

ARGUS

Copper Test Manual

Version: 1.90 / EN

for ARGUS 300 and ARGUS 260

Important note:

Depending on the range of functions supplied, various menu options or functions may be hidden.

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1 Introduction

ARGUS Copper tests

The copper tests for ARGUS 300 and ARGUS 260 enable you to detect dangerous voltages and currents early on and reliably assess the physical quality of the line – particularly when DSL synchronisation is not possible or the data rate is low due to asymmetry, interference sources or other mechanical line problems.

Technical features of the ARGUS copper tests at a glance:

Copper tests Multimeter

- Multiple, preconfigured measurement profiles can be executed as an **auto test**.
- **Voltage measurement** enables measurement of the supply voltage, as well as external voltages caused e.g. by contact between two wires or isolation faults.
- With the aid of **capacitive symmetry measurement**, it is possible to detect asymmetry in the subscriber line that can result in signal distortions or transmission errors.
- **Capacitance measurement** detects interruptions as well as typical input capacitances of connected devices and enables estimation of line lengths.
- **Isolation resistance measurement** reveals damage to cable isolation, moisture penetration or oxidised contact points.
- With the aid of **resistance symmetry measurement**, it is possible to detect irregularities in the subscriber line that can result in signal distortions or transmission errors.
- **Resistive fault location (RFL)** can display resistance to fault (R_x), distance to fault, resistance from fault to short circuit (R_y), loop resistance (R_s), line length, and fault resistance (R_{fault}).
- **Loop resistance measurement** aids detection of short circuits and estimation of line lengths.
- **DC current measurement** can be used to detect emergency, external and normal power feeds as well as breaks in the line.
- **Unbalance measurement (LCL)**: This measurement uses a frequency of 1 MHz to measure asymmetry in a line pair.
- **NEXT measurement**: Measurement of near-end crosstalk at a frequency of 1 MHz.
- **Signature detection** is used to detect the signatures and test terminations (PPAs) connected to the subscriber line.
- The **fast cable check** verifies the correctness of a three-pole (Tip/Ring/Ground) connection.
- The **integrated remote kit control** lets you remotely set the line end to the desired state either manually or automatically using a variety of electronic instrument kits.

Copper tests Oscilloscope

- **Line Scope**: High-performance realtime Line Scope with display in time and frequency range (FFT) up to 35 MHz
- **TDR**: Time domain reflectometer to measure line lengths and locate faults



Note:

You can download the latest manuals at <http://www.argus.info/service/downloads> or simply contact one of our service representatives:

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2 Safety information copper tests

There are the following safety specifications:

VDC	0 V to 200 V
VAC	0 V to 200 V
IDC	0 mA to 150 mA
ISO	105 VDC, max. 2 mA
R	13 VDC, max. 15 mA

The following special instructions must be observed for the individual measurements:

Voltage

Be sure to observe the permissible measuring range specified above when measuring voltage.

Capacitance/capacitive symmetry

Before measuring, make sure that the voltage thresholds given in the table below are not exceeded during the measurement. Certain measurements can require a longer settling time. An automatic "TRG-opt." measurement can thus take some time.

Isolation resistance

Before measuring, make sure that the voltage thresholds given in the table below are not exceeded during the measurement. During the measurement, the ARGUS can apply a measuring voltage of up to 105 V (max. 1 mA) to the line. Certain measurements can require a longer settling time. An autotest can thus take some time.

Loop resistance/resistance symmetry

Before measuring, make sure that the voltage thresholds given in the table below are not exceeded during the measurement. During the measurement, the ARGUS can apply a measuring voltage of up to 13 V (max. 15 mA) to the line.

DC current

Be sure to observe the permissible measuring range specified above when measuring DC current. Make sure you connect the ARGUS in the circuit in series.

Longitudinal conversion loss (LCL)/NEXT

Before measuring, make sure that the voltage thresholds given in the table below are not exceeded during the measurement. When measuring LCL or NEXT using the ARGUS, any type of additional measurement lead can falsify the measurement. Both the length and the position of the measurement leads with respect to each other can influence the measurement result significantly.

Signature detection/fast cable check/remote kit control

Before measuring, make sure that the voltage thresholds given in the table below are not exceeded during the measurement.

Measurement	Voltage thresholds	
	UDC (V) to	UAC (Veff) to
R*	3,5	30
R-Sym*	30	30
ISO-R*	5	30
C*	17	17
C-Sym*	17	17
LCL	10	7
NEXT	10	7
Signature	3	3
Fast cable check**	5	30
Remote Box	3	3

* Measured on 200 kΩ load

** Loop limit value 10 kΩ

Measuring accuracies copper tests:

Voltage:		
DC voltage measurement (U=):		
Measuring range:	Resolution:	Accuracy:
0 V - 9.99 V	0.01 V	±(0.5 % + 2 digits)
10 V - 200 V	0.1 V	±(0.5 % + 2 digits)
AC voltage measurement (sine, 50 Hz) (U~):		
Measuring range:	Resolution:	Accuracy:
0 V - 9.99 V	0.01 V	±(2 % + 2 digits)
10 V - 200 V	0.1 V	±(1.5 % + 2 digits)
Frequency: 10 Hz to 200 Hz; 0.2 Hz; ±(1.5 % + 2 digits); sine		
When measuring voltages, the input resistance depends on the measuring range:		
- Measuring range 1: 0 V - 25 V; Input resistance: 1.694 MΩ		
- Measuring range 2: 25 V - 200 V; Input resistance: 1.05 MΩ		
As soon as the total of all voltages exceeds 25 V, the measurement is switched over.		

Capacitive symmetry measurement (CSym):		
Measuring range:	Resolution:	Accuracy of capacity difference:
10 nF - 4 µF	0.01 nF	0.1% of the capacity to ground

Capacitive measurement, measuring frequency 8 Hz (C):		
Measuring range:	Resolution:	Accuracy:
0.01 nF - 9.99 nF	0.01 nF	±(4 % + 4 digits)
10 nF - 99.99 nF	0.01 nF	±(4 % + 4 digits)
100 nF - 999.9 nF	0.1 nF	±(3 % + 1 digit)
1 µF - 8 µF	1 nF	±(3 % + 1 digit)
* All specifications relate to a comparison measurement using film capacitors.		

Isolation resistance measurement with 105 V, max. 2 mA (Iso.):		
Measuring range:	Resolution:	Accuracy:
0.1 k Ω - 99.9 Ω	0.1 k Ω	$\pm(2\% + 1 \text{ digit})$
100 k Ω - 999 k Ω	1 k Ω	$\pm(2\% + 1 \text{ digit})$
1 M Ω - 9.99 M Ω	10 k Ω	$\pm(2\% + 1 \text{ digit})$
10 M Ω - 99.9 M Ω	100 k Ω	$\pm(5\% + 1 \text{ digit})$
100 M Ω - 1 G Ω	100 k Ω	$\pm(5\% + 1 \text{ digit})$
Isolation resistance measurement with 8 V, max. 8 mA (Iso.):		
Measuring range:	Resolution:	Accuracy:
0.1 k Ω - 99.9 k Ω	0.1 k Ω	$\pm(2\% + 1 \text{ digit})$
100 k Ω - 999.0 k Ω	1 k Ω	$\pm(2\% + 1 \text{ digit})$
1 M Ω - 9.99 M Ω	10 k Ω	$\pm(2\% + 1 \text{ digit})$
10 M Ω - 40 M Ω	100 k Ω	$\pm(5\% + 1 \text{ digit})$

Resistance difference (RSym):		
Measuring range:	Resolution:	Accuracy:
10 Ω - 5 k Ω	0.1 Ω	$\pm 0.2\%$ of $R_{Loop} \pm 0.2 \Omega$

Resistive fault location (RFL):		
Display of:	Measuring ranges:	Accuracy R_x at $L_x/L = 0.1$
Resistance to fault (R_x), distance to fault	Loop resistance (R_s): 10..9999 Ω	$R_s = 2000 \Omega: \pm 0.3\%$ $\pm 0.05 \Omega$
Resistance from fault to short circuit (R_y)	Fault resistance (R_{fault}): 0..20 M Ω	$R_s = 200 \Omega: \pm 1.0\% \pm 0.06 \Omega$
Loop resistance (R_s), line length		
Fault resistance(R_{fault})		

Loop resistance measurement with 13 V, max. 15 mA (Iso.):		
Measuring range:	Resolution:	Accuracy:
1 Ω - 999.9 Ω	0.1 Ω	$\pm(1\% + 3 \text{ digits})$
1 k Ω - 9.999 k Ω	1 Ω	$\pm(1\% + 1 \text{ digit})$
10 k Ω - 99.99 k Ω	10 Ω	$\pm(1\% + 1 \text{ digit})$
100 k Ω - 999.9 k Ω	100 Ω	$\pm(1\% + 1 \text{ digit})$
1 M Ω - 9.999 M Ω	1 k Ω	$\pm(2\% + 1 \text{ digit})$
10 M Ω - 40 M Ω	10 k Ω	$\pm(5\% + 1 \text{ digit})$

DC current measurement (I=):		
Measuring range:	Resolution:	Accuracy:
0 mA - 150 mA	0.1 mA	$\pm(2.5\% + 3 \text{ digits})$

Unsymmetric balance at 1 MHz (LCL):		
Measuring range:	Resolution:	Accuracy:
0 dB - 55 dB	0.1 dB	$\pm 1.5 \text{ dB}$
55.1 dB - 65 dB	0.1 dB	$\pm 3 \text{ dB}$
The length of the measuring leads can significantly affect the measurement. Therefore, always use the original accessories for measuring.		

Near-end crosstalk at 1 MHz (NEXT):		
Measuring range:	Resolution:	Accuracy:
0 dB - 65 dB	0.1 dB	$\pm 1 \text{ dB}$
The length of the measuring leads can significantly affect the measurement. Therefore, always use the original accessories for measuring.		

Reference conditions (calibration):
- Temperature: +23 °C to ± 5 °C
- Humidity: 50 % ± 20 %, relative, non-condensing
- Frequency of measurement quantity: 50 Hz ± 5 Hz, sine

3 Copper tests

The ARGUS displays the menu options "Copper tests multimeter" and "Copper tests oscilloscope" in the access menu. These tests can be used to detect dangerous voltages and currents at an early stage and to reliably assess the physical condition of the cable.

In the following, the operation of the various functions is briefly presented. Since the results are usually only available in graphical form, they can only be correctly interpreted in conjunction with knowledge about the line on which measurements are being made. The ARGUS supports you with various tools, such as the zoom or cursor function.

3.1 Copper tests multimeter

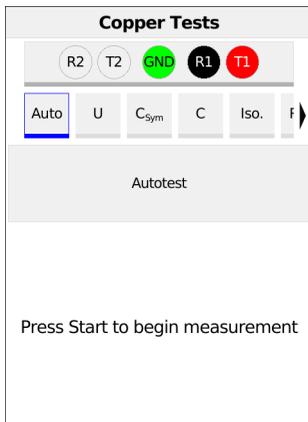
3.1.1 Auto test

The ARGUS executes various tests automatically, depending on the configured auto test profile. Ten user-configurable profiles (including remote kit control) are available for auto test.



A voltage check is performed before every measurement (except current measurement) in which the voltage limits given in the table (see page 7) may not be exceeded.

The measuring ranges, resolutions and accuracies of the respective measurement may be found in the chapter Technical data, see page 8.



Auto Test Settings	
Auto Test Profile	Autotest
Temperature	20,0 °C
Wire Types	PE 0.5 AWG24
Remote Kit Command	
Remote Kit	TX91x + 900/905 Remote

Selection of the auto test (see picture on the left).

After selecting the "Menu" softkey, 10 CU Auto test profiles can be configured at "CU Auto test Profile".



See the respective chapters for details on the individual measurements.

Auto Test Profile	
<input checked="" type="radio"/>	Auto test
<input type="radio"/>	Auto test with Remote Kit
<input type="radio"/>	CU Auto test 3
<input type="radio"/>	CU Auto test 4
<input type="radio"/>	CU Auto test 5
<input type="radio"/>	CU Auto test 6
<input type="radio"/>	CU Auto test 7
<input type="radio"/>	CU Auto test 8
<input type="radio"/>	CU Auto test 9

Auto Test Profile	
Auto Test Sequence	
Note	[Empty]
Profile Name	Autotest

Select the profile to be edited and open it with <Edit>.
The auto test is configured under Auto test configuration.



You can obtain further information on the auto test settings in the ARGUSpedia on the instrument.

3.1.2 Voltage measurement (U= and U~)

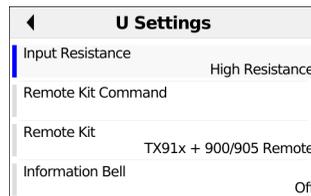
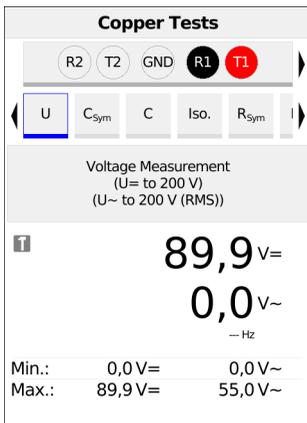
Voltage measurement enables detection of e.g. connected accesses (such as POTS) and supply voltages and external voltages, such as a connection to another line.

In AC voltage measurement, the frequency (10 - 200 Hz) is additionally displayed. This also enables identification of call switching and coupled voltages as well as carrier or power frequencies.



Note that unexpected or hazardous mixed voltages or hazardous voltage peaks can occur.

See the chapter Technical data page 8 for information on measuring ranges, resolutions and accuracies of voltage measurement.



Selection of voltage measurement.

Voltage measurement starts automatically when the Copper tests are activated. In this example, the

- Current voltage in volts
 - Current frequency of AC voltage in hertz
 - Minimum voltage in volts
 - Maximum voltage in volts
- are measured.

After selecting the "Menu" softkey, the following settings can be made:

- Input Resistance
- Remote Kit Command
- Remote Kit
- Information Bell



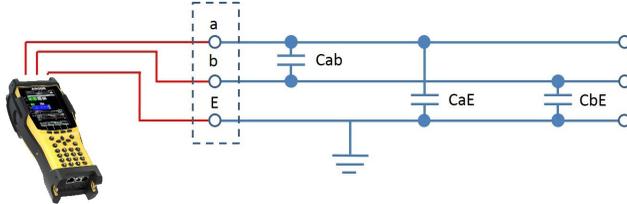
You can obtain further information on the settings in the ARGUSpedia on the instrument.

<Hold> The continuing measurement is paused.

<Go> Continues measuring.

3.1.3 Capacitive symmetry measurement (C_{sym})

With the aid of capacitive symmetry measurement, it is possible to detect irregularities in the wiring that can result in signal distortions or transmission errors. The line must be open. In a real line, a network of serial and parallel capacitances is formed between the individual reference points, as illustrated in the following diagram.



The total capacitance C_{ab} of the series connection of C_{aE} and C_{bE} is actually measured between a (tip) and b (ring).

The measured value shows the mutual capacitance (C_m) value. This applies correspondingly for measurements between a (tip) and ground (E) and between b (ring) and ground. These measurements form the basis for calculating the actual values of C_{ab} , C_{aE} and C_{bE} . The calculated values are then used in determining symmetry. Additionally, the absolute deviation of the two capacitances C_{aE} and C_{bE} with respect to ground and the relative deviation are determined.

$$\text{Relative deviation (in \%)} = 2 \times \frac{\text{absolute deviation (} C_{aE} - C_{bE} \text{)}}{C_{aE} + C_{bE}}$$

$$\text{Absolute deviation (in nF)} = \text{absolute difference (} C_{aE} - C_{bE} \text{)}$$

The calculated values represent the actual values C_{aE} , C_{bE} and C_{ab} for the individual capacitances. As the capacitances with respect to ground C_{aE} and C_{bE} are particularly important for the symmetry of a line, the absolute and percentage values are also given here for the sake of clarity. The relative value should not exceed 1 % (recommendation). The absolute deviation is of particular importance on extremely short lines, as even small differences here can result in a higher-percentage deviation. It must be reviewed on a case-by-case basis whether this is acceptable.



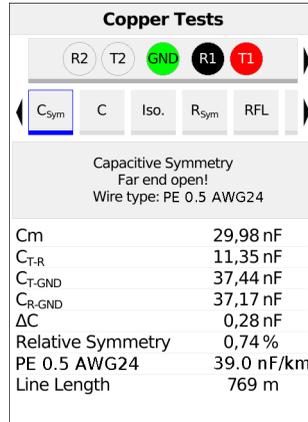
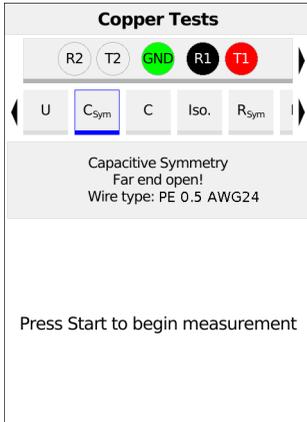
The line must be open. This can be achieved e.g. using the instrument kit function "open circuit". A voltage check is performed before the measurement in which the voltage limits given in the table (see page 7) may not be exceeded.



Always make sure that no instrument kit is connected when measuring capacitance on extremely short lines (< 100 m). If this occurs, the decoupling capacitance of the instrument kit may also be measured, which will significantly falsify the measuring results. On the TS916, for example, an additional capacitance of 3.3 nF is measured at a measuring frequency of 8 Hz.

See the chapter Technical data page 8 for information on measuring ranges, resolutions and accuracies of voltage measurement.

Capacitive symmetry measurement settings



Selection of the capacitive symmetry measurement

After activating the capacitive symmetry measurement, the following is measured:

- Cm (operating (mutual) capacitance) (in nF)
- Cab (capacitance between Tip and Ring) (in nF)
- CaE (capacitance between Tip and Ground) (in nF)
- CbE (capacitance between Ring and Ground) (in nF)
- ΔC (absolute deviation between CaE and CbE) (in nF)
- Relative deviation (in %)

After selecting the "Menu" softkey, the following settings can be made:

- Wire Types
- Susceptibility
- Remote Kit Command
- Remote Kit



You can obtain further information on the settings in the ARGUSpedia on the instrument.



When you select the susceptibility "insecure (fast)", the red warning "ATTENTION: susceptible" appears on the display.



When a wire type is selected the specific capacitance and measured operating capacitance are used to calculate the line length.



When a cable type has been selected, it is shown in the display.



Under certain circumstances, the capacitive symmetry measurement can abort. Possible causes include the presence of an external voltage, absence of a line or the existence of a loop.

3.1.4 Capacitance measurement (C)

Capacitance measurement shows the typical input capacitance of connected devices or the capacitance of the open line.



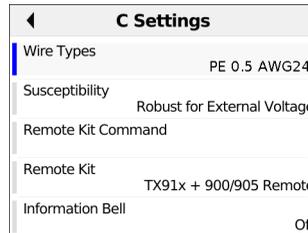
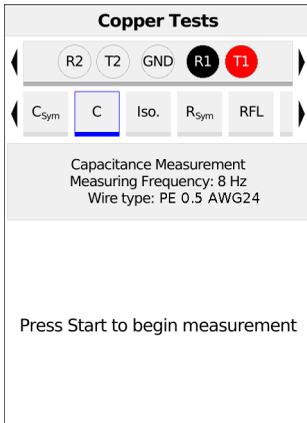
The line must be open. This can be ensured using the instrument kit function "open circuit". Before the measurement, a voltage check is performed in which the voltage limits given in the table (see page 7) may not be exceeded.



Always make sure that no instrument kit is connected when measuring capacitance on extremely short lines (< 100 m). If this occurs, the decoupling capacitance of the instrument kit may also be measured, which will significantly falsify the measuring results. On the TS916, for example, an additional capacitance of 3.3 nF is measured at a measuring frequency of 8 Hz.

See the chapter Technical data page 8 for information on measuring ranges, resolutions and accuracies of voltage measurement.

Capacitance measurement settings



After selecting the "Menu" softkey, the following settings can be made:

- Wire Types
- Susceptibility
- Remote Kit Command
- Remote Kit
- Information Bell



You can obtain further information on the settings in the ARGUSpedia on the instrument.



When you select the susceptibility "insecure (fast)", the red warning "ATTENTION: susceptible" appears on the display.



Once you have measured C-symmetry, you no longer need to measure capacitance.

3.1.4.1 Calculating line length

Every telecommunication cable has a certain loop resistance and operating capacitance per unit of length. As the type of cable laid is generally known, this value too is known. The values are design-related and relatively constant, as the cables are laid in the earth and subject to relatively minor temperature and humidity effects. However, a typical subscriber line can consist of multiple segments. In these segments, the wire cross-sections, and thus the technical specifications, can vary. These parameters can also be stored in the device. If the C or R measurement is now carried out, an evaluation of the measured line is obtained with regard to its probable length in relation to the selected cable type.

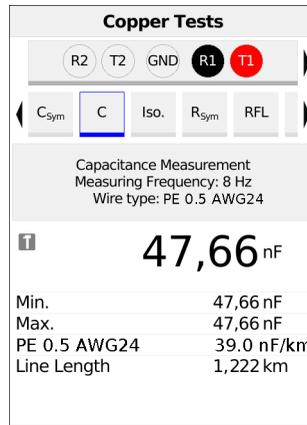
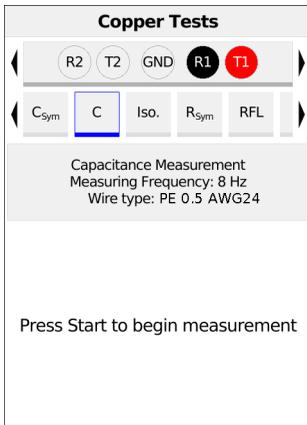
This can only be determined for a measurement between the Tip- and Ring-wires. The measurements with respect to Ground can be subject to random influences and thus cannot be specified with a general capacitance or resistance value per unit of length. The line length calculations can then be compared with the line length, which is generally also known, thus providing information about faults. Using the calculated value, you can roughly compare the line lengths and conduct further fault-finding (e.g. with a TDR) in the event of discrepancies.

A wire type must be selected to enable calculation of the line length using a C or R measurement. The wire type can be selected and configured during or after the measurement.



You can obtain further information on the settings in the ARGUSpedia on the instrument.

Starting capacitance measurement



In this example, capacitance measurement is carried out with a measuring frequency of 8 Hz and the values stored for wire type 2.

It is important to select a cable type, the default is „No cable type“.

In this example (see picture on the right), a capacitance of approx. 47.66 nF is measured between Tip/Ring. On the basis of the values stored under wire type PE 0.5 AWG24, this corresponds to a 1000 m line.

For a two-pole measurement the measured value is displayed in real time.



The wire type can be selected and configured during or after the measurement.

3.1.5 Isolation resistance measurement (Iso.)

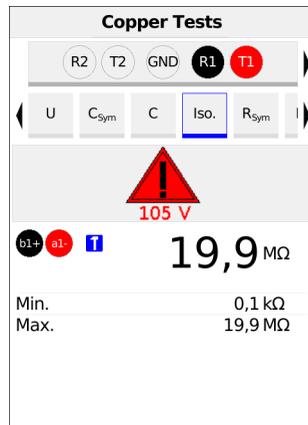
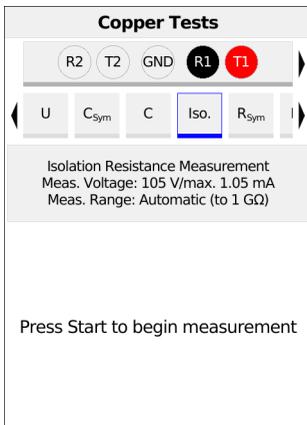
Isolation resistance measurement can indicate damage to cable isolation, moisture penetration or oxidised contact points on the line.



A voltage check is performed before the measurement in which the voltage limits given in the table (see page 7) may not be exceeded.

See the chapter Technical data page 9 for information on measuring ranges, resolutions and accuracies of isolation resistance measurement.

Isolation resistance measurement settings



Before the measurement, the selected test parameters are displayed.

- Measuring voltage (in this example 105 V)
- Measuring current (in this example max. 1.05 mA)
- Polarity (in this example Automatic, to 1GΩ)

After selecting the "Menu" softkey, the following settings can be made:

- Polarity
- Measuring range
- Measuring voltage
- Susceptibility
- Remote kit command
- Remote kit
- Information bell

The configuration options can vary depending on the selected sockets.



You can obtain further information on the settings in the ARGUSpedia on the instrument.



When Isolation resistance measurement is started, a warning is displayed when a measurement voltage of 105 V is used.

The ARGUS generates a voltage of 105 V at the start of the measurement. Special care is necessary due to this generated voltage.

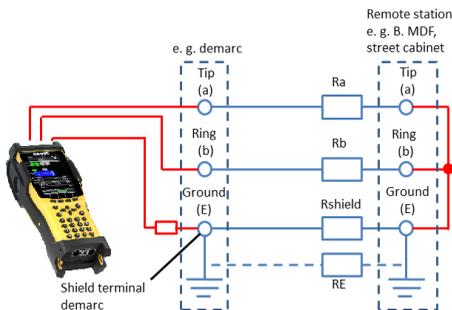
3.1.6 Resistance symmetry (R_{Sym})

This measurement determines the resistance symmetry of a line. Of primary importance for resistance symmetry are the two resistances R_a and R_b , i.e. the resistances of the two signal wires. To great a difference in resistance between the two wires can result in signal distortions and transmission errors. In a real line, a network of serial resistances is formed between the individual reference points, as illustrated the following diagram.



The measuring loops between Tip-Ring-Ground can be realised manually or using an electronic instrument kit.

Ideal measuring configuration:

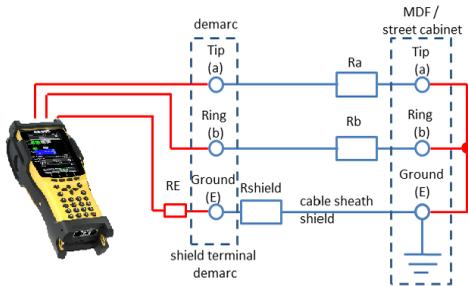


Values R_a , R_b and R_E are not measured directly, but instead are calculated from three individual measurements (R_{ab} , R_{aE} , R_{bE}). The calculated values are then used in determining symmetry.

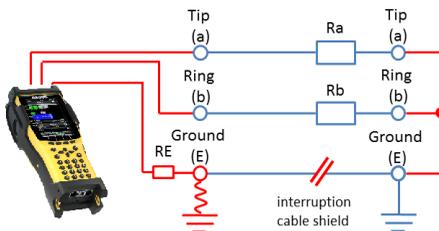
R_E is dependent on the measuring current here and is an auxiliary quantity. R_E is generally significantly less ($R_E \ll R_a$ resp. R_b) than R_a or R_b .

The cable shield is generally connected to ground at the main distribution frame resp. at the cable branch box. When the demarcation point is earthed, an electrical connection exists via both the cable shield and the ground connection. Always make sure that the measuring loops are properly connected to ground.

If the Tip-Ring-Ground measuring loops are not earthed, the measurement cannot be conducted (e. g. clamping to painted, non-conducting termination frames with crocodile clips).

Special features for RE (Examples):**1a. Measuring site, e. g. demarcation point:**

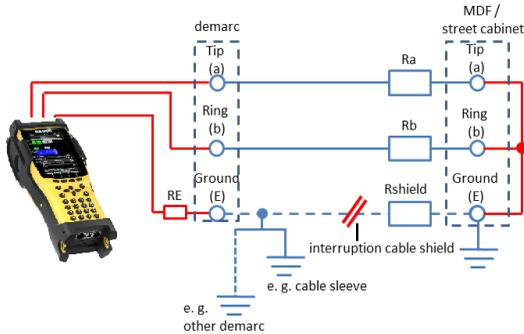
The demarcation point is not earthed. The Copper box (GND socket) is disconnected from the shielding terminal of the demarcation point. The measurement works when the cable shield is continuous. The displayed RE measurement is the R-cable shield (R_{shield}). The measurement works even if e. g. a shield terminal in the earth cable becomes high-ohm due to an installation error or a lightning strike. This can then be recognised from the high RE measured value.



1b. However, if the cable shield is not continuous (see image) or too high-ohm, the measurement will no longer function ($RE > 10\text{ k}\Omega$).

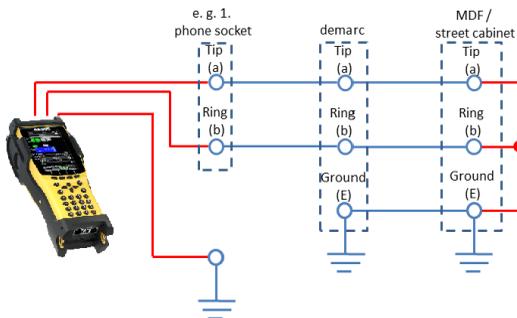
As a remedy, the resistance symmetry measurement can be conducted using the building potential equalisation rail or an earthed metal water or heating pipe. If this is not possible either, trained electricians can, after checking the building configuration (TN-S, TT), use the PE (protective ground) line as an earthing point after verifying that it is voltage-free. In general, attention must be paid to ensuring secure contact, particularly to oxidised or corroded earthing points.

The measurement does not work when the earthing is interrupted at one of the connection points. However, it will work for a poor ground connection. Reason for cancellation of measurement ($RE > 10\text{ k}\Omega$).



2. Measuring site, e. g. demarcation point:

The demarcation point is not earthed. The cable shield is interrupted at the site shown in the illustration. However, the resistance symmetry measurement can still work if the cable shield at the demarcation point is connected to one of the earthing points shown in the picture. However, the RE measurement is not Rshield, as the shield can have an ground potential of varying quality due to the lead sleeve in the ground (obsolete construction method). The ground potential can also come from a network of building accesses (other earthed demarcation points) in the branch cable: In the main cable area, the ground potential can come from another cable branch box. In practice, a combination of the two examples is quite common. All these effects lead to varying RE measurements.

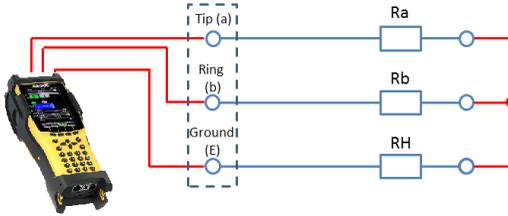


3. TAE (residence)

Resistance symmetry is often faulty in the last mile, e. g. due to a poor splice (rat-tail splice, poorly crimped conductor connections, loose screw connection).

A measurement is possible if the last mile is connected to a buried, continuous shield conductor (this case is not illustrated). However, this is seldom the case. Thus, you must either lay an auxiliary conductor, e. g. from the potential equalisation point to the measurement, or use earthed hating pipes in the residence.

If it does not work, trained electricians can, after checking the building mains configuration (TN-S, TT), use the PE (protective ground) line as an earthing point after verifying that it is voltage-free. In general, attention must be paid to ensuring secure contact, particularly to oxidised or corroded earthing points.



4. If an intact conductor is used as an auxiliary conductor instead of ground, $RE=RH$, RH is then entirely on the order of magnitude of R_a and R_b . A complete twisted pair (Tip-Ring) can also be used for this.

Calculation basis:

The following calculation basis is used for a 3-way measurement R_{ab} , R_{aE} , R_{bE} , with R_1 , R_2 , R_3 as the total resistance of the respective line pairs.

$$R_a = \frac{R_{ab} + R_{aE} - R_{bE}}{2} \quad R_b = \frac{R_{ab} - R_{aE} + R_{bE}}{2} \quad R_E = \frac{-R_{ab} + R_{aE} + R_{bE}}{2}$$

Additionally, the absolute deviation of the two resistances R_a and R_b and the relative deviation are determined.

$$\text{Relative deviation (in \%)} = 2 \times \frac{\text{absolute deviation (} R_a - R_b \text{)}}{R_a + R_b}$$

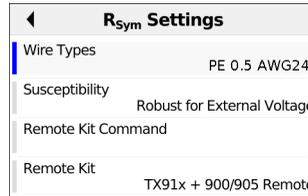
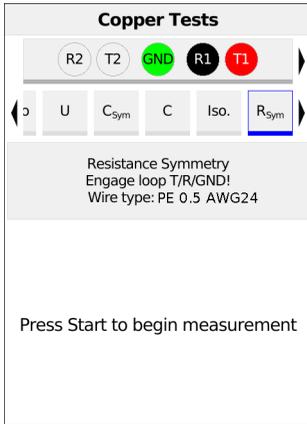
$$\Delta R \text{ (absolute deviation in } \Omega \text{)} = \text{absolute deviation (} R_a - R_b \text{)}$$



A voltage check is performed before the measurement in which the voltage limits given in the table (see page 7) may not be exceeded. A loop must be created between Tip-Ring-Ground. This can be achieved using the instrument kit function "Tip-Ring-Ground".

See the chapter Technical data page 9 for information on measuring ranges, resolutions and accuracies of resistance symmetry measurement.

Resistance symmetry measurement settings



After selecting the "Menu" softkey, the following settings can be made:

- Wire Types
- Susceptibility
- Remote Kit Command
- Remote Kit



You can obtain further information on the settings in the ARGUSpedia on the instrument.



When you select the susceptibility "insecure (fast)", the red warning "ATTENTION: susceptible" appears on the display.



If a wire type has been selected, this is shown in the display.



Under certain circumstances, the resistance symmetry measurement can abort. Possible causes include the presence of an external voltage, absence of a line or of a loop.

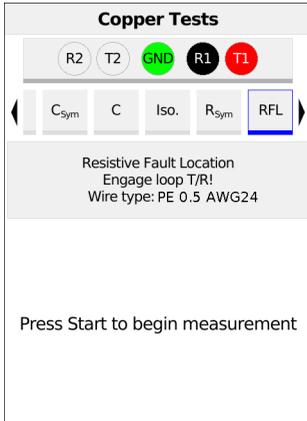
Copper Tests	
<div style="display: flex; justify-content: space-around; align-items: center;"> R2 T2 GND R1 T1 </div>	
<div style="display: flex; justify-content: space-between; align-items: center; border: 1px solid gray; padding: 2px;"> R_{sym} RFL R I= LCL N </div>	
Resistance Symmetry Engage loop T/R/GND! Wire type: PE 0.5 AWG24	
Loop Resistance	132,59 Ω
R _a	66,24 Ω
R _b	66,35 Ω
R _E	16,97 Ω
ΔR	0,11 Ω
Relative Symmetry	0,17 %
PE 0.5 AWG24	80 Ω/km
Line Length	1,657 km

Display:

- Loop resistance (in Ω)
- R_a (resistance of Tip-wire) (in Ω)
- R_b (resistance of Ring-wire) (in Ω)
- R_E (resistance of Ground) (in Ω)
- ΔR (absolute deviation between Ra and Rb) (in Ω)
- Relative Symmetry (in %)
- Wire Type (in Ω/km)
- Line Length (in m)

3.1.7 Resistive fault location (RFL)

This measurement can display resistance to fault (R_x), distance to fault, resistance from fault to short circuit (R_y), loop resistance (R_s), line length, and fault resistance (R_{fault}).



After selecting the "Setting" softkey, the following settings can be made:

- Temperature
- Wire Types
- Susceptibility
- Remote Kit Command
- Remote Kit



You can obtain further information on the settings in the ARGUSpedia on the instrument.



When you select the susceptibility "insecure (fast)", the red warning "ATTENTION: susceptible" appears on the display.

Copper Tests

R2 T2 GND R1 T1

← Iso. R_{sym} **RFL** R I= I →

Resistive Fault Location
Engage loop T/R!
Wire type: PE 0.5 AWG24

Loop Resistance	132,57 Ω
R _x	66,24 Ω
R _y	0,04 Ω
R _f	16,94 Ω
Temperature	20,0 °C
PE 0.5 AWG24	80 Ω/km
Line Length	1,657 km
Distance to Fault	1,644 km

In this example, the loop resistance is displayed.

3.1.8 Loop resistance measurement (R)

Loop resistance measurement enables you e.g. to detect short-circuits and estimate line lengths, among other things.



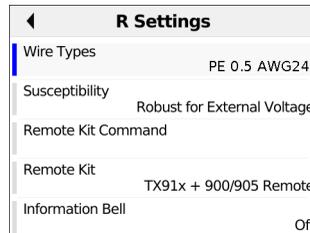
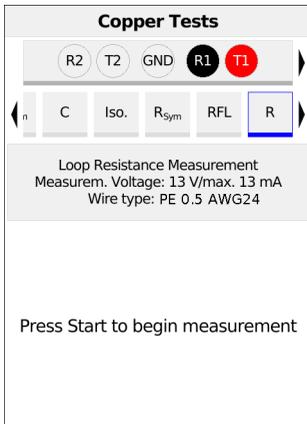
A voltage check is performed before the measurement in which the voltage limits given in the table (see page 7) may not be exceeded. A loop must be created. This can be ensured using the instrument kit function "short circ. Tip-Ring-Ground".



Loop resistance measurement is not intended for single-wire determinations. Use resistance symmetry measurement for this purpose.

See the chapter Technical data page 10 for information on measuring ranges, resolutions and accuracies of loop resistance measurement.

Loop resistance measurement settings



After selecting the "Menu" softkey, the following settings can be made:

- Wire Types
- Susceptibility
- Remote Kit Command
- Remote Kit
- Information Bell

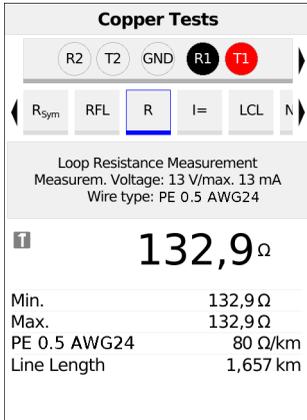


You can obtain further information on the settings in the ARGUSpedia on the instrument.



When you select the susceptibility "Insecure (fast)", the red warning "ATTENTION: susceptible" appears on the display.

Loop resistance is always measured continuously.



In this example, a loop resistance of 132,9 Ω is measured.



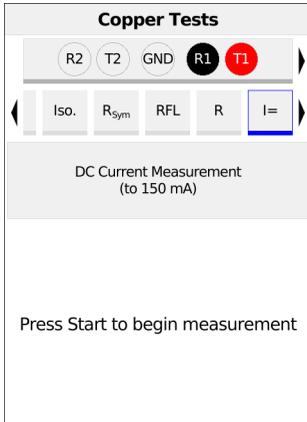
Loop resistance measurement can also return no result (---) e.g. due to excessive influence. The polarity is reversed up to 20 k Ω .

See page 20 for calculation of line length using the R-values.

3.1.9 DC current measurement (I=)

DC current measurement enables detection e.g. of feeds, emergency feeds or line terminations.

The measuring range, resolution and accuracy of DC current measurement are described in the chapter Technical data, see page 10.



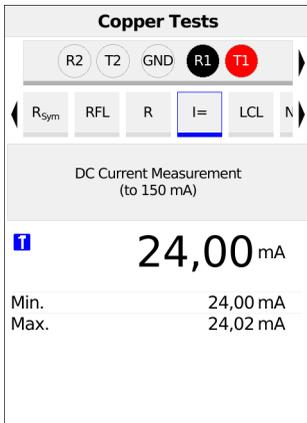
After selecting the "Menu" softkey, the following settings can be made:

- Remote Kit Command
- Remote Kit
- Information Bell



You can obtain further information on the settings in the ARGUSpedia on the instrument.

The DC measurement is always performed continuously.



In this example, a DC current of 24.00 mA is measured.

Min/Max: Display of minimum and maximum measured values.

3.1.10 Longitudinal conversion loss (LCL)

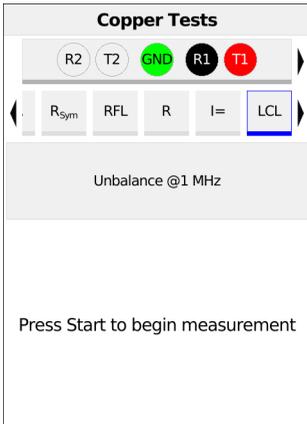
LCL measurement (asymmetry attenuation) looks at the balance between the Tip-wire with respect to Ground (GND) compared to the Ring-wire with respect to Ground. In this measurement, a tone is fed symmetrically to the wires with respect to Ground at 1 MHz. If a difference can be measured between the two wires, an asymmetry is present.



A voltage check is performed before the measurement in which the voltage limits given in the table (see page 7) may not be exceeded.

The length of the measuring leads can significantly affect the measurement, so you should always perform your measurements using the original accessories.

The measuring ranges, resolutions and accuracies of the LCL measurement are set out in the chapter Technical data, see page 10.

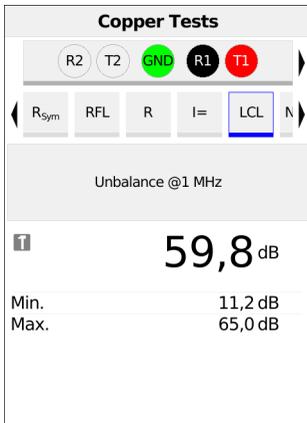


After selecting the "Menu" softkey, the following settings can be made:

- Remote Kit Command
- Remote Kit
- Information Bell



You can obtain further information on the settings in the ARGUSpedia on the instrument.



In this example, an asymmetry attenuation of 59.8 dB is measured.

Min/Max: Display of minimum and maximum measured values.

3.1.11 Near-end crosstalk (NEXT)

The ARGUS generates a 1 MHz tone on line pair 1 and measures the crosstalk on the adjacent line pair 2, which can cause severe performance issues for DSL. A customer's line can pass through multiple segments. In this case, the measurement must be performed segment by segment, and different line pairs may need to be used as the measuring lines.

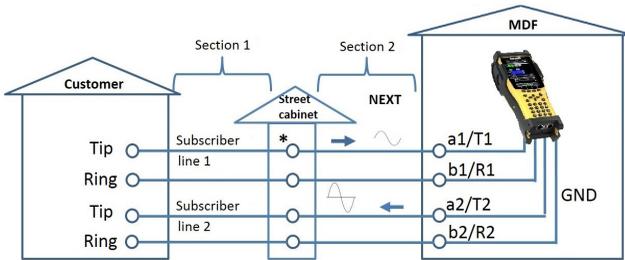


A voltage check is performed before the measurement in which the voltage limits given in the table (see page 7) may not be exceeded.

The length of the measuring leads can significantly affect the measurement, so you should always perform your measurements using the original accessories.

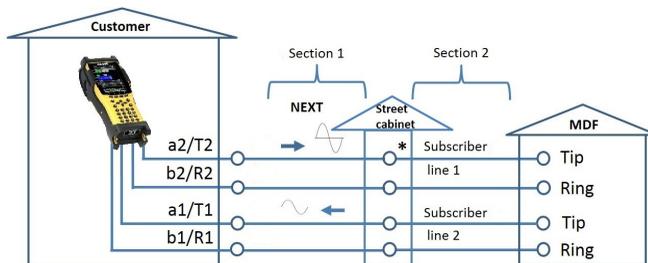
The measuring ranges, resolutions and accuracies of NEXT measurement are set out in the chapter Technical data, see page 10.

Connection example (towards to the customer):

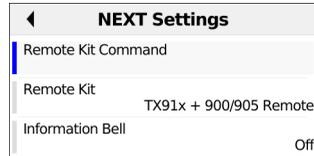
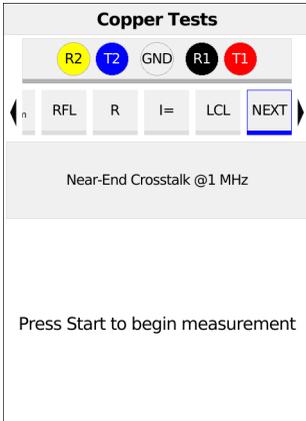


* Measurement is also possible from the street cabinet towards the customer (segment by segment).

Connection example (towards to the MDF):



* Measurement is also possible from the street cabinet towards the MDF (segment by segment).

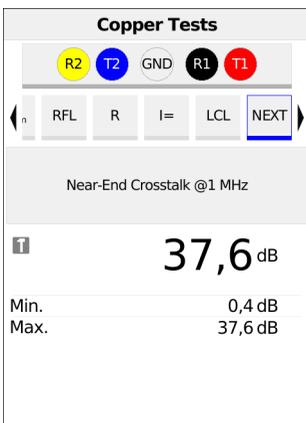


After selecting the "Menu" softkey, the following settings can be made:

- Remote Kit Command
- Remote Kit
- Information Bell



You can obtain further information on the settings in the ARGUSpedia on the instrument.



In this example, a crosstalk attenuation of 37.6 dB is measured.

Min/Max: Display of minimum and maximum measured values.

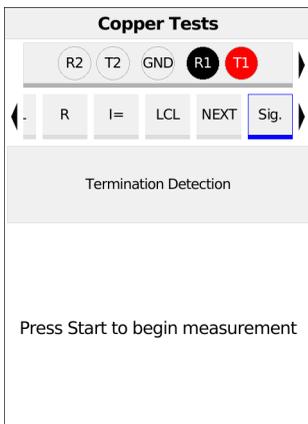
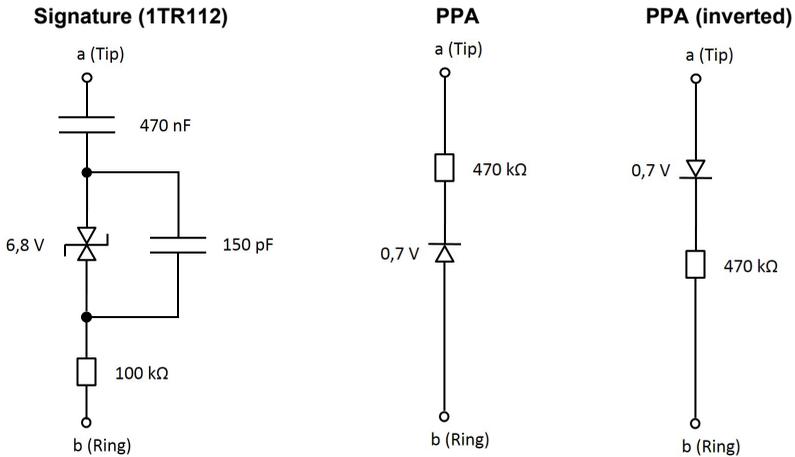
3.1.12 Signature detection/termination detection

Signature detection makes it possible to detect e.g. a passive test termination (PPA).



A voltage check is performed before the measurement in which the voltage limits given in the table (see page 7) may not be exceeded.

Circuit diagrams:

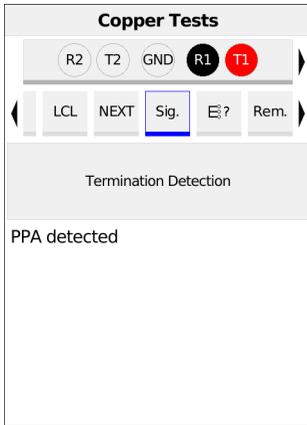


After selecting the "Menu" softkey, the following settings can be made:

- Remote Kit Command
- Remote Kit



You can obtain further information on the settings in the ARGUSpedia on the instrument.



In this example, a passive test termination (PPA) was detected between Tip and Ring.

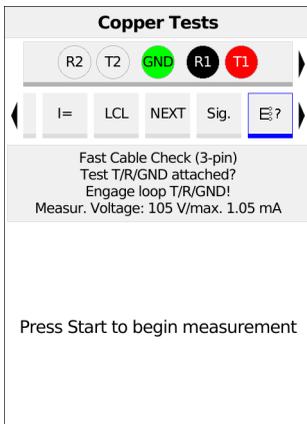
3.1.13 Fast cable check

The fast cable check checks the correctness of a three-pole connection (Tip/Ring/Ground) against a loop, in other words whether Tip/Ring/Ground is properly connected for subsequent tests.

To achieve this, the cable check measures the resistance. All values below a threshold of 10 k Ω , are interpreted as a loop, and all values greater as an open line. The cable check can be performed as a standalone test or as part of the auto test. In auto test, an audible alarm sounds when a fault is detected and the auto test sequence is stopped.



The loop between Tip/Ring/Ground can be realised manually or using an electronic instrument kit.

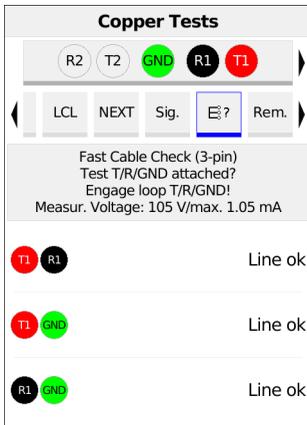


After selecting the "Menu" softkey, the following settings can be made:

- Remote Kit Command
- Remote Kit



You can obtain further information on the settings in the ARGUSpedia on the instrument.



The result of the check is displayed, e.g. OK or open.

3.1.14 Remote kit control (Rem.)

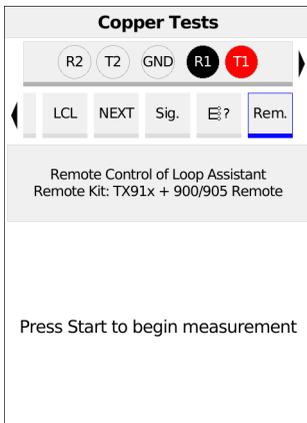
The Copper Box remote instrument kit control (Rem.) function enables the ARGUS to control commonly available electronic instrument kits, such as the TX915/916.



Before using the remote control function, make sure that the voltage limits specified in the table on page 7 are not exceeded during the measurement.



Remote control of other electronic instrument kits that may offer additional functions is only possible using the commands listed below (see ARGUSpedia).

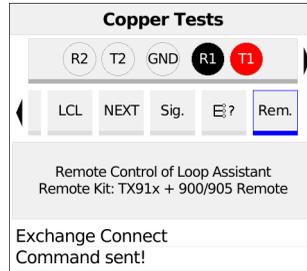
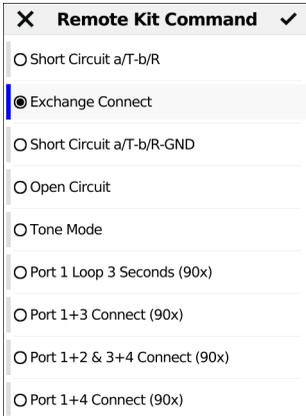


After selecting the "Menu" softkey, the following settings can be made:

- Remote Kit



You can obtain further information on the settings in the ARGUSpedia on the instrument.



In this example, the command "Exchange connect" is selected (see picture on the left). The command "Exchange connect" is sent to the remote unit (see picture on the right).



You can obtain further information on the settings in the ARGUSpedia on the instrument.

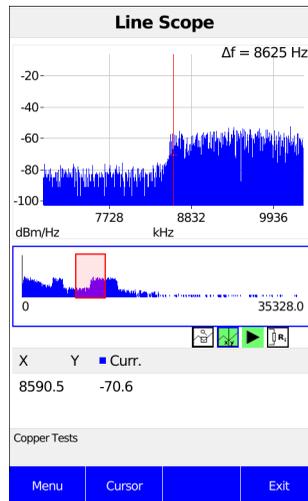
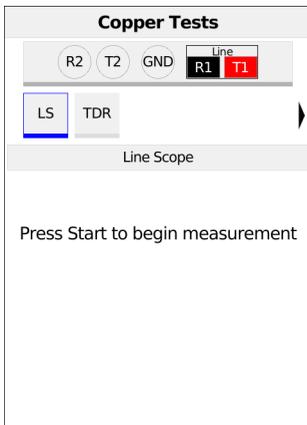
3.2 Copper tests Oscilloscope

3.2.1 Line Scope

With the line scope, ARGUS performs a real-time analysis on the connected line. The high-ohm line scope can e.g. be patched into an existing link between modem and DSLAM. You can display the results in either the time or frequency range (FFT).



The voltage on the line may not exceed 200 V DC or 100 V_{pp} AC.



The line scope can identify a variety of states or occurrences on the line. This example shows the VDSL connection established between the modem and DSLAM.

Finding the modem:

In addition to the general state of the line/connection, a variety of events can be detected. In this example, we can see the handshake tones that a modem connected to the line sends periodically in order to establish a connection with the DSLAM. This also reveals whether or not an active modem is connected to the other end of the line.

In addition to the wanted signals such as the DSL spectrum or the handshake tones, the line scope can also detect unwanted signals such as temporary interference sources (real-time operation) or peculiarities in noise (with respect to background noise).

Connection example:**Gain:**

To ensure optimum detection of different signals, match the gain (y-axis) with the reduction of the frequency range shown (x-axis). The ARGUS always begins with the lowest gain (-26 dB in the frequency range up to 3 MHz). Measuring range: -130 to +10 dBm/Hz.



Gain-Y: Gain settings:
-26 dB, -20 dB, 0 dB, 20 dB

The ARGUS displays all measuring results as dBm/Hz values. These values are only comparable with others when the resolution of the measured frequency band is taken into account, as here the total energy of the frequency band is determined „per Hz“. The bandwidth ARGUS is measuring is indicated in the display as Δf .

Frequency range:

A frequency range of from 20 kHz to 30 MHz is available for measurement; the resolution varies depending on the selected range.

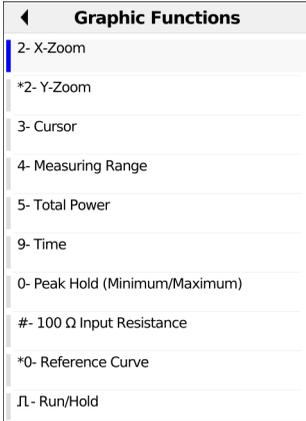
The bandwidth Δf at the top right in the display shows which frequency range is being shown in the display.



Frequency-X: Setting the displayed frequency range. Every press of the cursor key halves, respectively doubles the displayed range.

3.2.2 Graph functions

The graph functions Zoom and Cursor enable detailed analyses of the graphs.



<Menu> Opens graph functions.

Zoom:

If the magnifying glass is on a white background, the graphic has not yet been zoomed. If the magnifying glass is on a green background, the graphic has been zoomed in.

Cursor:

When the Cursor function is started, a red cursor line appears in the middle of the graph.

<Cursor> You can toggle the cursor on and off as needed using the Cursor softkey after activating it in the menu.

You can use the left and right cursor keys to move the cursor to any position on the graph to measure it. Briefly pressing a cursor key causes the cursor to jump to by one position in the graph. When the cursor key is held down, the steps the cursor covers in the graph become progressively larger.

The zoom function and the cursor function can also be combined. For example, you can determine a certain value using the cursor more easily when you have previously zoomed in on a specific range. However, the starting position of the cursor can vary..



When the Stop function is activated, you can move the cursor faster.

Measuring range:

When the line scope starts, it is in the measuring range in the status display. You can set the frequency range (x) and the gain (y) in the measuring range. If you have hidden the measuring range in order to work with the cursor or zoom, you can restore it.

<Menu> Restores measuring range.



Total power :

The ARGUS displays the total power. The total power is the sum of all individual power measurements (Δf) over the entire visible range .

<Menu> Restores total power display



Time:

In the line scope, you can switch from the frequency range to the time..

<Menu> Opens time domain. In this respect, the line scope operates like an oscilloscope that permits display of AC voltages from 0 to 40 V_{pp} with a resolution of 2 mV_{pp}. This makes it easy to recognize different AC voltage signals, e.g. the square-wave signal of an E1 access.



The gain and time base can be set using the horizontal and vertical cursor keys analogous to the frequency range.



The cursor functions are also available in the time domain for analysing the signal. However, there is no zoom function.

If the ARGUS detects that the connected signal regularly exceeds a certain threshold, the ARGUS tries to trigger automatically in response to this so as to optimally display the signal in the time domain.

The trigger symbol is green. If no signal is present or the level is too low, the trigger symbol is red. The ARGUS does not trigger.

Peak Hold (Minimum/Maximum):



Additionally activate the peak-hold function.

When the peak-hold function is used, positive (dark blue) and negative (light blue) peaks are shown graphically. The result is a blue curve of maxima and a yellow curve of minima over time. The instantaneous values continue to be displayed in red.

In the maximum values in particular, sporadic fliers (interference pulses) are visible and permit comparison between different lines (e.g. particularly clearly with the aid of a suitable current clamp).

100 Ω Input resistance :

Particularly when using a suitable current clamp, it may be necessary to adjust the input resistance of the line monitor. The red symbol  indicates that the line monitor is operating with an input resistance of 100 Ω .



A suitable current clamp is available as an accessory for the ARGUS; please ask our Support team.

Reference curve:

The reference curve enables e.g. comparison of the signal from one line with that from another.

To do this, start the line scope and connect it to line a. After obtaining the desired reference signal by setting the measuring range in the display, set the curve. Now switch to line b without closing the line monitor and compare the two signals.



and



Displays the reference curve selection.

<Set>

Set reference curve. When the reference curve is set, an orange line is displayed in the graph.

<Hide>

Hide reference curve.

<Set>

Set a new reference curve.

Run/Hold:

You can stop and restart a running test (realtime mode) at any time.



Stop and restart test.

Clipping:

Frequency range:

If the signal at the line scope input is too strong or the gain in the frequency range and time domain are displayed as too large, the input stage of the line scope is overdriven.

In this case, the ARGUS displays the clipping symbol .

The displayed signal is clipped both in the frequency range and the time domain. You can remedy this by reducing the gain.

3.3 TDR

The TDR function enables you to determine line lengths in realtime or localise interference sources. Correct interpretation of the pulses displayed by the ARGUS permits e.g. detection of stub lines, poor contacts or short-circuits. For this purpose, the ARGUS transmits a pulse on the connected line and displays its reflection response.



The line may not carry a DC voltage greater than 200 V DC and must be free of AC voltage components.



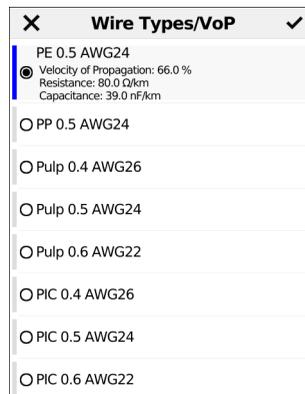
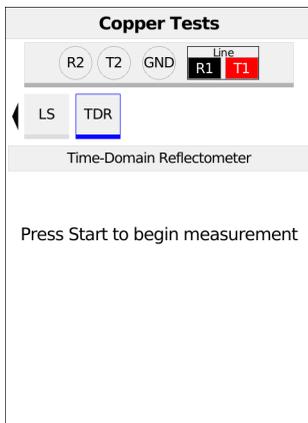
The result of a TDR measurement in the ARGUS display may give the impression of multiple interference sources on the line. It is recommended that you eliminate the first interference source on the line and then repeat your measurement. It is possible that the first interference source caused one or more reflections, which can greatly falsify the reflection at the second interference source. Often, there is no second interference source on the line.



The ARGUS generates a reflection at approx. 3 m. To precisely measure short lines and avoid this reflection, using e.g. a 5 m long connection lead is recommended. The pulse continues to be displayed in the graph but using the cable ensures that this is not on the line.



This operating mode is a test that may only be performed on lines that are not connected. Before carrying out the tests, the user must ensure by means of suitable pre-tests that the line is open or not connected.



After selecting TDR, the wire type can be selected. 20 wire types are already preconfigured by default.

3 Copper tests

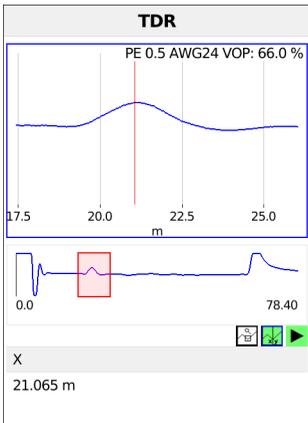
Wire Type Param.	
Velocity of Propagation	66.0 %
Line Resistance	80.0 Ω /km
Capacitance	39.0 nF/km
Name	PE 0.5 AWG24

After selecting "Edit", the velocity of propagation, line resistance, capacitance and name can be set.



You can obtain further information on the wire types in the ARGUSpedia on the instrument.

TDR status display:



The ARGUS displays possible interference sources on the copper twisted pair directly.

The adjustable range, the gain and the graph functions permit more detailed analysis.

To ensure optimum detection of pulse reflections, match the function for adjusting the gain (y-axis) with the reduction/enlargement of the range shown (x-axis).

The ARGUS always starts with the lowest gain (-26 dB) at a range of 1500 meters.

The measurements with the TDR can take place in a measuring range of from 3.5 to 6000 meters. The resolution is approx. 0.3 % of the displayed measuring range.



The accuracy is approx. ± 2 % of the measuring range.

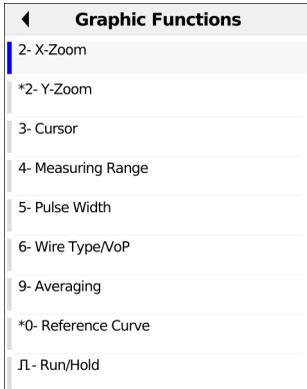
When determining the distance, try to determine the start of a pulse where possible, and not the relative maximum.



Range-X: Sets the displayed measuring range. Every press of the cursor key halves or doubles the displayed range.

3.3.1 Graph functions

The graphic functions Zoom and Cursor enable detailed analyses of the graphs.



<Menu> Opens graph functions.

Zoom:

When the magnifying glass shown in the display rests on a white background, it has not yet been zoomed.

When the magnifying glass is placed over a green background, the graph is zoomed.

You can vary the graph size from 25% to 100% using the zoom softkeys. This doubles or halves the resolution. When concurrently using the cursor, you can precisely localise the reflection on the measured line.

Cursor:

When the Cursor function is started, a red cursor line appears in the middle of the graph.

<Cursor> You can toggle the cursor on and off as needed using the Cursor softkey after activating it in the menu.

Use the left and right cursor keys to move the cursor to any position on the graph to measure it. Briefly pressing the cursor key causes the cursor to jump to a new position in the graph. When the cursor key is held down, the steps the cursor covers in the graph become progressively larger.

The Zoom function and the Cursor function can also be combined. For example, you can determine a certain value using the cursor more easily when you have previously zoomed in on a specific area. However, the starting position of the cursor can vary.



If the stop function is activated, the cursor can be moved with greater speed.

Measuring range:

When the TDR function starts, it is in the measuring range in the status display. You can set the range (x) and the gain (y) in the measuring range. If you have hidden the measuring range in order to work with the cursor or zoom, you can restore it:

<Menu> Restores the measuring range.



Pulse width

The pulse width setting can be used to appropriately configure the pulse that the ARGUS sends to the line.

The pulse width sets the duration of the pulse ARGUS outputs to the line in nanoseconds (ns). The default value is **500 ns**, but you can increase this up to 2000 ns (2 μ s) depending on the measuring range. Just like a more powerful pulse, a longer pulse contains more energy, and thus is generally more suitable for use on longer lines. However, a longer pulse can also conceal important reflections, which can then no longer be correctly interpreted.

Wire type/VoP:

The absolute VoP value must always be less than 1. However, ARGUS always displays this in percent. In a wire with a VoP value of 0.7, a signal propagates at 70 % of the speed of light (c_0).

For many cable types, the pulse time is also specified in V/2: $V/2 = \text{VoP} [\%] * 1.5$.



To measure e.g. building wiring precisely, it is important to set the correct VoP value. You can determine the correct VoP using a reference cable of known length before the measurement.

Averaging:

Determination of the average value based on the specified value (Min= 1, Max= 20).

Reference curve:

The reference curve is used, for example, to compare the signal of one line with the signal of another line.

For this purpose, start the line monitor and connect it to line a. If you have the desired reference signal by setting the measuring range in the display, you set the curve. Now, without terminating the line monitor, switch to line b and compare both signals with each other.

 and  Show reference curve selection.

<Set> Set reference curve.
When the reference curve is set, an orange line is displayed in the graph.
<Hide> Hide reference curve.
<Set> Set a new reference curve.

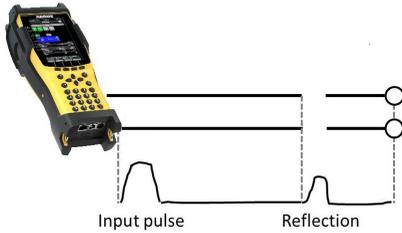
Run/Hold:

You can stop and restart a running test (realtime mode) at any time.

 Stop and restart test.

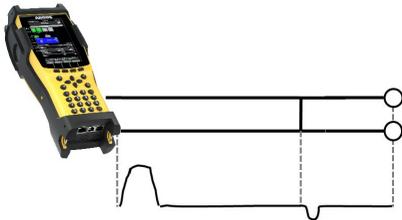
3.3.2 Examples

The following signal forms can help you in interpreting the reflection responses that ARGUS displays.



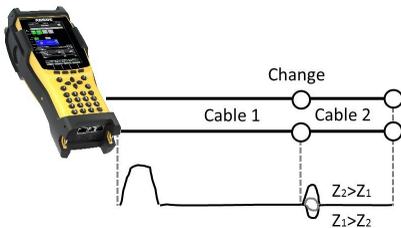
Open cable

The reflected pulse is positive. No proximate interference sources or the far end of the line can be seen.



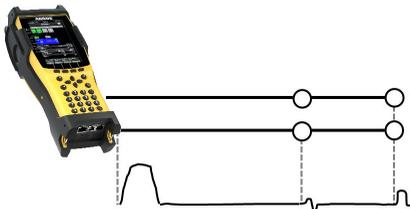
Short-circuit

The reflected pulse is negative. No proximate interference sources or the far end of the line can be seen.



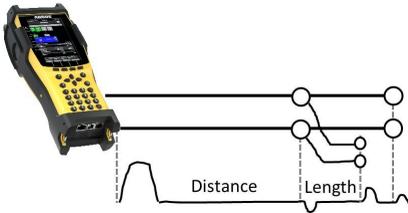
Mismatch

Different line cross-sections were used. The greater the mismatch, the greater the amplitude of the reflection.



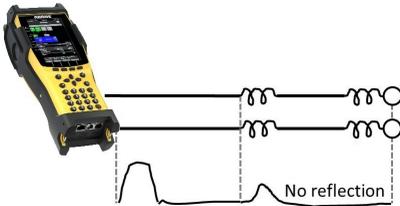
Poor contact point

A poor contact between two lines distorts the reflection into an S-shape. The worse the contact, the greater the reflection.



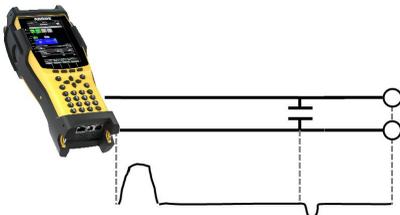
Stub line

The beginning of a stub line appears in the form of a negative reflection, followed by a positive reflection corresponding to the length of the stub line when the end of the stub line is open.



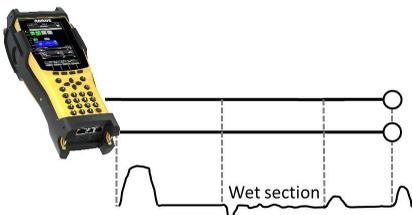
Loading coils

Loading coils deployed on the line are optimally designed for transmitting voice frequencies. They do not let DSL signals through. The TDR function enables you to detect the first coil in a line. The reflection is positive with a long tail in the direction of the end of the line. The following faults cannot be detected.



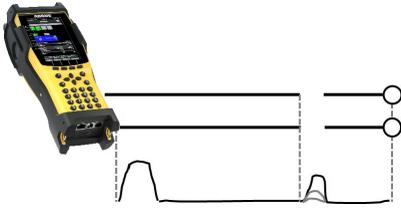
Capacitive network

Like a short-circuit, the reflection from a capacitive network is negative.



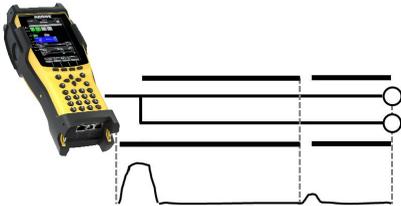
Moisture

Moisture penetrating the cable has the same effect on the reflection as a stub line. However, the zone between the negative and positive reflection appears significantly noisier than for a normal stub line.



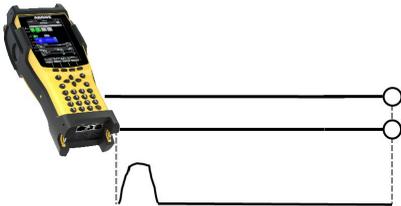
Loose/intermittent contact

Realtime operation is extremely suitable for detecting intermittent contacts. The amplitude of the positive reflections varies depending on the intermittent contact frequency.



Open shielding

Broken or open cable shielding can be detected by connecting the "a" and "b" cores to the ARGUS via one contact and the shielding to a second. The reflection looks like an open line.



Correct line termination

When the line is properly and correctly terminated, the pulse generated by ARGUS is completely absorbed. No further reflections are visible.

4 Appendix

A) Hotkeys

Graphic functions:

After starting the xDSL interface or a test, like Line scope or TDR, you can use the following graphic functions in the result displays:

Hotkey	Line Scope	TDR
Number key 1	-	-
Number key 2	Zoom	Zoom
Number key 3	Cursor	Cursor
Number key 4	Measuring range	Measuring range
Number key 5	Total power	Pulse width/height
Number key 6	-	Wire type/VoP
Number key 7	Probe	-
Number key 8	Symmetry	-
Number key 9	Time/FFT	-
Number key 0	Peak hold	-
Number key #	100 Ω input resistance	-
	-	-
	Run/Hold	Run/Hold
Press one after another  and 	Reference curve	Reference curve

B) Software Licenses

The ARGUS firmware includes code from what are known as Open Source packages, which have been published under various licenses (GPL, LGPL, MIT, BSD, etc.).

Additional information can be found at

http://www.argus.info/web/download/Software_License.

In the event that you are interested in the sources licensed under GPL or LGPL, please contact support@argus.info. A machine-readable copy of the source code can be obtained from intec Gesellschaft für Informationstechnik mbH for a minimal fee - to cover the cost of physically copying the code. This offer is valid for 3 years.

C) Abbreviations

Characters	
ΔC	Absolute deviation between CaE and CbE
Δf	Bandwidth
ΔR	Absolute deviation between Ra and Rb
Ω	Ohm (unit of electrical resistance)
A	
a	a-wire (tip)
A	Ampere
AC	Alternating Current or Access Server
B	
b	b-wire (ring)
C	
C	1. Celsius 2. Capacitance
c_0	Speed of light
Cm	Operating capacitance (mutual capacitance)
Cp	Parallel capacitance
C_{Sym}	Capacitive symmetry
D	
dB	Decibel
dBm/Hz	Performance measurement with the reference quantity 1 mW (milliwatt) per hertz
DC	Direct Current
DIN	Deutsches Institut für Normung - German Institute for Standardization
DSLAM	Digital Subscriber Line Access Multiplexer
E	
E	Ground (earth)
EC	European Community
EMC	Electromagnetic compatibility
EN	European standard
F	
F	Farad (unit of electrical capacitance)
G	
GND	Ground (earth)
H	
Hz	Hertz (unit of frequency)
I	
I	Electric current
IDC	DC current

Iso.	Isolation resistance measurement
	L
LCL	Longitudinal Conversion Loss
	M
m	Meter
MDF	Main Distribution Frame
mV_{pp}	milli Volt peak-to-peak
	N
NEXT	Near-End-Crosstalk
	P
PPA	Passive test termination
PoI.	Polarity
	R
R	1. Resistance (electrical resistance) 2. Ring (b-wire)
Ra	Resistance a-wire
Rb	Resistance b-wire
RC	Resistance (R) and capacitance (C)
RE	Ground resistance
Rem.	Remote (instrument kit control)
RFL	Resistive fault location
RH	Widerstand der Hilfsadern
Ri	Internal resistance
Ring	b-wire
RoHS	Restriction of hazardous substances
Rs	Loop resistance
R_{Sym}	Resistance symmetry
	S
S/N	Serial number
Sig.	Signatures
Sym	Symmetry
	T
T	1. Tip (a-wire) 2. Trigger
TDR	Time Domain Reflectometry
TRG	Tip, Ring, Ground
	U
U	Voltage
U_{AC}	AC voltage
U_{DC}	DC voltage

USB	Universal Serial Bus
V	Volt
VoP	Velocity of Propagation
V_{pp}	Volt peak-to-peak
W	
WEEE	Waste Electrical and Electronic Equipment

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