



User Guide 2024

PiezoBrush PZ3-c evaluation kit

Connecting the PiezoBrush PZ3-c to your MCU



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Connecting the PiezoBrush PZ3-c to your MCU

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Connecting the PiezoBrush PZ3-c to your MCU

Introduction

This application note provides an overview of the PiezoBrush PZ3-c and the PiezoBrush PZ3-c Evaluation Kit, including its features, specifications, and connectivity options. It also contains instructions for setting up and using the components, as well as sample code and project examples to help developers get started. Furthermore, it provides an easy-to-use platform for developers to explore the capabilities of the PiezoBrush PZ3-c, test firmware, and prototype designs. This application note will provide valuable insights and resources for making the most of the PiezoBrush PZ3-c and the evaluation board.

The purpose of the PiezoBrush PZ3-c evaluation kit:

- Easily conveys a first impression of TDK's PiezoBrush PZ3 cold plasma solution.
- Shows how the communication with the control of the PiezoBrush PZ3-c integration components work.
- Provides an example integration using an STM32 controller from STMicroelectronics and a display.

The PiezoBrush PZ3-c is designed to be integrated directly into other products and must always be combined with a suitable change module to produce plasma. An integration example is described based on the evaluation board.

Safety

Like with every technical product, incorrect or not intended use can be dangerous. The general instructions for operation must be followed to minimize residual risks. These can be found in the glossary included in this application note.

Caution – High electrical voltage!

Danger from sparks on the piezo element: Do not touch the piezo element or into the area of the plasma discharge.

Caution – Hot surfaces!

The change modules and treated surfaces can become hot during operation. Do not touch them until they have cooled down.

Caution – Emissions!

Dangerous amounts of the reaction gas ozone (O₃) may be produced during device operation.

- Volumes of ozone more than 0.2 mg/m³ may be produced.
- Note that national health and safety measures must be observed when operating the device.
- Only use the device in well-ventilated areas or in conjunction with a suitable extraction device.
- Do not leave the device running unattended.
- Do not point the device at people during operation.

Attention – Damage to device!

The piezo element inside the module may get damaged without proper cooling. For the cooling effect, an air flow of 8-15 l/min through the module is recommended. A maximum temperature of +85 °C must not be exceeded.

Fields of applications

Treating surfaces with atmospheric plasma has several advantages. These are e.g., the increase of surface energy to improve the wettability of the surface. An optimal surface wetting is the first and often decisive step to achieve excellent print quality, homogeneous coating, uniform varnishing, or an integrally bonded application of adhesives. The bond at this interface often determines the durability and adhesive strength of this material pairing.

Many different material classes can be efficiently processed under atmospheric pressure, such as metals, plastics, composite materials, glass, ceramics, natural stone, leather, natural fibers, etc.

Since plasma treatment is always just one part of the entire process, it is important to know the overall influences on the surface properties to achieve an optimum result.

Typical influencing factors are:

- Plasma process: distance to the substrate, speed
- Substrate/workpiece: material composition, contamination, electrical and thermal conductivity, moisture content
- Workpiece treatment: contamination before or after the process, the time between the plasma process and the follow-up process

Treatment examples can be requested directly from relyon plasma, a TDK Group Company.

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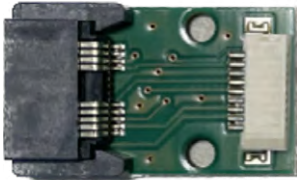
Scope of delivery

PiezoBrush PZ3-c (Z63000Z2910Z1Z87 – prototype)

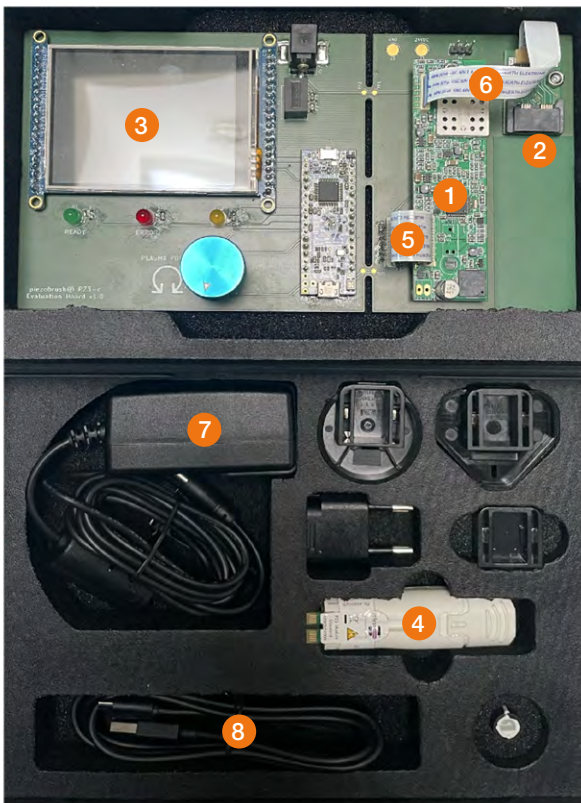
1. PiezoBrush PZ3-c driver board



2. PiezoBrush PZ3-c adaptor board



PiezoBrush PZ3-c evaluation kit (Z63000Z2910Z1Z82 – prototype)



1. PiezoBrush PZ3-c adaptor board
2. PiezoBrush PZ3-c evaluation board
3. PiezoBrush PZ3 module standard
4. 15-pin FFC cable
5. 9-pin FFC cable
6. Power supply
7. USB-A to micro USB-B cable

Connecting the PiezoBrush PZ3-c to your MCU

PiezoBrush PZ3-c components

Overview

PiezoBrush PZ3-c consists of the driver board and the adaptor board. The driver board is the central control unit that receives control signals and outputs status messages via a serial interface (see 15-pin Molex FFC connector). It also controls the connected PiezoBrush PZ3 module that is plugged into the adaptor board which is connected to the driver board.

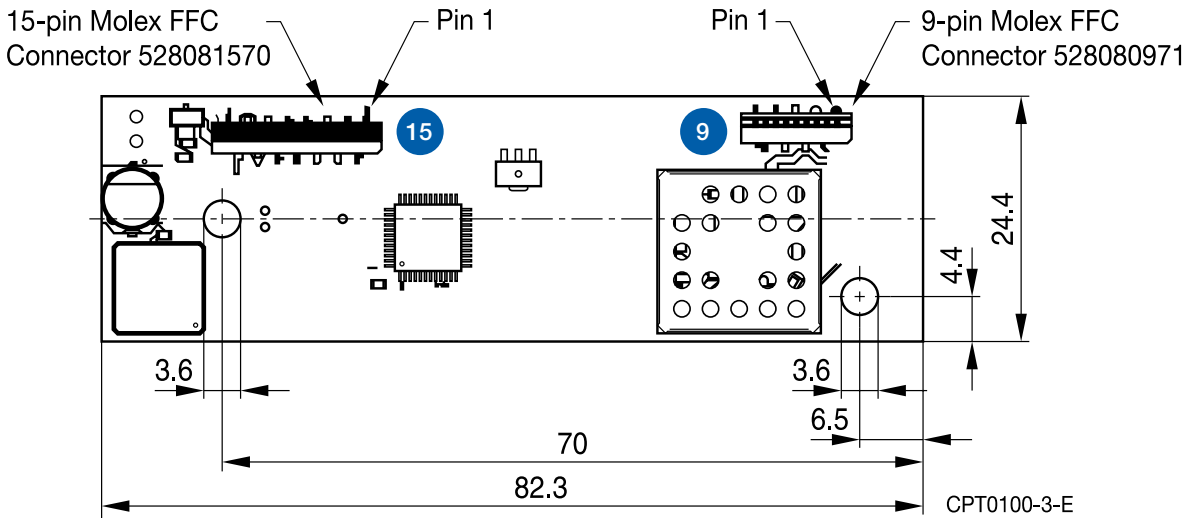


Figure 1: PiezoBrush PZ3-c driver board

Further documentation:

1. Product Profile PiezoBrush PZ3
2. Preliminary Datasheet PZ3-c
3. Preliminary Datasheet PZ3-c evaluation kit

15-pin molex FFC connector

| 15 Pin-Belegung/PIN CONFIGURATION | |
|-----------------------------------|-------------------------|
| Pin # | Bezeichnung/NAME |
| 1 | -not connected- |
| 2 | on/off |
| 3 | RS232 RX |
| 4 | -reserved / do not use- |
| 5 | RS232 TX |
| 6 | -reserved / do not use- |
| 7 | -reserved / do not use- |
| 8 | -not connected- |
| 9 | ERROR |
| 10 | -not connected- |
| 11 | PLASMA OK |
| 12 | +24V DC SUPPLY VOLTAGE |
| 13 | GND |
| 14 | -reserved / do not use- |
| 15 | -reserved / do not use- |

Pin 2: Analog 3.3 V input for switching plasma on/off.

Note: This input is not used when using UART API (see Activating UART API).

Pin 3: UART RX (driver board serial interface receive)

Pin 5: UART TX (driver board serial interface transmit)

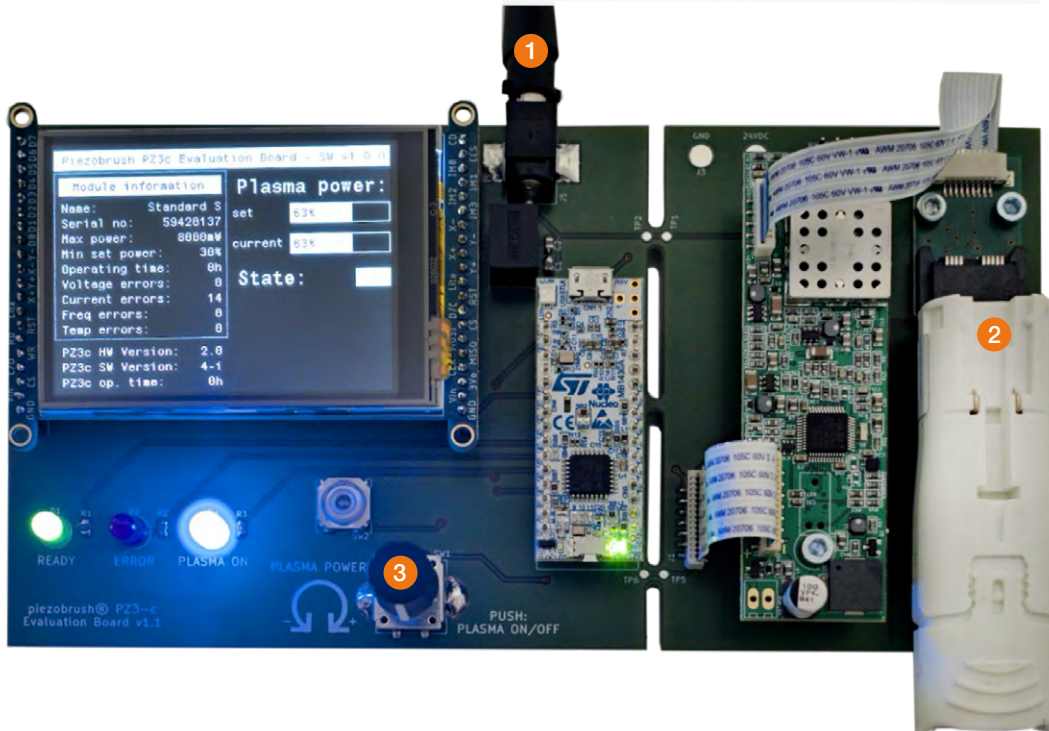
Pin 12: +24 V DC

Pin 13: GND

Connecting the PiezoBrush PZ3-c to your MCU

PiezoBrush PZ3-c evaluation board usage

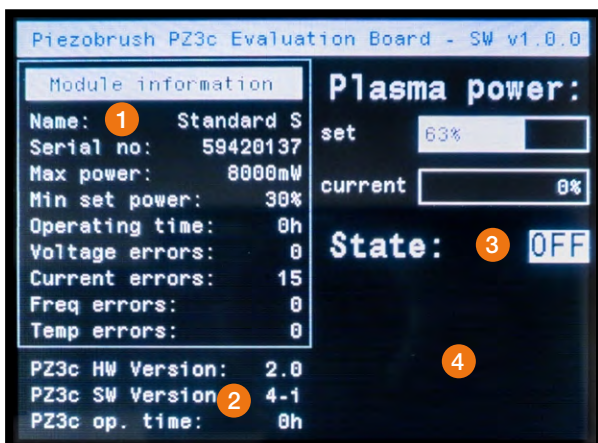
Starting the evaluation kit



1. Connect the 24 V DC power supply (1).
2. Insert a PiezoBrush PZ3 module into the adaptor board (2).
3. Set the desired plasma output power in % relative to maximum power of the module by rotating the knob (3).
4. Start plasma generation by pressing the knob (3).
5. To stop the plasma generation, press the knob again (3).

Information shown in the display

The display of the evaluation board only shows a selection of the available parameters. For a full list of available parameters see Protocol description: reply (data frame from PiezoBrush PZ3-c).



1. Module information

This section displays information about the currently connected module, like serial number, maximum plasma power, minimal power setting, etc. When no module is connected, the values are empty.

2. Driver information

This section shows some basic information about the driver board.

3. Plasma power

This section displays the setpoint and the actual value of the plasma power. It also shows if the plasma generation is running.

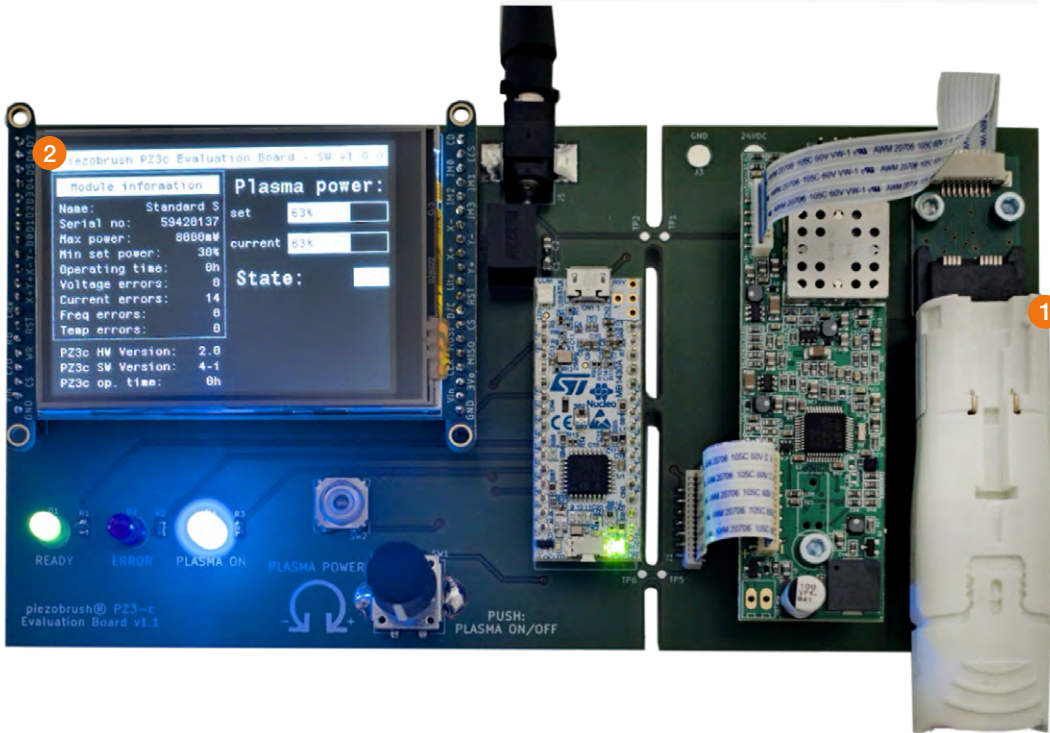
4. Warnings/alarms

This section displays possible warnings and alarms

Connecting the PiezoBrush PZ3-c to your MCU

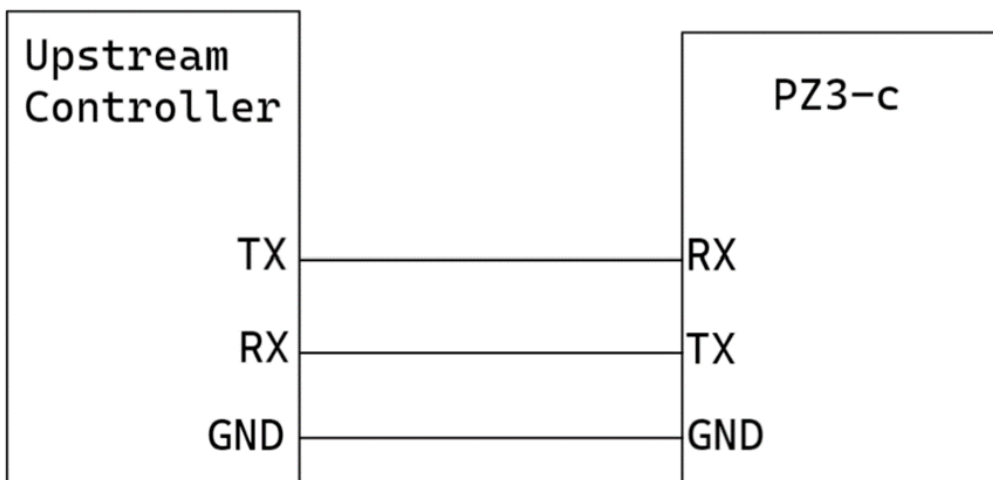
PiezoBrush PZ3-c evaluation board usage

Provoking a plasma error



The easiest way to provoke an error is to hold a screwdriver in front of the plasma jet (1). The driver board detects this condition and informs the MCU of the evaluation board, which shows a message in the display (2). Before the plasma generation can be restarted, an error reset must be done on the driver board. The MCU on the evaluation board will do this when the rotary encoder is pressed for at least 2 seconds.

Connecting the PiezoBrush pz3-c to an upstream controller



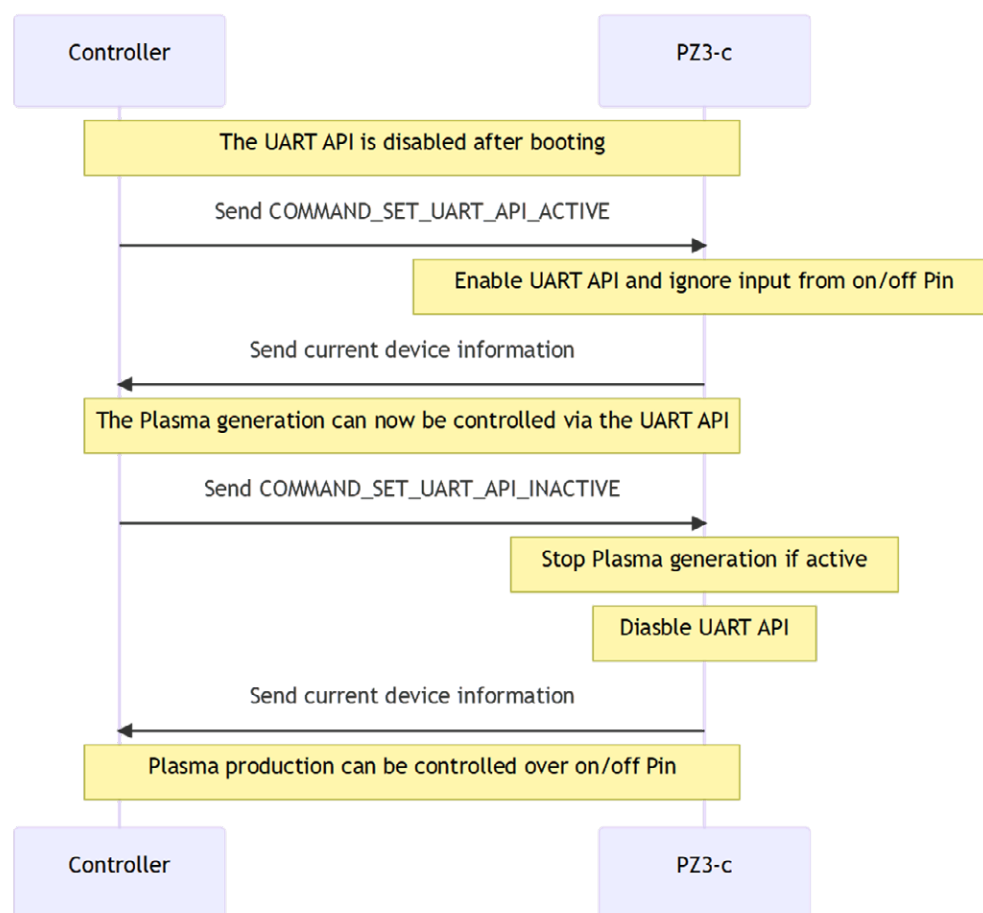
To connect the PiezoBrush PZ3-c to an upstream control unit (MCU or PC) the RX and TX pins must be connected as shown above. The PiezoBrush PZ3-c requires a signal level of 3.3 V. If the control unit uses a different voltage for the signals, a level converter must be used.

Connecting the PiezoBrush PZ3-c to your MCU

Communicating with the PiezoBrush PZ3-c

- Activation of UART API is necessary to be able to control the PiezoBrush PZ3-c over UART.
- UART API must be activated after each power cycle.
- After UART API activation, the on/off pin (see 15-pin Molex FFC connector) cannot be used anymore. Thus, plasma generation can be controlled via UART API only.
- The controller always sends a DriveCommand_t package (see protocol description: Command (data frame to PiezoBrush PZ3-c)) to the driver board.
- The driver board always answers with a DriveReply_t package (see protocol description: reply (dataframe from PiezoBrush PZ3-c)).

Activating UART API



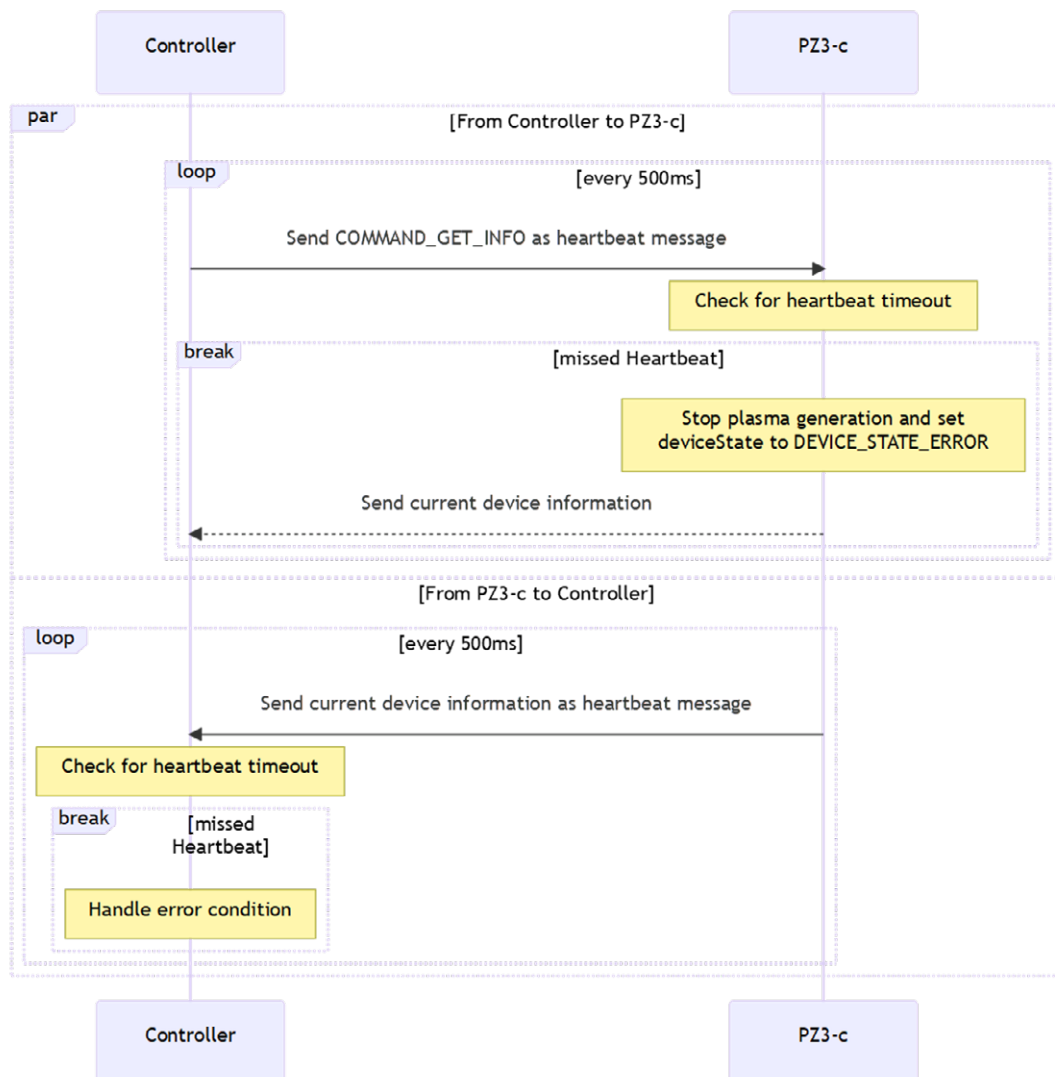
When the PiezoBrush PZ3-c is switched on, control via the UART interface is deactivated. Control is only possible via pin 2 on the 15-pin connector. To enable control via the UART interface, the command 'COMMAND_SET_UART_API_ACTIVE' must be sent to the device. For a description of the command structure see the appendix Protocol description: Command (data frame to PiezoBrush PZ3-c).

To deactivate the control via the UART interface the command 'COMMAND_SET_UART_API_INACTIVE' must be sent to the PiezoBrush PZ3-c. Afterwards, the device can be controlled again via pin 2 at the 15-pin connector.

Connecting the PiezoBrush PZ3-c to your MCU

Communicating with the PiezoBrush PZ3-c

Heartbeat protocol



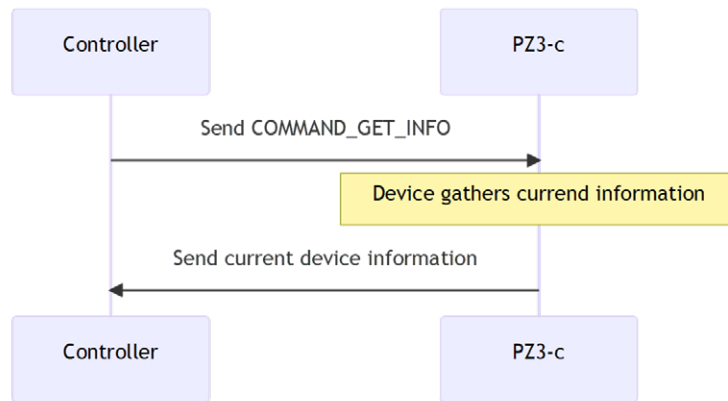
The PiezoBrush PZ3-c uses a heartbeat protocol to monitor the connection to the upstream controller. If this connection is interrupted, plasma generation is stopped immediately. The heartbeat monitoring starts and ends with the activation/deactivation of the UART interface. If this interface is activated, the device sends a data packet of type DriveReply_t every 500 ms.

In return, the PiezoBrush PZ3-c expects a DriveCommand_t package from the higher-level controller at regular intervals. The command 'COMMAND_GET_INFO' can be used as a heartbeat message. If this heartbeat message is missing for more than 5 s, the plasma generation is stopped, and an error is triggered.

Connecting the PiezoBrush PZ3-c to your MCU

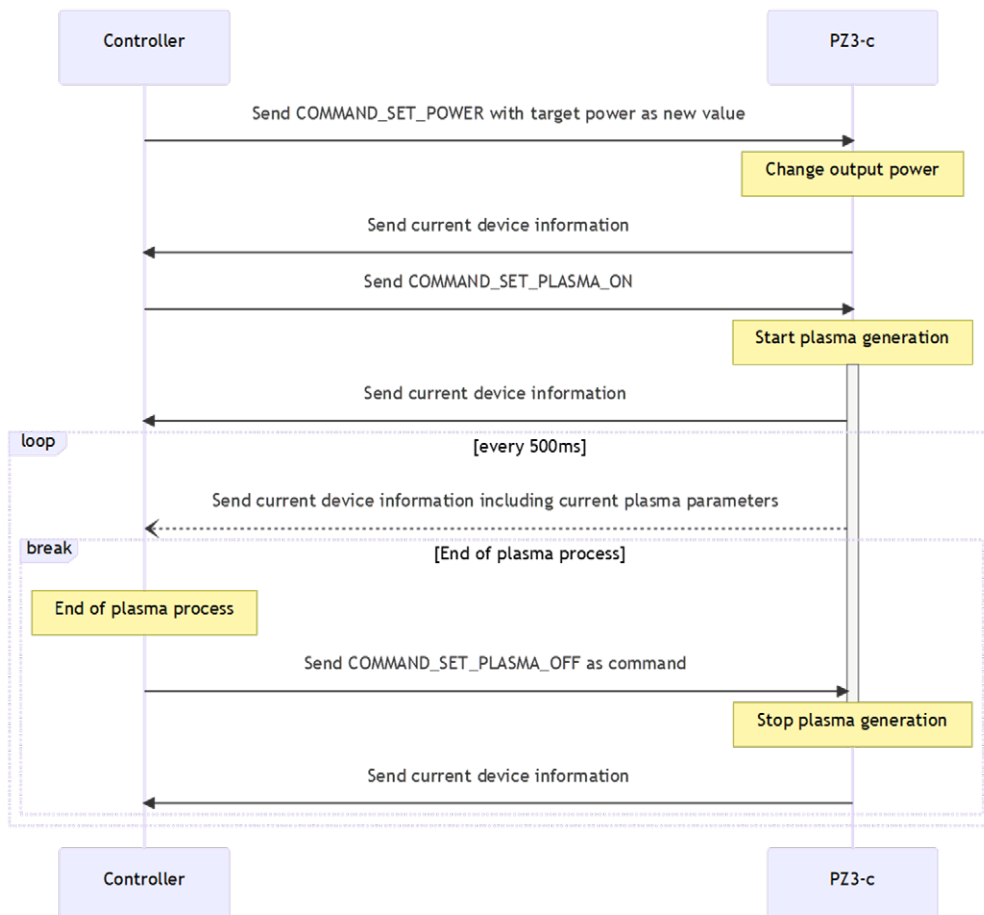
PiezoBrush PZ3-c components

Request the current device information



After the UART API has been activated, the current device information can be queried at any time with the command 'COMMAND_GET_INFO'.

Controlling plasma generation



Connecting the PiezoBrush PZ3-c to your MCU

PiezoBrush PZ3-c components

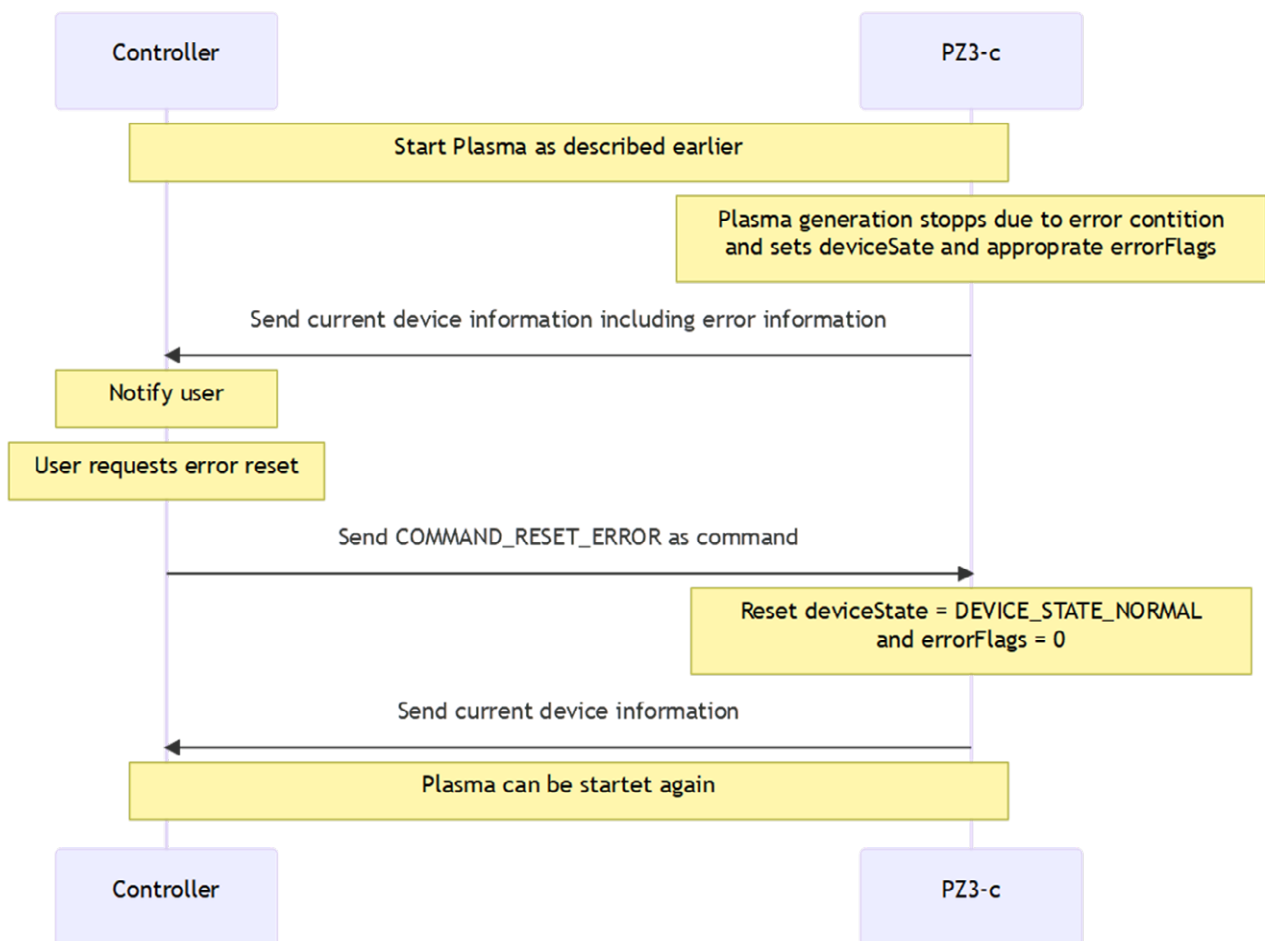
After activating the UART API, the plasma generation can be started with the command 'COMMAND_SET_PLASMA_ON'. With the command 'COMMAND_SET_POWER' the desired plasma power in percent can be set in the field 'value'.

Note: The attempt to set a lower power than specified by the module will be ignored by the PiezoBrush PZ3-c.

To stop the plasma generation the command 'COMMAND_SET_PLASMA_OFF' must be sent.

Important: It is recommended to explicitly set the value of the plasma power before starting the plasma generation!

Error condition and reset



If an error has occurred, the PiezoBrush PZ3-c stops the plasma generation and prevents a restart. Before plasma generation can be restarted, the higher-level controller must reset the error. This is done by sending the command 'COMMAND_RESET_ERROR'. The PiezoBrush PZ3-c then responds with its current device information. The contents of the 'deviceState' and 'errorFlags' fields can be used to check whether the error was successfully reset.

Module change

With each module change (insertion/removal), new device information is sent from PiezoBrush PZ3-c to the controller. After changing the module, the power setting is kept at the current value by PiezoBrush PZ3-c drive. The PiezoBrush PZ3-c evaluation board sets the power setting to 100% after changing the module.

Connecting the PiezoBrush PZ3-c to your MCU

Using the example code

Installing the IDE

To work with the provided program example, we recommend the use of the software 'STM32CubeIDE'.

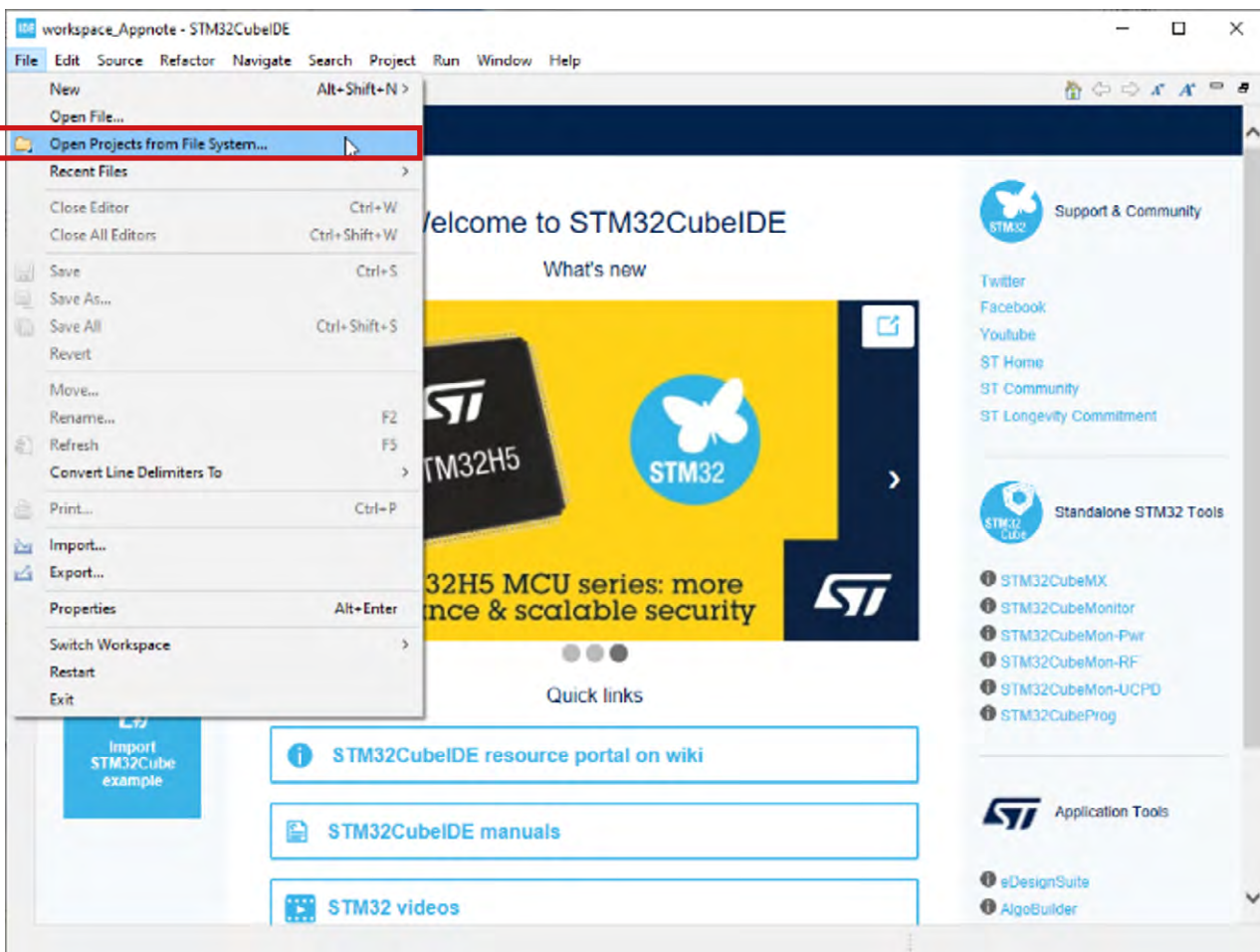
This can be downloaded free of charge under the following link: <https://www.st.com/en/development-tools/stm32cubeide.html>

For installation, please follow the manufacturer's instructions:

https://www.st.com/resource/en/user_manual/um2563-stm32cubeide-installation-guide-stmicroelectronics.pdf

Compiling the example code

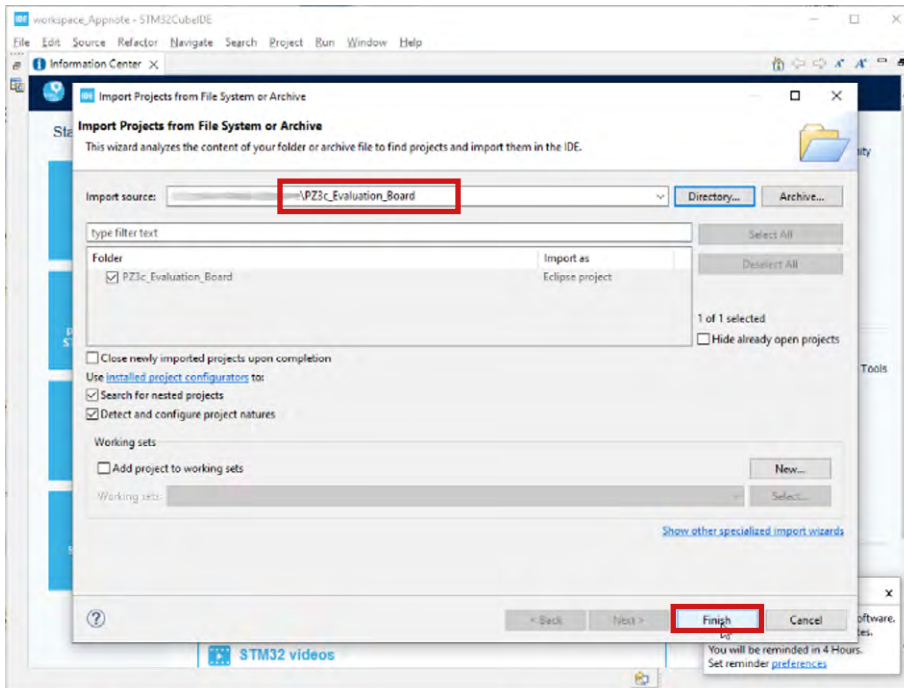
Open the provided code example in STM32CubeIDE.



Connecting the PiezoBrush PZ3-c to your MCU

Using the example code

Compiling the example code



Now the evaluation board can be connected to a PC and the run button can be pressed. The IDE will compile and upload the code.

Structure of example code

| | | | |
|-----|------------------------------------|--------------------|--|
| IDE | PZ3c_Evaluation_Board | -crc | Initialization and calculation of CRC |
| > | Binaries | -dma | Initialization of DMA used for SPI and USART |
| > | Includes | -gpio | Initialization of GPIO pins |
| > | Core | -spi | Initialization of SPI used for the display |
| > | Inc | -stm32g4xx_hal_msp | STM32 specific hardware initialization functions |
| > | Src | -stm32g4xx_it | STM32 specific interrupt functions |
| > | crc.c | -syscalls | STM32 specific minimal system call functions |
| > | dma.c | -system | STM32 specific memory management functions |
| > | display.c | -system_stm32g4xx | STM32 specific clock initialization functions |
| > | gpio.c | -tim | Initialization of timers |
| > | ili9341_font.c | -usart | Initialization of USART |
| > | ili9341_gfx.c | | |
| > | ili9341.c | | |
| > | main.c | | |
| > | pz3c_communication.c | | |
| > | spi.c | | |
| > | stm32g4xx_hal_msp.c | | |
| > | stm32g4xx_it.c | | |
| > | syscalls.c | | |
| > | system.c | | |
| > | system_stm32g4xx.c | | |
| > | tim.c | | |
| > | usart.c | | |
| > | Startup | | |
| > | Drivers | | |
| > | Debug | | |
| > | Release | | |
| > | Release | | |
| > | PZ3c_Evaluation_Board.ioc | | |
| > | PZ3c_Evaluation_Board.Debug.launch | | |
| > | STM32G431KBTX_FLASH.ld | | |

Connecting the PiezoBrush PZ3-c to your MCU

Application mode modules

These autogenerated modules can contain user code that will not be changed when autogenerated again.

These user code parts must be inside of specific comment sections (e.g. `/* USER CODE BEGIN XXX */` and `/* USER CODE END XXX */`), otherwise the user code parts will be deleted when autogenerated again

The following application code modules exist:

- `display` Functions for UI elements using ili9341_x modules
 - `ili9341_font` Font definition for used display
 - `ili9341_gfx` Graphic primitives for used display
 - `ili9341` Hardware driver for used display
 - `main` Application code
 - `pz3c_communication` Functions for PiezoBrush PZ3-c communication
-

Connecting the PiezoBrush PZ3-c to your MCU

Appendix

Driver board control

All pins needed to power or communicate with the driver board are located on the 15-pin Molex FFC connector.

The digital communication interface is a serial interface (UART) with the following configuration:

| | |
|---------------|--------|
| Interface | RS-232 |
| Voltage Level | 3.3 V |
| Baud rate | 115200 |
| Data bits | 8 |
| Stop bits | 1 |
| Parity | None |

Warning: The interface only supports 3.3 V signal levels. Higher voltages will damage the device.

Protocol description: command (data frame to PiezoBrush PZ3-c)

DriveCommand_t

| Name of variable | Type | Description |
|------------------|----------|---|
| header | char[3] | ASCII Characters "PZ3" |
| command | uint8_t | 00h = COMMAND_GET_INFO 01h = COMMAND_SET_UART_API_ACTIVE (disables on/off pin on 15-pin Molex FFC connector) 02h = COMMAND_SET_UART_API_INACTIVE (enables on/off pin on 15-pin Molex FFC connector) 03h = COMMAND_SET_PLASMA_ON 04h = COMMAND_SET_PLASMA_OFF 05h = COMMAND_SET_POWER 06h = COMMAND_RESET_ERROR (so that the device gets back to DEVICE_STATE_NORMAL) Other values are ignored |
| value | uint8_t | additional parameter (e.g., set plasma power in percent) |
| crc | uint32_t | CRC32 Checksum of the previous data fields |

Protocol description: reply (data frame from PiezoBrush PZ3-c)

DriveReply_t

| Name of variable | Type | Description |
|------------------|-------------------------|--|
| header | char[3] | ASCII Characters "PZ3" |
| deviceInfo | DeviceInfo_t (40 bytes) | Device information struct |
| moduleInfo | ModuleInfo_t (34 bytes) | Module information struct |
| crc | uint32_t | CRC32 Checksum of the previous data fields |

Connecting the PiezoBrush PZ3-c to your MCU

Appendix

Protocol description: reply (deviceinfo struct)

DeviceInfo_t

| Name of variable | Type | Description |
|-----------------------|----------|---|
| firmwareVersion | char[3] | Firmware version string |
| hardwareVersion | char[3] | Hardware version string |
| deviceState | uint8_t | 00h = DEVICE_STATE_NORMAL (no warning and no error) 01h = DEVICE_STATE_WARNING (at least one warning; Warning will be reset automatically when the state changes.) 02h = DEVICE_STATE_ERROR (at least one error; Reset by reset error command necessary to get the device back to normal state.) |
| deviceFlags | uint8_t | 01h = Module inserted 02h = Plasma on 04h = UART API active 08h = plasma error mitigation active (plasma errors are treated as warnings) |
| operatingTimeSeconds | uint32_t | Operating time in seconds during which the plasma was switched on |
| warningFlags | uint8_t | Warning flags when deviceState in warning state: 01h = Plasma (Driver stage parameters for plasma generation are not in optimal range) 02h = Temperature (Device temperature is getting too high.) |
| errorFlags | uint8_t | Error flags when deviceState in error state: 01h = Plasma (Plasma generator is not working correctly.) 02h = Temperature (Device temperature is too high – plasma generation can't be started.) 04h = Module (Module EEPROM contains invalid data) 08h = Heartbeat (too many missing heartbeats from the upstream controller) |
| powerSettingPercent | uint8_t | Plasma power setting in percent relative to maxPowerMilliWatts of module |
| frequencyHz | uint32_t | Current operating frequency of driver stage |
| voltageV | uint16_t | Current operating voltage of driver stage |
| currentmA | uint16_t | Current operating current of the driver stage |
| effectivePowermW | uint16_t | Current operating effective power of driver stage |
| phasemDegree | int32_t | Current operating phase angle of the driver stage |
| impedancemOhm | uint16_t | Current operating impedance of driver stage |
| temperatureCelsius | int8_t | Current temperature of the driver stage |
| errorVoltageCount | uint16_t | Error counter of all used modules for operation in voltage limitation (e.g., when using Nearfield module) |
| errorCurrentCount | uint16_t | Error counter of all used modules for operation in current limitation (e.g., standard module) |
| errorFrequencyCount | uint16_t | Error counter of all used modules for operating frequency could not be found (e.g., fractured CeraPlas) |
| errorTemperatureCount | uint16_t | CRC32 checksum of the previous data fields |

Connecting the PiezoBrush PZ3-c to your MCU

Appendix

Protocol description: reply (moduleinfo struct)

ModuleInfo_t

| Name of variable | Type | Description |
|------------------------|----------|---|
| name | char[15] | Module name in ASCII |
| serialNumber | uint32_t | Serial number |
| operatingTimeSeconds | uint32_t | Operating time in seconds during which the plasma was switched on |
| maxPowerMilliWatts | uint16_t | Maximum power in milliwatts |
| minPowerSettingPercent | uint8_t | Minimum power setting in percent that is needed to be able to create plasma |
| errorVoltageCount | uint16_t | Error counter for operation in voltage limitation (e.g., when using Nearfield module) |
| errorCurrentCount | uint16_t | Error counter for operation in current limitation (e.g., standard module) |
| errorFrequencyCount | uint16_t | Error counter for operating frequency couldn't be found (e.g., broken PiezoBrush) |
| errorTemperatureCount | uint16_t | Error counter for driver stage overheating |

Glossary

| Symbols | Terms |
|---------|---|
| API | Application programming interface |
| CRC | cyclic redundancy check |
| DC | Direct current |
| FFC | Flat flexible cable |
| IDE | Integrated development environment |
| MCU | microcontroller unit |
| RS-232 | Standard for serial communication |
| RX | Receive channel |
| TX | Transmit channel |
| UART | Universal Asynchronous Receiver Transmitter |

Connecting the PiezoBrush PZ3-c to your MCU

Cautions and warnings



Note: No warranty or liability shall arise for the supplier out of and in connection with these products. The use shall be at the sole risk of the purchaser. The supplied product is a development sample and has prototype status only and may not be used in series products of the purchaser. Our products are subject to a continuous improvement process, which may lead to changes in product specifications. Therefore, we ask you to contact your sales channel or visit our TDK website to find out more about the current specification status of our products for your follow-up orders.

General

- Do not use the change module for purposes not identified in our specifications, application notes, and data books.
- Ensure the suitability of the components by testing them for reliability during design-in. Always evaluate the components under worst-case conditions.

Design notes

- Do not use the components in safety-relevant applications.
- Ensure that the surface temperature does not exceed the maximum operating temperature.
- Specified values only apply to change modules that have not been subject to prior electrical, mechanical, or thermal damage.

Storage

- Store the components in a dry place. This will prevent corrosion of the electrical contacts.
- Only store the components in their original packaging. Do not open the package before storage.
- Do not store the components where they are exposed to heat or direct sunlight. Otherwise, the packaging material may be deformed.
- Avoid contamination of the components during storage, handling, and processing.
- Avoid storing the components in harmful environments where they are exposed to corrosive gases, for example SO_x, Cl.

Handling

- Do not drop the components.
- Do not touch the piezo element and the contact board.
- Avoid contamination of the components during handling.
- Do not touch the piezo element during operation (danger of high voltage, damping the acoustic wave inside the ceramic body, damaging the ceramic body).
- Do not reach into the work area during plasma generation.
- Read the data sheet and safety requirements of the used PiezoBrush PZ3 change modules carefully before assembling, installing, and starting up the device.

Connecting the PiezoBrush PZ3-c to your MCU

Cautions and warnings

Operation

- Use the components only within the specified operating temperature range.
- Use the components only within specified voltage and power ranges.
- Use the components only with PiezoBrush PZ3 change modules.
- The components must be operated in a dry atmosphere, which must not contain any additional chemical vapor or substances.
- Environmental conditions must not harm the components. Only use them in normal atmospheric conditions.
- Prevent the components from contacting liquids and solvents. Make sure that no water enters the components.
- Avoid dewing and condensation.
- The components are mainly designed for encased applications. Under all circumstances avoid exposure to:
 - direct sunlight
 - rain or condensation
 - steam, saline spray
 - corrosive gases
 - atmosphere with reduced oxygen content
 - explosive zones
 - areas with severe build-up of dust
 - altitudes more than 2000 m above sea level
 - strong vibrations
- Avoid electrically conducting materials closer than 60 mm to the front third of the PiezoBrush PZ3 when using the change module "Standard".
- High voltage hazard! The piezo element can reach voltages of up to 10 kV!
- The components can become hot during operation. Do not touch them until they have cooled down.
- The workpiece to be treated can become heated up by the plasma process depending on the process parameters. If necessary, allow the workpiece to cool down before handling it.
- Take special care of the toxicity of ozone! Use a ventilation system to remove the ozone. Depending on air flow around the output of the transformer the ozone concentration can reach very high values!
- Use air or inert gases only! Do not use flammable working gases!
- TDK is not responsible for any harm during the operating and testing of the components!
- Read the installation and safety information of the change modules before assembling, installing, and starting up the device.
- Always follow the safety instructions because non-compliance may result in serious or fatal injury.

This listing does not claim to be complete but merely reflects the experience of TDK.

Important notes

The following applies to all products named in this publication:

1. Some parts of this publication contain **statements about the suitability of our products for certain areas of application**. These statements are based on our knowledge of typical requirements that are often placed on our products in the areas of application concerned. We nevertheless expressly point out **that such statements cannot be regarded as binding statements about the suitability of our products for a particular customer application**. As a rule we are either unfamiliar with individual customer applications or less familiar with them than the customers themselves. For these reasons, it is always ultimately incumbent on the customer to check and decide whether a product with the properties described in the product specification is suitable for use in a particular customer application.
2. We also point out that **in individual cases, a malfunction of electronic components or failure before the end of their usual service life cannot be completely ruled out in the current state of the art, even if they are operated as specified**. In customer applications requiring a very high level of operational safety and especially in customer applications in which the malfunction or failure of an electronic component could endanger human life or health (e.g. in accident prevention or life-saving systems), it must therefore be ensured by means of suitable design of the customer application or other action taken by the customer (e.g. installation of protective circuitry or redundancy) that no injury or damage is sustained by third parties in the event of malfunction or failure of an electronic component.
3. **The warnings, cautions and product-specific notes must be observed**.
4. In order to satisfy certain technical requirements, **some of the products described in this publication may contain substances subject to restrictions in certain jurisdictions (e.g. because they are classed as hazardous)**. Useful information on this will be found in our Material Data Sheets on the Internet (www.tdk-electronics.tdk.com/material). Should you have any more detailed questions, please contact our sales offices.
5. We constantly strive to improve our products. Consequently, **the products described in this publication may change from time to time**. The same is true of the corresponding product specifications. Please check therefore to what extent product descriptions and specifications contained in this publication are still applicable before or when you place an order.

We also **reserve the right to discontinue production and delivery of products**. Consequently, we cannot guarantee that all products named in this publication will always be available.

The aforementioned does not apply in the case of individual agreements deviating from the foregoing for customer-specific products.
6. Unless otherwise agreed in individual contracts, **all orders are subject to our General Terms and Conditions of Supply**.
7. **Our manufacturing sites serving the automotive business apply the IATF 16949 standard**. The IATF certifications confirm our compliance with requirements regarding the quality management system in the automotive industry. Referring to customer requirements and customer specific requirements ("CSR") TDK always has and will continue to have the policy of respecting individual agreements. Even if IATF 16949 may appear to support the acceptance of unilateral requirements, we hereby like to emphasize that **only requirements mutually agreed upon can and will be implemented in our Quality Management System**. For clarification purposes we like to point out that obligations from IATF 16949 shall only become legally binding if individually agreed upon.
8. The trade names EPCOS, CarXield, CeraCharge, CeraDiode, CeraLink, CeraPad, CeraPlas, CSMP, CTVS, DeltaCap, DigiSiMic, FilterCap, FormFit, InsuGate, LeaXield, MediPlas, MiniBlue, MiniCell, MKD, MKK, ModCap, MotorCap, PCC, PhaseCap, PhaseCube, PhaseMod, PhiCap, PiezoBrush, PlasmaBrush, PowerHap, PQSine, PQvar, SIFERRIT, SIFI, SIKOREL, SilverCap, SIMDAD, SiMic, SIMID, SineFormer, SIOV, ThermoFuse, WindCap, Xield-Cap are **trademarks registered or pending** in Europe and in other countries. Further information will be found on the Internet at www.tdk-electronics.tdk.com/trademarks.

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