PRECISION WATTMETER
MODEL 104B

OPERATING AND
MAINTENANCE MANUAL

Infratek

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1. INTRODUCTION AND SPECIFICATION

1.1. Introduction

This manual provides preliminary specification and operating instructions for the model 104B Precision Power Analyzer.

1.2. The 104B Precision Power Analyzer

The model 104B Precision Power Analyzer measures and computes 16 quantities simultaneously. Four of these are displayed on the 40 character vacuum fluorescent display (selectable by front panel controls). The current- and voltage input are galvanically isolated and may float 1400V (peak) against each other and against ground. They cover the frequency range DC to 200kHz. Current and voltage are measured by converters. Power is determined by sampling the instantaneous values of current and voltage. Averaging can be selected in 4 steps. A special measuring mode allows determination of average current, voltage, and power over a selectable time interval of up to 15000 seconds. From current, voltage, and power the remaining quantities are computed.
The Precision Power Analyzer is also capable of performing transient power measurements. Start-up power of systems can be monitored. The measurement starts to a control input from the front- or a trigger input from the rear panel. Twenty measurements of instantaneous power (in front panel selectable time intervals 0.05 sec., 0.1 sec., 0.15 sec., and 0.2 sec.) are performed and stored. After termination the measured values can be viewed on the display. The recorder output DC-signal is proportional to displayed power. In the transient measurement mode the output is proportional to instantaneous power as measurement is performed.
The IEEE-Interface allows complete control of the instruments functions including scaling.

1.3. Features

Features of the model 104B include:

- 0.1 % accuracy
- Simultaneous measurement of 16 quantities
- Simultaneous display of 4 quantities
- Inputs galvanically isolated
- Wide frequency range, DC to 200kHz (DC-400kHz)
- AC- or AC+DC-Coupling
- Automatic or manual ranging
- Timer function

- Transient power measurement
- 7 voltage ranges; 0-2V, 0-6V, ..., 0-1000V
- 6 current plug-ins, 2mA to 200A
- Simple operation
- Voltage, current- and power scaling
- Selectable averaging time
- Non-volatile memory
- Versatile Talk-only operation

Options: IEEE-488 Interface, recorder output, koaxial shunts

1.4. Measured Quantities and their Definitions

The 104B measures simultaneously the following 16 quantities:

Current input (AC- and AC+DC-Coupling)

- True RMS
- Rectified Mean
- Mean
- Charge = Rectified Mean x time

Voltage Input (AC- and AC+DC-Coupling)

- True RMS
- Rectified Mean
- Mean

Current and voltage input (AC- and AC+DC-Coupling)

- Power
- Apparent Power
- Magnitude of reactive power
- Power Factor
- Energy (positive and negative)
- Time
- Magnitude of load impedance
- Resistive part of load impedance
- Twenty measurements of transient power in time intervals 0.05 sec., 0.1 sec., 0.15 sec., or 0.2 sec.

The table below shows the mathematical definitions of the measured quantities.

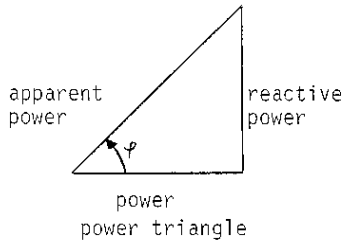
True RMS (A_r, V_r): $(1/nT \int_0^{nT} i^2\ dt)^{1/2}$, $(1/nT \int_0^{nT} v^2\ dt)^{1/2}$

Rectified Mean (A_t, V_t): $1/nT \int_0^{nT} |i|\ dt$, $1/nT \int_0^{nT} |v|\ dt$

Mean (A=, V=): $1/nT \int_0^{nT} i\ dt$, $1/nT \int_0^{nT} v\ dt$

Power (W): $1/nT \int_0^{nT} v \cdot i \cdot dt$

Apparent Power (VA) = $I_{RMS} \cdot V_{RMS}$



power
power triangle

Magnitude of reactive power (VAR) = $I_{RMS} \cdot V_{RMS} \cdot \sin\varphi$

Power Factor (PF) = Power / Apparent Power

Energy (Wh) = $\int_0^t$ power dt

Charge (Ah) = $\int_0^t$ (current rectified mean) $\cdot$ dt

Magnitude of load impedance ($|Z|$) = V_{RMS} / I_{RMS}

Resitive part of load impedance (ReZ) = $\frac{V_{RMS}}{I_{RMS}} \cdot \cos\varphi$

1.5. Specifications

CURRENT

Ranges:	
200mA plug-in:	2mA, 6mA, 20mA, 60mA, 200mA
20A plug-in:	200mA, 600mA, 2A, 6A, 20A[1])
60A plug-in:	20A, 60A[1],[2]
200A shunt:	20A, 60A, 200A[1],[2]
2A coaxial shunt plug-in:	20mA, 60mA, 200mA, 600mA, 2A
20A coaxial shunt plug-in:	200mA, 600mA, 2A, 6A, 20A
55A coaxial shunt plug-in:	2A, 6A, 20A, 60A
Voltage plug-in:	1mV=1A, range 0-20mV, ..., 0-2V
Maximum Save Input:	200mA plug-in: 2A max 3 min. 20A plug-in: 20A max 3 min. 60A plug-in: 70A max 3 min. 200A shunt: 200A max 1 min. 2A coax. shunt plug-in: 2A (cont.) 20A coax. shunt plug-in: 20A (cont.) 55A coax. shunt plug-in: 55A (cont.) Voltage plug-in: 20V max.
Display:	0-2045 for 2/20/200 ranges 0-6135 for 6/60/600 ranges
with scaling	0-99999
Frequency Range:	DC+AC-Coupling: DC-200kHz AC-Coupling: 15Hz-200kHz
Accuracy:	1 year, 18-25°C, all ranges

True RMS (Ar) Rect. Mean (At) Mean (A=)	±(0.1 % of input + 0.1 % of range) ±(0.1 % of input + 0.2 % of range)	40Hz-1000Hz DC:15Hz-40Hz 1kHz-20kHz
True RMS Mean Rect. Mean True RMS (Opt.13)	±(0.5 % of input + 0.5 % of range) ±(2.0 % of input + 0.5 % of range) ±(1.0 % of input + 0.4 % of range) ±(5.0 % of input + 1.0 % of range)	20kHz-100kHz 100kHz-200kHz 20kHz-100kHz 200kHz-400kHz

1) Accuracy limited to 1 min. operating time for currents >15A, >60A, and >150A, respectively.

2) Multiply accuracy percentage figures given for current and power by 2.

Crest Factor:	Exceeds 3:1 at 50 % full scale
Temp. Coefficient:	±(0.01 % of range) /°C

VOLTAGE

Ranges:	2V, 6V, 20V, 60V, 200V, 600V, 1000V[3]
Maximum Input:	All ranges: 1000V RMS or 1400V peak
Display:	0-2045 for 2V, 20V, 200V, 1000V ranges 0-6135 for 6V, 60V, 600V ranges
with scaling	0-99999
Frequency Range:	DC+AC-Coupling: DC-200kHz AC-Coupling: 15Hz-200kHz
Accuracy:	1 year, 18-25°C, all ranges

True RMS (Vr)	±(0.1 % of input + 0.1 % of range)	40Hz-1000Hz
Rect. Mean (Vt)	±(0.1 % of input + 0.2 % of range)	DC:15Hz-40Hz 1kHz-20kHz
Mean (V=)	±(0.3 % of input + 0.3 % of range)	20kHz-50kHz
True RMS	±(0.8 % of input + 0.4 % of range)	50kHz-100kHz
Mean	±(2.8 % of input + 0.8 % of range)	100kHz-200kHz
Rect. Mean	±(1.0 % of input + 0.4 % of range)	50kHz-100kHz
True RMS (Opt. 13)	±(5.0 % of input + 1.0 % of range)	200kHz-400kHz

[3] Accuracy limited to 1 minute operating time at voltages >700V.

Crest Factor:	Exceeds 3:1 at 50 % full scale
Temp. Coefficient:	±(0.01 % of range) /°C
Input Impedance:	1Mohm / 20pF
Volt-Hertz Product:	1 x 10^8VHz

POWER

Ranges:	(Power ranges result by multiplying current range x voltage range)
200mA plug-in:	4mW, 12mW, 36mW, ..., 200W
20A plug-in:	400mW, 1200mW, 3.6W, ..., 20kW
60A plug-in:	40W, 120W, 360W, ..., 60kW
200A plug-in:	40W, 120W, 360W, ..., 200kW
2A coax. shunt plug-in:	40mW, 120mW, 360mW, ..., 2kW
20A coax. shunt plug-in:	400mW, 1200mW, 3.6W, ..., 20kW
55A coax. shunt plug-in:	4W, 12W, 36W, ..., 60kW
Voltage plug-in for external shunts:	power ranges depend on shunt resistance

Display (20A plug-in): with scaling	0-418.2mW, 0-1254mW, 0-3.764W etc. 0-999999
Maximum Input:	As in current and voltage section
Frequency Range:	DC+AC-Coupling: DC-200kHz AC-Coupling: 15Hz-200kHz
Temp. Coefficient:	±(0.02 % of range) /°C
Overload:	Voltage and current levels exceeding the linear operating range for power measurement are indicated by "I-UP" and "U-UP" Led and by display blanking.
Accuracy:	1 year 18-25°C, power factor 0.5 to 1.0, all ranges

Continuous sampling	±(0.1 % of input + 0.1 % of range) ±(0.1 % of input + 0.2 % of range) ±(0.2 % of input + 0.35 % of range)	40Hz-400Hz 5Hz-40Hz, 400Hz-1kHz DC
Random sampling AVG=4	±(0.5 % of input + 0.3 % of range) ±(1.0 % of input + 0.5 % of range) ±(2.0 % of input + 0.8 % of range) ±(4.0 % of input + 0.8 % of range) typ. ±(6.0 % of input + 0.8 % of range) typ.	DC-20kHz 20kHz-60kHz 60kHz-100kHz 100kHz-150kHz 150kHz-200kHz
(Opt. 13), typical	±(8.0 % of input + 5.0 % of range)	200kHz-400kHz

Accuracy limited to 1 minute operating time at voltages >700V, and currents >15A (20A plug-in), >60A (60A plug-in) and, >150A (200A shunt).

For power factor <0.5 multiply accuracy percentage figures by 2.

Apparent Power:	Add accuracy percentage figures given for RMS voltage and RMS current.
Magnitude of reactive Power:	Add percentage figures given for RMS voltage, RMS current, power and apparent power. For power factors from 0.8 to 1.0 multiply accuracy percentage figures by 2.
Power Factor:	Add accuracy percentage figures given for power and apparent power.

Energy:	Continuous sampling: 0.4 % of reading Random sampling: 1 % of reading DC-20kHz; 3 % of reading, 20kHz-100kHz.
Charge:	0.4 % of reading, DC-20kHz 1.4 % of reading, 20kHz-200kHz.
Magnitude of load impedance:	Add accuracy percentage figures given for RMS voltage and RMS current.
Resistive part of load impedance:	Add accuracy percentage figures given for RMS voltage, RMS current, and power factor.

GENERAL

Input Type:	Floating type, inputs are galvanically isolated. Isolation voltage 3kV/50Hz for 1 minute between input and case.
Commom Mode Rejection:	Current input 120dB at 50/60Hz Voltage input 100dB at 50/60Hz
Display:	40 character, 5mm high vacuum fluorescent display. Four quantities including sign and units are simultaneously displayed. The selected averaging 1, 2, 3, or 4 is always shown in the last character (to the right of the display).
Controls:	The controls below the display are defined in the section "mathematical definition". The two controls Wh/Ah and $\|Z\|$/ReZ have double function purpose. The control field to the left of the display is for selection of the ranging- or coupling mode. The control field to the right of the display is for the selection of the sampling mode, and run/hold- or transient mode. Sampling: For periodic signals below 1kHz "CONT SAMPLING" should be selected. For signals above 1kHz "RAND SAMPLING" must be chosen.

Response time:	Current and voltage: 1 second to rated accuracy. Power and related quantities: response time depends on sampling mode and averaging. Min. 0.5 seconds (cont. sampling, AVG=1), max. 6.0 sec. (rand. sampling, AVG=4).
Ranging:	Automatic for current and voltage section, or manual with up-range- and down range-control.
Warm-up time:	2 minutes for reading within specified accuracy.
Power:	220V (110V) +20%/ -10%, 50-60Hz, 28VA.
Size:	H x W X D; 132mm x 450mm x 300mm.
Weight:	6.3kg
IEEE-488 Interface Function:	Option allows complete control and data output capability, and supports, the following interface function subsets: SH1, AH1, T5, L4, SR1, RL1, DC1, DT1, E1, PPO, and CO.
Options include:	IEEE-488 interface; Current plug-in: 0-200mA, 0-20A, 0-60A, and 0-200A; koaxial shunt plug-in: 0-2A, 0-55A. Programmable recorder output for power, rms voltage, or rms current (+1V output). Multifunction recorder output for simultaneous output of power, rms voltage, and rms current (0-2V output). 19-inch Rack Adapter; Frequency measurement DC-8kHz.

Specifications are subject to change without notice.

1.6. Model 104A Precision Wattmeter

The model 104A include all the features of the 104B with the following exceptions:

- No scaling
- No timer function
- No time measurement
- No multifunction recorder output
- No frequency measurement
- Only one display for energy
- No selectable averaging time
- No selectable talk-only output functions

1.7. Summary of Programming Functions

Setting Scaling Factors:

Select "HOLD" ⟶ Press "SCALE" ⟶ *Press "SCALE A" for current scaling factor setting / Press "SCALE V" for voltage scaling factor setting / Press "AVG" for power scaling factor setting ⟶ Set scaling factor from keyboard numbers ⟶Press "ENTER" (Go back to * to change other scaling factors)⟶Press "RUN".

Setting Energy Timer Function and Time:

Select "HOLD" ⟶ Press "SCALE" ⟶ Press "Ah/Wh-Reset" (/T/ toggels, Timer is activated when /T/ is displayed)⟶Press "RUN".

Setting Time of Timer:

Select "HOLD" ⟶ Press "SCALE" ⟶ Press "SAMPLING" (Talk-only setting, time for talk-only and energy timer, and MT=measurement time are displayed). ⟶ Press "ENTER" ⟶Set time in seconds Press "ENTER"⟶Press "RUN".

Setting Talk-only Output Functions:

Select "HOLD" ⟶ Press "SCALE" ⟶ Press "SAMPLING" (Talk-only setting, timer, and MT=measurement time are displayed) ⟶ Press all function keys (Ar, At, ...) you want to output to your printer ⟶Press "ENTER" (the new set of output functions is now displayed) ⟶ Select time in seconds from keyboard numbers Press "ENTER" ⟶Press "RUN".

Setting Measurement Time (Averaging Time):

Select "HOLD" ⟶ Press "SCALE" ⟶ Press "SAMPLING" ⟶ Press "ENTER" twice (104B is ready to accept MT input) ⟶ Set measurement time (MT) in seconds ⟶Press "ENTER" ⟶Press "RUN".

2. OPERATING INSTRUCTIONS

2.1. Introduction

This section provides instructions for installing and operating the 104B. Refer to section 3 for measurement consideration.

2.2. Installation

The 104B has a rear panel power-line fuse in series with the power supply. A 200mA, 250V slo-blo fuse is installed in the factory and the voltage selector switch is set for 195V-250V operation. For operation with power-line voltages of 98V to 125V, the fuse must be replaced by a 500mA, 250V slo-blo fuse and the voltage selector switch set for 98V to 125V operation.

WARNING: To avoid electric shock, remove the power cord before replacing the line fuse.

2.3. Connecting to Line Power

WARNING: To avoid shock hazard, connect the instrument power cord to a power receptacle with earth ground. To avoid damage, check that the rear panel line voltage selector switch is set to the correct line voltage.

2.4. Adjusting the Tilt Stand

At the bottom plate of the instrument are four tilt stands to adjust the viewing angle for bench-top use. To adjust their position, press in one end and rotate them to a stop position.

2.5. Rack Mounting Kit

You can mount the 104B in a standard 19-inch rack panel using the two rack ears. One rack ear is installed on each instrument side panel.

2.6. Operating Features

When the 104B is turned on, it performes an initialisation of its internal digital circuitry. It then reads in the type of current

plug-in in use, determines the options installed, and sets the internal status. The 104B then assumes the following configuration:

- AUTORANGE: Starting in the 1000V range and in the highest current range.
- Continuous Sampling
- Run (continuous measurement)
- AC-Coupling
- Averaging 1, MT=1
- Display: I_{RMS}, U_{RMS}, P, Power Factor

NOTE: When the current plug-in is changed, the 104B must be turned off. A new initialisation is required.

2.7. Front and Rear Panel Features

Front panel features are explained in Figure 2.1. Rear panel features are explained in Figure 2.2. Refer to section 1.4. for the definition of the measured quantities.

2.8. Display Features

The 104B features a 40 character vacuum fluorescent display. In the normal RUN- or HOLD-mode four quantities including units are displayed. These quantities are selected in the control field below the display. The last character of the display shows the selected averaging indicated by number 1, 2, 3, or 4.

2.9. Overrange / Underrange Indication

A current or voltage input is overrange if it exceeds the full scale of that range or if the instantaneous peak values exceed the operating range of the A/D-Converters. The 104B indicates an input is overrange by lighting the I-UP or U-UP Led in the range control field. A display overrange is indicated by blanking the corresponding quantity on the display. When the input falls below 30 % of selected range the I-DOWN or the U-DOWN Led is lighted.

CAUTION: There is no additional overrange indication, other than described above, when inputs exceed maximum allowable values.

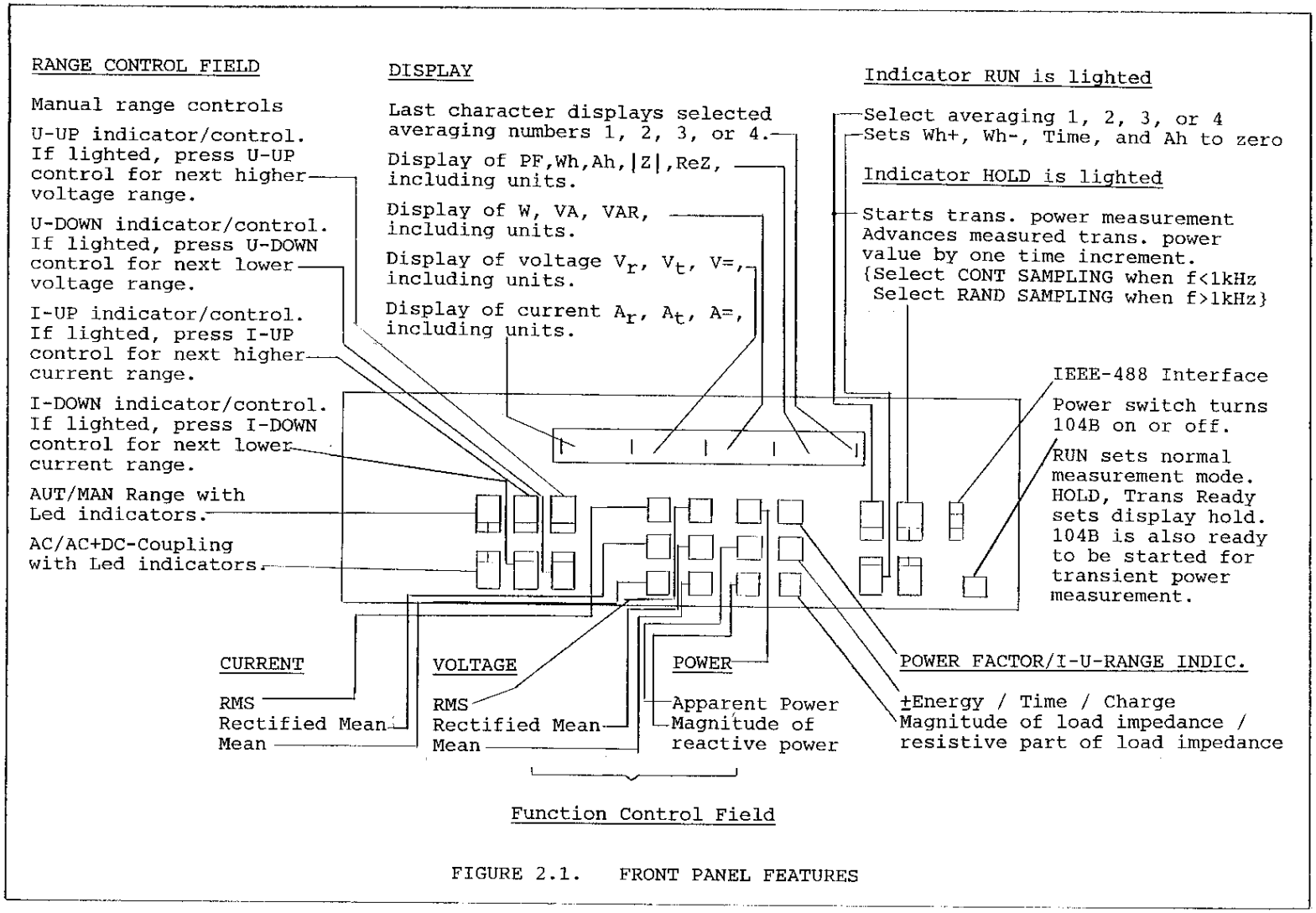


FIGURE 2.1. FRONT PANEL FEATURES

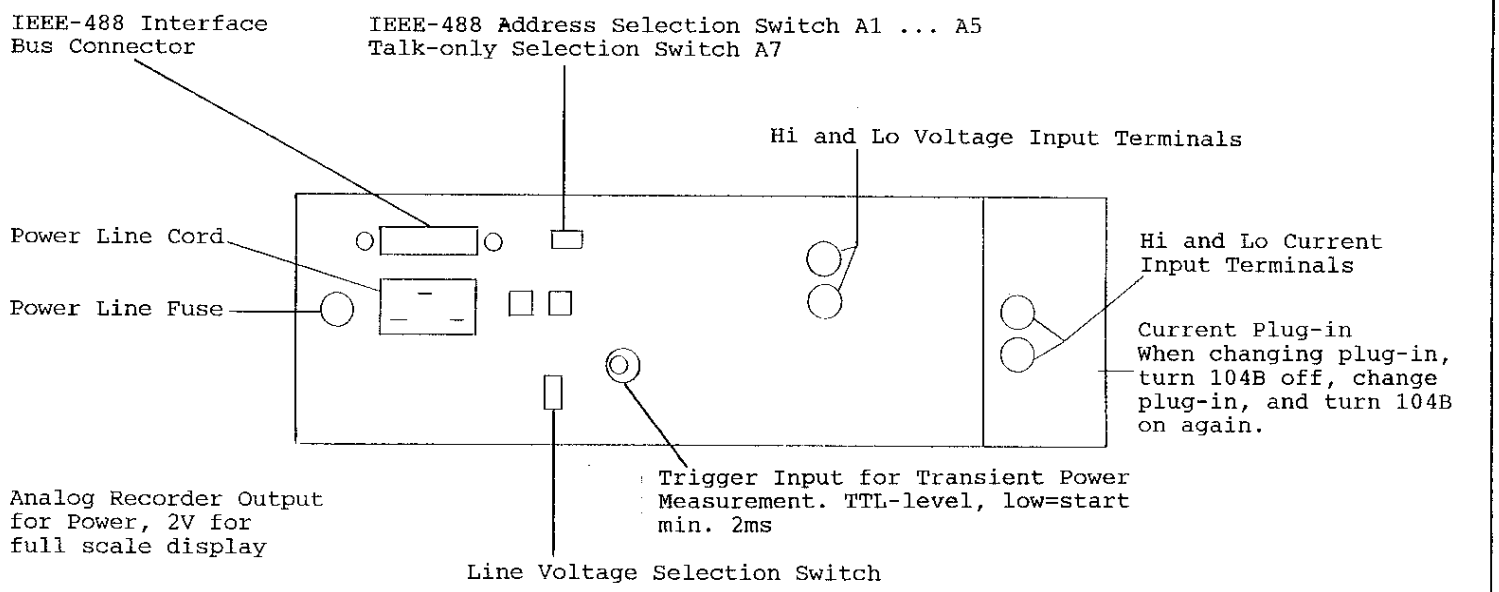


FIGURE 2.2. REAR PANEL FEATURES

2.10. Ranging

Measurement ranges can be selected using either autorange (Led AUTO is lighted) or manual range (Led MAN is lighted). The 104B displays explicit units in every current and voltage range, so that the displayed quantities may be read directly.

AUTORANGE: In autorange the 104B goes to a higher range when the current or voltage input exceeds 2000, or 6000rms (ranges are 2/ 6/ 20/ ...). The 104B goes to a lower range when the input falls below approx. 30 % of full scale (600, resp. 1800 counts).

MANUAL RANGE: In manual range, the 104B remains fixed in the selected range until you select another range or press AUTO RANGE. The user is guided by the UP- and DOWN range Led indicators. To select the next higher current range press the I-UP control once. To select the next lower range press the I-DOWN control once. The same procedure applies for the voltage ranges. The range controls are disabled in the HOLD- and the TRANSIENT mode. Select the needed ranges prior to making transient power measurements.

2.11. Sampling

CONT (continuous) or **RAND** (random) sampling is selected and indicated in the control field to the right of the display. The instrument starts up in the CONT sampling. To select RAND sampling press the sampling control once (Led RAND lights up). To go back to CONT sampling press the sampling control again.

CONT SAMPLING: When the fundamental frequency of current and voltage to be measured is less than 1kHz select CONT sampling. Power is now determined from a minimum of 3000 continuous samples of current and voltage. High harmonic content does not introduce errors. For most power measurements averaging 1 will suffice. CONT sampling should always be selected when the fundamental frequency is less than 1kHz because higher accuracy for power and faster measurement cycles result. Precise power measurements of periodic signals down to 3Hz within one measurement cycle (approx. 0.5 sec.) can be made.

RAND SAMPLING: When the fundamental frequency of current and voltage to be measured is greater than 1kHz you must select RAND sampling. If this rule is violated, false power measurements may result. In RAND sampling mode, power is determined from 1 to 8 measurement cycles. Each measurement cycle consists of 4000 randomly modulated samples of current and voltage. The displayed power value is the average of a number of measurement cycles determined by the selected AVG (averaging) as follows:

AVG	Number of measurement cycles	Number of samples
1	1	4,000
2	2	8,000
3	4	16,000
4	8	32,000

Best accuracy is obtained with AVG=4. With increasing AVG the response time of the instrument to attain the final power value is increased, and is for AVG=4 approximately 6 seconds.

2.12. Averaging AVG

The averaging is selected by the control AVG and is always displayed as a number from 1 to 4 in the right most character of the vacuum fluorescent display. Each time AVG is pressed, the AVG number is increased until it reaches 4. Pressing AVG again will reset the AVG number to 1, etc. The AVG-number only affects the power averaging, that is, the number of samples taken for power measurement is controlled by the AVG-number. It does not affect the voltage- or current measurement. The table below shows the dependance of the number of samples and instrument response time to reach final value (P, S, Q, PF, Z) to a step input.

AVG	Number of Samples		Power response time, step input	
	CONT	RAND	CONT	RAND
1	> 3,000	4,000	∿ 0.5 sec	∿ 0.75 sec
2	> 6,000	8,000	∿ 1.0 sec	∿ 1.5 sec
3	>12,000	16,000	∿ 2.0 sec	∿ 3.0 sec
4	>24,000	32,000	∿ 4.0 sec	∿ 6.0 sec

NOTE: In CONT sampling we recommend to use AVG=1. Only for noisy signals it may be required to increase the averaging.
In RAND sampling the display fluctuates more when a lower averaging number is selected.

2.13. Signal Averaging over a Preset Measuring Time

When the 104B is turned on it initializes to the standard measurement time MT≠1. MT can be increased up to 15000 seconds to obtain averaged values of current, voltage, power, and all other computed quantities including elapsed time. The time setting from 2 to 15000 seconds is accurate to within ±0.5 seconds. For this type of measurement manual ranging must be used.
Proceed as follows: Set up 104B in the desired operating configuration. Program MT: Select "HOLD" ⟶ Press "SCALE" ⟶ Press "SAMPLING" (the talk-only setting, the timer, and MT are displayed) ⟶ Press "ENTER" twice ⟶ Select MT in seconds Press "ENTER" ⟶ Press "RUN" to start the first measurement.
While the measurement is in progress the "RUN"-Led flashes. The measurement can be stopped by pressing the "HOLD" control. When during a measurement an overload for more than 0.3 seconds occurs the 104B goes into "HOLD". Such an overload can be recognized by reading the averaging time, which in this case will be less than the MT-setting.
The 104B operates differently for MT≤100s and MT>100s. For MT≤100s the new values are displayed after finishing measurement and the HOLD-Led lights up for about 3 seconds. Then, the next measurement is initiated. When the HOLD-Led is lighted, the measurement can be stopped by pressing the "HOLD" control. For MT>100s the 104B goes into "HOLD" after finishing measurement. The next measurement is started by pressing the "RUN" control.
Whenever a measurement is interrupted the displayed values are valid average values and the elapsed time between start and stopp can be read from the display.
The measurement time MT can be programmed via the IEEE-Interface using the S5 command. We recommend to always use triggered operation for MT>1 (K6/Trigger/K7/Commands). During measurement the controller has no access to the 104B, and has to wait until the "HOLD" state is reached. SRQ can be activated using P8. In talk-only operation, the 104B sends data whenever the HOLD state is entered.

2.14. Energy Timer Operation

A programmable timer for energy summation is a standard feature of the 104B. The timer can be set between 0 and 32760 seconds (9.1 hours). When pressing the "WhRes"-key positive energy, negative energy, charge, and elapsed time are reset to zero. After resetting, energy and charge is summed until the elapsed time has reached the preset time of the timer. Energy summation is stopped until reset or until the timer value is increased. Positive and negative energy is summed separately and can also be displayed and transmitted over the interface bus as two separate quantities.
When pressing the "Wh"-key the first time, positive energy is displayed. Pressing the "Wh"-key the second time, negative energy is displayed. Pressing the "Wh"-key the third time, elapsed time is displayed, and finally, pressing the "Wh"-key the fourth time, charge is displayed.

NOTE: The energy computation and charge computation is deactivated whenever a measurement time MT>1 is selected (section 2.13).

To activate the programmable timer the following two steps are required:

1. Activate the timer function as follows:

   ——→ Select "HOLD"

   ——→ Press "SCALE"

   ——→ Press "Ah/Wh Reset"
   The display shows now scaling factors, and /-/ (Timer not active) or /T/ (Timer active)
   When pressing "Ah/Wh Reset" the timer function toggels.

2. Set the desired time as follows:

   ——→ Select "HOLD"

   ——→ Press "SCALE"

   ——→ Press "SAMPLING"
   The Talk-only programming and time are now displayed.

   ——→ Press "ENTER"

   ——→ Select the desired time in seconds (max. 32760 s) and press "ENTER" again. The preset time is now displayed.

——→Press "RUN"

2.15. HOLD / Transient Power Measurement

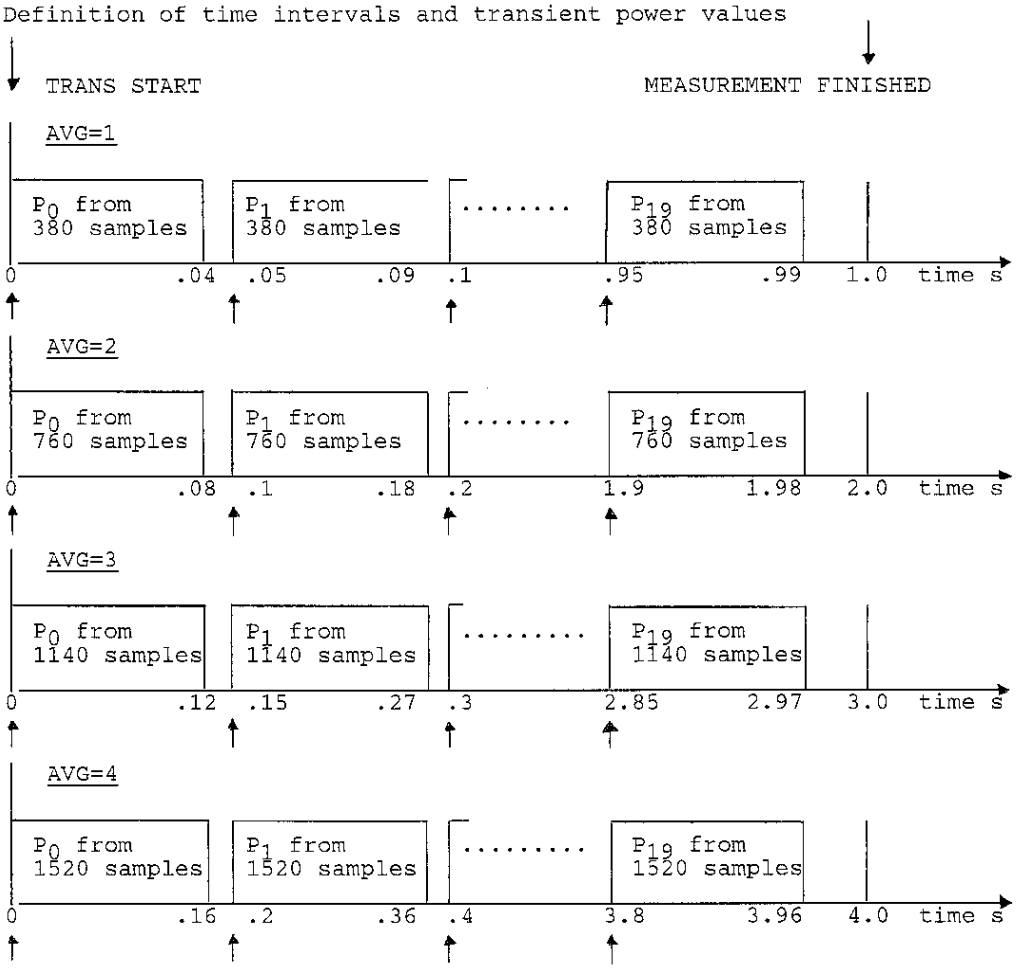
All controls in the control field to the right of the display have double function purpose. To make a display HOLD, simply press the RUN/HOLD, Trans Ready control. To continue, press the control again. Prior to making a transient power measurement, always select AC+DC-Coupling, select the appropriate voltage and current ranges to assure that no overload condition during measurement will occure (manual ranging). Also select the desired time interval with AVG as follows:

AVG	Time interval	Total measurement time
1	0.05 sec.	1 sec.
2	0.1 sec.	2 sec.
3	0.15 sec.	3 sec.
4	0.2 sec.	4 sec.

Now bring the instrument into the HOLD, Trans Ready state. To start the transient power measurement, either press the AVG/Trans Start control or short the rear panel trigger input to ground.
When the measurement of the twenty transient power values is finished, the first value P_0 determined during time interval t_0=0.00 sec. is displayed. The values can now be viewed on the display by means of the Trans Display control. Each time the Trans Display control is pressed the next transient power value P_0, P_1, ..., P_{18}, P_{19}, P_0, P_1 ..., etc. is displayed. The table below defines the transient power values, time intervals, and number of continuous samples as determined by the selected AVG.

NOTE: During transient power measurement the CONT/RAND sampling control is deactivated.

Definition of time intervals and transient power values



Times shown on the display

2.16. External Trigger Input

The rear panel external trigger input is a TTL-level input which can be used to trigger transient power measurements. A measurement is started on a low level on the input. The input is normally pulled high internally, it can also be controlled by a normally open switch. The minimal pulse duration should be more than 2ms. To repeat a transient power measurement using the trigger input, the 104B must be switched to the RUN state and back to the HOLD (Trans Ready) state. Now the 104B is ready to be started by the trigger input.

2.16.1. Current- and Voltage Scaling

Although the 104B offers a broad input current range (2mA-200A) and a broad input voltage range (2V-1000V), the scaling of current and voltage becomes necessary when current- and voltage transformers, or external high current shunts are used. All 16 quantities are scaled and their correct values displayed. Also power can be scaled. This feature is usable when the 104B is used for power measurements in 3-phase systems.
The following maximum display values are possible:

Current: 99999kAr (kAt) (kA=)
Voltage: 99999kAr (kVt) (kV=)
Power: 999999 MW (MVA) (MVAR)

The voltage-, the current-, and the power scaling factor can be set anywhere in the range from 0.0001 to 999999.

The scaling factors are changed by means of the front panel controls as described below:

——→ Select "HOLD" mode

——→ Press "SCALE"

——→ Press "SCALE A" for current scaling factor change. The 3 scaling factors are now displayed. Enter scaling factor as follows: e.g. 10; format 10/10./10.0 ——→Press "ENTER". (The scaling factor 10.000 is now displayed).

——→ Press "SCALE V" for voltage scaling factor change. Enter scaling factor as follows: e.g. 0.75; format 0.75/.75/.750 ——→Press "ENTER". The scaling factor 0.75 is now displayed. ——→Press "RUN".

⟶ Press "AVG" for power factor change.
Enter scaling factor as follows: 1.732 ⟶Press "ENTER".

NOTE 1: The decimal point is set by the "AC/AC+DC"-key.

NOTE 2: When either scaling factor differs from 1.0 a display indication results. The 40th display character will alternately display AVG/F.

Scaling when using External Current Shunts

Use Option 012, current plug-in for voltage input with input sensitivity 1mV=1A. Below 3 examples for scaling factor determination are given:

Shunt Resistance	Sensitivity	Scaling Factor
1.071mΩ	1.071mV=1A	1mV/1.071mV = 0.9337
20.000mΩ	20.00mV =1A	1mV/20.00mV = 0.05
0.180mΩ	0.180mV=1A	1mV/0.180mV = 5.555

2.17. Frequency Measurement (Option 15)

When Option 15 is installed the frequency of the current wave form is displayed by pressing the "At"-control. The frequency is read over the IEEE-488 with the "F2" command.

Specifications

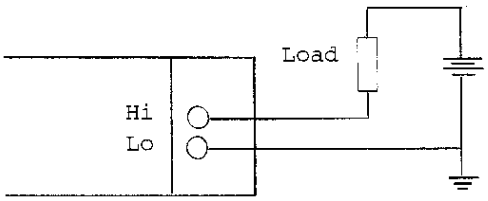
Frequency range: 10Hz-8000Hz
Accuracy: 0.2 % ±4Hz
Sensitivity: Selectable by current range

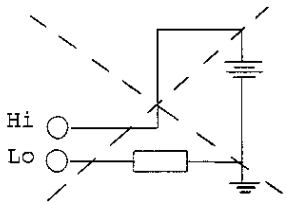
2.18. Making Measurements

WARNING: To avoid shock hazard and/or instrument damage, do not apply input potentials that exceed the input overload limits specified in section 1.5.

The specified maximum inputs may be applied to the 104B on any voltage and current range without damage.

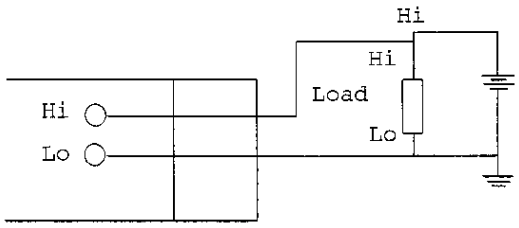
2.19. Measuring Current





Measure current preferably on the ground side to minimize common mode voltage. Although the 104B shows excellent common mode rejection, high common mode voltages at frequencies above 50kHz may result in incorrect measurements.

2.20. Measuring Voltage

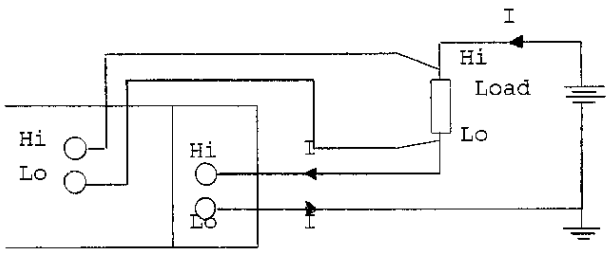


Measure voltage preferably by connecting the Lo-side on the load to the Lo-voltage input and the Hi-side of the load to the Hi-voltage input.

2.21. Measuring Power

Measuring power is a difficult task. A high degree of amplitude- and phase-accuracy is required to obtain reliable measurements. There are many wrong ways to hook up a system and only one right way.

RULE: Measure current always at the point which is closest to ground potential.
Connect the Hi-side of the load to the Hi-voltage input and the Lo-side to the Lo-voltage input.



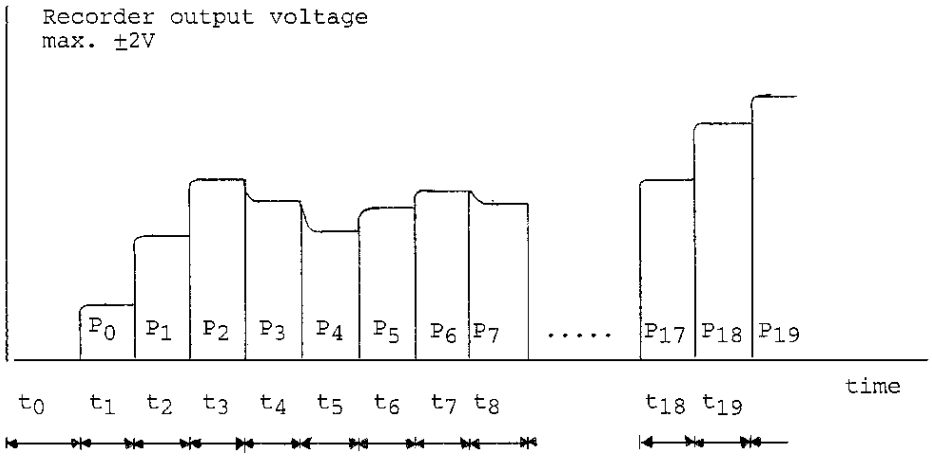
Observing this rule, minimizes the common mode effects, precise power measurements up to 200kHz can be made.
Measuring current on the Hi-side of the load will expose the current input to large common mode voltages. Particularly at high frequencies the common mode signals increase and introduce amplitude- and phase errors, which in turn yield ambiguous power measurements.

2.22. Programmable Recorder Output (Option 05)

The recorder output option gives the 104B the ability to output a positive or negative analog signal proportional to power. In the normal RUN mode the recorder output is proportional to displayed power. ±Full scale display corresponds to ±2V. The sensitivity is determined from:

Recorder output sensitivity = 2V / Full scale power

When transient power measurements are performed, the transient power values P_0, P_1, P_2, ..., P_{19} are applied in real time to the recorder output. A delay of one time interval results as shown below.



Recorder output when 104B performs transient power measurement.

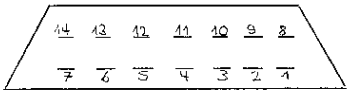
Programming the Recorder Output

This recorder output version allows to output power as described in section 2.19. as well as RMS current, or RMS voltage. On power-up the recorder output is initialized to output power. To select RMS current proceed as follows: Select AVG=1 ⟶ press "HOLD" ⟶ press "RANGE" ⟶ and finally, ⟶ press "RUN" to return to the normal "RUN" mode. Similarly, RMS voltage (AVG=2), or power (AVG=3) is selected.
The table below summarizes the recorder output capabilities.

Recorder Output	AVG	Output at full scale display
Irms	1	2V (200mA / 600mA / ...)
Urms	2	2V (2V / 6V / ...)
P	3	±2V (+400.0mW /±1200mW / ...)
Control sequence for recorder output selection: Select "AVG" ⟶ Press "HOLD" ⟶ Press "RANGE" ⟶ Press "RUN"		

2.23. Multifunction Recorder Output (Option 14)

This option outputs 3 signals proportional to rms current, rms voltage, and power. Full scale display (2V, 2A, 4W) corresponds to 0 to 2V at the recorder outputs. The outputs are updated with the display update.



pin 7: Current
pin 14: Voltage
pin 6: Power
pin 8: Ground

2.24. Other 104B Programming Functions

The programming functions described below are factory installations. Accidental manipulation may remove or alter the software installation. In this case simply repeat the steps described below.

1. Option Initialisation

→ Select "AVG=4"

→ Select "HOLD"

→ Press "SCALE"

→ Press "U UP" (Sets internal status)

→ Press "RUN"

2. Multifunction Recorder Installation (Option 14)

No further programming action is required.

3. Programmable Recorder Installation (Option 05)

→ Select "AVG=3"

→ Select "HOLD"

→ Press "SCALE"

→ Press "U UP" (Sets internal status)

→ Press "RUN"

4. Frequency Measurement Installation (Option 15)

——→ Select "AVG=2"

——→ Select "HOLD"

——→ Press "SCALE"

——→ Press "U UP" (Sets internal status)

——→ Press "RUN"

Display must show "/Hz". Control "U UP" toggels between "/Hz" and "/--" (deactivated).

3. REMOTE PROGRAMMING

3.1. Introduction

The IEEE-488 Interface turns the 104B into a fully programmable instrument for use with the IEEE-488 Interface bus. With the interface, the 104B can become part of an automated measurement system. The 104B can be under complete, interactive control from a remote bus controller; or it can be set to the talk-only mode, connected to one or more listeners.

3.2. Capabilities

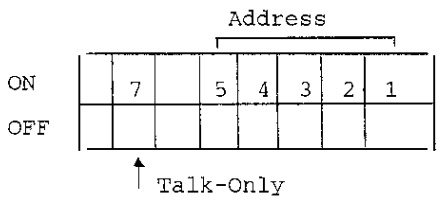
The IEEE-488 Interface provides remote control of all front panel controls except for the Power. Other features include:

- Full talk/listen capability, including talk-only operation.
- Comprehensive command set
- Fast measurement throughput
- Full remote/local capability
- Full serial poll capability, with bit-maskable SRQ
- External trigger
- Two bus triggers
- Selectable output terminators
- Programmable Talk-only mode, timer

The 104B supports the following interface function subsets: SH1, AH1, T5, L4, SR1, RL1, DC1, DT1, PP0, and C0.

3.3. Bus Set-Up Procedure and Address Selection

a) Turn the 104B Power switch Off and set the rear panel address switch as shown below.



Address	A5	A4	A3	A2	A1
01	0	0	0	0	1
02	0	0	0	1	0
03	0	0	0	1	1
04	0	0	1	0	0
05	0	0	1	0	1
⋮					

b) Switch on the 104B
The address of the 104B is factory set to address 05 and talk-only mode off.

3.4. Device-Dependent Command Set

Device-dependent commands are the heart of the 104B remote control. They tell the 104B how and when to make measurements, when to put data on the bus, when and under what conditions to make service requests, and what data to put on the display. The complete set of device-dependent commands is listed in Figure 3.1. The commands are entered using upper case letters. For the 104B to receive them, they must be sent over the IEEE bus when the 104B is in remote and has been addressed as a listener.

3.5. Output Function Command Fn, Hn

The output function command tells the 104B which quantity to load in the output buffer. When the 104B is addressed to talk, it will put the contents of the output buffer on the bus.

Example	Explanation
"F4"	The output buffer will be loaded with the value of Urms, e.g. +221.8Vr.
"F8H2"	F8 will be ignored. The output buffer will be loaded with the value of Wh+, Wh-, time (H2), e.g. 1.759 + 1Wh -3.891-1Wh, 301.2 Wh+/Wh-/s.

3.6. Output Function Commands An, Bn

The output function commands An, and Bn are meaningfull only after a transient power measurement has been performed. For the definition of transient power values and time intervals refer to section 2.13. The output function command A0, ..., A9 will load the transient power values P0, ..., P9 into the output buffer. The output function commands B0, ..., B9 will load the transient power values P10, ..., P19 into the output buffer.

Example	Explanation
"A5"	The output buffer will be loaded with the transient power value P5, e.g. +178.2W.

3.7. Range Commands In, Un

The range commands tell the 104B which current and voltage range to select. The range commands are accepted when autorange C2 is off. For example, "I3U5" selects the 2A (20A plug-in), and 200V range. The range setting can be read using the G1 command.

3.8. Display Commands Dn, En

The display commands duplicate the function controls below the display. The display commands allow the user to select 4 quantities to be displayed. One out of the following groups can be selected: {D1, D2, D3}, {D4, D5, D6}, {D7, D8, D9}, {E1, E8}, {E2, E3, E4, E5}, and {E6, E7}.

Example	Explanation
"D3,D4,D8,E2"	Imean, Urms, apparent power S, and positive energy Wh, will be displayed.
"D1"	Irms will be selected. The remaining three displayed quantities will not change.

3.9. Mode Commands

The mode commands C1, ..., C9, and K1, ..., K5 duplicate the front panel controls to the left and right of the display. The mode commands K6 and K7 is a feature accessible only via the interface.

Example	Explanation
"C2 C3C8K4C9"	Selects Autorange off (interface ranging), Continuous sampling, Averaging 4, AC-Coupling, RUN.
"K1"	Puts 104B into hold mode. Displayed values are held, 104B is ready to perform transient power measurement.
"K2"	Starts transient power measurement.
"C9 K6"	RUN mode, triggered measurement on. One measurement cycle is started on an interface trigger input. The following 12 quantities are determined: Irms, Irect., Imean, Urms, Urect., Umean, P, S, Q, PF, |Z|, and |ReZ|. (Wh and Ah are no longer valid). Averaging 1 is selected unconditionally.

3.10. SRQ Mask Command Pn

The SRQ mask commands P0 through P8 are used to program the 104B to make service requests or user-specified conditions.

Example	Explanation
"P4"	SRQ on transient power measurement finished.

3.11. Terminator Commands Wn

The terminator commands select what terminators the 104B appends to every output string. The terminators are: Carriage Return (CR), Line Feed (LF), and EO1 (End Or Identify). CR and LF are ASCII control codes, sent over the data bus just like output data. EO1 is a uniline message which is sent simultaneously with the last character in the output string. Normally, each output string is terminated with CR followed by LF and EO1.
The terminator selection can be read using the G1 command. The 104B sets to W1 on power-up.

3.12. Get Commands Gn

The G1 command copies the 104B current range, voltage range, SRQ mask, and terminator selected into the output buffer in the format shown below.
The G2 command copies the 104B status into the output buffer (autorange on/off, sampling, averaging, coupling).

Command	Output String	Meaning
G1	frst	f = 1-5 as in I-range commands r = 1-7 as in U-range commands s = 1-8 as in SRQ mask commands t = 1-4 as in Terminator commands
G2	frst	f = 1 = Autoranging on f = 0 = Autoranging off r = 1 = Continuous sampling r = 0 = Random sampling s = 1-4, AVG = 1-4 t = 1 = AC-Coupling t = 0 = DC+AC-Coupling

Output Function Commands

F0	Irms, Vrms, W, VA, Power Factor		
F1	I rms	H1	Power Factor
F2	I rectified mean	H2	Wh+, Wh-, time
F3	I mean	H3	Ah
F4	U rms	H4	Z
F5	U rectified mean	H5	ReZ
F6	U mean		
F7	Power P		
F8	Apparent Power S		
F9	Reactive Power Q		

Output Function Commands for transient power measurements

A0	Power at t_0	B0	Power at t_{10}
A1	Power at t_1	B1	Power at t_{11}
A2	Power at t_2	B2	Power at t_{12}
A3	Power at t_3	B3	Power at t_{13}
A4	Power at t_4	B4	Power at t_{14}
A5	Power at t_5	B5	Power at t_{15}
A6	Power at t_6	B6	Power at t_{16}
A7	Power at t_7	B7	Power at t_{17}
A8	Power at t_8	B8	Power at t_{18}
A9	Power at t_9	B9	Power at t_{19}

(For the definition of time intervals for transient power measurement refer to Section 2.13.).

Range C Range Commands

Plug-in	0-200mA	0-20A	0-60A
I1	2mA	200mA	20A
I2	6mA	600mA	60A
I3	20mA	2A	200A
I4	60mA	6A	600A
I5	200mA	20A	2000A

U1	2V
U2	6V
U3	20V
U4	60V
U5	200V
U6	600V
U7	1000V

Figure 3.1. Device - Dependent Commands

Display Commands

D1	Display I rms	(default)
D2	Display I rectified mean	
D3	Display I mean	
D4	Display U rms	(default)
D5	Display U rectified mean	
D6	Display U mean	
D7	Display P	(default)
D8	Display S	
D9	Display Q	
E1	Display PF	(default)
E2	Display Wh+	
E3	Display Wh-	
E4	Display time	
E5	Display Ah	
E6	Display |Z|	
E7	Display ReZ	
E8	Display Ranges I=x U=y	

Mode Commands

C1	Autorange on	(default)
C2	Autorange off	
C3	Continuous sampling	(default)
C4	Random sampling	
C5	Averaging AVG=1	(default)
C6	Averaging AVG=2	
C7	Averaging AVG=3	
C8	Averaging AVG=4	
C9	RUN	
K1	HOLD (or transient ready)	
K2	Transient power measurement start	
K3	Ah/Wh reset	
K4	AC-Coupling	(default)
K5	DC+AC-Coupling	

K6 Triggered measurement on (measurement is started on interface trigger command, 104B must be programmed with C9 RUN). All quantities except Wh, Ah, and P-transient are determined in 1 measurement cycle.

K7 Triggered measurement off.

Set Commands (Send only 1 command at a time)

S1 Set current scaling factor, e.g. "(S1 3.000)", "(S1 3)"

S2 Set voltage scaling factor

```
S3   Set power scaling factor, e.g. "(S3 1.732)"
S4   Set instrument serial number, F digits, no leading 0.
S5   Set measuring time MT in seconds (no decimal), standard
     setting=1
```

Figure 3.1. Device - Dependent Commands (cont.)

SRQ Mask Commands

```
P0   SRQ disabled                    (default)
P1   SRQ on I-overrange
P2   SRQ on U-overrange
P3   SRQ on I-, or U-overrange
P4   SRQ on transient power measurement finished
P5   SRQ on I-over, or transient power measurement finished
P6   SRQ on U-over, or transient power measurement finished
P7   SRQ on I-, or U-over, or transient power measurement finished
P8   SRQ on triggered measurement finished (K6), or on MT>1
     measurement finished
```

Terminator Commands

```
W1   CR / LF / EOI                   (default)
W2   CR / LF
W3   EOI only
W4   disable all terminators
```

Get Commands

```
G1   Get range I/U; SRQ mask; terminator
G2   Get Command status (C1/2; C3/4; C5/ ... 8; K4/5)
G3   Get instrument serial number
G4   Get current scaling factor
G5   Get voltage scaling factor
G6   Get power scaling factor
```

Typical command string as it might be sent to the 104B.

```
HP-85 Controller                 Fluke 1720A Controller
REMOTE 705                       REMOTE   5
OUTPUT 705; "C2K4I3U5"           PRINT    5, "C2K4I3U5"
OUTPUT 705; "D1D8F7"             PRINT    5, "D1D8F7"
ENTER 705; A$                    INPUT    5, A$
CLEAR 705                        CLEAR    5
OUTPUT 705; "K6F4"               PRINT    5, "K6F4"
TRIGGER 705                      TRIG
B=SPOLL (705)                    B%=SPL (5)
```

Figure 3.1. Device - Dependent Commands (cont.)

3.13. Input Processing

An input string can contain as many commands as required. Commands are executed in the sequence they are received. Commands which can not be recognized by the 104B will be ignored. A command string must be terminated with CR (Carriage Return), and LF (Line Feed). EOI is optional. Most controllers finish a command string with CR LF pair. If a controller does not have this feature, the programmer must transmit a terminator explicitly.
The 104B accepts alphabetic characters in upper case. Spaces are ignored.

3.14. Syntax Rules

Three syntax rules should be followed when writing input command strings. They are:

Rule 1: Read output data only once.
To prevent old data from being read a second time by mistake, the output buffer is always cleared after it has been read. If the output buffer is read twice without an intervening output command, the 104B will not respond to the second attempt to read the output buffer. However, if the 104B is in T0, no intervening command is necessary.

Rule 2: Use no more than one output command per input command string.
If an input command string contains more than one output, only the data from the last command can be read.

Rule 3: Read the output data generated by one input command string before sending the next input command string. Output data remains available in the output buffer until it is read, or until the next input command string is received.

3.15. Output Data

The following describes the data that can be loaded into the 104B output buffer and sent to the interface bus. It describes how and when data is loaded into the output buffer, and the types of output data.
The 104B can also send data to the IEEE-488 bus from the serial poll register.

3.16. Loading Output Data

The 104B is preprogrammed to send output data when it receives an output command, e.g. "F7". The data are not actually loaded onto the interface bus until the controller addresses the 104B as a talker. This is done by sending the interface message MTA (My Talk Address). The types of output data are shown in Figure 3.2. Numeric data including units are sent to the IEEE-488 bus in the same format as displayed on the display. When data are overrange the suffix "OVER" is appended to the data.
Status data is the output in response to G1 and G2 commands. The data is formatted as shown in Figure 3.2. and is interpreted in Section 3.12.
The terminators appended to numeric data and status data are user-selected by the terminator commands W1 ... W4.

Output Data Type	Format Examples	
Numeric Data	+ 4.023mW	Measured Value
	+182.3mAr	Measured Value
	- 2.047V = Over	Overrange
	+ 3.15E+2Ah	Measured Value
	+358.3Vc Over	Measured Value
Instrument Configuration Date:	G1: 3431 - Terminator W1,SRQ P3 └──U-range 4, I-range 3	
	G2: 0121 - AC-Coupl.,Averaging 2 └──Cont.Sampl., Auto. off	
Output from SRQ	decimal 72	SRQ on triggered measurement finished

Figure 3.2. Output Data Types

3.17. Service Requests

Service requests let bus instruments get the attention of the system controller. The requests are sent over the SRQ line. If more than one instrument on the bus is capable of sending service requests, the controller can learn which one made the request by taking a serial poll. The 104B responds to the poll by sending the contents of its serial poll register.
contents of its serial poll register. The serial poll register indicates whether or not the device requests service, and if so, the reason for the request.

The 104B may be programmed to make a service request on user-specified conditions. The conditions are specified by entering a value for the service request mask (SRQ mask).

3.18. The Serial Poll Register

The serial poll register is a binary-encoded register which contains eight bits, as illustrated in Figure 3.3. The controller can read the 104B serial poll register by taking a serial poll. Because serial poll data is loaded directly onto the bus, reading the serial poll register leaves data in the output buffer intact. The eight bits of the serial poll register are described below. Note that the SRQ mask uses bits 1 through 4 to set bit 7 (the SRQ bit). Bit 7 sets the SRQ line true, which generates a service request. Bits 1 through 4 are set, depending on the selected SRQ mask P1 ... P8, as follows:

Selected SRQ mask	Decimal value bit 1 through 4
P1	1 I-overrange
P2	2 U-overrange
P8	8 Triggered meas. finished

Bit:	8	7	6	5	4	3	2	1
	0	SRQ	0	0	4 bits used for SRQ generation			
Decimal		64	32	16	8	4	2	1

Figure 3.3. Serial Poll Register

Taking a serial poll clears bit 7 of the serial poll register. Bits 1 through 4 are also set when no SRQ is desired (P0 user-specified). In this case bit 7 is not set and the service request line is not set true.

3.19. Interface Messages

The Interface messages understood by the 104B are the following three main classes described in IEEE-488 standard: address messages, universal commands, and addressed commands. All interface messages described here originate at the controller.

Address Messages

MLA:	My Listen Address	-	Addresses a device to listen
MTA:	My Talk Address	-	Addresses a device to talk
UNL:	Unlisten	-	Addresses all listeners to unlisten
UNT:	Untalk	-	Addresses all talkers to untalk

Universal Commands

ATN: Attention - A uniline message which causes the 104B to interpret multiline messages as interface messages. When false, multiline messages are interpreted as device-dependent messages.

REN: Remote Enable - A uniline message which, when received with MLA, switches the 104B to remote. In remote the 104B front panel controls are deactivated.

DCL: Device Clear - A multiline message which is loaded into the input buffer. DCL sets the 104B to the following operating conditions:

- Autorange on
- Display Irms, Urms, P, PF
- AC-Coupling
- Continuous Sampling
- Averaging = 1
- Triggered measurement off

SPE: Serial Poll Enable - A multiline message which causes the serial poll data (rather than the output buffer data) to be transferred on the bus once ATN becomes false.

SPD: Serial Poll Disable - Removes the serial poll enable state.

Addressed Commands

GET: Group Execute Trigger - When executed, GET initiates a measurement (prior to GET the 104B must be programmed with K6).

GTL: Go To Local - Causes the 104B to switch to local (front panel) control.

SDC: Selected Device Clear - Identical to DCL, but is accepted to current listeners only.

3.20. Talk-Only Mode

The talk-only mode lets the user take advantage of the remote capability of the 104B without having to use an instrument controller.
If programming of the Talk-only output functions prior to Talk-only operation is required proceed to section 3.21 for programming instructions.
To put the 104B in the talk-only mode:

1. Turn the 104B power switch off.
2. Set the rear panel talk-only switch (bit 7 of address switch) to the up position (on).
3. Connect the 104B via the IEEE-488 bus to your data receiving device (listener hand-shake capabilities are required).
4. Turn the 104B power switch on.
5. Configure the 104B with the front panel controls. (The 104B can also be operated in the talk-only mode when in remote).

The 104B reads the talk-only bit switch on power-up and sends the programmed data in the programmed time interval. Data are also output when the "HOLD" state is entered.

3.21. Talk-Only Programming

The Talk-Only start-up procedure is described in section 3.20. The printer used must have IEEE-488 hand shake capabilities, otherwise data will not be transferred in an orderly manner.

The programming of the desired printer output is done as follows:

Step 1: Press "HOLD"

Step 2: Press "SCALE"

Step 3: Press "SAMPLING"
The present programming status is now displayed. "F 1 2 3..." and "H 1 2 3 ..." correspond to the output function commands on page 3.2 of this manual.
"Time xxx s" is the time interval for printer outputs (1 s to max 32670 s).

Step 4: Press now all those controls in the function control field (in center below the display) which give you the desired printer output (Ar, At, A =, Vr, Vt, V=, W, Va, VAR, PF, Wh, Z).
To terminate the output function selection press "ENTER".

In case you do not want to change the output functions shown on the display, you must still press "ENTER" to proceed to step 5.

Step 5: In this step the time interval is selected by pressing the appropriate number (0 1 2 ...) in the function control field below the display. The maximum number to be entered is 32760 s, larger numbers are truncated. To terminate the time interval selection press "ENTER". If no time interval change is required, press "RUN" to leave the Talk-Only programming mode.

Step 6: Press "RUN" to terminate the programming cycle.

Press "SAMPLING" to repeat the Talk-Only programming if desired. This brings you back to step 3. Furthermore, the described programming can be interrupted at any step by pressing "RUN".
To start the Talk-Only-Operation follow the procedure described in section 3.20.
In Talk-Only operation data are printed in the programmed time intervals. Furthermore, data are printed everytime the "HOLD" mode is entered.
By setting a long time interval, this way a manual printer activation is achieved whenever the "HOLD" control is pressed.