

# RG 2040

## REGULATION SYSTEM

**User's Manual**

**Version 2.0**

**(Revision 1.0)**

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## HOW TO USE THIS MANUAL

Firstly read the introduction in order to get an idea of the RG 2040's range of functions.

Secondly Chapter 2 "THEORY OF OPERATION" gives you more details on the operations of the system.

To work with the PT 2025 / RG 2040 METROLAB Teslameter / Regulation system (refer to as "PT/RG" in the manual), follow carefully the details of operation which are given in Chapter 5 "DETAILS OF OPERATION".

Chapter 6 gives the syntax of all commands accepted by the PT/RG unit.

Should you have any questions or need additional information, please do not hesitate to contact us. We welcome your comments.

Note: the RG 2040 plug-in unit can perform all the functions of the standard I/O board of the PT 2025 Teslameter





## 1 INTRODUCTION

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The RG 2040 option gives the METROLAB 2025 Teslameter the possibility to regulate the magnetic field generated by electromagnets having resistive or superconductive coils with iron or air cores.

The stability of a permanent magnet may also be controlled using auxiliary coils.

Physically the RG 2040 consists of a unit which may be plugged into the PT 2025 Teslameter, in the slot normally used for the board containing the IEEE 488 and RS 232 C digital interfaces. However, all the previous features of these interfaces are maintained.

Two RS232C (one floating), one IEEE 488 and two analog ports allow the RG 2040 to adapt to many different Magnet Power Supplies (MPS) and correcting device configurations which will be described in detail in Chapter 4.

The MPS may communicate with the RG 2040 via an RS 232 C or IEEE 488 link.

The host computer may communicate with the RG 2040 via an RS 232 C or IEEE 488 link (e.g. the PSION XP hand-held microcomputer which we can supply, which connects to the RS 232 C port). Moreover, a "transparent" mode allows the host computer direct interaction with the MPS.

The correction system may be driven linearly via a  $\pm 20$  mA or  $\pm 5$ V output or digitally via RS 232 C or IEEE 488 links.

In some NMR regulation systems, the resonance frequency tracking loop is opened. The NMR probe is driven by a given radio frequency source (e.g. RF synthesizer) which supplies the reference value. The difference between the resonance frequency and this reference value generates a proportional error signal which is used to regulate the current of the MPS. However, this type of signal is noisy and a filter with a long time constant is required. This repudiates the claimed rapidity of the system and the method becomes equivalent to the software regulation performed with the RG 2040 option.

Note: the RG 2040 does not require the expensive use of an RF synthesizer.

The “philosophy” of the RG 2040 regulation consists in adding a small correcting magnetic field to the main one, without interacting with the PID regulation loop of the MPS.

In the PT/RG system, the value of the magnetic field is periodically read by the microprocessor and compared with a given field value. This comparison generates the correction which is then sent to the correction device.

The correction field may be produced acting on the reference parameter of the MPS. For example, an additional coil may be wound on to the DCCT (Direct Current Current Transformer) which measures the main current of the electromagnet.

Alternatively, an auxiliary coil may be used. It is important to note that, if the MPS is already regulated with a Hall probe, the only way to avoid it “competing” with the NMR one is to act on the MPS's own setting value.

**This principle of operation assumes that the MPS can alone guarantee the required short term stability during, at least, a few seconds.**

The RG 2040 will then provide long term stability at the level of the PT 2025 accuracy. Higher stabilities may also be achieved using the HS-High Stability option (refer to the PT 2025 specification).

During the regulation process, the RG 2040 software controls all operations: i.e. MPS's COARSE setting, correcting device driving, etc...

## **2 THEORY OF OPERATION**

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The PT/RG system is able to control the MPS operations via a digital link. An initialization phase is required at installation in order to store all the parameters of the complete system Magnet-MPS-Probes in an Electrically Erasable Prom (EEPROM).

### **2.1 INITIALIZATION**

Eighteen microswitches are available on the rear panel of the RG 2040 unit. They define the general configuration of the system including: type of interfaces, addresses, baud rates, etc. (see Chapter 5).

The following parameters, which will be described in detail in Chapter 5 must be entered via the host computer:

- the format of the MPS COARSE setting command together with the maximum value of the current parameter "Pc" of the MPS **[EFC...]\***;
- the format of the FINE setting command of the MPS, if available, with the maximum corresponding Pf parameter value **[EFF...]**;
- the approximate value of the maximum field settling time **[ES...]** ;
- the minimum and maximum field value in units of Pc which can be measured by the NMR probe set installed in the magnet; this gives the NMR regulation range **[ECL...]** and **[ECH...]**.

When all the above parameters are stored, the function B(Pc) is stored into EEPROMs as an array. The array contains 2 points for air core magnets, or 20 points (which are automatically measured **[ECS]**) for iron core magnets.

The initialization operations may be repeated at any time, the new parameters replacing the old ones in the EEPROM.

The expressions **[XXX...]** refer to commands which are described in detail in Chapter 5.

## 2.2 REGULATION

The set of data comprising one field target value and the chosen regulation parameters may be considered as a vector. Up to 20 vectors thus defined (regulation vectors) may be stored in the EEPROM registers 1 to 20 by the command **[EBM...]** or recalled to the foreground register 0 by the command **[ER1...]** which simultaneously starts the regulation. Only the vector in the foreground drives the regulation and may therefore be modified.

A regulation vector consists of:

field target value **[EB...]**

regulation window **[EB...]**

cumulative correction gain adjustment **[EKI...]**

proportional correction gain adjustment **[EKP...]**

correction setting delay **[ET...]**

number of samples in the sliding average **[EM...]**

digital filter rejection level **[EH...]**

digital filter sample number **[EX...]**

display reading rate **[V...]**

Once a) and b) are given, the RG 2040 automatically measures the domain of activity of the correcting device and calculates the correcting gain.

The points c) to h) may be adjusted during the regulation process.

At any moment, the MPS status may be checked (temperature, water flow, etc..) via the "transparent" mode, thus allowing the host computer to dialogue directly with the MPS.

After the regulation start command, the RG 2040 sets the MPS to the required coarse value of the field. Then the PT/RG searches and locks on the NMR probe signal. If the actual field does not fall within the central third part of the regulation window, the MPS coarse value (Pc) is readjusted to meet this condition. Henceforth, the MPS COARSE setting is fixed during the regulation process. The correction device alone will guarantee the long term stability of the field.

The range of action of the correction device (regulation window **[EB...]**) should not be greater than approximately 1500 ppm of the maximum field value in order to ensure a reasonable resolution for the correction (12 bit DAC).

The actual value of the field is given by a sliding average of the last “n” field measurements **[EM...]**. The difference between this actual average and the fixed regulation value gives the new value of the parameter which is subsequently sent to the correction device. In this way, the cumulative **[EKI...]** and proportional **[EKP...]** gain adjustments optimise the regulation process.

Each measurement of the field is triggered after a delay **[ET...]** which is long enough to allow the field correction to be carried out.

A digital filter holds the measurements whose difference from the target value is greater than a given threshold **[EH...]**. These erroneous measurements occasionally occur due to EMI or other accidental events, but are rejected unless they are repeated a given **[EX...]** number of times.

The command **[ERO]** stops the regulation and “freezes” the correction value.

The command **[EI...]** can be used to increment the field target value during the regulation process within the limits of the regulation window. The initial target field **[EB...]** remains unchanged.

At any time, a listing of the regulation vectors may be obtained **[EBS...]**.



## **3 RG 2040 SPECIFICATIONS**

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### **3.1 SPECIFICATIONS**

- Packaging: plug-in module replacing the I/O board in the METROLAB PT 2025 Teslameter comprising two single Euro boards (220 mm length) and a rear panel.
- Analog. outputs: two analog outputs floating together, isolated from ground at 500 VAC and 1 KV peak. They supply:  $\pm 5V$  (max. 1 mA) (optionally 0 to +10 V) and  $\pm 20$  mA (max. 8 V) (optionally  $\pm 2$  mA).
- Digital links: one IEEE 488 and one RS 232 C port grounded (for the host computer). One floating RS232C port for the MPS. It is isolated from ground at 500 VAC and 1 KV peak.

### **3.2 PERFORMANCE**

The performance of the RG 2040 regulation system used with a particular MPS relies upon the following points:

- the MPS specifications;
- the signal/noise ratio of the NMR signal generated by the probe. This ratio is essentially dependent on :
  - ❖ field homogeneity,
  - ❖ type of NMR probe,
  - ❖ frequency in use within the full specified probe frequency range (the S/N ratio is higher in the upper zone of the probe frequency),
  - ❖ ambient Electro-Magnetic Interferences (EMI);
- the choice of parameters in the regulation vector.

The number of the elements in the sliding average of the field values gives the accuracy of the regulation and determines the RG 2040 system response time. For example, in stable conditions, a long term stability of 0.1 ppm requires about  $n=10$ . This will give a response time of approximately 10 seconds. However, these numbers depend strongly on the overall system specifications.

It is important to verify the mutual matching of the MPS, the magnet and the RG 2040 system and also to check that the effective regulating frequency spectra of the two devices overlap sufficiently.

The expected long term stability relies on the PT 2025 specifications, in particular on the use of the optional HS High Stability version of the frequency counter (refer to the PT 2025 specifications).



## **4 CONFIGURATIONS**

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### **4.1 THE PT/RG INTERFACES**

The PT/RG is equipped with two RS 232 C interfaces and an IEEE 488 interface. The desired interface can be selected by using microswitch A9 situated on the back panel: "0" = RS 232 C and "1" = IEEE 488.

Via these interfaces the user has control of the regulation functions, the front panel functions and can access the measured field value as well as the instrument status. Chapter 6 describes in detail the syntax of the commands.

#### **4.1.1 The two operating modes of the RS 232 C Interface**

The RS 232 C interface marked "host" can function in two ways.

The first is called "conversational" and allows the user to send messages to the PT/RG as well as read the last measured field value or the internal instrument status registers (see chapters 5 and 6).

The second method is called "autonomous" and consists of the PT/RG sending the last measured value to the "host" RS 232 C interface at regular intervals. In this mode any incoming messages are ignored and it is not possible to use the field regulation functions.

This mode is used to connect the PT/RG to a printer without needing an external controller. To select this mode, microswitch A8 must be set to 0. The message format is described in section 6.2.1. The intervals between each output can be defined by microswitches B1 to B5 as shown in the following table:

Microswitches	Interval
5 4 3 2 1	
<hr/>	
0 0 0 0 0	no message transmission
0 0 0 0 1	sends every measured value
0 0 0 1 0	sends every 2 <sup>nd</sup> measured value
0 0 0 1 1	sends every 3 <sup>rd</sup> measured value
0 0 1 0 0	sends every 4 <sup>th</sup> measured value
0 0 1 0 1	sends every 5 <sup>th</sup> measured value
0 0 1 1 0	sends every 6 <sup>th</sup> measured value
0 0 1 1 1	sends every 7 <sup>th</sup> measured value
0 1 0 0 0	sends every 8 <sup>th</sup> measured value
0 1 0 0 1	sends every 9 <sup>th</sup> measured value
0 1 0 1 0	sends every 12 <sup>th</sup> measured value
0 1 0 1 1	sends every 16 <sup>th</sup> measured value
0 1 1 0 0	sends every 20 <sup>th</sup> measured value
0 1 1 0 1	sends every 27 <sup>th</sup> measured value
0 1 1 1 0	sends every 36 <sup>th</sup> measured value
0 1 1 1 1	sends every 48 <sup>th</sup> measured value
1 0 0 0 0	sends every 60 <sup>th</sup> measured value
1 0 0 0 1	sends every 80 <sup>th</sup> measured value
1 0 0 1 0	sends every 100 <sup>th</sup> measured value
1 0 0 1 1	sends every 150 <sup>th</sup> measured value
1 0 1 0 0	sends every 180 <sup>th</sup> measured value
1 0 1 0 1	sends every 240 <sup>th</sup> measured value
1 0 1 1 0	sends every 300 <sup>th</sup> measured value

1 0 1 1 1	sends every 420 <sup>th</sup> measured value
1 1 0 0 0	sends every 540 <sup>th</sup> measured value
1 1 0 0 1	sends every 720 <sup>th</sup> measured value
1 1 0 1 0	sends every 900 <sup>th</sup> measured value
1 1 0 1 1	sends every 1200 <sup>th</sup> measured value
1 1 1 0 0	sends every 1600 <sup>th</sup> measured value
1 1 1 0 1	sends every 2100 <sup>th</sup> measured value
1 1 1 1 0	sends every 2700 <sup>th</sup> measured value
1 1 1 1 1	sends every 3600 <sup>th</sup> measured value

Note: one measurement takes approximately 1 second.

### **4.1.2 The two operating modes of the IEEE 488 Interface**

The IEEE 488 interface of the PT/RG can perform the following functions: SH1;AH1;T5;L4;SR1;RL1;PPO;DC1;DT1;CO;E2.

It has two modes of operation.

The first one is called "Listener/Talker" and allows the user to dialogue with the host computer. To receive messages the PT/RG must be addressed as a Listener. The PT/RG reacts to the standard IEEE 488 functions such as REMOTE, LOCAL etc. It is also possible for the user to access data contained in the PT/RG; in this case the instrument must be addressed as a Talker.

The second mode is called "Talker only". It consists of the PT/RG sending the last measured value to the IEEE 488 bus at regular intervals. In this mode any incoming messages are ignored and it is not possible to use the field regulation functions.

This mode is used to connect the PT/RG to a printer without needing an external controller. To select this mode, microswitch A7 must be set to 1. The message format is described in section 6.2.1. The intervals between each output can be defined by the microswitches A1 to A5 as shown in section 4.2.1.

## **4.2 MICROSWITCH SETTINGS**

### **4.2.1 Microswitch block "A" (link with host computer)**

The first 8 microswitches of block "A" have different functions according to the interface which is used to link to the host computer. Microswitches 9 and 10 do not change their function.

**BLOCK "A"****RS 232 C LINK WITH HOST**

	"0"	"1"	SW.
	BAUD RATE (SEE 4.2.2)		1
			2
			3
NUMBER OF BITS	7	8	4
STOP BITS	1	2	5
PARITY	NO	YES	6
PARITY	EVEN	ODD	7
MODE	AUTO-NOMOUS (1)	CONVERSATIONAL	8

**IEEE 488 LINK WITH HOST**

	"0"	"1"	SW.
	DEVICE ADDRESS OR PRINTING RATE (SEE 4.1.1)		1
			2
			3
			4
	ALWAYS 0		5
MODE	TALKER/ LISTENER	TALKER ONLY	6
CR-LF	NO	YES	7
			8 (2)

	« 0 »	« 1 »	SW.
HOST LINK	RS232C	IEEE 488	9

MPS DIGITAL LINK	NO	YES	10
------------------	----	-----	----

- (1) In this case microswitches B1 to B5 must be used to set the printing rate according to the table shown in section 4.1.1
- (2) Microswitch 8 in the case of the IEEE 488 interface allows the user to include the two ASCII characters CR and LF at the end of a message.

#### 4.2.2 Microswitch block "B"

Block "B" of microswitches allows the user to set the status of the RS 232 C link with the MPS and to choose the mode of correction, linear or digital.

In the autonomous RS 232 C mode (printer) which is obviously not possible in the regulation mode, block "B" allows the printing rate to be set.

#### **BLOCK "B"**

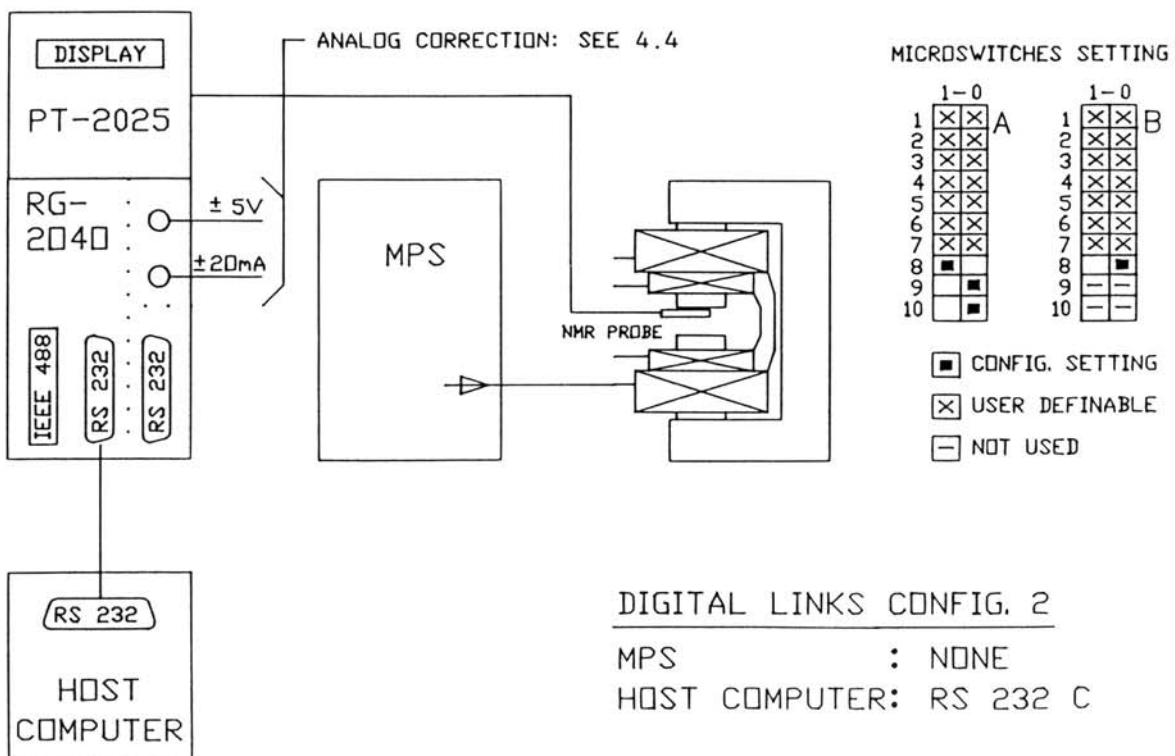
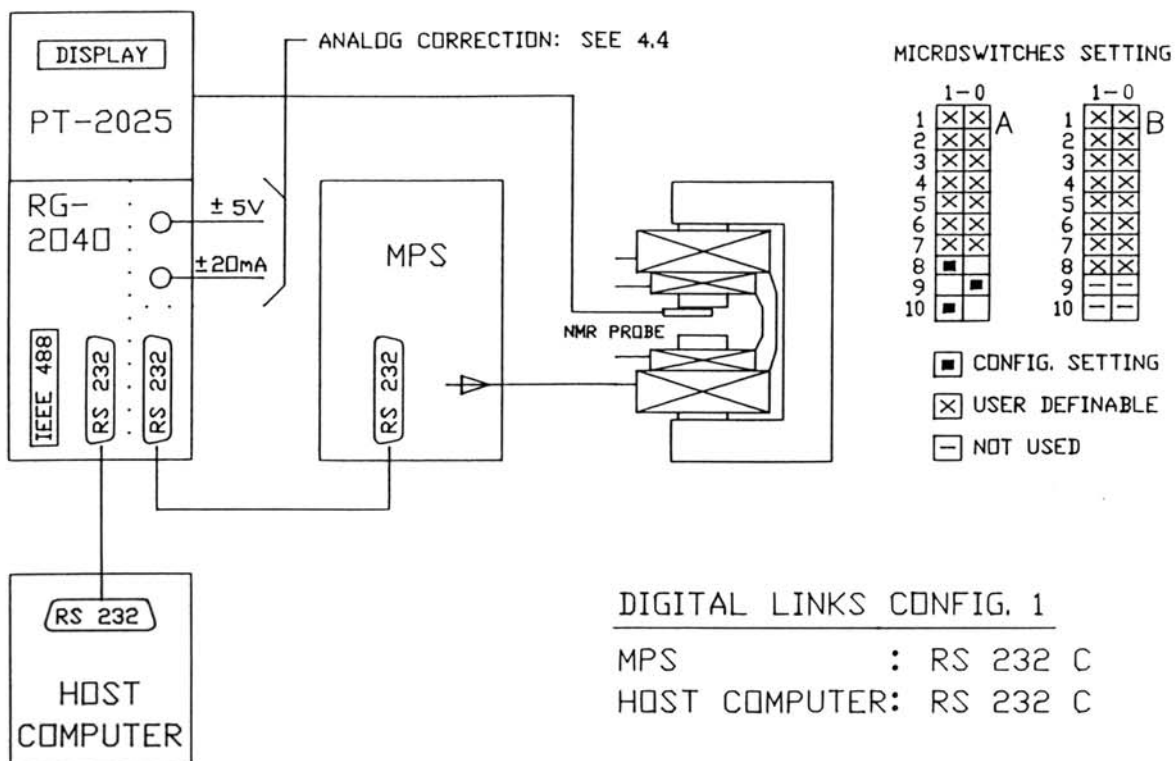
	"0"	"1"	SW.
	BAUD RATE (SEE BELOW)		1 2 3
NUMBER OF BITS	7	8	4
STOP BITS	1	2	5
PARITY	NO	YES	6
PARITY	EVEN	ODD	7
CORRECTION	LINEAR	DIGITAL	8
	NOT USED		9 10

Note: switches B1 to B7 refer to the RS 232 C link with the MPS.

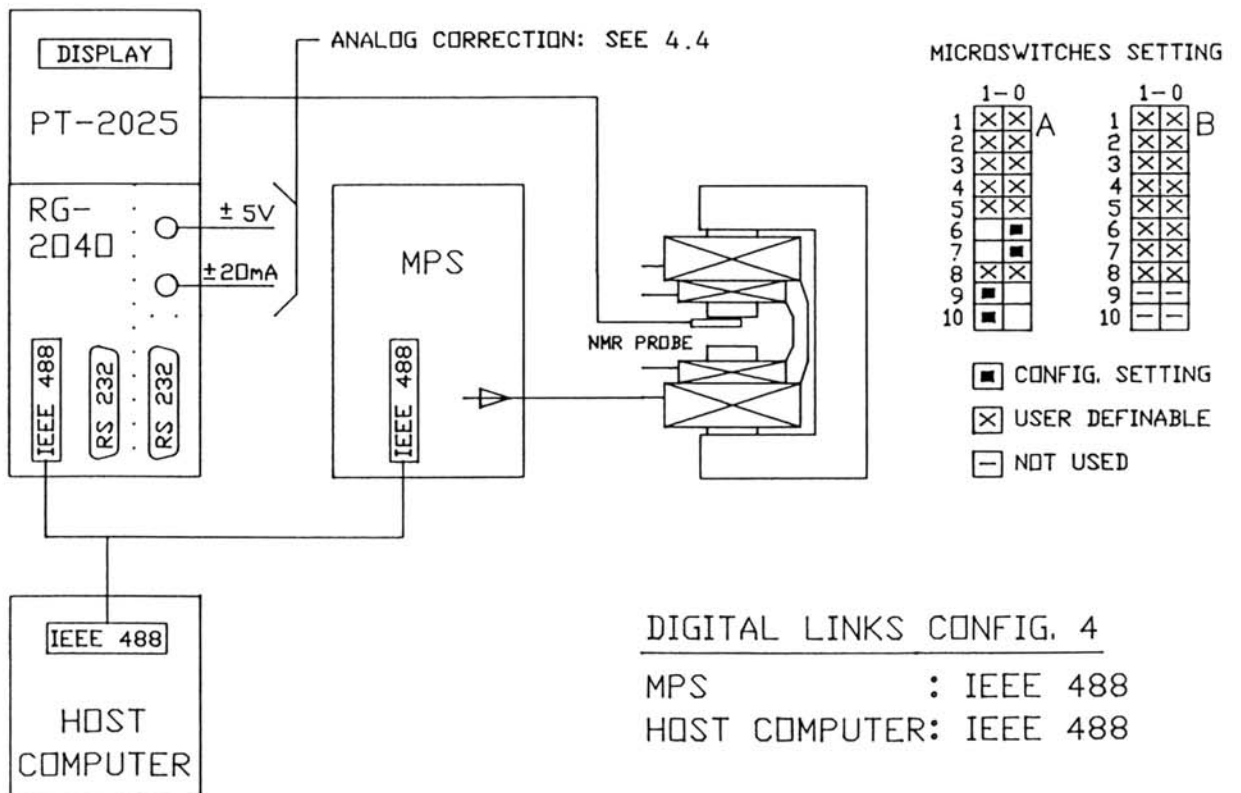
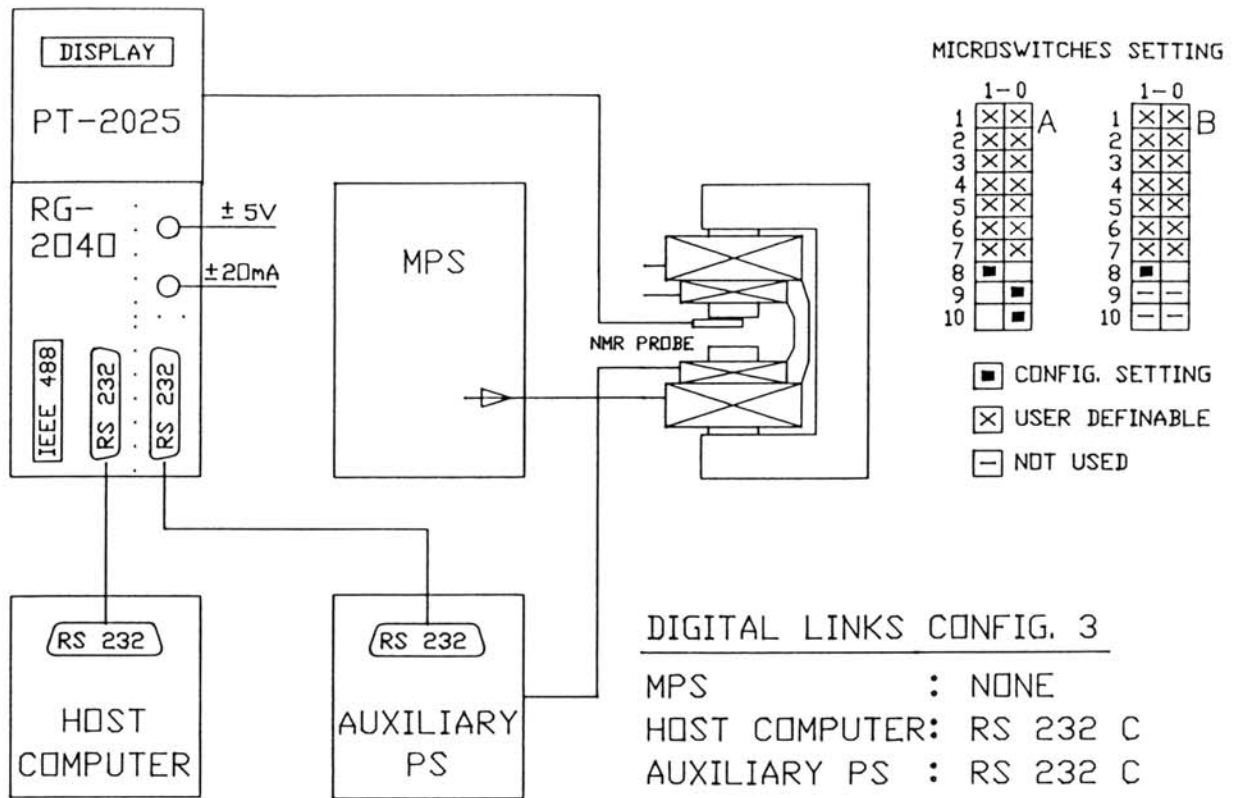
**BAUD RATE SELECTION**

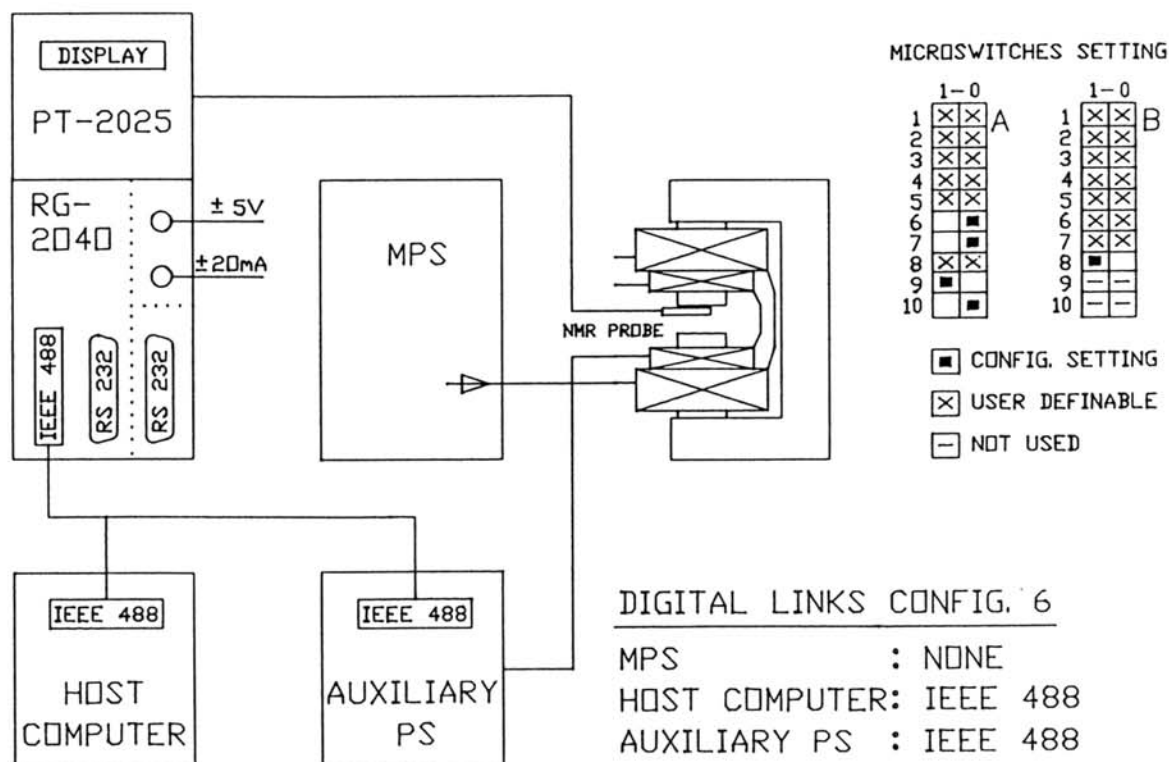
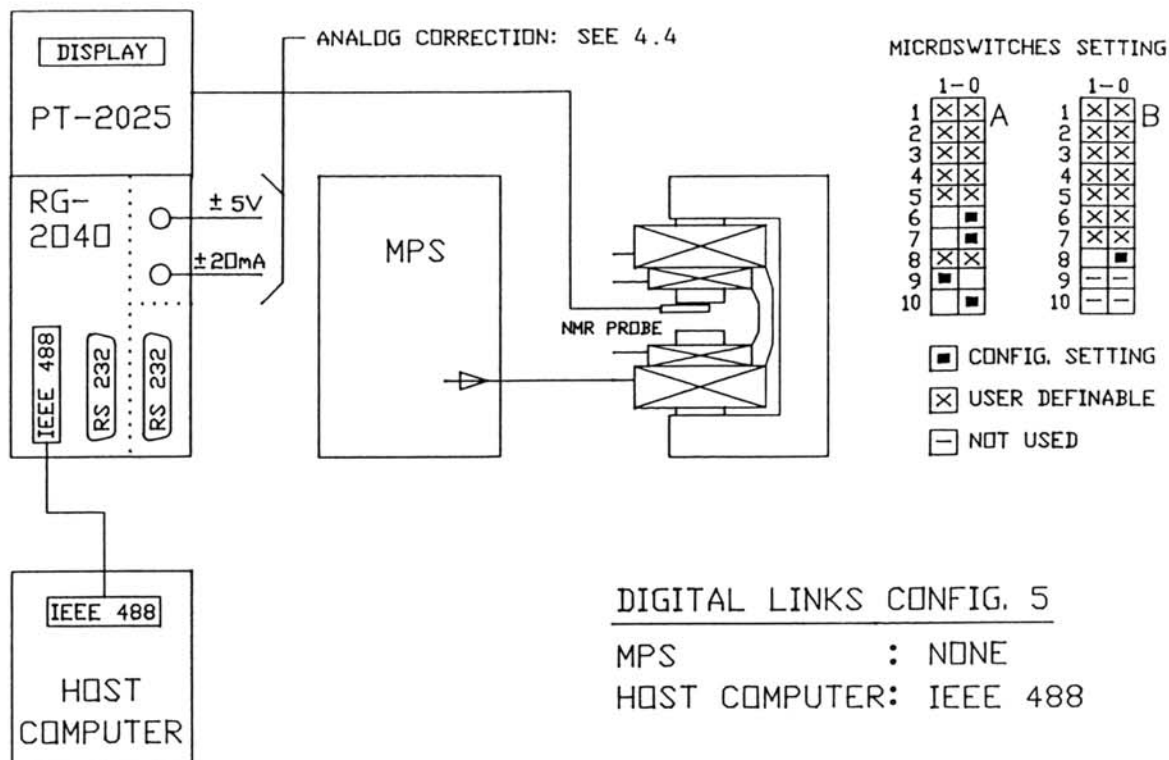
MICROSWITCH			BAUDS
3	2	1	
0	0	0	300
0	0	1	300
0	1	0	600
0	1	1	1200
1	0	0	2400
1	0	1	4800
1	1	0	9600
1	1	1	19200

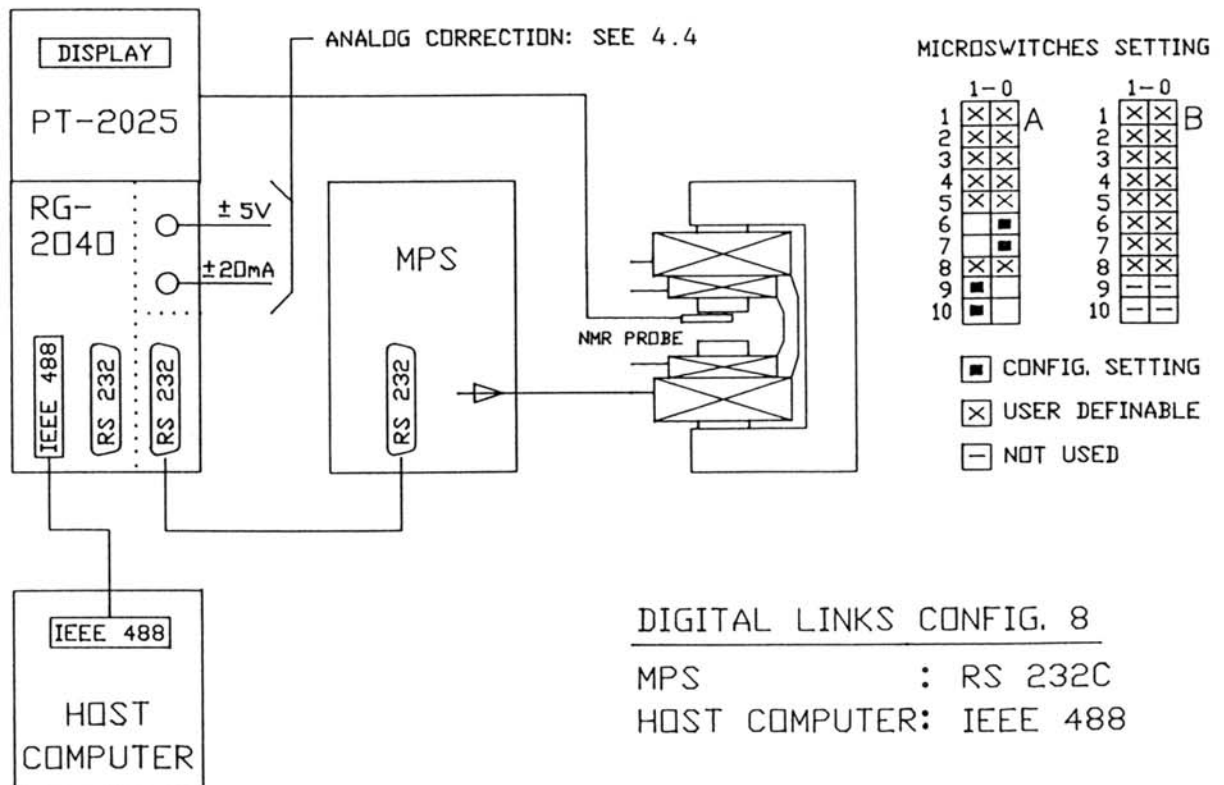
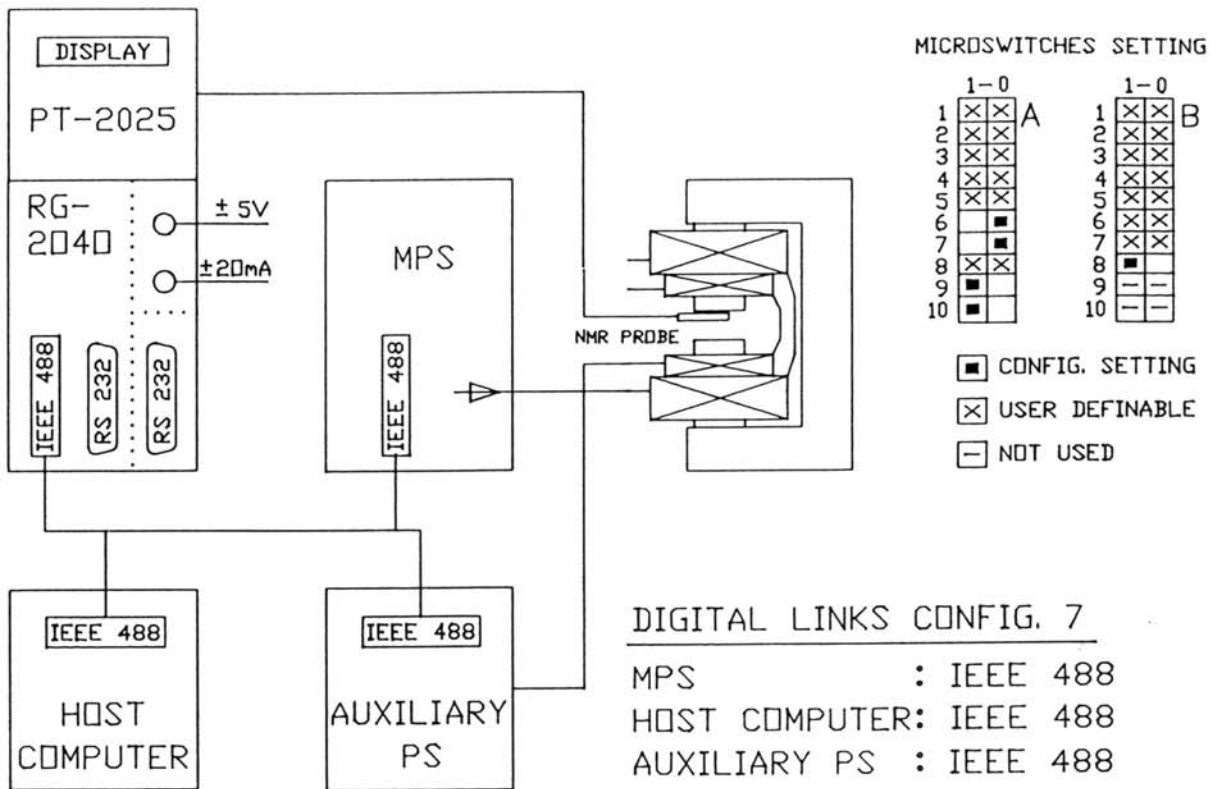
### 4.3 DIGITAL CONFIGURATION



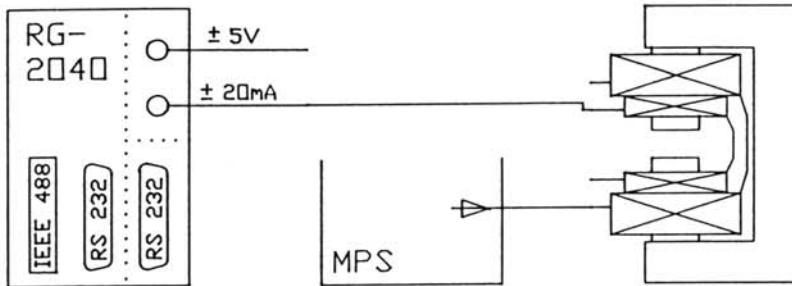






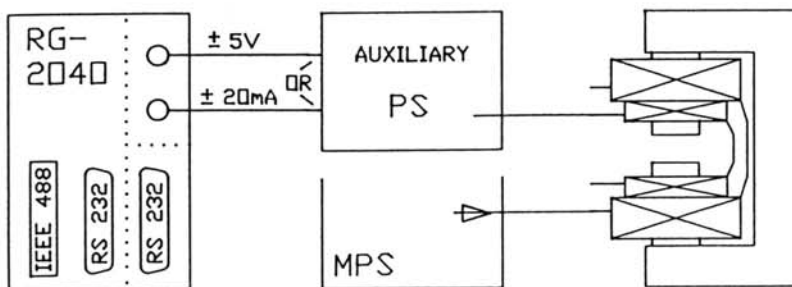


#### 4.4 LINEAR CORRECTION CONFIGURATION

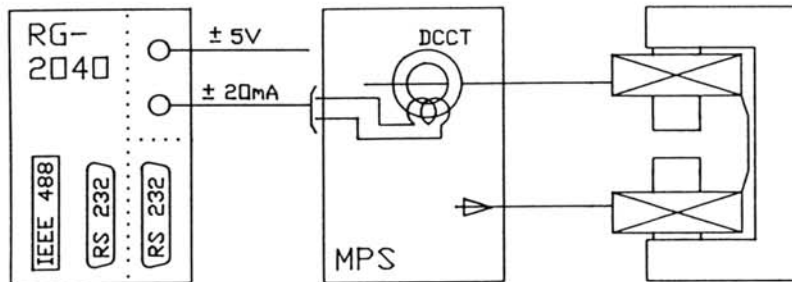


THE AUXILIARY COILS ARE DRIVEN DIRECTLY

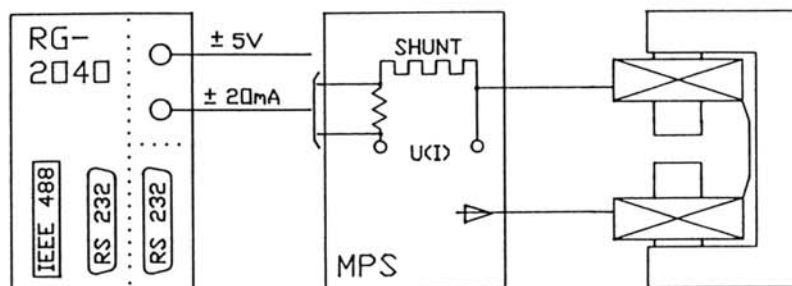
MPS : MAGNET POWER SUPPLY



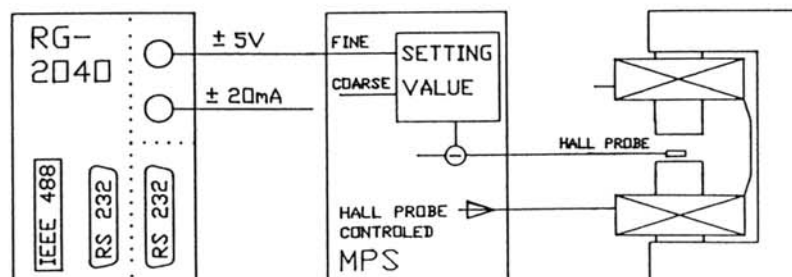
THE AUXILIARY COILS ARE DRIVEN BY A BIPOLAR, LINEARLY CONTROLLED, POWER SUPPLY



AN ADDITIONAL COIL IS WOUND ON THE MAIN CURRENT MEASURING DCCT (Direct Current Current Transformer)



A SUMMING RESISTOR IS ADDED TO THE MAIN CURRENT MEASURING SHUNT



THE FINE CONTROL OF THE MPS IS USED DIRECTLY

## 5 DETAILS OF OPERATION

---

### WARNING:

- Before sending commands to the PT 2025/RG 2040 system (henceforth referred to as PT/RG) it is imperative to put it in the REMOTE mode otherwise the commands will be ignored.
- All commands which have not been correctly constructed or without meaning will generate a syntax error indicated by bit 3 of STATUS 1 being set to 1.
- All regulation commands (beginning with the letter "E") requiring the field to be measured, must be executed with the display of the PT/RG set to TESLA. Setting to FREQUENCY will generate an error.
- RESET push button:
  - microprocessor reset (push button for less than 4 seconds);
  - microprocessor reset **and** EEPROM clear (push button for more than 8 seconds).

Note: the syntax of all the commands is described in detail in CHAPTER 6.

### 5.1 INITIALIZATION

#### 5.1.1 Introduction

As it has been explained in the previous section, the microswitches which are located in the rear panel allow the system configuration to be defined: type of interfaces, link with the MPS, linear or digital correction, etc...

The PT/RG system must now be "prepared" to perform the field regulation by supplying the detailed information concerning the MPS, the type of probes which are connected, etc... This set of data is stored in a non volatile memory (EEPROM) and therefore must be entered at least once.

The following table outlines the initialization commands as a function of the configuration (see Chapter 4.3). The left column "priorities" will be discussed after the table:

P R I O R I T I E S	C O M M A N D S	D I G I T A L L I N K W I T H M P S (A10 = 1)			N O D I G I T A L L I N K W I T H M P S (A10=0)	
		L I N E A R R E G U L A T I O N (B8=0)	D I G I T A L R E G U L A T I O N (B8=1)		L I N E A R R E G U L. (B8=0)	F I N E D I G I T A L R E G U L. (B8=1)
			F I N E	C O A R S E		
1	EFC	***	***	***		
1	EFF		***			***
2	ES	***	***	***		
3	ECL,ECH	***	***	***	###	###
4	ECS	###	###	###		
-	EP	###	###	###	###	###

[ \*\*\* ] : MANDATORY

[ ### ] : OPTIONAL

[     ] : NO SIGNIFICATION

### The priorities:

The initialization commands must be executed in the order of priority. If this is not done, the flashing of the PT/RG display will indicate the error.

The same applies for the modifications: all commands whose priority number is greater than the one changed will be erased. For example, if the ECL command (priority 3) is executed again due to a change in probe, for example, the magnet calibration, which has been previously effected with the ECS command (priority 4), must be executed again. On the contrary, the MPS being the same, there is no reason to repeat the EFC command (priority 1).

## **5.1.2 The digital link with the MPS and the "transparent" mode**

### **What is meant by "digital link with the MPS" ?**

The PT/RG system is able to drive the MPS. The MPS must have an RS 232 C (or IEEE 488) link. The MPS must be connected to the female RS 232 C connector (marked "M.P.S.") located on the rear panel of the RG 2040.

The host computer, which can be a PC or a PSION XP hand-held microcomputer or even a simple terminal, will be connected to the male RS 232 C connector (marked "HOST").

The microswitch A10 must be set to position 1.

Once the initialization commands have been performed, the field target value (in units of  $10^{-7}$  Tesla) can be given to the PT/RG system via the host computer. The PT/RG itself will calculate the current parameter to achieve the required field, the PT/RG will then send the customized message to the MPS and it will wait for the current to stabilize before starting to control the field.

This system greatly facilitates the user's task, it avoids searching for the main current of the magnet to achieve the approximate field value around which regulation is to be performed.

### **What is meant by "transparent" mode ?**

The MPS is not connected directly to the computer. However, the user may like to check the status values of the MPS or start operations which are not related to the regulation. A mode called "transparent", which effectively "short circuits" the two RS 232 C connectors

(HOST and MPS) allows for this. Therefore, each character which is issued by the computer will be sent directly to the MPS and vice versa, without affecting the PT/RG. For the syntax of the "transparent" mode refer to the [N] command in section 6.5.1.

Note: the transmission specifications, i.e. baud rate, number of bits, number of stopbits, etc. may be completely different between the MPS and the host computer, the RG 2040's buffered communications handling the necessary translation.

### **What about the IEEE 488 bus ?**

When the host computer, the MPS and the PT/RG system are interconnected via the IEEE 488 bus, the "transparent" mode does not operate. In fact in this case only the host computer may address the MPS directly.

Moreover, the PT/RG system cannot be controller of the bus. Consequently, when the PT/RG has to change the current of the MPS, it has to inform the host computer with status bit, or with an SRQ, that a message addressed to the MPS is ready. The host must read this message and retransmit it, with no interpretation, to the MPS. The role of the host is to simply relay the message to the MPS. This system is less direct and more complicated to use than the RS 232 C link.

### **5.1.3 The COARSE setting of the MPS; EFC (priority 1)**

[The syntax of this command is given in section 6.4.1]

**With this command the PT/RG "learns" the format of the message that the MPS must receive in order to set the main current of the magnet.** This message depends on the particular type of MPS in use and the user should refer to the MPS manual for details. The message can be divided in two parts:

- the identification characters which are fixed and are decoded by the MPS interface to mean that the current must be changed.
- the current parameter. It consists of a parameter which is proportional to the current. In the EFC command the maximum value which the MPS may accept must be entered (the number which corresponds to the nominal current).

The correct execution and storage of this command in the EEPROM is indicated by bit 0 of STATUS 5 being set to 1. This bit is reset to 0 when the status is read.



#### 5.1.4 The FINE setting of the MPS: EFF (priority 1)

(Only if the digital FINE control is implemented).

[The syntax of this command is given in section 6.4.2]

**This command is quite similar to ECC with the difference that the FINE message will be used for the correction of the field.**

The PT/RG assumes that the FINE message is bipolar and a sign + or - will be present at the beginning of the message which is sent to the MPS.

If EFF is omitted and the digital correction is selected (microswitch B8 set to 1), the regulation will be performed only with the coarse control of the MPS. It is assumed, in this case, that the coarse command resolution will be sufficient.

The EFF command without any parameters has the effect of erasing the previous message in the EEPROM.

The correct execution and storage of this command in the EEPROM is indicated by bit 0 of STATUS 5 being set to 1.

#### 5.1.5 MPS settling time: ES (priority 2 )

[The syntax of this command is given in section 6.4.3]

**This command gives the time (in seconds) which is required to reach the nominal current specified by the maximum current parameter in the EFC command.**

Each time the PT/RG changes the value of MPS current, it will calculate a time proportional to that given by ES.

Example:

Suppose you have executed: ES20. This means that the MPS takes 20 seconds to reach its nominal current, say 100 Amps. The current of the MPS is actually 25 Amps. and you wish to regulate the field around a value corresponding to 75 Amps. The PT/RG will send the message to the MPS to reach 75 Amps. and wait a time X:

$$X = [(75A - 25A)/100A]*20 \text{ s} = 10 \text{ s}$$

necessary for the MPS to reach 75 Amps., before starting to measure the field.

The PT/RG waits always 3 seconds more than the value thus calculated for safety. The real result for the above example will then be 13 seconds.

## **IMPORTANT**

The MPS setting time is only the time required to change the coarse value of the current. This time has nothing to do with the time constant of the regulation process. This is true even if the regulation is performed via the MPS COARSE setting.

### **5.1.6 Low and High point acquisition: ECL and ECH (priority 3)**

[The syntax of these commands is given in sections 6.4.4 and 6.4.5 ]

The ECL and ECH commands are interpreted differently according to the configuration which has been chosen (A10=1, see point A below or A10=0, see point B in this section).

#### **A) There is a digital link with the MPS (A10=1)**

The ECL and ECH commands allow the relationship between the magnetic field and the current parameter to be memorized. They have the same priority level and are complementary. They must both be executed but the order does not matter. Moreover, they allow the user to memorize the type of the NMR probe which is connected (or the probes when the multiplexer MUX 2031 is in use).

ECL allows the definition of the low point, i.e. the minimum value of the field which can be measured with the "lowest" probe. The ECL command must include the value of the MPS current parameter corresponding to that field. In order to determine it we suggest the following procedure:

- use the [Pc] command to select (see 6.2.9) the NMR probe which can measure the lowest field;
- using the "transparent" mode, send a current parameter to the MPS whose corresponding field falls approximately in the middle of the probe range;
- start the SEARCH mode using the command [H<CR><LF>] (see 6.2.10);

- note the measured field value;
- send a current parameter to the MPS smaller than the previous one but still corresponding to a field in the probe range;
- restart the SEARCH mode and measure the field. Use the differences of the current parameters and of the measured fields in order to determine the current parameter which corresponds approximately to the minimum field which the probe can measure;
- by measuring the field check if the current parameter is determined with sufficient precision; if not restart the procedure;
- when the right current parameter “n” has been found, send the ECLn<CR><LF> command to the PT/RG
- bit 0 of STATUS 5 is set to 1 when the command is executed and data are memorized in the EEPROM.

ECH allows the definition of the high point, i.e. the maximum value of the field which can be measured with the “highest” probe or the highest field which can be reached with the MPS. The ECH command must include the value of the MPS current parameter corresponding to that field. In order to determine it we suggest following the procedure outlined for the ECL command making the obvious changes to search for the high point.

## **WARNING**

Since the SEARCH mode cannot achieve 100% of the PT 2025 COARSE range, we suggest using as the high point a value which is lower than that given by the position 9.7 of the COARSE button or by the command [C3850<CR><LF>] if the PT/RG is in the REMOTE mode.

Once both ECL and ECH commands have been executed, the PT/RG calculates the slope of the straight line connecting the two points; it scans, in increasing order, all the multiplexer channels between the ones used to define ECL and ECH and finally stores the types of the NMR probes it has found in the EEPROM.

Resuming: when both ECL and ECH have been executed, the PT/RG has measured a field interval outside which all field target values will be rejected; then it has calculated the slope of the field as a function of the current parameter and finally it has found the NMR probes connected on the multiplexer.

As a consequence when the user gives a field target value (in units of  $10^{-7}$  Tesla), the PT/RG firstly checks if this value falls in the interval specified above; then it calculates the current parameter necessary to achieve the approximate value of the field as given by the straight characteristic  $B=B(p)$ ; it will choose the NMR probe which is adequate for this measurement and select the multiplexer channel where this probe is connected.

If the magnet has a function  $B=B(p)$  which is not linear, the curve  $B=B(p)$  must be measured (refer to section 5.1.7 [ECS]).

**IMPORTANT**

- a) Probe arrangement on the MUX 2031: suppose that probes 2, 3, 4 and 5 are connected: (1 and h show the channels used for ECL and ECH)

			1				h		
MUX channel	A	B	C	D	E	F	G	H	
Probe N°			2	3	4	5			

**CORRECT**

This configuration is correct and recommended; the probe number increases following the increasing order of the multiplexer channels. This configuration is mandatory if the ECS command is to be executed, i.e. if the characteristic field/current parameter is not linear.

Only in the case of a linear calibration is it possible for the probes not to be ordered sequentially or for a channel to be empty as shown below:

			1				h		
MUX channel	A	B	C	D	E	F	G	H	
Probe N°			2			4	5		

**CORRECT**

- b) If the number of probes or their disposition has been changed, the ECL and ECH commands should be reexecuted.

## **B) No digital link with the MPS (A10=0)**

Both ECL and ECH commands are optional. If they are performed, the current parameters must **not** be given.

Having performed the ECL and ECH commands is useful if the EB command is performed it allows the automatic selection of the appropriate NMR probe. Moreover, if EB is executed with no field indication the SEARCH mode will automatically be activated over all connected probes without having to select the multiplexer channel (see section 5.2.2.4 or section 5.2.2.5).

In order to execute the ECL and ECH commands the following procedure should be followed:

- use the [Pc] command to select (see section 6.2.9) the multiplexer channel where the "lowest" probe is connected;
- adjust the MPS to obtain a signal in the low field region of the probe;
- send the [ECL<CR><LF>] command;
- bit 0 of STATUS 5 is set to 1 when the command is executed and data are memorized in the EEPROM.

ECH allows the definition of the high point, i.e. the maximum value of the field which can be measured with the "highest" probe or the highest field which can be reached by the MPS. We suggest following the procedure outlined for the ECL command making the obvious changes to search for the high point.

### **WARNING**

Since the SEARCH mode cannot achieve 100% of the PT 2025 COARSE range, we suggest using as the high point a value which is lower than that one given by the position 9.7 of the COARSE button or by the command [C3850<CR><LF>] if the PT/RG is in the REMOTE mode.

If the number of probes or their disposition has been changed, the commands ECL and ECH should be executed again.

### 5.1.7 Measuring the Field/Current curve: ECS (priority 4)

[The syntax of this command is given in section 6.4.6]

After the ECL and ECH commands have been executed, the functional relationship between the magnetic field and the current parameter is assumed to be linear. **If this is not the case, e.g. in an iron core magnet, the ECS command allows this curve to be measured automatically with 20 equally spaced points of the current parameter which are located between the lowest point [ECL...] and the highest one [ECH...].**

This curve, which is then memorized in the EEPROM will allow the PT/RG to find the current parameter to send to the MPS when given the field setting.

#### IMPORTANT

When the Multiplexer is used, the probes must be connected in the order of increasing probe and channel numbers without having “holes” (see examples given in section 5.1.6).

### 5.1.8 Correction and field polarity (FIELD +/-) coupling: Epn

[The syntax of this command is given in section 6.4.7]

No priority level has to be given to this command. EPO will disable the function and EP1 will enable it.

**When this function is enabled, it couples the sign of the correction with the actual field polarity.** This is important if the correction is performed via a device whose correction field is not automatically reversed when the main field polarity is changed (e.g. auxiliary coils) and if the user wishes to use the **same** target value [EB...] but with the field reversed.

By default, the function EPn is disabled. If enabled its value is stored in the EEPROM and it will remain until an EPO is executed.

## 5.2 REGULATION

### 5.2.1 Introduction

As we have already mentioned in Chapter 2, the field regulation needs different parameters to be measured, calculated or simply chosen in order to optimize the performances of the regulation. We saw that the variable parameters in a regulation vector are:

- a) field target value **[EB...]**
- b) regulation window **[EB...]**
- c) cumulative correction gain adjustment **[EKI...]**
- d) proportional correction gain adjustment **[EKP...]**
- e) correction setting delay **[ET...]**
- f) number of samples in the sliding average **[EM...]**
- g) digital filter rejection level **[EH...]**
- h) digital filter sample number **[EX...]**
- i) display reading rate **[V...]** (Refer to 6.2.16).

Up to 20 regulation vectors can be stored in the EEPROM in 20 registers, 1 to 20, register 0 being used in the foreground. The regulation function always uses the vector stored in register 0.

All parameters have a default value except the field target value **[EB...]** which must be given.

Once the initialization and the EB commands have been executed, the regulation can be started with the command ER1 (see section 5.2.7). **During** the regulation process all the other parameters of the regulation vector may be adjusted. The field value may be changed with the EI command within the regulation window. In this way it is possible to adjust the regulation parameters dynamically and, when the results have been optimized, store **[EBM...]** all of them in one of the 20 registers.

### 5.2.2 Field target value: EB (priority 5)

[The syntax of this command is given in section 6.4.8]

**EB is a complex command which not only defines the value of the field at which regulation will take place, but also measures the dynamic characteristics of the correcting device (window) and calculates the correction factor (with its sign) defined as the ratio between the regulation window and the correction parameter (e.g. 4096 steps of the regulation DAC).**

The general syntax of EB is as follows:

**Ebn {,w} {,D} {,M} <CRXLF>**

Note: the braces { } specify the options. The order of the options in the command is not important.

- |   |  |
|---|--|
| n | field target value in units of 10 <sup>7</sup> Tesla.  |
| w | size of the regulation window in units of 10 <sup>-7</sup> Tesla.  |
| D | ASCII character "D" (Dec 66, Hex 44) which means that all the parameters in the regulation vector must be set to their default values (see section 5.2.2.6). |
| M | ASCII character "M" (Dec 77, Hex 4D) means that the regulation must be performed manually (see section 5.2.2.7).   |

**The command [EB...] is executed in a different manner according to the configuration of the overall system.** In the following table the sections in this manual relative to one particular configuration are listed.



DIGITAL LINK WITH MPS (A10=1)			NO DIGITAL LINK WITH MPS (A10=0)	
LINEAR REGULATION (B8=0)	DIGITAL REGULATION (B8=1)		LINEAR REGULATION (B8=0)	DIGITAL FINE REGULATION (B8=1)
	FINE	COARSE		
5.2.2.1	5.2.2.2	5.2.2.3	5.2.2.4	5.2.2.5

### 5.2.2.1 Digital link with MPS and linear regulation

Following the execution of the command EB, the PT/RG performs a series of operations which are now described:

- calculation of the current parameter corresponding to the approximate value of the field and transmission of the COARSE message to the MPS;
- wait for the calculated settling time to allow the current being set to reach a stable value;
- select the multiplexer channel (if it exists) where the appropriate NMR probe is connected;
- set the linear output to + 20 mA (+ 5V) and measure the field (average of 5 measurements);
- set the linear output to - 20 mA (- 5V) and measure the field (average of 5 measurements);
- the difference between these last two measurements gives the default regulation window and the dynamic characteristics of the correcting device;
- calculate the correcting factor;
- set the linear output to 0 mA (0V);
- store the data (measured or calculated) in register 0, i.e.

- ❖ the field target value
- ❖ the regulation window
- ❖ the correction factor
- ❖ the MUX channel which has been selected

## IMPORTANT

The other values of the regulation vector remain unchanged.

- set bit 0 of STATUS 5 to 1 if the command has been correctly executed.

## Discussion on the regulation window

The regulation window is thus measured each time the EB command is executed and corresponds to the field variation generated by the linear output set successively to + 20 mA (+5V) and to - 20 mA (-5V) . Both the analog outputs are driven by a 12 bit DAC (4096 steps). So it is recommended to design the correcting device in such a way that the regulation resolution meets the stability requirements. About 1000 ppm of the field to regulate would seem appropriate for the majority of applications. The resolution will be then approx. 0.25 ppm/DAC step. The RG 2040 is designed so that the user may define a window smaller than the one which is measured whilst keeping the same DAC resolution of 12 bits! The window which is specified in EB must be smaller or equal to the measured one and greater than the 1/12 of it. If not, an error will be indicated by the display flashing.

Example:

you require the field regulated at 0.504 Tesla. So you send the PT/RG the command:

EB5040000 (5040000 \* 10<sup>-7</sup> Tesla)

Your correcting device is designed such that the measured window is 9072\*10<sup>-7</sup> Tesla, i.e. 1800 ppm of the field setting. The resolution will be:

1800/4096 ≈ 0.44 [ppm/DAC step]

If you wish to have a resolution of 0.1 ppm/DAC step, the window would have to be  $4095 \times 0.1 \approx 410$  ppm, i.e.:

410 ppm of 5040000 is 2066

If you send to the PT/RG the command:

EB5040000, 2066

the real window will be  $2066 \times 10^{-7}$  Tesla and the resolution 0.1 [ppm/DAC step]. The maximum and minimum limits of the regulation window will be: max. 9072 (equal to the measured window) , min. 756 (equal to 1/12 of the measured window)

**\*\*\* NOW REFER TO SECTION 5.2.2.6 \*\*\***

### **5.2.2.2 Digital link with the MPS and digital FINE regulation**

(If the EFF command (see section 5.1.4) has been executed, the regulation will then be performed with the FINE message being sent to the MPS).

Following the execution of the EB command, the PT/RG performs a series of operations which are now described:

- calculation of the current parameter corresponding to the approximate value of the field and transmission of the COARSE message to the MPS;
- wait for the calculated settling time to allow the current to reach a stable value;
- select the multiplexer channel (if it exists) to which the appropriate NMR probe is connected;
- send the FINE message (with "+F" as a parameter where F is the parameter declared in the EFF command) and measure the field (average over 5 measurements) ;
- send the FINE message (with "-F" as a parameter where F is the parameter declared in the EFF command) and measure the field (average over 5 measurements);
- the difference between these last two measurements gives the default regulation window and the dynamic characteristics of the correcting device;

- calculate the correcting factor;
- send the FINE message with the parameter "+0";
- store the data (measured or calculated), in the register 0, i.e.
  - ❖ the field target value
  - ❖ the regulation window
  - ❖ the correction factor
  - ❖ the MUX channel which has been selected

### IMPORTANT

The other values of the regulation vector remain unchanged.

- set bit 0 of STATUS 5 to 1 if the command has been correctly executed.

### Discussion on the regulation window

The regulation window is measured each time the EB command is executed and corresponds to the field variation produced by the result of the FINE message sent to the MPS (max. and min.).

The resolution of the correction depends on the characteristics of the MPS and on the resolution of the FINE message which is sent to the MPS.

Since this resolution cannot be changed, the option of the regulation window is meaningless and is ignored if it is introduced.

Example:

Sending the command:

EB5040000,5000 (target value 0.504 T with a regulation window of  $5000 \cdot 10^{-7}$  T)

will generate the same effect as:

EB5040000 (target value 0.504 T with no specified window).

Therefore the real window will be the one measured.

**\*\*\* NOW REFER TO SECTION 5.2.2.6 \*\*\***

### 5.2.2.3 Digital link with the MPS and digital COARSE regulation

(If the EFF command (see section 5.1.4) has not been executed, the regulation will then be performed with the COARSE message)

For this configuration two cases will be described:

- A) The relationship Field/Current is linear
- B) The relationship Field/Current is non-linear (e.g. iron magnet)

#### A) Linear relationship

In this configuration, the PT/RG uses the Field/Current slope measured with the execution of the ECL and ECH commands (see section 5.1.6) as a correction factor.

The resolution of the correction depends on the characteristics of the MPS and on the resolution of the COARSE message which is sent to the MPS.

Since this resolution cannot be changed, the option of the regulation window is meaningless and is ignored if it is introduced.

Example:

Sending the command:

EB5040000,5000 (target value 0.504 T with a regulation window of  $5000 \cdot 10^{-7}$  T)

will generate the same effect as:

EB5040000 (target value 0.504 T with no specified window)

Therefore, the real window will be equal to the difference of the fields between the ECH's high point and the ECL's low point.

When EB is executed the PT/RG makes no field measurement. It simply copies to the register 0 the following data:

- ❖ target value
- ❖ regulation window (calculated from ECH & ECL)
- ❖ correction factor (Field/Current slope)
- ❖ multiplexer channel selection (if it exists)

## **IMPORTANT**

The other values of the regulation vector remain unchanged. The PT/RG sets bit 0 of STATUS 5 to 1 if the command has been correctly executed.

**\*\*\* NOW REFER TO SECTION 5.2.2.6 \*\*\***

### **B) Non linear relationship**

The ECS command which is used to measure the non linear characteristic of the magnet must be executed before the procedure described below.

In this configuration, the correction factor, which regulates the MPS, is the relationship between the magnetic field and the COARSE parameter of the MPS. This relationship being non-linear must be measured around the target value and in a region small enough to be considered as linear. The regulation window will be equal to the value declared in the option "window" of the EB command. If this option is omitted, it will be equal to 1600 ppm of the nominal field (here the nominal field is defined the one corresponding to the current parameter which was given the EFC command).

The resolution of the correction does not depend on the size of the regulation window but only on the characteristics of the MPS.

After the execution of the EB command, the PT/RG performs a series of operations which are now described:

- selects the multiplexer channel (if it exists) where the appropriate NMR probe is connected;
- calculates the current parameter of the MPS which is required to achieve approximately the target field value plus  $\frac{1}{2}$  the regulation window, if defined, or 800 ppm of the nominal field if omitted. Then it sends the COARSE message to the MPS;
- waits for the calculated settling time to allow the current to reach a stable value;
- measures the field (average over 5 measurements) ;
- calculates the current parameter of the MPS which is required to achieve approximately the target field value less  $\frac{1}{2}$  the regulation window, if defined, or 800 ppm of the nominal field if omitted. Then it sends the COARSE message to the MPS;

- waits for the calculated settling time [ES...] to allow the current to reach a stable value;
- measures the field (average over 5 measurements);
- sends the COARSE message with a parameter which approximately sets the MPS to the field target value (center of the regulation window);
- calculates the correcting factor;
- stores the data (measured or calculated) in register 0, i.e.

- ❖ the field target value
- ❖ the regulation window
- ❖ the correction factor
- ❖ the multiplexer channel which has been selected

### IMPORTANT

The other values of the regulation vector remain unchanged.

- set bit 0 of STATUS 5 to 1 if the command has been correctly executed.

**\*\*\* NOW REFER TO SECTION 5.2.2.6 \*\*\***

### 5.2.2.4 No digital link with the MPS and linear regulation

In this case the field must be manually set close to its target value. Once the field has been set, the EB command can be sent to the PT/RG. The instrument then carries out the following steps:

- selects the multiplexer channel (if it exists and the ECL and ECH commands have been performed) to which the appropriate NMR probe is connected;
- sets the linear output to +20 mA (+ 5V) and measures the field (average over 5 measurements);
- sets the linear output to -20 mA (- 5V) and measures the field (average over 5 measurements);

- the difference between these two measurements gives the default regulation window (dynamic characteristic of the correcting device);
- calculates the correction factor;
- sets the linear output to 0 mA (0V) and measures the field. Its value must be within the central 1/3 of the regulation window. If this is not the case, an error will be indicated (LED display flashing) and the data will not be stored. The field must be readjusted and the EB command re-executed.
- stores the data (measured or calculated) in the register 0, i.e.
  - ❖ the field target value
  - ❖ the regulation window
  - ❖ the correction factor
  - ❖ the multiplexer channel which has been selected

### **IMPORTANT**

The other values of the regulation vector remain unchanged.

- set bit 0 of STATUS 5 to 1 if the command has been correctly executed.

Note: EB with no specified target value

When there is no digital link with the MPS it is possible to execute the EB command without specifying the field target value. In this case the PT/RG sets the linear output at the zero value and searches for the field. The measured value is taken as the field target value.

If the ECL and ECH commands have been performed the field is "tracked" over all the multiplexer probes range starting from the "lowest" probe. However, the user must select the appropriate channel (command [Pc], section 6.2.9) before executing EB.

The optional parameters given in the [EB...] command remain valid.

Example:

EB, 5000, D

is correct. The field target value is not given and will be measured; two options are defined: a regulation window of  $5000 \cdot 10^{-7}$  Tesla and the other data in the regulation vector are taken with their default values.



### Discussion on the regulation window

The regulation window is thus measured each time the EB command is executed and corresponds to the field variation generated by the linear output set successively to + 20 mA (+5V) and to - 20 mA (-5V).

Both the analog outputs are driven by a 12 bit DAC (4096 steps). So it is recommended to design the correcting device in such a way that the regulation resolution meets the stability requirements. About 1000 ppm of the field to regulate would seem appropriate for the majority of applications. The resolution will be then approx. 0.25 ppm/DAC step.

The RG 2040 is designed so that the user may define a window smaller than the one which is measured whilst keeping the same DAC resolution of 12 bits!

The window which is specified in EB must be smaller or equal to the measured one and greater than the 1/12 of it. If not, an error will be indicated by the display flashing.

Example:

You require the field regulated at 0.504 Tesla.

So you send the PT/RG the command:

EB5040000 (5040000 \* 10<sup>-7</sup> Tesla)

Your correcting device is designed such that the measured window is 9072\*10<sup>-7</sup> Tesla, i.e. 1800 ppm of the field setting. The resolution will be:

$1800/4096 \approx 0.44$  [ppm/DAC step]

If you wish to have a resolution of 0.1 ppm/DAC step, the window would have to be 4095\*0.1  $\approx$  410 ppm, i.e.:

410 ppm of 5040000 is 2066

If you send to the PT/RG the command:

EB5040000, 2066

the real window will be  $2066 \cdot 10^{-7}$  Tesla and the resolution 0.1 [ppm/DAC step]. The maximum and minimum limits of the regulation window will be: max. 9072 (equal to the measured window) , min. 756 (equal to 1/12 of the measured window)

**\*\*\* NOW REFER TO SECTION 5.2.2.6 \*\*\***

### **5.2.2.5 No digital link with the MPS and digital FINE regulation**

(If the EFF command (see section 5.1.4) has been executed the regulation will then be performed with a FINE message being sent to the correcting device).

In this case the field must be manually set close to its target value. Once the field has been set, the EB command can be sent to the PT/RG. The instrument then carries out the following steps:

- selects the multiplexer channel (if it exists) where the appropriate NMR is connected;
- sends the FINE message (with "+F" as a parameter where F is the parameter declared in the EFF command) and measures the field (average on 5 measurements);
- sends the FINE message (with "-F" as a parameter where F is the parameter declared in the EFF command) and measures the field (average on 5 measurements);
- the difference between these last two measurements gives the default regulation window and the dynamic characteristics of the correcting device;
- calculates the correcting factor;
- sends the FINE message (with the parameter "+0") and measures the field. Its value must be within the central 1/3 of the regulation window. If this is not the case, an error indication will follow (LED display flashing) and the data will not be stored. The field must be readjusted and the EB command re-executed;

- stores the data (measured or calculated) in the register 0, i.e.
  - ❖ the field target value
  - ❖ the regulation window
  - ❖ the correction factor
  - ❖ the multiplexer channel which has been selected

### **IMPORTANT**

The other values of the regulation vector remain unchanged.

- set bit 0 of STATUS 5 to 1 if the command has been correctly executed.

Note: EB with no specified target value

When there is no digital link with the MPS it is possible to execute the EB command without specifying the field target value. In this case the PT/RG sets the linear output at the zero value and searches for the field. The measured value is taken as the field target value.

If the ECL and ECH commands have been performed the field is “tracked” over all the multiplexer probes range starting from the “lowest” probe. However, the user must select the right channel (command [Pc], section 6.2.9) before executing EB.

The optional parameters given in the [EB...] command remain valid.

Example:

EB, 5000, D

is correct. The field target value is not given and will be measured; two options are defined: a regulation window of  $5000 \cdot 10^{-7}$  Tesla and the other data in the regulation vector are taken with their default values.

### **Discussion on the regulation window**

The regulation window is thus measured each time the EB command is executed and corresponds to the field variation produced by the result of the FINE message sent to the MPS (max. and min.).

The resolution of the correction depends on the characteristics of the MPS and on the resolution of the FINE message which is sent to the MPS.

Since this resolution cannot be changed, the option of the regulation window is meaningless and is ignored if it is introduced.

Example:

Sending the command:

EB5040000,5000 (target value 0.504 T with a regulation window of  $5000 \cdot 10^{-7}$  T)

will generate the same effect as:

EB5040000 (target value 0.504 T with no specified window).

Therefore the real window will be the one measured.

**\*\*\* NOW REFER TO SECTION 5.2.2.6 \*\*\***

#### **5.2.2.6 The option “D” of the EB command**

When the EB command is performed without the D option, all the regulation vector parameters which are stored in the register 0 keep their original values excepted that ones which are directly modified by the [EB...] command.

The option “D” will attribute to the all these parameters their default values (see Summary).

#### **5.2.2.7 The “M” option of the EB command**

When the amplitude of the NMR signal is particularly small (e.g. non homogeneous field) it is possible that the automatic procedures started by the EB command are not able to “find” the NMR signal. In this case the option “M” will allow the user to work in a semi-manual mode. This option is valid for all configurations unless when the regulation is performed using the MPS coarse control (see section 5.2.2.3).

## WARNING

When EB is executed with the "M" option, the front panel control is returned to the operator. However, the PT/RG is considered as being in the REMOTE mode. Therefore, all commands are accepted! The user must, therefore, take great care not to send commands which are in conflict with this situation.

Moreover, the "M" option does not take into account the eventual digital link with the MPS. Therefore, the power supply must be manually adjusted even if the microswitch for the digital link (A10) is set to 1.

The procedure to be followed is:

User: adjusts the MPS current to give the required field. This can be done manually or using the transparent mode via the host computer.

User: sends the EB command with the "M" option (e.g.: EB6080000, M (target value: 0.608T))

PT/RG: makes the PT/RG front panel available to the user. WARNING: the PT/RG is still in the REMOTE mode.

PT/RG: sets the correcting device to its maximum value either via the linear output or with the FINE message. Wait for the NMR signal to be locked.

User: selects the appropriate NMR probe using the multiplexer switch located on the front panel.

User: manually searches for the NMR signal using the COARSE and FINE buttons (**do not use the SEARCH mode!**). When the signal has been found, lock it by putting the button AUTO/MAN on AUTO.

PT/RG: the user has 255 seconds to find and lock the NMR signal. After this time an alarm will be generated and the full procedure must be restarted. Once the NMR signal has been locked, the PT/RG measures the field, averaging over five samples.

- PT/RG: sets the correcting device to its minimum value either via the linear output or with the FINE message. Waits for the NMR signal to be locked.
- User: again searches for the signal in case the system has lost it. Proceed manually and lock the signal as before with the button AUTO/MAN in position AUTO.
- PT/RG: the user has 255 seconds to find and lock the NMR signal. After this time an alarm will be generated and the full procedure must be restarted. Once the NMR signal has been locked, the PT/RG measures the field averaging on five samples.
- PT/RG: the difference between the two measurements gives the regulation window. The PT/RG calculates the correction factor.
- PT/RG: sets the correcting device to the position "0" using both the linear output or the FINE message. It waits for the NMR signal to be locked.
- User: again searches for the signal in case the system has lost it. Proceed manually and lock the signal as before with the button AUTO/MAN in position AUTO.
- PT/RG: the user has 255 seconds to find and lock the NMR signal. After this time an alarm will be generated and the full procedure must be restarted. Once the NMR signal has been locked, the PT/RG checks that the field corresponds to the central 1/3 of the regulation window. If this is not the case, an alarm will be generated. The current of the MPS must be more accurately adjusted and the procedure repeated.
- PT/RG: if the field falls within the central 1/3 of the regulation window, the execution of the EB command will continue normally.

PT/RG: stores in register 0 the following data:

- ❖ the target value
- ❖ the regulation window
- ❖ the correction factor
- ❖ the information that EB command has been performed in the semi-manual mode.

**IMPORTANT**

The other data of the regulation vector remain unchanged.

PT/RG: sets bit 0 of STATUS 5 to 1 if the command has been correctly executed.

### 5.2.3 The correction algorithm and its coefficients: EKI & EKP (no priority)

[The syntax of these commands is given in sections 6.4.9 and 6.4.10]

While regulating, the PT/RG sends, to the correcting device, a correcting value “**CV**” after each field measurement. "CV" is calculated according to the following algorithm:

$$CV = CI + CP$$

“CI” is the integral or cumulative part of the correction. “CP” is the proportional part:

$$CI_n = CI_{n-1} + \Delta B_n * K * x/100$$

$$CP_n = \Delta B_n * K * y/100$$

where:      **CI** is the integral correction;  
              **CP** is the proportional correction;  
               **$\Delta B$**  is the difference between the measured and the target field value;  
              **K** is the effectiveness of the correcting device calculated when the EB command is performed (correction factor);  
              **x** is the coefficient of CI in %;  
              **y** is the coefficient of CP in %;  
              **n** is the measurement number.

The coefficients “x” and “y” allow the optimization of the response time and control the stability of the regulation. Their default values are x=100 and y=0. In principle these values give the best results when the regulation is performed without using a sliding average of the field measurements. If the default values do not give good results the “x” and “y” values must be optimized. The table shown in section 5.2.5 can be used as guideline.

Note: some values of “x” or “y” may cause the system to diverge or not regulate at all!



Example:

EKI85

sets the coefficient of the integral correction to 85%

#### 5.2.4 Correction setting delay: ET (no priority)

[The syntax of this command is given in section 6.4.11]

The response time of the correcting device being finite, the PT/RG is not enabled to make a new field measurement immediately after having sent the correction until it has taken effect. **Therefore, the system must wait a certain time allowing the correction to be established before taking a new measurement.**

The time to wait between one correction and the successive measurement is given in 1/10 seconds. The default value is 3/10 seconds.

#### 5.2.5 Sliding average: EM (no priority)

[The syntax of this command is given in section 6.4.12]

The PT/RG has the possibility of correcting the field using a sliding average of measurements. This means that each new measurement replaces the oldest one. In this way the field correction is calculated on the average of the last n measurements. This gives a better stability in the regulation assuming that the stability of the MPS is sufficient over a period of time equal, at least, to the time required to make the n measurements.

**The EM command defines the number of samples in the sliding average which has a default value of 1.**

The cumulative and proportional parameters of the correction factor must be adjusted in order to optimize the regulation process. Given below are a few values which give a good compromise between the response time and the stability:

EM1*	EM2	EM10 (or>10)
EKI100*	EKI108	EKI120
EKPO*	EKP8	EKP20

\* Default values

### 5.2.6 Digital filter: EX and EH (no priority)

[The syntax of these commands is given in sections 6.4.13 and 6.4.14 ]

**The digital filter rejects measurements which can be assumed to result from an external perturbation (e.g. the starting of an electrical motor or, in general, EMI perturbations).**

Two commands specify the characteristics of the digital filter:

- EHm      the rejection threshold where m is given in units of  $10^{-7}$  T relative to the target value;
- EXn      the filter buffer length, analogous to a time constant, where n is the number of samples in the buffer.

Each measurement is stored in the filter buffer, the newest measurement replacing the oldest. At the start of regulation (i.e. after the ER1 command), the filter is **not active**. Therefore, all measurements are taken into account.

When all the values which have been registered in the filter buffer are less or equal to the threshold, the filter is **active** and bit 4 (Hex 08) of STATUS 5 is set to 1. Once the filter is activated all measurements which are greater than the threshold **are rejected**.

In the case that the magnetic field has actually changed its value due, for example, to a ferromagnetic mass which has been put in the proximity of the magnet, if the measurements are greater than the threshold they will be rejected. The regulation is "frozen" but the measurements are still stored in the filter buffer. When ALL the values in the buffer are greater than the threshold, the filter is **disabled** (bit 4 of STATUS 5 is set to 0) and the measurements are no longer rejected. Therefore, the PT/RG will now correct the effect of the perturbation. When all the values in the buffer become less or equal to the threshold, the filter will be reactivated.

Example:

EH30

indicates that all measurements which differ by  $30 \cdot 10^{-7}$  T from the target value will be rejected when the digital filter is active.

EX4

indicates that the filter buffer consists of 4 elements. Therefore, in the case of a field perturbation, 4 successive PT/RG measurements greater than the threshold will be needed before the filter is deactivated and the PT/RG corrects this perturbation.

### 5.2.7 The regulation: ER (priority 5)

[The syntax of this command will be given in sections 6.4.15 and 6.4.16 ]

**The regulation is started or stopped with the command ER whose syntax is as follows:**

ERn{,r}

where "n" has two values, 0 or 1. The value 1 will start the regulation and the value 0 will stop it. When "n" equals zero, the option {,r} is not allowed.

If "r" is not specified, the register "0" is assumed by default. If "r" is specified it can take values from 1 to 20 and indicates the number of the register where the regulation vector is stored. The corresponding register is firstly copied into register "0" thus replacing the previous data.

The field regulation proceeds as follows:

- 1/ The PT/RG verifies that the microswitches indicate the same configuration as that one existing when the EB command was executed. If not, an error will be generated and the procedure aborts here.

- 2/ The appropriate probe is selected via the MULTIPLEXER.
- 3/ The correcting value is set to 0.
- 4/ The PT/RG calculates the current parameter of the MPS and sends it. Then, it waits for the field to stabilize (field settling time, [ES...]).
- 5/ The PT/RG measures the magnetic field. If the value falls within the central 1/3 of the regulation window (the center of the window being the field target value), the process continues (point 6/). Otherwise, using the present field measurement the PT/RG calculates a better current parameter value, sends it to the MPS and repeats the measurement. If necessary, this process is repeated 15 times, after which an alarm will be generated.
- 6/ Bit 0 of STATUS 5 is set to 1 to indicate that the real regulation has started.
- 7/ The PT/RG measures the field and checks that it is valid (i.e. the NMR signal is still locked).
- 8/ The measurement is put into the digital filter.
- 9/ If the measurement passes the filter, the correction is calculated following all the criteria described previously.
- 10/ The correction is sent to the correcting device.
- 11/ The PT/RG waits for the correction to come into effect (correction setting delay, [ET...]).
- 12/ Return to point 7/.

Note: The above operations refer to the case of a digital link with the MPS. If this is not the case, then point 4/ is not valid and the user must set the field where required for the regulation. Care must be taken to ensure that this value falls between the central 1/3 of the regulation window, otherwise an error will be generated, (see point 5/).

During the regulation process and when step 6/ has been performed, the PT/RG can receive and processes several commands, i.e. ones which modify the regulation vector. Thus it is possible to observe “dynamically” the effects of each command. When all the values are adjusted accordingly, it is possible to save the complete vector in one of the 20 registers available for this purpose and all this without leaving the regulation mode (see the EBM command, section 5.2.9). Moreover, during the regulation, the regulating vector may be displayed on the host computer (see the EBS command, section 5.2.10).

Together with all commands\* which do not start with the letter “E” the following commands are permitted during the regulation:

ERO	stops the regulation.
EKlx	adjustment of the integral coefficient
EKPy	adjustment of the proportional coefficient.
ETn	trigger delay.
EMn	number of samples in the sliding average.
EHm	threshold of the digital filter.
EXn	number of samples in the digital filter.
Elsn	increment of the field target value.
EBM, r	saving the regulation vector in register r.
EBS, r	display the regulation vector.
EN	special command (see section 6.6.5).

**\*WARNING**

Several commands may cause the loss of regulation.

**Loss of the NMR signal during regulation:**

If, for any reason, the NMR signal is lost during regulation, the PT/RG will try to recover it for about 10 seconds keeping the correcting value “frozen”. If it succeeds, the regulation continues normally. Bit 1 of STATUS 7 will have been set to 1 to indicate that the stability of the regulation might have been perturbed when the signal was lost. If after 10 seconds the signal has not been relocked the PT/RG stops the regulation process. Bit 2 of STATUS 7 is set to 1 indicating that the NMR signal has been lost definitively.

### The semi-manual regulation:

If the target value has been given with the "M" option, the regulation will be performed in the semi-manual mode. The process is identical to that when there is no digital link with the MPS except that the PT/RG's front panel functions are available to the user to search manually for the NMR signal. The field must be displayed in TESLA and the correct probe selected via the multiplexer switch. When the PT/RG is locked on the NMR signal (this must be accomplished within 255 seconds, otherwise an error will be generated) the regulation process continues normally as described for points 5/ to 12/ above. If the user leaves the regulation mode with the ER0 command the front panel returns to software control.

### 5.2.8 Incrementing the field target value: EI

[The syntax of this command is given in section 6.4.17]

This command is permitted only when the PT/RG is in the regulation mode [ER1]. **The command is used to modify the field target value with an increment given in units of  $\pm 10^{-7}$  Tesla.** This modification should not go out of the regulation window, otherwise an error will be generated.

The command is "relative", i.e. each time an increment is given it will algebraically **add** to the field target value.

The result of the EI command is not stored in the EEPROM (even with the use of the EBM command) and it is lost when the regulation mode is stopped. The initial target value remains unchanged.

Example:

The target value is 0.803 Tesla and the T/RG is in regulation mode.

EI550 (or EI+550) generates the regulation of a field of  $8030550 \cdot 10^{-7}$  Tesla.

A new command: EI45 (or EI+45) changes the regulation value to  $8030595 \cdot 10^{-7}$  Tesla.

In the same way, the command EI-103 will give a field of  $8030492 \cdot 10^{-7}$  Tesla. The EI command may allow a slow field sweeping within the regulation window.

### 5.2.9 Saving the regulation vector: EBM (priority 6)

[The syntax of this command is given in section 6.4.18]

As it has already been mentioned **the regulation vector in the foreground register 0 may be stored by the EBM command in one of the 20 registers available for this purpose.**

The syntax of this command is the following:

EBM, r where "r" is one of the 20 registers (1 to 20)

The EBM command may be executed after the EB command and even during the regulation process.

If the EBM command is performed without specifying the register, the command will be ignored except if the PT/RG is in regulation mode. In this case the regulation vector will be saved in the register which was used to start the regulation.

#### **WARNING**

If the register "r" already contains a vector, it will be definitively lost!

### 5.2.10 Displaying the regulation vector: EBS

[The syntax of this command is given in section 6.4.19]

This command sends back to the host computer the contents of a regulation vector. It can be performed during the regulation process. The syntax is as follows:

EBS{,r}

r = 1 to 20 indicates the source register, or

r = ASCII character "c" (Hex 43, Dec 67) indicates the "calibration" parameters.

r = 0 by default.

Example:

When the [EBS, 4] command is executed the PT/RG sends back to the host computer the following list (values are indicative):

- |    |                     |   |
|----|---------------------|---|
| a) | VECTOR Nb=4         | Register number.  |
| b) | TARGET VAL.=1040500 | Field target value-in units of $10^{-7}$ Tesla [EB...] without increment.   |
| c) | INCREMENT=-850      | The sum of all increments which have been sent with EI. This line is returned only when regulating!                   |
| d) | MPS param.=6349     | Value of the current parameter. It is given only if the digital link with the MPS exists [EB...].                     |
| e) | WINDOW=18434        | Size of the regulation window in units of $10^{-7}$ T [EB...].  |
| f) | CUM.COEF.adj.=100   | Adjustment coefficient of the cumulative correction factor in % [EKI...].   |
| g) | PROP.COEF.adj.=0    | Adjustment coefficient of the proportional correction factor in % [EKP...].   |
| h) | TRIG. DELAY=5       | Trigger delay for a new field measurement in 1/10 seconds [ET...].  |
| i) | MEAN dim.=1         | N° of samples in the sliding average [EM...].   |
| j) | FILTER dim.=4       | Length of the digital filter buffer [EH...].  |
| k) | FILTER threshold=50 | Threshold of the digital filter in units of $10^{-7}$ T [EH...].  |
| l) | MUX channel=D       | Multiplexer channel. This line will be displayed only if two or more probes are detected by the ECL and ECH commands. |
| m) | END                 | Message indicating the end of the list.   |

When reading an empty register, the response will be:

```
CONSIGNE TABLE NOT DEFINED  
END
```



In the same way the list of a vector whose configuration does not correspond to that one defined by the microswitches will generate the following reply:

CONSIGNE TABLE NOT ADAPTED  
END

When [EBS, C] is performed, the PT/RG returns the values measured during ECL and ECH as follows:

FIELD, CURR. param

912018, 50000 The field in units of  $10^{-7}$  Tesla and the MPS current parameter measured during the ECL execution;

10102345, 605000 The field in units of  $10^{-7}$  Tesla and the MPS current parameter measured during the ECH execution;

PROBE/CHANNEL

2C,3D,4E Indicates which probe is connected to each channel.

END

The above response is that given for a linear calibration. If the ECS command has been performed (nonlinear calibration) every measured point will also be displayed. When the ECL and ECH commands have not been performed, the response will be:

NOT DONE !

END

## **5.3 THE IEEE 488 BUS COMMANDS**

### **5.3.1 The “?” command (message to the MPS)**

[The syntax of this command is given in section 6.6.2]

When the host computer, the MPS and the PT/RG are connected to the IEEE 488 Bus, the PT/RG can not directly address a message to the power supply since it cannot be the bus Controller. Therefore, the messages are stored in a buffer and the host computer must read them and then send them to the MPS.

When the PT/RG has to send a message to the MPS, it places it in the buffer and waits indefinitely for the host to read it. Once the message has been read the PT/RG operations will continue normally. The PT/RG assumes that the host retransmits the message to the MPS without delay!

When a message is ready in the buffer, bit 7 of STATUS 5 is set to 1 to inform the controller of the presence of a message for the MPS. This bit can be scanned periodically by the host or more conveniently can generate a SERVICE REQUEST (see 6.6.1).

To read the buffer, the host must address the PT/RG as a Listener and send to it the ASCII character “?” (Dec 63, Hex 3F) . Then the PT/RG is addressed as Talker. It sends to the bus the contents of the message. If the buffer is empty, the response will be: <CR><LF> (Dec 13, Hex 0D and Dec 10, Hex 0A).

### **5.3.2 The “!” command (message to the host)**

[The syntax of this command is given in section 6.6.3]

This command is very similar to the “?” command. The only difference is that it contains messages which are intended for the host itself and not for the MPS. Bit 6 of STATUS 5 is set to 1 to indicate the presence of a message for the host.

Example:

The host addresses the PT/RG as Listener and then sends the message:

EBS, 5

to display the vector 5.

The PT/RG places in the host buffer the first line of the list pertaining to the regulation vector. Then it indicates via STATUS 5 that a message is ready for the host. The host addresses the PT/RG as a Listener and sends it:

!

then addresses it as a Talker. The first line is sent to the host:

VECTOR Nb=5

The second line is then placed in the buffer and the process repeats until the last line has been transferred.

### 5.3.3 The command EGPIB

[The syntax of this command is given in section 6.6.4]

As discussed in Chapter 4 it is possible to configure the system with the host computer connected to the PT/RG via the IEEE 488 bus and the MPS linked to the PT/RG via the RS 232 C link.

In order to achieve this configuration, the PT/RG must be informed that the MPS is connected via an RS 232 C link with the command:

EGPIB0

Following the execution of this command, the “?” command is no longer necessary because messages will be sent directly to the MPS.

EGPIB1 represents the default value and has the opposite effect, i.e. declaring the MPS connected to the IEEE 488 bus.

This command is valid only if a digital link with the MPS is declared (microswitch A10=1) and the host computer is connected to the PT/RG via the IEEE 488 bus (microswitch A9=1). In all other cases it will be ignored.

The command is stored in the EEPROM.

### **5.3.4 The command EN**

[The syntax of this command is given in section 6.6.5]

The EN command can only be issued following the EGPIB0 command, i.e. when the MPS is connected to the PT/RG via an RS 232 C link. It allows the host computer to send messages to the MPS via the PT/RG. All characters following the letter N of the command will be sent without modifications, until the ASCII characters <CR> and <LF> are encountered.

The EN command allows a one-way transparent mode of operation. The MPS cannot send back messages to the host!

## **6 SYNTAX OF COMMANDS AND STATUS DESCRIPTION**

### **6.1 INTRODUCTION**

In this chapter we describe the syntax of all the commands which are recognized by the PT/RG together with the commands pertaining to the standard I/O board. To maintain continuity in this manual we have preferred to reproduce here all commands which are accepted by the PT/RG. Therefore, the commands of the standard I/O board described in the PT 2025 user's manual will be reproduced.

Some of the commands have a different syntax depending on the type of connection RS 232 C or IEEE 488. In this case the descriptions are given separately for both types.

You should only read the part you are concerned with.

#### Note on symbols:

{...}	the characters inside the braces are optional.
< >	carriage return + line feed
==>	indicates a repetition

In general, a command consists of one or more mnemonic letters plus an associated value. If the command is "logical", the value is 0 (disable) or 1 (enable). If the command requires parameters to be specified, they are added sequentially with commas as a separator.

All commands specifically concerning the regulation start with the letter E (Extended function).

## 6.2 FIELD MEASUREMENT COMMANDS

### 6.2.1 Reading the displayed value

#### RS 232 C

Message format: <ENQ> ASCII Code Hex 05

After the reception of the ASCII character <ENQ> the displayed value is transmitted to the user in the following message format:

**vdd.ddddF<CR><LF>**  
**vdd.dddddT<CR><LF>**

- v** the ASCII character "L" (for "Locked") indicates that the Teslameter was "locked" during the measurement cycle and therefore the displayed value is valid.  
The character "N" (for "Not Locked") indicates that the Teslameter has not seen an NMR signal during the measurement cycle and therefore the displayed value is invalid.  
The character "S" (for "Signal") indicates an occurrence of the NMR signal in the last measurement cycle; it may also indicate that the signal is present but the PT/RG is not in AUTO mode.  
The character "W" (for "WRONG") indicates that the data given has no significance and should be ignored (e.g. after a trigger which has interrupted a frequency measurement).
- d** the displayed value is composed of an ASCII character between 0 and 9 inclusive; leading 0 suppression is performed.
- .** the decimal point is represented by the ASCII character "." and is included in every messages.
- F** represents the ASCII character "F" to indicate that the value of an NMR frequency is in MHz.
- T** represents the ASCII character "T" to indicate that the value is converted into Tesla.

**<CR><LF>** represents the ASCII characters "carriage return" and "line feed". These characters are always transmitted at the end of an RS 232 C message.

Note: in the display fast reading mode the last digit is not visible.

### **IEEE 488**

When the PT/RG is addressed as a Talker, it sends the displayed values according to the format described above. The EOI signal is set true before the last character is transmitted in order to indicate the end of the message. The <CR><LF> characters are sent only if microswitch A8 is set to 1.

## **6.2.2 REMOTE**

### **RS 232 C**

Message format: **R**

This message disables the front panel of the PT/RG (with the exception of the LOCAL push button) and puts the instrument into the RS 232 C REMOTE mode. The instrument will now respond to the messages described in this chapter. Messages issued prior to the remote message will be ignored with the exception of the reading of the displayed value and the seven status registers. When the PT/RG is put into the REMOTE state, the front panel controls are disabled (with the exception of the LOCAL push button). The PT/RG retains the same configuration it had before the REMOTE state was selected, except for the pre-selection of the radio frequency.

Note: the DAC has a default value of 2048 which represents the middle of the frequency range.

### **IEEE 488**

#### **REMOTE**

The PT/RG is put into the REMOTE mode when the REN line of the IEEE 488 bus is set true and the instrument is addressed as a Listener. When the PT/RG is put into the REMOTE state the front panel controls are disabled (with the exception of the LOCAL push button). The PT/RG retains the same configuration it had before the REMOTE state was selected, except for the pre-selection of the radio frequency.

Note: the DAC has a default value of 2048 which represents the middle of the frequency range.

When the PT/RG is not in the REMOTE state it cannot be addressed as a Listener.

### **6.2.3 LOCAL**

#### **RS 232 C**

Message format: **L**

This message forces the PT/RG to the LOCAL state. The front panel controls become operational.

Pressing the LOCAL push button once when the instrument is in the REMOTE state has the same effect as the LOCAL message provided that the button has not been disabled by the LOCAL lockout message (see below).

#### **IEEE 488**

##### **GO TO LOCAL**

The IEEE 488 command GTL (Go To Local) forces the PT/RG to the LOCAL state. The front panel controls become operational.

Pressing the LOCAL push button once when the instrument is in the REMOTE state has the same effect as the Go To LOCAL command as long as the button has not been disabled by the LOCAL lockout command (see below).



## 6.2.4 LOCAL Lockout

### RS 232 C

Message format: **K**

Since this message disables the LOCAL push button on the front panel of the PT/RG, only the "L" message or a RESET can return the instrument to LOCAL (front panel) mode.

### IEEE 488

#### **LOCAL LOCKOUT**

The IEEE 488 command LLO (LOCAL LOCKOUT) disables the LOCAL push button on the front panel of the PT/RG, thus only the GTL (LOCAL) command or a RESET can return the instrument to LOCAL (front panel) mode.

## 6.2.5 Preselection of the Radio Frequency

It is possible to pre-select the radio frequency via either interface, thereby replacing the use of the COARSE potentiometer.

The pre-selected value can be sent either in binary or in decimal form. (The value is then sent to a 12 bit digital/analog converter in order to select the radio frequency.)

The range of the DAC is from 0 to 4095. Should a value greater than 4095 be received by the PT/RG, it is therefore interpreted as 4095.

### Decimal Format

Message format: **Cdddd<CR><LF>**

**C** the ASCII character "C" signifies that pre-selected value is expressed in decimal.

- d** represents the pre-selected value given in ASCII characters from 0 to 9 inclusive. The user may perform leading 0 suppression on the pre-selected value.
- <CR><LF>** the ASCII characters "carriage return" and "line feed" respectively must terminate the message.

Example:

C1068<CR><LF>

### Binary Format

Message format: **Bnn**

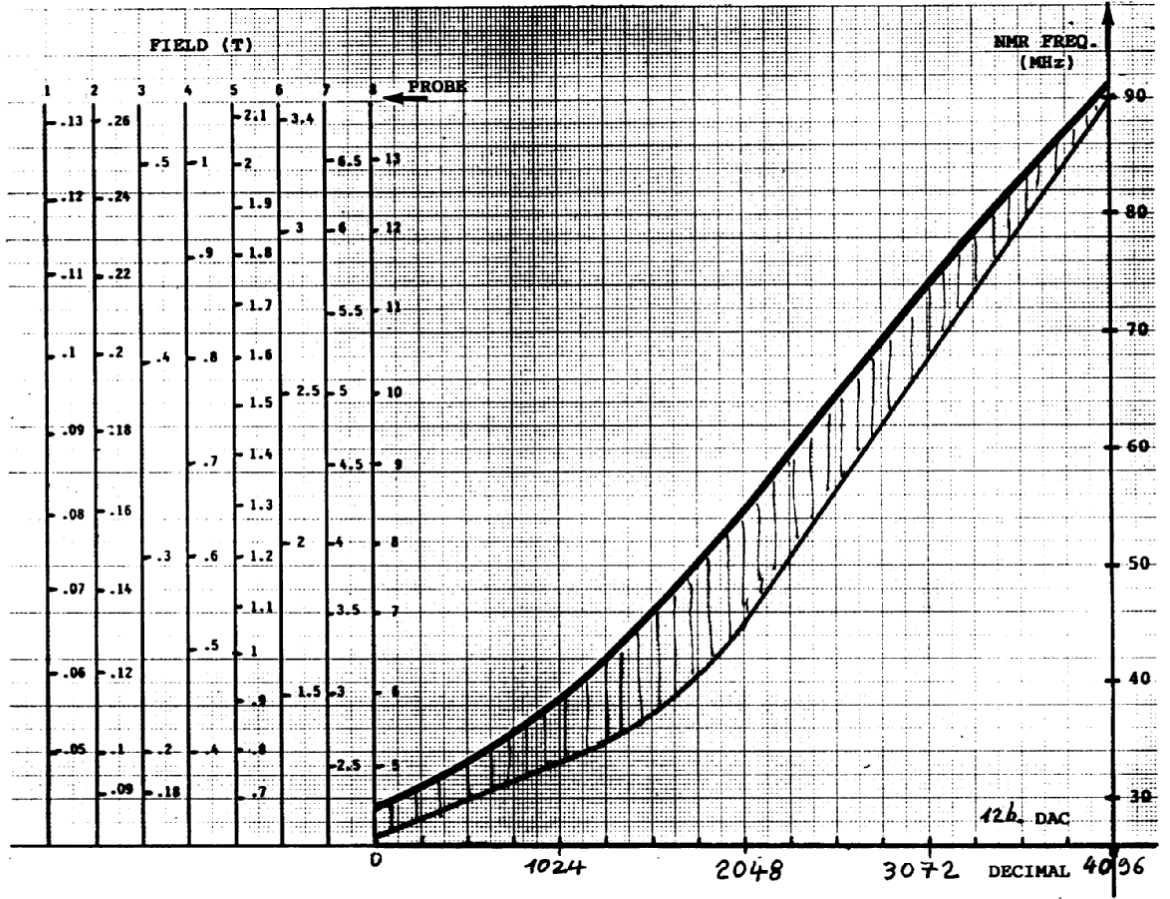
- B** the ASCII character "B" signifies that the pre-selected value is expressed in binary.
- n** represents a two byte pre-selected value (0 to 4095 inclusive).

Example:

"Bx1" (corresponds to 1329) or "B"&CHR\$(4)&CHR\$(12) (corresponds to 1042).

Note: the 4 most significant bits of the 16 bit pattern given by these two digits are not used as the DAC has only 12 bits.

There is not a linear relationship between the pre-selected value and the NMR frequency. The following figure shows the typical relationship between the NMR frequency versus the DAC setting.



### 6.2.6 Selecting MANUAL or AUTO Mode

Message format: **An**

Where  $n = 0$  for MANUAL mode  
 $n = 1$  for AUTO mode

This message selects the AUTO or MANUAL mode. Refer to the Section 4.2 of the PT 2025 user's manual.

### 6.2.7 Selecting field sense

Message format: **Fn**

where  $n = 0$  or  $-$  (for negative fields)  
 $n = 1$  or  $+$  (for positive fields)

This message determines the sense of the field to be measured with respect to the orientation of the probe.

### 6.2.8 Selecting Field or Frequency Display

Message format: **Dn**

where  $n = 0$  for MHz  
 $n = 1$  for Tesla.

This message determines whether the displayed value is given in Tesla or in MHz. It also effects the format of the measured value given via the interface.

### 6.2.9 Selecting multiplexer channel

Message format: **Pc**

where  $c$  is one of A, B, C, D, E, F, G or H and represents the appropriate multiplexer channel.

### 6.2.10 Activate SEARCH Mode

Message format: **H{nnnn}<CR><LF>**

nnnn is optional and can be any value between 0 and 4095 inclusive.

This message (H for Hunt) activates the automatic field searching algorithm (see section 4.3 of the PT 2025's user's manual). An optional start frequency can be supplied if the approximate field value is known. This has the advantage of reducing the search time.

If no DAC value is specified (i.e. H<CR><LF>) then searching starts at the minimum frequency (DAC=0).

When the PT/RG is in the SEARCH mode it can still receive messages with the exception of An, Bnn, Cdddd and Fn which would interfere with the search and are therefore ignored.

Note: the SEARCH mode can be made to work over several channels of the multiplexer to allow searching over larger field ranges (see the "X" message).

Example:

"H"&CHR\$(13)&CHR\$(10) activates searching at the lowest frequency for the selected probe.

"H934"&CHR\$(13)&CHR\$(10) activates searching at the frequency corresponding to the DAC value of 934.

### 6.2.11 Quit SEARCH mode

Message format: **Q**

When this message is received and the PT/RG is in SEARCH mode, it deactivates the search in progress and leaves the configuration as it was at the instant the "Q" message was received.

## 6.2.12 Selecting Number of Multiplexer channels used in SEARCH mode

Message format: **Xn**

where n is a number from 1 to 8 inclusive (X1 is selected on power up or RESET). This message tells the PT/RG the number of multiplexer channels that are to be scanned in the SEARCH mode. When the PT/RG enters the SEARCH mode it starts its search on the channel that was last selected (either by the multiplexer switch when the instrument was put into REMOTE mode, or the last value received in the "Pc" message). If the signal is not found on this channel, the PT/RG will follow on to the next channel and so on up to the number of channels given by the "Xn" message. When the last channel has been searched and no signal is detected the search restarts on the first selected channel and the cycle is then repeated.

Example:

Consider that probes 3,4 and 5 are connected to channels B,C and D of the multiplexer.

Execute the following messages:

"PB"                    select channel "B"  
"X3"                    select search over 3 channels  
"H"&CHR\$(10)        start SEARCH mode.

The search will in this case start on channel "B" (probe 3) and if no NMR signal is found it will continue on channel "C" (probe 4) and then on channel "D" (probe 5). If the search fails to locate a field the PT/RG will start again the search on channel "B".

If an NMR signal is detected the PT/RG will "lock" on to it. The SEARCH mode has been designed to follow the NMR signal even if it goes out of one probe's range by changing to the next channel "C" (probe 4) : if the field drifts to a value of less than 0.35 T then the PT/RG will select channel "B" and continue with probe 3 (the algorithm functions in both positive and negative drift conditions).

In this example the PT/RG can therefore search and follow an NMR signal in a field ranging from 0.175 T (low end of probe 3) up to 2.10 T (high end of probe 5). In order that this scan should operate correctly it is necessary to ensure that the probes are connected in an ascending order vis-à-vis the multiplexer channels.

**Note:** if the first channel scanned is selected as "G" and the PT/RG is programmed to search over 4 channels, then the sequence for scanning is "G", "H", "A" and "B".

### **6.2.13 Select the SEARCH Speed**

Message format: **On**

where n is a number from 1 to 6 (n=3 on power up or RESET).

This message allows the speed of the search to be changed.

The number 1 corresponds to the most rapid (i.e. 9 seconds to scan the field range of a probe). Each increase in n slows up the search by 3 seconds.

It may be necessary to slow the scan slope used in the PT/RG under certain critical field conditions, for example if the NMR signal is diminished due to a non-homogeneous field. It is possible to change the scan slope even if the search is in progress.

### **6.2.14 Reset frequency meter Time-base (Trigger)**

#### **RS 232 C**

Message format: **T**

This message forces a reset of the frequency counter time-base thus starting a new measurement cycle.

Note: the PT/RG will return the letter "W" until a valid cycle has been completed.

#### **IEEE 488**

#### **TRIGGER**

The IEEE 488 command GET (Group Execute Trigger) forces a RESET of the frequency counter time-base thus starting a new measurement cycle.

Note: if the PT/RG is addressed as a Talker it will return the field value with the letter "W" until a valid cycle has been completed (see Sect 5.1.3 of the PT 2025 user's manual).

### Enable/Disable Trigger

Message format: **Tn**

where            n = 0 disables the TRIGGER message (default value)  
                    n = 1 enables the TRIGGER message.

When n = 0 the PT/RG does not respond to the TRIGGER command. In order that the PT/RG can accept the TRIGGER command the user must send a "T1" message.

Example:

"T1" the PT/RG will respond to the trigger command.

## **6.2.15 Request Status**

### RS 232 C

Message format: **Sn**

where n is 1,2,3,4,5,6 or 7 and indicates the status register to be read. The status registers are described in section 6.3 of this manual.

Immediately following receipt of this message, the PT/RG sends back the requested status in the format shown below:

Shh            where "S" is the ASCII character "S" meaning status and "h" is an hexa-decimal character.

### IEEE 488

Message format: **Sn**

where n is 1,2,3,4,5,6 or 7 and indicates the status register to be read. The status registers are described in section 6.3 of this manual.

Following reception of this message, when the PT/RG is subsequently addressed as a Talker, it sends back to the controller the value of the requested status instead of the last measured field value.



The message sent by the PT/RG after a request for status has the following format:

Shh            where "S" is the ASCII character "S" meaning status and "h" is an hexadecimal character.

If switch A8=1 then the status will be followed by a <CR><LF>.

The following examples demonstrate the sequence in which the measured value should be read and how to access status register 2:

Example: (for HP 85 computer)

100 ENTER 708;F\$ ! address as Talker

110 DISP F\$

F\$ = "L82.125867F"

180 OUTPUT 708;"S3" ! request STATUS 2

190 ENTER 708;F\$

200 DISP F\$

F\$ = "S4A"

## 6.2.16 Display fast reading rate

Message format: **Vn**

where            n = 0 or N (for Normal rate)

                  n = 1 or F (for Fast rate)

This message determines the display reading rate i.e. Normal (about 1 per second) or Fast (about 10 per second). In the fast rate the last digit of the display is not visible and is not transferred to the computer. Therefore the PT/RG resolution is reduced by a factor 10.

Fast reading mode and regulation: the regulation can be performed in the fast reading mode. When the EB command is executed, the display rate status is memorized into EEPROM. Therefore, the regulation starts with a display rate given by the regulation vector and not that one active before performing the ER1 command (ER1 starts the regulation process).

Note: the EB command uses always the normal reading mode even when the fast mode has been selected. In the EB command field values are given always in units of  $10^{-7}$  Tesla.

### 6.3 INSTRUMENT STATUS REGISTERS

The PT/RG has 7 internal status registers which can be accessed by the user (see Section 6.2.16). The format of these seven registers is now given:

#### 6.3.1 STATUS 1: Internal Instrument Status (1 byte)

This register is cleared after reading and together with the SRQ Mask is used to form the SQR Status Register.

Bit							
7	6	5	4	3	2	1	0
Hex							
80	40	20	10	08	04	02	01
**	**	NMR Lock	LOCAL BUTTON	REGULATION	Syntax Error	NMR Signal seen	Data ready
POWER ON or RESET							

\*\* Depending if RS 232 C or IEEE 488.

**bit 7**            **RS 232 C:** "N/A" (not applicable)

**IEEE 488:** "Power On or RESET"

This bit is set to 1 on power on, or on return of current after a power failure, or after having pressed the RESET button located on the rear panel.

**bit 6**            **RS 232 C:** "Power ON or RESET"

**IEEE 488:** "N/A"

This bit is set to 1 on power on, or on return of current after a power failure, or after having pressed the RESET button located on the rear panel.

**bit 5            NMR lock**

This bit is set when the instrument becomes "locked". It is cleared by reading the Internal Instrument Status Register or when the PT/RG is no longer "locked".

**bit 4            LOCAL push button**

This bit is set by pushing the LOCAL button situated on the front panel.

**bit 3            Regulation**

When a bit of the STATUS 5 is set to 1, this bit is also set to 1. It indicates that the "Regulation Status Byte" (STATUS 5) is now different from 00.

**bit 2            Syntax error**

This bit is set to 1 if an incoming message does not conform to the formats described in this manual. The command generating a syntax error is ignored!

**bit 1            NMR signal seen**

This bit is set to 1 if the instrument detects the appearance of the NMR signal (or noise) since this register was last read. This bit is only reset by the reading of this status.

**bit 0            Data ready**

This bit is set to 1 after each measurement cycle and can be used to inform the controller of the end of a measurement cycle.

### 6.3.2 STATUS 2: NMR Signal Status (1 byte)

Bit							
7	6	5	4	3	2	1	0
Hex							
80	40	20	10	08	04	02	01
N/A	N/A	N/A	N/A	NMR Signal seen	NMR Signal state	TOO HIGH	TOO LOW

N/A = not applicable

**bit 4-7**            **always set to 0.**

**bit 3**            **NMR signal seen**

This bit is set to 1 if the instrument detects the appearance of the NMR signal (or noise) since this register was last read. This bit is only reset by the reading of this register.

**bit 2**            **NMR signal state**

This bit gives the state of the NMR signal at the time this register is read. A 1 indicates the presence of the NMR signal and a 0 the absence of the NMR signal.

**bit 1**            **TOO HIGH**

A1 indicates that at the time of reading this register, one or several of the "TOO HI" LEDs were lit.

**bit 0**            **TOO LOW**

A1 indicates that at the time of reading this register, one or several of the "TOO LO" LEDs were lit.

### 6.3.3 STATUS 3: Front Panel Status (1 byte)

Bit							
7	6	5	4	3	2	1	0
Hex							
80	40	20	10	08	04	02	01
FAST DIS- PLAY	Multiplexer Channel			SEARCH Mode	Field +/-	AUTO MANUAL Mode	Display Tesla/Mhz

**bit 7**            **A1 indicates that the fast reading mode is active (about 10 readings/sec). A 0 indicates the normal mode (about 1 reading/sec).**

**bits 6, 5, 4: Multiplexer channel**

These three bits indicate which channel of multiplexer is selected:

Bits	6 5 4	Channel
	0 0 0	A
	0 0 1	B
	0 1 0	C
	0 1 1	D
	1 0 0	E
	1 0 1	F
	1 1 0	G
	1 1 1	H

**bit 3            SEARCH mode**

A 1 indicates that the SEARCH mode is active.

**bit 2            Field +/-**

This bit indicates if the field is positive or negative with respect to the probe orientation. A1 indicates a positive field (+).

**bit 1                    MANUAL/AUTO mode**

This bit indicates whether the PT/RG is in MANUAL or AUTO mode. A0 indicates MANUAL and a 1 AUTO.

**bit 0                    DISPLAY mode (data format mode)**

A1 indicates that the displayed value is given in Tesla and a 0 in MHz.

**6.3.4 STATUS 4: DAC Status (2 bytes)**

These two bytes give the contents of the RF frequency selecting DAC.

**6.3.5 STATUS 5: Regulation Status (1 byte)**

Bit							
7	6	5	4	3	2	1	0
Hex							
80	40	20	10	08	04	02	01
Want to talk to MPS	Want to talk to host	N/A	N/A	State of the digital filter	Alarm in STATUS 7	Alarm in STATUS 6	Task is finished
**	**						

N/A = not applicable

\*\* Depending if RS 232 C or IEEE 488

With the exception of bit 3, if any of these bits are set to 1, then bit 3 of STATUS 1 is also set to 1.

**bit 7                    RS 232 C:** set to 0  
**IEEE 488:** ready to talk to MPS

Exists only for the IEEE 488. It indicates that the PT/RG has a message to send to the MPS. This bit is cleared when this status register is read.

**bit 6**            **RS 232 C:** set to 0  
                  **IEEE 488:** ready to talk to host

Exists only for the IEEE 488. It indicates that the PT/RG has a message to send to the host computer. This bit is cleared when this status register is read.

**bit 5 and 4**    **always set to 0**

**bit 3**            **State of the digital filter**

Indicates the state of the digital filter. This bit is set to 1 if the filter is active and 0 when the filter is not active (see Section 5.2.6).

**bit 2**            **Alarm in STATUS 7**

If any one of the bits of STATUS 7 is set to 1, this bit is equally set to 1. This bit is cleared by reading of STATUS 7.

**bit 1**            **Alarm in STATUS 6**

If any one of the bits of STATUS 6 is set to 1, this bit is equally set to 1. This bit is cleared by reading of STATUS 6.

**bit 0**            **Task is finished**

This bit is set to 1 when any one of the regulation tasks is terminated (see following list). This means that the PT/RG is ready to receive a new regulation command (ones starting with "E"). This bit is cleared when read or at the beginning of a task. The list of the regulation tasks which change the value of this bit are:

<b>EFC...</b>	<b>EFF...</b>	<b>ECL...</b>	<b>ECH...</b>
<b>ECS...</b>	<b>EB...</b>	<b>ER...</b>	<b>EBS...</b>

### 6.3.6 STATUS 6; Alarm configuration Status (1 byte)

Bit 7	6	5	4	3	2	1	0
Hex 80	40	20	10	08	04	02	01
Error in writing EEPROM	Configuration not correct	Error in data value	Target value out of range	Window too large	Window too small	Error in the probe connection	Missing command

If any of these bits are set to 1, two following occurs:

- a) bit 1 of STATUS 5 will be set to 1;
- b) the LED display will start to flash indicating an error. The flashing of the display can be stopped either by reading the byte, by executing any one of the regulation commands (starting with the letter "E" or even "E<CR>") or by putting the PT/RG in LOCAL mode.

Note: the LEDs flashing does not perturb the operation of the instrument.

#### **bit 7            Error in writing to the EEPROM**

This bit indicates that a data value has been badly copied to the EEPROM.

#### **bit 6            Configuration not correct**

This bit indicates that the actual command you are executing is not compatible with the configuration selected with the microswitches.



**bit 5            Error in data value**

Indicates the arithmetic overflow result of a measurement or a calculation.

**bit 4            Target value out of range**

Indicates that the field target value given in the EB command is out of the range of the probe(s).

**bit 3            Window too large**

Indicates that the regulation window, which has been specified in the option of the EB command (see sections 5.2.2.1 and 5.2.2.4), is greater than the actual capability of the correcting device.

**bit 2            Window too small**

Indicates that the regulation window, which has been specified in the option of the EB command (see sections 5.2.2.1 and 5.2.2.4), is smaller than 1/12 of the actual capability of the correcting device.

**bit 1            Error in probe connection**

This bit is set to 1 when, during the execution of the ECS command, the probes connected to the multiplexer are not ordered according to the sequential channel number (see section 5.1.7).

It is also set to 1 when, during the execution of the EB command, the PT/RG does not find the NMR probe which is appropriate for the field target value. This is the case if the multiplexer probe connection has been changed after the initialization.

**bit 0            Missing command**

Indicates that a command with a higher level of priority than the one relative to the command you are now issuing has not yet executed.

### 6.3.7 STATUS 7: Alarm measurement Status (1 byte)

Bit	6	5	4	3	2	1	0
Hex	40	20	10	08	04	02	01
N/A	Display not in Tesla	Correction out of window	Not in the center of the window	MPS not stable	NMR signal lost while regulating (definitively)	NMR signal lost while regulating (Temporary)	NMR signal not found

If any of these bits, excluding bit 1, is set to 1, two following occurs:

- a) bit 1 of STATUS 5 will be set to 1;
- b) the LED display will start to flash indicating an error. The flashing of the display can be stopped either by reading the byte, by executing any one of the regulation commands (starting with the letter "E" or even "E<CR>") or by putting the PT/RG in LOCAL mode.

Note: the LEDs flashing does not perturb the operation of the instrument.

**bit 7**                    **always set to 0.**

**bit 6**                    **Display not in Tesla**

Indicates that the display is not in Tesla at the moment you issue the EB command or ER1 command in the semi-manual mode (see section 5.2.2.7 and last part of section 5.2.7).

**bit 5            Correction out of window**

Indicates that the correction value has gone out of the regulation window. This may result from a too large field drift or field increment given by the user (see section 5.2.8).

**bit 4            Not in the center of the window**

Indicates that the magnetic field value does not fall within the central 1/3 of the regulation window.

**bit 3            MPS not stable**

This bit signifies that the PT/RG cannot measure the field correctly. It assumes that the field is not stable enough.

**bit 2            NMR signal lost while regulating**

Indicates that the NMR signal has been **definitively** lost during the regulation process. Therefore the regulation process has been stopped.

**bit 1            NMR signal lost while regulating**

Indicate that the NMR signal has been **temporarily** lost during the regulation process and then found again. The regulation process is not stopped.

**bit 0            NMR signal not found**

This bit signifies that the PT/RG did not find and lock the NMR signal in the given time.

## 6.4 REGULATION COMMANDS

All of these functions start with the letter "E". Their respective priority has already been defined in section 5.1.1

### 6.4.1 COARSE message to the MPS

Format: **EFC{t/==>t},{h}<DC4>n<DC4>{e}<CR><LF>**

Mnemonic: Format Coarse

Priority: 1

Description: section 5.1.3

**h** **sequence** of ASCII characters representing the fixed part of the MPS message sent **prior** to the current parameter.

**<DC4>** ASCII character (Dec 20, Hex 14)  
(in general: Ctrl-T).

**<DC4>** delimitates the variable part of the message. It will not be sent to the MPS.

**n** MPS current parameter. Here the maximum value which the MPS can reach must be introduced.

**e** **sequence** of ASCII characters representing the fixed part of the MPS message sent **after** the current parameter.

**<CR><LF>** carriage return and line feed characters terminating the command. They will also belong to the message sent to the MPS unless other terminating characters are used (see below).

**t/** decimal number representing the ASCII character used as terminator for the MPS. If more than one terminator is used, they must be separated with a slash (/).

Example:

EFC,CUR<DC4>9999<DC4><CR><LF>

the message the PT/RG will send to the MPS takes the form:

CUR1234<CR><LF>

ECF12/4,ABC<DC4>9999<DC4>DEF<CR><LF>

the message the PT/RG will send to the MPS takes the form:

ABC1234DEF<FF><EOT>

where:            <FF> is the ASCII character  
                      Dec 12  
                      <EOT> is the ASCII character  
                      Dec 4

#### 6.4.2 FINE message to the MPS

Format:            **EFF<t/==>t),{h}<DC4>n<DC4>{e}<CR><LF>**

Mnemonic:        Format Fine

Priority:           1

Description:      section 5.1.4

**h**                    **sequence** of ASCII characters representing the fixed part of the MPS message sent **prior** to the fine current parameter.

**<DC4>**                ASCII character (Dec 20, Hex 14)  
 (in general: Ctrl-T).

DC4 delimits the variable part of the message. It will not be sent to the MPS.

**n**                    MPS fine current parameter. Here the maximum value which the MPS can reach must be introduced.

**e**                    **sequence** of ASCII characters representing the fixed part of the MPS message sent **after** the fine current parameter.

**<CR><LF>**            the carriage return and line feed characters terminating the command. They will also belong to the message sent to the MPS unless other terminating characters are used (see below).

**t/**                    decimal number representing the ASCII character used as terminator for the MPS. If more than one terminator is used, they must be separated with a slash (/).

Note: in the message received by the MPS, the sign + or - will proceed the variable part.

Example:

EFF,FI<DC4>2048<DC4><CR><LF>

The message the PT/RG will send to the MPS takes the form:

FI+1234<CR><LF>

EFF12/4,ABC<DC4>2048<DC4>DEF<CR><LF>

The message the PT/RG will send to the MPS takes the form:

ABC-1234DEF<FF><EOT>

where:           <FF> is the ASCII character  
                  Dec 12  
                  <EOT> is the ASCII character  
                  Dec 4

### 6.4.3 MPS settling time

Format:        **Esn<CR><LF>**

Mnemonic:     Settling time

Priority:       2

Description:   section 5.1.5

**n**            decimal number ranging from 1 to 6550 included. It represents the time in seconds to achieve the MPS maximum current defined by the current parameter value given in the EFC command.

Example:

ES20<CR><LF>

This means that the MPS takes 20 seconds to reach its maximum current.

#### 6.4.4 Low point acquisition

Format: **ECLn<CR><LF>** (if digital link with MPS, i.e. A10=1)  
**ECL<CR><LF>** (if no digital link with MPS, i.e. A10=0)

Mnemonic: Calibration Low point

Priority: 3

Description: section 5.1.6

**n** decimal number ranging from 0 to the value given as current parameter in the EFC command. It represents the current parameter giving the field corresponding to the low point of the "lowest" NMR probe which is connected.

Example:

ECL522<CR><LF>

#### 6.4.5 High point acquisition

Format: **ECHn<CR><LF>** (if digital link with MPS, i.e. A10=1)  
**ECH<CR><LF>** (if no digital link with MPS, i.e. A10=0)

Mnemonic: Calibration High point

Priority: 3

Description: section 5.1.6

**n** decimal number ranging from 0 to the value given as current parameter in the EFC command. It represents the current parameter giving the field corresponding to the high point of the "highest" NMR probe which is connected.

Example:

ECH9999<CR><LF>

### 6.4.6 Acquisition of the curve Field/Current

Format: ECS<CR><LF>

Mnemonic: Calibration Start

Priority: 4

Description: section 5.1.7

When this command is executed, the PT/RG measures the curve of the magnetic field as a function of the current parameter for a non linear magnet. It then stores it in the EEPROM.

### 6.4.7 Correction and FIELD+/- coupling

Format: EPn<CR><LF>

Mnemonic: Polarity coupling

Priority: none

Description: section 5.1.8

n = 0 ==> the coupling between the FIELD +/- and the correction sign is disabled.

n = 1 ==> the coupling between the FIELD +/- and the correction sign is enabled.

### 6.4.8 Field target value

Format: EBn{,w} {,D} {,M}<CR><LF>  
(if digital link with MPS, ie A10=1)

EB(n) {,w} {,D} {,M}<CR><LF>  
(if no digital link with MPS, ie A10=0)

Mnemonic: B is the symbol of the magnetic induction

Priority: 4

Description: section 5.2.2



- n** field target value in units of  $10^{-7}$  Tesla. The upper and low limits are equal to those measured with the ECL and ECH commands.
- w** size of the regulation window in units of  $10^{-7}$  Tesla (see section 5.2.2).
- D** ASCII character "D" (Dec 68, Hex 44), it indicates that the other data values of the regulation vector must be set to their default values (see section 5.2.2.6).
- M** ASCII character "M" (Dec 77, Hex 4D), it indicates that the field measurement must be done in the semi-manual mode (see section 5.2.2.7).

Example:

```
EB8095500<CR><LF>
```

```
EB12044500,D,10000<CR><LF>
```

#### 6.4.9 Adjustment of the integral coefficient

Format: **EKI{n}<CR><LF>**

Mnemonic: **K** is the symbol of the correction factor and **I** for integral (cumulative)

Priority: none

Description: section 5.2.3

Default value:100

- n** decimal number ranging from 0 to 250. Indicates the adjustment rate of the correction factor in %

Example:

EKI85<CR><LF> means that the integral coefficient is reduced of 15%

EKI<CR><LF> is equivalent to the command EKI100<CR><LF>

#### 6.4.10 Adjustment of the proportional coefficient

Format: **EKP{n}<CR><LF>**

Mnemonic: **K** is the symbol of the correction factor and **P** for Proportional.

Priority: none

Description: section 5.2.3

Default value: 0

**n** decimal number ranging from 0 to 250. Indicates the adjustment rate for the correction factor in %.

Note: if **n** is not given, the default value is taken.

Example:

EKP10<CR><LF> means that the proportional coefficient is 10%.

EKI<CR><LF> is equivalent to the command EKPO<CR><LF>.

#### 6.4.11 Trigger delay

Format: **ET{n}<CR><LF>**

Mnemonic: Trigger delay

Priority: none

Description: section 5.2.4

Default value: 3

**n** decimal number from 0 to 999. It indicates the delay in 1/10 seconds between one correction and the start of the next field measurement.

Example:

ET12<CR><LF> means that the trigger delay is 1.2 seconds

ET<CR><LF> is equivalent to the command ET3<CR><LF>

### 6.4.12 Sliding average

Format: **EM{n}<CR><LF>**

Mnemonic: Sliding Mean

Priority: none

Description: section 5.2.6

Default value: 1

**n** decimal number from 0 to 99. It indicates the number of samples in the sliding average.

Example:

EM8<CR><LF> means that the average consists of 8 samples.

EM<CR><LF> is equivalent to the command EM1<CR><LF>

### 6.4.13 Length of the digital filter buffer

Format: **EX{n}<CR><LF>**

Mnemonic: none

Priority: none

Description: section 5.2.6

Default value: 0

**n** decimal number from 0 to 10. It indicates the length of the digital filter buffer

Example:

EX4<CR><LF> means that digital filter buffer has 4 elements

EX<CR><LF> is equivalent to the command ET0<CR><LF>

#### 6.4.14 Digital filter threshold

Format: **EH{n}<CR><LF>**  
Mnemonic: **TH**reshold of the digital filter  
Priority: none  
Description: section 5.2.6  
Default value:15

**n** decimal number from 0 to 32000. It indicates the digital filter threshold in units of  $10^{-7}$  Tesla.

Example:

EH120<CR><LF> means that the digital filter threshold is  $\pm 120 \cdot 10^{-7}$  T.

EH<CR><LF> is equivalent to the command EH15<CR><LF>

#### 6.4.15 Starting the regulation mode

Format: **ER1{,r}<CR><LF>**  
Mnemonic: **Regulation mode**  
Priority: 5  
Description: section 5.2.7  
Default value:0

The regulation mode is started using the regulation vector contained in the register r. If r is omitted the current register 0 is taken as default.

**r** register number ranging from 1 to 20 and containing the regulation vector.

Example:

ER1<CR><LF> starts the regulation with the vector contained in reg. 0.

ER1,3<CR><LF> starts the regulation with the vector contained in reg. 3.

#### 6.4.16 Stopping the regulation mode

Format: **ER0<CR><LF>**  
Mnemonic: **R**egulation mode  
Priority: none  
Description: section 5.2.7

The regulation mode ceases and the correction value is “frozen”.

Example:

ER0<CR><LF> stops the regulation.

#### 6.4.17 Increment of the field target value

Format: **Elsn<CR><LF>**  
Mnemonic: field Incremente  
Priority: none  
Description: section 5.2.8  
Default value:0

**s** sign + or – (Default value = +)

**n** decimal number from 0 to 32767 or equal to the regulation window, which is the greater. The units are  $10^{-7}$  Tesla.

Example:

EI-2120<CR><LF> means that the magnetic field being regulated is reduced by  $2120 \cdot 10^{-7}$  Tesla.

EX950<CR><LF> is equivalent to the command EI+950<CR><LF>. The field in regulation is increased by  $950 \cdot 10^{-7}$  Tesla.

#### 6.4.18 Saving the regulation vector

Format: **EBM,r<CR><LF>**  
Mnemonic: **B** for the magnetic induction and **M** for Memorize

Priority: 5  
Description: section 5.2.9

**r** register number ranging from 1 to 20. It indicates the register where the regulation will be saved. During regulation "r" may be omitted. The vector will be then saved in the same register used to start the regulation.

Example:

EBM,8<CR><LF> stores the vector in the register 8.

#### 6.4.19 Listing of the regulation vector

Format: **EBS{,r}<CR><LF>**  
Mnemonic: **B** for the magnetic induction and **S** for Store  
Priority: none  
Description: section 5.2.10  
Default value:0

**r** register number ranging from 1 to 20. It indicates the register whose contents are to be listed. If r is omitted the register 0 will be taken as the default.

Example:

EBS,5<CR><LF> lists the regulation vector stored in register 5.

#### 6.4.20 Software version

Format: **EZV<CR><LF>**  
Mnemonic: **V**ersion of the RE 2040's software  
Priority: none  
Description: none  
Default value:0

When this command is executed, the PT/RG returns to the Host a message indicating the software version. The message takes the form: RG2040 VER x.x<CR><LF>

## 6.5 THE RS 232 C ONLY COMMANDS

### 6.5.1 Transparent mode

Format: **N{c}<CR><LF>**

Mnemonic: none

Description: section 6.5.1

Default value:<Ctrl-C>

**c** is an ASCII character. When the command has been executed, all characters issued by the Host computer are transmitted to the MPS. The "transparent" mode is started. In the same way, all characters issued by the MPS are sent to the host. This continues until the host sends the character "c" which cancel the "transparent" mode. If "c" is omitted, the character <Ctrl-C> (Dec 03, Hex 03) is taken as the default.

Example:

N£<CR><LF>

**All of these characters written in <CR><LF> bold are transmitted identically <CR><LF> to the MPS<CR><LF>.**

£ : this last character has stopped the "transparent" mode.

## 6.6 THE IEEE 488 BUS ONLY COMMANDS

### 6.6.1 SRQ Mask command

[Refer to the section 5.2 of the PT 2025 user's manual for details on the Service Request capabilities]

Message format: **Mno**

- M** the ASCII character "M" indicates that the two following bytes of data constitute the byte mask for the internal status of the PT/RG.
- n** signifies the ASCII character from 0 to 7 relating to the mask pattern, in octal, for bits 3, 4 and 5.
- o** the ASCII characters from 0 to 7 relate to the mask pattern, in octal, for bits 0, 1 and 2.

This message allows the user to set up a mask for the SRQ register in order to prevent the PT/RG from interrupting the controller when a particular event occurs. On power up or RESET the **default value** for the mask is M00.

SRQ Mask register:

	bits	5 4 3			2 1 0			
		n				o		
		Value				Value		
M = Masked A = Active	0	M	M	M	0	M	M	M
	1	M	M	A	1	M	M	A
	2	M	A	M	2	M	A	M
	3	M	A	A	3	M	A	A
	4	A	M	M	4	A	M	M
	5	A	M	A	5	A	M	A
	6	A	A	M	6	A	A	M
	7	A	A	A	7	A	A	A

Note: it is not possible to mask bits 6 and 7. On power up and RESET both bits are active.

Example:

OUTPUT 708;"M00" gives all bits masked

OUTPUT 708;"M77" gives all bits active.



### 6.6.2 The “?” command

Format:       ?**<CR><LF>**

Description:   section 5.3.1

Following the reception of this message and when the PT/RG is addressed as a Talker, it sends back to the controller (host) its buffer contents (message for the **MPS**). The host should transmit, without delay the message to the MPS. If the buffer is empty, the controller will receive only the two characters **<CR>** and **<LF>**.

### 6.6.3 The “!” command

Format:       !**<CR><LF>**

Description:   section 5.3.2

Following the reception of this message and when the PT/RG is addressed as a Talker, it sends back to the controller (host) its buffer contents (message for the host). If the buffer is empty, the controller will receive only the two characters **<CR >** and **<LF>**.

### 6.6.4 The EGPIB command

Format:       **EGPIBn<CR><LF>**

Mnemonic:   **General Purpose Interface Bus** (alternative name for the IEEE 488 bus)

Priority:     none

Description:   section 5.3.3

n = 1         the host computer, the PT/RG and the MPS are connected to the IEEE 488 bus.

n = 0         the host computer is connected to the PT/RG via the IEEE 488 bus, but the MPS is connected to the PT/RG via an RS 232 C link.

### 6.6.5 The EN command

Format: **ENcc<CR><LF>**

Mnemonic: none

Priority: this command is possible only after that "EGPIBO" has been executed!

Description: section 5.3.4

**cc** represents a string of ASCII characters which will be directly transmitted to the MPS inclusive of <CR><LF>.

## **7 HARDWARE**

---

### **7.1 CONNECTORS**

#### **IEEE 488**

Standard 24 p. connector. For the signals refer to the IEEE 488 standard. The bus drivers are tri-state type.

#### **RS232 C HOST**

Connector sub-D 25 p. (male) to link via RS 232 C the host computer. For the signals refer to the RS 232 C standard. Pin assignment is as follows:

Pin 1 : Shield GND. This pin supplies 10.5 V, 100 mA for the "PSION ORGANIZER". When connected to GROUND, the power supply is automatically disenabled.

Pin 2 : Transmit data (TX).

Pin 3 : Receive data (RX).

Pin 7 : Signal GND.

#### **RS 232 C MPS**

Connector sub-D 25 p. (female) to link via RS 232 C the MPS. For the signals refer to the RS 232 C standard. The connector is isolated in respect to the instrument's crate and the linear outputs up to 500 VAC (1 kV peak). The pin assignment is the following:

Pin 1 : Shield GND.

Pin 2 : Transmit data (TX).

Pin 3 : Receive data (RX).

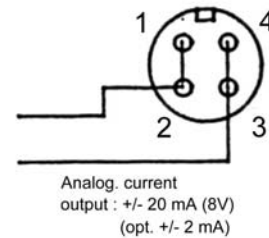
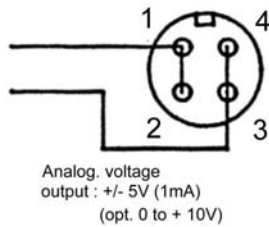
Pin 7 : Signal GND.

### ± 5V LINEAR OUTPUT

LEMO 4 p. connector to drive (voltage) the correcting device linearly. It can supply  $\pm 5V$  (1 mA) in 4096 steps. Optionally (see section 7.2) the output may be changed to supply 0 to 10V (1 mA). Pin assignment is shown below.

### ± 20 MA LINEAR OUTPUT

LEMO 4 p. connector to drive (current) the correcting device linearly. It can supply  $\pm 20$  mA (8V) in 4096 steps. Optionally (see section 7.2) the output may be changed to supply  $\pm 2$  mA (8V). Pin assignment shown below:

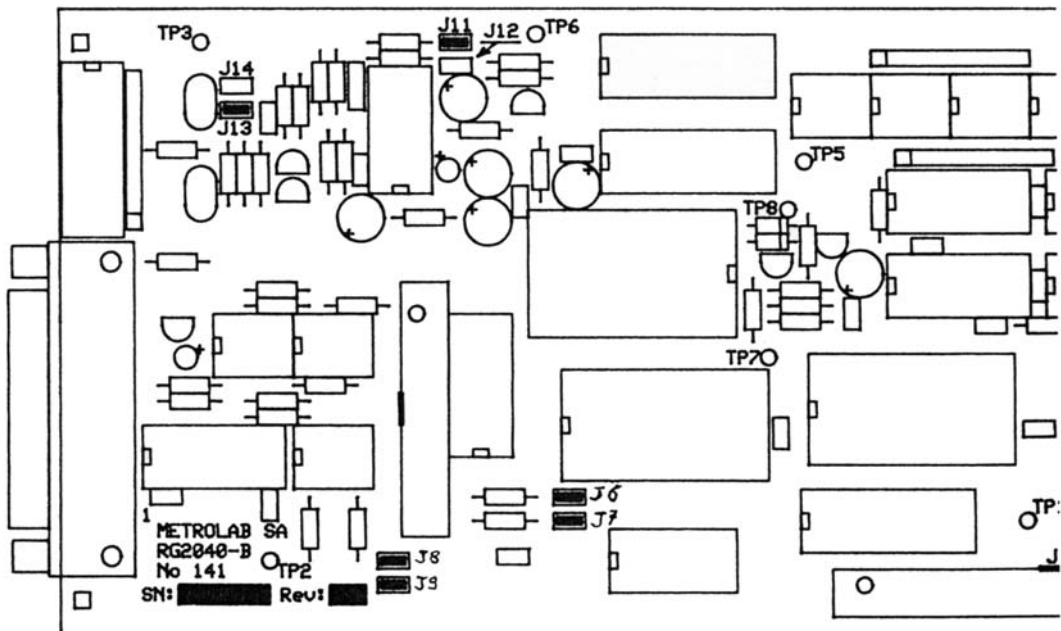


Note: the GROUND of the two linear outputs is common (pin 4 and 3) for the two LEMO connectors but isolated in respect to the instrument's chassis and to the RS 232 C - MPS output up to 500 VAC (1 kV peak).

## 7.2 LINEAR OUTPUT RECONFIGURATION

The linear outputs may be reconfigured to have 0 to +10 V linear voltage output (and  $\pm 20$  mA linear current output) according to the following procedure:

- Turn off the PT/RG.
- Completely unscrew the four retaining screws on the RG 2040 module situated on the rear panel.
- Remove the RG 2040 module by using the knurled screws as leverage.
- Choose the required configuration by moving the jumpers to the desired position as shown in the following picture:



When J11 is closed and J12 is open, the linear voltage output supplies  $\pm 5$  V (1 mA) as the factory setting.

When J11 is open and J12 is closed, the linear voltage output supplies 0 to +10 V (1 mA).

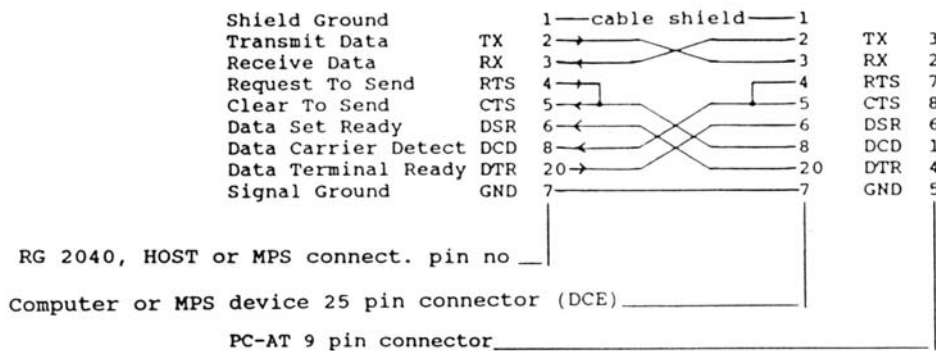
When J13 is closed and J14 is open, the linear current output supplies  $\pm 20$  mA (8V) as the factory setting.

When J13 is open and J14 is closed, the linear current output supplies  $\pm 2$  mA (8V).

Reinstall the RG 2040 module in the instrument's crate following the inverse procedure.

### 7.3 RS 232 C CONNECTOR

The PT/RG is a DCE device; the connectors for serial communication are a sub-D 25 male connector for the host and a sub-D 25 female connector for the MPS. We recommend the following pin to pin connections:



#### Host connector

Jumper J6    CLOSED = CTS disable  
                   OPEN = CTS enable

Jumper J7    CLOSED = DCD disable  
                   OPEN = DCD enable

#### MPS connector

Jumper J8    CLOSED = CTS disable  
                   OPEN = CTS enable

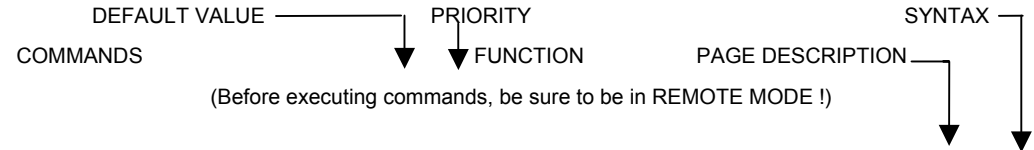
Jumper J9    CLOSED = DCD disable  
                   OPEN = DCD enable

## FIELD MEASUREMENT COMMAND SUMMARY

RS 232 C	IEEE 488	FUNCTION	SYNTAX
R	REMOTE* (REM)	ALLOWS THE PT/RG TO ACCEPT COMANDS	65
L	LOCAL* (GTL)	RETURNS THE PT/RG UNDER THE FRONT PANEL CONTROL	66
K	LOCAL LOCKOUT*	BLOCKS THE LOCAL PUSH BUTTON FUNCTIONS	67
	Cnnnn<CR><LF>	DECIMAL LOAD OF THE PRESELECTING RF FREQUENCY DAC (12 BITS)	67
	Bnn	BINARY LOAD OF THE PRE-SELECTING RF FREQUENCY DAC (12 BITS)	68
	Dn	DISPLAY IN MHZ: (n=0) OR IN TESLA: (n=1)	70
	Fn	FIELD POLARITY: "+" (n=0) "- " (n=1)	70
	An	SELECT MODE: MANUAL (n=0) AUTO (n=1)	70
	Vn	DISPLAY           NORMAL (n=0) RATE:             FAST (n=1)	75
	Pc	SELECT MUX CHANNEL	70
	H{n}<CR><LF>	START THE SEARCH MODE	71
	Q	QUIT THE SEARCH MODE	71
	Xn	SELECT THE MUX RANGE	72
	On	SELECT THE SEARCH SPEED	73
-	Tn	ENABLE (n=1) OR DISABLE (n=0) THE IEEE 488 "TRIGGER" COMMAND	74
T	TRIGGER* (GET)	RESET THE RF FREQUENCY COUNTER TO START A NEW MEASUREMENT	73
-	Mno	PROGRAM THE SRQ MASK REGISTER	98
	Sn	ASK FOR THE STATUS REGISTER	74
ENQ	PT AS A TALKER	READ THE DISPLAY	64

\* THESE ARE IEEE 488 COMMANDS (NOT TO BE CONFUSED WITH ASCII MESSAGES)

# SUMMARY



## STATUS DESCRIPTION

BIT	7	6	5	4	3	2	1	0
HEX	80	40	20	10	08	04	02	01
STATUS 1	POWER ON OR RESET (1)		NMR LOCK	LOCAL BUTTON	REGULATION	SYNTAX ERROR	NMR SIGNAL SEEN	DATA READY
STATUS 2	0	0	0	0	NMR SIGNAL SEEN	NMR SIGNAL RATE	TOO HIGH	TOO LOW
STATUS 3	FAST DISPLAY	MULTIPLEXER CHANNEL			SEARCH MODE	FIELD +/-	AUTO/MAN.	TESLA/MHZ
STATUS 5	WANT TO TALK TO MPS (2)	WANT TO TALK TO HOST (2)	0	0	STATE OF DIGITAL FILTER	ALARM IN STATUS 7	ALARM IN STATUS 6	TASK IS FINISHED
STATUS 6 (3)	ERROR IN WRITING EEPROM	CONFIGURATION NOT CORRECT	ERROR IN DATA VALUE	TARGET VALUE OUT OF RANGE	WINDOW TOO LARGE	WINDOW TOO SMALL	ERROR IN THE PROBE CONNECTION	MISSING COMMAND
STATUS 7	0	DISPLAY NOT IN TESLA	CORRECTION OUT OF WINDOW	NOT IN CENTER OF WINDOW	MPS NOT STABLE	NMR SIGNAL LOST WHILE REGULATING (DEFINITELY)	NMR SIGNAL LOST WHILE REGULATING (TEMPORARELY)	NMR SIGNAL NOT FOUND
STATUS 4	CONTENTS OF THE PRESELECTING RF DAC (2 BYTES)							

## INITIALIZATION COMMANDS

EFC,{h}<DC4>n<DC4>{e}<CR><LF>	-	1	Coarse message of the MPS	26	86
EFF,{h}<DC4>n<DC4>{e}<CR><LF>	-	1	Fine message of the MPS	27	87
ESn<CR><LF>	-	2	MPS settling time	27	88
ECLn<CR><LF>*	-	3	Low point acquisition	28	89
ECHn<CR><LF>*	-	3	High point acquisition	28	89
ECS<CR><LF>	-	4	Acquisition of the curve Field/Current	32	90
Epn<CR><LF>	0	-	Sign of the correction and Field +/- coupling	32	90
<b>REGULATION COMMANDS</b>					
EBn,{W}{D}{M}<CR><LF>*	-	4	Field target value	33	90
EKI{n}<CR><LF>	100	-	Adj of the cumulative correction coef (n in %)	50	91
EKP{n}<CR><LF>	0	-	Adj of the proportional correction coef (n in %)	50	92
ET{n}<CR><LF>	3	-	Trigger delay (n in 1/10 sec)	51	92
EM{n}<CR><LF>	1	-	Nb. of samples in the sliding average	51	93
EX{n}<CR><LF>	0	-	Nb. of samples in the digital filter buffer	52	93
EH{n}<CR><LF>	15	-	Threshold of the digital filter (n in 10 <sup>-7</sup> Tesla)	52	94
ER1,{r}<CR><LF>	0	5	Starting the field regulation	53	94
ER0<CR><LF>	-	-	Stopping the field regulation	53	95
Elsn<CR><LF>	-	-	Increment of the field target value (n in 10 <sup>-7</sup> T)	56	95
EBM, r<CR><LF>	-	5	Saving the regulation vector in register "r"	57	95
EBS,{r}<CR><LF>	0	-	Listing the regulation vector	57	96
			(or the Field/Current curve)	57	96
EZV<CR><LF>	-	-	Software version	96	97

### Notes :

- RS 232 link with host : bit 6 (bit 7=N/A)  
IEEE 488 link with host : bit 7 (bit 6=N/A)

2) Only for IEEE 488

3) A bit of this Status set to 1 implies the flashing of the display.

It can be stopped by reading the byte or executing a command starting with "E"

### RS 232 C

### IEEE 488

N{c}<CR><LF>	-	-	Transparent mode	25	97
-	?	<CR><LF>	Ask for a MPS message	60	99
-	!	<CR><LF>	Ask for a host message	60	99
-	EGPIBn	<CR><LF>	n=0 means: the MPS is on a RS 232 C link	61	99
-	EN{c}	<CR><LF>	Transparent mode between IEEE488 and RS 232c (MPS)	62	100

\* The exact syntax depends on the configuration