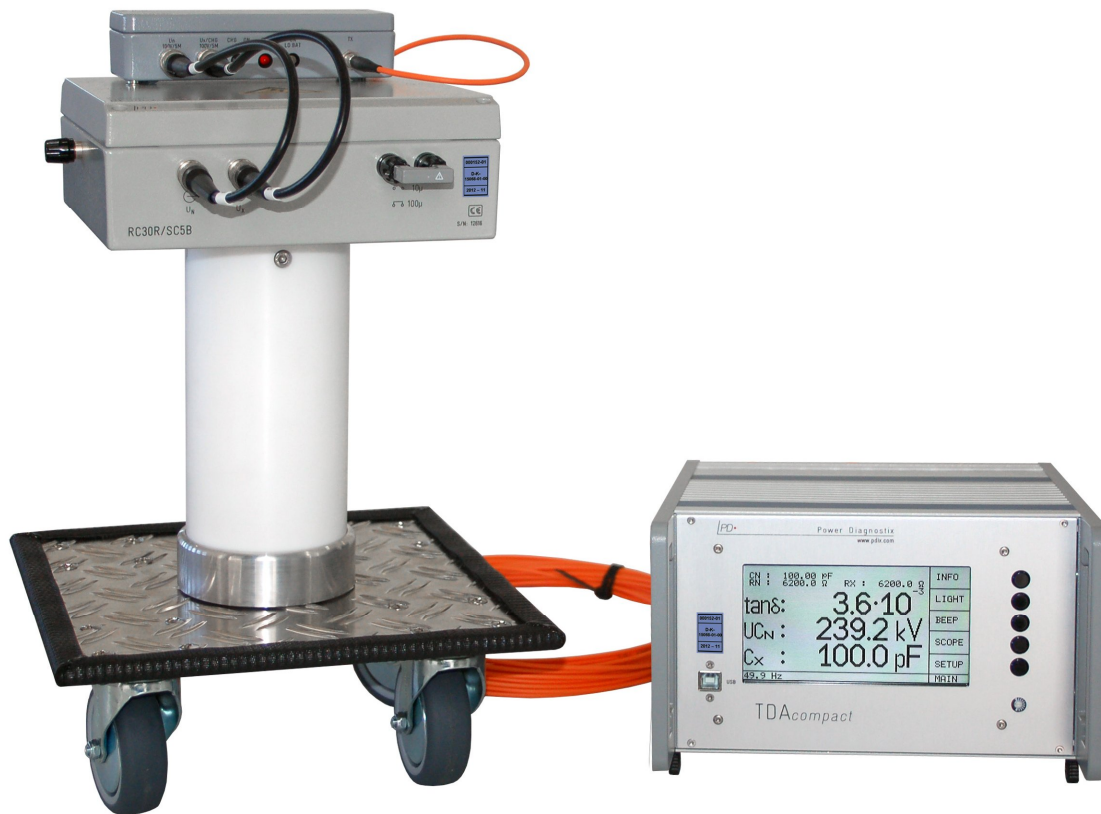


# TDAcompact

Loss Factor (Tan Delta),  
Capacitance,  
and Voltage Measurement



## User Manual

Rev. e2.33

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## I General

### I.1 About this Manual

This manual describes the hardware, software, and usage of the TDAcompact in its current version. Software updates are available through Power Diagnostix' web site ([www.pdix.com](http://www.pdix.com)). The access to the download area of that Web Site is password protected and requires a valid software maintenance contract. Please contact Power Diagnostix for details. Revisions of this manual and the current brochures are available for download (Adobes PDF-Format) through that web site as well.

### I.2 Instrument Safety

Before using the TDAcompact, read the following safety information and this manual carefully. Especially read and obey the information that are marked with the words 'Warning' and 'Caution'. The word 'Warning' is reserved for conditions and actions that pose hazards to the user, while the word 'Caution' is reserved for conditions and actions that may damage the instrument or its accessories, or that may lead to malfunction.

Always obey the safety rules given with the warnings and with this chapter. Especially take care of the safety issues while performing field measurements. Never disregard safety considerations even under time constraints found often with on-line and off-line test on site.



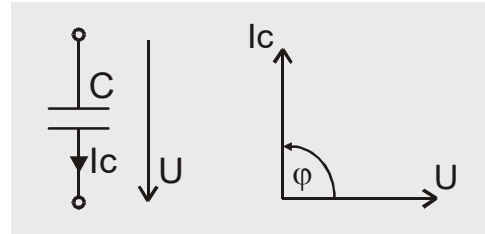
#### Warning:

- Always provide solid grounding of the instrument and the coupling units. Never operate the instrument without protective grounding.
- Use isolation techniques, such as isolation transformers or fibre optic isolation, to avoid hazard and injury. With applications bearing a high risk of electrical shock or breakdown use fibre optic isolation in general.
- Avoid working alone.
- Do not allow the instrument to be used if it is damaged or its safety is impaired.
- Inspect the ground leads and signal cables for continuity.
- Select the proper coupling circuit and connection for your application.

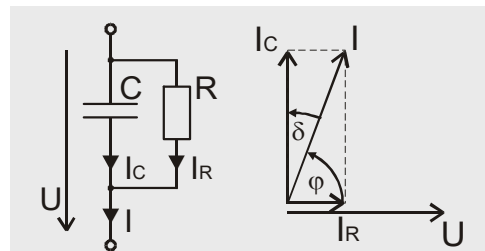
### I.3 What is the Loss Factor (or Dissipation Factor) Tan Delta?

Building high voltage equipment requires using insulation material. Commonly used insulation materials show losses due to resistive currents or polarisation currents of dipoles. Often, the magnitude of these losses can be used as an indicator for the quality of the insulation. Especially, in case of assessing the quality of aged insulation, increased dissipation indicates oil or paper decomposition (transformers), humidity, electrochemical processes (water-trees in polymeric cables), or, for instance, heavy partial discharge.

With an ideal capacitor (C), the resistance of the insulation material (dielectric) is infinitely large. When an AC voltage (U) is applied, the current (I<sub>C</sub>) leads the voltage by exactly  $\varphi = 90^\circ$ . A component close to this ideal capacitor with a negligible resistance should be used as standard (or reference) capacitor for the reference branch of a dielectric loss analyser. For the TDAcompact, in case of a known and reproducible deviation, a correction factor ('TDN' or tan delta) can be entered within the SETUP menu.



Technical insulation systems are usually built of less perfect insulation material resulting in a small current (I<sub>R</sub>) in phase to the supplied voltage (U). This current can be described by a parallel resistor (R) to an ideal capacitor (C). The phase difference between the real current (I) and the ideal current (I<sub>C</sub>) can be described as phase angle: 'δ'.



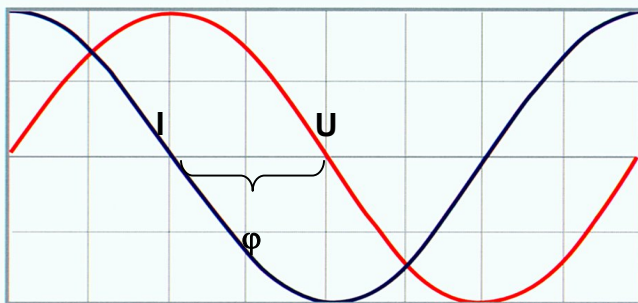
Because  $P = Q \cdot \tan \delta$ , the losses which are proportional to tan delta, will usually be given as a value of tan delta to express the quality of an insulation material. Therefore, the angle δ is described as loss angle and tan delta as loss factor.

Loss factor (Dissipation factor)

$$\tan \delta = \frac{I_R}{I_C} = \frac{P}{Q} = \frac{1}{\omega \cdot C \cdot R}$$

Quality Factor

$$QF = \frac{1}{\tan \delta} = \frac{I_C}{I_R} = \frac{Q}{P} = \omega \cdot C \cdot R$$

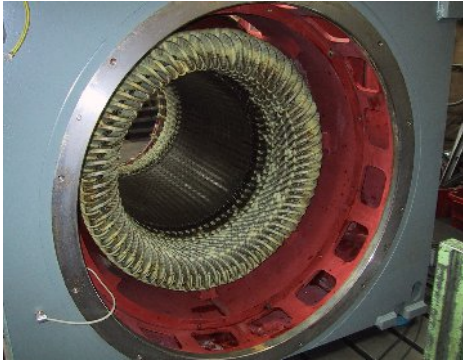


With a good insulation of low-loss capacitors ( $\delta \sim 0^\circ$  and  $\varphi \sim 90^\circ$ ), the ideal current 'I<sub>C</sub>' is approximately equal to the real current 'I'; resulting in a negligible deviation of the values tan δ and cos φ. In Europe, the dissipation factor tan δ is mostly used to describe the dielectric losses, while in North America the Power Factor (PF = cos φ) is commonly used. The software of the TDAcompact displays both values together with the calculated capacitance, the voltages, and the frequency.

## I.4 Principle of Operation

The TDAcompact is a portable capacitance and tan delta analyser. The focus of the instrument's application is on the analysis of the epoxy-mica insulation of rotating machines. Besides this, the unit is applicable for oil-paper insulation systems and especially for mass-impregnated cables.

Analysing the dissipation factor (tan delta) is a traditional method to assess the condition of an insulation system. With the analysis of the dissipation factor, emphasis is more put on the overall health of the insulation system, whereas with partial discharge analysis, the focus is on individual defects producing discharge activity. Therefore, the application of tan delta measurements concentrates on insulation systems, which are relatively stable against partial discharge.



Most prominently, the health of an epoxy-mica insulation of a rotating machine can be assessed using a tan delta analyser. Especially, the presence of humidity within the winding, the surface contamination of field grading elements, or the polarisation losses of improperly cured resin, can be detected. Thus, the tan delta analysis is still a good complement to the partial discharge testing.

The TDAcompact simultaneously samples the AC current drawn by the device under test and the voltage of a reference capacitor. Subsequently, the two traces are evaluated and the capacitance, the tan delta, and the level of the high voltage are calculated. The unit continuously displays and refreshes these results.

Therefore, the instrument does not require any user interaction as with the traditional Schering Bridge, nor does the refresh of the display take that long as with automatic adjusting bridge-type analysers. The basic resolution of the tan delta measurement is  $5 \cdot 10^{-4}$ , which fulfils the requirements for rotating machine testing as well as for testing on mass-impregnated cables.

### Modular Concept

Generally, measurement instruments of Power Diagnostix are built on a modular concept. Thus, adaptation to the specific needs of an application is made by the proper selection of the accessories. Here, choosing the external accessories such as shunt impedance, fibre-optic transmitters, or reference capacitors provides this adaptation. Besides basic standard accessories, tailor-made shunt impedance and reference capacitors in combination with the fibre optic transmission can be provided. A correctly chosen set of accessories is the key to precision and repeatability of the measurement results.

Besides the stand-alone field test application of the TDAcompact, the instrument can also become a part of a larger and automated test system. Using the software HVpilot, the instrument will be read according to a pre-programmed test sequence. Besides tan delta measurements, such automated test systems further include partial discharge measurements and so-called step tests.

Upon request, Power Diagnostix can supply complete portable tan delta testers including the high voltage transformer.

## II Installation

### II.1 Acquisition Unit

The standard TDAcompact package includes the acquisition unit and one or two remote fibre optic transmitters of the FOT2 series including their fibre optic (FO) cables. To adapt this system to the specific needs of an application, a broad range of accessories such as the shunt capacitors ( $C_{SX}$ ,  $C_{SN}$ ) and reference capacitors ( $C_N$ ) can be provided.

The TDAcompact is an autonomous instrument, which can be used as stand-alone device. However, it is equipped with a serial interface on its front for downloading data and controlling the instrument via the software TDAcompact.



Fig. II.1: TDAcompact

The instrument is operated using the five control buttons that are arranged to the right-hand side of the LCD panel. The brightness adjustment of the LCD is accessed using a small screwdriver beneath the control buttons. The connector for the power supply, the wing nut for ground connection, the computer interfaces as well as the fibre optic connectors for the FOT2 preamplifier are located on the rear panel of the standard instrument.

These options are available on request:

- Full 19" wide sub-rack to mount the TDAcompact into a standard 19" rack.
- TDAcompact software: Standard software to record and store measurement data, automate test sequences, and create report documents. Using the TDAcompact software together with the GPIB interface will increase the precision of the  $\tan \delta / \cos \varphi$  resolution up to  $1 \cdot 10^{-4}$ .
- HVpilot software: This software is designed to record data and interact with multiple instruments for automated test sequences. It connects to the STEPcompact (voltage control), the ICMcompact (partial discharge measurement), and the TDAcompact.



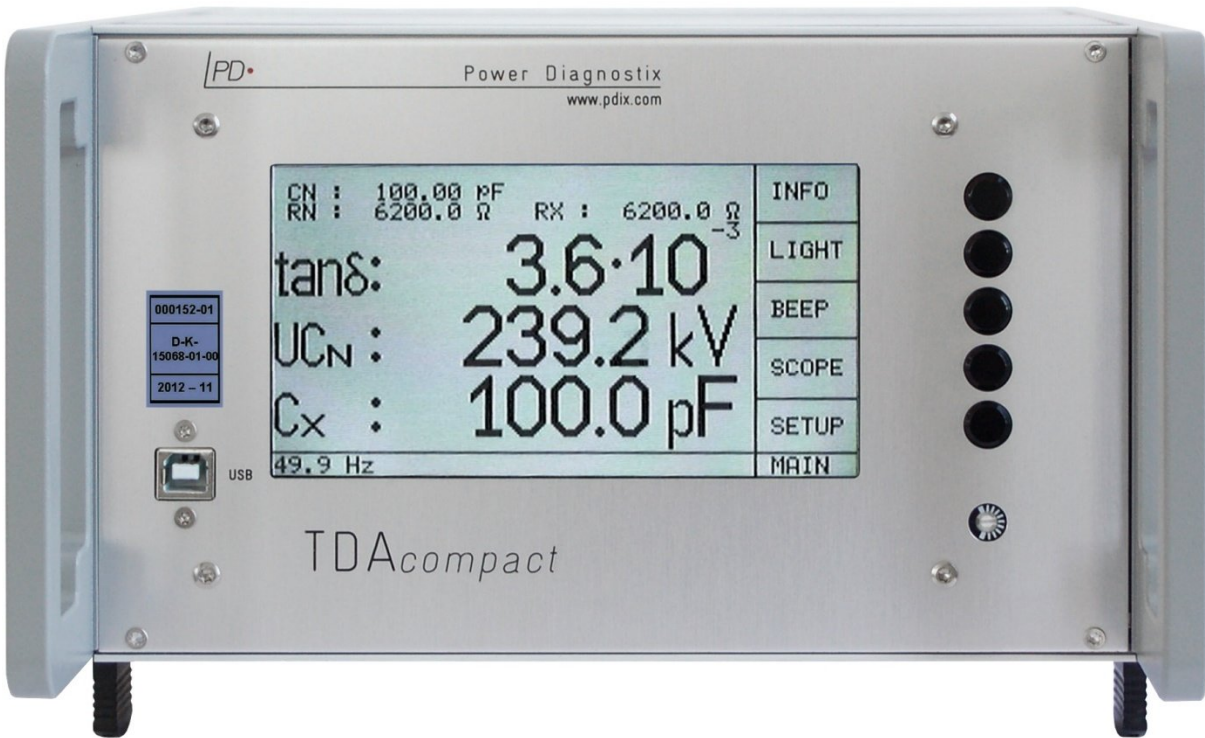


Fig. II.2: TDAcompact front panel



Fig. II.3: TDAcompact rear panel



## II.2 Connectors

The rear panel of the standard TDAcompact contains all connectors necessary to set up the instrument.

- The mains supply accepts voltages from 100 V<sub>AC</sub> up to 240 V<sub>AC</sub> at 50/60 Hz. The connector block with the power switch also holds the main fuse and an additional spare fuse (0.5 A time-lag).
- Wing nut: For a safe operation the instrument should always be connected to the ground potential by the wing nut terminal (M5).
- The two SMA jacks connect the transmitter FOT2B/FOT2C.

U<sub>N</sub> Takes the signal coming from the standard (reference) capacitor, when using the FOT2B. With use of the transmitter FOT2C it takes additionally the signal coming from the specimen.

U<sub>X</sub> Takes the signal coming from the specimen, when using the FOT2B.

- CHARGE: The two BNC connectors underneath offer the 15 V<sub>DC</sub> supply to charge the transmitters.

These transmitters (see next section) are fitted with Ni-MH batteries, which ensures a minimum continuous operating time of 20 hours with fully charged batteries. These batteries feature a (virtually) absent memory effect (reduced capacity if partially discharged batteries are regularly recharged).

While the CHG switch is in the 'ON' position, a transmitter can be charged via the charging jack of the instrument. The charging circuit is contained in the transmitter, so that an FOT can also be charged by applying a voltage of 15 V<sub>DC</sub> to the BNC jack (inner conductor = positive pole). The circuit contains a constant-current charging circuit and a monitoring of the end-of charge voltage. Complete charging takes about 24 hours. Charging during longer periods does not pose any risk, because the transmitter switches to the idle mode when the battery is fully charged.

For communication between the instrument and a computer with the TDAcompact software an easily accessible USB connector can be found on the front panel.

## II.3 Transmitters

The transmitters serve to amplify the voltage signals coming from the shunt capacitors and to isolate the acquisition unit from the shunts. Thus, the shunt capacitors can be placed into the ground connection as well as into the high voltage connection.

The FOT2B and FOT2C is available with three different input ranges to adapt the transmitter to the used test voltage. It is available with 20 V<sub>p</sub> and an input impedance of 1 MΩ, 100 V<sub>p</sub> and an input impedance of 5 MΩ, or 200 V<sub>p</sub> and an input impedance of 10 MΩ (the required range must be specified on order). The range must also be set in the SETUP1 menu at FOT N and FOT X to enable a correct calculation of the voltage and C<sub>x</sub>.

The transmitter is installed in a cast aluminium enclosure. It is fitted with a battery for a minimum operating time of 20 hours. The amplifier works in the frequency range of 0 to 20 kHz (-3 dB).

A red lit LED (ON/LO BAT) and a continuous beeping of the FOT2B indicate a low battery. The battery can be charged by setting the CHG switch to 'ON' and connecting the BNC cable to one of the CHARGE outputs of the TDAcompact. A charging time of minimum 12 hours should be kept allowing an operation time of 8 to 10 hours. Once the battery is charged, the instrument will turn to trickle charging to protect the battery. The transmitters should not be stored fully discharged. If they will not be used for a short time (< 1 month), they should be charged for 12 to 24 hours, before, and then stored. Before using the transmitters again, they should be charged for 24 hours.

If the transmitters will not be used for a longer period (> 1 month), they should be stored in a cool place (10°C to 20°C) and not fully charged. Therefore, discharge the batteries until the transmitter starts beeping. Then charge it for about 12 hours. To prevent the batteries from getting exhaustively discharged, they should be charged every 5 month for 12 hours. Before using the transmitters again, they should be charged for 24 hours.



Fig. II.4: Fiber-optic transmitters FOT2B and FOT2C

### II.3.1 FOT2B

The FOT2B is used for measurements with a separate reference capacitor and two shunt capacitors (one for the reference capacitor, one for the test object).

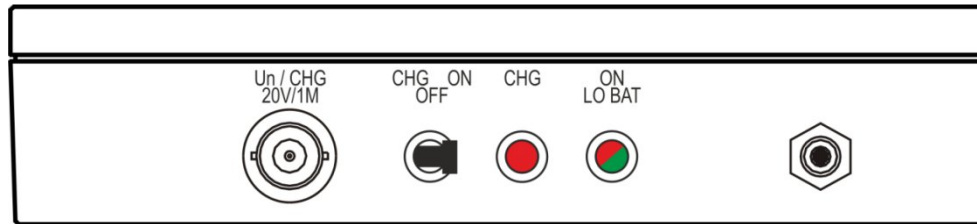


Fig. II.5: Drawing of the FOT2B with input range of 20 V and input impedance of 1 M $\Omega$

The transmitter FOT2B is fitted with the following controls (from left to right):

- Un / CHG 20V/1M<sup>1</sup>  
BNC jack as measuring input and charger connection.
- CHG ON/OFF  
Switch for activating/deactivating the charge status.
- CHG  
This red LED is lit during charge operation.
- ON/LO BAT  
This bicolour LED is lit green during normal operation. If the battery status is low, its light will change to red.
- Transmitter diode  
SMA jack for the fibre optic cable used for transmission.

### II.3.2 FOT2C

The two-channel FOT2C takes the two signals  $U_N$  and  $U_x$  and transmits them via one FO cable to the TDAcompact. This transmitter model is the preferable solution for signal transmission when reference capacitor and test object are in proximity to another.

This transmitter can be used with Power Diagnostix' RC30R/SC5B that combines a reference and a shunt capacitor in one housing. The enclosure of the FOT2C fits into the bolts on top of the RC30R/SC5B.

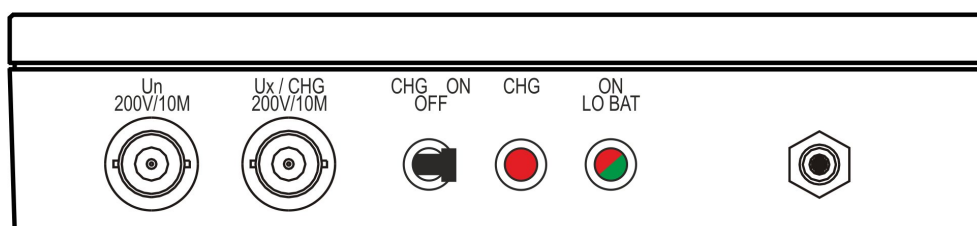


Fig. II.6: Drawing of the FOT2C with input range of 200 V and input impedance of 10 M $\Omega$

The transmitter FOT2C is fitted with the following controls (from left to right):

- Un / CHG 200V/10M<sup>1</sup>  
BNC jack as measuring input and charger connection.
- Ux / CHG 200V/10M<sup>1</sup>  
BNC jack as measuring input and charger connection.

<sup>1</sup> Label is depending on transmitter range

- CHG ON/OFF  
Switch for activating/deactivating the charge status.
- CHG  
This red LED is lit during charge operation.
- ON/LO BAT  
This bicolour LED is lit green during normal operation. If the battery status is low, its light will change to red.
- Transmitter diode  
SMA jack for the fibre optic cable used for transmission.

## II.4 Optical Fibres

The use of optical fibres does not cause any problems and is comparable to the use of coaxial cables in terms of mechanical properties. Excessive stress and bending of optical fibres and their plug connections can, however, affect the optical properties of these components. Accumulation of dirt must be avoided because of the close fit between the male and the female connectors of optical fibres. Suitable cleaning agents are ethanol and isopropanol. Enormous pressure can build up between male and female connectors which can cause damage unless the cleaning agents can evaporate.

Optimal use of the excellent insulation properties of optical fibres is only possible if a suitable configuration is adopted in order to minimise surface discharge phenomena at the boundary layers in the optical fibre cable. Major potential differences (voltages more than 20 kV) require suitable measures in order to control the orientation of the electric field along the optical fibre. Under these conditions, the optical fibre cable should be connected to the reference potential both at the high-voltage end and at the earth end by means of a metal toroid which should be generally used as a precaution at the earth end whenever high-voltage applications are involved! The electric strength of the chosen measuring set-up must be determined and/or optimised by suitable initial test, specifically in the case of continuous tests. The optical fibres feature a typical attenuation of around 7 dB/km with a working wavelength of 860 nm. This means a maximum transmission distance of 500 m with a sufficient system reserve. More powerful transmission diodes permit safe operation over a range of up to 1000 m.



Fig. II.7: Fiber optic cable

## II.5 Accessories

### II.5.1.1 Shunt / Standard Capacitors

The shunt capacitor is used in combination with a reference capacitor. Its input range is adapted to the maximum voltage that is used during measurement. Besides that, a second shunt capacitor is needed to be used with the test object. Power Diagnostix offers a broad range of shunt capacitors with different ranges. Please contact us for more details.

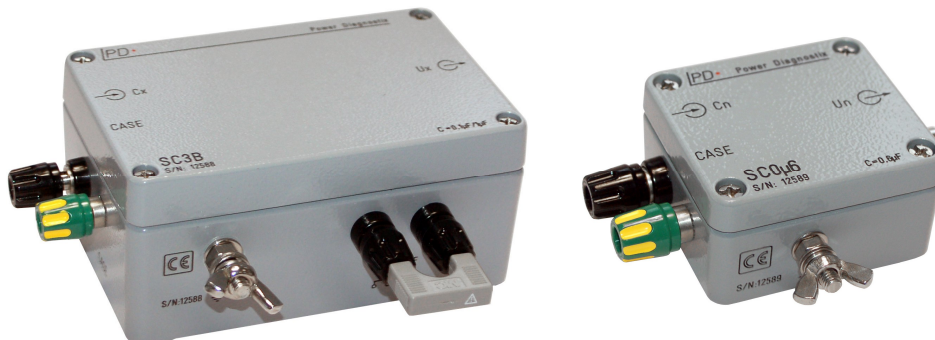


Fig. II.8. Two different shunt capacitors

Typically, the shunt capacitor for the test object is used in the high voltage path. In this case the high voltage is connected to the shunt capacitor's 'CASE' jack and the test object is connected to the 'Cx' jack of the shunt capacitor. The BNC jack is connected to the FOT2B (see figure II.12).



### Warning:

- If the shunt capacitors are used in the high voltage path, the whole enclosure is on high voltage potential!
- In this case, the shunt capacitor box must be isolated from ground potential!

Besides using an existing reference capacitor along with the shunt capacitors, the nominal voltage and phase position can be measured using a standard capacitor with a built-in shunt capacitor. There is a broad range of standard capacitors, please contact Power Diagnostix for more details.

The standard capacitor can be connected directly to the high voltage supply of the test object and the ground. The output BNC connector is to be connected to the FOT2B transmitter.

Additionally, also combined couplers for partial discharge testing, voltage measurement, and tan delta analysis are available (e. g. CC25B/V).

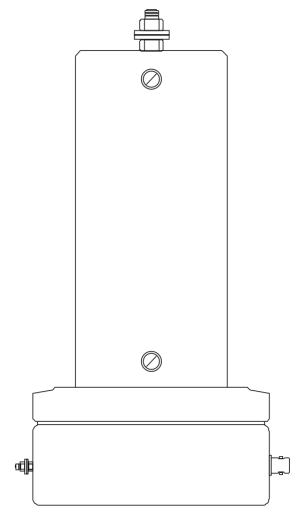


Fig. II.9: Standard capacitor with integrated shunt capacitor

#### II.5.1.2 Combined Reference and Shunt Capacitor RC30R/SC5B

Another assembly for the shunt capacitors is shown in figure II.14: Here, the shunt capacitor and the standard capacitor are built together in one construction. The standard capacitor with the built-in shunt capacitor on the bottom and the shunt capacitor for the test object path on top (here: SC5B).

The high voltage is connected to the 'CASE' jack of the SC5B. The test object is connected to the 'Cx' jack. The SC5B offers the two ranges 10  $\mu$ F and 100  $\mu$ F. If there is no bridge between the 10  $\mu$  and 100  $\mu$  sockets, its range is 10  $\mu$ F. Otherwise, the shunt capacitance is 100  $\mu$ F. The  $U_N$  and  $U_X$  connectors must be connected to the appropriate FOT2C inputs by using short BNC cables. The wing nut at the ground plate of the RC30R/SC5B must be grounded.

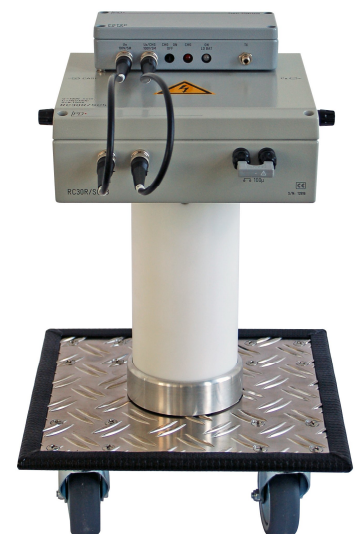


Fig. II.10: RC30R/SC5B

### II.5.1.3 Pre-dividers

A pre-divider can be used, if the voltage at the output of the shunt capacitor exceeds the input range of the FOT2. The pre-dividers are directly connected to the FOT2. Pre-dividers with the following divider ratios are available: 1:2, 1:3, 1:4, 1:5 and 1:10. Typically the pre-dividers are designed, that the input impedance of the FOT2 remains 1 M $\Omega$ .

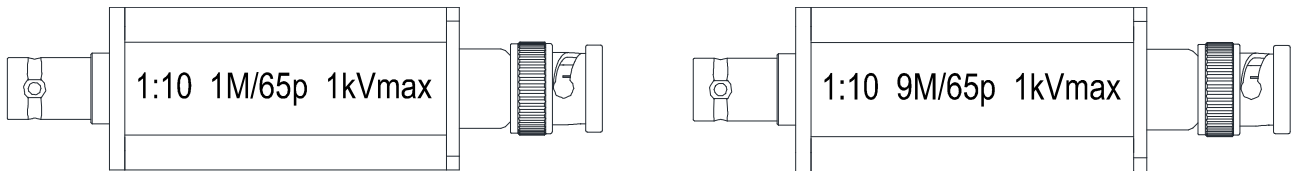


Fig. II.11: Pre-dividers



II.6 Circuits and Abbreviations (Examples)

II.6.1 Two FOT2Bs and one Shunt Capacitor on High Voltage Potential

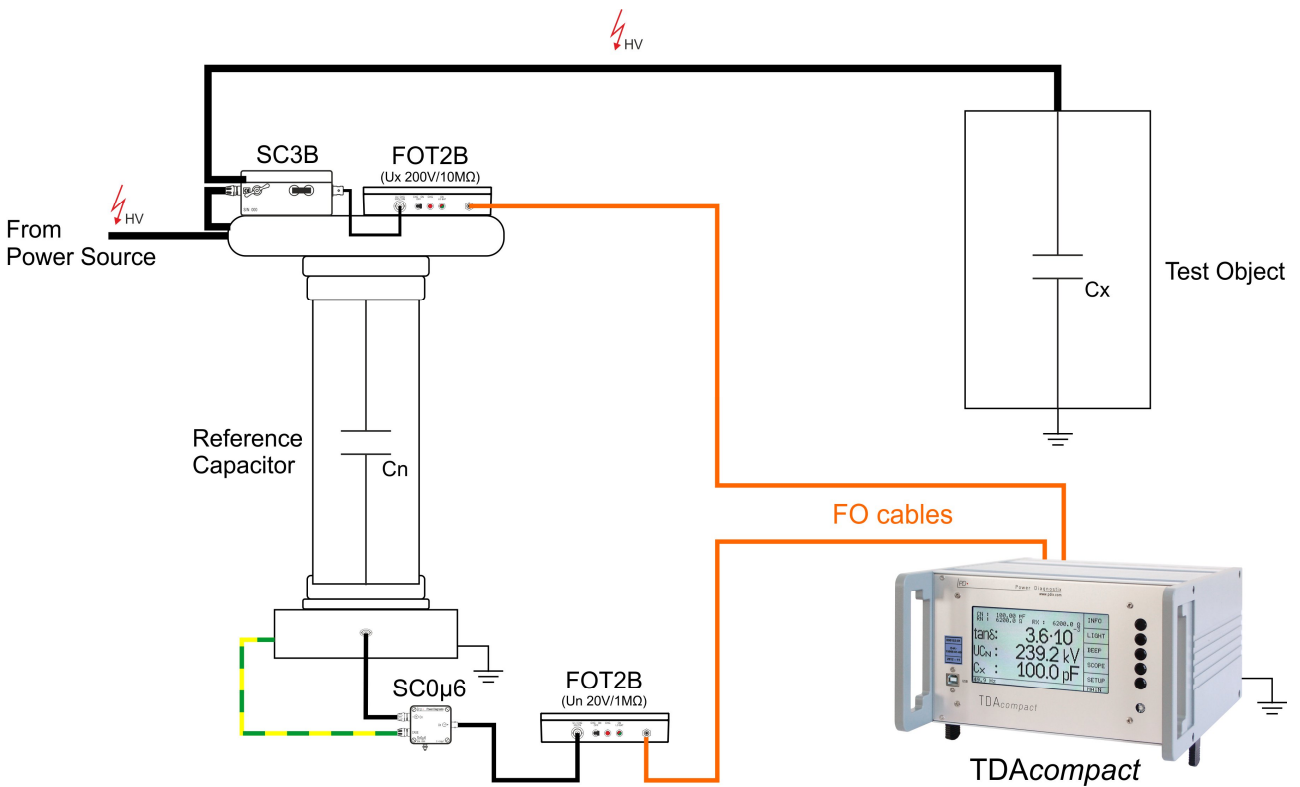
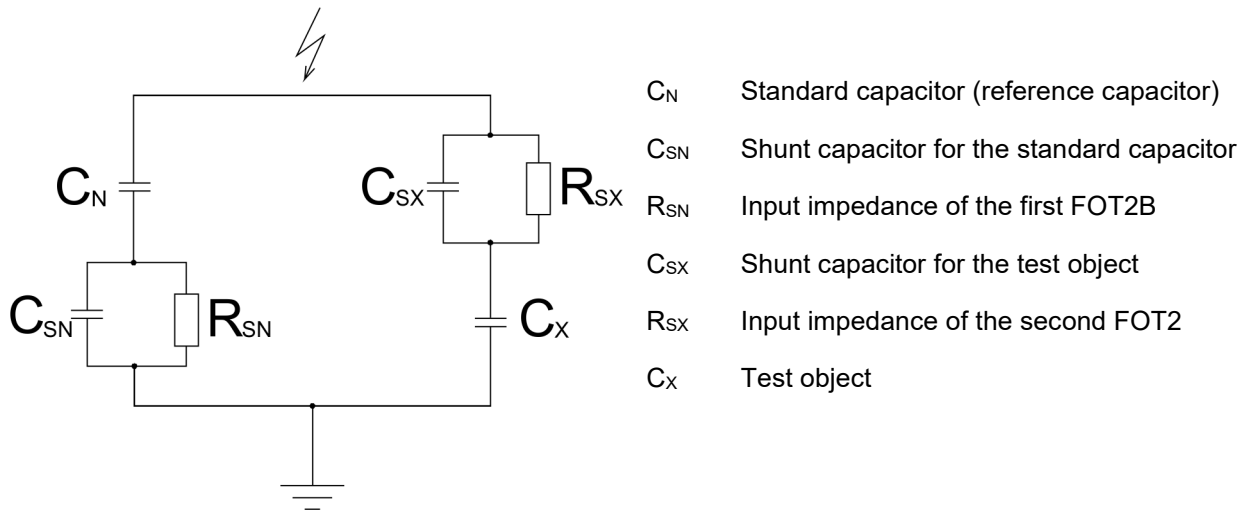
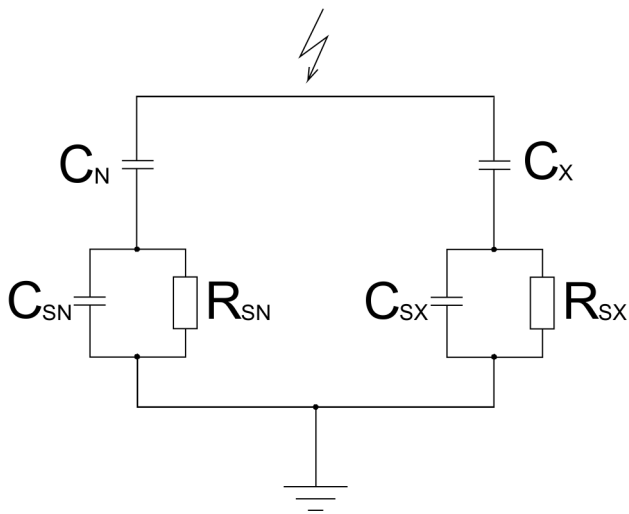


Fig. II.12: Example test setup with two FOT2B and one shunt capacitor on high voltage potential

II.6.2 Two FOT2Bs and two Shunt Capacitors on Earth Potential



- $C_N$  Standard capacitor (reference capacitor)
- $C_{SN}$  Shunt capacitor for the standard capacitor
- $R_{SN}$  Input impedance of the first FOT2B
- $C_{SX}$  Shunt capacitor for the test object
- $R_{SX}$  Input impedance of the second FOT2B
- $C_X$  Test object

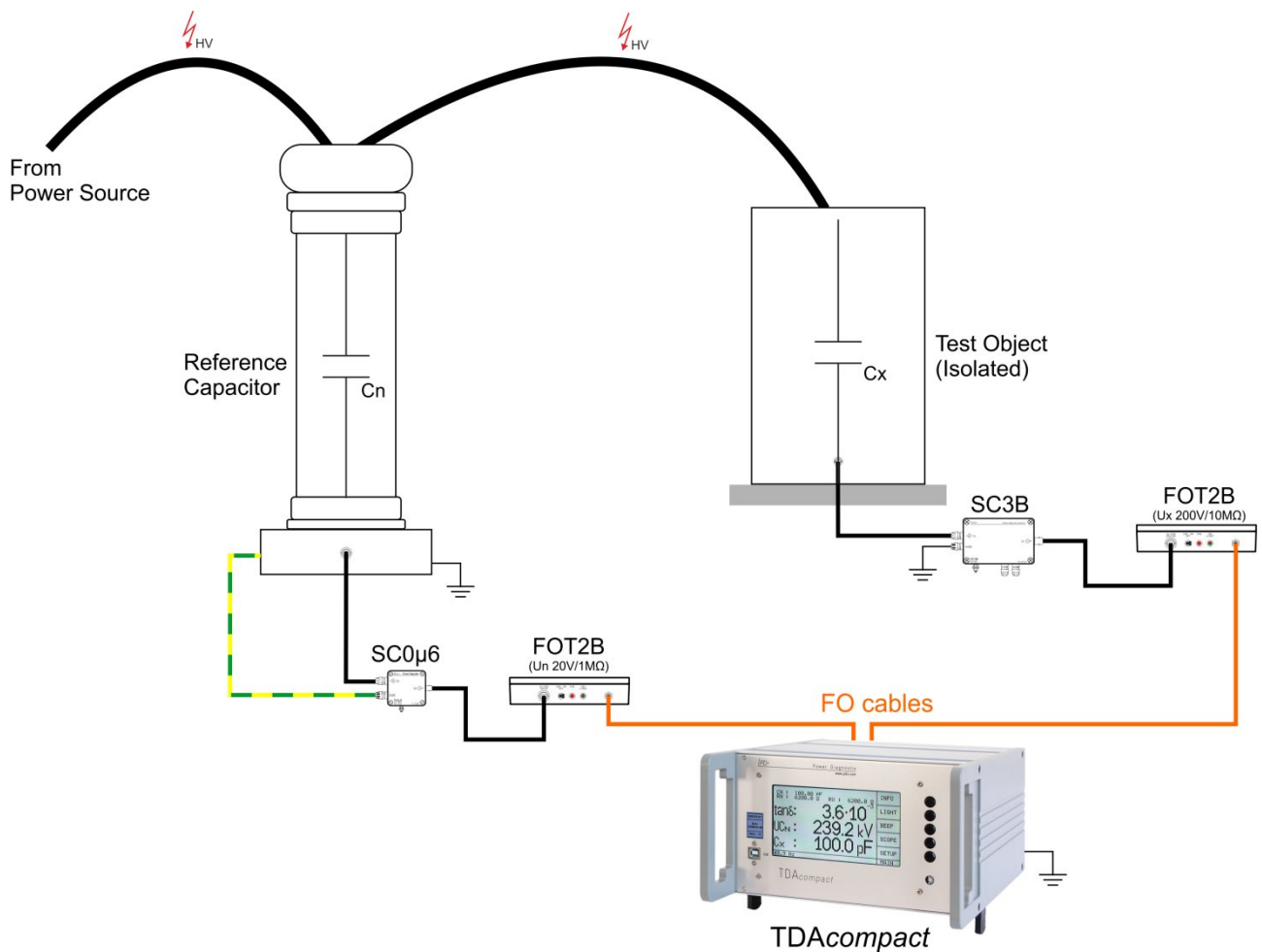
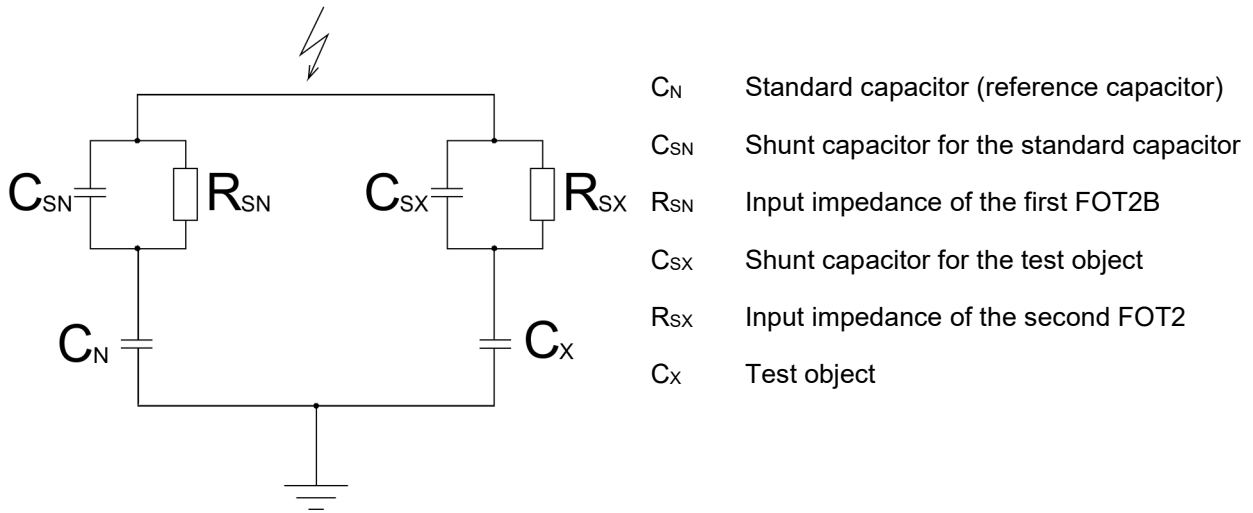


Fig. II.13: Example test setup with two FOT2B and two shunt capacitors on earth potential

II.6.3 One FOT2C and two Shunt Capacitors on High Voltage Potential



- C<sub>N</sub> Standard capacitor (reference capacitor)
- C<sub>SN</sub> Shunt capacitor for the standard capacitor
- R<sub>SN</sub> Input impedance of the first FOT2B
- C<sub>SX</sub> Shunt capacitor for the test object
- R<sub>SX</sub> Input impedance of the second FOT2
- C<sub>X</sub> Test object

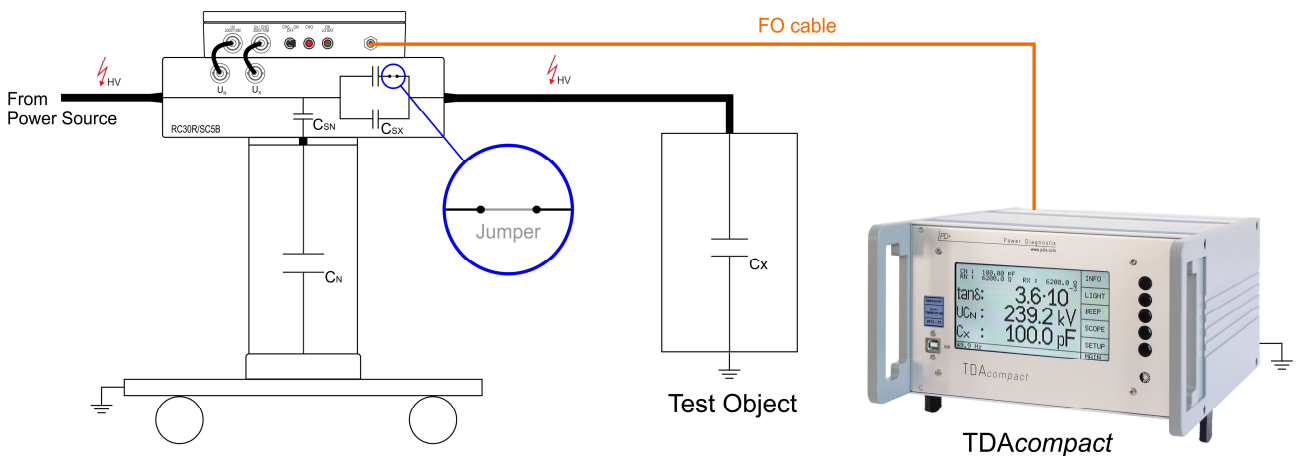


Fig. II.14: Example test setup with FOT2C and RC30R/SC5B

### III Operation

#### III.1 Main Function

After switching on the TDAcompact, the LC screen displays the TDAcompact logo and software version for about two seconds. The instrument is controlled by the five pushbuttons on the front panel. The individual functions are assigned to each button by the menu fields on the right-hand side of the display. There are two display modes and sub-menus available. The instrument automatically selects the display mode and submenu that was active when the instrument was switched off. In order to activate the MAIN menu, the EXIT (or BACK) button should be pressed several times. There are two MAIN menus offering the same functions and submenus but having different display modes. The MAIN M displays the measured and calculated values whereas the MAIN S shows the two captured voltage waveforms.

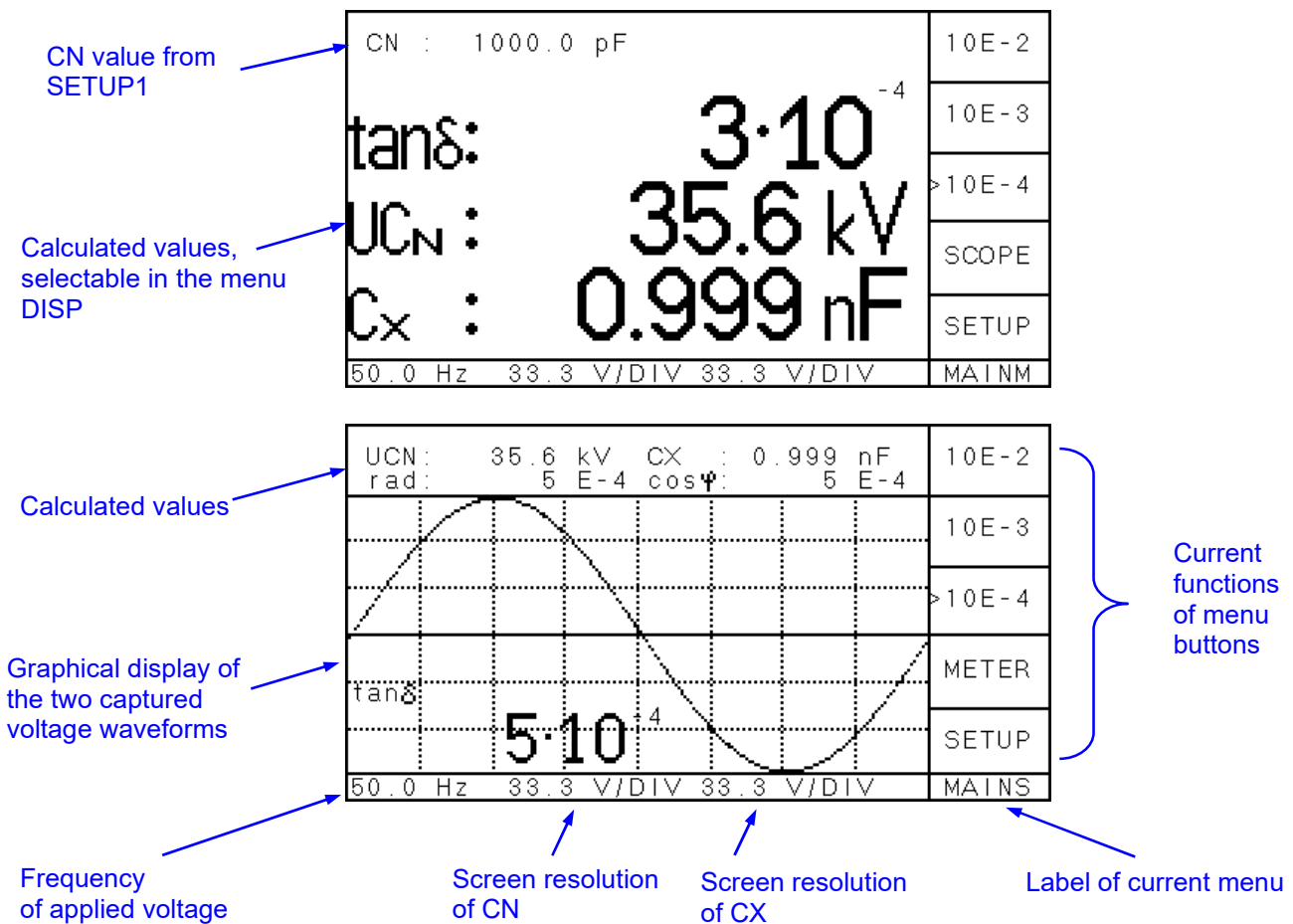


Fig. III.1: The two main TDAcompact display modes and the available measurements

The display of the TDAcompact consists of graphic elements like the grid and the voltage curve and additional text elements like the menu description and the values. Some conditions are displayed as abbreviations at the lower side. The following table shows these abbreviations and its meaning.

Abbreviation    Meaning

REM ..... Remote control via the software. The display is not refreshed, and the buttons are locked.

N/A ..... No scaling available. Transmitter (FOT2) signal is missing.

### III.2 Display Menus

There are two display modes to show the captured data. The SCOPE mode displays the captured waveform, whereas the METER mode only shows the calculated values using large characters. The menu buttons within these modes are the same. The menu buttons METER and SCOPE allow toggling between the two display modes.

Some of the values can be displayed in both modes:

U: The calculated voltage across the standard capacitor (C<sub>N</sub>).

C<sub>x</sub>: The calculated capacitance of the specimen.

cos φ: The calculated power factor (PF) with values from 0 to 1.

tan δ: The calculated dissipation factor (loss factor). Since the mathematical range of the tangent is from 0 to ∞, the instrument limits this value from 0 to <10.

The frequency (fundamental) of the applied voltage (U<sub>N</sub>) is always shown in the lower left corner.

#### Scope Display

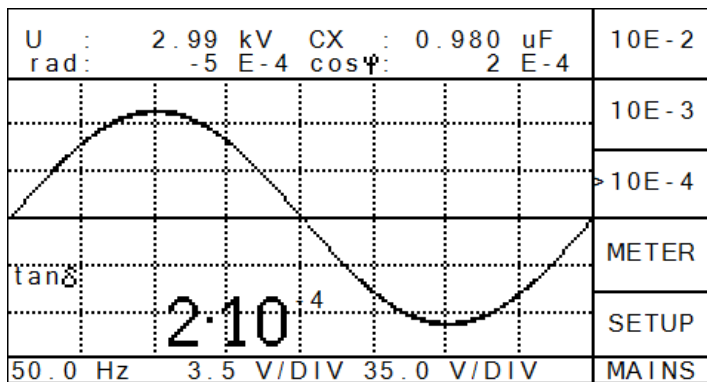


Fig. III.2: Scope display

Some values are only shown in the SCOPE mode. The phase angle of δ is here also shown in the circular measure (radian) with values from 0 to π/2. For small phase angles the values of rad, tan δ and cos φ differ only little.

The two voltage waveforms from the FO terminals (C<sub>N</sub> and C<sub>X</sub>) are shown simultaneously. The scaling factors can be found in the bottom line whereas C<sub>N</sub> is the left and C<sub>X</sub> the right value. The display shows the input voltages of the FOT2 and the scaling factor in volt per division (V/DIV) at the input of the FOT2 transmitter.

#### Meter Display

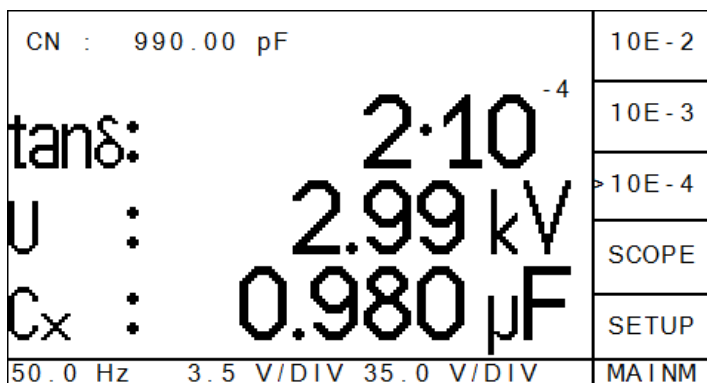


Fig. III.3: Meter display

The top line of the METER display shows the pre-set value of the standard capacitor C<sub>N</sub>, which can be changed in the SETUP1 menu. The following three lines can be used to display three of the four calculated values:

tan δ, cos φ, U, C<sub>x</sub>.

Within the submenu SETUP2 / MISC / DISP the values to be shown can be selected and deselected. Since only three values can be displayed, firstly, one value must be deselected before the new entry can be chosen.

**Setup**

The SETUP menu allows fitting the instrument to the physical measurement setup. The values can also be entered via the software and uploaded to the instrument.

The measurement circuit in principle is shown in the HELP menu. However, by using the FO transmitter, the shunt impedance (CS and RS) can be placed in the ground connection (as with the CN path) or into the HV connection (as with the specimen CX path).

▶ CN :	990.0 pF	TDN:	0 E-5	UP
RSN:	1 MΩ	FOT N:	10 V	DOWN
CSN:	505 nF	DIV N:	1:1	SET
RSX:	1 MΩ	FOT X:	10 V	MORE...
CSX:	50 uF	DIV X:	1:10	EXIT
50.0 Hz UN: 5.86 V UX: 57.56 V				SETUP1

Fig. III.4: Settings in the SETUP mode

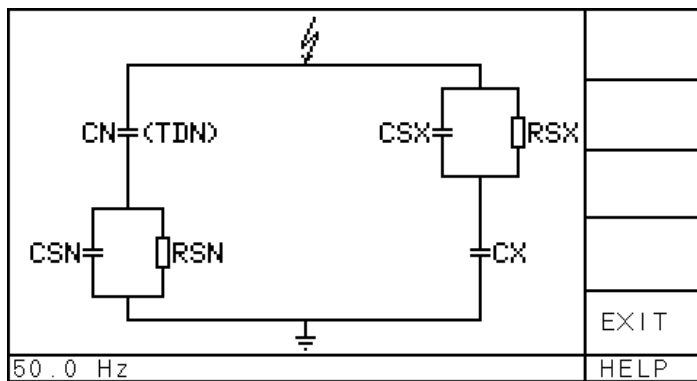


Fig. III.5: HELP mode

Following values have to be adjusted before a correct measurement can be done.

- CN Standard capacitor (reference capacitor)
- TDN If the standard capacitor has a known tan delta, this value can be entered here as a correction factor.
- RSN Input impedance of the FOT2
- FOT N The voltage input level of the FOT2 transmitter connected to the standard capacitor must be set here.
- CSN Shunt capacitor for the standard capacitor
- DIV N If a pre-divider is used at the input of the FOT2, its value must be set here. Selectable values are: 1:1, 1:2, 1:3, 1:4, 1:5, 1:10.
- RSX Input impedance of the FOT2
- FOT X The voltage input level of the FOT2 transmitter connected to the shunts in the specimen path must be set here.
- CSX Shunt capacitor of the test object
- DIV X If a pre-divider is used at the input of the FOT2, its value must be set here. Selectable values are: 1:1, 1:2, 1:3, 1:4, 1:5, 1:10.



### III.3 Key Menus

#### III.3.1 Menu Overview

The acquisition unit is controlled using the five push buttons at the right-hand side of the built-in LC display. A menu table displayed in the utmost right section of the LC screen assigns the function of each button depending on the menu selected. The unit stores the settings and the information of the menu currently chosen in a non-volatile memory. Thus, the screen and setting that were active before are restored, when the unit is powered up again.

With the lower section of the screen, one line displays status information concerning the synchronisation frequency and the Y-axis grid for both voltages. On top of the LC display, two lines indicate the measurements.

The following section explains the function of the instrument's control menus.

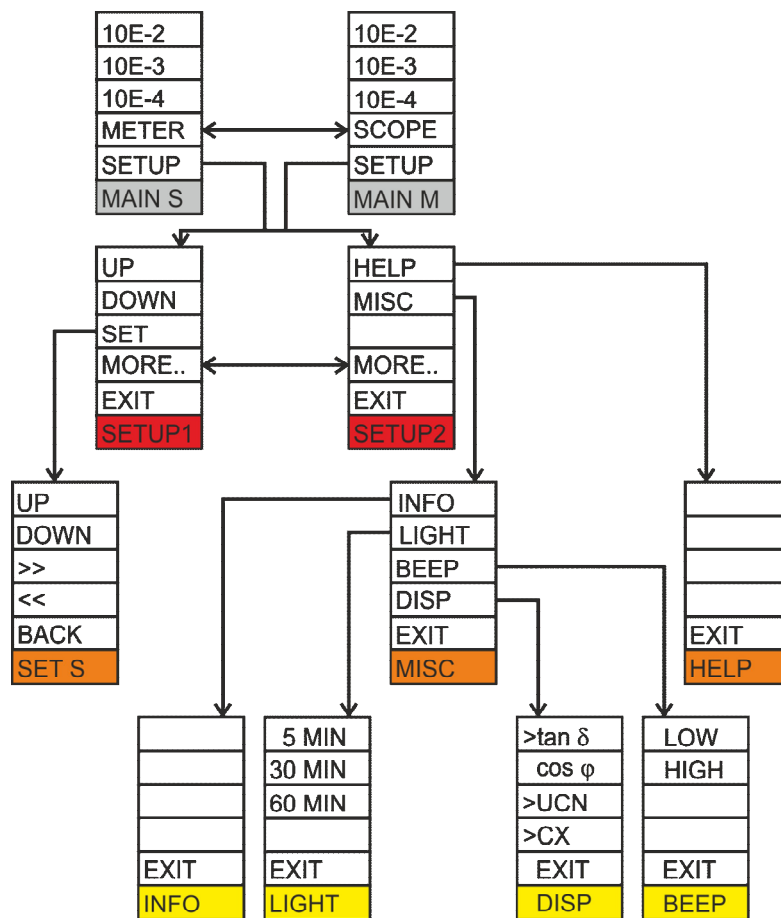


Fig. III.6: Menus of the TDAcompact

III.3.2 Key Menus Description

**MAIN S**

**Scope Display**

10E-2	10E-2	Sets the display format of the tan delta value to x.x A 10 <sup>-2</sup> .
>10E-3	10E-3	Sets the display format of the tan delta value to xx.x A 10 <sup>-3</sup> .
10E-4	10E-4	Sets the display format of the tan delta value to xxxx A 10 <sup>-4</sup> .
METER	METER	Toggle button to switch to the 'METER' display, showing all important values in an overview.
SETUP	SETUP	Calls the SETUP submenu for setting the sampling rate and trigger options, for instance.
<b>MAIN S</b>		

**MAIN M**

**Meter Display**

10E-2	10E-2	Sets the display format of the tan delta value to x.x A 10 <sup>-2</sup> .
>10E-3	10E-3	Sets the display format of the tan delta value to xx.x A 10 <sup>-3</sup> .
10E-4	10E-4	Sets the display format of the tan delta value to xxxx A 10 <sup>-4</sup> .
SCOPE	SCOPE	Toggle button to switch to the 'SCOPE' display, showing the voltage in an oscilloscope display.
SETUP	SETUP	Calls the SETUP submenu for setting the sampling rate and trigger options, for instance.
<b>MAIN S</b>		

**SETUP1**

**Setup 1: Settings**

UP	UP	Use this button to select the value to be set.
DOWN	DOWN	Use this button to select the value to be set.
SET	SET	Selects the chosen value and toggles to the 'SET S' menu
MORE..	MORE..	Calls the second setup menu.
EXIT	EXIT	Returns to the previous menu, i. e. one level up.
<b>SETUP1</b>		

**SETUP2**

**Setup 2: Settings**

HELP	HELP	Use this button to show the circuit diagram of a principle test setup.
MISC	MISC	Calls a submenu for miscellaneous settings and device information.
	MORE..	Toggles back to the SETUP1 menu.
MORE..	EXIT	Returns to the previous menu, i. e. one level up.
EXIT		
<b>SETUP2</b>		

**SET S**

UP
DOWN
>>
<<
BACK
<b>SET S</b>

**SET Menu**

- UP        Increases the current value at the cursor position.
- DOWN    Decreases the current value at the cursor position.
- >>       Sets the cursor position one step to the right.
- <<       Sets the cursor position one step to the left.
- BACK    Returns to the previous menu SETUP1.

**HELP**

EXIT
<b>HELP</b>

**Help Menu**

The HELP menu shows a circuit diagram of the test setup in principle to help identifying the setup values.

- EXIT       Returns to the previous menu, i. e. one level up, e. g. MAIN S or MAIN M.

**MISC**

INFO
LIGHT
BEEP
DISP
EXIT
<b>MISC</b>

**Miscellaneous Settings**

- INFO       Calls the INFO display, which contains information on the instrument and its version, for instance.
- LIGHT    Calls the submenu LIGHT to set the delay of the display's shutoff function.
- BEEP     Calls the BEEP submenu for switching the sound mode of the pushbuttons.
- DISP     Calls the submenu DISP to select the displayed values within the meter display
- EXIT       Returns to the previous menu, i. e. one level up, e. g. MAIN S or MAIN M.

**INFO**

EXIT
<b>INFO</b>

The INFO menu contains information about:

- The type of instrument and its serial number.
- The actual firmware version and release day (SW version, SW release)
- The hardware version (HW version).
- Contact details of Power Diagnostix.

EXIT Returns to the previous menu, i. e. one level up.

**LIGHT**

5 MIN
10 MIN
>30 MIN
EXIT
<b>LIGHT</b>

**Automatic Shutdown of the Backlight**

5MIN The display's back light is shut down automatically after 5 minutes of idle time to avoid wear of the lamp.

10MIN The display's back light is shut down automatically after 10 minutes of idle time to avoid wear of the lamp.

30MIN The display's back light is shut down automatically after 30 minutes of idle time to avoid wear of the lamp.

EXIT Returns to the previous menu, i. e. one level up.

**BEEP**

LOW
>HIGH
EXIT
<b>BEEP</b>

**Key Sound**

LOW Selects the lower pitch key sound.

HIGH Selects the higher pitch key sound.

EXIT Returns to the previous menu, i. e. one level up.

**DISP**

>tan $\delta$
cos $\varphi$
>UCN
>CX
EXIT
<b>DISP</b>

**Display Mode**

tan  $\delta$  Selects the tan delta within the METER display.

cos  $\varphi$  Selects the cos  $\varphi$  within the METER display.

UCN Selects the voltage value across the standard capacitor for the METER display.

CX Selects the calculated capacitance of the specimen for the METER display.

Since only three values can be displayed, the user has to deselect a value before the new value can be chosen (if three values are active).

**III.3.3 Reset to Default Settings**

To restore the factory default settings of an TDAcompact, press the top and bottom buttons of the push button line at the left-hand side simultaneously when switching on the device.

## IV Software

### IV.1 Overview and Main Functions

The TDAcompact can be fully controlled by the software running on a common PC or laptop. It allows exporting the results in a standard text format '.html', which can be read by common internet browser or programs like MS Excel or MS Word. Additionally, the 'Record' panel allows exporting the measurement results directly into the Excel format '.xls'.

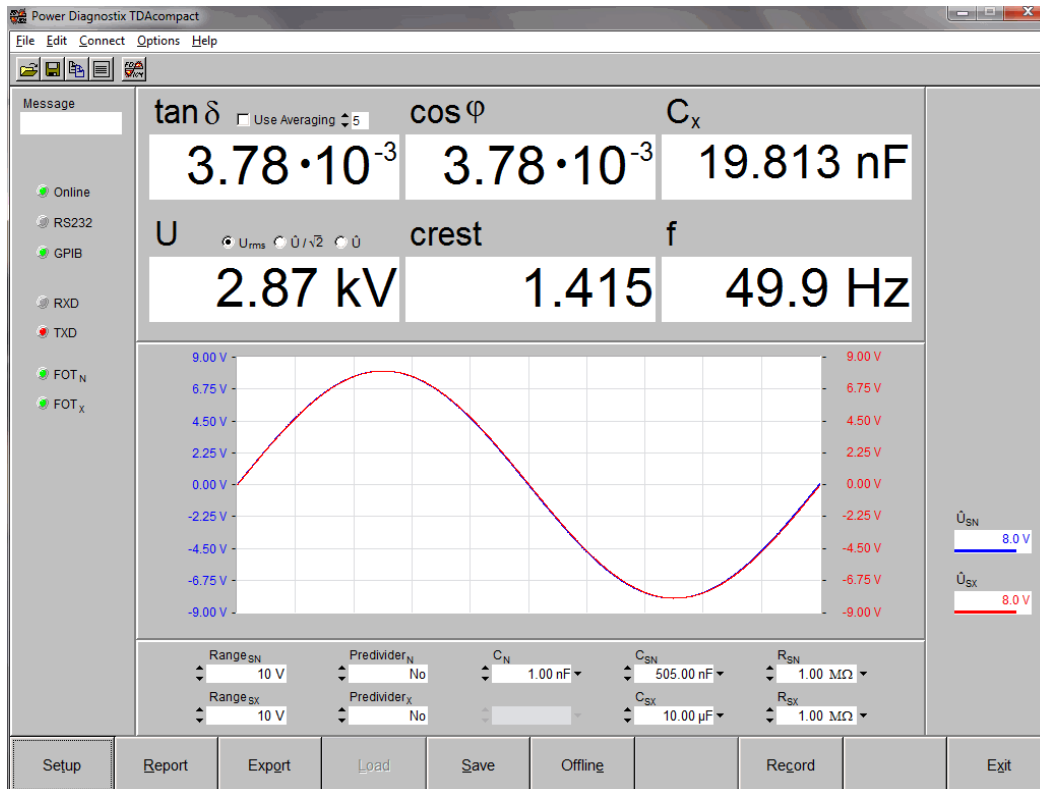


Fig. IV.1: Main panel of the TDAcompact software

Remark: If the application window appears very small when started on a PC with Windows 10, please refer to section IV.2.1 "HDPI Scaling" on page 24.


Main functions of the program are controlled by a row of buttons at the lower end of the display. An overview regarding the shortcut keys is given on the following pages.

The central display area shows the results of the current or a re-loaded measurement. The display area at the main display's left-hand side indicates the status of the communication channel and the loaded file. Upon start-up, the software checks the ports for a valid connection to an instrument and loads the setup of the instrument after the connection is established.

The top two lines show in large characters the calculated results of the measurement. The type of displayed voltage value ( $U_{rms}$ ,  $\hat{U}/\sqrt{2}$ ,  $\hat{U}$ ) can be selected by clicking the related check mark. The two lines on the right-hand side display the input voltage of the FOT2 and the selected input range. If the displayed values change to red colour, the maximum input voltage is exceeded, and the range must be changed.

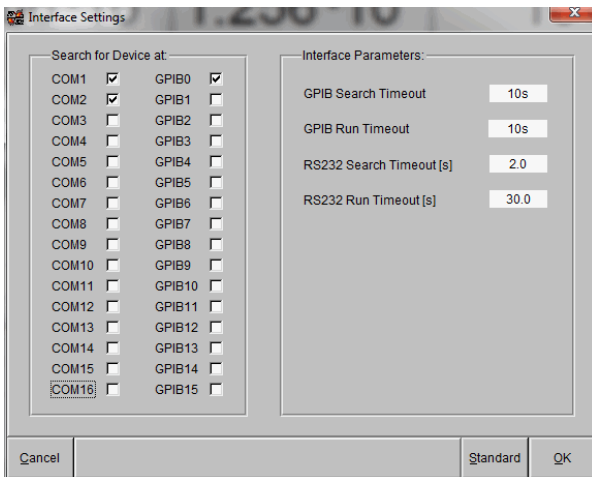
The area underneath the voltage graph shows the main settings of the TDAcompact. Those can also be changed here. The new setting will be sent to the instrument, then. For a detailed description see section IV.2.3.

## IV.2 Installation

The software for the TDAcompact is installed by the installer  setup.exe, which will guide through the installation process. An icon of the TDAcompact software will be placed on the desktop.

In case a GPIB interface card is needed, the driver of the GPIB interface needs to be installed before physically installing the interface card!

In the first online session the device code of the instrument has to be entered to keep the serial connection. The PC will then actively communicate with the instrument and take the measurement values. This code comes with the installation CD-ROM or can be requested from Power Diagnostix.



After starting the installed software, all selected connections will be checked for an acquisition unit.

For speeding up the search process, only the connections which are used should be selected in the menu 'Options / Interface Settings'. Usually, this is GPIB0 only.

Fig. IV.2: Interface settings



IV.2.1 HDPI Scaling

On PCs running Windows 10 with the Creator's Update of 2017 the TDAcompact application window may appear very small on high resolution monitors. To enlarge the display size of the software, please take the following steps:

1. Right-click on the application short cut on the desktop.
2. Choose "Properties" from the context menu, which will open the Properties window.
3. Enable "Override high DPI scaling behaviour" and set "Scaling performed by" to "System" on the "Compatibility" tab.
4. If you have administrator rights, you can change the settings for all users by clicking the corresponding button.
5. Approve the change by clicking "OK".

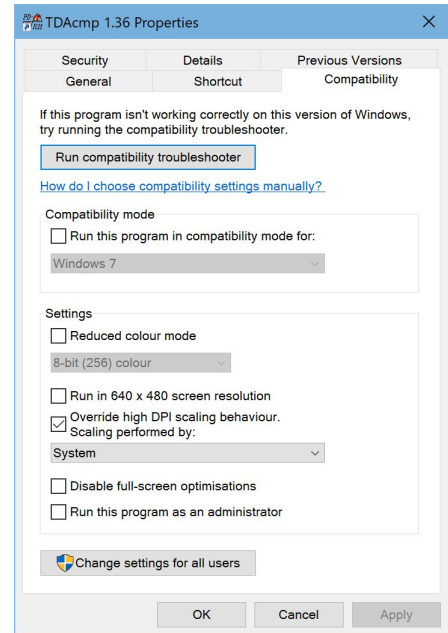


Fig. IV.3: Properties window

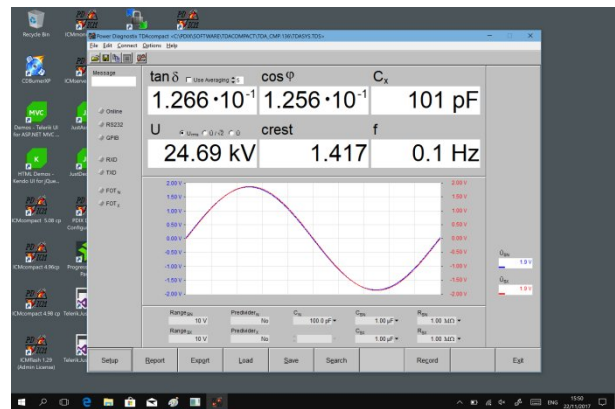
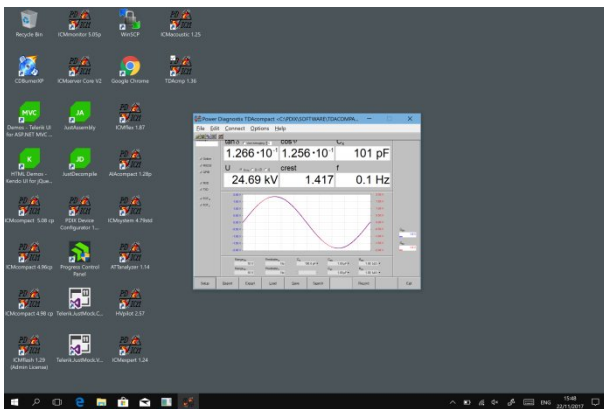


Fig. IV.4: Desktop before and after change of scaling behaviour

## IV.2.2 General

### Copy

By means of the standard copy function (<Ctrl> + C) the current content of the main display is copied to the clipboard. The graph of the waveforms is copied along with calculated values ( $\tan \delta$ ,  $\cos \varphi$ ,  $C_x$ , U, crest, f) as a bitmap to allow easy pasting into reports and other documents.

### Help

The version numbers of the firmware and software can be found under 'Help' \ 'About' together with contact details of Power Diagnostix. If you encounter problems with the TDAcompact please don't hesitate to contact us.

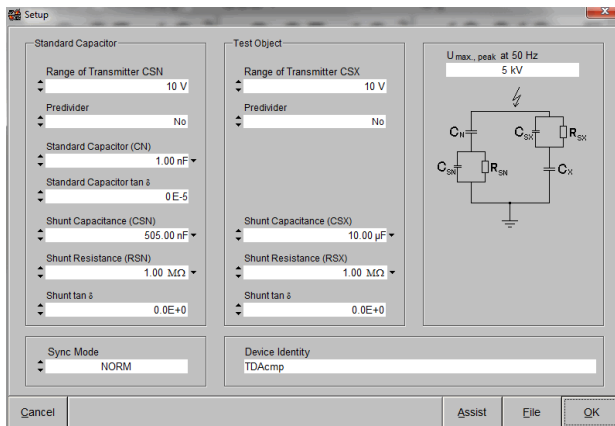
### Display Resolution

The default display resolution of 1024x768 pixels is designed for standard monitors. In case a smaller display is used, the resolution can be changed manually or to an automatic mode ('Options' \ 'Display Resolution').

### Scaling Mode

By default, the scaling of the voltage curves are adjusted automatically so that all eight height divisions are used to display the curve. If the scaling mode is changed to 'manual' ('Options' \ 'Scaling Mode'), the eight height represent the full range of the transmitter (FOT2). The scaling factor is then fixed to fit to the maximum input voltage. The marked function is active.

## IV.2.3 Setup



Before starting a measurement, the setup data must be entered to fit the instrument to the physical measurement setup. The setup values can be entered either at the instrument itself or via the software menu 'Setup' and then be uploaded. The upload of the changed values to the instrument is done after pressing the 'OK' button while the instrument is connected. The setup data is automatically downloaded from the instrument after a connection is established.

Fig. IV.3: Setup window

The setup data can also be saved on the computer using the 'Save' button (F5) within the MAIN panel. The button 'File' within the SETUP panel will load a saved setup file (\*.tds) and send it to the instrument. This allows setting the instrument to the status of a done and saved measurement.

Range of transmitter CN  
Range of transmitter CX

The voltage range (1V, 2V, 5V, 10 V, 20 V, 50 V, 100 V) selected on the transmitter FOT2 must also be set in the software to allow a correct calculation of the voltage and  $C_X$  value. The values can be different at the FOT2 of the standard capacitor ( $C_N$ ) and of the test object ( $C_X$ ).

Pre-divider

A pre-divider can be used to extend the useable voltage range of the FOT2. The divider ratio (1:2, 1:3, 1:4, 1:5, 1:10) must be set here to allow a correct calculation of the voltage and  $C_X$  value.

Standard capacitor (CN)

The size of the standard capacitor (or reference capacitor) must be entered here. The value can be set in pF, nF or  $\mu$ F, dependent on the selection of the unit setting.

Standard capacitor tan  $\delta$

If the standard capacitor has a known tan delta, this value can be entered here as a correction factor.

Shunt capacitance (CSN)  
Shunt capacitance (CSX)

The size of the shunt capacitors in the two branches ( $C_N$  and  $C_X$ ) must be set in the software. These values are required for the calculation of the angles,  $C_X$ , and the voltages ( $U_{CN}$  and  $U_{CX}$ ).

Shunt resistance (RSN)  
Shunt resistance (RSX)

In case of known parasitic resistances within the shunts these values should be entered to increase the accuracy of the measurement. The input resistance of the FOT2 is about 1 M $\Omega$  / 10 M $\Omega$  and should be added to this value.

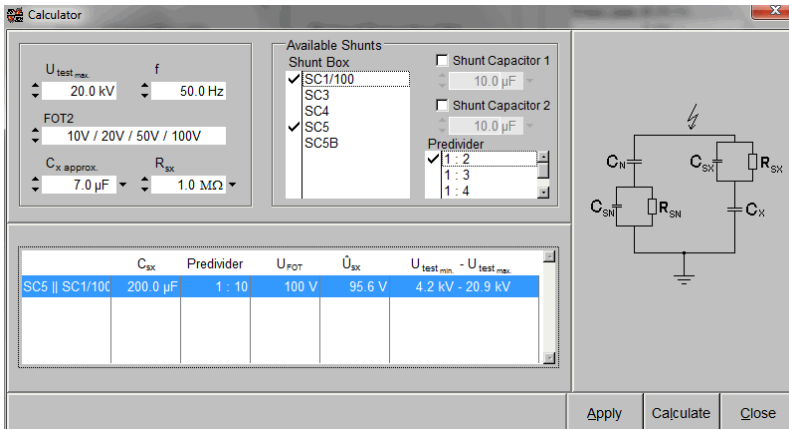
Shunt tan  $\delta$

Known parasitic resistances within the shunts can also be entered as tan delta value. Both values RSN and shunt tan delta, respectively RSX and its shunt tan delta are added and taken into account for the calculation of the dissipation factor. This value is considered in the software only.

$U_{max.}$  at 50 Hz

The voltage  $U_{max.}$  is calculated from  $C_N$ ,  $C_{SN}$  and the maximum input voltage of the FOT2. It shows the maximum voltage that can be applied without over-ranging the branch of the standard capacitor.

For the calculation of the correct shunt capacitance, assistance is available. Pressing the 'Assist' button, opens the following window:



On the left-hand side the measurement parameter must be set. The 'Available Shunts' area lists the existing shunt capacitors and allows selecting the available ones. Additionally, the pre-dividers can be selected. By pressing the 'Calculate' button, the results table shows all possible combinations of shunt capacitors and pre-dividers. Pressing the 'Apply' button, transfers the selected solution to the setup.

Fig. IV.4: Assistance for calculating the correct shunt capacitor

### IV.3 Function Keys

Main functions of the program are controlled by a row of buttons at the lower end of the display. These buttons represent the computer's function keys F1 to F10. Both clicking to that button and pressing of the according function key will cause the action indicated by the button's label. E. g. The button representing the function key F6 is labelled 'Search' in case no instrument is connected. The same function can also be found in the pull-down menu 'Connect' / 'Search'.

Setup	Report	Export	Load	Save	Search		Record		Exit
F1	F2	F3	F4	F5	F6		F8		F10

#### Setup (F1)

Before measurements can be taken, some setup data must set. More details can be found in the previous chapter.

#### Report (F2)

The 'Report' window allows entering fix measurement data like: Date, Time, Report No., details to the test object and the testing person. These data will be added to the results in the exported report file.

#### Export (F3)

The 'Export' function allows to create a report file in a text format (\*.html) which can be read by standard internet browser or programs like MS Excel and MS Word. The default language of this report can be chosen between English, French and German and is defined in 'Options \ Report Language'. Additional information to the measurement data can be entered in the field 'Report' (or F2).

#### Load (F4)

The 'Load' function is only available while the software is offline. It loads a saved measurement (.tds) including the setup data, the last voltage values, and the sequence voltages. The test sequence measurements, visible after pressing the 'Record' button, have to be loaded separately. For this the 'Test Sequence' panel has to be opened (Record) and the Load (F4) button pressed. All setup data, report entries, test sequence data as well as the last voltage curves can be recalled from the '.tds' file.

#### Save (F5)

The 'Save' function allows to save a whole measurement including the voltage curve, the setup data, the report data, and the record data (see next chapter). The file is stored in a binary format extended by '.tds' and can only be read by the TDAcompact software.

#### Search / Offline (F6)

In case no instrument is connected, the button 'Search' tries to connect to a TDAcompact via the ports selected in the 'Interface Setting'. To disconnect an instrument the same button now labelled 'Offline' must be pressed.

#### Record (F8)

The two modes of the record function are described in the next chapter.

#### Exit (F10)

The 'Exit' button will end the program.

#### Default Directory (F11)

The directory which is accessed by default with the 'Load' and 'Save' dialog can be set in this function. It is also available in the menu 'File \ Default Directory'.

### IV.4 Record

The record function allows a continuous observation and recording of the measured data on a 'strip chart'. The selected voltage value, the tan delta value, and the  $C_x$  value are printed continuously into this chart. The current values are shown underneath the 'strip chart'. The colours of the graphs can be changed by a single click on the coloured box next to the related value. Single measurement values are collected in a table underneath the 'strip chart'. To monitor the input voltage of the transmitter and prevent an over ranging of the signal, the signal voltages are shown on the left-hand side of the measured values together with the set maximum ranges. On the left-hand side the status of the communication and the FOT transmitter are indicated.

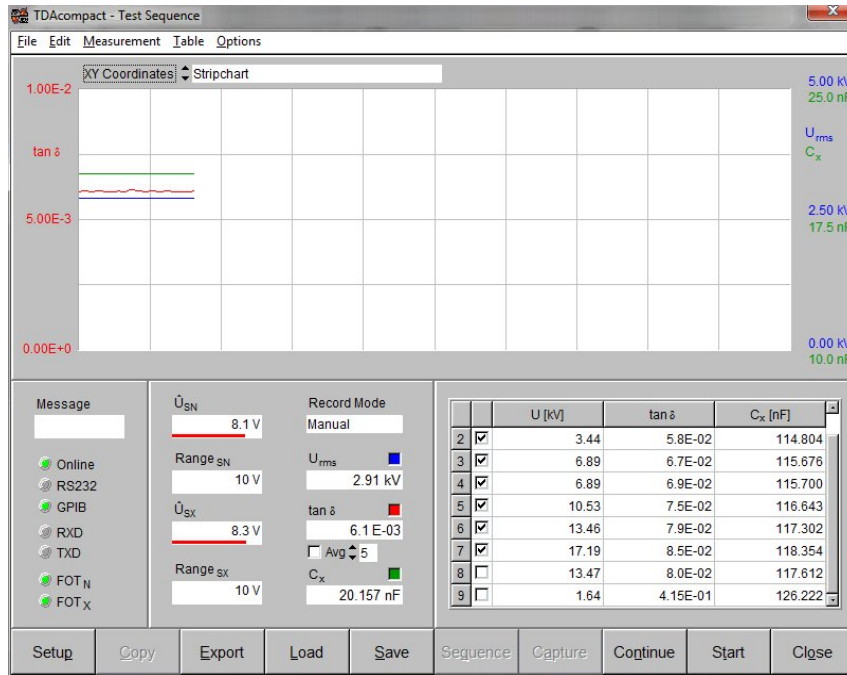


Fig. IV.4: Test Sequence panel for the record function

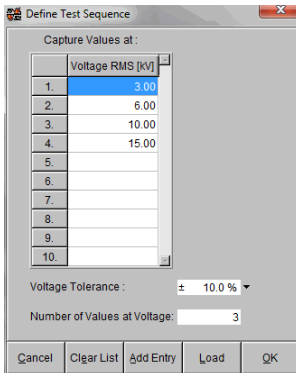
Two modes are available for recording single data sets in the table. Before starting the record function, the mode must be selected by a click on the **Record Mode** field. A new record can be started by pressing the 'Start' button, then. It is possible to resume an interrupted or loaded record by pressing the 'Continue' button.

#### Manual Mode

With the manual mode the record is run by the 'Start' button. The 'strip chart' displays the continuously captured measurement data, while the table records only requested data by the button 'Capture'. These data will be put together with the entered report data and can be exported as an Excel sheet (.xls) by the button 'Export'.



### Test Sequence (Automatic Mode)



With the automatic mode the record can be set up with the 'Sequence' button. The voltage levels, at which measurement data should be taken, can be entered by a double click in the 'Voltage' box. To allow the measured voltage a tolerance, a relative [%] or absolute [V] voltage band around the set voltage should be entered. By the black arrow down the voltage tolerance can be changed from relative [%] to absolute [V] values. Measurements are taken in the sequence of the field number. Additional fields can be added by the 'Add Entry' button. The test will end with a '-1' or no further voltage value in the table.

Fig. IV.5: Define Test Sequence panel

### Storing and Display of the Data

Once a test sequence is set up, it can be saved to allow a later reloading of the sequence without changing other setup parameters. The test will start automatically once the sequence values and the general report data are entered. A running test is indicated by a red lit 'Stop' button. After the test is finished or the 'Stop' button pressed, the recorded data together with the entered report data can be exported as an 'Excel sheet' (.xls) by the 'Export' function.

The whole test can be kept by the 'Save' function to allow a later analysis of the measurement data. This will generate a '.tds' file containing:

- the sequence template (voltage values where measurement data are put into the table)
- the recorded curves from the 'strip chart' with the tan delta, voltage and  $C_x$  values
- the captured measurement data from the table
- the report entries
- the setup entries
- the last two voltage waveforms

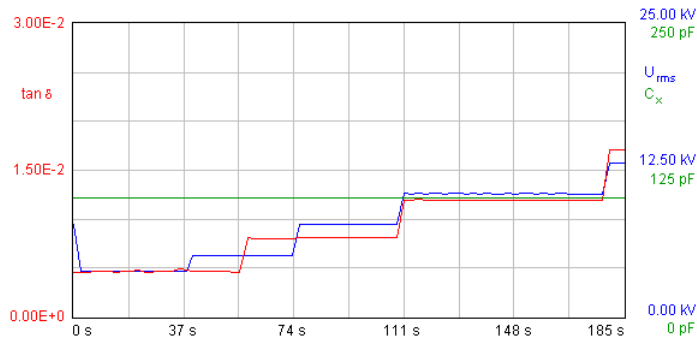
If some of the recorded data sets are not correct, it is possible to remove them. First, these data sets must be deselected in the record table. This will remove them from the charts and these sets will not be exported, but still stored in the '.tds' file. To remove these data sets completely, the 'Table / Remove Deselected Items' menu item must be selected.

Once a test is finished, the 'strip chart' can be displayed in two further forms. To change this display forms, the arrows next to 'XY Coordinates' must be pressed.

**Strip chart**

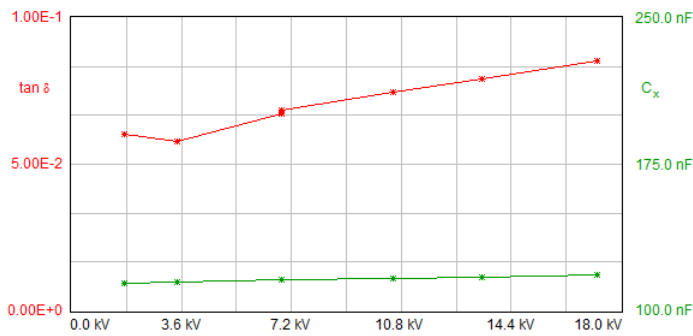
The 'strip chart' continuously plots the three measurement values. The speed of the acquisition and the refresh rate of the chat depend on the connection to the instrument. Therefore, the time axis cannot be scaled while taking the measurements.

**Values versus Time**



All three values (U, tan delta and C<sub>x</sub>) are shown on a scaled time axis for the period of the whole test.

**Dissipation factor and capacitance value versus voltage**



The captured tan delta and capacitance values are shown in relation to the voltage values. Only the values from the table are taken for this graph.

## V Miscellaneous

### V.1 Maintenance

The TDAcompact does not require any maintenance on a regular basis and there is no fine adjustment on a regular basis required.

### V.2 Shipment Instructions

In case a unit needs to be returned to the factory, make sure the acquisition unit is packed safely. As the units are relatively small, shipment by couriers, such as DHL, FedEx, or equivalent is the recommended mode of transportation. If possible, declare the instrument as 'used instruments for evaluation' at a relative low value. Consult Power Diagnostix for further details. Additionally, Power Diagnostix may provide you with a temporary replacement unit, in case of urgent needs.

### V.3 Declaration of Conformity

Power Diagnostix Instruments GmbH  
Vaalser Strasse 250  
52074 Aachen  
Germany



declares, that the instrument as specified below, meets the requirements of the standards and/or normative documents as listed below.

Product: TDAcompact

Description: Capacitance and dissipation factor analyser

Guidelines: Low Voltage Directive 2014/35/EU  
EMC Directive 2004/108/EG  
RoHS Directive 2011/65/EU

Standards: EN 61010-1:2010, EN 61326-1:2013  
EN IEC 63000:2018

Date:

Mihai Huzmezan (managing director)

## VI Technical Data

### VI.1 TDAcompact

Mains supply:	85–264 V <sub>AC</sub> , 47–440 Hz	(automatic)
Line fuse:	1.6 A	(time-lag)
Power requirements:	Approx. 20 VA	
Display:	Backlit LCD	
Display resolution:	128 x 240 Pixel S/W	
Operation:	5 menu supported pushbuttons	
Operation temperature:	10–40 °C	(non-condensing)
Size (incl. connectors): <sup>2</sup>	Height: 133 mm Width: 236 mm Depth: 301 mm	
Weight:	Approx. 4 kg	
Input:	2x fibre optic with SMA jacks	
Measured frequency range:	20 ... 510 Hz	
Accuracy (tan $\delta$ , cos $\varphi$ ):	0.02 (reading) + 5 x 10 <sup>-4</sup>	(with the software 10 <sup>-4</sup> )
Accuracy (capacitance):	0.02 C + 10 pF	
Accuracy (voltage):	0.02 U	(for sine waveforms)
Values displayed:	tan $\delta$ , cos $\varphi$ , rad, U <sub>CN</sub> , C <sub>X</sub>	
Adapted display:	The voltage curves are adjusted automatically	

### VI.2 FOT2B/FOT2C Transmitter

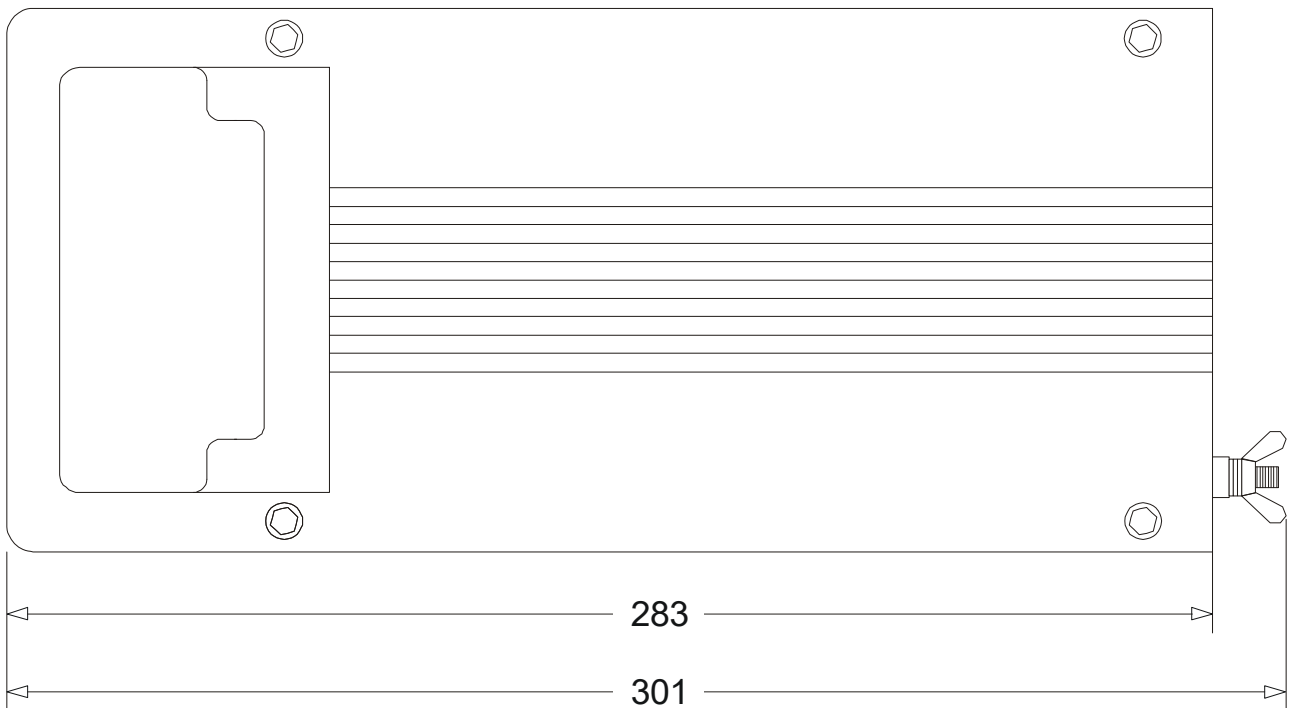
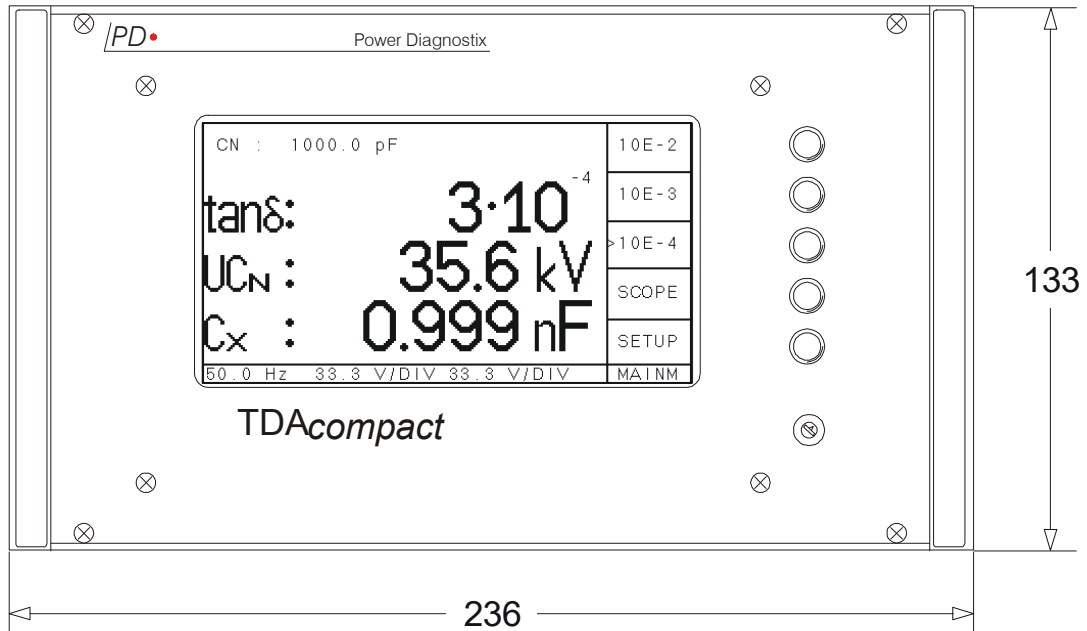
Maximum voltage input:	20, 100, or 200 V <sub>peak</sub> (with Autogain)
Input impedance:	1 M $\Omega$ (20 V <sub>p</sub> ), 5 M $\Omega$ (100 V <sub>p</sub> ), or 10 M $\Omega$ (200 V <sub>p</sub> )
Transmitted frequency range:	0 to 20 kHz (-3 dB)
A/D converter:	$\pm$ 11 bits
Connectors:	Input: 1x BNC, output: 1x SMA (FOT2B) Input: 2x BNC, output: 1x SMA (FOT2C)
Size:	Height: 35 mm Width: 50 mm Depth: 65 mm (including jacks: 80 mm)
Weight:	Approx. 600 g

<sup>2</sup> Allow about additional 100 mm to connect the cables.

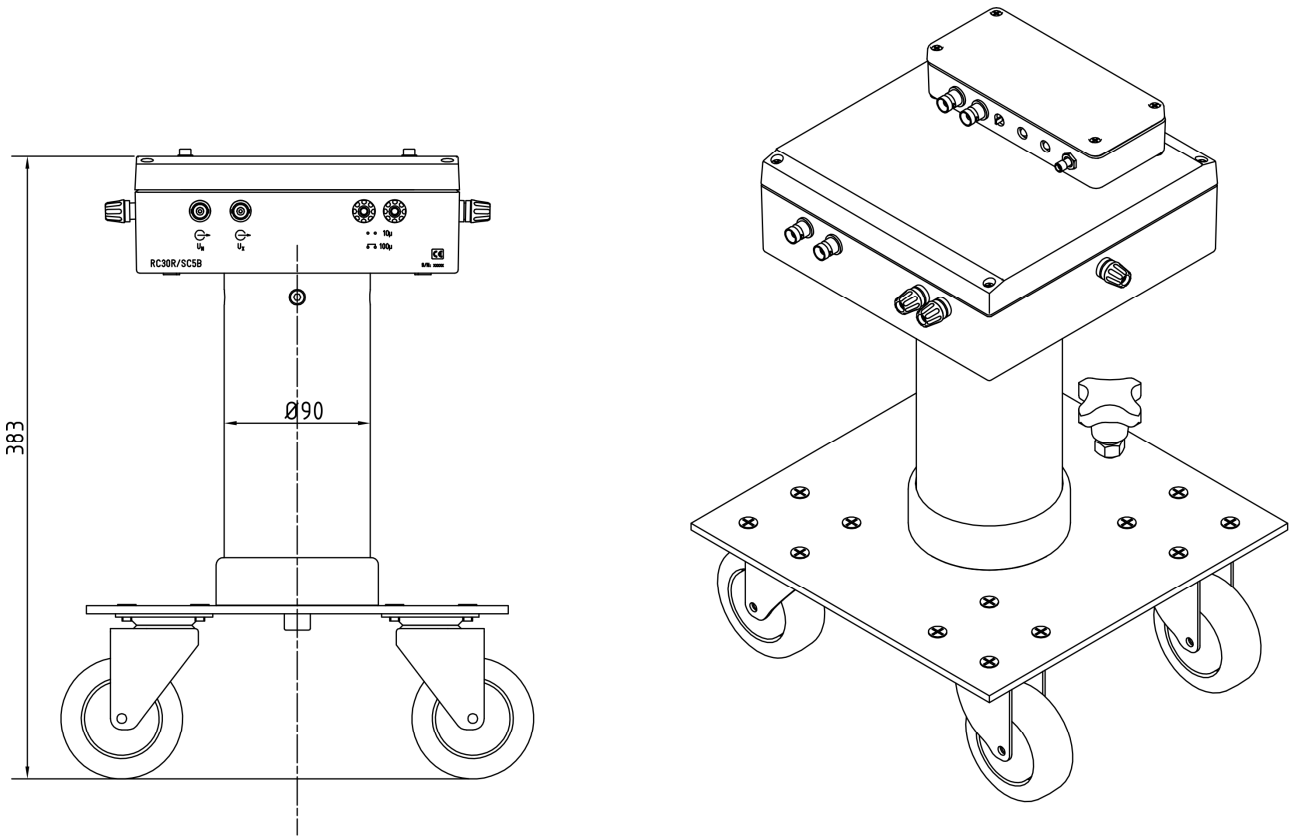
## VII Appendix

### VII.1 Scale Drawings

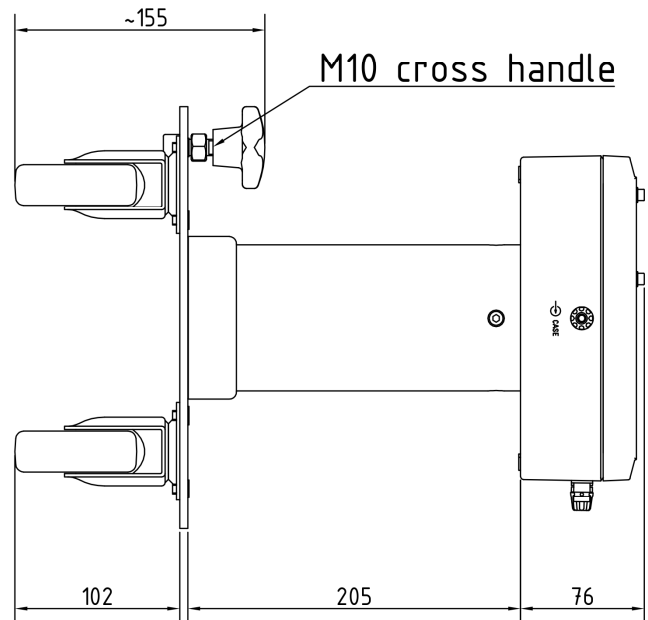
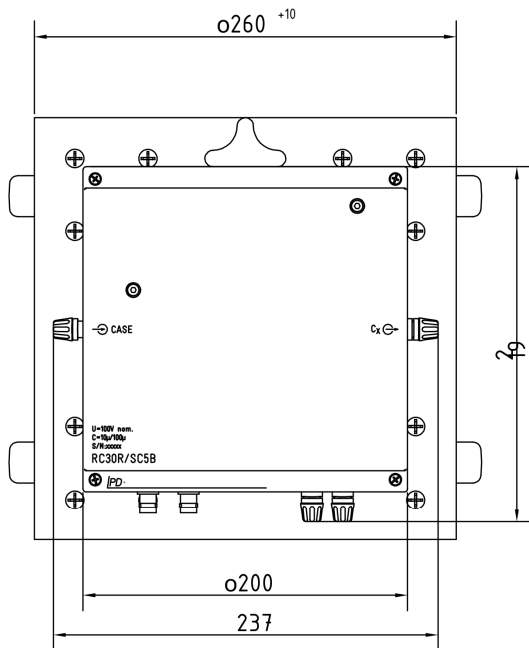
#### VII.1.1 Acquisition Unit



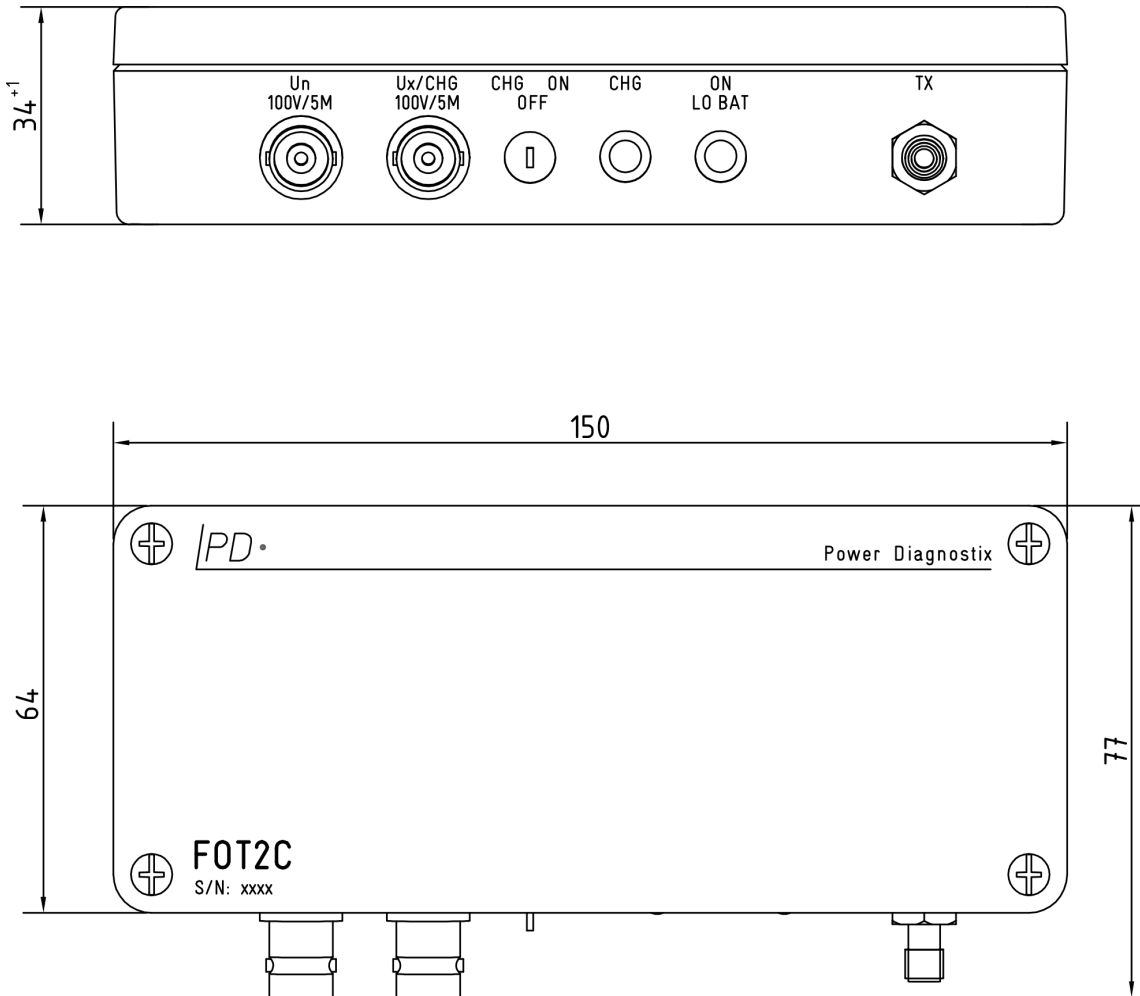
VII.1.2 Combined Shunt and Reference Capacitor RC30R/SC5B



RC30R/SC5B shown with FOT2C



VII.1.3 Transmitter FOT2C





## VII.2 National Instruments Hardening Guide

### VII.2.1 Introduction

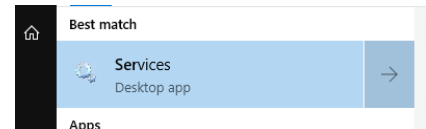
This manual will guide you through the Power Diagnostix proposed cyber security operation system hardening after the installation of a National Instruments based software product. The configuration refers to the Power Diagnostix software products, only. If any other 3<sup>rd</sup> party National Instruments based software products are installed or required, the proposed configuration should be adjusted with the configuration of the responsible manufacturer.

This configuration guide will close three unnecessary National Instruments services. Furthermore, the local Port 3848 UDP and TCP opened by these services will be closed.

nidmsrv.exe	3848	TCPV6	[0:0:0:0:0:0:1]	49672	[0:0:0:0:0:0:1]	49673	ESTABLISHED
nidmsrv.exe	3848	TCPV6	[0:0:0:0:0:0:1]	49673	[0:0:0:0:0:0:1]	49672	ESTABLISHED
nidmsrv.exe	3848	TCP	DESKTOP-Q5NEF6E	59111	DESKTOP-Q5NE...	0	LISTENING
nidmsrv.exe	3848	UDP	DESKTOP-Q5NEF6E	5000	*	*	
nidmsrv.exe	3848	UDP	DESKTOP-Q5NEF6E	6000	*	*	

### VII.2.2 Step-by-Step Guide

1.) Open the windows start menu and type "services.msc".



2.) Click onto the search result named "Services". The "Services" window will open.

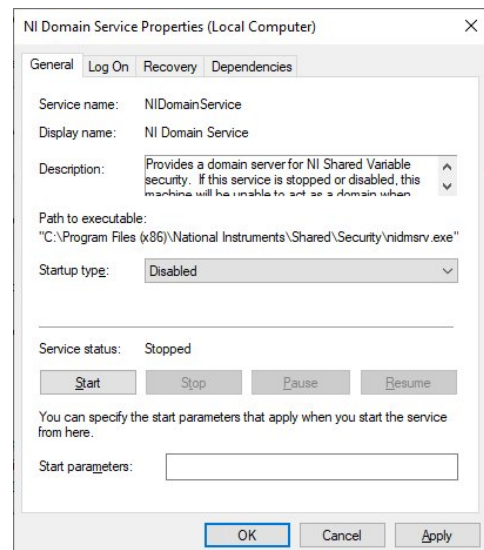
3.) Locate these services in the service list:

- NI Domain Service
- NI PSP Service Locator
- NI Time Synchronization

NI Domain Service	Provides a domain server for NI Shared Variable se...	Running	Automatic	Local System...
NI PSP Service Locator	Locates servers at the request of network variable c...	Running	Automatic	Network S...
NI Time Synchronization	Allows this machine to keep its time synchronized ...	Running	Automatic	Local System...

4.) Open the configuration popup by double click **each service** and change the "Startup type" to "Disabled".

5.) Save the changes with the button "OK".



### VII.2.3 Service Description

<http://www.ni.com/product-documentation/14487/en/>

<b>NI Domain Service</b>
<b>Service:</b> NIDomainService <b>Process:</b> nidmsrv.exe
<b>Description:</b> Provides a domain server for NI Shared Variable security.  <b>If Disabled:</b> If this service is stopped or disabled, this machine will be unable to act as a domain when configuring shared variable security.
<b>NI PSP Service Locator</b>
<b>Service:</b> lkClassAds <b>Process:</b> lkads.exe
<b>Description:</b> Locates servers at the request of network variable clients and other proprietary NI network protocols.  <b>If Disabled:</b> If this service is stopped or disabled, network variables and network streams will stop working.
<b>NI Time Synchronization</b>
<b>Service:</b> lkTimeSync <b>Process:</b> lktsrv.exe
<b>Description:</b> Allows this machine to keep its time synchronized with a master time server, or to act as a time server for other machines. This feature is configured with the Shared Variable Engine settings in LabVIEW.  <b>If Disabled:</b> If this service is stopped or disabled, this form of time synchronization will not be available.

## VII.3 Measurement Parameters

Description	Setup	Value	Type	S/N	Calibration Date
Standard / reference capacitor	CN	1 nF	RC30R	356	07/07/2017
tan $\delta$ of reference capacitor	TDN	2 E <sup>-5</sup>	RC30R	356	07/07/2017
Input impedance of FOT2 (reference path)	RSN	1 M $\Omega$	FOT2B	773	
Input range of FOT2 (reference path)	FOT N	20 V	FOT2B	773	
Shunt capacitor (reference path)	CSN	500 nF	RC30R	356	07/07/2017
Pre-divider (reference path)	DIV N	1:2	1M//65p		
Input impedance of FOT2 (test object path)	RSX	1 M $\Omega$	FOT2B	774	
Input range of FOT2 (test object path)	FOT X	100 V	FOT2B	774	
Shunt capacitor (test object path)	CSX	50 $\mu$ F	SC5B	521	
Pre-divider (test object path)	DIV X	1:10	1M//65p		

Tab. 1: Measurement parameters (example configuration with RC30R/SC5 und FOT2B)

Description	Setup	Value	Type	S/N	Calibration Date
Standard / reference Capacitor	CN				
tan $\delta$ of reference capacitor	TDN				
Input impedance of FOT2 (reference path)	RSN				
Input range of FOT2 (reference path)	FOT N				
Shunt capacitor (reference path)	CSN				
Pre-divider (reference path)	DIV N				
Input impedance of FOT2 (test object path)	RSX				
Input range of FOT2 (test object path)	FOT X				
Shunt capacitor (test object path)	CSX				
Pre-divider (test object path)	DIV X				

Tab. 2: Template for measurement parameters of the customer's configuration

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