SYSCAL (V 11.4++)

Resistivity-meter with automatic voltage switch

-

Multi-Electrode mode

User's manual

November 2001

CONTENT

ANNEXES

MAINTENANCE

I. RESISTIVITY-METER AT A GLANCE

I.1.GENERALITIES

The SYSCAL type resistivity-meters range of *IRIS INSTRUMENTS* are fully automatic resistivity-meters ; they have been designed for intensive exploration of the ground thanks to DC electrical methods. They allow to study the variations of the resistivity in regards to the depth (vertical electrical sounding) together with the lateral variations observed along a profile (electrical profiling). They allow also to compute the chargeability (Induced Polarisation) of the ground.

Their compactness make these equipments very efficient to carry out intensive field measurements.
These equipments have two internal batteries, one for the circuitry supplying, and the other for the generation of the injection current, and can be also supplied by a 12 V external battery (car battery type) for this function.
To generate the current into the ground, the resistivity-meter use its internal converter, which will convert the 12 V of the battery (internal or external) by a greater value.

The measurement is made fully automatically through the control of a microprocessor:
- Automatic spontaneous polarization (Sp) correction
- Automatic ranging
- Digital stacking for signal enhancement
- Error display in case of procedure troubles

All the parameters like intensity, voltage, geometrical parameters, station number,… are stored in the memory. A serial link permits to transfer the data to a PC for data processing and interpretation.

Those resistivity-meters can be remote controlled through the serial link (reading of the stored measurement points, control of the whole functions). They can be also connected to an intelligent nodes network to be used as an automatic switching system (**Multi-Electrode** mode - cf. Annex 5).

These SYSCAL combine the power source, the transmitter and the receiver in the same housing (cf. I.2.2.).
They are specially designed for medium depth exploration and can be used in many civil engineering and ground water projects to solve problems such as depth to bedrock determination, weathered bedrock areas localization, clay-gravel determination, shallow aquifer depth and thickness determination, salinity control and pollution monitoring.

The resistivity-meters concerned by this manual are the SYSCAL Junior (Jr) and R1 Plus.

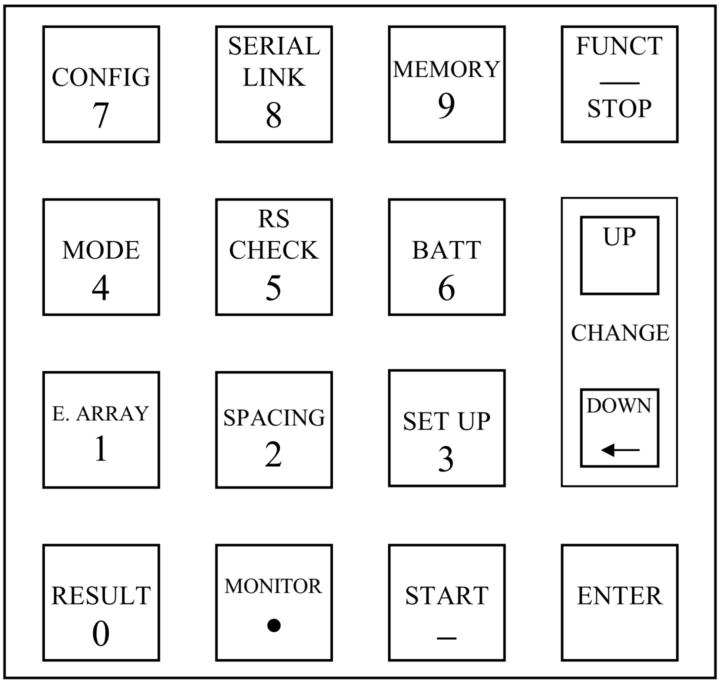
I.2. GENERAL DESCRIPTION

For these resistivity-meters, the full control is made from their front panel:

- A 16-key function and numeric keypad:
  The function keys are used for setting the unit up, starting and stopping the measurement, managing the internal memory.
  The numeric keys are used for introducing data such as the station numbers, the lengths of the lines, etc...
- A two-line 20 characters alpha numeric LCD display
- A three pins plug (SERIAL LINK) for the PC communication
- Plugs to connect the electrodes (in standard mode, or for the remote electrodes in **Multi-Electrode** mode):
  A,B for the current electrodes (C) – M,N for the potential electrodes (P)
- A connector (Rx) for the charge of the system battery
- A connector (Tx) for the charge of the transmitter battery
- Tow plugs for the connection of an external battery for the current generation (Tx)
- Warning led for the Tx battery

I.2.1. KEYBOARD

The keyboard of these resistivity-meters features some keys designed to be used either in **numeric** or in **function** mode. No confusion can be done between these modes, because the device knows precisely, at any step of the use, in which mode it has to set itself:



Then, the resistivity-meters are driven by the operator through interactive menus.

Note:
The description of these keys is relative to the standard mode (for the Multi-Electrode mode, cf. Annex 5).

The function keys of the keyboard allow to select a menu, the "UP" and "DOWN" keys permit to scroll up and down in the current menu and the "ENTER" key permits notably to select an option of the menu.

→ Some operations have to be carried out at the beginning of a survey:

BATT:	to check the voltage of the system battery. This operation has to be repeated from times to times
MODE:	to select the operating mode (Standard or **Multi-Electrode**)
SET UP:	to select the timing parameters and the reception voltage desired
E. ARRAY:	to select the electrode configuration that will be used (Dipole-Dipole, ...)
CONFIG:	to select the type of parameters that will be displayed during the acquisition
MONITOR:	to visualize the level of ambient noise

→ The following operations have to be carried out at each new measurement:

SPACING:	to introduce the geometrical parameters (line lengths, station number...)
START:	to start the injection of current ; intensity, voltage and dispersion of readings will be displayed at each new stack
STOP:	to stop the injection of current
RESULT:	to read the average values of the previous parameters, the apparent resistivity and eventually the chargeability
MEMORY:	to store the data into the internal memory

→ For the communication

SERIAL LINK: to transfer the data and to operate in remote control

I.2.2. SUPPLYING

→ The SYSCAL resistivity-meter owns two internal batteries, whose the characteristics are the following ones: 12 V – 7 Ah
- One battery is used to supply the electronics (Rx connector for the recharge)
- One battery is used to supply the transmitter (Tx connector for the recharge)

Note that the internal batteries have to be periodically recharged (or changed if necessary), even if they haven't be used during a long time.
The battery chargers delivered with the resistivity-meter permit to charge seal lead-acid 12 V batteries up to 24 Ah. This charger must be supplied by 220 or 110 V – 50 Hz (an inside switch permits the selection) ; a green led lighted off on the chargers will notify that the batteries are fully charged.

→ Lithium pile:
A ten years long life lithium dry cell (3.6 V) located on the CPU board prevents from loosing the data kept in the instrument memory when the battery is discharged or when the instrument is no more supplied (internal battery taken out and external battery not connected).

→ For the generation of current:
Use of the Tx internal battery or 1 external 12 V battery, car battery type

In case of an external battery is used, its voltage doesn't have to overcome 15 V. Above this value, permanent damage can occur in the unit. The instrument has an internal protection against reverse of external battery polarity, so in such a case, it won't be supplied and only the external battery can be damaged.

Important note about the Tx battery:
Internal battery autonomy (7 Ah with 200 mA / 400V injected): about 1 h of measure
External battery autonomy (40 Ah with 200 mA / 400V injected): about 6 h of measure
An intensive use of the SYSCAL requires so the connection of an external battery to supply the transmitter ("+", "-" plugs of Tx).

The current injection value is established by the introduction of a voltage value the user wishes to receive. The injection current and voltage values will so get determined automatically in regards to that parameter (this has to be chosen in the "SET UP" function).

Available choices of the V_{MN} range value:
- « Save energy » mode : battery saving mode : Vmn minimum
- 50 mV
- 150 mV
- 300 mV
- Max Vmn value

Important remark:
The « Save energy » mode will permit to get a good quality of measurement in most field configurations and save in the same time the transmitter battery.
However, in the following cases, it could be judicious to select rather a Vmn range of "300 mV" or "Max":
- Use of large spacing between the electrodes (4 or 5 meters)
- Use of an array where the reception voltage values drop quickly with the increasing of the spacing between the injection and reception dipoles (case of the dipole-dipole).
- Wish of reaching large investigation depth

This type of SYSCAL has an automatic process about the reception voltage measurement. If a Sp (spontaneous polarization) variation appeared between the two first pulses, a greater value for the injection voltage will be used.

II. SET UP

II.1. GENERAL SET UP

Procedure to follow:

→ Connect the wires and electrodes for current (A, B) and potential (M, N) according to the electrode array you chose (cf. II.5.).
Try to get a good contact between the electrodes and the ground. In particular, the resistance of the potential electrode circuit should be less than 20 kohm.

→ Set the unit on a dry place, if possible. Protect it against the direct radiation of the sun in case of high temperature.

→ Make sure that the internal batteries are in good condition.

Switch the unit ON: a message should be appear during a while «SYSCAL Jr (V 11.2a)» followed by: "Select Function".

Check the level of the internal supply by pressing the "BATT" key: the following message appears:

Rx battery = 12.24 V capacity = 72 %

A full charge will indicate: 12.7 V – 100%
A null charge will indicate: 10 V – 0%

Press any key to come back to the "Select Function" message.

The battery voltage of the system is continuously tested during the injection of current.

The unit won't operate if the value is lower than 10.5 V ; the following message will be displayed after the "ENTER" key has been pressed:

POWER FAILED

However, if the voltage drops down 11.5 V after the injection, the following message will be displayed each time the "START" key will be pressed:

LOW BAT

But the instrument will operate without any problem as long as the limit value is not reached.

<u>Note</u>:
About the transmitter battery (Tx), a led will warn the user of a too low voltage (green/red winking if the value is between 10 and 11V and red if the value is below 10V).

II.2. GENERAL USE OF THE KEYBOARD

The unit is driven by the operator, through interactive menus, which are selected by the function keys of the instrument. To select a given function, first press the "FUNCT/STOP" key, and then the function key ("BATT", "SPACING", "START"...).

To scroll up and down in the menu, use the "UP" and "DOWN" keys. A prompt ">" in front of the option of the menu indicates the option that will be used if the "ENTER" key is pressed at this stage.

If a numeric value is expected, use the numeric keys ("0", "1",..., "9","-", "•") to enter the value. In case of error, use the backspace ("←") key to correct the wrong digit introduced. When the value has been corrected, use the "ENTER" key to validate the new value displayed. When a numeric value is expected at the current stage of the menu, it is not possible to escape from the menu and go to another function.

It is always possible to switch the instrument off at any stage of the operating procedure. The data that have been introduced before the instrument has been switched off will remain available after the instrument is switched on again.

II.3. CURRENT WAVEFORM SELECTION ("MODE" FUNCTION)

The various modes available in the resistivity-meter SYSCAL *Switch* type are the following ones:

- Rho
- Rho and IP
- Multi-Electrode:
    - Rho
    - Rho and IP

The **Rho mode** allows to inject alternatively into the ground a succession of positive and negative current pulses. This mode allows to inject a current between the A,B electrodes, to measure a potential between the M,N electrodes and to compute thus the apparent resistivity.

The **Rho and IP mode** allows to inject alternatively into the ground a succession of positive and negative current pulses. with cut-off between each of them. This mode allows to inject a current between the A,B electrodes, to measure a potential between the M,N electrodes and to compute thus the apparent resistivity and the global chargeability.

The **Multi-Electrode** mode has to be selected if you wish to work in automatic switching mode. In that mode, the function keys have different menus than from the previous modes (called standard mode) ; please cf. annex 5 for further information.

- The ***Rho mode*** has to be selected for resistivity only measurements.
- The ***Rho and IP mode*** has to be selected for resistivity and IP measurements.

<u>Warning</u>:
When you swap between the standard mode and the Multi-Electrode mode, the following message will be displayed:
"New mode ?: CLEAR MEM
Confirm: <09-7>".
So, it will be necessary to delete all the data stored in the memory. So, take care to transfer the data before doing this operation (Cf. Annex. 3).

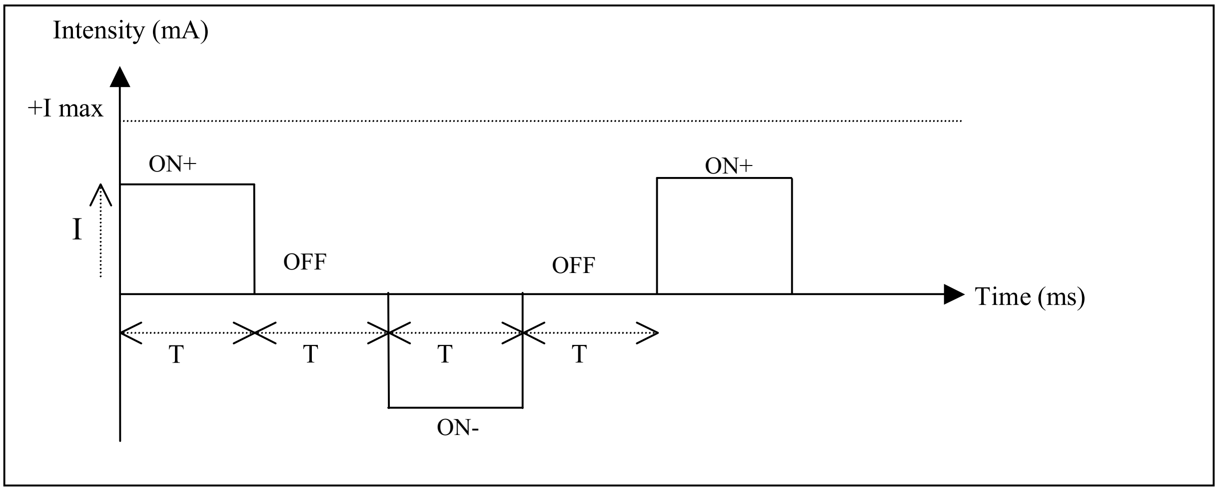


Figure 1: Current waveform: Rho mode / Multi-Electrode (Rho mode) (ON+, OFF, ON-, OFF)

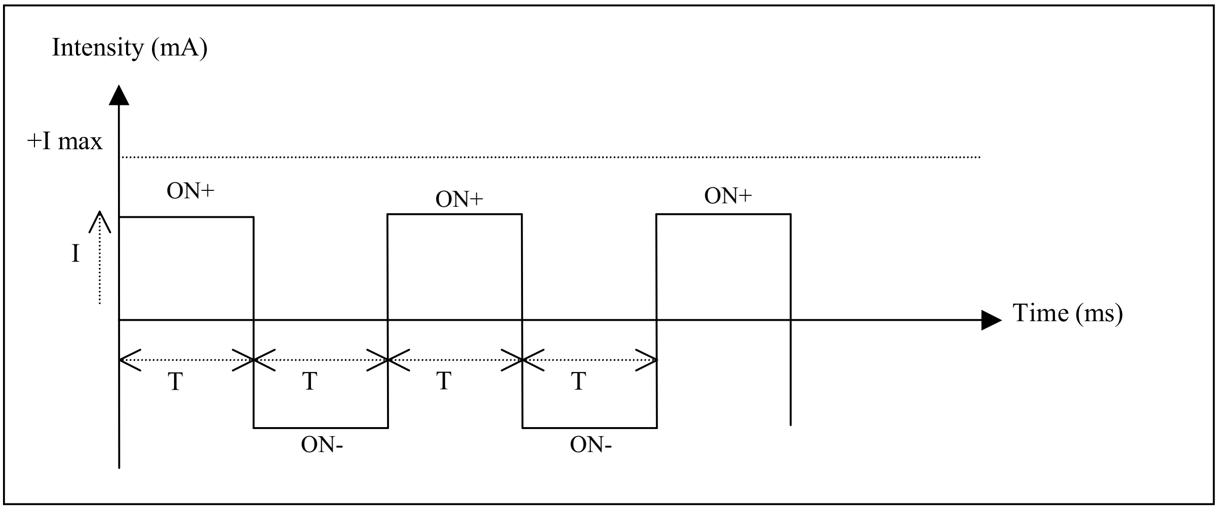


Figure 2: Current waveform: Rho and IP mode / Multi-Electrode (Rho and IP mode) (ON+, ON-)

<u>Note</u>:
The following paragraphs are referred to the standard modes. About the Multi-Electrode mode, please refer to the annex 5.

II.4. TIMING PARAMETERS SELECTION ("SET UP" FUNCTION)

In standard mode, two programming options are available.

II.4.1. PRESET TIMES OPTION

Rho / Rho and IP modes:

In that menu, it is possible to select one of the preset pulse duration values which are: 250 ms, 500 ms, 1000 ms and 2000 ms (use the "UP" and "DOWN" keys to select and the "ENTER" key to confirm your choice). Note that for the 250 ms duration, no IP measurement will be made.

In principle, the final result is independent of this duration. However, long durations better eliminate effects due to transient responses: setting up of the current, induced polarization responses, electromagnetic coupling (especially in case of a conductive ground and of long transmitting lines). The best quality of measurement is obtained with the 2000 ms time. However, if a precision of a few percents is sufficient, which is the case in most applications, times of 1000 or 500 ms can also be used. The interest of short times is the large numbers of readings that are displayed, which lead to quicker measurements. It is recommended not to change the pulse duration in a given set of readings, in order to keep the measurements more homogeneous.

After the choice of the injection current time, the number of stacks to do for each measurement has to be specified:
This option permits to make automatic acquisition by optimizing quality, time and battery autonomy. It's a criterion of quality measurement (cf. Annex 2)

Range 1/249 Stacks min : 3

Key in the value for minimum number of stacks and press the "ENTER" key.

Range 3/249 Stacks max : 10

Key in the value for maximum number of stacks and press the "ENTER" key.

Range 0/100 Q max (%) : 3

Key in the value for the maximum standard deviation of the measurement desired and press "ENTER".

Set TX power for : "Save energy" mode

Select the reception voltage range desired thanks to the "UP" and "DOWN" keys. The value of the injected current will be established automatically in regards to that parameter.

Note:
The **Rho and IP** mode allows to realize more an induced polarization measurement (IP) ; the Preset times option sets the IP parameters to default values (cf. Annex 2).

II.4.2. PROGRAMMABLE TIMES OPTION

✓ **Rho mode**:

In that menu, you'll have the possibility to choose the pulse duration in the following range:

```
Range 250/10000
Time (ms) = 3000
```

Introduce the required value and then press the "ENTER" key.

You'll have then to select the V_DLY time, which is the time from which samples (sampling rate: 10ms) will be taken into account after the injection began, both for intensity and voltage measurements:

```
Range 150/2990
V_DLY (ms) = 1500
```

Taking a long delay time will permit to be sure that all transient effects like IP and EM responses will be vanished when samples for primary voltage will begin to be taken into account.

Then,

```
Range 1/249
Stacks min : 3
```

Key in the value for minimum number of stacks and press the "ENTER" key.

```
Range 3/249
Stacks max : 10
```

Key in the value for maximum number of stacks and press the "ENTER" key.

```
Range 0/100
Q, E max (%) : 3
```

Key in the value for the maximum standard deviation of the measurement desired and press "ENTER".

```
Set TX power for :
"Save energy" mode
```

Select the reception voltage range desired thanks to the "UP" and "DOWN" keys. The value of the injected current will be established automatically in regards to that parameter.

✓ **Rho and IP mode**:

In that menu, you'll have the possibility to choose the pulse duration in the following range:

Range 250/10000 Time (ms) = 3000

Introduce the required value and then press the "ENTER" key.

You'll have then access to the IP parameters (cf. Annex 2):

You'll have then to select the V_DLY time, which is the time from which samples (sampling rate: 10ms) will be taken into account after the injection began, both for intensity and voltage measurements:

Range 150/2990 V_DLY (ms) = 1500

Taking a long delay time will permit to be sure that all transient effects like IP and EM responses will be vanished when samples for primary voltage will begin to be taken into account.

Select the M_DLY parameter that is the time from which the samples in voltage measurement (sampling: 10ms) will be taken into account after the current cut off:

Range 20/2930 M_DLY (ms) = 100

Then enter the widths of the four partial IP windows: this will allow to compute the global average chargeability (cf. Annex 2).

Range 10/2840 T_M1 (ms) = 200

Range 0/2640 T_M2 (ms) = 500

Range 0/2140 T_M3 (ms) = 800

Range 0/1340 T_M4 (ms) = 1000

Then,

Range 1/249 Stacks min : 3

Key in the value for minimum number of stacks and press the "ENTER" key.

Range 3/249 Stacks max : 10

Key in the value for maximum number of stacks and press the "ENTER" key.

Range 0/100 Q, E max (%) : 3

Key in the value for the maximum standard deviation of the measurement desired and press "ENTER".

Set TX power for : "Save energy" mode

Select the reception voltage range desired thanks to the "UP" and "DOWN" keys. The value of the injected current will be established automatically in regards to that parameter.

The following tables sum up the various operating modes of the SYSCAL *Switch* type resistivity-meter .

	Standard mode	
MEASURING TYPE	Apparent resistivity measurement	Apparent resistivity and chargeability measurement
CURRENT WAVEFORM	ON+, ON-	ON+, OFF, ON-, OFF
MODE SET UP	**Rho**	**Rho and IP**
PRESET TIMES	Select T among: 250, 500, 1000, 2000 (ms)	Select T among: 500, 1000, 2000 (ms)
	V_DLY automatically determined	V_DLY, M_DLY, T_Mi automatically determined (cf. Annex 2 for the IP parameters)
PROGRAMMABLE TIMES	To specify: T, V_DLY	To specify: T, V_DLY, M_DLY, T_Mi

Table 1: Standard mode: Selection of the parameters thanks to the "MODE" and "SET UP" keys.

	Multi-Electrode mode	
MEASURING TYPE	Apparent resistivity measurement	Apparent resistivity and chargeability measurement
CURRENT WAVEFORM	ON+, ON-	ON+, OFF, ON-, OFF
MODE SET UP	**Rho**	**Rho and IP**
PRESET TIMES	Select T among: 250, 500, 1000, 2000 (ms)	Select T among: 500, 1000, 2000 (ms)
	V_DLY automatically determined	V_DLY, M_DLY, T_Mi automatically determined (cf. Annex 2 for the IP parameters)

Table 2: Multi-Electrode mode:: Selection of the parameters thanks to the "MODE" and "SET UP" keys.

II.5. ELECTRODE ARRAY SELECTION ("E. ARRAY" FUNCTION)

The common electrode arrays have been introduced into the operating program of the instrument, so that apparent resistivity values can be directly computed by the instrument. These electrode arrays, described in Annex 1, can be listed on the display by pressing the "E.ARRAY" key and the "UP" and "DOWN" keys. The location of the electrodes for each array is described in table 3.

The selection of an electrode array is done placing ">" on the corresponding line and validating by the "ENTER" key.

II.6. OPTIONS SELECTION ("CONFIG" FUNCTION)

Various options, which generally don't have to be modified frequently, are available through the "CONFIG" key.

→ Type of IP values:
Raw: the true chargeability values will be displayed during the measurement (generally used)

Normalized: the chargeability values that will be displayed will be referred to a standard IP decay curve (see Annex 2). This type is not available in the "Programmable times" option (so not in the **Multi-Electrode** mode).
The two types of values will be able to be displayed at the end of the measurement (thanks to the "RESULT" or the "MEMORY|READ" functions (cf. III.6.)).

→ Type of readings:
Running: the values displayed during the measurement will be the average values of the three latest consecutive pulses. After having stopped the acquisition, the average value of all previously displayed readings will be computed. This option permits to continuously monitor the natural or artificial electric noise superimposed to the actual signal to be measured (generally used).

Cumulative: the values displayed during the measurement will be the average values of all the pulses from the beginning of the measurement. This option permits to check that the average value converges toward the actual signal to be measured, if the noise of course is not too strong.

→ Sign of voltage:
Unsigned: the primary voltage will be given at the end of the measurement in absolute value, whatever the polarity of the MN actual voltage is compared to that of the AB current (generally used).

Signed: the sign of the voltage/intensity ratio (that is to say of $(V_M-V_N)/I_{AB}$) will be affected to the value of the primary voltage and also to the resistivity.

→ Type of grid unit:
Metric: the spacings will have to be introduced in meters, the apparent resistivity value will be computed in Ohm.meters (generally used).

Foot: the spacings will have to be introduced in feet, the apparent resistivity value will be computed in Ohm.meters (recall: 1 foot = 30.48 cm)

III. MEASUREMENT

III.1. GEOMETRICAL PARAMETERS INTRODUCTION ("SPACING" FUNCTION)

After the selection of the electrode array has been done with the "E.ARRAY" key, one must introduce the lengths of the lines so that the instrument can compute the apparent resistivity values after the measurement has been taken. Also, station and line numbers can be introduced.

This operation is possible by pressing the "SPACING" key ; the asked parameters are mentioned for each electrode array with their definition in table 3.

The name of the parameter to be introduced is displayed on the LCD. Key in its value with the numeric keyboard. In case a wrong number is introduced, press the backspace key ("←") that will clear the last figure displayed. When the value has been correctly introduced, press "ENTER" and introduce the value of the next parameter.

Example (Schlumberger sounding):

AB/2 = 5	ENTER
MN/2 = 1	ENTER
Line = 17	ENTER
Opt1 = 1	ENTER

Note:
In that case, the line number can be the number of the sounding. The maximum allowed value is 999.

The first geometrical parameter displayed is the one that changes most during successive measurements: the parameters that do not change from one measurement to the following one do not have to be re-introduced. Just press "ENTER" to confirm their values.

ELECTRODE ARRAY	GEOMETRICAL PARAMETERS			
Dipole-Dipole	XC	XP	D	Line
Pole-Dipole	XC	XP	D	Line
Pole-Pole	XC	Li C	Li P	CP
Grad. RCTGL	XP	Line	± D	AB/2
Schlum. VES	AB/2	MN/2	Line	Opt 1
Schlum. PRF	X	AB/2	MN/2	Line
Wenner VES	AB/3	Line	Opt 1	Opt 2
Wenner PRF	X	AB/3	Line	Opt 1
Hole surf.	Li X	Li Y	MN/2	Ref
Other	K	Opt 1	Opt 2	Opt 3

Table 3: Geometrical parameters for each electrode array

AB/2 : half-distance between A and B.
AB/3 : a third of the distance between A and B.
MN/2 : half-distance between M and N.
D : length of MN dipole. In Dipole-Dipole, common length of dipoles. In Grad. RCTGL, D can be positive or negative and sets the position of N (|D| = |MN|).
X: : abscissa of the center of MN, the direction is AB and the origin is 0 an arbitrary point of AB line.
Line : float number allowing a distinction between two profiles during storage. In Grad. RCTGL, Line is the ordinate of potential electrodes. The origin 0 is the middle of AB (abscissa axis 0x = AB line).
XC : abscissa of the nearest injection electrode from the MN dipole.
CP : distance from B to M for the Pole-Pole (electrodes A and N considered very far)
XP : - in Dipole-Dipole and Pole-Dipole, abscissa of the nearest receiving electrode, from the AB dipole.
- in Grad. RCTGL, abscissa of M receiving electrode, the origin 0 is the middle of AB and the abscissa axis 0x is the AB line.
Li C : float number allowing a distinction between different profiles of C (for Pole-Pole lateral).
Li P : float number allowing a distinction between different profiles of P (for Pole-Pole lateral).
Li X : float number in the X direction allowing to parameter the common point N of the potential dipoles M N and M' N.
Li Y : float number in the Y direction allowing to parameter the common point N of the potential dipoles M N and M' N.
Ref : the Hole surf. array uses two perpendicular dipoles ; Ref serves to distinguish between the dipoles during a storage. In Hole surf., the geometrical factor K is taken arbitrarily at 1000.
Opt 1 : float number (optional) defined by the operator as he wants.
Opt 2 : float number (optional) defined by the operator as he wants.
Opt 3 : float number (optional) defined by the operator as he wants.
K : geometrical factor

Remarks:

• *When the electrode array is modified, the geometrical parameters are re-initialized to zero. In that case, it is necessary to introduce anew all these parameters.*

• *The "metric" reminds that the length should be introduced in meters ; the "foot" indication reminds that the length should be introduced in feet (cf. III.6.).*

• *In the "Other" array, the operator has to introduce by himself the geometrical coefficient of the quadripole he is using (K =...). This option can be used for instance in case of downhole measurements with short normal (spacing 16 inches, K = 5.11m) or long normal (spacing 64 inches, K = 20.43m) arrays.*

• *The "Opt" parameters are optional parameters that the operator can define as he wants.*

III.2. GROUNDING RESISTANCE MEASUREMENT ("RS CHECK" FUNCTION)

Before transmitting the current, it’s advisable to check that the electrodes are correctly connected to the instrument. The ground resistance of the electrodes can be checked by pressing the "RS CHECK" key: the measurement is made between the A and B plugs of the SYSCAL.

The value will be given in kohm (if this one is greater than 1 Mohm (electrodes not connected), the SYSCAL will display an unstable value "R = xxx.xx").

It’s recommended to operate with the lowest possible values of ground resistances, both for A, B and for M, N electrodes (a value lower than 3 kohm is a good value ; 20 kohm should be considered as a value that shouldn’t be exceeded).

Please note that the spontaneous polarization (Sp) is automatically compensated during the earth circuit resistance measurement.

III.3. NOISE MONITORING ("MONITOR" FUNCTION)

It is possible to check the level of noise between the receiver electrodes (M,N) before the measurement by pressing the "MONITOR" key. This option features a voltmeter function. The value of the voltage coming from the ground without the unit transmitting any signal will be displayed in mV. This allows to estimate the signal level of ambient noise and spontaneous polarization.

Vmn = 0.6 mV

By pressing the "ENTER" key, the relative value will be displayed, that is to say the difference between the observed voltage and the reference value:

Vmn = 0.0mV	REL

To come back to the absolute value, press "ENTER" again.

Press the "FUNCT/STOP" key to come back to the "Select Function" message.

III.4. START/STOP OF MEASUREMENTS

The voltage of the system battery is automatically checked before a measurement ; in case this voltage is low, a displayed message will warn the operator (cf.II.1.).
For each operating modes, some displays are specific. The **Multi-Electrode** mode is described in the Annex 5.

III.4.1. RHO MODE

The unit generates the current between A-B electrodes and measures the voltage between M-N electrodes in order to compute the apparent resistivity.

To start the injection of current press the "START" key:

Sp = 3 HV = 400V - - -

With,

Sp: spontaneous polarization value measured just before the injection, in mV
HV: high voltage supplied (V_{AB}) – The dashes mean that the first pulses of current are being transmitted. This message is displayed during three pulses (cf. III.5.3.).

During the acquisition (after the first three pulses, the display will be:

v = 26.4	i = 13.5
q = 0	# 3

With,

v: measured voltage between M and N, in mV
i: intensity of the transmitted current between A and B, in mA
q: standard deviation of the v/i ratio that is to say also the standard deviation of the apparent resistivity, in %
#: running number of stacks

The display will change, at each new pulse, with values of v and i, which can be slightly different, if there is some ambient noise in the field.

The current is injected until the stacks min (or the stack max) has been reached. The "FUNCT/STOP" key can be also used to stop the measurement at the end of the running half cycle (1 half cycle = 1xTIME).

After acquisition, the results of the latest measuring point can be visualized pressing the "RESULT" key:

V = 26.371	Sp = 0
I = 13.46	

With,

V: average value of the reception voltage V_{MN}, in mV
I: average value of the transmitted current I_{AB}, in mA
Sp: spontaneous polarization value measured just before the injection, in mV

And to have access directly to the resistivity value, press the "ENTER" key:

Rho = 304.6
Q = 0

With,

Rho: apparent resistivity value computed from the previous V and I values, in Ohm.m
Q: standard deviation of the resistivity (quality factor), in %

It is then possible to come back to the first display of the "RESULT" function by pressing the "ENTER" key again.

III.4.2. RHO AND IP MODE

The unit generates the current between A-B electrodes and measures the voltage between M-N electrodes in order to compute the apparent resistivity and the global chargeability (IP).

The changes relative to the previous mode are the following ones:

During the acquisition (after the three first pulses), the display will be:

v = 26.4	i = 13.5	
m = 14	q = 0	# 3

With,

v: measured voltage between M and N, in mV
i: intensity of the transmitted current between A and B, in mA
m: global chargeability, i.e. the weighted average of the partial chargeabilities, in mV/V (‰)
q: standard deviation of the v/i ratio that is to say also the standard deviation of the apparent resistivity, in %
#: running number of stacks

The current is injected until the stacks min (or the stack max) has been reached. The "FUNCT/STOP" key can be also used to stop the measurement at the end of the running half cycle (1 half cycle = 1xTIME).

After acquisition, the results of the latest measuring point can be visualized pressing the "RESULT" key:

V = 26.371	Sp = 0
I = 13.46	

With,

V: average value of the reception voltage V_{MN}, in mV
I: average value of the transmitted current I_{AB}, in mA
Sp: spontaneous polarization value measured just before the injection, in mV

And, to have access directly to the resistivity and chargeability values, press the "ENTER" key:

Rho = 304.6	
Q = 0	M = 13.9

With,

Rho: apparent resistivity value computed from the previous V and I values, in Ohm.m
M: average value of the global chargeability, in mV/V (‰)
Q: standard deviation of the resistivity (quality factor), in %

Once more "ENTER" key:

M_1 = 37.1	M_2 = 25.1
M_3 = 14.6	M_4 = 7.3

With

Mi: average value of the partial chargeability "i", in mV/V (‰)

<u>Remark</u>:
The number of partial chargeability windows used for the measurement depends on the current injection time, in the "Preset times" option (cf. Annex 2).

It is then possible to come back to the first display of the RESULT function by pressing the "ENTER" key again.

<u>General remarks</u>:

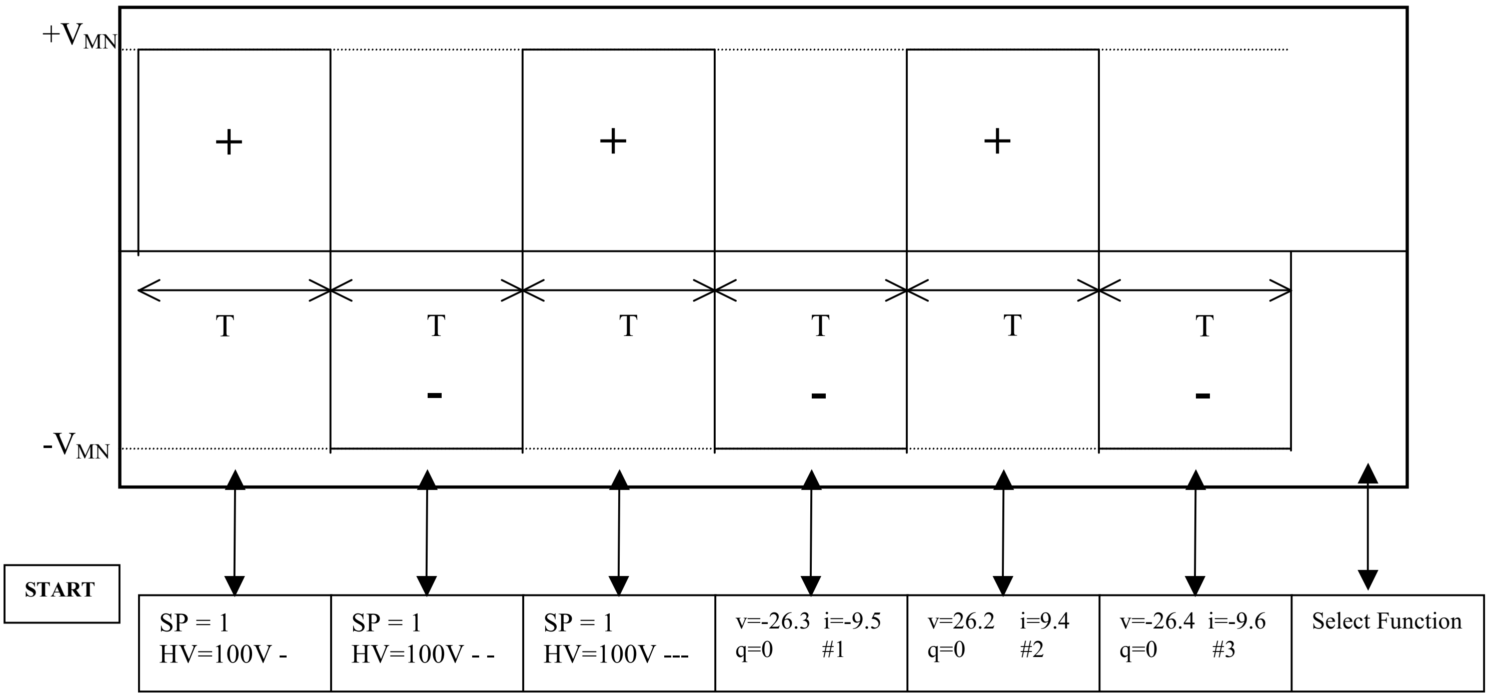
- *If the voltage overcomes the limit value(due to a quick variation of Sp for example) , the "OVLD" message will be displayed during the measurement (instead of the running stacks number). In that case, the operator will have to increase the grounding resistance of the current electrodes or to decrease the length of MN.*

- *If the geometrical parameters have not been introduced before the measurement, the apparent resistivity can't be computed and the "RO = ****" message will be then displayed. It is then possible to introduce the parameters ("SPACING" key) and read the value of resistivity ("RESULT" key) without having to make a new measurement.*

<u>Warning</u>:
The DC-DC internal converter that permits to increase the voltage of the battery features a thermal circuit breaker that stops the injection of the current as soon as the temperature overcomes 90° C. Then, the displayed values of the voltage and of the current will be equal to zero. Please wait for the instrument to be cooled before going on with the measurements.

III.4.3. MEASUREMENTS DISPLAYS

<u>Example</u>:
Rho mode: ON+, ON-
Injection Time: T
Stacks min: 3



III.5. GENERAL REMAKS ABOUT THE DISPLAYED VALUES

<u>During the acquisition</u>:

• In case the "Running values" option has been selected in the "CONFIG" function (cf. II.6.), the displayed values of the voltage and of the current intensity during the acquisition are: v and i instead of respectively V and I (used for "Cumulative values" option) to remind that they correspond to running values.

• Those resisitivity-meters have an "intelligent initiative" during the measurement:
When the signal is greatly disturbed by noise, the message "NOISE OR ERROR TIME" is displayed, the current data are kept and the measuring process is tried again. This operation avoids bad quality measurements and permits to work without loosing too much time by keeping the running data. The instrument will go on measuring when the working conditions will be correct.

<u>After the acquisition</u>:

In case the "Normalized values" option has been selected in the "CONFIG" function, the displayed values by the "RESULT" function about the chargeability will be: N, Ni, instead of M, Mi ("Raw values") to remind that they correspond to normalized values.
The two types can be displayed for a measurement with the "RESULT" or the "MEMORY/READ" functions (in case of stored data reading) only by selecting the corresponding option.
In case of data transfer, one must care to select the desired option before the operation.

IV. USE OF THE INTERNAL MEMORY

The operations concerning the internal memory of the unit are controlled by the "MEMORY" and "SERIAL LINK" keys. They are common to all the resistivity-meters SYSCAL *Switch* type
With the "MEMORY" key, it is possible to "STORE" a reading, to "READ" a reading previously stored and to "CLEAR" the internal memory. Use the "UP" and "DOWN" keys to scroll up and down in that menu and the "ENTER" key to validate (Figure 3 shows these various possibilities).

With the "SERIAL LINK" key, it is possible to transfer the data to a printer or a computer and to control the unit through a computer.

IV.1. DESCRIPTION

The instrument features a working area, a reading zone and a memory divided into 818 storage areas.

In the working area, the operator can perform all the functions described in parts II and III.

In the reading area, it is possible to read some data previously stored. The reading of a storage zone doesn't delete the previous working area. So it is possible to read a memorized data without loosing the working data area. Accordingly, it is impossible to delete or change any value for a stored measurement.

Remark:
All the operations using the memory must be validated by pressing the "ENTER" key.

This memory structure is displayed in the figure 3:

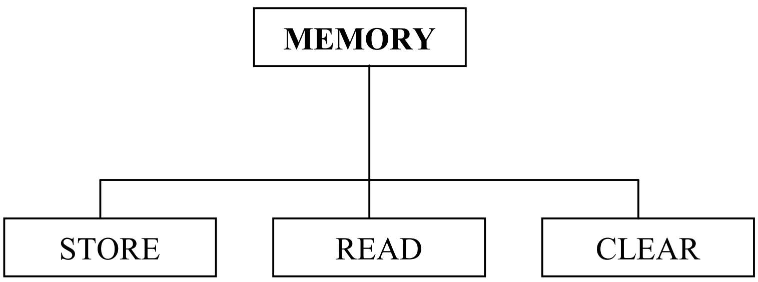


Figure 3: Options of the "MEMORY" menu

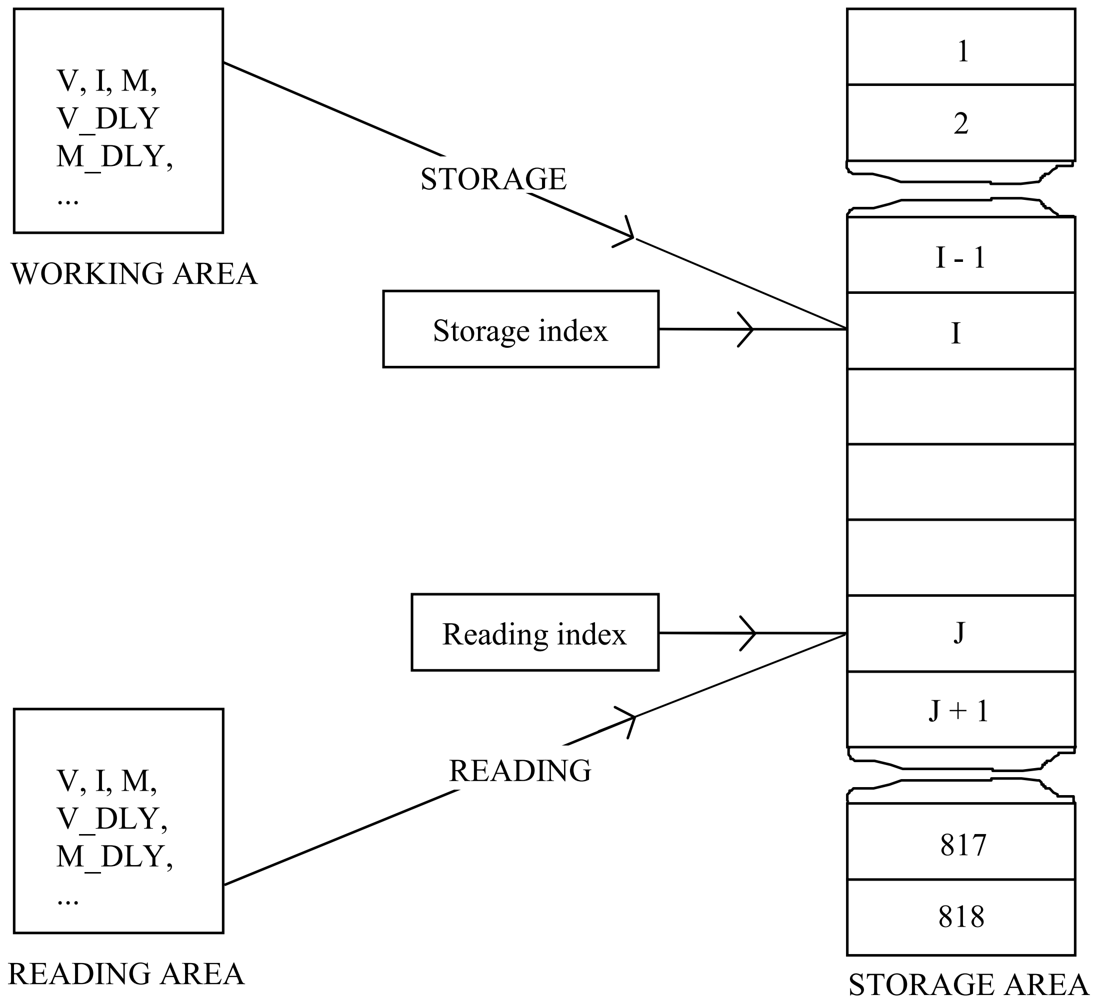


Figure 4: Structure of the internal memory

IV.2. DATA STORAGE ("MEMORY" FUNCTION)

Select the "MEMORY|STORE" function by pressing "ENTER" key when the prompt ">" is in front of the "STORE" line.
The display will be then:

```
RANGE 1/818
Store # 1
```

The first line of the display reminds that the memory can accept a total of 818 readings. The second line indicates in which storage area the current set of data will be stored if the "ENTER" key is pressed (#1 in this example). In order to make easier the storage, this index is automatically incremented after each new storage ; however, it can be modified at any time, if required, by pressing the backspace key ("←") and then by introducing the new number with the numeric keyboard and finally by pressing the "ENTER" key.

After the "ENTER" key has been pressed, the display will be:

DATA STORED IN # 1

This confirms that the data have been stored in area #1 of the memory. Each set of data stored includes the type of array used, the lengths of the lines, the voltage, the current, the spontaneous polarization, the standard deviation and the timing parameters (pulse duration, and V_DLY and eventually M_DLY and T_Mi – cf. Annex 2).
The apparent resistivity and the global chargeability are not stored because they are easily re-computable from the memorized parameters.

Remarks:
• *Trying to store a set of data in a memory zone already full (by changing the number during the "STORE" operation), involves such a display:*

Clear previous data? Yes: Enter   No: Change

Then the operator answers but let's note that the storage of measurements in this memory already full (by pressing the "ENTER" key) deletes the data set previously stored in this memory zone.

• *The microprocessor board of these types of resistivity-meter includes a ten years long life lithium battery. This battery saves the data in the memory when the internal battery is taken out of the instrument to be replaced.*

IV.3. DATA READING ("MEMORY" FUNCTION)

It is possible to display data which have been previously stored in the internal memory, through the "MEMORY|READ" function.

Press the "ENTER" key when the prompt ">" is in front of the "READ" line. The display will be:

RANGE 1/818 Read # 15

Select the storage area you wish to read. This index is automatically incremented at the end of each reading ; however, it can be modified at any time, if required, by pressing the backspace key ("←") and then by introducing the new number with the numeric keyboard and finally by pressing the "ENTER" key.

Note that the index used in the "STORE" and "READ" procedures are completely independent.

After the "ENTER" key has been pressed, all the information corresponding to the set of data recalled, can be visualized by successively pressing the "ENTER" key. The apparent resistivity and the global chargeability although not stored in the memory, are re-computed and displayed in the "READ" procedure.

If an attempt is made to read data in a memory area where no datum point has been stored, the message will be:

Read # 120 no data

IV.4. MEMORY ERASING ("MEMORY" FUNCTION)

The memory can be completely deleted by using the "MEMORY|CLEAR" function. Since this operation is irreversible (after clearing the memory, all data are definitively lost), it must be performed with care.

Press the ENTER key when ">" is in front of "CLEAR". The display will be then:

Clear memory ? Confirm : <09-7>

Press successively the "0", "9", "-" and "7" keys to clear the memory. Let's note that such an operation doesn't affect the working area that keeps its stored measurements.

To escape from the clearing procedure (when this clearing is not desired), press any key.

In short, all the "MEMORY" options are depicted in figure 5.

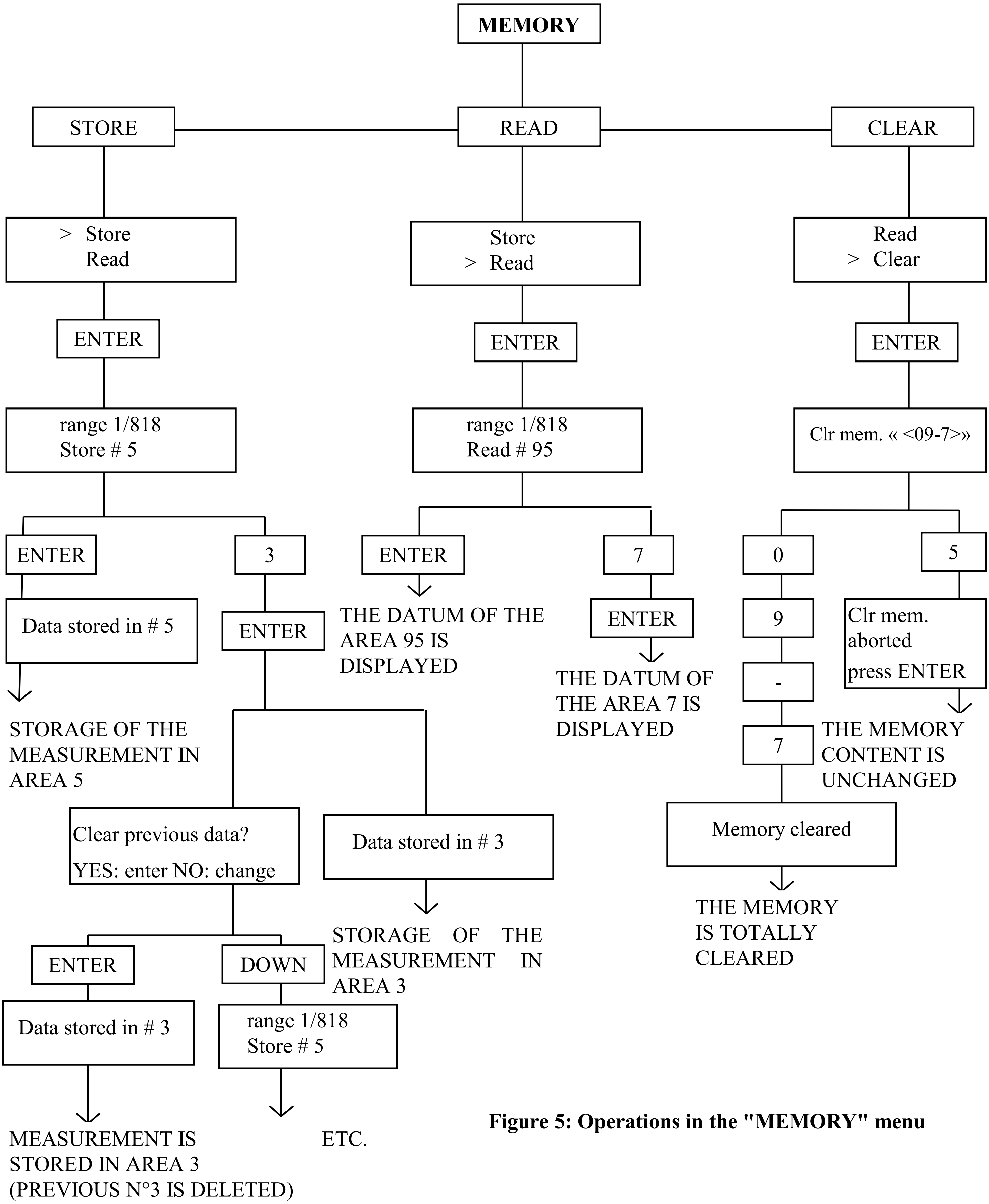


Figure 5: Operations in the "MEMORY" menu

IV.5. DATA TRANSFER ("SERIAL LINK" FUNCTION)

The data stored in the internal memory of the unit can be transferred to a PC through a RS232 link. This function is controlled by the "SERIAL LINK" key. The options available in that menu are the following ones (use the "UP" and "DOWN" keys to scroll up and down): "BAUD RATE", "DUMP HEXA", "SERVER".

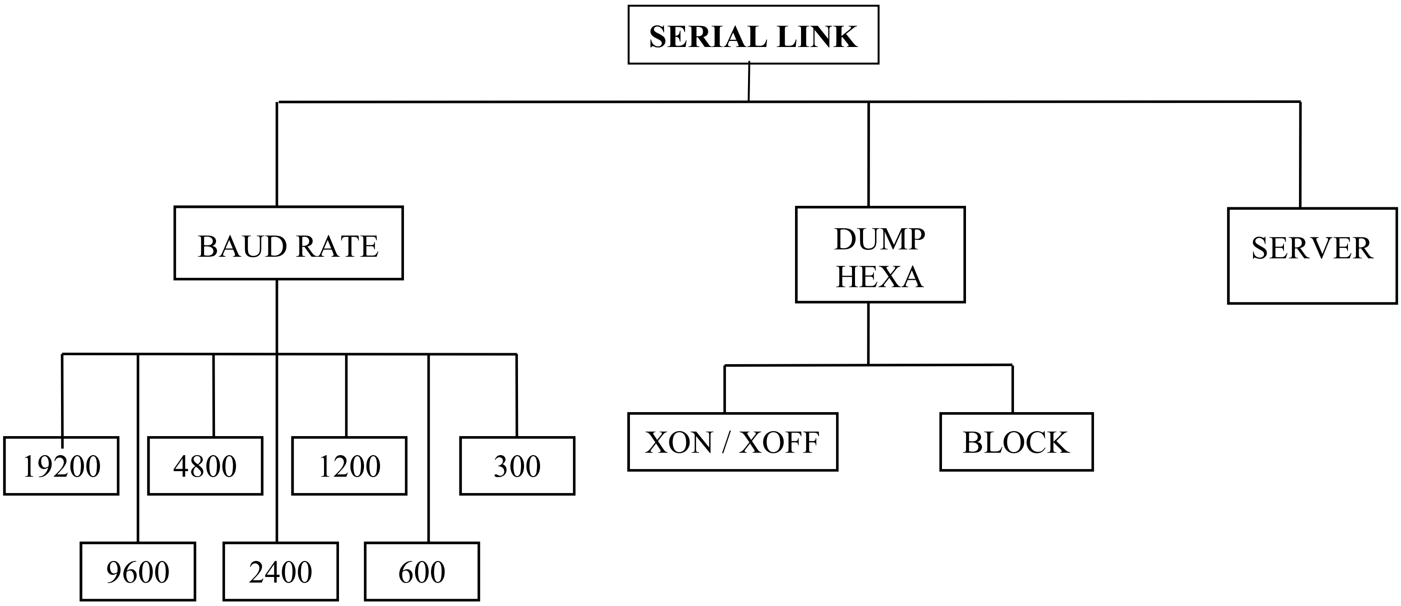


Figure 6: Options of the "SERIAL LINK" menu

IV.5.1. BAUD RATE OPTION

The "BAUD RATE" option is used to set up the transmission speed of the data sent through the serial link. Select the transmission speed in the range [19200, 9600, 4800, 2400, 1200, 600, 300 bauds] using the "UP" and "DOWN" keys and the "ENTER" key to validate.

Please note that the other characteristics of the link are the standard ones:
- format = 8 bits
- 1 stop bit
- no parity
- ASCII characters
- XON/XOFF handshaking

IV.5.2. DUMP HEXA OPTION

This option permits to transfer the data stored in the unit in a binary format, with the E-TX program (Dos program). This transmission toward a PC or a console is performed with the serial link cable (RS232 type) delivered with the instrument. Two choices are available:

- XON/XOFF transmission by XON/XOFF procedure,
- BLOCK transmission by data blocks.

IV.5.3. SERVER OPTION

With the "SERVER" option, the SYSCAL can be managed in Multi-Electrode mode from a PC. The COMSYS software has to be used for this type of operating.

V. TECHNICAL SPECIFICATIONS

V.1. MEASURE

- Automatic stacking process (to improve the signal/noise ration) and display of the number of stacks
- Measure of the following parameters:
Current intensity - Voltage – Spontaneous polarization - Standard deviation – Partial chargeabilities (if **Rho and IP** mode).
- Computation of the following parameters:
Apparent resistivity – Global chargeability (if **Rho and IP** mode).
- Test of the internal system battery
- Monitor of the ambient noise before injection
- Data storage in the internal memory (up to 818 measurements in standard mode): the data stored for each measurement are:
Station and line numbers - Electrode array - Lengths of lines – Spontaneous polarization - Timing parameters - Voltage - Intensity - Partial chargeabilities (if **Rho and IP** mode) - Standard deviation.

V.2. TRANSMITTER

- Maximum output voltage: 400 V (Junior) - 600 V (R1 Plus)
- Maximum output current: 1200 mA (Junior) - 2500 mA (R1 Plus)
- Maximum output power: 100 W (Junior) – 200 W (R1 Plus)
- Current waveform:
    - **Rho** Mode: ON+, ON-
    - **Rho and IP** Mode: ON+, OFF, ON-, OFF
- Current:
    - Resolution: 10 µA
    - Accuracy: 0.3% typical, 1% maximum over the whole operating temperature range
- A thermal circuit breaker stops the transmission when the internal temperature is too high

V.3. RECEIVER

- Input impedance: 10 Mohm
- Input voltage range: -5 V to +5 V (Protection against overload)
- Automatic compensation of the spontaneous polarization (Ps) with correction for linear drift up to 1 mV/s
- Rejection filter 50 Hz and 60 Hz.
- Voltage:
    - Resolution:
        - During the measurement:10µV
        - After stacking: 1µV
    - Accuracy: 0.3% typical, 1% max over the whole temperature range

V.4. GENERAL

- Weather proof case
- Dimensions: 31 x 21 x 16 cm
- Weight: 7 kg (including internal batteries)
- Temperature range:
  - Operating: -20°C to +70°C
  - Storage: -40°C to +80°C
- Supplying: 12V batteries (internal, or external for the transmitter)

ANNEXES

ANNEX 1: GEOMETRICAL PARAMETERS AND RESISTIVITY

The methods to measure the subsurface resistivity by DC current injection are all based on the same principle:

- A current **(I)** is sent in the ground through two electrodes (denoted A and B - electrodes connected to the transmitter part).
- The current creates an equipotential distribution making it possible to measure a potential difference **(I)** between two other electrodes, denoted M and N - electrodes connected to the receiver part).
- An apparent resistivity is then defined by: **Rho = K.V/I** where K (geometric factor) only depends on the geometric array of the electrodes in the field and is expressed by:

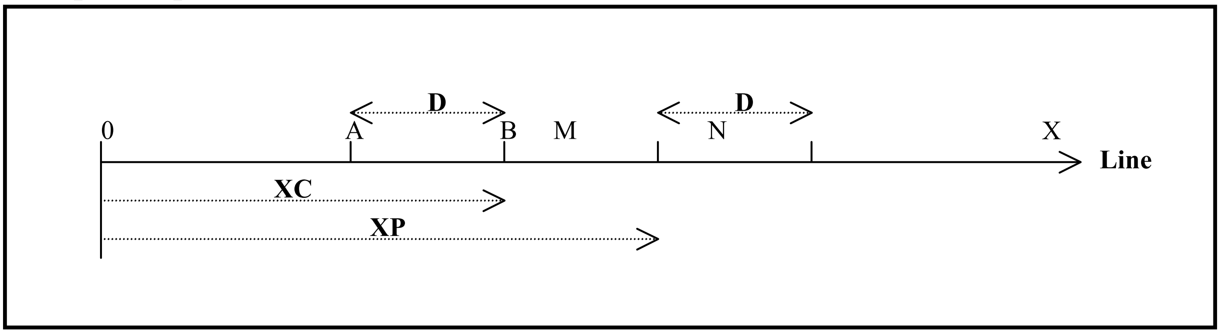
$$\mathbf{K = 2\pi / |AM^{-1} - AN^{-1} - BM^{-1} + BN^{-1}|}$$

The various configurations only differ by the position of the electrodes with K assuming a more specific expression.

Following the chosen electrode array ("E.ARRAY" key), to compute the K factor, you'll have then several parameters to enter ("SPACING" key): cf. III.1. table 4.

<u>Note</u>:
In the following pictures, the X axis is defined as the AB axis, the Y axis is directly perpendicular to AB.

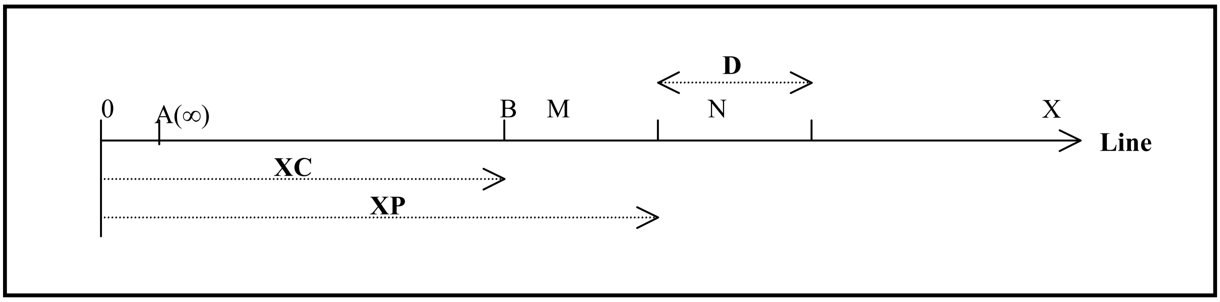
→ Dipole-Dipole



- **XC**: abscissa of the nearest current electrode from the MN dipole
- **XP**: abscissa of the nearest potential electrode from the AB dipole
- **D**: length of dipoles (current and potential): |D| = |AB| = |MN|
  : shift of the array
- **Line**: number allowing a distinction between different profiles

By setting nD as the distance between the midpoints of AB and MN, we have:
$K = \pi \, nD \, (n^2 - 1)$

→ Pole-Dipole



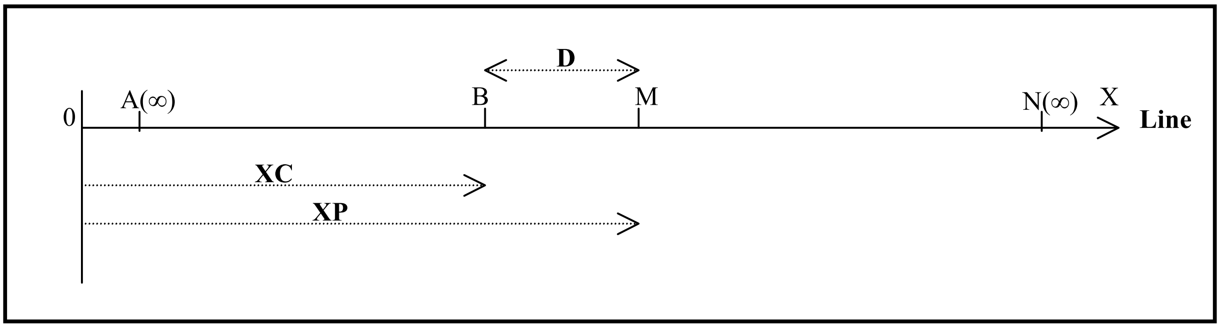
The current electrode A has to be placed sufficiently far to be able to ignore AM^{-1} and AN^{-1}.

- **XC**: abscissa of the nearest current electrode from the MN dipole
- **XP**: abscissa of the nearest potential electrode from the B electrode
- **D**: length of the potential dipole: |D| = |MN|
- : shift of the array
- **Line**: number allowing a distinction between different profiles

$K = 2\pi / (BM^{-1} - BN^{-1})$

→ Pole-Pole

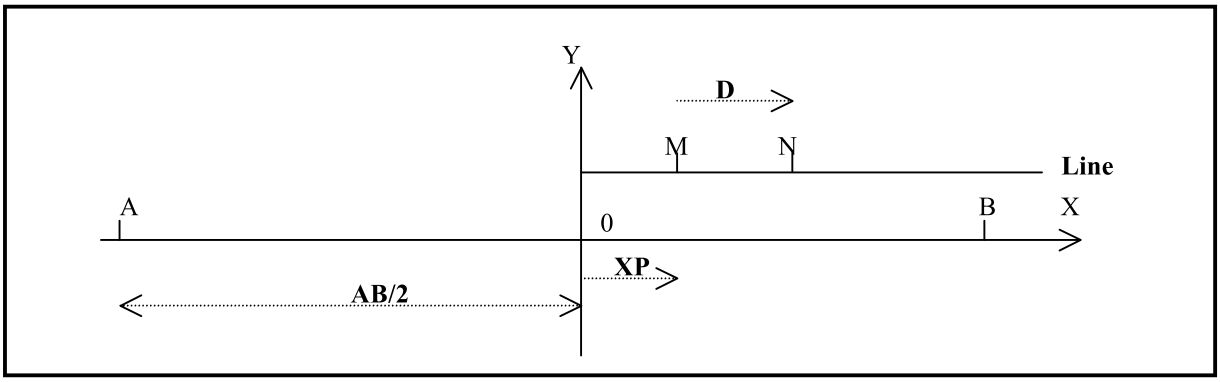
The A and N electrodes are placed sufficiently far from the B and M electrodes to be able to ignore $(AM)^{-1}$, $(AN)^{-1}$ and $(BN)^{-1}$.



- **XC**: abscissa of the nearest current electrode from the M electrode
- **XP**: abscissa of the nearest potential electrode from the B electrode
- **D**: distance between the electrodes: |D| = |BM|
- : shift of the array
- **Line**: number allowing a distinction between different survey lines

$K = 2\pi/(BM)^{-1}$

→ **Grad. RCTGL** (Gradient rectangle)



In this array, the A,B electrodes are fixed and the M,N electrodes are moved parallel to AB inside an area located in the central part of AB. This array serves to observe variations in resistivity on a surface for a relatively high investigation depth without the need to move the current electrodes.

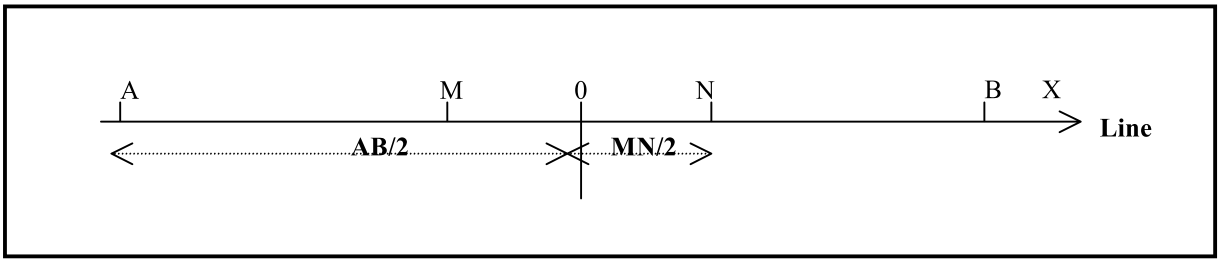
- **XP**: abscissa of M, the origin 0 being the middle of AB and the abscissa axis 0x being the AB line.
- **Line**: ordinate of the potential electrodes
- **± D**: length of the potential dipole
- **AB/2**: half distance of the current electrodes

$K = 2\pi / |AM^{-1} - AN^{-1} - BM^{-1} + BN^{-1}|$

$AM = [(XP + a)^2 + Line^2]^{½}$	A (-a, 0)
$AN = [(XP + D + a)^2 + Line^2]^{½}$	B (+a, 0)
$BM = [(XP - a)^2 + Line^2]^{½}$	M (XP, Line)
$BN = [(XP + D - a)^2 + Line^2]^{½}$	N (XP + D, Line)

<u>*Remark*</u>:
The term Gradient is reserved for the case in which the investigation is only performed on AB line.

→ **Schlum. VES** (Schlumberger sounding)



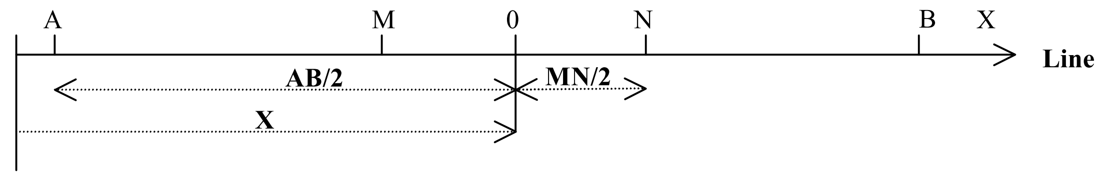
The potential electrodes MN are placed symmetrically at the centre of AB and the origin 0 is their common mid point.

At each measurement, the current electrodes (A,B) are moved of AB/2 from 0.

- **AB/2**: half-distance between the current electrodes.
- **MN/2**: half-distance between the potential electrodes.
- **Line**: number allowing a distinction between different profiles

K then assumes a simplified expression:
If AB/2 > MN/2: $K = \pi (AM^{-1} - AN^{-1})$ (symmetrical array)
If AB/2 = a and MN/2 = b: $K = \pi (a^2 - b^2) / 2b$
In the case of the classical Schlumberger sounding, MN is small in comparison with AB and so K can be treated as $\pi a^2 / b$.

→ **Schlum. PRF** (Schlumberger profile)



The electrodes keep constant relative positions (identical to those of Schlum. VES).

- **X**: abscissa of the centre of MN (Mid) (the direction being AB)
- **AB/2**: half-distance between the current electrodes
- **MN/2**: half-distance between the potential electrodes
- **Line**: number allowing a distinction between different profiles

K is a constant of the profile:
$K = \pi (a^2 - b^2) / 2b$ (if AB/2 > MN/2)

→ **Wenner VES** (Wenner sounding)

Wenner sounding is a restriction of the Schlumberger sounding: MN = AB/3

- **AB/3**: a third of the distance between the current electrodes
- **Line**: number allowing a distinction between different profiles during storage

so $K = 2 \pi AB/3$

→ **Wenner PRF** (Wenner profile)

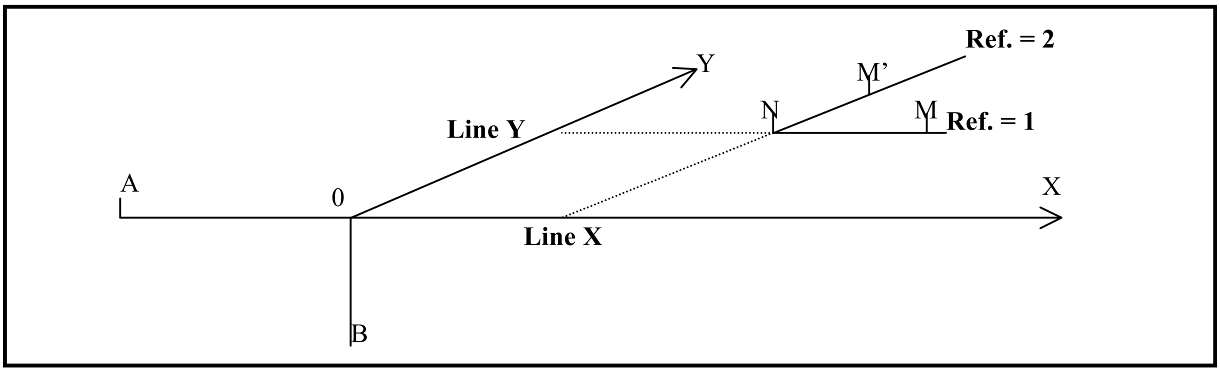
The Wenner profile is a restriction of the Schlumberger profile: MN = AB/3

- **X**: abscissa of the centre of MN (Mid) (the direction being AB)
- **AB/3**: a third of the distance between the current electrodes.
- **Line**: number allowing a distinction between different profiles during storage

So K remains constant all along the profiling axis.

→ **Hole surf.** (Mise à la masse)

Array used to determine the directions of extensions of polarizable zones.
With electrode B lowered in a borehole and electrode A as a remote electrode, the potential is measured on two perpendicular dipoles with coordinates X and Y (0 being the borehole).



- **Line X**: number in the X axis direction allowing to parameter the common point N of the potential dipoles MN and M'N
- **Line Y**: number in the Y axis direction allowing to parameter the common point N of the potential dipoles MN and M'N
- **MN/2**: half-distance between the potential electrodes
- **Ref.**: this array uses two perpendicular potential dipoles (MN and M'N) ; this parameter serves to distinguish between these ones

In this configuration the value of K is taken arbitrarily at 1000.

ANNEX 2: IP PARAMETERS AND CHARGEABILITY

The partial chargeabilities measurements (Mi) and the weighted average global chargeability deduced (M) give us information regarding the ability of the soil to charge itself due to a current flow.

The partial chargeability of the window "i" is measured thanks to the following formula:

$$\mathbf{Mi} = \int_{T\_Mi} \mathbf{Vdt} \;/\; \mathbf{T\_Mi.V_{MN}} \qquad (1)$$

And the global chargeability is computed thanks to the following formula:

$$\mathbf{M} = \sum_{i=1}^{n} \mathbf{(Mi.T\_Mi)} \;/\; \sum_{i=1}^{n} \mathbf{T\_Mi} \qquad (2)$$

With

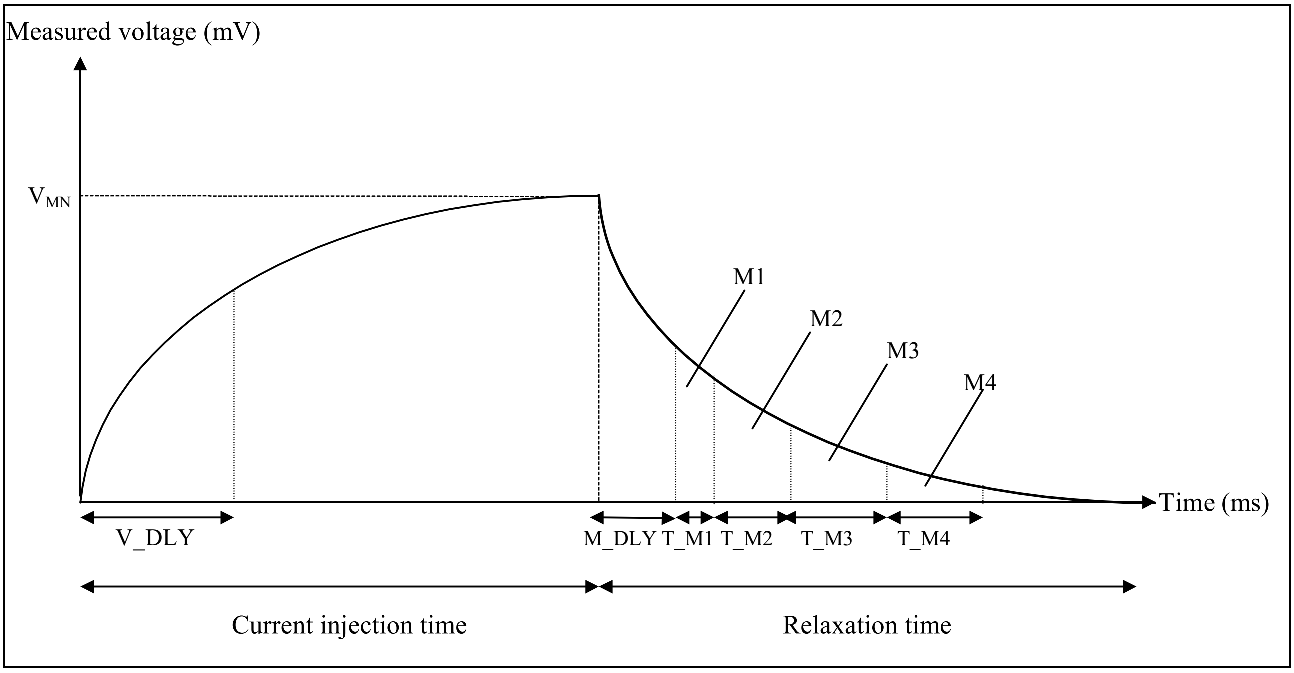
n: number of IP windows

T_Mi: width of the partial chargeability window "i"

<u>*Remark*</u>:

The M and Mi values are expressed in mV/V (‰)

The discharge phenomenon observed during the relaxation time can be described according to the following curve:



With this type of resistivity-meter, up to 4 IP windows can be used to compute the global chargeability.

⇒ **Current injection times** (ms) available (cf. II.4.):
500 - 1000 - 2000: "Preset times" option
[250 - 10000]: "Programmable times" option

→ In the "Programmable times" option, the number of IP windows available for the measurement is fixed by the operator.

→ In the "Preset times" option:
The number of IP windows available for the measurement depends on the current injection time ; the program will choose also automatically the IP parameters (M_DLY, V_DLY, T_Mi) that will be used for the measurement. The next table give the values in ms:

Pulse duration	**TIME**	**250**	**500**	**1000**	**2000**
Delay time before the first V-sample measurement	V_DLY	120	240	580	1260
Delay time before the first M-sample measurement	M_DLY	0	160	160	160
First IP window width	T_M1	0	80	120	120
Second IP window width	T_M2	0	180	220	220
Third IP window width	T_M3	0	0	420	420
Fourth IP window width	T_M4	0	0	0	820

Example:

Mode: **Rho and IP**
Pulse duration: 2000 ms
"SET UP" option: "Preset times"
In this configuration, 4 IP windows will be used for the measurement.
T_M1 = 120 ms
T_M2 = 220 ms
T_M3 = 420 ms
T_M4 = 820 ms

At the end of the measurement, when the "RESULT" key is pressed, the average values of the partial chargeabilities (Mi) and their weighted average (M) will be displayed.

The formula *(2)* gives:

M = 120.M1 + 220.M2 + 420.M3 + 820.M4 / (120 + 220 + 420 + 820)

About the type of IP values, note that the changing "raw (R) ⇔ normalized (N)" can be done after the acquisition (cf. II.6.).

The normalization allows to homogenize the data that have been obtained with various injection and integration times. This is made with respect to a standard decay curve, which is the one obtained with the following parameters:

Pulse duration:	2000 ms
V_DLY:	1260 ms
M_DLY:	160 ms
TM1:	120 ms
TM2:	220 ms
TM3:	420 ms
TM4:	820 ms

The coefficients to multiply, allowing to go from a type to the other one, are indicated in the following table:

	500 ms		**1000 ms**		**2000 ms**	
	R ⇒ N	N ⇒ R	R ⇒ N	N ⇒ R	R ⇒ N	N ⇒ R
M	1.32	0.76	1.16	0.86	1	1
M1	1.06	0.94	0.72	1.38	0.51	0.95
M2	1.47	0.68	1.02	0.98	0.67	1.50
M3			1.53	0.66	0.95	1.05
M4					1.43	0.70

Example:

Mode: **Rho and IP**
Pulse duration: 500 ms
"SET UP" option: "Preset times"
"CONFIG" option: "Raw values"

After the measurement, we obtain:
M = 28.0 mV/V
M1 = 33.9 mV/V
M2 = 25.5 mV/V

So, the corresponding normalized values will be:
N = 36.9 mV/V
N1 = 35.9 mV/V
N2 = 37.5 mV/V

ANNEX 3: DATA TRANSFER

This annex describes the instructions to follow to transfer data to a PC.

With this type of instrument, a CD ROM containing notably the following software is supplied:

- ELECTRE II (for the creation of sequences in **Multi-Electrode** mode).
- PROSYS (for data transfer, processing and export in standard and **Multi-Electrode** mode).

The serial link cable has to be used to connect the resistivity-meter to a PC (by its serial port).
The PROSYS program allows to transfer the data (in standard mode) from a resistivity-meter to a PC equipped with a serial port. It allows also to process the data and to export them with various formats.

The PROSYS software is a Windows 32 bits based version. The installation has to be made thanks to the « SYSCAL Utilities » CD ROM supplied with the system.

PROSYS owns an integrated on-line help file to support you.
The procedure to follow for data downloading is precisely described in this help file.

The DUMP HEXA option allows to transfer the data in a binary format. The structure is the following one:

COM: 8 bits, 1 stop bit, no parity, 19200 bauds.

HANDSHAKE: Xon/Xoff: data will be transferred under Xon/Xoff
Block: one structure will be transferred after receiving 0x07 end of transmit 0x04

STRUCTURE:
Short data1;
Short data2;
Float vp;
Float in;
Short m[4];
Short ps;
Short e;
Short nbr_cren;
Float g[4];
Short time;
Short vdly;
Short mdly;
Short tm[4];
Char mode;

Char el_array

Data1:	NO DATA	0	
	STORED DATA	ffff	
Data2:	reserved		
Vp:	primary voltage (signed mV)		
In:	current (mA)		
M(4):	windows (1..4) IP parts per 10000		
ps:	self potential (mV)		
e:	standard deviation of Vp/In % in Tx-Rx mode		
Nbr-cren:	stack number		
G(4):	spacing parameters (m or ft)		
	see el_array		
Time:	duration (ms)		
Vdly:	delay time before Vp (ms)		
Mdly:	delay time before chargeability measurements (ms)		
Tm[4]:	width of chargeability windows (ms)		
Mode:	Rho mode	0	
	Rho and IP mode	3	
El_array:	DIPOLE_DIPOLE	0	xc,xp,d,li
	POLE_DIPOLE	1	xc,xp,d,li
	POLE_POLE	2	xc,lic,lip,spa
	RECTANGLE	3	xp,li,d,ab/2
	QP_VES	4	ab/2,mn/2,li,opt1
	QP_PRF	5	x,ab/2,mn/2,li
	W_VES	6	ab/3,li,opt1,opt2
	W_PRF	7	x,ab/3,li,opt1
	IP_BUR	8	r,lix,liy,mn/2
	OTHER	9	k,opt1,opt2,opt3

ANNEX 4: SUM UP OF THE MAIN INSTRUCTION (STANDARD MODE)

This annex describes the main instructions of the resistivity-meter in standard mode (**Rho mode** or **Rho and IP mode**). The display are relative to the **Rho and IP mode.**

OPERATIONS to perform before running the measurement

FUNCTION	KEY	DISPLAY	REMARKS
System battery checking	BATT	Rx Battery = 12.3 V Capacity = 77%	System battery voltage (V): 12,7 = new battery 10 = battery to be charged
Current waveform selection	MODE DOWN DOWN	Rho mode Rho and IP mode Multi-Electrode	Choose the type of the operating mode
Timing parameters selection	SET UP ENTER	Timing selection: Programmable times	Selection of: T (preset or programmable), V_DLY, M_DLY, T_Mi Stacks V_{MN} range
Electrode array selection	E.ARRAY DOWN DOWN DOWN DOWN DOWN DOWN DOWN DOWN DOWN	Dipole-Dipole Pole-Dipole Pole-Pole Grad. RCTGL Schlum. VES Schlum. PRF Wenner VES Wenner PRF Hole Surf. Other	Choose the electrode array you wish to implement
Choice of the displayed values types	CONFIG ENTER ENTER ENTER	Readings: Running	Select the type of the values that will be displayed: reading, sign, unit, IP

OPERATIONS to perform at each measurement

FONCTION	TOUCHE	AFFICHAGE	REMARQUES
Introduction of the geometrical parameters	SPACING ENTER ENTER ENTER ENTER	(SCHLUM VES) AB/2 = 10 MN/2 = 2 Line = 1 Opt1 = 0	Introduce the length (meters or feet) and optional numbers to define and locate the survey
Grounding resistance checking	RS CHECK	Rab = 3.00 kohm	Grounding resistance measured between the A,B plugs: Rab = xxx.xx if Rab is unstable
Noise monitoring	MONITOR	Vmn = 0.5 mV	Checking of the ambient noise before running the measurement
Current injection	START STOP	Sp = 1 HV = 100V --- v = 3.70 i = 6.6 m = 1 q = 0 #7 Select Function	Sp: Spontaneous polarization HV: high voltage supplied (V_{AB}) v: v_{MN} (mV) i: i_{AB} (mA) m: chargeability (mV/V) q: standard deviation of v/i (‰) #: number of stacks realized
Results display	RESULT ENTER ENTER	V = 3.71 SP = 1 I = 6.62 Rho = 11.8 M = 0.35 Q = 0 M1 = 0.5 M2 = 0.3 M3 = 0.1	V: average value V_{MN} (mV) Sp: Spontaneous polarization measured before current injection (mV) I: I_{AB} (mA) Rho: apparent resistivity (Ohm.m) M: global chargeability (mV/V) Q: standard deviation of Rho (%) Mi: partial chargeabilities (mV/V)
Data storage	MEMORY ENTER	Memory: Store Range 1/818 Store #50	Data stored in the memory area #50 Index increases automatically unless a new number is introduced (max 818)
Data reading	MEMORY ENTER ENTER	Memory: Read Range 1/818 Read #50	Display the set of data stored in area #50 together with the configuration parameters (timing, e-array, mode)

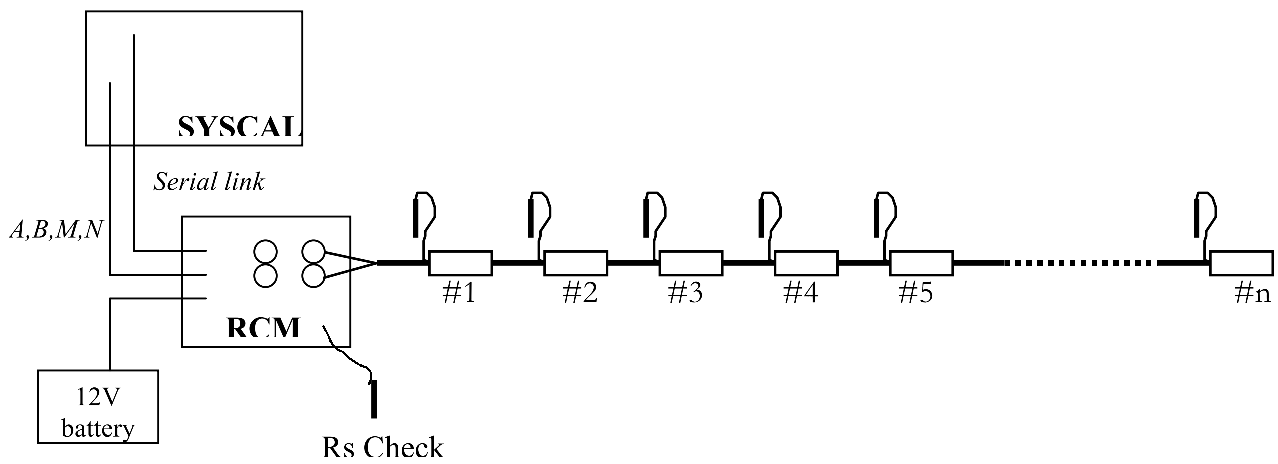
ANNEX 5: MULTI-ELECTRODE MODE

I. PRESENTATION OF THE MULTI-ELECTRODE SYSTEM

The full system contains the following items:

- 1 resistivity-meter
- 1 interface communication box (RCM) between the resistivity-meter and the intelligent nodes network
- 1 12 V CC battery to supply the RCM
- 1 reference metallic stake connected to the "RS CHECK" plug of the RCM. This, to check the grounding resistance of all the stakes of the system
- Segment of mono-conductor cables to link each electrode of a box to a stake (Multinode system) or to connect each node to a stake (electrodes string system)
- Intelligent nodes, each of them having a specific internal number (1 to 255).
Two types of system are available:
    - **Multinode** box (16 outputs)
    - **Electrodes string** (n nodes each x meters)
- Metallic stakes, each of them being connected to an intelligent node of the system

Here are the connections to do to realize an acquisition in that automatic mode (system of the electrode string described in that example):



II. ACCESSORIES

II.1. RCM INTERFACE

This module is the communication interface between the resistivity-meter and the intelligent nodes network.

Supplying:
The RCM has to be supplied by an external 12 V CC battery: connect the 12V cable coming from the front panel of the module to the "+" and "-" plugs of the battery. Once this operation has been made, switch on the RCM (a small led will light on if the supplying is correct).

Note:
The RCM is protected against polarity inversions and overload.
However, it's strongly recommended to supply it with a 12 V maximum battery, if not the fuse would burn and would risk to damage other components.

Connections:
- Connect the RCM on a 12 V CC battery thanks to the appropriate cable (red wire on the "+" plug and black wire on the "-" plug).

- Connect the A, B, M, N cables to the corresponding plugs of the resistivity-meter and the serial link RS 232 to the "Serial link" connector.

- Connect a cable with a male plug to the "RS check" plug of the RCM. This cable has first to be connected to a metallic stake that will be used as a reference stake for the grounding measurement of all the stakes of the system.

Connect the cables of the intelligent nodes network to the connectors of the RCM. The connectors are 2 by 2 identical. For a better quality of measurement, the AB and MN lines are indeed separated: there's a 7 pins connector (for A,B) and a 4 pins connector (for M,N). The RCM can also be located in the middle of the configuration thanks to these double connectors (in that case, you have to be particularly careful with the sequence of quadripoles you programmed). This RCM owns a small led to warn the operator of an insufficient voltage of the battery.

Fuse:
The RCM is equipped with a fuse having the following characteristics: 250 V – 1 A - Size 5-20 - fast ; this is a standard component used in most of the electrical applications. Moreover, a spare fuse is also present inside.
When the fuse is broken, the RCM can't more communicate with the resistivity-meter, and the lamp can't no more light on. This can be due to a damaged electrode.
The fuse can also be damaged by an input overload.

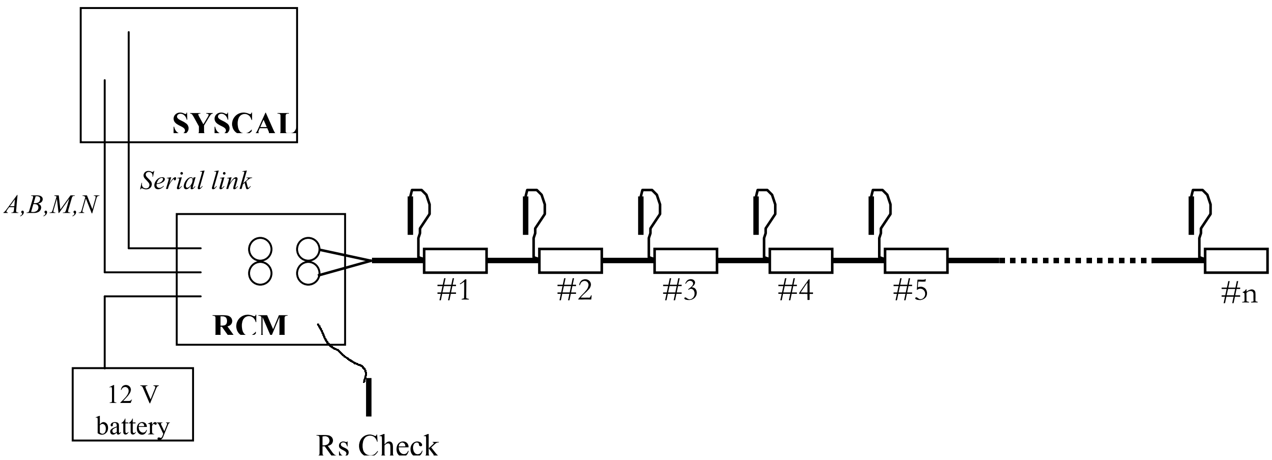
Consumption:
With a 12 V battery, the consumption of the RCM is: 70 mA
Each electrode not commuted consumes 2 mA
Each electrode commuted consumes 20 mA
Thus a full system with 20 electrodes will consume:
70 + 4x20 + 16x2 = 182 mA

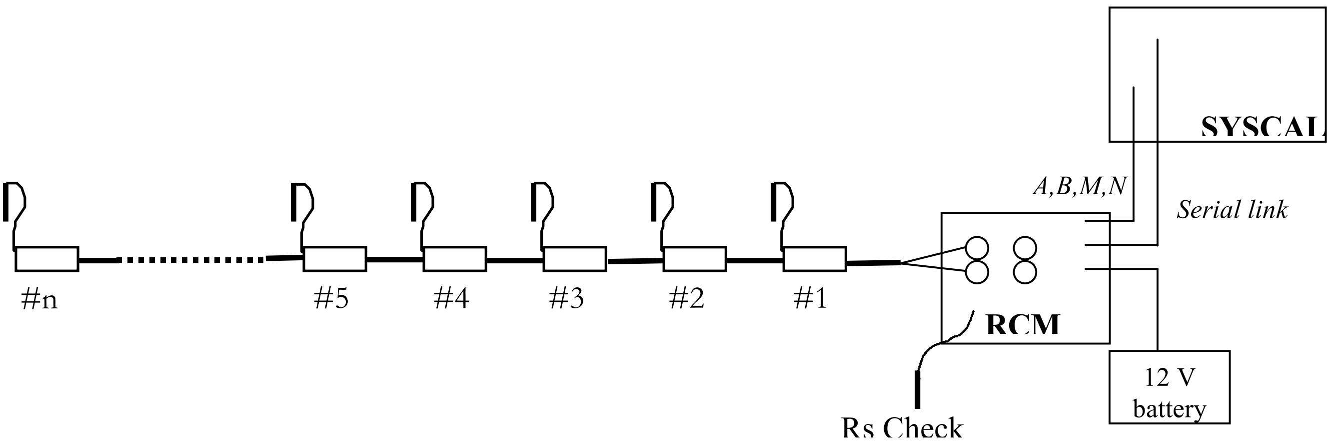
II.2. IN-THE-FIELD IMPLEMENTATION

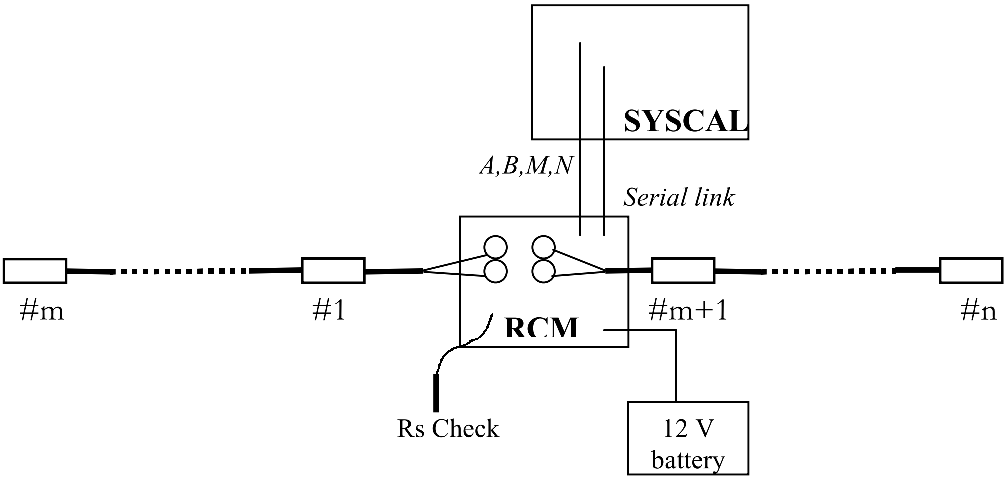
Here are the various possible configuration to implement the system in **Multi-Electrode** mode. These configurations are described without remote electrodes.

Warning:
Whatever the location of the RCM is, you'll have to respect the following rule: implement the electrodes network always in the sense of commutation (electrode #1, the first electrode connected to the RCM, and so on…).

II.2.1. Electrodes string system





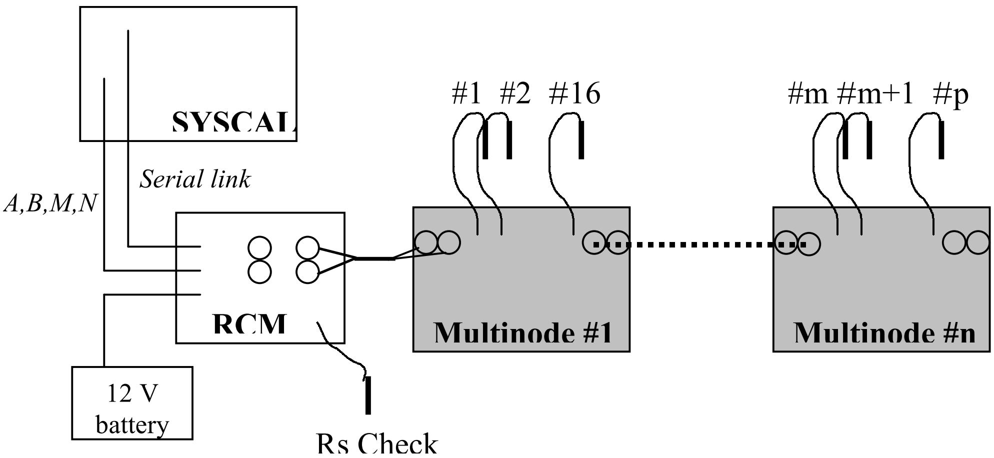


II.2.2. Multinode system

The Multinode system is a box with 16 internal intelligent nodes.
This tool is particularly practical for the field configuration where small spacing are used between the electrodes.

A Multinode box owns 4 connectors: 2 input connectors and 2 output connectors to connect to an other Multinode input (up to 16 Multinodes can be connected).
Each Multinode owns 16 intelligent nodes. Thus, up to 16 metallic stakes can be connected to each of these boxes (thanks to mono-conductor standard cables).

Here are the connections to make for an acquisition automatic **Multi-Electrode** system thanks to several Multinodes:



The other configurations described with the electrodes string system can be also implemented with the Multinode box system.

<u>Particular case</u> :
Configuration with remote electrodes:

You can use some remote electrodes, linking them directly to the corresponding plugs (A, B, M or N) of the resistivity-meter front panel.
For example, if "A" is a remote electrode for a sequence of quadripoles, set a remote stake and connect it directly to the "A" plug of the resistivity-meter with a standard mono-conductor cable. In that case, this electrode won't be assigned of a number in that sequence of measurement.

<u>Note</u> :
Estimation of duration time realized according to the following set-up:
- Time = 1s
- Stacks min = 3
- Stacks max = 6

So, the average duration by data point (based on a value of 4 stacks by measurement):
(3 (fixed) + 4 (stacks)) * 1s (time) + 1s (commutation) = 8 s

Then, with this set-up, the acquisition of one measuring point will take about 8 seconds.

Example of a measuring sequence with their corresponding acquisition time:
Sequence #1: Dipole-dipole / 48 electrodes 5 meters spaced (426 measurements): **57 minutes**
Sequence #2: Dipole-dipole / 48 electrodes 5 meters spaced programmed in roll along (275 measurements): **37 minutes**

III. MEMORY

In the **Multi-Electrode** mode, the structure of the memory of the resistivity-meter is divided in two areas: the SEQUENCE area and the DATA FILE area.

The SEQUENCE area permits to store sequences in the resistivity-meter. These will be kept in memory even if the operator select newly a standard mode and so erase the data of the memory.

SEQUENCE area:

- 9 sequences maximum
- 1200 quadripoles maximum per sequence
- 1500 quadripoles maximum for all the stored sequences

The DATA FILE area permits to store the measurements into the memory of the unit in data files. Each data file contains the readings (V, I, Rho) corresponding to each quadripole of the sequence which has been selected for the acquisition.

DATA FILE area:

- 83 data files maximum
- 1200 readings maximum per data file
- 2730 readings maximum for all the stored data files

***<u>Warning</u>*:**
When you swap between one of the standard mode and the Multi-Electrode mode, the following message will be displayed:
"New Mode ?: CLEAR MEM
Confirm: <09-7>".
So, if you want to change the mode type (standard ⇔ Multi-Electrode), it will be necessary to delete all the data stored in the memory. So, take care to transfer the data before doing this operation (cf. Annex. 3).

IV. FUNCTIONS

The **Multi-Electrode** mode has to be selected by the "MODE" key. This operating mode allows to the resistivity-meter to drive an electrodes network and to perform automatically sets of measurements.

In the **Multi-Electrode** mode, some function keys of the keypad have a different menu, but all of them keep the same numeric meaning.

IV.1. TERMINOLOGY

This paragraph features a brief list of terms commonly used in the **Multi-Electrode** acquisition system, and useful for the reading of next paragraphs:

QUADRIPOLE: set of 4 electrode numbers defining a set of stakes (A, B, M, N).
SEQUENCE: set of quadripoles, defining the order of measurements.
DATAFILE: set of measurements performed by using a given sequence.

<u>*Example*</u>:

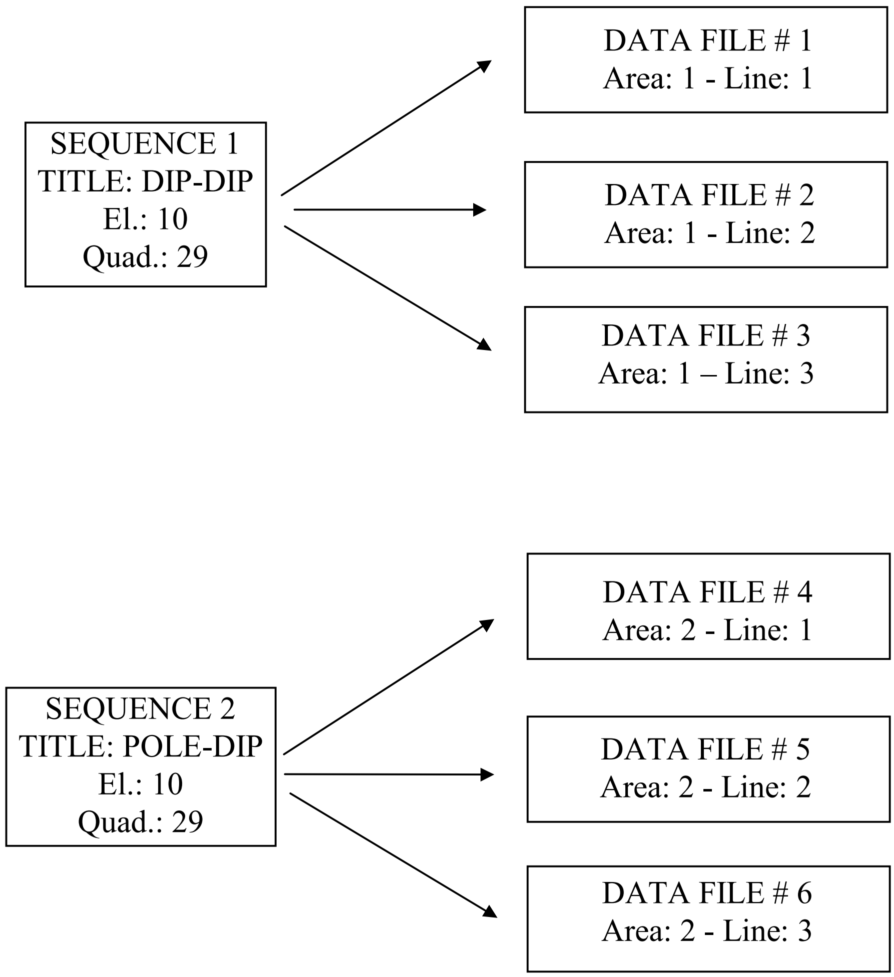
SEQUENCE FILE - DIPOLE-DIPOLE (24 electrodes – n quadripoles)

Electrode	**A**	**B**	**M**	**N**
Quadripole 1	1	2	3	4
Quadripole 2	1	2	4	5
Quadripole 3	1	2	5	6
Quadripole 4	2	3	4	5
.	.	.	.	.
Quadripole n	21	22	23	24

DATA FILE - DIPOLE-DIPOLE (24 electrodes - n quadripoles)

	A	**B**	**M**	**N**	**V_{MN} (mV)**	**I_{AB} (mA)**	**Rho (ohm.m)**	**q (%)**
Meas. 1	1	2	3	4	37.18	6.61	66.5	0
Meas. 2	1	2	4	5	.	.	.	.
Meas. 3	1	2	5	6	.	.	.	.
Meas. 4	2	3	4	5	.	.	.	.
Meas. 5	2	3	5	6	.	.	.	.
.	.	.	.	.	.	.	.	.
Meas. n	21	22	23	24	34.21	6.64	60.4	0

So from each sequence of quadripoles, several data files can exist and in the header, only the "Area" and "Line" parameters can permit to distinguish them.



IV.2. Menus description

The following table shows the various menus available in the **Multi-Electrode** mode.

KEY	CORRESPONDING FUNCTION
BATT	Permits to check the voltage value of the internal system battery.
LOW BAT	The system battery is lower than 11.5 V.
POWER FAILED	The system battery is lower than 10.5 V.
CONFIG	Permits to transfer a sequence from the PC to the unit thanks to the ELECTRE II software.
> Load new Sequence	
Insufficient memory 9 sequences max	This message appears when 9 sequences are already stored in the memory of the unit.
Insufficient memory Only x quad free	This message appears when the sequence to transfer is too long for the size of the free space memory.
> Del all Sequences	Delete all the sequences previously stored in the unit. This operation will delete in fact the whole memory of the system (Protection code: press successively: "0","9","-","7").
> Type of readings	During the acquisition, the displayed data can be "running values" or "cumulative values" (cf. II.6.).
E. ARRAY	
Range: 5/9 Select sequence: # 3	Permits to select the quadripoles sequence that will be used for the measurement.
ENTER	
Title: DIP-DIP El: 10 - Quad: 29	Displays the title, the number of electrodes, the number of quadripoles, for the selected sequence.

SET UP	
Range: 1/249 Stacks min: 2	Introduce the minimum number of stacks to do for each measurement of the sequence.
ENTER Range: 2/249 Stacks max: 6	Introduce the maximum number of stacks to do for each measurement of the sequence. The min value of the range being the value previously selected.
ENTER Range: 0/100 Q,E max (%): 5	Introduce the standard deviation maximal of Rho (or M), in %, for each measurement (while Q (or E) stills superior to this max value, the measurements will go on up to the stack max).
ENTER Time selected: >1000	Allows to select the current injection time, in ms.
ENTER Mode: Rho mode	Possibility at this stage to select the current waveform (resistivity or IP) in this automatic mode (cf. II.3.).
ENTER Set TX power for : "Save energy"	Permits to specify the reception voltage value desired. The injection current and voltage values will be established in regards to that parameter.

RS CHECK	Allows to check automatically the connection of each node with its metallic stake before running the acquisition. Two types are available ("Automatic" or "manual") : • "Automatic" ("ENTER" key) : each dipole is automatically tested. If some electrodes are remote electrodes, disconnect them from the plugs of the SYSCAL then reconnect them after the Rs Check process. - If the electrodes are correctly connected, the resistance value will be stable ; the unit will check then automatically the resistance of the next dipole, and so on… - If not, the measurement will be unstable : one have then to check the connection of the nodes with their metallic stake (for the concerned dipole). As soon as the resistance measurement becomes stable, the measuring process will go on automatically to the next dipole. • "Manual" ("UP" key) : allows to select numbers for the A and B electrodes (enter "0" and "0" and connect the remote electrodes to the plugs for a pole-pole sequence).

MONITOR ENTER A, B, M, N A:1 Press ENTER and introduce the numbers for A, B, M, N > RS CHECK > MEASURE > MONITOR	Allows to check the values of a measurement for a given quadripole (useful before beginning to run the complete acquisition). Select a quadripole choosing 4 electrode numbers. This allows to display the exact value of the resistance of the AB dipole. Performs a measurement only for the quadripole you selected. At this stage, "ENTER" allows to monitor the Sp value in mV between the electrodes M and N. Please note that, in this case, the A and B numbers have no meaning. **This operation is important to select correctly the output voltage, the number of stacks and the pulse duration, before running the sequence of measurements.**

START	Starts the acquisition of the sequence selected in "E. ARRAY". The measurements are automatically stored into the memory while the acquisition
A1 B2 M3 N4 1/24 HV = 100V- - -	Before each measurement, the quadripole number is displayed together with the voltage value V_{AB} supplied (HV).
OVLD	This message appears when the V_{MN} value is higher than 5 V. However the measurement can go on. In that case, the corresponding stored value will be: 5000.000 mV. Then, the operator will have to consider that the result is not reliable, since it's due to an overload.
Transmitter stopped	This message appears if a saturation problem comes up
Transmitter LOW BAT	The voltage value of the battery of the transmitter is too low.
DOWN	To pause the running sequence of measurement. Please refer to the functions relative to the menu "Pause" at the end of this table.
FUNCT/STOP	Allows to stop the acquisition of the selected sequence of quadripoles before its end.

SPACING AREA: 1 LINE: 1 For each parameter, enter the numeric value and then press ENTER to validate.	Introduction of optional parameters allowing to define the location of each profile of measurement. It's highly recommended to enter these values, because they will permit to distinguish easily the location of each data file.

RESULT Range: 5/83 Read data file: 3 Title: DIP-DIP EL: 10 Quad: 29 ENTER AREA: 1 LINE: 3 ENTER Sp = 10 ENTER A1 B2 M3 N4 Rho = 15.5 . .	To edit the results of a data file to select. All the comments (title, number of electrodes, number of measurements (number of quadripoles)), location, Sp (mV), V_{MN} (mV), I_{AB} (mA) and Rho (Ohm.m) will be displayed for each reading. If you performed a measurement in **Rho and IP** mode, the chargeabilities (global and partial) will be also displayed.

MEMORY > LIST ENTER 10 data files stored 83 max. > Del. last Datafile > Del. all Datafiles	**Features the list of data files stored in the memory.** Allows to delete the latest stored file. Allows to delete all the files of the memory. This operation has to be confirmed pressing successively: "0","9","-","7". The sequence files won't be erased of the memory with this operation.

SERIAL LINK	Allows to transfer the whole data files towards the PC.

FUNCT/STOP	Allows to stop the running acquisition before its end.

THE PAUSE FUNCTION	
START	The sequence of measurement is running.
Press DOWN during a while	The sequence of measurement stops.
PAUSE: > Continue	This option is useful if you need to change the output voltage or the stack number during the measurement. Press "ENTER" at this stage to resume the sequence.
PAUSE: > Interruption	This option is useful if you need to switch OFF the unit. Pressing "ENTER" at this stage will display the following message: "Select Function LAST FILE NOT ENDED" At this stage, you have thus the possibility to: - Switch off the unit (if you need to change the battery): switch OFF. The previous message will reappear once you will switch it on. - Change the sequence of measurement: "E. ARRAY" and then run the acquisition of this new sequence. The previous message will reappear then, and validate "No" by the "UP" key. - Change the quality criterion (Stacks min, Stacks max, q max) and visualize the injection time: SET UP and then resume the same sequence ("START" / "YES") - Visualize the parameters "AREA" and "LINE": "SPACING" and then resume the same sequence ("START" / "YES") - Resume the sequence: "START": the following message will be then displayed: "Continue last data file Yes: ENTER No: UP"
ENTER	The program will resume the measurement at the quadripole where the acquisition has been stopped.
or	
UP	The program will stop definitively the sequence that has been paused. The data taken before the pause will be kept in the memory.

V. PROCEDURE

→ Creation and transfer of a sequence from the PC to the resistivity-meter (thanks to the ELECTRE II software)

→ In-the-field measurement

→ Transfer of a data file from the resistivity-meter to the PC (thanks to the PROSYS software)

→ From PROSYS software, data processing and export for interpretation (to software such Res2dinv or Res3dinv)

V.1. CREATION AND UPLOAD OF A SEQUENCE

From ELECTRE II :

→ Create a sequence of measurement ("New" button of the sequence area of the master window)

→ Upload that sequence in the SYSCAL ("Set of sequences|Upload" menu) and select on the SYSCAL, the "Load new sequence" option of the "CONFIG" menu.

Please refer to the on-line help file of ELECTRE II software for further information.

V.2. IN THE FIELD MEASUREMENT

→ Switch on the SYSCAL

→ Check the system battery condition: "BATT" key.

→ Select a sequence of quadripoles: "E.ARRAY" key.

→ Introduce the "Area" and "Line" parameters: "SPACING" key (those parameters will be present in the results files and will permit to locate easily your various measuring profiles).

→ Check the connections of each node with its metallic stake and the correct operating of each of them: "RS CHECK" key.

→ Select two quadripoles (one with a low spacing between AB and MN, and the other one with a large spacing) in order to check the reception signals levels: that operation is very important for the data quality: "MONITOR" key.

→ You can now modify the measurement set-up (injection time, stacks) before running the acquisition and also select the reception voltage value desired (V_{MN}): that operation is essential in regards to the field productivity: "SET UP" key.

→ Run the measurement: "START" key.

In **Multi-Electrode** mode, the data storage is made automatically.

→ At the end of the measurement, one can check the resistivity values obtained: "RESULT" key.

V.3. DATA TRANSFER

→ From PROSYS, select the "Communication|Data download|Syscal/ElrecT|Multi-electrodes" option and follow the instructions given by the program.

<u>Warning</u>:
To perform the transfer of a data file from the resistivity-meter, it's necessary to have on the PC the corresponding sequence file ("*.ele" stored in the "ELECTREII / Syscal" directory while the creation of the sequence).

V.4. DATA MANAGING FROM PROSYS

The PROSYS software allows to process the data and export them to various formats:

From PROSYS:
→ Once the data file is displayed in the master window, several processing can be performed.

→ Then, for a 2D data interpretation, select the "File|Export and save|Res2dinv / Res3Dinv" menu.
That export allows to create a file with the RES2DINV format for a further interpretation (other types of export are available).

Please refer to the on-line help file of PROSYS software for further information.

ANNEX 6: MAIN ERROR MESSAGES TABLE

MESSAGE	DIAGNOSTIC	SOLUTION
Insufficient memory 9 sequences max	9 sequences are already stored in the unit.	Delete some sequences previously stored.
Insufficient memory Only 10 quad free	The sequence you are trying to transfer is too long for the free space in the resistivity-meter memory.	Delete some sequences previously stored.
R = xxx.xx « Unstable measurement »	The grounding resistance measured is unstable. The measurement is performed continuously : as soon as the resistance becomes correct, the measurement goes automatically to the next dipole. Press the "UP" key to go on manually the process to the next dipole.	Check the connection of the nodes with their metallic stake or try to improve the grounding resistance if the value is high (more than 20 kohm) (pour some salt water if necessary)
LOW BAT	The system battery voltage dropped between 10.5 V and 11.5 V during the measurement. However, the measurement can go on.	Recharge the internal battery (Rx)
POWER FAILED	The system battery voltage is lower than 10.5 V. In that case, no more measurement will be performed.	Recharge the internal battery (Rx)
TRANSMITTER STOPPED	Problem of over limit during the measurement. The SYSCAL stops then automatically.	Select in the "SET-UP" function, a lower reception voltage (Vmn range) or try to increase the grounding resistances R_A and R_B in order to generate less injection current.
TRANSMITTER LOW BAT	The voltage of the transmitter battery is too low.	Recharge the transmitter battery (Tx) or connect an external battery
RO = ****	The apparent resistivity is not computed because the geometrical parameters have not been introduced or have been cleared after the operator has pressed the "E. ARRAY" key	Introduce the geometrical parameters. Press the "RESULT" key ; the apparent resistivity is then computed with the values I_{AB} and V_{MN} of the latest measurement.

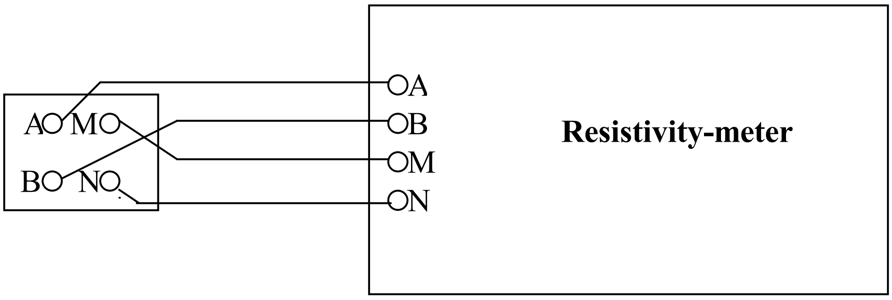
MESSAGE	DIAGNOSTIC	SOLUTION
Read #26 No data	No data have been stored in the unit in this storage zone	
FLOATING EXCEPTION	Internal computation problem	Switch off and on the SYSCAL

PROBLEM	DIAGNOSTIC	SOLUTION
Measured values of I_{AB} and V_{MN} are very weak	The current is not properly driven into the ground and so the measurement of V_{MN} is wrong	Check the output voltage with a voltmeter in parallel with transmitter plugs (A,B) before and during the injection of current Check the connections and the battery condition
Measured values of V_{MN} are not stable	The natural noise is strong or the signal V_{MN} measured is weak	Try to decrease the R_A and R_B resistances or make more stacks

MAINTENANCE

I. Test Box

A test box can be supplied with your system to check the correct operating of your unit in case of doubts.



Time = 2000 ms
Stacks min = 5
Stacks max = 5
q = 0

Values given with an output voltage of 50V:

VP = HIGH

$I_{AB} \approx 15.1$ mA	Sp = 0
$V_{MN} \approx 99$ mV	Q = 0

VP = LOW

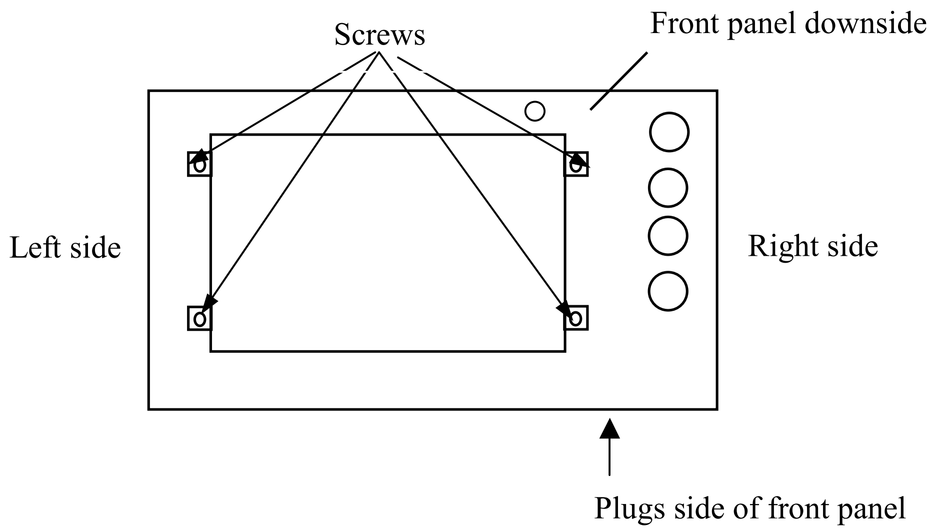
$I_{AB} \approx 15.1$ mA	Sp = 0
$V_{MN} \approx 5$ mV	Q = 0

II. EPROM CHANGING – AUTO INIT

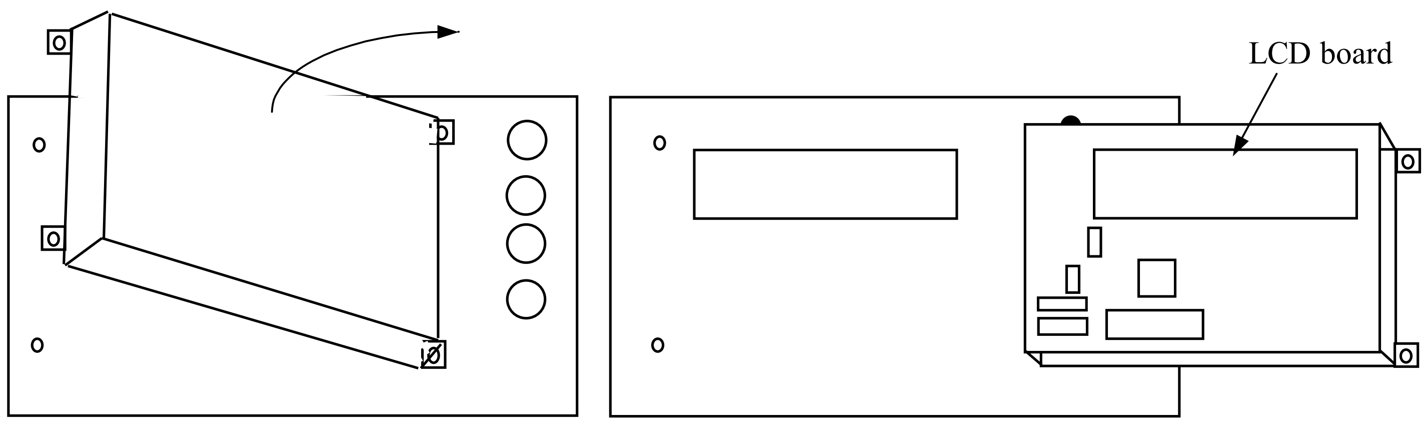
Please follow these instructions if you need to change the EPROM of your resistivity-meter:

***Warning*:**
Before this operation, transfer your data in the memory to a PC, otherwise they will be lost.

So:
- Unscrew the 10 screws of the front panel and take them out
- Take out very carefully the front panel from the casing
- Set the front panel with upside on the table and unscrew the 4 screws holding the internal frame to the front panel.

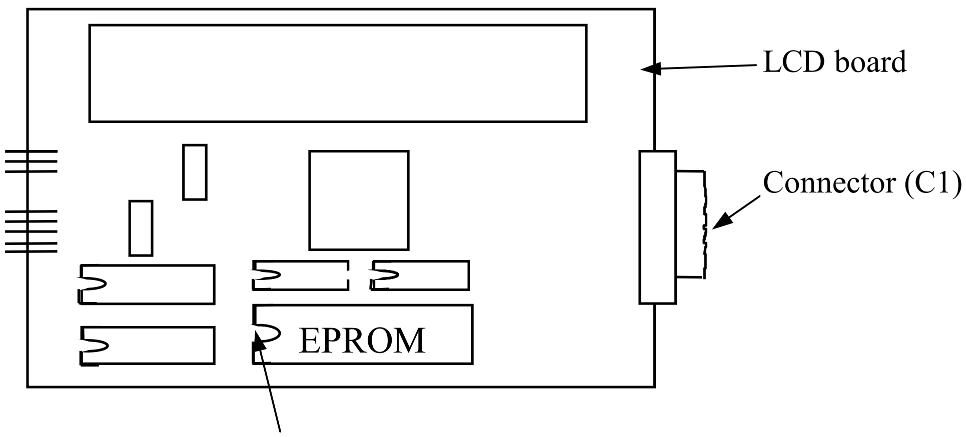


- Respect the positions of the above figure, pull up the metallic frame in order to turn it on the right side, and disconnect the keypad connector. See next scheme:



- Disconnect the connector (C1, see next scheme) from the right side of the LCD board and wait for about 5 minutes (to allow the discharge of the lithium cell) before doing the next operation

- Take out carefully the EPROM from the LCD board with a small screwdriver. Then, set the new one, taking care to respect the connection side determined by the " " shape. See next scheme.



This shape " " has to be placed on this side

- Connect newly the connector (C1).

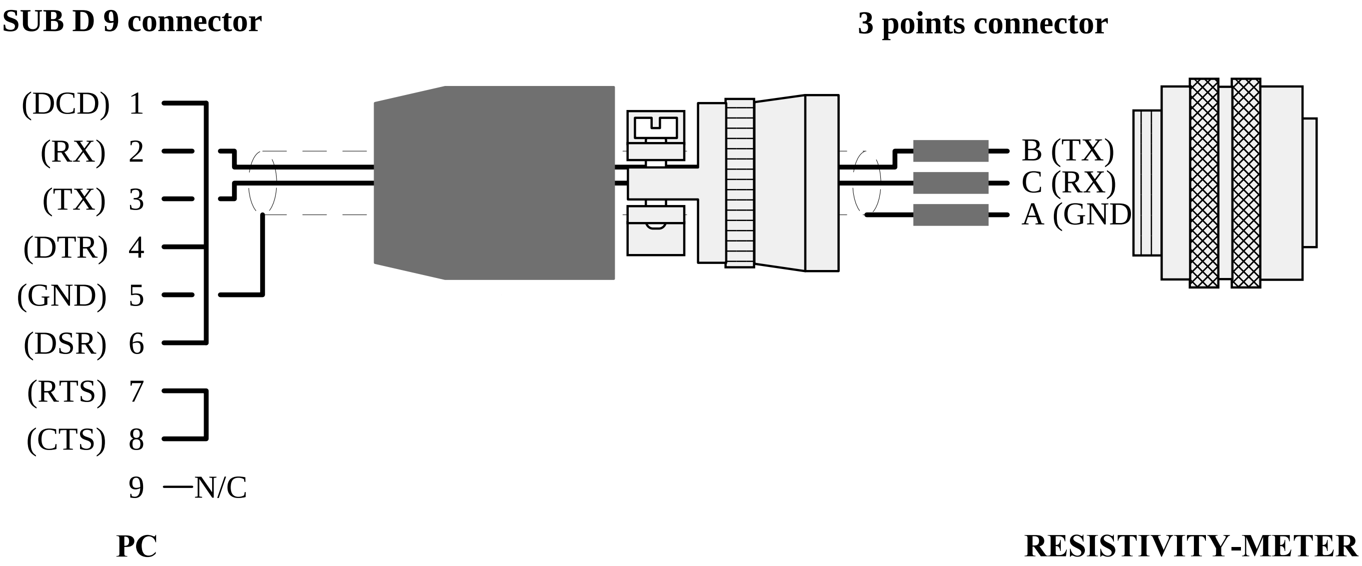
- Once the EPROM has been set, you can check the cleanliness of the LCD and of the front panel glass before re-assembling. Then, pull up the metallic frame, assemble the key-pad connector, and set again the frame on the front panel with the 4 screws (well screwed, you can add an unscrewing product). Take care not to stuck any wire. Then, assemble the front panel on the case with the 10 screws.

- Switch on the unit ; it has to be reinitialized:
The following message then appears on the screen:
« FS : <5> or <1>0 V »
Select then the value corresponding to your SYSCAL (full scale of the input range : 5 or 10 Volts)

The following message then appears on the screen:
« **Enter measured value :**
Vab = 10.6 »
This is a standard value. For an higher precision, enter the value measured by a voltmeter connected in AB.
Then press the "ENTER" key. The dispaly reachs then the « Select Function » message.
Then the instrument is now ready to operate with the new version.

III. SERIAL LINK CABLE WIRING

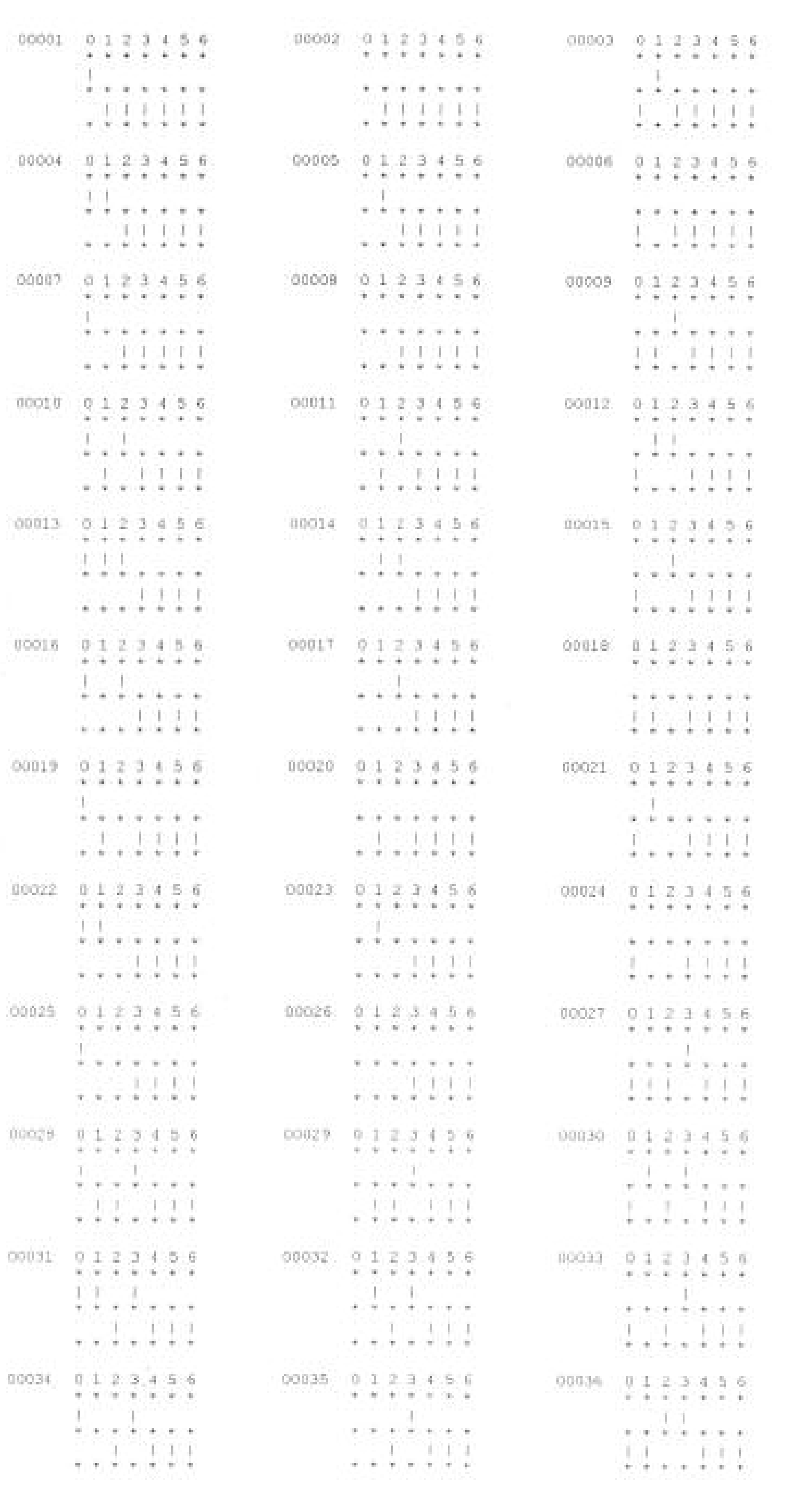
Here is the wiring diagram of the serial link RS232 cable for the resistivity-meter SYSCAL *Switch* type:



Linking procedure:
2 to B
3 to C
5 to A

Connectors pins definition:
GND : Ground
DSR : Data Set Ready
RX : Receive data
TX : Transmit data
DTR : Data Terminal Ready
N/C : Unused pin

IV. INTELLIGENT NODES NUMBERING (straps position)



```
00037  0 1 2 3 4 5 6
       + + + + + + +
       |   | |
       + + + + + + +
         |     | | |
       + + + + + + +

00038  0 1 2 3 4 5 6
       + + + + + + +
           | |
       + + + + + + +
         |     | | |
       + + + + + + +

00039  0 1 2 3 4 5 6
       + + + + + + +
         | | |
       + + + + + + +
       |       | | |
       + + + + + + +

00040  0 1 2 3 4 5 6
       + + + + + + +
       | | | |
       + + + + + + +
               | | |
       + + + + + + +

00041  0 1 2 3 4 5 6
       + + + + + + +
         | | |
       + + + + + + +
               | | |
       + + + + + + +

00042  0 1 2 3 4 5 6
       + + + + + + +
           | |
       + + + + + + +
       |       | | |
       + + + + + + +

00043  0 1 2 3 4 5 6
       + + + + + + +
       |   | |
       + + + + + + +
               | | |
       + + + + + + +

00044  0 1 2 3 4 5 6
       + + + + + + +
           | |
       + + + + + + +
               | | |
       + + + + + + +

00045  0 1 2 3 4 5 6
       + + + + + + +
             |
       + + + + + + +
       | |     | | |
       + + + + + + +

00046  0 1 2 3 4 5 6
       + + + + + + +
       |     |
       + + + + + + +
         |     | | |
       + + + + + + +

00047  0 1 2 3 4 5 6
       + + + + + + +
             |
       + + + + + + +
         |     | | |
       + + + + + + +

00048  0 1 2 3 4 5 6
       + + + + + + +
         |   |
       + + + + + + +
       |       | | |
       + + + + + + +

00049  0 1 2 3 4 5 6
       + + + + + + +
       | |   |
       + + + + + + +
               | | |
       + + + + + + +

00050  0 1 2 3 4 5 6
       + + + + + + +
         |   |
       + + + + + + +
               | | |
       + + + + + + +

00051  0 1 2 3 4 5 6
       + + + + + + +
             |
       + + + + + + +
       |       | | |
       + + + + + + +

00052  0 1 2 3 4 5 6
       + + + + + + +
       |     |
       + + + + + + +
               | | |
       + + + + + + +

00053  0 1 2 3 4 5 6
       + + + + + + +
             |
       + + + + + + +
               | | |
       + + + + + + +

00054  0 1 2 3 4 5 6
       + + + + + + +

       + + + + + + +
       | | |   | | |
       + + + + + + +

00055  0 1 2 3 4 5 6
       + + + + + + +
       |
       + + + + + + +
         | |   | | |
       + + + + + + +

00056  0 1 2 3 4 5 6
       + + + + + + +

       + + + + + + +
         | |   | | |
       + + + + + + +

00057  0 1 2 3 4 5 6
       + + + + + + +
         |
       + + + + + + +
       |   |   | | |
       + + + + + + +

00058  0 1 2 3 4 5 6
       + + + + + + +
       | |
       + + + + + + +
           |   | | |
       + + + + + + +

00059  0 1 2 3 4 5 6
       + + + + + + +
         |
       + + + + + + +
           |   | | |
       + + + + + + +

00060  0 1 2 3 4 5 6
       + + + + + + +

       + + + + + + +
       |   |   | | |
       + + + + + + +

00061  0 1 2 3 4 5 6
       + + + + + + +
       |
       + + + + + + +
           |   | | |
       + + + + + + +

00062  0 1 2 3 4 5 6
       + + + + + + +

       + + + + + + +
           |   | | |
       + + + + + + +

00063  0 1 2 3 4 5 6
       + + + + + + +
           |
       + + + + + + +
       | |     | | |
       + + + + + + +

00064  0 1 2 3 4 5 6
       + + + + + + +
       |   |
       + + + + + + +
         |     | | |
       + + + + + + +

00065  0 1 2 3 4 5 6
       + + + + + + +
           |
       + + + + + + +
         |     | | |
       + + + + + + +

00066  0 1 2 3 4 5 6
       + + + + + + +
         | |
       + + + + + + +
       |       | | |
       + + + + + + +

00067  0 1 2 3 4 5 6
       + + + + + + +
       | | |
       + + + + + + +
               | | |
       + + + + + + +

00068  0 1 2 3 4 5 6
       + + + + + + +
         | |
       + + + + + + +
               | | |
       + + + + + + +

00069  0 1 2 3 4 5 6
       + + + + + + +
           |
       + + + + + + +
       |       | | |
       + + + + + + +

00070  0 1 2 3 4 5 6
       + + + + + + +
       |   |
       + + + + + + +
               | | |
       + + + + + + +

00071  0 1 2 3 4 5 6
       + + + + + + +
           |
       + + + + + + +
               | | |
       + + + + + + +

00072  0 1 2 3 4 5 6
       + + + + + + +

       + + + + + + +
       | |     | | |
       + + + + + + +
```

```
00073  0 1 2 3 4 5 6
       * * * * * * *
       |
       * * * * * * *
         |     | | |
       * * * * * * *
```

```
00074  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
         |     | | |
       * * * * * * *
```

```
00075  0 1 2 3 4 5 6
       * * * * * * *
         |
       * * * * * * *
       |       | | |
       * * * * * * *
```

```
00076  0 1 2 3 4 5 6
       * * * * * * *
       | |
       * * * * * * *
               | | |
       * * * * * * *
```

```
00077  0 1 2 3 4 5 6
       * * * * * * *
         |
       * * * * * * *
               | | |
       * * * * * * *
```

```
00078  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
       |       | | |
       * * * * * * *
```

```
00079  0 1 2 3 4 5 6
       * * * * * * *
       |
       * * * * * * *
               | | |
       * * * * * * *
```

```
00080  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
               | | |
       * * * * * * *
```

```
00081  0 1 2 3 4 5 6
       * * * * * * *
               |
       * * * * * * *
       | | | |   | |
       * * * * * * *
```

```
00082  0 1 2 3 4 5 6
       * * * * * * *
       |       |
       * * * * * * *
         | | |   | |
       * * * * * * *
```

```
00083  0 1 2 3 4 5 6
       * * * * * * *
               |
       * * * * * * *
         | | |   | |
       * * * * * * *
```

```
00084  0 1 2 3 4 5 6
       * * * * * * *
         |     |
       * * * * * * *
       |   | |   | |
       * * * * * * *
```

```
00085  0 1 2 3 4 5 6
       * * * * * * *
       | |     |
       * * * * * * *
           | |   | |
       * * * * * * *
```

```
00086  0 1 2 3 4 5 6
       * * * * * * *
         |     |
       * * * * * * *
           | |   | |
       * * * * * * *
```

```
00087  0 1 2 3 4 5 6
       * * * * * * *
               |
       * * * * * * *
       |   | |   | |
       * * * * * * *
```

```
00088  0 1 2 3 4 5 6
       * * * * * * *
       |       |
       * * * * * * *
           | |   | |
       * * * * * * *
```

```
00089  0 1 2 3 4 5 6
       * * * * * * *
               |
       * * * * * * *
           | |   | |
       * * * * * * *
```

```
00090  0 1 2 3 4 5 6
       * * * * * * *
           |   |
       * * * * * * *
       | |   |   | |
       * * * * * * *
```

```
00091  0 1 2 3 4 5 6
       * * * * * * *
       |   |   |
       * * * * * * *
         |   |   | |
       * * * * * * *
```

```
00092  0 1 2 3 4 5 6
       * * * * * * *
           |   |
       * * * * * * *
         |   |   | |
       * * * * * * *
```

```
00093  0 1 2 3 4 5 6
       * * * * * * *
         | |   |
       * * * * * * *
       |     |   | |
       * * * * * * *
```

```
00094  0 1 2 3 4 5 6
       * * * * * * *
       | | |   |
       * * * * * * *
             |   | |
       * * * * * * *
```

```
00095  0 1 2 3 4 5 6
       * * * * * * *
         | |   |
       * * * * * * *
             |   | |
       * * * * * * *
```

```
00096  0 1 2 3 4 5 6
       * * * * * * *
           |   |
       * * * * * * *
       |     |   | |
       * * * * * * *
```

```
00097  0 1 2 3 4 5 6
       * * * * * * *
       |   |   |
       * * * * * * *
             |   | |
       * * * * * * *
```

```
00098  0 1 2 3 4 5 6
       * * * * * * *
           |   |
       * * * * * * *
             |   | |
       * * * * * * *
```

```
00099  0 1 2 3 4 5 6
       * * * * * * *
               |
       * * * * * * *
       | |   |   | |
       * * * * * * *
```

```
00100  0 1 2 3 4 5 6
       * * * * * * *
       |       |
       * * * * * * *
         |   |   | |
       * * * * * * *
```

```
00101  0 1 2 3 4 5 6
       * * * * * * *
               |
       * * * * * * *
         |   |   | |
       * * * * * * *
```

```
00102  0 1 2 3 4 5 6
       * * * * * * *
         |     |
       * * * * * * *
       |     |   | |
       * * * * * * *
```

```
00103  0 1 2 3 4 5 6
       * * * * * * *
       | |     |
       * * * * * * *
             |   | |
       * * * * * * *
```

```
00104  0 1 2 3 4 5 6
       * * * * * * *
         |     |
       * * * * * * *
             |   | |
       * * * * * * *
```

```
00105  0 1 2 3 4 5 6
       * * * * * * *
               |
       * * * * * * *
       |     |   | |
       * * * * * * *
```

```
00106  0 1 2 3 4 5 6
       * * * * * * *
       |       |
       * * * * * * *
             |   | |
       * * * * * * *
```

```
00107  0 1 2 3 4 5 6
       * * * * * * *
               |
       * * * * * * *
             |   | |
       * * * * * * *
```

```
00108  0 1 2 3 4 5 6
       * * * * * * *
             | |
       * * * * * * *
       | | |     | |
       * * * * * * *
```

```
00109  0 1 2 3 4 5 6
       + + + + + + +
       |     | |
       + + + + + + +
         | |     | |
       + + + + + + +
```

```
00110  0 1 2 3 4 5 6
       + + + + + + +
             | |
       + + + + + + +
         | |     | |
       + + + + + + +
```

```
00111  0 1 2 3 4 5 6
       + + + + + + +
         |   | |
       + + + + + + +
       |   |     | |
       + + + + + + +
```

```
00112  0 1 2 3 4 5 6
       + + + + + + +
       | |   | |
       + + + + + + +
           |     | |
       + + + + + + +
```

```
00113  0 1 2 3 4 5 6
       + + + + + + +
         |   | |
       + + + + + + +
           |     | |
       + + + + + + +
```

```
00114  0 1 2 3 4 5 6
       + + + + + + +
             | |
       + + + + + + +
       |   |     | |
       + + + + + + +
```

```
00115  0 1 2 3 4 5 6
       + + + + + + +
       |     | |
       + + + + + + +
           |     | |
       + + + + + + +
```

```
00116  0 1 2 3 4 5 6
       + + + + + + +
             | |
       + + + + + + +
           |     | |
       + + + + + + +
```

```
00117  0 1 2 3 4 5 6
       + + + + + + +
           | | |
       + + + + + + +
       | |       | |
       + + + + + + +
```

```
00118  0 1 2 3 4 5 6
       + + + + + + +
       |   | | |
       + + + + + + +
         |       | |
       + + + + + + +
```

```
00119  0 1 2 3 4 5 6
       + + + + + + +
           | | |
       + + + + + + +
         |       | |
       + + + + + + +
```

```
00120  0 1 2 3 4 5 6
       + + + + + + +
         | | | |
       + + + + + + +
       |         | |
       + + + + + + +
```

```
   0 1 2 3 4 5 6
       + + + + + + +
       | | | | |
       + + + + + + +
                 | |
       + + + + + + +
```

```
00122  0 1 2 3 4 5 6
       + + + + + + +
         | | | |
       + + + + + + +
                 | |
       + + + + + + +
```

```
00123  0 1 2 3 4 5 6
       + + + + + + +
           | | |
       + + + + + + +
       |         | |
       + + + + + + +
```

```
00124  0 1 2 3 4 5 6
       + + + + + + +
       |   | | |
       + + + + + + +
                 | |
       + + + + + + +
```

```
00125  0 1 2 3 4 5 6
       + + + + + + +
           | | |
       + + + + + + +
                 | |
       + + + + + + +
```

```
00126  0 1 2 3 4 5 6
       + + + + + + +
             | |
       + + + + + + +
       | |       | |
       + + + + + + +
```

```
00127  0 1 2 3 4 5 6
       + + + + + + +
       |     | |
       + + + + + + +
         |       | |
       + + + + + + +
```

```
00128  0 1 2 3 4 5 6
       + + + + + + +
             | |
       + + + + + + +
         |       | |
       + + + + + + +
```

```
00129  0 1 2 3 4 5 6
       + + + + + + +
         |   | |
       + + + + + + +
       |         | |
       + + + + + + +
```

```
00130  0 1 2 3 4 5 6
       + + + + + + +
       | |   | |
       + + + + + + +
                 | |
       + + + + + + +
```

```
00131  0 1 2 3 4 5 6
       + + + + + + +
         |   | |
       + + + + + + +
                 | |
       + + + + + + +
```

```
00132  0 1 2 3 4 5 6
       + + + + + + +
             | |
       + + + + + + +
       |         | |
       + + + + + + +
```

```
00133  0 1 2 3 4 5 6
       + + + + + + +
       |     | |
       + + + + + + +
                 | |
       + + + + + + +
```

```
00134  0 1 2 3 4 5 6
       + + + + + + +
             | |
       + + + + + + +
                 | |
       + + + + + + +
```

```
00135  0 1 2 3 4 5 6
       + + + + + + +
               |
       + + + + + + +
       | | |     | |
       + + + + + + +
```

```
00136  0 1 2 3 4 5 6
       + + + + + + +
       |       |
       + + + + + + +
         | |     | |
       + + + + + + +
```

```
00137  0 1 2 3 4 5 6
       + + + + + + +
               |
       + + + + + + +
         | |     | |
       + + + + + + +
```

```
00138  0 1 2 3 4 5 6
       + + + + + + +
         |     |
       + + + + + + +
       |   |     | |
       + + + + + + +
```

```
00139  0 1 2 3 4 5 6
       + + + + + + +
       | |     |
       + + + + + + +
           |     | |
       + + + + + + +
```

```
00140  0 1 2 3 4 5 6
       + + + + + + +
         |     |
       + + + + + + +
           |     | |
       + + + + + + +
```

```
00141  0 1 2 3 4 5 6
       + + + + + + +
               |
       + + + + + + +
       |   |     | |
       + + + + + + +
```

```
   0 1 2 3 4 5 6
       + + + + + + +
       |       |
       + + + + + + +
           |     | |
       + + + + + + +
```

```
00143  0 1 2 3 4 5 6
       + + + + + + +
               |
       + + + + + + +
           |     | |
       + + + + + + +
```

```
00144  0 1 2 3 4 5 6
       + + + + + + +
           |   |
       + + + + + + +
       | |       | |
       + + + + + + +
```

```
00145  0 1 2 3 4 5 6
       * * * * * * *
       |   |   |
       * * * * * * *
         |       | |
       * * * * * * *

00146  0 1 2 3 4 5 6
       * * * * * * *
           |   |
       * * * * * * *
         |       | |
       * * * * * * *

00147  0 1 2 3 4 5 6
       * * * * * * *
         | |   |
       * * * * * * *
       |         | |
       * * * * * * *

00148  0 1 2 3 4 5 6
       * * * * * * *
       | | |   |
       * * * * * * *
                 | |
       * * * * * * *

00149  0 1 2 3 4 5 6
       * * * * * * *
         | |   |
       * * * * * * *
                 | |
       * * * * * * *

00150  0 1 2 3 4 5 6
       * * * * * * *
           |   |
       * * * * * * *
       |         | |
       * * * * * * *

00151  0 1 2 3 4 5 6
       * * * * * * *
       |   |   |
       * * * * * * *
                 | |
       * * * * * * *

00152  0 1 2 3 4 5 6
       * * * * * * *
           |   |
       * * * * * * *
                 | |
       * * * * * * *

00153  0 1 2 3 4 5 6
       * * * * * * *
               |
       * * * * * * *
       | |       | |
       * * * * * * *

00154  0 1 2 3 4 5 6
       * * * * * * *
       |       |
       * * * * * * *
         |       | |
       * * * * * * *

00155  0 1 2 3 4 5 6
       * * * * * * *
               |
       * * * * * * *
         |       | |
       * * * * * * *

00156  0 1 2 3 4 5 6
       * * * * * * *
         |     |
       * * * * * * *
       |         | |
       * * * * * * *

00157  0 1 2 3 4 5 6
       * * * * * * *
       | |     |
       * * * * * * *
                 | |
       * * * * * * *

00158  0 1 2 3 4 5 6
       * * * * * * *
         |     |
       * * * * * * *
                 | |
       * * * * * * *

00159  0 1 2 3 4 5 6
       * * * * * * *
               |
       * * * * * * *
       |         | |
       * * * * * * *

00160  0 1 2 3 4 5 6
       * * * * * * *
       |       |
       * * * * * * *
                 | |
       * * * * * * *

00161  0 1 2 3 4 5 6
       * * * * * * *
               |
       * * * * * * *
                 | |
       * * * * * * *

00162  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
       | | | |   | |
       * * * * * * *

00163  0 1 2 3 4 5 6
       * * * * * * *
       |
       * * * * * * *
         | | |   | |
       * * * * * * *

00164  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
         | | |   | |
       * * * * * * *

00165  0 1 2 3 4 5 6
       * * * * * * *
         |
       * * * * * * *
       |   | |   | |
       * * * * * * *

00166  0 1 2 3 4 5 6
       * * * * * * *
       | |
       * * * * * * *
           | |   | |
       * * * * * * *

00167  0 1 2 3 4 5 6
       * * * * * * *
         |
       * * * * * * *
           | |   | |
       * * * * * * *

00168  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
       |   | |   | |
       * * * * * * *

00169  0 1 2 3 4 5 6
       * * * * * * *
       |
       * * * * * * *
           | |   | |
       * * * * * * *

00170  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
           | |   | |
       * * * * * * *

00171  0 1 2 3 4 5 6
       * * * * * * *
           |
       * * * * * * *
       | |   |   | |
       * * * * * * *

00172  0 1 2 3 4 5 6
       * * * * * * *
       |   |
       * * * * * * *
         |   |   | |
       * * * * * * *

00173  0 1 2 3 4 5 6
       * * * * * * *
           |
       * * * * * * *
         |   |   | |
       * * * * * * *

00174  0 1 2 3 4 5 6
       * * * * * * *
         | |
       * * * * * * *
       |     |   | |
       * * * * * * *

   0 1 2 3 4 5 6
       * * * * * * *
       | | |
       * * * * * * *
             |   | |
       * * * * * * *

00176  0 1 2 3 4 5 6
       * * * * * * *
         | |
       * * * * * * *
             |   | |
       * * * * * * *

00177  0 1 2 3 4 5 6
       * * * * * * *
           |
       * * * * * * *
       |     |   | |
       * * * * * * *

00178  0 1 2 3 4 5 6
       * * * * * * *
       |   |
       * * * * * * *
             |   | |
       * * * * * * *

00179  0 1 2 3 4 5 6
       * * * * * * *
           |
       * * * * * * *
             |   | |
       * * * * * * *

00180  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
       | |   |   | |
       * * * * * * *
```

```
00181  0 1 2 3 4 5 6
       * * * * * * *
       |
       * * * * * * *
         |   |   | |
       * * * * * * *
```

```
00182  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
         |   |   | |
       * * * * * * *
```

```
00183  0 1 2 3 4 5 6
       * * * * * * *
         |
       * * * * * * *
       |     |   | |
       * * * * * * *
```

```
00184  0 1 2 3 4 5 6
       * * * * * * *
       | |
       * * * * * * *
             |   | |
       * * * * * * *
```

```
00185  0 1 2 3 4 5 6
       * * * * * * *
         |
       * * * * * * *
             |   | |
       * * * * * * *
```

```
00186  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
       |     |   | |
       * * * * * * *
```

```
00187  0 1 2 3 4 5 6
       * * * * * * *
       |
       * * * * * * *
             |   | |
       * * * * * * *
```

```
00188  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
             |   | |
       * * * * * * *
```

```
00189  0 1 2 3 4 5 6
       * * * * * * *
             |
       * * * * * * *
       | | |     | |
       * * * * * * *
```

```
00190  0 1 2 3 4 5 6
       * * * * * * *
       |     |
       * * * * * * *
         | |     | |
       * * * * * * *
```

```
00191  0 1 2 3 4 5 6
       * * * * * * *
             |
       * * * * * * *
         | |     | |
       * * * * * * *
```

```
00192  0 1 2 3 4 5 6
       * * * * * * *
         |   |
       * * * * * * *
       |   |     | |
       * * * * * * *
```

```
00193  0 1 2 3 4 5 6
       * * * * * * *
       | |   |
       * * * * * * *
           |     | |
       * * * * * * *
```

```
00194  0 1 2 3 4 5 6
       * * * * * * *
         |   |
       * * * * * * *
           |     | |
       * * * * * * *
```

```
00195  0 1 2 3 4 5 6
       * * * * * * *
             |
       * * * * * * *
       |   |     | |
       * * * * * * *
```

```
00196  0 1 2 3 4 5 6
       * * * * * * *
       |     |
       * * * * * * *
           |     | |
       * * * * * * *
```

```
00197  0 1 2 3 4 5 6
       * * * * * * *
             |
       * * * * * * *
           |     | |
       * * * * * * *
```

```
00198  0 1 2 3 4 5 6
       * * * * * * *
           | |
       * * * * * * *
       | |       | |
       * * * * * * *
```

```
00199  0 1 2 3 4 5 6
       * * * * * * *
       |   | |
       * * * * * * *
         |       | |
       * * * * * * *
```

```
00200  0 1 2 3 4 5 6
       * * * * * * *
           | |
       * * * * * * *
         |       | |
       * * * * * * *
```

```
00201  0 1 2 3 4 5 6
       * * * * * * *
         | | |
       * * * * * * *
       |         | |
       * * * * * * *
```

```
00202  0 1 2 3 4 5 6
       * * * * * * *
       | | | |
       * * * * * * *
                 | |
       * * * * * * *
```

```
00203  0 1 2 3 4 5 6
       * * * * * * *
         | | |
       * * * * * * *
                 | |
       * * * * * * *
```

```
00204  0 1 2 3 4 5 6
       * * * * * * *
           | |
       * * * * * * *
       |         | |
       * * * * * * *
```

```
00205  0 1 2 3 4 5 6
       * * * * * * *
       |   | |
       * * * * * * *
                 | |
       * * * * * * *
```

```
00206  0 1 2 3 4 5 6
       * * * * * * *
           | |
       * * * * * * *
                 | |
       * * * * * * *
```

```
00207  0 1 2 3 4 5 6
       * * * * * * *
             |
       * * * * * * *
       | |       | |
       * * * * * * *
```

```
00208  0 1 2 3 4 5 6
       * * * * * * *
       |     |
       * * * * * * *
         |       | |
       * * * * * * *
```

```
00209  0 1 2 3 4 5 6
       * * * * * * *
             |
       * * * * * * *
         |       | |
       * * * * * * *
```

```
00210  0 1 2 3 4 5 6
       * * * * * * *
         |   |
       * * * * * * *
       |         | |
       * * * * * * *
```

```
   0 1 2 3 4 5 6
       * * * * * * *
       | |   |
       * * * * * * *
                 | |
       * * * * * * *
```

```
00212  0 1 2 3 4 5 6
       * * * * * * *
         |   |
       * * * * * * *
                 | |
       * * * * * * *
```

```
00213  0 1 2 3 4 5 6
       * * * * * * *
             |
       * * * * * * *
       |         | |
       * * * * * * *
```

```
00214  0 1 2 3 4 5 6
       * * * * * * *
       |     |
       * * * * * * *
                 | |
       * * * * * * *
```

```
00215  0 1 2 3 4 5 6
       * * * * * * *
             |
       * * * * * * *
                 | |
       * * * * * * *
```

```
00216  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
       | | |     | |
       * * * * * * *
```

```
00217  0 1 2 3 4 5 6
       * * * * * * *
       |
       * * * * * * *
         | |     | |
       * * * * * * *

00218  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
         | |     | |
       * * * * * * *

00219  0 1 2 3 4 5 6
       * * * * * * *
         |
       * * * * * * *
       |   |     | |
       * * * * * * *

00220  0 1 2 3 4 5 6
       * * * * * * *
       | |
       * * * * * * *
           |     | |
       * * * * * * *

00221  0 1 2 3 4 5 6
       * * * * * * *
         |
       * * * * * * *
           |     | |
       * * * * * * *

00222  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
       |   |     | |
       * * * * * * *

00223  0 1 2 3 4 5 6
       * * * * * * *
       |
       * * * * * * *
           |     | |
       * * * * * * *

00224  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
           |     | |
       * * * * * * *

00225  0 1 2 3 4 5 6
       * * * * * * *
           |
       * * * * * * *
       | |       | |
       * * * * * * *

00226  0 1 2 3 4 5 6
       * * * * * * *
       |   |
       * * * * * * *
         |       | |
       * * * * * * *

00227  0 1 2 3 4 5 6
       * * * * * * *
           |
       * * * * * * *
         |       | |
       * * * * * * *

00228  0 1 2 3 4 5 6
       * * * * * * *
         | |
       * * * * * * *
       |         | |
       * * * * * * *

00229  0 1 2 3 4 5 6
       * * * * * * *
       | | |
       * * * * * * *
                 | |
       * * * * * * *

00230  0 1 2 3 4 5 6
       * * * * * * *
         | |
       * * * * * * *
                 | |
       * * * * * * *

00231  0 1 2 3 4 5 6
       * * * * * * *
           |
       * * * * * * *
       |         | |
       * * * * * * *

00232  0 1 2 3 4 5 6
       * * * * * * *
       |   |
       * * * * * * *
                 | |
       * * * * * * *

00233  0 1 2 3 4 5 6
       * * * * * * *
           |
       * * * * * * *
                 | |
       * * * * * * *

00234  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
       | |       | |
       * * * * * * *

00235  0 1 2 3 4 5 6
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       * * * * * * *
         |       | |
       * * * * * * *

00236  0 1 2 3 4 5 6
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       * * * * * * *
         |       | |
       * * * * * * *

00237  0 1 2 3 4 5 6
       * * * * * * *
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       * * * * * * *
       |         | |
       * * * * * * *

00238  0 1 2 3 4 5 6
       * * * * * * *
       | |
       * * * * * * *
                 | |
       * * * * * * *

00239  0 1 2 3 4 5 6
       * * * * * * *
         |
       * * * * * * *
                 | |
       * * * * * * *

00240  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
       |         | |
       * * * * * * *

00241  0 1 2 3 4 5 6
       * * * * * * *
       |
       * * * * * * *
                 | |
       * * * * * * *

00242  0 1 2 3 4 5 6
       * * * * * * *

       * * * * * * *
                 | |
       * * * * * * *

00243  0 1 2 3 4 5 6
       * * * * * * *
                 |
       * * * * * * *
       | | | | |   |
       * * * * * * *

00244  0 1 2 3 4 5 6
       * * * * * * *
       |         |
       * * * * * * *
         | | | |   |
       * * * * * * *

00245  0 1 2 3 4 5 6
       * * * * * * *
                 |
       * * * * * * *
         | | | |   |
       * * * * * * *

00246  0 1 2 3 4 5 6
       * * * * * * *
         |       |
       * * * * * * *
       |   | | |   |
       * * * * * * *

00247  0 1 2 3 4 5 6
       * * * * * * *
       | |       |
       * * * * * * *
           | | |   |
       * * * * * * *

00248  0 1 2 3 4 5 6
       * * * * * * *
         |       |
       * * * * * * *
           | | |   |
       * * * * * * *

00249  0 1 2 3 4 5 6
       * * * * * * *
                 |
       * * * * * * *
       |   | | |   |
       * * * * * * *

00250  0 1 2 3 4 5 6
       * * * * * * *
       |         |
       * * * * * * *
           | | |   |
       * * * * * * *

00251  0 1 2 3 4 5 6
       * * * * * * *
                 |
       * * * * * * *
           | | |   |
       * * * * * * *

00252  0 1 2 3 4 5 6
       * * * * * * *
           |     |
       * * * * * * *
       | |   | |   |
       * * * * * * *

00253  0 1 2 3 4 5 6
       * * * * * * *
       |   |     |
       * * * * * * *
         |   | |   |
       * * * * * * *

00254  0 1 2 3 4 5 6
       * * * * * * *
           |     |
       * * * * * * *
         |   | |   |
       * * * * * * *

00255  0 1 2 3 4 5 6
       * * * * * * *
         | |     |
       * * * * * * *
       |     | |   |
       * * * * * * *
```