

# Radon Monitor

## Radim 5

### Instruction Manual

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## 1.0 Description of the Monitor

The monitor was designed on the basis of the requirement for an apparatus that would determine the average radon concentration in residential areas with acceptable sensitivity. Estimation of the radon risk in residential areas is usually based on year-round measurements using tracker detectors. In justified cases, it is also possible to estimate the risk on the basis of the average radon concentration, which is measured simultaneously in several rooms of the residence of interest for at least one week. These measurements are usually carried out using electret detectors, which are sometimes subject to random self discharging. The Radim 5 monitor is intended to replace electret detectors and extends their capabilities using a computer that stores the results of the measurements and thus permits the determination of variations in time.

### Concept of the instrument:

The instrument is based on experience gained with the Radim3 and Centra monitors and the need to design an instrument

- that would determine the average value of the radon concentration (RC) and also changes in this concentration in time,
- in which the processed data would be completely transferred to a PC,
- that would be small (Hand-held Radon Monitor Radim5),
- that would be simple and inexpensive,
- that would be powered by AA-alkaline batteries and have a sufficient operating time.

### Concept of the detector:

The concentration of radon is determined by measuring the  $\alpha$ -activity of the decay products of the conversion of radon,  $^{218}\text{Po}$  (RaA) and  $^{214}\text{Po}$  (RaC'), collected from the detection chamber on the surface of a semiconductor detector by an electric field. Half of the hemispherical chamber consists of a grid, covered with two layers of material. The material captures the radon products formed in the external space and protects the detector against light and dust. As a majority of the radon decay products formed are positively charged, the chamber is connected to the positive pole of a high-voltage source (hereinafter HV) and the surface of the detector is connected with the negative field - ground of the HV source. Positively charged radon decay products (hereinafter dpRn) are neutralised by negative ions. This effect is dependent on the air humidity - the effectiveness of the detection system is thus humidity-dependent. To decrease the effect of humidity, it is useful to increase the HV and design the chamber so that most of the electrical lines of force are directed towards the surface of the semiconductor detector. The shape of the chambers and especially the surroundings of the detector were computer-modelled in the radon detectors of the Radim2 and Radim3 types. The detection efficiency of the system in the Radim2 and Radim3 monitors attains enormous values and the dependence on the humidity was decreased to a minimum (it has been estimated that 80% of the positively charged dpRn are collected on the detector surface). The dimensions of the Radim5 detection chamber were decreased compared to Radim 3 to a volume of 140 ml, so that the entire instrument fitted into a small casing. As the chamber dimensions are smaller, a source of only 400 V is used in Radim5, in place of the 2 kV source used in Radim3. A further difference between Radim3 and Radim5 lies in the fact that Radim3 counts impulses formed in the decay of RaA, and the equilibrium between the concentration of radon (RC) and the number of impulses is established after 15 minutes - the time response of Radim3 is very short. In order to increase the overall sensitivity of Radim5 to an acceptable level, the Radim5 monitor records the impulses formed by decay of

RaA and also RaC' - equilibrium between RC and the total number of impulses is established after 3 hours.

**Concept of the electronics:**

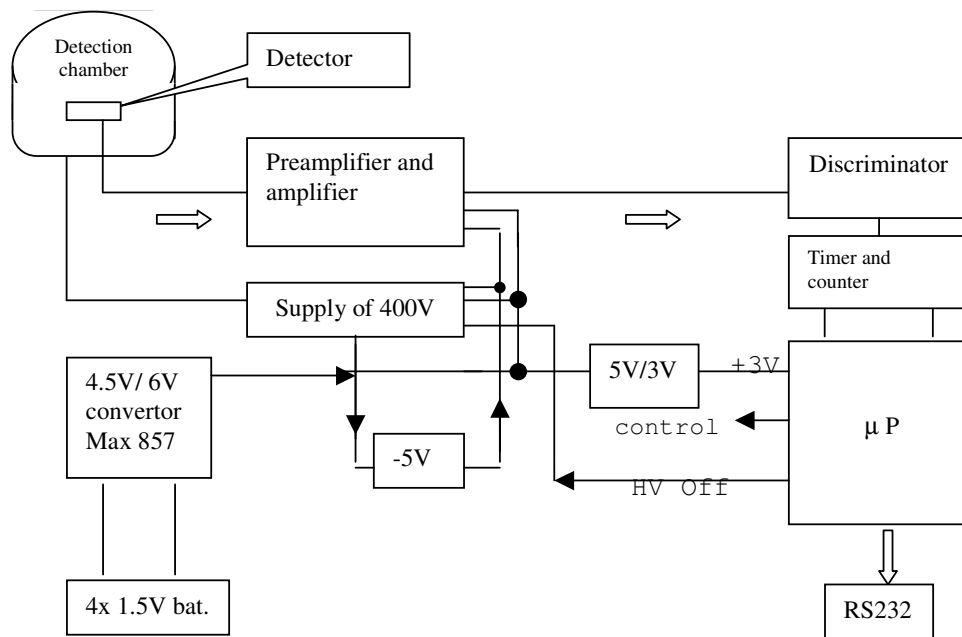
This was based on the requirements of:

- decreasing the power input to a minimum,
- storing the results of 0.5 hour measurement in a memory with the measuring time,
- starting the measurement by turning the measurement on, stopping the measurement by turning the instrument off,
- the start of the measurement being dependent on no error being present - the "Err" light does not come on. This light comes on if
  1. the test that starts up automatically at the beginning of each measuring interval is unsuccessful,
  2. the battery voltage is too low.

**A decrease in the power input is achieved:**

- by using a MAX 857 DC-DC converter, with low standby consumption, high efficiency at low current and ability to convert the voltage in the range 2.4 to 6 V - thus the entire voltage range of AA batteries can be utilised,
- by the use of low-power operational amplifiers,
- by the design of the HV source,
- by the fact that only the amplifier, HV source and CMOS - impulse counter and timer are active.

A block scheme of the monitor is depicted in the following diagram:



## 2.0 Physical Tests of the instrument

### 2.1 - Determination of the dependence of the instrument response on the high voltage

High voltage applied to the chamber affects the sensitivity of the instrument and the humidity dependence. The voltage must be such that the sensitivity basically does not depend on its value. In order to decrease the overall consumption of the instrument, it is useful to employ as low a voltage as possible. It is thus necessary to find a compromise. Thus, the following experiment was carried out:

In place of the large detection chamber, the Radim5 detection chamber was placed in the Radim3 instrument and the Radim3 electronics were connected in the usual manner, i.e. a window was adjusted around the RaA peak and measurement of the spectrum using an external multi-channel analyzer was employed to determine that the ratio of the number of impulses in the window around the RaA peak to the overall area of the spectrum equals 0.528 when RaA is in equilibrium with RaC' (the Radim3 electronics were employed because the Radim3 instrument is especially useful for automatic data storage, Radim3 measures the temperature, humidity and pressure and the instrument has a feature for remote control and reading of the results). The detection chamber was not connected to the internal high-voltage (HV) source, but to an external source that was adjustable from 0 to 2000 V.

The Radim3 instrument with the Radim5 chamber was immersed in a barrel with a volume of 100 l together with a reference Radim3 instrument. Uranium ore was used as a radon source with a concentration of about 8000 Bq/m<sup>3</sup>; the relative humidity was 68% and the temperature was 22 °C. The air in the barrel was homogenized using a small ventilator placed in the barrel. The number of impulses in the window around the RaA peak was measured at voltages of 600V, 500V, 400V and 300V. As the barrel is not perfectly sealed, RC changes in time (the decrease in RC is substantially compensated by the continuous production of radon by the radon source); the measured number of impulses was related to RC measured by the reference Radim3 instrument. The results of measuring the  $N_{RaA}/RC$  ratio and the responses are given in Table 1. The instrument response, defined as (number of impulses/hour)/(Bq/m<sup>3</sup>) was calculated by multiplying the ratio  $N_{RaA}/RC$  by a coefficient of 2/0.528 (the number of impulses  $N_{RaA}$  was measured at half-hourly intervals and Radim5 registers impulses in the whole spectrum).

Tab. 1 Dependence of the response on HV

High voltage	$N_{RaA}/OAR$	Standard deviation	Response (impulse/h/Bq/m <sup>3</sup> )	Standard deviation
600 V	0.0884	± 0.002	0.334	± 0.008
500 V	0.0909	± 0.002	0.343	± 0.009
400 V	0.0861	± 0.004	0.325	± 0.014
300 V	0.0837	± 0.005	0.315	± 0.016

The change of the response with the voltage lies within the range of the statistical error; nonetheless, a regression straight line was fitted through the results by using the least squares method ( $R = 0.81$ ):

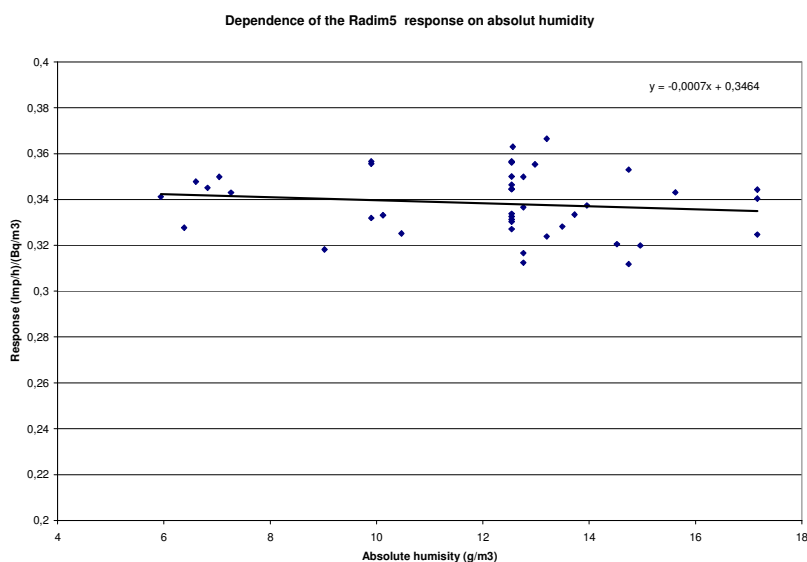
$$\text{Response} = 0.296 + 0.00007 \text{ HV}$$

And thus, at 400V, a response of 0.324 is obtained and, at 500V, 0.331. A change in HV by 100V causes a change in the response by 2.3%. It is apparent that the working **voltage can be decreased to 400V**.

## 2.2 - Determination of the humidity dependence of the response

Experimental method:

The Radim3 instrument with the Radim5 chamber and a reference Radim3 instrument were left in the barrel. The relative humidity in the barrel was decreased to about 20% using an external vessel containing silica gel, through which the air from the barrel was forced. The external vessel with the desiccant were disconnected and radon from an external source was injected into the barrel. The humidity was gradually increased automatically to about 35% and then about 0.5 ml of water was injected into the barrel - the humidity increased to 45%. Through gradual injection of water, the humidity was then increased up to 85% over about 18 hours. Similarly to above, the number of impulses  $N_{RaA}$  was related to RC determined using the reference Radim3 instrument (the Radim3 monitor automatically introduces a correction for humidity and the correctness of this adjustment has been verified in a great many experiments). The response was then calculated from this ratio. Fig. 1 depicts the dependence of the response on the absolute humidity.



It is apparent that the humidity dependence of the response is negligible - a straight line was fitted to the measured values:

Dependence on the relative humidity (RH) :  $\text{response} = (0.346 \pm 0.009) - (0.00015 \pm 0.00017) \times \text{RH}$

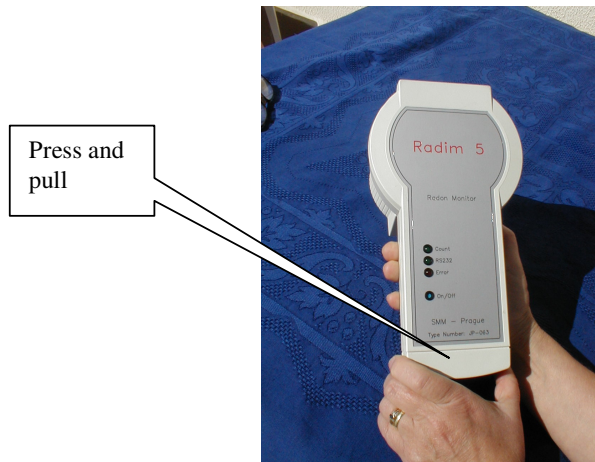
Dependence on the absolute humidity (RH) :  $\text{response} = 0.346 - 0.007 \times \text{AH}$

A change in the humidity from 50% to 90% causes a change in the response of -4.1%.

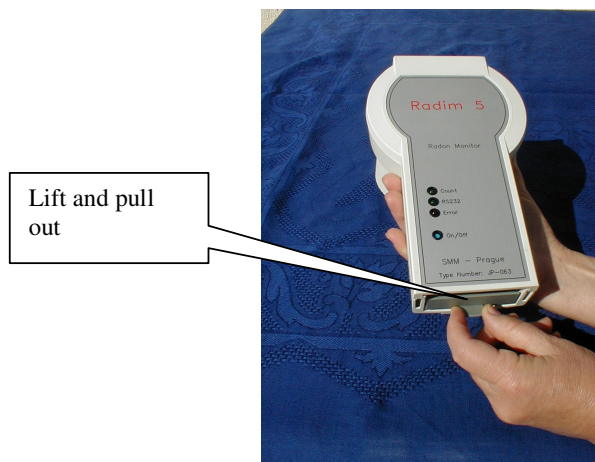
### 3.0 Operation of the Instrument

#### 3.1 - Inserting the battery

- A. Press the grooved surface in the bottom part of the instrument cover and slide the cover out of the instrument - see Fig.



- B. A grey box appears in the uncovered part of the instrument - see Fig. 3, in which the batteries are located. The bottom part of this box is braced against the instrument casing; grasp the band, lift the box slightly and pull it out of the instrument



- C. Unscrew the screw connecting the two halves of the box and insert the batteries as depicted in the following figure. **MAKE SURE THE BATTERIES ARE INSERTED IN THE RIGHT DIRECTION!** (the fifth battery slot remains empty).
- D. Screw the box back together and place the box back in the instrument so that the band is at the bottom of the instrument. As the contacts on the battery are quite thick, it is necessary to press hard on the box and then to press it downwards to prevent it sliding out again, so that the edges of the box are braced against the instrument casing.

After inserting the box with the batteries, the green LED may flash weakly; however, then **the red LED “Error” must flash brightly**. If this does not happen, the batteries must be disconnected by pulling out the box with the batteries, wait 30 seconds and then reinsert the box. The correct functioning can be checked by starting the measurement. After inserting the batteries, the instrument is brought into the regime STOP, all records remain preserved and information on connection to the power source is stored.

Note: It is possible to take out and insert the batteries during the measurement; however, when the measurement is restarted, information on the time without power is lost. Thus, it is useful to write down the date and time of starting the new measurement.

### **3.2 - Start and stop measurement**

RADIM5 is controlled by a single button on the front panel, which can be used to start and stop the measurement. In order to prevent pressing this button accidentally, the following procedure should be followed when starting or stopping the measurement:

- Press and release the button; the time of pressing is not important; when the button is pressed, the red LED – “Error” comes on.
- After about 1 second, the red LED “Error” again comes on and the button must be pressed again during led lighting , hold it down and when the LED goes off, to **immediately release it**.

If an incorrect procedure is followed, the red LED – “Error” flashes for long interval; otherwise the following states are indicated:

- 3x long flashes of red LED - Error                      STOP measurement
- 3x short flashes of green LED - RS232                START measurement in the BCKG regime
- 3x long flashes of the green LED - RS232            START measurement in the MEAS or TEST regime

### **3.3 - Choice of operating regimes**

Choice of the operating regime, adjustment of parameters and other functions are carried out **using a PC**. The data records of the individual regimes are, understandably, different. RADIM5 can be operated in one of three measuring regimes:

#### **A. Regime MEAS - basic measurement of the radon concentration**

This is the basic measurement regime with HV source turned on. After this is started, LED RS232 flashes three times. At half-hour intervals, the number of impulses is stored in the memory for later processing by the PC. Prior to commencing each measuring interval, it controls the state of the batteries, the remaining memory capacity and the detection part (self-testing). LED-IMP and LED RS232 flash briefly. If an error is found in any parameter, an entry is made in the memory and this state is notified by flashing of the red LED-Error at intervals of about 10 seconds. If only a low power voltage is found, further measurements are possible; otherwise, the measurement is stopped. Detection of each impulse is signalled by flashing of LED-Count. After the measurement is stopped, it can be started again at any time by starting up the instrument measurement regime again.

#### **B. TEST regime**

In this regime, the instrument generates impulses that it send to the input to the amplifier and counts the resulting impulses. The counted number is compared with the number of impulses measured. This regime is intended only for testing the instrument. It can be adjusted or cancelled only using the PC.

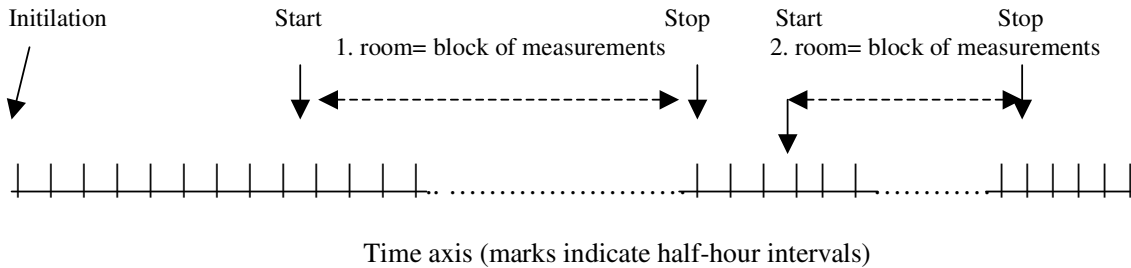
### C. BCKG regime - measuring the background

Using the PC, the BCKG regime is selected, which differs from the Meas regime only in that the HV source is turned off. For measuring the background, **the instrument must be placed in an environment with low RC level** - preferably out in the open.

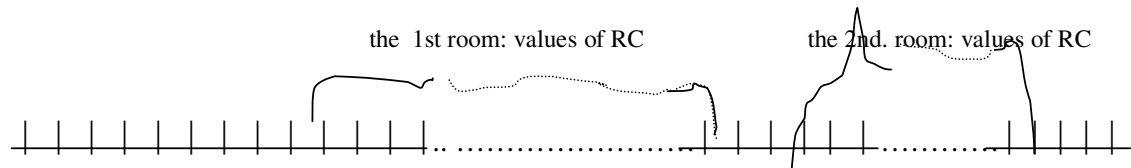
After starting the background measurement, LED-RS232 flashes briefly 3x, the number of impulses is counted and the record is stored in the memory as in the other regimes. After stopping the measurement, this regime is automatically turned off and, after starting up again, the standard measurement is started in the MEAS regime.

#### 3.4 - Manner of storing data and timing

Information on the measuring results must be accompanied in the monitor by information on the time when the individual measurements were started up. This requirement is usually met using a special memory, equipped with a constantly running clock. The Radim5 instrument is not equipped with this memory because it has quite high current consumption. The aspect of "timing" is resolved in Radim5 by using a precise oscillator and counter of "half-hour" impulses, which is read off together with the counter of the impulses produced by the radon detector. The "time" is then derived from the instant of zeroing the time counter. This zeroing is carried out using the "Initiation" function in the PC program. Time runs from this instant to the instant of the next initiation. As the start and end of the measurement are set manually and need not be fully synchronized with the initiation, **the first and last measurement in the half-hour interval may be affected if start and stop of the measurement are not carried out at a time that is a multiple of the half-hour interval from initiation.** The situation can be depicted as follows:



The results of all the measurements, stored in the Radim5 memory and depicted by the PC program, will then have the following appearance:



and the results of measurement of a great many rooms - blocks - can be stored in the Radim5 instrument.