ICM*compact*

Partial Discharge Detector

User Manual

Rev. e4.21

Contents

I   General

I.1   About this Manual

This manual describes the hardware, software, and usage of the ICM*compact* in its current version. Some of the hardware features of the most recent versions are not available with earlier versions of the instrument. It is possible to upgrade most of the previous instruments to the features of the current instruments. Please contact Power Diagnostix for details.

Software updates are available through Power Diagnostix's web site (www.pdix.com). The access to the download area of that Web Site is password protected and requires a valid software maintenance contract. Contact Power Diagnostix for details. Current brochures and revisions of this manual are available for download (Adobes PDF-Format) through that Web Site as well.

This manual describes the ICM*compact* including its miscellaneous functions. These functions have to be ordered separately and are marked as optional functions. For information regarding the accessories and special applications of the ICM*compact* please contact Power Diagnostix.

I.2   Instrument Safety

Before using the ICM*compact*, read the following safety information and this manual carefully. Especially read and obey the information, which 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 section. 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. Use the rear side wing nut terminal for ground connection (system ground see section II.3.1) 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 damage, or its safety is impaired.

- Inspect the ground leads and signal cables for continuity.

- Select the proper coupling circuit and connection for your application.

- Do not use the instrument in condensing or explosion endangered environment.

I.3   Principle of Operation

The ICM*compact* partial discharge detector is designed for quality assurance and quality control tests of high, medium, and low voltage insulation in a test laboratory environment. The instrument may be adapted to non-conventional testing tasks such as field testing and diagnostics by use of various preamplifier and couplers. The standard set (figure I.1, marked blue) of the ICM*compact* consists of a coupling unit CIL4L, a preamplifier RPA1 and the instrument.

The ICM*compact* partial discharge detector is an autonomous instrument. Simple screen shots and storage of results can be done by means of the optional serial interface and a PC program. A precise evaluation of the measurements is possible using databases, specific knowledge bases or getting in contact with Power Diagnostix' people. For tasks requiring extended computer control, protocol functions and data manipulation we recommend the ICM*system*.
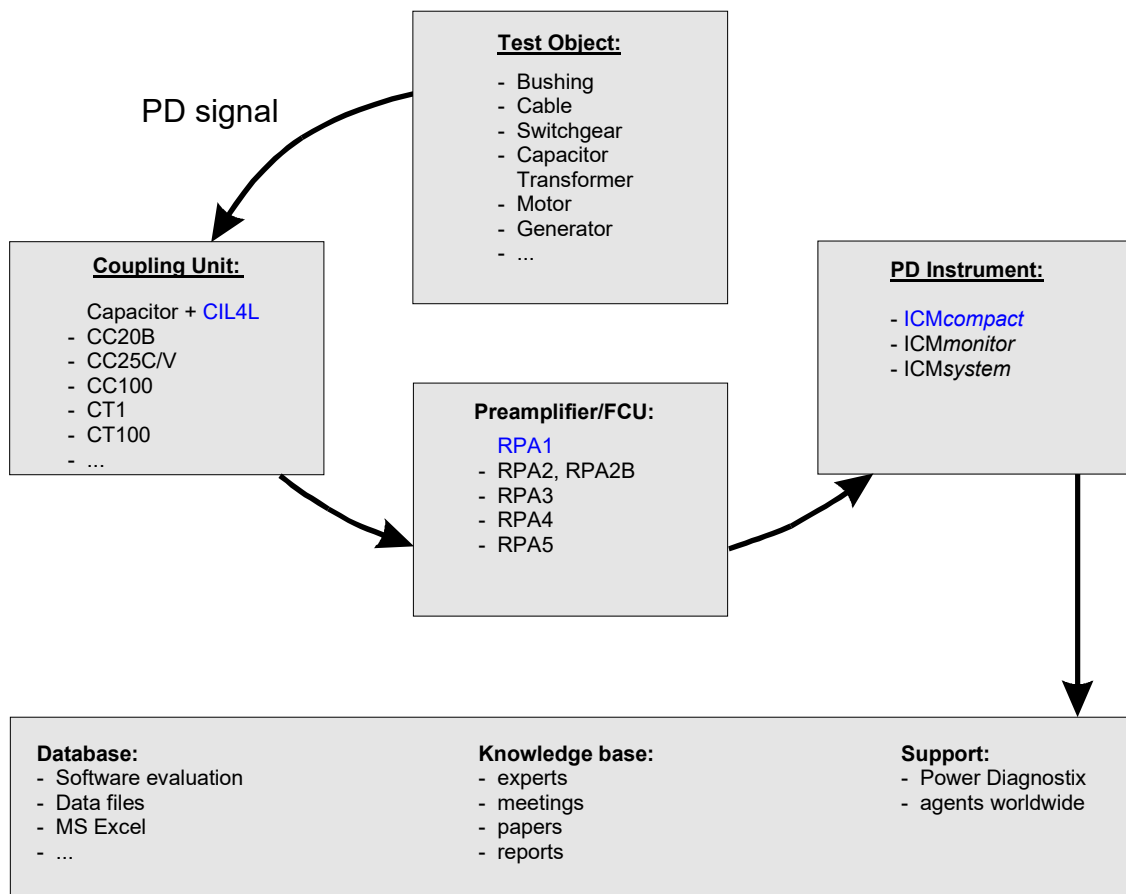
Fig. I.1: Principle of PD measurement

The ICM*compact* is easy to use. The operator can choose between several display modes of the integrated LCD screen, e. g. meter display, scope display or partial discharge pattern display. All instrument settings including calibration are done via the on-screen menus by pushing the five buttons on the right side of the instrument. These settings are automatically stored in a non-volatile memory when the system is shut down. The following section describes the use of the ICM*compact* PD detector.

II   Hardware

II.1   Acquisition Unit

The standard ICM*compact* package includes the partial discharge detector, the remote-controlled pre-amplifier and the standard coupling unit CIL4L. All PD detectors of Power Diagnostix' are built on a modular concept. Therefor it is possible to vary all external accessory parts like i. e. coupling units, preamplifiers, or calibration impulse generators. For more details about all accessories please contact Power Diagnostix. It depends on each application, what kind of combination for coupling unit and preamplifier will bring the best results.

Figure II.1 shows the instrument as rack mountable version, while a photo of the instrument in a half 19" rack (desktop version) is shown with figure II.2. The layout of an ICM*compact* in a robust outdoor case is shown with figure II.3. The backlit liquid crystal display of all three models has a resolution of 240 x 128 pixels.
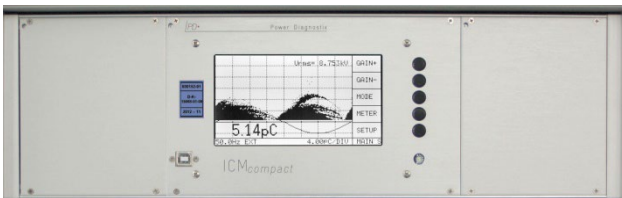
Fig. II.1: ICM*compact* as rack mountable version
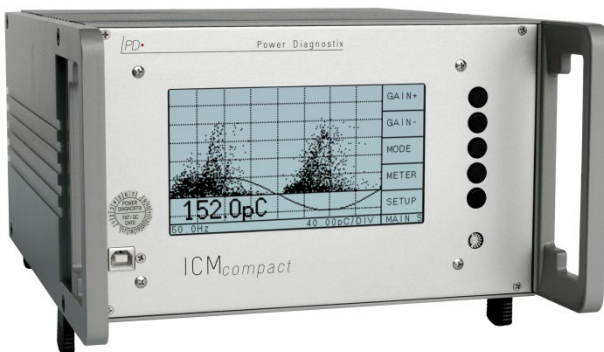
Fig. II.2: ICM*compact* in a half 19" rack

Fig. II.3: ICM*compact* in a rugged case

The control buttons are arranged at the right-hand side of the LCD panel. The brightness adjustment of the LCD is accessed using a small screwdriver, immediately beneath the control buttons. A temperature deviation of the environment will be compensated by the device itself.

On the rear panel of the standard (½ 19" wide) and the rack mountable (19" wide) instrument are found the BNC connectors for signal input 'AMP IN', the strip chart recorder output 'REC OUT', the input for external synchronisation 'SYNC IN', and the input for TTL and gating as well as the output for several different signals (SIG OUT), among others a signal for testing purposes according to IEC 60270. Further connectors for optional functions, such as a fibre optic serial connector 'COM (TTL)', the input for analogue gating ('GATE IN'), or the input for a reference signal for RIV measurements (REF IN) can also be found here.

The instrument operates with mains supply in the range from 85 V_{AC} up to 264 V_{AC} @ 47 to 440 Hz. The standard preamplifier RPA1 is connected to the AMP IN terminal with a normal 50 Ω coax cable, i. e. RG58. The amplified partial discharge signals as well as supply voltage and remote-control signals to the preamplifier are carried via this cable. The RPA1 acts as a 50 Ω line driver and thus significantly increases overall sensitivity when working with longer cables (up to 200 m). Furthermore, the RPA1 enhances the sensitivity of the coupling unit, essentially acting to match it to connecting cable impedance. This requires that the RPA1 be connected as close as possible to the coupling unit.
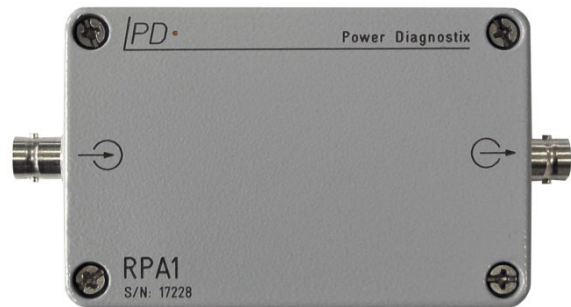
Fig. II.4: Preamplifier RPA1
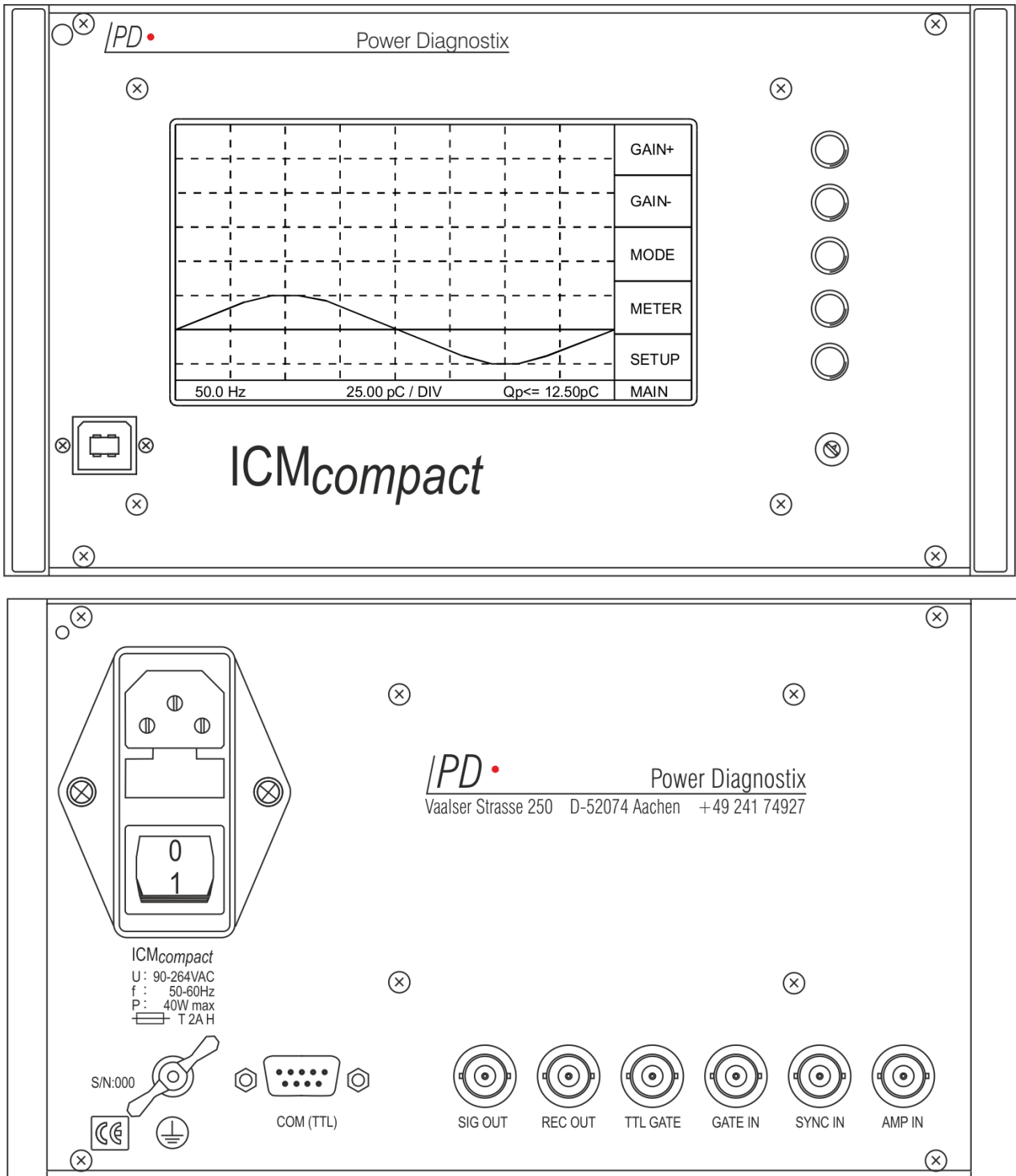
Fig. II.5: Front panel (top) and rear panel (bottom) of the ICM*compact*'s standard desktop version with COM (TTL) connector
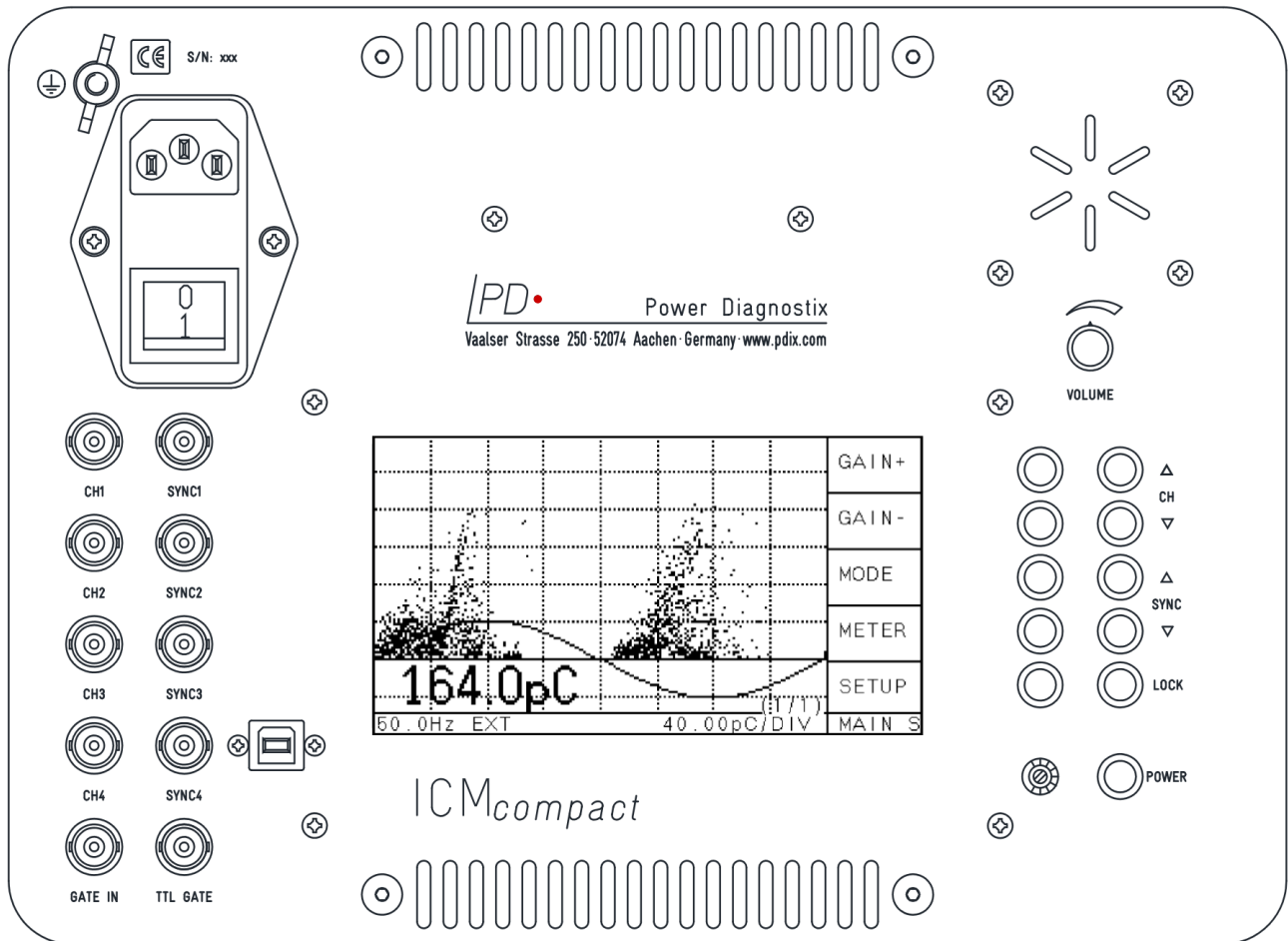
Fig. II.6: All-in-one panel of an ICM*compact* in an outdoor case with MUX4 option

The CIL4L standard coupling unit is a so-called RL coupling unit (inductance-resistance), which is tuned to coupling capacitors in the range of 600 pF to 2500 pF. Its permissible maximum charging current is 50 mA. Other coupling units can be supplied by Power Diagnostix on request.

Figure II.7 shows the standard coupling unit for the ICM*compact.*

Fig. II.7: Quadrupole CIL4L

II.2   Options for the ICM*compact*

The instrument can be equipped with several optional features as:

- SPEC board offers an additional frequency spectrum display for PD spectrum analysis.

- DSO board for cable fault location. Single PD pulses and their echoes are captured with a high sampling rate to localize faults in long cables. The extended software version stores and analyses the data (see also section III.3.4 and section IV.2).

- Additional voltage measurement and display, HVM display (see also section III.3.2) and VLF (very low frequency) functionality that allows measurements with 0.1 Hz, 0.05 Hz, and 0.02 Hz (see also section III.3.3).

- MUX4 or MUX12. The channel multiplexer allows manual switching between 4 or 12 different PD sources.

- AUX4. The auxiliary inputs record further data like power, temperature, speed (see also section III.3.7).

- STP12. A quick change of 12 different setups including the calibration data (see also section III.3.8).

- Software driver. If the ICM*compact* should be controlled by others than the original software, a driver for 'C' is available. This driver is only useful for software programming. (on request)

- Fibre optic link (COM TTL). Offers a safe insulation and an extended distance between ICM*compact* and the PC/laptop.

- Analogue gating input (GATE IN). Allows capturing disturbance signals via an onboard preamplifier RPA6G, which is used to blind out the noise signal (see also section III.4.4).

- FO TTL gating input. Via an FO connector at the rear panel, a TTL signal allows to blind out disturbance signals (see also section III.4.3). The signal is converted into an analogue TTL signal that is logically OR connected with the internal gate trigger signal of the analogue circuit if the instrument is equipped with an analogue gating option.

- RIV measurement. Adds a radio influence voltage measurement function to the instrument (needs the SPEC option and includes the MUX4 option).

- Software to record PD measurements and create report documents via a PC is available (see also section IV). Optional version for the cable fault location, only to use with the DSO option.

- LAN. The instrument is equipped with an additional RJ45 LAN connector or, alternatively, with a WLAN antenna.

II.3   Installation

II.3.1   Connections

There are various circuits to take measurements of PD with the ICM*compact*. The diagram below (figure II.8) illustrates the basic connections among the elements of the partial discharge measuring setup with the ICM*compact.* Here the coupling device (CIL4L) is put in series with the high voltage capacitor. So, the test object can be connected in parallel to the high voltage capacitor and the voltage supply.

Caution: The **AMP IN** may only be connected to a pre´-amplifier or a spectrum analyzer. The supply voltage for the pre-amplifier may damage the output circuit of the signal source. Be sure not to connect anything but an RPA to this terminal or to turn OFF the supply voltage. Only the **SYNC IN** terminal can take voltages up to ~200 V_{peak}. Do not apply any voltage to the **REC OUT** terminal (min. 100 Ω input impedance).

Fig. II.8: Basic connections for PD measurement on a test set up (not drawn to scale)

In order to prepare a measurement, connect the input (CC) of the coupling unit CIL4L to the low side terminal of the HV capacitor and the ground input (GND) of the coupling unit to ground. The output of the coupling impedance is directly connected to the RPA1 preamplifier preferably using a BNC/BNC adapter or a BNC cable of short length. This minimizes the capacitive loading of the coupling unit and exploits the relatively high input impedance (10 kΩ//50 pF) of the RPA1. The quality of the connecting cable between the RPA1 output and the ICM*compact* display unit (AMP IN) is fairly uncritical. Up to lengths of 50 m we recommend normal RG58 BNC cable; RG213 cable (having a lower attenuation) is recommended for lengths up to 200 m.

Figure II.9 shows an examples test setup for measurements on a distribution transformer with an ICM*compact* with MUX option. Here, a coupling capacitor with built-in quadrupole (e. g. CC35B/V) acts as decoupling unit and provides a voltage signal for synchronisation. If only one channel is used for testing, the MUX output ('MUX OUT') must be connected to the 'AMP IN' terminal.

Fig. II.9: Connections of the setup for measurements on distribution transformers with an ICM*compact* with MUX option (not drawn to scale)

Figure II.10 shows a test-setup on a power transformer using an ICM*compact* with MUX option. If only one preamplifier is connected to the instrument, the MUX output ('MUX OUT') must be connected to the 'AMP IN' terminal.
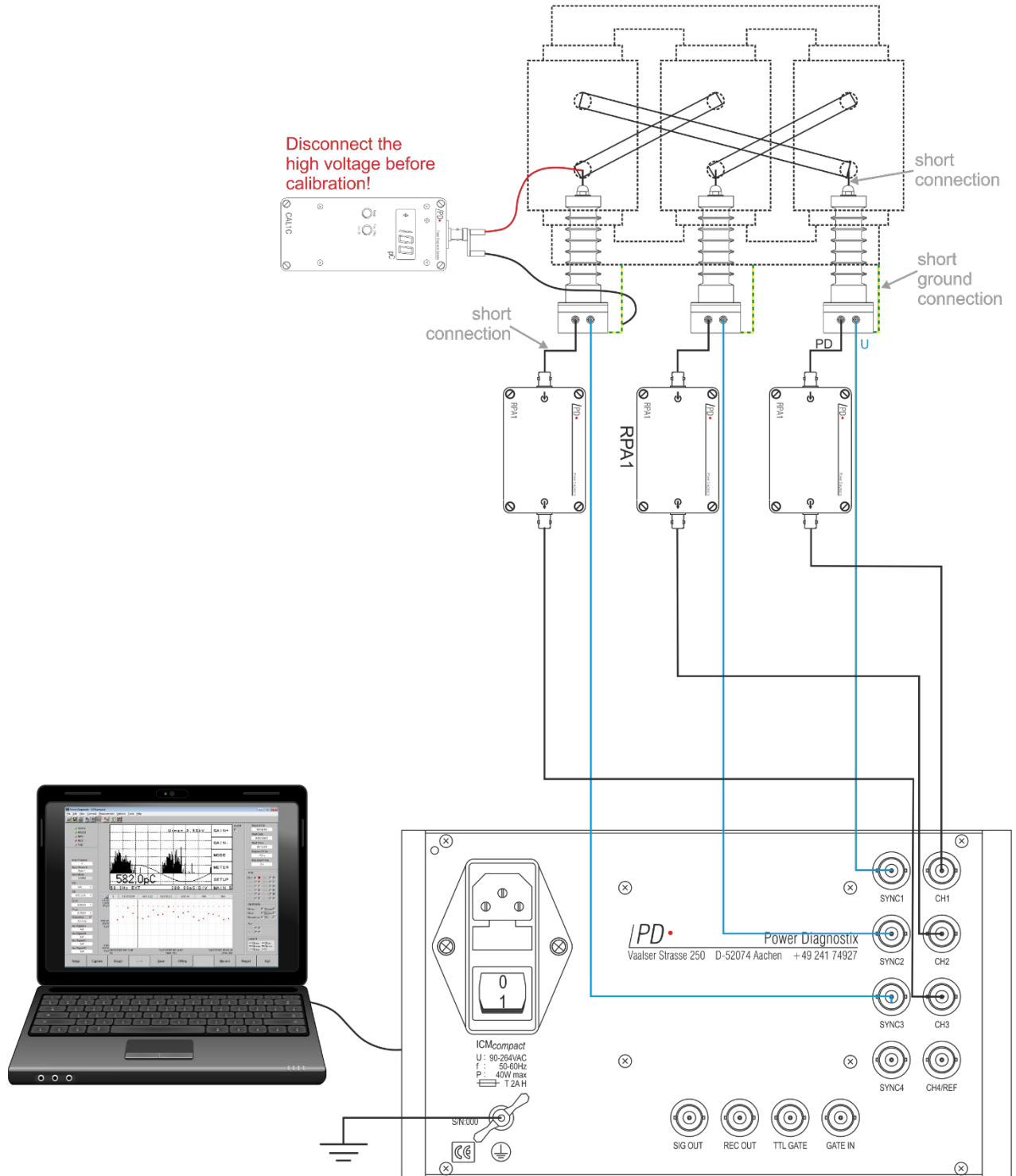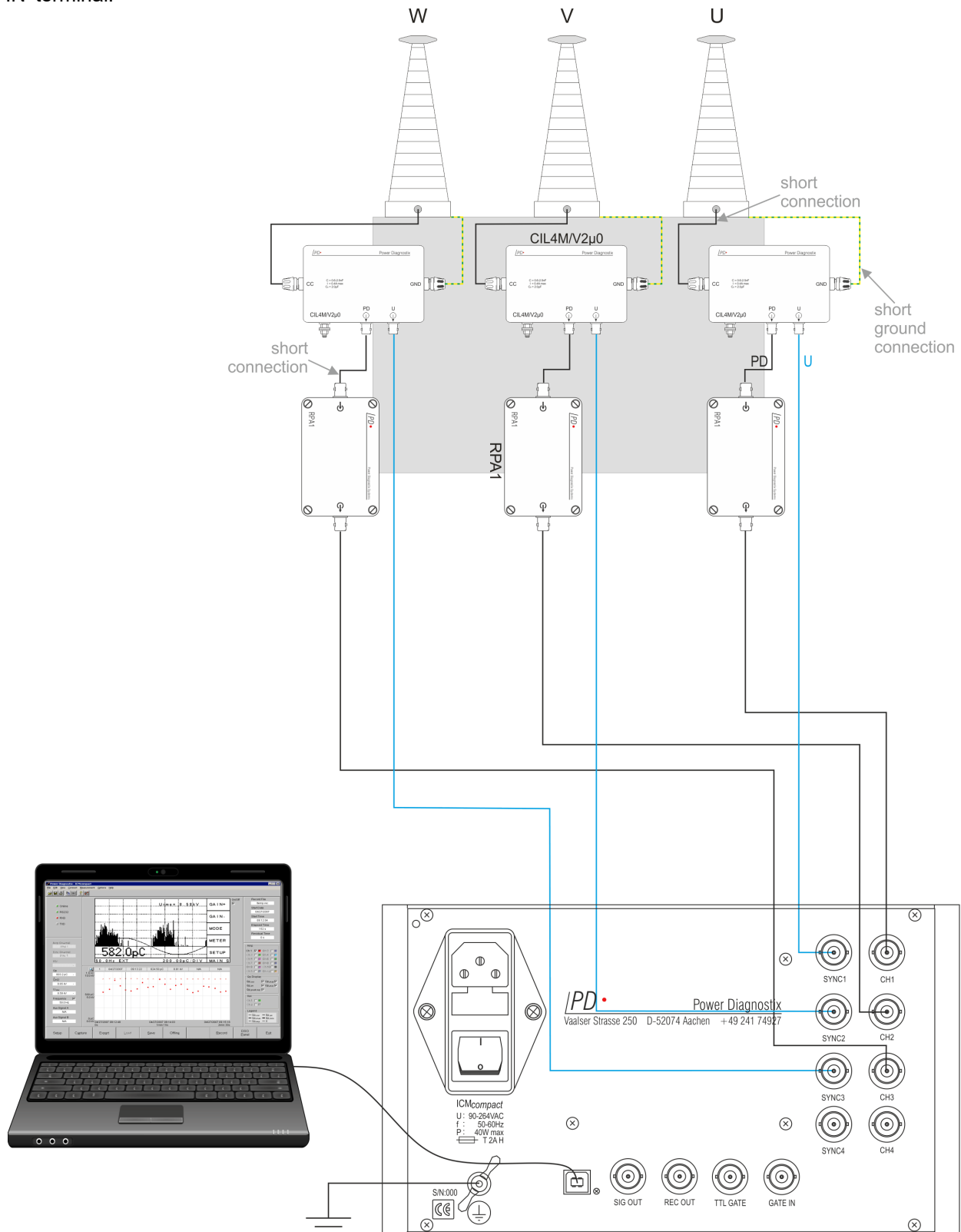

Fig. II.10: Connections of the setup for measurements on power transformers with an ICM*compact* with MUX option (not drawn to scale)

The connections to the standard ICM*compact* are made by several BNC connectors, one wing nut screw, and one serial connector. The functions of the connectors are as follows:

AMP IN: The AMP IN input is connecting the PD signal with the ICM*compact*. The AMP IN connector must be connected to a remote preamplifier (RPA). Notice the direction of the arrows engraved on the RPA; the arrows must point **toward** the ICM*compact*.

REC OUT: The REC OUT terminal of the ICM*compact* may optionally be connected to a paper recorder or other device to provide a graph of the average charge magnitude. For the output level see section III.2.3, table 1.

SYNC IN: The SYNC IN can optionally be used for external synchronisation of the ICM*compact* to the frequency of the applied high voltage. This can be the output of a voltage divider (such as the voltage divider included with some Power Diagnostix quadrupoles) or of some other customized circuit. If the SYNC IN is not connected, the ICM*compact* will synchronise on the mains supply frequency (usually 50 or 60 Hz).

USB: The USB terminal provides the connection to a PC for remote communications

TTL GATE: Input connector for triggered noise cancellation (TTL). The TTL gating signal can be used to blind out disturbance signals provided by a resonant test set during switching, for instance.

GATE IN (optional): The GATE IN terminal, which is not included in all models of the ICM*compact*, can be used for noise rejection during measurements. To do so, connect the output of an additional RPA, carrying the unwanted noise signal, to the GATE IN.

SIG OUT: The SIG OUT BNC connector provides a test signal according to IEC 60270. Please refer to the IEC60270 specification for detailed information. In SPEC mode SIG OUT provides the demodulated test signal, while it provides a TTL gating signal when 'GT OUT' is activated within the menu GT SET.

Mains supply: The mains (power supply) plug must be connected to a power outlet providing power in the voltage range 85 V_{AC} up to 264 V_{AC}, frequency 47–440 Hz. The on/off switch for the unit is located beneath the mains plug. A power supply fuse is located between the on/off switch and the mains power inlet.

GND: The wing nut must be connected to ground.

RPA: The output arrow ⟳ engraved on the RPA (preamplifier) must be connected to the AMP IN of the ICM*compact*. The input arrow ⟲ of the RPA must be connected to the output of a quadrupole (measuring impedance) or other PD signal sources (such as a current transformer).

The connection between the output of the coupling impedance and the RPA1 preamplifier should be with a BNC/BNC adapter or a short length of BNC cable, in order to minimize the capacitive loading of the coupling unit and fully benefit from the relatively high input impedance (10 kΩ//50 pF) of the RPA1. The quality of the connecting cable between the RPA1 output and the ICM*compact* display unit (AMP IN) is fairly uncritical. Normal RG58 BNC cable is recommended for lengths up to 50 m; RG213 cable (which has a lower attenuation) is recommended for lengths up to 200 m.

Quadrupole: The quadrupole captures the PD signal from the coupling capacitor, or alternatively, from the test object itself. Power Diagnostix offers quadrupoles as separate modules or as built-in components of coupling capacitor units. The output of the quadrupole must be connected to the input of a preamplifier. The input marked "CC" must be connected to the low side of the coupling capacitor (or alternatively to the low side, or neutral, of the test object). The terminal marked "GND" must be connected to the system ground.

If the quadrupole has an optional voltage divider, the output marked "U" is a low voltage copy of the high voltage applied to the test object and coupling capacitor. This output can be used for external synchronisation when connected to the "SYNC IN" terminal of the ICM*compact*.

The minimum connections that must be made in order to use the ICM*compact* are the mains power supply, the AMP IN, and the system ground.

II.3.2   Synchronising the ICM*compact*

In the absence of an external synchronisation signal, the ICM*compact* will automatically synchronise to the sine wave of the line voltage of the supplying power for the ICM*compact*. Often, the high voltage applied to the test setup is not in phase with the line voltage and may not even be the same frequency as the line voltage. In such cases, it is best to synchronise the ICM*compact* with an external signal.

To synchronise the ICM*compact* on the high voltage applied to the test setup, a voltage divider is needed to create a copy of the voltage wave. The SYNC IN input is designed for voltage in the range of 1 V to 100 V_{RMS} (max. 200 V_{peak}). Regard, the input impedance of the SYNC IN input is about Z_{in} = 1 MΩ//200 pF. With the optional VLF function switched on it's about 10M Ω.

If you use a coupling unit from Power Diagnostix, either quadrupole or capacitor with a built in quadrupole, the once with the extension .../V (like CC25C**/V** or CIL4M**/V**) will have an extra output labeled 'U'. Connect this low-voltage copy of the applied voltage to the SYNC IN connection on the rear of the ICM*compact*. Additionally, a TTL type trigger signal can be supplied to the SYNC IN connection to force synchronisation.

III   Operation

III.1   Main Functions

After switching on the ICM*compact*, the LC screen displays the ICM*compact* 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 side of the display. There are several display modes and submenus available.

After power up and display of the ICM*compact* logo, the instrument automatically selects the display mode and submenu that were active when the instrument was last switched off. In order to activate the MAIN menu, you may need to press the EXIT button several times. In this MAIN menu you can select either the METER (MAIN M) or the SCOPE (MAIN S) display mode. If implemented, also the HVM (high voltage meter) is available. Devices with an additional acquisition board (DSO board) for cable fault location have an additional display called DSO. Figure III.1 shows the ICM*compact* in the menu 'MODE S'. An overview of the key menus can be found in section III.2.1.
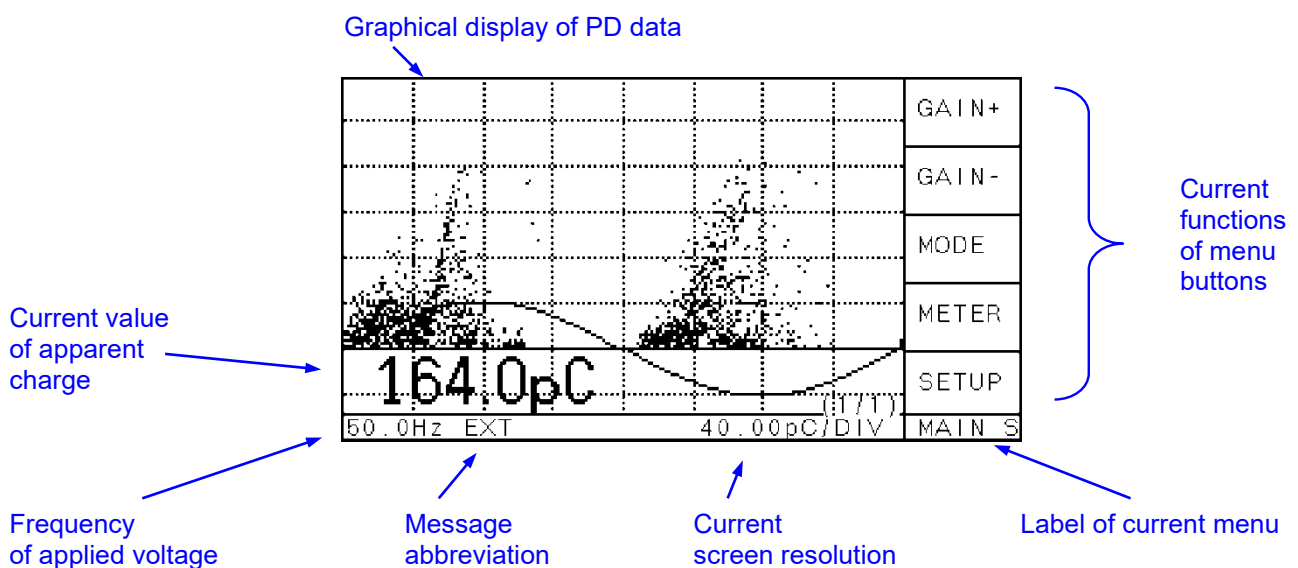
Fig. III.1: Parts of the ICM*compact* display

The display of the ICM*compact* consists of graphic elements like the grid, the voltage curve and the PD pattern and additionally text elements like the menu description, the values shown at the lower border and settings written at the upper border. Some conditions are displayed as abbreviations at the lower left side. The following table shows these abbreviations and its meaning.

Abbreviation	Meaning
RPA?	Missing preamplifier or damaged cable between preamplifier (i. e. RPA1) and input of the ICM*compact* (AMP IN).
EXT	External synchronisation; the device selects automatically the synchronisation source, means that the line voltage will be used if there is no external voltage connected to the SYNC IN at the rear panel. For this, the ESYNC must be enabled.
RPA OFF	Within the submenu MISC the control voltage for the preamplifier can be turned off.
G	External gating is turned on (see section III.4.4).

There are two displays to indicate the captured PD activity. In the 'Scope' display every PD signal is shown on a phase resolved graph. In the 'Meter' display the peak value is shown on an analogue meter.

III.1.1   Scope

Within the Scope mode there are 4 ways to display the PD pattern. These types can be selected in the menu MODE / DISPL and will be explained now.
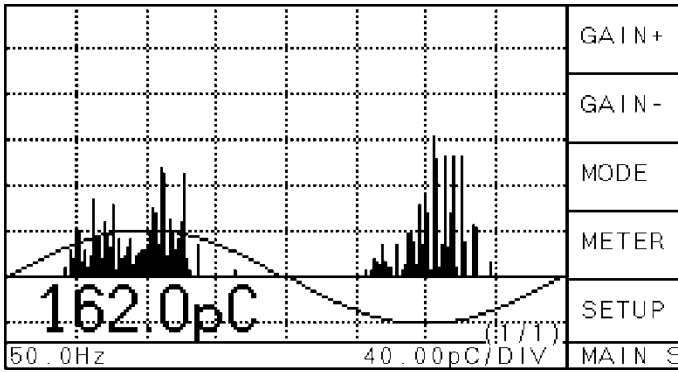
Fig. III.2: Scope display (NORM mode)

Figure III.2 shows the Scope display with **NORM** mode activated (see menu description for menu MAIN S): Every partial discharge pulse is displayed as a vertical line at the phase angle where it occurs. The length of the line is proportional to the apparent charge amplitude. The display refresh rate of the ICM*compact* is about 0.1 s, thus every picture shows the discharge pulses accumulated over the last five cycles of the test voltage (at 50 Hz!). The displayed sine wave helps to identify the phase position of the discharge impulses.
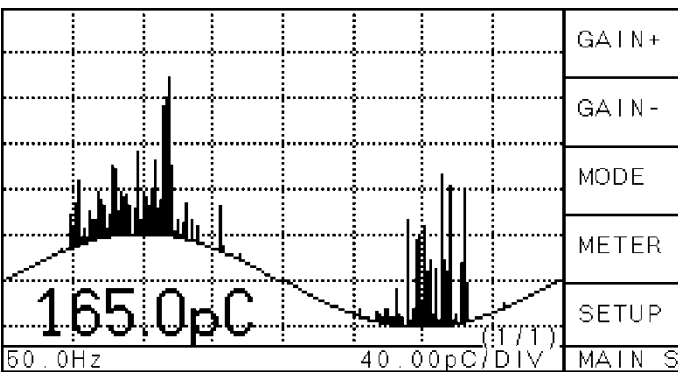
Fig. III.3: Scope display (SINE mode)

Figure III.3 shows the scope display with **SINE** mode active. The only difference between NORM mode and SINE mode is that in the SINE mode, the impulses are superimposed onto the sine wave.
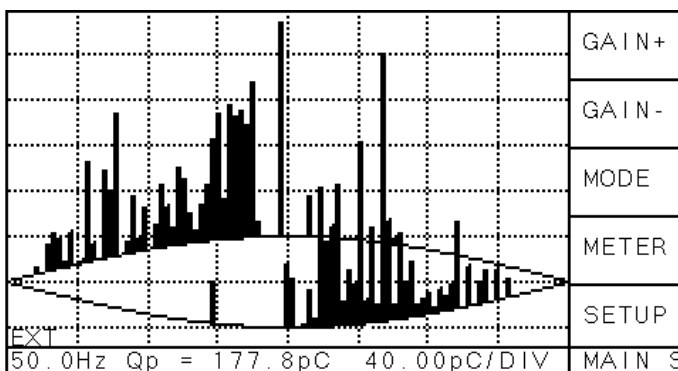
Fig. III.4: Scope display (LISSA mode)

Figure III.4 shows the scope display with **LISSA.** mode active. In this mode the phase positions from 0° to 360° are divided into two parts represented by two half sine waves. The upper part displays the phase positions from 0° to 180° (left to right). The lower part represents the positions from 180° to 360° (right to left). As the resolution of the instrument is not changed, every impulse is displayed as a double vertical line.

In the **HOLD** mode every partial discharge impulse activates a display pixel at the location according to the pulse magnitude and the phase angle of occurrence. Note that in this case the display is refreshed every 100 ms which allows a visualization of the build-up dynamics of a partial discharge pattern (also called PD-Map or phase-amplitude distribution). Changing the gain will reset this display mode. Despite the fact that the ICM*compact* can only 'count' up to 1 (pixel on/off) and that other technical differences exist between the ICM*compact* and the ICM*system*, the PD maps can be easily recognized and compared to the results obtained by the ICM*system*. The resolution of the ICM*system* is ±128 x 256 x 65536 (16 bit) whereby the ICM*compact* is unipolar and has a resolution of 80 x 196 x 1 (amplitude x phase x count depth).

Fig. III.5: Scope display (HOLD mode)

At the bottom of the display the synchronisation frequency (left), the scaling of the y-axis in coulomb per division (right) and the current maximum value of discharge (large letters) is shown. This maximum is ca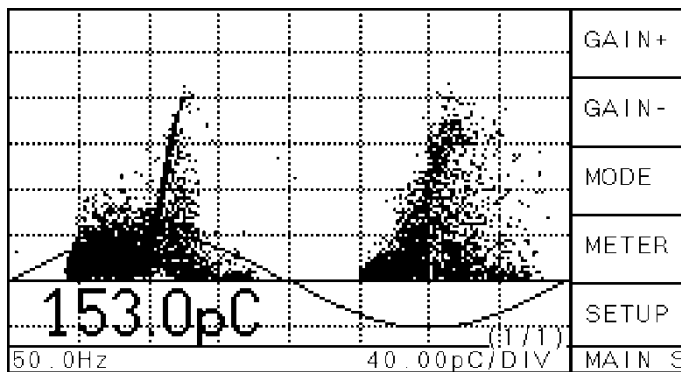lculated from voltage periods during the last refresh cycle. For best results the gain should be set so that this maximum appears in the range of 50–90% of the y-axis total range. In case the PD values are out of this range no valid Q_p can be shown. This happens if the gain is either too high or too low. In the first case '>' (max. value) and in the second case '<' (min. value) is displayed. The setting of the gain can be adapted manually or automatically by turning on or off the AUTO mode. This option is accessible at the MODE S or MODE M menu.
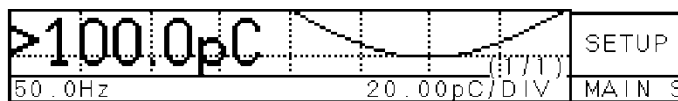

Fig. III.6: MAIN menu; charge level out of range

The evaluation of the PD pattern, measured in HOLD mode, enables to determine the kind of fault within the test object. Most PD faults like e. g. isolation damages, voids, surface discharges or floating points will have completely different PD pattern. Typical criteria to classify these patterns are:

- phase position of the maximum
- phase position of the starting electron
- the gradient of discharges
- the shape of discharges in the positive and negative half-cycle
- the absolute value of discharge in pC or nC
- short-time or continuous discharges

Some installations make it necessary to correct the phase position of the pattern. For example, measuring on a three-phase system without using the external synchronisation, where the line synchronisation comes from one of the two other phases. In that case a correction of 120° would be necessary. This phase shift can be set at the menu SETUP2 \ LLDSET. Please notice that the correct phase position is very important for proper evaluations of the PD pattern. To avoid the need for applying a phase shift, coupling units that include a voltage divider circuit should be used to provide a signal for external synchronisation (e. g. CC20B).

For successful interpretation it is also necessary to get as much information as possible about the test object and its environment. Such information can be, for example, temperature, installation condition, age of the test object, previous faults, or weather conditions. It is useful to store typical PD patterns of known faults in an archive. This can be done by using the PC software (see "Standard Software ICM*compact*", section IV.1). This customer specific database will be helpful for later evaluation on other test objects.

III.1.2   Meter

Figure III.7 shows the instrument's display in the MAIN menu and METER mode. The buttons **GAIN+** and **GAIN-** increase or decrease gain resp. amplification factor. Meter scaling automatically tracks the actual calibration and gain factor. The button **SCOPE**, **DSO** or **HVM** activates the next display mode, and the button **SETUP** calls the configuration menus. The line beneath the meter, displays the synchronisation signal frequency (line voltage, or the external signal at the SYNC IN terminal), the scaling of the meter, and the actual peak value of the apparent charge 'Q_P'. MODE calls a submenu for controlling the pointer movement and speed (see figure III.8) and the Auto Gain Mode.
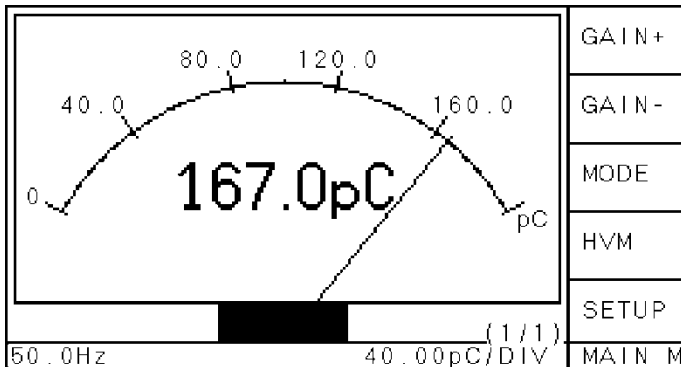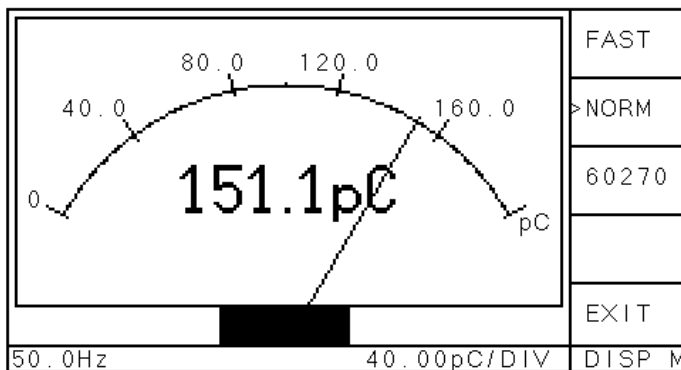
Fig. III.7: Meter display (MAIN menu)

Within the menu DISP M, three different speeds for the pointer can be selected. The chosen option is marked with an arrow ahead. In >**FAST**, the actual peak charge value of an acquisition cycle is displayed; this may lead to unstable readings (i. e. jerky movement of the pointer) when the pulse repetition rate is slower than about 5 s^{-1}. The actual peak value is also displayed in >**NORM** mode, but here the pointer is stabilized: New pulse values are shown immediately yet the pointer falls back slowly until a bigger pulse occurs.

Fig. III.8: Meter display (MODE menu)

The option >**IEC620270** treats the pulses with a weighting curve as mentioned in the actual revision drafts of the IEC 60270. This weighting, which displays rarely occurring pulses only with a fraction of their real amplitude (≥40%), leads to a strong stabilization of the pointer and a reduced reading.

The buttons **AUTO** and **AUTO F** of the Mode M menu activate the auto-range mode in which the gain is automatically adjusted: It is reduced if the display reading continuously exceeds 90% full-range and increased when the reading remains under 20% of the selected scale. The fast Auto Gain Mode (AUTO F) adjusts the gain immediately to the optimum, whereas in normal Auto Gain Mode the gain is changed step by step after each display refresh. Each change in gain is indicated by a short beep from the built-in loudspeaker. From 1000 pC upwards, the displayed unit changes from [pC] to [nC]. Note: Using sensitive coupling with high charge levels, the system can be over-ranged. In this case Power Diagnostix can provide input attenuators (1:10 and 1:100). The **EXIT** button moves back to the MAIN menu.

III.2   Key Menus

All functions described in this section is based on the firmware version 4.08. You can find the firmware number either by start up at the info-screen or by selecting the INFO submenu while the instrument is running. Older releases are not completely compatible to the newer ones. Please contact Power Diagnostix to get update possibilities and prices.

Each menu consists of five entries (one for each button) and a name for the menu at the lower right-hand side. The background of the menu names are coloured in the respective level-colour. Each arrow shows the menu that the user enters when pushing that button. The EXIT button jumps back to the previous menu on the upper level.

III.2.1   Overview

Figure III.9 gives an overview of the whole menus being accessible with the ICM*compact* instruments. The dimmed menus are optional and explained separately in the following figures. Menus with a grey shadow are optional menus (e. g. HVM, VLF, DSO and gating). They are only accessible if the respective function is included.
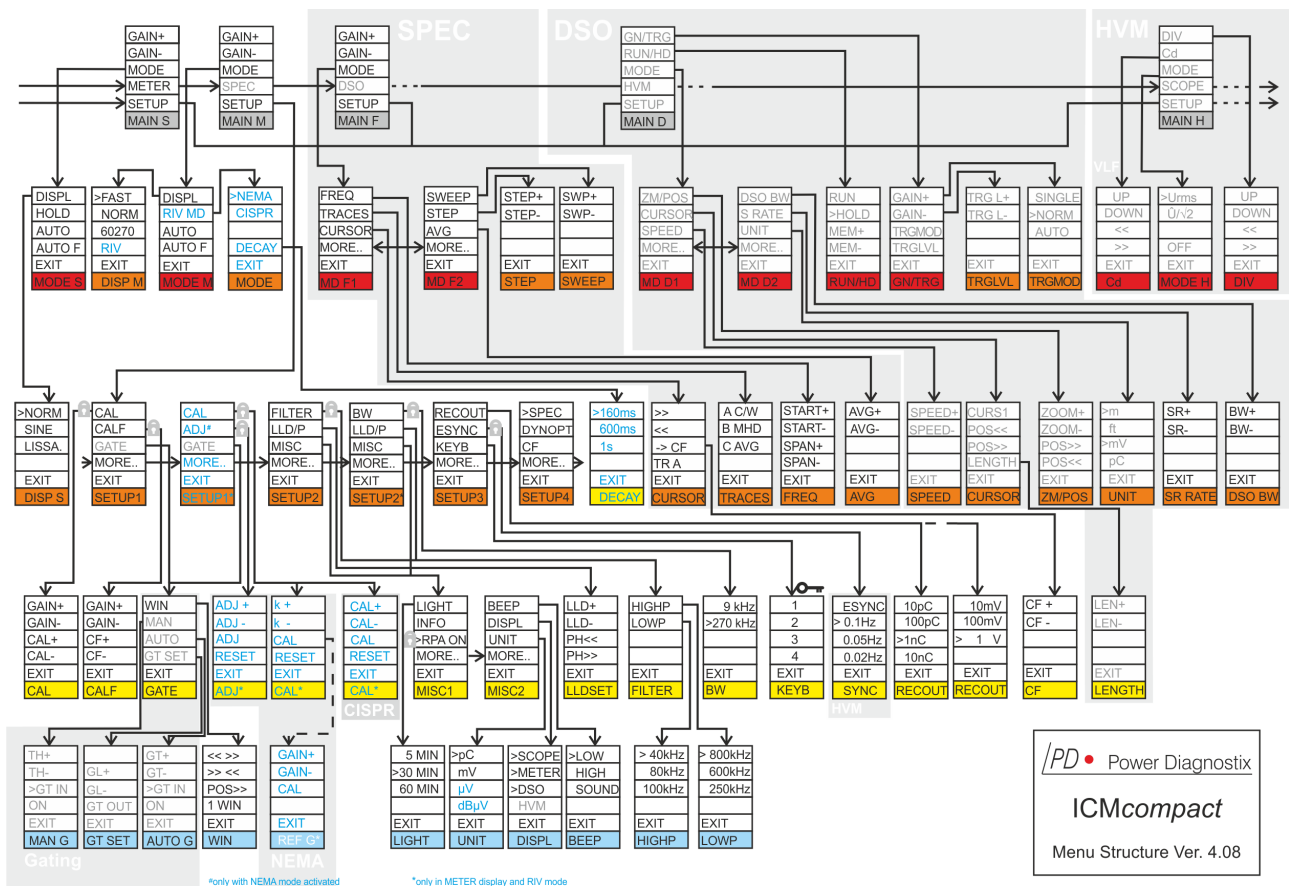
Fig. III.9: Menu overview

Some text entries can vary, depending on the several setup settings and of the state of the device. All exit buttons will bring you back to the menu one level higher. This path is not shown in the overview. The arrows are showing the way from menu to menu if pushing the appropriate button. At the bottom of each menu its name is written (level-wise coloured background).

III.2.2 Optional Key Menus
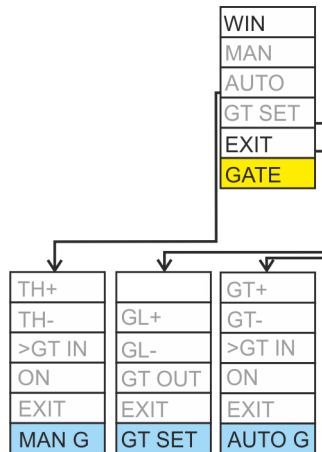
Fig. III.10: Optional menus for gating (GATE)

Figure III.10 shows the optional gating menus. These menus become visible if the device has an activated external **GATE IN** input channel. In this case, the ICM*compact* is equipped with an onboard logarithmic preamplifier RPA6G. The noise signal can directly be connected to the GATE IN channel.
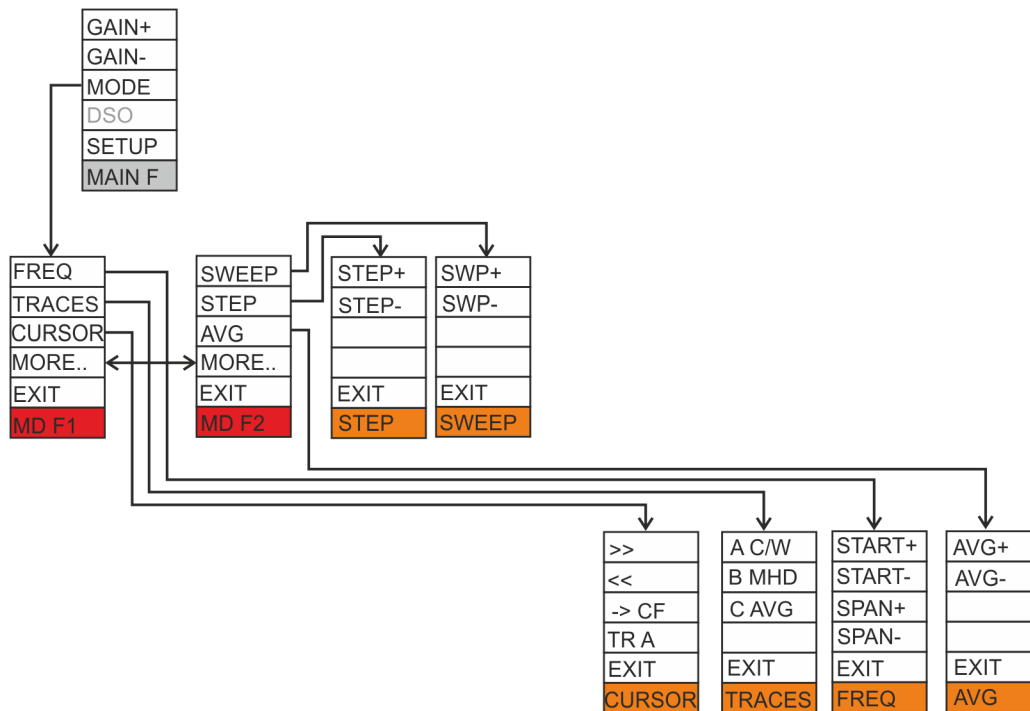
Fig. III.11: Optional menu for spectrum function (SPEC)
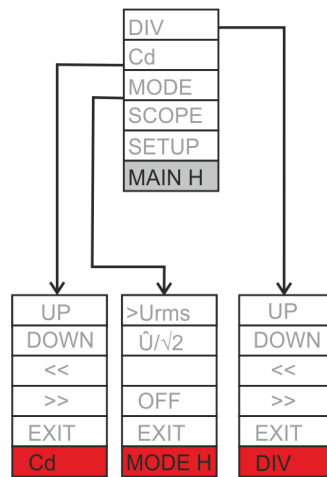
Fig. III.12: Optional high voltage meter menus (HVM)
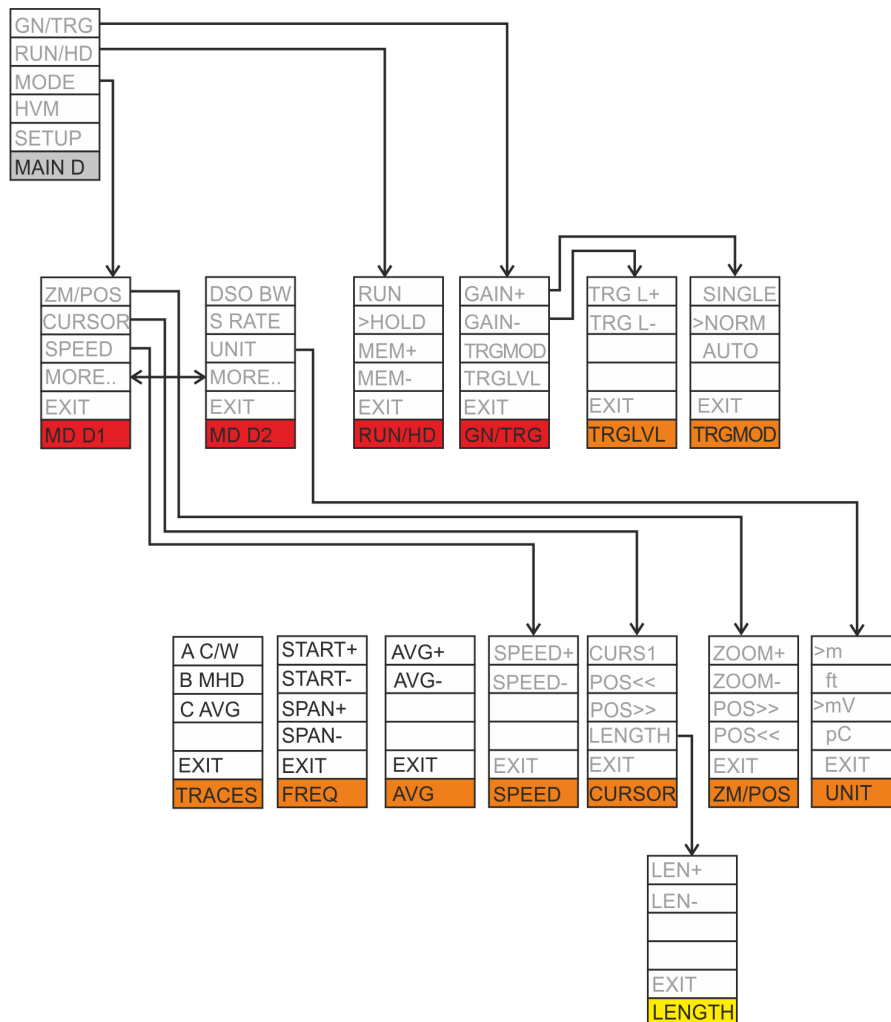
Fig. III.13: Optional menus (DSO extension)

Devices with a DSO acquisition board for cable fault location get the entry **UNIT** within the MD D2 / UNIT menu. This option allows to select the display unit for cable fault positions. There will also be an additional menu **MAIN D** for working with the DSO board. This is shown in figure III.13.

III.2.3 Key Menus Description

The following list explains step by step all menus coming with the standard ICM*compact* firmware releases higher than version 4.00.

GAIN+
GAIN-
MODE
METER
SETUP
MAIN S

GAIN+ / GAIN-

Sets the amplification of the ICM*compact* signal path up or down. The total amplification is a combination of pre-amplification (external preamplifier, i. e. RPA1) and main amplification (internal). By selecting the automatic mode (see MODE S), the gain will be adjusted automatically to the current maximum discharge level. The peaks of discharges should be visible at 60 to 90 percent of the total display range. With very high gain settings the noise becomes visible on the screen. If there is no phase dependency of the signals (no discharges), set the noise level to 5% of the total range of the display. This ensures that all newly appearing discharges will be recognized if their level is higher than the noise at the input.

MODE

Pushing this button changes to the MODE S menu.

METER, DSO or HVM

Depending on the optional DSO acquisition board and the switched-on displays (see menu DISPL) this function switches to the next display type.

SETUP

Pushing this button changes to the setup menu. As there are several setup menus, this function enters the last setup you've been before.

GAIN+
GAIN-
MODE
SPEC
SETUP
MAIN M

GAIN+ / GAIN-

See explanation above.

MODE

Pushing this button changes to the MODE M menu.

METER or SPEC

Depending on the optional SPEC function and the switched-on displays (see menu DISPL) this function switches to the next display type.

SETUP

Pushing this button changes to the setup menu. As there are several setup menus, this function enters in the last setup you've been once before.

Depending on the optional functions three main menus and their submenus are added. For more information see:

MAIN F   III.3.1 SPEC - Spectrum Function

MAIN D   III.3.4.6 Key Menus for the DSO

MAIN H   III.3.2 HVM - High Voltage Meter Display

DISPL
HOLD
AUTO
AUTO F
EXIT
MODE S

DISPL

Pushing this button changes to the DISP S menu.

HOLD

Setting this option (>) enables the 'hold' visualization for the phase resolved PD display (SCOPE). Pushing this button again will freeze the current display. Pushing this button for the third time will clear the frozen hold display and will continue with the Hold Mode.

AUTO

Setting this mode (>) means that the gain will be adjusted automatically to the maximum level of the current PD-pulses. In this mode the gain is adjusted slowly. This mode is useful if a PD level is quite constant, or if random spikes will disturb a continuous measurement.

AUTO F

Setting this mode (>) means that the gain will be adjusted very fast. The FAST mode is useful if rapid changes of the PD level should be captured e.g. when measuring the inception voltage of a specimen. A single PD level which will over range the preamplifier stops the acquisition and the gain is adjusted instantly.

EXIT

Pushing this button changes to the MAIN S menu.

>NORM
SINE
LISSA.
EXIT
DISP S

NORM

Setting this option (>) enables the normalized visualization for the phase resolved PD display (SCOPE). The differences between NORM, SINE, HOLD, and LISSA. are described in section III.1.1.

SINE

Setting this option (>) enables the 'sine' visualization for the phase resolved PD display (SCOPE).

LISSA.

Setting this option (>) enables the 'Lissajous' visualization for the phase resolved PD display (SCOPE).

EXIT

Pushing this button changes to the MODE S menu.

DISPL
RIV MD
AUTO
AUTO F
EXIT
MODE M

DISPL

Pushing this button changes to the DISP M menu.

RIV MD

Push this button to access the MODE menu for RIV measurements.

AUTO

Setting this mode (>) means that the gain will be adjusted automatically to the maximum level of the current PD-pulses. In this mode the gain is adjusted slowly. This mode is useful if a PD level is quite constant, or if random spikes will disturb a continuous measurement.

AUTO F

Setting this mode (>) means that the gain will be adjusted very fast. The FAST mode is useful if rapid changes of the PD level should be captured e.g. when measuring the inception voltage of a specimen. A single PD level which will over range the preamplifier stops the acquisition and the gain is adjusted instantly.

EXIT

Pushing this button changes to the MAIN M menu.

>FAST
NORM
60270
RIV
EXIT
DISP M

FAST

Setting this option enables the fast movement speed of the pointer in the METER display.

NORM

Setting this option enables the normal movement speed of the pointer in the METER display.

60270

Setting this option enables IEC60270 mode for updating the pointer in the METER display.

RIV

Setting this option enables RIV mode. In this mode the RIV level is shown in µV. For more information see section III.3.5.

EXIT

Pushing this button changes to the MODE M menu.

NEMA
CISPR
DECAY
EXIT
MODE

NEMA

Sets the calibration mode according to NEMA 107 standard.

CISPR

Sets the calibration mode according to CISPR 18-2 standard.

DECAY

Pushing this button changes to the menu DECAY for setting the decay time.

EXIT

Pushing this button returns to the menu MAIN.

>160ms
600ms
1s
EXIT
DECAY

160ms

Sets the decay time to 160 ms.

600ms

Sets the decay time to 600 ms.

1s

Sets the decay time to one second.

EXIT

Pushing this button changes to the menu MODE.

Depending on the optional functions several mode menus and their submenus are added. For more information see:

MD F1/2

III.3.1 SPEC Display

MD D1/2

III.3.4 DSO Display

MODE H

III.3.2 HVM Display

CAL
CALF / ADJ
GATE
MORE..
EXIT
SETUP1

CAL

Pushing this button changes to the calibration menu CAL.

CALF

Pushing this button changes to the menu CALF. Here the calibration factor can be set directly.

ADJ *(only in METER / RIV mode with activated NEMA mode)*

If the display is in meter mode and RIV mode is enabled, the CALF button changes to ADJ. Pushing this button changes to the adjust menu for the RIV function. Further information can be found in section III.3.5.

GATE

Pushing this button changes to the menu GATE. The gating function reduces noise coming from e. g. antennas and pre-processes the analogue disturbance signal. To use this option the device needs to be equipped with an external gating input and the hardware of the device has to be greater than ver. 2.60. A special logarithmic preamplifier (RPA6G) is also needed to amplify the disturbance signal.

MORE..

Pushing this button changes to the setup menu SETUP2.

EXIT

Pushing this button changes to the main menu (MAIN S, MAIN M, MAIN F, or MAIN D).

FILTER / BW
LLD/P
MISC
MORE..
EXIT
SETUP2

FILTER

Pushing this button changes to the filter setting menu FILTER.

BW*(only with SPEC mode activated)*

Pushing this button changes to the bandwidth setting menu BW.

LLD/P

When SCOPE display is active, pushing this button changes to the menu LLDSET to adjust the low level discriminator.

MISC

Pushing this button changes to the menu MISC for miscellaneous settings.

MORE

Pushing this button changes to the setup menu SETUP3.

EXIT

Pushing this button changes to the main menu one level up.

RECOUT
ESYNC
KEYB
MORE..
EXIT
SETUP3

RECOUT

Pushing this button changes to the menu RECOUT. Here the ratio of charge value to output voltage can be set.

ESYNC

If this button is selected (>) the frequency measurement and synchronisation signal is taken from the SYNC IN input, if possible. To manually turn to the line (mains) sync., deselect the button.

With the optional 'HVM', this button changes to the menu SYNC. See also section III.3.3.

KEYB

Pushing this button changes to the menu KEYB. In here crucial menus, which will directly affect the PD measurement settings, can be locked and unlocked. To unlock the keyboard, a sequence of the numbers: 3 4 3 2 must be entered.

MORE

Pushing this button changes to the setup menu SETUP4.

EXIT

Pushing this button changes to the main menu (MAIN S, MAIN M, MAIN F, or MAIN D).

>SPEC
DYNOPT
CF
MORE..
EXIT
SETUP4

SPEC

Activates the SPEC path for display. When not activated, the AMP path is displayed.

DYNOPT

This entry sets the gain strategy. If activated, the internal gain settings are optimized to accept PD signal with strong dynamic, while the gain settings are focusing on overall low noise, if not selected. Thus, choosing dynamic optimization is recommended for PD signals with high signal amplitudes, while noise optimization should be used if high sensitivity and low noise is needed.

CF

Pushing this button changes to menu CF. Here the centre frequency for the SCOPE and METER mode can be set.

MORE..

Pushing this button changes to the set-up menu SETUP1.

EXIT

Pushing this button changes to the main menu.

GAIN+
GAIN-
CAL+
CAL-
EXIT
CAL

GAIN+/GAIN-

Pushing this button increments/decrements the total gain by one step. The calibration signal should be 50%-90% of the total y-axis range. Changing the gain does not calibrate the system. Use the buttons CAL+ or CAL- to recalibrate.

CAL+/CAL-

These buttons can be used to enter the calibration value. Together with the measured peak charge level, the calibration factor is calculated and stored. There is no possibility to make it undone! The value should be set equal to the value shown on the connected pulse generator (e. g. CAL1A). For detailed information's about the calibration procedure see section III.5.

EXIT

Pushing this button changes to the setup menu SETUP1.

k+
k-
CAL
RESET
EXIT
CAL

(NEMA Mode)

(only available in the METER display, when RIV mode is selected and NEMA mode activated)

k+ / k-

Pushing this button increments/decrements the calibration factor (k) of the RIV measurement directly. If known from a previous calibration, the factor can be set here to skip further calibration. The set value is immediately stored in a non-volatile memory.

CAL

Pushing this button will start one measurement on the reference input ('REF' input) for about 1 second. Thereafter one measurement is done on the selected input channel CHx. The calculated correction factor (k) can be seen in the bottom right-hand side of the display. This circuit RIV factor is defined as the ratio of the voltage at the input channel (CHx input) to the signal generator voltage (REF input) $k = V_{CH} / V_{REF}$.

If the signal of the 'REF' input is too strong, the ICM*compact* changes automatically to the menu REF G.

RESET

Pushing this button will undo the calibration and reset the factor to k=1. See also section III.3.5.

EXIT

Pushing this button changes to the set-up menu SETUP1.

GAIN+
GAIN-
CAL
EXIT
REF G

(NEMA Mode)

GAIN+ / GAIN-

Sets the amplification of the reference input 'REF' up or down.

CAL

Pushing this button starts one measurement on the 'REF' input for about 1 second. Thereafter one measurement is done on the selected input channel CHx. The calculated correction factor (k) is indicated at the bottom right-hand corner of the LC display. This circuit RIV factor is defined as the ratio of the voltage at the input channel (CHx input) versus the signal generator's voltage facing the load (REF input) $k = V_{CH} / V_{REF}$.

EXIT

Pushing this button changes to the menu CAL.

CAL+
CAL-
CAL
RESET
EXIT
CAL

(CISPR Mode)

CAL+ / CAL- *(only available in the METER display, when RIV mode is selected and CISPR mode activated)*

These buttons allow setting the value for calibration. The value should be set according to the voltage set on the signal generator (CAL3D).

CAL

Pushing this button adjusts the instrument by comparing the measured voltage with the set voltage (e. g. CAL: 100 µV).

RESET

Pushing this button will undo the calibration and reset the factor to k=1. See also section III.3.5.3.

EXIT

Pushing this button changes to the set-up menu SETUP1.

GAIN+
GAIN-
CF+
CF-
EXIT
CALF

GAIN+/GAIN-

Pushing this button increments/decrements the total gain by one step. This will have no impact on the calibration factor.

CF+/CF-

These buttons can be used to set the calibration factor directly. This function can be used to copy a previously done calibration. For more detailed information about the calibration procedure see section III.5.

EXIT

Pushing this button changes to the setup menu SETUP1.

(only available in the METER display, when RIV mode is selected and NEMA mode activated)

ADJ+
ADJ-
ADJ
RESET
EXIT
ADJ

(NEMA Mode)

ADJ+ / ADJ-

These buttons allow to set the value for adjustment. The value should be set according to the voltage set on the signal generator (e. g. CAL3A).

ADJ

Pushing this button will adjust the instrument by comparing the measured voltage with the set voltage (e. g. ADJ: 100 µV). See also section III.3.5.2.

RESET

Pushing this button will undo the adjustment. See also section III.3.5.2.

EXIT

Pushing this button changes to the set-up menu SETUP1.

WIN
MAN
AUTO
BANDW
EXIT
GATE

WIN

Pushing this button changes to the menu WIN. The 'window' function makes it possible to blind out pulses with respect to their phase position. With older devices (firmware <2.00) this function was called GATE.

MAN, AUTO, BANDW

Gating with an external sensor (analogue gating) is an optional function. An ICM*compact* with this gating function will have an onboard preamplifier (RPA6G) and a 'GATE IN' terminal (BNC).

EXIT

Pushing this button changes to the setup menu SETUP1.

<< >>
>> <<
POS>>
1 WIN
EXIT
WIN

<< >>

Pushing this button widens the window(s) for blinding out the pulses on the display. The width of the windows is displayed at upper right side of the screen.

>> <<

Pushing this button scales down the window(s) for blinding out the pulses on the display.

POS>>

Pushing this button changes the position of each window. The phase position value is shown at upper left side of the display.

1 WIN (2 WIN, 3 WIN, OFF)

Selects the number of windows for software gating. The phase distance using two windows is 180° and 120° for three windows. Press '1 WIN' if you want to get one window for gating. The key always indicates the next option.

EXIT

Pushing this button changes to the setup menu GATE.

HIGHP
LOWP
EXIT
FILTER

HIGHP

Pushing this button changes to the menu HIGHP for setting up the lower cut-off frequency.

LOWP

Pushing this button changes to the menu LOWP for setting up the upper cut-off frequency.

EXIT

Pushing this button changes to the setup menu SETUP2.

>40kHz
80kHz
100kHz
EXIT
HIGHP

>40KHZ

Pushing this button sets the lower cut-off frequency to 40 kHz.

80KHZ

Pushing this button sets the lower cut-off frequency to 80 kHz.

100KHZ

Pushing this button sets the lower cut-off frequency to 100 kHz.

EXIT

Pushing this button changes to the setup menu FILTER.

>800kHz
600kHz
250kHz
EXIT
LOWP

>800KHZ

Pushing this button sets the upper cut-off frequency to 800 kHz.

600KHZ

Pushing this button sets the upper cut-off frequency to 600 kHz.

250KHZ

Pushing this button sets the upper cut-off frequency to 250 kHz.

EXIT

Pushing this button changes to the setup menu FILTER.

LLD+
LLD-
PH<<+
PH>>
EXIT
LLDSET

LLD+/LLD-

Pushing these buttons increments or decrements the level of the low level discriminator. This value is displayed at the upper right side of the screen in percent. All discharges below that level are deleted and not displayed on the screen.

PH<</PH>>

Pushing these buttons increments or decrements the position of the PD in relation to the zero point of the voltage synchronisation line. This value is displayed at the upper left side of the screen in degree.

EXIT

Pushing this button changes to the setup menu SETUP2.

LIGHT
INFO
>RPA ON
MORE..
EXIT
MISC1

LIGHT

Pushing this button changes to the menu LIGHT for setting up the timer for the screen saver.

INFO

Pushing this button changes to the INFO display. This display gives information about the current firmware (SW version) and hardware version (HW version), release day (SW release), optional instrument functions, and contact details of Power Diagnostix.

>RPA ON

If this button is selected (>) the power supply for the preamplifier is turned on. Pushing this button until the checkmark is off, turns off the supply to the preamplifier and enables to use the AMP IN terminal directly without preamplifier.

MORE..

Pushing this button will change to MISC2.

EXIT

Pushing this button changes to the setup menu SETUP2.

BEEP
DISPL
UNIT
MORE..
EXIT
MISC2

BEEP

The sound when pushing one of the five keys can be modified here.

DISPL

Display modes (SCOPE, METER, DSO and HVM) can be deselected in this menu.

UNIT

The unit for the SCOPE and METER displays can be selected here.

MORE..

Pushing this button will change to MISC1.

EXIT

Pushing this button changes to the setup menu SETUP2.

5 MIN
>30 MIN
60 MIN
EXIT
LIGHT

5 MIN, 30 MIN, 60 MIN

Pushing these buttons sets the automatic screen saver to 5, 30 or 60 minutes. That means, when for about 5, 30 or 60 minutes no button has been pressed, the background lighting of the display will be turned off. The light will be turned on by pushing any button.

EXIT

Pushing this button changes to the menu MISC1.

LOW
HIGH
>SOUND
EXIT
BEEP

LOW, HIGH

Pushing these buttons switches between a higher or lower sound for the buttons.

SOUND

Pushing this button enables (>) or disables the audible indicator for the partial discharge signals.

EXIT

Pushing this button changes to the menu MISC2.

>SCOPE
>METER
DSO
HVM
EXIT
DISPL

The display modes which are installed in the instrument can be deselected if they are not currently visible. Modes which are deselected in this menu cannot be selected in the MAIN menu and will be skipped. This will increase the handling, especially when the modes are changed frequently.

EXIT

Pushing this button changes to the menu MISC2.

>pC
mV
EXIT
UNIT

pC

Setting this mode (>) changes from the acoustic measurement mode ('mV') back to the charge measurement mode.

mV

Setting this option (>) changes the display unit to 'mV' for the acoustic measurement. For a correct calculation of the input voltage, it is mandatory to connect the RPA1D pre-amplifier or to disconnect the RPA supply in the menu MISC1. Within this mode, the CAL and CALF menus are blocked, and the FILTER setting is fixed to the frequency range 40 to 800 kHz. All these settings are stored before and will be recalled when changing back to the 'pC' display mode.

EXIT

Pushing this button changes to the menu MISC2.

(Only available, when SPEC mode is activated)

9 kHz
>270 kHz
EXIT
BW

9 kHz / 270 kHz

Pushing this button sets the measuring bandwidth to 9 kHz or 270 kHz. The selected frequency is marked by '>'.

EXIT

Pushing this button changes to the set-up menu SETUP2.

10pC
>100pC
1nC
10nC
EXIT
RECOUT

10pC, 10pC, 1nC, 10nC

Pushing these buttons sets the level of the analogue voltage output RECOUT. The scaling is linear.

Record output	Button 10 pC	Button 100 pC	Button 1 nC	Button 10 nC
0 V	0 pC	0 pC	0 nC	0 nC
5 V	5 pC	50 pC	0.5 pC	5 nC
10 V	≥10 pC	≥100 pC	≥1 nC	≥10 nC

Tab.1: Ranges of the voltage output

EXIT

Pushing this button changes to the setup menu SETUP3.

ESYNC
0.1Hz
0.05Hz
0.02Hz
EXIT
SYNC

ESYNC

If this button is selected (>) the frequency measurement and synchronisation signal is taken from the SYNC IN input, if possible. To manually turn to the line (mains) sync., de-select the button.

0.1Hz, 0.05Hz, 0.02Hz

For the acquisition with the VLF (very low frequency) option, the external voltage signal from the SYNC IN is mandatory. Selecting one of the three VLF frequencies will deselect the external frequency measurement and set the sampling time according to the set VLF. The synchronisation is done automatically by the SYNC IN input.

EXIT

Pushing this button changes to the setup menu SETUP3.

LOCK
EXIT
KEYB

LOCK

This button allows to lock the keyboard, leaving only the functions available, which will not affect the parameters of the instrument. The locked functions are labelled in the menu structure (section III.2.1) by 🔒. Entering the KEYB menu while being locked, the buttons are labelled 1, 2, 3, 4, EXIT. To unlock the keyboard a sequence of the numbers: 3 4 3 2 must be pressed.

EXIT

Pushing this button changes to the setup menu SETUP3.

III.2.4 Reset to Default Settings

To restore the factory default settings of an ICM*compact*, press the top and bottom push buttons simultaneously when switching on the device. If the instrument is equipped with two lines of push buttons, use the buttons on the left-hand side for a reset.

III.3   Optional Functions

III.3.1 SPEC - Spectrum Function

The SPEC display shows the frequency spectrum of the input signal up to 10 MHz. Three traces for the current input channel allow to store, compare and process this spectrum. The figure below shows an example of a SPEC display with two traces. The cursor is placed on the lower trace at 570 kHz and has a magnitude of 13.77 mV.
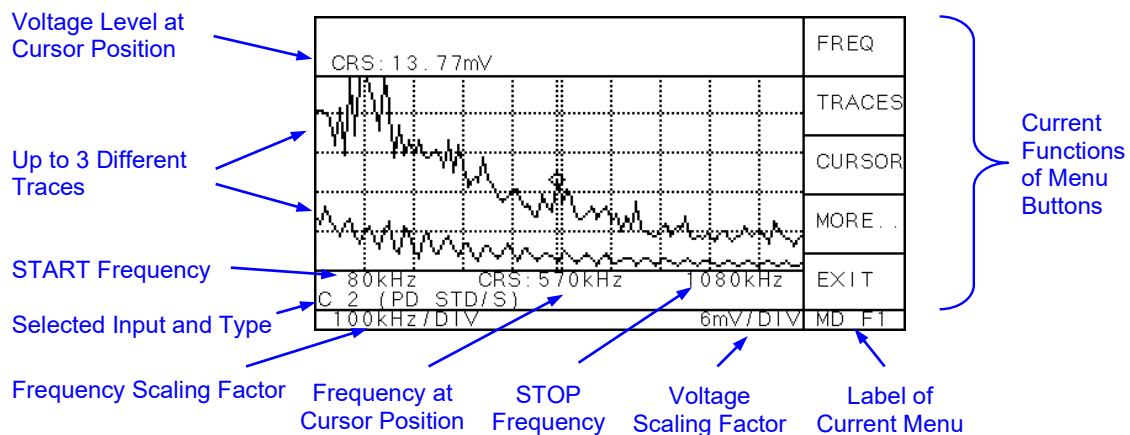

Fig. III.14: SPEC display

There are two MODE menus for adjusting the spectrum scan. 'MORE..' toggles between 'MD F1' and 'MD F2'. These menus are explained as followed.

FREQ

The **start** frequency can be set in steps of 10 kHz whereas the **span** (start frequency – stop frequency) has a variable step-size. The steps are set to get an even scaling factor (kHz/DIV). Therefore, the maximum frequency of 10 MHz can only be reached if e. g. the start frequency is 0 kHz, 2000 kHz.

TRACES

Accesses the trace softkeys that allow storing and manipulating trace information. The ICM*compact* updates the information for any active trace with each sweep. The three traces (A, B and C) can be defined separately in five different modes:

    OFF Turns off the trace; graph is not visible.

    C/W Clears and writes the trace with every sweep.

    MHD The maximum values of all sweeps are updated and hold.

    VW   Freezes the current view of trace.

    AVG The average of the last 1 to 10 values is shown. The number of values taken is set in the menu MD F2 / AVG.

CURSOR

The cursor can be shifted along the set frequency ('>>' and '<<') whereas the actual frequency is shown in the lower part next to 'CRS: '. With '->CF', this frequency is taken as 'centre frequency' (or measuring frequency) for the display modes SCOPE and METER, since these modes have only one fixed measuring frequency. This will not change the frequency spectrum of the SPEC mode. The current value at the cursor position is shown in the top line and taken from the selected trace. To change the trace, press the softkey 'TR_x', this will toggle through all three traces.

SWEEP

Dwell-time (DWT) is the pause on one frequency during which demodulation takes place. The sweep-time (SWP) is calculated from the dwell-time, the span, and the step-frequency. Sweep-time is the required time for one sweep i. e. scanning through the whole span of frequencies. If the sweep-time exceeds one second, the progress is indicated by an expanding line in the top of the display. To get the whole frequency spectrum of a pulse during on cycle (50 Hz or 60 Hz) in one sweep, the dwell-time should be set to 20 ms (16 ms). I. e. for measuring the frequency spectrum of the calibration pulse of a CAL1A, the dwell time should be at least 20 ms. The dwell time can be set in steps of 1 ms from 2 ms to 25 ms.

STEP

The STEP size defines the frequency steps between each demodulation within one sweep. It can be adjusted between 10 kHz and 1 MHz, however the minimum number of demodulation's is limited to ten steps (frequencies) per sweep. Together with the dwell-time and the span, the sweep-time is calculated by: SWP = (DWT + 0.5 ms) * SPAN / STEP

AVG

A trace can be smoothed with the average function (TRACES / A_AVG). The degree of smoothing can be adjusted from 1 (fast) to 10 (slow) in the menu MD F2 / AVG. This setting is valid for all three traces (A,B,C).

FREQ
TRACES
CURSOR
MORE..
EXIT
MD F1

FREQ

Pushing this button changes to the submenu FREQ. Here the start frequency and the span (range) of frequencies can be set.

TRACES

Pushing this button changes to the submenu TRACE. Here the information of the three traces can be changed.

CURSOR

Pushing this button changes to the submenu CURSOR. Here the cursors can be shifted and the centre frequency set.

MORE..

Pushing this button changes to the next menu MD F2.

EXIT

Pushing this button changes to the MAIN F menu

The following menus are only available if one channel is in SPEC mode (SETUP3 / MUX / SPEC N(/D)) and if the SPEC display is active.

START+
START-
SPAN+
SPAN-
EXIT
FREQ

START+ / START-

Pushing this button increments/decrements the start frequency in steps of 10 kHz.

SPAN+ / SPAN-

Pushing this button increments/decrements the span of measured frequencies. The step size is set automatically, so that an even scaling factor (kHz/DIV) is given.

EXIT

Pushing this button will change to the menu MD F1.

A_AVG
B_MHD
C_C/W
EXIT
TRACES

A_, B_, C_,
OFF, C/W, MHD, VW, AVG

There are three traces (A_, B_ and C_) to display different curves. Pushing one of the three buttons will alter through the 5 available modes.

EXIT

Pushing this button will change to the menu MD F1.

>>
<<
-> CF
TR_A
EXIT
CURSOR

>> <<

Pushing these buttons will shift the cursor along the frequency axis.

-> CF

Pushing this button takes the current cursor frequency as centre frequency (or measuring frequency) for the other display modes (SCOPE, MON, PROJ, TIME).

TR_A, _B, _C

Pushing this button changes the current trace. The measured value of the current trace is shown in the upper left corner (CRS:). The cursor position is indicated by ◇.

EXIT

Pushing this button will change to the menu MD F1.

SWEEP
STEP
AVG
MORE..
EXIT
MD F2

SWEEP

Pushing this button changes to the submenu SWEEP. There the sweep-time can be changed via the dwell-time.

STEP

Pushing this button changes to the submenu STEP. There the step size of frequency steps can be set.

AVG

Pushing this button changes to the submenu AVG. There the average function can be adjusted.

MORE..

Pushing this button changes to the next menu MD F1.

EXIT

Pushing this button changes to the MAIN F menu.

SWP+
SWP-
EXIT
SWEEP

SWP+ / SWP-

Pushing this button will directly increase / decrease the dwell-time (DWT). It will also change the sweep-time (SWP).

EXIT

Pushing this button will change to the menu MD F2.

STEP+
STEP-
EXIT
STEP

STEP+ / STEP-

Pushing this button will increase / decrease the frequency step size between each demodulation. It can be set from 10 kHz to 1 MHz.

EXIT

Pushing this button will change to the menu MD F2.

AVG+
AVG-
EXIT
AVG

AVG+ / AVG-

Pushing this button will increase / decrease the number of values taken for the smoothing function (average).

EXIT

Pushing this button will change to the menu MD F2.

III.3.2   HVM - High Voltage Meter Display

Instruments with the option of a HVM display (high voltage meter) are able to calculate and display the volt-age waveform connected to the SYNC IN terminal. The scaling of the amplitude and time base is done automatically so that one full waveform is displayed. The calculated values U_{RMS} and $\hat{U}/\sqrt{2}$ can also be shown in the other selected displays (SCOPE, METER, DSO), however this will decrease their refreshing rate. The software ICM*compact* is able to record these values together with PD level and the date/time. Please also regard the software introduction in section IV and the technical data in section VII.

The displayed waveform has no impact on the calculation of the values shown in the top two rows or other menus. The crest factor (Crest) is calculated by $\dfrac{\hat{U}}{U_{RMS}} = \dfrac{peak\_voltage}{effective\_voltage}$ resulting in a factor of 1.41 for not distorted sine waves.
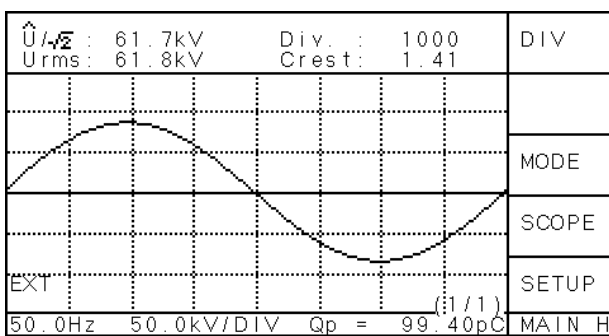
Fig. III.15: HVM display showing voltage waveform

To adjust the signal voltage entering (SYNC IN) to the measured voltage the divider factor (DIV.) can be changed by using the buttons DIV+ and DIV-. Holding these buttons will increase the step width.

The voltage frequency and the scaling factor for the displayed waveform are shown in the bottom row together with the peak PD value taken from the AMP IN terminal.
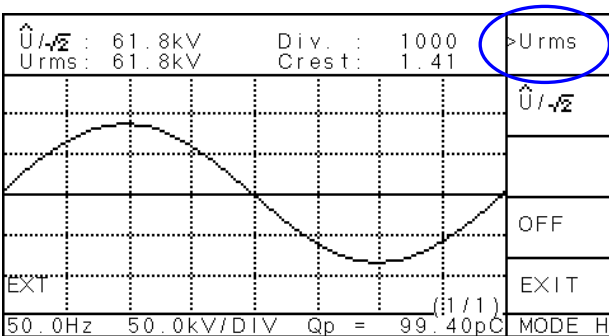
Fig. III.16: MODE menu for the HVM mode

To select a value (U_{RMS}, $\hat{U}/\sqrt{2}$) which should be displayed in SCOPE, METER or DSO mode switch to MODE H and select the respective value.
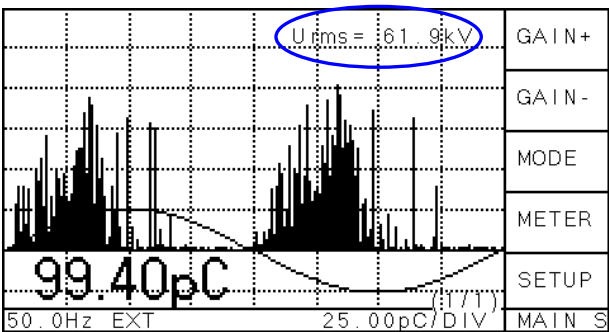
Fig. III.17: SCOPE display with U_{RMS} value

DIV
Cd
MODE
SCOPE
SETUP
MAIN H

DIV

Changes to the submenu DIV. There the divider ratio of the high voltage divider can be set.

Cd

Changes to the submenu Cd. There the low voltage capacitance can be entered. This menu is only visible if one of the three VLF is selected in the menu SYNC.

MODE

Pushing this button changes to the MODE H menu (see menu MODE H).

SCOPE, DSO or METER

Depending on the optional DSO acquisition board this function switches to the next display type.

SETUP

Pushing this button changes to the last selected SETUP menu.

This menu is only visible, if one of the three VLF is selected in the menu SYNC.

UP
DOWN
<<
>>
EXIT
Cd

UP / DOWN

Sets the low voltage capacitance. The selected character (.) can be increased (UP) or decreased (DOWN) by pushing the button.

<< / >>

To select the character which should be changed the cursor (.) can be moved up (<<) or down (>>) in range by these buttons.

UP
DOWN
<<
>>
EXIT
DIV

UP / DOWN

Sets the divider ratio of the high voltage divider. The selected character (.) can be increased (UP) or decreased (DOWN) by pushing the button. The ratio has to be inserted as a factor of 1/x. E. g. with a divider factor of DIV = 1000 a maximum measuring range of 140 kV$_{rms}$ is possible, since the maximum input voltage is 140 V$_{rms}$ or 200 V$_{peak}$.

<< / >>

To select the character which should be changed the cursor (.) can be moved up (<<) or down (>>) in range by these buttons.

Urms
Û/√2
>OFF
EXIT
MODE H

Urms

Setting this option displays additionally the root-mean-square value of the voltage in the further selected displays (see figure III.17).

Û/√2

Setting this option displays the peak value divided by 1.414 in the further selected displays.

OFF

Turns off the additional display of the voltage value in the selected displays (see menu DISPL). This will increase the refreshing cycles in the other displays since the voltage value is not calculated.

III.3.3 VLF – Very Low Frequency

Instruments with the optional VLF acquisition are able to synchronise (trigger) at very low frequencies like 0.1 Hz. Since the synchronisation is done by the supplied high voltage, the instrument needs also to have the optional high voltage measurement HVM. An ICM*compact* with the VLF function has an additional sub-menu 'SYNC' which is accessible in the SETUP3 menu (see section III.2.3). With an ICM*compact* without the VLF function this key is labelled 'ESYNC'.

ESYNC
0.1Hz
0.05Hz
0.02Hz
EXIT
SYNC

ESYNC

If this button is selected (>) the frequency measurement and synchronisation with frequencies >10Hz is taken from the SYNC IN input, if possible. To manually turn to the line (mains) sync., deselect the button.

0.1Hz, 0.05Hz, 0.02Hz

Selecting one of these buttons (>) will activate the VLF measurement mode. For the acquisition with this option, an external voltage signal from the VLF system is recommended. Selecting one of the three VLF frequencies will deselect the external frequency measurement. The zero crossing of the voltage signal will be determined by the internal firmware automatically. The frequency has to be chosen according to the settings at the VLF high voltage source.

III.3.3.1 VLF – Installation, Connection

For partial discharge measurement on a medium voltage cable, the core of the specimen has to be connected to a coupling capacitor C_C (e. g. 1 nF). The low voltage side of C_C is then connected to a quadrupole (e. g. CIT4L) suitable to stand the max. current determined by C_C, U_{max}, and frequency of the test voltage. A broad-band preamplifier should be connected with a short link (coax or BNC-adapter) to the quadrupole. Power Diagnostix offers two preamplifiers suitable for this purpose. The RPA1L is designed for laboratory environment and production line and the RPA1H which is suitable for field test. Both preamplifiers have a frequency range of 40 kHz to 20 MHz. The test voltage (VLF high voltage source) is also connected to the specimen core. To minimize noise and unwanted oscillations of the PD signal, the coupling capacitor C_C should be connected as close as possible to the cable under test. The earthing connections should be kept short as well. The specimen screen should be connected closely to the quadrupole.

The fault location on cable (TDR) requires a point of reflection; therefore, the cable specimen should not be terminated at the far end nor short circuit.

III.3.3.2 VLF – Calibration

Charge Calibration

The calibration for a PD pattern acquisition in the VLF mode can be done in advance, while in the line sync mode (50/60 Hz). This is described in section III.5.3. However, it is also possible to calibrate in the VLF mode (e. g. 0.1 Hz). Both modes will result in the same calibration factor (CF), but CF is more facile to get in the line sync mode since the calibration signal is easier to identify.

The calibration of the cable length for the TDR is described in section III.3.4.3.

Divider Factor Adjustment

The HVM option (**h**igh **v**oltage **m**eter) is mandatory to get the correct phase synchronisation with the VLF mode. Therefor, the divider factor (DIV) should also be adjusted. The divider factor can either be read off the coupling unit directly (e. g. CC50/V with DIV=500) or calculated by:

$$DIV = \frac{C_C + C_d}{C_C}$$ whereas C_C relates to the HV coupling capacitor and C_d to the low voltage capacitor.

For $C_d >> C_C$ applies DIV ≈ C_d / C_C.

Phase Shift Adjustment

The ICM*compact* will adjust the phase shift (PH) due to the lower frequency automatically. This calculation requires the nominal divider factor and the low voltage capacitor (C_d) of the coupling unit. These values can be set in the menu 'MAIN H' while the synchronisation frequency is set to one of the three VLF's (e. g. SETUP3 / SYNC / >0.1 Hz). Usually, these values can be found on the coupling capacitor. Using the combined Filter-Coupler unit TCC, the following table shows the relevant values:

Coupler type:	C_d	Divider factor at 50 Hz
TCC25	250 nF	250
TCC30	500 nF	500
TCC50	500 nF	500
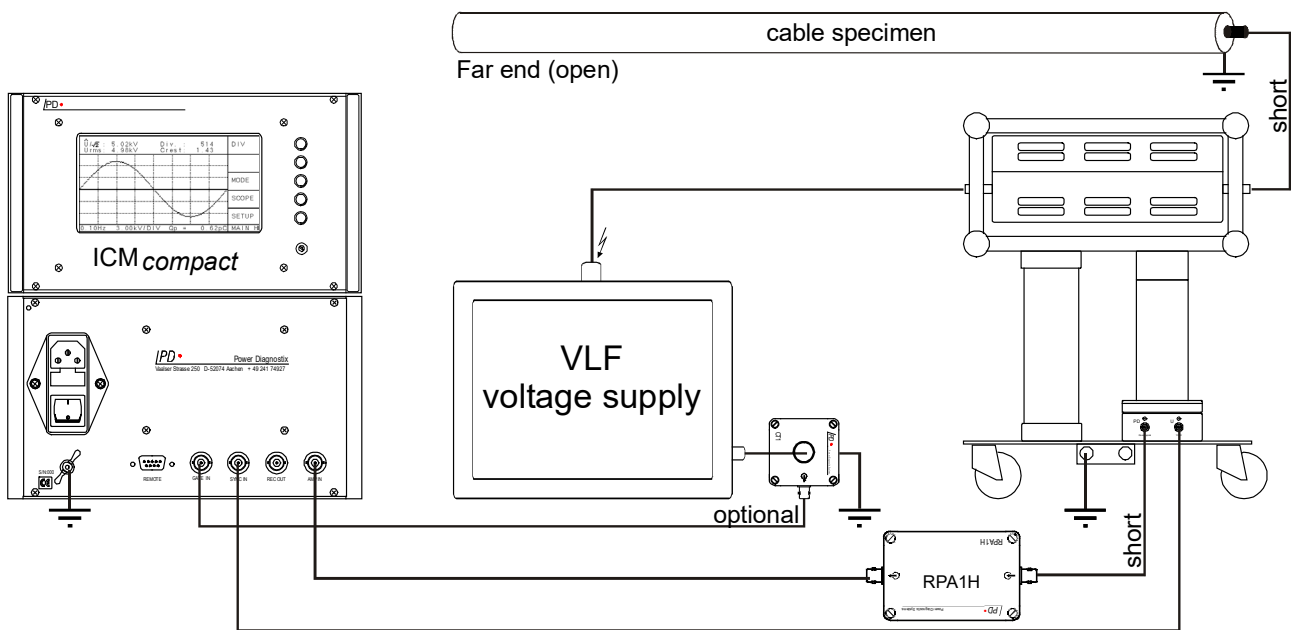
Fig. III.18: Example test set-up for a VLF measurement on a HV cable with a TCC filter-coupler-unit

III.3.4   DSO – Digital Storage Oscilloscope for TDR Measurements

Instruments with an optional DSO acquisition board for cable fault location (TDR) are able to process and display PD signals on a time-based curve. Single PD pattern can be triggered and recorded with a resolution of 10 ns (= 100MSamples/s) and a maximum total display range of 80 µs (with Firmware $\leq$ 2.16: 60 µs). This results in a maximum cable length of about 5 km (max. measuring time 80 µs and pulse velocity of v_C=140 m/µs). Since the LCD resolution is limited to 200 pixel the data display is compressed. Using the PC software extended by 'c', e. g. ICM*compact* 5.05**c,** offers full advantage of the high resolution. This software is specialized to locate faults in long cables using the TDR (time domain reflectometry) at the cable terminations. Please note, that due to high frequency effects (i. e. attenuation, dispersion) it is not possible to locate partial discharge faults after approximately 3 km. The cable length should be at least 10 m. Please also regard the software description in section IV.2.

III.3.4.1 Measurement Principle of TDR with the DSO

The TDR (time domain reflectometry) uses the travel time of pulses. Long high-voltage cables behave as a wave conductor. Therefore, a pulse which is generated e. g. by a discharge, travels to both cable ends. If these ends do not have the characteristic impedance of the cable (open ends), the pulse will be reflected to the opposite end. The distance from the fault (pulse source) to the end of the cable is calculated from the time difference (Δt) the two pulses occur at the measured end (coupling unit). Figure III.19 shows an HV cable with a fault. The traveling ways of the first three pulses entering the coupling unit are displayed on top.
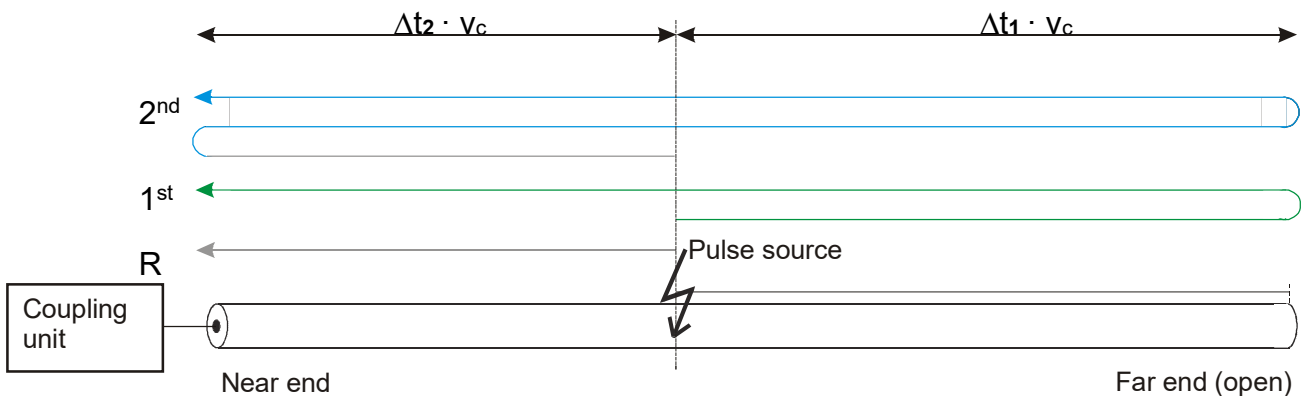
Fig. III.19: Propagation of a pulse in a cable

Figure III.20 shows the time diagram of the three pulses entering the coupling unit. The reference pulse ('R') travels the direct way to the coupling unit. The 1st reflection has travelled the opposite direction and is reflected at the open end of the cable; thus, resulting in a time delay Δt_1 which indicates the distance of the pulse source to the far end.
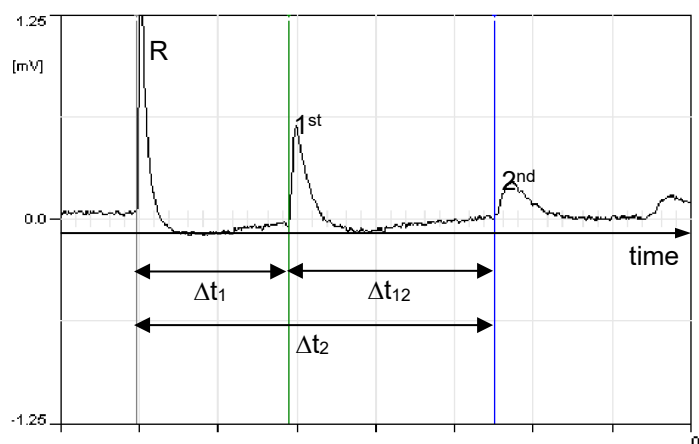
The 2nd reflection results from a reflection of the reference pulse at the near end and thereafter at the far end. The time difference between the 1st and 2nd reflection (Δt_2) indicates the distance of the pulse source to the near end.

Fig. III.20: Time diagram

III.3.4.2 DSO – Software

The set-up for the acquisition of PD pulses in TDR (single PD pulses are observed) has the same principle as for the PD pattern acquisition. A detailed description of this set-up is already given with the VLF mode in section III.3.3; except, that the external synchronisation (SYNC) to the HV is not necessary.
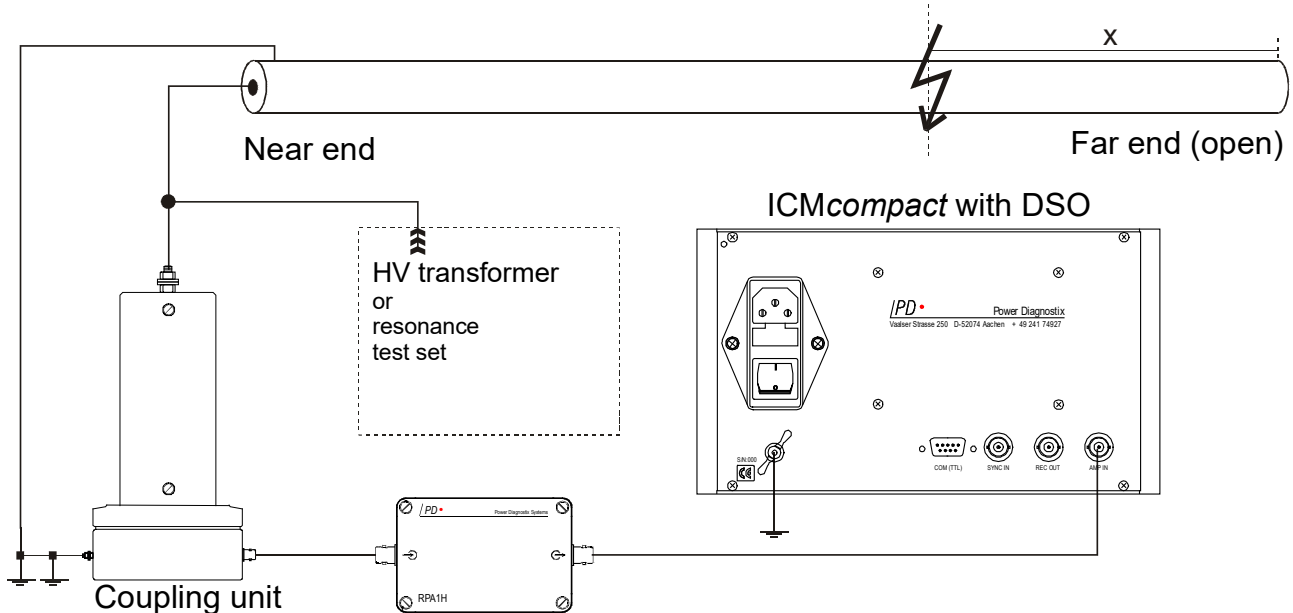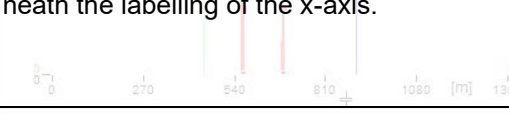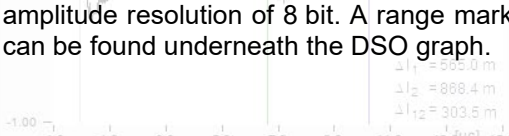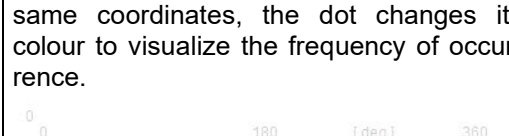

Fig. III.21: Example test set up for PD location on an HV cable

Although the ICM*compact* can be used as standalone instrument for cable fault location, the optional software extension greatly simplifies the acquisition and analysis with the DSO board. For this, each instrument has a USB connector, used to connect to a common PC. To protect the PC, a proper earthing of the instrument is necessary. Additionally, an insulating fibre optical link for the USB is available. There are USB/FOL converters available which can be connected to the COM TTL connector at the rear side. The connector for the COM TTL interface is on the instrument side a 9-pol SUB-D (or 'DE9') **male** plug. This is not to confuse with old serial interface (RS-232) which has had a 9-pol SUB-D **female** plug.

With the first online session, the device code of the instrument has to be entered in the software. After a successful initialization of the instrument, the set-up values of the instrument are loaded e. g. range, gain, trigger level, cable length, pulse velocity.

A software with the DSO extension has a function button (F9) labelled 'DSO Panel'. Pushing this button changes to the panel for cable fault location. This panel has two x-y-graphs.

Power Diagnostix - Cable Fault Location

All functions of the software are accessible by the pull-down menu in the top line. This menu will change with the selection of 'Main' or 'DSO' panel.

The upper x-y-graph (**LOC**) displays the results of evaluated measurement curves. After the acquisition of multiple PD events, the user has to process each pulse by positioning the three cursors (R, 1 and 2) within the lower graph. Marks for cable specific elements like sleeves or terminations are also shown with this display beneath the labelling of the x-axis.

The fields in the centre of the DSO panel display actual processed values like the charge and voltage value. The charge value is calculated by the single displayed PD pulse, whereas the voltage value is taken from the HVM menu. Hence, the charge meter must be calibrated within the DSO again. The divider factor for the voltage meter is taken from the HVM menu. Additionally, four LED indicate the status of the instrument's communication interface.

The oscilloscope-like display on the upper right-hand side shows every PD signal on a phase resolved graph. Every partial discharge pulse is displayed as a vertical line at the phase angle where it occurs. The length of the line is proportional to the amplitude.

The lower x-y-graph displays the '**DSO graph**'. Here, the single PD pulses are shown, which are transmitted from the instrument. The time axis (X-axis) can be zoomed from 2 µs to 80 µs. With a fixed A/D conversion time of 10 ns this relates to 200 to 8000 values. Each value has an amplitude resolution of 8 bit. A range mark can be found underneath the DSO graph.

The display on the lower right-hand side represents the pulse-amplitude-phase-height-distribution, whereas every single grey dot stands for an acquired PD pulse at this specific phase position (x-axis) and at this specific amplitude position (y-axis). In case more than one pulse occurs at the same coordinates, the dot changes its colour to visualize the frequency of occurrence.

Beneath the graph displays one line with control fields allows changing the settings for the instrument and software. These values can be set by the user directly.

The most frequently used functions are additionally placed at the bottom line. They can also be accessed by the function button F1 to F12 (left to right).

After launching the program and entering the DSO panel, there are two applications possible:

a) Online measurement for cable testing
    Pushing the 'Run DSO' button (or F1) will start a continuous online acquisition. This mode displays the acquired curves quickest possible on the software, according to the transmission rate and the set trigger mode.

b) Offline use for data evaluation
    To evaluate recorded data, the software should be disconnected from the instrument by pushing the button 'Offline'. This will disable the 'Run DSO' button and change the 'Start Scan' button to 'Start Replay'. Pushing this button opens another window for selecting the stored measurement files. One file displays one fault within the cable. All relevant files should be added and will then be shown in an extra window. Here two cursors can be set manually to determine the different fault locations. The result of this evaluation is shown in the LOC graph by red bars, relating to the distance and number of faults.

Position

The displayed range of the x-axis can be shifted by the value 'Position' or the scroll bar above the graph, whereas the trigger is always set as zero position of the x-axis and a pre-trigger time of -1 µs is fixed by the instrument. However, while in RUN mode, the 'Position' will change this pre-trigger time. In HOLD mode or when the instrument is offline, the 'Position' will change the displayed range but not the acquired data. 'Position' and 'Zoom' will be adjusted in the HOLD mode automatically if one value is out of range.
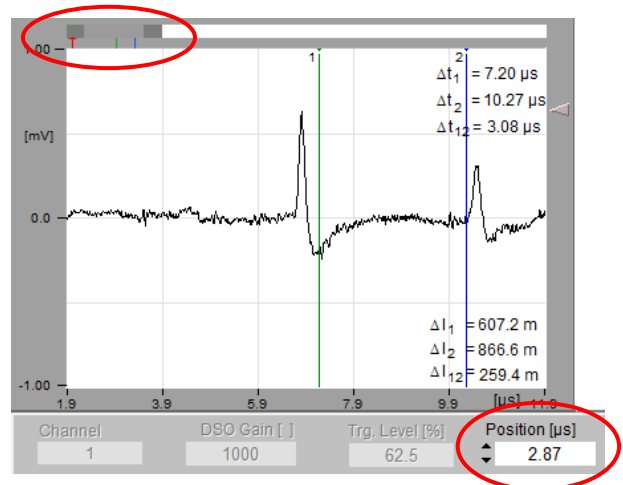
Fig. III.22: Screenshot of the DSO graph

Range / Zoom

While in RUN mode this value defines the total range in µs. This time base should be kept short to avoid unnecessary data transmission between the instrument and the software.

Example: The ideal range for a cable of 1.4 km length and a known pulse velocity of 165 m/µs is between 18 and 20 µs (2 x 1400 m / 165 m/µs = 16.9 µs).

Due to the dispersion within the cable, the time range should be set 10–20% higher than calculated. This will ensure to get the complete reflected signal. The value must be a multiple of 2 µs and cannot exceed 80 µs. The white bar underneath the DSO graph indicates the maximum possible range. The grey bar indicates the actual set range. Within the HOLD mode, a light grey bar indicates the displayed range of the measured data.

It is also possible to adjust the 'Position' and 'Zoom'/'Range' by the mouse cursor. The mouse arrow will change to a hand for shifting the position or to a double-headed arrow for changing the range/zoom. The coloured lines underneath the bar (grey, green and blue) indicate the cursor positions within the DSO graph. The red 'T' stands for the trigger position and is fixed.
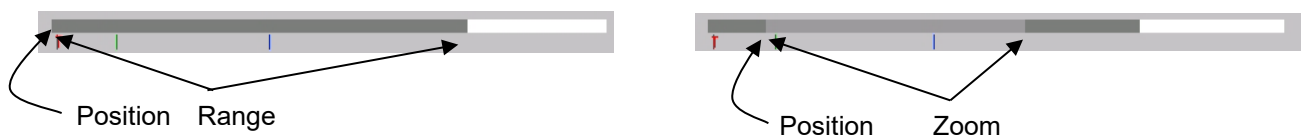
Fig. III.23: Marking of the range within RUN mode   and in HOLD mode

The visible part within HOLD mode (zoom) can only be part of the acquired data (i. e.: zoom ≤ range). Therefore, the range during the measurement should be large enough to be able to zoom during the analysis.

Gain, Trigger Level

The 'Gain' value defines the total amplification of the high frequent signal. The gain can be set between 1 and 80000 (0–98 dB) in different steps. The trigger level ('Trg.Level') can be set between 0 and 100%. Both values are only accessible in RUN mode. Possible reasons for a lack of a repeating signal on the DSO graph are listed as followed:

- gain level too low; the trigger level is not reached

- trigger level too high; with weak signals, a lower trigger level might be necessary

- no partial discharge activity; even with very high gain only noise signals are triggered-on

A sensible combination of gain and trigger level can be achieved by using a calibrator signal (as described in section III.5). The trigger level should be set between 50% and 90% of the calibration signal. The gain should be set, so that the reflection of the cable end is seen clearly, and the first pulse is not too much over-ranged. For a subsequent data analysis, it is mandatory to capture at least one reflection.

Green arrow: trigger o.k.

Red arrow: no trigger, gain too low or trigger level too high

Trigger level in percent; no distinction between positive and negative pulses; the arrow is movable with the mouse or settable by the 'Trg. Level' value.

Trigger mode selectable between: Auto / Normal / Single shot
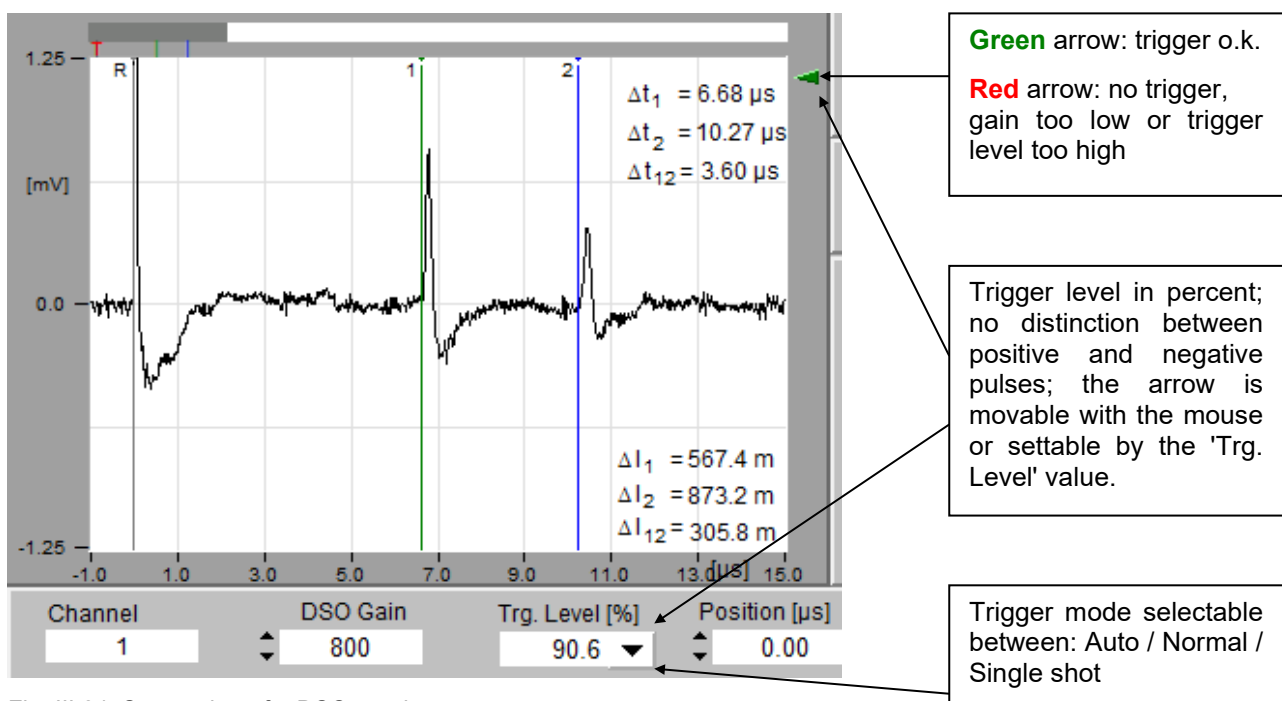
Fig. III.24: Screenshot of a DSO graph

The arrow button next to the 'Trg. Level' ▼ selects the trigger mode. With the 'Auto' mode, the DSO graph is updated continuously, independently of a trigger event. With the 'Normal' mode, only triggered signals are displayed. With the 'Single shot' mode, just one trigger event is shown (the first possible) then the software turns to the HOLD mode.

Max. Display

This value limits the indicating range of the x-axis within the LOC graph. It is possible to choose a value greater than the cable length, however a sensible range is limited by the 'Range' and the pulse velocity. The maximum acquired length can be calculated by:

$$\text{Max.Display}_{max} = \frac{V_C \cdot \text{Range}}{2}$$

Calibration of the Cable Length

The values for the cable length and the pulse velocity can be entered in the fields directly, if known. If only one value is known, the second value can be determined with a calibration measurement.
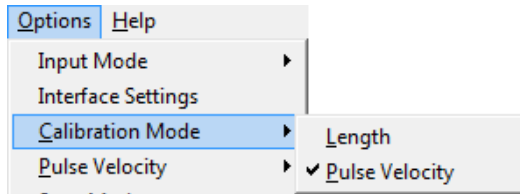
The selection of the calibrated value is done in the menu of the DSO panel: Options / Calibration Mode / Length.

If the pulse velocity of the cable type is known, it can be entered in the related field. The cable length can then be calibrated by injecting an impulse at preferably the near end of the cable.

For this an impulse generator (CAL1A, CAL1B, or equivalent) must be connected to the coupling unit. During the calibration the high voltage must be turned off, otherwise the impulse generator might be damaged. To get continuously new curves on the graph, the software must be connected ('Online') and put into the 'RUN' mode. While injecting a pulse with the calibrator, the gain and the trigger level should be adjusted so that a triggered pulse is seen. The range should be adjusted in the way that the first reflection of the pulse at the cable head is seen clearly.

Fig. III.25: Cursor positioning for length calibration
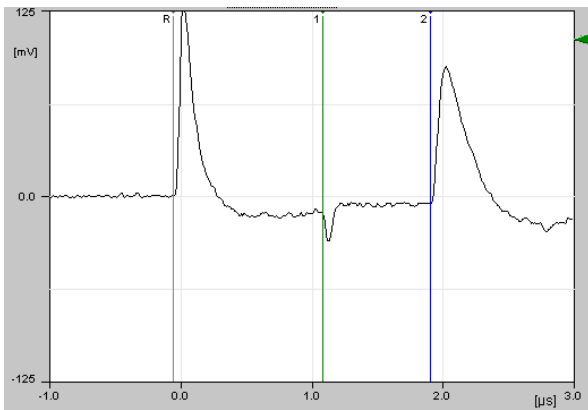
The grey cursor labelled 'R' can now be placed at the beginning of the first pulse, which is around 0.0 µs (see figure III.25). The blue cursor labelled '2' should be placed at the beginning of the first pulse reflection from the cable head. The green cursor ('1') is not used during the calibration. Now the 'Start Calibration' button (or F7) should be pressed. After selecting a suitable folder and number of files to be recorded (usually one is sufficient), the record starts. Each triggered curve is saved in a separate *.dso file, and the position of the blue cursor ('2') within this graph is transferred to the LOC graph (right) and summed up in the red bars. Finally, the calibration files can be saved together with further information about the specimen (Report) in a *.cfl file. After the acquisition has finished, the cable length is automatically calculated by the entered velocity (Vc) and the tallest red bar.

Calibration of the Pulse Velocity (V$_c$)

If the cable length is known, the pulse velocity can be calibrated. This calibration should be done as described above. With a double click of the left mouse button at the position of the red bar a new window will pop up. By entering the precise cable length into this window, the pulse velocity will be calculated automatically.
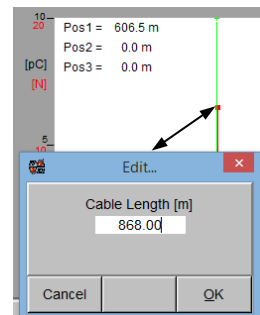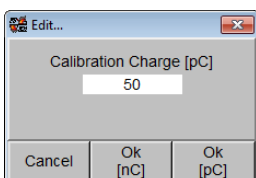

Fig. III.26: V$_c$ calibration

Calibration of the Charge Value (Qp Cal)

The button 'Qp Cal' within the charge meter allows calibrating the current DSO curve. The entered PD value will be assigned to the area underneath the triggered pulse. Thus, this charge value represents the single displayed curve, whereas the charge value shown in the Main panel represents the peak charge value since the last data refresh.

Description of the Functions

The function keys at the bottom of the window offer the major functions needed for a cable fault location. In the following these are described in detail as well as the different conditions of the program. Active function keys are marked with dark grey. The keys are labelled with the function that will start when pressed. They are **not** showing the current state of the program. E. g if the program is in the HOLD mode, the first key (F1) is labelled RUN. By pushing this button, the program turns to the run-mode (starts the acquisition) and the button is labelled HOLD. Without a serial connection to an instrument, the program cannot be turned into the RUN mode.

Run DSO	Start Replay	Report	Load	Save	Search	Start Calibration	Start LOC	Main Panel	Exit

Fig. III.27: Offline (instrument not connected)

Run DSO	Stop Replay	Report	Load	Save	Search	Start Calibration	Stop LOC	Main Panel	Exit

Fig. III.28: Offline, replay function started

Hold DSO	Start Scan	Report	Load	Save	Offline	Start Calibration	Start LOC	Main Panel	Exit

Fig. III.29: Online, in RUN mode

Hold DSO	Stop Scan	Report	Load	Save	Offline	Stop Calibration	Start LOC	Main Panel	Exit

Fig. III.30: Online, in RUN mode with scan and calibration function started

Run / Hold DSO (F1, Ctrl+u, or Ctrl+o)

The program has two states for the DSO graph. With the first state 'RUN' the program takes continuously data from the instrument. Depending on the trigger mode, the DSO graph is updated continuously as well. Three trigger modes can be selected by pushing the arrow ▼ next to the 'Trig. Level' field:

- With the **AUTO** mode selected, each transmitted curve is displayed.

- With the **NORM** mode selected, only triggered curves are displayed.

- With the **SINGLE** mode selected, only the first triggered curve is displayed, then the program turns to the HOLD mode.

The HOLD mode always displays the last triggered curve or the last file which was loaded. The program must be in the HOLD mode to start a replay of recorded data.

Start/Stop Replay, Start/Stop Scan (F2, Ctrl+A)

The second function key (F2) changes its function depending on the program status. You find there the most important functions for the data acquisition (SCAN) and evaluation (REPLAY). The SCAN function can only be used if the software has an online connection to the instrument. While 'offline', the REPLAY function is available. Both functions are closely linked.

The SCAN function saves measurement data in different files. These files will have the extension '*.dso' and can be loaded and processed later, while the software is offline. The dso files contain only raw data to minimize the memory requirements.
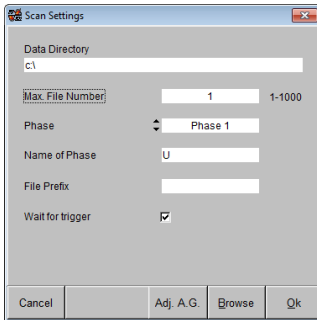
Fig. III.31: Settings entry window

After the SCAN function is started, a window like the one shown in figure III.31 pops up. The entry 'Data Directory' defines the destination folder where all recorded files are stored. It can either be entered manually or chosen from the existing folder structure by the button 'Browse'. The entry 'File Prefix' defines the name of the data-files. The later file name is put together from the entry in 'File Prefix', the chosen 'Phase' name, a consecutive number, and the extension '.dso'. The quantity of files recorded can be set in the 'Max. File Number' field. A value between 1 and 1000 can be chosen. The option 'Scan non triggered' allows saving files which are not generated by a trigger event of the pulse. This option might be helpful, if heavily distorted signals are present and a firm triggering to dominant PD pulses is not possible. With this option, randomly taken data are recorded and analysed later. For this, the 'range' should be long enough to search for PD pulses and their reflections within the data stream. The acquisition is started by the 'Ok' button and stopped by the 'Cancel' button or if the number of files is complete.

Fig. III.32: File selection window

The Replay function can only be started if the instrument is offline. It will open a sub-window in which the scanned data-files can be selected. It must be pointed out that only data with the same time-range should be selected at once.

Fig. III.33: Replay window for data analysis

After confirming the selection with the OK button, a new sub-window opens. Here the recorded graphs are shown one after the other together with two cursors. The path and filename of the current displayed graph is shown in the upper right-hand corner. Now the user can place the grey cursor at the base of the trigger-pulse around 0 µs). The red cursor should be placed at the base of the first reflection of that pulse. 'Select' will take this cursor interpretation, save the cursor positions, and put one red bar into the LOC graph of the main window. If there is already a red bar at that position, it will increase the length (number) of this bar. 'Select All' will take the saved cursor positions of all selected files and add the results to the LOC graph in the main window. This should only be done, if an interpretation of the graphs was already done and saved in the *.dso files. 'Skip' will ignore the displayed graph and move to the next selected one without action. 'Back' moves one selected graph back and deletes the last result in the LOC graph, e. g. to correct a misinterpretation. 'Delete File' will remove the displayed file from the disc. With 'Save File As', the current file can be copied and renamed. 'Cancel' stops the whole replay function.

Each selected file is automatically counted in the LOC graph. The position of the red cursor determines the marking of a defect within the LOC graph.

Report (F3, Ctrl+R)

Fig. III.34: Report entry window

This report is saved together with each cfl file created by the 'Save' (F5) function. It allows the user to add comments and further information to the measurement data. The report will be printed and exported to text-files. 'Set Date&Time' places the current PC time into the related entries. 'Load Report' allows to change the *.dso graph which is saved together with the report data. 'Edit Accs' (Edit Accessories) opens a further sub-window where the 'List of Accessories' can be changed. They are also saved with the cfl file. With the 'Browse Data Dir' the destination of the cfl file can be changed. 'Export' will save the report data as a standard ASCII file (*.txt).

Load (F4, Ctrl+L)

In the offline mode saved files can be loaded and displayed. Both types can be loaded, the pure scanned graphs (*.dso) and the project files (*.cfl). The project files contain the last displayed DSO graph together with the setup information of the instrument, the report entries, as well as the fault location within the LOC graph.

Save (F5, Ctrl+S)

Saves the currently displayed data in a cfl file.

Search/Offline (F6, Ctrl+E)

This function connects or disconnects the link to an ICM*compact* instrument. During the connection all selected ports are scanned for possible instruments. This are by default the ports COM1 and COM2, however up to 16 COM ports as well as GPIB and virtual LAN ports can be selected. The selection can be changed in the MAIN Panel / Options / Interface Settings / RS232 or GPIB or LAN. During the program launch and when changing the panel, the search function is activated automatically.

Start Calibration (F7, Ctrl+B)

This function calibrates either the cable length or the pulse velocity. A detailed description is given on page 46. The calibration of the charge magnitude is done by the 'Qp Cal' button within the 'Charge' meter, whereas the voltage magnitude can be adjusted by the 'Divider' button within the voltmeter.

Start LOC (F8, Ctrl+T)

This function starts the fault location (LOC / Location). To activate the automatic mode, the option 'Options / LOC Graph / Calculations / Auto' must be selected. The processing of the measurements is based on the correlation frequency distribution and the results are shown in the right-hand graph (LOC graph). Each triggered curve which can be seen in the DSO graph is put into correlation with a reference pulse. This reference pulse was prior artificially 'aged' i. e. the dispersion of the cable is already taken into account. After the correlation, the maxima are put together in a three-dimensional field. With an increasing measuring time, the reflection position will show accumulation points. The sum of this accumulation points within on segment of the x-axis are pictured by red vertical bars also called projections within the LOC graph. But only points which exceed the set level are considered. This level can be seen as red arrow next to the LOC graph.

The most frequent maxima (also called peak distribution) are indicated as faulty positions underneath the LOC graph next to 'Pos1'...3. Via the menu 'Options / LOC Graph' different results can be shown or disabled. Two cursors can here be activated to 'measure' distances. The results of the cursor distances are shown underneath the LOC graph. The sensitivity for the projections (red bars) can be adjusted as well.

The LOC function is automatically started with the replay of saved measurements. It must be pointed out, that the counting within the LOC graph starts from the far end. The display range for the x-axis ('Max. Display') should always be larger than the cable length, otherwise faults can be overlooked.

Note: The automatic analysis of the curves (correlative peak distribution) should not be the only criterion for the fault location. To verify the results the original DSO curves, the installation plan and the impact of disturbances should be taken into account!

If the software is offline, the 'Start LOC' button will start the manual fault location as does the button 'Start Replay'.

Main Panel (F9, Ctrl+P)

This button changes the instrument back to the PD mode, the software will also change its acquisition mode. One brief interruption during this switch is usual.

Exit (F10, Ctrl+X)

The program is terminated by the EXIT button.

Menu Options

Some additional functions are accessible via the menu block at the top of the program window. In the following those functions of the menu block are described, which are not accessible within the main user interface.

With the buttons '**PgUp**' and '**PgDown**', the next respectively previous DSO file can be loaded from the current folder. The program has to be in the offline mode. A brief message will give a warning if no DSO file can be found in the selected folder.

The function '**Export Results**' will put the calculated fault positions, shown in the LOC graph, into an ASCII text file. The 'Report' data are also added.

With the function '**Default Directory**', a folder can be selected which is automatically opened with the 'Load' or 'Save' function.

Fig. III.35: Pull down menu 'File'

The menu 'Edit' offers functions like '**Copy** DSO', 'Copy LOC' and 'Copy DSO+LOC' to put one or both graphs into the Windows clipboard. From here, they can easily be exported into other programs by 'Ctrl+V'.

The basic settings for a scan can be changed without starting a scan and even without being online by the '**Scan Settings**' menu.
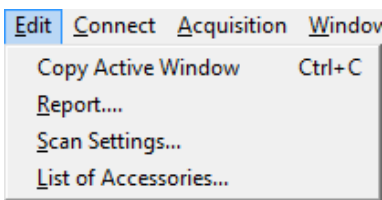
Fig. III.36: Pull down menu 'Edit'

The '**List of Accessories**' is a helpful tool to add information into the LOC graph. In here, cable accessories like sleeves, junctions or terminations can be added and will be shown as small icons within the LOC graph.

The pull-down menu ' Acquisition' repeats functions, which are already described on the previous pages. The LOC graph on the right-hand side can be disabled to enlarge the DSO graph. This is helpful, especially with long cable specimen to get a better resolution for the positioning of the measurement cursor. By default, the 'DSO+LOC' is set to see both graphs.
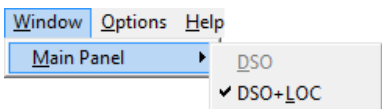
Fig. III.37: Pull down menu 'Window'

The 'Pulse Velocity' (propagation speed of electrical signals within the cable) can be displayed as absolute value '**v**' or as halved value '**v/2**'.

The units in which length and speed are shown, can be altered between the '**SI-System**' (MKS = meter, kilo, second) and the 'fps-System' (= feet, pounds, second).
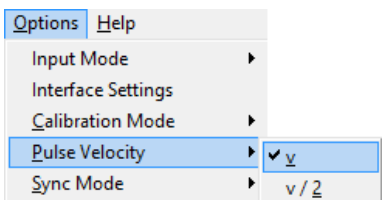
Fig. III.38: 'Options \ Pulse Velocity'
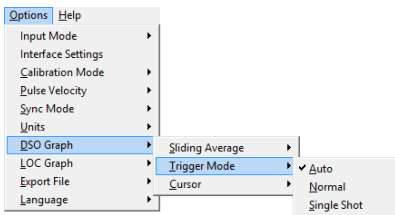
Fig. III.39: 'Options \ DSO Graph'

If the 'Sliding Average' is 'on', multiple acquisitions of the DSO graph are averaged before they are displayed. For this it is necessary to trigger always to the same fault signal.

The 'Trigger Mode' allows selecting 'Auto', 'Normal' and 'Single Shot'. This mode affects the repetition of the acquired graphs.

The cursor within the DSO graph can be hidden 'off' or shown 'on', so can the cursor within the LOC graph.

Most of the settings refer to the LOC graph.

The analysis of the LOC graphs (LOC Graph / Calculations) can be done automatically or manually. However, if the graph is more complex it is recommended to do a manual analysis to avoid misinterpretations.
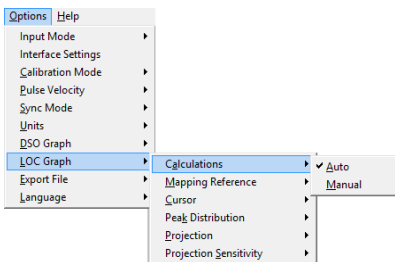
Fig. III.40: 'Options \ LOC Graph'

By the physical properties of TDR, the cable measurement always starts from the far end i. e. the opposite end with no sensor. Therefore, the default display also measures and shows the results from the 'Far End'. However, the 'Mapping Reference' can be changed to start with the 'Near end'. This will be indicated by a capacitor symbol as sensor at the zero position of the cable.

Fig. III.41: Coupling capacitor symbol
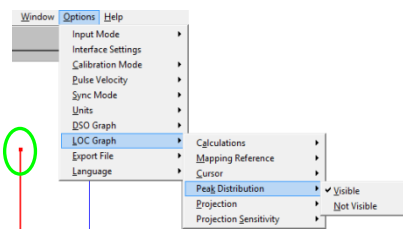
Fig. III.42: 'Options \ LOC Graph'

The 'Peak Distribution' shows each measurement result by a small 'x'. This function can be enabled ('Visible') or disabled ('Not Visible').

The 'Projections' (red bars) indicate the quantity of measured faults at one cable position. They also can be shown ('on') or hidden ('off').

The 'Projection Sensitivity' defines kind of summation. Depending on the setting 'High', 'Medium' or 'Low', the segments in which the peak distribution is summed up as one red bar can be changed. A 'High' projection sensitivity results in small segments which will increase the total number of red bars and decrease the number of counts.
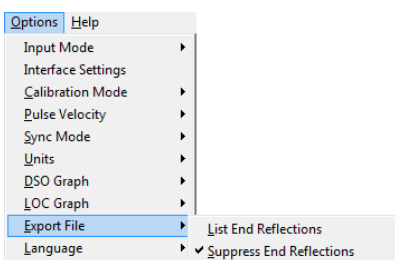
Fig. III.43: 'Options \ Export File'

When exporting the data from the LOC graph and the Report entries, the selection 'Export File' allows suppressing pulses from the cable ends ('Suppress End Reflections'). This is helpful, if the user is only interested in faults within the cable and doesn't want to see pulses from the cable terminations.

With 'Language' the inscription of the software as well as in the report files can be changed between English, German and Spanish. Some shortcuts used with 'ALT+...' will change also. Generally, the letter which is underlined on a function button can be used as a shortcut. Outside the pull-down menu the 'ALT' button has to be pressed while using the shortcut letter. Within the pull-down menu the underlined letter can be pressed directly to jump into the specific function.

### III.3.4.3 Calibration for the TDR

Before raising the voltage on a cable for the actual PD location, a TDR snapshot is done for calibrating the PD magnitude. This can also provide information on the length of the cable, locations of joints, condition of the neutral wire, and the level of sensitivity you can expect to obtain with PD measurements. For the calibration following calibrators are recommended to use:

XLPE (polymeric cable) $\Rightarrow$ **CAL1B** (0.1 to 10 nC)   or **CAL1D** (10 to 1000 pC)

Mass impregnated cable $\Rightarrow$ **CAL1B** (0.1 to 10 nC)   or **CAL1E** (1 to 50 pC)

Laboratory measurements $\Rightarrow$ **CAL1A** (1 to 100 pC)

A list of all available calibrators can be found in section III.5.1.

Caution: For calibration the system has to be de-energized.

With the cable de-energized the calibrator has to be connected to the conductor and neutral by two short leads at the near end of the cable (see figure III.44). After increasing the gain of the ICM*compact*, the magnitude of the calibration pulse should be increased until the pulse reflections are visible. Either the pulse velocity (V_c) of the cable or the cable length can be determined by the instrument or the software.

Fig. III.44: Connection of the calibrator

Fig. III.45: Time diagram taken from the ICM*compact* software
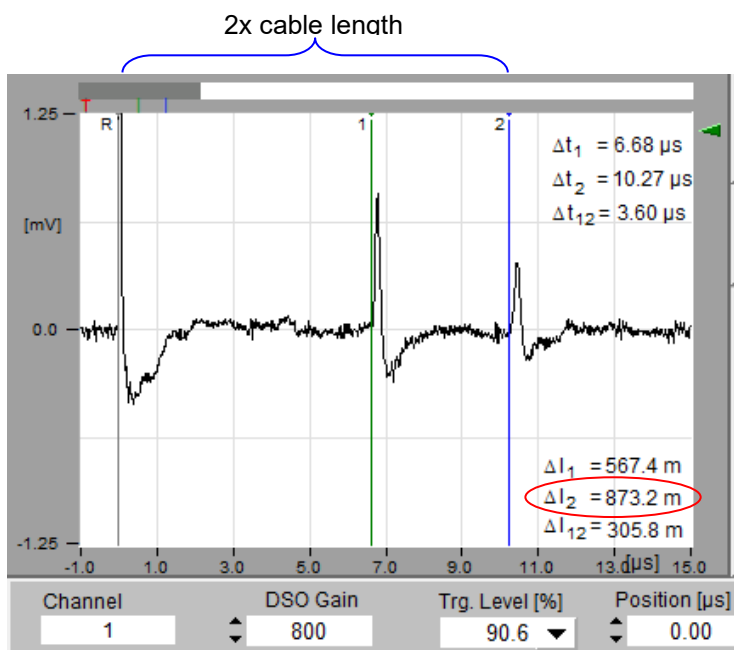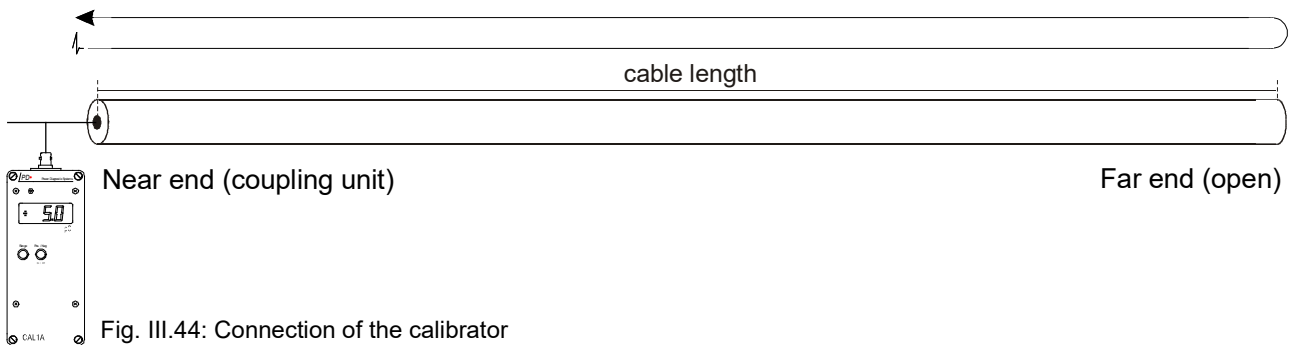
In the example given in figure III.45 the pulse velocity (V_C = 170 m/μs) was inserted. After the two cursors were positioned, the cable length (Δl2 = 873.2 m) was calculated (The factor of 2 is automatically computed and must not be considered).

It is also possible to calculate the pulse velocity, if the cable length is known.

III.3.4.4 Measurement example with the TDR

The next figures show measurement examples of a cable having a cable joint. In figure III.47 a joint was detected at 305.8 m measured from the far end.

Fig. III.46: Joint location

Fig. III.47: Joint location on a cable
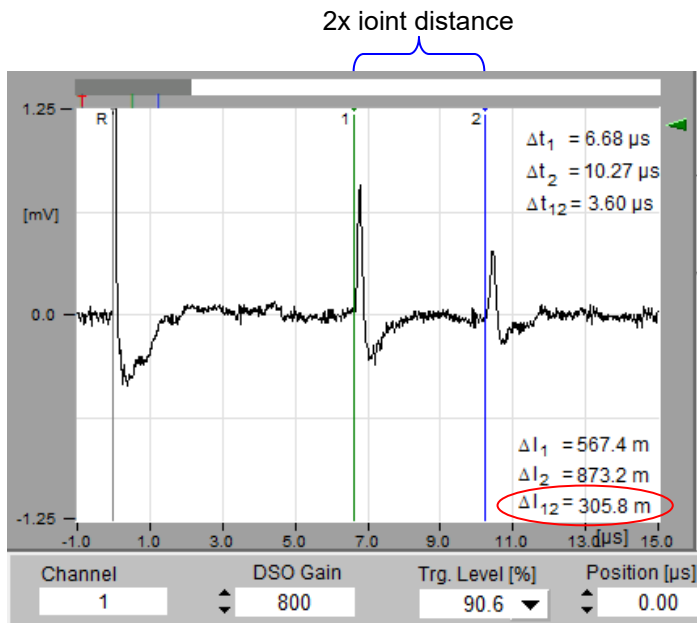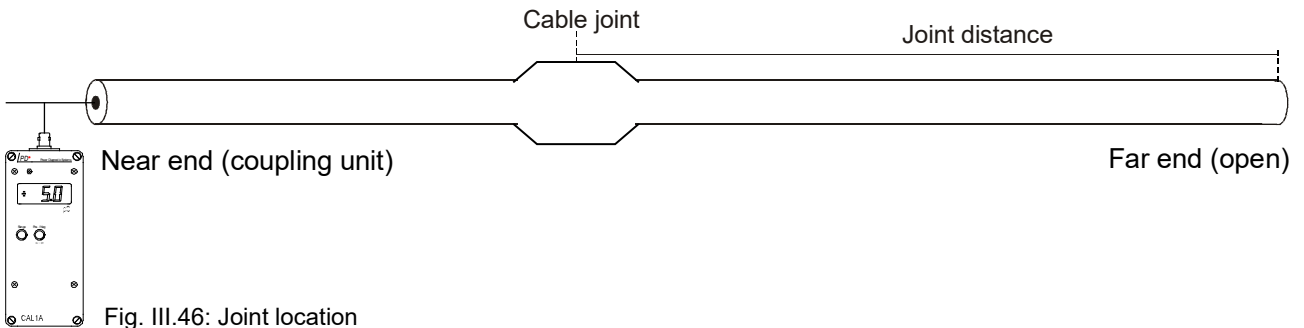
Once the cable length has been specified and the joints are located, the cable can be energized. Figure III.49 shows a measurement with one fault at 567.4 m taken from the far end. Consider that the distance is now taken between the 1st and 2nd cursor (grey and green) but not between the 1st and 3rd (grey and blue), as it was during calibration.
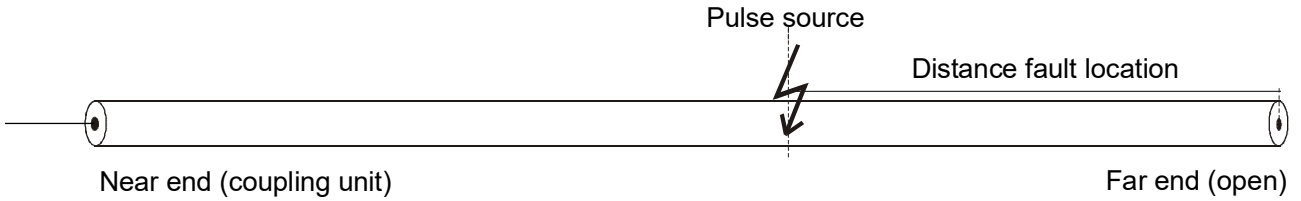
Fig. III.48: PD location on a cable

Fig. III.49: Time diagram of a PD location

III.3.4.5 Functions for the DSO

To get a proper PD pulse, the gain and trigger values have to be set correctly. These factors are **independent** from the calibration factor described in section III.5.3. Figure III.50 shows an example of a triggered PD pulse with all its echoes taken from an HV test cable. Setting the trigger level and the amplification can be done in the submenus GN/TRG resp. TRGLVL, which is found under the main menu MAIN D. The gain has to be increased until a trigger event occurs. Pushing one of the two gain buttons (**GAIN+** / **GAIN-**) will display the absolute gain value at the upper right border of the screen for a short moment (provided a preamplifier is connected). The gain can be set from 2 to 80000 in 17 steps. With a very high amplification the trigger level reaches the range of the input noise. The trigger level should be set between 50 and 90 percent of the y-axis range. Pushing the trigger buttons (**TRG+**/**TRG-**) in the TRGLVL submenu will display the trigger level as a horizontal line for about three seconds. The trigger makes

Fig. III.50: Set trigger level

no difference between positive or negative pulses, it is an absolute value. For better evaluation it is necessary to see the area in front of the trigger pulse. This pre-trigger is fixed to 1 µs (100 samples).

For cable fault location, it is mandatory to use a preamplifier with a high bandwidth. Power Diagnostix offers for this application the preamplifier RPA1L or RPA1H (40 kHz–20 MHz). The higher bandwidth is necessary to measure the pulses and its reflections running over the HV cable without attenuation and distortion of the preamplifier. The time-distance of the pulses is the decisive criteria for the location. Parameters like pulse velocity or cable length will be needed to precisely calculate the fault position within the cable. These settings can be changed with the menus **SPEED** or **LENGTH**. The user can select between the units meter and feet within the menu **UNIT**. This submenu can be entered via the menu MODE D.

Fig. III.51: Indicator for the displayed area

After setting the correct trigger and gain, the PD pulse becomes visible. The triggered pulse and two reflections should be displayed before going on with further evaluations. Adjust the zoom if less or more reflections are visible.

After a single PD pulse has been captured and is hold (menu MAIN D, **HOLD**), the current display can be zoomed. Each step of zooming (**ZOOM+** / **ZOOM-**) will increase or decrease the visible part by 2 µs (200 Samples). The black stripe at the lower side of the display illustrates the relation of visible time to the total acquired time of 80 µs (60 µs). Shifting the left position of the visible area by pushing the buttons **POS>>** or **POS<<** enables to analyse the complete wave in a high resolution.
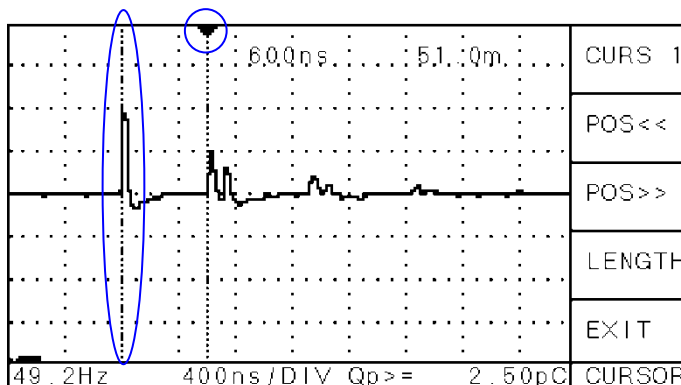
Fig. III.52: Cursor measurement on a PD pulse

The easiest way to evaluate the pulses is using the cursor functionality for the display. Two cursors are supported. Each of them can be set individual to a time position by pushing the buttons **POS>>** or **POS<<** within the menu CURSOR. Select first the cursor by pushing the upper button (**CURS1** or **CURS2**). Always the active cursor will be marked with a black filled triangle at the upper end of the vertical dotted line. It is best to hold first the running acquisition before setting the cursors. Moving the cursors will automatically calculate the new time distance and the result for the distance in meter (feet). These values can be read off from the upper border of the display. The distance on the HV cable is measured beginning from the far end of the measurement point (also see section III.3.4.1). A sensible result can only be ensured if the pulse velocity is set correctly.
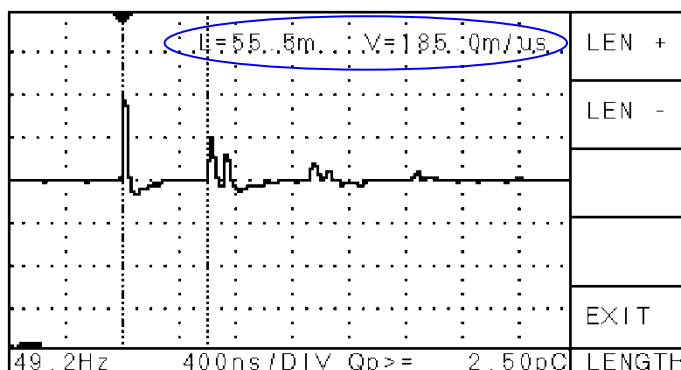
Fig. III.53: Cursor settings: Length and velocity

The pulse velocity can be calculated if the cable length is known. For this a calibration impulse has to be injected into the near end of the cable.

Caution: For calibration the HV supply has to be turned off!

Once the trigger is set to the first (largest) pulse, also the echoes become visible. Setting one cursor to the first pulse and the other to the second pulse will read the calculated cable length. Within the menu **LENGTH** the precise cable length can be set. The pulse velocity is then calculated automatically using the settings of the cursors which are displayed at the upper right-hand side.

Another possibility to get the specimen settings is to modify the pulse velocity directly. This can be done in the menu **SPEED** which is accessible from the menu MODE D. This function is useful if the cable length is not known but the type of cable. A calibration is not obligatory.

III.3.4.6 Key Menus for the DSO

Following menus are accessible with an ICM*compact* including the DSO for cable fault location.

GN/TRG
RUN/HD
MODE
SCOPE
SETUP
MAIN D

GN/TRG

Pushing this button changes to the submenu GN/TRG. Within that menu the user can set the gain, trigger level and trigger mode for the PD display in time domain (DSO display).

HOLD / RUN

Pushing this button changes to the submenu RUN/HD.

MODE

Pushing this button changes to the submenu MD D1. This submenu gives access to several settings of the DSO display as zoom, position and cursor settings.

SCOPE / METER

Depending on the switched-on displays (see menu DISPL) this function switches o the next display type.

SETUP

Pushing this button changes to the SETUP menu. As there are several setup menus, this function enters ever in the last setup you've been once before.

GAIN+
GAIN-
TRGMOD
TRGLVL
EXIT
GN/TRG

GAIN+/GAIN-

Pushing this button increments / decrements the total gain (details see above). These settings are independent from the gain settings in the menus SCOPE and METER.

TRGMOD

Pushing this button changes to the submenu TRGMOD.

TRGLVL

Pushing this button changes to the submenu TRGLVL.

EXIT

Pushing this button changes to the MAIN D menu.

SINGLE
>NORM
AUTO
EXIT
TRGMOD

SINGLE

Pushing this button sets the SINGLE trigger mode. In this mode only the first triggered curve is displayed, then the instrument turns to the HOLD mode.

NORM

Pushing this button sets the NORM trigger mode. In this mode only triggered curves are displayed.

AUTO

Pushing this button sets the AUTO trigger mode. In this mode each measured curve is displayed.

EXIT

Pushing this button changes to the GN/TRG menu.

TRG L+
TRG L-
EXIT
TRGLVL

TRG L+/TRG L-

Pushing this button displays and changes the trigger level. More details are described above.

EXIT

Pushing this button changes to the GN/TRG menu.

RUN
>HOLD
MEM+
MEM-
EXIT
RUN/HD

RUN

Activates/deactivates the RUN mode for the DSO display.

HOLD

Activates/deactivates the HOLD mode for the DSO display.

MEM+/MEM-

Pushing this button toggles through the records of last 16 trigger events.

EXIT

Pushing this button changes to the setup menu MAIN D.

ZM/POS
CURSOR
SPEED
MORE..
EXIT
MD D1

ZM/POS

Pushing this button changes to the submenu ZM/POS. Within that menu the user can set the zoom and the zero position for the DSO display.

CURSOR

Pushing this button changes to the submenu CURSOR

SPEED

Pushing this button changes to the submenu SPEED.

MORE..

Pushing this button changes to the menu MD D2.

EXIT

Pushing this button changes to the setup menu MAIN D.

ZOOM+
ZOOM-
POS>>
POS<<
EXIT
ZM/POS

ZOOM+ / ZOOM-

With these buttons the zoom can be adjusted.

POS>> / POS<<

With these buttons the displayed position can be adjusted. More details are described above.

EXIT

Pushing this button changes to the setup menu MODE D.

CURS 1
POS<<
POS>>
LENGTH
EXIT
CURSOR

CURS 1, CURS 2

Pushing this button toggles between the two cursors. The selected cursor is indicated by a black filled triangle at the upper end of the dotted cursor line.

POS<<, POS>>

Pushing these buttons will shift the selected cursor to the corresponding side. If the cursors are out of the display, push POS<<, POS>> or increase the value of ZOOM-.

LENGTH

Pushing this button changes to the menu LENGTH for setting up the cable length.

LEN+
LEN-
EXIT
LENGTH

LEN+, LEN-

Pushing this button changes the setting for the cable length. The calculated value for the distance between the two cursors can be set accordingly. This will also alter the pulse velocity. Please regard the calibration described above.

EXIT

Pushing this button changes to the menu CURSOR.

SPEED+
SPEED-
EXIT
SPEED

SPEED+, SPEED-

Pushing this button changes the setting for the pulse velocity. This value is used to calculate the distance of the cursors.

EXIT

Pushing this button changes to the setup menu MD D1.

III.3.5 RIV - Radio Interference Voltage Measurement

The RIV mode is for the measurement of 'Radio Interference Voltage' according to NEMA 107-1987 and other relevant standards. In this mode, the bandwidth is fixed to 9 kHz. Technically it is a selective µV-meter. However, the meter reading is weighted according to the CISPR weighting curve, whereas the repetition rate has a strong impact on the reading. The calibration of the RIV mode is done with the one of the calibrators from Power Diagnostix' CAL3x series.

III.3.5.1 RIV – Calibrators
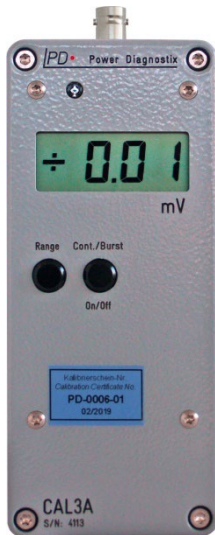
Power Diagnostix offers three different models of calibration signal generators for RIV measurements: the CAL3A, CAL3B, and CAL3D. CAL3A and CAL3B have a 50 Ω output impedance, as needed for calibration according to NEMA 107-1987. In contrast, the CAL3D comes with an internal voltage source of 10 mV to 1 V and an output impedance of 30 kΩ, which causes a voltage drop of the indicated 10 µV to 10 mV across the 300 Ω impedance as required by IEC CISPR 18-2.
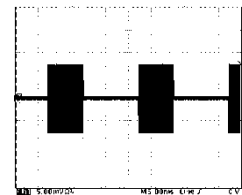
Fig. III.54: Burst mode

The calibrators are switched on with the pushbutton 'On/Off'. This button must be pressed for more than one second to switch the generator off, while automatic switch-off occurs after approximately eight minutes. The same button allows toggling between the continuous mode (Cont.) and the burst mode (Burst). The burst mode is indicated by a blinking '+' sign. During the burst mode, the calibration signal is turned on for about 8 ms each cycle (20 ms for the 50 Hz version).

The 'Range' button sets the amplitude in following steps: 10 µV, 20 µV, 50 µV, 100 µV, 200 µV, 500 µV, 1 mV, 2 mV, 5 mV, 10 mV.

Fig. III.55: Calibrator

The rotary switch on the left side of the calibrator is used to select the signal frequency. The top position '0' selects 600 kHz for the CAL3A. It is increased in steps of 50 kHz up to 1350 kHz. The standard frequency of 1 MHz is selected at lowest position '8'. The CAL3B and CAL3D offer a range of 400 kHz to 1900 kHz in steps of 100 kHz. The following table shows the position of the switch and the corresponding frequencies in kHz for all three calibrator types.

	0		2		4		6		8		A		C		E	
CAL3A	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350
CAL3B	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
CAL3D	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900

Tab. 3: Calibrator output frequencies in kHz

III.3.5.2 RIV Adjustment

Before taking measurements with the ICM*compact*, the system set-up should at least once be adjusted. This will correct any instrument drift and the impact of the signal path between the calibrator (CAL3x) and the acquisition unit. For the adjustment, the CAL3x is to be connected to the 'REF' input of the ICM*compact* with the coax cable usually used with measurements. The lead between the specimen and the calibrator has to be disconnected. It should be ensured, that the same frequency is selected at the CAL3x and the ICM*compact*, which is typically 1 MHz. This can be set in the menu SETUP1 / CF or CURSOR / -> CF. Within the menu 'ADJ' the buttons 'ADJ+' and 'ADJ-' allow to set the induced voltage of the CAL3x. Pushing the 'ADJ' button will correct the calculated value. This adjustment is permanently stored until a new adjustment is done or the adjustment is removed at all by the 'RESET' button. However, it is recommended to check the adjustment on a regular basis.

III.3.5.3 NEMA 107-1987 Compliant RIV Calibration

The ICM*compact* is able to automatically measure, calculate, and store the circuit RIV factor (k). This calibration should be done after the instrument is adjusted. However, if this factor is already known from a previous calibration, it can be entered in the 'CAL' menu by 'k+' and 'k-'. This 'CAL' menu is only accessible while in the RIV mode and in the METER display. The actual factor is displayed in the bottom right-hand side of the display ('k= '). It should be between 0.25 and 1 for composite type bushings.
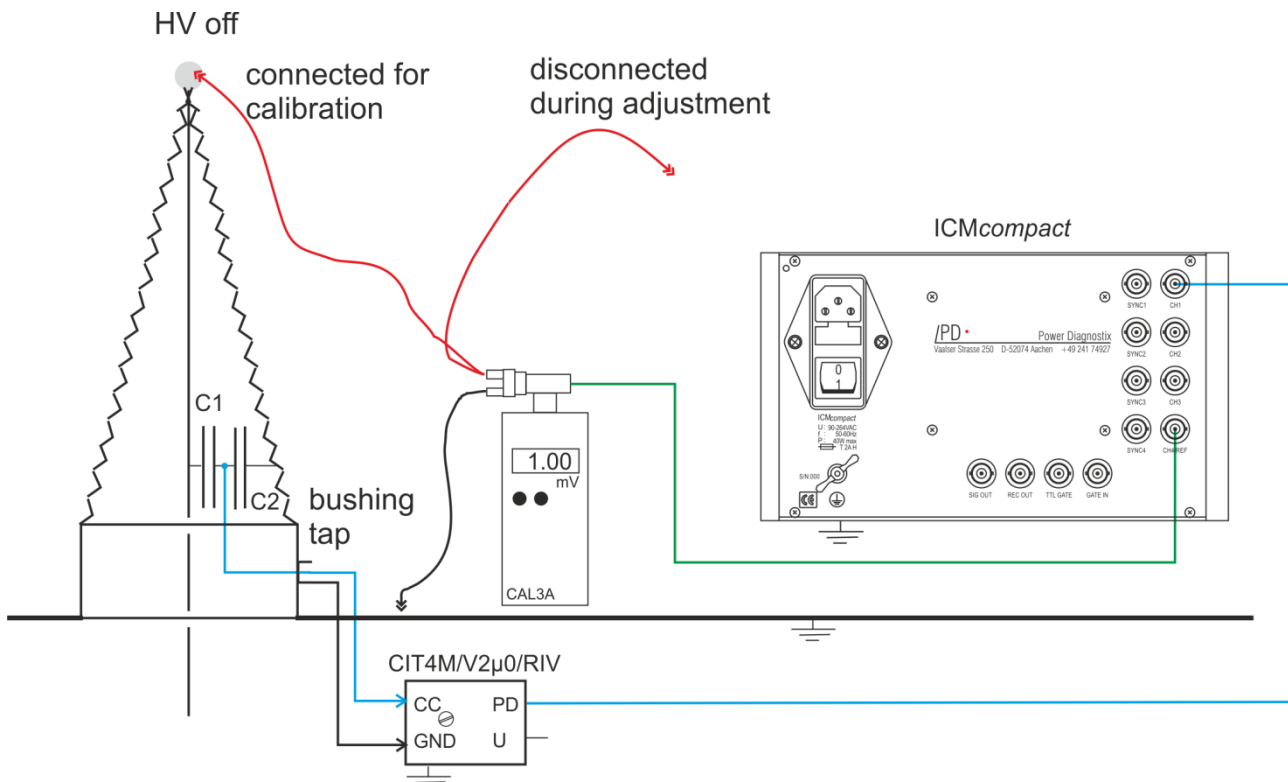
Fig. III.56: Example test set-up on a transformer bushing for the adjustment and calibration according to NEMA 107-1987

For calibration the HV conductor is to be disconnected and the calibrator (CAL3A or CAL3B) should be connected as close as possible to the actual RIV source. Figure III.56 shows an example of a calibration on a transformer bushing. By using a BNC T-connector, the calibrator can also stay connected to the 'REF' input of the ICM*compact* (as it was done during adjustment). Pushing the 'CAL' button within the RIV / CAL menu will start one measurement on the 'REF' input for about one second. Thereafter, one measurement is done on the selected input channel CHx. The calculated correction factor (k) can be seen in the bottom right-hand side of the display.

III.3.5.4 CISPR 18-2 Compliant RIV Calibration

The CISPR 18-2 follows the idea of having a calibrator acting as current source, which causes a voltage drop of the desired calibration voltage across the specified resistor of 300 Ω. This requires that the source resistance of the calibrator is large against the measuring impedance. The standard specifies "at least 20 kΩ". Power Diagnostix' CAL3D comes with an internal source resistance of 30 kΩ. Additionally, this calibration principle requires that the high voltage source is not acting as RF bypass. Hence, a filter has to be inserted into the HV lead between device under test and source. This filter is a parallel resonant circuit. Here as well, an impedance (at resonance) of >20 kΩ is specified.

If using off-shelf measurement receivers, the CISPR 18-2 standard specifies determining both the circuit attenuation and the network attenuation factor in dB. This result is then added to the receiver's reading taken in dBµV. However, the ICM*compact* as a dedicated instrument allows automatic calculation of the combined correction factor and displays the corrected reading after calibration.

With the CISPR selected in the MODE menu, the CAL menu offers choosing the calibration magnitude (CAL+/-) and the calibration CAL, which calculates the overall attenuation and corrects the displayed magnitude. Figure III.57 shows a typical setup.
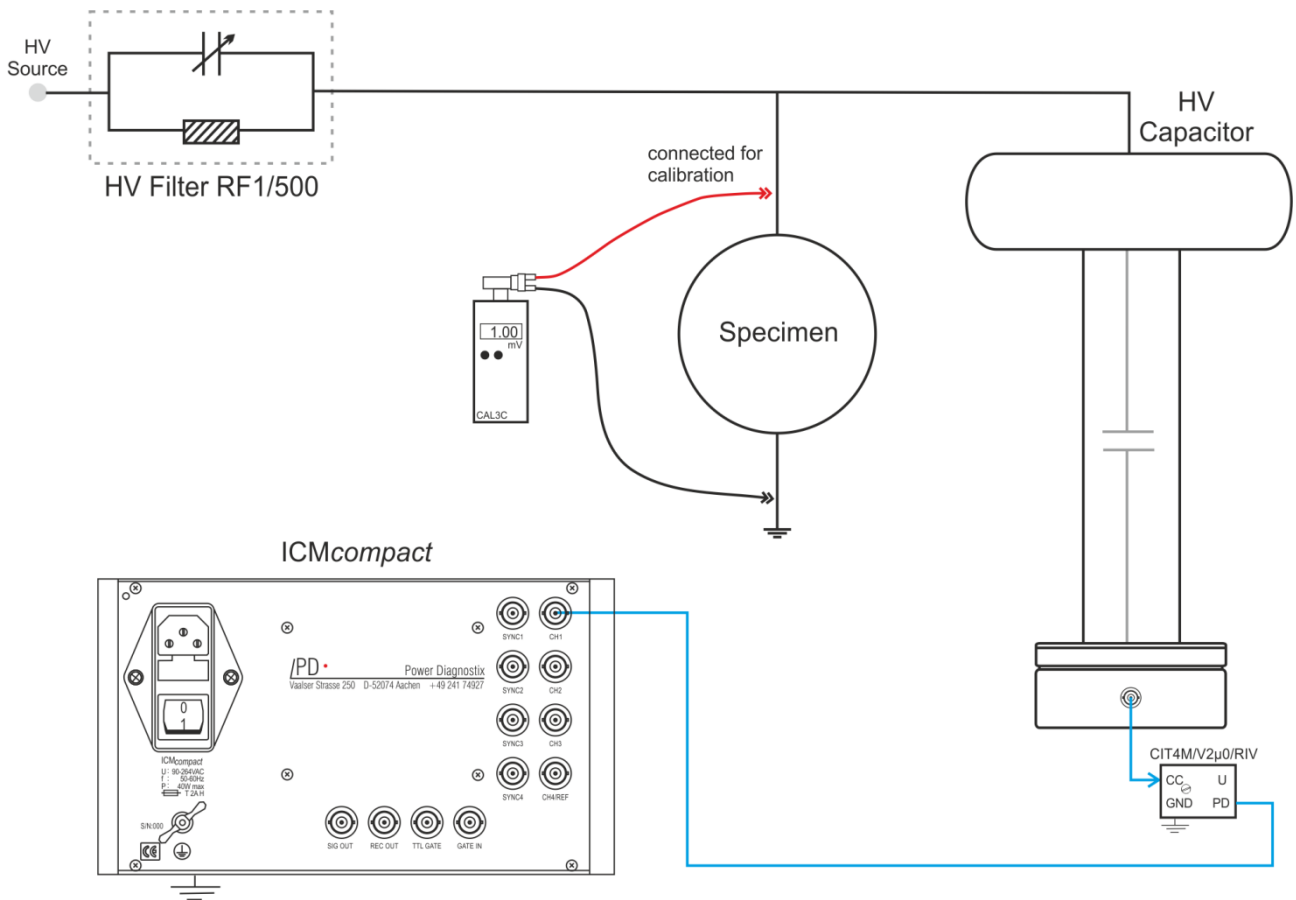
Fig. III.57: Example of a test set-up for calibration according to CISPR 18-2

III.3.6 MUX – Channel Multiplexer

Instruments with a built-in multiplexer (MUX) are able to switch between 4 or 12 different channels. The front panel of an instrument with this option includes five extra buttons labelled '∆ CH ∇', '∆ SYNC ∇' and 'LOCK'. These buttons enable to directly select one of the 4 or 12 signal sources. Hereby, the partial discharge signal (CH) and the voltage signal (SYNC) are split and can be selected separately. The gain setting, calibration factor and divider factor (if HVM is installed) are stored separately for each channel.
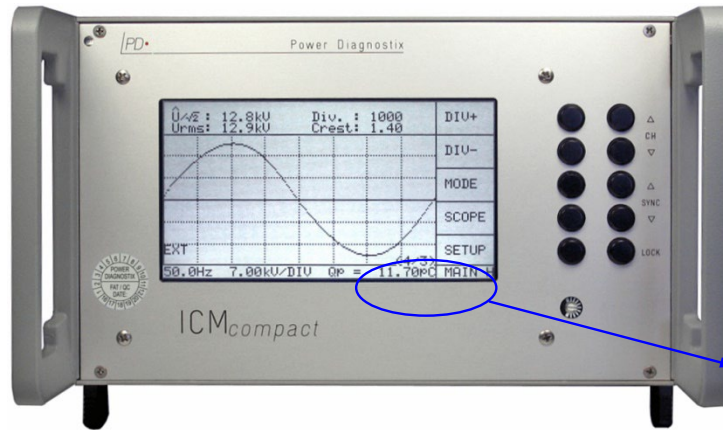
Fig. III.58: ICM*compact* with MUX (multiplexer) and HVM
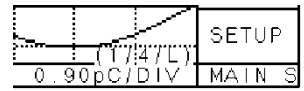
Fig. III.59: Status display

In the lower right-hand corner, the selected channel is displayed. The first number indicates the AMP channel for the PD signal. The next number shows which channel is taken for the SYNC or voltage measurement. To avoid an unintended change of the channels, the five extra buttons can be locked and unlocked by the button 'LOCK'. This is indicated in the display by an 'L'. In the example in figure III.59 channel 1 is selected or the PD signal, channel 4 for voltage measurement and synchronisation. And the right keyboard is locked.

Two multiplexers are available for the ICM*compact*:

1) 4x CH and 4x SYNC

2) 12x CH and 12x SYNC
    (with external remote-controlled box RB2/24)

Fig. III.60: Back panel with MUX4 and RIV input

Fig. III.61: Back panel with MUX12 and TTL gating input

Fig. III.62: RB2/24

III.3.7   AUX – Auxiliary Inputs

Fig. III.63: AUXIN connector
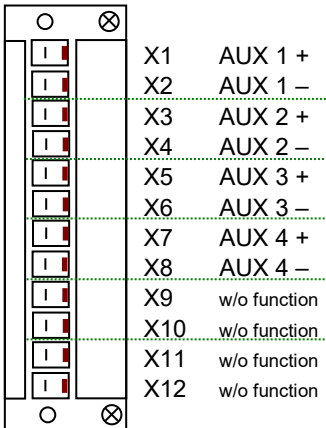
Up to four auxiliary input channels (AUX) can be ordered for the ICM*compact*. These inputs can be used to record extra signals like power, temperature, pressure etc. Commonly used input levels of either 4 to 20 mA or 0 to 10 V_{DC} are available.

Remark: X9 to X12 are for future purposes and without function at the moment.

Caution: The AUX inputs are only to be connected with their designed signal magnitude. Overvoltage (e. g. from the signal for the SYNC input) might harm your instrument.

A USB interface is used to link the ICM*compact* instrument with the software, running on a standard PC. With this ICM*compact* software it is possible to label and scale the AUX inputs. Figure III.64 shows the setup window for a 4-channel system. Within the main frame of the software the processed AUX values are displayed together with the PD pattern and the voltage values (if the HVM

Fig. III.64: Screenshot of the AUX input settings

is installed). Long term records of the PD, voltage and AUX data are easily done and can be exported to standard data file format. However, to access the AUX signal data, the ICM*compact* software is mandatory.

III.3.8   STP – Additional Setups (Optional)

If the ICM*compact* is frequently used at different places, the optional function STP can store up to twelve different setups. Three extra buttons are added to the front panel to swap between the different setups. The top buttons 'Δ SETUP ∇' will change the setup number, whereas the lower button will lock this function. The current setup number is shown in the lower right corner of the display.
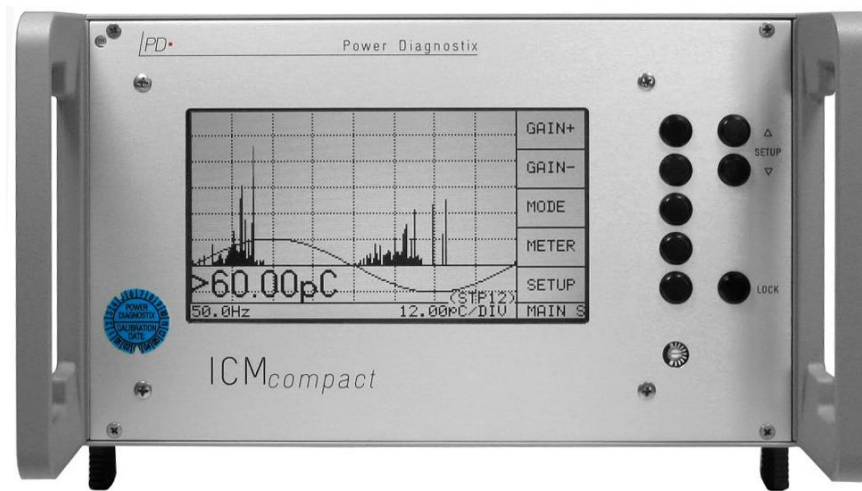
Fig. III.65: ICM*compact* with twelve selectable setups

III.4   Noise Reduction

III.4.1   LLD Noise Ground (Low Level Discriminator)
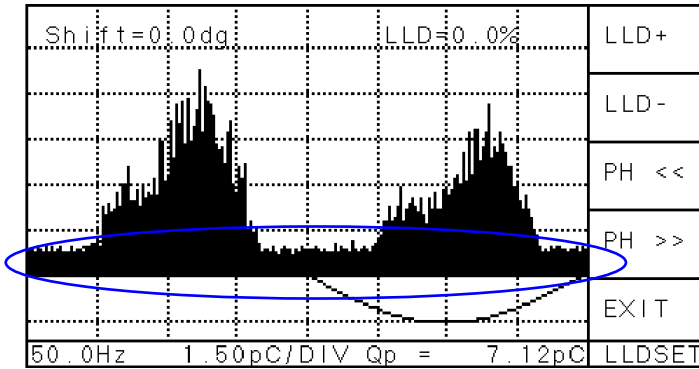
Fig. III.66: PD pattern including noise level (LLD=0%)

Depending on the environment and the test circuit, different levels of background noise are visible (see figure III.66). Since this noise level is usually stable for the whole phase (360°), it can be removed by the LLD function (low level discriminator). All PD pulses falling beneath the LLD threshold are deleted. This will remove the broad black band in the NORM and SINUS mode of the SCOPE display.
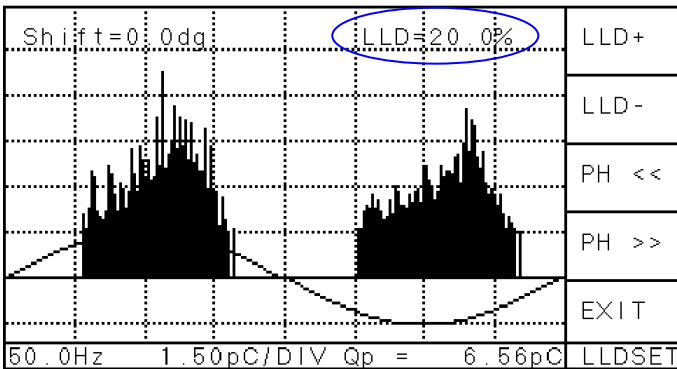
Fig. III.67: PD pattern without noise level

The LLD can be set in the menu SETUP2 \ LLD/P by the buttons LLD+ and LLD-. The standard setting is 10%. The LLD function is not active in the METER display.

III.4.2 Window Mask (Software)
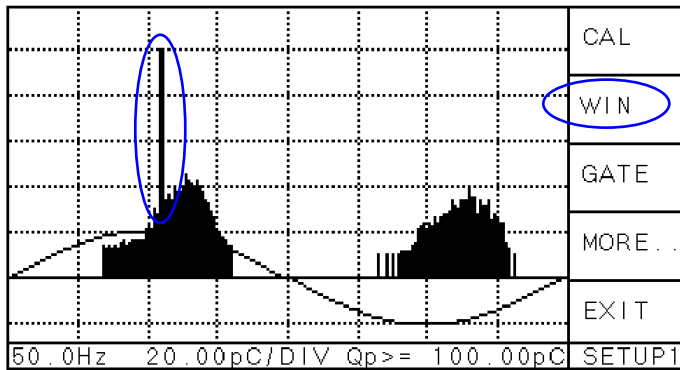
Fig. III.68: PD pattern with one phase stable disturbance

Some disturbances like thyristor firing are phase stable. They can be removed by the software function WIN. This function selects up to three windows which blank out pulses occurring in these windows. Pulses occurring within these windows will neither contribute to the displayed charge peak value of the SCOPE display, nor will they affect the reading of the meter.

Figure III.68 and figure III.69 show the same measurement, whereby in figure III.69 one window is set to blind the respective phase position.

The menu SETUP1 \ WIN offers to set 0 to 3 windows. The number of windows can be changed by 'OFF', '1 WIN', '2 WIN', '3 WIN' and is displayed at the bottom line. The width of each window is identic and can be increased by '<<>>' or decreased by '>><<'. The phase position is changed by 'POS>>'.

Fig. III.69: PD pattern with one window at 93.2°
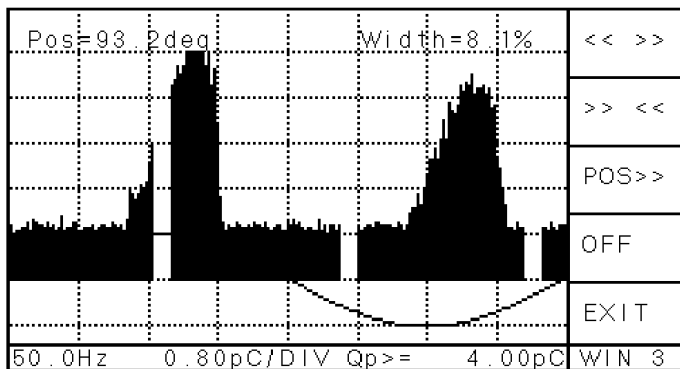
If a second window is selected, the distance to the first will be 180°, for three windows the distances are 120°.

As in the previous menu, the window parameters remain stored after deactivating the window function or when the instrument is switched off.

III.4.3 External Signal Gating (TTL Gating)

If disturbances, like switching of a relay or thyristor firing, have a known source, it might be possible to create a TTL signal prior to the disturbance. This signal can be used to blind out the PD measurement path. ICM*compact*s with this function have a BNC connector on the back panel labelled 'TTL GATE'. If a signal source is connected to this input, the TTL signal is used at any time and can't be disabled. For the time this input is logically high (5 V_{DC}; TTL standard) no signal is taken from the AMP IN terminal, i. e. no PD signal is recorded.

III.4.4 Gating With External Sensor (Analogue Gating, Optional)

An effective noise reduction is required in case the ICM*compact* is used for partial discharge measurements in an environment with high frequency (HF) disturbance. HF disturbances, which hamper partial discharge detection and which can be handled by the gating function, are, for instance, radar signals, corona discharge, or thyristor firing. Using the analogue gating function blinds out such impulse noise. Continuous radio frequency signals from broadcasting, for example, cannot be removed by the gating function. Here, the active bridge adapter AB1 is used.
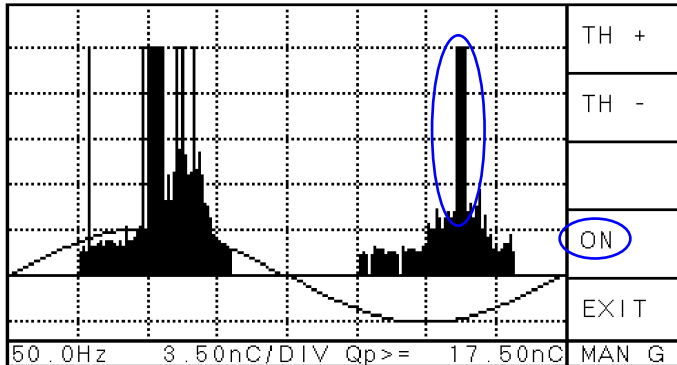
Fig. III.70: PD pattern including disturbances

The analogue gating function is optional and has to be ordered separately. An ICM*compact* with a gating function comes with an onboard preamplifier (RPA6G) and a 'GATE IN' terminal (BNC) on the rear panel. An antenna such as the DA1 or another sensor that picks up the disturbance signal is connected to this 'GATE IN' terminal. With some applications a CT1 (current transformer) is used to acquire the disturbance signal from a ground conductor or from the screen of a signal cable (see figure III.72).

Fig. III.71: PD pattern after manual gating

The gating function is activated in the menu MAN G or AUTO G (see section III.2.2 'Optional Key Menus'). '>ON' indicates activated gating. In case the (disturbance) signal at the 'GATE IN' terminal exceeds a threshold, the processing of the analogue signal is blocked for 10 μs (default) at 50 Hz. Thus, the signals falling in this period does not contribute to the instrument's display and derived quantities.
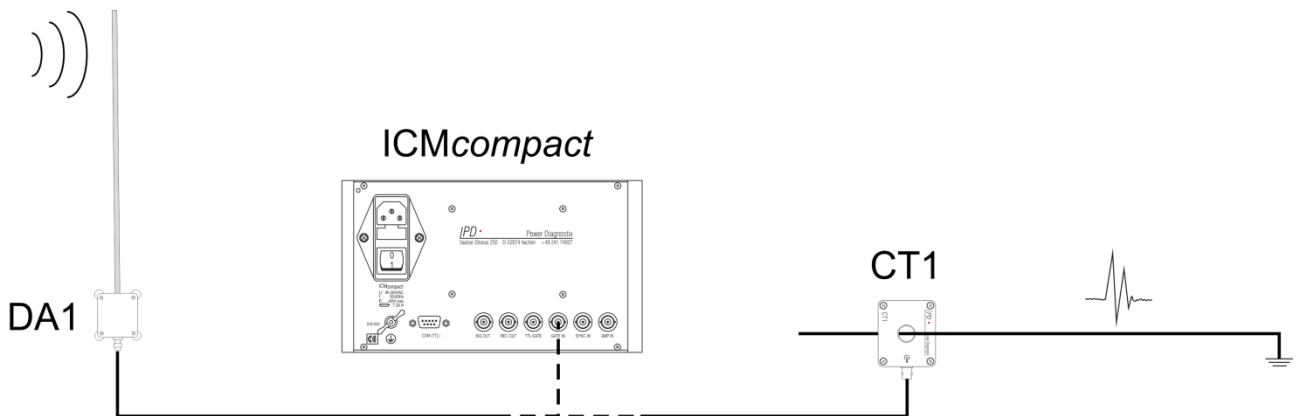
Fig. III.72: Gating connections with DA1 or CT1

Two different modes of setting the trigger can be selected from the menu 'GATE':

MAN G - The manual mode offers to set the trigger from 1 to 100 % of the peak disturbance level. This threshold is displayed in the upper right corner of the display (MAN G) once this mode is active. To change the trigger level, press 'TH+' and 'TH-'. This option is used to remove a known disturbance source in a stable environment.

AUTO G - The automatic mode calculates a gating time as a fixed portion of the measured time. E. g. setting the gating time to 10% results in a total blind-out time of 2 ms for 20 ms @ 50 Hz. The trigger level will be set accordingly to this time. The total gating time, when activated, is displayed in the upper right corner of the menu 'AUTO G'. Pushing 'GT+' and 'GT-' allows changing the gating from 1% to 50%. This option is used when the noise situation is likely to change over time.

The onboard preamplifier (RPA6G) has a logarithmic amplification and is suitable for frequencies of 100 kHz to 10 MHz (1 kΩ input impedance).

An ICM*compact* equipped with the gating function offers the following additional menus. They can be accessed only in the 'SCOPE' display 'SETUP1/ GATE' menu:

MAN
AUTO
GT SET
EXIT
GATE

MAN

Pushing this button changes to the submenu for manual gating MAN G.

AUTO

Pushing this button changes to the submenu for automatic gating AUTO G.

GTSET

Pushing this button changes to the sub-menu GT SET, where the frequency bands of the preamplifier (RPA6G) can be set.

EXIT

Pushing this button changes one level up to the menu SETUP1.

TH+
TH-
GT IN
>ON
EXIT
MAN G

TH+/TH-

Pushing these buttons increments or decrements the gating threshold level. This value is displayed at the upper right side of the screen in percent. If the gating analogue signal exceeds this level, then the measurement PD signal is blocked for 100 μs at 50 Hz. The gating time per noise event Tg depends on the synchronisation frequency and is calculated by

(where f$_{sync}$ is the sync frequency displayed in the left bottom corner of the display):

$$T_g = \frac{1}{f_{sync} \cdot 197}$$

GT IN (>GT IN)

If this item is activated (>GT IN), the instrument's display shows the gating signal instead of the PD signal. This function is automatically deactivated, when leaving the MAN G menu.

ON (>ON)

This button turns the gating function on (>ON) or off (ON). The gating function remains off if no preamplifier is connected to the gating input. Usually, the preamplifier is built in.

EXIT

Pushing this button changes one level up to the menu GATE.

GT+
GT-
GT IN
>ON
EXIT
AUTO G

GT+/GT-

Pushing these buttons increments or decrements the total gating time. This value is displayed at the upper right side of the screen in percent. The instrument automatically adjusts the threshold level. If the gating signal exceeds this automatically set level, then the PD signal (AMP IN) is blocked for maximum 100 µs at 50 Hz.

GT IN (>GT IN)

If this item is activated (>GT IN), the instrument's display shows the gating signal instead of the PD signal. This function is automatically deactivated, when leaving the AUTO G menu.

Fehler! Textmarke nicht definiert.Fehler! Textmarke nicht definiert.ON (>ON)

This button turns the gating function on (>ON) or off (ON). The gating function remains off if no preamplifier is connected to the gating input. Usually, the preamplifier is built in.

EXIT

Pushing this button changes one level up to the menu GATE.

GL+
GL-
GT OUT
EXIT
GTSET

GL+/GL-

Pushing this button increments or decrements the period, during which the measured signal is blocked, if the threshold level is exceeded. Values from 5 to 255 µs are available by steps of 1 µs. The default value is 10 µs.

GT OUT (>GT OUT)

This button activates (>GT OUT) or deactivates (GT OUT) the TTL gating signal at the SIG OUT output. It should be deactivated if not needed.

EXIT

Pushing this button changes one level up to the menu GATE.

For devices manufactured before 2016, please see also section VIII.1.

III.5   Calibration

PD measurements refer to the apparent charge and are relative measurements. Therefore, each new installation, changes of relevant quantity (e. g. bandwidth, coupling capacitance etc.) requires a new calibration. This is done by injecting a known PD pulse close to the origin of the real PD source (test object) and from this calculating the scale factor for the measurement. The injected PD pulse should be in the range of 50 % to 200 % of the expected PD magnitude.

III.5.1   Calibration Impulse Generator

There is a broad range of impulse generators offered by Power Diagnostix for different purposes. Table 2 gives an overview of these calibrators. All calibrators allow the calibration of PD measurements according to IEC 60270:2000, except the CAL2B/C/D, since the CAL2B/C/D have left out the injection capacitor to enable calibration on GIS (gas insulated switchgear).

Calibrator	Range	Output	Frequency
CAL1A	1, 2, 5, 10, 20, 50, 100 pC	Injection capacitor <1 pF	50 Hz (60 Hz)
CAL1B	100, 200, 500 pC, 1, 2, 5, 10 nC	Injection capacitor <100 pF	50 Hz (60 Hz)
CAL1C	1, 2, 5, 10, 20, 50, 100 pC	Voltage output (50 Ω)	50 Hz (60 Hz)
CAL1D	10, 20, 50, 100, 200, 500, 1000 pC	Injection capacitor <10 pF	50 Hz (60 Hz)
CAL1E	0.5, 1, 5, 10, 20, 50 nC	Injection capacitor <500 pF	50 Hz (60 Hz)
CAL1F	0.2, 0.5, 1, 2, 5, 10, 20 nC	Injection capacitor <200 pF	50 Hz (60 Hz)
CAL1G	0.02, 0.05, 0.1, 0.2, 0.5, 1, 2 nC	Injection capacitor <20 pF	50 Hz (60 Hz)
CAL1H(/V+S)	0.5, 1, 2, 5, 10, 20, 50 pC	Live injection via stray capacitance*	50 Hz (60 Hz)
CAL1J	10, 20, 50, 100, 200, 500, 1000 pC 100, 200, 500, 1000, 2000, 5000, 10000 pC	100 pF 1 nF (external, switchable)	50 Hz (60 Hz)
CAL2B(/500)	2, 5, 10, 20,30, 40, 50 V (into R_L=50 Ω)	Voltage output (50 Ω)	50 Hz (60 Hz)
CAL2C(/500)	1, 2, 5, 7, 10, 12, 15, 17, 20 V (into R_L=50 Ω)	Voltage output (50 Ω)	50 Hz (60 Hz)
CAL2D(/500)	5, 7.5, 10, 15, 20, 30, 40 V (into R_L=50 Ω)	Voltage output (50 Ω)	50 Hz (60 Hz)

* pF value to be specified by the customer

Tab. 2: Output and frequency ranges of PD calibrators
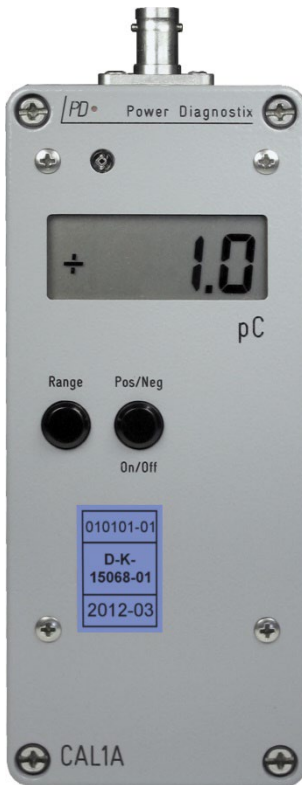
All calibrators are switched on with the pushbutton On/Off. Both amplitude (Range) and polarity (Pos/Neg) of the single charge pulse per cycle are displayed and can be adjusted by pushing the two buttons. The instrument is synchronised to line frequency by a photo diode. In case of insufficient pick-up of power frequency light, it will automatically select the internal quartz oscillator (50 Hz and 60 Hz versions available). The button On/Off must be pressed for more than one second to switch the pulse generator off, while automatic switch-off occurs after approximately 15 min.

Operation time of up to 200 hours are obtainable with the 9 V lithium battery due to an average supply current of approx. 5 mA (quiescent current is negligible). An alkaline battery resulting in approx. 90 hours of continuous operation may replace the lithium battery. A weak battery is indicated by the LO BAT sign of the LC display.

Warning: While changing battery, be aware of internal parts carrying up to 125 V of DC potential!

Power Diagnostix delivers its standard calibrators with a fully traceable calibration. This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI). The DAkkS (**D**eutsche **Akk**reditierung**s**stelle) is signatory to the multilateral agreement of the European co-operation for Accreditation (EA) for the mutual recognition of calibration certificates.

Fig. III.73: Calibrator

III.5.2   Calibration Test Set-up

The entire signal path from the discharging source to the instrument, as well as some instrument properties as filters, for instance, are introducing an overall attenuation which is not precisely known. Thus, the calibrator (CAL1A or equivalent) has to be connected to the actual PD source as close as possible. Figure III.74 shows an example of a calibration circuit diagram.
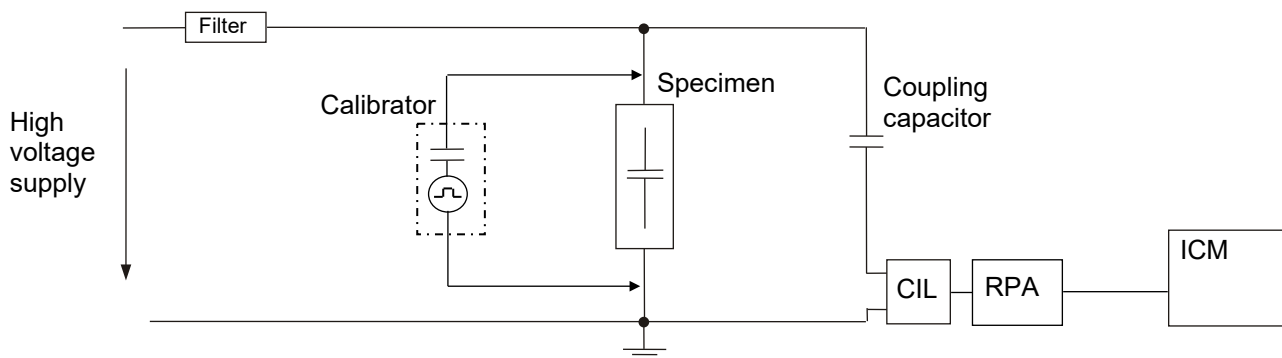
Fig. III.74: Example of calibration set-up

To calibrate a test setup where a current transformer (as CT1 or CT100) is used, place the positive clip of the calibrator on the high voltage side of the test object, and the negative clip of the calibrator on the low voltage side of the test object. This will ensure that the calibration pulse will take the same signal path as the actual PD pulse.

III.5.3   Calibration Menu

The ICM*compact* offers a calibration menu (CAL) which can be found as first item in the menu SETUP1. To have the complete information for doing the calibration, it is best to be in the SCOPE display. However, the menu CAL is not available, when the optional displays HVM or DSP are visible. Figure III.75 shows the calibration menu in the SCOPE mode.

Fig. III.75: Scope display during calibration
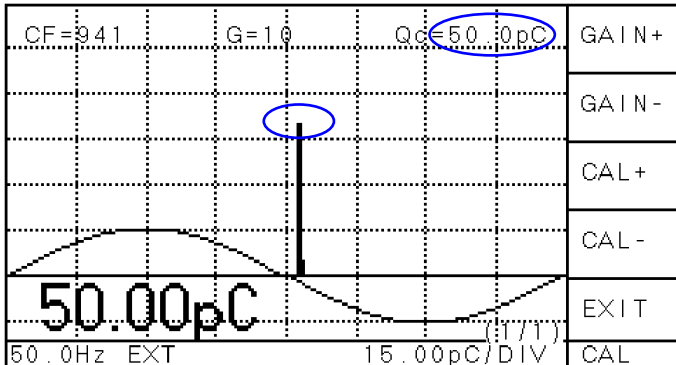
Once the calibration pulse is displayed on the screen, GAIN+ and GAIN- should be used to place the calibration signal reading between 50% and 90% of full scale (i. e. four divisions, since maximum is at five divisions). The CAL+ and CAL- buttons then adjusts the calibration value (shown in the upper part of the display). This value has to be set equal to the one on calibration impulse generator. The calibration factor (CF) is calculated accordingly. There is no possibility to make it undone!

Calibration factor and all other parameters remain stored when the system is switched off and are automatically recalled when the system is switched on again. Be sure, that the calibration is only changed in case of test setup modifications to keep the integrity of the monitoring results.

Fig. III.76: Setting the calibration factor
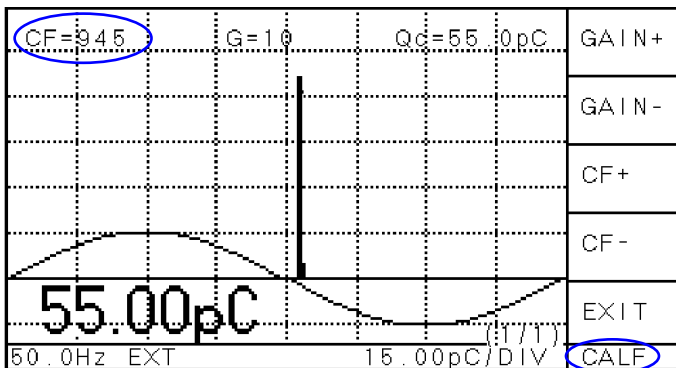
If the calibration factor is known from previous calibrations or from an identical test setup, it is also possible to directly enter this value in the menu 'CALF'. For this change, it is not necessary to adjust the gain since there is no processing of the measurement value. The calibration factor (CF) is displayed in the top left corner and relates to a virtual gain of 1.

The software ICM*compact* as well as HV*pilot* offer to save the whole instrument settings (as *.cmp rep. *.hvp) and thus enable to repeat a test with the same settings and calibration. For using a stored calibration, it has to be ensured, that the test circuit is the same. For saving and loading the instrument settings, see the respective software manual.

Caution: For calibration the system has to be de-energized.

IV   Software for the ICM*compact*

There are two software packages available to communicate with the ICM*compact* via serial link (USB or COM TTL).

- **ICM*compact***:   Standard software to record and save PD measurement data.
  Optional version for the cable fault location, only to use with the DSO extension.

- **HV*pilot***:   Used to take measurements over long periods. Useful only in combination with the STEP*compact*.

Software has to be ordered separately and is delivered on a CD ROM. Software updates can be download-ed from Power Diagnostix' web site (www.pdix.com) using a valid login and password. After downloading the requested software and extracting the files, the program 'setup.exe' will start the installation.

IV.1   Standard Software ICM*compac*t

The standard software is also called ICM*compact* and shows an image of the LCD (display) from the in-strument. The acquired data, like PD, voltage (if the optional HVM installed) and AUX (if installed) are con-stantly refreshed. The five menu buttons can be used like on the real instrument which allows a remote control even over longer distance. For this, the serial link can be extended by a fibre optic or a LAN inter-face.

Please install the ICM*compact* software <u>before</u> connecting the instrument to the PC!

Remark: If the application window appears very small when started on a PC with Windows 10, please refer to section VI.1 "FAQ" on page 89.
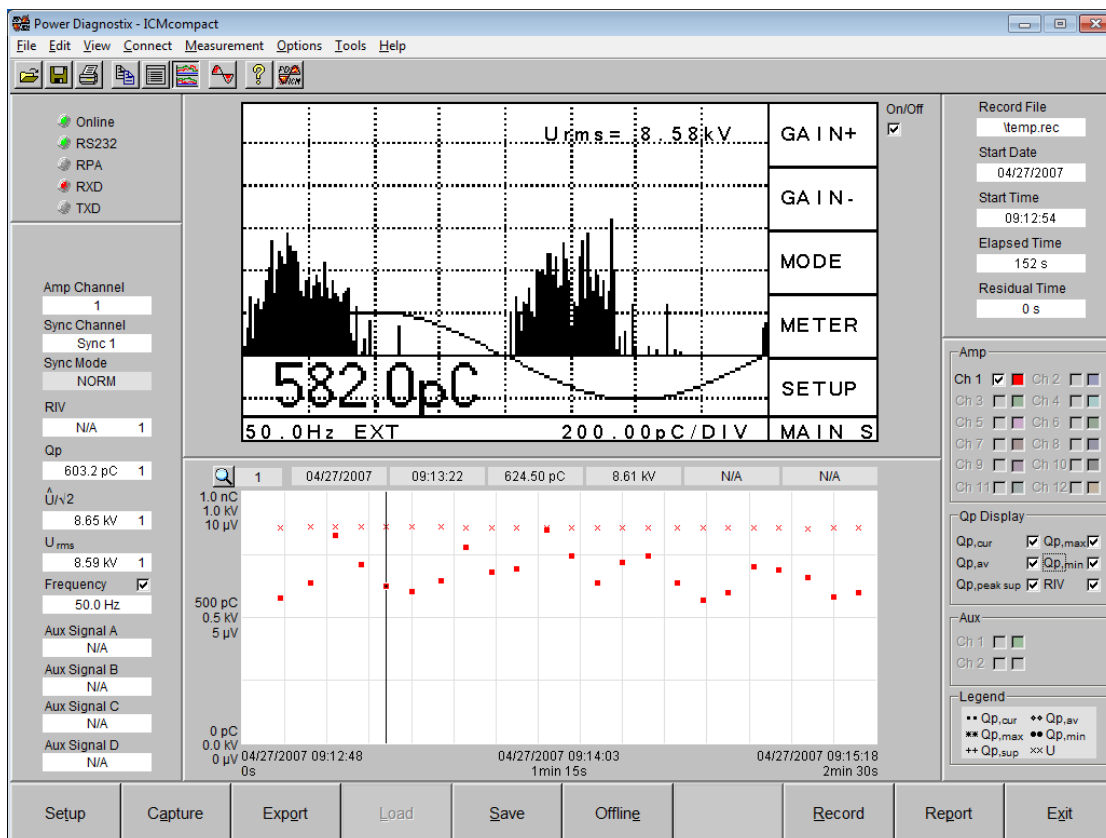
Fig. IV.1: Main control panel of the standard software ICM*compact*

The ICM*compact* software can be used online and offline. 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 PD pattern and measurement values. These acquired data can be stored and exported in different ways, so that a repetition or later analysis of the measurement is feasible. The export functions allow an easy way to create reports with all necessary information like data, pattern, and graphs.

IV.1.1 Pattern Acquisition

The pattern acquisition panel shows the pulse-amplitude-phase-height-distribution, whereas every single gray dot stands for an acquired pulse at this specific phase position (x-axis) with respect to the synchronisation source used and this specific amplitude position (y-axis). In case more than one pulse occurs at the same coordinates, the dot changes its colour to visualize the frequency of occurrence. Figure IV.2 shows an example of such a partial discharge pattern with the acquired shape of the high voltage super-imposed.

The display block at the left-hand side of the pattern contains mainly status information regarding the current file or measurement and the communication channel used. The status of the communication interface used is shown with the five 'LED'-like indicators. The first indicates an active connection (Online). In case of such an active connection, the upper red LED indicates ongoing transmission of data (commands and setup strings) to the instrument (RXD), while the lower red LED refers to a transmission of data (measurements) from the instrument (TXD). The RS232 indicator shows that an ICM*compact* is connected to the software via USB or RS232, while the third indicator shows if a preamplifier unit is connected. The lower part of this display block shows up to five text displays.
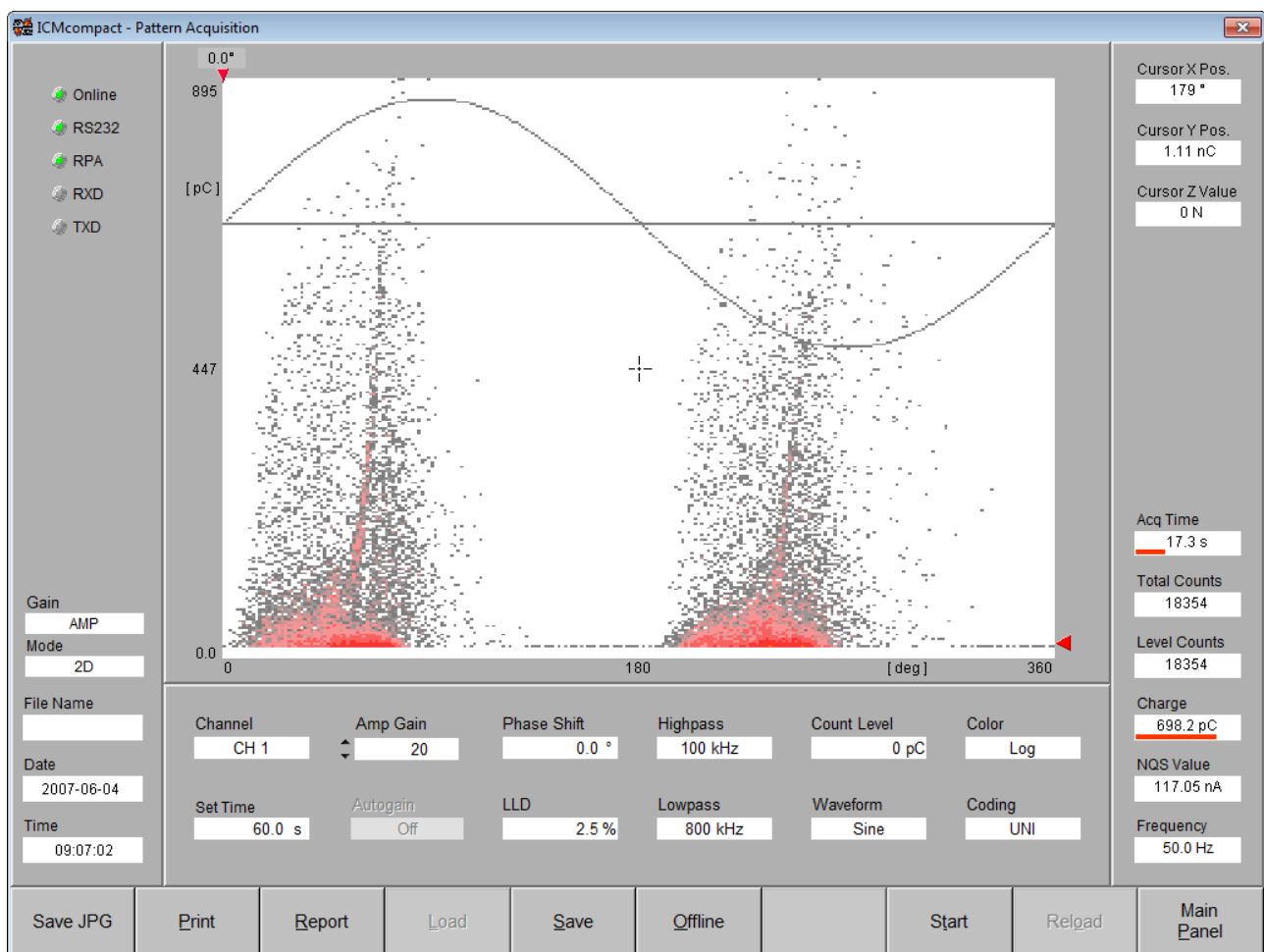
Fig. IV.2: Pattern acquisition panel

If the ICM*compact* is equipped with a spectrum analysis board, it's possible to choose between the normal AMP path and SPEC path for pattern acquisition. While a pattern acquisition using the AMP path is limited

to fixed cut-off frequencies, pattern acquisition using the spectrum path offers selection of a centre frequency up to 10 MHz with a bandwidth of 9 kHz or 300 kHz. 'Mode' shows if the pattern is presented as 2D or 3D view. The next text item shows the file name of the current data set. The date and time shown with the two remaining displays are referring to the moment when the acquisition of the current data set was started.

The right-hand block bears nine items. The first three fields display the current cursor position. The fourth item shows the acquisition time. It is a combined indicator, where the red bar graph shows the relation between pre-set acquisition time and the amount of time passed already. The following two entries are to display the number of counts of the current acquisition. 'Level Counts' displays the counts raising the level set. The seventh item indicates the current peak charge measured. Again, the bar graph reads the utilization. The NQS value is a derived quantity. It is the average discharge current, calculated by dividing the sum of the charge of all discharge pulses acquired by the acquisition time. The last item of this block is the frequency field that shows the automatically calculated frequency of the sync source (6 Hz to 505 Hz).

The ICM*compact* software offers a variety of setup parameters to be modified in order to cope with different measurement environments. A subpanel underneath the main display area controls the ICM*compact*'s setup. Upon start-up the setup displayed will reflect the setup that was active when the software was shut down the previous time. With every file reloaded the complete setup of that file is displayed and, in case of an instrument connected, sent to the acquisition unit as well. This makes sure, that the instrument is reset completely to the state it had, when the reloaded measurement was taken. On the other hand, take care to save your current setup to file before over-writing it by reloading a file. The subpanel contains the following entries:

Channel	Current measurement channel
Set Time	Entry to pre-set the acquisition time. Shortest time possible is 0.1 s. An acquisition may be stopped earlier by means of the 'Stop' button.
Amp Gain	For setting, increasing, and decreasing gain, i. e. the amplification factor, respectively. If the acquisition mode is set to AMP or SPEC (only available with instruments that were manufactured 2015 or later), this entry is labelled 'AMP Gain' or 'SPEC Gain' respectively.
Autogain	The automatic gain adjustment can help to find the best gain setting for the PD measurement path. If the PD signal rises 95% of the y-axis, the software automatically decreases the level, if the level drops down below 10%, the gain level will be incremented.
	If the PD level is bouncing strongly it may be sensible to disable the automatic mode.
Phase Shift	In case the sync source used is not of the same phase as the high voltage causing the current discharge pattern, this entry serves to adjust the phase position by filling in a phase shift. Depending on the 'Waveform' setting, the discharge pattern and/or the superimposed sine wave is being shifted. Double clicking onto this field offers the choice of 0°, 60°, 120°, 180°, 240°, and 300° as value for phase shifting.
LLD	Entry to set the low level discriminator. The LLD acts symmetrically on positive or negative pulses. A minimum level of 2% should be set to eliminate small noise pulses. The level refers to the 100% full scale of the y-axis of the pattern graphs.
Highpass	Setting for the lower cut-off frequency of the PD bandpass filter.
Lowpass	Setting for the upper cut-off frequency of the PD bandpass filter.
Count Level	With some applications it is wanted to know the number of pulses exceeding a certain level. This entry serves to enter such level. Further, this entry reads the level adjusted by means of the blue slider arrow at the right-hand edge of the main display. The level counts and the total counts are displayed in the right-hand display block.
Waveform	The shape of the acquired sine wave of the high voltage and a base line can be displayed along with the partial discharge pattern not only to validate the phase relation between pattern and high voltage, but also to evaluate the influence of saturation effects or harmonics of the voltage on the pattern.

Color   The z-axis (i. e. the distribution of the colour) may be coded linear ('Norm') or logarithmic ('Log').

Coding   This entry is only available with newer instruments. PD pulses can be separated by its polarity. Bipolar ('BI') shows positive and negative pulses separated, whereas Unipolar ('UNI') does not consider the polarity.

There's a row of function key labels at the lower end of the display as shortcuts for the main functions of the software.

Copy	Print	Report	Load	Save	Search		Start	Reload	Main Panel

Fig. IV.3: Function keys of the panel for pattern acquisition

IV.1.2 Data Record Mode
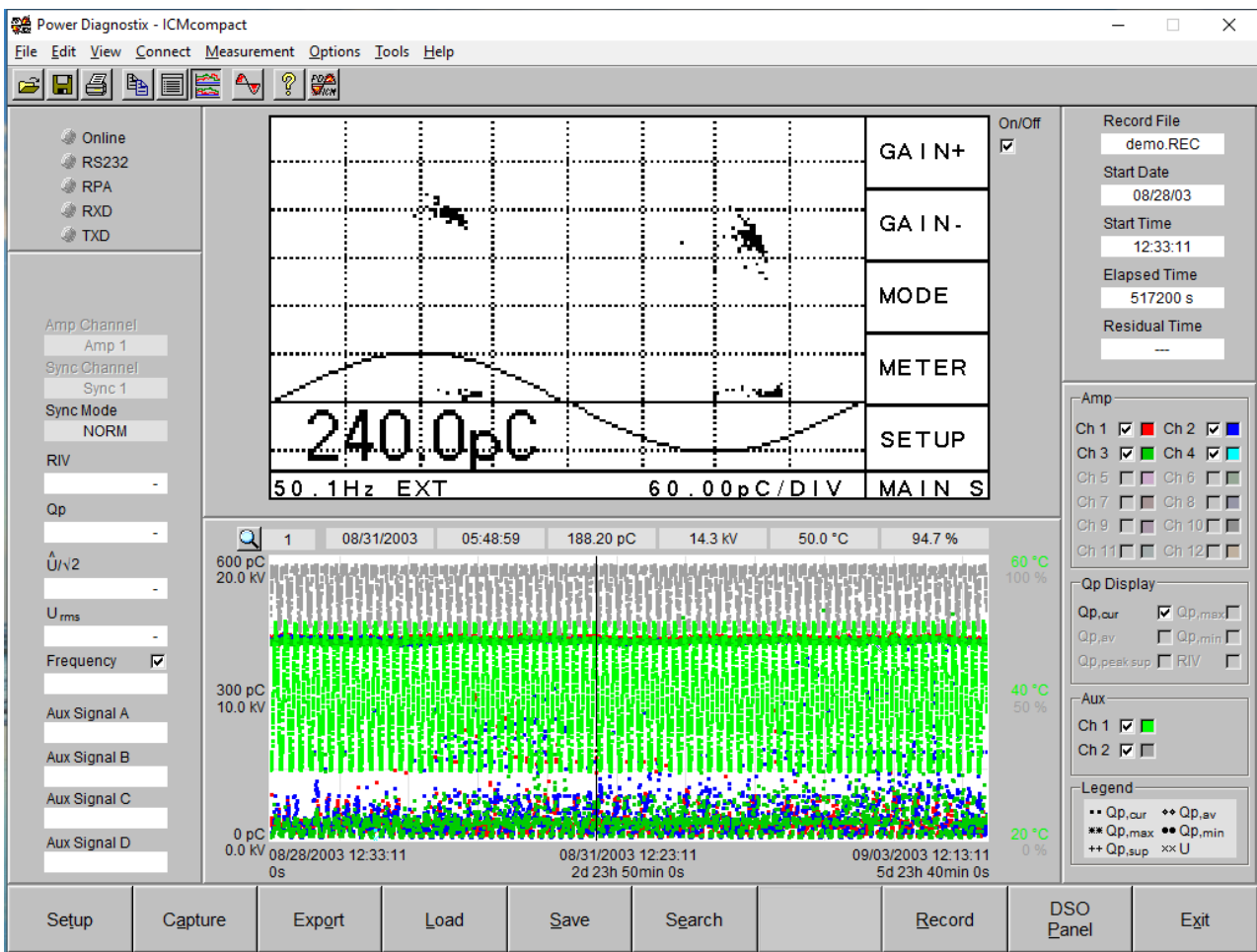
Fig. IV.4: Main panel with record view enabled

The data record mode of the ICM*compact* allows to log the Qp, voltage and optional auxiliary values over time. The data is stored in a proprietary file format (.rec file) and can be exported to an Excel, HTML or text file (menu: File – Save Record). The values are displayed on the strip chart in the lower part of the main panel if the *Record View* mode is enabled (menu: View – Record Panel). The row above the graph shows the values at the cursor position. The values, shown here; are: Multiplexer channel, date, time, Qp value, voltage value, auxiliary signal 1, auxiliary signal 2. The chart graph can be copied to the clipboard and then pasted to any application that supports the import of bitmap files.

The record mode can be configured by the *Data Record Settings*. Select the *Edit / Data Record Settings* menu item to open the following window.
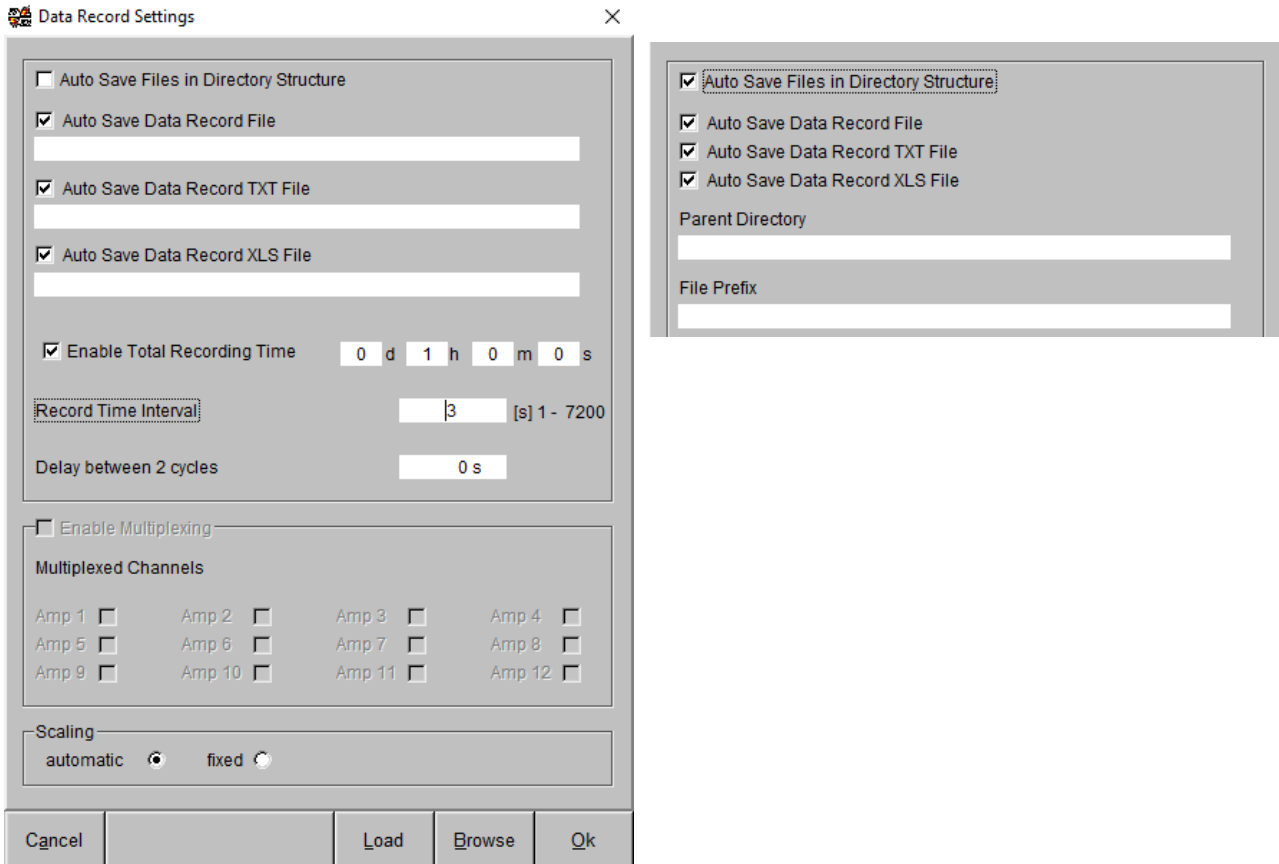
Fig. IV.5: Data record settings

By selecting the *Auto Save Data Record File*, *Auto Save Data Record TXT File,* or *Auto Save Data Record XLS File*, the recorded values are stored in the selected file formats. The names of the files can be set by left clicking on the corresponding fields below the check marks und entering a name. These filenames should be set for each new record, otherwise the files will be overwritten after a warning. By selecting the *Auto Save Files in Directory Structure* option, the selected files will be stored in a certain directory structure with an added increasing number. The directory structure is built as follows:

ParentDirectory\Year_Month_Day\FilePrefixXXXX
(with XXXX increasing number)

To set a time after which the record stops automatically, the *Enable Total Recording Time* option must be selected, and the time must be set. Otherwise, the record must be stopped manually. The *Record Time Interval* sets the time between two stored data sets. With *Delay between 2 cycles* an additional delay between two stored data sets can be set. This option is mostly used in combination with the Multiplexer option, to add a delay after changing the multiplexer channel. The *Enable Multiplexer* option is only active if an ICM*compact* with a multiplexer is connected. Then the channels for the recording can be selected. After a data set is stored, the software will switch to the next selected channel.

The recording can be started by pressing the *Record* button or selecting the *Measurement – Start / Stop Data Record* menu item. One data set contains the following values: Date/time, measurement channel, synchronisation channel, current charge value, mean charge value, median charge value, maximum charge value, minimum charge value, accumulated charge value, RMS voltage value, square root of voltage value, frequency value, auxiliary value 1, auxiliary value 2, and RIV value. During the *Record Time Interval* several values are recorded, but only the latest values will be stored, except for the charge values. The charge values are calculated over the set *Record Time Interval*, and the current charge value is the latest value in the interval.

On the right-hand side of the main panel, the values, which should be displayed in the chart graph, can be selected. Only those values can be selected that are available with the instrument. If no multiplexer is available, only the values of one channel can be displayed, and the *Amp* area will be dimmed. The same applies if no auxiliary signals are available: The corresponding area will be dimmed.

IV.2   Extended Software with Cable Fault Location

The optional software extension for cable fault location is specialized for high or medium voltage cable di-
agnostic. This requires an ICM*compact* instrument with the optional acquisition board 'DSO'. For the gen-
eral functionality of this board and a detailed description of this software extension, see also section III.3.4
'DSO – Digital Storage Oscilloscope for TDR Measurements'. Older instruments can be upgraded with the
DSO board, please contact Power Diagnostix for details.
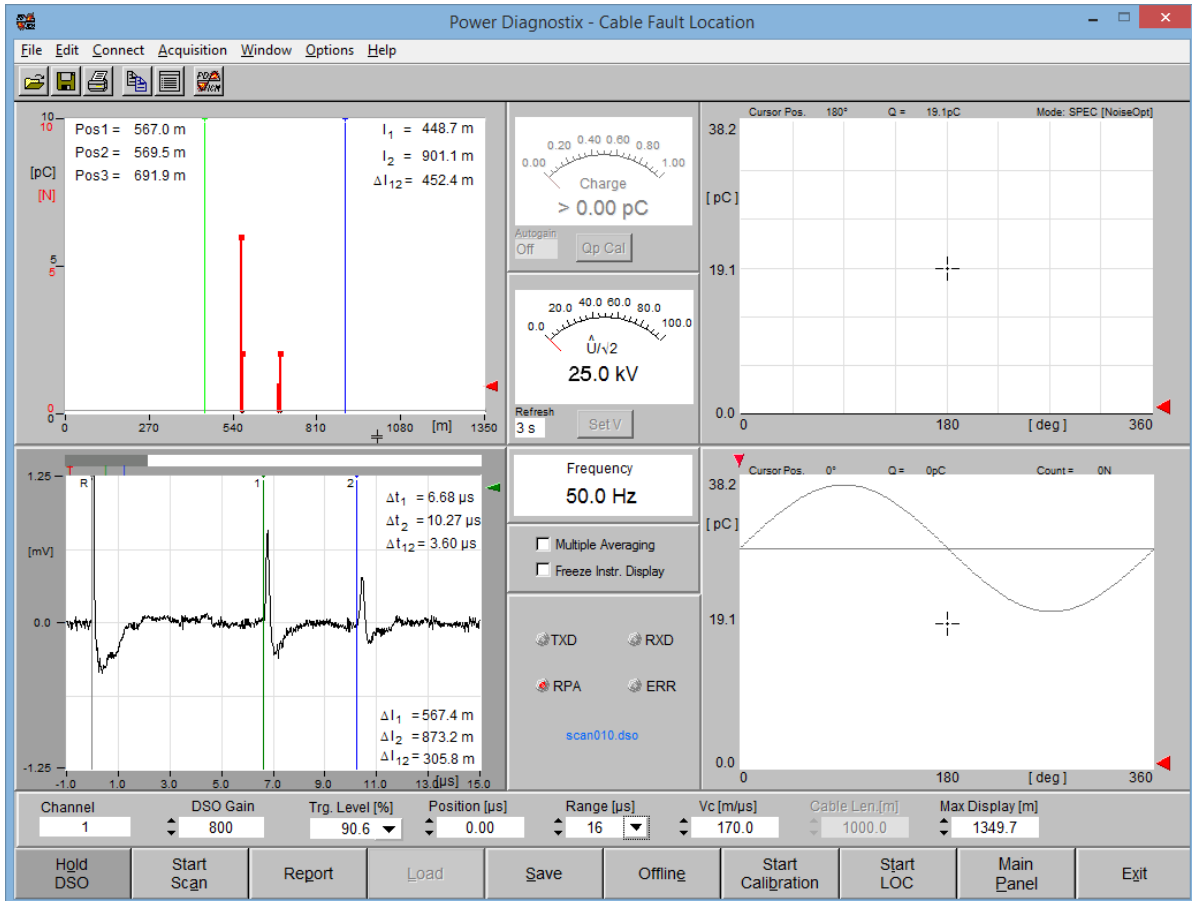
Fig. IV.6: Main panel of ICM*compact* with the LOC graph (upper left) and the DSO graph (lower left)

The main panel shows at the left-hand side two graphs (LOC and DSO) as can be seen in figure IV.6.

The DSO graph (digital storage oscilloscope) displays the actual PD waveform including its reflection at the
cable terminations. This is in principle the same graph as shown on the display of the instrument just with a
higher resolution. The software offers three coloured cursors to evaluate the PD pulse. Since the time dif-
ference of the reflections refers to the fault position, the calculated values in time and meter/feet are listed at
the right-hand side of the graph.

Usually, multiple PD pulses are recorded and evaluated. This ensures to capture further PD sources and to
state more precisely the position of single defects. The graph on the upper left-hand site collects the results
from the distance evaluation of the DSO graph. This localization graph (LOC graph) is usually created of-
fline by a manual or automatic mode. It requires for the calculation either the total cable length or the pulse
velocity. The number and charge of all captured PD pulses is then displayed as a function of the cable
length. Finally, the fault positions can be measured by two cursors (blue and green) directly.

IV.3   Specialized Software HV*pilot* (Optional)

The HV*pilot* software is designed to control the voltage for a test set up and to take measurements of voltage (high voltage site), partial discharge (PD), tanδ (dissipation factor) , C$_x$ (ideal capacitance of the test object).

For this task, three further instruments beside a PC are necessary:

- The STEP*compact* to control the variac of a high voltage transformer, observing the voltage for a possible break down, and supply the HV*pilot* with the actual voltage value

- The ICM*compact* to take PD measurements of the test object

- The TDA*compact* (optional) to measure the tanδ and capacitance of the test object

The STEP*compact* together with the HV*pilot* software are developed to automate high voltage test sequences. The three instruments are connected to a PC via serial link (RS-232) and exchange data with the HV*pilot* software. This software also provides the possibility to program a test sequence, analyse the measured data and generate a report automatically. Several different test sequences can be created to customize the program for special measurement tasks. The report files are created as doc or *.html and can also easily be customized.
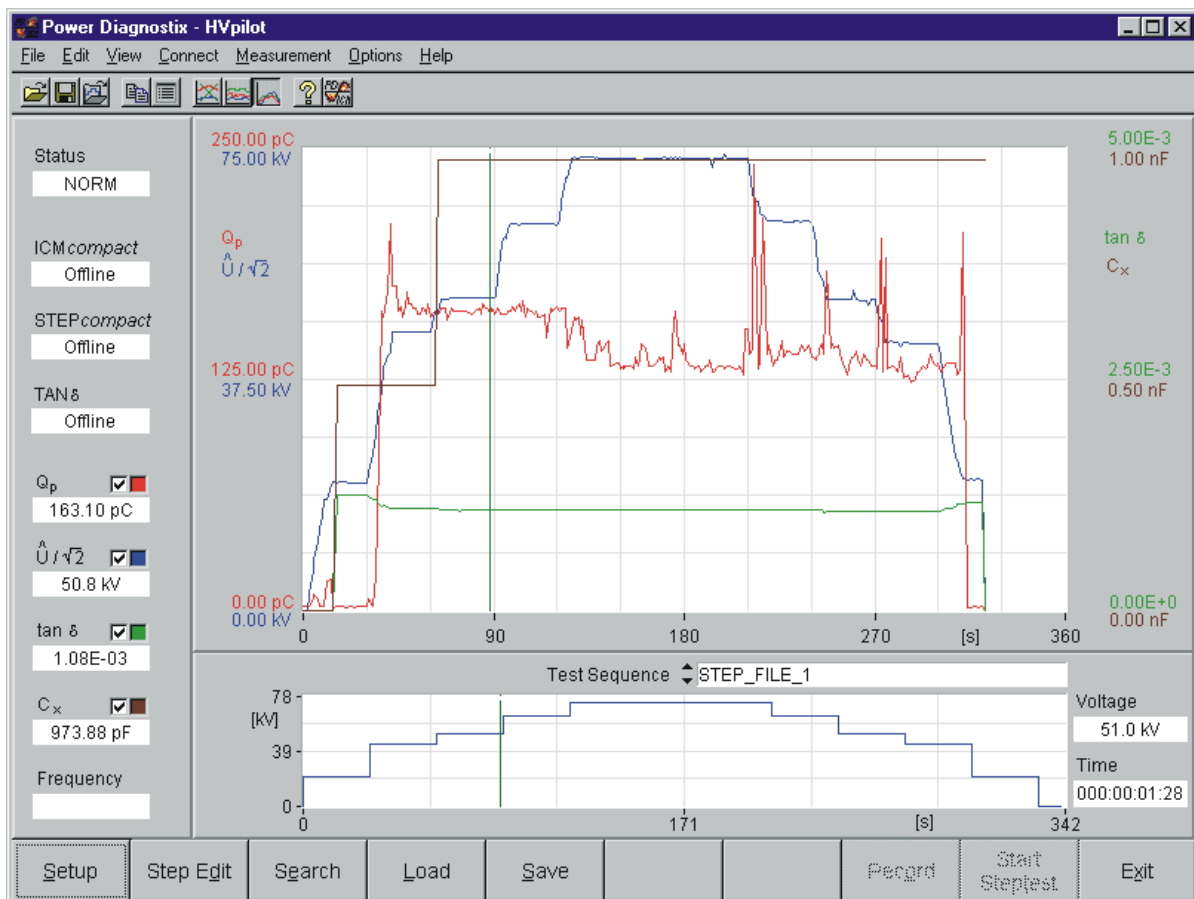
Fig. IV.7: Main panel of the HV*pilot* software for the automation of high voltage tests

The main panel of the HV*pilot* software displays the four measurement values (Û/√2, PD, tanδ, C$_x$) continuously on a time axis. Beneath this, the programmed test voltage curve is displayed to follow a running test or to compare the measured data later on. Actual measurement values from the cursor position are displayed on the left-hand site. The ten function buttons in the bottom row give a quick access to the main program functions.
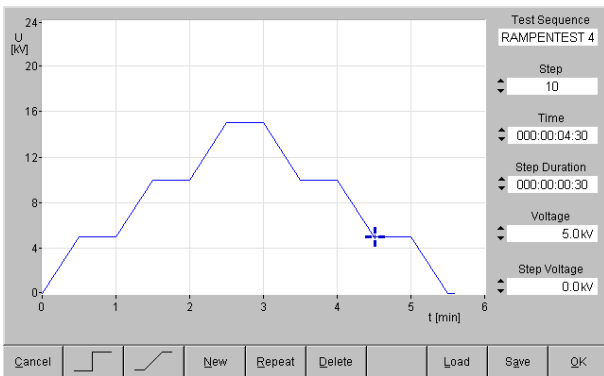
Fig. IV.8: Panel to create the step voltage curve

The first step to create a test sequence is the step voltage curve. This can be done offline (without the instruments) and downloaded later to the STEP*compact* (for the voltage control). Figure IV.8 shows the function panel to create the step voltage curve.

The next step is to define the kind of test, which has to be done. Three different kinds of test sequences are offered:

- The first is designed for tests which plainly acquire the PD activity and the tan δ / C_X at predefined voltage levels.

- The second allows setting maximum PD levels at certain voltage values for e. g. acceptance tests.

- The third is designed for breakdown tests. E. g. several test specimens have to withstand an over voltage for a certain time. The voltage is increased continuously stepwise, and the test procedure must be continued after a failed specimen is removed.

Fig. IV.9: Specification field

Once the test sequence is specified and saved, the automated test can be started by loading the wanted sequence. The specification data for the report have to be entered and the test can be started. The test report will then be saved as can be seen in figure IV.9.

Test Report   230123001
                                                                      Reference No.

Object	: **Outdoor Wall Bushing**	Quantity	: 1
Type	: **CTkf 73-400**	Drawing	:
Client	: ABC Power	Preliminary test	
Client Order No.	: 121212	Test spec.	: IEC 137

Serial No.   : 230123100

1. Tests carried out

1.0 Tightness test 1,5 bar rel., 1 hour
1.1 Measurement of dielectric dissipation factor and capacitance: see pos. 3.
1.2 Measurement of dielectric dissipation factor and capacitance: see pos. 3.
1.3 Check of dielectric dissipation factor and capacitance: no change
1.4 Measuring tap test 3 kV, 50 Hz, 1 min., carried out together with the measurement of capacitance: see pos. 3.

2. Test conditions

Test date   :
1.1 to 1.4   : Bushing complete, lower part in oil / Ambient air temperature ≈ 18.0 °C
1.2   : Measuring circuit acc. IEC 270 / Measuring instrument: ICMcompact / Background noise: 2 pC

3. Individual results

	1.1		1.2		1.4	
U (kV)	tanδ (%)	C (pF)	PD (pC) ↓	PD (pC) ↑	C (pF)	tanδ (%)
3.0					9701	0.173
21.0	0.109	885				
44.0	0.110	902	128	136		
51.0			131	137		
63.0	0.110	915	↓	↑		

4. Assessment

The bushing corresponds to the test specification.

Edition A   Issued by: bh   Manager testing section:

5. Remark

/PD •   Vaalser Strasse 250
        52074 Aachen   Tel. +49 241 74927   Power Diagnostix
        Germany   Fax +49 241 79521

Fig. IV.10: Example report

IV.4   Installation of Software and Drivers

The software comes with an install-er and is suitable for Microsoft Windows 7, 8, and 10. It is developed with National Instruments' LabWindows/CVI. Starting the program setup.exe, which is located on the provided CD-ROM, will install the software and the required CVI run time engine. The installer will guide you through the installation process.

The installation directory can be chosen individually, you may alter the location. In case you want to maintain access to different releases of the ICM*compact* software you may place the software in a tree of subdirectories as C:\pdix\Software\ICMcompact\ICMcompact_5.04p\, for instance. By pressing the 'Finish' button, the program files are extracted, and a program folder is created. It is rec-

Fig. IV.11: Installation process

ommended to create a special data directory. Avoid placing the data directory as a subfolder into the program directory, as a de-installation of the program could lead to a loss of your data!

The installation package also comes with a driver for the standard USB interface for communication with the instrument. This driver has to be installed manually. The install file can be found in the installation directory of the software, e. g. C:\pdix\Software\ICMcompact\Icmcompact_5.04p\USBDriver\FTDI.

Double clicking on setup.exe starts an installation wizard that will guide you through the installation process. It's necessary to confirm the license agreement for a successful installation of the USB driver.
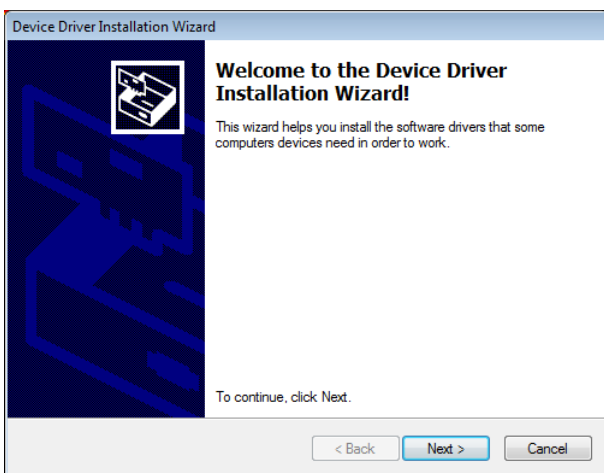
Fig. IV.12: First step of the USB driver installation process
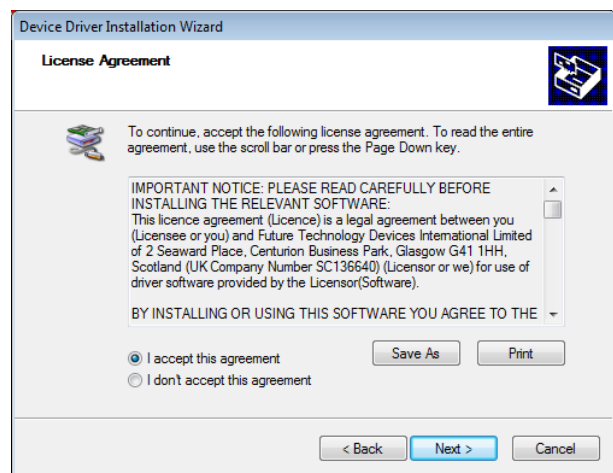
Fig. IV.13: License Agreement window
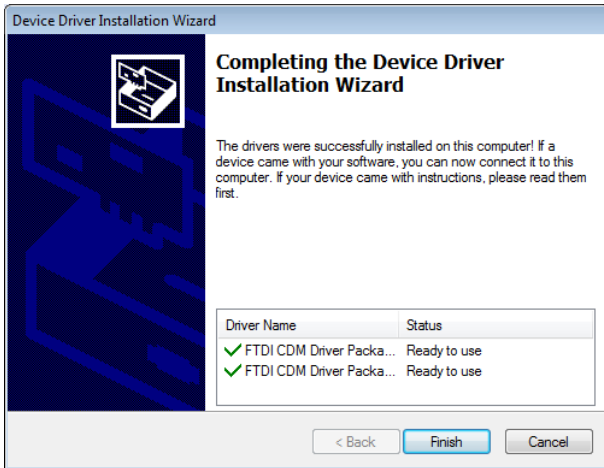
Fig. IV.14: By pressing the 'Finish' button the installation is completed.

If the software does not find the instrument at the correct COM port, it is possible to set the COM port manually. First open the Windows device manager with only the ICM*compact* connected to the computer to find the COM port of the instrument. The device should be listed as an item of 'Ports'.
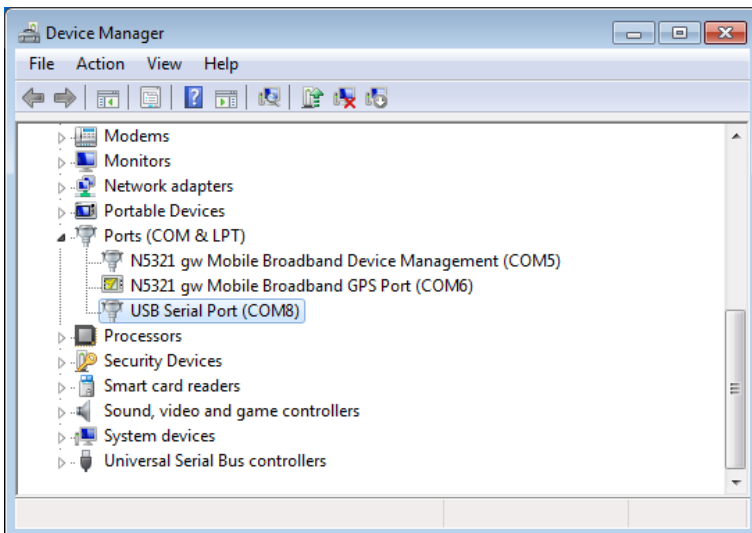
Fig. IV.15: Windows Device Manager

Then open the 'Interface Settings' of the software using the 'Options' menu and activate the checkbox, which corresponds to the COM port in the device manager. Additionally, select the 921600 baud rate.
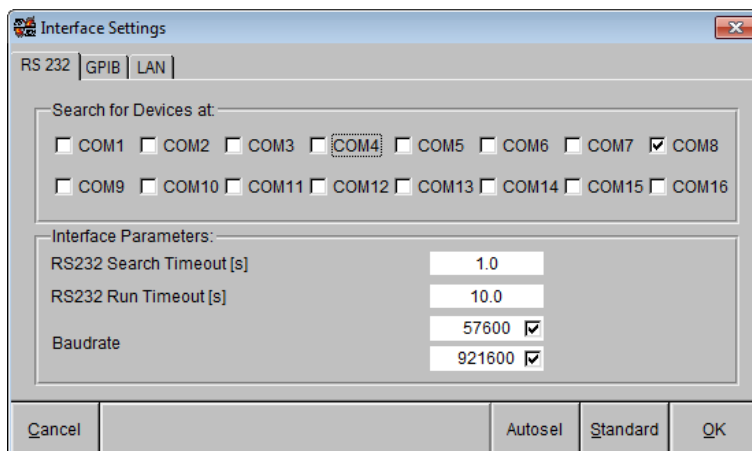
Fig. IV.16: Interface settings

V   Miscellaneous

V.1   Maintenance

The ICM*compact* does not require any maintenance on a regular basis. There is no fine adjustment on a regular basis required, as the partial discharge measurement is a relative measurement that is calibrated with a reference source prior to a measurement. The calibration impulse generator as the reference source, however, must be calibrated on an annual basis to ensure that its output signal remains within the recommended boundaries.

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 urgent cases.

V.3   Declaration of Conformity

The manufacturer
Power Diagnostix Instruments GmbH
Vaalser Strasse 250
52074 Aachen
Germany

$C\epsilon$

declares, that the product

ICM*compact*
Partial discharge detector

provided it is installed, maintained, and used for which it was made, in accordance with relevant installation standards and manufacturer's instruction, meets the requirements of the following directive(s):

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

It complies with the following standards and/or normative documents:

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

Aachen, 09.12.2022
Dr. Mihai Huzmezan
(CEO, Power Diagnostix Instruments GmbH)

Note: Since the measurement of partial discharge pulses is done in frequency bands partly occupied by radio transmission, and since further test leads may act as antennas, disturbance free measurements may require well shielded environments and/or additional filter techniques.

V.4   UK Declaration of Conformity

The manufacturer
Power Diagnostix Instruments GmbH
Vaalser Strasse 250
52074 Aachen
Germany

declares, that the product

ICM*compact*
Partial discharge detector

provided it is installed, maintained, and used for which it was made, in accordance with relevant installation standards and manufacturer's instruction, meets the requirements of the following Statutory Instruments:

SI 2016 no. 1101   **The Electrical Equipment (Safety) Regulations 2016**

SI 2016 no. 1091   **The Electromagnetic Compatibility Regulations 2016**

SI 2012 no. 3032   **The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012**

It complies with the following standards and/or normative documents:
EN 61010-1:2010,
EN 61326-1:2013
EN IEC 63000:2018

Aachen, 09.12.2022
Dr. Mihai Huzmezan
(CEO, Power Diagnostix Instruments GmbH)

Note: Since the measurement of partial discharge pulses is done in frequency bands partly occupied by radio transmission, and since further test leads may act as antennas, disturbance free measurements may require well shielded environments and/or additional filter techniques.

V.5   Troubleshooting

V.6   FAQ

This section lists some problems that may be encountered in using the ICM*compact* along with possible causes and remedies.

The ICM*compact* doesn't do anything when powered up.

The power fuse might be blown. Unplug the unit and check the power supply fuse. This fuse is located on the rear panel of the ICM*compact* (desktop and rack mountable version) or in the upper left corner (Explorer case version) above the on/off switch (see figure II.5 and figure II.6 in section II.1).

The personal computer cannot find the ICM*compact*

A communications error with the serial connection to the ICM*compact* might have occurred. Within the ICM*compact* PC software, check to be sure that the serial com port selected in the menu 'Options->Interface settings' is the com port to which the ICM*compact* is actually connected. Within the Windows Device Manager check if the USB driver was properly installed (see section IV.4).

Try rebooting both the ICM*compact* and the PC.

The ICM*monitor* application window appears very small on high resolution monitors und Windows 10.

On PCs running Windows 10 with the Creator's Update of 2017 the ICM*compact* 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".
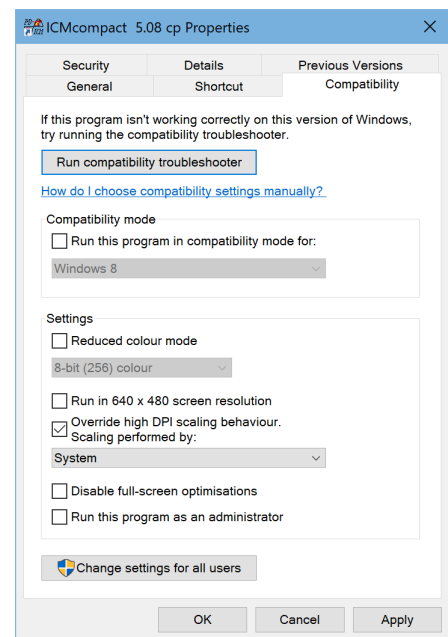
Fig. VI.1: Properties windows
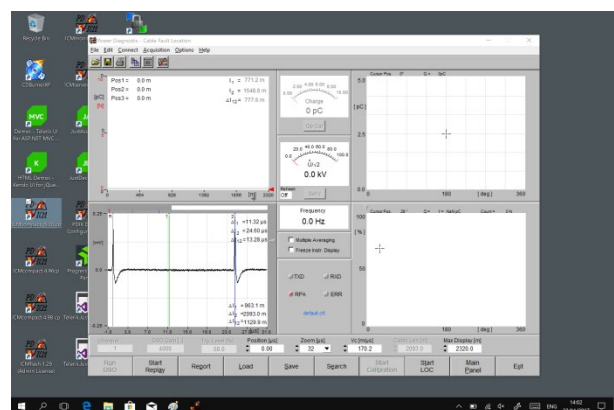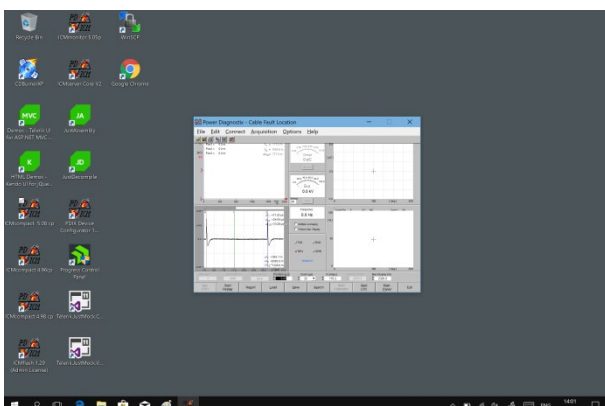
Fig. VI.2: Desktop before and after change of scaling behavior

The 'RPA?' message appears in the lower left portion of the data display of the LCD panel, even though the RPA (preamplifier from Power Diagnostix) is connected.

The RPA might be installed improperly (backwards). Check to be sure that the BNC connector marked with ➤) leads from the sensor (quadrupole, CT, or coupling capacitor), and that the BNC connector which is marked by the sign (➤ leads to the BNC connector labelled 'AMP IN' on the rear panel of the ICM*compact*.

The preamplifier must be enabled if an RPA is connected. Ensure the >RPA ON is marked (see section III.2.3, page 29). Try substituting the BNC cables to be sure that the problem is not in the cables themselves.

The calibration pulse is not visible on the LCD panel.

First check that the calibrator is still on. The calibrator will shut off automatically after several minutes without having its buttons pushed. Check that the low battery indicator is not showing on the LCD panel of the calibrator.

The calibration pulse setting might be too weak for test setup. Try increasing the magnitude of the calibration impulse applied to the test setup.

The calibration pulse on-screen might be present but too small to be easily visible. Try putting the ICM*compact* into SCOPE / Norm mode. This will make the calibration pulse appear as a vertical bar, which makes it easier to see on-screen that it appears in the Hold mode.

Sometimes the calibration pulse is lost if the high-voltage power supply is connected to the test setup when the calibration is performed, even if the high-voltage supply is completely powered off. Try physically disconnecting the high-voltage supply from the test setup during calibration. The calibrator will then be connected across only the test object quadrupole, and the coupling capacitor (if present).

If the problem persists, please contact Power Diagnostix for technical support.

Other problems

The FAQ section of the ICM*compact* manual is evolving. If you encounter problems with your ICM*compact* that you think would be helpful to add to this troubleshooting section, please submit them to Power Diagnostix. Thank you for your assistance.

VI   Technical Data

VI.1   ICM*compact* (Standard)

Mains supply:	90–264 V_{AC}, 47–440 Hz	(automatic)
Line fuse:	1.6 A	(time-lag)
Power requirements:	Approx. 40 VA	
Display:	Backlit LCD	
Display resolution:	128 x 240 pixels b/w	
Operation:	5 menu supported pushbuttons	
	5 fix function pushbuttons with multi-channel version	
	or remote controlled via software	
Recorder output:	0–10 V with R_O=100 Ω	(re-converted analogue value of the meter reading)
Operation temperature:	10–40°C	(non-condensing)
Size:	236 x 133 x 300 mm^3	(desktop model, exclusive BNC-connectors)
(W x H x D)	305 x 144 x 270 mm^3	(Explorer case version, closed)
	305 x 360 x 270 mm^3	(Explorer case version, open)
Weight:	Approx. 4.0 kg	(desktop model)
	Approx. 4.4 kg	(Explorer case version)

Standard PD Mode

Lower cut-off (-6 dB):	40, 80, or 100 kHz	(software controlled)
Upper cut-off (-6 dB):	250, 600, or 800 kHz	(software controlled)
Input sensitivity:	< 500 μV_{rms} / 5 pC	(without preamplifier)
Gain range:	1, 2, 4, 8, 10, 20 …, 200, 400, 800	

Preamplifier

Input impedance:

RPA1/RPA1D/RPA1G/RPA4:	10 kΩ ǁ 50 pF
RPA1L/RPA1H:	1 kΩ ǁ 50 pF
RPA2:	50 Ω ǁ 50 pF

Input sensitivity:

RPA1/RPA1D/RPA1G/RPA4:	< 50 μV_{rms}/0.03 pC
RPA1L:	< 15 μV_{rms} /0.02 pC
RPA1H:	< 40 μV_{rms}/0.05 pC
RPA2:	< 800 μV_{rms}/1 pC

Bandwidth:

RPA1/RPA1D/RPA1G/RPA4:	40–800 kHz
RPA1L/RPA1H:	40 kHz–20 MHz
RPA2:	2–20 MHz

Synchronisation / HVM

Sync. Frequency:	5–505 Hz / VLF (0.02/0.05/0.1 Hz)
Maximum voltage:	200 V_{peak} (140 V_{rms}), 100 V_{rms} nom.
Input impedance:	10 MΩ
A/D converter:	±15 bit
Precision:	Typ. < 1.5 %

Spectrum Function

Input sensitivity	< 5 μV_{rms} / 0.5 pC	(270 kHz bandwidth)
	< 1 μV_{rms} / 2 pC	(9 kHz bandwidth)
Max. input voltage	120 mV_{rms}	(270 kHz bandwidth)
	5 mV_{rms}	(9 kHz bandwidth)
	2.5 mV_{rms}	(RIV)
Frequency range	10 kHz–10 MHz	(in steps of 10 kHz)
Bandwidth	9 kHz or 270 kHz	
Precision:	Typ. < 5%	

Cable Fault Location (CFL)

Trigger:	0 to 100 % of input signal	(step width of 3.125 %)
A/D Converter:	± 7 bit	
Samples:	100 MSamples/s	(T_{sample} = 10 ns)
Reduced sample rates:	50 MS, 25 MS	
Displayed time window:	200 ... 8000 Samples	(2 ... 80 µs @ 100 MS / 8 … 320 µs @ 25 MS)
Specimen cable length:	10 to 5000 m, for 80 µs & v_c=140 m/µs	
	(CFL at cables > 3000 m not possible because of pulse attenuation)	
Localization precision:	1 m + 0.1 % of cable length	

VII   Annex

VII.1   Preamplifier for Gating with Older Hardware Versions

Bandwidth mode	Frequency range
MODE1	40 kHz to 800 kHz
MODE2	2 MHz to 20 MHz
MODE3	200 MHz to 600 MHz

With older hardware versions (manufactured before 2016) instruments with gating function came with a built-in preamplifier RPA6. The preamplifier had a logarithmic amplification and could be set to three different frequency ranges, which were selected in the submenu 'GT SET' with the entry BANDW. The table at the left-hand side lists the frequency bands for the three available modes.
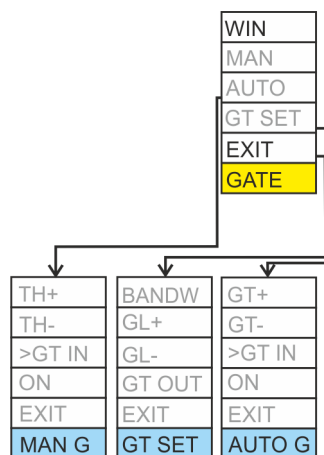
Fig. VIII.1: Old optional key menu for gating

Since the new gating preamplifier RPA6G has a fixed frequency range, the BANDW entry in the gating menu is no longer available.

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 3rd 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   [0:0:0:0:0:0:0:1]    49672    [0:0:0:0:0:0:0:1]    49673    ESTABLISHED
nidmsrv.exe    3848   TCPV6   [0:0:0:0:0:0:0:1]    49673    [0:0:0:0:0:0:0:1]    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".
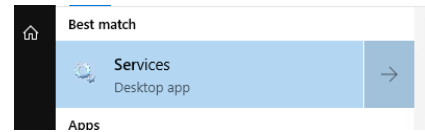
2.) Click onto the search result named "Services". The "Services" window will open.

3.) Locate these services in the service list:
   - NI Domain Service
   - NI PSP Service Locator
   - NI Time Synchronization

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".
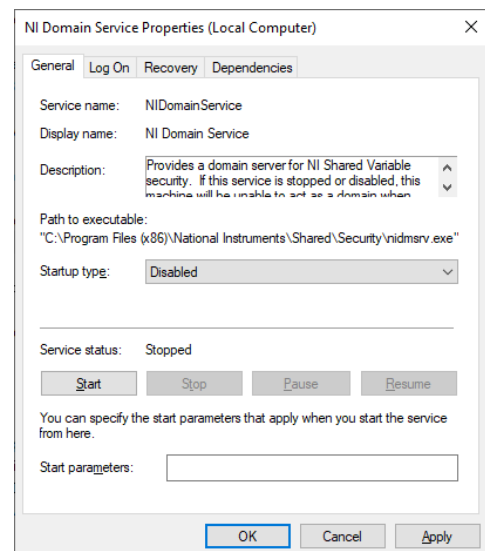
VII.2.3 Service Description

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

NI Domain Service

Service: NIDomainService
Process: nidmsrv.exe

Description: Provides a domain server for NI Shared Variable security.

If Disabled: If this service is stopped or disabled, this machine will be unable to act as a domain when configuring shared variable security.

NI PSP Service Locator

Service: lkClassAds
Process: lkads.exe

Description: Locates servers at the request of network variable clients and other proprietary NI network protocols.

If Disabled: If this service is stopped or disabled, network variables and network streams will stop working.

NI Time Synchronization

Service: lkTimeSync
Process: lktsrv.exe

Description: 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.

If Disabled: If this service is stopped or disabled, this form of time synchronization will not be available.

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