EVALUATION OF 'INTELLIGENT' MEASUREMENT INSTRUMENTS

– *IT and metrology* –

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Outline

- ‘Intelligent’ instruments
- Evaluation aim and approach
- Results
  - hardware
  - software
- Summary
- Conclusions

‘Intelligent’ instrument

Instruments become more ‘intelligent’:
embedded software makes adjustments (justification to nominal) and self calibrates instrument

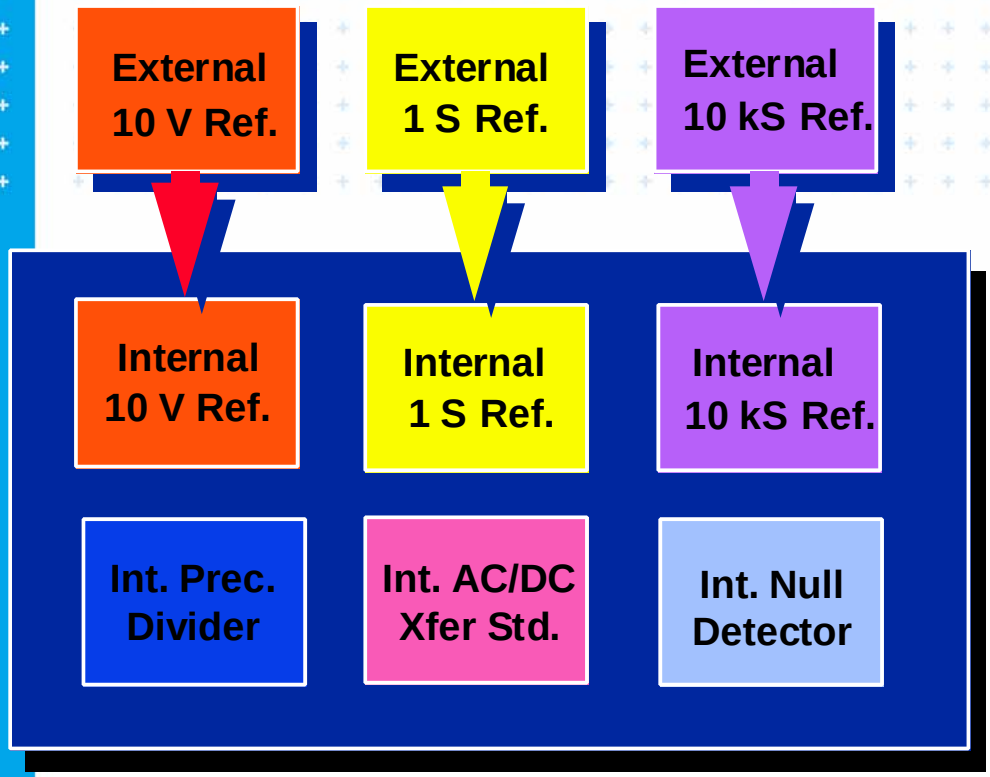
(smart sensors)

Advantages:

- Efficient (time, costs)
- Repeatable and reliable
- Effective → high accuracy, large range
- Increased confidence

‘Intelligent’ instrument

How does it work?



External references

Instrument with internal references

extra hardware and firmware

Two step process:

1. internal references
2. extra / derived parameters

Can we use it?

The self calibration or adjustment procedure
- brings the instrument back to nominal
- The hardware and firmware replace the metrologist and its measurement laboratory

We can use it … when it is evaluated!
- assess before use in an accredited laboratory just like the accredited laboratory has to be assessed

Problem: Instrument with software is ‘black box’

NMi evaluation projects

Three projects at NMi (1996 – 2004)

- Fluke 5700 multifunctional electrical calibrator
- QuadTech 7600 RCL meter (impedance)
- Sartorius CC1200 mass balance

Prerequisites:

- Hardware *and* software expertise (SP, NPL)
- Instrument has self adjustment routine
- Cooperation of manufacturer
  (extra documentation; source code; contact point)

Evaluation aim & approach

Aim of the projects:

Evaluate whether instrument is adjusted to nominal value within its specifications by the internal adjusting procedure

Evaluation filosophy:

Follow lines of ISO17025 accreditation of a ‘normal’ calibration laboratory

- HW $\leftrightarrow$ equipment
- SW $\leftrightarrow$ metrologist

Hardware evaluation

- Measurement principles used
- Implementation of the principles
  → unbroken chain realised?
  → uncertainty realistic?

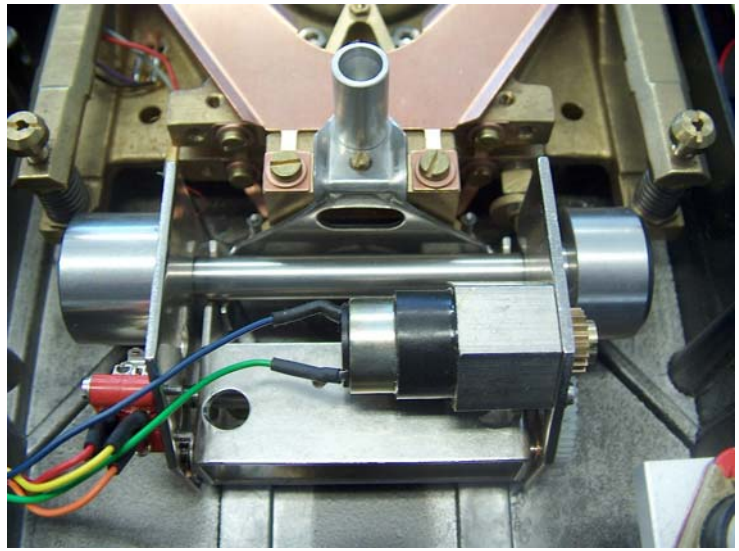
- Practical tests
  - Black box — normal procedure
  - Opaque box — shifted ref. values
  - Glass box — details

CC1200 mass balance

- Range: 1200 g; resol. 0.1 mg
- Internal weight

Test: change *T* to
20 ºC and 25 ºC
and adjust with
internal weight

⇒ balance within specification back to nominal



CC1200 mass balance

Conclusion:

internal adjustment can be used as self calibration

provided that

- Internal *T* and *Rh* is measured
- More than 1 internal weight is present
- Density of internal weights are known
- Internal weights are carefully handled by the internal weighing procedure

Software evaluation

Aim: to increase our confidence in correct functioning of the calibration software

- no ‘95% confidence level’
- focus on metrological functionality

Activities: (white box)

- overview of software
- digital hardware
- determination of critical procedures

- test of critical parts

Software evaluation – overview

- Digital hardware
  ⇒ typically two CPUs, (EEP)ROM
- Overview of software structure
  - general structure functional blocks
    ⇒ unraveled via reverse engineering
  - details of the SW in CPU subsystems
    ⇒ determination of critical procedures
- Quality system for development, validation and maintenance of software
  ⇒ version control; documentation; comments

Software evaluation – general

- Checking of RAM and ROM
- Main ↔ slave CPU communication
- Watchdog timers
- Error handling routines
- Self Diagnostic routines
  Fluke 5700: thorough testing of the critical analog hardware a.o. the central switch matrix board ⇒ an artificial error was indeed detected

- Data exchange and data storage
  ⇒ copies of cal.data; checksums; protection

Calibration procedures

Two questions:

- are the calibrations correctly performed?
- is the calculation of the final result OK?

F5700: tested for all functions (*V*, *I*, *R*), with emphasis on DC voltage since that is the basic measurement activity

Q7600: calibration process checked, and calculations checked (complex numbers)

⇒ no errors were found

Reporting

Advantage of self calibration:

SW adjustment instead of HW adjustment

→ no loss of history! (in principle)

Crucial requirement:

Report of the internal process should contain sufficient information to build up history

⇒ Report shifts in constants / output values with uncertainty (typically a few 100)

Summary of evaluation results

Instrument	Evaluation extent		Result
Fluke 5700	*****	HW & SW	Selfcal is working
Quadtech 7600	***	HW & SW	HW positive SW no errors, but adaptations needed
Sartorius CC1200	*	HW	Good possibilities for selfcal

Conclusion

Self calibration is efficient and effective
…. but needs evaluation!

Evaluation:

- Along ISO17025 accreditation
- Supported by manufacturer
- Cooperation HW & SW specialists

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