ECKEL DFM-R

Intelligent digital integrating fluxmeter with rotor test functions

Operating Manual

Preliminary version

V 1.0

Content

1. General description of the ECKEL DFM-R

Intelligent digital integrating fluxmeter with rotor test functions

DFM-R for magnetic flux measurement with extended rotor test functions

10 years after introduction of world's first digital integrating fluxmeter DFM 1, ECKEL Magnet Test Equipment now presents the new DFM-R, allowing more simple, more exact and new types of measurements that were not possible before.

Unlike all other fluxmeters on the market, the DFM-R is not an "electronic integrating" fluxmeter with digital readout (= analogue integrating) but a true digital integrating fluxmeter like the DFM 1 and DFM 2 before.

The powerful signal processor and a 24-bit A/D conversion at 32 kHz sample rate with 64-bit integration allow extreme accuracy and a wide variety of special functions that no other fluxmeter can offer.

The DFM-R is drift free due to continuous automatic offset correction. It can automatically detect start and end of a measurement, thus can set Reset and Hold / Evaluation itself and no manual or remote operation is necessary.

The DFM-R can detect all poles of any rotor or stator if one of them is turned and evaluate the poles in various ways.

The DFM-R can operate as standalone unit or connected to a PC. If connected to a PC all integrated samples are transmitted to the PC in real time. Thus they can be displayed, stored or exported to Excel. Sample rate for transmission can be adjusted from 1 to 32 kHz. Also all parameters can be set or read by PC.

The DFM-R is connected to the PC via USB 2.0. Necessary graphical user interface is included in the DFM-R package.

The measurement range covers pVs up to 1000 Vs with auto range function. For Helmholtz coils the magnetic moment Am² is displayed. A change from SI to CGS units is possible.

Input amplification starts with divisor 64 (+/- 320V) and increases up to amplification 16384 (+/- 305 µV). Input signal must be potential free.

At input overload as well as insufficient load the DFM-R automatically changes input amplification and after error message a repeat of measurement with correct input amplification is proposed.

Result can be scaled for 1 up to 99999 coil windings as well as to a free scaling factor from 0.1000 to 9.9999. For a Helmholtz coil the K-factor of the coil is entered instead of number of windings.

The result can be compared to upper and lower limits and if not in range it is possible to send an alarm to PC. The range between upper and lower limit can be divided in up to 3 classes.

The DFM-R automatically adapts to all slowly changing distortions, displays and compensates them. After sudden changes the algorithm can be restarted manually.

In Track mode the offset is continuously tracked. This offset is compensated during measurement. Accuracy of this compensation is 30 ppt (part per trillion) of full range. Thus real drift is far below display resolution during any realistic measurement time.

In Track mode also measurement start detection is continuously adjusted to actual noise level.

For high amplifications or noisy input signals the DFM-R offers six different analog filters with time constants from 0.1 to 33 ms as well as corresponding digital filters.
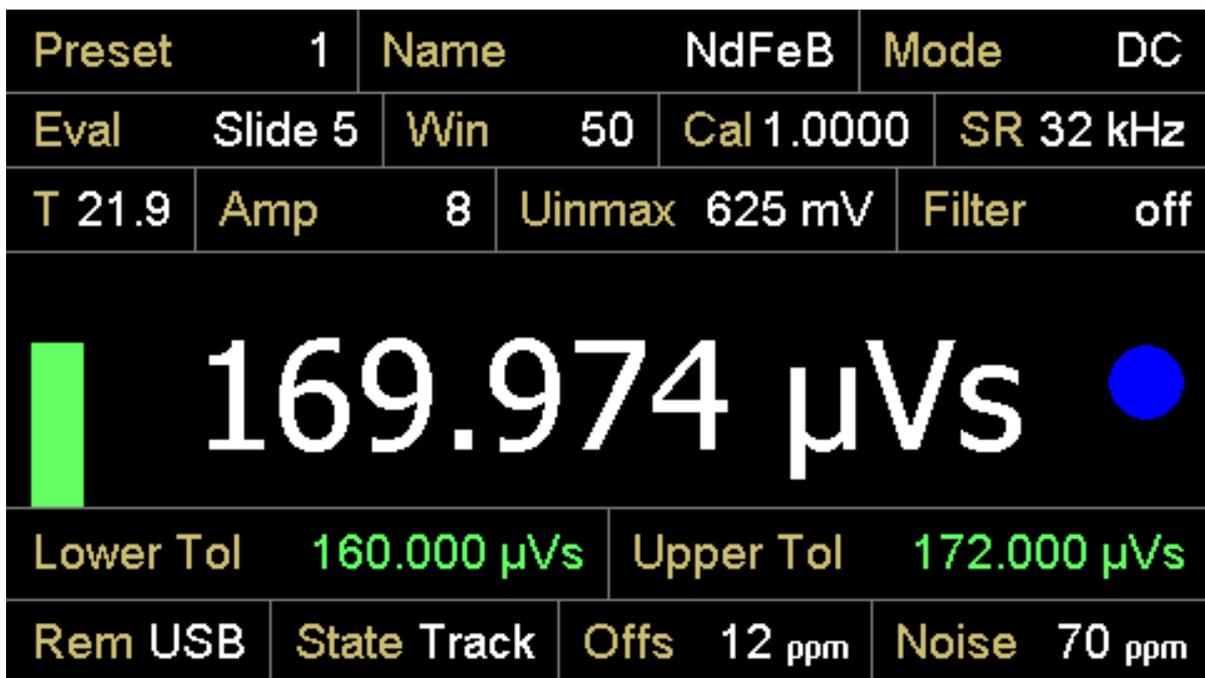
Display DFM-R

The DFM-R offers a large color display, showing all parameters at same time, as well as menu-guided intuitive input functions.

At the touch of a button or fully automatically a result can be sent to the PC and thus entered directly to a quality assurance system.

The DFM-R automatically can detect 16 different measurement devices and load appropriate parameters. Alternatively 250 sets of parameters can be stored and loaded manually.

The DFM-R includes a high accurate room temperature measurement by external Pt1000 sensor.
Thus optionally the result can be temperature compensated to 20°C.
The temperature correction factor can be entered manually or selected from a list of magnet materials.

The DFM-R offers a General Purpose I/O port with 7 configurable in- or outputs.
Here hardware like relays, switches or light barriers can be connected.

For a useful program execution a chargeable programming according to customers' requirements is necessary.

By evaluating data via software the DFM-R benefits permanently from performance enhancements which are provided by software updates. Also firmware of the DFM-R can be updated by the user. Adequate programs will be provided at our website free of charge. Individual software modules for motor control or connection to a special quality assurance system will be charged.

Updates for operating manual will be provided for download on our website too.

The DFM-R is self-calibrating at all input amplifications and has a reference signal output to perform an external calibration and certification using any calibrated multimeter.

2. Functional overview of the DFM-R

The DFM-R has a simple design. By realizing nearly all functions by software on the Digital Signal Processor (DSP) many hardware elements could be omitted.

The software is stored on the Flash memory of the DSP and can be updated via PC.
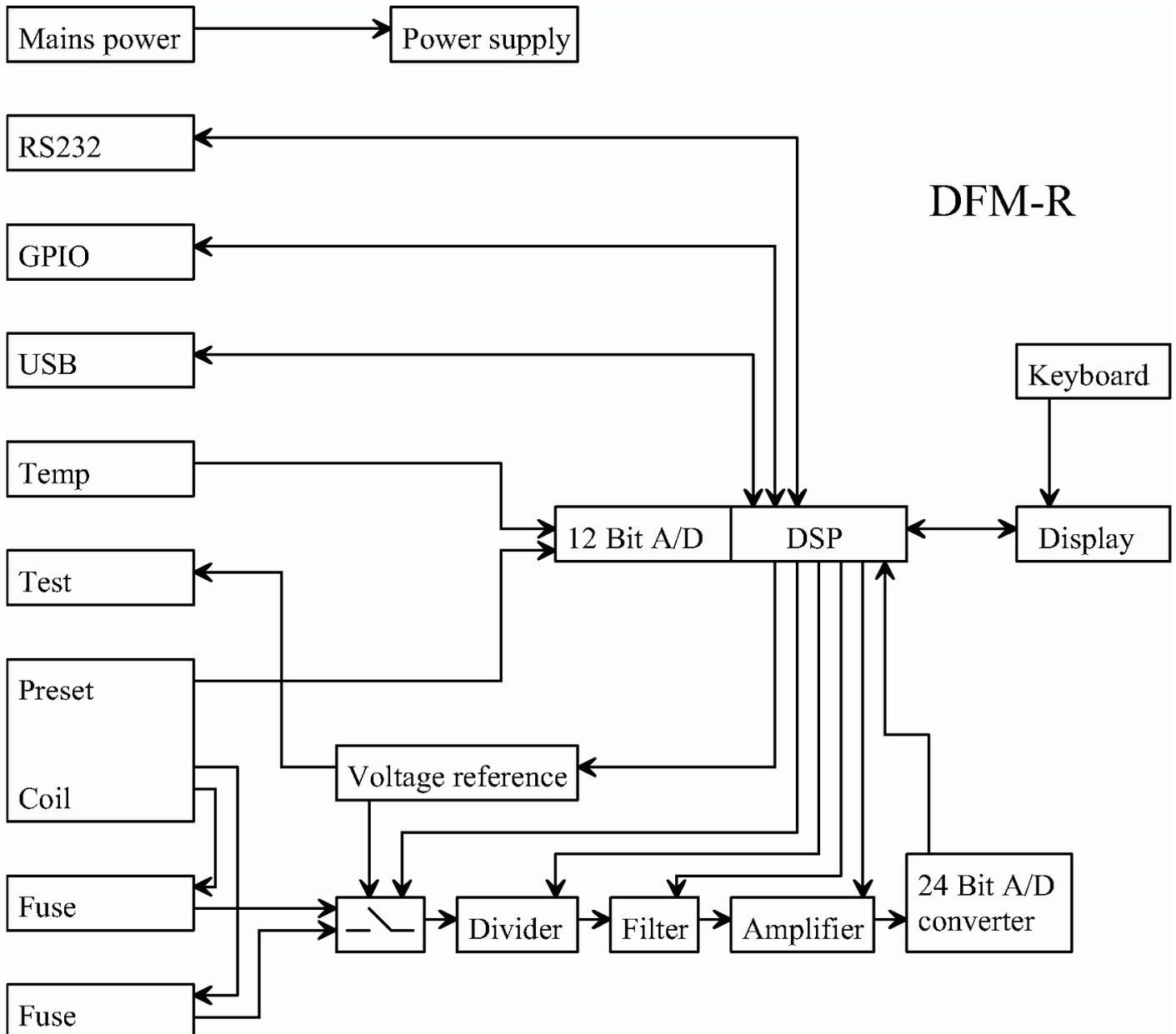
Functional diagram of the DFM-R

The divider divides by 64. The amplifier can be set to 1 to 16384 in steps of factor 2.

The voltage reference generates suitable reference signals for all possible amplifications.

The temperature measurement and preset selection are connected to the DSP's internal A/D converter.

3. Connections at the back of the DFM-R
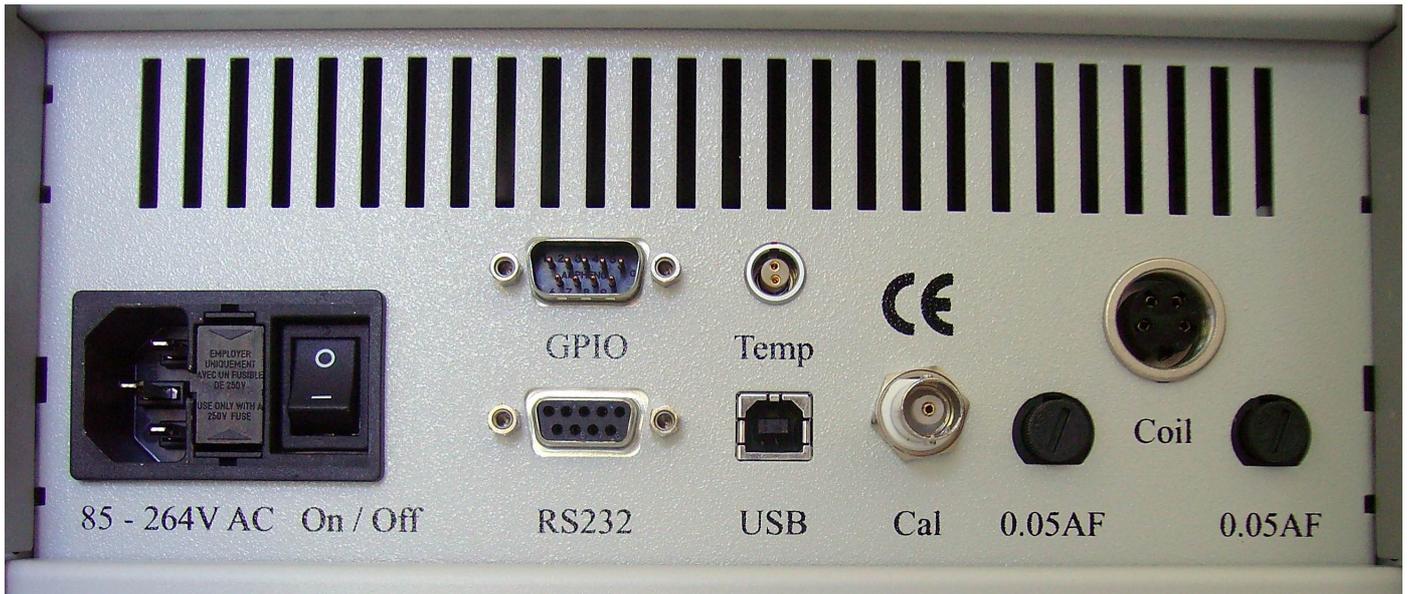
Back view of the DFM-R

Main Power

The main voltage connector fits to every standard power cable according to IEC 60230-1 C13 as for PC or monitors. Select a cable suitable to your local standards. The mains power must have a protective ground contact.

Input power is 85-264 VAC (120-370 VDC) 47-63 Hz. Maximum power is 18 W.

In the drawer there are 2 fuses of 0.63 A slow.

The DFM-R is switched on and off with this main power switch.

RS232

The RS232 connector is a female 9 pole Sub-D connector DE-9. In the moment this connector is only used for emergency recover. Thus it is no standard user interface.

In future other functions may be implemented to this interface.

GPIO

The General Purpose Input / Output connector is a male 9 pole Sub-D connector DE-9. The 9 pins are connected as follows:

Pin 1:   3.3 V
Pin 2 to 8: Independent inputs / outputs
Pin 9:   Gnd

To protect the power supply the 3.3 V output has a series resistor of 100 Ohm. Thus only small currents can be drawn.

The 7 inputs / outputs have a serial resistor of 10 kOhm.

If any of the inputs is connected to the 3.3V output, input will be recognized logic high.
If any of the inputs is connected to the Gnd output, input will be recognized logic low.

If driven by an external source, maximum input voltage for the inputs is 5V.
Do not drive the Gnd or 3.3V outputs!

If configured as output, output voltage is Gnd or 3.3V. Due to 10 kOhm series resistors only high impedance sinks as semiconductor gates can be driven.

The GPIO can be programmed to customers' requirements. Please ask for a quotation.
Alternatively there is a default configuration:

Pin 2: Input Reset, low active
Pin 3: Input Hold / Evaluate, low active
Pin 4: Output Status, low = track, high = measure
Pin 5: Output Overflow, low = active
Pin 6: Output Underload, low = active
Pin 7: Output Result in tolerance, low = active
Pin 8: Output Result out of tolerance, low = active

USB

USB 2.0 full speed connection to PC. Use a standard USB A/B cable for connection to the PC. Do not use USB cables longer than 5m. Due to internal circuit the maximum total data transfer is limited to 3 Mbit/s.

Temp

The temperature sensor connector is a 2 pole Lemo connector EGG.0B. It fits to a Lemo FGG.0B plug and is used to connect a Pt1000 temperature sensor in 2 wire technology. We use a HEL705-U-1 sensor from Honeywell.
Temperature range is 0°C to 40°C. Resolution is 0.015°C. Accuracy of the Pt sensor is 0.1%.

Cal

This BNC connector is used to connect a certified multimeter during calibration procedure. Please look at chapter XXXX External calibration.

Coil

The Coil connector is a Lumberg KFV40 connector. It fits to a Lumberg SV40 plug.
At poles 3 and 4 the flux measurement coil is connected. Polarity does not matter for result but can change start point of rotor algorithms.
Coil must be potential free. 1 to 99999 windings are possible but input impedance is 2.5 MOhm. Thus high impedance coils may reduce the result.

At poles 1 and 2 the preset resistor is connected.
If left open, the DFM-R will not leave "Open" state and will not measure!

If preset by resistor is not required, connect pole 1 to pole 2 by wire. Then the last stored general parameters will be used instead of individual coil parameters and Preset will show "Off".

If one of the 16 preset resistors is connected from pole 1 to 2, one of the 16 different parameter settings is automatically loaded when the plug is inserted

The preset resistors are:

1:      1.10 kOhm
2:      1.96 kOhm
3:      2.87 kOhm
4:      4.02 kOhm
5:      5.23 kOhm
6:      6.81 kOhm
7:      8.66 kOhm
8:      10.7 kOhm
9:      13.3 kOhm
10:     16.9 kOhm
11:     21.0 kOhm
12:     27.4 kOhm
13:     35.7 kOhm
14:     49.9 kOhm
15:     73.2 kOhm
16:     130 kOhm

At delivery of the DFM-R a bag with all 16 resistors is included.

If preset is set to "Manual" or "Off" state, the value of the resistor does not matter. Anyway a resistor or a bridge must be present to leave "Open" state.


Fuses

The 2 fuses are 0.05 A fast type. This is the input protection for coil signal. If higher voltages than 5 V are connected to the input and divider is not set, input voltage is limited to 5 V. The 50 mA fuses limit the maximum current.
If divider is set and voltage at coil input exceeds 360 V again the fuses limit the input current.

Do not exchange fuses to higher values! If higher voltage is given to the input and the fuses do not protect the input, serious damage of the DFM-R may occur.

4. Display and Keyboard
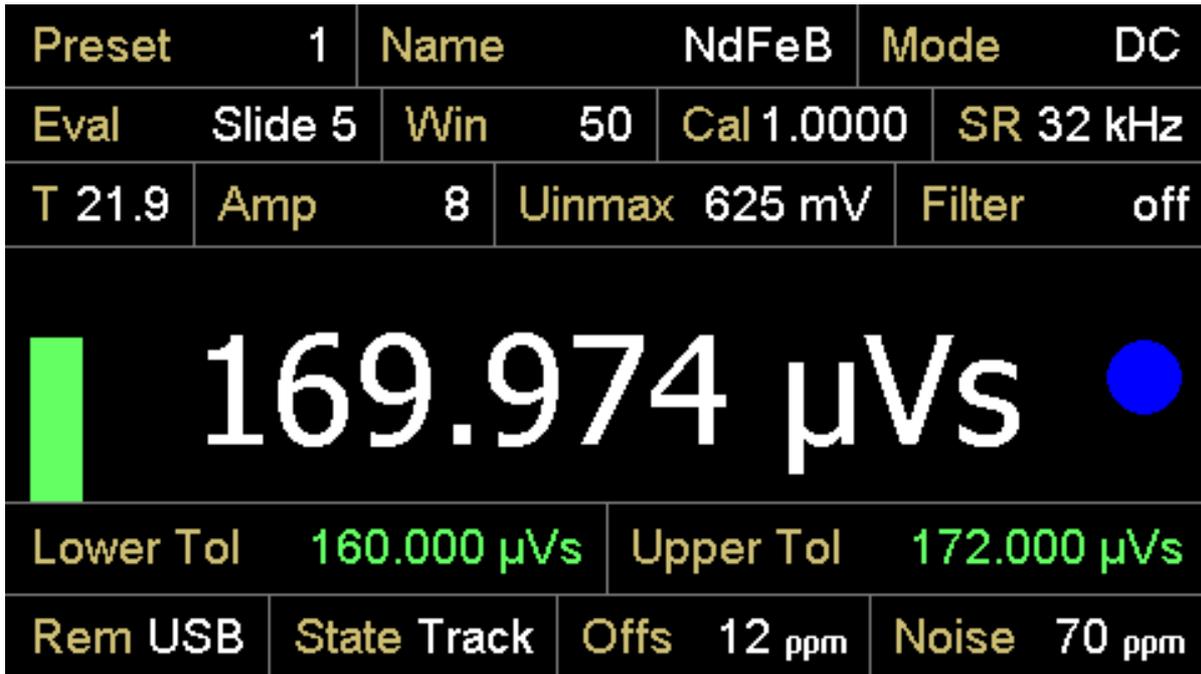
Display DFM-R

The Display is a 480 x 272 pixel graphic color display. In default mode most parameters of measurement are shown.

Preset:

Number from 1 to 16 in white if hardware preset by resistor has been selected.
Number from 1 to 250 in green if manual preset has been selected. (Not yet activated!)
"Off" if preset input has been bridged and hardware preset was selected, or "Off" state was selected manually.
"NC" if preset input is open.

With a valid preset, the preselected parameters are loaded automatically.

Name:

Free input field for any name of selected preset. Input field is 30 characters long. The number of visible characters depends on character width. If the name is longer than visible area, the name will be scrolled.

Mode:

Measurement mode. See chapter 5.

Eval:

Evaluation mode.

Win:

Number of windings of measurement coil. 1 to 99999 is possible. The integrator result will be divided by the number of windings to show the result related to the flux independent of number of windings.

Cal:

Free calibration factor from 0.1000 to 9.9999. Result will be multiplied with this factor.

SR:

Sample rate. The internal sample rate is always 32 kHz. But here the sample rate for data transfer to the PC is shown. A transfer rate of 32 kHz may be too fast for slower PCs. Thus it can be adjusted from 1 kHz to 32 kHz.

T:

Temperature in deg. Celsius. If temperature compensation has been selected, the temperature is shown in white. If compensation is off, temperature is shown in red. If no temperature sensor is connected, "NC" is shown. If temperature compensation is on, the "NC" is red, otherwise it is white.

Amp:

Actual amplification. Including the divider by 64, amplifications from 1/64 to 16384 can be selected in steps of factor 2.
At amplifications below 1 the divider is set and maximum input voltage is 360 V.
At amplifications of 1 or higher, the divider is not set and maximum input voltage is 5 V.
At higher input voltages the fuses may burn.

Uinmax:

Corresponds to the selected amplification and shows the maximum input voltage that can be measured.
At input voltages higher than displayed an overload condition will occur.

Filter:

Shows the time constant $\tau = R*C$ of the analog input filter. According to the selected analog filter a digital filter is used after analog/digital conversion.
Filters are used for noise reduction. Filters may be only used for standard DC measurement. Typical application is Helmholtz Coil measurement.
If no filter is selected, "Off" will be shown.

Left main area:

The bar in this area shows maximum A/D converter excitation.
If excitation is too low, resolution becomes lower and result accuracy is reduced. This is indicated by a yellow bar. In this case use a higher amplification.
If excitation is over 90% of maximum, the bar becomes red. In this case use a lower amplification next time.
Green bar indicates good excitation.

Result:

Result is shown in 6 digit resolution with auto range function.
The lowest range used for selected operation has to be defined.
At some modes several results can be shown here consecutively.
If no coil is connected (no resistor and no bridge at preset inputs) the display will show "Open".
If excitation is too high and reaches maximum value, an overload condition will occur and measurement must be repeated with lower amplification. In this case result is wrong since some parts of the input signal could not be measured. Thus integration is stopped and actual integration value changes to red color.

Right main area:

This area can show several different results. First an optical result can be shown. For different classes of result different colors can be shown. They all are within main tolerance. If result is outside of tolerance, red arrows show above tolerance (↑) and below tolerance (↓).
Depending on mode also a good (green) / bad (red) decision can be shown.
In modes with more than 1 result, type and number of result are shown in this area.

Lower Tol:

Minimum tolerance. In case of multi class evaluation this is the minimum of lowest class.

Upper Tol:

Maximum tolerance. In case of multi class evaluation this is the maximum of highest class.

Rem:

Remote. Standard remote input is USB if connected to PC. Also GPIO can be selected. Later RS232 may be possible. Local operation is always possible.

State:

Open = No coil is connected (no resistor and no bridge at preset inputs).
Track = Tracking of Offset and Noise. No measurement.
Meas = Measurement.
Hold = Rotor measurement finished.
Ovrfl = Overflow of A/D converter. Input voltage was too high.
Trim = Setting new values for Offset and Noise after Restart.

Offs:

Shows actual offset related to full input range. Offset depends on temperature and time and thus is tracked during Track and Trim mode and subtracted from input voltage during measurement.

Noise:

Shows actual noise related to full input range. Noise depends on amplification and external conditions and thus is tracked during Track and Trim mode. The actual noise level is used to determine start and end of a measurement as exactly as possible. Abnormal noise conditions due to external reasons can be detected regarding this value.
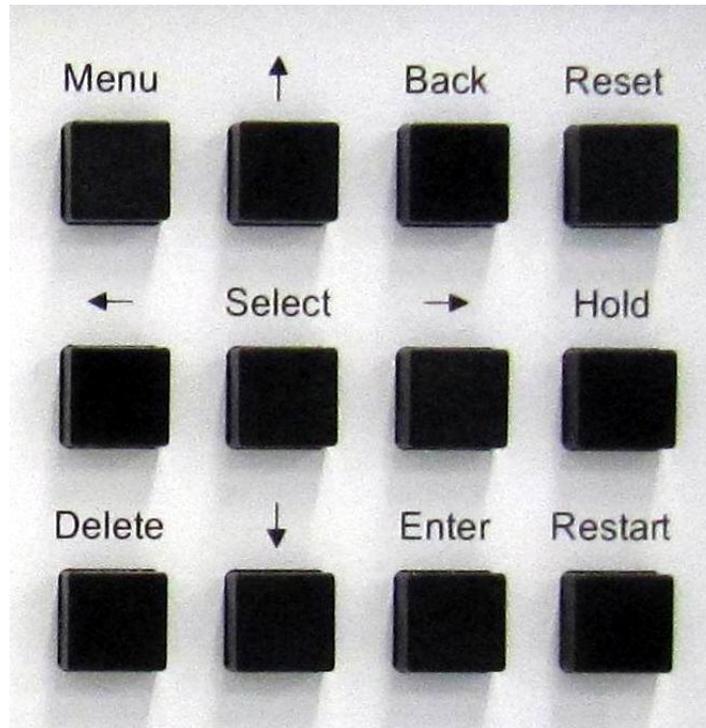
Keyboard

Functions of the keyboard:

Reset: Sets result to zero. Some types of measurement have automatic reset.

Restart: If automatic offset and noise cancellation algorithms do not work correctly anymore due to sudden changes of environment conditions and the DFM-R starts to drift, the algorithms can be restarted by this button.

Select: If no cursor is visible, this button will show the curser. Pressing this button again at visible cursor will activate the setting of parameter for actual position. After selecting the desired parameter by arrow buttons, pressing "Select" will take this parameter as actual value.
The DFM-R will not perform any measurement as long as a cursor is visible or parameter setting is activated.

Arrows: The arrow buttons are used to move the cursor up, down, left and right. They also move through the list of parameters if selected.

Back: At parameter selection this button will leave the parameter settings without changes. At visible cursor this button will finish that state and return to measurement.

Menu, Hold, Delete and **Enter** are not yet activated.

Some parameters, as number of windings, need numerical input. Therefore a virtual numerical keyboard is shown in the display. Then the keyboard works as shown in this virtual keyboard.

Parameters that need characters as input can only be set by PC until now.

5. Local setting of parameters

Pressing the button "Select" with cursor on "**Preset**" saves the actual parameters for this coil. All parameters will be loaded automatically if this coil is connected again to the DFM-R.

At "**Name**" any text can be entered to give a name to this coil or type of measurement. This is only possible by PC in the moment.

Mode: Measurement mode. DC, Helm, Rot and Rot 2-16 are selectable.
DC is standard integrating flux measurement.
Helm is the same for Helmholtz coils but showing magnetic moment or polarization instead of flux. (Not yet activated!).
Rot for a rotor with unknown number of poles.
Rot 2 to Rot 16 for rotors with given number of poles.

A higher number of poles can be implemented on demand.

Eval: Different evaluations can be selected depending on measurement mode.
- DC
  - Norm 3-5: Normal integration with 3 to 5 tolerance ranges
  - Slide 3-5: Magnet measurement by slide (Result = Max – end value) with 3 to 5 tolerance ranges
- Helm: Helmholtz
  - Moment
  - Polarisation
- Rot: Any Rotor
  - Max Diff: Peak to peak value of the flux (Max pos to max neg)
- Rot 2-16: Rotor measurement with given number of poles
  - Max Diff: Peak to peak value of the flux (Max pos to max neg)
  - Pol Aver: Average of absolute value of all poles
  - Pol Dev: Maximum deviation between absolute values of poles
  - Rot Chk: Test of correct magnet placement in the rotor

Win: Number of windings of the coil. The result is divided by this number to relate the result to the flux.

Cal: Free calibration factor from 0.1000 to 9.9999. Result is multiplied with this factor.

SR: Sample Rate, 32 kHz

T: Temperature. By selecting this field temperature compensation can be activated or deactivated, a temperature coefficient can be selected from a list or entered.
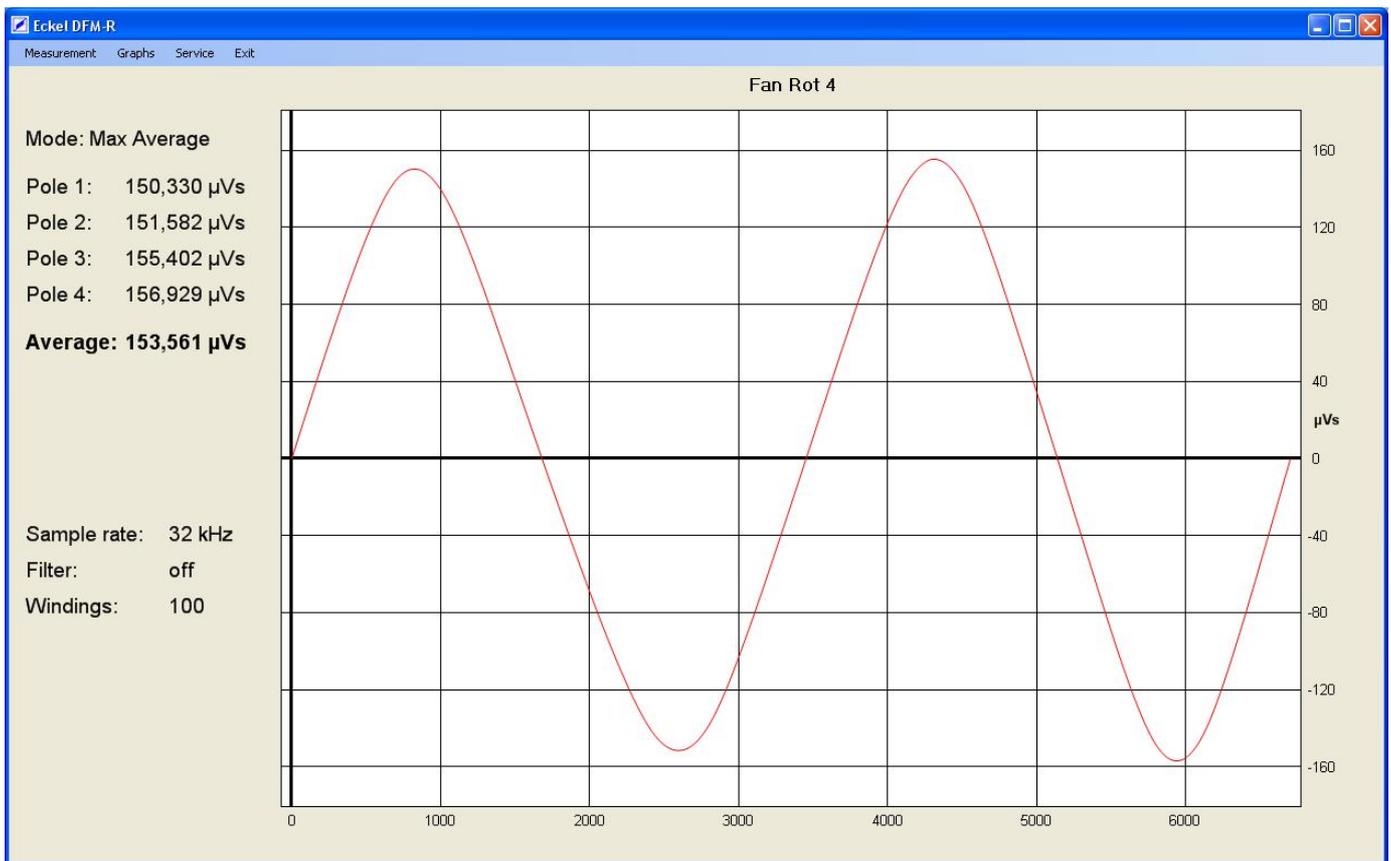
Amp: Adjustment of input amplification. Input amplification is correct if after measurement the bar left of result is green. If the bar is yellow, increase the amplification. If the bar is red, decrease the amplification.

Uinmax: Adjustment of input range. This parameter is depending on input amplification. Both parameters have the same function. Adjusting one of them will change the other.

Filter: Different lowpass filters. The time constant $\tau = R * C$ of the analog input filter is shown.
Must be "off" for all rotor and slide measurements.

Lower and **Upper Tol**: Selecting this field allows entering all tolerance limits as selected in evaluation. Tolerance values will be sorted automatically.

6. User interface on the PC

Eckel DFM-R

Measurement   Graphs   Service   Exit

Fan Rot 4

Mode: Max Average

Pole 1:   150,330 µVs
Pole 2:   151,582 µVs
Pole 3:   155,402 µVs
Pole 4:   156,929 µVs

Average: 153,561 µVs

Sample rate: 32 kHz
Filter: off
Windings: 100

Evaluation on PC

Installation: Execute setup.exe from CD ROM. Then execute the USB driver CDM20824_Setup.exe before connecting the DFM-R to the PC.

The software automatically detects the DFM-R if connected to the PC.

To record the samples on the PC, "Connect to unit" must be selected at "**Measurement**".

Graphs: Different signals can be viewed here. Also the samples of the graph can be exported to excel. Samples of the graph are transmitted with 8 kHz in the moment. Slower PCs may have problems with higher transmission rates.
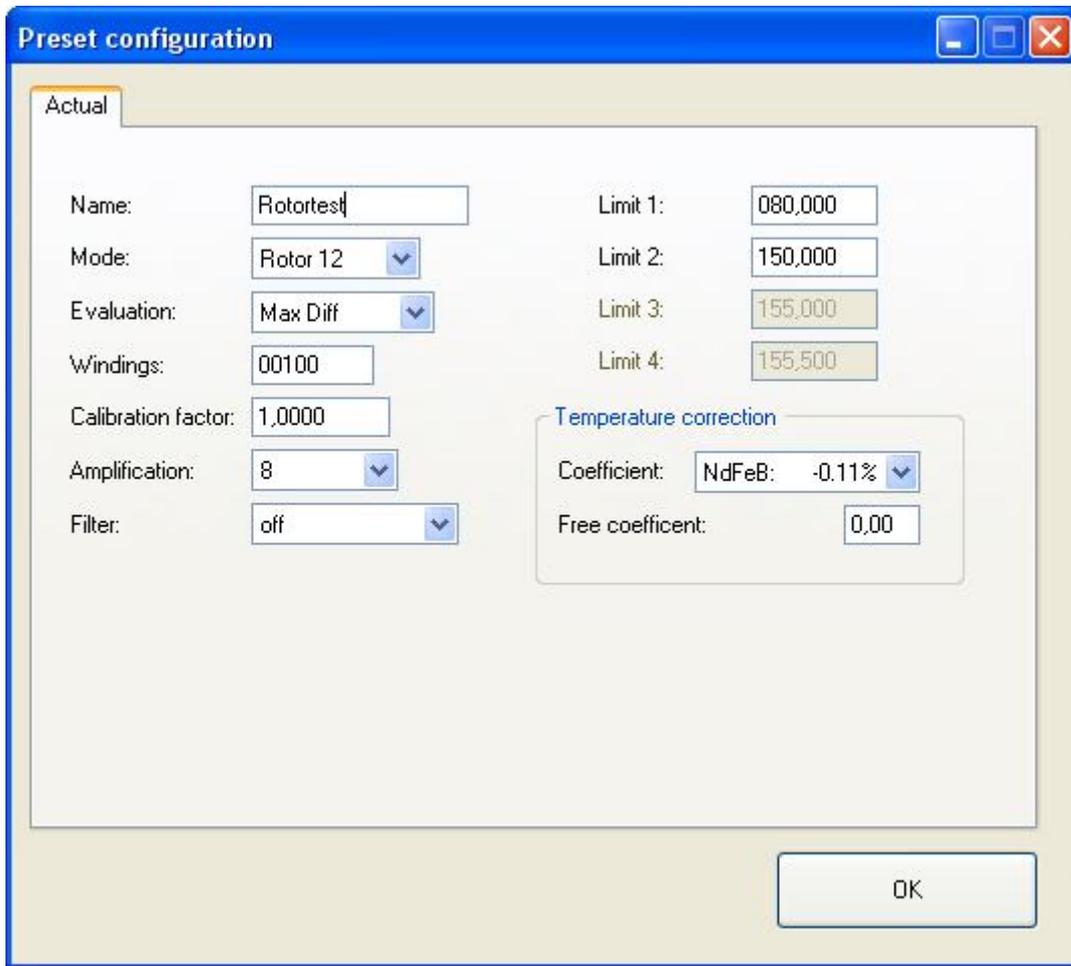
Preset window

Service:

Edit Preset opens the Preset window to enter all parameters for actual coil by PC keyboard. Data are transmitted when the window is closed by OK. If the window is only closed, data are not transmitted.

Update Firmware updates the firmware of the DFM-R. You will be informed as soon as a new firmware is available.

Update Display updates only the display memory. This is only necessary if we ask for it.

At **Options** folder and file name for storing of results is selected. By "**Select**" a file selector box is opened.
In the moment results are written as .txt file. Every new result is added to this file. The file can be imported to Excel.

Lower and Upper Limit determine the range of results to store. Results outside these limits are not stored. The DFM-R is very sensible. Moving a magnet near the coil may start a measurement and create a senseless result. But this result will be very low and must not be stored.
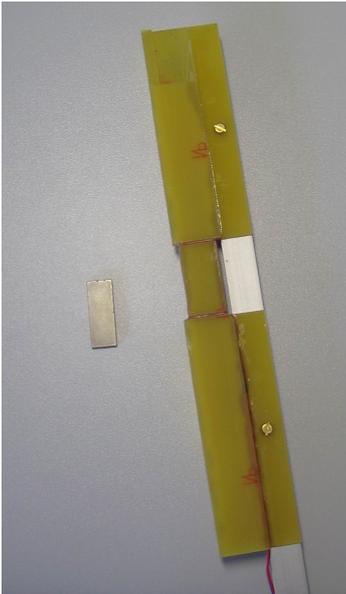This is only active for slide measurements in the moment.

7. Measurements

7.1. Standard integrating flux measurement
7.2. Helmholtz integrating flux measurement

For standard integrating measurement the magnet is taken out of a coil. This can be a Helmholtz coil or a coil fitting to the magnet shape. Also a coil can be pulled out of the magnet field.

7.3. Slide mode

Slide Mode

In slide mode the magnet glides on a slide and passes a coil that fits to magnet shape.

Start and end of measurement are detected automatically. Also the difference between maximum flux and end of measurement is evaluated automatically, sent to PC and there entered to a list.

Neither the fluxmeter nor the PC needs a manual input. Thus time between measurements can be very short. A 100% test becomes possible.

Error measurements by stray fields during external magnet movement are eliminated by adjustable limits.

Slide with coil in the center

7.4. Rotor modes

Except standard simply integrating flux measurement the DFM-R offers several **fully automatic measurement procedures** not offered by any other producer.

For rotor measurements, where the rotor or pole housing is turned, different evaluations are available.

For measurements with unknown number of poles only display of difference between strongest North Pole and strongest South Pole is available (MaxDiff).

With known number of poles the corresponding mode is selected (Rot 2 to Rot 16). Thus the DFM-R knows when a full turn has been completed. This allows additional evaluations:

- o Max Diff: Peak to peak value of the flux (Max pos to max neg)
- o Pol Aver: Average of absolute value of all poles
- o Pol Dev: Maximum deviation between absolute values of poles
- o Rot Chk: Test of correct magnet placement in the rotor

Together with the result all pole values are displayed on the PC. On the DFM-R all poles can be displayed by using the up and down arrows after measurement is finished.

If an exact angle corresponding evaluation is needed, turning the rotor or pole housing must be driven by a constantly turning motor. This motor can be controlled by PC and DFM-R software or by the DFM-R itself. Thus more exact evaluations regarding pole positions and pole widths are possible.
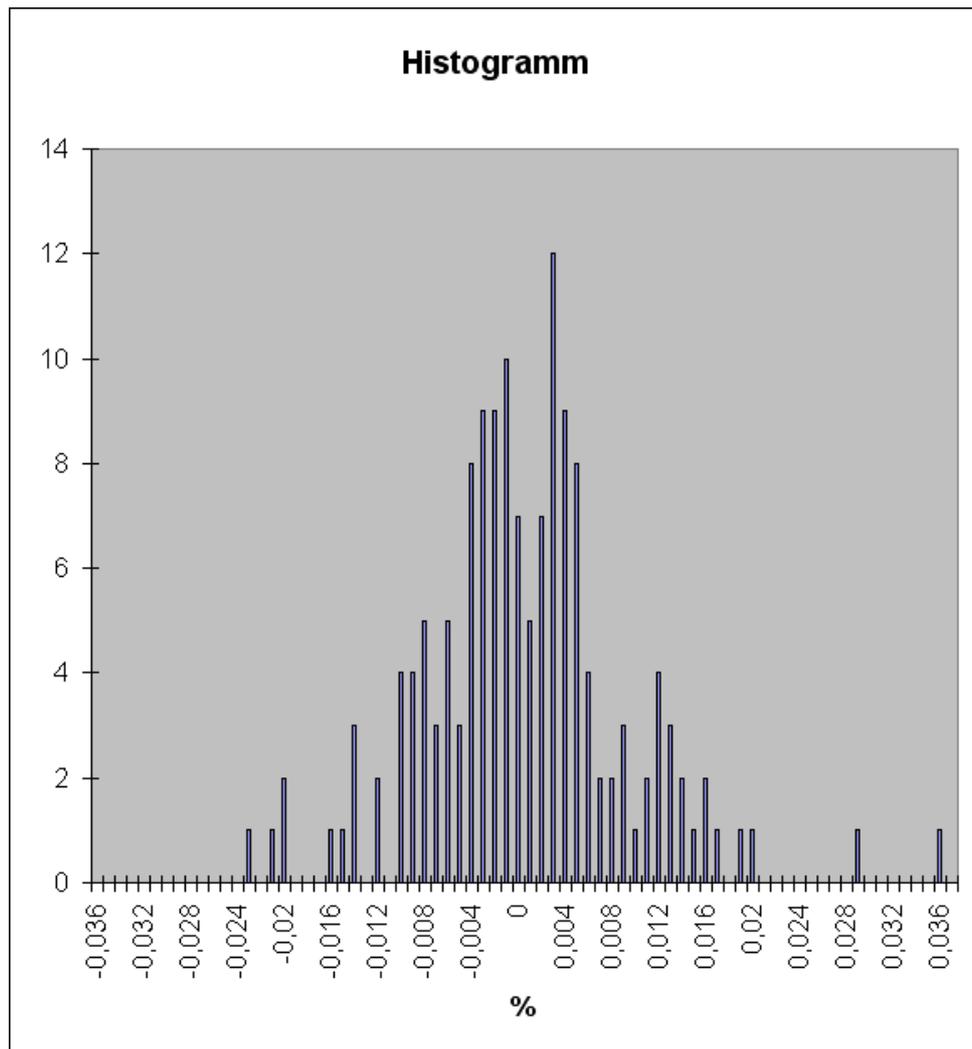
All evaluations that need the complete flux curve can only be executed by PC.

Technical specifications

Due to its high resolution the DFM-R is **extremely accurate**. At 150 measurements of the same magnet in Slide Mode with a mean value of 85 µVs, we got the following typical deviation in percent:
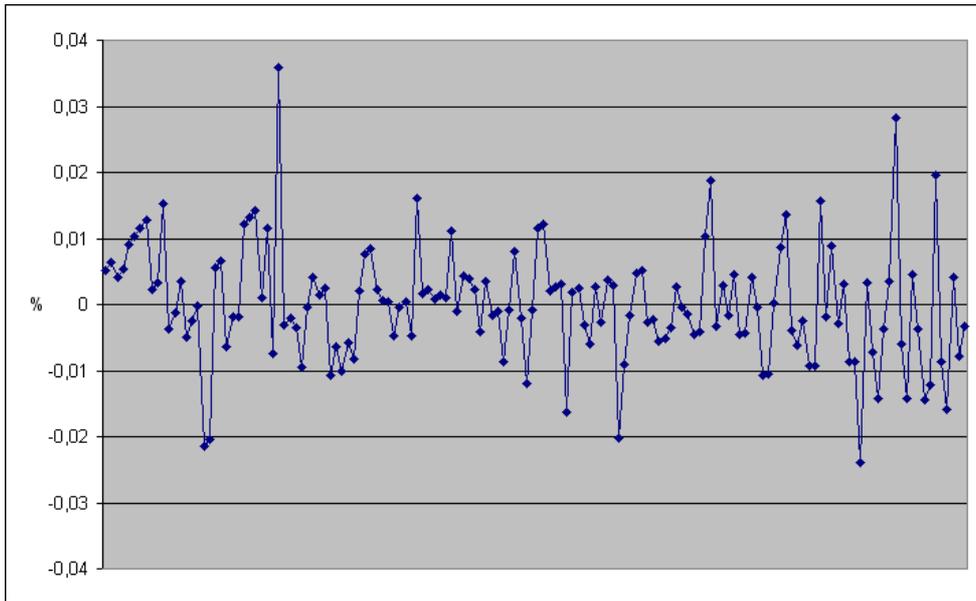
Deviation from mean value in percent

Result statistics around mean value in percent

Standard deviation for this manual measurement was 0.00879 % = **87.9 ppm**.

In general it must be considered that accuracy of measurement depends on type of measurement, external noise fields, temperature changes of the magnet and repeatability of mechanical procedure.

The DFM-R is 26 x 26 x 12 cm wide and can be connected to all usual mains voltages and frequencies. Power consumption is max 15 W.