METROLAB
Instruments SA

# NMR FIELD REGULATION

## RG 2040 PLUG-IN MODULE

2040/89/6

- **Plug-in module for the Metrolab Type 2025 NMR Teslameter**
- **Provides long term NMR regulation of magnetic fields**
- **Operates in many different configurations of Magnet Power Supply (MPS), correcting device and host computer**


- **Full MPS control**
- **Automatic measurement of magnet characteristics**
- **All operating parameters stored in non volatile memory**
- **Analog or digital fine correction**

*Specifications of the products described in this brochure are subject to change without prior notice*

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## General description

Many applications of magnetic fields require a closed loop control of the field value.

Resistive magnets are typically stabilized by using a current regulated power supply, but this does not compensate for magnet dimensional or reluctance changes, the nonlinear excitation curve, or hysteresis in iron yoke magnets.

Generally, superconducting magnets are operated in the persistent mode. However, in several applications such as medical MRI mobile systems, field stabilization is necessary.

Permanent magnets are not usually stabilized, but resistive shimming coils can be used to obtain high stability and high homogeneity fields in magnetic medical imaging and spectroscopy systems.

The RG 2040 unit gives the METROLAB 2025 Teslameter the possibility to regulate the magnetic field generated by electromagnets having resistive or superconductive coils and iron or air cores. The stability of a permanent magnet may be also 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 RS 232 C (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.

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

The host computer communicates with the RG 2040 via an RS 232 C or IEEE 488 link (e.g. the PSION XP* handheld microterminal, shown on the front page, which connects to the RS 232 C port). Moreover, a «transparent» mode allows direct interaction with the MPS in order to check its status (temperature, water flow, etc...).

The correction system may be driven linearly via a ± 20 mA or ± 5V (or 0 to +10 V) output or digitally via RS 232 C or IEEE 488 links.

* The PSION XP is not delivered with the RG 2040.

## Principle of operation

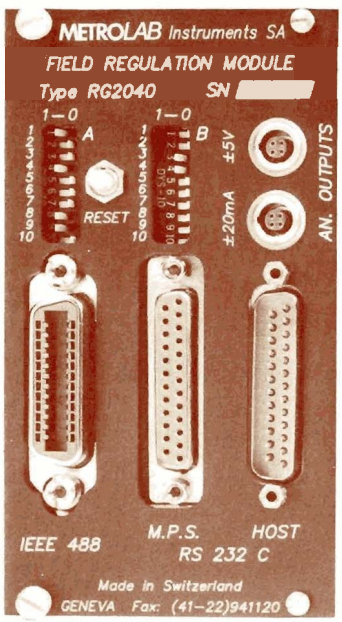
In some NMR regulation systems, the resonance frequency tracking loop is opened. The NMR probe is driven by a given radio frequency source (generaly an RF synthetizer) which supplies the reference value. The difference between the resonance frequency and this reference value generates a proportional 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 also that the RG 2040 does not require the use of an expensive RF synthetizer.

In the METROLAB PT 2025/RG 2040 system, the NMR frequency tracking loop is not opened. 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 can be powered directly by the linear ± 20 mA output or by means of an optional auxiliary power supply. It is important to note that if the MPS is already regulated with a Hall probe, the only way to avoid its «competing» with the NMR one is to act on the MPS's own setting value.

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

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).




## Specifications

**Linear outputs**
Two analog outputs floating together, isolated from ground at 500 VAC and 1 KV peak. They supply: ± 5V (max. 1 mA) (optionally 0 to +10 V) and ±20 mA (max. 8 V) (optionally ±2 mA).

**Digital Links**
One IEEE 488 for the host computer; one RS 232 C for the host computer; one RS 232 C (floating) for the MPS. It is isolated from ground at 500 VAC and 1 KV peak.

**Reset**
Push button for microprocessor reset and EEPROM clear.

**Microswitches**
20 microswitches (group A and B) for hardware system configuration and digital interfaces setting.

**Packaging**
Plug-in module replacing the I/O board in the METROLAB PT 2025 Teslameter comprising two single Euroboards (220 mm in length) and a rear panel.

**Performances**
When used with an adequate high stability power supply and correction device as well as with an appropriate choice of the regulation parameters (e.g. the number n of elements in the sliding average of the field values), the RG 2040 can ensure a field stability of 0.1 ppm. The number n 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.

**Noise**
Using a VARIAN 12" magnet, a high stability power supply (DANFYSIK 858, 1ppm) and a pick up coil system introducing a background noise of 0.1 $\mu$T to 0.5 $\mu$T, no appreciable noise generated by the RG 2040 can be detected. The measurements are executed with an HP 3561A Spectrum Analyzer at 1 T and in the range 20 mHz to 8 Hz.

## Mode of operation

On initialization, the hardware system configuration is defined by means of appropriate microswitches and information such as the format of the MPS COARSE and FINE (if it exists) setting commands, the approximate value of the nominal field settling time and the regulation range is sent to the host computer. All initialization parameters are stored in EEPROM.

Then, the function giving the field value versus the MPS current parameter is stored into EEPROM as an array of 2 points for air core magnets, or an array or 20 points, which are automatically measured for iron core magnets.

After initialization, which is performed only once, the field target value and the regulation parameters must be given. This set of data may be considered as a vector. Up to 20 vectors thus defined (regulation vectors) may be stored in the EEPROM registers 1 to 20 or recalled in the foreground register 0. Only the vector in the foreground drives the regulation and may therefore be modified.

A regulation vector consists of:
a) field target value
b) regulation window
c) cumulative correction gain adjustment
d) proportional correction gain adjustment
e) correction setting delay
f) number of samples in the sliding average
g) digital filter rejection level
h) digital filter sample number.

Once a) and b) are given, the RG 2040 automatically measures the domain of activity of the correcting device and calculates the correcting gain. Points c) to h) may be adjusted during the regulation process.

After the regulation start, the RG 2040 sets the MPS to the required coarse value of the field. Then it searches for and locks on to the NMR probe signal. If the actual field does not fall within the central third part of the regulation window, the MPS coarse value is readjusted to meet this condition. Henceforth, the MPS coarse setting is no longer modified during the regulation process.

The range of action of the correction device should not be greater than approximately 1500 ppm of the maximum field value in order to secure a reasonable resolution of the correction (12 bit DAC).