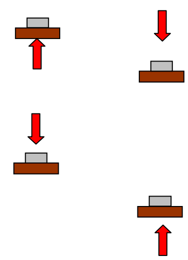
Wireless World

Feasibility of Die Attach testing

- Die attach qualification can be done by measuring transient temperature responses.
- Three components of the problem:
  - Heating
  - Movement
  - Sensing
- Possible solutions:

Heating

- **Heating** can be
  - **contact**
  - **non contact**
  - **source above**
  - **source below**
  - **constant energy**
  - **constant power**
  - **constant temperature**
  - **of different timing**



Heating sources

S - inherent from hot die attach process
(i.e. eutectic **S**oldering)
source below, constant temperature, step (negative!)

P - hot **contactPoint**
contact, source below, constant temperature, wide pulse

A - hot **A**ir flow
non contact, source below/above, constant temperature, wide pulse/ pulse series

B - row of incandescent **B**ulbs (infrared)
non contact, source below/above, constant power, pulse series

C - chopped incandescent **B**ulb (infrared)
non contact, source below/above, constant power, pulse series

Heating sources **(cont):**

F - laser **F**lash

non contact, source below/above, constant power, short pulse/ pulse series

H - **H**igh frequency induction heating

non contact, source inside, constant power, any timing

Very wide pulse or long series of pulses at constant power converge to constant temperature.

Wide pulse can be treated as two step functions superposed

Heating **(cont) :**

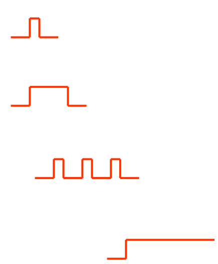
timing for heating can be:

– short pulse

– wide pulse

– series of pulses

– long time heating (step)



Movement :

► **Movement** can be

- **continuous**
- **stepwise**
- **standing** (no movement)

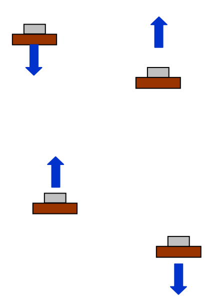
Sensing

► **Sensing** can be

- **contact**
- **non contact**

- **sense from above**
- **sense from below**

- **one point**
- **detailed**
- **integral**



Sensing

- Contact and one-point methods are not very promising for die attach qualification

ca - infrared **C**amera

*non contact, sense **A**bove, detailed*

cb - infrared **C**amera

*non contact, sense **B**elow, rather integral*

is - infrared **S**ensor

*non contact, sense **A**bove/ **B**elow, integral*

li - **L**aser **I**nterferometry

*non contact, sense **A**bove,* ***integral***

(dilatation of die influenced by total temperature change, although measured at single point)

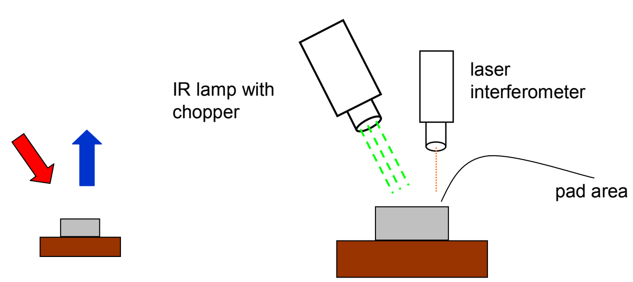
Example : PhD study at BME

Die attach characterization by laser interpherometry

Method: C3li

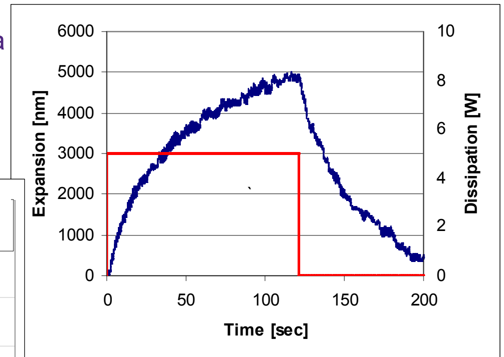
Infrared bulb Chopped (**C**) from above (or other),
no movement (**3**),sensing by **l**aser **i**nterferometry(**li**) from above.

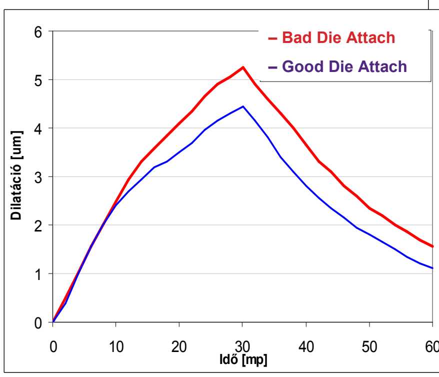
Proposed time interval - few seconds



Die attach characterization by laser interpherometry

- Resolution : 10 nm
- Problem: automated search for a pad





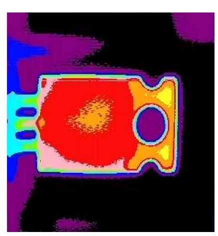
Measured dilatation at the centre of the chip

Don't touch ! *ART and FACT*

- **Thermal imaging:**

  temperature distribution in space (maybe, in time, but slow)

  - **IR thermography**



Heating inside, measurement outside

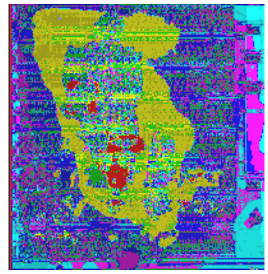
Results in transfer thermal impedances

- Transfer to a less interesting range from the most interesting one, results in *transfer thermal impedances*
- Needs complicated preparations

Don't touch ! *ART and FACT*

- **Thermal imaging:**

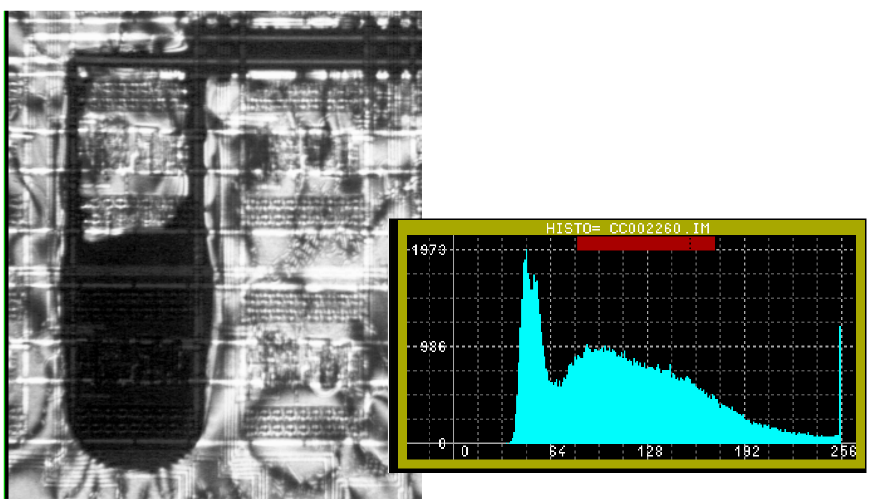
  Liquid crystal based mapping



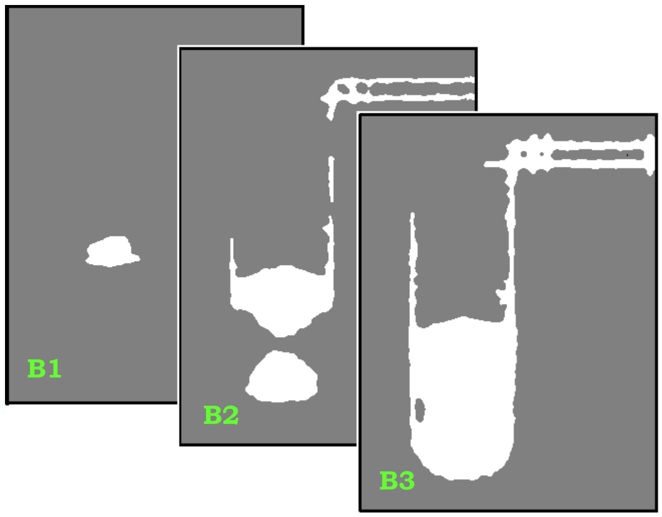
  Thermoreflectance measurements

  all need accurate calibration and thorough preparations

Liquid crystal based mapping



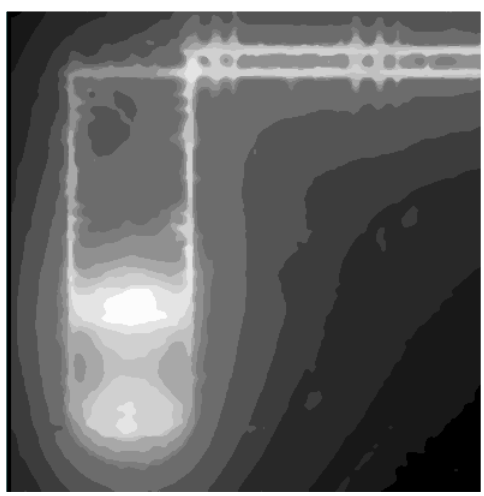
Liquid crystal based mapping



Liquid crystal based mapping

"Added image"

$$A = \sum_i Bi$$



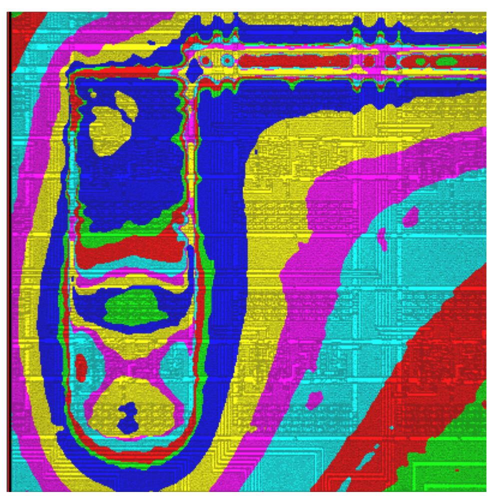
Liquid crystal based mapping

"Fake color" display

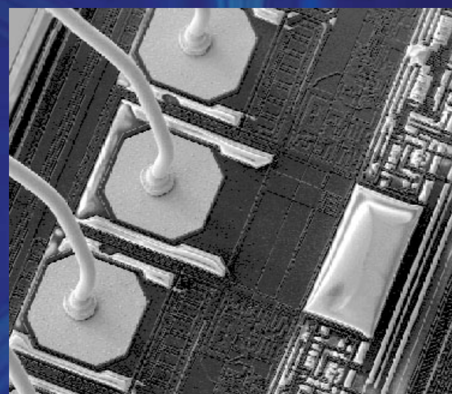
Pixel value	Color
0	blue
1	green
2	red
3	cyan
4	magenta
5	yellow
6 →	start again

Liquid crystal based mapping

Put layout behind

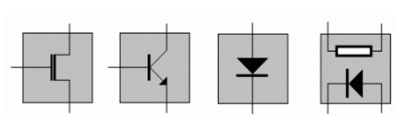


Wired – measurements of electronic components



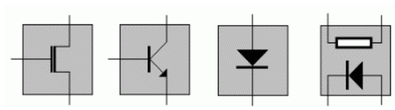
Less ambitious for a while

- Typical simple thermal measurement
  - one point excitation,
  - small heater ,
  - multiple small sensors
- heater : diode, etc
- voltage or current change causes power change



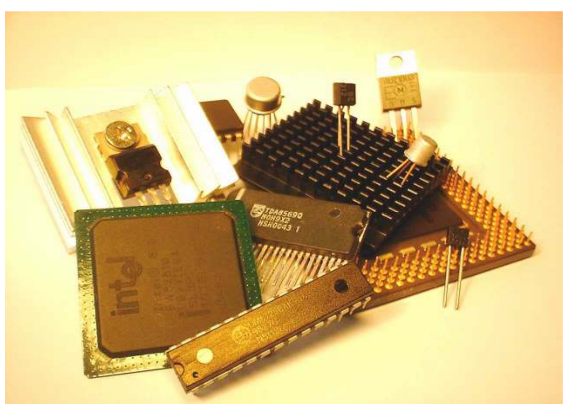
Less ambitious for a while

- Sensors: diode, etc
  - semiconductor devices are *thermometers* (temperature to voltage converters)
  - as a side effect, they rectify, amplify, produce light etc. ☺
- Measurement equipment can be very simple :
  - Multimeter (static measurement)
  - Oscilloscope (transient measurement)



Typical test structures
when using test equipment

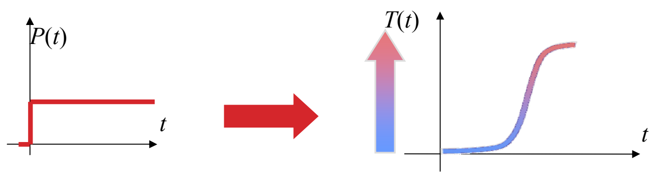
Almost all kinds of semiconductor devices can be measured:



How do we measure ?

- Power switched
- we get voltage in time
- we convert it to temperature

- We see the reality – with certain accuracy
- We make errors – and artifacts

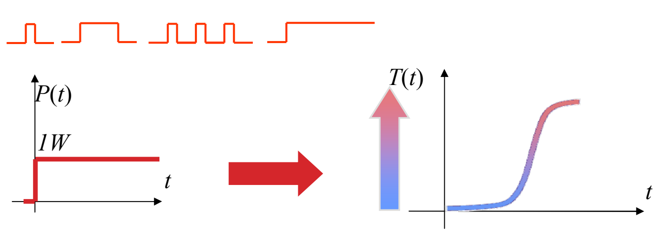


- Device “artifacts”
  - Wrong perception how the device carries out temperature – voltage conversion
- Circuitry artifacts
  - Device placed into improper component set causing distortion, delay
- Equipment artifacts
  - Distortion, delay in the measurement instrument

- Experimental artifacts (boundary artifacts)
  - We place the device into a physical environment not corresponding to our intention or prescribed standard
- Data sheet artifacts
  - We sell the result as truth to the customer

Linear problems

- Typical simple thermal measurement
- one point excitation, small heater , sensing
  - Can we get more than just temperature in time?
  - if the problem is linear, yes
- we can normalize
- we can calculate the response for typical excitations
- and even more



Scope

We may want to measure at

- component level
- subassembly level
- system level

This may need different

- equipment
- power
- measurement time

Pars pro toto

We can never measure a

- chip
- package
- component
- subassembly
- system

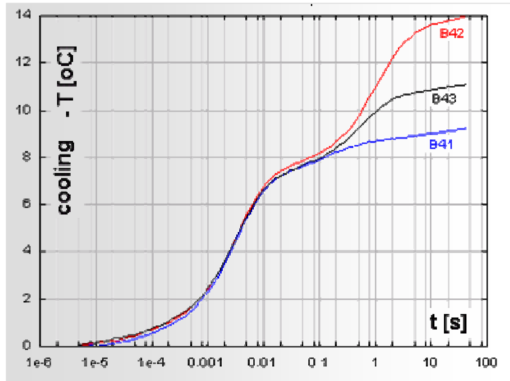
We can only measure the total heat conducting path

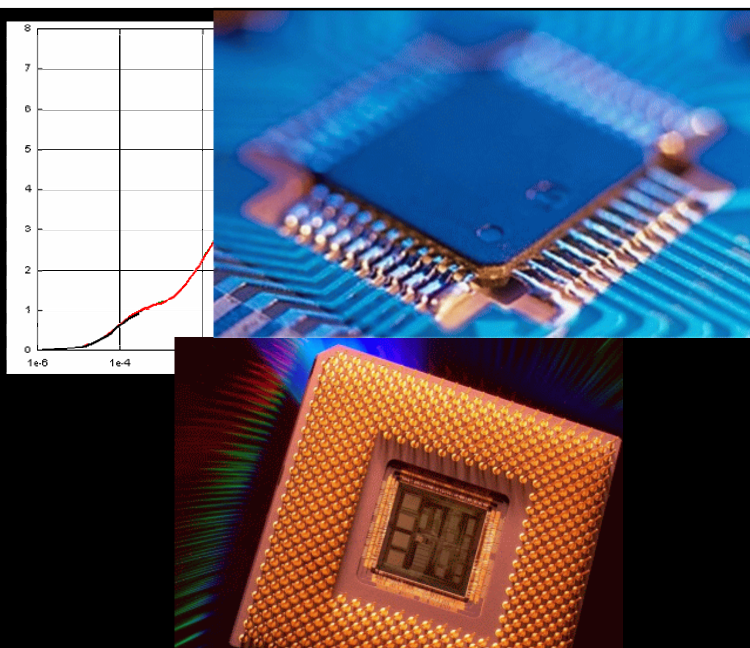
(but we can make a premature stop ☺)

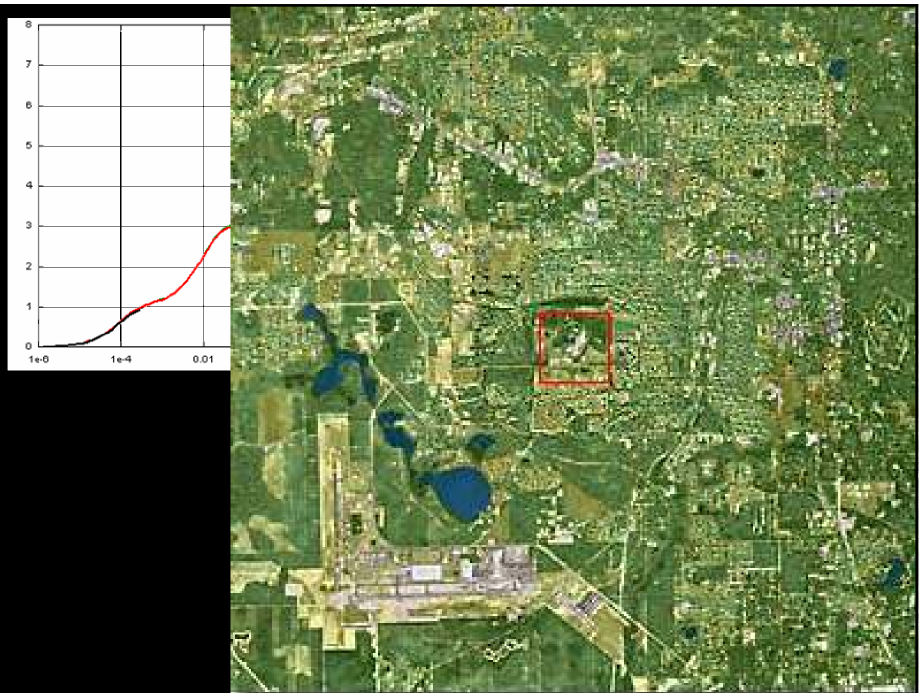
The bumpy curve

- Repeatable, or not ?

- Is this an advantage, or disadvantage ?







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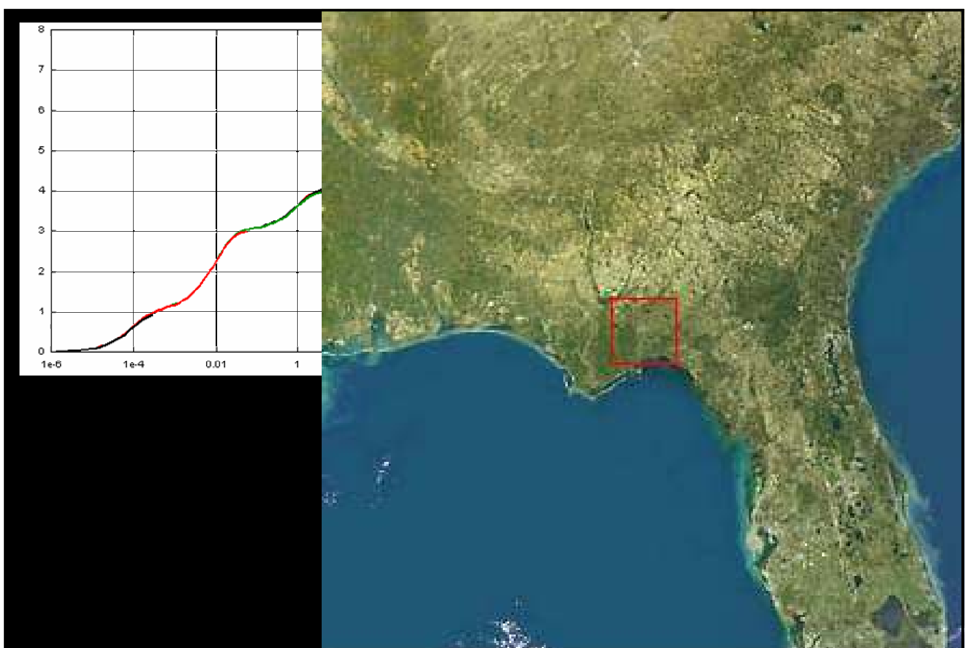

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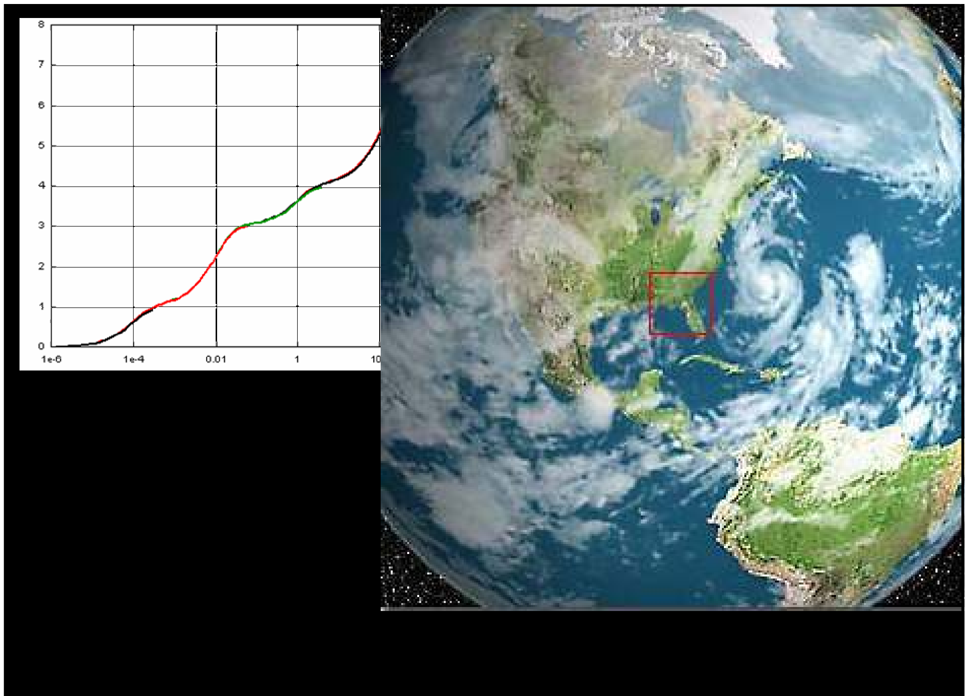
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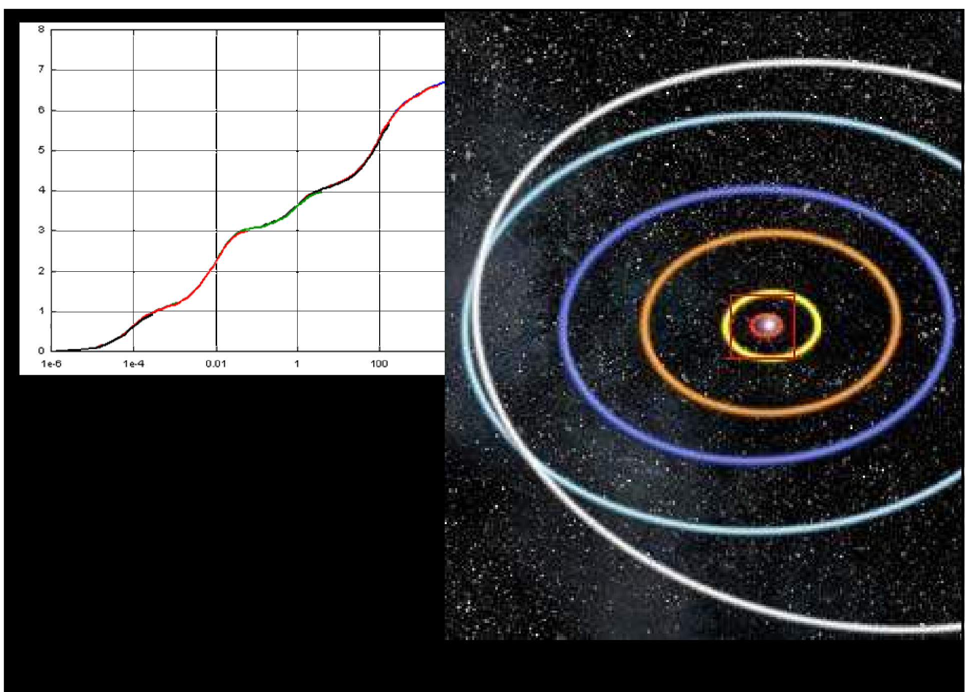
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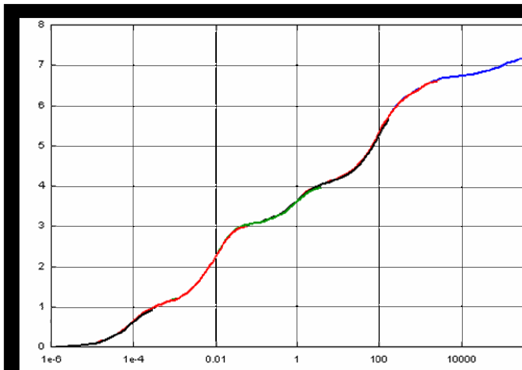
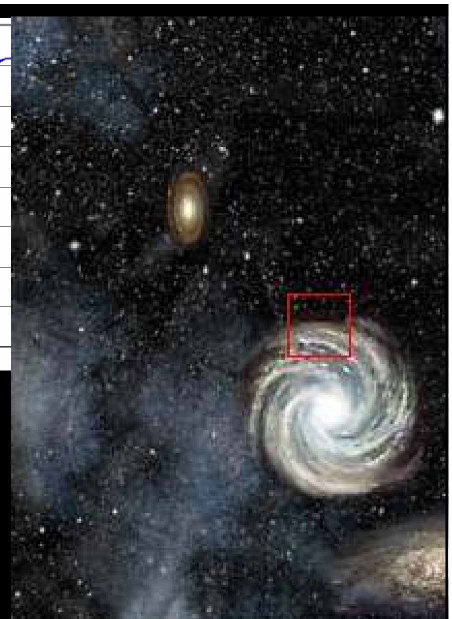
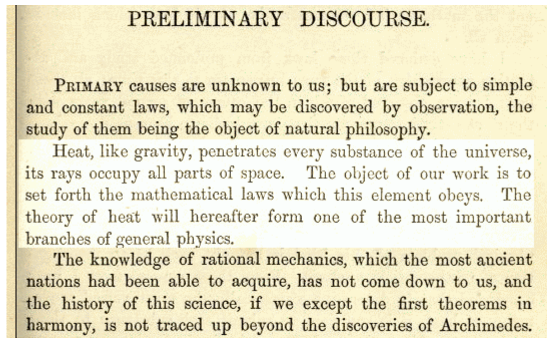




- How far can we really see ?
- How deep can we really see?

- baron Joseph Fourier
- 1768 - 1830



PRELIMINARY DISCOURSE.

PRIMARY causes are unknown to us; but are subject to simple and constant laws, which may be discovered by observation, the study of them being the object of natural philosophy.

Heat, like gravity, penetrates every substance of the universe, its rays occupy all parts of space. The object of our work is to set forth the mathematical laws which this element obeys. The theory of heat will hereafter form one of the most important branches of general physics.

The knowledge of rational mechanics, which the most ancient nations had been able to acquire, has not come down to us, and the history of this science, if we except the first theorems in harmony, is not traced up beyond the discoveries of Archimedes.

- How far can we really see ?
- How deep can we really see?
- A nice space for artifacts
- Our limits depend on three factors

POWER ???

NOISE

SENSITIVITY

Artifacts can be produced again

MORAL

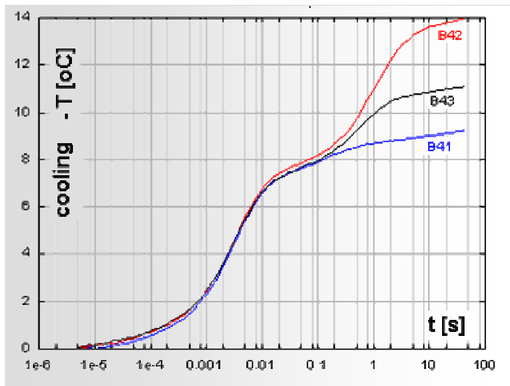
- There is nothing wrong if we make some interpolations / extrapolations
- But do not sell them as facts
- Let us call them “possible reconstruction”
- With clear reference to the part which we know and which we synthesize only

Space Adventure

- in the linearized world

The bumpy curve

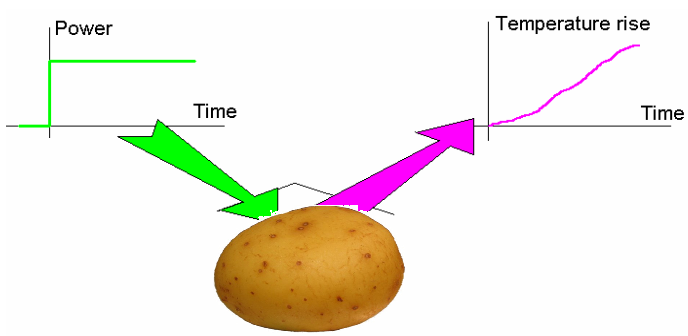
- Repeatable, or not ?
- Is this an advantage, or disadvantage ?
- We stop at a plateau flat enough
- How many points should we collect, at what resolution ?



Put this aside for a time while thinking

…linearized world

- Measure : temperature in time, at one point, small heater
- DUT : General case, some RC body
- Excitation waveform:
  - Dirac δ
  - Step
  - Periodic
  - Sinusoid
  - Arbitrary



…linearized world

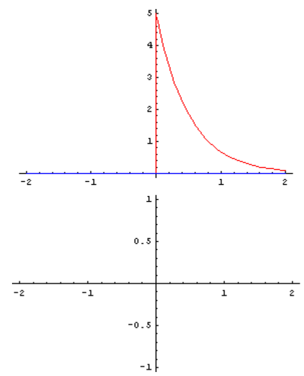
The linearity offers a superposition technique: knowing the response on Dirac δ,

we can compose the response on arbitrary excitation

by adding all pulse responses in time

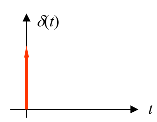
(each pulse smashed in the RC world)

We cannot produce high energy pulses, but it is not expected at all

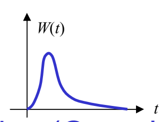


Convolution in time

$\delta(t)$



$W(t)$



Dirac-delta

weight function (Green's function)

Response to *any* excitation:

$$T(t) = \int_0^\infty W(y)\, P(t-y)\, dy$$

measurement

or shortly:

$$T(t) = W(t) \otimes P(t)$$

$\otimes$ = convolution

If the T response to the P excitation is known:

$$W(t) = T(t) \otimes^{-1} P(t)$$

structure identification

$\otimes^{-1}$ = deconvolution (to be calculated numerically)

The fathers

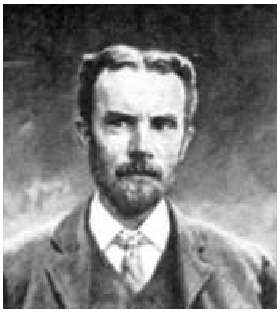
- George Green
- 1773 - 1841

- Vito Volterra
- 1860 - 1940

The fathers

- Paul Adrien Dirac
- 1902 - 1984

- Oliver Heaviside
- 1850 - 1925



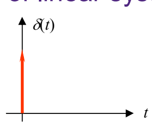
Special excitations

Dirac δ   Unit Step

Convolution in time

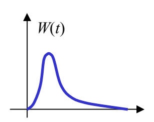
- Theory of linear systems

$\delta(t)$



Dirac-delta

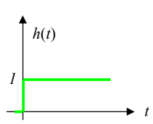
$W(t)$



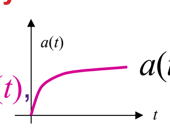
weight function (Green's function)

- The $h(t)$ **unit-step function** is more **easy to realize** than the $\delta(t)$ Dirac-delta

$h(t)$



$a(t)$,



$$a(t) = W(t) \otimes h(t)$$

$a(t)$ is the **unit-step response function**

If we know the $a(t)$ *step-response function*, we ***know everything*** about the system

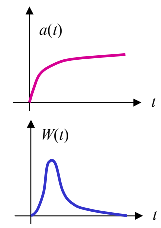
the system is ***fully characterized.***

Convolution in time

$$a(t) = W(t) \otimes h(t) = \int_{-\infty}^{\infty} W(y) \cdot h(t-y)\, dy$$

$$a(t) = \int_{-\infty}^{\infty} W(y) \cdot h(t-y)\, dy = \int_{0}^{\infty} W(y) \cdot 1\, dy$$

$$\frac{d}{dt} a(t) = W(t)$$



- The $a(t)$ **unit-step response function** is another **characteristic function** of a linear system.
- The **advantage** of $a(t)$ the unit-step response function over $W(t)$ weight function is that $a(t)$ can be **measured** (or simulated) since it is the response to $h(t)$ which is easy to realize.

Convolution in space