We help ideas meet the real world

DELTA

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"Electronic drivers for LEDS - why are many failing ?"

Birger Schneider, DELTA a part of FORCE Technology

Source: Ford Motor Company

- *Concerns about reliability and maintenance of street lighting are not a new phenomena*

Shortest life component controls the system life

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- *LED lighting consists of an LED element and an electronic driver in additions to optics, etc..*
- *The LED light element itself may have a life timer of >100.000 hours.*
- *The electronics of the driver, however, may have a much shorter life.*
- ***In any system, it is the element with the shortest life that controls the life of the system.***

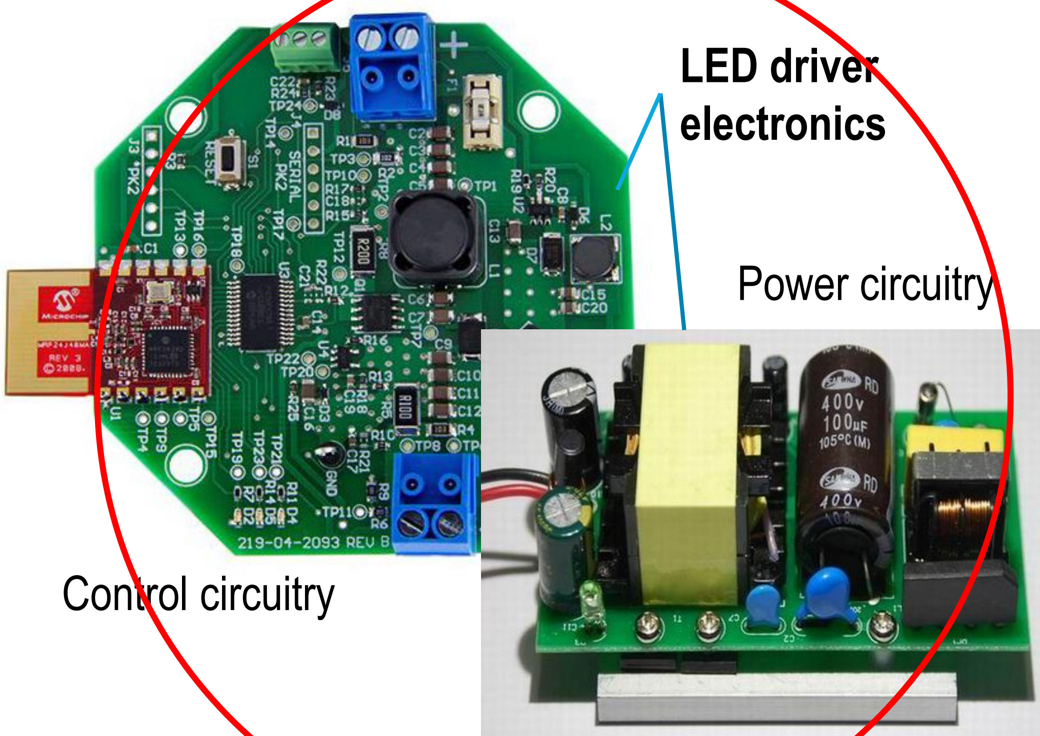
Elements of an LED light source

- *Primary components of an LED source:*
  - *LED diode (chip)*
  - *LED power driver & control*

Integrated LED source

LED driver electronics

Power circuitry

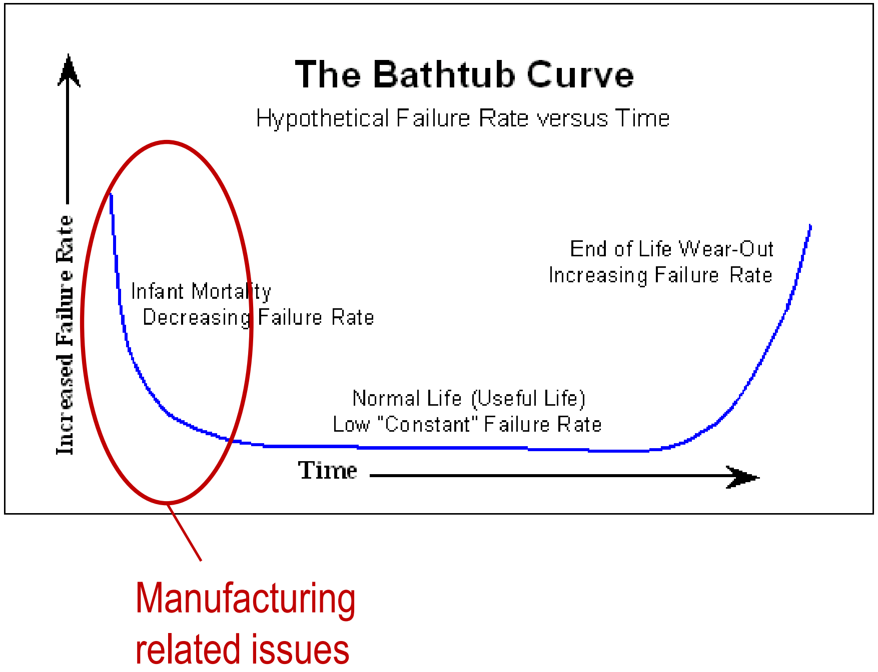


Control circuitry

Diskrete LED source incl. separate
LED element & ***electronic driver***

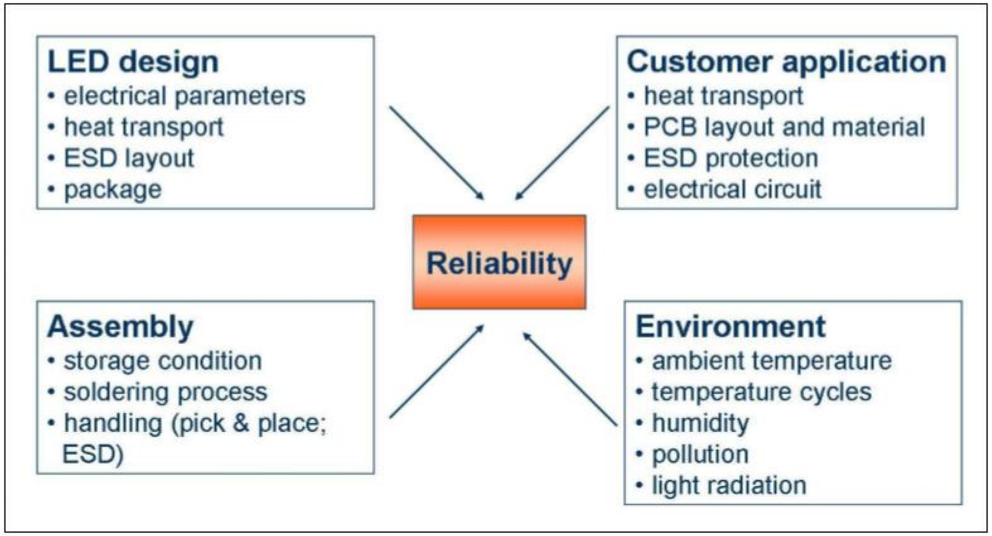
Life cycle

- *LED lighting lifetime is basically governed by driver electronics.*
- *As such the reliability for LED lighting follows the basic rules of electronics.*
- *Some major considerations controls the life of the systems:*
  - ***Thermal conditions***
  - ***Critical components***
  - ***Influence of manufacturing process***
  - ***Electrical environment (transients)***



Reliability factors

- *Reliablity of drivers are affected by several factors:*
  - *The design*
  - *The assembly*
  - *The application*
  - *The environment*



What do users experience (street lighting)?

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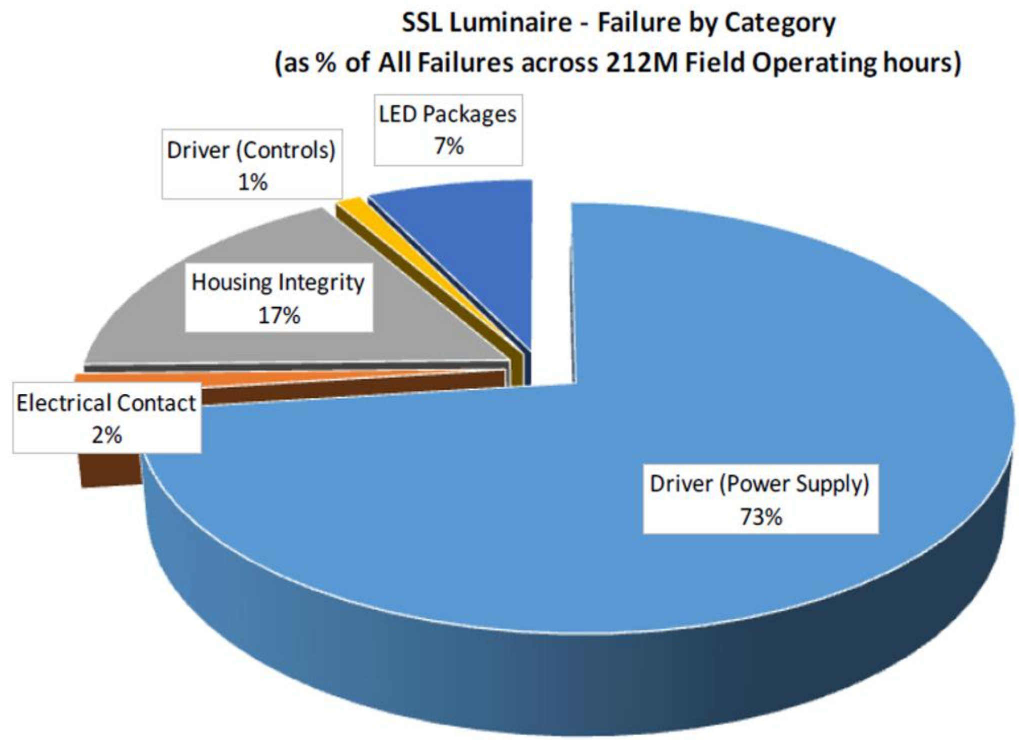
- *A US study by Appalachian Lighting Systems (212 million hours of field use).*
  - *>5% over 7 years*
- *A Danish study by ÅF Lighting in 2017 (8 large municipalities & 4 energy suppliers)*
  - *On average >4% failures, 80% of these related to electronic drivers*
  - *5% of luminaries substituted*
  - *2% repaired*



Causes

- *Driver problems may have several causes.*
- *Some typical causes are related to:*
  - *Themal effects*
  - *Critical components*
  - *The elctrical environmnet*

Thermal Effects

Limiting thermal conditions

- ***High temperatures*** *(junction temperatures are critical to electronics components).*
  - *Junction temperature depends on:*
    - *Input power*
    - *Heat removal*
      - *Junction to case*
      - *Case to ambient*
- ***Temperature cycling*** *may often be critical (creates mechanical tension in components)*
  - *Stress depends on:*
    - *Type of component*
    - *Temperature extremes (Tmin, Tmax)*
    - *Rate of change of temperature*
    - *Potting*
    - *Others*

Estimations of life at elevated temperatures

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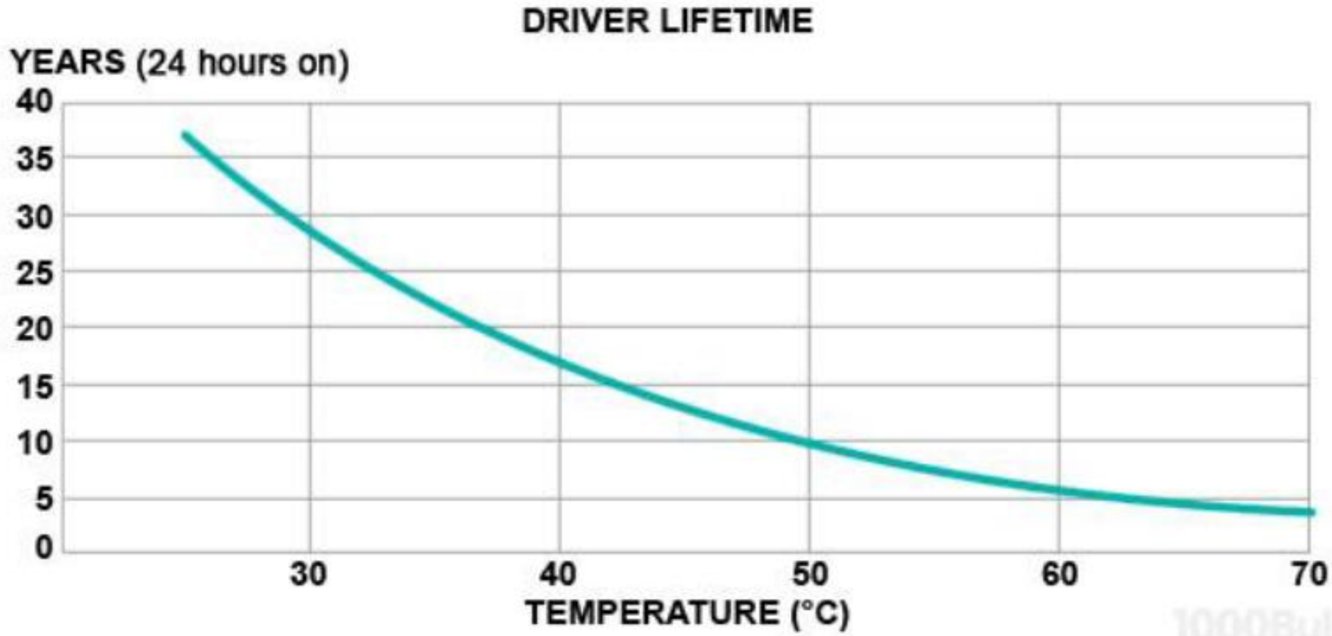
- *If a driver is used at a temperature close to its limiting temperature "TC point", it will have a shorter lifespan than if it were operated at a lower temperature.*
- *A high TC point will ensure a longer life than drivers with a low TC point.*

Hotspot temperatues



Source: 1000bulbs.com
”Understanding LED drivers”

Some typical Mfr. guarantees

- *Many electronics drivers come with fine lifetime estimations – but reality sometimes is often cruel.*
- *According to Illuminating Engineering Society, IES, ”rated life” like B_{50} at 10.000 hours, means that at least 50% of the units will survive 10.000 hours of life.*
- *Some examples:*

	Life time [Hours]	MTBF [hours]	Comments
Driver 1	50.000		T_{case} max= 80°C, $T_{ambient}$ max =50 °C
Driver 2	79.000	484.000	80% load, $T_{ambient}$ =45 °C
Driver 3	50.000		Typical 116.000 hours
Driver 4	120.000	600.000	Life at 80% load, T_{case} = 60°C, T_{case} max= 75°C, MTBF at 25 °C

High Temperatures critical - Temp cycling may be worse!

- *Many electronics drivers come with fine lifetime estimations – but sometimes reality is cruel:*
  - *In one project almost 50% of all lamps (several thousands) failed within 3 -4 years after installation*

Potting of electronics

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- *Potting of electronics is normally considered a good approach (better mechanical protection, better humidity resistance, with correct filler use also better temperature distribution, etc.*
- *But potting can also create problems !*

IP rating chart

- *Ingress protection (IP) tell users the environmental protection that a driver's outer casing provides.*

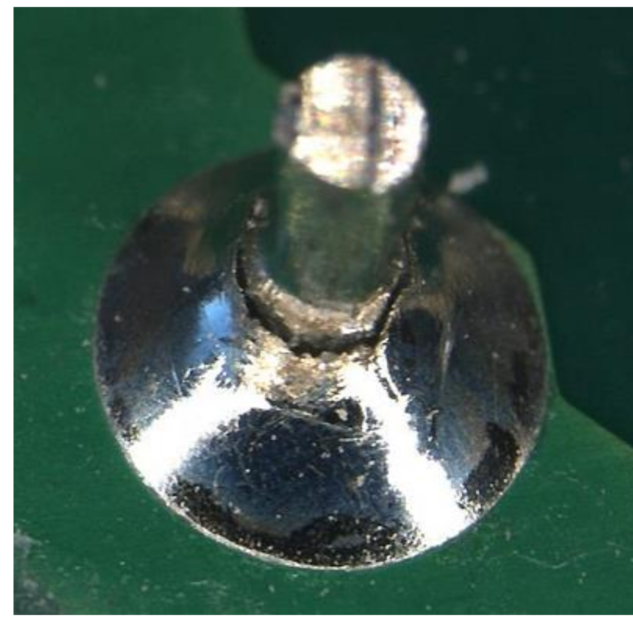
1st Digit	Solid Object Protection	2nd Digit	Water Protection
0	Not protected	0	Not Protected
1	Protected against solid objects greater than 50mm (e.g. accidental bump of hand)	1	Protected against vertically dripping water
2	Protected against solid objects greater than 12.5mm (e.g. fingers)	2	Protected against sprays of water when tilted up to 15 degrees vertically
3	Protected against solid objects greater than 2.5mm (e.g. tools and wires wires)	3	Protected against sprays of water when tilted up to 60 degrees vertically
4	Protected against solid objects greater than 1mm (e.g. small wires)	4	Protected against water sprayed in all directions
5	Protected against dust	5	Protected against low-pressure jetting water from all directions
6	Dust tight (total protection)	6	Protected against powerfully jetting water from all directions
IP 6 7 — Code Letters, 1st Digit, 2nd Digit		7	Protected against temporary immersion in water (under 30 minutes)
		8	Protected against continuous immersion in water

Potting

- *Thermal cycling applications:*
  - *A high Tg indicates that the adhesive will perform well as temperatures rise, while flexibility allows the adhesive to absorb thermally- induced stresses and resist cold-temperature brittleness.*
- *Challenges*
  - *Wear/abrasion*
  - *Cracking*
  - *Loss of adhesion*
  - *Bubbles*
  - *Blistering*
  - *Charring*
  - *Degradation*
  - *Lack of sufficient fillers*
  - *Chemical attack*

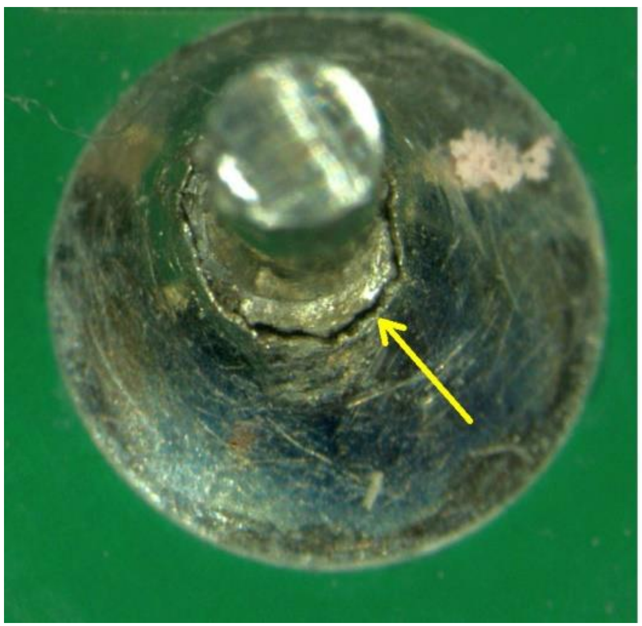
Temp cycling may cause mechanical tension!

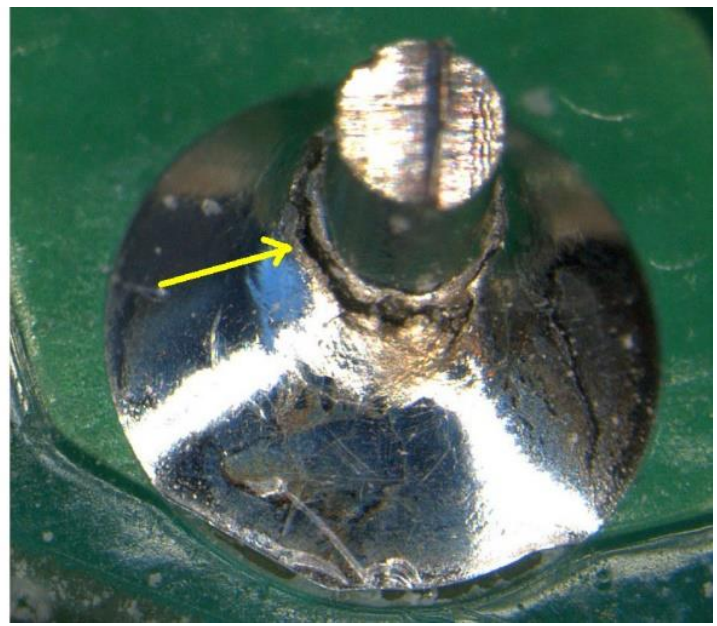
- *Temperature cycling can prove a much more difficult challenge than high temperature.*
- *E.g. on a cold winter day, the ambient temperature may change from -10°C to + 50°C, TC point temperature even more.*



Soldering broken

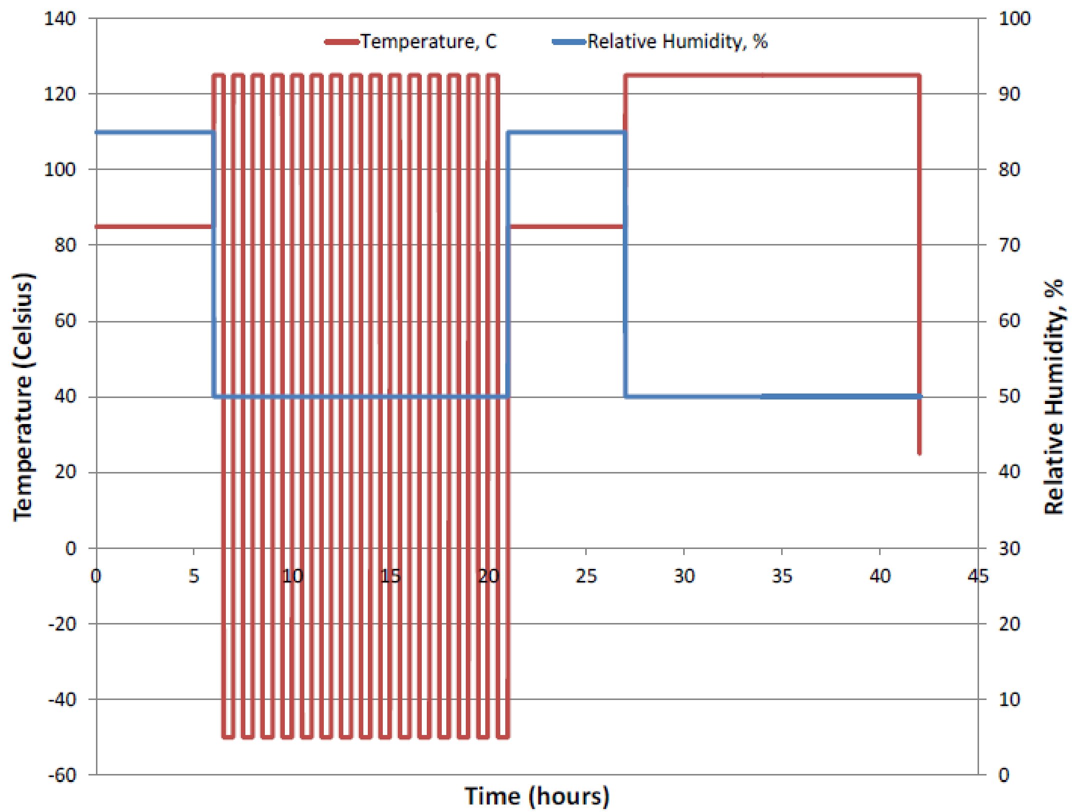
- *Axial leads on large components are under extensive mecahnical tension during temperature cycling.*





The ”Hammer” test for luminaires
(accelerated life testing)

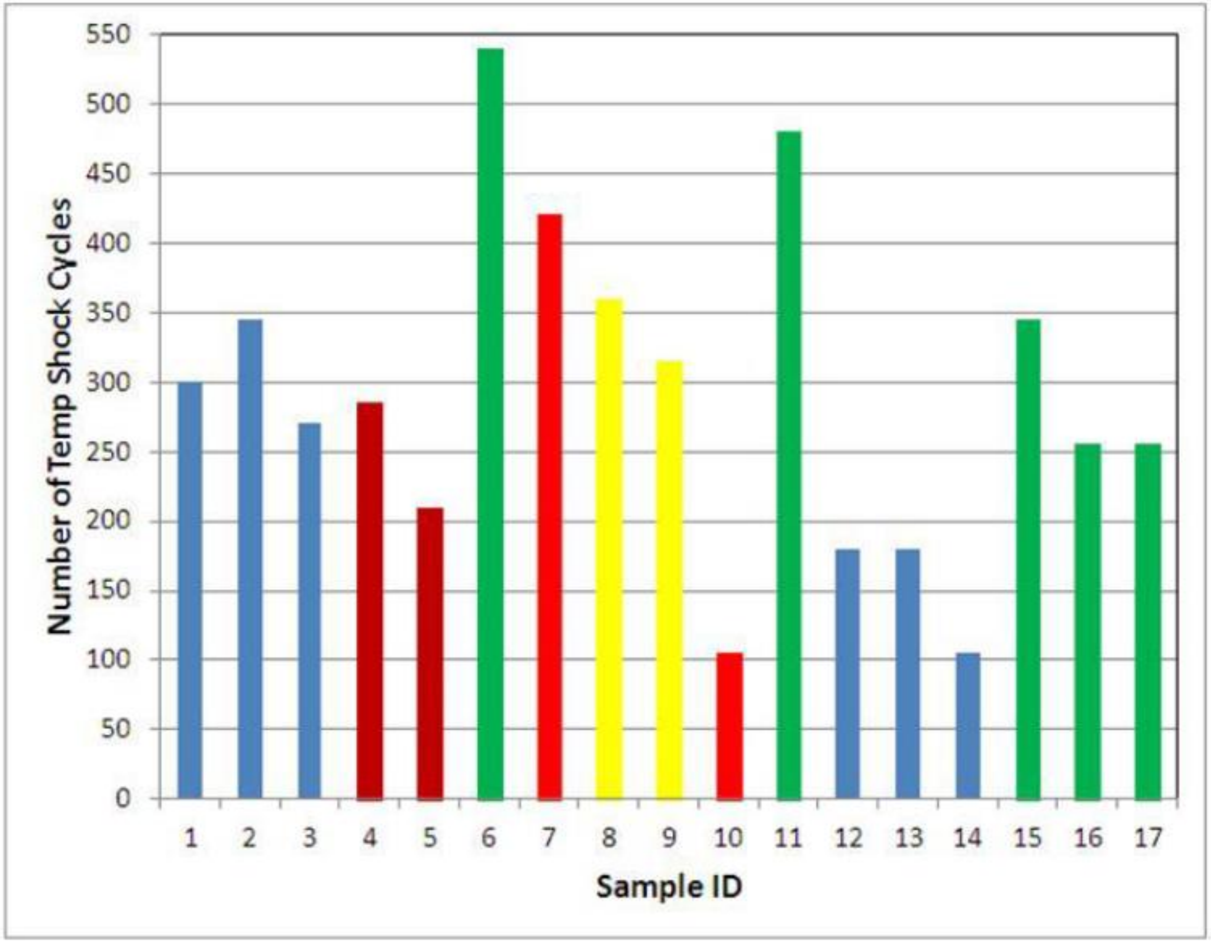
- *Stage 1: Steady-state temperature humidity biased life test consisting of 6 hours at 85°C and 85% relative humidity (RH).*
- *Stage 2: Temperature shock consisting of 15 hours cycling at –50°C to +125°C (air-to-air). Hold time at each extreme was 30 minutes.*
- *Stage 3: Steady-state temperature humidity biased life test consisting of 6 hours at 85°C and 85% RH.*
- *Stage 4: High-temperature operational lifetime consisting of 15 hours at 120°C.*



Source: Hammer Testing Findings for Solid-State Lighting Luminaires ”US Department of Energy

”Hammer test” results

- *Hammer test performed on luminaires for in-door applications.*
- *Code:*
  - *Blue: PCB failure*
  - *Dark red: Capacitor*
  - *Light red: Other components.*
  - *Yellow: Solder interconnects*
  - *Green: Still operating.*



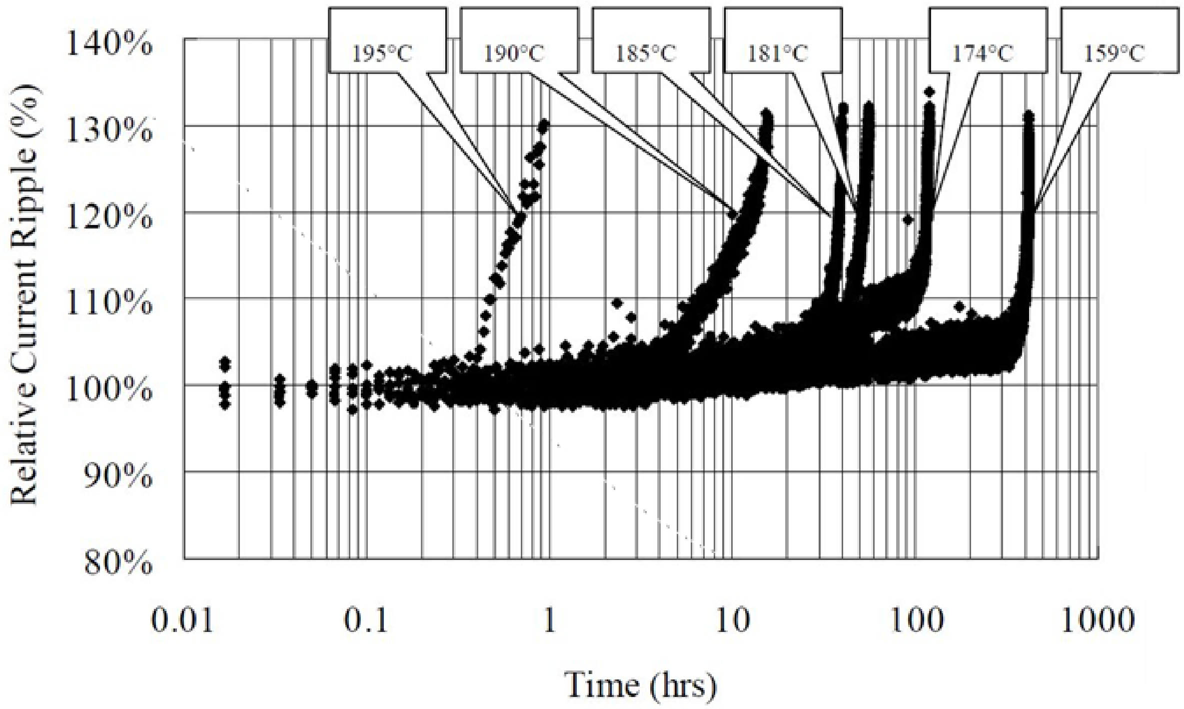
Critical Components

Components that may prove critical

- *Electrolytic capacitors*
- *Varistors*
- *Microelectronics*
- *Others*

Critical components in electronic drivers

- *Electrolytic capacitors are frequent causes of errors in electronic drivers*



The electrolytic capacitor – a critical component

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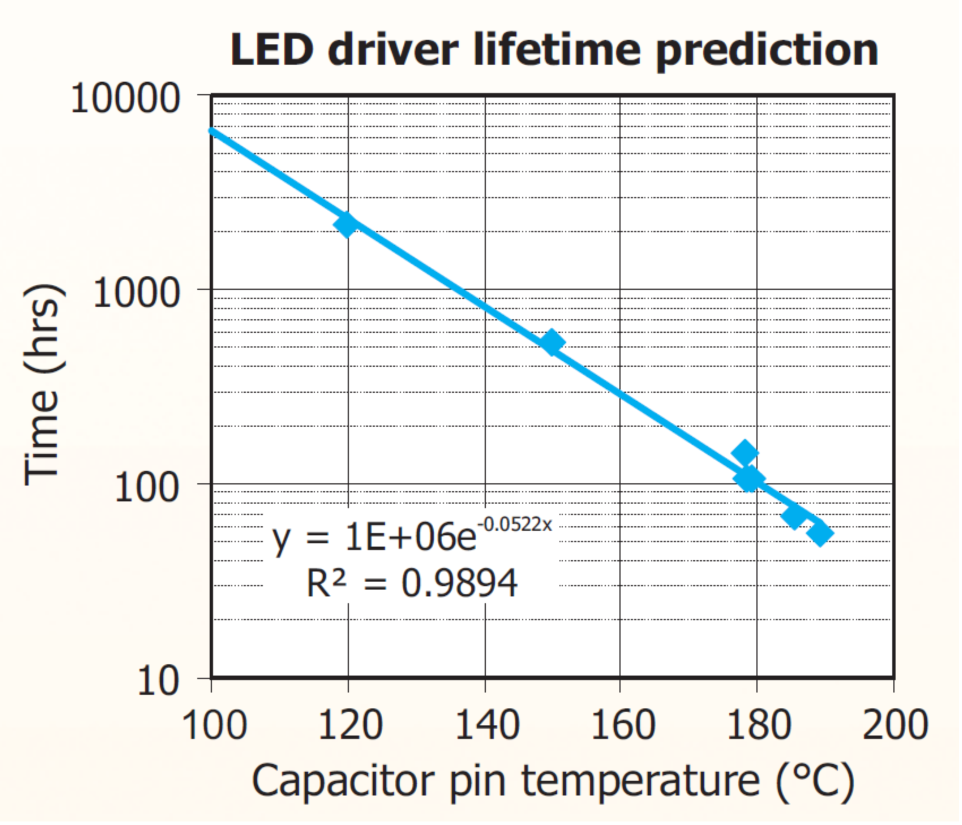
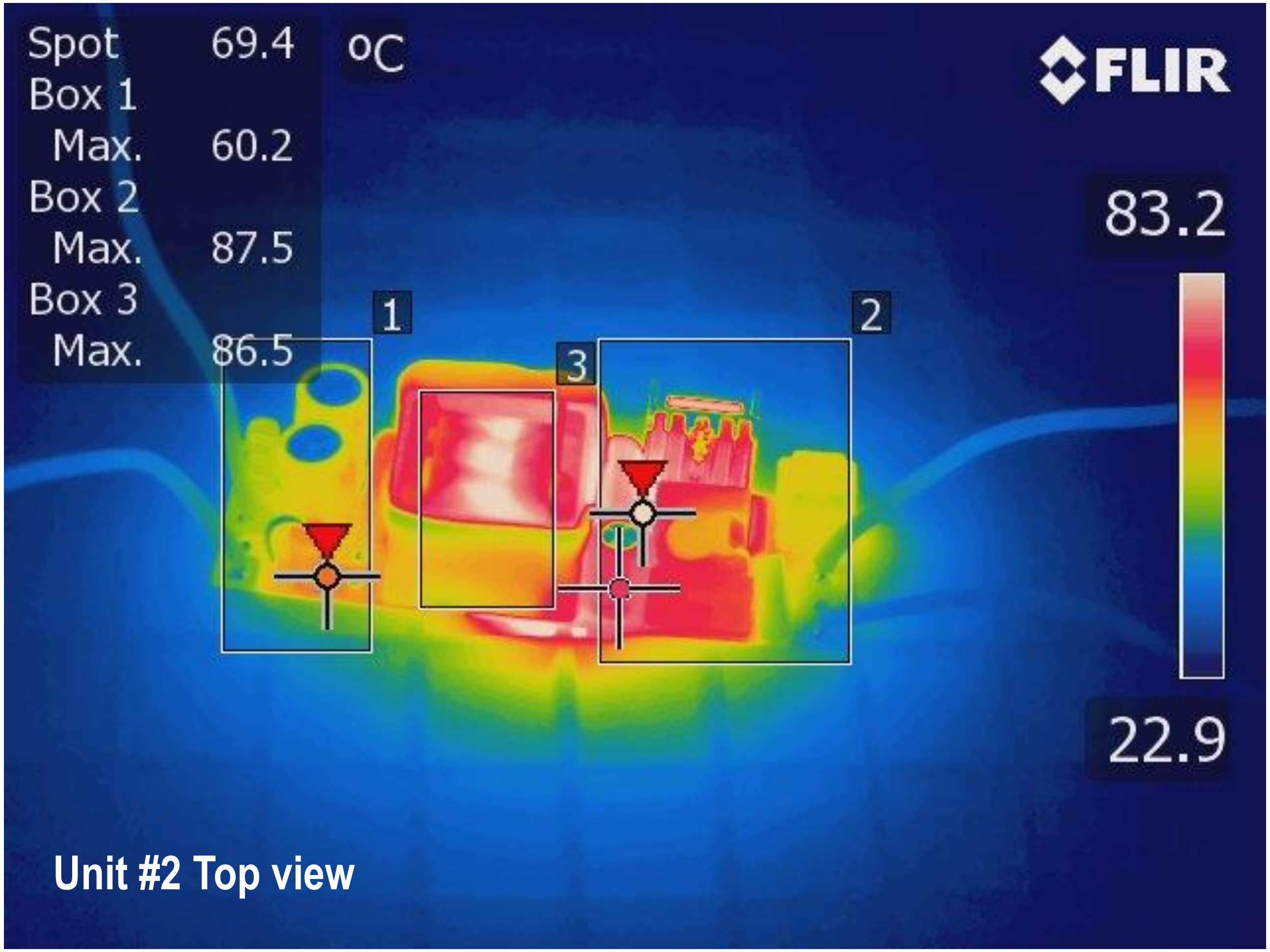
- *Experiments have shown that electrolytic capacitors are typical the most sensitive electronic component in term of reliability.*
- *In the example (right):*
  *T_A = **85°C** and T_{PIN} = **100 °C**.*
  Estimated lifetime approx. 7.000 hours.
- *For every 10°C increase in temperature, the life time typically decreases by 50%.*
- *Electrolytic capacitors come in many classifications.*
  – *Look for long-life electrolytic capacitors*



Source: Lighting Research Center
Rensselaer Polytechnic Institute, USA

- *Other components such as varistors, microelectronics, etc. may also be limiting factors of a design.*
- *At TestForum 2015 in Oslo, I showed some examples of critical microelectronic parts in driver design.*

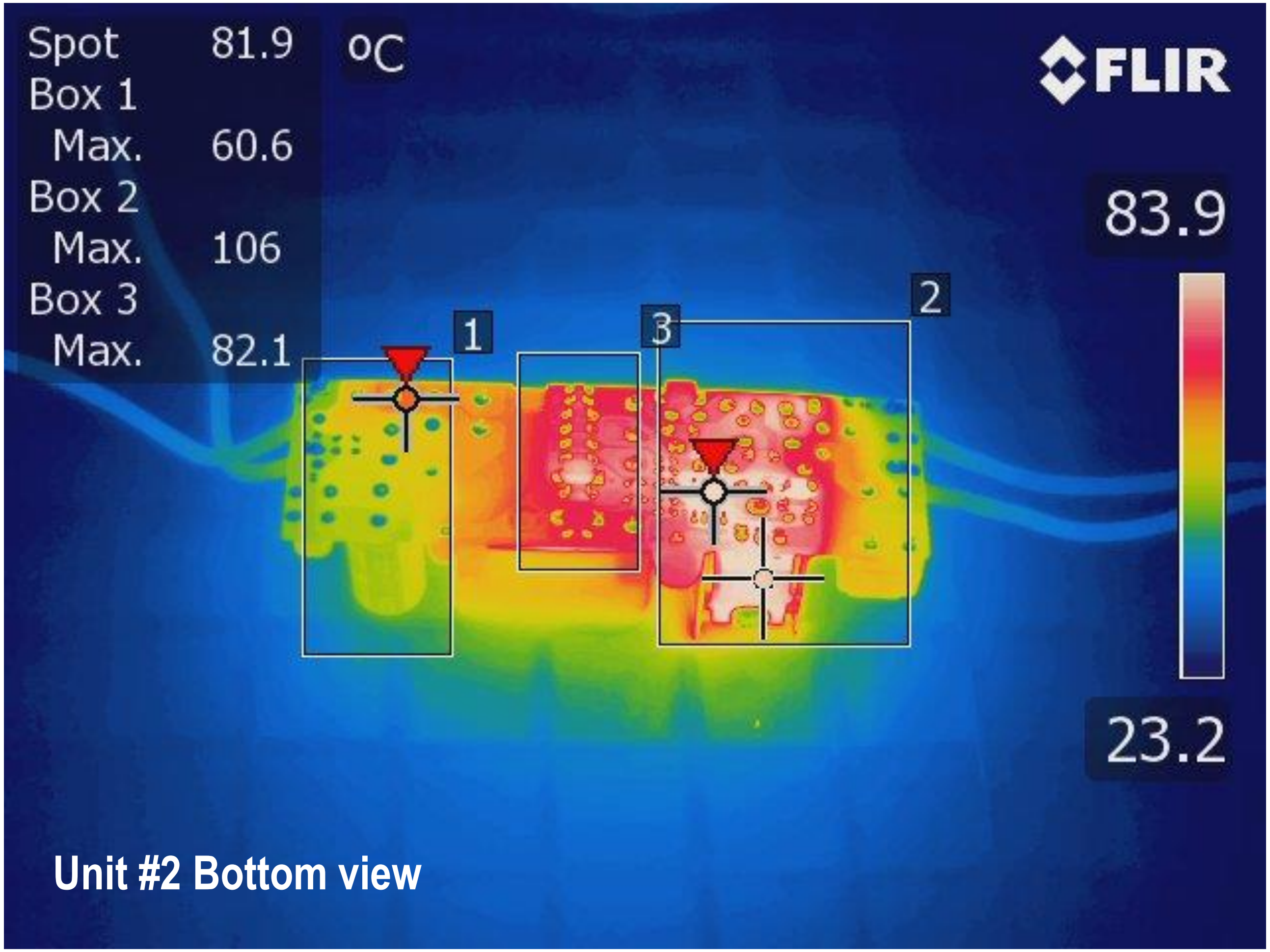


Shenzhen Qihan Power Co.,Ltd.

230V AC

QH-40W10-18x3W							
Vac	Vout	Iout	Pin	Pout	Efficiency	Max T1	MaxT2
100 VAC	58	0,493	37	28,6	77%	87,5 diode bridge	Transformer 84
230 VAC	58	0,543	39,3	33,75	80%	87,5 Transformer	84 PCB
100 VAC B						80 snubber diode	74 Power IC
230 VAC B						106 IC?	82 snubber diode/PowerMOSFET

Source:
DTU Electro



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Source:
DTU Electro

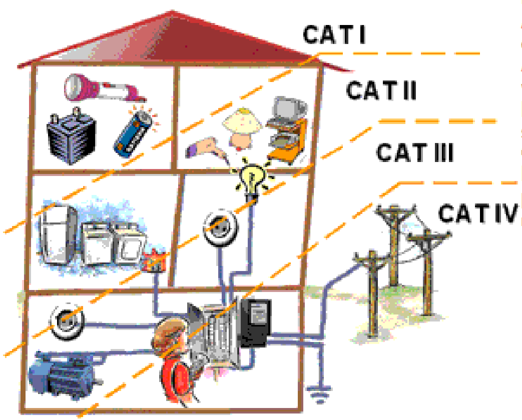
Electrical environment (transients)

Electrical application environments

- *Electrical applications environments have different challenges whether for use in building applications or use in e.g. rough outdoor applications.*

Level	Open-circuit test voltage	
	Line-to-line	Line-to-ground
1	-	0,5 kV
2	0,5 kV	1 kV
3	1 kV	2 kV
4	2 kV	4 kV
X	Special	Special

Measuring Category
The following measuring categories have been established by the EN 61010-1 standard.

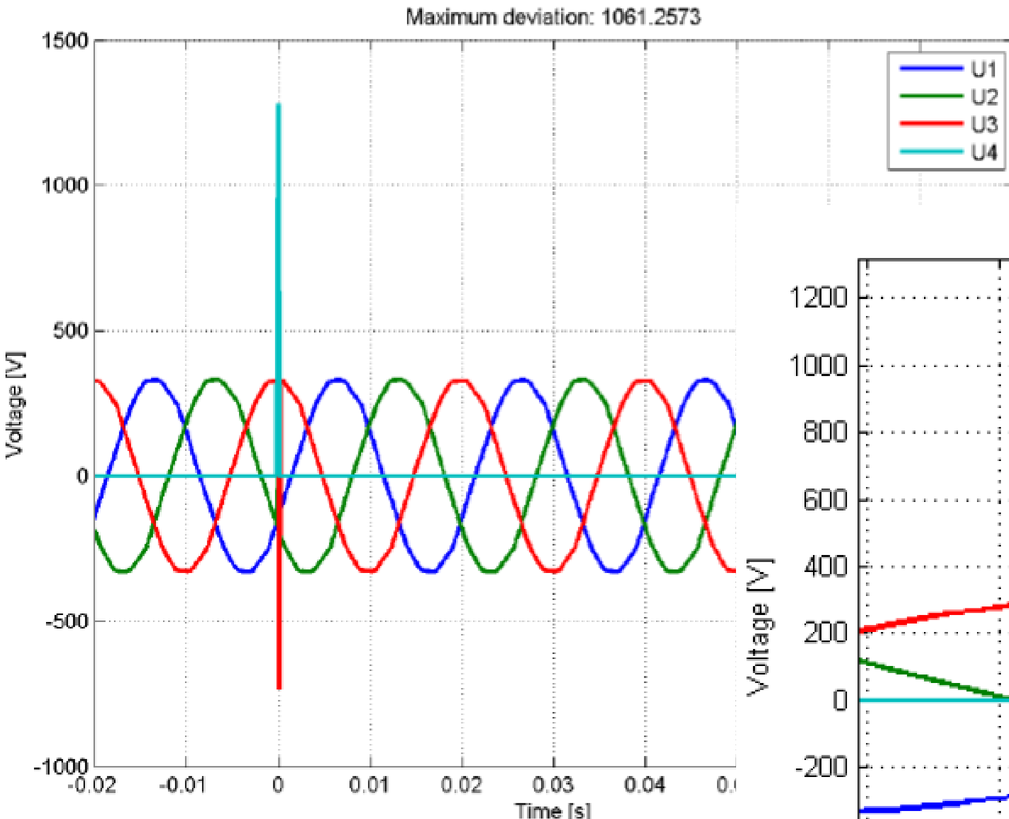


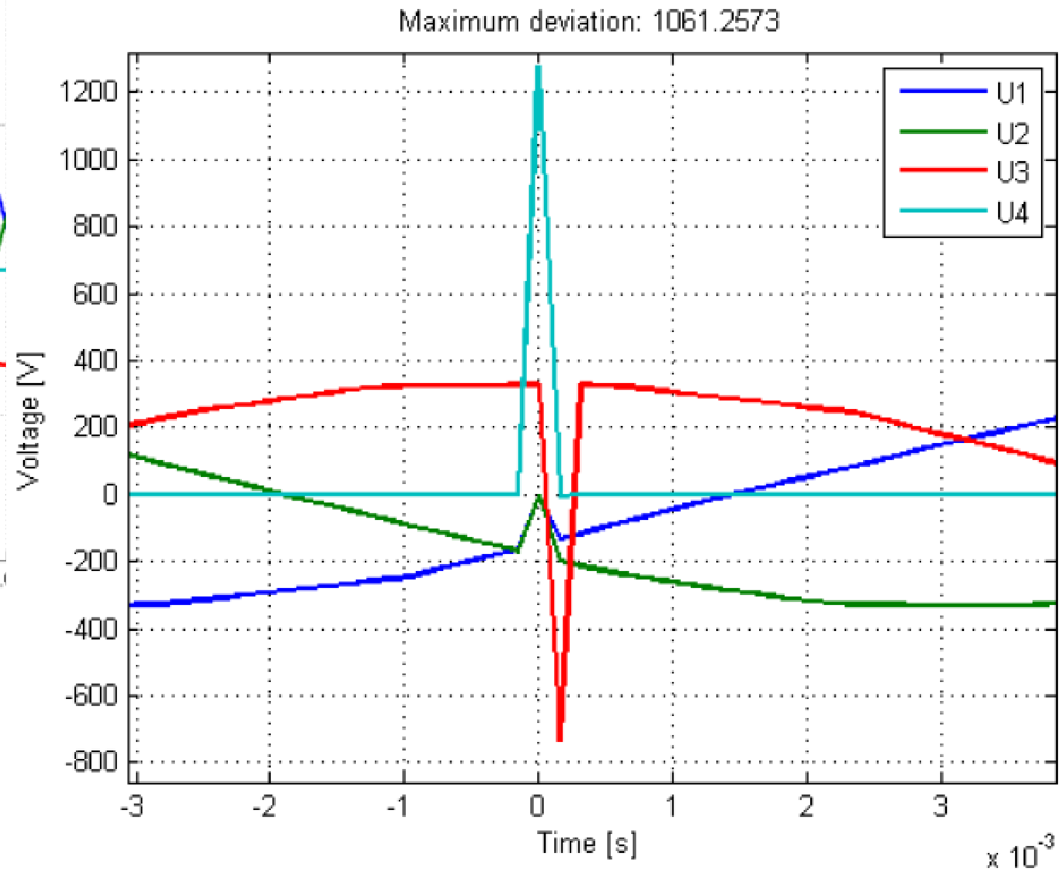
Measurements in **electrical circuits**, which:
Are not directly connected to the mains
e.g. batteries
Are directly connected to the mains
via plug, e.g. in household, office and laboratory applications
Measurements in building installations:
stationary power consumers, distributor terminals, devices connected permanently to the distributor
Measurements at
power sources for low-voltage installations:
meters, mains terminals, primary overvoltage protection

Transients, resulting for example from lightning strikes or load switching, become greater and more energetic as the distance from the point of measurement to the power source for the low-voltage system decreases.

IEC 61000-4-5:2014
Test conditions

Transients: Few millisec or less

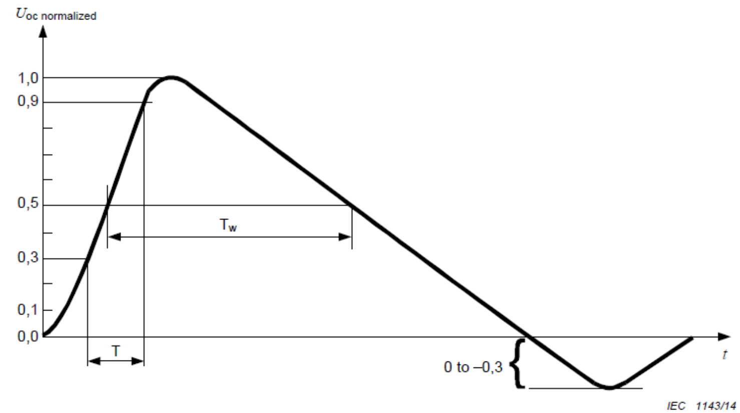




Power Quality – Denmark

- *Denmark: high quality power grid.*
- *Basically all power through cables.*
- *Systematic recordings sin 2009*
- *Approx. 70 years of accumulated recording time (22 recorders in use9*
- *Thousands of transients recorded:*
  - *>23.000 events of >100V instantaneous deviations from nominal 230V*
  - *>3.500 events of >200V from nominal 230V*
  - *Transients up to 7,5kV$_{peak}$ observed*

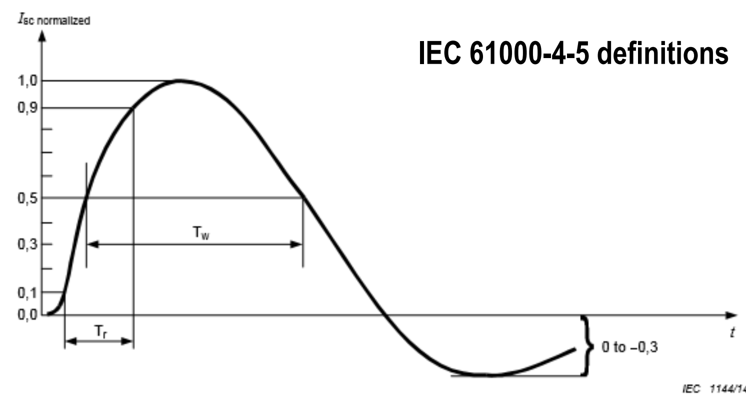
Open circuit voltage



Front time: $T_f = 1,67 \times T = 1,2\ \mu s \pm 30\ \%$
Duration: $T_d = T_w = 50\ \mu s \pm 20\ \%$

Short circuit current

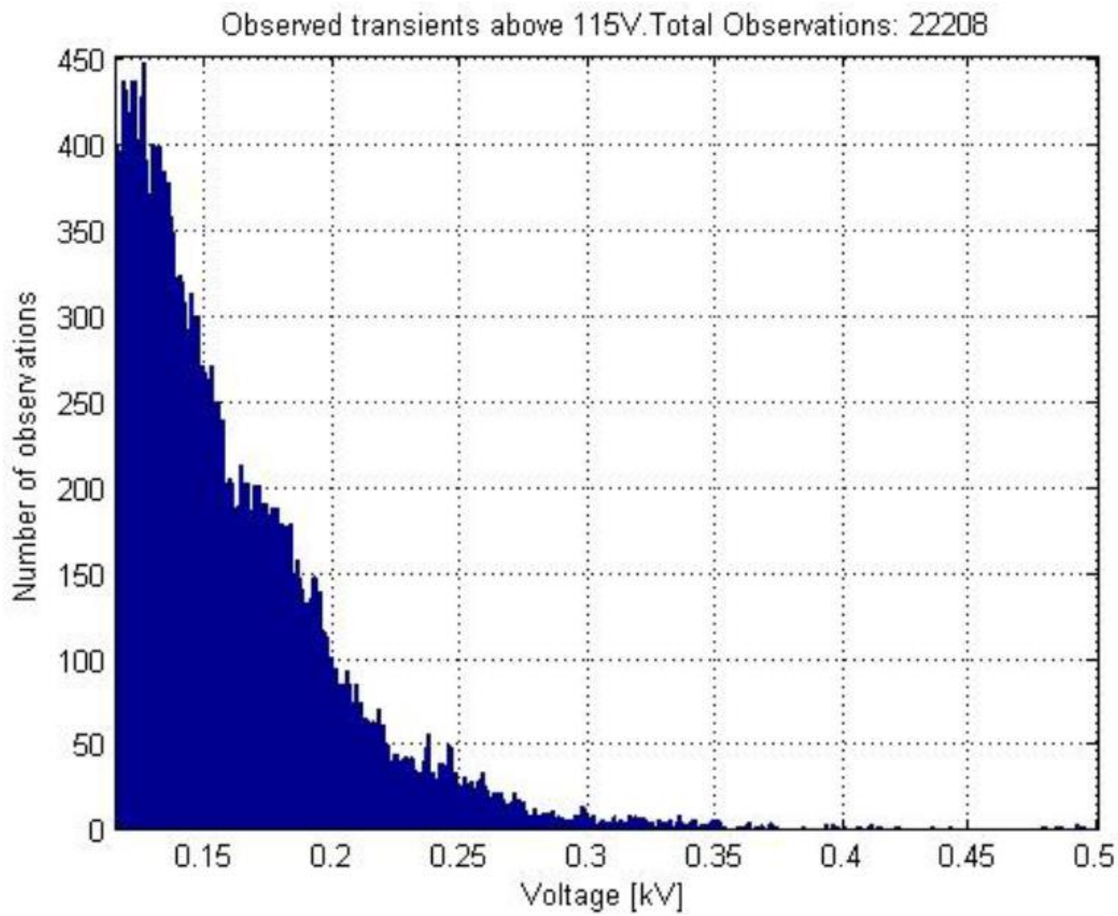
IEC 61000-4-5 definitions



Front time: $T_f = 1,25 \times T_r = 8\ \mu s \pm 20\ \%$
Duration: $T_d = 1,18 \times T_w = 20\ \mu s \pm 20\ \%$

Power Quality – Denmark

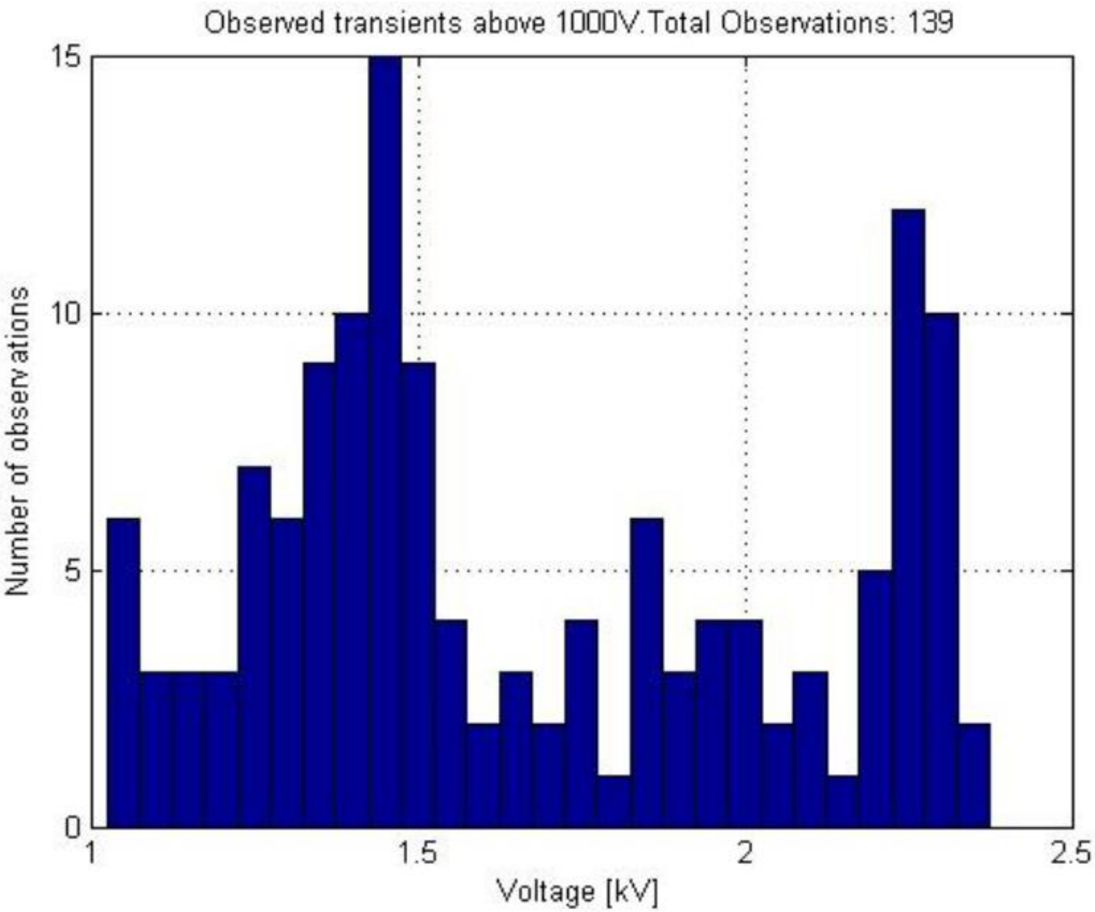
- *22.208 transients*
  115V < U < 500V
- *Majority of transients*
  < 300V_{peak}
- *Many transients*
  within ± 315 V range
- *Probability:*
  1 every 27,6 minutes



Source: Dansk Energi

Power Quality – Denmark

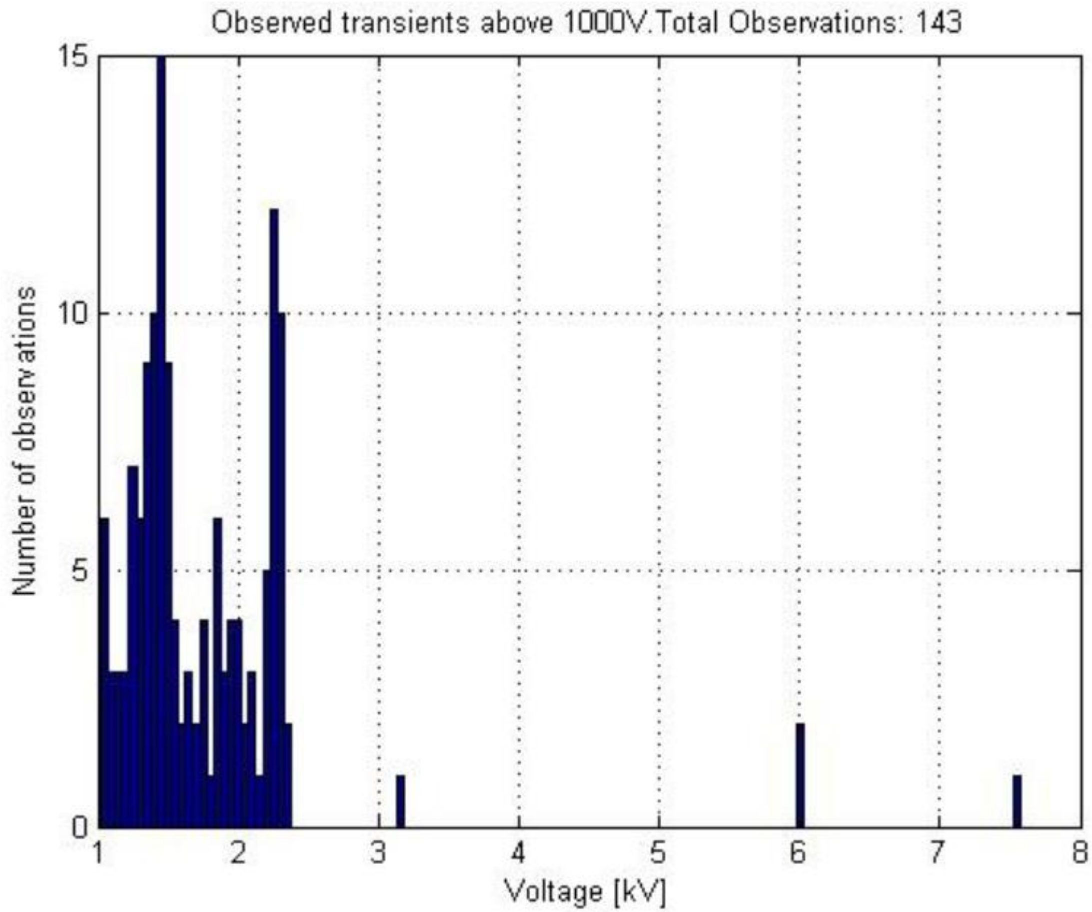
- *139 transients*
  1kV < U < 2,5kV
- *Transients between 1kV and 2,5kV are rare*
- *Probability:*
  1 every ½y year



Source: Dansk Energi

Power Quality – Denmark

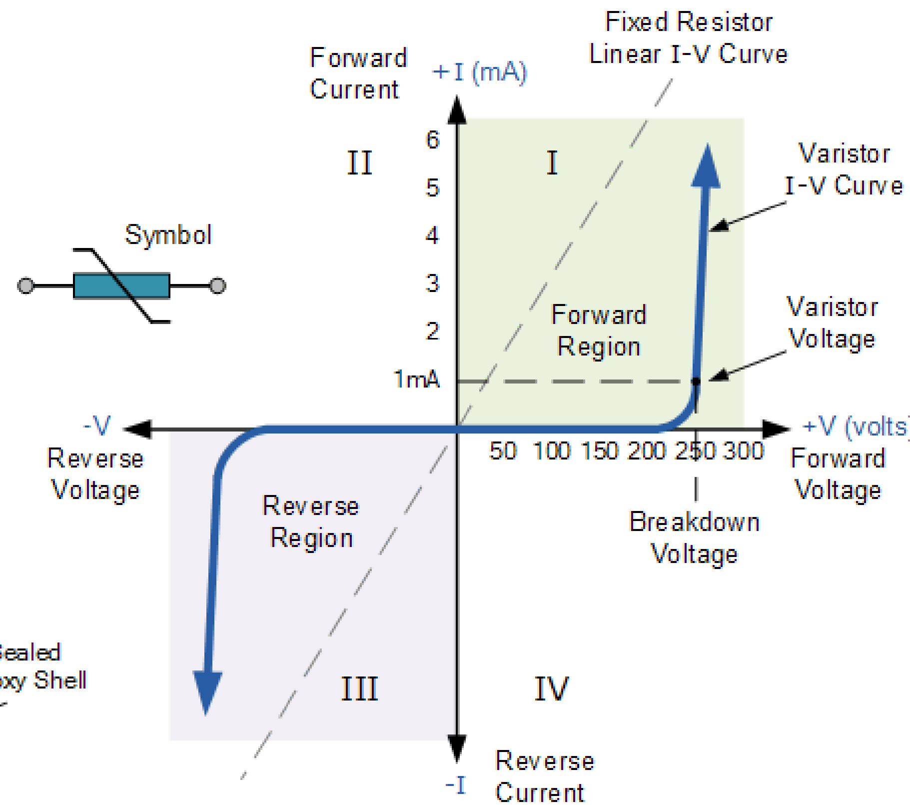
- *Only few transients above 2,5 kV are observed*
- *Probability:*
  4 transients above 2,5 kV observed I a total of 70 accumulated measurement years (= 1 in every 18 recorded years)

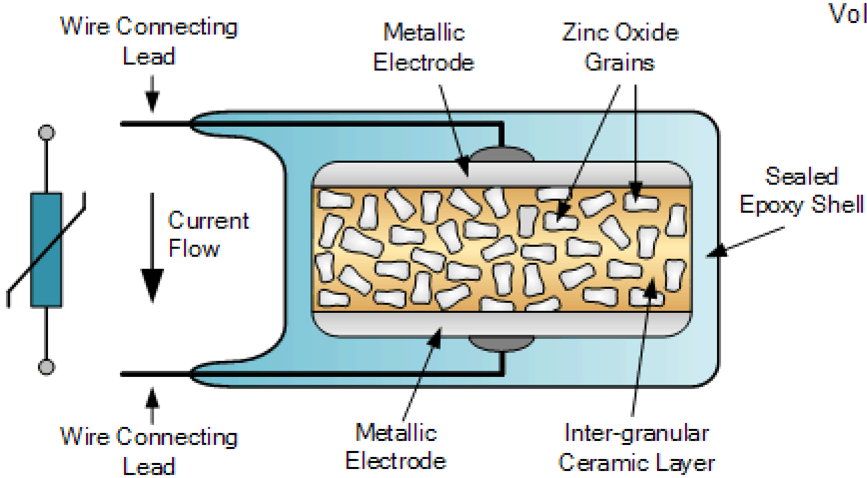


Source: Dansk Energi

Varistors

- *Varistor = **VARI**abel resi**STOR***
- *Has bidirectional characteristics making it suitable for protection.*
- *Usually based on metal-oxide technology*





Electrical overstress

- *Electrical overstress damages components, here:*
  - *Microelectronics*
  - *Varistor*