1 D/E

AC/DC Power Analyzer D 5235

Gebrauchsanleitung
Operating Instructions

NORMA

G E L T U N G S B E R E I C H :

Diese Gebrauchsanleitung gilt für Geräte mit

Listen-Nr. A 4603 30410 (4 stellige Anzeige)

und

Listen-Nr. A 4603 30411 (5 stellige Anzeige)

und ab dem Fertigungs-Kennbuchstaben PA.

Der Fertigung-Kennbuchstabe ist aus der Instrumenten-Nr. ersichtlich.

O P E R A T I N G   I N S T R U C T I O N S

A C / D C -   P O W E R   A N A L Y Z E R   D 5 2 3 5

List No. A 4603 30410

List No. A 4603 30411

A P P L I C A B I L I T Y :

These Operating Instructions only apply to instruments with

List No. A 4603 30410 (4 digit display)

and

List No. A 4603 30411 (5 digit display)

and with production codes from PA upward.

The production code forms part of the instrument number.

CONTENTS:

1.GENERAL

This Power Analyzer is a two-channel digital measuring instrument which processes DC, AC and composites quantities irrespective of curve form. It features selectable coupling mode (AC+DC and AC) and supplies a total of 10 simultaneously established measured values. The instrument supports the following measurements:

Curent measurements (with channel 1):

1.RMS current value:

TRUE-RMS (AC+DC - coupling)
RMS (AC coupling only)

2.Arithmetic mean (DC portion):

MEAN (AC+DC-coupling)

3.Arithmetic mean of absolute value (rectified mean):

REC MEAN (AC+DC or AC - coupling)

Voltage measurements (with channel 2):

4.RMS voltage value:

TRUE-RMS (AC+DC - coupling)
RMS (AC coupling only)

5.Arithmetic mean (DC voltage portion):

MEAN (AC+DC-coupling)

6.Arithmetic mean of the absolute value (rectified mean):

REC MEAN (AC+DC or AC - coupling)

Power measurements (with both channels):

7.Active power (independent of curve form)

8.Power factor (cos phi for sinusoidal signals)

9.Absolute value of apparent power(|Z|)

10.Effective resistance (Real(Z))

The maximum and minimum of any of the above quantities may be determined over an arbitrary number of measurements.

The large number of measuring options and the large scope of range permit applications of the instrument both in communication engineering (e.g. measurement of transmission losses) and in industrial electronics (e.g. measurements in switched mains section) and power engineering (e.g. on electrical machinery).

Among the instrument's special features is the possibility of having both channels float both mutually and with respect to earth/ground up to 1000 V (RMS) or û = 1400 V. This facilitates two-channel measurements, most particularly in the fields of industrial electronics.

The frequency range extends from 0 to 400 kHz. The input of scale factors for current and voltage permits the display to be correct in both value and decimal with sign and unit, even if external shunts or transformers are used.

Measurement is effected by simultaneous scanning of current and voltage with fast A/D converters and following computation of measured values in the arithmetic unit. The shortest averaging period is 120 ms and may be extended in 8 steps up to 15.4 s. Two averaging methods (exponential and linear) are available. For an averaging interval of 120 ms, the measured value is obtained from 2592 scanned values.

The measuring operation may be started both manually and via the BUS (trigger mode) and is in the linear averaging mode terminated automatically on expiration of the selected averaging period.

Measured values are shown on a 20-digit alphanumeric display and may also be output digitally via the interface or in analog mode via the programmable analog output (for recording).

Operation of the instrument is either manual from a clearly arranged foil-type keyboard (with prompting on the display) or from the built-in interface. When the instrument is switched off, all setting and calibrating data remain available (in a C-MOS RAM), thus greatly simplifying operation.

1.1 Measuring principle:

The Power Analyzer features two voltage inputs, one for voltage mesurement and one for current measurement measuring the voltage drop across shunts. The connection of this shunt-voltage input is effected either by a plug-in shunt or by a guarded four-pole plug and a special guarded two- pole cable.

After signal-level matching by voltage divider and pre-amplifier, the measured signal on either channel is passed to a 12-bit A/D converter. In AC coupling mode the DC component is first blanked.

These A/D converters work on the principle of successive approximation and synchronously poll the instantaneous values of the two signals at approx. 22 kHz. In the following computation only 8 bits are used to keep computational overhead to a reasonable value. Even so, sufficient resolution is obtained through the use of a special interpolaion method in the least significant bit.

For this purpose a sawtooth of single-bit size is superimposed on the analog signal. This makes the data at the ADC output fluctuate statistically about the instaneous signal value. Averaging over a large number of instantaneous values yields the correct interpolated value. To avoid interference with the measured signal, the polling frequency is automatically adjusted by a beat detector.

The digitalized polled values are subsequently passed to the arithmetic unit by special pulse transformers. These pulse transformers also isolate the floating input components from the arithmetic unit, which is at earth/ground potential. The arithmetic unit then computes the averaged measured values (U, I, P) from the instantaneous values. In the case of the smallest time constant, measured values are computed from 2592 instantaneous values.

In the case of linear averaging, computation is terminated on expiration of the time constant. In exponential averaging the old mesured value is corrected by the new one in accordance with an RC function. All other measured values are only computed before output in accordance with formulas given in Chapter 4.

Computation of measured values and control of the measuring process are effected by two bipolar 4-bit microprocessor slices, cascaded to 8 bits. The data are passed via the microprocessor bus to the main processor for data output, to the D/A converter for analog value output, and to the display processor for showing the values in the display area. The display processor also transmits the data entered at the foil-type keyboard to the main processor. In TALK-ONLY mode data output is controlled by the internal timer.

Overrange recognition is implemented by the A/D converters, while underrange recognition is derived from the measured value; both are optically indicated by LEDs on the keyboard and may also be recalled from the interface. On calling the internal calibrating program, the operator is prompted on the display to apply suitable DC levels. Correction values are thereby obtained and stored in the buffered C-MOS-RAM

The trigger facility via the interface or the external trigger jack permits synchronization of the measuring process with other instruments used within the measuring or testing system. The interface basically permits remote control of <u>all instrument functions</u> and recall of all measurement results.

2.IMPORTANT NOTE:

To avoid discharging of the buffer battery for the C-MOS memory and hence loss of the calibration and setting data, we recommend that the instrument should be operated continuously from the mains for 24 hours at least every 6 months; this will recharge the buffer battery.

3.SAFETY INSTRUCTIONS:

3.1 Notes for Operation:

This measuring device must only be used by skilled or trained staff and only within its technical specification combined with the following safety instructions and regulations.

For each application the additional legal and safety regulations applicable thereto must be complied with. Similar precautions apply to the use of accessories made by other manufacturers.

If there is reason to believe that safe operation is no longer possible, the instrument must be switched off and protected against unintential restarting.

Safe operation should be deemed to be no longer possible if:

- the instrument shows visible damage;
- the instrument no longer works;
- the instrument has been exposed to unfavorable conditions (e.g. storage outside the climatic declaration without adaption to ambient temperature etc.);
- the instrument has been exposed to major stresses in transport (e.g. dropped from some height even without external damage, etc.).

3.2 Maintenance:

Servicing (e.g. readjustment) must only be performed by trained, skilled staff. When performing repairs, the instrument design parameters must on no account by altered to the impairment of safety; assembled parts must conform to the original spares and be suitable reassembled (i.e. to factory condition).

4. TECHNICAL DATA:

Current measurement: in channel CH 1-A

Coupling: selectable between AC+DC and AC

Ranges: 4 shunt-voltage ranges, stepped $\sqrt[3]{15} = 2,47$ with overrange and underrange indication

Range	Resolution at scale factor 1 mA/mV	
	Version 4 digit	Version 5 digit
10 mV 25 mV	10 µA	1 µA
60 mV 150 mV	100 µA	10 µA

Crest factor: 3, at full scale value

Scale factor: 10 EXP-6 ....10 EXP+5 A/mV

Display range: 10 µA ... 15 MA

Limits of error: for input quantities from 10...300 % of range for 1 year at nominal conditions

Coupling	Function	Frequency Range	Limits of Error ±(x % mv. + y % range
AC + DC	RMS MEAN REC.MEAN	0........20 kHz > 20 kHz...100 kHz >100 kHz...200 kHz >200 kHz...300 kHz >300 kHz...400 kHz	±(0.2 % + 0.2 %) ±(0.6 % + 0.2 %) ±(0.9 % + 0.4 %) ±(1.5 % + 0.6 %) ±(2.4 % + 1.2 %)
AC	RMS REC.MEAN	15 Hz... 40 Hz > 40 Hz... 20 kHz > 20 kHz...100 kHz >100 kHz...200 kHz >200 kHz...300 kHz >300 kHz...400 kHz	±(0.6 % + 0.2 %) ±(0.2 % + 0.2 %) ±(0.6 % + 0.2 %) ±(0.9 % + 0.4 %) ±(1.5 % + 0.6 %) ±(2.4 % + 1.2 %)
Typical values at nominal signal level			
AC + DC	RMS, MEAN REC.MEAN	>100 kHz...200 kHz >200 kHz...300 kHz >300 kHz...400 kHz	- 1.0 % mv - 1.5 % mv - 2.5 % mv
AC	RMS REC.MEAN		

Input impedance: 100 kΩ//30 pF in all ranges

Temperature coefficient: ± 0,05 % of range per Kelvin

Noise current in input: ≤ 100 pA

DC input voltage for AC-coupling:
max. 10 V

Noise voltage rejection:
Common Mode Rej.: MEAN : 140 dB bei DC
RMS, REC MEAN: 160 dB bei 50/60 Hz, 1 kΩ in High

Overload: max. 250 V RMS in all ranges, but max. peak 500 V

Voltage frequency product:
max. 0,5 . 10 EXP+7 VHz

Voltage measurement: in channel CH 2 - V

Coupling: selectable between AC+DC and AC

Ranges: 16 voltage ranges, stepped at $\sqrt[15]{5000} = 1.76$
with overrange and underrange indication

Range	Resolution at scale factor 1 V/V	
	Version 4 digit	Version 5 digit
0,10/0,17/0,3 V	100 µV	10 µV
0,54/0,96/1,70/3,0 V	1 mV	100 µV
5,40/9,60/ 17/ 30 V	10 mV	1 mV
50/ 90/ 160/280 V	100 mV	10 mV
500 V	1 V	100 mV

Crest factor: 3, at full-scale value

Scale factor: 10 EXP-1 ....10 EXP+7 V/V

Display range: 10 mV ... 5 GV

Limits of error, frequency ranges, coupling and functions:
as for the current channel

Input impedance: 10 MΩ//20 pF in all ranges

Temperature coefficient: ± 0.03 % of range per Kelvin

Noise voltage rejection:
Common Mode Rej.: MEAN : 140 dB bei DC
RMS, REC MEAN: 120 dB bei 50/60 Hz, 1 kΩ in High

Overload: max. 1000 V RMS in all ranges,
but max. peak 1400 V

Voltage-frequency product:
max. 10 EXP+8 VHz

Power measurement:

Power ranges: results from:
voltage range x voltage scale factor x
current range x current scale factor

Limits of error: for signal level in the power range from 1 % to 900 %
and power factors of at least 0.85
for 1 year at nominal conditions

Coupling	Function	Frequency Range	Limits of Error ±(x % mv. + y % range
AC + DC	W	0.........20 kHz	±(0.5 % + 0.2 %)
		> 20 kHz...100 kHz	±(0.8 % + 0.4 %)
		>100 kHz...200 kHz	±(1.9 % + 0.6 %)
		>200 kHz...300 kHz	±(3.1 % + 0.9 %)
		>300 kHz...400 kHz	±(4.3 % + 1.8 %)
AC	W	15 Hz... 40 Hz	±(0.8 % + 0.4 %)
		> 40 Hz... 20 kHz	±(0.5 % + 0.2 %)
		> 20 kHz...100 kHz	±(0.8 % + 0.4 %)
		>100 kHz...200 kHz	±(1.9 % + 0.6 %)
		>200 kHz...300 kHz	±(3.1 % + 0.9 %)
		>300 kHz...400 kHz	±(4.3 % + 1.8 %)
Typical values for nominal signal level and power factor = 1			
AC + DC	W	>100 kHz...200 kHz	- 2.0 % mv
		>200 kHz...300 kHz	- 3,0 % mv
DC		>300 kHz...400 kHz	- 4.5 % mv
Limits of error for signal levels on both channels from 100 % to 200 % and power factor < 0.85			
AC + DC	W	45 Hz....65 Hz	±(0.5 % + 0.1 %)

<u>Example</u>: Signal level U = 100 %, signal level I = 100 %, cos phi = 0.1:
Frequency: 50 Hz
Resulting signal level P = 10 %
hence typical error: ± 1.5 % of mesasured value

The **resolution of the power display** is automatically multiplied by a factor of 10 if the most significant digit on the display would be a zero. The most significant digit is determined by the highest displayable value.

Max. displayable value = power range x 9 x 1.06

Note: This value is only attainable for DC or for rectangular signals at cos phi = 1. For sinusoidal signals, their crest factor (C=√2) only permits attaining of half the maximum displayable value.

Temperature coefficient: ± 0.08 % of range per Kelvin

Angular error between inputs:
for AC+DC: ± 0.1 ° for 0...... 20 kHz
± 0.5 ° for 20 kHz...100 kHz
for AC : ± 0.3 ° for 15 Hz....45 Hz
± 0.1 ° for 45 Hz....20 kHz
± 0.5 ° for 20 kHz...100 kHz

Channel separation: 140 dB (0.......100 kHz)

Limits of error for computed quantities:

Power factor: Sum of errors for voltage, current and active power

Effective resistance: Sum of errors of 2 x current and active power

Absolute value of impedance:
Sum of errors of voltage and current

Analog output: -10 V....0....+10 V DC, max. load 2 mA
Assignment of the measured quantity to the analog output value is programmable at keybord and BUS.
Additional error: ±(0.25 % of full-scale value + 0.03 %/K)
Permissible external voltage: max. 125 V RMS, but max. peak 180 V

General:

Digital display: 20-digit fluorescent display (green), 5 x 7 dot matrix, 9 x 6.3 mm character size

Display of single values: 4 digit version: 0....9999, with sign, unit and function
5 digit version: 0....99999 with sign, unit and function

Display of two values: 4-digits with sign, unit and function. The measured values for display are freely selectable.

Display of three values: 4-digits; preset display of Ieff, Ueff and P (with sign)

Measuring principle: Simultaneous polling of both channels, A/D conversion and subsequent computation of measured values

Polling frequency: 22 kHz, statistically wobbled

Averaging time: selectable in 8 steps:
0.12; 0.24; 0.48; 0.96; 1.92; 3.84; 7.68; 15.40 s

Measuring time for linear measurement:
same as averaging time

Range and mode selection:
manually at front panel by foil-type keyboard or remote operation via interface

System Interface:	IEC 625 or IEEE-Standard 488/1978
Interface functions:	SH1, AH1, T5, L4, SR1, RL1, PPO, DCO, DT1, CO, E2
Test modes:	Display test and internal memory test after every startup
Calibration mode:	Prompted calibration process for all ranges with external DC voltage source. Deviations are stored for computation of measured values. The instrument may also be calibrated for other reference temperatures, thus eliminating the influence of the temperature coefficient.
Buffering:	A Ni-Cd storage battery permits buffering of the internal RAM (for up to 1/2 year when the instrument is switched off). This preserves the latest calibration and setting data even when the instrument is switched off.
Climatic class:	KYG as per DIN 40040
Working temperature:	0....40 °C, rel.humidity max. 65 % (average)
Nominal temperature:	23 °C
Storage temperature:	-20 °C....+50 °C
Test voltage:	3 kV : between input circuits mutually and with respect to case and mains circuit 1.5 kV: main circuits with respect to input circuits and case
Safety regulations:	VDE 0411 part 1/10.73 and DIN 57411 sheet 1, as well as IEC 348 2nd edition
Protective class:	I, protective impedance in HIGH wire
Mains connection:	115/220 V, + 15 % - 10 %, 45....65 Hz approx. 77 VA
Warm-up time:	approx. 30 min
Protective type:	DIN 40050 - IP 20 (IEC 529)
Dimensions:	142 mm high by 431.5 mm wide by 454 mm deep 19" 3 height units.
Mass:	approx. 8.5 kg

5. DESCRIPTION OF CONTROLS:

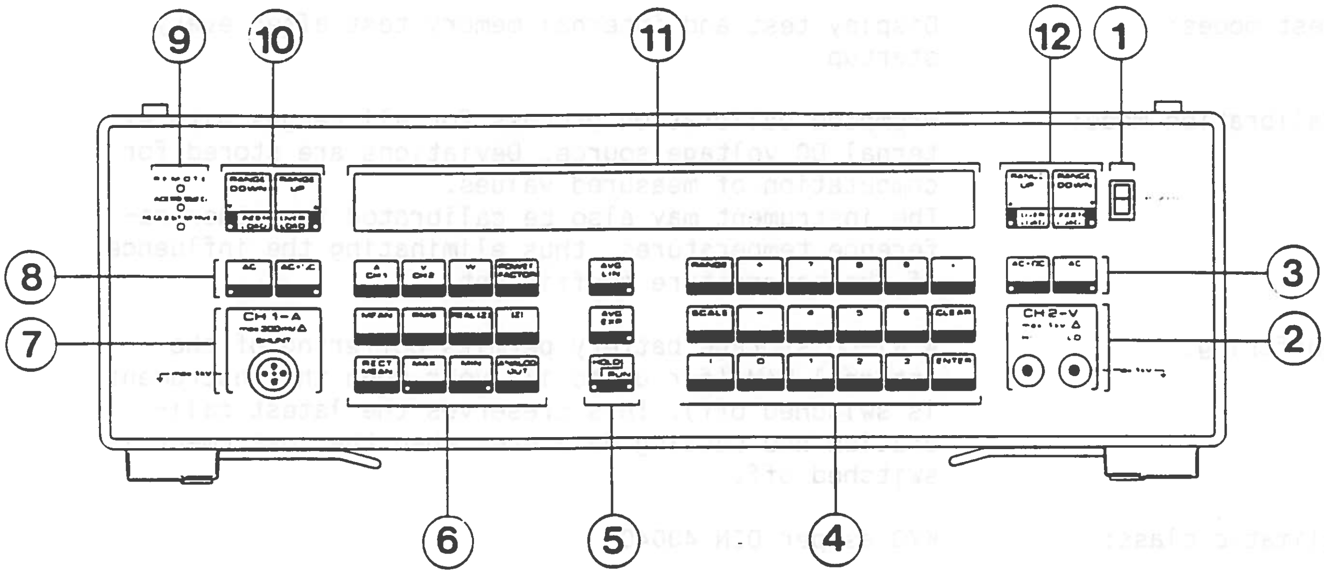


Fig. 5.1: Instrument Front

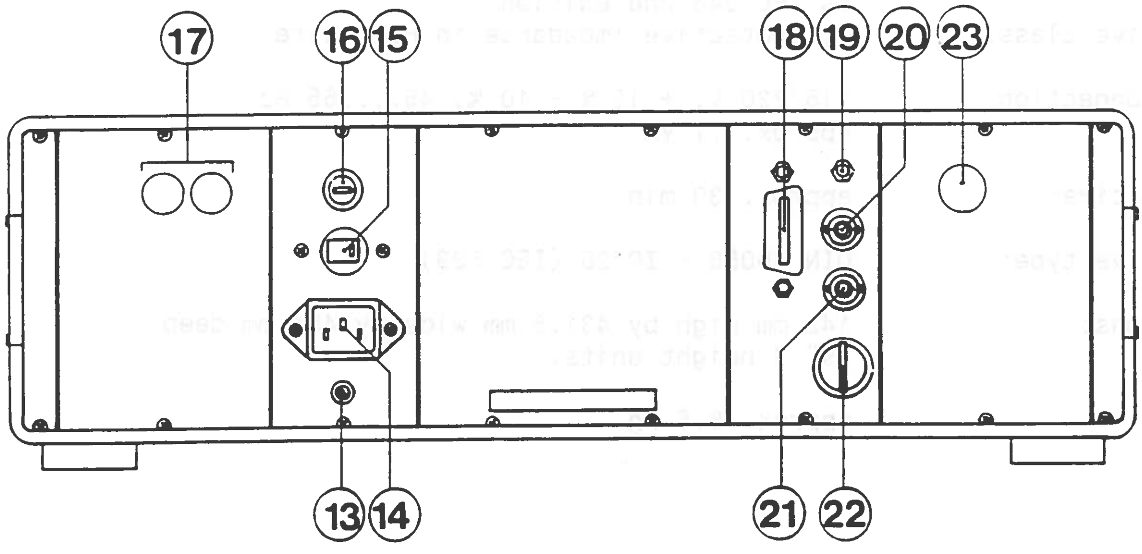


Fig. 5.2: Instrument Rear

Located at *instrument front* are:

(1) Mains switch
disconnects both poles of the instrument from the mains

(2) Safety input jacks for the voltage channel

(3) Coupling-mode selector for the voltage channel

The selected coupling mode (AC+DC or AC) is indicated by a lighted LED and can be changed by pressing the appropriate key.

(4) Keys for input routines

Pressing any of these keys will call an appropriate input routine (e.g. RANGE, SCALE, T).
The flashing cursor indicates that the instrument is in an input routine and which digit is currently open to change (with the number keys). On pressing a number key that digit is passed into the display, and the cursor jumps one position to the right.

Each input routine should be terminated by pressing the "ENTER" key. This passes the input value to memory, and the instrument returns to the measuring cycle.

Without operating the number key, the cursor may be moved to the right with the Start key and to the left with the "CLEAR" key, both with wrap-around.

"RANGE" key: calls the input routine for range selection.
"SCALE" key: calls the input routine for the scale factors.
"T" key : calls the input routine for the time constant.

The "." (decimal point) and "ENTER" keys have multiple functions, whose purpose will be described in the section of the display of measured values (7.7), the analog recorder output (7.8) and the digital printer output (7.9) respectively.

(5) Keys for selection of the type of averaging

Pressing the key "AVG.LIN." stops the measuring processes and switches on the state of linear averaging (LED "HOLD" lights).

Measurement is started by pressing the "HOLD/RUN" key (LED "RUN" lights) and automatically terminated after the preset measuring time. The "HOLD" LED is relit, and the value averaged over the measuring time is displayed. Premature pressing of the "HOLD/RUN" key stops the measuring process, and the old measured value is displayed.

The exponential averaging is selected by pressing the "AVG.EXP." key, the almost resent HOLD/RUN state is retained.
At start of measurement by pressing the HOLD/RUN key, the first averaging is done with the shortest averaging time (0.12 s). At each further averaging the time is increased for one step until the preselected value is reached. So independent of the selected T a first display-value is obtained quickly.
When pressing the HOLD/RUN key within the RUN-state, the averaging will be stopped and the most recent measured value will be displayed.

The lit LED indicates the current status.

6 Keys for selection of the measured quantity and mode

The desired mode is selected by pressing any of the keys A/CH-1, V/CH-2, W, POWER FACTOR, REAL (Z) or |Z|. This displays the appropriate measured value, together with sign, unit and function.

For the "A" and "V" quantities, the measuring mode as selected by the "RMS", "MEAN" or "REC MEAN" is also displayed.

In the "RMS" and "REC MEAN" modes, measured values below 2.5 % of the nominal signal level are displayed as zero.

For the computed quantities POWER FACTOR, REAL (Z) or |Z| flashing '88888' is displayed instead of the measured value if any of the quantities required for computation of the measured value becomes less than 3 % of the full-scale value.

Pressing the "MAX" or "MIN" key activates an extreme-value memory. If the appropriate LED on the keyboard lights, the extreme value of the most recently selected extreme-value function is shown in the display area.

To change the extreme-value storage, first select the new measured quantity (A, V, RMS, MEAN, REC-MEAN, W etc.); then clear the old extreme value formation with the new function.

Pressing the "ANALOG OUT" key calls the input routine for programming the analog output (jack (21) at instrument rear). Programming (see Section 7.8) should again be terminated with the "ENTER" key.

7 Input jack for the current channel

This special input jack serves for connection of the plug-in shunts (see Accessories) or of a user shunt by means of the supplied shunt-connecting cable.
Low and guard are interconnected within the instrument.

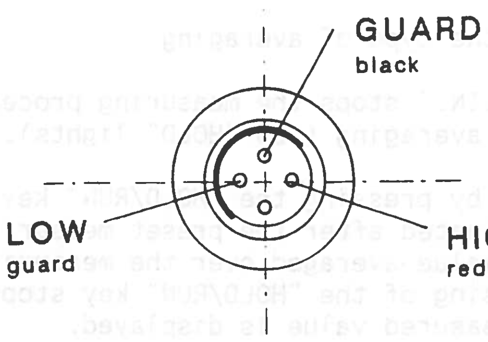


Fig. 5.3: Input jack for the current channel

8 Coupling-mode selector for the current channel

The selected coupling mode (AC+DC oder AC) is indicated by a lit LED and may be changed by pressing the appropriate key.

(9) Indication of BUS functions

The LED "REMOTE" lights after the Controller has put the instrument into remote-control state.
The LED "ADDRESSED" lights when the instrument is being addressed by the Controller or is transmitting data.
The LED "REQUEST SERVICE" lights when the instrument is sending a SERVICE REQUEST.

(10) Semi-automatic range selection of the current channel

"RANGE DOWN" : sets the next lower range
"RANGE UP" : sets the next higher range

The LED "UNDERLOAD" lights if the RMS value of the measured quantity is less than approx. 63 % of the full-scale value.
The LED "OVERLOAD" lights if the peak value of the measured value exceeds approx. 300 % of full-scale value.

If the crest factor is 4.8 or higher, both LEDs light. Ignore the LED "UNDERLOAD" in this case, but keep selecting higher ranges with the "RANGE UP" key until the LED "OVERLOAD" is extinguished.

(11) Display

Green 20-digit fluorescent display in 5-by-7-point matrix.
Digit size: 9 x 6,3 mm.

Besides the measured values, scale factors and ranges it is also possible to display the device address, the individual program steps for TALK-ONLY mode and various test functions.

Single-value display: 4 digit version: max. 9999, with sign, unit and function.
5 digit version: max. 99999, with sign, unit and function.
Two-value display: 4 digits with sign, unit and function. Both measured values may be freely selected.
Three-value display: 4 digits without unit and function. The sequence current (RMS), voltage (RMS) and active power is preset.

(12) Semi-automatic range selection of the current channel

"RANGE DOWN" : sets the next lower range
"RANGE UP" : sets the next higher range

The LED "UNDERLOAD" lights if the RMS value of the measured quantity is less than approx. 93 % of the full-scale value.
The LED "OVERLOAD" lights if the peak value of the measured value exceeds approx. 300 % of full-scale value.

If the crest factor is 3.3 or higher, both LEDs light. Ignore the LED "UNDERLOAD" in this case, but keep selecting higher ranges with the "RANGE" "UP" key until the LED "OVERLOAD" is extinguished.

Located at ***instrument rear*** are:

(13) Protective-wire terminal
To connect the protective wire (protective class I).
Caution: due to security, always connect protective wire, when measuring dangerous contact voltage, because the mains cable might be removed.

(14) Mains jack
for connection to the supply voltage.

(15) Mains voltage selector (115/220 V)

(16) Mains fuse DIN 41661: slow-acting 0.63 A for 220 V
slow-acting 1 A for 115 V

(17) Rear connecting jacks for the voltage channel
Turning of the insert and exchanging of the two covers pemits relocation of the voltage connection to instrument rear.

(18) BUS connection
"D" standard jack: IEEE-Standard 488/IEC 625 - 24 poles (e.g. Amphenol)

(19) Return to local
Operation of this key removes the instrument from remote control (e.g. for peforming manual settings).
Transmission of the next set of remote-control data by the Controller returns the instrument to remote-control mode.
The key may be disabled by transmitting "LLO" (Local lock out) at the start of the program.

(20) External trigger input: Jack: BNC
Level: TTL, negative logic
Application of LOW potential starts a measuring cycle in the "HOLD" state. Triggering may be repeated on expiration of the measuring and output period.

If the trigger input is kept LOW for more than one measuring cycle, the next measuring cycle is started automatically and terminated without regard to the trigger.

(21) Analog output
Caution: Do not apply any external voltage to the output jack!
For programming see Section 7.8.

(22) Key switch
Serves for internal calibration, for which see Chapter 8.

(23) Rear connecting terminals of the current channel

Turning the inset and changing the two covers permits reloction of the shunt connection to instrument rear.

6.COMPUTATION OF MEASURED VALUES:

Single-channel measurements:

RMS values: $U_{eff} = \sqrt{\frac{1}{T}\int_0^T u^2_{(t)}\,dt}$, $I_{eff} = \sqrt{\frac{1}{T}\int_0^T i^2_{(t)}\,dt}$

Mean values: $\bar{U} = \frac{1}{T}\int_0^T u_{(t)}\,dt$, $\bar{I} = \frac{1}{T}\int_0^T i_{(t)}\,dt$

Rectified mean values: $|\bar{U}| = \frac{1}{T}\int_0^T |u_{(t)}|\,dt$, $|\bar{I}| = \frac{1}{T}\int_0^T |i_{(t)}|\,dt$

Two-channel measurements:

Active power: $P = \frac{1}{T}\int_0^T u_{(t)} \cdot i_{(t)}\,dt$

This involves simultaneous measurement of U and I (RMS, MEAN, REC.MEAN)

Power factor: $PF = \frac{P}{U_{eff} \cdot I_{eff}}$

Absolute value of impedance: $|Z| = \frac{U_{eff}}{I_{eff}}$

Real part of impedance: $Re_{(Z)} = \frac{P}{I^2_{eff}}$

Averaging method:

Selectable averaging times: 0.12; 0.24; 0.48; 0.96; 1.92; 3.84; 7.68; 15.4 s

a) Linear averaging: Here the measuring time is the selected time constant. Subsequent filtering ensures a stable display.

b) Exponential averaging: This type of measured-value formation emulates the reponse time of an RC filter. Emulation is by the formula:

$$M = Ma + \frac{Mn - Ma}{\frac{T}{2}}$$

M .... displayed measured value
Ma ... old measured value
Mn ... new measured value

Table of individual timing steps:

Timing step		0	1	2	3	4	5	6	7
Time constant (s)	T	0.12	0.24	0.48	0.96	1.92	3.84	7.68	15.4
Setting time (s)	T99	0.24	2.4	8.4	38	144	600	2280	9300

7.INSTRUMENT STARTUP:

7.1 Items Supplied and Accessories:

FUNCTIONMETER with analog output -10 V....0....+10 V
and interface

Supplied accessories:

1 Mains connecting cable, 1.5 m long
2 spare fuses
1 pair of safety mesuring leads, 1 m long, with banana plug and test tips
1 shunt connecting cable, 1.5 m long, with guarded plug, second end free
1 set of operating instructions (German / English)

Available accessories:

Plug-in shunt 100 mA (approx. 100 mV), cl. 0.2
Plug-in shunt 1 A (approx. 100 mV), cl. 0.2
Plug-in shunt 10 A (approx. 10 mV), cl. 0.2
Plug-in shunt 100 A (approx. 30 mV), cl. 0.2

The exact value of shunt factor in A/mV is indicated on the shunt.
Nominal frequency range: 0 .... 100 kHz
Angular error at 20 kHz: ± 0.2 °
Maximum current: 3 times nominal current, except for 100 A plug-in shunt

High-current shunt: 300 A (approx. 150 mV), max. 540 A
bandwidth 2.2 MHz
High-current shunt: 1000 A (approx. 125 mV), max. 1090 A
bandwidth 0.14 MHz

The exact resistance value is indicated on the shunt +/- 0.2 %.
The conducting case is at current potential.

AC/DC-current converter: input current : 100 A
output current: 100 mA
limits of error: 0...1 kHz: ± 1% for I and P for cos phi ≥ 0,8 up
bandwidth: 0 ... 50 kHz
insertion hole: 10 mm diameter
mains connection: 220 V, 45 ... 65 Hz

Zero resistance: input voltage: 0.1 V ... 500 V
input impedance: 3 x 100 kΩ//450 pF
limits of error: DC: ± 0,2%
0...100 kHz: ± 1%

Thermal printer P4996:	with mains cable and 2 rolls of thermal paper mains connection: 220 V, 50 Hz
Thermal printer P4996:	with mains cable and 2 rolls of thermal paper mains connection: 110 V, 50 Hz
Pin printer P 9995:	for DIN A4 size
Plug adapter for printer:	for LISTEN-ONLY mode (if printer cannot be switched to LISTEN-ONLY mode)
Interface cable:	for IEEE-488 bus, 24 poles, 1 m long
Coaxial cable:	BNC at either end, 1 m long
Coacial cable:	BNC-banana, 1 m long, with earth/ground wire 0.15 m long
Carrying case:	for portable applications of the Power Analyzer
Rack-mounting kit:	for 19 inches, 3 height units

7.2 Startup Preparations:

After unpacking the instrument and accessories, make a visual check of completeness and any damage sustained in transport.

CAUTION: Check before switching-on whether the mains voltage selector (10) has been positioned correctly and whether the correct mains fuse (11) has been inserted. Correct either or both as necessary.

For 220 V: slow-acting fuse 0.63 A, DIN 41662
For 115 V: slow-acting fuse 1, DIN 41662

Thereafter the instrument may be connected to a three-pin outlet with the supplied mains connecting cable and switched on with the mains switch (1). If there is no three-pin outlet, suitable earthing/grounding should be connected to the protective-wire terminal (3).

CAUTION: The case is of protective class I; therefore operation is only permitted with the case earthed/grounded.

If major voltage drops occur in the supply system, a buffered supply (VBS) must be inserted to avoid instrument cut-off for undervoltage.

7.2.1 Relocation of Measuring Inputs at Rear:

The instrument is normally supplied with the measuring inputs at front. For 19" rack mounting and for certain measuring setups it may be preferable to relocate the measuring inputs at rear. To do this, proceed as follows:

1. Before refitting be sure to disconnect the mains cable and all measuring connections from the instrument.

2. Remove front panel.
   Remove cover and bottom plates.
   Remove the four screws in the corner pieces of the front frame
   Swivel out front panel.
   Disconnect cable connections from front panel and remove it.

3. Disconnect cable connections to analog input divider 4603-05 S50 and 4603-05 S 60.

4. Loosen the two screws (S); see Fig. 7.1.

5. Remove cover plates and cover caps at instrument rear.

6. Pull out the two inserts, turn them and reinsert them from the rear.

7. Refasten the inserts with the screws (S).

8. Reassemble the rear cover plates and reinsert cover caps in front panel.

9. Connect the two inserts as per Fig. 7.1.

10. Connect and insert front panel in reverse order of disassembly (described in 2.). Be sure not to get any cable connections pinched.

11. Reassemble cover plate; also bottom plate if required.

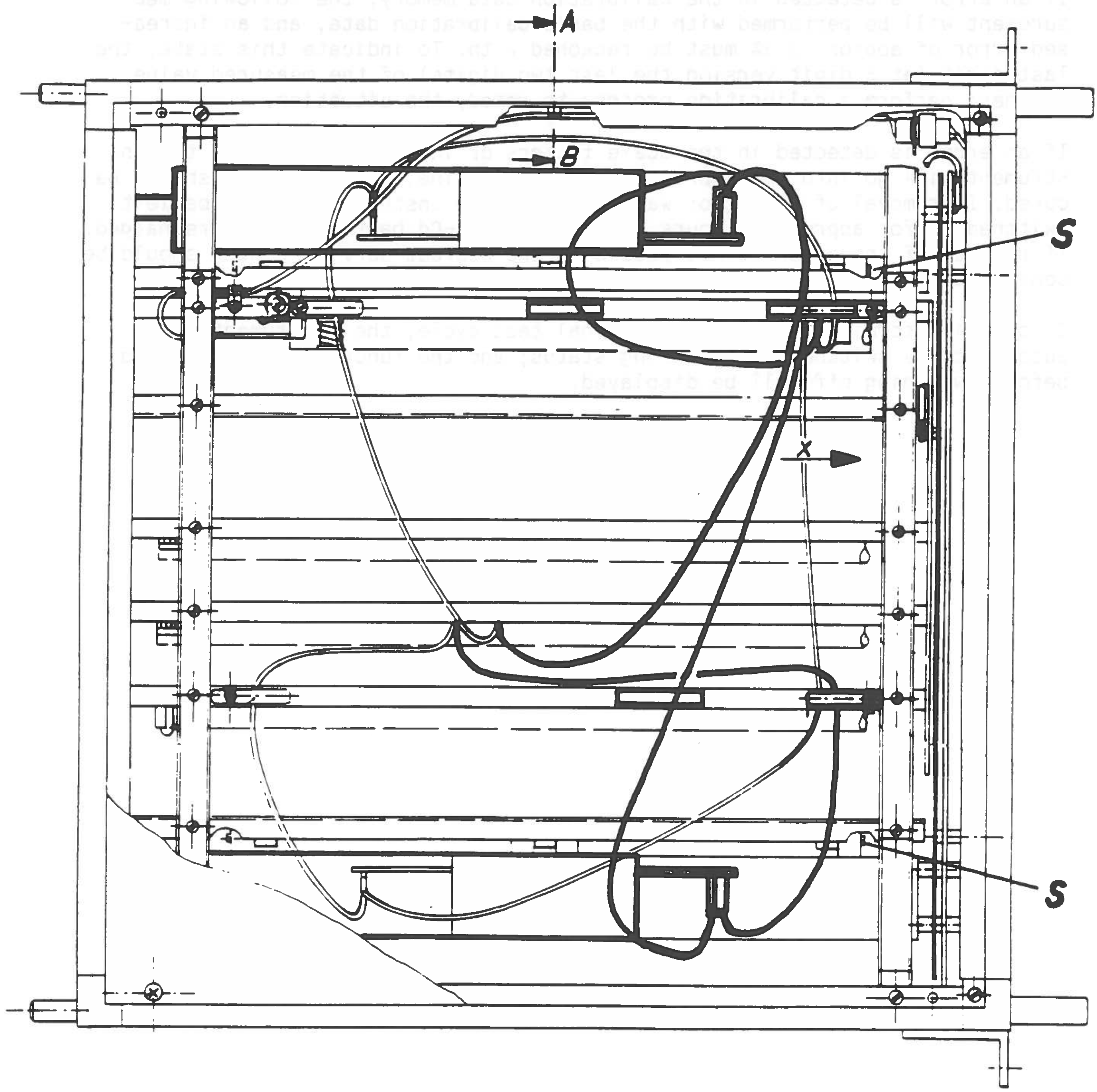


Fig. 7.1: Disassembly of front panel

7.2.2 Startup State and Memory Test:

After switching on the instrument, an internal testing cycle will be performed. During this cycle, first all 20 matrix positions of the display are tested sequentially, with a subsequent test of all LEDs. The internal test program checks the checksum of the memory that holds the calibration data.

If an error is detected in the calibration-data memory, the following measurement will be performed with the basic calibration data, and an increased error of approx. ± 3% must be reckoned with. To indicate this state, the last digit (at 5 digit version the last two digits) of the measured value flashes; perform a calibration process to remedy the situation.

If an error is detected in the scale factors or in the BUS address, the instrument will go into the appropriate input routine, and the error should be cured. If removal of the error was possible, the instrument should be left switched on for approx. 24 hours, so that the Ni-Cd battery can be recharged. If removal of the error is not possible, the nearest service center should be contacted.

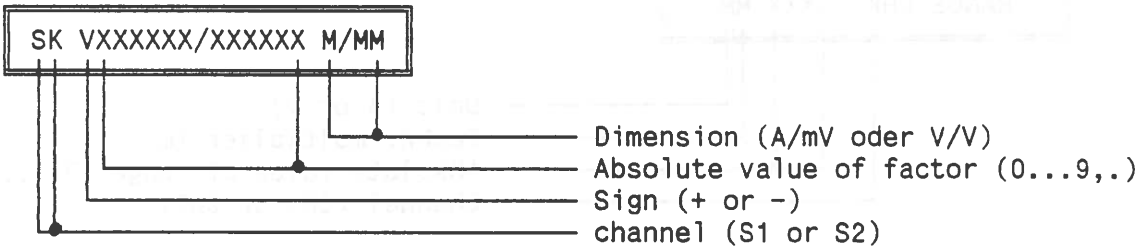
On positive termination of this internal test cycle, the instrument is automatically switched to measuring status; and the function last selected before switching off will be displayed.

7.3 Input of Scale Factors:

The scale factor takes into account the multiplication factors or ratios of external measuring transformers or shunts. The display will therefore always show the correct (primary) measured value, no further recomputations being necessary.

From the state of display of the measured value, pressing the "SCALE" key calls the input routine, which first causes the most recently selected scale factor S1 or S2 (depending on the type of measured value most recently displayed) to be displayed. A choice of the scale factor to be changed (S1 or S2) is now possible by means of the keys "CH1-A" and "CH2-V" respectively.

The flashing cursor shows which position can be altered by subsequent pressing of any numeric key (0....9,.). See also the description of the keyboard in Chapter 5.



<u>Input ranges:</u> .00001 ... 999999/.00001 ... 999999

On termination of input, press "ENTER"; the scale factor will be stored, and the input routine for the range will become active, with the instrument selecting and displaying the most favorable range (see also Section 7.4).

If the display of the scale factor remains static even after pressing the "ENTER", an input error has occured. Storage is only possible after correction of the illegal input (e.g. 1.5.00/60.000 A/mV).

<u>Examples</u>:

for a shunt 1500 A/60 mV set: S1 + 1500.0/60.000 A/mV
for a transformer 25 kV/100 V set: S2 + 25000./100.00 V/V

The following input would be respectively equivalent to the above examples:
S1 + 001500/000060 A/mV and
S2 + 025000/000100V/V

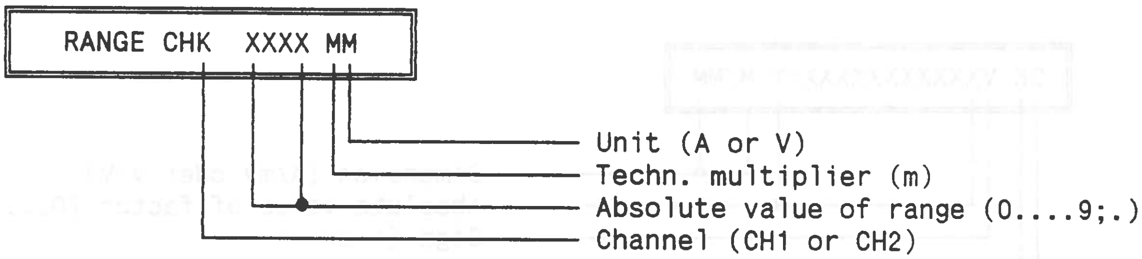
The six-digit input for the scale factors offers the possibility to reduce the maximum limits of error of the measuring setup (measuring instrument + shunt or transformer) if it is known, e.g. from a test certificate, that the shunt has a negative error of - 0.12 %. In this case the scale factor should be set to S1 + 1500.0/59.928.

7.4 Input of Range:

The input routine for the range may be entered in two ways:

a) after terminating the scale-factor input with "ENTER": In this case the most favorable range (derived from the second part of the scale factor) is automatically selected and displayed. If no change is desired, only termination with "ENTER" is required. Else the proposed range is overwritten with the numeric keys, followed by storage with "ENTER".

b) from the measured-value display status by directly calling the input routine with the "RANGE" key. In this case the currently valid range is displayed. Subsequently proceed as for (a). The scale factor will of course remain unchanged by this procedure.



Input ranges: CH1: 10 ..... 150 mV
CH2: 0.1 .... 500 V

Examples: RANGE CH1 150 mV
RANGE CH2 500 V

In the above example, two nominal ranges (see Technical Data) have been selected. If no nominal range has been entered with the numeric keys, the resultant intermediate value is not used but changed to the next higher nominal range, which is stored.

Example:

If RANGE CH2 has been set to 220 V, "ENTER" passes the 280 V range to memory. For a measured value of 220 V this would result in a signal level of 78 %. It is, however, possible, to improve the signal level and thus the limits of error by utilizing the overload capacity of 300 %.

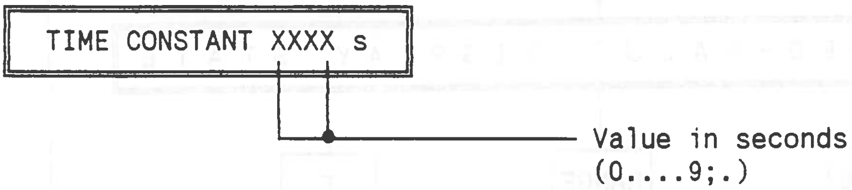
This means that for 220 V (sinusoidal, $C = \sqrt{2}$), setting of the 160 V range is still possible without an overload occurring. In case the selected range should be too low (e.g. because $C > \sqrt{2}$), this is signaled as "OVERLOAD" and can of course be corrected at any time with the "RANGE UP" key without having to return to the input routine.

Note: without using the input routine the ranges can be changed with the keys "RANGE UP" and "RANGE DOWN". See description of controls.

7.5 Input of Averaging Time:

For adaption to different signal structures, the averaging time is selectable in eight steps from 120 ms to 15.4 s (see also Chapter 6).

For this purpose, starting from the measured-value display status, call the input routine with the "T" key; the most recently selected value will then appear in the display.



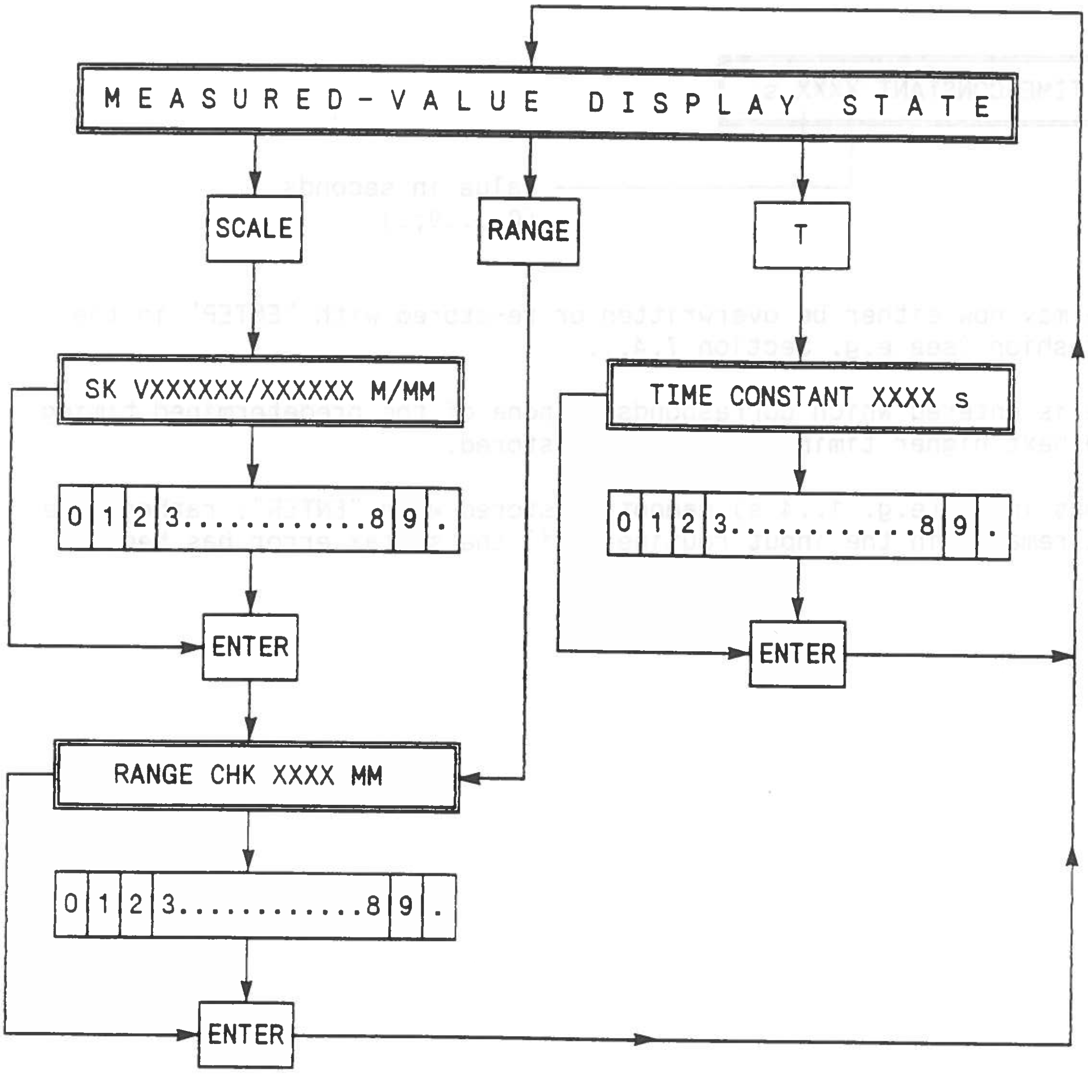
This value may now either be overwritten or re-stored with "ENTER" in the familiar fashion (see e.g. Section 7.4.).

If a value is entered which corresponds to none of the predetermined timing steps, the next higher timing step will be stored.

An erroneous input (e.g. 1..4 s) cannot be stored with "ENTER"; rather, the instrument remains in the input routine until the syntax error has been cleared.

7.6 Flowchart for Input Routines:

This flowchart illustrates the input routines decribed above, i.e. for scale factors, ranges and averaging periods, as well as the ways to ask for previously selected values (stored by the instrument).



To terminate one of those routines, always press "ENTER", which will return the instrument to the measured-value display state.

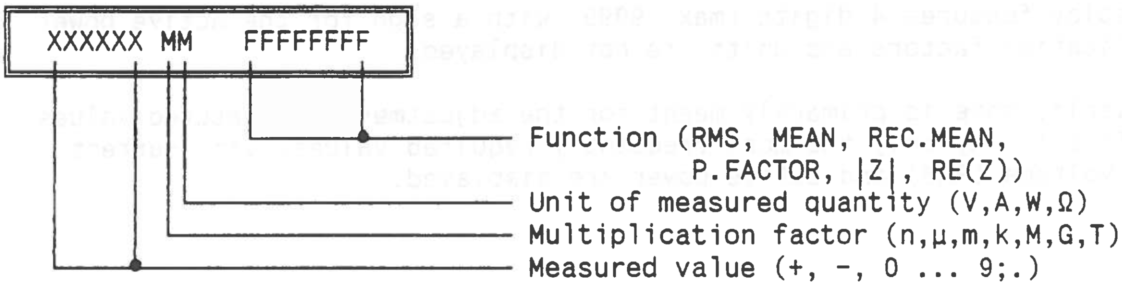
7.7. Display Selection for the Measured Values:

For optimum adaptation to the measuring task, different modes of measured-value display may be selected, i.e. single, double or triple display.

From the single display, repeated presses of the "." key will switch first in to double, then triple display, and from there back to single display.

7.7.1 Displaying One Measured Value:

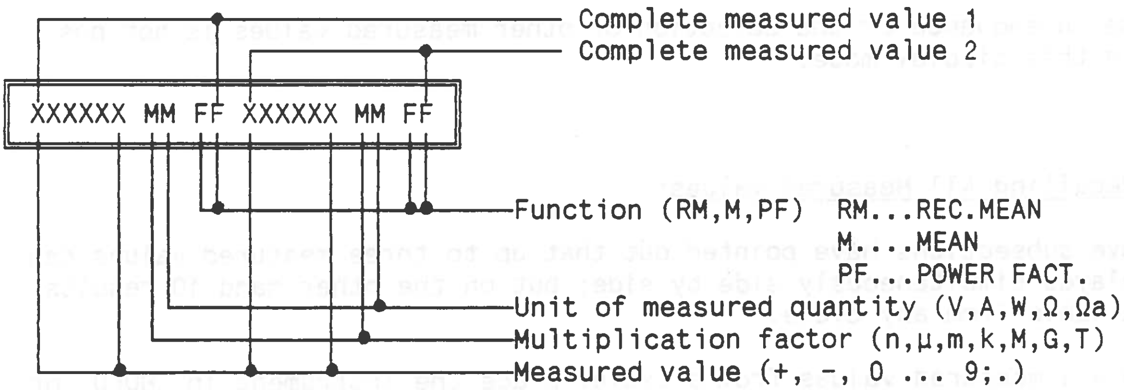
The display features 4 digits (max. 9999) with sign, unit and function or 5 digit (max.99999 in the 5 digit version). If a measured value cannot be computed, flashing "8888" is displayed.



The selection of the measured value to be displayed is made from the keyboard (6), as described in Chapter 5.

7.7.2 Displaying Two Measured Values:

The display features 4 digits (max. 9999) with sign, unit and function. If a measured value cannot be computed, flashing "8888" is displayed.



Selection of the two measured values to be displayed is made in two ways:

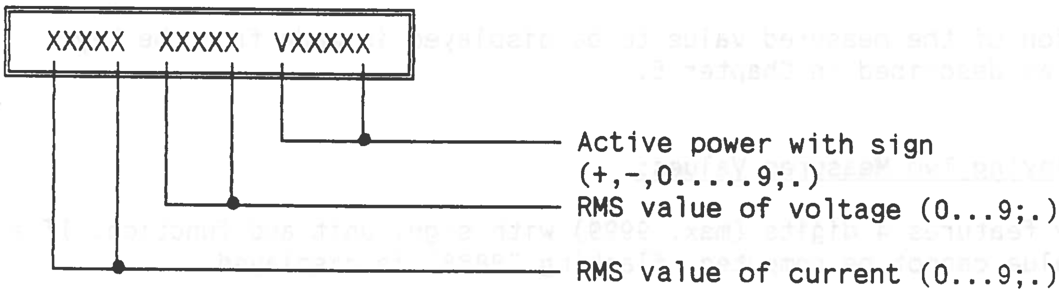
a)automatically: on entering double display, the function selected for the previous single display is used as measured value 1, while for measured value 2, that function within the most recent double display is used.

b)manually: if a change is desired, press key "1" for measured value 1, followed by the desired function, and similarly for measured value 2.

7.7.3 Displaying Three Measured Values:

The display features 4 digits (max. 9999) with a sign for the active power, Multiplication factors and units are not displayed.

This display mode is primarily meant for the adjustment of measured values only. This is why only the most frequently required values, viz. current (RMS), voltage (RMS) and active power are displayed.



A change in sequence or the selection of other measured values is not possible in this display mode.

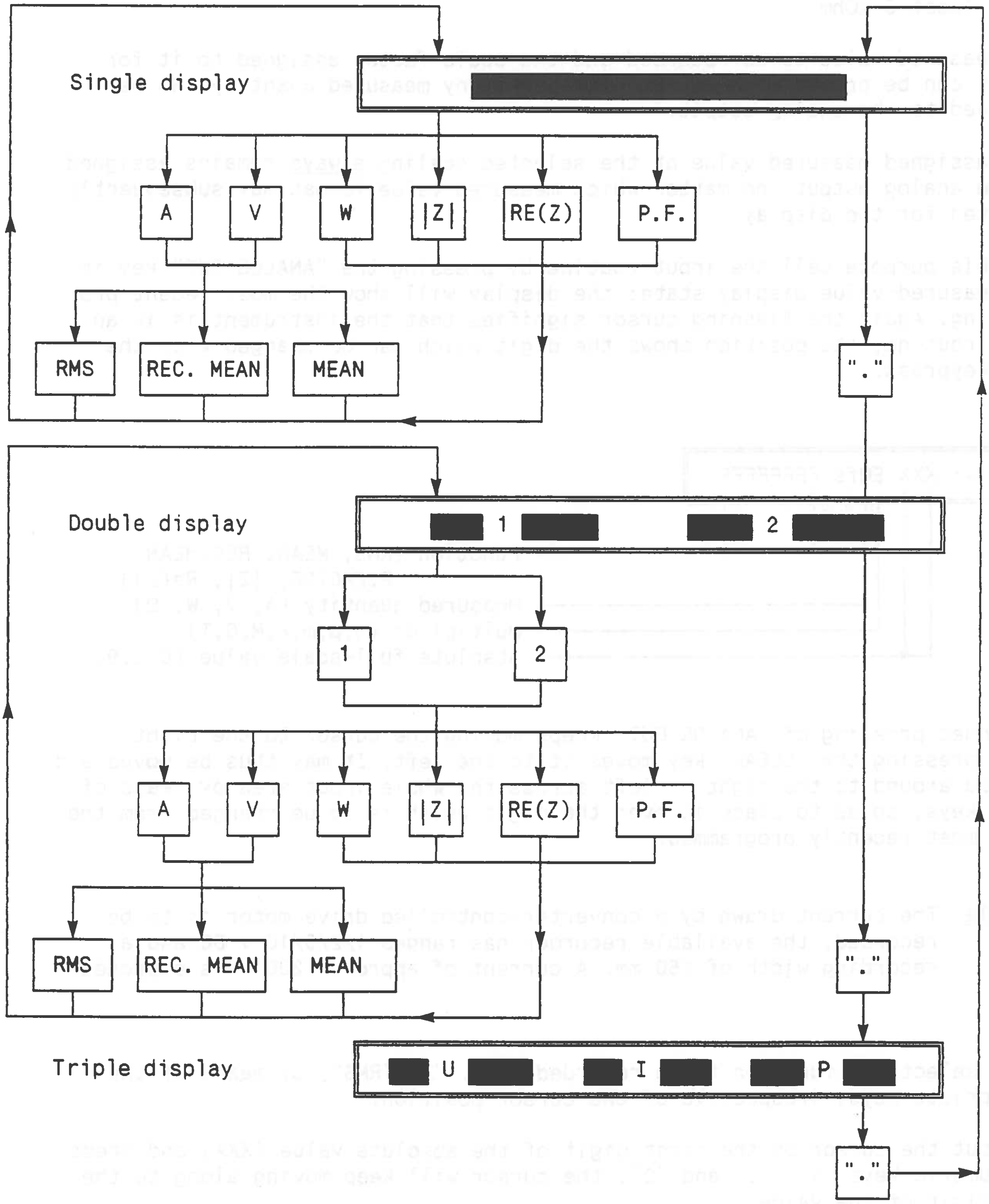
7.7.4 Recalling All Measured Values:

The above subsections have pointed out that up to three measured values can be displayed simultaneously side by side; but on the other hand 10 results are available from any cycle.

To read all measured values from a cycle, place the instrument in "HOLD" or wait until the averaging time has expired; then recall the measured values into the display in the desired order for reading.

For printing and BUS output see the corresponding Sections.

7.7.5 Flowchart for Display Selection:



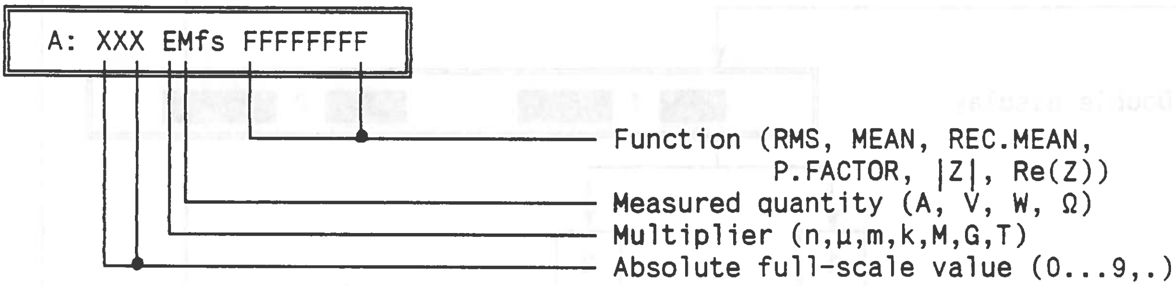
7.8 Analog Recorder Output:

To record measured values, a recorder output is available at instrument rear (jack (21), "ANALOG OUT"). It supplies a voltage of -10 V...0...+10 V DC and may be loaded at max. 2 mA, i.e. the input resistance of the recorder should be at least 5 kOhm.

The measured value to be recorded and the scale factor assigned to it for output can be programmed from the keyboard. Any measured quantity can be assigned to the analog output.

This assigned measured value at the selected scaling <u>always</u> remains assigned to the analog output, no matter which measured-value format may subsequently selected for the display.

For this purpose call the input routine by pressing the "ANALOG OUT" key in the measured-value display state; the display will show the most recent programming. Again the flashing cursor signifies that the instrument is in an input routine; its position shows the digit which can be changed with the next keypress.



Continued pressing of "ANALOG OUT" keeps moving the cursor to the right, while pressing the "CLEAR" key moves it to the left. It may thus be moved and wrapped around to the right or left across the whole input area by means of these keys, so as to place it over the digit which is to be changed from the value most recently programmed.

<u>Example</u>: The current drawn by a converter-controlled drive motor is to be recorded; the available recorder has ranges 1/2/5/10 V DC and a recording width of 250 mm. A current of approx. 1200 A is expected.

First select the function to be recorded (e.g. "A" "RMS") by means of the appropriate keys, irespective of the cursor position.

Next put the cursor on the first digit of the absolute value (XXX) and press the numeric keys "1", "." and "2"; the cursor will keep moving along to the last digit of the value.

Next place the cursor to the position corresponding to the multiplier (E) and select multiplier k by pressing the key ".".

Successive pressing of the "." key would cycle through the possible multiplication factors.

This terminates the input itself; the display must now show

A: 1.2 kAfs RMS

and the input routine only needs termination by "ENTER". The values are now stored, and the measured-value display status is resumed.

Based on this programming, a current of 1200 A (= 1.2 kA) will now cause an instrument voltage output of +10 V DC; hence scaling for the recorder is 4.8 A/mm.

Moreover the instrument features a very useful adjustment aid, e.g. for cases of recorders of variable amplification (sensitivity). This permits optimum adaption of the line chart to the available chart width.

To call up this adjustment aid, place the cursor in the original input routine on the cursor position ":" and keep pressing the "." key. The first keypress shows

A: TEST ZERO

in the display, and zero voltage is applied to the output jack. Now the recorder's zero may be tested or changed without having to set the measured value itself to zero.

The second and third presses of the "." key result in a display of

A: TEST + fs	and	A: TEST - fs

respectively, corresponding to an application of +10 V DC and - 10 V DC respectively to the output jack. This permits check of and adjustments to the recorder's full-scale value, again irrespective of the measured quantity.

Returning from this recorder setting to the measured-value display mode requires pressing either the "CLEAR" or the "ANALOG OUT" key.

7.9 Digital Printer Output for TALK-ONLY Mode:

7.9.1 Programming:

In the programmable "TALK ONLY" mode, the instrument can make a hard copy of measured values in selectable time intervals through the IEEE 488 Interface. This does not require a Controller.

The necessary printer settings depend on its make. In general the following actions should be performed:

a) Switch off the timer, if there is one.
b) Switch off auto line feed, if it is on.
c) Switch the printer to "LISTEN ONLY".
d) Connect instrument and printer by Interface cable.

If the printer used does not support self-addressing as "LISTENER", it can be addressed by means of a plug-on adapter by pressing the key provided on it. This is available as an accessory, set to address 4. It should be plugged into the Interface cable (see Fig. 7.1. and 7.2.).

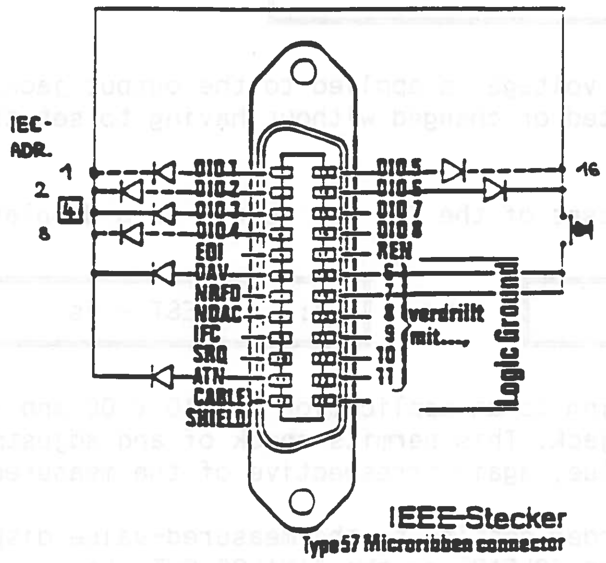


Fig.7.1: Plug-On Adapter for TALK-ONLY Mode

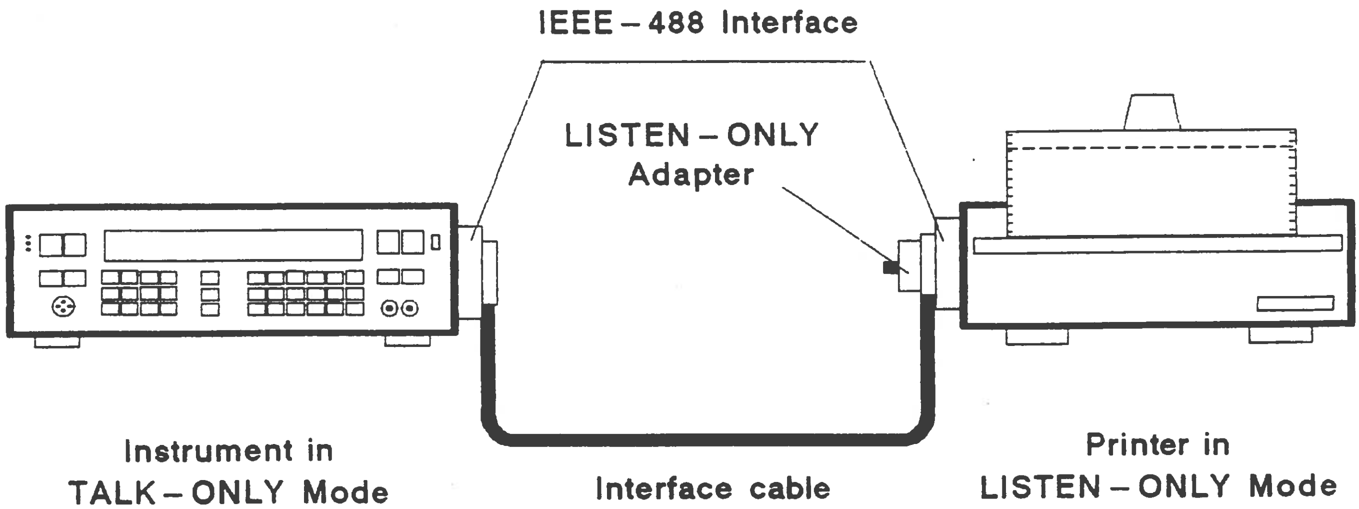
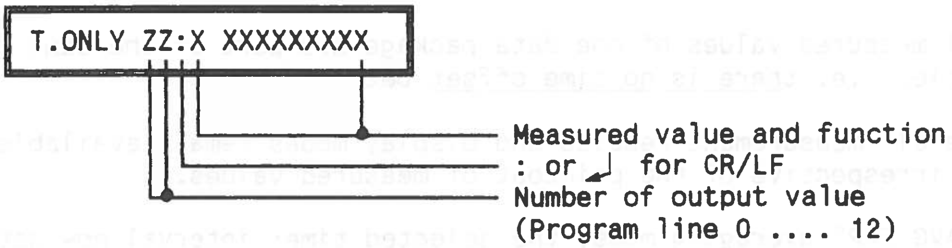


Fig.7.2 : Wiring for TALK-ONLY Mode

From the measured-value display mode, call the input routine with the keys "ENTER" and ".". This makes the first line (i.E. ZZ = 01) of the previous programming appear in the display.



Now start by selecting the measured quantity (e.g. A and RMS) for the first value to be printed. Next select whether after this measured value a CR/LF (carriage return + line feed) is to be generated. This can be selected with the "CLEAR" key and cleared by again pressing the same key. When "CR/LF" has been sent, the symbol "↲" appears instead of ":" in the display. This terminates the programming of the first output value, which can be stored by pressing "ENTER".

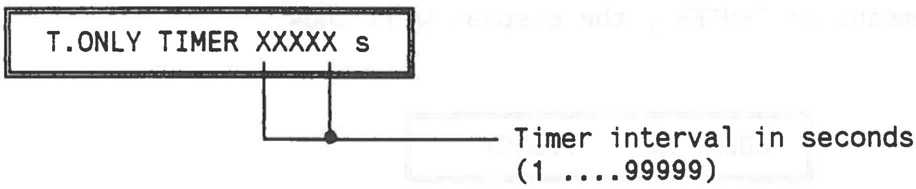
Now the second line (ZZ = 02) will be displayed with the most recent programming; and the measured value to be printed in second place is again programmed as described above.

For better visual structuring of a printout (e.g. by insertion of a blank line), a "BLANK" may be programmed instead of a measured value.

This is done by one of the multiple functions of the "." key. Repeated keypresses will cycle through "BLANK", "END" and the previously selected measured quantity in the display. "BLANK" and "END" are always combined with the symbol "↲", i.e., a CR/LF is always transmitted after them.

Once all desired measured values have been programmed, "END" (see above) may be set and stored. The next lines will be skipped, and the next mode will call for timer-interval input.

This input cycle may, however, be continued until the last output value (ZZ = 12) has been stored, upon which the display will automatically show



and the TIMER intervall between two printouts should be selected. The flashing cursor shows the position (decade) to be keyed in; after a numeric keypress it will move to the right, while pressing "CLEAR" will move it to the left.

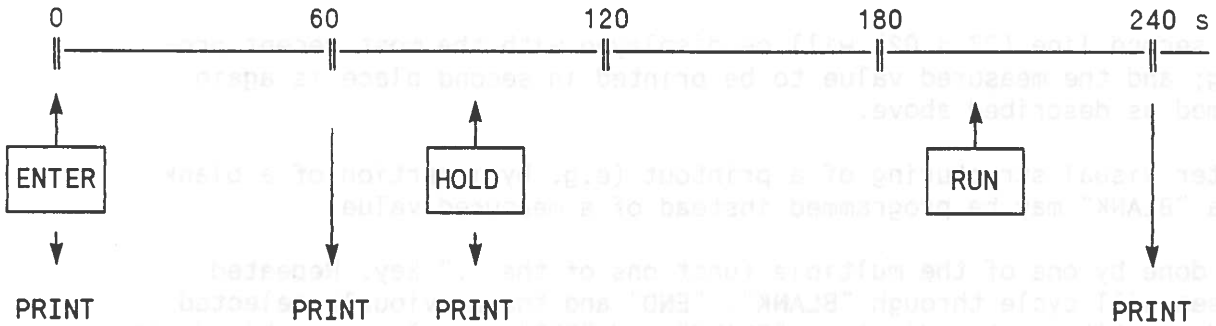
<u>Note:</u> When entering the timer interval (in s), be sure to make it longer than the printer takes to print the programmed number of measured values (this includes programmed BLANKS). Else the instrument will be unable to comply with the timer interval.

From the moment the timer interval is stored with "ENTER", timing is started, and the first package of measured values is output to the printer. The LED "ADDRESSED" on the instrument's front panel lights, and the meter returns to measured-value display.

<u>NOTE:</u> All measured values of one data package are part of the same mesuring cycle, i.e. <u>there is no time offset</u> between them.

Of course all measurement results and display modes remain available for display, irrespective of the printout of measured values.

In the "AVG EXP" averaging mode, the selected timer interval now determines output timing. If an intermediate printout is desired, it can be triggered at any time with "HOLD". If the instrument is left in "HOLD", no further values will be printed, since the acquisition of new measured values has been stopped, too. The set timer interval, however, continues to run in the background. As soon as the instrument is returned to "RUN", the timing pattern resumes control of the measured-value output to the printer. The following line diagram illustrates this situation for a timer interval of 60 s.



For purely manual or remote-controlled printer triggering, set the timer interval to 99999 s; this manual triggering of the measured-value printout at any time by means of "HOLD" and "RUN".

In the "AVG LIN" averaging mode, the printout always occurs at the end of the averaging period, irrespective of the timer interval.

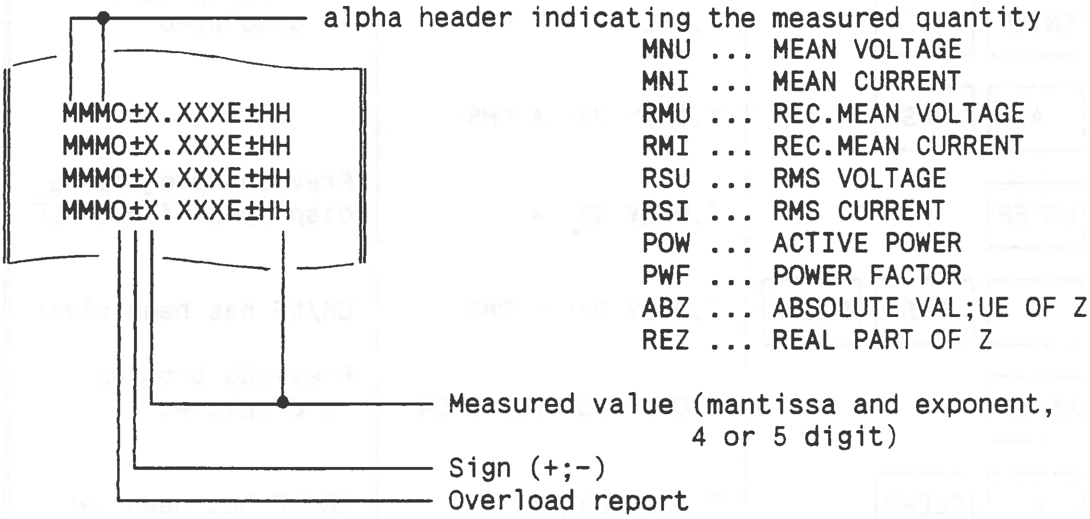
To terminate TALK-ONLY mode, make another call of the start of the input routine by means of "ENTER"; the display will show

ADDR. XX   T.ONLY

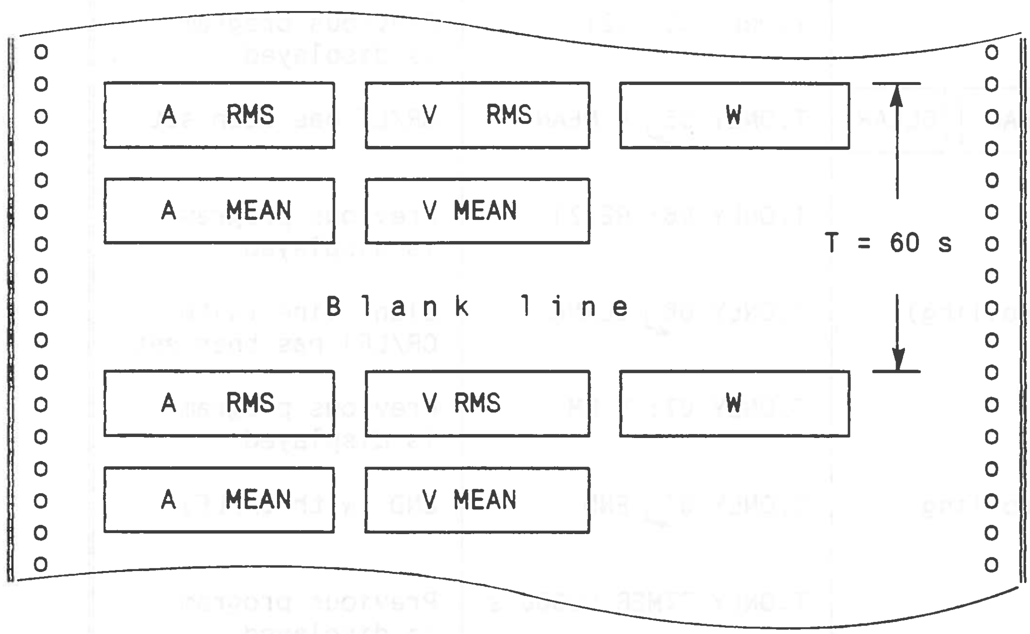
indicating that TALK-ONLY mode is still active. "CLEAR" interrupts the output cycle, "T.ONLY" disappears from the display, and the LED "ADDRESSED" on the front panel is extinguished. "ENTER" now returns to measured-value display.

7.9.2 Data Format and Print Formatting:

Each measured value is output as 14 bytes (or 15 bytes for 5 digit version) and if so programmed, terminated with CR/LF.



Example: On a printout with 80 characters per line and at 5 lines per second, the following format is desired:



For this example the individual program lines should be set as follows:

	Key sequence:	D i s p l a y:	N o t e :
1	ENTER "."	T.ONLY 01: V RMS	Previous program is displayed
2	A RMS	T.ONLY 01: A RMS	
3	ENTER	T.ONLY 02↲ W	Previous program is displayed with CR/LF
4	V RMS CLEAR	T.ONLY 02: V RMS	CR/LF has been clear
5	ENTER	T.ONLY 03: P.FACTOR	Previous program is displayed
6	W CLEAR	T.ONLY 03↲ W	CR/LF has been set
7	ENTER	T.ONLY 04: V MEAN	Previous program is displayed
8	A MEAN	T.ONLY 04: A MEAN	
9	ENTER	T.ONLY 05: |Z|	Previous program is displayed
10	V MEAN CLEAR	T.ONLY 05↲ V MEAN	CR/LF has been set
11	ENTER	T.ONLY 06: RE(Z)	Previous program is displayed
12	"." (rolling)	T.ONLY 06↲ BLANK	Blank line (with CR/LF) has been set
13	ENTER	T.ONLY 07: V RM	Previous program is displayed
14	"." (rolling)	T.ONLY 07↲ END	END (with CR/LF)
15	ENTER	T.ONLY TIMER 00360 s	Previous program is displayed
16	0 0 0 6 0	T.ONLY TIMER 00060 s	60 s timer interval
17	ENTER	MEASURED VALUE DISPL.	PRINTOUT STARTS

8. CALIBRATION:

The calibration process is prompted on the display. It permits complete DC calibration of the instrument. It requires an adjustable DC voltage source with sufficient stability at least in the short term.

Before calibrating: wait for **the thirty minutes required for warm-up.**

The calibration process is started by turning the detachable-key switch to the "CAL" position; this will make

CAL: CH2 0.25 V

appear in the display, prompting for calibration of the 0.1 V range in channel 2. The suggestion is to apply this suggested optimum voltage (250 % of the nominal range), i.e. 250 mV in this case. If this voltage is not available, the suggested value can be modified to an available value by means of the numeric keys.

To obtain the highest possible accuracy, the calibrating voltages to be applied must of course be situated between certain minimum and maximum values. These are tabulated below.

Channel	Range	Minimum permiss.	Suggested default	Maximum permiss.
		Calibration voltage		
U	0.10 V	0.17 V	0.25 V	0.29 V
	0.17 V	0.30 V	0.43 V	0.51 V
	0.30 V	0.52 V	0.75 V	0.91 V
	0.54 V	0.91 V	1.35 V	1.58 V
	0.96 V	1.59 V	2.40 V	2.79 V
	1.70 V	2.80 V	4.25 V	4.92 V
	3.00 V	4.93 V	7.50 V	8.69 V
	5.40 V	8.70 V	13.5 V	15.30 V
	9.60 V	15.40 V	24.0 V	27.00 V
	17.0 V	27.10 V	42.5 V	47.70 V
	30.0 V	47.80 V	75.0 V	84.20 V
	50.0 V	84.30 V	125 V	148 V
	90.0 V	149 V	225 V	262 V
	160 V	263 V	400 V	462 V
	280 V	463 V	700 V	816 V
	500 V	817 V	999 V	999 V
I	10.0 mV	11.8 mV	25.0 mV	28.8 mV
	25.0 mV	28.9 mV	62.5 mV	71.0 mV
	60.0 mV	71.1 mV	150 mV	175 mV
	150 mV	176 mV	375 mV	450 mV

When the voltage applied coincides with the voltage displayed, pressing "RUN" will start the internal calibration process. Once this calibration step is terminated, the display promptes for the application of the optimum voltage for the next higher range.

After calibration of the highest voltage range, the process continues with application of the required voltages to the shunt channel, following the procedure above.

On termination of the last calibration process (shunt channel, 150 mv range), the display will return to the format shown at the start of the calibration sequence.

The normal instrument status is now reestablished by returning the detachable-key switch to the "RUN" position and by pressing the appropriate keys. We recommend that the key be removed and stored to avoid unintentional miscalibration.

It is not always necessary to calibrate all ranges, if, say, the instrument is only used for one voltage. In this case use the numeric keys to enter the default value - or at worst a value between the minimum and maximum - for the range in question, thus preparing the instrument for calibration of that range.

Example: As the only range to be used is the 90 V range of CH2, this range only is to be calibrated. The available source supplies 200 V DC; i.e. a voltage permissible for this range (see table).

Precedure:
1) Turn detachable key switch to "CAL" position.
2) Overwrite the default value of 0.25 V (displayed) with 0200 V the instrument is now ready for calibration of the 90 V range.
3) Connect calibration voltage and press "RUN".
4) On termination of the error-free calibration process the display.

CAL:	CH2	400 V

i.e., the instrument would now be ready for calibration of the next higher range (= 160 V). As this is not required in the present instance, turn the detachable-key switch back to "RUN". Calibration is now complete.

If, however, a calibration process becomes necessary through RAM error (e.g. because the buffer battery has become discharged), it is absolutely necessary to perform all steps of calibration; else erroneous measured values would be displayed in the non-calibrated ranges.

After a calibration step, a flashing "* F *" may be displayed as a prefix to the unchanged voltage value. In such a case, check the input voltage for deviation from the value displayed and repeat the calibration step. If the second attempt also fails, the current range is outside tolerance to such an extent (± 3 %) that a fault in the input section must be considered possible. It is, however, possible to attempt continued calibration for the following ranges by entering the next higher calibration voltage.

If an attempt is made to perform the calibration process with a voltage higher than the maximum permissible voltage for the channel concerned (e.g. 450 mV for CH1 or 999 V for CH2), a flashing "* 0 *" will be prefixed to the voltage value.

If the value set on the display exceeds a value of 300 % of the nominal signal level, the calibration routine automatically selects the next higher range and calibrates there.

9. FUNCTIONAL DESCRIPTION:

Signal processing and analog/digital conversion work in the same way in both channels, the only differences being in the number and type of divider steps and the magnitude of the amplification of A1. The block diagram of the instrument is shown in Fig. 9.1.

9.1 Analog Section:

The input signal is passed to the voltage divider via the inverting amplifier A1. Switching of the divider ratio is made by means of FET switches. In coupling mode AC, the output signal of amplifier A1 is used as negative feedback on the input by means of integrator A2, thus suppressing DC voltages and low-frequency AC voltages. Beyond the divider, a standardized signal of U = 95 mV for a 100 % level is available.

9.2 Analog/Digital Conversion:

Analog-digital conversion uses the principle of successive approximation. The signal is passed to a sample-hold circuit in order to store the instantaneous signal value for the duration of a conversion. The SH circuit consists of the voltage follower A3 with high slew rate, the MOSFET switch and the storage capacitor with following amplifier A4.

The sampling frequency is approx. 22 kHz. In analog-digital conversion (ADC) by the successive approximation method, the sampled signal value is compared with the output signal of a digital/analog converter (DAC). The DAC is controlled by the successive approximation register (SAR), which successively sets each bit, starting with the most significant bit (MSB). Depending on the decision of comparator A6, the bit will be either accepted or reset. Besides the parallel outputs for controlling the DAC, the SAR also features a serial output DO. Data transmission takes place in the so-called OFFSET BINARY CODE.

Measurements are possible up to a sampling frequency of 20 kHz, because the mesured signal is not analyzed in its entirety, only the instantaneous values and the phase being necessary for averaging.

The narrow-band characteristic of the digital (Chebysheff) filter and the variation of the sampling frequency in case of beat frequencies help to avoid erroneous measurements at the harmonics and subharmonics of the sampling frequency.

A filter factor corresponding to a Chebysheff characteristic evaluates the sum of each package of 32 samle values; the average is then formed from the 81 part sums. This evaluation method reduces the error caused by not performing averaging over integer multiples of the signal period. Thus a steadier display is obtained even at low signal frequencies and short averaging time. The averaging time should be about four times the duration of a cycle of the measured signal.

Any digitalization is always subject to a quantifiying error, since the continuous measured signal is represented by a finite number of voltage steps. In the present case an 8-bit code is used, resulting in a resolution of 2 EXP 8 = 256 steps.

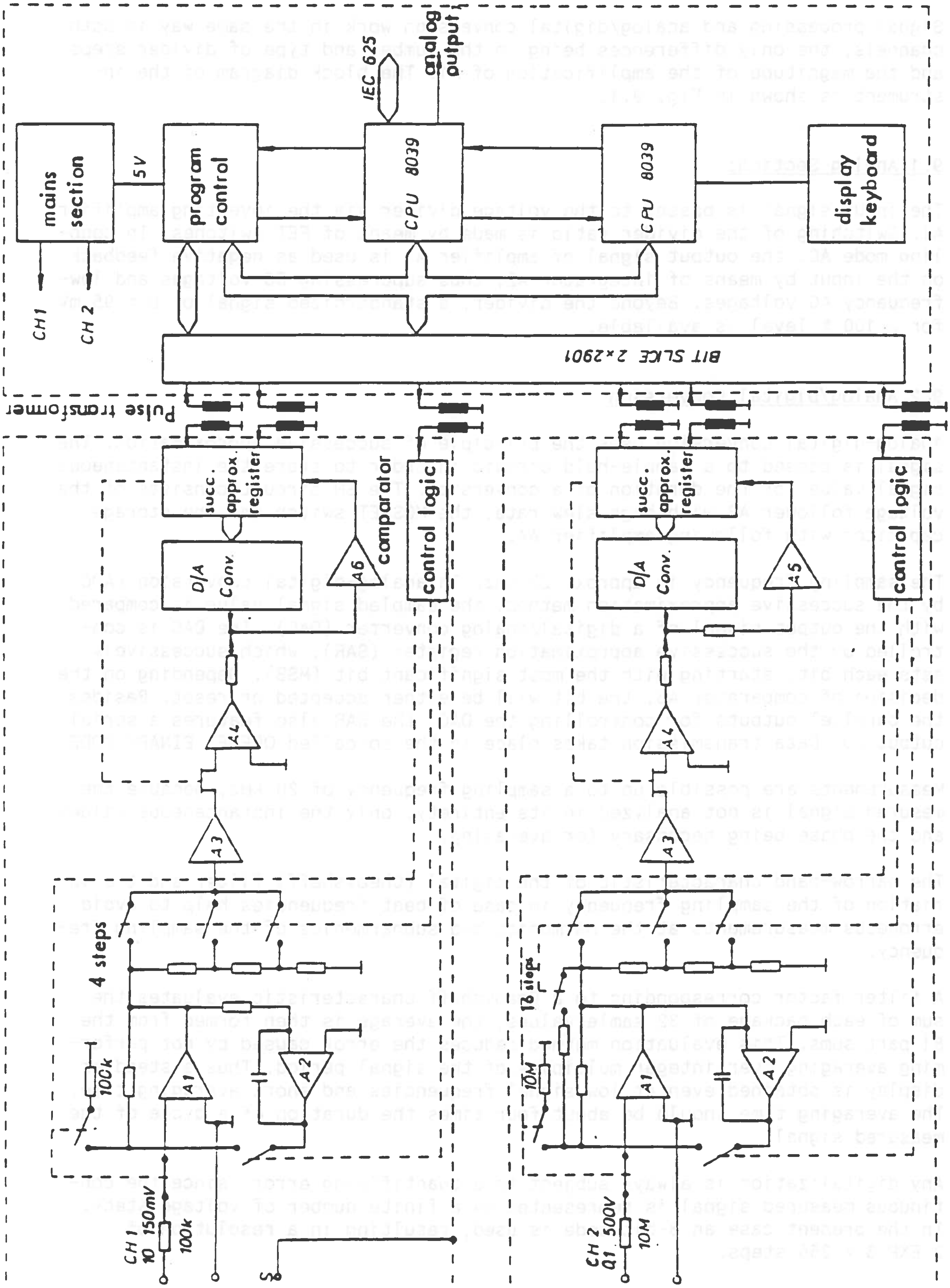


Fig. 9.1: Block Diagram of the instrument

A special interpolation algorithm over the range of the LSB (least significant bit) permits an enhanced resolution without increasing the number of steps. Since at the ADC output the data fluctuates about the instantaneous value of the signal, averaging over a sufficient number of successive data bytes will yield the correct interpolation value.

A timer constant of 120 ms is assigned an interpolated value from 2592 sampling values. The number of sampling values is directly proportional to the timer constant.

9.3 Arithmetic and Administrative Unit:

The arithmetic unit works with two 4-bit microcontrollers (bit slices), cascaded to 8 bits. Program control comprises the program memory of 512 x 48 bits and run control.

In this arithmetic unit (see Fig. 9.2), the sampling values of the two analog sections are processed by appropriate arithmetic operations, averaging and digital filtering. The offset voltage of the two analog sections is measured at intervals of 30 s and taken into account in the computation of measured values. Furthermore, arithmetic routines are performed for the administrative unit.

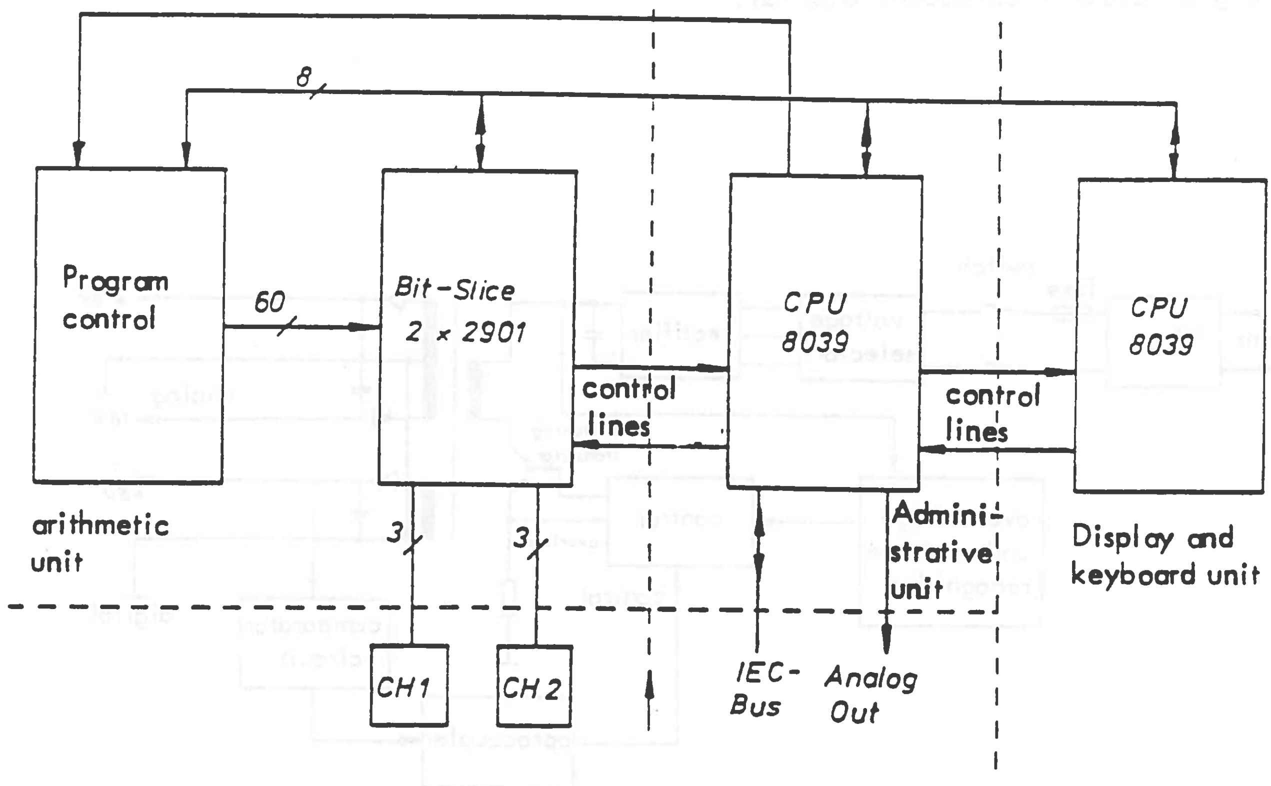


Fig. 9.2: Arithmetic and administrative unit

The control data for the analog sections (range, coupling and offset measurement) are accepted in parallel by the administrative unit and passed serially to the analog sections, simultaneously with reading the conversion values. The measured values formed in the arithmetic unit (RMS value, mean value, rectified mean value and power) are offered to the administrative unit every 120 ms to 15.4 s depending on the selected averaging time.

The administrative unit works with an 8-bit microprocessor (8039). Here the measured values supplied by the arithmetic unit in binary form are multiplied by the calibration and scaling factors, converted to BCD format and stored in a format suitable for the display and the interface.

Furthermore, these measured values serve as a basic for computation of the power factor, real part of Z and absolute value of Z by means of the routines in the arithmetic unit; these, too, are stored in a format suitable for output. The administrative unit also takes charge of all tasks for the interface and the analog output. It also processes information from the keyboard and supplies data for display. The prompted calibration routine is also controlled by the administrative unit.

All instrument data is stored in a CMOS RAM and buffered with a Ni-Cd storage battery, thus remaining available even after switching the instrument off.

9.4 Display and Keyboard Unit:

Each key of the membrane-type keyboard transmits a unique code to the administrative unit via the display processor (8039).

The display processor evaluates the data supplied by the administrative unit to control the 17 LEDs on the front panel and, by a multiplexing process, the 20-digit vacuum-fluorescent display.

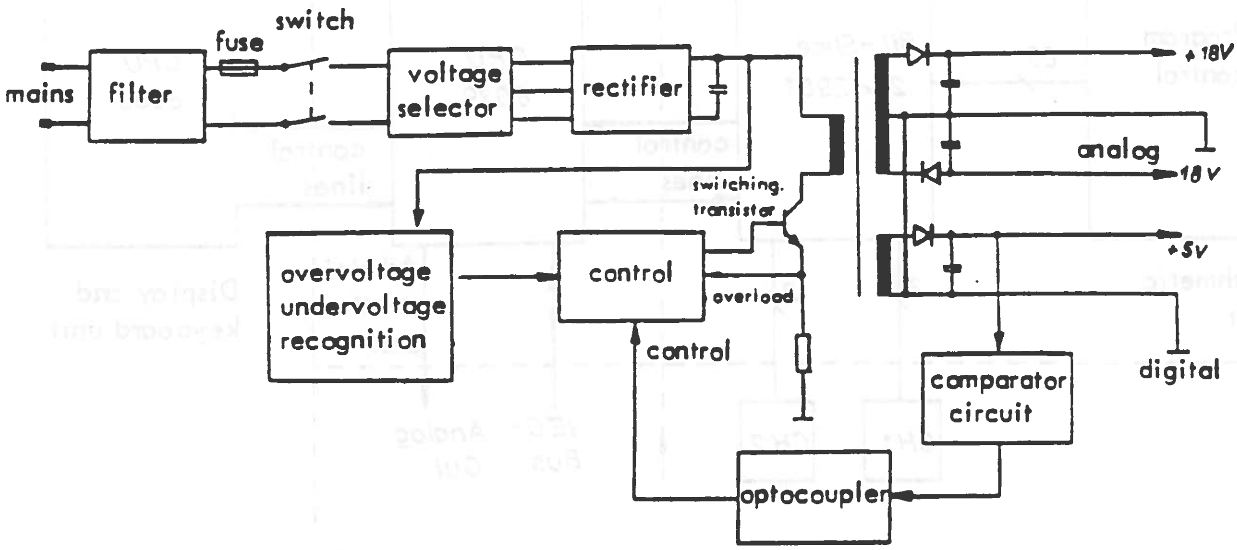


Fig. 9.3: Power supply of the instrument

9.5 Voltage Supply and Floating:

The switched mains section furnishes a suitably stabilized +5 V for supplying the digital section. Other, specially insulated and guarded secondary windings of the main transformer furnish the supply voltages for the two analog sections.

Overvoltage and undervoltage recognition protects the instrument against demage and misoperation caused by too high or too low mains voltage, switching it off in these cases.

Power supply of the analog sections in the two input channels and data transmission between the analog sections and the arithmetic and administrative unit is effected via voltageproof pulse transformers. This permits floating of the two inputs, both mutually and with respect to earth/ground, up to 1400 V (peak).

10. CONNECTION DIAGARMS:

The specification of this instrument makes it applicable for measurements in high frequency ranges and with floating signals. For such measurements, the setup of the circuit should to be planned with great care. Erroneous measurements are a particular risk in cases of insufficient circuit setup near the design limits.

For the current input, total guarding of the shunt voltage drop must be ensured. This condition is already met by the plug-in shunts on our list. If other shunts are used, they should be connected by means of the supplied shunt-connecting cable as per Fig. 5.3. A sufficient frequency range should be ensured.

If shunts of too low frequency range are used, shunt inductivity will boost the high frequencies, resulting in totally erroneous measurement results. In the absence of a DC component it is also possible to use current and voltage transformers with a sufficient frequency range. When performing power (two-channel) measurements, the angular error of any shunts, current and voltage transformers used should be taken into account, paricularly for measurements at low power factor.

Though both inputs are floating, they should be kept "LOW" if possible (particularly the shunt input), so as to minimize the influence of the common-mode voltage.

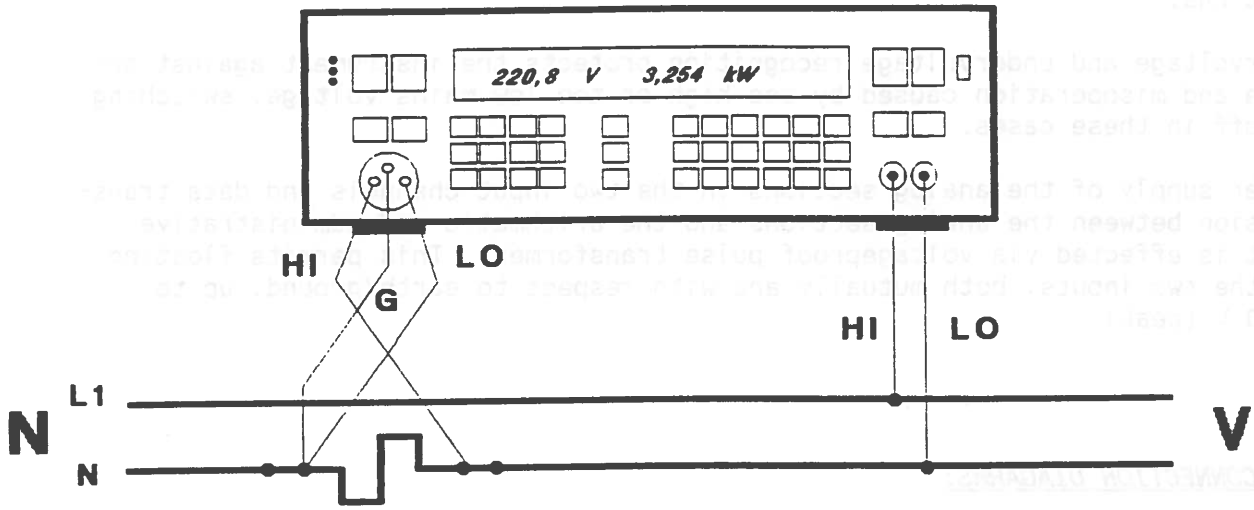
When measuring signals with a high voltage-frequency product, care should be taken to have both "LOW" inputs at the same potential or at worst float only minimally.

As the above considerations shows, it is always necessary to make a detailed adaptation of the proposed circuit to the requirements in each case. It is therefore impossible to suggest any catch-all circuit. Still, the following diagrams show the basic circuits most frequently used.

In the diagrams, "N" indicates the end closer to the source, "V" the end closer to the consumer.

10.1 Single-Phase AC:

An analogous circuit may of course be used for DC systems.

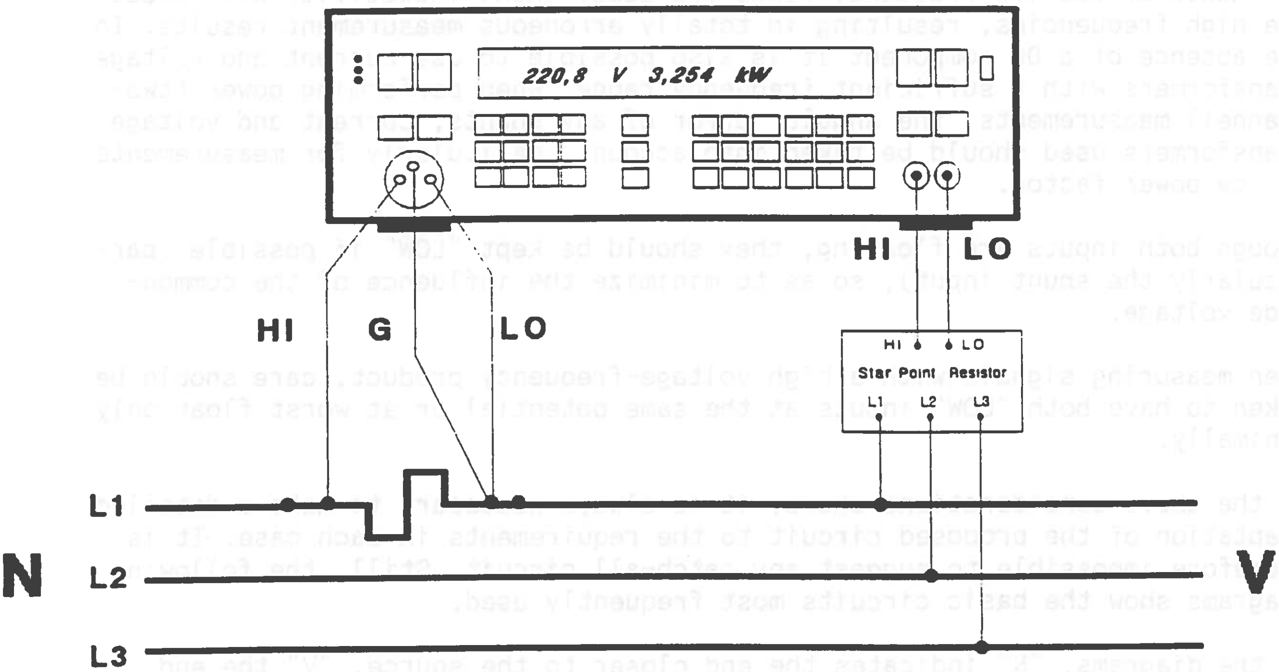


Measurement of reactive power in single-phase AC systems is only possible with an additional 90° phase-shifting link. It should, however, be noted that the phase shift is frequency-dependent.

10.2 Three-Phase Three-Wire System:

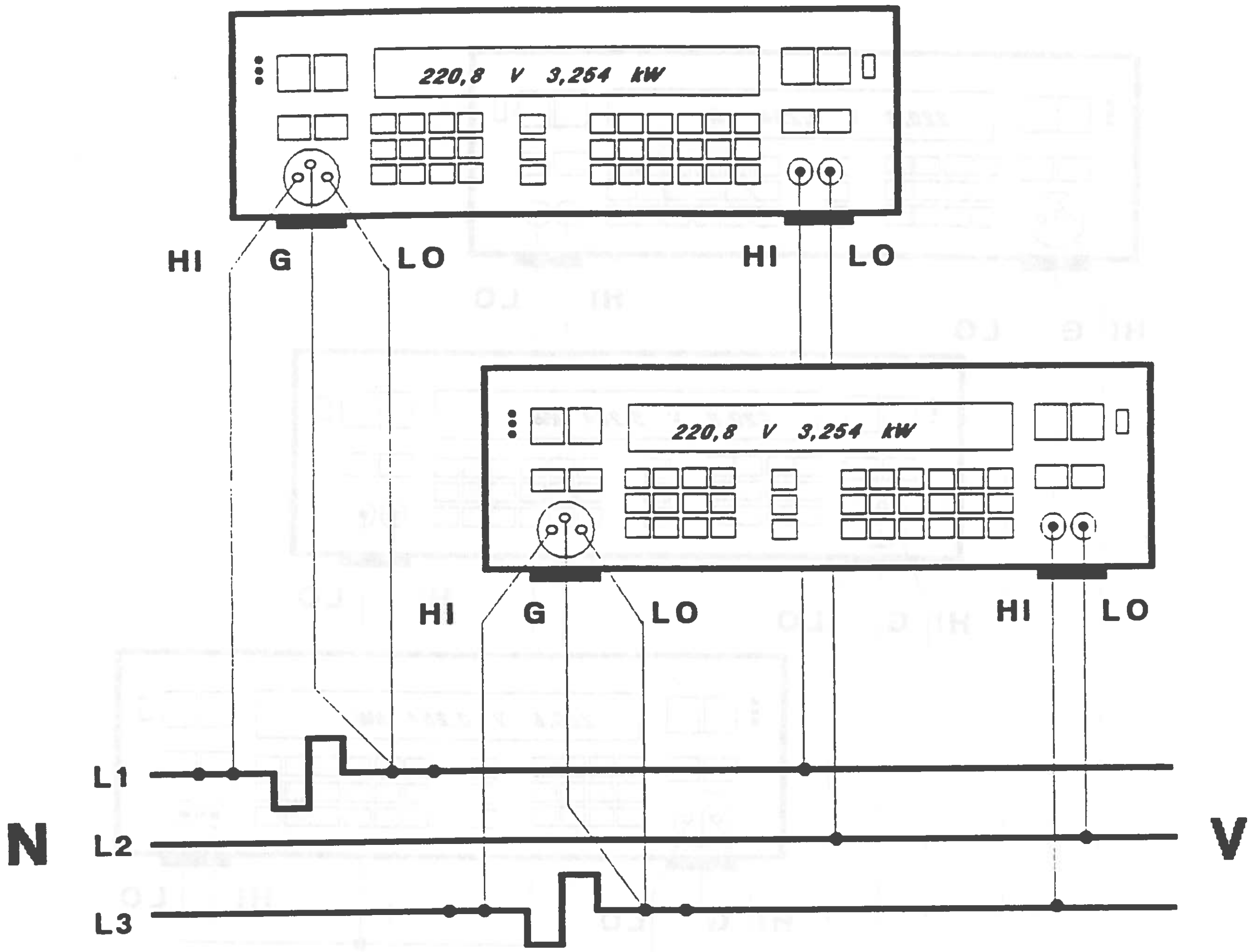
10.2.1 Measuring single-phase active power at symmetric load:

The phase voltage required for this method is formed by connection the zero resistor (see Accessories) in series.



Three-phase power: displayed value * 3
|Z| and Re(Z) : displayed value / 3

10.2.2 Measuring two-phase active power at asymmetric load:
(so-called Aron connection):



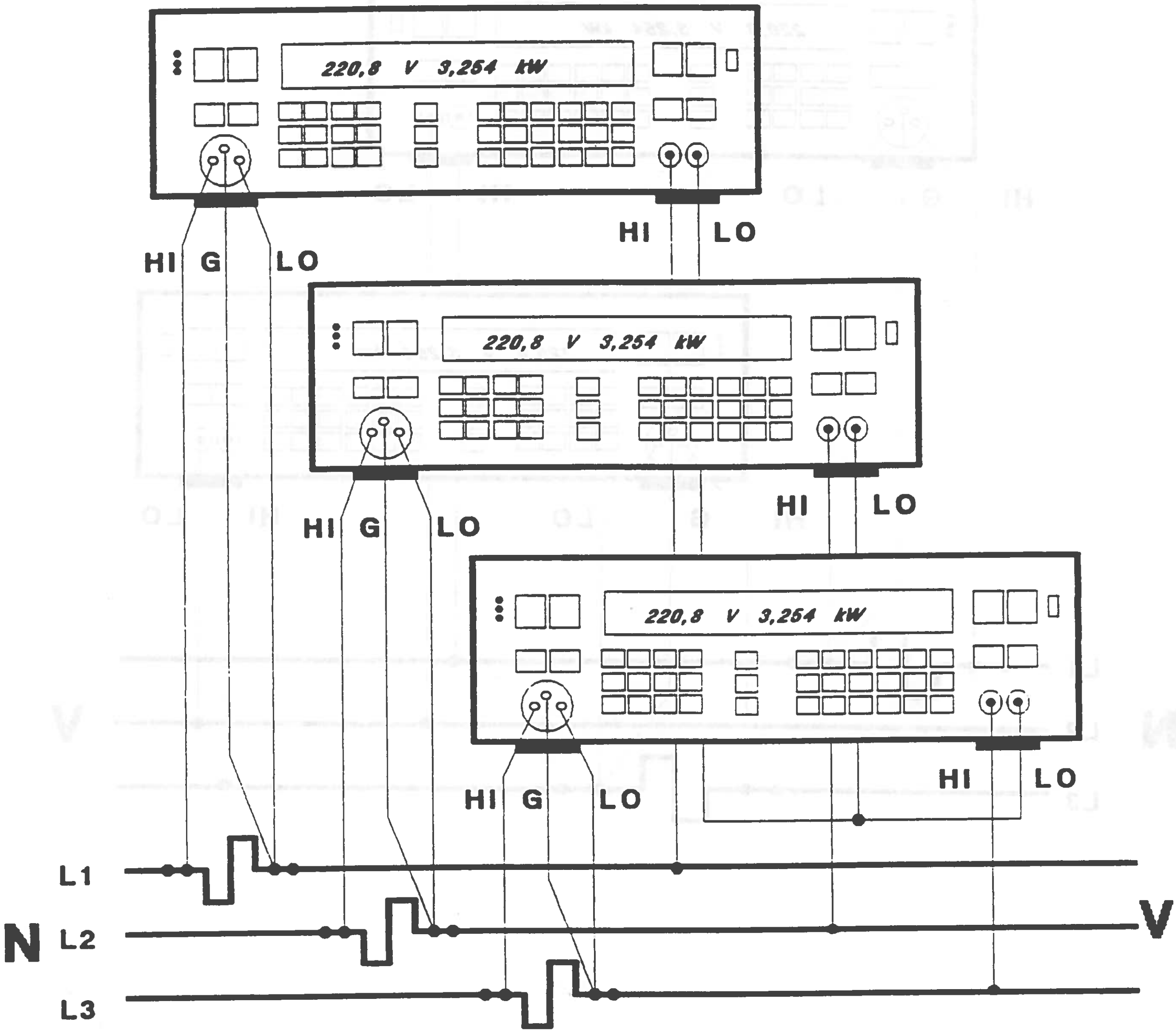
Under the theory of the Aron connection, the indications given by the two wattmeters have no physical referent; their sum, however, yields the correct three-phase power. Similarly the two displayed power factors, |Z| and Re (Z) are incorrect.

Three-phase power: P = P1 + P2
Power factor: Lambda = P/U*I

P1, P2 ..... Displayed value of the two powermeters

10.2.3 Measuring three-phase active power at asymmetric load:

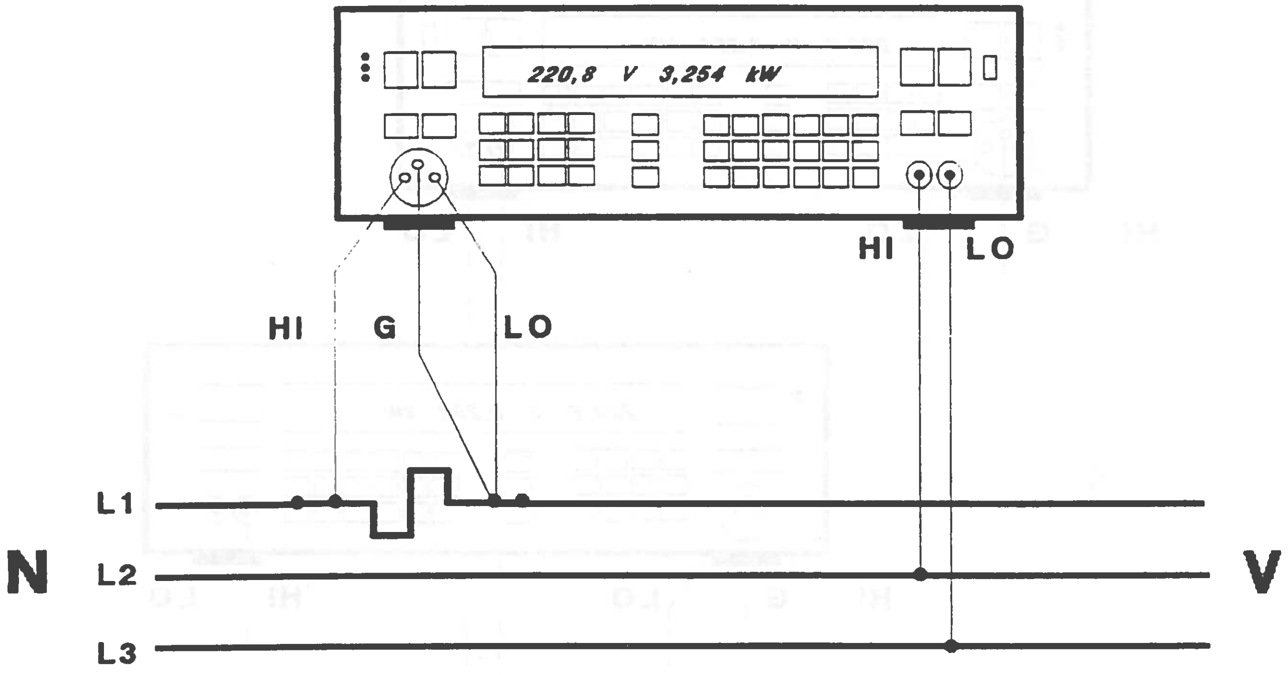
All displayed values have the corresponding phase values as physical referents. The input resistances of the three voltage channels form the artificial zero point.



Three-phase power: P = P1 + P2 + P3

10.2.4 Measuring single-phase reactive power at symmetric load:

Caution: In measurements of reactive power, external circuitry connected to the instrument will cause an artificial phase shift. Thus the power factor and the effective resistance are not computed correctly !

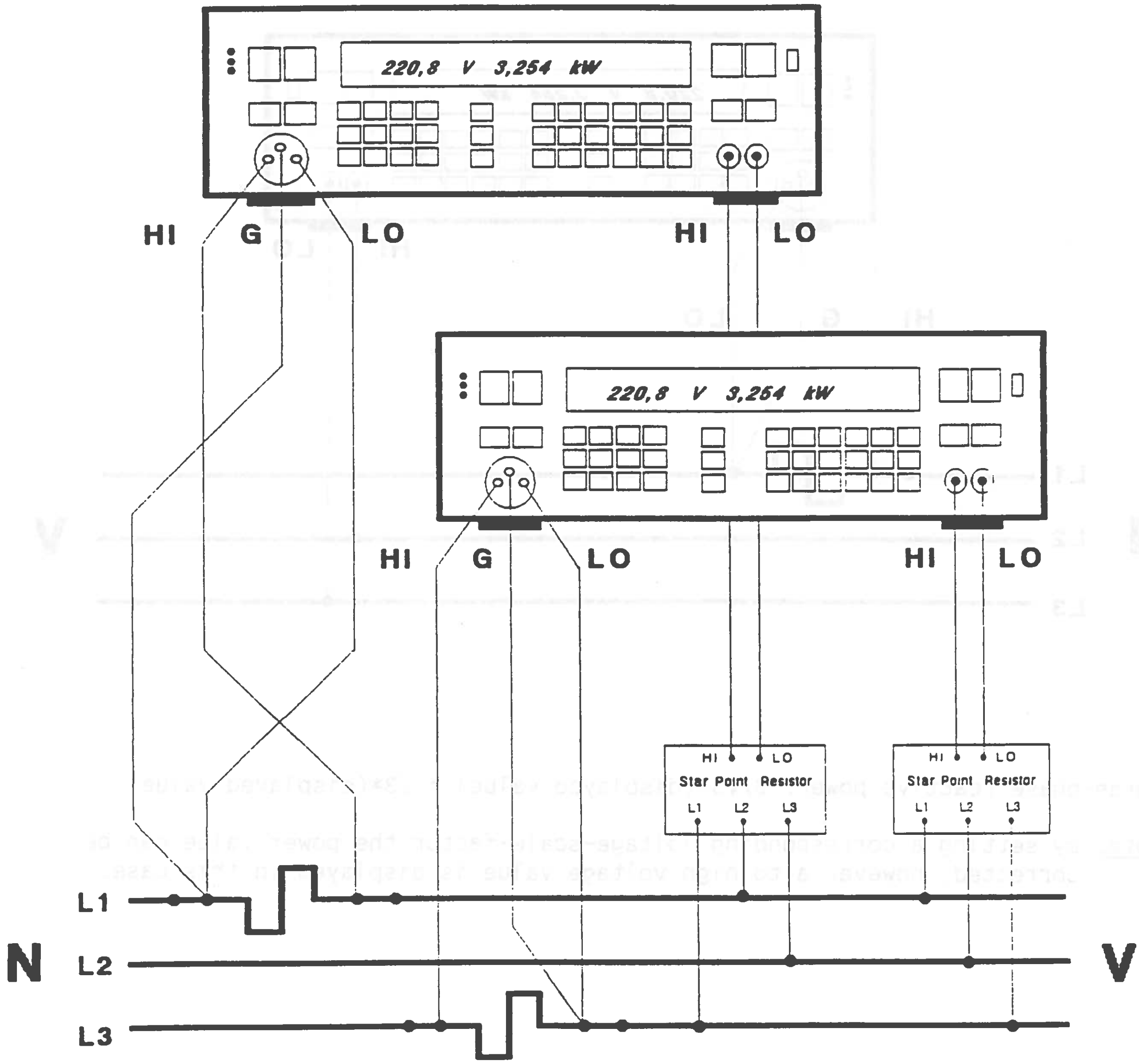


Three-phase reactive power: 3/√3*(displayed value) = √3*(displayed value)

Note: by setting a corresponding voltage-scale-factor the power value can be corrected, however a to high voltage value is displayed in this case.

10.2.5 Measuring two-phase reactive power at asymmetric load:

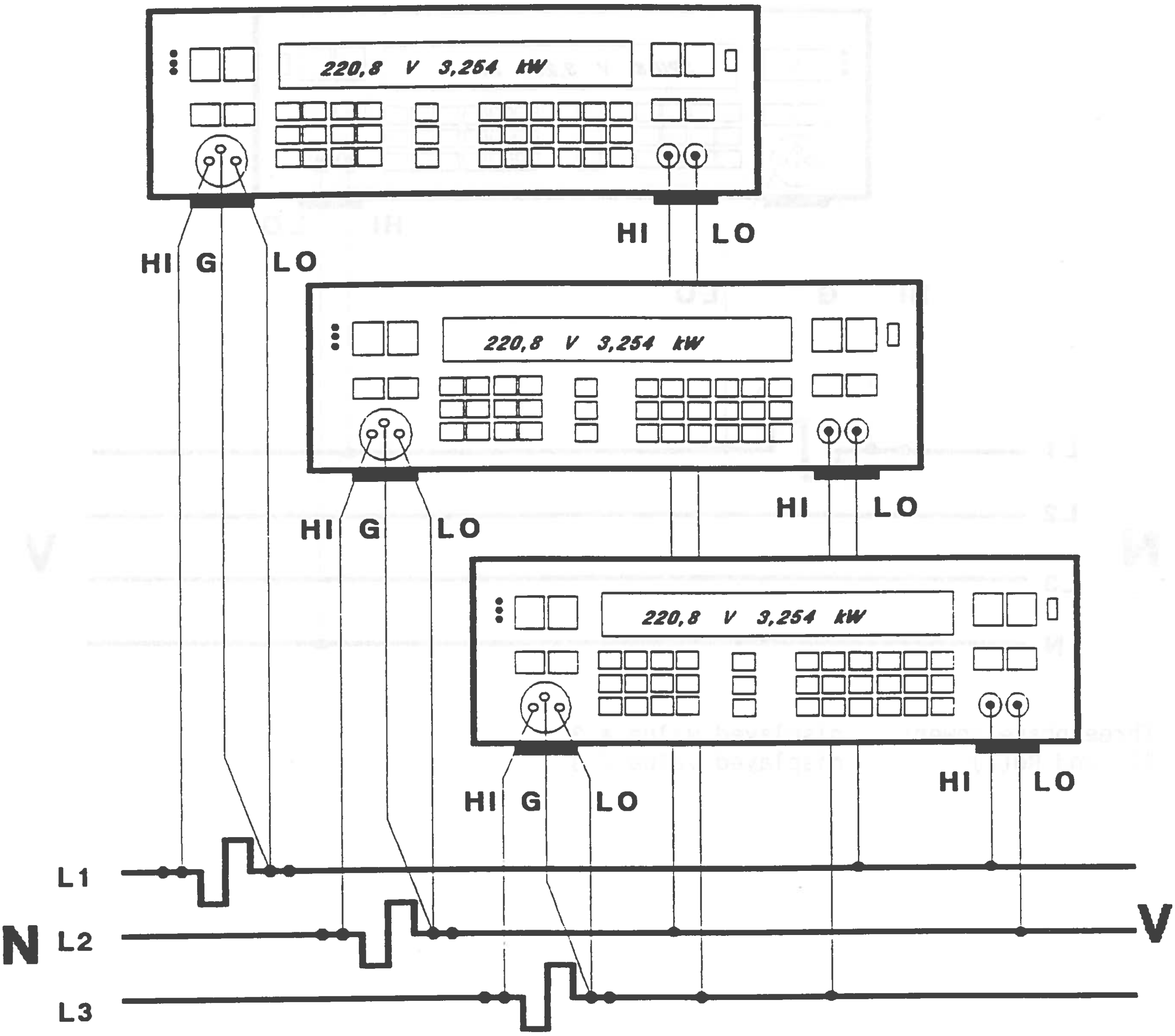
The phase shift of the two voltage paths required for measurement of reactive power is obtained by connecting the two zero resistors.



Three-phase reactive power: Q = √3*(Q1 + Q2)

Note: by setting a corresponding voltage-scale-factor the power value can be corrected, however then the delta voltage is displayed instead of the measured star voltage.

10.2.6 Measuring three-phase reactive power at asymmetric load:

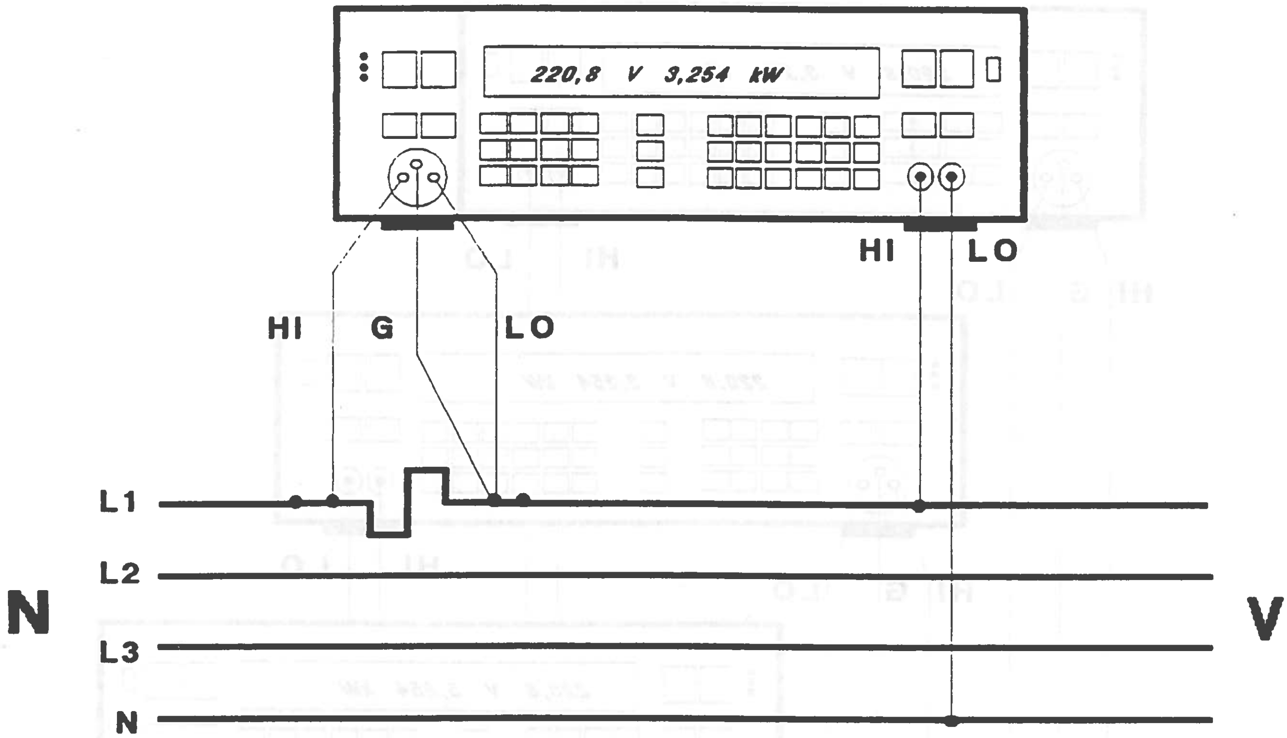


Three-phase reactive power: $Q = (Q1 + Q2 + Q3)/\sqrt{3}$

Note: by setting a corresponding voltage-scale-factor the power value can be corrected, however the star voltage is then displayed instead of the measured delta voltage.

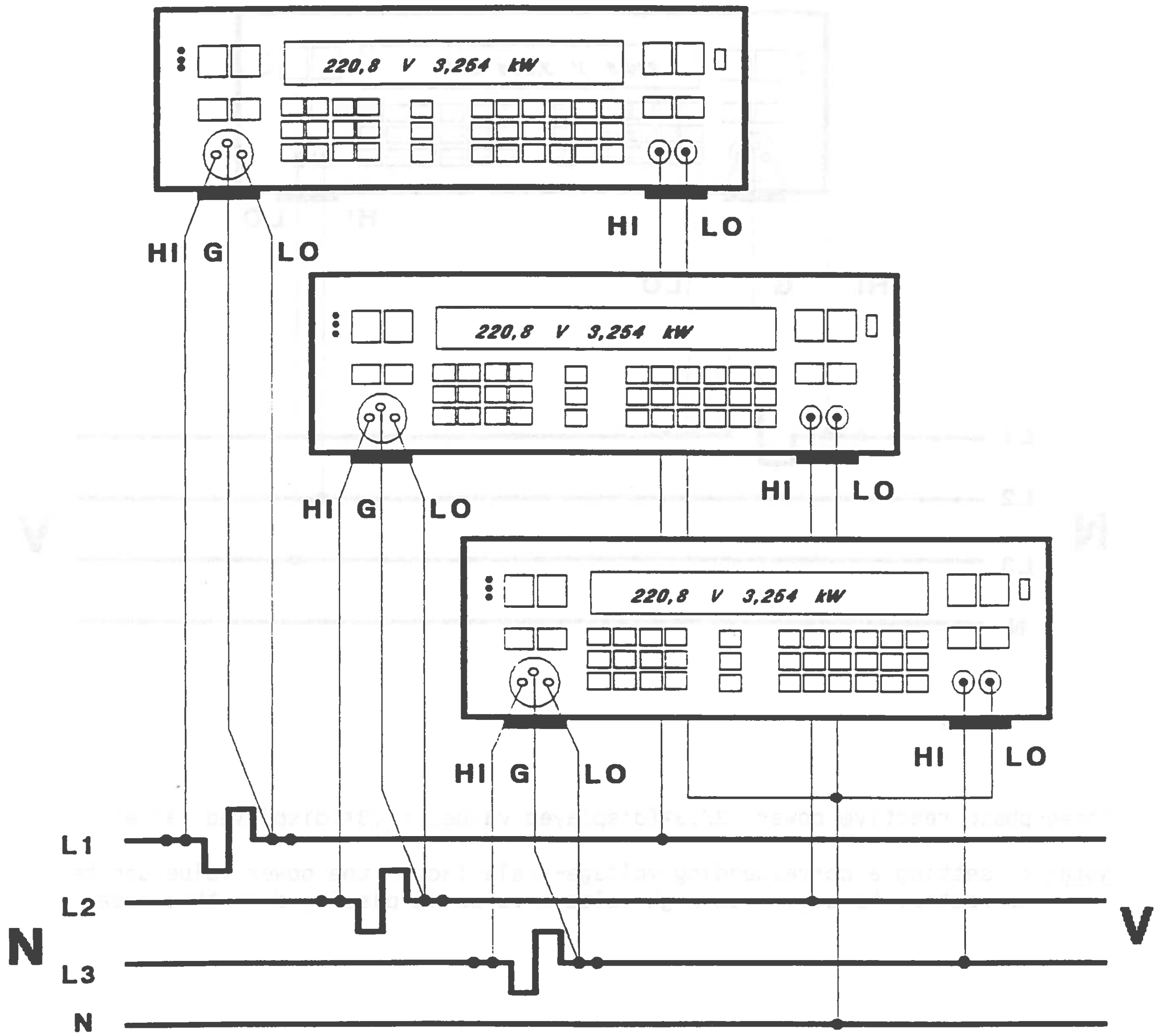
10.3 Three-Phase Four-Wire System:

10.3.1 Measuring single-phase active power at symmetric load:



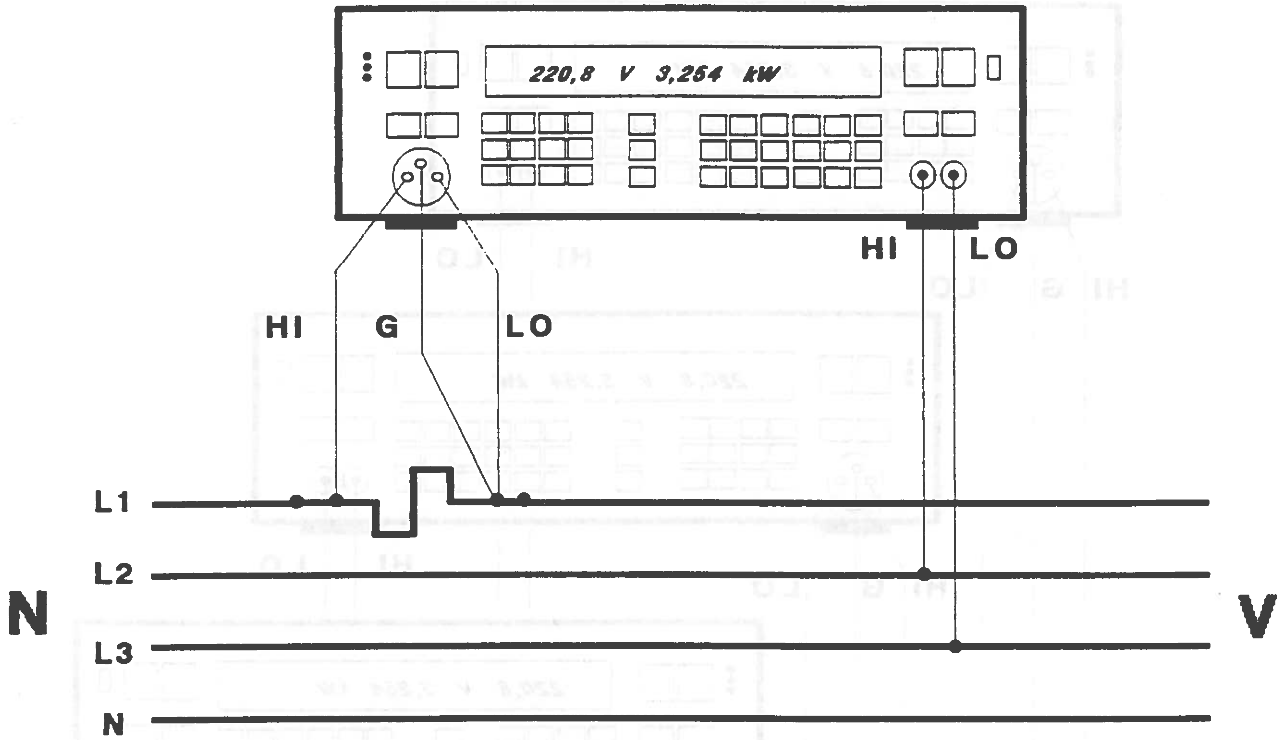
Three-phase power: displayed value * 3
|Z| and Re(Z) : displayed value / 3

10.3.2 Measuring three-phase active power at asymmetric load:



Three-phase power: P = P1 + P2 + P3

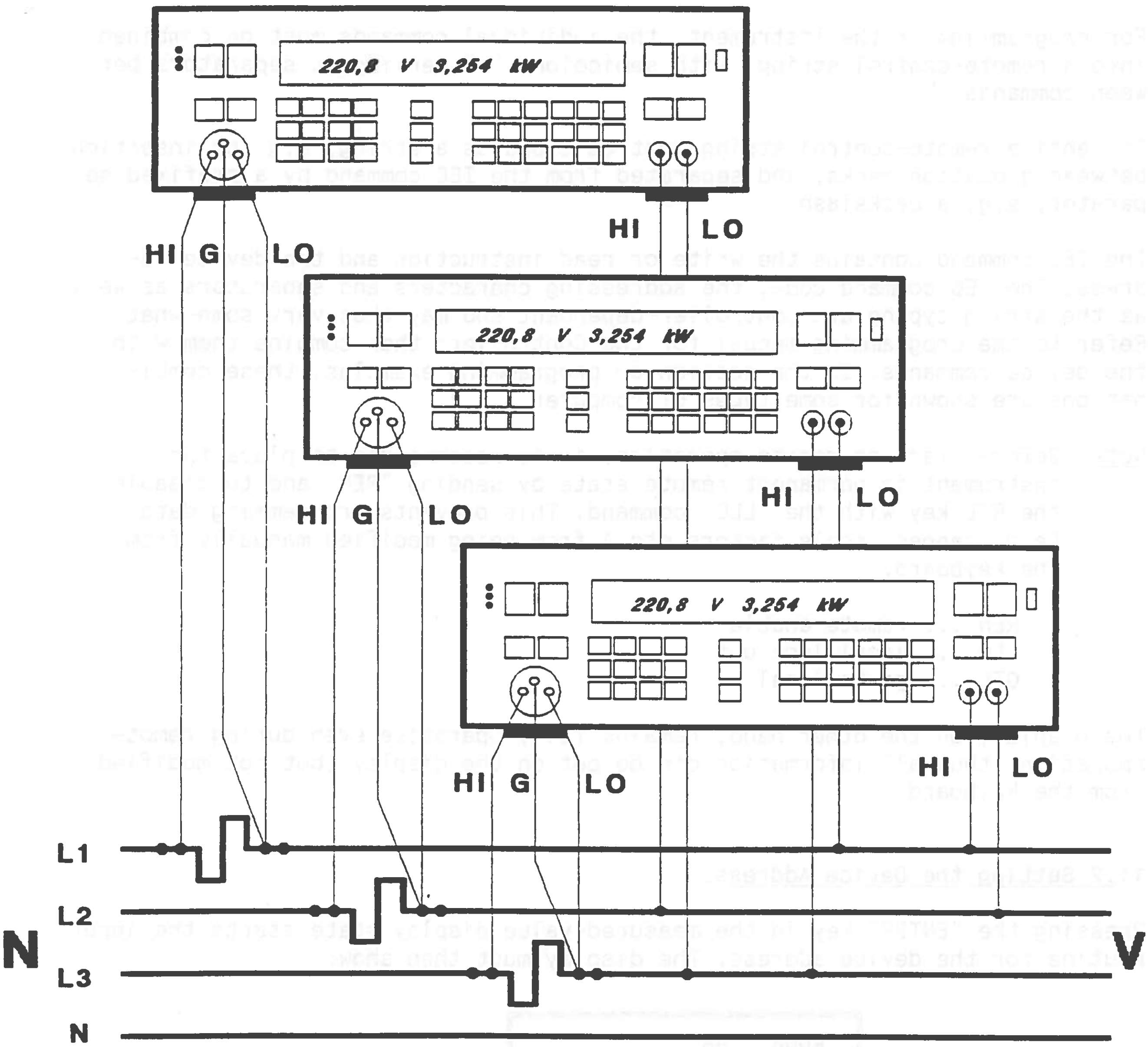
10.3.3 Measuring single-phase reactive power at symmetric load:



Three-phase reactive power: 3/√3*(displayed value) = √3*(displayed value)

Note: by setting a corresponding voltage-scale-factor the power value can be corrected, however a to high voltage value is displayed in this case.

10.3.4 Measuring three-phase reactive power at asymmetric load:



Three-phase reactive power: Q = (Q1 + Q2 + Q3)/√3

Note: by setting a corresponding voltage-scale-factor the power value can be corrected, however the star voltage is then displayed instead of the measured delta voltage.

11.REMOTE OPERATION - INTERFACE:

11.1 General Programming Remarks:

For programming of the instrument, the individual commands must be combined into a remote-control string, with semicolons ";" serving as separators between commands.

The entire remote-control string must be typed as a string, e.g. by insertion between quotation marks, and separated from the IEC command by a prefixed separator, e.g. a backslash.

The IEC command contains the write or read instruction and the device address. The IEC command code, the addressing characters and separators as well as the string typing are controller-dependent and may thus vary some-what. Refer to the programming manual for the Controller; then combine them with the device commands. In the section on programming examples, these combinations are shown for some types of computer.

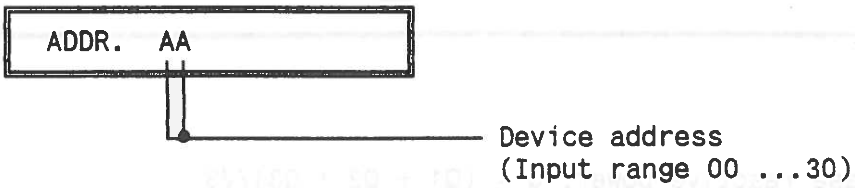
Note: Before starting remote operation, it is recommended to place the instrument in permanent remote state by sending "REN" and to disable the RTL key with the "LLO" command. This prevents programming data (e.g. ranges, scale factors etc.) from being modified manually from the keyboard.

REN ... remote enable
LLO ... local lock out
GTL ... go to local

The display, on the other hand, remains fully operative even during remote operation; thus all information can be put on the display (but not modified) from the keyboard.

11.2 Setting the Device Address:

Pressing the "ENTER" key in the measured-value display state starts the input routine for the device address. The display must then show:



The flashing cursor indicates the input position. The old address may now be overwritten with the numeric keys and stored again with "ENTER". The instrument then returns to the previous measured-value display mode.

If an address over 30 is entered by mistake, this cannot be stored, as "ENTER" will reset the address to 30, and the instrument remains in the input routine until a legal value is entered.