Accurate efficiency measurement of DIN rail power supplies

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Efficiency with AC/DC: 230V, 24V/10A

Efficiency	Input power [W]	Power losses [W]	Reduction in power losses		Market launch Series
95.2%	105	**5**	-27%		**2015** CP10
93.5%	107	**7**	-37%		**2005** QS10
90.0%	111	**11**	-19%		**1998** SL10
88.0%	114	**14**	0%		**1994** DP157
88.0%	114	**14**	-		**1991** DP177

Sample calculation: Output 100 [W]

Influence of measuring errors on determining the loss

Δ	P_{out}	P_{in}	η	Δ	P_V	
	100W	111.11W	**90.0%**		11.11W	
1%	**99W**	"	89.1%	0.9%	12.11W	**+9%**
1%	100W	**112.22W**	89.1%	0.9%	12.22W	**+9%**
	100W	105.26 W	**95.0%**		5.26W	
1%	99W	"	94.1%	0.9%	6.26W	+19%
1%	100W	106.32W	94.1%	0.9%	6.32W	**+20%**

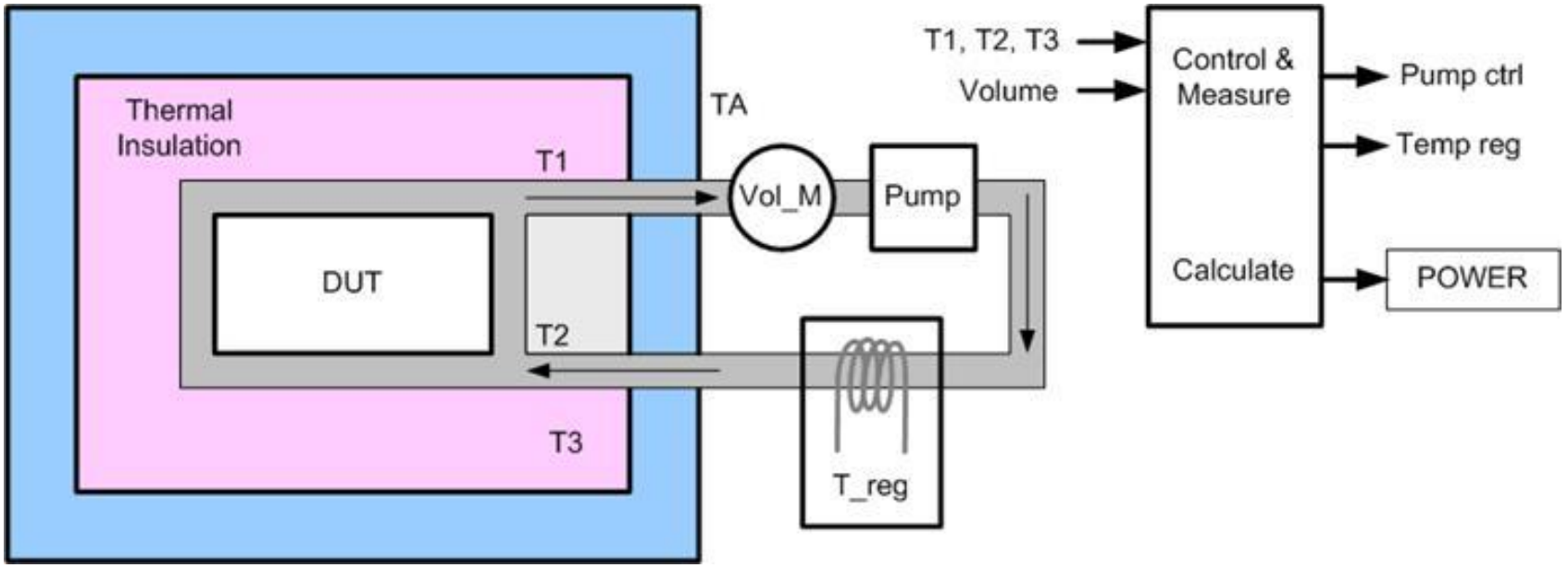
1% measuring error
= 20% difference in the power losses

Problem: Indirect measurement

- Goal: Loss measurement, because it is the cause of heating
- Input power − output power = power losses
- = Measure large values to determine a small value.

Alternative: **Calorimetric measurement** for direct loss measurement

Disadvantage: Too elaborate



Measuring instruments: Voltmeter and ammeter

Measure four values and calculate power losses and efficiency.

- Only works where there is a stable DC voltage available, e.g. on the output.
- With **AC input**, the **apparent** power is measured, but the correct measurement for the power losses is the **active** power = **No go!**
- **Highly accurate** measuring instruments required.
- Current measurement is generally too inaccurate, but possible with a very accurate external **shunt of 0.01%**.
- If there are fluctuations on the input or load, it is inaccurate because of lack of synchronisation of the measurements.

Measuring instruments: Data logger

One measuring unit is used multiple times by multiplexing.

- As a result, many **measuring errors cancel one another** out.
- **Highly accurate** 6.5-digit measuring unit, e.g. Agilent 34970: 0.004% of measured value, 0.0007% of final value (1V range).
- **Accurate shunt** required.
- **Only suitable for DC measurements**: DC output or with DC/DC converters

Measuring instruments: Wattmeter

- Basically correct with AC input: **Multiply momentary values** of **current and voltage,** then **calculate average** = Definition of power.

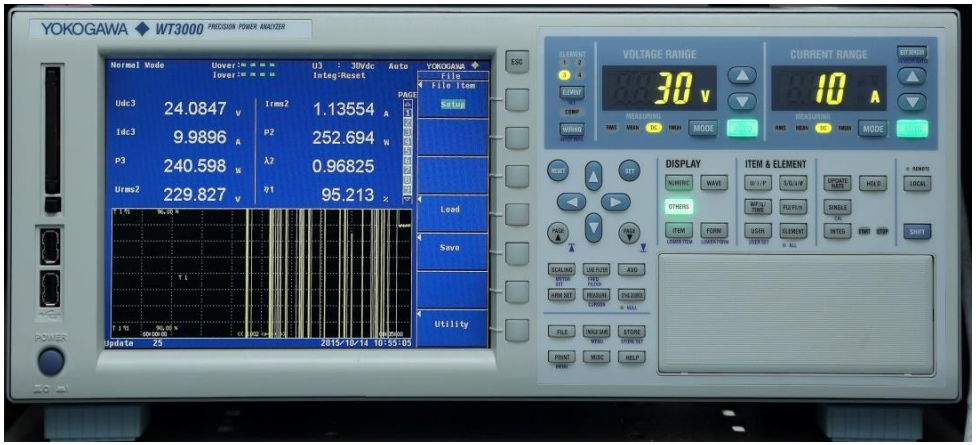
- Usual wattmeter is **often too inaccurate**, only precision instruments are practical.

- The loss still needs to be determined by calculation, **no synchronisation** between input and output power.

- Fluctuating values are difficult to interpret.

Measuring instruments: Power analyzer

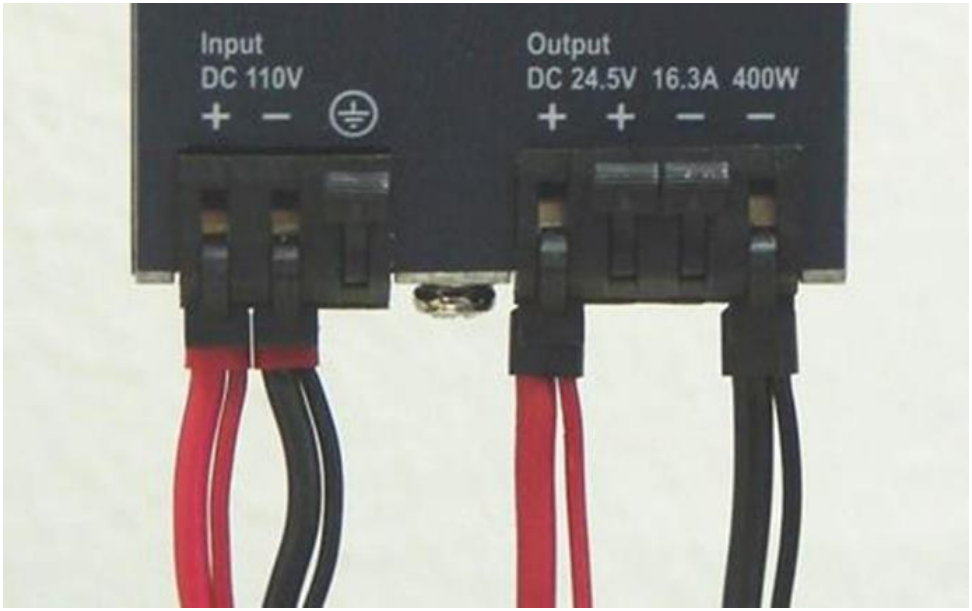
- Best solution but **expensive**
- **Direct display:** Power losses, efficiency
- **Precision instruments** available, e.g Yokogawa WT3000: 0.02% of measured value)
- Synchronous measurement of input and output
- Also for measurements on the **3-phase system**
- **Automatic** measuring series possible



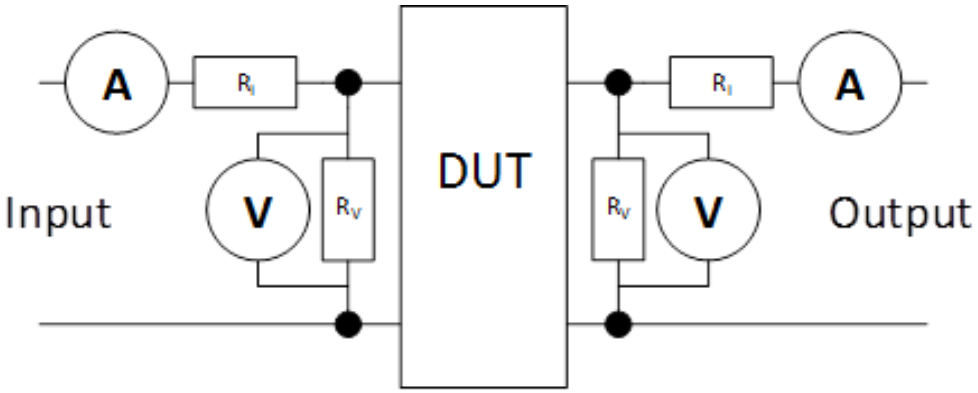
Measurement setup – cabling

All power losses that do not come from the device under test (DUT) are not allowed to be included in the measurement!

- power losses on **feeder cables,** correct voltage measurement
- **Current shunt**
- Additional EMC **inductors**

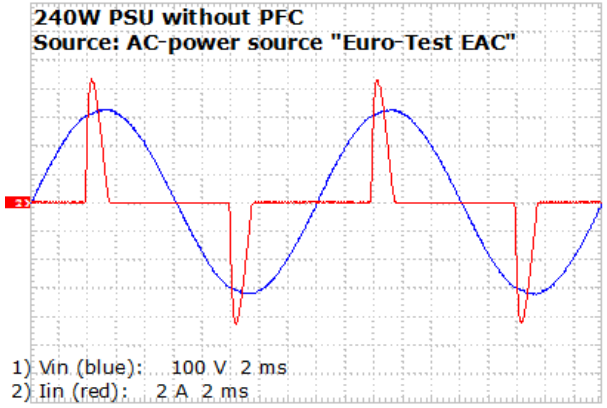
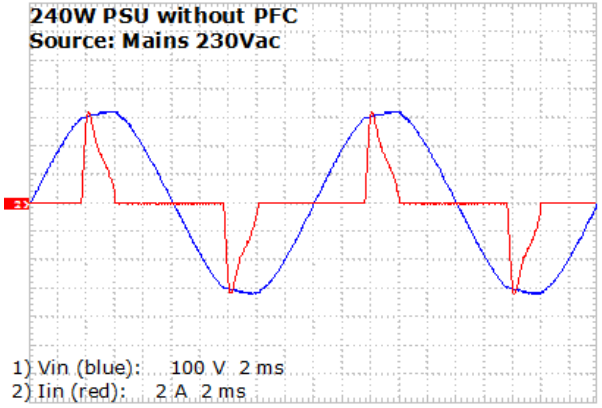
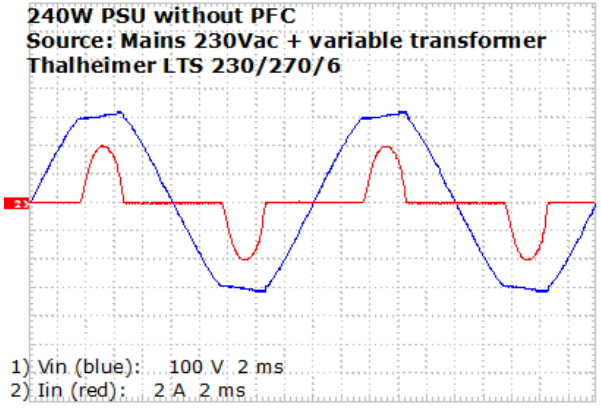


The instrument's own **terminal resistors** belong to the DUT.



DO NOT! Connect laboratory cables one inside another

Measurement setup AC-power sources: Critical "without PFC"

	AC-power source	Power system direct	Disconnection point transformer
			
Efficiency	**91.2%**	**91.5%**	**91.6%**
Power factor	0.50	0.59	0.68
Input current	**2.3A**	1.9A	**1.7A**

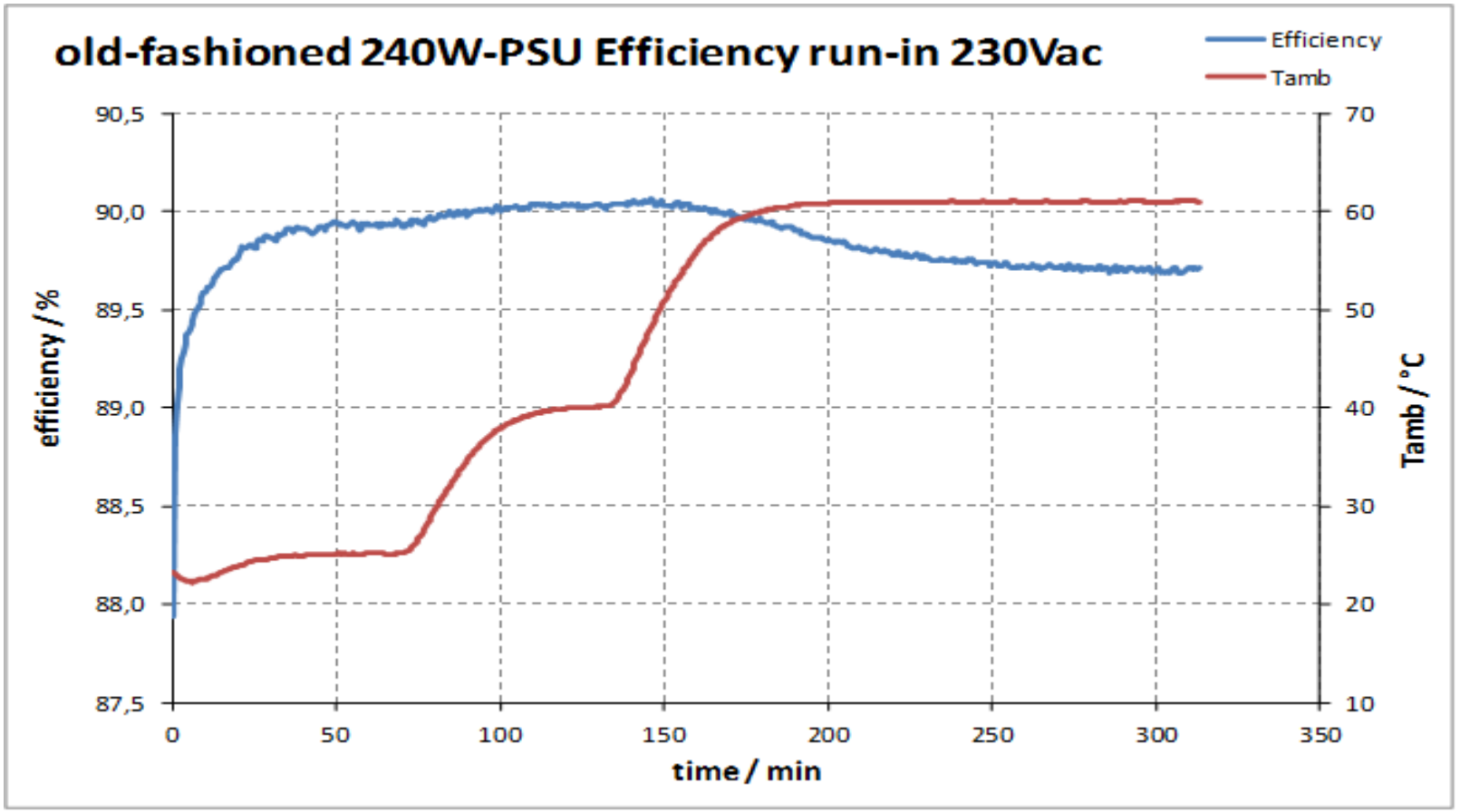
Measurement setup – miscellaneous

1. **No EMC interference** from the device under test (DUT)
   - High-frequency superimposed currents and voltages exceed the capabilities of the measuring instruments.
   - Provide external additional filters for prototypes.
   - Do not include power losses from the additional filters in the measurement.
   - EMC interference can also lead to fluctuating loads.

2. Preferably take **I-loads**, because the current remains stable.

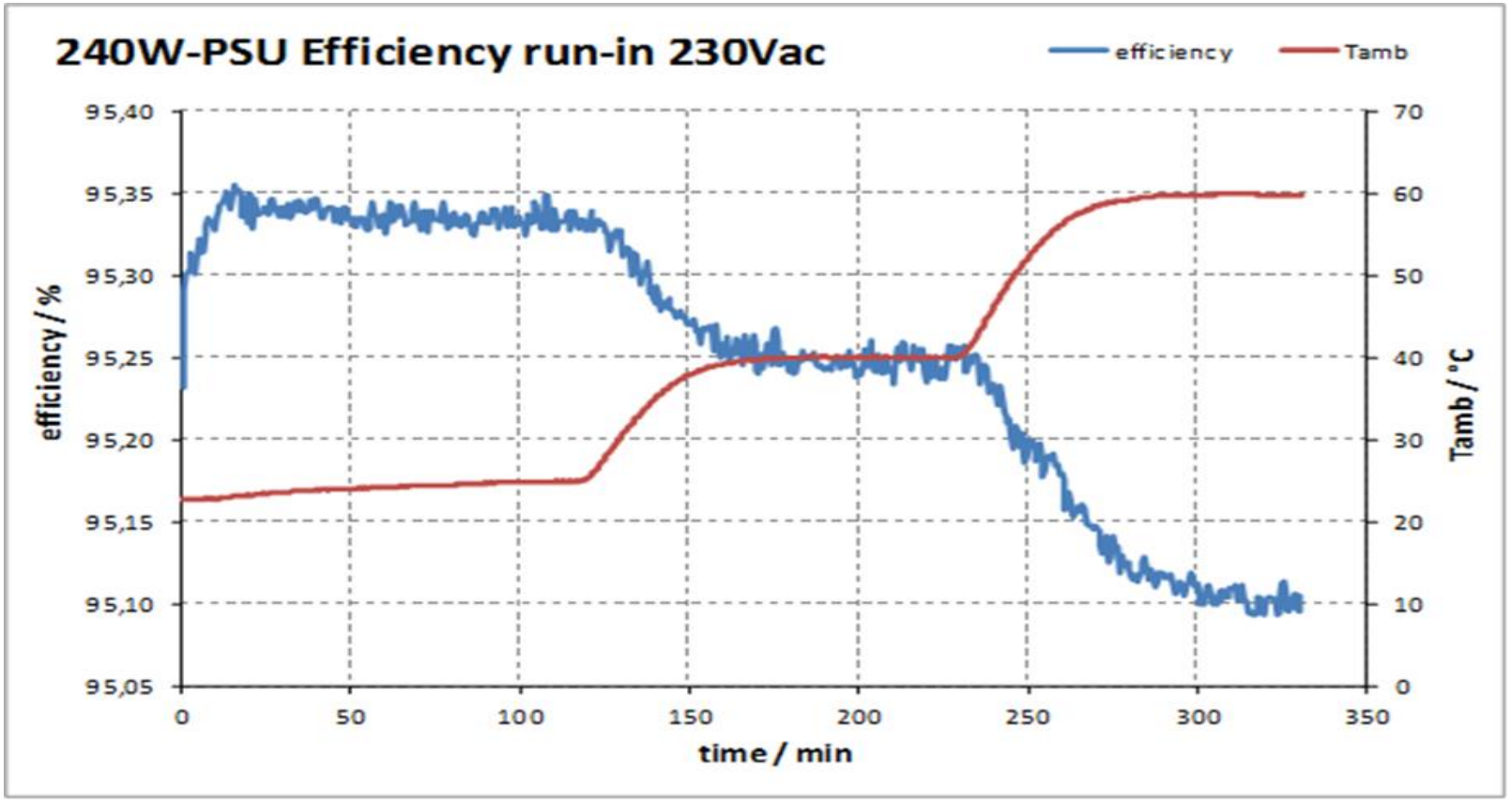
3. **Electronic AC-power sources** produce reproducible conditions.

Temperature of the device under test – old technology



- **1%** rise in efficiency after switching on
- Input inrush NTCs become warm and have fewer power losses
- Component temperature: Self-heating (time) + ambient temperature

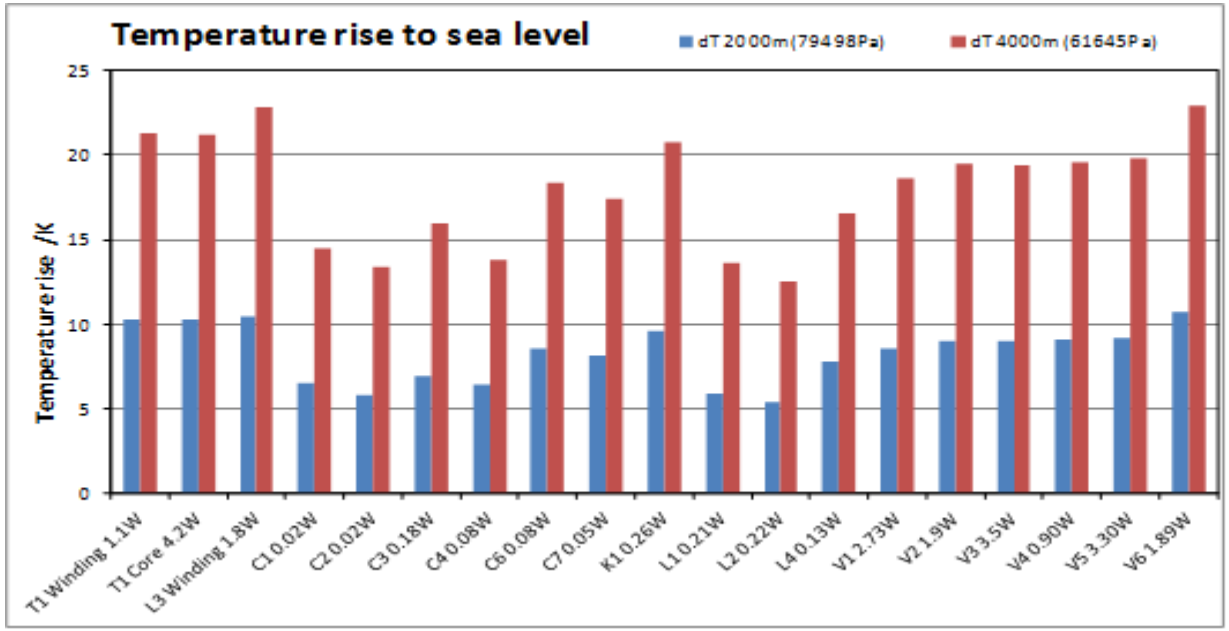
Temperature of the device under test – new technology



- **0.23%** change in efficiency over temperature
- Active input inrush current limiter instead of NTCs

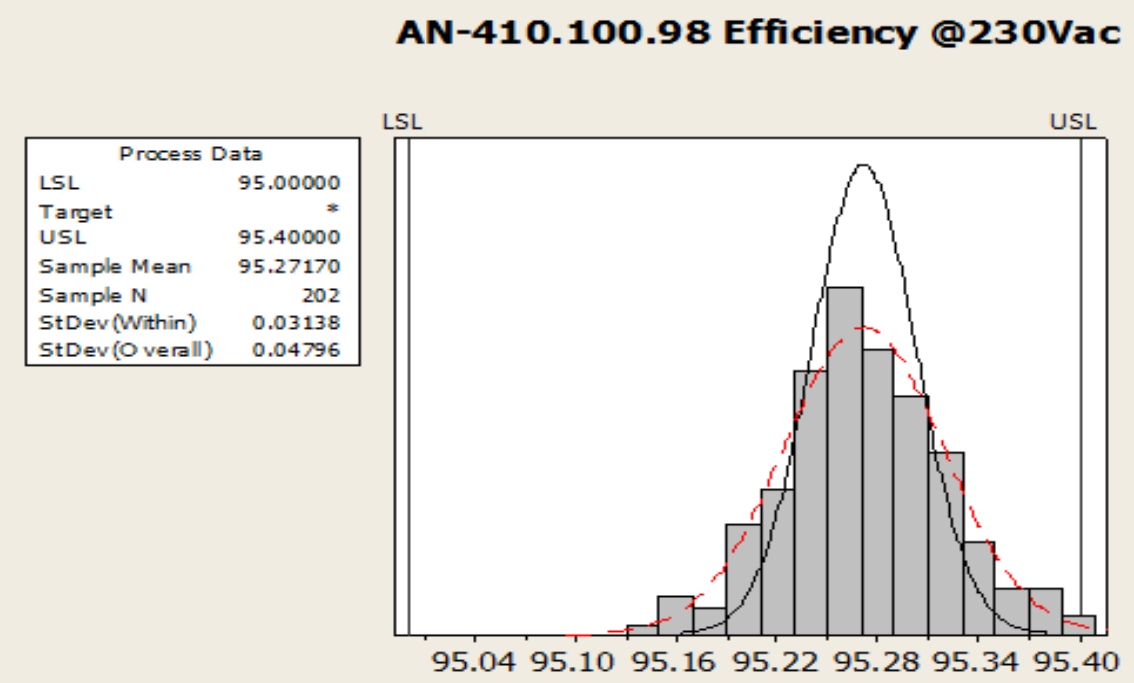
Factors influencing the temperature of the device under test

- **Altitude** above mean sea level



- **Mounting position** because of self-heating
- **Test sequence** because of self-heating
- Humidity has practically no influence

Sample distributions – measurements in production



Mean 95.27% **Range +/-0.15%**

Min. 95.13% Max. 95.43%

Batch size 202 units

Conclusion – five recommendations

1. Highly accurate **measuring instruments**, if possible use wattmeter or better still power analyzer.

2. Make sure the **cabling** is correct and that you are measuring the correct voltage.

3. For AC, if possible use an electronic **AC-power source**.

4. **EMC interference** from the device under test.

5. Pay attention to influences of **temperature** and time.

Bibliography:

[1] *Schönenberger, H.; Grigore, V.; Stiedl, A.:* Accurate Efficiency Measurements, White Paper. European Power Supply Manufacturers Association, (EPSMA) 2015.

[2] *Müller, Lukas, PULS GmbH*: Kleiner Unterschied – große Wirkung, Elektronik (Small Difference – Big Effect, Electronics) special edition Power II-2015 dated 27 October 2015.