Enhanced Digital Wide Range Neutron Flux Monitor

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TEST RESEARCH AND TRAINING REACTORS

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- **TK 240**
  - First NFMS system based on purely analog signal processing

- **proTK™ current generation**
  - Incl. all NFMS channels of the TK 250 family: DAK 250, <u>DWK 250</u>, DGK 250, …
  - Qualified acc. KTA, IEC, …; extensive operational experience

- **proTK™ next generation**
  - New channel DWK 260 based on the proven concept of the current generation of proTK™ channels (TK 250) with improved features,
  - Full qualification according to relevant international standards, regulations and guides (IEC, IEEE, USNRC, IAEA, …)

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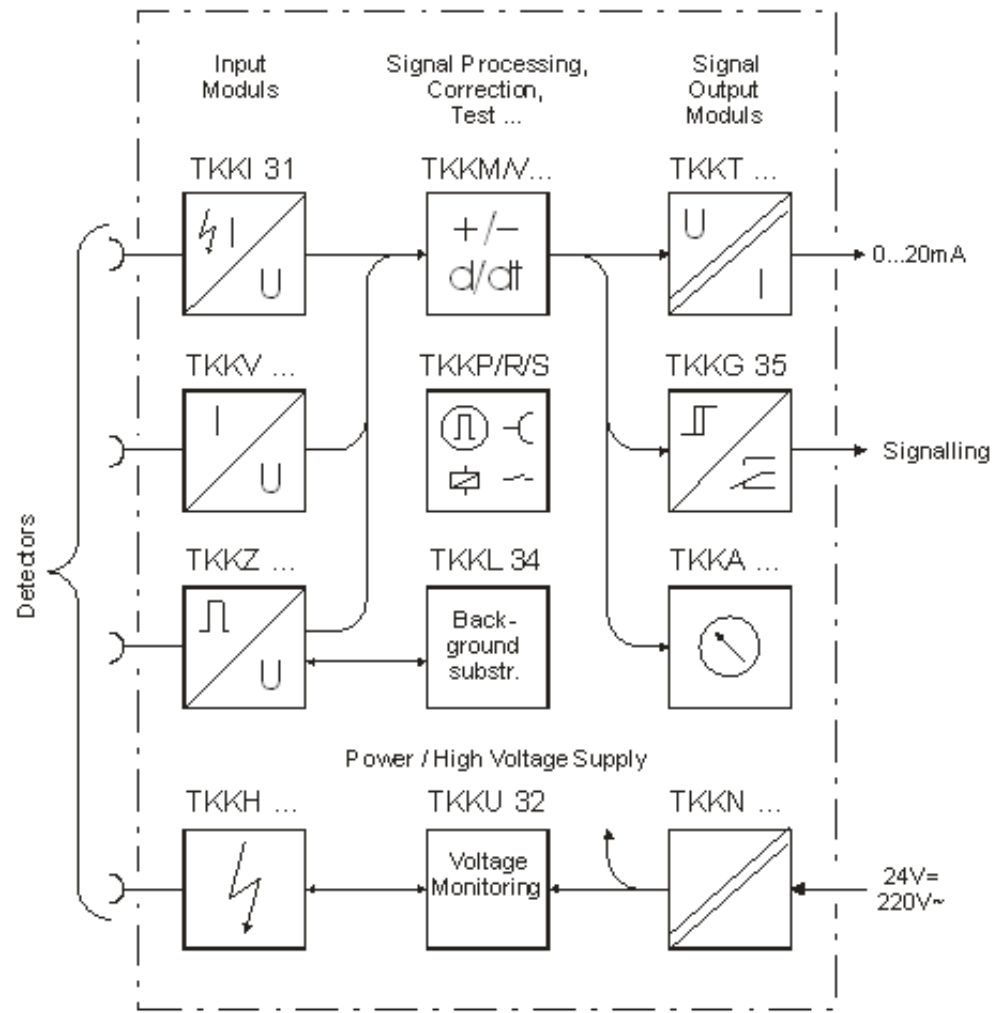**MIRION** TECHNOLOGIES

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Digital Neutron Flux Monitoring System proTK™ / TK 250 – Overview

The neutron flux monitoring system NFMS 250 combines long term experience in design and manufacturing of both detectors and signal processing electronics. These products are strictly oriented to the highest level of safety relevance and reliability and are qualified by several type tests and proven by an excellent operational experience.

The system NFMS 250 covers the requirements for measuring equipment used for the reactor protection system according to IEC 61226 cat A.

- **FEATURES**
  - **Modular construction**
  - **Versatile applications**
  - **Robust and reliable**
  - **Proven by operational experience**

- **APPLICATIONS**
  - **Operational process monitoring**
  - **Measurement & monitoring of the neutron flux density from start-up range to the power range for research reactors**
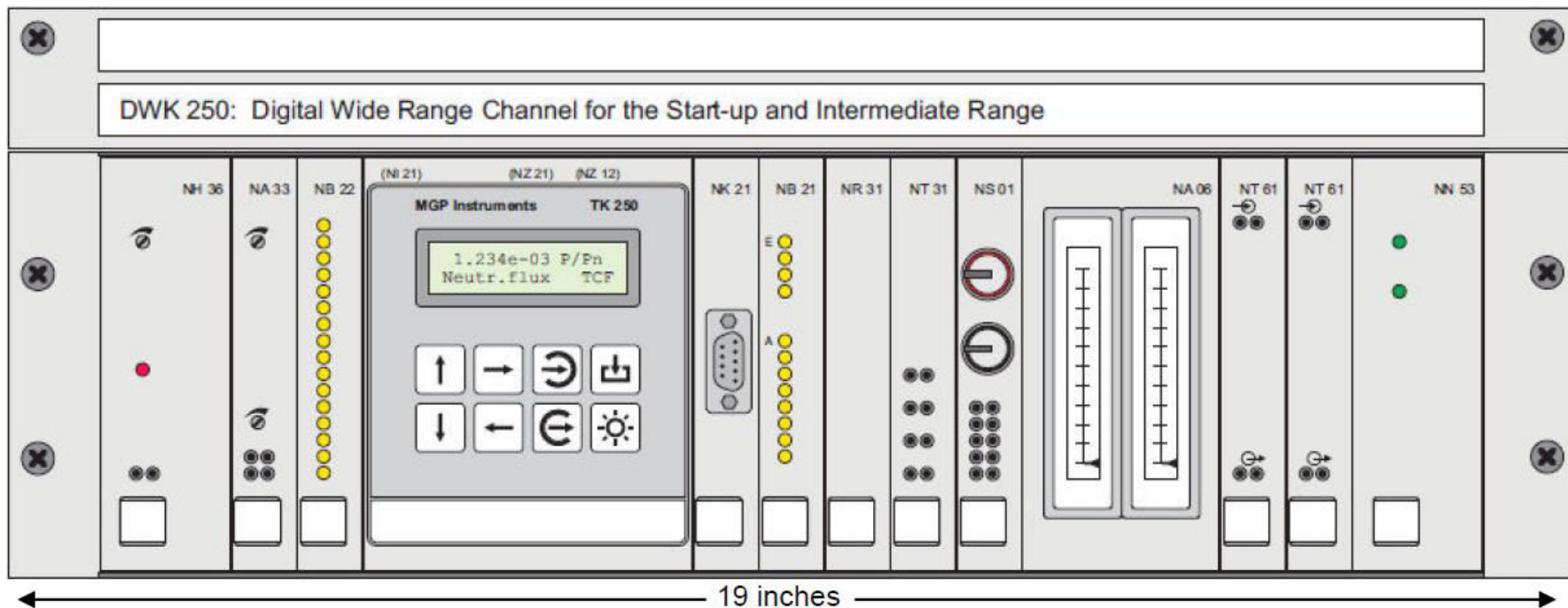
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DWK 250: Digital Wide Range Channel for the Start-up and Intermediate Range

19 inches

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DAK 250

Source range or intermediate range monitoring

With pulse processing or DC signal processing; reactimeter optional
also used for N-16 monitoring with e.g. gamma ionization chamber

DWK 250

Wide range monitoring

With combined pulse processing and Campbell signal processing for in-core & out-core fission chambers

DGK 250

Power range monitoring

With 1 or 2 signal paths for neutron ionization chambers or fission chambers

…

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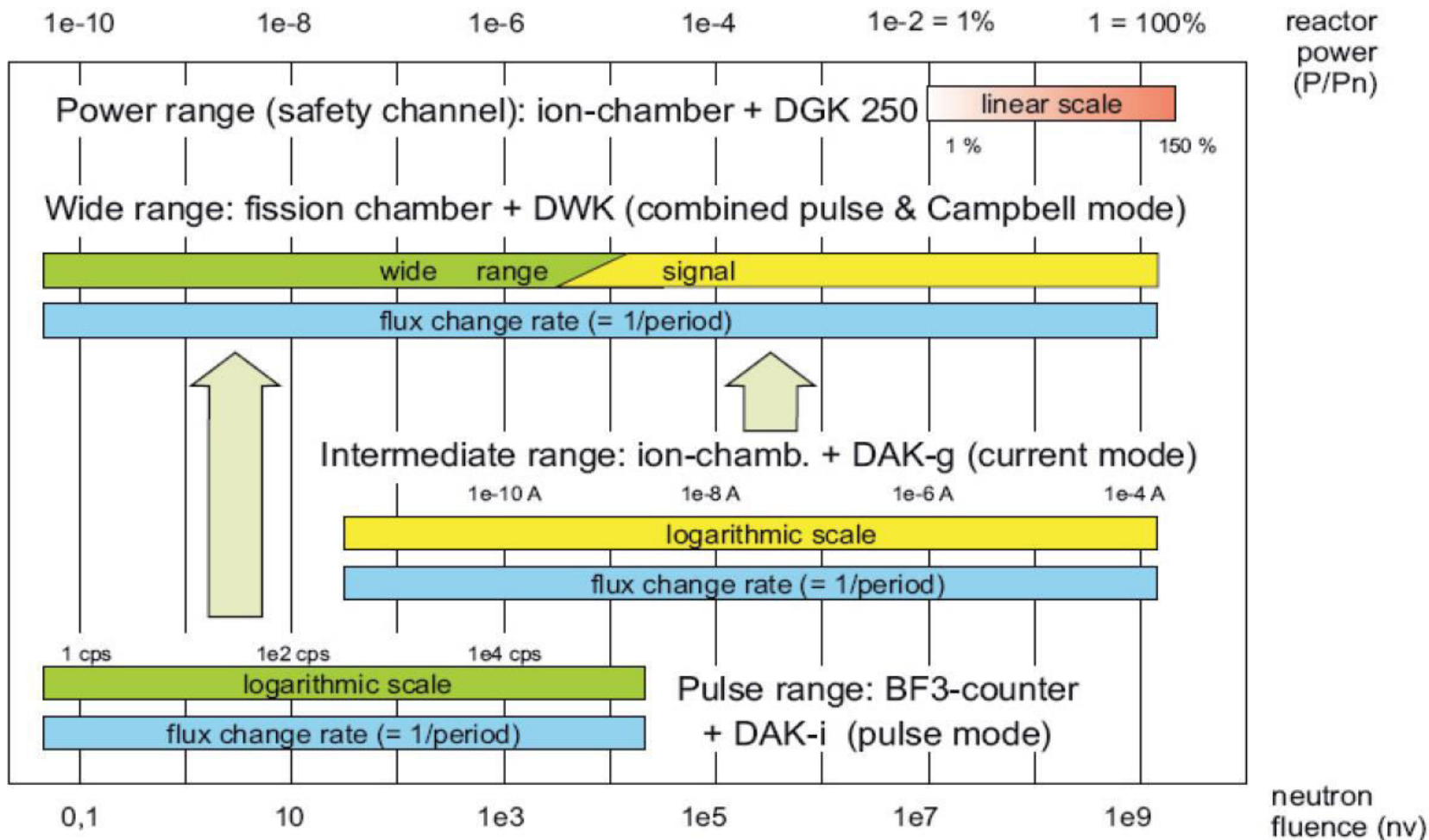
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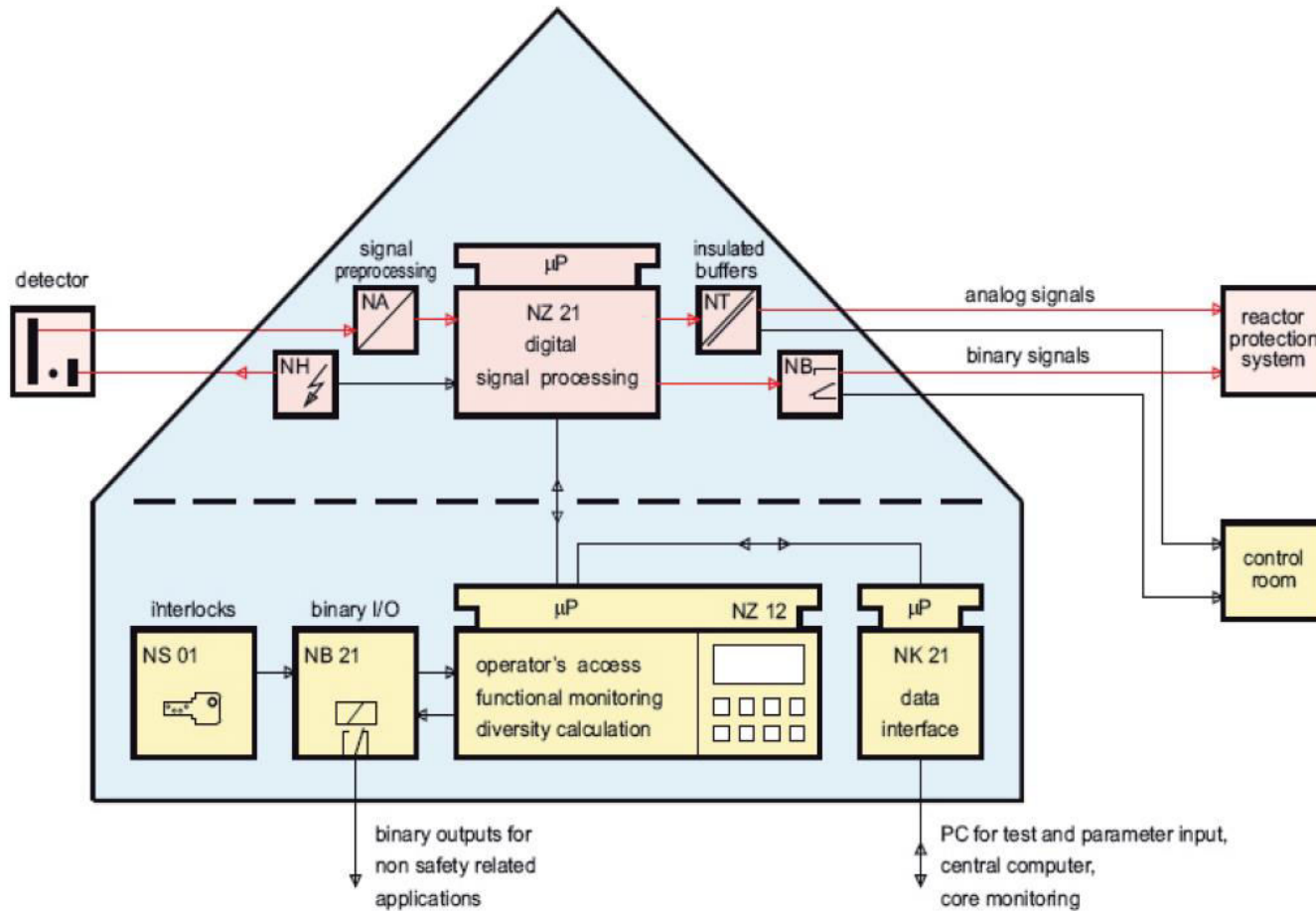**Radiation Monitoring Systems Division**

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Digital Neutron Flux Monitoring System proTK™ – Design is Clear, Simple, Efficient

- **The functions for the safety signal path are concentrated on the independent I/O-micro-processor board NZ 21:**
  - **The software is purely sequential and deterministic**
  - **The software operates cyclic in a fixed time grid, e.g. 10 ms**
  - **Therefore, the response time is predictable**
  - **There is no operating system**
  - **The volume of the software is as small as 3 to 8 kByte**

- **All other functions e.g. operator's access or self monitoring are allocated on the "main processor board" NZ 12**

- **Re-use of type-tested and proven software modules**

- **The target: zero-fault software**
  - **Designed and developed by experienced engineers**
  - **Verified in type tests - supervision/review by indep. experts (TÜV)**
  - **Reliability proven through long-term operational experience**

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- **Measures against CCF of the software**

  - **Additional to the simple and clear design there is:**

    - **No use of interrupts on NZ 21, only 1 timer interrupt on NZ 12**
    - **No use of real time clock or calendar**
    - **NZ 12 has no direct access to NZ 21 and its**
      - ✓ **Program sequence**
      - ✓ **Data or parameter memory**
    - **NZ 21 is hardware-locked by key switch against access to parameters and test-procedures**
    - **A variety of self monitoring devices, some of them complementary between NZ 12 and NZ 21**

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- **A variety of items is used to detect faults of hardware and software, e.g. monitoring of internal voltages, arithmetics, timing, micro-processors, data transmission, data and program memory. Additional, there are two very efficient tools:**

  - **NZ 12 performs a "re-calculation" of the results**
    - ✓ **Using a snapshot of data transferred from NZ 21**
    - ✓ **Using a different software and arithmetic package (e.g. floating point package instead vs. fixed point arithmetics)**
    - ✓ **Comparing the results and generating an alarm if necessary**

  - **A cycle counter on NZ 21 is interpreted periodically by NZ 12**
    - ✓ **The differences of two readings are compared with setpoints**
    - ✓ **NZ 12 & NZ 21 are monitoring their cycle times one another**
    - ✓ **The response of NZ 12 is additionally monitored by a watch dog**

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- **Different tools make periodical testing efficient but easy:**

  - **Test generators in pre-amps or input-boards of the channel:**
    - ✓ **May be activated remotely without manipulation in the wiring**
    - ✓ **Insert a reference signal to the input of the electronic channel**

  - **The tool "simulation" enables to:**
    - ✓ **Insert arbitrary numbers at defined points of the signal path**
    - ✓ **Generate all desired output values for analog signals or alarms**

  - **Binary outputs (relays) may be activated or deactivated**
  - **All testing tools are locked by key-switch and generate a flag signal**
  - **The basic procedure for periodical testing**
    - ✓ **Is described in the user manual**
    - ✓ **Was checked by TÜV during type test**

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- **The access to parameters and testing is locked by 2 key switches**
  - o **Without key: parameters may be displayed, but not modified**
  - o **DGK 250 additionally has a separated access to re-calibration**

- **A parameter protocol may be generated on a PC via serial interface using purely read-only instructions**

- **The variety of functions and parameters is limited by "configuration" according to user requirements:**
  - o **Delete (enable and hide) unused functions**
  - o **Establish "fixed parameters", e.g. scalings or trip thresholds**
  - o **Use of modified text tables, e.g. language version**
  - o **Any new configuration is done by Mirion Technologies and checked by TÜV**
  - o **Configuration data are stored in EPROM**

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- **The type test of hardware was performed according to KTA 3505**
  - **Theoretical and practical tests observed and checked by TÜV**
  - **Test results transferable to IEEE 323 or IEC 60780**
  - **Data of operational experience for all boards available**

- **Software type test also was performed by independent experts:**
  - **DPK 251 and DSK 250 by ISEB-TÜV-Rheinland/Köln**
  - **DAK, DGK, DLK 250 and all other channels by TÜV-Nord/Hamburg**
  - **Both institutes used different testing strategies and tools**
  - **IEC 880 was applied for DAK, DGK and DLK 250, elements of FMEA**
  - **Result: the SW is <u>qualified for use at RPS level</u>**

- **Finally an integration test of hardware and software was performed:**
  - **e.g. functions, characteristics, dynamic response, EMC**
  - **Tests under worst-case conditions**

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Digital Neutron Flux Monitoring System
proTK™ – Extensive Operational Experience

Electronics channels in operation   > 300

Cumulated years of operation   > 3,000 years

Average MTBF of electronic boards   > 4,000,000 hours

Total number of **software faults**   0

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Digital Neutron Flux Monitoring System proTK™ / TK 250 – Summary

- **Modular, multi-microprocessor system with a separate microprocessor for the safety signal path**

  ✓ *Simple & clear*

- **Cycle time of signal processing starting with 5 ms**

  ✓ *Fast*

- **Low heat C-MOS technology**

  ✓ *Safe*

- **Software fixed in EPROM, efficient self monitoring**

  ✓ *Reliable*

- **Remote signal generators and signal simulation**

  ✓ *Testable*

- **Qualified according to KTA 3501/3505, IEC 60 880**

  ✓ *Type-tested*

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Digital Neutron Flux Monitoring System proTK™ – Wide Range Channel DWK 250

With over 20 years of successful operation in nuclear power plants and research reactors, the DWK 250 is a direct replacement of traditional pulse and intermediate range channels; has a smaller "footprint" and isn't "power hungry"! The combination of pulse signal and RMS-signal is performed by a digital algorithm – that is precise, stable and reliable. Using a variety of self-checks for continuous functional monitoring, the DWK 250 provides highly reliable remote test generators and signal simulation for periodic testing.

- Signal filtering w/variable time constant
- Calculation of flux change rate (1 / reactor period)
- Calibration of wide range signal to neutron flux or power units (nv, P/Pn)
- Two analog outputs, defined by user (linear or logarithmic)
- Up to 16 adjustable alarm setpoints
- Dedicated analog & binary output signals for reactor protection system
- Remote test generators, also in preamplifier (periodic testing w/o external equipment)
- Digital adjustable parameters, lockable & non-volatile
- Full operation (e.g. testing) & data exchange via serial data interface
- Continuous functional self checks (e.g. program flow, interfaces, memory)
- Qualified by TÜV according to KTA 3501/05 (similar to IEC 61226 category A)

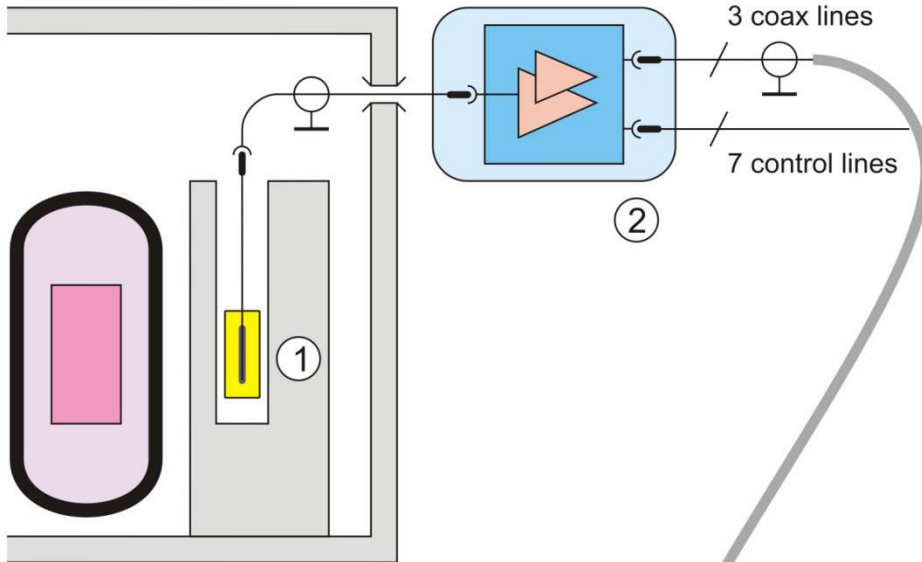Mirion offers an array of solutions and services for managing radiological hazards.
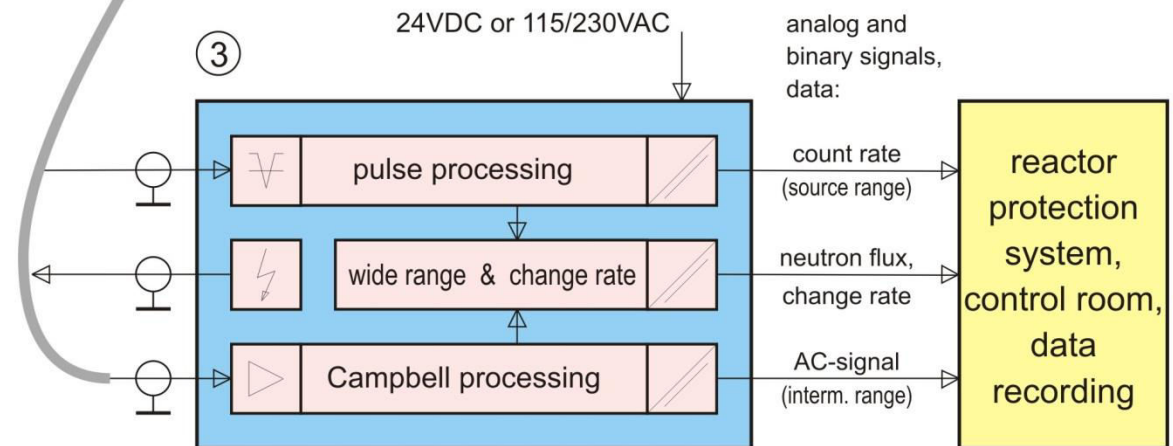
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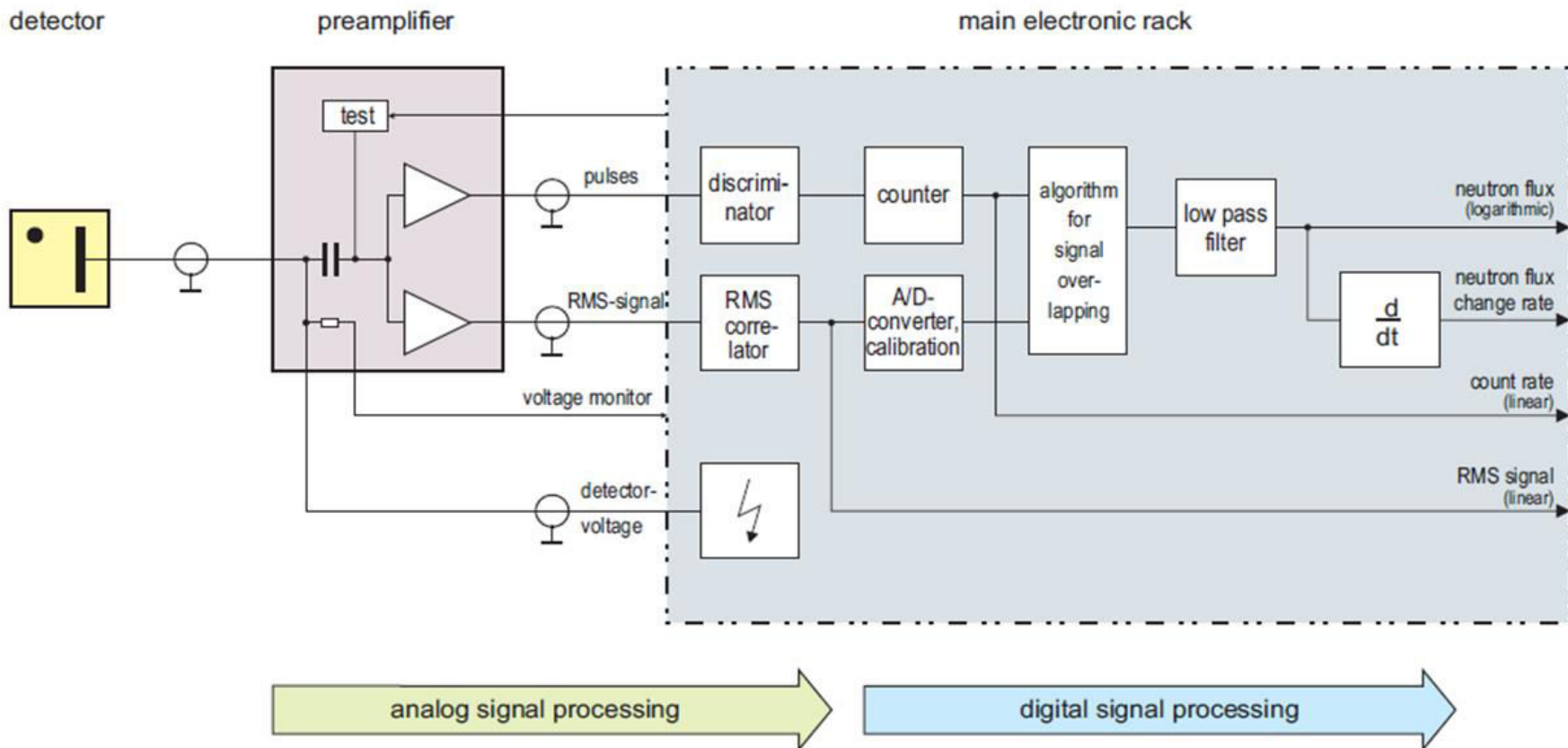
Wide Range Neutron Flux Monitoring with the DWK 250

3 coax lines

7 control lines

1. Wide range fission chamber e.g. CFUL 08

2. Preamplifier TKV 23

3. Digital Wide Range Channel DWK 250

1.470e+04 Bq/h
Abs.Rate 1 P

24VDC or 115/230VAC

analog and binary signals, data:

pulse processing — count rate (source range)

wide range & change rate — neutron flux, change rate

Campbell processing — AC-signal (interm. range)

reactor protection system, control room, data recording

MGP H&B

Digital Neutron Flux Monitoring System proTK™ – DWK 250 functional diagram

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- **Current Wide Range Monitor DWK 250**

  - Was the first channel of the TK 250 (now proTK™) family
  - Generating the wide range signal by digital signal processing proved an immense benefit
  - More than 20 years of opperational experience

  So why developing a new generation?

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Digital Neutron Flux Monitoring System proTK™ next generation – DWK 260

Though very successful, some users (mostly NPPs) would benefit if the following limitations of the wide range monitor DWK 250 would be addressed:

- Limited processing power with current I/O module NZ 21
- As a consequence the wide range signal is calculated on second processor module NZ 12 and therefore reducing the response time of these signals
- Limited capability of evaluating the DC current from wide range fission chamber
- Number of analog inputs/outputs
- Qualification acc. to KTA 350x from the 1980/90s. Transfer to current international standards possible but requires a significant effort. A complete new qualification in line with international standards is the key to faster acceptance by users and regulatory bodies.

Next Generation

Wide Range Channel DWK 260
of the proTK ™ family

- **New μController on board:**

  - With significantly improved cycle time -> improved response time
    - Currently 100 ms and 200 ms for NZ 21 and NZ 12, respectively.
  - New SW modules for evaluation of DC-signal and generation of „Super-Wide-Range Signal"
  - Based on proven SW algorithm for generating wide range signal (overlapping of pulse and AC/Campbell signals)
  - Additional analog, binary and digital I/Os on the NZ 21 (e.g. a fast RS-485 and/or Ethernet output only).

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Next Generation

Wide Range Channel DWK 260
of the proTK ™ family

- New pre-amplifier NV 230
  - With additional output of DC-signal

- Full qualification acc. to international standards
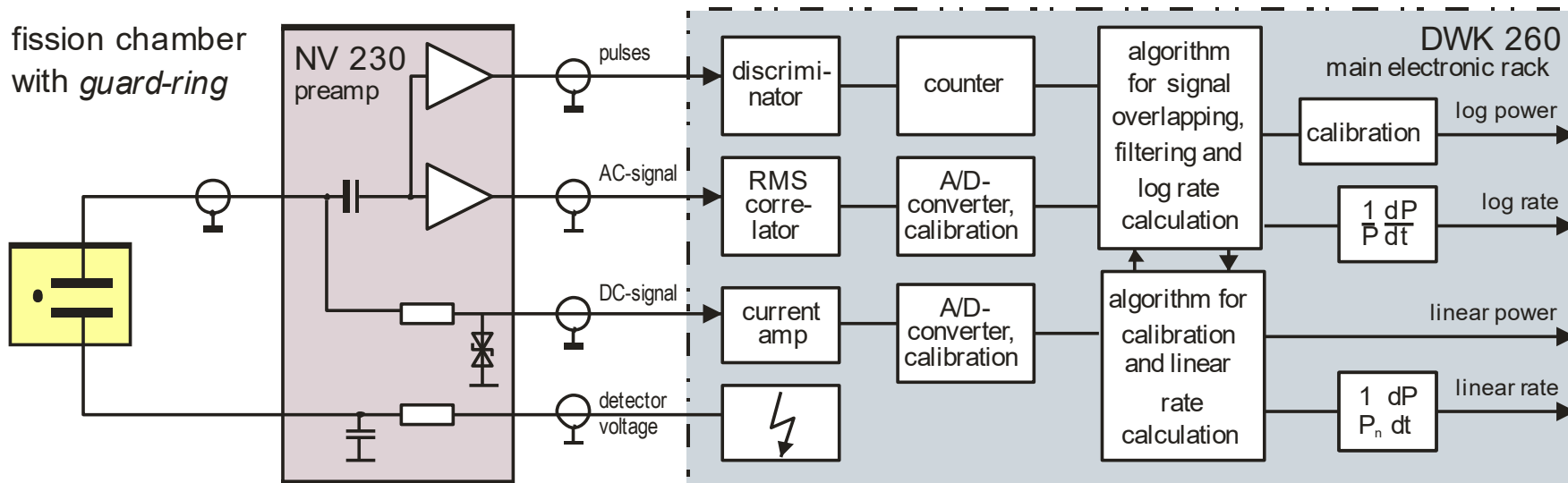 (e.g. IEC 61513/60880, IEEE 323/7-4.3.2, NRC RGs, ASME NQA-1, etc.)

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Next Generation

Wide Range Channel DWK 260

of the proTK ™ family

fission chamber with *guard-ring*

NV 230 preamp

pulses

AC-signal

DC-signal

detector voltage

DWK 260
main electronic rack

discrimi-nator

counter

algorithm for signal overlapping, filtering and log rate calculation

calibration → log power

RMS corre-lator

A/D-converter, calibration

$\dfrac{1}{P}\dfrac{dP}{dt}$ → log rate

current amp

A/D-converter, calibration

algorithm for calibration and linear rate calculation

→ linear power

$\dfrac{1}{P_n}\dfrac{dP}{dt}$ → linear rate

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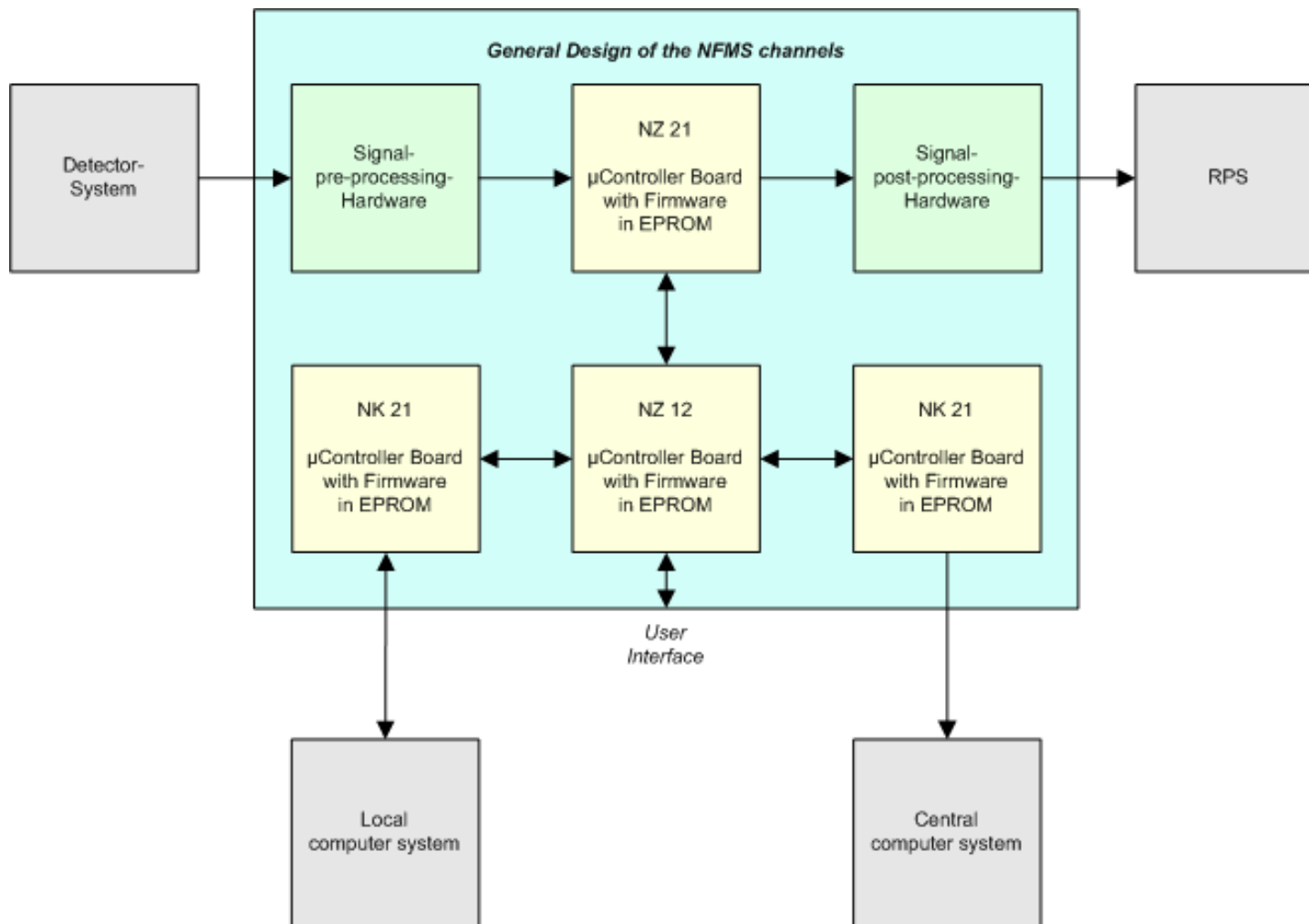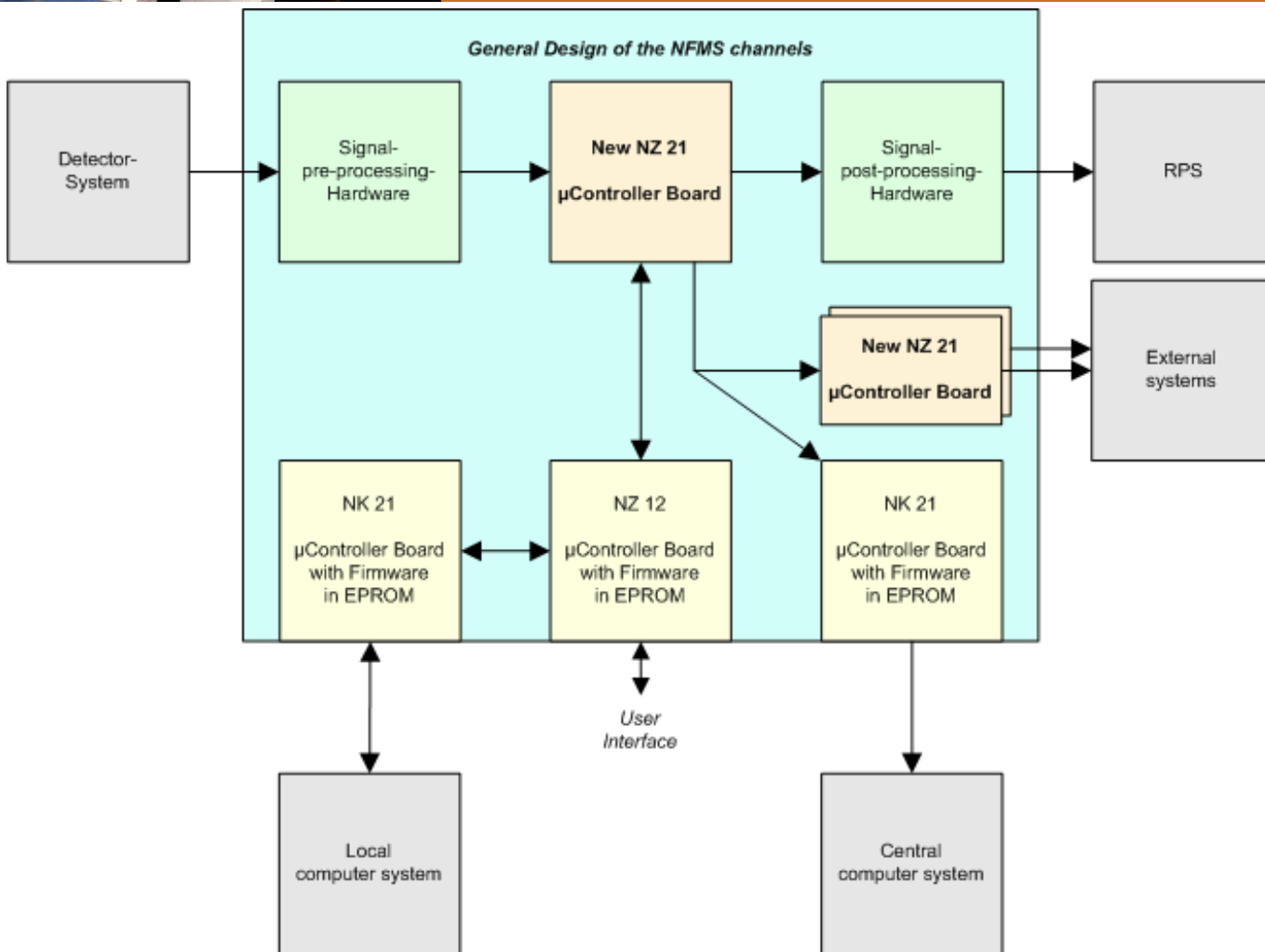**Radiation Monitoring Systems Division**

General Design of the NFMS channels

Detector-System → Signal-pre-processing-Hardware → NZ 21 µController Board with Firmware in EPROM → Signal-post-processing-Hardware → RPS

NK 21 µController Board with Firmware in EPROM ↔ NZ 12 µController Board with Firmware in EPROM ↔ NK 21 µController Board with Firmware in EPROM

User Interface

Local computer system

Central computer system

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General Design of the NFMS channels

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- With proTK™ Mirion offers a full range of neutron flux monitoring channels for BWR, PWR and test, research and training reactors.

- The modularity of SW and HW allows its implementation virtually in any NPP or other nuclear facility (existing or new).

- These neutron flux monitors are designed and qualified for providing signals of highest safety standards, i.e. for the reactor protection system (RPS) and also fast signals for reactor control

- proTK™ channels have accumulated > 3,000 years of operational experience

- Next Generation proTK™ channels are based on the long experience of current proTK™/TK 250 monitors while integrating new customer requirements, e.g. faster response times and additional I/Os.

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Questions?

Comments?

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