

## **Digital Transducer "SIMEAS T"**

7KG6000-8AA/AB to 7KG6000-8EA/EB

### **Description of functions**

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## 1 General Remarks

This device serves as a largely universal transducer for measured power supply quantities. It is designed for the measuring of voltages and currents in single-phase, three- and four-wire systems and for the determination of derived quantities. It is equipped with three analog outputs for the connection of moving-coil instruments or other systems designed for the display of analog measured quantities, such as controllers. The results can be accessed via a serial interface V.28. Optionally the device can be operated with connection to a bus in accordance with IEC 870-5-103, whereby the device must be equipped with an EAI RS485 interface. The connection of an external converter to optical fiber is possible. The output of analog measured quantities is not adversely affected by the bus connection, however one of the channels has a galvanic connection with the bus potential if the bus was connected in accordance with the EAI RS-485 standard. This restriction does not apply for operation with optical fiber.

The calibration of the transducer does not require the use of a single potentiometer or another regulating unit, however it determines offset values on the basis of predetermined reference values received from a suitable device and setpoints received from a personal computer which are stored in non-volatile memory. Mechanical devices for the system transfer are only required for the selection of the output variables  $\pm 20$  mA or  $\pm 10$  V.

The selection of the measuring range and the method of measurement, the parameter assignment, also requires the use of a personal computer connected to the serial interface.

## 2 Circuit Description

### 2.1 Input of Measured Quantities

Voltages and currents are connected via transformers. These transformers are mounted on separate printed-circuit boards.

#### 2.1.1 Voltages

The voltage is measured by current transformers with series resistors of 120 k $\Omega$ . The three transformers are connected in a star circuit, the three inputs (resistors) and the neutral star point are connected to terminals.

On the output side, resistors short the transformers (301  $\Omega$ , 1%, DIN 0207, 0.6 W, TK50). The voltage drop at the terminator should be 0.884 V at an input voltage of 450 V.

Determination of the resistance value:

With an input voltage of 90 V, an external series resistor of 120 k $\Omega$ , and 41 k $\Omega$  inside the transformer the peak voltage at the ADC input should be  $\pm 2.5$  V, this is equivalent to  $1.77 V_{\text{rms}}$ . In this case the following rule applies to the multi-range matching amplifier: lowest input voltage equals highest amplification times ten. The results is a voltage setpoint of 0.177 V.

On the input side, and due to the actual transformation ratio of 1:1 also on the output side, the current through the transformer is 0.5625 mA (Equation 1).

$$\text{Equation 1} \quad \frac{90}{(120 + 41) \cdot 10^3} = 0.0005625 \text{ A}$$

In accordance with Equation 2 the resistance is 315  $\Omega$ .

$$\text{Equation 2} \quad \frac{0.177}{0.0005625} = 315 \text{ } \Omega$$



## 2.1.2 Currents

Toroidal-core transformer, core 16x10x6 mm VITROPERM F800, 1000 windings, 0.1 CuL

The primary winding has to be connected to the input terminals. The voltage drop at the terminator should be 0.884 V at an input current of 10 A. The transformer should be operated with sufficient margin to the saturation point. Terminal resistance is theoretically 88.4  $\Omega$ , the next standard value of 91  $\Omega$  is selected.

## 2.1.3 Frequency

The frequency is determined from the period of oscillation of the voltage  $U_{L1-N}$ . The signal is switched via a comparator to one of the HSI inputs of the 80C196.

## 2.1.4 Scanning

The six input signals are each captured by individual sequential holding circuits and can therefore be measured at the same time. Within a 100  $\mu$ s interval, the signal is not allowed to show a variation of more than 0.4 mV from the starting value. The nominal scanning frequency is 1.6 kHz for each input.

The overall low-pass effect of RC elements is not allowed to have a 3dB cut-off frequency of less than 7000 Hz.

The six inputs are connected in the following order: three voltages ( $U_{L1-N}$ ,  $U_{L2-N}$ ,  $U_{L3-N}$ ), three currents ( $I_{L1}$ ,  $I_{L2}$ ,  $I_{L3}$ ).

The circuit consists of an analog-value selector with sequential capacitor. It was taken into consideration that the injection charge for the switching of the analog-value selector cannot cause an error greater than or equal 1/10 of the ADC resolution. The margin of 1/10 was chosen because the input signal is amplified up to ten times by the matching amplifier. In addition, the input current of the impedance transformer is not allowed to cause a major error during the hold phase. The hold time is approximately 100  $\mu$ s.

## 2.2 Matching Amplifier

A matching amplifier with high-resistance input and multi-range amplification is used behind the multiplexer. It features three amplification factors: 2.0, 5.0 and 10.0, with a tolerance of  $\pm 5\%$ . The three voltages always share one of the amplification factors, the same applies to the three currents.

### 2.2.1 Nominal Values, Measuring Ranges

Nominal value V	End-of-scale value V	Gain
57, 63.5	90	10
100, 110, 120	180	5
200, 230	450	2

Table 1: Voltage measuring ranges

Nominal value A	End-of-scale value A	Gain
1	2	10
2	4	5
5	10	2

Table 2: Current measuring ranges

## 2.2.2 Output Amplifier

The three output amplifiers are controlled by pulse. Two of them are separated from the measuring part by means of transformers. The control occurs to the noise-shaping principle, cf. Firmware. Plug-in bridge circuits are used to determine whether the output will be  $\pm 10\text{ V}$  or  $\pm 20\text{ mA}$ . In the case of unilateral or unsigned measurands (r.m.s. values), only the positive direction will be used. The nominal load impedance in both cases is  $750\ \Omega$ .

The open-circuit voltage of the current output is limited to  $21\text{ V}$ , the maximum current to approx.  $26\text{ mA}$ . The voltage of the voltage output is limited to  $21\text{ V}$ , the short circuit current to  $50\text{ mA}$ .

## 2.2.3 Pulse Output

An optocoupler output is used as an alternative display for operative readiness or out-of-limit alarm. In addition, it can be used to deliver operational pulses, for example kWh.

## 2.2.4 Serial Interface

A serial interface V.28 or optionally RS-485 is available. It can be operated at 2400, 4800, 9600, or 19200 baud. The basic operating mode uses 8 data bits, no parity, and one stop bit with the availability of all four clock-pulse rates. In "bus" mode in accordance with IEC 870-5-103, even parity and the clock-pulse rates from 4800 to 19200 are used.

The interface allows communication with a PC which carries out the parameter assignment and which is capable of reading out currently measuring values or of bus operation. It is not electrically isolated from the first analog output.

## 3 Firmware Function

As far as the function of the firmware is concerned, there is a vital difference between the basic operating mode in which the measured quantities are normally sent to the analog outputs and the operating mode IEC 870-5-103, which usually prefers output via the serial interface. The acquisition of measurands (3.1) and the output of analog measuring values (3.2) share identical functions, the parameter assignment and the calibration are also identical. However, there are vital differences in communication and the kind of measuring values which are supplied. Details can be found in the appropriate sections, a detailed description of the interface in accordance with IEC 870-5-103 can be found in Chapter 5. Version V01... only supports the basic mode, versions V02... and following include the operating mode in accordance with IEC 870-5-103.

### 3.1 Acquisition of Measurands

#### 3.1.1 Scanning

The measuring cycle depends on the frequency of the measured quantity  $U_{L1-N}$ . With a network frequency of  $50\text{ Hz}$  it is  $625\ \mu\text{s}$  which is equivalent to  $1.6\text{ kHz}$ . The six measuring points (voltages  $U_{L1-N}$ ,  $U_{L2-N}$ ,  $U_{L3-N}$ , currents  $I_{L1}$ ,  $I_{L2}$ ,  $I_{L3}$ ) are measured at the same time and the results of the three voltages for the last eight clock-pulses are stored. The values for the last eight clock-pulses are required to calculate the reactive power. They are displaced by exactly  $90^\circ$ . In order to make sure that the displacement is correct even if the frequency departs from the nominal  $50\text{ Hz}$ , the frequency of the measured quantity (voltage  $U_{L1-N}$ ) is continuously checked and the control of the measuring cycle adapted accordingly. The measurement of the frequency for the scanning control is effective within a range of  $45$  to  $65\text{ Hz}$  and from  $11.67$  to  $21.67\text{ Hz}$ .

The system transfer of the amplification to a valid value for current measurement follows the voltage measurement and the system transfer for voltage measurement follows the current measurement.

Three cycles are measured in order to obtain a scanning frequency apparently three times greater than the frequency which would be required in consideration of the harmonics. The starting position is

shifted by an angle of  $3.75^\circ$  for each cycle. Each cycle requires an initial "advance" of  $90^\circ$ , i. e. eight clock pulses, which is used to store only those voltages which are used for the phase displacement needed to determine the reactive power.

During the span of one measuring cycle, all measuring points for each one of the six channels are added. The value is divided by the number of captured points and the result is the residual deflection. The data is stored and subtracted from the measured quantity during the scanning of the measuring points and before further processing.

### 3.1.2 Calculation of Results

The extensive calculation of the results follows the acquisition of the measured quantities during which sampling can stop or at least the sampled values are no longer processed. The specifications for the calculation are described in the following. They describe the sampling phase as the regular time interval during which data from the measuring points is collected, it consists of three periods for each frequency of the voltage  $U_{L1-N}$ . This is followed by an extensive mathematical calculation phase to determine the results during which the collection of data stops.

#### R.m.s. values for voltage and current

During the sampling phase, the measuring values for voltage and current are immediately squared after subtracting the zero error and the results are accumulated.

During the calculation phase the sums of the 96 measuring values collected from each measuring point are divided by 64 to obtain their mean value. 64 is used as the divisor instead of 96 because it is a power of two which avoids the time-consuming division by moving 6 digits to the right. The square root of the result is then multiplied with the appropriate offset value.

Results:  $U_{L1-N}, U_{L2-N}, U_{L3-N}, U_{L12}, U_{L23}, U_{L31}, I_{L1}, I_{L2}, I_{L3}$ . Unsigned numbers.

#### Active power

During the sampling phase, after the zero error has been subtracted, values for current and voltage are mutually multiplied in pairs. During the calculation phase their sum is divided by the number of collected values. The result is then multiplied with a compensation factor which takes the errors for voltage and current into account.

Five different cases must be considered:

##### a) Single-phase system

Only one voltage and one current must be considered. The voltage is  $U_{L1-N}$ , the current is  $I_{L1}$ . The power is

$$P = \frac{\sum_1^n (U_{L1-N} \cdot I_{L1})}{n} \cdot \sqrt{3}$$

Equation 3

##### b) Three-wire system with random load

During the sampling phase  $(U_{L1-N} - U_{L2-N}) \cdot I_{L1}$ ,  $(U_{L3-N} - U_{L1-N}) \cdot I_{L3}$  must be calculated. Both products are accumulated in P1 and P2. The division is followed by the correction, the sum of the two values is the result.

$$\text{Equation 4} \quad P = \frac{\sum_1^n ([U_{L1-N} - U_{L2-N}] \cdot I_{L1}) + \sum_1^n ([U_{L3-N} - U_{L1-N}] \cdot I_{L3})}{n}$$

c) Three-wire system with equal load

The voltages  $U_{L1-2}$  and  $U_{L3-1}$ , and the current  $I_{L1}$  are given. The power is calculated in accordance with Equation 5.

$$\text{Equation 5} \quad P = \frac{\sum_1^n \left( U_{L1-2} - \frac{U_{L3-1}}{2} \right) \cdot I_{L1}}{n} \cdot \frac{2}{3} \sqrt{3}$$

d) Four-wire system with random load

During the sampling phase  $U_{L1-N} \cdot I_{L1}$ ,  $U_{L2-N} \cdot I_{L2}$  and  $U_{L3-N} \cdot I_{L3}$  are calculated. The three products are accumulated separately in P1, P2 and P3. The division is followed by the correction. The sum of the three values is the result.

$$\text{Equation 6} \quad P = \frac{\sum_1^n (U_{L1-N} \cdot I_{L1}) + \sum_1^n (U_{L2-N} \cdot I_{L2}) + \sum_1^n (U_{L3-N} \cdot I_{L3})}{n}$$

e) Four-wire system with equal load

Only the current  $I_{L1}$  and the voltage  $U_{L1-N}$  are used.

$$\text{Equation 3} \quad U = \frac{1}{n} \cdot \sum_1^n (U_{L1-N} \cdot I_{L1}) \cdot 3$$

Result: P      signed numerals

### Reactive power

The reactive power is determined like the active power, however, instead of the current values for  $U_{L1-E}$  the quantity which was collected 90° earlier is chosen.

Result: Q      signed numbers.

### Apparent power

The apparent power is the sum of the products from  $U_{L1-N}$  and  $I_{L1}$ ,  $U_{L2-N}$  and  $I_{L2}$ ,  $U_{L3-N}$  and  $I_{L3}$ , an unsigned number.

### Power factor cos φ

The power factor is the ratio of active power to apparent power. It is negative for capacitive load and positive for inductive load. The value must be a number in the range of -0.1..+0. Results greater than 1.0, due to rounding errors, are reduced to 1.0.



In the operating mode IEC 870-5-103, the qualifying symbol of the measuring value transferred through the bus depends on the energy flow direction of the active power.

If the apparent power is less than 1 % of the measuring range, the  $\cos \varphi$  is set to one because the measuring accuracy deteriorates and the resulting dispersion of the measured quantity becomes too large. This applies to program versions from V02.00.07 on, for previous versions the limit value is 5 %.

### Phase angle

The phase angle is calculated from reactive power/active power (tangent) and active power/apparent power (cosine). At first the quadrant is determined, then the angle is obtained from tables as arctan (up to 45°) or arccos (between 45 and 90°).

For the analog output, please consider that the total measuring range extends from -216 to +216 degrees, i. e. that it contains 10% hysteresis in order to prevent jumping between -180 and +180.

0° is equivalent to 0 points, 90° is equivalent to +2048 points. If the apparent power is less than 1 % of the measuring range, the phase angle is set to zero because the measuring accuracy deteriorates and the resulting dispersion of the measured quantity becomes too large. This applies to program versions from V02.00.07 on, for previous versions the limit value is 5 %.

### Frequency

The duration of three cycles is measured and the frequency is calculated with a resolution of 1.25 mHz. The deviation in mHz of the frequency from the nominal value is stated as the result. The central value, 50 or 60 Hz, is entered with the parameters. If the voltage  $U_{L1-N}$  is less than 20% of the measuring range, the frequency display is set to -5Hz,. The scanning frequency, however, maintains the value which was determined by the last measured system frequency. If the voltage is less than 30V, the frequency display and the scanning frequency remain unchanged.

### 3.1.3 Application of Correction Factors

The measuring values are multiplied with the appropriate correction factors. Correction factors are the reciprocal of the relative errors in the measuring chain from the input to the A/D-converter. They are determined during the calibration. More details in Chapter 4.2.

## 3.2 Output of Analog Measuring Values

The device is equipped with three channels for the output of analog values  $\pm 10\text{ V}$  or  $\pm 20\text{ mA}$ . In regular intervals a pulse is sent to the output amplifiers or is terminated. A complete cycle has a total of 2048 pulses. The mean values of the pulses in proportion to the period of oscillation determine the measuring value. The zero point is 1024. The ripple content of the output signal is less than 0.5% of the en-of scale limit. The noise-shaping method is used instead of the simpler pulse-width modulation in order to limit the time factor for the filtering process.<sup>1</sup> Impulses have a duration of 128  $\mu\text{s}$ . 262 ms are required for the complete cycle of 2048 steps.

Note:

This interface is electrically connected to the analog output 1. If the interface is earthed (for bus operation or in notebooks without battery), analog output 1 must not be earthed. The transducer could be destroyed if this is disregarded.

<sup>1</sup>Reinhard Fritz, Armin Holz, An alternative to pulse width modulation, Elektronik 19/1993

### 3.2.1 Calculation of Ranges

The total range of the output quantity is 0 to 2047 pulses. The signal is provided with the offset 1024 due to the two possible energy flow directions. However, the output signal is not limited to the upper range value 20 mA or 10 V respectively which allows an over-range of at least 20% in each direction. The numerical values required for the modulation are adjusted together with the offset value discussed below.

### 3.2.2 Application of Correction Values

Output amplifiers are marked by zero point and amplification errors. The appropriate corrections are memorized and included in the output in accordance with Equation 8.

Equation 8 
$$A = (M \cdot K) + N + 1024$$

A	Output value in points
M	Measured result
K	Correction of amplification error
N	Correction of offset error

### 3.3 Numerical Output

The measuring results can be delivered in numerical form via the serial interface. More details can be found in the section "Parameter Assignment - Scan for Measuring Values". Five positions are reserved for each result, four digits and one negative qualifying symbol. The numbers are always left-justified and any missing digit positions are filled with blanks. In the program version V01... the measuring value zero is treated the same as non-existing measuring points, i.e. by displaying blanks. However, program version V02.00.07 and later treat the measuring value zero by displaying a zero with four subsequent blanks. The following table contains a few examples.

Numerical value	Output format	Program version
1129	1129#	all
-4096	-4096	all
7	7####	all
-2	-2###	all
0	#####	up to V02.00.03
0	0####	from V02.00.07 on

Table 3: Numerical format

The symbol # represents a blank. The measuring value zero is treated differently depending on the program version. These numerical values are dimensionless and have to be calculated into results with proper dimensions by considering the set ranges and the used transformers. The ranges are taken from Table 7 and the appropriate numerical values from Table 8. The calculation follows Equation 9.

Equation 9 
$$M = \frac{Z}{K} \cdot B$$

M	correctly dimensioned measuring value
Z	output numerical value
K	range constant from Table 8
B	measuring range from Table 7

The transmission ratios of any connected transformers also have to be taken into consideration.

Example 1:

preconditions:	Z = 1129	B = 90 V
from Table 8:	K = 4096	

according. to Equation. 9:  $M = \frac{1129}{4096} \cdot 90 = 24.8V$

Example 2:

preconditions:  $Z = 392$   $B = 90 V \times 2 A \times 3 = 540 W$   
(factor 3 due to four-wire measurement)

from Table 8:  $K = 8192$

according to Equation 9:  $M = \frac{392}{8192} \cdot 90 \cdot 2 \cdot 3 = 25.84 W$

Example 3:

preconditions:  $Z = -2$   $B = 50 \pm 5 Hz$

from Table 8:  $K = 4096$

according to Equation 9:  $M = \frac{-2}{4096} \cdot 5 = -2.44 mHz$

This value is the deviation from the nominal value 50.000 Hz, the result is therefore 49.998 Hz.

### 3.4 Input of Correction Values

Zero point errors of amplifiers, deviations of resistance values from nominal values, transformation errors of transformers, and errors in reference voltages result in measuring errors. Reference signals are applied to the device in order to determine these errors and the appropriate correct numerical values are transferred via the serial interface. The transducer calculates the required correction factors and stores them in an EEPROM.

#### 3.4.1 Corrections for Measuring Errors on the Input Side

The calibration of the devices requires a reference source which can be set to specific signals by manual control or by means of a personal computer. The corresponding setpoint values are transferred via the serial interface. Following a transient recovery time of one second, the transducer calculates and stores the errors and offset values for currents and voltages. The data is collected separately for each input and for three voltage ranges and three current ranges, i.e. a total of 18 offset values, cf. Table 1. The calculation method is stated in Equation 9. The PC program transfers the "correct values" as points of the operand.

Equation 10 
$$K = \frac{\text{correct value}}{\text{measured value}} \cdot 1024$$

Measured quantity	Gain	Correction value
voltage $U_{L1}$	2	K11
	5	K12
	10	K13
voltage $U_{L2}$	2	K21
	5	K22
	10	K23
voltage $U_{L3}$	2	K31
	5	K32
	10	K33
current $I_{L1}$	2	K41
	5	K42
	10	K43
current $I_{L2}$	2	K51
	5	K52
	10	K53
	2	K61

current $I_{L3}$	5	K62
	10	K63

Table 4: correction factors for inputs

### 3.4.2 Corrections for Errors on the Output Side

The correction of the output amplifier errors requires the measurement of the output signals 10 V and 20 mA. For each output channel only the errors for one signal type, current or voltage can be determined. For this reason, the correct setting of the bridge circuits must be ensured.

Via the serial interface, commands for the output of zero point and nominal value of the output variables are issued to the transducer. The corresponding values are measured at its output and errors are returned via the interface to the transducer. Here, three offset values and three correction factors are stored.

## 3.5 Parameter Assignment

The parameter assignment tells the transducer which measuring ranges apply for current and voltage, which method of measurement to use, which results are passed to the outputs, and which ranges must be set up for this purpose. Furthermore, the data signaling rate is set and various data are stored which are not required for the operation of the transducer, but which are needed for the parameter assignment and the calibration by the program SIMEAS PAR. Finally, several operating modes can be selected, i.e. the basic operating mode and various operating modes of the IEC 870-5-103 bus protocol.

### 3.5.1 Response Delay

The parameter assignment of a transducer with bus interface in accordance with RS-485 with the help of the program SIMEAS PAR requires a delay of the transducer response. This is necessary in order to allow the program sufficient time to switch the interface from sending to receiving mode. This delay can be set from 0 to 3 seconds in increments of 0.1 s. It must be noted that the communication during the parameter assignment is slowed down by this. The telegram (cf. 4.3.1 Setting the Operating Mode) contains the data for the parameter assignment.

An additional response delay applies to the operation in accordance with IEC 870-5-103. Before responding to a command from the central processor, a waiting time of four characters (44 increments) is always maintained. This allows the central processing unit to switch the data direction to reception before the first response character arrives.

### 3.5.2 Input Values

The transducer features three measuring ranges for current and voltage. In order to ensure the highest possible measuring accuracy on the one hand and on the other hand to avoid overloads, the measuring ranges need to be switched in accordance with the input. This is done by switching the amplification. For each one of the current inputs and for each one of the voltage inputs, three measuring ranges and accordingly three amplification factors are available. The data is listed in Table 5. The voltages apply for the connection between conductor and earth (terminals  $U_{L1-N}$ ,  $U_{L2-N}$ ,  $U_{L3-N}$  of the transducer), i.e. star-connection in a three-phase system. In a three-wire system, the star point is formed in the transducer. For single-phase connection the value between terminals U and N applies.

Voltage range V	Voltage gain	Current range	Current gain
90	10	2	10
180	5	4	5
450	2	10	2

Table 5: Measuring ranges and gain factors

The program for parameter assignment SIMEAS PAR automatically determines the two gain factors on the basis of the user defined nominal values for current and voltage. The values given for the current are absolute upper range values which will cause additional measuring errors if exceeded.

Voltages in the 90 V range are tolerated up to twice the nominal value. However, this does not apply to the 180 and 450 V ranges.

### 3.5.3 Methods of Measurement

Six different methods of measurement can be selected:

- M1 Single-phase system  
Only the voltage connection UL1-N and the current connection IL1k-IL1l are used.  
All transformers can be present. Then, one must consider that the measured voltage quantity covers other ranges.  
Note:  
If only one transformer is used to save costs, the series resistor must be doubled.
- M2 Three-wire system with random load  
All three phase-to-phase voltages (without zero point) must be present, also the currents IL1 and IL3.
- M3 Three-wire system with equal load  
Voltages as in case 2, current only IL1.
- M4 Four-wire system with random load  
All three voltages and all three currents must be present.
- M5 Four-wire system with equal load  
All three voltages present, but only current IL1.
- M6 Special version Individual Phase Power  
Four-wire system with random load, only certain measurands.

Depending on the applied method of measurement, up to 25 results are possible. All of them are calculated at all times. From the first 16, a random selection of three can be distributed to the three outputs, cf. Table 6.

	Mode	M1	M2	M3	M4	M5	M6
R no.	Measuring point						
1	$U_{L1-N}$	AB			AB	AB	A
2	$U_{L2-N}$				AB		A
3	$U_{L3-N}$				AB		A
4	$I_{L1}$	AB	AB	AB	AB	AB	A
5	$I_{L2}$				AB		A
6	$I_{L3}$		AB		AB		A
7	$U_{L1-2}$		AB	AB	AB		A
8	$U_{L2-3}$		AB	AB	AB		A
9	$U_{L3-1}$		AB	AB	AB		A
10	P	AB	AB	AB	AB	AB	A
11	Q	AB	AB	AB	AB	AB	A

12	S	AB	AB	AB	AB	AB	A
13	$\cos \varphi$	AB	AB	AB	AB	AB	A
14	$\varphi$	AB	AB	AB	AB	AB	A
15	F	AB	AB	AB	AB	AB	A
16	$U_{E-N}$				B		
17	$P_{L1}$						B
18	$P_{L2}$						B
19	$P_{L3}$						B
20	$Q_{L1}$						B
21	$Q_{L2}$						B
22	$Q_{L3}$						B
23	$\cos \varphi_{L1}$						B
24	$\cos \varphi_{L2}$						B
25	$\cos \varphi_{L3}$						B

Table 6: Results for various methods of measurement

M1	Single-phase system
M2	Three-wire system with random load
M3	Three-wire system with equal load
M4	Four-wire system with random load
M5	Four-wire system with equal load
M6	Special version Individual Phase Power
R NR. 1... 25	Results

## Explanation of symbols

A	Only used for analog outputs
B	Only used for IEC 870-5-103
AB	Used for analog outputs and IEC 870-5-103

From the results R1 to R15, a random selection of three can be distributed to the outputs. R1 to R8 and R12 are unsigned quantities which create one-sided output signals. All others can create signals of changing polarity for the analog output. The results 17 to 25 are reserved for the special case M6 and are only used for IEC 870-5-103. Result 16 is also reserved exclusively for transfer in IEC 870-5-103.

The allocation of measuring points to analog outputs and bus is defined by the parameter software SIMEAS PAR and the standard DOS version. Following a suitable modification of the programs, the measuring points labeled only with B could also be used for this purpose.

### 3.5.4 Amplitudes of Output Values

In order to define the amplitudes of the outputs, factors are entered which transform the results determined by the input variables into output variables. Due to the complicated calculations which are required only once during the parameter assignment, these factors are calculated by the program "SIMEAS PAR" in a PC and transferred to the transducer.

For the measuring points voltage and current, three input ranges must be considered which result from the amplification factors. The result is a specific number for volt or ampere per point. However,

the r.m.s. value of the end-of-scale value for current and voltage is always 4096 points for the upper range value. For the derived quantities active and reactive power, the range is -8192 to +8192 points, apparent power 0-8192 points. These larger values allow for permissible overcurrents and overvoltages and consequently that nominal values reach only a fraction of their numerical value.

The power factor  $\cos \varphi$  ranges from -4096 to +4096 for  $\cos (-90^\circ)\dots\cos (0^\circ)\dots\cos (90^\circ)$ . The absolute value is the basis for the calculation of the active power, which allows the representation of quadrants three and four in exactly the same way as quadrants one and two. However, the energy flow direction can be indicated via the binary output.

Special provisions must be considered for the phase angle. In the intended range of  $\pm 180^\circ$ , it can happen that the measuring value reciprocates between negative and positive full-scale deflection if systems of alternating energy flow direction approach an active power of zero. This behavior can neither be accepted for mechanical indicators nor for recording instruments and, therefore, a hysteresis is required. This is the reason why the range was defined as  $\pm 216^\circ$ . Only if this limit is exceeded, a jump of  $180^\circ$  occurs.

End-of-scale value current	Current gain	End-of-scale value voltage	Voltage gain	End-of-scale power per phase (W, VA, Var)
2 A	10	90V	10	180
4 A	5	90 V	10	360
10 A	2	90 V	10	900
2 A	10	180 V	5	360
4 A	5	180 V	5	720
10 A	2	180 V	5	1800
2 A	10	450 V	2	900
4 A	5	450 V	2	1800
10 A	2	450 V	2	4500

Table 7: End-of-scale values of the effective measured quantity for the point value 4096 (for powers 8192)

Table 8 contains points for possible ranges of all measured quantities.

Measured quantity	Start points	End points	Phys. range
r.m.s. values	0	4096	cf. Table 7
outputs	-8192	8192	cf. Table 7
angle	-4915	4915	-216 +216°
power factor	-4096	4096	-0...1...+0
frequency	-4096	4096	$\pm 5$ Hz

Table 8: Machine value of measuring values

For the control of the output amplifiers, the calculated point values are converted to numerical values which allow a positive control with sufficient resolution, e.g. 2048 points for the range from -20 to +20 mA.

The frequency is multiplied with a weighting factor which represents the deviation from the central value in available points. An offset value allows the displacement of the central value to one side. More details in Chapter 4.1.3.

### 3.5.5 Scan for Parameters

The basic logic function allows the output on demand of all memorized operational parameters as a telegram via the serial interface. This telegram includes the program version and the date of the last parameter modification. The structure of the telegram is described in the section on "Telegram Formats".

A scan for parameters is not included in the operating mode IEC 870-5-103. The basic logic function needs to be selected first. More details can be found in Chapter 5.3.4.

### 3.5.6 Scan for Measuring Values

On demand all current measuring results which comply with the parameters for the method of measurement (cf. Table 6) can be read out as telegram via the serial interface. The telegram structure for the basic logic function is described in the section on telegram formats. Details on the corresponding functions in the operating mode IEC 870-5-103 can be found in Chapter 5.

## 4 PC Interface

The interface for the PC supports three functions: parameter assignment, calibration, and testing of the transducer. The calibration is usually carried out by the manufacturer for all possible measuring ranges. The parameter assignment can be carried out by the manufacturer or the customer, it defines measuring ranges and methods of measurement, and also the allocation of measuring points to the outputs. Testing involves the transfer of currently measured quantities to the personal computer and, by comparison with applied quantities, the calculation of measuring errors.

These functions are not active in the operating mode IEC 870-5-103. The interface is exclusively reserved for bus traffic in this mode.

### 4.1 Parameter Assignment

#### 4.1.1 Measuring Ranges

The parameter assignment involves the input of the gain factors and is used to inform the transducer of the applicable measuring ranges for voltage and current. Each of the three factors for both quantities are set by the manufacturer one after the other which is followed by a calibration. Before shipping or on the customer's premises the required range is selected by another parameter assignment.

#### 4.1.2 Allocation of Outputs

The measuring results are filed in a table in the transducer. Up to three of these quantities (cf. Table 6) can be assigned to the three outputs. In this fashion, resulting quantities are linked with outputs. In addition to this the display range for each output must be set. This range must not be the same as the nominal value of the result (cf. Chapter 4.1.3).

#### 4.1.3 Setting the Display Range for Outputs

The device is equipped with different input ranges for current, voltage, power etc. Likewise, there are different output ranges, e.g. 0 to 20 mA, 0 to 10 V etc. Standard values are used for both inputs and outputs in order to allow a simple representation of the settings for output ranges and their allocation to the input ranges. Every input range, regardless whether current or voltage, power or frequency, is allocated to the range

**-1..0..+1.**

The same applies to the outputs which, independent of type, current or voltage, and of the range ( $\pm 20$  mA,  $\pm 10$  V), are also set to a standard

**-1..0..+1**

However, some measured quantities are absolute values that can never become negative, such as the r.m.s. values for voltages and currents. In most cases the outputs are used for one side only (0..20 mA). In these cases the negative portion is simply ignored.

In rare cases will the total input range be mapped in a 1:1 ratio onto the output range. However, the usual case will be that a portion of the possible input range is mapped by part of the output range whereby both values can be different fractions of one. This requires input of a factor which effects the adjustment. The following example will explain this. A setting to 2 A and 180 V results in a power for



the measuring range on the input end of 360 W per phase, i. e. a range of ±1080 W. Provided an output of ±20 mA and a factor of 1, this current has a power of exactly this magnitude. But, if the customer desires another correlation, e.g. ±1000 W for ±20 mA, then the factor must be greater than one because a smaller input range would lead to a full-scale deflection. The factor is determined by:

Equation 11 
$$\text{Factor} = \frac{\text{normalized output range}}{\text{normalized input range}}$$

Rule:

Equation 12 
$$\text{normalized output range} = \frac{\text{nominal value}}{\text{range}} = \frac{20 \text{ mA}}{20 \text{ mA}} = 1$$

and

Equation 13 
$$\text{normalized input range} = \frac{\text{nominal value}}{\text{range}} = \frac{1000 \text{ W}}{1080 \text{ W}} = 0.926$$

The factor is determined in accordance with Equation 11:

Equation 14 
$$F = \frac{1}{0.926} = 1.08.$$

The zero point of the input quantity in this case is the same as the zero point of the output signal, i. e. no displacement by entering an offset value is required, and it is also zero.

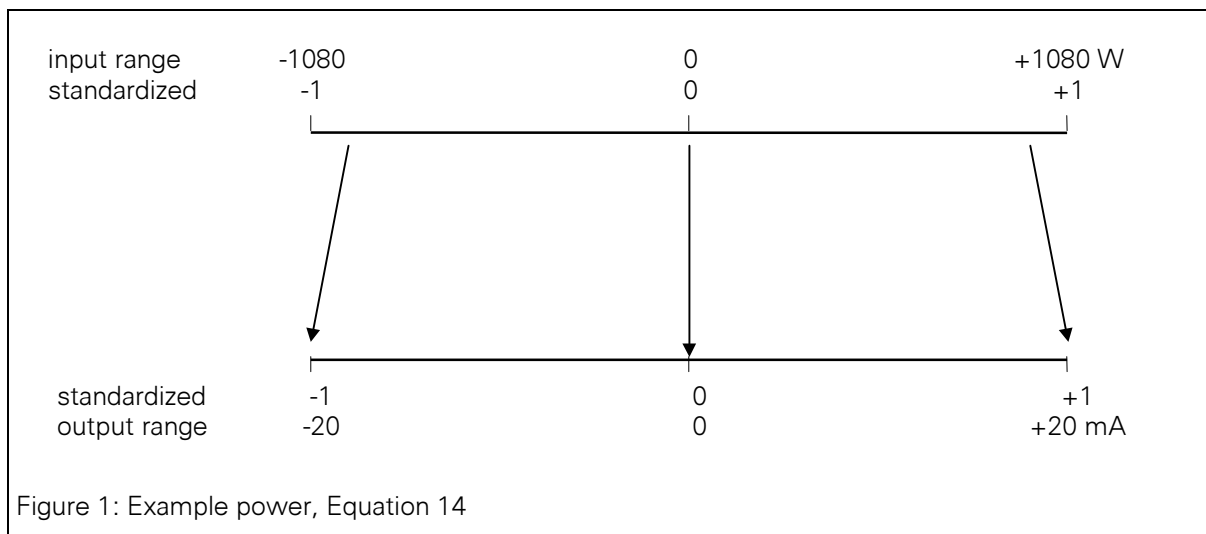


Figure 1 shows how the range of ±1000 W is projected to the output by the factor calculated in Equation 14.

This factor is transferred to the transducer not as a decimal fraction, but in the form of numerator and denominator of a proper fraction, whereby the denominator should be a power of two, if possible not smaller than 4096, and have not more than four digits.

If the measuring value to be displayed refers to the primary side of the transducer, voltage, current, and power must be converted to secondary values before Equation 14 can be used, and consequently Equation 19 must be used for the example from above.

Equation 15: voltage 
$$U_{\text{secondary}} = U_{\text{primary}} \frac{\text{transformer}_{\text{secondary}}}{\text{transformer}_{\text{primary}}}$$

$U_{secondary}$  voltage at the transducer  
 $U_{primary}$  primary voltage  
 $transformer_{secondary}$  nominal value of voltage of transformer on the secondary side  
 $transformer_{primary}$  nominal value of voltage of transformer on the primary side

Equation 16: current 
$$I_{secondary} = I_{primary} \frac{transformer_{secondary}}{transformer_{primary}}$$

$I_{secondary}$  current at the transducer  
 $I_{primary}$  primary current  
 $transformer_{secondary}$  nominal value of current of transformer on the secondary side  
 $transformer_{primary}$  nominal value of current of transformer on the primary side

Equation 17: power 
$$P_{secondary} = P_{primary} \frac{U_{secondary}}{U_{primary}} \cdot \frac{I_{secondary}}{I_{primary}}$$

$P_{secondary}$  power at the transducer  
 $P_{primary}$  primary power  
 $U_{secondary}$  nominal value of voltage of transformer on the secondary side  
 $U_{primary}$  nominal value of voltage of transformer on the primary side  
 $I_{secondary}$  nominal value of current of transformer on the secondary side  
 $I_{primary}$  nominal value of current of transformer on the secondary side

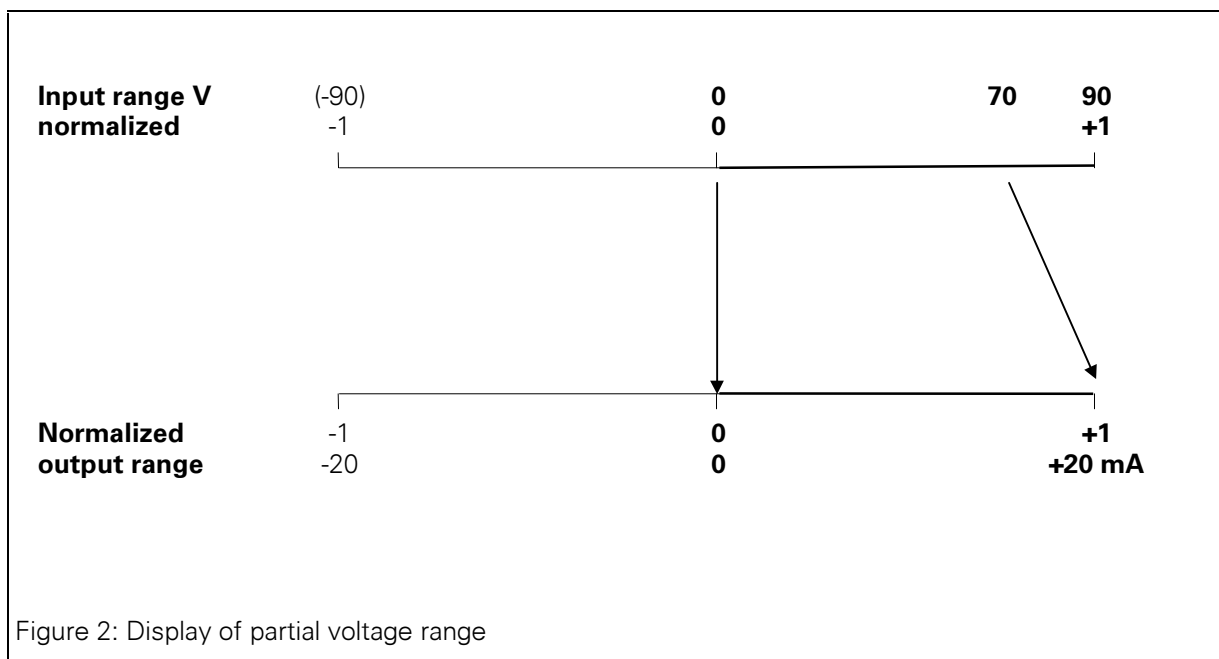


Figure 2 is another example of how the partial range from 0 to 70 V out of the measuring range 0 to 90 V is projected onto the output from 0 to 20 mA.

In this example: **0**=0 V and **+1**=90 V.

Only the positive output signal is used for the output quantity, **0**=0 mA and **+1**=20 mA.

The standardized output range in accordance with Equation 12 is 1.

The standardized input range in accordance with Equation 13 is 70/90.

This yields a factor of 1.2857. Following the multiplication with 4096 it becomes the numerator of the fraction to be transferred, the denominator is 4096.

For the example from Figure 2 the following applies to the calculation of the factor:

Equation 18 
$$F = \frac{\text{normalized output range}}{\text{normalized input range}} = \frac{1}{\frac{70}{90}} = \frac{1}{0.7777} = 1.2857 = \frac{5266}{4096}$$

The zero point of the output current also yields the zero point of the input voltage. There is no displacement and therefore the value for the offset is zero.

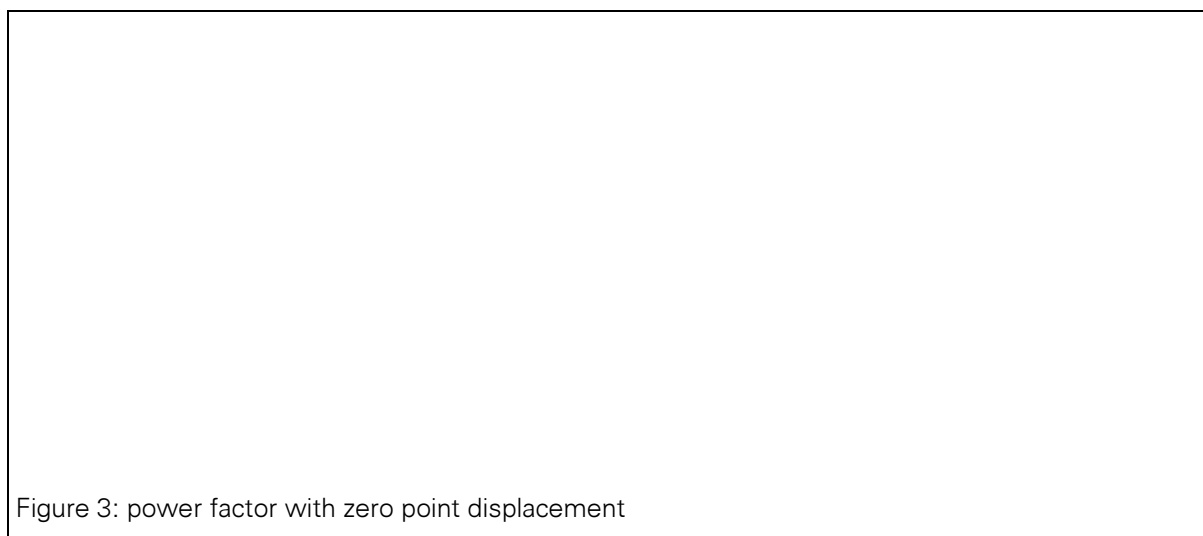


Figure 3: power factor with zero point displacement

**Input cos φ**      -0                      -0.5                      1                      +0.5                      +0  
**normalized**      -1                      -0.5                      0                      +0.5                      +1

Using the power factor as an example, here is a demonstration for factor and offset for a measured quantity of alternating polarity. Figure 3 shows how the range of ± 0.5 of the power factor is projected on the current from 0 to 20 mA.

Here the factor is calculated in accordance with the following equation:

Equation 19 
$$F = \frac{\text{normalized output range}}{\text{normalized input range}} = \frac{0 - 1}{+0.5 - (-0.5)} = 1 = \frac{4096}{4096}$$

The factor 1 is transferred as the number 4096, the corresponding denominator is also 4096.

Offset is +0.5, since the standardized measurand -0.5 is to be projected on the standardized output value 0. The corresponding equation is:

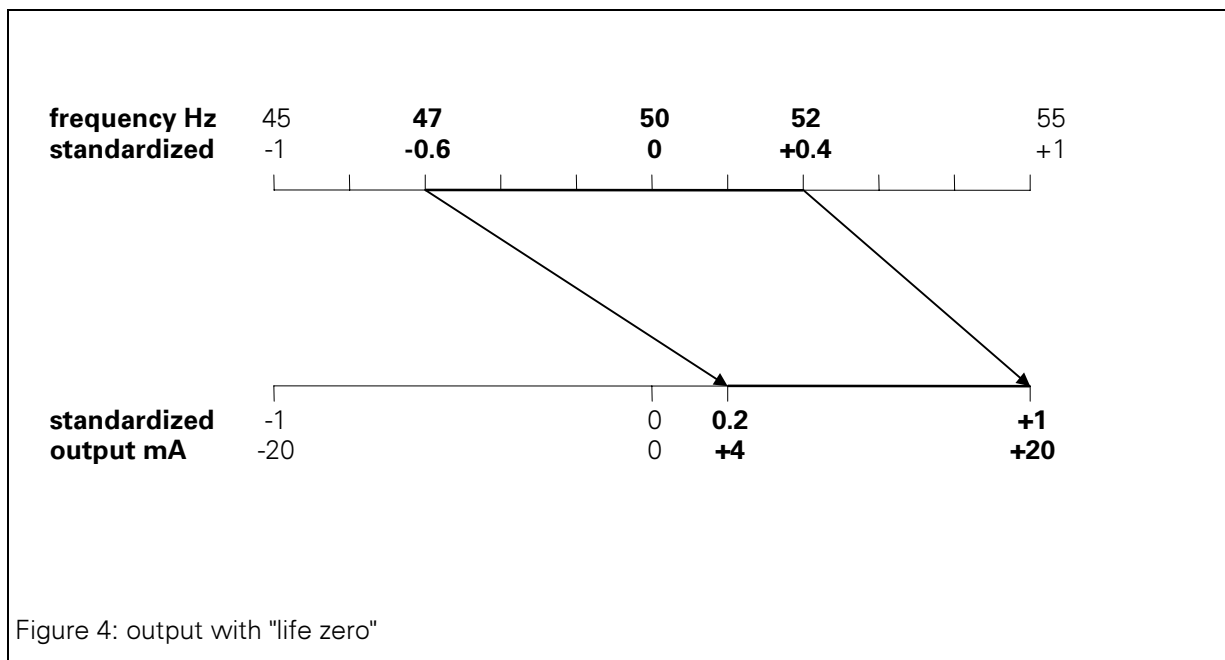
Equation 20 
$$O = A_N - M_N \cdot F = 0 - (-0.5 \cdot 1) = 0.5 = \frac{2048}{4096}$$

- O      offset
- A<sub>N</sub>    standardized output value for zero
- M<sub>N</sub>    standardized measurand, intended as zero point
- F      factor from Equation 19

The offset is transferred as the number 2048 (numerator). The appropriate denominator is 4096, the same as for the factor.

This example can be adapted to other measurands of alternating polarity, such as power, frequency and angle if they are intended for display as unipolar output signal.

The consideration of "life zero" is demonstrated in the following example with Figure 4. Here the partial range from 47 to 52 Hz of the total measuring range of 45 to 55 Hz is projected on an output of 4 to 20 mA.



The factor is calculated in accordance with Equation 11:

Equation 21 
$$F = \frac{1 - 0.2}{0.4 - (-0.6)} = \frac{0.8}{1.0} = 0.8$$

Numerator and denominator of the fraction are therefore 0.8·4096=3276.8 and 4096. Standard business rounding converts the first decimal behind the decimal point to zero and it is deleted, the value before the decimal point increases by one and the result is 3277. The resulting error is negligible.

The offset is the difference between the standardized output value for the zero point and the standardized measured input value for the zero point.

Equation 22 
$$O = A_N - M_N \cdot F$$

O normalized offset  
 A<sub>N</sub> zero point normalized output  
 M<sub>N</sub> standardized measured input value for the output zero point  
 F factor from Equation 21

The values from Figure 4 used in Equation 22 yield the following:

Equation 4 
$$O = 0.2 - (-0.6) \cdot 0.8 = 0.68$$

Only the numerator has to be calculated since the denominator is already defined as 4096. The numerator is calculated as follows:

Equation 5 
$$Z = 0.68 \cdot 4096 = 2785.28$$

After rounding the result is the integer number 2785.

#### 4.1.4 Methods of Measurement

The system constellation, existing instrument transformers, or the customer's requirements determine which method of measurement is to be chosen. The method of measurement "four-wire system" must be used for calibrations.

### 4.2 Calibration

The transducer is factory calibrated for all possible measuring ranges. Offset values are stored internally.

#### 4.2.1 Readjustment of Inputs

The device is switched to the method of measurement four-wire system. For the calibration of the voltage channels, a reference voltage is applied in parallel to all three voltage inputs and the transducer is informed by the PC of the magnitude of the applied voltage. It has to be constant for at least two seconds and should lie between 50 and 75% of the full-scale deflection. For the currents the corresponding channels are series-connected and the above method is suitably adapted. In both cases the calibration must be carried out for all three measuring ranges.

#### 4.2.2 Readjustment of Outputs

Telegram "K" is used by the PC to inform the transducer of zero point and full-scale deflection for all three outputs. The actual output quantity is measured, the error is determined, and the offset value is given in points per channel. If 2048 was entered as the end-of-scale value, a correction to 22 mA or 11 V normally follows, except if overload capability is not required.

### 4.3 Telegram Formats

The transmission takes place in ASCII code, 2400 baud, 8N1. This is verified by forming a three-digit check sum. The basic structure of telegrams to the transducer is the following:

```
STX  A1  A2  BK1 BK2  Z1  Z2  Z3  data...  PS1  PS2  PS3  ETX
```

Explanation:

STX	02H	start character
A1, A2		device address
		00 to 99, decimal to program version V02.00.03
		00 to 0FFH, hexadecimal, from program version V02.00.07 on
BK1, BK2		command identifiers
Z1, Z2, Z3		number of characters in the data field, hundreds, tens, ones
data		data record, described below
PS1, 2, 3		arithmetic check sum from A1 to the last data character
		modulo 256, hundreds, tens, ones
ETX	03H	end character

Day, month, and year are stored in the transducer every time parameters or offset values are stored. In order not to expand the reception memory of the processor unnecessarily, the parameters are transferred one by one and not altogether in one packet.

In the program version V01, all addresses other than 1 to 99 are ignored, in version V02 ff. all addresses other than 0 to 254. The address 0 in version V01 and address 255 in version V02 are used for "broadcast transmission". Independent of the pre-set address, all devices accept telegrams with this address. This feature is used in V01 to address the transducer during parameter assignment and calibration even if its address is unknown. In the operating mode for IEC 870-5-103, this feature has additional significance for the communication process.

### 4.3.1 Data Direction PC - Transducer

#### Enable operation

STX '0' '0' 'A' '0' '0' '0' '0' PS1 PS2 PS3 ETX

This command disables the permanent output values intended for calibration and enables the output of measuring values if the first ones are available. The transmission of measuring values via the serial interface is stopped if it was in operation.

#### Send measuring values

STX '0' '0' 'B' '0' '0' '0' '0' PS1 PS2 PS3 ETX

The transducer is requested to send all currently measuring values once via the serial interface.

#### Send operational parameters

STX '0' '0' 'C' '0' '0' '0' '0' PS1 PS2 PS3 ETX

The transducer is requested to send all currently stored operational parameters once via the serial interface. These are

- method of measurement (system configuration)
- amplification factors
- allocation of outputs
- control variables for outputs (amplification, offset)
- program version
- date of last calibration

#### Send correction data

STX '0' '0' 'D' '0' '0' '0' '0' PS1 PS2 PS3 ETX

The transducer is requested to send all currently stored corrections once via the serial interface.

#### Amplification increments

STX '0' '0' 'E' '0' '0' '0' '2' D1 D2 PS1 PS2 PS3 ETX

D1 '0', '1', '2' for factors 2, 5, 10 of the voltage channels

D2 '0', '1', '2' for factors 2, 5, 10 of the current channels

The amplification for the three voltage and the three current inputs is set to the specified values.

#### Method of measurement

STX '0' '0' 'F' '0' '0' '0' '1' D1 PS1 PS2 PS3 ETX

D1 method of power measurement in accordance with the following scheme

- '0' single-phase system
- '1' three-wire system with random load
- '2' three-wire system with equal load
- '3' four-wire system with random load
- '4' four-wire system with equal load
- '5' special version "single-phase outputs"

#### Allocation of output variables

STX '0' '0' 'G' '0' '0' '0' '6' D1 D2 D3 D4 D5 D6 PS1  
 PS2 PS3 ETX

- D1 number of the result value allocated to output 1, two digits  
 D2 number of the result value allocated to output 2, two digits  
 D3 number of the result value allocated to output 3, two digits  
 D4 zero limitation markers for output 1, one digit.  
 bit 0: 0 - 0mA , 1- 4mA  
 bit 1: 0 - no limitation , 1 - active limitation.  
 D5 zero limitation markers for output 2.  
 D6 zero limitation markers for output 3.

The numbers 1 to 15 are used for the numbering of the results R1 to R15 from Table 6.

### Range for output variables

STX '0' '0' 'H' n '0' '1' '5' D1 D2 D3 PS1 PS2 PS3 ETX

- n '0'...'2', the output number  
 D1 four-digit number with qualifying symbol and numerator. Offset for zero point (Th, H, T, O)  
 D2 four-digit number with qualifying symbol, numerator (Th, H, T, O)  
 D3 four-digit number with qualifying symbol, numerator (Th, H, T, O)

D2/D3 gives a factor with which the result is multiplied in order to use it as an output signal.  
 D1/D3 is the zero point offset

### Calibration by means of reference voltage

STX '0' '0' 'I' '0' '0' '1' '0' D1t D1h D1z D1e  
 Tz Te Mz Me Jz Je PS1 PS2 PS3 ETX

- D1n four-digit numerical value (thousands, hundreds, tens, ones) which results after applying a reference voltage to the inputs R-0, S-0 and T-0. Normalized to 2048 points.  
 D, M, Y 6 digits, date of calibration.

The individual numerical values always have the same number of digit positions and do not have a decimal point. This command is issued to the transducer after the reference values were applied unchanged for at least one second. The transducer compares these setpoint values with actual measuring values, calculates correction factors, and stores them with the date if the deviation was less than approximately 10%. Successful correction or error (if deviation too large) is reported back.

### Calibration by means of reference current

STX '0' '0' 'J' '0' '0' '1' '0' D1t D1h D1z D1e  
 Tz Te Mz Me Jz Je PS1 PS2 PS3 ETX

- D1n four-digit numerical value (thousands, hundreds, tens, ones) which results from the reference current flowing through the circuits  $I_R$ ,  $I_S$ , and  $I_T$ . Normalized to 2048 points.

D, M, Y 6 digits, date of calibration.  
 (cf. "Calibration by Means of Reference Voltage").

**Definition of output variables**

STX	'0'	'0'	'K'	'0'	'0'	'0'	'4'
	D1t	D1h	D1z	D1e			
	PS1	PS2	PS3	ETX			

D1 four-digit numerical value for random deflection, e.g. 0000 for minimal value or 2048 for maximum value.

**Correction of zero point error of an output**

STX	'0'	'0'	'L'	n	'0'	'1'	'1'				
	D1v	D1t	D1h	D1z	D1e	Tz	Te	Mz	Me	Jz	Je
	PS1	PS2	PS3	ETX							

n '0'...'2', the output number

D1 four-digit numerical value with qualifying symbol (5 digit positions, -4096 to +4096)

D, M, Y date

D1 is added to the output signal in order to correct the zero point error.

**Correction of the amplification error of an output**

STX	'0'	'0'	'M'	n	'0'	'1'	'5'				
	D1v	D1t	D1h	D1z	D1e	D2t	D2h	D2z	D2e		
	Tz	Te	Mz	Me	Jz	Je	PS1	PS2	PS3	ETX	

n '0'...'2', the output number

D1 numerator, four-digit numerical value with qualifying symbol (5 digits)

D2 denominator, four-digit numerical value without qualifying symbol (4 digits) = 4096

D, M, Y date

The output signal is multiplied with D1/D2 in order to correct the amplification error.

**Configuration of transducer address**

STX	'0'	'0'	'N'	'0'	'0'	'0'	'2'
	D1z	D1e	PS1	PS2	PS3	ETX	

D1 two-digit number

up to program version V02.00.03: decimal 00 to 99

from program version V02.00.07 on: hexadecimal 00 to 0FFH

00 is the broadcast address for the basic operating mode, telegrams with this address can be identified by all transducers in basic operating mode,

255 is the broadcast address for the operating mode IEC 870-5-103, telegrams with this address can be identified by all transducers in operating mode IEC 870-5-103.

**Entering central values for frequency**

STX	'0'	'0'	'0'	'0'	'0'	'1'
	D1	PS1	PS2	PS3	ETX	

D1 one-digit number, 0=16 2/3 Hz, 1=50 Hz, 2=60 Hz



**Setting the binary signal function**

STX '0' '0' 'P' '0' '0' '0' '7'  
 D1 D2 PS1 PS2 PS3 ETX

- D1 one-digit number,  
 1=signal active, if device is in operation.  
 2=generate energy pulses.  
 3=signal active for positive active power.  
 4=signal active for limit underflow of cos φ.
- D2 five-digit number with qualifying symbol. Either energy pulse or limit value for cos φ, depending on D1.  
 energy per pulse = 14745600/number of pulses per hour at end-of-scale power value.  
 limit value = cos φ \* 4096.

**Entering the transmission ratio for main transformer**

STX '0' '0' 'Q' '0' '0' '2' '0'  
 D1 D1 D1 D1 PS1 PS2 PS3 ETX

- D1 five-digit number, primary voltage in kV
- D1 five-digit number, secondary voltage in V
- D1 five-digit number, primary current in A
- D1 five-digit number, secondary current in A

**Sending the transmission ratio of main transformers**

STX '0' '0' 'R' '0' '0' '0' '0' PS1 PS2 PS3 ETX

The transducer is requested to send the transmission ratio of the main transformers once via the serial interface.

**Extended parameters - entering the measuring ranges for outputs**

STX '0' '0' 'S' '0' '0' '3' '0'  
 D1v D1t D1h D1z D1e  
 D2v D2t D2h D2z D2e  
 D3v D3t D3h D3z D3e  
 D4v D4t D4h D4z D4e  
 D5v D5t D5h D5z D5e  
 D6v D6t D6h D6z D6e  
 PS1 PS2 PS3 ETX

- D1,D2 measuring range min/max for output 1
- D3,D4 measuring range min/max for output 2
- D5,D6 measuring range min/max for output 3

**Request for extended parameters**

STX '0' '0' 'T' '0' '0' '0' '0'  
 PS1 PS2 PS3 ETX

The transducer is requested to send the data packet "extended parameters".

**Extended parameters - entering the nominal ranges of the inputs**

STX	'0'	'0'	'U'	'0'	'0'	'1'	'3'
	D1e						
	D2z	D2e					
	D3z	D3e					
	D4z	D4e					
	D5h	D5z	D5e				
	D6h	D6z	D6e				
	PS1	PS2	PS3	ETX			

D1                    operating mode  
D2, D3, D4        measuring ranges of display devices  
D5, D6             nominal input range for voltage and current.

**Setting the operating mode**

STX	'0'	'0'	'V'	'0'	'0'	'0'	'9'
	D1	D2	D3				
	D4h	D4z	D4e				
	D5h	D5z	D5e				
	PS1	PS2	PS3	ETX			

D1, D2        operating mode in accordance with the following scheme:

D1:            operating mode

'0'	basic operating mode with analog outputs
'1'	bus IEC 870-5-103
'2'	Profibus

D2:        version

For D1 = '0' hitherto only '0', D2 is ignored

For D1 = '1' the following applies to D2:

'0'	bus IEC 870-5-103, standard, 9 measuring values, ASDU 9
'1'	bus IEC 870-5-103, standard, 16 measuring values, ASDU 140
'2'	bus IEC 870-5-103, single-phase outputs, 9 measuring values, ASDU 140
'3'	reserve

D3:        baud rate

'0'	2400
'1'	4800
'2'	9600
'3'	19200

D4:        response delay in 1/10 seconds, 0 to 30, three-digit

D5:        "critical value", 0...255, number of inquiries for measuring values which yielded a response of "data not present" until another measuring value is sent.

**Scan for operating mode**

STX '0' '0' 'W' '0' '0' '0' '0'  
 PS1 PS2 PS3 ETX

The transducer is requested to send the currently selected operating mode.

**4.3.2 Data Direction Transducer - PC**

In this direction the transducer always sends its own address.

**Acknowledgment signal positive**

STX A1 A2 'a' '0' '0' '0' '0' PS1 PS2 PS3 ETX

The last received command was successfully executed.

**Acknowledgment signal negative**

STX A1 A2 'b' '0' '0' '0' '0' PS1 PS2 PS3 ETX

The last received command was not executed.

**Operational parameters**

STX A1 A2 'c' '0' '0' '7' '7'  
 D1 D2u D2i  
 D3<sub>1z</sub> D3<sub>1e</sub> D3<sub>2z</sub> D3<sub>2e</sub> D3<sub>3z</sub> D3<sub>3e</sub>  
 D4v D4t D4h D4z D4e  
 D5v D5t D5h D5z D5e  
 D6v D6t D6h D6z D6e  
 D7v D7t D7h D7z D7e  
 D8v D8t D8h D8z D8e  
 D9v D9t D9h D9z D9e  
 D10v D10t D10h D10z D10e  
 D11v D11t D11h D11z D11e  
 D12v D12t D12h D12z D12e  
 D13  
 D14  
 D15  
 D16  
 D17v D17zt D17t D17h D17z D17e  
 D18  
 D19<sub>1</sub> D19<sub>2</sub> D19<sub>3</sub> D19<sub>4</sub> D19<sub>5</sub> D19<sub>6</sub>  
 D20<sub>1</sub> D20<sub>2</sub> D20<sub>3</sub> D20<sub>4</sub> D20<sub>5</sub> D20<sub>6</sub>  
 PS1 PS2 PS3 ETX

- '0 7 7' 3 characters number of subsequent characters in data field, hundreds, tens, ones.
- D1 1 character method of measurement from '0' upward, as entered
- D2 2 characters amplification steps for voltage and for current, as entered
- D3 6 characters allocation of outputs, as entered
- D4-6 3 numbers integer numbers with offset values for outputs
- D7-9 3 numbers integer numbers with output factors, 3 numerators
- D10-12 3 numbers integer numbers with output factors, 3 denominators
- D13-15 3 characters bit markers for zero limitation of outputs  
 cf. "Allocation of Output Variables"
- D16 1 character binary output function; cf. "Setting the Binary Signal Function".
- D17 1 number energy per pulse or limit for cos φ times 4096.
- D18 1 character 0=16 2/3 Hz, 1=50 Hz, 2=60 Hz

D19	6 characters	program version, e.g.: 020103 stands for version V02.01.03
D20	6 characters	day, month, year of last calibration

### Corrections

STX	A1 PS3	A2 ETX	'd'	'0'	'0'	'6'	'0'	D1	...	D12	PS1	PS2
D1	1 number		integer number, normalized to 0-2048, correction $U_{L1-N}$									
D2	1 number		integer number, normalized to 0-2048, correction $U_{L2-N}$									
D3	1 number		integer number, normalized to 0-2048, correction $U_{L3-N}$									
D4	1 number		integer number, normalized to 0-2048, correction $I_{L1}$									
D5	1 number		integer number, normalized to 0-2048, correction $I_{L2}$									
D6	1 number		integer number, normalized to 0-2048, correction $I_{L3}$									
D7	2 numbers		integer number, normalized to 0-2048, correction factor output 1, numerator, denominator									
D8	2 numbers		integer number, normalized to 0-2048, correction factor output 2, numerator, denominator									
D9	2 numbers		integer number, normalized to 0-2048, correction factor output 3, numerator, denominator									
D10	1 number		integer number, normalized to 0-4096, correction zero point output 1									
D11	1 number		integer number, normalized to 0-4096, correction zero point output 2									
D12	1 number		integer number, normalized to 0-4096, correction zero point output 3									

### Current measuring values

STX	A1	A2	'e'	'0'	'0'	'7'	'5'
	D1v	D1t	D1h	D1z	D1e		
	D2v	D2t	D2h	D2z	D2e		
	D3v	D3t	D3h	D3z	D3e		
	D4v	D4t	D4h	D4z	D4e		
	D5v	D5t	D5h	D5z	D5e		
	D6v	D6t	D6h	D6z	D6e		
	D7v	D7t	D7h	D7z	D7e		
	D8v	D8t	D8h	D8z	D8e		
	D9v	D9t	D9h	D9z	D9e		
	D10v	D10t	D10h	D10z	D10e		
	D11v	D11t	D11h	D11z	D11e		
	D12v	D12t	D12h	D12z	D12e		
	D13v	D13t	D13h	D13z	D13e		
	D14v	D14t	D14h	D14z	D14e		
	D15v	D15t	D15h	D15z	D15e		
	PS1	PS2	PS3	ETX			

D1 to D15 are integer numbers with the corresponding results R1 to R15 (cf. Table 6, four digits with qualifying symbol). The numbers are the values before the conversion to quantities for analog output. Results that are not present in the chosen method of measurement are wildcards represented by blanks.

### Transmission ratio of main transformer

STX	A1	A2	'f'	'0'	'0'	'2'	'0'
	D1zt	D1t	D1h	D1z	D1e		
	D2zt	D2t	D2h	D2z	D2e		
	D3zt	D3t	D3h	D3z	D3e		

	D4zt	D4t	D4h	D4z	D4e
	PS1	PS2	PS3	ETX	
D1	1 number		primary voltage		in kV
D2	1 number		secondary voltage		in V
D3	1 number		primary current		in A
D4	1 number		secondary current		in A

**Extended parameters**

STX	A1	A2	'g'	'0'	'0'	'4'	'3'
	D1v	D1t	D1h	D1z	D1e		
	D2v	D2t	D2h	D2z	D2e		
	D3v	D3t	D3h	D3z	D3e		
	D4v	D4t	D4h	D4z	D4e		
	D5v	D5t	D5h	D5z	D5e		
	D6v	D6t	D6h	D6z	D6e		
	D7e						
	D8z	D8e					
	D9z	D9e					
	D10z	D10e					
	D11h	D11z	D11e				
	D12h	D12z	D12e				
	PS1	PS2	PS3	ETX			

D1,D2            measuring range min/max for output 1  
D3,D4            measuring range min/max for output 2  
D5,D6            measuring range min/max for output 3  
D7                operating mode  
D8, D9, D10     measuring ranges for display units  
D11,D12         nominal input range for voltage and current

**Report operating mode**

STX	A1	A2	'h'	'0'	'0'	'0'	'9'
	D1	D2	D3				
	D3h	D3z	D3e				
	D4h	D4z	D4e				
	PS1	PS2	PS3	ETX			

D1, D2            operating mode in accordance with the following scheme:

D1:                operating mode

- '0'            basic operating mode with analog outputs
- '1'            bus IEC 870-5-103
- '2'            reserve

D2:                version

For D1 = '0' hitherto only '0', D2 is ignored  
For D1 = '1' the following applies to D2:  
'0'            bus IEC 870-5-103, standard, 9 measuring values , ASDU 9  
'1'            bus IEC 870-5-103, standard, 16 measuring values, ASDU 140  
'2'            bus IEC 870-5-103, single-phase outputs, 9 measuring values, ASDU 140  
'3'            reserve

D3: baud rate

- '0' 2400
- '1' 4800
- '2' 9600
- '3' 19200

D4: response delay in 1/10 seconds, 0 to 30, three-digit

D5: "critical value", 0...255, number of inquiries for measuring values which yielded a response of "data not available" until another measuring value is sent.

### 4.3.3 List of Telegram Codes

To the transducer	
Code	Function
A	Ready for operation
B	Send measuring values
C	Send operational parameters
D	Send corrections
E	Adjust amplification steps
F	Set method of measurement
G	Allocate outputs
H	Set range for outputs
I	Calibration by means of reference voltage
J	Calibration by means of reference current
K	Specification of permanent output values
L	Zero point correction for output
M	Correction of amplification for output
N	Adjust transducer address
O	Parameter assignment for frequency
P	Parameter assignment for relay function
Q	Enter transmission ratio for main transformers
R	Send transmission ratio of main transformers
S	Extended parameters - measuring ranges
T	Request for extended parameters
U	Extended parameters - output ranges
V	Set operating mode
W	Request for operating mode

Table 9: Telegram codes to transducer

to PC	
Code	meaning
a	Acknowledgment signal positive
b	Acknowledgment signal negative
	Send operational parameters to PC
d	Send correction values to PC
e	Send current measuring values
f	Send primary and secondary parameters
g	Send extended parameters
h	Send operating mode

Table 10: Telegram codes to PC

### 4.4 Connections

Following the parameter assignment of the operating mode of a transducer, the used connections can be displayed and printed. Rule:

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
<b>SIEMENS</b>														
<b>Transducer SAMPLE</b>														
Serial number														
Auxiliary power														
Measured quantity														
Output														
I1			I2			I3								
k	l		k	l		k	l		N	L1	L2	L3		
1	2		3	4		5	6		7	8	9	10		

Figure 5: Transducer terminals

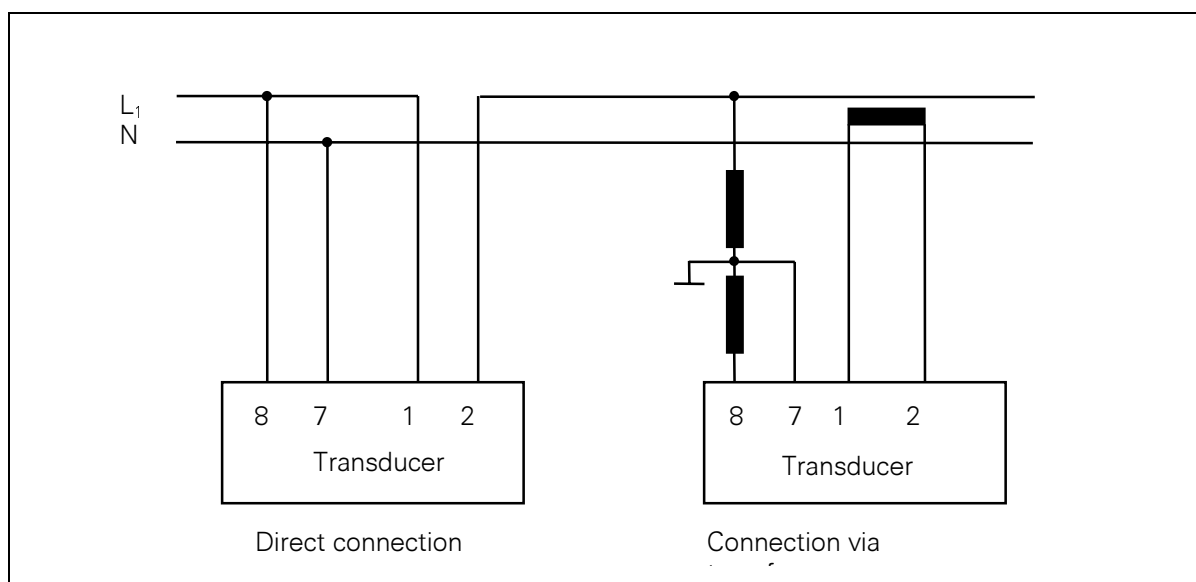


Figure 6: Single-phase network

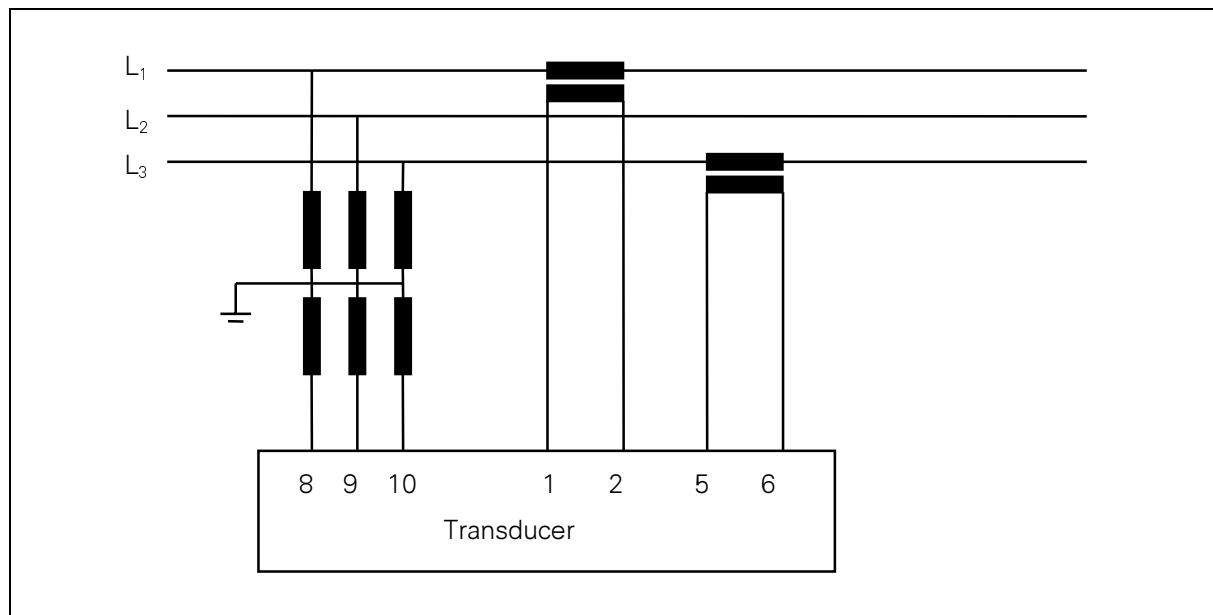


Figure 7: Three-wire system, transformer connection

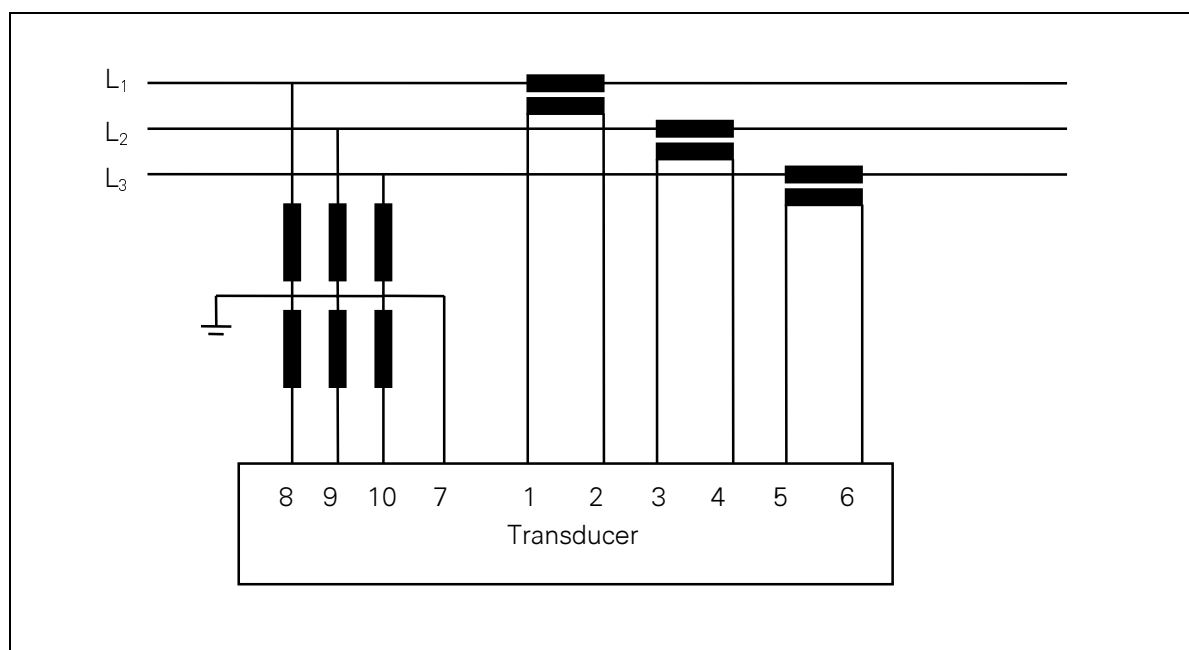


Figure 8: Four-wire system, transformer connection



## 5 Model IEC 870-5-103

The model designed for operation with IEC 870-5-103 is equipped with a processor with larger main memory than the basic version. In addition the EEPROM has twice the capacity. The serial interface is equipped in accordance with the EIA RS-485 standard.

### 5.1 Field of Application

The transducer can also be connected to bus systems configured in accordance with IEC 870-5-103. In accordance with the selected operating mode, up to 16 measuring values can be read. Their presentation is determined by DIN 19244 and VDEW.

The output of analog measured quantities is not adversely affected by the bus connection. However, one of the channels has a galvanic connection with the bus potential if the bus was connected in accordance with the EAI RS-485 standard. This restriction does not apply for operation with optical fibers. An external conversion unit RS485/LWL can be used to allow the connection of optical fibers.

### 5.2 Standards

The following standards were applied:

IEC 870-5-1	TELECONTROL EQUIPMENT AND SYSTEMS, PART 5: Transmission protocols, Section 1: Transmission frame formats.
IEC 870-5-2	TELECONTROL EQUIPMENT AND SYSTEMS, PART 5: Transmission protocols, Section 2: Link transmission procedures.
IEC 870-5-3	TELECONTROL EQUIPMENT AND SYSTEMS, PART 5: Transmission protocols, Section 3: General structure of application data.
IEC 870-5-4	TELECONTROL EQUIPMENT AND SYSTEMS, PART 5: Transmission protocols, Section 4: Definition and coding of application information elements.
IEC 870-5-5	TELECONTROL EQUIPMENT AND SYSTEMS, PART 5: Transmission protocols, Section 5: Basic application functions.
IEC 870-5-103	TELECONTROL EQUIPMENT AND SYSTEMS, PART 5: Transmission protocols, Section 103: Protection communication companion standard.
EAI RS-485	Standard for electrical characteristics of generators and receivers for use in balanced digital multipoint systems.

### 5.3 Protocol Structure

The protocol in accordance with IEC 870-5 is based on the three-layer model "Enhanced Performance Architecture" (EPA). This is defined in IEC 870-5-3, Section 4. The "physical layer" makes use of CCITT recommendations which provide binary-symmetrical and memory-free transmission with the necessary means. The data link layer provides the control functions which control and ensure the process of information transfer. Finally, the application layer describes the functions which include the transmission of "service data units" (ASDU), i.e. telegrams, commands, messages, measuring values between source and target.

### 5.3.1 Physical Layer

The physical interface of the device is equipped in accordance with the EIA RS-485 standard. A maximum of 32 users can be connected.

**Note:**

This interface is electrically connected to the analog output 1. If the interface is earthed (for bus operation or in notebooks without battery), analog output 1 may not be earthed. The transducer could be destroyed if this is disregarded.

In accordance with the accompanying standard, the data signaling rate is defined to be 19.2 kbit/s or 9.6 kbit/s. However, for testing purposes and for operation without a bus, the frequencies 2400 and 4800 can be selected.

### 5.3.2 Data Link Layer

The following basic standards apply

IEC-870-5-1: data transfer telegram formats  
IEC 870-5-2: transfer procedures of the data link layer

#### 5.3.2.1 Telegram Format

The format FT1.2 is used which is described in detail in IEC 870-5-1. Essential transducer characteristics for bus operation are described in this section.

The format of a character is 8E1. Therefore, the number of bits is 11 of which 8 contain the actual information.

0	XXXXXXXX	P	1
Start bit	Octet of data bits	Parity bit	Stop bit

The start bit is always 0, the data bits have the value 20 to 27, the parity bit is added to make an even number out of the number of one-bits, the stop bit is always one. Likewise, the conductor in non-operative state is set to level 1.

No breaks are allowed between the characters of a telegram.

After the detection of a transfer error (cf. below) a break of at least 33 steps of level 1 must be maintained.

A telegram (LDPU = Link Protocol Data Unit) has  $i$  characters, a maximum of 255. These are added to form the arithmetical cross-check sum modulo 256 and as symbol the number  $i+1$  is attached to its end, also supplemented by a parity bit.

The data link layer checks received telegramss as follows:

per character

start bit, stop bit and parity bit (to supplement the character to have an even number of ones in the information section).

per telegram

the start character, the check sum and the end character, and if an error is detected the transfer break of at least 33 steps.

Two types of telegram are possible, those of variable length and those with fixed length. The latter do not contain any user data, they are also referred to as short telegrams. They can be distinguished by their start character. This is explained in Figure 1.



Code	Telegram type	Service function	FCV
0	SEND/CONFIRM anticipated	reset link	0
3	SEND/CONFIRM anticipated	user data	1
4	SEND/NO REPLY anticipated	user data	0
7	all	set FCB and FCV to 0	0
9	REQUEST/RESPOND anticipated	request link status	0
10	REQUEST/RESPOND anticipated	class 1 request	1
11	REQUEST/RESPOND anticipated	class 2 request	1

Table 11: Function codes of control field during sending from primary station

Code	Telegram type	Service function
0	CONFIRM	ACK
1	CONFIRM	NACK, message not received
8	RESPOND	user data
9	RESPOND	NACK, data not available
11	RESPOND	link status

Table 12: Function codes of control field during sending from secondary station

### 5.3.2.2 Procedures of the Data Link Layer

#### Asymmetrical transmission

The measuring transducer is a "substation". A central control station initiates all transmissions by sending commands or requests for data to the substation. The transducer only reacts to such requests, it never sends data automatically.

#### Maximum response time

The addressed substation must respond within 50 ms or it is registered as not present or inoperative. In this case it must be initialized again. The time is measured from the end of the stop command of the inquiry telegram until the beginning of the start command of the response telegram.

Normally the device will continuously receive telegrams, however, only those are considered which contain specific device addresses or which are directed to all bus stations.

#### Elementary functions

All three transfer procedures SEND/NO REPLY, SEND/CONFIRM, and REQUEST/RESPOND are used.

SEND/NO REPLY	The LDPU is sent, an acknowledgment is not expected.
SEND/CONFIRM	After the LDPU is sent a waiting period of 50 ms starts for confirmation.
REQUEST/RESPOND	The primary station sends a request for information which the secondary station responds to with the corresponding
LDPU	

#### Address of the substation

All substations have a unique address. They range between 0 and 254. Address 255 is used to address all substations simultaneously.

**Basic application functions**

The auxiliary standard IEC-870-5-103 "Protection Communication Companion Standard" specifies usage of the following "basic application functions" defined in IEC 870-5-5:

- STATION INITIALIZATION
- GENERAL INTERROGATION
- CLOCK SYNCHRONIZATION
- COMMAND TRANSMISSION

The auxiliary standard defines four additional functions:

- TEST MODE
- BLOCKING OF MONITORING DIRECTION
- TRANSMISSION OF DISTURBANCE DATA
- GENERIC SERVICES

Not applicable to the transducer are:

**CLOCK SYNCHRONIZATION**

An ASDU 6 (time synchronization with address) is answered by ACK, however, it is ineffective because the transducer is not equipped with a time system. A time synchronization addressed to all stations is ignored. A "REQUEST class 1" is responded to with the ASDU time synchronization and the stated time is 0. The type code is 6, COT is 8.

**TRANSMISSION OF DISTURBANCE DATA**

The transducer never sends the ASDU 23 and consequently does not receive a request for the sending of specific malfunction data. A request is answered with a short message with function code 9, data not available.

**COMMAND TRANSMISSION**

The transducer is unable to execute commands. The command is answered by a short message with function code 9, data not available.

**TEST MODE**

The transducer cannot be switched to test mode, the function is not applicable.

**BLOCKING OF MONITORING DIRECTION**

As in the case of the test mode, this is a function which has to be set locally and is not supported by the transducer.

**5.3.2.3 "STATION INITIALIZATION"**

An initialization procedure is activated by the central unit. This occurs during the initialization of the central (master) unit and also if the transducer does not respond within the time  $t_{WZ}$ , i.e. if it is switched off or if the link is interrupted.

If the device was out of operation it will only respond to a reset command and will ignore all other requests or commands. There are two different reset commands, RESET-CU (function code 0 in the control field) and RESET-FCB (function code 7 in the control field). Both commands have the effect that the internal FCB bit in the transducer is set to zero and that the reset procedure starts.

The transducer responds to the RESET command by sending a short confirmation message with the function code 0 (=ACK). The control field C (cf. Figure 9) will look like this:

	MSB					LSB			
	RES	PRM	ACD	DFC	2 <sup>3</sup>	2 <sup>2</sup>	2 <sup>1</sup>	2 <sup>0</sup>	
	0	0	1	0	0	0	0	0	
bit:	8	7	6	5	4	3	2	1	

Figure 11: Control field "ACK"

The total telegram is:

10H 20H XX CS 16H

XX address  
CS check sum

A subsequent request of the primary station with "REQUEST class 1" (function code 10) is answered by the transducer with the identification telegram (ASDU 5). COT contains RESET CU (4), if RESET CU (function code 0) or RESET FCB (3), or RESET FCB (function code 7) was received before.

Another request "REQUEST class 1" is required as the next step which is responded with "data not available". It is only then that the link is re-established and additional requests "REQUEST class 2" are responded with measuring value-ASDUs. Requests "REQUEST class 1" are responded with the telegram "NACK, data not available" (cf. Table 12).

**5.3.2.4 "GENERAL INTERROGATION"**

The primary station responds to a general interrogation with an ACK with ACD=1. The ACD in measuring value telegrams is then also 1. The first interrogation with "Request class 1" after this receives the response "outgoing fault message". The next interrogation "Request class 1" is responded to with ASDU 8. From then on the bit ACD again contains zero.

**5.3.2.5 "GENERIC SERVICES"**

These functions are not used.

**5.3.3 Application Layer**

**5.3.3.1 General Remarks**

For this layer the international standards apply.

- IEC 870-5-3: General structure of application data
- IEC 870-5-4 Definition and coding of information elements on the application layer.
- IEC 870-5-5 Basic application functions

Protocol data units LDPU are exchanged between substation and central station. Each one of them contains here no more than one service data unit.

**5.3.3.2 Structure of Service Data Unit**

The service data unit consists of one "data unit identification field" and one or more information objects. The ID field has always the same structure and consists of four octets:

- 1 octet TYPE IDENTIFICATION
- 1 octet VARIABLE STRUCTURE QUALIFIER
- 1 octet CAUSE OF TRANSMISSION
- 1 octet COMMON ADDRESS OF ASDU

SERVICE DATA UNIT OF APPLICATION LAYER	IDENTIFICATION FIELD OF DATA UNIT	TYPE IDENTIFICATION	TYPE OF DATA UNIT
		VARIABLE STRUCTURE QUALIFIER	
		CAUSE OF TRANSMISSION	
		COMMON ADDRESS OF ASDU	
INFORMATION OBJECT	INFORMATION OBJECT	TYPE OF FUNCTION	IDENTIFICATION FIELD OF INFORMATION OBJECT
		INFORMATION NUMBER	
		RECORD OF INFORMATION ELEMENTS	

Diagram1: Structure of SERVICE DATA UNIT OF APPLICATION LAYER

### 5.3.3.2.1 Type Code

The octet type code defines structure, type, and format of the following information object(s). For the transducer, 140 is defined as type identifier and the information objects described below are identified accordingly. The standard ASDU 9, MEASURANDS II, is also available.

### 5.3.3.2.2 Variable Structure Identifier

SQ=0 determines that the "information element record" contains a sequence of identical information elements. This applies to a list of measuring values. The number of values in the standard ASDU is 16.

SQ	$2^6$			number			$2^0$
----	-------	--	--	--------	--	--	-------

Diagram 2: Variable structure code

For example the transfer of a list containing 16 measuring values requires the code 00010000.

### 5.3.3.2.3 Cause of Transmission

The cause of transmission is represented by a number between 1 and 255. For the transducer the following causes are possible:

#### Use of CAUSE OF TRANSMISSION in direction of central station

- 2 answer on cyclic interrogation of measured quantities
- 5 with ASDU 5 after cold restart
- 10 with ASDU measuring values as answer on general interrogation

#### Use of CAUSE OF TRANSMISSION in direction of transducer

- 20 general command
- 9 general interrogation

### 5.3.3.2.4 Common Address of ASDU

The "common ASDU address" is always identical to the address which was specified for the data link layer. It lies between 1 and 254. 255 is reserved for the simultaneous addressing of all devices and is not used in the transducer.

### 5.3.3.2.5 Type of Function

The function type for measuring values can be 9 (compatible, for 9 measuring points) or the incompatible value 134 which specifies that in the normal version 16 measuring points are used, and in the special version "individual phase power" 9 measuring points (details in Chapter 5.4). The type is specified with the help of SIMEAS PAR.

### 5.3.3.2.6 Information Number

The information number is an octet. For ASDUs with measuring values it depends on the method of measurement specified with the help of SIMEAS PAR.

Number of method of measurement	Method of measurement	Information number
1	single-phase	80
2	three-wire, random load	81
3	three-wire, equal load	82
4	four-wire, random load	83
5	four-wire, equal load	84
6	special version individual phase power	85

Table 13: Information numbers for ASDU with measuring values

The following numbers are also used in direction of the central station:

- 0 end of general interrogation
- 4 cold restart

The following numbers are used in direction of the transducer:

- 0 initialize general interrogation

### 5.3.3.2.7 Information Element - Measuring Values

All measuring values are transferred as per-unit value with two octets which contain the value with 12 bit and qualifying symbol together with error and overflow marks.

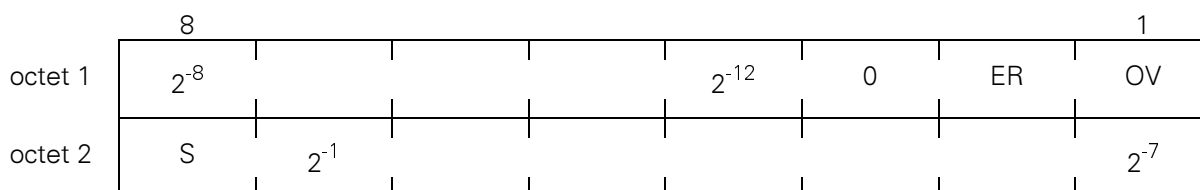


Diagram 3: Per-unit value with qualifying symbol, overflow and error marks

- OV is the overflow mark, the measuring value remains on the highest value.
- ER is set to 1 if the value is invalid. This is the case if the respective point does not exist in the chosen operating mode, e.g. IL2 in the three-watt metering method.

The range of values is  $\pm 1$  (to be precise  $\pm 0.99976$ ). These are 8193 quantizing levels (-4096 to +4095). This is equivalent to  $\pm 120\%$  of the corresponding nominal values. 100% is equivalent to:

- 1) r.m.s. values  $U_{L1-N}, U_{L2-N}, U_{L3-N}$ : 90 V, 180 V, 450 V
- 2) r.m.s. values  $U_{L-L}$ :  $90\sqrt{3}$ ,
- 3) r.m.s. values I: 2 A, 4 A, 10 A
- 4) frequency deviation from nominal value:  $\pm 5$  Hz
- 5) power for single-phase measurement:  $2 \cdot U \cdot I$ , all possible U and I from 1) and 3)
- 6) power, three-phase:  $2 \cdot U \cdot I \cdot \sqrt{3}$ , all possible U and I from 2) and 3)
- 7) angle:  $180^\circ$
- 8) power factor: 1

For the power factor the correlation described in Table 14 applies. Contrary to the usual procedure, the direction of the active power is used as the qualifying symbol, import is positive, supply is negative.

power factor	-0	-0.5	1.0	+0.5	+0
carried value	-200%	-100%	0	+100%	+200%

Table 14: measuring value for power factor



### 5.3.3.2.8 Transfer of Measuring Values

The measuring points collected by the transducer and passed on with the ASDU depend on the chosen operating mode. They are listed in the following tables. An X in the name column represents invalid measuring points for which the ER bit is set to 1.

No.	Name	Dimension
1	$I_{L1}$	A
2	$U_{L1-N}$	V
3	FREQ	Hz
4	cos phi	
5	phi	°
6	S	VA
7	P	W
8	Q	Var
9	X	
10	X	
11	X	
12	X	
13	X	
14	X	
15	X	
16	X	

Table 15: Measuring points for method 1, single-phase network, ASDU 140

No.	Name	Dimension
1	$I_{L1}$	A
2	$I_{L3}$	A
3	FREQ	Hz
4	$U_{L1-2}$	V
5	$U_{L2-3}$	V
6	$U_{L3-1}$	V
7	cos phi	
8	phi	°
9	S	VA
10	P	W
11	Q	Var
12	X	
13	X	
14	X	
15	X	
16	X	

Table 16: Measuring points for method 2, three-wire system with random load, ASDU 140

No.	Name	Dimension
1	$I_{L1}$	A
2	FREQ	Hz
3	$U_{L1-2}$	V
4	$U_{L2-3}$	V
5	$U_{L3-1}$	V
6	cos phi	
7	phi	°
8	S	VA
9	P	W
10	Q	Var
11	X	
12	X	
13	X	
14	X	
15	X	
16	X	

Table 17: Measuring points for method 3, three-wire system with equal load, ASDU 140

No.	Name	Dimension
1	$I_{L1}$	A
2	$I_{L2}$	A
3	$I_{L3}$	A
4	$U_{L1-N}$	V
5	$U_{L2-N}$	V
6	$U_{L3-N}$	V
7	U0	V
8	FREQ	Hz
9	$U_{L1-2}$	V
10	$U_{L2-3}$	V
11	$U_{L3-1}$	V
12	cos phi	
13	phi	°
14	S	VA
15	P	W
16	Q	Var

Table 18: Measuring points for method 4, four-wire system with random load, ASDU 140

No.	Name	Dimension
1	$I_{L1}$	A
2	$U_{L1-N}$	V
3	FREQ	Hz
4	cos phi	
5	phi	°
6	S	VA
7	P	W
8	Q	Var
9	X	
10	X	
11	X	
12	X	
13	X	
14	X	
15	X	
16	X	

Table 19: Measuring points for method 5, four-wire system with equal load, ASDU 140

No.	Name	Dimension
1	$P_{L1-N}$	W
2	$P_{L2-N}$	W
3	$P_{L3-N}$	W
4	$Q_{L1-N}$	Var
5	$Q_{L2-N}$	Var
6	$Q_{L3-N}$	Var
7	$\cos \phi_{L1-N}$	
8	$\cos \phi_{L2-N}$	
9	$\cos \phi_{L3-N}$	

Table 20: Measuring points for method 6, special version for individual phase power, ASDU 140

NR.	name	dimension
1	$I_{L1}$	A
2	$I_{L2}$	A
3	$I_{L3}$	A
4	$U_{L1-N}$	V
5	$U_{L2-N}$	V
6	$U_{L3-N}$	V
7	P	W
8	Q	Var
9	FREQ	Hz

Table 21: Measuring points ASDU 9, MEASURANDS II

### 5.3.3.2.9 Rejection of Requests for Measuring Values

For each inquiry from the substation control and protection center the, transducer has an entire measuring value record. However, it is not always desirable to send it since under certain conditions the central memory becomes overloaded. Therefore, a parameter can be entered for the rejection of multiple inquiries. For this purpose, the short message "NACK, requested data not available" is sent instead of the measuring data record.

telegram type    respond  
 function code    9  
 ACD x            DFC 0        PRM 0

Description of character	Decimal	Hexadecimal
start character 2	16	0x10
control field	41 or 9	0x29 or 0x09
address field		
check sum		
stop character	22	0x16

Table 22: Short message "requested data not available"

The number of NACK messages between two measuring data records can be set to between 0 and 255.

**5.3.3.2.10 Used ASDU Types**

**ASDU 5 - Identification Message**

This ASDU contains 12 ASCII characters in the information object. Eight for the name of the manufacturer, an additional four to identify the software. The name in the present case is "SIEMENS" followed by a blank (20H) to fill the eighth position. Four characters are available to identify the software. The following code is intended:

- 1<sup>st</sup> character: letter for program type
- 2<sup>nd</sup> character: version
- 3<sup>rd</sup> and 4<sup>th</sup> character: release 00..99

Example: A0100

7.3.1.5 TYPE IDENTIFICATION 5: Identification Message									
0	0	0	0	0	1	0	1	TYPE IDENTIFICATION	<b>DATA UNIT</b>
1	0	0	0	0	0	0	1	VARIABLE STRUCTURE QUALIFIER	<b>IDENTIFIER</b>
defined in 7.2.3								CAUSE OF TRANSMISSION	defined in 7.2
defined in 7.2.4								COMMON ADDRESS OF ASDU	
defined in 7.2.5.1								FUNCTION TYPE	<b>INFORMATION</b>
defined in 7.2.5.2								INFORMATION NUMBER	<b>OBJECT</b>
defined in 7.2.6.3								COL	defined in 7.2
defined in 7.2.6.2								ASC := CHARACTER 1	
defined in 7.2.6.2								ASC := CHARACTER 2	
defined in 7.2.6.2								ASC := CHARACTER 3	
defined in 7.2.6.2								ASC := CHARACTER 4	
defined in 7.2.6.2								ASC := CHARACTER 5	
defined in 7.2.6.2								ASC := CHARACTER 6	
defined in 7.2.6.2								ASC := CHARACTER 7	
defined in 7.2.6.2								ASC := CHARACTER 8	
free assignment								MANUFACTURER'S INTERNAL SOFTWARE IDENTIFICATION	
free assignment									
free assignment									
free assignment									

**Note:** The ASCII characters are used for the name of the manufacturer. For „empty“ fields ASCII blanks, i.e. 20H, must be used. The last four octets are for free assignment by the manufacturer.

Figure 12: ASDU 5 from IEC 870-5-103

Explanation:

- CAUSE OF TRANSMISSION: 9 (response to general interrogation)
- COMMON ADDRESS OF ASDU: filed address
- FUNCTION TYPE: 134
- INFORMATION NUMBER: 0

ASDU 9 - MEASURANDS II

**7.3.1.8 TYPE IDENTIFICATION 9: Measurands II**

0	0	0	0	1	0	0	1		TYPE IDENTIFICATION	<b>DATA UNIT</b>	
0	number i of information elements								VARIABLE STRUCTURE QUALIFIER	<b>IDENTIFIER</b>	
defined in 7.2.3								CAUSE OF TRANSMISSION		defined in 7.2	
defined in 7.2.4								COMMON ADDRESS OF ASDU			
defined in 7.2.5.1								FUNCTION TYPE	<b>INFORMATION</b>		
defined in 7.2.5.2								INFORMATION NUMBER	<b>OBJECT</b>		
defined in 7.2.6.8								MEA := CURRENT L <sub>1</sub>		defined in 7.2	
defined in 7.2.6.8								MEA := CURRENT L <sub>2</sub>			
defined in 7.2.6.8								MEA := CURRENT L <sub>3</sub>			
defined in 7.2.6.8								MEA := VOLTAGE L <sub>1</sub> -E			
defined in 7.2.6.8								MEA := VOLTAGE L <sub>2</sub> -E			
defined in 7.2.6.8								MEA := VOLTAGE L <sub>3</sub> -E			
defined in 7.2.6.8								MEA := ACTIVE POWER P			
defined in 7.2.6.8								MEA := REACTIVE POWER Q			
defined in 7.2.6.8								MEA := FREQUENCY f			

**Note:** P and Q are the 3-phase active and reactive powers

**Note:** It is possible to transmit only a part of the measurands indicating the number in the VARIABLE STRUCTURE QUALIFIER starting always with the Current L<sub>1</sub>.

Figure 13: ASDU 9 from IEC 870-5-103

**ASDU 140 - Measurands, not compatible**

The ASDU is equivalent to the one of ASDU 9. The number of information elements (measuring points) is 16, their assignment is described in Table 15 to Table 19. In the various methods of measurement, not all measuring points are used. Missing ones are marked as invalid by the bit ER in information element measuring values (cf. Chapter 5.3.3.2.7).

In the special version individual phase power the ASDU has only 9 information elements.

Explanation:

CAUSE OF TRANSMISSION: 2 (cyclic)  
 FUNCTION TYPE 134  
 INFORMATION NUMBER 80 to 84, Eletropaulo 85

Representation of measurands in two octets each as described above in " INFORMATION ELEMENT measuring values ".

**5.3.4 Operating Mode BUS / Parameter Assignment**

It is not intended to assign the parameters of the transducer via the substation control and protection system LSA but via its interface by using a PC with the program SIMEAS PAR or the DOS program P473 (V02.00.03). In order to be able to establish communication with the transducer, the PC must first detect the configuration of the interface (cf. Chapter 2.2.4) and the active operating mode, basic

operating mode or IEC 870-5-103. For this purpose, the telegram "R" is sent after the start of the program, starting with 2400 baud and increasing baud rates, to the transducer and a response is anticipated. An incoming response indicates that the connected transducer is set to basic operating mode, the baud rate is also indicated and the responding address can be derived from the response. If no readable response arrives, the LDPU described below is sent, also with varying baud rates, to the transducer switching it into parameter assignment mode as soon as the correct baud rate is reached. Before this occurs it sends the telegram "ACK" which tells the program to maintain the current data signaling rate. Any further activities, parameter assignment, calibration, output of measurands, can be done as described in Chapter 4.

Character	Hexadecimal	Decimal
start character	68H	104
length	09H	9
length repeated	09H	9
start character repeated	68H	104
control field	47H	71
ASDU address	FFH	255
type identification	06H	6
Variable structure qualifier	81H	129
cause of transmission	00H	0
ASDU address	FFH	255
type of function	86H	134
information number	00H	0
information element	FFH	255
check sum	51H	81
end character	16H	22

Figure 14: LDPU for switching to parameter assignment mode (basic operating mode)

## 5.4 Special Version Individual Phase Power

Contrary to the basic version, this device acquires the following measurands with the code '5':

$P_{L1}$	active power L1
$P_{L2}$	active power L2
$P_{L3}$	active power L3
$Q_{L1}$	reactive power L1
$Q_{L2}$	reactive power L2
$Q_{L3}$	reactive power L3
$\cos \varphi_{L1}$	power factor L1
$\cos \varphi_{L2}$	power factor L2
$\cos \varphi_{L3}$	power factor L3

These data items are transferred by means of the ASDU 9 in the specified order instead of the standard data.

**List of versions**

Version	Date	Change
V06	02.08.96	Correction Tables 6 and 13
V07	03.09.96	Firmware V02.00.09: transmission delay 4 characters in IEC 870-5-103, Firmware V02.00.10: response delay of 0-3s in parameter assignment mode, Firmware V02.00.10: measurand threshold 0 to 255 interrogations
V08	21.01.97	Correction of initialization sequence, Chapter 5.3.2.3