CAYLAR
INSTRUMENTATION SCIENTIFIQUE

NMR20 Teslameter

High Precision Teslameter
version 2022

USER MANUAL

Caylar SAS
14 avenue du Québec
BP 612
91140 Villebon-sur-Yvette
France
Tél +33 1 69 29 91 62

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1. INTRODUCTION

The NMR20 Gaussmeter measures magnetic fields using the principle of Nuclear Magnetic Resonance. NMR is the most precise and accuracy technical for absolute magnetic field reading without temperature drift.

Nuclear Magnetic Resonance comes from high frequency excitation of a material, in presence of a magnetic field. There is a direct relationship between the magnetic field and a frequency resonance named “Gyromagnetic Ratio”.

The principle is to place the “NMR sample” in the magnetic field. Then this material is excited by a wideband variable high frequency wave generated by the NMR20.
An absorption resonance is detected at precise frequency, the magnetic field value can be deduced from this frequency measured by the NMR20.

For example, we use the proton for low field and medium field probes.
We use the “Proton Gyromagnetic Ratio “. This is a Fundamental Physical Constant referenced in the Source of the CODATA internationally recommended values.

The relationship existing between the magnetic field and the resonance allows a high accuracy. Thus, the absolute precision of the measurement of the magnetic field is in the order of 10^{-7}. The relative precision, pertains to the frequency measurement, is ten times better, in the order of 10^{-8}.

2. PARTS OF NMR SYSTEM

2.1. NMR Probes

The probe contains the NMR sample, the excitation coil and all the electronics for frequency generation and magnetic resonance signal extraction.
The probes also feature a Hall sensor for rapid field monitoring.

The signal and frequency generated are transmitted to a preamplifier.

2.2. PAMUX Preamplifier

The preamplifier amplifies and filter the NMR signal and control the amplitude of the frequency generated by the NMR probe for long distance travel.

1, 2 and 4-channel preamplifiers are available for connecting several probes.

The signal and frequency preamplified are transmitted to the NMR20 Teslameter.

2.3. SWMUX – Switch MUX

The switch can be used to connect several preamplifiers.

4-channel and 8-channel switches are available.

All signals are routed to the NMR20.

2.4. NMR20

The NMR20 locks the frequency to the location where the NMR peak is detected.
The frequency is read by the NMR20's frequency-meter and converted into a magnetic field value by applying the sample's gyromagnetic ratio.

The user can read the values and control several parameters, such as filters and NMR signal amplitude to optimize magnetic field detection and measurement under the most critical conditions, such as low homogeneity.

2.5. Cables

- R51: The R51 cable supplies, controls and recovers the NMR and Hall signal.
- R52: The R52 cable supplies, controls PA-MUX and SW-MUX to switch channels.
- RCX: 50 Ω coaxial cable, it routes the high frequency signal (HF) to the NMR20.

3. PANNELS DESCRIPTION

3.1. Front panel

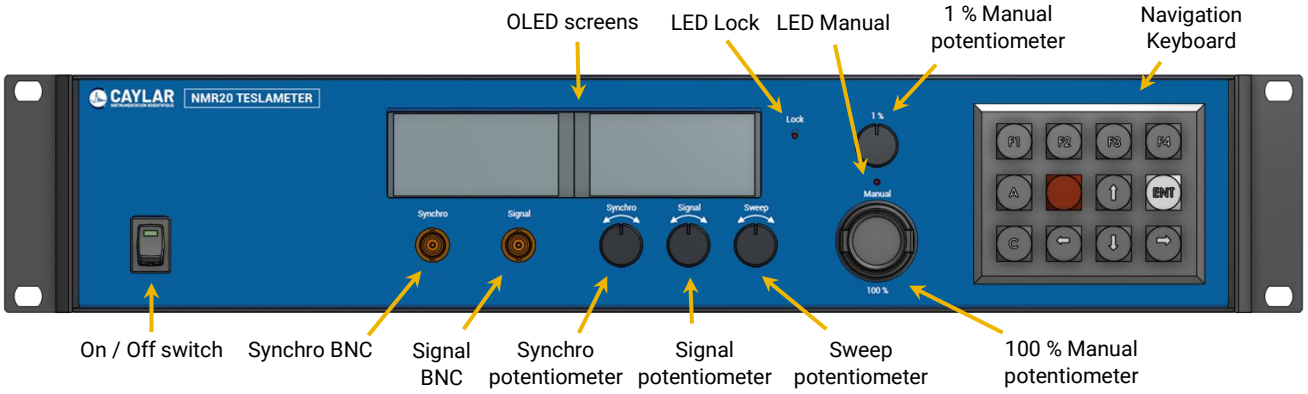
The gaussmeter's front panel contains the elements needed to set parameters and adjust the gaussmeter locally.

It includes:

- The main switch.
- Two OLED displays.
- Two BNCs for signal and synchro outputs for displaying the NMR signal on an oscilloscope.
- 3 digital potentiometers you can turn and press:
  - **Synchro**: to adjust the position of the NMR signal on an oscilloscope set to trigger on the synchro signal, also acts on the position of the signal during acquisition by command.
  - **Signal**: to adjust gaussmeter input stage gain and control the amplitude of the NMR signal.
  - **Sweep**: is used to adjust the sweep amplitude to find a maximum signal value.

Increases or decreases the corresponding value by 1 with each step, cycles between 0 -> 50 -> 100 -> 0 with each press

- Two potentiometers 100 % and 1 % for manual search of the NMR signal.
- A « Lock » LED
  Indicate NMR signal detection.
- A « Manual » LED
  Indicate that the gaussmeter is in manual mode and that the two potentiometers 100 % and 1 % are used to search for the resonance signal.
- A keyboard for menu navigation and system configuration.

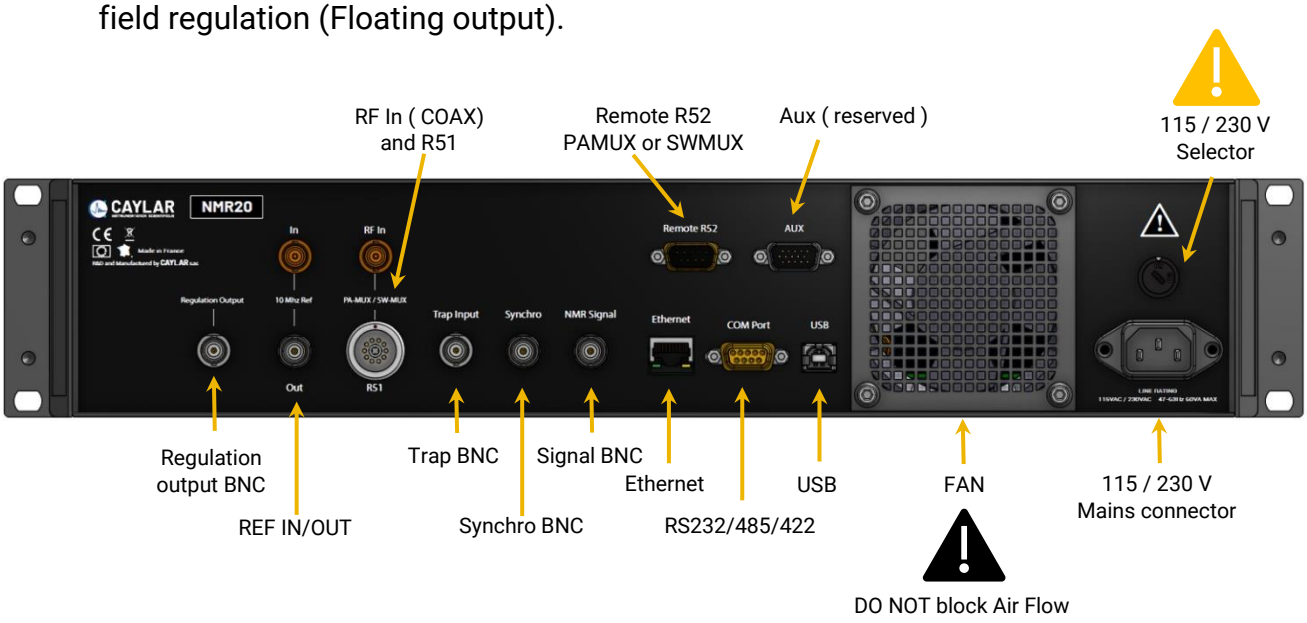


3.2. Rear Panel

The rear panel of the gaussmeter contains all the connections.

It includes:

- Mains input filter.
- 115 / 230 V Selector
- Communication connectors including:
  - USB 2.0 type B connector.
  - COM Port SUBD-9 F connector for RS232/RS485/RS422 communication.
  - Ethernet connector
- AUX SUBD-15 M (Reserved)
- Two BNCs for signal and synchro outputs for displaying the NMR signal on an oscilloscope.
- BNC connector for Trap signal input
  - Used to freeze the gaussmeter during an external high energy pulse.
- Connector to connect the rest of the NMR system
  - R51 connector, 14 pin LEMO for connecting analog signals to and from a PAMUX or SWMUX.
  - RF In connector, BNC to connect the RF signal from a PAMUX or SWMUX.
  - R52 connector, SUBD-9 M connector to control a PAMUX2/4 or SWMUX.
- BNC connectors for 10 MHz reference in/out.
- BNC connectors for Regulation Output (OPTION) ± 10 V for power supply control and field regulation (Floating output).



4. INSTALLATION AND CONNECTIONS

4.1. Installation of the probe

On one end of the probe box there is a mark to show where the resonant material is located. Place this end of the probe into the gap of the electromagnet to be measured in a such a way that the magnetic field is perpendicular to the electrical axis of the probe.
Be careful to electrically isolate and to firmly secure the probe.

When using standard probes, one can simply tape the side of the probe to the magnet pole, while making sure that the mark is located at approximately the center of the pole.
In addition, prevent that part of the probe cable which is located in the magnetic field from moving.

4.2. Installation of the preamplifier

If possible, attach the preamplifier to the magnet.
Electrically isolate the preamplifier from ground.
Connect the probe(s) cable to one side of the amplifier and the R51 and coaxial cable to the other side, if needed connect also the R52 cable (only for PAMUX2/PAMUX4).

4.3. Installation of the switch (option)

Connect the R51, R52 and coaxial cables from the gaussmeter to the “Input” port of the SWMUX.
If more than one SWMUX is used, connect the cables from the “Input” of the second SWMUX to the “Next-SWMUX” output of the first SWMUX.

Connect cables from preamplifiers to corresponding channels.

4.4. Installation of the gaussmeter

On the front panel set the switches to the "low" position to set the ON/OFF switch to the OFF position

On the back panel:

- Set the power supply voltage switch to the appropriate voltage level than connect the gaussmeter to the main.

- Connect the R51 and coaxial cables to the PAMUX or SWMUX
  - Caution: It is important that the connection between the cable and gaussmeter be properly made. A bad connection can generate noise which will adversely affect readings.
    Also, avoid making measurements close to wires which carry a lot of current or contain much noise.
- If needed connect also the R52 cable (only for PAMUX2/PAMUX4 and SWMUX)

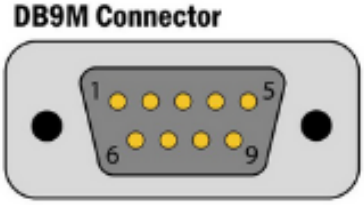
- Additional connections:
  - Ethernet, COM Port or USB Cable for remote control
  - Regulation Output to control Magnet Power Unit (MPU)
  - 10 MHz Input reference

Verify the voltage selected

4.4.1.COM Port Pinout

The COM port support 3 modes of operation, RS232, RS485 and RS422.

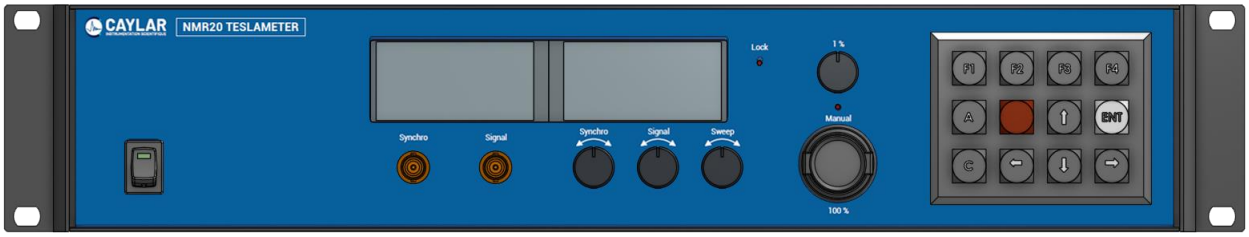
For each configuration the pinout is as follow:



	RS232	RS485	RS422
1			RX -
2	RX	A	TX +
3	TX		RX +
4		B	TX -
5	GND	GND	GND
6			
7	RTS		
8	CTS		
9			

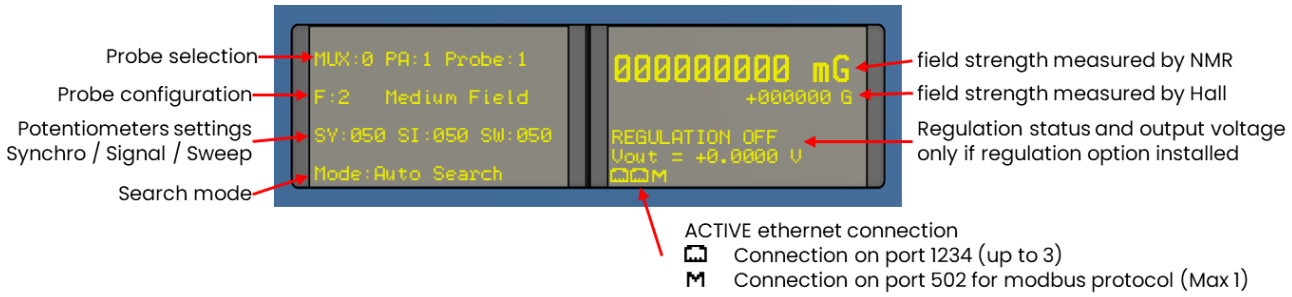
5. START, DESCRIPTIONS AND PARAMETERS OF THE NMR20

5.1. Startup



Once the switch on the front panel of the Gaussmeter is ON, the system starts.
System takes a few seconds to initialize and displays the progress of initialization on the 1st display.

Once the system is ready, it displays the main gaussmeter parameters and the field measured.



You can now start using the system.

5.2. Description of Parameters

Some parameters to be known and understand the working of the device:

- **MUX / PA / Probe:** Represents the path of the selected probe. MUX represents the selected multiplexer (0 preamplifier directly connected to the gaussmeter). PA represents the preamplifier selected if a MUX number other than 0 is defined. Probe corresponds to the selected channel on the preamplifier.

- **Filter and Field Type:** Each probe is calibrated to work with a particular filter and field type depending of the range of the probe. Though, the probe can work with other filters settings, it works better and is calibrated for the defined filter (marked at the end of the probe).

Four filters are available: 1, 2, 3 and 4. You are free to use any other filter depending of your condition of measurement (gradient)

You should use those filters in the best conditions:

Filter	1	2	3	4
Probe Range (Gauss)	140 – 400 200 – 1000 300 – 1500 400 – 2000	500 – 2500 800 – 4000 1600 – 8000 1800 - 9000	3000 – 15000 7000 - 30000	4500 - 21000

Field Type	Low Field	Medium Field	High Field
Probe Range (Gauss)	140 – 400 200 – 1000 300 – 1500	400 – 2000 500 – 2500 800 – 4000 1600 – 8000 1800 – 9000 3000 – 15000 7000 – 30000	Probe with special sample 2 T – 5 T

- **Signal:** This is the gain of the gaussmeter. This should be adjusted according to different factors like, probe, field strength, noise. The signal should be low in noisy signal conditions to not lock on noise. The signal should be high in case of weak signal, to stay in lock condition.
  Set at 50 % for initial use. This can be adjusted manually on the front panel or by command. Value between 0 and 100.

- **Sweep:** This is to adjust the stability of locking. Adjust the "SWEEP" knob to find a maximum signal value. Set at 50 % for initial use. Value between 0 and 100.

- **Synchro:** This provides a signal with a frequency corresponding to the signal. This can be used to trigger the signal on an external scope. Changing the synchro value adjusts the position of the NMR signal on the scope screen.

5.3. Search Modes introduction

Mode: This represents the current operating mode of the gaussmeter. The purpose of the Gaussmeter is mainly to search and lock on a field in the range of the probe.

- **Manual search**, you can search an NMR signal with the two potentiometers 100% and 1% on the front panel gaussmeter. A LED (between the two potentiometers) is on when the manual mode is activated.

- **Auto search**, the gaussmeter automatically searches for the resonance signal, scanning the entire range of the probe.

- **HALL TRACKING,** the gaussmeter automatically searches for the resonance signal by scanning over a reduced area of the probe range. The search area (10% of the range) is around the value measured by the hall sensor.
  - The probe and the Hall sensor need to be calibrated to use this mode (see menu F3).

- **Digital search**, equivalent to Hall tracking mode but the field value around which to search is user-defined.
  - The probe needs to be calibrated to use this mode (see menu F3).
  - The field around which to search is defined in the F3 menu

__HALL TRACKING__ and __DIGITAL SEARCH__ are useful to rapidly find the NMR signal.

5.4. First automatic magnetic field measurement

1. Set the Gaussmeter in AUTO search in the F4 menu.
2. Select a probe to do the measurement
   - Set MUX to 0 if there is no multiplexer in the system, otherwise select the MUX to which the preamplifier corresponding to the desired probe is connected.
   - Set PA to the corresponding channel of the MUX if used, otherwise the value assigned to PA is not important.
   - Set the PROBE number corresponding to the preamplifier channel to which the NMR probe is connected
3. Set Signal and Sweep to 50.
4. Set the Filter accordingly with the selected probe.
5. Observe the numeric display. The value displayed should slowly vary between the extreme values of the range of the probe. The probe is now automatically searching for a resonance signal.

Once the resonance signal is detected, the "LOCK" light is turned on and the value of the magnetic field is displayed. Now go directly to step 9.

Otherwise, if the signal is not found, the search continues on until a resonance signal is detected.
After two full sweeps cycles you can:

6. Increase the gain of the gaussmeter by turning the "SIGNAL" knob up to 100 and letting the meter continue its search for at least one complete cycle.
7. Keeping the settings of the "signal" knob described in (3), turn the 'SWEEP" knob all the way to the left for a zero sweep and let the meter continue its signal search for at least one complete cycle. Then, turn the same knob all the way to the right for a maximum sweep and wait at least a full cycle again.
8. Secure the probe to the center of the magnet gap where the field is probably the most uniform and repeat the measurement starting with step (1).

If the resonance signal cannot be found, proceed to the "MANUAL MEASUREMENT" chapter (5.5).

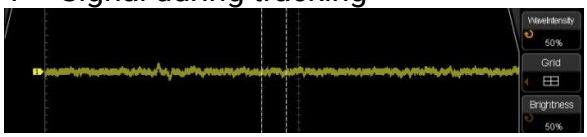
When the resonance signal is found, the "SIGNAL" indicator lights up and the digital display indicates the magnet's field.
To obtain better measurements, the settings of the gaussmeter can be adjusted in the following way:

9. To optimize the sweep value:
   Attach an oscilloscope to the "SIGNAL" BNC connector. Set the vertical sensitivity of the scope to 5 Volts / Div.
   Set the "TRIGGER" switch of the scope to "EXTERNAL" and connect the external trigger port to the "SYNCHRO" BNC of the gaussmeter. Set the sweep rate of the scope to 2 milliseconds.
   Using the "SYNCHRO" knob of the gaussmeter, bring the resonance signal image to the middle of the oscilloscope screen.
   Using the "SIGNAL" knob, make the resonance signal measure 10 volts on the oscilloscope screen.

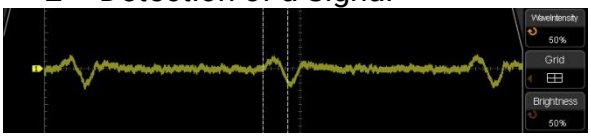
Adjust the "SWEEP" knob to find a maximum signal value.
Then, as above, make this signal measure 10 volts.

10. To optimize the uniformity of the magnetic field around the probe:
    Slowly move the probe inside the gap and search for a position for which the resonance signal takes on a maximum value. Optimize the value of the "SWEEP" as in (9).

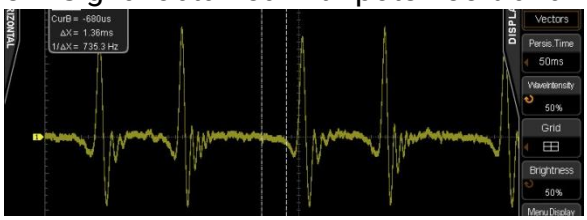
1 – Signal during tracking



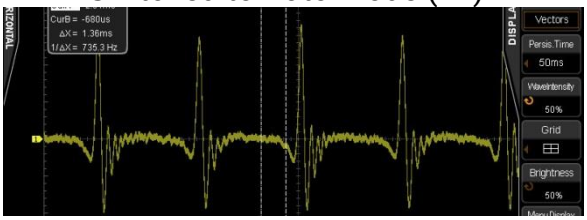
2 – Detection of a Signal



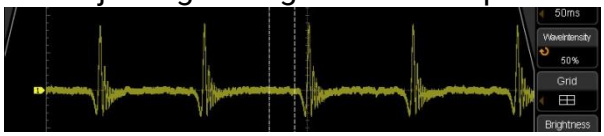
3 – Signal obtained with pots 100% and 1%

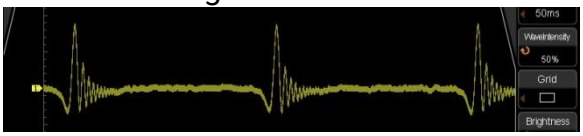


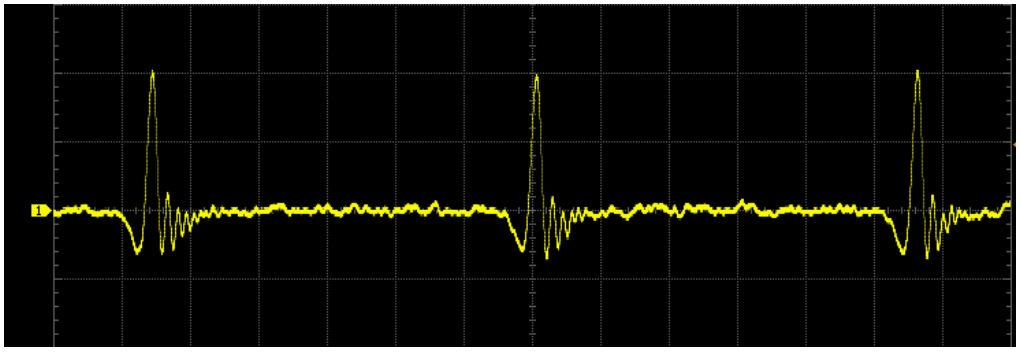
4 – Switched to Auto Mode (F4)



5 – Adjusting the signal and sweep to have the best reading of the field.







5.5. Manual measurement

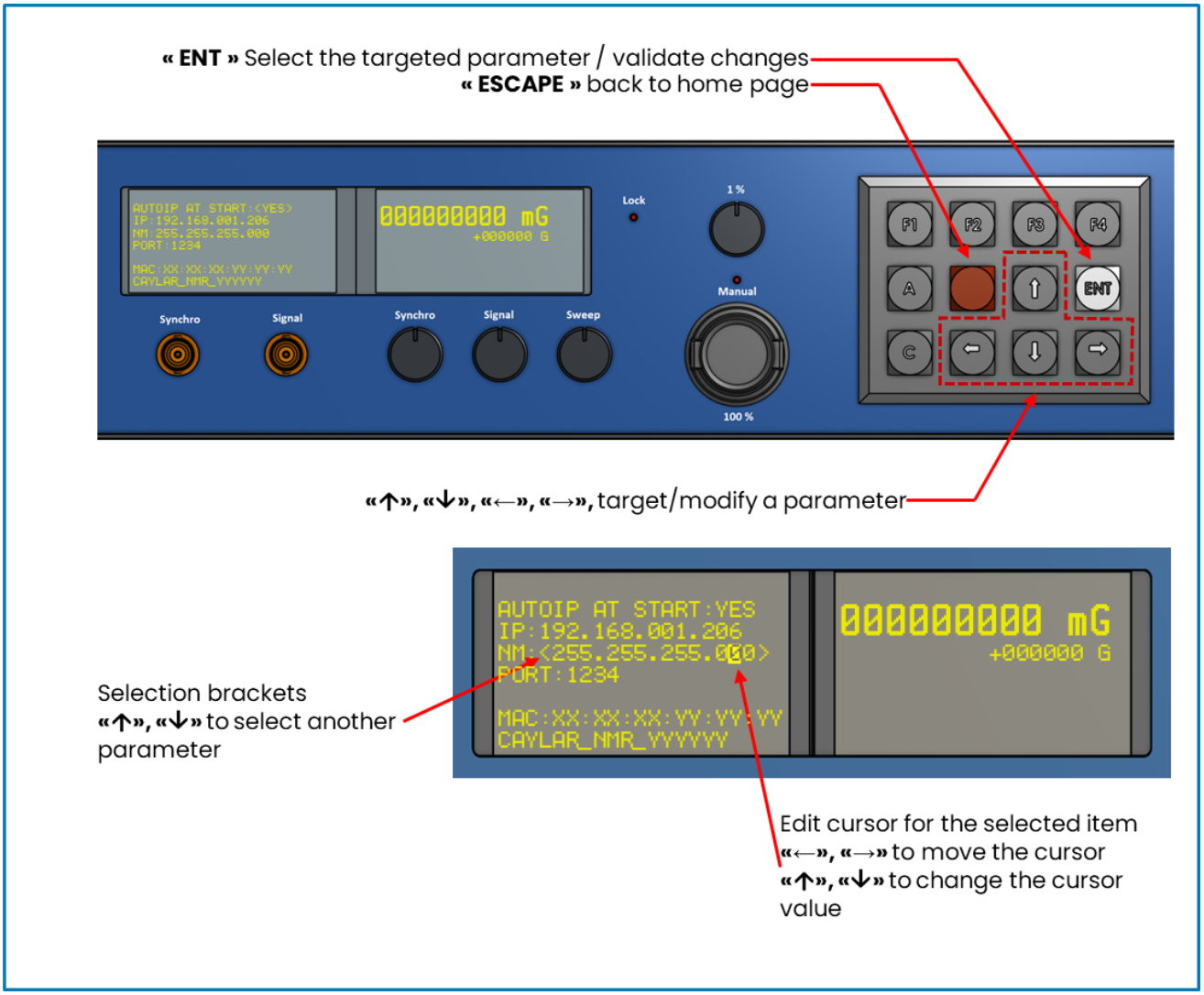
In certain cases, when the magnetic field lacks uniformity, a manual measurement must be made.

1. Attach the probe to the middle of the magnet gap where the field is probably the most uniform.
2. Using the technical information available to you on the magnet, estimate the strength of its field. Verify that the probe used can measure a field of this strength. Determine the location of the approximate field value in the probe range. This location will give you an idea where to look for the resonance signal.
3. Set the Gaussmeter in AUTO search in the F4 menu.
4. Select the probe to be used to do the measurement
   - Set MUX to 0 if there is no multiplexer in the system, otherwise select the MUX to which the preamplifier corresponding to the desired probe is connected.
   - Set PA to the corresponding channel of the MUX if used, otherwise the value assigned to PA is not important.
   - Set the PROBE number corresponding to the preamplifier channel to which the NMR probe is connected
5. Set Signal and Sweep to 50
6. Set the Filter selection to the number of the probe to be used.
   Attach an oscilloscope to the "SIGNAL" BNC connector.
   Set the vertical sensitivity of the scope to 5 Volts / Div.
   Set the "TRIGGER" switch of the scope to "EXTERNAL" and connect the external trigger port to the "SYNCHRO" BNC of the gaussmeter.
   Set the sweep rate of the scope to 20 milliseconds.
7. Use the manual adjustment potentiometer to find the resonance signal.
   Slowly turn this potentiometer starting from the zero position.
   Observe the screen for a variation in the standard signal.
   If needed, set SIGNAL to 100 to set the gain to its maximum.
   When a signal is detected, determine if it is really a resonance signal by adjusting the SWEEP which should make the signal varies. Find the maximum value of this signal.
8. Set the sweep rate of the oscilloscope to 2 milliseconds. Place the signal in the middle of the screen by adjusting the SYNCHRO.
9. To optimize the uniformity of the field around the probe:
   Slowly move the probe inside of the gap and search for a position in which the signal takes on a maximum value.
   Using the SIGNAL knob, adjust the height of the signal on the screen to 10 volts.
10. When the resonance signal is found and its strength is sufficient, the LOCK light should come on. Set the Gaussmeter in AUTO search in the F4 menu.
11. If the LOCK light does not come on or the gaussmeter lost the signal in the AUTO mode, return to MANUAL. Turn the manual potentiometer until the two resonance signals present on the screen are superimposed on top of each other. At this point, the value of the magnetic field is display on the screen.

6. MENU

Local control via keyboard.

6.1. Keyboard and screen description

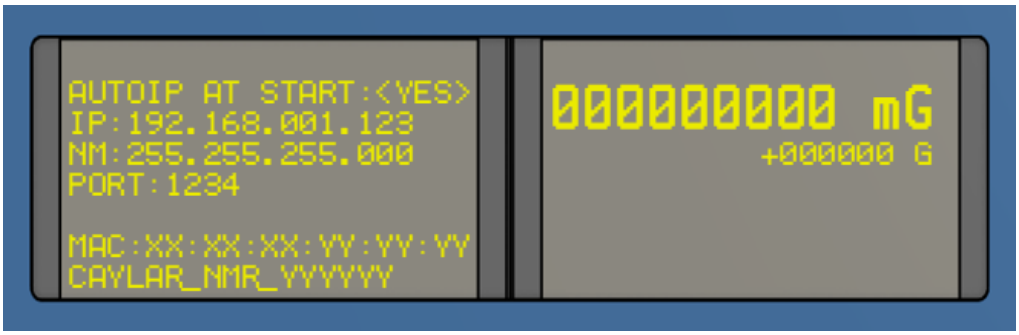


Menu listing:

- F1 Communication configuration (Ethernet config and COM Port / USB config)
- F2 Probe selection and configuration
- F3 Digital research, range calibration, HALL calibration
- F4 Search mode, field format, auto calibration hall
- C NMR Regulator configuration (option)

6.2. menu F1: Communication configuration

6.2.1.Screen 1: ETHERNET Configuration



- **AUTOIP AT START (YES / NO)**: This option enables the IP address and netmask to be set automatically when the instrument is started up. If you select Yes, the instrument will attempt to obtain an IP address from a DHCP server the next time it starts up. If this fails, the instrument reverts to the last configuration.

- **IP / NM**: IP address and netmask are to be set manually if "AUTO IP AT START" is set to no. The network mask must be the same as that of the network to which the gaussmeter is connected, and the IP address must be set to a free address on the said network.

- **PORT**: The port used to connect to the gaussmeter, cannot be changed.

- **MAC Adress:** ethernet interface physical address, unique for each gaussmeter.

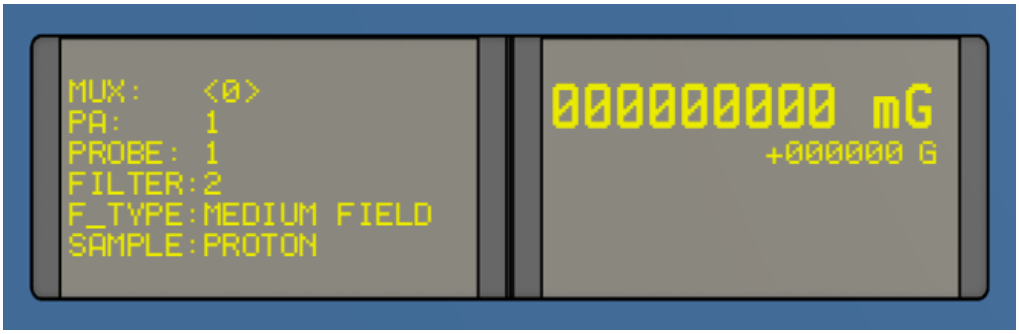
- **HOSTNAME:** Can be used to connect to the gaussmeter if "AUTO IP AT START" is set to YES

6.2.2.Screen 2: COM Configuration

Not yet implemented.

- Default settings for COM and USB port communication
  - RS232 for COM port
  - 115200 Baud
  - 8 bits
  - 1 stop bit
  - Parity NONE
  - Hardware flow control NONE

6.3. menu F2: Probe selection and configuration



- **MUX**: Select the MUX number to which the probe is connected, if there is no MUX set to 0

- **PA**: Selects the preamp to which the probe is connected if a MUX is used. Otherwise, any value can be set

- **PROBE**: Selects the preamplifier channel where the probe is connected.

- **FILTER**: Select the FILTER to be used for the selected probe. The number of the filter to be used is indicated on the probe.

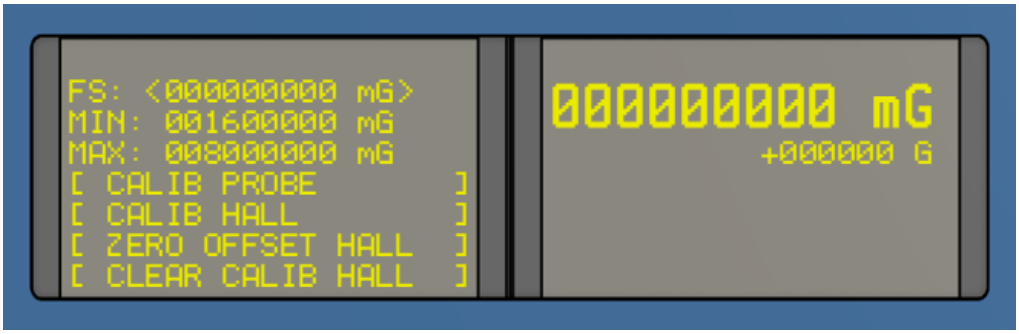
Filter	1	2	3	4
Probe Range (Gauss)	140 – 400 200 – 1000 300 – 1500 400 – 2000	500 – 2500 800 – 4000 1600 – 8000 1800 - 9000	3000 – 15000 7000 - 30000	4500 - 21000

- **F_TYPE**: Select the filter type (low field/medium field/high field) according to the probe range.
  - **Low Field** For probe with maximum field of 2000 Gauss
  - **Medium Field** For probe with maximum field > 2000 Gauss
  - **High Field** For probe with special sample for measuring > 3 Tesla

Field Type	Low Field	Medium Field	High Field
Probe Range (Gauss)	140 – 400 200 – 1000 300 – 1500	400 – 2000 500 – 2500 800 – 4000 1600 – 8000 1800 – 9000 3000 – 15000 7000 – 30000	Probe with special sample 2 T – 5 T

- **SAMPLE**: Selection of sample type to adjust gyromagnetic ratio to be applied to frequency measurement for frequency/field conversion. Only high-field probes > 3 T use other materials than “PROTON”

6.4. menu F3: digital research, range calibration, HALL calibration

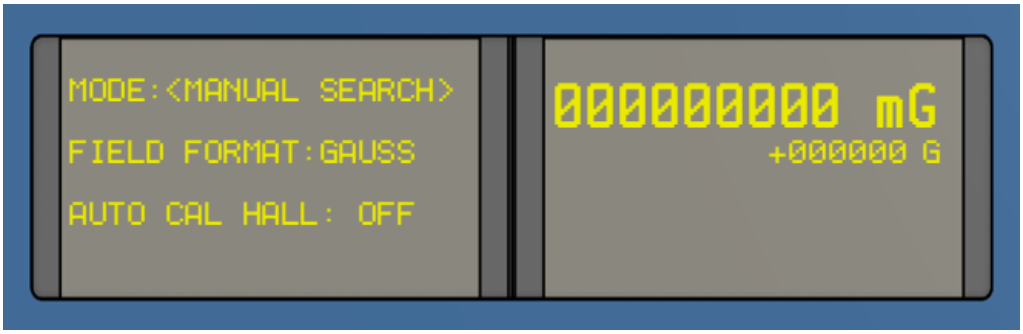


- **FS (Field Set)**:
  Used to define the field value to be searched, switches the gaussmeter to "digital search" mode and limits the search area to 10 % of the range around the defined field value.
  The min/max values must have been measured by "calibrating" the probe.
- **MIN / MAX**:
  Displays the min and max values of the probe range.
  These values are measured when a "calib probe" is performed and then saved in the gaussmeter for the current probe location.
- **CALIB PROBE**:
  Starts a probe calibration. The gaussmeter measures the probe's range to find out its min and max, and its variation curve.
  This information is then stored in the gaussmeter and used for "digital" and "Hall tracking" modes.
  The gaussmeter measures the probe's range to find out its min and max, and its variation curve.
  This information is then stored in the gaussmeter and used for "digital" and "Hall tracking" modes.

When a new probe is installed, it must be "calibrated" in order to use the "digital" or "hall tracking" modes.

- **CALIB HALL**:
  Calibrates the value read by the hall sensor.
  The gaussmeter needs to be locked to a magnetic field.
  Calibration of the hall sensor should be carried out when connecting a new probe or in cases where the value measured by the hall sensor is too far from the value read by NMR.
  This can happen when a probe is used to measure different magnetic field values, if a gradient is present, the distance between the hall sensor and the sample is enough to cause several gauss of difference to appear as the field varies.
- **ZERO OFFSET HALL:**
  Removes the offset from the Hall measurement, must be carried out off-field.
- **CLEAR CALIB HALL:**
  Resets Hall sensor calibration values to default value.

6.5. menu F4 : Search mode, field format, auto calibration hall



- **MODE:**
  Allows you to choose the operating mode of the gaussmeter between.

  - **MANUAL SEARCH:**
    manual mode, use the two potentiometers 100% and 1% on the front panel to search for the resonance signal.
  - **AUTO SEARCH:**
    Automatic mode, the gaussmeter automatically searches for the resonance signal, scanning the entire probe range.
  - **HALL TRACKING:**
    Automatic mode with reduced range, the gaussmeter automatically searches for the resonance signal by scanning over a reduced area of the probe range. The search area (10% of the range) is around the value measured by the hall sensor.
  - **DIGITAL SEARCH:**
    Only accessible from the "F3" menu, equivalent to Hall tracking mode but the field value around which to search is user-defined.

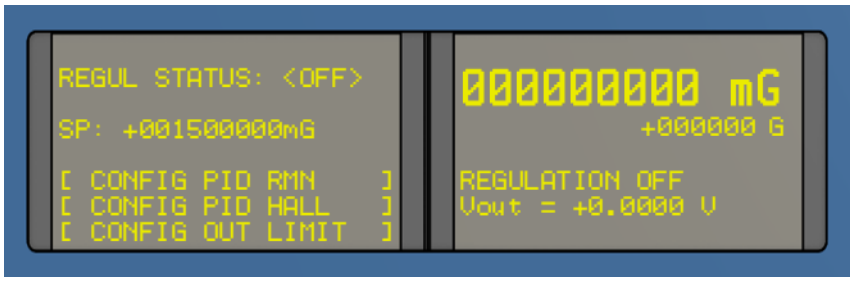
- **FIELD FORMAT:**
  Defines display format and default format for field values returned by read command.

  - **mGauss**
  - **Gauss**
  - **µTesla**
  - **mTesla**
  - **Tesla**

- **AUTO CAL HALL (YES / NO):**
  If active, allows the gaussmeter to recalibrate the value of the hall sensor so that it reads the same value as the NMR.

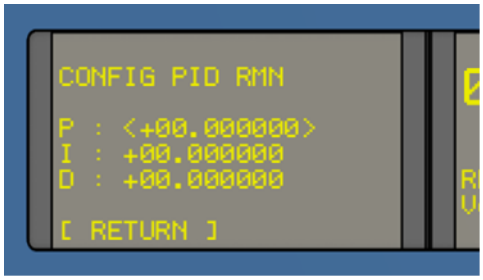
6.6. menu C : NMR Regulator configuration (option)

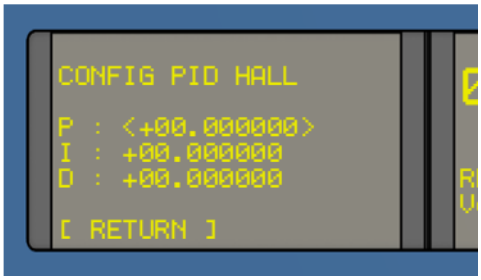
6.6.1.Main Menu



- **REGUL STATUS**:
  - **OFF**: Stop regulation and return control to zero.
  - **ON**: Starts or resumes regulation if it was paused.
  - **PAUSE**: Pause regulation, control voltage no longer moves.
- **SP**: Used to define the value of the field required for regulation. If the field value is outside the probe range, the gaussmeter will only regulate with the hall sensor.
- **CONFIG PID RMN**: Accesses the menu for setting the PID values of the NMR control loop.
- **CONFIG PID HALL**: Accesses the menu for setting the PID values of the HALL control loop.
- **CONFIG OUT LIMIT**: Menu access for setting min and max control voltage values.

6.6.2.PID Configuration Menus



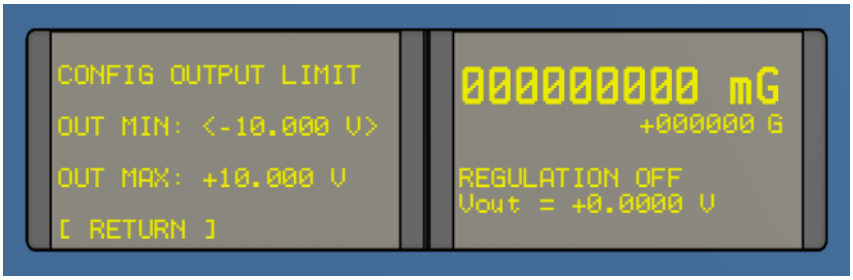


These menus are used to modify the parameters of the two RMN and HALL regulation loops. These parameters can be modified dynamically during regulation.

- **P**: adjustment of the Proportional part of the corresponding control loop.
- **I**: adjustment of the Integral part of the corresponding control loop.
- **D**: adjustment of the Derivate part of the corresponding control loop.

Be careful when modifying PID parameters, especially for the HALL loop, as too large a modification can lead to a large step in control voltage.

6.6.3.Output configuration



- **OUT MIN:** used to define the Minimum voltage that can be applied to the output.
- **OUT MAX:** used to define the Maximum voltage that can be applied to the output.

7. NOTES

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