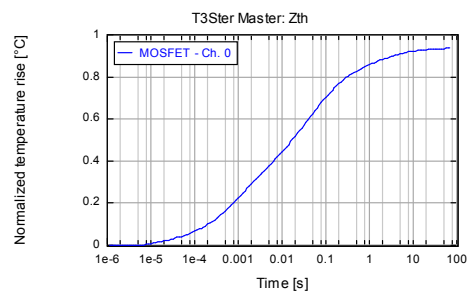


# Gallop in the linear theory

1

## What did we gain ?

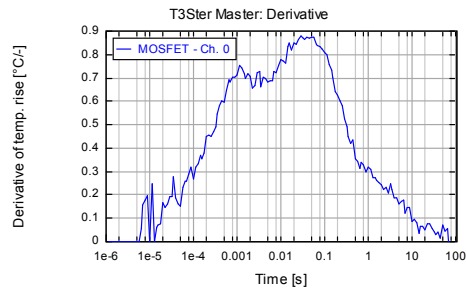
- Several **views** of the same facts
  - Zth curve



2

## What did we gain ?

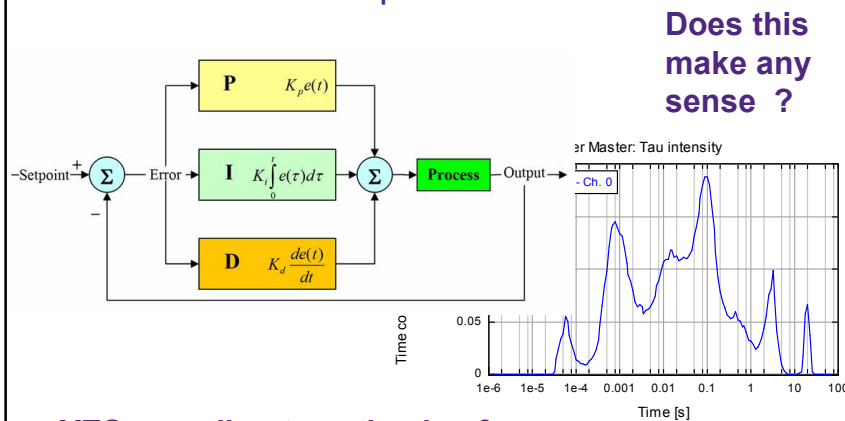
- Several **views** of the same facts
  - Zth curve
  - Derivative curve (resembles Green function)



3

## What did we gain ?

- Several **views** of the same facts
  - Time constant spectrum



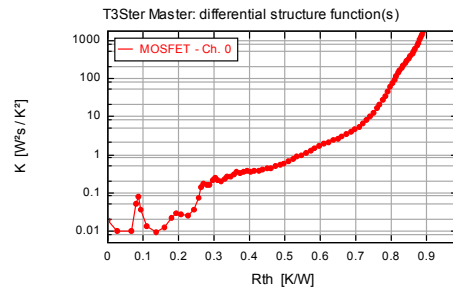
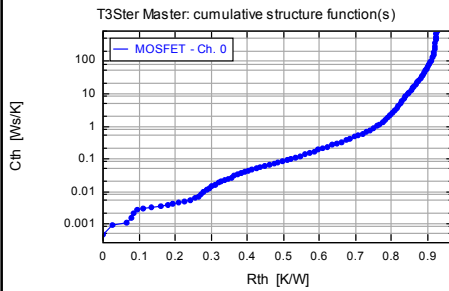
Does this  
make any  
sense ?

**YES, e.g. direct synthesis of a  
PID controller of a thermostat**

4

## What did we gain ?

- Several **views** of the same facts
  - Zth curve
  - Derivative curve
  - Time constant spectrum
  - Structure functions

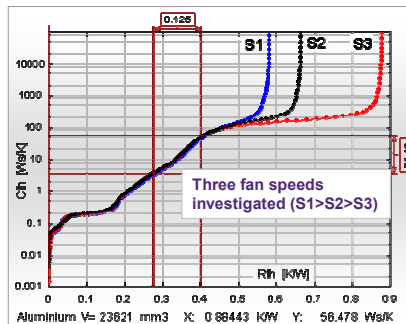
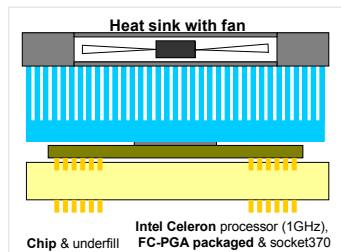


5

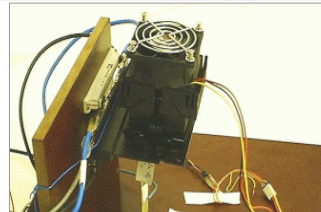
## Analysis in the structure function domain

- **Heat sink characterization**
  - Performance in application
  - All scales (inc. micro-coolers)

**Intel Celeron Processor with fan-cooled heat sink.** Thermal transient measured, cumulative structure functions calculated.



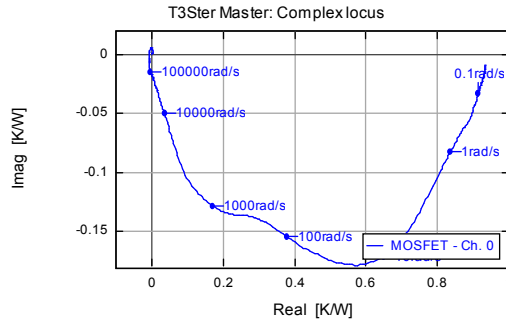
Heat sink and fan **characteristics** easily seen.  
Volume of the Al heat sink is **properly predicted**.



6

## What did we gain ?

- More **views** of the same facts
  - Complex locus



Does this make any sense ?

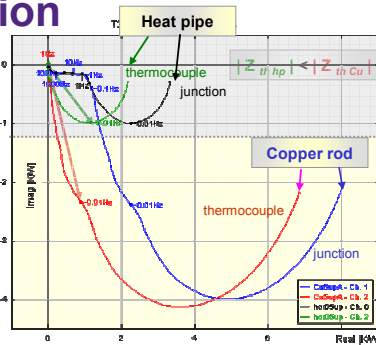
7

## Analysis in the frequency domain

### • Heat pipe characterization

- To check out  $\Delta T$  vs.  $Q$ 
  - Including speed of response
  - In any orientation
  - With heat pipe bent as per application
- Determination of critical heat flux

Thermal transient at the transistor measured, complex loci calculated.



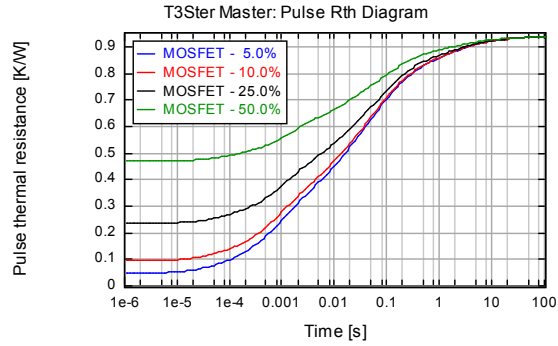
Better performance of the heat pipe proven at *all possible frequencies*, not only at steady state



8

# What did we gain ?

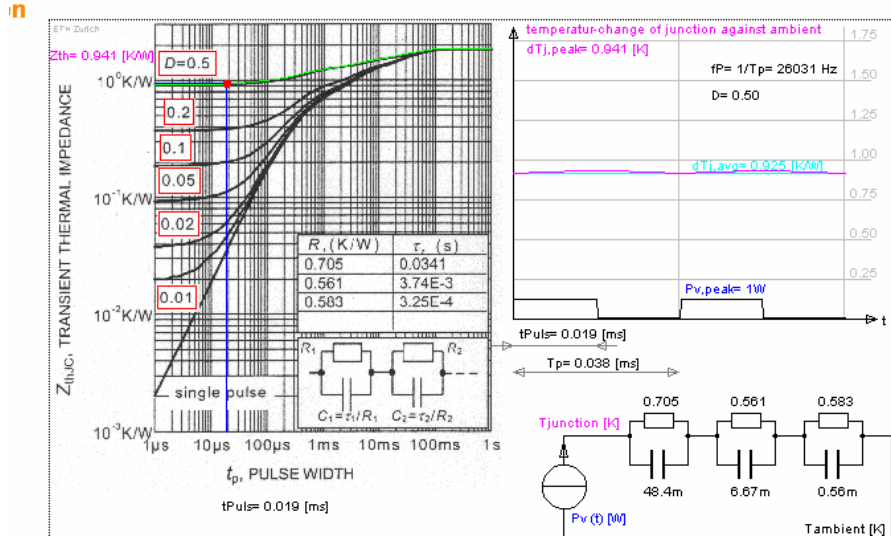
- More **views** of the same facts
  - Complex locus
  - Transient thermal impedance

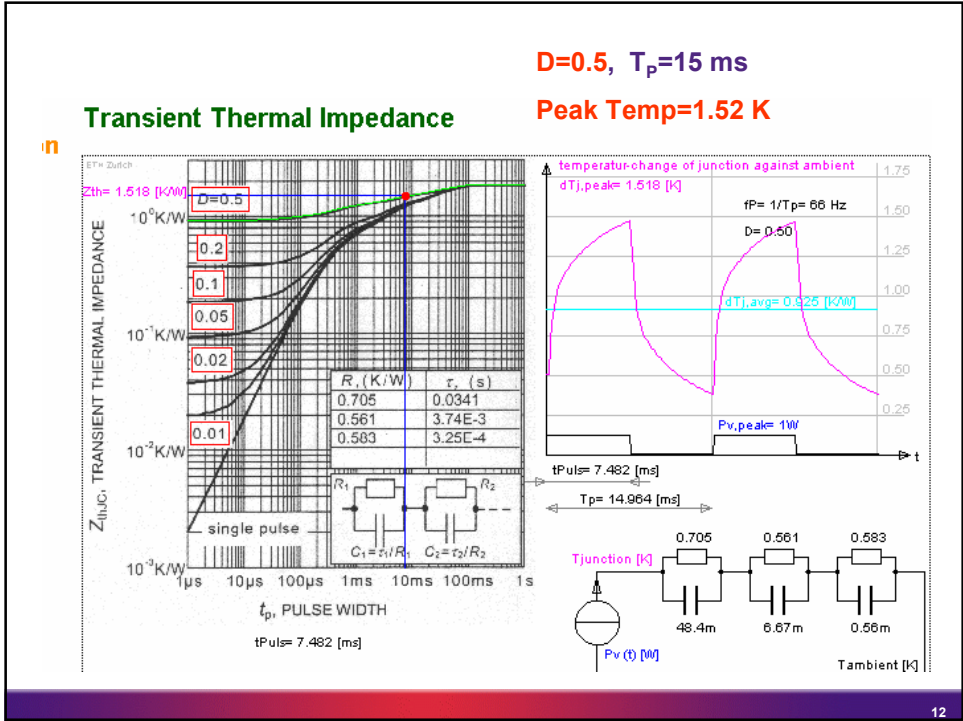
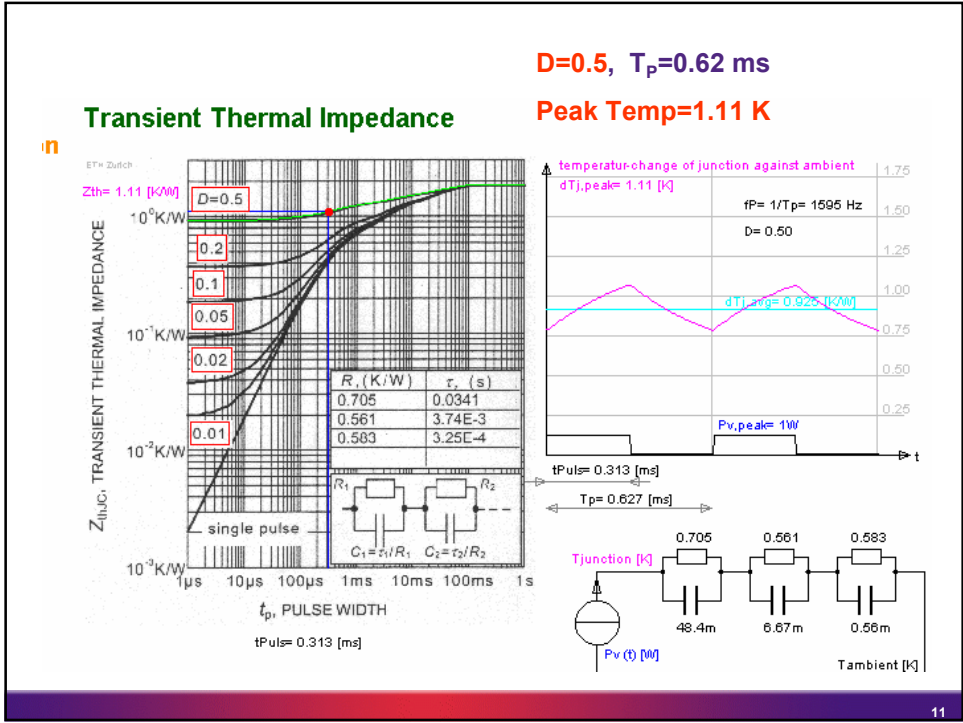


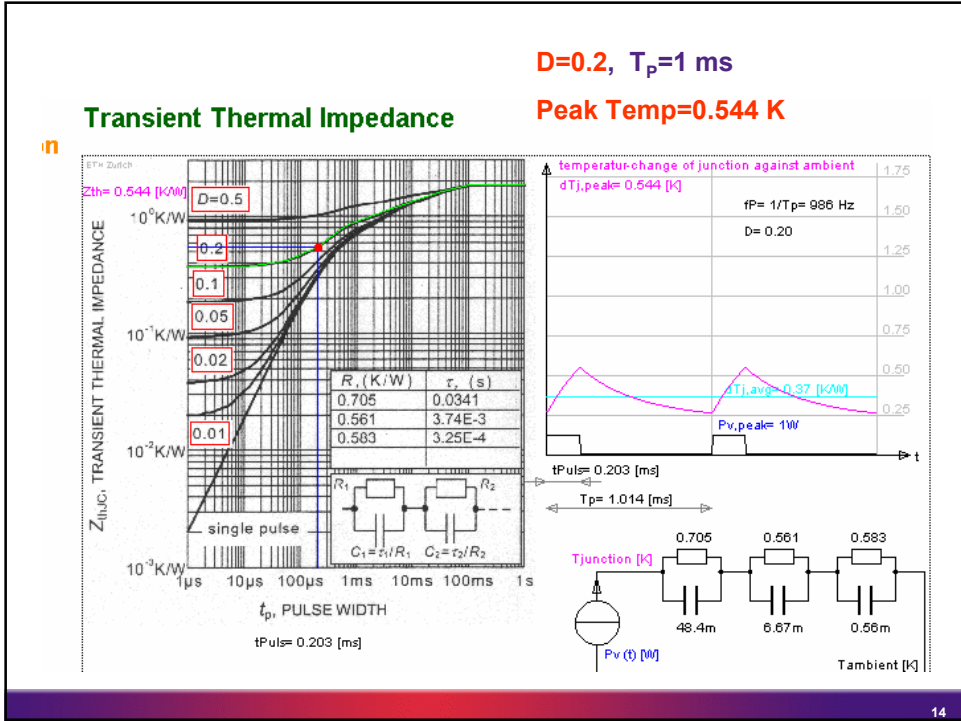
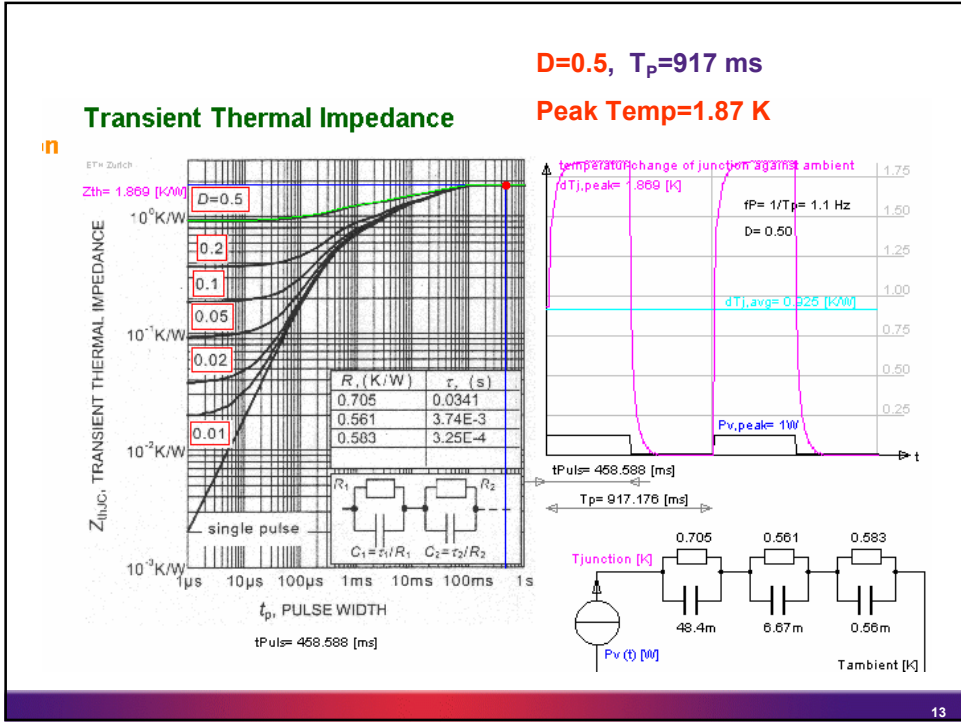
## Transient Thermal Impedance

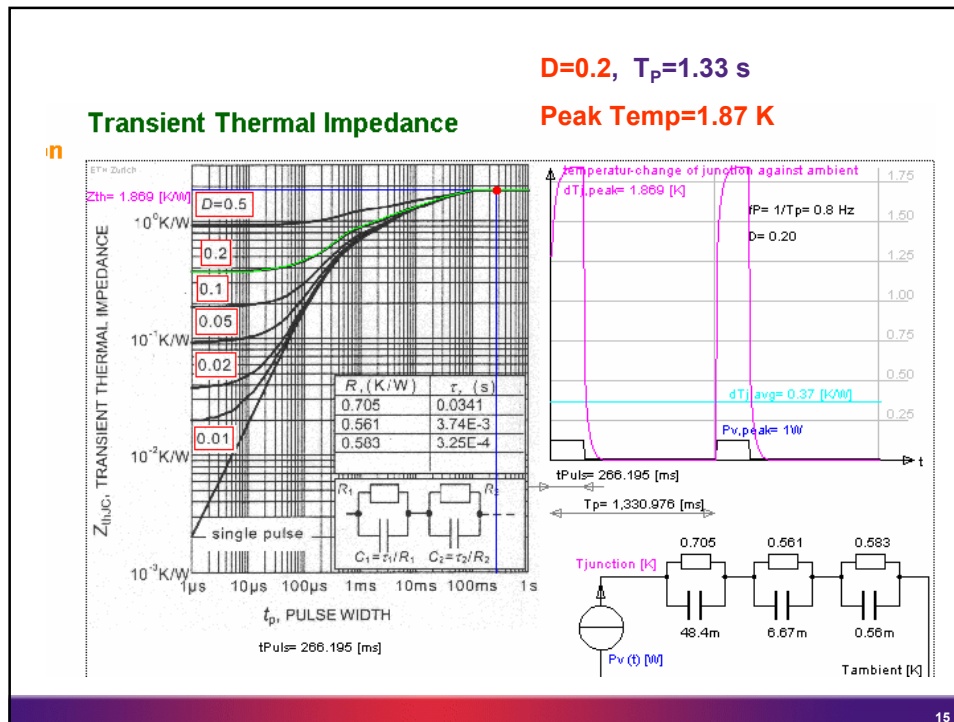
$D=0.5, T_p=0.038 \text{ ms}$

Peak Temp=0.941 K









## Good summary of thermal problems

- ETH Zürich
- <http://www.ipes.ethz.ch/ipes/2002thermal/thermisch.html>
- For example:
- [One dimensional heat conduction](#)
- [Compact model of heat conduction](#)



## Analysis of a MOS transistor

- One decade before the first time constant and one decade after the last is needed to produce correct structure functions !
- Square root extrapolation is prescribed in the appropriate MIL standard