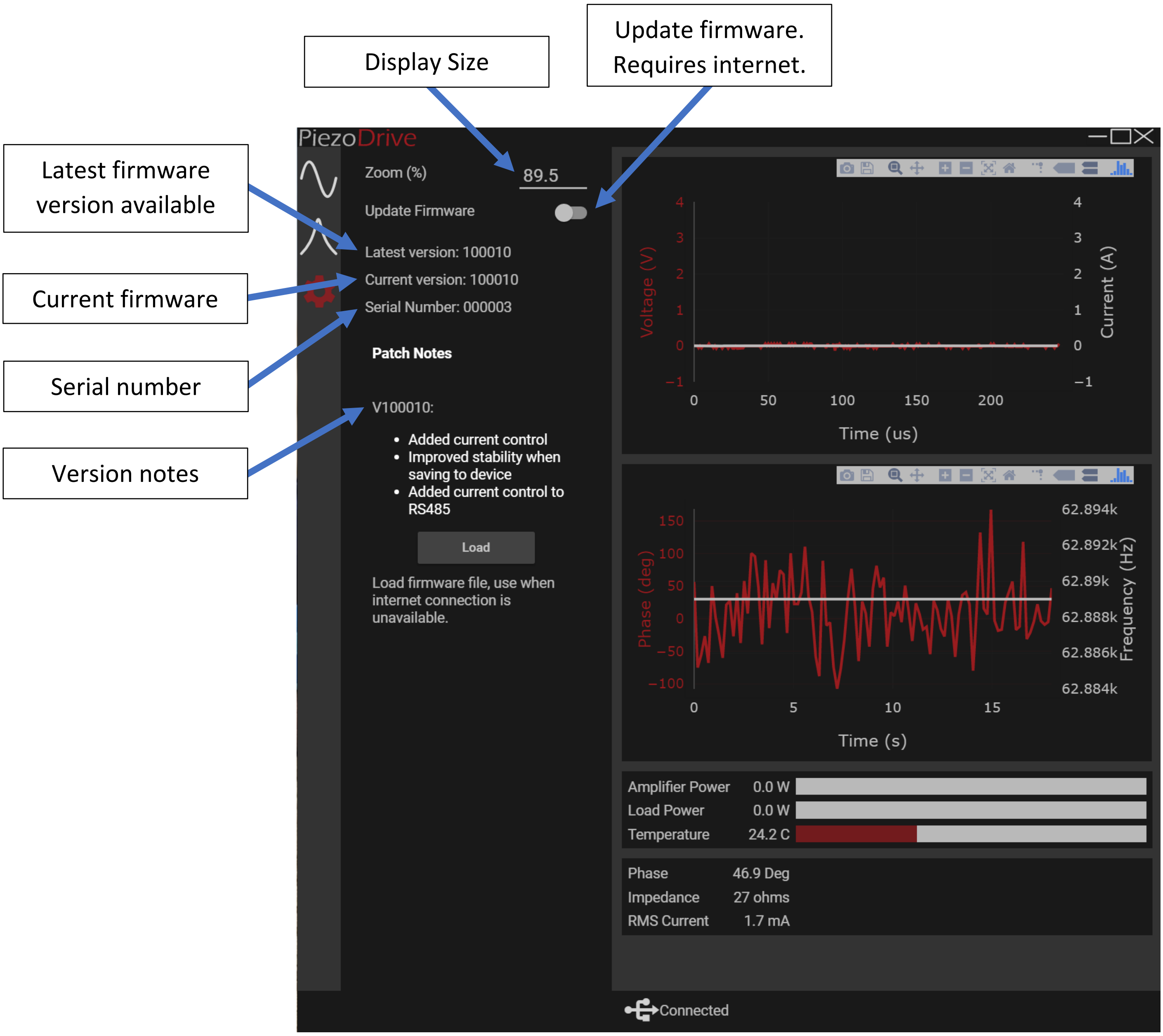
To Start

Run PiezoDrive.exe

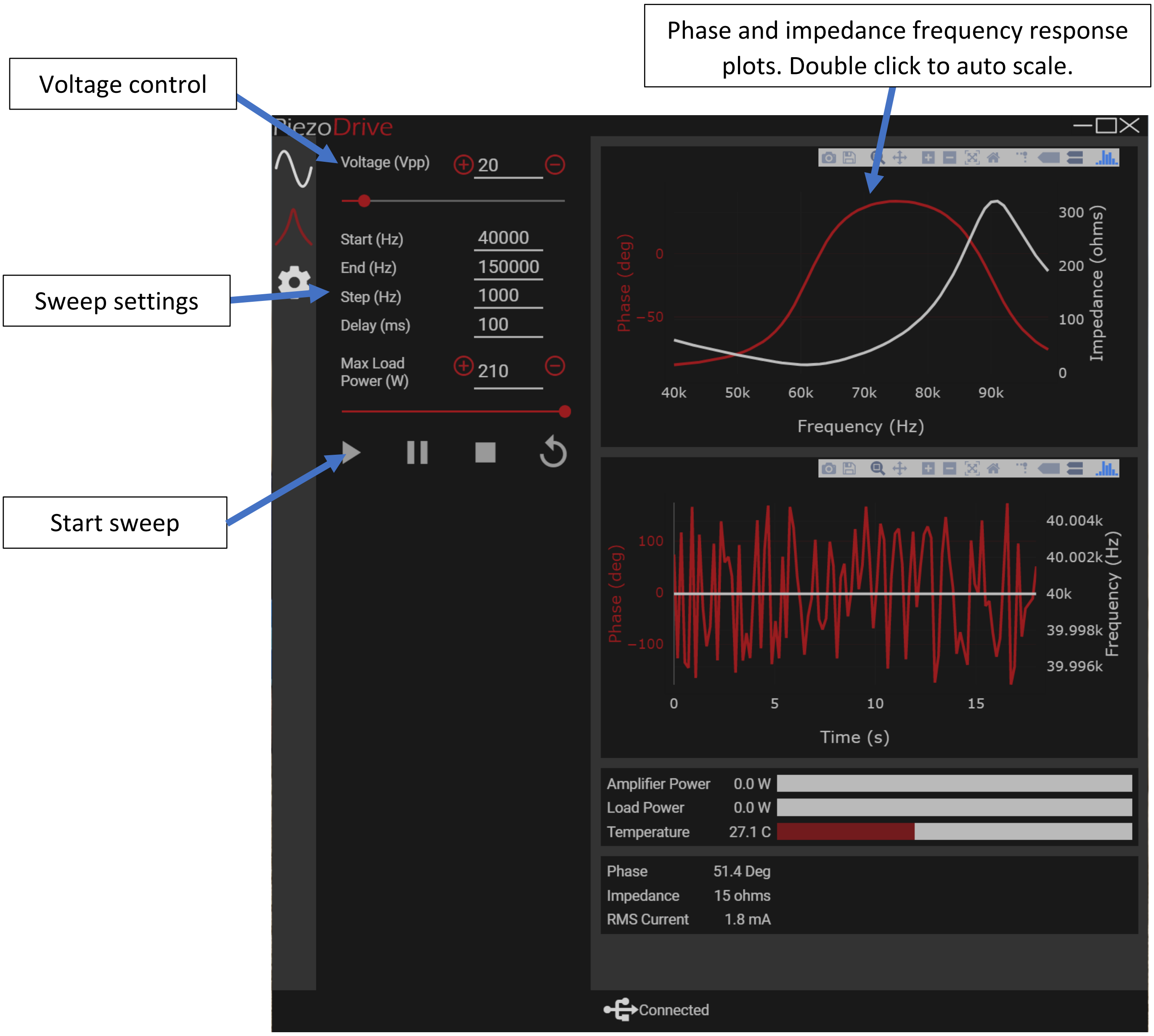
User Interface Overview



Settings Overview



Frequency Sweep Overview



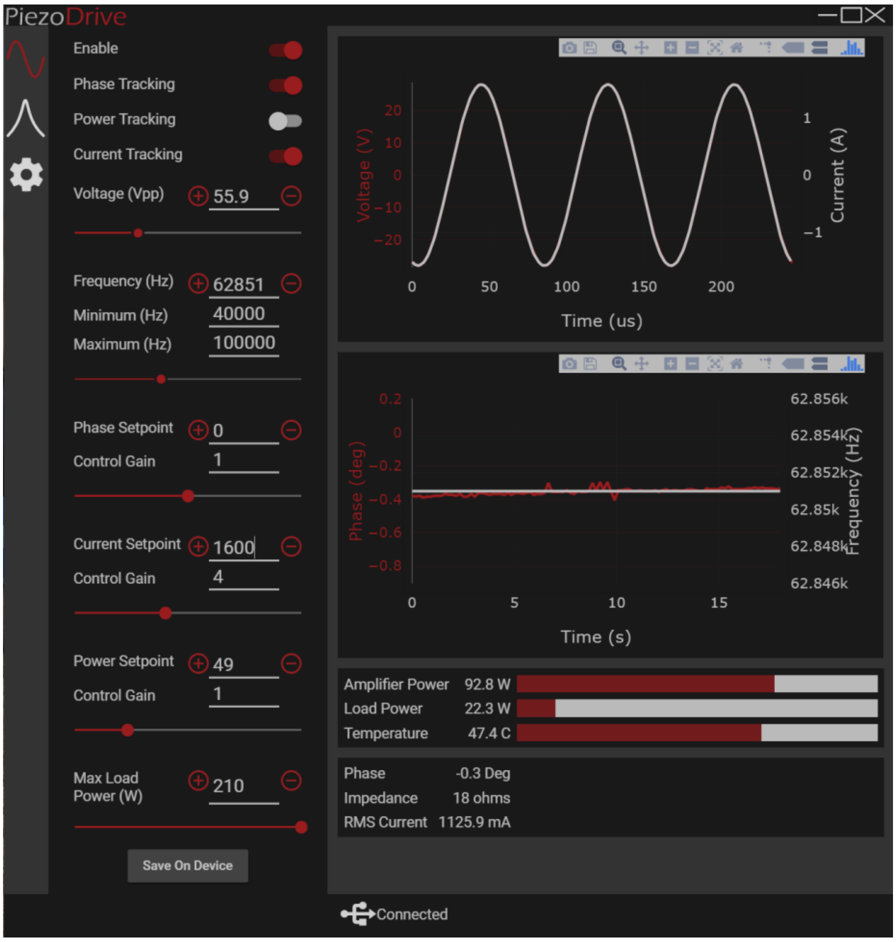
To Track a Series Resonance

1) Perform a frequency sweep to identify the resonance of interest

- Start with a low voltage, e.g. 1 Vpp
- Identify the frequency limits and the desired phase
- Increase voltage to improve resolution

2) Enter the frequency limits and desired phase set point (usually zero degrees)

- To track a series resonance (impedance minima), set the control gain to a positive value, e.g. +1
- Enable the output
- Enable phase tracking
- Check the measured phase is reaching the set point
- (Optional) Current tracking can now be enabled



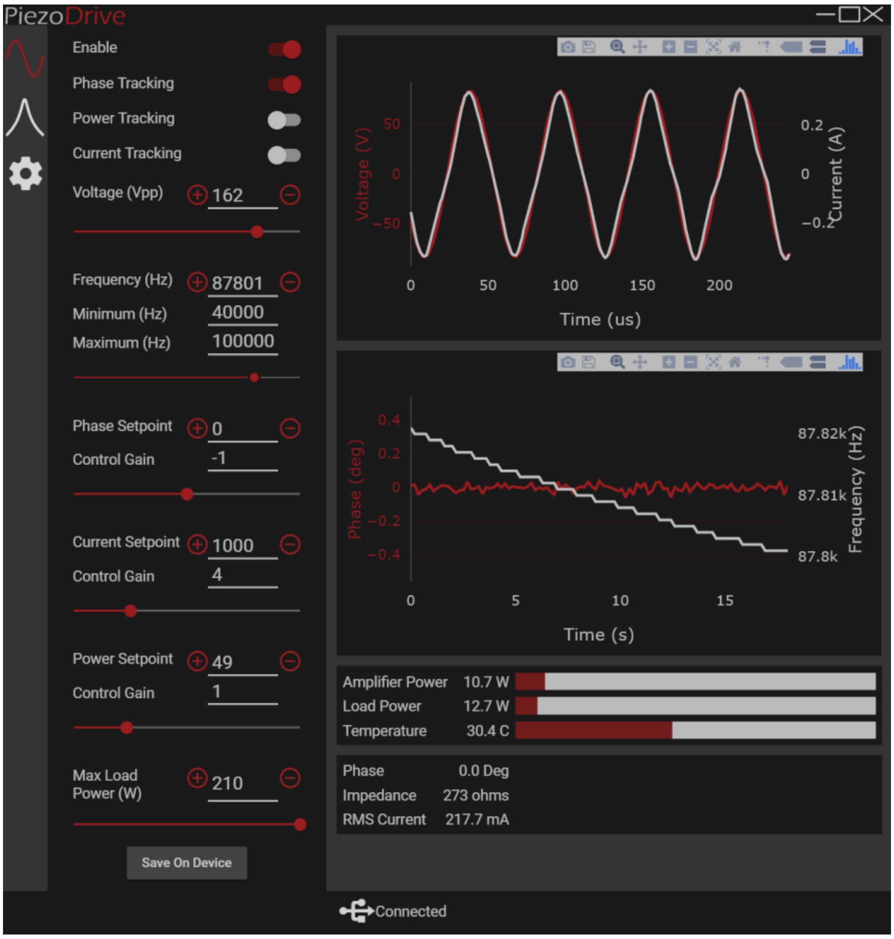
To Track a Parallel Resonance

1) Perform a frequency sweep to identify the resonance of interest

- Start with a low voltage, e.g. 1 Vpp
- Identify the frequency limits and the desired phase
- Increase voltage to improve resolution

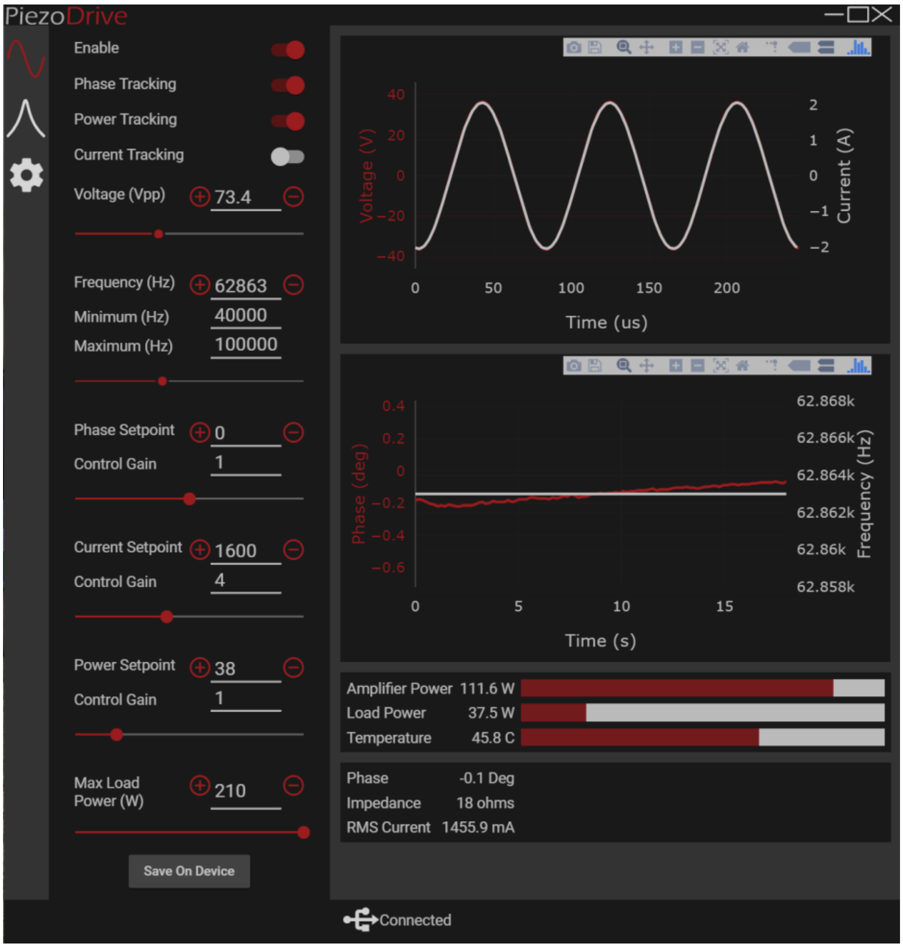
2) Enter the frequency limits and desired phase set point (usually zero degrees)

- To track a parallel resonance (impedance maxima), set the control gain to a negative value, e.g. -1
- Enable the output
- Enable phase tracking
- Check the measured phase is reaching the set point



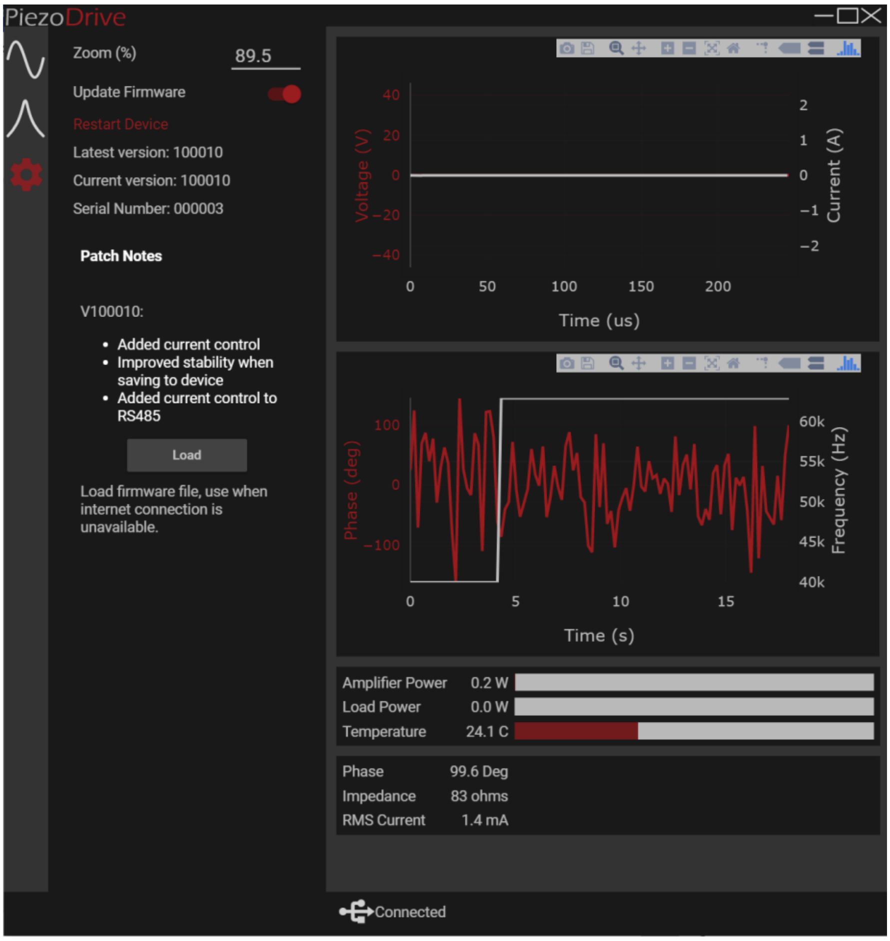
Power and Current Tracking

- Successfully track a resonance using phase tracking and manual voltage control
- Enter the desired power or current setpoint
- Set the control gain to 0.2, this controls the rate at which the voltage is updated.
- Enable power or current tracking
- The voltage will be updated to achieve the desired load power dissipation or current.



To Update Firmware

- Enter settings mode
- Toggle the update firmware button
- Restart amplifier when prompted
- Latest compatible firmware will be downloaded and installed
- Desktop software and amplifier will restart

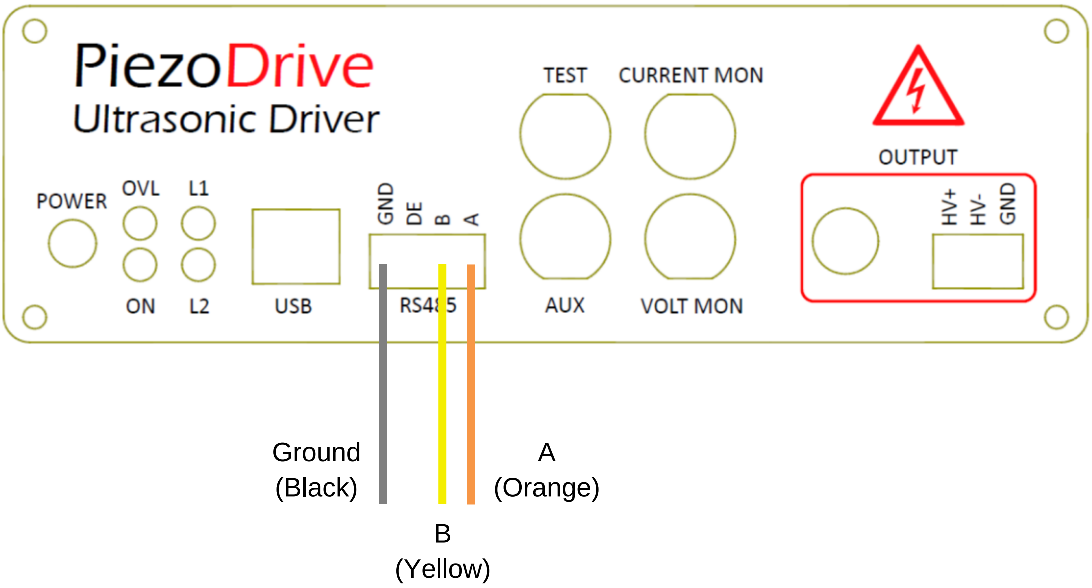


RS485 Interface

RS485 is a two-wire communication standard, commonly used for industrial machine-to-machine, and computer-to-machine communications (Introduction to RS485).

The PDUS210 responds to the commands described in https://github.com/PiezoDrive/RS485-API

For testing purposes or to control the amplifier from a PC, an RS485 USB cable is required, for example, FTDI USB-RS485-WE-1800-BT. The connection diagram below is recommended. A text based application such as Putty can be used to send or receive commands.



Baud Rate	9600
Data Bits	8
Stop Bits	1
Parity	None

USB-RS485-WE-1800-BT Cable

Digital Inputs and Outputs

The DIO connector on the rear panel has four digital inputs and outputs. The default operation of these pins is:

- Pin 2 (In1) A logic high will disable the amplifier and create a Hardware Overload condition as described in Overload Protection. To enable the amplifier, Pin 2 (In1) must be low or floating, and an enable command must be generated by the desktop software via USB or through the RS485 interface.
- Pin 4 (Out1) outputs a logic high (3.3V, or 24V optional) when the amplifier is disabled due to an overload or software disable, and 0V when the amplifier is enabled. The output impedance is 100 kOhm.

At present, the PDUS210 cannot be operated as a stand-alone device, it must be controlled via the USB or RS485 interface. However, a remote controller is in development which will permit control via a handheld device.

The In2 and Out2 signals are not currently assigned and are reserved for future use by a hand-held control unit.

The inputs and outputs are not isolated or protected against overload.

Warranty and Service

The PDUS210 is guaranteed against manufacturing defects for 12 months from the date of purchase.

Contact your distributor or info@piezodrive.com for service. Please include the amplifier serial number.