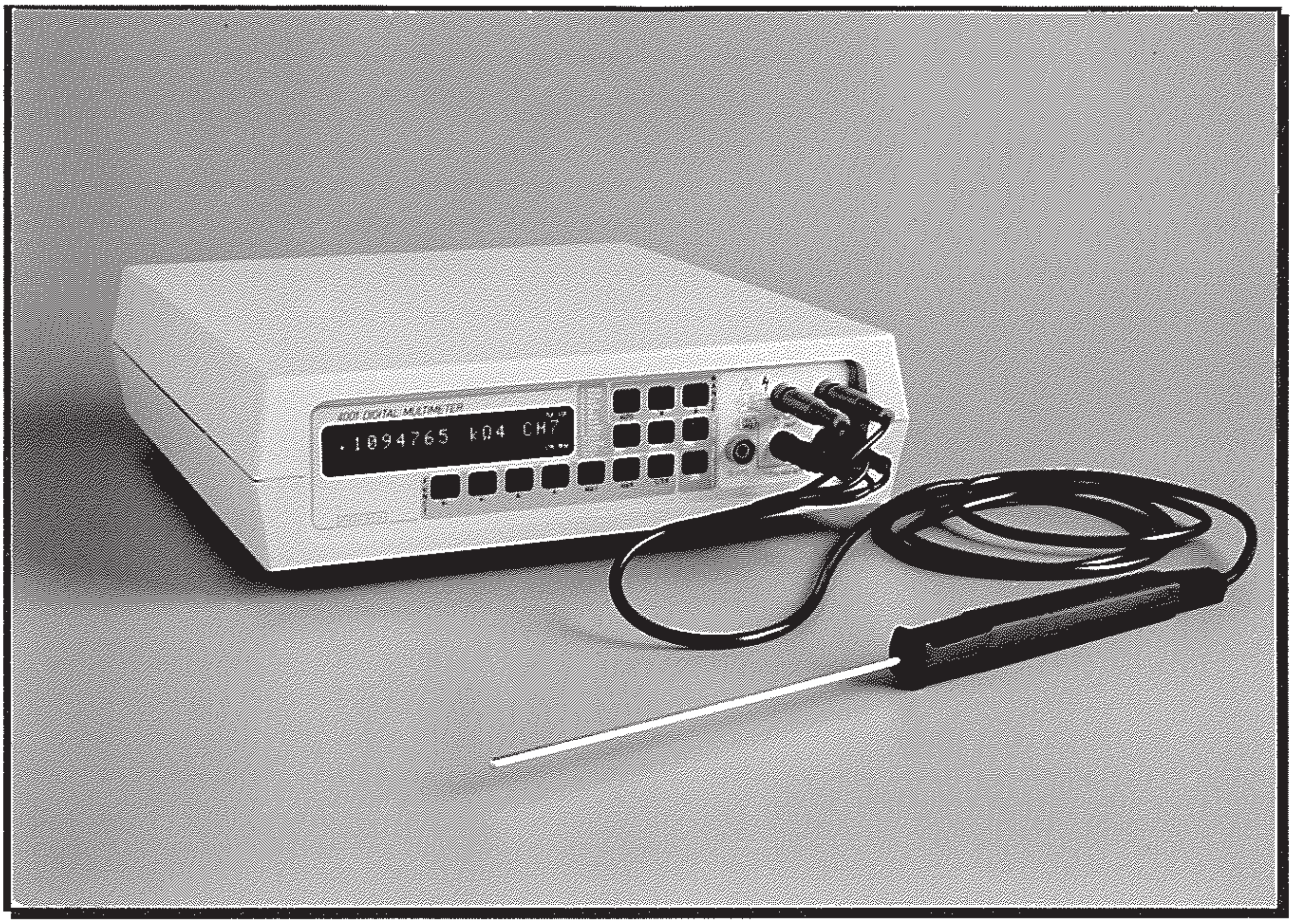

Digital Multimeter

DMM 4001

Operation Manual

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Bz / 4001e - 9502
subject to technical changes without notice

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1. Introduction

This manual describes the Model 4001 precision digital multimeter. Chapter 2 contains an exact listing of the technical data for each function of these meters. The other sections describe instrument construction as well as manual and remote control capabilities via the IEEE-488-Bus.

1.1. General Description

The 6 1/2-digit PREMA Model 4001 digital multimeter is an instrument with an outstanding capability to price ratio and provide the following measurement functions:

- Direct voltage measurements with 100nV resolution
- Alternating voltage measurement for true rms values with 1μV resolution
- Direct current measurement with 1nA or 1μA resolution
- Alternating current measurement with 10nA or 10μA resolution
- Resistance measurement with the 4001 either 2- or 4-wire
- Temperature measurement by means of the Pt-100 sensor

In addition, for these measurement functions, the instrument is provided with many interesting, and advantageous feature as later described in detail.

- greater than 1GΩ Input Resistance up to ± 2V
- Selectable integration times of 50ms, 100ms, 0.5s, 1s, 5s and 10s
- Choice of internal mathematics programs: offset, % deviation, growth, ratio, dB and dBm
- Digital offset correction allows compensation, for example, for thermo voltages and test lead resistances

The PREMA Multiple Ramp Technique, which is used for the analog to digital conversion, offers the guarantee for outstanding linearity and long-term stability during the continuous integration of the measurement signal without disturbing measurement interruptions.

These multimeters can be equipped with a 10-channel, four-pole Multiplexer (optional). The maximum switch voltage is 125V, the maximum switch current 2A, and the thermo voltages on the contacts are less than 1μV.

The standard IEEE-488-Bus Interface allows the remote control and supervision of all functions of the multimeter including digital calibration. An excellent ground division between the multimeter and the IEEE-signal bus helps allow a faultless 100nV resolution during direct voltage measurements in system operation.

An easy to use digital calibration feature is offered with these multimeters. A single debit value to be used for offset can be entered via the keyboard or IEEE-488-Bus, and is usually sufficient for calibration of a measurement field. Every measurement field of every function can be independently recalibrated as desired. A recessed switch on the back of the multimeter protects against unintentional changes of these correction factors.

PREMA designs and manufactures certain key integrated circuit chips (ASICs), uses their patented A/D conversion process, and also has almost twenty years manufacturing experience in high precision measurement products. For these reasons, PREMA digital multimeters use fewer critical and other components than competition which results in a more dependable multimeter with a longer service life.

1.2. Measurement Principle

The PREMA Multiple Ramp Technique for analog to digital conversion (GPD # 2114 141, US-Patent 3765012) is the basis for a dependable digital multimeter with exceptional linearity and extraordinary long-term accuracy using continuous integration of the measured signal without distorting interruptions.

An amplifier which is connected as the integrator with a capacitor C (Figure 1.2.1) integrates a measuring voltage Ue continuously that is proportional to current Ie.

This procedure has very high linearity since the input voltage does not need to be switched off. Therefore, errors are avoided that are caused by the capacitance of the transistors now commonly used as switches in other conversion methods.

The capacitor (Figure 1.2.2) is discharged periodically by a current Iref from the reference voltage source Uref. This current has opposite polarity with respect to the input signal with (discharge time t1 to tn). Since the same reference voltage and resistance are used for all down integrations for both polarities, the value of the display is the same on reversing the input voltage, with a tolerance of only one digit.

The end of the down integration is determined by the coincidence of a comparator response and a pulse flank of the crystal time oscillator. Since the total change of charge on the capacitor during one measuring period is zero, the following occurs:

$$\frac{1}{T}\int U_e dt = -\frac{R_e}{R_o T} U_{ref} \Sigma t_i$$

that means, the sum of the discharge time ti is proportional to the mean value of the input voltage and is indicated as the measurement result.

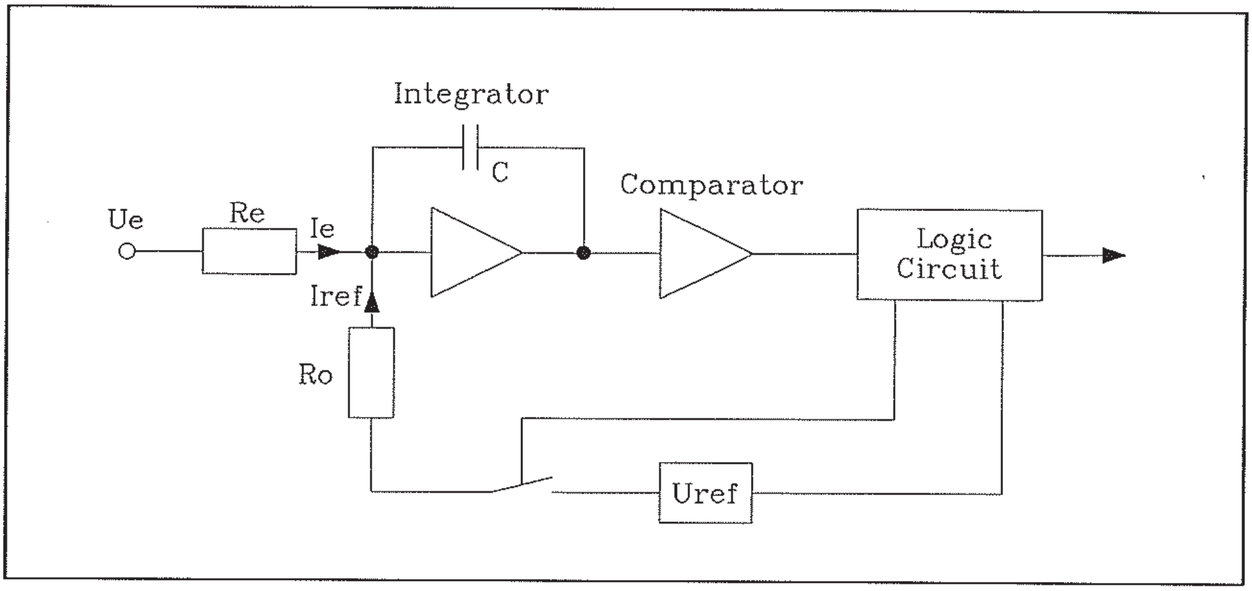


Fig. 1.2.1: Simplified Circuit Diagram

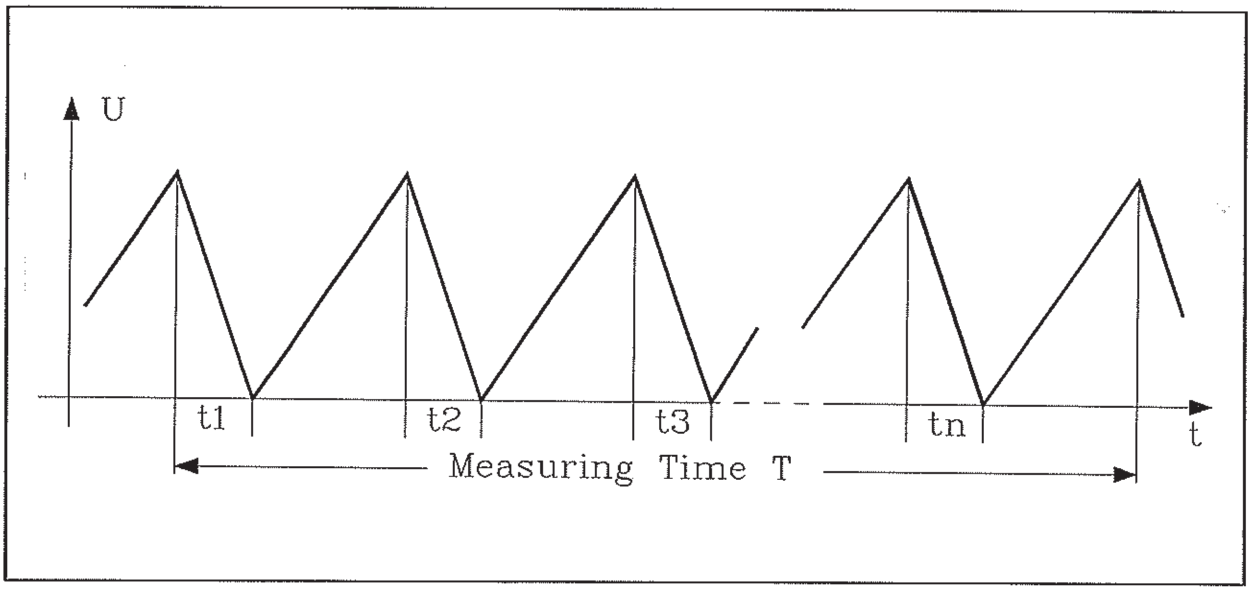


Fig. 1.2.2 : Output Signal of the Integrator

In this type of voltage to time conversion, the result is not distorted by the loss factor or by any drifting of the capacitor C. It is also independent of the frequency of the time oscillator used for time measurement since the setting of T and all ti is made with the same frequency. Drift and speed of the comparator are also not critical with the PREMA Multiple Ramp Technique. Therefore, a reasonably low-cost, highly reliable design is possible for these digital multimeters which achieve world-class leadership in stability and linearity.

2. Technical Data

The accuracy and calibration of this instrument are traceable to Physikalisch Technische Bundesanstalt (PTB) in Braunschweig Germany through equipment which is calibrated at planned intervals by comparison to certified standards. The ambient temperature maintained during calibration is 23 °C ± 1°C.

2.1. DIRECT VOLTAGE

RANGE	± 0.2V / ± 2V / ± 20V / ± 200V / ± 1000V		2)
RANGE SELECTION	manual, automatic or by remote control		
MEASUREMENT TIMES	50 / 100 / 500 ms	1 / 5 / 10 s	
MAX. DISPLAY SPAN (up to 200V)	199 999	1 999 999	
(1000 V range without Scanner)	100 000	1 000 000	
(1000 V range with Scanner)	125 00	125 000	
MAX. RESOLUTION	1 µV	100 nV	

STABILITY (24 hours) **ACCURACY (1 year)**
each ±(% of reading (%rdg) + % of full scale (%f.s.)) 1), 3), 4)

RANGE	24h, 23°C ± 1°C		1year, 23°C ± 5°C	
	%rdg.	%f.s	%rdg.	%f.s
200mV	0.0015	0.0007	0.0035	0.0008
2V	0.0015	0.0005	0.0035	0.0006
20V	0.0015	0.0004	0.0035	0.0005
200V 2)	0.0015	0.0005	0.0035	0.0006
1000V 2)	0.0015	0.0005	0.0035	0.0007

Then giving these values it is assumed that the display range which is dependent on measurement time is set long enough to achieve the appropriate accuracy. For errors in percentage of the maximum display (% f.s.) the natural curve error of ± 1 digit is to be added. In addition, the "Guard" is connected to the "V/Ohm-LO".

1) Add ± 1 digit after offset correction
2) Max. 125V peak with scanner (option 6000/01).
3) Valid for constant input signal; there are ± 0.0005 % f.s. within 1 s and 0.005 % f.s. within 100 ms after signal changes to be added.
4) % f.s. covers a range of 1 999 999

TEMPERATURE COEFFICIENTS

RANGE	(10°C-18°C and 28°C-40°C) ± (%rdg. + %f.s)/°C		(0°C-10°C and 40°C-50°C) 1), 2) ± (%rdg. + %f.s)/°C	
200mV	0.0005	0.0003	0.0010	0.0006
2V	0.0004	0.0002	0.0008	0.0004
20V	0.0004	0.0002	0.0008	0.0004
200V 2)	0.0004	0.0002	0.0008	0.0004
1000V 2)	0.0004	0.0002	0.0008	0.0004

ZERO

Offset voltage
(after 1 hour warm-up)

Temperature coeff.: better than 0.3 µV/°C
Long-term stability: better than 5 µV over 90 days)

INPUT RESISTANCE

RANGE	
± 0.2V, ±2V	>1 GOhm
± 20V, ±200V, ±1000V	10 MOhm

INTERFERENCE REJECTION

Series mode rejection

50/60 Hz mains: better than 60 dB

Common mode rejection
(Up to 1 kΩ in the "Lo"-lead; guard connected to the "V,Ohm-Lo"-socket)

Direct Voltage: 140 dB
50/60 Hz mains: 140 dB

MEASUREMENT DELAYS
after range or function change, respectively after changing of channels with option 6000/01

range	measurement delay
200mV	100 ms
2V to 1000V 1)	87,5 ms

MEASUREMENT METHOD

fully integrating PREMA-Multiple Ramp Technique
(DBP. No. 2114141, US-Pat. No. 3765012)

POLARITY CHANGE

automatic

1) % f.s. covers a range of 1 999 999
2) Max. 125V peak with scanner (option 6000/01).

OVERLOAD LIMITS (in Vdc)

between "V/Ω-HI" and case	± 1000V peak with max. 60 Hz or ± 1000V direct voltage	
between "V/Ω-HI" and "V/Ω-LO"-input	±0.2V, ±2V -ranges for 60 sec continuous	± 1000V 1) ± 500V 1)
	±20V, ±200V, ±1000V- ranges continuous	± 1000V 1)
	with scanner 6000/01 in all ranges continuous	± 125V peak with the limit of $2 \times 10^6 \times V \times Hz$

During direct voltage measurements the "V/Ω-LO" socket and the "A-LO" socket are joined internally. The maximum permitted current between these sockets is ± 0.1 A.

between "V/Ω/LO" input and guard	125V direct or peak voltage
between guard and case	125V direct or peak voltage
"V/Ω/LO to case	125V direct or peak voltage

1) Max. 125V peak, with scanner (Optional 6000/01).

2.2. RESISTANCE

MEASUREMENT METHODS	2-wire and 4-wire method with direct current
RANGES	200 Ω / 2 kΩ / 20 kΩ / 200 kΩ / 1.6 MΩ / 16 MΩ 4)
RANGE SELECTION	manual, automatic or remote control
MEASUREMENT TIMES	50 / 100 / 500 ms 1 / 5 / 10 s
MAX. DISPLAY SPANS	199 999 1 999 999
	in 1.6 and 16 MΩ-range 160 000 1 600 000
MAX. RESOLUTION	1 mΩ (2-wire) 100 μΩ (4-wire)

STABILITY
± (% of reading (% rdg) + % of full scale (% f.s.)) 1),2),3),5)

RANGE	24h, 23°C ± 1°C	
	% rdg	% f.s.
200 Ω	0.0020	0.001
2 kΩ	0.0020	0.0005
20 kΩ	0.0020	0.0005
200 kΩ 6)	0.0020	0.0005
1,6 MΩ 4)	0.005	0.001
16 MΩ 4)	0.01	0.003

ACCURACY
± (% of reading (% rdg) + % of full scale (% f.s.)) 1),2),3),5)

RANGE	1 year, 23°C ± 5°C	
	% rdg.	% f.s
200 Ω	0.005	0.002
2 kΩ	0.005	0.0005
20 kΩ	0.005	0.0005
200 kΩ 5)	0.005	0.0005
1,6 MΩ 4)	0.01	0.001
16 MΩ 4)	0.04	0.006

1) Values each ± 1 digit and after offset correction
2) Valid for constant input signal; there are ± 0.0005 % f.s. within 1 s and 0.005 % f.s. within 100 ms after signal changes to be added.
3) % f.s. refers to a display capacity of 1 999 999
4) 1.6 and 16 MΩ range in 2 wire measurement
5) values valid for 5 and 10 seconds integration time

TEMPERATURE COEFFICIENTS
(10°C-18°C and 28°C-40°C)

	± (%rdg. +	%f.s)/°C
200 Ω	0.0020	0.0005
2, 20, 200 kΩ	0.0015	0.0005
1.6 MΩ	0.0020	0.0005
16 MΩ	0.01	0.0005

TEMPERATURE COEFFICIENTS
(0°C - 10°C and 40°C - 50°C)

RANGE	± (%rdg. +	%f.s)/°C
200 Ω	0.004	0.001
2, 20, 200 kΩ	0.003	0.001
1,6 MΩ	0.004	0.001
16 MΩ	0.02	0.001

CURRENT FLOWING THROUGH THE MEASURED RESISTANCE 2)

RANGE	
200 Ω, 2 kΩ	0.7 mA
20 kΩ	70 μA
200 kΩ, 1.6 MΩ	7 μA
16 MΩ	0.7 μA

VOLTAGE AT OPEN CIRCUIT TERMINALS about 14 V max.

MEASUREMENT DELAYS
after range or function change, respectively after changing of channels with option 6000/01

range	measurement delay
200 Ω	100 ms
2 kΩ to 1.6 MΩ	87.5 ms
16 MΩ	900 ms

OVERLOAD LIMIT ± 300 V peak 1)

1) Max. 125V peak, with inbuilt scanner (option 6000/01).
2) The absolute values for the current depends on each device

2.3 ALTERNATING VOLTAGE

CONVERSION METHOD	True rms value for the sum of direct and alternating voltage	
RANGES	0.2V; 2V; 20V; 200V; 700V	1)
RANGE SELECTION	manual, automatic or remote control	
MAX. DISPLAY SPAN	199 999	
in 1000V-range	70 000	1)
INTEGRATION TIMES(sec.)	0.05 / 0.1 / 0.5 / 1s / 5 / 10s	
MAX. RESOLUTION	1 μV	

ACCURACY (1 year, 23°C ± 5°C) ± (% of display (% rdg) + % of full scale (% f.s.) 2)

RANGE	20Hz to 40Hz	40Hz to 1kHz	1kHz to 10kHz	10kHz to 50kHz	50kHz to 100kHz
0.2 V	0.3 + 0.03	0.15 + 0.03	0.3 + 0.07		
2 V	0.2 + 0.03	0.08 + 0.03	0.3 + 0.07	1 + 0.3	3 + 0.4
20 V	0.2 + 0.03	0.08 + 0.03	0.3 + 0.07	1 + 0.3	3 + 0.4
200 V	0.2 + 0.03	0.08 + 0.03	0.3 + 0.07	1 + 0.3	3 + 0.4
700 V	0.2 + 0.03	0.08 + 0.03	0.3 + 0.07		

For this data, the sinusoidal signal is greater than 5% of full scale with the "Ground" connected to "V/Ω-LO".

Direct Voltage ± (0.1 % rdg + 0.05 % f.s.)

TEMPERATURE COEFFICIENT
(10°C - 18°C and 28°C - 40°C)

0 - 20 kHz	± (0.01% of reading + 0.004 % of full scale)/°C
20 - 100 kHz	± (0.04% of reading + 0.02 % of full scale)/°C

TEMPERATURE COEFFICIENT
(0°C - 10°C and 40°C - 50°C)

0 - 20 kHz	± (0.02% of reading + 0.008 % of full scale)/°C
20 - 100 kHz	± (0.08% of reading + 0.04 % of full scale)/°C

1) Maximum input voltage is restricted to 125 V peak with the inbuilt scanner (option 6000/01)
2) % f.s. always refers to a display capacity of 1 999 999

CREST-FACTOR	7 : 1 The peak value must not be greater than 1.5 times the nominal range or 1000 volts, whichever of these limits is the smaller.
INPUT RESISTANCE	1 GΩ ‖ less than 60pF up to 2V range 10 MΩ ‖ less than 60pF from 20V to 1000V range 1)

MEASUREMENT DELAYS
after range or function change, respectively after changing of channels with option 6000/01

range	measurement delay
200mV	625 ms
2V and 20V	425 ms
200V and 700V 1)	525 ms

OVERLOAD LIMITS (in Vac)

between "V/Ω-HI" and case	± 1000V peak with max. 60 Hz or ± 1000V direct voltage	
between "V/Ω-HI" and "V/Ω-LO"-input	0.2V, 2V -ranges for 60 sec	± 1000V 1)
	continuous	± 500V 1)
	20V, 200V, 700V- ranges continuous	± 1000V 1)
	with scanner 6000/01 in all ranges continuous	± 125V peak with the limit of 2×10^6 x V x Hz

The "V/Ω-LO" box and the "A-LO" socket are connected together internally in the alternating voltage function. The maximum permissible current between these sockets is ± 0.1A.

between "V/Ω/LO" input and guard	125V direct or peak voltage
between guard and case	125V direct or peak voltage
"V/Ω/LO to case	125V direct or peak voltage
TRANSIENT RESPONSE TIME	0.5 s to reach final reading within 0.1%

1) Max. 125V peak, with optional scanner

2.4. DIRECT CURRENT

RANGE	± 2mA; ± 2A
RANGE SELECTION	manual, automatic or remote control
MAX. DISPLAY SPAN	1 999 999
MEASUREMENT TIMES (sec.)	0.05 / 0.1 / 0.5 1 / 5 / 10
MAX. RESOLUTION	10nA; 10 μA 1 nA; 1 μA

Stbility (24hours) **ACCURACY** (1 year)
(up to 1A) ± (% of reading (% rdg) + % of full scale (% f.s.), 23°C ± 5°C 1)

RANGE	%rdg.	%f.s.	% rdg.	% f.s.
2mA	0.004	0.004	0.025	0.005
2A	0.008	0.004	0.010	0.005

TEMPERATURE COEFFICIENT
(10°C - 18°C and 28°C - 40°C) (0°C - 10°C and 40°C - 50°C)

RANGE	±(%rdg. +	%f.s.)/°C	±(%rdg. +	%f.s.)/°C
2A	0.002	0.001	0.004	0.002
2mA	0.002	0.001	0.004	0.002

VOLTAGE BURDEN

RANGE	
2mA	less than 20mV
2A	less than 0.6V
2A with option 6000/01	less than 1 V

MEASUREMENT DELAYS
after range or function change, respectively after changing of channels with option 6000/01

range	measurement delay
2 mA	87.5 ms
2 A	87.5 ms

OVERLOAD LIMITS

max. 250V peak 2) (fuse protection of 3A)

During direct current measurement the "V/Ω-LO" socket and the "A-LO" socket are internally connected. The maximum current allowed between these sockets is ± 0.1A.

1) Values each ± 1 digit and after offset correction
2) Max. 125V peak, with optional scanner

2.5. ALTERNATING CURRENT

RANGES	± 2mA; ± 2A
RANGE SELECTION	manual, automatic or remote control
MAX. DISPLAY SPAN	199 999
MEASUREMENT TIMES (sec.)	0.05 / 0.1 / 0.5 / 1 / 5 / 10
MAX. RESOLUTION	10nA; 10 μA

ACCURACY ± (% of reading (% rdg) + % of full scale (% f.s.) 1 year, 23°C ± 5°C 1)

RANGE	20Hz	1 kHz	5 kHz
2mA, 2A	/----0.05 + 0.04---/----0.2 + 0.07---/		

Direct Current ± (0.1 % rdg + 0.05 % f.s.)

TEMPERATURE COEFFICIENT

(10°C - 18°C and 28°C - 40°C)	± (0.01 % rdg + 0.004 % f.s.)/°C
(0°C - 10°C and 40°C - 50°C)	± (0.02 % rdg + 0.008 % f.s.)/°C

CREST FACTOR 7 : 1

The peak value must not be greater than 1.5 x the nominal measuring range value or 2.828 A.

VOLTAGE BURDEN

RANGE	
2mA	less than 20mV
2A	less than 0.6V
2A with option (6000/01)	less than 1V

MEASUREMENT DELAYS
after range or function change, respectively after changing of channels with option 6000/01

range	measurement delay
2 mA	500 ms
2 A	800 ms

OVERLOAD LIMITS

max. 250V peak 2) (fuse protection of 3A)
During alternating current measurements the "V/Ω-LO" socket and the "A-LO" socket are internally connected. The maximum permitted current between these two sockets is ± 100mA.

SETTLE TIME 0.5 s for 0.1% error of reading

1) Sinusoidal signal greater than 5% of the maximum reading with black input socket at main ground potential
2) Max. 125V peak, with optional scanner

2.6 TEMPERATURE °C, °F,

MEASURING METHOD 4-wire, Pt 100 (RTD 100)-measurement with linearisation

DISPLAY SPAN	Display Span	Resolution
Celsius	- 200°C to + 850°C	0.01°C
Fahrenheit	- 328°F to + 1562°F	0.01°F
Kelvin	+ 73 K to + 1123 K	0.01 K

MEASUREMENT CURRENT about 0.7 mA

VOLTAGE AT OPEN-CIRCUIT about 14 V

MEASUREMENT TIMES 500 ms / 1 s / 5 s / 10 s

MEASUREMENT DELAYS after range or function change, respectively after changing of channels with option 6000/01: 100 ms

ACCURACY ± 0.05°C over the total range in 23°C ± 5°C for 1 year (without sensor tolerance)

TEMPERATURE COEFFICIENTS

(10°C - 18°C, 28°C - 40°C)	0.003°C/°C
(0°C - 10°C, 40°C - 50°C)	0.006°C/°C

SENSOR ALIGNMENT with any precisely known temperature anywhere within the entire range with choice of °C, °F or Kelvin

LINEARISATION conforming to DIN IEC 751 standard specifications

2.7 TRIGGER INPUT

TRIGGERING	positive flank
min. pulse height	+ 2V
max. pulse height	+ 15V
overload limit	± 25V
plug connection	3.5 mm ϕ jack plug
max. voltage between socket and main ground	50V

The trigger socked is electrically isolated from the chassis. The ground connection of the socket (outer visible sleeve) is connected to the ground potential of the IEEE-bus interface.

2.8 SCANNER 6000/01 (Option)

SWITCHING MODE	4-pole, 1 out of 10
CHANNELS	10
CONTACTS PER CHANNEL	4, this means every function, including the 4-wire resistance measurement and the temperature measurement, can be measured for all 10 channels.
SWITCHING TYPE	monostable mechanical switches
THERMOELECTRIC EMF	less than 1 µV after 1.5h warm up
PROTECTIVE SHIELD	present
MAX. VOLTAGE BETWEEN 2 CONTACTS OF ONE CHANNEL	125 V-peak with the limit of $1 * 10^6$ V * Hz.
MAX. MEASURED VOLTAGE	125V-peak with the limit of $1 * 10^6$ V * Hz.
MAX. SWITCHED CURRENT	2A
TIME BETWEEN 2 SWITCHING CYCLES	shorter than 100 ms
DELAY OF THE MEASUREMENT START AFTER CHANNEL SWITCHING	The delay for measurement start depends on the selected function of the channel. The exact delay times are listed under point "MEASUREMENT DELAY" in the specifications of the corresponding function.
MAX. CONTINUOUS SEQUENCE CHANNEL SWITCHING FREQUENCY.	5 Hz
MAX. SERIES RESISTANCE (per signal line)	0.3 Ω
SERVICE LIFE	$1 * 10^8$ switching cycles(0.1 A, 10 Vdc)
INSULATION RESISTANCE BETWEEN 2 CONTACTS	3 GΩ with relative air humidity of max. 60%
INSULATION RESISTANCE TO THE CHASSIS	3 GΩ with relative air humidity of max. 60%
CAPACITANCE BETWEEN CONTACTS	smaller than 100 pF

2.9 IEEE-488-INTERFACE

OPERATING MODES	Talker/Listener or Talk only
ISOLATION FROM INPUT	Electrically isolated from the input stage
OUTPUT INFORMATION	numerical data of measurement result, function, range, measurement time, arithmetic result and display text
INPUT INFORMATION	Function, range, measurement time, start command, nominal value for calibration, mathematics program and display text
ADDRESS	selectable from 0 to 30 and TALK ONLY mode. It can be set via the keyboard
SUPPORTED FUNCTIONS	SH1, AH1, T5, L3, RL1, DC1, DT 1, SR1
KEYBOARD	can be switched off with REN and LLO, can be switched on with GTL or with "LOCAL"-key
TERMINATORS	9 different combinations are available to choose from
COMPATIBILITY	IEEE-Standard-488 (1978) and IEC 625 Part 1 and 2
BUS-PLUG CONNECTOR	24-pole connector corresponding to IEEE-488

2.10 GENERAL INFORMATION

WARM-UP TIME — 20 minutes to reach 1-year accuracy, 1.5h for full accuracy

RELATIVE HUMIDITY

up to 25°C	max. 75% relative humidity
over 25°C	max. 65% relative humidity

POWER SUPPLY

Voltage	110V, 120V, 220V, 240V; switched on rear;(240V optional)
Power consumption	17 VA
Frequency	50/60 Hz

WEIGHT — about 3.4 kg

CHASSIS — sturdy Aluminium case

DIMENSIONS — Bench top configuration

Height without feet	67.5 mm
Height with feet	84 mm
Width	255 mm
Depth	276 mm

ACCESSORIES — 19" rack mounting kit

3. Putting Into Operation

3.1. Delivery Information

Every PREMA measurement instrument is carefully tested before being shipped to insure proper operation and compliance with specifications. Therefore, the instrument should be received in perfect mechanical and electrical condition. In order identify any damage that happened during shipment, the instrument should be tested immediately after being received. If any shipping damage is discovered, a claim should be filed with the delivery agent. Also, you should immediately compare the contents with the packing slip to insure all shipped items were received.

3.2. Connection of Instrument to Main Power

This PREMA measurement instrument is capable of being connected to the following mains voltages: 100V/120V/220V/240V, and frequencies: 50/60Hz.
Although the instrument should be correctly optioned for the voltage standard in the country where shipped, it is a good idea to check using the below procedure before connection to main power. The connection for main power uses the DIN cold instrument plug with a safety contact and is found on the back of the instrument.

Changing to other mains voltages

The voltage selection option is integrated with the main fuse assembly and the line power connection on the back of the instrument. If your local line voltage is different than the one indicated by the green arrow on this assembly, or if you want to check or change the line voltage the following procedure applies:

- First, remove the power cord. A slot is then accessible on the connector assembly edge.

- Use a small screwdriver to lift out the voltage selection/fuse assembly.

- Make sure the arrow on the rear of this assembly points to the voltage desired. If not, pry out the green selection square, rotate to select the correct voltage, and reinsert.

- Install the correct fuse (0.2A for 110/120V and 0.1A for 220/240V). Reassemble.

When converting the instrument to a different main frequency, see the Calibration chapter. Voltage changes of ± 10% and frequency changes of ± 4% are allowed. Power consumption is rated at about 20VA.

Directly above the line power connector, is a rocker switch for on/off operation of the multimeter.

3.2.1 Grounding

For the user's protection the instrument chassis is grounded using a three prong, grounded power cable into a suitable receptacle. The multimeter chassis ground is separated from the protection (GUARD) ground, the trigger input ground and the IEEE-interface ground.

3.3. Accident Prevention

During the operation of this measurement instrument the basic electrical safety directions for use of measurement instruments must be followed.

3.4. Scanner Installation and Limitations

When the optional, ten channel scanner is installed, the following considerations for the protection of the user and the multimeter apply. A maximum of 125 Vdc for the measured signal must be observed. Damage to the scanner which results from disregard of this limit is not covered by the warranty responsibilities.

3.5. Warranty

PREMA guarantees the reliable functioning of the instrument and the accuracy of the calibration data for a period as specified in the sales agreement. Within this time period any repairs required due to defective workmanship or materials will be performed without charge.

Damage which is caused by improper use of the instrument or exceeding the given data limits is not covered by the warranty. Consequential damage is also not covered.

3.6. Switching on the Instrument

Switching on state of the instrument

The instrument is switched on by means of the rocker switch on the back of the instrument. After powering on, the instrument automatically runs a series of self test routines, during which the proper functioning of the electronic components within the instrument and the relays are tested with any error conditions being indicated on the front display panel. The instrument then selects the direct voltage measurement 1000V range or the 200V range if the scanner 6000/01 is installed. The auto ranging is turned off. All multiplexer entries for the optional scanner are turned off. The integration time of 1 sec is selected with the instrument showing the measurement result. No further mathematics program are selected. The trigger entry is turned off and the instrument is ready for manual operation, thus it is not in remote control.

The following applies during the operation of the instrument with IEEE-Bus:
The basis instrument address is set at the factory for Address 7 with the terminator set for (EOI). Display operation and SRQ-operation are turned off. Long-string output is also automatically selected. The basis instrument address can be changed by the user (see Chapter IEEE-Bus).

Attention!
The switching on state for some functions can be changed by the user. The state mentioned above refers to the factory setting of PREMA. (see chapter 5.7. "Storing the switching on state")

4. Instrument Construction

4.1. Functional Construction

The Model 4001 multimeter is subdivided into several different functional sections which are all connected and controlled with a central microprocessor. This microprocessor controls the start and finish of a measurement, the keyboard testing, the display, the switching of range and function relays as well as the switching on and off of measurement channels when the optional scanner is installed. Further, it also controls internal data traffic and external data exchange on the IEEE-488 interface.

In addition to the above mentioned hardware control, the microprocessor also controls software functions such as: the mathematics and analog programs, the digital calibration, and the internal test and error routines.

The microprocessor, analog and scanner (if installed) boards are spaced in a well designed manner to avoid any electrical or thermal interference. Also, serial data transfer between the analog section and the microprocessor are isolated using opto-coupler techniques. This precludes any influence between the analog and digital sections of the multimeter.

The digital multimeter aluminium case provides excellent isolation against outside interference as well as providing a good deal of durability for these multimeters.

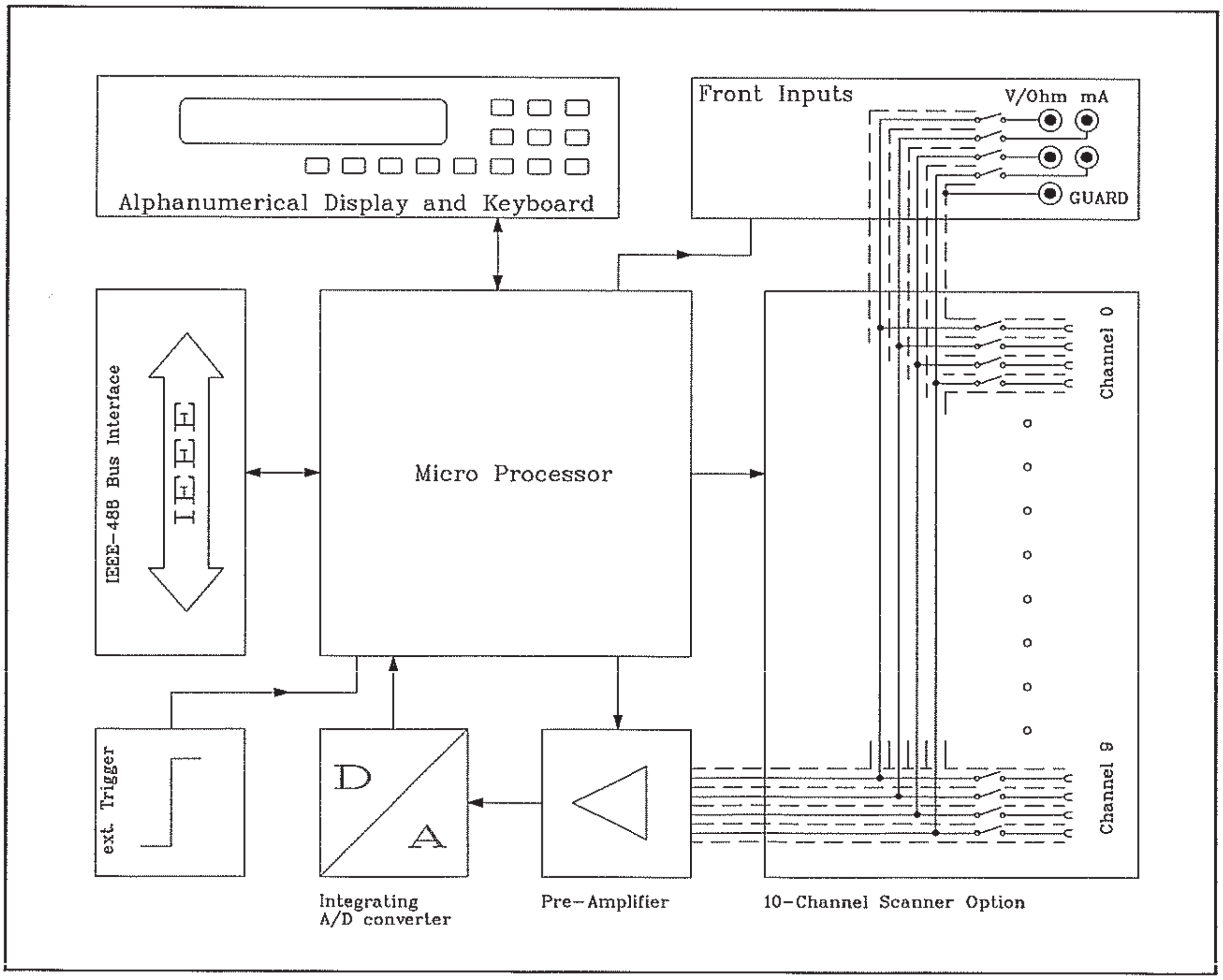


Fig. 4.1.: Functional Construction of the DMM 4001

4.2. Display Field

The alphanumeric LED-display on the front of the multimeter shows measurement value, measurement function, and the associated channel (if the optional scanner is installed) and the mathematics program selected. Short text lines in the display describe the input of constants and other user information when mathematics programs are being used.

Display Information

Display elements (left to right)

1 to 9	Display of the 5 1/2 or 6 1/2-digit measurement or calculated value.
10 to 12	The selected function is shown.
13	Blank if autoranging is not selected; an arrow shows when in autoranging.
14 to 16	The selected scanner channel (when installed), the selected mathematics program, the number of stored measurement value, or IEEE-status.

Examples:

Display element	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	+	1	.	9	9	9	9	9	9	V	=			C	H	0

-Vdc measurement at channel zero

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	-	.	1	9	9	9	9	9	9	k	Ω	4		O	f	s

-Offset program in the function 4-wire-ohm

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	+	1	9	9	9	.	9	9	9	m	A	=		0	2	3

-measurement value storage in the function mA dc;
the 23th value has just been stored.

See Chapter 5 for more description on the use and meaning of the program displays.

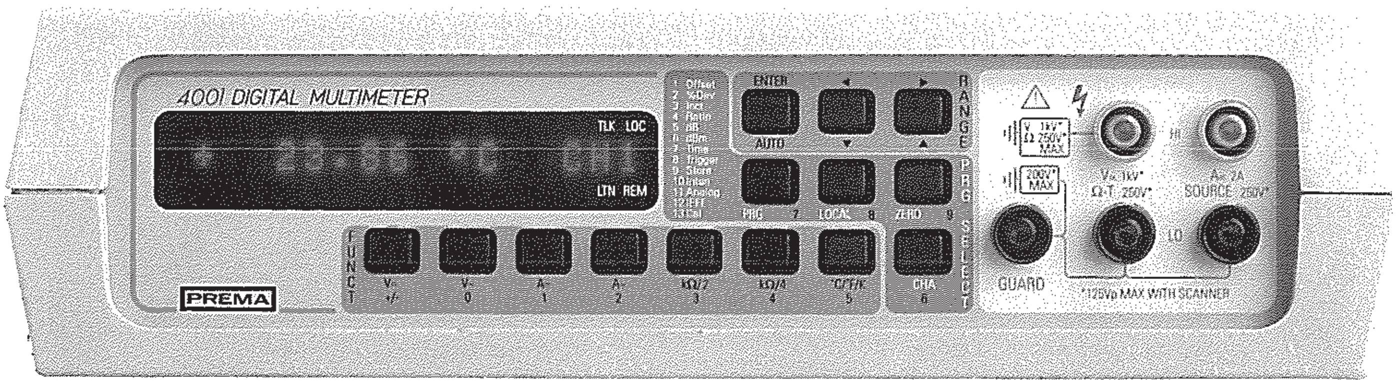


Fig. 4.2. Front Panel of the DMM 4001

4.3. Keyboard Fields

The keyboard of the multimeter is subdivided into the function field (FUNCT), the program selection field (PRG SELECT) and into the range selection field (RANGE). These individual fields are separated from each other using colour zones. Also, keys have two levels of use as described below. In the first or normal operational keyboard level the use of the key is described in black or white letters below the key. Use of these keys achieves the identified function, program, and range. The blue letters which are also below the key except in the range section field describe the secondary level. This level is effective upon pressing the "PRG"-key and is used when working with the mathematics programs and for entering constants.

4.3.1. Function Field (FUNCT)

In the function field, the keys are assigned as follows:

V=	= Direct voltage measurement
V~	= Alternating voltage measurement
A=	= Direct current measurement
A~	= Alternating current measurement
kΩ/2	= Two-wire resistance measurement
kΩ/4	= Four-wire resistance measurement
°C/°F/K	= Temperature measurement using a Pt 100 (RTD 100) sensor

4.3.2. Program Selection Field (PRG SELECT)

Key

"PRG": The "PRG" key switches to the arithmetic or Program Selection mode. A program can be selected and its number entered using the keyboard. All programs are listed by number and short description besides the display.

"LOCAL": This key is used to return control of the instrument from IEEE-Bus operation to "Local" keyboard control.

"ZERO": This key is used for offset correction.

"CHA": This key is only used in multimeters with the optional scanner (option 6000/01). It is used to select the channel to be switched closed.

4.3.3. Range Selection Field (RANGE)

"<", ">": Downward and upward keys to select the next highest or lowest measurement range

"AUTO": Automatic range selection "↕"

4.4. Measurement Leads

The digital multimeter has special low thermo voltage safety sockets on the front panel to connect the measurement leads. When the optional scanner is installed, the front sockets can be controlled as channel #11.

4.4.1. Connection of the Measurement Leads

Measurement leads should always be connected so that the signal at or nearest ground potential is connected to the black input socked (LO). The signal with the higher potential is connected to the red input socket (HI). The display will then show a measurement value with a positive sign. If the potential on the black socket is greater, then the display will show a negative sign.

All voltage measurements as well as two-wire resistance measurements are carried out using the two left sockets (black and red) labelled with V, Ohm-T. Measurements for four wire resistance and temperature use these two sockets as well as the two on the right side labelled A, Source. Insure you observe correct polarisation (HI-HI, LO-LO). Current is measured using the two right sockets.

4.4.2. Data Limits for Measurement Inputs

Always observe the below limits when making measurements. These limits are noted on the front panel in red lettering by the sockets. Note the different limits if the optional scanner is installed.

Measurement Input	without scanner	with scanner
HI-LO	1000 V peak	125 V peak
LO-Ground	125 V peak	125 V peak
GUARD-Ground	125 V peak	125 V peak
GUARD-LO	125 V peak	125 V peak
Ohm-Source		
HI-LO	250 V peak	125 V peak
	2 A peak	2 A peak
LO-Ground	125 V peak	125 V peak

4.4.3. Protection (GUARD)

In critical cases, a high rejection factor for direct voltage and common mode voltage can be obtained by use of the "Guard" input For optimum shielding effect, connect the guard input to a direct voltage potential equal to that of the "LO" input such that currents flowing in the shield do not flow through resistances in the voltage source circuit and voltage measuring leads. When the ten channel scanner is installed, the one shield for all ten channels is internally connected with the "Guard".

4.5. Trigger Function

4.5.1. Trigger Input

Single measurements can be started with a short trigger pulse using the trigger jack which is located on the back of the multimeter. In order to use an external trigger, the instrument must be set with **Program 8** to the "**Trig= on**" mode.

The trigger connection is a 3.4 mm jack plug. The trigger signal uses TTL level voltages (0V=LOW,5V=High).

The outer conductor of the socket is connected to the microprocessor ground (IEEE-bus ground); the inner conductor is for the TTL signal (figure 4.5.1.).

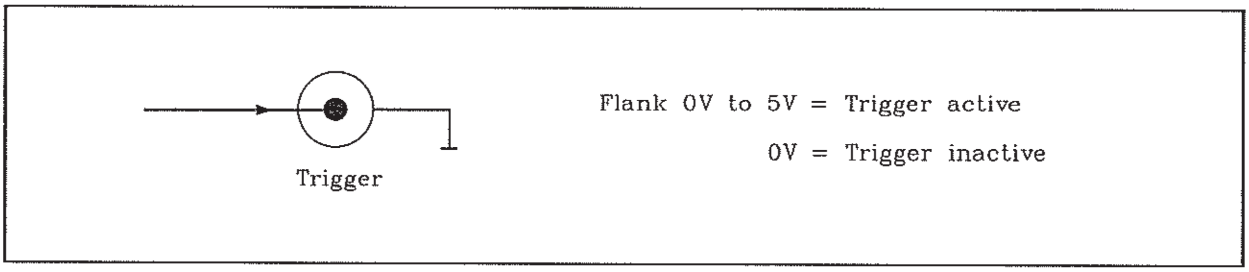


Figure 4.5.1.: Connections to the Trigger Socket

The trigger socket is separately grounded from the protection ground. The starting time for a single measurement is the ascending flank of the trigger pulse with a time uncertainty of 12.5 msec (figure 4.5.2.). Every trigger pulse starts a new measurement. If a new trigger pulse arrives during a measurement, the current running measurement is aborted and a new measurement is started.

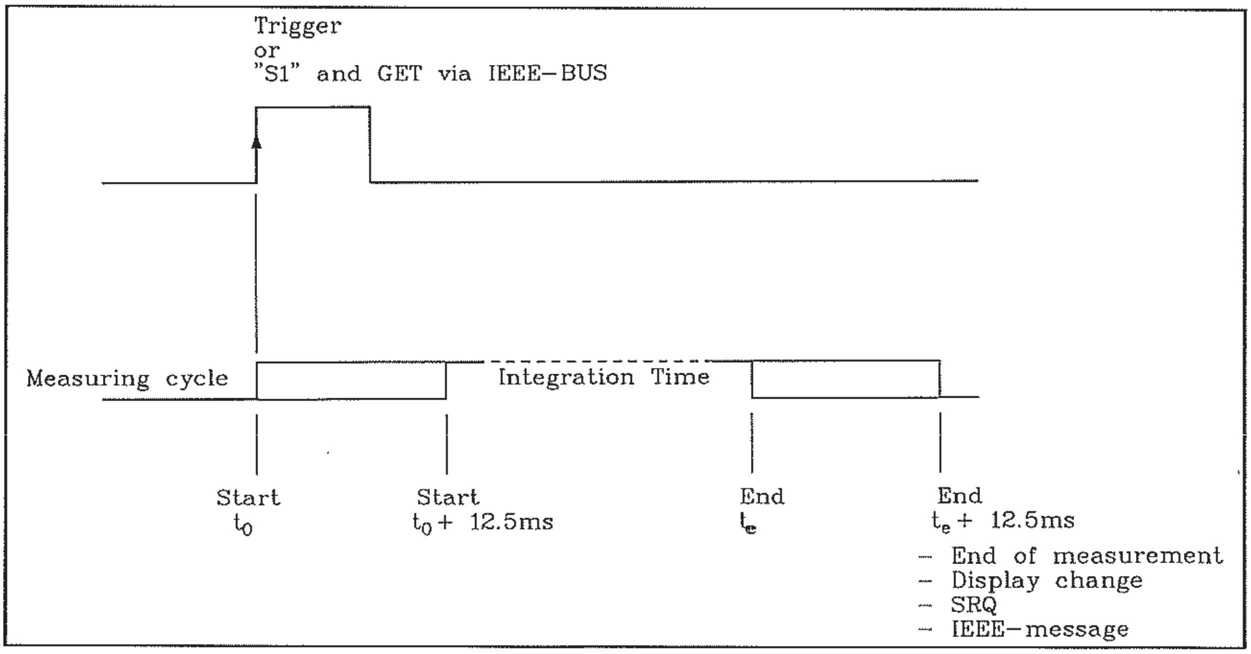


Figure 4.5.2.: Start of a Measurement by Trigger Signal

The trigger signal must be at least 2V, with a maximum of 15V and can cause damage if it goes +/- 25V. The maximum tolerated voltage between the trigger signal and ground is 50V. The duration of the trigger pulse must be at least 400 µsec.

4.5.2. Triggering using the IEEE-488-Bus

The IEEE-bus can also be used for trigger operations. Both the external trigger start and IEEE-start share the same chronological course.

Using the IEEE-bus, the DMM is reset with the command "S1" into the start operation. Now, every further sending of "S1" starts a triggering as stated above. The DMM can also be triggered using the addressed command GET (Group Execute Trigger). At the end of the measurement, the display and the IEEE-message are refreshed. If the operation call is switched on, the SRQ lead is activated. In the "TALK ONLY" mode, the DMM sends a message to a connected device in the "LISTEN ONLY" operation.

4.6. IEEE-488-Bus-Interface

The 24-conductor IEEE connector is used to connect a computer controller using the IEEE-488-bus interface. According to the standard, a maximum of 16 instruments may be connected to the IEEE-bus with a total lead length of a maximum of about 20 meters with the distance between any two instruments being a maximum of 2 meters.

The computer (CONTROLLER), which is connected via IEEE cables, can address the digital multimeter to receive data as LISTENER or to send data as TALKER and can exchange data with the instrument. The exchange of data occurs on 8 data lines using a procedure with three transfer control lines: DAV, NRFD and NDAC (Handshake). Five interface control lines are used by the Controller to manage the bus. The connection layout (figure 4.6.1.) of the leads on the 24-pole socket corresponds to the IEEE-488 standard.

DIO1	1	13	DIO5	Data bus:		INPUT/OUTPUT
DIO2	2	14	DIO6	DIO1-DIO8	Data bits 1-8	I/O
DIO3	3	15	DIO	Transfer control bus:		
DIO4	4	16	DIO8	DAV	DATA VALID	I/O
EOI	5	17	REN	NRFD	NOT READY FOR DATA	I/O
DAV	6	18	GND(6)	NDAC	NO DATA ACCEPTED	I/O
NRFD	7	19	GND(7)	Interface control bus:		
NDAC	8	20	GND(8)	IFC	INTERFACE CLEAR	I
IFC	9	21	GND(9)	ATN	ATTENTION	I
SRQ	10	22	GND(10)	SRQ	SERVICE REQUEST	O
ATN	11	23	GND(11)	REN	REMOTE ENABLE	I
SHIELD	12	24	GND	EOI	END OR IDENTIFY	I/O

GND Signal ground (Microprocessor-Board)
SHIELD Protection

Fig. 4.6.1: Connection and Meaning of IEEE-Bus-Signals

All IEEE-Bus signal levels are TTL-compatible and are active LOW; therefore, true when the signal level is = 0. The drivers of the IEEE-bus interface can typically sink 48mA current for LOW signals. The IEEE-interface is electrically isolated with respect to the measuring circuit inputs.

The instrument address which is required for the operation of the digital multimeter on the IEEE-bus is set under software control.

4.7. Scanner (Option 6000/01)

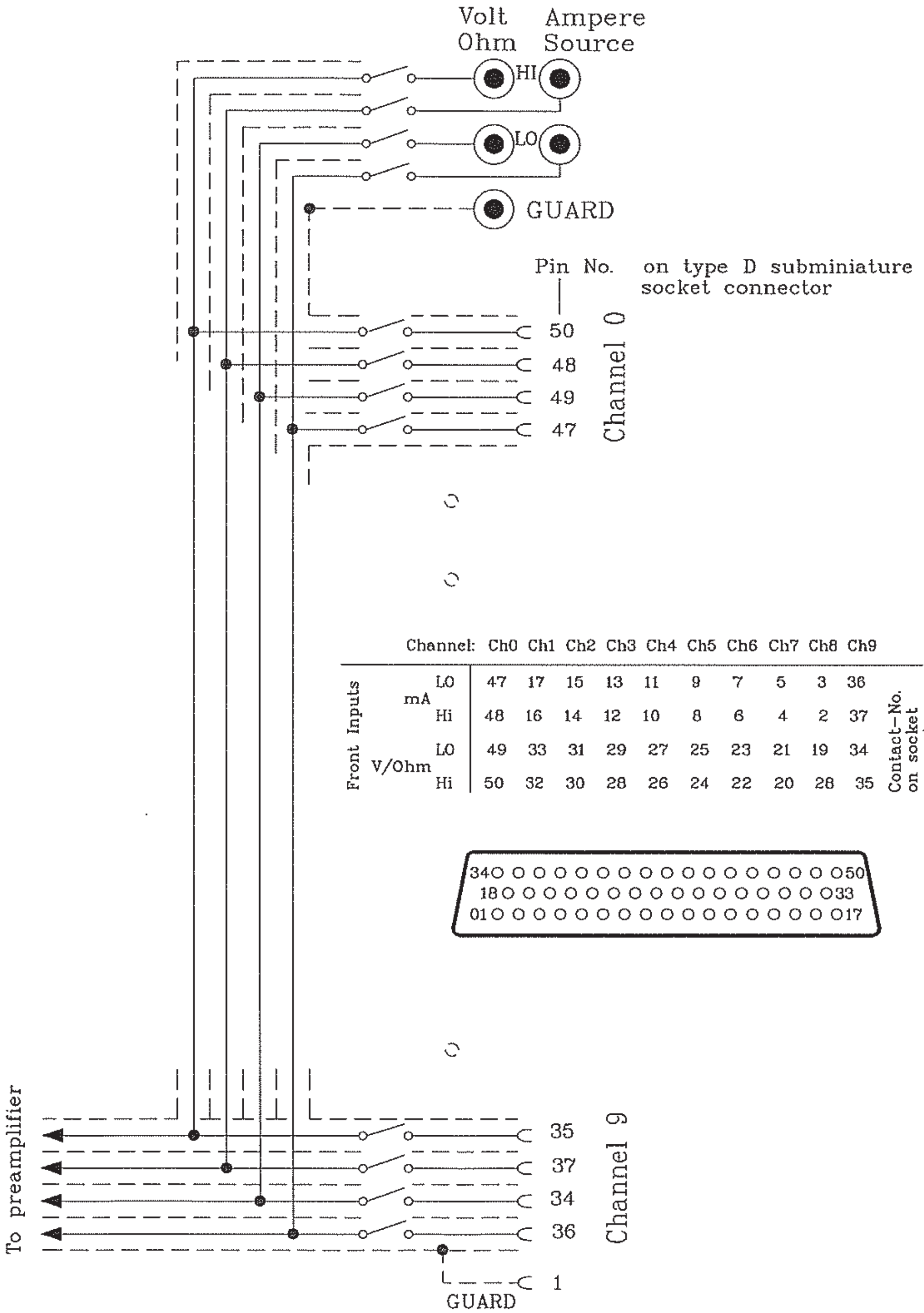
The digital multimeter can be optionally equipped with a low thermo voltage, 10 channel, 4-pole scanner. With this scanner installed, the maximum voltage is 125V-peak with a limit of 1 000 000 x V x Hz on both the "V/Ohm" input and the 50-pole subminiature-D-socket for the scanner. This limit applies at all times whether or not the scanner is being used.

The scanner switching is of type 1 out of 10, which means that one channel at a time can be switched internally to the multimeter section. If a new channel is desired, the channel presently selected is opened before the new channel is switched closed (Break before Make). This prevents short circuit conditions when using the scanner.

The scanner channel inputs are combined on a 50-pole subminiature-D-socket which is on the back of the instrument. The 4 output leads of the scanner multiplexer are internally connected with the analog section of the instrument. The front cannel sockets are also switched much as the scanner channels using 2 separate relays. Consequently, they can be used as the 11th channel, and one must remember that they are switched open prior to another channel being selected. When the multimeter is powered on, the front sockets are switched closed for use and the scanner channels are all switched open.

Pin 1 of the subminiature socket is connected to the shield line and to the blue "GUARD" socket. See Fig. 4.7.

PREMA offers an adaptercard with screw terminals for all leads for use with the scanner option. This accessory is described in more detail in chapter 12.



Front Inputs		Channel:	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9
	mA	LO	47	17	15	13	11	9	7	5	3	36
		Hi	48	16	14	12	10	8	6	4	2	37
	V/Ohm	LO	49	33	31	29	27	25	23	21	19	34
		Hi	50	32	30	28	26	24	22	20	28	35

Contact-No. on socket connector

Fig. 4.7.: Connection of the 10-channel scanner

4.8. Calibration switch

Certain basic instrument settings, which are activated when the 4001 DMM is turned on, can be changed and stored in the battery buffered RAM so that the meter will default to these new values when turned on in the future. The "CAL" - "MEAS" switch (figure 4.8.1) on the back of the multimeter is used to open the RAM when you want to store new instrument settings such as integration time, IEEE-instrument address, etc., and to recalibrate measurement functions. During normal operations of the instrument the switch is left in the "MEAS" position. The instrument data stored in the battery buffered CMOS-RAM is protected. If the switch is moved, by using a small screwdriver, from the "MEAS" position to the "CAL" position, the data stored can be overwritten. The instrument is then in the CALIBRATION MODE.

ATTENTION !!!!!!!!

In the CALIBRATION MODE, great care is necessary to prevent any unintentional change of data. The digital multimeter should not be turned off when in this mode, otherwise original data from the EPROM memory will be loaded into the RAM when the meter is turned back on. If this happens, a series of steps will be required to reprogram front panel offsets, metrology calibrations, etc. (see Chapter on Calibration).

After changing the instrument basic settings or calibration data, immediately set the sliding switch back to the "MEAS" position to prevent any unintentional overwrite of data.

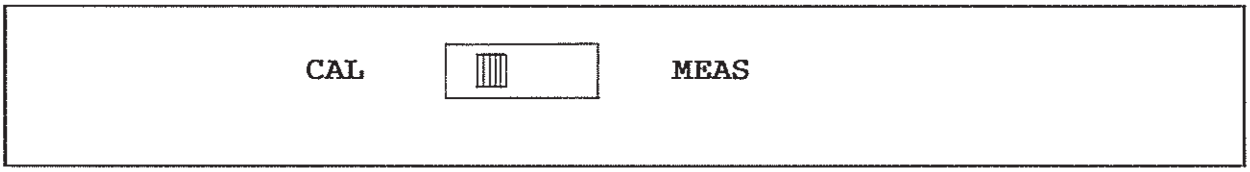


Fig. 4.8.1.: Adjustments of the Calibration Switch

5. Manual Operation

5.1. Selecting the Functions

All measurement functions of the digital multimeter are selected with one touch of a key. When a key is pressed, the selected measurement function appears immediately on the display. The first measurement value will appear after one complete integration cycle plus a short internal wait time.

5.2. Range Selection

The measurement range scale can be manually set or can be selected so the multimeter automatically selects the correct range scale. For automatic range selection, use the "AUTO" key. For manual selection, use the upward and downward arrow keys. The location of the decimal point specifies the selected measurement range.

The following table gives an overview of the adjustable measurement ranges:

Range	Function	Range	Function	Range	Function
0.2	Vdc, Vac	0.2	kΩ/2,kΩ/4		
2	Vdc, Vac	2	kΩ/2,kΩ/4	2	mAdc, ac
20	Vdc, Vac	20	kΩ/2,kΩ/4		
200	Vdc, Vac	200	kΩ/2,kΩ/4		
1000	Vdc,700 Vac	1600	kΩ/2	2000	mAdc, ac
		16000	kΩ/2		

5.3. Selecting Mathematics Programs

The first six internal mathematics programs carry out the mathematical function as shown on the front panel. The operator decides the program to be run and follows the below procedure. In principle, the operator needs to observe that a blinking sign in the meter's display always requires the user to press the appropriate key (<, >, <┘) or to enter a constant. With pressing the "PRG" key, the multimeter goes into the program mode and the blue legend use of the keyboard comes into force. While in this mode, the "<" and ">" keys serve for cursor control or are also for certain other program entries.

The "ENTER" key (<┘) confirms the input and always starts the program once selections and constants have been entered.

The calculated value is displayed as a floating point number.

The "+/-" key sets the sign and also the decimal point of any constant being entered. If the cursor with the current display blinking is set on the sign and the "+/-" key is pressed, the sign will change. If the cursor is set elsewhere, pressing the "+/-" key will set a decimal point at the cursor location.

The "0-9" keys serve for numeric entries. All six mathematics programs are discussed below. More detail is provided as an example for the first program "OFFSET", with the same principles applying to all programs.

Return to measuring mode:
To quit the running program a function key has to pressed. During the adjustment of a program it is not possible to quit, it has to be executed completely.

Integration times in calculation mode

The first four programs can be used with every integration time.
The programs dB and dBm only runs with integration times greater than 1s.

Program-No. 1 Offset:

In the offset program, the measurement value (MW) is subtracted from the constant (a) and the arithmetic result (R) is directly displayed. R = MW-a

Key | **Display**

"PRG" Prog# (1-13) = ..

This text line serves for selecting the chosen program. The field toward the right of the display is blinking which means that an input is expected here.

"1" Prog# (1-13) = 1 <┘

The right two fields blink to show that an action is required. If a number between 0-3 is pressed, a program from 10-13 can be performed. This input can be corrected with the "<" key. A press of the "ENTER" key confirms the input.

" <┘ " Offs = Meas - a <┘ Enters the selected Offset program #1.

" <┘ " a = Num < or > Meas

This displays a choice of whether the constant to be entered is based on the last measurement or a new number. If the "<" key is pressed, a number can be imputed directly by the keyboard as a constant. If the ">" key is used, then the measurement value which was shown before starting the programming is taken on the constant.

"<" a = +.0000000 <┘

The constant to be entered is displayed. The entered number appears on the display and the decimal point then moves one digit to the right. To change the sign of the constant, move the cursor to that field and press the "+/-" key. The constant entry is set by pressing "ENTER".

">" a = +1.999999 <┘

If the last measurement value is recalled to be the constant, it is still possible to change it using the numeric and cursor keys. Again, use "ENTER" to set the constant.

+1.999999 Ofs

The mathematics program calculation is performed using the entered constant and the current reading and the result is displayed. To quit the offset program a function key has to be pressed.

Program-No. 2% Dev:

The percentage of the difference between the measurement value and the constant b is displayed. R=100*(Meas-b)/b

Key	Display	
"PRG"	Prog# (1-13)= ..	
"2"	Prog# (1-13)=2 <┘	
<┘	%=100(Meas-b)/b<┘	
<┘	b=Num< or >Meas	
"<"	b= +1.999999 <┘	(numerical constant)
or		
">"	b= +1.999999 <┘	(measurement value when pressing "PRG")
	+100.000...... %Dv	

Program-No. 3 Incr:

The incremental program directly shows the difference of two measurement values that immediately following each other. $R=MW_n-MW_{n-1}$

"PRG"	Prog# (1-13)= ..	
"3"	Prog# (1-13)=3 <┘	
"<┘ "	Incr=Diff(Meas) <┘	
"<┘ "	+1.999999..... Inc	

Program-No. 4 Ratio:

The ratio program gives the proportion of the measurement value to a stored constant c. R=MW/c

"PRG"	Prog# (1-13)= ..	
"4"	Prog# (1-13)=4 <┘	
"<┘ "	Ratio=Meas/c <┘	
"<┘ "	C=Num< or >Meas	
"<"	C= +........ <┘	(numerical constant)
or		
">"	C= +........ <┘	(measurement value when pressing "PRG")
"<┘ "	+....... Rat	

Program-No. 5 dB

This program gives the increase of the measurement value to a constant d using a logarithmic function. R = 20*log(MW/d)

"PRG"	Prog# (1-13) = ..	
"5"	Prog# (1-13) = 5 <┘	
"<┘ "	db = 20lg(Meas/d) <┘	
"<┘ "	d = Num < or > Meas	
"<"	C = +....... <┘	(numerical constant)
or		
">"	C = +....... <┘	(Measurement value when pressing "PRG")
"<┘ "	+ ..... dB	

Program-No. 6 dBm

The logarithmic increase is given out: R = 20*log (MW/e)

Whereby e = 0.775 on a 600 Ohm termination with voltage and e = 1.29 mA with current

"PRG"	Prog# (1-13) = ..
"6"	Prog# (1-13) = 6 <┘
"<┘ "	dBm = 20lg(Mea/e) <┘
"<┘ "	+....... dBm

5.4. Selecting Programs 7 to 13

Program-No. 7 Time

The integration time to be used by the multimeter can be selected with this program. The up key press increases to the next longer integration time with the down key to the next shorter time. The selection is entered using the "ENTER" key.

"PRG"	Prog# (1-13) = ..	
"7"	Prog# (1-13) = <┘	
"<┘ "	time = 1 s > < <┘	(pre-selection)
"<"	time = 500ms > < <┘	
or		
">"	time = 5 s > < <┘	
"<┘ "	Measurement value display	

Program-No. 8 Trigger:

This program is used to activate or deactivate the external trigger socket.

"PRG"	Prog#(1-13) = ..
"8"	Prog#(1-13) = 8 <┘
"<┘ "	trig = off >on <┘
">"	trig = on >off <┘
"<┘ "	Measurement value display

Program-No. 9 Store

Up to 100 measurement values can be stored and recalled for display

"PRG"	Prog# (1-13) = ..
"9"	Prog# (1-13) = 9 <┘
"<┘ "	Store < > Recall
"<"	Cont < > Start
	"Cont" means that the last 100 measurement values will always be stored. **"Start"** means that the storage mode will be triggered externally or via the IEEE-Bus
"<"	Measurement value display. ("Cont" operation of the memory)

- Storing measurement values in the "Start" mode.

">"	Num of meas = .. <┘
"99"	Num of meas = 99 <┘
"<┘ "	+..... V= 001

- Measurement values selected on keyboard

"<┘ "	Store < > Recall
">"	Begin at No. <┘
"<┘ "	Down < > up (appears for about 2s)
	+..... V= 009
">"	+..... V= 010
or	
"<"	+..... V= 008

Press a function key to returns to the measurement mode.
All measurement values are stored and displayed as a floating point number.

Program-No. 10 Intens

The brightness of the display is regulated using this program.

Prg	Prog# (1-13) = ..	
"10"	Prog# (1-13) = 10 <┘	
"<┘ "	Intens.(1-7) = 2 <┘	(pre-selection)
"4"	Intens.(1-7) = 4 <┘	(Display gets brighter)
"<┘ "	Measurement value display	

Program-No. 11 Analog

The difference from a preselected 100 digit value f is displayed, +/- 100 digits, with a dot matrix graph. The decimal location of the preselected value determines the sensitivity. When f is first called up, it is always given in 6 1/2 digits. The number of places can be reduced with the cursor key. This means the cursor should be moved to the last (right) place of the displayed f. If one then moves the cursor to the left, the place which one leaves is erased. The last two visible place value will be displayed +/-100 digits by the dot matrix graph.

"PRG"	Prog# (1-13) = ..	
"11"	Prog# (1-13) = 11 <┘	
"<┘ "	Analog = f ± 100Dig <┘	
"<┘ "	f = Num < or > Meas	
"<"	f = +... <┘	(num. constant)
or		
">"	f = +... <┘	(Measurement value when pressing "PRG")
"<┘ "	+.....	

example:
You want to adjust a voltage to 5.000 V, whereby the last two digits should be shown as a 100 dot matrix. Now have to enter the constant f = 5.000 with exactly three digits behind the point. If the input voltage is 5.055 volts you will see the "+" sign and 55 dots in the last four display elements. Is it 4.060 volts you will see 40 dots with the "-" sign.

Program-No.12 IEEE

Using this program, the IEEE-488 address and the desired terminator and also the IEEE-bus condition display may be selected.

"PRG"	Prog# (1-13) = .. <┘
"12"	Prog# (1-13) = 12 <┘
"<┘ "	Addr < > Talk only

"<"	Addr(0-30) =07 <┘ (pre-selection)
XX	Addr(0-30) =XX <┘
"<┘ "	EOS=EOI < > <┘ (pre-selection)
"<"	EOS=LF+CR < > <┘
"<┘ "	Bus Display y< > n

With "<", the IEEE-bus status is shown in the last 2 display elements.

With ">", no bus status is displayed

Program-No. 13 Cal

Serves for calibration of the measurement instrument. For a further description see the Calibration Chapter.

"PRG"	Prog# (1-13)= ..
"13"	Prog# (1-13)=13 <┘
"<┘ "	Calib. value=v <┘
"<┘ "	v= +... <┘
XXXXXXX	v= +xxxxxxx <┘
"<┘ "	+xxxxxxx

5.5 Channel Selection

The optional internal scanner has 10 four-pole channels (No. 0 - 9). The front sockets of the multimeter can be used as channel 11. This is shown with "CH-" in the last display element.

CHA	Chan. (0-9,-)=- <┘
"5"	Chan. (0-9,-)=5 <┘
"<┘ "	+..... CH5

Storing the Channel Settings

The instrument settings (integration time and function) for one channel are stored by selecting the channel twice and thereafter pressing the "ENTER" key. However, this data selection will not be retained once the instrument is turned off.

example:
You have just selected channel 5 (see above) and change the function to 2-wire-Ohm and the integration time to 5s. To store these adjustments press the "CHA" key, the display shows now "chan. (0-9)=5 <┘ ". Next press "<┘ "-key to terminate storage. Now you get this adjustment after every selection of channel 5.

5.6. Offset Correction

An offset value resulting from thermoelectric EMFs or lead resistances can be corrected using the "ZERO" key. "Zero" will appear in the display for voltage and current measurements. In the resistance function, "ZERO" will be displayed until there is a valid measurement value. For temperature measurements "done" appears on the display after the offset correction. See Chapter 6 for a more detailed explanation regarding this function.

5.7. Storing the Switching-On State

Specific switching-on configurations for the instrument can be stored in the battery-RAM. These set-up configurations include: Integration Time, IEEE488-Bus-Address and Terminator (Endsign).

First move the CAL-switch on the rear of the instrument to the "CAL" position. The DMM will then alternatively display the measurement value and "CAL". Next, select and set the configurations desired using the DMM front key-panel. Finally, return the CAL-switch to the "MEAS"-position. This will store the new selections into nonvolatile storage. Thus, they won't be lost even when the instrument is turned off.

This ability to store the different settings is especially useful when selecting the correct IEEE488-Address and endsign (terminator) needed for your system. Once selected and stored within the instrument, the DMM will correctly respond to the user-software commands without having to reset the address and endsign each time the instrument is turned on.

6. Offset Correction

Zero point drift is a possible source of error. Normally, it is immediately evident by a display reading differing from Zero with the input shorted. Therefore, it is useful to carry out an offset correction prior to making measurements. Offset corrections for voltage and resistance measurements are made with the input sockets or leads short-circuited. Offset corrections for current measurements are made with the current sockets opened. Unless these offsets are entered using the calibration feature described in another section, they will remain only until power is lost or turned off to the meter.

A zero offset correction for all functions can be started using the "Zero" key.

6.1 Offset Correction for Voltage Measurements

Establish a short circuit on the "VOhm" sockets or at any point in the external circuit and press the "Zero" key. The instrument performs a zero measurement in the selected range using the set integration time. Until the zero offset is attained correctly, the display shows "zero". If auto ranging is selected, then all voltage ranges will be corrected, one after another. During this period, the keyboard is locked out to prevent mistaken entries.

6.2 Offset Correction for Current Measurements

Establish an **open circuit** on the "current" sockets and follow the above procedure.
In the 2mA range a short circuit on the "current" sockets will cause a display which differs from "zero".
The reason for this is the active amperemeter circuit in this range, but the DMM works faultless in normal current measurement.

6.3 Offset Corrections for Resistance Measurements

Follow the procedure for Voltage Measurement offsets with the multimeter set for either two or four wire resistance. Separate offsets will be required for two and four wire modes. Remember to provide a short circuit for two wire and a short-circuit bridge for four wire.
The meter will display "zero" for integration times smaller 500ms on each range until a zero offset is achieved.
The offset correction will be directly done for integration times from 1 to 10s without the "zero" display.

6.4. Offset Correction in the Temperature Measurement

Similar with the other measurement functions, an offset correction can also be performed for the temperature measurement function. However, because of the conversion and linearisation curve of the PT-100, the meter displays are somewhat different. First, as in four-wire resistance, a short-circuit bridge of "V-T" and "Source" (Figure 6.4) is required. The meter announces an overload, "Overflow". The previous offset-correction is erased with the display showing "Zero". Then, after successful new offset corrections, "done" appears in the display. The offset is now completed, and the first temperature measurement value appears after the short-circuit is removed.

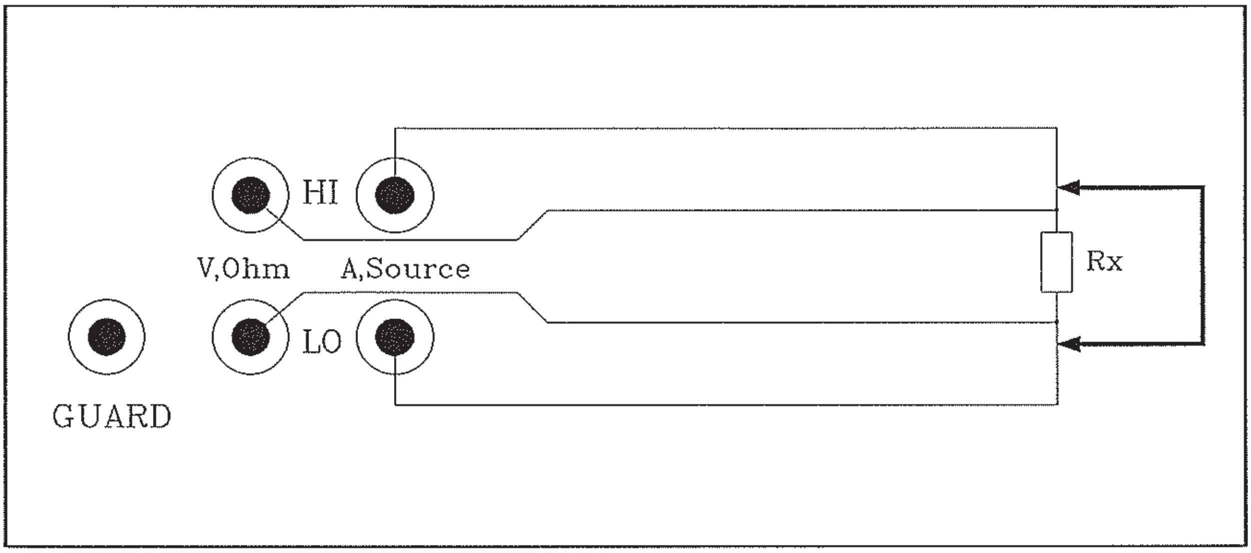


Fig. 6.4.: Switching to Offset Correction

7. Error Messages and Self Test

7.1. Error Messages

The digital multimeter recognises the below operator errors. They are indicated on the main display and via the IEEE bus with the given IEEE bus error report code as shown in brackets.

Overflow (Error 1)	Overflow for Measurement: The reading exceeds the allowed numerical range
Comp. error (Error 2)	Overflow for Computation: The calculation result exceeds the allowed numerical range
Offset too Large (Error 4)	Error during Offset Measurement: The offset present at the input sockets is too large for compensation
CAL. too small (Error 5)	Error during Calibration: The nominal value is smaller than 5% or greater than 100% of the display span
CAL switch (Error 5)	The Calibration switch on the rear of the meter is set on "MEAS"
Buffer overflow (Error 6)	Error in IEEE bus interface: The meter has received more than 30 characters in a device message.
RAM-Error (Error 8)	Error during Self Test 2: Check sums for the RAM do not agree, likely caused by the lithium battery being exhausted or a problem in the non-volatile memory. To solve the problem, the original calibration data and the firmware of the EPROM can be reloaded in to the RAM (see chapter 10.1 "Reloading the ORIGINAL Calibration Data).
ROM-Error (Error 9)	Error during Self Test 3: Errors in the program ROMs

7.2. Self Test

The digital multimeter executes an automatic self-test routine after being powered on. The multimeter display indicates the status of these tests. If an error condition exists, this error is reported by a corresponding error message and the multimeter aborts further self-test routines until the operator touches any key. No voltage greater than 300 V should be present at the input sockets of the multimeter during self-test.

Hardware Check:	Initialises the multimeter and tests correct functioning of the analog section
RAM Check;	Calculates a check-sum of the calibration factors stored in the RAM and compares this with a control value
EPROM Check:	Calculates a check-sum of the ROM programs and compares this with a control value
Battery Check:	The battery voltage is checked when the multimeter is turned on with an open calibration switch

8. Operating Instructions

8.1. Operating Instructions for Direct Voltage Measurements

8.1.1 Connecting the voltage to be measured

Connect the voltage to be measured to the two input sockets marked "V/Ohm". A voltage which is positive at the red socket relative to the black socket will give a positive reading in the display. Make sure that the maximum allowed limits of 125V direct or peak volts between the "LO" socket and "GUARD" and between the "GUARD" and case (see Protection section) are not exceeded. This is especially important when selecting polarities for high voltage circuits that are not isolated for the main power.

8.1.2. Input Resistance Direct Voltage

The input resistances for voltage measurement is extremely high especially up to 2 Volts. This design feature is to make full use of the excellent linearity of the PREMA patented measurement method. Accurate measurements up to ± 2 volts are possible even when the internal resistance of the measured voltage source is 100 kOhms. In the 20 V, 200 V and 1000 V direct voltage ranges; 100 Ohms of internal resistance of the measured voltage gives an error of 1 digit when using 100,000 digit resolution. The input resistance, display span and resolution are summarised in the following table:

Range	Maximum Display	Input Resistance	Maximum Resolution
200 mV	.1999999 V	> 1 GOhm	100 nV
2 V	1.999999 V	> 1 GOhm	1 µV
20 V	19.99999 V	10 MOhm	10 µV
200 V 1)	199.9999 V	10 MOhm	100 µV
1000 V 1)	1000.000 V	10 MOhm	1 mV

8.1.3. Overload Protection

All ranges are well protected against destruction by excessive voltages. The overload constraints:

±0.2 V, ±2 V Range for 60 sec.	±1.000 V	1)
or continuous	±500 V	1)
±20 V, ±200 V, ±1000 V Range continuous	±1.000 V	1)

It is important to keep in mind that heavy overloads in the lower ranges will inevitable cause a heat-up of the safety resistors and diodes with the resulting thermoelectric EMFs possibly causing a zero displacement until internal temperature equilibrium is establish.

1) When being equipped with scanner (Option 6000/01) max. 125 V. 1000 V-range results.

8.1.4. Common mode suppression

Common mode rejection of a multimeter is the capability of indicating only the difference signal between the "HI" and "LO" input with the ideally complete suppression of any common voltage with respect to ground that is present on both input terminals. Stray capacitances, finite insulation resistance and resistive circuit asymmetry will convert a portion of the common mode voltage to a series voltage. The common mode rejection factor of these multimeters is better that 140 dB when the resistive asymmetry of the measuring leads has any value up to 1 kOhm.

8.1.5. Shielding

When no difficulties are expected due to common mode voltages, the "GUARD" socket (blue socket) is connected to the "LO" input (black socket).

A high rejection factor for both direct and common mode voltage can be obtained by use of the "GUARD" input. Direct mode voltages are those between the lower and ground potential of the voltage to be measured. These voltages tend to allow current in the same direction on both input sockets. For optimum shielding, connect the "GUARD" input to a direct voltage potential equal to that of the "LO" input such that these currents flowing in the shield do not flow through resistances in the voltage source circuit or measuring leads which could effect the measurement value.

8.2. Operating Instructions for Resistance Measurement

Resistance measurements using a digital multimeter are carried out in the following manner: A constant current (I) is passed through the resistance (Rx) that is being measured and at the same time also passed through a known internal range resistor. The resulting voltage drop across Rx is measured on the input socket of V=, and its ratio to the drop across the internal known resistance is obtained. Thus, ageing or drift of the reference voltage source does not affect the resistance measurement.

8.2.1. Two-Wire Measurements

The model 4001 digital multimeter can perform resistance measurements using the standard two-wire technique. Use of the offset correction feature of the multimeter is necessary for high accuracy when measuring small resistances. Otherwise, errors will result from thermoelectric EMFs and measurement lead resistances.

One shielded cable is used with the inner conductor being connected to the "V-kOhm" input "HI" and the outer conductor connected to the "LO" socket. Before making a measurement especially with low source resistance, short the test leads at the source end and perform a "ZERO" offset correction.

Attention !!!!

Shielded leads should always be used when measuring large source resistances (from 100 kOhm) whereby the shielding is connected with ground to prevent power frequency disturbances. Also, select an integration time of greater than one second to help integrate out such disturbances.

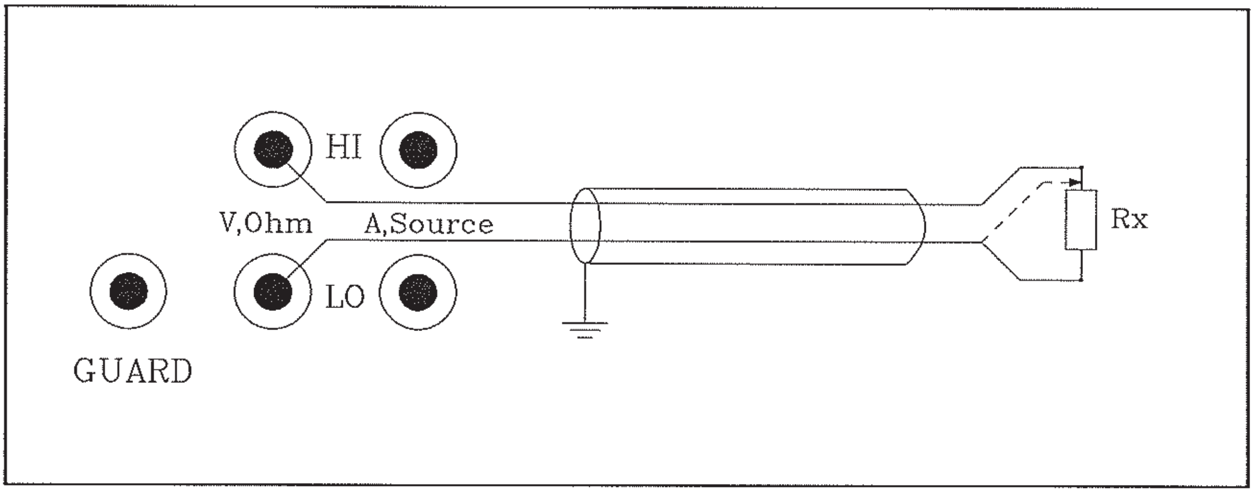


Figure 8.2.1. Two-Wire Resistance Measurement

This two-wire technique (see figure 8.2.1.) produces acceptable measurement results in normal working ranges. However, in working with high resistance sources, current leakage problems will arise due to the parallel connection of Rx and the cable insulation resistance. In low resistance ranges, especially in the 100 Ohm range, the series resistance of the measurement leads becomes noticeable. In these cases, a four-wire measurement is recommended to obtain the most accurate results.

8.2.2. Four-Wire Measurement

The measurement arrangement for a four-wire measurement is shown in figure 8.2.2. Each respective inner conductor is connected with the "HI" connection of the "V-kOhm" socket or the "OHM-Source" socket, The shielding is connected to the respective "LO" sockets.

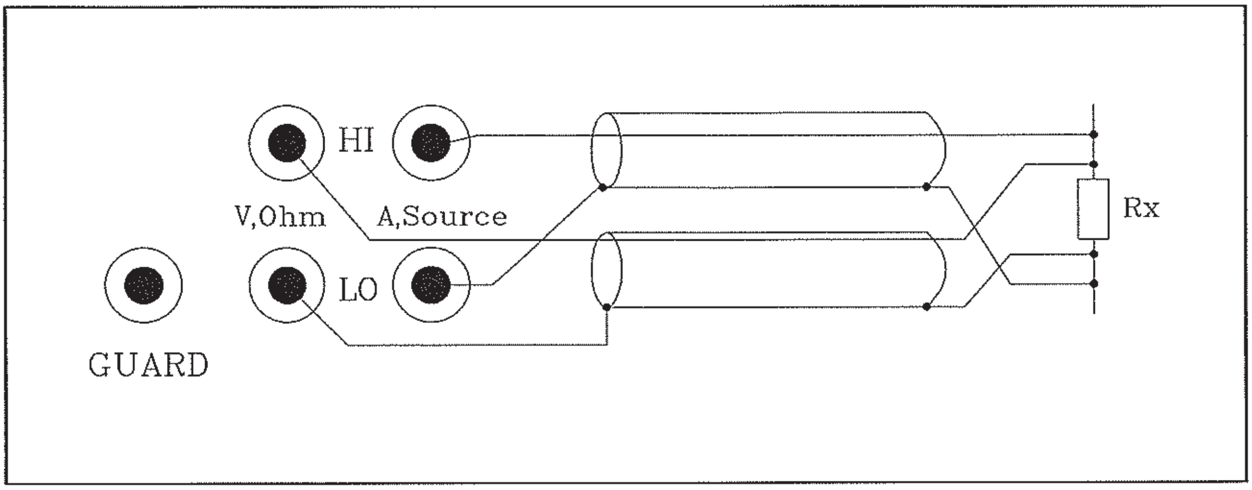


Figure 8.2.2.: Four-Wire Measurement Configuration

Using the four-wire technique, one eliminates the effect of the resistance of the connecting leads. However, cables with Teflon insulation must be used when measuring high resistances. A voltage drop of up to about 0.5 V in each line is tolerated between the "Ohm-Source" inputs. An overflow due to too large a Rx is indicated with "Overflow".
Measurements greater than 200 kOhm can not be performed using the four-wire technique with the Model 6001. For these measurements, use two-wire with "GUARD" shielding and integration times longer that 1 second.

Polarity and Size of the Measurement Current:

The polarity of the measuring current across Rx is determined such that the end of Rx which is connected to the upper "HI" socket of the "V/Ohm" input has a negative potential with respect to the other end of Rx (see Figures 8.2.1. and 8.2.2.).

The value of the currents through the resistance to be measured are found in a table in Chapter 2.2.

8.3. Measurement of Alternating Voltages Vac

The digital multimeter measures the true value (RMS) which includes the applied direct and alternating voltage components.

A recommended arrangement for measuring alternating voltage consists of a two-conductor shielded cable with the shield being connected to the "GUARD" input. (figure 8.3.1.). For all measurements, the "Guard" and the "V/ Ohm-LO" sockets should be connected to the measurement point which is closest to the ground potential.

A somewhat poorer shielding is obtained by using a single coaxial cable and establishing a link between the "GUARD" and the "V/Ohm-Lo" sockets. This frequently used technique is sufficient for most measurements except when working with very small voltages or very high ambient noise levels.

In the 200 V and 700 V ranges when measuring higher frequencies (200 V range over 100 kHz, 700 V range over 10 kHz), it is important to insure that the applied alternating voltage does not exceed the RMS product of 10,000,000 V x Hz.

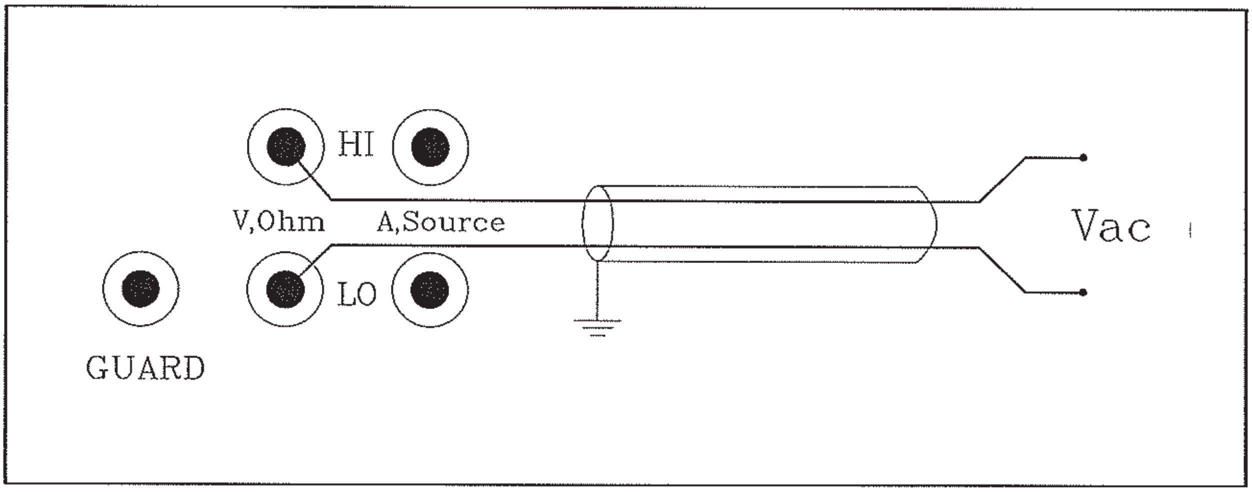


Figure 8.3.1.: Alternating voltage measurement using a shielded two wire cable

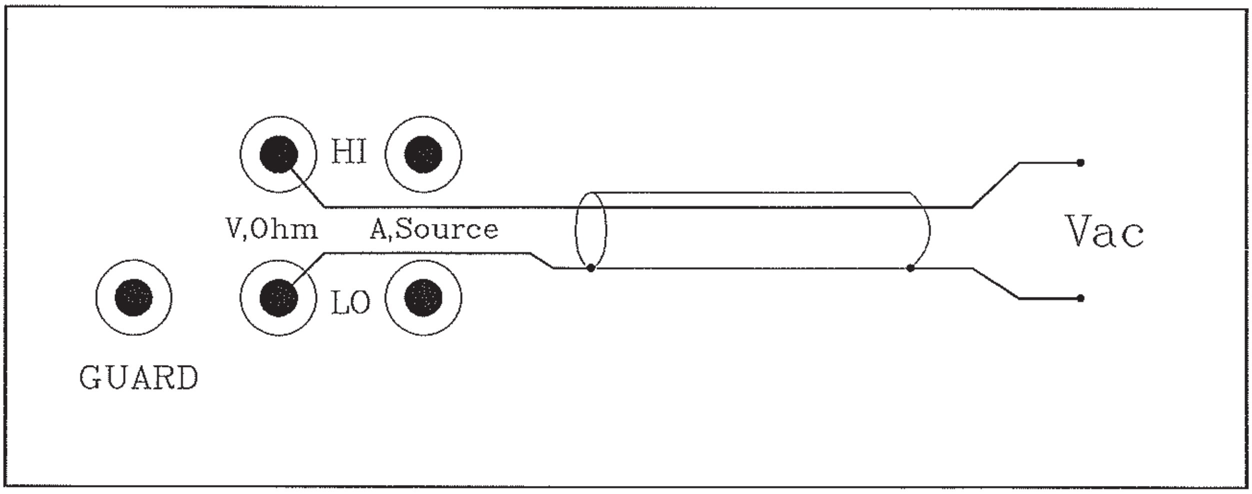


Figure 8.3.2.: Alternating voltage measurement using a coaxial cable

8.4. Operating Instructions for Measuring Direct and Alternating Current

Direct and alternating currents can also be measured with these multimeters using the "A = SOURCE" sockets. Simultaneous connection of current sources to the current sockets and voltage sources to the voltage sockets should be avoided. This is because the meter could be damaged if there is a potential difference between the respective measuring points. The internal connection between the "V/Ohm socket and the "A" "LO" is protected against current overload by a 0.1 A fuse (slow blow).

An offset correction in the current ranges is possible by using the "ZERO" key. However, it should be noted that this offset must be performed with the input sockets open and not shorted as with other offsets (see the "Offset Correction" chapter).A 0.1 Ohm-Shunt is used in the 2 A range. In the 2 mA range, a current compensation circuit is used which permits load voltages smaller than 20 mV for the DMM 4001.

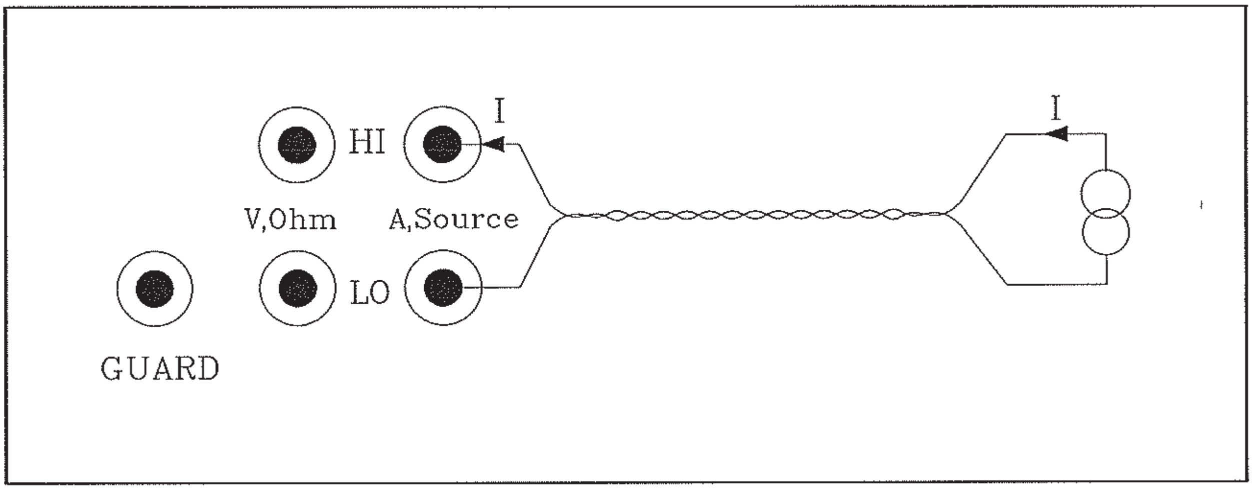


Figure 8.4.1.: Current Measurement using a two wire cable

Autoranging can be activated for the current measuring ranges. The current ranges are protected using power diodes and a quick blow 3 A fuse.

****
ATTENTION
****

Before replacing blown fuses, always disconnect the main power cord and all measuring leads. To open the multimeter case, remove the centre screw on the bottom of the case. Then carefully lift off the top half of the case being careful not to pull off the ground wire that connects the top case with the ground in the bottom half. There should be enough slack in this wire to set the top half aside such that you can get to the fuse. Also, watch that the front and rear panels remain with the bottom half. The 3 A (quick blow) fuse is located near the 0.1 Ohm shunt and the 0.1 A (slow blow) is located parallel to the current relay, K9, near the front sockets on the right front of the measurement instrument (see the appendix for the layout configuration diagram of the pre amplifier board).

8.5. Operating Instructions for Temperature Measurements (Model 6001 only)

Temperature measurements are made using a PT-100 sensor which is connected in a four wire configuration to the "Ohm-T-HI-LO" and "Source-HI-LO" sockets. When connecting this sensor, observe the polarity of the measuring lines is "HI-"HI" and "LO"-"LO". These measurements are based on a four-wire resistance measurement with an excitation current of about 1 mA. This resistance reading is linearized (conforming to DIN IEC 751) and then converted by calculation to the corresponding temperature reading in °Celsius, ° Fahrenheit or Kelvin. The instructions for four-wire resistance measurement mentioned in Figure 8.2. and Section 8.2.2. are also valid for temperature measurements.

Sensor Calibration

The PT-100 sensor can be calibrated using a precisely known reference temperature or with help of a precisely known reference resistance (Figure 8.5.2.). An offset correction should be performed before using the sensor (see Chapter 6.4. Offset Correction). After making the offset correction, the sensor compensation can be made using the reference temperature or resistance (see chapter on "Calibration").

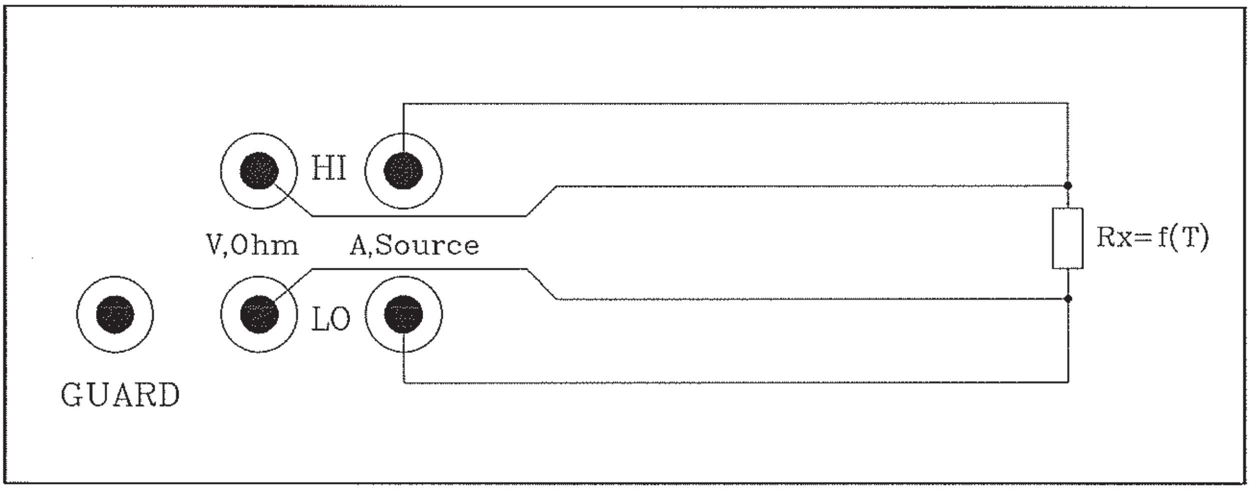


Fig. 8.5.2: PT-100 Sensor Alignment

8.6. Automatic Filtering

With this feature, when the difference of two successive measurements is within a specific range of digits, the DMM will record the floating mean over the last 10 measurement periods. When the successive reading difference exceeds the allowed range (window), the mean formation starts completely new.

During voltage measurements, filtering will be ended when a difference of about 40 digits occurs and a new filtering process will then be started. The for resistance measurements is about 70 digits.

Turning OFF Filtering

Pushing a function key again will stop ongoing filtering and start a new filtering process.

Filtering can be permanently turned off by using the "PF" command via the IEEE488 bus. Sending of "P0" (ZERO) command or turning on the instrument off and back on will reactivate the floating mean filter.

Also, the first measurement value after a channel, function or measurement time change is not filtered.

9. IEEE488 Bus Interface

All functions can be operated using the keyboard or via the IEEE-Interface. The only exceptions is the setting of the device address and terminating character sequence, both of which can only be set via the keyboard.

9.1. Operation on the IEEE-Bus

The keyboard is disabled for manual control once the instrument receives its first command over the IEEE interface. Thereafter, manual control via the keyboard is possible only when the computer enables the keyboard (Command "GTL) or when the "REN"-line goes to the inactive state which cancels the remote control status of the instrument. This is also possible with the "LOCAL"-key. During remote control, the "REM"ote segment indicator is lit in the right part of the main display.

The instrument understands up to 30 characters within a command message. All characters are ASCII-symbols (ISO-7-bit Code). Many multiple commands can be combined in one symbol chain (i.e. "VDR5A1"); but some commands must be sent alone.

The specific commands for control and data transmission via the IEEE-Interface can usually be found in the handbook for the computer be used as the controller or in the instructions for the IEEE-Bus-Interface (IEC-Bus) board being used.

Blanks (SPACE, ASCII-Code 20 H) contained in the character string sent by the computer are ignored. If a character string contains more than 30 characters, the message "ERROR 6" is sent on the bus. This also will be the case if the terminator is incorrectly set. The instrument can receive commands (operation as LISTENER), as well as outputting device messages reporting its status (operation as TALKER).

The time instant at which the instrument outputs messages on the bus can be determined by the computer. One possibility is that the computer addresses it as TALKER to read the device message. The second possibility is to operate in the SRQ-operation. The instrument will then request attention from the computer when a status change has taken place. SRQ operation can be switched on by command. The basic setting after switch-on is operation without SRQ.

9.1.1. Capabilities of the IEEE 488-Bus-Interface

The IEEE-bus computer interface has the following capabilities conforming to the IEEE-488 standard:

SH 1	Handshake Source Function
AH 1	Handshake Sink Function
T6	TALKER Function
L3	LISTENER Function
RL1	Remote Control
DC1	Reset Function
DT1	Originate Function
SR1	Service Request Function

9.1.2. Interface Functions

The instrument understands the global commands of DCL, SPE and SPD. The DCL command sets the instrument into its basic state (Vdc, 1000V). The addressed commands GET, GTL, LLO and SDC are understood. The commands have the following effects:

DCL	Device Clear	Vdc, 1000V, Scanner off, Long string, automatic off, trigger, SRQ, display and calculation mode off
SDC	Selected Device Clear	see Device Clear
GTL	Go To Local	Remote Control is cancelled
LLO	Local Lock Out	Instrument can't be switched to manual control at the keyboard
SPE	Serial Poll Enable	Preparing for Serial Polling
SPD	Serial Poll Disable	Terminating the Serial Polling
GET	Group Execute Trigger	Start the addressed instruments

9.1.3. Setting the multimeter for operation on the IEEE-Bus

To operate the instrument with a computer using an IEEE-Bus interface, some more conditions must be fulfilled apart from the correct physical connections. The following settings are necessary so that the computer and instrument can communicate with each other.

The instrument must be set to an unique address from which it can be communicated with by the computer. The IEEE-488 standard allows address numbers 00-30 for selective addressing devices.

For proper data exchange between the computer and the instrument, the character sequence for terminating a data transmission, TERMINATOR, must also be programmed into the multimeter. This TERMINATOR generally differs from one computer to another, and is determined by consulting the manual for your computer or for the IEEE bus interface card.
The instrument provides a choice of nine TERMINATOR sequences as listed in the below table. The correct one as required by your computer must be determined and entered using the below procedure.

TERMINATOR	Typical Computer
CR + EOI-Lead	Apple
CR	
LF + EOI-Lead	IBM
LF	IBM
CR + LF + EOI-Lead	IBM
CR + LF	HP
LF + CR + EOI-Lead	
LF + CR	
EOI-Lead	Commodore

9.1.4. Setting the Device Address and Terminator

The device instrument address and terminator required for IEEE-bus operation must be set via the keyboard.

As an example, assume you want to operate the instrument with an IBM-PC/XT/AT. Review of the computer manual identifies the required terminator sequence as LF+EOI-Lead. Also,in our example, we have chosen the instrument address of #17 as one which does not interfere with any others on the bus.

We then select Program 12 on our multimeter. On the display appears: "Addr< > Talk Only". After pressing the "<"-key, "Addr(0-30)=07" appears, for example. Using the keyboard, one can now set the address 17 and confirm it with "Enter". After that, "EOS=EOI" is displayed. Using the upward and downward cursor keys, you can then choose the desired end-symbol, here LF+EOI, and confirm this choice with "Enter". Now "Bus Display y< >n" appears. If we do not desire to see the bus display, we press the ">" key to return to the measurement mode. The instrument is now set on address 17 with the terminator LF+EOI. Bus status conditions will not be displayed.

Storing IEEE-Address Selections in the protected RAM

If you desire to permanently set the new address and terminator such that the setting is not lost when power to the meter is turned off, the following procedure is required. Before entering Program 12, move the "CAL" "MEAS" switch (S2 on the back of the multimeter to the "CAL" position. After the desired IEEE address and terminator settings are made, return that switch to the "MEAS" position before turning off power. Again, you need to do this as quickly as possible, as all data in the RAM including calibration data is not protected if power is interrupted or errors are made in keyboard operation while this switch is in the "CAL" position.

9.2. Operation of the Digital Multimeter as Listener

To prepare the instrument to receive commands it must be addressed as LISTENER. Instructions for this should be contained in the computer manual. The "LTN" segment on the right side of the display will flash when the multimeter has been address as LISTENER if the bus display is turned on.

The instrument understands the following commands:

"VD" Selects the "Direct voltage" measurement function in the digital multimeter

"VA" Selects the "Alternating voltage" measurement function. The true rms value of the alternating and direct voltage is measured

"O2" Selects the "Resistance" measurement function. Measurement is in 2-wire.

"O4" Selects the "Resistance" measurement function. Measurement is in 4-wire.

"ID" Selects the "Direct Current" measurement function.

"IA" Selects the "Alternating Current" measurement function. The true rms value of the alternating and direct voltage is measured.

"TC" Selects the "Temperature" measurement function using a Pt-100 sensor.
The display appears in °Celsius.

"TF" Selects the "Temperature" measurement function with a Pt-100 sensor.
The display appears in °Fahrenheit.

"TK" Selects the "Temperature" measurement function with a Pt-100 sensor.
The display appears in Kelvin.

"RX" The measurement range is selected with "RX". "X" is the number for the desired range. It should be noted that different fields can only be selected with the accompanying measurement function, i.e. R6 only with kOhms.

"A0" (A/Zero) turns off autoranging

"A1" Turns on autoranging.

"TX" Selects the integration time and the number of places in the display that correspond with that integration time resolution. On the IEEE 488-Bus 6 1/2 digits are always sent.

"ZO" Erases an offset correction. The discussions in the "Offset Correction" chapter are valid.

"S0" (S/Zero) starts the continuous measurement sequence.

"S1" Switches over to the start mode; every S1 command starts a measurement. During both commands, the delay until start of measurement can be up to a maximum of 12.5 ms.
The S1 command should be send at the end of a string.

"STxx" Starts the measurement value memory. xx gives the number of measurement values to be stored into memory. (xx = 0 to 99)

"SC" Switches the measurement value memory into the Continuous Mode, which means that the last 100 measurement values are put into memory each time.

"RCxx" Determines the start locations during the reading of measurement value memory. Every additional count of an instrument message gives the measurement value of the next memory place. (xx = 0 to 99)

"MX" Turns on a scanner channel. With "MO" (Letter O) the scanner is turned off; with "M0 (M/Zero)-M9" the corresponding scanner channel is turned on.

"L0" (L/Zero) Short format, the multimeter outputs only thee first message sections (measurement data and text message).

"L1" Long format, the multimeter gives both message sections (measurement data/text message and program data).

"Q0" (Q/Zero) the multimeter sends no SRQ.

"Q1" the multimeter sends a SRQ with:
- every new measurement result
- an error report
- a reset

"P0" The last used program (P1-P6) is terminated and switches into measuring status. The measurement result is shown on the display.

"P1" Selects the program for offset correction. The value of R = MW-a is displayed.

"P1EN" Stores the last measurement value in the constant a.

"P2" Selects the program for calculating the %-difference. The value of R = 100.(MW-b)/b is displayed.

"P2EN" Stores the last measurement value in the constant b.

"P3" Selects the Incremental program (R=MWn-MWn-1)

"P4" Turns on the ratio measurement program (R=MW/c)

"P4EN" Stores the last measurement value in the constant c

"P5" Selects the program for calculating the increase in dB. (R=20.lg (Meas/d))

"P5EN" Stores the last measurement value in the constant d.

"P6" Selects the program for calculating dBm levels. The value of R = 20.log (MW/e) is displayed. C has the value of 0.775 V in voltage and 1.29 mA in current.

"PF" turns the floating average filter off (see chapter 8.6.)

"AFxxxxxxx" enters the constant f for the analog display. The last two digits of the constant are of interest for the deviation of +/- 100 digits.

"AF" Start the analog display with the stored constant f

"Cx" " Constant entry", After "C" the digital multimeter awaits a constant number. For example, if "CA" is entered, the value of constant A appears in the main display of the digital multimeter. As additional symbols, the digital multimeter expects the numerical value of the constants. If no new value is entered or the entry is stopped, a program number of "PX" or measurement time of "TX" must always (even when the transmission of the instrument message is interrupted) be sent in the next device command for a conclusion.

Constants can be entered as floating point numeral with mantissa and exponent.

The mantissa can have up to 8 points. The comma can be at any point of the mantissa. The sign can be changed at any desired time. The exponent is marked with an "E" and its value cannot be longer than one place and greater than 7. The sign must be changed before the exponent. If no sign is given for the exponent, the exponent is considered positive. For example: The value of +300.581 for constant A can be entered as CA300.581 or CA+300.581E0 or CA3.00581E2.

"D1 text" After "D1", text desired to be displayed on the multimeter panel can be entered.

"D0" Turns off the display operation. The measurement result or computed result will now appear in the display.

"Ix" Regulates the intensity of the display (x = 0 to 7)

"ID?" With the next reading the device identity is sent (i.e. DVM4001/SC)

"NVxxxxxxxx" after NV the multimeter expects a 8-digit, no-sign, integer decimal number as nominal value for calibration via the IEEE 488-Bus. Transmission of a nominal value must be made alone with no other command listed in the same string. The multimeter starts the calibration measurement after transmission of this nominal value.

9.2.1. Table of Commands Accepted by the Instrument

VD	Direct voltage
VA	Alternating voltage
02	Resistance 2-wire-measurement
04	Resistance 4-wire-measurement
ID	Direct current
IA	Alternating current
TC	Temperature in °C
TF	Temperature in °F
TK	Temperature in K

R1	Range	0.2	Vdc, Vac,	0.2	kΩ2/kΩ4	....	°C,°F,K
R2	Range	2	Vdc, Vac,	2	kΩ2/kΩ4	2 mAdc, mAac	
R3	Range	20	Vdc, Vac,	20	kΩ2/kΩ4	....	
R4	Range	200	Vdc, Vac	200	kΩ2/kΩ4	....	
R5	Range	1000	Vdc, Vac,	1600	kΩ2/	2000 mAdc, mAac	
R6	Range			16000	kΩ2		

A0 (A/Zero) Autoranging off
A1 Autoranging on

T1	Integration time	50ms;	Display	5 1/2-digit
T2	"	100ms;	"	5 1/2 "
T3	"	0.5 s;	"	5 1/2 "
T4	"	1 s;	"	6 1/2 "
T5	"	5 s;	"	6 1/2 "
T6	"	10 s;	"	6 1/2 "

Z0 Zero, offset correction

S1 Start mode, Start
S0 (S/Zero) continuous measuring
STXX Starts measurement value storing with XX memory places (XX = 0 to 99)
RCXX Identifies the memory location from which to start the return of stored measurement values. (XX= 0 to 99)

MO	Scanner turned off (Letter O)		
M0	Scanner-channel		0 set (M/Zero)
M1	"	"	1
M2	"	"	2
M3	"	"	3
M4	"	"	4
M5	"	"	5
M6	"	"	6
M7	"	"	7
M8	"	"	8
M9	"	"	9

L0 (L/Zero) DMM gives only measurement result
L1 DMM gives measurement result and status (long string)

Q0 (Q/Zero) without SRQ
Q1 with SRQ

NVXXXXXXXX Nominal value (for calibration), in direct voltage and temperature always with a sign.

P1	Display of the offset corrected measurement value R = MW-a	
P2	%-difference	R = 100. (MW-b)/b
P3	Incremental	R = MWn-Mn-1
P4	Ratio	R = MW/c
P5	dB-display	R = 20.log (X/d)
P6	dBm-display	R = 20.log (X/e) with e = 0.775V for voltages at 600Ohm and e = 1.29mA for current
PF	turn off the floating average filter	

Cx Selects the constant Cx (x=a to e). If a number follows it will be takes as constant

AF Starts the analog display. If a number follows it will be taken as constant "f".

PxEN Measurement values take over for program constants of P1, P2, P4 and P5, x=1, 2, 4, 5

D1 Display-operation on.
D0 Display-operation off.

IX Intensity adjustment of the display. (X = 0 to 7) X = 0 turns the display dark.

9.2.2. Display Mode

In the display mode, the computer can send text to display on the instrument independent of other instrument functions. The display operation is turned on with "D1". The following ASCII-symbols are written as text on the display. All other symbols cause a dark display area. Any spares, which are sent after "D1" and the non-printable text, are ignored. If "D1 text" is used along with other commands within a data chain, then "D1 text" must be the last command in that chain. With "D0", the display operation is turned off, and the set function and range reading returns to the display area.

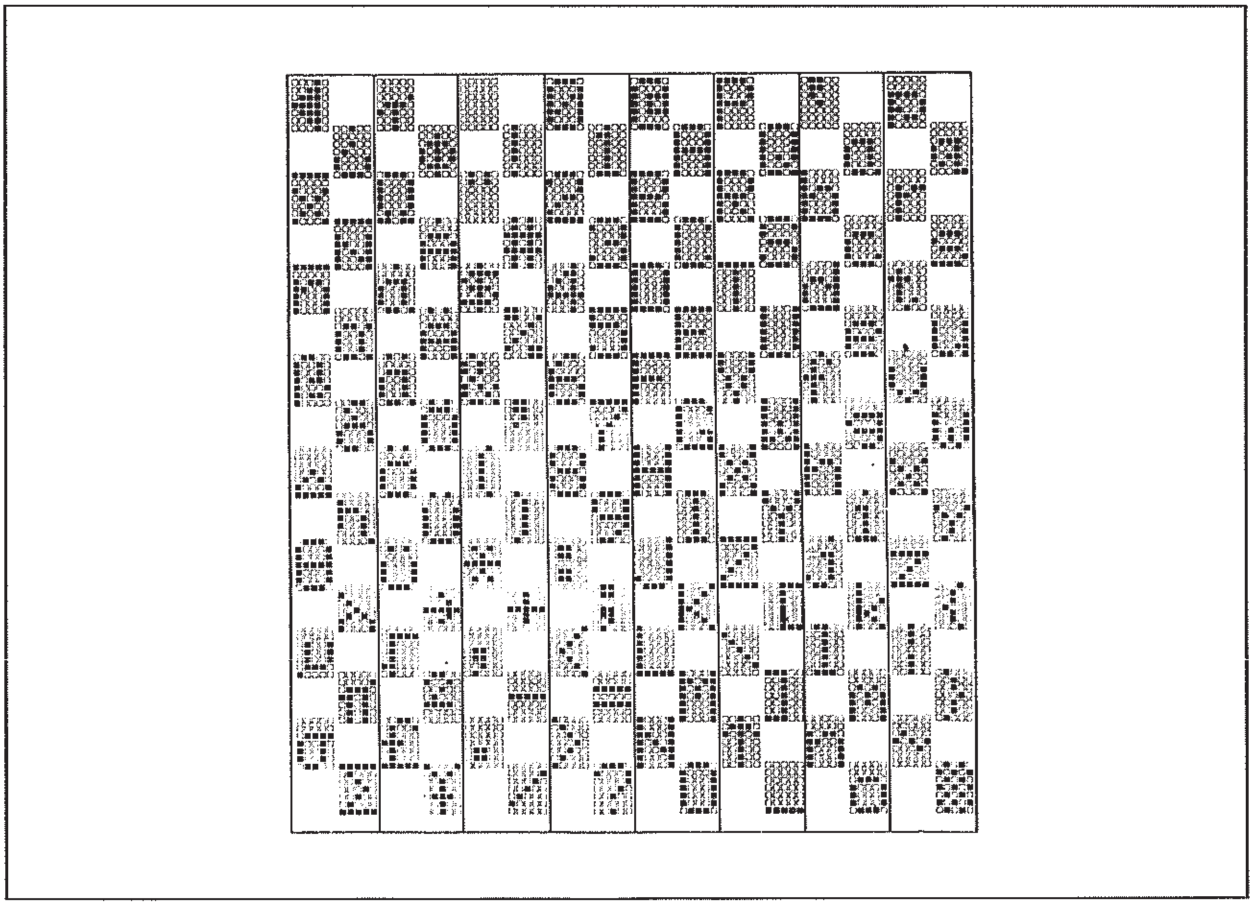


fig. 9.2.2 Symbols, which can be displayed

9.3. Operation of the digital multimeter as TALKER

The messages sent by the multimeter consist of two parts. The first part of the message contains the most recent measurement or calculation result. The second part contains the programmed status information. Both parts are transmitted together and each part is of fixed length. The length of the first part of the message is 12 characters with the second part being 18 characters followed by the preset terminator character. If the transmission of the message string is discontinued before the terminator has been transmitted (before the TIDS talker idle state) is reached, then the transmission will restart with the first character of the message string in response to the next call-up.

See the chapter of "Programming of the Digital Multimeter on the IEEE 488-Bus-Interface" for information on the terminator character selection. Instrument messages use the ISO-7-Bit Code.

Instrument messages are always sent by the DMM after the end of a measurement. However, they are only sent once and one must wait until another integration time is completed to get another measurement or calculation result. A reading can be requested anytime during that integration to save bus time, but, as stated, the result won't arrive until the end of that integration.

During "Single Measurement" or "Start Operation" modes, the multimeter delivers a new instrument message as soon as available.

Therefore, waiting periods for a new measurement result do not need to be considered in the control program. They are controlled by the DMM itself according to the selected measurement time.

9.3.1. Description of the Transmitted Message String

The measurement/calculation results or certain text is given out in a 12 character string. The measurement results are always right justified, i.e. given out ending with the 12th place.

The first character in direct voltage and current measurements is always the "+","-" sign. All leading places before the measurement result that are not required are filled with zeros. In resistance, alternating voltage and current measurements, there is no sign given out and all leading places before the measurement result that are not required are filled in with zeros. Measurement results are given in exponential form without a blank symbol, i.e. "**+01.9876E+2**".

The text reports possible in this string consist of
"ERROR X", "ZERO", "CAL", "No value" (in start mode)
"DVM4001/SC" Device identity, here DMM 4001 with inbuilt scanner

The messages are always left justified, which means they start with the first place. All places not required are filled in with a blank symbol (Blank).

The second string starts with the 13th character. In this string, the programmed status of the multimeter is given out. With the command of "L0" (L/ZERO) or "L1", the output of the second string can be turned off or on respectively. (see Chapter: Programming the Digital Multimeter on the IEEE-488-Bus-Interface).

In the "TALK ONLY" operation the second message string, which presents the instrument status, is automatically restricted to the "Range" and "Channel" information. The string then has, for example;
"**+1.234567E+1R3M5**". The other status information is dropped.

9.3.2. Table of instrument messages sent by the multimeter

Principle form of the instrument message

```
1. Symbol          13. Symbol                32. Symbol + End symbol
!                  !                         !
+X.XXXXXXE+XVDR1A0T1S0Q0MOP0D0B0
-              -   VA  2  1  2 1  1  0  1  1  1
                   O2  .     3       .  2     .
                   O4  .     4       .  3     .
                   ID  6     5       9  4     9
                   IA        6          5     A
                   TC                   6     .
                   TF                   B     E
                   TK                   F                + EOI, EOS1, EOS2

(----------------)   (------------------------------------)
1. message           2.  message string
   string
```

+/-	Sign of the Mantissa in VD,ID,TC,TF,TK Zero in VA, 02, 04 and IA
X.XXXXXX	7 place Mantissa
E+X	1 place Exponent with sign
VD,VA,O2,O4 ID,IA, TC,TF,TK	Measurement function: VD - Direct voltage VA - Alternating voltage O2 - Resistance 2-wire-measurement O4 - Resistance 4-wire-measurement ID - Direct current IA - Alternating current TC - Temperature measurement with Pt100 in °C TF - Temperature measurement with Pt100 in °F TK - Temperature measurement with Pt100 in K
R1-R6	Measurement Range:

R1 =	0.2	Vdc, Vac,	0.2	kOhm, ..., ...
R2 =	2	Vdc, Vac,	2	kOhm, mAdc, mAac
R3 =	20	Vdc, Vac,	20	kOhm, ..., ...
R4 =	200	Vdc, Vac,	200	kOhm, ..., ...
R5 =	1000	Vdc, Vac,	1600	kOhm, mAdc, mAac
R6 =	10000	..., ...,	16000	kOhm, ..., ...

A0, A1 — Automatic Field (0(=Zero)=without, 1=with)

T1-6	Integration time,	Resolution
T1	50ms	5 1/2
T2	100ms	5 1/2
T3	0.5s	5 1/2
T4	1s	6 1/2
T5	5s	6 1/2
T6	10s	6 1/2

S0, S1 Continuous measuring, Start (trigger) operation or Start (trigger)

Q0, Q1 SRQ-operation type (0(=Zero)=without, 1=with SRQ)

P0	Measurement result (P/zero), Floating average filter ON	
P1	Computet result offset correction	R=X-a
P2	Computet result %-difference	R=100. (MW-b)/b
P3	Computet result Incremental	R=MWn-Mn-1
P4	Computet result Ratio	R=MW/c
P5	Computet result dB	R=20.log (MW/d)
P6	Computet result dBm	R=20.log (MW/e) with C=0.775V on 600 Ohm for voltages and C=1.29 mA for current
PF	Floating average filter OFF	

M0, M0-9 M0 = Scanner is turned off
M0(M/Zero)-M9 = Scanner-channel 0-9 is selected

D0, D1 Display operation (0=Zero) = turned off
1 = turned on

Bx Selected Key: As the last key, the key of "x", x=1,...,9 and A, B, C, D, E was pressed.

EOI EOI-Signal active with the last character sent when a terminator containing EOI has been selected

EOS1
EOS2 Terminator agreement EOS1, EOS2 (End of String) at the end of the instrument message, optionally with or without EOI-Signal during output of the last character. Whether only one terminating character (EOS1) or two (EOS1+EOS2) are sent out depends on the selected terminator code of the DMM.

9.3.3. Service request function (SR interface function)

The IEEE-Bus-Interface on the digital multimeter is equipped with a service request function (SR-function). The individual status bits transmitted with a service request have the following meaningS:

Bit 0: End of measurement
Bit 3: Error messages
Bit 6: SRQ
Bit 7: Pressed button

Bit 0: End of Measurement can appear together with the other status bits, in order not to falsify the SRQ in the case of fast measurement sequences.

9.3.4. Interrogation of the Keyboard via the IEEE-Bus

In the remote control status, the DMM does not perform the corresponding function when a key is pressed, but does place the numerical code for the last pressed key into the device message string. This information can be used by the computer to make the DMM operate as a command unit in remotely controlled test systems. The keypresses can be used to send requests for specific programs to the computer, for Yes/No-Answers for testing procedures, or for entering numbered responses.

The fourteen keys have the codes shown in figure 9.2., with the string response always starting with the letter "B". Each time a key is pressed, the IEEE-output buffer is updated with the new code. Once this message is selected the key code is reset on B0. The DMM will print B0 as long as no key is pressed. As soon as a key is pressed the DMM transmits the corresponding key code once. Once this is transmitted the DMM prints B0 again, until the next key is pressed. If the SRQ-function is selected, each keypress produces a SRQ-request.

					B1	B2	B3
					B4	B5	B6
B7	B8	B9	BA	BB	BC	BD	BE

Fig. 9.3.1.: Key Code for Keyboard Interrogation

9.3.5. String Length Selection

The digital multimeter can send different length messages to the computer. The computer selects the length of the desired string with the commands "L0" or "L1". If the computer sends the command of "L0", then the latest measurement result is given out. The status information is not given out with "L0". After "L1" the instrument sends the most recent measurement result and the status information to the computer.

9.4. Programming examples for IEEE-Bus-Interface

Before the digital multimeter can be operated on the IEEE-Bus-Interface, the instrument address and terminator must be set as explained at the beginning of this chapter. In the two following examples for the Commodore and Tektronix computer the address "7" is selected and EOI is recommended as the terminator.

9.4.1. COMMODORE CBM 3032

Operation of the digital multimeter with the CBM 3032. The CBM 3032 is CONTROLLER, the digital multimeter is LISTENER.

```
100 print "your entry please"
110 input a$
120 open 1,7                    ( "7" is the instrument address of the DMM)
130 print #1,a$
140 close 1
150 goto 100
```

Reading the symbol chain of the digital multimeter with the CBM 3032. The CBM 3032 is CONTROLLER, the DMM is TALKER.

```
200 open 2,7                    ("7" is the instrument address of the DMM)
210 input #2,b$
220 close 2
230 print b$
240 goto 100
```

9.4.2. TEKTRONIX 4051

Operation of the DMM with the Tektronix 4051:
The Tektronix is CONTROLLER, the DMM is LISTENER.

```
100 PRI "YOUR ENTRY PLEASE"
110 INP A$
120 PRI @7:A$                   ("7" is the instrument address of the DMM)
130 GOTO 100
```

Reading of the character chain of the DMM with Tektronix 4051:
The Tektronix is CONTROLLER, the DMM is TALKER.

```
140 INP @7:B$                   ("7" is the instrument address of the DMM)
150 PRI B$
160 GOTO 100
```

9.4.3. HEWLETT PACKARD HP 85

The instrument address of the digital multimeter is 7, the terminator is CR + LF without EOI.

Operation of the digital multimeter with the computer HP 85.
The HP 85 is CONTROLLER, the DMM is LISTENER.

```
130  PRINT "YOUR ENTRY PLEASE"
140  INPUT B$
160  OUTPUT 707;B$
190  END
```

Reading of the character chain of the digital multimeter with the HP 85.
The HP 85 is CONTROLLER, the DMM is TALKER.

```
530  DIM A$[50]        Field size declaration, very large size chosen,
                       reserve at least 32 places
540  ENTER 707;A$
580  DISP A$
590  END
```

9.4.4. HEWLETT PACKARD HP 87

The instrument address of the digital multimeter is 7, the terminator is CR + LF without EOI.

```
10 DIM A$[50] ,B$[30]      Field size declaration, at least 32 places necessary,
                           DIM A$ at least 32
```

Operation of the digital multimeter with the computer HP 87.
The HP 85 is CONTROLLER, the DMM is LISTENER.

```
20 INPUT B$                Entry on the keyboard of the HP 87
30 OUTPUT 707;B$           String-transmission by the HP 87 to the DMM
```

Reading of the character chain of the digital multimeter with the HP 87.
The HP 87 is CONTROLLER, the DMM is TALKER.

```
40 ENTER 707;A$            String-transmission by the DMM to the HP 87 computer
50 PRINT A$
60 GO TO 20
```

9.4.5. HEWLETT PACKARD HP 87

Operation of the digital multimeter as before, only now with SRQ.

The instrument address of the digital multimeter is 7, the terminator is CR + LF without EOI.

`10 ON INTR 7 GOSUB 500`	waits for IRQ with IEEE-488-Bus
`20 DIM A$[50], B$[50]`	Field size, at least 32 places necessary
`30 INPUT B$`	Input on the HP87 keyboard, i.e."Q1" for SRQ mode ON
`40 OUTPUT 707;B$`	String transmission of HP 87 to the digital multimeter
`50 ENABLE INTR 7;8`	enables IRQ with SRQ
`60 GO TO`	Line number of the user program
`500 STATUS 7,1; W`	
`510 P=SPOLL (707)`	Transmission of the SRQ Status Register
`520 IF P>63 THEN GOSUB 1000`	Analysis of the register contents
`530 ENABLE INTR 7,8`	enables IRQ with SRQ
`540 RETURN`	
`1000 ENTER 707;A$`	reading-in the message from the digital multimeter
`1010 PRINT A$, P, "Instrument No.7"`	Output to screen together with status information
`1020 RETURN`	

9.4.6.HP 9816 (200th Series) and Digital Multimeter

```
1000 !********Data transmission HP 9816 -- Digital Multimeter
1010 !
1020 !Declaration of the Variables
1030 !
1040 COM / DMM 4001/ @Dmmnr, Setup$[32], Display$[32]
1050 !
1060 !Address assignment -->  7 = @Dmmnr
1070 !
1080 ASSIGN @Dmmnr TO 707
1085 ON INTR 7,1 CALL Serialpoll
1090 !
1100 ! READ-IN OF THE DESIRED SETUPS FROM THE KEYBOARD
1110 !
1120 INPUT Setup$
1130 OUTPUT @Dmmnr;Setup$
1140 !
1150 ! INTERRUPT ENABLE
1160 !
1170 ENABLE INTR 7;2           !IRQ ON APPEARANCE OF A SRQ
1180 Main:    !
1190          GO TO Main      !User program
1200          END
1210 !.....................................................
1220 !.....................................................
1230 !SUB Serialpoll
1240 !CHECKS INSTRUMENT FOR SERVICE REQUEST, READS OUT WHEN
1250 !REQUIRED AND RETURNS TO WAITING LOOP OF THE MAIN PROGRAM
1260 !PROGRAM
1270 !
1280 COM /Dmm 4001/ @Dmmnr, Setup$[30], Display$[50], P
1290 !
1300 P=SPOLL (@Dmmnr)
1310 !
1320 IF P>63 THEN CALL Reading
1330 ENABLE INTR 7
1340 SUBEND
1350 !....................................................
1360 !.....................................................
1370 SUB Reading
1380 !
1390 ! READS-IN THE LATEST MEASUREMENT VALUE FROM DMM
1400 !
1410 COM/Dmm 4001/@Dmmnr, Setup$[32], Display$[32], P
1420 ENTER @Dmmnr; Display$
1430 PRINT Display$,P
1440 SUBEND
```

9.4.7. APPLE II with CCS Interface Module 7490

```
2   PRINT
3   PRINT "SET DMM TO ADDRESS IEEE.07.0."
5   PRINT
6   PRINT "WHEN THIS HAS HAPPENED, "
7   PRINT "PRESS THE RETURN KEY"
8   INPUT C$
12  PRINT:PRINT
15  PRINT "YOUR ENTRY PLEASE"
20  INPUT B$
30  PR#3                     Initial Slot #3 for output
40  PRINT "@`:"              In Address mode, REN and ATN active, Listener
                             address 7 is sent, @ switches to address mode, ` sends
                             Listener address 7, : switches back into Command Mode

50  PRINT "`";B$;"`"         the message is transmitted, `switches text mode on and
                             off
60  PRINT "@G:"              in the address mode the talker address 7 is sent
                             @ switches in address mode,
                             G sends Talker address 7,
                             : switches back to Command Mode;

70  PR#0                     Data from IEEE-Bus is sent directly to the screen

80  INPUT " ";A$             Read-in of the message from IEEE-Bus

90  IN#0                     Input/Output is switched over to the keyboard

99 CALL 1002                 see note below

100 GO TO 20
```

All program line numbers which are not multiples of 10 (10, 20, 30 ... etc.) serve as user command or can be omitted.

With the command PR#3 in the program, the DOS-functions are uncoupled, so for example no more disc operations are possible. With CALL 1002, the DOS-functions are restored. With the use of the complicated Syntax PRINT CHR$(4);"PR#3", this problem is avoided. However, one must handles problems during the screen output when text format is given out.

9.4.8. IBM Personal-Computer or Compatible with National Instruments Interface Card PC2A

```
1000 CLEAR    ,50000!           ' BASIC Declarations '
1010 IBINIT1 = 50000!
1020 IBINIT2 = IBINIT1 + 3
1030 BLOAD "bib.m",IBINIT1
1040 CALL
IBINIT1(IBFIND,IBTRG,IBCLR,IBPCT,IBSIC,IBLOC,IBPPC,
     IBBNA,IBONL,IBRSC,IBSRE,IBRSV,IBPAD,IBSAD,IBIST,IBDMA,
     IBEOS,IBTMO,IBEOT,IBRDF,IBWRTF)
1050 CALL
IBINIT2(IBGTS,IBCAC,IBWAIT,IBPOKE,IBWRT,IBWRTA,IBCMD,
IBCMDA,IBRD,IBRDA,IBSTOP,IBRPP,IBRSP,IBDIAG,IBXTRC,IBRDI,
     IBWRTI,IBRDIA,IBWRTIA,IBSTA%,IBERR%,IBCNT%)
1060 REM
1070 PRINT " --- MULTIMETER CONTROL SOFTWARE ---"
1080 PRINT
1090       CMD$ = SPACE$(30)
1100      WRT$ = SPACE$(30)
1110       RD$ = SPACE$(40)
1120      EOS$ = CHR$(13)
1130 REM --- SEARCH IN THE INSTRUMENT TABLE ---
1140 PRINT"INSTRUMENT NAME IS DEV1,ADDRESS SEE IN IBONF.EXE"
1150 PRINT"INSTRUMENT ADDRESS ON IEEE.01.0 PLACES(IEEE-KEY)"
1160 PRINT"INSTRUMENT ADDRESS IS ON THE TABLE IBCONF.EXE   "
1170 PRINT:PRINT:PRINT:PRINT
1180 PRINT " *** Correct Address-Terminator combination ***"
1190 PRINT " *** test in IBCONF.EXE ***"
1200 PRINT
1210 REM
1220 REM --- DETERMINING THE ADDRESS ---
1230 REM-----------------------------------------------------
1240   BDNAME$ = "DEV1":CALL IBFIND (BDNAME$,DEV1%)
1242 REM-----------------------------------------------------
1250 PRINT "INPUT OF A COMMAND TO THE MULTIMETER "
1254 PRINT "SEE CHAPTER 11, IEEE COMMANDS i.e.VD,VA,T1, ..."
1256 PRINT "RETURN Forces the reading of device message"
1260 LINE INPUT CMD$
1261 PRINT CHR$(12);CMD$
1262 IF CMD$="" THEN 1268
1264 GOSUB 1280:REM SEND COMMAND
1265 FOR I=1 TO 1000:NEXT I: REM CA. 1 SEC WAIT
1268 GOSUB 1340:REM READ MESSAGE
1269 GO TO 1250
1270 REM-----------------------------------------------------
```

Subroutines for the output of commands and reading the instrument messages

```
1270 REM-----------------------------------------------------
1280 REM --- OUTPUT OF COMMANDS TO THE MULTIMETER ---
1290 WRT$=CMD$+EOS$:REM COMMAND AND TERMINATOR (EOS)
1300 CALL IBWRT (DEV1%,WRT$)
1310 RETURN
1320 REM --- OUTPUT OF COMMANDS TO THE MULTIMETER ---
1330 REM-----------------------------------------------------
1340 REM ---READING OF DEVICE MESSAGES FROM THE DMM---
1350 CALL IBRD (DEV1%,RD$)
1360 MW=VAL(RD$)
1370 PRINT RD$;MW
1380 RD$=SPACE$(40)
1390 RETURN
1400 REM ---READING OF DEVICE MESSAGES FROM THE DMM---
1410 REM-----------------------------------------------------
```

9.4.9. Controlling the DMM with Turbo Pascal on an IBM PC or compatible and the PCIIA - IEEE488 interfacecard from National Instruments

```
program example;     {reads 2 channels of the DMM in SRQ-Mode and shows
                      the results on the monitor}
uses tpdecl,crt;     {Includes the Turbo Pascal driver "tpecl" of the PCIIA card}

Type
    cbuf  = array[1..6] of char;
    rbuf  = array[1..12] of char;

Var cmd     : cbuf;        (* command buffer                    *)
    rd      : rbuf;        (* read data buffer                  *)
    wrt     : cbuf;        (* write data buffer                 *)
    bd      : integer;     (* board or device number            *)
    dvm     : integer;     (* device number                     *)
    v       : integer;     (* "value" parameter                 *)
    cnt     : integer;     (* byte count for transfers          *)
    mask    : integer;     (* events to be waited for           *)
    ppr     : char;        (* parallel poll response byte       *)
    spr     : char;        (* serial poll response byte         *)
    brdname: nbuf;         (* board name buffer                 *)
    devname: nbuf;         (* device name buffer                *)
    i,j     : integer;
    srq     : integer;
    status : string;

const
     on :integer=1;
     off:integer=0;


procedure  prvars;
begin
  writeln ('ibsta=',ibsta,'iberr=',iberr,'ibcnt=',ibcnt);
end;

procedure finderr;
begin
  writeln (' Find error');
end;

procedure error;
begin
  writeln (' Error');
  prvars;
end;

procedure dvmerr;
begin
  writeln (' DVM error');
  prvars;
end;
```

```
procedure sp_byte;      {Analisys of the Serial Poll Byte}
begin
     srq:=ord(spr);
     str(srq,status);
     if srq = 65 then status :='Meas.  ok.';
     if srq = 192 then status :='KEY press.';
     if srq = 72 then status :='ERROR     ';
end;


{********* main programm ***********}
begin
  brdname := 'gpib0  ';
  bd := ibfind(brdname);          {declaration of the interfacecard}
  devname:='dev7   ';
  dvm:=ibfind (devname);          {declaration of the DMM}
  if (dvm < 0) then finderr;
  ibsre(bd,on);                   {set REMOTE ENABLE}
  ibclr(dvm);                     {Device Clear of the DMM}
  if ((ibsta AND ERR) <> 0) then error;
i:=0;
j:=0;
  clrscr;
  mask:=timo or rqs;              {masks on SRQ and Timeout}
  wrt:='o2l0q1';                  {switches the DMM to 2-wire-Ω "o2",
                                  short string "l0" and SRQ-Mode "q1"}
  ibwrt (dvm,wrt,6);              {sends a command string to the DMM}
  while not keypressed or (I=1000) do
  begin
     i:=i+1;
     j:=j+1;
     wrt:= 't4r3m5';              {1s Integration time, 20kΩ-Range, channel 5}
     ibwrt (dvm,wrt,6);           {sends the command string to DMM}
     ibwait (dvm,mask);           {waits for SRQ or Timeout}
     ibrsp (dvm,spr);             {reads the Serial Poll Byte}
     sp_byte;
     ibrd (dvm,rd,12);            {reads the measurement}
     gotoxy(1,j);
     write(rd, '  ** ', status,' **');
     wrt:='t2r4m6';               {100ms Integration time, 200kΩ-Range, channel 6}
     ibwrt (dvm,wrt,6);           {sends the command string to DMM}
     ibwait (dvm,mask);           {waits for SRQ or Timeout}
     ibrsp (dvm,spr);             {reads the Serial Poll Byte}
     sp_byte;
     ibrd (dvm,rd,12);            {reads the measurement}
     gotoxy(40,j);
     write(rd, '  ** ', status,' **');
if j=25 then j:=0;
end;
ibloc (dvm);                      {set the DMM into LOCAL-Mode}

end.
```

10. CALIBRATION

Allow the instrument to warm-up for 2-3 hours after switching-on, before performing calibration changes.These digital multimeters have a digital calibration feature with which individual measuring ranges or all measuring ranges can be recalibrated. It is not necessary to open the instrument case, and calibrations can be performed using either the front panel keyboard or via the IEEE-488 bus. The initial calibration data as determined at the factory (ORIGINAL) for the particular unit, has been entered into an EPROM memory. This data has also been loaded into a battery backed CMOS-RAM along with certain offsets for the front panel. The lifetime of the internal lithium battery is about ten years. The below procedures describe how the operating calibration data in the CMOS can be changed, and also how, if desired, the ORIGINAL calibration data (which can't be changed) can be recalled back to the CMOS.

The CMOS-RAM is protected from unintentional data changes by a concealed slide switch (S2) which is visible through a small slot on the right, rear side of the instrument and is labeled with "MEAS" and "CAL". Should you want to enter changes in the calibration or status data of the multimeter it is first necessary to change the S2 switch from "MEAS" to "CAL" with the help of a small screwdriver or a similar tool. The display of the meter will show "CAL" periodically to indicate the multimeter is in the calibration mode. When the multimeter is in the "CAL" mode, the current correction values in the CMOS-RAM are not protected and can be overwritten. Once all changes have been entered, the switch should be returned to the "MEAS" as soon as possible to protect the CMOS-RAM from unintentional changes.

10.1. Reloading the ORIGINAL Calibration Data

If the correction values as stored in the CMOS-RAM are inadvertently lost during improper calibration attempts and the multimeter is not being recalibrated using external calibration sources, you can recall the ORIGINAL calibration data stored in the EPROM and load that data into the CMOS-RAM. The original EPROM data is recalled to the CMOS anytime the S2 switch is in the "CAL" position and the power to the meter is turned off and then back on. Thus, if you do this, the ORIGINAL calibration data of the EPROM will be automatically restored into the buffered CMOS-RAM. However, all offset correction values such as front panel offsets are lost, and so it will be necessary to enter new offset corrections using the below procedures. Also, you should note that if for any reason you experienced a power failure to the multimeter when the S2 switch was set to "CAL", the same procedures apply and are necessary.

To enter new offset corrections with the "CAL" switch set, you first need to short circuit the "V/Ω-T" sockets and insure the "A/SOURCE sockets are open (except for 4-wire resistance and temperature where they also are shorted in a 4 way bridge). Select the "Vdc" and "Auto" functions and then press the "Zero" key. The multimeter now automatically corrects all zero points of the Vdc-measurement fields, one after another, and stores the new correction values in the protected RAM. The offset correction of a single measurement range is also possible in that range was selected with "Auto" being turned off. One proceeds in the same manner for all other functions (comply with Chapter 9.1.-9.4.).

10.2. Calibration of the Direct Voltage Ranges Using External Reference Sources

The following procedure describes how the multimeters can be calibrated using external reference sources. First, the measurement function and range are selected and a precisely known positive or negative reference voltage source, which may be between 5% and 100% (preferably between 50% and 100%) of the display range of the prevailing function, is connected to the input sockets. The multimeter now will show a measurement value on the display which was calculated using its current calibration data. If the displayed value and actual value of the reference are outside specifications, it will be necessary to recalibrate the multimeter function.

First insure the required warm-up times to reach stability for the multimeter and for the reference standard have been met. The S2 switch needs to be in the "CAL" position. Then, select program 13 and by then pressing the "PRG"-key, the displayed measurement value will be automatically stored. If the "Cal" switch has not been set, "CAL switch!" will be displayed for a short time as an error report. Use the keyboard (blue keys) to enter the correction value (difference between standard and current reading including entering the correct sign with consideration of the polarity of the determined voltage. After the entry of the correction value, the calibration is concluded by pressing the ENTER key. The newly calibrated measurement value is then displayed after the next integration.

The above principles apply should other functions or ranges require recalibration.

ATTENTION !!!!!

At the completion of the complete calibration, the S2 switch on the back of the instrument must absolutely be set back from "CAL" to "MEAS", so that the calibration data will be protected.

Calibration on the IEEE 488-Bus

The calibration using the IEEE 488-Bus is basically analogous to procedures using the keyboard of the meter for operation on the front panel. To set the nominal value, specify it as an integer number with the command "NVxxxxxxxx" or in temperature measurement "NV+xxxxxxx" or "NV-xxxxxxx" (see operation instructions in the IEEE 488-Bus-Interface chapter). The calibration program and the calibration measurement are started automatically on transmission of the nominal value. Again, it is necessary that the measurement standard is stable before starting calibration. When you finish calibrations, terminate the calibrating procedure by switching back from "CAL" to "MEAS".

10.3. Calibrating Resistance

Calibrate the resistance measuring ranges using the four-wire and the two-wire circuit configuration. First compensate the zero point as described in the chapter "Offsetcorection" above. Comply with the instructions in the "Operation Tips Ohm/kOhm" chapter especially for the compensation of measurement lead resistances. The calibration process for resistance is similar to the calibration of direct voltage as described above.

10.4. Calibration of Alternating Voltage

This adjustment is carried out with alternating voltage with direct voltage coupling. The alternating voltage ranges should be calibrated with a sinusoidal alternating voltage.

Sine voltages are required for reference in accordance with the following table. Before calibrating the instrument, the linearity of the alternating voltage measurement is set or checked as follows:

1) Do short circuit in the voltage input
2) Select 2V range, Vac
3) Do Vac offset correction with "ZERO" key
4) Connect 1V/1KHz and calibrate according to chapter 10.2.
5) Connect 10mV/1kHz and set with trimmer R23
6) Repeat process 4) and 5) until both voltage values (1V and 10mV) are displayed.

The calibration of the single ranges has to be done with the below calibration values(voltage/frequency).
After the calibration a frequency adjustment for the ranges from 10V can be carried out.
The calibration values at 90Hz have to be checked after the frequency adjustement at 1 kHz.

Range/Vac	**Calibration value**		**Adjustment**	
	Voltage	Frequency	Frequency	Trim Capacitor
0,2 V	0,1 V	1 kHz	---	---
2 V	1 V	1 kHz	---	---
20 V	10 V	90 Hz	1 kHz	C5
200 V	100 V	90 Hz	10 kHz	C3
700 V	600 V	90 Hz	10 kHz	C7

10.5. Calibration of Direct and Alternating Current

The above described calibration preparation procedures also apply to calibration of the current functions and ranges. Direct or 1 kHz sinusoidal currents are necessary as source references. The calibrating current must not exceed 1 A in the 2 A range. The calibration process is analogous to direct voltage.

10.6. Calibration of Temperature

Before calibration of the temperature measurement, an offset correction must be carried out. The offset correction is performed with all the input sockets short circuited. (See Chapter 6.5., figure 6.5.1.). After the offset correction is completed, "done" is displayed or appears via the IEEE-Bus. This is for the internal offset correction of the amplifiers and does not include any corrections for the PT-100 sensor. For alignment of that sensor, put that PRT into a subject of well known temperature and enter the resulting value by keyboard or via the IEEE bus.

All temperatures in the area of -200°C to +850°C are allowed for calibration. Calibration can also be made using an exactly known resistance as reference. Use the resistance reading to enter the DIN IEC 751 reference table for the correct corresponding temperature.

When calibrating on the IEEE-Bus, send the command "NV+xxxxxxx" or "NV-xxxxxxx". For example, use NV+0017486 for a temperature of +174.86°C.

****
* **After calibration do not forget to return the** *
* **CAL/MEAS switch to the "MEAS" position.** *
****

11. Construction of an Independent System for Automatic Recording of Measurement Values

11.1. Instructions for the Measurement Construction

A measurement data recording system for 20 channels (4-pole), which will work independently without control by a computer, can be constructed using a PREMA Model 4001 digital multimeter and a Model 2024 20-channel scanner. The data collected can be printed with an Epson RX 80 with Interface 8165 set with IEEE-Bus-Interface (Operation "LISTEN ONLY"). The multimeter is set (Operation "TALK ONLY") and is connected using an IEEE-cable with the printer. Other configurations and hardware selections are also possible with this discussion meant to present the capabilities of the PREMA meter and scanner.

The model 2024 Scanner and the Model 4001 Digital Multimeter trigger socket are connected using a trigger cable. The front meter sockets are connected using test leads with the appropriate front sockets on the scanner. On the rear of the Model 2024 scanner, the 20 channels are connected using the available 50-pole subminiature-D socket. Only one meter function (voltage, current, resistance or temperature) can be measured without external control of the multimeter, so the function desired should be selected in the meter, and the twenty channels connected to the sources to be measured and logged. Also, enter a specific range or autoranging in the meter.

The measurement channels, measurement times and switch intervals will be determined by the scanner. The scanner will give a trigger signal within the turn-on time of a measurement channel and cause the multimeter to perform a measurement. At the end of a measurement, the multimeter will sent the measurement value to the connected printer.

11.2. Example of a Measurement Run

Every 10 minutes, for example, CH 10 - CH 19 channels are desired to be automatically measured with a turn-on timeevery 15 seconds. The result of the measurement is to go to the printer.

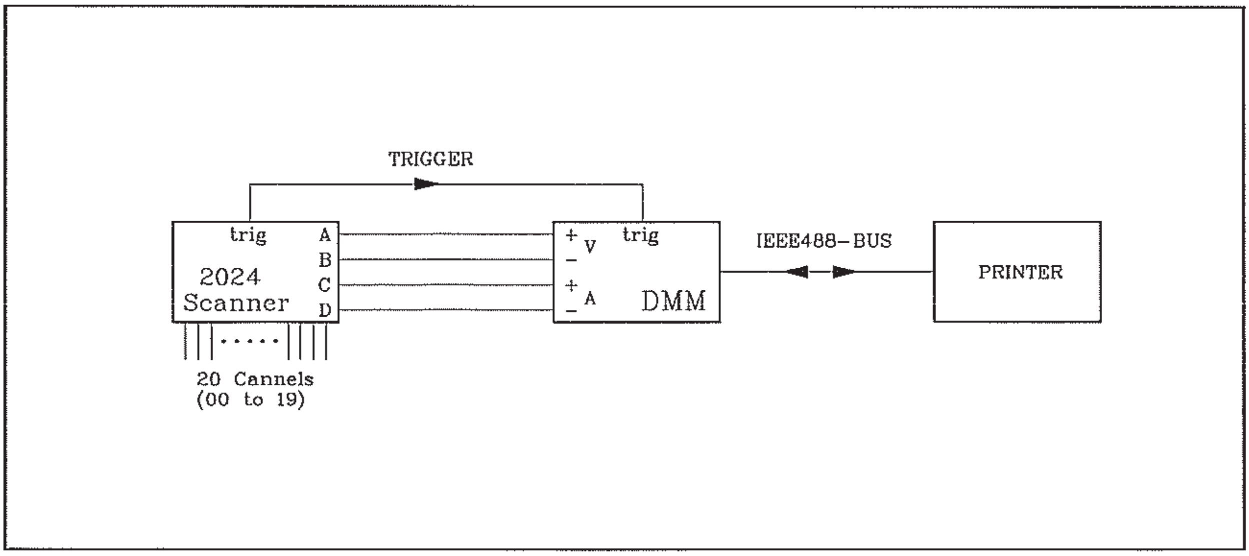


Fig. 11.1. Construction of an independent system

11.2.1.Adjustments of the 2024 Scanner and 4001 Multimeter

On the model 2024 scanner,the CH 10 - CH 19 channels are first selected, the interval time is set on 10 minutes, the turn-on time is set to 15 seconds and the trigger delay time is set at 2 seconds. The IEEE-adjustment must be carried out on "AUTO" (between 00 and 30) to activate the trigger. The front sockets of the A, B, C, D scanner must be switched on (CONTROL).

On the model 4001 multimeter, for example, the integration time is set on 10 seconds. An IEEE-adjustment results in "TALK ONLY", CR + LF is selected as the terminator symbol and the trigger operation is turned on. In order to always obtain maximum resolution, switch on autoranging.

On the IEEE-Bus connection of the multimeter, the printer ("LISTEN ONLY") is connected.

11.2.2. Start of the Measurement System

The start and stop of the measurement system occurs with the scanner in Automatic-Single-Scan. After the start, Channel CH 10 connects through, after a 2 second wait period the model 2024 Scanner will send a trigger pulse which starts the measurement of the multimeter. After the preset integration time of 10 seconds, the multimeter sends the measurement data along with the condition information about function, range, etc. to the printer. After 15 seconds, CH 10 turns off and CH 11 turns on with the above measurement and logging process repeated. After the last channel is opened (CH 19), the preset 10 minute interval time elapses and a new measurement cycle starts unless stopped by the operator.

11.2.3. Print Out to a Computer

If the multimeter is set to an instrument address instead of to "TALK ONLY" and the terminator symbol corresponding to the computer is set along with having SRQ-operation selected, then a SRQ will be given out at the end of a measurement. Instead of using the printer, a computer must then be connected which selects the measurement value on the basis of the SRQ. The computer, however, does not need to undertake any controlling, but rather can be used for pure data gathering. The same adjustments for the other instrument parameters for the scanner and multimeter can be maintained.

To use different measurement functions at the channels it will be necessary to built up a system which is completely controlled by a PC with an IEEE488 interface card. Thus your application will be more flexible and it will be no problem to extend the number of channels by using an additional Scanner 2024.

12. ACCESSORIES

12.1. Mating Plug for Sub-D (Option 6000/03)

A 50-wire subminiature type D connecter can be used for each set of 10 channels. This connector has solder connections for each wire and a cable outlet for round cables up to 12mm diameter.

12.2. Adapter Card (Option 6000/02)

The adapter card can be connected externally into the 50-wire subminiature type D connector on the rear of the digital multimeter equipped with the scanner option 6000/01. This card contains screw terminals for the incoming wires and so it is especially useful when you need to change the configurations of sources being scanned and don't want to make a permanent configuration using the above mentioned mating plug. The adapter card can be fitted with two antiparallel (see layout diagram of the adapter card on page 13-11).
These clamp diodes may be removed for other applications, especially when switching currents greater than 0.5 Amps peak are switched. One adapter card is required for connecting all 10 channels of the inbuilt scanner.

Maximum Current (without clamp diodes)	2 Amps
Maximum Current (with clamp diodes)	0.5 Amps peak
Maximum Voltage	40 V

************ * **Warning** * ************	Personnel safety consideration require that no voltages greater than 40 V against ground be connected at this card, because the screw terminals are not protected against accidental human contact.
Dimensions	about 115 mm * 123 mm (see page 13-11)

12.3. Test Lead Set (3014)

The test lead set consists of two, 1 meter long cables with shrouded, 4mm banana plugs and two probe tips. The contacts of the plugs have low thermoelectrical voltages, which is necessary for precise measurements.

12.4. Set of Short Circuit Plugs

The set contains 3 gold plated short circuit plugs, which can be connected together. In this design it is possible to do a very good short circuit for the offset correction in voltage measurements with one plug. With three plugs you can do an excellent short circuit in 4 wire resistance measurement.

12.5. Pt100 (RTD100) Surface Temperature Probe with handle (3011)

Pt100 (Platinum 100) temperature sensor in 4-wire connection. Connection to the DMM via a 1.5 m long cable with 4 gold plated banana plugs.

Probe length:	160 mm (without handle)
Diameter of the contact surface:	7 mm
Temperature range:	-50°C to +200°C with 1/3 DIN accuracy

12.6. Pt100 (RTD100) Immersion Temperature Probe with handle (3011)

Pt100 (Platinum 100) temperature sensor in 4-wire connection. Connection to the DMM via a 1.5 m long cable with 4 gold plated banana plugs.

Probe length:	160 mm (without handle)
Diameter of the probe pipe:	3 mm
Temperature range:	-50°C to +60°C with 1/3 DIN accuracy

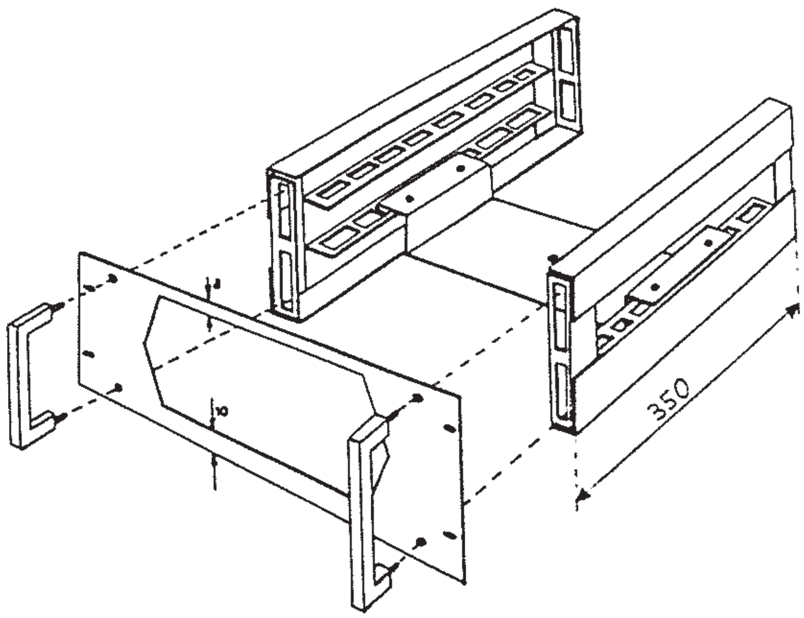
12.7. Current Shunt (3017))

10 Amp Current Shunt for the voltage inputs of DMM 4001. Resolution 10mV/Amp with an accuracy of 0.1% DC and 0.5% AC (up to 1 kHz).

12.8. 19-inch Rack Mounting Kit (Option 6000/04)

Using this accessory, the DMM can be easily mounted in a 19" rack.

Height: 2HU



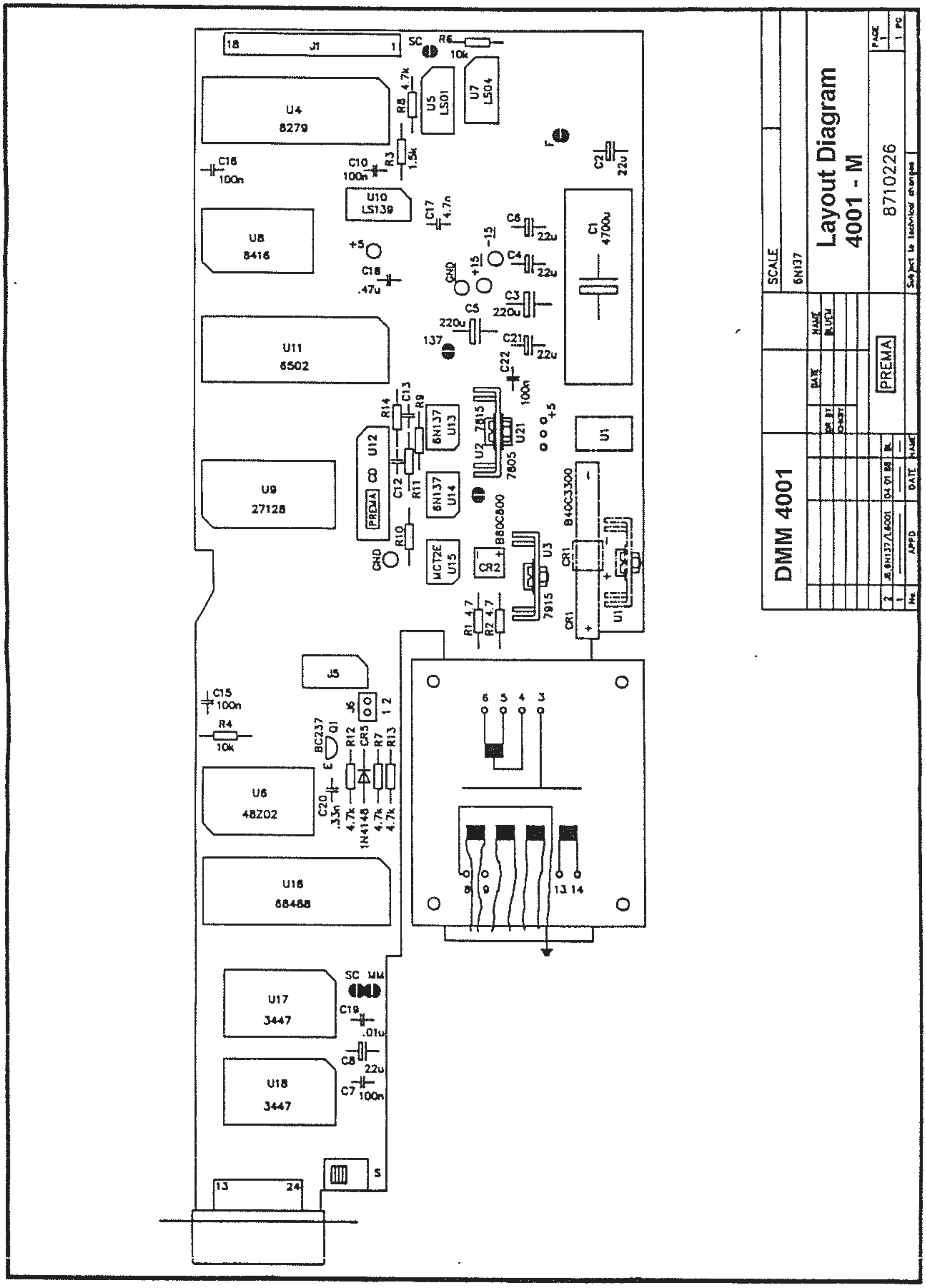


Fig 13.1. Layout diagram of the microprocessor

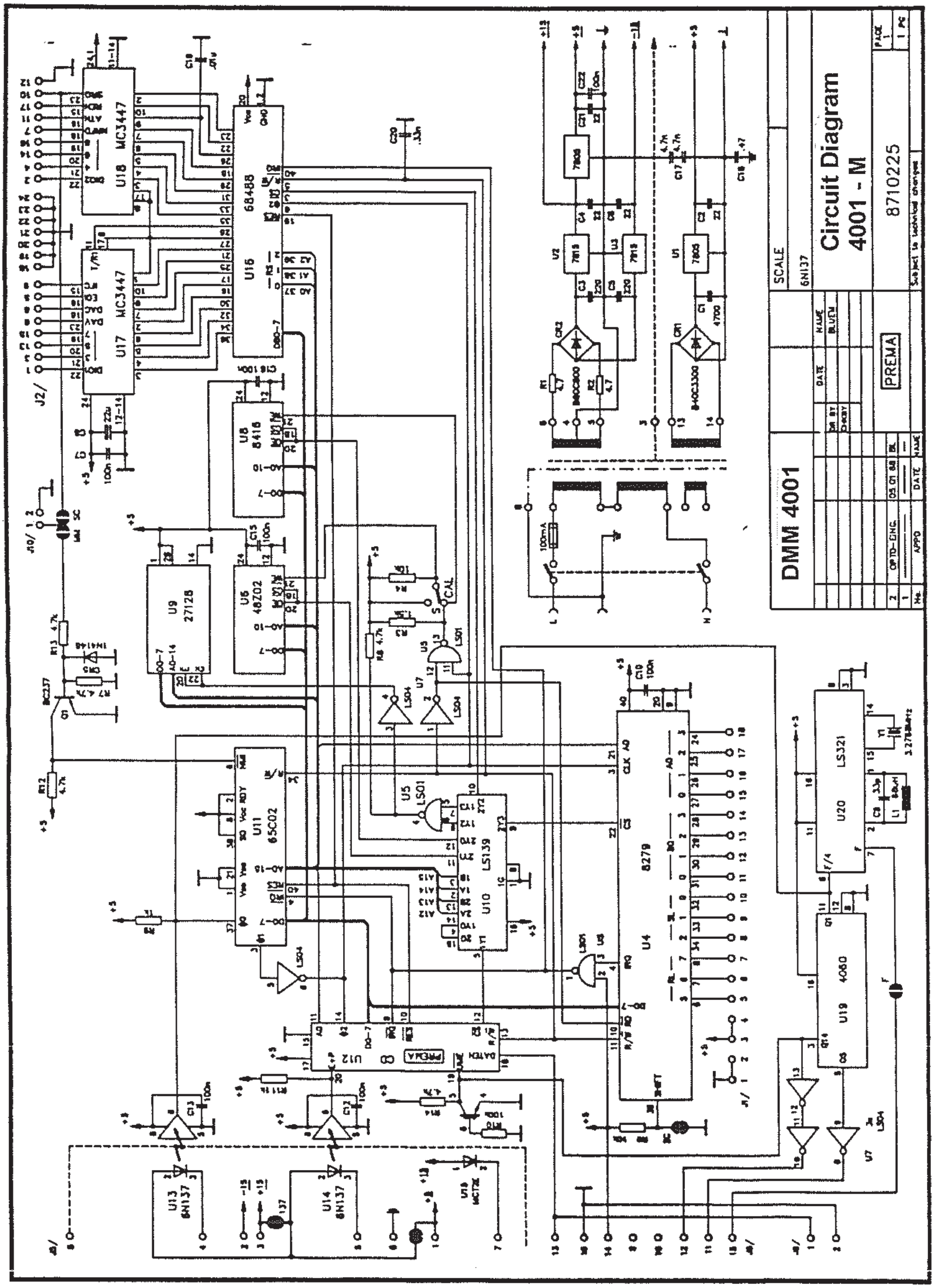


Fig 13.2. Circuit diagram of the microprocessor

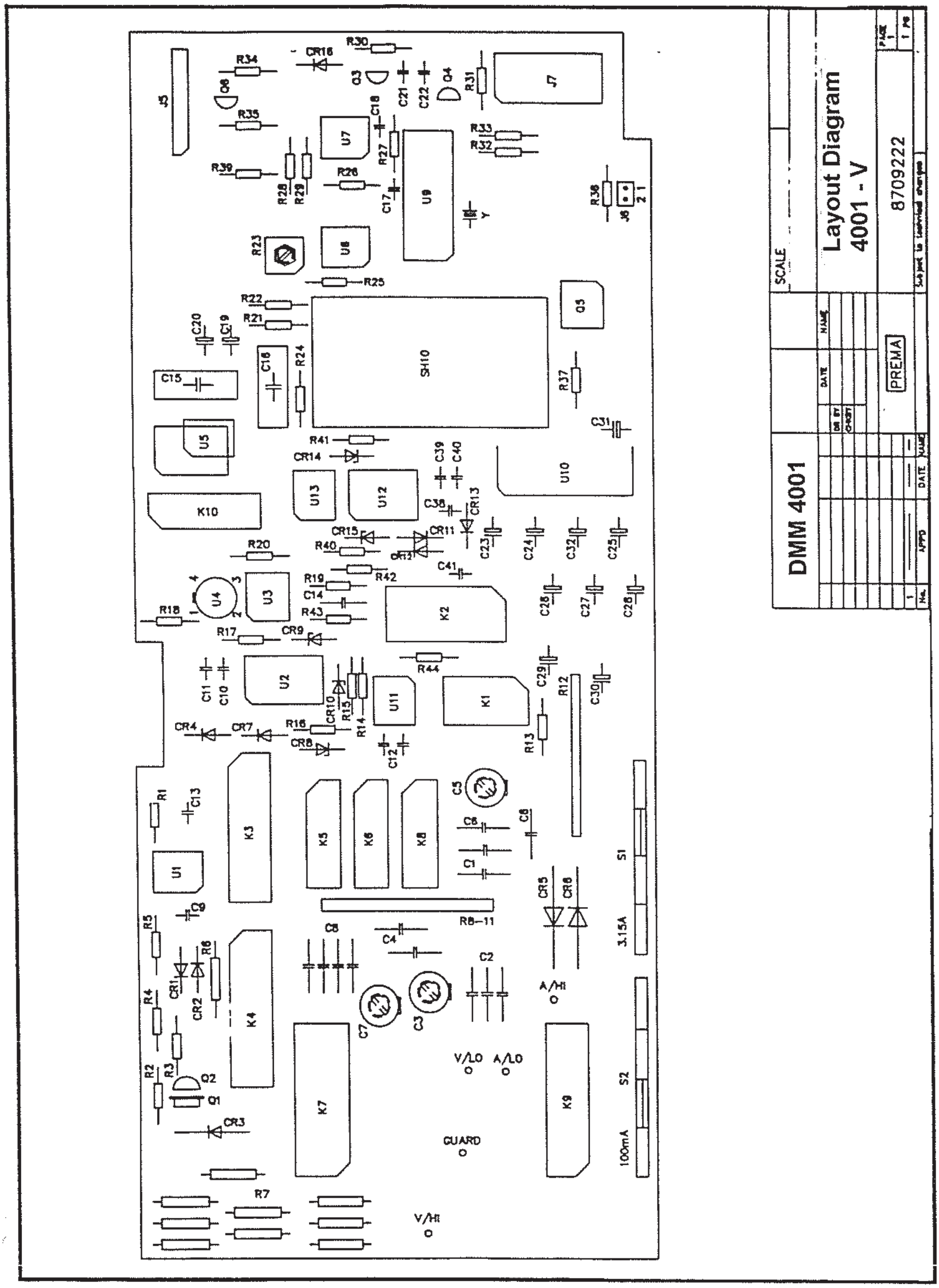


Fig 13.3. Layout diagram of the preamplifier

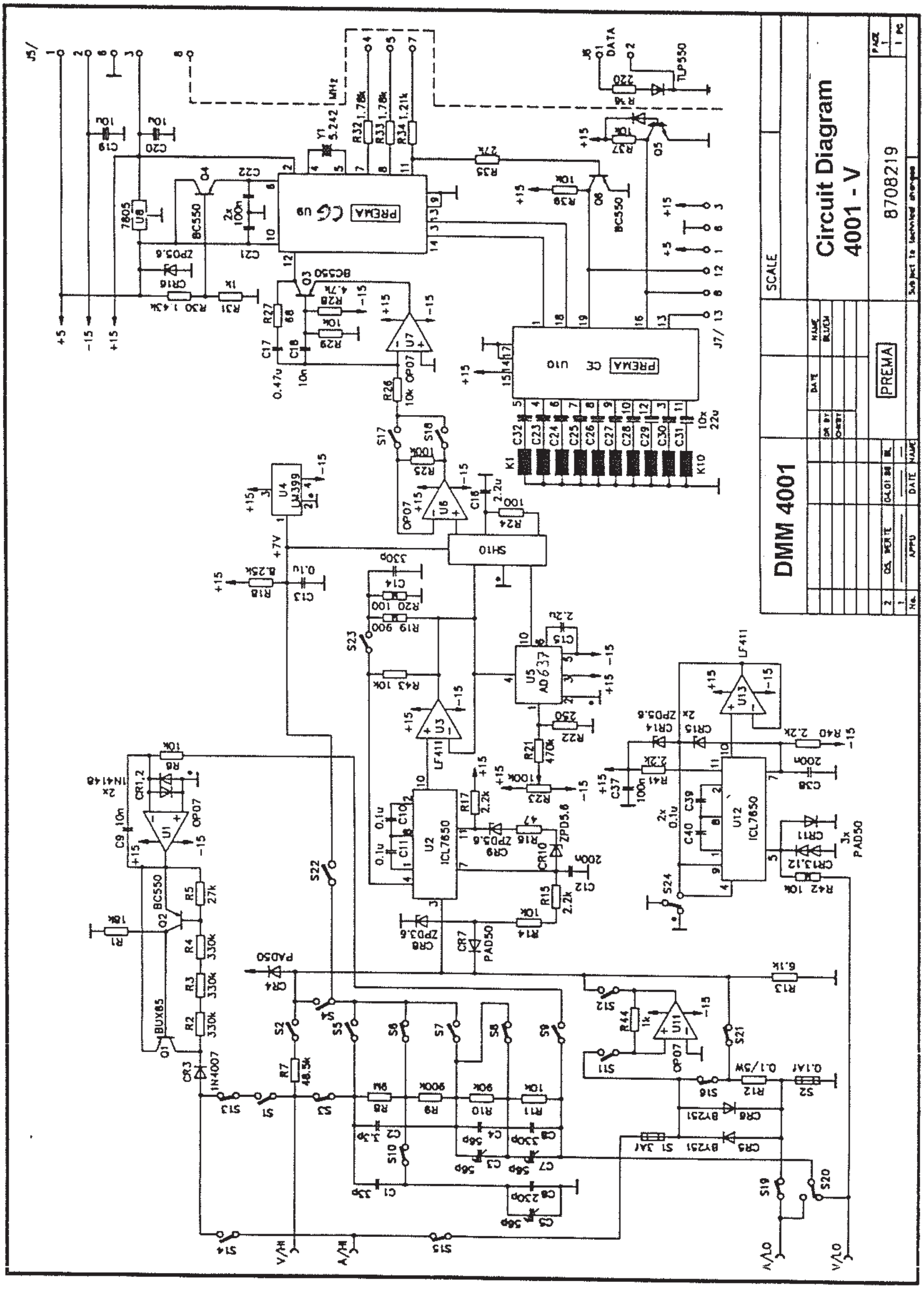


Fig 13.4. Circuit diagram of the preamplifier

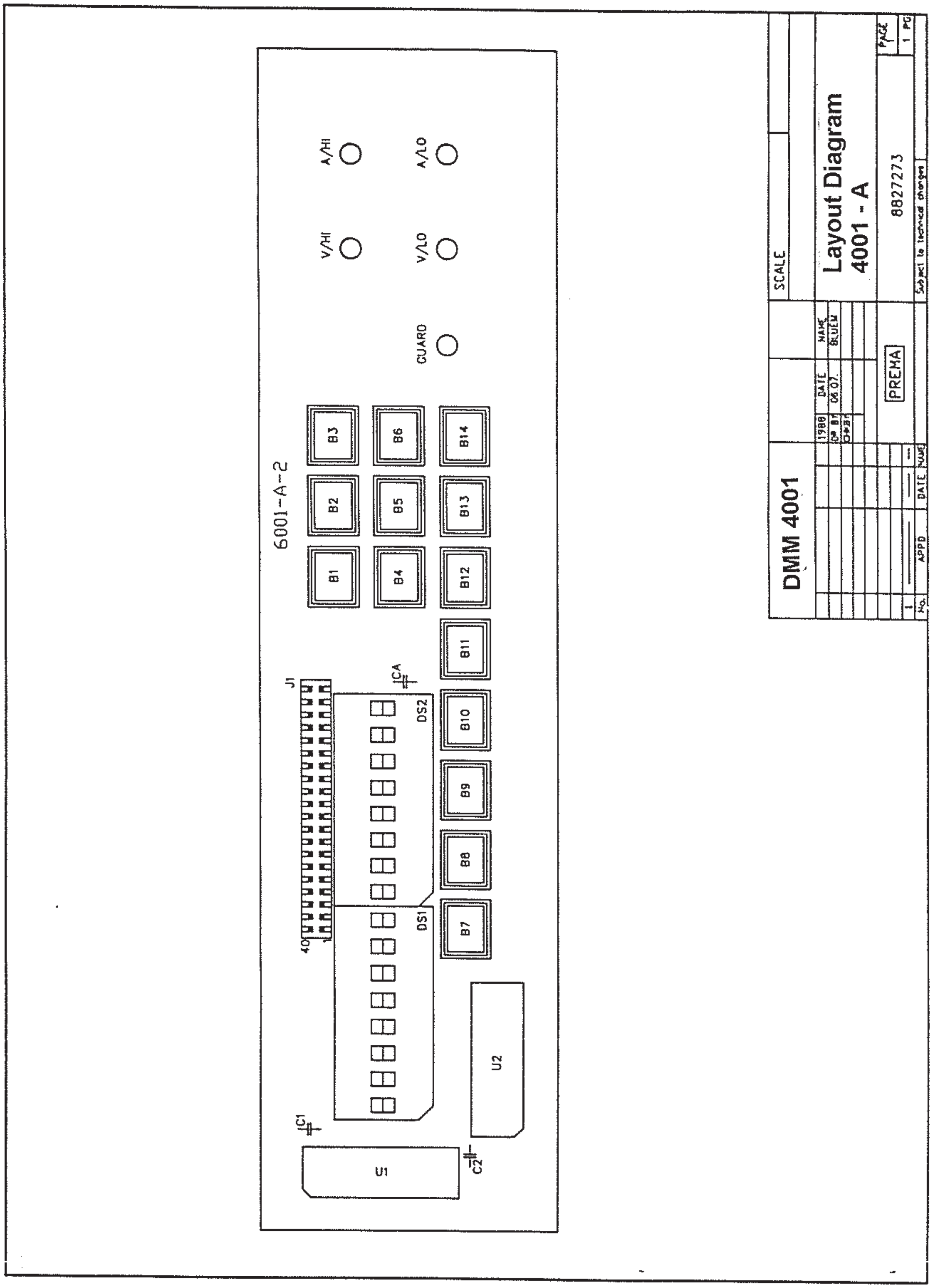


Fig 13.5. Layout diagram of the display

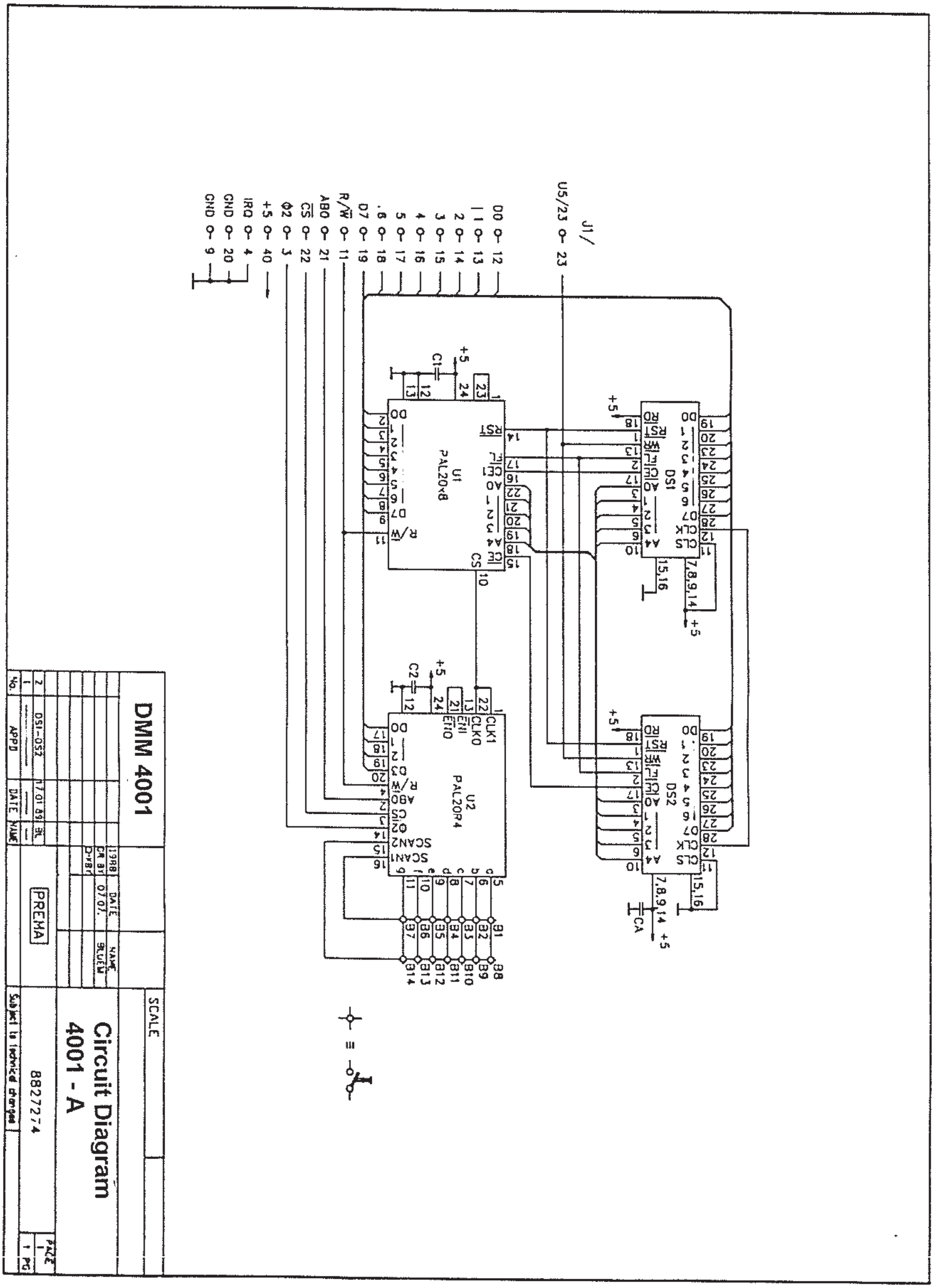


Fig 13.6. Circuit diagram der Display

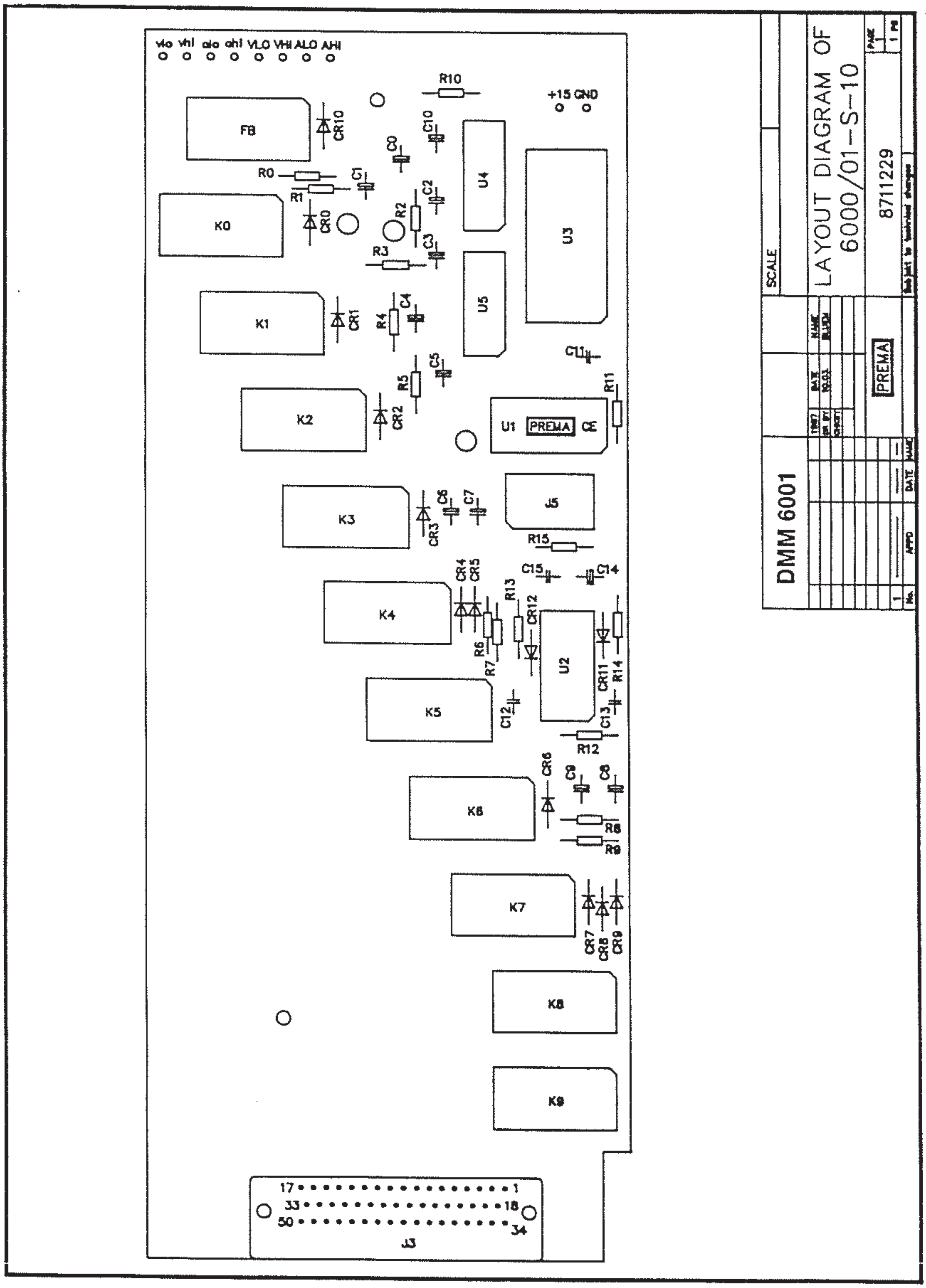


Fig 13.7. Layout diagram of the scanner (option 6000/01)

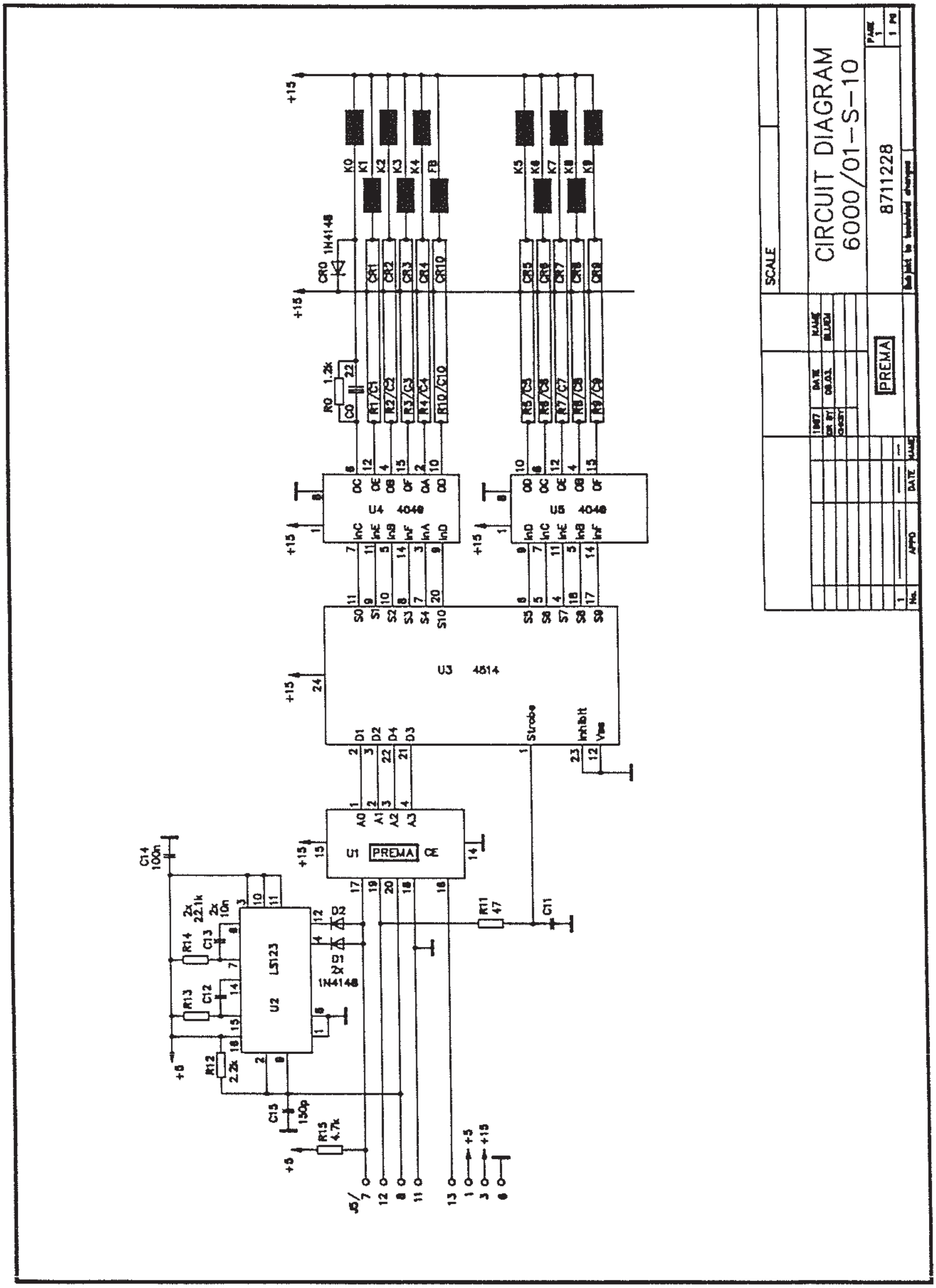


Fig 13.8. Circuit diagram of the scanner board (option 6000/01)

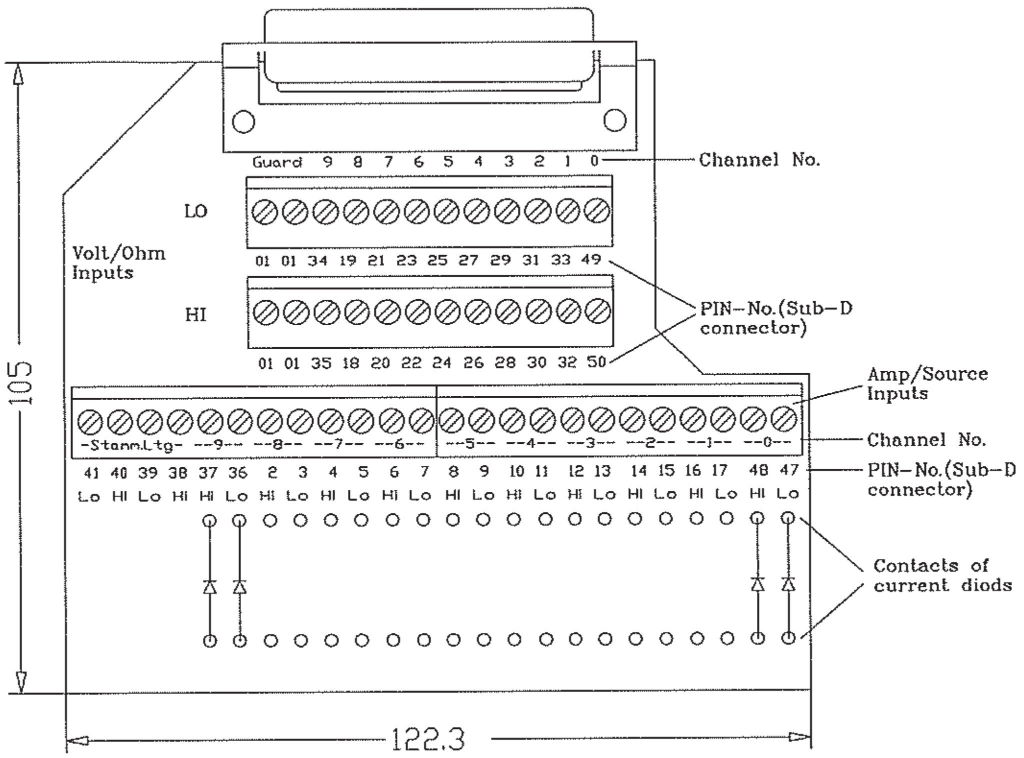


Fig 13.9. Layout diagram of the adapter card