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FLUXMETER

Model 'Digital Flux'

Instructions manual

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1 INTRODUCTION

1.1 MAGNETIC QUANTITY

A conductor in which flows an electrical current produces in the space a magnetic field with intensity proportional to the current itself.

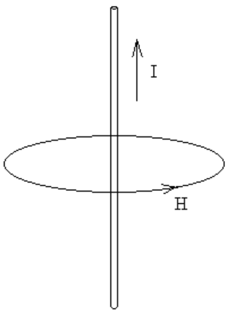


Figure 1

In the case of a current *i* flowing in a long linear wire, ***the magnetic field H*** at a distance *r* from the conductor is:

$$H = \frac{i}{2\pi r}$$

Since the current unit is ampere (A) and the radius unit is meters (m), the unit of H is ampere/metre (A/m). This is the units of H in SI International System of measure, but it is still often used the CGS unit, the oersted (Oe) that is

1 Oe = 79.58 A/m

While the magnetic field *H* is associated only with electrical currents, the ***magnetic induction B*** consider all magnetic sources, like fields produced by magnetic materials. In vacuum (and with optimum approximation in air), *H* and *B* are correlated by the

$$\boldsymbol{B} = \mu_0 \boldsymbol{H}$$

where μ_0 is the *vacuum permeability*, which value is $4\pi \cdot 10^{-7}$ henry/metre (H/m).
If the mean is a ferromagnetic material (for example iron), ***B*** is correlated with ***H*** by the

$$\boldsymbol{B} = \mu\boldsymbol{H} = \mu_{r0}\mu_0\boldsymbol{H}$$

where μ is the permeability of the material, defined as the product of the vacuum permeability and the *relative permeability*, μ_r, that depends on the material.
For some materials, like iron, cobalt and nickel, the relative permeability can have very high value. For example, for iron it is about 5000 at low *H* fields; it means that the magnetic field *H* is amplified by a factor 5000 by the iron presence.
The SI unit of magnetic induction B is the tesla (T). It is still often used the CGS unit, the gauss (G) that is:

$$1 \text{ G} = 10^{-4} \text{ T}$$

In vacuum and in air there is no difference to use H or B (even if B is preferred). Considering fields inside materials, it is necessary to consider H and B as separate quantities.
The ***magnetic flux Φ***, in a surface of area A, crossed by a perpendicular magnetic field of constant intensity B, is defined as

$\Phi = B \cdot A$	**Definition of magnetic flux**

If the field is not constant, a more general definition is

$$\Phi = \oint_S \boldsymbol{B} \cdot d\boldsymbol{S}$$

The flux unit is then tesla × square metre ($T \cdot m^2$), that is named weber (Wb).
The CGS unit is the maxwell (Mx), that is

$$1 \text{ Mx} = 10^{-8} \text{ Wb}$$

The ***magnetic moment m*** of a round turn of area *A* in which flows an electrical current *i* is defined as:

$$m = iA$$

Its unit is the ampere·m^2. The magnetic moment is for magnetism the analogue of electrical charge for electrostatic. It is like a small magnet, with a north and a south pole (see figure).

At atomic scale, the rotation of electrons around nuclei together with their spin, originates magnetic moments. So that, electrons are like small magnets inside the materials. These magnets can be oriented in all different directions (giving no net macroscopic effect, and the material is non magnetic) or can be all oriented in the same direction, to give a macroscopic effect (case of magnetic materials).

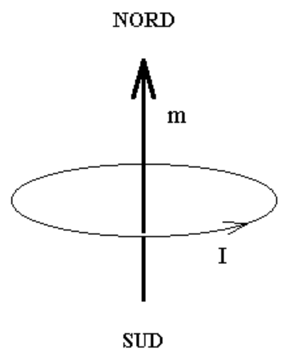


Figure 2

The ***magnetization M*** is defined as the vector sum of all elementary moments divided by the volume of the moments:

$$M = \frac{\sum \boldsymbol{m}}{V}$$

(the symbol Σ means "sum"). The unit of magnetization is the ampere/metre (A/m), the same of the magnetic field H.

The three fields *H*, *B* and *M* are correlated by the fundamental relation of magnetism:

$\boldsymbol{B} = \mu_0(\boldsymbol{H} + \boldsymbol{M}) = \mu_0\boldsymbol{H} + \boldsymbol{J}$	**Fundamental relation of magnetism**

The total magnetic field B is the sum of H (associated with electrical currents) and M (associated with magnetic materials). It is also indicated the usual notation of intrinsic magnetization J, equal to μ_0M. The intrinsic magnetization is only a useful way to express the magnetization M in tesla (or gauss) instead of A/m

Table I resumes main magnetic quantities and their units, while Table II shows conversions between them.

Quantity	Symbol	SI unit	C.G.S. unit
Magnetic field intensity	H	ampere/metre (A/m)	oersted (Oe)
Magnetic induction	B	tesla (T)	gauss (G)
Magnetization	M	ampere/metre (A/m)	
Intrinsic magnetization	J	tesla (T)	gauss (G)
Magnetic moment	M	ampere·metre^2 (A·m^2)	
Magnetic flux	Φ	weber (Wb)	maxwell (Mx)

Table I – Units

	G	Oe	A/m	T
G	-	1	79.58..	10^{-4}
Oe	1	-	79.58..	10^{-4}
A/m	0.01257..	0.01257..	-	$10^7/4\pi$
T	10^4	10^4	$7.96\cdot10^5$	-

Flux
1 Wb = 10^8 Mx
1 Mx = 10^{-8} Wb

Table II - Conversions

1.2 WORKING PRINCIPLE

The fluxmeter is an instrument that measures magnetic flux. The measure is done integrating an induced voltage on the coil's terminals, in accordance with the *Faraday's induction law*: the variation of flux respect time originates a voltage V (induced).

$$V = -\frac{d\Phi}{dt}$$

Faraday's induction law (general)

From this relation, between the time t_1 and t_2 the difference of flux is the integral of voltage:

$$\Delta\Phi = \Phi(t_2) - \Phi(t_1) = \int_{t_1}^{t_2} V dt$$

Directly from Faraday's induction law

Looking to the plot of induced voltage versus time (Figure 3), the flux is graphically the area under the curve (integral).

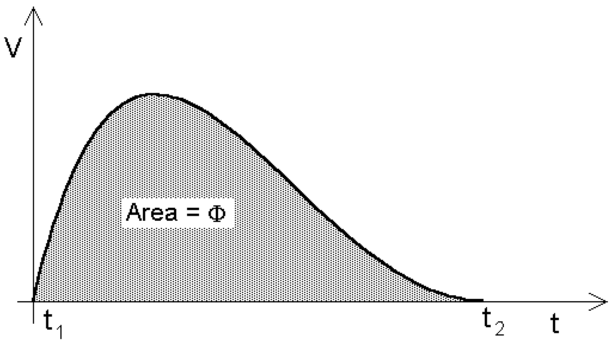


Figure 3

The fluxmeter is basically an electronic integrator. The principle electrical diagram of an integrator circuit is shown in Figure 4.

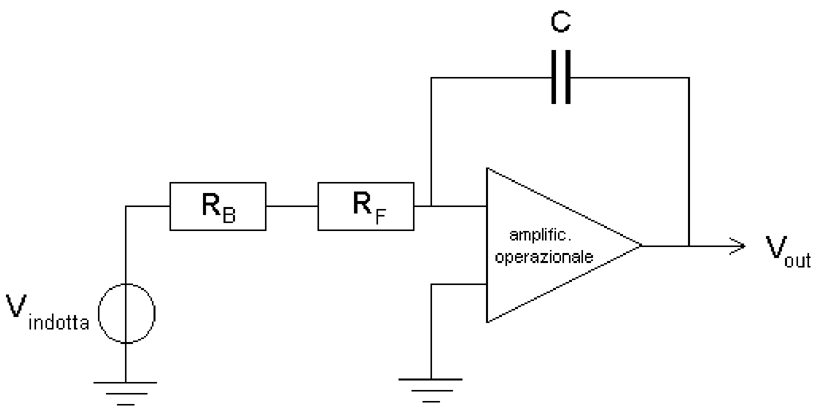


Figure 4

The output voltage V_{out} is proportional to the integral of the input voltage V_{in}:

$V_{out} \propto \frac{1}{R_F C} \int V_{in} dt$	**Output voltage from the integrator circuit**

where R_F and C are the input resistance and capacitance of the fluxmeter.
If the resistance R_B of the measuring coil is negligible respect R_F , then the input voltage V_{in} is the same of the one generated by the flux variation, so:

$$\Phi_{read} \propto V_{out}$$

If the resistance R_B of the measuring coil is negligible respect R_F , then the input voltage V_{in} is less than the one generated by the flux variation, so that the read flux is lower than the real one.
To have the real flux it is necessary to multiply the read flux value by the factor $(R_F + R_B)/R_F$:

$\Phi_{reale} = \frac{R_F + R_B}{R_F} \cdot \Phi_{read}$	**Effect of the resistance of the coil**

2 FUNCTIONS DESCRIPTIONS

2.1 FRONT PANEL

On the front panel are all the manual relations and the reading display; remote control and power connections are located in the back panel.

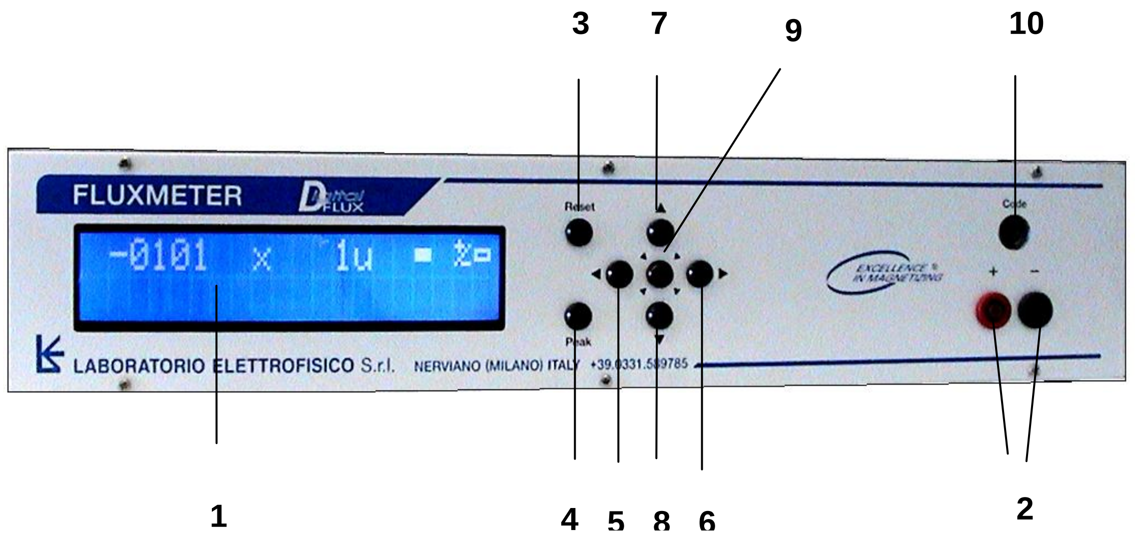
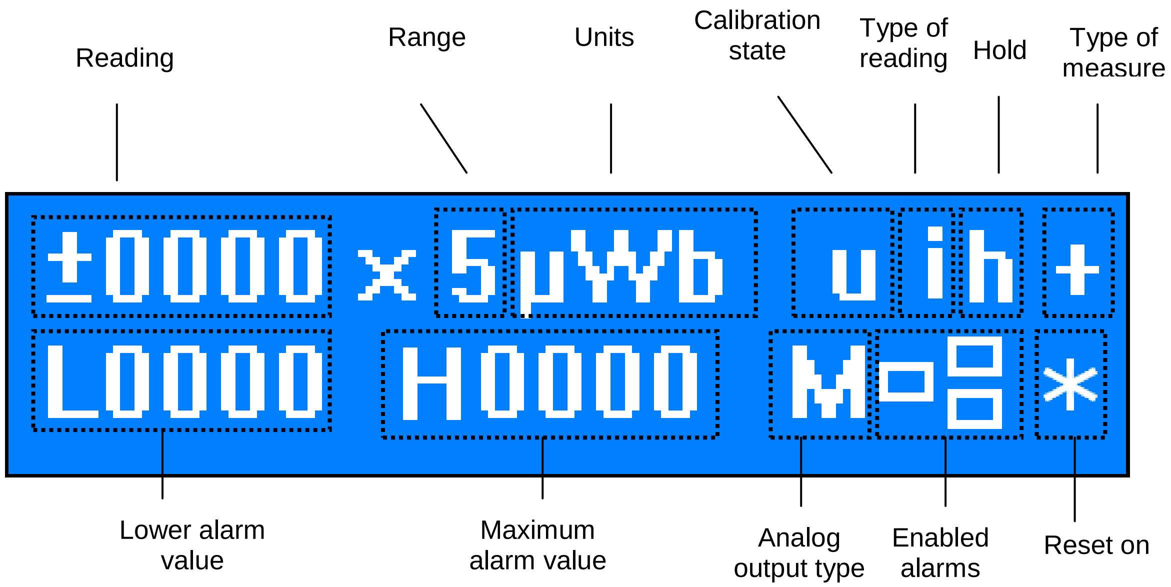


Figure 5

1. Digital Display (2 rows)
2. Coil's input (+ and -)
3. RESET: reset button
4. PEAK: selector for unipolar-bipolar-peak measure
5. Negative drift control ◄
6. Positive drift control ►
7. Select next range ▲
8. Select previous range ▼
9. Enter pushbutton. Press 5 seconds to open menu
10. CODE: code connector (not enabled)

Display description



Reading	Flux reading (with sign)
Range	Range (1, 2, 5, 10, 20, 50, 100)
Unit	μWb, μVs, Mx
Calibration state	Calibration state (it is visualised a 'u' = uncalibrated if expired)
Type of reading	Direct or inverse (in this case a 'i' is visualised
Hold	Hold (it is visualised a 'h' is enabled)
Type of measure	Normal (±), unipolar (+), peak (Pk)
Minimum	Minimum value of alarm (if enabled)
Maximum	Maximum value of alarm (if enabled)
Analog output	Not corrected (M = Monitor) or Corrected as shown in the display (D = Display)
Enabled alarms	AL1 inserted = 1 rectangle on the left, AL2 inserted = 2 rectangles on the right
Reset	It is visualised an asterisk when on

Quick selections

Enter + ◄	Alarm 1 settings
Enter + ►	Alarm 2 settings
Enter + ▲	Units selection (μWb, μV·s, Mx)
Enter + ▼	Analog output selection
Enter + Reset	Fix the flux value (Hold)

2.2 BACK PANEL

In the back panel are located all connectors for power supply, analog output and remote controls (RS232, USB, IEEE-488, services). It is also available a 3-poles connector for signal input.

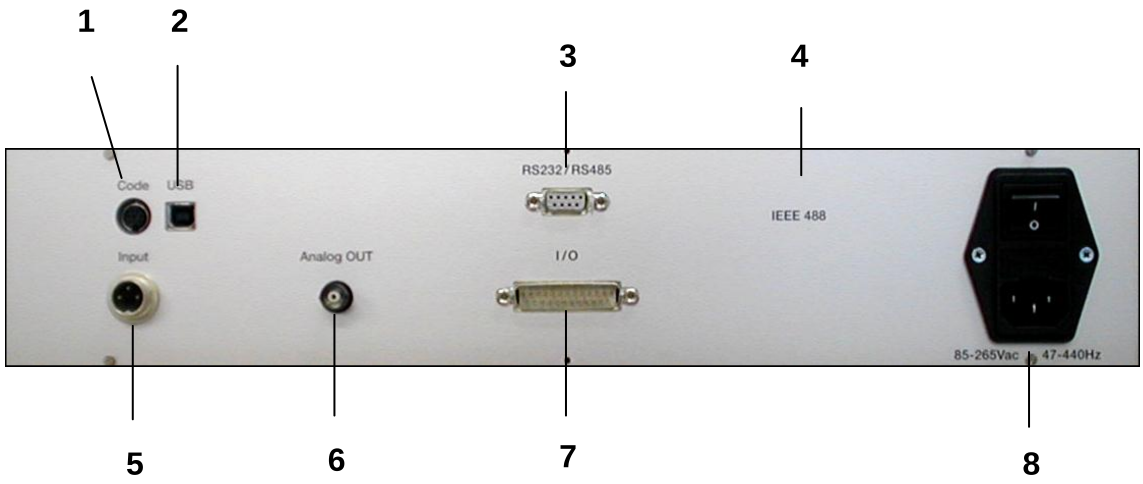


Figure 6

1. Code connector (not enabled)
2. USB (not enabled)
3. Serial port RS232
4. IEEE-488 (optional)
5. Coil's input
6. Analog output
7. Services Input / Output
8. Power supply + main switch

2.3 MENU DIAGRAM

To open the menu, press for 5 seconds the Enter button (central button).
To move horizontally in the table, use ◄ and ►.
To move vertically in the table, use ▲ and ▼.
To confirm, press Enter.
To go back, press Peak, or select EXIT.

			Deafault value
MEASURE	FILTER	50 Hz	X
		60 Hz	
		OFF	
	READING	DIR	X
		INV	
	UNITS	Wb	X
		Mx	
		Vs	
	PROBE	Not used	
	AUTODRIFT	OFF	X
		ON	
	KR ENABLE	ON	
		OFF	X
	KR VAL.	0.1000 – 4.0000)	1.0000
	KR MODE:	"X"	X
		":"	
ALARMS	AL1 MODE	OFF	X
		ON	
		EXT	
		INV	
		DIR	
	AL1 VAL.	XXXX (0 – 9999)	-
	AL1 SRC	READING	X
		PEAK -	
		PEAK +	
	AL2 MODE	OFF	X
		ON	
		EXT	
		INV	
		DIR	
	AL2 VAL.	XXXX (0 – 9999)	-
	AL2 SRC	READING	X
		PEAK -	
		PEAK +	
DISPLAY	UPD/SEC	XX (0 - 25)	10
COMUNIC.	ADDR	XX (00 – 99)	07
	BAUD	9600	X
		4800	
		2400	
	TX DELAY	XXX (0 – 999)	015
	DATA OUT	OFF	X
		TIME	
		HOLD	
ANALOG	MODE	MONITOR	X
		READING	
LAB. EL.	PASSWORD	Restricted area	

2.4 FUNCTIONS DESCRIPTION

All the instruments Digital Flux come out from Laboratorio Elettrofisico Engineering already set for optimal and typical use. After first switch on, the instrument is ready to measure and doesn't need any initial adjustment or setting.
There are several different conditions of use, that can be set by operator.

2.4.1 Reading modality

The value of flux is on the first row of the display in the form:

(flux value) x (range)   (mode: ±, +, $\pm P_k$, $+P_k$)

The flux value (with its unit) is the number of digits multiplied by the range:

Flux (μWb) = Digit x Range

Unit is indicated on the right of the range. 3 different units are available:

Unit	Symbol	Conversion
microweber	μWb	(1 μWb = 1 μVs = 100 Mx)
microvolt·second	μV·s	(1 μVs = 1 μWb = 100 Mx)
maxwell	Mx	(1 Mx = 0.01 Wb = 0.01 μVs)

For example, reading 120 digits, with range 5 with μWb unit, the total flux is:

Flux = 120 x 5 = 600 μWb.

Use buttons ▲ and ▼ to change the range.
To change the measuring unit it is possible to use the quick combination 'Enter + ▲'.
The modality symbol indicates the type of reading:

±	Bipolar reading. Flux is visualised with its sign (+ or -)
+	Unipolar reading. It is visualised the absolute value of flux (only positive).
P_K	The actual flux is visualised on the first row; in second row are visualised the minimum and maximum values in the form: `L MIN           H MAX`

To change modality, press Peak button.

2.4.2 Signal input connector

Every coil or wires configuration that links magnetic field lines can be used as a measuring sensor. Remember that it is the variation of flux that produces the induced voltage (that is integrated by the fluxmeter), so that it is necessary to move the coil or the magnetic field source in case of static field (like for Helmholtz coils) or change the field intensity (like in hysteresisgraph measurements).

2.4.3 Reset

Reset button set to zero the reading on the display. An asterisk visualises the reset operation. The reset operation disables the automatic drift control if it is in use.

2.4.4 Drift control

Due to input potentials, due to thermo-electrical effects or other effects, it is often present a drift of the value of flux. This drift doesn't come from flux variation, and it is generally more severe at low ranges. These disturbs can be balanced in static conditions, so that the variation is only due to variation of magnetic flux.
Drift control balance is done by the two buttons ◄ and ► (Figure 5). The drift control intensity is represented by a number between 0 and 4095. A low value moves the drift to negative values; a high value moves the drift to positive values. The drift value is shown in the second row when one of the two pushbuttons ◄ and ► is pressed.
Drift can be balanced automatically or manually:

Automatic control

Automatic control is activated pressing the two buttons ◄ and ► in the same time. When the control is active, a small blinking rectangle is visualised on the right of the measuring unit. The automatic drift control works only if the value is lower than 50 digits. Press Reset to disable automatic drift control.

Manual control

If the drift is negative, i.e. the number of digits decrease, it is necessary to balance this reduction pressing the button ► for a time that depends on the drift rate.

Vice versa, if the drift is positive, it is necessary to press the ◄ button.

Pressing one time, the drift change of one unit. Keeping pressed the button, the drift change with steps of 5 units.

Suggestion: to better understand the drift sign, it is convenient reset the flux and wait for a reading change.

2.4.5 Alarms

To set the alarms, enter in the Menu (press for 5 second the Enter button), select `ALARMS` and enable the alarms selecting `MODE`. It is also possible to quick set the alarms with the buttons combination Enter + ◄ (Alarm 1) and Enter + ► (Alarm 2).

The `MODE: DIR` gives an alarm if the flux is higher than the set value.

The `MODE: INV` gives an alarm if the flux is lower than the set value.

For example, to have an alarm if the value is lower than Alarm1 and higher than Alarm2, set `AL1 MODE` on `INV` e `AL2 MODE` on `DIR` .

setting `MODE:ON`, it is as the alarm is always on, independently from the flux value.

When Alarm1 is enabled, a small rectangle (□) appears near letter `D`, on right bottom.

When Alarm2 is enabled, two small rectangles appear near letter `D`, on right bottom. If one alarm occurs, the rectangle is full (□), otherwise is empty (□).

2.4.6 Analog output

The analog output has two modality: not calibrated (M, Monitor) and calibrated (D, Display).
The two modalities can be set from the menu or directly using the quick combination Enter + ▼.
The analog output is a voltage in mV equal to the flux value on the display (except the range). For example, two readings, one 1234 x 2 μWb and another 1234 x 5 μWb give the same value of analog output voltage (1234 mV).
The monitor output (symbol M) is corrected with internal coefficient, and it is less affected by analog-digital conversion errors:

→ *Normal use is M, that gives a calibrated value.*

The use of D modality is limited to internal laboratory controls.

2.5 USING THE MULTIPLICATION FACTORS

Under the MEASURE menu, it is possible to set a numerical factor to multiply or to divide the flux by this number.
The purpose of the numerical factor is to have a final result which gives a different physical quantity related with the flux and a particular coil. This numerical factor, named KR, can be set from 0.100 to 4.000.
The use of the factor (KR) can be enabled/disabled.
When disabled, even if the factor is set different than one, the flux reading is shown unchanged.
When enabled, the flux reading cab be multiplied or divided by KR, depending on the setting of KR MODE: "X" multiplies the flux, ":" divides the flux by KR.
Enabling KR, the peak function will be automatically disabled. The display will show 2 lines: in the upper lines it will be displayed the real flux reading, in the lower line it will be displayed the flux multiplied or divided by KR. The letter K displayed on the right will remember that the function KR was enabled.

Examples:

Real flux = 1500 x 5 µWb KR ENABLE: MODE ON KR VAL: 2.000 KR MODE: "X" Result shown in the second line: 3000	
Real flux = 1500 x 5 µWb KR ENABLE: MODE ON KR VAL: 2.000 KR MODE: ":" Result shown in the second line: 750	
Real flux = 1500 x 5 µWb KR ENABLE: MODE ON KR VAL: 0.500 KR MODE: "X" Result shown in the second line: 750	

Real flux = 1500 x 5 µWb
KR ENABLE: MODE ON
KR VAL: 0.500
KR MODE: ":"

Result shown in the second line: 3000

The overrange of fluxmeter is always ±1999 digits. When real flux is higher than 1999, even if the calculation results in a lower value, an overrange condition is displayed with ---- in the bottom line

The serial output and the analog output will give the real flux, and not the elaborated one.

2.6 REMOTE OPERATIONS

2.6.1 RS232 port

The following parameters should be set on the computer or PLC to match that of the fluxmeter.

BAUD RATE:	9600
CHARACTER LENGTH:	8
PARITY:	NONE
STOP BITS:	1

The interface connector is a standard 9-pin “D” female type connector. Three signals are supported as shown in Figure.

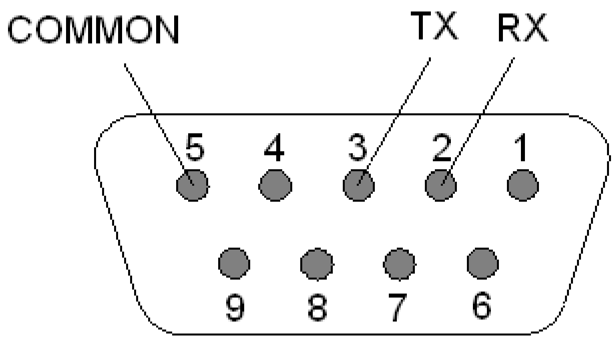


Figure 7

The connection cable with a PC should be Pin-To-Pin, i.e. Pin 2 on PC should be connected with Pin 2 on fluxmeter

2.6.2 Communication format

The string format to *read* a parameter is in the following form:

```
*00:RXX#[CR][LF]
```

where XX is a number that correspond to the particular parameter to read:

XX	Parameter
00	Measure
01	Range
08	Address
19	Serial Number

[CR] and [LF] is a notation to indicate ‘Carriage Return’ and ‘Line Feed’.

The string format to *write* a parameter is in the following form:

`*00:WYY=ZZZZZ#[CR][LF]`

where YY is a number that correspond to the particular parameter to write and ZZZZZ is the value of the parameter YY (not always necessary):

YY	Parameter
01	Range
29	Reset ON
30	Reset OFF

2.6.3 Examples

Range setting
The string is “`*00:W01=PPPPP#[CR][LF]`”, where

Range	PPPPP
1	00001
2	00002
5	00003
10	00004
20	00005
50	00006
100	00007

Range reading

The string is "*00:R01#[CR][LF]"; the response string will be of type "*=RRRRR#[CR][LF]" where

Range	RRRRR
1	00001
2	00002
5	00005
10	00010
20	00020
50	00050
100	00100

Measure

To read a measured value on display, write "*00:R00#[CR][LF]"; the response string will be of type "*=MMMMM#[CR][LF]" where MMMMM is the measure.

Reset

To reset the fluxmeter, send *both* the following strings:

"*00:W29#[CR][LF]"
(then delay 0.5 seconds)
"*00:W30#[CR][LF]"

Serial number

To read the serial number of the fluxmeter, write "*00:R19#[CR][LF]"; the response string will be of type "*=SSSSSSSSS#[CR][LF]" where SSSSSSSSS (9 characters) is the serial number.

2.6.4 25 poles male connector (back panel)

Alarm 1

8	Normally Closed (N.C.)
9	Common
10	Normally Open (N.O.)

Alarm 2

20	Normally Closed (N.C.)
21	Common
22	Normally Open (N.O.)

External signals

16	External Reset
4	External Reset
17	External Hold
5	External Hold

Auxiliary supply 24 Vdc

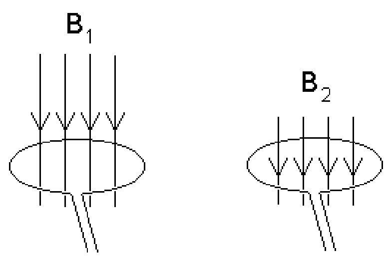
Positive pins	12, 13, 25
Negative pins	1, 2, 14

3 MEASURE

3.1 FLUX VARIATION

The measure of flux is done by the fluxmeter integrating the induced voltage produced by a flux *variation* (Faraday's law): to measure a flux, it is necessary to have a variation of flux.
If the magnetic field is variable with time, then the flux variation is produced directly by the field variation.
If the magnetic field is static and constant, then the variation must be produced by the coil, for example moving it in an area of different intensity. The following table shows this difference.

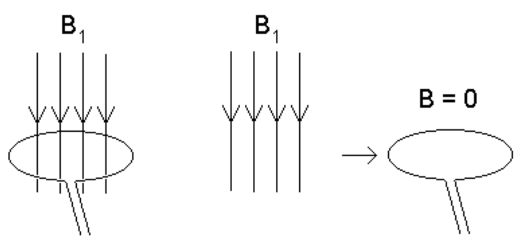
Variable field



$$\Delta\Phi = NA \cdot (B_2 - B_1)$$

Magnetic field changes its intensity from B_1 to B_2. The measuring coil, with magnetic area *NA* remains in the same position and takes the variation of flux directly from the variation of field.

Constant field



$$\Delta\Phi = NA \cdot (0 - B_1)$$

The magnetic field remains constant. To generate a variation of flux it is necessary to move the coil in a place with a null or different value of field.

3.2 MEASURE OF STATIC MAGNETIC FIELD

The flux linked with a coil of *N* turns with area *A* placed normally to a magnetic field of average intensity *B*, is given by the formula:

$$\Phi = N \cdot A \cdot B$$

Having a coil with known area *A* and number of turns *N*, it is possible to obtain the value of magnetic field *B* from the value of flux.
To measure the value of field from a value of flux it is necessary a flux variation. If the variation is obtained between a condition of coil fully inserted in the field (Figure 8-a) and another with the coil in a place with zero (or negligible) field (Figure 8-b), the flux will be exactly equal to the product *NAB*.

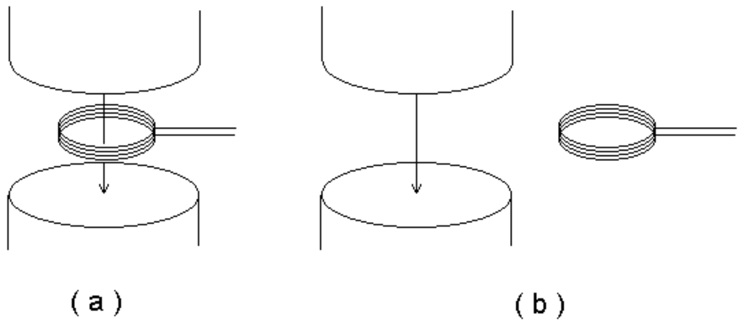


Figure 8

Measuring procedure
1. Insert the coil’s terminals in the fluxmeter input (front or back);
2. Select a range and control the drift;
3. position the coil in normally to the magnetic field to measure;
4. Reset the fluxmeter;
5. Take out the coil and place it in a zero (or negligible) field region;
6. The reading on the display multiplied by the range is the value of flux (with the selected unit selected).

Example
Suppose to have a reading of 1250 digits on range 2 using a coil with 10 turns which area is 500 mm^2 (consider only 1 layer of turns).

Suppose that the unit is the μWb (suggested unit).
The total flux will be:

Total flux = 1250 x 2 =2500 μWb

The mean value of magnetic field B is given by:

B = 2500·10^{-6} Wb / (10 x 500·10^{-6} m^2) = 0.5 Wb/m^2 = 0.5 tesla

(or 5000 gauss, remembering that 1 T = 10000 G).
If the measure is in air, the magnetic field intensity H is simply B divided by the air permeability:

$$H = \frac{B}{\mu_0} = \frac{0.5}{1.256 \cdot 10^{-6}} = 3.98 \cdot 10^{5}\ A/m$$

Note that A/m is a small unit. Generally, it is preferred to use gauss or millitesla (mT).

Example using the KR

The use of KE allows to have directly displayed the value of field in gauss (remembering that B = Φ/magnetic area) but it must be taken in consideration the range of the fluxmeter.
Using a certain range, KR must be set as the magnetic area/range.

Setting to have B in gauss:	$KR = \frac{\text{magnetic area (in mm}^2\text{)}}{\text{Range} \cdot 10000}$

For example, suppose to use a coil having magnetic area 7000 mm^2 (typical value of the LPH-200 search coil) and the fluxmeter in range 5.
In this case, set KR = 7000/50000 = 0.14, and `KR MODE` = “:”.
A reading of 1120 digits on range 5, for example, will give directly the value of 1120 / 0.14 = 8000 G.

Remember to change the KR value in case you need to lower or rise the range of the fluxmeter.

3.3 MEASURE WITH HELMHOLTZ COILS

Helmholtz coils (Figure 9) are made with two coaxial coils put in a particular configuration to give the maximum uniformity volume inside them. Helmholtz coils permits the measure of intrinsic magnetization of a permanent magnet in its working point J_W. For ferrite, NdFeB and Sm-Co, this value is very similar to the residual induction (Jr or Br).

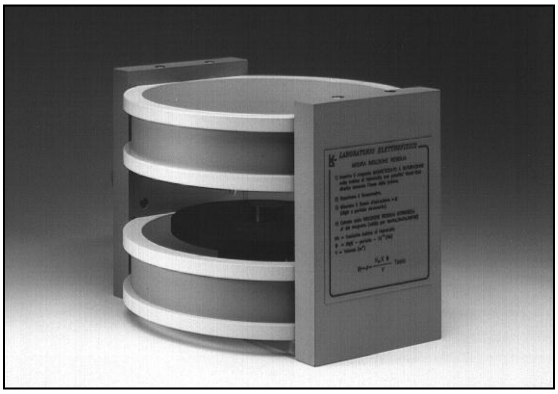


Figure 9

For alnico, generally the working point is very different from the Br.
To determine the J of the working point of a permanent magnet follow these simple instructions:

Measure procedure:

1. Measure the volume of the sample and magnetize it to saturation level. The magnetization must be bipolar, and the sample must be measured in the direction of magnetization.
2. Put the Helmholtz coils in a place far from any ferromagnetic material and connect it to the fluxmeter;
3. Select a range that gives higher value without going in over-range;
4. Control fluxmeter's drift;
5. Regulate the internal platform in a way that the centre of the magnet stay in the middle of the two coils;
6. Put the magnet in the coils with its axes parallel to the axes of the coils;
7. reset the fluxmeter;
8. Take out the magnet, placing it far from the influence zone of the coil. Eventually repeat steps 6-8 to control accuracy;

The value of the J_W of the working point (similar to the Br) is obtained by the relation:

$$B_r = J_r \approx J_W = \frac{K_H \cdot \Phi}{V}$$

Helmholtz coils formula

where :
K_H is the Helmholtz coils constant (in m), indicated in the coil's label;
Φ is the flux (in Wb), given by the product of number of digits and the range
V is the volume of the sample (in m^3).
The result is in tesla (T).

Example
Suppose to have a cylindrical magnet in ferrite with a diameter of 20 mm and a thickness of 10 mm. Using a Helmholtz coil with constant $K_H = 2.345 \cdot 10^{-3}$ m the reading is 260 digits on range 2, using μWb units. Using the formula:

$$B_r \approx J_W = \frac{2.345 \cdot 10^{-3} \cdot 260 \cdot 10^{-6} \cdot 2}{\left(\frac{20}{2}\right)^2 \cdot \pi \cdot 10 \cdot 10^{-9}} = 0.388\,T$$

The lower is the initial slope of the second quadrant curve, the more similar is the residual induction to the J_W. Typically, it is between 1 ÷ 5 % lower.

Example using the KR
In the previous example, we calculate:

$$B_r \approx J_W = \frac{2.345 \cdot 10^{-3} \cdot 260 \cdot 10^{-6} \cdot 2}{\left(\frac{20}{2}\right)^2 \cdot \pi \cdot 10 \cdot 10^{-9}} = 0.388\,T$$

This can be also written as

$$B_r \approx J_W = 260 \cdot 0.001492 = 0.388\,\mathrm{T}$$

Supposing we have to measure a lot of magnets all with the same dimensions, we could incorporate this coefficient as KR and simply multiply the flux by this constant.
Since KR can be set only between 0.100 and 4.000, it can be convenient to use the unit mT instead of T in the final result. In this case, the final result can be written as 388 mT, and KR as 1.492.

Further measurement will come out very easily in this way. For example, with a flux of 265x2 µWb, the second line will display the value of 265 x 1.492 = 395 (in units mT).

Always keep in mind the units of the result, and set the units to use an allowed KR value.

3.4 MEASURE WITH POTENTIAL COIL

The potential coil is basically a long winding covered with a protective layer. The potential coil permits the measure of the internal demagnetization field H_W in the working point of a permanent magnet.
Every coil has a proper constant between flux and H_W. The constant is indicated in the handle of the coil.
The measure must be done on magnets with parallel surfaces. The magnet must be saturated in a two poles configuration.

Measure procedure

1. Measure the thickness *d* of the magnet to measure;
2. Put the Helmholtz coils in a place far from any ferromagnetic material and connect it to the fluxmeter;
3. Select a range that gives higher value without going in over-range;
4. Control fluxmeter's drift;
5. Pot the end of the coil on one surface of the magnet, parallel to the magnetization direction.
6. Reset fluxmeter;
7. Move away the coil in a space without magnetic fields;
8. Repeat eventually steps 5-7 to control repeatability of the procedure.

The value of H_W can be obtained from the relation:

$$H_W = \frac{2 \cdot K_P \cdot \Phi}{d}$$

Potential coil formula

where :

- K_P is the coil's constant (in A/Wb), indicated in the coil's label;
- Φ is the read flux (in Wb), given by the product of the reading in digits and the range
- *d* is the thickness of the magnet (in m).

The measure of H_W comes out in ampere/metre (A/m) unit.

Example

A Ferrite magnet with thickness of 8 mm is measured with a potential coil with a constant of $K_P = 5.65 \cdot 10^6$ A/Wb.

Reading 48 digits on range 2, with μWb units, the formula gives:

$$H_W = \frac{2 \cdot 5.65 \cdot 10^6 \cdot 48 \cdot 10^{-6} \cdot 2}{8 \cdot 10^{-3}} = 135600 \, A/m$$

3.5 MEASURE WITH COILS WITH HIGH RESISTANCE

The resistance of the measuring coil is in series with the input resistance of the fluxmeter's integrator circuit. This gives a loss of the signal, more the resistance of the coil, more is the loss (see also § 1.2).
To consider this effect, the flux read on the display must be multiplied by the factor $(R_F + R_B)/R_F$, that is always higher than one. The results is the real flux linked with the coil:

$\Phi_{real} = \frac{R_F + R_B}{R_F} \cdot \Phi_{read}$	**Effect of the coil's resistance**

The input resistance of the fluxmeter R_F is 10 kΩ multiplied by the range.

Example
Using a measuring coil with a resistance of 2000 Ω the reading on the fluxmeter is 1500 digits on range 2, using μWb unit. The real flux is:

Φ_{read} = 1500 x 2 μWb = 3000 μWb

R_F = 10 kΩ x 2 = 20 kΩ

$$\Phi_{real} = \frac{R_F + R_B}{R_F} \cdot \Phi_{read} = \frac{20000 + 800}{20000} \cdot 3000 = 3120 \, \mu\text{Wb}$$

The real flux is 3120 μWb against the 3000 read, i.e. 4 % higher.

When the resistance of the coil is less than 50 Ω, the effect can be neglected on all the ranger, because the error should be only 0.5 % maximum.

4 SPECIFICATIONS

Power supply	220 volt 50/60 Hz
Absorption	0.3 A
Range	1 -2 -5 -10 -20 -50 –100 μWb/digit
Full scale value	± 2000 digit x range
Resolution	1 digit x range
Display	LED LCD
Accuracy	± 0.5 %
Warm up time	15 min.
Drift	< 1 digit/min
Drift control	panel / remote
Flux reset	panel / remote
Interface	RS232
Analog output	± 2 V (± 5 mV offset)
Input impedance	10 kΩ x range
Max input voltage	60 volt peak
Working temperature	10 - 40 °C
Humidity	80%
Dimensions	483 x 380 x 88 mm
Weight	5 kg

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