OSX – Open-SDI12-Blue

Version Conductivity (inductive), Type 450

1 Quick setup

OSX Conductivity (IP68 for permanent immersion until max. over pressure)

The **OSX Conductivity** is a SDI12 Conductivity Transmitter, based on an inductive measurement system. Because of its high sensitivity it is ideal for use with Sweet Water and irrigation. Compared to sensors based on galvanic measurement systems, the **OSX Conductivity** was designed for long term monitoring in the medium.

By default the OSX is configured as:

- Conductivity Ranges: 0 – 2000 µS/cm, 0 – 20 mS/cm, 0 – 60 mS/cm, Resolution: 0.05 %FS
- Long Term Stability: typ. ± 0.1 %FS, max. ± 0.2 %FS
- Conductivity Accuracy: max. ± 0.15 %FS
- Ultra-Low-Power operation of the sensor
- Easy calibration
- Temperature: -40 – +85°C, Resolution 0.25 °C
- Temperature Accuracy (uncalibrated): typ. ca. +/- 1 °C
- Sensor size ca. 120 mm x 35 mm x 35 mm

SDI-12-Cable (core cable ends or optionally with Connector (AKL-169-04 (RIA CONNECT, RM 3.5mm)):

YELLOW:	GND
WHITE:	7.5V-16V Supply
GREEN:	SDI-12 Signal

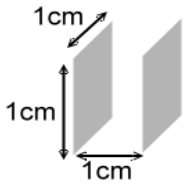
2 Overview and Operation Principle

The electrical conductivity of liquids is a very important industrial parameter. Electrical conductivity is not only a measure of purity, potability or contamination in the case of water, but also, for example, in the quality control of milk or in agricultural engineering in general.

Especially for water, however, the range is quite high:

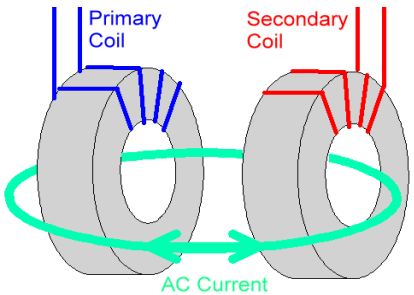
- Very pure water is in the range <1 µS/cm
- Drinking water typ. in the range 300 - 1000 µS/cm
  E.g. (according to Internet and at 25°C):
  - Stadtwerke Karlsruhe: 700 µS/cm
  - Stadtwerke Bochum: 400 µS/cm
- Sea and dirty water in the range of 50 mS/cm

For example, 1µS/cm means that there is an electrical resistance of 1 MOhm between two cross-sections of 1 cm², while 50 mS/cm corresponds to a resistance of 20 Ohms.
To determine the conductance, the electrical resistance between the two plates is measured:



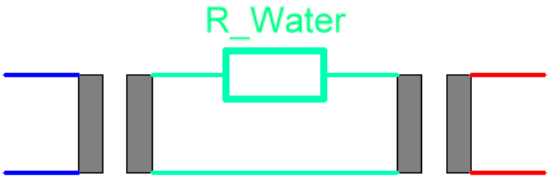
Unfortunately, this direct resistance measurement is not trivial because electrical contact between the plates and the water is quite difficult due to boundary layers, electrical passivation, biofilms, fouling, long-term stability or electrolytic effects, and is only reasonably easy with laboratory sensors and clean water (Conductivity is generally measured at 25°C, but has a negligible, slight temperature dependence here).

For practical, industrial or continuous applications, a second method exists which inductively couples an electrical voltage into the liquid:



Structure of the Inductive Sensor

Explanation: The two coils form a double transformer, with the water path (green) forming the middle part of the inner transformer:



Equivalent circuit of the inductive method

On the primary side a sinusoidal oscillation in the range of approx. 10 kHz - 1000 kHz, but mostly approx. 30 kHz - 100 kHz, is usually coupled in; lower frequencies are more suitable, but are technically more difficult to implement. The water forms the secondary circuit of the first transformer and the primary circuit of the second transformer. The conductance (R_Water) results from the secondary voltage of the right side.

3 Basic commands

The command set is based on standard SDI12 (V1.3) command set. Most important commands:

aAn! : Change Address from ‘a’ to ‘n’. (a might be always be a ‘?’ as wild card).

aI! : Identify Node (should identify as ‘a13TT_CondI_0450_OSXxxxxxxxx’)

aM! : Start measure (also ‘aMC!’). This will start the measure. After finishing all measured values are available in an internal cache. Up to 2 data may be read with the „D“- command: 0.) Conductivity and 1.) Temperature

aM1! : Start measure (also ‘aMC1!’). This will start the measure including Supply Voltage. After finishing all measured values are available in an internal cache. Up to 3 data may be read with the „D“- command:
0.) Conductivity, 1.) Temperature and 2.) Voltage

aM9! : Start measure (also ‘aMC9!’). This will start the measure including Data for calibration. After finishing all measured values are available in an internal cache. Up to 6 data may be read with the „D“- command:
0.) Conductivity, 1.) Temperature, 2.) Voltage, 3.) Conductivity (uncompensated), 4.) Raw Signal and 5.) Reference Signal

aD0! : This will read the 1 to max. 6 measures from the preceding „M“- command.

Error codes (all values lower than -999):

- 999: Voltage low

others: Displayed as text in BLX.JS or BlueShell

4 The Open-SDI12-Blue platform

OSX Sensors are based on an open platform:

Link: https://github.com/joembedded/Open-SDI12-Blue

Important: the range of the Bluetooth-Signal is limited to ca. < 1 meter (in air) and the Bluetooth signal is very strongly attenuated by water. Therefore, communication via Bluetooth is only possible when the sensor is outside of water or very close to the surface.

5 Software

5.1.1 Software to access the sensor

OSX Sensors can accessed by SDI12 (V1.3) or Bluetooth BLE or SDI12 via Bluetooth.

- BlueShell for PC (Windows 10 / 11)
- BLX.JS (PC (Browsers: Chrome, Edge, Opera, …) or Android). No APP required!

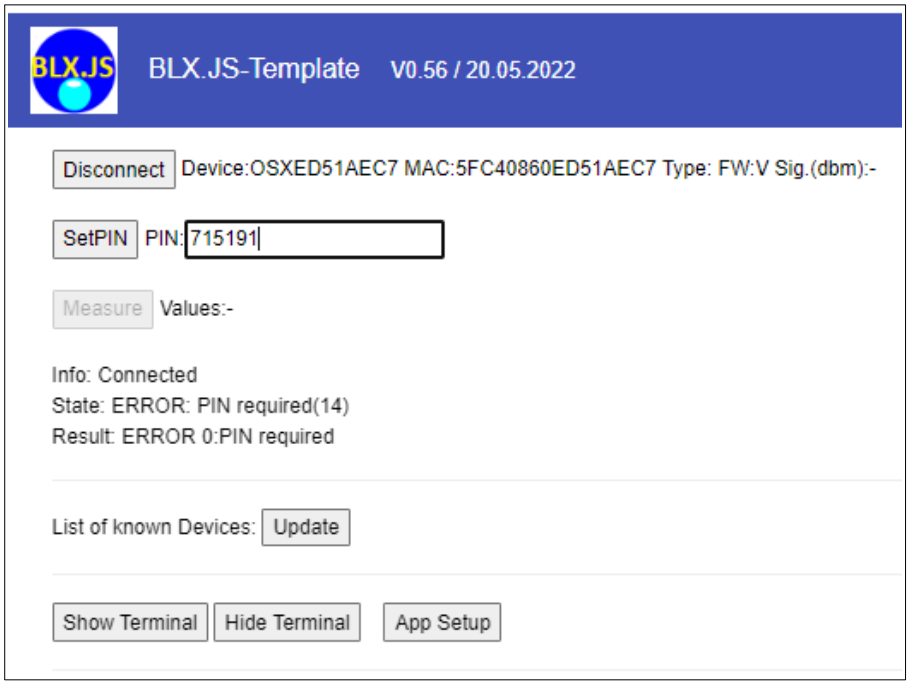
Link: Download Link BlueShell or BLX.JS

5.1.2 Software for SDI12

- A simple SDI12Term for PC (Windows) (connect SDI12 sensors via RS232)

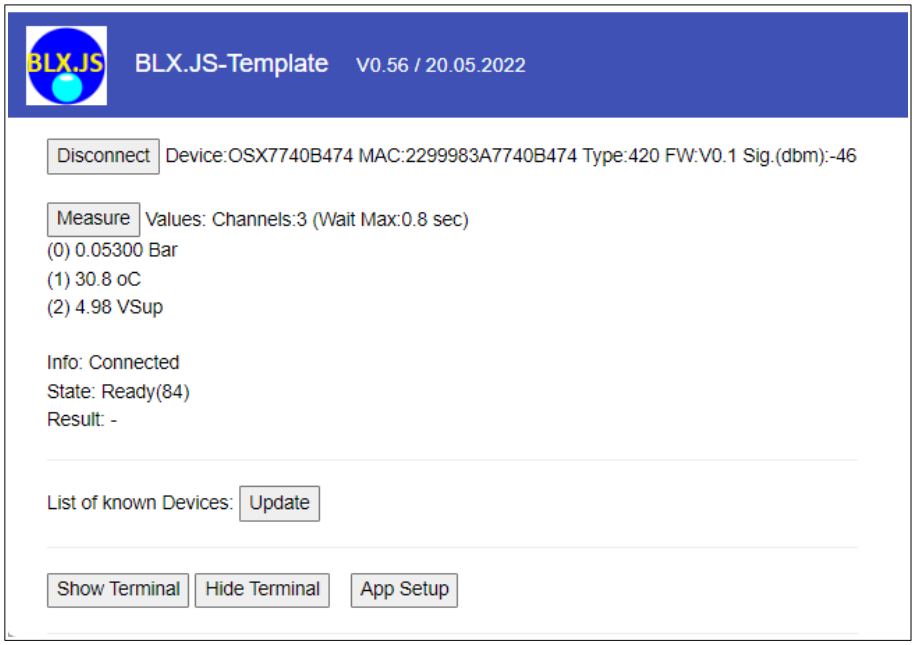
Link: https://github.com/joembedded/SDI12Term

6 Sample session BLX.JS



Enter PIN only required once!

The sensors are locked with a 6 digit PIN (Authentification method: Challenge-Response)



Measure

7 Commands

A selection of commands for setup (enter via BLX.JS or BlueShell Terminal)

7.1.1 Commands for this type (Type 450):

Measure:

- M or MC or M1 or MC1 or M9 orf MC9 starts the measure, measure takes < 1 sec (optionally the Warm-Up Time can be changed, see below)
- D replies the values

7.1.2 Standard commands for Open-SDI12-Blue (SDI12 via BLE):

All „SDI12 via BLE“ commands are preceded by ‚z‘:

> z?I!	SDI12 via BLE: Identify
Reply: '013TT_CondI_0450_OSX7740B474<CR><LF>'	
End: 'OK' (Runtime: 229 msec)	
> z?M!	SDI12: Measure
Reply: '00012<CR><LF>'	
Reply: '0<CR><LF>'	
End: 'OK' (Runtime: 358 msec)	
> z?D0!	SDI12: Values
Reply: '0+0.00032+26.36<CR><LF>'	
End: 'OK' (Runtime: 302 msec)	
> z?MC!	SDI12: Measure+CRC
Reply: '00012<CR><LF>'	
Reply: '0<CR><LF>'	
End: 'OK' (Runtime: 387 msec)	
> z?D0!	SDI12: ‚@|‘ is CRC
Reply: "0+0.00025+30.8@C|<CR><LF>'	
End: 'OK' (Runtime: 290 msec)	
> z?XDevice!	SDI12: XDevice
Reply: '0M:2299983A7740B474,T:450,V1.0, P:321144!<CR><LF>'	SDI12: Red: Device.PIN
End: 'OK' (Runtime: 299 msec)	
> z?XSensor!	SDI12: Get Sensor Info
Reply: '0CondInductive!<CR><LF>!	
End: 'OK' (Runtime: 100 msec)	
> z?XFactoryReset!	SDI12: Factors Reset:
Disconnected while Busy('z?XFactoryReset!')	SDI12: New setup
ERROR: Disconnected ('z?XFactoryReset!')	SDI12: required!

7.1.3 Some standard commands for BLX.JS (not available with BlueShell):

(Remark: BLX.JS is our BLE driver written in JavaScript, it could easily be used with other HTML too).

> .a	.a or .audio: „Finder“
Audio: RSSI: OFF, Term: ON	
> .audio 1 1	Audio & Finder ‚ON‘
Audio: RSSI: ON, Term: ON	
> .firmware	Secure firmware update
Select new firmware (*.sec)...	

7.1.4 Special commands for Open-SDI12-Blue (SDI12 via BLE):

Sensor setup / scan commands:

Important: our sensors are are delivered “ready-2-run” and normally no special setup is required (except e.g. after Factory Reset or if sensor configuration was changed or for calibration).

Installation specification: For good measuring accuracy, it is very important that the sensor head is completely and as freely as possible in the water. The distance of the sensor head to other elements should be >= 4 cm if possible.

- Operation principle (for understanding the calibration process)

  - The analog drivers generate a Signal, depending on the Gain (Coefficient K5):
    Gain 1.0 (Default): Sensor Range: 0 – 2000 µS/cm
    Gain 0.1: Sensor Range: 0 – 20 mS/cm (Display in uS/cm)
    Gain 0.45: Sensor Range: 0 – 60 mS/cm (Display in uS/cm)
  Please use other Gains only after connection us.

  - This signal generates 3 values:
    $EC_{\_raw}$: A value for the (raw) conductivity: Range: 0 .. 650000,
    Values >650000 are clipped to 65000
    $EC_{\_ref\_unc}$: A value for the Reference Signal, Range typically 370000 * Gain
    T_raw: The raw value for the temperature

  - $EC_{\_ref\_unc}$ (Reference Signal) is only informative, we recommend to linearise it to ca. 1.0000 to check for correct function / long term driving signal strength of the power driver. Changes of ca. +/- 1% are OK for this Signal. But this step is optional and not required!
  Calculation: $EC_{\_ref} = EC_{\_ref\_unc} * K6 - K7$

- $EC_{\_t}$ is the linearised value of EC_raw:
  Calculation: $EC_{\_t} = EC_{\_raw} * K0 - K1$

- Temperature compensation '$EC_{\_25}$'
  Linear TK (in Percent). The TK is dependant on the Electrolytes in the Water For natural water typically a value of 2.0 is used and linear temperature compensation in the range from -10°C to +30°C. (Remark: for extreme high accuracy, industrial wastewater and higher temperatures, laboratory equipment sometimes uses a non-linear TK calibration, as e.g. described in EN 27888, but for mainly natural water linear TK is absolutely sufficient).

  The result of the TK compensation is the equivalent conductivity for 25°C, often called '$EC_{\_25}$'. Here $EC_{\_t}$ is the measured conductivity at Temperature $T_{\_t}$

  $EC_{\_25} = EC_{\_t} / (1 + (T_{\_t} – 25°C) * TK)$

- The 8 Coefficients:
  For easy display the command 'k' shows the current coefficients:
  K0: Conductivity Multi (Default: 1.0)
  K1: Conductivity Offset (Default: 0.0)
  K2: Temperature Multi (Default: 1.0)
  K3: Temperature Offset (Default: 0.0)
  K4: Temperature Compensation TK in Percent (Default: 2.0)
  K5: Gain (Strength of the driving Signal (Default: 1.0, Allowed range: 0.045 – 1.0))
  K6: Reference Multi (Default: 1.0)
  K7: Reference Offset (Default: 0.0)
- The command for a calibration measure is 'e9' (similar to SDI-12 'M9')

A typical calibration

Hint: There is a spreadsheet for easy calculating of the linearisation coefficients:
https://joembedded.de/x3/ltx_firmware/Open-SDI12-Blue-Sensors/0450_Conductivity_Inductive/OSXConductivityCalibration.ods

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> .k	Display Coefficients
K0: 1.000000 Cond.Multi	Here: New or uncalibrated
K1: 0.000000 Cond.Offset	
K2: 1.000000 Temp.Multi	
K3: 0.000000 Temp.Offset	
K4: 2.000000 Cond.TK(%)	
K5: 1.000000 Gain	
K6: 1.000000 Ref.Multi	
K7: 0.000000 Ref.Offset	
> e9	Calibration measure in Air
#0: 7181 uS/cm	TK compensated Conductivity
#1: 24.5 oC	
#2: 8.02 Vsup	Supply (must be >= 7.5V)
#3: 7109 uS/cm(uncomp)	Uncompensated Conductivity
#4: 7109 RawSignal	The Raw Signal (measured)
#5: 368291.18 Ref.Signal(lin)	Reference Signal (informative)
End: 'OK' (Runtime: 1102 msec)	
> e9	Calibration in 1413 µS/cm Sol.
#0: 532864 uS/cm	
#1: 24.5 oC	
#2: 8.05 VSup	
#3: 527535 uS/cm(uncomp)	
#4: 527535 RawSignal	
#5: 367812.40 Ref.Signal(lin)	
End: 'OK' (Runtime: 1100 msec)	
> z?XK0=0.002715!	Enter Coefficients
0K0=0.002713<CR><LF>	
>z?XK1=19.3015!	
0K1=19.284299<CR><LF>	
> e9	Check
#0: 1417 uS/cm	TK compensated
#1: 24.5 oC	
#2: 8.02 VSup	
#3: 1413 uS/cm(uncomp)	Excellent fit!
#4: 527848 RawSignal	
#5: 368478.81 Ref.Signal(lin)	
> z?XWrite!	Save Settings to Flash
Reply: '0<CR><LF>'	
End: 'OK' (Runtime: 162 msec)	

Explanation:

7109 equals 0 µS/cm (air),
527535 equals 1413 µS/cm (Calibration solution)

With the spreadsheet K0 and K1 can be calculated to
K0: 0.002715
K1: 19.3015

The result (1413) is OK!. Don't forget to save the changed coefficients!

(Alternatively 2 calibration solutions, e.g. 147 µS/cm and 1413 µS/cm could be used for the Coefficients K0 and K1)

The same system can be used for Reference linearisation (optional) or temperature calibration (also optional).

8 Power Supply

The OSX Sensor (and Bluetooth) works from 2.8V to 16V (see Open-SDI12-Blue documentation), however for analog drivers require at least 7.5 Volt to work!

Measure: < 100mA for ca. 800 msec (Default, if Warm-Up Time is set to 0, the sensor element is constantly powered).

Measurement frequency: 31.25 kHz, Drive Level (Loop voltage): ca. 3 Vpp

Operating Temperature: -40°C - +85°C
Medium Temperature: -10°C - +30°C for best performance

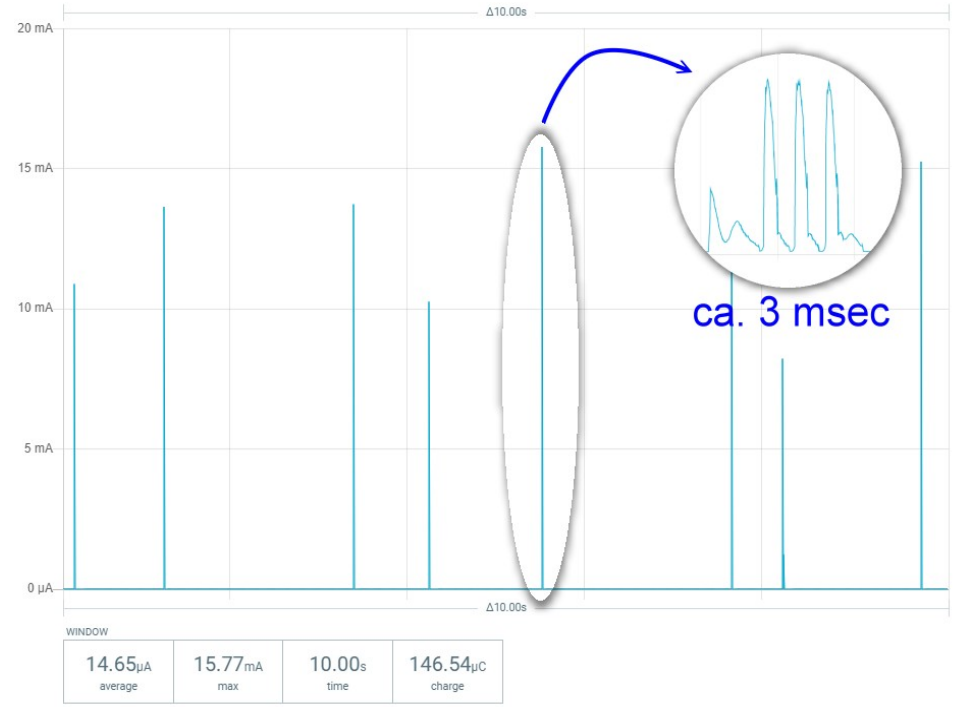
8.1 Power Profile

8.1.1 Power Up Sequence

The Sensor is ready after ca. 250 msec.

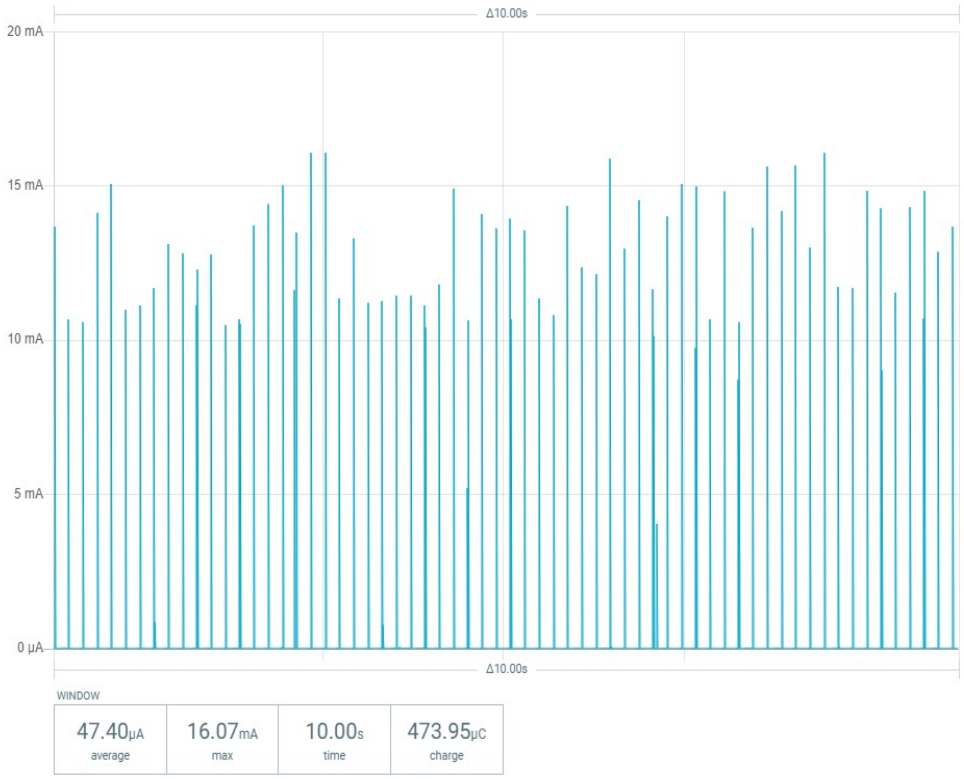
8.1.2 Advertising (in deep sleep)

Average power consumption in deep sleep is <15 µA @ 5V



Advertising power consumption (one peak zoomed)

8.2 Connected Mode



Connected power consumption

In Connected Mode (active BLE connection) the average power consumption is <50 µA @ 4V

9 Compliance (Version: Conductivity (ind.), Type 450)

9.1 Compliance: CE, RoHS

- EN 55022 Emission, class B < 30 dBµV/m (0.03...1 GHz)
- EN 61000-4-2 Electrostatic discharge 4 kV contact / 8 kV air
- EN 61000-4-3 Irradiated RF 10V/m (0.1...1 GHz)
- EN 61000-4-4 Transients (burst) 4 kV
- EN 301 489-1 V2.1.1 and EN 301 489-17 V3.1.1 EMC
- EN 300 328 V2.1.1 EN 300 330 V2.1.1 Radio Emission
- Bluetooth SIG listed: ID 138612

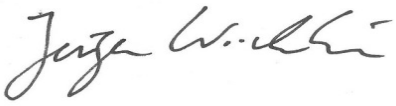
The sensor OSX – Version Conductivity (inductive), Type 450 complies with the essential requirements of Radio Equipment Directive (RED) 2014/53/EU and with the Directive 2011/65/EU (EU RoHS 2) and its amendment Directive (EU) 2015/863 (EU RoHS 3).

Manufacturers:

GeoPrecision GmbH
Am Dickhäuterplatz 8
D-76275 Ettlingen

Terratransfer GmbH
Ottostr. 19a
D-44867 Bochum

02.08.2023



Jürgen Wickenhäuser (R&D)

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